Deutsche Physikalische Gesellschaft DPG

Virtual DPG Meeting

of the Matter and Cosmos Section (SMuK)

with its Divisions

Extraterrestrial Physics, Gravitation and Relativity, Hadronic and Nuclear Physics, Theoretical and Mathematical Physics,

the further Divisions

Short Time-scale Physics and Applied Laser Physics, Plasma Physics, Environmental Physics,

and the Working Group

Philosophy of Physics.

DPG SMuK21

30 August – 3 September 2021

smuk21.dpg-tagungen.de

Verhandlungen der Deutschen Physikalischen Gesellschaft (ISSN 2751-0522 [Online])
Reihe VI, Band 56 (2021)
Zitiertitel: Verhandl. DPG (VI) 56, 5/2021
Erscheinungsweise: Jährlich 3 - 6 Online-Hefte, je nach Bedarf

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Content

Dear Participants,

On behalf of the German Physical Society (DPG), I would like to welcome you to the virtual DPG Meeting of the Matter and Cosmos Section (SMuK).

Due to the ongoing pandemic and the associated hygiene regulations, this meeting cannot yet take place in person, contrary to our hopes. Nevertheless, I am very pleased that our DPG Meeting will again offer an outstanding and exciting programme. This is all the more impressive as the organisation has taken place under difficult conditions.

This conference is of inestimable importance for scientific exchange in physics. But it is also an important contribution of the DPG as the world's largest physical society and communication platform to strengthen the acceptance and awareness of the importance of basic research, scientific thinking and facts, for the existence and future development of our society in politics and the public; and to do so with the special responsibility that those working in science have a particularly high degree for shaping the whole of human life. The DPG has committed itself to this through its statutes, which is more urgently needed than ever to deal with the major challenges facing society; such as pandemics in particular, as well as climate change with its dramatic consequences for all life on our planet – as the Intergovernmental Panel on Climate Change (IPCC) report has once again warned.

I would like to express my great and heartfelt thanks to all those responsible for the success of this DPG Meeting. My special appreciation goes to the conference organisers, Prof. Karl-Henning Rehren (Chair of the Matter and Cosmos Section, Institut für Theoretische Physik, Universität Göttingen) and Prof. Andreas Wipf (Local conference organisation Jena, Theoretisch-Physikalisches Institut, Universität Jena) as well as the programme committee –consisting of the chairpersons of the divisions and working groups involved – for the outstanding programme of this conference. I would also like to thank the staff of the DPG Head Office for their support and supervision of all meetings.

I would also like to express my sincere thanks to the Wilhelm and Else Heraeus-Stiftung for again providing generous financial support to our young members.

I wish you all an exciting conference and many new insights.

Dr. Lutz Schröter
President of the
Deutsche Physikalische Gesellschaft e.V.

Organisation

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Scientific Organisation

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Programme

The scientific programme consists of **572** contributions:

9	Plenary talks
1	Evening talk
4	Prize talks
62	Invited talks
32	Group Reports
365	Talks
99	Posters

Acknowledgement

The Deutsche Physikalische Gesellschaft (DPG) wants to thank the following institutions for supporting the conference:

- Wilhelm and Else Heraeus-Stiftung, Hanau
- DGM-Inventum GmbH
- and all staff who make the success of the conference possible.

Information for Participants

The virtual conference will be held in the period 30 August – 3 September, 2021.

Conference Location
Web-based Conference – Login information will be provided a few days before the event starts.

Conference Time Zone
Central European Summer Time (CEST), UTC+2.

Conference Website
https://smuk21.dpg-tagungen.de/

Conference Platform Functionalities
To use all features of the digital conference, you need an up-to-date browser. The latest versions of Chrome, Firefox, Safari, and Edge with Blink engine are fully supported. JavaScript must be active. For video calls, permission to access your microphone and camera is required. Please note that firewalls of company or institute networks can also limit the functionality.
Immediately after logging in (with your credentials), you will be directed to the conference platform, which is the central access point on the web during the entire event. Here, all functionalities of the platform are available clearly and intuitively. In case of any technical issue please contact us at: +49 (0)69 75306 777.

In the header, you will find the main menu, which allows you to access the different areas of the conference – and to switch back and forth between them:

⇨ **Your Profile**
In the upper right corner of the screen, you will find access to your profile. All stored data concerning your person can be viewed here. Additionally, you are welcome to introduce yourself with a short description or a statement and mark your interests. Should you wish to network more closely with other participants, authors, or exhibitors during the conference, you can send them your virtual business card. Your e-mail address will also appear on this card.

⇨ **Schedule**
Here you will find an overview of the individual conference days and the respective contributions including short descriptions.

⇨ **Poster Hall**
View the submitted poster contributions and the corresponding abstracts and exchange ideas with the authors. During the poster sessions you will also have the opportunity to join a group video chat at each poster to exchange and discuss.

⇨ **Discussion Board**
Use the opportunity to exchange ideas with participants or start a thematic exchange via the „Create Thread" button. Fill out the form and publish your contribution, which can now be commented on and discussed. A video chat room is linked to each contribution, where you can exchange ideas in small groups during the breaks, for example.

⇨ **Meet & Mingle**
Are you missing the real life coffee corner meetings at conferences? Then join our virtual breaks and meet colleagues in small or large groups!

⇨ **Directory**
Find other conference participants - also by areas of interest - and network via the contact request!

⇨ **Search**
If you want to find specific content and/or programme items, use the search function to find them very quickly. On the right side of the header, you will find your profile as well as a list of your contacts, and

access to the chat function. The latter includes conversations already held with conference participants, but you can also start new conversations or individual video chats.

Electronic Programme Guide
Join the live stream or live zoom session to follow the current presentation.
Browse the programme for each day. By clicking on the individual contributions you will get additional information, such as the abstract. In addition to the basic information, you can ask the author a question about his or her contribution. This is publicly accessible. If you send a contact request to the participating authors, they can also exchange information bilaterally or arrange for an individual video chat. If you want to mark contributions in the run-up to or during the conference, you can highlight them with a „star". You will find the programme items marked in this way under „My Schedule".

Time Shift & On-Demand Content
If you have missed a presentation or want to listen to it again, you can still access the contributions up to 14 days after the event using your access data. The poster contributions and the networking opportunities with other conference participants will also be available to you until two weeks after the conference.

Conference Office
During the conference, you will find the conference office team in the Meet & Mingle area at the „Conference Office table". Opening hours are Mon-Thu, 8:30 am to 4 pm, Fri 8:30 am to 12:00 am. The team will be happy to answer any questions you may have about the conference.

Notice Board
All changes regarding the schedule of the conference will be updated currently. The information is identical to the programme updates of the scientific programme and is available at the scientific programme in other formats as well (ordered by publication date, filterable by conference part and as an rss-feed). Please use the form at *https://smuk21.dpg-tagungen.de/programm/notice-board-form* to submit amendments, cancellations, etc.

Wilhelm and Else Heraeus Communication Programme
Within this programme, the active participation by young DPG members – from Germany and abroad – at the virtual DPG Meetings is financially supported.
For the virtual DPG-Meetings, the conference fee (and exclusively the "early bird rate") is subsidised at 100% (*submission of an application was open until 2 August 2021. Subsequent applications are not possible*). After the conference, your participation in the conference will be checked on the basis of the login data and the funding will be finally confirmed or rejected if no participation took place. Payment will be made – after prior notification by e-mail – by the end of October 2021 at the latest by bank transfer to the account you specified in your application.

The Deutsche Physikalische Gesellschaft thanks the Wilhelm and Else Heraeus-Stiftung for the generous financial support of young academic talents. We hope that young physicists will continue to seize the offered opportunity for active scientific communication at scientific conferences. A total of about 35,000 young academics were supported by this programme so far.

Information for Speakers
All speakers are invited to use our offer for a test session one week before the conference starts. The nessesary information for the test session about day, time and login information will be send out by e-mail to the speakers. We would like to ask you to consider the following points for your presentation:

- Please use the same equipment with which you successfully completed your technical check to avoid technical problems during your presentation.
- Please be in the Zoom session of the virtual room where you will give your presentation at least 10 minutes before the session starts.
- Please sign in at Zoom with your full name so that the technical support can identify you as a speaker and give you the rights to share your screen, microphone and camera in Zoom.
- Please make sure that you respect your presentation time!

Information for Poster Presentations

The interactive poster sessions combine the classic contributed talks and posters in an attractive digital form. In addition to the posters, which are accessible throughout the whole conference, it is also possible to present the core messages of the poster in a short 3 minute video abstract, which can also be accessed on-demand.

We would like to ask you to consider the following points when creating your posters and videos:

- Please create your poster as a JPG/PNG file in portrait format (DIN A0; 84.10 cm wide and 118.90 cm high). The file must not exceed a maximum size of 25 MB.
- Please create your 3 minute video abstract in MP4 format. The file must not exceed a maximum size of 150 MB.
- The above criteria are based on the technical requirements of the conference platform used. Therefore, different formats are not possible unfortunately.

Presenting authors are requested to be available to answer questions and discuss via group video chat during the entire poster session at their poster.

Recording of Posters and Presentations

The posters, video abstracts, and the presentations will be available during and until 14 days (via the time-shift function) after the conference for all registered conference participants and are deleted after the conference. The DPG does not offer the presentations for (public) download.

Social Events

Opening

by the Chair of the Matter and Cosmos Section (SMuK)
Prof. Dr. Karl-Henning Rehren, University of Göttingen
Monday, 30 August, 08:55, Audimax. All participants are kindly invited.

Annual General Meetings of the DPG Divisions and the Working Group

Division / Working Group		Date	Time	Location
(EP)	Extraterrestrial Physics	Thursday, Sep 2	15:00	H8.1
(GR)	Gravitation and Relativity	Thursday, Sep 2	19:00	H9.1
(K)	Short Time Scale Physics and Applied Laser Physics	Thursday, Sep 2	15:00	H2.1
(P)	Plasma Physics	Wednesday, Sep 1	17:45	H5.1
(UP)	Environmental Physics	Thursday, Sep 2	18:00	H8.1
(AGPhil)	Philosophy of Physics	Wednesday, Sep 1	18:30	H8.1

Public Evening Lecture

Tuesday, 31 August, 19:00, Audimax.1 (via Live-Stream on YouTube):
https://smuk21.dpg-tagungen.de/programm/oeffentlicher-abendvortrag-in-deutscher-sprache
Prof. Dr. Reinhard Genzel, Max-Planck-Institut für Extraterrestrische Physik, Garching, will speak about *„Galaxien und Schwarze Löcher"*

Who inspires you?

Since the anniversary year 2020 the DPG presents inspiring personalities on Instagram (@dpgphysik) and at www.175inspirierende.dpg-physik.de. Submit online suggestions for the 175 Inspirers: 175inspirierende@dpg-physik.de .

Synopsis of the Daily Programme

Monday, August 30, 2021

08:55	Audimax		**Opening**
			Plenary Talks
09:00	Audimax	PV I	Measurement theory for quantum fields •Christopher Fewster
09:45	Audimax	PV II	What's in a Shadow •Heino Falcke

SYMD

			Session
14:00	Audimax	SYMD 1	Symposium SMuK Dissertation Prize 2021

SYEN

			Invited Talks
16:30	Audimax	SYEN 1.1	Squeezed and entangled light – now exploited by all gravitational-wave observatories •Roman Schnabel
17:10	Audimax	SYEN 2.1	Entanglement and Explanation •Chris Timpson
17:50	Audimax	SYEN 3.1	Entanglement and complexity in quantum many-body dynamics •Tomaz Prosen
			Sessions
16:30	Audimax	SYEN 1	Entanglement in Experiments
17:10	Audimax	SYEN 2	Entanglement and Interpretation
17:50	Audimax	SYEN 3	Entanglement and Complexity

EP

			Invited Talks
11:00	H7	EP 1.1	The onset mechanism and a physics-based prediction of large solar flares •Kanya Kusano
12:00	H7	EP 1.4	Coronal bright points (small-scale loops) in the solar atmosphere •Maria S. Madjarska
16:30	H7	EP 2.1	How can small satellites help advancing our physical understanding in heliospheric physics •Noé Lugaz, Christina O. Lee, Nada Al-Haddad, Réka Winslow, Dave Curtis, Rob Lillis, Toni Galvin
			Sessions
11:00	H7	EP 1	Sun and Heliosphere I
16:30	H7	EP 2	Sun and Heliosphere II

GR

			Session
11:00	H2	GR 1	Black Holes

HK

			Invited Talks
11:00	H1	HK 1.1	Recent results of collinear laser spectroscopy in the vicinity of the magic tin isotopes

Monday, August 30, 2021

HK

			•Liss Vázquez Rodríguez
11:30	H1	HK 1.2	Highlights from the COMPASS Experiment and the AMBER Proposal •Boris Grube
12:00	H1	HK 1.3	Characterizing baryon dominated matter with HADES measurements •Szymon Harabasz
			Sessions
11:00	H1	HK 1	Invited Talks – I
16:30	H1	HK 2	Heavy-Ion Collisions and QCD Phases I
16:30	H2	HK 3	Instrumentation I
16:30	H3	HK 4	Hadron Structure and Spectroscopy I
16:30	H4	HK 5	Nuclear Astrophysics
16:30	H5	HK 6	Instrumentation II

MP

			Sessions
11:00	H3	MP 1	AdS-CFT I
10:30	P	MP 20	Poster (permanent)

P

			Invited Talks
11:00	H5	P 1.1	Diagnostics of magnetized high frequency technological plasmas •Julian Schulze, Moritz Oberberg, Birk Berger, Julian Roggendorf, Dennis Engel, Christian Wölfel, Jan Lunze, Ralf Peter Brinkmann, Peter Awakowicz
11:00	H6	P 2.1	Predictive modelling of beryllium erosion, transport and deposition during H, He and DT plasmas in ITER •Juri Romazanov, Sebastijan Brezinsek, Andreas Kirschner, Richard A. Pitts, Vladislav S. Neverov, Christian Linsmeier
16:30	H6	P 3.1	An overview of the theoretical description and modelling of low-current arcs at small gap distances •Margarita Baeva
			Sessions
11:00	H5	P 1	Low Pressure Plasma Sources I
11:00	H6	P 2	Magnetic Confinement, Plasma-Wall Interaction & Helmholtz Graduate School I
16:30	H6	P 3	Atmospheric Pressure Plasmas and their Applications I

AGPhil

			Invited Talks
11:00	H4	AGPhil 1.1	What‘s so special about initial conditions? •Matt Farr
12:15	H4	AGPhil 1.3	Structuralism as a Stance •Kerry McKenzie
			Session
11:00	H4	AGPhil 1	Metaphysics of Physics

Tuesday, August 31, 2021

			Plenary Talks
09:00	Audimax	PV III	ASDEX Upgrade tokamak: 30 years of science and technology development for a fusion power plant •Arne Kallenbach
09:45	Audimax	PV IV	Superheavy Element Research at GSI •Michael Block

EP

			Invited Talks
11:00	H8	EP 3.1	Erforschung des Weltraumwetters am DLR Institut für Solar-Terrestrische Physik •Jens Berdermann
16:30	H8	EP 4.1	Using multiple radar stations to examine atmospheric tides and their variabi-lity •Patrick Espy, Willem van Caspel, Robert Hibbins
			Sessions
11:00	H8	EP 3	Near Earth Space I
16:30	H8	EP 4	Near Earth Space II

GR

			Invited Talks
11:00	H6	GR 2.1	The Sagnac effect in General Relativity •Jörg Frauendiener
16:30	H6	GR 4.1	News from the Gravitational-Wave Sky •Alessandra Buonanno
			Sessions
11:00	H6	GR 2	Classical GR-1
14:00	H6	GR 3	Classical GR-2
16:30	H6	GR 4	Gravitational waves

HK

			Invited Talks
11:00	H1	HK 7.1	First observation of neutrinos from the CNO fusion cycle in the Sun •Daniele Guffanti
11:30	H1	HK 7.2	The Compressed Baryonic Matter experiment at FAIR •Alberica Toia
12:00	H1	HK 7.3	Ab initio perspectives on strongly correlated nuclei •Alexander Tichai
			Sessions
11:00	H1	HK 7	Invited Talks – II
14:00	H1	HK 8	Instrumentation III
14:00	H2	HK 9	Outreach
14:00	H3	HK 10	Hadron Structure and Spectroscopy II
14:00	H4	HK 11	Instrumentation IV
16:30	H1	HK 12	Heavy-Ion Collisions and QCD Phases II
16:30	H2	HK 13	Instrumentation V
16:30	H3	HK 14	Hadron Structure and Spectroscopy III
16:30	H4	HK 15	Structure and Dynamics of Nuclei I

Tuesday, August 31, 2021

MP

Invited Talks

11:00	H7	MP 2.1	KPZ universality in mathematics and physics •Patrik Ferrari
11:45	H7	MP 3.1	Path integral based non-equilibrium quantum field theory of non-relativistic pairs inside an environment •Tobias Binder
17:00	H7	MP 7.1	Stochastic Dynamics in Quantum Mechanics •Denis Bernard

Sessions

11:00	H7	MP 2	HV 1: Stochastic Non-Equilibrium
11:45	H7	MP 3	HV 2: Non-Equilibrium Quantum Field Theory
14:00	H7	MP 4	AdS-CFT II
15:00	H7	MP 5	Loop Quantum Gravity
16:30	H7	MP 6	Quantum Statistical Mechanics
17:00	H7	MP 7	HV 3: Stochastic Quantum Mechanics
17:45	H7	MP 8	Non-equilibrium Statistical Mechanics

P

Invited Talks

11:00	H5	P 4.1	Overview on turbulence in the shear- and scrape-off layer at W7-X •Andreas Krämer-Flecken, Olaf Grulke, Xiang Han, Carsten Killer, Elisee Trier, Thomas Windisch, Haoming Xiang
16:30	H5	P 6.1	The Wendelstein 7-X Scrape-Off Layer •Carsten Killer, W7-X Team

Sessions

11:00	H5	P 4	Magnetic Confinement II
14:00	P	P 5	Poster I
16:30	H5	P 6	Magnetic Confinement III & Helmholtz Graduate School II

AGPhil

Invited Talk

11:00	H4	AGPhil 2.1	Quantum Metaphysics •Alastair Wilson

Sessions

11:00	H4	AGPhil 2	Quantum Theory 1
14:00	H5	AGPhil 3	Quantum Theory 2

Public Evening Lecture

19:00	Audimax	PV V	Galaxien und Schwarze Löcher •Reinhard Genzel

Wednesday, September 1, 2021

			Plenary Talk
09:00	Audimax	PV VI	Low pressure dusty plasmas for the synthesis of nanocrystals and quantum dots •Uwe Kortshagen

SYAW

			Prize Talks
10:15	Audimax	SYAW 1.1	Prospects for understanding the physics of the Universe •Hiranya Peiris (Laureate of the Max Born Prize 2021)
10:45	Audimax	SYAW 1.2	The ^{229}Th nuclear isomer •Benedict Seiferle (Laureate of the Gustav-Hertz-Prize 2021)
11:30	Audimax	SYAW 1.3	A Sustainable Future Model of Energy and Mobility •Michael Düren (Laureate of the Robert-Wichard-Pohl-Prize 2021)
12:00	Audimax	SYAW 1.4	Digital manipulation of single ions for high-precision mass spectrometry •Jost Herkenhoff (Laureate of the Georg-Simon-Ohm-Prize 2021)
			Session
10:15	Audimax	SYAW 1	Awards Symposium

SYEP

			Invited Talks
14:00	Audimax	SYEP 1.1	Requirements for Earth-like habitats •Helmut Lammer
14:30	Audimax	SYEP 1.2	Geological drivers of habitability •Raymond T. Pierrehumbert
15:00	Audimax	SYEP 1.3	Space Weather from an Active Young Sun and Its Impact on Early Earth •Vladimir Airapetian
15:30	Audimax	SYEP 1.4	Habitable zones around stars and the search for extraterrestrial life •James F. Kasting
			Session
14:00	Audimax	SYEP 1	What makes an exoplanet habitable

EP

			Invited Talk
16:30	H9	EP 5.1	Planets are Places: Characterization of Other Worlds in the 2020s and Beyond •Laura Kreidberg
			Session
16:30	H9	EP 5	Exoplanets and Astrobiology I

GR

			Sessions
14:00	H6	GR 5	Alternative aspects and formulations
16:30	H6	GR 6	Numerical relativity

HK

			Invited Talks
14:00	H1	HK 16.1	Short-Range Correlations in neutron-rich nuclei •Meytal Duer

Wednesday, September 1, 2021

HK

14:30	H1	HK 16.2	The BGOOD experiment at ELSA – exotic structures in the light quark sector? •Thomas Jude
15:00	H1	HK 16.3	The Muon g-2 Experiment at Fermilab •Martin Fertl
15:30	H1	HK 16.4	The muon (g-2) from lattice QCD and experiments: 4.2 sigma, indeed? •Zoltan Fodor

Sessions

14:00	H1	HK 16	Invited Talks - III
16:30	H1	HK 17	Heavy-Ion Collisions and QCD Phases III
16:30	H2	HK 18	Instrumentation VI
16:30	H3	HK 19	Hadron Structure and Spectroscopy IV
16:30	H4	HK 20	Fundamental Symmetries

MP

Sessions

14:00	H7	MP 9	Anomalies in Quantum Field Theory
15:00	H7	MP 10	Nonrelativistic Quantum Field Theory
16:30	H7	MP 11	Quantum Information
17:50	H7	MP 12	Quantum Mechanics

P

Invited Talk

14:00	H5	P 8.1	Visualizing the Dynamics of a Plasma-Based Particle Accelerator •Malte Kaluza

Sessions

14:00	H4	P 7	Helmholtz Graduate School III
14:00	H5	P 8	Laser Plasmas I
16:30	H5	P 9	Codes and Modelling (Methods)
17:45	H5.1	P 10	Annual General Meeting of the Plasma Physics Division

AGPhil

Sessions

14:00	H8	AGPhil 4	Quantum Theory 3
16:30	H8	AGPhil 5	Quantum Theory 4
18:30	H8.1	AGPhil 6	Annual General Meeting of the Working Group on Philosophy of Physics

Thursday, September 2, 2021

			Plenary Talks
09:00	Audimax	PV VII	Direct high-efficiency generation of the third harmonic wavelength in interference layer systems •Marco Jupe, Detlev Ristau, Wolfgang Rudolph
09:45	Audimax	PV VIII	Geophysics in Elysium Planitia – First Year Results from the InSight Mars Mission •Matthias Grott, Bruce Banerdt, Suzanne Smrekar, Tilman Spohn, Philippe Lognonne, Christopher Russel, Catherine Johnson, Don Banfield, Justin Maki, Matt Golombek, Domeniko Giradini, William Pike, Anna Mittelholz, Yanan Yu, Attilio Rivoldini

SYNS

			Invited Talks
14:00	Audimax	SYNS 1.1	Binary neutron stars: from gravitational to particle physics •Luciano Rezzolla
14:40	Audimax	SYNS 1.2	Probing subatomic physics with gravitational waves •Tanja Hinderer
15:20	Audimax	SYNS 1.3	A NICER view of neutron stars •Anna Watts
			Session
14:00	Audimax	SYNS 1	Symposium on Neutron Stars

EP

			Invited Talk
11:00	H8	EP 6.1	The CoPhyLab: How to Study Comets in the Laboratory •Bastian Gundlach
			Sessions
11:00	H8	EP 6	Planets and small Objects
14:00	H8	EP 7	Exoplanets and Astrobiology II
15:00	H8.1	EP 8.1	Mitgliederversammlung AEF und DPG-EP

GR

			Sessions
11:00	H9	GR 7	Experimental tests
12:00	H9	GR 8	Quantum field theory in curved spacetimes
16:30	H9	GR 9	Cosmology
17:30	H9	GR 10	Scalar-tensor and non-local gravity theories
18:00	H9	GR 11	Didactical and heuristic aspects
19:00	H9.1	GR 12	Annual General Meeting of the Gravitation and Relativity Division

HK

			Invited Talks
11:00	H1	HK 21.1	Charming bound states of the strong interaction •Frank Nerling
11:30	H1	HK 21.2	Baryon Spectroscopy with the CBELSA/TAPS experiment at ELSA •Annika Thiel
12:00	H1	HK 21.3	Mass measurements of the most exotic nuclei and their relevance for nuclear structure •Timo Dickel, FRS Ion Catcher Collaboration, TITAN Collaboration

Thursday, September 2, 2021

HK

Sessions

11:00	H1	HK 21	Invited Talks – IV
16:30	H1	HK 22	Heavy-Ion Collisions and QCD Phases IV
16:30	H2	HK 23	Instrumentation VII
16:30	H3	HK 24	Hadron Structure and Spectroscopy V
16:30	H4	HK 25	Astroparticle Physics

K

Invited Talk

11:00	H2	K 1.1	Information als Basis physikalischer Gesetze, basiert Gravitation auf der Information von Abständen? •Rudolf Germer

Sessions

11:00	H2	K 1	New Methods – Applications
14:00	H2	K 2	Light Sources and Diagnostics
15:00	H2.1	K 3	Annual General Meeting of the Short Time-scale Physics and Applied Laser Physics Division

MP

Invited Talks

11:00	H6	MP 13.1	Exact solution of the scalar QFT Φ^4 model on the 4-dimensional noncommutative Moyal space •Alexander Hock
11:45	H6	MP 14.1	Temperature and entropy-area relation of quantum matter near spherically symmetric outer trapping horizons •Rainer Verch

Sessions

11:00	H6	MP 13	HV 4: Quantum Field Theory in Noncommutative Spacetime
11:45	H6	MP 14	HV 5: Quantum Field Theory near Black Hole Horizons
14:00	H6	MP 15	Quantum Field Theory: Renormalization
15:00	H6	MP 16	Strongly Interacting Quantum Field Theory
16:30	H6	MP 17	Entropy in Quantum Field Theory

P

Invited Talks

11:00	H4	P 11.1	Microfluidic flow in single-layer dusty plasmas •Peter Hartmann, Truell W. Hyde
11:00	H5	P 12.1	Planetary and astrophysical high Mach-number shocks: kinetic simulations vs in-situ measurements •Artem Bohdan, Martin Pohl, Paul Morris
14:00	H4	P 13.1	How turbulence sets boundaries for fusion plasma operation •Peter Manz, Thomas Eich, the ASDEX Upgrade Team
14:00	H5	P 14.1	Streamer inception and imaging in various atmospheres •Sander Nijdam, Siebe Dijcks, Shahriar Mirpour
16:30	H5	P 15.1	Physics studies with high-power electron cyclotron heating (ECRH) on ASDEX Upgrade •Jörg Stober, ASDEX Upgrade Team

Sessions

11:00	H4	P 11	Complex Plasmas and Dusty Plasmas I
11:00	H5	P 12	Astrophysical Plasmas & Laser Plasmas II
14:00	H4	P 13	Magnetic Confinement IV & Helmholtz Graduate School IV

Thursday, September 2, 2021

P

14:00	H5	P 14	Atmospheric Pressure Plasmas and their Applications II
16:30	H5	P 15	Magnetic Confinement V & Helmholtz Graduate School V

UP

Invited Talks

14:00	H3	UP 2.1	BLUESKY – Atmospheric Composition Changes during the Corona Lockdown 2020 •Christiane Voigt, Jos Leliefeld, Johannes Schneider, Daniel Sauer, Ralf Meerkötter, Silke Groß, Ulrich Schumann, Mira Pöhlker, Laura Tomsche, Mariano Mertens, Hans Schlager
14:50	H3	UP 2.4	Nucleation and growth of atmospheric aerosol particles: Recent results from CLOUD at CERN •Joachim Curtius

Sessions

11:00	H3	UP 1	Oceanography and Climate Modelling
14:00	H3	UP 2	Clouds and Aerosols
18:00	H8.1	UP 3	Annual General Meeting of the Environmental Physics Division

AGPhil

Invited Talk

11:00	H7	AGPhil 7.1	Four Attitudes Towards Singularities in the Search for a Theory of Quantum Gravity •Karen Crowther

Sessions

11:00	H7	AGPhil 7	Quantum Gravity 1
14:00	H7	AGPhil 8	Quantum Gravity 2
16:30	H7	AGPhil 9	General Relativity and Black Holes

Friday, September 3, 2021

			Plenary Talks
09:00	Audimax	PV IX	Renaissance of nuclear physics at the LHC •Laura Fabbietti
09:45	Audimax	PV X	How does the heat get to the ice? – Comprehensive year-round observations of ocean-ice-atmosphere interactions in the high Arctic Ocean •Christian Haas, MOSAiC Team

EP

			Invited Talks
11:00	H5	EP 9.1	Exo-Kuiper Belts in Planetary Systems •Alexander Krivov
12:15	H5	EP 9.5	The SOFIA legacy program FEEDBACK •Nicola Schneider, Alexander Tielens
			Sessions
11:00	H5	EP 9	Astrophysics I
14:00	H5	EP 10	Astrophysics II

GR

			Session
11:00	H4	GR 13	Quantum gravity and cosmology

HK

			Invited Talks
11:00	H1	HK 26.1	Studying the Universe from deep underground: the LUNA experiment •Rosanna Depalo
11:30	H1	HK 26.2	Double parton scattering and double parton distributions •Peter Plößl
12:00	H1	HK 26.3	BSM physics in hadronic and nuclear beta decays: challenges and opportunities •Chien Yeah Seng
			Sessions
11:00	H1	HK 26	Invited Talks – V
14:00	H1	HK 27	Heavy-Ion Collisions and QCD Phases V
14:00	H2	HK 28	Instrumentation VIII
14:00	H3	HK 29	Hadron Structure and Spectroscopy VI
14:00	H4	HK 30	Structure and Dynamics of Nuclei II

MP

			Sessions
11:00	H6	MP 18	Constructive Tools for Quantum Field Theory
14:00	H6	MP 19	Fundamental Ideas

P

			Invited Talk
11:00	H2	P 16.1	Configurational temperature of multi species complex (dusty) plasmas •Dietmar Block, Frank Wieben, Michael Himpel, Andre Melzer
			Sessions
11:00	H2	P 16	Low Pressure Plasmas II & Dusty Plasmas II
14:00	P	P 17	Poster II

Friday, September 3, 2021

UP

Invited Talk

14:00	H7	UP 5.1	Ozone in the troposphere responds to reduced precursor emissions during the COVID-19 pandemic •Wolfgang Steinbrecht

Sessions

11:00	H7	UP 4	Measurement Techniques & Miscellaneous
14:00	H7	UP 5	Atmospheric Trace Gases
16:30	P	UP 6	Poster Session

AGPhil

Session

11:00	H3	AGPhil 10	Quantum Mechanics, Time and Information

Plenary and Evening Talks

Plenary Talk PV I Mon 9:00 Audimax

Measurement theory for quantum fields — •Christopher Fewster — Department of Mathematics, University of York, Heslington, York YO10 5DD. United Kingdom

Great emphasis is placed on the problem of measurement in quantum mechanics. However, a parallel discussion for quantum field theory (QFT) is much less well-developed, despite its foundational importance and the conceptual interest arising from the inclusion of relativity.

This talk will describe how the measurement chain can be described in QFT. Measurements of a quantum system are made by temporarily coupling it to a probe (itself a quantum system). Once the coupling is removed, the probe is measured and the results are interpreted as the measurement of a system observable. This arrangement is called a *measurement scheme* for the latter observable; although measurement schemes have been studied extensively in quantum mechanics, they have rarely been discussed in the context of quantum fields and still less on curved spacetimes.

I will describe how measurement schemes may be formulated for quantum fields on curved spacetime within the general setting of algebraic QFT. This allows the discussion of the localisation and properties of the system observable induced by a probe measurement,and the way in which a system state can be updated thereafter. The framework is local and fully covariant, allowing the consistent description of measurements made in spacelike separated regions. In particular, it sheds light on an old problem due to Sorkin concerning "impossible measurements" in which measurement apparently conflicts with causality.

Plenary Talk PV II Mon 9:45 Audimax

What's in a Shadow — •Heino Falcke — Radboud University, The Netherlands

The inside of black holes is shielded from observations by an event horizon, a virtual one-way membrane through which matter, light and information can enter but never leave. This loss of information, however, contradicts some basic tenets of quantum physics. Does such an event horizon really exist? What are its effects on the ambient light and surrounding matter? How does a black hole really look? Can one see it? Recently we have made the first image of a black hole and detected its dark shadow in the radio galaxy M87 with the global Event Horizon Telescope. Detailed supercomputer simulations faithfully reproduce these observations. Simulations and observations together provide strong support for the notion that we are literally looking into the abyss of the event horizon of a supermassive black hole. The talk will review the results of the Event Horizon Telescope, the nature and meaning of the black hole shadow, its scientific implications and future expansions of the array.

Plenary Talk PV III Tue 9:00 Audimax

ASDEX Upgrade tokamak: 30 years of science and technology development for a fusion power plant — •Arne Kallenbach — Max-Planck-Institut für Plasmaphysik, Garching

This year, 30 years of plasma operation at the ASDEX Upgrade tokamak in Garching have been completed. Over these three decades, the world map of fusion research facilities has undergone significant changes. ASDEX Upgrade has delivered numerous contributions towards the realization of nuclear fusion as clean and almost exhaustless energy source. Many elements of the experiment can be regarded as blueprint for a future reactor, like e.g. its tungsten plasma facing components and the use of impurity injection for gentle power exhaust. After a short introduction into the basics of nuclear fusion utilizing magnetic confinement and the actually favored reactor design, the talk will address important achievements and remaining obstacles and how they could be overcome. Examples are the rapidly growing understanding of plasma transport and stability, as well as solutions related to the occurrence of repetitive edge instabilities, plasma current disruptions and requirements of steady state operation. In addition to improved physical understanding, the increase of computational power and new numerical tools help in extrapolating the ASDEX Upgrade results to a reactor. Newly developed control techniques may even be directly applicable in any large device.

Plenary Talk PV IV Tue 9:45 Audimax

Superheavy Element Research at GSI — •Michael Block — GSI Helmholtzzentrum für Schwerionenforschung — Helmholtzinstitut Mainz — Universität Mainz

The investigation of superheavy elements (SHE) was one of the motivations for the foundation of the GSI Helmholtzzentrum in Darmstadt about fifty years ago. Around that time, shell-stabilized SHE were predicted to exist in the region Z = 114, N = 184 and to form a region of long-lived nuclei, the famous island of stability. In the following decades SHE up to element 118 were synthesized with the help of accelerators, among them six elements were discovered at GSI. Despite this progress several open questions remain, for example what the heaviest element that can exist will be. At the GSI in Darmstadt, we perform a comprehensive research program addressing all aspects of this multifaceted science field. Within the FAIR phase-0 program we performed several experiments investigating atomic, nuclear and chemical properties of SHE. Recent highlights comprise nuclear spectroscopy of Fl isotopes, laser spectroscopy of Fm and No isotopes, and high-precision mass measurements up to Db shedding light on the nuclear structure evolution of these exotic nuclei. In this contribution, I will present select results from the recent FAIR phase-0 campaigns and discuss future perspectives.

Evening Talk PV V Tue 19:00 Audimax

Galaxien und Schwarze Löcher — •Reinhard Genzel — Direktor, MPI für extraterrestrische Physik, Garching — Professor of the Graduate School, Physics and Astronomy, University of California, Berkeley, USA

Seit der Entdeckung der Quasare vor etwa 50 Jahren haben sich die Indizien gehäuft, dass in den Zentren von Milchstraßensystemen massive Schwarze Löcher sitzen, die durch Akkretion von Gas und Sternen effizient Gravitationsenergie in Strahlung umwandeln. Durch hochauflösende Messungen im Infrarot- und Radiobereich ist es jetzt im Zentrum unserer eigenen Milchstraße gelungen, einen überzeugenden Beweis für diese Hypothese zu liefern, und gleichzeitig neue und unerwartete Resultate über den dichten Sternhaufen in der unmittelbaren Umgebung des Schwarzen Lochs erbracht. Hierbei haben neue Entwicklungen in der Infrarotinstrumentierung und der adaptiven Optik und Interferometrie am neuen Großteleskop der ESO, dem VLT, eine wichtige Rolle gespielt. Gleichzeitig ist es klargeworden, dass die meisten Galaxien massive Schwarze Löcher beherbergen, und dass diese Schwarzen Löcher bereits etwa eine Milliarde Jahre nach dem Urknall entstanden sein müssen. Es werden diese neuen Messungen und ihre Konsequenzen für die Entstehung von Schwarzen Löchern im frühen Universum diskutiert.

Plenary Talk PV VI Wed 9:00 Audimax

Low pressure dusty plasmas for the synthesis of nanocrystals and quantum dots — •Uwe Kortshagen — University of Minnesota, Minneapolis, MN, USA

Chemically reactive nonthermal plasmas at low pressure are an interesting environment for the growth of nanocrystals. Molecular precursors are dissociated by electron impact reactions and the resulting molecular fragments and radicals, many of them charged, nucleate to form clusters and nanocrystals. Energetic surface reactions can heat these initial clusters to temperatures that exceed the gas temperature by hundreds of Kelvin. This enables plasmas to form crystalline nanoparticles even of materials with very high melting points. This presentation briefly discusses the physics of the plasma nanocrystal growth mechanisms and then highlights some examples of applications of plasma synthesized nanocrystals. Silicon quantum dots with the proper surface functionalization exhibit strong photoluminescence, different from bulk silicon material, and have shown promising properties for solar luminescent concentrators. The ability of plasmas to produce doped nanocrystals has recently enabled new insights into the electronic transport in nanocrystal films, including the first observation of the insulator-to-metal transition in plasma-produced nanogranular media. Plasma produced nanocrystals also have interesting properties for new photonic applications.

This work was supported by the U.S. National Science Foundation (award DMR-1420013) and the Army Research Office MURI grant W911NF-18-1-0240.

Plenary Talk PV VII Thu 9:00 Audimax

Direct high-efficiency generation of the third harmonic wavelength in interference layer systems — •Marco Jupe[1], Detlev Ristau[2], and Wolfgang Rudolph[3] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8 30419 Hannover, Germany — [2]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [3]Dept. Physics and Astronomy, University of New Mexico, Albuquerque, NM 87131 USA

The direct generation of third harmonics delivers significant technical advantages for integration in optical systems. In particular, the compact form of the one-step conversion process can prove to be a decisive advantage over the classical, two-step second-order conversion processes. In addition, centrosymmetric materials can be used for the third-order process, which significantly expands the material spectrum. A major technical challenge for the conversion is the strong dispersion of the refractive index and the associated phase mismatch, which cannot be compensated even by exploiting birefringence. Here, a concept based on interference filters to solve this problem was developed by UNM. The interference filters are designed to generated the THG in the high refractive index layer and compensated in the low refractive index layers. Additionally, exploiting resonant structures increases the conversion efficiency. In the presentation, theoretical and experimental results up to now are presented. For the designs, six different concepts have been developed and evaluated up to now. In application, the damage threshold of the materials currently limits the efficiency. Nevertheless, efficiencies of just under two percent have been shown.

Plenary Talk PV VIII Thu 9:45 Audimax

Geophysics in Elysium Planitia - First Year Results from the InSight Mars Mission — •Matthias Grott[1], Bruce Banerdt[2], Suzanne Smrekar[2], Tilman Spohn[1], Philippe Lognonne[3], Christopher Russel[4], Catherine Johnson[5], Don Banfield[6], Justin Maki[2], Matt Golombek[2], Domeniko Giradini[7], William Pike[8], Anna Mittelholz[5], Yanan Yu[4], and Attilio Rivoldini[9] — [1]German Aerospace Center, Berlin, Germany — [2]Jet Propulson Laboratory, Pasadena, USA — [3]IPGP, Paris, France — [4]UCLA, Los Angeles, USA — [5]University of British Columbia, Canada — [6]Cornell University, Ithaca, USA — [7]ETHZ, Zürich, Switzerland — [8]Imperial College, London, UK — [9]Royal Observatory, Brussels, Belgium

On November 26, 2018, NASA's InSight mission landed in Elysium Planitia, Mars, and installed the first geophysical station on the planet. InSight's primary payload consists of a seismometer, a heat flow probe, and a radio tracking experiment to determine the planet's rotational state. In addition, the lander is equipped with a robotic arm that has been used to deploy the seismometer and heat flow probe, two cameras, a radiometer, and an atmospheric and magnetic field package. InSight's primary objectives are to determine the interior structure, composition, and thermal state of Mars, as well as constrain present-day seismicity and impact cratering rates. While the heat flow probe was able to emplace sensors to a depth of 0.37 m only, the seismometer has been successfully installed. Here we will provide a mission overview and report on results obtained during the first year of operations on Mars.

Plenary Talk PV IX Fri 9:00 Audimax

Renaissance of nuclear physics at the LHC — •Laura Fabbietti for the ALICE-Collaboration — Technische Universität München, München, Germany

High energy LHC experiments provide a unique laboratory for nuclear and hadron physics studies that have a wide breadth of possible applications to astrophysics. This talk will report on recent and truly interdisciplinary studies carried out within the ALICE collaboration. On the one hand, we can address the formation process and properties of light anti-nuclei that constitute a pivotal ingredient in searches for dark matter in cosmic rays. On the other hand, we have carried out high precision studies of kaon-nucleon, hyperon-nucleon and hyperon-hyperon interactions and properties of (anti)hypernuclei that are fundamental to study the equation-of-state of neutron stars. As case in points we will highlight the recent measurement of the $^3\bar{He}$ absorption cross section and its impact for the indirect search of dark matter and the unprecedented measurements of the p-Σ, p-ϕ p-Ξ, p-Ω and p-Λ interactions and the consequences for the equation of state of hyperon stars. The perspectives for the upcoming Run 3 and Run 4 campaigns at the LHC will also be discussed.

Plenary Talk PV X Fri 9:45 Audimax

How does the heat get to the ice? - Comprehensive year-round observations of ocean-ice-atmosphere interactions in the high Arctic Ocean — •Christian Haas[1,2] and MOSAiC Team[1] — [1]Alfred Wegener Institute, Bremerhaven, Germany — [2]Institute of Environmental Physics, University of Bremen, Germany

Arctic sea ice retreats rapidly with profound consequences for climate and the ecosystem, however the underlying processes and their interactions are still poorly understood quantitatively, and regional and climate model projections are uncertain. In 2019/20 the international Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) set out to improve process understanding and model parameterizations by collecting the most comprehensive, year-long observations ever of the atmosphere, ice, ocean, and ecosystem and their interactions in the high Arctic Ocean. The German research icebreaker Polarstern was used as a drifting base camp to support the work in, under, and above the ice. Here we briefly summarize the events of the expedition and its most important results. These show the importance of heat fluxes in the atmospheric and oceanic boundary layers for the growth and melt of sea ice, and of the wind and current driven redistribution of snow and ice for the sea ice mass balance. Attempts to budget energy and matter fluxes and their impact on sea ice growth and melt show the challenges related to inconsistent satellite data products and to distributed measurements of parameters subject to variability on different temporal and spatial scales.

Symposium SMuK Dissertation Prize 2021 (SYMD)

jointly organised by
the divisions of the Matter and Cosmos Section (SMuK)

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The Matter and Cosmos Section, with the divisions Extraterrestrial Physics (EP), Gravitation and Relativity (GR), Hadronic and Nuclear Physics (HK), Theoretical and Mathematical Physics (MP), Radiation and Medical Physics (ST), and Particle Physics (T), awards a dissertation prize in recognition of outstanding research in the context of a doctoral thesis and its excellent communication. The award committee selects upto four candidates from the nominations who will present their doctoral theses at this symposium.

Overview of Invited Talks and Sessions

(Lecture hall Audimax)

Sessions

SYMD 1	Mon	14:00–16:00	Audimax	**Symposium SMuK Dissertation Prize 2021**

The abstracts of the candidates will be published at https://www.dpg-verhandlungen.de prior to the conference.

Awards Symposium (SYAW)

organised by
the Matter and Cosmos Section (SMuK)

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The laureates of the Max-Born-Prize, the Gustav-Hertz-Prize, the Robert-Wichard-Pohl-Prize, and the Georg-Simon-Ohm-Prize, awarded by the DPG in 2021, present their work to a broader audience.

Overview of Prize Talks and Sessions

(Lecture hall Audimax)

Prize Talks

SYAW 1.1	Wed	10:15–10:45	Audimax	**Prospects for understanding the physics of the Universe** — •Hiranya Peiris
SYAW 1.2	Wed	10:45–11:15	Audimax	**The ^{229}Th nuclear isomer** — •Benedict Seiferle
SYAW 1.3	Wed	11:30–12:00	Audimax	**A Sustainable Future Model of Energy and Mobility** — •Michael Düren
SYAW 1.4	Wed	12:00–12:30	Audimax	**Digital manipulation of single ions for high-precision mass spectrometry** — •Jost Herkenhoff

Sessions

SYAW 1.1–1.4	Wed	10:15–12:30	Audimax	**Awards Symposium**

Sessions

– Prize Talks –

SYAW 1: Awards Symposium

Time: Wednesday 10:15–12:30 Location: Audimax

Prize Talk SYAW 1.1 Wed 10:15 Audimax

Prospects for understanding the physics of the Universe — •Hiranya Peiris — University College London, U.K. — Oskar Klein Centre, Stockholm University, Sweden — Laureate of the Max-Born-Prize 2021

The remarkable progress in cosmology over the last decades has been driven by the close interplay between theory and observations. Observational discoveries have led to a standard model of cosmology with ingredients that are not present in the standard model of particle physics: dark matter, dark energy, and a primordial origin for cosmic structure. Their physical nature remains a mystery, motivating a new generation of ambitious sky surveys. However, it has become clear that formidable modelling and analysis challenges stand in the way of establishing how these ingredients fit into fundamental physics. I will discuss progress in harnessing advanced machine-learning techniques to address these challenges, giving some illustrative examples.

Prize Talk SYAW 1.2 Wed 10:45 Audimax

The ^{229}Th nuclear isomer — •Benedict Seiferle — LMU Munich, Garching b. München, Germany — Laureate of the Gustav-Hertz-Prize 2021

While nuclear transitions are typically situated in the keV or MeV range, the first nuclear isomeric excited state in ^{229}Th (^{229m}Th) with an excitation energy of only ≈8 eV [1, 2] occupies an exceptional position in the nuclear landscape. Such a low excitation energy is accessible with today's lasers and thus ^{229}Th can principally be excited with laser radiation. Together with an expected (radiative) lifetime of several 1000 s ^{229m}Th can be used as a basis for a nuclear optical clock [3] which could be employed in the search for new physics.

In this talk I will give an overview on the progress that has been reached during the last years and present the current status of the ^{229m}Th research at LMU Munich.

[1] B. Seiferle et al., Nature 573, 243-246, 2019.
[2] T. Sikorsky et al., PRL 125, 142503, 2020.
[3] E. Peik und C. Tamm, Europhys. Letters, 61, 2, 181-186, 2003.

15 min. break

Prize Talk SYAW 1.3 Wed 11:30 Audimax

A Sustainable Future Model of Energy and Mobility — •Michael Düren — Justus-Liebig-Universität Giessen, Germany — Laureate of the Robert-Wichard-Pohl-Prize 2021

The future of our civilization is challenged by overpopulation, the reduction of biodiversity and climate change. Energy and mobility are preconditions of a modern society where we as physicists can search for an optimum future model. Solutions for energy supply that work on a global scale are those renewable sources, that are abundantly available: solar, wind and marine power. To minimize resources and waste, energy should be harvested in the most viable places. In a physicist's world, we should start to manage the energy flow of our planet globally and transport energy across borders and continents using high voltage DC lines and other energy carriers.

Electrification of mobility is another must of a future society that minimizes resources and optimizes efficiencies. From simple physics arguments follows that electric railways can save a factor of 10 in energy consumption compared to the current individual mobility. If rail transport is taken seriously as a future mainstream of transport, it is clear that the current automobile infrastructure has to be reused to minimize additional land consumption. The author proposes a system of speed-trams that run on the 'Auto-Bahn' with batteries and overhead lines. Their batteries are simultaneously used as short-term storage to stabilize the national energy grid.

Prize Talk SYAW 1.4 Wed 12:00 Audimax

Digital manipulation of single ions for high-precision mass spectrometry — •Jost Herkenhoff — Max-Planck-Institut für Kernphysik, Heidelberg, Germany — Laureate of the Georg-Simon-Ohm-Prize 2021

The mass of a nuclide is an important property, as it provides detailed insights into its binding energies and nuclear structure. Today, Penning traps provide one of the most precise mass measurements, making them an ideal testbed for theories like quantum electrodynamics or neutrino physics. By measuring the tiny oscillations of a single ion stored within a magnetic and electric field, its mass can be determined with a relative precision of up to 10^{-11}. The measured ion signal can be electronically fed back to the ion itself, allowing control over the ion's motion.

In this talk, a new feedback system architecture based on digital signal processing is presented, which opens the possibility for advanced ion manipulation techniques. Multiple applications, including feedback cooling of a single ion down to 1 K or the implementation of a single-ion self-excited oscillator are illustrated. The digital architecture allows highly-dynamic variation of feedback parameters, which was used to realize a phase-sensitive ion detection technique. Its impact on the precision of the Pentatrap experiment is discussed.

Symposium Entanglement (SYEN)

jointly organised by
the Theoretical and Mathematical Physics (MP),
the Gravitation and Relativity (GR), and
the Working Group on Philosophy of Physics (AGPhil)

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Entanglement has gone a long way from a puzzle about some peculiar quantum mechanical states, triggering illustrous disputes about the interpretation of QM, to a dominant effect in finite-temperature solid-state physics, a resource in quantum computation, a driving agent in black hole thermodynamics, and a tool in quantum measurement. The symposium aims to present some of these amazing facets with interest to many communities.

Overview of Invited Talks and Sessions

(Lecture hall Audimax)

Invited Talks

SYEN 1.1	Mon	16:30–17:10	Audimax	**Squeezed and entangled light - now exploited by all gravita-tional-wave observatories** — •Roman Schnabel
SYEN 2.1	Mon	17:10–17:50	Audimax	**Entanglement and Explanation** — •Chris Timpson
SYEN 3.1	Mon	17:50–18:30	Audimax	**Entanglement and complexity in quantum many-body dynamics** — •Tomaz Prosen

Sessions

SYEN 1.1–1.1	Mon	16:30–17:10	Audimax	**Entanglement in Experiments**
SYEN 2.1–2.1	Mon	17:10–17:50	Audimax	**Entanglement and Interpretation**
SYEN 3.1–3.1	Mon	17:50–18:30	Audimax	**Entanglement and Complexity**

Sessions

– Invited Talks –

SYEN 1: Entanglement in Experiments

Time: Monday 16:30–17:10 Location: Audimax

Invited Talk SYEN 1.1 Mon 16:30 Audimax

Squeezed and entangled light - now exploited by all gravita-tional-wave observatories — •Roman Schnabel — Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Since 2010, the gravitational-wave (GW) detector GEO600 has been using light with a squeezed quantum uncertainty in basically all of its searches for GWs. The successful nonclassical sensitivity improvement that was achieved with the squeeze laser built in my group [1] triggered the implementation of squeeze lasers also in Advanced LIGO and Advanced Virgo. Since April 1st, 2019, these observatories have provided an increased GW event rate of up to 50% that is due to the exploitation of squeezed states of light [2,3,4]. Injecting a squeezed laser field into an interferometer generates strong entanglement between the light fields in the two arms [5]. The entanglement is actually the quantum resource that reduces the measurement noise behind the differential arm length signal below the semi-classical limit. In this talk, I explain how squeezed and high-quality entanglement (Einstein-Podolsky-Rosen-entanglement) has been produced in my laboratories over the past 15 years, with the goal to improve GW observatories and to enable otherwise impossible applications.

[1] LIGO Scientific Collaboration, Nature Physics 7, 962 (2011);
[2] M. Tse et al., Phys. Rev. Lett. 123, 231107 (2019);
[3] F. Acernese et al., Phys. Rev. Lett. 123, 231108 (2019);
[4] R. Schnabel, Annalen der Physik 532, 1900508 (2020);
[5] T. Eberle et al., Phys. Rev. A 83, 052329 (2011).

SYEN 2: Entanglement and Interpretation

Time: Monday 17:10–17:50 Location: Audimax

Invited Talk SYEN 2.1 Mon 17:10 Audimax

Entanglement and Explanation — •Chris Timpson — Faculty of Philosophy, University of Oxford

The last thirty years have seen significant increases in our understanding (and exploitation) of the phenomenon of quantum entanglement. Much of this (quantitative and qualitative) understanding has been driven by developments in quantum information theory. However many traditional conceptual puzzles about how we should understand entanglement remain, particularly when we seek to explain the violation of Bell Inequalities in correlations between spacelike separated measurement events. Perhaps surprisingly, there remain good reasons why even so straightforward a question as whether such an explanation must involve nonlocality continues to be disputed. I will sketch this landscape of debate out, with a particular focus on the questions 1) of what kind of explanation one might seek, and 2) on whether John Bell's formal statement of his informal Local Causality principle in fact fully captures the informal idea when considering families of theories which may involve fundamental non-separability like entanglement.

SYEN 3: Entanglement and Complexity

Time: Monday 17:50–18:30 Location: Audimax

Invited Talk SYEN 3.1 Mon 17:50 Audimax

Entanglement and complexity in quantum many-body dynamics — •Tomaz Prosen — University of Ljubljana, Faculty of Mathematics and Physics, Jadranska 19, SI-1000 Ljubljana, Slovenia

The question of characterising the complexity of dynamics of quantum systems with many interacting particles is, at the same time, very attractive and extremely illusive. Although a generalisation of the notion of Kolmogorov complexity to (non-commutative) quantum dynamical systems has existed for a long time, it does not provide a very useful measure of complexity. For example, it assigns positive complexity even to quasi-free or non-interacting evolutions in the so-called thermodynamic limit.

Within a recent intense burst of studies on dynamical chaos in many-body systems, which were largely motivated by the proposals of Kitaev, Maldacena, Stanford and others on holographic models of black holes, new, more intuitive and more useful, measures of dynamical complexity have been proposed. Amongst the most promising one is the concept of the so-called operator spreading with a complexity indicator given by operator entanglement. Most recently, even non-trivial, exactly solvable models of many-body dynamical chaos appeared, where measures of state and operator entanglement can be computed and the transitions from regularity to chaos analytically shown. These models are particularly topical, as they provide physical examples that may be used to demonstrate quantum supremacy of the currently emerging quantum computers.

Symposium What makes an exoplanet habitable (SYEP)

jointly organised by
the Extraterrestial Physics Division (EP) and
the Environmental Physics Division (UP)

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Overview of Invited Talks and Sessions

(Lecture hall Audimax)

Invited Talks

SYEP 1.1	Wed	14:00–14:30	Audimax	**Requirements for Earth-like habitats** — •Helmut Lammer
SYEP 1.2	Wed	14:30–15:00	Audimax	**Geological drivers of habitability** — •Raymond T. Pierrehumbert
SYEP 1.3	Wed	15:00–15:30	Audimax	**Space Weather from an Active Young Sun and Its Impact on Early Earth** — •Vladimir Airapetian
SYEP 1.4	Wed	15:30–16:00	Audimax	**Habitable zones around stars and the search for extraterrestrial life** — •James F. Kasting

Sessions

SYEP 1.1–1.4	Wed	14:00–16:00	Audimax	**What makes an exoplanet habitable**

Sessions

– Invited Talks –

SYEP 1: What makes an exoplanet habitable

Time: Wednesday 14:00–16:00 Location: Audimax

Invited Talk SYEP 1.1 Wed 14:00 Audimax

Requirements for Earth-like habitats — •Helmut Lammer — Austrian Academy of Sciences, Space Research Institute, Schmiedlstr. 6, 8042 Graz, Austria

Factors such as stellar and geophysical conditions that allow complex multicellular life forms to originate on terrestrial planets with N_2-O_2-dominated atmospheres, so-called Class I habitats, will be discussed. Recent findings on how earliest accretion processes set the initial parameter stages for terrestrial planets to end up as a Class I habitat are also addressed. Here, the focus will be i) on the lifetime of the protoplanetary disk, how fast a protoplanet can accrete mass within the gas disk so that Earth-size/mass planets may end up inside the habitable zone as sub-Neptunes with H_2-He-dominated atmospheres, and ii) on the availability of the initial amount of heat producing radioactive elements such as ^{40}K, ^{238}U, and ^{232}Th on early planets. These elements determine the heat production budget of a planet, which exerts a first order control on its thermal evolution, tectonics, and hence its likelihood for habitability. Since all three elements can be lost during planet formation, compared to Earth one can expect a wide diversity of planets inside the habitable zone with different heat budgets and tectonic regimes, resulting most likely in CO_2-dominated atmospheres. Finally, a new formula for the estimation of the number of possible Class I habitats in the Galaxy, which can be fine-tuned and constrained by the detection of main atmospheric constituends, obtained from future space and large ground-based telescopes, will be presented.

Invited Talk SYEP 1.2 Wed 14:30 Audimax

Geological drivers of habitability — •Raymond T. Pierrehumbert — University of Oxford

Atmospheres of rocky planets are dynamic entities, and their evolution is governed by the balance between outgassing from the planetary interior, crustal sinks of atmospheric or oceanic volatiles, and escape of volatiles to space. It is increasingly recognized that geological processes (and not just a planet's position in the nominal habitable zone) are crucial to determining habitability. The role of the deep carbon cycle in determining whether planets near the outer edge of the nominal habitable zone can maintain enough atmospheric CO2 to attain the maximum-greenhouse limit is particularly stark, but there are also issues regarding the circumstances in which the silicate weathering thermostat can prevent CO2 from building up to levels that render the planet uninhabitable. Geological processes also govern other aspects of atmospheric composition having a bearing on emergence of life (as we know it), and of interpretation of biosignatures. These include methane abundance and nitrogen cycling.

In this talk, I will review some of the key processes involved in geological drivers of habitability, including supply of uranium and thorium, representation of continental and seafloor weathering, composition of volcanic outgassing, and the role of magma oceans. Some remarks on special features of hydrogen-dominated atmospheres will be offered. A number of critical unresolved issues will be highlighted.

Invited Talk SYEP 1.3 Wed 15:00 Audimax

Space Weather from an Active Young Sun and Its Impact on Early Earth — •Vladimir Airapetian — NASA Goddard Space Flight Center/SEEC and American University

The early Solar System was a chaotic place, likely subject to frequent large impacts as well as the violently changing space weather (energetic ionizing radiation flux from the solar corona, wind and transient events) from the infant (< 100 Myr) and toddler(400-600 Myr) Sun. Understanding the conditions that allowed for the emergence of life on early Earth, and whether other inner planets in our Solar System possibly also supported habitable conditions early in their histories is a promising way to address these questions. Thus, the knowledge of the heliospheric environments surrounding the early Venus, Earth and Mars is critical for evaluation of the basic requirements for life as we know it including liquid water and organic compounds. Here I will describe recent observations of young solar-like stars and the Sun as inputs for our 3D MHD models of the corona, the wind and transient events (flares, coronal mass ejections and solar energetic particle events) and discuss their impact on atmospheric erosion and chemistry of our planet. I will use these constrained energy fluxes to describe our recent atmospheric chemistry models impacted by energetic particles from the young Sun and formation and precipitation of biologically relevant molecules. I will then highlight our results of laboratory experiments of proton irradiation of mildly reduced gas mixtures and their implications to the climate, prebiotic chemistry and the rise of habitability on early Earth and young exoplanets.

Invited Talk SYEP 1.4 Wed 15:30 Audimax

Habitable zones around stars and the search for extraterrestrial life — •James F. Kasting — Penn State University, University Park, PA USA

All life on Earth depends on liquid water during at least part of its existence, and it is conservative to assume that life elsewhere has this same requirement. To be detectable remotely, life must also be able to colonize the surface of a planet so that it can modify the planet's atmosphere to an extent that would be detectable from a great distance. Hence, the habitable zone (HZ) around a star is typically defined as the region within which a rocky planet can support liquid water on its surface. The tools needed to estimate the boundaries of the HZ are those of meteorology: 1-D and 3-D climate models. I will discuss the current state of the art in HZ climate modeling, as well as future space telescopes that should eventually allow us to look for habitable planets around nearby stars and use spectroscopy to determine whether they are actually inhabited. NASA's James Webb Space Telescope, which launches in October, 2021, may be able to perform transit spectroscopy on some rocky planets orbiting M stars. Direct imaging of rocky planets around more Sun-like stars will require direct imaging space telescopes such as NASA's LUVOIR or HabEx, or ESA's LIFE (Large Interferometer for Exoplanets).

Symposium Neutron stars (SYNS)

jointly organised by
the Gravitation and Relativity Division (GR) and
the Hadronic and Nuclear Physics Division (HK)

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Neutron stars belong to the most extreme objects in our universe, whose properties stretch our imagination to its limits. Here are two examples: 1) On such a star, the weight of a teaspoon full of its average matter is comparable to that of a mass of our entire Moon placed on the surface of the Earth. 2) Strengths of magnetic fields exceed the critical one, at which the energy difference of a spin-up and spin-down electron is at the pair-production threshold. Clearly, the understanding of such objects poses an outstanding challenge to modern physics, involving an unusually rich and complex combination of our most fundamental theories. Our symposium aims to shed some light from various angles on the current status of this rapidly evolving and most fascinating field.

Overview of Invited Talks and Sessions

(Lecture hall Audimax)

Invited Talks

SYNS 1.1	Thu	14:00–14:40	Audimax	**Binary neutron stars: from gravitational to particle physics** — •Luciano Rezzolla
SYNS 1.2	Thu	14:40–15:20	Audimax	**Probing subatomic physics with gravitational waves** — •Tanja Hinderer
SYNS 1.3	Thu	15:20–16:00	Audimax	**A NICER view of neutron stars** — •Anna Watts

Sessions

SYNS 1.1–1.3	Thu	14:00–16:00	Audimax	**Symposium on Neutron Stars**

Sessions

– Invited Talks –

SYNS 1: Symposium on Neutron Stars

Time: Thursday 14:00–16:00 Location: Audimax

Invited Talk SYNS 1.1 Thu 14:00 Audimax

Binary neutron stars: from gravitational to particle physics — •Luciano Rezzolla — Institute for Theoretical Physics, Frankfurt, Germany

I will argue that if black holes represent one the most fascinating implications of Einstein's theory of gravity, neutron stars in binary system are arguably its richest laboratory, where gravity blends with astrophysics and particle physics. I will discuss the rapid recent progress made in modelling these systems and show how the gravitational signal can provide tight constraints on the equation of state for matter at nuclear densities, as well as on one of the most important consequences of general relativity for compact stars: the existence of a maximum mass. Finally, I will discuss how the merger may lead to a phase transition from hadronic to quark matter. Such a process would lead to a signature in the post-merger gravitational-wave signal and open an observational window on the production of quark matter in the present Universe.

Invited Talk SYNS 1.2 Thu 14:40 Audimax

Probing subatomic physics with gravitational waves — •Tanja Hinderer — Institute for Theoretical Physics, Utrecht University, NL

The gravitational waves from merging binary systems carry unique information about the internal structure of compact objects. For neutron stars – objects comprising matter compressed by strong gravity to supra-nuclear densities where novel phases emerge – this opens unique opportunities for advancing our understanding of matter and fundamental interactions in largely unexplored regimes. Measuring this information in the data analysis relies on accurate models of the interplay of matter with strong-field, dynamical gravity. I will discuss the imprints of neutron star matter on the gravitational wave signals during the binary inspiral epoch, and the need for modeling these effects with a tapestry of approximation schemes for the interplay of dynamical gravity and matter. I will also highlight what we can learn from binaries involving a neutron star and a black hole and summarize the new insights we have gained from recent gravitational-wave measurements of such systems as well as from double neutron star events. I will conclude with an outlook onto the remaining challenges and exciting prospects for the next years, as gravitational-wave science continues to move towards an era of precision physics.

Invited Talk SYNS 1.3 Thu 15:20 Audimax

A NICER view of neutron stars — •Anna Watts — University of Amsterdam

NICER, the Neutron Star Interior Composition Explorer, is an X-ray telescope on the International Space Station. Its mission is to study the nature of the densest matter in the Universe, found in the cores of neutron stars. NICER uses Pulse Profile Modeling, a technique that exploits relativistic effects on X-rays emitted from the hot magnetic polar caps of millisecond pulsars, to make simultaneous measurements of neutron star masses and radii. These depend directly on the dense matter Equation of State. Pulse Profile Modeling also lets us map the hot emitting regions, which form as magnetospheric particles slam into the stellar surface at the magnetic polar caps. I will present NICER's latest results - including a measurement of the radius for the highest mass pulsar known - and discuss the implications for our understanding of ultradense matter, pulsar emission, and neutron star magnetic fields.

Extraterrestial Physics Division
Fachverband Extraterrestrische Physik (EP)

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Overview of Invited Talks and Sessions

(Lecture halls H5, H7, H8, and H9)

Plenary Talk of the Extraterrestial Physics Division

PV VIII	Thu	9:45–10:30	Audimax	**Geophysics in Elysium Planitia - First Year Results from the InSight Mars Mission** — •Matthias Grott, Bruce Banerdt, Suzanne Smrekar, Tilman Spohn, Philippe Lognonne, Christopher Russel, Catherine Johnson, Don Banfield, Justin Maki, Matt Golombek, Domeniko Giradini, William Pike, Anna Mittelholz, Yanan Yu, Attilio Rivoldini

Invited Talks

EP 1.1	Mon	11:00–11:30	H7	**The onset mechanism and a physics-based prediction of large solar flares** — •Kanya Kusano
EP 1.4	Mon	12:00–12:30	H7	**Coronal bright points (small-scale loops) in the solar atmosphere** — •Maria S. Madjarska
EP 2.1	Mon	16:30–17:00	H7	**How can small satellites help advancing our physical understanding in heliospheric physics** — •Noé Lugaz, Christina O. Lee, Nada Al-Haddad, Réka Winslow, Dave Curtis, Rob Lillis, Toni Galvin
EP 3.1	Tue	11:00–11:30	H8	**Erforschung des Weltraumwetters am DLR Institut für Solar-Terrestrische Physik** — •Jens Berdermann
EP 4.1	Tue	16:30–17:00	H8	**Using multiple radar stations to examine atmospheric tides and their variability** — •Patrick Espy, Willem van Caspel, Robert Hibbins
EP 5.1	Wed	16:30–17:00	H9	**Planets are Places: Characterization of Other Worlds in the 2020s and Beyond** — •Laura Kreidberg
EP 6.1	Thu	11:00–11:30	H8	**The CoPhyLab: How to Study Comets in the Laboratory** — •Bastian Gundlach
EP 9.1	Fri	11:00–11:30	H5	**Exo-Kuiper Belts in Planetary Systems** — •Alexander Krivov
EP 9.5	Fri	12:15–12:45	H5	**The SOFIA legacy program FEEDBACK** — •Nicola Schneider, Alexander Tielens

Invited talks of the joint symposium What makes an exoplanet habitable (SYEP)

See SYEP for the full program of the symposium.

SYEP 1.1	Wed	14:00–14:30	Audimax	**Requirements for Earth-like habitats** — •Helmut Lammer
SYEP 1.2	Wed	14:30–15:00	Audimax	**Geological drivers of habitability** — •Raymond T. Pierrehumbert
SYEP 1.3	Wed	15:00–15:30	Audimax	**Space Weather from an Active Young Sun and Its Impact on Early Earth** — •Vladimir Airapetian
SYEP 1.4	Wed	15:30–16:00	Audimax	**Habitable zones around stars and the search for extraterrestrial life** — •James F. Kasting

Sessions

EP 1.1–1.4	Mon	11:00–12:30	H7	**Sun and Heliosphere I**
EP 2.1–2.8	Mon	16:30–18:45	H7	**Sun and Heliosphere II**
EP 3.1–3.5	Tue	11:00–12:30	H8	**Near Earth Space I**
EP 4.1–4.4	Tue	16:30–17:45	H8	**Near Earth Space II**
EP 5.1–5.5	Wed	16:30–18:00	H9	**Exoplanets and Astrobiology I**
EP 6.1–6.4	Thu	11:00–12:15	H8	**Planets and small Objects**
EP 7.1–7.3	Thu	14:00–14:45	H8	**Exoplanets and Astrobiology II**
EP 8	Thu	15:00–16:30	H8	**Mitgliederversammlung AEF und DPG-EP**
EP 9.1–9.6	Fri	11:00–13:00	H5	**Astrophysics I**
EP 10.1–10.4	Fri	14:00–15:00	H5	**Astrophysics II**

Mitgliederversammlung der AEF und DPG-EP

2. September 2021 15:00–16:30 virtuell über ZOOM

Begrüßung

Wahl eines Protokollführers

Feststellung der Beschlussfähigkeit

Kenntnisnahme des Protokolls der Mitgliederversammlung 2020

Bericht des Vorstandes

Höhepunkte und Veranstaltungen 2020, 2021

Bericht aus DPG und der DPG-Sektion Materie und Kosmos (SMuK)

Bericht des Schatzmeisters (AEF)

Bericht des Geschäftsführers (AEF)

Webseiten und Mitgliederverwaltung (AEF)

Entlastung des Vorstandes (AEF)

Bericht aus den Kommissionen

- Astrophysik
- Erdnaher Weltraum und Internationale Weltraumwetterinitiative ISWI
- Exoplaneten und Astrobiologie
- Planeten und kleine Körper
- Sonne und Heliosphäre

Kommissionsstruktur

Wahlen

- Vorsitz AEF und DPG-EP
- Zwei stellv. Vorsitzende AEF und DPG-EP
- Vorsitz und stellv. Kommission Astrophysik
- Vorsitz und stellv. Erdnaher Weltraum und ISWI
- Vorsitz und stellv. Exoplaneten und Astrobiologie
- Vorsitz und stellv. Planeten und kleine Körper
- Vorsitz Sonne und Heliosphäre

Sonstiges

Sessions

– Invited and Contributed Talks –

EP 1: Sun and Heliosphere I

Time: Monday 11:00–12:30 Location: H7

Invited Talk EP 1.1 Mon 11:00 H7

The onset mechanism and a physics-based prediction of large solar flares — •Kanya Kusano — Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan

What determines the onset of large solar flares is not yet well understood, although various models have been proposed. Therefore, their prediction mostly relies on empirical methods, and the accurate prediction of large flares is still difficult. Here, we report a new physics-based method, κ-scheme, that can predict imminent large solar flares (Kusano et al. 2020, Science). The κ-scheme is based on the theoretical model that a small magnetic reconnection between two sheared magnetic loops triggers the new ideal MHD instability, named the double-arc instability (Ishiguro & Kusano 2017, ApJ), driving a solar flare. We applied the κ-scheme to 198 active regions (ARs) with the largest sunspots recorded from 2010 to 2017 using the SDO SHARP dataset. While only 7 ARs in them produced solar flares larger than class X2, we demonstrated that the κ-scheme could clearly discriminate the 6 ARs in them out of the ARs not producing the large flare. It is also shown that the κ-scheme can predict even the precise position where a large flare begins. Based on the results, we conclude that magnetic twist flux density close to a magnetic polarity inversion line determines when and where solar flares may occur and how large they can be. Finally, we also discuss an attempt to extend the κ-scheme to predict eruptive flares and coronal mass ejections (Lin et al. 2020 & 2021, ApJ).

EP 1.2 Mon 11:30 H7

Helicity Shedding by Flux Rope Ejection — •Bernhard Kliem and Norbert Seehafer — Universität Potsdam, Institut für Physik und Astronomie

It has been suggested that magnetic helicity must be shed from the Sun by coronal mass ejections to limit its accumulation in each hemisphere. However, the efficiency of such helicity shedding and its dependence on source region parameters are not yet known. We perform a parametric simulation study of flux rope ejection from marginally stable force-free equilibria to address these questions. By varying the ratio of guide and strapping field and the flux rope twist, different ratios of self and mutual helicity are set and the onset of the torus or helical kink instability is obtained. The helicity shed is found to vary in a broad range from a minor to a major part of the initial helicity, with self helicity being largely or completely shed and mutual helicity, which makes up the larger part of the initial helicity, being shed only partly, up to a configuration-dependent base level. The torus-unstable configuration without a guide field and with only a relatively weak twist sheds nearly 2/3 of the initial helicity, while the highly twisted, kink-unstable configuration sheds only 1/4. The initial flux-normalized helicity of the former configuration is 0.21, a value presumably not far from the maximum helicity that a stable force-free flux rope equilibrium can contain. These results numerically demonstrate the conjecture of helicity shedding by coronal mass ejections and provide a first account of its parametric dependence.

EP 1.3 Mon 11:45 H7

Flux rope reformation as a model for homologous solar flares and coronal mass ejections — •Alshaimaa Hassanin[1,2], Bernhard Kliem[2], Tibor Toeroek[3], and Norbert Seehafer[2] — [1]Faculty of Science,Cairo University, Cairo, Egypt — [2]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany — [3]3Predictive Science Inc., 9990 Mesa Rim Road, Suite 170, San Diego, CA 92121, USA

In this study we model for the first time a sequence of a confined and a full eruption, employing the flux rope reformed in the confined eruption as the initial condition for the ejective one. The full eruption develops as a result of imposed converging motions in the photospheric boundary which drive flux cancellation. In this process, a part of the positive and negative sunspot flux converge toward the polarity inversion line, reconnect, and cancel each other. Flux of the same amount as the canceled flux transfers to the flux rope, building up free magnetic energy. With sustained flux cancellation and the associated progressive weakening of the magnetic tension of the overlying flux, we find that a flux reduction of ≈ 8.9% leads to the ejective eruption. These results demonstrate that homologous eruptions, eventually leading to a coronal mass ejection (CME), can be driven by flux cancellation.

Invited Talk EP 1.4 Mon 12:00 H7

Coronal bright points (small-scale loops) in the solar atmosphere — •Maria S. Madjarska — Max-Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany

When observed in extreme-ultraviolet (EUV) and X-rays, the million degree solar atmosphere, the solar corona, is predominantly populated by loops with a wide range of sizes. During the maximum of the solar activity cycle, bright active-region loops connect the opposite polarity strong magnetic fields of sunspots. Back in 1969 the first X-ray observations astonished the solar scientists by revealing that the solar corona that has been known as quiet and homogenous, is occupied by many bright point-like X-ray emission sources. They were named X-ray Bright Points (XBPs, now called Coronal Bright points, CBPs). Later, the Skylab observations showed that the XBPs actually represent dynamically evolving small-scale loops that confine plasma heated to up to 3 million degrees. It is now known that these small-scale loops are the main building blocks of the solar atmosphere outside active regions uniformly populating the solar atmosphere including active-region latitudes and coronal holes. I will present this essential class of solar phenomena, giving an overview of the current knowledge about their general, plasma, and magnetic properties as well as transient dynamic phenomena associated with them. The observationally derived energetics and the theoretical modelling that aims at explaining the CBP formation and eruptive behaviour, and their role in coronal heating and their contribution to the solar wind, will also be reviewed.

EP 2: Sun and Heliosphere II

Time: Monday 16:30–18:45 Location: H7

Invited Talk EP 2.1 Mon 16:30 H7

How can small satellites help advancing our physical understanding in heliospheric physics — •Noé Lugaz[1], Christina O. Lee[2], Nada Al-Haddad[1], Réka Winslow[1], Dave Curtis[2], Rob Lillis[2], and Toni Galvin[1] — [1]Space Science Center, University of New Hampshire, Durham, NH, USA — [2]Space Science Laboratory, University of California, Berkeley, CA, USA

The past decade has witnessed a significant growth in the private space industry, with new companies building small spacecraft and offering private launch opportunities. Here, I will discuss recent developments and ongoing projects taking advantage of the lower costs of space hardware and the increase in launch opportunities. In particular, this may present opportunities and challenges on how we think of and design space missions, as new orbits and swarms of spacecraft become more important than new instrumentations. In addition, the desire to lower costs and obtain uniform datasests must be balanced by the need to continue promoting diversity in the centers, laboratories and universities building space hardware.

Interplanetary and space weather sciences may be especially ripe for such developments since they are dominated by large and costly missions (Solar Orbiter, Parker Solar Probe, SWFO-L1, L5 mission) and must often rely on single-spacecraft measurements to understand complex three-dimensional solar eruptions, shocks, solar wind structures and energetic particle events. I will end by discussing some recent concepts that may take advantage of smallsat technology to advance our understanding of interplanetary transients.

EP 2.2 Mon 17:00 H7

The Solar Physics Research Integrated Network Group - SPRING — •Markus Roth — Leibniz-Institut für Sonnenphysik, Freiburg

Large, high-resolution solar telescopes admit only a small field of view. However, context data showing the big picture of the dynamics and magnetism at different heights of the solar atmosphere are equally important to understand the Sun in general. Real-time information about the variation of surface velocity, magnetic field, and intensity at different solar layers is an essential input to fundamental solar physics and space weather prediction. There is a consensus that a worldwide distributed network of a suite of small, dedicated telescopes which observe the entire solar disk is needed to obtain these data on a continuous basis. In this talk, I will report about the current status of designing such a network * SPRING * which is currently developed under SOLARNET (High-resolution Solar Physics Network). The key scientific products of this facility will be arc-second resolution images of the Sun in various wavelengths, synoptic vector magnetic fields, synoptic surface velocity fields with high time cadence, and observations of transient events such as flares.

EP 2.3 Mon 17:15 H7

Global solar coronal magnetic field modelling — •Thomas Wiegelmann[1], Thomas Neukirch[2], Iulia Chifu[3,1], and Dieter Nickeler[4] — [1]Max-Planck-Institut für Sonnensystemforschung, Göttingen — [2]School of Mathematics and Statistics, University of St. Andrews, UK — [3]Institute for Astrophysics, University of Göttingen — [4]Astronomical Institute, Czech Academy of Sciences, Czech Republic

Computing the solar coronal magnetic field and plasma environment is an important research topic on it's own right and also important for space missions like Solar Orbiter and Parker Solar Probe to guide the analysis of remote sensing and in-situ instruments. In the inner solar corona plasma forces can be neglected and the field is modelled under the assumption of a vanishing Lorentz-force. Further outwards (above about two solar radii) plasma forces and the solar wind flow has to be considered. Finally in the heliosphere one has to consider that the Sun is rotating and the well known Parker-spiral forms. We have developed codes based on optimization principles to solve nonlinear force-free, magneto-hydro-static and stationary MHD-equilibria.

EP 2.4 Mon 17:30 H7

3He measurements by the Suprathermal Ion Telescope on STEREO-A during solar cycle 24 and their association with electrons observed by SEPT and STE — •Marlon Köberle[1], Radoslav Bucik[2], Bernd Heber[1], Andreas Klassen[1], and Linghua Wang[3] — [1]Christian-Albrechts-Universität zu Kiel, Germany — [2]Southwest Research Institute, San Antonio, USA — [3]Institute of Space Physics and Applied Technology, Peking University, Peking, China

^{3}He-rich solar energetic particle (SEP) events are characterized by a peculiar elemental composition with rare species like ^{3}He or ultra-heavy ions tremendously enhanced over the solar system abundances. Previous studies have shown that the enormous enhancement of ^{3}He up to a factor of 10^4 above coronal abundances seems to be uncorrelated with the enhancement factor of heavier ions, indicating different acceleration mechanisms. The Suprathermal Ion Telescope (SIT) is a time-of-flight mass spectrometer designed to measure ions in the energy range of a few tens of keV up to several MeV per nucleon. The mass resolution of SIT doesnt allow to easily distinguish between ^{3}He and ^{4}He especially in cases of a low ^{3}He to ^{4}He ratio.

Here we present our semi-automatic detection approach that allowed us to identify 112 3He rich periods between 2007 and 2020, covering the whole solar cycle 24. A comparison between the Fe/O and ^{3}He/^{4}He ratios showed no correlation supporting the present picture. Additionally an association of ≈60% of the periods could be found with in-situ electron measurements by STEREO-SEPT and STEREO-STE.

EP 2.5 Mon 17:45 H7

First widespread solar energetic particle event observed by Solar Orbiter on 2020 November 29 — •Alexander Kollhoff[1], Athanasios Kouloumvakos[2], David Lario[3], Nina Dresing[4], Bernd Heber[1], and Robert Wimmer-Schweingruber[1] — [1]IEAP, Christian Albrechts-Universität zu Kiel, Kiel, Germany — [2]IRAP, Université Toulouse III - Paul Sabatier, CNRS, CNES, Toulouse, France — [3]NASA Goddard Space Flight Center, Heliophysics Science Division, Greenbelt, USA — [4]Department of Physics and Astronomy, University of Turku, Finland

With the launch of Solar Orbiter on 2020 February 10 a new era of multi-spacecraft observations opened up. An excellent example for the potentials of this era are the observations of the first widespread solar energetic particle event of solar cycle 25 on 2020 November 29. During this event relativistic electrons as well as protons with energies >50 MeV were observed by Solar Orbiter (SolO), Parker Solar Probe (PSP), the Solar Terrestrial Relations Observatory (STEREO)-A and multiple near-Earth spacecraft. The particle event was associated with an M4.4 class X-ray flare and accompanied by a coronal mass ejection (CME) and an extreme ultraviolet (EUV) wave as well as a type II and multiple type III radio bursts. Here we will present the in situ particle and remote sensing observations of this event and compare the timing of energetic particles observed at the four different locations with remote sensing observations of the solar source. We will particularly highlight the measurements of energetic electrons and protons by the Energetic Particle Detector (EPD) on board Solar Orbiter.

EP 2.6 Mon 18:00 H7

Non-thermal electron velocity distribution functions generated by kinetic magnetic reconnection in the solar atmosphere — •Xin Yao[1,2], Patricio Muñoz[2], and Jörg Büchner[2,1] — [1]Max Planck Institute for Solar System Research, 37077 Göttingen, Germany — [2]Centre for Astronomy and Astrophysics, Technical University of Berlin, 10623 Berlin, Germany

Magnetic reconnection in solar flares can generate non-thermal electron beams. Those accelerated electrons can, in turn, emit radio waves via kinetic instabilities. We aim at investigating the properties of those electrons beams that are relevant for those instabilities (sources of free energy) and their resulting radio emission. For this sake we utilize fully kinetic Particle-In-Cell simulations. Our results show that: (1) Parallel sources of free energy due to magnetized electrons are mainly generated in the diffusion region below/above the X point and separatrices, which can cause bump-on-tail instabilities and generate harmonics of electrostatic Langmuir waves. (2) Perpendicular sources of free energy due to unmagnetized electrons are formed in the diffusion and outflow region near the midplane of the reconnection, which can cause electron cyclotron maser instabilities and generate electrostatic Bernstein waves. In particular, a crescent-shaped EVDF in the velocity space perpendicular to local magnetic field is found. (3) The strength of external field has a negative influence on the formation of perpendicular sources of free energy. Our results allows us to remote diagnose some local plasma properties at the source regions of coronal magnetic reconnection via its radio emission.

EP 2.7 Mon 18:15 H7

Heating of Helium ions in a low-beta multi-ions plasma — •Zhaodong Shi[1], Patricio Munoz[1], Joerg Buechner[1], and Siming Liu[2] — [1]Center for Astronomy and Astrophysics, Berlin Institute of Technology — [2]Purple Mountain Observatory, Chinese Academy of Sciences

We study the heating of Helium ions ($^4He^{2+}$) in a multi-ions plasma consists of electrons, protons, and Helium ions via the 2D hybrid simulation using CHIEF code. Our results show that the eigenmodes of cold plasma waves in such a plasma can be recovered in our simulation. We find that Helium ions are heated both in the parallel and perpendicular directions (relative to the background magnetic field), while the perpendicular heating is preferred. Protons are also heated in the parallel direction, however, the perpendicular heating is very weak for them. And we find the significant parallel heating for both Helium ions and protons is due to the formation of ion beams and plateaus along the background magnetic field in their velocity distribution functions, while the perpendicular heating for Helium ions can be attributed to the increase of their perpendicular temperature. Our results are useful for understanding the preferential heating of ^{3}He and other heavy ions in the ^{3}He-rich solar energetic particle events, because Helium ions play a crucial role as the background ions regulating the behaviors of plasma in these events.

EP 2.8 Mon 18:30 H7

Thermal-nonthermal energy partition in solar flares: current state and first results from STIX on Solar Orbiter — •Alexander Warmuth — Leibniz - Institut für Astrophysik Potsdam (AIP)

Solar eruptive events are characterized by a complex interplay of energy release, transport, and conversion processes. A quantitative characterization of the different forms of energy therefore represents a crucial observational constraint for models of solar eruptions in general, as well as for magnetic reconnection, heating, and particle-acceleration processes in particular. This talk will focus on the energy partition between the thermal plasma and the nonthermal particles and review recent studies that have tried to constrain this partition using X-ray, EUV, and bolometric observations. Theses studies have shown large discrepancies, and an effort will be made to identify the reasons for this. Finally, the first results on energy partition from the STIX instrument on Solar Orbiter will be presented.

EP 3: Near Earth Space I

Time: Tuesday 11:00–12:30 Location: H8

Invited Talk EP 3.1 Tue 11:00 H8

Erforschung des Weltraumwetters am DLR Institut für Solar-Terrestrische Physik — •Jens Berdermann — DLR Institut für Solar-Terrestrische Physik, Kalkhorstweg 53, 17235 Neustrelitz

Das Weltraumwetter hat einen erheblichen Einfluss auf die Leistung und Zuverlässigkeit von weltraumgestützten und bodengestützten technologischen Systemen und kann hierdurch auch indirekt Menschenleben gefährden. Angesichts der wachsenden Bedeutung von Weltraumwetterinformationen ist 2019 die Gründung eines neuen DLR-Instituts am Standort Neustrelitz erfolgt. Das Institut für Solar-terrestrische Physik (SO) befindet sich aktuell in der Aufbauphase und forscht im Bereich Weltraumwetter von den Grundlagen bis zur Anwendung. SO untersucht zeitlich variable Bedingungen auf der Sonne und im Sonnenwind sowie deren Wirkung auf das gekoppelte Ionosphären-Thermosphären-Magnetosphären-System und analysiert Weltraumwettereffekte auf betroffene Technologien in den Bereichen Kommunikation, Navigation, Luftfahrt, Satellitenbetrieb, bemannte Raumfahrt, elektrischer Netzbetrieb und Landvermessung. SO wird mit seinen Forschungsergebnissen zu wissenschaftlichen und technologischen Anwendungen z.B. im Bereich der Satellitenkommunikation und Navigation, der Erdbeobachtung, des Krisenmanagements, der Kommunikation für die Luftfahrt und der automatisierten Mobilität beitragen. Im Vortrag wird ein Überblick über die existierenden und geplanten Aktivitäten zum Thema Weltraumwetter am DLR Institut für Solar-Terrestrische Physik, sowie deren Einbindung in internationale Weltraumwetteraktivitäten gegeben.

EP 3.2 Tue 11:30 H8

Exploring radiation belt electron precipitation — •Alina S. Grishina[1,2], Yuri Y. Shprits[1,2,3], Michael Wutzig[1], Hayley J. Allison[1], Nikita A. Aseev[1,2], Dedong Wang[1], and Matyas Szabo-Roberts[1,2] — [1]GFZ, Potsdam, Germany — [2]University of Potsdam, Potsdam, Germany — [3]University of California, Los Angeles, Los Angeles, CA, USA

The near-Earth space environment is filled with charged particles gyrating around magnetic field lines, bouncing between the two hemispheres, and drifting around the Earth. The particle flux in this region can increase by orders of magnitude during geomagnetically active periods, driven by plasma sheet injections. Additionally, particles can be lost from the magnetic trapping region via precipitation into Earth's atmosphere, potentially affecting atmospheric chemistry and temperature. To explore this relationship further, we require information about the energy spectrum and energy range of the precipitating particles.

In this research, we concentrate on ring current electrons and investigate precipitation mechanisms using a numerical model based on the Fokker-Planck equation. Chorus wave-particle interactions are included using diffusion coefficients from Wang et al. [2019], and interactions with plasmaspheric hiss waves are included via the diffusion coefficients of Orlova et al. [2016]. The precipitating flux is calculated for discrete values of energy values from 1 to 300 keV. Model output is compared with observations from the POES satellite mission, that allows us to validate the calculated precipitating fluxes at different MLTs, over the ring current energy range.

EP 3.3 Tue 11:45 H8

Validation of SSUSI derived auroral ionization rates and electron densities — •Stefan Bender[1,2], Patrick Espy[1,2], and Larry Paxton[3] — [1]Norwegian University of Science and Technology, Trondheim, Norway — [2]Birkeland Centre for Space Science, Bergen, Norway — [3]APL, Johns Hopkins University, Laurel, Maryland, USA

Solar, auroral, and radiation belt electrons enter the atmosphere at polar regions leading to ionization and affecting its chemistry. Climate models usually parametrize this ionization and the related changes in chemistry based on satellite particle measurements. Precise measurements of the particle and energy influx into the upper atmosphere are difficult because they vary substantially in location and time. Widely used particle data are derived from the POES and GOES satellite measurements which provide in-situ electron and proton spectra.

Here we use the electron energy and flux data products from the Special Sensor Ultraviolet Spectrographic Imager (SSUSI) instruments on board the Defense Meteorological Satellite Program (DMSP) satellites. This formation of currently three operating satellites observes the auroral zone in the UV from which electron energies and fluxes are inferred in the range from 2 keV to 20 keV. We use these electron energies and fluxes to calculate ionization rates and electron densities in the lower thermosphere (≈90–150 km), and validate them against EISCAT ground-based measurements. We find that with the current standard parametrizations, the SSUSI-derived auroral electron densities (90–150 km) agree well with the ground-based measured ones.

EP 3.4 Tue 12:00 H8

Dorman function of the DOSimetry TELescope (DOSTEL) count and dose rates aboard an aircraft — •Lisa Romaneehsen, Sönke Burmeister, Bernd Heber, Konstantin Herbst, Johannes Marquardt, Christoph Senger, and Carsten Wallmann — Christian-Albrechts-Universität zu Kiel, Institut für Experimentelle und Angewandte Physik, Abteilung Extraterrestrische Physik, Deutschland

The Earth is continuously exposed to high energetic charged particles of galactic cosmic rays. The flux of these particles is altered by the magnetized solar wind in the heliosphere and the Earth's magnetic field. If cosmic rays hit the atmosphere, the formation of secondary particles depends on the atmospheric density above the observer. Therefore, the ability of a particle to approach an aircraft depends on its energy and the position and altitude of the aircraft.

The radiation detector of the detector system NAVIDOS (NAVIgation DOSimetry) is the DOSimetry Telescope (DOSTEL) measuring the count and dose rate in two semiconductor detectors. From 2008 to 2011 two instruments were installed in two aircraft. The access for energetic charged particles to the current position of the observer is given by the so-called cut-off rigidity. To analyze the data we corrected them for pressure variation by normalizing them to one flight level. We found that the normalization parameters vary with the solar modulation parameter and the cut-off rigidity as expected. These corrected data were utilized to determine the cut-off rigidity dependence by fitting the so called Dorman function to the observation.

EP 3.5 Tue 12:15 H8

Dependence of the ISS DOSTEL Dorman function on the used external geomagnetic field — •Hanna Giese, Sönke Burmeister, Bernd Heber, Konstantin Herbst, Lisa Romaneehsen, and Carsten Wallmann — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Kiel, Germany

The Earth is constantly hit by energetic particles originating from galactic sources. The flux of these particles is altered by the magnetized solar wind in the heliosphere and the Earth's magnetic field. For this reason, the ability of a particle to approach a spacecraft in Low Earth Orbit (LEO) depends on its energy and the position of the spacecraft within the Earth's magnetosphere, characterized by the so-called cut-off rigidity. This cut-off rigidity depends on the activity state of the heliosphere and magnetosphere that are described by models of different complexity. The DOSimetry TELescope (DOSTEL) aboard the International Space Station (ISS) monitors the radiation field within the European module Columbus, which varies with the geomagnetic positions. The correlation between the measured count rates and the corresponding cut-off rigidity is described by the Dorman function. In this contribution we compute cut-off rigidities along the ISS trajectory utilizing three Earth magnetosphere models during different solar and magnetospheric activity. As a result we find major differences between the resulting Dorman functions, which depend on and increase with the external solar wind pressure and exceed the uncertainty in intervals with a mean solar wind pressure of more than 3nPa.

EP 4: Near Earth Space II

Time: Tuesday 16:30–17:45 Location: H8

Invited Talk EP 4.1 Tue 16:30 H8

Using multiple radar stations to examine atmospheric tides and their variability — •Patrick Espy[1,2], Willem van Caspel[1,2], and Robert Hibbins[1,2] — [1]Norwegian University of Science and Technology, Trondheim, Norway — [2]Birkeland Centre for Space Science, Bergen, Norway

Atmospheric tides and planetary waves (PWs) play an important role in shaping the day-to-day and seasonal variability of the Mesosphere-Lower-Thermosphere (MLT). Measurements of tidal and PW variability in the mid-latitude MLT have however remained sparse. This study uses a new analysis technique on the meteor radar winds from a longitudinal array of SuperDARN radars. These provide hourly measurements of the meridional wind at ~95km altitude from which we are able to investigate tides and PWs in the MLT at 65 degrees North. Using the array of SuperDARNs, we can identify east and westward traveling S1, S2 and S3 wave components over a broad range of frequencies spanning tidal to planetary wave oscillations. We present a study of the variability of the migrating and non-migrating tides and the longitudinal variability resulting from their interaction. Additionally we examine the variability of the 2 and 5-day waves in the MLT, and their interaction with tides during stratospheric warming events.

EP 4.2 Tue 17:00 H8

The mid-to high-latitude migrating semidiurnal tide: Results from SuperDARN meteor wind observations and mechanistic simulations — •Willem van Caspel[1,2] and Patrick Espy[1,2] — [1]Norwegian University of Science and Technology, Trondheim, Norway — [2]Birkeland Centre for Space Science, Bergen, Norway

Meteor wind observations of the migrating semidiurnal tide (SW2) made by a longitudinal chain of high-latitude SuperDARN radars are compared against simulations made using a mechanistic primitive equation model. The model is a three-dimensional, non-linear and time-dependent spectral model. The modeled background zonal mean zonal winds and temperatures are nudged to daily mean data from the Navy Global Environmental Model - High Altitude (NAVGEM-HA) meteorological analysis system up to ~95 km altitude. The SW2 tide is forced using 3-hourly temperature tendency fields from the Specified Dynamics Whole Atmosphere Community Climate Model With Thermosphere and Ionosphere Extension (SD-WACCMX). To compare the model to observation, the model is sampled according to the meteor echo distribution of the SuperDARN radars at the locations of available measurements for the year 2015. Our model accurately reproduces the observed seasonal variations in the SW2 amplitude and phase. Model experiments are performed to investigate the role of the background atmosphere, tidal forcing, and dissipation terms in establishing the simulated SW2 tide. Notably, the dissipation terms include a seasonally varying mesospheric eddy diffusion, and a surface friction layer.

EP 4.3 Tue 17:15 H8

Comparison of the chemical impact of extreme solar events with the Halloween solar proton event (SPE) in late October 2003 in the middle atmosphere using a 1D ion-chemistry model — •Monali Borthakur[1], Thomas Reddmann[1], Miriam Sinnhuber[1], Ilya Usoskin[2], Jan-Maik Wissing[3], and Olesya Yakovchuk[3] — [1]Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]University of Oulu, Oulu, Finland — [3]University of Rostock, Rostock, Germany

Strong eruptions in the Sun can accelerate protons to high energies, causing solar proton events (SPEs) and inducing geomagnetic disturbances. Such energetic particles can precipitate upon the Earth's atmosphere, mostly polar regions. We considered an extreme solar event combining an extreme SPE and a geomagnetic storm as derived from historical records of cosmogenic nuclides. The ionization rates (IRs) were calculated for strong directly observed events and scaled to represent extreme events. The chemical composition changes of different atmospheric components (Ozone, NOx, HOx, Cl) due to the extreme solar event and the Halloween SPE are compared in the middle atmosphere doing simulations in a 1D box model of the atmospheric neutral and ion composition. The motivation behind using this model is that it assumes canonical NOx/HOx per ion pair used in chemistry climate models (CCMs). Temperature, pressure and the initial state of the neutral atmosphere are input into the model that were obtained from the EMAC CCM using IRs from AIMOS. The IRs for the Halloween SPE were obtained from AISSTORM data.

EP 4.4 Tue 17:30 H8

synthetic aperture radar satellite imaging of Earth's upper atmosphere and its potential application for upcoming Venus missions — •Hiroatsu Sato[1] and Jun Su Kim[2] — [1]DLR Institute for Solar-Terrestrial Physics, Neustrelitz, Germany — [2]DLR Microwaves and Radar Institute, Wessling, Germany

Modern space-borne synthetic aperture radar satellite (SAR) can provide meter-scale resolution imaging of Earth*s ground surface. When SAR radio waves undergo propagation effects from the ionized atmosphere between the satellite and ground, the resulting SAR image contains information of the atmospheric plasma structures. Recent studies show that plasma density structures in Earth's ionosphere can be captured in L-band SAR images. Different SAR processing techniques using interferometry and sub-band data have been developed to extract the two-dimensional variation of plasma density irregularities We present case studies of SAR imaging of Earth ionospheric density and discuss its potential application for recently selected SAR missions for Venus whose ionosphere is not yet fully understood.

EP 5: Exoplanets and Astrobiology I

Time: Wednesday 16:30–18:00 Location: H9

Invited Talk EP 5.1 Wed 16:30 H9

Planets are Places: Characterization of Other Worlds in the 2020s and Beyond — •Laura Kreidberg — Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg

The past 25 years have revealed a diversity of exoplanets far beyond what was imagined from the limited sample in the Solar System. With new and upcoming observing facilities and a rapidly growing number of nearby planets, we are poised to bring this diversity into focus, with detailed follow-up characterization of the planets' atmospheres. In this talk, I will discuss frontier questions in exoplanet atmosphere characterization, including: what can we learn about a planet's formation conditions from its present-day atmosphere composition? Where is the dividing line between rocky and gaseous worlds? How are climate, atmospheric circulation, and cloud properties affected by the planet's irradiation environment? And finally, under what conditions do terrestrial planets maintain their atmospheres? Finally, I will conclude with my outlook on the search for biosignatures in the atmospheres of inhabited worlds.

EP 5.2 Wed 17:00 H9

Spectral signature of atmospheric winds in high resolution transit observations — •Engin Keles — Leibniz-Institut für Astrophysik Potsdam (AIP)

Exoplanet atmospheres show large diversity and especially Jupiter type exoplanets, the so-called hot and ultra-hot Jupiters which orbit their host star in close orbits, have been studied in detail. As those planets are tidally locked, atmospheric winds, such as zonal jet streams, become triggered due to the temperature difference between the day- and nightside. Spatially resolved absorption lines, for instance the NaD-lines, from high-resolution transit observations, could be a good tracer for such winds, giving insights into the dynamics of the planetary atmosphere. Comparing Na-lines detected on gas giants from different high-resolution transit observations, the findings suggest that the Na-line broadening is tendentially stronger for planets with lower equilibrium temperatures. If caused by zonal winds, this would hint that zonal winds become stronger on cooler planets introducing stronger line broadening within the investigated temperature range, being in agreement with theoretical expectations.

EP 5.3 Wed 17:15 H9

The LIFE initiative - developing a space mission to search for life outside the Solar System — •Sascha P. Quanz[1] and LIFE Initiative[2] — [1]Institute for Particle Physics and Astrophysics, ETH Zurich — [2]www.life-space-mission.com

In the context of its Voyage 2050 process the European Space Agency has recently identified the detection and characterization of rocky, temperate exoplanets as a potential science theme for a future L-class mission. Since its official kick-off in 2018, the LIFE initiative (LIFE=Large Interferometer For Exoplanets) has been working towards exactly that goal: to develop the science, the technology and a roadmap for an ambitious mid-infrared space mission that will allow humankind to detect and characterize the atmospheres of hundreds of nearby extrasolar planets including dozens that are similar to Earth. In this talk I will summarize the current status of the LIFE initiative, highlight the unprecedented scientific potential of the LIFE mission, discuss synergies with other ground- and space-based exoplanet instruments and missions, and elaborate on remaining technological challenges.

EP 5.4 Wed 17:30 H9

Redox hysteresis of super-Earth exoplanets from magma ocean circulation — •Tim Lichtenberg — Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, United Kingdom

From an astronomical perspective, planets that formed under similar conditions should exhibit comparable compositional trends, such as volatile inventory, which can be compared to hypothetical M-R relations. However, internal redox reactions may irreversibly alter the mantle composition and volatile inventory of terrestrial and super-Earth exoplanets, which can affect their outgassed atmospheres and decouple the initial accreted composition from long-term climate. The global efficacy of these mechanisms hinges on the transfer of reduced iron from the molten silicate mantle to the metal core. Using scaling analysis I demonstrate that turbulent diffusion in the internal magma oceans of sub-Neptune exoplanets can kinetically entrain liquid iron droplets and quench core formation. This suggests that the chemical equilibration between core, mantle, and atmosphere may be energetically limited by convective overturn in the magma flow. Hence, molten super-Earths possibly retain a compositional memory of their accretion path. Redox control by magma ocean circulation positively correlates with planetary heat flow, internal gravity, and planet size. The presence and speciation of remanent atmospheres, surface mineralogy, and core-mass fraction of atmosphere-stripped exoplanets may thus constrain magma ocean dynamics and can be probed by upcoming observational facilities.

EP 5.5 Wed 17:45 H9

INCREASE - An updated model suite to study the INflucence of Cosmic Rays on Exoplanetary AtmoSpherEs — •Konstantin Herbst[1], John Lee Grenfell[2], Miriam Sinnhuber[3], and Fabian Wunderlich[2] — [1]IEAP, Christian-Albrechts-Universität zu Kiel, 24108 Kiel, Germany — [2]PF, Deutsches Zentrum fuer Luft- und Raumfahrt (DLR), 12489 Berlin, Germany — [3]Institut fuer Meteorologie und Klimaforschung, Karlsruher Institut fuer Technologie (KIT), 76344 Eggenstein-Leopoldshafen, Germany

The first opportunity to detect indications for life outside of the Solar System may be provided already within this decade. However, the harsh stellar radiation and particle environment of planets in the habitable zone of their host stars could lead to photochemical loss of atmospheric biosignatures. A self-consistent model suite of combined state-of-the-art tools has been developed by Herbst et al. (2019) to study the impact of the radiation and particle environment on atmospheric particle interactions, composition, and climate interactions. Here we present our updated model suite to study a wide range of possible exoplanetary atmospheres and stellar environments tackling the following questions: (1) What processes determine whether (rocky) worlds around cooler stars can retain their atmospheres? (2) How do different atmospheres evolve for cool star systems?, and (3) How do results from our studies compare with observations? Thereby, we will focus on the impact of stellar activity on planetary climate, atmospheric escape, density and composition, surface radiation dose, and the impact on potential observables.

EP 6: Planets and small Objects

Time: Thursday 11:00–12:15 Location: H8

Invited Talk EP 6.1 Thu 11:00 H8

The CoPhyLab: How to Study Comets in the Laboratory — •Bastian Gundlach — Institut für Geophysik und extraterrestrische Physik, Technische Universität Braunschweig, Deutschland

Comets are kilometer-sized objects, composed of different volatile and refractory species, i.e., ice and dust. They formed in the protoplanetary disc by the gravitational collapse of pebble clouds, typically consisting of mm- to cm-sized aggregates of dust and ice. After their formation, comets were scattered into the outer regions of our solar system and the bulk cometary material remained almost unaltered. Thus, comets are among the most primitive objects of our solar system. When a cometary nucleus enters the inner solar system, the cometary surface warms up and the volatile components start to sublimate. Particles, aggregates and chunks are then ejected off the cometary surface into space. This process leads to the formation of the cometary coma, the dust tail and the dust trail. However, the physical processes related to the ejection of material are still not understood. Laboratory experiments are one possible tool to investigate the activity of comets. This task is currently addressed by the CoPhyLab (Comet Physics Laboratory), an international collaboration among six Partner Institutes, with the aim to study the physical processes connected to cometary activity by various experiments and thermophysical modeling.

EP 6.2 Thu 11:30 H8

Atmospheric processes affecting methane on Mars — •John Lee Grenfell[1], Fabian Wunderlich[1,2], Miriam Sinnhuber[3], Konstantin Herbst[4], Ralph Lehmann[5], Markus Scheucher[2,6], Stefanie Gebauer[1], Gabriele Arnold[1], and Heike Rauer[1,2,7] — [1]Institut für Planetenforschung (PF), Deutsches Zentrum für Luft- und Raumfahrt (DLR), Berlin, Germany — [2]Technische Universität Berlin (TUB), Germany — [3]Karlsruhe Institute of Technology (KIT), Germany — [4]Kiel University (CAU), Germany — [5]Alfred Wegener Institute (AWI), Potsdam, Germany — [6]Now at: NASA Jet Propulsion Laboratory (JPL), Pasadena, USA — [7]Freie Universität Berlin (FUB), Germany

We investigate a range of atmospheric phenomena concerning their potential to address the Martian methane lifetime discrepancy. This refers to the overestimate of the modelled lifetimes compared to observations by a factor of up to 600. We apply a newly developed atmospheric photochemical model where we vary in a Monte Carlo approach the chemical rate and eddy mixing coefficients within their uncertainties. Atmospheric pathways are identified and quantified in which methane is oxidized to its stable products. We also investigate the effect of air shower events due to galactic cosmic rays and solar cosmic rays. Our results suggest that the current uncertainty in chemical rates and transport together with seasonal changes in the water column and recently observed high abundances of chlorine in the Martian atmosphere can together account for a factor of 27.7 lowering (within 2-sigma) in the modelled Mars methane lifetime.

EP 6.3 Thu 11:45 H8

Magnetfeldmodellierung der Merkurmagnetosphäre mit dem KTH-Modell — •Kristin Pump und Daniel Heyner — IGEP, TU Braunschweig

Der Merkur ist der kleinste und innerste Planet unseres Sonnensystems und besitzt ein dipolartiges internes Magnetfeld. Hierdurch bildet sich eine Magnetosphäre aus, deren Strukturen Gegenstand aktueller Forschung sind. Die Magnetosphäre des Merkur ist im Vergleich zur der der Erde um ein Vielfaches kleiner, dynamischer und durch die nordwärtige Verschiebung des Dipols nicht symmetrisch in Nord-Süd-Richtung. Um die dort auffindbaren Strukturen und Prozesse zu verstehen, werden mithilfe der MESSENGER-Messdaten Modelle entwickelt, um beobachtete Signaturen erklären zu können und die anschließend dabei helfen sollen, die Magnetfeldmessungen der aktuellen BepiColombo-Mission noch genauer planen zu können.

In diesem Vortrag wird das KTH-Modell vorgestellt, ein modulares Modell, mit dem sich das Magnetfeld innerhalb der Merkurmagnetosphäre berechnen lässt. Dieses überarbeitete Modell beinhaltet zum ersten Mal ein realistisches Neutralschichtmodell, dass an den MESSENGER-Daten orientiert ist. Eine Residuenanalyse zeigt, dass mit diesem neuen Modul die Signaturen der feldparallelen Ströme und der zugehörigen Schließungsströme besser erkennbar sind. Darüber hinaus bietet das Modell Potential für eine Verbesserung der Hauptfeldbestimmung.

EP 6.4 Thu 12:00 H8

New dynamo models with a stably stratified layer as an explanation for Mercury's unique magnetic field — •Patrick Kolhey[1], Daniel Heyner[1], Johannes Wicht[2], and Karl-Heinz Glassmeier[1] — [1]Institut für Geophysik und extraterrestrische Physik, TU Braunschweig — [2]Max Planck Institute for Solar System Research, Göttingen

Since the discovery of Mercury's peculiar magnetic field it has raised questions about the dynamo process in the fluid core. The surface magnetic field is rather weak, strongly aligned to the planet's rotation axis and its magnetic equator is shifted towards north. Especially the latter characteristic is difficult to explain using common dynamo model setups. One promising model suggests a stably stratified layer right underneath the core-mantle boundary. As a consequence the magnetic field deep inside the core is efficiently damped by passing through the stably stratified layer due to a so-called skin effect. Additionally, the non-axisymmetric parts of the magnetic field are vanishing, too, such that a dipole dominated magnetic is left at the planet's surface. In this study we present new direct numerical simulations of the magnetohydrodynamical dynamo problem which include a stably stratified layer on top of the outer core, which can also reproduce the shift of the magnetic equator towards north. We explore a wide parameter range, varying mainly the Rayleigh and Ekman number under the aspect of a strongly stratified layer. We show which conditions are necessary to produce a Mercury-like magnetic field and give a inside about the planets interior structure.

EP 7: Exoplanets and Astrobiology II

Time: Thursday 14:00–14:45 Location: H8

EP 7.1 Thu 14:00 H8

Hidden water in magma oceans — •Caroline Dorn[1] and Tim Lichtenberg[2] — [1]University of Zürich, Zürich, Switzerland — [2]University of Oxford, Oxford, United Kingdom

Over the past years, there has been huge progress in our understanding of the bulk properties of Super-Earth and Sub-Neptune exoplanets. Because hot and close-in planets are abundant in the exoplanet population, phase transitions in the interiors of small, dominantly rocky planets have come into sharper focus. Here, we use coupled structural models of the interior and atmosphere of up to super-Earth-sized exoplanets to explore the effect of water partitioning into the interiors of rocky planets inside the runaway greenhouse transition and calculate the effect on the total radius of planets compared to recent models that ignore this effect. The two end-member assumptions lead to a deviation in total planet radius on the order of 5-10%, which is within current accuracy limits for individual systems and will be statistically testable with next-generation transit surveys. In consequence, the inferred water content for a given observed radius of a specific planet may be underestimated by up to two orders of magnitude if volatile partitioning between planetary sub-reservoirs is not accounted for.

EP 7.2 Thu 14:15 H8

Modeling the permittivity profile of Enceladus' tiger stripe region to a simulate radar exploration with an autonomous melting probe — •Alexander Kyriacou, Pia Friend, Gianluca Boccarella, and Klaus Helbing — University of Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

Enceladus possibly hosts extra-terrestrial life, due to the presence of a subsurface ocean. Plumes containing microscopic ice particles erupt from geysers into space, the latter of which mostly fall onto the surface and create a layer of deposited material. The geysers are fed by water-filled fractures connected to the ocean. These aquifers are a target for a future lander mission, Enceladus Explorer, carrying a self-navigating melting probe, using an integrated orbital, surface and subsurface radar system to map the intervening ice and localize the water pockets and potential hazards. The deposition of ice particles results in an in-homogeneous permittivity profile, and we quantify the effect this has on the positional uncertainty of radar. First, we predict the density, temperature and impurity level of Enceladus' surface ice. Using data from the Cassini mission deposition of ice particles is modelled, as well as densification processes such as sintering in the presence of heat from the geysers. We find that the ice grains remain unconsolidated on most of the surface and will only experience sintering within 1 km of active geysers. With the derived profile, we simulate radar propagation through the surface using ray-tracing and parabolic equation methods and reconstruct target positions. We compare the results with simulations of terrestrial glacier ice and field measurements.

EP 7.3 Thu 14:30 H8

Response of a coupled climate-chemistry column model to step by step increases in insolation: Towards the simulation of a giant steam atmosphere at the close of the magma ocean period — •Alexander Esau[1], Fabian Wunderlich[2], John L. Grenfell[2], and Heike Rauer[1,2,3] — [1]Centre for Astronomy and Astrophysics (ZAA), Berlin Institute of Technology (TUB), Hardenbergstr., 10623 Berlin, Germany — [2]Department of Extrasolar Planets and Atmospheres (EPA), Institute for Planetary Research (PF), German Aerospace Centre (DLR), Rutherfordstr. 2, 12489 Berlin, Germany — [3]Institut für Geologische Wissenschaften, Freie Universität Berlin, Malteserstr. 74-100, 12249 Berlin, Germany

Using the coupled climate-photochemical column model 1D-TERRA, we perform 11 scenarios varying the net, top-of-atmosphere incoming insolation (S) with values of S = 1 to S = 1.5. Results suggest surface temperature increases to 356 K mainly due to increasing insolation and associated greenhouse heating from enhanced water vapor via ocean evaporation. Surface pressure increases as a result from 1.02 bar (control) up to 1.54 bar in scenario 11 with the highest insolation. Near the tropopause, results suggest a warming of the cold trap and a weakening of the temperature inversion with increasing insolation. The cold trap and temperature inversion are no longer evident in the lower stratosphere in scenario 11, where a penetration of H2O into the stratosphere occurs consistent with tropospheric greenhouse heating and weakened upwards vertical mixing. We plan to investigate the photochemical and H-escape responses with our extensive chemical scheme.

EP 8: Mitgliederversammlung AEF und DPG-EP

Time: Thursday 15:00–16:30 Location: H8

https://zoom.us/j/98987066486?pwd=eFJ6cmhKKzlNdndyeXJvTTNtWkJ6Zz09 Meeting-ID: 989 8706 6486 Kenncode: 854932

EP 9: Astrophysics I

Time: Friday 11:00–13:00 Location: H5

Invited Talk EP 9.1 Fri 11:00 H5

Exo-Kuiper Belts in Planetary Systems — •Alexander Krivov — AIU, Friedrich Schiller University Jena, Germany

While planets are the most treasured outcome of the planet formation process, they are not the sole component of planetary systems. Another component is debris disks, which are belts of comets and asteroids akin to the Kuiper belt and asteroid belt of the Solar system. These belts also include dust that is produced by mutual collisions of comets and asteroids and other disintegration processes. It is thermal emission and stellar light scattered by that dust that make debris disks observable. This talk focusses on the most prominent, outer components of debris disks, which are considered analogous to the Kuiper belt. These “exo-Kuiper belts” are found around nearby stars nearly as frequently as planets, and more than 150 of them have been imaged by now. To illustrate how exo-Kuiper belts help us understand planetary systems, I will concentrate on two particular aspects. First, exo-Kuiper belts are sculpted and structured by planets in the systems. While possibilities of direct exoplanet detection still remain very limited, the debris disk structure seen in the resolved images can be used to pinpoint the perturbing planets and can also tell us where there are no planets. Second, being descendants of protoplanetary disks, exo-Kuiper belts serve as sensitive tracers of formation and evolution history of planetary systems. Interpreting debris disk observations with the help of models allows one, for instance, to constrain mechanisms of planetesimal accretion, formation of planets, and their subsequent dynamical evolution (scattering, migration) in the past.

EP 9.2 Fri 11:30 H5

From Starspots to Stellar Coronal Mass Ejections - Revisiting Empirical Stellar Relations — •Konstantin Herbst[1], Athanasios Papaioannou[2], Vladimir Airapetian[3,4], and Dimitra Atri[5] — [1]IEAP, Christan-Albrechts-Universität zu Kiel, Leibnizstr. 11, 24118 Kiel, Germany — [2]IAASARS, National Observatory of Athens, I. Metaxa & Vas. Pavlou St., 15236 Penteli, Greece — [3]NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA — [4]American University, 4400 Massachusetts Ave NW, Washington, DC 20016, USA — [5]Center for Space Science, New York University Abu Dhabi, P.O. Box 129188, Abu Dhabi, UAE

Upcoming missions, including the James Webb Space Telescope, will soon characterize the atmospheres of terrestrial-type exoplanets in habitable zones around cool K- and M-type stars by searching for atmospheric biosignatures. Recent observations suggest that the ionizing radiation and particle environment from active cool planet hosts may be detrimental to exoplanetary habitability. Since no direct information on the radiation field is available, empirical relations between signatures of stellar activity, including the sizes and magnetic fields of starspots, are often used. Here, we revisit the empirical relation between the starspot size and the effective stellar temperature and evaluate its impact on estimates of stellar flare energies, coronal mass ejections, and fluxes of the associated stellar energetic particle events.

EP 9.3 Fri 11:45 H5

Topology-driven magnetic reconnection — •Raquel Mäusle[1], Jean-Mathieu Teissier[1], and Wolf-Christian Müller[1,2] — [1]Technische Universität Berlin, Berlin, Deutschland — [2]Max-Planck/Princeton Center for Plasma Physics, Princeton, NJ, USA

Magnetic reconnection is a process that occurs in plasmas, during which the topology of the magnetic field is changed in the presence of finite electrical resistivity. It is observed in solar flares, the Earth's magnetosphere as well as magnetic confinement devices.

We study a three-dimensional model of reconnection driven by magnetic field topology. In this framework, a high entanglement of magnetic field lines amplifies the influence of resistive effects and can thereby trigger reconnection. We investigate this model numerically using a finite-volume scheme to solve the magnetohydrodynamic (MHD) equations. This is done with a simple setup, in which an initially constant magnetic field is driven to high complexity. We study the dynamics of this system, the correlation between the field line entanglement and the occurrence of reconnection events, as well as the dependence of the reconnection rate on the magnetic diffusivity.

EP 9.4 Fri 12:00 H5

Modern methods to solve nonlinear fluid equations – chances, issues and consequences for astrophysical fluid flows — •Dieter Nickeler — Astronomical Institute, Czech Academy of Sciences, Ondrejov, Czech Republic

During the last decades several methods to solve nonlinear equations of hydrodynamics and magneto-hydrodynamics exactly have been developed. The idea is to construct a broad range of solution classes, to get insight into physical and topological properties of the usual physical fluid theories. We discuss the mapping theories such as non-canonical and algebraic transformations, based on the existence of at least one first integral of the corresponding vector field. These mappings enable us to construct fields of higher complexity out of much more simple solutions, e.g. nonlinear fields out of potential fields. In 2D the calculation of potential magnetic fields/flows is facilitated by solving the 2D Laplace equation via conformal mapping theory. In 3D, the Whittaker method is a generalization of conformal mappings, by applying complex analysis to solve the Laplace equation in 3D. Taking advantage of these general solutions, by determining a first integral of the corresponding vector field, the above mentioned transformations are used to construct nonlinear solutions. Due to the nonlinear transformations and the special choice of linear equilibria they are based on, specific topological characteristics, e.g. separatrices (astropauses) and physical effects, e.g. current sheets or vortex sheets, possibly triggering dissipation or magnetic reconnection, are calculated.

Invited Talk EP 9.5 Fri 12:15 H5

The SOFIA legacy program FEEDBACK — •Nicola Schneider[1] and Alexander Tielens[2,3] — [1]I. Physik. Institut, University of Cologne — [2]Leiden Observatory, Leiden — [3]Dep. of Astronomy, University of Maryland

Massive stars play a key role in the evolution of the interstellar medium (ISM) in galaxies because they impact the ISM through ionization, stellar winds, and supernova explosions. This stellar feedback regulates the physical conditions of the ISM, sets its emission characteristics, and ultimately governs the star formation activity.

I present here the first results of the SOFIA (Stratospheric Observatory for Infrared Astronomy) legacy program FEEDBACK. The project has been granted 96 hours observing time and started in 2019 in order to map Galactic star-forming regions in the emission lines of ionized carbon ([CII]) at 158μm and oxygen ([OI]) at 63μm. The major results so far are that (i) we discovered in all FEEDBACK sources expanding bubbles seen in the [CII] line, driven by stellar winds, that trigger further star formation, (ii) large amounts of cold [CII] that is ionized by cosmic rays and associated with atomic hydrogen, and (iii) dynamic signatures of molecular cloud collisions seen with [CII].

The FEEDBACK program thus fullfills its expectation to quantify the relationship between star formation activity and energy injection and the negative and positive feedback processes involved, and link that to other measures of activity on scales of individual massive stars, of small stellar groups, and of star clusters.

EP 9.6 Fri 12:45 H5

Nebular kinematics and variability of the Galactic B[e] supergiant star MWC 137 — •Michaela Kraus — Astronomical Institute, Czech Academy of Sciences, Ondrejov, Czech Republic

The Galactic object MWC 137, with its large-scale optical bipolar ring nebula and high-velocity jet and knots, is a rather atypical representative of the B[e] supergiant class. To shed light on the physical conditions and kinematics of the nebula we performed multi-wavelength observations spreading from the optical to the radio regimes. Our data reveal a new bow-shaped feature at a distance of 80" from MWC 137. Moreover, we found that large amounts of cool molecular gas and warm dust embrace the large-scale optical nebula in the east, south, and west. The radial velocities of the nebula display a complex behavior but, in general, the northern nebular features are predominantly approaching while the southern ones are mostly receding. The electron density shows strong variations across the nebula with higher densities closer to MWC 137 and in regions of intense emission. In regions with high radial velocities the density decreases significantly. A disk of hot molecular gas revolves the star on small scales and possibly triggers the jet. The emission of this disk is reflected by dust arranged in arc-like structures and clumps surrounding MWC 137. Furthermore, we detect a period of 1.93 d in the time series photometry collected with the TESS satellite, which could suggest stellar pulsations. Other, low-frequency variability is seen as well. Whether these signals are caused by internal gravity waves in the early-type star or by variability in the wind and circumstellar matter currently cannot be distinguished.

EP 10: Astrophysics II

Time: Friday 14:00–15:00 Location: H5

EP 10.1 Fri 14:00 H5

Structure formation in isothermal supersonic plasmas: magnetic helicity inverse transfer — •Jean-Mathieu Teissier[1] and Wolf-Christian Müller[1,2] — [1]Technische Universität Berlin, Berlin, Deutschland — [2]Max-Planck/Princeton Center for Plasma Physics, Princeton, NJ, USA

The interstellar medium exhibits large-scale magnetic structures and a wide range of turbulent sonic Mach numbers (from subsonic to Mach numbers of order 10 and beyond), with different turbulent drivers. A mechanism to explain the presence of large-scale structures is the inverse transfer of magnetic helicity, a quadratic ideal invariant describing some topological aspects of the magnetic field. Its inverse transfer has been investigated in direct numerical simulations (DNS), up to this work, only in incompressible and low Mach number cases. We present results from DNS in the isothermal case with Mach numbers ranging up to about 10 with different turbulence drivers and point out differences and similarities with the incompressible case, in particular with respect to spectral scaling laws and Fourier shell-to-shell transfers.

Our work suggests that some incompressible dynamical balances are extended in the supersonic regime and that the driving type affects the dynamics more significantly than the turbulent Mach number alone.

EP 10.2 Fri 14:15 H5

Der AGN TXS 0506+056 als Quelle hochenergetischer Neutrinos — •Maximilian Albrecht und Felix Spanier — Universität Heidelberg - ITA

Aktive Galaktische Kerne sind bereits seit längerer Zeit in der Diskussion als mögliche Beschleuniger hochenergetischer kosmischer Strahlung. Als der Blazar TXS 0506+056 infolge einer groß angelegten Multimessenger-Kampagne als Quelle des vom IceCube-Teleskop 2017 detektierten hochenergetischen Muon-Neutrinos (IceCube-170922A) identifiziert wurde, war dies ein erster Hinweis auf mögliche Korrelationen der erhöhten spektralen Aktivität solcher Quellen und ihrer Neutrinoproduktion. Studien dieser Korrelation durch Simulation der im Jet stattfindenden Beschleunigungsprozesse und ihrer Photonen- und Neutrinoemission, lassen daher durch den Vergleich mit den beobachteten Flüssen Rückschlüsse auf die Zusammensetzung des Jet-Plasmas zu.

In diesem Beitrag sollen die Ergebnisse einer Modellierung des Ausbruchs von TXS 0506+056 aus dem Jahr 2017 anhand der vorhandenen Multimessenger-Daten mit dem Zwei-Zonen-Modell UNICORN-0D vorgestellt werden. Im Gegensatz zu vorherigen Modellen wurde dabei die Emission der Host-Galaxie berücksichtigt. Dann konnte mittels Dopplerfaktor, Magnetfeld und den Protron- und Elektrondichten der Quelle die erwartete IceCube Detektion ermittelt und mit den Daten verglichen werden.

EP 10.3 Fri 14:30 H5

The MAGIX Trigger Veto System — •Sebastian Stengel for the MAGIX-Collaboration — Johannes Gutenberg University Mainz, Institute for Nuclear Physics, Germany

The MAGIX setup will be used for Dark Photon searches using the visible as well as the invisible decay channel. The MAGIX trigger veto system will enable the fast timing characteristics needed for investigating the visible Dark Photon decay channel A* -> e+e-. It will further be used for energy-loss measurements and will provide the basic hit and position information for the triggered readout of the MAGIX time projection chamber. The MAGIX trigger veto system will consist of one segmented trigger layer of plastic scintillator bars and a flexible veto system of additional scintillation detectors and lead absorbers placed beneath the trigger layer. The data readout will use the ultrafast preamplifier-discriminator NINO chip developed for use in the ALICE detector followed by FPGAs programmed as TDCs.

EP 10.4 Fri 14:45 H5

Representation of Subatomic Particles as focal points and the repercussion on extra-terrestrial gravitation. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

An approach is presented where a subatomic particle (SP) is represented as a focal point of rays of Fundamental Particles (FPs) that move from infinite to infinite. The energy of a subatomic particle is stored at its FPs as rotation defining angular momenta. With this representation all SPs interact permanently through the angular momenta of their FPs, according to the Mach principle that postulates that physical laws are determined by the large-scale structure of the universe. The approach explains gravitation as the result of the physical reintegration of migrated electrons and positrons to their nuclei. Gravitation is so composed of a Newton and an Ampere component, with the Newton component dominant at sub galactic distances and the Ampere component at galactic distances. A positive Ampere component explains the speed flattening of galaxies and a negative Ampere component the expansion. As with this approach SPs are permanently interacting through their FPs, there is no need to introduce carrier particles in the theoretical model to explain their interactions, carriers like gluons, gravitons, W and Z Bosons, etc. All four known forces are the result of electromagnetic interactions. More at: www.odomann.com

Gravitation and Relativity Division
Fachverband Gravitation und Relativitätstheorie (GR)

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Welcome to the annual meeting of the *General-Relativity and Gravitation* division of the DPG at - virtually - Jena. Despite the adverse circumstances, forcing us to hold this meeting in a purely online format, we have again a rich scientific program, including some outstanding highlights. We will take part in two symposia, one on "Entanglement" (Monday) the other on "Neutron Stars" (Thursday). There will be two distinguished plenary-like talks, one by Alessandra Buananno (MPI Golm), who would have been our plenary speaker last year and who will speak on "News from the Gravitational-Waves Sky", the other by Heino Falcke (Radboud U.) on how Black-Holes look like. Last not least, on Tuesday evening, this year's Nobel-Prize laureate Reinhard Genzel will deliver an evening talk on the Galctic Black-Hole. Let me also draw your attention to our General Assembly of Members on Thursday evening, starting at 19:00. Finally, I wish all of you a pleasant and informative week!

Overview of Invited Talks and Sessions

(Lecture halls H2, H4, H6, and H9)

Plenary Talk of the Gravitation and Relativity Division

PV II	Mon	9:45–10:30	Audimax	**What's in a Shadow** — •Heino Falcke

Invited Talks

GR 2.1	Tue	11:00–11:45	H6	**The Sagnac effect in General Relativity** — •Jörg Frauendiener
GR 4.1	Tue	16:30–17:15	H6	**News from the Gravitational-Wave Sky** — •Alessandra Buonanno

Invited talks of the joint symposium Entanglement (SYEN)

See SYEN for the full program of the symposium.

SYEN 1.1	Mon	16:30–17:10	Audimax	**Squeezed and entangled light - now exploited by all gravita-tional-wave observatories** — •Roman Schnabel
SYEN 2.1	Mon	17:10–17:50	Audimax	**Entanglement and Explanation** — •Chris Timpson
SYEN 3.1	Mon	17:50–18:30	Audimax	**Entanglement and complexity in quantum many-body dynamics** — •Tomaz Prosen

Invited talks of the joint symposium Neutron stars (SYNS)

See SYNS for the full program of the symposium.

SYNS 1.1	Thu	14:00–14:40	Audimax	**Binary neutron stars: from gravitational to particle physics** — •Luciano Rezzolla
SYNS 1.2	Thu	14:40–15:20	Audimax	**Probing subatomic physics with gravitational waves** — •Tanja Hinderer
SYNS 1.3	Thu	15:20–16:00	Audimax	**A NICER view of neutron stars** — •Anna Watts

Sessions

GR 1.1–1.6	Mon	11:00–12:30	H2	**Black Holes**
GR 2.1–2.4	Tue	11:00–12:30	H6	**Classical GR-1**
GR 3.1–3.8	Tue	14:00–16:00	H6	**Classical GR-2**
GR 4.1–4.6	Tue	16:30–18:30	H6	**Gravitational waves**
GR 5.1–5.7	Wed	14:00–15:45	H6	**Alternative aspects and formulations**
GR 6.1–6.8	Wed	16:30–18:30	H6	**Numerical relativity**
GR 7.1–7.4	Thu	11:00–12:00	H9	**Experimental tests**
GR 8.1–8.2	Thu	12:00–12:30	H9	**Quantum field theory in curved spacetimes**
GR 9.1–9.4	Thu	16:30–17:30	H9	**Cosmology**
GR 10.1–10.2	Thu	17:30–18:00	H9	**Scalar-tensor and non-local gravity theories**
GR 11.1–11.2	Thu	18:00–18:30	H9	**Didactical and heuristic aspects**
GR 12	Thu	19:00–20:30	H9	**Annual General Meeting**
GR 13.1–13.5	Fri	11:00–12:15	H4	**Quantum gravity and cosmology**

Mitgliederversammlung des Fachverbands Gravitation und Relativitätstheorie

Donnerstag 19:00–20:30 MVGR

- Bericht des Vorsitzenden
- Wahl zur Neubesetzung des Vorsitzes
- Wahl des Beirats
- Verschiedenes

Sessions

– Invited and Contributed Talks –

GR 1: Black Holes

Time: Monday 11:00–12:30 Location: H2

GR 1.1 Mon 11:00 H2

Microlensing in terms of an exact lens map — •Volker Perlick — ZARM, University of Bremen, Germany

In spherically symmetric and static spacetimes, gravitational lensing can be formulated in terms of an exact lens map, in close analogy to the weak-field formalism of lensing. Whereas in the latter case the lens map is a map from a lens plane to a source plane, the exact lens map is a map from the celestial sphere of the observer to a sphere where the light sources are thought to be situated. It is demonstrated that, with the help of the exact lens map, microlensing light curves can be calculated exactly. Several examples are presented, including microlensing by a Barriola-Vilenkin monople and by a Schwarzschild black hole.

GR 1.2 Mon 11:15 H2

Gravitational Lensing by Charged Accelerating Black Holes — •Torben Frost — ZARM, Universität Bremen, Bremen, Germany — ITP, Leibniz Universität Hannover, Hannover, Germany

Current astrophysical observations show that on large scale the Universe is electrically neutral. However, locally this may be quite different. Black holes enveloped by a plasma in the presence of a strong magnetic field may have acquired a significant electric charge. We can also expect that some of these charged black holes are moving. Consequently to describe them we need spacetime metrics describing moving black holes. In general relativity such a solution is given by the charged C-de Sitter-metric. In this talk we will assume that it can be used to describe moving charged black holes. We will investigate how to observe the electric charge using gravitational lensing. First we will use elliptic integrals and functions to solve the geodesic equations. Then we will derive lens equation, travel time and redshift. We will discuss the impact of the electric charge on these observables and potential limitations for its observation.

GR 1.3 Mon 11:30 H2

Photon region and shadow in a spacetime with a quadrupole moment — •Jan Hackstein and Volker Perlick — ZARM, University of Bremen, Germany

A black hole's shadow is expected to deform under the influence of an external gravitational field caused by matter present in its vicinity. This talk aims to characterise the distortion of a Schwarzschild black hole shadow due to a non-zero quadrupole moment c_2 by qualitatively investigating the behaviour of light rays close to the black hole horizon. In particular, the numerical investigation in the meridional plane for $1 \gg c_2 > 0$ finds four non-circular closed geodesics and their neighbouring geodesics exhibit chaotic behaviour that is not present in the undistorted Schwarzschild spacetime. The black hole shadow is therefore approximated by restricting the observational setup accordingly. In that case, the black hole shadow's eccentricity indicates a prolate deformation for static observers. The photon sphere in the Schwarzschild spacetime deforms into a photon region with a crescent-shaped projection on the meridional plane. Furthermore, the resulting boundary curve of the black hole shadow is visualised.

GR 1.4 Mon 11:45 H2

Application of the Gauss-Bonnet theorem to lensing in the NUT metric — •Mourad Halla and Volker Perlick — ZARM, Universität Bremen

We show with the help of Fermat's principle that every lightlike geodesic in the NUT metric projects to a geodesic of a two-dimensional Riemannian metric which we call the optical metric. The optical metric is defined on a (coordinate) cone whose opening angle is determined by the impact parameter of the lightlike geodesic. We show that, surprisingly, the optical metrics on cones with different opening angles are locally (but not globally) isometric. With the help of the Gauss-Bonnet theorem we demonstrate that the deflection angle of a lightlike geodesic is determined by an area integral over the Gaussian curvature of the optical metric. A similar result is known to be true for static and spherically symmetric spacetimes. The generalisation to the NUT spacetime, which is neither static nor spherically symmetric (at least not in the usual sense), is rather non-trivial.

GR 1.5 Mon 12:00 H2

Spin-Induced Scalarized Black Holes — Emanuele Berti[1], Lucas Collodel[2], Burkhard Kleihaus[3], and •Jutta Kunz[3] — [1]Johns Hopkins University Baltimore — [2]University of Tübingen — [3]University of Oldenburg

When General Relativity is supplemented with a Gauss-Bonnet term coupled to a scalar field, scalarized black holes arise. For appropriately chosen coupling functions Kerr black holes remain solutions of the field equations, but undergo a tachyonic instability, where curvature induced scalarized black holes arise. For slow rotation, these scalarized rotating black holes are connected to the static black holes. However, for fast rotation a second set of scalarized black holes arises, which exist only above the value of the Kerr rotation parameter $a = 0.5\,M$. In this talk such even and odd parity black hole solutions with spin-induced scalarization are presented, and their properties are discussed.

GR 1.6 Mon 12:15 H2

Quasinormal modes of hot, cold and bald Einstein-Maxwell-scalar black holes — Jose Luis Blázquez-Salcedo[1], Carlos A. R. Herdeiro[2], •Sarah Kahlen[3], Jutta Kunz[3], Alexandre M. Pombo[2], and Eugen Radu[2] — [1]Universidad Complutense de Madrid, Spain — [2]Universidade de Aveiro, Portugal — [3]Universität Oldenburg, Germany

In Einstein-Maxwell-scalar (EMs) theory, gravity is coupled to a Maxwell field and a scalar field ϕ, with some function f coupling the two fields. The choice of that function strongly influences the properties of the resulting black hole solutions. In the talk, static spherically symmetric EMs black hole solutions with coupling function $f(\phi) = 1 + \alpha\phi^4$ are dealt with. For fixed coupling constant α, there are two branches of solutions. The quasinormal modes, the eigenvalues of the linearly perturbed field equations, that can be categorized into axial and polar modes, are presented for both these branches. This allows for statements about their stability, and it is furthermore demonstrated how the presence of the scalar field influences different types of modes and breaks the isospectrality between polar and axial modes, which e.g. holds for Reissner-Nordström black holes in Einstein-Maxwell theory and for Schwarzschild black holes.

GR 2: Classical GR-1

Time: Tuesday 11:00–12:30 Location: H6

Invited Talk GR 2.1 Tue 11:00 H6

The Sagnac effect in General Relativity — •Jörg Frauendiener — University of Otago, Dunedin, New Zealand

The Sagnac effect can be described as the difference in travel time between two photons traveling along the same path in opposite directions. In this talk we explore the consequences of this characterisation in the context of General Relativity. We derive a general expression for this time difference in an arbitrary space-time for arbitrary paths. In general, this formula is not very useful since it involves solving a differential equation along the path. However, we also present special cases where a closed form expression for the time difference can be given. We discuss the effect in a small neighbourhood of an arbitrarily moving observer in their arbitrarily rotating reference frame. Time permitting we may also discuss the special case of stationary space-times and point out the relationship between the Sagnac effect and Fizeau's "aether-drag" experiment.

GR 2.2 Tue 11:45 H6

Gravitational Properties of Light — •Dennis Rätzel — HU Berlin

The properties of light are premises in the foundations of modern physics: they were used to derive special and general relativity and are the basis of the concept of time and causality in many alternative models. Therefore, it is worthwhile to study the gravitational field of light with its rich phenomenology, even though the effects are in general very weak. In this talk, an overview is given of the gravitational properties of light, in particular, of laser pulses and focused laser beams with well-defined angular momentum. The time-dependence in the case of a laser pulse enables the investigation of the formation of the gravitational field of light. The stationary case of the gravitational field of a focused laser beam shows effects of the fundamental wave properties of light. I will also present results on the effect of angular momentum of light: frame dragging, the gravitational Faraday effect and gravitational spin-spin coupling of light.

GR 2.3 Tue 12:00 H6

General Relativistic Geodesy — •Claus Lämmerzahl and Volker Perlick — ZARM, University of Bremen

Geodesy in a Newtonian framework is based on the Newtonian potential. The general relativistic gravitational field, however, possesses more degrees of freedom. Accordingly, the full gravitational field of a stationary source can be decomposed into two scalar potentials and a tensorial spatial metric, which together serve as basis of a general relativistic geodesy. One of the scalar potentials is a generalization of the Newtonian potential while the second is related to the rotational degree of freedom of gravitating masses for which no non-relativistic counterpart exists. The operational realizations of these two potentials are discussed, as well as of the spatial metric. For analytically given space-times the two potentials are exemplified and their relevance for practical geodesy on Earth are discussed.

GR 2.4 Tue 12:15 H6

Chronometric Height: a genuine general relativistic definition of height in geodesy — •Dennis Philipp — ZARM, Universität Bremen

The Newtonian gravity potential is one of the main objects for conventional geodesy and employed for basic concepts, such as the definition of heights. A modern height definition in terms of geopotential numbers can offer a variety of advantages. Moreover, from the theoretical point of view, such a definition is considered more fundamental. We know, however, that relativistic gravity (General Relativity) requires to reformulate basic geodetic notions and to develop a consistent theoretical framework, relativistic geodesy, to yield an undoubtedly correct interpretation of contemporary and future (high-precision) measurement results. The new framework of chronometric geodesy that builds on the comparison of clocks at different positions in the gravitational field offers fundamental insight into the spacetime geometry if a solid theoretical formulation of observables is underlying all observations. For chronometry, high-performance clock networks, i.e., optical clocks connected by dedicated frequency transfer techniques, are capable to observe the mutual redshift with incredible accuracy. Here we approach a genuine relativistic definition of the concept of height. Based on the relativistic generalization of geopotential numbers, a definition of chronometric height is suggested, which reduces to the well-known notions in the weak-field limit. This height measure is conceptually based on the so-called time-independent redshift potential, which describes the gravitoelectric degree of freedom in General Relativity.

GR 3: Classical GR-2

Time: Tuesday 14:00–16:00 Location: H6

GR 3.1 Tue 14:00 H6

Geometrically thick tori around compact objects with a quadrupole moment — •Jan-Menno Memmen and Volker Perlick — Znetrum für angewandte Raumfahrttechnologien und Mikrogravitation, Bremen, Deutschland

We study geometrically thick perfect-fluid tori with constant specific angular momentum, so-called "Polish doughnuts", orbiting deformed compact objects with a quadrupole moment. More specifically, we consider two different asymptotically flat, static and axisymmetric vacuum solutions to Einstein's field equation with a non-zero quadrupole moment, the q-metric and the Erez-Rosen spacetime. It is our main goal to find features of Polish doughnuts in these two spacetimes which qualitatively distinguish them from Polish doughnuts in the Schwarzschild spacetime. As a main result we find that, for both metrics, there is a range of positive (Geroch-Hansen) quadrupole moments which allows for the existence of double tori. If these double tori fill their Roche lobes completely, their meridional cross-section has the shape of a fish, with the body of the fish corresponding to the outer torus and the fish-tail corresponding to the inner torus. Such double tori do not exist in the Schwarzschild spacetime.

GR 3.2 Tue 14:15 H6

A wild doughnut chase: Polish doughnuts around boson stars and their peculiarities — •Matheus C. Teodoro[1], Lucas G. Collodel[2], and Jutta Kunz[1] — [1]Institute of Physics, University of Oldenburg 26111 Oldenburg, Germany — [2]Theoretical Astrophysics, University of Tübingen 72076 Tübingen, Germany

In this talk we shall investigate and analyse some examples of polish doughnuts with a uniform constant specific angular momentum distribution in the spacetimes of rotating boson stars. These thick tori can exhibit peculiar features not present in Kerr space-times, specially in the context of retrograde tori. They may be endowed with two centers connect or not by a cusp or even present static surfaces. Inside these surfaces the fluid moves in prograde direction, while outside in the retrograde direction. All these features and how they appear will be the topic of this talk.

GR 3.3 Tue 14:30 H6

Influence of the relativistic Frequency-Shift on Continuous Variable Quantum Key Distribution — •Roy Barzel and Claus Lämmerzahl — ZARM, Universität Bremen

Quantum-Key-Distribution (QKD) offers the possibility to exchange confidential information unconditionally secure between two or more parties, in the sense that the security of the protocol does not depend on the computational or material limitations of a potential adversary intending to break the key. Since the quantum repeater technology is still far from being applicable to intercontinental quantum communication in the short term satellite-based free-space links today look like the most promising solution to achieve long-distance QKD. Therefore space-qualified, robust optical components, that will allow for stable data flow of high performance are required. Only making use of approved standard telecommunication technology for state preparation and detection continuous variable quantum key distribution (CV-QKD) today is one of the most promissing ways of implementation of a globaly operating network of secure quantum communication. Apart from atmospheric distortion effects like absorbtion recent studies revealed the sensitivity of CV-QKD against relativistic effects like the relativistic Doppler-shift and the gravitational redshift. In this talk it is shown how to quantify the influence of relativistic effects on the performance of CV-QKD in a quantum field theoretical framework. Methods are shown how to derive analytic formulas for the secret key rates in CV-QKD protocolls between satellites and ground stations, which depend on the orbital parameters of the communicators.

GR 3.4 Tue 14:45 H6

Tidal g-mode resonances in coalescing binaries of neutron stars as triggers for precursor flares of short gamma-ray bursts — •Hao-Jui Kuan — University of Tübingen

In some short gamma-ray bursts, precursor flares occurring ~ seconds prior to the main episode have been observed. These flares may then be associated with the last few cycles of the inspiral when the orbital frequency is a few hundred Hz. During these final cycles, tidal forces can resonantly excite quasi-normal modes in the inspiralling stars, leading to a rapid increase in their amplitude. It has been shown that these modes can exert sufficiently strong strains onto the neutron star crust to instigate yieldings. Due to the typical frequencies of g-modes being ~ 100 Hz, their resonances with the orbital frequency match the precursor timings and warrant further investigation. Adopting realistic equations of state and solving the general-relativistic pulsation equations, we study g-mode resonances in coalescing quasi-circular binaries, where we consider various stellar rotation rates, degrees of stratification, and magnetic field structures. We show that for some combination of stellar parameters, the resonantly excited g_1- and g_2-modes may lead to crustal failure and trigger precursor flares.

GR 3.5 Tue 15:00 H6

On the properties of metastable hypermassive hybrid stars — •Matthias Hanauske[1,2], Horst Stöcker[1,2], and Luciano Rezzolla[1,2] — [1]Institut für Theoretische Physik, Max-von-Laue-Straße 1, 60438 Frankfurt, Germany — [2]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Straße 1, 60438 Frankfurt, Germany

Hypermassive hybrid stars (HMHS) are extreme astrophysical objects that could be produced in the merger of a binary system of two neutron stars. In contrast to their purely hadronic counterparts, hypermassive neutron stars (HMNS), these highly differentially rotating objects contain deconfined strange quark matter in their slowly rotating inner region. HMHS and HMNS are both metastable configurations and can survive only shortly after the merger before collapsing to rotating black holes. The properties of a HMHS/HMNS (e.g. rotational property, density and temperature distribution) and the space-time distortion it causes, have been computed by fully general-relativistic hydrodynamic simulations and the complicated dynamics of the collapse from a HMNS to a more compact HMHS have been analysed in detail. The interplay between the density and temperature distributions and the differential rotational profiles in the interior of the HMHS, produces a clear gravitational wave signature of the production of quark matter, if the hadron-quark phase transition is strong enough. During the collapse of the HMHS to a Kerr Black the color degrees of freedom of the pure strange quark matter core gets macroscopically confined by the formation of the event horizon.

GR 3.6 Tue 15:15 H6

Consistent solution of Einstein-Cartan equations with torsion outside matter — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil

The Einstein-Cartan equations in first-order action of torsion are considered.

From Belinfante-Rosenfeld equation special consistence conditions are derived for the torsion parameters relating them to the metric. Inside matter the torsion is given by the spin which leads to an extended Oppenhaimer-Volkov equation. Outside matter a second solution is found besides the torsion-free Schwarzschild one with the torsion completely determined by the metric and vice-versa. This solution is shown to be of non-spherical origin and its uniqueness with respect to the consistence is demonstrated. Unusual properties are discussed in different coordinate systems where the cosmological constant assumes the role of the Friedman parameter in Friedman-Lamaître-Robertson-Walker cosmoses. Parameters are specified where wormholes are possible. Transformations are presented to explore and map regions of expanding and contracting universes to the form of static metrics. The autoparallel equations are solved exactly and compared with geodesic motion. The Weyl tensor reveals that the here found solution is of Petrov-D type. [arXiv:2010.01393]

GR 3.7 Tue 15:30 H6

The gravitating kinetic gas - Lifting the Einstein Vlasov system to the tangent bundle — •Christian Pfeifer — ZARM, University of Bremen, Bremen, Germany

In this talk I will present a new model for the description of a gravitating kinetic gas, by coupling the 1-particle distribution function (1PDF) of the gas directly to the gravitational field, described directly by the geometry of the tangent bundle of spacetime. This procedure takes the influence of the velocity distribution of the kinetic gas particles on their gravitational field fully into account, instead of only on average, as it is the case for the Einstein-Vlasov system.

By using Finsler spacetime geometry I construct an action for the kinetic gas on the tangent bundle, which is added as matter action to a canonical Finslerian generalisation of the Einstein-Hilbert action. The invariance of the kinetic gas action under coordinate changes gives rise to a new notion of energy-momentum conservation of a kinetic gas in terms of an energy-momentum distribution tensor. The variation of the total action with respect to the spacetime geometry defining Finsler Lagrangian yields the gravitational field equation, which determines the geometry of spacetime directly from the full non-averaged 1PDF.

GR 3.8 Tue 15:45 H6

Teleparallel Newton–Cartan gravity — •Philip K Schwartz — Institute for Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany

We discuss a teleparallel version of Newton–Cartan gravity. This theory arises as a formal large-speed-of-light limit of the teleparallel equivalent of general relativity (TEGR). Thus, it provides a geometric formulation of the Newtonian limit of TEGR, similar to standard Newton–Cartan gravity being the Newtonian limit of general relativity. We show how by a certain gauge-fixing the standard formulation of Newtonian gravity can be recovered.

GR 4: Gravitational waves

Time: Tuesday 16:30–18:30 Location: H6

Invited Talk GR 4.1 Tue 16:30 H6

News from the Gravitational-Wave Sky — •Alessandra Buonanno — Max Planck Institute for Gravitational Physics, Potsdam

The solution of the two-body problem in General Relativity is playing a crucial role in observing gravitational waves from binary systems composed of black holes and neutron stars, and inferring their astrophysical, cosmological and gravitational properties. After reviewing the synergistic approach that successfully combines analytical and numerical relativity to produce highly accurate waveform models, I will discuss the most compelling and puzzling findings from the most recent LIGO-Virgo observing run.

GR 4.2 Tue 17:15 H6

GW190521: A dynamical capture of two black holes — •Rossella Gamba — TPI, Friedrich-Schiller-Universität Jena

We analyze the gravitational-wave signal GW190521 under the hypothesis that it was generated by the merger of two nonspinning black holes on hyperbolic orbits. The best configuration matching the data corresponds to two black holes of source frame masses of $81^{+62}_{-25}M_\odot$ and $52^{+32}_{-32}M_\odot$ undergoing two encounters and then merging into an intermediate-mass black hole. Under the hyperbolic merger hypothesis, we find an increase of one unit in the recovered signal-to-noise ratio and a 14 e-fold increase in the maximum likelihood value compared to a quasi-circular merger with precessing spins. We conclude that our results support the first gravitational-wave detection from the dynamical capture of two stellar-mass black holes.

GR 4.3 Tue 17:30 H6

Training Strategies for Deep Learning Gravitational-Wave Searches — Marlin Benedikt Schäfer[1,2], •Ondřej Zelenka[3,4], Alexander Harvey Nitz[1,2], Frank Ohme[1,2], and Bernd Brügmann[3,4] — [1]Max-Planck-Institut für Gravitationsphysik, Albert-Einstein-Institut, D-30167 Hannover, Germany — [2]Leibniz Universität Hannover, D-30167 Hannover, Germany — [3]Friedrich-Schiller-Universität Jena, D-07743 Jena, Germany — [4]Michael Stifel Center Jena, D-07743 Jena, Germany

Deep learning may be capable of finding gravitational wave signals where current algorithms hit computational limits. We restrict our analysis to signals from non-spinning binary black holes and systematically test different strategies by which training data is presented to the networks. To assess their impact, we reanalyze the first published networks and directly compare them to an equivalent matched-filter search. We find that the deep learning algorithms can generalize low signal-to-noise ratio (SNR) signals to high SNR ones but not vice versa. As such, it is not beneficial to provide high SNR signals during training, and fastest convergence is achieved when low SNR samples are provided early on. We found that the networks are sometimes unable to recover any signals when a false alarm probability $< 10^{-3}$ is required. We resolve this by applying a modification we call unbounded Softmax replacement (USR) after training. With this alteration we find that the machine learning search retains $\geq$ 97.5% of the sensitivity of the matched-filter search down to a false-alarm rate of 1 per month.

GR 4.4 Tue 17:45 H6

A Deep Learning Gravitational-Wave Coincidence Search — •Marlin Benedikt Schäfer[1,2] and Alexander Harvey Nitz[1,2] — [1]Albert-Einstein-Institut, D-30167 Hannover, Germany — [2]Leibniz Universität Hannover, D-30167 Hannover, Germany

Gravitational waves emitted by a coalescing binary system of compact objects are now routinely observed by Earth bound detectors. The most sensitive search algorithms convolve many different pre-calculated waveform models with the detector data and look for coincident matches between different detectors. Machine learning is now being explored as an alternative search algorithm that has the prospect to reduce computational costs and target more complex signals. In this work we construct a two detector machine learning search from a neural network trained on non-spinning binary black hole data from a single detector. The network is applied to the data from both observatories independently and we check for events coincident in time between the two. We compare our findings to an equivalent matched filter search and a comparable two-detector neural network search.

GR 4.5 Tue 18:00 H6

Search for lensing signatures in the gravitational-wave observations from the first half of LIGO-Virgo's third observing run — •David Keitel for the LIGO-Virgo-Collaboration — Departament de Física, Edifici Mateu Orfila, Universitat de les Illes Balears, Carretera de Valldemossa, km 7,5, 07122 Palma de Mallorca, Illes Balears, Spain

The Advanced LIGO and Advanced Virgo detectors are now observing large numbers of gravitational-wave signals from compact binary coalescences, with 50 entries in the latest catalogue GWTC-2. With this rapidly growing event rate, our chances become better to detect rare astrophysical effects on these novel cosmic messengers. One such rare effect with a long and productive history in electromagnetic astronomy and great potential for the future of GW astrophysics is gravitational lensing. This presentation covers the first LIGO-Virgo collaboration search for lensing signatures in data from the O3a observing run. We study: 1) the expected rate of lensing at current detector sensitivity and the implications of a non-observation of strong lensing or a stochastic gravitational-wave background on the merger-rate density at high redshift; 2) how the interpretation of individual high-mass events would change if they were found to be lensed; 3) the possibility of multiple images due to strong lensing by galaxies or galaxy clusters; and 4) possible wave-optics effects due to point-mass microlenses. Overall, we find no compelling evidence for lensing in the observed gravitational-wave signals from any of these analyses.

GR 4.6 Tue 18:15 H6

Dark Sirens to Resolve the Hubble-Lemaître Tension — •Ssohrab Borhanian[1,2], Arnab Dhani[2], Anuradha Gupta[3], K.G. Arun[4], and Bangalore Sathyaprakash[2] — [1]Friedrich-Schiller-Universität Jena, Jena, Germany — [2]Institute for Gravitation and the Cosmos, State College, USA — [3]University of Mississippi, Oxford, USA — [4]Chennai Mathemartical Institute, Chennai, India

The planned sensitivity upgrades to the LIGO and Virgo facilities could uniquely identify host galaxies of dark sirens, compact binary coalescences without any electromagnetic counterparts, within a redshift of z = 0.1. This is aided by the higher-order spherical harmonic modes present in the gravitational-wave signal, which also improve distance estimation. In conjunction, sensitivity upgrades and higher modes will facilitate an accurate, independent measurement of the host galaxy's redshift in addition to the luminosity distance from the gravitational-wave observation to infer the Hubble-Lemaître constant to better than a few percent in five years. A possible Voyager upgrade or third-generation facilities would further solidify the role of dark sirens for precision cosmology in the future.

GR 5: Alternative aspects and formulations

Time: Wednesday 14:00–15:45 Location: H6

GR 5.1 Wed 14:00 H6

The Dark Matter Problem and a General Solution — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

The problem of dark matter in the rotation of galaxies has existed for 90 years. Further unexplained phenomena in astronomy are also related to this title, such as gravitational lensing, structure formation, the excessive number of small galaxies and the Bullet Cluster.

The solutions attempted by contemporary physics assume invisible 'dark' particles, or else modified Newton dynamics (MOND). But neither yields a solution for all cases. And even worse: Each theory is in conflict with observations covered by the other solution. This means: no solution exists. - And no evidence of dark matter particles has been found despite intense efforts.

A general solution may be provided by an approach to gravity which was initially pursued by Einstein in 1911, before switching to his space-time structure. In it, Einstein used the variation of the speed of light c in a gravitational field. - If this variation is applied to the internal oscillations in a particle, it causes grav. acceleration. Now, the cause of the variation in c is not plausibly the mass of the source, because light particles, as neutrinos and photons, reduce c equally as all other objects around them and so contribute to the gravitational field.

This alternative view on gravity can be shown to explain all aspects of dark matter. In particular, rotation curves can be calculated quantitatively. It also covers those cases for which both the present solutions provide nothing, such as luminosity-dependent phenomena (Renzo / Tully-Fisher). And it conforms to GR.

GR 5.2 Wed 14:15 H6

Time velocity - handling time dilation between two points in space-time — •Bjørn Ebbesen — Hamburg, Germany

Combining SRT with static gravitation, as done in the following, could have been a forerunner to the ART.

This approach leads to a concept of time velocity, which not only simplifies handling time dilation. Without relying on ART we get straight forward a variety of old and new insights on gravitation, energy, matter and space.

Some suggestions for theoretical and experimental physics are given.

Finally, concept of time velocity enables a new interpretation of cosmological red-shift.

GR 5.3 Wed 14:30 H6

Re-defining the basic concept of Time and Space — •Harjeet Singh — HCL Technologies, Vilnius, Lithuania

This paper aims at a new understanding on the basic concept of *Time and Space* dimension that can supersede the present *Spacetime* dimension. Hence, it can contribute in exploring time beyond the Big Bang * the edge of Spacetime dimension.

The approach in this research is based on scientific skepticism, which is further based on interpretation of relevant theories related to Time and Space. The present research not only introduces and proves the hypothesis that the Entire-Existence is the sole all-inclusive entity comprising of all the physical entities, but also changes the entire notion of Spacetime from being a physical entity to being two different physical dimensions *Time and Space*. The term *dimension* is the measure of a particular property of any physical entity such as Mass, Length, Temperature etc. Thereby, this research redefines *Time* as a dimension to measure the change of state of Entire-Existence and *Space* as a dimension to measure the spatial expanse of Entire-Existence. This research eventually solves several paradoxes concerning time travel and examines the possibility and scope of actual time travel.

Nevertheless, the testable predictions have been observed based on the proved hypothesis, as per which the empirical investigations can be performed further. This research will certainly expand the horizons of our current known Universe.

GR 5.4 Wed 14:45 H6

Gravitation represented as a physical interaction of subatomic particles instead of a geometrical space-time curvature model. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

GR is the theory of gravitation of the SM. It is a mathematical approach from 1915, based on the representation of subatomic particles as isolated entities in space, arriving to the wondrous concept of space-time curvature. GR resists all intents of integration into a unified field theory and is not compatible with quantum mechanics. An approach is presented for a gravitation theory that is based on the representation of a subatomic particle (SP) as a focal point of rays of Fundamental Particles (FPs) that move from infinite to infinite. The energy of a subatomic particle is stored at its FPs as rotation defining angular momenta. With this representation all SPs interact permanently through the angular momenta of their FPs, according to the Mach principle that postulates that physical laws are determined by the large-scale structure of the universe. The approach explains gravitation as the result of the physical reintegration of migrated electrons and positrons to their nuclei. Gravitation is so composed of a Newton and an Ampere component, with the Newton component dominant at sub galactic distances and the Ampere component at galactic distances. A positive Ampere component explains the speed flattening of galaxies and a negative Ampere component the expansion. More at: www.odomann.com

GR 5.5 Wed 15:00 H6

Methode um die Bewegung zum Gravitationsfeld zu messen. — •Karl-Herbert Darmer — Meyertwiete 7, 22848 Norderstedt

Haben wir die Relativität schon richtig verstanden? Dazu zwei grundlegende Fragen: Gibt es etwas im *leeren Raum* das bestimmt, ob ein Körper rotiert? Wenn es etwas gibt, zu dem man rotieren kann, dann kann man sich auch geradlinig dazu bewegen. Was haben Uhren mit der *Zeit* zu tun? Atomuhren gehen auf dem Berg schneller und Pendeluhren langsamer als im Tal. Ich gehe davon aus, dass beide mit der Zeit gleichviel zu tun haben. Nur die angezeigten Messwerte werden durch Umgebungs- veränderungen unterschiedlich beeinflusst, weil sie unterschiedliche Messprinzipien haben. Ein anderes Beispiel: Man misst eine Masse mit einer Balkenwaage und einer Federwaage. Das wiederholt man auf dem Mond und erhält bei der Federwaage ein anderes Ergebnis. Die Frage ist: Was haben Waagen mit der Masse zu tun? Bei der Rotation zeigen die Uhren einen eindeutig unterschiedlichen Gang. Siehe Universal Time Coordinated und die Satellitennavigation. Unter Einsteins Gleichzeitigkeitsdefinition sind die Verhältnisse identisch zu Inertialsystemen. Bei der Rotation kann aber gezeigt werde, dass hier die räumliche Gleichzeitigkeit nicht Einsteins Gleichzeitigkeitsdefinition entsprechen kann. Aus dem Gang von Licht- oder Atomuhren kann eine Methode abgeleitet werden, mit der man die Relativbewegung zu dem messen kann, was den Gang der Uhren bestimmt. Das geht dann nicht nur bei der Rotation, sondern auch bei der geradlinigen oder inertialen Bewegung. Mehr dazu unter www.darmer.de/2021SMuK

GR 5.6 Wed 15:15 H6

Relativity expressed as a speed problem instead of a space-time problem, as done in special relativity. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

Variables of one physical event expressed in two relative moving inertial reference systems are defined by the constant relative speed. Special relativity is built on space and time instead of only the relative speed to get the constant light speed in both reference systems. Unphysical relative variables of time and space and contradictions (twin paradox) are the results. The present paper is a work where relativity is treated exclusively as a speed problem to get the constant light speed in both reference systems. The result is that time and space are absolute variables without contradictions. The Lorentz transformation gives the well-known relativistic equations for the momentum, acceleration, energy and longitudinal Doppler-Effect. The approach also concludes that light is emitted with light speed in the reference system of its source and that it arrives to the second inertial reference system with the speed c+-v, contrary to Einstein*s postulate, that light moves always with light speed independent of its source. More at www.odomann.com

GR 5.7 Wed 15:30 H6

Lorentzianische Relativität — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

Warum lorentzianisch? Die Relativität von Einstein beruht auf der Annahme, dass die gemessene Konstanz der Lichtgeschwindigkeit eine physikalische Realität ist, kein bloßes Messergebnis. Sie führt jedoch zu Komplikationen. Sie erforderte den Ansatz einer verwobenen Raumzeit, welche die viel einfachere euklidische Geometrie ersetzten musste. Einsteins Ansatz führt dabei zu logischen Konflikten, sobald es sich nicht um lineare Bewegung, sondern um Drehung handelt. Einstein hat diese Konflikte sogar gegenüber seinem Kollegen Lorentz eingeräumt, und er hat nie eine echte Lösung dafür angeboten.

Folgt man dem Ansatz von Lorentz, werden sowohl die mathematische Behandlung als auch die Vorstellbarkeit grandios einfacher. Die logischen Konflikte bei Einstein werden vermieden. Offene Probleme der heutigen RT wie vor allem die Dunkle Energie entfallen gänzlich.

GR 6: Numerical relativity

Time: Wednesday 16:30–18:30 Location: H6

GR 6.1 Wed 16:30 H6

The rotating mass shell in general relativity — •Florian Atteneder[1], Tobias Benjamin Russ[2], Reinhard Alkofer[3], and Helios Sanchis-Alepuz[3] — [1]Theoretical Physics Institute, University of Jena, Jena, Germany — [2]Theoretical Physics, Ludwig Maxmillians University, Munich, Germany — [3]Institute of Physics, University of Graz, Graz, Austria

The model of a rotating mass shell (RMS) was initially introduced to judge if rotation has only relative meaning. It comprises a description of a spacetime with an energy-matter content that is assembled in a statically rotating quasi-spherical shell with zero radial extension. Latest perturbation theory (PT) calculations have shown that relativity of rotation is indeed realized in such a spacetime. However, because this conclusion was based on PT, its validity is limited to slowly RMSs. This work pursues a numerical treatment of the problem, where the mathematical formulation involves a splitting of the spacetime into a region that is flat and one that is asymptotically flat. The latter is used as a reference to define relative rotation. The RMS forms at the common boundary of these two regions. On the basis of previous work, we formulate Einstein's equations as a free-boundary value problem and solve them numerically using a pseudo-spectral method. As a result we obtain a three-parameter solution that is characterized by the shell's polar radius, its gravitational mass and angular momentum. The existence of the solution is enough to positively answer the question if Mach's idea of relativity of rotation can be extended for rapidly RMSs.

GR 6.2 Wed 16:45 H6

Hyperbolic-like Encounters of Binary Black Holes — •Hannes Rüter and Harald Pfeiffer — Albert Einstein Institute, Potsdam, Germany

We present results on the encounter of two black holes that are initially on a hyperbolic-like orbit simulated with the numerical relativity code SpEC. The two black holes either become bound due to the emission of gravitational waves or they escape to infinity. We present trajectories and waveforms for both cases and extract the scattering angle for the latter.

GR 6.3 Wed 17:00 H6

Prompt Collapse - The Effect of Mass Ratio — •Maximilian Kölsch[1], Tim Dietrich[2,3], Maximiliano Ujevic[4], and Bernd Brügmann[1] — [1]Theoretisch-Physikalisches Inst., FSU Jena — [2]Institut für Physik und Astronomie, Universität Potsdam — [3]MPI for Gravitational Physics (AEI), Potsdam — [4]Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, Brazil, São Paulo

The outcome of a binary neutron star merger dominantly depends on the total mass of the system and the equation of state describing the matter. However, the mass ratio also influences the postmerger evolution, in particular, whether there is a prompt or delayed collapse. Furthermore, the mass ratio influences which fraction of the initial baryonic mass ends up in a disc around a so formed black hole, and the mass of the latter. We investigate with a new set of general relativistic simulations the prompt collapse threshold for various total masses, mass ratios, and three equations of state. We propose a fitting formula for the dependence of the threshold mass on the mass ratio.

GR 6.4 Wed 17:15 H6

Axisymmetric gravitational wave collapse with bamps. — •Sarah Renkhoff[1], David Hilditch[2], Daniela Cors Agulló[1], Isabel Suárez Fernández[2], and Bernd Brügmann[1] — [1]Friedrich-Schiller-Universität Jena, 07743 Jena, Germany — [2]CENTRA, University of Lisbon, 1049 Lisboa, Portugal

The new adaptive mesh refinement in our pseudospectral code bamps allows us to improve on previous results near the threshold of black hole formation. In particular, by leveraging the increased performance and scaling behaviour of the code, we can fine tune closer to the critical point between gravitational collapse and dispersed fields. We evolve six one-parameter families of Brill wave initial data: three prolate and three oblate, including two centred and four off-centred. Time permitting, we will discuss the relevance of our results in the context of critical collapse beyond spherical symmetry.

GR 6.5 Wed 17:30 H6

GR-Athena++: puncture evolutions on vertex-centered oct-tree AMR — •Francesco Zappa — Friedrich Schiller Universität, Jena, Germany

Numerical relativity is key to explore the strong-field gravity regime of black hole and compact binary systems. Multi-messenger astronomy requires accurate numerical relativity simulations in order to construct and develop precise gravitational-wave models and to study the outcome of black hole and neutron star mergers in regions of the parameter space which have not been explored yet. Such simulations can be very costly and thus highly performant and scalable codes, capable of efficiently using the modern massively-parallel architectures available nowadays, are needed.

We present GR-Athena++, an extension of the astrophysical code Athena++ which solves the Z4c equations to evolve the dynamical spacetime employing an oct-tree based adaptive mesh refinement strategy. We test our code comparing results from simulations of binary black hole mergers against other numerical relativity codes and performing comparisons against state-of-the-art effective-one-body waveforms. GR-Athena++ exhibits excellent scalability properties, inherited from Athena++ task-based parallelism strategy. Our tests show strong scaling efficiencies above 90% for up to $\sim 10^4$ CPUs and almost perfect weak scaling up to $\sim 10^5$ CPUs.

These results demonstrate that GR-Athena++ can perform accurate binary black hole evolution efficiently on a large number of CPUs, providing a viable option for exascale numerical relativity.

GR 6.6 Wed 17:45 H6

A discontinuous Galerkin elliptic solver with task-based parallelism for the SpECTRE code — •Nils Fischer — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

I present the solver for linear and nonlinear elliptic partial differential equations for SpECTRE, the next-generation numerical relativity code currently in development by the SXS collaboration. The solver combines nodal discontinuous Galerkin methods and task-based parallelism to target challenging elliptic problems in numerical relativity and beyond. In particular, I report on first results solving for black-hole binary and neutron-star binary initial data using our new numerical technology and I demonstrate the code's ability to scale to the capacity of the Minerva supercomputer at AEI Potsdam.

GR 6.7 Wed 18:00 H6

Long term simulations of magnetic fields in isolated neutron stars — •William Cook[1], Ankan Sur[2], Brynmor Haskell[2], David Radice[3,4,5], and Sebastiano Bernuzzi[1] — [1]Theoretisch-Physikalisches Institut, Friedrich-Schiller Universitat Jena, 07743, Jena, Germany — [2]Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Bartycka 18, 00-716 Warsaw, Poland — [3]Institute for Gravitation & the Cosmos, The Pennsylvania State University, University Park, PA 16802, USA — [4]Department of Physics, The Pennsylvania State University, University Park, PA 16802, USA — [5]Department of Astronomy & Astrophysics, The Pennsylvania State University, University Park, PA 16802, USA

We present the results of long term simulations of magnetised, isolated, neutron stars in the Cowling approximation, performed with the Athena++ code, lasting 490ms. By evolving neutron stars with initially poloidal and toroidal magnetic fields we investigate the long term development of the relative strengths of these components, as well as the onset of turbulent behaviour driven by an initial instability. We further investigate how the scaling of the energy spectrum evolves through the course of the simulation.

GR 6.8 Wed 18:15 H6

Binary neutron star merger simulations: ejecta, nucleosynthesis, EM counterparts — •Vsevolod Nedora — Theoretisch-Physikalisches Institut, Jena, Germany

GW170817 provided a plethora of information on binary neutron star (BNS) mergers and properties of matter at supranuclear densities. We further explore the remaining open questions with long-term numerical relativity (NR) BNS merger simulations with state-of-the-art numerical methods. Simulations include neutrino emission and reabsorption, the magnetic field induced viscosity via an effective model, and microphysical equations of state (EOSs) with finite temperature effects.

We find that (i) post-merger evolution is accompanied by massive outflows, spiral-wave wind, driven by complex dynamical interaction between the remnant NS and the disk and finite temperature effects; (ii) the electromagnetic (EM) signature of this new outflow corresponds to the "blue" kilonova (kN); (iii) the rapid neutron capture, r-process, nucleosynthesis final abundances in total ejecta from our simulations are compatible with solar; (iv) non-thermal kN afterglow, emitted by the ejecta interacting with the interstellar medium is compatible with the recently observed change in GRB170817A afterglow.

Overall, our results highlight the importance of the ab-initio NR BNS merger simulations with microphysical EOSs and allow to place certain tentative constraints on the properties of GW170817 and, ultimately, NS EOS.

GR 7: Experimental tests

Time: Thursday 11:00–12:00 Location: H9

GR 7.1 Thu 11:00 H9

Perspectives of measuring gravitational effects of laser light and particle beams — Felix Spengler[1], •Dennis Rätzel[2], and Daniel Braun[1] — [1]Eberhard-Karls-Universität Tübingen, Institut für Theoretische Physik, 72076 Tübingen, Germany — [2]Humboldt Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489 Berlin, Germany

We can expect the gravitational field of light to be extremely weak. However, studying the gravitational field of light could give new fundamental insights to our understanding of space and time as well as classical and quantum gravity and it is worthwhile to investigate if gravitational effects of light may be experimentally accessible in the near future. Similarly, the gravitational properties of relativistic particle beams have not been experimentally tested. Their total relativistic mass is dominated by their kinetic energy and the same dominance for the gravitational field is predicted by general relativity. Therefore, the gravitational field of particle beams shows strong similarities to that of laser beams. In addition, both can be brought into non-trivial quantum states. We present a short overview of the gravitational properties of light and relativistic particle beams and the prospects to measure them in experiments by means of sensors based on resonant mechanical oscillators. With an optimized pendulum or torsion balance combined with the planned high-luminosity upgrade of the LHC as a source, a signal-to-noise ratio substantially larger than 1 should be achievable in principle.

GR 7.2 Thu 11:15 H9

Constraining modified gravity with quantum optomechanics — •Sofia Qvarfort[1,2], Dennis Rätzel[3], and Stephen Stopyra[2] — [1]QOLS, Blackett Laboratory, Imperial College London, SW7 2AZ London, United Kingdom — [2]Department of Physics and Astronomy, University College London, Gower Street, WC1E 6BT London, United Kingdom — [3]Institut für Physik, Humboldt-Universität zu Berlin, 12489 Berlin, Germany

In this talk, I will present some recent results on estimating the performance of quantum optomechanical sensors for searches of modified gravity. Specifically, I will show how we derive the best possible bounds that can be placed on Yukawa– and chameleon–like modifications to the Newtonian gravitational potential with a cavity optomechanical quantum sensor. We do so by modelling the effects from an oscillating spherical source on the optomechanical system from first-principles. To then estimate the sensitivity to chameleon-like modifications, we take into account the size of the optomechanical probe and quantify the resulting screening effect for the case when both the source and probe are spherical. Our results show that an optomechanical system in high vacuum could, in principle, further constrain the parameters of chameleon-like modifications to Newtonian gravity.

GR 7.3 Thu 11:30 H9

BECs with Yukawa-type gravitational selfinteraction — •Sandro Gödtel and Claus Lämmerzahl — ZARM, University of Bremen, Germany

The theories of Newtonian and Einsteinian gravity are extremely powerful in describing the macroscopic world. On the other side, however, we still do not have a widely accepted description of short-range gravity. Nowadays many theories going beyond the standard model predict deviations from Newtonian gravity, commonly in the form of a Yukawa-like potential. Different experiments so far have found upper boundaries for the strength and the range of this deviation. However, most of the experiments are focused on a test body in an external gravitational field.

In this talk we present a model for a Bose-Einstein condensate which particles interact via a Newton and a Yukawa potential. In a selfconsistent manner, we determine the influence of such gravitational potentials onto the condensate. We derive the changes in the width of the cloud and the frequencies of the collective oscillations. With this, we are able to set boundaries for the parameters of the Yukawa potential and compare them to the results of current experiments.

GR 7.4 Thu 11:45 H9

The secret of planets perihelion between Newton and Einstein — •Christian Corda — Istituto Livi, via Marini 9, 59100 Prato, Italy

It is shown show that,contrary to a longstanding conviction older than 160 years, the advance of Mercury perihelion can be achieved in Newtonian gravity with a very high precision by correctly analyzing the situation without neglecting Mercury mass. General relativity remains more precise than Newtonian physics, but Newtonian framework is more powerful than researchers and astronomers were thinking till now, at least for the case of Mercury. The Newtonian formula of the advance of planets perihelion breaks down for the other planets. The predicted Newtonian result is indeed too large for Venus and Earth. Therefore, it is also shown that corrections due to gravitational and rotational time dilation, in an intermediate framework which analyzes gravity between Newton and Einstein, solve the problem. By adding such corrections, a result consistent with the one of general relativity is indeed obtained. Thus, the most important results of this Lecture are two: (i) It is not correct that Newtonian theory cannot predict the anomalous rate of precession of the perihelion of planets orbit. The real problem is instead that a pure Newtonian prediction is too large. (ii) Perihelion precession can be achieved with the same precision of general relativity by extending Newtonian gravity through the inclusion of gravitational and rotational time dilation effects.

GR 8: Quantum field theory in curved spacetimes

Time: Thursday 12:00–12:30 Location: H9

GR 8.1 Thu 12:00 H9

Quantum fields near Cauchy horizons of charged black holes — •Christiane Klein, Jochen Zahn, and Stefan Hollands — Institut für theoretische Physik, Universität Leipzig, Germany

Reissner-Nordström-de Sitter spacetimes contain a Cauchy horizon: beyond it, the evolution of the spacetime is no longer governed solely by the initial data. A combination of analytical and numerical results indicate that there is a range of the physical parameter space for which the metric can be extended across the Cauchy horizon even when considering generic classical perturbations of the initial data. This is a violation of Penrose's strong cosmic censorship conjecture. However, it has been demonstrated by Hollands et.al., that in these cases the energy flux of a real scalar quantum field will diverge quadratically at the Cauchy horizon for any Hadamard state, rendering the metric inextendible. In this talk we present numerical results indicating that the described quadratic divergence of the energy flux is present for a wide range of parameters, and that it can change its sign. In addition, we extend the results by considering charged scalar fields. Apart from the energy flux, we derive and study the current of these fields. We demonstrate that the current diverges at the Cauchy horizon and that its leading divergence can have either sign, in contrast to naive expectations.

The talk is based on Phys.Rev.D 102 (2020) 8, 085004, arXiv:2104.06005 and arXiv:2103.03714, which is joint work with S. Hollands and J. Zahn.

GR 8.2 Thu 12:15 H9

Effective Quantum Dust Collapse via Surface Matching — •Johannes Münch — Aix-Marseille Universite, Universite de Toulon, CNRS, CPT, Marseille, Frankreich

The fate of matter forming a black hole is still an open problem, although models of quantum gravity corrected black holes are available. In loop quantum gravity (LQG) models were presented, which resolve the classical singularity in the centre of the black hole by means of a black-to-white hole transition, but neglect the collapse process. The situation is similar in other quantum gravity approaches, where eternal non-singular models are available. A strategy is presented to generalise these eternal models to dynamical collapse models by surface matching. Assuming 1) the validity of a static quantum black hole spacetime outside the collapsing matter, 2) homogeneity of the collapsing matter, and 3) differentiability at the surface of the matter fixes the dynamics of the spacetime uniquely. It is argued that these assumptions resemble a collapse of pressure-less dust and thus generalises the Oppenheimer-Snyder-Datt model. The junction conditions and the spacetime dynamics are discussed generically for bouncing black hole spacetimes, as proposed by LQG, although the scheme is approach independent. A global spacetime picture of the collapse for a specific LQG inspired model is discussed.

GR 9: Cosmology

Time: Thursday 16:30–17:30 Location: H9

GR 9.1 Thu 16:30 H9

Intensity Mapping Observables of Cosmology — •Caroline Heneka — Hamburg Observatory, UHH

Intensity Mapping (IM) of line emission targets the Universe from present time up to redshifts beyond ten when the Universe reionized and the first galaxies formed, from small to largest scales. Similar to CMB measurements, the power spectra of intensity fluctuations inform about the underlying cosmology; imagine the information encoded in thousands of intensity maps at different redshifts and for multiple emission lines, forming full tomographic lightcones. In this talk I review IM as a test for cosmology and fundamental physics during cosmic dawn and the epoch of reionization. I show how power and cross-power spectra as well as global temperature measurements probe our cosmology, properties of dark matter and of astrophysical sources. The measurement of deviations from the gravitational constant G and a possible dark matter – dark energy coupling are highlighted in general modified gravity scenarios. The ability of upcoming instruments like the SKA to constrain these modifications is demonstrated. Going beyond 'traditional' summary statistics, I furthermore show how 3D neural networks are able to directly infer e.g. dark matter and astrophysical properties from such tomographic line fluctuation lightcones without an underlying Gaussian assumption.

GR 9.2 Thu 16:45 H9

The functional renormalisation group of dark matter gravitational dynamics — •Alaric Erschfeld and Stefan Flörchinger — Institut für Theoretische Physik Heidelberg

While standard cosmological perturbation theory is applicable for the description of cosmic structure formation on large scales, it fails to accurately describe the mildly non-linear regime. The functional renormalisation group of the effective action describing the gravitational dynamics of dark matter, naturally allows for non-perturbative approximation schemes, either by the use of underlying symmetries or via a truncation of the effective action theory space. We show that Galilean invariance of the system gives rise to a Ward identity which allows to solve the renormalisation group flow equations in the limit of small scales and is related to the so-called 'sweeping effect'. Further, we study the flow of an ansatz similar to a derivative expansion of the effective action, which describes dark matter in an effective theory with local dynamics. We find attractive ultraviolet fixed point solutions for the relevant flow parameter, which naturally capture the sweeping effect observed in Eulerian response functions. Further, the full renormalisation group flow is solved for the density and velocity power spectra in the perfect pressureless fluid approximation.

GR 9.3 Thu 17:00 H9

Mori-Zwanzig formalism for general relativity: a new approach to the averaging problem* — •Michael te Vrugt[1], Sabine Hossenfelder[2], and Raphael Wittkowski[1] — [1]Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany — [2]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

Cosmology provides a coarse-grained description of the universe that is valid on very large length scales. However, the Einstein field equations are not valid for coarse-grained quantities since, due to their nonlinearity, they do not commute with an averaging procedure. Thus, it is unclear in which way small-scale inhomogeneities affect large-scale cosmology (backreaction). In this work, we address this problem by extending the Mori-Zwanzig projection operator formalism, a highly successful coarse-graining method from statistical mechanics, towards general relativity. This allows to derive a dynamic equation for the Hubble parameter in which backreaction is taken into account through memory and noise terms. Our results are linked to cosmological observations.

**Funded by the Deutsche Forschungsgemeinschaft (DFG) – WI 4170/3-1*

GR 9.4 Thu 17:15 H9

Considering cosmological red-shift originated in an increase of universes time velocity — •Bjørn Ebbesen — Hamburg, Germany

Thus far, the imagination of an expanding universe is widely accepted. But some physical laws claimed are not approved by local experiments.

This approach considers cosmological red-shift as effect of universes time velocity increasing in time. (Two time velocities spans a time dilation.)

Reevaluating observations so far leads to the perspective of a shrinking universe.

It is stated that a cosmological process takes place, where universes time velocity evolves from and influences universes gravitation. A simplified model of the process is derived.

GR 10: Scalar-tensor and non-local gravity theories

Time: Thursday 17:30–18:00 Location: H9

GR 10.1 Thu 17:30 H9

Core collapse in scalar-tensor theory with massive fields — •Roxana Rosca-Mead — FSU, Jena, Germany

Though General Relativity has been successfully tested so far, concepts such as dark energy and string theory suggest the need of modifying it. Scalar-tensor theory is one of the most popular alternatives discussed. The key motivation for looking at the ones with massive fields is that they are far less constrained by binary pulsar observations, in contrast to the massless case. In this talk, I will demonstrate studies in stellar core collapse in spherical symmetry, that were performed by adapting the numerical code GR1D to the case of massive scalar-tensor gravity. The addition of a mass term allows, within present constraints, much stronger gravitational wave emission than in the massless case, while the dispersion in the propagation of the scalar leads to a quasi-monochromatic signal, potentially detectable by LIGO /Virgo with existing analysis pipelines.

GR 10.2 Thu 17:45 H9

Topological defects and regularity in non-local gravity — •Jens Boos — William & Mary, Williamsburg, United States

Non-local gravitational theories with infinitely many derivatives may solve the gravitational singularity problem without introducing ghost-like degrees of freedom that one typically encounters in higher-order gravity. However, due to the complexity of the non-linear non-local field equations, so far only the linear regime is understood well. In this talk I will focus on cosmic string solutions obtained in weak-field non-local gravity. These have an interesting feature: non-locality regularizes the curvature defect at the location of the cosmic string. Since spacetime is now simply connected one might assume that the angle deficit vanishes, but this is not true: asymptotically one recovers the string solution of General Relativity. Non-locality hence challenges the way we think about topological defects in connection with topological properties of spacetime. If time permits, I shall also comment on similar effects regarding Aharanov–Bohm phases in non-local quantum mechanics, and their possible observational signatures.

GR 11: Didactical and heuristic aspects

Time: Thursday 18:00–18:30 Location: H9

GR 11.1 Thu 18:00 H9

2+1D-sector models of curved spacetimes — •Corvin Zahn and Ute Kraus — Hildesheim University

Sector models can represent curved surfaces, spaces, and spacetimes. The basic principle is the subdivision of the surface/space/spacetime into small parts, and the approximation of each small part by a small flat part. Sector models can be used to study geometry, e.g. to determine curvature and to construct geodesics.

We present sector models of several spacetimes (with one spatial dimension suppressed) and illustrate the test for curvature components.

References:

European Journal of Physics, vol. 35 (2014), 055020
European Journal of Physics, vol. 40 (2019), 015601
European Journal of Physics, vol. 40 (2019), 015602

GR 11.2 Thu 18:15 H9

Liegt der Schlüssel zur Neuen Physik unter der Laterne des Althergebrachten? — •Thomas Görnitz — FB Physik, Goethe-Univ. Frankfurt/M

Erklären bedeutet Komplexes aus Einfacherem zu konstruieren. Quantenfeldtheorien - Systeme einer unbegrenzten Anzahl von Feldquanten (Teilchen) - sind das Beste für komplexe Situationen. Teilchen sind somit einfacher als Quantenfelder. Seit dem Higgs-Teilchen wurde von unzähligen prognostizierten Quantenfeldern (GUT, SUSY, Strings, Inflation, Dunkle Materie, Dunkle Energie) kein Feldquant nachgewiesen.

Immer höhere Energien sollen bei immer kleineren Strukturen Auswege aus der aktuellen Krise der Physik eröffnen - ohne über diese Absurdität zu reflektieren. Erst neue Vorstellungen führen aus der Sackgasse des räumlich Kleinen heraus.

Die Quantentheorie konstruiert aus einfachen Strukturen komplexe mit dem Tensorprodukt der Zustandsräume. Dem "atomaren" Vorurteil (einfachste Strukturen sind am wenigsten ausgedehnt) entgegnet sie, dass diese dann die größten Energiekonzentrationen enthielten.

Die mathematisch einfachste Quantenstruktur besitzt einen zweidimensionalen Zustandsraum. Man kann sie ein AQI (Abstract Bit of Quantum Information) nennen. Im Vortrag werden mit den AQIs neue mathematisch fundierte Antworten für Kosmologie, Gravitation, Teilchen und quantische Wechselwirkungen gegeben.

GR 12: Annual General Meeting

Time: Thursday 19:00–20:30 Location: H9

Annual General Meeting

GR 13: Quantum gravity and cosmology

Time: Friday 11:00–12:15 Location: H4

GR 13.1 Fri 11:00 H4

Solution of the H0 Tension — •Hans-Otto Carmesin — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — Bahnhofstraße — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

In the standard model of cosmology, the Hubble constant should not vary as a function of the time.

However, when the Hubble constant H0 is measured, then probes that have been emitted at an earlier time or at a corresponding redshift z are used, and it turns out that the observed values of H0 depend on that redshift z, H0=H0(z,observation). That discrepancy is called H0 tension.

I derive a theory of dark energy, based on quantum physics and gravity. With my theory, I derive a term for the above function, H0(z,theory). That term is in precise accordance with observation, so my theory of the dark energy solves the H0 tension. I emphasize that the only numerical input used in my theory is the present day time after Big Bang combined with the universal constants G, c, kB and h.

Moreover, my theory solves various other fundamental problems of physics, see Carmesin, Hans-Otto (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin, Dr. Köster Verlag, see also Carmesin, Hans-Otto (2019): Die Grundschwingungen des Universums - The Cosmic Unification - With 8 Fundamental Solutions based on G, c and h. Berlin: Dr. Köster Verlag.

GR 13.2 Fri 11:15 H4

Solution of the Horizon Problem — •Philipp Schöneberg[1] and Hans-Otto Carmesin[1,2,3] — [1]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — [2]Studienseminar Stade, Bahnhofstraße 5, 21680 Stade — [3]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

In the early universe, the density was very high. As a consequence, there occurred gravitational instabilities and dimensional phase transitions. These have been derived in three very different physical systems, see Carmesin, Hans-Otto (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin, Dr. Köster Verlag.

Using these phase transitions, the light horizon as a function of time R(t) can be calculated, ranging from the Planck length to the present day value. With it we derive the solution of the horizon problem.

GR 13.3 Fri 11:30 H4

The equivalence of gravity and gravitational time dilation in general relativity and in quantum mechanics — •René Friedrich — Strasbourg

The curved spacetime of the Schwarzschild metric seems to be incompatible with quantum mechanics. But gravity may not only be represented by curved spacetime, it is also entirely described by gravitational time dilation in flat, uncurved space.

This talk is the third part of the concept of quantum gravity without need for any additional theory: Gravity modulates in the form of gravitational time dilation the proper time parameter of the worldlines of quantum systems.

GR 13.4 Fri 11:45 H4

Für ein einheitliches Weltbild der Physik — •Helmut Hille — Heilbronn, Fritz-Haber-Straße 34

Es ist nur menschliche Sehgewohnheit, getrennt Gesehenes als definitiv getrennt Existierendes zu halten, obgleich schon das System Sonne-Erde-Mond das Gegenteil beweist. Keiner dieser Körper hätte ohne den anderen seine Bahn und es gäbe auf der Erde keine Gezeiten. Verschränkte Quanten haben gezeigt, dass ihr gemeinsamer Ursprung sie sich als Eines verhalten lassen. Ebenso ist der Big Bang der gemeinsame Ursprung aller Materie unseres Kosmos zu einer neuen immanenten Einheit, die sich in Form der Gravitation zusammenhalten möchte, während sie äußerlich gleichzeitig expandiert. Die Gravitation ist nur ein weiterer Beleg über die Macht des Unsichtbaren, die es endlich zu akzeptieren gilt. Heute sucht man als Ausweg das Unsichtbare in dunkler Materie und Energie. Aber das Unsichtbare, um das es mir geht, ist kein Teilchen. Es ist nur die Rückseite des Sichtbaren, die wir mit der Gravitationskonstante erfassen. So ist die Gravitation eine Form der Verschränkung aller betroffenen Materie (auch Strahlung ist Materie), von mir hier Superverschränkung genannt. In der Verbindung mit drei weiteren Prämissen ergibt sich ein einheitliches Weltbild der Physik von großer Schönheit, das ein rationales ist, das auf klaren, einsichtigen Prämissen beruht, die jedermann nachvollziehen kann.

GR 13.5 Fri 12:00 H4

Quantum gravity by elimination of spacetime — •René Friedrich — Strasbourg

General relativity without curved spacetime? Unconceivable, you might say. But why? For Marcel Grossmann, the Riemannian geometry was nothing more than an efficient tool for the description of Einstein's main postulates of general relativity, in particular the equivalency principle. And today, spacetime turns out to be the only reason why things are going wrong in quantum gravity.

Eliminating spacetime means to restitute to the universe its absolute, observer-independent character. In spacetime, particle worldlines are parameterized by the coordinate time of the observer, and different observers with different spacetime coordinate systems get different results. Instead, we must parameterize each worldline by its respective proper time, in order to get a universe on which all observers agree and which complies with quantum mechanics.

The result is a completely Lorentz-invariant description of the universe: In a manifold of absolute space without common time axis, worldlines are parameterized by their respective proper time. Accordingly, lightlike phenomena such as electromagnetic and gravity fields with zero proper time are reduced to zero. But what about gravity? Gravity may not only be expressed as curved spacetime but equivalently also as gravitational time dilation in absolute, flat space, modulating the proper time parameter of worldlines.

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Overview of Invited Talks and Sessions

(Lecture halls H1, H2, H3, H4, H5, H6, and H8)

Plenary Talks of the Hadronic and Nuclear Physics Division

PV IV	Tue	9:45–10:30	Audimax	**Superheavy Element Research at GSI** — •Michael Block
PV IX	Fri	9:00– 9:45	Audimax	**Renaissance of nuclear physics at the LHC** — •Laura Fabbietti

Invited Talks

HK 1.1	Mon	11:00–11:30	H1	**Recent results of collinear laser spectroscopy in the vicinity of the magic tin isotopes** — •Liss Vázquez Rodríguez
HK 1.2	Mon	11:30–12:00	H1	**Highlights from the COMPASS Experiment and the AMBER Proposal** — •Boris Grube
HK 1.3	Mon	12:00–12:30	H1	**Characterizing baryon dominated matter with HADES measurements** — •Szymon Harabasz
HK 7.1	Tue	11:00–11:30	H1	**First observation of neutrinos from the CNO fusion cycle in the Sun** — •Daniele Guffanti
HK 7.2	Tue	11:30–12:00	H1	**The Compressed Baryonic Matter experiment at FAIR** — •Alberica Toia
HK 7.3	Tue	12:00–12:30	H1	**Ab initio perspectives on strongly correlated nuclei** — •Alexander Tichai
HK 16.1	Wed	14:00–14:30	H1	**Short-Range Correlations in neutron-rich nuclei** — •Meytal Duer
HK 16.2	Wed	14:30–15:00	H1	**The BGOOD experiment at ELSA - exotic structures in the light quark sector?** — •Thomas Jude
HK 16.3	Wed	15:00–15:30	H1	**The Muon g-2 Experiment at Fermilab** — •Martin Fertl
HK 16.4	Wed	15:30–16:00	H1	**The muon (g-2) from lattice QCD and experiments: 4.2 sigma, indeed?** — •Zoltan Fodor
HK 21.1	Thu	11:00–11:30	H1	**Charming bound states of the strong interaction** — •Frank Nerling
HK 21.2	Thu	11:30–12:00	H1	**Baryon Spectroscopy with the CBELSA/TAPS experiment at ELSA** — •Annika Thiel
HK 21.3	Thu	12:00–12:30	H1	**Mass measurements of the most exotic nuclei and their relevance for nuclear structure** — •Timo Dickel, FRS Ion Catcher Collaboration, TITAN Collaboration
HK 26.1	Fri	11:00–11:30	H1	**Studying the Universe from deep underground: the LUNA experiment** — •Rosanna Depalo
HK 26.2	Fri	11:30–12:00	H1	**Double parton scattering and double parton distributions** — •Peter Plössl
HK 26.3	Fri	12:00–12:30	H1	**BSM physics in hadronic and nuclear beta decays: challenges and opportunities** — •Chien Yeah Seng

Invited talks of the joint symposium Neutron stars (SYNS)

See SYNS for the full program of the symposium.

SYNS 1.1	Thu	14:00–14:40	Audimax	**Binary neutron stars: from gravitational to particle physics** — •Luciano Rezzolla
SYNS 1.2	Thu	14:40–15:20	Audimax	**Probing subatomic physics with gravitational waves** — •Tanja Hinderer
SYNS 1.3	Thu	15:20–16:00	Audimax	**A NICER view of neutron stars** — •Anna Watts

Sessions

HK 1.1–1.3	Mon	11:00–12:30	H1	**Invited Talks - I**
HK 2.1–2.7	Mon	16:30–18:30	H1	**Heavy-Ion Collisions and QCD Phases I**
HK 3.1–3.7	Mon	16:30–18:30	H2	**Instrumentation I**
HK 4.1–4.7	Mon	16:30–18:30	H3	**Hadron Structure and Spectroscopy I**
HK 5.1–5.7	Mon	16:30–18:30	H4	**Nuclear Astrophysics**
HK 6.1–6.6	Mon	16:30–18:15	H5	**Instrumentation II**
HK 7.1–7.3	Tue	11:00–12:30	H1	**Invited Talks - II**
HK 8.1–8.7	Tue	14:00–16:00	H1	**Instrumentation III**
HK 9.1–9.7	Tue	14:00–16:15	H2	**Outreach**
HK 10.1–10.6	Tue	14:00–16:00	H3	**Hadron Structure and Spectroscopy II**
HK 11.1–11.7	Tue	14:00–16:00	H4	**Instrumentation IV**
HK 12.1–12.7	Tue	16:30–18:30	H1	**Heavy-Ion Collisions and QCD Phases II**
HK 13.1–13.6	Tue	16:30–18:15	H2	**Instrumentation V**
HK 14.1–14.7	Tue	16:30–18:30	H3	**Hadron Structure and Spectroscopy III**
HK 15.1–15.6	Tue	16:30–18:30	H4	**Structure and Dynamics of Nuclei I**
HK 16.1–16.4	Wed	14:00–16:00	H1	**Invited Talks - III**
HK 17.1–17.7	Wed	16:30–18:30	H1	**Heavy-Ion Collisions and QCD Phases III**
HK 18.1–18.7	Wed	16:30–18:30	H2	**Instrumentation VI**
HK 19.1–19.6	Wed	16:30–18:15	H3	**Hadron Structure and Spectroscopy IV**
HK 20.1–20.6	Wed	16:30–18:45	H4	**Fundamental Symmetries**
HK 21.1–21.3	Thu	11:00–12:30	H1	**Invited Talks - IV**
HK 22.1–22.7	Thu	16:30–18:30	H1	**Heavy-Ion Collisions and QCD Phases IV**
HK 23.1–23.7	Thu	16:30–18:30	H2	**Instrumentation VII**
HK 24.1–24.7	Thu	16:30–18:30	H3	**Hadron Structure and Spectroscopy V**
HK 25.1–25.7	Thu	16:30–18:45	H4	**Astroparticle Physics**
HK 26.1–26.3	Fri	11:00–12:30	H1	**Invited Talks - V**
HK 27.1–27.8	Fri	14:00–16:15	H1	**Heavy-Ion Collisions and QCD Phases V**
HK 28.1–28.6	Fri	14:00–15:45	H2	**Instrumentation VIII**
HK 29.1–29.7	Fri	14:00–16:00	H3	**Hadron Structure and Spectroscopy VI**
HK 30.1–30.8	Fri	14:00–16:30	H4	**Structure and Dynamics of Nuclei II**

Sessions

– Invited Talks, Group Reports, and Contributed Talks –

HK 1: Invited Talks - I

Time: Monday 11:00–12:30 Location: H1

Invited Talk HK 1.1 Mon 11:00 H1

Recent results of collinear laser spectroscopy in the vicinity of the magic tin isotopes — •Liss Vázquez Rodríguez — Experimental Physics Department, CERN, 1211 Geneva 23, Switzerland — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

High-resolution collinear laser spectroscopy has been performed in a long sequence of tin (Z=50) species, spanning from N=58 to the very neutron-rich isotopes beyond the N=82 shell closure. Hyperfine structures and isotope shifts have been measured using the COLLAPS instrumentation at ISOLDE/ CERN. Simple linear and quadratic trends are observed for the electromagnetic moments and differences in charge radii between the lowest 1/2, 3/2, and 11/2 states in 117-131Sn. These regular patterns will be discussed in the framework of nuclear structure.

Invited Talk HK 1.2 Mon 11:30 H1

Highlights from the COMPASS Experiment and the AMBER Proposal — •Boris Grube — Physik-Department E18, Technische Universität München

The COMPASS experiment, which is the largest multi-purpose fixed-target spectrometer setup at the CERN Super Proton Synchrotron, studies the structure and spectrum of hadrons by scattering high-energy beams of hadrons and polarized muons off various targets. The broad physics program aims at a deeper understanding of the strong interaction, which is described by quantum chromodynamics (QCD). The studied processes include soft reactions of hadrons to test the breaking of the chiral symmetry of QCD, production and decay of meson resonances to perform detailed studies of the excitation spectrum of light-quark mesons, and scattering of high-energy muons and pions off nucleons to unravel the role of spin and internal dynamics in the quark-gluon structure of the nucleon. We will present highlights from recent analyses.

Based on the very successful running of COMPASS, the new AMBER experiment was proposed recently. The physics program includes a wide variety of measurements addressing fundamental questions of QCD. We will discuss the first part of the proposed program, which is intended to start 2022 and aims, among other things, at a measurement of the charge radius of the proton via elastic scattering of high-energy muons off target protons in order to shed more light on the proton-radius puzzle.

Invited Talk HK 1.3 Mon 12:00 H1

Characterizing baryon dominated matter with HADES measurements — •Szymon Harabasz for the HADES-Collaboration — TU Darmstadt / GSI, Darmstadt, Germany

In heavy-ion reactions at beam energies of a few GeV per nucleon on stationary targets, QCD matter is substantially compressed (2-3 times nuclear saturation density) while temperatures are expected not to exceed T = 70 MeV. Matter under such conditions is being studied with HADES at SIS18.

This contribution discusses new experimental results on the mechanisms of strangeness production, the emissivity of matter and the role of baryonic resonances herein. The multi-differential representations of hadron and dilepton spectra, collective effects and particle correlations will be confronted with results of other experiments as well as with hitherto model calculations.

To provide a deeper understanding of the temperature and density dependence of the intriguing results obtained in the Au+Au and Ar+KCl runs, HADES has completed a run studying Ag+Ag collisions at $\sqrt{s_{NN}}$ = 2.55 GeV, optimized to reach a high enough beam energy for abundant strangeness and vector meson production while yet realizing a large interaction volume. The results obtained for heavy-ion collisions are confronted to studies of elementary reactions serving as a reference for medium effects.

HK 2: Heavy-Ion Collisions and QCD Phases I

Time: Monday 16:30–18:30 Location: H1

Group Report HK 2.1 Mon 16:30 H1

Space-charge distortions in the ALICE TPC in Run 3 — •Matthias Kleiner for the ALICE-Collaboration — Institut für Kernphysik, Goethe-Universität Frankfurt

The Time Projection Chamber (TPC) is the main tracking and particle identification detector of the ALICE experiment at the CERN LHC. For Run 3, starting in 2022, interaction rates of 50 kHz in Pb-Pb collisions require a major upgrade of the TPC readout system. The Multi-Wire Proportional Chambers (MWPCs) were replaced by stacks of four Gas Electron Multiplier (GEM) foils, allowing continuous data acquisition. Due to intrinsic properties of the GEMs, a significant amount of ions produced during the electron amplification drifts into the active volume of the TPC, leading to space-charge distortions of the nominal drift field. Various effects, such as variations in the number of collisions for a given time interval, cause fluctuations of the space-charge distortions on very short time scales. These fluctuations have to be corrected in time intervals of 5-10 ms to preserve the intrinsic space point resolution of the TPC of 100 μm. To accomplish this challenging task, a dedicated correction scheme based on data-driven machine learning techniques is developed.

In this talk, an overview about space-charge distortions and distortion fluctuations in the ALICE TPC in Run 3 will be presented, along with simulations of the expected distortions and the planned correction procedures.

Supported by BMBF and the Helmholtz Association

HK 2.2 Mon 17:00 H1

Reconstruction of Bottom Jets in Proton-Proton Collisions at $\sqrt{s}$ = 13 TeV with ALICE — •Katharina Demmich for the ALICE-Collaboration — Westfälische Wilhelms-Universität Münster

When traversing the Quark-Gluon Plasma (QGP), partons lose energy via collisional and radiative processes. The amount of lost energy depends on the particle mass and manifests in a reduced jet multiplicity in heavy-ion collisions with respect to proton-proton collisions, for which no QGP is expected to form. A detailed knowledge about the charm and bottom-jet production in proton-proton collisions is thus inevitable for further investigations on particle energy loss within the QGP.

Owing to the relatively large lifetimes and the cascade of weak decays of B hadrons, transverse impact parameter spectra, as a measure for the distance between particle tracks and the primary vertex, offer a great opportunity to investigate the bottom-jet production. Results of a performance analysis of a bottom-jet selection algorithm based on transverse impact parameter spectra will be presented for 13 TeV proton-proton collisions.

supported by the DFG GRK2149 and BMBF ErUM FSP-T01 ALICE 0519PMCA1

HK 2.3 Mon 17:15 H1

Neutral pion identification from merged clusters with machine learning methods in ALICE — •Jan Honermann for the ALICE-Collaboration — Institut für Kernphysik, Münster, Deutschland

The ALICE detector at CERN LHC is designed for the study of hot nuclear matter. Historically, one of the first probes to confirm the presence of such hot nuclear matter in heavy-ion collisions were neutral pions. The production of neutral pions was found to be significantly suppressed in heavy-ion collisions compared to pp or deuteron-gold collisions. Most traditional identification methods for neutral pions in these studies rely on an invariant mass analysis of the decay products. When the energy of the neutral pion becomes too large, these methods stop working though, since hits of decay products can not be resolved individually any longer. In this talk, initial efforts to distinguish between these merged clusters from neutral pions and coincidental hits from background processes with the help of neural networks in 13TeV pp-collisions will be presented.

HK 2.4 Mon 17:30 H1

Identification of photon conversions from Monte-Carlo simu- lations in ALICE using XGBoost — •Xuan-Xuyen Nguyen — Physikalisches Institut, Heidelberg, Baden Württemberg

ALICE measures photons by reconstructing photon conversions in the detector material. In the standard analysis a photon candidate sample is obtained by applying a sequence of manually set cuts. In order to improve the photon identification, a XGBoost classifier was trained on Monte-Carlo simulated data in this study. The simulated events were obtained by propagating proton-proton collisions generated with PYTHIA and lead-lead collisions generated with HIJING through the detector setup using the GEANT simulation package. The XGBoost models achieve a more constant and an up to 10% higher signal efficiency than the cut-based model at the same purity. A comparison between the XGBoost and the Random Forest models showed that both make similarly good predictions.

HK 2.5 Mon 17:45 H1

Studies of the ALICE material budget between TPC and TOF — •Oscar Castro Serrano and Ivan Vorobyev for the ALICE-Collaboration — Technische Universität München

The material located between the Time Projection Chamber (TPC) and Time-of-Flight (TOF) detectors is one of the most dense parts of the ALICE apparatus at mid-rapidity, with the main contribution coming from the Transition Radiation Detector (TRD). However, the description of this material budget used in Monte Carlo simulations was not yet validated with experimental data. The knowledge of this material budget plays significant role in various ALICE analyses which employ TOF detector for particle identification.

In this talk we show the method which facilitates validation of the ALICE detector material between TPC and TOF with pure sample of protons and pions, for which the inelastic cross sections for interactions with matter are well known from the experiment. The analysis is performed in p-Pb collisions at 5.02 TeV using pure samples of protons from lambda decays and pions from K0 decays reconstructed with the Inner Tracking System (ITS) and TPC detector. The number of protons and pions matched to a hit in the TOF detector is compared with the number of protons and pions in the TPC. The obtained TOF/TPC matching efficiency is compared to the results from full-scale ALICE simulations using GEANT3 and Geant4 toolkits for propagation of particles through the ALICE detector. As a result, the material budget between TPC and TOF can be validated in the momentum range of 0.5<p<5.0 GeV/c within ~5% precision.

HK 2.6 Mon 18:00 H1

Spadic response to single photon ionization based signals — •Marius Kunold for the CBM-Collaboration — Goethe-Universität Frankfurt am Main, Deutschland

The aim of the Compressed Baryonic Matter experiment at the Facility for Antiproton and Ion Research is to explore the QCD phase diagram in the region of high net-baryon densities. The Transition Radiation Detector is designed to identify light nuclei and deliver information for the global track reconstruction. Therefore, 4 layers of multi-wire proportional chambers with a segmented cathode readout will be installed. The signals will be readout by the Self-triggered Pulse Amplification and Digitization ASIC (SPADIC). For a successful particle identification a precise knowledge of the originally deposited energy and the position and time of the traversing particle is mandatory. Therefore, it is of high importance to have a detailed knowledge about the response of the SPADIC to the signals on the cathode plane.

The poster presents an analysis of the SPADIC response to single photons from a ^{55}Fe source. Especially the theoretical expectations are compared to the measured signal-shapes. The investigation is an initial step towards more elaborate time and charge reconstruction methods. To extract the charge and absolute time of the single signals a fit of the ADC sample distribution, based on the theoretical response function together with effective parameters, is performed. This new method is compared to the old charge extraction by reproducing an iron-spectrum.

HK 2.7 Mon 18:15 H1

Using CMOS technologies in ALICE for high luminosity experiments — •Abhishek Nath for the ALICE-Collaboration — Physikalisches Institut, Ruprecht Karl University of Heidelberg, Germany

The LHC may extend the heavy-ion program to Run 5 (2033) using lighter ions to achieve a large luminosity increase. To further contribute to the characterization of the macroscopic QGP properties with unprecedented precision, the ALICE Collaboration is writing an LOI of a next-generation multipurpose detector, the ALICE 3. It is a fast and light detector based on the use of monolithic active pixel sensors (MAPS) in combination with deep sub-micron commercial CMOS technologies. It has an excellent vertexing and tracking performance (Si tracker of about 100 m^2), and a large pseudorapidity coverage of $\Delta\eta = 8$. The rate capabilities should be a factor of about 50 higher with respect to ALICE in Run 4, being able to exploit the whole delivered p−A and A−A luminosity. The physics potential of the ALICE 3 experiment is very broad. For example, the search for de-confinement and coalescence with multi-charmed baryons, precision measurements of dileptons and in-medium interaction. Moreover, the unprecedented low momentum reach and particle identification properties of the detectors can be used to carry on searches in low energetic dielectrons and photons giving an opportunity to test theories like Low's theorem. In this talk, an overview of the ALICE 3 experiment and its capabilities to identify low energetic electrons via preshower detector will be presented.

HK 3: Instrumentation I

Time: Monday 16:30–18:30 Location: H2

Group Report HK 3.1 Mon 16:30 H2

Status of the Upgraded ALICE TPC — •Philip Hauer for the ALICE-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, Bonn

During the long shutdown 2 of the LHC, the ALICE Time Projection Chamber (TPC) was upgraded in order to cope with the increased Pb-Pb interaction rate of 50 kHz planned for Run 3. The MWPC-based amplification system was replaced by Gas Electron Multipliers (GEM). These avoid the long dead time caused by the ion gating grid of the MWPC, and allow for a continuous readout. To this end, also the front-end and readout electronics had to be replaced.

In August 2020, the TPC was moved back to its designated position at LHC interaction point 2 and an extensive commissioning program was started. It includes measurements of laser tracks, cosmic particles and the irradiation of the TPC with an X-ray source to carry out a pad-by-pad gain calibration. During this measurement campaign, the TPC operated at nominal conditions and the continuous readout capability was tested successfully.

The talk will summarise the performance and challenges during the commissioning phase. Furthermore, the present status and plans for the future will be discussed.

Supported by BMBF.

HK 3.2 Mon 17:00 H2

Simulations of the X-ray spectrum measured with the ALICE TPC — •Ankur Yadav, Philip Hauer, Philipp Bielefeldt, and Bernhard Ketzer — Universität Bonn, Helmholtz-Institut für Strahlen- und Kernphysik, Bonn, Germany

The ALICE Time Projection Chamber (TPC) was upgraded with a Gas Electron Multiplier (GEM) readout. In the scope of a commissioning program, several measurements were already conducted. This includes the irradiation of the TPC with an X-ray source. The pulse height spectrum recorded with the new front end electronic showed three distinct peaks on a Bremsstrahlung background. In addition to the characteristic peak of the Ag anode, the second peak could be attributed to fluorescence from the Cu layer of the GEM.

In order to clarify the origin of the third peak, the GEANT4 toolkit was used to simulate the interaction of X-rays and associated secondary particles with the detector gas and the surrounding passive material. A complete detector simulation chain was developed, including drift, diffusion and gas amplification.

In the talk, we will present the comparison of the simulation with the measured data.

Supported by BMBF.

HK 3.3 Mon 17:15 H2

Photon detection with THGEMs — •Thomas Klemenz[1], Laura Fabbietti[1], Piotr Gasik[2], and Roman Gernhäuser[1] — [1]Technische Universität München — [2]GSI Helmholtzzentrum für Schwerionenforschung

Traditional devices for photon detection like Photomultiplier tubes or more recent technologies such as Silicon Photomultipliers are very cost-intensive. Therefore, especially with large area experiments in mind it is exciting to investigate new ways of detecting photons. In this project we are taking the approach of combining a photosensitive material with a Thick GEM (THGEM) to produce a gaseous photon detector. THGEMs are robust, low-cost devices, which can be easily implemented in large area applications. One side of the THGEM is coated with a photosensitive material and placed within an electrical field. Photons captured by the active surface lead to a release of electrons that drift into the THGEM holes where they undergo avalanche multiplication due to strong electric fields applied. Below the THGEM an anode is reading out the amplified electron signal. Depending on the gain of the THGEM this could enable single photon detection. We want to study the potential of this approach while trying different photosensitive materials. Ultimately, we aim to measure visible wavelength photons and to provide a low-cost, large area solution for neutrino observation in water and ice environments. In the talk the current status of the project is discussed.

HK 3.4 Mon 17:30 H2

Characterizing new (TH)GEM coating materials using spectroscopy methods — •Berkin Ulukutlu[1], Piotr Gasik[2], Tobias Waldmann[1], Lukas Lautner[1], and Laura Fabbietti[1] — [1]Technische Universität München — [2]GSI Helmholtzzentrum für Schwerionenforschung

Gas Electron Multiplier (GEM) has become a commonly employed technology for modern high-rate particle and nuclear physics experiments. Nonetheless, one of the key limitations to the long-term sustainability of these devices are electrical discharges which might occur during high gain operation. Discharge events lead to dead-times and can even result in irreparable damage on the detector components, therefore, there has been extensive research aiming to develop methods to mitigate or subdue such events. This effort has yielded great success and enabled the development of very reliable and stable instruments. However, there are still major unanswered questions remaining concerning the fundamental mechanisms leading to the formation of electrical discharges in GEMs. In our studies, we investigated discharge formation in GEMs and Thick-GEMs (THGEM) produced with various conductive layer materials replacing the standard copper with aluminium, molybdenum, tantalum, and tungsten. Moreover, we employed optical spectroscopy to study the light emitted from such discharges as a probe to analyze the material content of the formed plasma. The measurements provide new insight into the mechanism of the secondary discharge creation.

HK 3.5 Mon 17:45 H2

Validation studies of Lightyield non-linearity implementation within the PandaRoot simulation framework — Kai-Thomas Brinkmann, •Simon Glennemeier-Marke, and Markus Moritz for the PANDA-Collaboration — Justus-Liebig-University Giessen

The PANDA detector at FAIR/GSI Darmstadt will utilize an electromagnetic calorimeter to measure the energies of photons being generated in proton-antiproton collisions. The calorimeter will use tapered PWO-II crystals and will cover a significant fraction of the 4π solid angle. These crystals show a strong tapering along their length. Due to this asymmetric geometry and absorption phenomena, the light yield varies non-uniformly along the long axis of the crystals. This project utilizes simulations within the PandaRoot simulation framework to validate the computational implementation of the non-uniformity and compare it to experimental results of previous studies. This project was supported by BMBF, GSI and HFHF.

HK 3.6 Mon 18:00 H2

Machine Learning based calibration of Low Gain Avalanche Detector — •Vadym Kedych[1], Wilhelm Krueger[1], Adrian Rost[1,4], Jerzy Pietraszko[2], Tetyana Galatyuk[1,2], Sergey Linev[2], Jan Michel[3], Michael Traxler[2], Michael Traeger[2], and Joachim Schmidt Christian[2] — [1]Technische Universität Darmstadt, Germany — [2]GSI GmbH, Darmstadt, Germany — [3]Goethe-Universität Frankfurt, Germany — [4]FAIR GmbH, Darmstadt, Germany

Linacs suffer from high power consumption for particle acceleration when high energies are desired. Because of this there is a huge interest to accelerators with idea of energy recovery. ERL allow to recirculate beam to the main linac second time with a phase shift of 180° which cause to deceleration of the beam and returning energy to RF cavities. The S-DALINAC at TU Darmstadt allows the possibility to operate it in an ERL mode. Optimization of the acceleration and deceleration processes are extremely important for efficiency operation S-DALINAC in ERL mode. For these purposes setup based on LGAD are being developed. LGAD is a silicon detector optimized for 4D-tracking with timing precision below 50ps thanks to internal low gain which makes it an ideal candidate for precise timing monitoring at S-DALINAC.

In this contribution we present status of a machine learning based calibration for LGAD using deep learning and neural network (NN). Experimental data from proton beam run at the COoler SYnchrotron (COSY) facility in Jülich is used to train the calibration model.

This work has been supported by DFG under GRK 2128.

HK 3.7 Mon 18:15 H2

Experiments and reconstruction methods for NeuLAND, the New Large Area Neutron Detector — •Jan Mayer and Andreas Zilges for the R3B-Collaboration — Institute for Nuclear Physics, University of Cologne

NeuLAND, the New Large Area Neutron Detector, is a core component of the Reactions with Relativistic Radioactive Beams (R^3B) setup at the Facility for Antiproton and Ion Research (FAIR), Germany.

In this talk, we give an overview of the detector performance achieved in experiments performed at the upgraded GSI facility. Reconstruction of the multiplicity and the first interaction points from the complex hit patterns is challenging. We present challenges, possible solutions, and results obtained with a diverse set of approaches including classical statistical methods and Machine Learning.

Supported by the BMBF (05P19PKFNA) and the GSI (KZILGE1416).

HK 4: Hadron Structure and Spectroscopy I

Time: Monday 16:30–18:30 Location: H3

Group Report HK 4.1 Mon 16:30 H3

Observation of a structure in the M(pη) invariant mass distribution at 1700 MeV in the γp - p $\pi\eta$ reaction — •Volker Metag and Mariana Nanova for the CBELSA/TAPS-Collaboration — II. Physikalisches Institut Universität Giessen

The present work extends earlier studies of the $\gamma p \rightarrow p\pi^0\eta$ reaction and has been motivated by the recently claimed observation of a narrow structure around an excitation energy of 1678 MeV [1]. The existence of this structure cannot be confirmed. Instead, for E_γ = 1400 - 1500 MeV and the cut $M_{p\pi^0} \leq 1190$ MeV a statistically significant structure in the $M_{p\eta}$ invariant mass distribution near 1700 MeV is observed with a width of $\Gamma \approx 35$ MeV.The most likely interpretation is that it is due to a triangular singularity in the $\gamma p \rightarrow pa_0 \rightarrow p\pi^0\eta$ reaction.

[1] V. Kuznetsov *et al.*, JETP Lett. **106**, 693 (2017).

*Supported by DFG through SFB/TR16.

HK 4.2 Mon 17:00 H3

$K^0_S\Sigma^0$ photoproduction at the BGOOD experiment — •Katrin Kohl for the BGOOD-Collaboration — Physikalisches Institut, Nussallee 12, D-53115 Bonn

The BGOOD experiment at the ELSA accelerator facility uses an energy tagged bremsstrahlung photon beam to investigate hadronic excitations in meson photoproduction.

The associated photoproduction of K^0_S and hyperons is of particular interest. A cusp-like structure observed in the $\gamma p \rightarrow K^0_S\Sigma^+$ reaction at the K^* threshold is described by models including multi-quark resonances through dynamically generated vector meson-baryon interactions. This is the same model which predicted the P_C pentaquark states observed at LHCb through D^*-Σ_c interactions. In analogy, in the s-quark sector a peak like structure in $K^0_S\Sigma^0$ photoproduction off the neutron is predicted, associated with a K^*-Σ type configuration.

This talk presents the measurement of the $\gamma n \rightarrow K^0_S\Sigma^0$ differential cross section from threshold to a beam energy of 2600 MeV. Within the available statistics the results appear consistent with the predicted peak like structure.

*Supported by DFG projects 388979758/405882627 and the European Union's Horizon 2020 programme, grant 824093.

HK 4.3 Mon 17:15 H3

a_0 photoproduction at the BGOOD experiment — •Adrian Sonnenschein for the BGOOD-Collaboration — Physikalisches Inst., Nussallee 12, 53115 Bonn

In recent years hadron spectroscopy has experienced a renaissance due to the discovery of tetra- and pentaquark systems including c and b quarks. Similar structures are expected similar structures are expected in the sector of light u,d,s quarks. The BGOOD experiment at the ELSA electron accelerator facility is studying this through the photoproduction of mesons close to production threshold. Recent results suggestthat the $K\bar{K}$ threshold is of particular interest.

This is where the isovector meson resonances $a_0(980)$ is located, slightly below the $K\bar{K}$ threshold. Photoproduction of a $\pi^0\eta$ pair off a proton $\gamma p \rightarrow \pi^0\eta p$ is a favourable reaction channel to study the $a_0 p$ threshold, since $a_0(980)$ has a dominant $\pi_0\eta$ decay mode.

This talk presents the measurement of the $\pi_0\eta$ mass distribution and the determination of differential cross sections.

*Supported by DFG projects 388979758/405882627 and the European Unions's Horizont 2020 programm, grant 824093.

HK 4.4 Mon 17:30 H3

Determination of the target asymmetry T in the reaction $\gamma p \rightarrow p\pi^0$ — •Sebastian Ciupka — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn

Photoproduction experiments provide a tool to further our understanding of the experimentally observed nucleon excitation spectra, which show discrepancies to predictions based on e.g. lattice QCD. Since the resonances are strongly overlapping, a partial wave analysis is needed to disentangle the states. To unambiguously determine the complex amplitudes of the analysis, it is not enough to conduct unpolarised measurements, therefore measurements with a polarised beam, a polarised target or with a recoil nucleon polarimeter have to be realised.

At the CBELSA/TAPS experiment in Bonn a linearly polarised photon beam and a longitudinally or transversely polarised target are provided, giving access to single and double polarization observables. The two main detectors of the experiment are the Crystal Barrel (CB) calorimeter and the MiniTAPS calorimeter in forward direction, which in combination provide nearly 4π coverage.

This talk presents preliminary results for the target asymmetry T in π photoproduction, determined from data collected after the upgrade of the CB readout system at the end of 2017. The data are compared with previously collected data and theoretical predictions.

HK 4.5 Mon 17:45 H3

Prospects for a Partial Wave Analysis of the $\overline{\Xi}\Lambda K^-$ Final State at $\overline{\text{P}}$ANDA — •Jennifer Pütz and James Ritman for the PANDA-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

For a deep insight into the mechanisms of non-perturbative QCD it is essential to understand the excitation pattern of baryons. Up to now only the nucleon excitation spectrum has been subject to systematic experimental studies while very little is known about the excited states of double or triple strange baryons. In studies of antiproton-proton collisions the $\overline{\text{P}}$ANDA experiment is well-suited for a comprehensive baryon spectroscopy program in the multi-strange sector. A large fraction of the inelastic $\bar{p}p$ cross section is associated to final states with a baryon-antibaryon pair together with additional mesons, giving access to excited states both in the baryon and the antibaryon channel.

In earlier Monte Carlo studies, it has been demonstrated that with an expected cross section in the order of μb $\overline{\text{P}}$ANDA will be able to observe the $\overline{\Xi}^+\Lambda K^-$ channel with a negligible background contribution. In this study, the feasibility of $\overline{\text{P}}$ANDA to determine the mass, width, spin and parity of two specific Ξ resonances, $\Xi(1690)$ and $\Xi(1820)$, is investigated by making use of a partial wave analysis employing the PAWIAN framework.

HK 4.6 Mon 18:00 H3

Two-particle correlations with high-p_T Λ baryons and K^0_S mesons in pp collisions at ALICE — •Lucia Anna Husová — IKP, WWU Münster, Germany

Complementary to jet reconstruction, two-particle correlations in $\Delta\eta$ and $\Delta\varphi$ are used to study jets, in particular, their particle composition. While in Pb–Pb collisions, this is done to characterize the Quark-Gluon Plasma, pp and p-Pb collisions serve as a reference and are of interest on their own for their input into the understanding of particle production mechanisms. Recent ALICE results on the production of strange particles in small systems (pp and p–Pb collisions) reveal the possibility of having similar strange hadron production mechanisms in all collision systems. We study two-particle correlations triggered with strange hadrons (K^0_S, Λ, $\bar{\Lambda}$) in pp collisions at 13 TeV.

In this talk, the dependence of the per-trigger yields of primary charged hadrons on the wide range of the transverse momenta of the trigger and associated particles, as well as on the event multiplicity, will be presented on both the near-side and away-side. Moreover, the ratios of these yields to the yields extracted from the h-h correlation function will be shown. The presented results will be compared among the three hadron species. In addition, a comparison to different MC generators will be presented, which will allow us to better understand the strangeness production in jets.

supported by BMBF ErUM FSP-T01 ALICE 0519PMCA1

HK 4.7 Mon 18:15 H3

New experimental limits on the effective hadron interaction with strangeness = -3 by ALICE — •Georgios Mantzaridis for the ALICE-Collaboration — Technische Universität München

Accessing experimentally the hadron-hadron interactions for systems of various quark content is essential to validate theoretical calculations, first principles and effective models alike. In the case of nucleon-nucleon (NN) interactions scattering experiments provide good constrains for the theory. However, the nucleon-hyperon (NY) interaction is difficult to access with traditional experimental techniques, and mostly limited to the strangess -1 sector.

Recent results from the ALICE collaboration demonstrated the feasibility of using two-particle correlation techniques to investigate the interaction between pairs containing multi-strangeness. We present measurements in the strangeness -3 sector using the p-Ω^- and the Λ-Ξ^- channels, both studied in high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV with ALICE at the LHC.

We have compared the p-Ω^- interaction to first principle lattice QCD calculations and found that they agree with the measured data if the inelastic channels are neglected. In particular the p-Ω^- system couples to Λ-Ξ^- and the strength of this coupling depends on the strength of the interaction itself. Thus, we have measured the Λ-Ξ^- correlation and compared the results to chiral effective field theory calculations. A shallow Λ-Ξ^- interaction is supported, which is compatible with a weak contribution to the p-Ω^- correlation.

HK 5: Nuclear Astrophysics

Time: Monday 16:30–18:30 Location: H4

Group Report HK 5.1 Mon 16:30 H4

Investigation of nuclear physics properties for p process nucleosynthesis — •Martin Müller, Felix Heim, Yanzhao Wang, Svenja Wilden, and Andreas Zilges — Institute for Nuclear Physics, University of Cologne

More than 60 years after the ground breaking paper by Burbidge, Burbidge, Fowler and Hoyle [1] many questions about the nucleosynthesis of neutron deficient nuclei in the p process remain unsolved. While the number of p nuclei is small, the number of reactions involved in their production is extremely large, necessitating a detailed and precise theoretical description. This talk will provide a brief overview of our group's contributions to the experimental determination of nuclear cross sections as well as studies of the underlying nuclear physics parameters such as the γ-ray strength function, the nuclear level density and the α-optical model potential. Recent experiments on proton- and α-induced reactions along with comprehensive comparisons with statistical model calculations will be presented [2-5].

Supported by the DFG (ZI 510/9-1).

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[4] F. Heim *et al.*, *Phys. Rev. C* **103**, 055803 (2021)
[5] F. Heim *et al.*, *Phys. Rev. C* **103**, 054613 (2021)

HK 5.2 Mon 17:00 H4

Gravitational wave signatures of the hadron-quark phase transition in binary neutron star mergers — •Matthias Hanauske[1,2], Horst Stöcker[1,2], and Luciano Rezzolla[1,2] — [1]Institut für Theoretische Physik, Max-von-Laue-Straße 1, 60438 Frankfurt, Germany — [2]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Straße 1, 60438 Frankfurt, Germany

The long-awaited detection of a gravitational wave from the merger of a binary neutron star in August 2017 (GW170817) marked the beginning of the new field of multi-messenger gravitational wave astronomy. Reaching densities a few times that of nuclear matter and temperatures up to 100 MeV, such mergers also represent potential sites for a phase transition from confined hadronic matter to deconfined quark matter (HQPT). The appearance of a HQPT in the interior region of the merger remnant and its conjunction with the spectral properties of the emitted gravitational wave can be calculated by fully general-relativistic hydrodynamic simulations. The results show, that binary neutron star mergers probe a broad region of the QCD phase diagram, with matter crossing the phase boundary over a large range in densities and temperatures. Depending on the properties of the HQPT, a gravitational wave signature can be created promptly after the merger or during the post-merger evolution. Especially during the post-merger evolution of the produced hypermassive/supramassive hybrid star the occurrence of a "delayed HQPT" might give a clear gravitational wave signature of the production of quark matter.

HK 5.3 Mon 17:15 H4

Long-time simulations of neutron star mergers — •Maximilian Jacobi[1], Federico Guercilena[1], Almudena Arcones[1,2], Wolfgang Kastaun[3,4], Takami Kuroda[3], Bruno Giacomazzo[5,6,7], and Martin Obergaulinger[8] — [1]Technische Universität Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung — [3]Max Planck Institute for Gravitational Physics — [4]Leibniz Universität Hannover — [5]Universitá degli Studi di Milano - Bicocca — [6]INFN, Sezione di Milano-Bicocca — [7]INAF, Osservatorio Astronomico di Brera — [8]Universitat de València

Merging binary neutron stars (BNS) typically form a massive accretion disk around a compact object that can eject mass for up to several seconds. Explosive r-process nucleosynthesis in these ejecta make up a large contribution to the total mass of heavy elements produced in the event and play an important role in its optical and infrared transient (kilonova). Therefore, to interpret multi-messenger events such as GW170817, it is essential to perform long-term simulations. I will present GR simulations of BNS mergers following the in-spiral, merger, and accretion disk phases. Shortly after merger, we transition from 3D to 2D which significantly reduces the computational cost of the simulation. This setup allows us to simulate merging neutron stars consistently from the in-spiral to the accretion disk phase on the time scale of seconds.

HK 5.4 Mon 17:30 H4

Weak r-process nucleosynthesis: the impact of (α,xn) reactions — •Athanasios Psaltis[1], Almudena Arcones[1,2], Melina Avila[3], Max Jacobi[1], Zach Meisel[4], Peter Mohr[5], Fernando Montes[6], and Wei Jia Ong[7] — [1]TU Darmstadt, Germany — [2]GSI, Darmstadt, Germany — [3]Argonne National Laboratory, Argonne, IL, USA — [4]Ohio University, Athens, OH, USA — [5]ATOMKI, Debrecen, Hungary — [6]NSCL/MSU, East Lansing, MI,USA — [7]Lawrence Livermore National Laboratory, Livermore, CA, USA

'Light' heavy elements (Z = 38 – 47) can be synthesized in the neutrino–driven ejecta of core–collapse supernovae via the weak r–process [1]. This nucleosynthesis scenario exhibits uncertainties from the absence of experimental data from (α,xn) reactions on neutron–rich nuclei, which are currently based on statistical model calculations. A recent sensitivity study identified the most important

(α,xn) reactions that can affect the production of 'light' heavy elements under different astrophysical conditions [2]. The current status of weak r–process nucleosynthesis calculations and the planning of experiments to experimentally determine (α,xn) reaction rates using the MUSIC detector at Argonne National Laboratory [3] and the SECAR recoil separator at FRIB [4] will be discussed.

References

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[4] G. Berg et al., NIM A 877, 87 (2018)

HK 5.5 Mon 17:45 H4

Mass Measurements of Proton-Rich Strontium Isotopes for rp-Process Studies — •Tobias Murböck[1], Jack Henderson[1,2], Zach Hockenbery[1,3], Ania A. Kwiatkowski[1,4], and Daniel Lascar[1,5] for the TITAN-Collaboration — [1]TRIUMF, Vancouver, Canada — [2]Univ. of Surrey, England — [3]McGill Univ., Montreal, Canada — [4]Univ. of Victoria, Victoria, Canada — [5]Northwestern Univ., Evanston, Illinois, US

The rp-process (rapid proton-capture process) consists of a series of radiative proton captures along the N=Z line up to the proton dripline. It is believed to be the primary source of nuclei that are not generated via either the rapid or slow neutron-capture process.

The energy released during the rp-process may power type-I X-ray bursts which occur in binary star systems where a neutron star accretes material from its larger partner. The calculated luminosity from an X-ray burst crucially depends on the mass values of the involved nuclei, which affect the reaction flow through the the rp-process waiting points. Here we present high-precision mass measurements of the neutron-deficient isotopes $^{74-76}$Sr. Specifically, the mass of ^{74}Sr allows one to determine the two-proton separation energy of the 2p reaction from the waiting point ^{72}Kr. The achieved uncertainties of a few 10 keV/c^2 are precise enough to provide stringent constraints on the nuclear reaction rates in this region of the rp-process. The experiment has been performed with the multi-reflection time-of-flight mass spectrometer (MR-ToF-MS) which has been recently added to TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN).

HK 5.6 Mon 18:00 H4

Measurement of ^{39}K(p,γ)^{40}Ca resonance strengths below 900 keV for classical novae nucleosynthesis — •Philipp Scholz, Richard J. deBoer, Joachim Görres, Rebeka Kelmar, Shahina Shahina, and Michael Wiescher — Department of Physics, University of Notre Dame, IN

Classical novae are one of the most frequent explosive nucleosynthesis events in our universe but are still not sufficiently understood.

To this day, nuclear astrophysics cannot explain the endpoint of the nucleosynthesis networks in classical novae which is mainly due to a scarce experimental data base of nuclear reaction rates of proton-induced reactions in the the mass-region above silicon at temperatures between 0.1 GK and 0.4 GK.

Because some nova ejecta hint on the production of elements in the calcium range (Centauri V1065) and some possibly even up to the iron region (Cygni V1974), it is of utmost interest to investigate possible paths towards heavier elements.

Here we report on new measurements of resonance strengths of the ^{39}K(p,γ)^{40}Ca reaction below 900 keV at the 5U accelerator of the University of Notre Dame and their implications on the (p,γ) reaction rate on ^{39}K.

HK 5.7 Mon 18:15 H4

Production and study of new neutron-rich nuclei via a novel MNT-induced process using 238U+164Dy — •Deepak Kumar[1], Paul Constantin[2], and Timo Dickel[1] for the FRS Ion Catcher-Collaboration — [1]GSI Helmholtz Center for Heavy Ion Research and Justus-Liebig University of Giessen, Germany — [2]ELI-NP/IFIN-HH, Magurele, Romania

The crux of measuring the nuclear properties of heavy neutron-rich exotic nuclei and nuclear data with reduced uncertainties for known nuclei is to explore the r-process abundance pattern of the elements heavier than iron (Fe). However, the production of these neutron-rich nuclei is beyond the accessible limit of conventional methods. Nevertheless, a new possible alternative is the Multi-Nucleon Transfer (MNT) approach that manifests a strong potential to achieve this goal. In order to establish a new direction of research for the MNT-induced neutron-rich products using the FRS Ion Catcher (IC) facility at GSI, the 238U beam at 500 MeV/u has been proposed to deliver from the SIS18 and allowed to bombard on 164Dy target at 10 MeV/u placed inside the Cryogenic Stopping Cell (CSC). It offers a promising way to produce a significant amount of several new neutron-rich nuclei that have been speculated by the most reliable state-of-the-art Langevin-type model calculations. This research direction is based on a universal, fast, and efficient method to measure production cross-section and broadband masses of reaction products, including long-lived isomers. The developed methods and instrumentation will be extended to be utilized for LEB at the Super FRS facility with neutron-rich unstable beams.

HK 6: Instrumentation II

Time: Monday 16:30–18:15 Location: H5

Group Report HK 6.1 Mon 16:30 H5

The new APD Based Readout of the Crystal Barrel Calorimeter — •Christian Honisch, Peter Klassen, Johannes Müllers, and Martin Urban for the CBELSA/TAPS-Collaboration — HISKP, University of Bonn, Nussallee 14-16, 53115 Bonn

The Crystal Barrel is an electromagnetic calorimeter located at the electron accelerator ELSA. The detector consisting of 1320 CsI(Tl) scintillator modules is used to detect the decay products of baryon resonances, $\vec{\gamma}\vec{\mathrm{n}} \rightarrow N^{*} \rightarrow \mathrm{n}\pi^{0} \rightarrow \mathrm{n}\gamma\gamma$.
To comprehensively study reactions that have no charged particles in the final state, an exchange of the readout electronics was necessary to achieve a high and uniform trigger efficiency for such reactions.
The upgrade was finished in 2017 and this talk gives an overview over the key challenges:
- Fast signals from CsI(Tl) while maintaining a reasonable SNR,
- Clustering in the 26 matrix in 100 ns,
- APD gain measurement and stabilization.
The talk will introduce the new readout and present its achieved performance in prototype tests and the first production beamtimes.

HK 6.2 Mon 17:00 H5

Energy resolution optimization for the $\overline{\mathrm{P}}$ANDA EMC regarding the LAAPD gain — •Kim Tabea Giebenhain for the PANDA-Collaboration — Justus-Liebig-Universität, Gießen, Deutschland

For the future Facility for Antiproton and Ion Research, the $\overline{\mathrm{P}}$ANDA experiment will be a unique opportunity to study proton antiproton collisions. One of the most crucial detector parts is the electromagnetic calorimeter. In order to meet the high precision demands in reconstruction and particle identification, its energy resolution is an important factor. The energy resolution depends on the signal to noise ratio of the front-end, especially at the crucial low energies. To improve the calorimeter performance beyond its design goal, for potential future even more demanding requirements, a study was done to find the optimal bias voltage for the utilized Large Area Avalanche Photo Diodes for energy ranges between 10 MeV and 2 GeV, using a light pulser system to simulate the PWO-II scintillation light. Since the dynamic range of the read-out chain is limited, additional simulation studies were conducted to find out, if the optimum bias voltage can be used for higher beam momenta.

Supported by BMBF, GSI/FAIR, HFHF

HK 6.3 Mon 17:15 H5

APD-Gain optimization for the $\overline{\mathrm{P}}$ANDA Barrel EMC — •Aniko Tim Falk, Markus Moritz, Hans-Georg Zaunick, Kai-Thomas Brinkmann, Valera Dormenev, Kim Tabea Giebenhain, Christopher Hahn, Marvin Peter, Matthias Sachs, and René Schubert for the PANDA-Collaboration — II. Physikalisches Institut, Justus-Liebig-Universität, Gießen

The future electromagnetic calorimeter of the PANDA Experiment will provide an excellent energy resolution over a wide dynamic range. In order to reveal the full potential of its readout, the gain of the APDs can still be further optimized. With the goal to detect high energy photons over a wide energy range from a few dozens of MeV up to 15 GeV, the system must provide a most excellent energy resolution over the whole spectrum whilst maintaining the required dynamic range of the individual readout-electronics. The progress made on this subject over the last two years shall be briefly summarized in this contribution. Various measurements have been made on a complete setup, including an accelerator experiment at MAMI with tagged photons, that is very close to the final read out of the $\overline{\mathrm{P}}$ANDA EMC. To match environmental conditions during operation, the setup was cooled to −25 °C. The analysis of the data is still in progress to this date. This project is supported by BMBF, GSI and HFHF.

HK 6.4 Mon 17:30 H5

Construction and testing of the crystal Zero Degree Detector for BESIII — •Frederic Stieler[1], Achim Denig[1], Peter Drexler[1], Leonard Koch[2], Wolfgang Kühn[2], Werner Lauth[1], Jan Muskalla[1], Saskia Plura[1], Christoph Redmer[1], and Yasemin Schelhaas[1] — [1]Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Deutschland — [2]II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Deutschland

The crystal Zero Degree Detector (cZDD) is a proposed addition to the BESIII experiment in China in the near future. In order to measure hadronic cross sections with the Initial State Radiation (ISR) method for a more precise calculation of the hadronic vacuum polarization contribution to the anomalous magnetic moment of the muon, ISR photons have to be detected. Since these photons are mostly emitted at small angles in relation to the colliding particles, the cZDD was conceived to measure ISR at low angles of about 1.5 mrad to 10.4 mrad, that are not covered yet by the already existing detectors at BESIII.
In this presentation the construction of the detector as well as test measurements using the read out electronics are presented.

HK 6.5 Mon 17:45 H5

Status report on the progress on the analysis of the NewSUBARU data — •Nikolina Lalić[1], Thomas Aumann[1,2], Martin Baumann[1], Patrick Von Beek[1], Ioana Gheorghe[3], Heiko Scheit[1], and Dmytro Symochko[1] — [1]TU Darmstadt — [2]GSI Helmholtzzentrum — [3]"Horia Hulubei" National Insitute for R&D in Physics and Nuclear Engineering (IFIN-HH), 30 Reactorului 077125 Bucharest-Magurele
The photoneutron cross sections of 112Sn,116Sn,120Sn and 124Sn were measured in(g,xn)reactions, where x =1-4, using a quasi-monochromatic laser Compton-scattering g-ray beam at the NewSUBARU facility. The goal of the experiment is to resolve the long-standing discrepancy of the total and partial cross sections measured by the Livermore and the Saclay groups. Measurements were done with g energies from 8 MeV to 38 MeV. As a neutron counter a detector with a flat-efficiency was used to take advantage of the direct neutron-multiplicity sorting technique. After the cross sections are obtained they will be compared to both data sets.The talk will be focused on current results of the analysis of the data from 2019. measured at NewSUBARU facility.

HK 6.6 Mon 18:00 H5

PANDA backward end-cap calorimeter support system — •David Rodriguez Pineiro[1], Alaa Dbeyssi[1], Frank Maas[1,2,3], Luigi Capozza[1], Oliver Noll[1], Sahra Wolff[1], Peter-Bernd Otte[1], Dong Liu[1], Alexander Christian Geriner[1], Julian Moik[1], and Samet Katilmis[1] for the PANDA-Collaboration — [1]Helmholtz-Institut Mainz, Germany — [2]Institute of Nuclear Physics, Johannes Gutenberg University, Mainz, Germany — [3]Prisma Cluster of Excellence, Mainz, Germany
The PANDA experiment will be one of three experimental pillars at the new accelerator facility FAIR in Darmstadt. The PANDA detector system has been designed to record antiproton annihilations at high rate and with high resolution and thus contribute to the understanding of the strong interaction in the non-perturbative regime. The group in Mainz is constructing the backward end-cap (BWEC) of the PANDA electromagnetic calorimeter, which will be used at the MAMI electron accelerator for a FAIR/Phase0 experiment at Mainz.

In order to mount and calibrate the detector a support system has been designed and built. All mechanical parts (shafts, bearings, connecting elements and a high ratio worm gearbox) have been chosen to comply with a safety factor of about two. It allows for a rotation by 90° changing between assembling position (mounting plate horizontal - crystals vertical) and working position. Both positions will also be used for the calibration with cosmic muons. The mechanical design of the backward end-cap will be discussed.

HK 7: Invited Talks - II

Time: Tuesday 11:00–12:30 Location: H1

Invited Talk HK 7.1 Tue 11:00 H1

First observation of neutrinos from the CNO fusion cycle in the Sun — •Daniele Guffanti — Institute of Physics and Excellence Cluster PRISMA, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany
The Sun, as all the other stars, is fuelled for most of its life by the fusion of hydrogen into helium taking place in its core. Neutrinos produced in such reactions are the only direct probe to the innermost part of our star and real time messengers of its engine. Decades of experimental and phenomenological efforts allowed us to study in detail the driving energy production mechanism in the Sun, the proton-proton chain, which is responsible for ≈ 99% of the solar luminosity. The fusion processes accounting for the remaining 1% are believed to be catalysed by the presence of Carbon, Nitrogen and Oxygen (CNO-cycle) in the solar interior, but a direct evidence of the occurrence of such mechanism was still missing.

After years-long efforts, the Borexino experiment at the Gran Sasso National Laboratories has recently reported the first direct observation of solar neutrinos produced in the CNO-cycle. In this talk I will present the Borexino findings and I will discuss the importance of CNO neutrinos for astrophysics and for our understanding of the Sun.

Invited Talk HK 7.2 Tue 11:30 H1

The Compressed Baryonic Matter experiment at FAIR — •Alberica Toia for the CBM-Collaboration — Goethe University Frankfurt — GSI
The study of QCD matter at extreme temperature and density such as existing shortly after the Big Bang or in the core of neutron stars, can bring new insights into the innermost structure of matter and the fundamental forces between its building blocks.

While gravitational wave events reveal a glimpse of QCD matter at these extreme conditions, the future Facility for Antiproton and Ion Research (FAIR) will directly create and investigate its properties in the laboratory. For the very high net-baryon densities, produced by nucleus-nucleus collisions at SIS100 beam energies (3.5-12 AGeV), phenomena such as first order phase transition between hadronic and partonic matter which may terminate at a critical point or even more exotic phases may be expected.

The Compressed Baryonic Matter (CBM) experiment is a dedicated heavy-ion investigation designed to explicitly access rare observables sensitive to the detector media, employing fast and radiation hard detectors, self-triggered detector front-ends and a free-streaming readout architecture.

Several of the CBM detector systems, the data read-out chain and event reconstruction for several of the CBM detector subsystems are commissioned and already used in experiments for FAIR phase 0 and for a full-system setup at GSI SIS18. The physics program of CBM will be reviewed and the current status of the experiment will be reported.

Invited Talk HK 7.3 Tue 12:00 H1

Ab initio perspectives on strongly correlated nuclei — •Alexander Tichai — Institut für Kernphysik, Darmstadt, Germany
The description of nuclear many-body systems has witnessed tremendous progress in the last years due to the development of i) high-precision nuclear interaction models derived from chiral effective field theory and ii) the development of many-body expansion techniques building upon a suitably chosen A-body reference state [1]. The mild computational scaling of such expansion methods extends the reach of ab initio calculations that were previously limited by the capacity of large-scale diagonalization techniques. Nowadays, this allows for targeting up to one hundred interacting nucleons from first principles [2]. In this talk, I review the status of many-body expansion techniques applied to strongly correlated open-shell systems and discuss challenges that emerge for heavy nuclei well above the tin region.

For the description of open-shell nuclei symmetry-breaking techniques have been shown to provide a simple alternative to conceptually more involved multi-reference techniques [3]. Therefore, recent developments will be reviewed that build upon deformed mean-field states to capture the static correlations that emerge in nuclei away from shell closures. Finally, I provide an outlook on future perspectives for heavy nuclei that are out of reach of current ab initio technology [4].

[1] H. Hergert, Front. Phys. 8, 379 (2020) [2] T. Morris et al., Phys. Rev. Lett. 120, 152503 (2018) [3] A. Tichai et al., Phys. Lett. B, 786, 195 (2018) [4] A. Tichai et al., arXiv:2105.03935 (2021)

HK 8: Instrumentation III

Time: Tuesday 14:00–16:00 Location: H1

Group Report HK 8.1 Tue 14:00 H1

The Silicon Tracking System of the CBM experiment: towards series production — •Adrian Rodriguez Rodriguez for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
The Silicon Tracking System (STS) is the central detector for charged-particle identification and momentum determination in the future CBM experiment at the new FAIR accelerator facility. It is designed to measure up to 1000 charged particles in nucleus-nucleus collision at interaction rates up to 10 MHz, achieve

a momentum resolution better than 2% inside 1 Tm magnetic field, and identify complex particle decays topologies. The STS comprises eight tracking stations equipped with double-sided silicon microstrip sensors. Two million channels are read out with self-triggering electronics, matching the experiment's data streaming and online event analysis concept. The STS functional building block is the detector module. It consists of a sensor, micro-cables, and two front-end electronics boards, carrying the custom-developed readout ASIC. The test and characterization of the first detector modules, part of the pre-series production, have been performed in the laboratory and the beamline as part of the FAIR Phase 0 activities. This presentation shows an overview of the STS project and its focus towards the series production; special emphasis is drawn to the quality assurance and current status of the module components, readout chain, and system integration.

HK 8.2 Tue 14:30 H1

The Silicon Strip Detector setup for the MAGIX Experiment — •Jennifer Geimer for the MAGIX-Collaboration — Institute for Nuclear Physics, Mainz, Germany

The MAGIX-Experiment (Mainz Gas Injection Target Experiment) will be a high precision electron scattering experiment located at the MESA accelerator at the *Institute for Nuclear Physics* in Mainz. The experimental setup comprises a windowless gas jet target which allows direct interaction between beam electrons and target nuclei. It can be operated with different types of target gas and therefore allows investigation of a wide physical program. While the scattered electrons will be detected by two magnet spectrometers, the detection of nuclear fragments of the target will be done by using several recoil detectors. The centerpiece of the recoil detector design is a *Silicon Strip Detector* with size of 50 x 50 mm^2. To completely stop protons with an energy of $\mathcal{O}$(70 MeV), the silicon detector will be equipped with an additional plastic scintillator layer read out by silicon photomultipliers. The channels of the silicon detector as well as the silicon photomultipliers will be processed by the APV25 Chip, while the trigger signal is simultaneously produced using an additional frontend board.

This presentation gives a short overview of the MAGIX experiment and the resulting design parameters for the recoil detector. It focuses on the working principle and the current state of development of the *Silicon Strip Detector*.

HK 8.3 Tue 14:45 H1

Characterization of the MAGIX windowless gas jet target in high-intensity electron beams — •Maximilian Littich for the MAGIX-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Deutschland

MAGIX is a fixed target electron scattering experiment at the upcoming MESA accelerator. It will be operated in the energy recovery linac mode of the accelerator which allows to reach beam currents of at least 1 mA. This operation mode requires a very thin target for which MAGIX will use an internal, windowless gas jet target. This cryogenic supersonic gas jet target will be able to run with different gases, e.g. hydrogen, deuterium, helium, oxygen, argon or xenon.

At the existing A1 multi-spectrometer facility at the electron accelerator MAMI detailed studies have been carried out using hydrogen as the target gas. This talk will show the results of these studies, the challenges of the operation and the performance of the target under real beam condition.

HK 8.4 Tue 15:00 H1

Development of a lithium target for $^3_\Lambda H$ observation — •Julian Geratz[1], Patrick Achenbach[1], Philipp Eckert[1], Philipp Herrmann[1], Pascal Klag[1], Josef Pochodzalla[1], and Marcell Steinen[2] for the A1-Collaboration — [1]Inst. für Kernphysik, JGU Mainz — [2]Helmholtz Institut Mainz

Studies of light hypernuclei offer insights into the strong nuclear force. For this purpose, the $^4_\Lambda H$ has been observed at the electron accelerator MAMI in Mainz through pionic decay. In this experiment, beryllium was used as target material. Observation of the hypertriton, the lightest hypernucleon, by this method would require an increase in luminosity by about a factor of 10. To study the $^3_\Lambda H$ a new target was designed and has been tested. This new target for hypertriton observation uses lithium as target material. As target material, lithium offers higher $^3_\Lambda H$ yield than beryllium, as it has fewer possible fragmentation channels. Furthermore, its low density enables a new target geometry, with a thick target along the beam and a small transverse dimension, thus limiting the energy loss variations of the decay pions.

The dimensions of the target are 1.5 × 50 × 50 mm^3, the electron beam will travel through 50 mm of lithium. As a material, lithium is difficult to handle due to its low melting point and high reactivity.

The challenges of using lithium as target material, their solutions and the advantages of lithium are the topic of this presentation.

Supported by DFG (PO 256/7-1) and by the European Union's Horizon 2020 programme, No 824093.

HK 8.5 Tue 15:15 H1

Measurements of the accelerator beam quality and lifetime at COSY with the $\overline{\text{P}}$ANDA Cluster-Jet Target — •Hanna Eick, Philipp Brand, Benjamin Hetz, Daniel Klostermann, Christian Mannweiler, Sophia Vestrick, and Alfons Khoukaz for the PANDA-Collaboration — Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany

The internal, windowless $\overline{\text{P}}$ANDA Cluster-Jet Target developed at WWU Münster will be the Day-1 target of the antiproton storage ring facility HESR, which is currently under construction at the future GSI/FAIR facility. With a target thickness of more than 2×10^{15} atoms/cm^2 without temporal substructures and a distance from the target nozzle of more than 2 m to the interaction point, it is suitable for 4π experiments with a high luminosity. Of particular interest during the test beam time at COSY are the studies of the beam-target interaction. In August 2019, special attention was paid to the measurements of the accelerator beam quality and lifetime in conjunction with the $\overline{\text{P}}$ANDA target and the elements of the stochastic cooling of the HESR also installed at COSY. An overview of the $\overline{\text{P}}$ANDA Cluster-Jet Target and measurements performed at COSY in August 2019 will be presented in this talk.

This project has received funding from BMBF (05P19PMFP1) and the European Union's Horizon 2020 programme (824093).

HK 8.6 Tue 15:30 H1

Angular error correction by analysing the Fresnel diffraction in an undulator interferometer — •Pascal Klag[1], Patrick Achenbach[1], Philipp Eckert[1], Toshiyuki Gogami[2], Philipp Herrmann[1], Masashi Kaneta[3], Sho Nagao[3], Satoshi Nakamura[3], Josef Pochodzalla[1], and Yuichi Toyama[3] for the A1-Collaboration — [1]Johannes Gutenberg-Universität Mainz — [2]Kyoto University, Kyoto — [3]Tohoku University, Sendai

The Mainz Microtron is an electron accelerator, which delivers electron energies up to 1.6 GeV, with a small spread of the energy $\sigma_{beam} < 13keV$. The uncertainty for the absolute energy for all available beam energies was limited to 160 keV. A novel method is used to improve the uncertainty for energies of 180 and 195 MeV. The method is based on interferometry with two spatially separated light sources (undulators) driven by relativistic electrons. The improved resolution of the setup revealed the modification of the undulator interference by Fresnel diffraction. A detailed analysis allowed to compensate for this structure and led to an enhanced accuracy of the measurement. The determination of the angle of observation strongly benefited from the diffraction. High precision beam stabilization has been used to fix the electron beam at optimal conditions. Supported by DFG (PO 256/7-1) Supported by the European Union's Horizon 2020 programme, No 824093.

HK 8.7 Tue 15:45 H1

Studies and Developments for the $\overline{\text{P}}$ANDA Cluster-Jet Target — •Philipp Brand, Daniel Bonaventura, Hanna Eick, Clara Fischer, Jost Froning, Benjamin Hetz, Niklas Humberg, Christian Mannweiler, Jeremy Runge, Sophia Vestrick, Michael Weide, and Alfons Khoukaz for the PANDA-Collaboration — Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany

The $\overline{\text{P}}$ANDA cluster-jet target will be the Day-1 target for the $\overline{\text{P}}$ANDA experiment at HESR at FAIR. With this device a target thickness of more than 10^{15} atoms/cm^2 is achieved at the interaction point more than 2 m below the nozzle. The cluster-jet is then pumped away using a beam dump which is again more than 2 m below the interaction point. The long and narrow jet pipe in between makes a precise adjustment of the complete target system and the use of various monitor systems at different positions necessary. Therefore, a new beam dump is developed which allows the integration of monitor systems. Additionally, due to the large distances between the vacuum pumps of this 4π detector, it is crucial to understand the complete vacuum system including the source of residual gas. For this purpose, extensive studies and calculations are ongoing. Furthermore, studies on the production of new Laval nozzles and the process of cluster formation are performed. Within this talk, the current and future developments at the $\overline{\text{P}}$ANDA cluster-jet target will be discussed. This project has received funding from BMBF (05P19PMFP1), GSI FuE (MSKHOU1720 and MSKHOU2023) and the EU's Horizon 2020 programme (824093).

HK 9: Outreach

Time: Tuesday 14:00–16:15 Location: H2

Group Report HK 9.1 Tue 14:00 H2

Netzwerk Teilchenwelt als bundesweite Plattform für Outreach in der Hadronen- und Kernphysik sowie in der Teilchen- und Astroteilchenphysik — •Uta Bilow[1], Achim Denig[2], Christian Klein-Bösing[3], Michael Kobel[1] und Barbara Valeriani-Kaminski[4] für die Netzwerk Teilchenwelt-Kollaboration — [1]Technische Universität Dresden — [2]Johannes Gutenberg-Universität Mainz — [3]Westfälische Wilhelms-Universität Münster — [4]Universität Bonn

Für die "Physik der kleinsten Teilchen" existiert mit dem Netzwerk Teilchenwelt eine einzigartige Struktur, in der sich bundesweit Forschungsgruppen aus 30 Instituten zusammengeschlossen haben, um ihre wissenschaftliche Arbeit einem breiten Publikum zugänglich zu machen. Jugendliche lernen bei Projekttagen die faszinierende Forschung an Beschleunigern kennen oder führen eigene Messungen mit Detektoren durch. Interessierte Schülerinnen und Schüler können mehrtägige Programme an Forschungseinrichtungen absolvieren. Junge Studierende vernetzen sie sich über ein Fellow-Programm frühzeitig mit den Forschungsgruppen. Außerdem werden junge Forscherinnen und Forscher zur Wissenschaftskommunikation motiviert und befähigt. Seit 2010 stellt Netzwerk Teilchenwelt Programme und Strukturen für diese Aktivitäten bereit, die vom BMBF durch das Projekt KONTAKT/KONTAKT2 gefördert werden. Wir berichten über Erfahrungen und Entwicklungen im Projekt; außerdem stellen wir die Angebote sowie Beteiligungsmöglichkeiten für interessierte Forscherinnen und Forscher vor.

Group Report HK 9.2 Tue 14:30 H2

PANDA Outreach Projects — •Mustafa Schmidt — II. Physikalisches Institut, Justus-Liebig-Universität Gießen

PANDA is a fixed-target experiment that is going to address a wide range of open questions in the hadron physics sector by studying the interactions between antiprotons and a stationary proton target. In 2019, a small outreach task force was founded by the PANDA collaboration with the main intention of designing a dedicated PANDA Masterclass for the Netzwerk Teilchenwelt (NTW). Since then, the number of participants has increased constantly and many new outreach projects were initiated. The most advanced one is a 1:10 scale LEGO model of the PANDA detector that has been designed purely virtually with the software LeoCAD and will be constructed after finalizing the tendering process. In addition to that, a new exhibition model, that mainly consists of 3D printed parts, of the PANDA detector with the same scale as the LEGO model is currently under development in Bochum. With the help of LED strips that are connected to a microcontroller, certain events, simulated with the PANDA simulation framework PandaRoot, will be displayed within the model and on a computer screen. A new project in Upsala focuses on the implementation of the PANDA geometry into the graphics engine Unity. This is considered to be the first step of creating a framework for Virtual Reality (VR) glasses with a virtual 3D model of the PANDA detector in combination with selected events. Two more projects will additionally be discussed in this talk: a card game to easily explain the fundamental parameters related to hadron physics, and the graphics rendering of the final detector.

HK 9.3 Tue 15:00 H2

Streubretter - Ein mechanisches Analogen zu Fixed-Target Experimenten — •Stephan Aulenbacher[1], Achim Denig[1] und Wiebke Kött[2] — [1]Institut für Kernphysik, Mainz, Germany — [2]Institut für Physik, Mainz, Germany

Streuexperimente wie sie an Beschleuniger Anlagen durchgeführt werden, sind für Menschen ohne physikalischen Hintergrund nur schwer zu begreifen. Wie kann das beschießen eines Materials mit Teilchen Aufschluss über die Struktur der Materie geben? Um diese frage der Öffentlichkeit zugänglich zu machen, wurde an der Johannes-Gutenberg Universität Mainz ein mechanisches Analogon zu solchen Experimenten entwickelt. Kleine Stahlkugeln werden an einer Geometrischen Form gestreut, welche nach dem Streuprozess durch Lichtschranken rollen, um den Streuwinkel detektieren. Aufgrund der so entstehenden Histogramme kann die geometrische gestalt des Streuzentrums identifiziert werden. Das experiment kann sowohl in Schülerversuchen als auch als Demonstrationsobjekt in Öffentlichen Vorträgen genutzt werden. Einfache geometrische Strukturen wie ein Dreieck bis hin zum 3D gedruckten 1/r Potential können als Streuzentrum eingesetzt werden. Als didaktische Hilfsmittel stehen den Experimentatoren interaktive Simulations Tools zur verfügung. Erfahren Sie in diesem Vortrag die Bauweise, das Didaktische Konzept im Detail und die Grenzen der Streubretter.

HK 9.4 Tue 15:15 H2

OPAL Masterclass mit maschinellem Lernen — •Nicolas Tiltmann und Christian Klein-Bösing für die Netzwerk Teilchenwelt-Kollaboration — Institut für Kernphysik, WWU Münster, Germany

Die Teilchenphysik-Masterclasses sind eine inzwischen etablierte Methode zur Vermittlung aktueller Forschung. In diesem Vortrag wird ein Konzept vorgestellt, welches Teilchenphysik-Inhalte mit Methoden des maschinellen Lernens kombiniert.

Die Basis bildet die schon bestehende Masterclass zum OPAL-Experiment. Dort wurden Z-Bosonen über deren Zerfallsprodukte mit Hilfe des Event-Displays identifiziert. Hier wird statt der Erkennung per Hand ein künstliches neuronales Netz mit einem kleinen Teil der gesamten Datenmenge trainiert, um anschließend die restlichen Ereignisse auf Basis der gelernten Merkmale automatisch klassifizieren zu lassen. Die Programmierung erfolgt in Python mittels Jupyter-Notebooks und ist so vereinfacht, dass keine Vorkenntnisse nötig sind.

Neben Aspekten der Teilchenphysik wird den Teilnehmenden insbesondere ein Gefühl für die Funktionsweise von maschinellem Lernen vermittelt und auch Probleme und Grenzen dieser Methoden thematisiert.

Gefördert durch BMBF KONTAKT 05P19PMOA1.

HK 9.5 Tue 15:30 H2

Virtuelle Führung am Beschleuniger MAMI — •Stephan Aulenbacher[1], Denig Achim[1] und Kött Wiebke[2] — [1]Institut für Kernphysik, Mainz, Deutschland — [2]Institut für Physik, Mainz, Deutschland

Führungen durch die Beschleuniger Anlage MAMI für Interessierte aller Art, haben in Mainz, am Institut für Kernphysik eine langjährige Tradition. Jährlich werden mehrere hundert Schüler, Studenten, Politiker oder einfach Physik interessierte durch die Anlage geführt. Währen der Covid-19 Krise konnten diese Führungen leider nicht stattfinden. Daher erstellte das Mainzer Outreach team ein Virtuelles Konzept für eine solche Führung, welches auch nach der Covid-19 Krise in Kombination mit der physischen Führung weiter bestand haben soll, da sich zeigte dass die Virtuelle Führung viele, in der reellen Führung nicht umsetzbare, Vorteile bietet. In diesem Vortrag werden die Mittel zur Umsetzung so wie das Didaktische Konzept der Virtuellen Führung präsentiert.

HK 9.6 Tue 15:45 H2

3D und Virtual-Reality-Umgebung zur Vermittlung von Grundlagenforschung am Beispiel des ALICE-Detektors am CERN-LHC — •Christian Klein-Bösing[1], Philipp Bhatty[2], Stefan Heusler[3] und Reinhard Schulz-Schaeffer[2] für die Netzwerk Teilchenwelt-Kollaboration — [1]Institut für Kernphysik, WWU Münster, Germany — [2]Department Design, HAW Hamburg, Germany — [3]Institut für Didaktik der Physik, WWU Münster, Germany

Detektoren in der Elementarteilchenphysik, wie der ALICE-Detektor am LHC, können in der Regel der breiten Öffentlichkeit nur an Hand von Bildern oder Filmen präsentiert werden. Die Darstellung in einer Echtzeit-3D-Umgebung, wie einer Virtual-Reality- und Web3D- Applikation, ermöglicht hingegen direkt die Größe des Experimentes erfahrbar zu machen, aber auch neue, virtuelle Handlungsräume und Handlungsoptionen zu erforschen und zielgruppengerecht einzusetzen. Die Entwicklung einer solchen Web3D-Lernumgebung sowie einer VR- Lernapplikation, inklusive der empirischen Bewertung verschiedener Darstellungsoptionen, der Gestaltung von Nutzerinteraktion und interaktiver Lernaufgaben, erfordert eine enge Kooperation zwischen Grundlagenforschung in der Elementarteilchenphysik, der Didaktik der Physik und der Wissenschaftsillustration. Wir präsentieren den aktuellen Entwicklungsstatus basierend auf einer interaktiven Visualisierung des ALICE-Detektors in VR und Web-3D erste Anwendungen im Kontext eines Workshops für Jugendliche zur Konstruktion des ALICE-Detektors aus LEGO.

HK 9.7 Tue 16:00 H2

Konzeption und Bau eines ALICE Lego Modells im Rahmen einer Erlebnisstation — •Marcus Mikorski[1], Christian Klein-Bösing[2] und Sascha Mehlhase[3] für die Netzwerk Teilchenwelt-Kollaboration — [1]Goethe Universität Frankfurt, Institut für Kernphysik, 60438 Frankfurt — [2]Wilhelmsuniversität Münster, Institut für Kernphysik, 48149 Münster — [3]Ludwig-Maximilians-Universität München, Fakultät für Physik, 80799 München

Im Rahmen einer ALICE-Erlebnisstation für den ErUM-Forschungsschwerpunkt wurde ein ALICE-Lego-Modell konzipiert und gebaut und dabei durch BMBF FSP T01 und BMBF KONTAKT unterstützt. Ziel war es, ein Modell gemeinsam mit Jugendlichen am Computer zu designen und real mit Legosteinen zusammenzubauen. Das Projekt diente dazu, Schüler*innen und jüngeren Studierenden die Möglichkeiten zu geben, sich mit der Detektortechnologie und den Physikfragen von ALICE auseinanderzusetzen und das Arbeiten in einer Forschungskollaboration zu erfahren. Von Januar 2021 bis Juni 2021 waren 17 Teilnehmende damit beschäftigt das Modell digital zu entwerfen und an einem Wochenende an den Standorten Frankfurt und Münster zusammen zu bauen. Die beim realen Bau gewonnen Erfahrungen dienen der weiteren Optimierung und sollen demnächst zur Veröffentlichung des ALICE-Modells führen. Das Konzept dieses Projekts lässt sich auf andere Detektoren und Großanlagen übertragen, sowohl zur Konzeption neuer Modelle als auch zum Nachbau bestehender Modelle, begleitet durch entsprechende Einblicke in die aktuelle Forschung.

HK 10: Hadron Structure and Spectroscopy II

Time: Tuesday 14:00–16:00 Location: H3

Group Report HK 10.1 Tue 14:00 H3

Experimental Inputs to the Hadronic Light-by-Light Contributions to $(g-2)_\mu$ from BESIII — •Max Lellmann, Achim Denig, and Christoph Florian Redmer — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

The long-standing discrepancy between Standard Model prediction and direct measurement of the muon anomalous magnetic moment $a_\mu = (g-2)_\mu/2$ has recently been confirmed by a new measurement by the Muon-g-2-collaboration at Fermilab. In order to establish the significance of the discrepancy between the prediction and direct measurement of currently 4.2σ, both, experiment and theory, need to be improved.

The Standard Model prediction of a_μ is limited by its hadronic contributions, due to the non-perturbative nature of the strong interaction at the relevant energy scales. A large contribution to the uncertainty of the Standard Model calculation stems from the hadronic light-by-light scattering contribution. Its accuracy depends heavily on the knowledge of transition form factors of light pseudoscalar mesons and the production of meson systems from two-photon collisions.

The BESIII experiment, a τ-charm-factory located at the Institute of High Energy Physics in Beijing, China, offers a perfect test bed for the investigation of two-photon processes in the momentum transfer range, which is most relevant to the a_μ calculations. In this presentation we discuss recent results, ongoing projects, and future prospects of the measurements of transition form factors at BESIII.

Group Report HK 10.2 Tue 14:30 H3

Experimental Inputs to the Hadronic Vacuum Polarization Contribution to the Anomalous Magnetic Moment of the Muon at the BESIII Experiment — •Riccardo Aliberti — JGU Mainz

The recent result from the Muon $g-2$ Experiment has confirmed the tension between the Standard Model (SM) prediction of the anomalous magnetic moment of the muon (a_μ) and the experimental measurement at a 4.2 σ level. To understand the origin of this discrepancy further improvements of experiment and theory are necessary.

The uncertainty on the SM prediction is dominated by hadronic contributions and particularly by the Hadronic Vacuum Polarization (HVP) component, which is evaluated with a dispersive formalism from the measurement of hadron production cross sections in electron-positron annihilations. Therefore, improvements in the cross section measurements directly reflect in a reduction of the uncertainty on the HVP contribution to a_μ

The BESIII Experiment, located at the BEPCII collider in Beijing, has collected the world largest dataset of e^+e^--annihilations in the τ-charm energy region. In this talk, the current status and perspective for the measurement of hadron production cross sections, entering the evaluation of the HVP contribution to a_μ, at BESIII are reviewed. The author of this talk is supported by DFG.

HK 10.3 Tue 15:00 H3

Small Angle ISR Analysis of the Pion Form Factor with BESIII — •Yasemin Schelhaas and Achim Denig for the BESIII-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Deutschland

The anomalous magnetic moment of the muon $a_\mu = (g_\mu - 2)/2$ is one of the most precisely measured variables in modern physics. However, there is a discrepancy of 4.2 standard deviations between the Standard Model (SM) prediction and the experimental average of the latest direct measurements, known as the Muon $(g-2)$-puzzle. The main uncertainty of the SM prediction arises from hadronic contributions and can be improved systematically using experimental measurements of hadronic cross sections at e^+e^- colliders. One of the most important processes is $e^+e^- \to \pi^+\pi^-$. Using a data set of 3.1 fb^{-1} at a center of mass energy of 4.18 GeV, the $\pi^+\pi^-$ cross section is measured at the BESIII experiment located at the BEPCII collider in Beijing, exploiting Initial State Radiation (ISR) at small angles. The analysis aims to determine the pion form factor at masses above 0.8 GeV, which is also interesting for hadron spectroscopy. In this presentation an overview of the current status of the analysis is given.

Supported by DFG.

HK 10.4 Tue 15:15 H3

Feasibility Studies of Axial Meson Production in Two-Photon Fusion Processes at BESIII — •Nick Effenberger, Christoph Redmer, and Achim Denig for the BESIII-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität, Mainz, Deutschland

The Standard Model prediction of the muon's anomalous magnetic moment, a_μ, is completely limited in precision by the knowledge of the hadronic contributions. Data driven approaches have been developed to improve the calculations. Recent estimates demonstrate the importance of axial mesons with masses larger than 1 GeV for the hadronic Light-by-Light scattering contribution to a_μ.

The BESIII experiment, located at the BEPCII collider in Beijing, China, has collected data with center-of-mass energies residing in the τ-charm region. These can be used to study the production of axial mesons in two-photon fusion processes with quasi-real or virtual photons. In this presentation, we discuss the prospects of studying axial mesons decaying into the four pion final state containing charged pions only.

HK 10.5 Tue 15:30 H3

Measurement of proton–deuteron correlations in pp collisions at $\sqrt{s}$ = 13 TeV — •Michael Jung[1] and Bhawani Singh[2] for the ALICE-Collaboration — [1]Goehte-Universität Frankfurt — [2]Technische Universität München

The first measurement of p–d two-particle correlations in high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV will be presented. The studies of source sizes in these collision systems by the ALICE Collaboration enabled the possibility to study final-state interactions using two-particle momentum correlations. The measured correlation functions as well as comparisons with theoretical predictions using the Lednický-Lyuboshits model will be presented. The theoretical correlations include two interaction models using only the Coulomb force as well as both Coulomb and strong interaction. For the later the measured scattering lengths of proton–deuteron pairs from scattering experiments were taken. However both predictions cannot reproduce the measured correlation function. This deviation might give a hint for a different production mechanism of deuterons such as a late formation of these light nuclei in high-energy pp collisions. Finally we present briefly the status of an analysis of Λ–d correlations.

HK 10.6 Tue 15:45 H3

Investigation of the p–ϕ and p–D interaction in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE — •Emma Chizzali for the ALICE-Collaboration — TUM, Munich, Germany

The strong hadron-hadron interaction can be investigated with high precision using two-particle momentum correlations, as demonstrated by recent ALICE studies performed in pp collisions. This also includes hyperons (Y), for which the existing experimental uncertainties related to their two- and three-body interaction with nucleons (N) prohibits theoretical calculations to obtain firm conclusions on the nuclear equation of state (EoS). This has a direct consequence on the modeling and composition of neutron stars. In this context, the strong Y–Y interaction can be mediated by the ϕ meson within certain effective meson exchange models. This requires experimental input related to the N–ϕ and Y–ϕ systems. Additionally, understanding the N–ϕ interaction provides valuable input to interpret the signs of partial restoration of chiral symmetry in the nuclear medium. The latter can further be studied by means of the interaction between open charm hadrons and nucleons. An experimentally accessible system is the p–D, which has the benefit of also providing information regarding the nature of the newly observed heavy quarkonium-like states and charm pentaquarks. In this talk, the first direct experimental investigation, using correlation techniques, of the p–ϕ and p–D systems will be presented. This has been achieved by the ALICE collaboration, using data from high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV. These results are capable of providing new constraints to existing theoretical models.

HK 11: Instrumentation IV

Time: Tuesday 14:00–16:00 Location: H4

Group Report HK 11.1 Tue 14:00 H4

A new free running DAQ for future measurements at the M2 beamline at CERN — •Benjamin Moritz Veit for the AMBER DAQ-Collaboration — Institut für Kernphysik der Johannes Gutenberg-Universität, Mainz

Several new measurements with muon and hadron beams at the M2 beamline of the CERN SPS were approved. For the experiments, it is planned to transform the current classical DAQ approach to a free running (streaming) DAQ scheme, which is based on a trigger-less read-out of all detectors with local data processing and later online and offline data reduction stages based on FPGA and

X86 filter technologies (High-Level Triggers). Few levels of FPGA multiplexers perform real-time tasks of processing timestamped hit information from the detectors, buffering, merging, and distributing data between read-out computers. The read-out computers transfer data to a local storage system. From this storage, an asynchronous running HLT system is fetching the data. On the HLT system, the data will be partially reconstructed, analyzed, and eventually reduced before it is written to permanent storage. One of the approved experiments is the measurement of the proton charge radius by elastic muon proton scattering. For this experiment, two data taking phases are foreseen. For the first phase, with a low-intensity muon beam, a full, not reduced data sample will be written to disk. This allows a complete unbiased data analysis and the validation of the filtering scheme. An overview of this novel DAQ and filtering approach will be presented.

HK 11.2 Tue 14:30 H4

Recent developments of the slow-control of the barrel part of the PANDA EMC front-end bus system* — •Christopher Hahn for the PANDA-Collaboration — II. Physikalisches Institut, Gießen,Deutschland

One of the main components of the upcoming PANDA experiment at the future FAIR complex in Darmstadt will be an Electromagnetic Calorimeter (EMC) inside a 2 T solenoid. Due to the required energy resolution, timing and spacial constraints, the individual high-voltage adjustments for the Large Area Avalanche Photodiodes (LAAPDs) that read out the EMC crystals demand innovative and specialized electronics, such as, for example, the individual bias voltage adjustments for the Photodiodes need to be accurate down to 0.1V. At the same time, space constraints in the inner detector volume limit options for individual cable routing and connections for the LAAPD bias voltage. The key elements of the high voltage adjustment concept will be described, with a special focus on the first and the second iteration of the dedicated control ASICs for the front-end bus system, the so-called SerialAdapter ASICs (SAA). The SAAs are also utilized for the communication and control of the APFEL preamplifier ASICs, which read out the APD photodetectors. The different versions of the SerialAdapter ASICs were utilized in the preproduction versions of the High-voltage control for the LAAPDs. The results of these preproduction tests will be presented. *gefördert durch das BMBF, GSI und HFHF.

HK 11.3 Tue 14:45 H4

Implementation of a MiniTAPS Trigger Board for the CBELSA/TAPS Experiment — •Lisa Richter, Annika Thiel, Janis Hoff, Peter Klassen, and Christian Honisch for the CBELSA/TAPS-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn

The nucleon excitation spectrum is probed by the CBELSA/TAPS experiment by studying different photoproduction reactions using real photon beam on a polarized or unpolarized target. The experimental setup comprises mainly two electromagnetic calorimeters, the Crystal Barrel and the MiniTAPS detector, focusing on neutral mesons in the final state that decay to photons. Since the CBELSA/TAPS is a fixed target experiment, many decay particles are boosted in forward direction.

Here, the MiniTAPS detector is located, which consists of 216 hexagonal BaF2 crystals which are read out via photomultiplier tubes. It covers the forward angle between 1° and 12° and can capture photons with energies between 10 MeV and 2.0 GeV. To avoid wrong trigger information due to overlapping clusters, the crystals are arranged in four sectors and the number of hits in a sector in one event is determined by the trigger. The new MiniTAPS trigger replaces the old MCU (multiple coincidence unit) electronics. It is realized by a single FPGA in a VME module. This not only simplifies the electronics but also allows for more sophisticated trigger algorithms including e.g. a fast cluster finder. The new setup of the trigger and the current status of the analysis will be presented in this presentation.

HK 11.4 Tue 15:00 H4

Designing FPGA Readout Firmware with the help of Vivado HLS — •David Schledt for the CBM-Collaboration — Infrastructure and Computer Systems in Data Processing, Frankfurt, Deutschland

Traditionally FPGA firmware was developed solely with Hardware Description Languages (HDL) like verilog or VHDL. However, with the steady improvements of tools like Vivado HLS (High Level Synthesis) it is now possible to write parts of the firmware with higher level languages like C++. Using HLS allows faster development cycles, easier code reuse and, most importantly, to efficiently write complex algorithms for the FPGA.

The Compressed Baryionic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) will investigate the QCD phase diagram at high net-baryon densities. The experiment employs a free streaming data acquisition with radiation hard self-triggered front-end electronics (FEE). At interactions rates of up to 10 MHz the readout firmware has to process very high data loads. The detector data is marked with timestamps by the FEE, which has to be sorted in time to speed up the online event finding. This requires complex data processing inside the FPGA. In this talk I will present how the readout firmware for the CBM Transition Radiation Detector (TRD) was developed aided by Vivado HLS.

This work is supported by BMBF-grant 05P19RFFC1.

HK 11.5 Tue 15:15 H4

HLS C++ Template Library for Detector Readout and Data-Preprocessing using FPGAs — •Thomas Janson and Udo Kebschull — IRI, Goethe-Universität Frankfurt am Main, Max-von-Laue-Straße 12, 60438 Frankfurt am Main, Germany

In this talk, we discuss a methodology of implementing massive parallel algorithms using the C++ high-level synthesis. We show that the methodology is applicable for preprocessing in FPGA based detector readout widely used in high-energy physics experiments. The focus is on feasibility for this field by using modern C++ programming techniques with the help of generic template programming. It has been shown that with this methodology the resource consumption remains acceptable low compared to an HDL implementation. The Intel HLS compiler and C++17 language features are used to implement algorithms in the style of data flow programming, which are particularly well suited for processing data streams. The idea is to present an algorithm as a data flow graph and implement it as a deep pipeline on an FPGA. For this we are developing an HLS C++ template library for detector readout and data pre-processing targeting FPGAs. A first draft of this library is shown in this talk.

HK 11.6 Tue 15:30 H4

The HADES electromagnetic calorimeter upgrade: Current status and future perspectives* — •Adrian Rost for the HADES-Collaboration — FAIR GmbH, Darmstadt, Germany — TU Darmstadt, Darmstadt, Germany

The HADES spectrometer at GSI Helmholtzzentrum für Schwerionenforschung GmbH in Darmstadt was recently upgraded with a new electromagnetic calorimeter (ECAL). In March 2019 a four week physics production beam time with an "Ag+Ag" beam at 1.58*A* GeV was carried out. In this contribution the performance of the new detector system under beam conditions will be presented. Particular emphasis will be put on its FPGA-TDC based read-out electronics and the performance.

**This work has been supported by BMBF ErUM - FSP C.B.M. (05P18RDFC1), by DFG under GRK 2128 and European Union's Horizon 2020 research and innovation programme (871072).*

HK 11.7 Tue 15:45 H4

Low Gain Avalanche Diodes for timing applications in HADES — •Wilhelm Krueger[1], Tetyana Galatyuk[1,2], Vadym Kedych[1], Sergey Linev[2], Jan Michel[3], Jerzy Pietraszko[2], Adrian Rost[1,4], Michael Traeger[2], Michael Traxler[2], and Christian Joachim Schmidt[2] — [1]TU Darmstadt, Germany — [2]GSI GmbH, Darmstadt, Germany — [3]Goethe-Universität Frankfurt, Germany — [4]FAIR GmbH, Darmstadt, Germany

A reaction-time (T0) determination with a precision of $\sigma_{T0} < 50$ ps is required by the HADES physics program in order to ensure e.g. an excellent particle identification via Time-of-Flight measurements. In addition, monitoring of beam properties such as position, width and time structure is necessary. In order to fulfill these tasks, the recently emerged Low Gain Avalanche Diode (LGAD) technology seems to be a fitting candidate. A timing precision of $\sigma_t \approx 47$ ps was demonstrated with an LGAD based prototype T0 detector at COSY (Juelich), with a 1.92 GeV proton beam. Therefore, it is planed to use LGADs in upcoming experiments with proton, pion and possibly ion beams. The so far reached results will be presented in this contribution. In addition, future plans on development of dedicated ASICs capable of dealing with high rates and a high number of readout channels will be mentioned. This work is supported by F&E, TU Darmstadt and HGS-HIRe.

HK 12: Heavy-Ion Collisions and QCD Phases II

Time: Tuesday 16:30–18:30 Location: H1

Group Report HK 12.1 Tue 16:30 H1

Charm production and hadronisation at the LHC with ALICE — •Jianhui Zhu for the ALICE-Collaboration — GSI Helmholtz Centre for Heavy Ion Research

Recent measurements of charm-baryon production at midrapidity by the ALICE collaboration show baryon-to-meson yield ratios significantly higher than those in e^+e^- collisions for different charm-hadron species, suggesting that the charm fragmentation is not universal across different collisions systems. Thus, measurements of charm-baryon production are crucial to study the charm quark hadronisation in proton–proton collisions, relevant also for the description of heavy-flavour mesons. In large systems such as Pb-Pb collisions, the charm baryon-to-meson yield ratio is expected to be further enhanced if charm quarks hadronise via recombination with the surrounding light quarks in the QGP.

In this talk, the measurements of Λ_c^+, $\Xi_c^{0,+}$ and the first measurement of Ω_c^0 baryons performed with the ALICE detector at midrapidity in pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV, as well as the total charm cross section and charm fragmentation fractions will be presented. In Pb-Pb collisions, the measurement of Λ_c^+ production, the nuclear modification factor and the Λ_c^+/D^0 ratio will be discussed. These results will be compared to predictions from Monte Carlo event generators and theoretical calculations based on the statistical hadronisation model and on the hadronisation via coalescence.

HK 12.2 Tue 17:00 H1

Λ_c^+ cross section in p–Pb collisions down to $p_T = 0$ at $\sqrt{s_{NN}}$ = 5.02 TeV measured with ALICE — •Annalena Sophie Kalteyer for the ALICE-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

In this contribution, the latest ALICE measurement of Λ_c^+ production performed down to $p_T = 0$ in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV is presented. This allows to show the first measurement of Λ_c^+/D^0 and Λ_c^+ nuclear modification factor (R_{pPb}) down to $p_T = 0$ in this system. The baryon-to-meson ratio is significantly enhanced with respect to the one in e^+e^- collisions, suggesting that the charm fragmentation is not a universal process across different collision systems. Furthermore, the ratio as a function of the transverse momentum is shifted to higher p_T in p–Pb collisions with respect to pp collisions. The reason for this momentum shift could be a modification of the charm hadronisation mechanism and/or the presence of radial flow in p–Pb collisions. Typically this is observed in heavy-ion collisions where a hot deconfined medium is created. In addition, the R_{pPb} is useful to investigate possible initial state effects such as shadowing in the collisions of a proton with a heavy nucleus. R_{pPb} can help disentangling initial from final state effects, which would involve the presence of a medium. The results are compared with theoretical calculations including initial and final state effects.

HK 12.3 Tue 17:15 H1

Blast-wave description of Upsilon elliptic flow at LHC energies — Klaus Reygers[1], Alexander Schmah[1], •Anastasia Berdnikova[1], Nadine Gruenwald[1], and Xu Sun[2] — [1]Physikalisches Institut, Ruprecht-Karls-Universitat Heidelberg, Heidelberg, Germany — [2]Georgia State University, Atlanta, Georgia 30303, USA

A simultaneous blast-wave fit to particle yields and elliptic flow (v_2) measured as a function of transverse momentum in Pb–Pb collisions at LHC energies is presented. A compact formula for the calculation of $v_2(p_T)$ for an elliptic freeze-out surface is used which follows from the Cooper-Frye ansatz without further assumptions. Over the full available p_T range, the Υ elliptic flow data is described by the prediction based on the fit to lighter particles. This prediction shows that, due to the large Υ mass, a sizable elliptic flow is only expected at transverse momenta above 10 GeV/c.

HK 12.4 Tue 17:30 H1

Heavy-quark diffusion current in the Quark-Gluon Plasma — •Federica Capellino[1,2], Andrea Dubla[2], Stefan Floerchinger[3], Eduardo Grossi[4], Silvia Masciocchi[1,2], Jan M. Pawlowski[3], Ilya Selyuzhenkov[2], and Johanna Stachel[1] — [1]Physikalisches Institut Heidelberg, Universität Heidelberg, 69120 Heidelberg, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [3]Institut für Theoretische Physik, Universität Heidelberg, 69120 Heidelberg, Germany — [4]Center for Nuclear Theory, Department of Physics and Astronomy, Stony Brook University, Stony Brook, New York 11794-3800, USA

A hydrodynamic approach to the transport of heavy quarks in the Quark-Gluon Plasma is presented. We exploit the conservation of the number of heavy quark - antiquark pairs within the evolution of the plasma to construct causal second-order hydrodynamic equations of motion. The hydrodynamic transport coefficients associated to the heavy-quark diffusion current are then compared with the momentum-diffusion coefficients obtained in the standard Fokker-Planck formalism. The purpose of the present work is to provide further insights on the level of thermalization of charm and bottom quarks inside the expanding Quark-Gluon Plasma by investigating the relation between the two approaches and determining if their merging is able to capture the complexity of the heavy-quark in-medium dynamics. This work is funded via the DFG ISOQUANT Collaborative Research Center (SFB 1225).

HK 12.5 Tue 17:45 H1

Measurements of J/ψ production in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV with ALICE — •Minjung Kim for the ALICE-Collaboration — Physikalische Institut, Unversität Heidelberg, Heidelberg, Germany

Measurements of J/ψ production in p–Pb collisions are a valuable probe to study cold–nuclear–matter effects as well as possible final state mechanisms, which can modifiy its production with respect to the one in pp collisions.

In ALICE (A Large Ion Collider Experiment), J/ψ production is measured at midrapidity via the dielectron decay channel relying on the electron identification capability provided by the Time Projection Chamber (TPC). Excellent track pointing resolution provided by the Inner Tracking System (ITS) allows the contribution of J/ψ from a weak decays of beauty hadrons (non-prompt J/ψ) statistically separated based on the long life time of beauty hadrons.

In this presentation, we will show measurements of inclusive and non-prompt J/ψ production in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV from a high–p_T electron enriched data sample collected using the trigger capabilities of the Transition Radiation Detector (TRD).

HK 12.6 Tue 18:00 H1

Recent measurements of charged-particle production in ALICE — •Youssef El Mard Bouziani for the ALICE-Collaboration — Institut für Kernphysik, Goethe-Universität Frankfurt

The ALICE experiment at the LHC is designed to investigate the properties of the Quark-Gluon Plasma by studying high-energy A–A collisions. Medium effects like parton energy loss can be examined by comparing the production of charged particles at high transverse momentum (p_T) in heavy-ion collisions with the one in pp collisions where no hot QCD medium is expected. This comparison is usually expressed by means of the nuclear modification factor R_{AA}. In addition, the correlation between p_T spectra and event multiplicity of charged particles can give insight in the different production mechanisms.

In this talk, we report on a study of charged-particle production in pp, p-Pb, Xe–Xe and Pb–Pb collisions at all available LHC beam energies. By comparing to QCD-inspired models, this measurement can help to understand the energy and system size dependence of charged-particle production at LHC.

Supported by BMBF and the Helmholtz Association.

HK 12.7 Tue 18:15 H1

Charged Kaon and ϕ Reconstruction in Ag+Ag Collisions at $\sqrt{s_{NN}}$ = 2.5 GeV with HADES — •Marvin Kohls for the HADES-Collaboration — Goethe-Universität Frankfurt am Main

Heavy ion collisions in the few GeV energy regime probe similar temperatures and densities as created in neutron stars, which gives us a tool to probe the matter created in those macroscopic collisions in earthly laboratories [1].

In March 2019, the HADES collaboration recorded $13 \cdot 10^9$ Ag(1.58A GeV)+Ag events as part of the FAIR Phase-0 program. Within this talk we present the status of the reconstruction of K^+, K^- and ϕ and further discuss preliminary results.

Due to the fact, that these strange hadrons are produced at or below the free nucleon-nucleon production threshold, they are a good probe for in-medium effects with respect to their steep excitation function. Furthermore, comparing the production yields in pheripheral collisions to those in central collisions will provide additional information about the system size dependence of strangeness production.

The work has been supported by BMBF (05P19RFFCA), GSI and HIC for FAIR.

[1] Adamczewski-Musch, J., Arnold, O., Behnke, C. et al. *Probing dense baryon-rich matter with virtual photons.* Nat. Phys. 15, 1040*1045 (2019) doi:10.1038/s41567-019-0583-8

HK 13: Instrumentation V

Time: Tuesday 16:30–18:15 Location: H2

Group Report HK 13.1 Tue 16:30 H2

CBM TRD performance at DESY and in mCBM at FAIR-Phase0 — •Adrian Meyer-Ahrens for the CBM-Collaboration — Institut für Kernphysik, Münster, Deutschland

The Transition Radiation Detector (TRD) of the Compressed Baryonic Matter (CBM) experiment is composed of irregular polyethylene (PE) foam radiators and Multi-Wire Proportional Chambers (MWPCs). It will serve as intermediate tracker and for heavy fragments and electron identification. A high yield of TR generated by electrons passing through the radiator is crucial for electron identification. In a dedicated electron testbeam campaign, two TRD chambers were set up at DESY in August of 2019 and tested with electron beams using various radiator thicknesses.

In the first part of this talk, results on the performance of the detector in this testbeam campaign as well as comparisons to radiator simulations will be presented. The second part focuses on the participation of the TRD in the mCBM campaigns at GSI at SIS18. High-rate collisions on a fixed-target are used here for CBM detector and readout performance measurements. This talk presents the TRD performance in continuous readout mode in the measurement campaigns of 2020 and 2021.

This work is supported by BMBF grant 05P19PMFC1.

HK 13.2 Tue 17:00 H2

ALICE TRD Trigger Performance Study and its Application on the Hypertriton Analysis in p–Pb collisions at the LHC — •Benjamin Brudnyj for the ALICE-Collaboration — Institut für Kernphysik, Goethe Universität, Frankfurt am Main

At the Large Hadron Collider (LHC) at CERN significant production rates of light (anti-)(hyper-)nuclei have been measured in heavy-ion collisions. The production of such nuclei has recently become a topic of high interest. One interesting example is the lifetime of the lightest hypernucleus, the hypertriton (a bound state of a proton, a neutron and a Λ hyperon). Several measurements have shown a significant deviation from the theoretical expectation, in particular in heavy-ion collisions. Therefore, it is important to also measure these rare nuclei in p–p and p–Pb collisions.

Due to their short lifetime, only their decay products can be measured, e.g. the charged two body decay channel ${}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{-}$. In order to be able to measure these rare (anti-)fragments also in p–p and p–Pb collisions, a trigger on nuclei was implemented on p–Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV to increase the statistics by using the ability of the ALICE TRD to perform fast trigger decisions.

In this talk the performance of a nuclei trigger in terms of enhancement factors and transverse momentum sensitive effieciencies for the different light nuclei will be shown. In addition, the current status of a hypertriton analysis on p–Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV will be presented.

HK 13.3 Tue 17:15 H2

Design of a luminosity monitor for the P2 parity violating experiment at MESA — Sebastian Baunack[1], Kathrin Imai[1], Rahima Krini[1], Frank Maas[1,2,3], •Tobias Rimke[1], David Rodriguez Pineiro[2], and Malte Wilfert[1] — [1]Institut für Kernphysik, Johannes Gutenberg-Universität Mainz — [2]Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — [3]PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz

The P2 experiment at the future MESA accelerator in Mainz plans to measure the weak mixing angle $\sin^2(\theta_W)$ in parity violating elastic electron-proton scattering. The aim of the experiment is a very precise measurement of the weak mixing angle with a precision of 0.15% at a low four-momentum transfer of $Q^2 = 4.5 \cdot 10^{-3}$ GeV^2. In order to achieve this precision, it is necessary to monitor the stability of the electron beam and the liquid hydrogen target. Any helicity correlated fluctuations of the target density lead to false asymmetries.

Therefore, it is planned to install a luminosity monitor in forward direction close to the beam axis. The motivation and challenges for designing and testing an air Cherenkov luminosity monitor will be discussed in this talk.

HK 13.4 Tue 17:30 H2

The filling process in the neutron lifetime experiment τSPECT — •Kim Ulrike Ross for the tauSPECT-Collaboration — Department of Chemistry, Johannes Gutenberg University, Mainz

The τSPECT experiment aims to measure the neutron lifetime τ_n using a 3D magnetic storage technique with spin flip loading. Due to the neutron's magnetic moment, very low-energetic neutrons (ultracold neutrons, UCN) with a maximum energy of ≈ 50 neV can be stored in the magnetic trap with a volume of ≈ 10 L. Counting surviving UCN after varying storage times, the neutron lifetime can be extracted from an exponential fit. The target uncertainty in the neutron lifetime is $\Delta\tau_n = 1.0$ s in phase I of the experiment.

The overall measurement duration to achieve this goal is currently limited by UCN statistics, so an optimised filling process is crucial. Two filling techniques have been investigated so far, which are using either one or two adiabatic fast passage spin flippers.

This talk will give a short introduction into spin flipping UCN in τSPECT as well as the current status of the filling optimisation process.

HK 13.5 Tue 17:45 H2

Measuring the free neutron lifetime with τSPECT — •Noah Yazdandoost for the tauSPECT-Collaboration — Department of Chemistry, Johannes Gutenberg University, Mainz

The τSPECT experiment aims to measure the free neutron lifetime. Neutrons with energies in the range of nano electron-volts are loaded by spin flipping into τSPECT's storage volume, where they are confined by magnetic fields only. Magnetic storage of the neutrons will reduce the systematic errors with respect to previous experiments with material confined neutrons since there is no interaction between stored neutrons and wall atoms. With the τSPECT experiment, the free neutron lifetime can be extracted by counting the surviving neutrons in the storage volume after different storage times. This talk gives an overview of the magnetic field configuration, the measurement process, and the data analysis strategies of the τSPECT experiment.

HK 13.6 Tue 18:00 H2

Performance Studies of Micromegas based Detectors — •Tobias Waldmann[1], Rossana Facen[1], Berkin Ulukutlu[1], Piotr Gasik[2], and Laura Fabbietti[1] — [1]Technische Universität München — [2]GSI Helmholtzzentrum

Micro Mesh Gaseous Structures (Micromegas) and Gas Electron Multipliers (GEM) are detectors implemented in a wide range of modern particle physics experiments. Among their major advantages are high achievable gains, good energy resolution and intrinsic ion backflow suppression. One method to improve their performance even further is to stack a Micromegas and a GEM. Still, a huge limiting factor to the performance is the formation of electrical discharges between the electrodes, which can eventually blind or permanently damage the involved detector components. Therefore, the limits of safe operation of such detectors need to be studied in detail. In our studies we, hence, investigated the performance of a Micromegas and a GEM + Micromegas detector. Firstly, we performed scans of the various parameters contributing to the detector performance, including the applied electric fields and the geometry of its components. Here, a special focus was put on ion backflow reduction and energy resolution optimization. Optimal working regions with respect to a set of boundary parameters can thus be defined. Secondly, we investigated the discharge stability of the two detectors, which provides further limits for the safe working regions.

HK 14: Hadron Structure and Spectroscopy III

Time: Tuesday 16:30–18:30 Location: H3

Group Report HK 14.1 Tue 16:30 H3

Exploring the 3D nucleon structure with CLAS at JLAB and PANDA at FAIR — •Stefan Diehl for the CLAS and PANDA-Collaboration — II. Physikalisches Institut, JLU Gießen, 35390 Gießen, Germany — University of Connecticut, Storrs, Connecticut 06269, USA

Exploring the 3-dimensional structure of the nucleon can help to understand several fundamental questions of nature, such as the origin of the nucleon spin and the charge and density distributions inside the nucleon. The 3D momentum distribution of the partons can be accessed by transverse momentum dependent distribution functions (TMDs) measured in semi-inclusive deep inelastic scattering (SIDIS) or Drell-Yan processes, while the distribution in transverse coordinate and longitudinal momentum space is described by generalized parton distributions (GPDs), which can be accessed by deeply virtual Compton scattering (DVCS) and hard exclusive meson production (DVMP). Based on the high quality data of CLAS and the recently upgraded CLAS12 detector at Jefferson Laboratory (JLAB), a detailed study of these distribution functions can be performed. In the future also PANDA at FAIR will be able to contribute to this field in various aspects of 3D nucleon structure studies. The talk will present the results of recent SIDIS and DVMP studies with CLAS and CLAS12 and their impact on the understanding of the 3D nucleon structure. In addition the potential of PANDA to contribute to this field will be presented. *The work is supported by BMBF and HFHF

HK 14.2 Tue 17:00 H3

Analysis of COMPASS data on DVCS — •Johannes Giarra — on behalf of the COMPASS collaboration - Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Johann-Joachim-Becher-Weg 45, 55099 Mainz

In 2016 and 2017 a measurement of the exclusive single photon production was performed at the M2 beamline of the CERN SPS, scattering a 160 GeV positive and negative charged muon beam off a liquid hydrogen target. During the measurement all particles participating in the process were measured. To perform an exclusive measurement the COMPASS spectrometer was supplemented by an additional electromagnetic calorimeter to increase the acceptance for the detection of large angle photons. The recoiling protons were measured by a time of flight (TOF) detector surrounding the target.

The talk will summarize the current status of the analysis to determine the cross section of the Deeply Virtual Compton Scattering (DVCS). Thereby the focus will be on determining the Bethe-Heitler contribution to the cross section as well as the method to determine and remove the π^0 contamination from the exclusive single photon sample.

HK 14.3 Tue 17:15 H3

Measuring Generalized Distribution Amplitudes from the $\bar{p}p \rightarrow \pi^0\gamma$ channel with PANDA at FAIR — •Faiza Khalid, Stefan Diehl, and Kai Thomas Brinkmann for the PANDA-Collaboration — II. Physikalisches Institut, Justus Liebig Universität Gießen, 35392 Gießen, Germany.

The future PANDA experiment at FAIR with the HESR antiproton beam provides unique possibilities to study the 3D nucleon structure with exclusive channels in $\bar{p}p$ annihilation. One of the channels of interest for the measurement of Generalized Distribution Amplitudes (GDAs) is $\bar{p}p \rightarrow \pi^0\gamma$. Several simulations for different antiproton beam momenta of $s = 2.5$ GeV/c , $s = 5$ GeV/c , $s = 10$ GeV/c and $s = 15$ GeV/c were done for both the signal channel ($\bar{p}p \rightarrow \pi^0\gamma$) and for the main background channel ($\bar{p}p \rightarrow \pi^0\pi^0$) to check the feasibility of the measurement. The talk will present the feasibility study for the measurement of the $\cos(\theta)$ dependence of the differential cross-section for $\bar{p}p \rightarrow \pi^0\gamma$ at different integrated luminosities. The cross sections have been estimated based on data, which is available in a limited kinematic range from the E760 experiment at Fermilab. Results of count rate estimates and estimates of the expected statistical uncertainty for different integrated luminosity values as well as the signal to background ratio will be presented. Different event selection cuts have been investigated to optimize the signal to background ratio while keeping a reasonable reconstruction efficiency.

*The work is supported by BMBF and HFHF

HK 14.4 Tue 17:30 H3

Improving Kaon-Pion Identification with Machine Learning Techniques for CLAS12 — •Áron Kripkó, Stefan Diehl, and Kai-Thomas Brinkmann for the CLAS-Collaboration — II. Physikalisches Institut, Justus Liebig Universität Gießen, 35392 Gießen, Germany

For semi-inclusive deep inelastic scattering (SIDIS), a reliable particle identification and background estimation is a key requirement. This is especially true for Kaon SIDIS, where a strong pion contamination can be expected at high momenta if only time of flight measurements are used for the particle identification. For the SIDIS Kaon production from the scattering of 10.6 GeV electrons in the recently upgraded CLAS12 detector, Kaons are hardly distinguishable from pions above 3 GeV with a pure time of flight based PID. Currently a RICH detector, which will provide good separation above 3 GeV is only available in one sector. Here advanced PID methods based on neural networks, exploiting the information from all detector components can help improve the situation.

In this talk machine learning methods, which could complement the other traditional particle identification methods, are described and compared. Based on multiple independent checks, the best method can efficiently reduce the pion contamination in the kaon sample in the whole momentum range, by still keeping the statistics on a reasonable level.

This work is supported by HFHF.

HK 14.5 Tue 17:45 H3

Electromagnetic form factors of the proton with the PANDA experiment at FAIR — •Alaa Dbeyssi[1], Frank Maas[1,2,3], Iris Zimmermann[1], Manuel Zambrana[1], Luigi Capozza[1], Oliver Noll[1], David Rodriguez Pineiro[1], Sahra Wolff[1], Alexander Greiner[1], Julian Moik[1], Samet Katilmis[1], Dong Liu[1], and Peter-Bernd Otte[1] for the PANDA-Collaboration — [1]Helmholtz-Institut Mainz, Germany — [2]Institute of Nuclear Physics, Johannes Gutenberg University, Mainz, Germany — [3]Prisma Cluster of Excellence, Mainz, Germany

Precise measurements of the proton electromagnetic form factors in the time-like region are planned at the future PANDA experiment at FAIR using the $\bar{p}p \rightarrow \ell^+\ell^-$ ($\ell = e, \mu$) annihilation processes. The feasibility of measuring these processes with the PANDA detector are investigated. Simulations on signal reconstruction efficiency and background rejection are performed using PANDARoot, the simulation and analysis software of the PANDA experiment. The expected precisions on the measurements of the proton form factors at PANDA are determined taking into account the staged approach for the detector setup and for the delivered luminosity from the accelerator. In addition, first order radiative corrections to the reaction $\bar{p}p \rightarrow e^+e^-$ are calculated including virtual and real photon emission. A Monte Carlo event generator to be used in the framework of the PANDA experiment is developed on the basis of the calculated radiative cross section. The results of these studies will be reported in this talk.

HK 14.6 Tue 18:00 H3

Azimuthal single- and double-spin asymmetries in semi-inclusive deep-inelastic lepton scattering by transversely polarized protons — •Gunar Schnell — University of the Basque Country UPV/EHU & IKERBASQUE, Bilbao, Spain

A comprehensive set of azimuthal single-spin and double-spin asymmetries in semi-inclusive leptoproduction of pions, charged kaons, protons, and antiprotons from transversely polarized protons is presented. These asymmetries include the previously published HERMES results on Collins and Sivers asymmetries, the analysis of which has been extended to include protons and antiprotons and also to an extraction in a three-dimensional kinematic binning and enlarged phase space. They are complemented by corresponding results for the remaining four single-spin and four double-spin asymmetries allowed in the one-photon-exchange approximation of the semi-inclusive deep-inelastic scattering process for target-polarization orientation perpendicular to the direction of the incoming lepton beam. Among those results, significant non-vanishing cos(phi-phi_s) modulations provide evidence for a sizable worm-gear (II) distribution, g_1T. Most of the other modulations are found to be consistent with zero with the notable exception of large sin(phi_s) modulations for charged pions and positive kaons.

HK 14.7 Tue 18:15 H3

Inclusive production of two hadrons in electron-positron annihilation at Belle — •Gunar Schnell — University of the Basque Country UPV/EHU & IKERBASQUE, Bilbao, Spain

Fragmentation functions (FFs), describing the formation of hadrons from partons, are an indispensable tool in the interpretation of hadron-production data, e.g., in the investigation of nucleon structure via semi-inclusive deep-inelastic scattering. The cleanest process to access FFs is hadron production in electron-positron annihilation. However, little information can be derived on charge-separated FFs from single-inclusive hadron production. A better handle on the flavor contributions can be gotten by flavor correlations or tagging: the hadron type in one hemisphere puts constraints on the parton flavor in the other hemisphere and thus on the flavor decomposition of the hadronization process. This can be exploited in inclusive hadron-pair production in electron-positron annihilation. While two hadrons in the same hemispheres, e.g., originating from the same parton, open an avenue to an unusual class class of FFs, dihadron-FFs, two hadrons in opposite hemispheres can be used for flavor and polarization tagging of single-hadron FFs. These scenarios have recently been subject to renewed studies at the Belle experiment. The dependences of the production cross section of pairs of identified light mesons (charged pions and kaons) as well as of (anti)protons on the individual z of the hadrons or on the combined z will be presented in this talk. In addition, azimuthal modulations of such cross sections for pions and the eta meson, related to the spin-dependent Collins effect, will be discussed.

HK 15: Structure and Dynamics of Nuclei I

Time: Tuesday 16:30–18:30 Location: H4

Group Report HK 15.1 Tue 16:30 H4

Recent results from the FRS Ion Catcher — •Gabriella Kripkó-Koncz for the FRS Ion Catcher-Collaboration — II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany

The atomic masses of exotic nuclei provide key information for the understanding of nuclear structure and astrophysics. The FRS Ion Catcher experiments at the FRagment Separator FRS at GSI enable high precision mass measurements or isobar and isomer separation with thermalized projectile and fission fragments by combining a Cryogenic Stopping Cell (CSC) and a Multiple-Reflection Time-Of-Flight Mass Spectrometer (MR-TOF-MS). Incorporating several novel and unique concepts, the MR-TOF-MS enables the highest performance, such as a mass resolving powers at FWHM of up to 1,000,000 and relative mass accuracies down to $1.7 \cdot 10^{-8}$.

Mass and half-life measurements of projectile fragments in the vicinity of ^{100}Sn were performed, including the first mass measurement of the ^{101}In ground state and the discovery of a new isomeric state in ^{97}Ag. A novel technique for measuring half-lives and decay branching ratios was developed and demonstrated experimentally. These results including the most recent experiments, recent technical upgrades, and the status of the next-generation CSC for the Low-Energy-Branch of the Super-FRS at FAIR will be presented.

Group Report HK 15.2 Tue 17:00 H4

DSAM lifetime measurements using particle-γ coincidences at SONIC@HORUS — •Sarah Prill, Anna Bohn, Christina Deke, Felix Heim, Michael Weinert, and Andreas Zilges — University of Cologne, Institute for Nuclear Physics, 50937 Köln, Germany

The Doppler-shift attenuation method (DSAM) has been used in recent years to successfully determine lifetimes of excited low-spin states of various nuclei in the sub-picosecond range [1,2]. Especially by the use of particle-γ coincidence data taken at the SONIC@HORUS spectrometer in Cologne [3], the direct selection of levels via their excitation energy is possible. This greatly reduces background and eliminates feeding from levels of higher energies, as well as gives complete knowledge over the reaction kinematics. This contribution will give an overview of the method and show recent results from experiments on Ru, Sn [2] and Te isotopes. Additionally, a complementary approach to the conventional DSA technique to extract lifetimes from weak transitions and excited states with low statistics will be presented. A first estimation of its feasibility is discussed.
Supported by the DFG (ZI-510/9-1).
[1] A. Hennig *et al.*, Nucl. Instr. and Meth. A **794** (2015) 717.
[2] M. Spieker *et al.*, Phys. Rev. C **97** (2018) 054319
[3] S. G. Pickstone *et al.*, Nucl. Instr. and Meth. A **875** (2017) 104.

HK 15.3 Tue 17:30 H4

High-precision mass measurements in the direct vicinity of the doubly magic ^{100}Sn(N=Z=50) at ISOLDE/CERN — •Jonas Karthein for the ISOLTRAP-Collaboration — CERN, 1211 Geneva, Switzerland — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — present address: Massachusetts Institute of Technology, Cambridge, MA 02139, USA

This contribution reports on high-precision mass measurements of $^{99-101}$In isotopes and isomers with the ISOLTRAP mass spectrometer at ISOLDE/CERN. Applying the Multi-Reflection Time-of-Flight (MRToF) method, the masses of ^{99}In and ^{100}In (the β-decay daughter of ^{100}Sn) were measured for the first time with high precision. Additionally, the recently implemented Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique [S. Eliseev et al. PRL 110 (2013) 082501] will be discussed in the context of these measurements. This revolutionary Penning-trap mass spectrometry technique allowed for the first time a direct mass determination of both the ground and the isomeric states of ^{101}In in a Penning trap with resolving powers exceeding m/Δm > 5*10^5 in only 62 ms phase-accumulation time. Our mass spectrometry results, recently accepted for publication in *Nature Physics*, will be compared with pioneering *ab-initio* many-body calculations in this heavy mass region. The 100-fold improvement in the precision of the ^{100}In mass value highlights a discrepancy in the so-far published atomic mass values of ^{100}Sn, which could previously only be derived from β-decay results.

HK 15.4 Tue 17:45 H4

Nuclear structure investigations on $^{253-255}$Es by laser resonance ionization spectroscopy — •Steven Nothhelfer — Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — Helmholtz-Institut Mainz, 55099 Mainz, Germany — GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

Experimental data on the hyperfine structure splittings and isotope shifts of spectral lines in transuranium elements are required to reveal valuable information about the structure of their atomic nuclei. In this talk we will present results of laser resonance ionization spectroscopy performed on the rare isotopes $^{253-255}$Es at the RISIKO mass separator in Mainz. With small sample sizes ranging down to fg, the prominent 351.5 nm ground-state transition was measured in all three Es isotopes, and four additional ground-state transitions were measured in ^{254}Es. Hyperfine structure analysis resulted in spin values of $I(^{254}\mathrm{Es}) = 7$ and $I(^{255}\mathrm{Es}) = 7/2$. From the extracted coupling constants, nuclear magnetic dipole moments as well as spectroscopic electric quadrupole moments were derived. The literature value of the nuclear magnetic dipole moment for ^{254}Es obtained from the angular anisotropy of ^{254}Es α-radiation deviates from our more precise value of this quantity.

HK 15.5 Tue 18:00 H4

Precision calculation of deuteron form factors in chiral effective field theory — Arseniy A. Filin[1], •Daniel Möller[1], Vadim Baru[1,2,3], Evgeny Epelbaum[1], Hermann Krebs[1], and Patrick Reinert[1] — [1]Ruhr-Universität Bochum, Fakultät für Physik und Astronomie, Institut für Theoretische Physik II, D-44780 Bochum, Germany — [2]Institute for Theoretical and Experimental Physics, B. Cheremushkinskaya 25, 117218 Moscow, Russia — [3]P.N. Lebedev Physical Institute of the Russian Academy of Sciences, 119991, Leninskiy Prospect 53, Moscow, Russia

We employ the precise two-nucleon potentials worked out to fifth order in chiral effective field theory to perform high-accuracy calculations of the deuteron form factors. The corresponding electromagnetic charge and current operators are derived and regularized consistently with the potentials. The single-nucleon contributions to these operators are expressed in terms of the proton and neutron form factors, for which up-to-date empirical parametrizations are employed. The short-range two-nucleon operators contain undetermined parameters which are fixed from the deuteron static moments and/or the world data of deuteron form factors, allowing for different kinds of predictions. A comprehensive error analysis is carried out, including a Bayesian analysis of the uncertainty stemming from the truncation of the chiral expansion.

Supported by DFG (CRC 110)

HK 15.6 Tue 18:15 H4

Systematic treatment of hypernuclear data and application to the hypertriton — •Philipp Eckert, Josef Pochodzalla, Patrick Achenbach, Marcell Steinen, Pascal Klag, and Julian Geratz for the A1-Collaboration — JGU Mainz, Germany

A new database is under construction to offer a complete collection of published information on hypernuclei. A key aspect is the combination of measurements to average values in a systematic manner together with a proper treatment of errors. The focus lies on lifetimes, Lambda binding energies and excitations of hypernuclei.

The capability of the database will be demonstrated for the case of the hypertriton.

Supported by the Deutsche Forschungsgemeinschaft, Grant Number PO 256/7-1 and the European Union's Horizon 2020 research and innovation programme No. 824093.

HK 16: Invited Talks - III

Time: Wednesday 14:00–16:00 Location: H1

Invited Talk HK 16.1 Wed 14:00 H1

Short-Range Correlations in neutron-rich nuclei — •Meytal Duer — TU Darmstadt, Darmstadt, Germany

When nucleons come in close proximity they experience the short-range part of the nucleon-nucleon interaction. These states are referred to as Short-Range Correlated (SRC) nucleon-nucleon pairs, with large relative momentum and small cente-of-mass momentum with respect to the Fermi momentum. SRC pairs are formed as temporary fluctuations with high density, several times the nuclear saturation density. These are densities that exist in neutron stars, but are difficult to study in the lab.

Most of the knowledge we have to date about SRC comes mainly from electron scattering experiments. These demonstrated that at any given moment, about 20% of the nucleons in nuclei are members of such neutron-proton SRC pairs. Electron scattering experiments are limited, however, to stable nuclei. To overcome this limitation, to access very neutron-rich nuclei, radioactive-ion beams are the only way to do so. The next generation of proposed experiments includes the use of hadronic probes in inverse kinematics.

Our recent experiment at JINR, Russia showed for the first time that SRC pairs are accessible in inverse kinematics. This showcases a new ability to study SRC in short-lived exotic nuclei at the R3B setup at GSI and in the future at FAIR. The first experiment with radioactive nucleus, ^{16}C, will be performed at R3B in 2022. A successful experiment will pave the way for systematic studies of the neutron excess for example along isotopic chains.

Invited Talk HK 16.2 Wed 14:30 H1

The BGOOD experiment at ELSA - exotic structures in the light quark sector? — •Thomas Jude for the BGOOD-Collaboration — Physikalisches Institut, Universität Bonn

The recent discoveries of the pentaquark, P_C, states and XYZ mesons in the charmed quark sector initiated a new epoch in hadron physics. The existence of exotic multi-quark states beyond the conventional three and two quark systems has obviously been realised. Intriguingly, similar states may be evidenced in the light, uds sector in meson photoproduction. Access to a low momentum exchange and forward meson production region is crucial. The BGOOD photoproduction experiment is uniquely designed to explore this kinematic region; it is comprised of a central calorimeter complemented by a magnetic spectrometer in forward directions.

Our results indicate a peak-like structure in the $\gamma n \to K^0\Sigma^0$ cross section consistent with a meson-baryon interaction model which predicted the charmed P_C states. The same $K^*\Sigma$ molecular nature of this proposed N*(2030) is also supported in our measurement of $\gamma p \to K^+\Lambda(1405)(\to \pi^0\Sigma^0)$. Additionally, a sharp drop in the $\gamma p \to K^+\Sigma^0$ cross section at very forward angles is observed.

In the non-strange sector, coherent meson photoproduction off the deuteron enables access to proposed dibaryon states. Preliminary data supports recent experimental claims of isoscalar and isovector dibaryons.

Supported by DFG projects 388979758/405882627 and the European Union*s Horizon 2020 programme, grant 824093.

Invited Talk HK 16.3 Wed 15:00 H1

The Muon g-2 Experiment at Fermilab — •Martin Fertl for the Muon g-2-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The E989 collaboration has recently published the most precise measurement of the muon anomalous magnetic moment a_μ with an uncertainty of 460 ppb. The new experimental world average of a_μ (with an uncertainty of 350 ppb) differs by 4.2 standard deviations from the Standard Model prediction provided by the Muon g-2 Theory Initiative. The emerging results from ab-initio lattice QCD calculations allow to scrutinize this tantalizing hint for physics beyond the Standard Model for the first time in a three way comparison. To extract the value of a_μ a clock comparison experiment is performed with spin-polarized muons confined in a superbly controlled electric and magnetic field environment. The deviation of the Larmor from the cyclotron frequency, the anomalous spin precession frequency, is determined while a high-precision measurement of the magnetic field environment is performed using nuclear magnetic resonance techniques. I will discuss the most recent result from the first science data run in 2018 and will report on the experimental improvements implemented to achieve the ultimate goal of 140 ppb uncertainty on a_μ.

Invited Talk HK 16.4 Wed 15:30 H1

The muon (g-2) from lattice QCD and experiments: 4.2 sigma, indeed? — •Zoltan Fodor — University of Wuppertal

Twenty years ago, in an experiment at Brookhaven National Laboratory, physicists detected what seemed to be a discrepancy between measurements of the muon's magnetic moment and theoretical calculations of what that measurement should be, raising the tantalizing possibility of physical particles or forces as yet undiscovered. The Fermilab team has just announced that their precise measurement supports this possibility. The reported significance for new physics is 4.2 sigma just slightly below the discovery level of 5 sigma. However, an extensive new calculation of the muon's magnetic moment using lattice QCD by the BMW-collaboration reduces the gap between theory and experimental measurements. The lattice result appeared in Nature on the day of the Fermilab announcement. In this talk the theoretical aspects are summarized with two possible narratives: a) almost discovery or b) Standard Model re-inforced. Details of the lattice calculation are also shown.

HK 17: Heavy-Ion Collisions and QCD Phases III

Time: Wednesday 16:30–18:30 Location: H1

Group Report HK 17.1 Wed 16:30 H1

Global polarization of Λ hyperons as a probe for vortical effects in A+A collisions with HADES — •Frederic Kornas[1], Ilya Selyuzhenkov[2], and Tetyana Galatyuk[1,2] for the HADES-Collaboration — [1]TU Darmstadt, Darmstadt, Germany — [2]GSI Helmholtzzentrum, Darmstadt, Germany

Large orbital momenta occur in non-central heavy-ion collisions which might transfer to the particle spins resulting in a global polarization of the produced particles. Such a global polarization can be measured using weakly decaying particles, e.g. the Λ hyperon. The results of the Λ polarization measurement in Au+Au collisions at $\sqrt{s_{NN}}$ = 2.4 GeV and Ag+Ag collisions at $\sqrt{s_{NN}}$ = 2.55 GeV will be reported. For the latter, the polarization will be shown as a function of centrality, rapidity and transverse momentum. The magnitude of the measured polarization by HADES follows the increasing trend with decreasing collision energy observed by the STAR and ALICE collaborations at higher energies. In addition, directed flow v_1 measurements of the Λ will be shown. The v_1 slope at midrapidity will be compared to the protons measured in the same collision systems in HADES and put in the context of previous measurement.

HK 17.2 Wed 17:00 H1

Measurement of light (anti-)nuclei production in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE — •Michael Habib[1,2] and Luca Barioglio[3] for the ALICE-Collaboration — [1]GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt — [2]Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 9, 64289 Darmstadt — [3]Physik Department, Technische Universität München, James-Franck-Straße 1, 85748 Garching bei München

Understanding the production mechanism of light (anti-)nuclei is one of the key challenges of contemporary nuclear physics. It has important consequences for astrophysics since it provides input for indirect dark matter searches with space-bound experiments. In this talk, the latest results on light (anti-)nuclei production obtained with ALICE in pp collisions at $\sqrt{s}$ = 13 will be presented and compared to coalescence and thermal model predictions. In particular, the measured coalescence parameters for deuterons and helium nuclei will be compared with parameter-free theoretical predictions. The latter are constrained by femtoscopic source radius measurements and they depend directly on the nuclear wave functions.

HK 17.3 Wed 17:15 H1

Machine Learning Application for Λ Hyperon Reconstruction in CBM at FAIR — •Shahid Khan[1], Ali Imdad Khan[1], Viktor Klochkov[1], Olha Lavoryk[2], Oleksii Lubynets[3,4], Andrea Dubla[3], and Ilya Selyuzhenkov[3,5] for the CBM-Collaboration — [1]University of Tübingen — [2]University of Kyiv — [3]GSI, Darmstadt — [4]University of Frankfurt — [5]NRNU MEPhI, Moscow

The Compressed Baryonic Matter (CBM) experiment at FAIR will investigate the QCD phase diagram in the region of high net-baryon densities (B > 500 MeV) in the collision energy range of $\sqrt{s_{NN}}$ = 2.7-4.9 GeV with high interaction rate, up to 10 MHz, provided by the SIS100 accelerator. Enhanced production of strange baryons can signal a transition to a new phase of the QCD matter. Λ hyperons are the most abundantly produced strange baryons. They weakly decay, with a branching ratio of 64%, into a proton (p^+) and a pion (π^-). To reconstruct the $\Lambda \rightarrow p^+ + \pi^-$ decay kinematics, Particle-Finder Simple package is used. It uses the mathematics of the Kalman Filter Particle package and provides a convenient interface to control the reconstruction parameters. For the reduction of combinatorial background specific selection criteria need to be applied to the proton and π^- tracks and Λ-candidates decay topology.

In this work, the performance for Λ reconstruction in CBM with Machine Learning algorithms such as XGBoost will be presented. These algorithms allow efficient, non-linear and multi-dimensional selection criteria to be implemented whilst achieving high signal to background ratio in the region around the Λ candidate invariant mass peak.

HK 17.4 Wed 17:30 H1

Comparison of light (hyper-)nuclei from PHQMD simulations with experimental data from heavy-ion collisions — •Susanne Glässel[1], Christoph Blume[1,2], Elena Bratkovskaya[1,2], and Gabriele Coci[2] — [1]Goethe University Frankfurt — [2]GSI Darmstadt

Simulations of light nuclei production in heavy-ion collisions up to date have been limited to the modeling of a sudden transition from a dynamical transport model to clusterization (via coalescence or statistical model). However, a better understanding of the cluster formation and of how such weakly bound objects are formed and survive in the dense and hot environment created in heavy-ion collisions cannot be established that way. The newly developed Parton-Hadron-Quantum-Molecular-Dynamics (PHQMD) approach allows a dynamical cluster formation continuously during the time evolution of the collision. The microscopic n-body transport model describes the interactions between baryons on the basis of Quantum Molecular Dynamics (QMD) which allows to propagate n-body correlations in phase-space, essential for the cluster formation. The clusters are recognized by the Minimum Spanning Tree (MST) algorithm. Collisions among hadrons, the Quark-Gluon-Plasma formation and parton dynamics are adopted from the Parton-Hadron-String-Dynamics (PHSD) transport approach. A comparison of light nuclei and hypernuclei simulated with PHQMD and experimental data from AGS to RHIC energies will be presented, also providing valuable predictions for the upcoming CBM and NICA experiments. DFG-grant BL 982/3-1, DFG-grant BR 4000/7-1.

HK 17.5 Wed 17:45 H1

CBM performance for the measurement of Λ hyperons' directed flow in Au+Au collisions at FAIR SIS-100 energies — •Oleksii Lubynets[1,2] and Ilya Selyuzhenkov[1,3] for the CBM-Collaboration — [1]GSI, Darmstadt, Germany — [2]Goethe Universität Frankfurt, Germany — [3]NRNU MEPhI, Moscow, Russia

The main goal of the CBM experiment is to study highly compressed baryonic matter produced in collisions of heavy ions. The SIS-100 accelerator at FAIR will enable investigation of the QCD matter at temperatures up to about 120 MeV and net baryon densities 5-6 times the normal nuclear density. Hyperons produced during the dense phase of a heavy-ion collision provide information about the equation of state of the QCD matter. The measurement of their anisotropic flow is important for understanding the dynamics and evolution of the QCD matter created in the collision.

We will present the status of performance studies for Λ hyperon directed flow measurement for the CBM experiment at FAIR. Λ hyperons decay within the CBM detector volume and are reconstructed via their decay topology. The Particle-Finder Simple package, which provides an interface to the Kalman Filter Particle (KFParticle) mathematics, is used to reconstruct $\Lambda \rightarrow p\pi^-$ decay kinematics and to optimize criteria for Λ candidates selection. Directed flow of Λ hyperons is studied as a function of rapidity, transverse momentum and collision centrality. The effects on flow measurement due to non-uniformity of the CBM detector response in the azimuthal angle, transverse momentum and rapidity are corrected using the QnTools analysis package.

HK 17.6 Wed 18:00 H1

Linear and Nonlinear Kinetic Description of Momentum Anisotropies in pp and pA Collisions in RTA — •Clemens Werthmann and Sören Schlichting — Universität Bielefeld, Bielefeld, Germany

Momentum anisotropies caused by collective flow phenomena in HICs have been known to convey a rich amount of information on the collision geometry. In pp and pA collisions the system size is too small for the hydrodynamic description of these anisotropies to be applicable. Instead, a microscopic description of the non-equilibrium dynamics has to be employed. Indeed, kinetic theory simulations have reproduced the anisotropies, but detailed insight into the mechanisms of their emergence is obscured by the algorithmical implementation. This prompts attempts to complement them with analytical treatments, which is highly nontrivial. We present an in-depth study of analyitcal and numerical descriptions of the problem formulated in relaxation time approximation. The analytical description employs an opacity expansion scheme of the Boltzmann equation and a linearization in small anisotropic perturbations on top of an isotropic Gaussian background. The nonlinear numerical description allows to estimate the range of validity of these appoximations via comparison and to study how the flow behaviour evolves from the free-streaming to the hydrodynamic regime.

HK 17.7 Wed 18:15 H1

Relativistic heavy-ion collisions and multiharmonic/large-order flow cumulants — •Seyed Farid Taghavi — Physics department, Technical University of Munich, James-Franck-Straße 1, 85748 Garching bei München

In the past years, significant progress has happened in high-energy nuclear physics models. A more robust and quantitative picture has replaced the qualitative descriptions of heavy nuclei collisions in the earlier days, enabling us to have a clearer picture of different stages of a heavy-ion collision. These models typically have $O(10)$ free parameters. The free parameters are tuned by Bayesian analysis in recent years, where the ALICE measurements are used as inputs.

In this presentation, our focus is on anisotropic flow observables. We introduce a method to extract anisotropic flow cumulants systematically. Employing a Monte Carlo simulation tuned by Bayesian analysis results, we predict the value of few low-order flow harmonic cumulants with significant signals that have not been reported by the LHC so far. We address how the new observables can modify the Bayesian analysis results. The large-order flow cumulant ($v_n\{2k\}$ with large k) contains a unique piece of information about the underlying flow distribution. In particular, we discuss the relation between the nonvanishing Lee-Yang zero phase and large-order flow cumulant ratios at ultra-central, ultra-peripheral, large, and small collision systems.

Based on:

S. F. Taghavi, (2020), arXiv:2005.04742 [nucl-th] (will be appeared in Eur.Phys.J.C)

HK 18: Instrumentation VI

Time: Wednesday 16:30–18:30 Location: H2

Group Report HK 18.1 Wed 16:30 H2

High-D: F&E für hochsegmentierte mehrdimensionale Detektoren für zukünftige Experimente — •Silvia Masciocchi für die High-D-Kollaboration — Universität Heidelberg und GSI

Zukünftige Experimente für Higgs-Präzisionsmessungen, die Suche nach Physik über das Standardmodell hinaus, sowie für die Untersuchung des Quark-Gluon-Plasmas und die Erforschung des QCD-Phasendiagramms, verlangen eine neue Generation von Hochpräzisionsdetektoren mit beispielloser räumlicher, zeitlicher und energetischer Auflösung. Die Anforderungen an solche 5-dimensionale (5D) Messungen können nur durch die Kombination von Detektoren mit extremer Granularität und neuartigen Rekonstruktionsmethoden erreicht werden. Eine höhere Segmentierung wird durch neu zu entwickelnde mikroelektronische Technologien, Halbleiterdesigns, Segmentierungskonzepte und Ausleseelektronik möglich werden. Diese Forschung auf der Detektorseite muß von neuartigen Algorithmen begleitet werden, die die bereitgestellte 5D-Information effektiv nutzt. Sie geht darin weit über einen einzelnen Detektor hinaus, indem sich alle Komponenten von einem Detektorsystem ergänzen, um eine optimale Rekonstruktionspräzision zu gewährleisten. High-D ist ein neuer vom BMBF geförderter Verbund, in dem die Gemeinschaften der Elementarteilchen-, Kern- und Hadronenphysik erstmalig miteinander gemeinsam an der Entwicklung verschiedener grundlegender Technologien zu solchen 5D-Detektoren zusammenarbeiten. Der Vortrag gibt einen Überblick über die geplanten Arbeiten und Projekte.

HK 18.2 Wed 17:00 H2

In-beam characterisation of bent ALPIDE MAPS in view of the ALICE Inner Tracking System 3 — •Pascal Becht for the ALICE-Collaboration — Physikalisches Institut Heidelberg University, Germany

The ALICE Inner Tracking System (ITS) has been recently upgraded to a full silicon detector based on Monolithic Active Pixel Sensors (MAPS). Prospectively, ALICE intends to replace the three innermost layers of this new ITS with a novel vertex detector. The proposed design features wafer-scale, ultra-thin, truly cylindrical MAPS. The new sensors will be thinned down to 20–40 μm, leading to an unprecedented low material budget of below 0.05 % X_0 per layer and will be arranged around the beam pipe, as close as 18 mm from the interaction point.

An extensive R&D programme is established with active participation in the BMBF funded High-D consortium for future particle detector development efforts. Investigating the feasibility of curved MAPS, already existing 50 μm-thick ALPIDE sensors were successfully bent, even below the targeted innermost radius. Their particle detection performance was assessed using electron test beams at DESY. First results from the testbeam data analysis for curved ALPIDE sensors will be presented and show that the current ALPIDE technology (180 nm) retains its properties after bending. The results show an inefficiency that is generally below 10^{-4}, independent of the beam inclination with respect to the sensor surface. This outcome proves curved MAPS to be an exciting possibility for future silicon detector designs.

HK 18.3 Wed 17:15 H2

Developement of a cooling system for the PANDA Barrel -EMC * — •Thorsten Erlen for the PANDA-Collaboration — II. Physikalisches Institut, JLU Gießen, Deutschland and for the PANDA Collaboration

The Electromagnetic Calorimeter (EMC) of the future PANDA-Experiment at the FAIR complex in Darmstadt will use lead tungsten scintillator crystals (PWO II). In its barrel part two Large Area Avalanche Photo Diodes (LAAPD) per crystal will be used to measure the amount of scintillation light created. Main characteristics of both the scintillator and the photosensors are temperature dependent. With decreasing temperature the light yield (photons per MeV) of the scintillators increases and the noise of the photosensors is reduced, while their gain-factor at a fixed voltage increases. The nominal operating temperature for the EMC is -25 °C to meet the desired properties and allow the EMC to perform according to the needs of the experiment. Energy resolution and threshold depend on a system that is capable of achieving and maintaining stable crystal and photosensor temperatures. Topic of this talk will be the ongoing developement of the cooling and monitoring system for the barrel part of the calorimeter. Methods in CAD design and simulation as well as design solutions will be presented in detail.

*gefördert durch das BMBF, GSI und HFHF.

HK 18.4 Wed 17:30 H2

FAIR Phase-0 Readiness of the PANDA Backward Calorimeter — Luigi Capozza[1], Alaa Dbeyssi[1], Alexander Greiner[1], Samet Katilmis[1], Dong Liu[1], Frank Maas[1,2,3], Julian Moik[1], •Oliver Noll[1], Peter Otte[1], David Rodriguez Pineiro[1], and Sahra Wolff[1] for the PANDA-Collaboration — [1]Helmholtz-Institut Mainz, Germany — [2]Institute of Nuclear Physics, Johannes Gutenberg University, Mainz, Germany — [3]Prisma Cluster of Excellence, Mainz, Germany

The $\bar{\text{P}}$ANDA FAIR Phase-0 experiment at the Mainz Microtron Facility (MAMI) is set to determine the double-virtual transition formfactor (TFF) of the pion. As a consequence, the uncertainty in the hadronic light-by-light (HLbL) calculation for the anomalous magnetic moment of the muon can be reduced. The detector system for the experiment is a modified version of the $\bar{\text{P}}$ANDA backward calorimeter, which was developed by the group at HI-Mainz. In contrast to the $\bar{\text{P}}$ANDA experiment, the detector will operate in forward direction at a fixed target electron scattering experiment. Thus, new challenges arise for the radiation load of the components and the handling of high rates with the data acquisition. The talk addresses the major hardware, electronics, and data acquisition modifications to the $\bar{\text{P}}$ANDA backward calorimeter to achieve Phase-0 readiness.

HK 18.5 Wed 17:45 H2

Calibration of Pt100-temperature sensors in an electromagnetic calorimeter — •Samet Katilmis[1], Frank Maas[1,2,3], Alexander Greiner[1], Julian Moik[1], Oliver Noll[1], David Rodriguez Pineiro[1], Sahra Wolff[1], Luigi Capozza[1], Alaa Dbeyssi[1], Peter-Bernd Otte[1], and Dong Liu[1] for the PANDA-Collaboration — [1]HI-Mainz, Mainz, Germany — [2]Institute of Nuclear Physics, Mainz, Germany — [3]PRISMA Cluster of Excellence, Mainz, Germany

The PANDA Backward Endcap Calorimeter (BWEC) consists of tightly packed

PbWO scintillators with a highly temperature dependent light yield (LY). The LY increases by 3% per °C with decreasing temperature to a value of 500 photons per MeV at -25°C and thus has to be monitored to avoid a deterioration of the energy resolution. The flat sensors consist of a thin Platinum wire covered by two kapton sheets. They fit between the tight structure of the scintillator matrix of the calorimeter because of their low thickness. The resistance of the platinum wire changes with its temperature and can be measured with the method of "four terminal sensing" which allows the use of long cable lengths. All the flat sensors show a different characteristic resistance-temperature relation and must be calibrated. The flat sensors are calibrated inside subunits (submodules) of the calorimeter (in-situ calibration) with the help of multiple reference temperature sensors and a climate chamber which approaches different temperature plateaus. At the temperature plateaus, calibration points are taken to calibrate the flat sensors with an accuracy of 0.14 °C .

HK 18.6 Wed 18:00 H2

A new calibration system for 180° electron scattering experiments — •Maximilian Spall, Maxim Singer, Johann Isaak, Jonny Birkhan, Peter von Neumann-Cosel, and Norbert Pietralla — Institut für Kernphysik, Technische Universität Darmstadt

An electron scattering experiment at 180° is an excellent tool to investigate magnetic excitations of nuclei, due to the minimum of the longitudinal differential cross section at this angle. The 180° electron scattering system at the QCLAM spectrometer [1] is presently upgraded. A new system for the calibration of the scattering angles has been designed and is currently under construction, since precise knowledge of the horizontal and vertical scattering angles is necessary to reconstruct the experimental scattering angle. With the help of the new calibration system, it is possible to measure the transport matrix for the whole magnetic system, including the QCLAM spectrometer, without the need to change to a normal configuration as described in [1]. In this talk the new calibration system will be presented.

Supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 279384907 - SFB 1245.

[1] C. Lüttge et al., Large-aperture system for high-resolution 180° electron scattering. Nuclear Inst. and Methods in Physics Research, A. 366, 325-331 (1995).

HK 18.7 Wed 18:15 H2

Design of a cryopump for PANDA at FAIR — •Christian Mannweiler, Benjamin Hetz, Daniel Bonaventura, Jeremy Runge, Philipp Brand, Sophia Vestrick, and Alfons Khoukaz for the PANDA-Collaboration — Westfälische Wilhelms Universität, Münster, Deutschland

The PANDA experiment at the future HESR accelerator at FAIR will explore open questions about the strong interaction, the existence of exotic particles as well as other topics by utilising anti-proton-proton collisions. For these studies, optimal vacuum conditions are crucial for event reconstruction, background suppression as well as for antiproton beam lifetime.

To this end, a custom designed cryopump is in development for the antiproton beam line of the PANDA experiment. In a cryopump, activated charcoal is cooled down to cryogenic temperatures of well below 20K. At these temperatures, even hydrogen molecules are adsorbed, creating a highly efficient pumping mechanism.

Several different cryopump geometries were studied with respect to their impact on the vacuum situation at PANDA and the attainable minimum temperatures using the software packages MOLFLOW+ and Autodesk CFD, respectively. Additionally, experimental studies were performed with regard to the capacity and pumping speed of such a cryopump. The results obtained through these studies will be presented and discussed.

This project has received funding from BMBF (05P19PMFP1) and GSI (FuE) - MSKHOU2023

HK 19: Hadron Structure and Spectroscopy IV

Time: Wednesday 16:30–18:15 Location: H3

Group Report HK 19.1 Wed 16:30 H3

Search for resonant states with $c\bar{c}s\bar{s}$ quark content at BaBar and Belle — •Elisabetta Prencipe[1], Dmytro Meleshko[1], Ashish Thampi[2], Soeren Lange[1], and James Ritman[2] — [1]JLU - University of Giessen — [2]Forschungszentrum Juelich

The study of exotics with charm- and strange- quark content has recently gained a lot of attention. In fact, the LHCb collaboration has already published on this topic three papers. In the latest submission, LHCb has shown interesting results by analyzing the invariant mass of the $J/\psi\phi$ and $J/\psi K$ systems in B decays. Former studies were conducted by the CDF, D0, CMS and BaBar collaborations, with controversial interpretation regarding possible resonant states in the $J/\psi\phi$ invariant mass. All previous studies were performed by analyzing B meson decays only, *e.g.* $B \to J/\psi\phi K$. We recently started this study with the whole Belle data set collected at the energy in the center of mass of $\Upsilon(4S)$. We decide to perform the analysis to look for $c\bar{c}s\bar{s}$ exotics at B factories, and combine data sets of 2 experiments (BaBar and Belle) to cure problems of insufficient statistics. We perform our study not only through B decays (charged and neutral B modes), but also in the continuum. This offers the possibility to cross-check the presence of such resonant states -if any- in different decay modes and different production mechanisms. The state of the art of the analysis of $B \to J/\psi\phi K$, $e^+e^- \to J/\psi\phi X$ and $e^+e^- \to D_s^- D_s(2317)^+ X$ is here presented. A DFG project has been submitted and approved on this topic for 3 years.

HK 19.2 Wed 17:00 H3

Search for couplings of vector charmonia to the $p\bar{p}\eta'$ final state at BESIII — •Johannes Bloms[1], Nienke Balz[1], Helge Balzen[1], Anja Brüggemann[1], Christopher Fritzsch[1], Titus Heinig[1], Nils Hüsken[2], Sascha Lennartz[1], Frederik Weidner[1], and Alfons Khoukaz[1] for the BESIII-Collaboration — [1]Westfälische Wilhelms-Universität, Münster, Germany — [2]Indiana University, Bloomington, USA

The BESIII experiment at the Beijing Electron Positron Collider (BEPCII) has collected a large amount of high luminosity data sets at various center-of-mass energies between $\sqrt{s}$ = 3.7 GeV and $\sqrt{s}$ = 4.7 GeV, which offers a unique opportunity to study hadron spectroscopy and enables dedicated studies of exotic charmonia. The $\psi(4230)$ with $J^{PC} = 1^{--}$ and a mass around $m_{\psi(4230)} = 4.23$ GeV/c^2 is one example for an exotic candidate. Many detailed investigations regarding the $\psi(4230)$ have been made both experimentally and from theory, but there is still no consensus regarding its inner structure. Surprisingly, only a small coupling to open-charm final states has been found. Instead, the $\psi(4230)$ is prominently observed in charmonium transitions like $\psi(4230) \to J/\psi\pi^+\pi^-$, $\psi(4230) \to h_c\pi^+\pi^-$ and $\psi(4230) \to \psi(2S)\pi^+\pi^-$. So far, no observations have been made of charmless decays of the $\psi(4230)$ to light hadrons. In order to search for those possible decays of the $\psi(4230)$, the final state $p\bar{p}\eta'$ is investigated. The current status of the determination of the energy-dependent Born cross section $\sigma^B(e^+e^- \to p\bar{p}\eta')$ will be presented and discussed. This work is funded by the DFG - 269952272, 271236083 and 443159800.

HK 19.3 Wed 17:15 H3

Study of the $B \to J/\psi\phi K$ decay channel at Belle — •Ashish Thampi[1], Elisabetta Prencipe[2], and James Ritman[1] — [1]Forschungszentrum Juelich, Juelich, Germany — [2]JLU-University of Giessen, Giessen, Germany

Even though the $B \to J/\psi\phi K$ process is most likely a three body decay, it can also proceed as a quasi-two body decay where J/ψ and ϕ are daughters of a hybrid or charmonium state. Investigating this decay is important in the search for possible $c\bar{c}s\bar{s}$ exotic states in the $J/\psi\phi$ invariant mass system. The LHCb has found resonant states in the $J/\psi\phi$ and the $J/\psi K$ invariant mass distributions in the charged B decay mode. In order to provide a better understanding of the process and disclose the nature of these enhancements, we analyze the invariant mass systems in both, charged and neutral B meson decays, $B^\pm \to J/\psi\phi K^\pm$ and $B^0 \to J/\psi\phi K^0_S$. This analysis is performed using the $771 fb^{-1}$ integrated luminosity data collected at the energy in the center of mass of $\Upsilon(4S)$ resonance by the Belle detector. We measure the branching fraction for these B decays and observe resonant states in the $J\psi\phi$ and the $J/\psi K$ invariant mass systems. This analysis is a part of the DFG project no. 389090153.

HK 19.4 Wed 17:30 H3

Search for the X17 boson at the BESIII experiment — •Saskia Plura, Achim Denig, and Christoph Redmer for the BESIII-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Deutschland

In 2016, the ATOMKI collaboration proposed the existence of a new neutral boson with a mass of 17 MeV to explain their observation of a significant enhancement in the angular correlations of $e^+ e^-$ pairs in nuclear transitions of ^{8}Be and ^{4}He. This particle is referred to as the X17 boson, which sparked interest in the particle physics community.

As the X17 should couple to nucleons, we developed a Monte Carlo generator to evaluate the possibility to search for the X17 boson in $J/\psi \to p\,\bar{p}\,e^+\,e^-$ decays, where the (anti-)proton radiates off an X17. J/ψ decays provide a clean source of nucleon-antinucleon pairs at $e^+\,e^-$-colliders. We considered both possibilities of the X17 being either a pseudoscalar or an axial vector particle, as well as the QED background.

In this talk, we discuss the feasibility of searching for the X17 at BESIII, located at the BEPC-II collider in Beijing, China, using a collected data sample of 10^{10} J/ψ events. - Supported by DFG.

HK 19.5 Wed 17:45 H3

Studies on Midrapidity J/ψ Production as a Function of Charged-Particle Multiplicity with ALICE — •Ailec de la Caridad Bell Hechavarria and Tabea Eder — Institut für Kernphysik, WWU. Wilhelm-Klemm-Straße 9, 48149 Münster

Previous ALICE studies have shown a stronger than linear relative increase of the inclusive J/ψ production at mid-rapidity as a function of the mid-rapidity charged-particle multiplicity in proton-proton collisions at the LHC. Studies on Monte Carlo simulations with PYTHIA 8 attributed this behavior to autocorrelation effects. In this regard, interesting results were obtained studying the correlation of the J/ψ production with the charged-particle multiplicity in different regions of the azimuthal angle with respect to the flight direction of the J/ψ meson.

With experimental data on pp collisions at $\sqrt{s}$=13 TeV TeV and pPb collisions at $\sqrt{s}$=5.02 TeV, collected with ALICE during Run 2 of data taking at the LHC, current results of the relative J/ψ yield as a function of the charged-particle multiplicity, measured at mid-rapidity (|y|<0.9) in the di-electron decay channel, will be shown and compared to theoretical predictions from the PYTHIA8 Monte Carlo event generator.

HK 19.6 Wed 18:00 H3

Hypertriton production in 13 TeV pp collisions — •Michael Hartung — Institut für Kernphysik, Goethe Universität, Frankfurt, Germany

The $^{3}_{\Lambda}$H is a bound state of proton, neutron and lambda. Studying its characteristics provides insights about the strong interaction between the lambda and ordinary nucleons. In particular, the $^{3}_{\Lambda}$H is an extremely loosely bound object, with a large wave-function. As a consequence, the (anti-)$^{3}_{\Lambda}$H production yields in pp collisions are extremely sensitive to the nucleosynthesis models. Significant hypertriton yields have so far only been measured in Pb–Pb collisions at the LHC. Due to the excellent particle identification through the energy-loss measurement in the Time Projection Chamber in combination with the capabilities to separate primary particles from those from secondary decays, provided by the Inner Tracking System, it is possible to identify the hypertriton in pp collisions. With the precision of the presented production yields some configurations of the Statistical Hadronisation and Coalescence models can be excluded leading to tighter constraints to available theoretical models. Supported by BMBF and the Helmholtz Association.

HK 20: Fundamental Symmetries

Time: Wednesday 16:30–18:45 Location: H4

Group Report HK 20.1 Wed 16:30 H4

Probing charged lepton flavor violation with the Mu2e experiment — •Stefan E. Müller, Anna Ferrari, Oliver Knodel, and Reuven Rachamin for the Mu2e-Collaboration — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The Mu2e experiment, currently under construction at the Fermi National Accelerator Laboratory near Chicago, will search for the neutrinoless conversion of muons to electrons in the field of an aluminum nucleus. In the Standard Model, this process, which violates charged lepton flavor conservation, is highly suppressed and undetectable. However, scenarios for physics beyond the Standard Model predict small but observable rates. The Mu2e experiment aims for a sensitivity which is four orders of magnitude better than previous experiments. This is achieved by rigorous control of all backgrounds that could mimic the monoenergetic conversion electron signal.

At the Helmholtz-Zentrum Dresden-Rossendorf, we use the ELBE radiation facility to study the performance of the detectors that will monitor the rate of stopped muons in the aluminum target. For these detectors we have ported several software analysis algorithms to FPGA hardware using High-Level Synthesis, which will be tested at the next ELBE beamtime. Additionally, we perform extensive Monte Carlo simulations for shielding studies and rate comparisons.

In the presentation, the design and status of the Mu2e experiment and its detectors will be presented, and results from ELBE beamtimes and the simulation studies will be shown.

Group Report HK 20.2 Wed 17:00 H4

Parity violating electron carbon scattering at the P2 experiment — Sebastian Baunack[1], Kathrin Imai[1], Rahima Krini[1], Frank Maas[1,2,3], Tobias Rimke[1], David Rodriguez Pineiro[2], and •Malte Wilfert[1] for the P2-Collaboration — [1]Institut für Kernphysik, Johannes Gutenberg-Universität Mainz — [2]Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — [3]PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz

The weak mixing angle $\sin^2\theta_W$ can be measured in parity violating elastic electron-proton scattering. The aim of the P2 experiment is a very precise measurement of the weak mixing angle with a precision of 0.15% at a low four-momentum transfer of $Q^2 = 4.5 \cdot 10^{-3}\,\mathrm{GeV}^2$. This precision is comparable to existing measurements at the Z pole. The experiment will be built at the future MESA accelerator in Mainz.

In addition to the measurement using a liquid hydrogen target, the possibility of other targets for measuring the parity violating elastic electron scattering are considered. The motivation and challenges for a measurement using a solid carbon target will be discussed in this talk.

Group Report HK 20.3 Wed 17:30 H4

The search for electric dipole moments of charged particles on storage rings — •Vera Shmakova for the JEDI-Collaboration — IKP, Forschungszentrum Jülich, 52425 Jülich, Germany

One of the main problems of modern particle physics is the inability of the Standard Model (SM) of Particle Physics to explain the matter-antimatter asymmetry in the Universe. The pursuit of physics beyond the SM is required and one way to achieve it is to strive for the highest precision in the search for electric dipole moments (EDMs). Permanent EDMs of particles violate both time reversal and parity invariance and, through the CPT-theorem they also violate the combined CP symmetry. Hence, EDM measurements of fundamental particles are capable to probe new sources of CP-violation, and finding an EDM would be a convincing indicator for physics beyond the SM. Storage rings make it possible to measure EDMs of charged particles by observing the effect of the EDM on the spin motion in the ring. The direct search for proton and deuteron EDMs bears the potential to reach sensitivity beyond 10^{-29} e cm. The Cooler Synchrotron COSY at the Forschungszentrum Jülich provides polarized protons and deuterons with momenta up to 3.7 GeV/s, which is an ideal starting point for such an experimental program. The JEDI (Jülich Electric Dipole moment Investigations) collaboration is currently aiming at the first direct (precursor) measurement of the deuteron EDM in COSY. The technical design of the prototype EDM storage ring is the next milestone of the JEDI research program. The talk will present the JEDI program for the measurement of proton and deuteron EDMs and discuss recent results.

HK 20.4 Wed 18:00 H4

Frequency extraction of NMR signal to measure the magnetic field in the Fermilab Muon g−2 experiment — •Mohammad Ubaidullah Hassan Qureshi, René Reimann, and Martin Fertl for the Muon g-2-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The Fermilab Muon g − 2 collaboration recently published its first result for the anomalous magnetic moment of the muon, a_μ, to an unprecedented precision of 460 ppb. The new result deviates of 3.2σ from the latest Muon g − 2 Standard Model Theory Initiative prediction and combined with Brookhaven National Laboratory (BNL) result the deviation increases to 4.2 sigma. The Muon g − 2 experiment determines the ratio of the muon anomalous precession frequency, w_a, to the proton spin precession frequency, w_p. The w_p value allows us to precisely account for the magnetic field experienced by the precessing muons. In this talk I will discuss the current methodology of precisely measuring the magnetic field using nuclear magnetic resonance (NMR) probes. This is achieved by extracting the frequency of the NMR signal generated due to spin precession of hydrogen atoms in our probe. Furthermore, I will also talk through plans for upcoming Run 2/3 analysis to systematically check and improve probe frequency extraction to a value below the Run 1 uncertainty for frequency extraction.

HK 20.5 Wed 18:15 H4

Tracking the magnetic field in the Fermilab Muon g–2 storage ring — •René Reimann, Mohammad Ubaidullah Hassan Qureshi, and Martin Fertl for the Muon g-2-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

Recently the Muon g–2 collaboration published the most precise measurement of the anomalous magnetic moment of the muon, a_μ, with a 460 ppb uncertainty based on the Run 1 data. The measurement principle is based on a clock comparison between the anomalous spin precession frequency of spin-polarized muons, which is the deviation of the Larmor- from the cyclotron-frequency, and a high-precision measurement of the magnetic field environment using nuclear magnetic resonance (NMR) techniques, expressed by the (free) proton spin-precession frequency. To achieve the ultimate goal of a 140 ppb uncertainty on a_μ, the magnetic field in the storage region of the muons needs to be tracked with an uncertainty better then 70 ppb. The magnetic field tracking is composed of three main components, an absolute calibrated NMR probe, a movable array of NMR probes that can be pulled through the storage region of the muons and a set of NMR probes in the vicinity of the storage region. In this talk, we present the measurement and tracking principle of magnetic field and point out improvements for the upcoming analysis of the Run 2 and 3 data.

HK 20.6 Wed 18:30 H4

Coalescence in MC generators and implications for cosmic ray studies — •Maximilian Horst, Laura Serksnyte, Luca Barioglio, and Laura Fabbietti — Technische Universität München

Coalescence is one of the main models used to describe the formation of light (anti)nuclei in high-energy collisions. It is based on the assumption that two nucleons close in phase space can coalesce and form a nucleus. Coalescence has been successfully tested in hadron collisions with various experiments, from small (pp collisions) to large collision systems (Au-Au and Pb-Pb collisions). However, in Monte Carlo simulations (anti)nuclear production is not described by event generators. A possible solution is given by the implementation of so-called coalescence afterburners, which can describe nuclear production on an event-by-event basis. This idea finds its application especially in astrophysical studies, allowing for precise description of (anti)nuclear fluxes in cosmic rays, which are crucial for indirect Dark Matter searches.

In this talk we present the implementation of event-by-event coalescence afterburners for MC generators. Different approaches to this implementation will be discussed, and the comparison with available experimental results from various collision systems will be shown.

HK 21: Invited Talks - IV

Time: Thursday 11:00–12:30 Location: H1

Invited Talk HK 21.1 Thu 11:00 H1

Charming bound states of the strong interaction — •Frank Nerling — Helmholtz Forschungsakademie Hessen für FAIR (HFHF), Frankfurt, Germany

Quantum chromodynamics, the quantum field theory of the strong interaction, allows for and predicts exotic bound states beyond the simple quark model. Even though experimental searches are performed since decades, most of them were not conclusive — the reported candidates are heavily disputed in the community. The discovery of the first so-called charmonium-like (exotic) XYZ states at the beginning of the millennium, however, has initiated a new era. With the observation of tetraquark candidates, the BESIII experiment has discovered manifestly exotic states in the meson sector. Other facilities such as the upcoming PANDA experiment at FAIR offer unique possibilities to finally clarify the nature of e.g. one of the first and most famous XYZ states that still 15 years after the observation is not yet understood.

Invited Talk HK 21.2 Thu 11:30 H1

Baryon Spectroscopy with the CBELSA/TAPS experiment at ELSA — •Annika Thiel — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn

The dynamics of the quarks and gluons inside the nucleon are a long-standing question in hadron physics. To shed more light on this topic, the excitation spectrum of the nucleons needs to be measured and compared to theoretical models like constituent quark models or lattice QCD calculations.

The extraction of the resonance spectrum is a recent research project by several different experiments. One of them is the CBELSA/TAPS experiment, which is located at the ELSA accelerator in Bonn. The CBELSA/TAPS experiment features a detector system with nearly full 4π angular coverage and a high detection efficiency for photons, which makes it the ideal tool for the measurement of final states comprising neutral mesons. One of its special features is the use of linearly or circularly polarized photon beams impinging on a longitudinally or transversely polarized butanol target. This allows for the measurement of single or double polarization observables, which are of major importance in the identification of small resonance contributions.

In this presentation, an overview of the recent status in baryon spectroscopy at the CBELSA/TAPS experiment will be given. This includes measurements of different polarization observables, as well as a review of their impact on the excitation spectra of the nucleons. Supported by the DFG (SFB/TR16).

Invited Talk HK 21.3 Thu 12:00 H1

Mass measurements of the most exotic nuclei and their relevance for nuclear structure — •Timo Dickel[1,2], FRS Ion Catcher Collaboration[1,2], and TITAN Collaboration[3] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [2]Justus-Liebig-Universität Giessen, Giessen — [3]TRIUMF, Vancouver, Canada

High-performance multiple-reflection time-of-flight mass spectrometers (MR-TOF-MS) developed at Justus Liebig University Gießen have been used for nuclear physics experiments using the FRS Ion Catcher experiment at the in-flight fragment separator FRS at GSI and the TITAN experiment at the ISOL facility ISAC at TRIUMF, Canada. The unprecedented sensitivity and mass resolving powers of these MR-TOF-MS allows to study the nuclear structure and astrophysics at the extremes of the nuclear chart. A wide range of cases will be presented, from investigations of the astrophysical scenario of the r-process to nuclear structure effects like the island of inversion or the shell structure at the outskirts of the nuclear chart.

In addition, the use of these MR-TOF-MS goes even beyond precision mass measurements, e.g., they can be employed to unambiguously identify and analyze ions independent of their decay properties. This enables novel and universal approaches to measure reaction cross-sections, fission yields, half-lives, and branching ratios. Recent highlights and outlook for both experiments at GSI and TRIUMF will be presented.

HK 22: Heavy-Ion Collisions and QCD Phases IV

Time: Thursday 16:30–18:30 Location: H1

Group Report HK 22.1 Thu 16:30 H1

Soft dielectron production in pp and Pb–Pb collisions with ALICE — •Jerome Jung for the ALICE-Collaboration — IKF, Goethe University Frankfurt, Germany

The production of soft dielectrons is an exceptional and versatile tool to study the underlying mechanisms and properties of hadron-hadron and heavy-ion collisions (HIC). In HIC, the STAR collaboration observed first a clear excess of dielectrons produced at low pair momenta which exceeded the hadronic decay background. These soft dielectrons can be attributed to coherent photoproduction originating in the interaction of the highly contracted electromagnetic fields of the colliding ions, a sole QED process. In hadronic collisions, several experiments observed an excess at low momenta for real as well as virtual photons beyond hadronic decays which could not be explained by initial- and final-state bremsstrahlung either. As this soft-photon puzzle is absent in purely leptonic collisions, the origin of the effect seems to be connected to QCD.

In this talk, ALICE measurements of dielectron production in pp and (semi-) peripheral Pb–Pb collisions, will be presented. The pp collisions are recorded with a reduced magnetic field of the central barrel solenoid of 0.2 T. This enables the investigation of a kinematic domain at low invariant mass m_{ee} and pair transverse momentum $p_{\mathrm{T,ee}}$, which was previously inaccessible at the LHC. Comparison of the measured dielectron yield to the hadronic decay cocktail indicates a clear enhancement of soft dielectrons in both systems. Finally, the excess spectra are extracted and compared to theoretical model calculations.

HK 22.2 Thu 17:00 H1

Centrality and system size dependence of the thermal dilepton excess yield in HADES — •Niklas Schild for the HADES-Collaboration — TU Darmstadt, Darmstadt, Germany

Electromagnetic probes offer a unique opportunity to study the conditions in heavy-ion collisions throughout their whole evolution. In particular, the spectral shapes of dilepton distributions entail information about the temperature of the hot and dense fireball, while the integrated dilepton yield can be connected to the lifetime of the colliding system.

The collision centrality as well as the beam energy are arguably the two major determinants for the conditions reached in heavy-ion collisions. Less clear is the impact of the ion species or the spectator matter. For this reason, the HADES collaboration has recorded events for two collision systems at the same energy: Au+Au in April 2012 and Ag+Ag in March 2019, both at 1.23A GeV.

We present first results of the measured Ag+Ag thermal dilepton radiation and compare the extracted temperature of the fireball as well as the normalised excess yield to the measurements from Au+Au collisions.

HK 22.3 Thu 17:15 H1

Thermal dileptons in a coarse-grained transport and hydrodynamics — •Maximilian Wiest[1], Tetyana Galatyuk[1,2], Ralf Rapp[3], Florian Seck[1], Joachim Stroth[2,4], and Jan Steinheimer[4,5] — [1]TU Darmstadt — [2]GSI, Darmstadt — [3]Texas A&M Univ, College Station, USA — [4]Goethe-Universität, Frankfurt — [5]FIAS, Frankfurt

Dileptons provide a unique way to access the properties of the fireball created in heavy-ion collisions. Hadrons are not suited for doing this in the same way, since their properties are subject to the strong interactions in the fireball. We study dilepton production in the SIS18 energy range by utilizing an approach that uses coarse-grained transport simulations to calculate thermal dilepton emission applying state-of-the-art in-medium spectral functions from hadronic many-body theory. To ensure an accurate description of the fireball, we have used several microscopic transport models and compared the effect of the space-time evolution on resulting dilepton spectra. We will also present a systematic comparison of the results for different colliding nuclei as well as for the number of individual participants in the collision (system size) and different collision energies as measured recently by the HADES Collaboration.

Supported by VH-NG-823, DFG CRC-TR 211 and GSI

HK 22.4 Thu 17:30 H1

Direct Photon Production in pp collisions at $\sqrt{s}$ = 13 TeV as a Function of Multiplicity with ALICE — •Ilya Fokin für die ALICE-Kollaboration — Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany

Thermal direct photons are a sign of the production of a quark-gluon-plasma (QGP). They have been measured in PbPb collisions by ALICE while measurements in pp collisions showed no enhancement over the decay photon cocktail. Some collective effects, which could be explained by a QGP, such as long-range two-particle correlations have been observed not only in heavy-ion collisions, but also in high-multiplicity pp collisions. An enhancement of the direct photon production at low transverse momentum in high-multiplicity collisions compared to low-multiplicity collisions would suggest the creation of a QGP also in pp collisions.

In this talk, a measurement of the direct photon production in pp collisions at 13 TeV as a function of the charged particle multiplicity with ALICE is presented. Photons are reconstructed using the photon conversion method, relying on pair conversions in the detector material. π^0 and η mesons are reconstructed via their two-photon decay channels for the calculation of the decay photon cocktail.

HK 22.5 Thu 17:45 H1

Dielectron physics opportunities with ALICE 3 — •Florian Eisenhut for the ALICE-Collaboration — IKF, Universität Frankfurt am Main, Deutschland

The ALICE 3 experiment is planed as a compact, next-generation multipurpose detector at the LHC as a follow-up to the present ALICE experiment. It will provide unprecedented tracking and vertexing capabilities down to a few tens of MeV/c in pp, pA and AA collisions at luminosities up to a factor 50 times higher than what will be possible with the upgraded ALICE detector. Such detector performances allow to study the very soft dielectron productions connected to the electric conductivity of the medium via thermal dielectrons in heavy-ion (AA) collisions. At higher dielectron invariant masses (m_{ee}), the measurement of thermal radiation from the hadron gas is possible, which becomes sensitive to the chiral symmetry mixing between ρ and a_1 mesons. Overall, these conditions will provide unique opportunities for dielectron measurements.

This talk will give an overview of the performance studies for dielectron analyses with the ALICE 3 experiment aiming at specific criteria to optimise the layout of the detector. A possible way to identify electrons using different PID scenarios will be presented together with the resulting track and pair efficiencies and the expected m_{ee} resolution. Finally the capability to reject the heavy-flavour background will be discussed based on the expected raw dielectron yield in central AA collisions as a function of the pair distance-of-closest approach to the primary vertex.

HK 22.6 Thu 18:00 H1

Photon and dilepton rates in the low energy regime and electrical conductivity — •Charlotte Gebhardt and Stefan Flörchinger — Institut für Theoretische Physik, Universität Heidelberg

We combine next to leading (NLO) computations on the thermal spectral function with results from hydrodynamic simulations with mode expansion (FluiduM) to study the eletrical conductivity of the Quark Gluon Plasma (QGP). Therefore we fit and modify the thermal spectral function, such that electrical conductivity can be varied. Further we present how this has an impact on the thermal particle spectra in the low energy regime. Results are shown for a simulated QGP of a Pb-Pb-collision at $\sqrt{s_{NN}} = 2.76\,TeV$ and $\sqrt{s_{NN}} = 5.02\,TeV$. The aim is to find a way to gain insights on the electrical conductivity of the QGP from measurements of thermal photons and dileptons.

HK 22.7 Thu 18:15 H1

Measurement of Neutral Mesons in pp Collisions at $\sqrt{s}$ = 13 TeV with ALICE — •Joshua König for the ALICE-Collaboration — IKF, Goethe-Universität Frankfurt

ALICE, the dedicated heavy-ion experiment at the LHC, investigates the properties of the quark-gluon plasma (QGP) that is believed to be produced in central AA collisions at high center-of-mass energies. Measurements in pp collisions provide a baseline for the AA collision system and can furthermore constrain the description of hadronization and fragmentation. Multidifferential measurements of neutral meson (π^0, η, ω) production as function of p_{T} and the multiplicity can give further constraints on the particle production mechanisms. Moreover, these measurements provide the baseline for direct-photon analyses.

The reconstruction of neutral mesons via their two photon-decay channel can be realized in ALICE with several complementary methods, utilizing the calorimeters and the TPC. In this talk, the status of the light neutral meson analyses in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE will be presented.

Supported by BMBF and the Helmholtz Association

HK 23: Instrumentation VII

Time: Thursday 16:30–18:30 Location: H2

Group Report HK 23.1 Thu 16:30 H2

Status of the CBM Time-of-Flight project — •Ingo Deppner and Norbert Herrmann for the CBM-Collaboration — Physikalisches Institut, Uni. Heidelberg

In order to provide an excellent particle identification (PID) of charged hadrons at the future high-rate Compressed Baryonic Matter (CBM) experiment the CBM-TOF group has developed a concept of a large-area Time-of-Flight (ToF) wall equipped with multi-gap resistive plate chambers (MRPC). The MRPC detectors reached by now the close to final design and were extensively tested in several beam campaigns at particle fluxes of up to a 25 kHz/cm^2. Prior to its destined operation at the Facility for Antiproton and Ion Research (FAIR) - starting in 2025 - this high-rate timing MRPC technology is being used for physics research at two scientific pillars of the FAIR Phase-0 program. At STAR, the fixed-target program of the Beam Energy Scan II (BES-II) relies on 108 CBM MRPC detectors for forward PID at interaction rates of up to 2.5 kHz with 3 to 31.2 AGeV Au beams. At mCBM, high-performance benchmark runs of Λ production at top SIS18 energies (1.5/1.9 AGeV for Au/Ni beams) and CBM design interaction rates of 10 MHz will become feasible with a PID backbone consisting of 25 CBM MRPC detectors. Apart from the physics perspectives, these FAIR Phase-0 involvements allow for high rate detector tests and long term stability tests and will help gathering experience in operating the final CBM TOF wall. The current status of the CBM-TOF project and latest achievements from our Phase-0 involvements will be presented. The project is partially funded by BMBF contract 05P15VHFC1.

HK 23.2 Thu 17:00 H2

Development of a high resolution scintillation time measurement system — Kai-Thomas Brinkmann, •Lara Dippel, Valera Dormenev, and Hans-Georg Zaunick — II. Physikalisches Institut, Justus-Liebig-Universität, Gießen

This project is dedicated to the development of a system optimized for coincidence time resolution (CTR) measurements, potentially utilized in the context of scintillation kinetics or time-of-flight measurements. Testing through a selection of different electronic and detector components available in our lab, we were able to assemble a setup with promising results for scintillation kinetics measurements. The most promising setup employs a TDC7200 on a custom board read out by a RaspberryPi and a BaF crystal coupled to a PMT as a reference detector, measuring against another "naked" PMT optimized for fast timing. However, the setup predominantly measures the prompt photons emitted by the material tested, effectively suppressing the slower components. To measure the full-timing response of the material, further adjustments to the setup are needed. This work was carried out in the framework of BMBF Project 05K2019 - UFaCal

HK 23.3 Thu 17:15 H2

Magnetic field performance of the latest 2-inch MCP-PMTs — •Steffen Krauss, Merlin Boehm, Katja Gumbert, Albert Lehmann, and Daniel Miehling for the PANDA-Collaboration — Physikalisches Institut , Universität Erlangen-Nürnberg

The PANDA experiment at FAIR will employ two Cherenkov detectors of the DIRC-type for pion/kaon separation. Since the focal planes of both DIRC detectors are located in a ≥1 Tesla B-field, Microchannel-Plate Photomultipliers (MCP-PMTs) are the only viable option to detect the generated Cherenkov photons. Their magnetic field performance is an essential characteristic of the MCP-PMTs and was investigated at conditions similar to those of the later experiment.

In this context the most important quantity is the gain behavior as a function of the B-field strength and direction. MCP-PMTs from Photonis with 10 μm pores, varied internal dimensions, and anode layout with 8×8 and 3×100 pixels were investigated. The further studied MCP-PMTs from Photek Ltd with 6 μm pore diameter show a different B-field behavior. Also internal properties like crosstalk and charge cloud width, time resolution and electron recoil distributions were measured with a FPGA based TRB/PADIWA DAQ system. This was done with xy-scans across the photo cathode inside the B-field for the first time.

- Funded by BMBF and GSI -

HK 23.4 Thu 17:30 H2

Performance of highly pixelated Microchannel-Plate PMTs — •Katja Gumbert, Merlin Böhm, Steffen Krauss, Albert Lehmann, and Daniel Miehling — Physikalisches Institut, Universität Erlangen-Nürnberg

In the PANDA experiment at the new FAIR facility two DIRC detectors will be employed to identify hadrons using Cherenkov light. Since the photo-sensors of these detectors will be located inside magnetic fields of $\gtrapprox 1$ Tesla, Microchannel-Plate Photomultipliers (MCP-PMTs) are the chosen type of sensors. One of the two DIRCs, the Endcap-Disc-DIRC (EDD), which is located in the forward direction of the interaction point, requires a high spatial resolution in one dimension to reconstruct the Cherenkov angles. For this purpose PHOTONIS has built 2-inch MCP-PMTs with a backplane of 3x100 anode pixels.

In Erlangen measurements are being carried out to verify that these MCP-PMTs meet the performance requirements of the EDD. The sensors must have a high detection efficiency (DQE = QE · CE) because only a small number of single photons is expected per track. Thus the quantum efficiency (QE) and the collection efficiency (CE) have to be high. Furthermore the gain needs to be at least 10^6 and should not drop significantly in the magnetic field. Moreover the sensors are required to have a good time resolution of $\lessapprox 100$ ps and need to sustain high photon rates of up to 10 MHz/tube. The results of the performance measurements of four tubes will be presented in this talk.

- Funded by BMBF and GSI -

HK 23.5 Thu 17:45 H2

Development of a Raspberry Pi high resolution time-to-digital converter board for scintillatior based detectors — Kai-Thomas Brinkmann, Valera Dormenev, •Marvin Peter, and Hans-Georg Zaunick — II. Physikalisches Institut, Justus-Liebig-Universität, Gießen

A Raspberry Pi time-to-digital converter (TDC) board based on the TDC-GPX2 chip from Sciosense has been developed for measuring scintillator-based detector signals with high time resolution. Coincidence time measurements (CTR) based on different scintillator setups have been conducted utilizing the TDC board. Its design and performance measurements will be presented. This work was carried out in the framework of BMBF Project 05K2019 - UFaCal.

HK 23.6 Thu 18:00 H2

A Beam Halo Veto Detector for the MAGIX Experiment — •Judith Schlaadt for the MAGIX-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

The MESA accelerator will host the MAGIX experiment, which is based on the scattering of an electron beam on a gas jet target. This enables the scattering on gases like hydrogen without scattering on any other materials before and after the scattering process. The gas jet target is realized by using a nozzle to inject the gas into the scattering chamber as well as a funnel-shaped structure called the catcher, into which the gas streams behind the interaction zone.

So-called beam halo electrons can occur in the accelerator. These do not move exactly along the beam axis and can increase background by interacting with the catcher and the nozzle. To reject these scattering reactions, the beam halo veto detector was implemented. This detector is positioned upstream of the gas jet target inside the scattering chamber. It allows the detection of single electrons by using a scintillator, a lightguide and a photomultiplier tube. Therefore, covering the front of the nozzle and the catcher with this detector allows suppressing the described background.

HK 23.7 Thu 18:15 H2

Performance of the MAGIX Jet Target with an optimized Nozzle Geometry — •Philipp Brand, Daniel Bonaventura, Sophia Vestrick, and Alfons Khoukaz for the MAGIX-Collaboration — Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany

The MAGIX experiment (MAinz Gas Internal target eXperiment) aims for high precision measurements of, e.g., electromagnetic form factors, the astrophysical S-factor, and to search for light dark matter. It will be located in the energy recovery arc of the MESA accelerator which is currently under construction in Mainz. This extensive physics program requires a windowless gas target, that achieves target thicknesses of more than 10^{18} atoms/cm^2 and that can operate with various gases like, e.g., hydrogen, oxygen, or argon.

Therefore, a cryogenic gas-jet target was developed at the University of Münster which is already installed at the A1 experiment within the MAMI facility at Mainz. The jet leaves the target through a convergent-divergent Laval nozzle and already several millimeter below the nozzle the interaction with the electron beam takes place. The jet is then pumped away through a conical catcher that is connected to a powerful pumping station. The jet divergence is crucial for the target performance, since a smaller jet would increase the target thickness at the interaction point and the efficiency of the catcher system. To reduce the divergence of the jet, different Laval nozzle designs have been studied in numerical simulations. The results of measurements with an optimized nozzle will be presented and compared to the simulations.

HK 24: Hadron Structure and Spectroscopy V

Time: Thursday 16:30–18:30 Location: H3

Group Report HK 24.1 Thu 16:30 H3

Measurement of the proton radius with the PRES experiment at MAMI — •Vahe Sokhoyan — Universität Mainz, Institut für Kernphysik

The so-called "proton radius puzzle" originated due to significant discrepancies between some of the results for the proton charge radius measured in experiments with electronic or muonic hydrogen and in electron-proton scattering experiments. Recently, the PRad Collaboration published new results favoring smaller proton radius compared to many of the previous electron-proton scattering measurements. Further scattering experiments utilizing new concepts for detection of particles in the final state are underway.

We are planning to perform a new measurement of the electron-proton scattering cross section at low momentum transfer at the Mainz Microtron (MAMI). The project is conducted in the framework of the PRES Collaboration with participation of the University of Mainz, Petersburg Nuclear Physics Institute, and collaborators from other contributing institutions. The experimental setup consisting of a Hydrogen Time Projection Chamber, Forward Tracker, and beam monitoring system will allow us to measure the energy and the angle of the recoil proton in combination with the angle of the scattered electron and to determine the electron flux with high accuracy. The performance of this experiment will open avenue for further studies of this kind using deuterium and helium targets. In this talk, the current status of this project and the future plans will be presented.

HK 24.2 Thu 17:00 H3

Isoscalar electromagnetic form factors of the nucleon in $N_f = 2 + 1$ lattice QCD — Dalibor Djukanovic[1,2], Georg von Hippel[3], Harvey B. Meyer[1,2,3], Konstantin Ottnad[3], •Miguel Salg[3], Jonas Wilhelm[3], and Hartmut Wittig[1,2,3] — [1]Helmholtz Institute Mainz, Staudingerweg 18, D-55128 Mainz, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [3]PRISMA$^+$ Cluster of Excellence and Institute for Nuclear Physics, Johannes Gutenberg University of Mainz, Johann-Joachim-Becher-Weg 45, D-55128 Mainz, Germany

We present results for the isoscalar electromagnetic form factors of the nucleon computed on the CLS ensembles with $N_f = 2 + 1$ flavors of $\mathcal{O}(a)$-improved Wilson fermions and an $\mathcal{O}(a)$-improved conserved vector current. In order to estimate the excited-state contamination, we investigate several source-sink separations and apply the summation method. For the computation of the quark-disconnected diagrams, a stochastic estimation using the one-end trick is employed. By these means, we obtain a clear signal for the form factors including the quark-disconnected contributions, which have a distinguishable effect on our data.

HK 24.3 Thu 17:15 H3

Monte Carlo Simulations to estimate the Efficiency of an Electromagnetic Calorimeter to detect neutral Pions — •Julian Moik[1], Frank Maas[1,2,3], Alaa Dbeyssi[1], Luigi Capozza[1], Oliver Noll[1], David Rodriguez Pineiro[1], Sahra Wolff[1], Peter Bernd Otte[1], Dong Liu[1], Alexander Christian Greiner[1], and Samet Katilmis[1] for the PANDA-Collaboration — [1]Helmholtz-Institut Mainz, Germany — [2]Institute of Nuclear Physics, Johannes Gutenberg University, Mainz, Germany — [3]Prisma Cluster of Excellence, Mainz, Germany

The PANDA experiment at the future FAIR facility requires a complex detector system, whose backward calorimeter is being developed by the group at the Helmholtz Institute in Mainz. For the FAIR Phase-0 experiment at the electron accelerator MAMI it is planned to use this detector for a measurement of the electromagnetic transition form factor of the neutral pion.

To estimate the efficiency of the experimental setup regarding the pion detection, a Monte Carlo simulation of the pion decay and the detection of the decay photons in the software environment *primasoft* was performed. By reconstructing the pion events from the photon energy measurement, the efficiency of the pion detection was determined as a function of the pion energy and momentum direction. This analysis helped to choose between two different calorimeter geometries and allowed for the calculation of the effective cross-section of the pion production in this experimental setup.

HK 24.4 Thu 17:30 H3

Measurement of the $\omega \to \pi^0\gamma$ decay at A2/MAMI, towards an $\omega\pi^0$ transition form factor analysis — •Daniel Maurer, Achim Denig, and Lena Heijkenskjöld — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Deutschland

Electromagnetic meson Transition Form Factors (TFF) describe the interaction between mesons and photons (real or virtual). Studies of meson TFFs are an important input to the understanding of the anomalous magnetic moment of the muon (a_μ). Currently, the most precise experimental results of a_μ deviate from the Standard Model (SM) predictions by a total of ~4.2σ and thus giving hints at physics beyond the SM. Additionally, the $\omega\pi^0$ TFF is interesting to study due to the significant deviations between existing precise experimental measurements and theory predictions. Data has been collected at the A2/MAMI experiment aiming to improve the precision of the $\omega\pi^0$ TFF. Within the project presented here, the first steps towards such an analysis has been taken by studying the $\omega \to \pi^0\gamma$ channel, which has a ~100 times larger decay width than the rare $\omega \to \pi^0 e^+ e^-$ channel. Furthermore, the $\omega \to \pi^0\gamma$ channel is needed as a normalization to the $\omega\pi^0$ TFF analysis. As a result ~ $(420 \pm 1) \cdot 10^3$ $\omega \to \pi^0\gamma$ events were observed with good MC-data agreement.

—Supported by DFG.

HK 24.5 Thu 17:45 H3

Accessing the annihilation dynamics using femtoscopic correlations with ALICE at LHC — •Valentina Mantovani Sarti for the ALICE-Collaboration — TUM

Baryon–antibaryon ($\mathrm{B\overline{B}}$) systems are characterised, already at threshold, by a relevant contribution of several multi-meson channels related to the presence of short-range annihilation processes. Predictions on the formation of bound states (baryonia) from the attractive elastic $\mathrm{B\overline{B}}$ interaction have been suggested but a precise understanding of the role played by the annihilation interaction is required to assess the possibility of forming such states.

In this talk, we will present the most precise measurements on the baryon–antibaryon interaction ($\mathrm{p\overline{p}}$, $\mathrm{p\overline{\Lambda}}$ and $\Lambda\overline{\Lambda}$) at low momenta by means of correlation studies in high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV measured by the ALICE Collaboration. The effect of annihilation channels on the correlation function and a quantitative determination of the inelastic contributions in the three different pairs will be discussed.

HK 24.6 Thu 18:00 H3

Antihyperons in nuclear matter at PANDA Phase One — •Falk Schupp[1], Patrick Achenbach[1], Michael Bölting[1], Josef Pochodzalla[2], and Marcell Steinen[2] for the PANDA-Collaboration — [1]Helmholtz Institute Mainz, Mainz, Germany — [2]Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Germany

The PANDA experiment will be located in the Facility for Antiproton and Ion Research (FAIR) currently under construction at GSI in Darmstadt (Germany). Even in the early experimental phase (Phase One) the high energy storage ring (HESR) at FAIR will supply a high intensity antiproton beam in the GeV range respresenting an unparalleled factory for various hyperon-antihyperon pairs. The study of antihyperons in convential nuclear matter provides a unique opportunity to elucidate strong in-medium effects in baryonic systems. Quantitative information on the antihyperon potentials may be obtained via exclusive antihyperon-nuclear interactions. The collision of antiprotons with Neon-20 nuclei is simulated using the hadronic transport model simulation tool GiBUU and different effective antihyperon potentials. The event reconstruction with the PANDA detector is simulated with Geant3/4 using the PandaRoot framework and the effect of the antihyperon potential on the observables studied.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824093.

HK 24.7 Thu 18:15 H3

The Study of Genuine Three-Body Interactions in pp collisions with ALICE — •Laura Serksnyte for the ALICE-Collaboration — Technische Universität München

The femtoscopic studies done by the ALICE Collaboration provided results with unprecedented precision for the short-range strong interactions between different hadron pairs. The next challenge is the development of the three-particle femtoscopy which will deliver the first ever direct measurement of genuine three-body forces. Such results would be a crucial input for the low-energy QCD and neutron star studies. In particular, the momentum correlation of p–p–p triplets can provide information about genuine three-nucleon forces while the p–p–Λ interaction is a necessary piece to understand if the production of Λ hyperons occurs in neutron stars.

In this talk, the first study of p–p–p and p–p–Λ correlations will be presented. The results were obtained using high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV measured by ALICE at the LHC. The measured three-body correlation functions include both three- and two-particle interactions. The cumulant method was applied to subtract lower-order contributions and infer directly on the genuine three-body forces. The two-particle contributions were estimated both experimentally by applying mixed-event technique, and mathematically by projecting known two-body correlation functions on the three-body systems. The measured p–p–p and p–p–Λ correlation functions and the corresponding cumulants will be shown.

HK 25: Astroparticle Physics

Time: Thursday 16:30–18:45 Location: H4

Group Report HK 25.1 Thu 16:30 H4

Detecting CEvNS and searching for new physics with the CONUS experiment — •Janine Hempfling for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik (MPIK), Heidelberg

The CONUS experiment aims to detect coherent elastic neutrino nucleus scattering (CEvNS) in the fully coherent regime at the nuclear power plant of Brokdorf, Germany. This talk will present the experimental setup of the CONUS experiment with its four very low energy threshold germanium detectors within an elaborate shield at 17 m distance from the 3.9 GW thermal power reactor core. A full spectral analysis of Run-1 and Run-2 data of the running experiment yields the current best limit on CEvNS with reactor antineutrinos. Additionally latest results for analyses of physics beyond the standard model will be discussed, including bounds on non-standard neutrino interactions (NSIs) and light scalar and vector mediators.

HK 25.2 Thu 17:00 H4

Pulse shape discrimination for the CONUS experiment — •Jakob Henrichs for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The CONUS experiment, using four 1 kg-sized point-contact high-purity germanium detectors (HPGe) aims at the detection of coherent elastic neutrino nucleus scattering (CEνNS) in the fully coherent regime. It is located close to the reactor core of the nuclear power plant in Brokdorf, Germany. For the success of the experiment a very good background suppression is crucial. Therefore, a sophisticated shield as well as a muon anticoincidence veto system were installed, to reduce efficiently the overall background. Further, the analysis of the pulse shape of each event offers a new opportunity for an additional background reduction. Depending on whether the incoming particle interacts in the fully depleted bulk region or in the transition layer of the detector, the resulting pulse shapes are different. The transition layer is an outer layer of the Ge diode, where the charge collection efficiency is below 100%. In this talk a technique to discriminate the different low energy interactions based on a rise time fit of their pulses will be presented. In addition, it will be demonstrated how this technique can also be applied to distinguish between multi-site and single-site events at higher energies.

Group Report HK 25.3 Thu 17:15 H4

Status and Prospects of the XENON Dark Matter Search Experiment — •Sebastian Lindemann — Physikalisches Institut, University of Freiburg, Germany

XENON1T was a dual-phase liquid xenon time projection chamber that operated deep underground at Italy's Gran Sasso National Laboratory from 2016 to 2018. Primarily designed to search for WIMP dark matter, XENON1T featured a ton-scale target mass, keV-scale energy threshold, and ultra low background rate that together led to several world-leading results on a variety of rare-event processes. XENON1T's successor, XENONnT, features a larger target mass and a further reduced background level. It is currently being commissioned and will be able to probe the parameter space of interest with improved sensitivity. This talk will summarize recent XENON1T results and detail the power of its successor XENONnT.

HK 25.4 Thu 17:45 H4

Measurement of the antinuclei nuclear inelastic cross sections with ALICE and implications for indirect Dark Matter searches — •Stephan Königstorfer for the ALICE-Collaboration — Technische Universität München

Light antinuclei in cosmic rays such as antideuteron or antihelium-3 are considered a unique probe for signals from exotic physics like WIMP Dark Matter annihilations. Indeed, these channels are characterised by a very low astrophysical background, which comes from antinuclei produced by high-energy cosmic ray interactions with ordinary matter.

In order to make quantitative predictions for antinuclei fluxes near earth, both the production and annihilation cross sections of antinuclei need to be accurately known down to low energies. In ultra relativistic pp, p-Pb and Pb-Pb collisions at the CERN LHC, matter and antimatter are abundantly produced in almost equal amounts, allowing us to study the production of antinuclei and measure their absorption in the detector material. The antinuclei absorption cross section is evaluated on the average ALICE material. Using this result, we can predict the transparency of our galaxy to antihelium-3 nuclei from both dark matter annihilations and high-energy cosmic ray collisions.

In this talk we present the first measurements of the antideuteron and anti-3He absorption cross section with ALICE and we discuss the implications of these results for indirect Dark Matter searches using cosmic antinuclei.

HK 25.5 Thu 18:00 H4

Neutrinoless double beta decay with XENON1T and XENONnT — •Tim Michael Heinz Wolf — Max Planck Institut für Kernphysik, Heidelberg

Liquid xenon (LXe) time-projection-chambers (TPCs), such as XENON1T or its successor XENONnT, are primarily used for low energy Dark Matter (DM) searches but also for other rare decay searches such as neutrinoless double beta (0vbb) decay. The large active mass of LXe (several tonnes) and its low background rate are beneficial for the sensitivity to detect Weakly Interacting Massive Particles (WIMPs) or rare decays such as 0vbb. The isotope Xe136 with a natural abundance of 8.9% is a known emitter of two-neutrino double beta decay and it is a potential emitter of the hypothetical process of 0vbb decay with a Q-value of 2457.8keV. The discovery of the 0vbb process would imply lepton number violation and would confirm the Majorana nature of neutrinos, a property that has never been seen before in nature for fundamental particles. I will review the ongoing efforts in XENON1T and XENONnT in this context.

HK 25.6 Thu 18:15 H4

Monte Carlo simulation of background components in low level Germanium spectrometry — •Nicola Ackermann[1], Hannes Bonet[1], Christian Buck[1], Janina Hakenmüller[1], Gerd Heusser[1], Matthias Laubenstein[2], Manfred Lindner[1], Werner Maneschg[1], Jochen Schreiner[1], and Herbert Strecker[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Laboratori Nazionali del Gran Sasso, Via G. Acitelli 22, 67100 Assergi L'Aquila, Italy

This talk presents Monte Carlo simulations of the background spectra of the four gamma-ray Ge-spectrometers GeMPI 1 - 4 at the Gran Sasso Underground Laboratory (LNGS) using the Geant4 based framework MaGe. These detectors are very low background Ge-spectrometers located at a depth of 3800 m w.e. and they currently achieve one of the best sensitivities worldwide for primordial U and Th concentrations in materials at a level of μBq/kg. With these detectors material samples are tested to confirm that they meet the stringent requirements of rare event experiments.

The three main background components that are taken into consideration in the simulations are muons, neutrons and intrinsic contaminations in the detector and shielding materials. A detailed understanding of the composition of the background spectra allows for improvements in the sensitivity of next generation screening detectors.

HK 25.7 Thu 18:30 H4

Suppressing radon emanation by coating techniques — •Hardy Simgen, Florian Jörg, and Mona Piotter — Max-Planck-Institut für Kernphysik / Heidelberg

Radon-induced signals are a challenging source of background in most low-background experiments searching for rare events. The dominant radon source is emanation from detector materials, which contain traces of primordial uranium and thorium. While the problem is usually addressed by dedicated material screening and selection programs, novel radon mitigation techniques are required to fulfill the demanding needs of next-generation experiments.

In this talk we present our work on coating techniques to reduce radon emanation from metallic surfaces. A stable, tight and clean coating should reduce the radon emanation rate of materials significantly. Electro-deposition of copper turned out to be the most promising approach. We will discuss systematic studies of the parameters of our coating process and present achieved reduction factors for the emanation rate of the short-lived ^{220}Rn. Practically more relevant is the emanation of ^{222}Rn due to its much longer half-life. However, appropriate samples are hard to obtain. We present first results on the coating of a ^{222}Rn-emanating stainless steel sample which was custom-produced at the ISOLDE facility at CERN.

HK 26: Invited Talks - V

Time: Friday 11:00–12:30 Location: H1

Invited Talk HK 26.1 Fri 11:00 H1

Studying the Universe from deep underground: the LUNA experiment — •Rosanna Depalo — Università degli Studi di Milano and INFN Milano

Nuclear cross sections are crucial ingredients to understand the production of energy inside stars and the synthesis of the elements. In stars, nuclear reactions take place at energies well below the Coulomb barrier. As a result, their cross sections are often too small to be measured in laboratories on the Earths surface, where the signal would be overwhelmed by the environmental background. An effective way to suppress the background is to perform experiments in underground laboratories. The Laboratory for Underground Nuclear Astrophysics (LUNA) is a unique facility located at Gran Sasso National Laboratories (Italy). The extremely low background achieved at LUNA allows to measure nuclear cross sections directly at the energies of astrophysical interest. Over the years, many crucial reactions involved in stellar hydrogen burning as well as Big Bang Nucleosynthesis have been measured at LUNA. The presentation will provide an overview on underground Nuclear Astrophysics and discuss the latest results and future perspectives of the LUNA experiment.

Invited Talk HK 26.2 Fri 11:30 H1

Double parton scattering and double parton distributions — •Peter Plössl — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Double parton scattering (DPS) describes the situation when two individual hard scattering reactions occur in a single hadron-hadron collision. In some regions of phase space DPS may give sizeable contributions to the production of multiparticle final states and thus constitutes an important background to single parton scattering (SPS) in channels suitable for the search for physics beyond the standard model. Besides this DPS is also an interesting phenomena in its own right, as it gives insight into the correlations of partons inside of hadrons.

A theoretical description of DPS processes from first principles can be achieved by deriving factorisation theorems akin to the ones known from SPS, with a central building block being the double parton distributions (DPDs). However, these DPDs are presently basically unknown as experimental data is still lacking.

As a consequence one has to rely on physically motivated models for DPDs to be able to calculate DPS contributions to a given process. One important constraint for such models is given by number and momentum sum rules for DPDs in close analogy to the well known PDF sum rules. Another constraint can be obtained by observing that in the limit of small distances between the two partons DPDs can in fact be matched onto regular PDFs with perturbative matching kernels.

Invited Talk HK 26.3 Fri 12:00 H1

BSM physics in hadronic and nuclear beta decays: challenges and opportunities — •Chien Yeah Seng — Helmholtz-Institut für Strahlen- und Kernphysik and Bethe Center for Theoretical Physics, Universität Bonn, 53115 Bonn, Germany

In the past years, several significant anomalies have been observed in the beta decay of mesons, nucleon and nuclei, which make them promising avenues for the search of the physics beyond the Standard Model (BSM). However, the current significant level of the observed anomalies is not yet sufficient to declare a discovery, and the major limiting factor is the precision level of the Standard Model (SM) theory inputs instead of experiments. In this talk, I will describe the major theory improvements needed to increase the significance level of the existing beta decay anomalies to 5 standard deviations, assuming that BSM physics is the underlying reason. They include high-precision studies of radiative corrections, isospin-breaking corrections and nuclear structure corrections to various beta decay processes.

HK 27: Heavy-Ion Collisions and QCD Phases V

Time: Friday 14:00–16:15 Location: H1

Group Report HK 27.1 Fri 14:00 H1

New developments in flow analyses techniques — •Ante Bilandzic for the ALICE-Collaboration — Technical University of Munich, Germany

With the advent of large statistics heavy-ion datasets at RHIC and LHC it is becoming feasible to study the properties of Quark–Gluon Plasma with unprecedented precision. One of the most informative probes in such studies is the collective anisotropic flow.

In this talk, we present the new developments in flow analysis techniques. We reconcile for the first time the strict mathematical formalism of multivariate cumulants with the usage of cumulants in anisotropic flow analyses. This yields to the next generation of observables to be used in flow analyses: *Event-by-event cumulants of azimuthal angles*, *Symmetric and Asymmetric cumulants of flow amplitudes*, *Cumulants of Symmetry Plane Correlations*. We show that properties of cumulants are preserved only for the stochastic observables on which the cumulant expansion has been performed directly, and if there are no underlying symmetries due to which some terms in the cumulant expansion are identically zero [1].

We derive for the first time the analytic solutions for the contribution of combinatorial background in the measured 2- and 3-particle correlations [2].

[1] A. Bilandzic, M. Lesch, C. Mordasini, S. F. Taghavi, [arXiv:2101.05619 [physics.data-an]]

[2] A. Bilandzic, [arXiv:2106.05760 [hep-ph]]

HK 27.2 Fri 14:30 H1

Tracing the emergence of collective phenomena in small systems — •Pragya Singh and Soeren Schlichting — University of Bielefeld

Event geometry and initial state correlations have been invoked as possible explanations of long-range rapidity correlations (ridge) observed in high multiplicity pp and pPb collisions. We study initial state momentum correlations and event-by-event geometry in p+Pb collisions at $\sqrt{s}$ = 5.02 TeV by following the approach of extending the impact parameter dependent Glasma model (IP-Glasma) to 3D using JIMWLK rapidity evolution of the incoming nuclear gluon distribution [1].

Investigating the non-trivial rapidity dependence of the observables, we find that geometry is correlated across large rapidity intervals whereas initial state momentum correlations are relatively short range in rapidity. Based on our results, we discuss implications for the relevance of both effects in explaining the origin of collective phenomena in small systems.

[1]. B. Schenke and S. Schlichting, Phys. Rev. C 94,044907, arXiv: 1605.07158 [hep-ph]

HK 27.3 Fri 14:45 H1

Non-Equilibrium Transport of Conserved Charges in High-Energy Heavy Ion Collisions — •Philip Plaschke — Bielefeld University, Germany

Non-equilibrium Green*s functions provide an efficient way to describe the pre-equilibrium evolution of macroscopic quantities in early stages of heavy-ion collisions. Within the kinetic theory framework we derived a new method to calculate time dependent non-equilibrium Green*s functions describing the evolution of energy and momentum perturbations on top of an evolving far-from-equilibrium background. We further extend this formalism to describe the evolution of conserved charges. Within kinetic theory in relaxation time approximation we will study the pre-equilibrium evolution of the homogeneous background for non-vanishing initial charge densities and compute the Green*s functions for the charge current for initial charge perturbations around zero density on top of the background. By calculating the Green's functions, we show that only modes with long wavelength survive up into the hydrodynamic regime.

HK 27.4 Fri 15:00 H1

Exploring the Pre-Equilibrium Dynamics of Longitudinal Fluctuations in Heavy-Ion Collisions — •Stephan Ochsenfeld — Bielefeld University, Bielefeld, Germany

Non-equilibrium Green*s functions provide an efficient way to describe the pre-equilibrium evolution of macroscopic quantities in early stages of heavy-ion collisions. Within the kinetic theory framework we derive a new method to calculate time dependent non-equilibrium Green*s functions describing the evolution of energy and momentum perturbations on top of an evolving far-from-equilibrium boost invariant background. As extension to transverse perturbations we also consider fluctuations parallel to the beam direction. By calculating the Green*s functions in relaxation time approximation, we show that in both types of perturbations only modes with long wavelength survive up into the hydrodynamic regime, albeit inhibiting sightly different behavior.

HK 27.5 Fri 15:15 H1

FluiduM: fluid dynamics with mode expansion for fast simulations of relativistic heavy-ion collisions — •Andreas Kirchner[1], Federica Capellino[2], Giuliano Giacalone[1], Eduardo Grossi[3], Daniel Boness[4], Damir Devetak[8], Andrea Dubla[5], Stefan Floerchinger[1], Dhevan Gangadharan[6], Sarah Görlitz[2], Silvia Masciocchi[5,2], Ilya Selyuzhenkov[5], Christian Sonnabend[2], and Kianusch Yousefnia[7] — [1]ITP Heidelberg — [2]Physikalisches Institut, Universität Heidelberg — [3]Department of Physics, SUNY Stony Brook — [4]Fachbereich Physik, Universität Konstanz — [5]GSI Darmstadt — [6]University of Houston — [7]IPhT, Université Paris Saclay — [8]VINCA Inst. Nucl. Sci., Belgrade

We introduce FluiduM, a code to simulate the quark-gluon plasma (QGP) formed in relativistic heavy-ion collisions. Based on a background-fluctuation splitting of the QGP and its initial conditions, in FluiduM the 2+1D hydrodynamic QGP evolution is replaced with a system of de-coupled 1+1D equations, leading to a reduction of orders of magnitude in computation time compared to more traditional codes. The framework implements state-of-the-art initial conditions, second order Israel-Stuart hydrodynamics, and QGP freeze-out supplemented with viscous corrections and resonance decays. We validate the code through calculations of particle yields and average hadron momenta. FluiduM provides a new powerful tool to test our understanding of heavy-ion collisions, with potentially far-reaching consequences for the realization of the goals of the heavy-ion collision program.

HK 27.6 Fri 15:30 H1

Anisotropic flow coefficients in mode-by-mode hydrodynamics: moving towards precision in heavy-ion collision phenomenology — •Giuliano Giacalone[1], Federica Capellino[2], Andreas Kirchner[1], Eduardo Grossi[3], Daniel Boness[4], Stefan Floerchinger[1], Andrea Dubla[5], Silvia Masciocchi[2,5], and Ilya Selyuzhenkov[5] — [1]ITP Heidelberg — [2]Physikalisches Institut, Universität Heidelberg — [3]Department of Physics, SUNY Stony Brook — [4]Fachbereich Physik, Universität Konstanz — [5]GSI Darmstadt

Anisotropic flow coefficients, v_n, carry information about the transport properties of the quark-gluon plasma (QGP) formed in heavy-ion collisions, and are measured today with an amazing degree of precision at colliders. Theoretically, sophisticated models and tools of data analysis have been developed since the appearance of event-by-event (ebye) hydrodynamic simulations, but the intrinsic issue of the slowness of ebye codes remains present today, tampering with our ability of characterizing the physical properties of the QGP from experimental data. In this contribution, we overcome such an issue by means of the newly-developed FluiduM code, based on a background-fluctuation splitting of the QGP evolution, and mode-by-mode hydrodynamic equations. We show that the calculation of v_n coefficients in Fluidum is faster by orders of magnitud than in standard hydro simulations. We present, thus, results for ultra-central collisions, largely inaccessible to ebye codes, where precision data has been recently collected at LHC and RHIC. These results pave the way for future theory-to-data comparisons of unprecedented quality in the context of heavy-ion collisions.

HK 27.7 Fri 15:45 H1

Recent developments in the measurements of genuine multi-harmonic correlations in Pb–Pb collisions — •Cindy Mordasini for the ALICE-Collaboration — Technische Universität München, James-Franck-Straße 1, 85748 Garching bei München

Recently, one of the fundamental steps in constraining the transport properties of the quark–gluon plasma (QGP) was the definition of the Symmetric Cumulants (SCs), which measured the genuine correlations between two different flow amplitudes. Naturally, questions like the existence of genuine correlations between more than two flow amplitudes arose. Quantifying them would provide new information on the properties of the QGP.

The approach shown here focuses on using the flow amplitudes in the cumulant expansion to define these new observables, contrary to the usual method based on the azimuthal angles[1]. This new formalism is illustrated for the three-harmonic SCs, with the first results obtained with ALICE in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV[2] and 5.02 TeV. Finally, the Asymmetric Cumulants, where the flow amplitudes are raised to different powers, will be introduced[3]. For all these observables, predictions from hydrodynamics models will be shown.

1. C. Mordasini, A. Bilandzic, D. Karakoç, S.F. Taghavi, PRC 102, 024907 (2020)
2. ALICE Collaboration, arXiv:2021.02579 (2021) Submitted to PRL
3. A. Bilandzic, M. Lesch, C. Mordasini, S.F. Taghavi, arXiv:2101.05619 (2021)

HK 27.8 Fri 16:00 H1

Symmetry plane correlations in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV with ALICE — •Marcel Lesch for the ALICE-Collaboration — Technische Universität München, James-Franck-Straße 1, 85748 Garching bei München

The study of collective phenomena in ultra-relativistic heavy-ion collisions are nowadays to a great extent built on the so-called flow amplitudes v_n and symmetry planes Ψ_n. Both appear as two distinct degrees of freedom in the Fourier series expansion used to parametrize the distribution of azimuthal angles of produced particles. While analyses techniques for flow amplitudes v_n have advanced over the past years, observables used for measuring symmetry planes Ψ_n are often plagued by built-in biases. However, recent developments [1] in this direction introduced the so-called Gaussian Estimator (GE) which provides a new and more precise technique to measure symmetry plane correlations (SPC) in flow analyses.

In this talk, we present first experimental results of SPC measured with this newly developed GE using ALICE data for Pb–Pb at $\sqrt{s_{NN}}$ = 2.76 TeV (2010). The results are compared to theoretical predictions for the initial coordinate space provided by the MC-Glauber model and for the momentum space obtained with the state-of-the-art model iEBE-VISHNU.

1. A. Bilandzic, M. Lesch, S. F. Taghavi, "New estimator for symmetry plane correlations in anisotropic flow analyses", Phys. Rev. C 102, 024910 - 2020

HK 28: Instrumentation VIII

Time: Friday 14:00–15:45 Location: H2

Group Report HK 28.1 Fri 14:00 H2

Status of the CBM-MVD* — •Michael Deveaux for the CBM-MVD-Collaboration — GSI Darmstadt

The Compressed Baryonic Matter Experiment (CBM) is one of the core experiments of the future FAIR facility. It will explore the phase diagram of strongly interacting matter in the regime of high net baryon densities. Its Micro Vertex Detector (MVD) will contribute to the secondary vertex determination on a 10 μm scale, background rejection in di-electron spectroscopy and reconstruction of weak decays of multi-strange baryons. The detector comprises four stations placed next to the target in vacuum. The stations will be populated with 50 μm thin, highly-granular dedicated Monolithic Active Pixel Sensors (called “MIMOSIS”), which are being developed aiming at a spatial precision in the order of ~ 5 μm, a readout speed of less than 5 μs/frame, a radiation tolerance of ~ 7×10^{13} n_{eq}/cm^2 and 5 MRad. This contribution will summarize the status of activities towards constructing the MVD, that involve in particular the commissioning and beam tests of the first full size sensor prototype MIMOSIS-1 carried out in partnership with IPHC-Strasbourg.

*This work has been supported by BMBF (05P19RFFC1), GSI, HFHF and CREMLINplus.

HK 28.2 Fri 14:30 H2

Test beam performance of a digital pixel calorimeter — •Tim Sebastian Rogoschinski — Institut für Kernphysik, Goethe-Universität Frankfurt

A prototype of a digital pixel electromagnetic calorimeter, EPICAL-2, has been designed and constructed. It consists of alternating W absorber and Si sensor layers, with a total thickness of 20 radiation lengths, an area of 30 mm × 30 mm, and 25 million pixels. The design is the next step in pixel calorimetry, building on and refining a previous prototype using MIMOSA sensors [1]. The new EPICAL-2 detector employs the ALPIDE sensors developed for the ALICE ITS upgrade. This R&D is performed in the context of the proposed Forward Calorimeter upgrade for ALICE, but it also serves the general understanding of a fully digital calorimeter. The Allpix2 framework [2] was used to perform MC simulations of the detector response and shower evolution in EPICAL-2. We will report on first results on calibration from cosmic muons and on the calorimeter performance measured with the DESY electron beam. The prototype shows good energy resolution and linearity, comparable with those of a SiW calorimeter with analog readout. Electron test beam results can be reproduced by simulation.

[1] JINST13 (2018) P01014
[2] NIM A901 (2018) 164-172

HK 28.3 Fri 14:45 H2

Simulation of collision fragments impinging the CBM-MVD* — •Hasan Darwish for the CBM-MVD-Collaboration — Goethe University Frankfurt am Main

The Micro Vertex Detector (MVD) of the CBM experiment will be located close to the target. Consequently, it will be exposed to a dense flux of charged particles from different origins. With respect to the radiation hardness of the sensor, one major question is whether the CMOS Monolithic Active Pixel Sensors of the MVD will be exposed to harmful impacts of nuclear fragments coming from the target, which can potentially lead to a significant damage. We present studies based on GEANT invoking two different models simulating the production of nuclear fragments from relativistic heavy ion collisions. The simulation results and their impact on the requirements for the MVD will be discussed.

*This work has been supported by BMBF (05P19RFFC1), GSI, HFHF and CREMLINplus.

HK 28.4 Fri 15:00 H2

First Observations from Mimosis-1 Single Event Upset Beam Tests.* — •Benedict Arnoldi-Meadows for the CBM-MVD-Collaboration — Goethe-Universität Frankfurt am Main

Mimosis-1 is the first full-sized prototype for the final cmos Monolithic Active Pixel Sensor to be used in the cbm Micro Vertex Detector (mvd). In the mvd, the sensors will be placed in close proximity to the beam and thus be exposed to ~ 1 kHz/cm^2 heavy ions from the beam halo. Moreover, in the event of a failing dipole, the beam will be displaced and may hit sensors.

Two beam tests with mimosis-1 were conducted to determine single event effects induced by ~ 1 A GeV heavy ions. First and preliminary results from the ongoing analysis of the tests will be presented.

*This work has been supported by bmbf (05P19RFFC1), gsi, cremlinplus and hfhf.

HK 28.5 Fri 15:15 H2

Radiation damage and annealing studies of $PbWO_4$ scintillation crystals for the $\overline{P}$ANDA-EMC — •Pavel Orsich[1], Valery Dormenev[1], Markus W. H. Moritz[1], Hans-Georg Zaunick[1], Kai-Thomas Brinkmann[1], and Mikhail Korjik[2] — [1]II. Physikalisches Institut, Justus-Liebig-Universität, Gießen — [2]Institute for Nuclear Problems, Minsk, Belarus

Lead tungstate scintillation crystals – PbWO 4 (PWO-II) – will be used in the Electromagnetic Calorimeter (EMC) of the high energy physics experiment $\overline{P}$ANDA at the high-luminosity accelerator facility FAIR (Darmstadt). During the operation of the experiment a degradation of the optical transmission of these crystals will occur due to creation of color centers via radiation damage and as a consequence this leads to the deterioration of the energy resolution of the calorimeter. In order to partially reverse this radiation damage the phenomenon of the stimulated recovery in scintillation crystals have been investigated via illumination by visible and infrared light.

A model of the radiation-induced absorption and its recovery in lead tungstate crystals will be presented. The mechanisms of the radiation damage under γ-radiation and the recovery under light will be discussed.

This work is supported by BMBF, GSI and HFHF.

HK 28.6 Fri 15:30 H2

Radiation dose simulation for FAIR phase-0 experiment at MAMI — •Alexander Greiner[1], Frank Maas[1,2,3], Oliver Noll[1], Sahra Wolff[1], Luigi Capozza[1], Julian Moik[1], David Rodriguez Pineiro[1], Samet Katilmis[1], Alaa Dbeyssi[1], Peter-Bernd Otte[1], and Dong Liu[1] for the PANDA-Collaboration — [1]Helmholtz-Institut Mainz, Germany — [2]Institute of Nuclear Physics, Johannes Gutenberg University, Mainz, Germany — [3]PRISMA Cluster of Excellence, Mainz, Germany

A complex detector system is being developed for the PANDA experiment at the FAIR accelerator facility in Darmstadt.

The group in Mainz is constructing the backward end cap (BWEC) of the PANDA electromagnetic calorimeter, which will be used at the MAMI electron accelerator for a FAIR/Phase0 experiment at Mainz to measure the electromagnetic transition form factor of the $\pi^0 \to \gamma\gamma$ transition.

In order to check whether the planned set-up of the BWEC can withstand the radiation exposure of the experiment without impairing the data acquisition through malfunctions, GEANT4 simulations of the experimental setup were carried out to record the radiation exposure of the entire experimental setup and individual important components.

This presentation will explain how the simulations were carried out. We will present the results of the estimated radiation exposure and compare these estimates with various radiation resistance measurements of some components from the R&D phase.

HK 29: Hadron Structure and Spectroscopy VI

Time: Friday 14:00–16:00 Location: H3

Group Report HK 29.1 Fri 14:00 H3

The scalar glueball from radiative J/psi decays — •Eberhard Klempt[1], Igor Denisenko[2], Andrey Sarantsev[3], and Ulrike Thoma[1] — [1]Hiskp, Universität Bonn — [2]Jinr, Dubna — [3]Pnpi, Gatchina

Evidence for the scalar glueball is reported. The evidence stems from an analysis of BESIII data on radiative J/Ψ data into $\pi 0\pi 0$, KsKs, $\eta\eta$, and $\Phi\omega$. The coupled-channel analysis is contrained by a large number of further data. The data are described by ten scalar isoscalar mesons, covering the range from f0(500) to f0(2330). Five resonances are interpreted as mainly-singlet states in SU(3), five as mainly-octet states. The mainly-singlet resonances are produced over the full mass range, the production of octet state is limited to the 1500 to 2100 MeV mass range. The peak is interpreted as scalar glueball. Its mass, width and yield are determined.

HK 29.2 Fri 14:30 H3

Reconstruction of complex decay channels using genetic algorithm — •Áron Kripkó, Markus Moritz, and Kai-Thomas Brinkmann for the PANDA-Collaboration — II. Physikalisches Institut, Justus Liebig Universität Gießen, 35392 Gießen, Germany

A common problem in the topic of hadron spectroscopy is the reconstruction of complex decay channels. During the procedure cuts are applied to the properties of the reconstructed candidates along the decay tree with the aim of maximizing the significance. In case of complex decay channels, finding the optimal set of cuts is not obvious.

The application of genetic algorithm to this problem was investigated in PANDARoot. Genetic algorithm is an optimization algorithm inspired by the process of natural selection. PANDARoot is the common simulation framework for feasibility studies of the PANDA experiment.

The talk will present the reconstruction for complex decay channels with 9 final state particles for a predicted hybrid charmonium state ($\tilde{\eta}_{c1}$) with $J^{PC} = 1^{-+}$ using genetic algorithm.

This work is supported by GSI, HFHF and BMBF.

HK 29.3 Fri 14:45 H3

Investigation of the decays $\chi_{cJ} \rightarrow \eta'\pi^+\pi^-$ and search for the spin exotic meson π_1(1600) at BESIII — •Frederik Weidner[1], Nienke Balz[1], Helge Balzen[1], Johannes Bloms[1], Anja Brüggemann[1], Christopher Fritzsch[1], Titus Heinig[1], Nils Hüsken[2], Sascha Lennartz[1], and Alfons Khoukaz[1] — [1]Westfälische Wilhelms-Universität, Münster, Germany — [2]Indiana University, Bloomington, USA

In recent years the search for exotic hadrons has produced more and more states which seem to be incompatible with the conventional classification as a two or three quark state. However, in most of these cases the classification of these particles is inconclusive. An interesting opportunity is given by states with quantum numbers which cannot be produced by the conventional quark model, such as $J^{PC} = 1^{-+}$ in case of the $\pi_1(1600)$, which was seen in multiple experiments.
With the BESIII experiment decays of the χ_{cJ} mesons can be investigated through their production in the radiative decays of the $\psi(2S)$ meson. Here, a large number of events has been recorded by the BESIII detector and additional data taking is ongoing. When considering the decay of these charmonia into three pseudoscalar mesons spin exotic quantum numbers like $J^{PC} = 1^{-+}$ can be accessed. In this talk the current status of the search for the $\pi_1(1600)$ in the decay $\chi_{c2} \rightarrow \eta'\pi^+\pi^-$ by the means of a partial wave analysis will be presented.
This work is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - 269952272, 271236083 and 443159800.

HK 29.4 Fri 15:00 H3

Determination of the branching ratio of $\eta_c \rightarrow \eta' K^+K^-$ and search for exotic content in K^+K^- intermediate states at BESIII — •Anja Brüggemann[1], Nienke Balz[1], Helge Balzen[1], Johannes Bloms[1], Christopher Fritzsch[1], Titus Heinig[1], Nils Hüsken[2], Sascha Lennartz[1], Frederik Weidner[1], and Alfons Khoukaz[1] for the BESIII-Collaboration — [1]Westfälische Wilhelms-Universität Münster, Germany — [2]Indiana University Bloomington, USA

The BESIII detector at the e^+e^- collider BEPCII in Beijing, China, provides the world's largest data sample of the charmonium J/ψ with 10 billion events taken from 2009 to 2019.

We analyse the reaction $\eta_c \rightarrow \eta' K^+K^-$ that results from the radiative J/ψ decay to $\gamma\eta_c$. Until now this η_c decay is still unlisted in the particle data group database. We determine the corresponding branching ratio. Furthermore, it is a common approach to search for exotic states in gluon-rich environments of decaying mesons, like the decaying η_c charmonium into hadrons. Thus, our analysis of $\eta_c \rightarrow \eta' K^+K^-$ further offers the opportunity to investigate possible exotic content within intermediate states decaying to K^+K^-, that lie in the mass region below 2 GeV$/c^2$, where the lightest glueball is predicted.

Our study is based on a partial wave analysis, which gives access to the partial decay widths of contributing K^+K^- resonances. These widths are directly comparable to theory predictions.

The current status of the analysis will be presented.

This work is funded by DFG - 269952272, 271236083 and 443159800.

HK 29.5 Fri 15:15 H3

Analysis of Light Isovector Resonances in the Diffractively Produced $\pi^-\pi^-\pi^+$ Final State at COMPASS — •Florian Kaspar for the COMPASS-Collaboration — Technische Universität München, Garching bei München, Deutschland

The COMPASS experiment at CERN can help us to better understand the excitation spectrum of light-quark meson resonances, which consist of up, down, or strange quarks. COMPASS collected a world-leading sample of diffractively produced $\pi^-\pi^-\pi^+$ events. We present our improved analysis of the isovector resonances accessible in this data, where we studied in particular systematic effects in the partial-wave analysis of this final state. In addition, we will discuss our new results focusing on the $J^{PC} = 0^{-+}$ sector that contains the $\pi(1800)$ resonance.

HK 29.6 Fri 15:30 H3

Model Dependence of the $\pi_1(1600)$ signal — •Fabian Krinner — Max Planck Institut für Physik, München, Deutschland

The COMPASS experiment has collected a large data set for diffractive $\pi^-\pi^+\pi^-$ production. We use this data set to investigate contradictions found by previous partial-wave analyses of the same channel for the signal of a spin-exotic partial wave with spin, parity and charge conjugation quantum numbers 1^{-+}. We find a strong dependence of the signal for this wave on the used analysis model to cause the observed contradictions. We construct a large analysis model tuned to minimize such model-dependencies and study the robustness of this model with the freed-isobar partial-wave analysis method.

HK 29.7 Fri 15:45 H3

Fit of the $a_1(1420)$ as a triangle singularity — •Mathias Wagner and Bernhard Ketzer — HISKP, Uni Bonn, Germany

In the recent past several new particle candidates were found which do not fit into the simple constituent-quark models for mesons and baryons. Different concepts were introduced in order to find an explanation for these exotic states. One of them is a rescattering effect. Here, triangle diagrams can produce resonance-like signals, both in the intensity and the relative phase of the corresponding partial wave.

One prominent example is the $a_1(1420)$ signal, observed by the COMPASS experiment in the $J^{PC} = 1^{++}$ partial wave decaying to $f_0(980)\pi$ in a P-wave.

We present the fit results of the finalized model, where we properly include all involved spins via a dispersive integral over a partial wave projection of the $K\bar{K}\pi$ final state onto the 3π final state. It shows that the $a_1(1420)$ can be fully explained by the decay of the ground-state $a_1(1260)$ into $K^*\bar{K}$ and subsequent rescattering through a triangle singularity into the observed final state $f_0(980)\pi$ without the need of a new genuine a_1 resonance. The effect of the triangle singularity, which is expected to be present, is sufficient to explain the observation. (accepted PRL)

HK 30: Structure and Dynamics of Nuclei II

Time: Friday 14:00–16:30 Location: H4

Group Report HK 30.1 Fri 14:00 H4

Studying the Low-Energy Electric Dipole Response of Different Nuclei with SONIC@HORUS — •Michael Weinert, Florian Kluwig, Miriam Müscher, Julius Wilhelmy, Barbara Wasilewska, and Andreas Zilges — University of Cologne, Institute for Nuclear Physics, 50937 Cologne, Germany

The specific structures that generate the low-energy electric dipole response (LEDR) in medium to heavy mass nuclei have been highly debated and investigated over the past two decades. Deeper knowledge was obtained by comparing direct measurements of the nuclear photo-response in real-photon scattering experiments with the response to other probes, such as alpha particles or high energy protons, and trying to reproduce the differing responses with theoretical models. This contribution will present the recent developments in Cologne, where specific single-particle structures in the LEDR of ^{120}Sn could be studied in a $(d, p\gamma)$ reaction at E_d=8.5 MeV using the SONIC@HORUS setup, extending the established capabilities of the transfer reaction [1]. Also, for the first time, a consistent theoretical approach was developed to predict the shape of the LEDR, and also the excitation and decay behavior in the experiment. A comparison to ^{120}Sn$(\alpha, \alpha'\gamma)$ under forward angles will be drawn and results from ^{124}Sn$(p, p'\gamma)$ [2] and a recent ^{40,44,48}Ca$(p, p'\gamma)$ campaign with SONIC@HORUS will be presented.

[1] M. Spieker, *et al.*, Phys. Rev. Lett. **125**, 102503 (2020)
[2] M. Färber, *et al.*, Eur. Phys. J. A (2021) 57:191

Group Report HK 30.2 Fri 14:30 H4

Study of the dipole response in ^{58}Ni — •Isabelle Brandherm[1], Johann Isaak[1], Peter von Neumann-Cosel[1], Hiroaki Matsubara[2], Achim Richter[1], Marcus Scheck[3], Jaqueline Sinclair[3], and Atsushi Tamii[2] — [1]IKP, TU Darmstadt, Germany — [2]RCNP, Osaka, Japan — [3]UWS, Paisley, UK

Inelastic proton scattering at very forward angles is an excellent tool for studying the dipole response in nuclei [1]. Reactions with intermediate proton energies and scattering angles close to 0° are particularly suited to investigate the isovector spin-flip M1 resonance. In addition the electric dipole response can be measured over a wide excitation energy range. This provides information about the electric dipole polarizability which is related to the neutron-skin thickness and the density dependence of the symmetry energy. In this talk the analysis of an experiment with a 295 MeV proton beam on a ^{58}Ni target will be presented, which was performed at the Research Centre for Nuclear Physics (RCNP) in Osaka. The dipole strength distribution of ^{58}Ni has been extensively measured with nuclear resonance fluorescence [2,3] and inelastic electron scattering [4]. A comparison of the different methods can shed light on various features of nuclear structure such as spin and orbital contributions to the magnetic dipole strength.

[1] P. von Neumann-Cosel and A. Tamii, Eur. Phys. J. A 55, 110 (2019). [2] M. Scheck et al., Phys. Rev. C 88, 044304 (2013). [3] J. Sinclair, priv. com. (2019). [4] W. Mettner et al., Nucl. Phys. A473, 160 (1987). Supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 279384907, SFB 1245.

HK 30.3 Fri 15:00 H4

Status report on the progress on the analysis of the NewSUBARU data — •Nikolina Lalić[1], Thomas Aumann[1,2], Takashi Ariizumi[3], Martin Baumann[1], Patrick van Beek[1], Ioana Gheorghe[4], Philipp Kuchenbrod[1], Heiko Scheit[1], Dmytro Symochko[5], and Hiroaki Utsunomiya[3] — [1]TU Darmstadt, Germany — [2]GSI Helmholtzzentrum, Germany — [3]Department of Physics, Konan University, Japan — [4]"Horia Hulubei" National Insitute for R & D in Physics and Nuclear Engineering (IFIN-HH), 30, Reactorului 077125, Bucharest-Magurele, Romania — [5]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

The photoneutron cross sections of ^{112}Sn, ^{116}Sn, ^{120}Sn and ^{124}Sn were measured in (γ, xn) reactions, where $x \in [1, 4]$, using a quasi-monochromatic laser Compton-scattering γ-ray beam at the NewSUBARU facility. The goal of the experiment is to resolve the long-standing discrepancy of the total and partial cross sections measured by the Livermore and the Saclay groups. Measurements were done with γ energies from 8 MeV to 38 MeV. As a neutron counter a detector with a flat efficiency was used to take advantage of the direct neutron*multiplicity sorting technique. The (γ, xn) cross sections $x \in [1, 4]$ will be determined as well as the total photo absorption cross sections.

In this report the experiment and the current state of the ongoing analysis will be presented.

Suported by HMWK (LOEWE centre "Nuclear Photonics") and DFG (SFB 1245).

HK 30.4 Fri 15:15 H4

Collinear laser spectroscopy across the ^{56}Ni doubly magic nucleus — •Sommer Felix[1], König Kristian[2], Rossi Dominic[1], Everett Nathan[2], Garand David[2], de Groote Ruben[3], Incorvati Anthony[2], Imgram Phillip[1], Kalman Colton[2], Klose Andrew[5], Lantis Jeremy[2], Liu Yuan[4], Miller Andrew[2], Minamisono Kei[2], Nörtershäuser Wilfried[1], Pineda Skyy[2], Powel Robert[2], Renth Laura[1], Romero-Romero Elisa[4], Sumithrarachchi Chandana[2], and Teigelhöfer Andrea[6] — [1]Technische Universität Darmstadt — [2]Michigan State University — [3]University of Jyväskylä — [4]Oak Ridge National Laboratory — [5]Augustana University — [6]TRIUMF

We will present laser spectroscopic measurements of neutron-deficient nickel isotopes at and across the N=28 neutron shell closure. Nickel is a particularly interesting case to study nuclear shell evolution. Its isotopic chain includes the N=Z=28 doubly magic nucleus ^{56}Ni, which is the first self-conjugated doubly magic nucleus that occurs due to a shell gap driven by the spin-orbit force and is considered to be a soft core. Using the BECOLA facility at the National Superconducting Cyclotron Laboratory at Michigan State University, we achieved the first determination of the mean-square charge radii of ^{54}Ni, ^{55}Ni, and ^{56}Ni as well as an updated value of the magnetic dipole moment of ^{55}Ni. Details of the experiment and results will be discussed.

HK 30.5 Fri 15:30 H4

Mass measurements of neutron-deficient Yb isotopes and nuclear structure at the extreme proton-rich side of the N = 82 shell — •Beck Sönke[1,2], Kootte Brian[3,4], and Dedes Irene[5,6] for the TITAN-Collaboration — [1]Justus-Liebig Universität, Giessen — [2]GSI, Darmstadt — [3]TRIUMF, Vancouver, Canada — [4]University of Manitoba, Winnipeg, Canada — [5]Polish Academy of Sciences, Kraków, Poland — [6]Marie Curie-Skłodowska University, Lublin, Poland

The nuclear mass reflects the binding energy of a nucleus and provides key information for nuclear structure, nuclear reactions and related fields like nuclear astrophysics.

High-accuracy mass measurements of neutron-deficient Yb isotopes were performed at TRIUMF using TITAN's multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS). For the first time, the novel technique of mass selective re-trapping was used in an on-line experiment with short-lived ions. With this technique, the MR-TOF-MS can act as its own isobar separator, enabling measurements two isotopes further away from stability.

The ground state masses of ^{150,153}Yb and the excitation energy of the long lived $J^{\pi} = 11/2^{-}$ isomer ^{151}Yb^{m} were measured for the first time. As a result, the persistence of the $N = 82$ shell with almost unmodified shell gap energies was established up to the proton dripline. Furthermore, the puzzling systematics of the $h_{11/2}$-excited isomeric states of the $N = 81$ isotones were unraveled using state-of-the-art mean field calculations.

HK 30.6 Fri 15:45 H4

Mass measurements and spectroscopy of actinides at IGISOL and FRS Ion Catcher — •Ilkka Pohjalainen for the FRS Ion Catcher-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

There is a significant lack of experimental data on fundamental nuclear properties such as nuclear masses of actinides. At the IGISOL facility of the University of Jyväskylä, Finland, light-ion fusion reactions with actinide targets provide unique possibilities to perform decay- and optical spectroscopy as well as direct mass measurements of actinide isotopes. Recently, decay spectroscopy of several short-lived isotopes including ^{225,226}Pa have been performed with protons (up to 65 MeV) on ^{232}Th targets. Penning trap mass spectrometry utilizing the Phase-Imaging Ion Cyclotron Resonance method at JYFLTRAP is to be used for high-precision mass measurements, but also to obtain production yield of long-lived isotopes such as ^{229}Th, which is of special interest due to the extremely low energy isomer. A wider range of isotopes is now also available due to more exotic targets fabricated via a novel drop-on-demand printing technique at the Nuclear Chemistry Institute of Johannes Gutenberg-Universität of Mainz.

In addition, the recently performed mass measurements in the actinide region at the FRS Ion Catcher (FRSIC) at the Fragment Separator at GSI will be presented. By impinging a 1 GeVA ^{238}U beam on a Be target, the isotopes are produced in fragmentation reactions. The ions are stopped in the cryogenic stopping cell and measured with the high resolution multiple-reflection time-of-flight mass spectrometer.

HK 30.7 Fri 16:00 H4

High-precision mass spectrometry of heavy and superheavy nuclides at SHIPTRAP: overview of the latest experiments — •Francesca Giacoppo for the SHIPTRAP-Collaboration — GSI Darmstadt, Germany — HIM Mainz, Germany

In 2018 high-precision Penning Trap Mass Spectrometry (PTMS) crossed the doorway towards the region of superheavy elements (Z≥104) with the first direct mass measurement of the ground state of ^{257}Rf accomplished with a small number of detected ions (<10) with the SHIPTRAP setup. This was made possible by the first application of the highly efficient Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique in the region of the heaviest nuclides. In addition, exploiting the superior mass resolving power and precision of PI-ICR, several low-lying isomeric states in elements with $Z = 102 - 103$ have been probed with high accuracy. These results have been achieved thanks to careful investigations and improvements of the efficiency of the SHIPTRAP setup. In an online run in 2020, the rate of ^{257}Rf extracted from the cryogenic gas cell was increased by about an order of magnitude. This boost allowed in the latest campaign in spring 2021 to carefully investigate both the ground state and the low-lying isomer of ^{257}Rf and the more exotic element dubnium with Z=105, available at even lower yields. The PI-ICR technique, established nowadays as a complementary tool to decay spectroscopy, was also applied to disentangle many isomeric states in heavy nuclei with $Z = 82 - 98$. In this contribution, the results of the latest campaigns performed within the FAIR Phase-0 program will be reviewed.

HK 30.8 Fri 16:15 H4

Subatomic particles represented as focal points — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

Examples of approaches to represent subatomic particles (SPs) are point-like, strings, wave-packets, etc. The present work is based on an approach where (SPs) are represented as focal points of rays of Fundamental Particles (FPs) that move from infinite to infinite. FPs are emitted from the focal point and at the same time regenerate it. FPs store the energy of a SP as rotation defining angular momenta. Interactions between SPs are the product of the interactions of the angular momenta of their FPs. One important finding is that the interaction between two charged SPs tends to zero for the distance between them tending to zero. Atomic nuclei can thus be represented as swarms of electrons and positrons that neither attract nor repel each other. As atomic nuclei are composed of nucleons which are composed of quarks, the quarks can also be seen as swarms of electrons and positrons. The charge quantum number Q of a quark is now interpreted as the relative charge of electrons and positrons. No fractional charges Q are required and the charge of an electron or positron is thus the unit charge of nature. Another important finding is that all four forces are electromagnetic forces and described by QED. As quantum-mechanics rely heavily on classical physics, all new findings of the latter have repercussions on the former. More at: www.odomann.com

Short Time-scale Physics and Applied Laser Physics Division
Fachverband Kurzzeit- und angewandte Laserphysik (K)

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Overview of Invited Talks and Sessions

(Lecture hall H2)

Plenary Talk of the Short Time-scale Physics and Applied Laser Physics Division

PV VII	Thu	9:00– 9:45	Audimax	**Direct high-efficiency generation of the third harmonic wavelength in interference layer systems** — •Marco Jupe, Detlev Ristau, Wolfgang Rudolph

Invited Talks

K 1.1	Thu	11:00–11:45	H2	**Information als Basis physikalischer Gesetze, basiert Gravitation auf der Information von Abständen?** — •Rudolf Germer

Sessions

K 1.1–1.3	Thu	11:00–12:15	H2	**New Methods - Applications**
K 2.1–2.4	Thu	14:00–15:00	H2	**Light Sources and Diagnostics**
K 3	Thu	15:00–15:30	H2	**Annual General Meeting**

Annual General Meeting of the Short Time-scale Physics and Applied Laser Physics Division

Thursday 15:00–15:30 after Session 2 MVK

- Bericht
- Verschiedenes

Sessions

– Invited and Contributed Talks –

K 1: New Methods - Applications

Time: Thursday 11:00–12:15 Location: H2

Invited Talk K 1.1 Thu 11:00 H2

Information als Basis physikalischer Gesetze, basiert Gravitation auf der Information von Abständen? — •Rudolf Germer — ITPe.V. — TU-Berlin

Mit Messungen und Theorie gelingt es, die materielle Welt physikalisch zu beschreiben. Dabei treten Wirkungen als Folge von Ursachen auf, aber es gibt auch Bereiche, in denen der Zufall dominiert und teilweise existieren gequantelte Struk-turen. Ein Blick in Richtung kleinster Informationseinheiten zeigt, daß es lokale "atomistische" Erscheinungen gibt, aber auch Information, die erst großen Gruppen zugeordnet werden kann. Bei kleinen Informationsmengen begegnet uns das Wirkungsquantum h als eine abzählbare Größe. Ein Photon, das Information transportiert, liefert in Zeit und Raum eine Genauigkeit, die durch Frequenz und Wellenlänge bestimmt ist. Die Energie korreliert dabei mit der Informationsmenge, viele interferierende Photonen können die gleiche Information liefern wie wenige höherenergetische. Beispiele zeigen, wie der Beobachter selektiert und interpretiert. Die Energie im Gravitationsgesetz zeigt den gleichen räumlichen 1/r Zusammenhang wie das Coulombgesetz oder die Energie eines Photons. Wenn man dies als Information über Abstände von Massen interpretiert, gelangt man zu der Hypothese, daß Basis der Gravitationskonstante die räumliche Verteilung der Massen im Universum ist.

K 1.2 Thu 11:45 H2

Identifying metastatic melanoma early: A novel approach with pump-probe microscopy — •David Grass[1], Martin Fischer[1,2], and Warren Warren[1,2,3,4] — [1]Department of Chemistry, Duke University, USA — [2]Department of Physics, Duke University, USA — [3]Department of Radiology, Duke University, USA — [4]Department of Biomedical Engineering, Duke University, USA

More people die from melanoma after a Stage I diagnosis (local melanoma) than after a Stage IV diagnosis (distant metastatic disease), because the tools available to clinicians do not identify which early-stage cancers will be aggressive. We pursuit an alternative approach, complementary to conventional histopathology, based on femtosecond pump-probe microscopy. The nonlinear optical interactions reveal the ultrafast electronic and vibrational dynamics of the tumor intrinsic pigment melanin, that correlate with metastatic disease. Visualization of these changes in melanin and model development are the first steps for new diagnostic and prognostic biomarkers such that the patient can be treated to interrupt disease progression.

K 1.3 Thu 12:00 H2

Anti-Stokes laser cooling of ytterbium-doped fluorite-structure crystals — Felix Mauerhoff, Stefan Püschel, Christian Kränkel, and •Hiroki Tanaka — Leibniz-Institut für Kristallzüchtung, Berlin, Germany

We report the first laser cooling of ytterbium (Yb^{3+})-doped fluorite-structure crystals by antiStokes fluorescence. High quality Yb^{3+}(5 at.%):CaF_2 and Yb^{3+}(5 at.%):SrF_2 single crystals were grown by the Czochralski method. Room temperature fluorescence spectroscopy revealed the mean fluorescence wavelengths to be 997.2 nm and 994.6 nm for Yb:CaF and Yb:SrF, respectively. We characterized the crystals by laser-induced temperature modulation spectroscopy (LITMoS) in a vacuum chamber. All-side polished parallelepiped-shaped samples of both crystal were excited by wavelength-tunable laser sources: a Ti:sapphire laser and a home-built Yb^{3+} : Lu_2O_3 thin-disk laser. The temperature of the samples was measured with a thermal camera through an anti-reflection coated germanium window. The Yb:CaF and Yb:SrF samples exhibited cooling down by 6.6 K and 3.9 K from room temperature under excitation at 1040 nm at few 100 mW of absorbed power. The evaluation of the external quantum efficiency, background absorption coefficient, and the expected minimum achievable temperature will be reported at the conference.

K 2: Light Sources and Diagnostics

Time: Thursday 14:00–15:00 Location: H2

K 2.1 Thu 14:00 H2

Dual channel, high repetition rate OPCPA at 800 nm and 2 μm with stable CEP — •Ekaterina Zapolnova[1], Thomas Braatz[1], Sebastian Starosielec[1], Torsten Golz[1], Jan Heye Buss[1], Michael Schulz[1], Robert Riedel[1], and Mark J. Prandolini[1,2] — [1]Class 5 Photonics GmbH, Notkestraße 85, 22607 Hamburg, Germany — [2]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

For attosecond technology, carrier envelope phase (CEP) stabilization in the few-cycle regime combined with high repetition rates is essential for studying ultrafast electronic processes in atoms, molecules, solids, and complex many body systems. Therefore, a laser system was designed, where the laser pulses are generated from a single white-light-generation (WLG) source operating at 1 MHz, provding dual simultaneous CEP stable pulses at 2 μm and 800 nm with pulse duations of <40 fs and <10 fs, and pulse energies of 1 μJ and 1.2 μJ, respectively. The system is robust and compact, with a footprint of less than a square meter.

K 2.2 Thu 14:15 H2

Modeling of ultrafast X-ray induced demagnetization in magnetic multilayer systems — •Beata Ziaja-Motyka — CFEL, DESY, Notkestrasse 85,22607 Hamburg,Germany — INP PAN, Radzikowskiego 152, 31-342 Krakow, Poland

Here we report on the results obtained with the modeling tool, XSPIN constructed to describe ultrafast demagnetization induced by X-ray free-electron laser radiation in ferromagnetic materials. The tool enables nanoscopic description of the predominant processes occurring in the X-ray irradiated magnetic material. With this model, we have studied the evolution of magnetic multilayer systems previously investigated experimentally with magnetic small angle X-ray scattering technique: (i) Co/Pt multilayer at the M-edge of Co (photon energy of 60 eV), and (ii) Co/Pd multilayer system at the L-edge of Co (photon energy of 778 eV). Our results show that the magnetic scattering signal decreases with time as the result of its progressing demagnetization due to electronic excitation and relaxation processes both in the cobalt and in platinum/palladium layers. The decrease becomes stronger with the increasing fluence of the incoming radiation, following accurately the trends observed in the experimental data.

K 2.3 Thu 14:30 H2

Hybride Modenkopplung in einem Thulium-dotierten Mamyshev Faseroszillator — •Veronika Adolfs[1], Benedikt Schuhbauer[1], Andreas Wienke[1,2], Jörg Neumann[1,2] und Dietmar Kracht[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Deutschland — [2]Exzellenzcluster PhoenixD (Photonics, Optics, and Engineering Innovation Across Disciplines), Hannover, Deutschland

Ultrakurzpulslaser im Wellenlängenbereich um 2 μm haben in den letzten Jahren stark an Relevanz gewonnen. Sie finden mittlerweile häufig Anwendung in der direkten Materialbearbeitung oder in der Spektroskopie. Der Mamyshev Oszillator (MO) erlaubt hierbei die Erzeugung hoher Pulsenergien direkt in einem Oszillator. Dabei wird die spektrale Verbreiterung durch Selbstphasenmodulation und eine alternierende spektrale Filterung durch Bandpassfilter (BPF) zur Modenkopplung eingesetzt. Hier stellen wir erstmalig einen selbststartenden hybrid modengekoppelten MO bei 2 μm vor. Der Selbststartmechanismus wurde durch die nichtlineare Polarisationsdrehung bei überlappenden BPF und darauffolgender Separation der Filter ermöglicht. Mit diesem MO wurde eine Pulsenergie von 1,6 nJ bei einer Repetitionsrate von 16,55 MHz erreicht. Das optische Ausgangsspektrum hatte eine Halbwertsbreite von 35,5 nm. Die unkomprimierten Pulse des Oszillators konnten mit einem Gitterkompressor von 4,5 ps auf 360 fs komprimiert werden. Zur weiteren Skalierung der Pulsenergie wird derzeit im zweiten Arm des MO als reines Verstärkersystem ein Mantelpumpkonzept erprobt und dabei Pulsenergien bis zu 30 nJ erreicht.

K 2.4 Thu 14:45 H2

Near-field spectrally resolved phase diagnostics of intense ultrashort laser pulses — •Sergej Poplavski, Bastian Hagmeister, Sebastian Tesch, and Georg Pretzler — Heinrich-Heine-Universität, Düsseldorf

Ultrashort laser pulses can generate ultrahigh intensities by concentrating moderate amounts of energy into tiny temporal and spatial intervals. This is achieved by subtle dispersion management for the temporal domain and by high-quality focusing in the spatial domain. However, spatial and spectral phase imperfections of such a laser pulse may lead to spatio-temporal aberrations in the focus, which might significantly reduce the anticipated intensities and are difficult to detect directly.

We present a novel spectrally resolved wavefront diagnostic which is intrinsically quasi-self-referencing. This device can be employed for obtaining a complete description of the laser pulse's spatial and temporal distribution in the near field. No calibration procedure is needed for investigating the different spectral components of an ultrashort laser pulse.

We present the concept of the setup in this poster and demonstrate a proof-of-principle measurement with spectral resolution.

K 3: Annual General Meeting

Time: Thursday 15:00–15:30 Location: H2

Annual General Meeting

Theoretical and Mathematical Physics Division
Fachverband Theoretische und Mathematische Grundlagen der Physik (MP)

Johanna Erdmenger
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Includes classical and quantum field theory, curved spacetime and entropy, equilibrium and non-equilibrium systems, complexity and quantum information theory. Presents progress in methods and concepts, model studies and structure analysis.

Overview of Invited Talks and Sessions

(Lecture halls H3, H6, and H7; Poster P)

Invited Talks

MP 2.1	Tue	11:00–11:40	H7	**KPZ universality in mathematics and physics** — •Patrik Ferrari
MP 3.1	Tue	11:45–12:25	H7	**Path integral based non-equilibrium quantum field theory of non-relativistic pairs inside an environment** — •Tobias Binder
MP 7.1	Tue	17:00–17:40	H7	**Stochastic Dynamics in Quantum Mechanics** — •Denis Bernard
MP 13.1	Thu	11:00–11:40	H6	**Exact solution of the scalar QFT Φ^4 model on the 4-dimensional noncommutative Moyal space** — •Alexander Hock
MP 14.1	Thu	11:45–12:25	H6	**Temperature and entropy-area relation of quantum matter near spherically symmetric outer trapping horizons** — •Rainer Verch

Invited talks of the joint symposium Entanglement (SYEN)

See SYEN for the full program of the symposium.

SYEN 1.1	Mon	16:30–17:10	Audimax	**Squeezed and entangled light - now exploited by all gravita-tional-wave observatories** — •Roman Schnabel
SYEN 2.1	Mon	17:10–17:50	Audimax	**Entanglement and Explanation** — •Chris Timpson
SYEN 3.1	Mon	17:50–18:30	Audimax	**Entanglement and complexity in quantum many-body dynamics** — •Tomaz Prosen

Sessions

MP 1.1–1.3	Mon	11:00–12:15	H3	**AdS-CFT I**
MP 2.1–2.1	Tue	11:00–11:40	H7	**HV 1: Stochastic Non-Equilibrium**
MP 3.1–3.1	Tue	11:45–12:25	H7	**HV 2: Non-Equilibrium Quantum Field Theory**
MP 4.1–4.2	Tue	14:00–14:50	H7	**AdS-CFT II**
MP 5.1–5.2	Tue	15:00–15:50	H7	**Loop Quantum Gravity**
MP 6.1–6.1	Tue	16:30–16:55	H7	**Quantum Statistical Mechanics**
MP 7.1–7.1	Tue	17:00–17:40	H7	**HV 3: Stochastic Quantum Mechanics**
MP 8.1–8.1	Tue	17:45–18:10	H7	**Non-equilibrium Statistical Mechanics**
MP 9.1–9.2	Wed	14:00–14:50	H7	**Anomalies in Quantum Field Theory**
MP 10.1–10.2	Wed	15:00–15:50	H7	**Nonrelativistic Quantum Field Theory**
MP 11.1–11.3	Wed	16:30–17:45	H7	**Quantum Information**
MP 12.1–12.1	Wed	17:50–18:15	H7	**Quantum Mechanics**
MP 13.1–13.1	Thu	11:00–11:40	H6	**HV 4: Quantum Field Theory in Noncommutative Spacetime**
MP 14.1–14.1	Thu	11:45–12:25	H6	**HV 5: Quantum Field Theory near Black Hole Horizons**
MP 15.1–15.2	Thu	14:00–14:50	H6	**Quantum Field Theory: Renormalization**
MP 16.1–16.2	Thu	15:00–15:50	H6	**Strongly Interacting Quantum Field Theory**
MP 17.1–17.4	Thu	16:30–18:10	H6	**Entropy in Quantum Field Theory**
MP 18.1–18.3	Fri	11:00–12:15	H6	**Constructive Tools for Quantum Field Theory**
MP 19.1–19.2	Fri	14:00–14:50	H6	**Fundamental Ideas**
MP 20.1–20.1	Mon	10:30–11:00	P	**Poster (permanent)**

Sessions

– Invited Talks, Contributed Talks, and Posters –

MP 1: AdS-CFT I

Time: Monday 11:00–12:15 Location: H3

MP 1.1 Mon 11:00 H3

Geometry of Complexity in Conformal Field Theory — •Mario Flory[1] and Michał Heller[2] — [1]Instituto de Física Téorica IFT-UAM/CSIC, Universidad Autonoma de Madrid, 28049, Madrid, Spain — [2]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), 14476 Potsdam-Golm, Germany

We utilize the Fubini-Study metric in order to define a notion of distance and hence circuit complexity on the Virasoro group. The resulting problem is mathematically equivalent to geodesic motion in infinite dimensions, with integro-differential equations of motion. We discuss the properties of these equations and of their solutions.

MP 1.2 Mon 11:25 H3

Realizing Computational Complexity in Conformal Field Theory — Johanna Erdmenger, Marius Gerbershagen, and •Anna-Lena Weigel — Julius-Maximilians-Universität Würzburg, 97074 Würzburg, Germany

An important question for the AdS/CFT correspondence is how the bulk geometry is encoded in the boundary field theory. A useful quantity proposed in this context is computational complexity. This is a concept adapted from quantum information that counts the minimum number of simple steps, gates, necessary to perform a calculation. While there exist concrete proposals for complexity in the AdS gravity theory, it remains an open question how to define it in a CFT. To make progress in this direction, a recent proposal suggests to restrict the allowed set of gates to symmetry transformations. This was employed to compute complexity for conformal transformations in 2d CFTs [1]. We generalize this approach to Kac-Moody symmetries and show that the complexity is equal to actions defined on coadjoint orbits of the according symmetry group. In this way, we calculate the complexity for several examples of CFTs [2]. The coadjoint orbit actions also arise from 3d gravity theory. We comment on connections between these gravity actions and complexity.

[1] P. Caputa, J. Magan. "Quantum Computation as Gravity". In: Phys. Rev. Lett. 122 (2019), p. 231302. arXiv:1807.04422 [hep-th].

[2] J. Erdmenger, M. Gerbershagen, A. Weigel. "Complexity measures from geometric actions on Virasoro and Kac-Moody orbits". In: JHEP 11 (2020) 003. arXiv:2004.03619 [hep-th].

MP 1.3 Mon 11:50 H3

Complexity as a holographic probe of strong cosmic censorship — Mohsen Alishahiha[1], •Souvik Banerjee[2], Joshua Kames-King[3,4], and Emma Loos[2] — [1]School of Physics, Institute for Research in Fundamental Sciences (IPM), Tehran, Iran — [2]Institut für Theoretische Physik und Astrophysik, Julius-Maximilians-Universität Würzburg, Würzburg, Germany — [3]Bethe Center for Theoretical Physics and Physikalisches Institut der Universitaet Bonn, Bonn, Germany — [4]Kavli Institute for Theoretical Physics, University of California, Santa Barbara, USA

Based on reasonable assumptions, we propose a new expression for Lloyd's bound, which confines the complexity growth of charged black holes. We then compute the holographic complexity for charged black branes in the presence of a finite cutoff using complexity = action proposal. Using the proposed Lloyd's bound, we find a relation between the ultraviolet and the behind the horizon cutoffs. This relation is found to be consistent with the factorization of the partition function at leading order in large N. We argue that the result may be thought of as a holographic realization of strong cosmic censorship.

MP 2: HV 1: Stochastic Non-Equilibrium

Time: Tuesday 11:00–11:40 Location: H7

Invited Talk MP 2.1 Tue 11:00 H7

KPZ universality in mathematics and physics — •Patrik Ferrari — Bonn University

I will describe the Kardar-Parisi-Zhang universality class of stochastic growth models and discuss how some of the limiting distribution functions (and processes) arise also in mathematical and physical models, which are a-priori unrelated with growth models.

MP 3: HV 2: Non-Equilibrium Quantum Field Theory

Time: Tuesday 11:45–12:25 Location: H7

Invited Talk MP 3.1 Tue 11:45 H7

Path integral based non-equilibrium quantum field theory of non-relativistic pairs inside an environment — •Tobias Binder — Kavli IPMU, Kashiwanoha, Japan

We derive differential equations from path-integral based non-equilibrium quantum field theory, that cover the dynamics and spectrum of non-relativistic two-body fields for any environment. For concreteness of the two-body fields, we choose the full potential non-relativistic Quantum Electrodynamics Lagrangian in this work. After closing the correlation function hierarchy of these equations and performing consistency checks with previous literature under certain limits, we demonstrate the range of physics applications. This includes Cosmology such as Dark Matter in the primordial plasma, Quarkonia inside a quark gluon plasma, and superconductivity and Ferromagnetism in Condensed or strongly Correlated Matter physics. Since we always had to take limits or approximations of our equations in order to recover those known cases, our equations could contain new phenomena. In particular they are based on Green's functions that can deal with non-hermite potentials. We propose a scheme for other Lagrangian based theories or higher N-body states such as molecules to derive analog equations.

MP 4: AdS-CFT II

Time: Tuesday 14:00–14:50 Location: H7

MP 4.1 Tue 14:00 H7

Effective Transport Coefficients in Time-Dependent Field Theory: Far-from-Equilibrium Shear Viscosity via Holography — •Michael Florian Wondrak[1,2], Matthias Kaminski[3], and Marcus Bleicher[1,2,4] — [1]Helmholtz Forschungsakademie Hessen für FAIR, Frankfurt am Main, Germany — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt am Main, Germany — [3]Department of Physics and Astronomy, University of Alabama, Tuscaloosa, USA — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The gauge/gravity duality offers an elegant way of characterizing field theories at strong coupling. Close to equilibrium, hydrodynamic transport coefficients have been calculated successfully. Far from equilibrium, the main focus has been on thermalization based on the thermodynamic properties of the theory.

In this talk, we generalize transport coefficients from the near-equilibrium to

the highly dynamic regime. Our approach is based on Wigner transformations in combination with Green–Kubo relations. Furthermore, we contrast field-theory and bulk-spacetime generalizations of the entropy density.

We consider a conformal field theory at time-dependent temperature and chemical potential corresponding to an accreting black hole in the bulk. At early and late times, we consistently recover the well-known near equilibrium value of the ratio of shear viscosity and entropy density. During the dynamic regime, there are substantial deviations of order unity.

MP 4.2 Tue 14:25 H7

Berry Phases Probing the Fine-Structure of Entanglement — Souvik Banerjee[1], •Moritz Dorband[1,2], Johanna Erdmenger[1,2], Emma Loos[1,2], René Meyer[1,2], Flavio Nogueira[3], and Jeroen van den Brink[2,3,4] — [1]Institute for Theoretical Physics, Julius-Maximilians-Universität Würzburg, 97074 Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat — [3]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [4]Institute for Theoretical Physics, TU Dresden, 01069 Dresden, Germany

We consider the notion of Berry phase for simple quantum mechanical models as well as for wormholes in gravity and their interpretation in the light of the AdS/CFT correspondence. In both cases the Berry phases arise due to unitary transformations acting on subsystems of the considered models. In the quantum mechanical case, we act with a rotation on half of the system while in the wormhole case, only one throat undergoes time evolution. Since both these transformations are unitary the entanglement properties of the systems are not distinguishable by a local measurement. We substantiate these results for the wormhole by an explicit calculation in two-dimensional gravity.

We furthermore discuss how Berry phases are related to non-exact symplectic forms in parameter space. Again we consider simple quantum mechanical models and gravity wormholes in that regard.

MP 5: Loop Quantum Gravity

Time: Tuesday 15:00–15:50 Location: H7

MP 5.1 Tue 15:00 H7

Super Cartan geometry, loop quantum supergravity and applications — •Konstantin Eder — FAU Erlangen-Nürnberg

This talk is devoted to the quantization of supergravity in a formulation in which (part of) supersymmetry manifests itself in terms of a gauge symmetry. Applications we have in mind are supersymmetric black holes and loop quantum cosmology.

We will derive the Holst variant of the MacDowell-Mansouri action for N=1 and N=2 supergravity in D=4 for arbitrary Barbero-Immirzi parameters. We will show that these actions provide unique boundary terms that ensure local supersymmetry invariance at boundaries. The chiral case is special. The action is invariant under an enlarged gauge symmetry, and the boundary theory is a super Chern-Simons theory. The action also implies boundary conditions that link the super electric flux through, and the super curvature on, the boundary.

We will also study chiral symmetry reduced models with local supersymmetry. The enlarged gauge symmetry of the chiral theory is essential as it allows for nontrivial fermionic degrees of freedom even if one imposes spatial isotropy.

MP 5.2 Tue 15:25 H7

Revisiting loop quantum gravity with selfdual variables — •Robert Seeger — Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)

Loop quantum gravity (LQG) in its current formulation is a the quantisation of the SU(2) gauge theory of gravity in Ashtekar-Barbero variables. It started out as an SL(2,C) gauge theory in Ashtekar's selfdual variables, but the quantisation program was never fully carried out in this formulation. The two main obstacles are the non-compactness of the gauge group SL(2,C) and the necessity to implement complicated reality conditions. The latter ensure reality of the spatial metric and its evolution.

We revisit the original formulation by considering the selfdual part of complexified general relativity in Ashtekar variables. These are a complex flux and an SL(2,C) connection. We show that one is lead to a classical theory that is holomorphic in the canonical variables, in order to have a non-degenerate symplectic structure. This does not allow to implement the reality conditions as additional constraints in the action, they have to be added by hand during the quantisation. We describe first steps to extend the holomorphic character also to the quantum theory, with SL(2,C) holonomies, holomorphic derivatives, and a notion of holomorphic spin networks. Thus, working in a holomorphic setup turns out to be natural, as anticipated by Ashtekar and others in early works on the selfdual theory. We will also comment on the implementation of the reality conditions.

MP 6: Quantum Statistical Mechanics

Time: Tuesday 16:30–16:55 Location: H7

MP 6.1 Tue 16:30 H7

Quantum vacuum physics in dielectric media with dispersion and dissipation — •Sascha Lang[1,2], Ralf Schützhold[1,3,2], and William G. Unruh[4] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [4]Department of Physics and Astronomy, University of British Columbia, Vancouver V6T 1Z1, Canada

Experiments on quantum radiation (particle creation from vacuum) often pose major challenges when probing relativistic quantum field theories. Sometimes, effective field theories in suitable condensed matter systems may be accessible more easily. However, such systems are generally affected by material properties such as dispersion and dissipation.

We study quantum vacuum physics in a dielectric medium featuring both dispersion and dissipation. To this end, we explicitly add an environment field to the standard 'Hopfield model' for dispersive but non-dissipative dielectric media. The refined model allows for an 'ab initio' treatment of dissipation and we consider an application in which the interplay of dispersion and dissipation plays a role.

MP 7: HV 3: Stochastic Quantum Mechanics

Time: Tuesday 17:00–17:40 Location: H7

Invited Talk MP 7.1 Tue 17:00 H7

Stochastic Dynamics in Quantum Mechanics — •Denis Bernard — Laboratoire de Physique de l'Ecole Normale Superieure, CNRS, ENS & Universite PSL, 75005 Paris, France.

Stochastic processes enter Quantum Mechanics from different corners: as results of quantum measurements and their effects on quantum systems, as noise providing stochastic models for environments interacting with quantum systems, or as models for typical quantum states and operations. I shall review aspects of these strongly interconnected topics, hopefully covering discussions of statistical aspects of non-demolition measurements, quantum state monitoring, and the emergence of quantum jumps and spikes, and of statistical fluctuations of quantum coherences in many-body quantum model systems at, or away from, equilibrium.

MP 8: Non-equilibrium Statistical Mechanics

Time: Tuesday 17:45–18:10 Location: H7

MP 8.1 Tue 17:45 H7

Correlational entropy by nonlocal quantum kinetic theory — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics - UFRN, Campus Universitário Lagoa nova, 59078-970 Natal, Brazil

The nonlocal kinetic equation unifies the achievements of the transport in dense quantum gases with the Landau theory of quasiclassical transport in Fermi systems. Large cancellations in the off-shell motion appear which are hidden usually in non-Markovian behaviors [1]. The remaining corrections are expressed in terms of shifts in space and time that characterize the non-locality of the scattering process [2]. In this way quantum transport is possible to recast into a quasi-classical picture [3]. The balance equations for the density, momentum, energy and entropy include besides quasiparticle also the correlated two-particle contributions beyond the Landau theory [4]. The medium effects on binary collisions are shown to mediate the latent heat, i.e., an energy conversion between correlation and thermal energy. For Maxwellian particles a sign change of the latent heat is reported at a universal ratio of scattering length to the thermal De Broglie wavelength. This is interpreted as a change from correlational heating to cooling [5]. [1] Ann. Phys. 294 (2001) 135, [2] Phys. Rev. C 59 (1999) 3052, [3] "Interacting Systems far from Equilibrium - Quantum Kinetic Theory" Oxford University Press, (2017) ISBN 9780198797241, [4] Phys. Rev. E 96 (2017) 032106, [5] Phys. Rev. B 97 (2018) 195142

MP 9: Anomalies in Quantum Field Theory

Time: Wednesday 14:00–14:50 Location: H7

MP 9.1 Wed 14:00 H7

Deformations of Supergravity and Supersymmetry Anomalies — •Markus B. Fröb[1], Camillo Imbimbo[2], and Nicolò Risso[3] — [1]Universität Leipzig, Leipzig, Germany — [2]Università di Genova, Genoa, Italy — [3]Università di Padova, Padua, Italy

We present a BRST analysis of supersymmetry anomalies of $\mathscr{N} = 1$ supersymmetric quantum field theories with anomalous R symmetry. To this end, we consider the coupling of the matter theory to classical $\mathscr{N} = 1$ new minimal supergravity. We point out that a supersymmetry anomaly cocycle associated to the $U(1)_R$ field does exist for this theory. It is non-trivial in the space of supergravity fields (and ghosts), but it becomes BRST-exact in the functional space that includes antifields. Equivalently, the $U(1)_R$ supersymmetry anomaly cocycle vanishes "on shell". It is therefore removable. However, to remove it — precisely because it is not trivial in the smaller space of fields — one needs to deform the supergravity BRST operator. This deformation is triggered, at first order in the anomaly coefficient, by a local operator S_1 of ghost number 1. We give a cohomological characterization of S_1 and compute it in full detail. At higher orders in the anomaly coefficient, we expect a priori that further deformations of the BRST rules are necessary.

MP 9.2 Wed 14:25 H7

Exploring anomalies by many-body correlations — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics - UFRN, Campus Universitário Lagoa nova, 59078-970 Natal, Brazil

The quantum anomaly can be written alternatively into a form violating conservation laws or as non-gauge invariant currents seen explicitly on the example of chiral anomaly. By reinterpreting the many-body averaging, the connection to Pauli-Villars regularization is established which gives the anomalous term a new interpretation as arising from quantum fluctuations by many-body correlations at short distances. This is exemplified by using an effective many-body quantum potential which realizes quantum Slater sums by classical calculations. It is shown that these quantum potentials avoid the quantum anomaly but approaches the same anomalous result by many-body correlations. A measure for the quality of quantum potentials is suggested to describe these quantum fluctuations in the mean energy. Consequently quantum anomalies might be a short-cut way of single-particle field theory to account for many-body effects. This conjecture is also supported since the chiral anomaly can be derived by a completely conserving quantum kinetic theory. [Eur. Phys. J. B 92 (2019) 176, Phys. Lett. A 383 (2019) 1362, arXiv:2004.01507]

MP 10: Nonrelativistic Quantum Field Theory

Time: Wednesday 15:00–15:50 Location: H7

MP 10.1 Wed 15:00 H7

Infraparticle states in the massless Nelson model - revisited — Vincent Beaud[1], •Wojciech Dybalski[2], and Gian Michele Graf[3] — [1]TU Munich, Germany — [2]AMU Poznań, Poland — [3]ETH Zürich, Switzerland

We provide a new construction of infraparticle states in the massless Nelson model. The approximating sequence of our infraparticle state does not involve any infrared cut-offs. Its derivative w.r.t. the time parameter is given by a simple explicit formula. The convergence of this sequence to a non-zero limit as time goes to infinity is then obtained by the Cook method combined with stationary phase estimates. To apply the latter technique we exploit recent results on regularity of ground states in the massless Nelson model, which hold in the low coupling regime.

MP 10.2 Wed 15:25 H7

Infravacuum Property and Local Normality — •Bartosz Biadasiewicz and Wojciech Dybalski — Adam Mickiewicz University, Poznan, Poland

This talk concerns an infravacuum representation introduced by K. Kraus, L. Polley and G. Reents. Due to the infravacuum property, it is not equivalent to the standard vacuum representation of a massless scalar free field on the Minkowski spacetime. But for subalgebras corresponding to measurements performed within double cones, restrictions of respective representations are quasi-equivalent. This means that the representation is locally normal. We give a straightforward proof of this fact which is based on the Araki-Yamagami criterion. There is also an interesting group-theoretic aspect that we investigated, the relative normalizer of a pair of subgroups, introduced by D. Cadamuro and W. Dybalski. In our recent work (arXiv: 2106.02032), it re-appeared in this local relativistic setting.

MP 11: Quantum Information

Time: Wednesday 16:30–17:45 Location: H7

MP 11.1 Wed 16:30 H7

Exploring the Limits of Open Quantum Dynamics I: Motivation, Results from Toy Models to Applications — •Thomas Schulte-Herbrüggen[1,2], Frederik vom Ende[1,2], Emanuel Malvetti[1,2], and Gunther Dirr[3] — [1]Dept. Chem., TU-München (TUM) — [2]Munich Centre for Quantum Science and Technology (MCQST) — [3]Institute of Mathematics, Universität Würzburg

Which quantum states can be reached by coherently controlling n-level quantum systems coupled to a thermal bath in a switchable Markovian way? To put this question of quantum engineering on a mathematical footing, we address reachable sets of coherently controllable open quantum systems with switchable coupling to a thermal bath of temperature T.

The core problem reduces to the dynamics of the eigenvalues of the density operator. It translates into a toy model of studying points in the standard simplex allowing for two types of controls: (i) permutations within the simplex, (ii) contractions by a dissipative semigroup. We show how toy-model solutions pertain to the reachable set of the original controlled Markovian quantum system. Beyond the case $T = 0$ (amplitude damping) we present results for $0 < T < \infty$ using more recent methods like extreme points of the d-majorisation polytope.

We put the problem into context and give a number of illustrating examples.

Ref.: arXiv:2003.06018

MP 11.2 Wed 16:55 H7

Exploring the Limits of Open Quantum Dynamics II: Gibbs-Preserving Maps from the Perspective of Majorization — •Frederik vom Ende — TU Munich, 85748 Garching, Germany — Munich Centre for Quantum Science and Technology, 80799 Munich, Germany

Motivated by reachability questions in coherently controlled open quantum systems coupled to a thermal bath, as well as recent progress in the field of thermo-/vector-d-majorization (arXiv:1911.01061) we generalize classical majorization from unital quantum maps to maps with an arbitrary fixed point of full rank. Such maps preserve some Gibbs-state and thus play an important role in the resource theory of quantum thermodynamics, in particular for thermo-majorization. Based on this we investigate D-majorization on matrices in terms of its topological and order properties, such as existence of unique maximal and minimal elements, etc. In the process we relate the notion of strict positivity to such maps as well as to Markovian processes in general. Moreover we characterize D-majorization in the qubit case via the trace norm and elaborate on why this is a challenging task when going beyond two dimensions.

MP 11.3 Wed 17:20 H7

Reachability and Stabilizability for Markovian Quantum Systems with Fast Hamiltonian Control — •Emanuel Malvetti[1,2], Frederik vom Ende[1,2], Thomas Schulte-Herbrüggen[1,2], and Gunther Dirr[3] — [1]Dept. Chem., TU-München (TUM) — [2]Munich Centre for Quantum Science and Technology (MCQST) — [3]Institute of Mathematics, Universität Würzburg

Markovian quantum systems with fast and full Hamiltonian control can be reduced to an equivalent control system on the eigenvalues of the density matrix describing the state. We explore this eigenvalue control system, whose state space is the standard simplex, by answering questions about reachability and stabilizability in the simplex. This has immediate applications to the cooling of Markovian quantum systems, for instance we give necessary and sufficient conditions for a system to be coolable. Furthermore, we show that for many tasks of interest the control Hamiltonian can be chosen to be independent of time.

MP 12: Quantum Mechanics

Time: Wednesday 17:50–18:15 Location: H7

MP 12.1 Wed 17:50 H7

Stability of quantum inequalities under scattering — •Henning Bostelmann[1], Daniela Cadamuro[2], and Gandalf Lechner[3] — [1]University of York, Department of Mathematics, York YO10 5DD, United Kingdom — [2]Universität Leipzig, Institut für Theoretische Physik, Brüderstraße 16, 04103 Leipzig — [3]School of Mathematics, Cardiff University, Senghennydd Road, CF24 4AG Cardiff, United Kingdom

Certain physical quantities that yield positive values in classical mechanics can have negative expectation values in quantum theory (e.g., the probability flux in the quantum backflow effect, or the averaged energy density in field theories). However, they typically possess a lowest negative eigenvalue. In other words, positive observables in classical theory often "quantize" to operators that are not necessarily positive, but bounded below ("quantum inequalities"). Here we investigate whether, for one quantum mechanical particle, such bounds are stable when the dynamics is perturbed by a scattering potential. This boils down to the question how fast the Møller operator Ω approaches the identity at high energies; more quantitatively, whether $\|(\Omega - 1)(1 + H_0)^\beta\| < \infty$ for suitable $\beta > 0$, where H_0 is the free Hamiltonian. We derive such bounds under generic assumptions on the free Hamiltonian and the scattering potential. In particular, $0 < \beta \leq 1/2$ is allowable for the Schrödinger Hamiltonian – independent of space dimension, and even in the matrix-valued case, i.e., when adding inner degrees of freedom.

MP 13: HV 4: Quantum Field Theory in Noncommutative Spacetime

Time: Thursday 11:00–11:40 Location: H6

Invited Talk MP 13.1 Thu 11:00 H6

Exact solution of the scalar QFT Φ^4 model on the 4-dimensional noncommutative Moyal space — •Alexander Hock — Mathematisches Institut Münster, Deutschland

Local QFT, as it is used in the Standard Model, can be generalized to a non-local QFT by introducing a noncommuting $\star$-product in the action functional. Mainly, we will focus on the scalar Φ^4 Model, which breaks down at the self-dual point and for large noncommutativity to a Matrix Model. In this limit, the tower of Dyson-Schwinger equations decouple to nonlinear integral equations. We will solve these equations and show the exact solution of the planar 2-point function in 4 dimensions.

Expanding this result for small coupling constants fits perfectly with the perturbative expansion into Feynman graphs renormalized by Zimmermann's forest formula. We emphazise that this model admits perturbatively the renormalon problem, but is nevertheless resummable.

MP 14: HV 5: Quantum Field Theory near Black Hole Horizons

Time: Thursday 11:45–12:25 Location: H6

Invited Talk MP 14.1 Thu 11:45 H6

Temperature and entropy-area relation of quantum matter near spherically symmetric outer trapping horizons — •Rainer Verch — Institut für Theoretische Physik, Universität Leipzig, Germany

We consider spherically symmetric spacetimes with an outer trapping which are generalizations of spherically symmetric black hole spacetimes where the central mass can vary with time. These spacetimes possess in general no timelike Killing vector field, but admit a Kodama vector field which provides a replacement. We investigate a scaling limit of Hadamard 2-point functions of a quantum field on the spacetime onto the ingoing lightlike congruence of a spherical horizon cross-section. The scaling limit 2-point function has a universal form and a thermal spectrum with respect to the time-parameter of the Kodama flow, where the inverse temperature is proportional to the surface gravity of the horizon cross-section. This can be seen as a local counterpart of the Hawking effect for an outer trapping horizon in the scaling limit. The scaling limit 2-point function as well as the 2-point functions of coherent states of the scaling-limit-theory have relative entropies behaving proportional to the cross-sectional horizon area. This is joint work with F. Kurpicz and N. Pinamonti, arXiv:2102.11547.

MP 15: Quantum Field Theory: Renormalization

Time: Thursday 14:00–14:50 Location: H6

MP 15.1 Thu 14:00 H6

A Rigorous Derivation of the Functional Renormalisation Group Equation — •Jobst Ziebell — TPI, Jena, Deutschland

The functional renormalisation group equation is derived in a mathematically rigorous fashion in a framework suitable for the Osterwalder-Schrader formulation of quantum field theory. To this end, we devise a very general regularisation scheme and give precise conditions for the involved regulators guaranteeing physical boundary conditions. Furthermore, it is shown how the classical limit is altered by the regularisation process leading to an inevitable breaking of translation invariance. We also give precise conditions for the convergence of the obtained theories upon removal of the regularisation.

MP 15.2 Thu 14:25 H6

Perturbative Renormalization in Combinatorially Non-local Field Theory — •Johannes Thürigen — WWU Münster

Renormalization in local quantum field theory relies on the possibility to subtract all subdivergences in a Feynman diagram as described for example by Zimmermann's forest formula or the Connes-Kreimer Hopf algebra. Here we show how this can be generalized to field theories with combinatorially non-local interactions such as matrix or tensor field theories. In particular, this gives a general recipe for renormalization of various field-theory approaches to quantum gravity.

MP 16: Strongly Interacting Quantum Field Theory

Time: Thursday 15:00–15:50 Location: H6

MP 16.1 Thu 15:00 H6

Non-perturbative contribution to the collisional broadening and medium induced radiation in QCD plasmas — Guy D. Moore[1], Soeren Schlichting[2], Niels Schlusser[1,3], and •Ismail Soudi[2] — [1]Institut fur Kernphysik, Technische Universitat Darmstadt — [2]Fakultat fur Physik, Universitat Bielefeld — [3]Department of Physics & Helsinki Institute of Physics

Due to the famous infrared problem of finite temperature QCD, perturbative calculation of transport phenomena can receive large non-perturbative contributions.

Here, we investigate the impact of non-perturbative contributions to jet-medium interactions, by incorporating non-perturbative contributions to the collisional broadening kernel $C(b_\perp)$, which determines the rate of medium induced radiation.

We construct the collision kernel $C(b_\perp)$ non-perturbatively, by matching lattice EQCD calculations [1] with the correct ultraviolet behavior of QCD.

By comparing the results for medium induced radiation in infinite and finite QCD plasmas [2] to leading order and next to leading order calculations, we assess the importance of non-perturbative aspects of momentum broadening for jet quenching calculations.

[1] - G. D. Moore and N. Schlusser, Phys. Rev. D101, 014505(2020), [Erratum: Phys.Rev.D 101, 059903 (2020)], arXiv:1911.13127 [hep-lat]

[2]- G. D. Moore, S. Schlichting, N. Schlusser and I. Soudi [arXiv: 2105.01679]

MP 16.2 Thu 15:25 H6

Lattice approximation of conformal symmetry — •Alexander Stottmeister — Leibniz Universität Hannover

We will discuss the application of the recently introduced framework of operator-algebraic renormalization to fermionic lattice systems. Focussing on the 1+1-dimensional case, we will illustrate how the scaling limit of the massless free fermion can be obtained. Moreover, we will show how conformal symmetry is recovered by a formula due to Koo and Saleur. This is joint work with T. J. Osborne.

MP 17: Entropy in Quantum Field Theory

Time: Thursday 16:30–18:10 Location: H6

MP 17.1 Thu 16:30 H6

Relative entropy of coherent states on general CCR algebras — Henning Bostelmann[1], •Daniela Cadamuro[2], and Simone Del Vecchio[2] — [1]University of York, Department of Mathematics, York YO10 5DD, United Kingdom — [2]Institut für Theoretische Physik, Universität Leipzig, Brüderstraße 16, 04103 Leipzig

The study of relative entropy between states in quantum field theory has recently attracted much attention in connection with the quantum null energy condition; usually one considers the vacuum and a coherent excitation, and the relative entropy with respect to a wedge algebra. In generalization of this, we study the relative entropy for a subalgebra of a generic CCR algebra between a general (possibly mixed) quasifree state and a coherent excitation of it. We give a formula for this entropy in terms of single-particle modular data. We also investigate changes of the relative entropy along subalgebras arising from an increasing family of symplectic subspaces, and study lower estimates for the second derivative of the relative entropy along this family, which replace the usual notion of convexity of the entropy. Our main input is a regularity condition for the family of subspaces (differential modular position) which generalizes the notion of half-sided modular inclusions. Examples include thermal states for the conformal U(1)-current.

MP 17.2 Thu 16:55 H6

Relative entropic uncertainty relation for scalar quantum fields — Stefan Flörchinger, •Tobi Haas, and Markus Schröfl — Institut für Theoretische Physik, Universität Heidelberg

Entropic uncertainty is a well-known concept to formulate uncertainty relations for continuous variable quantum systems with finitely many degrees of freedom. Typically, the bounds of such relations scale with the number of oscillator modes, preventing a straight-forward generalization to quantum field theories.

In this talk, I will present a way of overcoming this difficulty by introducing the notion of a functional relative entropy, which has a meaningful field theory limit. I will present the first entropic uncertainty relation for a scalar quantum field theory and illustrate that its bound remains finite also for an infinite number of oscillator modes.

MP 17.3 Thu 17:20 H6

Entanglement entropy between spatial regions of an interacting condensate — •Natalia Sánchez-Kuntz and Stefan Flörchinger — ITP, Heidelberg University, Philosophenweg 16, D-69120 Heidelberg, Germany

We treat a nonrelativistic limit of QFT in which the entanglement entropy is finite in the UV. Furthermore we show that a scaling of the entanglement entropy with the system size for relativistic phonons is recovered. We discuss the emergence of an IR divergence, and its relation to zero modes. We compare this with other theories with similar behaviour.

We show the results related to a Bose-Einstein condensate in 1+1 dimensions and comment on further questions we are exploring at the moment, along with some challenges that come our way.

MP 17.4 Thu 17:45 H6

Inverted c-functions in thermal states — •Matthias Kaminski and Casey Cartwright — Department of Physics and Astronomy, University of Alabama,514 University Boulevard, Tuscaloosa, AL 35487, USA

We first compute the effect of a chiral anomaly, charge, and a magnetic field on the entanglement entropy in N=4 Super-Yang-Mills theory at strong coupling via holography. Depending on the width of the entanglement strip the entanglement entropy probes energy scales from the ultraviolet to the infrared energy regime of this quantum field theory prepared in a given state. From the entanglement entropy, we then compute holographic c-functions and demonstrate an inverted c-theorem for them. That is, these c-functions in generic thermal states monotonically increase towards the infrared energy regime in contrast to the c-functions in vacuum states which decrease along the renormalization group flow from the ultraviolet to the infrared regime. In these thermal states, the c-functions in the infrared limit are proportional to the value of the thermal entropy.

MP 18: Constructive Tools for Quantum Field Theory

Time: Friday 11:00–12:15 Location: H6

MP 18.1 Fri 11:00 H6

A product picture for quantum electrodynamics — •Bernard Kay — Department of Mathematics, University of York, York, England

We exhibit a product picture for QED – i.e. a reformulation in which it has a total Hamiltonian, arising as a sum of a free electromagnetic Hamiltonian, a free Dirac Hamiltonian and an interaction term, acting on a Hilbert space which is a subspace (the "physical subspace") of the full tensor product of an electron/positron Hilbert space and an electromagnetic-field Hilbert space. The traditional Coulomb-gauge formulation of QED isn't a product picture in this sense because, in it, the longitudinal part of the electric field is a function of the Dirac ψ-field. We prove (at a formal level) our product picture is equivalent to Coulomb gauge QED. Also, in the product picture: (i) In all states in the physical subspace, the ψ field is entangled with longitudinal photons; (ii) Gauss's law holds as an operator equation; (iii) The electric field operator and the full Hamiltonian aren't self-adjoint on the full tensor-product Hilbert space, but they are self-adjoint on the physical subspace and so that's OK. Also (iv) The product picture resembles temporal gauge quantization but seems free from the well-known difficulties of that; (v) In the nonrelativistic limit, one obtains a reformulation of Schroedinger many body theory in which the usual Coulomb potential is absent and, instead, a term representing the kinetic energy of longitudinal photons is present so that, say, the binding energy of the Hydrogen atom is seen to arise as a byproduct of the entanglement of the proton and electron with longitudinal photons.

MP 18.2 Fri 11:25 H6

Quantum field theory without ghosts and indefinite metric – A program and some results. — •Jens Mund — Departamento de Fisica, Universidade Federal de Juiz de Fora, Brazil

Quantum field theories involving interacting vector fields with spin/helicity one (or higher) are usually based on gauge theory: One adds unphysical degrees of freedom in the form of "negative norm" states and "ghost" fields before the construction, and divides them out afterwards by requiring gauge (or BRST) invariance of the S-matrix and of observable fields. The construction of charge-carrying fields (like the Dirac field in QED) is notoriously difficult.

In the talk an alternative approach is presented: Instead of Hilbert space positivity, the localization of (unobservable) fields is weakened, in a way permitted by the principles of relativistic quantum field theory: The fields are localized on "Jordan-Mandelstam strings" extending to space-like infinity. They act in a true Hilbert space without ghosts. In contrast to gauge theory, our approach allows for a direct (perturbative) construction of charged interacting fields. I comment on partial results on (massive and proper) QED, (Abelian) Higgs model, and Yang-Mills models.

MP 18.3 Fri 11:50 H6

Renormalization in string-localized quantum field theory — •Christian Gass — Universität Göttingen, Germany

String-localized quantum field theory (SL QFT) provides an alternative to the usual gauge theoretic approaches. In the last one-and-a-half decades, many conceptual benefits of SL QFT have been discovered. However, a renormalization recipe for loop graphs with internal SL fields was not at hand until now.

In this talk, we present a proof that the problem of renormalization is not worse in SL QFT than in usual point-localized theories. This happens in spite of the analytic complexity of SL propagators and provided that one takes care in how to set up perturbation theory in SL QFT. Consequently, renormalization stays a pure short-distance problem and the improved short-distance behavior of SL fields remains a meaningful notion, which indicates that there can exist renormalizable models in SL QFT whose point-localized counterparts are non-renormalizable.

MP 19: Fundamental Ideas

Time: Friday 14:00–14:50 Location: H6

MP 19.1 Fri 14:00 H6

Electromagnetic interactions as the source of all known four forces. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

In theoretical physics different particle representations were already proposed; as points, as vortex, as strings, as wave-packets, etc. The present work is based on an approach where subatomic particles (SPs) are represented as focal points of rays of Fundamental Particles (FPs) that move from infinite to infinite. FPs store the energy of a SP as rotation defining angular momenta. Interactions between SPs are thus the product of the interactions of the angular momenta of their FPs. There is no need to introduce carrier particles like photons, gluons, W and Z Bosons, gravitons, etc. All four forces are due to electromagnetic interactions and can be described by QED. Another important finding of the approach is that the interaction between two charged SPs tends to zero for the distance between them tending to zero. Atomic nuclei can thus be represented as swarms of electrons and positrons that neither attract nor repel each other. As atomic nuclei are composed of nucleons which are composed of quarks, the quarks can also be seen as swarms of electrons and positrons. More at: www.odomann.com

MP 19.2 Fri 14:25 H6

Für ein einheitliches Weltbild der Physik — •Helmut Hille — Heilbronn, Fritz-Haber-Straße 34

Es ist nur menschliche Sehgewohnheit, getrennt Gesehenes als definitiv getrennt Existierendes zu halten, obgleich schon das System Sonne-Erde-Mond das Gegenteil beweist. Keiner dieser Körper hätte ohne den anderen seine Bahn und es gäbe auf der Erde keine Gezeiten. Verschränkte Quanten haben gezeigt, dass ihr gemeinsamer Ursprung sie sich als Eines verhalten lassen. Ebenso ist der Big Bang der gemeinsame Ursprung aller Materie unseres Kosmos zu einer neuen immanenten Einheit, die sich in Form der Gravitation zusammenhalten möchte, während sie äußerlich gleichzeitig expandiert. Die Gravitation ist nur ein weiterer Beleg über die Macht des Unsichtbaren, die es endlich zu akzeptieren gilt. Heute sucht man als Ausweg das Unsichtbare in dunkler Materie und Energie. Aber das Unsichtbare, um das es mir geht, ist kein Teilchen. Es ist nur die Rückseite des Sichtbaren, die wir mit der Gravitationskonstante erfassen. So ist die Gravitation eine Form der Verschränkung aller betroffenen Materie (auch Strahlung ist Materie), von mir hier Superverschränkung genannt. In der Verbindung mit drei weiteren Prämissen ergibt sich ein Weltbild der Physik von großer Einfachheir, Klarheit und Schönheit, das ein rationales ist, das auf klaren, einsichtigen Prämissen beruht, die jedermann nachvollziehen kann.

MP 20: Poster (permanent)

Time: Monday 10:30–11:00 Location: P

MP 20.1 Mon 10:30 P

A time-symmetric resolution of the Einstein's Boxes paradox — •Michael B. Heaney — 3182 Stelling Drive, Palo Alto CA 94303

The Einstein's Boxes paradox was developed by Einstein, de Broglie, and others to demonstrate the incompleteness of the Copenhagen Formulation of quantum mechanics. I explain the paradox using the Copenhagen Formulation. I then show how a Time-Symmetric Formulation of quantum mechanics resolves the paradox in the way predicted by Einstein and de Broglie. Finally, I describe an experiment that can distinguish between these two formulations.

Plasma Physics Division
Fachverband Plasmaphysik (P)

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Overview of Invited Talks and Sessions

(Lecture halls H2, H4, H5, and H6; Poster P)

Plenary Talks of the Plasma Physics Division

PV III	Tue	9:00– 9:45	Audimax	**ASDEX Upgrade tokamak: 30 years of science and technology development for a fusion power plant** — •Arne Kallenbach
PV VI	Wed	9:00– 9:45	Audimax	**Low pressure dusty plasmas for the synthesis of nanocrystals and quantum dots** — •Uwe Kortshagen

Invited Talks

P 1.1	Mon	11:00–11:30	H5	**Diagnostics of magnetized high frequency technological plasmas** — •Julian Schulze, Moritz Oberberg, Birk Berger, Julian Roggendorf, Dennis Engel, Christian Wölfel, Jan Lunze, Ralf Peter Brinkmann, Peter Awakowicz
P 2.1	Mon	11:00–11:30	H6	**Predictive modelling of beryllium erosion, transport and deposition during H, He and DT plasmas in ITER** — •Juri Romazanov, Sebastijan Brezinsek, Andreas Kirschner, Richard A. Pitts, Vladislav S. Neverov, Christian Linsmeier
P 3.1	Mon	16:30–17:00	H6	**An overview of the theoretical description and modelling of low-current arcs at small gap distances** — •Margarita Baeva
P 4.1	Tue	11:00–11:30	H5	**Overview on turbulence in the shear- and scrape-off layer at W7-X** — •Andreas Krämer-Flecken, Olaf Grulke, Xiang Han, Carsten Killer, Elisee Trier, Thomas Windisch, Haoming Xiang
P 6.1	Tue	16:30–17:00	H5	**The Wendelstein 7-X Scrape-Off Layer** — •Carsten Killer, W7-X Team
P 8.1	Wed	14:00–14:30	H5	**Visualizing the Dynamics of a Plasma-Based Particle Accelerator** — •Malte Kaluza
P 11.1	Thu	11:00–11:30	H4	**Microfluidic flow in single-layer dusty plasmas** — •Peter Hartmann, Truell W. Hyde
P 12.1	Thu	11:00–11:30	H5	**Planetary and astrophysical high Mach-number shocks: kinetic simulations vs in-situ measurements** — •Artem Bohdan, Martin Pohl, Paul Morris
P 13.1	Thu	14:00–14:30	H4	**How turbulence sets boundaries for fusion plasma operation** — •Peter Manz, Thomas Eich, the ASDEX Upgrade Team
P 14.1	Thu	14:00–14:30	H5	**Streamer inception and imaging in various atmospheres** — •Sander Nijdam, Siebe Dijcks, Shahriar Mirpour
P 15.1	Thu	16:30–17:00	H5	**Physics studies with high-power electron cyclotron heating (ECRH) on ASDEX Upgrade** — •Jörg Stober, ASDEX Upgrade Team
P 16.1	Fri	11:00–11:30	H2	**Configurational temperature of multi species complex (dusty) plasmas** — •Dietmar Block, Frank Wieben, Michael Himpel, Andre Melzer

Sessions

P 1.1–1.5	Mon	11:00–12:30	H5	**Low Pressure Plasma Sources I**
P 2.1–2.4	Mon	11:00–12:25	H6	**Magnetic Confinement, Plasma-Wall Interaction & Helmholtz Graduate School I**
P 3.1–3.6	Mon	16:30–18:15	H6	**Atmospheric Pressure Plasmas and their Applications I**
P 4.1–4.3	Tue	11:00–12:00	H5	**Magnetic Confinement II**
P 5.1–5.46	Tue	14:00–16:00	P	**Poster I**
P 6.1–6.3	Tue	16:30–17:50	H5	**Magnetic Confinement III & Helmholtz Graduate School II**
P 7.1–7.3	Wed	14:00–15:15	H4	**Helmholtz Graduate School III**

P 8.1–8.4	Wed	14:00–15:15	H5	**Laser Plasmas I**
P 9.1–9.4	Wed	16:30–17:30	H5	**Codes and Modelling (Methods)**
P 10	Wed	17:45–18:45	H5	**Mitgliederversammlung Plasmaphysik**
P 11.1–11.5	Thu	11:00–12:30	H4	**Complex Plasmas and Dusty Plasmas I**
P 12.1–12.4	Thu	11:00–12:15	H5	**Astrophysical Plasmas & Laser Plasmas II**
P 13.1–13.4	Thu	14:00–15:45	H4	**Magnetic Confinement IV & Helmholtz Graduate School IV**
P 14.1–14.7	Thu	14:00–16:00	H5	**Atmospheric Pressure Plasmas and their Applications II**
P 15.1–15.4	Thu	16:30–18:15	H5	**Magnetic Confinement V & Helmholtz Graduate School V**
P 16.1–16.5	Fri	11:00–12:30	H2	**Low Pressure Plasmas II & Dusty Plasmas II**
P 17.1–17.44	Fri	14:00–16:00	P	**Poster II**

Annual General Meeting of the Plasma Physics Division

Wednesday 17:45–18:45 MVP

Sessions

– Invited Talks, Contributed Talks, and Posters –

P 1: Low Pressure Plasma Sources I

Time: Monday 11:00–12:30 Location: H5

Invited Talk P 1.1 Mon 11:00 H5

Diagnostics of magnetized high frequency technological plasmas — •Julian Schulze[1], Moritz Oberberg[1], Birk Berger[1], Julian Roggendorf[1], Dennis Engel[2], Christian Wölfel[3], Jan Lunze[3], Ralf Peter Brinkmann[2], and Peter Awakowicz[1] — [1]Institute of Electrical Engineering and Plasma Technology, Ruhr-University Bochum — [2]Institute of Theoretical Electrical Engineering, Ruhr-University Bochum — [3]Institute of Automation and Computer Control, Ruhr-University

Capacitively coupled radio frequency magnetrons are frequently used for sputter deposition of ceramic layers. Many fundamentals of their operation are not understood. We characterize such a discharge operated in argon with oxygen admixture at low pressure by a synergistic combination of different diagnostics and find that the magnetron magnetic field induces a discharge asymmetry. This Magnetic Asymmetry Effect affects the DC self bias and ion flux-energy distributions functions at boundary surfaces, which can be controlled by adjusting the magnetic field. Tuning the magnetic field allows to magnetically control the self-excitation of plasma series resonance oscillations of the RF current and, thus, Non-Linear Electron Resonance Heating. PROES reveals space and time resolved insights into the dynamics of the electron power absorption in the presence of the magnetic field. Measurements are also performed as a function of the oxygen admixture to understand the plasma behavior during sputter applications that are affected by hysteresis effects. In parallel the deposition rate and composition of the deposited thin films are determined.

P 1.2 Mon 11:30 H5

Spectroscopic determination of rotational and vibrational temperatures in nitrogen microwave discharges from low to atmospheric pressure — •David Rauner[1], Alistair Brydon[2], Ante Hecimovic[2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Microwave (MW) discharges allow to cover a large pressure range: from the low-pressure, non-equilibrium regime of several Pa up to atmospheric conditions where heavy particle collisions play a dominant role and (partial) thermal equilibrium can typically be observed.

To demonstrate the transition between these low- and high-pressure regimes in MW plasmas, nitrogen discharges are excellently suited: via high-resolution optical emission spectroscopy and molecular spectra simulation, rotational and vibrational temperatures of different excited molecular species (N_2(B, C), N_2^+(B)) can be assessed. To cover the required large pressure range experimentally, two laboratory microwave plasmas driven at 2.45 GHz are utilized: a surface wave discharge (surfaguide) for the pressure range between 3 Pa and 2000 Pa and a microwave plasma torch, capable to operate at higher pressures up to atmospheric conditions. By assessing almost six orders of magnitude in pressure, a gradual equilibration of rotational and vibrational distributions is clearly seen and discussed in this contribution.

P 1.3 Mon 11:45 H5

Plasma enhanced chemical vapour deposition of ZrO_2 based layers — •Philipp A. Maass[1], Vitali Bedarev[1], Sebastian M.J. Beer[2], Marina Prenzel[1], Marc Böke[1], Anjana Devi[2], and Achim von Keudell[1] — [1]Experimental Physics II, Ruhr-University Bochum — [2]Inorganic Chemistry II, Ruhr-University Bochum

Chemical vapour deposition (CVD) is a widely applied technique used for thin film deposition. The combination with a plasma source (PECVD) enables the fine-tuning of parameters, opening new possibilities for the fabrication of functional coatings, such as thin thermal barrier coatings.

An evaporated metalorganic precursor is transported into the reaction chamber by a nitrogen-flow of 25-50 sccm at pressures of about 100 Pa. A ZrO_2 layer is deposited onto a heated substrate in the centre of the chamber. The desired layer growth rate lies at > 500 nm/h and the layer thickness at < 30 μm. To influence and improve the reaction chemistry, a microwave plasma source is mounted opposite the substrate surface. The discharge interacts with the incoming precursor molecules, with the aim to reduce the reaction temperature.

During this process, the growth rate and substrate temperature are monitored by in-situ ellipsometry to obtain insights into chemical kinetics and mass transport phenomena. The deposited layers are characterised in stoichiometry and crystallinity, using X-ray photoelectron spectroscopy (XPS) and X-ray diffraction (XRD). Depositions are carried out with and without the use of the plasma source. The different growth characteristics are investigated and compared.

P 1.4 Mon 12:00 H5

Infrared-spectrometric monitoring of the growth and surface treatment of a-C:H nanoparticles in a low-pressure plasma — •Oguz Han Asnaz[1], Niklas Kohlmann[2], Hauke Folger[1], Franko Greiner[1], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Faculty of Engineering, Kiel University, Germany

Due to their unique physical, mechanical, electrical, and optical properties, nanoparticles have found a wide range of applications ranging from drug carriers in biomedicine over catalysts to batteries and solar cells. Control of the particle's bulk and surface properties is required in many of these applications.

In this contribution, we present results for a-C:H nanoparticles generated in a capacitively coupled low-pressure plasma and monitored by means of in situ time-resolved FTIR spectroscopy during operation with a multipass cell with 24 passes. The particles reach a size of about 500 nm after 90 seconds of growth and can be confined easily for multiple hours for treatment with hydrogen and deuterium as a first reactive test treatment to investigate in situ the surface treatment or particle etching and reveal the potentials and sensitivity of these diagnostics for other reactive plasma treatments. Additionally, using an electrostatic particle extractor system (EPEX) developed in our group, particle samples are extracted at multiple moments during the treatment for further SEM analysis with negligible disturbance of the plasma.

P 1.5 Mon 12:15 H5

Ion energy and collisions in high power impulse magnetron sputtering discharges — •Julian Held, Sascha Thiemann-Monjé, Achim von Keudell, and Volker Schulz-von der Gathen — Experimentalphysik II, Ruhr-Universität Bochum

High power impulse magnetron sputtering (HiPIMS) discharges are important tools for the deposition of thin, hard coatings. In such discharges, the transport of sputtered and then ionized cathode material towards the substrate determines the deposition rate and, therefore, the usefulness of the discharge for application. To understand how this transport is affected by collisions, we measured the velocity distribution function (VDF) of titanium and chromium ions using high-resolution optical emission spectroscopy. The VDF was found to be mostly Maxwellian, with high temperatures of 9 eV and 4.5 eV for titanium and chromium ions, respectively. Such a Maxwellian distribution implies a surprisingly high frequency of heavy particle collisions. Different types of heavy-particle collisions are discussed and Coulomb collisions are identified as the most frequent process. A simple model is created, following the self-relaxation process of the VDF from the initial Thompson distribution, created by the sputtering, towards the observed Maxwellian distribution. This model shows good agreement to the measured distribution, indicating that the high ion energy is caused by a redistribution of energy from the energetic Thompson distribution into the partly thermalized Maxwell-like distribution, observed in the experiment.

P 2: Magnetic Confinement, Plasma-Wall Interaction & Helmholtz Graduate School I

Time: Monday 11:00–12:25 Location: H6

Invited Talk P 2.1 Mon 11:00 H6

Predictive modelling of beryllium erosion, transport and deposition during H, He and DT plasmas in ITER — •Juri Romazanov[1], Sebastijan Brezinsek[1], Andreas Kirschner[1], Richard A. Pitts[2], Vladislav S. Neverov[3], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung * Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, 13067 St.-Paul-lez-Durance Cedex, France — [3]National Research Centre Kurchatov Institute, Moscow, Russia

Beryllium (Be) will be the main chamber armor material for the international thermonuclear fusion reactor ITER, which is currently under construction in France. We present a comparison of the Be erosion for different plasma conditions, including the baseline DT burning plasma scenario with power gain Q=10, as well as the low-power hydrogen (H) and helium (He) plasmas foreseen in the ITER pre-fusion power operation (PFPO) phase. It is shown that in the latter ones, the gross erosion is two orders of magnitude smaller. Another important finding is the difference in Be migration: in the DT baseline scenario 90% of the eroded Be is redeposited in the main chamber, while in the H and He cases the redeposition is reduced to 44 and 56%, respectively. The remaining Be is deposited in the divertor. Finally, it is shown that in DT the erosion is dominated by Be self-impact, while in H and He the sputtering by energetic charge-exchange neutrals (CXN) dominates.

P 2.2 Mon 11:30 H6

In situ mechanical characterization of ion-irradiated tungsten — •Bailey Curzadd[1,2], Max Boleininger[3], Maximilian Fuhr[1,2], Till Höschen[1], Robert Lürbke[1,4], Johann Riesch[1], and Rudolf Neu[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technical University Munich, Garching, Germany — [3]CCFE, UKAEA, Abingdon, UK — [4]RWTH Aachen, Aachen, Germany

Although its low erosion and low retention of tritium make tungsten (W) the preferred plasma-facing material for future fusion reactors, its low-temperature brittleness is a critical vulnerability that could lead to the premature failure of plasma-facing components. Additionally, the degradation of essential material properties in the reactor environment – especially by neutron radiation and H/He trapped in the microstructure – greatly increases the likelihood of component failure, yet the degradation of W in a fusion environment is poorly characterized. For this reason, a novel in situ accelerator experiment was developed to characterize the mechanisms by which the mechanical properties of W are altered by radiation damage and trapped impurities, with a principle focus on the investigation of synergistic interactions between the factors that lead to material deterioration. This experiment uses thin drawn W wires prepared to a diameter of 5 *m to enable complete irradiation of the sample cross-section and allows simultaneous damaging and implantation of impurity atoms. The capabilities of the system and the results of the first experimental campaign examining radiation-induced relaxation of tensile stress in W will be presented.

P 2.3 Mon 11:55 H6

Conventional and non-conventional diagnostics on an atmospheric pressure DC glow microplasma discharge for in situ TEM studies — •Luka Hansen[1], Niklas Kohlmann[2], Ulrich Schürmann[2], Lorenz Kienle[2], and Holger Kersten[1] — [1]Institute of Experimental and Applied Physics, Kiel University, 24098 Kiel, Germany — [2]Institute of Materials Science, Kiel University, 24143 Kiel, Germany

Plasma surface interaction is one of the most discussed topics in plasma technology due to its relevance for the production or modification of micro- or even nano-structured surfaces. Still, state of the art analysis is mostly limited to the separation of plasma processing and surface analysis, since observing plasma induced surface changes in real time and nanoscale resolution is challenging. Based on the proof of principle experiments by Tai *et al.* [1] a DC microplasma discharge cell for in situ TEM integration is developed to overcome this limitation. Prior to introducing the cell close to the sensitive TEM optics extensive testing and diagnostics of the plasma discharge have to be done to ensure stability and reproducibility. Results of the conventional (electrical measurements, optical imaging, and emission spectroscopy) as well as non-conventional (calorimetry) diagnostics will be presented and a report on the current progress of the in situ measurements will be given.

[1] K Tai *et al* 2013 *Scientific Reports* **3** 1325

P 2.4 Mon 12:10 H6

Ion-induced secondary electron emission of metal surfaces analysed in an ion beam experiment — •Rahel Buschhaus, Marina Prenzel, and Achim von Keudell — Experimentalphysik II, Ruhr-Universität Bochum

Electron emission from surfaces during ion impact is one of the most fundamental plasma-surface-interaction. The surface conditions in plasmas strongly affect this electron emission and thus have an impact on the discharge itself. However, data of oxidized targets for instance, as they would appear in any reactive plasma discharge, are very spare and may even contain significant systematic errors, because they were often measured by modeling the complex behavior of plasma discharges. Many experimental and theoretical approaches address secondary electron emission coefficient determination (SEEC; amount of released electrons per incident ion) in literature [1,2]. However, this determination may remain rather indirect, because the process of ion-induced electron emission overlaps with other plasma-surface-interactions. Using beam experiments avoids this complication and allows a precise electron yield determination. SEECs of clean, untreated (air-exposed) and intentionally oxidized Cu and Ni foils are investigated in a beam experiment. Here, metal foils and oxidized foils are exposed to beams of Ar^+ with E_{ion}=200 eV - 10 keV and electron yields are determined precisely. A model for the electron emission is presented to explain the data. Surface conditions were analyzed by ex-situ XPS measurements. [1] D. Depla et al. J.Phys.D:Appl.Phys.,2008 [2] M. Daksha et al. J.Phys.D:Appl.Phys., 2016

P 3: Atmospheric Pressure Plasmas and their Applications I

Time: Monday 16:30–18:15 Location: H6

Invited Talk P 3.1 Mon 16:30 H6

An overview of the theoretical description and modelling of low-current arcs at small gap distances — •Margarita Baeva — Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

This contribution will present the achievements of a three-year research project that was concerned with the development of a unified non-equilibrium modelling of direct current electric arcs of short lengths at low currents. Such arcs are currently considered as promising tools in material processing. They are also encountered in switching devices among others.

A thorough analysis of the physical processes and arc plasma properties were carried out in order to provide knowledge about the spatial structure of the arc when the arc length was reduced to only a few millimeters and below one millimeter, and the electric current amounted a few Amperes. Results will be presented that demonstrate the arc-electrode interaction over different arc lengths, the spatial extension of the regions of space charge, and how these regions change when the arc length becomes minuscule. The challenges in modelling of short arcs between melting electrodes will be discussed.

The potentials and limitations of the modelling approach will be considered with respect to further developments.

The project on modelling of microarcs is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - project number 390828847.

P 3.2 Mon 17:00 H6

Kalorimetrische Messungen an Plasmaspritzanlagen unter Atmosphärendruck mit passiven Thermosonden — •Kristian Amand Reck[1], Maximilian Stummer[2], Thorben Kewitz[3], Rüdiger Foest[3] und Holger Kersten[1] — [1]Christian-Albrechts-Universität zu Kiel, Kiel, Deutschland — [2]INOCON Technologie GmbH, Attnang-Puchheim, Österreich — [3]Leibniz-Institut für Plasmaforschung und Technologie e. V.

Das Plasmaspritzen ist ein etabliertes Beschichtungsverfahren für metallische und keramische Schichten als auch für Polymere und Komposite auf verschiedenen Substraten. In der Industrie und Forschung besteht ein großes Interessen an der Kontrolle und der Optimierung des gesamten Prozesses. Aufgrund der höheren Energiedichte als bei anderen Plasmaquellen und der Zuführung von Beschichtungsmaterialien ist die Auswahl an Diagnostiken allerdings begrenzt.

Der Energiestrom bei Plasma-Oberflächen-Wechselwirkungen ist ein wichtiger Parameter für das Schichtwachstum. Zur Messung des Energiestroms wurden passive Thermosonden verwendet, die für die anspruchsvollen Bedingungen adaptiert wurden. Eine Anpassung und Erweiterung der Auswertung ist ebenfalls notwendig gewesen. Es wurden an zwei unterschiedlichen Plasmaquellen die räumliche Verteilung des Energiestroms und die Abhängigkeiten von der Leistung, Gasflüssen und Beschichtungsmaterialien untersucht. Die vorgestellten Messungen zeigen die vielseitigen Einsatzmöglichkeiten von passiven Thermosonden, auch um Plasmaspritzanlagen zu charakterisieren.

P 3.3 Mon 17:15 H6

Influence of the fluid flow description on the characteristics of a plasma spray torch — •Tao Zhu, Margarita Baeva, Thorben Kewitz, Holger Testrich, Detlef Loffhagen, and Rüdiger Foest — Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, Germany

In direct current plasma spray torches operated at current values of several hundred Amperes, the velocity of the generated plasma jet can approach the speed of sound, i.e. Mach numbers (Ma) close to one are reached. Then, the description of the fluid flow can affect the models' predictions. We present a two-dimensional and stationary magneto-hydrodynamic model of a plasma in local thermodynamic equilibrium for the steady operating mode of a plasma spray torch. Approaches related to both low- and high-Ma (bounded by Ma=0.3) are considered on the computational platform COMSOL Multiphysics for a laminar and compressible flow with flow rates from 40 to 80 normal litre per minute (NLPM).

The predicted pressure, plasma temperature, velocity, and electric potential differ depending on the approach employed. The thermal efficiency of the torch computed by the high-Ma model is between 50% and 60% and agrees well with experimental values. In contrast, a thermal efficiency of about 50% is predicted by the low-Ma model. It agrees with the measurements at a flow rate of 40 NLPM, but gradually decreases to about 40% for a flow rate of 80 NLPM.

This work is funded by the European Union and the Federal State of Germany Mecklenburg-Western Pomerania (Project number TBI-V-1-321-VBW-112).

P 3.4 Mon 17:30 H6

Spectroscopical analysis of an atmospheric pressure argon methane microwave plasma for methane pyrolysis — •Simon Kreuznacht, Marc Böke, and Achim von Keudell — Experimental Physics II, Ruhr University Bochum, Germany

Recently, the climate friendly and energy efficient production of hydrogen has gained a lot of interest. Today, hydrogen is used as an important precursor in the chemical industry, but hydrogen may also serve as energy carrier, for energy storage, or as climate friendly fuel in the future. Usually, hydrogen is produced by steam reforming of methane. However, this process produces a lot of CO_2 (9 t per ton of hydrogen). Methane pyrolysis in a microwave plasma, as an oxygen free technology, is a promising production method of hydrogen without the emission of greenhouse gases.

Here, we present a detailed spectroscopic analysis of an argon methane microwave plasma based on the evaluation of high resolution dicarbon emission spectra. The dicarbon rotational temperature deduced from these spectra can be used to estimate the space resolved gas temperature. The product gas stream was monitored using an online gas analyser at the same time. Since the gas temperature heavily influences the chemistry in the plasma, the space resolved determination of the gas temperature can be used to tune the microwave plasma methane pyrolysis for optimal conversion and energy efficiency.

P 3.5 Mon 17:45 H6

Photo-chemistry of organosilicon and hydrocarbon precursors initiated by VUV/UV-radiation from an atmospheric pressure RF plasma jet in argon and helium — •Tristan Winzer, Natascha Blosczyk, and Jan Benedikt — Institute for Experimental and Applied Physics, Kiel University, Kiel, Germany

Deposition of thin films using atmospheric pressure plasmas (APPs) has received increased interest in recent years. This is because APPs do not require expensive vacuum chambers and continuous material treatment is possible. However, hot electrons in the plasma lead to formation of negative ions and subsequently to particle formation, which can be incorporated as defects in the film.

APPs ignited in argon or helium emit intense VUV/UV-radiation from noble gas excimer species. In this study, this radiation is utilized to create ions and free radicals from a gas mixture of helium/argon and organosilicon or hydrocarbon precursors. A plasma source for separation of plasma generated species and photo-chemistry products will be presented. The electrons created by photo-ionization of the precursor gas remain cold and the production of negative ions via electron attachment is omitted. The photo-ionization products in dependence of plasma parameters and reactive gas admixture will be analysed using positive ion mass spectrometry. Deposited films are characterized using Fourier-transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM).

P 3.6 Mon 18:00 H6

Electric field strengths within a micro cavity plasma array measured by Stark shift and splitting of helium — •Sebastian Dzikowski[1], Syvain Iseni[2], Judith Golda[3], Marc Böke[1], and Volker Schulz-von der Gathen[1] — [1]Experimentalphysik II, Ruhr-Universität Bochum — [2]GREMI, Universität Orlèans — [3]Plasma Interface Physics, Ruhr-Universität Bochum

Over the last years micro-structured plasma devices have received increased attention for decomposition and reformation of volatile organic compounds (VOC) [1]. Here, we present a metal-based microcavity reactor which is a demountable alternative to silicon-based devices. This layer-structured reactor consists of a nickel foil operating as an electrode and an electrically grounded magnet. Both electrodes are separated from each other by a 40 microns thick dielectric foil. The nickel foil consists of four sub-arrays where hundreds to thousands of cavities in the 100 microns range are arranged equally. To obtain more control over charged particles, the electric field is of high importance. Here, the Stark effect of the allowed 492.19 nm Helium line and its forbidden 492.06 nm counterpart is exploited. By using a combination of a plane grating spectrometer and an attached ICCD camera the typical displacement of about 0.2 nm between both transitions can be resolved. With that technique spatial integrated and phase-resolved electric field strengths with a time resolution up to one microsecond can be measured for this reactor depending on operation and geometric parameters. Depending on the polarity of the applied voltage, the electric field increases with smaller cavity diameters up to 60 kV cm-1.

P 4: Magnetic Confinement II

Time: Tuesday 11:00–12:00 Location: H5

Invited Talk P 4.1 Tue 11:00 H5

Overview on turbulence in the shear- and scrape-off layer at W7-X — •Andreas Krämer-Flecken[1], Olaf Grulke[2], Xiang Han[1], Carsten Killer[2], Elisee Trier[3], Thomas Windisch[2], and Haoming Xiang[1] — [1]Institut für Energie- und Klimaforschung, Forschungszentrum Jülich, 52425 Jülich — [2]MPI für Plasmaphysik, Teilinstitut Greifswald, 17491 Greifswald — [3]MPI für Plasmaphysik, Teilinstitut Garching, 85748 Garching

The presentation intends to give an overview on mode and turbulence phenomena observed in the plasma edge, island divertor and scrape-off layer (SOL) at the stellarator W7-X. This region is investigated by a suit of probe heads measuring profile properties as well as characterizing turbulence in the SOL and island region. In the shear layer those measurements are continued by poloidal correlation reflectometry. Measurements of quasi coherent modes are reported in the shear layer located in the plasma edge. Furthermore a low frequency mode in plasmas with an edge iota of $\iota = 1$ are observed which show a modulation of the plasma flow as well.

During scans of the edge iota, plasmas with an increased diamagnetic energy due to variations in the positioning of the 5/5 island chain gained large interest. In these plasmas a low frequency modulation of the plasma rotation is observed, interrupted by fast events in the plasma current. Transient high frequency events in the range of 800 kHz – 1000 kHz precede the observation of spikes in the plasma current signal.

P 4.2 Tue 11:30 H5

Analytical model for collisional impurity transport covering all collisionality regimes — •Daniel Fajardo[1,2], Clemente Angioni[1], Patrick Maget[3], Pierre Manas[3], and the ASDEX Upgrade Team[1] — [1]Max-Plack-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Munich, Germany — [3]CEA/IRFM, Saint Paul-lez-Durance, France

In tokamak plasmas, collisional transport of impurities can be dominant over turbulent transport, particularly for heavy impurities. A recent analytical model for the Pfirsch-Schlüter (PS) flux, including the self-consistent coupling to the poloidal density distribution [P. Maget et al, Plasma Phys. Control. Fusion 62 (2020) 105001], is extended to cover all collisionality regimes, relaxing the condition of main ions in the deep banana regime. Additionally, a fully analytical model for the Banana-Plateau (BP) flux was developed, completing the neoclassical flux. This new model is compared to the drift-kinetic code NEO and the fluid code NCLASS, showing agreement with NEO on broad scans in collisionality, trapped particle fraction, charge and mass. A change in magnitude and even in sign in the temperature screening effect at the transition between the BP and PS regimes is identified and well reproduced. Radial profiles of transport coefficients are calculated for ASDEX Upgrade experimental profiles and ITER and DEMO predicted profiles, and successfully compared to NEO and NCLASS. This model is suited for fast integrated modelling applications due to its low computational cost.

P 4.3 Tue 11:45 H5

Impurity transport studies on Wendelstein 7-X by Tracer-Encapsulated Solid Pellets (TESPEL) — •René Bussiahn[1], Naoki Tamura[2], Kieran McCarthy[3], and the W7-X team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]National Institute for Fusion Science(NIFS), Toki, Japan — [3]Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas

During OP1.2b operation phase of the stellarator Wendelstein 7-X, the TESPEL injections have proven successfully as a complementary tool to Laser-Blow-Off (LBO) for impurity transport studies. Contrary to LBO - depositing tracers close to the plasma edge which are subsequently transported and spread out into the plasma, TESPEL can release the embedded impurity tracers instantly after the ablation of the protecting polystyrene shell in the core of the plasma within a well defined spatial region of a few cm^3. The deposited tracers are localized within the plasma from time-of-flight measurements. The temporal dynamics of the shell ablation is well reproduced by neutral gas shielding models. This confirms the applicability of the tracer localisation method. The spectral line emission time-traces of various tracer ion charge states show distinct differences between LBO and TESPEL, especially in their initial phase. Later, the curves are similar and the related impurity decay times are inversely proportional to the heating power. First impurity transport studies by means of the code STRAHL resulted in a good reproduction of the line emission time-traces and confirm the important role of anomalous transport in W7-X, as reported for LBO injections before.

P 5: Poster I

Time: Tuesday 14:00–16:00 Location: P

P 5.1 Tue 14:00 P

Introduction of quasilinear transport models to the Integrated Data Analysis framework — •Michael Bergmann, Rainer Fischer, and Frank Jenko — Max-Planck-Institute für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Combining the analysis of multiple diagnostics, well-chosen priors and Bayesian probability theory the Integrated Data Analysis (IDA, see [Fischer 2010]) is capable of providing density and temperature radial profiles of fusion plasmas. These profiles are then used for further analysis such as the simulation of discharges. Since IDA considers uncertain measurement data from a heterogeneous set of diagnostics but no transport physics, the estimated profiles and their gradients can be in contradiction to the profiles from transport solvers. Using transport solvers such as QLK and their much faster neural network models e.g. QLKNN we have created a loop in which simulated profiles are fed back into IDA as another prior thus providing constraints about the physically reasonable parameter space. This work feeds into a broader effort to make IDA more robust against measurement uncertainties by combining multiple transport solvers with different accuracies and computing costs in a multi-fidelity approach.

P 5.2 Tue 14:00 P

Dynamic structure factor of the magnetized one-component plasma — •Hanno Kählert — Christian-Albrechts-Universität zu Kiel, ITAP, Leibnizstr. 15, 24098 Kiel

Magnetized plasmas are known for a multitude of different wave modes. In this contribution, the focus is on the effect of strong particle interactions on waves in the magnetized one-component plasma. In particular, the dynamic structure factor is computed from molecular dynamics simulations. Collective modes that occur in a weakly coupled state are traced as the system enters the strong coupling regime. The resulting modification of the mode spectrum is studied for a variety of different magnetization parameters. The simulation results are complemented by analytical results for the dynamic structure factor of a magnetized plasma.

P 5.3 Tue 14:00 P

Ab Initio Plasmon Dispersion of the Warm Dense Electron Gas — •Paul Hamann[1], Tobias Dornheim[2], Jan Vorberger[3], Zhandos Moldabekov[2], and Michael Bonitz[1] — [1]Christian-Albrechts-Universität zu Kiel, Germany — [2]Center for Advanced Systems Understanding, Görlitz, Germany — [3]Helmholtz-Zentrum Dresden Rossendorf, Germany

The plasmon dispersion $\omega(q)$ and damping $\gamma(q)$ contain important information on the state of warm dense matter. On the other hand, x-ray Thomson scattering (XRTS) experiments provide accurate data for the dynamic structure factor S(q, ω) that is directly linked to the plasmon spectrum [1]. However, details of this link depend on the quality of the theoretical model for the dielectric function. Here we present the first ab initio data for the dielectric function that is obtained by quantum Monte Carlo simulations [2]. This allows us to obtain high quality results for $\omega(q)$ and $\gamma(q)$ of the electron component at warm dense matter conditions that differ significantly from previous models. Second, we critically analyze the commonly used weak damping approximation for the dispersion and improve it by performing the analytic continuation of the retarded dielectric function. This yields results that apply at strong damping and large wave numbers as well, which is the basis for a more accurate comparison with XRTS experiments [3].

[1] Glenzer et al., Phys. Rev. Lett.98, 065002 (2007)
[2] Dornheim et al., Phys. Rev. Lett.121, 255001 (2018)
[3] Hamann et al., Contrib. Plasma Phys.60, e202000147 (2020)

P 5.4 Tue 14:00 P

Full-6D Kinetic Simulations of Magnetically Confined Plasmas — •Mario Räth, Klaus Hallatschek und Katharina Kormann — Max Planck Institute for Plasmaphysics, Garching bei München, Germany

With the increase in computational capabilities over the past years it is possible to simulate more and more complex and accurate physical models. Gyrokinetic theory was introduced in the 1960s and 1970s to describe a plasma more accurately than with fluid equations, but still eliminate the complexity of the fast gyration about the magnetic field lines. Although current gyrokinetic computer simulations are in fair agreement with experimental results in core physics, the assumptions in the derivation make them unreliable in regimes of higher fluctuation amplitudes and stronger gradients, such as the tokamak edge. To correctly describe all phenomena in such regimes, more involved simulations might be necessary. We have developed a novel optimised and scalable semi-Lagrangian solver to simulate ion-temperature gradient modes with the full 6D kinetic equations. It has been verified extensively in the regime of gyrokinetics, including the growth of linear modes and the turbulent saturation. Furthermore, the excitation of high frequency Bernstein waves has been shown in the non-linear saturation phase. The presence of such waves provide a first insight into physics beyond gyrokinetic theory.

P 5.5 Tue 14:00 P

A research data management workflow for applied plasma science — •Markus M. Becker[1], Ihda Chaerony Siffa[1], Hans Höft[1], Fabian Hoppe[2], Detlef Loffhagen[1], Nick Plathe[1], Harald Sack[2], Volker Skwarek[3], Tabea Tietz[2], Simon Tschirner[3], and Laura Vilardell Scholten[1] — [1]Leibniz Institute for Plasma Science and Technology (INP) — [2]FIZ Karlsruhe – Leibniz-Institut für Informationsinfrastruktur — [3]Hamburg University of Applied Sciences

The necessity and potential of systematic archiving and publication of digital research data is currently a hot topic in the scientific landscape, due to various benefits such as ensuring reproducibility of research results and providing the basis for data-driven science. This requires measures to ensure data quality and particularly a documentation of stored data by means of metadata, which is understandable to both humans and machines. Machine-actionable metadata is not only important for findability and interoperability of the data but also enables automated data processing. This contribution introduces a workflow for data and metadata, which uses programmatic data aggregation, electronic lab notebooks, ontology-based metadata, and blockchain protocols for partly automated processing and documentation of raw data as well as quality assured data publication, respectively. The practical relevance of the suggested (meta)data workflow is demonstrated at the example of highly resolved current measurements for pulsed dielectric barrier discharges in a nitrogen-oxygen gas mixture.

This work was supported by the BMBF under grants 16QK03A, 16QK03B, 16QK03C and the DFG under grant 408777255.

P 5.6 Tue 14:00 P

Optische Manipulation von Mikropartikeln in einer kapazitiv gekoppelten Zwei-Frequenz-Entladung — •Jessica Schleitzer, Viktor Schneider und Holger Kersten — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität Kiel, Leibnizstr. 19, 24108 Kiel, Deutschland

Innerhalb der letzten Jahrzehnte wurde die Idee umgesetzt, extern injizierte, kleine Mikropartikel als nicht-invasive Sonden zu verwenden, die durch verschiedene Kräfte und Energieflüsse im Plasma beeinflusst werden. In dieser Arbeit werden optisch eingefangene Mikropartikel in einer optischen Pinzette verwendet, um die Randschicht einer Zwei-Frequenz-CCRF-Entladung zu untersuchen. Diese Entladung ist vornehmlich für ihre Besonderheit bekannt, den Ionenfluss und die Ionenenergie getrennt und unabhängig voneinander unter Ausnutzung elektrischer Asymmetrien im Plasma zu beeinflussen. Die Messgröße, welche bei der Verwendung optischer Pinzetten von besonderer Bedeutung ist, ist die äußere Kraft, die auf die Mikrosonde einwirkt. Diese erhält man, indem die Verschiebung des Partikels in der optischen Falle gemessen wird, während die eingefangene Mikrosonde durch das Plasma und die Randschicht und damit relativ zur Entladung bewegt wird. Anhand der erhaltenen Kraftprofile wird die Stärke der elektrischen Feldkraft in der Randschicht in Abhängigkeit vom Druck, sowie die Abhängigkeit vom Abstand der Mikrosonde zur HF-Elektrode und die Ausdehnung der Randschicht bestimmt. Dies wird sowohl für eine Ein- als auch für eine Zwei-Frequenz-Entladung geprüft.

P 5.7 Tue 14:00 P

Ion flux measurements in an expanding H_2 plasma utilizing a Mach probe — •Vinzenz Wolf[1], David Rauner[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Density gradients and electromagnetic fields in a low pressure plasma lead to a particle flux. In order to determine the orientation and the magnitude of the ion flux, a mach probe can be used, which typically consists of a specifically arranged set of differently orientated contacts with a limited collection angle. Using the ratio of currents measured with two opposed contacts, the ion flux direction and ion velocity (i.e. the Mach number) can be calculated, the latter relying on models for calibration factors. These are used to describe the influence of the plasma parameters on the ion flow towards the probe and are thus valid for a certain set of plasma parameters.

For characterization purposes a four pin mach probe is used in a cylindrical ICP discharge (1 MHz, 2 - 8 Pa, 200 - 800 W), consisting of a quartz glass tube (Ø 9 cm) where a hydrogen plasma is generated and expands into a stainless steel chamber (Ø 32 cm). The ion flux is determined in a two-dimensional section perpendicular to the cylinder axis of the plasma vessel. The influence of a variation of gas pressure and RF power on the ion flux is investigated, as well as plasma drifts induced by applying an external magnetic field in the expansion region.

P 5.8 Tue 14:00 P

Nitrogen-doped $NiCo_2O_4$ on carbon paper as a self-supported air cathode for Rechargeable Zn-air batteries — •He Li, Jan Benedikt, and Sadegh Askari — Institute of Experimental and Applied Physics, Kiel University, Germany

A noble-metal-free bifunctional oxygen evolution/reduction catalyst with outstanding activity and stability is of great importance for the development of rechargeable Zn-air batteries. $NiCo_2O_4$, a typical spinel oxide, is considered as one of the most promising bifunctional catalyst, but the electrocatalytic performance of this material is still unsatisfactory due to its poor conductivity and low surface area. Herein, we report an effective way to fabricate nitrogen-doped $NiCo_2O_4$ on carbon paper as a binder-free air cathode for rechargeable Zn-air batteries. After nitrogen plasma treatment, this modified material exhibits higher electrocatalytic performance than pristine $NiCo_2O_4$ because of the enhanced conductivity and more active sites. Both the liquid-state and the flexible all-solid-state Zn-air batteries with engineered nitrogen-doped $NiCo_2O_4$ show high operating potentials and excellent stability. This work provides an efficient and reliable approach for the modification of self-supported catalysts, thereby contributing to the development of rechargeable Zn-air batteries.

P 5.9 Tue 14:00 P

ZrO2 based layers investigated by the 3ω method — •Vitali Bedarev, Philipp A. Maass, Marina Prenzel, Marc Böke, and Achim von Keudell — Experimental Physics II, Bochum, Germany

Aim of the project is to develop a diagnostic technique to measure the thermal conductivity of thin ZrO2 layers which are deposited via PECVD and can be used for galvanic isolation. The 3ω method was selected as a surface-sensitive technique with high accuracy and short equilibration time. This method can be applied to bulk amorphous solids and crystals as well as to amorphous films tens of microns thick. A thin electrically conductive wire is deposited onto the specimen to measure its thermal conductivity. The wire serves both, as a heater and as a temperature sensor. Joule heating at a 2ω frequency occurs when an ac current with angular modulation frequency ω is applied to the wire. The generated thermal wave diffuses into the specimen. This causes a modulation of the resistance at 2ω due to the temperature dependence of the resistance. The voltage drop along the wire contains a contribution from a third harmonic that depends on the modulated temperature rise of the heater and could be used to calculate the thermal conductivity of the sample. We will present the setup, its characterization by using reference samples and first results on ZrO2 layers and the influence of the structure and morphology of these layers on the thermal conductivity.

P 5.10 Tue 14:00 P

Terahertz time-domain spectroscopy as a novel plasma diagnostic — •Jente Wubs, Klaus-Dieter Weltmann, and Jean-Pierre van Helden — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

In non-thermal plasmas, electrons determine, to a large extent, the plasma chemical behaviour, meaning that electron density measurements are crucial for understanding plasma chemical phenomena. In the case of low-pressure plasmas, Langmuir probes are commonly used for determining electron-related plasma parameters. However, at atmospheric pressure, these probes can no longer be reliably used due to their perturbative characteristics. Terahertz time-domain spectroscopy (THz-TDS) is a novel diagnostic technique for spectroscopic investigations of plasma densities, independent of the pressure. This technique requires ultrafast femtosecond laser pulses for the generation and detection of a broadband electromagnetic signal in the THz range. The signal is sampled in the time-domain using the principle of asynchronous optical sampling (ASOPS) and is subsequently Fourier transformed to obtain spectral information, with a resolution of 1 GHz. This approach allows for electron density measurements with high temporal resolution, whilst simultaneously yielding information on molecular densities within the plasma. This contribution explains the working principle of ASOPS-based THz-TDS. In addition, an exploratory characterisation of the experimental setup will be presented, including an overview of the possibilities and limitations for measuring with spatial resolution.

P 5.11 Tue 14:00 P

Quenching microwave plasmas via gas injection into the effluent: Effects on the conversion of CO_2 — •Christian Karl Kiefer[1], Ante Hecimovic[1], Federico Antonio D'Isa[1], and Ursel Fantz[1,2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]University of Augsburg, 86159 Augsburg, Germany

Negative-emissions technologies are required to reach the goal of the Paris Agreement that limits the global mean temperature increase to a maximum of 1.5°C. A plasma torch powered by 2.45 GHz microwaves offers a unique possibility to be used as a power-to-gas technology and thermally dissociate CO_2 into carbon monoxide and oxygen at high energy efficiencies. Very fast cooling of the plasma is essential to prevent recombination reactions towards CO_2, thereby maintaining the degree of conversion. For this purpose, an extension for the microwave plasma torch was developed that allows one to inject colder (room temperature) gases into the effluent of the plasma via four radial gas inlets. Experiments with atomic (He or Ar) as well as molecular (N_2 or CO_2) gas admixture were performed in the pressure range of 100 mbar up to atmospheric pressure, covering regimes of diffuse plasma as well as regimes of contracted plasma. The conversion of CO_2 was measured by the application of a mass spectrometer. To further characterize the setup, optical emission spectroscopy was used to determine the rotational and vibrational temperatures of the plasma.

P 5.12 Tue 14:00 P

Electrical characteristics of a coaxial dielectric barrier discharge for CO2 splitting at elevated pressure — •Rezvan Hosseini Rad, Milko Schiorlin, Michael Schmidt, Volker Brüser, and Ronny Brandenburg — Leibniz Institute for plasma science and technology, Greifswald, Germany

CO2 splitting using nonthermal plasmas is investigated for CO2 utilisation into valuable chemical compounds like methanol. In this work, an asymmetric, coaxial dielectric barrier discharge reactor for CO2 decomposition into CO is investigated. Beside the operation at atmospheric pressure, the effect of an increase up to 1.6 bar is studied. At first, the operation parameters for a full discharging in the reactor has to be carried out to keep the operating voltage amplitude moderate (below 10 kV) at elevated pressures. So, the electrical characteristics of the plasma reactor with three different inner electrode materials (stainless steel, copper, and aluminium) and with the addition of argon as an inert, electropositive gas with lower breakdown voltage than CO2 are studied in detail, and correlated with the CO formation. The discharge power, effective capacity, burning voltage, and area fraction covered by plasma in the reactor are determined by voltage-charge plots. The addition of Ar to CO2 (ratio Ar:CO2 =4:1) reduces the sustaining voltage and enables full plasma coverage in the reactor with voltage amplitudes below 10 kV even at the highest pressure. Increasing pressure or decreasing the argon admixture decreases the current peaks intensity as well as the discharge power. Stainless steel shows higher CO2 conversion, but copper shows higher CO generation.

P 5.13 Tue 14:00 P

Cold Atmospheric Plasma Sterilization for Planetary Protection — •Alisa Schmidt[1], Meike Müller[2], Markus H. Thoma[1], and Hubertus Thomas[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Germany — [2]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt e.V., Oberpfaffenhofen, Germany

In the search for extraterrestrial life, decontamination of the surface of spacecraft and lander is of great importance. Since currently used methods - dry heat and hydrogen peroxide - are effective but material damaging for sensitive surfaces, in this contribution the application of cold atmospheric surface micro-discharge (SMD) afterglow plasma sterilization for spacecraft decontamination was investigated. Inactivation tests were performed with Bacillus atrophaeus spores on stainless steel carriers placed at the bottom of stainless steel tubes with varying heigths and diameters. It could be shown, that spore inactivation was achieved inside the tubes but much slower than outside at a treatment time of 60 min. Furthermore, the height of the diffusion barriers did not result in significant differences in inactivation rates but with increasing diameter the sporicidal effect increased respectively. By operating a fan to circulate the gas in the treatment chamber, higher inactivation rates could be achieved at unchanged treatment times. Moreover, it could be demonstrated, that the method of applying spores to the sample carrier influences the inactivation rate of the plasma treatment.

P 5.14 Tue 14:00 P

RF-atmospheric pressure plasma jets as a source of vacuum-UV photons for photoionisation — •Natascha Blosczyk[1], Tristan Winzer[1], Judith Golda[1,2], and Jan Benedikt[1] — [1]Institute for Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]current address: Experimental Physics, Ruhr-Universität Bochum, Bochum, Germany

Vacuum-UV(VUV) radiation has great use, not only as a means of analysing gas mixtures by their emission and absorption spectra, but also as a way to induce chemical reactions in a target gas. Therefore, the aim of this work is to study VUV-radiation of different atmospheric plasma sources and develop a way to efficiently use it for photoionisation at atmospheric pressure. The VUV-radiation of helium and helium/argon plasmas with excimer continua and line-radiation is measured by VUV-spectroscopy in the 60 to 200 nm range as function of the input power and admixture of different reactive gases.

Acetylene is used as a model precursor to investigate the use of VUV-photons for photoionisation and follow-up chemistry, where the generated primary ions and ions formed in the polymerization reactions are detected by positive ion mass spectrometry. The VUV-generation in the plasma is separated from the diluted acetylene gas via a controlled gas flow. To further study the effects of the photons on the chemistry, the FTIR-spectrometry will be used to study the properties of deposited thin films from the VUV-photon activated gas mixture.

P 5.15 Tue 14:00 P

Self-similar expansion of a plasmoid supplied by pellet ablation — •Alistair Arnold, Pavel Aleynikov, and Per Helander — Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald

Cryogenic pellet injection is an important means of refuelling and terminating fusion plasmas, with fuel pellets exhibiting a range of phenomena beneficial to confinement and the energy balance between ions and electrons. We consider the self-similar expansion along magnetic field lines of the plasmoid produced by a small pellet. In particular, we consider the case when the expansion timescale is comparable to the time taken for the pellet gas cloud to cross a field line. It is shown that plasmoid ions acquire a significant fraction of the energy that is transferred to plasmoid electrons via collisions with the ambient plasma. This expansion is insensitive to the details of the profile of the gas cloud and details of ionisation - the plasma flux emerging from the gas cloud is the only quantity that affects the expansion.

P 5.16 Tue 14:00 P

Linear MHD stability analysis of pedestals in magnetically perturbed tokamak equilibria — •Jonas Puchmayr[1,2], Mike Dunne[2], Erika Strumberger[2], and Hartmut Zohm[2] — [1]Department of Physics, Ludwig-Maximilians-Universität, Schellingstr. 4, 80799 München, Germany — [2]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

In the regime of high confinement (H-mode), a region of self-organized suppression of turbulent transport at the plasma edge forms resulting in steep gradients of pressure, temperature and density evolve. The edge gradients provide free energy for a new type of instability, Edge Localized Modes (ELMs). These instabilities are well-described by linear MHD and can be identified as coupled peeling-ballooning modes. Experimentally, ELMs cause large quasi-periodic bursts of particle and energy loss, that will lead to severe damage in future fusion devices. For this reason, control of ELMs is inevitable for H-mode operation in future machines. Resonant magnetic perturbation (RMP) fields are observed to mitigate or suppress ELMs. These perturbation fields break the axisymmetry of tokamak equilibria, resulting in weakly 3D configurations.

In this work, the code CASTOR3D is used to study (non-)ideal MHD stability of weakly 3D tokamak equilibria. Toroidal mode coupling is observed and the ideal MHD energy functional, which is newly implemented in CASTOR3D, is used to analyze the eigenfunctions and understand the change that the 3D structure has on stability.

P 5.17 Tue 14:00 P

Challenges and expectations for the magnetic diagnostics during high-performance experiments at Wendelstein 7-X — •K Rahbarnia[1], S Vaz Mendes[1], J Schilling[1], H Thomsen[1], J Schmitt[2], M Khokhlov[1], T Bluhm[1], B B Carvalho[3], M Zilker[1], and Wendelstein 7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Auburn University, Auburn, AL, USA — [3]Instituto de Plasmas e Fusao Nuclear Instituto Superior Tecnico, Lisbon, Portugal

During the last experimental campaign at the Wendelstein 7-X stellarator the magnetic diagnostics were successfully operated. That involves equilibrium sensors, such as Rogowski coils, diamagnetic and saddle loops as well as Mirnov coils. The latter were used to study magnetohydrodynamic activity, which was mainly found within the frequency range up to 400 kHz and is of Alfvénic nature. Identifying their driving mechanism is crucial to understand the influence on plasma confinement properties. The measured data of the equilibrium sensors are suitable for equilibrium reconstructions, which are also relevant for the previously mentioned studies. In addition plasma energy and current measurements are directly embedded in machine safety systems, like the plasma heating interlock, and will in future campaigns also be integrated in the quench detection system. Fast and potentially critical plasma collapses are tracked and the impact on the main magnetic field coil system can be analysed. For future high-performance experiments electrical and mechanical improvements were implemented including an upgrade of the DAQ systems.

P 5.18 Tue 14:00 P

Characterization and driving mechanisms of dominant Alfvén eigenmodes at the W7-X Stellarator — •Sara Vaz Mendes, Kian Rahbarnia, Christoph Slaby, Thomsen Henning, Jonathan Schilling, Christian Brandt, Matthias Borchardt, Ralf Kleiber, and Axel Könies — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Electromagnetic Alfvén waves are often present in different scenarios of the W7-X stellarator plasmas. Induced magnetic fluctuations (between 100-450 kHz) were observed for 727 discharges during different magnetic configurations, heating scenarios and general plasma parameters. The measurements were performed using a system of 125 Mirnov coils, located in four out of five modules of W7-X.

The Alfvénic nature is proven through the scaling of dominant magnetic fluctuation frequencies with the plasma density. In addition, the correlation of the observed Alfvénic activity with different plasma parameters is being analyzed.

In the future operation of W7-X a bigger population of energetic particles (EPs) is expected and the possible resonant wave-particle transport of EPs must be avoided since it can result in degradation of plasma confinement or even damaging of plasma facing components. To better understand these risks the conditions for enhanced Alfvénic activity at W7-X are studied and possible driving mechanisms are discussed.

P 5.19 Tue 14:00 P

Development of a model based early heating advanced scenario for ASDEX-Upgrade — •Raphael Schramm, Alexander Bock, Maximilian Reisner, Jörg Stober, Hartmut Zohm, and The ASDEX Upgrade Team — Max-Planck Institut für Plasmaphysik, Garching, Germany

Advanced Tokamak scenarios offer improved stability, confinement and pulse length compared to standard scenarios due to an increase of the plasma's bootstrap current ($j_{bs} \propto q\nabla p$). They are accessed by manipulating the safety factor profile q through external actuators, which can be applied during the current ramp-up (early heating), or after an equilibrium is reached (late heating). The former allows for a longer discharge and more varied current distributions, but due to the volatility of the early plasma, creating such a scenario experimentally, with feed-forward control usually takes a lot of trial and error.

To combat this, a model, capable of predicting the plasma response to actuator changes with reasonable accuracy and a run-time of only a few minutes, has been developed in the transport code ASTRA. It includes Gyro-Bohm based core transport, edge transport according to a recently developed scaling law as well as the L/H-transition based on the heating power at the separatrix. Multiple fitting factors have been scaled according to a set of reference discharges and a good agreement between simulation and experiment has been achieved.

Using this model, an advanced scenario with early heating and an elevated q-profile has been developed and successfully tested at ASDEX-Upgrade.

P 5.20 Tue 14:00 P

Statistical analysis of confinement data from pellet fueled high-density plasmas in ASDEX Upgrade — •Tobias Engelhardt[1], Peter Lang[2], Martin Prechtl[1], and ASDEX Upgrade Team[2] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmaphysik

A dataset of pellet-fueled discharges in the high density regime of ASDEX Upgrade (AUG) has been collected, covering 8 years of operation. It comprises scenarios with moderate performance, as well as attempts to achieve high performance by applying either N-seeding or high shaping. This data show that the H06 scaling [1] is more appropriate to describe plasma confinement in this regime, than the H98(y,2) scaling [2]. Additionally, the enhanced confinement gained by the different methods cannot be maintained when the density n_e exceeds the Greenwald density n_{Gw}.

According to observations at JET (with carbon wall), see e.g. [3], higher H-factors (H98(y,2)) at constant n_e/n_{Gw} were observed when the triangularity δ was increased. Whether this trend is also present at AUG (with tungsten wall and- divertor) will be investigated. The reduction of confinement when exceeding n_{Gw} can possibly be attributed to a rising separatrix density $n_{e,sep}$. The assumption that primarily the divertor density n_0^{Div} influences $n_{e,sep}$, may turn out to be too shallow. Therefore, potential other correlations between $n_{e,sep}$ and several other plasmaphysical parameters are planned to be analysed.

[1] Johner, FST **59** (2011), 308; [2] IPB, NF **39** (1999), 2175;
[3] Mukhovatov, PPCF **45** (2003), A235

P 5.21 Tue 14:00 P

Effects of thin surface oxide films on deuterium uptake in self-damaged tungsten - Evidence for permeation barrier effect — •Kristof Kremer[1,2], Thomas Schwarz-Selinger[1], and Wolfgang Jacob[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Deutschland — [2]Physik-Department E28, Technische Universität München, 85747 Garching, Germany

In a fusion reactor, the uptake of deuterium (D) and tritium fuel into the plasma-facing tungsten (W) components is a critical issue with respect to fuel loss and radioactive inventory. However, the possible influence of natural surface oxides on the D uptake in W is not fully understood yet.

Therefore, we investigated the D uptake in W through 33 and 55 nm thick oxide films. To trace the D, a 2 μm thick layer of self-ion-damaged W was created underneath the oxide. It acts as a getter layer and traps any D that permeates the oxide film. The sample was then exposed to a "gentle" D plasma (<5eV/D ion) at 370 K to a fluence of 10^{24} D/m^2. We measured the depth-resolved concentration of D and oxygen with nuclear reaction analysis and Rutherford backscattering spectroscopy and the surface modifications of the oxide film with scanning electron microscopy.

We observed a strong influence of surface oxide films on D uptake, i.e., the oxide films completely block D uptake into metallic W, although high D concentrations were found in the oxide film itself. We explain this by the difference in the heat of solution between W oxide and metallic W.

P 5.22 Tue 14:00 P

Comparing ion energy distributions of a symmetric capacitively coupled plasma with 1D-PIC/MCC simulations: an alternative approach to estimate γ coefficients? — •Christian Schulze[1], Zoltán Donkó[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Center for Physics, Hungary

Secondary electron emission (SEE) is an important effect since it directly influences not only the plasma ignition but also the plasma properties. Changes in plasma properties can be utilized to estimate SEE coefficients under realistic conditions for example from the I-V-characteristics of magnetron discharges [D Depla et al 2008 J. Phys. D: Appl. Phys. **41** 202003]. But plasma density, plasma potential and sheath thickness also have an impact on the ion transport through the sheath and on the ion energy distribution function (IEDF). Here, we critically

discuss potentials and challenges of using energy resolved ion mass spectrometry measurements of IEDFs and their comparison to 1D-PIC/MCC simulations for the estimation of SEE coefficients.
Two identical symmetric capacitively coupled plasma (CCP) electrodes are coated with Al and Al_2O_3, respectively, to investigate the impact of changed surface properties on the IEDF of Ar^+ ions. Since pressure, electrode distance and neutral gas temperature can have a similar impact on the IEDF as the SEE coefficient, their impact on the IEDFs need to be analyzed and they need to be determined with sufficient precision to avoid systematic errors.

P 5.23 Tue 14:00 P

Optimisation and characterisation of an ion-beam-driven permeation experimental setup — •Philipp Sand[1,2], Armin Manhard[1], Rodrigo Arrendondo Parra[1], and Udo von Toussaint[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Technical University Munich, 85748 Garching, Germany

Hydrogen permeability is an important property for many materials in future technologies such as, e.g., nuclear fusion. One method to determine permeation properties is to implant deuterium ions from a mass-filtered ion beam with a well-defined flux and energy into a sample foil. At the rear side of the foil, the effusion flux of the permeating species is then measured by a quadrupole mass spectrometer. The ion optics of such a setup is characterised for a 4.7 keV D_3^+ ion beam. The ions are decelerated by the sample bias voltage to implantation energies of 500 eV per D. The settings are optimised in order to obtain a high ion current to reach reasonable signal intensities and affordable experiment times. Another goal for the optimisation is to minimise the flux of charge exchange neutrals, which are created in the beamline. They will not be decelerated by but impinge on the sample with their full energy. They lead to degradation of the sample material due to displacement damage and sputtering and can also affect the permeation signal. The neutral fraction can potentially be minimised by electrostatically deflecting the beam after passing the volume of highest neutral generation rate. Photographs of the beam footprint are obtained using ion-induced fluorescence on a quartz plate.

P 5.24 Tue 14:00 P

Spectroscopic investigation of W7-X detachment induced via nitrogen seeding — •Frederik Henke, Maciej Krychowiak, Ralf König, Felix Reimold, Dorothea Gradic, and Thomas Sunn Pedersen — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

As power exhaust is one crucial aspect of a future fusion power plant, dissipation of the localized heat fluxes striking the divertor is needed. The regime, in which a large fraction of the input power is radiated isotropically into full solid angle while the peak heat- and particle-fluxes to the target are strongly reduced, is called detachment.
Stable detachment is accessible via two different paths in the island divertor of W7-X. First, increasing the density via hydrogen fueling can lead to the transition into the detachment regime with carbon as the intrinsic impurity being the main radiator. Because in a future power plant carbon will not be used at any first wall components due to strong tritium retention, extrinsically seeded low-Z impurities are investigated as the second way to reach detachment.
In this work nitrogen seeding experiments are analyzed applying a spectroscopic line-ratio model of singly ionized nitrogen to measure the local plasma parameters electron density n_e, electron temperature T_e and impurity concentration c_Z. From the analysis of data acquired in the previous operation campaign possible upgrades of the diagnostic, as well as extensions of the physics model to i.e. analyse carbon radiation are explored.

P 5.25 Tue 14:00 P

Determination of (quasi) coherent mode properties at the edge of improved confinement plasmas — •Joey Kalis[1,2], Gregor Birkenmeier[1,2], Michael Griener[2], Peter Manz[3], Takashi Nishizawa[2], Luiš Gil[4], and Ulrich Stroth[1,2] — [1]Physik-Department E28, TUM, Garching — [2]Max-Planck-Institut für Plasmaphysik, Garching — [3]Institut für Physik, Universität Greifswald, Greifswald — [4]Instituto de Plasmas e Fusão Nuclear, Universidade de Lisboa, Lisboa, Portugal

For future reactors based on the tokamak concept, it is necessary to establish the high confinement modes without type-I ELMs. In the past years, several natural ELM-free operation scenarios, such as the EDA H-mode, the I-mode and the QH-mode, have been achieved in ASDEX Upgrade. Each scenario is characterized by the appearance of quasi coherent fluctuations at the plasma edge, which may be responsible for the stabilization of the ELMs. For the comparison with theory, it is important to analyze the properties of all edge modes in more detail to identify their underlying driving forces and outline possible similarities and differences. The first focus is on the quasi-coherent mode (QCM), being present in the EDA H-mode. Due to its high spatial and temporal resolution, the He-beam diagnostic is used to outline different QCM properties. First, a time series analysis is performed to investigate the interaction of the QCM with other modes and general plasma parameters. Second, the propagation velocity and the wavenumber of the QCM is determined by means of spectral methods and compared with theoretical predictions.

P 5.26 Tue 14:00 P

Characterization of lanthanum-hexaboride electron emitters as cathodes in pressure gauges for strong magnetic fields — •Bartholomaeus Jagielski, Uwe Wenzel, Mirko Marquardt, Jiawu Zhu, and Thomas Sunn Pedersen — Max Planck Institute for Plasma Physics, Greifswald, Germany

In order to evaluate the particle exhaust rate at the sub-divertor, the neutral gas pressure can be measured. In the last operation phase (OP 1.2) of the Wendelstein7-X (W7-X) nine newly developed Crystal Cathode Pressure Gauges (CCPG) were tested during pressure recordings. While cathodes from thoriated tungsten regularly bent under the influence of the j x B forces (2,1T), the CCPGs, equipped with emitters made of lanthanum hexaboride, functioned satisfactorily[1]. The LaB_6 cathodes of the CCPGs have a simple geometry and due to the low work function of 2.5eV, the heating current was reduced to 2-3 A in W7-X in hydrogen atmosphere, whereby the stress under Lorentz forces was further reduced[2]. This makes the LaB_6-emitter a promising candidate for precise manometers in a range between 10^{-6} and 1mbar and an application in future fusion plants (ITER, DEMO).

Recently three different cathode designs have been tested in different environmental conditions and compared: a 8mm and a 6mm long cathode, and a new 2-emitter design. Results of the investigations within an external magnetic field of 3T, latest optimization and future plans for the CCPGs are presented.

[1] U. Wenzel et al, J. Instrum.12(09), C09008 (2017).
[2] U. Wenzel et al, Rev. Sci. Instrum., 90, 123507 (2019).

P 5.27 Tue 14:00 P

Reduced transport models for a Tokamak flight simulator — •Marco Muraca, Emiliano Fable, Clemente Angioni, Hartmut Zohm, and Teobaldo Luda — Max-Planck-Institut für Plasmaphysik, 85748, Garching bei München, Germany

A Tokamak flight simulator is a tool to predict the plasma behavior of a scheduled discharge, such that either actuator trajectories or plasma parameters satisfy the experimental goals, and to reduce probability of plasma disruptions and crossing of operational limits. It is based on the interaction between control system, plasma equilibrium and transport. The transport models have to be physics based to be reliable, but also fast to be used as an inter-discharge prediction tool. This compromise can be reached employing analytical models which are derived from first principle theories. An integrated model including every plasma region has been developed. The confined region is modeled in 1D, while the scrape-off-layer has a 0D structure. For the core region, a normalized temperature gradient threshold model has been adopted, while for the edge an average ELM model has been used. In the SOL a 2-point model for exhaust and a particle balance for the separatrix density have been implemented. Most of the models have been validated against several stationary cases, by fixing some parameters as boundary conditions and matching experimental data, exploiting the modular structure of the integrated model. For the confined region a first experimental case has been matched by using both core and edge models. Fully integrated simulations during ramp-up, flat-top and ramp-down are planned for the future.

P 5.28 Tue 14:00 P

Structure-property relations for thin drawn tungsten wires — •Maximilian Fuhr[1,2], Bailey Curzadd[1,2], Batuhan Sancak[1,2], Till Höschen[1,2], Martin Balden[1], Wolfgang Pantleon[3], Jürgen Almanstötter[4], Johann Riesch[1], and Rudolf Neu[1,2] — [1]Max-Planck-Insitut für Plasmaphysik, Garching, Deutschland — [2]Technische Universität München, Garching, Deutschland — [3]Technical University of Denmark, Lyngby, Dänemark — [4]OSRAM GmbH, Schwabmünchen, Deutschland

Tungsten (W) shows a ductile-to-brittle transition and fractures brittle below, but ductile above a certain transition temperature. This transition temperature, which is far above room temperature for coarse-grained W, can be shifted towards lower temperatures by wire drawing or other working processes. Wires drawn to very small diameters can deform ductilely at room temperature. The correlation between plastic deformation and the shift of the transition temperature is not fully understood, but the microstructure is thought to play a crucial role. In order to gain further insight into the open question of the enhanced ductility of worked tungsten, we investigated the mechanical properties (via uniaxial tensile testing) and microstructure (by EBSD) of four chemically identical wires drawn to diameters between 16 μm and 490 μm. Thorough quantitative analysis reveals the strong influence of the particular microstructure of the wires consisting of highly elongated grains with strong {110} fiber texture on their mechanical behavior and allow for formulating structure-property relations.

P 5.29 Tue 14:00 P

Heat conduction simulation in plasmas with magnetic field lines of mixed topology — •Gregor Pechstein, Brendan Shanahan, and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Fusion devices must dissipate heat before it reaches the plasma-facing components. For this purpose the W7-X stellarator relies on a chain of magnetic islands close to the plasma edge channelling the plasma to a divertor. Detachment, a scenario in which energy is radiated due to collisions with neutrals, is a promising method for reducing heat flux onto the divertor. First divertor experiments on W7-X exhibit stable detachment, whose main features are reproduced by the EMC3-Eirene edge transport code. With an increase in the radiated power fraction the position of the radiation front approaches the X-point and the separatrix of the magnetic islands. Here we seek to understand the stability and position of the detached radiation front using a heat conduction model. In contrast to 1-d analytical heat conduction models used in Tokamak divertors, perpendicular transport cannot be ignored in the islands of W7-X. The importance of transport perpendicular to the magnetic field is due to the long connection lengths in the islands. Accordingly, we perform 2-d heat conduction simulations in slab geometry with an island. These simulations employ a simplified radiation function as a heat sink. Depending on the parameter varied the radiation front exhibits different patterns and stability. Concomitant to the simulations, analytical limits of the parameter space are investigated. The implications for stable detachment in W7-X will be discussed.

P 5.30 Tue 14:00 P

PIC-Simulations of Perpendicular Collisionless Shocks in Multiple-Ion GRB Plasmas — •Jonas Graw, Martin Weidl, and Frank Jenko — Max Planck Institute for Plasma Physics

Ultra-high-energy cosmic rays (UHECRs) are electrically charged particles, which move throughout the universe with energies greater than about 1 EeV. Understanding where and how these particles are created, i.e., unravelling the nature of cosmic accelerators, is one of the biggest challenges in present-day astrophysics. One likely source of UHECRs are gamma-ray burst (GRBs). The latter eject gas parallel to the axis of rotation with high velocities. Shocks are formed in these jets, in which particles are believed to be accelerated to extremely high velocities. Due to such high energies, protons and neutrons fuse to alpha particles. In our research, we simulate an astrophysical plasma consisting of multiple ion species in a mildly relativistic shock. Presently, we examine both real and phase space and we explore how the highest energetic particles behave in such a plasma. We analyze different modes that both come from analytical considerations and simulations. Particularly interesting are the modes that do not exist in an electron-proton plasma. The acceleration of UHECRs is thereby strongly connected to particle-wave interactions inside the plasma. In our analysis, we deepen the understanding of the nature of possible acceleration mechanisms.

P 5.31 Tue 14:00 P

Current Filamentation Instabilities of Proton Beams in Proton Driven Wakefield Accelerators — •Erwin Walter[1], Martin S. Weidl[1], John P. Farmer[2,3], Patric Muggli[2], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Max Planck Institute for Physics, 80805 Munich, Germany — [3]CERN - 1211 Geneva 23 - Switzerland

Plasma wakefield accelerators can generate electric-field gradients magnitudes larger than conventional accelerators. Using this technology, particle-physics experiments could be performed in much more compact devices.

The Advanced Wakefield Experiment (AWAKE) is a proof-of-concept proton-driven wakefield accelerator located at CERN. Seeded self-modulation, a controlled excitation of the longitudinal self-modulation instability, is exploited to modulate the proton bunch into a train of multiple smaller bunches along its axis. However, for alternative beam parameters, the electromagnetic Weibel-like beam filamentation instability could result in magnetic field amplification, perpendicular scattering, emittance growth and possibly even the formation of a collisionless shock.

Our research investigates which beam parameters are required for filamentation to dominate and whether this parameter regime is accessible to the AWAKE experiment. We present and compare results of linear theory, quasi-static simulations and full-PIC simulations.

P 5.32 Tue 14:00 P

Generalized Fluid Models for Edge Turbulence Simulations — •Christoph Pitzal, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

Fluid models are a useful tool for simulations in the field of Plasma Physics. On the one hand, fluid models are less computationally intense than kinetic models. On the other hand, the models have limited predictive capabilities, since not all effects are captured, that are necessary to simulate a fusion device sufficiently. The effects which are not contained are primarily kinetic effects, which are lost due to the missing velocity space, e.g. Landau damping. Every fluid model introduces a hierarchy of moments, which connects a fluid moment with the next higher one and needs to be closed for the model to become applicable. Models with a collisional closure, as the Braginskii model [1], significantly overestimate for example the parallel heat conductivity due to the absence of Landau damping. By using particular closure approximations instead of the commonly used collisional closure the model can mimic certain kinetic effects, as first shown with Landau damping in [2]. The scope of this project is to study different kinetic effects and their applicability for current plasma fluid codes, such as GRILLIX [3]. Further steps will be the implementation of such a model and to compare the increase of fidelity and computational effort. [1] S. Braginskii and M. Leontovich Reviews of plasma physics, 1965. [2] G. W. Hammett and F. W. Perkins Phys. Rev. Lett., vol. 64, pp. 3019-3022, Jun 1990. [3] A. Stegmeir, A. Ross, T. Body, et al. Phys. Plasmas, vol. 26, p. 052517, 2019.

P 5.33 Tue 14:00 P

TALIF on H_2 Plasmas in Preparation of its Usage for Negative Ion Sources — •Frederik Merk, Christian Wimmer, Stefan Briefi, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Garching, Germany

Two-photon absorption laser induced fluorescence (TALIF) offers the possibility to measure both the velocity distribution function and the density of ground state H atoms in H_2 plasmas. Here, the atoms are excited via the simultaneous absorption of two photons followed by the emission of fluorescence which is used for diagnostic purposes. In order to generate the necessary 205.08 nm photons, a pulsed, frequency tripled dye laser is employed. In addition to the complexity of such an instrument, the diagnostic as a whole needs to be characterized thoroughly and calibration is necessary. This was done at a planar ICP where a 600 W, 13.56 MHz RF generator is used to drive H_2 plasmas. Here, TALIF is supplemented by optical emission spectroscopy on the Balmer lines and the molecular Fulcher-α transition in order to determine basic plasma parameters. The measurement results of scanning gas pressure and RF power coupled to the plasma are presented in this contribution. They are used to gain insight into the particle reactions taking place in the plasma. In addition, the implementation of TALIF at the H^-/D^- ion source BATMAN Upgrade is prepared from the knowledge that was gained at the ICP.

P 5.34 Tue 14:00 P

Performance of neutral pressure gauges using LaB6-emitters in deuterium plasmas — •Victoria Haak[1], Uwe Wenzel[1], and Gen Motojima[2] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]National Institute for Fusion Science, Toki, Japan

Neutral pressure gauges using a LaB6-crystal as an emitter, an advanced type of neutral pressure gauge optimized for the use in high magnetic fields are used to measure the neutral gas pressure in fusion experiments. They were successfully operated in hydrogen plasmas in Wendelstein 7-X (W7-X) during OP1.2b [1]. Due to the low heating current of 2-2.5 A, LaB6 neutral pressure gauges present a promising concept for measurements of the neutral gas pressure in future fusion devices. Two LaB6-neutral pressure gauges were installed and tested in the Large Helical Device for the last two campaigns in order to study the effect of neutrons on the electron emission properties of LaB6.

Both crystals showed stable electron emission during operation in hydrogen and helium atmosphere and were operated at a low heating current of 1.7 A. One of the emitters experienced an increase of the heating current from 1.7 to 4 A during deuterium operation. Apart from damage to the crystal, the neutral pressure gauge cannot be reliably used for measurements once the heating current reaches a given limit. As stability of the emission properties is essential for the use of LaB6 in neutral pressure gauges, degradation of the emission properties is studied in this contribution, in particular the role of neutron damage.

[1] U. Wenzel et al, Rev. Sci. Instrum., 90, 123507 (2019).

P 5.35 Tue 14:00 P

Generic Determination of Rotating and Locked MHD Mode Amplitudes on ASDEX Upgrade — •Felix Klossek, Marc Maraschek, Anja Gude, Hartmut Zohm, Louis Giannone, and the ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

When approaching a disruption in tokamaks, the plasma typically becomes unstable regarding a tearing mode which locks to the vessel. For the disruption to occur, multiple phase-locked tearing modes with different poloidal mode numbers m are considered necessary for producing a thermal shortcut by stochastisation. For rotating modes it has been possible for a long time to differentiate between different poloidal mode numbers at ASDEX Upgrade. Similar observations for locked modes could not be made until now, as the pick-up coils used for rotating modes rely on induction. The saddle coils used for locked mode detection are located at only one poloidal position on the high field side and therefore cannot resolve the poloidal mode numbers m.

A new method for evaluating magnetic mode signals, in particular the mode amplitude and phase, by projecting the signals on appropriate sine and cosine base vectors with the desired mode number is introduced. With this method, no compute intensive FFT algorithms are needed. For detecting the poloidal mode structure of locked modes for the first time the inactive RMP coils at ASDEX Upgrade are used in addition to the locked mode detector. It is shown that the mode structure is changed during the locking phase prior to the disruption.

P 5.36 Tue 14:00 P

Fast characterization of plasma states in W7-X with permutation entropy — •Juan Fernando Guerrero Arnaiz[1,2], Andreas Dinklage[1,2], Bernd Pompe[1], Matthias Hirsch[2], Udo Höfel[2], Christian Brandt[2], Henning Thomsen[2], Jonathan Schilling[2], Kian Rahbarnia[2], Tamara Andreeva[2], Ulrich Neuner[2], and the W7-X Team[2] — [1]Universität Greifswald, Greifswald Germany — [2]Max-Planck-Institut für Plasmaphysik, Greifswald Germany

Permutation entropy (PE) is applied on time series of plasma measurements. PE is a single number that represents the information rate to derive the ordinal properties of a time series. Here, we systematically characterize, by means of the PE, highly sampled multi-variate signals from a 32-channel electron cyclotron emission radiometer. Being capable to detect changes in bulk data, core localized spatio-temporal bifurcations of the plasma states were revealed from changes of the PE. Hereby, spontaneous transitions to high core-electron temperatures (Te) were detected at different heating powers and densities in the so-called low-iota configuration of W7-X. The transitions have been seen to go along with the occurrence of low frequency MHD activity, which ceases when Te increases. It is this MHD activity which PE is sensitive to. While visual a-posteriori inspection of the (noisy) data results in similar findings, the time to identify changes is much reduced. Therefore, PE is suggested to be employed for machine learning techniques to identify plasma state changes.

P 5.37 Tue 14:00 P

Tackling turbulence in the plasma edge pedestal with a revised version of the GENE code — •L. A. Leppin, P. Crandall, T. Görler, F. Jenko, M. Cavedon, M. G. Dunne, and The ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München, Germany

A major challenge for future fusion power plants is the turbulent plasma dynamics on the microscale, which causes detrimental levels of outward transport of energy and particles. Many open questions on the properties of this dynamics remain in particular for the plasma edge pedestal, which is characterized by strong gradients of temperature and density, causing strong electromagentic fluctuations. An important approach to advance the understanding of turbulent plasma dynamics in the edge are high-fidelity simulations based on 5D gyrokinetic theory. Here we present a new modification of the well-established gyrokinetic, Eulerian, delta-f code GENE (genecode.org), which enables numerically stable global, electromagnetic simulations at high beta values. This new "f-version" utilizes a slightly different definition of the underlying distribution function. The new f-version is fully integrated into the GENE code and can e.g. make use of block-structured grids in velocity space, which lower the resolution requirements dramatically. We demonstrate the successful implementation and give an outlook with first applications of the new GENE f-version to the plasma edge. By simulating turbulence at different timepoints within an edge localized mode (ELM) of an ASDEX Upgrade discharge we contribute to the characterization of turbulence in the pedestal within an ELM cycle.

P 5.38 Tue 14:00 P

Collisional Relaxation of an Anisotropic Two-Species System as a Verification of a Simplified Fokker-Planck-Type Collision Operator — •Philipp Ulbl[1], Dominik Michels[1], and Frank Jenko[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA

Collisions have significant effects on the properties of edge and scrape-off-layer turbulence in magnetic confinement fusion devices. State of the art simulations of plasma turbulence are built on the gyrokinetic equations and require the addition of a so-called collision operator. The typical choice in a plasma, a Fokker-Planck collision operator does yield physically accurate results but also heavily impacts the computational performance of numerical codes. Therefore, it can be beneficial to use simplified Fokker-Planck-type collision operators that capture most of the physics and are faster to calculate. In this work, we present the Lenard-Bernstein/Dougherty (LBD) collision operator [1, 2] that has been implemented in the gyrokinetic turbulence code GENE-X [3]. We show a verification of the physics based on the collisional relaxation of an anisotropic electron-deuterium system. Further, we compare the results with analytical estimations and with results from a Bhatnagar-Gross-Krook (BGK) collision operator [4].

[1] A. Lenard, and I. B. Bernstein, Phys. Rev. 112, 1456 (1958)
[2] J. P. Dougherty, Phys. Fluids 7, 1788 (1964)
[3] D. Michels, et. al., Comput. Phys. Commun. 264, 107986 (2021)
[4] P. L. Bhatnagar, et. al., Phys. Rev. 94, 511 (1954)

P 5.39 Tue 14:00 P

Disruption simulations in ASDEX Upgrade with JOREK-STARWALL — •Nina Schwarz, Matthias Hoelzl, Javier Artola, Gabriella Pautasso, and Mike Dunne — Max Planck Institute for Plasma Physics, 85748 Garching, Germnay

During major disruptions or due to a loss of the control system in tokamaks, the plasma becomes vertically unstable and eddy currents are induced in the conducting structures and halo currents appear in the SOL. The magnitude of the resulting vertical forces have not been successfully extrapolated to reactor sized tokamaks yet [Hender2007]. Also, horizontal forces can appear, when the plasma shows asymmetric features that may rotate. To estimate the magnitude and the distribution of halo currents as well as the forces during disruptions the extended non-linear MHD code JOREK is used together with the electro-magnetic code STARWALL to study the evolution of halo currents and forces during disruptions and hot VDEs in ASDEX Upgrade.

In particular, the discharge #25000 the vertical control system was intentionally shut off to produce a hot VDE and has been analyzed in detail [Pautasso2011]. This shot has been modelled before in the two dimensional codes DINA [Lukash2010] and TSC [Nakamura2010] to study the halo current magnitude during disruption following the vertical displacement. The aim of this contribution is to show first 2D calculations in JOREK to validate the magnitude of the halo currents at a given halo width and temperature. This will later be used as a basis to extend the simulation to 3D and observe non-axissymmetric effects of the plasma and halo current evolution.

P 5.40 Tue 14:00 P

Transport Studies in ASDEX Upgrad via Gaspuff Modulation Experiments — •Christian Schuster[1,2], Elisabeth Wolfrum[1], Emiliano Fable[1], Rainer Fischer[1], Michael Griener[1], Clemente Angioni[1], Ulrich Stroth[1,2], and ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching — [2]Physik-Department E28, Technische Universität München, Garching

To obtain sufficient fusion power in a future reactor, the core plasma has to be hot and dense. A large part of the radial density increase occurs at the edge of the plasma. Apart from the impact on fusion power the density profile also influences many different phenomena such as the L-H transition [Shao, PPCF 2016] or the achievable pedestal top pressure. The processes that determine the edge density profile are however still not understood sufficiently to be able to extrapolate to future devices.

Apart from particle transport, which we model by diffusion and a convection called pinch, fueling of the plasma by neutral atoms contributes to the density profile. The individual contributions cannot be distinguished by analyzing stationary profiles. We therefore modulate the gas flow and analyze the plasma response measured with various diagnostics in an integrated data approach. We find that the modulation, among other effects, causes a cold pulse whose propagation into the core can only be explained by time dependent transport models.

P 5.41 Tue 14:00 P

Impurity parallel transport in ITER using improved collisional closure in the SOLPS-ITER code — •Sergei Makarov[1], D Coster[1], V Rozhansky[2], E Kaveeva[2], I Veselova[2], S Voskoboynikov[2], I Senichenkov[2], A Stepanenko[3], V Zhdanov[3], and X Bonnin[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]SPbPU, St.Petersburg, Russia — [3]MEPhI, Moscow, Russia — [4]TER, St-Paul-Lez-Durance Cedex, France

Impurity transport in the Scrape-off layer of a tokamak is a challenging problem. Impurities occur in fusion plasmas naturally, for instance helium ash as a product of the D-T reaction, and artificially, for instance noble gasses are seeded into the tokamak for additional radiation and divertor target protection. When the impurity mass is significantly larger than the mass of the main ions the multi-species extension of the single ion Braginskii approach can be applied. However, usually impurity/main ion mass ratio can not be assumed infinitely large, and the Grad's 21N-moment method should be used for the transport coefficients estimation. This approach takes into account masses of ions are present in the plasma for coefficients calculation. It is the major improvement in comparison to the previous approach applied for the SOLPS-ITER code. This approach is implemented into the SOLPS-ITER code for multiple ion parallel transport description in collisional plasmas. The change in the impurity transport behavior in ITER is studied using improved method and taking into accout masses of ions. Significant differences are found in the ion transport, where the masses of ions are not sufficiently different.

P 5.42 Tue 14:00 P

Positron accumulation in a multi-cell Penning-Malmberg trap — •Martin Singer[1], Patrick Steinbrunner[1], Stephan König[2], Matthew R. Stoneking[1], James R. Danielson[3], Lutz Schweikhard[2], and Thomas Sunn Pedersen[1,2] — [1]Max Planck Institute for Plasma Physics, Germany — [2]Institute for Physics, University of Greifswald, Germany — [3]hysics Department, University of California, San Diego, USA

Positron-electron plasmas, which are examples of pair plasmas, are just beginning to be studied experimentally. Due to their equal mass constituents, many features that are found in electron-ion plasmas will not occur in pair plasmas, and they are expected to be extraordinarily stable when magnetically confined. The APEX collaboration aims to create the first magnetically confined, low energy pair plasma with a spatial dimension of several Debye lengths so that collective behavior can be observed. To create such a plasma numerous obstacles must be overcome, since positrons are rare. One crucial challenge is the accumulation of large numbers of moderated positrons. Therefore, a device is needed which is capable of storing up to 10^{11} positrons without heating and particle loss. One solution is the multi-cell Penning-Malmberg trap (MCT) concept, which separates the space charge of the positrons into an array of small Penning-Malmberg traps. We present first measurements with electrons stored in a single Penning trap that serves as the master-cell as well as in a prototype MCT. This MCT will be used to confine plasmas simultaneously in multiple cells, to investigate the confinement and different injection and ejection schemes.

P 5.43 Tue 14:00 P

Modeling the beam emission Balmer-α spectrum in neutral beam heated plasmas at Wendelstein 7-X — •Sebastian Bannmann[1], Oliver Ford[1], Udo Höfel[1], Peter Poloskei[1], Jakob Svensson[1], Benedikt Geiger[2], and Robert Wolf[1] — [1]IPP Greifswald — [2]University of Wisconsin, Madison, US

The optimized stellarator Wendelstein 7-X (W7-X) is equipped with a neutral beam injection (NBI) system. Knowledge about the particle and heat deposition of the beam in NBI shots is essential for further plasma physics analysis. The deposition depends on the beam and plasma parameters and information can be provided by measuring the Balmer-α light emitted by excited beam and halo particles. As the whole spectrum is too complex to be unambiguously fitted, a modular Bayesian inference network called Minerva is used. This requires implementing a detailed forward model with which one can infer beam and plasma parameters from the measured spectra. Existing modeling tools deploy Monte-Carlo techniques which is not feasible to use in combination with a Bayesian inference framework. The presented work focuses on the modeling of the neutral beam halo including collisional radiative processes to determine the fraction of neutrals in excited states. It is shown that the ballistic transport of halo particles can be described by a steady-state charge exchange diffusion equation. The possibility of inferring ion temperature profiles from the halo Balmer-α emission is investigated.

P 5.44 Tue 14:00 P

Proof of concept of a fast surrogate model of the VMEC code via neural networks in Wendelstein 7-X scenarios — •Andrea Merlo, Daniel Böckenhoff, Jonathan Schilling, Udo Höfel, Sehyun Kwak, Jakob Svensson, Andrea Pavone, Samuel Aaron Lazerson, Thomas Sunn Pedersen, and the W7-X Team — Max-Planck-Institute for Plasma Physics, 17491 Greifswald, Germany

In magnetic confinement fusion research, the magnetohydrodynamic (MHD) model is used to self-consistently calculate the effects the plasma pressure induces on the magnetic field used to confine the plasma. The VMEC is the most widely used to evaluate 3D ideal-MHD equilibria, however, considering the computational cost, it is rarely used in large-scale or online applications. Access to fast MHD equilbria is a challenging problem in fusion research, one which machine learning could effectively address. In this work, we present artificial neural network (NN) models able to quickly compute the equilibrium magnetic field of Wendelstein 7-X. Magnetic configurations that extensively cover the device operational space, and plasma profiles with volume-averaged normalized plasma pressure $\langle\beta\rangle$ ($\beta = \frac{2\mu_0 p}{B}$) up to 5% and non-zero net toroidal current are included in the data set. The achieved normalized root-mean-squared error ranges from 1% to 20% across the different scenarios. The model inference time for a single equilibrium is on the order of milliseconds. Finally, this work shows the feasibility of a fast NN drop-in surrogate model for VMEC, and it opens up new operational scenarios where target applications could make use of magnetic equilibria at unprecedented scales.

P 5.45 Tue 14:00 P

Modifications of the fusion reactor systems code PROCESS to general stellarators — •Jorrit Lion, Felix Warmer, and Robert C. Wolf — Max Planck Institute for Plasma Physics, D-17491, Greifswald, Germany

Stellarators are attractive candidates for a fusion power plant, owing to their inherent steady-state capability and absence of plasma-current driven instabilities. A convenient way to study different power plant designs is by applying systems codes, which aspire to model an entire fusion power plant within a single framework by using simplified 0D or 1D models to capture relevant reactor constraints. In this work, we report on modifications of the fusion reactor power plant systems code PROCESS to a general class of stellarator configurations. This is achieved by introducing a set of new models in PROCESS, which reflect the stellarator specific constraints of a fusion reactor, like inhomogeneous neutron wall loads, coil-force magnitudes, wall loads by fusion born alpha particle wall loads or stellarator specifics operational boundaries by an electron cyclotron resonance heating scheme. Previous models, as introduced in [1], were adapted and generalized to generic stellarators. Using these modifications, PROCESS now allows for a combined technological, physical and economical assessment of a very general class of stellarator power plants within a systems code framework.

[1] F. Warmer, et al., "Implementation and verification of a HELIAS module for the systems code PROCESS", Fusion Eng. Design, vols. 98 99 (2015)

P 5.46 Tue 14:00 P

A novel MMC-like topology for ASDEX Upgrade Toroidal Field Coils Power Supply — •Antonio Magnanimo[1], Markus Teschke[1], and Gerd Griepentrog[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität Darmstadt, 64283 Darmstadt, Germany

The modular multilevel converter (MMC) has become one of the most attractive converters for high-power applications such as fusion devices power supplies. This converter, thanks to the discrete-leveled output voltage and its identical submodules (SMs) by which it is composed, represents a promising alternative to replace the flywheel generator (FG) that actually provides electrical power to the toroidal field (TF) coils of ASDEX Upgrade (AUG). Due to the pulsed DC operation of these coils and their high power needs for each experiment, a small-scale adapted version of the MMC is under development with some differences compared to conventional ones: SM capacitors have been replaced with super-capacitor (SC) modules to increase the amount of available stored energy while SMs belonging to different arms are interconnected to simplify their control and increase the reliability of the converter. This poster shows first an overview of the conceptual full-scale converter that could replace in future one of the FGs of AUG and then the development and the operation of a single IGBT full-bridge (FB) SM highlighting advantages and challenges of this configuration.

P 6: Magnetic Confinement III & Helmholtz Graduate School II

Time: Tuesday 16:30–17:50 Location: H5

Invited Talk P 6.1 Tue 16:30 H5

The Wendelstein 7-X Scrape-Off Layer — •Carsten Killer and W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

The stellarator Wendelstein 7-X employs the island divertor concept, where the intersection of out-flowing plasma by the divertor takes places in a chain of large, intrinsic magnetic islands. The Scrape-Off Layer (SOL) formed by the magnetic islands is inherently three-dimensional and features rather long parallel connection lengths of typically several 100 m, adding additional transport channels and complexity compared to a typical tokamak SOL. Understanding the transport processes in the SOL is essential for controlled high performance plasma operation since the SOL profiles formed by the relation of parallel and perpendicular transport ultimately govern the heat flux distribution on the targets.

Using a multi-diagnostic approach with a focus on reciprocating probes, we show that the magnetic islands significantly affect the SOL plasma. Most notably, the islands result in a very wide SOL (~5 cm) with flat or even locally hollow/peaked profiles of T_e and n_e across the islands. In addition, the islands affect parallel and poloidal plasma flows. Finally, the role of turbulent radial particle transport is found to be smaller in the W7-X SOL compared to tokamaks.

P 6.2 Tue 17:00 H5

GENE-X: A Gyrokinetic Turbulence Code for the Edge and Scrape-Off Layer — •Dominik Michels[1], Andreas Stegmeir[1], Philipp Ulbl[1], Frank Jenko[1,2], and the ASDEX Upgrade Team[3] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]University of Texas at Austin, Austin, TX 78712, USA — [3]See author list of Meyer H et al 2019 Nucl. Fusion 59 112014

Plasma turbulence in the edge and scrape-off layer is characterized by steep gradients and large fluctuation amplitudes. As such, nonlinear effects caused by the coupling between the plasma background and fluctuations are important and a so called full-f treatment of the underlying equations is necessary. Furthermore, the poloidal magnetic field vanishes at the X-Point of a tokamak – which introduces a coordinate singularity in the commonly used flux coordinates.

To tackle these problems we have created the gyrokinetic turbulence code GENE-X [1], a new version of the established GENE [2] code. GENE-X implements a full-f gyrokinetic model and is able to perform simulations in single-null, double-null as well as other advanced divertor geometries by using the flux coordinate independent approach [3]. We present a careful verification of the GENE-X code and demonstrate its ability to simulate gyrokinetic turbulence in single null geometry at the example of ASDEX Upgrade.

[1] F. Jenko et al., Phys. Plasmas 7 (2000) 1904
[2] D. Michels et al., Comput. Phys. Commun. 264 (2021) 107986
[3] F. Hariri et al., Comput. Phys. Commun. 184 (2013) 2419

P 6.3 Tue 17:25 H5

Core plasma density fluctuations in Wendelstein 7-X ECRH plasmas — •Jan-Peter Bähner[1], Jorge A. Alcusón[1], Søren K. Hansen[2], Håkan M. Smith[1], Adrian von Stechow[1], Zhouji Huang[2], Eric M. Edlund[3], Miklos Porkolab[2], Olaf Grulke[1,4], and The W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]SUNY Cortland, Cortland, NY, USA — [4]Technical University of Denmark, Kongens Lyngby, Denmark

Ion-scale turbulence is thought to be the main driver for anomalous transport in the optimised stellarator Wendelstein 7-X (W7-X). The most important instabilities on this scale are the ion-temperature-gradient (ITG) mode and the trapped-electron mode (TEM). The Phase Contrast Imaging (PCI) diagnostic measures line-integrated density fluctuations throughout the plasma core with temporal and wavenumber resolution spanning the ITG and TEM scales. In edge-fuelled, electron cyclotron heated discharges, a localisation of density fluctuations to approximately 75% of the plasma minor radius is shown experimentally via a match of the dominant measured phase velocity of fluctuations to the profile of the $E \times B$ rotation velocity and via gyrokinetic simulations with GENE. The localisation and characteristics of the measured fluctuations and gyrokinetic simulations match the expectation of ITG dominated turbulence in W7-X. The dynamic evolution of multiple phase velocities connected to a qualitative change of turbulence during improved confinement after pellet injection as well as low frequency oscillations reminiscent of ZFOs are presented.

P 7: Helmholtz Graduate School III

Time: Wednesday 14:00–15:15 Location: H4

P 7.1 Wed 14:00 H4

Simplified nonlinear MHD models of external kink modes in stellarators — •Rohan Ramasamy[1,2], Matthias Hoelzl[1], Erika Strumberger[1], Guillermo Suárez López[1], Sophia Henneberg[3], Karl Lackner[1], and Sibylle Günter[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Max Planck Princeton Center for Plasma Physics, New Jersey, USA — [3]Max Planck Institute for Plasma Physics, Greifswald, Germany

Non-linear magnetohydrodynamic (MHD) codes are an important tool in improving the understanding of disruptions in tokamaks. Recently, there has been renewed interest in advancing state-of-the-art MHD codes to model stellarators. Herein, two simplified models are explored, using the nonlinear code, JOREK, and the equilibrium code, VMEC.

VMEC is used to calculate the nonlinear saturated state of ideal external kink modes in simplified $l = 2$ stellarators. These saturated states are then compared against a simpified axisymmetric approximation of the stellarator, implemented in JOREK. The axisymmetric approach includes the external rotational transform by means of a *virtual current* model.

This approach is then applied to an unstable quasi-axisymmetric configuration to assess the stabilising influence of increasing external rotational transform on the MHD activity. The results show that while the external modes are stabilised significantly, nonlinearly triggered internal modes degrade confinement further. A relatively large external rotational transform is necessary to avoid a significant loss of confinement.

P 7.2 Wed 14:25 H4

First results for stellarator simulations with JOREK — •Nikita Nikulsin[1], Rohan Ramasamy[1], Matthias Hoelzl[1], Alessandro Zocco[2], Karl Lackner[1], and Sibylle Guenter[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

The JOREK code has recently been extended to allow nonlinear fully 3D stellarator simulations. This is made possible by generalizing the JOREK reduced MHD model to support stellarator geometries, and by allowing the grid to be non-axisymmetric, so that it can be aligned to the flux surfaces in a stellarator.

The models differ mainly in that the magnetic field can be represented as any curl-free field plus a perturbation in the stellarator model, whereas in the tokamak model it is a toroidal field plus a perturbation. We implement the curl-free field as a gradient of a Dommaschk potential, which in turn is calculated from the vacuum magnetic field as given by the EXTENDER code. In order to run a stellarator simulation, we must initialize the reduced MHD variables using the data from the GVEC equilibrium code.

Finally, we present the very first stellarator simulation results. While force balance is not satisfied exactly in stellarator reduced MHD, we show the error to be small. For stable plasmas, a barely noticeable shift is seen, after which equilibrium is restored and persists for thousands of Alfvén times. We also simulate unstable plasmas and benchmark the growth rates against the linear MHD code CASTOR3D.

P 7.3 Wed 14:50 H4

MHD-kinetic hybrid code based on structure-preserving finite elements with particles-in-cell — •Florian Holderied[1,2], Stefan Possanner[1], and Xin Wang[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]Technical University of Munich, Arcisstraße 21, 80333 München, Germany

This talk presents a STRUcture-Preserving HYbrid code - STRUPHY - for the simulation of magneto-hydrodynamic (MHD) waves interacting with a small population of energetic particles (EPs) far from thermal equilibrium (kinetic species). Such configurations can appear e.g. in fusion reactors, where hot α-particles can resonantly interact with MHD waves and compromise confinement time. The implemented model features linear, ideal MHD equations in curved, 3d space, coupled nonlinearly to the full-orbit Vlasov equations via a current coupling scheme. The implemented algorithm is based on finite element exterior calculus for MHD and particle-in-cell methods for the kinetic part; it provably conserves mass, energy, and the divergence-free constraint for the magnetic field, irrespective of metric, mesh parameters and chosen order. The motivation for this work stems from the need for reliable long-time simulations of EP-physics in complex geometries. In STRUPHY, the finite element spaces are built from tensor products of univariate B-splines on the logical cuboid. Time-stepping is based on operator splitting with implicit sub-steps. After presenting the scheme, numerical results in different geometries including toroidal domains with a singularity at the magnetic axis are shown and discussed.

P 8: Laser Plasmas I

Time: Wednesday 14:00–15:15 Location: H5

Invited Talk P 8.1 Wed 14:00 H5

Visualizing the Dynamics of a Plasma-Based Particle Accelerator — •Malte Kaluza — Institut für Optik und Quantenelektronik, Max-Wien-Platz 1, 07743 Jena — Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena

Relativistic plasmas generated by high-power laser pulses are a potential candidate for future compact electron accelerators. In a plasma-electron accelerator, the driving laser pulse generates a high-amplitude plasma wave forming the electric field structure (the "wakefield"), which can trap and accelerate electrons to several GeV energies over distances of a few centimeters only. The properties of the generated electron pulses (spectrum, pulse duration, lateral dimensions) strongly depend on the parameters and the evolution of this accelerating structure. Therefore, a complete understanding of the physical phenomena underlying the acceleration process is mandatory to improve the controllability of the electron pulses, which will determine their potential applicability in the future. This presentation will give a short introduction to laser wakefield accelerators, discuss transverse optical probing as a diagnostic tool [1, 2] and present experimental results on the characterization and evolution of the electron pulses [3] and of the plasma wave [4,5].

[1] M. B. Schwab et al., Applied Physics Letters 103, 191118 (2013) [2] M. C. Downer et al., Reviews of Modern Physics 90, 035002 (2018) [3] A. Buck et al., Nature Physics 7, 543 (2011) [4] A. Sävert et al., Physical Review Letters 115, 055002 (2015) [5] E. Siminos et al., Plasma Physics and Controlled Fusion 58, 065004 (2016)

P 8.2 Wed 14:30 H5

Spin-polarized particle beams from laser-plasma based accelerators — •Lars Reichwein[1], Anna Hützen[2,3], Markus Büscher[2,3], and Alexander Pukhov[1] — [1]Institut für Theoretische Physik I, Heinrich Heine Universität Düsseldorf, Germany — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich, Germany — [3]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, Germany

Spin-polarized particles with high energies are needed for various experiments, i.a. to examine the structure of protons and neutrons for further insight of QCD or to probe the nuclear spin structure. A promising option is the acceleration of pre-polarized particles from a plasma using a high-intensity laser [1]. We give a brief overview of the state-of-the-art for this subject, for which proof-of-principle experiments are currently being prepared. Further, we will present the acceleration of protons via magnetic vortex acceleration (MVA) in more detail and discuss the effects of density down-ramps on the proton yield studied by means of particle-in-cell simulations [2]. We show that the beam's average spin polarization remains robust against moderate changes of the down-ramp length and is only affected by changes in the collimation process for a significant increase in length.

[1] M. Büscher et al., doi:10.1017/hpl.2020.35, High Power Laser Sci (2020)
[2] L. Reichwein et al., doi:10.1088/1361-6587/ac0614, Plasma Phys. Control. Fusion (2021)

P 8.3 Wed 14:45 H5

Multiparameter-controlled laser ionization of gases in the tunnel ionization regime — •Michael Stumpf and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Within the scope of developing a Plasma Photocathode for Wakefield Acceleration of electrons we present a novel optical setup to ionize gases with controlled and modifiable ionization volume, number of electrons and initial energy. The reflection-based setup, called AMBER (Axicon Mirror Beam ExpandeR), allows the implementation into a fs-laser beamline without disturbing the spectral phase of the laser pulse. By changing the beam profile, pulse duration and pulse energy of the laser a desired ionization volume and state can be achieved. The dedicated ionization simulations are in good agreement with the gained experimental results which allows a precise prediction of laser-gas interactions.

P 8.4 Wed 15:00 H5

Monoenergetic High-Energy Ion Source via Femtosecond Laser Interacting With a Microtape — •Xiaofei Shen and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

Intense laser-based ion sources are characterized by unsurpassed acceleration gradient and exceptional beam emittance. They are promising candidates for next-generation accelerator towards a broad range of potential applications. However, the ion beams achieved currently have limitations in energy spread and peak ion energy. In this talk, I will present our recent work on achieving monoenergetic proton beams with energy spread at 1% level and peak energy of hundred MeV. Using fully three-dimensional particle-in-cell simulations, we show that such proton beams can be stably generated by using a readily available femtosecond laser interacting with a microtape. As the laser pulse sweeps along the tape, it drags out a huge charge (~100 nC) of collimated energetic electrons and accelerates them along the tape surface to superponderomotve energies. When this dense electron current arrives at the rear edge of the tape, it induces a strong electrostatic field. Due to the excessive space charge of electrons, the longitudinal field becomes bunching while the transverse field is focusing for protons. Together, this leads to a highly monoenergetic energy spectrum and much higher proton energy as compared to simulation results from typical target normal sheath acceleration and radiation pressure acceleration at the same laser parameters.

P 9: Codes and Modelling (Methods)

Time: Wednesday 16:30–17:30 Location: H5

P 9.1 Wed 16:30 H5

Determination of 2D Plasma Parameters with Filtered Cameras - An Application to the X-Point Radiator — •Emanuel Huett[1,2], Matthias Bernert[1], Alexander Bock[1], Marco Cavedon[1,2], Pierre David[1], Tilmann Lunt[1], Korbinian Moser[1], Takashi Nishizawa[1], Ou Pan[1], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[1] — [1]Max-Plack-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Munich, Germany

A method for the determination of 2D plasma parameters with filtered cameras has been developed. Major advantages are a high spatial resolution, 2D electron temperature, electron density and neutral density. The camera system at the ASDEX Upgrade Tokamak was upgraded to measure the deuterium balmer alpha, beta, gamma spectral lines and a nitrogen II multiplett simultaneously. Reflections are taken into account and can make a substantial contribution. The method's application is of interest in divertor physics, but also for more exotic studies like plasma production for wall conditioning. The method has been successfully applied to discharges with a well developed X-point radiator, one of the most promising scenarios for power exhaust control in a fusion reactor. First results show that the X-point radiator successfully cools the plasma to a point where recombination dominates. This is supported by simulations. A first verification with the new divertor Thomson scattering and divertor spectroscopy shows a reasonable agreement.

P 9.2 Wed 16:45 H5

Full-wave simulations of measurements of the perpendicular velocity of density fluctuations with Doppler reflectometry at ASDEX Upgrade — •Antonia Frank[1,2], Klara Höfler[1,2], Tim Happel[2], Carsten Lechte[3], Tobias Görler[2], Ulrich Stroth[2,1], and the ASDEX Upgrade Team[2] — [1]Technische Universität München, Munich, Germany — [2]Max-Planck-Institut für Plasma Physik, Garching, Germany — [3]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie IGVP, Stuttgart, Germany

The perpendicular propagation velocity of turbulent density fluctuations $v_\perp$ is an important quantity in fusion plasmas since sheared plasma flows are crucial for the reduction of turbulence and thus a relevant input parameter for simulations of turbulent transport. In the recent past, poloidal asymmetries have been observed in various fusion devices using Doppler reflectometry and correlation reflectometry. An explanation of these asymmetries may lie in the diagnostic response. Hence, numerical investigation using synthetic diagnostics is of great interest. The IPF-FD3D full-wave code is used as a synthetic Doppler reflectometry diagnostic, simulating microwave propagation and scattering. Turbulence flows are studied in several geometries with different synthetic turbulence spectra. The influence of the measurement's poloidal location on the diagnostic response is investigated. Full-wave simulations are also applied to turbulence from the gyro-kinetic code GENE in ASDEX Upgrade geometry on basis of selected experimental data for direct comparison with measurements.

P 9.3 Wed 17:00 H5

Two-part simulation approach of the source plasma of the KATRIN experiment — •Jonas Kellerer[1] and Felix Spanier[2] — [1]Institut für Astroteilchenphysik, KIT, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Institut für Theoretische Astrophysik, Universität Heidelberg, Albert-Überle-Str. 2 und Philosophenweg 12, 69120 Heidelberg, Germany

The **Ka**rlsruhe **Tri**tium **N**eutrino (KATRIN) experiment aims to determine the effective neutrino mass through spectroscopy of gaseous Tritium β-decay. Those high energy β-decay electrons ionize the surrounding gas in the source and thus create a partly ionized plasma. The exterior experimental conditions generate unconventional plasma conditions resulting in a highly magnetized, partly collisional, multi-species, non-thermal (with thermal components), bound plasma. The combination of these properties make a self-contained analytical description impossible. Thus, we decided on a two-part iterative simulation approach: the slow ion physics will be covered by the newly developed Monte Carlo code KARL, which produces electron energy distributions and ion currents. The results of KARL will be used by a modified version of the well tested ACRONYM Particle in Cell code to resolve the fast electron-field interactions. The modifications include cylindrical boundaries and position dependent background currents and fields. The derived fields will in turn be used as input for the KARL code. In this presentation, key concepts and challenges of the iterative approach and the underlying codes will be presented.

P 9.4 Wed 17:15 H5

Effects of laterally shifted bunch collisions on QED processes — •Marko Filipovic[1], Christoph Baumann[1], Alexander Pukhov[1], Alexander Samsonov[2], and Igor Kostyukov[2] — [1]Heinrich-Heine-Universität, Düsseldorf, Germany — [2]Institute of Applied RAS, Nizhny Novgorod, Russia

The collision of ultrarelativsitic electron bunches is a promising opportunity to study quantum electrodynamic effects in extreme fields and densities, this includes quantum photon emission and pair production. It was even conjectured that the interaction of light and matter can become fully non-perturbative. In this talk, the results of three-dimensional particle-in-simulations will be presented. First, the basic idea of the fully non-perturbative particle collider [1] will be recalled. Subsequently the configuration will be modified by considering the collision of two laterally shifted bunches. In detail, the impact on photon and pair yields through the modification will be compared and assessed by previous Beam-Beam collision estimates. Finally, the influence of longer bunches in the collider configurations will be considered.

[1] V. Yakimenko et al., Phys. Rev. Lett. **122**, 190404 (2019)

P 10: Mitgliederversammlung Plasmaphysik

Time: Wednesday 17:45–18:45 Location: H5

Mitgliederversammlung P

P 11: Complex Plasmas and Dusty Plasmas I

Time: Thursday 11:00–12:30 Location: H4

Invited Talk P 11.1 Thu 11:00 H4
Microfluidic flow in single-layer dusty plasmas — •Peter Hartmann[1] and Truell W. Hyde[2] — [1]Wigner Research Centre for Physics, Budapest, Hungary — [2]CASPER, Baylor University, Waco, TX, USA
Experiments on strongly coupled dusty plasmas provide unique access to the microscopic details of macroscopic processes in condensed matter. Since the early years of this field, the application to hydrodynamic processes was one of the main motivations. In most cases, however, the complexities of the experiments prevented the drawing of universal conclusions. In our experiment, utilizing the control provided by a plane-parallel radio frequency (RF) discharge, two metallic disks are used to form an electrostatic potential channel. Dust particle flow through the channel was induced by indirect laser manipulation, which is essential in order to keep the external effects acting on the particles under control. By adjusting the argon gas pressure and RF power, the channel was tuned to allow the formation of single or multiple lanes of transiting dust particles. We use this system to address fundamental details of microfluidic flows like the acceleration and stopping of particles, lane formation and ordering in the channel, etc.

P 11.2 Thu 11:30 H4
String Formation and Recrystallisation — •E Joshi[1], M Pustylnik[1], M Schwabe[1], H Thomas[1], M Thoma[2], A Lipaev[3], A Zobnin[3], A Usachev[3], and A Ivanishin[4] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, Weßling, Germany — [2]I. Physikalisches Institut, Justus-Liebig Universität Giessen, Giessen, Germany — [3]Joint Institute for High Temperatures, Russian Academy of Sciences — [4]Gagarin Cosmonaut Training Center, Russia
Plasmas with micrometre sized particles embedded in them where the particles gain high negative charges and become strongly coupled are known as complex plasmas. These complex plasmas can be studied in microgravity conditions using the Plasmakristall-4 (PK-4) facility onboard the International Space Station. Recrystallisation was studied in a complex plasma with string-like structure using the PK-4 lab by turning the plasma off for a fraction of a second to destroy the stringy order, then turning the plasma on again to see how the structure reforms. We characterised the 'stringiness' of the system by the average number of string neighbours at a given time and noted how it changed during the experiment. We then performed molecular dynamics (MD) simulations using Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS) to compare with the experiment, and used a Yukawa + wake potential for the interparticle interactions. This lets us mimic the effect of ions in our simulation which led to string formation. We found that the simulations had a good agreement with experimental findings.

P 11.3 Thu 11:45 H4
Video aided 1D Extinction – a novel technique for nanodust density measurements — •Andreas Petersen, Alexander Schmitz, and Franko Greiner — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel
Extinction measurements are the basis of dust density diagnostics in nanodusty plasmas. Standard techniques are computed tomography (CT) for arbitrarily shaped clouds and Abel inversion (AIN) for cylindrically symmetric dust clouds. For density measurements in a plasma chamber, where no full optical access is possible, we developed a new technique, which utilizes a laser stripe, two CMOS line cameras and one 2D camera. The VaEM method can be used to measure the dust density along a slice through the dust cloud and does not require cylindrical symmetry.

P 11.4 Thu 12:00 H4
High precision in-situ particle size measurement — •Sören Wohlfahrt, Niklas Kohlmann, and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany
Microparticles are the essential component of a (dusty) complex plasma. The forces affect-ing these particles, as well as their accumulated charge, depend prominently on their size. In addition, the (complex) refractive index of the particles is of importance when optical tech-niques are used for particle manipulation or in-situ diagnostic purposes. Thus, a precise knowledge of these particle parameters is a key input for a quantitative description and modelling. However, in interaction with the plasma the particle properties can change. The size and refractive index of particles can be determined simultaneously with very high preci-sion by means of angle- and polarisation-resolved light scattering (APRLS), which is based on a comparison of experimental data with Lorentz-Mie theory [1]. We will present the time resolved evolution of the size and refractive index of silica (SiO2)- and melamine-formaldehyde (MF) microparticles. Especially the consistency and absolute precision of the measurements as well as the time resolved changes in the refractive index for MF-particles are discussed. [1] N. Kohlmann, F. Wieben, O. H. Asnaz, D. Block, F. Greiner, Phys. Plasmas 26, 053701 (2019)

P 11.5 Thu 12:15 H4
Charge measurement of SiO_2 nanoparticles in an RF-plasma by IR absorption — •Harald Krüger and André Melzer — Institute of Physics, University Greifswald
Dusty plasmas with nanoparticles have drawn increased attention in the last few years. We have performed measurements of the IR absorption of SiO_2 nanoparticles confined in an argon radio-frequency plasma discharge using an FTIR spectrometer. By varying the gas pressure of the discharge and duty cycle of the applied radio-frequency voltage we observed a shift of the absorption peak of SiO_2. We attributed this shift to charge-dependent absorption features of SiO_2. The charge-dependent shift has been calculated for SiO2 particles and from comparisons with the experiment the particle charge has been retrieved. With the two different approaches of changing the gas pressure and altering the duty cycle we are able to deduce a relative change of the particle charge with pressure variations and an absolute estimate of the charge with the duty cycle.

P 12: Astrophysical Plasmas & Laser Plasmas II

Time: Thursday 11:00–12:15 Location: H5

Invited Talk P 12.1 Thu 11:00 H5
Planetary and astrophysical high Mach-number shocks: kinetic simulations vs in-situ measurements — •Artem Bohdan[1], Martin Pohl[1,2], and Paul Morris[1] — [1]DESY, DE-15738 Zeuthen, Germany — [2]Institute of Physics and Astronomy, University of Potsdam, DE-14476 Potsdam, Germany
High-Mach-number collisionless shocks are found in planetary systems and supernova remnants (SNRs). Electrons are heated at these shocks to temperatures well above the Rankine-Hugoniot prediction. However, the processes responsible for causing the electron heating are still not well understood. We use a set of large-scale particle-in-cell simulations of nonrelativistic shocks in the high-Mach-number regime to clarify the electron heating processes. The physical behavior of these shocks is defined by ion reflection at the shock ramp. Further interactions between the reflected ions and the upstream plasma excites electrostatic Buneman and two-stream ion-ion Weibel instabilities. Electrons are heated via shock surfing acceleration, the shock potential, magnetic reconnection, stochastic Fermi scattering, and shock compression. The main contributor is the shock potential. The magnetic field lines become tangled due to the Weibel instability, which allows for parallel electron heating by the shock potential. The constrained model of electron heating predicts an ion-to-electron temperature ratio within observed values at SNR shocks and in Saturn's bow shock. We also present evidence for field amplification by the Weibel instability. The normalized magnetic field strength strongly correlates with the Alfvenic Mach number, as is in-situ observed at Saturn's bow shock.

P 12.2 Thu 11:30 H5
Detector characterisation for grating-based X-ray phase-contrast imaging — •Constantin Rauch, Bernhard Akstaller, Lisa Dietrich, Dennis Haag, Veronika Ludwig, Stephan Schreiner, Max Schuster, Andreas Wolf, Thilo Michel, Gisela Anton, and Stefan Funk — Ecap - Erlangen Centre for Astroparticle Physics, University Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen
Imaging at X-ray backlighter allow to capture fast dynamic processes due to extremely short exposure times. Grating-based X-ray phase-contrast imaging is expected to observe plasma shocks with higher contrast than absorption-based imaging due to its sensitivity to the differential phase-shift caused by local electron density variation present in plasma shocks. These rapid processes place special demands on the imaging system consisting of two gratings and a detector. Optimising the setup promises improvements in photon noise and sensitivity. This can be achieved by optimising the gratings, their positions and the detector. In this contribution, a methodology for characterising X-ray detectors according to their resolution, sensitivity and noise in phase-contrast imaging is introduced.

P 12.3 Thu 11:45 H5

X-ray phase contrast imaging as a plasma diagnostics technique — •Lisa Dietrich, Bernhard Akstaller, Stephan Schreiner, Veronika Ludwig, Max Schuster, Gisela Anton, and Stefan Funk — ECAP - Erlanger Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

A single-shot x-ray phase-contrast imaging technique with short exposure time allows to capture sharp images of fast dynamic processes, like laser-produced plasma shock-waves in high-energy density pump-prope experiments. Using grating-based x-ray phase-contrast imaging as a measurement technique, allows to determine the projected electron density distribution of a sample with a single acquisition. In this talk the methodology of grating-based phase-contrast imaging and its ability to retrieve electron density distribution is introduced. Further, the concept of a portable grating-based phase-contrast imaging setup is explained, which allows to adjust the interferometer at low repetion rate backlighter sources within a reasonable time using a fast-alignment method.

P 12.4 Thu 12:00 H5

Noise reduction for single-shot grating-based phase-contrast imaging at an x-ray backlighter — •Stephan Schreiner[1], Bernhard Akstaller[1], Lisa Dietrich[1], Paul Neumayer[2], Max Schuster[1], Andreas Wolf[1], Veronika Ludwig[1], Thilo Michel[1], Gisela Anton[1], and Stefan Funk[1] — [1]Friedrich-Alexander Universität Erlangen-Nürnberg, Erwin-Rommel-Straße 1, 91058 Erlangen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

X-ray backlighters allow to capture sharp images of fast dynamic processes , like laser-produced plasma shock-waves in high-energy density experiments, due to extremely short exposure times. Moiré imaging using a two-grating imaging setup enables to measure the absorption and differential phase-contrast (DPC) of these processes simultaneously, allowing to retrieve the electron-density distributions of the imaged object. However, acquiring images with one single-shot limits the x-ray photon flux, which can result in noisy images. In this contribution an implementation of a laser-driven x-ray backlighter experiment is presented and two noise reduction methods for single-shot images are evaluated.

P 13: Magnetic Confinement IV & Helmholtz Graduate School IV

Time: Thursday 14:00–15:45 Location: H4

Invited Talk P 13.1 Thu 14:00 H4

How turbulence sets boundaries for fusion plasma operation — •Peter Manz[1], Thomas Eich[2], and the ASDEX Upgrade Team[2] — [1]Institut für Physik, Universität Greifswald — [2]Max-Planck-Institut für Plasmaphysik, Garching

The operational space for safe and efficient operation of a tokamak is limited by several constraints. Well known examples are the Greenwald density limit and the accessibility of high confinement. Their extrapolation to reactor machine size is based on empirical scalings. Both phenomena are related to turbulent transport. Large turbulent transport can lead to a transition to low confinement or trigger events finally leading to a disruption (the L-mode density limit). The strength of turbulent transport in the plasma edge depends on the competition between rather gentle drift-wave and the rather violent resistive ballooning turbulence. The operation boundaries are derived in terms of a combination of dimensionless parameters describing interchange-drift-Alfven turbulence without any free adjustable parameter. This way, the disruptive density limit is related to a transition from the electrostatic to the electromagnetic resistive ballooning regime. At the L-H transition, drift-wave dominated turbulence is suppressed by a combination of flow shear, diamagnetic and beta stabilization. The derived boundaries are compared to about 300 discharges and agreement within experimental error bars.

P 13.2 Thu 14:30 H4

Multi-class disruption prediction at JET using a shapelet based neural-network. — •Victor Artigues[1], Frank Jenko[1], and JET Contributors[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]See the author list of 'Overview of JET results for optimising ITER operation' by J. Mailloux et al. to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th Fusion Energy Conference (Nice, France, 10-15 May 2021)

Disruptions, the very fast, uncontrolled, termination of plasma experiments in tokamaks, remain to this day an unsolved issue on the path towards fusion-based power plants. Due to the their complex nature, disruptions have been very hard to investigate with physics-based approaches. In recent years, progress has been made with data-driven methods to build disruption detection systems, but many questions remain open such as disruption type identification, or transfer between tokamaks.

We propose a Shapelet based neural-network for the task of multi-class disruption prediction, and compare it to two approaches from the literature, trained on our data: stacked Support-Vector Machines (SVM), and a Long Short-Term Memory (LSTM) neural-network. Two datasets of discharges from the Joint European Torus (JET) tokamak, have been compiled. One containing stable discharges and 7 different disruption types, before the installation of the ITER-Like Wall (ILW). The second, with fewer shots and binary classification, from the more recent C36 campaign with ILW. Using the binary and multi-class classification results on the different datasets, we report on the performance of the three models and discuss the advantages of our method.

P 13.3 Thu 14:55 H4

Alpha particle dynamics and Alfvenic instabilities in ITER post-disruption plasmas — •Andrej Lier[1], Gergely Papp[1], Philipp Lauber[1], Stefanie Braun[2], George Wilkie[3], and Ola Embreus[4] — [1]Max Planck Institute for Plasma Physics, D-85748 Garching, Germany — [2]Department of Physics, Chalmers University of Technology, SE-41296 Gothenburg, Sweden — [3]Princeton Plasma Physics Laboratory, Princeton NJ 08540, USA — [4]Department of Physics, Chalmers University of Technology, SE-41296 Gothenburg, Sweden

Fusion-born alpha particles in ITER disruption simulations are investigated as a possible drive of Alfvenic instabilities. The ability of these waves to expel RE seed particles is explored in the pursuit of a passive, inherent RE mitigation scenario in synergy with built-in RE mitigation systems. An analytical model is introduced that is able to compute the spatiotemporal evolution of the alpha particle distribution in a mitigated thermal quench. We use a linear gyrokinetic stability code to calculate the Alfven spectrum and find that the equilibrium is capable of sustaining a wide range of modes. The natural radial anisotropy of the alpha population provides free energy to drive Alfvenic modes during the quench phase of the disruption. The self-consistent evolution of the mode amplitudes and the alpha distribution is calculated utilizing wave-particle interaction methods. Intermediate mode number Toroidal Alfven Eigenmodes (TAEs) are shown to saturate at an amplitude of up to dB/B ~ 0.1% in the spatial regimes crucial for RE seed formation.

P 13.4 Thu 15:20 H4

2.5 MeV and 14 MeV neutron rate measurements on ASDEX Upgrade and predictions for Wendelstein 7-X — •Jan Paul Koschinsky[1], Christoph Biedermann[1], Sergey A. Bozhenkov[1], Joona Kontula[2], Simppa Äkäslompolo[1,2], Monika Koleva[3], Giovanni Tardini[3], C. F. B. Zimmermann[3], Ralf Nolte[4], Elisa Pirovano[4], Andreas Zimbal[4], G. A. Wurden[5], Robert C. Wolf[1], the W7-X Team[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, D-17491, Greifswald, Germany — [2]Aalto University, Espoo, Finland — [3]IPP, Garching — [4]PTB, Braunschweig — [5]LANL, US

Fast-ion confinement is crucial for realizing burning fusion plasmas, both in tokamaks and stellarators, as fast fusion-born alpha particles are meant to provide the self-heating of the plasma. Therefore, the possible application of a scintillating fiber neutron detector, SciFi, for studying fast ions in future deuterium plasmas of the Wendelstein 7-X stellarator, is investigated here.

In deuterium plasmas, 2.5 MeV neutrons and 1 MeV tritons are generated via two equally probable fusion channels, respectively. Depending on confinement and slowing-down processes, produced tritons will fuse with surrounding deuterons and give birth to 14 MeV neutrons. A time-resolved study of this triton burn-up process is attainable with SciFi, which can discriminate between 14 MeV and 2.5 MeV neutrons.

Triton burn-up studies with SciFi on the ASDEX Upgrade tokamak are presented. Moreover, predictions of neutron rates in W7-X and the resulting performance of SciFi are discussed.

P 14: Atmospheric Pressure Plasmas and their Applications II

Time: Thursday 14:00–16:00 Location: H5

Invited Talk P 14.1 Thu 14:00 H5

Streamer inception and imaging in various atmospheres — •Sander Nijdam, Siebe Dijcks, and Shahriar Mirpour — Eindhoven University of Technology, The Netherlands

Streamers are the first stage of many discharges involving high voltages. They consist of a propagating ionization front leaving behind a trail of conductive, quasi-neutral plasma. In this contribution we will show experiments on streamers revealing some of their most important properties: their inception and their propagation and branching behaviour.

We study streamer inception by applying repetitive high voltage pulses and studying the statistics of inception delay. By means of small bias pulses between the high voltage pulses, we are able to manipulate these statistics, which reveals a lot on the processes governing the inception.

Secondly, we study the propagation and branching of streamers by a combination of stereoscopic and stroboscopic measurements of 'low complexity' streamer discharges. We have developed automated routines which can determine propagation velocities, branching angles and much more from these.

Finally, we study single streamers in great detail, using optical imagining, optical emission spectroscopy, Raman scattering and E-FISH together to get a complete picture of the properties of these discharges and compare this to numerical simulations.

P 14.2 Thu 14:30 H5

From single- to multi-filament arrangements for pulsed dielectric barrier discharges — •Hans Höft, Manfred Kettlitz, and Ronny Brandenburg — Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Straße 2, 17489 Greifswald, Germany

It has been demonstrated that the discharge characteristics in pulsed-operated single-filament dielectric barrier discharges (DBDs) can be controlled by varying the pulse width of the applied high voltage (HV). The transfer of this knowledge to multi-filament DBDs is crucial for the further understanding and design of plasma reactors. Therefore, a direct comparison between a single-filament and a multi-filament arrangement driven by the same HV pulses with variable pulse width was performed in a gas mixture of 0.1 vol% O_2 in N_2 at 1 bar. Both arrangements feature a 1 mm gap with alumina-covered electrodes, with two hemispherical electrodes for the single-filament and two parallel tube electrodes for the multi-filament arrangement. The DBDs were characterised by electrical measurements (for energy, power, transferred charge, peak current) accompanied by synchronised iCCD imaging determining the filament number and the discharge development in the gas gap and on the surfaces. Generally, most physical quantities scale with the filament number. The impact of pre-ionisation on the DBD characteristics is very similar, although the filament number depends on the pre-ionisation.

This work was supported by the DFG-project MultiFil (DFG project number 408777255).

P 14.3 Thu 14:45 H5

Spatiotemporal emission of an atmospheric plasmoid — •Roland Friedl[1], Saskia Steibel[1], Victor Slavov[2,3], and Ursel Fantz[1,3] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Faculty of Physics, University of Sofia, 1164 Sofia, Bulgaria — [3]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

An atmospheric pressure plasmoid is generated via a high voltage discharge (4.8 kV) above a water surface. After around 150 ms the connection to the power supply is interrupted and the plasmoid enters an autonomous phase which lasts up to 400 ms. The plasmoid has a diameter of around 30 cm and ascends in air with a velocity of about 1–2 m/s. High speed video analysis (600 fps) and optical emission spectroscopy is applied to gain insight into the plasma dynamics.

Survey spectrometers ($\Delta\lambda \sim 1.4$ nm) are applied to determine the dominant radiating plasma constituents for the three main evolution phases of the plasmoid: ignition, formation, and autonomous phase. Photo diodes with interference filters ($\Delta\lambda \sim 10$ nm) are used for monitoring the emission of specific plasma constituents (H, OH, Na) with high temporal resolution (0.5 ms). High resolution spectroscopy ($\Delta\lambda \sim 0.16$ nm) with a high speed trigger system is applied to measure the OH-A-X emission system during the temporal evolution of the plasmoid. In order to gain access to the plasma chemistry, rotational and vibrational temperatures of the hydroxyl molecule are evaluated using Lifbase, while its absolute emissivity is analyzed by collisional-radiative modeling.

P 14.4 Thu 15:00 H5

Atomic oxygen density distributions in an atmospheric pressure plasma jet and its effluent — •David Steuer, Ihor Korolov, Sascha Chur, Julian Schulze, Volker Schulz-von der Gathen, Judith Golda, and Marc Böke — Ruhr-University Bochum, D-44801 Bochum, Germany

Micro atmospheric pressure plasma jets (μAPPJs) are attracting high attention due to their potential to treat temperature sensitive surfaces. For these applications, reactive species are produced in the plasma. In this work two-dimensional spatially resolved absolute atomic oxygen densities are measured within a μAPPJ (COST-Jet) and in its effluent. The plasma is operated in helium with an admixture of 0.5% of oxygen at 13.56 MHz and with a power of 1 W. Absolute atomic oxygen densities are obtained using two photon absorption laser induced fluorescence spectroscopy (TALIF). The results are reproduced by a combination of phase resolved optical emission spectroscopy (PROES) measurements and simple model calculations. Within the discharge, the atomic oxygen density builds up with a rise time of 600 μs along the gas flow and reaches a plateau of 8×10^{15} cm^{-3}. In the effluent, the density decays exponentially with a decay time of 180 μs (corresponding to a decay length of 3 mm at a gas flow of 1.0 slm). It is found that both, the species formation behavior and the maximum distance between the jet nozzle and substrates for possible oxygen treatments of surfaces can be controlled by adjusting the gas flow.

P 14.5 Thu 15:15 H5

Reaction kinetics of H2O2 in a cold atmospheric pressure plasma jet — •Sarah-Johanna Klose[1], Levin Krös[2], Igor L Semenov[1], and Jean-Pierre van Helden[1] — [1]Leibniz-Institut für Plasmaforschung und Technologie e.V. (INP), Felix-Hausdorff-Str. 2, Greifswald — [2]Universität Greifswald, Greifswald

Since cold atmospheric pressure plasma jets have gained high interest particularly for biomedical applications, the tailoring of the reactive species composition produced by the plasma jet is an important issue. To be able to adapt the reactive species composition and to comprehend the impact of plasmas on cells, a good understanding of the production and consumption mechanisms in the plasma jet is pivotal. Hydrogen peroxide (H2O2) for example is a species with a high impact on cells that works as a signalling agent for intracellular communications when dissolved in a cell containing liquid.

In this work, we present the density distributions of H2O2, HO2, and H and O atoms in the gas phase of the plasma jet kINPen without contact to a liquid and deduce the most important reaction mechanisms by comparing the results to a reaction kinetics model. The distributions were obtained by continuous wave cavity ring-down spectroscopy and picosecond two-photon absorption laser-induced fluorescence spectroscopy. We will discuss the reactions in the plasma zone and the impact of the effluent's surrounding gas composition on the chemistry leading to the formation and consumption of H2O2 and its precursors.

P 14.6 Thu 15:30 H5

3-dimensional density distributions of NO in the effluent of the COST-Reference-Microplasmajet — •Patrick Preissing[1], Ihor Korolov[2], Julian Schulze[2], Volker Schulz-von der Gathen[1], and Marc Böke[1] — [1]Ruhr-Universität Bochum, Experimentalphysik II — [2]Ruhr-Universität Bochum, Angewandte Elektrotechnik und Plasmatechnik

Plasma jets are known to generate a huge number of different reactive species. In that context Nitric Oxide is one of the key players, as it triggers many biological processes. In this study absolute densities of NO are measured in the effluent of an RF-driven micro atmospheric pressure plasma jet, that is operated in a He/N2/O2 mixture, by means of Laser Induced Fluorescence, with 3-dimensional spatial resolution. The densities are measured in two distinct atmospheres. In the first one, the jet is expanding into open air, whereas in the second configuration the jet is expanding into a controlled He/air mixture. From the time resolved LIF signals the quenching coefficients for He, air, N2 and O2 are determined, as well as the intrusion of the ambient air into the He gas flow expanding from the jet. It was found that the distribution as well as the absolute densities strongly depend on the surrounding atmosphere, due to quenching and collisions. Furthermore, the NO particles are strongly coupled to the He flow of the feed gas. Parameter studies, varying different parameters such as plasma power, gas flow and gas mixture have been performed and the influence on the absolute NO densities as well as its distributions are investigated.

P 14.7 Thu 15:45 H5

Loss processes of plasma-generated atomic oxygen in phenol solutions — •Kerstin Sgonina[1], Giuliana Bruno[2], Stefan Wyprich[1], Kristian Wende[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

Aqueous solutions treated by cold atmospheric pressure plasma jets contain high amounts of reactive species. It has already been shown that atomic oxygen produced by a cold atmospheric pressure plasma jet effectively reacts with organic molecules like phenol dissolved in water without any intermediate reaction steps [1]. However, it is unknown whether the reactions with atomic oxygen are liquid-surface or liquid-volume dominated.

To investigate the loss processes of atomic oxygen in liquid solutions, experimental results are combined with simulations of the reaction kinetics [2]. Phenol solutions were treated with the effluent of a He/O_2-plasma ignited in the COST-Jet which provides well-known densities of reactive oxygen species [3]. Variation of the phenol concentration allows an insight into the competing O-loss reactions in gas phase, liquid phase or at the liquid surface. The comparison to simulations of the reaction kinetics and transport from gas into liquid phase reveal the predominance of reactions of atomic oxygen at the liquid surface.

[1] J. Benedikt et al., Phys. Chem. Chem. Phys. 20 12037 (2018).
[2] K. Sgonina et al., J. Appl. Phys. accepted (2021).
[3] G. Willems et al., New J. Phys. 21 059501 (2019).

P 15: Magnetic Confinement V & Helmholtz Graduate School V

Time: Thursday 16:30–18:15 Location: H5

Invited Talk P 15.1 Thu 16:30 H5

Physics studies with high-power electron cyclotron heating (ECRH) on ASDEX Upgrade — •Jörg Stober and ASDEX Upgrade Team — MPI für Plasmaphysik, Garching, Germany

The ECRH system of ASDEX Upgrade has been upgraded over the last 15 years from a 2 MW, 2 s, 140 GHz system to an 8 MW, 10 s, dual frequency system (105/140 GHz). The power roughly equals the installed ion cyclotron resonance (ICRF) power. The power of both wave heating systems together (> 10 MW in the plasma) is about half of the available power from the neutral beam heating (NBI), allowing significant variations of torque input, of the shape of the electron and ion heating profiles even at high heating power.

This system allows addressing important issues fundamental to a fusion reactor: H-mode operation with dominant electron heating, accessing low collisionalities in full metal devices, novel scenarios without edge eruptions (ELMs), influence of Te/Ti and rotational shear on transport, dependence of impurity accumulation on heating profiles. Experiments on these subjects will be presented here. The adjustable localized current drive capability of ECRH allows dedicated variations of the shape of the q-profile and studying their influence on non-inductive Tokamak operation. The ultimate goal of these experiments is to use the experimental findings to refine theoretical models such that they allow a reliable design of operational schemes for reactor size devices. In this respect, recent studies comparing gyrofluid (TGLF) and gyrokinetic (GENE) modelling of non-inductive high beta plasmas will be reported.

P 15.2 Thu 17:00 H5

Investigation of increased core ion temperatures in high-beta advanced scenarios in ASDEX Upgrade — •Maximilian Reisner[1], Jörg Stober[1], Alessandro Di Siena[2], Rainer Fischer[1], Andreas Burckhart[1], Alexander Bock[1], Emiliano Fable[1], Rachael McDermott[1], Alejandro Bañon Navarro[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching bei München, Germany — [2]UT Austin, 201 E 24th St, Austin, Texas, USA — [3]See the author list of H. Meyer et al, Nucl. Fusion 59, 112014 (2019)

Non-inductive advanced scenarios are a possible way for future nuclear fusion power plants based on the tokamak design to run in non-pulsed operation. In these scenarios, the ohmic current is replaced by externally driven currents and the intrinsic bootstrap-current. Since the bootstrap-current is produced in the presence of pressure gradients, internal transport barriers or regions of reduced turbulent transport are favourable to such scenarios. Such local reductions in transport have been observed in non-inductive ASDEX Upgrade discharges. There are several parameters that are thought to be connected to local reductions of transport in the plasma core, such as the ExB-shear, the magnetic shear and the fast ion pressure. In this contribution, results of experiments conducted in the Tokamak ASDEX Upgrade will be presented, which aim to study the individual contributions of these parameters to the observed reductions in transport. These experimental findings are backed up by simulations using the quasilinear transport model TGLF and the gyrokinetic code GENE.

P 15.3 Thu 17:25 H5

Localization of magnetic reconnection during sawtooth crash in ASDEX Upgrade — •Oleg Samoylov, Valentine Igochine, Andreas Stegmeir, Hartmut Zohm, and The ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

The work discusses the toroidal localization of magnetic reconnection during sawtooth crashes. Numerical analysis with realistic heat diffusion coefficients shows that heat distributes itself helically along the torus faster than the temporal resolution of any existing ECE diagnostics. It makes local and global (helically axisymmetric) magnetic reconnection indistinguishable for an observer, while a local crash in which the heat stays confined within a finite helical region could be distinguished. Statistical analysis of sawtooth crashes with the ECEI diagnostic is conducted in ASDEX Upgrade. Our data reveals no evidence of a local sawtooth crash and supports the numerical results.

P 15.4 Thu 17:50 H5

Plasma electron acceleration up to 100 keV in the TJ-K stellarator — •Alf Köhn-Seemann[1], Gregor Birkenmeier[2,3], Eberhard Holzhauer[1], Mirko Ramisch[1], Gabriel Sichardt[1], and Ulrich Stroth[2,3] — [1]IGVP, University of Stuttgart — [2]Max Planck Institute for Plasma Physics, Garching — [3]Physics Department E28, TUM, Garching

In conventional microwave heating scenarios, the injected microwaves' frequency must be equal to or higher than the electron cyclotron frequency (ECF) to transfer their energy to the plasma. Here, we describe in contrast an operational regime at the stellarator TJ-K where the heating occurs well below the ECF, but still above the lower-hybrid frequency: energy is deposited at the so-called O-resonance. A population of high-energy electrons observed in the scenario is attributed to strong wave electric fields at this resonance. Simple physics considerations estimating the energy gain during a half-cycle of the wave electric field have been used to describe this acceleration scheme for plasma electrons. The model has been successfully compared with measurements using a pulse-height analyzer allowing to determine the fast electrons' energy.

P 16: Low Pressure Plasmas II & Dusty Plasmas II

Time: Friday 11:00–12:30 Location: H2

Invited Talk P 16.1 Fri 11:00 H2

Configurational temperature of multi species complex (dusty) plasmas — •Dietmar Block[1], Frank Wieben[1], Michael Himpel[2], and Andre Melzer[2] — [1]IEAP, Universität Kiel, Germany — [2]Institut für Physik, Universität Greifswald, Germany

The dust charge of the two species in a binary mixture of particles in a dusty plasma has been measured using the concept of configurational temperature. There, the dust charge and the respective dust charge ratio is determined from the comparison of the instantaneous particle positions and the kinetic temperature. For that purpose, experiments of binary mixtures of melamine-formaldehyde and silica particles have been evaluated. The configurational temperature approach has also been checked against simulations. From these analyses it is found that the charge ratio of the two species can be obtained quite accurately, whereas for the determination of the absolute charge values a good knowledge of the confining potential is required.

P 16.2 Fri 11:30 H2

Simulations and Experiments of Phase Separation in Binary Dusty Plasmas — •Stefan Schütt and André Melzer — Institute of Physics, University of Greifswald

Molecular dynamics simulations of binary dusty plasmas have been performed and their behavior with respect to the phase separation process has been analyzed. The simulated system was inspired by experimental research on phase separation in dusty plasmas under microgravity on parabolic flights. Despite vortex formation in the experiment and in the simulations the phase separation could be identified. From the simulations it is found that even the smallest charge disparities lead to phase separation. The separation is due to the force imbalance on the two species and it becomes stronger with increasing size disparity or decreasing mean particle size. In comparison, experiments on phase separation have been performed and analyzed in view of the separation dynamics. It is found that the experimental results are reproduced by the simulation regarding the dependency on the size disparity of the two particle species.

P 16.3 Fri 11:45 H2

Waves in binary dusty plasmas — •Lasse Bruhn and Dietmar Block — Institute of Experimental and Applied Physics, Kiel University, Germany

Complex plasmas containing charged dust particles are an ideal model system for research on strong coupling phenomena. In two-dimensional systems waves can be excited either thermally or by external manipulation. The dispersion of waves propagating in monodisperse complex plasmas is well understood. However, the dynamics of waves in binary mixtures, containing two differently sized particle species, are less examined, but an interesting field of research. In this contribution, a method to derive the dust charge ratio as well as the absolute charges of the two particle species from the thermal dispersion is presented.

P 16.4 Fri 12:00 H2

Wave turbulence in fluid complex plasmas — •Prapti Bajaj[1], Christoph Räth[1], Alexei Ivlev[2], and Mierk Schwabe[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR) — [2]Max-Planck-Institut für Extraterrestrische Physik

Turbulence is a physical phenomenon observed in out of equilibrium systems exhibiting non-linear properties, and it is being studied intensively in a plethora of fields like fluid dynamics, plasma physics et cetera. Here, we study wave turbulence in a complex plasma, which is a system of micrometer-sized particles embedded in a low-temperature plasma. Our experiment was conducted in the ground-based setup of PK-3 Plus, where microparticles were injected in a capacitively coupled RF-plasma chamber and a laser illuminated a vertical cross-section of the microparticle cloud. This makes it possible to study particle behaviour at the kinetic level by using high-speed imaging. Waves form spontaneously in the cloud of confined microparticles due to ion-streaming instability. Our analysis shows that the power spectrum exhibits a slope of -5/3 in Frequency-Fourier space, corresponding to the scaling law predicted for Kolmogorovian turbulence, also observed in many classically turbulent systems. Our aim is to investigate the spectrum of short-scale disturbances generated due to the cascade of different wave modes, and their isotropisation.

P 16.5 Fri 12:15 H2

Correlation of the void dynamics with transition events of the growth chain of nanodust in a reactive argon-acetylene plasma — Sebastian Groth[1], Nancy Fassheber[2], Gernot Friedrichs[2], and •Franko Greiner[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel — [2]Institut für Physikalische Chemie, Christian-Albrechts-Universität zu Kiel

Using imaging Mie ellipsometry in combination with 1D extinction measurements we have fully characterized the spatio-temporal size and density evolution of nanoparticles grown in a reactive argon acetylene plasma [Groth et al. PSST 2019, https://iopscience.iop.org/article/10.1088/1361-6595/ab5412]. The growth process is usually divided into four phases: (i) creation of precursors from acetylene, (ii) nucleation of nanometer-sized a:C-H clusters (nucleation phase), (iii) coagulation of the clusters to 50 nm nanoparticles (coagulation phase), and finally (iv) further growth of negatively charged particles by sticking of molecules and molecular ions (accretion phase).

The analysis of the dynamical behavior of a nanodust cloud completely embedded in another cloud, consisting of larger particles, can link events in the spatio-temporal evolution of the nanodust cloud to events along the growth chain of the nanoparticles. This permits the verification of theoretical predictions about the occurrence of specific plasma chemical events along the growth chain by means of laser spectroscopy.

P 17: Poster II

Time: Friday 14:00–16:00 Location: P

P 17.1 Fri 14:00 P

Minimal invasive extraction and ex situ analysis of nanoparticles synthesized in a reactive plasma — •Maren Dworschak, Franko Greiner, and Oguz Han Asnaz — Institut für Experimentelle und Angewandte Physik, CAU Kiel

Plasma systems generating nanometer-sized particles are relevant for a broad range of applications from biomedicine to catalysis and batteries where knowledge about the size of the generated particles and their size distribution is critical. In situ analysis of nanoparticles created in a reactive Ar/C2H2-plasma using kinetic Mie-ellipsometry encounters problems when trying to detect particles at both extremes of the size scale. Because it reaches its limits for small (<50 nm, Rayleigh regime) and very large particles (>250 nm, multiple scattering) ex situ analysis has to be done. An optimal particle extractor should (i) not disturb the plasma chemistry, (ii) not change the discharge properties, and (iii) be able to extract several samples during one growth cycle.

We present a device to extract nanoparticles at multiple moments during a single growth cycle, while not disturbing the process itself. The extraction method is based on the electrostatic force and allows to extract particles at eight stages of the growth process. During extraction, we monitor the dynamics of the particle cloud with a camera and the particle size via Mie-ellipsometry. The particles are diagnosed ex situ with atomic force microscopy to determine the particle size distribution. The particle charge can be estimated using force balance equations. [Dworschak et al., Plasma Sources Sci. Technol. (2021), https://iopscience.iop.org/article/10.1088/1361-6595/abe4c0]

P 17.2 Fri 14:00 P

Structural properties of binary dusty plasmas — •Charlotte Büschel, Lasse Bruhn, and Dietmar Block — Institut für Experimentelle Plasmaphysik der Christian-Albrechts-Universität zu Kiel, Leibnizstraße 11-19, 24118 Kiel, Deutschland

Complex plasmas with microparticles can be used to analyze strongly coupled systems on an individual particle level. Using binary mixtures of particles, i.e. two particle species of different material and size and thus different charge but at similar confinement conditions, opens up new possibilities to study polydisperse systems. To generate a binary mixture, both species have to have identical confinement conditions. Even small differences result in a separation of the species. That a fully mixed state is nevertheless possible was shown by Wieben et al. [1], where the size loss due to etching processes in the plasma was utilized. First experiments on binary mixtures studied waves [2] as well as thermodynamics [3] . These investigations focused on particle systems in a mixed state. So far, there were no studies about the process of mixing. In this contribution structural properties of binary systems are analyzed on their way from a demixed to a mixed state. Special emphasis is put on the density profile and configurational changes during the mixing process. Thus, this study aims at a global as well as local description of the structure of binary systems as a function of their mixing state.

1. F. Wieben et al., Phys. Plasmas , Vol. 24, No. 3, 2017)
2. Yang et al., EPL , Vol. 117, No. 2, 2017
3. Wieben and Block, Phys. Rev. Lett. , Vol. 100, 2019)

P 17.3 Fri 14:00 P

Fast 3D particle position reconstruction using a neural network — •Michael Himpel and André Melzer — Institut für Physik, Universität Greifswald

We present an algorithm to reconstruct the three-dimensional positions of a particle cloud using a convolutional neural network. The approach is found to be very fast (thousands of particles in less than one second) despite its relatively high accuracy. It is special to this algorithm that the computing workload is separated into two parts: The energy- and time comsuming training, followed by the framewise non-intense and fast reconstruction. This makes this algorighm especially suitable for remote applications. The algorithm is applied to synthetic as well as experimental data from parabolic flights.

P 17.4 Fri 14:00 P

Stereoscopic Meassurements of Dusty Plasmas under Microgravity — •Daniel Maier, Michael Himpel, Stefan Schütt, and André Melzer — Institut für Physik der Universität Greifswald, Greifswald, Deutschland

Stereoscopic measurements to calculate 3d positions and trajectories of particles in a dusty plasma are a key item for the investigation of transport processes in complex particle systems. Stereoscopy is used in our group for many years now and the experimental set-up is constantly developed further, with the implementation of new faster cameras with higher recording rates as the latest improvement. In this contribution the present state of our measurement set-up, the procedure to detect the dust particles and to calculate their 3d trajectories will be shown. This includes first results on the observation of particle chains in dusty plasmas.

P 17.5 Fri 14:00 P

Thermal gradient induced dust convections in a dc plasma under microgravity conditions — •Andreas Schmitz, Ivo Schulz, Michael Kretschmer, and Markus Thoma — I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Germany

Experiments with complex plasmas were conducted in an engineering model of the International Space Station's laboratory setup Plasmakristall 4 during ESA's 71th parabolic flight campaign in the A310 ZERO-G aircraft in May 2019. In some of these microgravity experiments a DC discharge plasma was generated within the elongated glass tube of PK-4. The investigated complex plasma was introduced to a thermal gradient caused by a heater ring mounted around the plasma chamber. The dust cloud was trapped near the heater where the cloud convected. It was concluded that this dust cloud convection was induced by a gas flow via drag. Analysis of the dust cloud convection showed this gas flow to have been caused by thermal creep, a phenomenon which is common in rarefied gases with a temperature gradient along a boundary.

P 17.6 Fri 14:00 P

"Zyflex": next generation plasma chamber for complex plasma research in space — •Christina A. Knapek[1], Uwe Konopka[2], Daniel P. Mohr[1], Peter Huber[1], Andrey M. Lipaev[3], and Hubertus M. Thomas[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Weßling, Germany — [2]Auburn University, Auburn, AL, USA — [3]Joint Institute for High Temperatures of the Russian Academy of Sciences, Moscow, Russia

Complex plasmas consist of highly charged micrometer-sized grains injected into a low temperature noble gas discharge. Since gravity has a strong influence on the particle system, experiments under microgravity conditions are essential. A novel plasma chamber (the "Zyflex" chamber) has been designed for complex plasma research in a future facility on the International Space Station (ISS). The cylindrical, radio-frequency driven discharge device includes a variety of innovations that for example allow to flexibly adjust plasma parameters and its volume. Compared to former chambers used in space based complex plasma facilities, it also supports much larger particle systems and can be operated at much lower gas pressures, thus reducing the damping of particle motion considerably. Beyond the technical description and particle-in-cell (PIC) simulation based characterization of the plasma vessel, we show sample results from experiments performed with this device in the lab as well as during parabolic flights. Further, an outlook on the future ISS facility COMPACT with the Zyflex chamber at its core is given. This work is funded by DLR/BMWi (FKZ 50WM1441).

P 17.7 Fri 14:00 P

Influence of the surface roughness on the adhesion of thermal plasma spray Al2O3 coatings — •Tony Krüger[1], Thorben Kewitz[1], Holger Testrich[1], Rüdiger Foest[1], and Franz Faupel[2] — [1]Leibniz Institute for Plasma Science and Technology, 17489 Greifswald, DE — [2]Kiel University, 24143 Kiel, DE

In industrial plasma spray processes, masks are used to protect areas of the work piece from unwanted coating. However, gradual accumulation of material on masks can lead to changes in the flow dynamics near masks causing loss of contour accuracy and coating quality. Hence, generating surfaces conditions for masks that affect film adhesion and promote swift delamination becomes attractive. In thermal spray processes, bonding between the coating and a substrate surface is mainly established by mechanical anchoring, next to physical and chemical interactions. Here, the influence of the surface roughness on the coating adhesion is studied systematically. The surface roughness of steel was varied by means of plasma electrolytic polishing in order to provide a series of samples with a defined range from $2.5\mu m \geq Ra \geq 0.02\mu m$, measured using surface profilometry and white light interferometry, for critical method comparison. Moreover, the effect of additional interface layers (TiN, SiOx) on the film adhesion was investigated. Samples were spray coated with Al2O3 (2kg/h) using a Oerlicon Metco F4MB-XL Spray Gun (DC, I=600A, gases: Ar (41 NLPM), H2 (14NLPM)). The relation between thin film adhesion and surface conditions (roughness and presence of interface layers) is examined (Funded by the EU and the State of Mecklenburg-Western Pomerania (TBIV-1-321)).

P 17.8 Fri 14:00 P

Control and monitoring of spatial discharge distribution in a barrier corona discharge at elevated pressures — •Hamed Mahdikia, Michael Schmidt, Volker Brüser, and Ronny Brandenburg — Leibniz Institute for Plasma Science and Technology, 17489, Greifswald, Germany

A barrier corona discharge in CO2 with admixture of Argon is studied. The aim is to investigate the operation at elevated pressures up to 5 bar for industrial scale CO2 conversion. Therefore, the coaxial asymmetric dielectric barrier discharge contains an inner brush electrode to intensify the electric field strength and to minimize the amplitude of the applied high voltage driving the discharge. Charge-voltage plots are used to characterize the discharge. Depending on the conditions (sinusoidal voltage amplitude, gas composition), full or partial coverage of the electrodes is obtained. This so-called partial discharging is monitored by the variation of the effective dielectric capacitance. It increases exponentially for a mixture of Ar and CO2 (1:4) at 1 bar and reaches its maximum (i.e. fully electrode covering discharge) as the amplitude of the applied high voltage exceeds 8 kV. It decreases linearly with the increasing the pressure. The cell capacitance remains constant under variation of gas and pressure. The higher the pressure the higher the sustaining voltage and the lower the surface coverage fraction of the plasma. This may be due to the fewer and weaker micro discharges due to the lower ionization rate at higher pressures.

P 17.9 Fri 14:00 P

Splitting of CO2 with negative nanosecond pulsed dielectric barrier discharge — •Sepideh Mousazadeh borghei, Raphael Rataj, Volker Brüser, and Juergen F Kolb — Leibniz Institute for Plasma Science and Technology (INP),Greifswald, Germany

Carbone dioxide, one of the inevitable by-products of human activities, is a notable contribution to the current climate change. Conversion of CO2 into value added chemicals and fuels namely CO and CH3OH has drawn remarkable attention as a potential solution. For the splitting of CO2 into CO and O2, harsh conditions are required, owing to the high stability of the CO2-bonds. Non-thermal plasma has provided an innovative way. The goal is to provide electrons with sufficient energy, i.e. temperature, while the gas temperature can remain close to room temperature. In the first step of our project, we studied the effects of gas flow rates and mixture ratios of CO2 with argon on CO2-splitting. Therefore, a cylindrical dielectric barrier discharge reactor was set up to investigate efficacies and efficiencies. The plasma was generated by the application of negative high voltage pulses of nominally -20 kV and a pulse duration of 500 ns to an inner rod-electrode that was insulated by a glass wall with gap distance of 4 mm from the surrounding grounded electrode with 90 mm in length. Pulse repetition rates were set to 1 kHz. Gas compositions after treatment were investigated by FTIR spectroscopy. The results demonstrated that the flow of the feed gases played a significant role in CO2-conversion. The highest conversion rate was achieved for the lowest flow rate of 30 sccm, yielding 6% of CO.

P 17.10 Fri 14:00 P

Plasma catalytic synergies of a non-equilibrium atmospheric pressure plasma jet and MnO_2 surface catalyst — •Christoph Stewig, Theresa Urbanietz, Laura Chauvet, Marc Böke, and Achim von Keudell — Ruhr-University-Bochum, Germany

Plasma catalysis has the goal to exploit potential synergies between plasma and surface catalytic reactions. With the advent of renewable energies, this could allow the utilization of excess electrical energy to produce value-added molecules and thus provide the chemical industry with important reactants or store this energy.

Potential synergetic effects are: (i) a reduction or prevention of catalyst poisoning due to a cleaning of the catalyst surface, hence (ii) a lowering of the catalyst activation temperature, and (iii) an increase in the catalyst activity due to the creation of additional reactive sites by the plasma. (iv) finally, specific molecular excitations could promote specific surface reactions.

Due to the temperature dependence of surface catalysis, it is necessary to avoid intense surface heating. Thus, we employ a RF driven temperature-controlled capacity coupled plasma jet. Fourier Transformed Infrared Spectroscopy (FTIR) measurements are conducted in the plasma and yield information on the excitation and density of noble gas diluted molecules like CO_2 or n-butane.

The effect of an MnO_2 surface catalyst for temperatures between 20°C and 200°C on the dissociation of CO_2 and n-butan is presented.

P 17.11 Fri 14:00 P

Diagnostic of temporal behavior of a plasma electrolytic polishing process — •Sehoon An[1], Luka Hansen[2], Thorben Kewitz[1], Gregor Gött[1], Sehyun Kwak[3], Maik Fröhlich[4], Rüdiger Foest[1], Katja Fricke[1], Antje Quade[1], Klaus-Dieter Weltmann[1], and Holger Kersten[2] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [3]Max Plank Institute for Plasma Physics, Greifswald, Germany — [4]Leupold Institute of Applied Sciences, University of Applied Sciences Zwickau, Zwickau, Germany

Plasma electrolytic polishing (PEP) has gained much attention owing to various surface modifications including oxidation or removal of material by selective dissolution of chemical compounds. During the PEP process, a volatilization of the electrolyte leads to a gas layer around the working electrode accompanied with spark discharges. The stability of the gaseous layer directly influences the material removal rate. Here, we investigate the temporal behavior of the gaseous layer involving numerous single discharges by synchronized electrical monitoring (current and voltage waveforms) and optical inspection (high-speed video, 1000 fps). We report on observations regarding oscillating discharge current and characteristic frequencies obtained by fast Fourier transformation (FFT) in relation to the process parameters and the temporal evolution of the workpiece temperature.

P 17.12 Fri 14:00 P

Diagnostics for the JT-60SA pellet source commissioning — •Jan-Henrik Ufer[1], Peter Lang[2], Bernhard Plöckl[2], Martin Prechtl[1], and ASDEX Uprade Team[2] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmaphsyik

JT-60SA is a superconducting tokamak currently under commissioning in Naka, Japan. It was built in a collaboration between Europe and Japan aiming to resolve key physics and engineering issues for ITER and a future fusion reactor. Equipped with superconducting coils it will be capable to investigate long lasting advanced modes of plasma operation for pulse durations up to 100 s. In this context, exploration of the high density regime and ELM control is envisaged. Therefore, a novel pellet system - pellets are mm sized solid hydrogen bodies - is under construction serving for both tasks. Any task got an accordingly designed pellet source attributed. Both the commercially supplied sources will be tested and commissioned in a dedicated European test stand. There, quality and mass throughput of the extruded ice rod as well as the quality and maximum achievable rate of pellets cut from this rod have to be diagnosed. A monochrome camera system comprises a video mode to record the initial ice extrusion and a stroboscopic mode to monitor pellet production with a flash laser. The laser is synchronised with the cutter actuation, emitting short light pulses imaging pellets avoiding movement blur. The contribution will show the designed layout of the pellet system, our diagnostics unit and the planned test sequences for the fuelling and the pacing pellet sources.

P 17.13 Fri 14:00 P

Towards the operation of a high-resolution mass spectrometer for exhaust gas analysis at ASDEX Upgrade — •Antonello Zito[1,2], Thomas Schwarz-Selinger[1], Volker Rohde[1], Athina Kappatou[1], and Marco Wischmeier[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany

The removal of helium, which is the product of the D-T reaction, in magnetic fusion devices must be as efficient as possible in order to avoid fuel dilution and not degrade the confinement properties. Optimizing the strategies for a good helium pumping is possible by monitoring the behavior of the exhaust gas in helium-seeded plasma discharges in currently operating devices. In the framework of helium exhaust studies, a high-resolution quadrupole mass spectrometer has been recently installed at the pumping ducts of the ASDEX Upgrade tokamak. This diagnostic has been proven successful in discriminating molecules of deuterium and atoms of helium, which have a tiny mass difference of only 0,025 AMU, with elevated accuracy. The capability of detecting even trace levels of helium (< 5%) in a deuterium gas has been confirmed. However, the harsh environment involving the presence of radiations and intense currents in proximity of the instrument is seen to strongly affect the reliability of the measurements during plasma operations. In this work we will present some of the challenges which were faced during the efforts towards the detection of helium in the exhaust gas of ASDEX Upgrade using this technique.

P 17.14 Fri 14:00 P

Determination of 2D Filament Temperatures and Densities at ASDEX Upgrade with the Thermal Helium Beam Diagnostic — •Daniel Wendler[1,2], Michael Griener[1], Gregor Birkenmeier[1,2], Rainer Fischer[1], Ralph Dux[1], Elisabeth Wolfrum[1], Ulrich Stroth[1,2], and the ASDEX Upgrade team[1] — [1]Max-Planck- Institut für Plasmaphysik, Garching, Germany — [2]Physik Department E28, TUM, Garching, Germany

In all plasma scenarios in magnetic confinement fusion, small filamentary structures appear in the scrape-off layer (SOL), with a locally strongly enhanced density, which propagate convectively outwards. Blobs contribute to reactor relevant phenomena like the density shoulder formation, large first wall particle fluxes and the broadening of the divertor heat flux fall-off length. To calculate the effective power flux which is carried by the filaments, temperature and density as well as the frequency and velocity of blobs have to be determined. While the measurements of mean blob velocities are possible with various diagnostics, the simultaneous non-invasive measurement of temperatures and densities of single filaments is now possible with the thermal helium beam diagnostic. By means of a grid of poloidally and radially distributed lines of sight, the temperature, density and velocities as well as the blob shape can be determined in two dimensions. Another way of measuring the filament temperature and density is beam emission spectroscopy, in the case here measured with a thermal helium beam diagnostic. First results of blob temperatures and densities will be shown and an extended collisional-radiative model will be presented.

P 17.15 Fri 14:00 P

Challenges in the tomographic reconstruction of radiation distributions of high temperature plasmas in Wendelstein 7-X stellarator — •Henning Thomsen, Christian Brandt, Sara Vaz Mendes, Kian Rahbarnbia, and Jonathan Schilling — MPI f. Plasmaphysics, Wendelsteinstr 1, 17491 Greifswald

The spatial-temporal dynamics of plasma radiation in the soft-X ray range is studied by means of the tomography diagnostic system (XMCTS) in Wendelstein 7-X stellarator. The radiation in this energy range originates mainly from Bremsstrahlung of the confined plasma. The quality tomographic inversion, the reconstruction of the radiation distribution in the plane spanned by the pinhole cameras from the line-integrated measurements, is strongly dependent on an accurate modelling of the diagnostic geometry. In this contribution we study the effect of the 3D shaped plasma in the observation volume. This effect is potentially more relevant in stellarators than in other magnetic confinement devices with simpler flux surfaces (like tokamaks).

P 17.16 Fri 14:00 P

Modelling of plasma ion heat flux in the edge of ASDEX Upgrade with EMC3-EIRENE for an improved understanding of the H-mode access — •Philipp Sauter[1,2], Thomas Eich[1], Dominik Brida[1], Marco Cavedon[1], Tilmann Lunt[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Universität Tübingen, 72074 Tübingen, Germany

The future nuclear fusion device ITER will be operated in an improved confinement regime.. The access to H-mode relies critically on the ion heat flux crossing the edge region of the plasma [1]. This work analyses the role of the ion heat flux on the transition from L-Mode to H-Mode The EMC3-Eirene simulation code is used to simulate plasma discharges in ASDEX Upgrade at different powers and densities with varying proportions of heating in electrons and ions. Parallel and perpendicular heat fluxes are obtained in order to quantify heat fluxes crossing the separatrix and being transported to the divertor. In particular, it is investigated if the collisional heat exchange from ions to electrons at high collisonalities is able to reduce the ion heat flux to a level where an H-L back transition is triggered. Also, the correlation of the ion electron temperature ratio at the separatrix with various plasma parameters is investigated. Here it is found that the ratio of ion to electron heat fluxes crossing the separatrix correlates with that ratio, while no correlation with the collisionality parameter suggested previously [2] was found. [1] Ryter F. et al 2016 PPCF 58 014007 [2] Stangeby P. 2000, The Plasma Boundary of Magnetic Confinement

P 17.17 Fri 14:00 P

Transport coefficients at W7-X based on target heat loads — •David Bold, Felix Reimold, Holger Niemann, Yu Gau, Marcin Jakubowski, and the W7-X team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

In the current study the divertor heat load distribution of Wendelstein 7-X (W7-X) has been analysed based on heatfluxes reconstructed from infrared temperature measurements. Due to the inherent 3D nature of the scrape-off layer (SOL) of W7-X, also the heatflux pattern is 2D on the target in nature, unlike in Tokamaks, where a 1D representation is regularly used.

At low densities most of the heatflux is deposited on the low-iota target, as expected from modelling. A narrow strike line, overlayed by a broad feature is observed. The narrow strike line is of the range of 2 to 4 cm, while the broad feature is around 10 to 20 cm wide for an attached case with low radiated power. Additionally to studying the strike line width, also the toroidal distribution on the target is studied. It is observed that in the experiment a significant amount of the power is deposited at the far end of the low-iota target, while with increasing density the power is more evenly distributed on the low-iota target.

The analysis of the experimental data is compared to EMC3-EIRENE simulations, where the diffusion coefficients are varied in order to match the experimental results. It is observed that a simple, constant diffusion coefficient is not sufficient to reproduce the experimental measurements. The impact of spatially varying diffusion coefficients is studied.

P 17.18 Fri 14:00 P

Causality study on the drift-wave turbulence – zonal-flow coupling at the TJ-K stellarator. — •Nicolas Dumérat, Bernhard Schmid, and Mirko Ramisch — IGVP, University of Stuttgart

We present a set of two non-parametric methods used for inferring causality amongst parameters measured in the same complex system. Convergent cross-mapping, a forecasting approach is introduced, based on time-delay embedding and state space reconstruction. This method showed good results for measuring the strength and direction of influence of causal relationships in synthetic datasets. A second method, called transfer entropy, is also investigated, the basis of which is the measurement of information flow between variables. The use of these methods allows for the identification of causal links between variables and can be extended to turbulence studies. In this frame, it is known that zonal flows are driven by the localized tilting of ambient turbulent structures. This deformation of the eddies can be caused by existing shear flows and measured experimentally via Reynolds stress. Langmuir probe measurements from the TJ-K stellarator are then used as experimental inputs for the presented methods. The results support the theoretically expected causal connection of eddy tilting to zonal-flows occurance.

P 17.19 Fri 14:00 P

Control of Spokes in HiPIMS Discharge — •Mathews George, Wolfgang Breilmann, Julian Held, and Achim von Keudell — Experimentalphysik II, Ruhr-University Bochum

Magnetron Sputtering is a Plasma Vapour Deposition (PVD) process widely used in industry and scientific communities. HiPIMS (High Power Impulse Magnetron Sputtering) produces plasma pulses of very high density of the order of $10^{19}\mathrm{m}^{-3}$ without overheating the target. The plasma appears to be homogeneous to the human eye, but shows localised zones of high brightness rotating in the **E x B** direction when observed with an ICCD camera with exposure times below 1μs. These local ionization zones, also called 'spokes' are assumed to play a role in the transport of particles and energy away from the target. This anomalous transport results in an enhanced deposition rate by counteracting the return effect. The primary objective of this project is to control spoke frequency in HiPIMS in-order to study its influence on the IEDF and metal ion flux from the target. Controlling metal ion flux from the target would lead to a better deposition rate and quality of the film. DCMS was chosen for the development of spoke control as an initial test object since the spokes in DC regime are more uniform compared to HiPIMS.

P 17.20 Fri 14:00 P

Control of Spokes in Magnetron Discharges — •Mathews George, Wolfgang Breilmann, Julian Held, and Achim von Keudell — Experimentalphysik II, Ruhr-University Bochum

Magnetron Sputtering is a Plasma Vapour Deposition (PVD) process widely used in industry and scientific communities. The plasma appears to be homogeneous to the human eye, but shows localised zones of high brightness rotating in the **E x B** direction when observed with an ICCD camera with exposure times below 1 μs. These local ionization zones, also called 'spokes' are assumed to play a role in the transport of particles and energy away from the target. This anomalous transport results in an enhanced deposition rate by counteracting the return effect. The primary objective of this project is to control spoke frequency in HiPIMS in-order to study its influence on the IEDF and metal ion flux from the target. Controlling metal ion flux from the target would lead to a better deposition rate and quality of the film. DCMS was chosen for the development of spoke control as an initial test object since the spokes in DC regime are more uniform compared to HiPIMS. Amplified rectangular signals are applied to a Langmuir probe to draw electron current from the plasma at the highest gradients in the **E x B** direction. The responses of the spoke frequency and intensity to the applied signal are measured with a flat probe. The metal ion flux from the target surface is measured time and energy resolved with a mass spectrometer. This study is then further extended to HiPIMS spokes by applying signals on multiple probes to achieve an effective control of spokes.

P 17.21 Fri 14:00 P

Updates on The He/Ne beam diagnostic for line ratio spectroscopy in the Island Divertor of Wendelstein 7-X — Erik Flom[1], Tullio Barbui[1,2], Oliver Schmitz[1], Marcin Jakubowski[3], Frederik Henke[3], Carsten Killer[3], Maciej Krychowiak[3], Ralf Koenig[3], Stuart Loch[4], Jorge Munoz-Burgos[5], John Schmitt[4], and •The W7-X Team[3] — [1]University of Wisconsin-Madison, Madison, WI — [2]Princeton Plasma Physics Laboratory, Princeton, NJ — [3]Max Planck Institute for Plasma Physics, Greifswald, Germany — [4]Auburn University, Auburn, AL — [5]Astro Fusion Spectre, San Diego, CA

A line-ratio spectroscopy system based on thermal helium and neon collisional radiative models (CRM) has been implemented and successfully shown to enable measurement of ne and Te above the horizontal divertor targets in two in the standard divertor configuration magnetically connected modules of the Wendelstein 7-X optimized stellarator. In this work, modeling results are presented for standard attached and detached conditions in the divertor of Wendelstein 7-X to show the helium and neon emissivity as a function of radial position above the divertor target. This work also includes first in-situ measurements of gas cloud atomic density distribution from an gas injector identical to the one utilized at W7-X. Also shown are comparisons between helium beam data and multipurpose manipulator probe data using a novel flux coordinate system, an improvement over previous field-tracing methods for diagnostic comparison within the 5/5 island chain.

P 17.22 Fri 14:00 P

Three-dimensional Finite Element Modelling of Magnetic Measurements of Tearing Modes in ASDEX Upgrade — •Magdalena Bauer, Marc Maraschek, Hartmut Zohm, Wolfgang Suttrop, Anja Gude, Felix Klossek, and the ASDEX Upgrade Team — Max Planck Institute for Plasma Physics, Garching

A tearing mode can be measured by various magnetic pick-up coil types characterized by their orientation and distance to the plasma and the surrounding conducting structures. Depending on the rotation frequency of the mode, screening currents are induced in these conductors that influence the magnetic measurements differently. A fast rotating mode can only be detected by the one coil type, whereas a locked mode signal is only available for the other type. In order to get a continuous description for all frequencies, a three-dimensional finite element model of the tokamak ASDEX Upgrade, including the geometry of the resonant surface of the tearing mode, the conducting vessel and passive stabilization loop (PSL), is implemented. The mode itself is described by a perturbation current density on the respective resonant surface from the equilibrium reconstruction. The simulated magnetic measurements of the mode, including the field of the mirror currents in the conducting structures, are used for a frequency dependent adaption of the experimentally determined magnetic perturbation field. The approach for adjusting the signals of the different types of magnetic measurements for various frequencies to get a unique perturbation amplitude, using the newly developed tool, is established and can be extended for the locked phase of the MHD mode.

P 17.23 Fri 14:00 P

Gaussian Process Surrogate Models for Uncertainty Quantification in Multiscale Turbulent Transport Simulations — •Yehor Yudin, Jalal Lakhlili, Onnie Luk, Udo von Toussaint, and David Coster — Max Planck Institute for Plasma Physics, Boltzmannstrasse2, 85748 Garching, Germany

One of the challenges in understanding fusion plasmas is quantifying the effects of micro-scale turbulent dynamics on energy and particle transport processes in a fusion device. In order to analyze such effects, one should numerically solve a model which couples system evolution on disparate spatial and temporal scales, as well as consider both aleatoric and epistemic uncertainty of such model. For such a solution the largest share of computational expense is spent on resolving turbulence related scales. This work proposes an application of a surrogate modelling approach to reduce computational costs for a solution in a case close to a quasi-steady state when it is sufficient to capture only statistics of turbulent dynamics. We studied a Multiscale Fusion Workflow that couples gyrofluid turbulence code GEM in flux tube approximation with core transport code ETS, and calculates transport coefficients from turbulent energy and particle fluxes. For that, we applied the VECMA toolkit to perform uncertainty quantification, as well as to train, test and utilize surrogate models. In this work, a data-driven probabilistic surrogate model based on Gaussian Process Regression is used to infer flux values computed by a turbulence code for given core profiles, and to calculate related uncertainties.

P 17.24 Fri 14:00 P

Extension of GENE-3D to a global electromagnetic turbulence code for stellarators — •Felix Wilms[1], Alejandro Bañón Navarro[1], Gabriele Merlo[2], Leonhard Leppin[1], Tobias Görler[1], Tilman Dannert[3], Florian Hindenlang[1], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München, Germany — [2]Oden Institute for Computational Engineering and Sciences, Austin,Texas 78712, USA — [3]Max Planck Computing and Data Facility, 85748 Garching, Germany

GENE-3D is a code that is capable of simulating gyrokinetic plasma turbulence in stellarators globally (Maurer et al., Journal of Computational Physics, 2020). It has recently been upgraded to an electromagnetic version, expanding the variety of turbulent features that can be studied with it. In this work, we present the underlying algorithm, together with verification studies against the established global tokamak code GENE (Jenko et al., Physics of Plasmas, 2000). Finally, we present a first application to stellarator physics, by investigating the influence of finite plasma-β on ITG turbulence in Wendelstein 7-X.

P 17.25 Fri 14:00 P

Study of slow wave propagation in IShTAR — •Felix Paulus, Volodymyr Bobkov, Roman Ochoukov, and Oleksii Girka — Max-Planck-Institute für-Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Ion cyclotron resonance heating (ICRH) is an established technique to reach fusion relevant temperatures in modern tokamaks. While the fast Alfven wave is launched intentionally to heat the plasma, it is believed that the parasitically launched slow wave is a source for electric fields parallel to the background magnetic field (Myra & D'Ippolito, 2008). Since the slow wave (sw) propagates in low density plasma its existence remained unconsidered in tokamaks for a long time. Recent developments suggest, that the plasma density in the far SOL of a tokamak drops below the lower hybrid resonance density opening a channel for sw propagation which might induce further plasma dynamics.

Here we show results from experiments carried out on IShTAR - a linear plasma device - where we measure the slow wave, that is launched into a magnetized low-density plasma by a wire loop antenna, with a floating probe. The results are compared to FEM simulations from RAPLICASOL (Tierens, et al., 2019) and further analytical considerations. Based on these results future experiments on the ASDEX Upgrade tokamak are proposed.

P 17.26 Fri 14:00 P

Divertor optimization for the stellarator experiment W7-X — •Amit Kharwandikar, Dirk Naujoks, Thomas Sunn Pedersen, Felix Reimold, and The W7X Team — Max Planck Institute for Plasma Physics, Greifswald, Germany

The Wendelstein 7-X (W7-X) is an advanced stellarator device operated in Greifswald, to provide the proof of principle that the stellarator concept can meet the requirements of a future fusion reactor. To fulfil this goal, several experimental campaigns have been conducted over the years. In the recent OP1.2 campaign, ten adiabatically loaded divertor units (Test Divertor Units (TDU)) have been installed in the plasma vessel together with baffles, toroidal/poloidal closures, etc. During the experiments, high heat loads onto in-vessel components have been observed, that exceed the specified limits under certain conditions. This immediate concern and the need to transition to fusion reactor relevant material (e.g. Tungsten) for plasma facing components (PFC) to achieve the long-term goals, motivate the need for a new divertor design. This poster discusses the investigation of the physics basis for such a new divertor concept with the objectives as heat load reduction and high gas exhaust. The important technical constraints are specified as well as the main modelling tools to be used, namely the Field Line Transport (FLT) code and EMC3-Eirene. As a current activity, example applications of FLT for studying erosion-redeposition and certain baffle overload scenarios have been described. Finally, the main conceptional ideas to achieve the desired optimized plasma facing surface for the W7-X divertor and baffle are presented.

P 17.27 Fri 14:00 P

Manipulating the radial deposition of positrons in a magnetic dipole trap — •Stefan Nissl[1,2], Eve Stenson[1,2,3], Juliane Horn-Stanja[1], Uwe Hergenhahn[1,7], Thomas Sunn Pedersen[1,4], Haruhiko Saitoh[6], Christoph Hugenschmidt[2], Markus Singer[2], Matthew Stoneking[1,5], and James Danielson[3] — [1]Max-Planck-Institute for Plasma Physics, Greifswald & Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]University of California, San Diego, La Jolla, CA — [4]University of Greifswald, Greifswald, Germany — [5]Lawrence University, Appleton, WI — [6]The University of Tokyo, Tokyo, Japan — [7]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

In a pair plasma, both particle species have the same mass. Compared to an electron-ion plasma, a pair plasma is predicted to have unique characteristics and excellent stability properties. A Positron-Electron eXperiment (APEX) has the goal to create such a kind of plasma in a magnetic dipole trap for the first time. An important step towards this goal is to know how parameters of the experiment, such as electrode biases, effect the radial deposition of positrons in the magnetic dipole field. For that, we reanalyzed experimental data, compared them to numerical single-particle simulations, and found multiple parameters that modify the radial deposition of positrons without deteriorating the required high injection efficiency. These results can be used to design upcoming experiments about long confinement and pulse stacking.

P 17.28 Fri 14:00 P

Investigating impurity transport at the plasma edge in different confinement regimes at ASDEX Upgrade via charge exchange recombination spectroscopy — •Tabea Gleiter[1,2], Ralph Dux[1], Marco Cavedon[1], Rachael McDermott[1], and the ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Physik-Department E28, Technische Universität München, Garching, Germany

In our recently started project, we investigate the impurity transport at the plasma edge in different confinement regimes at ASDEX Upgrade. In particular, we look at scenarios without or with only small (type-II) edge localized modes (ELMs), such as the I-mode, QCE-mode and EDA-H mode, in comparison to the standard type-I ELMy H-mode. Due to the considerable influence of ELMs on the particle exhaust at the plasma edge, the impurity transport is expected to differ significantly. This is especially of interest since future tokamaks such as ITER and DEMO could benefit from the reduced peak power fluxes at the divertor in 'ELM-free' regimes, but are also reliant on small impurity concentrations in the plasma core. In our experiments, we use active charge exchange recombination spectroscopy (CXRS) to study the temporal and radial evolution of the impurity densities. The detailed approach and first results will be presented.

P 17.29 Fri 14:00 P

Early stages of He cluster formation in tungsten single crystals — •Annemarie Kärcher[1,2], Vassily V. Burwitz[2], Thomas Schwarz-Selinger[1], and Wolfgang Jacob[1] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Technische Universität München, 85747 Garching, Germany

Tungsten (W) has been established as a main candidate for plasma-facing materials (PFMs) in future nuclear fusion reactors due to its favorable properties regarding the fusion environment. As PFM, tungsten will be subjected to intense impinging fluxes of helium (He). While the consequences of high He fluxes on the surface of tungsten materials have already been thoroughly studied, the mechanisms behind the early stages of the He cluster formation are still unclear. In order to understand the initial steps of the interaction of He with W, especially the impact of pre-existing defects, defined defects are induced in W111 single crystals and characterized by positron annihilation spectroscopy (PAS). Then, these are exposed to a low-temperature He plasma using an implantation energy below the displacement theshold. These He implanted samples are measured by PAS, elastic recoil detection analysis and thermal desorption spectroscopy. The experimental results are compared to simulation data.

P 17.30 Fri 14:00 P

Semilagrangian hybrid kinetic/driftkinetic code for the studying of fusion plasmas — •Aleksandr Mustonen[1], Felipe Nathan de Oliveira[1], Ken Hagiwara[2], Karen Pommois[1], Florian Allman-Rahn[3], Simon Lautenbach[3], Rainer Grauer[3], and Aleksandr Mustonen[3] — [1]Max-Planck-Institut für Plasmaphysik — [2]Ludwig-Maximilians-Universität München — [3]Ruhr-Universität Bochum

Modeling of the tokamak edge plasma is one of the most important problems we have to solve to achieve understanding of physics, taking place in the device. A lot of currently existing and well known codes used by the community employ gyrokinetic system of equations. This is a framework to resolve kinetic equations on a reduced 5D space, applicable for charged particles moving in a strong background magnetic field and valid until the phenomena scale gets as small as the Larmor radius. Presence of steep gradients at the edge region prevents us from usage of GK models in their present state.

One of the ways to avoid this complication is to use a fully kinetic 6D framework. However, the immense computational cost of such a direct approach makes it ill-suited for longtime simulations. Here we discuss the hybrid framework and its implementation in the ssV: a semi Lagrangian electrostatic code with fully kinetic ions and driftkinetic electrons to completely resolve ion physics and save computational resources on electrons, while retaining the most important kinetic effects. New found hybrid wave explained with the help of analytical dispersion solver FIDEL. Slab ITG testcase discussed.

P 17.31 Fri 14:00 P

Steps for implementation of divertor protection algorithms at Wendelstein 7-X — •Manuel Agredano-Torres[1], Simon Fischer[1], Heike Laqua[1], Aleix Puig Sitjes[1], Hans-Stephan Bosch[1], Wolfgang Treutterer[2], Axel Winter[1], and Wendelstein 7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

Wendelstein 7-X (W7-X) is the world's largest stellarator experiment and aims to proof the viability of stellarator devices as power plants. It is being upgraded including the installation of actively cooled divertors. In order to avoid damage in the divertors, their temperatures have to be kept below their maximum limit and a protection system, as part of W7-X control system, is required to ensure it. The divertors protection is based on the data obtained from thermography diagnostics. Fast Control Stations process the data in real-time to determine the risk of surpassing a temperature limit. In the next operational campaign, if the risk reaches a determined threshold, an alarm is triggered so the Safety System can act on time and stop the operation of the device. The final goal of the protection system is to allow a continuous operation W7-X, avoiding the overheating of the divertors by feedback control of heating systems and control coils. This contribution presents the overall system required for the divertors protection including relevant diagnostics and W-7X control system, an overview of the protection algorithms and the planning for their real-time implementation in the control system before the next operational campaign.

P 17.32 Fri 14:00 P

3D Monte-Carlo PIC modeling of plasma grid biasing and the co-extraction of electrons in negative ion sources — •Max Lindqvist[1], Dirk Wünderlich[1], Alessandro Mimo[1], Serhiy Mochalskyy[1], Adrien Revel[2], Tiberiu Minea[2], and Ursel Fantz[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Universite Paris-Saclay, CNRS, LPGP, Orsay, France

One of the factors limiting the performance of negative ion sources for the ITER Neutral Beam Injection (NBI) system is the co-extraction of e^-. By varying the positive bias potential of the Plasma Grid (PG) with respect to the source walls, the amount and temporal instability of co-extracted e^- is strongly decreased. This study investigates the mechanisms of this process by varying the bias of the PG using the already established 3D Monte-Carlo PIC code ONIX. The simulation domain covers the extraction region near one of the PG apertures in the ELISE ion source. In previous PIC simulations of this type, the boundary from the bulk plasma to the simulation domain is characterized by an artificial plasma sheath. Here, for the first time in a 3D PIC code for NBI sources, a flat potential transition is simulated, which allows for biasing the PG without extending the simulation domain to the source walls. Instead, the bias has been indirectly applied by varying the PG potential from −5 V (close to floating) to 1 V (e^- attracting sheath) with respect to the plasma potential. In agreement with experimental results, the co-extracted e^- current is decreased by over 50 %, caused by an increased flux of e^- towards the top and bottom of the PG, following the magnetic field lines.

P 17.33 Fri 14:00 P

Gyrokinetic modelling of anisotropic energeticparticle driven instabilities in tokamak plasmas — •Brando Rettino, Alberto Bottino, Alessandro Biancalani, Thomas Hayward-Schneider, Philipp Lauber, and Markus Weiland — Max Planck Institute for Plasma Physics, Garching, Germany

Energetic particles produced by plasma heating can excite instabilities in tokamaks. We study the effects of anisotropy of distribution functions on the excitation of such instabilities with ORB5, a gyrokinetic particle in cell code. Analytical anisotropic expressions for the distribution function are implemented and numerical results are shown for linear electrostatic simulations with ORB5. The growth rate is found to be sensitively dependent on the phase-space shape of the distribution function. Realistic neutral beam energetic particle anisotropic distributions are obtained from the heating solver RABBIT and are introduced in ORB5 as input distribution function.

P 17.34 Fri 14:00 P

Non-local neoclassical PIC simulations for the radial electric field in stellarators — •Michal Kuczynski, Ralf Kleiber, and Hakan Smith — Wendelsteinstraße 1, 17491 Greifswald

Transport in fusion plasma devices has typically two contributions: turbulent and neoclassical. The latter is most significant in stellarators and thus, for further experimental advances, a thorough understanding of the neoclassical transport is required. Perhaps one of the greatest achievements of the (local) neoclassical theory is the prediction of the neoclassical radial electric field. However, the

theory has its limitations. For instance, when the electric field changes sign (at the transition zone between the ion and electron roots), the theory may predict multiple values of the radial electric field, which is unphysical. To understand the physics in such scenarios we perform neoclassical PIC simulations with the addition of non-local terms and calculate the resultant electric field self-consistently.

P 17.35 Fri 14:00 P

Analysis of optimal quasi-isodynamic stellarator magnetic equilibria using a direct construction approach — •Katia Camacho Mata, Gabriel Plunk, Per Helander, and Michael Drevlak — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Two important requirements for a viable stellarator reactor are easy-to-build-coils and good confinement. Omnigenous configurations, those in which the time-averaged radial drift is zero, fulfill the good confinement properties requirement. Such configurations are traditionally found by numerical optimization, but these designs have been generally found to feature complex coils. However, it is unknown whether such complexity is fundamentally necessary. To explore this question, we will use a recently developed [1] method for the direct construction of omnigenous MHD(Magnetohydrodynamic) equilibria, which avoids the computational cost of conventional optimization, allowing a thorough survey of the space of omnigenous stellarators at large aspect ratio. We present an analysis of such solutions, focusing on the quasi-isodynamic case, a particular case of omnigeneity.

[1] Plunk, G. G., Landreman, M., & Helander, P. (2019). Direct construction of optimized stellarator shapes. Part 3. Omnigenity near the magnetic axis. Journal of Plasma Physics, 85(6).

P 17.36 Fri 14:00 P

Active learning and data augmentation using surrogate models of time series — •Katharina Rath[1,2], Christopher G. Albert[2], Bernd Bischl[1], and Udo von Toussaint[2] — [1]Ludwig-Maximilians-Universität München, Munich, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany

A comprehensive training data base is important to obtain satisfying and reliable results when working with neural networks. Gaussian processes (GPs) can act as surrogate models to enlarge the training data base and additionally provide the covariance structure. However, the computational complexity of standard GP regression increases with the third power of training data points and outliers are punished very severely, leading to unreliable uncertainty estimates. These drawbacks complicate the application of standard GP regression to noisy high-resolution time series data. Here, these difficulties are addressed using Student-t processes allowing a heavy tailed noise distribution in combination with a state space representation. While the Student-t process itself is more robust against outliers, the state space representation allows regression with computational complexity of order n, and thus can also be used if the time resolution is high. Besides a robust surrogate model for a comprehensive data base, the uncertainty estimates resulting from the stochastic process can be used in an active learning framework to determine which additional measurement data need to be incorporated in the training data set. The intended application is the robust augmentation of the training data base for the prediction of plasma disruptions.

P 17.37 Fri 14:00 P

Simulations of massive Deuterium injection into an MHD active ASDEX Upgrade plasma — •Fabian Wieschollek[1], Matthias Hoelzl[1], Eric Nardon[2], the JOREK Team[3], and the ASDEX Upgrade Team[4] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany — [2]CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France — [3]See the author list of M. Hoelzl et al 2021 NF 61, 065001 — [4]See the author list of H. Meyer et al 2019, NF 59, 112014

The foreseen disruption mitigation strategy for ITER is shattered pellet injection (SPI). In a realistic disruption scenario, the SPI is being triggered, when the plasma has already become MHD active; in particular 2/1 neoclassical tearing modes (NTM) are often present.

In this work, we investigate the interaction of Deuterium SPI and a preexisting 2/1 NTM in ASDEX Upgrade to assess its potential impact onto the mitigation strategy by means of the non-linear MHD code JOREK. Scans are performed of the initial island width, the number of atoms injected, and the relative injection phase with respect to the island O-point. Results indicate that preexisting islands do not render the mitigation ineffective. In case of small initial island sizes, no significant influence onto thermal quench (TQ) timing is observed independently of the injection phase. In case of larger islands, a delayed island growth and TQ onset is observed. This observation only changes when the injection is located to the direct vicinity of the X-point.

The studies are currently extended to take background impurities and multiple injection points into account.

P 17.38 Fri 14:00 P

Innovative Non-Resonant Divertors Applied to Compact Toroidal Hybrid (CTH) — •Kelly Garcia[1], Aaron Bader[1], Oliver Schmitz[1], John Schmitt[2], and Gregory Hartwell[2] — [1]University of Wisconsin-Madison, Madison, WI, United States of America — [2]Auburn University, Auburn, AL, United States of America

Non-resonant divertors separate the confined plasma from surrounding structures with the resulting boundary region comprised of cantori and/or stochastic regions, but without the presence of large islands. In contrast, island divertor configurations make use of low order rational surfaces with large islands mediating the confined plasma and the wall. These islands are highly sensitive to the value and shear of the rotational transform which can be affected by the evolution of the plasma equilibrium. CTH (Compact Toroidal Hybrid) can serve as a testbed for the non-resonant divertor solution for divertor optimization. The currents in the field coil and ohmic current drive systems of CTH are controlled to alter the rotational transform between $0.3 < \iota < 0.75$. Utilizing the FLARE fieldline following code, we calculate strike point locations for the exiting plasma for multiple ohmic current values. These calculations provide possible locations for divertor plates that will be built in the experiment to test non-resonant divertor resiliencies. These same techniques can be applied to other machines including ones that use the island divertor in the standard operation, like W-7X.

P 17.39 Fri 14:00 P

Experimental Survey of Plasma-Terminating Events in the Wendelstein 7-X Stellarator — •Jonathan Schilling, Henning Thomsen, Christian Brandt, Kian Rahbarnia, Ekkehard Pasch, Marc Beurskens, Sergey Bozhenkov, Hannes Damm, Golo Furchert, Evan Scott, Matthias Hirsch, Neha Chaudhary, Karsten Ewert, Udo Höfl, Johan Willem Oosterbeek, Torsten Stange, Gavin Weir, Jens Knauer, Tsuyoshi Akiyama, Kai Jacob Brunner, Tamara Andreeva, Ulrich Neuner, Oliver Ford, Sehyun Kwak, Andera Pavone, Jakob Svensson, Marco Zanini, and the W7-W Team 1 — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

An experimental data survey is conducted with a focus on global fast plasma-terminating events in the Wendelstein 7-X stellarator. These events associated with significant current drive may pose a risk for machine safety and need to be understood for reliable plasma operation in a future fusion power plant. Several such events were observed in recent campaigns of Wendelstein 7-X. Tomographic reconstruction of the soft X-ray emission pattern from the plasma allows to assess the spatio-temporal dynamics of these events with the necessary high resolution (f_s = 2 MHz; $\Delta R = \Delta Z$ = 4 cm). Those results are subsequently compared to experimental data from the Thomson scattering diagnostic (n_e, T_e profiles), the electron cyclotron emission diagnostic (T_e profile) and the single-channel interferometer ($\int n_e dl$).

P 17.40 Fri 14:00 P

Single-shot grating-based phase-contrast imaging at a laser-driven x-ray backlighter source — •Bernhard Akstaller, Stephan Schreiner, Max Schuster, Andreas Wolf, Veronika Ludwig, Thilo Michel, Gisela Anton, and Stefan Funk — Friedrich-Alexander Universität Erlangen-Nürnberg

We used a sub-picosecond x-ray flash, produced by a high-power laser and a tungsten backlighter wire, for phase-contrast imaging with short exposure times. With this, we demonstrated the feasibility of imaging a micron-sized (static) sample with a single-shot grating-based phase-contrast imaging setup. The obtained data is quantitatively analyzed and an enhancement of image quality is evaluated. The presented imaging technique allows to capture sharp images of fast dynamic processes like laser-produced plasma shock waves in the field of laboratory astrophysics, even if the absorption contrast is very low. The data was taken at the Petawatt High-Energy Laser for Heavy Ion Experiments at the GSI Helmholtzzentrum für Schwerionenforschung GmbH.

P 17.41 Fri 14:00 P

Comparison of Laser Induced Breakdown Spectroscopy (LIBS) results on deuterium loaded high Z materials from lasers of different pulse durations — •Steffen Mittelmann[1], Jannis Oelmann[2], Ding Wu[3], Gennady Sergienko[2], Sebastijan Brezinsek[2], Hongbin Ding[3], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, Germany — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, Germany — [3]Key Laboratory of Material Modification by Laser, Ion and Electron Beams, Dalian University of Technology, China

Impurities in the wall material of upcoming fusion reactors can endanger the lifetime and quality of the confined plasma. To get an idea of deuterium or tritium retention at the wall the diagnostic Laser induced breakdown spectroscopy (LIBS) is used. This widely applied technique is executed by lasers with different pulse durations from ns to fs. A big advantage of ultrashort laser pulses is the well-defined ablation area which leads to a high depth resolution. The results from LIBS experiments on tantalum exposed by deuterium in the linear plasma device PSI-2 with this laser system can be compared to ns- and ps-LIBS signals produced at Dalian University of Technology in China and the FZ Jülich, which are shown here. An important aim of these studies is to reach a deeper understanding of the basic processes governing ablation, plasma formation and spectral emission in the different pulse duration regimes for finally deciding which type of laser pulses is the most promising for future fusion reactor wall analysis.

P 17.42 Fri 14:00 P

The uniform electron gas in the thermodynamic limit: fermionic path integral Monte Carlo simulations — •Alexey Filinov[1,2], Pavel Levashov[2], and MichaeI Bonitz[1] — [1]Institut für Theoretische Physik und Astrophysik, CAU Kiel — [2]Joint Institute for High Temperatures, RAS, Moscow

The uniform electron gas (UEG) is one of the key models for the understanding of warm dense matter–an exotic, highly compressed state of matter between solid and plasma phases. The difficulty in modeling the UEG arises from the need to simultaneously account for Coulomb correlations, quantum and exchange effects. The most accurate results so far were obtained from QMC simulations. However, QMC for electrons is hampered by the fermion sign problem. Here we present results from a novel fermionic-propagator path integral Monte Carlo (FP-PIMC) in the restricted grand canonical ensemble (R-GCE). The ab-initio simulation results for the spin-resolved pair distribution functions and static structure factor are reported for two isotherms $T/T_F = 1, 2$. Furthermore, we combine the results from the linear response theory in the STLS-scheme with the QMC data to remove finite-size errors in the interaction energy. We present a new corrected parametrization for the interaction energy $v(r_s, \theta)$ and the exchange-correlation free energy $f_{xc}(r_s, \theta)$ in the thermodynamic limit, and benchmark our results against the RPIMC by Brown *et al.* [Phys.Rev.Lett. **110**, 146405 (2013)] and PBPIMC by Dornheim *et al.* [Phys. Rev.Lett. **117**, 115701 (2016)].

P 17.43 Fri 14:00 P

Optimized electron injection into a linear plasma wakefield by means of laser-solid interaction — •Vadim Khudiakov and Alexander Pukhov — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

We explore a hybrid plasma acceleration scheme via numerical simulations. The key feature of the method is to inject an electron bunch generated from laser-solid interaction into appropriate phase of a plasma wave. Recent work [1] demonstrates that a femtosecond laser pulse with energy of tens of mJ hitting a dense plasma target at 45 degrees angle expels well collimated electrons and accelerates them up to several MeVs in a direction close to pulse refection. In our work we reproduce these results with 3d particle-in-cell simulations using VLPL code and examine different injection parameters: injection angle, phase of plasma wake, laser pulse amplitude, in order to optimize trapped charge. An approximate trapping condition is derived for theoretical estimation of optimal injection parameters and is verified in simulations. Acceleration in a linear quasi-static wave with the parameters of AWAKE experiment provides bunches feature ~100 pC charge, ~60 micrometers transverse normalized emittance, and energies of several GeV with spread ~1%.

[1] I. Tsymbalov et al., Plasma Phys. Control. Fusion 61 (2019) 075016.

P 17.44 Fri 14:00 P

Time-resolved simulations of laser-induced ionization in the tunneling regime — •Michael Stumpf and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Ionization rate calculations are a common and necessary tool to simulate the interaction of laser pulses with matter. We used the ADK model and compared it with experimental results. For our simulations, we calculated the exact temporal and spatial field distributions within a fs-laser focus with high precision and used quasi-static approximations to simulate the ionization rates. In order to verify our simulations, we experimented with a wide range of parameters using the PHASER few-cycle Ti:Sa-system in Düsseldorf and a novel pulse energy attenuator as well as a new beam-shaping device called AMBER (Axicon Mirror Beam ExpandeR). The results are used to design the internal injection of electrons inside of a Plasma Wakefield structure following the Trojan Horse Injection model.

Environmental Physics Division
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Overview of Invited Talks and Sessions

(Lecture halls H3 and H7; Poster P)

Plenary Talk of the Environmental Physics Division

PV X	Fri	9:45–10:30	Audimax	**How does the heat get to the ice? - Comprehensive year-round observations of ocean-ice-atmosphere interactions in the high Arctic Ocean** — •Christian Haas, MOSAiC Team

Invited Talks

UP 2.1	Thu	14:00–14:20	H3	**BLUESKY - Atmospheric Composition Changes during the Corona Lockdown 2020** — •Christiane Voigt, Jos Lelieveld, Johannes Schneider, Daniel Sauer, Ralf Meerkötter, Silke Gross, Ulrich Schumann, Mira Pöhlker, Laura Tomsche, Mariano Mertens, Hans Schlager
UP 2.4	Thu	14:50–15:10	H3	**Nucleation and growth of atmospheric aerosol particles: Recent results from CLOUD at CERN** — •Joachim Curtius
UP 5.1	Fri	14:00–14:30	H7	**Ozone in the troposphere responds to reduced precursor emissions during the COVID-19 pandemic** — •Wolfgang Steinbrecht

Invited talks of the joint symposium What makes an exoplanet habitable (SYEP)

See SYEP for the full program of the symposium.

SYEP 1.1	Wed	14:00–14:30	Audimax	**Requirements for Earth-like habitats** — •Helmut Lammer
SYEP 1.2	Wed	14:30–15:00	Audimax	**Geological drivers of habitability** — •Raymond T. Pierrehumbert
SYEP 1.3	Wed	15:00–15:30	Audimax	**Space Weather from an Active Young Sun and Its Impact on Early Earth** — •Vladimir Airapetian
SYEP 1.4	Wed	15:30–16:00	Audimax	**Habitable zones around stars and the search for extraterrestrial life** — •James F. Kasting

Sessions

UP 1.1–1.7	Thu	11:00–12:45	H3	**Oceanography and Climate Modelling**
UP 2.1–2.8	Thu	14:00–16:10	H3	**Clouds and Aerosols**
UP 3	Thu	18:00–19:00	H8	**Annual General Meeting**
UP 4.1–4.6	Fri	11:00–12:30	H7	**Measurement Techniques & Miscellaneous**
UP 5.1–5.6	Fri	14:00–15:45	H7	**Atmospheric Trace Gases**
UP 6.1–6.8	Fri	16:30–18:30	P	**Poster Session**

Annual General Meeting of the Environmental Physics Division

Thursday 18:00–19:00 Link will be provided by e-mail

Sessions

– Invited Talks, Contributed Talks, and Posters –

UP 1: Oceanography and Climate Modelling

Time: Thursday 11:00–12:45 Location: H3

UP 1.1 Thu 11:00 H3

On the Serious Limitations of Current Field Measurements and Measuring Techniques for Air-Sea Gas Exchange — •Bernd Jähne — HCI am IWR, Universität Heidelberg — Institut für Umweltphysik, Universität Heidelberg

Despite half a century of field measurements of the gas transfer velocity across the air-ocean interface, it is still not possible to provide a reliable relation between the gas transfer velocity and the parameters driving the exchange process from these measurements. The basic limitations are two-fold. Firstly, the data mainly cover only medium wind speeds and show discrepancies which are not yet understood. Secondly, none of the existing field measuring techniques is really suitable for low-wind speeds. Mass balance methods suffer from the long time constants and eddy covariance measurements from too low fluxes. Active thermography does not work either, because of the need to heat a too large patch at the water surface. The floating chamber technique is not suitable at all to measure gas transfer velocity because it cuts off the wind shear at the water surface, sensible and latent heat transfer and disturbs the wind-wave field.

In consequence, novel field measuring techniques need to be invented, which avoid the disadvantages and shortcomings of the existing technique. In addition, laboratory measurements must be performed, which simulate the oceanic conditions in an appropriate way, close the fetch-gap and wave-age gap and give direct insight into the mechanisms.

UP 1.2 Thu 11:15 H3

Thermohaline circulation - the role of advection in dynamics and stability — •Leonie Neitzel and Edeltraud Gehrig — RheinMain University of Applied Science, Germany

In recent years ongoing research of climate and environmental problems reveal the importance of thermohaline circulation on climate changes. The large-scale ocean circulation is driven by density gradients created by global surface salinity and temperature distributions. It can be modelled with box-models for the polar and equatorial regions of the earth. The boxes are coupled by deep water currents and surface currents that, in turn, depend on the parameter values of salinity and temperature. The dynamic system represented by the boxes and the currents typically exhibits a characteristic dynamics including e.g. bifurcations revealing critical regimes and consequently abrupt changes in the climate. In our approach we couple the model quations to an advection equation describing the changes in the density distribution within a box. This allows to investigate the role of local density changes induced by e.g. environmental influences or pollution. Our results demonstrate that local density changes created by e.g. an initial perturbation enter the thermohaline circulation via the currents and additionally affect the dynamics and stability of the system. Our comparative study of selected box models (Stommel, Marotzke and Welander model) reveals an influence of the dynamics on advective processes as well as dependencies on parameters and model approach.

UP 1.3 Thu 11:30 H3

Horizontal Wave Number Spectra in the Upper Ocean — •Jan Eric Stiehler, Christian Mertens, and Maren Walter — Institut of Environmental Physics, University of Bremen

Even though the spectra of motions in the atmosphere are well known, the same does not hold for the ocean. This has a quite simple reason: velocity measurements in the atmosphere are way more available compared to ocean current measurements as a result of the large amount of airplanes. Resolving temporal and spacial time scales is also easier in the atmosphere due to planes being able to cover much greater areas in the same time compared to ship based measurements. Those motions can be divided into a horizontally rotational part which corresponds to vortex motions in geostrophic balance and a divergent part which resembles internal gravity waves. This is accomplished by calculating and decomposing the spectra of measured shipboard underway ocean current velocity sections and velocity data from a gravity wave resolving ocean general circulation model. The shapes of the resulting model spectra compare well to the observational spectra even though they have approximately an order of magnitude less energy. Both roughly follow a k^{-3} power law at scales of 50 km to 200 km and k^{-2} at scales larger than 200 km. The results will also be used to look further into the limits of applicability of this method.

UP 1.4 Thu 11:45 H3

A Virtual Field Campaign along the MOSAiC track — •Rajka Juhrbandt[1], Suvarchal K. Cheedela[1], Nikolay Koldunov[1,2], and Thomas Jung[1,3] — [1]Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven, Germany — [2]MARUM - Center for Marine Environmental Sciences, Bremen, Germany — [3]Institute of Environmental Physics, University of Bremen, Bremen, Germany

The recently completed Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) can serve as reference to evaluate current and future ocean state of the Arctic Ocean. With this premise, we perform a virtual MOSAiC expedition in historical and ssp370-scenario experiments in data generated by CMIP6 models. Results for other paths are presented additionally.

The timespan covered ranges from preindustrial times (1851-1860) through present-day up to a 4K world (2091-2100). Preliminary results using AWI-CM model suggest that for scenario simulations a thinning of the colder surface layer and a warming of the layer between 200 and 1200 m along the MOSAiC path can be expected, while there is no significant change in temperature below this depth.

The Python-centric tool used for the analysis simplifies preprocessing of a pool of CMIP6 data and selecting data on space-time trajectory. It exposes an interface that is agnostic to underlying model or its grid type. The tool's ease of use is presented to demonstrate the potential for similar virtual field campaigns using past observations and arbitrary trajectories

UP 1.5 Thu 12:00 H3

Arctic amplification: The role of moisture — •Felix Pithan — Alfred Wegener institute, Helmholtz Centre for Polar and Marine research, Bremerhaven

Global climate change is amplified in the Arctic mostly because of the surface albedo feedback and the stable stratification of the Arctic (wintertime) lower troposphere trapping most warming near the surface. While the water vapour feedback is much stronger at low than high latitudes, moist processes do have important implications for Arctic climate and climate change which will be discussed in this presentation. Much of the wintertime transport of moisture into the Arctic occurs in discrete intrusion events that substantially alter atmospheric profiles and the surface energy budget. Weather and climate models struggle to represent the air-mass transformations associated with such intrusions, causing important biases in temperature structures and surface fluxes. In a warmer climate, the amount of latent heat convergence in the Arctic increases at the expense of dry energy convergence. The corresponding increase in precipitation is substantially stronger than in the global mean, even when normalized by the regional warming. Improving the understanding and model representation of moist processes in the Arctic is necessary to better constrain projections of future Arctic warming and the associated sea-level rise and sea-ice retreat.

UP 1.6 Thu 12:15 H3

Water tracers in the general circulation model of intermediate complexity PlaSim — •Oliver Mehling[1], Elisa Ziegler[1], Heather Andres[2], Frank Lunkeit[3], Martin Werner[4], and Kira Rehfeld[1] — [1]Institute of Environmental Physics, Heidelberg University, Germany — [2]Memorial University of Newfoundland, St. John's, NL, Canada — [3]CEN, Institute of Meteorology, University of Hamburg, Germany — [4]Alfred Wegener Institute, Bremerhaven, Germany

Atmospheric water tracers provide a powerful tool to examine source-sink relations of water vapor in atmospheric general circulation models (GCMs). In particular, they offer insight into the variability of moisture transport and sources of precipitation. However, water tracers are computationally expensive, and allow only for short simulations or a small number of tracers in state-of-the-art models.

Here, we present the implementation of water tracers in a GCM of intermediate complexity, the Planet Simulator (PlaSim), which permits for millennial-length simulations with water tracers. We first show that the model can reproduce present-day precipitation patterns reasonably after tuning, and discuss the validation and remaining biases of the tracer-enabled model.

The water tracer framework is then applied to study moisture export from the Arctic in idealized experiments of warm and cold climate states using simulations forced by sea surface temperatures and sea ice concentrations from comprehensive Earth system models. We discuss the contributions of moisture evaporated in the Arctic to precipitation at high latitudes, both in the mean state and during extreme events.

UP 1.7 Thu 12:30 H3

Bayesian parameter estimation for EBMs: What can we learn about climate variability? — •Maybritt Schillinger[1,2], Beatrice Ellerhoff[1], Kira Rehfeld[1], and Robert Scheichl[2] — [1]Institute of Environmental Physics, INF 229 — [2]Institute of Applied Mathematics, INF 205, 69120 Heidelberg, Germany

Reliable climate projections in the face of global warming require an improved understanding of the internally-generated and externally-forced variability of Earth's climate. To this end, energy balance models (EBMs) provide a conceptual tool for studying climate dynamics. However, EBMs are typically based on a set of parameters with considerable uncertainties across empirical data and model hierarchies. To incorporate these uncertainties, we describe the global mean temperature as an inverse problem: We model the observed data as a function of the unknown parameters, given through the EBM's solution, and stochastic noise, representing the internal variability. With a Bayesian approach and a MCMC algorithm, we estimate the parameters as well as the best model fit to the data. In particular, we investigate how this estimate depends on the strength of internal variability compared to the response to external forcing. We discuss results for the zero-dimensional linear EBM and possible extensions with time-dependent feedback parameters. Our approach represents an application of state-of-the-art analytical and numerical techniques to the complex dynamics of Earth's climate. It can help to elaborate the potential, but also limitations, of the inverse problems approach and be readily applied to other dynamical systems with uncertain parameters.

UP 2: Clouds and Aerosols

Time: Thursday 14:00–16:10 Location: H3

Invited Talk UP 2.1 Thu 14:00 H3

BLUESKY - Atmospheric Composition Changes during the Corona Lockdown 2020 — •Christiane Voigt[1,2], Jos Lelieveld[3], Johannes Schneider[3], Daniel Sauer[1], Ralf Meerkötter[1], Silke Gross[1], Ulrich Schumann[1], Mira Pöhlker[3], Laura Tomsche[1], Mariano Mertens[1], and Hans Schlager[1] — [1]Deutsches Zentrum für Luft und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany — [2]Universität Mainz, Institut für Physik der Atmosphäre, Mainz, Germany — [3]Max-Planck Institut für Chemie, Mainz, Germany

Worldwide regulations to control the COVID-19 pandemic caused significant reductions in ground and airborne transportation in spring 2020, which provided the unique opportunity to directly measure the less perturbed atmosphere, notably near the tropopause. The BLUESKY mission employed the high-altitude, long-range research aircraft HALO and the DLR Falcon together with satellite observations and models to study the atmospheric composition changes. From 16 May to 9 June 2020, the 2 research aircraft performed 20 flights over Europe. Profiles of trace species were measured with an advanced in-situ trace gas, aerosol and cloud payload from the boundary layer to 14 km altitude. I will present an overview and selected highlights of the campaign. Continental aerosol profiles show significant reductions in aerosol mass in the boundary layer and lower organic aerosol mass fractions in the free troposphere. The reduced aerosol optical thickness above Germany has also been detected by MODIS and contributes to the observed *blue sky* during the lockdown period 2020.

UP 2.2 Thu 14:20 H3

Thermal imaging of freezing drizzle droplets: pressure release events as a source of secondary ice particles — Judith Kleinheins[1], Alexei Kiselev[2], Alice Keinert[2], Matthias Kind[2,3], and •Thomas Leisner[2,4] — [1]Department of Environmental Systems Science, ETH Zürich, Zürich, Switzerland — [2]Institute of Meteorology and Climate Research - Atmospheric Aerosol Research, Karlsruhe Insitute of Technology, Karlsruhe, Germany — [3]Institute of Thermal Process Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]Institut für Umweltphysik, Universität Heidelberg, Heidelberg, Germany

The freezing of supercooled water droplets freely falling through a mixed-phase clouds is an ubiquitous natural process fundamental for the formation of precipitation. During the freezing of a droplet a solid ice shell grows from the outside inwards, leading to a pressure increase inside the liquid core, which can result in violent rupture of the ice shell and the production of secondary ice particles. To investigate this process of ice multiplication, the evolution of the droplets surface temperature during the second freezing stage was measured with a high-resolution infrared thermography system (INFRATEC). Drops of about 300 micrometer in diameter were levitated in an electrodynamic trap under controlled conditions with respect to temperature, humidity and ventilation. Combining experimental results and comprehensive process modelling, we explore the thermodynamic conditions beneficial for secondary ice production upon freezing of freely falling drizzle droplets.

UP 2.3 Thu 14:35 H3

Cracking the problem of atmospheric ice nucleation: chemically induced fracturing of alkali feldspar makes it a better ice-nucleating aerosol particle — •Tilia Gädeke[1], Alexei Kiselev[1], Alice Keinert[1], Thomas Leisner[1], Christoph Sutter[2], Elena Petrisheva[3], and Rainer Abart[3] — [1]KIT, IMK-AAF, Karlsruhe, Germany — [2]Universität Heidelberg, IFU, Heidelberg, Germany — [3]University of Vienna, Department of Lithospheric Research, Vienna, Austria

Feldspar is a major constituent of magmatic, metamorphic, and sedimentary rocks on the Earths* surface. Consequently it is also an abundant constituent of the solid aerosol particles and induces heterogeneous freezing in cloud droplets. The freezing process changes cloud properties and precipitation formation. The mineralogy of feldspar has a crucial effect on its ability to induce freezing of water. The mechanisms relating the microstructure of feldspars and enhanced ice nucleation (IN) efficacy are not known and are currently debated.

The particularly high IN activity of alkali feldspar has been attributed to structural similarities between specific prism planes of ice and feldspar. In this study, the gem quality K-rich alkali feldspar was shifted towards more Na-rich compositions. The cation exchange induces parallel cracks with an orientation close to (100). Droplet freezing assay experiments performed on the cation-exchanged feldspars, revealed an increase of freezing efficacy with respect to the untreated feldspar. This contribution demonstrates how the natural complexity of rock-forming minerals can have a direct impact on Earth's climate.

Invited Talk UP 2.4 Thu 14:50 H3

Nucleation and growth of atmospheric aerosol particles: Recent results from CLOUD at CERN — •Joachim Curtius — Institut für Atmosphäre und Umwelt, Goethe Universität Frankfurt, Frankfurt am Main, Germany

Atmospheric aerosol particles influence cloud formation, climate and human health. A large fraction of the atmospheric aerosol forms by nucleation from the gas phase. In order to understand and predict atmospheric new particle formation it is of importance to perform experiments under well-controlled laboratory conditions to investigate the details of the formation of molecular clusters. By performing more than 2200 individual experiments over the past decade, the CLOUD project at CERN has studied the most relevant chemical systems for a large range of atmospheric conditions at unprecedented precision. It allows the direct and simultaneous measurement of all relevant variables at atmospheric conditions. The physico-chemical mechanisms (e.g. ion-induced vs. neutral path) for the formation and initial growth of molecular clusters are determined. For example, the nitric acid-sulfuric acid-ammonia system has been studied recently that is predicted to cause nucleation in such diverse conditions as East Asian megacities in winter or in the upper troposphere above the Indian monsoon. Overall, a greatly improved understanding has been reached for the role of new particle formation in the atmosphere and for characterizing the various factors that act as boosters or inhibitors for the nucleation and growth processes. An overview of the current understanding, including its role for cloud formation and climate is given.

UP 2.5 Thu 15:10 H3

A bird's eye view on the invisibile, unprecedented levels of ultrafine particles and the hydrological cycle — •Wolfgang Junkermann[1] and Jorg Hacker[2] — [1]Karlsruhe Institute of Technlogy, IMK-IFU — [2]Airborne Research Australia, Parafield, SA

Airborne measurements from small, slow flying aircraft have been used to identify and characterize major sources of ultrafine particles (UFP) and to quantify their contribution to the global aerosol number budget. UFPs are relevant as cloud condensation nuclei (CCN), with respect to size and number emission. State of the art fossil fuel flue gas cleaning techniques following clean air legislation are turning power stations into efficient UFP generators, doubling global primary number emissions. The subsequent enhancement of (CCN) modifies cloud microphysics, decreases droplet sizes and delays raindrop generation, suppressing certain types of rainfall, increasing cloud droplet evaporation and affecting the hydrological cycle. A subsequent transport of water vapour as latent energy into mid altitudes of the lower troposphere, in turn enhances torrential rain events, and via increased residence time of H2O in the atmosphere, might contribute to larger than regional scale climate warming through effects on the infrared radiation budget.

UP 2.6 Thu 15:25 H3

Occurrence of Polar Stratospheric Clouds as derived from ground-based zenith DOAS observations — •Bianca Lauster[1,2], Steffen Dörner[1], Udo Friess[2], Myojeong Gu[1], Janis Pukite[1], and Thomas Wagner[1] — [1]Max Planck Institute for Chemistry, Mainz, Germany — [2]Institute of Environmental Physics, University Heidelberg, Heidelberg, Germany

Polar Stratospheric Clouds (PSCs) are an important component of ozone depletion in the polar stratosphere. Although satellite observations already yield high spatial coverage, continuous ground-based measurements with high temporal resolution can be a valuable complement. Since 1999, a MAX-DOAS (Multi AXis-Differential Optical Absorption Spectroscopy) instrument has been operating at the German research station Neumayer (70° S, 8° W), Antarctica. Although typically used to retrieve slant column densities of trace gases such as BrO or OClO, this study investigates the so-called colour index (CI). Defined as the ratio between the observed intensities of scattered sun light at two wavelengths, it enables to monitor the occurrence of PSCs during twilight even in the presence of tropospheric clouds. Using the radiative transfer model McArtim, the analysis of CI variations with solar zenith angle enables the detection of PSCs. Here, it is advantageous that measurements are available in the UV and visible spectral range which allows a more extensive comparison of the wavelength choice. The aim is to improve and evaluate the potential of this method. It is then used to infer the occurrence of PSCs throughout the measurement time series of more than 20 years.

UP 2.7 Thu 15:40 H3

Satellite observations of volcanic eruptions leading to smaller average stratospheric aerosol sizes — •Felix Wrana[1], Christian von Savigny[1], and Larry W. Thomason[2] — [1]Institut für Physik, Universität Greifswald, Greifswald, Germany — [2]NASA Langley Research Center, Hampton, Virginia, USA

We present surprising results of our stratospheric aerosol size retrieval which is using the SAGE III/ISS solar occultation measurements, that started in 2017. Due to the broad wavelength spectrum covered by the instrument a robust and simultaneous retrieval of the median radius and mode width of monomodal lognormal size distributions is possible. We focus on three small to mid-intensity volcanic eruptions that were observed by SAGE III/ISS and that reached and perturbed the stratospheric aerosol layer: The Ambae eruptions (15.3°S) in spring of 2018 and the Raikoke (48.3°N) and Ulawun (5.05°S) eruptions, both in June 2019. While the Raikoke eruption led to an increase in the median radius of the stratospheric aerosols, which was to be expected and is in line with previous observations, the Ambae and Ulawun eruption had the opposite effect. After both eruptions the average aerosol size decreased, with lower median radii and narrower size distributions, while the number density increased strongly. The observation that volcanic eruptions may lead to smaller average stratospheric aerosol sizes, as also recently discussed by Thomason et al. (2021), is a novel one and should be of great interest to the modeling as well as remote sensing community. In our talk, we will present the temporal and spatial evolution of the size distribution parameters.

UP 2.8 Thu 15:55 H3

Estimating the impact of tropical volcanic eruptions on the thermal structure of the mesosphere by analyzing HALOE temperature data and UA-ICON simulations — •Sandra Wallis[1], Christoph Hoffmann[1], Hauke Schmidt[2], and Christian von Savigny[1] — [1]University of Greifswald, Greifswald, Germany — [2]Max Planck Institute for Meteorology, Hamburg, Germany

She et al. [1] published a paper in 1998 that analyzed Na lidar temperature profiles and reported an episodic warming of the mesopause region (up to 12.9 K in 100 km altitude) that they attributed to the 1991 Pinatubo eruption. Our study analyses temperature data for the middle atmosphere from the Halogen occultation experiment (HALOE) on the Upper Atmosphere Research Satellite that started its scientific observation 4 months after the eruption. A regression was performed including a volcanic term suggested by She et al., but it did not confirm the significantly higher values reported previously for the lidar measurements. An alternative fit is proposed that approximates the Pinatubo signature with an exponential decay function having an e-folding time of 6 months. We conclude that the HALOE time series probably captures only the decay of a Pinatubo-induced mesospheric warming and that the mesospheric response is more rapid than reported by She et al. The impact of a tropical volcanic eruption on the mesosphere was further investigated by simulations using the upper-atmosphere icosahedral non-hydrostatic (UA-ICON) general circulation model.

[1] She et al. Geophys. Res. Lett., 25(4):497-500, 1998.

UP 3: Annual General Meeting

Time: Thursday 18:00–19:00 Location: H8

Annual General Meeting

UP 4: Measurement Techniques & Miscellaneous

Time: Friday 11:00–12:30 Location: H7

UP 4.1 Fri 11:00 H7

Imaging of Formaldehyde in the Atmosphere — •Alexander Nies[1], Christopher Fuchs[1], Jonas Kuhn[1,2], Nicole Bobrowski[1,2], and Ulrich Platt[1,2] — [1]Institute of Environmental Physics, Heidelberg University, Germany — [2]Max Planck Institute for Chemistry, Mainz, Germany

Monitoring of atmospheric traces gases by imaging techniques is essential for the understanding of physical and chemical dynamics of the atmosphere. Hyperspectral imaging in the UV-VIS range allows highly selective measurements of several trace gases simultaneously, but scanning is necessary for image acquisition resulting in a low spatio-temporal resolution. Non-dispersive imaging techniques, e.g. SO2 cameras, reach high spatial and temporal resolution, but due to their strongly restricted spectral information they are limited to high abundances of SO2 only. Combining the benefits of both approaches using a Fabry-Perot-Interferometer in a filter camera setup enhances spectral information by matching its periodic transmission to the narrowband absorption structures of the target trace gas and leading to reduced cross interferences. The technique has been demonstrated for SO2 and we present a case study for HCHO in the atmosphere with a sensitivity of $4.7 \cdot 10^{-16} \frac{molec}{cm^2}$. Because of the similar absorption structures of HCHO and BrO in the UV wavelength range, the same instrument can be used for BrO measurements (for instance, highly abundant in volcanic plumes). Usually HCHO and BrO have no common sources, and therefore, potential cross sensitivities are only a minor problem. The calculated sensitivity for BrO is $1.6 \cdot 10^{-14} \frac{molec}{cm^2}$.

UP 4.2 Fri 11:15 H7

Fabry-Perot interferometer correlation spectroscopy - A novel technique for the imaging of atmospheric trace gases — •Jaro Heimann[1], Alexander Nies[1], Christopher Fuchs[1], Jonas Kuhn[1,2], Nicole Bobrowski[1,2], and Ulrich Platt[1,2] — [1]Institute of Environmental Physics, Heidelberg University, Germany — [2]Max Planck Institute for Chemistry, Mainz, Germany

Imaging of trace gases by optical remote sensing provides insights into the dynamics of physical and chemical processes within the atmosphere. However, dispersive techniques cannot resolve many processes on their intrinsic spatial and temporal scale, e.g. Imaging DOAS. Non-dispersive imaging techniques, e.g. SO_2 cameras, reach high spatial and temporal resolution, but due to their strongly restricted spectral information they show cross-interferences with other trace gases (e.g. O_3), aerosols, and clouds. We introduce a novel imaging technique for atmospheric trace gases, based on the application of a Fabry-Perot interferometer (FPI). The FPIs periodic transmission is matched to the periodicity of the vibronic narrowband absorption structure of the target trace gas absorption yielding high trace gas selectivity and thereby allowing a more precise determination of gas emission fluxes. The instrument response can be modelled using absorption cross sections and a solar atlas spectrum from the literature thereby avoiding additional calibration procedures, e.g. using gas cells. We present recent measurements which were performed at Mt. Etna for SO_2 with an imaging Fabry-Perot interferometer correlation spectroscopy (IFPICS) instrument with a detection limit of 3e17 molec/cm^2.

UP 4.3 Fri 11:30 H7

Moisture and humidity dependence of the above-ground cosmic-ray neutron intensity revised — •Markus Köhli[1,2], Jannis Weimar[1], Martin Schrön[3], and Ulrich Schmidt[1] — [1]Physikalisches Institut, Heidelberg University — [2]Physikalisches Institut, University of Bonn — [3]Helmholtz Centre for Environmental Research-UFZ, Leipzig

The novel method of Cosmic-ray neutron sensing (CRNS) allows non-invasive soil moisture measurements at a hectometer scaled footprint. Up to now, the conversion of soil moisture to a detectable neutron count rate relies mainly on the equation presented by Desilets et al. (2010). While in general a hyperbolic expression can be derived from theoretical considerations, their empiric parameterisation needs to be revised for two reasons. Firstly, we find a 3-parameter equation with unambiguous values equivalent to the 4-parameter equation. Secondly, high-resolution Monte-Carlo simulations revealed a systematic deviation of the count rate to soil moisture relation especially for extremely dry conditions as well as very humid conditions. That is a hint, that a smaller contribution to the intensity was forgotten or not adequately treated by the conventional approach. Investigating the above-ground neutron flux by a broad simulation campaign revealed a more detailed understanding of different contributions to this signal. The packages MCNP and URANOS were used to derive a function including the detector-specific response. The new relationship has been tested at three exemplary measurement sites and its remarkable performance allows for a promising prospect of more comprehensive data quality.

UP 4.4 Fri 11:45 H7

Energy Storage in Concentration Gradients — •Ulrich Platt and Florian Dinger — Universität Heidelberg, Inst. für Umweltphysik

Reliable systems for energy storage are a central component of energy supply systems with a high fraction of renewable energy. Here we propose energy storage using two reservoirs of water with different salt concentrations. Storage of excess energy takes place by reverse osmosis increasing the salt concentration in one reservoir. The produced fresh water will be stored in a second reservoir or discarded, e.g. in a river. Release of the stored energy by an osmosis power station (OPS), exploiting the osmotic pressure of the high concentration reservoir. Energy storage density can reach 8 kWh/m3, up to one order of magnitude higher than in typical pumped-storage hydroelectricity (PSH) at comparable efficiency. Besides the described onshore application using fresh water, an OPS can also be installed at the coast or offshore utilizing the still large concentration gradient between ocean water and saturated salt solution. The technology of such a system is readily available: Reverse osmosis for production of fresh water from ocean water is in widespread use and the technical components (large area membranes, pressure exchangers) are commercially available. Also, the principle of OPS was realized in a demonstration plant in 2009. Compared to PSH our new approach requires no altitude difference of reservoirs, therefore large storage capacities can be realized very economically. A series of different realization schemes and sample calculations of power and energy densities are provided.

UP 4.5 Fri 12:00 H7

Using the limits of photosynthesis to understand planetary habitability — •Axel Kleidon — MPI für Biogeochemie, Jena, Germany

Photosynthesis is the dominant process which supports life on Earth with the chemical energy it needs to sustain its metabolic activities. Here, I evaluate the factors that limit photosynthesis, focusing on terrestrial ecosystems, as these include the most productive ecosystems on Earth. I first use satellite-based datasets of gross carbon uptake by terrestrial ecosystems and solar radiation to show that the median efficiency of photosynthesis of terrestrial ecosystems of converting energy is less than 1%, consistent with long-standing ecological observations, but far below the maximum efficiency derived from thermodynamics. I show that this low efficiency can be explained by the thermodynamic limit on gas exchange, as ecosystems need to take up carbon dioxide from the atmosphere to produce chemical energy in form of glucose, and inevitably lose water when doing so. Gas exchange is limited by turbulent transport within the lower atmosphere, which in turn is limited by the heating of the surface. I show that the geographic variations of this gas exchange with respect to water can be explained by the thermodynamic limit of maximum power very well. What this implies is that the photosynthetic activity of the most productive ecosystems on Earth appear to be strongly constrained by thermodynamics through gas exchange. For habitability, this interpretation emphasizes the importance of mass exchange to sustain high levels of chemical activity that are needed to sustain life in planetary environments.

UP 4.6 Fri 12:15 H7

Does the solar 27-day variability influence the Madden-Julian oscillation in the tropical troposphere? — •Christoph G. Hoffmann and Christian von Savigny — Institut für Physik, Uni Greifswald, Deutschland

The solar irradiance is subject to variations on different time scales including the 27-day cycle. These variations are known to introduce variability in the upper and middle atmosphere. Implications for the troposphere are currently under discussion.

The Madden-Julian oscillation (MJO) is a major source of intraseasonal variability in the troposphere. We analyze whether the temporal evolution of the MJO phases could be linked to the solar 27-day cycle. We basically count the occurrences of particular MJO phases as a function of time lag after the solar 27-day extrema in about 38 years of MJO data.

We find indications for a synchronization between the MJO phase evolution and the solar 27-day cycle, which are most notable under certain conditions: MJO events with a strength greater than 0.5, during the easterly phase of the Quasi-biennial oscillation, and during boreal winter. The MJO appears to cycle through its 8 phases within 2 solar 27-day cycles. However, these results strongly depend on the used MJO index.

We point out that we do not claim to unambiguously prove this relationship; neither in a statistical, nor in a causal sense. Instead, we challenge these unexpected initial findings ourselves in detail by varying underlying datasets and methods.

UP 5: Atmospheric Trace Gases

Time: Friday 14:00–15:45 Location: H7

Invited Talk UP 5.1 Fri 14:00 H7

Ozone in the troposphere responds to reduced precursor emissions during the COVID-19 pandemic — •Wolfgang Steinbrecht — Deutscher Wetterdienst, Hohenpeissenberg, Germany

The COVID-19 pandemic has provided an accidental global air-quality experiment, which tests observational capabilities, and also our understanding of atmospheric chemistry and transport. Measures to curb spreading of the COVID-19 pandemic have reduced world-wide fuel consumption and associated emissions. Air-traffic and surface transportation were the sectors with the largest emission reductions, up to 80%. Both sectors are important sources of nitrogen oxides and volatile organic compounds (VOC), the main precursors for photochemical production of ozone in the troposphere. In spring and summer 2020, observations of ozone in the free troposphere show an unprecedented reduction by about 7%, over much of the Northern Hemisphere. Model simulations reproduce this ozone reduction. In addition, they attribute about one third each of the observed reduction to reduced air-traffic, reduced surface transportation, and 2020 meteorological conditions (including the exceptional ozone hole of the Arctic stratosphere in spring 2020). Different from the ozone reduction observed in the free troposphere, data from polluted urban and industrial regions often show increased ozone during the pandemic - consistent with well-known nonlinearities in tropospheric ozone chemistry (NOx saturation).

UP 5.2 Fri 14:30 H7

Charakterisierung der subarktischen Ökozone hinsichtlich der Modellierung von Ozonverschmutzung und Klimarisiken — •Stefanie Falk[1], Ane Victoria Vollsnes[2], Aud Eriksen[2], Lisa Emberson[3], Connie O'Neill[3], Frode Stordal[1] und Terje Koren Berntsen[1] — [1]Department of Geosciences, University of Oslo, Oslo, Norway — [2]Department of Biosciences, University of Oslo, Oslo, Norway — [3]Department of Environment and Geography, Stockholm Environment Institute, University of York, UK

Die Vegetation der subarktischen Ökozone wird durch die Verlängerung der Wachstumsperiode bei gleichzeitigem, steten Anstieg der troposphärischen Ozonkonzentration vermutlich mehr schädliches Ozon akkumulieren. Zur Untersuchen der Wechselwirkung subarktischer Vegetation mit Luftverschmutzung bedienen wir uns einer Klimaanalyse und Risikoabschätzung mittels Modellierung. Im Fokus stehen die Jahre 2018/19. 2018 war ein ungewöhnlich warmes Jahr mit überdurchschnittlich vielen Sonnentagen im Frühling und Sommer. Die gemessenen Ozonkonzentrationen zeigen eine Häufung von Spitzenwerten über 40 ppb im selben Zeitraum. Als mögliche Ursache identifizieren wir Waldbrände in Teilen Schwedens. Unter Verwendung des DO3SE-Modells untersuchen wir die Auswirkung des Wetters und Pflanzentypisierung (PFT) auf das Schadensrisiko. Die Verwendung von optimierten, subarktischen PFTs deutet auf eine mögliche Unterschätzung des Biomassenverlustes von 2.5–17.4 %. Maßgeschneiderte PFTs für die subarktische Ökozone haben daher das Potenzial biogeochemische Kreisläufe in regionalen und globalen Modellen zu verbessern.

UP 5.3 Fri 14:45 H7

Ermittlung von SO2 und NOx Emissionsraten fahrender Schiffe aus Langpfad-DOAS Messungen — •Kai Krause[1], Folkard Wittrock[1], Andreas Richter[1], Stefan Schmitt[2], Denis Pöhler[2], Andreas Weigelt[3] und John P. Burrows[1] — [1]Institut für Umweltphysik, Universität Bremen — [2]airyx GmbH, Heidelberg — [3]Bundesamt für Seeschifffahrt und Hydrographie (BSH), Hamburg

Schiffe sind eine wichtige Emissionsquelle von SO2 und NOx. Die Überwachung dieser Emissionen erfolgt üblicherweise über In-situ-Messungen am Ufer, nahe der Schifffahrtslinie. Diese Systeme sind auf günstige Windbedingungen angewiesen, unter denen die Abgase der vorbeifahrenden Schiffe zur Messstelle transportiert werden. Fernerkundung erlaubt die Messung dieser Emissionen auch bei ungünstigen Windverhältnissen und kann daher ergänzend zu den üblichen Messverfahren eingesetzt werden.

Im Rahmen des Projekts MESMART (Measurements of shipping emissions in the marine troposphere) wurden ein Jahr lang Langpfad-DOAS Messungen an der Elbe in der Nähe von Hamburg durchgeführt. In diesen Messungen wurden kurzzeitig erhöhte Konzentrationen (Peaks) von SO2 und NO2 detektiert und mit Hilfe von AIS-Daten einzelnen Schiffen zugeordnet. Mithilfe eines Gauß-Fahnenmodells lassen sich aus den Peakhöhen die Emissionsrate von SO2 und NO2 bzw. NOx ermitteln.

Die Höhe der ermittelten Emissionsraten korreliert dabei mit der Größe der Schiffe und der Geschwindigkeit über Grund. Des Weiteren zeigen Binnenschiffe und Seeschiffe unterschiedliche Emissionsraten.

UP 5.4 Fri 15:00 H7

Enhanced levels of nitrous acid during daytime derived from MAX-DOAS measurements during the AQABA campaign in late summer 2017 — •Steffen Dörner[1], Sebastian Donner[1], Lisa Behrens[2], Steffen Beirle[1], Sergey Osipov[1], Roland Rohloff[1], and Thomas Wagner[1] — [1]Max Planck Institute for Chemistry, Mainz, Germany — [2]University of Bremen, Science Institute of Environmental Physics, Bremen, Germany

During the Air Quality and Climate Change in the Arabian Basin (AQABA) campaign a MAX-DOAS instrument was set up on board of the Kommandor Iona. The ship route covered a variety of regions with different atmospheric compositions: Clean air in the Mediterranean and the Arabian Sea, anthropogenic air pollution near the oil fields in the Arabian Gulf or in areas of dense ship traffic like the Suez Channel or the dust clouds of the nearby deserts in the Red sea. The measured spectra in the UV/VIS spectral range (302 to 467nm) provide sufficient information for the retrieval of aerosol and trace gas profiles. In this study, we focus on evidences of direct nitrous acid emission sources in harbor areas around Jeddah and Kuwait. Since HONO daytime chemistry is debated in recent literature and missing sources are being discussed, we compared the results of the MAX DOAS measurements to WRF-Chem model output in order to identify potential daytime sources in maritime/harbor regions.

UP 5.5 Fri 15:15 H7

Analysis of global trends of total column water vapour from multiple years of OMI observations — •Christian Borger, Steffen Beirle, and Thomas Wagner — Max Planck Institute for Chemistry, Mainz, Germany

Atmospheric water plays a key role for the Earth's energy budget and temperature distribution via radiative effects (clouds and vapour) and latent heat transport. In this context, global monitoring of the water vapour distribution is essential for numerical weather prediction, climate modelling, and a better understanding of climate feedbacks.

Total column water vapour (TCWV) can be retrieved from satellite spectra in the visible "blue" spectral range (430-450nm) using Differential Optical Absorption Spectroscopy (DOAS). The UV-vis spectral range offers several advantages for monitoring the global water vapour distribution: for instance, it allows for accurate, straightforward retrievals over ocean and land even under partly-cloudy conditions.

To investigate climate changes in the global TCWV distribution, we make use of the long-term observations of the Ozone Monitoring Instrument (OMI) on board NASA's Aura satellite and present a global analysis of TCWV trends retrieved from multiple years of OMI measurements (2005-2020). Additionally, we put our results in context to trends of other climate data records of TCWV and surface air temperature and investigate if the changes in TCWV follow a Clausius-Clapeyron response. Moreover, we demonstrate that the OMI TCWV data set can also give insights into changes of the global atmospheric circulation.

UP 5.6 Fri 15:30 H7

Globale Betrachtung von Brommonoxid in Vulkanfahnen mit Hilfe von Sentinel-5 Precursor/TROPOMI — •Simon Warnach[1,2], Holger Sihler[1], Christian Borger[1], Nicole Bobrowski[1,2], Moritz Schöne[1,2], Steffen Beirle[1], Ulrich Platt[2] und Thomas Wagner[1] — [1]Max-Planck-Institut für Chemie, Mainz, Deutschland — [2]Institut für Umweltphysik, Heidelberg, Deutschland

Das Halogenradikal Brommonoxid (BrO) spielt in vielen chemischen Prozessen in der Atmosphäre eine Rolle. Neben dem wichtigen Einfluss von aus Vulkanen emittiertem Brom auf die Ozonchemie der Atmosphäre, ist das molare Verhältnis von Brom und Schwefel des Vulkangases eine wichtige vulkanologische Kenngröße für Magmazusammensetzung und dem eruptivem Verhalten eines Vulkans.

In dieser Studie präsentieren wir die Ergebnisse einer globalen Übersicht des BrO/SO2 Verhältnisses von Vulkanfahnen über einen drei-Jahres Zeitraum von TROPOMI Daten ermittelt mit Hilfe der Differentiellen Optischen Absorptions Spektroskopie (DOAS). Über den Zeitraum der Studie gelang die erfolgreiche Bestimmung eines BrO/SO2 Verhältnisses bei 84 dieser Eruptionen von 14 unterschiedlichen Vulkanen. Dies sind fast fünf Mal so viele erfolgreiche Messungen verglichen mit Messungen vorheriger Satelliten (GOME-2), da die feine räumliche Auflösung (von bis zu 3.5kmx5.5km) des S5-P/TROPOMI Instrumentes die Bestimmung eines BrO/SO2 Verhältnisses auch bei mittelgroßen Ausbrüchen ermöglicht.

UP 6: Poster Session

Time: Friday 16:30–18:30 Location: P

UP 6.1 Fri 16:30 P

Charge induced enhancement of water adsorption on nanoparticle ions — Mario Nachbar[3], •Thomas Dresch[1], Denis Duft[1], and Thomas Leisner[1,2] — [1]Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany — [2]Institute of Environmental Physics, University of Heidelberg, 69120 Heidelberg, Germany — [3]current address: Bruker AXS GmbH, 76187 Karlsruhe, Germany

Water and other polar molecules experience an attractive force in the inhomogeneous electric field of small molecular ions or charged nanoparticles. This charge induced attractive force increases the collision cross section, and, hence, impacts the adsorption rates compared to neutral particle interactions. While ion-molecule interactions have been studied extensively, experimental data are still lacking regarding the interaction of polar molecules with nanoparticles whose radii exceed the Langevin capture radius. Precise knowledge of this effect is crucial, e.g. for describing the formation and growth of atmospheric nanoparticles and for understanding the role of charged particles in cloud formation. We present experimental results for the charge induced enhancement of the collision cross section between H2O molecules and singly charged nanoparticles with radii between 1.4 nm and 3 nm. The enhancement factor Γ with respect to the geometrical cross section increases with decreasing particle size. We also present a new model for Γ based on Stark effect adiabatic dipole orientations, which is in excellent agreement with the experimental findings.

UP 6.2 Fri 16:30 P

Modelling optical twilight phenomena: Earth's shadow and the Belt of Venus — •Anna Lange[1], Alexei Rozanov[2], and Christian von Savigny[1] — [1]Institute of Physics, University of Greifswald, Germany — [2]Institute of Environmental Physics, University of Bremen, Germany

During clear civil twilights it is possible to see a combination of two optical phenomena above the antisolar horizon: The earth's shadow and the Belt of Venus (or antitwilight arch). Simulations with the radiative transfer model SCIATRAN and colour modelling based on the CIE (International Commission on Illumination) colour matching functions and CIE chromaticity values reproduce the phenomena accurately. Investigations on the influence of ozone show that it has a strong impact on the colours of both twilight phenomena. Although the Chappuis bands are clearly visible in the spectra of all segments, the colour of the earth's shadow differs from the sky above the antitwilight arch. Furthermore, a low optical depth in the troposphere is necessary to simulate the reddish colour of the Belt of Venus.

UP 6.3 Fri 16:30 P

Detektion von lokal erhöhten Methankonzentrationen durch Analyse von Sentinel-5 Precursor Satellitendaten — •Steffen Vanselow, Oliver Schneising, Michael Buchwitz und John P. Burrows — Institut für Umweltphysik (IUP), Universität Bremen FB1, Bremen, Deutschland

Methan (CH_4) ist ein wichtiges Treibhausgas und dessen steigende Konzentration in der Atmosphäre tragen signifikant zur globalen Erwärmung bei. Satellitenmessungen des vertikal gemittelten Mischungsverhältnisses (XCH_4) können für die Detektion und Quantifizierung von Methanemissionen genutzt werden. Dies ist wichtig, da die Emissionen vieler Methanquellen eine große Unsicherheit aufweisen und einzelne Emissionsquellen noch nicht bekannt sind.

Der im Oktober 2017 gestartete Sentinel-5 Precursor (S5P) Satellit gestattet u.a. die Messung von XCH4 mit einer räumlichen Auflösung von 7×7 km^2 und einer täglichen globalen Abdeckung.

Der an der Universität Bremen entwickelte WFM-DOAS Retrieval-Algorithmus erzeugt ein XCH_4-Datenprodukt mit einer Genauigkeit von ca. 1 %. Um lokal erhöhte Methankonzentrationen zu detektieren, die im Zusammenhang mit Emissionsquellen stehen, analysieren wir dieses Datenprodukt für die Jahre 2018-2020. Unser Detektionsalgorithmus identifiziert zeitlich stabile lokale XCH_4-Erhöhungen relativ zur Umgebung, indem verschiedene Filterkriterien, wie z.B. Schwellenwerte für die Methananomalien, verwendet werden.

Es werden der Algorithmus und erste Ergebnisse zur Detektion von lokalen Methanerhöhungen vorgestellt.

UP 6.4 Fri 16:30 P

Challenges and progress in the analysis of satellite-based measurements of methane in the Arctic — •Jonas Hachmeister, Matthias Buschmann, Justus Notholt, John P. Burrows, Oliver Schneising, and Michael Buchwitz — Universität Bremen, Deutschland

With the launch of the Sentinel-5 Precursor mission, carrying the TROPOMI instrument, an unprecedented high spatio-temporal resolution of the column-averaged mole fraction of various gases was made possible, e.g. methane (XCH4). Especially in the northern high-latitude regions, where few ground stations and in-situ measurements are available, this data promises new ways of understanding the methane distribution and variation on large scales. In addition to the operational Copernicus S5P XCH4 data product developed by SRON, the scientific WFMD algorithm data product was generated at the Institute of Environmental Physics at the University of Bremen. Comparisons of both products show significant differences, which are not yet well understood and their evaluation proves difficult due to the limited opportunities of validation because ground-based measurements, e.g. from TCCON and NDACC, are sparse in the Arctic. In this poster contribution we show comparisons with measurements from ground-based stations and different satellite XCH4 data products.

UP 6.5 Fri 16:30 P

Direct measurement of methane radiative forcing in Ny-Ålesund — •Lukas Heizmann, Mathias Palm, Justus Notholt, and Matthias Buschmann — Universität Bremen, Bremen, Germany

Methane is an important greenhouse gas with significant increase in concentration between pre-industrial times and today, corresponding to an associated estimated increase in radiative forcing of +0.48W/m^2 compared to +2.83W/m^2 for all well-mixed greenhouse gases (IPCC 2013). However direct measurement of the radiative forcing attributed to methane proved to be difficult. Feldmann et al. (2018) presented a a first study using ground-based measurement at a single location (ARM Southern Great Plains atmospheric observatory). We investigate the feasibility of such measurements in the Arctic using a calibrated FTIR emission spectrometer in Ny-Ålesund, Spitsbergen. Due to nearby water vapor absorption lines, methane radiative forcing is mediated by the thermodynamic state of the atmosphere. We thus retrieve water vapor and methane profiles simultaneously to produce counterfactual spectra in which the only difference from the true atmosphere consists in the methane mixing ratio. By differencing the true with the counterfactual spectra and integrating over the entire spectral range we obtain a measurement of the radiative forcing of methane.

UP 6.6 Fri 16:30 P

Influence of cruise ship emissions on local air quality in Ny-Ålesund, Svalbard — •André Seyler, Folkard Wittrock, Anja Schönhardt, Lisa K. Behrens, Tim Bösch, Andreas Richter, and John P. Burrows — Institute of Environmental Physics (IUP), University of Bremen, Germany

The IUP Bremen has performed Differential Optical Absorption Spectroscopy (DOAS) measurements in Ny-Ålesund, Svalbard, since 1995, when the first simple zenith-viewing instrument was installed. It was enhanced to a Multi-Axis-DOAS (MAX-DOAS) instrument in 1999 (1 off-axis direction), replaced with a newer instrument in 2002 (4 off-axis directions) and again replaced in 2011 with the current system with a pant-tilt-head allowing for measurements in multiple azimuth directions (Wittrock et al., 2004; Peters, 2013).

Shipping, a sector which featured enormous growth rates in the last decades, is one of the major contributors to air pollution, especially in coastal regions and harbor towns. In the last decade, the sea cruise industry has been a booming market with strong increases in the number of ships and and the size of the ships. Also the number of cruise ships operating in the Arctic is on the rise.

Ny-Ålesund, located at 79°N, is a remote location with many cruise ship calls and nearly no land-based pollution. This study investigates the influence of cruise ship emissions on the local air quality in Ny-Ålesund using MAX-DOAS Measurements of NO_2 and SO_2 taken from the roof of the AWIPEV observatory.

UP 6.7 Fri 16:30 P

Auswertung eines bodengestützen OH-(3-1) Rotations-Schwingungs-Spektroskopie-Datensatzes zur Bestimmung der Mesopausentemperatur — •Lukas Depenthal, Christian von Savigny und Julia Hoffmann — Universität Greifswald

Seit Anfang 2015 wird an der Universität Greifswald mit Hilfe eines Andor Shamrock SR-163 Infrarotspektrometers die OH-Meinel-Bande im Wellenlängenbereich von 1500 nm bis 1600 nm gemessen. Die mittlere Emissionshöhe beträgt dabei circa 87 km. Anhand der relativen Intensitäten der OH(3-1)-Linien werden mit Hilfe der Boltzmann-Methode Rückschlüsse auf die Mesopausentemperatur gezogen und hinsichtlich ihrer Variabilität untersucht. Dabei werden auch mögliche dynamische Prozesse in die Untersuchungen einbezogen. Aufgrund der zeitlichen Auflösung des Spektrometers von 15 s können Wellensignaturen mit Perioden von wenigen Minuten gemessen werden. Hierbei konnten mit Hilfe von Fourier-Transformations- und Wavelet-Analysen Variationen mit Perioden von ca. 5-20 Minuten festgestellt werden.

UP 6.8 Fri 16:30 P

COVID-19 in Berlin: Epidemische Wellen und Sommer 2020 — •Peter Carl — ASWEX - Angewandte Wasserforschung, Berlin

Der COVID-19 Ausbruch in Berlin ist auffällig korreliert mit der regionalen Dynamik des Saisonwechsels im Frühjahr 2020. Der Shutdown schuf eine 'Laborsituation', in der vor allem regionale extrinsische Bedingungen die intrinsische Dynamik des epidemischen Systems beeinflussten. Um dies nutzbar zu machen, wurde ein SEIR-Modell aufgesetzt, das unmittelbar zwei Typen der Systemantwort auf den Eintrag Infizierter zeigte: (i) eine epidemische Welle, die in *Zero-COVID* mündet, und (ii) eine gedämpfte Schwingung mit zwei Wellen, die in einen endemischen Zustand übergeht. Ein solches Systemverhalten war zu erwarten. Das Durchforsten sinnvoller Parameter-Einstellungen nach weiteren Lösungstypen wird begleitet von einer Struktur- und Funktionsanalyse, die innere Zyklen aufdecken und ihren dynamischen Einfluss bewerten kann. Neben der raschen Reaktion auf die Maßnahmen des Shutdown zeigt das Modell nämlich eine wesentlich längere Zeitskala der dynamischen Response, die zu dem Schluss führt, dass der epidemiologisch 'ruhige' Sommer 2020 ein Ergebnis des Shutdown vom März war. Eine frühere Intervention mit denselben Maßnahmen hätte das Modell-System zudem auf dem *Zero-COVID* Pfad gehalten und die Dauer der epidemischen Lage deutlich verkürzt. Die Wechselwirkung der Eigendynamik des Systems mit einem strukturierten Saisonverlauf wird anhand des Beobachtungsmaterials diskutiert. Die Aufklärung seiner Lösungsvielfalt ist jedoch vorrangige Bedingung für das Verständnis der Saisonalität und Dynamik von COVID-19.

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Overview of Invited Talks and Sessions

Invited Talks

AGPhil 1.1	Mon	11:00–11:45	H4	**What's so special about initial conditions?** — •Matt Farr
AGPhil 1.3	Mon	12:15–13:00	H4	**Structuralism as a Stance** — •Kerry McKenzie
AGPhil 2.1	Tue	11:00–11:45	H4	**Quantum Metaphysics** — •Alastair Wilson
AGPhil 7.1	Thu	11:00–11:45	H7	**Four Attitudes Towards Singularities in the Search for a Theory of Quantum Gravity** — •Karen Crowther

Invited talks of the joint symposium Entanglement (SYEN)

See SYEN for the full program of the symposium.

SYEN 1.1	Mon	16:30–17:10	Audimax	**Squeezed and entangled light - now exploited by all gravita-tional-wave observatories** — •Roman Schnabel
SYEN 2.1	Mon	17:10–17:50	Audimax	**Entanglement and Explanation** — •Chris Timpson
SYEN 3.1	Mon	17:50–18:30	Audimax	**Entanglement and complexity in quantum many-body dynamics** — •Tomaz Prosen

Sessions

AGPhil 1.1–1.3	Mon	11:00–13:00	H4	**Metaphysics of Physics**
AGPhil 2.1–2.4	Tue	11:00–13:15	H4	**Quantum Theory 1**
AGPhil 3.1–3.4	Tue	14:00–16:00	H5	**Quantum Theory 2**
AGPhil 4.1–4.4	Wed	14:00–16:00	H8	**Quantum Theory 3**
AGPhil 5.1–5.4	Wed	16:30–18:30	H8	**Quantum Theory 4**
AGPhil 6	Wed	18:30–19:00	H8	**Mitgliederversammlung der AGPhil**
AGPhil 7.1–7.3	Thu	11:00–12:45	H7	**Quantum Gravity 1**
AGPhil 8.1–8.3	Thu	14:00–15:30	H7	**Quantum Gravity 2**
AGPhil 9.1–9.3	Thu	16:30–18:00	H7	**General Relativity and Black Holes**
AGPhil 10.1–10.4	Fri	11:00–13:00	H3	**Quantum Mechanics, Time and Information**

Annual General Meeting of the Working Group on Philosophy of Physics

Wednesday 18:30–19:00 MVAGPhil

- Wahlen
- Bericht
- Planung 2021/22
- Verschiedenes

Sessions

– Invited and Contributed Talks –

AGPhil 1: Metaphysics of Physics

Time: Monday 11:00–13:00 Location: H4

Invited Talk AGPhil 1.1 Mon 11:00 H4

What's so special about initial conditions? — •Matt Farr — University of Cambridge, UK

The early universe is thought to be extremely low probability in a way that calls for explanation. Some have used the 'initialness defence' to argue that initial (as opposed to final) conditions are intrinsically special in that they don't require further explanation. Such defences commonly assume a primitive directionality of time to distinguish between initial and final conditions. I outline and support a deflationary account of the initialness defence consistent with an directionless ontology of time, and argue that although there is no intrinsic difference between initial and final conditions, once we have sufficient structure to discern them we should not seek explanations of low-probability initial conditions.

AGPhil 1.2 Mon 11:45 H4

The mereological problem of entanglement — •Paul M. Näger — Department of Philosophy, WWU Münster, Germany

The discipline of mereology treats the question how parts and wholes relate and has its roots in ancient Greek philosophy. Especially in the 20th century its concepts have been sharpened considerably resulting in a formalism called classical mereology. From this point of view, entangled quantum systems are an anomaly since they are well-known to involve some kind of holism in the sense that the quantum state of the whole cannot be reduced to the quantum state of the parts. Are entangled systems undivided wholes? In this talk I shall argue on the basis of the quantum mechanical formalism that they are not: When two objects are entangled, there are only these objects but no whole, and the holistic entangled property is carried collectively by these objects. (Paper available at: https://philarchive.org/rec/NGETMP)

Invited Talk AGPhil 1.3 Mon 12:15 H4

Structuralism as a Stance — •Kerry McKenzie — UC San Diego, USA

Bas van Fraassen argues in 'The Empirical Stance' that physicalism - the view that fundamentally all is physical - should be viewed not as a doctrine but rather as a 'stance': that is, as a cluster of attitudes, policies, and heuristics concerning how to theorize and conduct research. In this talk, I will argue that the same considerations support regarding ontic structuralism - the view that fundamentally all is structure - as a stance also. More specifically, I will argue that rather than a doctrine about how the world is fundamentally, structuralism should be viewed as the injunction to always foreground in one's metaphysics the fact that the language of physics is mathematics. Some benefits of doing so will be presented.

AGPhil 2: Quantum Theory 1

Time: Tuesday 11:00–13:15 Location: H4

Invited Talk AGPhil 2.1 Tue 11:00 H4

Quantum Metaphysics — •Alastair Wilson — University of Birmingham, Birmingham B15 2TT, UK

Philosophy, specifically natural philosophy, used to be our main route to understanding the deep underlying structure of reality. Physics emerged out of natural philosophy during the Scientific Revolution, and over the past few centuries it has come to seem as though physics is all we need to understand the natural world. But is there still any role for philosophy to play? In this talk I argue that philosophy and physics can work together to help us understand some of the deepest mysteries of nature: in particular, chance, possibility and necessity. I suggest that the Everett interpretation of quantum mechanics - if correct - can cast light on many core questions of metaphysics, while embedding the Everettian approach in a suitable metaphysical framework can strengthen it in turn. The overall method I advocate is 'naturalistic metaphysics' - theorizing about the most general aspect of reality in a way informed and constrained by our best physics - and I will end by asking how far this naturalistic approach can be taken.

AGPhil 2.2 Tue 11:45 H4

The Representation and Determinable Structure of Quantum Properties — •Samuel C. Fletcher and David E. Taylor — University of Minnesota, Twin Cities

Let us begin with a puzzle. Consider an electron with a two-dimensional Hilbert state space, and the properties of having spin in the x- and y-directions, respectively. On the one hand, it is standard to represent these as the Pauli operators σ_x and σ_y, whose eigenvalues represent the values of spin-up and spin-down in their respective directions. And it is well-known that these operators do not commute. On the other hand, it is also commonly acknowledged that projection operators, as self-adjoint operators, can also represent these quantities, whose eigenvalues represent the property obtaining or not. But each of these quantities is only plausibly represented by the identity operator on the Hilbert space, and these operators obviously commute. Operators commute iff the properties they represent are compatible. So the spin-x and spin-y properties are both compatible and not compatible: a contradiction. We propose to resolve this puzzle by denying that self-adjoint operators represent properties simpliciter: rather, they represent a determinable property, whose extension is the domain of the operator, **plus** a particular level of specification with associated determinates, which are named by the eigenvalues. So the different operators in the puzzle actually reflect different levels of specification of one and the same property. Thus it is not the properties of a quantum system which are incompatible in a non-classical way, but rather the levels of specification.

AGPhil 2.3 Tue 12:15 H4

Spatial Separation of Magnetic Moment and Location as an Argument for a Trope-Ontological Interpretation of Quantum Field Theory — •Karim Baraghith[1] and Nina Nicolin[2] — [1]Heinrich Heine Universitaet Duesseldorf, GER — [2]Heinrich Heine Universitaet Duesseldorf, GER

It has been suggested to interpret particles in quantum field theory (QFT, in particular AQFT) as bundles of tropes, see e.g. Kuhlmann (2010). In this reading, a *thing* (like a particle) does not *have* its properties, it is the specific combination of the properties which constitute the thing in the first place. We will present an empirical matter-wave interferometer experiment (Denkmayr et. al. [2014]), which shows that one can indeed separate a particle*s properties, experimentally (Chesire Cat phenomenon). It indicates that when sending neutrons through a silicon crystal interferometer, while performing weak measurements in or-der to probe the location of the particle and its magnetic moment, the system behaves as if the neutrons go through one beam path, while their magnetic moment travels along the other. Following a specific interpretation of these observations, it seems to be the case that what we call a *property* may exist fundamentally and independently of its particle (or at least can be isolated from it). We argue that a trope theoretical interpretation of quantum particles * which sees the particle*s properties and not the particle itself as fundamental * is probably the most com-patible ontological interpretation of this phenomenon.

AGPhil 2.4 Tue 12:45 H4

The Unactualized Certainty-Actuality Correspondence — •Armin Nikkhah Shirazi — University of Michigan, Ann Arbor, USA

This talk investigates the correspondence between unactualized certainties and actualities. It does this first through the lens of a recently proposed enrichment of axiomatic probability which makes it possible to distinguish mathematically between actualities and unactualized possibilities, including those which are certain. Two kinds of unactualized certainties are considered: those due to the sample space being a singleton, and those involving a sample space with more than one element.

After comparing standard axiomatic probability with the enrichment in regards to how they represent the distinction, attention is then focused on quantum mechanics. There, the correspondence will be examined through the lens of a recently proposed modification of the standard formalism, the Heisenberg Interpretation, which, unlike the standard quantum formalism but like the enriched axiomatization of probability, also permits formal distinctions between unactualized possibilities and actualities. Two situations are found to exemplify the correspondence there: one involving partially measured entangled systems and the other involving the Born rule.

AGPhil 3: Quantum Theory 2

Time: Tuesday 14:00–16:00 Location: H5

AGPhil 3.1 Tue 14:00 H5

Kurt Gödels Notizen zur Quantenmechanik — •Oliver Passon — Bergische Universität Wuppertal

Kurt Gödel hat unter anderem ein umfangreiches Erbe aus Notizen und Arbeitsbüchern in Gabelsberger Kurzschrift hinterlassen. Dieser Vortrag stellt die bisher unveröffentlichten Arbeitsbücher zur Quantenmechanik aus den Jahren 1935/36 vor. Ein Schwerpunkt liegt auf der Frage, welche Stellung Gödel zu den Grundlagenproblem und Interpretationsfragen der Quantentheorie eingenommen hat.

AGPhil 3.2 Tue 14:30 H5

Persistence and Nonpersistence as Complementary Models of Identical Quantum Particles — •Philip Goyal — University at Albany (SUNY), Albany, NY

In our ordinary conception of the physical world, it is tacitly assumed that the appearances perceived in the present moment are underpinned by objects that persist through time, and that are reidentifiable on the basis of their stable characteristic properties.

It is widely accepted that the quantum treatment of assemblies of identical particles brings this assumption into question, but no consensus on a modification of this assumption has thus far emerged.

In this talk, we propose a new understanding of identical particles based on a recent derivation of the symmetrization postulate [1].

We adopt an operational approach in which the raw data consists of identical localized events. We construct two distinct models of the event data, namely a persistence model and a nonpersistence model. These differ in whether or not it is assumed that successive events are generated by individual persistent entities ('particles'). We then show that these models can each be described within the Feynman formulation of quantum theory and be synthesized to derive Feynman's form of the symmetrization postulate.

On this basis, we propose that the quantal behaviour of identical particles reflects a complementarity of persistence and nonpersistence, analogous to the way in which the behavior of an individual electron reflects a complementarity of particle and wave.

[1] P. Goyal, New J. Phys. 17, 013043 (2015)

AGPhil 3.3 Tue 15:00 H5

Quantum modal realism and Everettian actualism: a methodological appraisal on scientific realism — Jonas Rafael Becker Arenhart[1] and •Raoni Wohnrath Arroyo[2] — [1]Federal University of Santa Catarina, Department of Philosophy, Florianópolis, Brazil. — [2]Federal University of Santa Catarina, Graduate Program in Philosophy, Florianópolis, Brazil.

A recent tension splits scientific realism into two types, 'shallow' and 'deep', depending on how they relate to metaphysics. The division is better appreciated by employing a distinction between 'ontology' and 'metaphysics' by their subject matter, the former dealing with existence-questions and the latter with nature-questions. Deep scientific realists argue that one should 'go deep' into metaphysical questions, otherwise one's scientific realism is not sufficiently informative about its realist content; hence, not genuinely realist. Shallow realism stops at the level of providing an ontology. With this methodological background, we consider two realist approaches to Everettian quantum mechanics: quantum modal realism and Everettian actualism; the former being a defense of the existence of a many-world ontology and the latter being a defense of a single-world ontology. This, in turn, produces a tension regarding the 'realism' of such approaches: the current debate revolves around existence questions concerning the multiplicity of worlds (leaving unanswered questions regarding their nature), so either the mentioned realist approaches are not realist enough by deep realists' standards or their very standard of dealing with metaphysical questions is not a reasonable one.

AGPhil 3.4 Tue 15:30 H5

Derivative metaphysical indeterminacy and quantum physics — •Alessandro Torza — Instituto de Investigaciones Filosóficas, UNAM

A growing literature regards quantum mechanics as a hotbed of metaphysical indeterminacy (MI), which is to say, indeterminacy with a nonrepresentational source. However, Glick (2017) has argued that quantum mechanics provides evidence of MI only if MI can be merely derivative (i.e., arising only at the non-fundamental level); and Barnes (2014) has argued that MI cannot be merely derivative. I will respond to both Glick and Barnes by providing two ways of understanding quantum mechanics as giving rise to merely derivative MI. My overarching argument is as follows:

1. MI is characterized relative to a logical space: MI arises in logical space L just in case there is a fact (state of affairs) in L which neither obtains nor fails to obtain.
2. A quantum system S defines both a classical logical space C_S (i.e., a logical space which is a model of classical logic) and a quantum logical space Q_S (i.e., a logical space which is a model of quantum logic). Crucially, MI arises in Q_S but not in C_S (Torza 2021).
3. Given a system S, there are two ways of understanding C_S as fundamental and Q_S as derivative: if a metaphysically privileged description of reality involves classical logic (Sider); and if reality is fundamentally isomorphic to a Hilbert space (Carroll & Singh ms).
4. Therefore, there are two ways of understanding quantum MI as arising derivatively (in Q_S) but not fundamentally (in C_S).

AGPhil 4: Quantum Theory 3

Time: Wednesday 14:00–16:00 Location: H8

AGPhil 4.1 Wed 14:00 H8

On the objectivity of measurements — •Elias Okon — UNAM (Mexico)

Recent arguments, involving entangled systems shared by sets of Wigner*s friend arrangements, allegedly show that the assumption that the experiments performed by the friends yield definite outcomes is incompatible with quantum predictions. From this, it is concluded that the results of (at least some) quantum measurements, cannot be thought of as being actual or objective. Here, I will show that these arguments depend upon a mistaken assumption, regarding the correlations between the results of "the friends" and those of "the Wigners," which leads to invalid predictions. It is not, then, that the assumption of definite outcomes leads to trouble, but that the results derived with such an assumption are contrasted with faulty predictions. I will trace these inadequate predictions to a lack of recognition i) that hidden variables, with their inevitable contextual and non-local nature, are being (implicitly) postulated, and ii) that, in spite of such features, signaling is fully avoided. As for the "correct" predictions for the scenarios under consideration, I will show that the proposed experiments would allow for an empirical discrimination between hidden-variable and objective collapse models. Along the way, I will illustrate my claims with explicit calculations in the context of pilot-wave theory.

AGPhil 4.2 Wed 14:30 H8

The Wave-Function Must Be Psi-Ontic — •Mario Hubert — California Institute of Technology

The PBR-theorem aimed at proving that the wave-function has to represent objective features of a single physical system. There have been many attempts to interpret the wave-function as not representing the objective physical state of a quantum system by abandoning one of the two explicit assumptions of the PBR-theorem: (i) the existence of objective physical states and (ii) preparation independence. I argue that each theory that violates either of these assumptions meets unsurmountable problems. Although these alternative theories are physically possible, they are for several reasons implausible or problematic. I, therefore, advocate to search for quantum theories that fulfill the assumptions of the PBR-theorem.

AGPhil 4.3 Wed 15:00 H8

Temporal global correlations in time symmetric collapse models — •Pascal Rodríguez — Utrecht University

We propose that time symmetric collapse models require the existence of temporal global correlations across histories. We elaborate on a recent discussion regarding whether time-symmetric quantum mechanics requires retrocausality (Price, 2012; Leifer and Pusey 2017), spooky-action-at-temporal-distance (Adlam 2018), or neither of them. The moral is that quantum theories meeting certain assumptions either violate time-symmetry or imply retrocausality. Adlam argues we should give up the assumption that every quantum correlation is λ-mediated, meaning that there is spooky-action-at-temporal-distance. We consider that both proposals are metaphysically strong, although the point needs to be taken seriously. We suggest an analysis of time-symmetric collapse models, in which the wave-function is taken as a temporally asymmetric predictive tool to make the theory Markovian (Bedingham and Maroney 2017). We propose that the model does not require retrocausality since not every correlation is mediated by an ontic state. Nevertheless, we show that it does not need action-at-temporal-distance either; the temporal correlations exhibited violate temporal outcome independence (TOI) across histories. Analogously to the spacelike case, these TOI should not be interpreted as action-at-temporal-distance, but as temporal global correlations. We conclude with remarks about whether these correlations involve violations of Measurement Independence in an EPRB-scenario.

AGPhil 4.4 Wed 15:30 H8

On the Explanatory Power of the Hidden Variables Hypothesis — •Louis Vervoort — School of Advanced Studies, University of Tyumen, Russian Federation

In the debate whether 'hidden variables' could exist underneath quantum probabilities, the 'no hidden-variables' position is at present favored. However, if the hidden variables are allowed to be superdeterministic, the hidden-variables hypothesis can answer three foundational questions, whereas the opposing thesis ('no hidden variables') remains entirely silent for them. These questions are: 1) How to interpret probabilistic correlation in a coherent way in the classic and quantum domain ?; 2) How to interpret the Central Limit Theorem ?; and 3) Are there degrees of freedom that could unify quantum mechanics and general relativity, and if so, can we (at least qualitatively) specify them ? As I will show in this talk, it appears that only the hidden-variables hypothesis can provide coherent answers to these questions; answers which can be mathematically proven in the deterministic case. This suggests that the hidden-variables hypothesis has the greater explanatory strength, and that, to the least, an open-minded attitude towards it is recommendable.

AGPhil 5: Quantum Theory 4

Time: Wednesday 16:30–18:30 Location: H8

AGPhil 5.1 Wed 16:30 H8

Mereological Atomism's Quantum Problems — •Ryan Miller — University of Geneva, Switzerland

The popular metaphysical view that concrete objects are grounded in their ultimate parts is often motivated by appeals to realist interpretations of contemporary physics (Feynman et al., 2015; Fine, 1992; Pettit, 1993; Loewer, 2009). Given that appeals to small-scale physics are fundamentally quantum mechanical, this paper argues first that mereological atomism is only plausible in conjunction with Bohmianism, and second that it exacerbates Bohmianism's existing tensions with serious Lorentz invariance. Neither of Bohmianism's leading realist competitors yields a decomposition of the physical world into a multiplicity of non-overlapping fundamental concrete objects. Everettians can't rely on decoherence for such a decomposition (Wallace, 2012; Crull, 2013; pace Ney, 2021) and none of the proposed ontological elements for GRW (mass density, flashes, flash families) can play the role of multiple synchronic atomic parts.

Bohmian particles, on the other hand, provide a natural set of ultimate parts for atomists. The trouble is that different reference frames have different particle numbers (Unruh & Wald, 1984), and in classical mereology concrete objects are invariant fusions of determinate parts, so the Bohmian hidden privileged reference frame corresponds to a set of hidden privileged macroscopic concrete objects. Mereological atomism is thus undercut rather than supported by contemporary physics.

AGPhil 5.2 Wed 17:00 H8

Non-Accessible Mass and the Ontology of GRW — •Cristian Mariani — Institut Néel (CNRS), Grenoble, FRANCE

The Mass Density approach to GRW (GRWm for short) has been widely discussed in the quantum foundations literature. A crucial feature of GRWm is the introduction of a Criterion of Accessibility for mass, which allows to explain the determinacy of experimental outcomes thus also addressing the tails problem of GRW. However, the Criterion of Accessibility leaves the ontological meaning of the non-accessible portion of mass utterly unexplained. In this paper I discuss two viable approaches to non-accessible mass, which I call anti-realist and realist, and will defend the latter. First, I show that the anti-realist approach suffers from various objections. Second, I develop an account of non-accessible mass density states as objectively indeterminate states of affairs. Finally, I discuss the main conceptual consequences of the realist approach to non-accessible mass with respect to the current debate on the Primitive Ontology of GRW.

AGPhil 5.3 Wed 17:30 H8

Master equations for Wigner functions with spontaneous collapse and their relation to thermodynamic irreversibility* — •Michael te Vrugt[1,2], Gyula I. Tóth[3], and Raphael Wittkowski[1] — [1]Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany — [2]Philosophisches Seminar, Westfälische Wilhelms-Universität Münster, D-48143 Münster, Germany — [3]Interdisciplinary Centre for Mathematical Modelling and Department of Mathematical Sciences, Loughborough University, Loughborough, LE11 3TU, United Kingdom

Wigner functions allow for a reformulation of quantum mechanics in phase space. They are, as shown in our recent work [1], very useful for understanding effects of spontaneous collapses of the wavefunction as predicted by the Ghirardi-Rimini-Weber (GRW) theory. We derive the dynamic equations for the Wigner function in the GRW theory and its most important variants. The results are used to test, via computer simulations, David Albert's suggestion that the stochasticity induced by spontaneous collapses is responsible for the emergence of thermodynamic irreversibility. We do not observe the equilibration mechanism proposed by Albert, suggesting that GRW theory cannot explain the approach to thermal equilibrium.

[1] M. te Vrugt, G. I. Tóth, R. Wittkowski, arXiv:2106.00137 (2021)

**Funded by the Deutsche Forschungsgemeinschaft (DFG) – WI 4170/3-1*

AGPhil 5.4 Wed 18:00 H8

Does Physics study the concrete? — •Samuel Dickson — University of York, York, UK

Metaphysicians classically divide objecthood into two categories, the abstract and the concrete. Physicists investigate the physical, and this is often taken to be part of the concrete. So physicists are investigating concrete objects. I think, however, that this is debatable. Concrete objects are typically taken to be both spatiotemporal and causal. However, I think the objects of fundamental physics, things like quarks and electrons, are not concrete objects, but this does not mean I think they are abstract. I think there is a middle ground between the abstract and concrete, and I think the objects of fundamental physics are in this middle ground, what I am calling exotic objects. For example, electrons are not categorised accurately with what we generally mean by spatial. Using the general sense, electrons do not exist in space (in that way). If this is the sense of spatial relevant for something to be a concrete object, then electrons are not concrete. If we soften what we mean by concrete to avoid this, then we will find equal need to soften what we mean by temporal and causal, meaning many things classed as abstract would become concrete. That is why we need a middle ground, the exotic.

AGPhil 6: Mitgliederversammlung der AGPhil

Time: Wednesday 18:30–19:00 Location: H8

Mitgliederversammlung der AGPhil

AGPhil 7: Quantum Gravity 1

Time: Thursday 11:00–12:45 Location: H7

Invited Talk AGPhil 7.1 Thu 11:00 H7

Four Attitudes Towards Singularities in the Search for a Theory of Quantum Gravity — •Karen Crowther — University of Oslo

Singularities in general relativity and quantum field theory are often taken not only to motivate the search for a more-fundamental theory (quantum gravity, QG), but also to characterise this new theory and shape expectations of what it is to achieve. Here, we first evaluate how particular types of singularities may suggest an incompleteness of current theories. We then classify four different 'attitudes' towards singularities in the search for QG, and show, through examples in the physics literature, that these lead to different scenarios for the new theory. Two of the attitudes prompt singularity resolution, but only one suggests the need for a theory of QG. Rather than evaluate the different attitudes, we close with some suggestions of factors that influence the choice between them. [Based on joint work with Sebastian de Haro]

AGPhil 7.2 Thu 11:45 H7

Conditions for Theoretical Equivalence, Duality, and Implications Thereof — •Konner Childers — University of Birmingham, UK

Recent attention in philosophy of physics literature has been directed towards dualities between physical theories, furthering the *theoretical equivalence* questions into a new domain. After re-introducing the distinction between theoretical equivalence and dualities, this paper shall seek to critically assess 1) the sense in which dualities are (not) equivalences, with special attention given to categorical and physical equivalence, 2) the role of semantics and reference in addressing duality relations between theories, and 3) issues regarding the criteria of empirical (in)equivalence and predictions with respect to T-duality and gauge/gravity duality. Finally, these results shall be applied to fermionic particle-vortex and recently proposed 3d bosonization dualities to both elucidate the formal and empirical relations and to suggest further avenues for research.

AGPhil 7.3 Thu 12:15 H7

Composing Spacetime Out of Nowhere — •Baptiste Le Bihan — University of Geneva

According to a number of approaches in theoretical physics spacetime does not exist fundamentally. Rather, spacetime exists by depending on another, more fundamental, non-spatiotemporal structure. A prevalent opinion in the literature is that this dependence should not be analysed in terms of composition. We should not say, that is, that spacetime depends on an ontology of non-spatiotemporal entities in virtue of having them as parts. But is that really right? On the contrary, a mereological approach to dependent spacetime is not only viable, but promises to enhance our understanding of the physical situation.

AGPhil 8: Quantum Gravity 2

Time: Thursday 14:00–15:30 Location: H7

AGPhil 8.1 Thu 14:00 H7

A Tale of Two Machs: Relationalism in Quantum Gravity — •Mark Shumelda — University of Toronto, Canada

Several approaches to quantum gravity are explicitly motivated by temporal relationalism. This is the notion, historically prefigured by Leibniz and Mach, that time is simply not part of our basic ontological framework.

Relational approaches to physics in general, and quantum gravity in particular, seek to describe the history of the universe not as curve in four-dimensional Minkowski spacetime, but rather in some kind of parametrization-invariant configuration space. Relational approaches such as loop quantum gravity are already well-known to philosophers. In my paper I begin a philosophical analysis of time in the light of two relatively new and very different approaches to quantum gravity: geometrogenesis and shape dynamics. In my analysis I contrast the opposing ways in which geometrogenesis and shape dynamics implement the basic tenets of Machian temporal relationalism.

It turns out that far from removing time altogether from the fundamental theory, both geometrogenesis and shape dynamics posit an ontologically robust sense of temporal passage, though in very different ways. I argue that while each approach has its philosophical merits, neither is able to describe time as a fully emergent concept. Time, it seems, is here to stay in the fundamental theory, even given a Machian, relationalist approach to dynamics.

AGPhil 8.2 Thu 14:30 H7

The fundamental role of the proper time parameter in general relativity and in quantum mechanics — •René Friedrich — Strasbourg

Einstein's relativity provides us with some hints about the nature of time which have not been fully taken into account in quantum gravity yet. The phenomenon of time dilation is replacing Newton's absolute time with a twofold, complementary time concept, consisting of the observer's coordinate time after time dilation and the observed object's proper time before time dilation.

Although many authors are highlighting the importance of proper time within GR, theories of quantum gravity are usually starting off with the assumption of a relative spacetime manifold. However, for fundamental questions about the nature of time we should not refer to coordinate time but to the more fundamental parameter of proper time. Following this approach, the universe of quantum gravity is composed of solipsistic worldlines which are parameterized by their respective proper time, including lightlike worldlines of fields whose length is zero.

The definition of proper time: "The time measured by a clock following a given particle" provides the particle with a well-defined physical property: its aging - in general relativity as well as in quantum mechanics. It will be shown that, in a first step, time is produced locally by the rest energy of mass particles in the form of proper time, and that only in a second step time is measured and synchronized by observers in the form of coordinate time.

AGPhil 8.3 Thu 15:00 H7

Simplicity and naturalness in a fundamental complex dynamics — •Aldo Filomeno — Universidad Católica de Valparaiso

Some traditional criteria for the fundamentality of a theory – naturalness, simplicity, unification, among other conditions – appear to be inconsistent with our current best physics. In light of this, while some expect these criteria to show up in future quantum gravity theories, others argue that such criteria ought to be abandoned. In this paper we stress that there is a third way of thinking about this situation. If such criteria are preserved, another qualitatively different physics at the fundamental level gains plausibility, in that it would restore the naturalness and simplicity: a highly complex dynamics at the fundamental level. This amounts to an account of fundamental laws of nature that has long been studied and defended in various (unorthodox) projects in physics, while it has been neglected in philosophical accounts of laws of nature.

AGPhil 9: General Relativity and Black Holes

Time: Thursday 16:30–18:00 Location: H7

AGPhil 9.1 Thu 16:30 H7

The History and Interpretation of Penrose's Singularity Theorem — •Dennis Lehmkuhl — Lichtenberg Group for History and Philosophy of Physics, University of Bonn

The Nobel Prize of 2020 was awarded to Roger Penrose for his singularity theorem of 1965, which the Nobel foundation interpreted as "the discovery that black hole formation is a robust prediction of the general theory of relativity." However, the 1965 paper does not mention the term "black hole" but speaks of gravitational collapse and spacetime singularities, starting with remarks on Schwarzschild's 1916 solution to the Einstein field equations. In this talk, I will put Penrose's singularity theorem in its historical context, starting with Einstein's and Schwarzschild's interpretation of the Schwarzschild metric in the late 1910s and 1920s, and discuss how the metric was linked to the question of gravitational collapse by Oppenheimer and Snyder in the late 1930s, and reconsidered by Wheeler and others in the 1950s and 1960s; and how Penrose drew on all these developments. I will describe which conceptual and technical advances Penrose had to invent and combine in order to come up with his singularity theorem to go beyond considerations of specific spacetimes like that of Schwarzschild, and show why the theorem was such a game-changer. Finally, I will discuss different possible interpretations of the theorem.

AGPhil 9.2 Thu 17:00 H7

Operational vs Descriptive Black Hole Complementarity — •Siddharth Muthukrishnan — Department of History and Philosophy of Science, University of Pittsburgh, Pittsburgh PA 15260 USA

To what extent does the black hole information paradox lead to violations of quantum mechanics? Black hole complementarity has emerged as an influential framework to prevent any such violations from being empirically problematic. I distinguish between an operational and a descriptive principle of black hole complementarity. Recent results applying quantum information theory and quantum computational complexity theory to black holes then imply that the operational principle is successful where the descriptive principle is not. Keeping this distinction in mind helps clarify why one seeks a solution to the information paradox, and what such a solution needs to explain. In particular, if the operational principle is accepted, then the black hole information paradox is no longer pressing.

AGPhil 9.3 Thu 17:30 H7

Why Einstein may have had good reason to oppose the geometrization of gravity in general relativity. — •Femke Kuiling — University of Minnesota, Minneapolis, USA

Using Einstein's Methodological Realism (Lehner 2014), I strengthen Lehmkuhl's argument for why Einstein refused to conclude (as most others have) that General Relativity somehow reduces gravity to geometry.

AGPhil 10: Quantum Mechanics, Time and Information

Time: Friday 11:00–13:00 Location: H3

AGPhil 10.1 Fri 11:00 H3

The Measurement Problem in Quantum Mechanics and the Surjective Environment — •Fritz Wilhelm Bopp — Department Physik, Universität Siegen, Siegen, Germany

Starting with unitary quantum dynamics, we investigate how to add measurements. Quantum measurements have four essential components: the furcation, the witness production, an alignment projection, and an actual choice decision. The first two components still lie in the domain of unitary quantum dynamics. Observations tell us that witnesses are essential for measurement processes and, in our opinion, interpretations in which they are not functional can be disregarded. They play a central role in the decoherence concept. Within such a concept, the alignment projection can be based on the requirement that witnesses reaching the end of time on the wave function side and the conjugate one have to match. No projection operator is needed, and simple quantum dynamics remains sufficient. The surjective environment conjecture explains the actual choice decision. It is based on a two boundary interpretation applied to the complete quantum universe. It offers a simple way to reduce these seemingly random projections and collapses to purely deterministic unitary quantum dynamics, eliminating aspects people like Einstein considered unacceptable for a complete theory.

AGPhil 10.2 Fri 11:30 H3

Deriving the local arrow of time — •Daniel Saudek — Philosophisch-Theologische Hochschule Sankt Georgen, Frankfurt a. M. (Germany)

This contribution provides a derivation of time*s ordering properties, its metric properties, and its irreversibility on the basis of simple axioms. It does so in three steps:

1. It starts with the notion of the set of states of an object. There is a characteristic asymmetry on this set which can be defined independently of time, but which can be exploited to define temporal order (*before*) in a way which corresponds, as will be shown, with the order known from everyday experience.
2. The object is equipped with a counting mechanism based on successive inclusion, providing a natural parameter (as in Kuratowski*s construction of the naturals), which can then be fine-grained further to yield a rational and a real parameter. The local parameter so established is shown to increase monotonically with the before-ordering developed in (1).
3. It is shown that, given an object with a particular local index t (as developed under 2), the notion of changing the event content associated with indices less than t leads to a contradiction, whereas there is no event content for indices greater than t. Thus, the local past is fixed, and the future open.

AGPhil 10.3 Fri 12:00 H3

Information: Vieldeutiges Etwas oder Einheit der neueren Physik? — •Emanuel Seitz — emanuel_seitz@web.de

Carl Friedrich von Weizsäcker hat die bekannte Behauptung aufgestellt: Information ist das Maß für die Menge an Form oder ein Maß für die Gestaltenfülle. Hinter diesen Begriffen steckt das altgriechische Begriffspaar eidos und morphé, wie sie von Platon und Aristoteles gedacht wurden. Doch wie ist das eigentlich möglich, dass Form eine Menge und ein Maß haben sollen? Ein Ball hat nicht mehr oder weniger Form als eine Tasse. In der neueren Wissenschaftsphilosophie, etwa bei Holger Lyre, gilt Information als ein letztlich wenig taugliches Wort, eine bloß nominale Vieldeutigkeit, um Zusammenhänge zu beschreiben, die eigentlich nicht die gleichen sind. In meinem Vortrag werde ich versuchen zu zeigen, dass der Begriff der Information * als Maß für die Wahrscheinlichkeit, für die Struktur oder für die Komplexität, als Bedeutung einer Nachricht oder biologische Präformation * auf ein- und dieselbe metaphysische Idee zurückgeht: auf das Verhältnis von Wesen und Ereignis.

AGPhil 10.4 Fri 12:30 H3

Quantentheorie verstehen — •Thomas Görnitz — FB Physik, Goethe-Univ. Frankfurt/M

Die Quantentheorie (QTh) ist die genaueste und beste Beschreibung der Realität. Unsere technische Zivilisation wäre ohne ihre Anwendungen undenkbar. Trotzdem finden sich noch immer Aussagen, die einem nicht mathematisch und physikalisch ausgebildeten Menschen ein Verstehen unmöglich machen.

Wird ihre mathematische Struktur gründlich reflektiert zeigt sich, dass die QTh unseren Erfahrungen sehr nah ist.

Unsere Handlungen werden von künftigen Möglichkeiten beeinflusst - so auch die Natur. Die QTh - eine Theorie über noch nicht faktische Möglichkeiten - genügt einer anderen Logik als die Fakten.

Zusammensetzungen zu komplexen Strukturen geschehen über das Tensorprodukt der Zustandsräume. Daher ist in der QTh ein Ganzes mehr als die Summe seiner Teile - so wie im Leben auch.

Quantenmechanik rechnet mit festen Anzahlen geladener Teilchen und deren Wechselwirkung mit einem (oft klassischen) elektromagnetischen Feld. Erst Quantenfeldtheorien (QFTh) erfassen, dass Teilchen entstehen und verschwinden, dass bereits virtuelle Teilchen reale Effekte bewirken. Ein QF kann verstanden werden als eine unbegrenzte Zahl von Quantenteilchen. Diese sind somit einfacher als ein QF.

Die einfachsten, also fundamentalen Quantenstrukturen sind AQIs (Absolute Bits of Quantum Information). Der Vortrag erklärt, wie mit ihnen wichtige Verständnisprobleme der Quantentheorie behoben werden.