P 16: Poster Session Plasma Physics

Time: Thursday 13:45–15:45 Location: Redoutensaal

P 16.1 Thu 13:45 Redoutensaal

GPU Acceleration and Portability of the TRIMEG Code for Global Gyrokinetic Plasma Simulations using OpenMP — •Giorgio Daneri, Zhixin Lu, and Matthias Hoelzl — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany

The TRIangular MEsh-based Gyrokinetic (TRIMEG) code solves the gyrokinetic equations using a particle-in-cell (PIC) scheme to simulate electromagnetic instabilities throughout the full tokamak volume.

In this work, we focus on the acceleration and portability of the TRIMEG code on multiple GPU architectures. The OpenMP framework is chosen as the methodological approach for GPU offloading in Fortran on NVIDIA and AMD platforms. The particle pushing procedure, as well as particle-to-grid operations have been adapted for GPU execution. The kernels were analyzed with the available profiling tools to gather metrics about resource occupancy, throughput, and memory usage. Their performance was evaluated by carrying out GPU grid size exploration, as well as multi-node scalability studies. In addition, the efficiency of hybrid MPI-OpenMP offloading parallelization was assessed.

The Ion Temperature Gradient (ITG) mode was simulated using the GPU-accelerated version for the economical Cyclone case and the TCV case, and its correctness was verified by comparing the physics results in terms of the energy growth rate and the two-dimensional mode structures.

P 16.2 Thu 13:45 Redoutensaal

Impact of RMPs on plasma rotation in ASDEX Upgrade — •Margherita Salerno[1], Matthias WIllensdorfer[1], Rachael McDermott[1], Tuomas Tala[2], Athina Kappatou[1], and Tabea Gleiter[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]VTT Technical Research Centre of Finland

Tokamaks, though designed for perfect axi-symmetry, experience unavoidable symmetry breaking from sources like toroidal field coil ripples, error fields, and resonant magnetic perturbation (RMP) coils used for ELM suppression. These non-axisymmetric perturbations are important as they drive non-ambipolar radial particle fluxes, resulting in the Neoclassical Toroidal Viscous (NTV) torque. This torque typically acts on the plasma by spinning-up or breaking the rotation, depending on the contributions from electrons and ions. For future devices like ITER, it is crucial to quantify the NTV torque as, in this device, it may be comparable to other applied and intrinsic torques and thus make a more important contribution to the momentum balance than typically observed in present-day beam-heated devices. This work will study the impact of RMPs on plasma rotation in ASDEX Upgrade. Our investigation will focus on i) radial distribution of the torque source via coil current modulations, ii) impact of the poloidal spectrum of the RMP coils on the torque and iii) impact of the ExB rotation frequency of the torque. The experimental results will be analyzed with GPEC, which is a linear code that works generalizing the perturbed equilibrium, and then benchmarked with other codes, like MARS-K and NEO-2.

P 16.3 Thu 13:45 Redoutensaal

Experimental Investigation into the Influence of Carbon on the Mechanical Properties of Tungsten — •Sebastian Estermann[1,2], Alexander Feichtmayer[1], Till Höschen[1], Johann Riesch[1], Thomas Schwarz-Selinger[1], and Rudolf Neu[1,2] — [1]Max Planck-Insitute for Plasma Physics, Boltzmannstr. 2, 85748 Garching — [2]Technical University Munich, Boltzmannstr. 15, 85748 Garching

Fusion power plants are a promising alternative for the electricity production with low CO_2 emission. In such power plants prevail extreme conditions, so likely used materials for plasma contact such as tungsten (W) must be well characterized for save operation. It is known, that even little amount of impurities, e.g. carbon (C) which can be present during manufacturing, can change the properties of W. Subject of this research is the change in mechanical properties of thin, ductile W wires under the influence of C. The embrittlement of W by C has so far only been investigated at temperatures well above 1100 °C. As materials behaviour also changes with temperature, there are two impacts combined. By irradiating the W wires with C ions, the implantation of C atoms into the W lattice is possible at temperatures below 1100 °C. This way the influence of the temperature from the influence of C itself can be seperated. A comparison to unirradiated samples that have been heat-treated for 8 h at 900 °C is done. For evaluation, the reduction in area at the fracture surface serves as a measure of ductility. In the range 0-2700 ppm C content, the wires retained their ductility and no systematic changes were observed.

P 16.4 Thu 13:45 Redoutensaal

Beat wave generation in the ion cyclotron frequency range by high power microwaves and how to measure them — •Niklas Simon Polei, Laurent Krier, Heinrich Peter Laqua, Dmitry Moseev, Sergiy Ponomarenko, Torsten Stange, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

The overlap of two waves will create a third wave beating with the frequency difference (Δf) of the two original waves. For the beat wave generation in the ion cyclotron frequency (ICF) range two gyrotrons of the electron cyclotron resonance heating system of Wendelstein 7-X (W7-X) are used. The gyrotrons are frequency stabilized by a phase locked loop, so that they are oscillating by 100kHz at most [1]. The Δf is set to the ICF in the overlap region, typically 35MHz to 37MHz.

The microwave beams can be either overlapped in the resonance region [2] or before the resonance region. Different processes are then transferring energy to the ions. In the latter case the overlap creates a strong electric field gradient, this results in an electron density wave created by the ponderomotive force. If the k-vector of the electron wave is chosen appropriately it can couple to the ion Bernstein waves.

So far only the ICRH antenna of W7-X was used in measurements. However, no waves or ion heating could be observed. Therefore, it is planned to use the collective Thomson scattering (CTS) system and the fast ion loss detector (FILD) to detect ion heating or fast ions.

[1] L. Krier, et al. doi: 10.1109/IRMMW-THz50926.2021.9566847
[2] H.P. Laqua, et al. 2018 Nucl. Fusion 58 104003

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Investigation of the Effects of Anomalous Heat Transport and Diffusion in the W7-X SOL — •Anja Hoffmeister[1], Nathan Barbe[2], Kelly Garcia[1], Nassim Maaziz[2], Felix Reimold[2], Victoria Winters[1], and W7-X Team[2] — [1]University of Greifswald, Institut for Physics, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany — [2]Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany

Anomalous heat and particle transport are expected to affect the performance of the Wendelstein 7-X (W7-X) island divertor scrape-off-layer (SOL). While the underlying physical principles are not yet well-understood, mean-field simulation codes like EMC3-Eirene require a suitable parameterization to mock-up their affects on the transport. Typically, this is done via specific input parameters to the simulation. However, previous simulation studies using EMC3-Eirene have indicated unexpected behavior of the plasma parameters with changes of the input anomalous heat and particle diffusion coefficients. The reason has thus far been poorly understood. This work presents a first systematic study of how the anomalous heat and particle diffusion input parameters independently affect the performance of the W7-X SOL in EMC3-Eirene simulations. The investigation focuses on heat-flux widths and density build up at the divertor target plate. First investigations have found that, at least in a convective regime, the anomalous heat diffusion coefficient influences divertor density build-up more strongly than the anomalous particle diffusion coefficient. Behavior at different plasma densities will be presented.

P 16.6 Thu 13:45 Redoutensaal

Gyrokinetic Turbulence in ECRH Reintroduction Scenarios in W7-X — •Emil Overduin, Josefine Henriette Elise Proll, Sebastian Bannmann, and Michael Jeffrey Gerard — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Recently, the neoclassically optimized stellarator Wendelstein 7-X (W7-X) has seen an increase in core ion temperature above the $\approx 2\,\mathrm{keV}$ clamping limit in the presence of peaked density profiles. Of special interest for this work are scenarios where the strong density gradient is created by Neutral Beam Injection (NBI), which is followed by an Electron Cyclotron Resonance Heating (ECRH) reintroduction.

The ECRH reintroduction leads to an increase of the ion temperature above the clamping limit in W7-X, while at the same time the core density peaking rate is reduced (ECRH pump-out). If the ECRH power is large enough a back-transition to a higher heat transport regime is observed. The ECRH power required for a back transition to occur is strongly dependent on the magnetic configuration of W7-X. This dependence is not well understood.

Using the local gyrokinetic code GENE the microinstabilities present in the plasma at parameters relevant for the pump-out and back-transition are investigated. The aim is to contribute to understanding the effect of turbulence on the density pump-out and back-transition. To this end, the simulations are performed at different radial locations in different configurations, and use experimentally consistent equilibria, corresponding to multiple time points during the discharges.

P 16.7 Thu 13:45 Redoutensaal

Integrated modelling of sawtooth cycles in tokamak plasmas — •Federico Stefanelli, Emiliano Fable, Clemente Angioni, Michael Bergmann, Davide Brioschi, Anja Gude, Philipp Lauber, Oleg Samoylov, Riccardo Stucchi, Markus Weiland, Haowei Zhang, and Hartmut Zohm — Max Planck Institute for Plasma Physics, Garching

Sawtooth cycles are periodic relaxations of the plasma core commonly observed in tokamak discharges. The cycle is characterized by a rapid MHD-driven collapse of the core temperature, density and current profiles, followed by a profile recovery driven by continued heating. Sawtooth cycles limit core pressure and thus lower the plasma performance. Even more critically, they can trigger secondary MHD instabilities, which in turn can lead to disruptions. On the other hand, the crash expels impurities from the core, aiding in the control of impurity and, in a reactor, helium ash accumulation. For these reasons, accurate modelling is essential for predictive transport simulations and reliable control of plasma behavior in future devices. An integrated model of these cycles is presented, which includes also the effects of additional MHD activity. The phases of a sawtooth cycle: (1) onset criterion, (2) collapse and (3) the recovery phase are modelled either via first-principles (1) and (3) or with an ad-hoc relaxation model (2). The collapse of the fast particle population and rotation profiles are also considered, as they actively and passively affect the sawtooth cycle and are in turn affected by it. The results are validated on ASDEX Upgrade discharges in presence of NBI and ECRH heating schemes.

P 16.8 Thu 13:45 Redoutensaal

Scaling observations of heat transport in the island divertor of W7-X — •Sebastian Thiede[1], Yu Gao[1], Marcin Jakubowski[1], Peter Manz[2], and the W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany

Efficient power exhaust is one of the most important aspects of magnetic confinement devices due to the risk of overloading plasma-facing components (PFCs). Scaling laws of important heat transport parameters are readily available for tokamaks, allowing educated extrapolation to reactor relevant regimes. In the case of stellarators extrapolations are more difficult to justify due to significantly less data being available. Wendelstein 7-X (W7-X) is one of the most advanced stellarators to date. In its recent operational phases the scanned device parameter range was expanded greatly, facilitating the derivation of empirical heat transport scaling laws. A key diagnostic for this derivation is the thermography system that monitors all 10 divertor units of W7-X. Together with the finite-difference code DELVER it is used to get estimates of the impinging heat flux patterns on PFCs. These can be seen as "fingerprints" of different transport processes, and are the main interest of this work. From the variation of the magnetic configuration, the magnetic field strenght and direction, heating power and plasma density we hope to extract trends and possibly quantitative assesment of the relative importance that different transport channels in the scrape-off-layer (SOL) have.

P 16.9 Thu 13:45 Redoutensaal

Fluid Turbulence Simulations in Geometries with Internal Magnetic Islands — •Miguel Madeira[1], Andreas Stegmeir[2], Christoph Pitzal[2], Barnabas Csillag[2], Felix Reimold[1], and Peter Manz[3] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [3]University of Greifswald, Institute of Physics, Greifswald, Germany

Understanding edge turbulence is crucial for improving plasma confinement. Magnetic islands are especially relevant for the island divertor concept and their potential involvement in the formation of internal transport barriers. The plasma fluid turbulence code GrilliX now supports 3D geometries, including circular toroidal equilibria with magnetic islands and MGRID equilibria. The latter enables simulating the neoclassically optimized stellarator W7-X, with validation currently underway.

W7-X can operate in various magnetic configurations. In several limiter configurations, where the 5/5 islands lie inside the last closed flux surface, the plasma energy increases, peaking in the so-called FMM configuration. This study aims to validate Grillix's new capabilities and to investigate turbulence around W7-X's 5/5 magnetic island chain in limiter configurations. A critical island width for ExB flow around the islands is shown in a circular toroidal geometry consistent with previous studies. In the first W7-X simulations, the perpendicular plasma flow shape previously measured for the FMM configuration is reproduced, showing the characteristic "W" shape.

P 16.10 Thu 13:45 Redoutensaal

RF resolved measurements of the plasma and beam properties in ion sources for the ITER NBI — •Jasper Knaack, Christian Wimmer, Araceli Navarro, and Ursel Fantz — Max Planck Institute for Plasma Physics, Boltzmannstraße 2, Garching bei München, Germany

The neutral beam injectors (NBI) for ITER will require powerful negative ion sources. In such a device, a plasma is ignited in a set of cylindrical drivers. The negative ions are then generated by surface production. Part of the ITER NBI design is the use of RF plasma drivers. The frequency of the RF power that is injected into the driver is 1 MHz. The plasma parameters, such as the plasma potential, of an RF plasma can strongly vary during an RF cycle. Predictions drawn from numerical simulations have also shown large electron flux oscillations in the RF timescale. It is not known how these variations in the plasma parameters influence the extraction of negatively charged particles and thus the beam properties on the RF timescale. In order to study the oscillations in the plasma parameters, diagnostics will be implemented at the Batman UpGrade (BUG) testbed to measure the plasma parameters in an RF-resolved manner. First tests with an avalanche photo-diode have proved to be successful. Moreover, high-speed beam diagnostics will be implemented to study the effect of these plasma parameter variations on the resulting beam. This contribution discusses the planned diagnostics to be implemented in BUG.

P 16.11 Thu 13:45 Redoutensaal

Expanding the physics modeling capabilities of ASTRA from core to SOL and from tokamak to stellarator towards application in a multi-device flight simulator — •Fabian Solfronk[1,2], Emiliano Fable[1], Pierre David[1], Matthias Bernert[1], Elisa Buglione-Ceresa[1], Giovanni Tardini[1], Marco Zanini[3], Sehyun Kwak[3], Ulrich Stroth[1], Ou Pan[1], Hartmut Zohm[1,2], the ASDEX Upgrade Team[4], and the W7-X Team[5] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, 80539 München, Germany — [3]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [4]see the author list of H. Zohm et al. 2024 NF 64 112001 — [5]see the author list of O. Grulke et al 2024 NF 64 112002

This work aims at augmenting the ASTRA transport code capabilities of simulating magnetic confinement fusion devices. In parallel, two avenues are pursued:

First, a generic equation for the current diffusion compatible with stellarator geometry is implemented, and the code is coupled to the equilibrium solver VMEC. The equation is benchmarked against theoretical expectations and validated using experimental data from Wendelstein 7-X.

Second, a reduced XPR model, predicting XPR radiation, position, and stability, is developed and implemented in ASTRA. The model is validated against ASDEX Upgrade discharges in the Fenix flight simulator.

P 16.12 Thu 13:45 Redoutensaal

Characterization of plasma turbulence during ELM suppression with Resonant Magnetic Perturbations in ASDEX Upgrade — •Bojana Stefanoska[1], Wolfgang Suttrop[1], Matthias Willensdorfer[1], Rachael M. McDermott[1], Florian Rath[2], Arthur Peeters[2], and the ASDEX Upgrade Team[3] — [1]Max

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ELMs pose a major challenge for future fusion reactors due to their potentially unsustainable heat loads on plasma-facing components. Resonant magnetic perturbations (RMPs) can mitigate or suppress ELMs, but the underlying physics of RMP-induced suppression remains unclear. Previous ASDEX Upgrade experiments have shown that the application of RMPs coincides with the onset of a characteristic turbulence regime at the plasma edge, leading to enhanced radial particle transport and a significant reduction of the pedestal density. However, the driving instability, the nonlinear saturation mechanism, and the structure of this turbulence remain open questions. The recently upgraded ECEI diagnostic at ASDEX Upgrade provides high-resolution, 2D measurements of electron temperature fluctuations and is expected to play a central role in the upcoming campaign. In preparation, we perform a systematic multi-diagnostic analysis of turbulence data in previous AUG RMP discharges to identify the dependencies of RMP-driven turbulence on plasma parameters and to guide future experimental strategies. The poster will present an overview of these findings.

P 16.13 Thu 13:45 Redoutensaal

Island divertor studies in 3D using GRILLIX — •Barnabas Csillag[1], Andreas Stegmeir[1], Christoph Pitzal[1], Konrad Eder[1], Miguel Madeira[2], Marion Finkbeiner[1], and Frank Jenko[1] — [1]MPI for Plasma Physics, Garching, Germany — [2]MPI for Plasma Physics, Greifswald, Germany

Understanding and predicting heat exhaust properties is one of the main challenges on the path towards a stellarator power plant. The island divertor is a key feature in the Scrape-Off Layer of most current stellarator reactor designs, and it is also experimentally investigated in the Wendelstein 7-X (W7-X) stellarator. Numerical modeling of island divertors usually relies on transport codes. However, discrepancies between these predictions and experimental data highlight the need for more sophisticated approaches.

In this work, we employ the transcollisional fluid turbulence code GRILLIX to simulate a simplified island divertor geometry. The configuration involves a helically perturbed circular toroidal magnetic field, generating a magnetic island chain at a rational surface. These islands are intersected by discrete target plates aligned with the island chain, mimicking the divertor topology of W7-X. Such model enables the investigation of general island divertor phenomena, including the structure of the electrostatic potential, and the influence of sheared poloidal flows. By analyzing these features, we advance our understanding of island divertor physics in tractable geometries - an essential step before tackling more complex geometries, like W7-X.

P 16.14 Thu 13:45 Redoutensaal

Predicting MANTIS performance in W7-X: Synthetic Modeling of the Expected Operational Regime Using EMC3-EIRENE — •Joey Louwe[1], Felix Reimold[1], Valeria Perseo[1], Victoria Winters[1], Nassim Maaziz[1], Alexander Knieps[2], Henry Greve[1], Mohammad Foisal Siddiki[1], and W7-X team[1] — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management*Plasma Physics, 52425 Jülich, Germany

Modern large-scale magnetic confinement fusion devices use divertors to optimize particle and heat exhaust. At the Wendelstein 7-X stellarator (W7-X), this is achieved with an Island Divertor concept, where magnetic islands guide particles and heat along field lines to dedicated target plates. Due to its 3D geometry, diagnosing transport across the island is challenging with existing diagnostics. To address this, the new MANTIS imaging system will be combined with helium gas puffs in upcoming campaigns to provide localized measurements of island plasma parameters and infer transport dynamics. Simulation studies using the EMC3-EIRENE plasma fluid transport code were conducted and a new synthetic forward modeling tool to assess MANTIS performance and operational viability was developed. These predictions, informed by existing W7-X data (helium puff spread, electron temperature, and density profiles), enable optimized MANTIS system design and deployment. This contribution presents simulation results, MANTIS performance predictions, and its current integration status.

P 16.15 Thu 13:45 Redoutensaal

Simulations and experiments of early-heating reversed-shear discharges — •Lea Hollendonner[1], Alexander Bock[1], Thomas Pütterich[1], Jörg Stober[1], Jörg Hobirk[1], and the ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]See author list of H. Zohm et al 2024 Nucl. Fusion 64 112001

Negative magnetic shear can lead to the suppression of microinstabilities and the formation of internal transport barriers (ITBs). These scenarios hold the potential of improved core confinement and high bootstrap-current fraction but may also lead to impurity accumulation in the core. In order to make predictions based on these scenarios, codes like TGLF must be able to capture the effects of negative shear on transport and quantitatively match experimental profiles in this regime. A prerequisite for these investigations is to achieve stable, distinct regions of negative shear in experiments, and to measure the q-profile with sufficient accuracy. The focus of this poster lies on the early-heating approach which slows down current diffusion of inductive current from the edge to the core region during the ramp-up phase of the discharge. Experiments of early-heating are presented that employ central counter-current ECCD during ramp-up. Based on these discharges, the timing and deposition of ECCD as well as the plasma current ramp is varied in simulations in order to investigate the effects of these actuators on the q-profile evolution.

P 16.16 Thu 13:45 Redoutensaal

Spontaneous density peaking in overdense W7-X plasmas — •Martina Licchelli, Josefine Proll, Golo Fuchert, Håkan Smith, Andreas Langenberg, and Torsten Stange — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Achieving reactor-relevant confinement in stellarators requires reducing both neoclassical and turbulent transport, which limit core temperature and density. In Wendelstein 7-X (W7-X), plasmas with peaked density profiles show reduced energy transport, likely linked to suppressed ion-temperature-gradient turbulence. Such profiles have mostly appeared in pellet- or NBI-fueled discharges, and how these scenarios scale to reactor conditions remains unclear.

A promising alternative is the spontaneous density peaking in overdense, O2-heated plasmas fueled solely by gas puffing. These plasmas exhibit a stable inward particle pinch under pure electron heating, attractive features for reactor operation. However, it is still uncertain whether the resulting density gradients are strong enough to suppress turbulence or whether the pinch mechanism itself changes, leaving important aspects of the scenario's physics unresolved.

This work presents experimental evidence of spontaneous density peaking in overdense W7-X plasmas, with measurements of density profiles, radial electric fields and transport coefficients showing changes in particle transport. Linear and nonlinear simulations identify microinstabilities in different regimes and preliminary analyses of the inward pinch are included. These results offer insight into density peaking and its potential relevance for future stellarator reactors.

P 16.17 Thu 13:45 Redoutensaal

Asymmetric scrape-off layer plasma parameter changes and their implications for diagnostic comparability in W7-X — •F Scharmer[1], A von Stechow[1], C Killer[1], SG Baek[2], S Ballinger[2], Y Gao[1], O Grulke[1,3], S Hörmann[1], M Jakubowski[1], E Maragkoudakis[1], S Thiede[1], A Tsikouras[1], M Vecsei[1], and the W7-X Team[1] — [1]MPI for Plasma Physics, Greifswald (Garching), Germany — [2]MIT PSFC, Cambridge, USA — [3]Department of Physics, TU Denmark, Lyngby, Denmark

The Wendelstein 7-X stellarator experiment uses the island divertor concept for power and particle exhaust. To characterize the scrape-off layer (SOL), different diagnostics view different magnetic islands. The five-fold toroidal symmetry is typically used to combine measurements of separate quantities from different islands. The gas puff imaging (GPI) diagnostic observes complex drift flow patterns in the islands. These flow patterns and SOL profiles are strongly dependent on the magnetic geometry of the island and discharge parameters, such as power and density. GPI measurements show sudden shifts in light emission and fluctuation parameters, indicating changes in plasma conditions. These transitions are not reflected in global core plasma parameters. In addition, divertor heat flux measurements and further SOL diagnostics viewing different islands show that these sudden transitions are often isolated to just one of the five islands. In this contribution, we investigate the prevalence and asymmetry of these SOL plasma parameter changes, as well as their implications for the comparability of physical quantities in different islands.

P 16.18 Thu 13:45 Redoutensaal

Profile Analysis of the Midplane Helium Beam for Scrape-off

Layer Characterization at Wendelstein 7-X — •Foisal B.T. Siddiki[1,2], Oliver Schmitz[1], Maciej Krychowiak[2], Frederik Henke[2], Dorothea Gradic[2], and Miklos Vecsei[2] — [1]University of Wisconsin-Madison, Madison, USA — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany

Optimizing the heat and particle exhaust system of Wendelstein 7-X (W7-X) requires a quantitative understanding of scrape-off layer (SOL) transport, informed by measurements of the electron temperature (Te) and density (ne). To investigate SOL transport, a new helium-beam system was installed at the midplane of W7-X and operated during the OP2.2 and OP2.3 experimental campaigns. The midplane helium-beam diagnostics consist of a controlled gas injection system and a high-resolution spectrometer, from which Te and ne are inferred using helium line ratios based on a collisional radiative model of atomic helium. In this work, we present the first results from the midplane helium beam and benchmark them against co-located alkali-beam measurements. Initial analysis of the midplane profiles reveals two distinct SOL transport regimes. SOL characteristic decay lengths and heat-flux width scaling derived from these profiles will also be presented.

P 16.19 Thu 13:45 Redoutensaal

Development of multi-diagnostic Bayesian analysis system for inference of plasma parameters in the W7-X edge — •Linnéa Björk[1], Felix Reimold[1], Chris Bowman[2], Takashi Nishizawa[3], and Gabriele Partesotti[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Culham Centre for Fusion Energy, Culham Science Centre, United Kingdom — [3]Kyushu university, Kasuga, Japan

The W7-X machine is an experimental fusion device designed to study the reactor relevance of the stellarator concept. Its complex three-dimensional geometry makes it difficult to measure the full field of plasma parameters, particularly in the scrape-off layer (SOL), where plasma behaviour can be highly localized. For future reactor design it is important to understand the physics and transport mechanisms in this region. Consequently, a system for integrated Bayesian analysis is implemented for W7-X which will enable the reconstruction of key plasma parameters from a limited diagnostic coverage.

The first steps in the building of the analysis tool and its adaptation to W7-X geometry are here presented. For benchmarking of the system, inversions of bolometry data have been performed and compared to results from Gaussian Process tomography. The two methods agree well, with the full Bayesian inference scheme handling large errors better but being more computationally costly. Further results include introducing divertor spectroscopy both as constraints to the tomographic inversions and as part of the later effort to infer electron density and temperature.

P 16.20 Thu 13:45 Redoutensaal

Helium exhaust studies in ASDEX Upgrade — •Simon Krumm[1], Athina Kappatou[1], Antonello Zito[1], Volker Rohde[1], Gerd Schall[1], Marco Wischmeier[1], Rachael M. Mcdermott[1], and the ASDEX Upgrade Team[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]see the author list of H. Zohm et al. 2024 NF 64 112001

Helium is one of the product of the fusion reaction used in future fusion power plants. Thermalised helium dilutes the fuel and has to be efficiently removed to sustain the fusion process. Recent work at ASDEX Upgrade (AUG) investigated the helium removal in Type-I ELMy H-modes both experimentally and numerically [A. Zito et al. 2023 Nucl.Fusion 63 096027 & 2025 Nucl.Fusion 65 046022]. Helium removal is hindered by its high wall retention in tungsten, as well as the inefficiency of active pumping in AUG. Most importantly, because of helium's high ionisation energy, its divertor retention is low compared to other impurities, leading to inefficient transport from the divertor to the pumping surfaces. The next step is to investigate reactor relevant scenarios - especially those compatible with power exhaust - to also assess their compatibility with helium exhaust. For this, neutral partial pressure measurements in the divertor are needed. We employ optical in-situ and ex-situ Penning gauges, as well as Threshold Ionization Mass Spectrometry in the pumping ducts. Additionally, utilising these diagnostics, the new activated charcoal cryopump [G. Schall et al. 2021 Fusion Eng. Des. 166 112316] recently installed on AUG can be characterised for its helium pumping capability.

P 16.21 Thu 13:45 Redoutensaal

Characterisation of phase velocities and dispersion relations in Wendelstein 7-X turbulence, assisted by sensitivity analysis of poloidal correlation reflectometry — Sander De Koker[1,2], Gavin Weir[2], Carsten Lechte[3], Andreas Krämer-Flecken[4], •Thomas Windisch[2], Olaf Grulke[2], and Peter Manz[1,2] — [1]University of Greifswald, Institute of Physics, Greifswald, Germany — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany — [3]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, University of Stuttgart, Stuttgart, Germany — [4]Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, Forschungszentrum Jülich GmbH, Jülich, Germany

Different instabilities in plasmas differ in terms of their phase velocity, which is therefore used to identify them. One diagnostic well suited for this is poloidal correlation reflectometry. The sensitivity of its measurement capabalities and its dependence on various parameters is however not fully understood. In order to improve the understanding of turbulence dispersion relations and phase velocities, an initial goal is to investigate and characterise this sensitivity. As a first step, full wave simulations have been performed, showing a dependence of the sensitivity on both turbulence poloidal wavenumber as well as antenna separation.

P 16.22 Thu 13:45 Redoutensaal

Towards photonic radiometry: Electron Temperature and Density profiles from broadband ECE spectra — •Taurino Reichert[1], Dmitry Moseev[1], Sergiy Ponomarenko[1], Vessen Vasilev[2], Ruwan Udayanga[2], Peter Andrekson[2], Annina Moser[3], and Benedikt Baeuerle[3] — [1]Max Planck Institut für Plasmaphysik, Greifswald, Germany — [2]Chalmers University of Technology, Göteborg, Sweden — [3]Polariton Technologies AG, Adliswil, Switzerland

The trend towards higher magnetic fields in future fusion experiments adds complexity to the design of heterodyne Electron Cyclotron Emission (ECE) radiometers used for measurement of electron temperature (T_e) profiles. The evaluation of a single ECE harmonic might require the acquisition of a broadband signal, effectively calling for multi stage systems or multiple separate radiometers. This work outlines the development of a proof-of-concept single stage broadband radiometer at W7-X. Here, ECE spectra between 140 GHz to 220 GHz will be acquired through up-conversion to the Short Wavelength Infrared (SWIR) range around 1550 nm using a plasmonic Mach-Zehnder-Modulator (MZM). The optical signals will be evaluated with a SWIR spectrometer. T_e profiles are directly obtained from the optically thick second harmonic X-mode (X2) while n_e profiles are reconstructed from the optically thin third harmonic X-mode (X3) using the ray-tracing code TRAVIS. The diagnostic is expected to yield ECE spectra with a frequency resolution of 1 GHz. The time resolution is yet to be found, aiming at a range between 1 ms to 10 ms.

P 16.23 Thu 13:45 Redoutensaal

Development of a surface retention model for plasma-wall interactions simulations in the SOLPS-ITER code package — •remo iannini[1,2], antonello zito[1], tim happel[1], david coster[1], klaus schmid[1], gregor birkenmeier[1,2], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching bei Munchen, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany

In a fusion reactor, particles escaping the last closed flux surface (LCFS) inevitably interact with the first-wall materials. These surfaces can behave as both sinks and sources for plasma particles, as these can be either absorbed or recycled. Accurately modelling these processes is therefore essential to predict the impact of plasma-wall interactions on plasma transport and exhaust. At present, the SOLPS-ITER code package represents the standard framework for plasma edge modelling. Processes contributing to a long-term retention of plasma particles within the wall surfaces are, however, not currently included within the code capabilities. This PhD project aims to develop a fully integrated, self-consistent wall retention module for the SOLPS-ITER framework, enabling more realistic simulations of plasma-wall interactions by allowing the presence of a temporary wall inventory of plasma particles. This would enable the assessment of impurity dynamics during plasma discharges, the long-term evolution of fuel retention in wall materials, and the prediction of the boronization layer lifetime for ITER.

P 16.24 Thu 13:45 Redoutensaal

GPU Acceleration of Hybrid Fluid-Kinetic Simulations of Runaway Electrons in JOREK — •edoardo carrà, patrik rác, hannes bergström, and matthias hölzl — Max Planck Institute for Plasma Physics

JOREK is a 3D nonlinear, extended magneto-hydrodynamic and hybrid fluid-kinetic code for investigating large scale transient plasma dynamics in realistic tokamak and stellarator fusion plasmas. In high-current tokamaks such as ITER, loss of plasma confinement in a disruption can generate highly energetic "runaway" electrons (REs), which can pose a serious threat to plasma-facing components. Understanding and predicting RE dynamics is therefore essential for safe operation of future fusion reactors. While JOREK supports MPI + OpenMP parallelization on CPUs, hybrid RE simulations span widely different timescales, making them computationally prohibitively expensive on conventional CPU architectures. This work addresses that challenge by porting the fluid and kinetic components of hybrid RE simulations to GPUs. Using OpenMP directives, we ensure portability and transparency across hardware platforms while achieving significant performance improvements. We detail the optimization strategies employed and present a comprehensive performance and verification study on NVIDIA and AMD accelerated architectures by benchmarking the linear growth rate of plasma instabilities in the presence of REs and performing a highly non-linear RE beam termination event as first large-scale physics application.

P 16.25 Thu 13:45 Redoutensaal

Characterising the Influence of E_r Magnitude and Shear on Turbulent Fluctuations in Wendelstein 7-X — •Jan Ricken, J. Proll, H. Smith, A. Langenberg, J. Bähner, G. Fuchert, E. Maragkoudakis, and G. Weir — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

In neoclassically optimised stellarators such as Wendelstein 7-X (W7-X), turbulence is the main driver of heat and particle losses, making its regulation crucial to understand. Although the radial electric field, E_r, and its shear are known to suppress turbulent transport in tokamaks, their quantitative impact in W7-X remains to be studied.

In this work, we present first results from a comprehensive database that link experimentally measured E_r profiles to (turbulent) fluctuations and transport indicators across a diverse set of W7-X programs. The database enables a systematic comparison of turbulence characteristics with both the magnitude and shear of E_r.

Experimentally observed trends are compared with neoclassical predictions from the code Neotransp to assess the consistency between measured and expected E_r profiles. In addition to providing neoclassical E_r estimates, Neotransp is also used to infer the level of turbulent transport required to satisfy power balance, thereby offering an estimate of turbulence-driven fluxes for a given E_r profile. Complementarily, GENE flux tube simulations are employed to isolate and quantify the sensitivity of turbulent fluctuations to experimentally relevant variations in the E_r shear.

P 16.26 Thu 13:45 Redoutensaal

Implementation of the non-linear Fokker-Planck collision operator for gyrokinetic codes using a moment approach — •Andrew Ivan Sulimro[1], Philipp Ulbl[1], Baptiste Frei[1], and Frank Jenko[1,2] — [1]Max-Planck Institute for Plasma Physics — [2]University of Texas at Austin

The performance of future magnetic confinement fusion power plants is primarily influenced by plasma confinement which is driven by turbulence. High-fidelity gyrokinetic simulations are key tools to investigate turbulence in fusion devices.

Accurate modeling of collisional physics is essential for these simulations. As the collision frequency is proportional to the square of the ion charge, a realistic collision operator is especially crucial for studying high-Z impurities. On the other hand, the full Fokker-Planck collision operator is computationally expensive due to its integro-differential form.

In this work, the non-linear Fokker-Planck collision operator is solved using a moment approach. This approach provides a systematic manner to capture collisions up to a desirable accuracy while maintaining performance. The implementation is verified through relaxation and conservation studies. We will also demonstrate the physical impact of collisions in zonal flow damping.

P 16.27 Thu 13:45 Redoutensaal

Neural ODEs for Density and radiated Power Modeling — •Vadim Munteanu, Daniel Böckenhoff, and Maciej Krychowiak — Wendelsteinstraße 1, 17491 Greifswald, Germany

Real-time capable simulations of plasma in experimental fusion devices, known as flight simulators, are of interest for fusion research as they permit more informed session planning and the development and validation of control schemes before experimentation. Although for tokamaks mature simulators exist at relevenat fidelity, because of stellarator*s more complex geometry, similar models are much more costly, rendering them unfeasible for flight simulation. Recently, with the advent of computing power, data abundance and democratization of machine-learning tool-boxes, data-driven methods became feasible in solving the above mentioned shortcomings of traditional modelling techniques. We are investigating if neural controlled differential equations, a deep learning architecture designed for modelling of irregular time series, can efficiently represent plasma dynamics and serve as a potential simulator for control tasks. We train the model on a small dataset from the last experimental campaign of W7-X to model the evolution of several plasma diagnostics under control parameters such as gas fueling, imputiry seeding and electron cyclotron heating. We show that the model is able to capture correlations between actuators and plasma diagnostics. Next we plan to increase the dataset and to extend plasma state with additional diagnostics, and perform a hyperparameter search.

P 16.28 Thu 13:45 Redoutensaal

Equilibrium and stability of an electron plasma in a levitated dipole trap — •Patrick Steinbrunner[1], Adam Deller[1,2], Thomas O'Neil[2], Veronika Bayer[1,3], Matthew Stoneking[4], and Eve Stenson[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]University of California San Diego, La Jolla, California, 92093 USA — [3]Technical University of Munich, 80333 Munich, Germany — [4]Lawrence University, Appleton, Wisconsin, 54911 USA

As part of the APEX collaboration (An Electron Positron eXperiment) this work supports the experimental results obtained with pure electron plasmas in a levitated dipole trap using two distinct computational methods. The levitated dipole trap confines electrons on closed, purely poloidal magnetic field lines around a superconducting coil that is floating in a vacuum chamber due to external magnetic fields. In combination with positrons coming from NEPOMUC (NEutron induced POsitron source MUnich) this trap will ultimately confine a first of its kind, non-relativistic pair plasma. First measurements of the local space charge potentials are used to reconstruct the electron density distribution assuming a local thermal equilibrium along magnetic field lines and solving the Poisson-Boltzmann equation. In addition, results of a 2D drift kinetic model are presented that extend a linear stability analysis conducted previously. This model resembles the large-aspect-ratio limit of the levitated dipole trap, an infinite, current-carrying wire. The implementation of the actual magnetic dipole field is subject to a future study.

P 16.29 Thu 13:45 Redoutensaal

Applications of Plasma-KG, a knowledge graph for low-temperature plasma physics — •Markus M. Becker[1], Ihda Chaerony Siffa[1], Hidir Aras[2], Holger Israel[3], Thomas Koprucki[4], Burkhard Schmidt[4], and Markus Stocker[3] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]FIZ Karlsruhe – Leibniz Institute for Information Infrastructure, Eggenstein-Leopoldshafen, Germany — [3]TIB – Leibniz Information Centre for Science and Technology, Hanover, Germany — [4]Weierstrass Institute (WIAS), Berlin, Germany

Knowledge graphs (KGs) play an important role in the structured representation and linking of data, information, and knowledge. As a result, knowledge graphs are finding broad application in the field of research data management. Building on the established plasma metadata schema Plasma-MDS and the plasma ontology Plasma-O, the development of Plasma-KG (https://vivo.plasma-mds.org) was initiated to represent reusable entities with persistent identifiers in the field of low-temperature plasma physics. This contribution introduces the essential concepts of Plasma-KG and shows how various data sources can be connected via these formally described entities. The addressed fields of application include content enrichment from knowledge graphs for patents, scientific articles, and mathematical models. It is demonstrated how the future physics information service 'FID Physik' can benefit from Plasma-KG as a semantic data platform.

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P 16.30 Thu 13:45 Redoutensaal

ERO2.0 code validation using boron erosion experiments at PSI-2 — •Andriy Tarasenko[1,2], Christoph Baumann[1], Juri Romazanov[1], Sebastijan Brezinsek[1,2], Marc Sackers[1], and Arkadi Kreter[1] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany — [2]Faculty of Mathematics and Natural Sciences, Heinrich Heine University Düsseldorf

Reliable predictions of plasma-wall interactions are essential for the design and operation of future fusion devices. In this work, the impurity transport code ERO2.0 is benchmarked against boron (B) erosion experiments performed at the linear plasma device PSI-2. Thin B layers on tungsten substrates were exposed to deuterium (D) plasmas with ion energies near the physical sputtering threshold, and erosion was quantified through post-mortem FIB-cuts analysis and optical emission spectroscopy. Experimentally inferred sputtering yields exceed classical BCA predictions, confirming earlier observations, such as those by Hechtl et al. of enhanced near-threshold B erosion. The exceeding yield can be caused by chemical erosion, which was investigated and compared with measured BD band emission. Using experimental plasma profiles, SDTrimSP sputter data, and synthetic emission line modelling, ERO2.0 reproduces key features of the measured impurity distribution and B emission profiles. The comparison highlights parameter sensitivities and demonstrates the capability of ERO2.0 to interpret PSI-2 measurements and support predictive modelling for ITER.

P 16.31 Thu 13:45 Redoutensaal

Secondary electron emission from coated plasma walls — •Franz Xaver Bronold and Felix Willert — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

Having in mind dielectrically coated metal electrodes, used in barrier discharges, we investigate–from a theoretical solid-state physics point of view–the emission of secondary electrons from solid structures consisting of a thin dielectric layer on top of a metallic or semiconducting halfspace. We thus extend the invariant embedding principle for the electron backscattering function, which we used so far for halfspaces [1], to a stack of two materials. In addition to two backscattering functions, one for the coating and one for the supporting material, the electron transmission function for the coating has to be computed now as well. Focusing on low energies, and describing the solid structure by a randium-jellium model, containing electron-phonon, electron-ion-core, and electron-electron scattering (leading to impact ionization inside the two materials), we obtain, as a function of layer thickness, the electron surface scattering kernel for the total structure as well as the energy- and angle-resolved secondary electron emission yield. Besides showing results for SiO_2/Si and SiO_2/Au, we also discuss the numerics used for integrating the set of matrix Riccati/Sylvester differential equations for the backscattering and transmission functions of the coatings, which now appear along with the algebraic equation for the support's backscattering function.[1] F. X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024). Supported by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)–495729137.

P 16.32 Thu 13:45 Redoutensaal

Microphysical boundary condition for the electron Boltzmann equation of a plasma — Felix Willert[1], •Clemens Hoyer[1], Gordon K. Grubert[2], and Franz X. Bronold[1] — [1]Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany — [2]Universitätsrechenzentrum, Universität Greifswald, 17489 Greifswald, Germany

We set up an energy- and angle-dependent boundary condition for the electron Boltzmann equation containing the electron microphysics inside the wall [1]. At low energies the boundary condition is based entirely on a computed electron surface scattering kernel [2], while at higher energies measured emission yields are, in addition, fed into the microscopic model to obtain plausible data also in this energy range. We incorporate the kernel within the expansion approach of solving the electron Boltzmann equation, expanding the electron distribution function in Legendre polynomials and linking the expansion coefficients to the moments of the electron flux at the plasma-wall interface, but it can be also implemented in a PIC-MCC simulation of the plasma's electron kinetics. Numerical results for argon, helium, and oxygen plasmas in contact with Si and SiO_2 surfaces are presented, showing in particular the significance of the inelasticity of the microphysics-based boundary condition compared to an energy- and angle independent phenomenological one. [1] F. Willert et al., arXiv:2511.20346 (2025). [2] F.X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024). F.X.B. and F.W. acknowledge support by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)–495729137.

P 16.33 Thu 13:45 Redoutensaal

Progress in modelling of shattered pellet injection experiments in fusion plasma — •Ansh Patel[1], Gergely Papp[1], Akinobu Matsuyama[2], Mengdi Kong[3], Stefan Jachmich[4], Umar Sheikh[3], Javier Artola[4], Paul Heinrich[1], and Eric Nardon[5] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Kyoto University, Uji, Kyoto, Japan — [3]EPFL, Swiss Plasma Center (SPC), Lausanne, Switzerland — [4]ITER Organization, France — [5]CEA, IRFM, France

Large tokamaks like ITER will require a disruption mitigation system (DMS) like the shattered pellet injection (SPI) to ensure machine protection during disruptions. The SPI system injects cryogenic pellets that are shattered before entering the plasma. For the DMS design validation, the effectiveness of SPI must be assessed by numerical simulations. For this purpose, reduced modelling is applied to scan the wide system parameter space available for optimisation and to understand experimental trends. In this poster, we present recent progress in the modelling of the SPI experiments at ASDEX Upgrade (AUG) and JET tokamaks using the INDEX code. We investigate the pre-thermal-quench (pre-TQ) duration trends for varying neon fraction injections in AUG, an important optimization parameter for multiple injections. We have also implemented a recently developed rocket-force model in INDEX and present some initial model estimates for AUG. Additionally, we also present simulation results of recent plasmoid-drift supression experiments at JET with neon doping.

P 16.34 Thu 13:45 Redoutensaal

EMC3-EIRENE predictions of radiative detachment scenarios in W7-X equipped with a tungsten based divertor — •Daniil Ryndyk[1], Derek Harting[1], Shuai Xu[1], Yuhe Feng[4], Florian Effenberg[3], Heinke Frerichs[2], Sebastijan Brezinsek[1], and W7-X team[4] — [1]FZJ GmbH, IFN-1, Jülich, Germany — [2]University of Wisconsin-Madison, Madison, WI, USA — [3]PPPL, Princeton, NJ, USA — [4]MPG IPP, Greifswald, Germany

The nuclear fusion experiment Wendelstein 7-X (W7-X) currently operates with carbon-fiber composite (CFC) plasma-facing components (PFC) forming the island divertor used for particle and power exhaust. In a future fusion reactor, carbon-based PFCs are not tolerable due to unacceptably high fuel retention. An alternative PFC material for a fusion reactor is tungsten (W), which shows in general low sputtering, low fuel retention, and good thermomechanical properties.

As a first systematic approach to study the impact of potential W PFCs in W7-X, we use EMC3-EIRENE as plasma boundary simulation code for 3D magnetic configurations. We investigate detachment scenarios with the standard magnetic configuration of W7-X equipped with a W divertor based on the current divertor geometry and analyze the dependence of detachment relevant parameters (e.g. target heat loads) on operation conditions (e.g. plasma density). In a comparison with the detachment behavior of the current C divertor, we discuss the accessibility of similar, impurity radiation determined detachment and the relevance of volume recombination processes.

P 16.35 Thu 13:45 Redoutensaal

Computational modeling of hot-cathode ionization gauges for fusion applications — •Alexander Glock[1,2], Michael Griener[1], Christian Drobny[1], Gregor Birkenmeier[1,2], Hans Meister[1], and Georg Schlisio[1] — [1]Max Planck Institute for plasma physics (IPP), Garching/Greifswald, Germany — [2]Technical University of Munich (TUM), Munich, Germany

In magnetic confinement fusion, the measurement of neutral gas densities is an essential metric for plasma control. Hot-cathode ionization gauges are commonly used for this purpose. The so-called ASDEX gauge is a diagnostic instrument designed to provide local and temporally resolved measurements of neutral gas pressure in the presence of strong magnetic fields. It is a hot-cathode ionization gauge with a linear geometry. Its operation relies on the measurement of an ion current produced when electrons emitted from the hot cathode collide with neutral gas particles. This gauge type has been successfully adapted for use in ASDEX Upgrade and Wendelstein 7-X, with further modifications developed for ITER. However, the linear geometry can also introduce signal instabilities due to complex particle interactions within the gauge head. The present project aims to deepen the understanding of the physical processes inside the gauge and to investigate these effects using a detailed computational model validated against experimental data. The gauge system is modeled with a kinetic Boltzmann approach solved through the particle-in-cell (PIC) method with Monte Carlo collisions (MCC), capable of performance prediction and design optimizations toward a robust and universal fusion diagnostic.

P 16.36 Thu 13:45 Redoutensaal

Towards neoclassical tungsten transport calculations in the edge and island divertor region of optimized stellarators — •Diogo Mendonça[1,2], Matthias Hoelzl[1], Orin Varley[1,2], Mate Szucs[1,2], and Luca Venerando Greco[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]TUM School of Natural Sciences, Boltzmannstraße 10, 85748 Garching, Germany

The successful operation of future nuclear fusion power plants requires strict control over tungsten (W) impurity transport during plasma discharges. If these high-Z impurities accumulate within the plasma, they may severely degrade fusion performance, or make it impossible altogether. This critical issue is not yet fully understood in tokamaks, and even less so in stellarators, which have recently seen renewed interest as promising magnetic confinement concepts. This contribution presents the first studies of collisional W transport using the kinetic model developed in the JOREK code, combined with its recently implemented reduced magnetohydrodynamics (MHD) stellarator model, focusing specifically in the trace impurity limit. By varying the initial positions of W particles within a fixed W7-AS stellarator equilibrium, we aim to quantify the influence of collisions, the electric field, and temperature around magnetic islands on the transport of W in the edge and island divertor region.

P 16.37 Thu 13:45 Redoutensaal

Reduced Modelling of MHD instabilities and Internal Transport Barriers — •Erik Eidsvig[1,2], Philipp Lauber[1,2], and the ASDEX Upgrade Team[2] — [1]Technical University of Munich — [2]Max Planck Institute for Plasma Physics

Experimentally, fishbones have been observed before the Internal Transport Barrier (ITB) formation in ASDEX Upgrade. In this work, the goal was to investigate the relationship between the fishbone instability and the internal transport barriers. As a first step, reduced models describing the fishbone dynamics and its relationship to turbulence were implemented numerically. The fishbone instability is connected to the turbulence through the current it generates, which drives a poloidal shear flow which can break up turbulent eddies. It was found that the deposition rate of trapped energetic particles, D was the most important factor for setting up the Internal Transport Barrier (ITB), agreeing with the findings from Liu and Fu (2023). The reduced models were tested on ASDEX Upgrade discharge #37114, and the simplified flow shear approximation alone is not sufficient to explain the temperature peaking in the shot. This may indicate that the magnetic shear plays a role in the ITB state observed in the shot.

P 16.38 Thu 13:45 Redoutensaal

A dual machine learning framework for electron density profile reconstruction — •Christos Vagkidis, Mirko Ramisch, Günter Tovar, and Alf Köhn-Seemann — IGVP, University of Stuttgart, Germany

Machine learning algorithms can be used either as surrogate models to replace high-fidelity codes or as tools to provide some physical information. In this work, a random decision forest is applied to replace a 3D full-wave model and a deep neural network (DNN) to reconstruct the electron plasma density profile.

The COMSOL Multiphysics software is used for the 3D modeling. A microwave is propagating through an axially symmetric plasma. The spatial power distribution of the wave is measured after the interaction with the plasma. The random forest is trained on these data and is able to predict the wave power for a given electron density profile.

A new dataset is created with the random forest and is used to train the DNN, which is used as an inverse model. By using the beam power as input, the DNN predicts the electron density. The final step is to test the DNN on actual experimental conditions. For this purpose, an atmospheric plasma torch will be used.

P 16.39 Thu 13:45 Redoutensaal

Full-wave Simulations of Helicon Waves for Plasma Wakefield Accelerators — •Luis Carlos Herrera Quesada[1], Nils Fahrenkamp[2], Stefan Knauer[2], Peter Manz[2], Günter Tovar[1], and Alf Köhn-Seemann[1] — [1]IGVP, University of Stuttgart — [2]University of Greifswald

The plasma wakefield mechanism appears as a solution to produce particles with higher energies than circular accelerators. To achieve the necessary high electric fields, the plasma medium must have a large electron density to create strong gradients. Helicon plasma discharges allow to achieve the plasma densities necessary for effective plasma wakefield accelerators. This study aims to understand helicon wave propagation in linear devices for plasma wakefield optimization and the influence of different antenna geometries on the efficiency of helicon wave excitation. Furthermore, the evolution of the radial plasma density gradient on the coupling to the helicon wave is studied. Numerical modeling of helicon discharges is made using a finite element method (FEM) analysis through the COMSOL Multiphysics code package. Antennas are modeled using the AC/DC and RF modules, then the plasma column response is simulated using the Plasma module. In parallel, the 3D finite-difference time-domain (FDTD) code FHELI (FOCAL for HELIcon) is used for comparative analysis. The code solves the Maxwell equations in conjunction with the fluid motion equation for electrons in a cold magnetized plasma. The numerical scenarios are based on the VINETA.75 device parameters and geometry.

P 16.40 Thu 13:45 Redoutensaal

Influence of a spacially variable plasma on a cavity's resonance structure for use in a multimodal microwave cavity resonance spectroscopy approach using 3D EM-simulations — •Johanna Vogt[1], Michael Friedrichs[1], Andreas Petersen[2], Franko Greiner[2], and Jens Oberrath[1] — [1]Modelling and Simulation, South Westphalia University of Applied Sciences, 59494 Soest, Germany — [2]Institute of Experimental and Applied Physics, Kiel University, 24118 Kiel, Germany

Several techniques have been developed to bridge the gap between measurable inputs and important plasma parameters, one group of which is active plasma resonance spectroscopy (APRS). In it, a wide-band electromagnetic (EM) signal is coupled into the plasma, and the frequency response of the system is evaluated via a model to yield certain parameters, which can then be used to determine the electron density. One such method is the microwave cavity resonance spectroscopy (MCRS), which analyses the shift of resonance frequencies of a cavity inside a reactor. A promising application due to its non-invasive nature is the characterisation of nanodusty plasmas, and a multimodal approach may yield a spatially resolved electron density profile.

To achieve this, a 3D-EM simulator is used to compare the spectra of a cavity filled with a spatially variable plasma to a vacuum case, and the resulting frequency shifts are analysed to determine local profiles.

We thank the Deutsche Forschungsgemeinschaft for funding this project under grant no. 531667910.

P 16.41 Thu 13:45 Redoutensaal

Probing Ion Drag and Electric Field Forces in CCRF Plasmas with Optical Tweezers — •Jessica Niemann, Viktor Schneider, and Holger Kersten — Institute of Experimental and Applied Physics, Christian-Albrechts-University Kiel, Germany

Many different diagnostics can be used to measure the spatial distribution and temporal evolution of plasma parameters. Over the past decade, the concept of utilizing externally injected microparticles as non-invasive probes, influenced by various forces and energy fluxes in plasmas, has been implemented. Information about local electric fields, energy fluxes, and momentum transfer by ions to the particles can be obtained based on their behavior in the plasma. Especially, the manipulation of microparticles by an optical tweezer is of interest, as it enables the microprobe to be positioned in areas of the plasma typically inaccessible to conventional diagnostic methods, such as the plasma sheath. In this study, optically trapped microparticles in a highly focused laser beam are used to investigate both the electrostatic field force in the sheath and the ion drag force in the presheath of a capacitively coupled radio-frequency discharge. These forces differ by roughly one order of magnitude, requiring adjustments of the trapping laser power to control the sensitivity of the optical trap accordingly. By observing the displacement of the trapped particle under varying gas pressure and phase angle in dual-frequency discharges, the spatial structure and parameter dependence of both forces are resolved. These measurements allow the experimental reconstruction of the fundamental plasma structure comprising bulk, presheath, and sheath.

P 16.42 Thu 13:45 Redoutensaal

In-vacuo DBD-XPS surface study of Au and Ag electrodes exposed to N_2/H_2 plasmas — •A.A. Ben Yaala[1], R. Antunes[1], T. Höschen[1], A. Manhard[1], A. Hecimovic[1], and U. Fantz[1,2]

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Dielectric barrier discharge (DBD) reactors are one of the most commonly studied discharges for plasma-assisted ammonia (NH_3) synthesis due to their simplicity, low gas temperatures, and compatibility with catalytic materials. However, the limited access to the catalyst's surface in conventional DBD designs hinders a detailed fundamental understanding of the plasma-surface chemistry responsible for NH_3 formation.

In this work, an in-vacuo planar DBD-XPS (X-Ray Photoelectron Spectroscopy) setup developed to investigate the chemistry of electrode surfaces exposed to N_2/H_2 plasmas is introduced. The use of noble surfaces such as gold (Au) and silver (Ag) prevents formation of metallic nitrides and enables studying the effect of adsorbed NH_x species. This contribution compares the concentrations of the adsorbates resulting from various plasma conditions with the ammonia synthesis rates determined with mass spectrometry.

P 16.43 Thu 13:45 Redoutensaal

Investigation and characterization of a linearly extended microwave plasma source for a metal foil pump — •Tim Werz, Stefan Merli, Andreas Schulz, Matthias Walker, and Günter Tovar — University of Stuttgart, Germany

Future fusion power plants use only a fraction of the fuel materials. Being able to separate and recirculate tritium and deuterium from the exhaust gas is a critical step towards industrialization. A promising design to achieve isotope separation is a metal foil pump (MFP). The MFP utilizes superpermeation of atomic hydrogen isotopes to separate it from molecular hydrogen, helium and plasma enhancing gases. This separation technique can even be used against a pressure gradient.

In order to generate the atomic isotopes on the upstream side, the Duo-Plasmaline, a linearly extended and highly scalable microwave plasma source, is utilized. This plasma source is being investigated via a number of different analysis techniques, such as optical emission spectroscopy and Langmuir-Probes. A energy dispersive mass spectrometer is used to obtain information about the ion energy and types. The plasma density, temperature, distribution and type of ions, as well as impurities and non metalic layers on the metal foil play a critical role in its performance. Besides hydrogen species, heavier atoms and ions such as carbon, nitrogen and oxygen are being investigated.

P 16.44 Thu 13:45 Redoutensaal

Design and simulation of a Cylindrical Deflection Analyzer — •Leo Zeidler, Thomas Trottenberg, and Holger Kersten — Christian-Albrechts-Universität Kiel

Electric propulsion (EP) thrusters have become standard in satellite systems since the 1990s [1]. The growing demand for space missions has accelerated the development and refinement of new thruster concepts [2]. The Ref4EP project, a collaboration between Kiel University, Giessen University, and IOM Leipzig, aims to standardize pre-flight testing procedures for EP devices. This involves the development of a 127° Cylindrical Deflection Analyzer (CDA) which is an alternative to traditional Retarding Potential Analyzers (RPAs) for measuring ion energy distribution functions (IEDFs) in ion beams. While on-flight diagnostics typically rely on robust top-hat analyzers, the CDA offers advantages for laboratory environments due to simple electrode geometry and higher energy resolution.

The final CDA design along with numerical simulations are presented.

[1] K. Holste et al., Rev. Sci. Instrum. 91 (2020) 061101
[2] T. Trottenberg et al., EPJ Tech. Instrum. 8 (2021) 16

P 16.45 Thu 13:45 Redoutensaal

The ALBATOR project: A 3.5-year visionary project pioneering a contactless solution for space debris removal — •Viktor Schneider for the ALBATOR-Collaboration — Institute of Experimental and Applied Physics, Christian-Albrechts University Kiel

ALBATOR, proposes the use of the Ion Beam Shepherd method as a concept for contactless space debris removal, which relies on momentum transfer from a collimated, multiple charged plasma beam. The project focuses on designing and developing an Electron Cyclotron Resonance (ECR)-like ion beam system. To achieve that ambition, ALBATOR will optimize the ion beam system by gaining a deep understanding of plasma discharge and plume expansion physics. It will create advanced models to simulate plasma discharge and its interaction with debris, accounting for factors such as multiple charged ions, electromagnetic wave behavior, and materials interactions like sputtering, which influence momentum transfer. A series of vacuum chamber tests will be conducted to characterize the ion beam's properties, such as ion current, energy, and composition, under simulated space conditions. Additionally, the interaction of the ion beam with various satellite materials will be studied to assess its efficieny in momentum transfer. The systems versatility will also be tested using different propellants. The results from these tests will contribute to simulations of various mission scenarios, including debris deorbiting and detumbling.

P 16.46 Thu 13:45 Redoutensaal

Simulation of a Birdcage Antenna for Efficient Helicon-Mode Excitation — •Bennet Schahl, Luis Herrera Queseda, Alf Köhn-Seemann, and Günter Tovar — IGVP, University of Stuttgart, Germany

Helicon discharges can generate plasma densities significantly higher than those of conventional radio-frequency sources at comparable input power, making them attractive for applications ranging from plasma wakefield accelerators and plasma propulsion to fusion-relevant experiments and semiconductor manufacturing. Helicon waves are bounded whistler waves belonging to the family of right-hand polarized waves.

Birdcage antennas offer a promising geometry for coupling RF power into magnetized low-temperature plasmas. They form resonant network structures consisting of repeated parallel assemblies of inductive and capacitive elements that support distinct sets of resonant modes. This work focuses on optimizing a birdcage antenna for efficient excitation of electromagnetic waves in the so-called "helicon regime".

The study is conducted using COMSOL Multiphysics with the primary objective of optimizing the birdcage antenna design. The electromagnetic properties of the antenna are modeled to identify parameters that maximize field structures favorable for helicon-mode excitation. Based on these optimized configurations, the model may optionally be extended to include a plasma domain, enabling the evaluation of power deposition, mode formation, and the resulting plasma response.

The combined results aim to guide the design of future experimental setups.

P 16.47 Thu 13:45 Redoutensaal

Simulation of electron swarms in cylindrical magnetrons and their interaction with a boundary — •Gibran Brune[1], Lukas Vogelhuber[1], Kevin Köhn[1], Dennis Krüger[1], Jens Kallähn[1], Yulia Sharova[1], Liang Xu[2], Denis Eremin[1], and Ralf Peter Brinkmann[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — [2]School of Physical Science and Technology, Soochow University, Suzhou 215006, China

In this work, the motion of electrons in a cylindrical magnetron is simulated using predefined analytical electric and magnetic fields. Electrons are modeled as particles with an initial Maxwell-Boltzmann velocity distribution and are uniformly initialized within the simulation domain. Particle trajectories are computed using the Boris algorithm formulated in cylindrical coordinates. Due to the underlying geometry, the magnetic field exhibits azimuthal symmetry typical of cylindrical planar magnetron configurations. A diagnostic routine is employed to evaluate electron impacts on the cathode. This simplified simulation yields characteristic impact profiles in a realistic geometry and provides insights into electron dynamics and their dependence on the magnetic field configuration. Furthermore, more complex boundary interactions are investigated under simplified conditions.

P 16.48 Thu 13:45 Redoutensaal

Electron dynamics in a linear magnetron magnetic field configuration — •Zahra Alinia[1], Lukas Vogelhuber[1], Kevin Köhn[1], Dennis Krüger[1], Jens Kallähn[1], Yulia Sharova[1], Liang Xu[2], Denis Eremin[1], and Ralf Peter Brinkmann[1] — [1]Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — [2]School of Physical Science and Technology, Soochow University, Suzhou 215006, China

Magnetrons are essential devices in both scientific research and industrial applications. They are highly versatile and are used in a wide range of geometrical configurations. Two prominent configurations are the cylindrical magnetron, characterized by its inherent azimuthal symmetry, and the linear magnetron, which is structurally more complex but of greater industrial relevance. In this work, we employ a particle-based simulation to study electron dynamics in a linear magnetron magnetic configuration. Electrons are traced using the Boris pusher in cartesian coordinates. The magnetic field is modeled analytically based on a spatial arrangement of magnetic dipoles. An optimal structuring of these dipoles produces a magnetic field geometry that closely resembles the field configuration of a linear industrial magnetron in a so-called "stadium geometry". Electrons moving in this magnetic field experience the Lorentz force and are therefore confined near the racetrack region. Electron dynamics in this stadium geometry are numerically investigated and analyzed.

P 16.49 Thu 13:45 Redoutensaal

Wave phenomena in plasmas - a students' experiment — •Alf Köhn-Seemann[1] and Bayane Michotte de Welle[2] — [1]IGVP, Uni Stuttgart, Germany — [2]NASA, Goddard Space Flight Center

This presentation describes a plasma physics experiment developed as part of a Master's level student lab course at the University of Stuttgart. The experiment is designed to convey fundamental plasma properties through the investigation of wave phenomena such as oscillations at the plasma frequency and ion acoustic waves. The plasma is generated by thermionic discharges in a double-plasma device. A multi-cusp magnetic field, produced by permanent magnets mounted on the vacuum vessel wall, leads to relatively high plasma densities while maintaining a magnetic field-free region in the plasma bulk. This enables clear observation of fundamental wave phenomena under well-controlled conditions. The experimental set-up allows great flexibility in the external control parameters, enabling students to gain hands-on experience with plasma diagnostics and wave excitation. The experiment has proven a versatile and robust platform for teaching key concepts in plasma physics.

P 16.50 Thu 13:45 Redoutensaal

System-theoretic view of the pMRP — •Paria Keramatbaksh[1], Dennis Krüger[1], Jens Oberrath[2], Crispin Ewuntomah[2], and Ralf Peter Brinkmann[1] — [1]Ruhr-University Bochum, Germany — [2]South Westphalia University of Applied Sciences, Germany

The term *Active plasma resonance spectroscopy (APRS)* denotes a family of diagnostic methods which exploit the ability of low-pressure plasmas to exhibit pronounced resonances when excited by a signal in the radio-frequency range. The *planar multipole resonance probe (pMRP)* implements this time-honored concept in a wall-embedded, non-intrusive geometry suited for industrial environments.

For modeling purposes, a system-theoretic point of view is adopted. The radio-frequency signal source is coupled via a $50\,\Omega$ coaxial transmission line to a spatially extended probe structure, which is interpreted as a four-port network. Through a planar interface, the probe is coupled to the plasma, represented as a two-port characterized by its spectral admittance $Y(k,\omega)$. Earlier studies have established a quantitatively accurate representation of $Y(k,\omega)$ based on kinetic theory [1]. In the present work, the focus is instead on the mathematical formulation of the coupling itself. As a deliberate simplification, the plasma response is described by the classical Drude model. This reduced description provides a transparent baseline for analyzing probe-plasma coupling and enables systematic comparison with commercial electromagnetic simulations.

[1] C. Wang et al. *Plasma Sources Sci. Technol.* **30**, 105011 (2021)

P 16.51 Thu 13:45 Redoutensaal

ICCD-Measurements of rf-discharges in the Zyflex chamber — •Baldo Bán Kabuss, Christina Knapek, and André Melzer — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

In dusty plasmas the properties of the discharge strongly affect how clouds of embedded microparticles behave. Usually forces created by the plasma induce a large void in the center of the dust cloud. The Zyflex chamber is a device with four independent rf electrodes which is capable of creating homogeneous dust clouds under microgravity conditions. In this contribution the shape and intensity of the plasma glow is observed on a nanosecond time scale using a very light-sensitive ICCD-camera. From this data the spatially and time resolved excitation is calculated. The investigation allows deeper understanding of how phase and/or amplitude differences between electrodes change the plasma and thus affect dust cloud shape and structure.

P 16.52 Thu 13:45 Redoutensaal

Dust particle dynamics in a pulsed discharge in microgravity — •Christina A. Knapek, Daniel P. Mohr, Stefan Schütt, Daniel Maier, and Andre Melzer — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

The charge of micrometer-sized particles immersed in a low-temperature plasma is determined mainly by the electron temperature. If the plasma is operated in a pulsed mode, it is partially in temporal afterglow, and the time-averaged electron temperature decreases. This is expected to impact the particle charge, as well as observable interactions and particle dynamics.

Experiments were performed as part of a parabolic flight campaign with the Zyflex chamber, a versatile plasma chamber designed for the future microgravity complex plasma facility COMPACT. Particles were injected into the plasma during the microgravity phase, while the plasma source, a four-channel radio-frequency generator connected to four separate electrodes, was operated in a pulsed mode. Different operation scenarios were applied (e.g. random successive pulsing of the four channels). One operation mode introduced "off"-times, during which the plasma was in the temporal afterglow for a short while. First experimental results of the impact of the pulsed mode on particle dynamics, and complementary plasma diagnostic measurements are presented.

This work was and is funded by DLR/BMWi (FKZ 50WM2161, 50WM2561).

P 16.53 Thu 13:45 Redoutensaal

Optical system for COMPACT — •Daniel P. Mohr, Stefan Schütt, Christina A. Knapek, Daniel Maier, and Andre Melzer — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

The future complex plasma facility COMPACT [1] will allow the investigation of large three-dimensional complex plasmas under microgravity conditions aboard a space station. COMPACT is a project with international scientific contributions, supported by space agencies (DLR, NASA, ESA) and NSF.

Camera-based observation of dust particles is the most important diagnostic for complex plasma experiments. So far, however, measuring their three-dimensional positions has not been possible in low Earth orbit.

For COMPACT a sophisticated optical system is foreseen, including 2D and 3D diagnostics. This system consists of the camera setup, the recording hardware and software as well as the evaluation software (e. g. [2]). We will present concepts/design for the camera setup as well as concepts for the evaluation.

This work was and is funded by DLR/BMWi (FKZ 50WM2161, 50WM2561).

[1] C. A. Knapek et al., DOI: 10.1088/1361-6587/ac9ff0
[2] D. P. Mohr et. al., DOI: 10.3390/jimaging5020030

P 16.54 Thu 13:45 Redoutensaal

Effects of electrode geometry and circuit on electric breakdown in atmospheric-pressure argon — Aleksandar Jovanović, •Margarita Baeva, and Markus M. Becker — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Electrical breakdown and subsequent re-breakdown are pivotal phenomena for the performance of switching and protective devices. This contribution presents a detailed modelling study of the electrical breakdown in argon at atmospheric pressure under direct current (DC) voltage in pin-plane geometry. A time-dependent and spatially two-dimensional fluid-Poisson model is employed to capture the spatio-temporal evolution of the discharge. An external electrical circuit involves the DC power supply, a series resistor, and an external capacitor. A parametric study of the influence of the resistance, capacitance and electrode shapes reveals distinct operation regimes, ranging from a low-current corona discharge to a high-current transient spark. The observed mode transitions are caused by the interplay of the circuit components and the discharge configuration. In all regimes, the gas and electrode temperatures differ considerably. Maximum temperature is localised in the cathode sheath, where the electric field is strongest and affects the cathode heating. The results reveal the coupling between geometry, electrical circuit and discharge, providing insights for optimisation of high-frequency switching and ignition devices.

The study was supported by the DAAD in the framework of Projekt-ID 57703239.

P 16.55 Thu 13:45 Redoutensaal

Analysis of spatio-temporal ignition patterns in dielectric barrier discharges — •Cristian Flores, Hans Höft, Klaus-

Dieter Weltmann, and Markus M. Becker — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

The occurrence of a repetitive spatio-temporal filament pattern in a dielectric barrier discharge (DBD) is analysed with a combined experimental, modelling, and equivalent circuit approach. The symmetric multi-filament DBD arrangement consists of two parallel tube electrodes (alumina-covered metal rods) separated by a 1 mm gas gap in synthetic air at atmospheric pressure. The system is driven by a high-voltage sinusoidal waveform with 11 kV_{pp} at 10 kHz. Under these conditions, it is observed that the filaments ignite in two stages at alternating positions during each half-period. A fluid-Poisson model is used to study the dynamics of the DBD and to validate the estimations of the filament ignition times obtained from the equivalent electric circuit (EEC) in terms of the breakdown voltage, transferred charge, and an initial condition for the gap voltage. The validated expressions of the EEC model are then used to interpret the experimentally observed filament ignition patterns. The results suggest that a spatial variation in the gap voltage is responsible for the observed effects.

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P 16.56 Thu 13:45 Redoutensaal

CO_2 Conversion and Oxygen Removal in the Effluent of a Plasma — •Katharina Wiegers[1], Thomas Schiestel[2], Rodrigo Antunes[3], Andreas Schulz[1], Matthias Walker[1], and Günter Tovar[1] — [1]University of Stuttgart, Stuttgart, Germany — [2]Fraunhofer IGB, Stuttgart, Germany — [3]Max-Planck-Institute IPP, Garching b. München, Germany

Plasmas offer a promising pathway for energy-efficient CO_2 conversion into CO. However, their performance is strongly influenced by the chemistry in the plasma effluent. Consequently, the suppression of back-reactions is essential, which can be achieved by employing tailored gas nozzle designs. This study investigates how the nozzle geometry enhances CO_2 conversion by modifying the effluent flow. A major challenge in CO_2 plasma conversion is the formation of oxygen in the product gas, which reduces the efficiency of subsequent reactions. Oxygen-conducting hollow-fiber membranes are employed to selectively extract O_2 from the effluent of an atmospheric microwave plasma torch. The influence of microwave power on the temperature distribution in the plasma membrane reactor and the resulting oxygen permeation flux is analyzed. Furthermore, the effect of a nozzle positioned between the plasma and the membrane module is examined; it alters flow and species distribution in the effluent, significantly affecting O_2 permeation. Finally, integration of up to 21 hollow-fiber membranes into the effluent stream demonstrates efficient and scalable oxygen removal.

P 16.57 Thu 13:45 Redoutensaal

Electron densities and temperatures of a microsecond pulsed plasma in water — •Oliver Krettek, Pia-Victoria Pottkämper, Neil Unteregge, Sven Weller, Nils Huber, and Achim von Keudell — Experimental Physics II, Ruhr-Universität Bochum, 44801 Bochum, Germany

Plasma ignition in liquids enables a wide range of applications, including the production of hydrogen peroxide, nanoparticle formation in solution and on surfaces, and plasma-assisted electrolysis, for example in the reactivation of copper catalysts for electrochemical reduction of CO_2. While nanosecond pulsed plasmas typically generate higher yields of reactive species, microsecond pulsed plasmas offer the advantage of easier integration into electrolysis cells. To better understand the behavior of such plasmas prior to their use in an electrochemical system, key plasma characteristics must be determined. In this study, optical emission spectroscopy is applied to investigate the H-alpha and O 777 nm emission lines of a microsecond pulsed plasma in water. By fitting the measured line profiles with a model incorporating Stark, van der Waals, and Doppler broadening, electron densities of up to $10^{22}\,m^{-3}$ and electron temperatures around 2500 K are obtained for different ignition voltages and pulse frequencies. Additionally, the ignition behavior as a function of electrode distance is examined. Experimental ignition thresholds for varying electrode gaps and voltages are compared with a simulation, showing very good agreement. Remaining discrepancies in the observed slopes may be related to transient bubble formation caused by Joule heating during ignition.

P 16.58 Thu 13:45 Redoutensaal

CH_4 Conversion with a microwave plasma torch — •Clemens Kranig[1], Ante Hecimovic[1], and Ursel Fantz[1,2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2 — [2]University of Augsburg, Universitätsstr. 1, D-86159 Augsburg

The use of microwave plasmas for converting various gases into value added chemicals is a promising technology, as the process relies solely on electrical power input and offers short start-up times - both advantageous when integrating such a technology with renewable power in terms of energy storage. In that regard, methane is an attractive feedstock due to its high volumetric hydrogen content. In a plasma torch, a low-temperature plasma with gas temperatures of 4000 - 6000 K is generated, enabling endothermic reactions such as methane pyrolysis ($CH_4 \rightarrow 2H_2 + C_s$) and dry reforming of methane ($CH_4 + CO_2 \rightarrow 2H_2 + 2CO$). Deposition of solid carbon and post-plasma water condensation complicate atomic balances (H, C, O), posing key challenges for process analysis. This contribution investigates the conversion of CH_4 and CH_4/CO_2 mixtures for H_2 or syngas production. Plasma characterization is performed via optical emission spectroscopy, complemented by downstream gas analysis using gas chromatography and mass spectrometry.

P 16.59 Thu 13:45 Redoutensaal

Modelling and experimental study of decomposition dynamics of nitric oxide in a helium radio frequency atmospheric pressure discharge — •Marjan Stankov[1], Florian Sigeneger[1], Ronny Brandenburg[1,2], Eva Wolfe[3], Aditya Bhan[3], and Peter Bruggeman[4] — [1]Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — [2]Institute of Physics, University of Rostock, Rostock, Germany — [3]Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, MN, USA — [4]Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN, USA

The reduction of nitric oxide (NO) in a helium radio frequency (13.56 MHz) atmospheric pressure plasma jet has been investigated using combined modelling and experimental approaches. The plasma jet under investigation comprises a quartz tube, a tungsten needle as the inner electrode, and a copper ring as the outer electrode. Using a plug-flow model, the modelling study couples particle balance equations for the considered species, mean electron energy equation and a heat equation, taking into account He-NO chemistry involving approximately 300 volume and surface reactions. The modelling results are validated using molecular beam mass spectrometry measurements of NO, N_2, O_2, O and NO_2 over a range of input powers, gas flow rates and initial NO concentrations. The model reproduces the measured trends, identifies the production and loss channels for the species considered, and reveals how varied parameters influence NO decomposition. This work has been funded by the DFG-NSF project no. 509169873.

P 16.60 Thu 13:45 Redoutensaal

CO_2-to-CO conversion in a micro cavity dielectric barrier discharge and initial data-driven analysis — •Michael Roloff, Henrik van Impel, David Eiselt, Volker Schulz-von der Gathen, Marc Böke, and Judith Golda — PIP, Ruhr-University Bochum, D-44801 Bochum

The micro cavity plasma array (MCPA) is an atmospheric pressure dielectric barrier discharge [1]. It serves as a research reactor to investigate ways of improving conversion by adding a catalyst. Fourier-transform infrared spectroscopy quantifies CO_2-to-CO conversion under different conditions. We present experiments using 1 slm helium with 0.1 % CO_2 and up to 2 W power, yielding conversion rates of 15.5 % (no catalyst), 14.5 % ($SrTiO_3$), and 12 % ($BaTiO_3$). Additionally, the gas flow pattern were optimized in order to increase conversion efficiency.

A second separately aspect of the project covers data-driven methods to extract useful information from plasma diagnostics. In first tests, we applied neural networks and simple statistical tools to measured signals (e.g. current or spectra) to understand method behavior and interpret basic plasma characteristics.

The experiments and data-driven analysis are intended to be combined in the future to enable machine learning-based parameter estimation.

`Supported by DFG within project A6 (SFB 1316)`

[1] Dzikowski et al. 2020 Plasma Sources Sci. Technol. 29 035028

P 16.61 Thu 13:45 Redoutensaal

A novel reactor to observe changes in ion composition *in operando* by continuously changing the plasma facing material — •Maurice Artz[1], Jannis Christiansen[1], Kerstin Sgonina[1], and Jan Benedikt[1,2] — [1]Institute of Experimental and

Applied Physics, Kiel University, Germany — [2]Kiel Nano, Surface and Interface Science (KiNSIS), Kiel University, Germany

In atmospheric pressure plasmas it is difficult to observe *in operando* the formation of ionic species. However, this observation is crucial e.g. for the understanding of the correlation of materials and plasma properties in the field of plasma-assisted catalysis. Therefore, a sub-atmospheric pressure radio frequency (RF) reactor was developed to bridge this research question. It allows for the *in operando* speciation analysis during the continuous change of the plasma facing material. The influence of the material facing the plasma region on the plasma composition can be observed in this reactor.

The sub-atmospheric RF reactor is operated in a pressure range from 20 to 80 mbar. The reactor is mounted atop the sampling orifice of an ion mass spectrometer, acting as a grounded electrode, so that the plasma is directly ignited above the orifice and created ions can be studied. Halfly coated walls can be moved along the plasma by continuously measuring the changes of ion fluxes. In first measurements the walls were coated with carbon for etching experiments or cobalt containing catalysts for conversion experiments.

P 16.62 Thu 13:45 Redoutensaal

Validation of nitrogen-seeded XPR simulations and comparison with other impurities on ASDEX Upgrade using JOREK — •Mate Szucs[1,2], Andres Cathey[1], Matthias Hölzl[1], Yu-Chih Liang[1], Matthias Bernert[1], Ou Pan[1], Daniel Maris[3], Sven Korving[2], Javier Artola[2], Richard Pitts[2], and The ASDEX Upgrade team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]ITER Organization, St. Paul Lez Durance Cedex, France — [3]DIFFER, Eindhoven, Netherlands

The X-Point Radiator (XPR) regime is a promising exhaust solution for future large-size tokamaks, featuring a cold, dense, highly radiative region above the X-point, inside the confined region. Such regimes have been achieved experimentally on several tokamaks, with different seeded impurities, and ELM suppression is seen when the XPR reaches a threshold height. Modeling with several codes has successfully reproduced several features seen in experiments. However the the effects on the pedestal which results in ELM suppression has not been studied. In this contribution, we present the current status of modeling of the XPR regime on the ASDEX Upgrade (AUG) tokamak with the visco-resistive nonlinear MHD code JOREK. An extension treats neutrals and impurities kinetically, including their interactions with the background fluid plasma. This extension is under constant development, allowing for benchmarking with other codes and experimental validation. Nitrogen-seeded simulations are compared to SOLPS-ITER and AUG experiments, further modeling is presented using different impurity species such as argon and neon.

P 16.63 Thu 13:45 Redoutensaal

Algorithms and optimizations for global non-linear hybrid fluid-kinetic finite element stellarator simulations — •Luca Venerando Greco[1], Matthias Hoelzl[1], Guido Huijsmans[2], and Edoardo Carrà[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany — [2]CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France

Predictive modeling of stellarator plasmas is crucial for advancing nuclear fusion energy, yet it faces unique computational difficulties. One of the main challenges is accurately simulating the dynamics of specific particle species that are not well captured by fluid models, which necessitates the use of hybrid fluid-kinetic models. The non-axisymmetric geometry of stellarators fundamentally couples the toroidal Fourier modes, in contrast to what happens in tokamaks, requiring different numerical and computational treatment.

This work presents a novel, globally coupled projection scheme inside the JOREK finite element framework. The approach ensures a self-consistent and physically accurate transfer of kinetic markers to the fluid grid, effectively handling the complex 3D mesh by constructing and solving a unified linear system that encompasses all toroidal harmonics simultaneously. To manage the computational complexity of this coupling, the construction of the system's matrix is significantly accelerated using the Fast Fourier Transform (FFT). The efficient localization of millions of particles is made possible by implementing a 3D R-Tree spatial index, which supports this projection and ensures computational tractability at scale.

P 16.64 Thu 13:45 Redoutensaal

High-strength material for fusion reactor magnet sections — •Fareeha Ashraf[1,2], Zahra Abbasi[2], and Klaus-Peter Weiss[2] — [1]IGVP, University of Stuttgart, Germany — [2]Karlsruhe Institute of Technology (KIT) , Institute for Technical Physics, Germany

The demand for high-strength materials for the mag- net sections of future fusion reactors requires a struc- tural material that can sustain exceptional mechani- cal performance at cryogenic temperatures. Conven- tionally used steels, such as 316LN, JK2LB, Incoloy 908, and JJ1, face limitations in achieving the tar- get properties of Yield Strength yield strength yield strength (YS) > 1500 MPa and fracture toughness (KIC)> 130 MPa m1/2. XM-19, a non-magnetic, Corrosion-resistant austenitic stainless steel offers high strength and toughness; however, its perfor- mance at cryogenic temperatures has not yet been finalized. This work focuses on XM-19 manufactured by controlled casting, forging, and heat-treatment routes. The mechanical testing, including tensile testing, fracture toughness evaluation, and fatigue assessment, combined with optical and electron mi- croscopy, will be used to correlate material response with deformation modes, grain characteristics, and precipitate stability. The results focus on the struc- tural evaluation of XM-19 under cryogenic opera- tions and its potential for large-scale fusion applica- tions.

P 16.65 Thu 13:45 Redoutensaal

Density dynamics of shattered pellet injection using a dispersion interferometer — •Andrew Moreau[1,2], Alexander Bock[1], Stefan Jachmich[3], Umar Sheikh[4], Gergely Papp[1], Anshkumar Patel[1], and Thomas Pütterich[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Ludwig Maximilian University, Munich, Germany — [3]ITER Organization, St Paul Lez Durance Cedex, France — [4]Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

High-current tokamaks contain a severe risk from unmitigated disruptions. Loss of plasma confinement in these scenarios could lead to excessive heat and force loads on a reactor and create runaway electron beams capable of causing intense localized damage inside the device. Shattered pellet injection is a promising candidate for disruption mitigation, controlling the thermal and current quenches during an unavoidable disruption.

The core density evolution following injected hydrogenic and neon-doped hydrogenic fragments is a key indicator of the disruption mitigation effectiveness. At ASDEX Upgrade, the line-integrated electron density through the core is evaluated using a dispersion interferometer. Results from the 2025 campaign show how a small quantity of neon doping ($\sim 0.1\%$) in a deuterium shattered pellet injection can result in significantly higher density retention ($\sim 4 \cdot 10^{20}\ \mathrm{m}^{-2}$) at much later phases in the current quench. Furthermore, the multiple pellet injection schemes have been shown to achieve high densities while lengthening the duration of the pre-thermal quench.

P 16.66 Thu 13:45 Redoutensaal

Self-consistent eddy and halo current coupling of a 3D non-linear MHD plasma with 3D realistic wall structures — •Raffaele Sparago[1,2], Javier Artola[2], Matthias Hoelzl[1], Nicola Isernia[3], Guglielmo Rubinacci[4], Nina Schwarz[2], Salvatore Ventre[5], and Fabio Villone[3] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]ITER Organization, 13067 St. Paul Lez Durance Cedex, France — [3]Università degli Studi di Napoli Federico II, Via Claudio 21, 80125 Napoli, Italy — [4]CREATE Consortium, Via Claudio 21, 80125 Napoli, Italy — [5]Università di Cassino e del Lazio Meridionale, Via Gaetano di Biasio 43, 03043 Cassino, Italy

Plasma **disruptions** in tokamak machines determine the interruption of confinement and the development of loss channels for the thermal and magnetic energies stored within the reactants into the containment structure, posing a threat for the machine's integrity. In this regard, tokamak design can be well informed by numerical codes modelling the electromagnetic interaction of the MHD plasma with the surrounding conducting structures. The latter provide predictions regarding disruptive plasma instabilities and the ensuing stresses on the walls. The here presented modelling activities have accomplished the **self-consistent** plasma-wall coupling of the induced (eddy) and source-sink (halo) currents flowing in the machine's structures during plasma instabilities; the framework leverages the interplay of the non-linear MHD code JOREK with the 3D wall codes STARWALL (thin) and CARIDDI (volumetric). The first reproduced instabilities are shown.

P 16.67 Thu 13:45 Redoutensaal

Study of finite Larmor radius physics with the gyrokinetic turbulence code GENE-X — •Jose Angel Capitan Garcia[1], Philipp Ulbl[1], Baptiste J. Frei[1], and Frank Jenko[1,2] — [1]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching bei München, Deutschland — [2]University of Texas at Austin, Austin, Texas 78712, USA

Turbulence is the primary driver of transport losses in magnetically confined plasmas, particularly in tokamaks and optimized stellarators, where it significantly impacts confinement. To optimize energy confinement in a reactor, minimizing turbulent losses is crucial. Achieving a deeper understanding of turbulence in the plasma core as well as the edge and scrape-off-layer (SOL) is essential to this goal.

The GENE-X code, an Eulerian solver of the full-f, collisional, electromagnetic gyrokinetic Vlasov equation, was developed to capture the physics of turbulence in the plasma edge and SOL. Until now, however, it relied on a long-wavelength model, limiting its ability to describe core turbulence and regions with steep gradients, where finite Larmor radius (FLR) effects become essential to capture the physics accurately.

In this work, we present an extension of GENE-X that incorporates FLR effects through Padé-approximated gyro-averaging operators. We will discuss the theoretical basis and first simulations investigating the impact of FLR corrections. This development enables GENE-X gyrokinetic simulations to extend across the entire plasma volume, from edge to core, for the first time in the code.

P 16.68 Thu 13:45 Redoutensaal

Impact of fishbone modes on core microturbulence with global gyrokinetic simulations — •Davide Brioschi[1], Alessandro Di Siena[1], Roberto Bilato[1], Alberto Bottino[1], Thomas Hayward-Schneider[1], Philipp Lauber[1], Alexey Mishchenko[2], Emanuele Poli[1], Alessandro Zocco[2], and Frank Jenko[1,3] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [3]Institute for Fusion Studies, The Univeristy of Texas at Austin, Austin, TX, USA

Fishbone instabilities (FBs) are a class of plasma modes which develop in tokamaks around rational surfaces. They are the energetic particle-driven branch of the n=m kink mode (with n and m toroidal and poloidal mode numbers). Numerical and experimental results show a possible relation between a suppression of (detrimental) turbulent transport inside tokamaks and the trigger of FBs. However, a clear causal relation between the destabilization of FBs and the core turbulent transport reduction has not been found yet. Therefore, it is clear the need for a description of the interaction of FBs with plasma turbulence. Our work aims to study such an interaction via gyrokinetic simulations with the codes GENE and ORB5, including both a FB mode and the ITG branches. These simulations are performed for an AUG discharge characterized by the presence of fishbone activity and plasma temperature peaking. Since the latter can be used as a proxy for core turbulence suppression, studying this case we can explore the physics of the interaction between FB instabilities and turbulence.

P 16.69 Thu 13:45 Redoutensaal

On the Nonlinear Excitation of Zero Frequency Zonal Flows by Alfvén Eigenmodes — •Riccardo Stucchi[1,2], Ph. Lauber[1], X. Wang[1], F. Zonca[3,4], M. V. Falessi[3], N. Chen[1,4], F. Stefanelli[1], and D. Korger[1] — [1]Max Planck Institute for Plasma Physics — [2]Technical University of Munich — [3]Center for Nonlinear Plasma Science and C.R. ENEA Frascati — [4]Institute of Fusion Theory and Simulation, Zhejiang University

As magnetic fusion plasmas move closer to ignition, increasing interest is raised by energetic particles (EPs) and Alfvén eigenmodes (AEs). As hinted by simulations and experiments, the interplay of EPs, AEs and background plasma can potentially lead to regulation of turbulence, and the aim of the present work is to build a reduced model to assess the impact on confinement of one particular mechanism of such interplay: the nonlinear generation of zero frequency zonal flows (ZFZFs) by AEs. The work is currently focused on modelling and un*derstanding the beat-driven generation by AEs of ZFZFs in the context of nonlinear gyrokinetic (GK) theory: on the one hand, we refine previous analytical expressions in the simplified case of well-circulating particles in circular cross section geometry; on the other hand we formulate a semi-analytical approach, presently being implemented in a linear GK eigenvalue code, valid in axis-symmetric toroidal geometry for both trapped and circulating particles. Future work including the comparison with nonlinear GK PIC simulations, the investigation of the nonlinear saturation regime for both AEs and ZFZFs, and the assessment of the impact of ZFZFs on the plasma confinement is foreseen.

P 16.70 Thu 13:45 Redoutensaal

Recent Advances in Efficient Preconditioning Techniques for 3D Nonlinear MHD Simulations in JOREK — •Patrik Rác[1], Omar Maj[1], Vandana Dwarka[2], Eric Sonnendrücker[1], and Matthias Hölzl[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Delft University of Technology, Delft, Netherlands

Enabling next-generation simulations of realistic magnetic confinement fusion devices is crucial for understanding and controlling large-scale plasma instabilities. JOREK is a leading simulation code that simulates plasma dynamics by solving the magnetohydrodynamic (MHD) equations in 3D toroidal geometry using a higher-order isoparametric finite element method in the poloidal plane and a spectral decomposition in the toroidal direction. To effectively address the rising computational demands linked to more detailed simulations, the code must exploit cutting-edge HPC systems in an optimal way to meet current and future needs. The linear systems arising in JOREK are large, sparse, and ill-conditioned. Thus, iterative solvers, such as GMRES, require optimized preconditioning to converge. Current preconditioning techniques rely on the direct factorization of sub-blocks corresponding to the toroidal modes of the global system. However, this approach limits scalability, performance, and portability to accelerated systems. We present recent developments in preconditioning methods for the iterative solution of the reduced MHD models in JOREK. Current research focuses, in particular, on deflation-based methods and novel multiphysics block and equation splitting approaches.

P 16.71 Thu 13:45 Redoutensaal

Statistical Analysis of Plasmoid Properties from Pellet Injections in Wendelstein 7-X — •Edgardo Villalobos Granados[1], Jügen Baldzuhn[1], Naoki Tamura[1], Ameer Mohammed[2], Larry Baylor[3], and Nerea Panadero[4] — [1]Max Planck Institute for Plasma Physics, Greifswald, MV, Germany — [2]Princeton Plasma Physics Laboratory, Princeton, New Jersey, United States — [3]Oak Ridge National Laboratory, Oak Ridge, TN, USA — [4]Laboratorio Nacional de Fusión, CIEMAT, Madrid, Spain

Hydrogen pellet injection is essential for core fueling in magnetic confinement fusion devices, such as stellarators. In particular, the Wendelstein 7-X (W7-X) stellarator aims to achieve steady state operation and demonstrate long pulse operation at high performance, which includes continuous particle fueling with the use of cryogenic hydrogen pellets. Understanding the dynamics of pellet ablation and the resulting plasmoid characteristics is a fundamental step for optimizing fueling strategies and improving plasma confinement. A statistical analysis of plasmoid properties generated during pellet injection in the W7-X. Plasmoid properties were inferred from visible range spectroscopic measurements of the hydrogen Balmer series. A dataset of over 2000 pellet injections across multiple magnetic configurations was analyzed to extract statistical distributions of plasmoid temperatures (typically 1-2 eV), densities on the order of 1e24 m-3, and corresponding pressure. The correlation between these properties and pellet and background plasma conditions was investigated. These results provide important experimental constraints for modeling pellet-plasma interactions

P 16.72 Thu 13:45 Redoutensaal

Overview of a MANTIS-II installation in AUG for runaway electron studies using synchrotron imaging — •Andres Orduna[1,2], Andreas Burckhart[1], Gergely Papp[1], Tijs Wijkamp[3], Mathias Hoppe[4], Artur Perek[5], Yanis Andrebe[5], Tilmann Lunt[1], Ralph Dux[1], and ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Ludwig-Maximilians-Universitat Munchen — [3]Dutch Institute for Fundamental Energy Research — [4]KTH Royal Institute of Technology, Stockholm, Sweden — [5]Ecole Polytechnique Fédérale de Lausanne, Swiss Plasma Center

The study of runaway electrons (RE) dynamics in present-day tokamak experiments requires the analysis of the RE momentum-space distribution function. Synchrotron radiation (SR) imaging using multispectral systems has proven capable of providing this information in TCV and AUG. For this purpose, the multispectral imaging system MANTIS consisting of 6 filtered cameras is being commissioned in AUG.

Technical considerations, such as filter wavelength, view port location, neutron flux, among others, have to be taken into account for the installation of the system. Synthetic images for the corresponding wavelengths and views are simulated using the SOFT synthetic diagnostic framework.

To validate the system performance and resilience in real conditions, a first commissioning phase was pursued. The first images of a RE synchrotron spot using a multispectral imaging system in AUG are presented.

P 16.73 Thu 13:45 Redoutensaal

Observed toroidal radiated power variations in Wendelstein 7-X — •Anastasios Tsikouras[1], Felix Reimold[1], Gabriele Partesotti[1], Kevin Andrea Siever[1], Takashi Nishizawa[2], Maciej Krychowiak[1], and Daihong Zhang[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Kyushu University, Kasuga, Japan

An accurate total radiated power (P_{rad}) proxy is important for the efficient and safe operation of a nuclear fusion device. Specifically in 3D devices such as the Wendelstein 7-X stellarator (W7-X), the P_{rad} distribution varies toroidally [1]. This poses a challenge in precise calculation the total P_{rad}. Although shown with synthetic data [1], the distribution of the radiation needs to be validated experimentally. This contribution presents the observed asymmetries on different P_{rad} proxies from different bolometer systems in W7-X. Data from different cross-sections reveal up to 8-fold increase in toroidal asymmetries for low plasma densities. The effect reduces with the increase in the density. For higher input powers the asymmetry increases. Furthermore, configurations with higher field line pitch and reduced plasma wall interaction exhibit a decrease in the asymmetries. In seeded cases, the asymmetries decrease with the increase in the fraction of radiated power which is directly linked with the impurity content in the machine. These results support the formulation of a more precise P_{rad} proxy.

[1] G. Partesotti, PhD thesis (Greifswald 2025)

P 16.74 Thu 13:45 Redoutensaal

ECRH power deposition measurements using ECE radiometers at W7-X — •Vaishnavi Murugesan, Matthias Hirsch, Gavin Weir, Torsten Stange, Juan Fernando Guerrero Arnaiz, Melina Arvanitou, Neha Chaudhary, Robert C Wolf, and the W7-X Team — Max Planck Institute for Plasma Physics

Electron Cyclotron Resonance Heating (ECRH) is a prominent heating scheme in many modern fusion devices. The narrow deposition width of ECRH makes it an effective tool for plasma profile shaping and turbulence control. The experimental validation of said narrow power deposition, however, has proved to be challenging, limited by the diagnostic capabilities and heat diffusion. ECRH modulation and switching experiments offer a unique way of deriving power deposition profiles in magnetically confined plasmas. ECRH modulation initiates perturbations in local electron temperature (Te) that are observed as an immediate response in the Electron Cyclotron Emission (ECE) signals. The instantaneous response of the ECE channels probing the magnetic flux surfaces in the vicinity of heating is used to derive power deposition profiles. This work presents narrow ECRH power deposition profiles measured using standalone calibrated ECE radiometers at Wendelstein 7-X (W7-X). Experimental results are discussed alongside mathematically derived ray-tracing profiles for plasma discharges from the experimental campaign 2.3 at W7-X.

P 16.75 Thu 13:45 Redoutensaal

Advancing Tokamak Edge Stability Predictions with Extended-MHD Modelling — •Michael Sieben[1], Michael Dunne[1], Jonas Puchmayr[1], Roxana Takacs[1], and the ASDEX Upgrade Team[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]See author list of H. Zohm et al 2024 Nucl. Fusion 64 112001

The high-confinement mode (H-mode) is an operational regime achieved in many present tokamaks, including ASDEX Upgrade (AUG), and is expected to be accessed in the future by ITER. In H-mode, a transport barrier, the so-called pedestal, forms at the plasma edge, where steep temperature and density gradients can drive magnetohydrodynamic (MHD) instabilities and trigger rapid heat and particle losses that can be hazardous for plasma-facing components. Predicting pedestal stability limits is therefore essential for H-mode operation. MHD models combined with an assumption on the transport in the pedestal, such as IPED [1], can be used to predict the pedestal structure prior to such events. Here, we present three extensions to IPED that improve edge stability predictions: (1) high-precision equilibrium reconstruction using the GVEC code [2]; (2) inclusion of extended-MHD physics through integration of CASTOR3D [3]; and (3) a robust growth-rate prediction based on an iterative search in the complex eigenvalue space. We demonstrate how these extensions affect predicted stability limits in both predictive and interpretive analyses of H-mode plasmas at AUG. [1] Dunne M.G. et al. 2017, [2] Hindenlang F. et al. 2019, [3] Strumberger E. et al. 2016.

P 16.76 Thu 13:45 Redoutensaal

Investigation of boron transport in the pedestal of ASDEX Upgrade — •Lucas Räss[1], Rachael McDermott[1,2], Tabea Gleiter[1], Dirk Stieglitz[1], Thomas Pütterich[1,2], Kiera McKay[3], Ralph Dux[1], Elisabeth Wolfrum[1,4], and The ASDEX Upgrade Team[5] — [1]Max-Planck-Institut für Plasmaphysik — [2]Ludwig- Maximilians-Universität München — [3]University of Seville — [4]TU Wien — [5]See author list of H. Zohm et al, 2024 Nucl. Fusion

Impurity transport across the edge of the confined plasma (pedestal) is of special interest for future fusion reactors, as it sets boundary conditions for the core impurity concentration. The transport is generally determined by a combination of collisional (neoclassical) and anomalous contributions, where neoclassical predictions for future reactors result in favourable hollow impurity density profiles.

This study investigates pedestal impurity transport between type-I edge localised modes (ELMs) in the high confinement regime (H-mode) at ASDEX Upgrade across a wide range of plasma parameters. For this purpose, a database of suitable discharges was established and for a subset the ratio of drift velocity to diffusion coefficient is inferred from experimental boron measurements and compared to neoclassical predictions. Our results support prior findings of transport near neoclassical levels in the steep gradient region, with most discharges agreeing well with neoclassical predictions while singular outliers, that occur in particular at low collisionality, are present. Due to uncertainties in these discharges, however, further analysis is needed to prove or disprove significant anomalous transport at low collisionality.

P 16.77 Thu 13:45 Redoutensaal

Flight-Simulators for the ASDEX Upgrade Tokamak: Development of a New Software-In-the-Loop Tool and Controller Design for Advanced Divertor Configurations — •Marco Biasizzo[1,2], Pierre David[1], Matthias Gehring[1], Renat Kermenov[1], Mariano Ruiz[2], Bernhard Sieglin[1], Wolfgang Treutterer[1], Hartmut Zohm[1], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]Grupo de Investigación en Instrumentación y Acustica Aplicada, Universidad Politécnica de Madrid, 28031 Madrid, Spain

Flight-simulators (FS) for tokamaks ingest a discharge program and return the time evolution of plant and plasma variables, enabling rapid testing of scenarios and control algorithms. The current ASDEX Upgrade (AUG) FS, Fenix, uses a physics-based model for the plasma and a Simulink model of the tokamak control system. An alternative software-in-the-loop (SIL) version is under development; it runs an exact replica of the control system, removing modelling limits and reducing execution time. Synchronization and communication between the control system and the plasma and plant models are presented.

The SIL simulator will be used to implement and test a novel controller to regulate desired advanced divertor configurations (ADCs) and key plasma shape geometric descriptors. Model-based controller synthesis has begun with ADCs data obtained from the current FS. Fenix results were benchmarked against recent AUG experiments, showing quantitative agreement. This integrated approach promises faster, reliable controller development while saving experimental time.

P 16.78 Thu 13:45 Redoutensaal

Modelling the Pellet-Produced Plasmoid Dynamics in Stellarators with JOREK — •Carl Wilhelm Rogge[1], Ksenia Aleynikova[1], Pavel Aleynikov[1], Rohan Ramasamy[2], Matthias Hoelzl[1], and Nikita Nikulsin[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald and Garching — [2]Proxima Fusion, München

Cryogenic pellet injection is expected to be a key technique for refuelling future fusion reactors based on the stellarator concept. While this technique is more mature in tokamak experiments, the departure from axisymmetry in stellarators introduces unique challenges and opportunities that remain insufficiently explored.

Here, we employ the stellarator extension of the 3D nonlinear MHD code JOREK to study the radial drift of a fully ionised plasmoid. Since this drift depends on the pressure evolution within the pellet-produced plasmoid, the parallel expansion has a strong impact on the final deposition profile of the injected material. Consequently, particular attention must be paid to accurately modelling the reheating of the plasmoid by hot background plasma particles, which drives the parallel expansion. Because the mean free path of background electrons in core-fuelling scenarios is very long, non-local heat transport effects need to be incorporated into the fluid description.

Two non-local heating schemes have been newly implemented in JOREK and verified against analytical theory. These new schemes are then applied to stellarator geometries, where the radial drift following complete pellet ionisation is investigated.

P 16.79 Thu 13:45 Redoutensaal

Investigating drift effects in island divertors with the mean-field Braginskii model — •Tobias Tork[1,2], Felix Reimold[1], David Bold[1], Ben Dudson[3], Andreas Stegmeir[4], and Peter Manz[2,1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Institute of Physics, University of Greifswald, 17489 Greifswald, Germany — [3]Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore CA 94550, USA — [4]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

The inclusion of drifts has been shown to be critically important for the boundary physics of tokamaks and has a significant impact on the predictions of divertor heat loads and impurity transport. Current state-of-the-art stellarator boundary simulations like EMC3-Eirene do not include drifts, but experiments in W7-X already show numerous indications of drift effects. Such effects could significantly alter the heat loads on the divertors or redistribute the plasma profiles.

In this contribution, we present the development of a 3D simulation for island diverted stellarators. The model is derived from the Hermes-2 physics model by parameterizing the divergence of the polarization drift with a set of anomalous diffusion coefficients. The simulation tool allows for the analysis of potential and current distributions in stellarators.

We will show results of drift effects in an island divertor. Stagnation points of the parallel ion flow demonstrate a significant poloidal shift which depends on the magnetic field direction.

P 16.80 Thu 13:45 Redoutensaal

Analysis on the plasma edge fluctuations in the X-point radiator regime in ASDEX Upgrade — •Yu-Chih Liang[1,2], Ou Pan[1], Matthias Bernert[1], Tim Happel[1], Ulrich Stroth[1,2], Gustavo Grenfell[1], Sebastian Hörmann[1], Alessandro Mancini[1], Konrad Eder[1], Mate Szuecs[1,2,3], and the ASDEX Upgrade Team[1] — [1]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [2]TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [3]ITER Organization, 13067 St. Paul Lez Durance Cedex, France

The power exhaust problem in large-scale fusion reactors necessitates operational regimes that can avoid extreme heat fluxes onto the plasma-facing components. One promising regime is the X-point radiator (XPR), featuring a highly radiative plasma volume forming above the X-point. Additionally, suppression of edge localized modes (ELMs) can be achieved when the XPR moves inside the confined region.

This contribution focuses on the plasma edge, where the complexity arises from the turbulence around the XPR volume, the interactions between the edge modes and the XPR, and the influence of the XPR on the edge turbulence transport. Using the thermal He beam diagnostics, the diode bolometry, and the magnetic coils in ASDEX Upgrade, the edge fluctuations in the XPR regimes both with and without large ELMs are studied. Furthermore, the presented analysis on the fluctuation measurements is extended from the outer midplane to the XPR volume, aiming to improve understanding on the interactions between the outer midplane plasma profile and the XPR.

P 16.81 Thu 13:45 Redoutensaal

Operational space of the ASDEX Upgrade tokamak and its proximity to that of future devices with burning plasma — •Daniela Kropáčková, Emiliano Fable, Ondřej Kudláček, Hartmut Zohm, and ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, Garching, D-85748, Germany

Present-day tokamaks are unable to capture the dynamic interaction between alpha heating and the plasma operational scenario during changing operating conditions as expected in future reactors. To enable these investigations, a method for emulating dominant alpha heating in existing tokamak experiments was introduced in [FableNF2023].

In this contribution, a database of operational scenarios of ASDEX Upgrade (AUG), covering ELM-free regimes such as EDA and QCE, scenarios with ELM suppression via resonant magnetic perturbations (RMPs), flux-pumping scenarios, and operation with a X-point radiator (XPR), is presented. The interesting operational space is characterized in terms of key non-dimensional parameters, e.g., ν_{eff}, β_N, ρ^*, and q_{95}. These parameters are compared with the expected values for a few considered fusion reactors, and the conditions under which relevant physical parameters can be matched are identified.

The selected scenarios are then used to calibrate the alpha heating power proxy through simulations performed with the flight simulator Fenix. Experimental validation of the obtained results is planned for a future campaign, followed by burn control studies.

P 16.82 Thu 13:45 Redoutensaal

Comparison of experimental radiation dynamics in the scrape-off layer of Wendelstein 7-X with transport simulations — •Kevin Andrea Siever[1], Felix Reimold[1], Satoshi Togo[2], Gabriele Partesotti[1], Takashi Nishizawa[3], Daihong Zhang[1], Nassim Maaziz[1], Anastasios Tsikouras[1], Valeria Perseo[1], Victoria Winters[1], Masahiro Kobayashi[4], Byron Peterson[4], and Kiyofumi Mukai[4] — [1]Max Planck Institute, Greifswald, Germany — [2]Plasma Research Center, University of Tsukuba, Tsukuba, Japan — [3]Kyushu University, Kasuya, Japan — [4]National Institute for Fusion Science, Toki, Japan

At Wendelstein 7-X (W7-X) the strongly 3D topology of the scrape-off layer (SOL) leads to a complex behavior of the impurity radiation structure. In this context, the 3D transport code EMC3-Eirene is often used to assess its SOL. This contribution aims at the validation of such simulations with experimental data, focusing on the radiation distribution. In the work [S. Togo et al (submitted) Plasma Phys. Control. Fusion], density scans have been simulated with EMC3-Eirene for 5 configurations corresponding to different radial positions of the islands. Matching W7-X density scan-experiments are chosen and data from the 3 available bolometry systems analyzed. In order to compare the simulated radiation structure to the experimental data, synthetic diagnostic data generation and 2D tomographic inversions are employed. This allows to compare with the simulations the experimental poloidal evolution of the emissivity localization as density is increased, for the different geometries.

P 16.83 Thu 13:45 Redoutensaal

Modelling of Island Divertor Topology and Edge MHD Instabilities in Stellarators with JOREK — •Orin Varley[1], Rohan Ramasamy[2], Jonas Puchmayr[1], Samet Kocbay[1], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Proxima Fusion, Munich, Germany

Large-scale MHD dynamics shape key aspects of stellarator performance, especially island divertor geometry and edge instabilities. This work examines these phenomena and summarizes recent advances in modelling capabilities.

Island divertors are the leading concept for particle and heat exhaust in stellarators, but their performance is highly sensitive to magnetic topology. Increasing plasma β can shift island position and width, enhance chaos, and, in some optimized quasi-isodynamic configurations, even induce phase transitions within the island structure. Using JOREK, we model these β-driven transitions, compare with HINT, and investigate the mechanisms that reshape island topology.

We also study MHD-driven edge instabilities with improved physics models, supported by ongoing developments in the JOREK stellarator framework, including a no-wall boundary condition and diamagnetic drift effects.

This poster presents an overview of these model improvements and their first applications to island divertor physics and edge instability studies, forming a basis for future work on plasma exhaust, detachment, and wall loading in stellarators.

P 16.84 Thu 13:45 Redoutensaal

The avalanche source for a 3D particle in cell model of runaway electrons — •Fiona Wouters[1], Matthias Hoelzl[1], Hannes Bergstroem[1], Guido Huijsmans[2,3], and Jan van Dijk[2] — [1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — [2]Eindhoven University of Technology, Groene Loper 3, 5612 AE Eindhoven, the Netherlands — [3]CEA, IRFM, 13115 Saint-Paul-lez-Durance, France

Disruptions, i.e. major instabilities in which plasma confinement is lost, are a significant threat to tokamak operation not only because of the large in vessel forces involved, but also because they may lead to the acceleration of some electrons to relativistic speeds. These so-called runaway electrons (REs) can exponentially multiply due to large-angle collisions with thermal electrons during the RE avalanche. As the RE avalanche is exponentially sensitive to the pre-disruption plasma current, this can lead to multi-MA RE beams in large future devices, which may cause severe localized wall damage. Therefore, simulations including the RE sources in realistic 3D fields are needed to further the understanding of RE generation and losses and develop viable mitigation scenarios. For this purpose 3D nonlinear MHD code JOREK contains a hybrid fluid-kinetic model that describes the REs with a full-f relativistic particle in cell (PiC) approach using either full-orbit or drift kinetic RE descriptions. We present the implementation of the relativistic large-angle collision operator and a resampling technique needed to limit the number of markers, along with first applications.

P 16.85 Thu 13:45 Redoutensaal

Radiative power exhaust in Alternative Divertor Configurations at ASDEX Upgrade — •Alessandro Mancini, Matthias Bernert, Tilmann Lunt, Dominik Brida, Felix Albrecht, and the ASDEX Upgrade team — Max Planck Institute for Plasma Physics (IPP Garching)

Power exhaust is a major challenge in the development of tokamaks as fusion reactors. The unmitigated power flux in a reactor is expected to be several orders of magnitude higher than the heat load limit for tungsten plasma facing components (PFCs).

Alternative Divertor Configurations (ADCs) feature an increased flux expansion and/or secondary X-Points to lower the heat load on the PFCs by easing the access to detachment, where the plasma recombines before reaching the wall. Therefore, ADCs may be taken into consideration for future tokamak reactors. The ASDEX Upgrade tokamak was recently upgraded with a new upper divertor that can produce ADCs, like X-Divertor (XD), Snowflake Minus (SF-), super Compact Radiative Divertor (sCRD). This work focuses on the power exhaust capabilities of ADCs, in particular on the radiated power distribution. Bolometer data is complemented by Langmuir probe data to characterize the detachment.

It is observed that ADCs highly modify the radiation distribution. The SF- configuration facilitates X-Point Radiators (XPR), even at low impurity seeding levels. Fast transitions in the radiation pattern are observed even with a slow variation of the ADC configuration.

P 16.86 Thu 13:45 Redoutensaal

Equilibrium reconstruction and toroidal current density analysis for high-β Wendelstein 7-X plasmas — •E. Hausten[1], K. Rahbarnia[1], H. Thomsen[1], L. van Ham[1], C. Brandt[1], T. Andreeva[1], C. Büschel[1], M. Kelly[1], P. Pons-Villalonga[1], S. Vaz Mendes[1], S. Lazerson[2], and the Wendelstein 7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Gauss Fusion GmbH, Parkring 29, 85748 Garching bei München, Germany

Accurate knowledge of the magnetohydrodynamic equilibrium is essential for interpreting diagnostics and inferring non-measurable plasma parameters in fusion experiments such as the Wendelstein 7-X (W7-X) stellarator. Equilibria can be reconstructed from experimental data using the STELLOPT code [1], which employs optimization methods to find equilibria that best match diagnostic measurements. A key challenge in reconstructions is determining the toroidal plasma current density, for which only limited experimental information is directly accessible. This becomes particularly relevant in high-β scenarios, where increased pressure gradients can drive stronger currents. In this contribution, we present reconstructed current density profiles for high-β plasmas obtained in W7-X experiments. We analyze the influence on rotational transform and Shafranov shift and compare with predictions from the current-evolution code THRIFT [2].

[1] S. A. Lazerson, 2015, Nucl. Fusion 55
[2] L. van Ham et al, 2025, Nucl. Fusion 65

P 16.87 Thu 13:45 Redoutensaal

On the role of density-potential coupling in the interplay of zonal-flow and intermittency formation — •Lilian Harumi Yoshida, Mirko Ramisch, and Ralph Sarkis — IGVP, University of Stuttgart, Germany

The destabilization of density perturbations in drift-wave turbulence is based on the decoupling of density ($\tilde{n}$) and potential ($\tilde{\phi}$) fluctuations. This decoupling mechanism is promoted by electron collisionality, which in turn tends to change the turbulent behaviour from adiabatic into a hydrodynamic one, where density becomes passively advected and resembles the intermittent vorticity. Decoupling is also intrinsic to the interchange drive of filamentary, intermittent density structures - so-called blobs - in the scrape-off layer (SOL). In contrast to blobs, strong coupling is essential for the Reynolds-stress drive of zonal-flows (ZF). However, recent studies showed a causal link between blob detachment from the bulk plasma and ZF generation inside the separatrix. In this experimental work, multiple Langmuir-probe arrays are used at the TJ-K stellarator to untangle the interplay of $\tilde{n} - \tilde{\phi}$ coupling with ZF and intermittency formation. Conditional sampling reveals a temporal correlation between net turbulent particle flux and zonal intermittency levels, which is in-line with the associated drift-wave destabilization. Furthermore, the coupling and intermittency dynamics across the separatrix is examined, shedding light on the role of blobs in ZF formation.

P 16.88 Thu 13:45 Redoutensaal

ECRH as a candidate for electron temperature and -density profile shaping towards confinement improvements in W7-X — •Melina Arvanitou, Matthias Hirsch, Kai Jakob Brunner, Neha Chaudhary, Golo Fuchert, Juan Fernando Guerrero Arnaiz, Vaishnavi Murugesan, Miklos Vecsei, Gavin Weir, Robert Wolf, and The W7-X Team — Max Planck Institute for Plasma Physics

At present T_i gradient clamping inhibits the establishment of high-confinement regimes in Wendelstein 7-X (W7-X) plasmas. Overcoming this constraint requires finite density gradients at mid-radius, which are believed to suppress ITG turbulence. Although achievable with deep fueling by Neutral Beam Injection (NBI) and pellets, both methods pose challenges for reactor-scale implementation. Since Electron Cyclotron Resonance Heating (ECRH) is already envisaged as the primary heating system in future reactor-scale stellarator concepts, any intrinsic profile-shaping capability would represent a built-in advantage for optimizing confinement. ECRH is well known to provide control over the T_e-profile while simultaneously impacting particle and impurity transport through mechanisms such as density pump-out. On- and off-axis application of localized X2 ECRH has been conducted to investigate its profile-shaping properties, with the resulting density and temperature profiles provided by Thomson scattering (TS) and alkali metal beam spectroscopy. Small heat-wave-like temperature perturbations in the Electron Cyclotron Emission (ECE) traveling away from the ECRH deposition zone indicate an associated transport effect.

P 16.89 Thu 13:45 Redoutensaal

Core neutral density measurements from Balmer-α emission at Wendelstein 7-X — •Lucas Nitzsche[1], Sebastian Bannmann[1], Oliver Ford[1], Felix Reimold[1], and Robert Wolf[1,2] for the w7-x team-Collaboration — [1]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Technical University of Berlin, Strasse des 17.Juni 135, 10623 Berlin, Germany

Wendelstein 7-X (W7-X) is a current state-of-the-art magnetic confinement fusion device of the stellarator type.

It was shown at W7-X, that the energy confinement time of its plasmas depends strongly on their density profile shape. This in turn is linked directly to controlling and knowing the particle-transport. Although the particle fueling of recycling neutrals into the confined region is an important quantity in corresponding calculations, it is not routinely measured and must be approximated by simplified modeling. Accessing this particle fueling is possible by measuring the density of neutral particles n_0 inside the plasma and combining it with ionization rates.

In this work, passive Balmer-α emissions from the confined region are analysed to estimate n_0-profiles along each measured line-of-sight (LOS). The previous modeling of the emissions was improved by including charge-exchange-reactions in the emission coefficients. From the evaluations, the n_0-distributions inside W7-X plasmas were estimated and compared to modeling with EMC3-EIRENE. Results are compared for two spectrometers at different toroidal positions at W7-X.

P 16.90 Thu 13:45 Redoutensaal

hybrid kinetic-MHD simulations of energy-dependent effects of runaway electron beams on MHD Instabilities — •Shijie Liu, Hannes Bergstroem, Haowei Zhang, and Matthias Hoelzl — Max Planck Institute for Plasma Physics,Garching b.m., Germany

Runaway electrons (REs) are of particularly importance to the safe operation of tokamaks. Electrons may be accelerated by the large toroidal electric field arising during a major disruption. Without adequate mitigation measures, these energetic electrons may eventually hit the first wall of the device focusing on an extremely localized area, which poses a serious threat to the safe operation of the device. To predict the runaway dynamics during a disruption and develop mitigation strategies, the mutual interaction between REs and the bulk plasma should be carefully considered.

In a cold plasma with a high-energetic runaway beam, the equilibrium cannot be force-free, and the RE curvature drift introduces an energy-dependent outward shift of magnetic flux surfaces. We investigate how these RE-induced orbit shifts affect both linear and nonlinear MHD instabilities, with a particular focus on tearing modes. A poloidal mode coupling mechanism is now observed due to (1,0) component of the RE curvature drift. Future work will extend efforts by comparing the resistive layer width with the characteristic width of RE orbits.

P 16.91 Thu 13:45 Redoutensaal

Turbulent Transport Mechanism in Island Divertors — •Ralph Sarkis[1], Mirko Ramisch[1], and Peter Manz[2] — [1]IGVP, University of Stuttgart, Germany — [2]Institute of Physics, University of Greifswald, Germany

Island divertors have demonstrated strong promise in controlling particle and heat exhaust. Considering the long parallel and short binormal connection lengths at the island divertor, it becomes clear that transport in the binormal direction plays an important role. This can broaden perturbations and modify the convective and diffusive transport, ultimately determining the divertor heat and particle flux pattern. In this contribution, we present an overview of an envisaged research project dedicated to the understanding of the fundamental dynamics in island divertors. This objective will be pursued through an integrated experimental and computational approach, jointly carried out by research groups at the University of Stuttgart and the University of Greifswald, thereby combining complementary expertise in diagnostics, modeling, and theoretical analysis to achieve a comprehensive understanding of transport in the island divertor.

P 16.92 Thu 13:45 Redoutensaal

Influence of Flow Shear Modulation on Turbulent Transport Regulation — •Carmen Sofia Vergara Interian, Mirko Ramisch, and Ralph Sarkis — IGVP, University of Stuttgart, Germany

In magnetically confined toroidal plasmas, zonal flows play a crucial role in regulating the cross-field turbulent transport. While this relation has been widely established, the detailed interrelation of transport with flow shear modulation has yet to be clarified. Hence, the spatiotemporal evolution of turbulent particle transport, together with the scale-resolved density and potential power distributions, is experimentally investigated with respect to modulation in the zonal potential as measured by a Langmuir probe array at the TJ-K stellarator. Contrary to positive zonal potential amplitudes, negative potentials are found to be associated with an increased particle flux, pointing to a weakened shear effect. Moreover, the density power spectrum reveals a cascading-like redistribution of power from small to large scales. This could indicate a mechanism in which turbulence both drives and responds to modulation in zonal potential. The effects of negative and positive zonal potential events are compared on the basis of their characteristic time scales and their influence on density-potential coupling with respect to the turbulent particle flux in magnetically confined fusion plasmas.

P 16.93 Thu 13:45 Redoutensaal

Study of boronization history effects on impurity control in Wendelstein 7-X — •Pei Ren[1,3], Yunfeng Liang[1,3], Shuai Xu[1], Frederik Henke[2], Alexander Knieps[1], Maciej Krychowiak[2], Birge Buttenschön[2], Alice Bonciarelli[2], Sebastijan Brezinsek[1], Dorothea Gradic[2], Daihong Zhang[2], Carsten Killer[2], Luo Yu[1,3], Marcin Jakubowski[2], Petra Kornejew[2], and Erhui Wang[1] for the w7-x team-Collaboration — [1]Institute of Fusion Energy and Nuclear Waste Management, Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Max Planck Institute for Plasma Physics, Greifswald, Germany — [3]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, Düsseldorf, Germany

Boronization is routinely applied for wall conditioning on W7-X, significantly improving plasma performance. This work investigates the history effects on impurity control using visible and UV spectroscopy. Results show that boronization strongly suppresses oxygen impurities, and although this effect gradually weakens, overall impurity control remains robust. Spearman correlation analysis indicates that, over time, oxygen impurity radiation becomes decoupled from total radiation, while carbon sputtering reaches a steady state. Analysis of OP2.2 data under identical conditions 1 day, 2 days, and 2 weeks after fresh boronization shows consistent trends: oxygen radiation slightly increases over time but remains within controlled levels. These findings confirm that multiple boronizations effectively maintain good wall conditioning.

P 16.94 Thu 13:45 Redoutensaal

Measurement of electron-temperature dynamics in TJ-K plasmas — •Rimae Lamara Mhend, Alf Köhn-Seemann, and Mirko Ramisch — IGVP, University of Stuttgart, Germany

Heat-flux analyses for energy confinement studies in magnetized plasmas require the resolution of the fast plasma-temperature dynamics. While the electron temperature T_e can be deduced from swept Langmuir probes, extending this procedure to time scales in the microsecond range is experimentally challenging. A simple approach using a triple probe diagnostic system, measuring the potential of a biased double probe against that of a single floating probe, provides direct access to fluctuations in T_e. In this work, a triple probe is set up for use in the magnetized plasmas of the torsatron TJ-K and tested against swept single-probe characteristics. Statistical properties of T_e fluctuations measured along radial profiles are presented and characterized under variation of the drift scale $\rho_s = \sqrt{T_e M_i}/eB$ for ion masses M_i ranging from hydrogen over helium to argon.

P 16.95 Thu 13:45 Redoutensaal

Preliminary study of boronization effect on divertor density regime in the standard configuration on W7-X — •Muzhi Tan[1,2], Shuai Xu[1], Yunfeng Liang[1,2], Yu Luo[1,2], Pei Ren[1,2], Yuhe Feng[3], Detlev Reiter[1], Daihong Zhang[3], Arun Pandey[3], and Golo Fucher[3] for the w7-x team-Collaboration — [1]Forschungszentrum Jülich GmbH, IFN-1 Plasma Physics, Jülich, Germany — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf, Germany — [3]Max-Planck-Institute für Plasmaphysik, Greifswald, Germany

Boronization is widely applied in magnetic confinement devices to sustain high-performance, steady-state plasma operation. In this work, we present a preliminary study of the boronization effect on divertor density regimes by comparing two density-ramp discharges with identical ECRH heating power (3 MW). Experimental observations show that boronization significantly suppresses intrinsic oxygen impurity sources. Before boronization, the downstream ion saturation current (Isat) increases slightly with rising radiated power; after boronization it rises much more rapidly and exhibits a clear roll-over when the radiation fraction exceeds 50%. Motivated by these experimental trends, EMC3-EIRENE simulations were performed to assess the impact of boronization on divertor density regimes. By comparing impurity transport at the same radiated power, simulations illustrate how oxygen influences the transition of divertor density regime. Simulations without oxygen impurities reproduce the Isat roll-over and highlight the beneficial role of boronization on modifying transport in W7-X.

P 16.96 Thu 13:45 Redoutensaal

First L-Mode experiments in Alternative Divertor Configurations in ASDEX Upgrade — •Felix Albrecht[1,2], Dominik Brida[1], Ou Pan[1], Tilmann Lunt[1], Michael Faitsch[1], Bernhard Sieglin[1], and ASDEX Upgrade Team[3] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Physics Department, Garching, Germany — [3]see author list of H. Zohm et al. 2024 *Nucl. Fusion* **64** 112001

All fusion devices need to exhaust the plasma heating power in a separate region from the core plasma called the divertor. There, most of the heat flux must be radiated away through plasma-neutral interactions, typically by seeded impurities, to protect the divertor target plates. If the impurity concentration is high enough, a favorable state of detachment can be reached, where the plasma recombines in front of the target. However, the required impurity concentrations might be too high for good core performance. Recent hardware upgrades in the tokamak ASDEX Upgrade enable access to alternative divertor configurations (ADCs), a possible solution to facilitate detachment with less impurities. Through increased flux expansion at the target (X-divertor, XD) or the introduction of another X-point in the divertor plasma (snowflake minus, SF^-), ADCs have been shown in other machines to be favorable for detachment *[Theiler NF 2017]*.

We present the first L-Mode experiments in ASDEX Upgrade with ADCs. In XD and SF^-, an earlier detachment of the primary strikepoint compared to single null was found. The results are interpreted with the plasma and neutral transport code SOLPS-ITER.

P 16.97 Thu 13:45 Redoutensaal

Towards the Application of the Gyrokinetic Code GENE-X to Tokamak and Stellarator Scrape-Off Layer Turbulence — •Yantong Tao[1], Philipp Ulbl[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

Predicting heat loads in the scrape-off layer (SOL) is a major challenge for future fusion divertors, largely due to the complex interplay between turbulence and boundary plasma physics. Gyrokinetic simulations provide a powerful tool for investigating SOL turbulence; however, their predictive capability critically depends on the incorporation of plasma sheath physics at the divertor targets. The plasma sheath plays a key role in regulating turbulent transport and heat exhaust, and its proper treatment is therefore crucial for reliable heat flux predictions and divertor design.

In this work, we will apply sheath boundary conditions to the full-f gyrokinetic turbulence code GENE-X in full tokamak and stellarator geometry, and present some preliminary results. Since the sheath structure cannot be fully resolved in gyrokinetic simulations, we start from a reduced sheath model that captures the essential physics while omitting the sheath complexity at the same time. Then we will study the impact of sheath boundary conditions and compare the results with TCV-X21 validation case.

P 16.98 Thu 13:45 Redoutensaal

Neural network surrogate-assisted Bayesian inference for input parameter of edge plasma simulations — •Yu Luo[1,2], Shuai Xu[1], Yunfeng Liang[1,2], Erhui Wang[1], Jianqing Cai[1], Yuhe Feng[3], Detlev Reiter[2], Alexander Knieps[1], Sebastijan Brezinsek[1,2], Derek Harting[1], Maciej Krychowiak[3], Dorothea Gradic[3], Pei Ren[1,2], Daihong Zhang[3], Yu Gao[3], Golo Fuchert[3], Arun Pandey[3], and Marcin Jakubowski[3] for the w7-x team-Collaboration — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — [2]Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany — [3]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

We present a neural network-accelerated workflow to efficiently infer EMC3-EIRENE input parameters from measurements on Wendelstein 7-X. A database of 3D EMC3-EIRENE edge-transport simulations is generated by varying key inputs, and a feed-forward neural-network surrogate is trained to map parameters to synthetic diagnostic signals. Embedded in a Bayesian inference framework with Dynamic Nested Sampling, the surrogate enables fast likelihood evaluations, explicitly incorporates diagnostic uncertainties, and yields posterior distributions and maximum a posteriori (MAP) estimates. EMC3-EIRENE simulations at these MAP parameters reproduce the measurements while greatly reducing computational cost and manual tuning, and the approach is transferable to other modeling tools.

P 16.99 Thu 13:45 Redoutensaal

Transient non-equilibrated plasma phases in the Wendelstein 7-X stellarator — •Christian Brandt, Charlotte Büschel, Edith Victoria Hausten, Kian Rahbarnia, Henning Thomsen, Sara Vaz Mendes, Tamara Andreeva, Martin Clifton Kelly, Ulrich Neuner, and Pedro Pons Villalonga — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Selected Wendelstein 7-X stellarator plasmas are investigated far away from an equilibrium state in certain experimental scenarios. A stable plasma phase was actively perturbed, e.g. by heating power steps, the injections of cryogenic pellets or impurities. Moreover, internal events temporarily destabilized the plasma, triggered by MHD instabilities. Analysis of highly spatiotemporally resolved soft X-ray (SX) tomographic measurements help to understand these transient phases by studying the topologic evolution of the SX emissivity in a poloidal cross section. An experimental survey of several types of transient phases analyzed by SX tomography is presented. Besides details of the plasma startup phase – sometimes accompanied by mode activity – we focus on the stability of high energy plateau phases.

P 16.100 Thu 13:45 Redoutensaal

High Frequency Dispersion Interferometry for Alfvén Mode Studies — •Vineeta Nair — Max Planck Institute for Plasma Physics, Greifswald

Dispersion interferometry is emerging as a preferred diagnostic for measuring line-integrated electron density in many fusion devices, offering a robust alternative to the traditional dual-color interferometers because its phase measurements are inherently immune to mechanical vibrations of optical components. At Wendelstein 7-X (W7-X), a phase-modulated dispersion interferometer based on a continuous-wave CO2 laser (10.6 μm) serves as the standard electron density diagnostic. Phase modulation in the current diagnostic setup is performed using a photo-elastic modulator, which offers a good modulation depth (ρ), but is limited to modulation frequencies (ωm) of only a few kHz due to its mechanical resonance based modulation. With the current diagnostic, fluctuations in electron density can be measured only up to 50 kHz. To investigate several instabilities*such as MHD modes, kinetic ballooning modes, and fast-ion*driven Alfvén modes*it is essential to extend the capabilities of the standard single-channel dispersion interferometer to a high-frequency, multi-channel system capable of localized electron density measurements. To achieve higher modulation frequency, a 40 MHz GaAs electro-optical modulator is planned for implementation. Using multiple plasma sightlines together with appropriate inversion techniques will allow spatially resolved, high-frequency electron density fluctuation measurements. This poster will outline the project plan, present the current status, and discuss the main technical challenges.

P 16.101 Thu 13:45 Redoutensaal

Quantification of tungsten content in Wendelstein 7-X — •Birger Buttenschön, Daihong Zhang, Christian Brandt, Felix Reimold, and W7-X Team — Max Planck Institute for Plasma Physics, Greifswald, Germany

The high-Z material tungsten (W) is one of the most promising candidates for the use as first wall material in magnetic confinement fusion devices. Its capability to bear high particle and energy loads makes it ideal for the first wall. However, plasma-wall interaction can release W into the confined plasma, where even small impurity concentrations give rise to significant radiative power losses. Especially in a stellarator, which tends to accumulate impurities in relevant scenarios, the knowledge of tungsten sources and transport and the control of total tungsten concentration is crucial for reliable high performance operation.

In this contribution, we present our current knowledge about the W content in Wendelstein 7-X (W7-X) plasmas. The evaluation comprises deliberate impurity injections, interpretation of the radiation structures observed by bolometry and x-ray tomography, and finally an estimate of the background intrinsic tungsten concentration during standard W7-X operation.

P 16.102 Thu 13:45 Redoutensaal

JANUS: a composite HTS tape for improved magnetic field performance — •Titouan Atane, Paul Huslage, and Eve Stenson — Max-Planck-Institut für Plasmaphysik, Garching b. München, Germany

ReBCO (Rare-earth barium copper oxide) high-temperature superconducting (HTS) tapes are a promising technology for the generation of strong magnetic fields (with potentially reduced cryogenic cooling requirements). Due to anisotropy of the crystal lattice however, the critical current (I_c) is strongly dependant on the magnetic field angle (θ) as well as magnetic field strength ($|\mathbf{B}|$), which puts challenging constraints on coil optimization and manufacturing, particularly for non-planar coils (often used, e.g, in stellarator design). To solve this problem, the proposed JANUS composite tape consists of two HTS tapes (with different I_c vs θ orientations) soldered together. This concept can allow for a higher critical current, and it can make JANUS more robust against coil manufacturing errors. It is planned to further develop initial feasibility calculations to get a reliable description of the tape's response in a coil winding pack, then validate these experimentally.

P 16.103 Thu 13:45 Redoutensaal

Electric Field Reconstruction via Impurity-Induced Rotation in Wendelstein 7-X — •Thomas Wegner, Henning Thomsen, Christian Brandt, and the W7-X Team — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

In stellarators, a self-generated radial electric field arises to fulfill ambipolarity and strongly shapes neoclassical transport by modifying particle orbits through the resulting ($E \times B$) drift. In this contribution, we present an experimental method to infer the radial electric field from the dynamics of impurities injected via laser blow-off and analyzed through tomographic inversion of line-integrated soft-X-ray measurements. The analysis of the poloidal motion of the resulting radiation pattern, driven by the $(E \times B)$ drift, enables a reconstruction of the radial electric field. This method is applied and compared across similar plasma scenarios with forward and reversed magnetic field configurations.

P 16.104 Thu 13:45 Redoutensaal

Localized probe measurements across magnetic islands: implications for divertor operation in W7-X — •Alice Bonciarelli[1], Carsten Killer[1], Olaf Grulke[1], Alexander Knieps[1,2], Yu Gao[1], Sebastian Thiede[1], Marcin Jakubowski[1], Arun Pandey[1], and W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management, Plasma Physics, 52425 Jülich, Germany

The optimized stellarator Wendelstein 7-X (W7-X) employs an island divertor. In this configuration, the scrape-off layer (SOL) is organized by a chain of resonant magnetic islands, which intersect the divertor targets placed accordingly. The latter act as a heat and particle exhaust system. The energy and particle transport processes are particularly challenging to disentangle in the complex three-dimensional magnetic geometry of the island divertor SOL. To investigate these complex edge regions, a suite of diagnostics is used, including a multi-user platform for reciprocating Langmuir probe measurements, that provides highly localized measurements of electron temperature and density as well as floating potential with high temporal resolution. The measurements indicate a complex distribution of plasma parameters in the island SOL, with well-localized features that presumably correlate to the island geometry and connection length distribution. By tracing magnetic field lines from the reciprocating probe sampling region to the divertor targets, local SOL measurements can be directly linked to divertor heat fluxes and plasma parameters.

P 16.105 Thu 13:45 Redoutensaal

Development of a Synthetic Helium Beam Diagnostic at ASDEX Upgrade — •Pietro Pecchini, Michael Griener, Sebastian Hoermann, Wladimir Zholobenko, Kaiyu Zhang, and Ondrej Grover — Max Planck Institute for Plasma Physics, Garching

Turbulent plasma behavior in the edge and scrape-off layer is a key factor for magnetic confinement fusion. Physics-based plasma boundary codes like GRILLIX, based on a two-fluid description of the plasma, can model these dynamics by simulating fundamental plasma parameters, such as electron density and temperature. However, experimental diagnostics - such as the helium beam diagnostic - measure derived quantities like spectral line emission intensities, making a direct comparison of measurement and simulation outputs challenging. To quantitatively validate the code output with experimental data, a synthetic helium beam diagnostic that translates simulation outputs into experimentally accessible signals is developed. A first implementation of this synthetic diagnostic for ASDEX Upgrade GRILLIX simulations is presented, and its performance is evaluated by comparing it with simplified models to quantify the impact of key effects. The importance of computing the ionization of the helium, considering simultaneously the time evolution of both helium particles and plasma, is investigated. The synthetic emission profile is decomposed to illustrate its dependence on electron density, helium density, and photon emissivity coefficients, for both an individual spectral line and the ratio between two spectral lines.

P 16.106 Thu 13:45 Redoutensaal

Absorption of high-intensity laser pulses in plasma gratings — •Sophie Opara and Götz Lehmann — Heinrich-Heine-Universität, Düsseldorf

Plasma transmission gratings are transient, periodic density structures in underdense plasmas that enable the manipulation of high-intensity laser pulses beyond the damage threshold of conventional solid-state optics. They are generated by the ponderomotive force of interfering driving pulses and can be reproducibly created on a shot-to-shot basis. With lifetimes on the picosecond timescale, they are well suited for controlling high-power femtosecond laser pulses. Potential applications include polarizers, wave plates, Bragg-type mirrors, and holographic lenses, among many others.

The optical response of these gratings is governed by their grating period, modulation depth, and plasma parameters, which in turn determine their transmission, reflection, and absorption characteristics. At sufficiently high intensities, a probe laser pulse can modify the density modulation and excite collective plasma dynamics, leading to energy absorption. This work investigates the absorption mechanisms in plasma transmission gratings and their dependence on laser and plasma parameters such as wavelength and plasma density. The results provide guidelines for their use either as efficient beam blockers or as low-loss, damage-free optical elements for high-intensity laser systems.

P 16.107 Thu 13:45 Redoutensaal

Laser pulse duration as a key parameter in plasma grating formation — •Götz Lehmann and Karl-Heinz Spatschek — Heinrich-Heine-Universität, Düsseldorf

Prompted by early experimental realizations of plasma-optical components, we examine how finite formation times affect the quality and scaling behavior of a plasma grating induced by the ponderomotive potential of two counter-propagating pump laser beams. Besides the plasma density, the ratio of thermal to ponderomotive pressure is known to be an important factor. Via full Vlasov simulations we show that the ratio of the laser pulse duration to the characteristic ion reaction time is another important parameter. These simulations also reveal that (linearized) kinetic models for electron-temperature-dependence need to be extended in order to recover the correct behavior for gratings generated by short laser pulses. A generalized simple hydrodynamic model allows to study the dependence of the grating amplitude on the pump laser amplitude a_0.

P 16.108 Thu 13:45 Redoutensaal

Particle Acceleration and Emission Signatures in Relativistic AGN Jets — •Nikita Nikita, Frank Rieger, and Frank Jenko — Max Planck Institut für Plasmaphysik

Relativistic jets from active galactic nuclei (AGNs) are among the most energetic phenomena in the universe, extending over kilo-parsec scales and interacting with their surrounding environment in highly complex ways. These jets develop complex structures through different MHD instabilities and turbulence, which strongly influence non-thermal particle acceleration in these systems. Using 3D RMHD simulations with PLUTO, we investigate jet-driven turbulence as a site for stochastic (second-order Fermi) acceleration in regimes where strong shocks are absent and magnetization is sufficient for stochastic processes to become relevant . We explore a semi-analytical treatment of turbulent acceleration and examine how different prescriptions for momentum diffusion coefficients and escape timescales shape the particle energization and the resulting spectra. By coupling these models to synthetic synchrotron emission, we aim to examine how variations in diffusion physics manifest in observable radio signatures from active galaxies, providing new constraints on the physical processes underlying particle acceleration in large-scale AGN jets.

P 16.109 Thu 13:45 Redoutensaal

energy dissipation in collisionless shocks: MMS observations — •Valentina Villaflor, Artem Bohdan, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

Collisionless shocks play a key role in space and astrophysical plasmas, enabling the conversion of large-scale kinetic energy into heat and non-thermal particle populations without relying on binary Coulomb collisions. Instead, these shocks are sustained by collective effects such as wave-particle interactions that are inherently kinetic and nonlinear. Despite significant observational and theoretical efforts, the precise mechanisms of energy dissipation in collisionless shocks remain debated. While it is widely accepted that dissipation occurs within the shock ramp, observations have shown that energy conversion may also extend involving other shock structures.

We analyze high-resolution measurements from the Magnetospheric Multiscale (MMS) mission across multiple quasi-perpendicular bow shock crossings. We quantify energy contribution of different particle species within a vicinity of the shock ramp to analyze energy transfer among electrons, ions. By correcting the measured ion and electron distribution functions for instrumental effects, we isolate the energy contributions of each species and examine how they vary throughout the shock structure. We calculate the theoretically expected values for thermal energy from mass conservation principles and Rankine-Hugoniot conditions to analyze the observed deviation from adiabatic behavior in collisionless shocks. Finally, we discuss how energy transfer between species depends on various shock parameters.

P 16.110 Thu 13:45 Redoutensaal

First interpretative local ERO2.0 modelling of tungsten erosion experiments at W7-X — •Claudio Maria De Simone[1], Chandra-Prakash Dhard[1], Dirk Naujoks[1], Juri Romazanov[2], and Sebastijan Brezinsek[2] — [1]Max-Planck Institute for Plasma Physics, Wendelsteinstrasse 1, 17491 Greifswald, Germany — [2]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany

Tungsten has been chosen as the most promising material for plasma-facing components (PFCs), in future fusion devices, due to its favorable thermo-mechanical properties, low fuel retention, and low sputtering. While in tokamak devices tungsten erosion, deposition and transport has been extensively investigated, in stellarators such studies remain limited. This work aims to extend PWI knowledge for W7-X with the use of ERO2.0 developed by FZJ. This 3D Monte-Carlo is used to model local W erosion and migration for some baffle modules equipped with W tiles. Different 3D plasma solutions and scenarios as generated by EMC3-EIRENE will be used as an input for ERO2.0 modeling. A material-mixing model will be applied to consider the change of W surface concentration due to the impact of carbon impurity ions. The results of these simulations will be validated against in-situ spectroscopy and post-mortem analysis of exposed samples.

P 16.111 Thu 13:45 Redoutensaal

Evaluation of wall boiling models for plasma facing components — •Ahmet Kilavuz[1,2], Jeong-Ha You[2,3], Bosjan Koncar[4,5], and Rudolf Neu[1,2] — [1]Technical University of Munich — [2]Max Planck Institute for Plasma Physics — [3]University of Ulm — [4]Jožef Stefan Institute — [5]University of Ljubljana

Subcooled flow boiling in fusion-device cooling channels can occur under conditions far beyond those of conventional nuclear applications, with plasma-facing components exposed to heat fluxes up to 40 $\mathrm{MW\,m^{-2}}$ and mass fluxes approaching 20,000 $\mathrm{kg\,m^{-2}\,s^{-1}}$. This study compares several wall-boiling models, including the Rensselaer Polytechnic Institute (RPI) model and the Massachusetts Institute of Technology Boiling (MITB) model, together with multiple bubble-parameter correlations, against fusion-relevant high heat- and mass-flux experiments. The RPI model shows intrinsic limitations at high mass fluxes, producing non-physical negative boiling-curve slopes within the partially developed nucleate boiling regime. It is suggested that this behaviour cannot be corrected by adjusting bubble-parameter correlations. The MITB model mitigates these issues through a sliding-conduction mechanism that scales with flow velocity, which is particularly important at high mass fluxes. This leads to more physically consistent behaviour and reduces the mean absolute error by approximately 65% compared to generic wall-boiling formulations.

P 16.112 Thu 13:45 Redoutensaal

Testing of Tungsten-Copper Joints for Plasma-Facing Components by Means of Cyclic High Heat Flux Loading — •Simone Cocchi[1,2], Alexander von Müller[2], David Dellasega[1], Robert Lürbke[2,3], Ahmet Kilazuv[2,3], Julien Schachter[2], Johann Riesch[2], and Bernd Böswirth[2] — [1]Politecnico di Milano, 20156 Milan, Italy — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]Technical University of Munich , 85748 Garching, Germany

In magnetic-confinement fusion devices, plasma-facing components (PFCs) have to face extreme heat loads. Decades of plasma-wall interaction research point to a design with plasma-facing tungsten tiles joined to a copper (Cu)-based heat sink. In so-called "flat-tile" configurations, thermal gradients and the coefficient of thermal expansion (CTE) mismatch between W and Cu induce critically high stresses at the material interface, often leading to component failure. To mitigate this, tailored W-Cu interfaces represent a possible solution to improve PFCs durability - now possible due to developments in additive manufacturing technologies. An experimental design was devised to test relevant W-Cu joint specimens under high heat loads. FEA simulations were conducted to model thermomechanical loading at the flat-tile joint, aiding design of a dedicated mock-up joint geometry for testing under thermal cycling in the high heat flux test facility GLADIS. Results were obtained for DEMO-relevant tile dimensions with different interface architectures.

P 16.113 Thu 13:45 Redoutensaal

Investigation of Grain Boundary Transport in Tungsten by Hydrogenography — •Fahrudin Delic[1,2], Armin Manhard[2], and Udo von Toussaint[2] — [1]Technical University of Munich, Munich, Germany — [2]Max Planck Institute for Plasma Physics, Garching, Germany

The permeation of deuterium through grain boundaries in tungsten was studied on recrystallized foils using the hydrogenography method, employing tungsten trioxide as a hydrogen indicator. The temperature dependence of grain boundary transport was analyzed on 50 μm foils up to 700 K, revealing an overall increase in permeation activity with rising temperature. At around 630 K, a distinct *halo* structure forms around several grain boundaries, indicating the onset of deuterium desorption from the boundaries and the gradual transition toward bulk-dominated permeation. To investigate geometrical influences on permeation behavior, the 50 μm results were compared with measurements on 25 μm foils. In thinner foils, the grain geometry facilitates bulk transport, and a depletion region of hydrogen permeation around certain grain boundaries becomes visible. The hydrogenography analysis is furthermore complemented by grain orientation mapping via EBSD.

P 16.114 Thu 13:45 Redoutensaal

Exploiting Tungsten Fibre-Reinforcement for Plasma-Facing Component Design — •Thomas Fox[1,2], Alexander von Mueller[1], and Rudolf Neu[1,2] — [1]Technical University Munich, Boltzmannstr. 15, 85748 Garching — [2]Max Planck-Insitute for Plasma Physics, Boltzmannstr. 2, 85748 Garching

The divertor of a magnetic confinement fusion device has extreme requirements for materials design due to the high heat fluxes combined with plasma erosion and neutron flux considerations. Current leading designs centre around tungsten (W) surface armouring joined to a copper (Cu)-based heat sink. The mismatch in coefficient of thermal expansion (CTE) between these base materials leads to high thermomechanical stresses during heat loading that can cause cracking and delamination of the W armouring. This can significantly hamper the performance and shorten the service lifetime of a divertor plasma-facing component (PFC).

In this work, a design will be presented, in which W-fibre reinforcement will be utilised to mitigate the CTE mismatch while also strengthening and toughening the W/Cu joint with cross-interface connections. By taking advantage of textile processes, complex fibre preforms can be constructed out of ductile, potassium-doped W fibres. These preforms can first undergo chemically vapour infiltration of W and then melt infiltration of Cu or Cu-based alloys for creating a highly damage resistant fibre-reinforced composite PFC design. The overall goal of this work is to design, manufacture and test a scalable concept that meets the extreme requirements of a fusion reactor divertor.

P 16.115 Thu 13:45 Redoutensaal

Dynamic evolutions of radiation and divertor target behavior during detachment with an island divertor configuration on J-TEXT — •Yutong Yang[1], Yunfeng Liang[1,2], Wei Yan[2], Jiankun Hua[2], and Song Zhou[2] — [1]Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management Plasma Physics, Jülich, Germany — [2]International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, China

On J-TEXT, the temporal evolution of the heat flux distribution on the divertor plate has been measured using an infrared camera with an island divertor configuration. In previous experiments employing this configuration, partial detachment was achieved by SMBI gas fuelling when the radiation front approached the last closed flux surface (LCFS). This observation is consistent with the results obtained on the W7-X stellarator. We conducted a series of experiments under different island divertor configurations to further validate this conclusion. By reconstructing the 2D radiation profile using AXUV arrays, we investigated the dynamic characteristics of edge radiation, heat and particle fluxes on divertor target during the detachment. The results highlight the critical role of magnetic topology in the onset and development of detachment, providing important insights into realizing stable detachment under 3D boundary conditions.

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Additive manufacturing for tailored tungsten copper joints in plasma-facing components — •Alberto Ambrogini[1,2], Alexander von Müller[1], and Rudolf Neu[1,2] — [1]Technical University of Munich — [2]Max Planck Institute for Plasma Physics

Additive manufacturing (AM) technology has progressed significantly in recent years and holds the potential to become a decisive technology for the fabrication of plasma-facing components (PFCs). In highly heat loaded divertor PFCs, issues regarding the joining of plasma-facing tungsten materials with copper based heat sink materials represent a major engineering challenge, considering the differing thermomechanical properties of these two materials. Under heat flux loadings in magnetic confinement fusion devices, this leads to stress concentrations at the joining interface, that in turn can lead to undesired failure of PFCs. One possible solution for improving such material joints is the tailoring of the interface between the two materials with the help of AM that enables control of the geometry, composition, and microstructure at the interface. This allows the creation of a tailored interfacial region where common failure mechanisms, like joint delamination, might be avoided. The contribution will present relevant AM technologies considered to be suitable for the realisation of tailored tungsten-copper interfaces and approaches to the design of such joints. Furthermore, plans for their testing under relevant loading situations will be outlined.

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Quantum kinetic methods for dense quantum plasmas in nonequilibrium — •Christopher Makait and Michael Bonitz — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

Standard kinetic approaches to plasma dynamics, such as the Boltzmann equation and the Lenard-Balescu equation (LB), face severe limitations when interaction energies, quantum effects, and ultra-short time scales - e.g. induced by intense laser pulses - become relevant [1]. These limitations can be overcome by non-Markovian quantum kinetic approaches such as nonequilibrium Green functions [2], reduced density matrices [3], or quantum fluctuations [4], each with their own advantages and disadvantages, in terms of accuracy and computational effort. Here, we systematically compare Markovian (LB) and non-Markovian results for electrical conductivity and stopping power in dense plasmas, and quantify the impact of non-Markovian memory effects.

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