P 25: Poster III

Time: Thursday 16:30–18:30 Location: ELP 6: Foyer

P 25.1 Thu 16:30 ELP 6: Foyer

Optical damage threshold of plasma density gratings — •Sophie Opara and Götz Lehmann — Heinrich-Heine-Universität, Düsseldorf

Plasma density gratings are periodic structures allowing the manipulation of high-power laser pulses with intensities far beyond the damage threshold level of solid state material. Such structures can be used as e.g. Bragg-type mirrors, polarizers, wave-plates and holographic lenses. The gratings are driven by beating laser pulses in underdense plasma and exist on the timescale of tens of pico-seconds, i.e. sufficiently long to manipulate high-power femto-second pulses. Since they can be re-created for every shot of the high-intensity pulse, they are usually considered as damageless optics.

However, the optical properties of density gratings depend on their periodic structure. Period and modulation amplitude determine their transmissive and reflective properties. Sufficiently strong laser pulses can manipulate the density distribution via their ponderomotive force and thus change the optical properties. The presented work aims to identify the intensity limit at which the gratings can not be anymore considered static and describe the underlying physical processes going along with the degradation of their structure.

P 25.2 Thu 16:30 ELP 6: Foyer

Uncertainty Quantification for Magnetohydrodynamic Equilibrium Reconstruction: A data driven approach — •Robert Köberl[1,2], Robert Babin[3], and Christopher G. Albert[3] — [1]MPI for Plasma Physics, Garching, Germany — [2]CIT, TU Munich, Garching, Germany — [3]Fusion@ÖAW, ITPcp, TU Graz, Graz, Austria

We report on progress towards a probabilistic framework for uncertainty quantification and propagation in analysis and numerical modeling of physics in magnetically confined plasmas in the stellarator configuration. A frequent starting point in this process is the calculation of a magnetohydrodynamic equilibrium from plasma profiles. Profiles and therefore the equilibrium are typically reconstructed from experimental data. What sets equilibrium reconstruction apart from usual inverse problems is that profiles are given as functions over a magnetic flux derived from the magnetic field, rather than spatial coordinates. This makes it a fixed-point problem that is traditionally left inconsistent or solved iteratively in a least-squares sense. The aim here is towards a straightforward and transparent process to quantify and propagate uncertainties and their correlations for function-valued fields and profiles in this setting. We propose a Bayesian inference framework that utilizes a low dimensional prior distribution of equilibria, constructed with principal component analysis. Additionally, neural-network- and polynomial-regression-surrogates of the forward model for synthetic diagnostics are trained. This enables faster sampling when approximating the posterior distribution of equilibria via Markov chain Monte Carlo sampling.

P 25.3 Thu 16:30 ELP 6: Foyer

Adding fluid neutrals to the gyrokinetic turbulence code GENE-X — •Sabine Ogier-Collin, Philipp Ulbl, Wladimir Zholobenko, and Frank Jenko — Max Planck Institute for Plasma Physiscs, Garching bei München, Germany.

Key objectives in the design of future magnetic confinement fusion reactors are the management of heat and particle exhaust to the wall, as well as optimal core confinement. Understanding the turbulent transport at the boundaries of the confined region, i.e. the plasma edge and the scrape-off layer (SOL), is critical in assessing these objectives. In addition to the main plasma, several ionic impurity species along with molecules and neutral atoms (neutrals) are present, especially in the SOL, and interact with the plasma through a complex set of collision processes. This has several non-negligible effects on the plasma parameters and confinement, e.g. changes in the radial plasma profiles and particle transport across the last closed flux surface.

GENE-X is a gyrokinetic code dedicated to the study of the edge and SOL turbulence in realistic geometries. To improve its predictive capabilities, a neutrals model and the plasma-neutrals interactions are added. The neutrals are evolved using a pressure-diffusion equation and interact with the gyrokinetic plasma through ionisation, recombination and charge exchange channels. The evolution of neutrals has been implemented using a 4th order central finite difference scheme. In a verification study, the order of accuracy has been recovered in multiple geometries including slab, circular and s-alpha. This allows for first test simulations in realistic geometries.

P 25.4 Thu 16:30 ELP 6: Foyer

structure-preserving hybrid code, STRUPHY: energy-conserving hybrid MHD-driftkinetic models. — •Byung Kyu Na[1,2], Stefan Possanner[1], Xin Wang[1], Dominik Bell[2], Yingzhe Li[1], and Nathan Marín[1,2] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Garching, Germany

A Python package STRUPHY (STRUcture-Preserving HYbrid codes) features a collection of PDE solvers based on Geometric finite element method (FEEC) and Particle-in-cell method (PIC). One of the main applications of the STRUPHY is a simulation of hybrid MHD-kinetic systems in curved three-dimensional spaces where the bulk plasma is treated as a MHD fluid and energetic particles(EPs) are described kinetically. We introduce energy-conserving hybrid MHD-driftkinetic models which were newly implemented in STRUPHY. Existing hybrid MHD-kinetic models often suffer from not conserving the total energy, especially when reduced kinetic models are used to describe EPs such as driftkinetic or gyrokinetic. However, this property was recently recovered by adding additional terms derived from variational principles. The investigation of the conservation laws on the discrete level will be considered with the preliminary results of the ITPA benchmark case.

P 25.5 Thu 16:30 ELP 6: Foyer

Numerical methods for stellarator simulations in BOUT++ — •David Bold[1], Brendan Shanahan[1], Jessica Bold[2], and Ben Dudson[3] — [1]Max Plank Institute for Plasma Physics, Greifswald, Germany — [2]University of Greifswald, Greifswald, Germany — [3]Lawrence Livermore National Laboratory, Livermore, California, USA

There is a significant need for reliable modelling of the scrape-off layer of fusion devices, which is challenging for stellarators due to the complex geometry involved. As field aligned approaches are challenging, the Flux Coorinate Independent (FCI) method is often employed.

In the FCI grid generator, Zoidberg, the fidelity to the experimental geometry has been improved, and several improvements have been made to ensure the grid is feasible even with such challenging conditions. At the same time options have been added to reduce the fidelity and improve runtime.

For the BOUT++ framework, a new finite volume operator has been implemented that does not fail in the case of non differentiable contours. The parallel FCI operators have also been rewritten to allow MPI parallelisation of the perpendicular slices, in addition to OpenMP. Scaling will be presented, showing the improved scaling using the new PETSc-based operators. The parallel boundary conditions generally rely on points within the domain to extrapolate into the boundary. However, this breaks down in the case of short connection lengths, where a field line is outside of the domain in the previous and next plane. In this case a lower order scheme is used automatically.

P 25.6 Thu 16:30 ELP 6: Foyer

Linear extended mhd equations in struphy — •Nathan Marin[1,2] and Stefan Possanner[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Technische Universität München, Garching, Germany

In this project, a Finite Elements Exterior Calculus discretization for the linearized homogeneous extended mhd equations is developed and implemented to obtain a solver of arbitrary degree of convergence that simulates plasma behavior. The discretization has been implemented as the newly available LinearExtendedMHD model in struphy ('A python package for energetic particles in plasma, developed since 2019 at Max Planck Institute for Plasma Physics in the Numerical Methods for Plasma Physics division'. Look at https://struphy.pages.mpcdf.de/struphy/index.html for more information about struphy).

The discretization was devised to preserve critical physical quantities that the continuous model conserves (magnetic helicity, energy, and magnetic field's divergence) so the simulation adequately describes the relevant physical phenomena. Finally, the analytical dispersion relation for the extended mhd equation was derived to use it as a test case for the code.

P 25.7 Thu 16:30 ELP 6: Foyer

The STØR experiment - a spherical toroidal magnetic confinement concept applied as a radiation source — •Nils Fahrenkamp, Sebastian Haag, Stefan Knauer, and Peter Manz — Institute of Physics, University of Greifswald, Greifswald, Germany

Extreme Ultraviolet (EUV) lithography is a crucial technology nowadays. EUV light is used to project high-resolution patterns onto silicon wafers, enabling the production of smaller and more powerful microchips. At the desired wavelength lasers are no longer available as light sources, so plasma sources have to be used. They need to generate extremely high power emitted in a very narrow spectral band around 13.5 nm (±0.135 nm, the so-called in-band) in a small source volume necessary for efficient radiation. Laser-produced plasmas (LPPs) prevailed because the discharge-produced plasmas (DPPs) did not achieve the desired parameters of $n_e \sim 10^{24}$ m^{-3} and $T_e \sim 30$ eV. Current state-of-the-art sources use laser irradiated tin (Sn) droplets as emitter because it has strong in-band emission. But a single unit weighs over 180 tons, consumes more than 1 MW electrical power and costs more than 100 million dollars. The inevitable high cost of LPPs means that low-cost or table-top systems will continue to rely on DPPs. Alternative magnetic confinement concepts are particularly well suited as radiation sources, as they contribute to reducing costs and improving accessibility for various research institutions. We present here an experimental setup allowing for magnetically confined compact plasma tori without external toroidal and poloidal magnets. These are ideal properties for a radiation source.

P 25.8 Thu 16:30 ELP 6: Foyer

Overview of mode observations at the Wendelstein 7-X stellarator — •Kian Rahbarnia[1], Ksenia Aleynikova[1], Tamara Andreeva[1], Jan-Peter Bähner[2], Charlotte Büschel[1], Christian Brandt[1], Neha Chaudhary[1], Dario Cipciar[1], Mykola Dreval[3], Carsten Killer[1], Ralf Kleiber[1], Axel Könies[1], Andreas Krämer-Flecken[4], Sara Vaz Mendes[1], Christoph Slaby[1], Adrian von Stechow[1], Henning Thomsen[1], Gavin Weir[1], and Wendelstein 7-X[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]MIT Plasma Science and Fusion Center, Cambridge, MA, USA — [3]Kharkov Institute of Physics and Technology, Kharkov, Ukraine — [4]Forschungszentrum Jülich GmbH, Jülich, Germany

During the recent operational phase OP2.1 at the optimized stellarator Wendelstein 7-X in Greifswald, Germany, a large variety of mode activity in a broad frequency range from about 1-1000 kHz has been observed. This work provides an overview of measurements, which are partly accompanied by theoretical calculations. The focus lays on Alfvénic activity around 200 kHz and potentially fast ion driven modes in plasmas heated by neutral beam injection or ion cyclotron resonance heating. Additionally observations of trapped electron modes are discussed. Mode activity around 10-50 kHz, which is specifically observed in higher beta plasmas, is related to theoretically predicted kinetic ballooning modes and finally low frequency island localized modes around 1 kHz are investigated. Both last aspects might have impact on confinement properties in future highest beta plasmas.

P 25.9 Thu 16:30 ELP 6: Foyer

Development of advanced accumulation techniques for a multi-cell Penning-Malmberg trap — •Martin Singer[1,2], Eve Stenson[3], and Lutz Schweikhard[2] — [1]Institut für Plasma Physik, Greifswald, Germany — [2]Institut für Physik, Universität Greifswald, Germany — [3]Institut für Plasma Physik, Garching, Germany

Penning-Malmberg (PM) traps are employed to accumulate large quantities of charged particles. However, this accumulation in single PM traps is often limited by the space charge. The multi-cell PM trap (MCT) avoids large space charges by distributing the particles into many traps [1]. These small-diameter storage traps are arranged on and off axis next to a large-diameter master trap that is used to catch and bunch of charged particles and to transfer them to the storage traps. The APEX ("A Positron Electron eXperimet") collaboration plans to use the MCT to accumulate unprecedented amounts of positrons. Subsequently, these positrons will be used to form the first confined electron-positron plasma either in the magnetic field of a levitating dipole magnet, or in an optimized tabletop stellarator [2]. This contribution will detail the latest MCT developments, and the techniques developed for the off-axis transfer [3]. We aim for the accumulation of 3×10^9 positrons in each off-axis cell. This will function as a proof of principle for the MCT concept and allow for the accumulation of up to 1×10^{10} positrons, the number needed for the positron-electron plasma creation. [1] D.R. Wittemann, et al. J. Plasma Phys. 89.4 (2023). [2] M.R. Stoneking, et al. J. Plasma Phys. 86.6 (2020). [3] M. Singer, et al. J. Plasma Phys. 89.5 (2023).

P 25.10 Thu 16:30 ELP 6: Foyer

Dynamics of impurity injection events in Wendelstein 7-X stellarator analysed by tomography — •Henning Thomsen, Thomas Wegner, Christian Brandt, Charlotte Büschel, Sara Mendes, Kian Rahbarnia, and W7-X team — Max-Planck Institute for Plasma Physics, Greifswald, Germany

The soft-X-ray tomography system [1] installed in the Wendelstein 7-X stellarator is capable of tracing the spatio-temporal dynamics of plasma perturbations in a poloidal plasma cross-section. The diagnostic has more than 300 lines of sight and a high bandwidth of more than 100 kHz. In this contribution we analyse the dynamics of a laser blow-off injection [2] of a high-Z impurity species into the plasma by means of tomographic inversion of the line-integrated soft-X-ray data. A singular value decomposition of the time sequence of tomographic images clearly shows the poloidal motion of the perturbation following the injection. We find that the propagation is following the direction of the ExB-rotation of the core plasma (the radial electric field in stellarators is predominantly governed by neoclassical transport processes). For sufficiently small plasma perturbation, this technique could be used to experimentally constrain the estimation of the radial electric field profile.

[1] C Brandt et al., Plasma Phys. Control. Fusion 62 (2020) 035010
[2] Th. Wegner et al., Rev. Sci. Instrum. 89 (2018) 073505

P 25.11 Thu 16:30 ELP 6: Foyer

Development of real-time control scheme for power exhaust via impurity seeding in Wendelstein 7-X — •Anastasios Tsikouras[1,3], Felix Reimold[3], Gabriele Partesotti[3], Matthijs van Berkel[2], Jesse T.W. Koenders[1,2], Victoria Winters[3], Valeria Perseo[3], Daihong Zhang[3], Marco de Baar[1,2], and W7-X Team[3] — [1]Eindhoven University of Technology, Eindhoven, Netherlands — [2]DIFFER, Eindhoven, Netherlands — [3]Max Planck Institute of Plasma Physics, Greifswald, Germany

In Wendelstein 7-X (W7-X) real-time control of operational parameters is crucial for the performance of the stellarator. The radiated power is such an operational parameter that can be controlled with injection of gaseous impurities (seeding). This contribution identifies the seeding-radiation dynamics, from the latest W7-X experiments, and optimizes controller parameters for specific operating conditions.

In W7-X, bolometers are used for calculating the total radiated power, which is assessed for control purposes. First, the seeding-radiation response is identified and modelled, by analysing square wave seeding pulses. Then simulations on the dynamics models, show the response of the system and its limits. An error of less than 1% in under 200 milliseconds in tracking a unit step reference is possible for optimized controller parameters, whereas different operational conditions require different control parameters to achieve optimal performance in terms of tracking accuracy and speed. Finally, we outline proposals for the input signal in perturbative experiments to accurately identify the W7-X radiation dynamics in future experiments.

P 25.12 Thu 16:30 ELP 6: Foyer

Theoretical investigation of impurity turbulent transport in W7-X — •Hugo Isaac Cu Castillo[1], Alejandro Bañón Navarro[1], Thilo Romba[2], Felix Reimold[2], Oliver Ford[2], Sebastian Bannmann[2], Péter Zsolt Pölöskei[2], Markus Wappl[2], Adrian von Stechow[2], Frank Jenko[1], and the W7-X team[2] — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

The presence of impurities in the core of fusion plasmas has a detrimental effect on the overall plasma performance via fuel dilution and core cooling through increased radiative losses. While steepened density profiles of the main plasma species, i.e. electrons and hydrogen ions, correlate with high-performance plasmas [1], these scenarios also lead to an undesired accumulation of impurities within the core. Previous experiments conducted under these conditions in the stellarator Wendelstein 7-X (W7-X) appear to indicate that for $\rho < 0.5$, impurity transport can be fully described by neoclassical transport in contrast to the turbulence-dominated transport observed for the main plasma species [2]. This work investigates the physical mechanism for this suppression of turbulent transport of impurities under steep density gradients of the main species using the gyrokinetic code GENE.

[1] S.A. Bozhenkov, et al. Nuclear Fusion 2020, 60: 066011
[2] T. Romba, et al. Nuclear Fusion 2023, 63: 076023

P 25.13 Thu 16:30 ELP 6: Foyer

Plasma termination due to tungsten TESPEL injection in large stellarators — •Hjördis Bouvain[1,2], Andreas Dinklage[1], Naoki Tamura[3], Hiroshi Kasahara[3], Kieran McCarthy[4], Daniel Medina-Roque[4], Hiroe Igami[3], and The LHD Experiment Team[3] — [1]Max-Planck-Institut for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald, Greifswald, Germany — [3]National Institute for Fusion Science, Toki, Japan — [4]Centre for Energy, Environmental and Technical Research, Madrid, Spain

Tungsten is being assessed to replace carbon as material for plasma-facing components in W7-X. In stellarators, it is assumed that exposure to massive amounts of tungsten may lead to thermal quenches but not to current quenches like in tokamaks. Still, a thermal quench releases energy rapidly and localised heat loads may affect the integrity of the plasma facing components. For first quantitative assessments of the impact of thermal quenches in helical devices, the plasma response to massive tungsten TESPEL injections ultimately leading to plasma termination was analysed in LHD. Above a threshold, plasma termination within one energy confinement time is due to the formation of cold fronts propagating from the injection point inwards to the plasma centre. We could show that the application of additional ECRH mitigates the termination process.

P 25.14 Thu 16:30 ELP 6: Foyer

Reduction of maximum gyrokinetic instability growth in maximum-J stellarators — •Paul Costello, Gabriel G. Plunk, and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

For the last decade, it has been known that the growth of many local gyrokinetic instabilities, which cause turbulence, is greatly reduced in stellarators which possess the maximum-J property [1]. This a result from linear, normal mode theory.

Here, we show that this benefit of the maximum-J property is also reproduced by gyrokinetic optimal mode theory [2,3]. In this analysis, upper bounds on the maximum allowable growth of instabilities are derived by finding the perturbations which can instantaneously maximise the growth of an energy measure of the gyrokinetic system. These optimal modes may not maintain their growth indefinitely, but their growth rate is greater than any normal mode in the system. Moreover, the optimal mode growth also bounds the total growth of instabilities in the nonlinear system. We apply this optimal mode analysis to a gyrokinetic system with gyrokinetic ions and bounce-averaged electrons. We construct the optimal modes of the generalised free energy [3] of this system in toy-model magnetic fields and find that those which possess the maximum-J property show a reduced optimal growth rate.

[1] J. H. E. Proll, P. Helander, J. W. Connor, and G. G. Plunk. PRL 2012.
[2] G. G. Plunk and P. Helander. JPP 2022.
[3] G. G. Plunk and P. Helander. JPP 2023.

P 25.15 Thu 16:30 ELP 6: Foyer

Onto Island Localized Modes in the Wendelstein 7-X scrape off layer — •Dario Cipciar[1], Carsten Killer[1], Jiri Adamek[2], Olaf Grulke[3], Kian Rahbarnia[1], Christian Brandt[1], and W7-X Team[1] — [1]Max- Planck-Institut für Plasmaphysik Greifswald, Germany — [2]IPP of the CAS Prague, Czech republic — [3]Technical University of Denmark, Lyngby, Denmark

In the Wendelstein 7-X stellarator scrape off layer, magnetic islands are present and partly intersected by divertor targets. Around the "O-point" of the islands, a region of uninterrupted, closed field lines can remain. Measurements with electric probes indicate that low frequency mode activity, which is also seen by other plasma diagnostics such as magnetics and X-ray tomography, is associated to this particular region. These modes challenge the current picture of the magnetic islands as stationary resonances of the external magnetic field. We investigate the possibility of local currents existing in the islands, which periodically modify the magnetic structure of the islands (compress and expand). These changes in the shape of the islands can lead to self-regulation of island transport channels might and provide an explanation to the observed low-frequency modulation of island density electron and ion temperature, and plasma potential.

P 25.16 Thu 16:30 ELP 6: Foyer

A high power, galvanically isolated power supply for current drive in the STØR experiment — •Sebastian Haag[1], Nils Fahrenkamp[1], Stefan Knauer[1], Simone Mannori[2], Alessandro Lampasi[2], and Peter Manz[1] — [1]Institute of Physics University of Greifswald, Greifswald, Germany — [2]ENEA, Rome, Italy

Extreme Ultraviolet (EUV) lithography is a crucial technology for projecting high-resolution patterns onto silicon wafers, enabling the production of smaller and more powerful microchips. At the desired wavelength, lasers are no longer available as light sources, so plasma sources have to be used. Laser-produced plasmas (LPPs) prevailed as radiation source because the discharge-produced plasmas (DPPs) did not achieve the desired parameters. The STØR experiment introduces an alternative magnetic confinement concept which is particularly well suited as radiation source, as it contributes to reducing costs and size. To ignite the plasma and drive the helical plasma current, a power supply has to be designed. It is capable of applying a voltage high enough to ignite the plasma and drive currents of up to 2 kA. By utilizing Supercaps as energy storage devices, we can achieve a high power system which is galvanically isolated to minimize plasma interactions with the vessel and provide a steady input voltage over the operating time. Voltage and current are controlled via a high-side and a low-side IGBT module in a buck converter configuration. Together with a custom design of the electrodes this allows for the setup of a magnetically confined compact plasma tori without external toroidal and poloidal magnets, which are ideal properties for a radiation source.

P 25.17 Thu 16:30 ELP 6: Foyer

Influence of collisionality on the electron dynamics in CCRF discharges — •Jens Kallähn, Denis Eremin, and Ralf Peter Brinkmann — TET, Ruhr University Bochum

In this contribution we investigate the influence of the pressure on the power absorption dynamics and electron transport in an rf cylindrical magnetron plasma.

Kinetic PIC simulations were utilized to gain insight into the electron heating and transport across the magnetic field.

They revealed the Hall heating to be a new magnetized electron heating mechanism different from the Ohmic heating it was classified as before. This mechanism is caused by an electric field at the edge of the sheath during the sheath expansion and by a reversed electric field during the sheath collapse. The related new operation mode was proposed to be called "mu-mode", because of its dominance in magnetized CCRF discharges and to differentiate it from other modes in rf plasmas.

While the Hall heating is dominant at low pressures, the collisional heating mechanism prevails in the high-pressure regime with a transition region where both are important.

The reversed electric field is generated for the charge balance at the powered electrode to be maintained during the sheath collapse via enhancing the electron flux. This increase occurs due to three different mechanisms: collisionless transport of electrons due to the polarization drift, collisional drift in the reversed electric field, and collisional diffusion through Hall heating.

P 25.18 Thu 16:30 ELP 6: Foyer

Tungsten Observation at Wendelstein 7-X — •Birger Buttenschön[1], Daihong Zhang[1], Thomas Pütterich[2], and W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, Garching, Germany

In the first part of the second operation phase of the Wendelstein 7-X (W7-X) stellarator, some 280 wall and divertor tiles were made from tungsten or a tungsten-coated material. Those tiles were located in differently loaded regions of the wall. The purpose was to investigate how plasma-wall interaction might lead to contamination of the plasma with tungsten. As a tool to assess the tungsten concentration in the plasma, vacuum-ultraviolet (VUV) spectroscopy is used in combination with 2D bolometry.

While a detailed analysis requires somewhat advanced fitting methods (e.g. for the 5nm quasi-continuum), first - mostly qualitative - results can be readily obtained from the measured VUV spectra. For example, the acquired data allows to roughly determine the tungsten concentrations in specific plasma discharges, and it is used to define a minimum tungsten concentration at which the VUV spectrometer registers a signal above noise.

This contribution shows a number of different tungsten experiments performed in W7-X, the corresponding VUV spectra and what can be learned from the existing data set.

P 25.19 Thu 16:30 ELP 6: Foyer

Computer Vision Deep Learning-Based Shattered Pellet Injection (SPI) Shard Tracking at ASDEX Upgrade — •Johannes Illerhaus[1,2], Paul Heinrich[1,2], Mohammad Miah[1,2], Gergely Papp[1], Tobias Peherstorfer[3], Wolfgang Treutterer[1], Bernhard Sieglin[1], Udo von Toussaint[1], Hartmut Zohm[1], Frank Jenko[1], and the ASDEX Upgrade Team[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Technische Universität Wien, Vienna, Austria — [4]see the author list of U. Stroth et al. 2022 \textit{NF} 62 042006

A computer vision deep learning pipeline was constructed to automate the analysis of the more than 1000 videos created in lab experiments on the SPI test bench at ASDEX Upgrade. Our machine learning (ML) models provide highly accurate segmentation of the fragments shown in these videos. This allows for the labeling of the entire dataset, of which previously only 177 videos had been labeled using a pipeline based on traditional computer vision. The ML models eliminate the previously necessary human supervision, reduce the run time from months to a few hours and increase the accuracy and robustness of labeling. The shards are then tracked between frames with the goal of estimating their size and speed distributions. This enables using the experimental results to validate theoretical models predicting the right system setup and pellet attributes to produce the fragment distributions for optimal disruption mitigation. This will ultimately help inform design decisions for the ITER SPI, ITER's primary disruption mitigation system.

P 25.20 Thu 16:30 ELP 6: Foyer

Spatially and temporally resolved simulations of the Cs dynamics in large negative hydrogen ion sources assisted by TDLAS measurements — •Daniele Mussini, Adrian Heiler, Dirk Wünderlich, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

Negative hydrogen ion sources for the ITER neutral beam injectors rely on the production of negative hydrogen ions on a low work function surface (plasma grid). To reduce the surface work function, a Cs layer is formed on the plasma grid by steadily evaporating Cs into the source. However, mainly due to plasma-surface interaction and Cs redistributions, it is not straightforward to generate a temporally stable and homogeneous Cs layer. In particular, this is a major challenge for the long pulse operation required for ITER (1000 s in H, 3600 s in D). To gain insight into the Cs dynamics by numerical modeling, the Monte-Carlo Test-particle code CsFlow3D was developed at IPP. The code uses many input parameters such as EM fields, plasma temperature and density profiles to determine the Cs dynamics within sources of different sizes. The current main objective is to investigate the Cs behavior during long pulses for both H or D operation. To do so, an updated version of input parameters must be implemented. In addition, the synthetic laser absorption diagnostic (TDLAS) needs to be simulated to benchmark the code against experimental results. This contribution is intended to show some preliminary results and to provide an outlook on future steps for the further development and improvement of the code.

P 25.21 Thu 16:30 ELP 6: Foyer

Deuterium Uptake in Tungsten Damaged at High Temperature — •Laurin Hess, Mikhail Zibrov, and Thomas Schwarz-Selinger — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching b. München

Retention of hydrogen fuel in the tungsten wall of future fusion reactors is an essential area of research, as it is an integral part of modelling the tritium inventory. It has been shown that hydrogen retention significantly increases due to displacement damage produced by 14 MeV neutrons. Until now, many experiments have simulated the displacement damage in a reactor by damaging the tungsten at low temperatures using high energy ions. However, recent experiments have shown that retention behaves differently when the damaging happens at high temperatures, as in a fusion reactor. One possible explanation for this would be the formation of nm-sized voids. It has been suggested that the formation of vacancy clusters depends on the damaging rate. To account for this, two damaging modes have been compared. One with a high intermittent damaging rate using a raster scanned focused beam and one with a low continuous damaging rate using a wobbled defocused beam. In addition, the lateral homogeneity of the two modes has been examined using proton Elastic Backscattering Analysis of gold implantation. Then, the deuterium uptake of tungsten damaged at 1350 K has been studied by decorating the samples with 5 eV deuterium ions.

P 25.22 Thu 16:30 ELP 6: Foyer

A Gyrokinetic Electron Model for BSL6D — •Maximilian Pelkner — Max Planck Institute for Plasma Physics, Garching

The goal of numerical plasma physics is to understand the behaviour of plasmas numerically, since analytical tools for solving the underlying Vlasov equation are limited. Only in recent years has computing power increased to the point where fully kinetic simulations of plasmas, i.e. simulations of the full phase space, are within reach. The BSL6D code is an example of such a "fully kinetic" code, but for computational reasons it so far simulates only fully kinetic ions with adiabatic electrons. The main goal of my work is to improve the simulation by implementing a drift kinetic electron model. In my poster I will present the principle of BSL6D, how the electron model will be implemented and also some comparisons between the code and existing analytical solutions (e.g. Ion Sound Wave).

P 25.23 Thu 16:30 ELP 6: Foyer

Atomic hydrogen density measurements with TALIF above a sample surface — •Julian Hörsch, Christan Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2D-85748, Garching bei München, Germany

Two photon Absorption Light Induced Fluorescence (TALIF) is a diagnostic technique that will be used in an upcoming research program in combination with other diagnostics to characterize the production of negative hydrogen ions in negative ion sources. These negative hydrogen ions can be produced by surface conversion of neutral hydrogen atoms on a low work function material as cesium. As TALIF allows the direct determination of the density and temperature of neutral hydrogen atoms it is of particular interest for characterizing the negative ion production mechanisms. In this project TALIF is applied to a small-scale experiment to study the available density of neutral hydrogen atoms for negative ion production above a sample, but without negative ion production itself. The TALIF signal is measured with varying distance to the surface of the sample and for various sample materials. In particular, the influence of the distance to the surface on the hydrogen properties and the isotopic differences between hydrogen and deuterium are investigated.

P 25.24 Thu 16:30 ELP 6: Foyer

heat conduction in the vicinity of an island — •Gregor Pechstein and Per Helander — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

In magnetically confined fusion plasmas, energy is transported across flux-surfaces toward the plasma edge and the surrounding vessel. It is a challenge to control and limit the wall loads since the tolerable energy flux onto plasma facing component is limited by a number of technical constraints. In order to control and reduce the loads, tokamaks and stellarators exploit divertor magnetic fields guide the heat flux onto target plates, and try to maximise radiation from the edge plasma. When the radiative losses are particularly high, the plasma sometimes "detaches" from the walls and the energy flux to the latter drops dramatically.

The key feature of plasma energy transport that allows for the use of a divertor is the fact that the transport is highly anisotropic. As a result, if the magnetic field is shaped in such a way that different field lines have different topology, the the heat flux can vary greatly across any surface across which the topology changes. We consider anisotropic heat conduction and radiation in the simplest possible mathematical setting in which the field lines change topology, namely, in the geometry of a single chain of magnetic islands. The aim is to shed light on the basic question of how a variation in field-line topology affects the location and amount of plasma radiation.

P 25.25 Thu 16:30 ELP 6: Foyer

Design of a new imaging diagnostic at ASDEX Upgrade for divertor fluctuation studies — •Manuel Herschel[1,2], Michael Griener[2], Tim Happel[2], Daniel Wendler[1,2], Ulrich Stroth[1,2], and The ASDEX Upgrade Team[3] — [1]Technical University of Munich, Physics Department, Chair for Plasma Edge and Divertor Physics, 85747 Garching, Germany — [2]Max-Planck-Institute for Plasma Physics, Garching, Germany — [3]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The divertor will play a critical role in future fusion power plants. The ASDEX Upgrade tokamak experiment (AUG) is currently being equipped with a flexible divertor that will offer new magnetic configurations such as compact radiative or snowflake divertors. To investigate the plasma exhaust in this divertor, good diagnostic coverage is required.

Gas Puff Imaging (GPI) is a well-established technique to observe the microscopic structures that constitute plasma turbulence. Active injection of thermal helium gas creates a spatially localized light emission depending on the local plasma conditions, while a fast camera captures the image with high spatial and temporal resolution.

In this work, an improved GPI diagnostic is designed for the new AUG divertor. A fast in-vessel piezo valve is combined with an optimized line-of-sight geometry and optics to image multiple spectral lines simultaneously, which is necessary for the correct interpretation of the data. This promises better understanding of the X-point and divertor region.

P 25.26 Thu 16:30 ELP 6: Foyer

Hybrid kinetic-MHD simulations of runaway electron beam termination events in realistic 3D tokamak geometry — •Hannes Bergstroem[1], Matthias Hoelzl[1], and Vinodh Bandaru[2] — [1]Max Planck Institute for Plasma Physics, Garching b. M. — [2]Indian Institute of Technology Guwahati, Assam

Disruption events and the associated generation of highly energetic runaway electrons (REs) remain one of the largest threats to future high current tokamak reactor designs like ITER and DEMO. Studies have indicated that even with systems in place to mitigate these events, a multi-MA RE beam may be unavoidable during the nuclear phase of ITER operation. The transport of REs in 3D MHD fields is however difficult to model and presents one of the largest uncertainties for these estimates, since it can have a substantial impact on the beam formation and the details of the ensuing termination. This is particularly challenging since REs carry most of the current at these stages and therefore dominate the dynamics of the plasma, rendering test particle approaches insufficient.

In this work we present a newly implemented hybrid kinetic-MHD model in JOREK, where the kinetic RE population is coupled to the MHD equations in realistic 3D tokamak geometry using a particle-in-cell approach. At first, results from analytical validation with respect to the force balance in a plasma with high RE current are shown. In addition we present results from a RE beam termination scenario in JET, as it occurs due to a burst of 3D MHD activity.

P 25.27 Thu 16:30 ELP 6: Foyer

Towards a stochastic variational principle for quasi-neutral two fluids — •Sayyed Amin Raiessi Toussi[1], Tomasz Tyranowski[2], and Omar Maj[1] — [1]Max Planck Institute for Plasma Physics, D-85748 Garching, Germany. — [2]Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, 7522NH Enschede, The Netherlands

Quasi-neutral multi-fluid models are commonly used to describe particle and energy transport in the edge and scrape-off layer (SOL) of magnetically confined fusion plasmas [R. Schneider, Contrib. Plasma Phys., 46, 2006].

For the purpose of developing particle schemes, a variational formulation is desirable and useful. In this work we use stochastic Euler-Poincaré reduction [Chen, Cruzeiro & Ratiu, J Nonlinear Sci 33, 5 (2023)] in order to formulate a variational principle for quasi-neutral two-fluid models, including non-ideal effects such as viscosity and heat fluxes. In this approach, the quasi-neutrality condition is treated as a constraint, the electric potential being the corresponding Lagrange multiplier. Therefore this variational principle combines elements from the theory of compressible non-ideal flows with Lagrangian constraints [Morrison, Andreussi, Pegoraro, J.Plasma Phys. 86 (2020)]. As a proof of concept, we discuss here simple models of viscosity and heat fluxes, together with some preliminary considerations about generalization to more realistic physics.

P 25.28 Thu 16:30 ELP 6: Foyer

Simulation of fully global electromagnetic turbulence in the stellarator W7-X — •Yann Narbutt[1], Alexey Mishchenko[1], Ralf Kleiber[1], Matthias Borchardt[1], and Edilberto Sánchez[2] — [1]Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17489 Greifswald, Germany — [2]Laboratorio Nacional de Fusión, CIEMAT, Avda. Complutense 40, Madrid 28040, Spain

Magnetic confinement fusion requires high $\beta = \langle p\rangle/(B^2/2\mu_0)$, the ratio of plasma pressure to magnetic pressure, to access high performances. Moderate β can be beneficial for ion-temperature-gradient (ITG) driven turbulence. However, as β is increased above a certain threshold, the so-called kinetic-ballooning-mode (KBM) can be destabilized. This is a plasma pressure gradient driven instability which is inherently electromagnetic and can lead to strong outwards directed heat fluxes, degrading plasma confinement in the process. While, linearly, KBMs have been successfully studied in the stellarator Wendelstein 7-X with flux-tube simulations, it was also shown that the instability tends to be most unstable while developing a global structure on the magnetic surface. While investigating linear simulations in Wendelstein 7-X geometry with the global gyrokinetic code Euterpe both KBMs and high-β trapped electron modes have been observed. Using this code non-linear simulations are conducted on the MareNostrum supercomputer to investigate the turbulent behaviour of these electromagnetic instabilities.

P 25.29 Thu 16:30 ELP 6: Foyer

In-situ spectral calibration of the Thomson scattering system at W7-X using Rayleigh scattering — •Jannik Wagner, Golo Fuchert, Ekkehard Pasch, Jens Knauer, Kai Jakob Brunner, Sergey A. Bozhenkov, Marcus Beurskens, Matthias Hirsch, Robert C. Wolf, and W7-X Team — Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald

In most high temperature fusion experiments, Thomson scattering is one of the main diagnostics for measuring electron temperature and density. So far, the spectral calibration at W7-X uses the light of a supercontinuum laser in combination with a monochromator scattered diffusively by a plate in front of the observation optics. Using this approach, however, the window between the plasma vessel and the observation optics is not part of the calibration and its transmission can vary during an experimental campaign due to coating.

To overcome these issues, a new in-situ calibration has been developed in recent years. Using an optical parametric oscillator (OPO), Rayleigh scattering inside the plasma vessel acts as tunable volumetric light source that can be observed with the exact same setup used for the Thomson scattering measurements. A proof-of-principle was demonstrated in 2018/19, but so far the quality was not sufficient to replace the existing calibration method.

In this work, improvements of the optical setup and in particular a more reliable energy measurement are presented. These measures reduce the experimental uncertainties in a new Rayleigh scattering experiment from which improved calibration curves could be determined.

P 25.30 Thu 16:30 ELP 6: Foyer

Design of a dispersion interferometer at ASDEX Upgrade for disruption studies — •Andrew Moreau[1,2], Alexander Bock[2], Kai Jakob Brunner[3], Andres Cathey[2], Matthias Hoelzl[2], Jens Knauer[3], Jens Meineke[3], and Thomas Puetterich[2] — [1]Ludwig Maximilian University of Munich, Faculty of Physics, 80799 Munich, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching, Germany — [3]Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

Disruptions significantly challenge the successful utilization of future tokamak-class fusion power plants which are predicted to be larger and operate at higher magnetic fields and plasma currents. The electron density is a key quantity needed in the investigation of plasma dynamics to understand the mechanisms of thermal and current quenches, the generation and suppression of runaway electrons and the mitigation or control of disruption effects. At ASDEX Upgrade (AUG) there are currently no interferometer diagnostics which can explore disruption or disruption mitigation scenarios free of fringe jumps, low signal-to-noise or vibration errors. We present work towards the commissioning of a dispersion interferometer at AUG which would harness the coherence conservation principle of second-harmonic generation in order to alleviate the need for a reference beam path. This reduces the complexity significantly and becomes intrinsically free of vibrational errors. With state-of-the-art nonlinear crystals, we increase the capabilities of this system in signal-to-noise. We then show how JOREK simulations can contribute to diagnostic modelling.

P 25.31 Thu 16:30 ELP 6: Foyer

Modelling ion orbits in the W7-X neutral beam box — •Lucas van Ham[1], Samuel Lazerson[1], Björn Hamstra[2], Paul McNeely[1], Norbert Rust[1], and Dirk Hartmann[1] — [1]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [2]Eindhoven University of Technology, 5612 AZ Eindhoven, The

Netherlands

Neutral beam injection (NBI) on Wendelstein 7-X (W7-X) is limited in duration by the heat loads experienced by the NBI components. Deposition patterns on these components have been observed to shift upwards when the main magnetic field of W7-X is on, suggesting stray magnetic fields are penetrating the neutral beam box. We aim to investigate the cause of this shift and how to mitigate this issue. In this work, ion orbits inside the W7-X NBI box will be investigated using the Monte Carlo particle following code BEAMS3D. Simulations will be performed to estimate calorimeter heat loads which will be compared against experimental results. Next, the bending magnet will be included in simulations and a similar investigation will be carried out for the H+ and H2+ ion dumps. Future simulations will focus on including the effect of the magnetization of the magnetic material inside the NBI box on the orbits of the ions.