# P 12: Poster II

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

P 12.1 Tue 16:30 ELP 6: Foyer

**Inference of transport coefficients in helium puff modulation studies at W7-X** — •Thilo Romba[1], Felix Reimold[1], Oliver Ford[1], Peter Zsolt Poloskei[1], Sebastian Bannmann[1], Tabea Gleiter[2], Erik Flom[3], and Thomas Klinger[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald 17491, Germany — [2]Max-Planck-Institute for Plasma Physics, Garching 85748, Germany — [3]University of Wisconsin-Madison, Madison, WI 53706, USA

The precise monitoring of the impurity content and the understanding of the transport mechanisms is crucial for future fusion reactor operation due to the associated restrictions to the operational parameter space via dilution and increased radiative losses.

This work aims to analyze the transport properties of the fusion ash helium in the confined region of the optimized stellarator Wendelstein 7-X (W7-X) [1]. Spatially and temporally densities of He2+ are measured using charge exchange recombination spectroscopy (CXRS) [2]. To introduce a time variation in the local density response, periodic helium puffs outside the confined region are imposed as the helium source.

Based on the local helium density response measured, local diffusion and convection coefficients of the helium particle transport are inferred with the 1.5D transport code aurora [3]. Experiments over varying magnetic configurations show dominant anomalous transport in all cases, consistent with previous results for higher Z impurities [4].

[1] Erckmann 1997, [2] Fonck RSI 1985, [3] Sciortino PPCF 2021, [4] T Romba PPCF 2023

P 12.2 Tue 16:30 ELP 6: Foyer

**Influence of density-potential cross-phase on particle and momentum transport in TJ-K** — •Ralph Sarkis, Mirko Ramisch, and Günter Tovar — IGVP, University of Stuttgart, Germany

Transport formation in magnetically confined plasmas is heavily dependent on the coupling between density and potential. Drift-waves can be destabilized when the electron response to a density perturbation is hindered and the positive potential perturbation that arises has a non-zero phase shift with respect to the density perturbation. The momentum transport, also called Reynolds stress, and particle transport have opposite promoting conditions with respect to the density-potential coupling, that is highly coupled and decoupled, respectively. To understand the conflicting occurrence of both transport phenomena peaking at comparable poloidal positions, as observed at the stellarator experiment TJ-K, a spatio-temporal analysis is performed by means of a poloidal Langmuir probe array, which allows for the spectral decomposition in order to determine the transports' interplay on the basis of the coupling/decoupling influence. Conditional sampling reveals a separation of particle and momentum transport peaks in time. Both transports dynamics are related to the evolution of the density-potential cross-phase in time, and differentiated from the amplitude modulation, to establish a time-based relation between the spectral components and the transport events. Scale separation of the components and of the transport phenomena in the time-based analyses provides a deeper insight of the weighted contribution of each scale investigated.

P 12.3 Tue 16:30 ELP 6: Foyer

**Hybrid kinetic-MHD simulations of the fishbone instability with JOREK** — •Felix Antlitz[1], Xin Wang[1], Matthias Hoelzl[1], and Guido Huijsmans[2,3] — [1]Max Planck Institute for Plasma Physics, Garching b. M., Germany — [2]CEA, Saint-Paul-Lez-durance, France — [3]Eindhoven University of Technology, Eindhoven, Netherlands

Energetic particles (EPs) will play a central role in future burning plasma experiments, as they can strongly interact with the bulk plasma and drive magnetohydrodynamic (MHD) instabilities. For instance the fishbone instability is the result of an internal kink mode destabilized by EPs in tokamaks. This contribution describes applications and developments of the nonlinear extended MHD code JOREK, whose kinetic module is used to investigate the interaction between EPs and core MHD instabilities both in the linear and the nonlinear regime. The kinetic module uses a particle-in-cell technique and describes the EP distribution function with a full-f formulation. The results will also be compared to gyrokinetic simulations performed with the ORB5 code. Furthermore, the current work on implementing a model in JOREK that describes also the thermal ions kinetically is presented.

P 12.4 Tue 16:30 ELP 6: Foyer

**Dynamics of a pellet produced plasmoid in a stellarator** — •Carl Wilhelm Rogge[1,3], Ksenia Aleynikova[1], Pavel Aleynikov[1], Rohan Ramasamy[2], Matthias Hoelzl[2], and Per Helander[1,3] — [1]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — [2]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [3]University of Greifswald

Pellet injection will play a critical role in refueling future tokamak and stellarator reactors. Although pellet plasmoid physics has been extensively studied in tokamak magnetic geometries, understanding in stellarator geometries remains less comprehensive. This gap partially arises due to the lack of numerical tools capable of accurately describing the 3D physics effects with sufficient spatial and temporal resolutions, covering extensive time spans that encompass the various timescales of key physical effects. The non-axisymmetry of the equilibrium field in stellarators increases the complexity of numerical analysis.

However, recent advancements in the stellarator extension of the JOREK non-linear 3D MHD code, which employs a reduced MHD model for stellarator geometry, show significant promise in addressing this challenge. Consequently, this project aims to leverage JOREK to gain a deeper understanding of pellet plasmoid dynamics in stellarator geometries. This poster offers an overview of pellet physics, employed physics and numerical models, and outlines future research inquiries.

P 12.5 Tue 16:30 ELP 6: Foyer

**Investigating density build-up in the W7-X island divertor** — •Nassim Maaziz, Felix Reimold, Victoria Winters, David Bold, Frederik Henke, and Yuhe Feng — Max-Planck-Institute for Plasma Physics, Greifswald 17491, Germany

The island divertor has been proposed for power and particle exhaust in stellarators and is investigated as a viable solution for a reactor in the Wendelstein 7-X (W7-X) experiment. The divertor capabilities increase with higher divertor densities. However, significantly lower densities have been measured in the W7-X divertor in comparison to tokamaks. We assess the impact of the island field line pitch on the density build-up with EMC3-EIRENE modeling and comparing to experimental measurements. The modeling shows an increase of field line pitch leads to higher achievable divertor densities. A more fundamental understanding of the density build-up motivated the development of a simplified geometry model for the island divertor, which we study with EMC3-EIRENE. We look at both, the impact of the field line pitch as well as the effect of the divertor geometry. The beneficial effect on the density build-up of increasing the field line pitch has been observed in this simplified case. A close divertor geometry appears to provide significantly higher achievable densities.

P 12.6 Tue 16:30 ELP 6: Foyer

**Towards a 3D Full MHD plasma model comprehensive of electromagnetic and halo current coupling with 3D conductive structures** — •Raffaele Sparago[1], Javier Artola[2], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]ITER Organization, St. Paul Lez Durance Cedes, France

An adequate modelling of the electromagnetic interaction of the plasma with the surrounding conductors is paramount for the correct reproduction of 3D plasma dynamics. Simulations of the latter provide in turn useful predictions regarding the plasma evolution, the related MHD modes leading to disruptions and the electromagnetic forces acting on the vacuum vessel's components when said disruptions occur. The latest modelling efforts with the 3D FEM non-linear JOREK code have been directed towards the eddy current coupling of a reduced MHD plasma model with thin and volumetric wall codes. In the context of this work, an eddy current coupling between the full MHD model of JOREK and the STARWALL code has been performed; this new coupling scheme relaxes all the degrees of freedom in JOREK's magnetic boundary conditions, allowing for three-dimensional interactions between the magnetic vector potential A and the magnetic field B. Preliminary benchmarks prove the consistency of the Full MHD coupling. Furthermore, this contribution features the recent theoretical development in view of the coupling of halo currents, which flow from the plasma to the wall and viceversa, thus originating additional electromagnetic loads on the vessel that require proper modelling.

P 12.7 Tue 16:30 ELP 6: Foyer

**Characterization of electromagnetic instabilities in high-beta plasmas at Wendelstein 7-X** — •Charlotte Büschel, Christian Brandt, Henning Thomsen, Kian Rahbarnia, Sara Vaz Mendes, Adrian von Stechow, and Jan-Peter Bähner — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

In the last campaigns of Wendelstein 7-X, comparable high plasma beta core values around $\beta_0 \sim 2.5\,\%$ have been reached in different scenarios, e.g. after the injection of frozen hydrogen pellets or with heating scenarios combining electron cyclotron resonance heating and neutral beam injection. However maintaining the plasma in this state with plasma energies up to 1.2 MJ and densities around $1.4 \times 10^{20}\,\mathrm{m}^{-3}$ has up to date been challenging. With increasing density, strong mode activity in the range of 20-50 kHz has been observed, which might contribute to the decrease of the plasma energy and density after a transient peak. To determine the driving instability, these modes are characterized by analyzing data from Mirnov coils, the phase contrast imaging diagnostic and the soft X-ray tomography system. Furthermore the dependency on local and global plasma parameters is investigated.

P 12.8 Tue 16:30 ELP 6: Foyer

**Tomographic localization of turbulent density fluctuations in the Wendelstein 7-X stellarator** — •Christian Brandt, Thomas Wegner, Charlotte Büschel, Sara Vaz Mendes, Kian Rahbarnia, Henning Thomsen, and and the W7-X Team — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

The soft X-ray tomography system in the Wendelstein 7-X stellarator is suited to spatially localize turbulence activity by elaborating X-ray radiation fluctuations, which are the results of turbulent density fluctuations. The amplitude of fluctuations investigated in poloidal-radial mappings of temporal evolving tomographic inversions suggests a connection to the flux surface geometry, especially to the flux surface compression. This effect is investigated for different plasma scenarios in terms of heating and density, which enable a variation of turbulent fluctuation levels as generally known from other measurements. The presented diagnostic approach as well as the link to the driving mechanism of turbulence are discussed.

P 12.9 Tue 16:30 ELP 6: Foyer

**Modulational instability in isolated dynamics of Geodesic-Acoustic-Mode packets** — •David Korger[1,2], Emanuele Poli[1], Alessandro Biancalani[3], Alberto Bottino[1], Omar Maj[1], and Juvert Njeck Sama[4] — [1]Max-Planck-Institut für Plasmaphysik, Garching, 85748, Germany — [2]Ulm University, Ulm, 89081, Germany — [3]École supérieure d'ingenieurs Léonard-de-Vinci (ESILV), Paris La Défense, F-92916, France — [4]Institut Jean Lamour, Université de Lorraine, Nancy, 54011, France

The geodesic-acoustic-mode (GAM) is a plasma oscillation observed in fusion reactors with toroidal geometry and is recognized to be the nonstationary branch of the zonal flows (ZFs). It was recently shown that the dynamics of the isolated, undamped GAM is well described by a (cubic) nonlinear Schrödinger equation (NLSE). This model equation predicts the susceptibility of GAM packets to the modulational instability (MI).

The necessary conditions for this instability are analyzed analytically and numerically using the NLSE model. The predictions of the NLSE are compared to gyrokinetic simulations performed with the global particle-in-cell code ORB5, where the GAM packets are created from initial perturbations of the axisymmetric radial electric field $E_r$. An instability of the GAM packets with respect to modulations is observed, in both cases in which an initial perturbation is imposed and when the instability develops spontaneously. However, significant differences in the dynamics of the small scales are discerned between the NLSE and gyrokinetic simulations.

P 12.10 Tue 16:30 ELP 6: Foyer

**Real-time vibration monitoring system for the pellet centrifuge at ASDEX Upgrade with empirically derived limit values** — •Fin Schmidt[1], Bernhard Ploeckl[2], Martin Prechtl[1], P. T. Lang[2], and ASDEX Upgrade team[3] — [1]Hochschule Coburg — [2]Max-Planck-Institut für Plasmaphysik — [3]see author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006

The ASDEX Upgrade centrifuge pellet launcher, utilized to reliably control the particle flux and ELM frequency, is now in operation for more than 30 years. The units age as well as its unique design necessitate a real-time vibration monitoring system, to reliably detect, warn and prevent damage or malfunctions. Due to space restrictions, two sensors were affixed close to the lower ball bearing. This configuration allows for an efficient monitoring of both the overall structure and at least one of the two bearings, providing some insight into the stability of the rotor. In the absence of literature and established standards for vibration control specific to this structure and application, the key to find vibrational limits is to derive them empirically. Setting a baseline for limit values considers the current operational values as optimal and establishes more precise limits based on the observed behavior of the unit during different operational states. Advanced tools, such as envelope analysis, are employed to monitor specific machine components, especially the ball bearings. Beyond enhancing the safety of pellet injection at ASDEX Upgrade, the current state of the system includes a scheme to safely shutting down the centrifuge before reaching threatening vibration magnitudes.

P 12.11 Tue 16:30 ELP 6: Foyer

**Parametrisation of target heat flux in W7-X** — •Johannes Droste[2], Felix Reimold[1], David Bold[1], and Ralf Schneider[2] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald

This poster presents an approach to address the complex behaviour of the W7-X strike line. It introduces a tool for parameterising the heat flux on to the W7-X island divertor. Particularly distinctive at high densities, the strike line profile exhibits multiple, sometimes overlapping features. The developed tool allows for the separation and characterisation of these features. Through a comparative analysis of feature positions and corresponding connection lengths, a link is established to different transport channels within the island. In addition, the methodology allows the localisation of errors in heat flux calculations due to material deposition and damage to the target surface of the divertor. The width and amplitude of the strike line are key parameters, providing valuable insight into transport and diffusion within the scrape-off layer. Accurate measurement of these parameters is essential for improving and validating scrape-off layer modeling. The influence of time dependent parameters like toroidal plasma current and its influence on strike line position is also investigated.

P 12.12 Tue 16:30 ELP 6: Foyer

**Parametrisation of target heat flux in W7-X** — •Johannes Droste[2], Felix Reimold[1], David Bold[1], and Ralf Schneider[2] — [1]Max-Planck Institute for Plasma Physics, Greifswald, Germany — [2]Universität Greifswald

This poster presents an approach to address the complex behaviour of the W7-X strike line. It introduces a tool for parameterising the heat flux on to the W7-X island divertor. Particularly distinctive at high densities, the strike line profile exhibits multiple, sometimes overlapping features. The developed tool allows for the separation and characterisation of these features. Through a comparative analysis of feature positions and corresponding connection lengths, a link is established to different transport channels within the island. In addition, the methodology allows the localisation of errors in heat flux calculations due to material deposition and damage to the target surface of the divertor. The width and amplitude of the strike line are key parameters, providing valuable insight into transport and diffusion within the scrape-off layer. Accurate measurement of these parameters is essential for improving and validating scrape-off layer modeling. The influence of time dependent parameters like toroidal plasma current and its influence on strike line position is also investigated.

P 12.13 Tue 16:30 ELP 6: Foyer

**Modelling of shattered pellet injection in ASDEX Upgrade** — •Peter Halldestam[1], Paul Heinrich[1], Gergely Papp[1], Mathias Hoppe[2], Oskar Vallhagen[3], Matthias Hoelzl[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching, Germany — [2]Royal Institute of Technology, Stockholm, Sweden — [3]Chalmers University of Technology, Göteborg, Sweden

One of the main issues threatening the success of future reactor-scale tokamaks is disruptions. It is the sudden loss of confinement where the plasma rapidly dissipates its energy onto the surrounding structures, exposing the device to excessive mechanical stress and heat loads. In addition, an electric field is induced that can accelerate a significant fraction of the electrons to relativistic energies, giving rise to runaway electrons (REs). Unmitigated disruptions could potentially cause severe damage to the device and thus, modeling such events is crucial for being able to assess the effectiveness of various mitigation techniques.

With the modeling framework DREAM [Hoppe CPC 2021], we self-consistently evolve in time the poloidal flux and parallel current density, ion charge state densities and temperatures, thermal electron temperature (their density follows from quasi-neutrality) as well as the RE density – all in a flux surface-averaged fluid description of the plasma. In this contribution we study the effects shattered pellet injection (SPI) of deuterium and neon has on disrupting plasmas for ASDEX Upgrade. Initial simulations show good agreement with experimentally observed current quench rates and radiated energy fractions.

P 12.14 Tue 16:30 ELP 6: Foyer

**An engineering tool for the minimization of leading edges in a tungsten-based divertor for W7-X** — •Antara Menzel Barbara[1,2], Joris Fellinger[1], Rudolf Neu[1,2], and Dirk Naujoks[1] — [1]Max Planck Institute for Plasma Physics, Greifswald/Garching, Germany — [2]Technical University of Munich, Munich, Germany

An innovative engineering tool is developed specifically for minimizing leading edges in the design of a future tungsten divertor for the Wendelstein 7-X fusion device. Traditionally, mitigating leading edges involves shadowing techniques such as tilting the divertor target or chamfering the problematic edges. However, as W7-X is capable of operating various magnetic configurations, this can lead to particle fluxes impinging from opposing directions on the same target surface, potentially exposing new leading edges when mitigating one. The tool harnesses an extensive ANSYS dataset to correlate heat flux and incidence angles from EMC3-Lite simulations with maximum temperatures at potential leading edges. It comprehensively evaluates major magnetic configurations across varied plasma pressures and toroidal currents, while considering manufacturing and assembly tolerances. In instances where chamfering is necessary, the tool analyzes possible chamfer geometries and assesses the resulting exposed leading edges on neighboring components under different magnetic configurations. Its computational efficiency, enabling analysis within minutes on a single core, allows seamless integration into broader optimization frameworks.

P 12.15 Tue 16:30 ELP 6: Foyer

**In-situ Uptake Measurement of Deuterium Atoms in Self Damaged Tungsten at Different Temperatures** — •Abdulrahman Albarodi[1,2], Thomas Schwarz-Selinger[2], and Klaus Schmid[2] — [1]Tech. Univ. München, 85748 Garching, Germany — [2]Max-Planck Institut für Plasmaphysik, 85748 Garching, Germany

Self-damaged tungsten samples (damage dose 0.23 dpa) were exposed to low energy deuterium (D) atoms ($<$ 5 eV) from a microwave plasma source at 400, 500 and 600 K to investigate D uptake and D retention at different temperatures. The time evolution of the D depth profile was observed in-situ with $_3$He nuclear reaction analysis after each uptake increment. Thermal desorption spectroscopy was performed ex-situ to determine the de-trapping energies and the surface adsorption energies in the tungsten samples. The deuterium flux was measured by an independent erosion measurement to be 2.1 x $10^{21}$ D/m$^2$/s. The macroscopic rate equation code TESSIM will be used to model the uptake using the measured de-trapping energies, D flux, the surface binding energy and the surface barrier energy in order to determine the incident particle energy. The results are expected to show an increase in the total retention and uptake of deuterium at higher exposure temperatures.

P 12.16 Tue 16:30 ELP 6: Foyer

**Build quality benchmark of tungsten powder bed fusion additive manufacturing processes** — •Robert Lürbke[1,2], Alexander von Müller[2], Georg Schlick[3], and Rudolf Neu[1,2] — [1]Technical University Munich, 85748 Garching, Germany — [2]Max Planck Institute for Plasma Physics, 85748 Garching — [3]Fraunhofer Institue for Casting, Composite and Processing Technology, 86159 Augsburg, Germany

Plasma-facing components (PFCs) in future magnetic confinement fusion reactors must sustain high heat fluxes and intense neutron irradiation. These extreme conditions might create the need for specially engineered materials. Tungsten (W) is currently considered the preferred plasma-facing material in fusion devices. To create a wall component, it has to be joined to an actively cooled heat sink. Additive manufacturing (AM) of W is a potentially helpful tool to create tailored structures to reinforce a high-conductivity copper matrix, forming a composite heat sink with optimized thermomechanical behavior. AM of W is a rapidly developing field, and various processes have been elaborated recently by research institutions and industry. The contribution will give an overview of AM powder bed fusion processes for W and highlight the development of a benchmark part based on which the processes shall be evaluated in view of their capabilities related to PFC production.

P 12.17 Tue 16:30 ELP 6: Foyer

**Validation of the GENE - KNOSOS - Tango Framework Using W7-X Discharges** — •Don Lawrence Carl Fernando[1], Alejandro Bañon Navarro[1], Daniel Carralero[2], Jose Luis Velasco[2], J. Arturo Alonso[2], Alessandro Di Siena[1], Felix Wilms[1], Frank Jenko[1], and W7-X Team[3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Laboratorio Nacional de Fusión, CIEMAT, 28040 Madrid, Spain — [3]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

A pre-requisite to carrying out plasma profile predictions using simulation codes are validation studies. Validation ensures the accuracy of the simulated quantities with respect to experimental results. For this reason, a validation study was carried out using four OP1.2b W7-X scenarios that exhibit different turbulence characteristics. The framework of GENE-KNOSOS-Tango, a coupling of gyrokinetic, neoclassical, and transport codes respectively, is used to predict plasma profiles.

The results of this study show the successful validation of this framework for the four scenarios. Additionally, different key effects are also touched upon, such as electron-scale turbulence and the neoclassical radial electric field and its shear. Finally, we looked into simulated turbulence characteristics, such as density fluctuations and heat diffusivity, and compared these with experimental values. Good qualitative agreement is observed as well. This is the first time that such a study has been done for stellarators. The validation of the GENE-KNOSOS-Tango framework enables us to make credible predictions of physical phenomena in stellarators and reactor performance.

P 12.18 Tue 16:30 ELP 6: Foyer

**GRILLIX: Turbulence validation efforts and simulations of advanced divertor concepts** — •Jan Pfennig, Wladimir Zholobenko, Andreas Stegmeir, Konrad Eder, Christoph Pitzal, Kaiyu Zhang, Garrad Conway, Gustavo Grenfell, Dominik Brida, and Frank Jenko — Max Planck Institute for Plasma Physics, 85748 Garching b. Muenchen, Germany

Predictive turbulence simulations represent a key tool to describing and understanding the anomalous transport of particles and energy across magnetic flux surfaces of tokamak fusion devices, which is commonly believed to be the main factor determining their confinement properties [1], and thus economic viability. In order to test and verify the physics quality of the locally field-aligned but flux coordinate independent edge turbulence code GRILLIX, extensive validation efforts against ASDEX Upgrade (AUG) L-mode have been performed. As a successive step, GRILLIX simulations of future machine advanced divertor concepts (ADCs), such as downscaled DEMO ADCs [2] as well as magnetic configurations of the new upper divertor in AUG [3], are performed and evaluated.

[1] - A. Dimits et al., Physics of Plasmas, Vol. 7, 2000, DOI 10.1063/1.873896

[2] - F. Militello et al., Nuclear Materials and Energy, Vol. 26, 2021, DOI 10.1016/j.nme.2021.100908

[3] - T. Lunt et al., Nuclear Materials and Energy, Vol. 12, 2017, DOI 10.1016/j.nme.2016.12.035

P 12.19 Tue 16:30 ELP 6: Foyer

**GRILLIX: Turbulence validation efforts and simulations of advanced divertor concepts** — •Jan Pfennig, Wladimir Zholobenko, Andreas Stegmeir, Konrad Eder, Christoph Pitzal, Kaiyu Zhang, Garrad Conway, Gustavo Grenfell, Dominik Brida, and Frank Jenko — Max Planck Institute for Plasma Physics, 85748 Garching b. Muenchen, Germany

Predictive turbulence simulations represent a key tool to describing and understanding the anomalous transport of particles and energy across magnetic flux surfaces of tokamak fusion devices, which is one of the main factors determining their confinement properties [1], and thus economic viability. In order to test and verify the physics description of the locally field-aligned but flux coordinate independent edge turbulence code GRILLIX, extensive validation efforts against ASDEX Upgrade (AUG) L-mode have been performed. As a successive step, GRILLIX simulations of future machine's advanced divertor concepts (ADCs), such as downscaled DEMO ADCs [2] as well as magnetic configurations of the new upper divertor in AUG [3], are performed and evaluated.

[1] - A. Dimits et al., Physics of Plasmas, Vol. 7, 2000, DOI 10.1063/1.873896
[2] - F. Militello et al., Nuclear Materials and Energy, Vol. 26, 2021, DOI 10.1016/j.nme.2021.100908
[3] - T. Lunt et al., Nuclear Materials and Energy, Vol. 12, 2017, DOI 10.1016/j.nme.2016.12.035

P 12.20 Tue 16:30 ELP 6: Foyer

**Hybrid gyrokinetics: Electromagnetic effects in weakly magnetized plasmas** — •Sreenivasa chary Thatikonda[1], Felipe nathan De Oliveira lopes[1], Aleks Mustonen[2], Rainer Grauer[2], Daniel Told[1], and Frank Jenko[1] — [1]Max planck institute for plasma physics, Garching, Germany — [2]Ruhr-Universität Bochum

We aim to study instabilities, turbulence and reconnection phenomena in weakly magnetized plasmas. Such conditions may be found in natural plasmas such as the solar wind, but also in laboratory applications, e.g. in the edge of fusion plasmas. Due to steep gradients in the edge of fusion plasmas and high frequencies in space plasmas, the ordering assumptions of gyrokinetic theory (like low frequency or moderate gradients) may be challenged, particularly for ions. To overcome these limitations, we derived equations for a hybrid model that includes fully kinetic physics for the ions, but gyrokinetic physics for the electrons. The hybrid model's electrostatic version has been numerically implemented into the existing simulation code, ssV. Semi-Lagrangian schemes (e.g., the PFC scheme [Filbet et al., JCP 2001])are employed in ssV.When implementing EM effects, we have to overcome some numerical problems such as the Ampere cancellation problem. To solve this problem, we need to have sufficient velocity space and evaluate the integrals with utmost care. Ongoing work on ssV includes it's applications to space and astrophysical plasmas: For example, magnetic reconnection at the ion scales.

P 12.21 Tue 16:30 ELP 6: Foyer

**Plasma-neutrals fluid turbulence modeling in the tokamak edge** — •Konrad Eder, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — MPG-IPP, Garching, Germany

Predictive studies of the plasma edge in prospective fusion reactors require self-consistent modeling of the turbulent transport involving an interplay of plasma, neutral gas, and impurity dynamics.

We present extensions to the edge turbulence code GRILLIX, which implements a drift-fluid plasma model and a diffusive neutral gas model. The latter has been upgraded to a 3-moment fluid, i.e. neutral gas density, momentum, and pressure. Furthermore, we show a scheme to implement neutrals recycling for the Flux-Coordinate-Independent (FCI) approach, on which GRILLIX is based and which enables it to handle complex diverted geometries.

The updated model is validated against ASDEX-Upgrade L-mode discharge #36190, demonstrating improved agreement in the divertor profiles of density and electron temperature. We note that: first, the recycling boundary conditions allow for a more realistic in-homogeneous neutrals distribution at the divertor. Second, the evolution of neutrals temperature allows it to decouple from the ion temperature, causing significant change in the poloidal morphology.

Simulations of a density ramp in AUG are carried out, which aim to reproduce detached divertor regimes observed in experiments. Finally, in fully detached conditions, we perform simulations with an X-point radiator to study its impact on turbulent transport, paving the way for predictive reactor simulations of ELM-free regimes.

P 12.22 Tue 16:30 ELP 6: Foyer

**Electromagnetic turbulence simulations of the tokamak edge plasma in the quasi-continuous exhaust regime** — •Kaiyu Zhang, Wladimir Zholobenko, Andreas Stegmeir, and Frank Jenko — Max Planck Institute for Plasma Physics, Garching, Germany

The global fluid turbulence code GRILLIX has undergone recent advancements to include electromagnetics. This extension has revealed that the electromagnetic flutter effectively reduces ExB transport by intervening in the dynamics of drift-wave turbulence on the tokamak edge [1]. As a result, it imparts stabilizing factors of 2 in L-mode and a remarkable 100 in H-mode.

With the improved capability to resolve electromagnetic turbulence, GRILLIX is now simulating the quasi-continuous exhaust (QCE) regime. QCE is acknowledged as a promising H-mode regime for reactors due to its suppressed type-I ELMs and broadened heat fall-off length [2]. Previous research suggested that these QCE advantages stem from enhanced transport near the separatrix. Our simulations establish self-consistent turbulence transport in QCE, and the turbulence mode structures will be diagnosed to unveil the underlying mechanisms for this enhanced transport.

[1] K. Zhang , et al. arXiv:2309.07763, 2023.
[2] M. Faitsch , et al. Nuclear Fusion, 2023, 63(7): 076013.

P 12.23 Tue 16:30 ELP 6: Foyer

**Validation of theoretical upper bounds on local gyrokinetic instabilities** — •Linda Podavini, Per Helander, Gabriel Plunk, and Alessandro Zocco — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

Turbulence in magnetic confinement fusion devices is driven by the presence of microinstabilities. In the last decades these instabilities have been studied considering various assumptions about plasma parameters and magnetic geometry, thus hampering a desirable unified theory.

The theory of upper bounds on the growth rates of local gyrokinetic instabilities [1,2,3] aims at filling this gap by introducing results which are valid for all microinstabilities. Moreover, they are independent of magnetic geometry and many plasma parameters, such as the number of particle species, beta and collisions.

We compare the upper bounds to solutions of the linear gyrokinetic equation. The latter are obtained through flux-tube simulations performed with the gyrokinetic code stella. The validation focuses on fusion-relevant instabilities and it is carried out for different magnetic field geometries and plasma parameters, to highlight the universality of the theory. The validation also includes a comparison with analytical results obtained in simple magnetic field geometries.

[1] P. Helander, and G. G. Plunk, PRL (2021)
[2] P. Helander, and G. G. Plunk, JPP (2022)
[3] G. G. Plunk and P. Helander, JPP (2022)

P 12.24 Tue 16:30 ELP 6: Foyer

**Adding global parallel magnetic fluctuations to the GENE code** — •Facundo Sheffield[1], Tobias Goerler[1], Felix Wilms[1], Gabriele Merlo[2], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]The University of Texas at Austin, USA

One of the main challenges of controlled nuclear fusion is the turbulent nature of the plasma itself, which causes increased transport of energy and particles. While great progress has been made, there are still many areas of active research. Among these, the inclusion of parallel magnetic fluctuations ($B_{1||}$) in turbulence simulations has become more and more relevant due to their impact on high beta and reactor relevant scenarios, potentially affecting the constraint of the edge/pedestal profiles in KBM driven scenarios.

Therefore, a long wavelength ($k_\perp \rho_s \ll 1$) approximation for parallel magnetic fluctuations was implemented on the global version of the gyrokinetic delta-f code GENE in order to improve its predictive power and asses its importance for global physics.

The approximation has been successfully tested with convergence tests and comparisons with the local version of GENE. The latter were done by porting the approximation to local GENE, which possesses an arbitrary wavelength solver, and verifying how well it agrees with the full local model. The LW approximation performs much better than previously established treatments for $B_{1||}$ and surprisingly good agreement with the full model is found even at smaller wavelengths. These results are encouraging to all global GK codes implementing or employing a LW approximation for $B_{1||}$. Further studies are ongoing.

P 12.25 Tue 16:30 ELP 6: Foyer

**Analysis of Nonlinear Dynamics of Shear Alfvén Waves Driven by Energetic Trapped Particles** — •Farah Atour — IPP Garching

In controlled fusion devices, shear-Alfven waves can be driven unstable by resonant interactions with energetic alpha particles. This results in many issues regarding the confinement of the particles and therefore can prevent thermalization of the plasma core or increase the thermal load on the material wall. The source of these particles is either from the nuclear fusion reaction produced by the background plasma and/or external heating systems. Due to the importance of these issues, there exists an extensive literature on this topic. These studies mostly focus on the nonlinear dynamics of passing particles since they have more significant impacts. However, the nonlinear dynamics of shear-Alfven waves driven by energetic trapped and anomalous particles deserves also depth analysis and will be the focus of this study. The overall goal of this work is to investigate on a deeper level the fundamental physical processes regarding both the linear stability properties and the nonlinear saturation. For this reason, to keep the context of the dynamical study simplified, these phenomena are investigated by HMGC code, which has a simple circular geometry and is based on the hybrid reduced MHD gyrokinetic model.

P 12.26 Tue 16:30 ELP 6: Foyer

**Research plan for investigating differences and similarities between hydrogen and deuterium operation in negative ions sources for fusion applications** — •Joey Rubin, Nicolaas den Harder, Dirk Wuenderlich, Christian Wimmer, and Ursel Fantz — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

Negative ion sources for fusion applications face demanding requirements. The ITER NBI system requires extracted negative ion current densities of 329 $A/m^2$ in hydrogen for 1000s and 286 $A/m^2$ in deuterium for 3600s, with co-extracted electron fraction below 1 for both isotopes. Testbeds BATMAN Upgrade and ELISE in operation at IPP Garching, have successfully demonstrated the feasibility of meeting these requirements in hydrogen. However, deuterium operation presents a challenge due to a higher and more unstable co-extracted electron current density. The increase in co-extracted electron current density limits the pulse length as the heat load on the extraction reaches the limit. The focus of this thesis is to delve into the physics underlying the different performance of negative ion sources for fusion in hydrogen and deuterium. The present poster outlines the research plan designed to reach this objective.

P 12.27 Tue 16:30 ELP 6: Foyer

**Influence of the presence of hydrogen isotopes on damage evolution in tungsten** — •Zeqing Shen, Thomas Schwarz-Selinger, Mikhail Zibrov, and Armin Manhard — Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, Garching D-85748, Germany

The influence of the presence of deuterium (D) on damage evolution at elevated temperatures was studied for self-ion irradiated tungsten (W). W samples were irradiated by 20 MeV W ions at room temperature to the peak damage dose of 0.23 dpa and loaded with a low-temperature D plasma at 370 K to decorate the created defects. To study the evolution of the defects with D being present, samples were heated during plasma loading to 4 different temperatures, ranging from 470 K to 770 K. The annealing time was calculated by the rate equation modelling code TESSIM-X. For comparison, annealing experiments at each temperature were carried out also in vacuum. After annealing, all samples were re-exposed to the same D plasma as before to decorate the surviving defects. The duration was calculated again by TESSIM-X. At various steps of the experiment, nuclear reaction analysis (NRA) was used to determine the deuterium depth profile. After the last re-exposure thermal desorption spectroscopy (TDS) was used to measure the total amount of deuterium and de-trapping energy of D. The final results will give a quantitative understanding of the influence of the presence of hydrogen isotopes on defect evolution at elevated temperature.

P 12.28 Tue 16:30 ELP 6: Foyer

**Atomic cascade computations for astro and plasma physics** — •Stephan Fritzsche — Helmholtz-Institut Jena, Germany — Friedrich-Schiller University Jena, Germany

Electronic structure calculations of atoms and ions have a long tradition in physics with many applications in astro and plasma physics. With the Jena Atomic Calculator (JAC), I here present a modern implementation of a (relativistic) electronic structure code for the computation of atomic amplitudes, properties and cascades. JAC [1,2] is based on Julia, a new programming language for scientific computing, and provides an easy-to-use but powerful platform to model excitation and decay processes of open-shell atoms and ions across the periodic table. This toolbox also provides useful features to predict plasma rate coefficients for different capture and ionization processes.

[1] S. Fritzsche. A fresh computational approach to atomic structures, processes and cascades. Comp.Phys.Commun., 240, 1 (2019), DOI:10.1016/j.cpc.2019.01.012.

[2] S. Fritzsche. JAC: User Guide, Compendium & Theoretical Background. https://github.com/OpenJAC/JAC.jl, unpublished (02.11.2023).

P 12.29 Tue 16:30 ELP 6: Foyer

**Influence of Plasma Instability for the Energy-loss of Relativistic Pair Beams from TeV Blazars** — •Suman Dey and Günter Sigl — II. Institut für Theoretische Physik, Universität Hamburg, 22761 Hamburg

The interaction of TeV photons from blazars with the extragalactic background produces a relativistic beam of $e^-e^+$ pairs streaming through the intergalactic medium, producing a cascade through upscattering low-energy photons. Plasma instability is considered one of the underlying energy-loss processes of the beams. This study aims to investigate the energy loss of beams due to plasma instability using a particle-in-cell (PIC) simulation. We extrapolated the instability growth trend observed in laboratory settings to the astrophysical scale, assuming no other important mechanisms. For relativistic jets, the beam undergoes a continuous influx of new particles by pair production, which persists in driving the instability. We estimated the saturated value of the energy-loss term and diffusion coefficient when equilibrium is achieved. Moreover, in extrapolating to astrophysical scales, we noted that the system started to develop secondary instability and emerged from a reactive to kinetic regime. Momentum broadening suppresses the secondary instability and saturates. We compared the energy-loss time scale ($\tau_{\rm loss}$) and diffusion time scale ($\tau_{\rm diff}$) with inverse Compton (IC) cooling time ($\tau_{\rm IC}$). We observed that the $\tau_{\rm loss}$ is almost comparable to $\tau_{\rm IC}$, whereas $\tau_{\rm diff}$ exceeds both. This opens a future scope to explore the effect of intergalactic magnetic field (IGMF) on instability using the modular structure of CRPropa code.

P 12.30 Tue 16:30 ELP 6: Foyer

**Turbulence in Molecular Clouds** — •Christian Heppe[1], Alexei Ivlev[2], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik — [2]Max-Planck-Institut für extraterrestrische Physik

In the Interstellar Medium a vast array of different plasma can be observed. Ranging from the almost fully ionized low density plasma in between stars to the cold, dense gas in Molecular clouds where ionization is solely governed by the presence of high energy cosmic rays. Where either magnetic or thermal pressure can dominate. In these environments the dynamics of the medium are governed by turbulence.

As the coupling between neutral and ionized gas can strongly vary in such inhomogeneous environments two fluid effects become necessary to account for. The coupling of the neutral and ionized gas is mediated by collisions and current theory suggests that one can identify three coupling regimes. At large scales, in the strongly coupled regime, the ionized and neutral gas move together as one fluid. Beyond this, in the weakly coupled regime, the dynamics of both species begin to decouple. Finally, in the decoupled regime at even smaller scales, both gases move independent of each other. Despite this, the current models lack physical insight and yield qualitative results that do not match relevant simulations.

By systematically probing different turbulent environments with two fluid MHD simulations we hope to find a phenomenological explanation as to how the turbulent cascade manages to bridge the decoupling regime and transport energy to smaller scales, possibly identifying an elementary turbulent interaction.

P 12.31 Tue 16:30 ELP 6: Foyer

**Study of structure and electron acceleration processes at planetary and astrophysical shocks using Particle-In-Cell simulations.** — •Valentine Devos, Artem Bohdan, and Frank Jenko — Max Planck Institut for Plasma Physics, Germany

The first aim of the project is to study the structure of shocks, at planetary and astrophysical scales, for intermediate Mach numbers using Particle-In-Cell simulations. More precisely, the transition between low Mach numbers instabilities (as shock whistler precursor, modified 2-stream instabilities, etc.) to high Mach numbers instabilities (Weibel instabilities, Buneman instabilities, etc.). The different processes of electron acceleration within these shocks will be also discussed. Those processes are notably the Diffusive Shock Acceleration, the Shock Surfing Acceleration or the Shock Drifting Acceleration