P 20: Magnetic Confinement Fusion/HEPP V

Time: Thursday 13:45–15:50 Location: ZHG102

Invited Talk P 20.1 Thu 13:45 ZHG102

First applications of the kinetic ion transport module in the EMC3-EIRENE code package — •Derek Harting[1], Dirk Reiser[1], Christoph Baumann[1], Sebastian Rode[1], Juri Romazanov[1], Sebastijan Brezinsek[1,2], Heinke Frerichs[3], Alexander Knieps[1], and Yuhe Feng[4] — [1]FZ-Jülich, Institute of Fusion Energy & Nuclear Waste Management - Plasma Physics — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences — [3]UW - Madison, Department of Engineering Physics — [4]MPG Institute for Plasma Physics

Impurity seeding in the scrape off layer plasma as well as controlling the contamination of the core plasma by high Z impurities are essential for ITER baseline scenarios. While fluid models are often used to describe impurity transport, short-lived lower ionization stages of high-Z impurities (e.g., W, Ar) may require a kinetic treatment due to their non-Maxwellian velocity distributions. To address these kinetic effects, the EMC3-EIRENE code package has been extended with a trace kinetic ion transport module in guiding center approximation. This module includes grad-B drifts, mirror-force effects and anomalous cross-field diffusion. Benchmarks with the kinetic ion transport code ERO2.0 showed fair agreement, validating the implementation. First simulations of a tungsten source in the ITER divertor region under an attached, medium-density L-mode plasma scenario demonstrate the module's capabilities. These advancements enhance predictions of impurity transport and plasma contamination control, crucial for ITER and future fusion devices.

P 20.2 Thu 14:15 ZHG102

About recent progress in collisional-radiative modelling of molecular hydrogen plasmas — •Richard Christian Bergmayr, Dirk Wünderlich, and Ursel Fantz — Max Planck Institute for Plasma Physics, Garching, Germany

Collisional-radiative (CR) models for molecular hydrogen are crucial for the quantitative analysis of molecular emission from low temperature plasmas (e.g. fusion divertor plasmas) and are suited to predict effective rate coefficients for neutral kinetic codes (e.g. EIRENE) in order to understand the extent to which molecules contribute to the detachment process. The accuracy of CR model predictions is limited by the availability of accurate reaction probabilities as model input. The latest advances in molecular input data motivate the development of a fully ro-vibrationally resolved CR model for molecular hydrogen. A multi-stage approach is pursued, in which population models with different detail level of (ro-vibrational) resolution are composed based on the Yacora solver. These models utilize specifically for their purpose composited databases of recent reaction probabilities, are successfully benchmarked on various experiments (e.g. divertor plasmas, linear devices and small scale laboratory experiments) and are employed for different, dedicated fields of applications. This includes the first time quantification of the influence of spin-mixing processes, post-processing EDGE2D-EIRENE JET L-mode profiles in comparison to predictions by the AMJUEL database (which is used as a standard in EIRENE) and unprecedentedly accurate, ro-vibrationally resolved Fulcher-α band emission predictions.

Invited Talk P 20.3 Thu 14:40 ZHG102

Simulating boundary turbulence in fusion reactors in different confinement, ELM and detachment regimes — •Wladimir Zholobenko[1], Andreas Stegmeir[1], Kaiyu Zhang[1], Konrad Eder[1], Jan Pfennig[1], Christoph Pitzal[1], Philipp Ulbl[1], Matthias Bernert[1], Michael Griener[1], and the ASDEX Upgrade Team[2] — [1]MPI for Plasma Physics, Garching, Germany — [2]see author list of H. Zohm et al., 2024 Nucl. Fusion

Magnetic confinement fusion reactors must combine high plasma energy confinement with manageable heat exhaust. Both are determined to a large degree by turbulent transport across the very plasma edge. While present day experiments focus on finding optimal regimes of operation, only first-principles based computer simulations can make reliable extrapolations to future fusion reactors.

This contribution focuses on recent progress with the GRILLIX code in understanding high-confinement, detached and ELM-free regimes on the ASDEX Upgrade tokamak. Transitions between various micro-instabilities, their non-linear dynamics and interaction with large-scale flows are shown to be important for the understanding of the varying plasma edge conditions. For optimal operation, plasma shaping and the control of the scrape-off layer and divertor dynamics are critical.

Turbulence is a multi-scale, chaotic, dynamical phenomenon. Simulating it challenges todays top tier supercomputers, in particular for even larger future machines. Therefore, optimized model complexity and software design are key to facilitate fusion reactor predictions.

P 20.4 Thu 15:10 ZHG102

Plasma turbulence modeling in detached regimes — •Konrad Eder, Wladimir Zholobenko, Andreas Stegmeir, Matthias Bernert, David Coster, and Frank Jenko — MPG-IPP, Garching, Germany

Predictive studies of the plasma edge in fusion reactors – particularly towards detachment – require self-consistent modeling of turbulent transport involving an interplay of plasma, neutral gas, and impurities.

We present extensions to the edge turbulence code GRILLIX, which applies 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. Particle recycling is modeled by introducing novel boundary conditions compatible with the Flux-Coordinate-Independent (FCI) approach, on which GRILLIX is based and which enables it to handle complex diverted geometries.

In simulations of an attached ASDEX-Upgrade (AUG) L-mode discharge we first investigate how the model extensions affect neutrals and plasma near the divertor. Next, the updated model is validated against a fully detached AUG discharge featuring an L-mode X-point radiator (XPR) as part of an L-H transition. We are able to reproduce the XPR structure (radiating >80% of input power), a first-of-its-kind for turbulence simulations, and find the simulations to be in good agreement with experimental measurements at the Outboard-midplane and the divertor. Finally, we analyze distinct interchange-type turbulence found near the XPR structure, which helps elucidate our understanding of the XPR regime.

P 20.5 Thu 15:35 ZHG102

Helium exhaust studies in ASDEX Upgrade with a quadrupole mass spectrometer — •Simon Krumm[1,2], Athina Kappatou[1], Volker Rohde[1], Thomas Pütterich[1,2], Andreas Redl[1], and the ASDEX Upgrade Team[3] — [1]Max-Planck- Institut für Plasmaphysik, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, 80539 München, Germany — [3]see the author list of H. Zohm et al. 2024 NF 64 112001

Helium is 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. To understand and optimise helium exhaust processes, diagnostics are necessary to measure helium from the plasma core all the way to the pump ducts. To measure helium in the pump ducts and to determine pumping speeds, quadrupole mass spectrometers are used. However, the low mass difference between molecular deuterium and helium makes mass spectrometry challenging. We present the application of the Threshold Ionisation Mass Spectrometry (TIMS) method to accurately measure He and D partial pressures with high time resolution. Following its performance characterisation in a laboratory we then utilise the diagnostic in ASDEX Upgrade plasmas to study helium exhaust dynamics and to determine the helium pumping speed achieved with ASDEX Upgrades's new activated charcoal coated cryopump.