P 6: Helmholtz Graduate School I

Zeit: Montag 16:30–18:30 Raum: HS Foyer

P 6.1 Mo 16:30 HS Foyer

Electron Cyclotron Emission Diagnostic Calibration and First Heatwave Analysis Results at Wendelstein 7-X — •Udo Hoefel[1,2], Hans-Jürgen Hartfuss[1], Matthias Hirsch[1], Sehyun Kwak[1], Gregor Pechstein[2], Stefan Schmuck[3], Torsten Stange[1], Jakob Svensson[1], Gavin Weir[1], Robert Wolf[1,2], and the W7-X team[1] — [1]IPP, Greifswald, Germany — [2]TU Berlin, Berlin, Germany — [3]Culham Science Centre, Abingdon OX14 3DB, United Kingdom

Wendelstein 7-X (W7-X) is equipped with a 32 channel electron cyclotron emission (ECE) radiometer (with 16 additional high spatial resolution channels), that requires for the localisation of the radiative temperature measurement absorption and reemission respectively an optically thick plasma. The absolute calibration is done via a hot/cold source and a corresponding model in the MINERVA framework is used in a first effort to infer the effective sensitivities with rigorously determined uncertainties.

The exclusive heating throughout the first operation phase (OP1.1) was a flexible 140 GHz electron cyclotron resonance heating (ECRH) system that allowed plasma scenarios with modulated power which were used for preliminary electron heatwave studies with both power deposition on and off the magnetic axis. This allows for a first comparison of electron heat diffusivities as obtained from heat pulse analysis and power balance analysis.

P 6.2 Mo 16:30 HS Foyer

Influence of pedestal top properties on ELM mitigation and first insights into the pump-out effect — •Nils Leuthold[1], Wolfgang Suttrop[1], Rainer Fischer[1], Athina Kappatou[1], Andrew Kirk[2], Rachael McDermott[1], Alexander Mlynek[1], Martin Valovic[2], Matthias Willensdorfer[1], the ASDEX Upgrade Team[1], and the EUROfusion MST1 Team[3] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]CCFE, Culham Science Centre, Abingdon, Oxon, OX14 3DB, U.K. — [3]See http://www.euro-fusionscipub.org/mst1

Edge Localized Modes (ELMs) are triggered by the steep edge gradients, which get formed in the high confinement mode of a tokamak device. They expell particles and energy in a burst like manner. While controlable ELMs provide a useful tool to avoid impurity accumulations, it is essential to find ways to mitigate or suppress ELMs in the next step fusion device ITER in order to reduce the harmful energy fluence to the first target. One encouraging method is the application of a magnetic perturbation (MP) field, but along with the ELM mitigation/suppression by the MPs comes also the so called "density pump-out" effect. It is triggered by the MPs and causes a degradation of the plasma confinement by expelling a significant amount of the particle inventory. The influence of the electron density and collisionality at the top of the H-mode pedestal on the energy losses caused by ELMs is shown as well as a first insight into the pump-out effect. An approach to test various theories regarding the pump-out effect on ASDEX Upgrade is presented.

P 6.3 Mo 16:30 HS Foyer

Low-Z impurity transport studies using CXRS at ASDEX Upgrade — •Cecilia Bruhn[1,2], Rachael McDermott[1], Alexander Lebschy[1,2], Ralph Dux[1], Athina Kappatou[1], Volodymyr Bobkov[1], Roman Ochoukov[1], Jakob Ameres[2,1], Clemente Angioni[1], Marco Cavedon[1], Thomas Pütterich[1], Eleonora Viezzer[3,1], and the Asdex Upgrade Team[1] — [1]Max-Planck-Insitut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]University of Seville, Seville, Spain

To achieve optimum fusion performance, future fusion reactors need to control the build up of high- and low-Z impurities in the plasma core. Thus, it is important to develop and validate our theoretical understanding of impurity transport. Recent experimental work on this topic at ASDEX Upgrade (AUG) has focused primarily on steady-state profiles, which deliver the ratio of the diffusive and convective transport coefficients. However, from a time dependent density profile the transport coefficients can be separately determined by solving an inverse problem. At AUG, a sinusoidal modulation of the boron density can be achieved by modulating the power from the ion cyclotron resonance frequency (ICRF) antennas. This signal can then be monitored with the charge exchange recombination spectroscopy (CXRS) diagnostics, which can make complete measurements of the boron density profiles with high spatial and temporal resolution. We will present a database of measured transport coefficient profiles, their dependencies on local plasma parameters and a first comparison to neoclassical theory.

P 6.4 Mo 16:30 HS Foyer

Dependence of Oxidation on the Grain Orientation of Tungsten — •Karsten Schlüter and Martin Balden — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany

Tungsten (W) is planned to be a plasma facing material of future fusion reactors. It can be oxidized in case of a loss of coolant with simultaneous air ingress. In such an incident, activated tungsten oxide could sublimate leading to a potential safety issue if the tungsten oxide is released into atmosphere. Oxidation processes are complex and for a deeper understanding, this study focuses on oxidation in relation to the grain orientations.

The grain orientations on a W sample were analyzed using electron backscatter diffraction. Subsequently, the sample was oxidized in a thermobalance, measuring the time dependent weight increase. The grain dependent oxidation rates were determined by measuring the thickness of the oxide layer of single grains by scanning electron microscope and confocal laser scanning microscope. W grains with {100} orientation have the highest and a two times higher oxidation rate in a range of 720 K to 870 K than to the lowest oxidation rates, e.g. like the oxidation rate of the {111} orientation. The derived oxidation rates are consistent with gravimetric measurements.

P 6.5 Mo 16:30 HS Foyer

Study of the gas balance of Wendelstein 7-X — •Georg Schlisio[1], Uwe Wenzel[1], Thomas Sunn Pedersen[1], Tom Wauters[2], and W7-X Team[1] — [1]Max-Planck-Institute for Plasma Physics, Greifswald — [2]KMS/RMA, Brussels, Belgium

The Wendelstein 7-X (W7-X) stellarator experiment is currently being prepared for its plasma operation phase OP1.2 with an island divertor. In the first operation phase (OP1.1) in 2016 the device was operated in a limiter configuration. We studied the gas balance during OP1.1 by balancing the neutral particle input and output. The components in the plasma vessel interact with the neutral gas, i.e. by wall pumping or outgassing. The neutral gas pressure and its constituents have a strong influence on the plasma performance. In order to gain a quantitative understanding of the gas balance, we are studying and modeling the sources and sinks.

To assess the gas removal rate, given by $Q = p \cdot S$ (p pressure, S pumping speed), an accurate calibration of the neutral pressure gauges is required. For OP1.2 an effective calibration scheme is presented that allows fast calibration of all pressure gauges simultaneously. Data collected in OP1.1 is analyzed to better understand neutral gas effects such as wall pumping, outgassing and runtime effects. We found that the gas balance was dominated by the effect of net outgassing. We studied the dependence on the magnetic configuration and on the heating power. We present an outline of the plans for assessing the gas balance in OP1.2, with pulse lengths of tens of seconds. We also present elements of a gas balance model being developed for OP2 (30min pulses).

P 6.6 Mo 16:30 HS Foyer

First numerical results towards a 3D MHD equilibrium solver via artificial relaxation mechanisms — •Camilla Bressan[1,2], Michael Kraus[1,2,3], Philip James Morrison[1,4], Omar Maj[1], and Eric Sonnendrücker[1,2] — [1]Max-Planck-Institute for Plasma Physics, Garching, Germany — [2]Technical University of Munich, Mathematics Department, Garching, Germany — [3]Waseda University, Tokyo, Japan — [4]The University of Texas at Austin, Physics Department and Institute for Fusion Studies, USA

First numerical experiments on a novel method to compute ideal MHD equilibria are presented. The method is based on metriplectic dynamics, initially proposed by Morrison (Physica D,18,410-419(1986)), and relies on the Hamiltonian structure of the MHD equations. Essentially, it consists in a relaxation method which is capable of dissipating selected functionals and norms of the MHD variables. As all relaxation methods, the approach does not suffer from topological restrictions (determined by the assumption of nested flux surfaces employed e.g. in the VMEC code), and yet it allows more control over the relaxation mechanism, through the choice of the dissipated functional.

The work presented applies the method in simple 2D models and represents a first step to prove its validity. We claim that this could be a good candidate for an efficient 3D equilibrium code which can address Stellarators as well as Tokamaks whose 3D effects (namely islands and ripples) are increasingly important.

P 6.7 Mo 16:30 HS Foyer

Optimal and Robust Multigrid Solver for Elliptic Problems with Application to Anisotropic Diffusion — •Mustafa Gaja[1], Ahmed Ratnani[1], Emmanuel Franck[2], Mariarosa Mazza[1], Jalal Lakhlili[1], and Eric Sonnendruecker[1] — [1]Max Planck Institute For Plasma Physics, Germany — [2]Inria Nancy Grand Est and IRMA Strasbourg, France

We investigate devising a robust and an optimal multigrid (MG) solver for the linear system arising from applying Isogeometric Analysis using B-Splines as basis functions for elliptic problems. The Laplacian and the Mass operators (H1 and L2 projectors, respectively) are inverted using MG as a solver and the acquired Toeplitz matrices from applying the Generalized Locally Toeplitz (GLT) theory as a preconditioner. The latter is used to construct an efficient preconditioner that eliminates the pathology ensuing from using high order B-Splines discretization. The goal is to have building blocks that are used for more complicated systems, thanks to physics based preconditioning and splitting schemes. We present the obtained results and show how we apply the method for anisotropic diffusion and present the corresponding results.

P 6.8 Mo 16:30 HS Foyer

A Phase Contrast Imaging Diagnostic for Turbulence Measurements in the Wendelstein 7-X Stellarator — •Lukas-Georg Böttger[1,2], Olaf Grulke[1], and Eric Matthias Edlund[3] — [1]Max-Planck Institute for Plasma Physics, 17491 Greifswald, Germany — [2]Technical University of Denmark, 2800 Kgs. Lyngby, Denmark — [3]Massachusetts Institute of Technology, Cambridge, MA, USA

The phase contrast imaging (PCI) diagnostic allows for a non-invasive imaging of electron density fluctuations in high temperature plasmas. Since the index of refraction in a plasma is a function of the electron density, an incoming laser beam experiences a phase shift, which can be converted to intensity variations by utilising a phase plate. Initially, the image contains only the line-integrated information along the beam path. However, if the magnetic field direction significantly varies along the beam path, a spatial resolution can be obtained by optical filtering.

The diagnostic is designed to operate in the range from large scale ion temperature gradient (ITG) to smaller scale trapped electron mode (TEM) and electron temperature gradient (ETG) turbulence. Simulations for ITG and TEM turbulence in W7-X geometry were performed (e.g. Helander et al., Nucl. Fusion 55 (2015) 053030) and show, inter alia, much more poloidally localised turbulent structures than in Tokamaks. Hence, the specific diagnostic location strongly influences the observations. Based on the simulations we discuss possible measurement results as a preparation for the upcoming operation phase OP 1.2 and give an update of the diagnostic design and testing process.

P 6.9 Mo 16:30 HS Foyer

Combining electromagnetic gyro-kinetic particle-in-cell simulations with collisions — •Christoph Slaby, Ralf Kleiber, and Axel Könies — Max-Planck-Institut für Plasmaphysik, D-17491 Greifswald, Germany

It remained an open question whether for electromagnetic gyro-kinetic particle-in-cell simulations pitch-angle collisions and the recently introduced pullback transformation scheme [A. Mishchenko et al., Physics of Plasmas **21**, 092110 (2014) and R. Kleiber et al., Physics of Plasmas **23**, 032501 (2016)] are consistent.

This question is answered by comparing the PIC code EUTERPE with an approach based on an expansion of the perturbed distribution function in eigenfunctions of the pitch-angle collision operator (Legendre polynomials) to solve the electromagnetic drift-kinetic equation with collisions in slab geometry.

It is shown how both approaches yield the same results for the frequency and damping rate of a kinetic Alfvén wave and how the perturbed distribution function is substantially changed by the presence of pitch-angle collisions.

First results concerning the non-linear saturation of a toroidicity-induced Alfvén eigenmode driven by energetic ions indicate that the saturation level is very sensitive to the collision frequency. The scaling is compared with analytical predictions.

P 6.10 Mo 16:30 HS Foyer

Parametric Decay Instability during Collective Thomson Scattering on ASDEX Upgrade — •Søren Kjer Hansen[1,2], Stefan Kragh Nielsen[2], Alf Köhn[1], Jörg Stober[1], and The ASDEX Upgrade Team[1] — [1]Max-Planck-Institut für Plasmaphysik, D-85748 Garching bei München, Germany — [2]Department of Physics, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark

A parametric decay instability (PDI) is a three-wave interaction where a strong electromagnetic (pump) wave decays into two electrostatic daughter waves. The present work is motivated by observation of such a PDI during collective Thomson scattering (CTS) experiments at the ASDEX Upgrade (AUG) tokamak [Nielsen et al., 2016]. Similar behaviour has been observed during CTS experiments at the LHD stellarator [Kubo et al., 2016]. The PDI, which has been investigated at AUG, is one in which the X-mode pump wave decays into a high-frequency electron Bernstein wave and a low-frequency warm lower hybrid wave. We have obtained estimates of the gyrotron power necessary to excite the PDI and the frequency shift of the electron Bernstein wave relative to the pump wave [Hansen, 2016], generalising the earlier results of [Porkolab, 1982]. Applying these results to an AUG experiment (shot 28286) yielded a gyrotron power threshold well below the one used in the experiment and a frequency shift similar to the one observed, thus validating the existence of a PDI.

P 6.11 Mo 16:30 HS Foyer

An approach to an electronic stability control for gyrotrons — •Fabian Wilde[1], Stefan Marsen[1], Ioannis Pagonakis[2], Konstantinos Avramidis[2], Torsten Stange[1], Heinrich Laqua[1], and John Jelonnek[2] — [1]Max Planck Institute for Plasma Physics (IPP), Wendelsteinstr. 1, D-17489 Greifswald, Germany — [2]Institute for Pulsed Power and Microwave Technology (IHM), Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, D-76131 Karlsruhe, Germany

Wendelstein 7-X (W7-X) uses electron cyclotron resonance heating (ECRH) by 140 GHz high-power microwave sources (gyrotrons) as primary heating method. Therefore a fast, electronic stability control for gyrotrons, allowing operation at highest possible output powers with maximum efficiency, is desireable. Such a control unit needs to implement a stabilization scheme using a reliable precursor for mode loss and a fast, automated mode recovery, if it fails.

Consequently shot spectrograms of the stray radiation were examined to identify a suitable precursor. A preliminary candidate appeared above 142 GHz, hence a D-band RF diode together with a high-pass filter was used to quantify the parasitic activity. A preliminary statistical analysis of 3000 shots yields a reasonable distribution for the probability of failure, nevertheless, a better precursor could be obtained using a 140 GHz notch filter to take into account the azimuthal neighbour mode. First experiments with a FPGA-based prototype, implementing the automated mode recovery, will be conducted soon. Multi-mode simulations, taking beam charge neutralization into account, will be used to describe a physical gyrotron reliability model.

P 6.12 Mo 16:30 HS Foyer

SOLPS Modeling of Partially Detached Plasmas in ASDEX Upgrade — •Ferdinand Hitzler[1,2], Marco Wischmeier[1], Felix Reimold[3], Xavier Bonnin[4], Arne Kallenbach[1], the ASDEX Upgrade Team[1], and the EUROfusion MST1 Team[5] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Forschungszentrum Jülich, Jülich, Germany — [4]ITER Organization, St. Paul-lez-Durance, France — [5]See http://www.euro-fusionscipub.org/mst1

Power exhaust in future fusion devices like ITER is a challenging issue which has to be addressed carefully. For an unmitigated power flux the power load limits for the divertor components of around $10\,\mathrm{MWm}^{-2}$ would be exceeded considerably. In order to be able to sustain operation under reactor conditions the power load at the divertor plates has to be reduced significantly. This reduction can be achieved via detachment, a divertor regime which is observed at high plasma densities and low divertor temperatures.

The goal of this contribution is the investigation of divertor detachment using the SOLPS code package for interpretative simulations. Since ITER is foreseen to be operated in a partially detached regime in H-mode, the main focus of this work is the transition from the high recycling to the partially detached regime. The width of this transition, the operational window, and possible advantages and disadvantages of different degrees of detachment are discussed. A code validation will be performed via comparison of the modeling results with experimental data from ASDEX Upgrade in nitrogen and argon seeded H-mode.

P 6.13 Mo 16:30 HS Foyer

Analysis and Modelling of JET Neon Seeded Discharges With High Radiative Power Fraction — •Stephan Glöggler[2,3], Marco Wischmeier[2], Matthias Bernert[2], Giuseppe Calabrò[4], Alexander Huber[5], Christopher Lowry[6], Matthew Reinke[7], Sven Wiesen[5], and JET Contributors[1] — [1]EUROfusion Consortium, JET, Culham Science Centre, Abingdon, UK — [2]IPP, Garching, Germany — [3]Physik-Department E28, TUM, Garching, Germany — [4]ENEA for EUROfusion, Frascati, Italy — [5]FZ Jülich GmbH, Jülich, Germany — [6]European Commision, Brussels, Belgium — [7]ORNL, Oak Ridge, USA

In future fusion devices as ITER and DEMO the power flux onto the divertor target plates will have to be reduced by deliberate seeding of impurities. In DEMO a major fraction of the induced radiative power losses must originate inside the last closed flux surface. As radiative power losses within the confined plasma might reduce the plasma confinement and impact the discharge stability it is crucial to determine and understand the underlying physical processes in high radiative discharges.

At JET neon seeded discharges were carried out and the influence of the seeding at high heating powers on the pedestal and the divertor profiles is examined. An inter-relation of these profiles with the radial radiation distribution is analyzed. Numerical simulations with the code package SOLPS-ITER (plasma fluid code B2.5 coupled with the Monte Carlo neutral code EIRENE) of these discharges are performed to complement the experimental findings.

P 6.14 Mo 16:30 HS Foyer

Non-Maxwellian fast particle effects in gyrokinetic GENE simulations — •Alessandro Di Siena[1], Tobias Goerler[1], Hauke Doerk[1], Jonathan Citrin[2,3], Thomas Johnson[4], Mireille Schneider[3], and Emanuele Poli[1] — [1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — [2]FOM Institute DIFFER, PO Box 6336, 5600 HH Eindhoven, The Netherlands — [3]CEA, IRFM, F-13108 Saint Paul Lez Durance, France — [4]VR Association, EES, KTH, Stockholm, Sweden

The understanding of the stabilising mechanism of fast particles on the main plasma turbulence is an essential task for a future fusion reactor, where the energetic particles can constitute a significant fraction of the main ions. While the consideration of equivalent Maxwellian distributed fast ions in the simulations has greatly improved the agreement with the experiment, the fast ion electromagnetic stabilization seems to be somewhat overestimated. However, it is well known that to rigorously model highly non thermalised particles, a non-Maxwellian background distribution function is needed. To this aim, a previous study on a particular JET plasma has been revised and analysed with the gyrokinetic code GENE. In order to study the impact of non-Maxwellian distribution functions on the plasma turbulence, the fast particle distributions have been modelled with a number of different analytic choices, as well as numerical distributions imported from the modelling tools NEMO/SPOT and SELFO. The analytical distributions best approximating the numerical ones are identified and linear and nonlinear results are shown.

P 6.15 Mo 16:30 HS Foyer

Bayesian inference of electron temperature and density from JET high resolution Thomson scattering and interferometer data — •Sehyun Kwak[1,2], Jakob Svensson[2], Sergey Bozhenkov[2], Joanne Flanagan[3], Mark Kempenaars[3], Young-chul Ghim[1], and JET Contributors[3] — [1]Dept. of Nuclear and Quantum Engineering, KAIST, Daejeon, South Korea — [2]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [3]Culham Centre for Fusion Energy, Abingdon, UK

A Bayesian model for inferring electron temperature and density profiles from a combination of the high resolution Thomson scattering (HRTS) and interferometer systems at JET has been developed. The HRTS system measures spectra of Thomson scattered light, which depends on the local temperature and density. The interferometer measures line integrated density along a number of lines of sight. As the spatial channels and lines of sight of the HRTS and interferometer systems are differently located the temperature and density profiles need to be mapped to normalised flux coordinates (here using the EFIT code) so that the forward model predicts both HRTS and interferometer data simultaneously given the profiles. The prior temperature and density profiles are modelled as Gaussian processes with spatially varying smoothness properties (determined by hyperparameters). The posterior distribution of the temperature and density profile as well as their hyperparameters is explored by a Markov chain Monte Carlo (MCMC) scheme. Since the model includes both HRTS and interferometer systems, the HRTS calibration is done automatically.

P 6.16 Mo 16:30 HS Foyer

Kinetic Simulations of 1D SOL Plasmas with KIPP-SOLPS Coupling Code — •Menglong Zhao, Alex Chankin, and David Coster — Max-Planck-Institut fuer Plasmaphysik, Boltzmannstraße 2, Garching

In order to investigate the kinetic effects in a systematic way, the 1D2V kinetic Vlasov-Fokker-Planck (VFP) code KIPP has been coupled to SOLPS to treat electron parallel transport kinetically. KIPP-SOLPS coupling code allows us to incorporate kinetic electrons into the already sophisticated fluid model (B2) self consistently. The simulation results of KIPP-SOLPS with pure deuterium and with carbon impurity in 1D geometry with stagnation point upstream and target downstream will be presented. These results are then compared to the results of only SOLPS simulation with or without heat flux limiter. Finally the cases with only SOLPS but including modified heat transmission coefficient are compared with KIPP-SOLPS coupling cases.