P 17: Magnetic Confinement V/HEPP VI

Time: Wednesday 16:30–18:35 Location: ELP 6: HS 3

Invited Talk P 17.1 Wed 16:30 ELP 6: HS 3

Finite Element Method to Describe Magnetic Measurements of Tearing Modes in ASDEX Upgrade — •Magdalena Bauer, Hartmut Zohm, Marc Maraschek, Anja Gude, Wolfgang Suttrop, Felix Klossek, Bernhard Sieglin, and Louis Giannone — MPI for Plasma Physics, Garching

In large tokamaks a disruption, i.e. a sudden loss of plasma current terminating the discharge, has to be avoided or at least mitigated. Tearing modes (TMs), resistive plasma instabilities, are common precursors to disruptions, particularly TMs with toroidal mode number n=1. Electromagnetic interaction with the vacuum vessel can slow down rotating TMs, which can eventually lock to the wall. Here, toroidal coupling, i.e. the coupling of modes with the same n but different poloidal mode numbers, m, plays an important role. Magnetic perturbations associated with TMs are detected by coils outside the plasma with different orientations and distances to conducting structures. To analyse TMs at all times, the frequency dependence of these measurements has to be described. For this purpose, a three-dimensional model using the finite element method is employed. A TM is introduced as a radially-localized helical current, while the plasma is modelled as vacuum. The vessel and additional conducting structures are integrated in a simplified form. The perturbed magnetic field measured by the coils is calculated taking into account induced currents in the conducting structures. In order to determine the mode composition in all stages of the locking process, agreement between model and measurement is required. The steps performed to achieve this are presented.

P 17.2 Wed 17:00 ELP 6: HS 3

Effect of magnetic islands on fast ion confinement in toroidal devices — •David Kulla[1,2], Samuel Lazerson[2], Athina Kappatou[1], Robert Wolf[2], and Hartmut Zohm[1] — [1]MPI für Plasmaphysik, Garching — [2]MPI für Plasmaphysik, Greifswald

We present applied modeling work with the newly validated BEAMS3D code for simulating neutral beam deposition and fast ion slowing down in tokamaks and stellarators. Fast alpha particles generated by fusion reactions have to heat the thermal plasma collisionally to reach self-sustaining conditions in a reactor and therefore be well confined in the magnetic field. Tokamaks are largely axisymmetric, but suffer from dynamic magnetic perturbations which can break this property and lead to increased fast ion transport and losses. Stellarators are intrinsically three-dimensional but are generally less prone to transient perturbations. In present experiments, neutral beam injection can be used to generate and study fast ions. Magnetic islands arise from helical perturbations of the background magnetic field, either internally from the plasma or externally from magnetic coils.

BEAMS3D has recently been verified against NUBEAM as well as validated against experimental data at the ASDEX Upgrade tokamak using fast-ion D-alpha light (FIDA). We present simulations studying the effect of internal magnetic islands in ASDEX-Upgrade (tokamak) and Wendelstein 7-X (stellarator), showing similarities and differences. The simulations are compared to experimental measurements where applicable.

P 17.3 Wed 17:15 ELP 6: HS 3

Neural Networks as ideal magnetohydrodynamic equilibrium solvers — •Timo Thun[1], Andrea Merlo[2], and Daniel Böckenhoff[1] — [1]Max-Planck- Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany — [2]Proxima Fusion, Am Kartoffelgarten 14, 81671 Munich, Germany

Quick and accurate solvers for the ideal magnetohydrodynamic (MHD) equilibrium in non axisymmetric magnetic fields can accelerate stellarator optimisation, facilitate high-fidelity real-time control and enable other data-driven algorithms like symbolic regression. Unfortunately, current MHD equilibrium solvers either require high computational wall-time or suffer from a lack of accuracy. Neural Network (NN) based solvers enable very fast inference by transferring the bulk of computational load to model training and the creation of datasets, possibly overcoming this dilemma.

Recent work presented a fast NN based ideal MHD surrogate model in the magnetic configuration space defined by the stellarator research device Wendelstein 7-X. Training the model required a dataset calculated by conventional solvers, but results improved with the addition of the physics-based ideal MHD equilibrium force-residual as an additional training target. Training without a dataset removes implicit biases of its solution strategy and avoids computational costs associated with its creation.

We present a first step towards this physics-based NN training paradigm by training a NN model only on the force residual of a single non-axisymmetric ideal MHD equilibrium.

P 17.4 Wed 17:30 ELP 6: HS 3

Electron cyclotron resonance during plasma formation in nonuniform magnetic fields — •Albert Johansson and Pavel Aleynikov — Wendelsteinstraße 1, 17491 Greifswald

Electron cyclotron resonance is used to start up various fusion experiment devices. In Wendelstein 7-X (W7-X), the second harmonic extraordinary mode (X2) is used for breakdown. Third harmonic extraordinary mode (X3) breakdown is of particular interest, as some future experiments intend to investigate the effects of a lower magnetic field strength. Presently, no experiment at W7-X has successfully used X3 for breakdown. Because the resonance depends on the gyrofrequency, proportional to magnetic field strength over Lorentz factor B/γ, an energy increase is associated with an increase in γ and the resonance condition breaks, causing a finite resonance width. It has been shown that for a uniform magnetic field this resonance width is not enough to ensure a breakdown process [1].

However, the magnetic field of a stellarator is not homogeneous. This opens the possibility of field gradients along the electron trajectory. When the magnetic field strength is increasing in step with the electron energy, the "width" of the resonance is extended considerably. In addition, when several beams are used, a "resonance overlap" can be constructed such that electrons gain almost hundred times the ionization energy of 13.6 eV. We discuss the effect of magnetic field inhomogeneity on energy gain and show how the composition of multiple beams can be optimised.

[1] D Farina. *Nuclear Fusion* 2018, 58(6):066012

P 17.5 Wed 17:55 ELP 6: HS 3

Development of an ECRH plasma start-up scenario for X3 heating at $1.8\,T$ at Wendelstein 7-X — •Niklas Simon Polei, Torsten Stange, Frank Noke, Frank Hollmann, Heinrich Peter Laqua, and W7-X Team — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald

One of the main goals of the Wendelstein 7-X stellarator is to show good confinement of fast particles in high beta scenarios. Beta is the ratio of kinetic pressure and magnetic pressure $\beta = \frac{2\bar{n}\bar{T}}{B^2/2\mu_0}$. The available power of the electron cyclotron resonance heating (ECRH) system is not sufficient to reach the necessary beta of 4-5% at $2.5\,T$, but higher beta values are expected at lower magnetic field. To still use the existing gyrotrons at $140\,GHz$, X3 heating has to be used at a field of $1.8\,T$, but a plasma start-up is not possible because $T_e > 0.5keV$ is needed for sufficient absorption. Therefore, the combination of ion cyclotron resonance heating and neutral beam injection has been considered as the start-up scenario so far. The usual ECRH X2 start-up is also possible, if one gyrotron is operated near its other operating point at $104\,GHz$.

However, operation at $101\,GHz$ is necessary and was succesfully demonstrated for $100\,ms$ with a power of $300\,kW$. Additionally, a multi-pass scenario with six passes through the plasma axis was developed to maximise the power density during the first $10-20\,ms$ of plasma initiation. For this purpose, two new tiles were designed and the beam positions of the different passes were verified in the plasma vessel in preperation for the next operation phase 2.2.

P 17.6 Wed 18:10 ELP 6: HS 3

The Disruptive H-Mode Density Limit and MARFE Behaviour — •Felix Klossek, Anja Gude, Marc Maraschek, Bernhard Sieglin, Matthias Bernert, Hartmut Zohm, and the ASDEX Upgrade Team — Max-Planck Insitute for Plasma Physics, Boltzmannstr. 2, 85748 Garching

The high confinement mode (H-mode) is an operational regime in tokamaks with suppressed turbulence near the edge, so that particles and energy are confined better. High densities, which are desirable in terms of fusion power, are prone to a density limit: a degradation of confinement and subsequent disruption.

When approaching a density limit disruption, a Multifaceted Asymmetric Radiation From the Edge (MARFE) forms as toroidal ring. It is strongly radiating and is therefore altering the power balance in the plasma and reducing the temperature in its vicinity. During the MARFE evolution, this effect becomes more pronounced. The MARFE starts near the X point, where it is also called X point radiator (XPR). It will subsequently move up on the high field side near the separatrix and stay some time at the top of the plasma, before approaching the low field side, entering the core and triggering MHD instabilities which finally lead to the disruption.

The MARFE position can be reconstructed using measurements from bolometer pinhole cameras. A robust and fast approach based on angular probability distributions for each camera is presented.