P 1: Magnetic Confinment Fusion/HEPP I

Time: Monday 13:45–15:55 Location: ZHG102

Invited Talk P 1.1 Mon 13:45 ZHG102

On the way to a fusion power plant — •Felix Warmer — Max Planck Institut für Plasmaphysik

The pursuit of controlled nuclear fusion for sustainable energy generation has long been a focal point of scientific research. Recent demonstration of significant energy gain in fusion experiments has triggered a wave of excitement around the world. In particular, a number of large, privately funded fusion startup companies have emerged that aim to bring fusion power to the grid. Is fusion power within our grasp? This talk will discuss the state-of-the-art in fusion reactor design, explore the remaining challenges, and sketch the way forward, focusing on magnetic confinement and the Stellarator concept.

P 1.2 Mon 14:15 ZHG102

Avenues to steady-state turbulence suppression at Wendelstein 7-X — •Markus Wappl, Sergey Bozhenkov, Jürgen Baldzuhn, Sebastian Bannmann, Håkan Smith, Edgardo Villalobos, and Pavlos Xanthopoulos — Max Planck Institute for Plasma Physics, Greifswald, Germany

Plasma scenarios of transient turbulence suppression, featuring improved energy confinement and high ion temperature, are well known at W7-X. By means of injecting neutral beams or frozen hydrogen pellets, the electron density gradient can be momentarily increased which suppresses ITG-driven turbulent heat transport in the ion channel to nearly zero. However, collapse of the density gradient and return to conventional turbulent heat transport usually occurs after only a few confinement times.

Recent plasma scenario development suggests paths to steady-state turbulence suppression. A newly commissioned steady-state pellet injector along with careful adjustment of microwave heating power allows to maintain the increased density gradient. In addition, a self-ordering process leading to a similar density gradient and turbulence suppression is observed in microwave heated plasmas at low power, following boronization of the first wall.

This talk provides an overview of a large turbulent transport database obtained by power balance analysis. Several transient and steady-state turbulence-suppressed plasma scenarios are discussed in detail and compared to gyrokinetic transport simulations. An outlook to future steady-state turbulence-suppressed scenarios is given.

P 1.3 Mon 14:40 ZHG102

Introduction of a 3D global non-linear full-f particle-in-cell model for runaway electrons in JOREK — •Hannes Bergstroem[1], Shi-Jie Liu[1], Vindoh Bandaru[2], and Matthias Hoelzl[1] — [1]Max Planck Institute for Plasma Physics, Garching b. M. — [2]Indian Institute of Technology Guwahati, Assam

Disruptions are a major challenge for ensuring reliable tokamak operation. The acceleration of electrons to relativistic energies, so-called *runaway electrons* (REs), being a significant concern for future large scale devices like ITER. Accurately predicting the formation and deposition of REs is critical for optimizing machine design and implementing effective disruption mitigation systems. This requires advanced modeling that captures the interplay between REs and the plasma, including the large-scale MHD activity characteristic of disruptions. The non-linear 3D extended MHD code JOREK provides a powerful framework for investigating disruption and RE dynamics. This talk introduces recent enhancements to JOREK, incorporating a hybrid fluid-kinetic model where REs are represented kinetically and coupled to the non-linear MHD equations through a full-f particle-in-cell approach. The model offers precise insight into the phase space distributions, drift dynamics, and transport and losses of REs in stochastic magnetic fields. Benchmarks are conducted for both 2D and 3D configurations, with results showing good agreement with analytical predictions. Additionally, a particularly challenging non-linear case with high relevance for large tokamaks is presented: a benign termination of REs triggered by a rapid burst of MHD activity.

P 1.4 Mon 15:05 ZHG102

Gyrokinetic instabilities and turbulence in stellarators — •Linda Podavini, Per Helander, Gabriel G Plunk, and Alessandro Zocco — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

The stellarator Wendelstein 7-X (W7-X) is designed to achieve reduced neoclassical transport through magnetic field optimization. Its confinement properties are thus predominantly determined by turbulence, which arises from instabilities active at kinetic scales. The stability of these turbulence-driving modes depends on various plasma parameters, such as the strength of temperature and density gradients, the mirror ratio, and the rotational transform of the confining magnetic field, for instance. Adjusting these parameters offers a pathway to optimising performance in W7-X and future stellarators alike. In this contribution, we present numerical investigations of kinetic plasma turbulence in W7-X within the context of gyrokinetic theory, paying attention to possible improvements in operating scenarios and performance. The high sensitivity of these instabilities on plasma parameters underscores the need for a unified theoretical framework capable of providing rapid stability proxies. The theory of upper bounds on the growth rates of local gyrokinetic instabilities addresses this need by offering results that are independent of magnetic geometry and several plasma parameters. However, comparisons with gyrokinetic simulations highlight the crucial role of magnetic geometry in achieving quantitatively accurate results.

P 1.5 Mon 15:30 ZHG102

Reduced kinetic modelling of shattered pellet injection in ASDEX Upgrade — •Peter Halldestam[1], Paul Heinrich[1], Gergely Papp[1], Mathias Hoppe[2], Matthias Hölzl[1], István Pusztai[3], Oskar Vallhagen[3], Rainer Fischer[1], and Frank Jenko[1] — [1]Max Planck Institute for Plasma Physics, Garching b. München, Germany — [2]Royal Institute of Technology, Stockholm, Sweden — [3]Chalmers University of Technology, Göteborg, Sweden

Plasma-terminating disruptions are a critical outstanding issue for reactor-relevant tokamaks. ITER will use Shattered Pellet Injection (SPI) as its disruption mitigation system to reduce heat loads, vessel forces, and to suppress the formation of runaway electrons. In this work we demonstrate that reduced kinetic modelling of SPI is capable of capturing the major experimental trends in ASDEX Upgrade SPI experiments, such as dependence of the radiated energy fraction on neon content, or the current quench dynamics. Simulations confirm the experimental observation of no runaway electron generation with neon and mixed deuterium-neon pellet composition. We also show that statistical variations in the fragmentation process only have a notable impact on disruption dynamics at intermediate neon doping, as was also observed in experiments.