P 11: Magnetic Confinement II

Time: Tuesday 14:00–16:35 Location: SPA HS202

Invited Talk P 11.1 Tue 14:00 SPA HS202
Simulation and optimisation of turbulence in stellarators — •Pavlos Xanthopoulos[1], Per Helander[1], Harry Mynick[2], Yuriy Turkin[1], Frank Jenko[3], Tobias Goerler[3], Daniel Told[3], Gabriel G. Plunk[1], Thomas Bird[1], and Josefine H.E. Proll[1] — [1]Max-Planck-Institut für Plasmaphysik, EURATOM Association, Wendelsteinstr. 1, 17491 Greifswald, Germany — [2]Plasma Physics Laboratory, Princeton University, Princeton, New Jersey 08543, USA — [3]Max-Planck-Institut für Plasmaphysik, EURATOM Association, Boltzmannstr. 2, 85748 Garching, Germany

In tokamaks and stellarators - two leading types of devices used in fusion research - magnetic field lines trace out toroidal surfaces on which the plasma density and temperature are constant, but turbulent fluctuations carry energy across these surfaces to the wall, thus degrading the plasma confinement. Using petaflop-scale simulations, we calculate for the first time the pattern of turbulent structures forming on stellarator magnetic surfaces, and find striking differences relative to tokamaks. The observed sensitivity of the turbulence to the magnetic geometry suggests that there is room for further confinement improvement, in addition to measures already taken to minimise the laminar transport. With an eye towards fully optimised stellarators, we present a proof-of-principle configuration with substantially reduced turbulence compared to an existing design.

Invited Talk P 11.2 Tue 14:30 SPA HS202
Der Turbulenz auf der Spur durch Vergleiche von Reflektometriemessungen mit gyrokinetischen Simulationen — •Tim Happel, Alejandro Bañón Navarro, Garrard D. Conway, Frank Jenko, Ulrich Stroth und das ASDEX Upgrade Team — Max-Planck-Institut für Plasmaphysik, 85748 Garching, Deutschland

Toroidal eingeschlossene Plasmen werden seit mehr als 50 Jahren zur Erforschung eines möglichen Konzepts zur Energiegewinnung, der thermonuklearen Fusion, verwendet. Dabei werden der Maximierung der eingeschlossenen Energie Grenzen durch verschiedene Arten von Turbulenz gesetzt. Ein grundlegendes Verständnis der beteiligten Prozesse ist deshalb zentrales Thema der Fusionsforschung.

Zur Intensivierung der Erforschung der Turbulenz wurde ein aus internationalen Partnern bestehendes "Virtuelles Institut" gegründet. Dieses untersucht mit einem breiten Spektrum von Reflektometern Plasmaprofile, -geschwindigkeiten und Turbulenzintensitäten am ASDEX Upgrade Tokamak. Weitere Bestandteile sind die Entwicklung neuartiger Antennen, die Interpretation der Daten durch Simulation der Mikrowellenpropagation und Vergleiche mit Turbulenzcodes.

Ein Überblick der zum Einsatz kommenden Methoden, Experimente und ersten Resultate wird gegeben. Insbesondere wird die Anwendung der Doppler-Reflektometrie zur Untersuchung der Reaktion skalenaufgelöster Turbulenz bei zusätzlicher Elektronenheizung an verschiedenen radialen Positionen im Plasma vorgestellt. Die experimentellen Beobachtungen werden schließlich mit Ergebnissen von nichtlinearen gyrokinetischen Simulationen mit GENE verglichen.

Topical Talk P 11.3 Tue 15:00 SPA HS202
The snowflake divertor, physics of a new concept for power exhaust of fusion plasmas — •Tilmann Lunt[1], Gustavo Canal[2], Yühe Feng[1], and Holger Reimerdes[2] — [1]Max-Planck-Institut für Plasmaphysik, Garching/Greifswald, Germany — [2]Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Fusion reactors based on the tokamak design will have to deal with very high heat loads on the divertor plates. One of the approaches to solve this heat load problem is the so called 'snowflake divertor', a magnetic configuration with two nearby x-points and two additional divertor legs. In this contribution we report on 'EMC3-Eirene' simulations of the plasma- and neutral particle transport in the scrape-off layer of the swiss tokamak TCV of a series of snowflake equilibria with different values of σ, the distance between the x-points normalized to the minor radius of the plasma. The constant anomalous transport coefficients were chosen such that the power- and particle deposition profiles at the primary inner strike point match the Langmuir probe measurements for the $\sigma = 0.1$ case. At one of the secondary strike points, however, a significantly larger power flux than that predicted by the simulation was measured by the probes, indicating the presence of an enhanced transport across the primary separatrix. We will discuss the possible reason for this enhanced transport as well as its scaling with machine size. Another prediction from the simulation is that the density as well as the radiation maximum are moving from the recycling region in front of the plates upwards to the x-point.

Topical Talk P 11.4 Tue 15:25 SPA HS202
Erzeugung relativistischer Elektronen über nichtresonante RF-Heizverfahren — •Torsten Stange, Heinrich Peter Laqua, Marion Dostal und Matthias Otte — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, EURATOM Association

Am Stellarator WEGA konnte ein neuartiges Heizszenario aufgeklärt werden, das auf der stochastischen Beschleunigung von Elektronen in einem elektrischen Wechselfeld beruht. Im Fall der verwendeten 2.45 GHz-Hohlleiterantenne an WEGA konnte eine hochrelativistische Elektronenkomponente mit Energien bis zu MeV nachgewiesen werden. Für eine effiziente Heizung von Fusionsplasmen sind so hohe Energien jedoch unerwünscht. Zur Unterbindung dieses Effekts wurde unter anderem der gleichzeitige Einsatz zweier Antennen untersucht, dessen 2.45 GHz-Wechselfeld in einer definierten Phasenbeziehung zueinander steht. Das vorrangige Ziel ist den für eine weitere Beschleunigung relevanten Energiebereich zu selektieren und nur schwach relativistische Elektronen zu erzeugen. Eine weitere Möglichkeit besteht in der Anhebung des Neutralgasdrucks. Der damit verbundene Anstieg der Bulk-Elektronendichte führt zu einem erhöhten Energietransfer von der überthermischen Elektronenkomponente hin zum Bulk-Plasma. Ein weiteres Heizverfahren konnte bei Elektronendichten weit über der cutoff-Dichte der Heizfrequenz identifiziert werden, das nur durch eine Anregung von Whistler-Wellen erklärt werden kann.

P 11.5 Tue 15:50 SPA HS202
Dynamic behaviour of magnetic flux tubes in the FlareLab experiment — •Felix Mackel, Sascha Ridder, Jan Tenfelde, and Henning Soltwisch — Ruhr-Universität Bochum

Rapidly evolving magnetic flux tubes are generated by a pulsed power plasma experiment. An external magnetic guide field is provided by a strong line current that initially leads to an almost perfect half torus of current-carrying plasma connecting both electrodes. Unbalanced magnetic pressure causes the expansion of the major radius. Measurements with invasive Rogowski coils reveal a saturation of the current that is flowing through the apex of the luminous arch structure soon after ignition. While the appearance of the plasma on ICCD images is rather collimated, the continuously rising discharge current diverges drastically above the footprints. Eventually, the arch loses the visual connection to the electrodes, while the total discharge current still continues to rise. Magnetic pickup coils surrounding the electrodes show that the current paths bulge outward quickly as a consequence of configuration-space instabilities which may be triggered by the preceding widening of the current channel. At the same time, radiation in the extreme ultraviolet spectrum is detected by a photodiode covered with a thin metal foil acting as a bandpass filter. A physical model is proposed to account for the generation of fast particles that possibly provoke the emission of EUV light.

P 11.6 Tue 16:05 SPA HS202
Towards an automated approach to magnetic divertor configuration design — •Maarten Blommaert[1], Wouter Dekeyser[2], Martine Baelmans[2], Nicolas Ralph Gauger[3], and Detlev Reiter[1] — [1]Institute for Plasmaphysics (IEK-4), FZ Jülich GmbH, D-52425 Jülich, Germany — [2]KU Leuven, Department of Mechanical Engineering, 3001 Leuven, Belgium — [3]Center for Computational Engineering Science, RWTH Aachen, D-52062 Aachen, Germany

At present, several plasma boundary codes exist that attempt to describe the complex interactions in the divertor SOL (Scrape-Off Layer). The predictive capability of these edge codes is still very limited. Yet, in parallel to major efforts to mature edge codes, we face the design challenges for next step fusion devices. One of them is the design of the helium and heat exhaust system. Therefore, already now, modern concepts of computational engineering (automated design) are being investigated regarding their conceptual suitability for the edge/divertor design problem. The application of these methods to magnetic field design is studied, using a somewhat reduced plasma-gas continuum flow model and a perturbation approach for the magnetic equilibrium.

The aim is to provide enhanced spreading of heat fluxes over the target plates. The methods are applied to a specific example based on a JET magnetic equilibrium and model parameters. For the current model, inner and outer target peak heat loads could be reduced by 48% and 38% respectively. This reduction is mainly achieved by an increased divergence of the magnetic field lines towards the target area.

P 11.7 Tue 16:20 SPA HS202

Stellarator-specific developments for the systems code PROCESS — •Felix Warmer[1], Peter Knight[2], Craig Beidler[1], Andreas Dinklage[1], Yühe Feng[1], Joachim Geiger[1], Felix Schauer[1], Yuriy Turkin[1], David Ward[2], Robert Wolf[1] und Pavlos Xanthopoulos[1] — [1]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, D-17491 Greifswald, Germany — [2]Culham Centre for Fusion Energy, Abingdon, Oxfordshire, OX14 3DB, United Kingdom

The ultimate goal of fusion research is to demonstrate the feasibility of economic production of electricity. The most promising concepts to achieve this by magnetic confinement are the Tokamak and the Stellarator. System codes are used to study the general properties of a fusion power plant. Built in a modular way systems codes describe the physical and technical properties of the power plant components. For the Helical Advanced Stellarator (HELIAS) concept modules have been developed in the frame of the existing Tokamak systems code PROCESS.

These include: A geometry model based on Fourier coefficients which represent the complex 3-D plasma shape, a divertor model which assumes diffusive cross-field transport and high radiation at the X-point, a coil model which uses a scaling based on the HELIAS design and a transport model which either employs empirical confinement time scalings or sophisticated 1-D collisional and turbulent transport calculations. This approach aims at a direct comparison between Tokamak and Stellarator power plant designs.