Towards first-principles simulations of the L- to H-mode transition with the global gyrokinetic turbulence code GENE-X

P. Ulbl[1,*], M. Bergmann[1], F. Jenko[1,2] and the ASDEX Upgrade Team[3]

[1]Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany
[2]University of Texas at Austin, Austin, TX 78712, USA
[3]See author list of H. Zohm et al, 2024 Nucl. Fusion https://doi.org/10.1088/1741-4326/ad249d

[*]philipp.ulbl@ipp.mpg.de

A thorough understanding of the interplay between turbulent transport in the plasma edge and the overall plasma confinement is essential for the future operation of fusion devices. Improved confinement regimes, most notably the H-mode, and the associated transitions from the L-mode, remain to be fully understood. First-principles, high-fidelity gyrokinetic simulations of the H-mode and the LH-transition are required to gain physical insight into the underlying processes that determine the plasma confinement. The complex geometry and steep gradient region present at the plasma edge make simulations particularly challenging and require the development of advanced computational tools.

In this work, we use the gyrokinetic turbulence code `GENE-X`, which is specialized for simulations of the plasma edge and scrape-off-layer (SOL). The code implements an electromagnetic, collisional, full-f, gyrokinetic model and uses the flux-coordinate independent (FCI) approach to allow for realistic geometry, including the magnetic X-point and separatrix. The full-f model allows the background profiles to change dynamically during a simulation, together with a self-consistently evolving radial electric field. The boundary conditions prescribe experimentally motivated density and temperature profile values at the inner and outer boundaries of the simulation domain, resulting in a flux-driven simulation mode. With these features, `GENE-X` is able to perform first-principles turbulence simulations in diverted geometry.

We present global gyrokinetic simulations of the AUG tokamak, starting with turbulence in a pre-LH-transition L-mode. We analyze the plasma profiles, heat fluxes and spectral characteristics of the turbulence in the confined region, as well as the heat exhaust on the divertor plates. We then perform a power ramp by adjusting the inner boundary condition to reflect the change in density and temperature due to fuelling and NBI heating during the experimentally observed LH-transition. We show the temporal evolution of the plasma profiles, the radial electric field, heat flux and turbulent spectra during the power ramp and analyze the change in confinement time. Finally, we discuss the possibility of simulating the transient processes of the LH-transition with global gyrokinetic simulations.