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# Numerical modelling of the transition from low to high confinement in magnetically confined plasma

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An outstanding issue in magnetic fusion research is the understanding of the transition from the Low (L-mode) to the High (H-mode) confinement regime. Although the H-mode is routinely achieved in a multitude of magnetic confinement devices, since the first observation more than 30 years ago, the transition still lacks full theoretical explanation and predictive modelling. This is a high priority topic since ITER will rely on operation in H-mode to achieve the goal of ignition.

We present numerical modelling of the L-H transition based on the first-principle fluid model HESEL (Hot Edge-Sol-Electrostatic). The model is a four-field drift-fluid model including generalized vorticity, density, electron and ion pressure equations and using the Braginskii closure for collisions. The model is solved on a 2D domain at the out-board mid-plane of a Tokamak including both open and closed field lines. The parallel dynamics is parameterized in the open field line region – the scape off layer - accounting consistently for the parallel losses.

The results, obtained for parameters typical for medium sized Tokamaks (MST), reveal different types of L-H-like transitions in response to ramping up the input power. For a fast rising input power we obtain an abrupt transition, and for a slow rising power we obtain the L-I-H transition with the intermediate I-phase displaying limit cycle oscillations (LCO). The L-I-H transition has been observed in several devices and investigated in great detail by applying advanced imaging systems. Direct comparisons with recent experimental findings in the Experimental Advanced Superconducting Tokamak – EAST [2] have revealed close agreement in a multitude of observables between simulations and experiment for the evolution of the L-I-H transition, specifically including the phase relations during the triggering events. Additionally, the model reproduces the experimentally determined L-H transition power threshold and the scaling that the ion power threshold increases with increasing particle density [3]. Presently the investigations are extended for comparisons with other MST devices, e.g., ASDEX Upgrade.

The simplified model presented here, lacking, e.g., toroidal geometry effects, appears to contain the necessary and essential ingredients for revealing the transition behaviors, but is still not a fully predictive model. The results presented form an essential step connecting zero- and one-dimensional heuristic transition models with a predictive model. Thus, the results hold promises for developing a full predictive modelling of the L-H transition, which is an essential step in understanding and optimizing fusion devices.

[1] A.H. Nielsen et al., (2014), http://arxiv.org/abs/1409.3186
[2] G.S. Xu et al., Nuclear Fusion **54** 013007. (2014)
[3] F. Ryter et al., Nuclear Fusion **54,** 083003 (2014)