Fast-ion losses induced by ELMs and externally applied magnetic perturbations in the ASDEX Upgrade tokamak

M. Garcia-Munoz[1], S. Akaslampolo[2], O. Asunta[2], J. Boom[3], I. G. J. Classen[3], R. Dux[4], T. E. Evans[5], N. Ferraro[5], S. Fietz[4], C. Fuchs[4], B. Geiger[4], M. Holzl[4], T. Kurki-Suonio[2], B. Kurzan[4], N. Lazányi[6], R. M. McDermott[4], M. Nocente[7], M. Rodriguez-Ramos[1], K. Shinohara[8], W. Suttrop[4], M. A. Van Zeeland[5], E. Viezzer[4], E. Wolfrum[4]
and the ASDEX Upgrade Team

[1]University of Seville, Spain,[2]Aalto University, Finland,[3]FOM Institute DIFFER, The Netherlands, [4]Max-Planck Institute for Plasma Physics, Germany, [5] General Atomics, USA, [6]BME NTI, Hungary, [7]Università degli Studi di Milano-Bicocca, Italy, [8]JAEA, Japan

The impact of Edge Localized Modes (ELMs) and externally applied Resonant and Non-Resonant Magnetic Perturbations (MPs) on fast-ion confinement / transport have been investigated in the ASDEX Upgrade tokamak by means of new diagnostic capabilities and numerical tools.

Filament-like bursts of fast-ion losses induced by ELMs dominate the losses in H-mode plasmas as measured by fast-ion loss detectors (FILDs) at different toroidal and poloidal positions. In low-collisionality H-modes, ELM and inter-ELM fluctuations in fast-ion losses are often strongly connected with main ELM properties and edge flows. Bursts of fast-ion losses are observed during ELMs, suggesting a strong interaction between fast-ions and the instabilities concomitant to the ELM cycle. Large changes in escaping-ion phase-space are observed within a single ELM.

Externally applied MPs have little effect on kinetic profiles, including fast-ions, in high collisionality plasmas with mitigated ELMs. During the mitigation / suppression of type-I ELMs by externally applied MPs, the large fast-ion bursts observed during ELMs are replaced by a steady loss of fast-ions with a broad-band frequency and an amplitude of up to an order of magnitude higher than the NBI prompt loss signal without MPs. A strong impact on kinetic profiles (density pump-out and rotation braking) is observed, however, in low-collisionality and low q_{95} plasmas with resonant and non-resonant MPs. A clear synergy in the overall fast-ion transport is observed between MPs and Neoclassical Tearing Modes (NTMs). The heat load on the first wall produced by the MP induced fast-ion losses has been measured with an infra-red camera. Fast-Ion D-Alpha (FIDA) spectroscopy has been used to monitor the confined fast-ion profile evolution when applying MPs. An enhancement of the fast-ion content in plasma is typically measured when MPs are applied and density pump-out is observed. The magnitude of the fast-ion response to n=1, n=2 and n=3 MPs follows, in general, the background plasma response. Measured fast-ion losses show a broad energy and pitch-angle range and are typically on banana orbits that explore the entire pedestal / Scrape-Off-Layer (SOL).

The plasma response has been simulated using the two fluid M3D-C1 code. In discharges with co-current rotation, resonant field amplification at rational surfaces with negligible electron rotation causes a stochastic layer in the pedestal due to island overlap. M3D-C1 simulations predict an efficient shielding in the plasma core. The perturbed background fields, including plasma response, are used to simulate the fast-ion transport due to externally applied MPs with the orbit following codes, ASCOT, F3D-OFMC and GOURDON. Full orbit simulations indicate that MPs push the loss boundary radially inwards opening and populating the loss cone with particles that would be otherwise well confined. The fast-ion response to externally applied MPs presented here may be of general interest for the community to better understand the MP field penetration and overall plasma response.