Numerical investigation of fast ion losses induced by resonant magnetic perturbations and edge localized modes at ASDEX Upgrade

M. Nocente¹, M. Garcia-Munoz²,³, N. Lazanyi⁴, M. Dunne³, J. Galdon-Quiroga², M. Hoelzl³, M. Rodriguez-Ramos³, L. Sanchis-Sanchez⁵, E. Strumberger⁵, WP15-ER/IPP-05 Contributors and the ASDEX Upgrade Team

¹Dipartimento di Fisica “G. Occhialini”, Università degli Studi di Milano-Bicocca, Piazza della Scienza 3, 20126, Milano, Italy
²Department of Atomic, Molecular and Nuclear Physics, University of Sevilla, Spain
³Max-Planck-Institut für Plasmaphysik, Garching, Germany
⁴BME NTI, Pf 91, H-1521 Budapest, Hungary

Electronic mail: massimo.nocente@mib.infn.it

A recent addition to the field of investigation on Edge Localised Modes (ELMs) has been the observation that fast ion losses can occur even when the ELMs are mitigated by means of resonant magnetic perturbations (RMPs) [1]. Such additional losses of energetic particles represent an added threat for machine protection and need to be understood and, eventually, controlled.

In this contribution we present the results of a numerical study aimed at unveiling the principle mechanisms responsible for the observed losses at ASDEX Upgrade. Collisionless simulations of the beam ion orbits in a realistic three-dimensional, perturbed magnetic equilibrium were performed by means of the GOURDON code. In the presence of RMPs, these were used especially to calculate geometrical resonances between the orbital frequencies of the beam ions and to evaluate their role in the loss mechanism. A class of trapped particles exploring the entire pedestal and scrape off layer is found to satisfy geometrical resonance conditions. Compared to non resonant particles, ions fulfilling geometrical resonances can experience increased losses, but also - quite surprisingly - enhanced confinement, depending on their toroidal turning point location. Starting from these results, calculations of fast ion losses in the case of a rigid or differential rotation of the RMPs to mitigate first wall heat loads are presented and compared to recent experimental findings [2].

In the case of unmitigated ELMs, realistic JOREK [3] calculations of the magnetic equilibrium of a full ELM cycle were used as input for the simulations. Similarly to experiment, GOURDON results show a filamentary temporal pattern for the losses, with maxima corresponding to characteristic structures appearing beyond the last closed flux surface of the magnetic equilibria. Unlike experiment [2], however, the predicted phase space structure of the unconfined ions does not show particles at pitch angles different from those observed in the case of prompt losses. Motivations behind such discrepancy are illustrated and possibilities for simulation improvements are discussed.