Acceleration of beam ions during edge localized modes in the ASDEX Upgrade tokamak

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Acceleration of charged particles is ubiquitous in space, astrophysical and laboratory plasmas. Magnetically confined fusion plasmas with in-situ measurements are an ideal testbed to elucidate the physics underlying the different acceleration mechanisms. Experiments at the ASDEX Upgrade tokamak provide, for the first time, evidence of beam ion acceleration during edge localized modes (ELMs). Fast-ion loss detector (FILD) measurements show bursts of enhanced fast-ion losses associated with individual ELM filaments [1]. Tomographic inversion techniques applied to the FILD signal allow us to determine the velocity distribution of the lost ions with unprecedented resolution in pitch angle and energy. A high-energy feature tens of keV above the main neutral beam injection energy is observed, which shows multiple pitch angle structures varying with the beam source and q_{95} values. These well-defined velocity space structures suggest that the acceleration results from a resonant interaction between the beam ions and parallel electric fields arising during ELM filament eruption, when magnetic reconnection is believed to take place. Consistent with the FILD measurements, at the onset of ELMs, bursts are often detected in electron cyclotron emission and also in soft X-ray channels with lines of sight tangential to the plasma edge. Similar bursts reported in the MAST spherical tokamak have been attributed to electron acceleration [2]. Full orbit fast ion simulations have been carried out including the 3D perturbation fields of the ELM modelled with JOREK [3]. The filamentary-like pattern of the temporal evolution of fast-ion losses can be reproduced and resonance structures associated with the energy gain of the ions are obtained. These findings motivate the incorporation of a kinetic description of fast particles in ELM models, which may shed light on the role of these fast particles in ELM stability as well as in the overall particle and energy loss during the ELM cycle.

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