Characterization of the fast ion loss dynamics in multiple confinement regimes

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The recently upgraded Fast Ion Loss Detector (FILD) installed on the TCV tokamak can simultaneously measure co- and counter-current fast-ion (FI) losses with high-temporal (1 microsecond) and high-spatial resolutions. This allows, for the first time, resolving sub-millisecond changes in the velocity-space of the FI losses. These new capabilities have been extensively used to characterise the FI confinement in plasma regimes, such as negative triangularity and H-mode. Among these, the interplay between the FI, the ELMs and the inter-ELM MHD activity has been extensively investigated. ELMy H-mode scenarios displaying different ELM frequencies and amplitudes have been explored. In the presence of large type-I ELMs, MHD modes precursing the ELMs, identified as ballooning and tearing modes [1], are observed in the magnetic pick-up coils, the Soft X-Ray (SXR) and the FILD, which measures a non-negligible-amount-of-FI losses before the ELM crash, consistent with a decrease in the neutron level. Additionally, FI non-neoclassical transport in the inter-ELM phase has been observed in regimes with higher ELM frequency, lower plasma density and higher electron temperature. These modes observed on the FILD before and during the ELM crash are also observed on the magnetic pick-up coils located on the vessel wall. These inter-ELM modes lead to significant FI losses in between ELMs, indicating that the FI confinement is adversely affected in between ELMs and not only by the ELM crash. These losses are similar in amplitude to the ones produced by the ELMs and display a characteristic pattern in velocity-space that exhibits apparent fast-ion acceleration [2] before and during the ELM crash. Bicoherence analysis of both the magnetics and FILD signals appears to indicate a non-linear mode-mode coupling before and during the ELM crash. The modes display a strong chirping and bursting behaviour ascribed to the non-linear coupling between them [3]. Fluid simulations and empirical observations indicate that these modes can be identified as Alfvén Eigenmodes (AEs). To assess the neoclassical expected FILD signal, orbit-following simulations are performed to generate a synthetic signal. The FI orbits are characterised by constants of motion, and the wave-particle coupling resonance condition for these plasmas has been computed and compared with the velocity-space of the FILD signal, further validating the resonance interaction of the FI with the inter-ELM MHD.

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