Experimental studies of fast-ion losses from MAST Upgrade

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The MAST-U spherical tokamak (ST) is equipped with on-axis and off-axis neutral beam injectors (NBI), external sources of super-Alfvénic fast ions that provide opportunities for studying a wide range of phenomena relevant to the physics of alpha-particles in future burning plasma devices such as STEP or ITER. High performance of MAST-U plasmas relies on adequate fast ion confinement, which can be degraded by instabilities and static 3D magnetic field perturbations. MAST-U is equipped with a scintillator-based Fast-Ion Loss Detector (FILD) [J. F. Rivero-Rodriguez et al., RSI 89, 10I112 (2018)] that makes it possible to infer the phase space of fast-ion losses at frequencies up to 2 MHz, providing new insights into the interplay between fast ions and both instabilities and 3D field perturbations in ST plasmas. The novel measurements in the range 1 – 2 MHz, coherent with compressional and global Alfvén eigenmodes (CAEs and GAEs), have shown for the first time that instabilities in the ion cyclotron range can trigger significant fast ion losses. Losses correlated with internal reconnection events (IRE) have been observed above the beam injection energy and pitch angles above 70°, revealing acceleration of deeply trapped fast ions. MAST-U is equipped with sets of magnetic perturbation (MP) coils above and below the midplane that make it possible to study the effect of MPs on fast-ion confinement in STs: a clear modulation has been found between fast-ion losses and the phase difference between upper and lower MPs. FILD, combined with other fast-ion diagnostics in MAST-U, including a neutron camera, a solid-state neutral particle analyser, and a fast-ion deuterium alpha spectrometer, enable high-resolution measurements of the confined and lost fast-ion distribution in an ST.

* See the author list of E. Joffrin et al. to be published in Nuclear Fusion (IAEA FEC, London, 2023).

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