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Influence of fishbone-induced fast-ion losses on rotation and transport barrier formation in MAST

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Radial currents, which occur when energetic particles are expelled from the core of a tokamak plasma, produce torques on the plasma in both toroidal and poloidal directions, due to return currents that maintain quasi-neutrality [1]. The poloidal component of this rotation is predicted to be damped on the ion-ion collision time [2], whilst the toroidal rotation component relaxes more slowly on the momentum confinement timescale. The resulting change of the flow shear can suppress turbulence and improve transport, leading to an internal transport barrier (ITB). This process has been observed in both tokamaks and stellarators alike (for non-optimized stellarators, flow is expected to be damped in all directions). Since transport barriers play a key role in scenario evolution, understanding the trigger for barrier formation is likely to be an important factor in determining the types of scenarios that can be realised in the Mega Amp Spherical Tokamak-Upgrade (MAST-U) and other machines. We investigate a possible role of fast particle losses and redistribution in this trigger.

In MAST ITBs often formed early in discharges during the current ramp [3] and tended to coincide with the occurrence of Toroidal Alfvén Eigenmode (TAE) bursts, which were eventually replaced with fishbone instabilities as the q profile decreases. The toroidal rotation shear increased as the transport barrier was forming during the early phase of the discharge. However it was difficult to establish a causal link between fast ion instabilities and the flow shear required to produce the transport barrier due to the limited time resolution of charge exchange recombination spectroscopy (CXRS) rotation diagnostics.

A Doppler back-scattering system (DBS) on MAST was used to measure the perpendicular phase velocity of density turbulence ñ (this was generally dominated by ExB drifts), as well as the ñ magnitude, with sub-ms time resolution. Recent careful analysis of DBS data from MAST has revealed that rapid changes in both the phase velocity and fluctuation amplitude coincided with fishbone bursts. The magnitude of the velocity changes will be compared with fast ion losses inferred from fast-ion diagnostics - including a fast ion deuterium-alpha (FIDA) spectrometer system and a neutron camera (NC), and this information will be used to establish the role of fast ion instabilities in transport barrier formation. The full-orbit code HALO, with imposed perturbation fields of the fishbones, will also be used to model the torques and fast ion losses.

[1] K.G. McClements & A. Thyagaraja 2006 Physics of Plasmas 13 042503

[2] S.D. Pinches et al 2002 Fishbone generation of sheared flows and the creation of transport barriers Proc. 28th EPS (Madeira) P1.008

[3] A.R. Field et al 2011 Nucl. Fusion 51 063006

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