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EX/P6-22: Fast Ion Physics Enabled by Off-Axis Neutral Beam Injection

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Off-axis injection of neutral beams into DIII-D has provided new insights into fast-ion instabilities that may impact alpha-particle and neutral-beam confinement in ITER. Off-axis injection alters the stability of reversed shear Alfvén eigenmodes (RSAE). The enhanced stability for off-axis injection is attributed to flattening of the fast-ion gradient that drives the modes unstable. Beam deposition for the off-axis beams peaks near the mode location so switching between on-axis sources that inject at the midplane and off-axis sources that aim below the midplane has a large local effect on the gradient. In contrast, at larger minor radius, the fast-ion gradient is similar for on- and off-axis injection. As a result, switching between on/off-axis beams has little effect on the stability of TAEs that appear in the outer portion of the plasma. Surprisingly, even though the gradient is flattened and the mode frequencies change, switching the vertical angle of injection also has little effect on the stability of beta-induced Alfvén-acoustic eigenmodes that are unstable near the magnetic axis. Two-dimensional measurements of RSAE mode structure show that the phase of the eigenfunction varies with radius [1]. This phase variation is not present in the ideal MHD model but does appear in gyrokinetic and gyrofluid calculations. The phase variation was originally attributed to symmetry breaking associated with the fast-ion gradient [1] but the recent comparisons show that hypothesis is incorrect.
Separate control of the gradient and of the trapped/passing fraction, which depends sensitively on the magnetic field pitch, is a powerful tool in fast-ion instability studies. This capability is used to explore the stability of off-axis fishbones that are driven unstable by resonance with the precessional motion of trapped fast ions [2]. These modes expel fast ions in a "beacon"that is measured by seven types of loss detectors. The new capability is also used to study transport of fast ions by microturbulence. Preliminary analysis suggests that departures from classical confinement are observed in some H-mode plasmas.

[1] B.J. Tobias, et al., Phys. Rev. Lett. 106, 075003 (2011).
[2] W.W. Heidbrink, et al., Plasma Phys. Cont. Fusion 53, 085028 (2011).
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Collaboration (if applicable, e.g., International Tokamak Physics Activities)

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