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Optimizing future burning plasmas through experiments to understand & control transport of fast ions by Alfvén eigenmodes*

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Experiments on the DIII-D tokamak show that multiple Alfvén eigenmodes (AEs) cause fast-ion transport to become "stiff" above a threshold, resulting in fast-ion density profiles that stop increasing despite higher beam power and neutron rates that approach only 50% of expected values. Comparison with theoretical analysis shows that the transport threshold corresponds to particle orbits becoming stochastic due to overlapping wave-particle resonances. Since AEs can perturb a portion of phase space and leave other parts unaffected, the measured threshold varies between fast-ion diagnostics that are sensitive to different regions in phase space. New measurements with an unprecedented scintillator-based imaging neutral particle analyzer (INPA) show that weak AE activity causes injected fast ions to move away from the core of the plasma to larger radii and lower energy, while strong AE activity drives a continuous outflow across the entire phase space measured by the INPA. Time-dependent TRANSP simulations using the "kick" model of AE transport accurately reproduce the measured signals, including a hollow fast-ion profile measured by the fast-ion Dα (FIDA) diagnostic, implying that treatment of AEs in phase space is important for accurately predicting density and current profiles. These studies provide the basis for understanding how to use techniques such as manipulation of equilibrium plasma profiles and the use of variable beam voltage to decrease AE–induced transport. Measurements are being used to develop a validated transport model that can efficiently calculate beam deposition, fast-ion profiles, and losses over a wide parameter regime for predictive discharge modeling and burning plasma scenario development.

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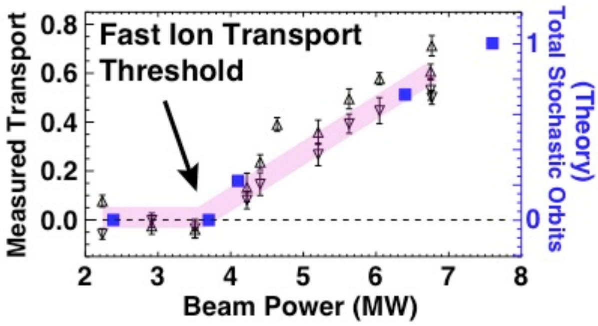

Figure 1. As AE activity increases with increased beam power, measured fast ion transport increases suddenly and becomes stiff above a stochastic orbit threshold.