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Critical Gradient Threshold for Alfvén Eigenmode Induced Fast-Ion Transport*

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Experiments on the DIII-D tokamak have identified how multiple simultaneous Alfvén eigenmodes (AEs) lead to overlapping wave-particle resonances and stochastic fast ion transport in fusion grade plasmas [1]. The behavior results in a sudden increase in fast ion transport at a threshold that is well above the linear stability threshold for Alfvn instability. This causes fast ion transport to become stiff, leading to virtually unchanged equilibrium fast-ion density profiles as beam drive increases further. A novel beam modulation technique [2] in conjunction with an array of fast-ion diagnostics probes the critical gradient by measuring the fast-ion flux in different phase-space volumes. Above a threshold, which occurs when more than four AEs are simultaneously destabilized, the modulated flux suddenly increases. Fast-ion Dα (FIDA) spectroscopy indicates the peak of the modulated flux is localized to mid-core radii, corresponding to the radial location of AEs.As distributions and instability behavior are manipulated further through variations in electron cyclotron heating and beam deposition, measured thresholds track the resulting shifts in resonances. Well above threshold, the fast-ion losses often become intermittent and exhibit a bursty behavior. Theoretical analysis confirms that fast-ion orbits become stochastic in the measured modes. This critical gradient transport, wherein the fast-ion pressure gradient destabilizes AEs and the fast ions respond by diffusing in phase space to flatten the pressure profile, suggests that reduced models for fast ion transport in ITER can effectively describe the fusion alpha and beam ion profiles.

[1] C.S. Collins et al., Phys. Rev. Lett. 116 (2016) 095001

[2] W.W. Heidbrink et al., Nucl. Fusion 56 (2016) in press

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