Alfvén Eigenmode Stability and Fast Ion Transport in DIII-D and ITER Reversed Magnetic Shear Plasmas

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Neutral beam injection into reversed magnetic shear DIII-D plasmas produces a variety of Alfvénic activity including toroidicity-induced Alfvén eigenmodes (TAEs) and reversed shear Alfvén eigenmodes (RSAEs) observed to cause fast ion loss. An example spectrum showing unstable RSAEs and TAEs is given in Fig. 1 along with a spectrum showing coherent losses of fast ions induced by these modes (as measured by a newly

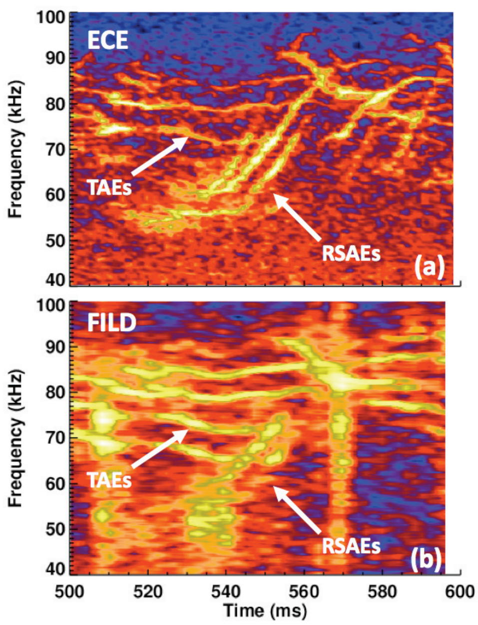

Fig. 1. DIII-D discharge 142111. (a) ECE spectrogram showing RSAEs and TAEs. (b) Fast ion loss detector data showing AE induced coherent fast ion losses.

installed scintillator diagnostic) [1]. With measured equilibrium profiles as inputs, the ideal MHD code NOVA [2] is used to calculate eigenmodes of these plasmas. The postprocessor code NOVA-K [3] is then used to model the actual stability of the modes, including finite orbit width and finite Larmor radius effects, and reasonable agreement with the spectrum of observed modes is found.

Using experimentally measured mode amplitudes, fast ion transport simulations have been carried out in the presence of the unstable eigenmodes and are found to reproduce the dominant energy, pitch, and temporal evolution of the measured losses [1]. The results of this modeling are shown in Fig. 2. While loss of both co- and counter current fast ions occurs, simulations show that the dominant loss mechanism observed is the mode induced transition of counter-passing fast ions to lost trapped orbits [3]. This loss mechanism relies on modes extending to regions near loss boundaries present in the plasma. As the discharge evolves and the current penetrates further, these loss boundaries move out/away from any mode activity and fast ion loss becomes significantly reduced. Modeling also reproduces a coherent signature of AE induced losses and it was found that these coherent losses scale proportionally with the amplitude; an additional incoherent contribution scales quadratically with the mode amplitude [1].

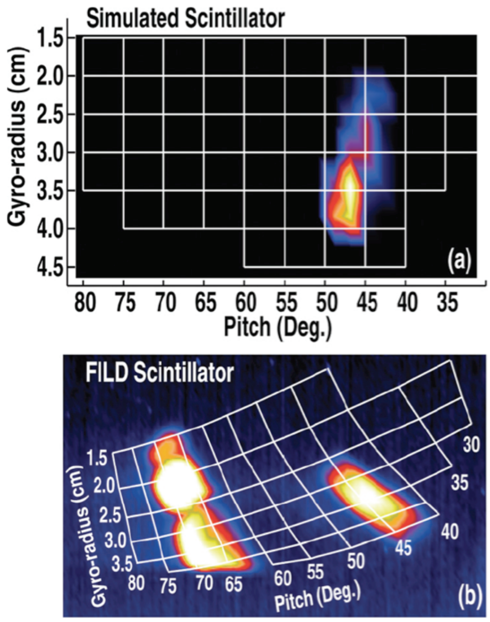

Fig. 2. DIII-D discharge 142111. *T* ~ 525 ms. (a) Simulated FILD scintil-lator and (b) actual FILD scintillator measurements showing the energy and pitch of lost fast ions. Near Gyroradius ~3.5 cm and Pitch ~45 deg. are losses due to AEs. Prompt losses between Pitch 65–70 deg. are not simulated**.**

The same analysis techniques applied to an 8 MA ITER steady-state plasma scenario with reversed magnetic shear and both beam ion and alpha populations, show Alfvén eigenmode instability. Both RSAEs and TAEs centered near mid-radius were found to be unstable with maximum growth rates occurring for toroidal mode number $n = 5 - 6$ and the majority of the drive coming from beam ions injected by the 1 MeV negative ion beams. Fast ion transport simulations using the unstable modes with a range of amplitudes $\left(\delta B / B = 10^{-5} - 10^{-3}\right)$ have been carried out and show negligible fast ion loss. The lack of fast ion loss is a result of loss boundaries being limited to large radii and significantly removed from the actual modes themselves.

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