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Alpha particle dynamics and Alfvénic instabilities in ITER post-disruption plasmas

A. Lier[1], G. Papp[1], P. W. Lauber[1], O. Embreus[2], G. J. Wilkie[3], S. Braun[4]
[1]Max Planck Institute for Plasma Physics, Garching (GER)
[2]Department of Physics, Chalmers University of Technology (SWE)
[3]Princeton Plasma Physics Laboratory, Princeton (USA)
[4]Center for Computational Engineering Science, RWTH Aachen University (GER)
e-mail (speaker): liera@ipp.mpg.de

Post-disruption formation of a runaway electron (RE) beam poses an intolerable risk to high-current tokamaks and is sought to be mitigated. We investigate fusion-born alpha particles in ITER disruption simulations as a possible drive of Alfvénic instabilities. The ability of these waves to expel RE seed particles is explored in the pursuit of a passive, inherent RE mitigation scenario in synergy with built-in RE mitigation systems.

During a thermal quench, the alphas – due to the low collisional frequency of energetic ions – thermalize at a rate slower than the background plasma (see figure 1). An analytical model is introduced that is able to compute the spatiotemporal evolution of the alpha particle distribution in a mitigated thermal quench. We use a linear gyrokinetic stability code [3] to calculate the Alfvén spectrum and find that the equilibrium is capable of sustaining a wide range of modes. The natural radial anisotropy of the alpha population provides free energy to drive Alfvénic modes during the quench phase of the disruption.

The self-consistent evolution of the mode amplitudes and the alpha distribution is calculated utilizing wave-particle interaction methods. Intermediate mode number Toroidal Alfvén Eigenmodes (TAEs) are shown to saturate at an amplitude of up to $\delta B/B \sim 0.1\%$ (see figure 2) in the spatial regimes crucial for RE seed formation. We find that the mode amplitudes are predicted to be sufficiently large to cause radial transport of runaway seed electrons during the thermal quench.

References
[1] Embreus, PoP, **22**, 5 (2015)
[2] Pinches, PhD thesis, "Nonlinear Interaction of Fast Particles with Alfvén Waves in Tokamaks" (1998)

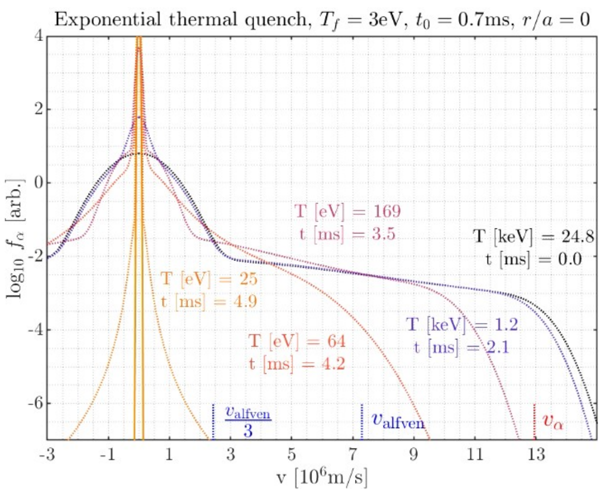

Fig. 1: Isotropic velocity space distribution of alpha population undergoing an exponential thermal quench. Alpha birth velocity and Alfvén velocities are drawn in as well. Computed using Fokker-Planck solver CODION [1].

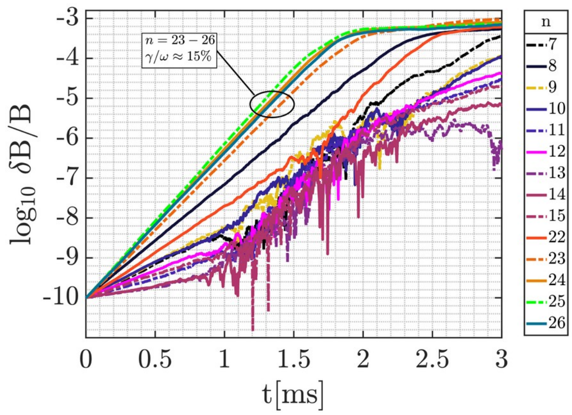

Fig. 2: Amplitude evolution of the TAEs present in the post-disruption MHD spectrum of an unmitigated ITER disruption. Growth is caused by resonant interaction with the remaining alpha population. Computed using wave-particle interaction tool HAGIS [2].