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Gyrokinetic Simulations of Enhanced Alpha Transport by De-stabilized Alfvèn Turbulence[1]

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Alfvèn turbulence, destabilized by fusion-produced α-particles, is expected to greatly enhance transport of these hot fusion products. Previously, the gyrokinetic code GYRO [1] was used to simulate the convective transport of fusion alpha particles by electrostatic ($\beta = 0$) ITG/TEM turbulence driven at low k ($0 < k_\theta \rho_s < 1$) by density and temperature gradients in the background plasma for the GA-standard case [2]. The present study, at $\beta_e = 0.002$, includes electromagnetic effects, allowing for driven Alfvèn turbulence. The alpha particles are modeled by a hot Maxwellian ($T_\alpha = 100\,T_e$) superimposed at trace density ($0.005 < n_\alpha/n_e < 0.025$ and $a/L_\alpha = 4$ fixed) on the background plasma. Linear stability studies show two high-frequency modes driven unstable at very long wavelength ($0 < k_\theta \rho_s < 0.14$) by a radial density gradient in the alpha population. A new eigenvalue solver within GYRO shows that the leading modes, identified as the toroidal Alfvèn eigenmode (TAE) and the energetic particle mode (EPM), exhibit hybrid "drift-Alfvèn" frequency scaling with $k_\theta \rho_s$ and n_α. At densities below the Alfvèn linear stability threshold ($n_\alpha/n_e \leq 0.005$), ITG/TEM turbulence dominates nonlinear simulations. In this limit, the transported alpha particles are passive tracers and ion and electron transport agrees well with $n_\alpha = 0$ results. Just above the alpha-particle density gradient threshold, Alfvènic (TAE/EPM) drive enhances transport in α-particle and background channels. This trend continues as n_α and TAE/EPM microturbulence drive increase. The focus is on conditions for obtaining stationary nonlinearly saturated transport avoiding any subcritical limit on the total beta gradient.

[1] J. Candy and R.E. Waltz, Phys. Rev. Lett. **91**, 045001 (2003).
[2] C. Estrada-Mila, *et al.*, Phys. Plasmas **13**, 112303 (2006).

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