16th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems - Theory of Plasma Instabilities

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Validation of the TGLF-EP+Alpha critical-gradient model of energetic particle transport in DIII-D scenarios for ITER

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The TGLF-EP [1] and Alpha [2] codes for the critical-gradient model (CGM) of energetic-particle (EP) transport have been unified and verified by nonlinear gyrokinetic simulations and validated against five DIII-D H-mode scenarios for ITER. This reduced model predicts the degree to which Alfvén eigenmodes (AEs) destabilized by EPs—in this case fast ions from neutral beam injection—radially flatten the classical slowing-down EP profile. It finds the steady-state solution of a local 1D radial transport equation under a stiff critical gradient approximation for AE transport with an estimated (small) contribution from microturbulence [3] and including the physical source and sink profiles. While such a reduced CGM neglects phase-space dynamics, finite orbit effects [4], and nonlinear effects such as transport intermittency and frequency chirping, kinetic simulations [5,6] combined with experimental evidence for EP profile resiliency [7] strongly suggest AE-EP transport is clamped to a critical gradient. Our validation study confirms broad applicability of the unified TGLF-EP+Alpha code in predicting the time-averaged density profile in DIII-D. The critical gradient, the model's key input, comes from linear solutions of the TGLF [8] gyro-Landau fluid code, optimized for EP-AE physics, automated, and highly parallelized by the TGLF-EP wrapper code. TGLF-EP+Alpha, under development by the SciDAC ISEP center as an EP module for the future fusion whole-device-modeling project, is fully physics based, requiring only the equilibrium and beam source as inputs. It is computationally inexpensive enough (<30 minutes turnaround time versus over one month for first-principles models) to perform scoping studies needed for scenario optimization. DIII-D cases considered represent a wide range of EP transport, with observed neutron production near classical predictions down to an 80% deficit. TRANSP simulations using the EP diffusion coefficient predicted by TGLF-EP+Alpha find neutron deficits within 20% of experimental observations in applicable cases. Predicted AEs are consistent with previous studies [9].

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