Contribution ID: **24** Type: **Oral**

Integrated, self-consistent quasilinear modeling of fast ion relaxation in tokamaks

Friday 10 December 2021 16:20 (20 minutes)

The success of burning plasma devices relies on their ability to confine fusion alpha particle products long enough for them to transfer a substantial fraction of their energies to the reacting thermal particles via collisions. It is, therefore, essential to develop efficient and robust capabilities to predict the level of energetic ion losses in tokamak experiments. This work self-consistently constructs from first principles a resonance-broadened quasilinear plasma transport theory that incorporates Fokker-Planck dynamical friction (drag) and scattering for marginally-unstable modes resonating with an energetic minority species. Recent analytic developments show that drag fundamentally changes the structure of the wave-particle resonance, breaking its symmetry and leading to the shifting and splitting of resonance lines. In contrast, scattering broadens the resonance in a symmetric fashion. Comparison with fully nonlinear simulations shows that the proposed quasilinear system preserves the exact instability saturation amplitude and the corresponding particle redistribution of the fully nonlinear kinetic theory. The broadened quasilinear model has been designed to efficiently evolve amplitudes of several interacting Alfvén modes, in regimes of both overlapping and isolated resonances, while self-consistently relaxing the fast ion distribution function in the presence of collisions and turbulence. An integrated, quasilinear numerical framework to quantify the losses of fast ions in tokamaks that is both fast and comprehensive has been realized through the development of the Resonance Broadened Quasilinear (RBQ) code. It formulates the quasilinear diffusive beam ion relaxation in action variables (i.e., in both the canonical toroidal momentum and the unperturbed particle kinetic energy) via a generalized alternating direction implicit method. The developed framework employs realistic eigenstructures, mode damping rates and wave-particle interaction matrices. Rigorous verification exercises have been undertaken in limiting cases in which there exist analytical solutions for single mode saturation levels. The quasilinear simulation output provide mappings of fast ion flows that are useful in informing phase-space engineering solutions for neutral-beam-driven instabilities. The simulations are integrated with TRANSP with the calculated neutron loss rate, yielding reasonable quantitative agreement compared with measurements from DIII-D, which suggests that the integrated model is a promising predictor of fast ion confinement in scenario development studies.

This work was supported by the US Department of Energy under Contract Nos. DE-AC02-09CH11466 and DE-FC02-04ER54698.

Speaker's Affiliation

Princeton Plasma Physics Laboratory

Member State or IGO

United States of America

Author: DUARTE, Vinicius (Princeton Plasma Physics Laboratory)

Co-authors: LESTZ, Jeff (UC Irvine); GORELENKOV, Nikolai (PPPL, Princeton University); PODESTA, Mario (Princeton Plasma Physics Laboratory)

Presenter: DUARTE, Vinicius (Princeton Plasma Physics Laboratory)

Session Classification: Multiscale Physics and Instabilities in Burning Plasmas

Track Classification: Transport of Energetic Particles