A Quasi-linear resonance broadened model for fast ion relaxation in the presence of Alfvénic instabilities

N. N. Gorelenkov[1], V. N. Duarte[1,2], M. Podesta[1]

[1]*Princeton Plasma Physics Laboratory, Princeton University,* [2]*Institute of Physics, University of São Paulo, Brazil*

We present a Quasi-linear model and simulations to find the solution to the problem of energetic particle distribution function relaxation in the presence of Alfvénic instabilities. This approach is numerically efficient and captures the evolution of fast beam ion distribution function [1]. The effect of Alfvénic eigenmodes (AE) is evaluated using the quasi-linear theory [2] generalized for this problem recently. The generalization involves the resonance line of wave-particle interaction (WPI) broadened due to several mechanisms including pitch angel scattering, the amplitude growth and the WPI itself. The interaction of fast ions and AEs is captured for the cases where there are either isolated or overlapping modes.

A new Resonance Broadened Quasi-linear code (RBQ) is build which takes into account the velocity space diffusion of the canonical toroidal momentum. The wave particle interaction can be reduced to one-dimensional dynamics where for the Alfvénic modes typically the particle kinetic energy is nearly constant. The diffusion equation is then one dimensional that is efficiently solved simultaneously for all particles with the equation for the evolution of the mode amplitudes. The evolution of fast ion constants of the unperturbed motion is governed by the QL diffusion equations which are adapted to find the ion distribution function.

W apply the RBQ code in the interpretive and predictive simulations to DIII-D plasma with elevated q-profile where the beam ion profiles show the stiff transport [3]. The sources and sinks are included via the Crook operator. The properties of AE driven fast ion profile relaxation are studied for validations of the applied QL approach in realistic conditions of DIII-D discharges.

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