Monte-Carlo simulation of fast ion transport in magnetic island regions

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There is theoretical evidence of the formation of magnetic islands in rational magnetic surfaces in toroidal fusion devices. Furthermore it has been shown that, in electron cyclotron resonance heating (ECRH) experiments, such regions may act as transport barriers for suprathermal electrons [1]. When the plasma heating is produced by neutral beam injection (NBI), a population of fast ions arises which interacts with the magnetic islands altering its transport.

Here we study the transport of a population of fast particles in the presence of a magnetic island configuration produced by collisions with a Maxwellian plasma background consisting of electrons and a single species of ions, which are described by Lorentz scattering [2]. We obtain the time evolution of the distribution function by solving Langevin equations for a large population of particles corresponding to ECRH or NBI. Then, transport coefficients are calculated.

The equations of motion for the guiding center (GC) of a charged particle in a strong magnetic are solved in 3 spatial dimensions (x, y, z) and 2D in velocity space represented by the normalized kinetic energy v^2 and the pitch angle λ. The set of equations which give the evolution of phase space variables can be expressed in the form of Langevin equations which simulate the effect of collisions of the test particle with the plasma background [3]. They include the energy and pitch angle stochastic collision operators [2].

In order to determine transport coefficients the time evolution of a test distribution function of N particles is obtained with Monte Carlo simulations, which is equivalent to solving the Fokker-Planck equation. The equations are solved with a fourth order Runge-Kutta algorithm with a random choice of the sign in the Lorentz collision operators at each time step. Additionally a radial electric field was included, which enhances the transport of particles. The diffusion coefficient was calculated from the standard expression $D = \frac{1}{2tN}\sum_{j=1}^{N}(x_j(t) - x_j(0))^2$ where $x_j(t)$ is the position of a particle at time t.

The results show that the island acts as a transport barrier for electrons, and the ions experience a significant modification of their transport across the island.

References

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