## §25. $\delta f$ DKPS Approach to Neoclassical Transport Calculation

Wang,W.X., Nakajima,N., Okamoto,M.

A particle simulation program $\delta f$DKPS, solving drift kinetic equations by $\delta f$ method, has been developed to study new collisional transport phenomena in reversed shear core plasma and H-mode edge plasma by taking into account finite banana width dynamics, strong radial electric field with large radial gradient, non-standard orbit topology near magnetic axis and etc. The kinetic equations being solved are

$$\frac{\partial f_1}{\partial t} + \vec{v_{\|}} \cdot \nabla f_1 - C(f_1, f_0) = -\vec{v_d} \cdot \nabla f_0 + C(f_0, f_1), \tag{1}$$

$$\frac{\partial f_1}{\partial t} + (\vec{v_{\|}} + \vec{v_d}) \cdot \nabla f_1 - C(f_1, f_0) = -\vec{v_d} \cdot \nabla f_0 + C(f_0, f_1). \tag{2}$$

In a little more detail, simulation particles (markers) are pushed along guiding center trajectories subject to random velocity changes which account for test particle Coulomb collisions; the source terms in the right side of the equations, arising from the linearization or accounting for collisional conservation laws, are modeled via weight method; the relevant transport quantities are computed from the dynamics of simulation particles. Two versions of the code are designed, corresponding to different drift orbit being followed. One is following the zeroth order drift orbit (corresponding to solving Eq.(1)) in toroidal coordinate; another is following the full nonlinear drift orbit (corresponding to solving Eq.(2)) in flux coordinate using a Hamiltonian guiding center motion formalism. In latter case, we can take into account finite banana width effects which may become substantial in present tokamak operation. Moreover, the utilize of Hamiltonian formalism in flux coordinate allows us to treat three-dimensional problems easily. Equation (1) is solved on a single magnetic surface and Eq.(2) is solved in whole poloidal cross section. The $\delta f$ method for neoclassical transport calculation has two advantages: 1. low noise and 2. thermodynamic "forces", such as $\nabla T$ and $\nabla p$ driving the plasma transport, being controllable. An improved like-particle model accurately conserving particle, momentum and energy is implemented and a general and accurate weighting scheme is employed in $\delta f$DKPS so as to upgrade its performance. To benchmark and test the code, a serious of simulation were carried out using an analytical MHD equilibrium. The test and benchmarking includes: 1. Electron neoclassical transport due to e-i collisions; The simulation results of particle flux, energy flux and bootstrap current in whole collisionality regime are in good agreement with the neoclassical theory. 2. Ion particle and energy fluxes and parallel velocity under zero banana width limit; A shifted Maxwellian solution is recovered $\nabla T = 0$, and the energy flux driven by non-zero $\nabla T$ is in good agreement with the theory. 3. Ion particle and energy fluxes and parallel velocity with finite banana width dynamics. A solution with zero-particle and energy fluxes over the whole region (Fig.1) (when $\nabla n \neq 0$ and $\nabla T = 0$) is demonstrated because of momentum and energy conservation of like-particle collisions. The investigation of neoclassical transport using $\delta f$DKPS is currently under active progress.

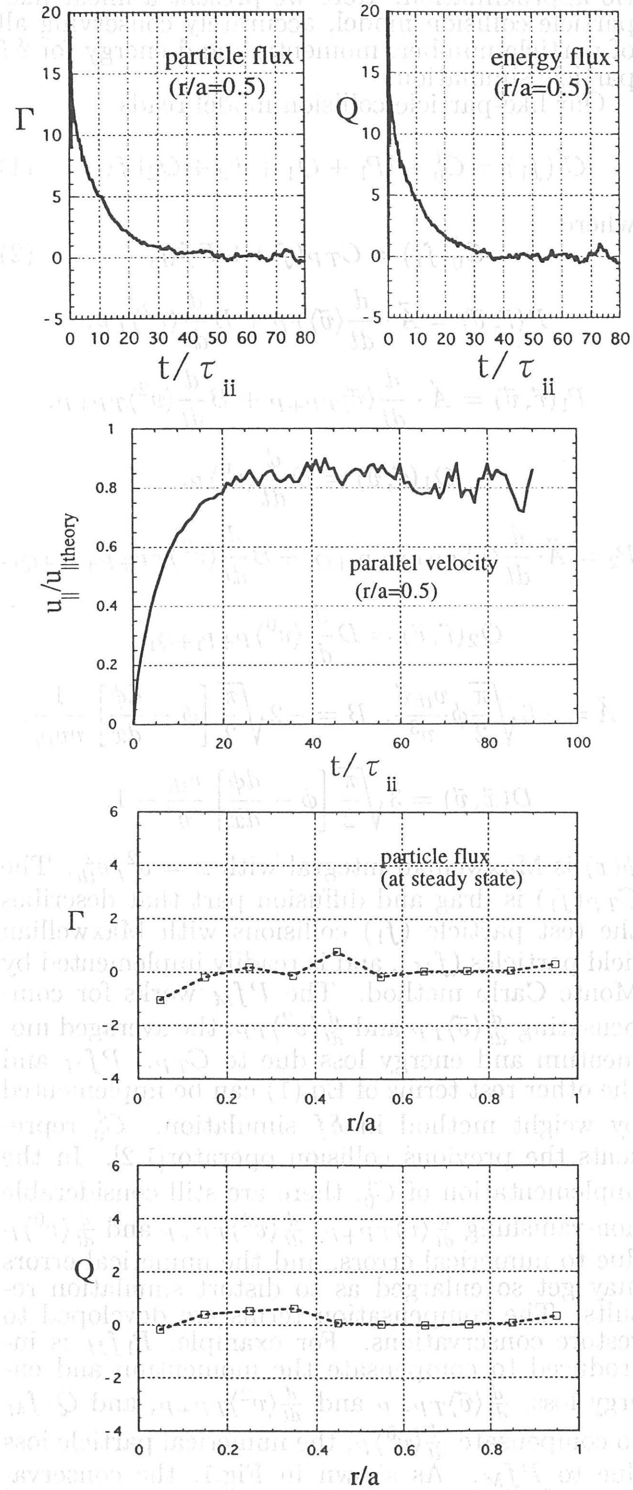


Fig. 1