

# Global $\delta f$ Particle Simulation of Neoclassical Transport and Ambipolar Electric Field in General Geometry

W.X. Wang, W. M. Tang, F. L. Hinton<sup>1</sup>, L. E. Zakharov and R. B. White

*Princeton Plasma Physics Laboratory, P.O. Box 451  
Princeton, NJ 08543*

<sup>1</sup>*General Atomics, San Diego, CA 92186*

In assessing the confinement properties of toroidal plasmas, it is important to accurately calculate the neoclassical dynamics, which set the irreducible minimum level of transport in such systems. There remain significant unresolved neoclassical issues – especially in spherical torus experiments such as NSTX. In the NSTX plasmas, typical features which violate basic assumptions of most theories include low aspect ratio, large orbit size, large trapped particle fraction (up to  $\sim 100\%$ ), large toroidal rotation with strong shear, etc. When these effects are properly taken into account, together with self-consistent calculation of the equilibrium electric field, it is obviously of interest to assess the possible strong impact on ion thermal transport and the bootstrap current. In the present investigation, the neoclassical physics of ST plasmas is systematically studied using a generalized particle-in-cell (PIC) 3-dimensional code, which employs the delta-f method to solve the drift kinetic equations together with the Poisson equation governing the ambipolar electric field in general toroidal geometry. Both ions and electrons are simulated, but can actually be decoupled in axisymmetric geometry thanks to small mass ratio. The present code has been carefully benchmarked in the large aspect ratio circular geometry limit with neoclassical theory. General geometry simulations are then used to assess plasma transport due to collisional relaxation in an ST plasma. This includes evaluation of the ion thermal flux, radial electric field dynamics and structure, poloidal flow, angular momentum transport and bootstrap current, with emphasis on finite orbit effects associated with large plasma gradients (pressure and rotation) and the shear of self-consistent electric field.

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