Nonrandom collision method for delta-f PIC simulations

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In delta-f simulations of tokamak physics, the distribution function is written as a background plus a small perturbation, where the background is usually taken to be Maxwellian. A Canonical Maxwellian is a function of particle constants of motion which reduces to a Maxwellian in the limit of zero orbit width. If the background is taken to be a Canonical Maxwellian in PIC simulations, the large orbit contribution to the rapid growth of the particle weights, and the associated statistical noise, would be eliminated. Another important contributor to statistical noise in turbulence simulations is the phase-space filamentation which develops over long times. This should be reduced by including Coulomb collisions as a velocity diffusion process. A linearized collision operator for simulating ion-ion collisions has been developed, which consists of a diffusive test-particle part plus a field-particle part constructed to maintain conservation laws and have the correct null space. The friction and diffusion coefficients in the test-particle operator are evaluated using a shifted Maxwellian with a parallel flow velocity consistent with a Canonical Maxwellian to second order in poloidal gyroradius. A Langevin method for use in delta-f PIC codes has also been developed, which is equivalent to the linearized collision operator. It provides update equations for the components of particle velocity parallel and perpendicular to the magnetic field, in the form of acceleration contributions from the collisional friction and field-particle drag, plus diffusive contributions modeled by sampling velocity increments in a way consistent with the diffusion coefficients in the test-particle collision operator. This method uses deterministic sampling as described in recent work[1], in which the samples are chosen as quadrature points in approximate evaluations of moments of the Fokker-Planck Green's function. This should eliminate the sampling noise which occurs in random sampling (Monte-Carlo) collision methods.

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[1] Fred L. Hinton, submitted to Physics of Plasmas