

## **Efficient Hybrid Methods for the Simulation of Plasmas with Coulomb Collisions\***

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Hybrid algorithms in plasmas can achieve high efficiency at moderately small Knudsen number by combining a fluid solver to evolve the mostly dominant Maxwellian part of the distribution function, and particle-in-cell and Monte-Carlo collision implementations to evolve the non-Maxwellian remainder.

Our algorithm allows for both binary and Langevin-equation-based Monte-Carlo collisions, and for the latter we present a new model with extended accuracy beyond Euler  $O(\Delta t^{1/2})$ -order time integration to the next higher [Milstein- $O(\Delta t)$ ] order.

Furthermore, nonlinear evolution of the distribution function generally precludes a priori allocation of computational resources i.e. particles, and so we introduce dynamic thermalization/dethermalization criteria to maximize efficiency.

This presentation will examine the performance of our hybrid simulation scheme and the relative benefits of the various options on relevant kinetic test problems including isotropization, heating, injection and sheath.

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