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# FULLY IMPLICIT, CONSERVATIVE, MULTIDIMENSIONAL ELECTROMAGNETIC PARTICLE-IN-CELL ALGORITHMS FOR MULTISCALE KINETIC PLASMA SIMULATION ON CURVILINEAR MESHES

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Particle-in-cell (PIC) simulation techniques are widely used for first-principles simulations of plasma dynamics. Classical PIC employs an explicit approach (e.g. leap-frog) to advance the Vlasov-Maxwell/Poisson system using particles coupled to a grid. Explicit PIC is subject to both temporal (CFL) and spatial (aliasing) stability constraints, challenging system-scale kinetic simulations, even with modern super-computers. Implicit algorithms can potentially eliminate these stability constraints, thus holding promise for significant speedups. Implicit PIC algorithms have been explored since the late 1970's, but have suffered from various ailments originating in the lack of non-linear consistency and of strict conservation properties.

In this presentation, we discuss a multi-dimensional, nonlinearly implicit, conservative electromagnetic PIC algorithm.[1,2] The approach delivers both accuracy and efficiency for multi-scale plasma kinetic simulations, and extends previous proof-of-principle 1D studies.[3] To avoid noise issues associated with numerical Cherenkov radiation for large implicit timesteps, we consider the Darwin approximation to Maxwell's equations, which projects out the light wave analytically. The formulation conserves exactly total energy, local charge, canonical momentum in the ignorable directions, and preserves the Coulomb gauge. Linear momentum is not exactly conserved, but errors are controlled by an adaptive particle sub-stepping orbit integrator. Key to the performance of the algorithm is a moment-based preconditioner, featuring the correct asymptotic limits. The formulation has been extended to curvilinear meshes,[2] which opens the possibility of accurate body-fitted and/or spatially adaptive PIC simulations. The superior accuracy and efficiency properties of the scheme will be demonstrated with various numerical examples.

## REFERENCES

[1] G. Chen, L. Chacón, Comput. Phys. Commun. 197, 73-87 (2015).
[2] L. Chacón and G. Chen, J. Comput. Phys., 316, 578–597 (2016)
[3] G. Chen, L. Chacón, and D.C. Barnes, J. Comput. Phys., 230 (18), 7018-7036 (2011).