1E23

# Hybrid Kinetic-MHD Simulations in General Geometry

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## Abstract

The dynamics of fusion plasmas lead to instabilities that can spontaneously erupt and degrade confinement and sometimes lead to catastrophic disruptions of the entire plasma itself. These instabilities occur in a broad range of spatial and temporal scales, spanning many orders of magnitude, often resulting from nonlinear interactions. Computational simulations are crucial to understanding these phenomena.

NIMROD(NonIdeal MHD with Rotation - Open Discussion) is a massively parallel three dimensional magnetohydrodynamic simulation utilizing finite elements (**FE**) to represent the poloidal plane and a fourier decomposition in the toroidal direction. The use of finite elements allows flexibility in the representation of the simulation domain. The ability to model experimental shots with NIMROD provides a platform to test new ideas of plasma behavior. To expand the physics capabilities of NIMROD, kinetic effects have been added to NIMROD by the addition of delta-f PIC(Particle in Cell) module. The addition of kinetic particle effects captures essential wave-particle interactions important in the saturation of various MHD instabilities such as the internal kink mode, sawtooth and fishbone instabilities, and toroidal Alfven eigenmodes. Particle simulation capabilities in NIMROD can also be extended to simulate various phenomena such as neutral beam injection, ion cyclotron resonance heating, and anomalous loss mechanisms. In addition, this hybrid kinetic-MHD technique lays the foundations for a kinetic closure to the MHD equations.

This poster will briefly introduce NIMROD and delta-f PIC in general, then detail the development of PIC in finite elements and their implementation and present preliminary results.