Contribution ID: **132** Type: **Poster**

Numerical Investigations of Coulomb Collisions and Energy Conservation in a Particle-in-Cell Model for Ion Source Applications

Thursday, 11 September 2025 11:15 (1h 45m)

LEPIC is a Particle-In-Cell (PIC) code developed at the LAPLACE Laboratory in Toulouse, originally designed to simulate the dynamics of charged particles in negative ion sources for the ITER collaboration. In this work, we present recent developments that extend the code's capabilities to better model the physical processes relevant to high-density, low-temperature plasmas such as those found in inductively coupled ion sources. Specifically, Coulomb collisions have been implemented using Nanbu's binary collision algorithm, allowing for a more accurate representation of collisional energy and momentum exchange between charged particles. Additionally, we investigate the implementation of energy-conserving time integration schemes within LEPIC. While the code currently conserves momentum, the lack of exact energy conservation imposes a mesh cell size of about the electron Debye length to limit the development of the so-called Finite Grid Instability (FGI), leading to numerical heating. The planned energy-conserving scheme aims to relax this constraint.
We apply the upgraded LEPIC algorithm to simulate plasma behavior in conditions representative of an ion source operated at D-Pace. The objective is to assess how different numerical schemes and collisional models influence quantities such as energy distribution functions, plasma density profiles, and ion fluxes. Although experimental validation is beyond the scope of this current work, the numerical results serve as a foundation for future comparisons with measured data.

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Session Classification: Poster Session

Track Classification: Fundamental processes in ion sources and plasmas