Parametric study of wall effects on plasma transport across the magnetic filter field in a negative ion source using 2D-3v PIC-MCC simulations

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This work presents a parametric study aimed at investigating the plasma asymmetry and transport in ROBIN (RF-operated beam source in India for Negative ions) using a 2D-3v PIC MCC model, focusing on the influence of boundary walls under multiple operating conditions. A parallel HYBRID particle-in-cell code, capable of running on a high-performance computer (HPC) with hundreds of cores, is used [1]. Plasma instabilities are observed in simulations with and without walls. Without walls, the plasma profile near the extraction plane is macroscopically uniform, with fine strip structures formed by instabilities in the Transverse Magnetic Filter (TMF) region inside the source. In contrast, the presence of walls induces asymmetry in these structures near the extraction plane. The TMF generates strong density, temperature, and potential gradients, providing free energy for the instabilities. When walls are absent, a double layer (DL) structure and non-Maxwellian ion energy distribution functions (IEDFs) appear[2]. Conversely, walls result in Maxwellian ion distributions and top-bottom asymmetries in the Electron Energy Distribution Function (EEDF) plots. Fast Fourier Transform (FFT) spectrogram analysis identified two types of instabilities: one at 10^5 Hz, corresponding to the ion cyclotron instability and its harmonics, and another at 10^7 Hz, associated with the lower hybrid instability and its harmonics. This paper demonstrates that the presence of a wall affects plasma transport across a magnetic filter field in a negative ion source, causing plasma asymmetry and associated instabilities, leading to an inevitable asymmetry in the negative ion beam profile, as recently observed experimentally. The flexibility to adjust the thread count for each module on the HPC facilitated comprehensive performance testing and parametric studies to determine the optimal thread count for various solvers in a parallel PIC code. Additionally, we perform convergence studies to highlight the importance of the trade-off between computational load and accuracy by varying the particle per cell (ppc) and grid sizes.

References

[1] Chaudhury et al. Hybrid Parallelization of Particle in Cell Monte Carlo Collision (PIC-MCC) Algorithm for Simulation of Low Temperature Plasmas *Communications in Computer and Information Science book series*

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