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Space Charge Compensation in Negative Hydrogen Ion Beams: A Particle-In-Cell Study

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Negative hydrogen ion sources have applications across many fields, from particle accelerators (e.g., for high-energy applications in facilities such as CERN, or in spallation neutron source facilities such as ISIS) to magnetic fusion experiments (e.g., those utilising neutral beam injection for plasma heating and diagnosis). In the case of particle accelerators, a common cause of transport losses is the beam divergence due to space charge effects in the low energy beam transport (LEBT) region. As such, space charge compensation (SCC) [1] is crucial to counteract the repulsive space charge forces and maintain efficient transport. In the case of the ISIS H- ion beamline source, the SCC process is mainly derived from interactions between the beam and a neutral background gas, which can produce positive compensating ions that help to reduce the local charge density and electric field.

The present work is a collaborative effort which aims to combine high-fidelity simulations and experimental diagnostics to explore the SCC process, with ultimate goals of supporting ISIS operations and informing designs for upgrades to the ISIS facility. The particle-in-cell (PIC) code PICLas [2] has been used to perform multi-reaction framework simulations of the SCC process in negative hydrogen ion beams, allowing for the exploration of how key parameters such as external magnetic fields, secondary electron emission, and boundary conditions can impact the SCC time and degree. Simulation results will be compared to diagnostic data from ISIS and the Front-End Test Stand (FETS), where experiments have been conducted to correlate the beam transport and light emissions with the SCC process.

REFERENCES

[1] C. A. Valerio-Lizarraga et al., Phys. Rev. Accel. Beams 18, 080101 (2015).
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