

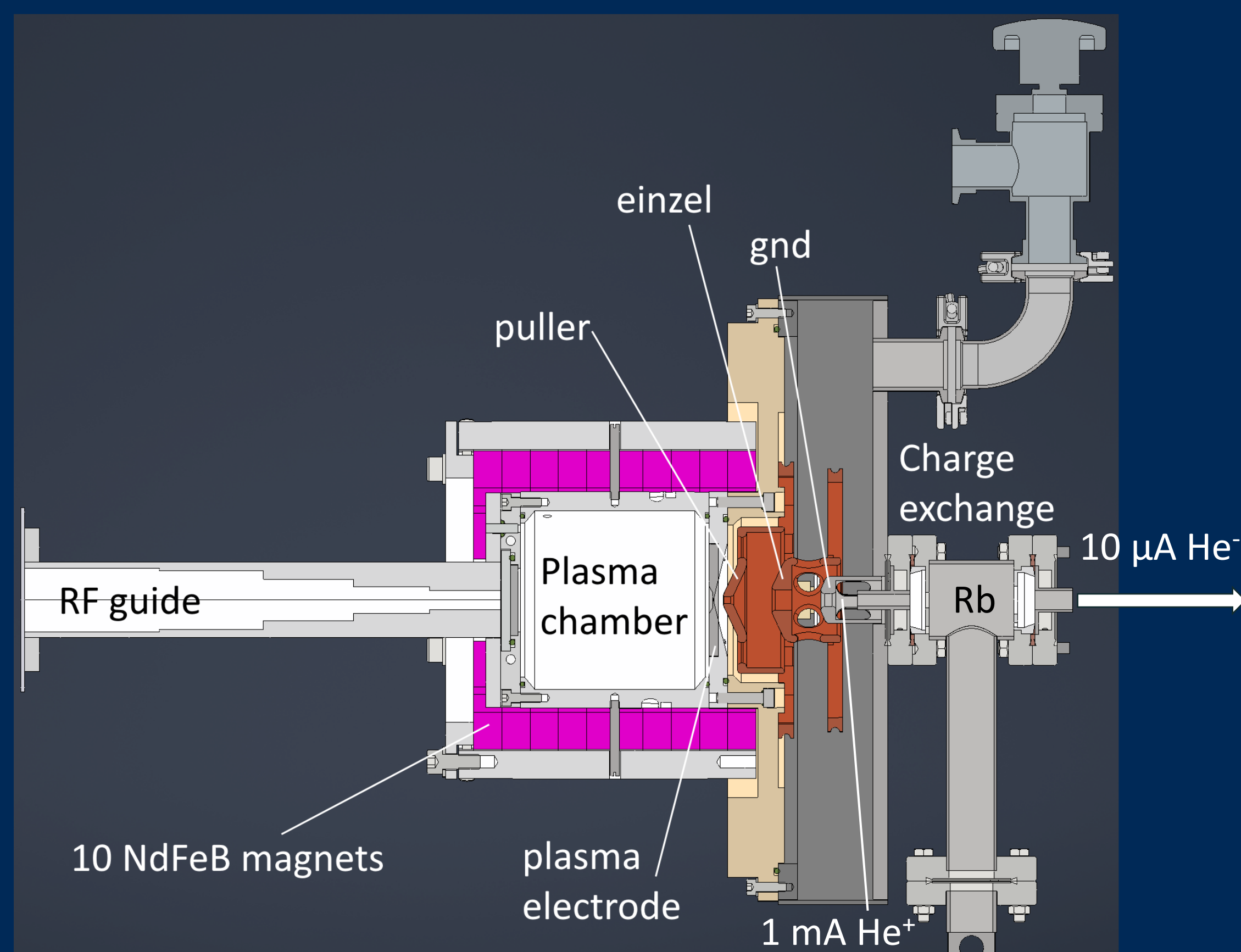
Mitigation of Secondary Electron Trapping in Permanent-Magnet Ion Sources by Extraction Geometry Design

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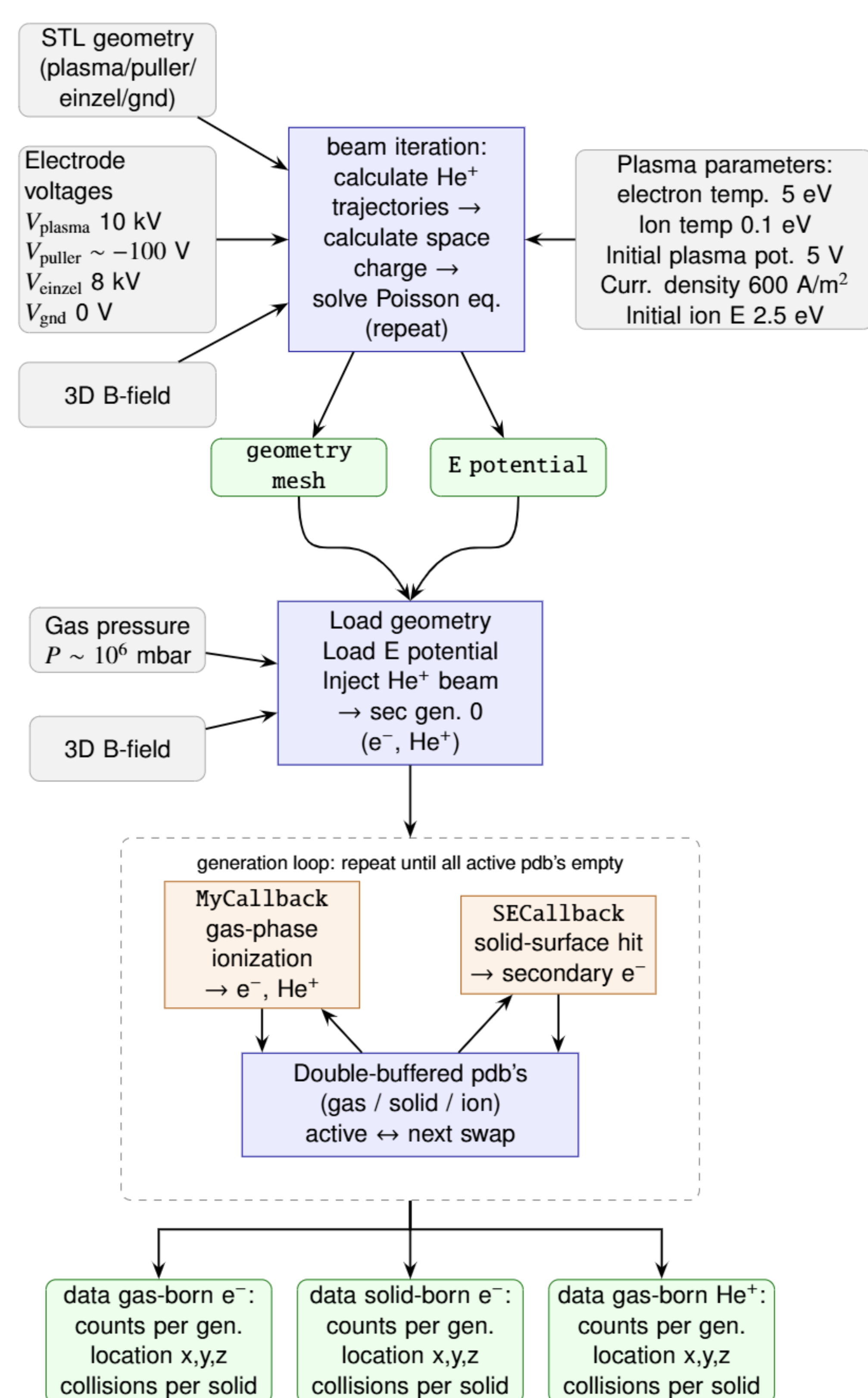


Motivation

A permanent-magnet-based, microwave-driven ion source is being developed for the production of negative helium beam. Electrical discharges in the extraction region limit the beam transport and focusing, motivating this investigation of secondary-particle accumulation. Because the local minima of permanent-magnet fields can trap low-energy secondary electrons, there is reason to suspect a multi-generation particle cascade — analogous to Townsend avalanche — that sustains the discharges. An IBSimu-based model is used to track per-generation particle counts, comparing the formation of secondaries in solenoidal and permanent-magnet field configurations.

Computational model

First, an initial He^+ beam is propagated through the electromagnetic fields defined by electrode potentials and an imported magnetic field, iterating space-charge with Poisson solving. Second, a fresh beam is injected into the pre-calculated field and propagated with two trajectory callbacks — one sampling gas-phase ionization via free-flight Monte Carlo, the other triggering threshold energy dependent secondaries on solid impacts. The secondary particles are iterated through the same process until no new particles are produced.



Results

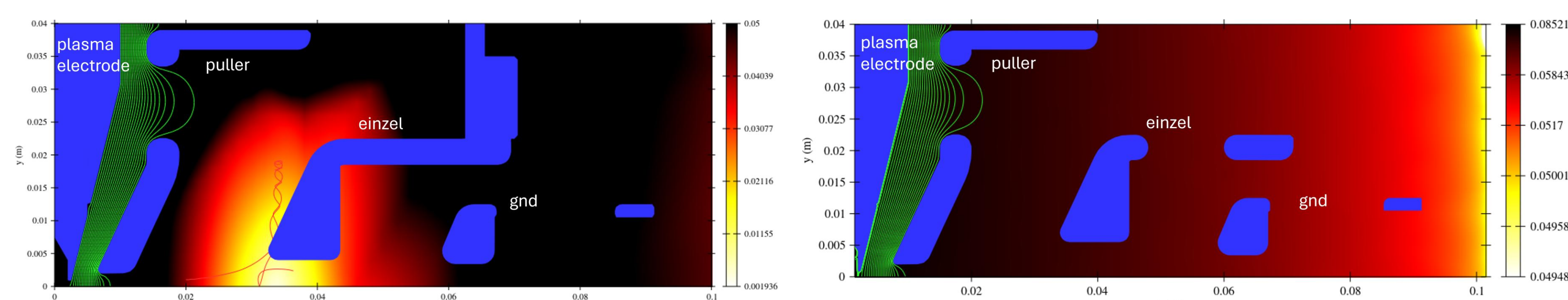
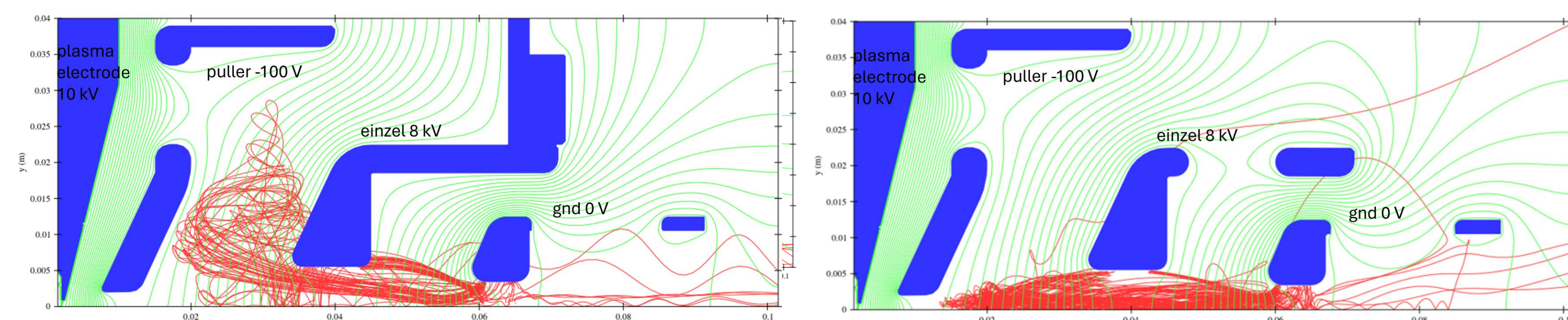
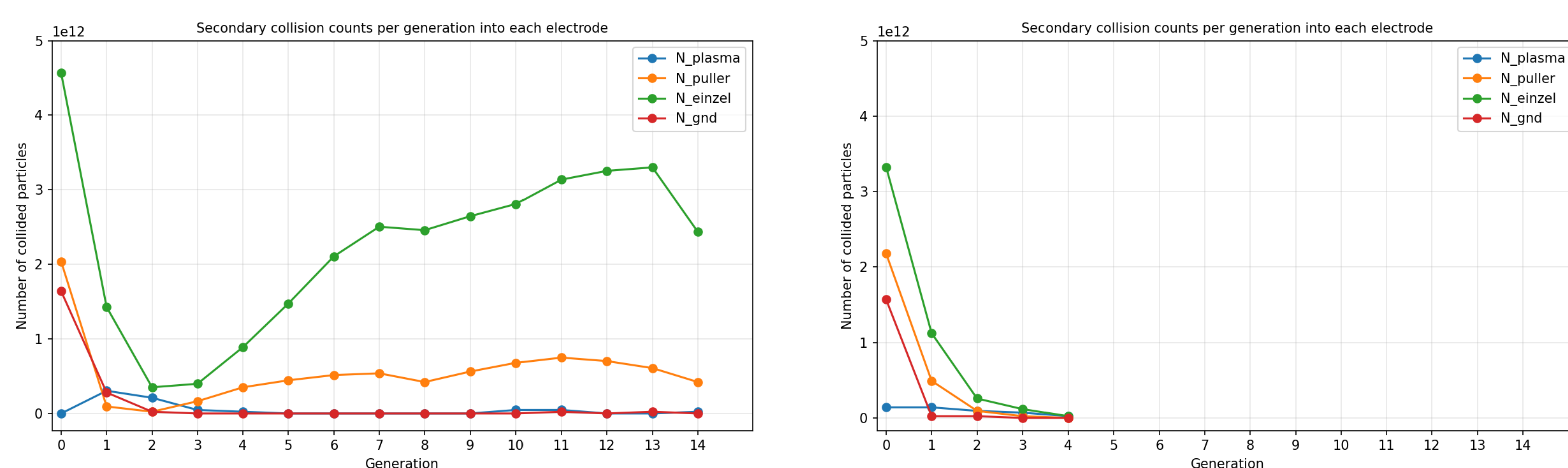


Illustration of the topologies of permanent-magnet (left) and solenoidal (right) magnetic fields.



First-generation secondary electrons generated in solid impacts in the permanent-magnet field (left) versus the solenoidal field (right). The solenoidal field steers particles straight onto solids, while the permanent-magnet field forms a magnetic mirror that allows particles to undergo further ionization.



Per-generation counts of secondary particles impacting each electrode. In the permanent-magnet field, most collisions occur on the einzel electrode; in the solenoidal field, the cascade dies out within a few generations. The permanent-magnet simulation is terminated by a manually set limit.

Conclusions

A cascade formation is observed within the extraction region in the permanent-magnet field, whereas in the solenoidal field it dies out. However, it is early to conclude whether the magnetic topology alone explains the experimentally observed discharges — the effects of electrode voltages, residual gas pressure and the geometry of the extraction need further investigation.

To mitigate this potential problem, the spatial overlap between the magnetic-field minimum and the extraction and focus electrodes has to be disentangled. This can be done either by extending the magnetic field over the extraction region — which may relocate the trap — or by moving the einzel and gnd electrodes further away, at the cost of the targeted compactness. Switching to diode extraction is also worth considering.