Properties of the negative ion beam extracted from a fusion-type ion source

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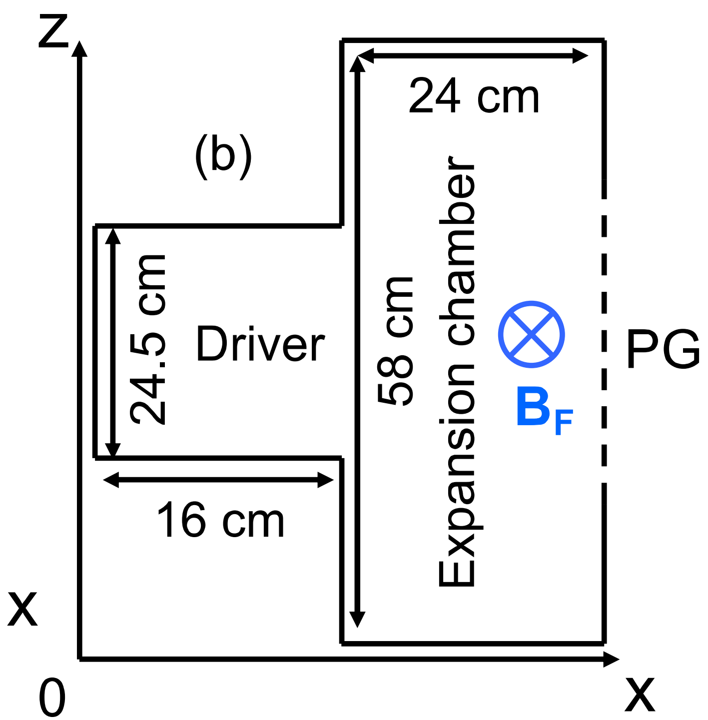
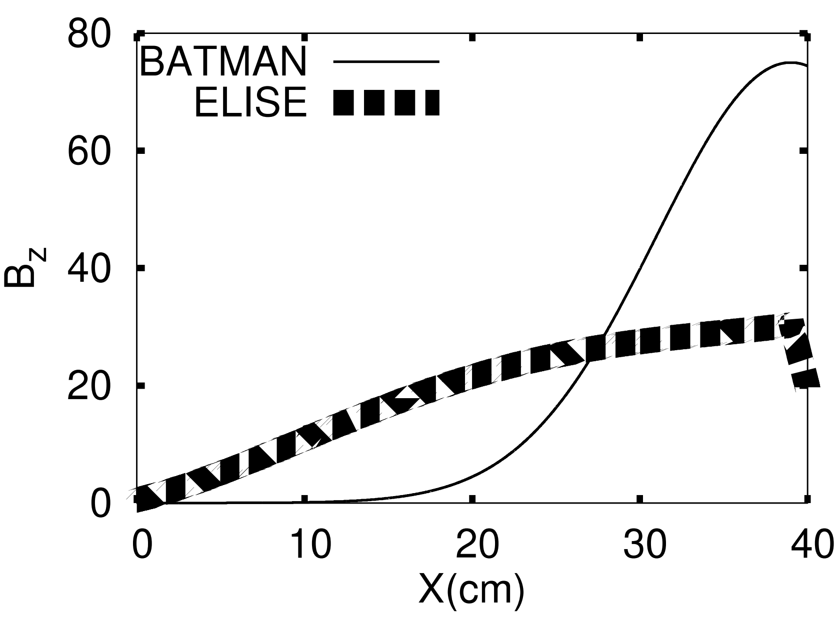
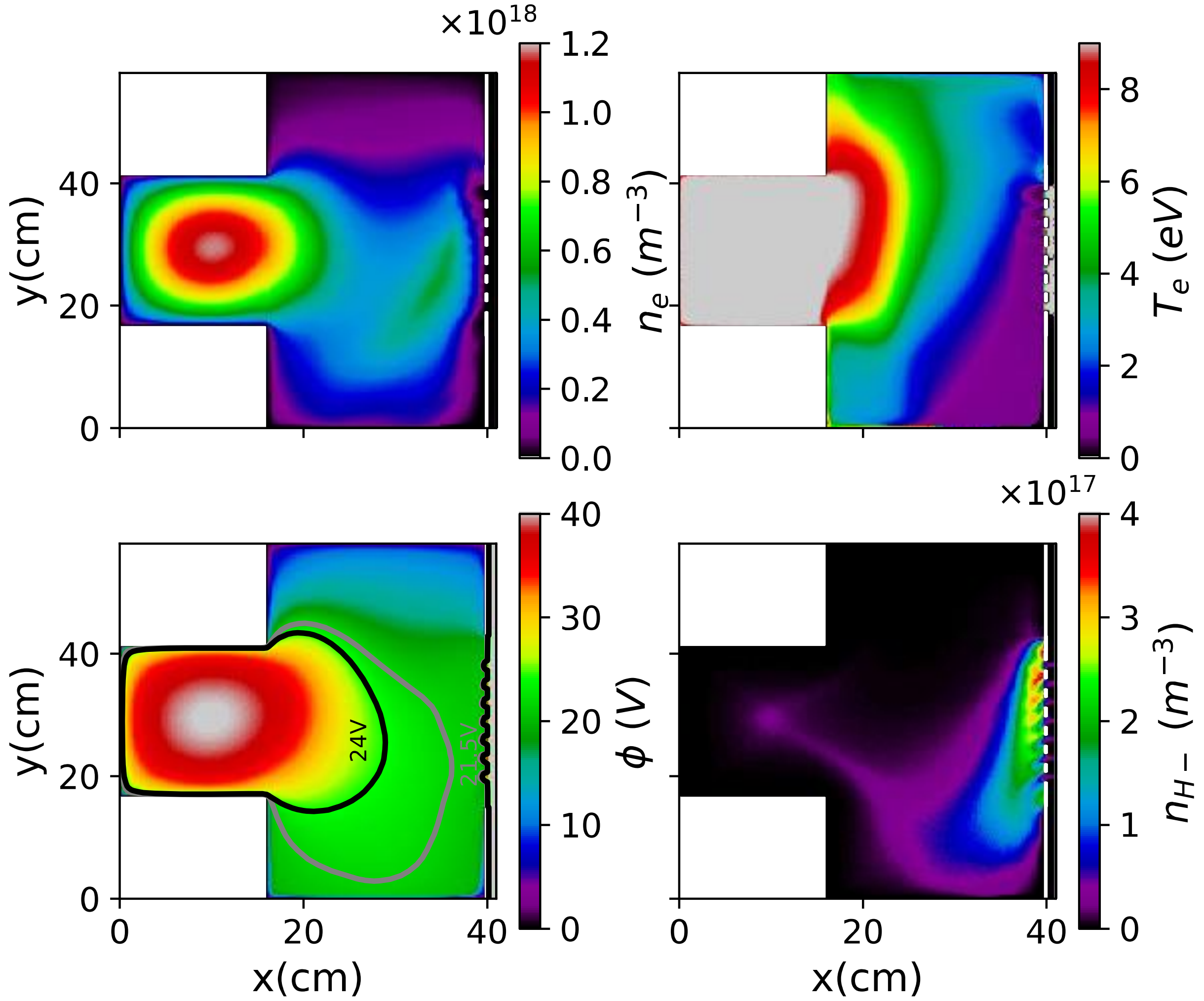
Model type/simulation domain

- 2.5D-3V Particle-In-Cell with Monte-Carlo Collisions (PIC-MCC)
- Numerical resolution of 4096 x 6144 nodes
- 320 nodes per apertures
- Comprehensive chemistry for H_2
- Plasma density of 2.5 x 10^{15} m^{-3} in the driver
  - A Scaling factor $\varepsilon/\varepsilon_0 = 400$ is used.

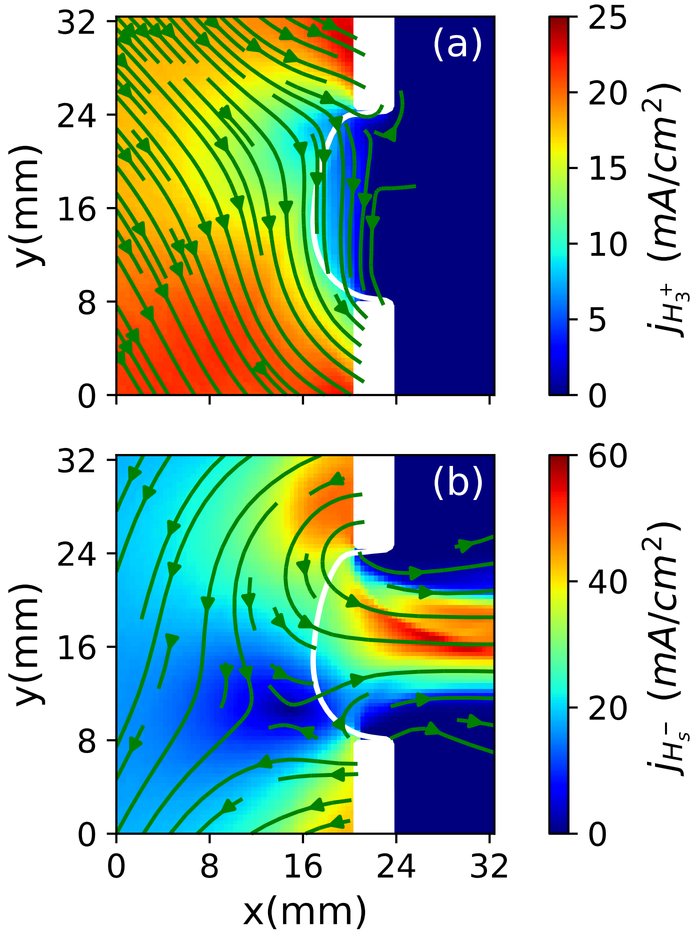




Plasma properties/effect of the electron Hall current

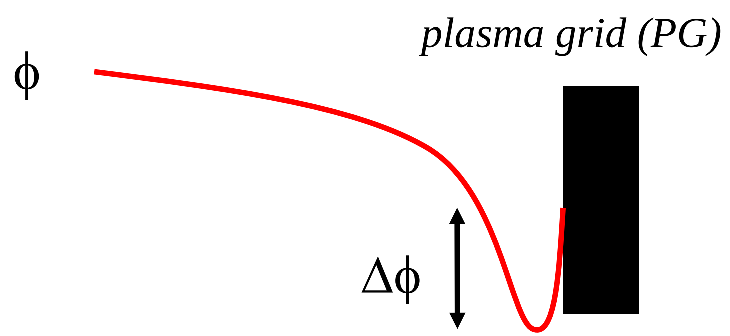


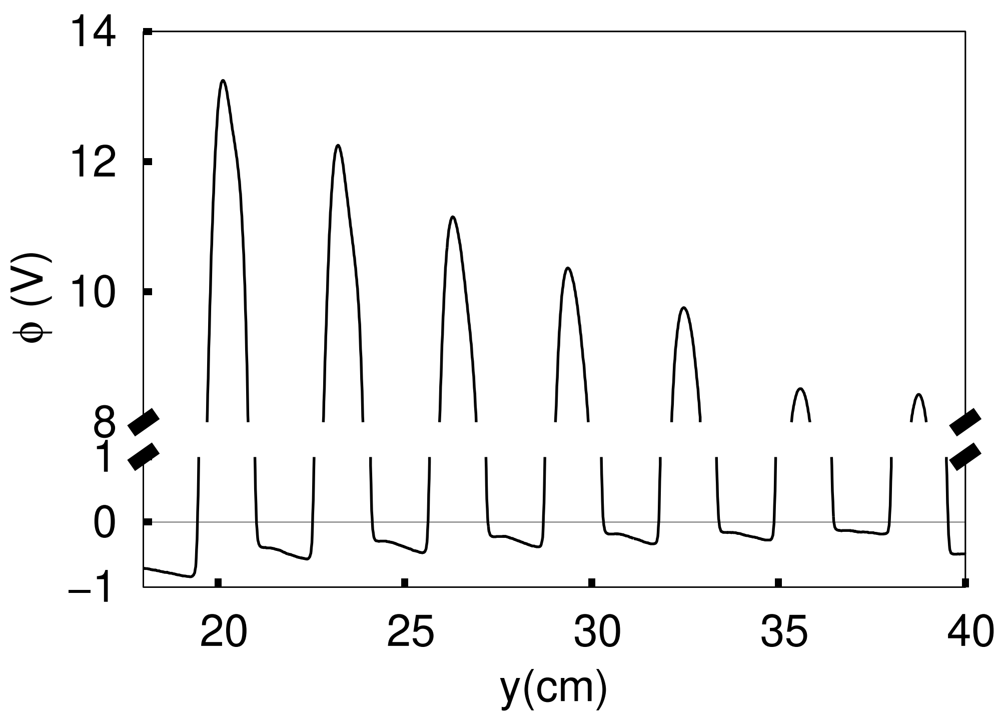
Zoom around one aperture



- Positive ion flux is tilted due to the asymmetry in the plasma parameters.
- Negative ions are slightly magnetized.
    - X-point is off axis.
    - Induce an asymmetry in the beamlet current density profile.
- Consistent with experiments.

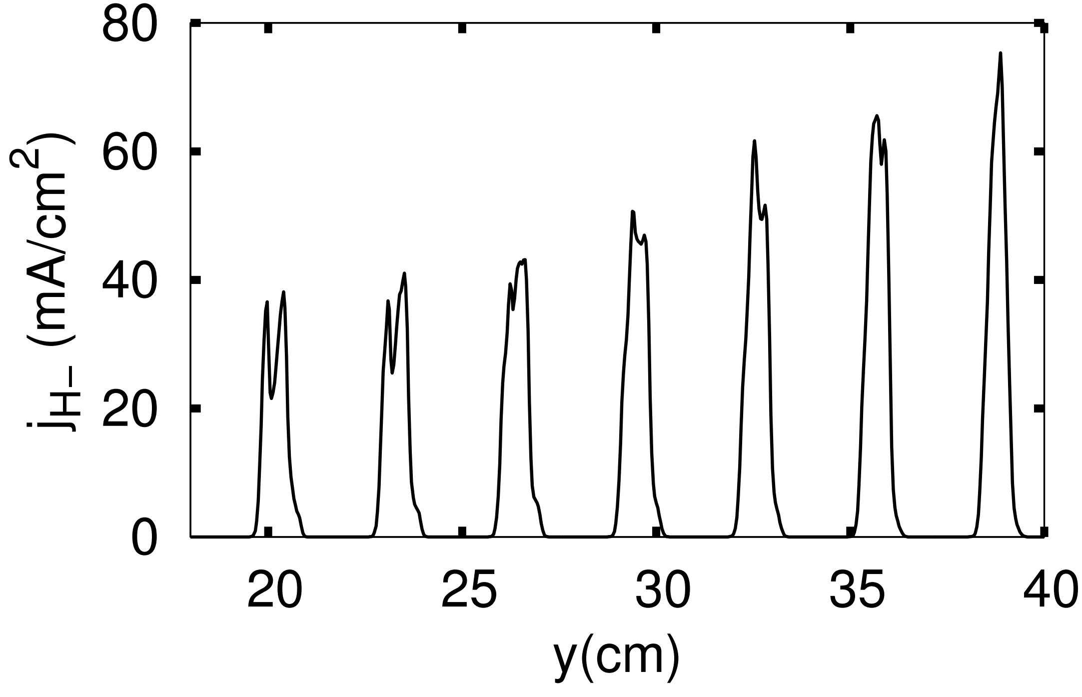
Virtual cathode profile along the PG



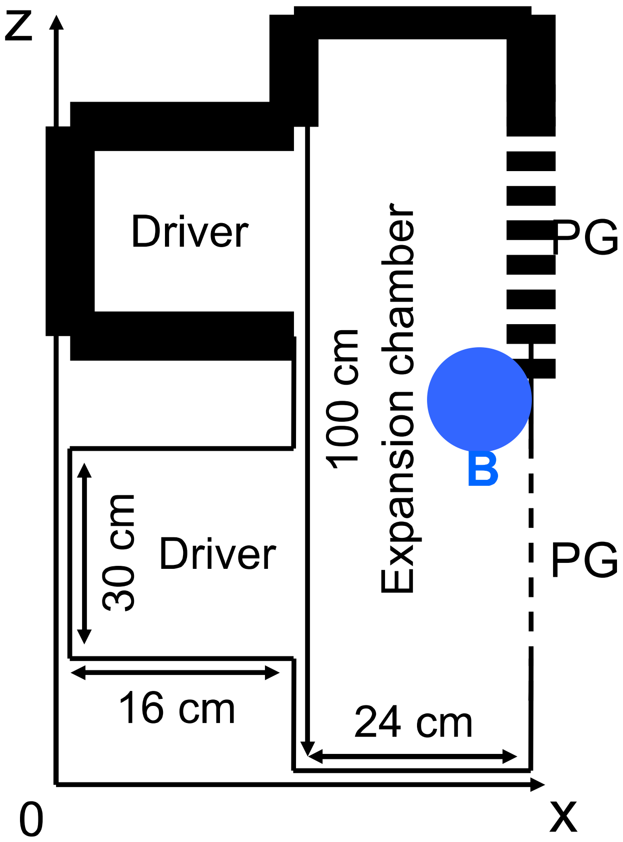


Depth of potential well in front of the PG surface is non-uniform which has an impact on the beam current density profile in the model

Extracted negative ion beamlet profile on the extraction grid (EG)

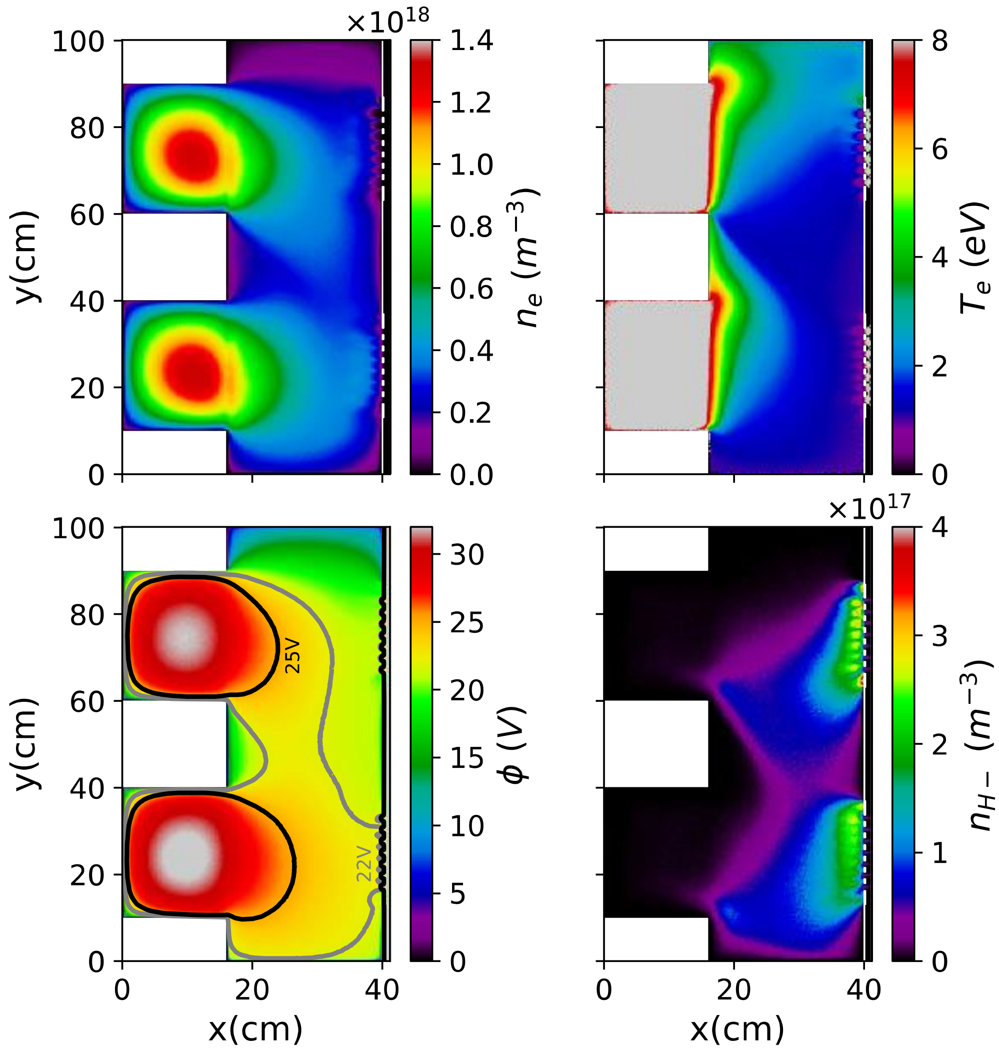


What about larger ion source volumes? : simulation domain

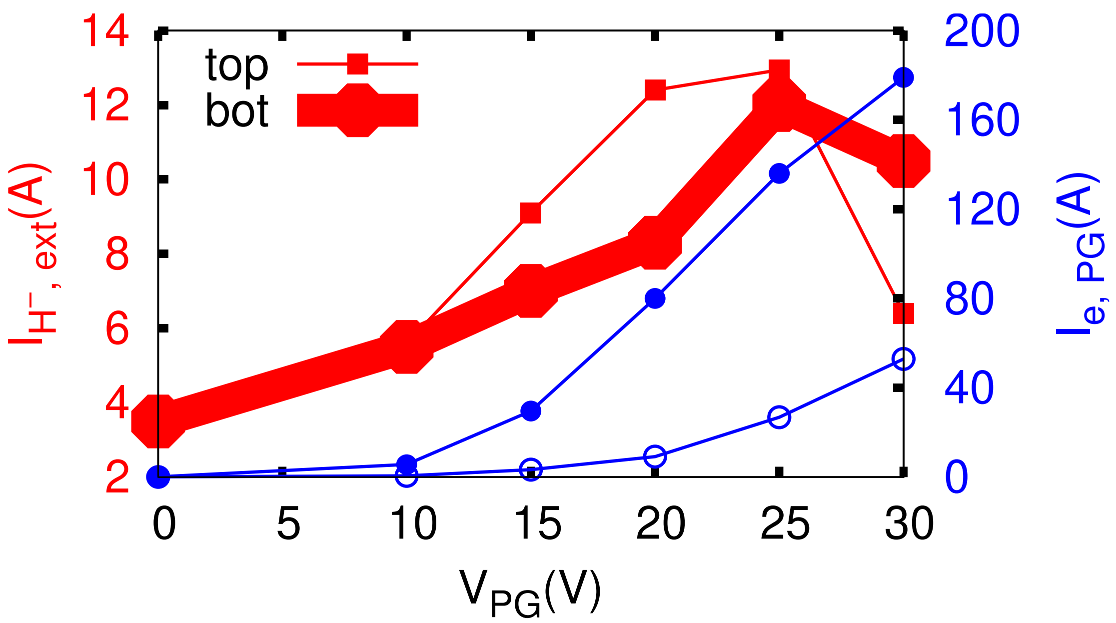


- 2.5D-3V PIC-MCC calculation
- Numerical resolution of 2048 x 6144 nodes
- 14 apertures (160 grid cell resolution for each one)
- Comprehensive chemistry for H_2
- A Scaling factor $\varepsilon/\varepsilon_0$= 400 is used.

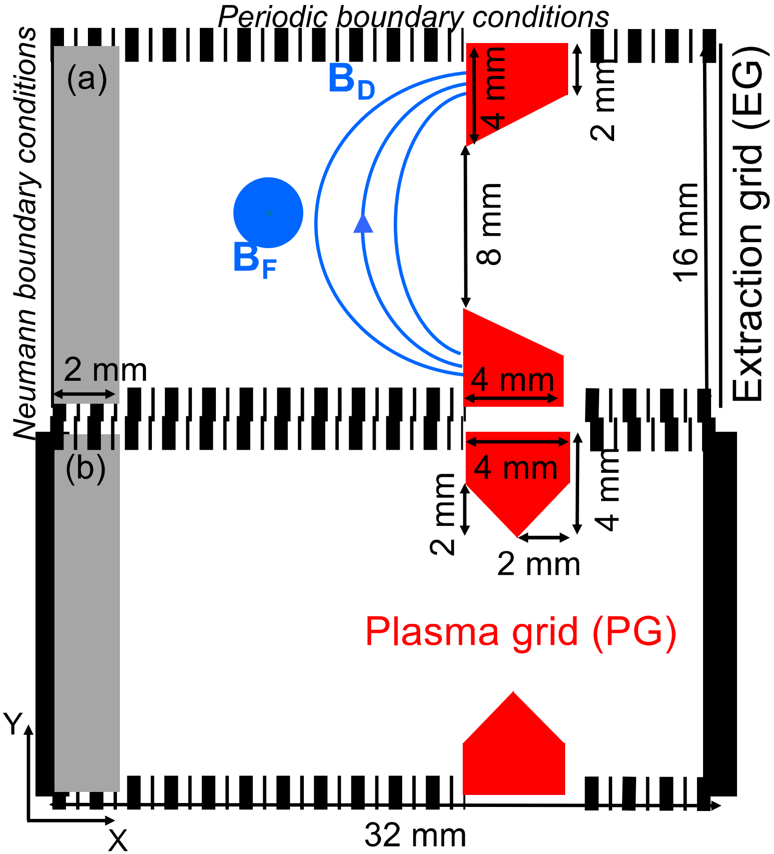
The electron Hall current in the plasma still induce a noticeable asymmetry



Top/bottom asymmetry also for the electron current on the PG and extracted negative ion current

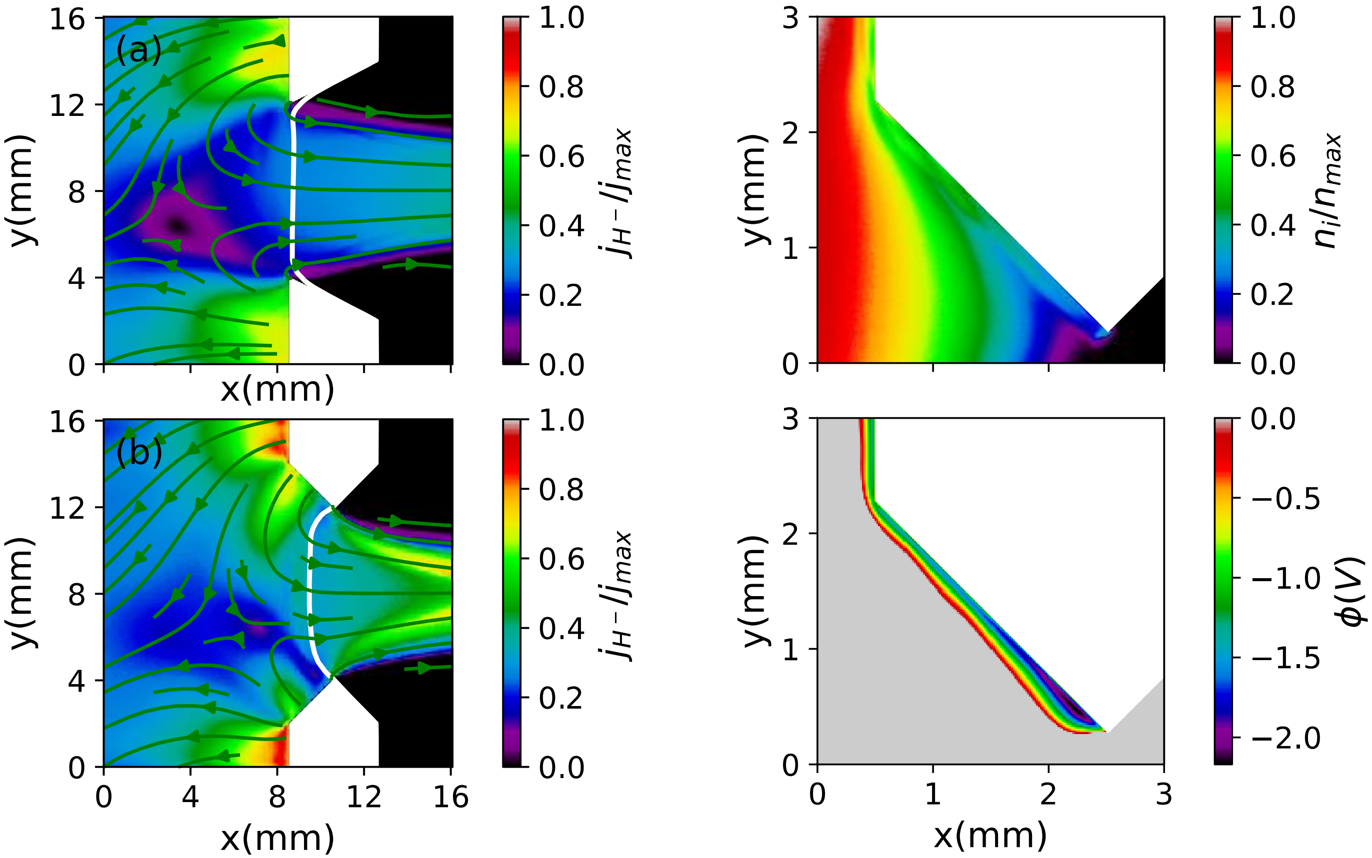


What about the effect of the grid geometry on the beamlet optics in the accelerator



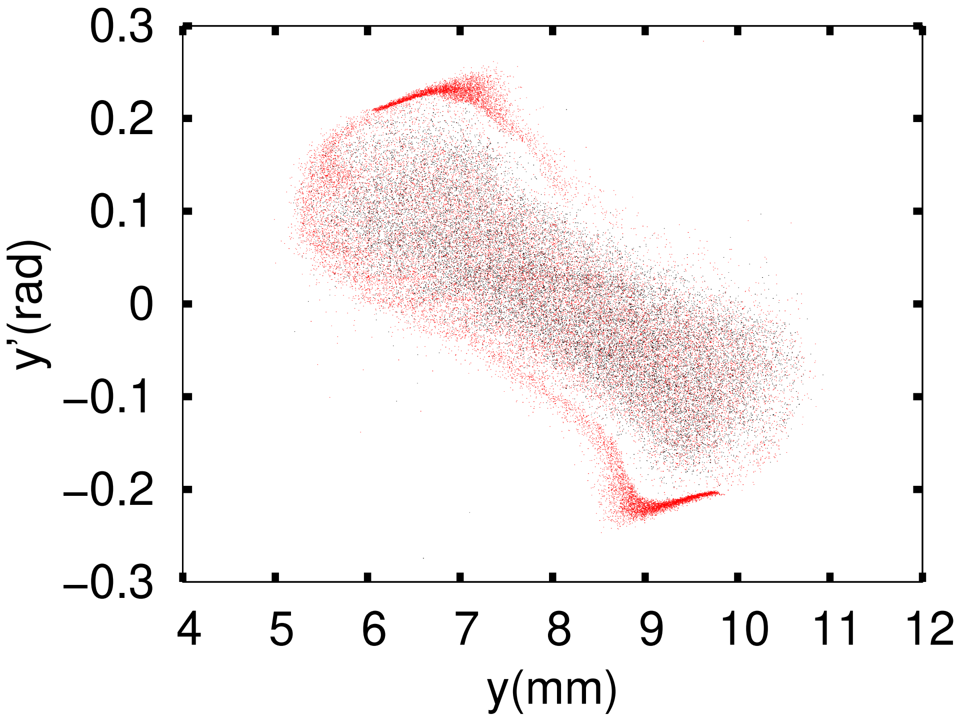
- Chamfered vs. bevel grid geometries
- 2D-3V PIC-MCC calculation (slit apertures)
- Numerical resolution of 2048 x 4096 nodes
- Necessary to resolve the virtual cathode profile
- Negative ions only produced on the PG surface
- Average plasma density of 3 x 10^{17} m^{-3}
    - No scaling factors ($\varepsilon/\varepsilon_0 = 1$)
- Simulation domain restricted to one aperture
- Plasma injected into “grey” area

What about the effect of the grid geometry on the beamlet optics in the accelerator (cont'd)



- Chamfered apertures generate aberrations in the beam
- 58% extraction probability on tilted side vs. 33% once an ion escape virtual cathode
  - But lower saturation current
- $(I_c/I_b)(S_b/S_c) \approx 1.2$, i.e, somewhat proportionnal to the surface *as in the experiments*

Halo visible on the beamlet phase-space distribution



Legend : black points for ions produced on the flat surface and red for the tilted one

Conclusion

- An asymmetry in the plasma parameters is observed in the plane perpendicular to the magnetic filter field.
  - This is caused by the electron Hall current intercepted by the ion source walls.
- The asymmetry affects the extracted electrons and ions as well.
  - Non-uniform saturation current profile along the PG for the ions.
- An additional asymmetry for the ions originates from their slight magnetization by the magnetic filter field.
- Comparing a chamfered vs. bevel grid geometry (slits), one finds an extracted current somewhat proportional to the surface area.
  - Higher extraction probability on the tilted surface but lower saturation current.
- Chamfered configuration generates a halo in the ion beam optics.
- Simulation required a large number of grid cells in 2D (4096 x 2048)
  - Feasibility of a 3D calculation questionable
- Conclusions from Particle-in-Cell model consistent with experimental observations.