Origin of beam non-uniformity in a large Cs-seeded negative ion source

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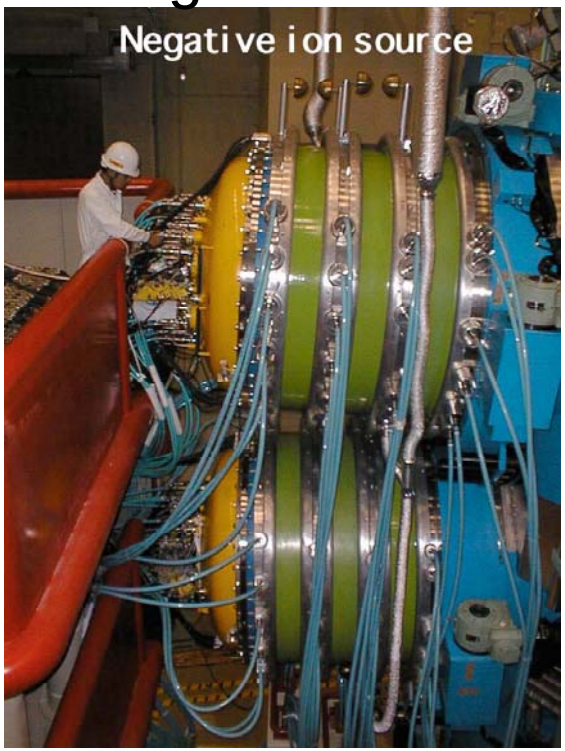
Summary

1. By probe measurements and electron trajectory analyses, it was suggested that the fast electron behaviour is influenced by B x ∇ B drift.
2. In pure volume, the H^- ion uniformity seems degrade by local electron detachment due to the fast electrons. In Cs seeded operation, H^- ion beam output is higher in high T_e, and hence, high n_e region.
3. To achieve uniformly high H^- ion output,
   1) filter strength was weaken,
   2) filament location was changed,

   both found effective to improve the beam uniformity without significant degradation of the beam intensity.
4. By 2) The uniformity of $\pm$10% was achieved.

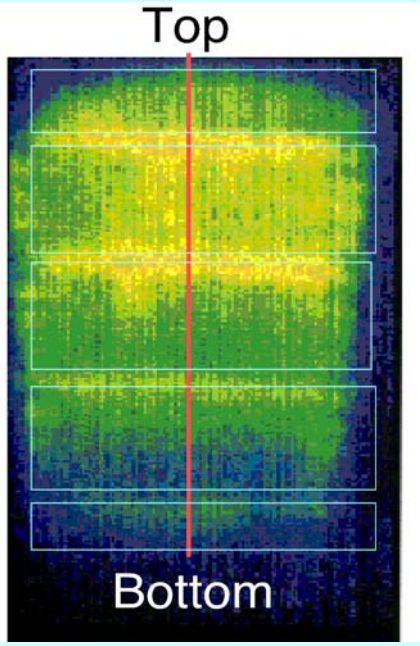
Uniformity issue in large negative ion sources

JT-60 Negative ion source

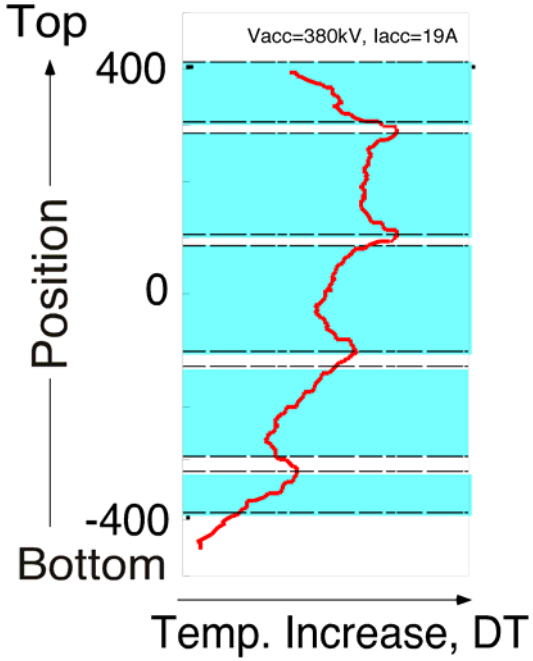


Uniformity issue

IR beam footprint



Target temp. profile

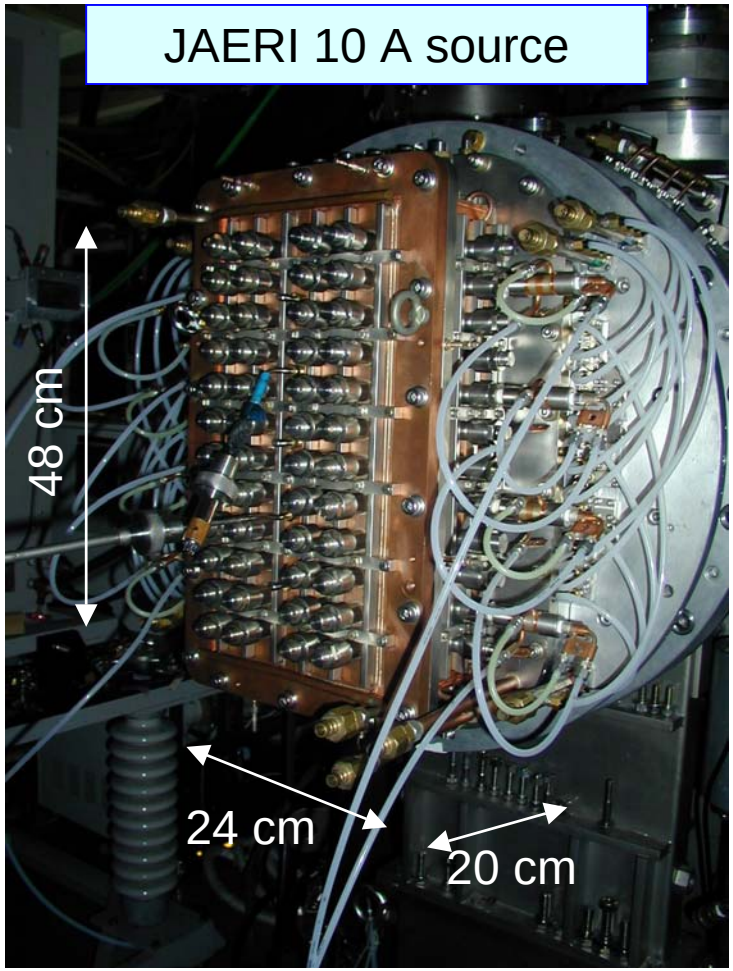


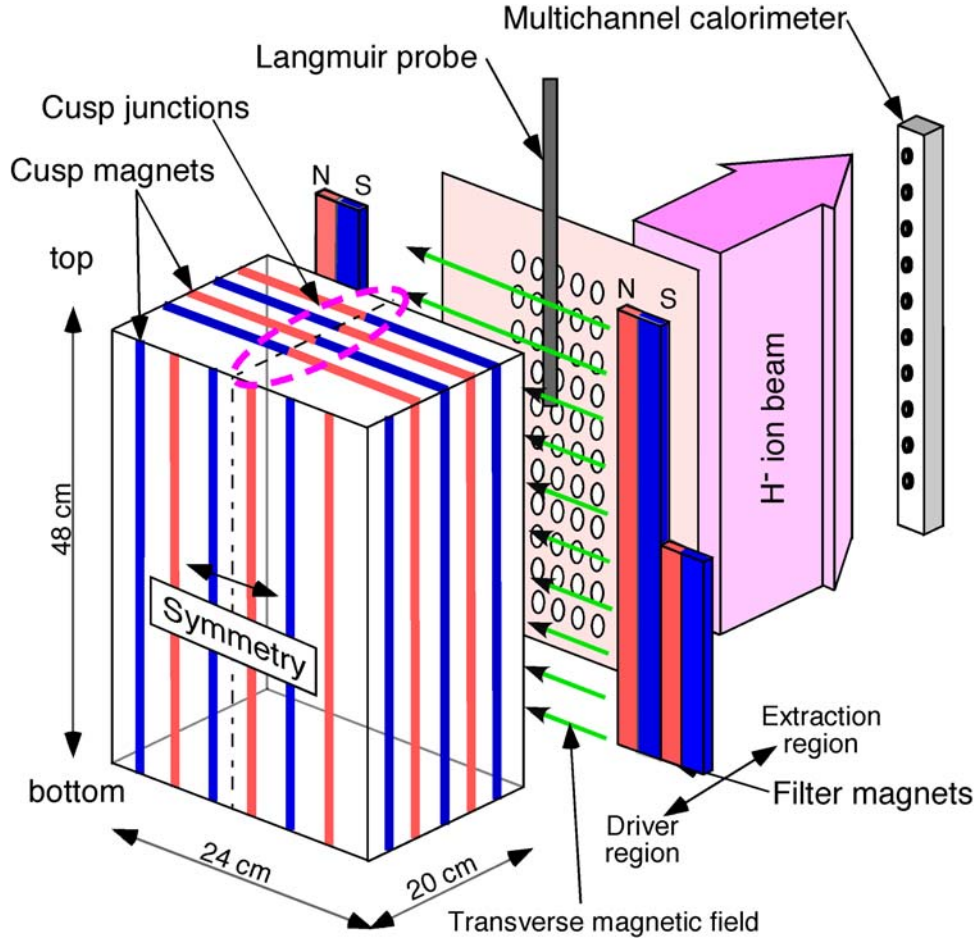
Design specifications
Beam current:22A
Beam energy :500keV
Pulse length:10 s

-No beam from top and bottom,
- Gradient in center 3 segments.

JAERI 10 A source

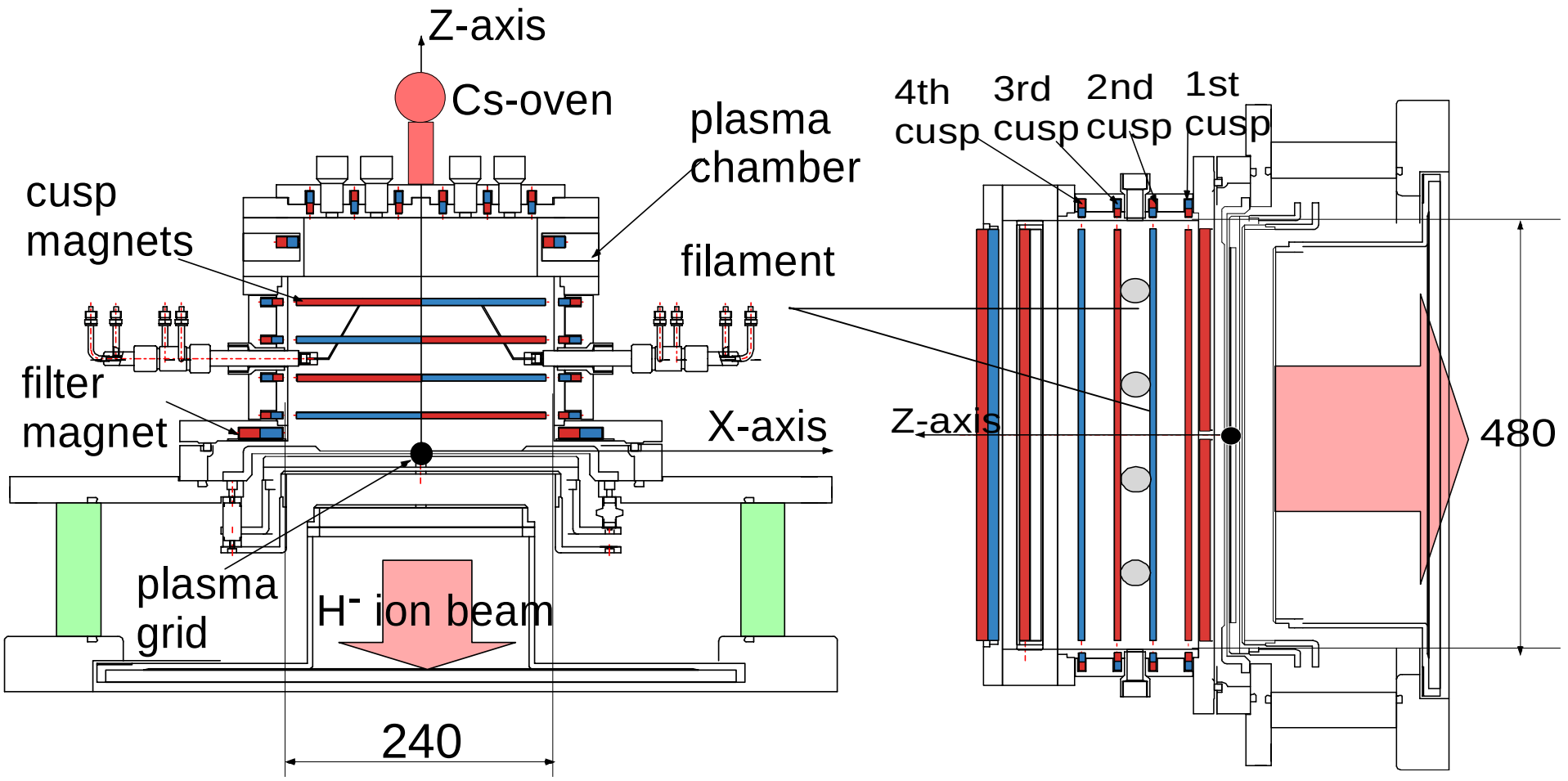
A large negative ion source, which produced 10 A H^- ion beam (1990).





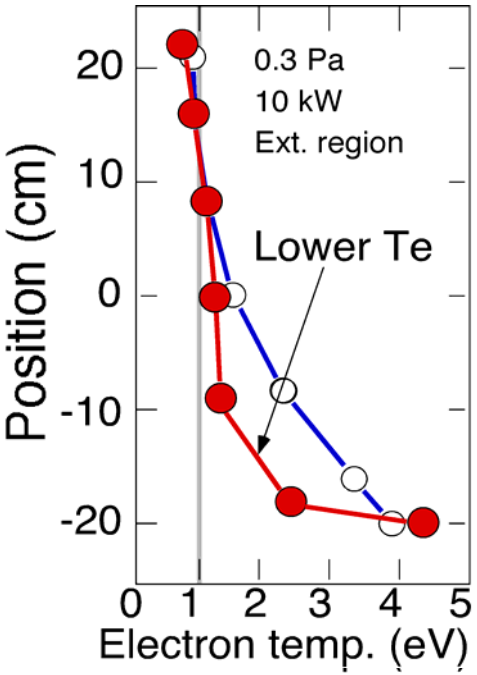
- Rectangular discharge chamber,
- Easy access by probes in xyz coordinates.

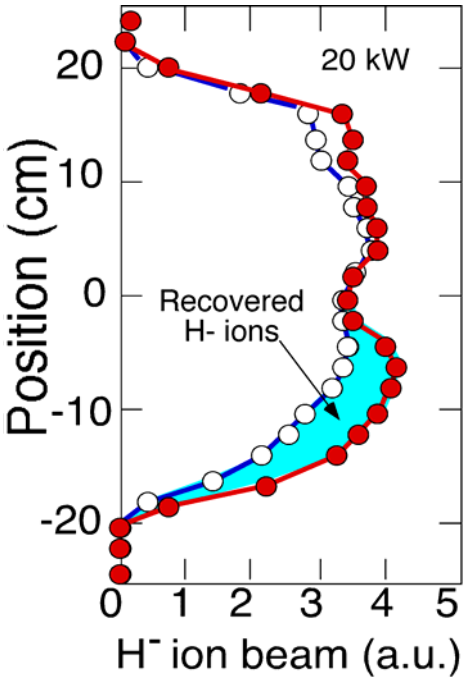
JAERI 10 A source



- Uniformity studied both with / without Cs.
- Key parameters: filament position, cusp positions.

Pure volume: Electron detachment and uniformity





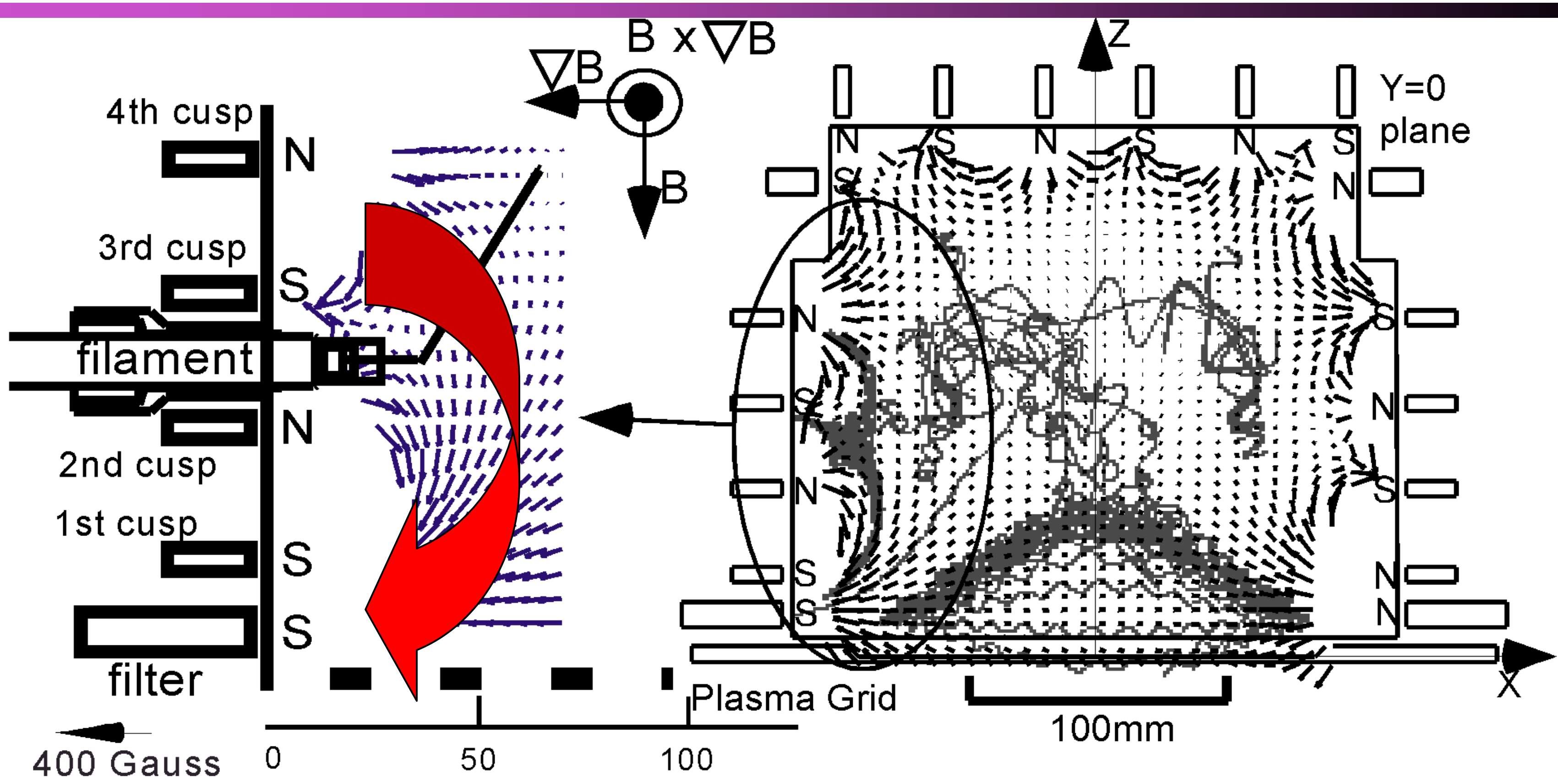
In pure volume operation:

- Temperature gradient,
- Low H^- intensity from region where Te > 1 eV.

- Lowering Te by:
  - locally strengthen Magnetic filter,
  - Intercepting fast electrons penetrating filter field,

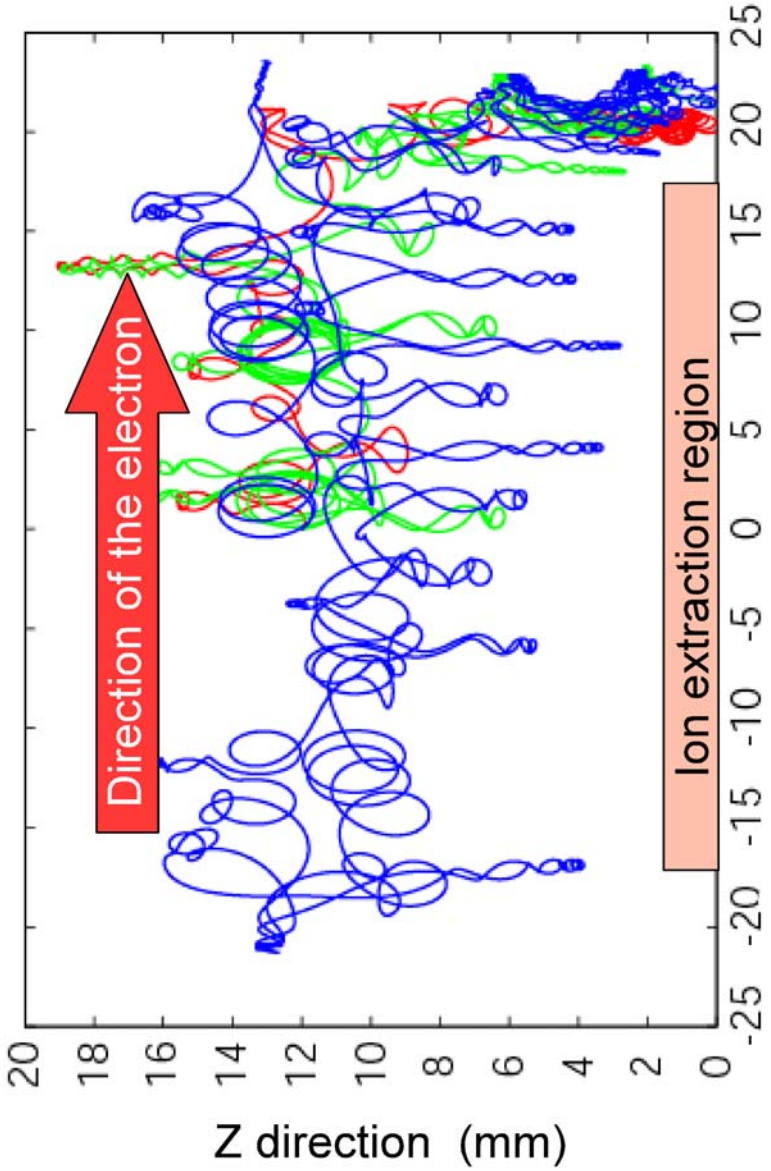
- Reduction of Te followed by H^- ion recovery.

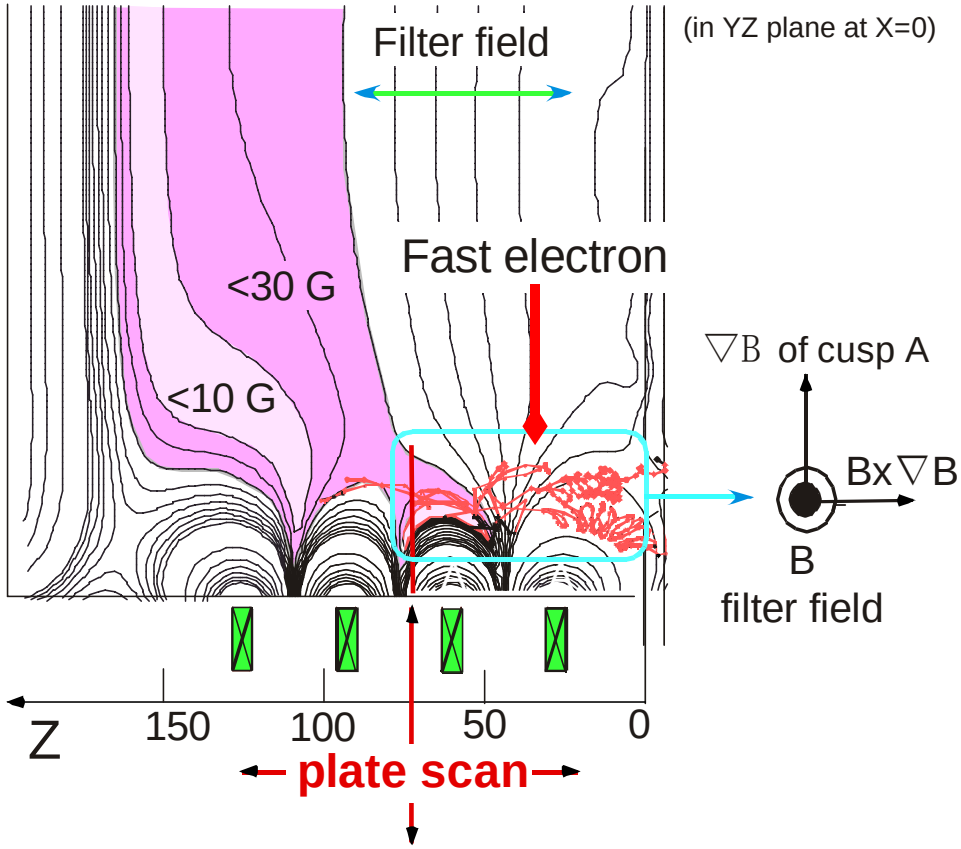
Fast electron trajectories



- Filaments immersed in the strong magnetic field, form by an irregular link between the magnetic filter field and the 3rd cusp line filed.
- The electrons from the filaments drift upward by B x ∇B.

Fast electron leakage through filter

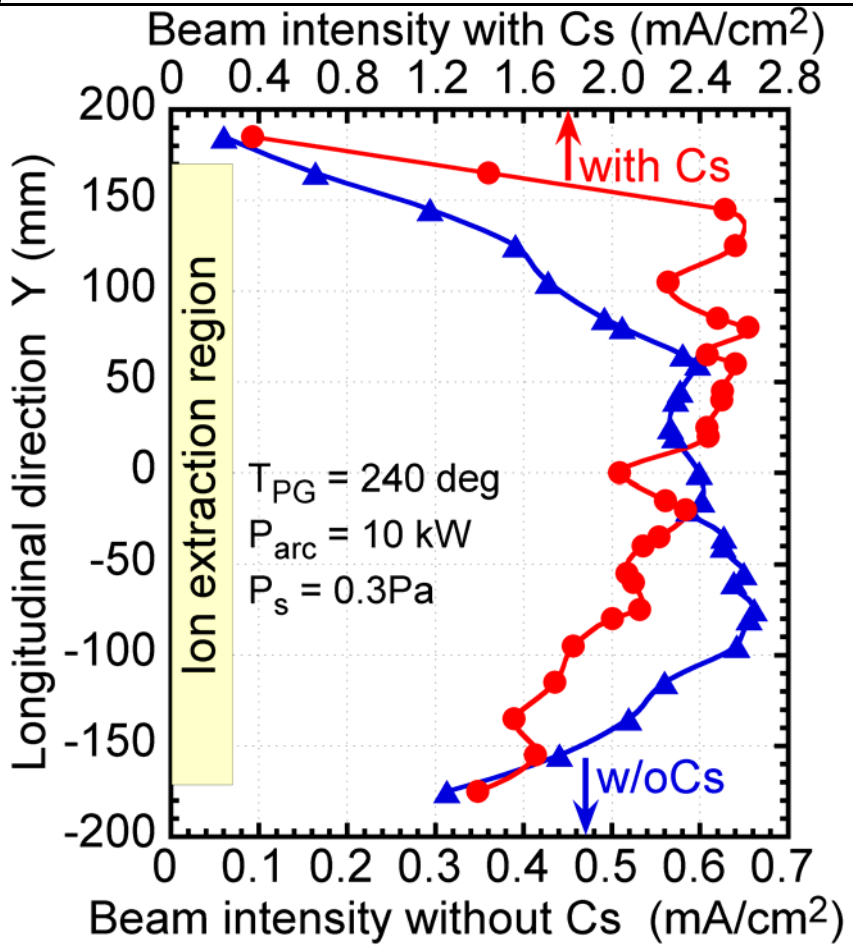




Fast electrons penetrate filter field at the bottom cusp junction by B x ∇B.

Beam uniformities with / without Cs

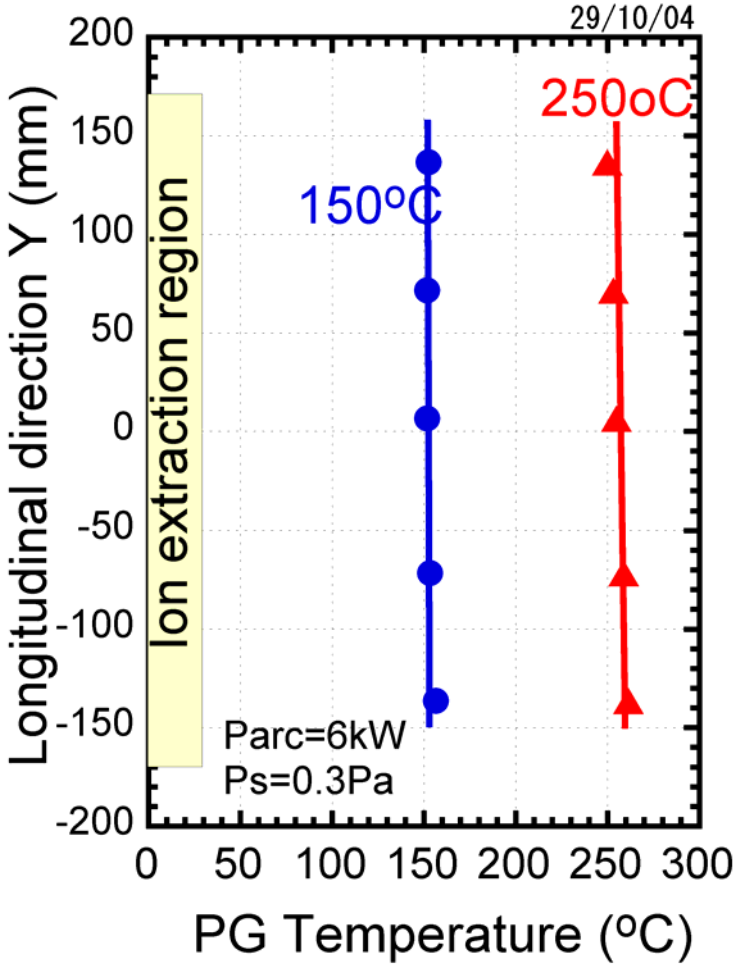
Longitudinal distribution of the beam intensity



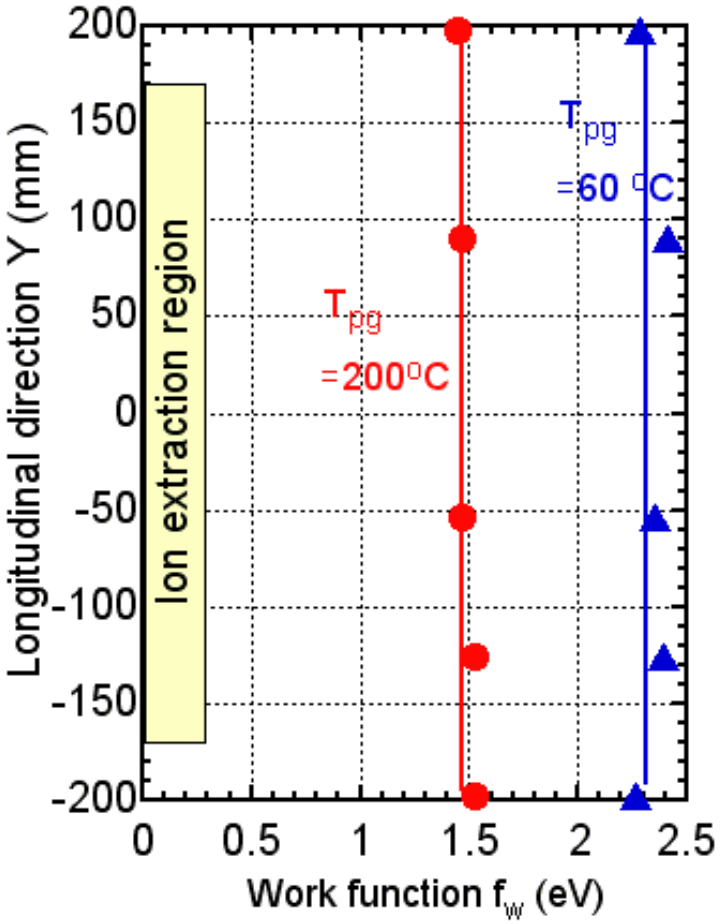
The beam profile with Cs was not uniform,
and the direction of non-uniformity is different from that without Cs

PG temperature and work function

PG temperature



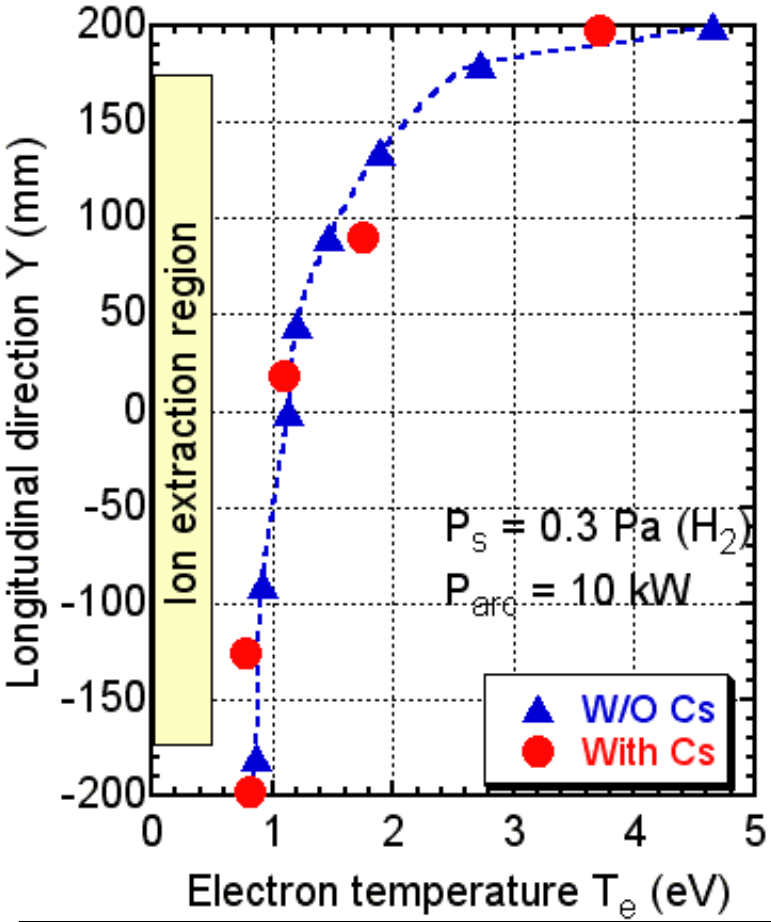
Work function



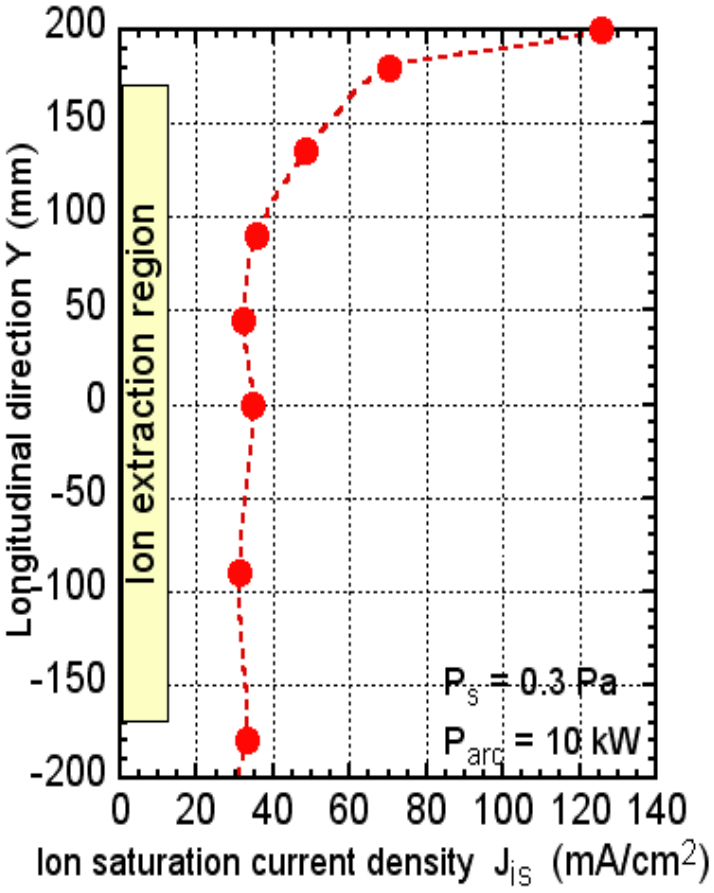
Both the PG temperature and the work function were uniform.

Plasma parameters near PG

Electron temperature (Te)



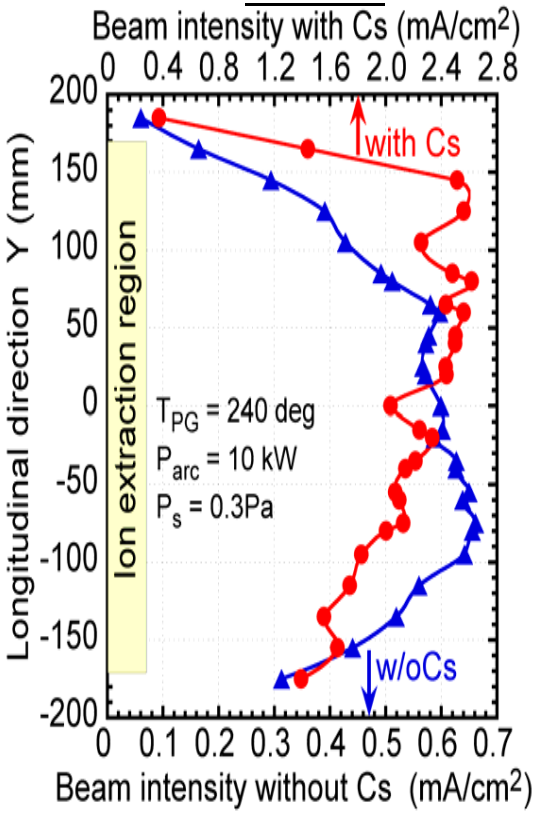
Ion saturation current density (Jis)



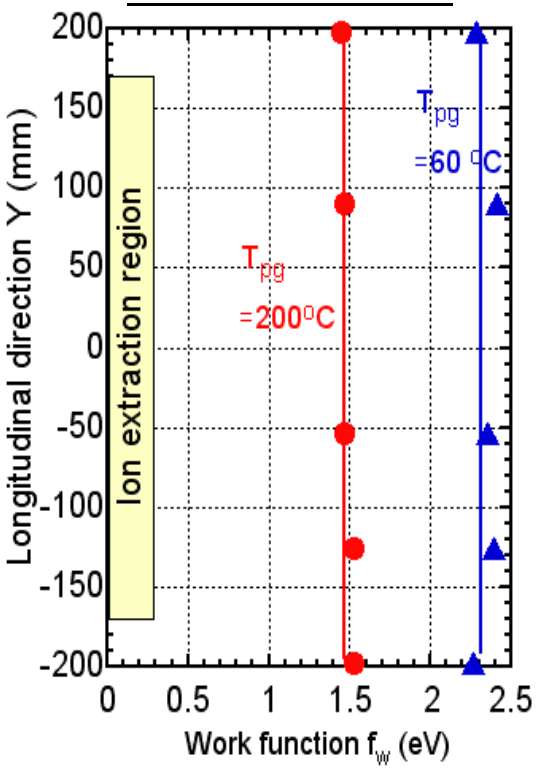
- Both Te and JIS are not uniform.
- H^- beam intensity is higher from the region high Te and high JIS (ne).

Comparison of profiles

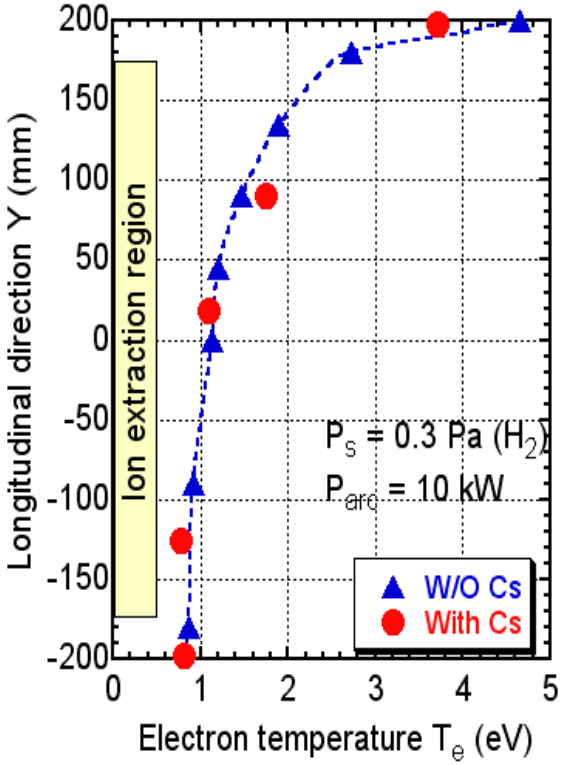
Beam



Work function

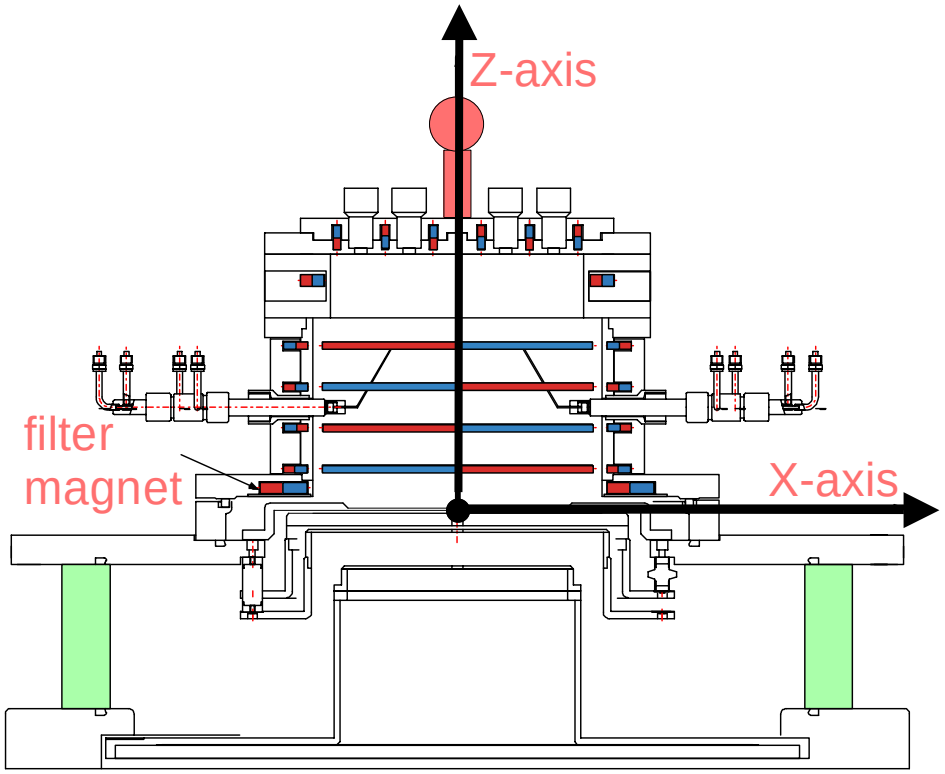


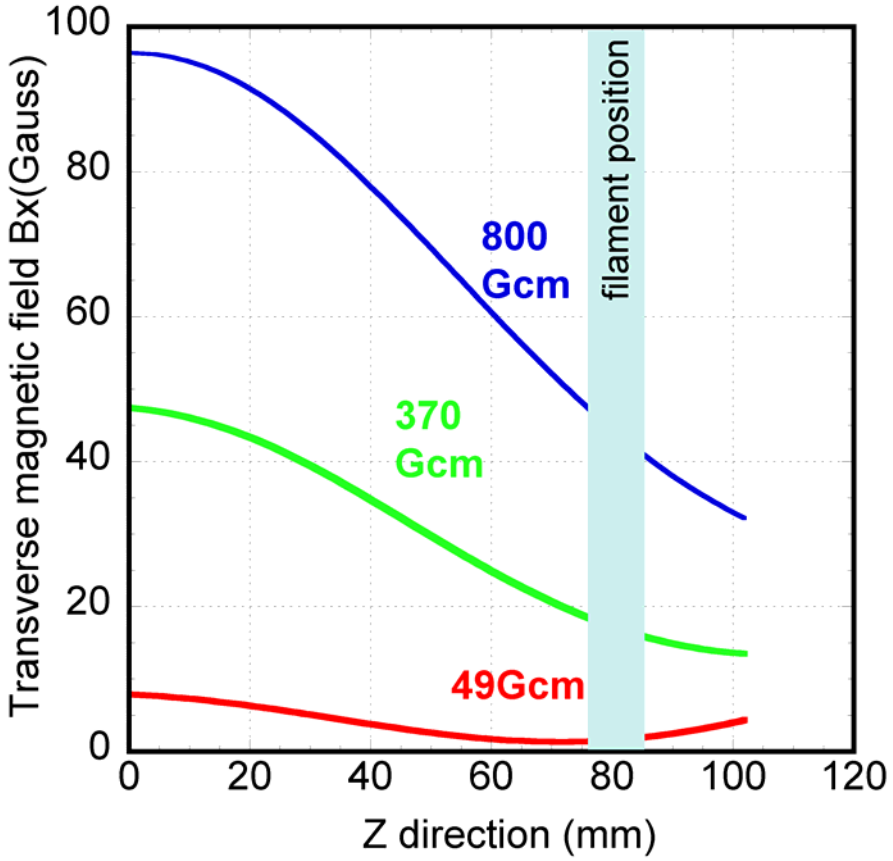
Te



- Electron temp. does not matter, and higher density seems preferable in Cs seeded operation. If so, it is worth testing:
  - Reduction of the filter field,
  - Filaments to locate near the PG.

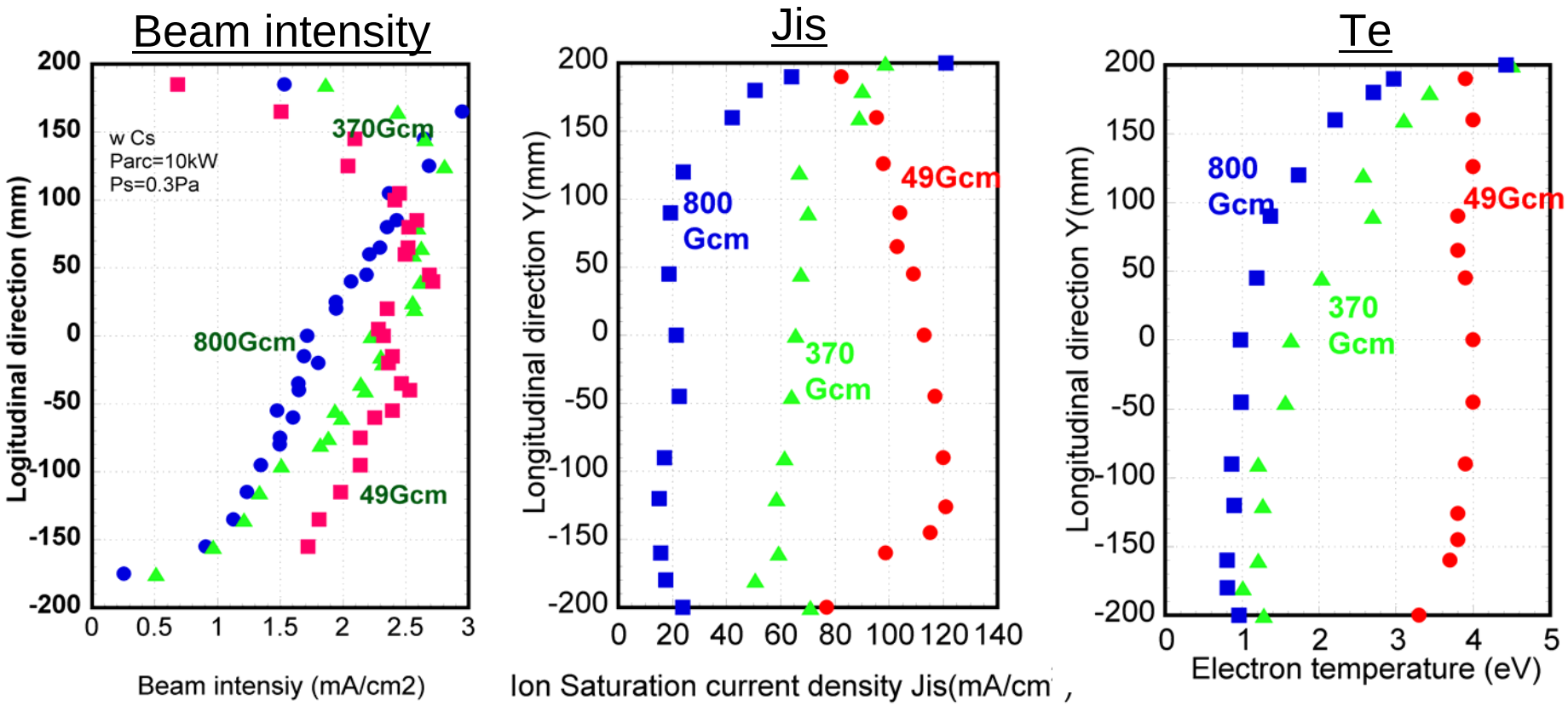
Reduction of the filter field





The magnetic filter was changed from 49 to 800 Gauss・cm.

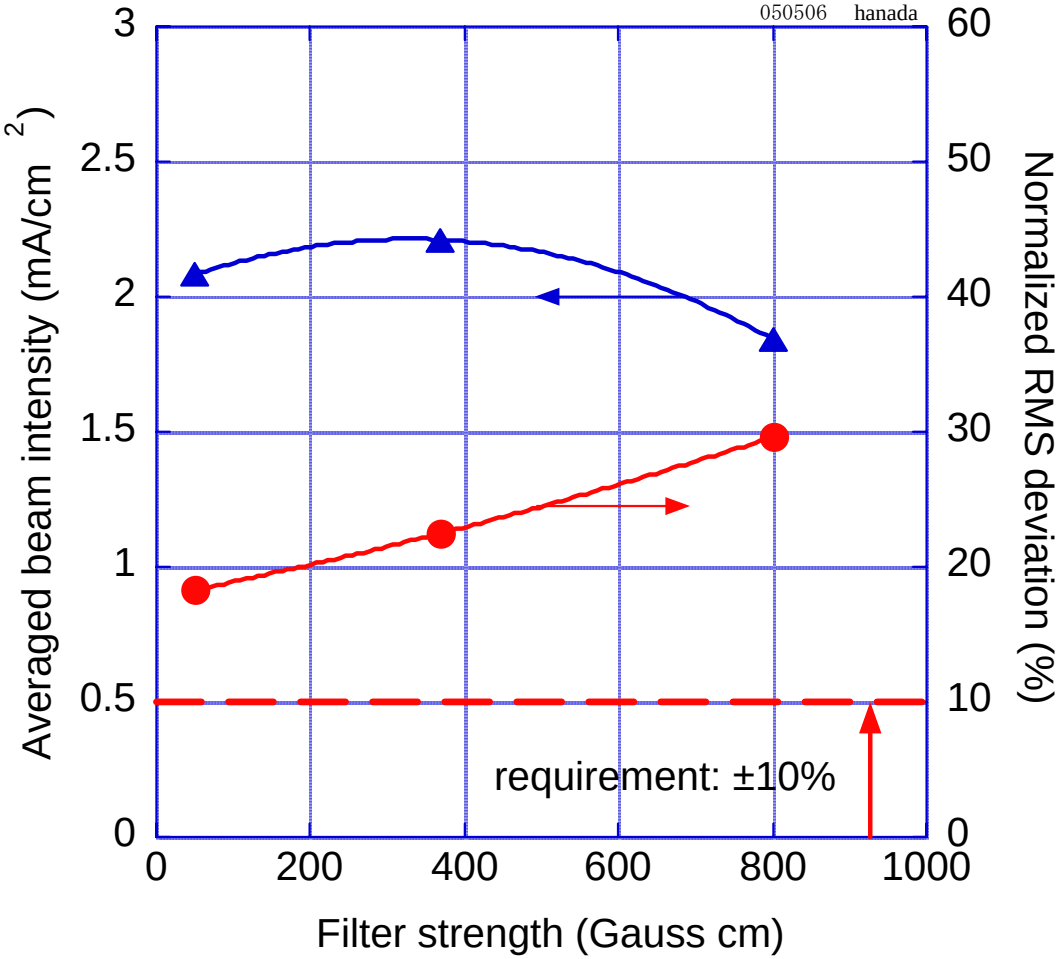
Filter strength and uniformity



By reducing the filter field, plasma parameter becomes uniform, resulting in improvement of the beam profile uniformity.

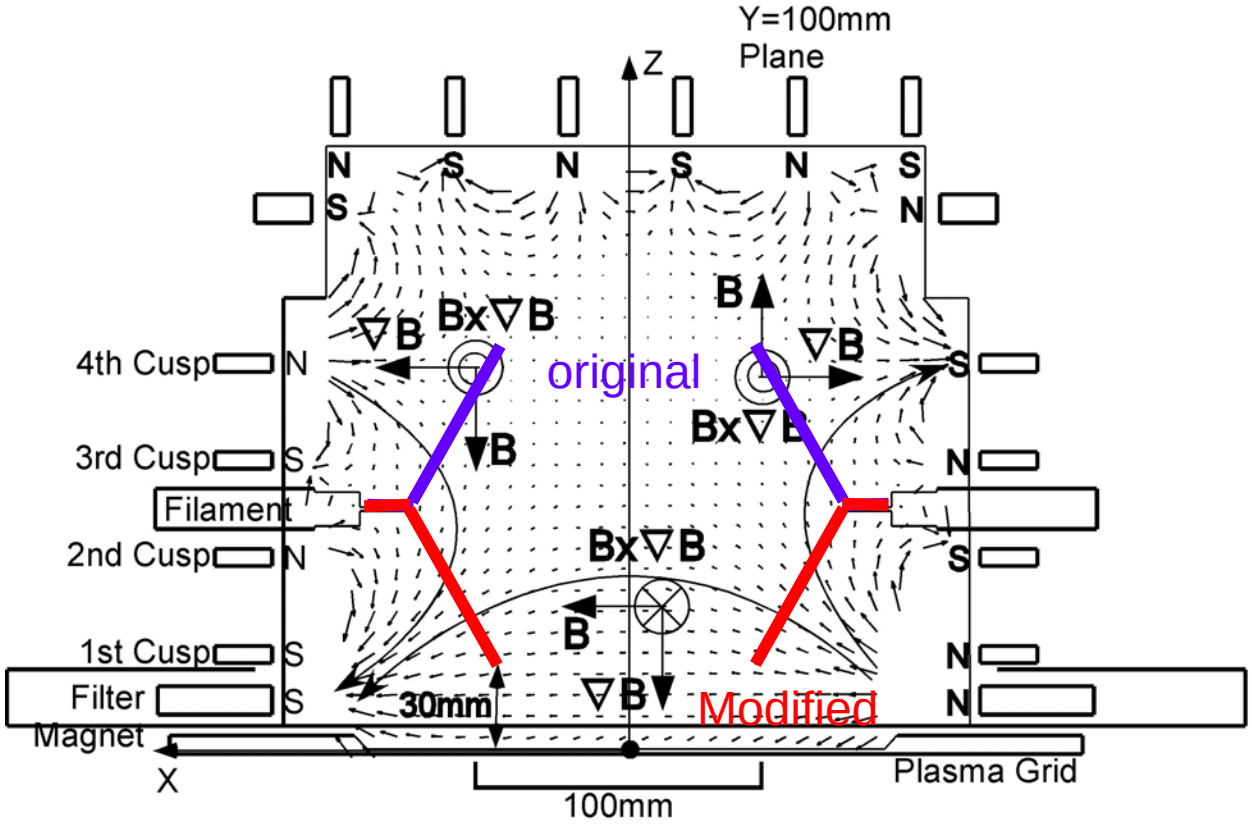
Filter strength and uniformity

Dependence on the filter strength



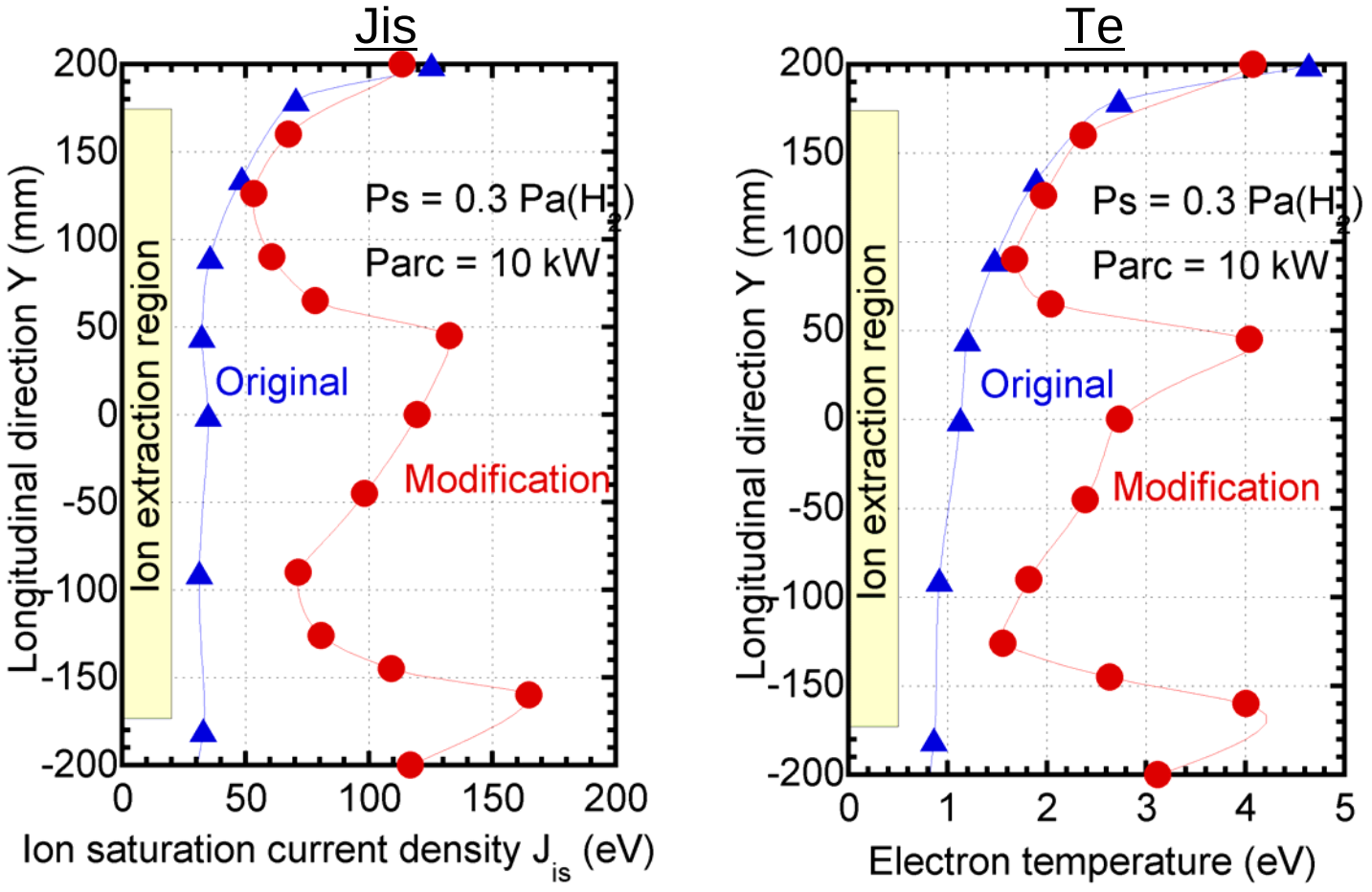
- The reduction of the filter strength is effective to improve the beam uniformity.
- Negative ion current is not sensitive to the filter strength.
- Electron current increases rapidly as the filter is weakened even in Cs seeded conditions.

Modification of filament position



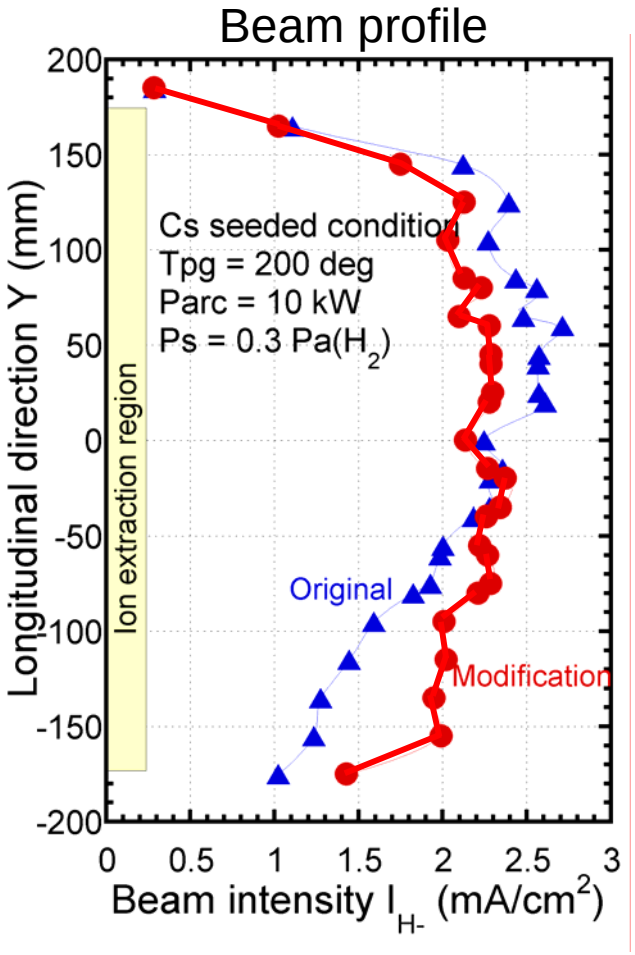
The filament was bent toward the plasma grid.

Plasma profiles after the modification



The plasma profile was dramatically varied by the filament modification.
High Te and high ne near the filaments, at 14 mm from the PG.

Beam profile after the filament modification



The beam profile was dramatically improved. The deviation of the beam intensity was reduced to ~10% of the averaged value, and a half of that before the filament modification.

Discussion

- The H^- ion profile in pure volume and Cesiated conditions are different. It should be noted that H^- intensity is higher even from Te > 1 eV in cesiated case.
- This may suggest that in Cs seeded surface production,
  - H^- ions produced on surface is extracted directly, independent of reactions such as destruction by electron detachment in plasma,
  - Negative ion surface production seems strongly enhanced by plasma, probably H^0 and H^+ densities.
- Less filter field and filaments located close to the PG is effective to achieve uniform H^- ion profile, probably by less B x ∇B drift and uniform H^0 and H^+ production near PG .
- However, these modifications increase co-extracted electron current by a factor of ~10. New issue could arise for the electron suppression.