

# Modification of an H<sup>-</sup> Ion Source for the Extraction of Negative and Positive Ions

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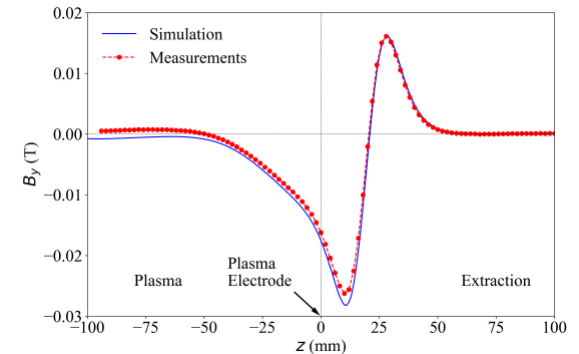
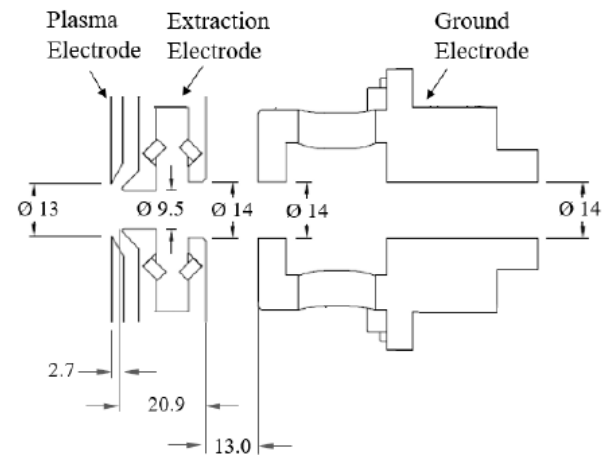
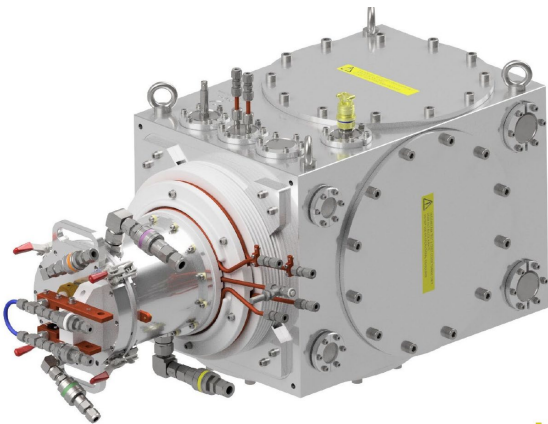
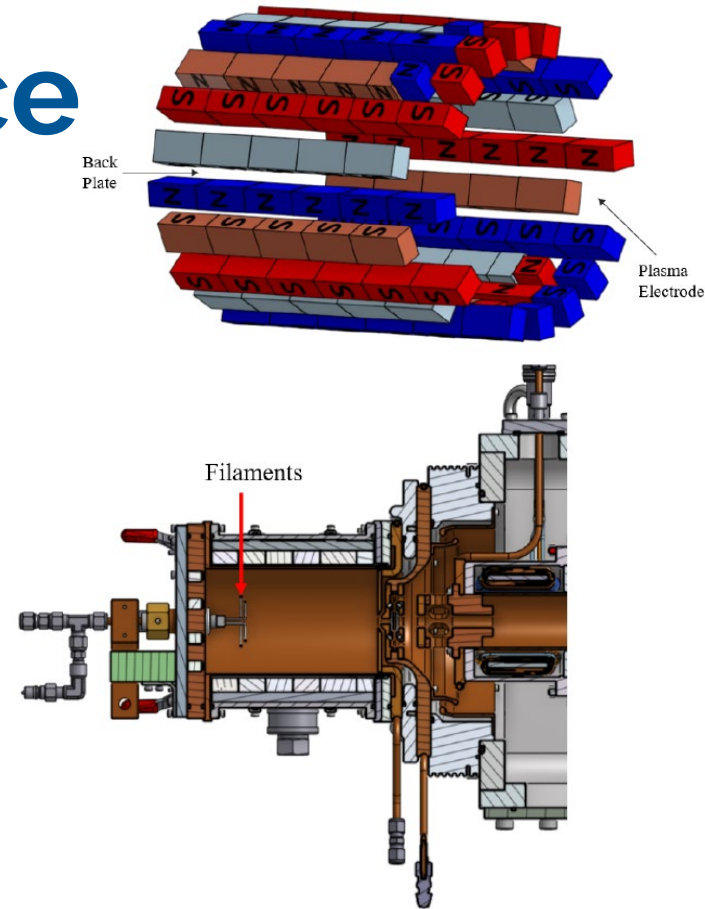
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# Need for +/- Ion Sources

- Cyclotrons
  - Extraction of  $\text{H}^-/\text{D}^-$  and  $\text{He}^+$  and  $\text{He}^{2+}$
- Tandem Accelerators
  - Many use charge exchange ion sources
  - Low yield and increase divergence
  - Solution: i. Use +/- ion source to extract  $\text{H}^-/\text{D}^-$  without no gas in charge exchange
  - ii. Use +/- ion source to  $\text{He}^+$  and use charge exchange to get  $\text{He}^-$
- Scientific interest: -How will the modifications to the ion source affect the  $\text{H}^-$  ?
  - Can we extract  $\text{He}^{2+}$  with this ion source?

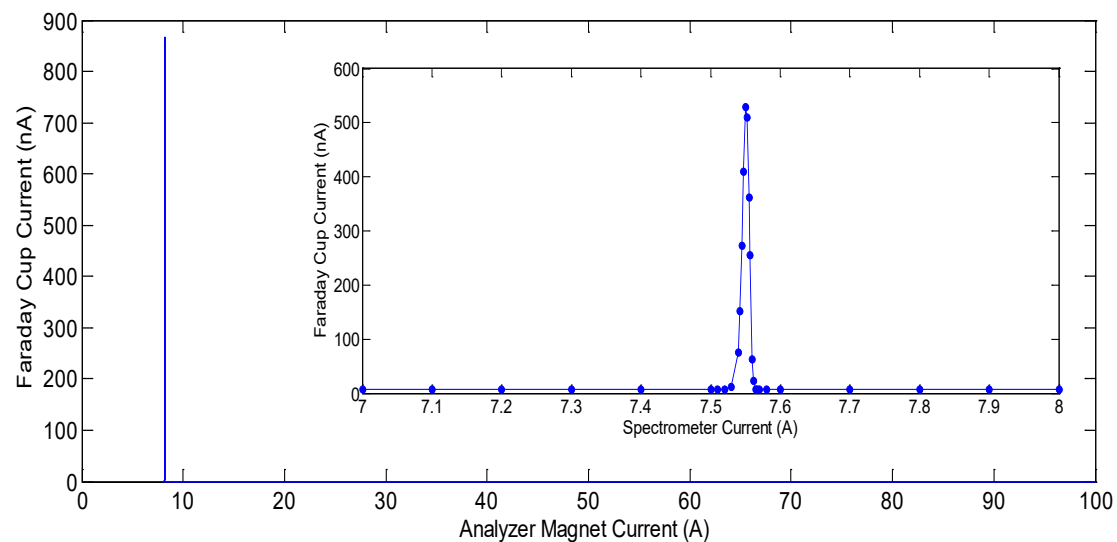
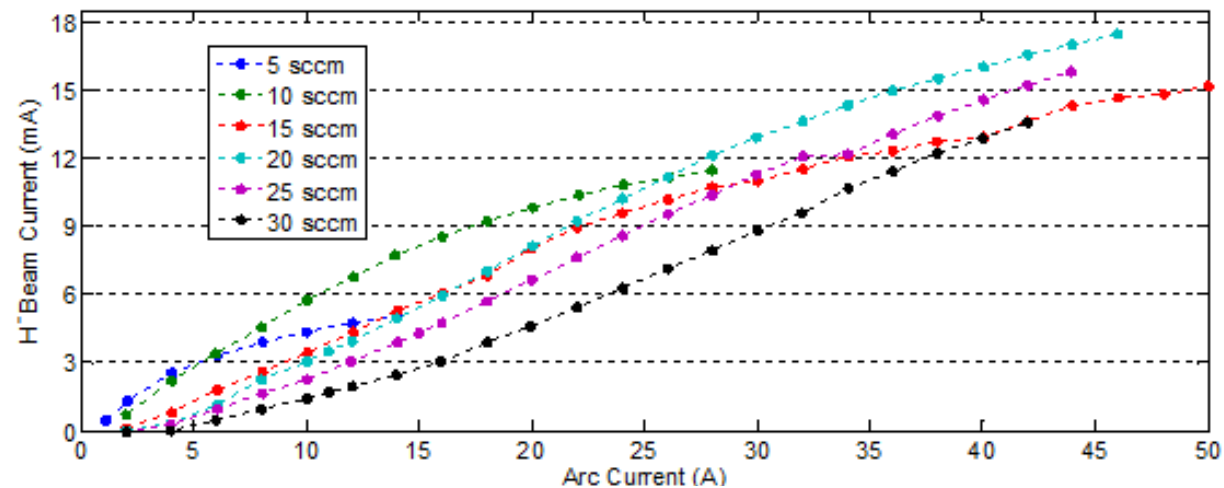
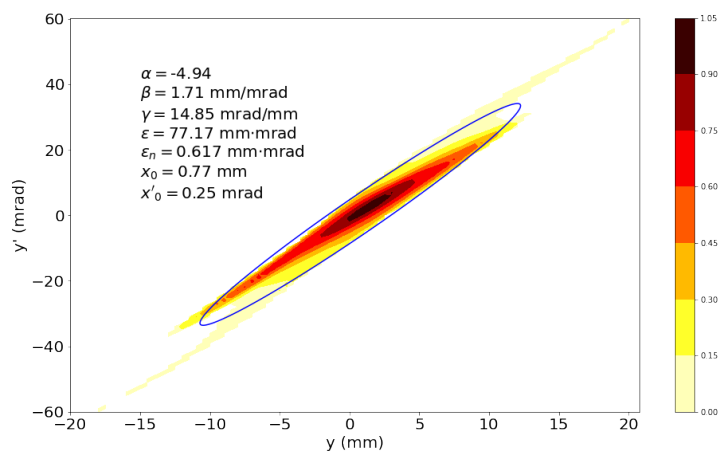
# Volume-Cusp H<sup>-</sup>/D<sup>-</sup> Ion Source

- Licensed from TRIUMF
- Tantalum filaments
- Relies on volume production: i.e. no Cesium
- 2-step process requiring “hot” and “cold” electrons
- Plasma chamber is divided by magnetic filter
- How will H<sup>-</sup> magnetic dipole filter affect extraction of positive ions?



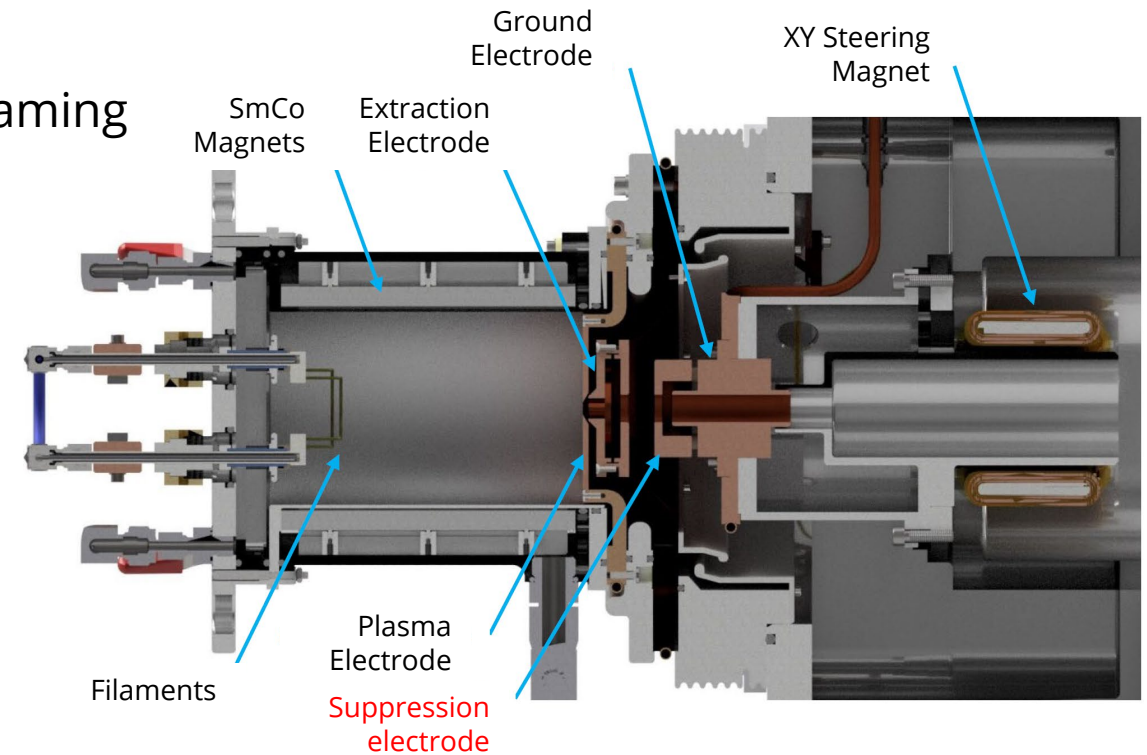
# Volume-Cusp H<sup>-</sup>/D<sup>-</sup> Ion Source

- Can get 15 mA of H<sup>-</sup> and 5 mA of D<sup>-</sup>
- No impurities
- Normalized 4RMS emittance of less than 1 mm·mrad
- 13 mm aperture



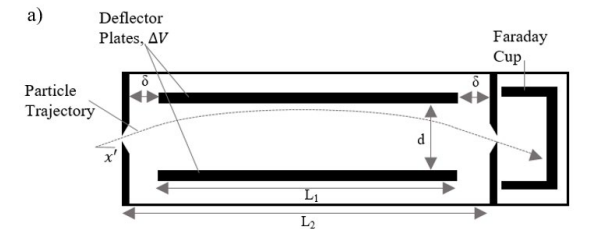
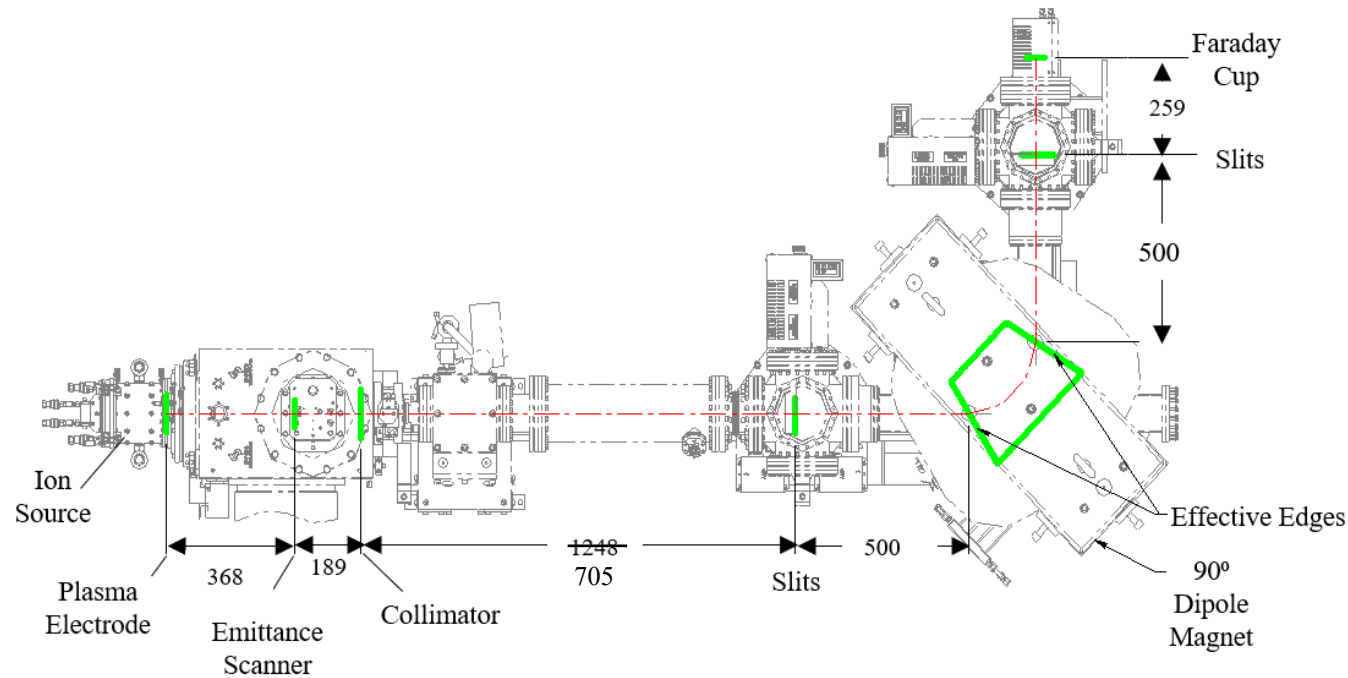
# Extraction of Positive Ions

- Tried reversing polarity of electrodes:
  - Frequent sparking
  - Charging up of extraction electrode due to back streaming electrons
- Added suppression electrode
- Biased at -2 kV (relative to GND)
- Spacing increase to achieve same electric field
- XY Steering magnet moved
- Plasma Electrode aperture reduced to 6 mm



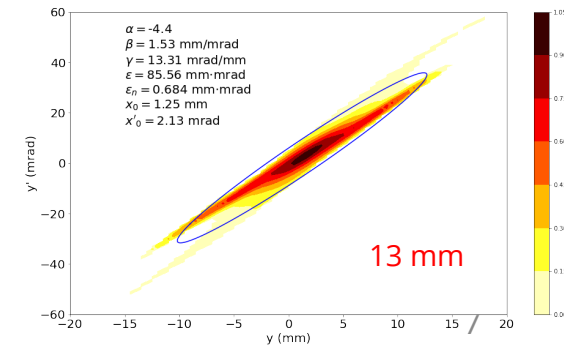
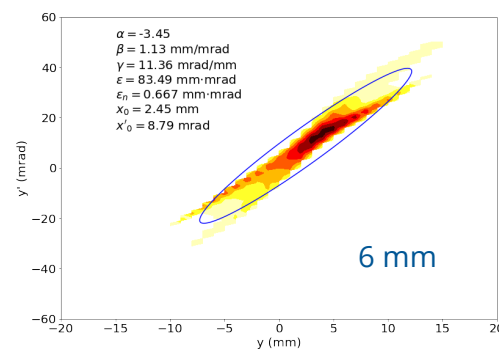
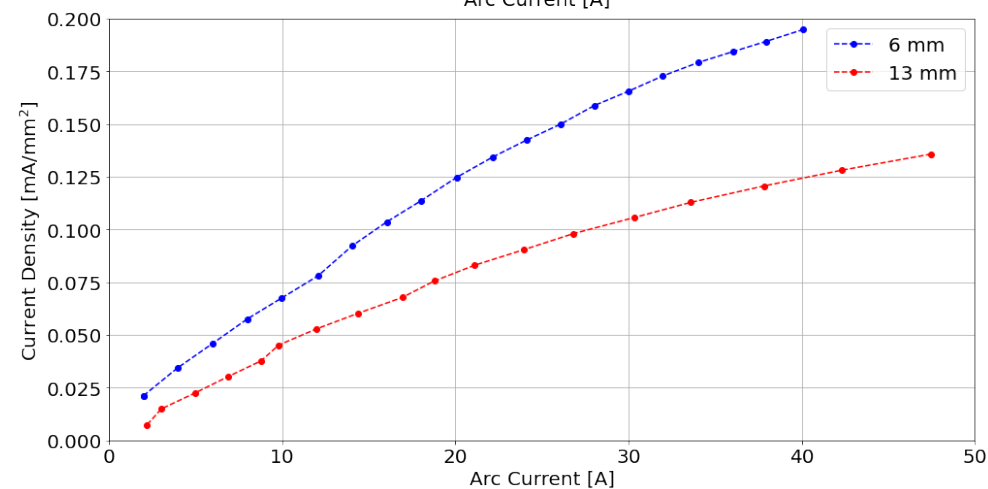
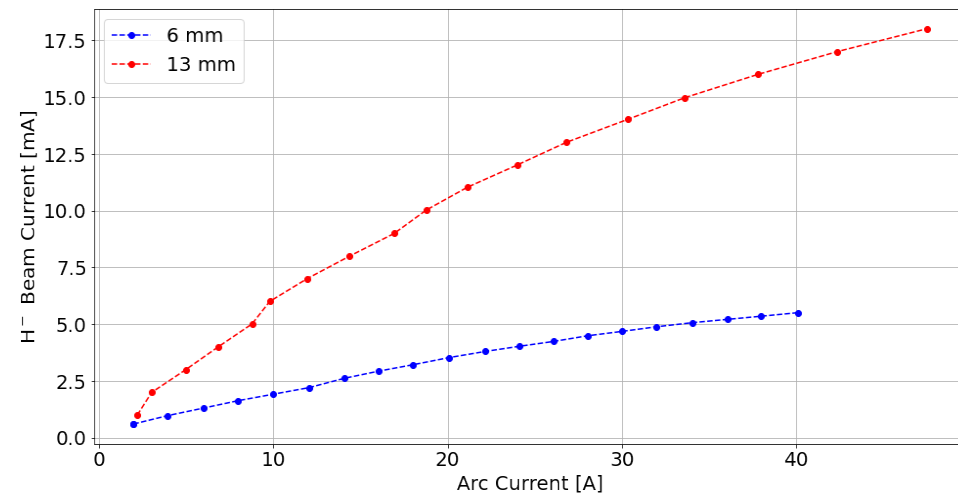
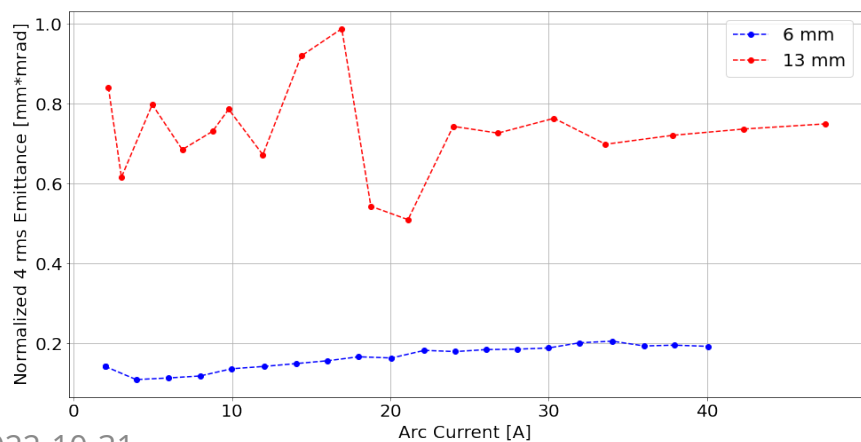
# Test Stand

- Emittance scanner scanning in y plane, 368 mm from plasma electrode
- F-Cup at 557 mm from plasma electrode
- 90 degree spectrometer system



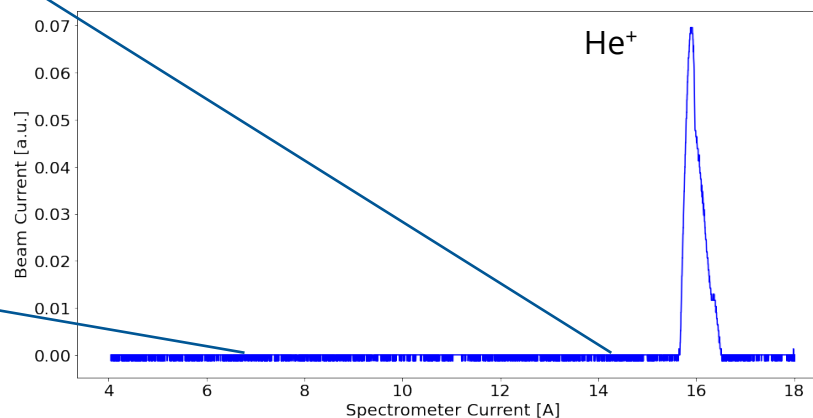
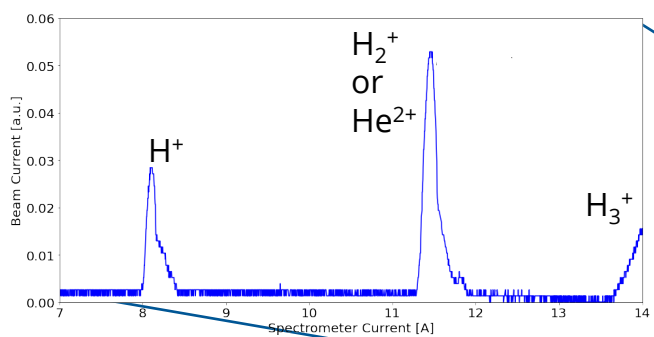
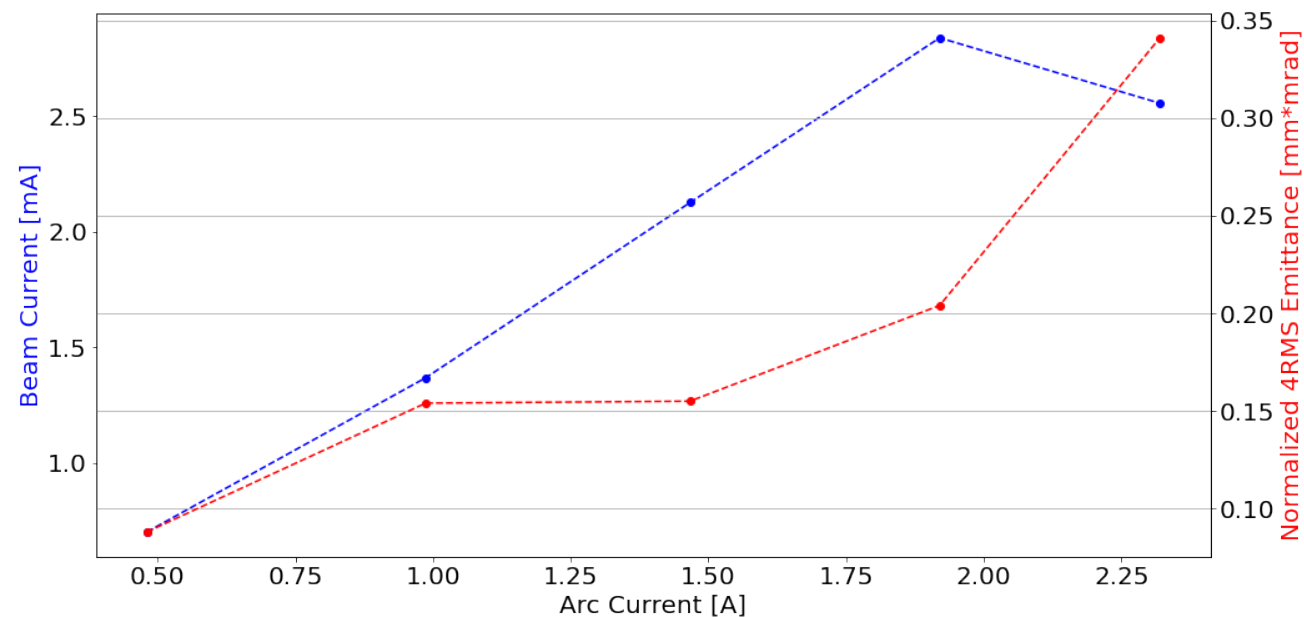
# H<sup>-</sup> Extraction Results

- Added electrode is not detrimental to H<sup>-</sup>
- As expected, lower beam current w/ smaller aperture
- But, higher current density
- Emittance considerably lower



# Positive He Extraction

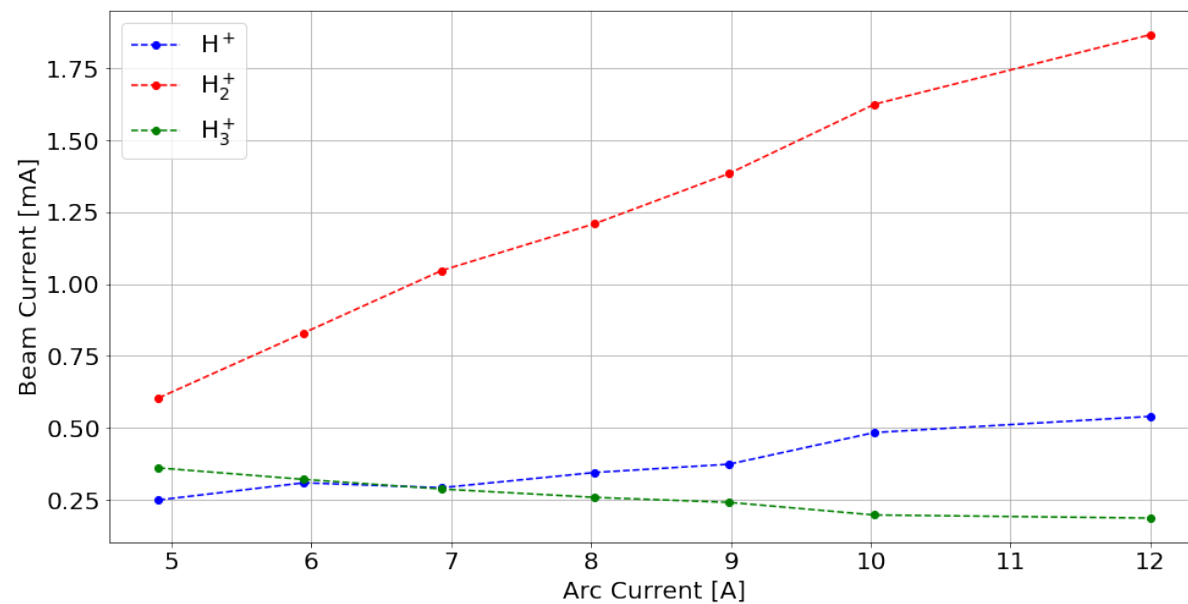
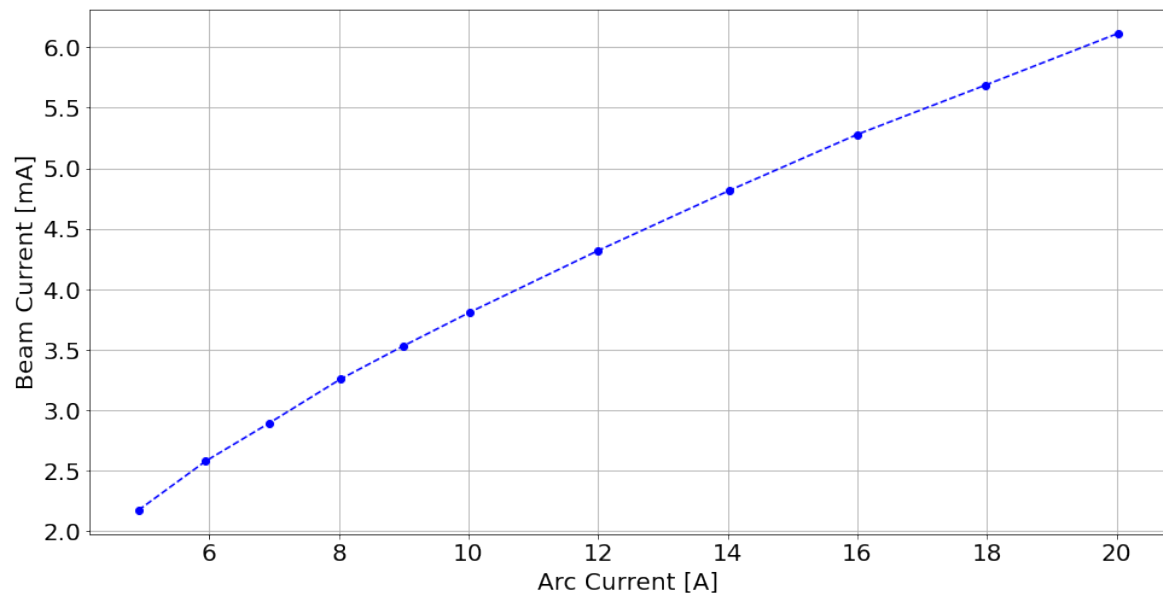
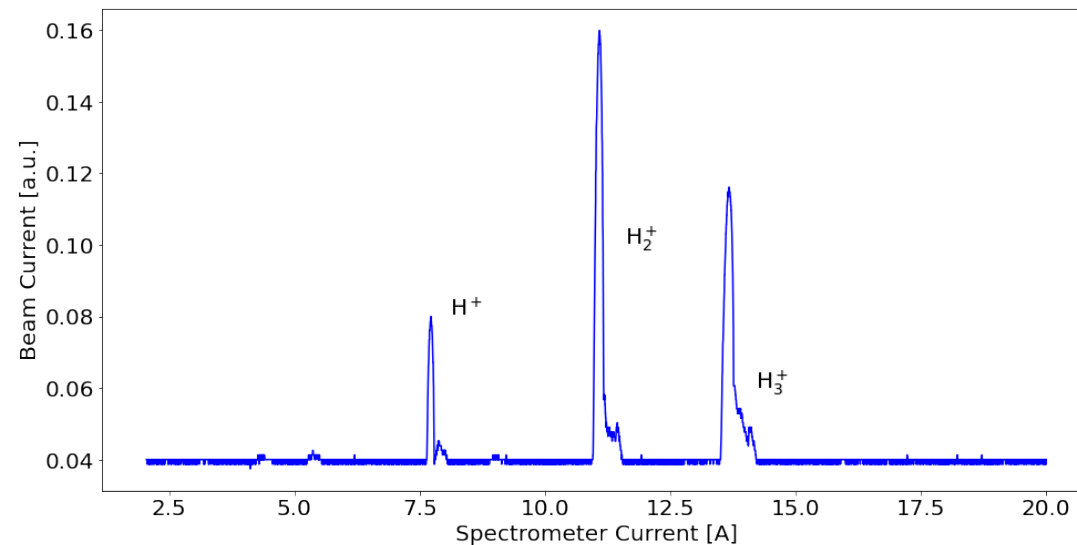
- ~2.5 mA of He<sup>+</sup> extracted
- Normalized 4RMS emittance <0.35 mm·mrad
- Became unstable above 2 A of arc current
- Small peak at He<sup>2+</sup> but also peaks at H<sup>+</sup> and H<sub>3</sub><sup>+</sup>





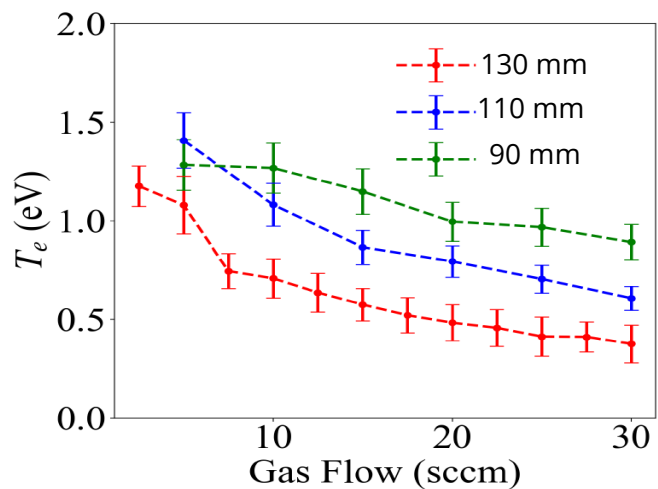
# Positive H Extraction

- Up to 6 mA of total current extracted.
- $H^+$ ,  $H_2^+$  and  $H_3^+$  are present
- $H_2^+$  increases with arc current
- No  $He^{2+}$  seen with He...



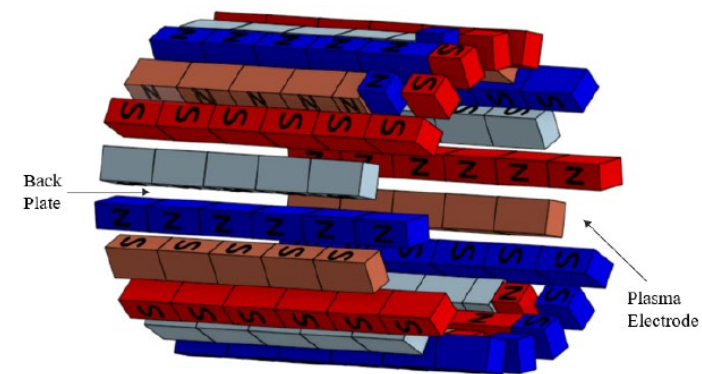
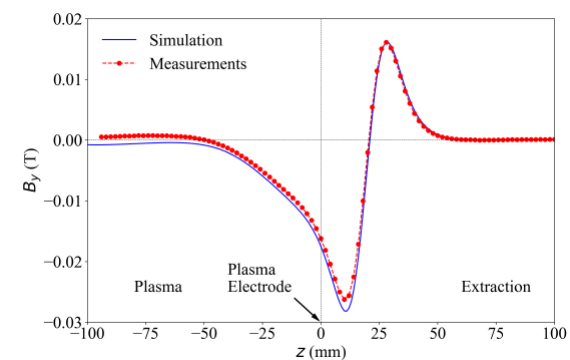
# Magnetic Filter Removal

- Higher electron energy is needed for alphas (54.4 eV)
- Filter in plasma chamber reduces electron temperature and density at extraction



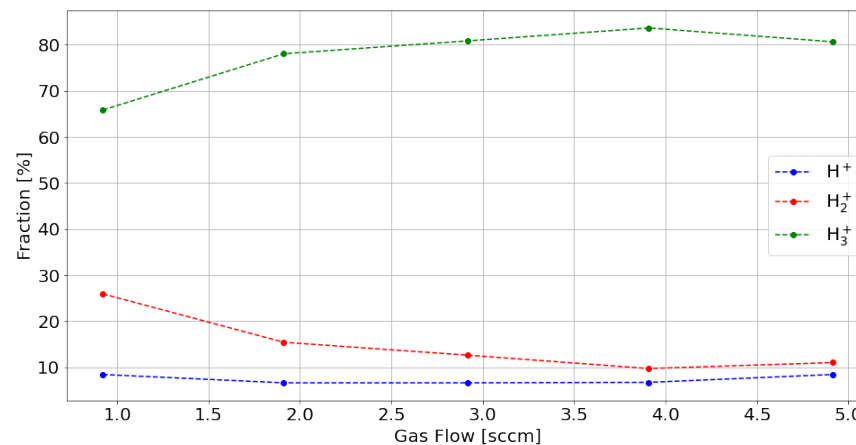
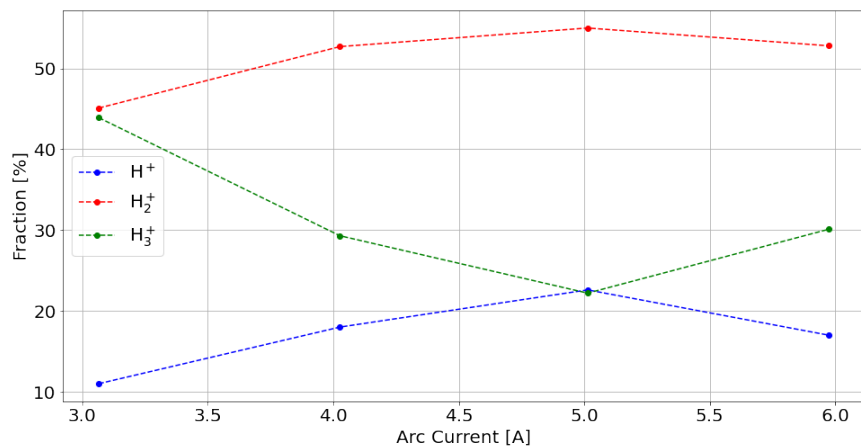
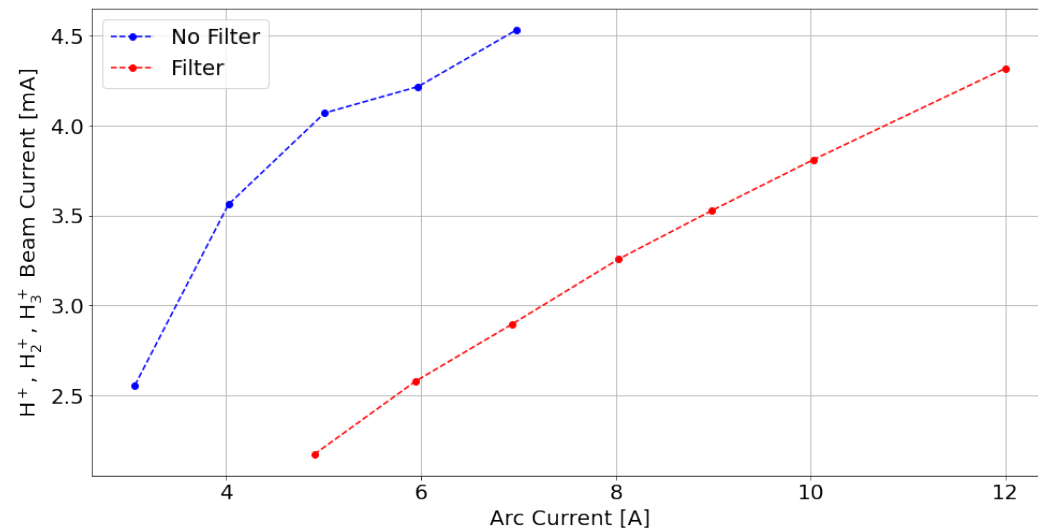
PE at 150 mm

- Filter removed, straight cusp throughout



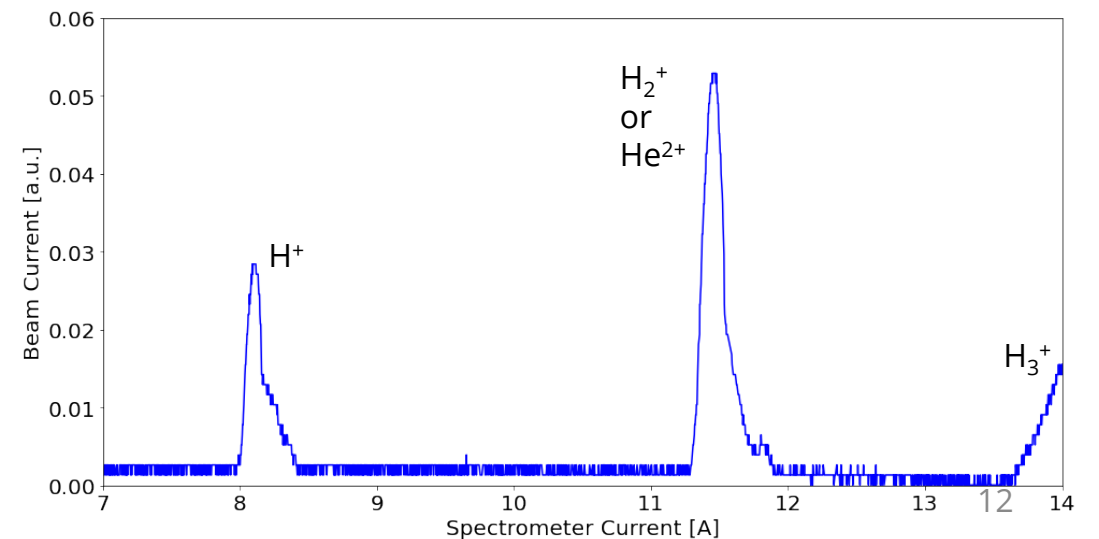
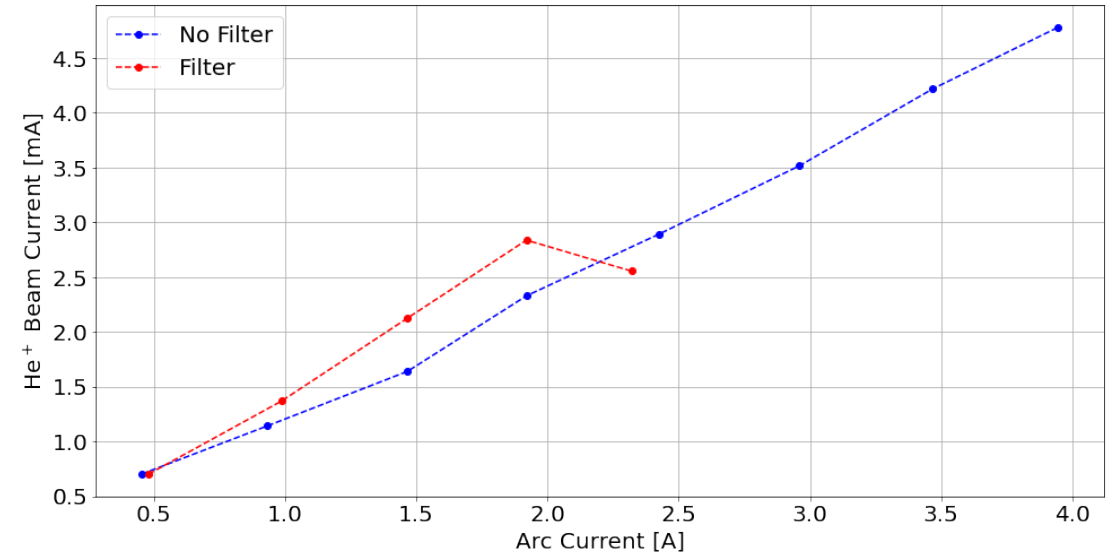
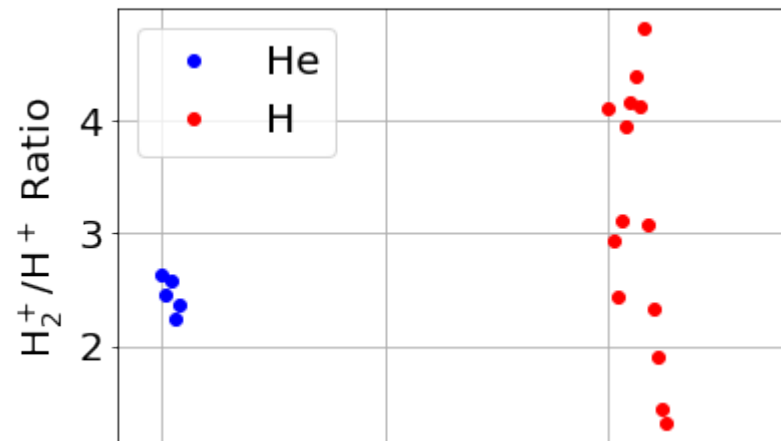
# H<sup>+</sup>, H<sub>2</sub><sup>+</sup>, H<sub>3</sub><sup>+</sup> Extraction – No Filter

- Higher total beam currents
- Higher H<sub>2</sub><sup>+</sup> current
- Higher T<sub>e</sub> leads to more H<sub>2</sub><sup>+</sup> at the extraction
- H<sub>2</sub> + e → H<sub>2</sub><sup>+</sup> + 2e
- Formation of H<sup>+</sup> needs atomic H in the plasma
- H has a high sticking factor in a Ta coated chamber



# He Extraction – No Filter

- Similar beam current
- Less beam instabilities at higher powers
- $H_2^+/H^+$  ratio constant across arc power and pressure
- Ratio lower than with H
- No evidence of  $He^{2+}$

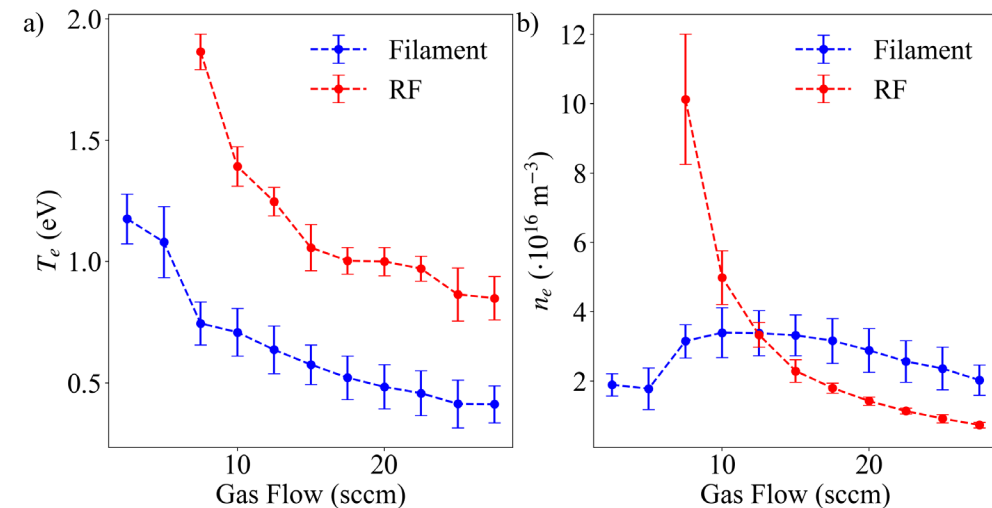
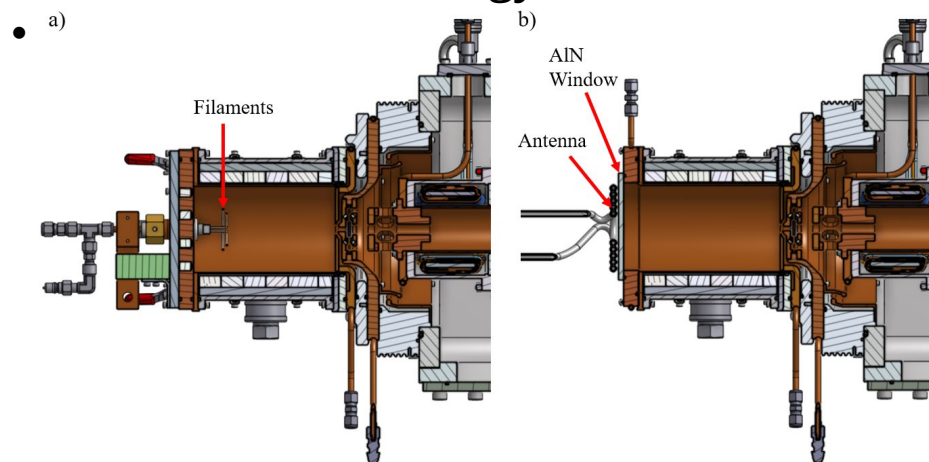


# Discussion

- Achieve a positive/negative ion source
- With magnetic filter, can extract  $\sim 5$  mA of  $H^-$  and 2.5 mA of  $He^+$
- No  $He^{2+}$  detected, removal of filter magnet had no effect

## Future work

- $D^-$  measurements (limited to 5 keV due to Neutrons)
- Use of RF technology instead of filaments.



# Thank you

