The Extraction of Negative Carbon Ions from a Volume Cusp Ion Source

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2. Buckley Systems
3. University of Jyväskylä

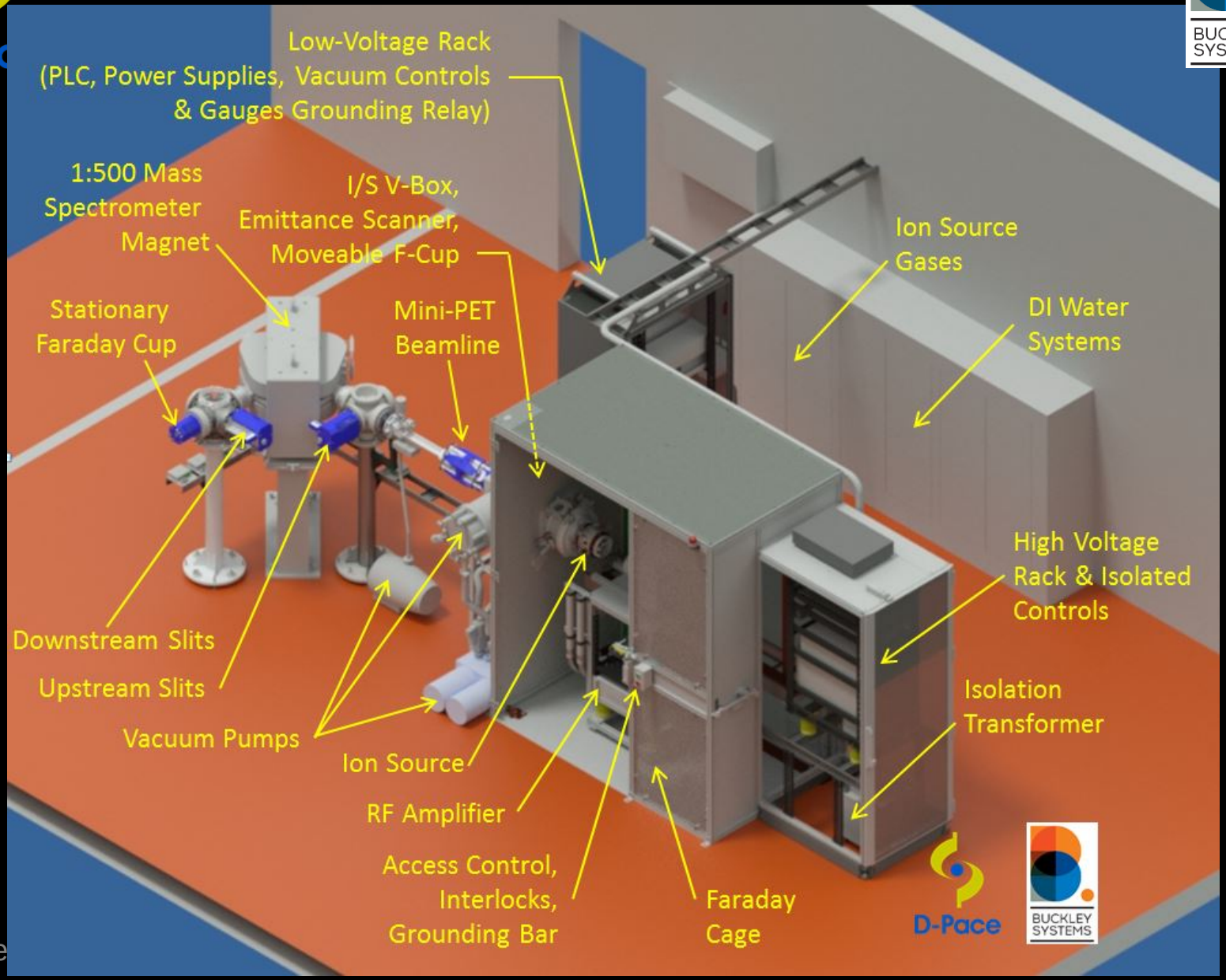
Ion Source Test Facility

Completed in March 2016.

Located at Buckley System in Auckland NZ.

Used to further develop D-Pace ion source and beam diagnostics technologies.

Ion Source Test Facility



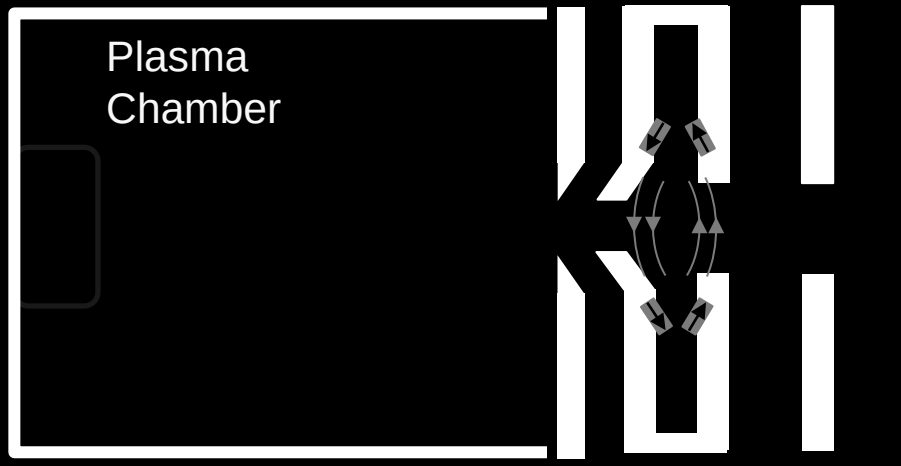
Filament-Powered Ions Source

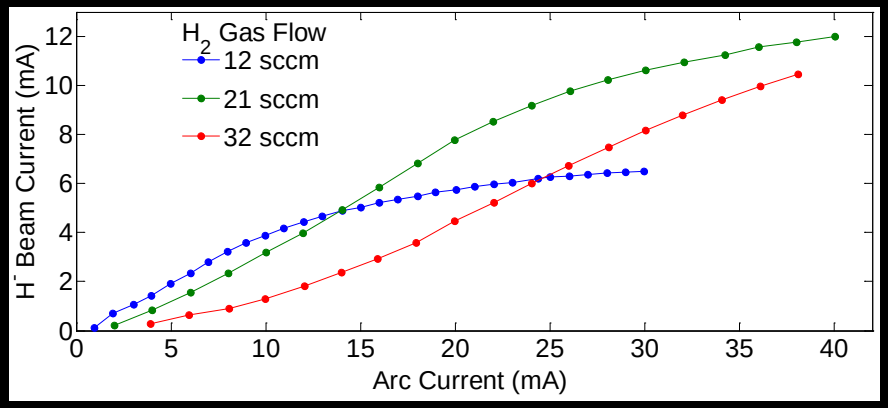
Licensed from TRIUMF.

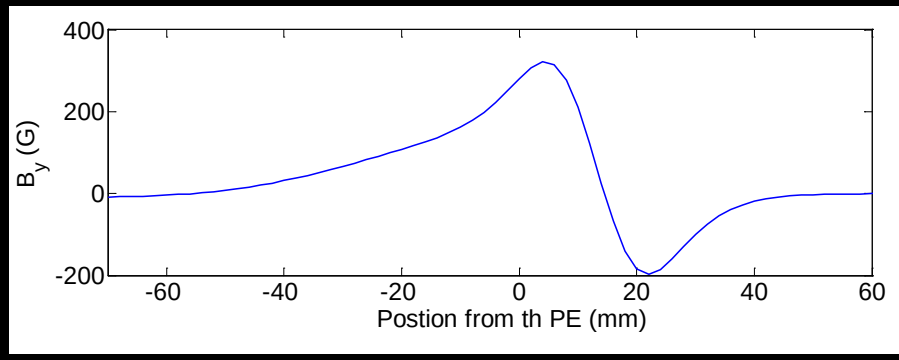
10 rows of Sm_2Co_{17} form the cusp fields.

Uses 4 Ta filaments.

Uses a 3 electrode extraction system. Electrons are dumped on the extraction lens by inversed dipole fields.







Negative Carbon Ions

Useful in ion implantation since the negative charge slightly compensate for the secondary electrons emitted from the sample.

Used in tandem accelerators.

Volume cusp ion sources don't require cesium.

Our goal is to achieve 1 mA of C^- or 0.5 mA of C_2^-.

Acetylene and carbon dioxide are being used instead of hydrogen.

Acetylene

$$H{-}C{\equiv}C{-}H$$

Dissociative Electron Attachment

$$AB + e^- \rightarrow AB^{-*} \rightarrow A^- + B$$

Dipolar Dissociation

$$AB + e^- \rightarrow AB^* + e^- \rightarrow A^- + B^+ + e^-$$

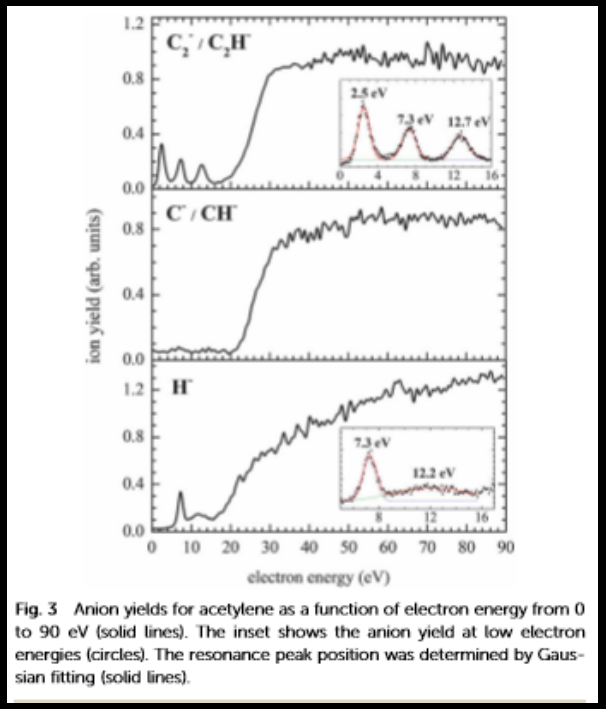
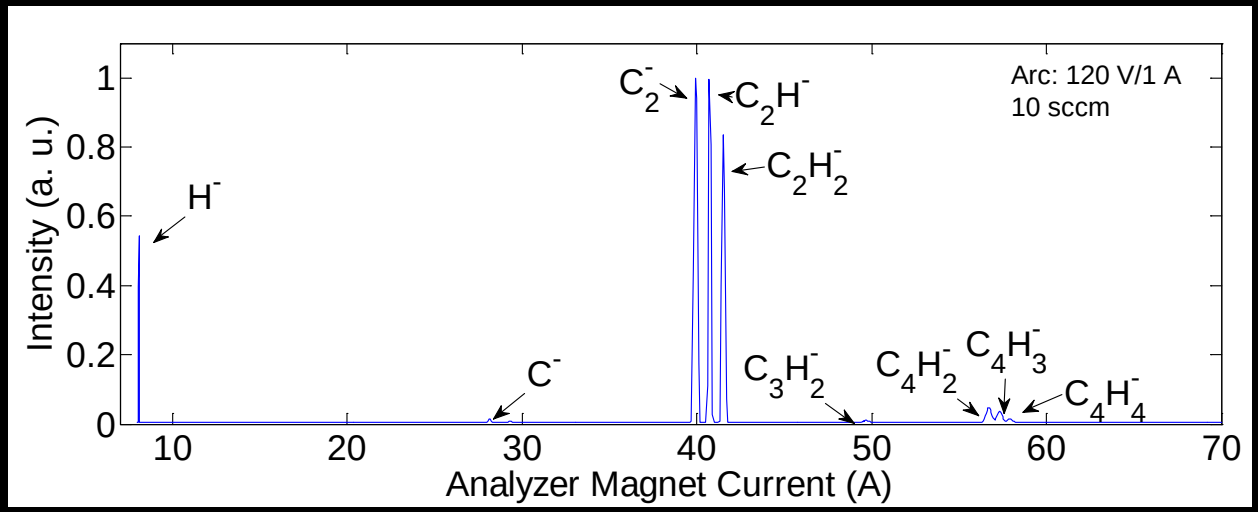


Fig. 3 Anion yields for acetylene as a function of electron energy from 0 to 90 eV (solid lines). The inset shows the anion yield at low electron energies (circles). The resonance peak position was determined by Gaussian fitting (solid lines).



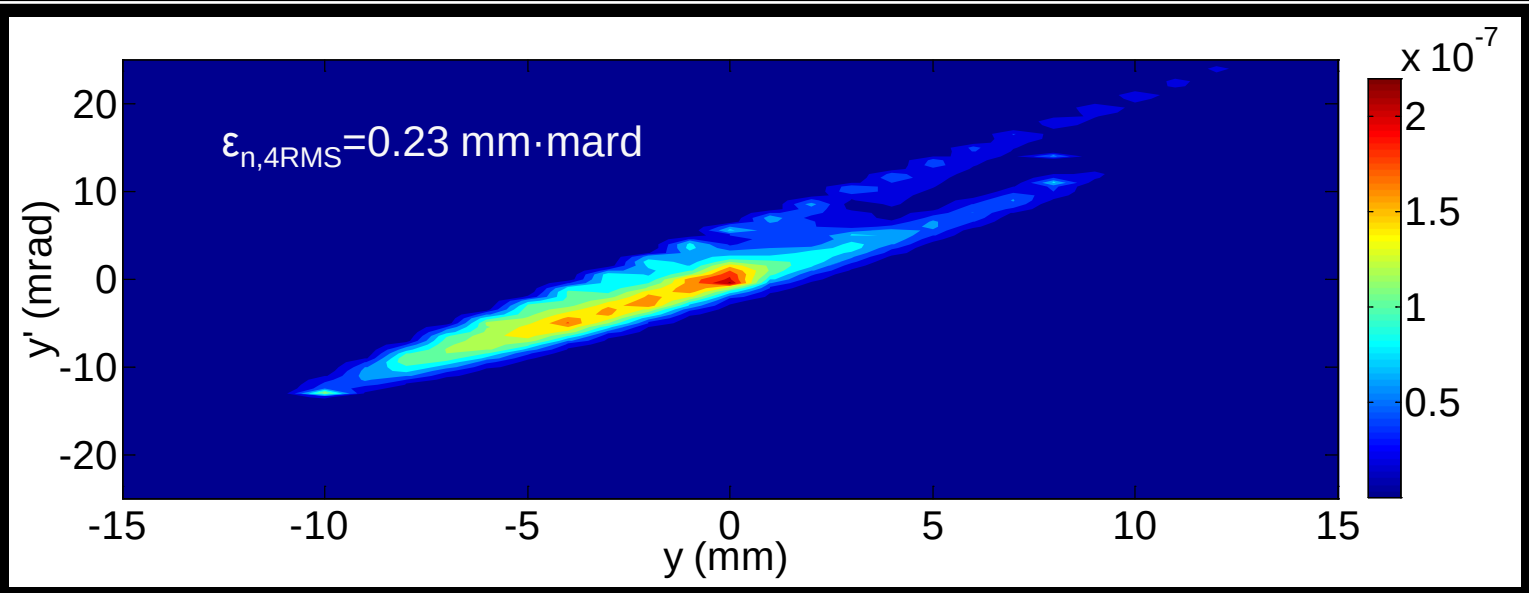
$C_2H_2^-$ from surface?
Polymerization ($C_{2n}H_{2n}$)

Szymańska, E., Čadež, I., Krishnakumar, E., & Mason, N. J. (2014). Electron impact induced anion production in acetylene. *Physical Chemistry Chemical Physics*, *16*(8), 3425-3432.

Acetylene

0.33 mA of total beam has been extracted.

Beam Current (mA)	Arc Current (A)	Arc Voltage (V)	Bias Current (mA)	Bias Voltage (kV)	Extraction Lens Current (mA)	Extraction Lens Voltage (kV)	Plasma Electrode Current (A)	Plasma Electrode Voltage (V)	Gas Flow (sccm)	Filament Current (A)	Filament Voltage (V)
0.33	3.30	120	0.70	24.97	24.48	2.88	3.00	20.0	5.00	163.4	5.11

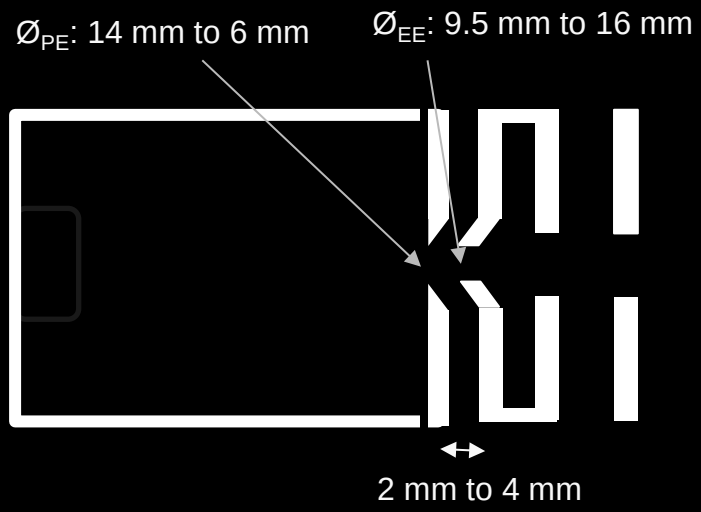


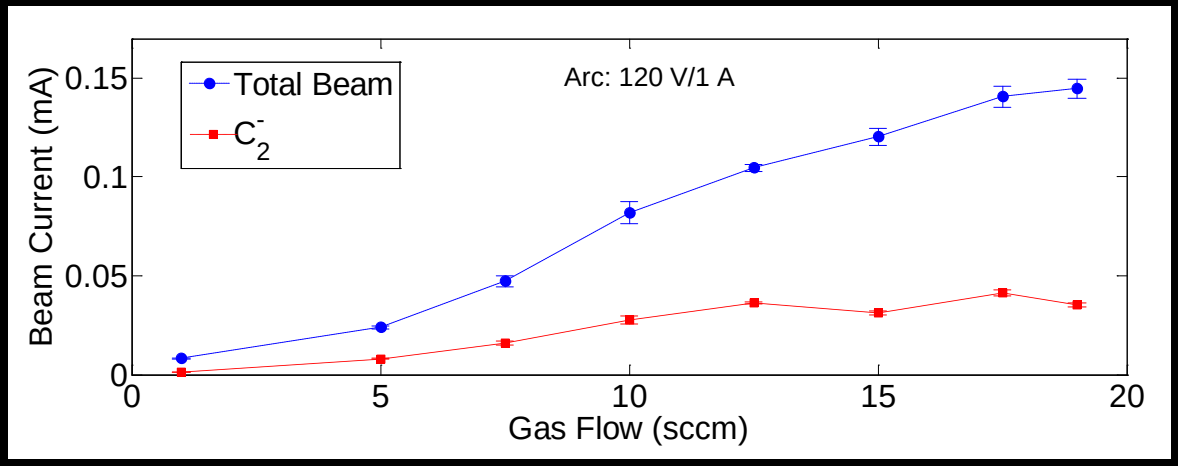
Phase space scan taken 27 cm after the ion source.

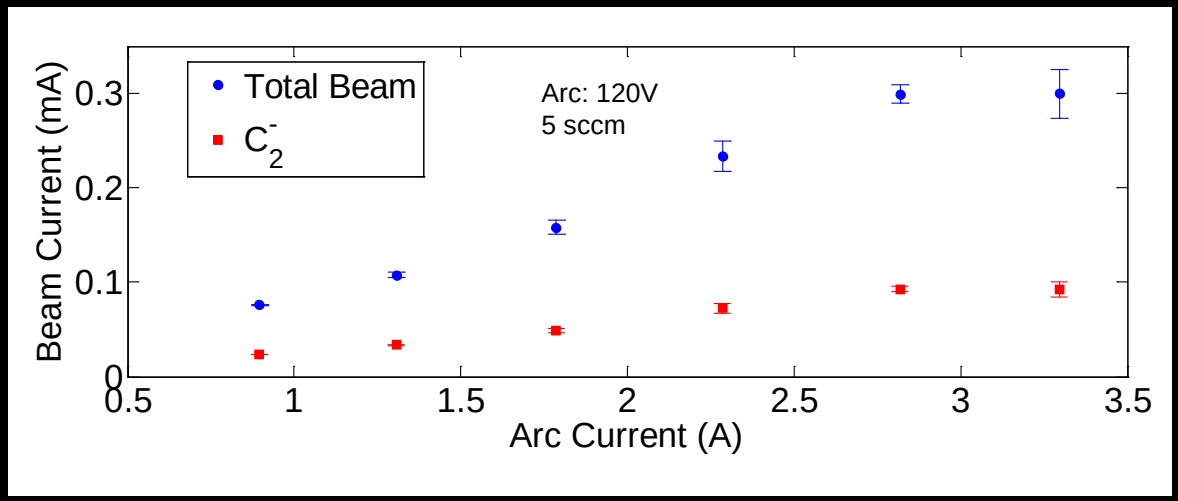
Total Beam Current

Increase in beam current with gas flow and arc current.

Difficulties with arcing.





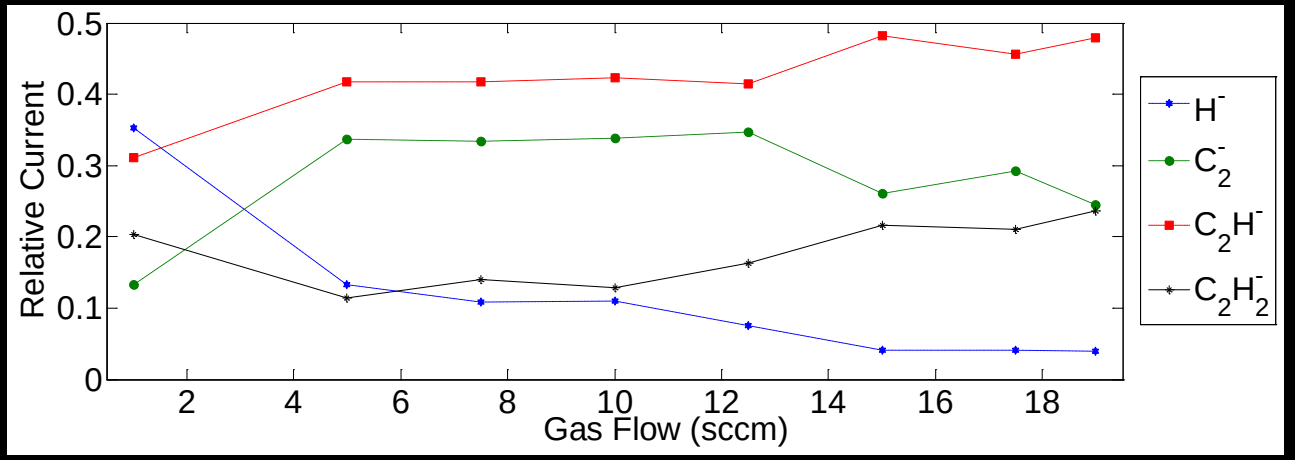


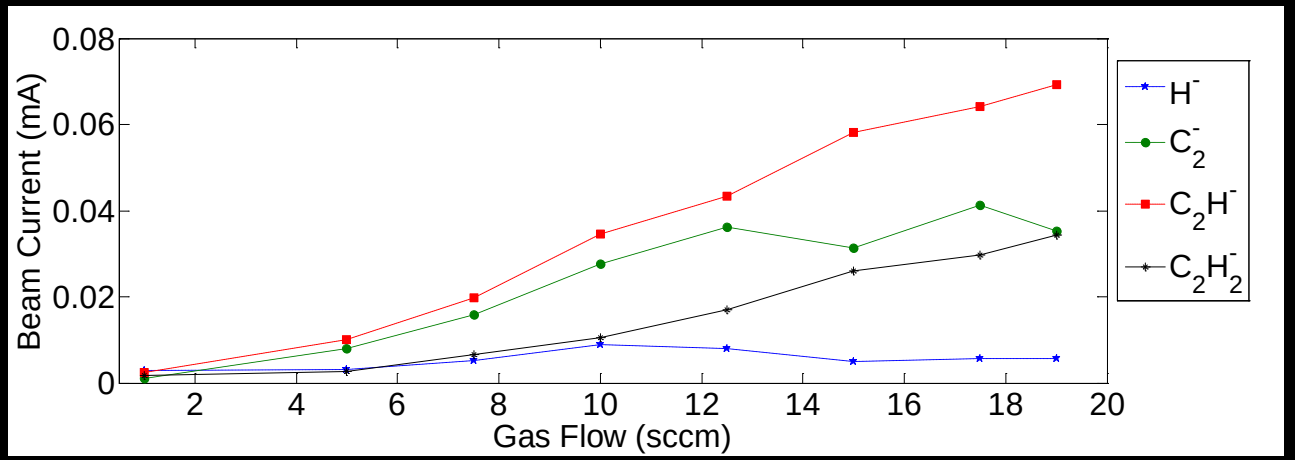
Beam Composition

Composition shows very little dependence on tuning parameters other than gas flow.

Increase in current for the heavier ions.

H^- stays relatively constant.

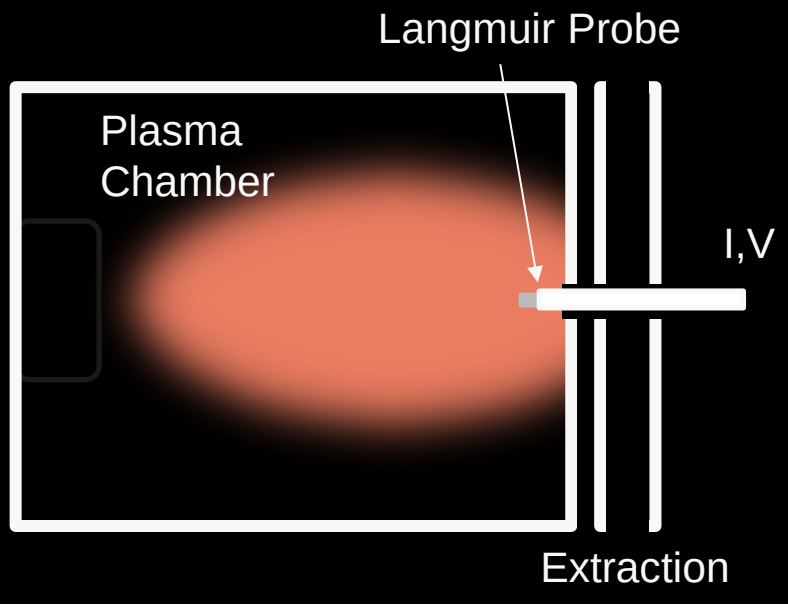




Langmuir Probe

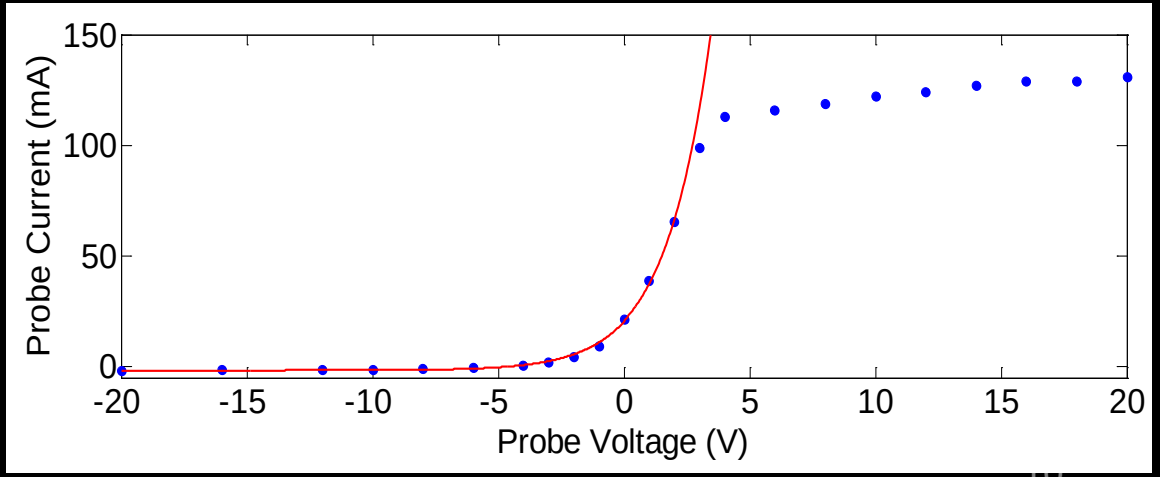
Inserted in the plasma through the extraction, 20 mm from the plasma electrode.

In the “cold” plasma region.



$$I = I_S \exp\left(\frac{e(V - V_p)}{kT_e}\right) + I_i$$

$$I_p = \frac{1}{4} n_e A \left(\frac{8kT_e}{\pi m}\right)^{1/2}$$

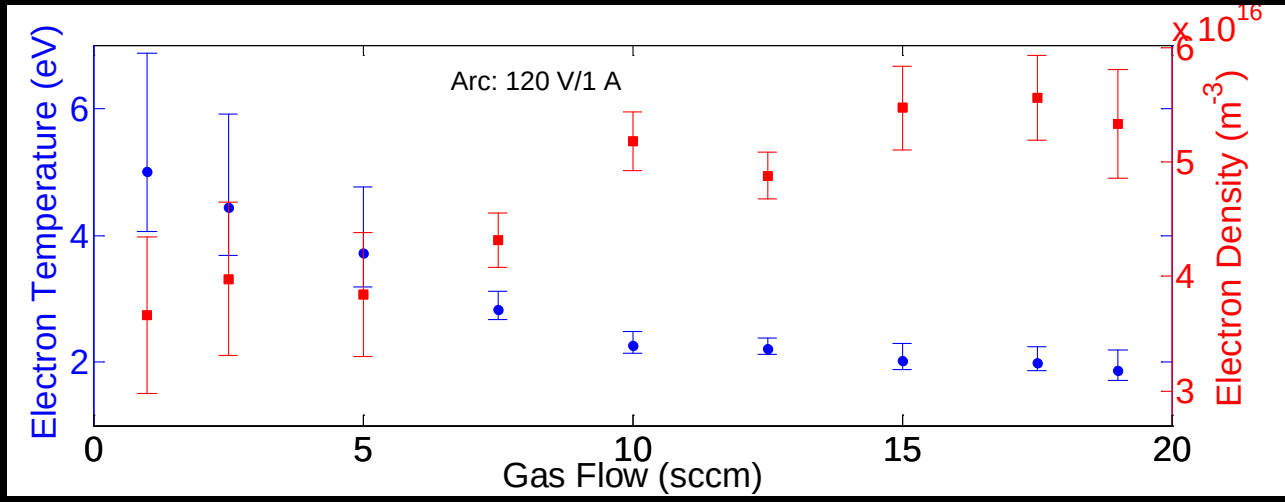


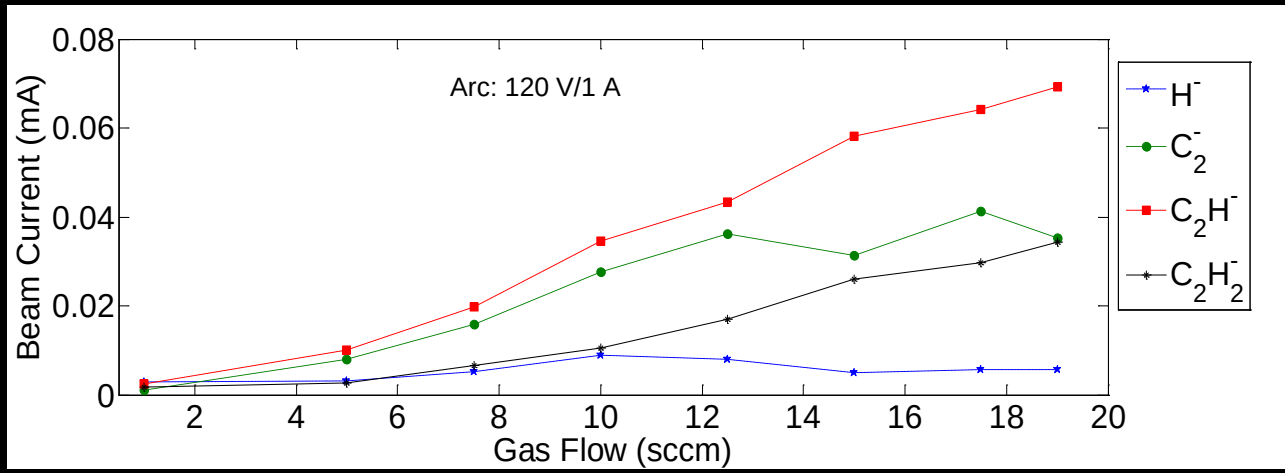
Plasma Parameters

Electron temperature flattens to about 2 eV.

Previous studies show a peak in production of $C_2H_x^-$ at 2.5 eV of electron energy.

Measurement with the probe not affecting the conductance will be completed.



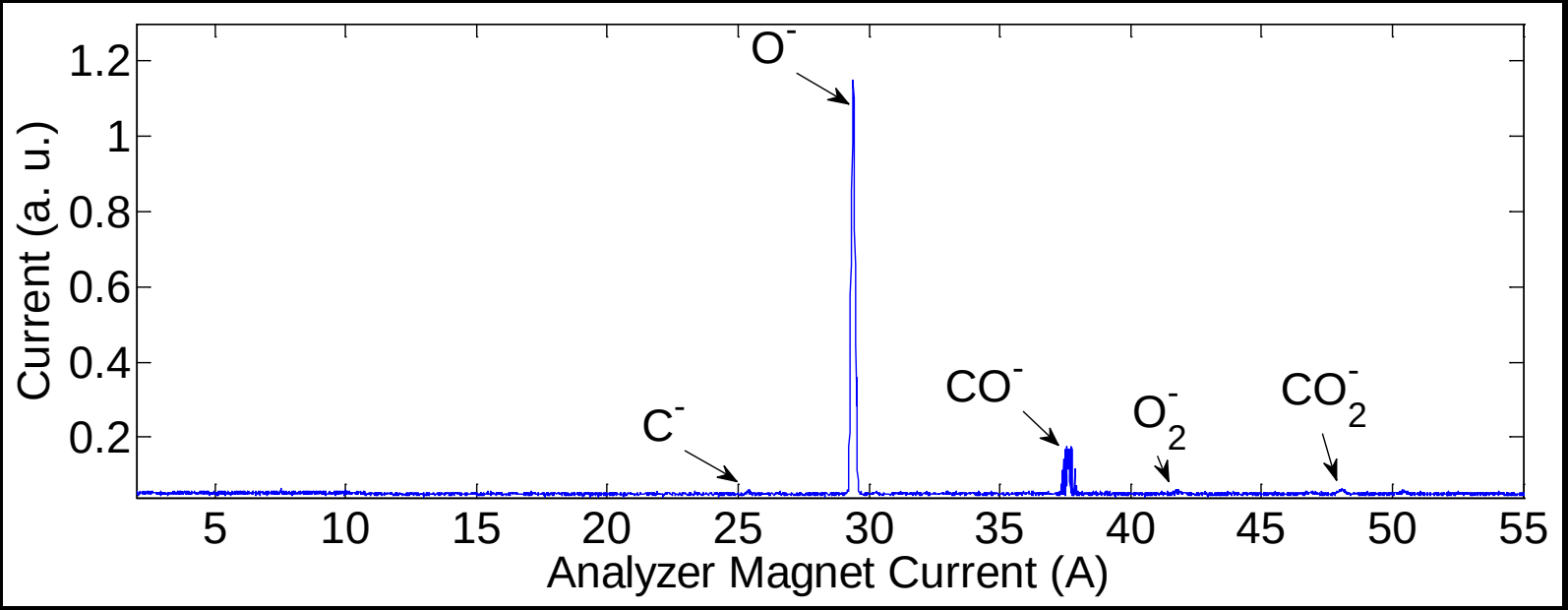


Carbon Dioxide

Very little C^- beam was extracted with CO_2.

O=C=O

Oxygen has a higher electron affinity than carbon (1.401 eV vs 1.246 eV).



Beam Current (mA)	Arc Current (A)	Arc Voltage (V)	Bias Current (mA)	Bias Voltage (kV)	Extraction Lens Current (mA)	Extraction Lens Voltage (kV)	Plasma Electrode Current (A)	Plasma Electrode Voltage (V)	Gas Flow (sccm)	Filament Current (A)	Filament Voltage (V)
0.22	8.51	120.00	2.75	24.99	143.83	3.34	6.29	20.00	2.50	153.4	4.03

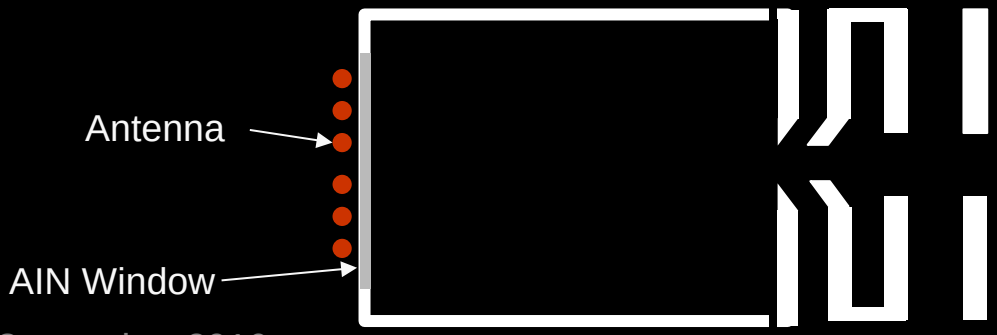
RF H^- Ion Source

Licensed from University of Jyväskylä.

We used TRIUMF source body and extraction system.

Plasma generated by an external antenna at 13.56 MHz.

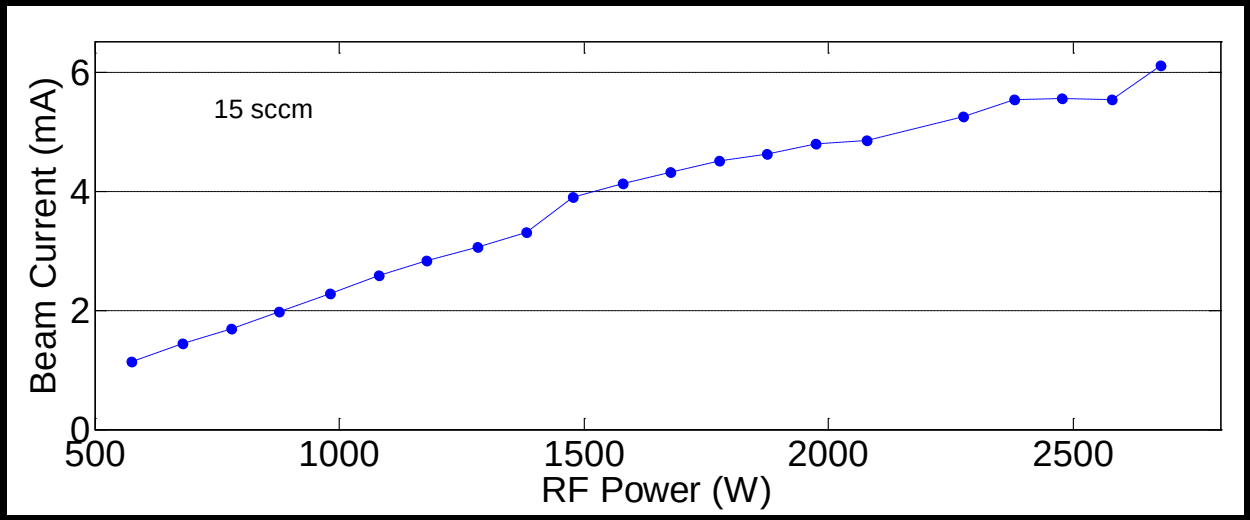
Uses an L-network impedance matching system with two variable capacitors.



RF H^- Ion Source

Thermal problems caused a crack in the RF window.

Further testing to higher powers will follow.



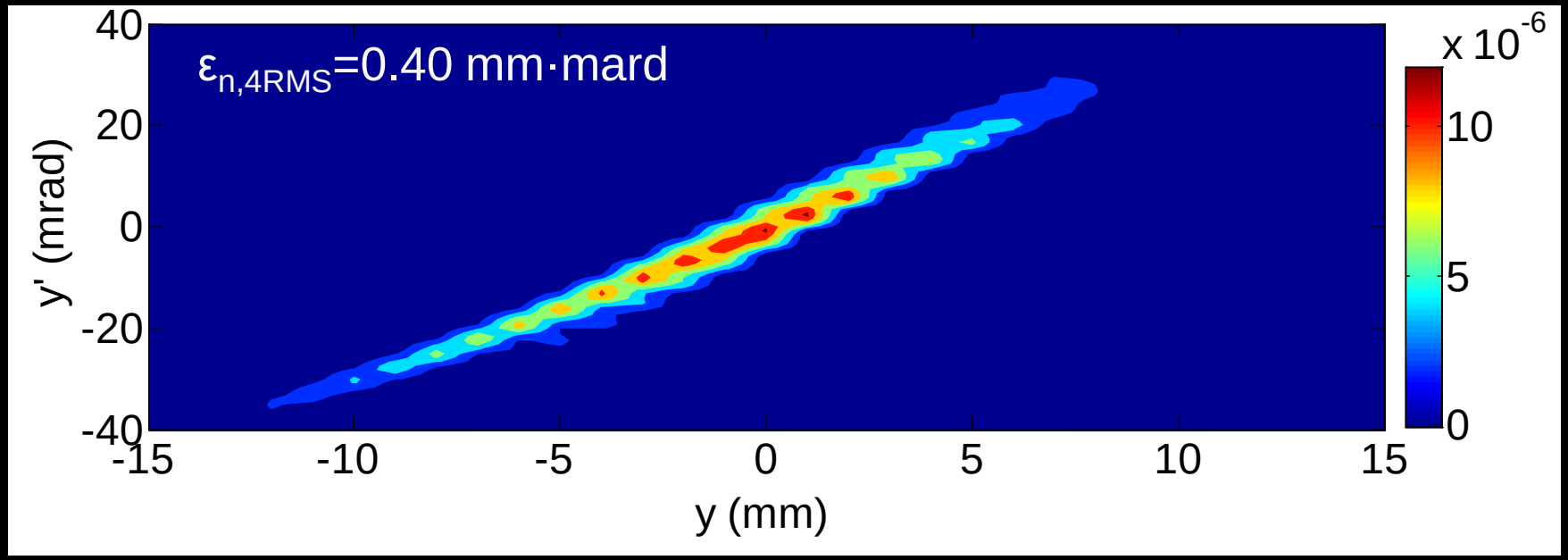
Source	j_{H^-} at 2.5 kW (mA/cm^2)
U of J RF	2.9
TRIUMF/U of J RF	3.5
TRIUMF Filament	5.4

RF H^- Ion Source

Higher co-extracted electron current.

e/H^- ratio of 6-7 vs 4-5 for filament-powered source.

Beam Current (mA)	RF Power (kW)	Bias Current (mA)	Bias Voltage (kV)	Extraction Lens Current (mA)	Extraction Lens Voltage (kV)	Plasma Electrode Current (A)	Plasma Electrode Voltage (V)	Gas Flow (sccm)
6.11	2.68	11.20	30.00	43.52	2.79	2.78	24.75	15.00



Summary

D-Pace now has their own test stand.

C_2^- beam is produced with acetylene in a filament-powered volume-cusp ion source.

Higher beam currents should be expected when the arcing issues are resolved.

Beam composition seems highly dependent on electron temperature.

Carbon dioxide produces very little carbon beam.

RF ion source with the filament ion source body and extraction system has produced more than 6 mA of H^- beam.

Further testing of negative carbon ion production with RF ion source.