Project X H^- Ion Source Acceptance Test and Future Plan

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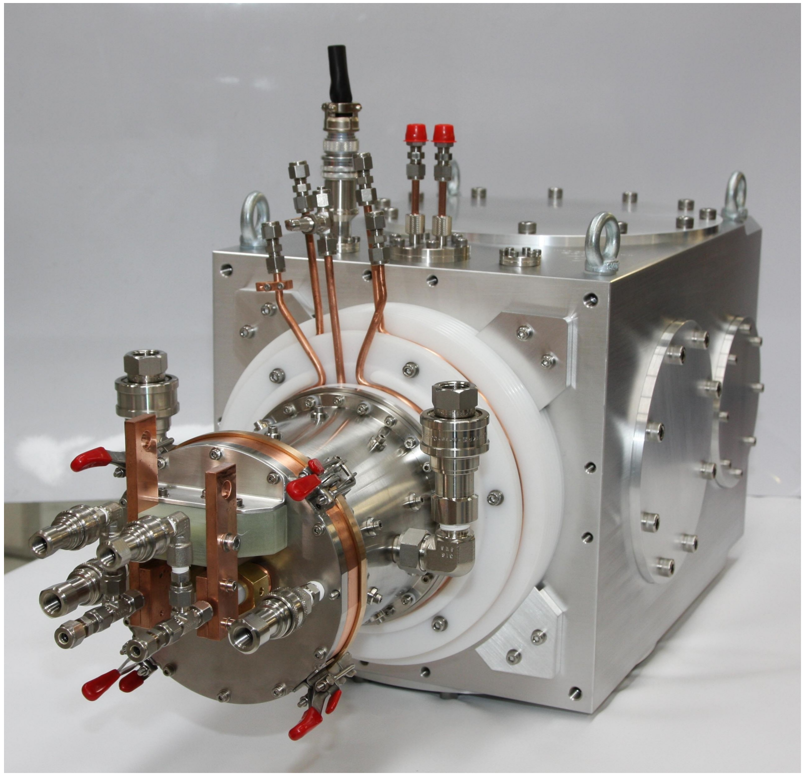
May 19, 2011

Project X Ion Source



- D-Pace Filament driven H^- source
  - cw operation, up to 15 mA
  - No Cs
- Plans for acceptance test
  - Verify beam current
  - Emittance measurement
  - Beam stability
  - e/H^- ratio

H^- Ion Source Acceptance Test

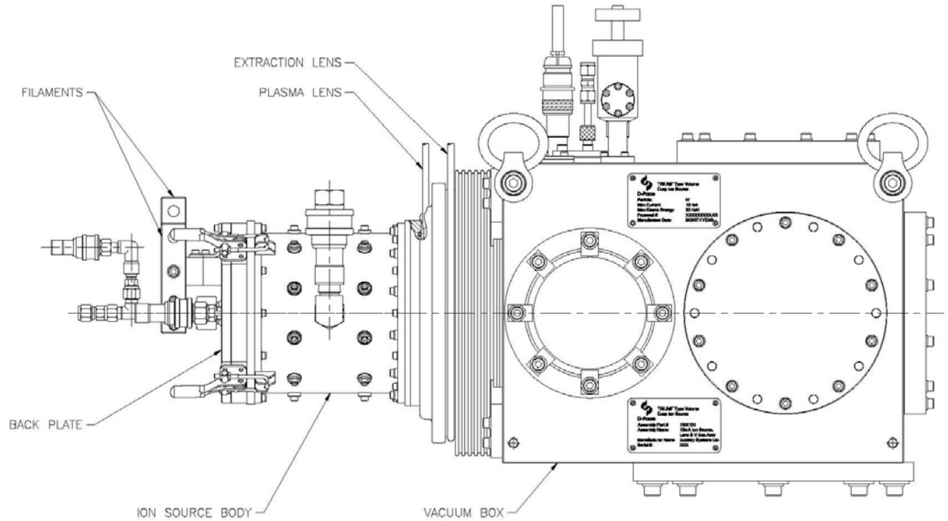
TRIUMF

- May 9 – 13, 2011
- Participants:
  - Gabriel Cojocaru (TRIUMF)
  - Keerthi Jayamanna (TRIUMF)
  - Thomas Stewart (D-Pace)
  - Lionel Prost (FNAL)
  - Qing Ji (LBNL)

H^- Ion Source Factory Acceptance Test

- **The H- ion source was manufactured and assembled in the machine shop (Buckley Systems Ltd., Auckland, New Zealand) and passed the Factory Acceptance Test before shipped to TRIUMF.**
  - Vacuum leak testing of entire assembly
  - Electrical isolation test
  - Verification of the magnetic fields in the Ion Source Body, Back Plate and Extraction Lens
  - XY Steering Magnet: electrical isolation, temperature and voltage, magnetic field direction tests and magnet current and magnetic flux densities.
  - Cooling water flow rate test

Ion Source Electrical Isolation Test



Electrical Isolation Test Measurements					
Record Resistance (Ω)	**Vacuum Box**	**Plasma Lens**	**Extraction Lens**	**Back Plate**	**Filaments**
Ion Source Body	>500MΩ	>500MΩ	>500MΩ	Not Electrically Isolated	>500MΩ
Filaments	>500MΩ	>500MΩ	>500MΩ	>500MΩ	
Back Plate	>500MΩ	>500MΩ	>500MΩ		
Extraction Lens	>500MΩ	>500MΩ			
Plasma Lens	>500MΩ				

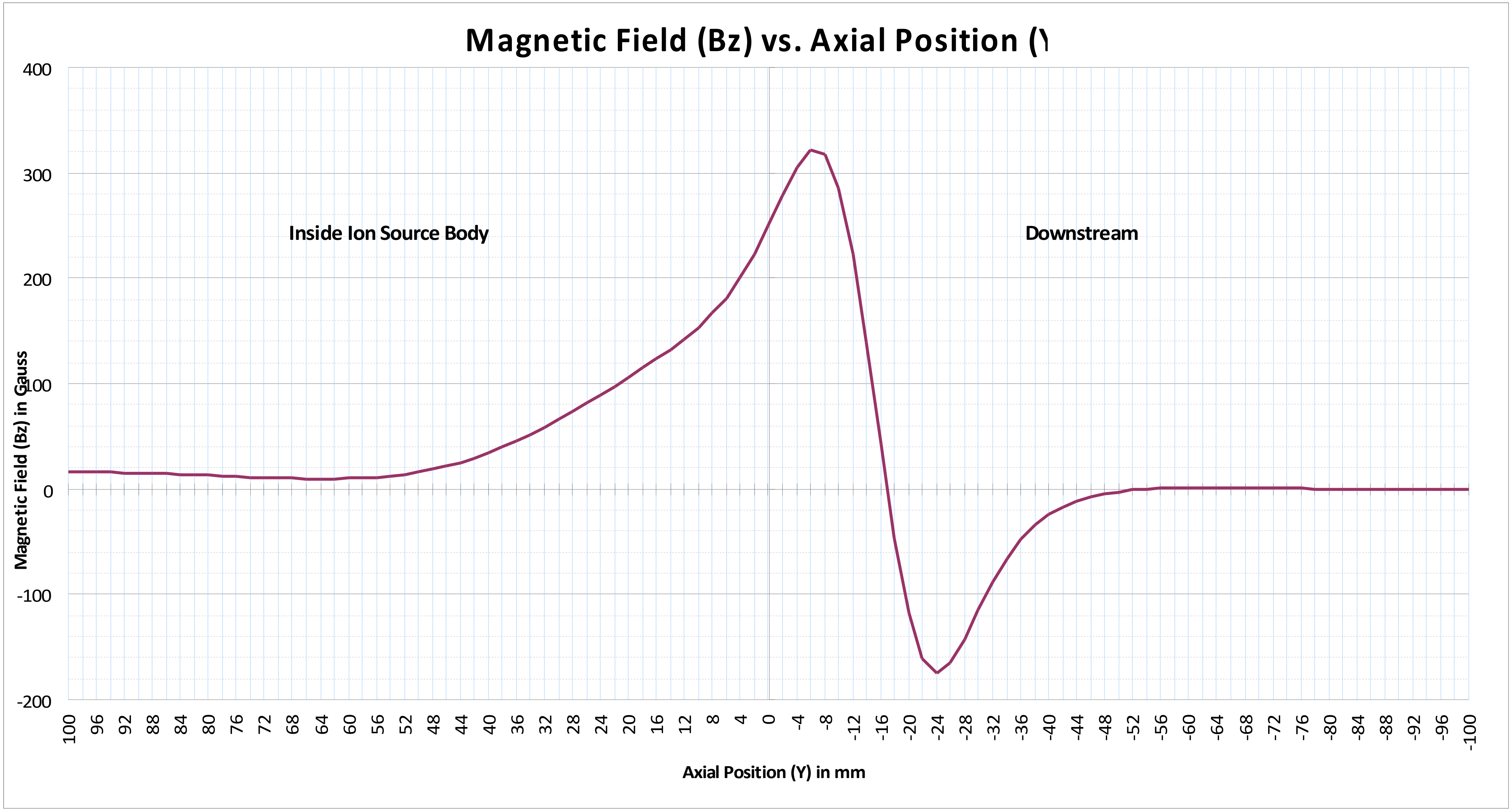
Verification of Magnetic Fields

Ion Source Body Field Verification Chart				
Magnet Row	**Center of Ion Source Body Polarity**	**Maximum/Minimum Field at Center of Ion Source Body (kG)**	**Extraction End Polarity**	**Maximum/Minimum Field at Extraction End (kG)**
1	-	-3.101	-	-2.097
2		0		0
3	+	+3.142	+	+2.165
4		0		0
5	-	-3.115	-	-2.046
6		0	-	-1.918
7	+	+2.941	-	-1.716
8		0	-	-1.851
9	-	-3.114	-	-1.910
10		0		0
11	+	+2.987	+	+2.107
12		0		0
13	-	-2.926	-	-2.096
14		0		0
15	+	+2.930	+	+1.938
16		0	+	+1.877
17	-	-2.928	+	+1.746
18		0	+	+1.845
19	+	+3.058	+	+1.938
20		0		0

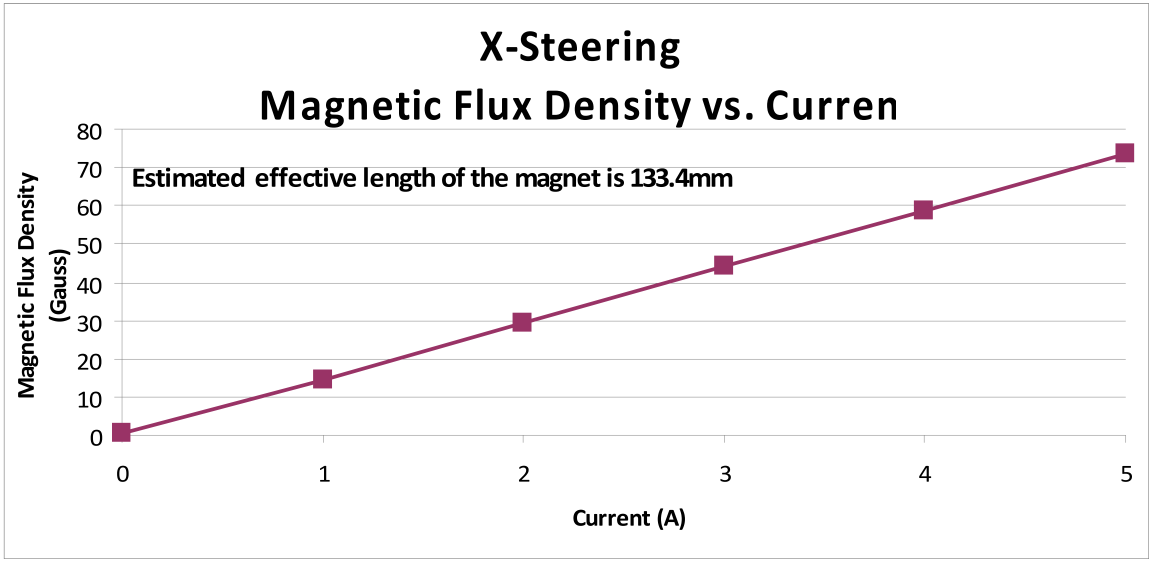
Back Plate Field Verification Chart		
Row	**Polarity**	**Max Field (kG)**
1	+	+2.156
2	-	-2.218
3	+	+2.218
4	-	-2.156

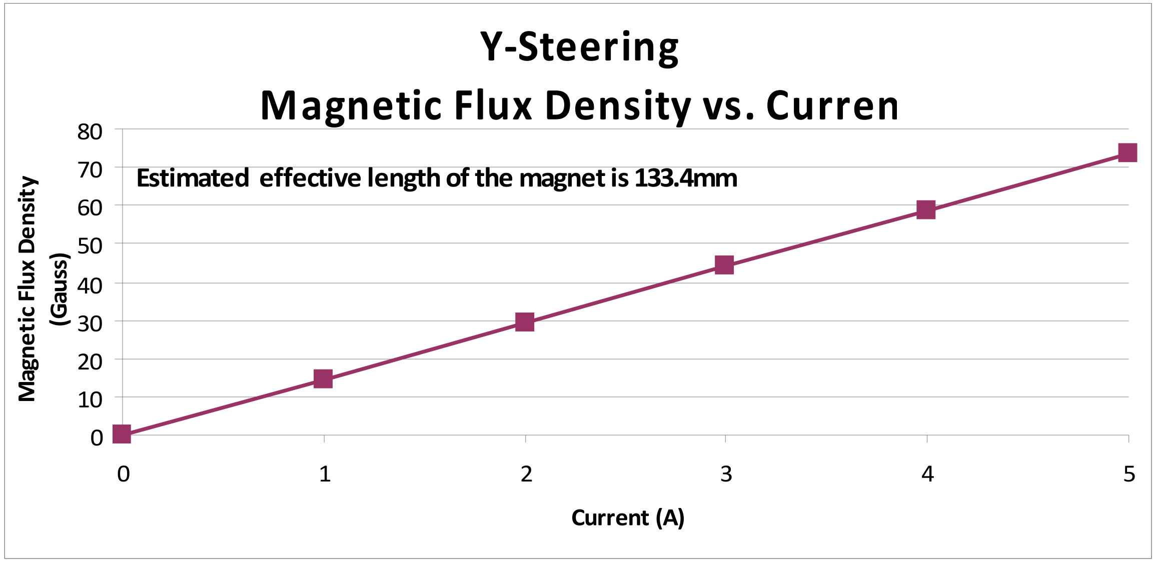
Extraction Lens Field Verification Chart		
Side	**Polarity**	**Max Field (kG)**
Upstream	+	+0.2384
Downstream	-	-0.2362

Axial Magnetic Field Verification

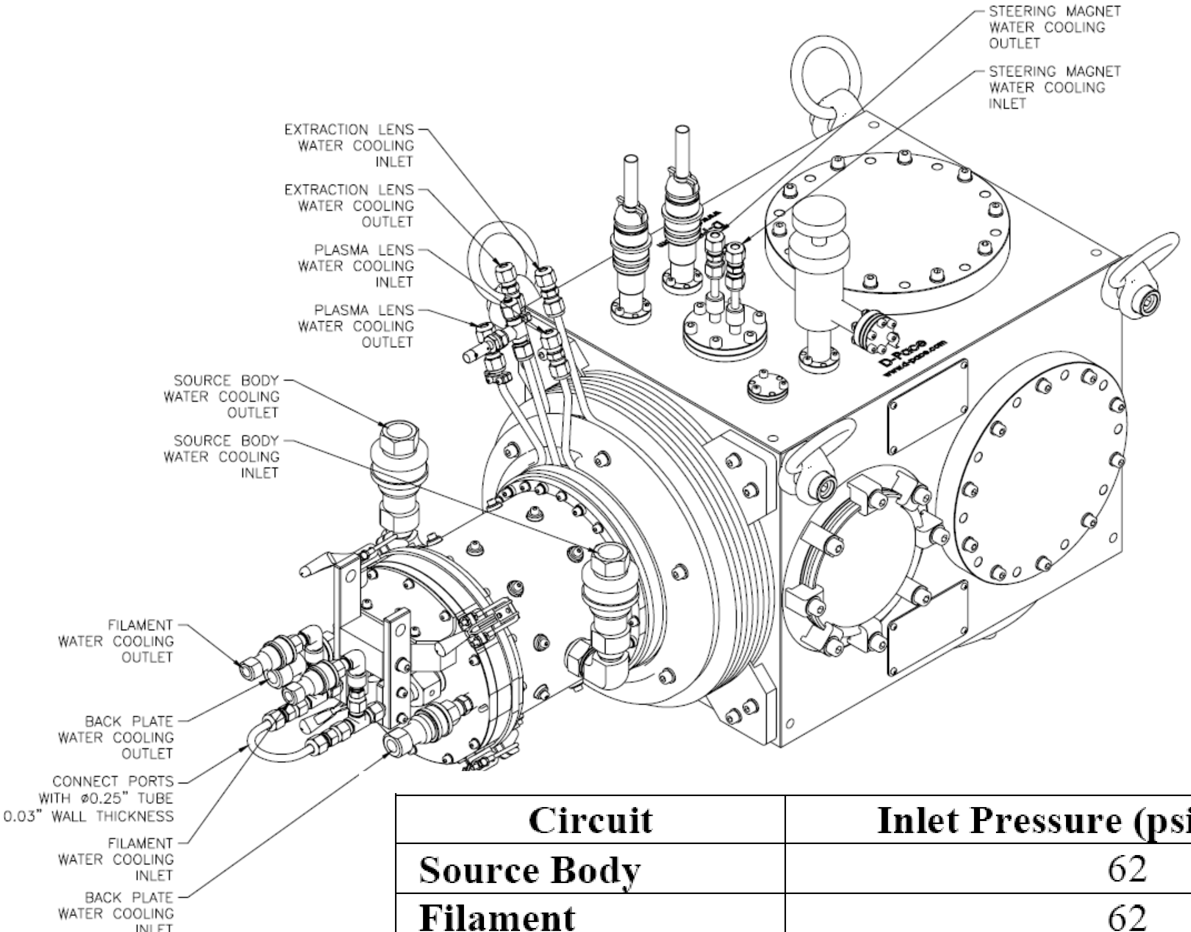


X-Y Steering magnetic Field Test





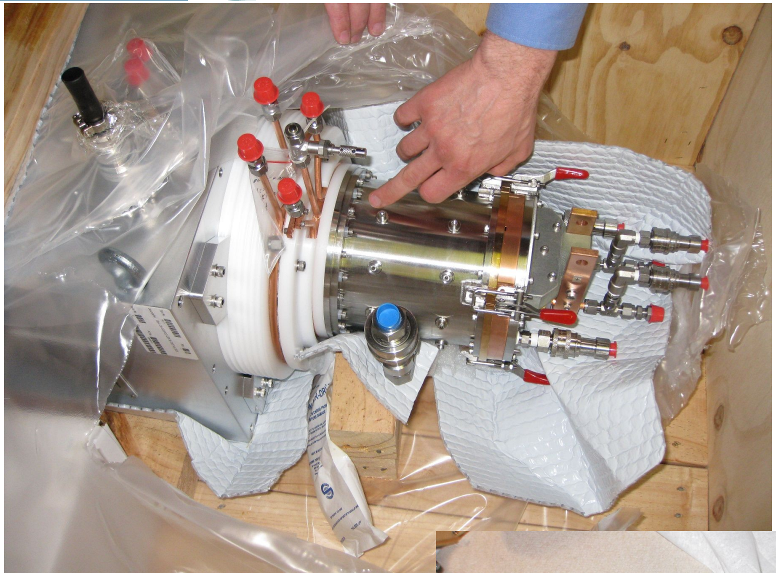
Ion Source Cooling Water Flow Test

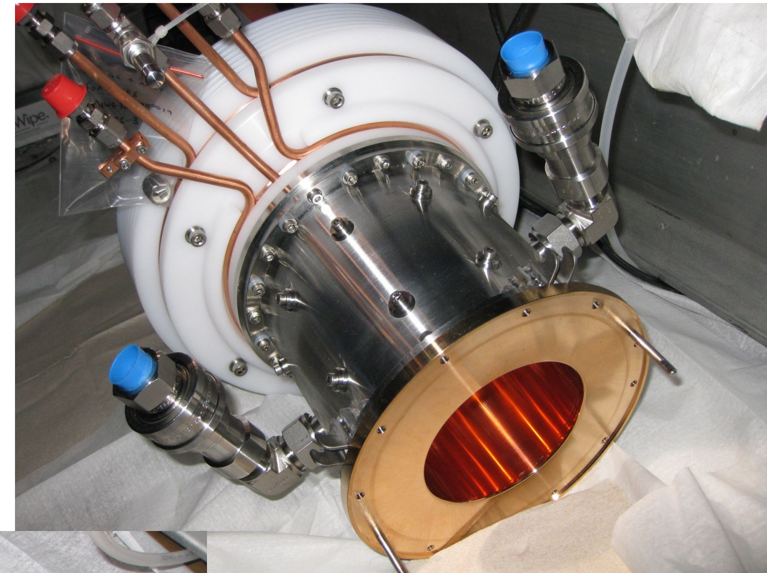


Circuit	Inlet Pressure (psig)	Flow (L/min)
Source Body	62	23
Filament	62	1.6
Back Plate	62	18
Plasma Lens	62	11
Extraction Lens	62	10
Steering Magnet	62	11

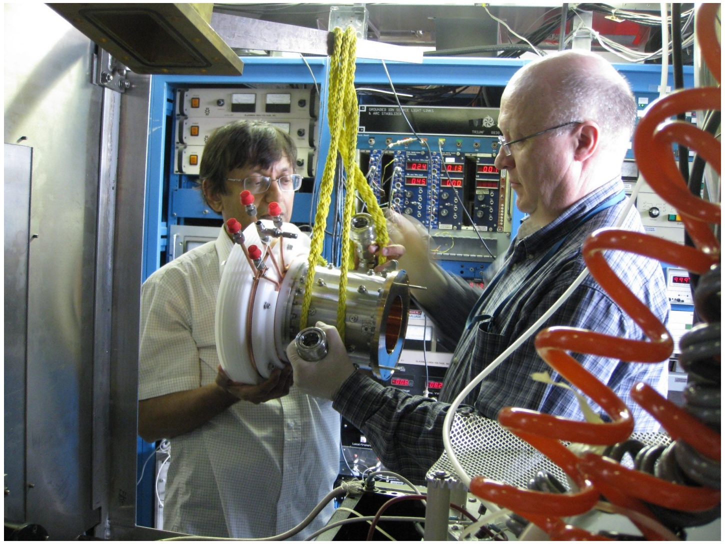
Ion Source Arrived at TRIUMF on May 9, 2011

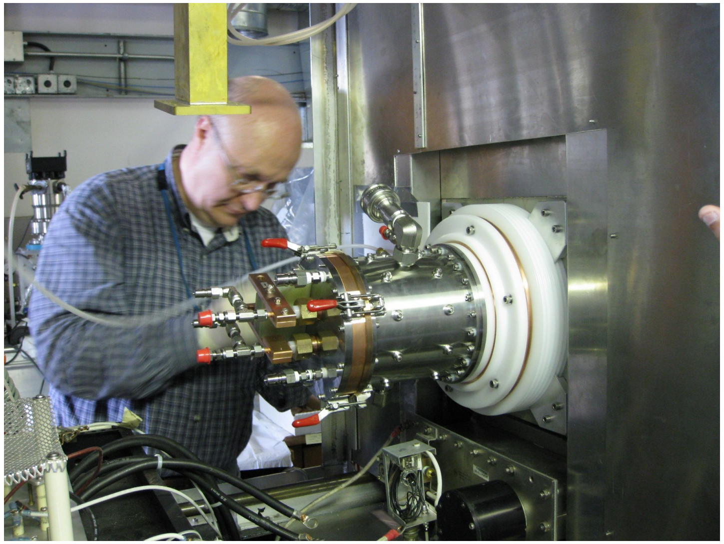
Ion Source Inspection

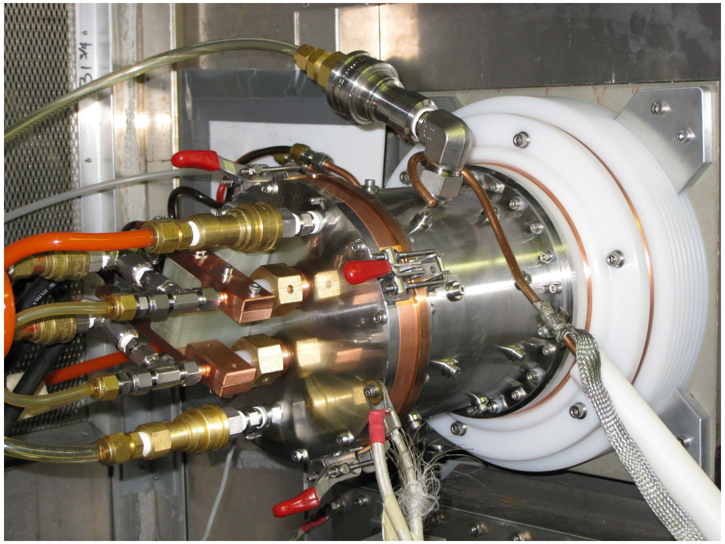




Ion Source Installed on the Test Stand





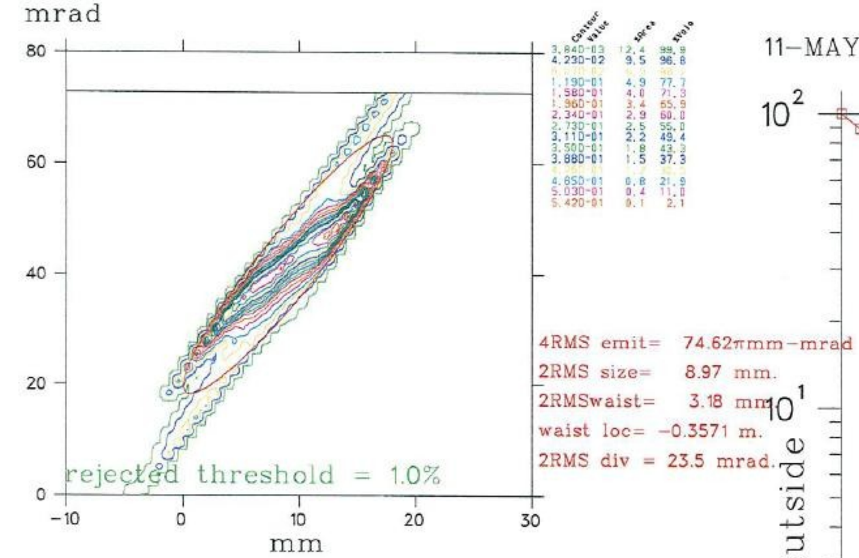


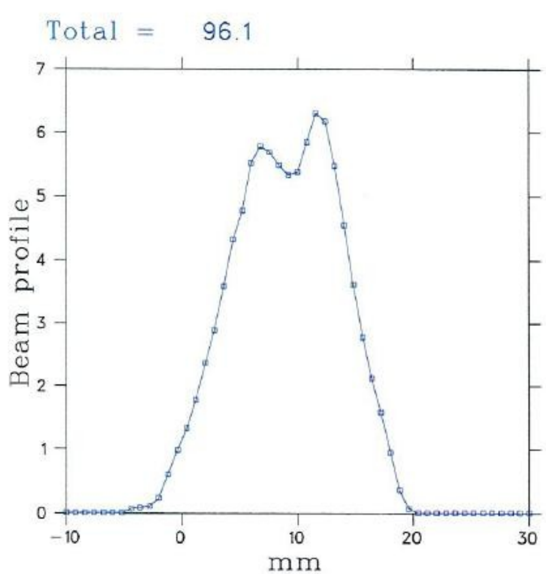
Beam Tests Activities

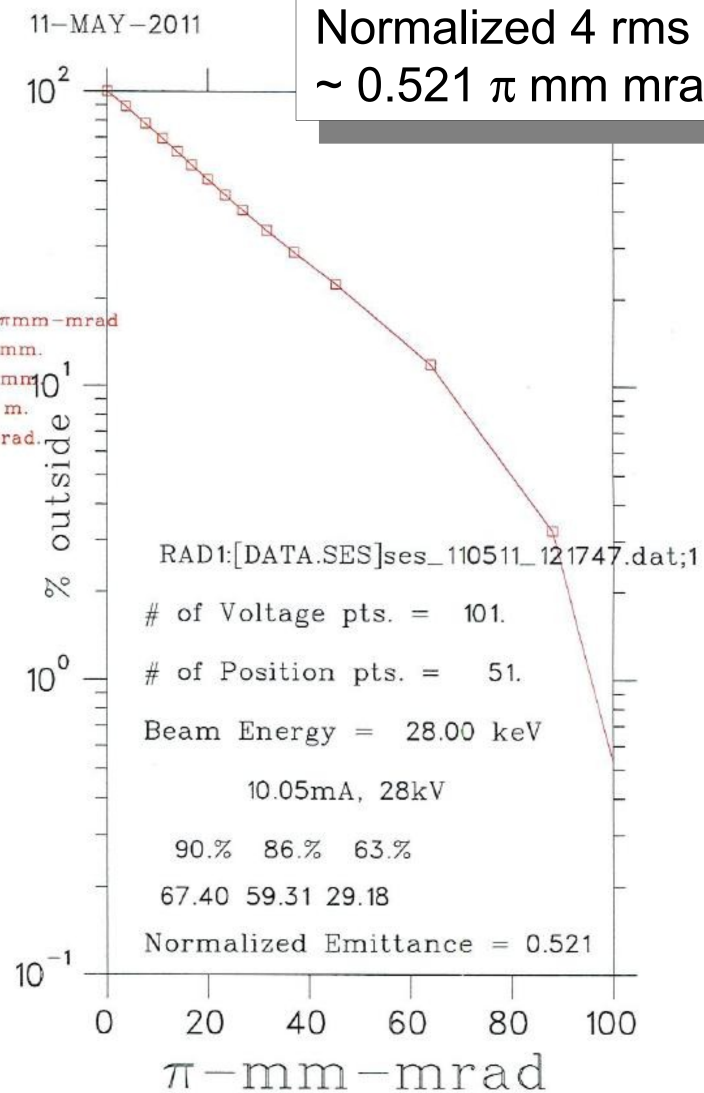
- **Beam tests at TRIUMF (May 10, 2011 – May 13, 2011)**
  - May 10: Ion Source has been pumped down sufficiently. Turn on cooling water, H_2 gas, and power supplies. No vacuum leak. Ramp up the power supplies slowly to "condition" the new filament and other HV components. Slowly increase the H- beam current from 1mA to 10mA.
  - May 11: Turn the beam, record all the parameters and take emittance scan from 1mA to 10mA, at 28keV and 20keV. Beam stability test at 5mA level at 28keV for two hours.
  - May 12: Turn the beam, record all the parameters and take emittance scan from 1mA to 10mA, at 30keV. Beam stability test at 10mA level at 28keV for over an hours.
  - May 13: Hands-on experience of source operation and tuning the beam at levels of 5mA and 10mA. Vent the system, take the ion source off the test stand, reassemble with the vacuum box. Pack and ready for shipping.

Emittance Measurement – 10mA, 28keV

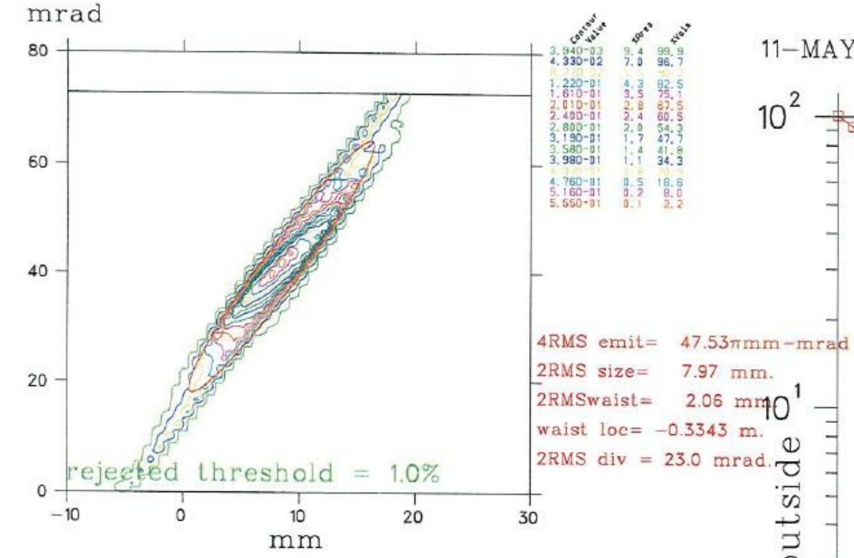
Normalized 4 rms emittance:
~ 0.521 π mm mrad

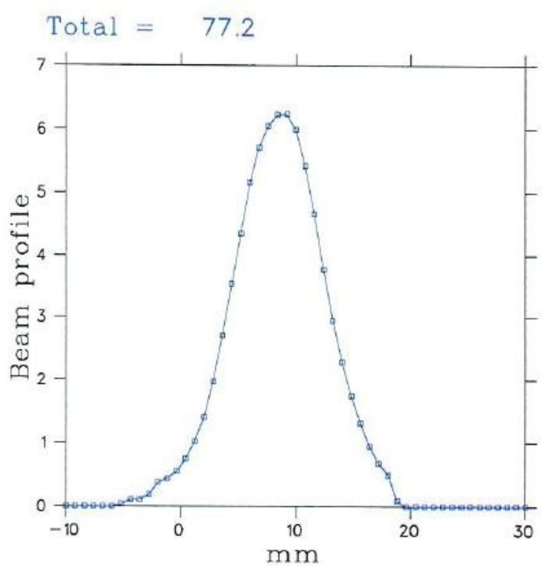


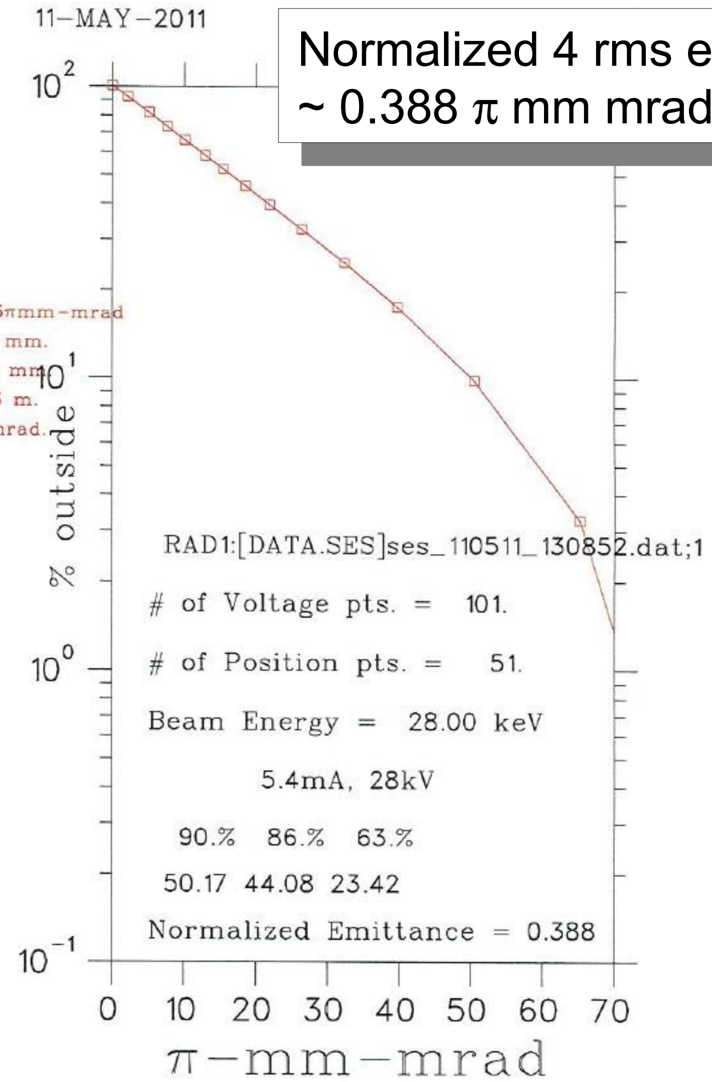




Emittance Measurement – 5mA, 28keV



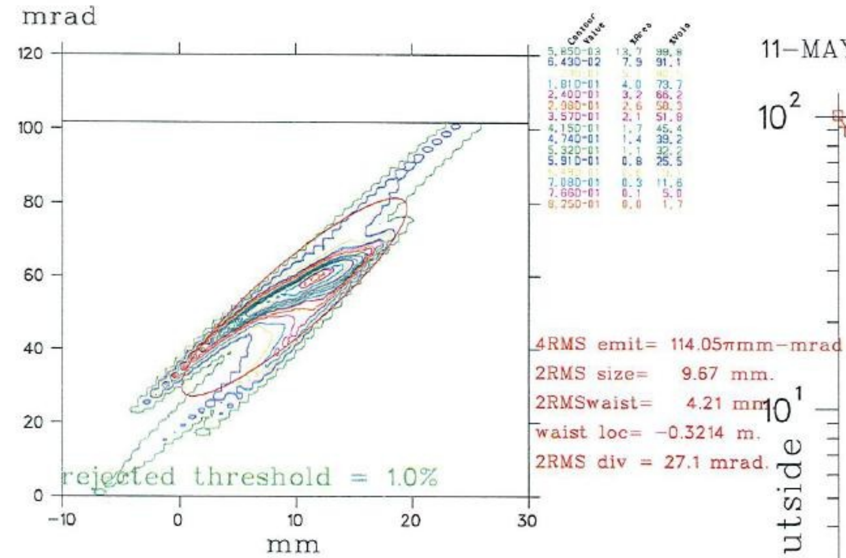


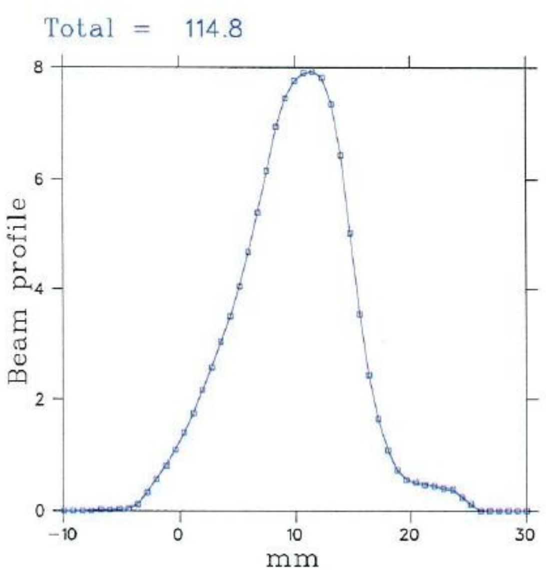


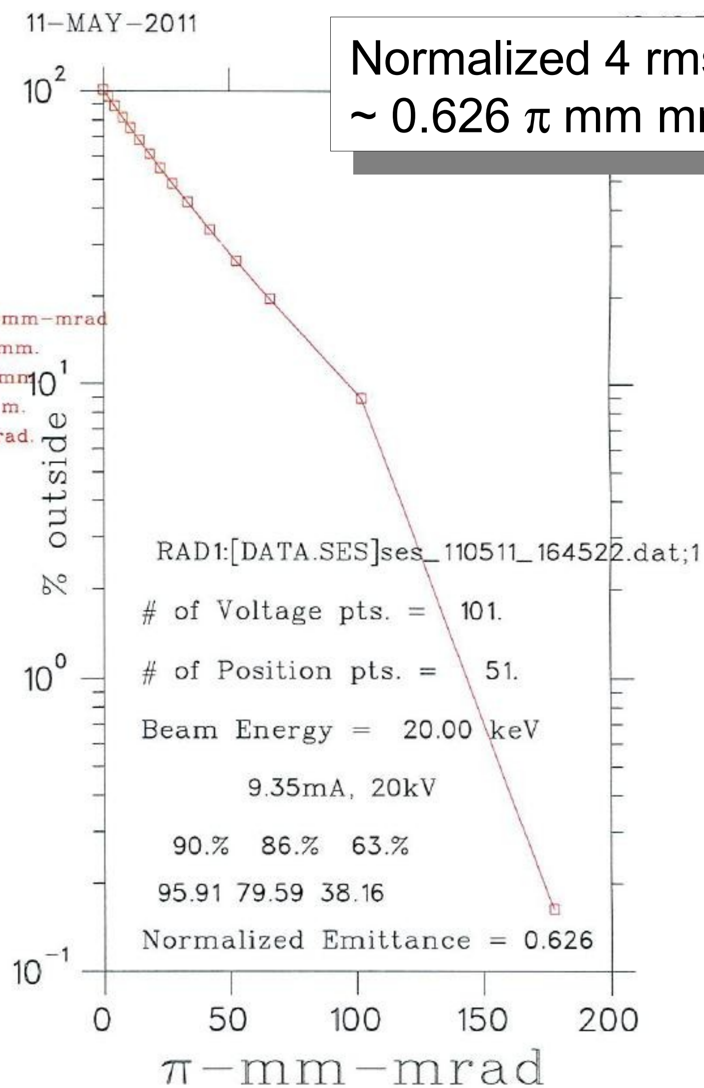
Normalized 4 rms emittance:
~ 0.388 π mm mrad

Emittance Measurement – 10mA, 20keV

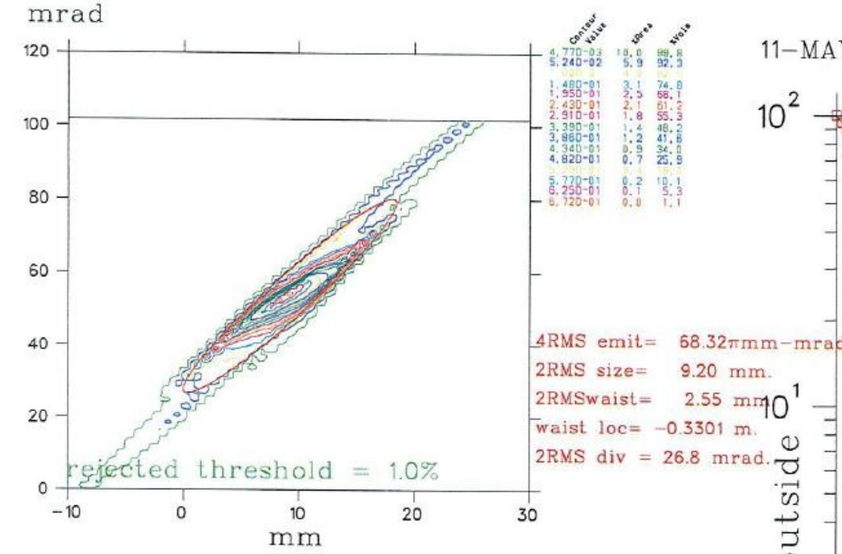
Normalized 4 rms emittance:
~ 0.626 π mm mrad

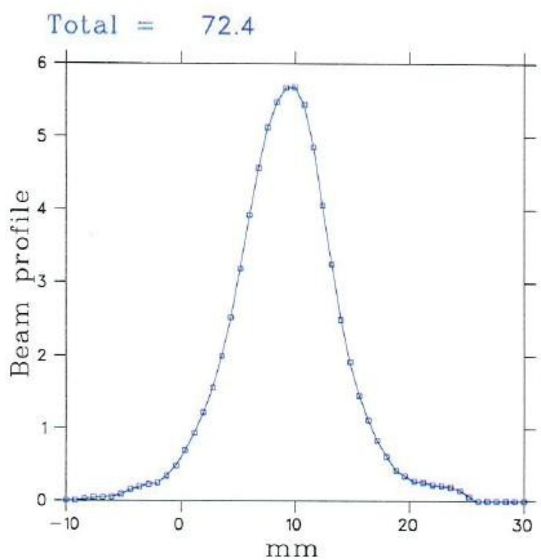


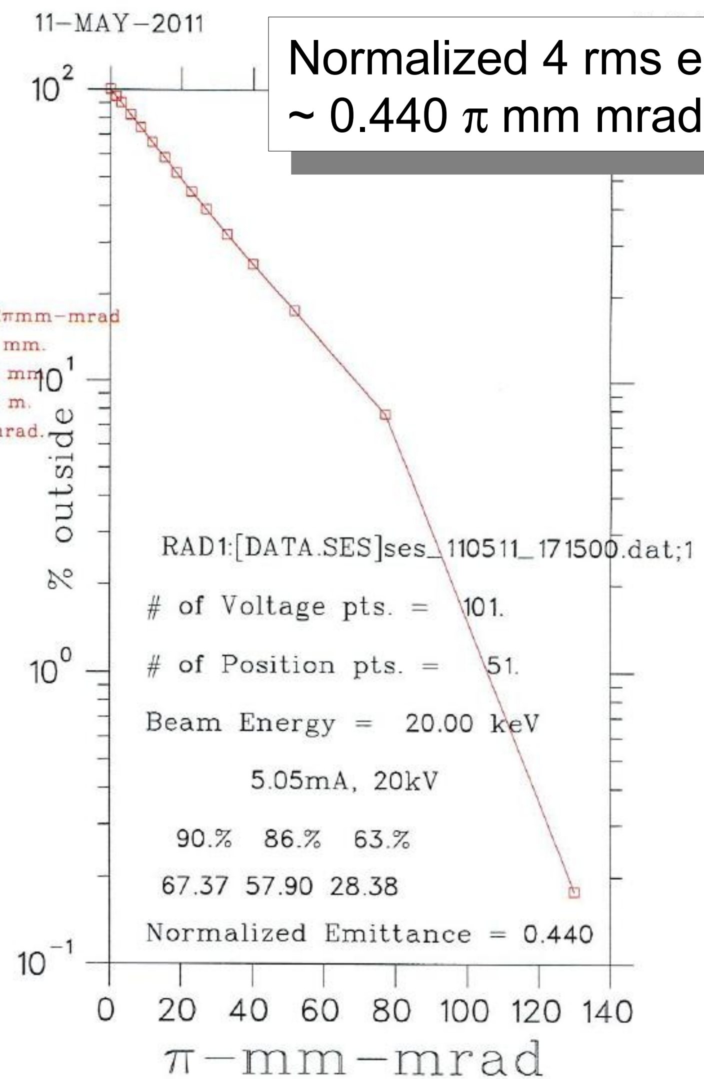




Emittance Measurement – 5mA, 20keV

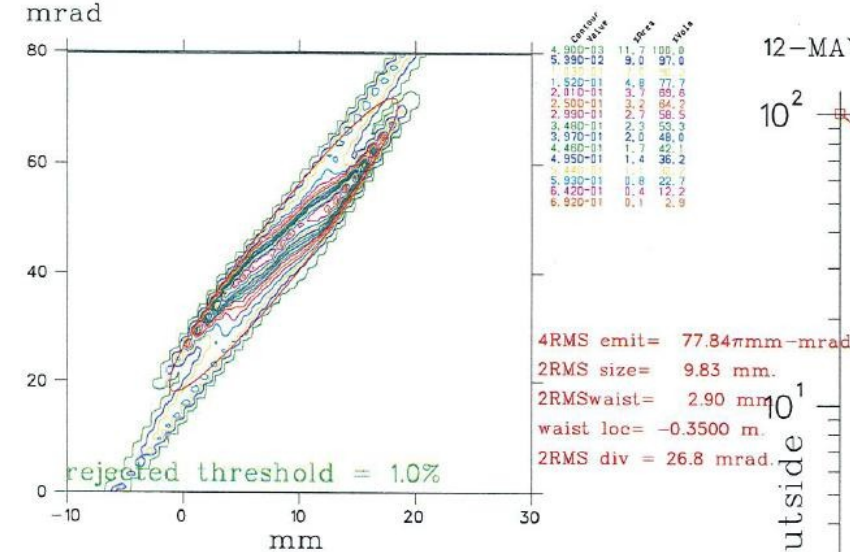


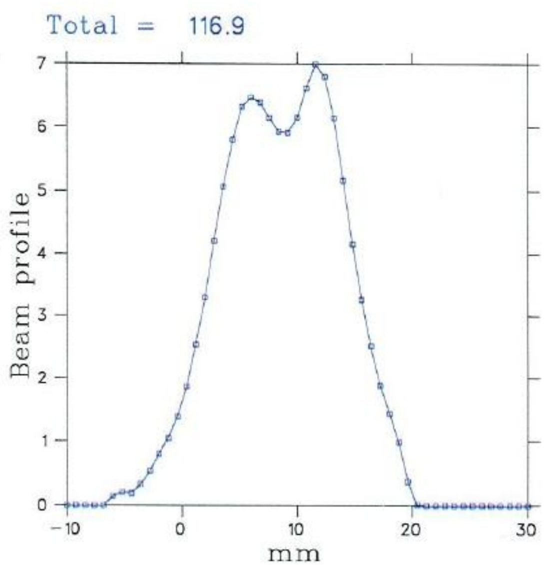


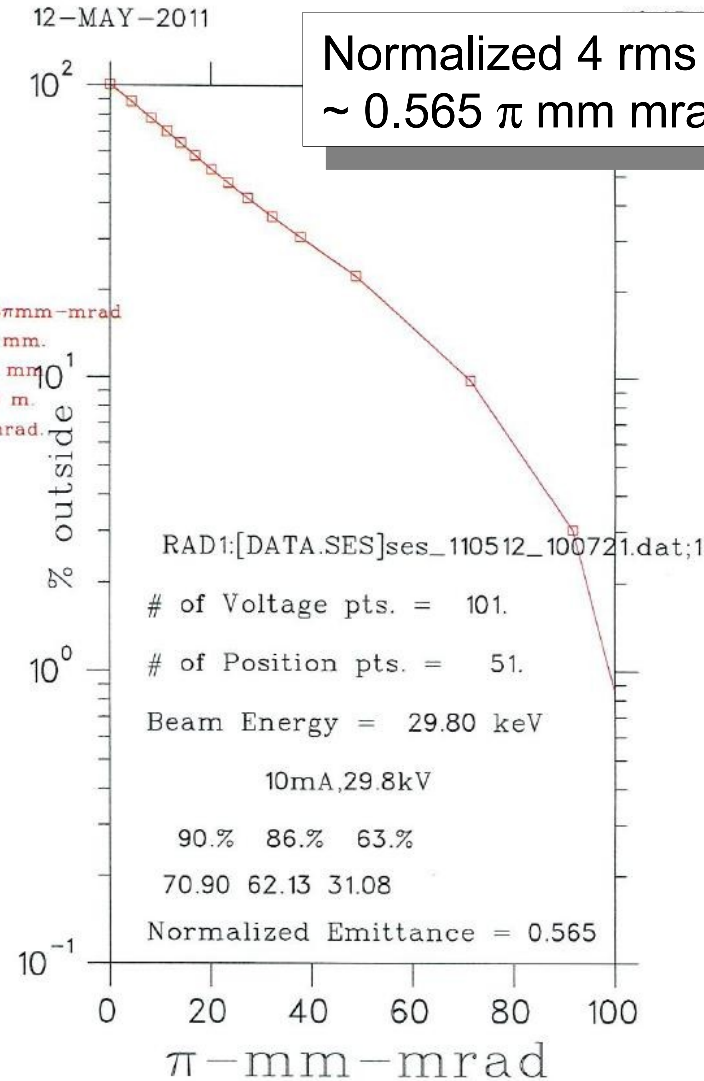


Normalized 4 rms emittance:
~ 0.440 π mm mrad

Emittance Measurement – 10mA, 30keV



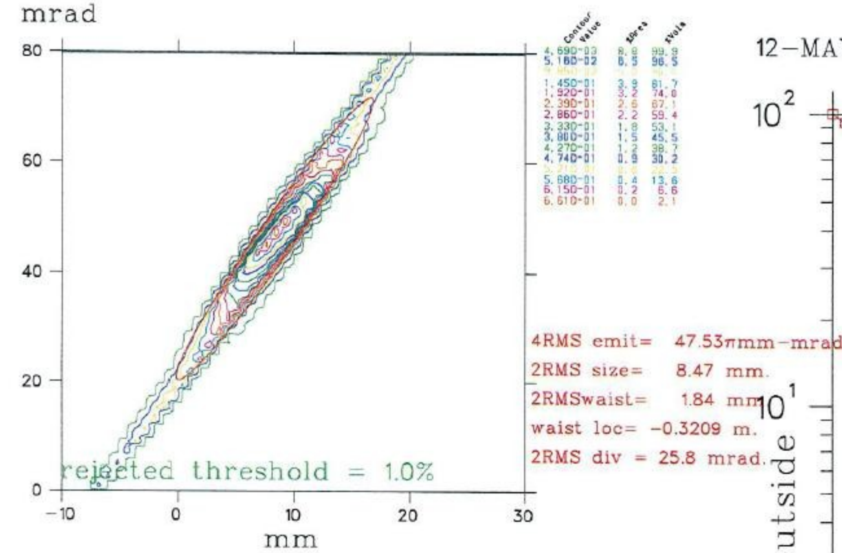


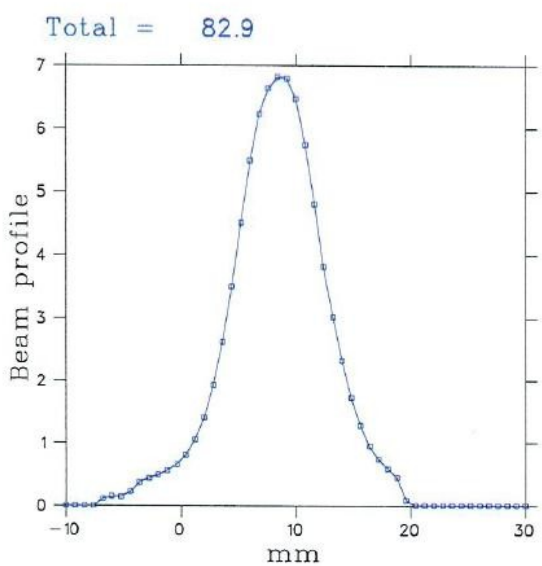


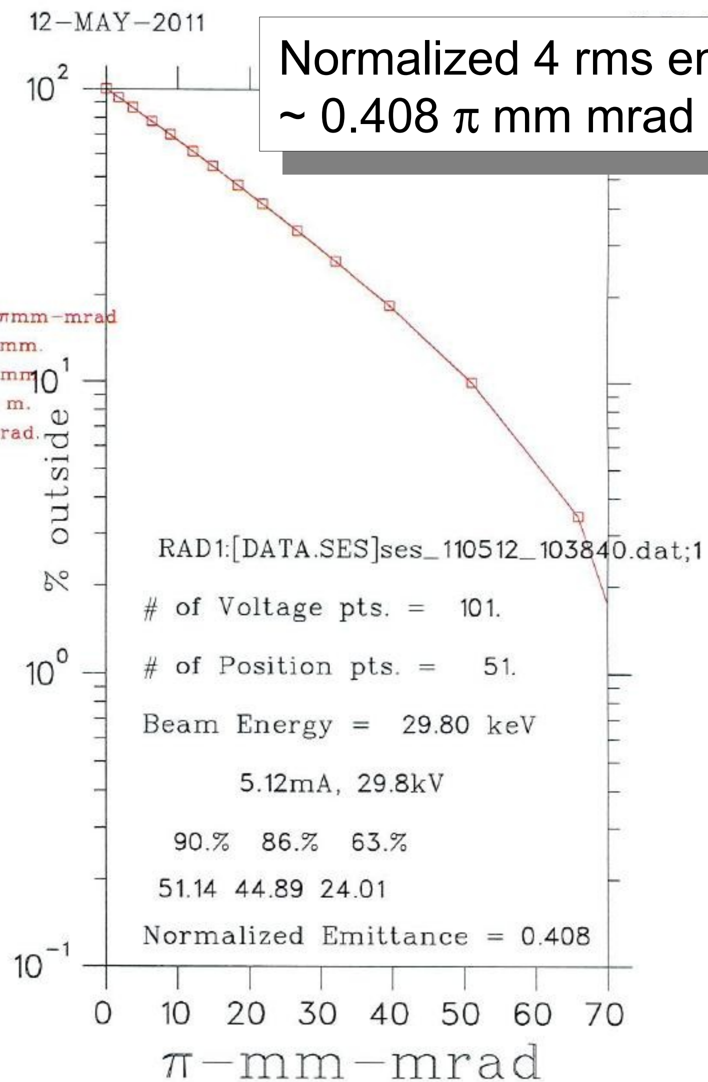
Normalized 4 rms emittance:
~ 0.565 π mm mrad

Emittance Measurement – 5mA, 30keV

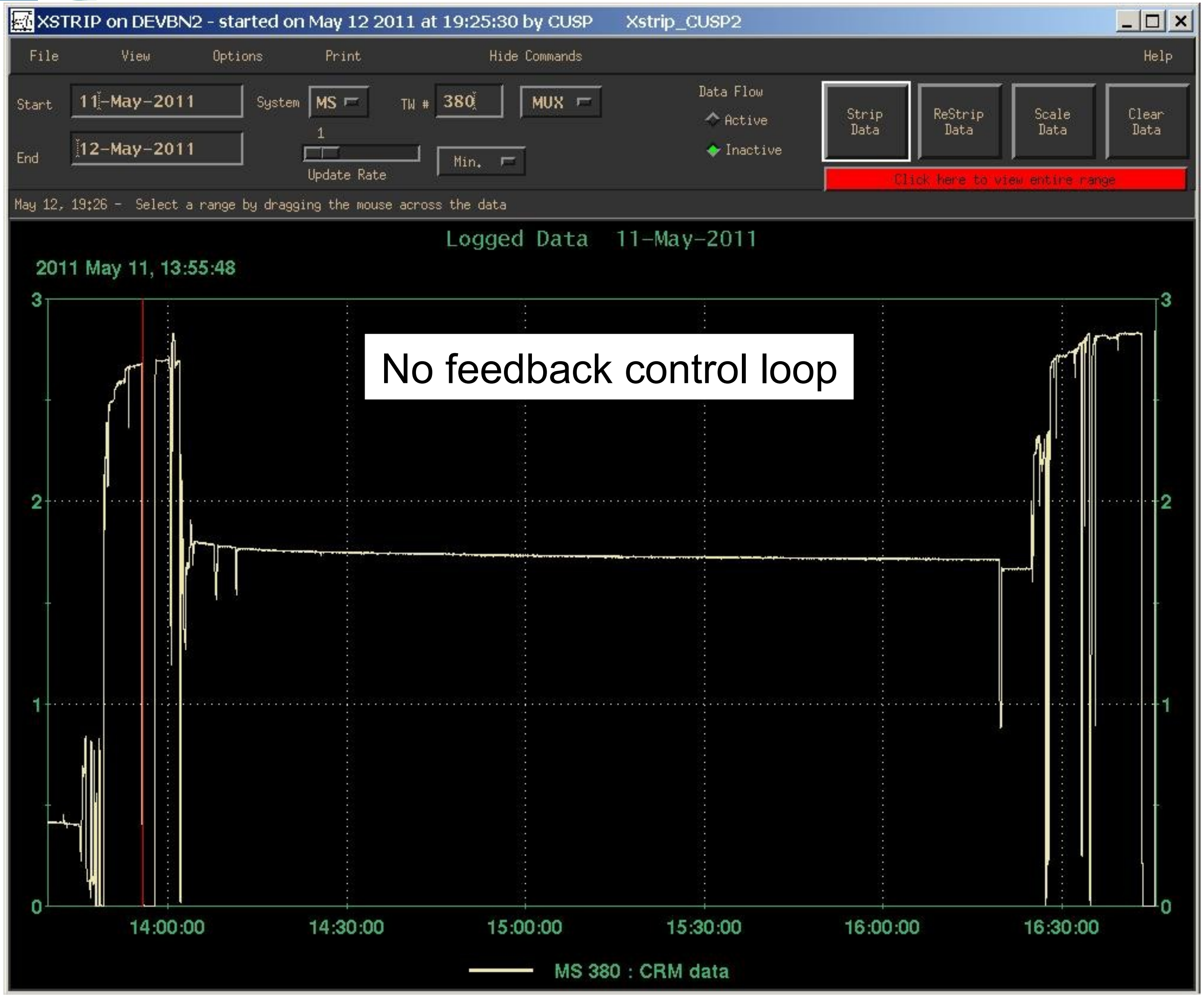
Normalized 4 rms emittance:
~ 0.408 π mm mrad



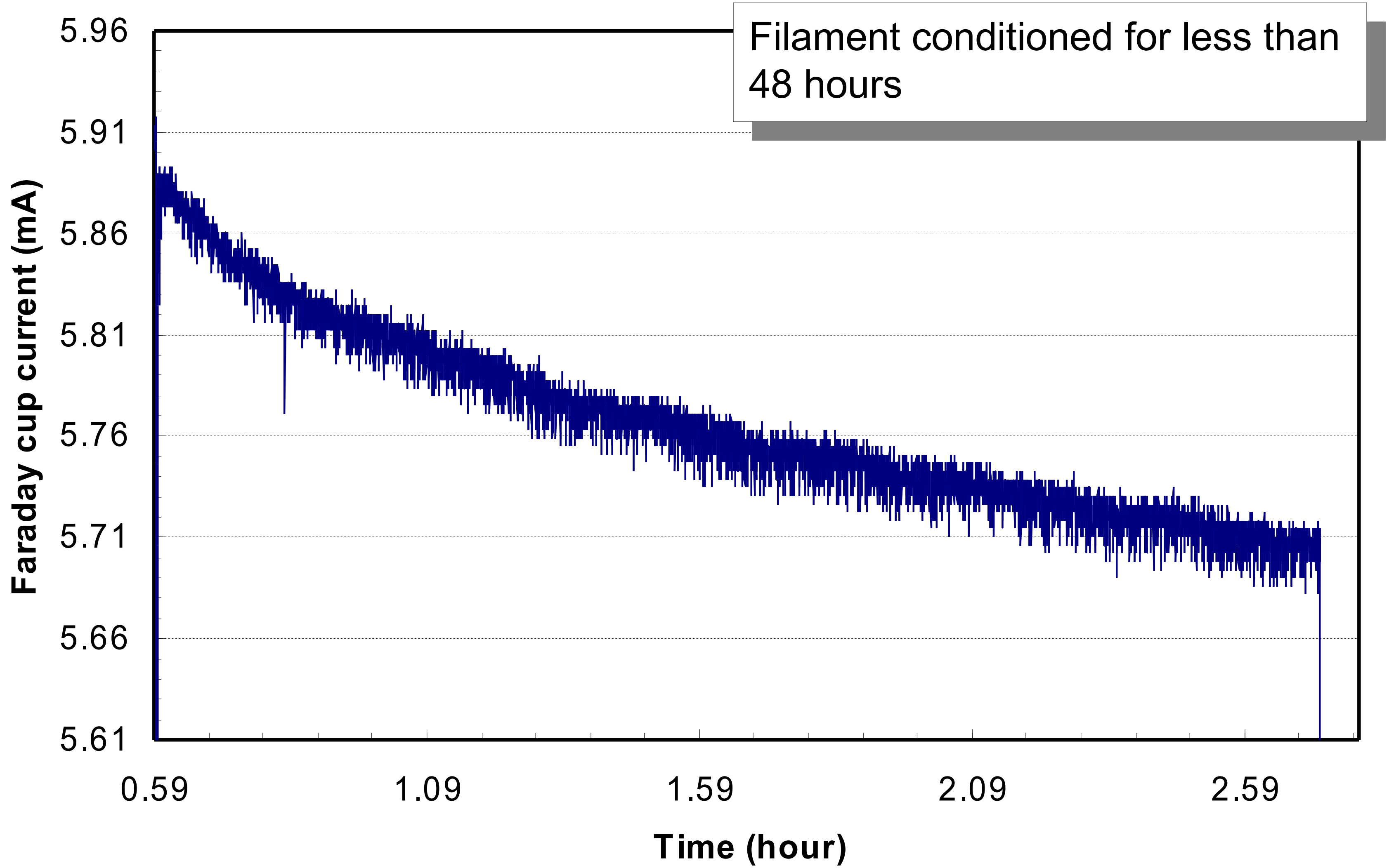




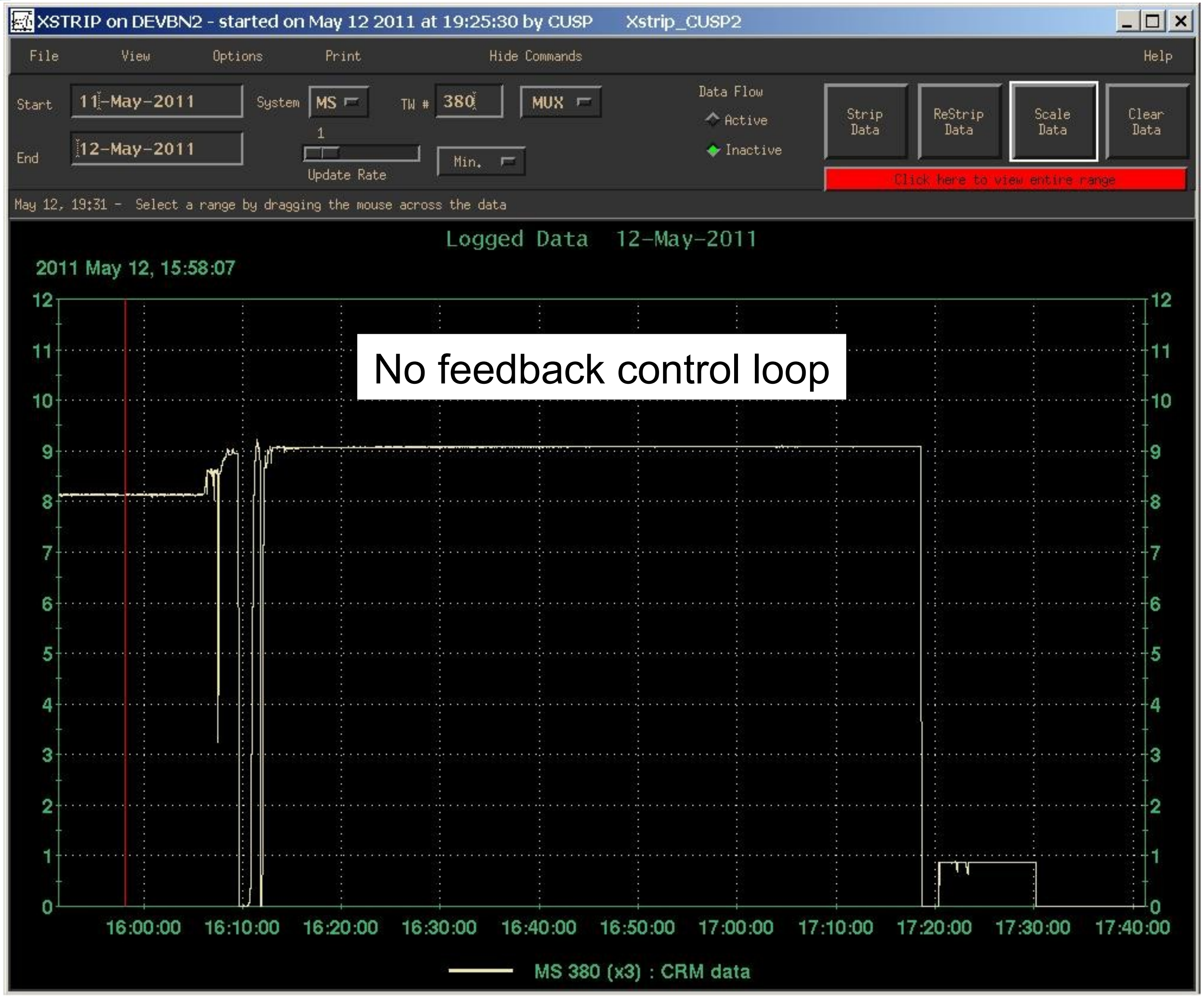
Beam Stability Test (5mA level)



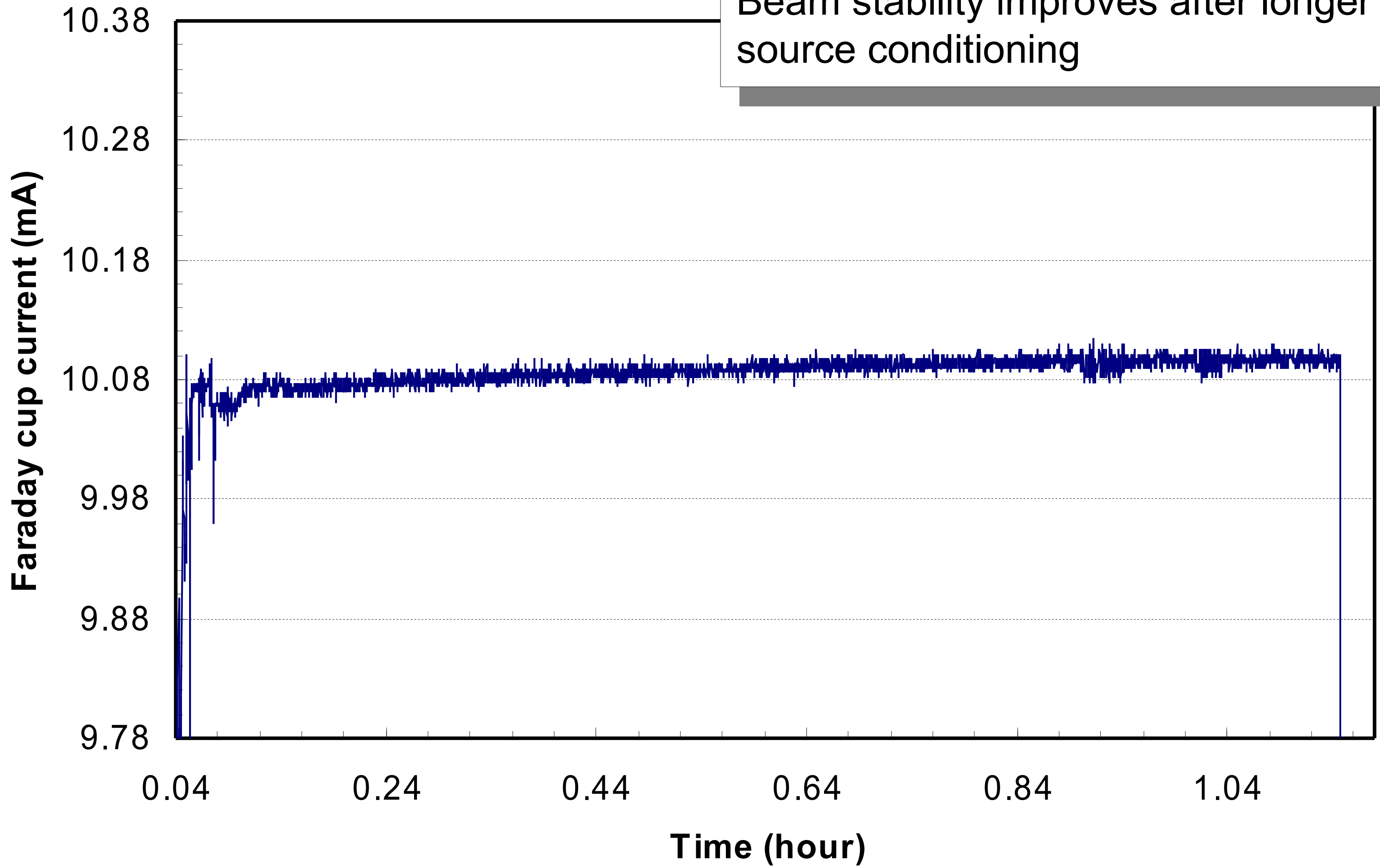
Beam Stability @5mA: ~ +/- 1.9%



Beam Stability Test (10mA level)



Beam Stability @10mA: ~ +/- 0.4%

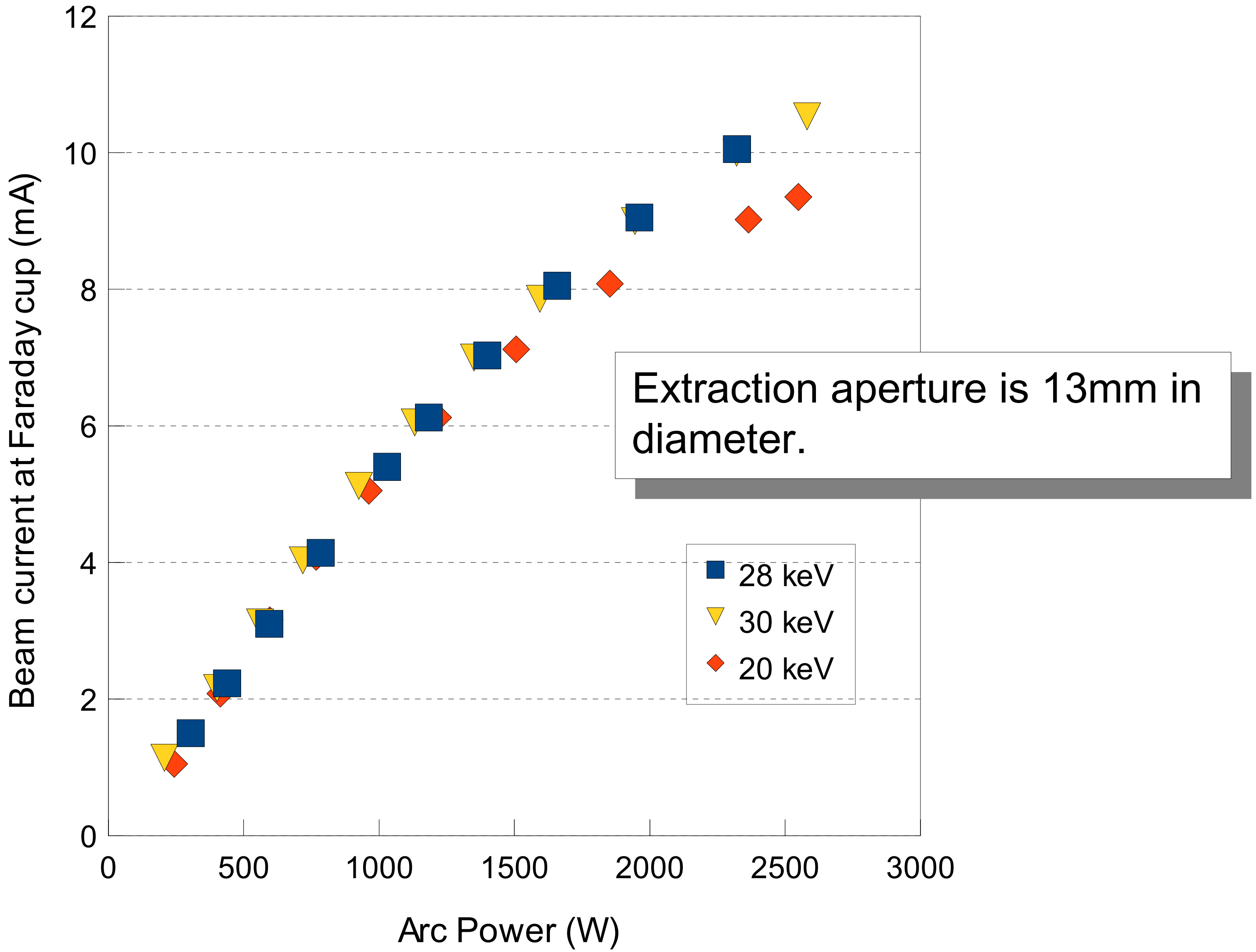


Beam stability improves after longer source conditioning

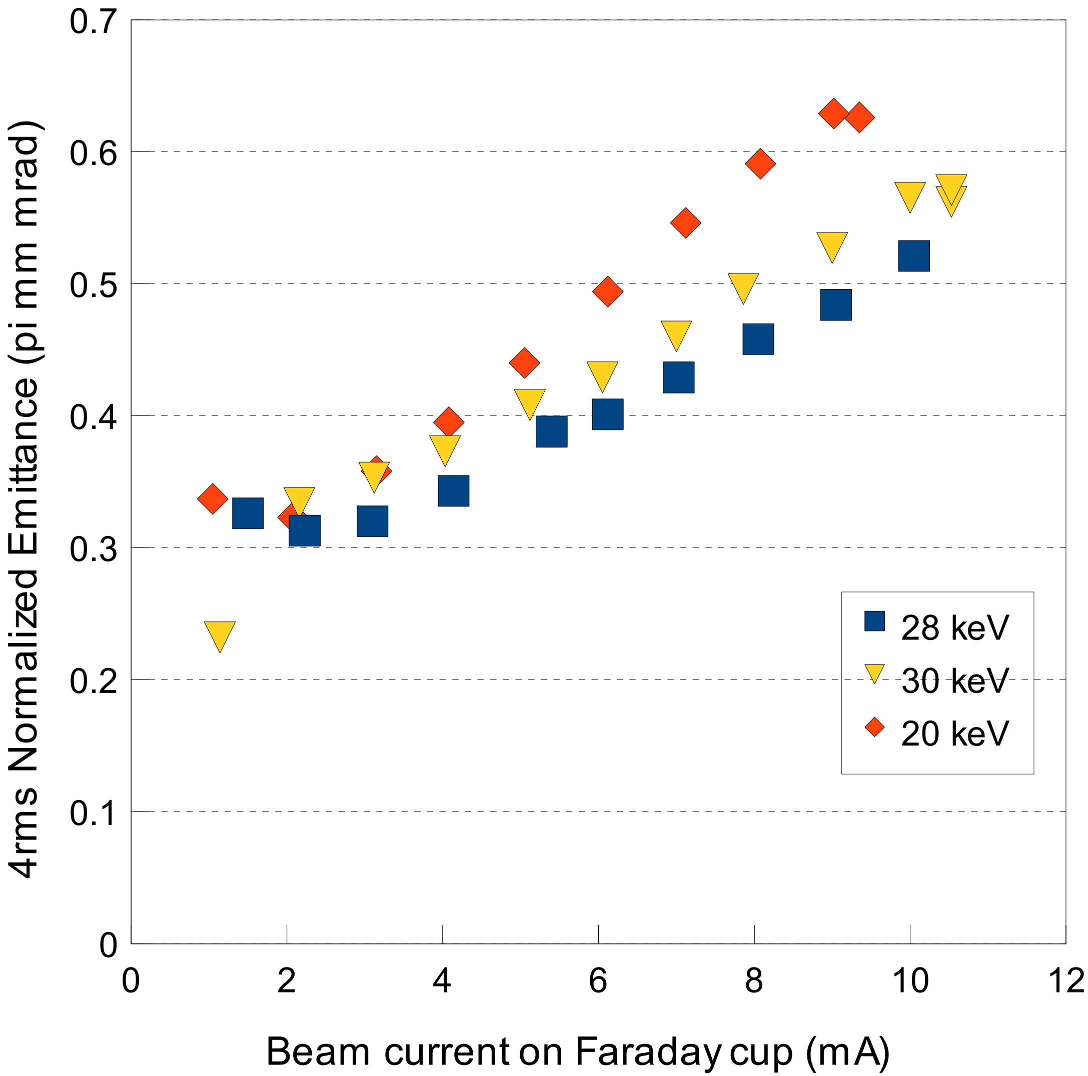
Summary

- We didn't experience any vacuum leak nor water leak on the ion source assembly.
- After filament and voltage conditioning, the H^- ion beam currents from 1mA to 10mA have been verified. The highest detected in the Faraday cup was 10.53mA, which was limited by the capabilities of the power supplies in the test stand.
- Emittance were measured from beam level from 1mA to 10mA, at various beam energy. Normalized 4 rms emittance were less than 0.63 π mm mrad, which met the specification.
- Beam stability was tested at beam level of 5mA and 10mA for over an hour each. Without any feedback control loop, the beam current stability was better than +/- 2%. The second beam stability test showed better results (< +/- 0.4%) after longer filament conditioning.
- e/H^- ratio was not physically measured during the acceptance test due to the limitation of the hardware setup. Based on TRIUMF experience, the electrons co-extracted from the ion source are properly dumped to plasma and extraction electrodes. Electron beams reaching the Faraday cup are negligible

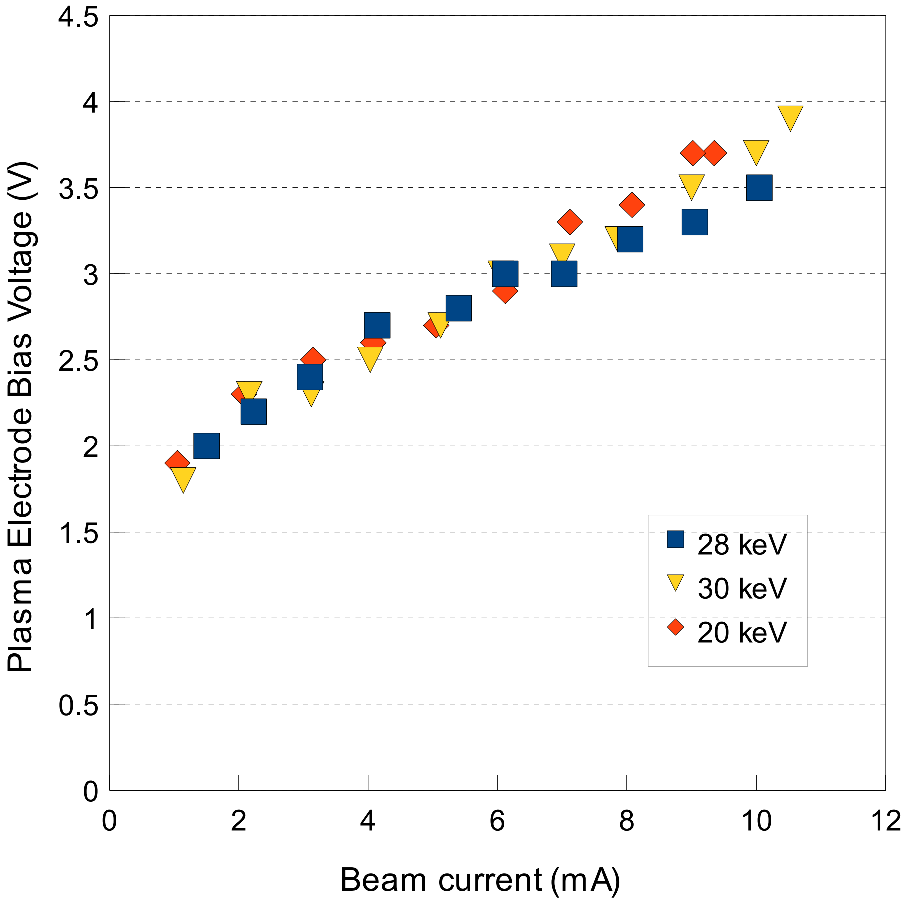
Beam Current vs. Arc Power

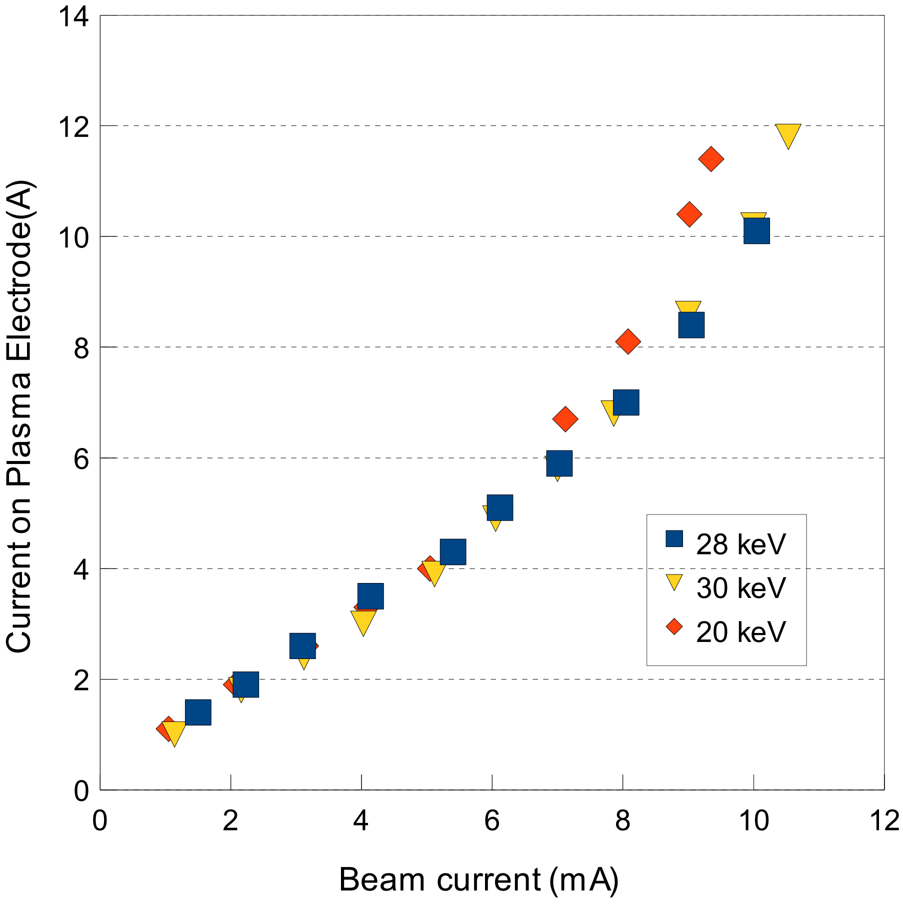


Normalized Emittance (4rms) vs. Beam current

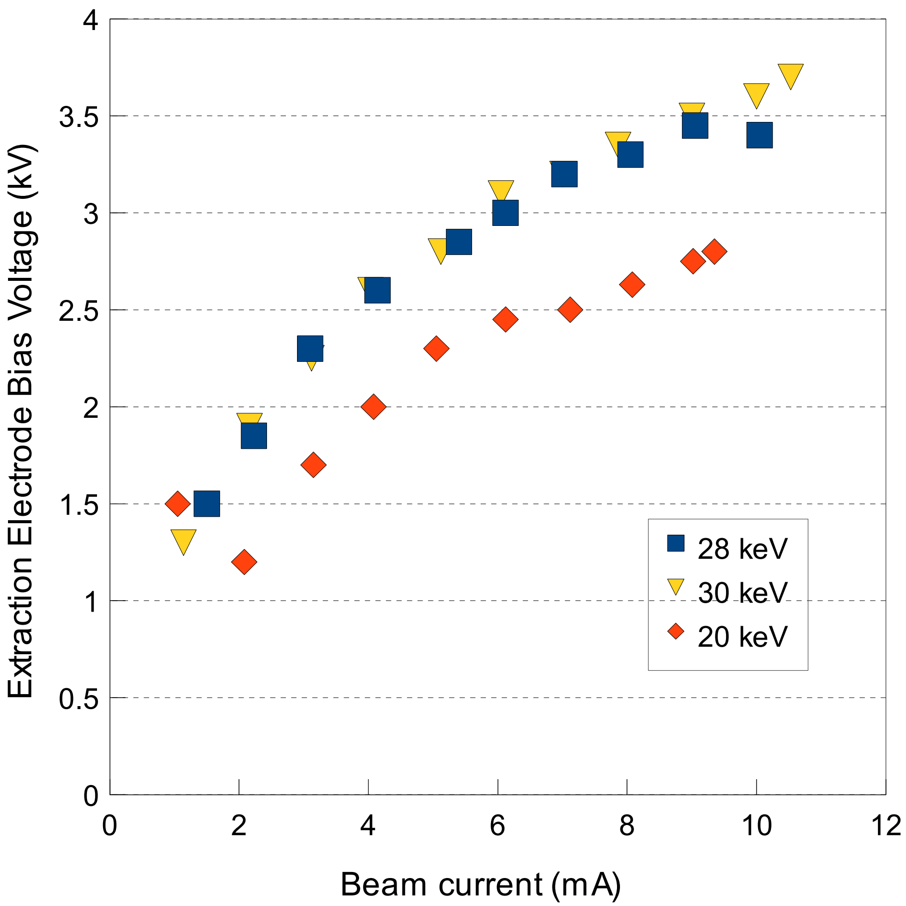


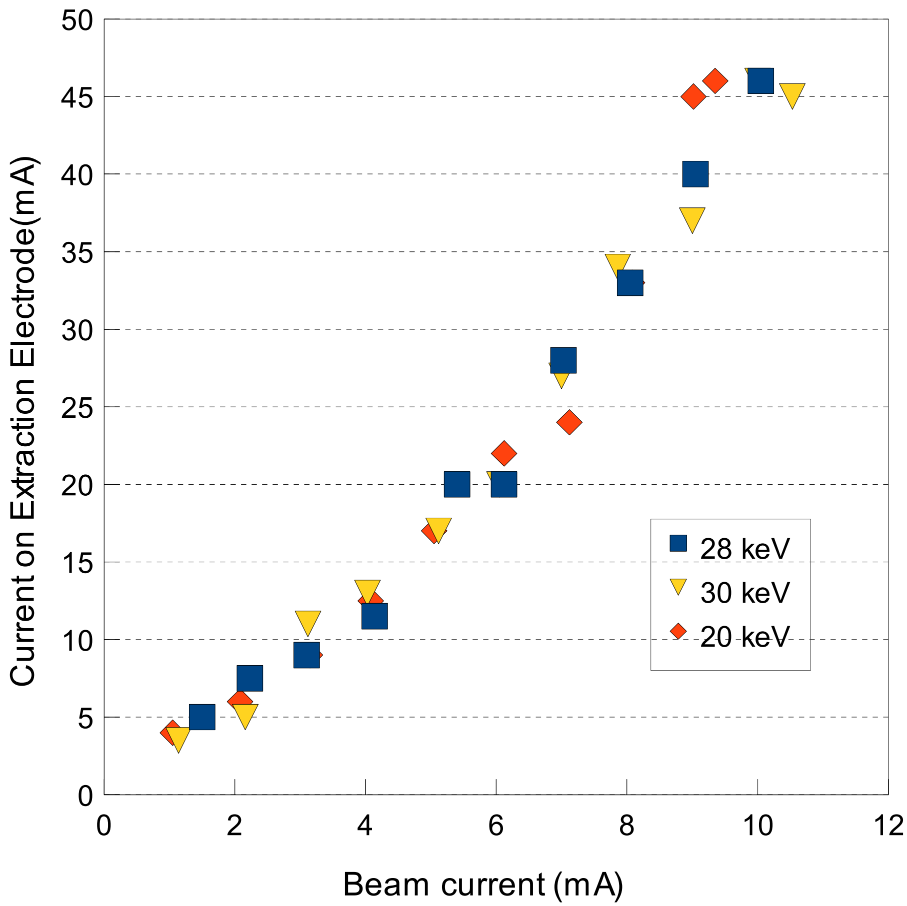
Plasma Electrode Parameters for Various Beam Output





Extraction Electrode Parameters for Various Beam Output





Current on extraction electrode may include dumped electrons and H- beam with large angles.

Clues of e/H$^-$ ratio?

Ref: T. Kuo et al, Rev. Sci. Instru., 67, 1314(1996).

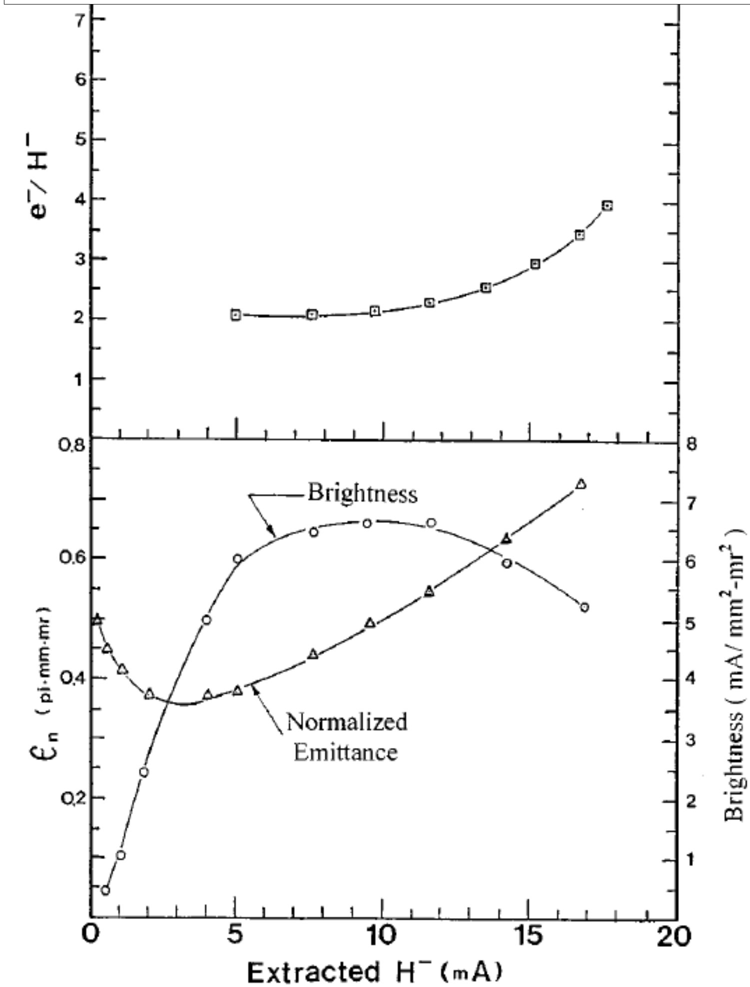
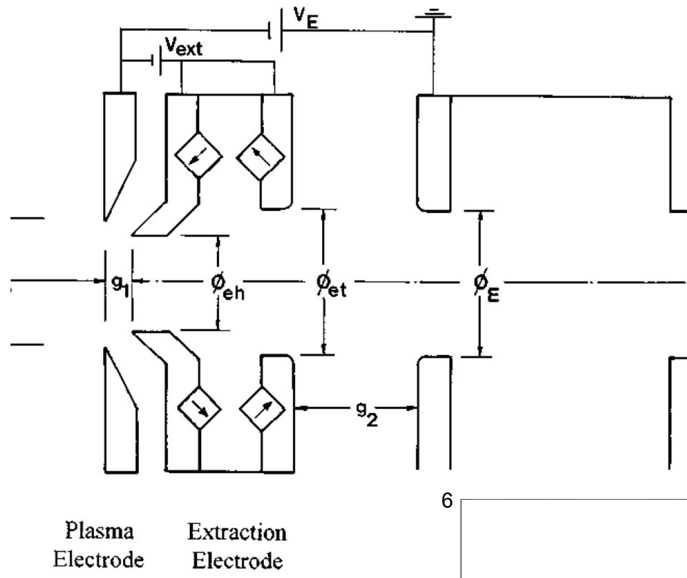
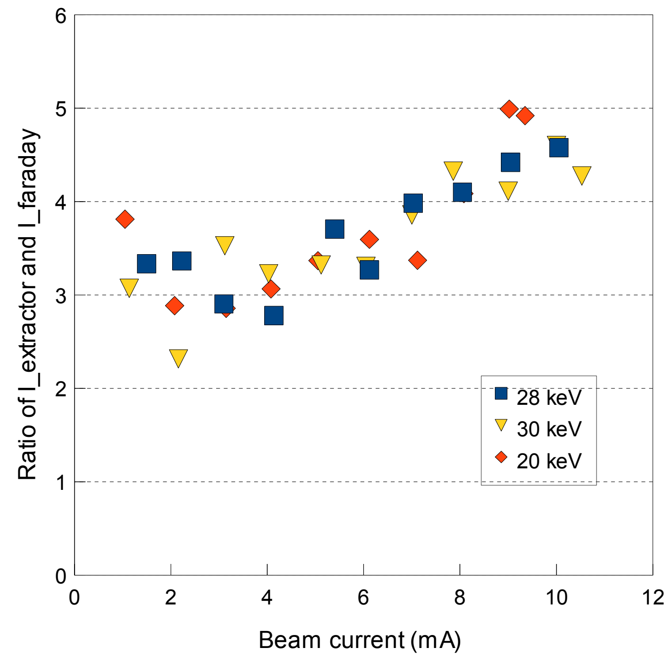
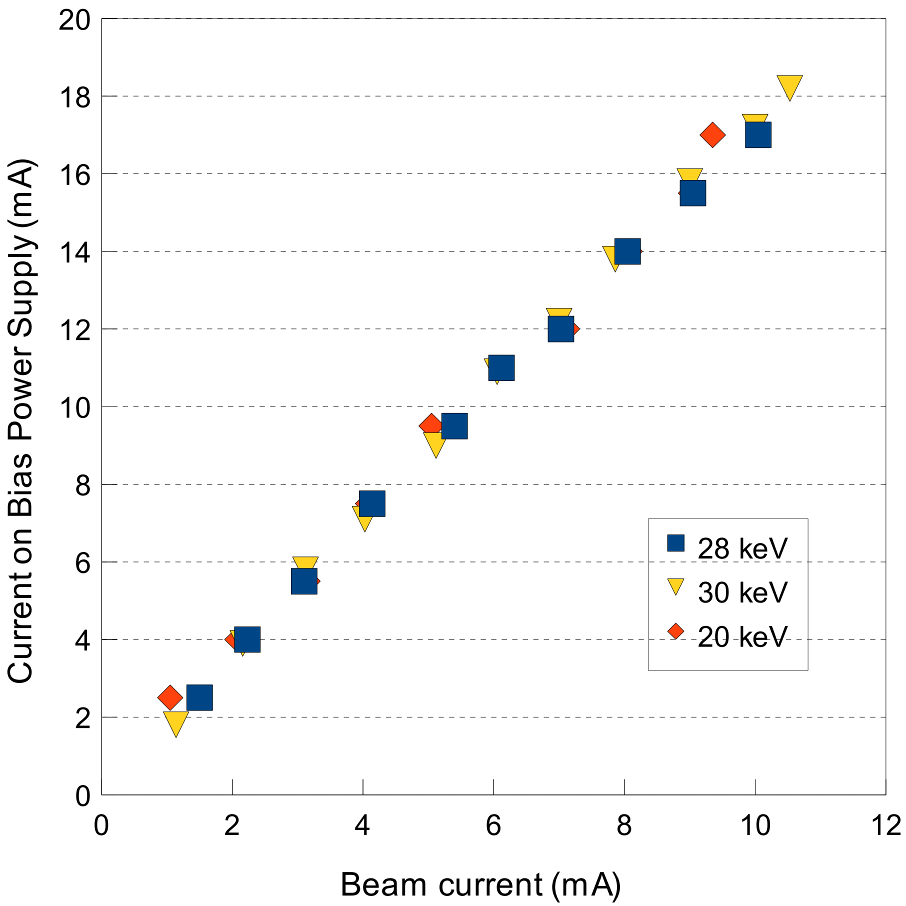


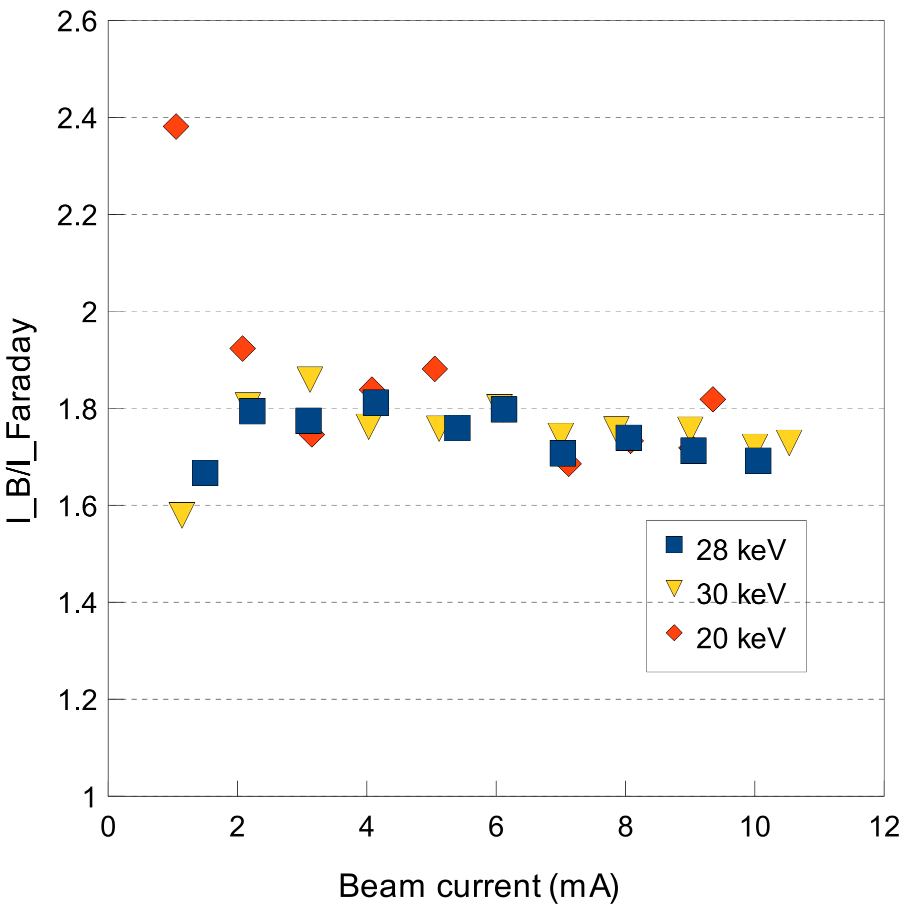
FIG. 4. Performance of the 15 mA dc H$^-$ source in terms of e/H$^-$ ratio, emittance, and brightness.



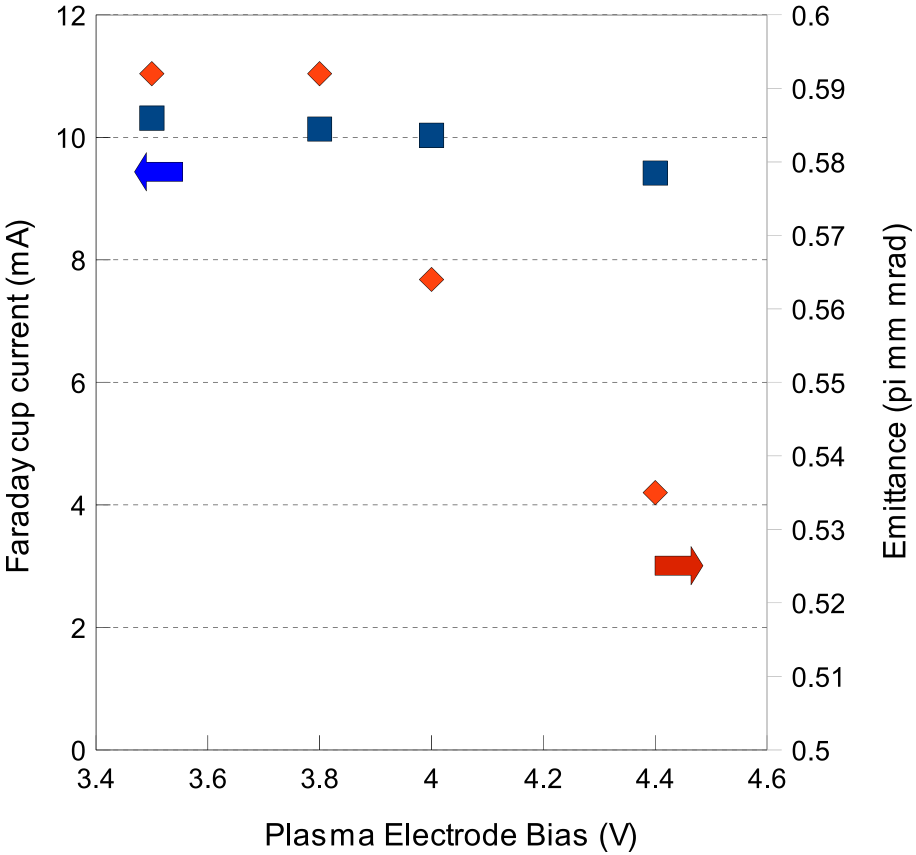


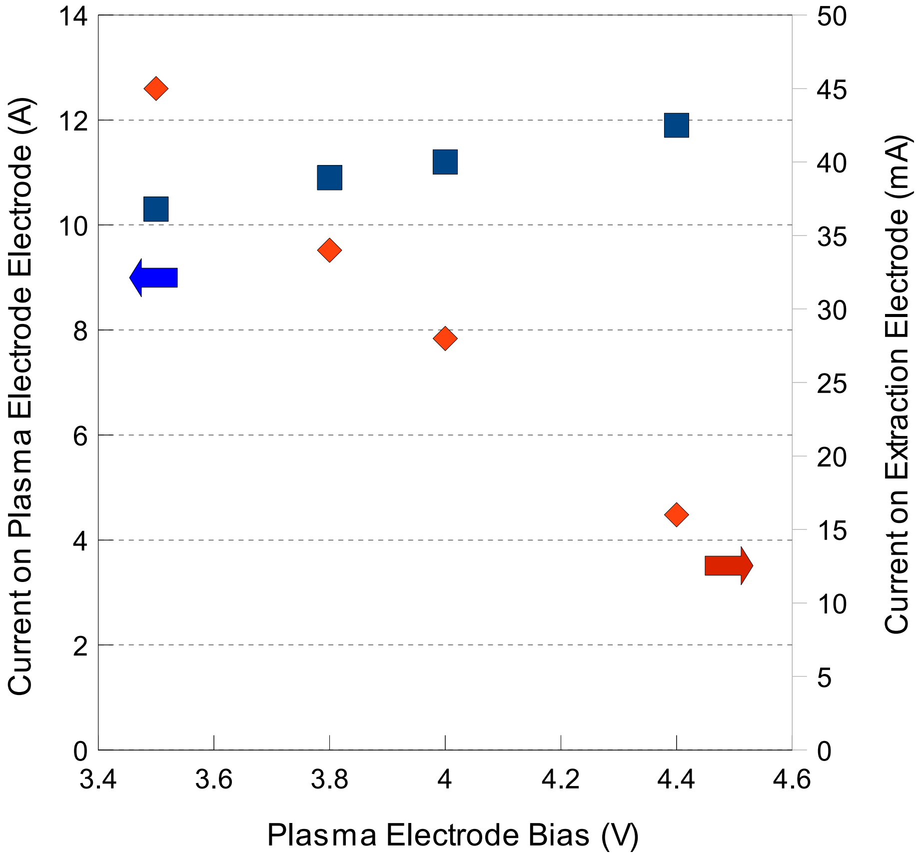
Bias Power Supply Parameters for Various Beam Output





Plasma Electrode Bias Dependence





Future Plan

- Near term:
  - LEBT beam dynamics study
    - Use the experimental data from acceptance tests to conduct end-to-end simulation on LEBT and RFQ
  - Ion Source
    - Setup of the ion source test stand at LBNL
    - Repeat the current and emittance measurement at LBNL
    - Optimization of the extraction system
- Long term:
  - LEBT design and beam test
    - Development of magnetic LEBT prototype incrementally
    - LEBT chopper and matching to RFQ
    - Beam testing