TRIUMF

Canada's particle accelerator centre
Centre canadien d'accélération des particules

Emittance measurements of H$^-$ ion source for the new ion source terminal at TRIUMF

S. Saminathan, K. Jayamanna, B. Minato, M. Lovera, O. Law and Y. Bylinski

TRIUMF, Vancouver, BC, Canada

Abstract

TRIUMF's 500 MeV cyclotron has been fed by an arc discharge H$^-$ ion source developed in-house 30 years ago. Since then, the operational (ISAC) and the new (ARIEL) rare isotope facilities in TRIUMF have required more and more proton beam current from the cyclotron. To satisfy the growing intensity of proton beams from cyclotron, the ion source beam current and brightness needed to be improved. The need for a state-of-the-art new ion source became an increasingly prominent concern. A new H$^-$ source is under developments to produce a high brightness H$^-$ beam with a long filament life for the new ion source injection terminal (I2) in addition to the existing terminal (I1). At present the source being characterized in our test bench (I3) equipped with an emittance scanner and beam intensity measuring devices, and source characterization is well underway.

Basic beam injection requirements for the TRIUMF's 500 MeV cyclotron

Required beam from the new injection terminal-2 (I2)

- Beam species: H$^-$
- Beam energy at the source exit: 25 – 30 keV
- Beam energy at the accelerator column exit: 300 keV
- Beam intensity: $\geq$1 mA
- Beam instability [RMS]: $<$5 %
- Normalized beam emittance [4 RMS]: $<$0.3 μm
- Energy spread [4 RMS]: $<$5 eV

New H$^-$ ion source at the I3 test terminal

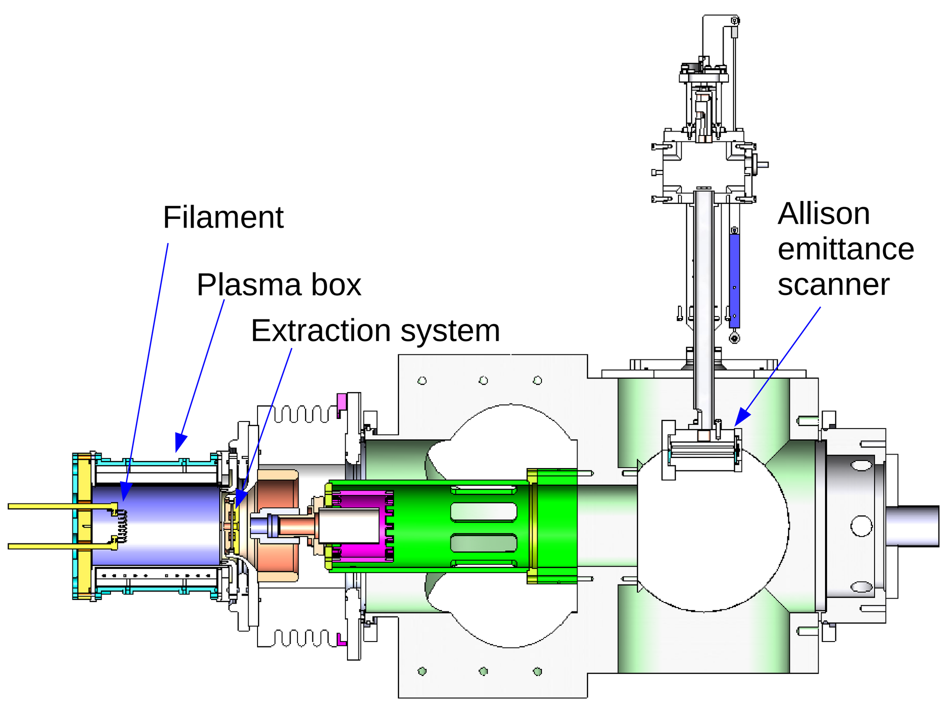

Figure 1: Schematic view of the prototype I2 ion source with an extraction system installed at the I3 test terminal.

Injection terminals I1 & I2 at TRIUMF

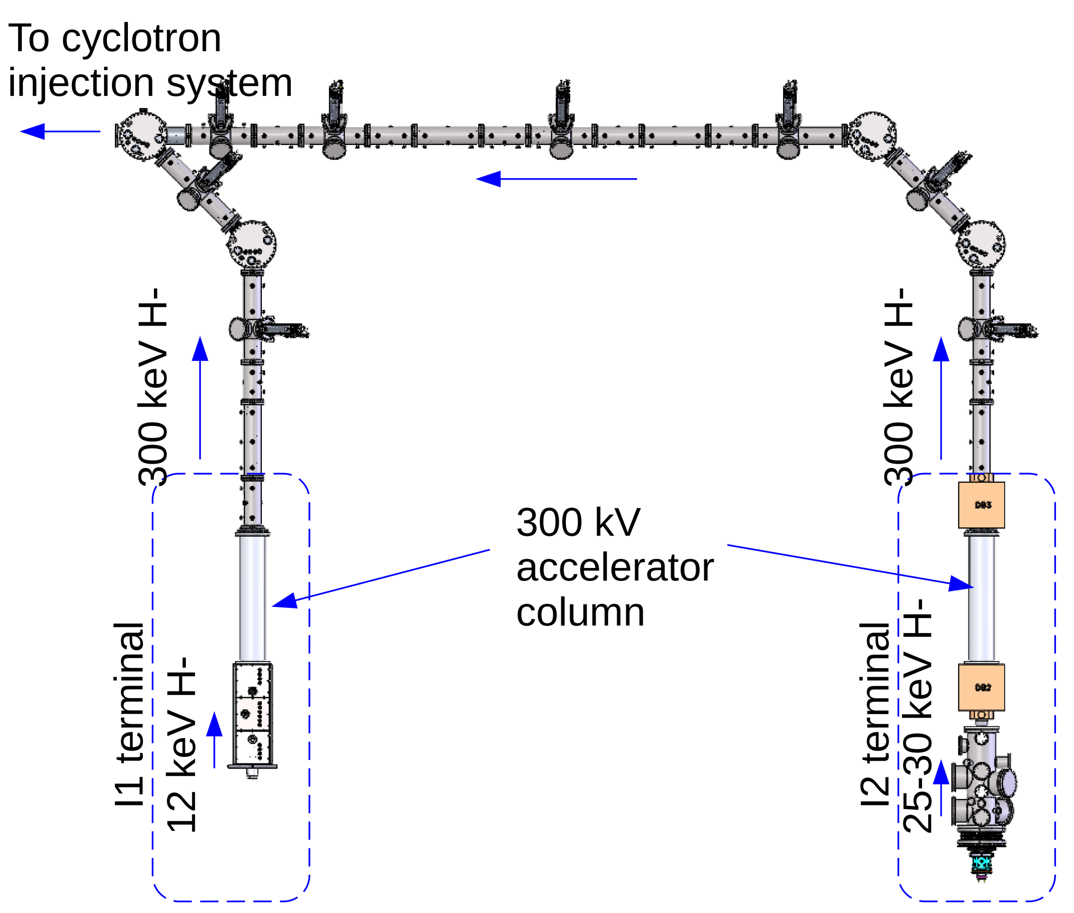

Figure 2: Layout of the existing injection terminal (I1) and the new injection terminal (I2).

Features

Features	Existing I1 terminal	New I2 terminal
Plasma source	Filament and arc based	Filament and arc based
Extraction aperture size	8.6 mm	6.0 mm
Magnet configuration	10 Row cusp (Bmax = 0.4 T)	20 Row Halbach configuration (Bmax = 1 T)
Beam intensity	Limited to 500 μA	Up to 1000 μA
Extracted beam energy	Limited to 12 keV	25 – 30 keV
Transport optics	Electrostatic elements	Magnetic elements

Table 1: Main features between the existing injection terminal (I1) and the new injection terminal (I2).

Measured phase-space for the I1 ion source terminal

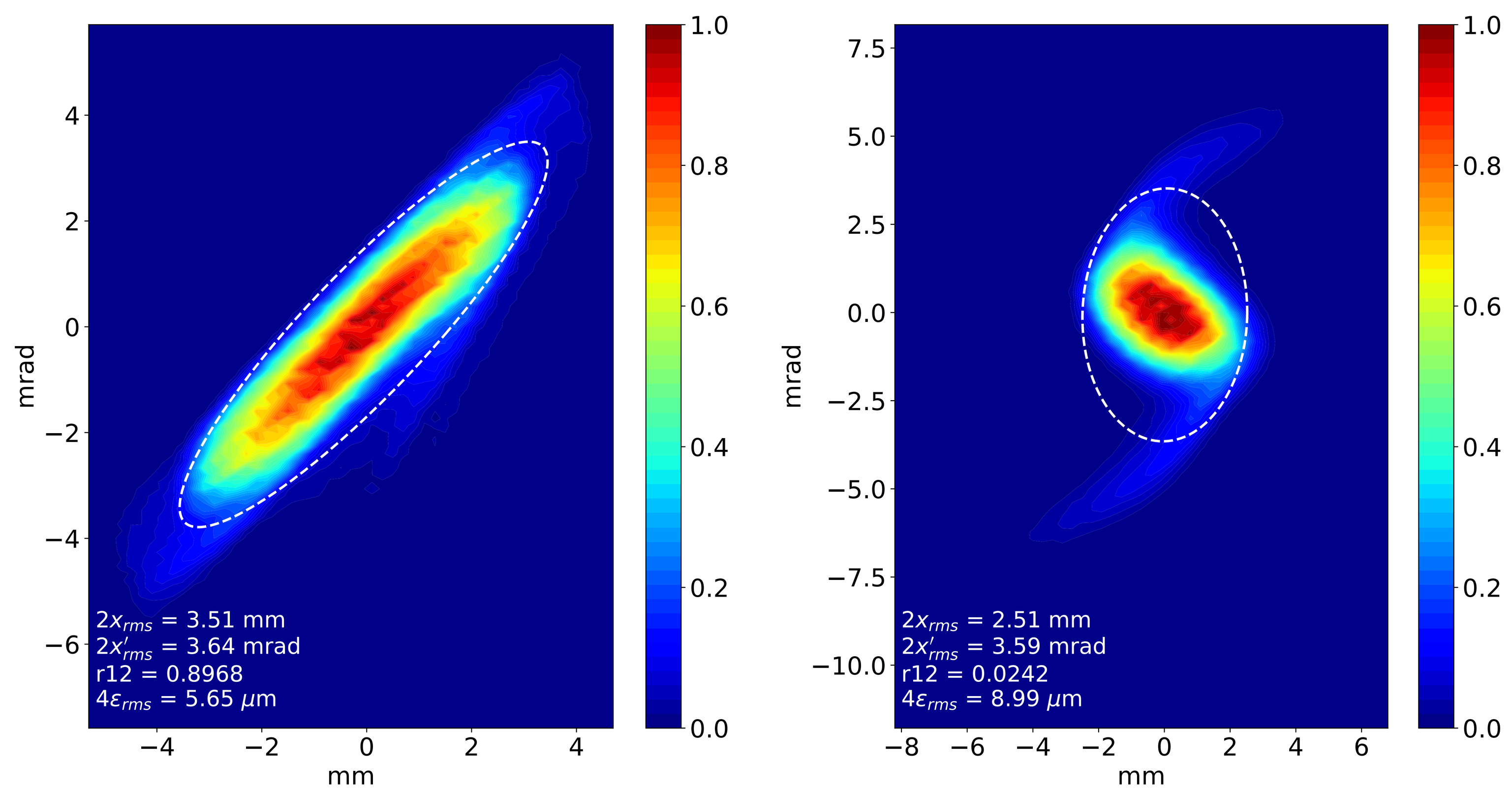

Figure 3: Left: Measured phase-space in the horizontal plane at the I1 accelerator column exit for a 300 keV H$^-$ beam. Right: Measured phase-space in the vertical plane at the I1 accelerator column exit for a 300 keV H$^-$ beam.

Measured phase-space for the new I2 source at the I3 test terminal

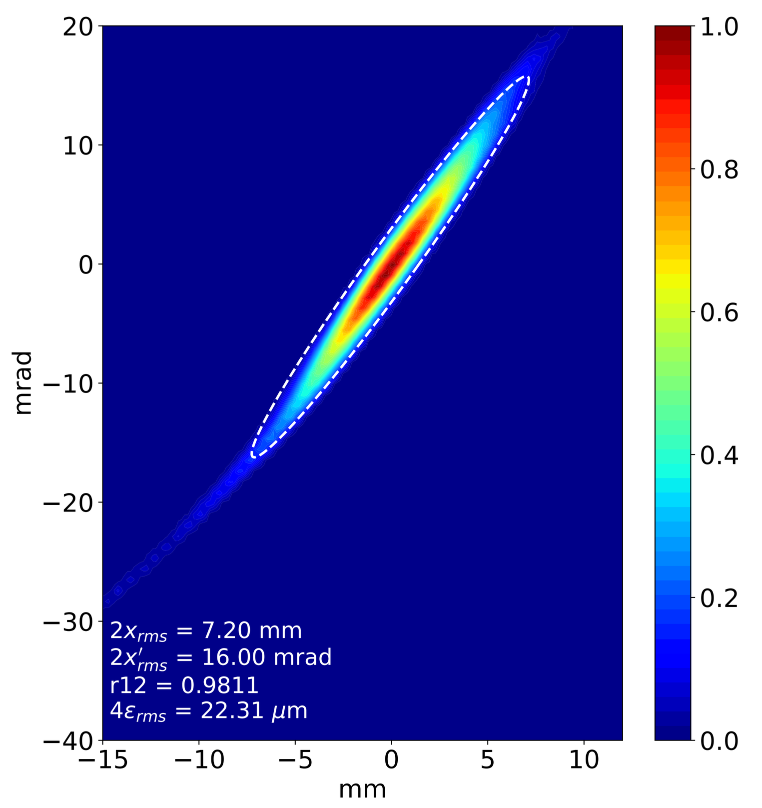

Figure 4: Measured phase-space in the horizontal plane at the source exit for a 25 keV H$^-$ beam with an extraction voltage of 1.4 kV.

Ion source	$n\epsilon_x$ (μm)	$n\epsilon_y$ (μm)	μA
I1	0.1418	0.2254	602
I2	0.1628	–	932

Table 2: Measured 4RMS normalized emittance ($n\epsilon$) at the existing ion source (I1) and the new ion source (I2) at the test bench.

Conclusion

- Within the cyclotron acceptance the beam intensity from the new prototype I2 ion source is about 55% higher compare to the I1 source terminal.

References

[1] T. Kuo, D. Yuan, K. Jayamanna, M. Mcdonald, R. Baartman, P. Schmor and G. Dutto. "On the development of a 15 mA direct current H multicusp source." Review of Scientific Instruments, 67, pp. 1314-1316, 1996.

[2] K. Jayamanna, I. Aguilar, I. Bylinskii, G. Cojocaru, R. L. Dube, R. Laplante, D., Louie, M., Lovera, B. Minato, m. Mouat and S. Saminathan. "A 20 mA H- Ion Source with Accel-Accel-Decel Extraction system at TRIUMF." Proceedings of Cyclotrons, TUPPT022, 2013.

[3] K. Jayamanna, F. Ames, I. Bylinski, M. Lovera and B. Minato. "A 60 mA DC H multi cusp ion source developed at TRIUMF." Nuclear Instruments & Methods in Physics Research Section A-accelerators Spectrometers Detectors and Associated Equipment, 895, pp. 150-157, 2018.

[4] K. Jayamanna, R. Baartman, I. Bylinski, T. Planche and R. Simpson. "Single ring permanent magnet lens." In International Particle Accelerator Conference. 2018.