CANREB Developments at TRIUMF

B. E. Schultz, M. Cavenaile, M. Hartmann, F. Ames, O. Kester, TRIUMF, Vancouver, Canada

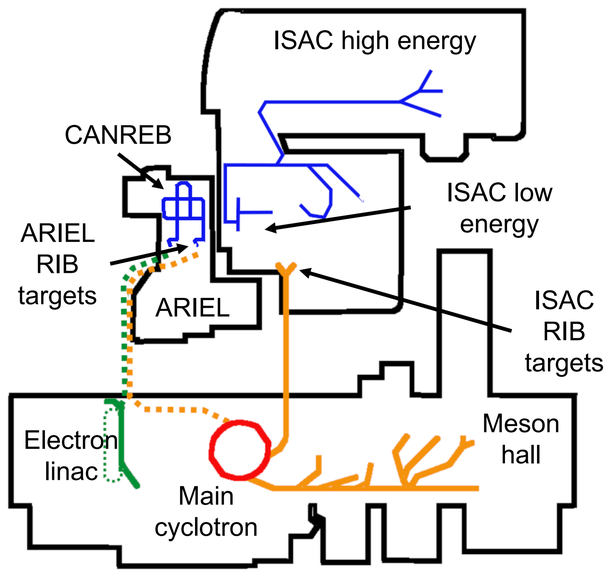

Figure 1: Layout of TRIUMF site.

1 Introduction

- TRIUMF's 500 MeV cyclotron provides up to 100 μA of p+ on target for rare isotope beam (RIB) production for experiments in the Isotope Separator and Accelerator (ISAC) facility [1]
- The Advanced Rare Isotope Laboratory (ARIEL) will add two additional RIB target stations: one driven by a 30 MeV (300 kW) electron linac and the other by an additional p+ driver beam → This will facilitate delivery of up to three simultaneous RIB beams to users
- Post-acceleration of ion beams requires A/q < 7 → For high-mass beams, charge state breeding is required, which is currently done using an ECRIS [2]
- Within ARIEL is the CANadian Rare isotope facility with Electron Beam ion source (CANREB), which will provide additional charge breeding capabilities using an EBIS
- CANREB also contains a high-resolution magnetic mass separator (R = 20,000) for isobaric purification of RIB from ARIEL targets [3]

2 CANREB overview

- CANREB contains an EBIS for charge state breeding of rare isotopes for post-acceleration
- Charge bred ions have A/q < 6 with an energy of 2.04 keV/nucleon
- Ions can be transported from existing OLIS and ISAC targets, and in future from ARIEL
- Beam is bunched in an RFQ cooler buncher and energy matched into the EBIS using a pulsed drift tube
- Ions are charge bred for up to 10 ms (@ 100 Hz)
- Charge bred beam is A/q-selected using a Nier spectrometer before injection into the linac
- Yield of charge bred RIB are measured at Yield station

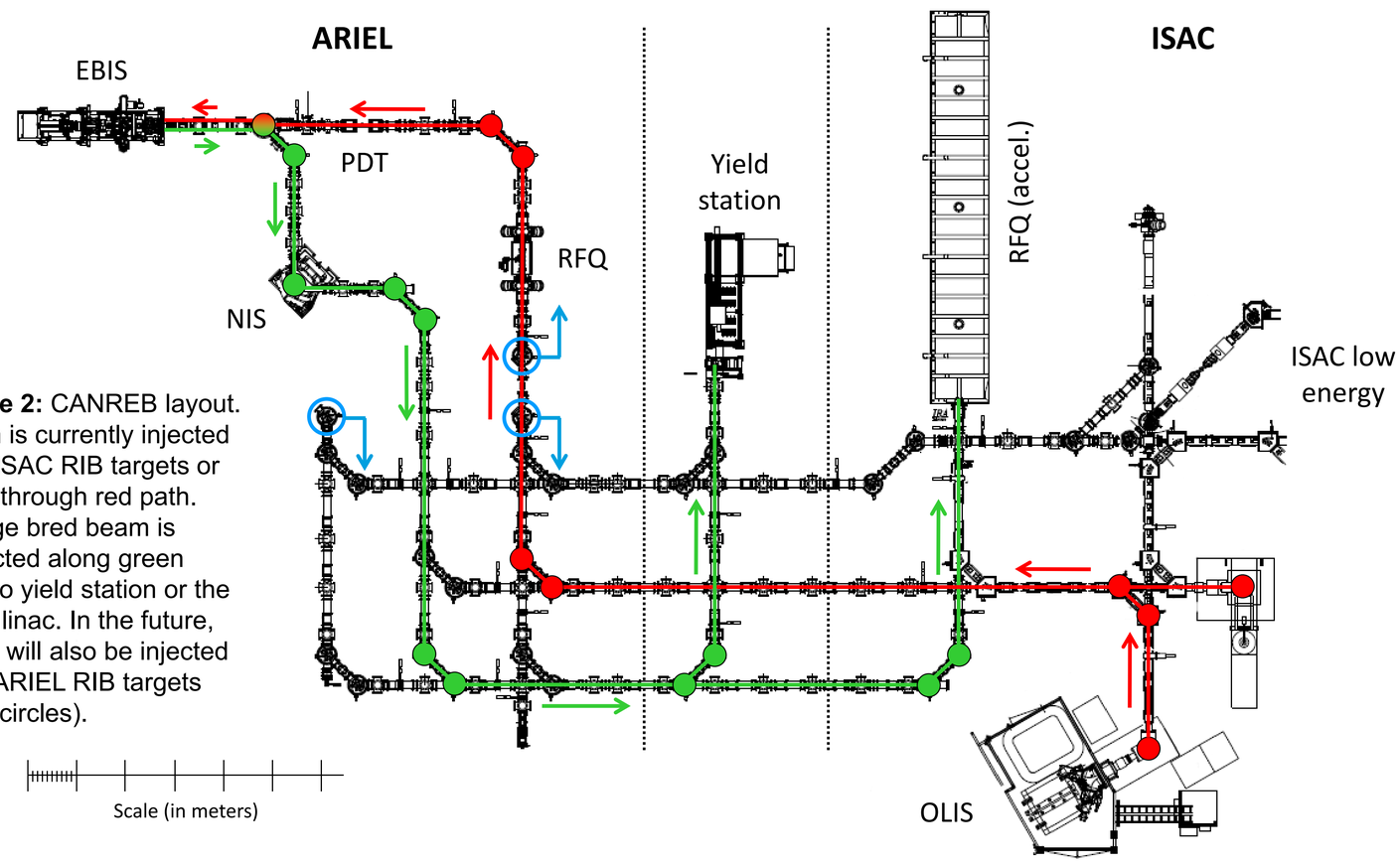

Figure 2: CANREB layout. Beam is currently injected from ISAC RIB targets or OLIS through red path. Charge bred beam is extracted along green path to yield station or the ISAC linac. In the future, beam will also be injected from ARIEL RIB targets (blue circles).

3 EBIS electron gun

- Current from electron gun was limited to < 30 mA before becoming unstable
- Investigations revealed electrode misalignment and a residual magnetization in soft iron as possible causes
- TITAN group at TRIUMF has designed a new e-gun for their system, and with minor modifications can be fabricated and installed in CANREB [4]
- TITAN is currently commissioning their e-gun: Extracted current of 100 mA has been achieved and work is being done to go higher
- CANREB version will be fabricated and commissioned in 2026

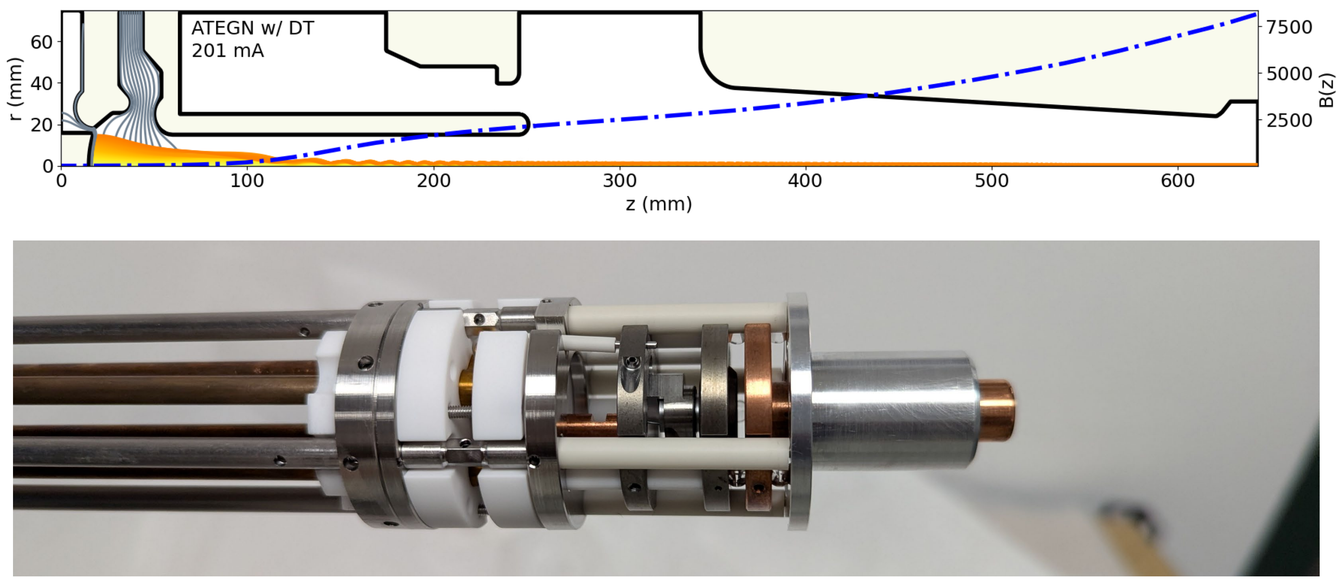

Figure 3: (Top) EGUN simulation of electron beam extraction into a 1 Tesla magnetic field. (Bottom) Picture of assembled cathode and optics assembly for the TITAN e-gun design.

4 EBIS pulse stretching

- Ion bunches injected into the EBIS are ~1 μs wide and contain ~10^6 particles → Instantaneous intensity ~10^{12} pps
- Pulses need to be stretched to prevent issues with experimenter's data acquisition systems
- Proof-of-principle pulse stretching up to 1 ms has been demonstrated using a simple step-wise ramp function [5]

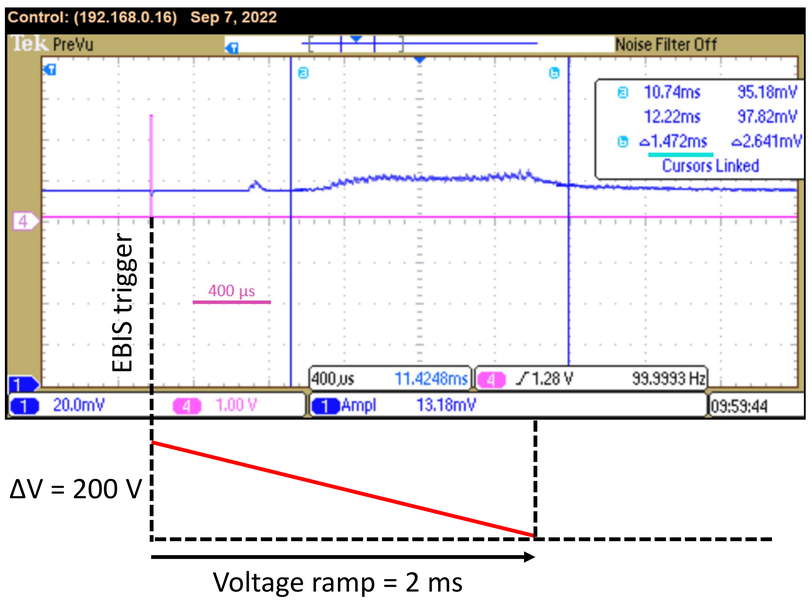

Figure 4: Oscilloscope trace of $^{85}Rb^{9+}$ ions extracted from the CANREB EBIS and detected on a CEM. The extraction function was a series of ~50 steps (total time 2 ms) with a total voltage drop of 200 V from trap open to trap closed.

5 CANREB status and plans

- EBIS performance limited by high voltage (HV) discharge [6] and electron gun issues
- Removal of thermal shields near the EBIS trumpet electrodes has improved the HV situation → Stable operation at 10 kV appears feasible (requires long-term testing), and A/q = 5 should be sufficient for ISAC science program
- E-gun testing will continue at TITAN in parallel with simulations
- Plan to have CANREB e-gun fabricated in early 2026 and bring CANREB to operational state for beam delivery in 2027

[1] ISAC and ARIEL: The TRIUMF Radioactive Beam Facilities and the Scientific Program ed J Dilling et al (Dordrecht: Springer).
[2] F. Ames, R. Baartman, P. Bricault and K. Jayamanna, Hyperfine Interact., vol. 225, pp. 63–67, 2014.
[3] M. Marchetto et al., Nucl. Instrum. Methods Phys. Res. B, vol. 463, pp. 227–231, 2020.
[4] J.D. Cardona et al, J. Phys. Conf. Ser. 2244 012075 (2022).
[5] M. Cavenaile et al, J. Phys. Conf. Ser. 2743 012077 (2024).
[6] C. Charles et al, J. Phys. Conf. Ser. 2244 012073 (2022).