A Real-Time AC Current Monitoring (ACCT) System for TRIUMF Driver Accelerators

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On behalf of
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TRIUMF

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- ACCT assembly and specifications
- External source test
- Beam test
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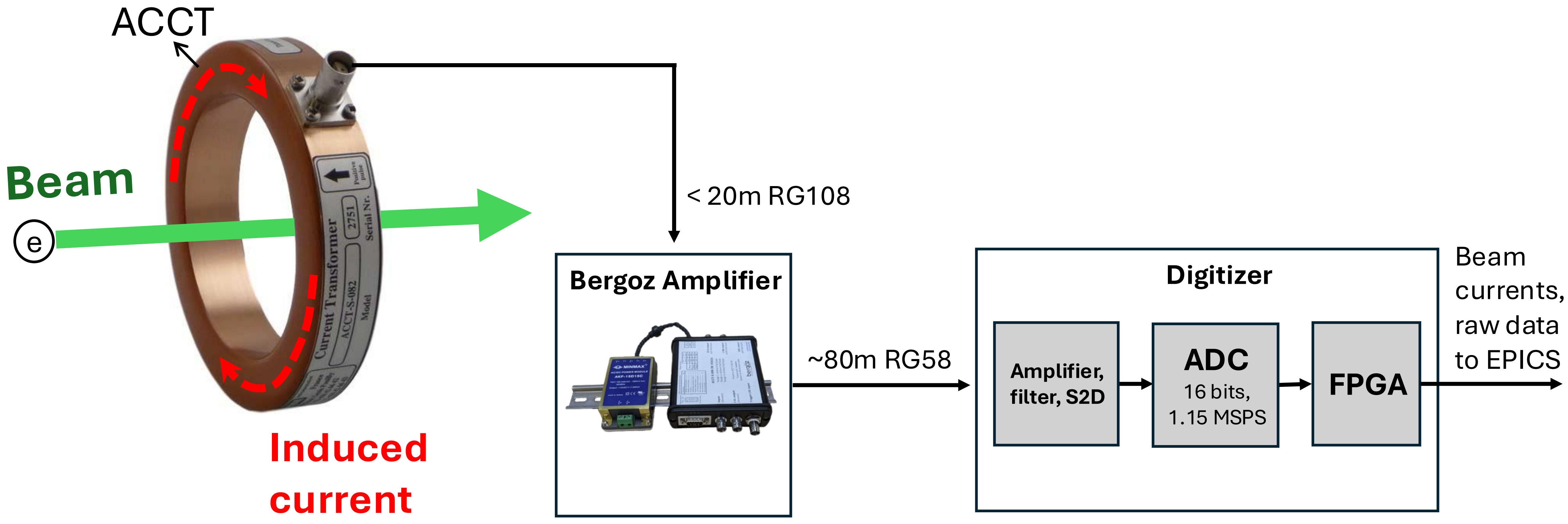
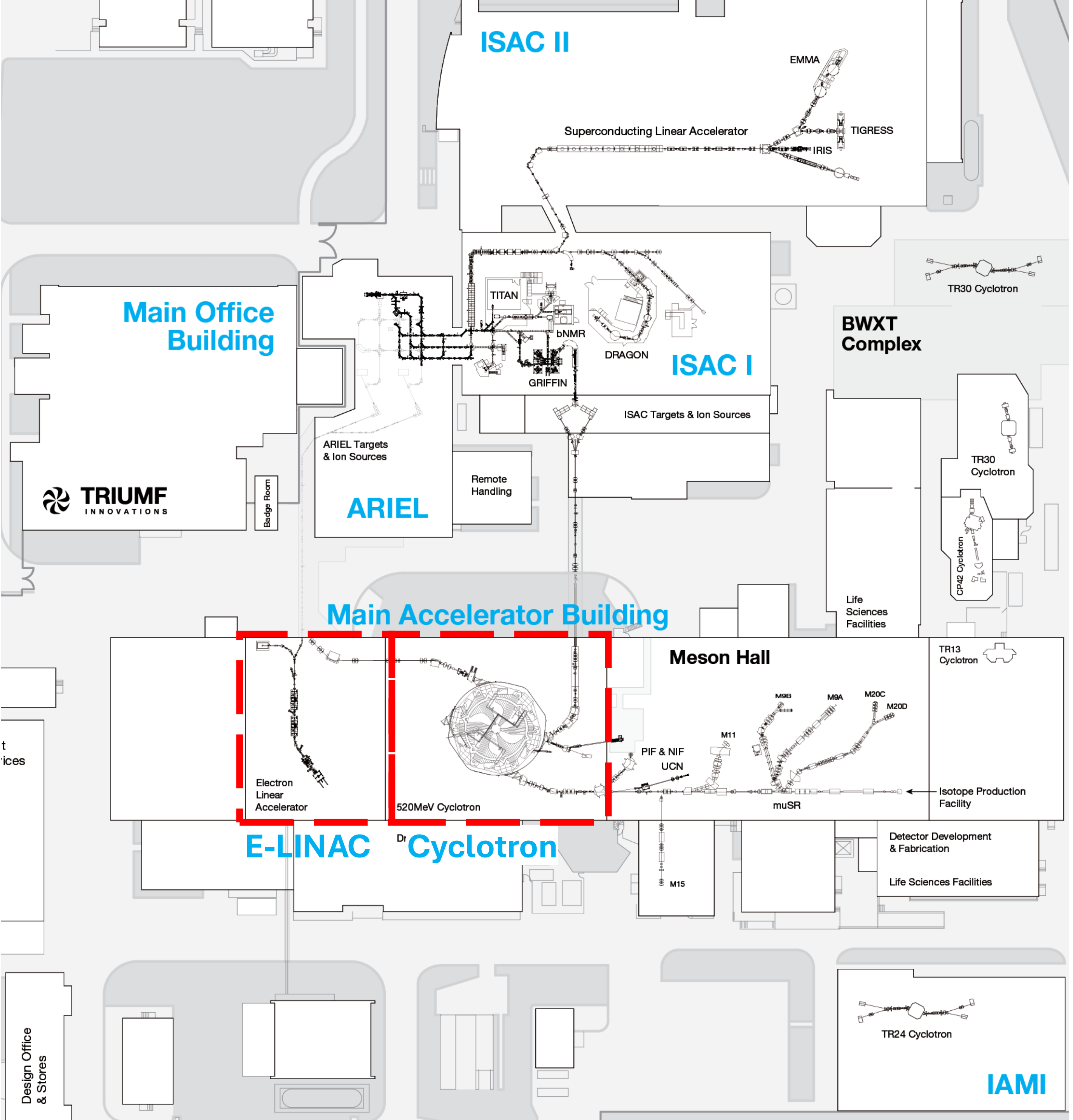
Introductions of AC Current Transformer (ACCT)



Main features of an ACCT

- Enables continuous, uninterrupted, non-invasive beam monitoring.
- Independent of the beam's temporal structure, position, shape and energy.
- Cannot be used for measuring a continuous (CW) beam current. The beam must be pulsed, with a macro-pulse repetition frequency that falls within the device's bandwidth.



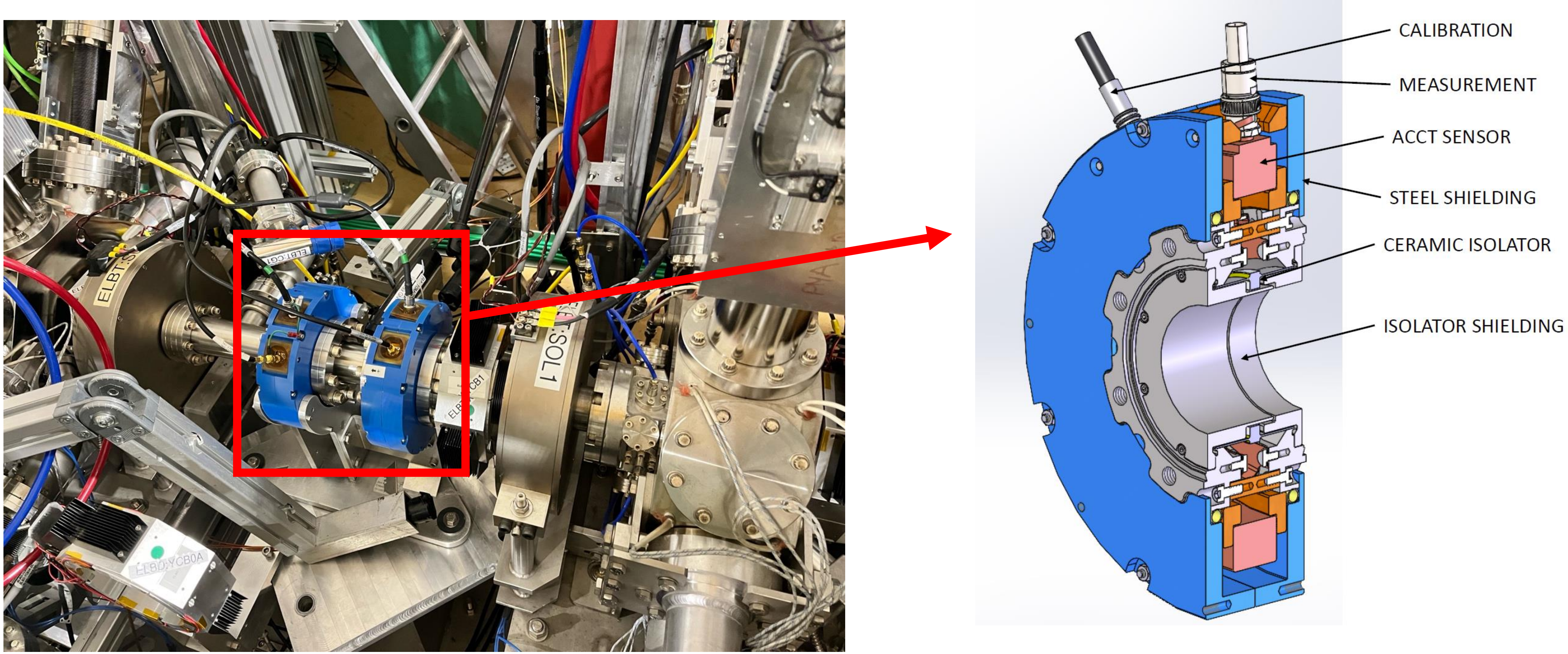
TRIUMF accelerator complex

Main high-power drivers:

- 520 MeV Cyclotron
- 100 kW e-LINAC

ACCTs used here

Example of ACCT Assembly



Specifications

Table 1: Specifications of the Bergoz ACCT Sensor with 25m RG108 cables [1].

Parameter	Value
Model name	Bergoz in-air ACCT sensor #ACCT-S-122-CAW1 (1-turn calibration winding, 122 mm ID)
Ratio accuracy error	< 0.1% F.S.
Frequency range (–3 dB)	3 Hz to 1 MHz
Rise time	350 ns (10% to 90%)
Noise @ 10 mA F.S.	≈ 0.5 μA (rms)
Noise @ 100 mA F.S.	< 5 μA (rms)

[1] Bergoz. ACCT User Manual Version 6.3. Technical report, 2026

Example of drooped signal

Droop corrections

$X(s)$ is the Laplace transform of the input signal $x(t)$,

$$X(s) = \mathcal{L}\{x\}(t)$$

Signal transformation between input and output signal:

$$X_{\text{out}}(s) = X_{\text{in}}(s) \cdot H$$

The first order transfer function for a high-pass filter:

$$H_{\text{high}}(s) = \frac{\frac{s}{\omega_c}}{1 + \frac{s}{\omega_c}}$$

$$X_{\text{in}}(s) = X_{\text{out}}(s) \cdot \frac{1}{H} = X_{\text{out}}(s) \left[\frac{\omega_c}{s} + 1\right]$$

Droop corrections

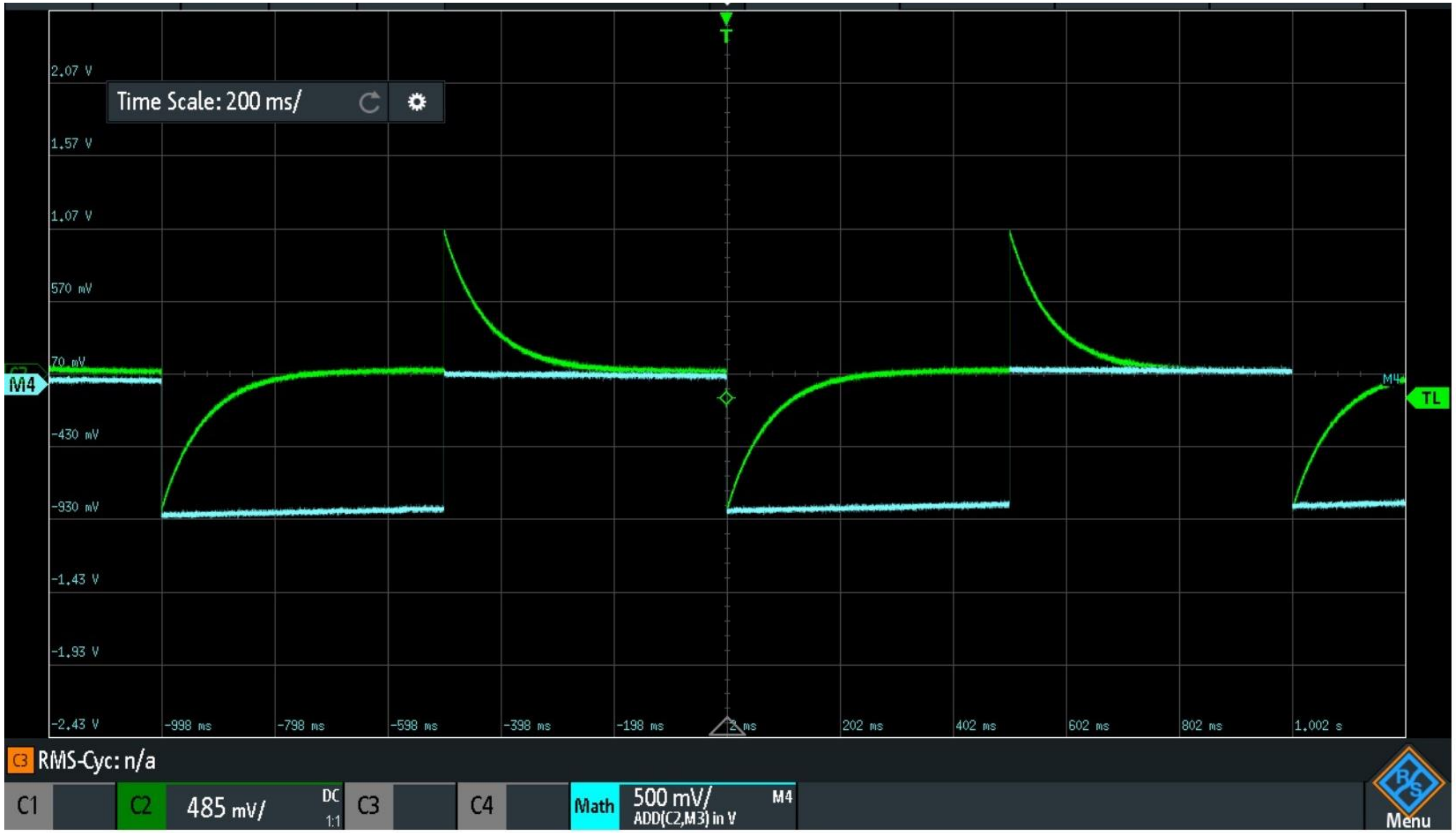
Perform the inverse Laplace transform to reconstruct the actual input signal :

$$\mathcal{L}^{-1}\{X_{\mathrm{in}}\}(s) = \mathcal{L}^{-1}\left\{\frac{\omega_c}{s}\, X_{\mathrm{out}}\right\}(s) + \mathcal{L}^{-1}\{X_{\mathrm{out}}\}(s)$$

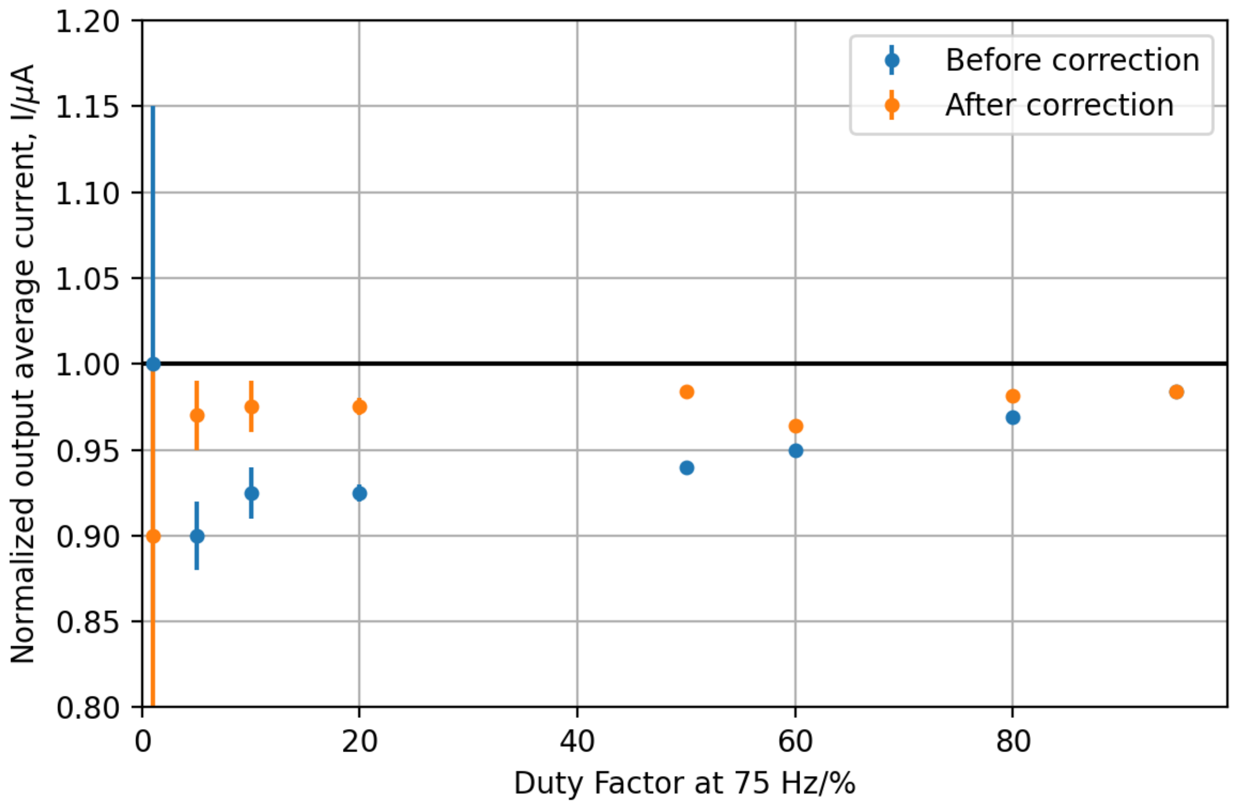
$$\boxed{\therefore\ x_{\mathrm{in}}(s) = \omega_c \int x_{\mathrm{out}}(t)dt + \ x_{\mathrm{out}}(t)}$$

Cutoff frequency, $\mathrm{f_c} = \frac{\omega_c}{2\pi} \approx 2.2\ \mathrm{Hz}$

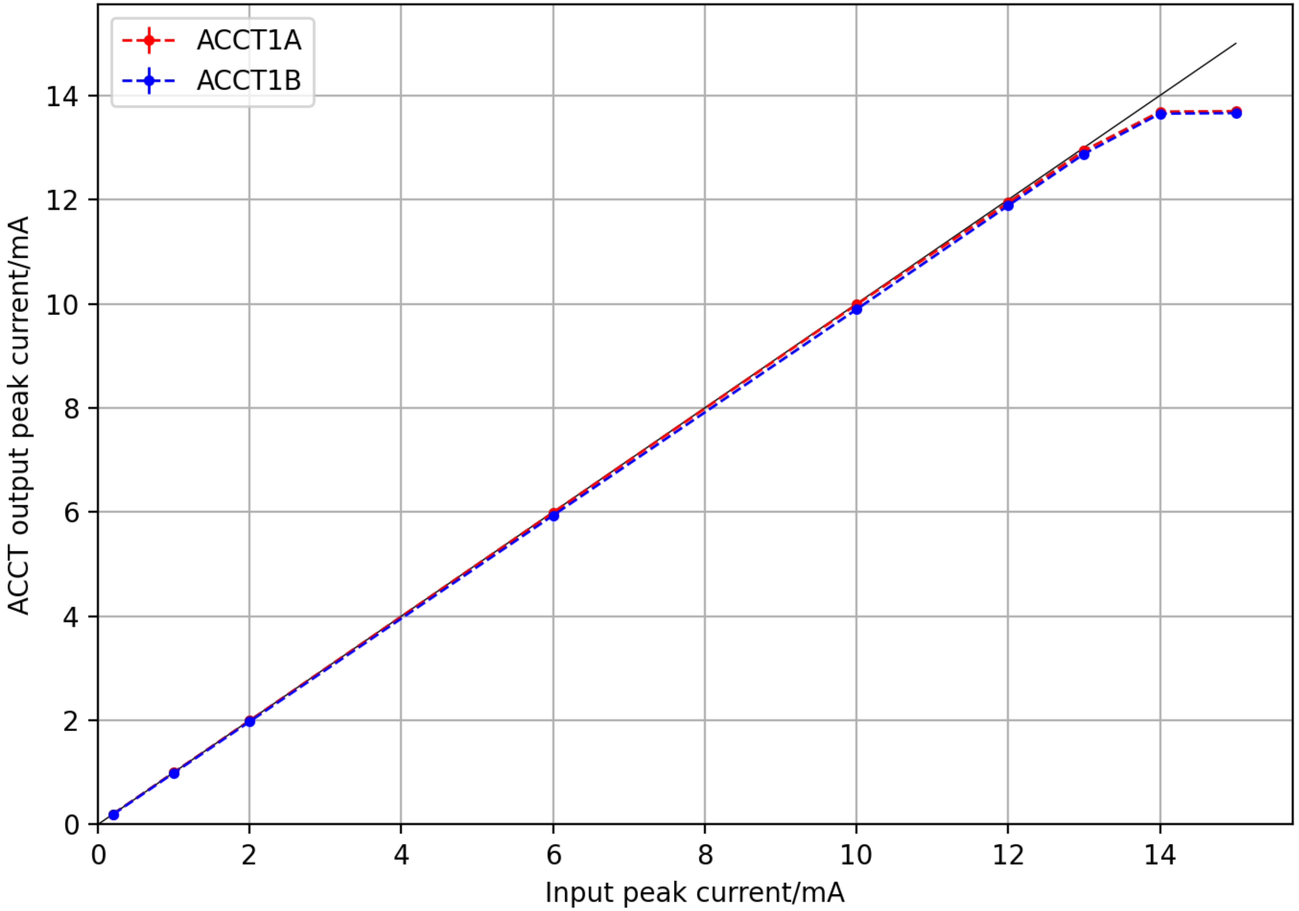
On-line droop correction



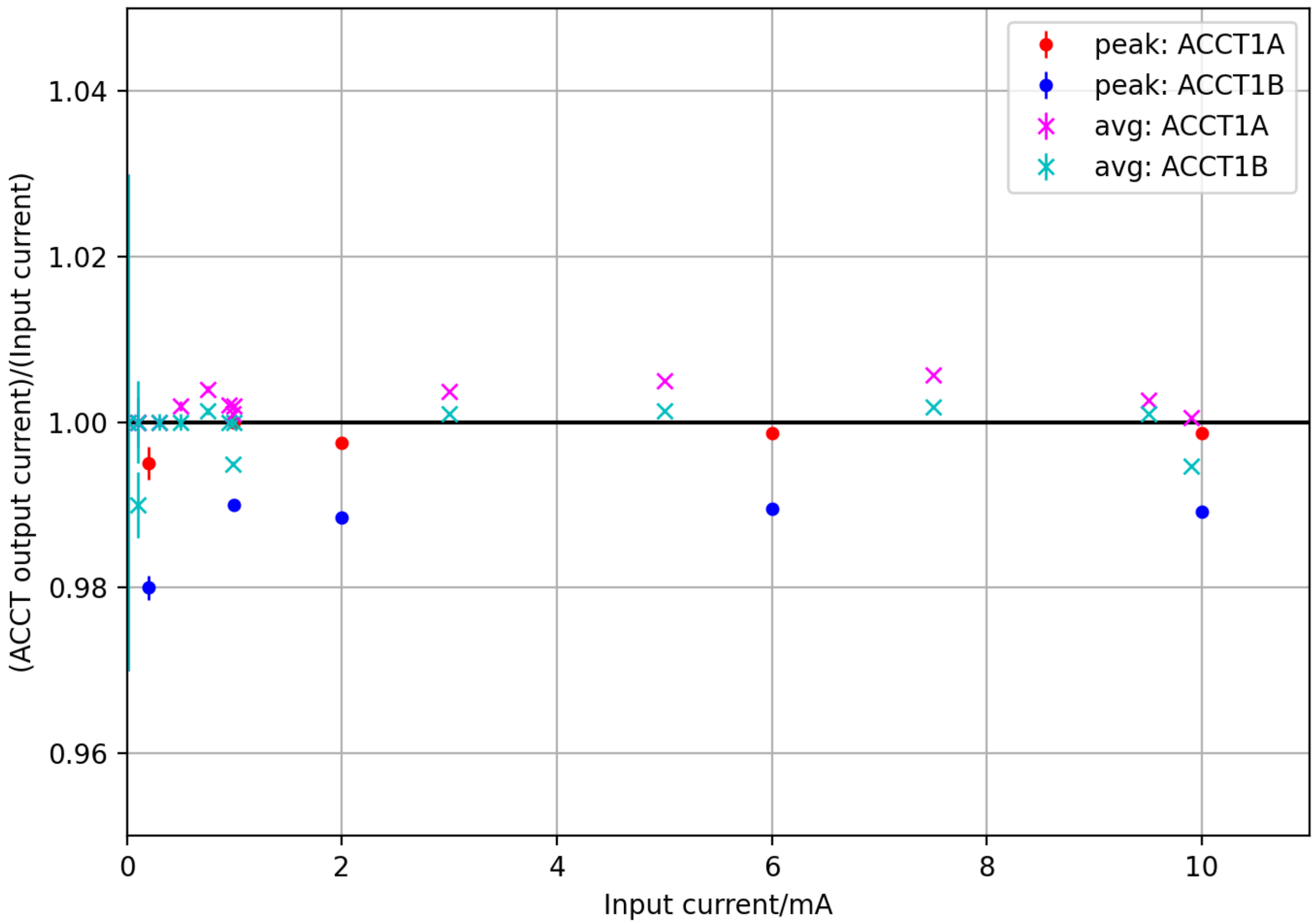
Comparison of average current after droop corrections



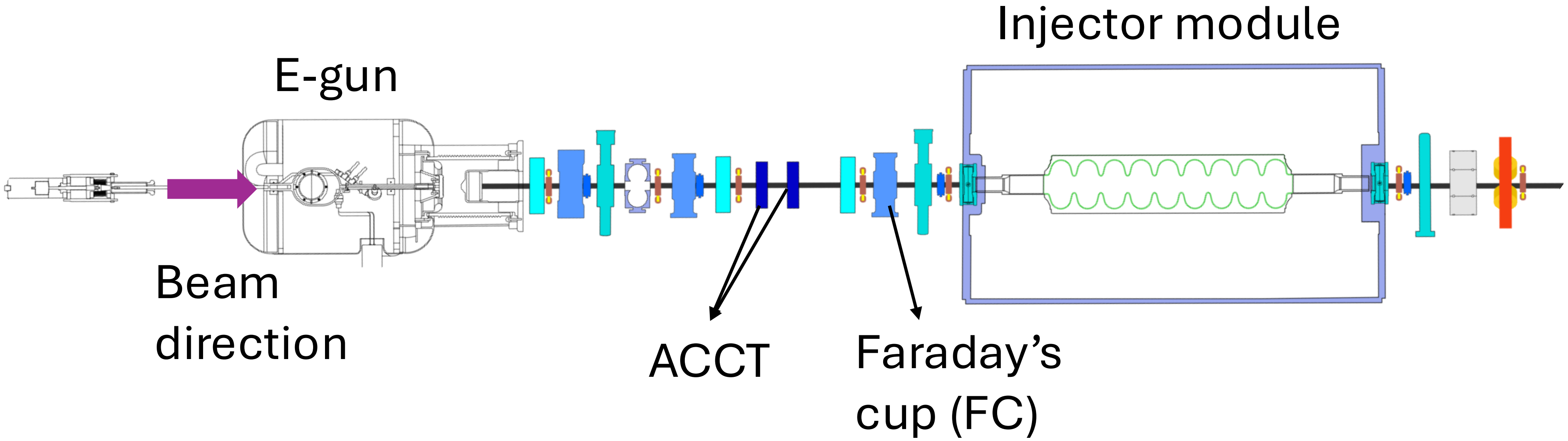
External source test: Operational current range



External source test: Relative error



ACCT Beam Test @ e-Linac:
Comparison between ACCT and FC



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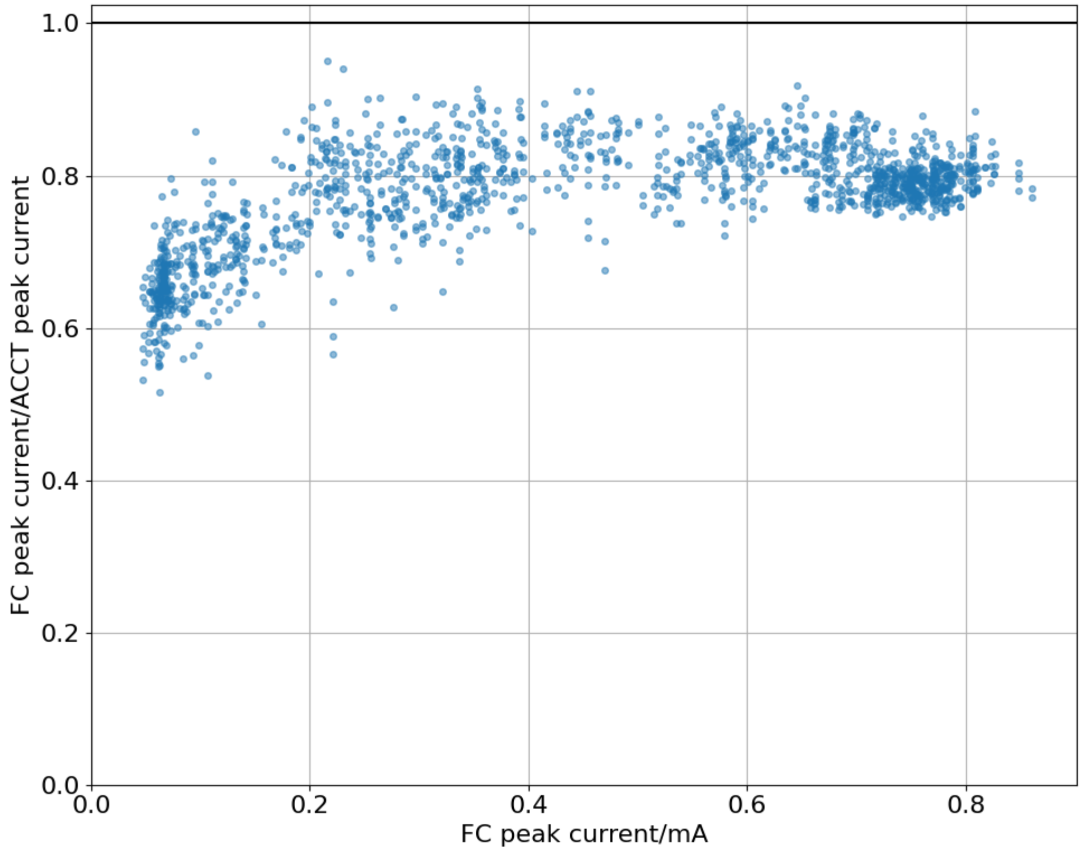
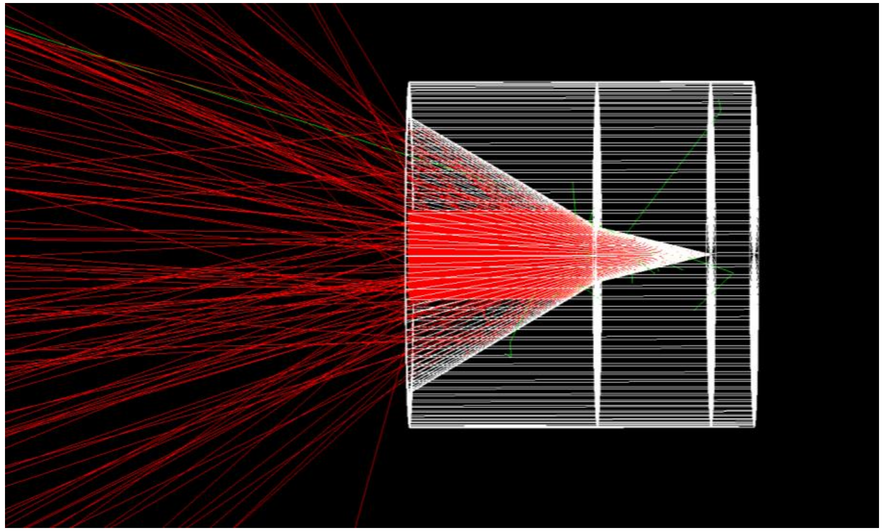
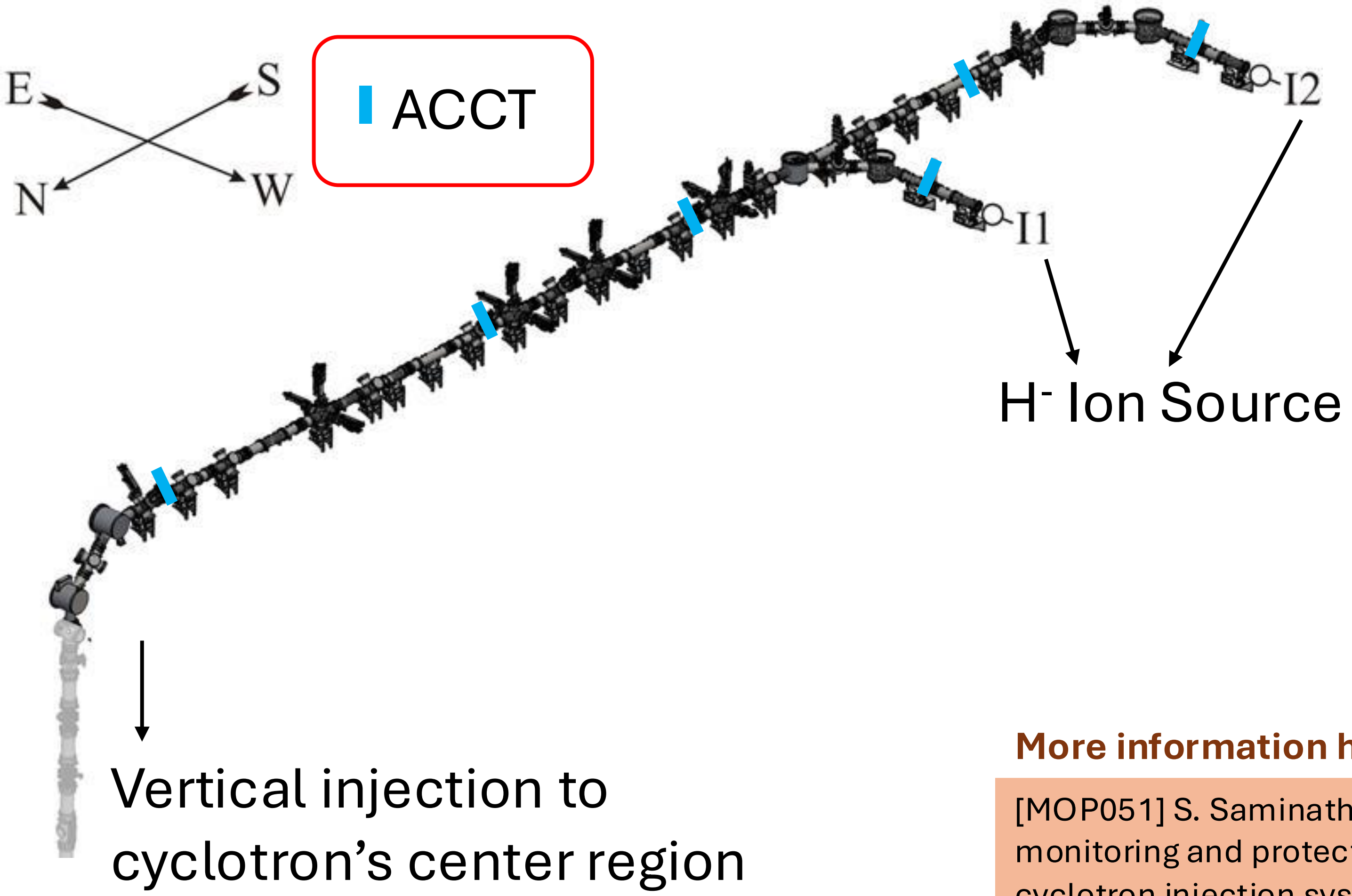




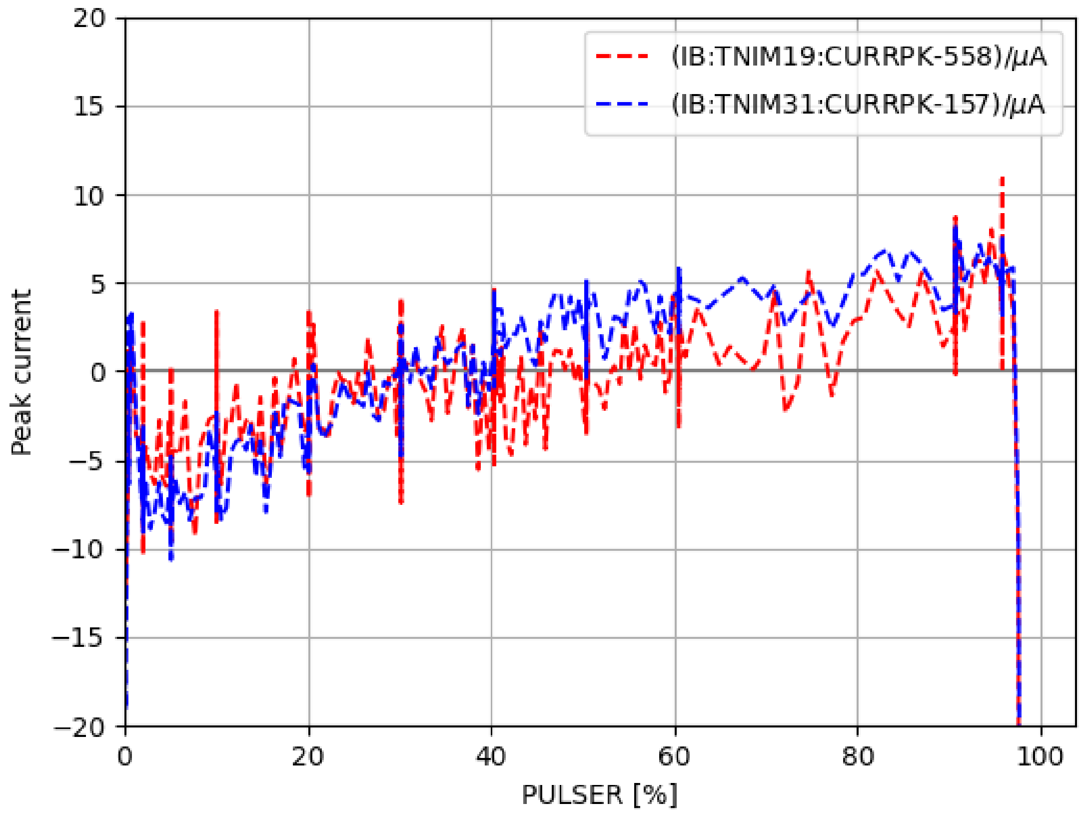
ACCT Beam Test @ Cyclotron Injection Beamline

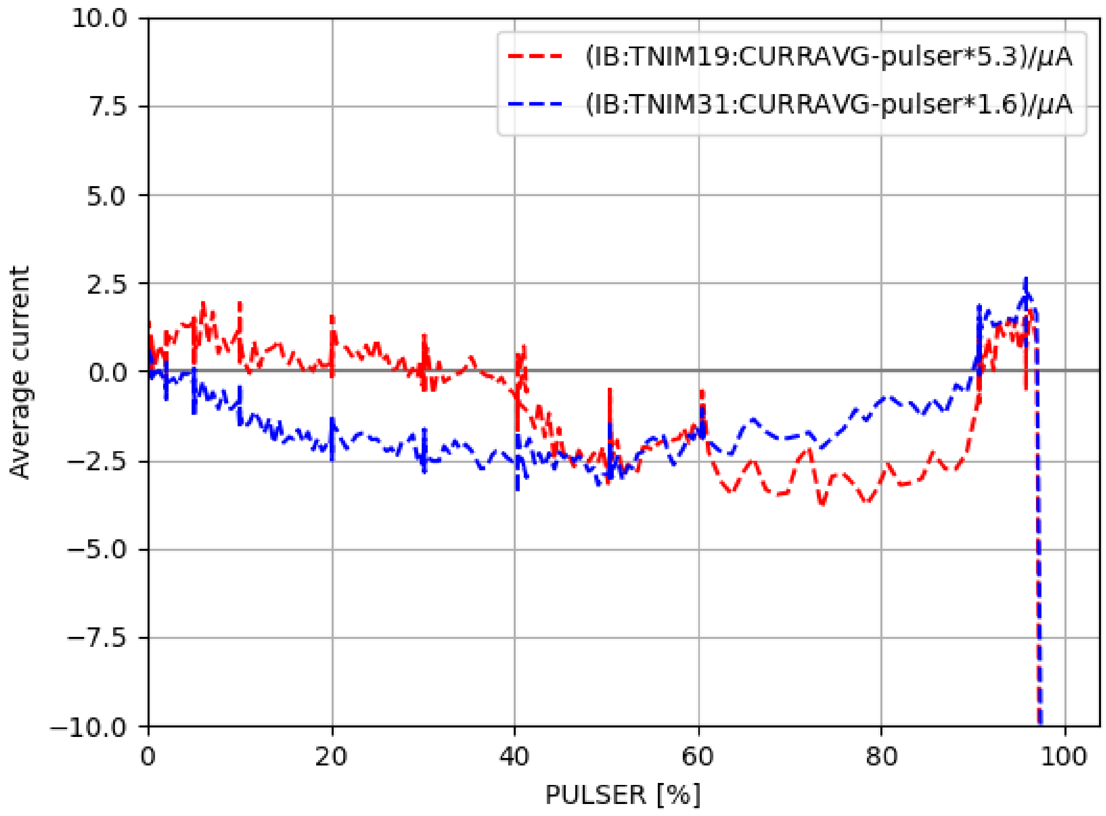


More information here:

[MOP051] S. Saminathan et Al. Beam loss monitoring and protection for the upgraded cyclotron injection system at TRIUMF

ACCT Beam Test @ Cyclotron Injection Beamline





Integration into Machine Protection System (MPS)

- **e-Linac**
  - Soft trip: $\text{Beam energy} \times \text{ACCT avg current} > \text{Selected power limit}$
  - Full trip: $\text{Beam energy} \times \text{latest ACCT avg current} > \text{Selected power limit}$ for 1 second

- **Cyclotron Injection Beamline (ISIS)**
  - Trip: $\Delta\text{ACCT avg current} - \sum^{n} \text{Beam loss on all watercooled surface} > 20\ \mu\text{A}$

Conclusions

- Overall, less than 2% measurement error with only a few µA noise, enabling real-time beam current monitoring.
- Confirmed as a reliable beam current monitor, outperforming interceptive devices such as the Faraday Cup (FC).
- Expanding ACCT installation in the new ARIEL beamlines (currently under construction) for continuous beam transmission monitoring across ~50 m, independent of beam shape, position, or structure.

More information here:

[MOP050] Martin Alcorta et Al. Design and Planned Commissioning of the ARIEL Beam Loss Monitors

Thank you

Merci

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