

Commissioning of the Ariel E-Linac Beam Loss Monitor System

Martin Alcorta
TRIUMF



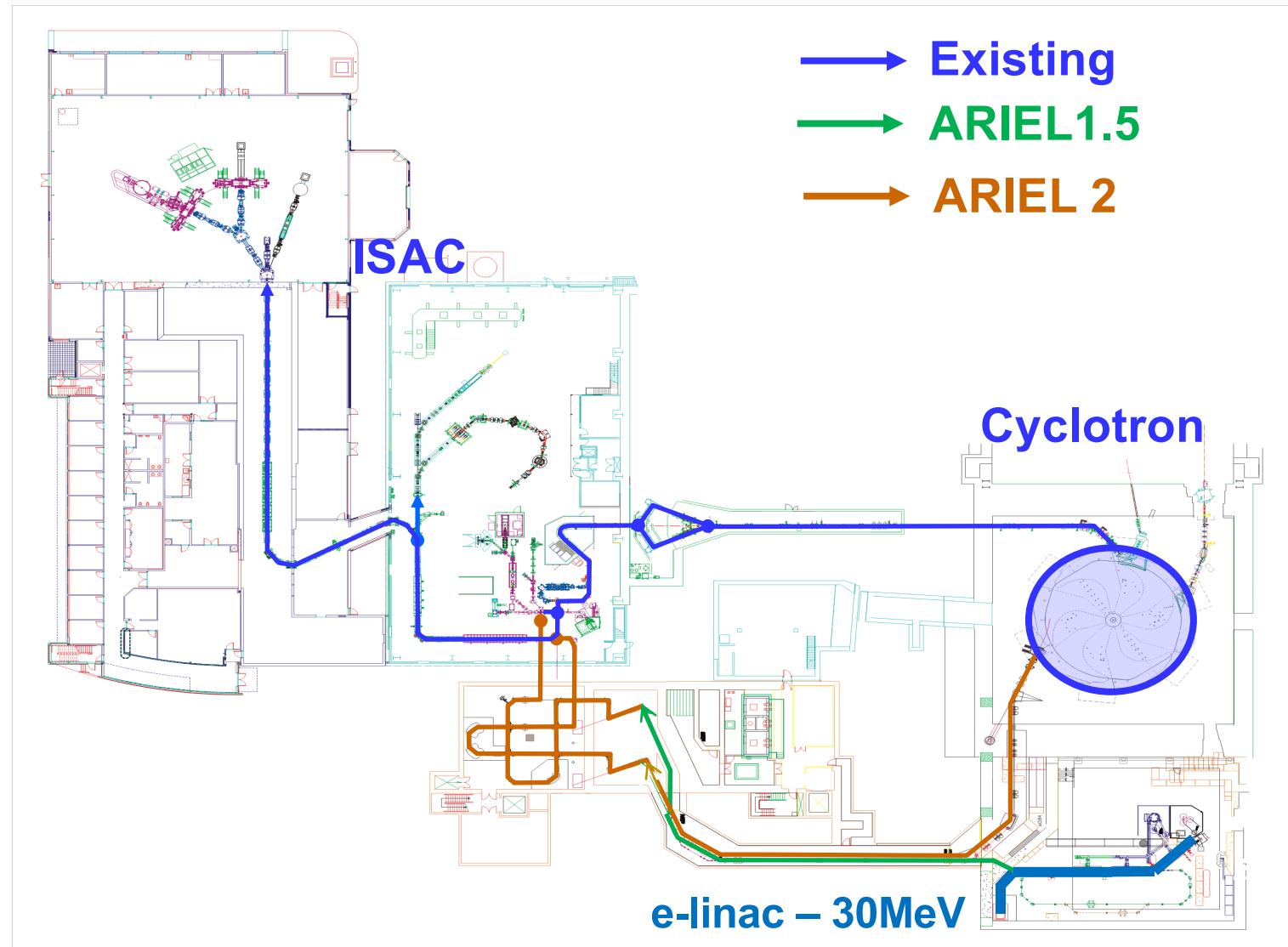
Outline

- **Overview of ARIEL**
- **Introduction to electron linac**
- **BLM overview**
- **Commissioning results**
- **Outlook**

Overview of ARIEL @ TRIUMF

Advanced Rare Isotope Laboratory (ARIEL)

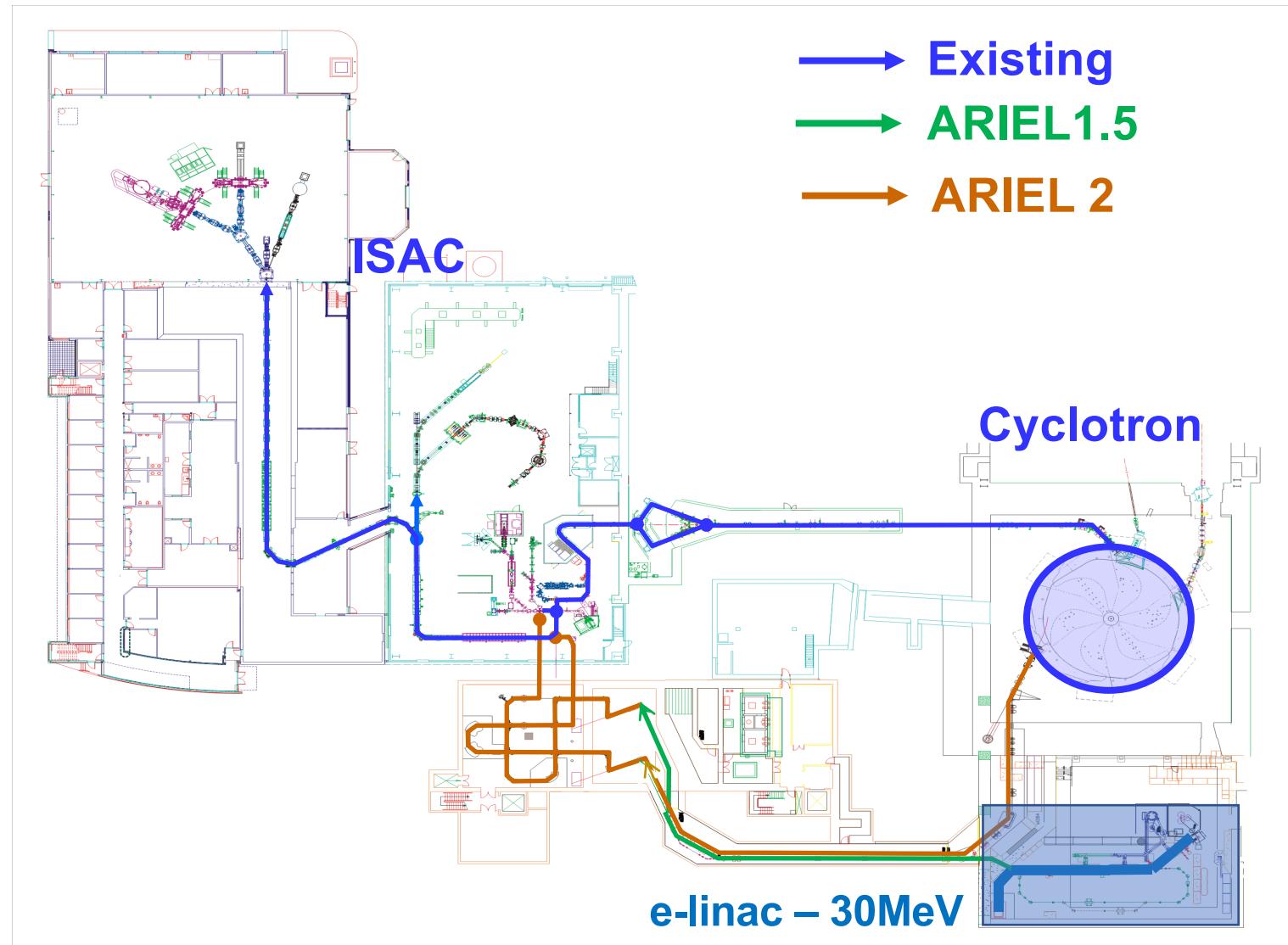
- Multi-user, multi-disciplinary RIB Facility
- Intense, clean RIB beams into ISAC experiments in several phases
 - **New 30 MeV, up to 10 mA superconducting electron linac**
 - New 100 kW electron beamline and target station
 - New 50 kW proton beamline and target station



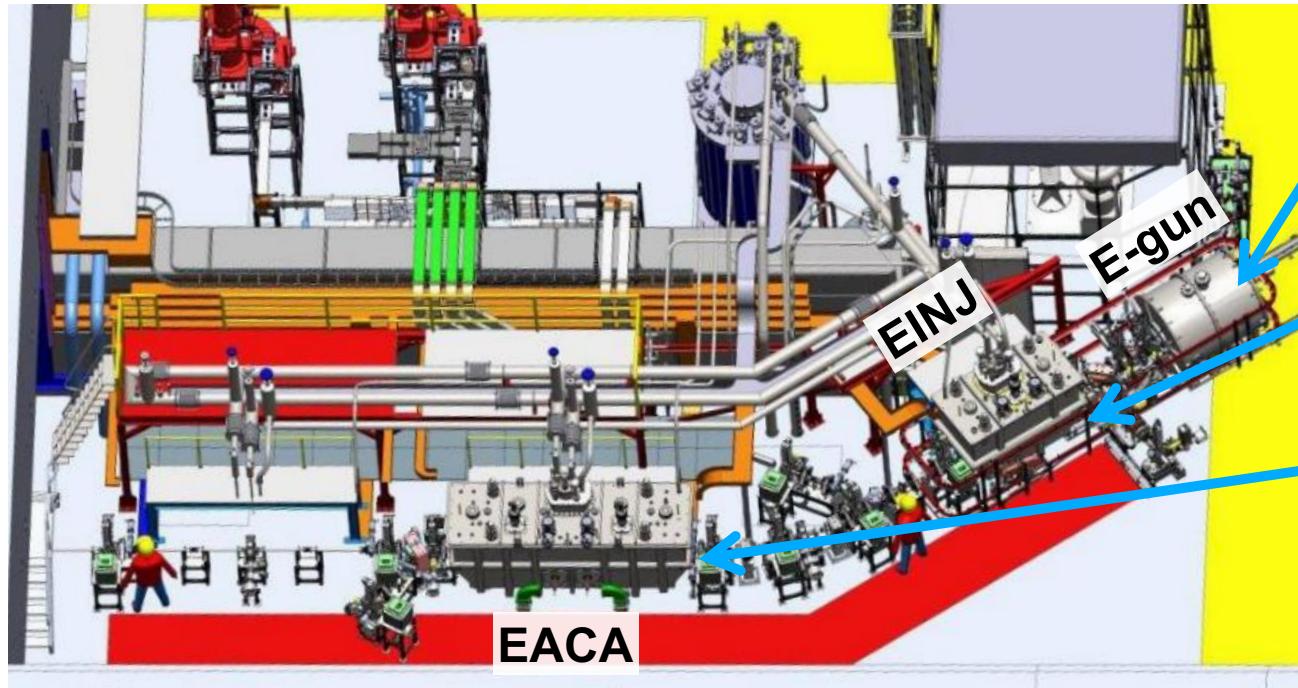
Overview of ARIEL @ TRIUMF

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- Intense, clean RIB beams into ISAC experiments in several phases
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Introduction – Electron linac

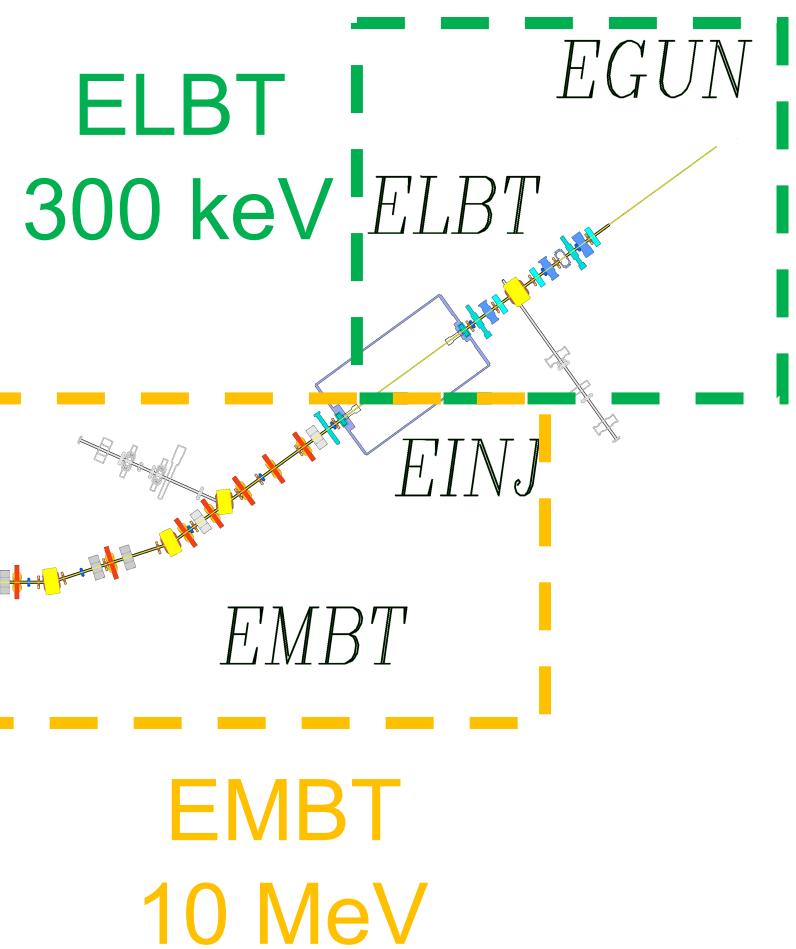
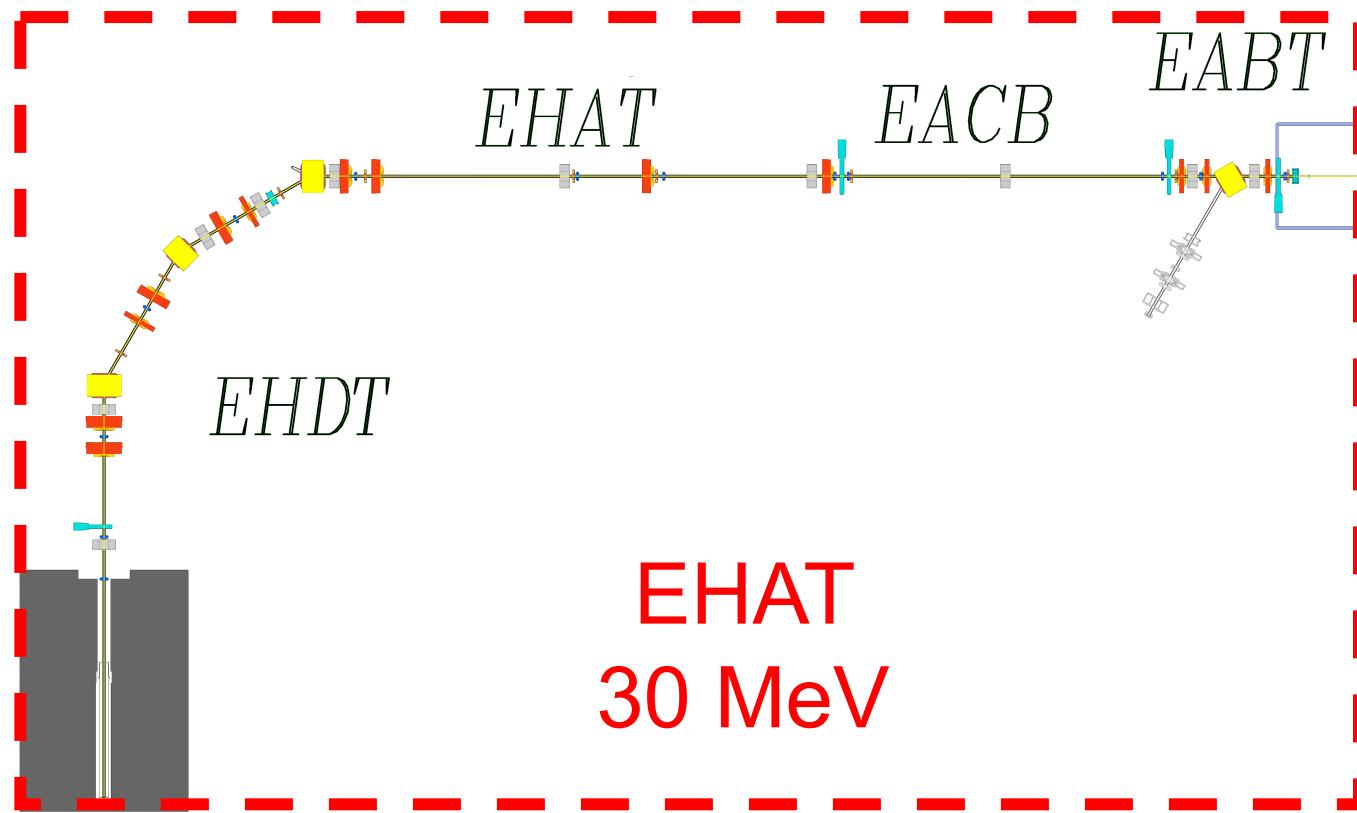


- E-gun: Up to 10 mA at 300 keV beam
 - Operates in CW and pulsed mode down to 5 μ s pulse width
- EINJ: Injector cryomodule accelerates up to 10 MeV
- EACA: Accelerator cryomodule further accelerates up to 30 MeV
 - Equipped with two cavities

Introduction – Electron linac

Layout of electron hall

- ELBT & EMBT BLMs commissioned
 - Next step is to increase to 1 kW
- EHAT BLMs scheduled for this year



Machine Protection System: BLM Requirements

Catastrophic loss: Integrated beam loss of 100 nC in 100 ms

- $10 \text{ mA} \times 10 \mu\text{s} \leftrightarrow 1 \mu\text{A} \times 100 \text{ ms}$
- Requires beam trip $< 10 \mu\text{s}$
- Requirement based on 200° C rise

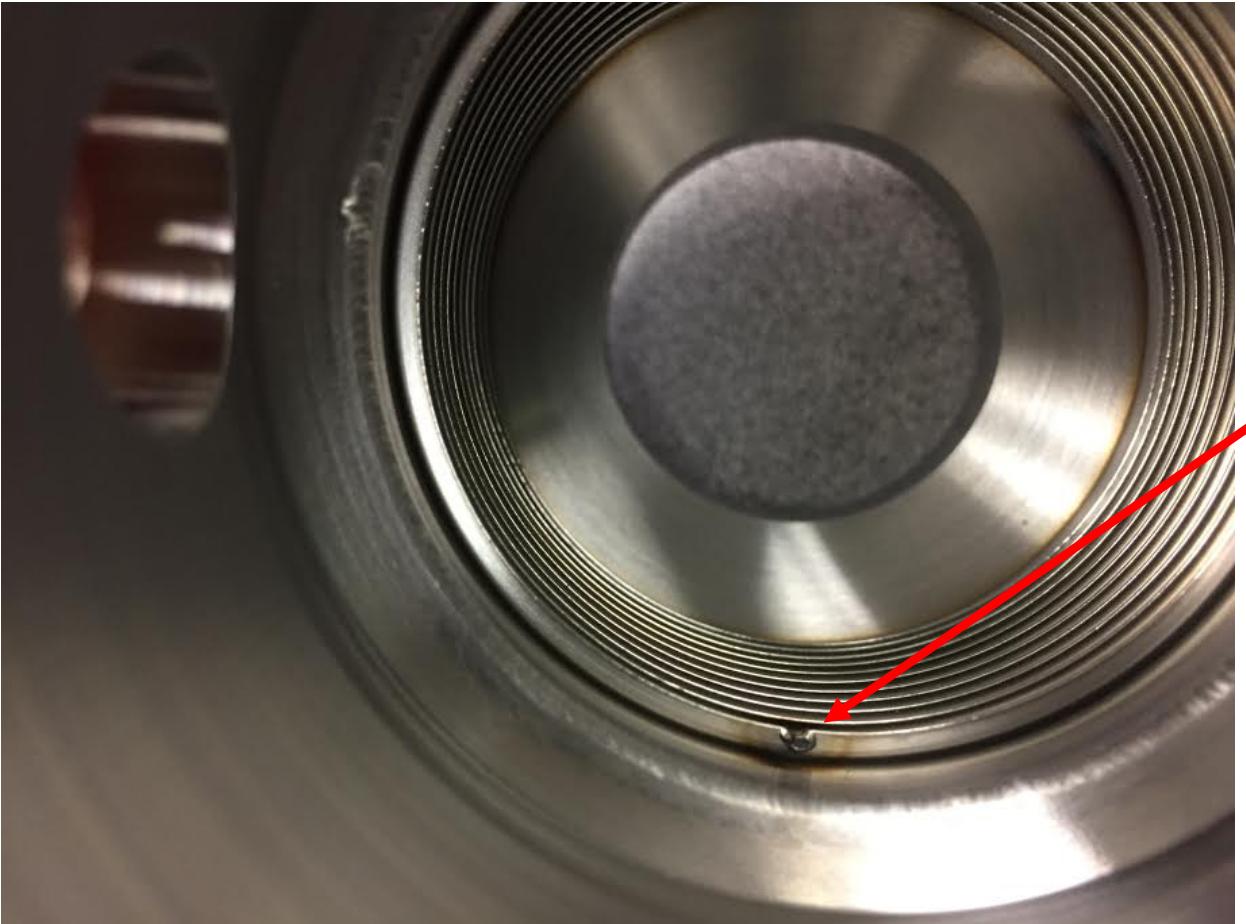
Chronic loss: 1 W/m beam loss

- $\sim 30 \text{ nA/m}$ spills
- Reduce activation for hands-on maintenance
- Provide warning to operators / scale back duty factor

Post-mortem analysis

- Record up to 1 s of data prior to trip on all BLMs

BLM Commissioning – History



Damage in bellows before MPS was commissioned

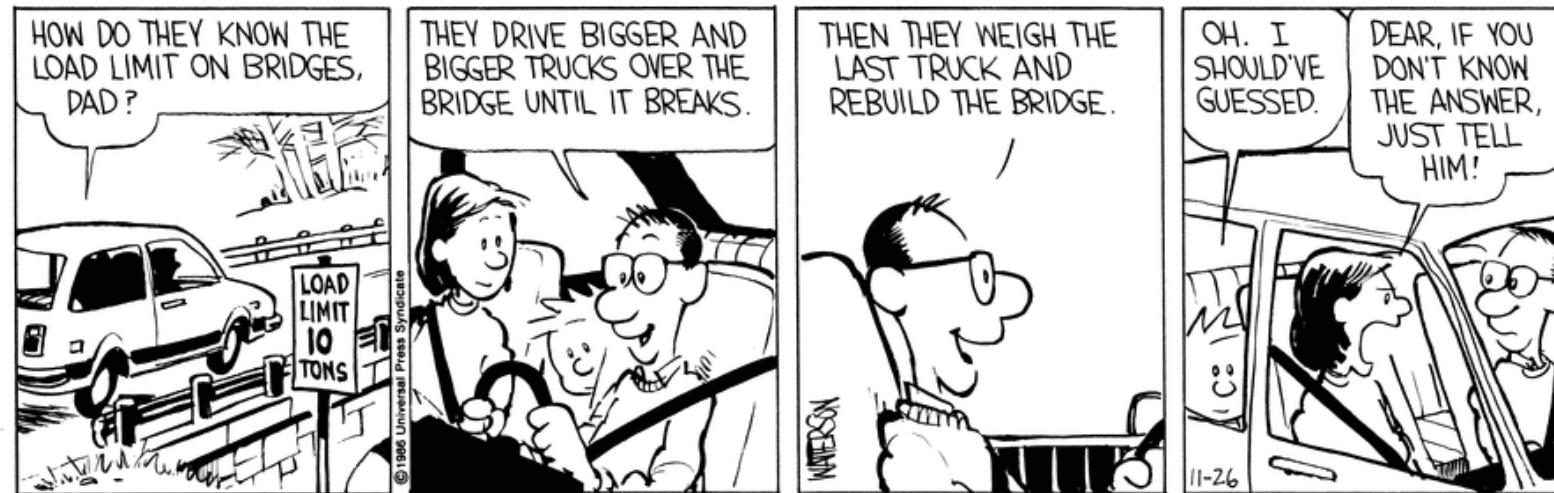
- Energy of electron gun was slowly increased while beam on
 - 200 W beam (660 uA, 300 keV)

Recently, caused damage to ion gauge after relaxing requirements specs in 300 keV section

BLM Commissioning – History



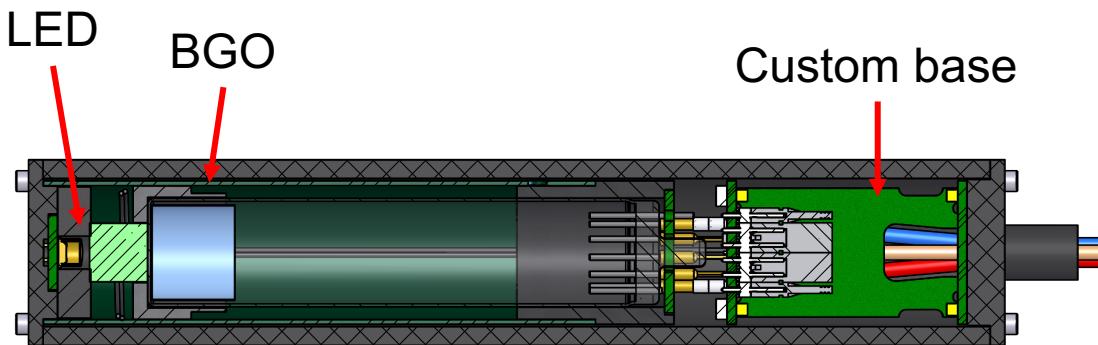
Calvin and Hobbes



Beam Loss Monitors Overview

BGO scintillator coupled to Photo-multiplier tube (PMT)

- 1 cm³ BGO crystal
- High sensitivity for chronic beam loss
- Modified rad-hard base with three possible gain settings
- LED cable used for calibration
- Response ~ 35 uC/Gy



Long Ionization Chamber (LIC)

- Manufactured from HELIAX cables
- Provides economical continuous coverage
- Length is variable (1.5m, 2m, 3m)
- Filled with Ar gas for prompt collection of electrons
- Positive HV outer conductor, signal inner conductor
- Response of 1m: 22 uC/Gy



TRIUMF Beam Loss Monitor Board (TBLM)



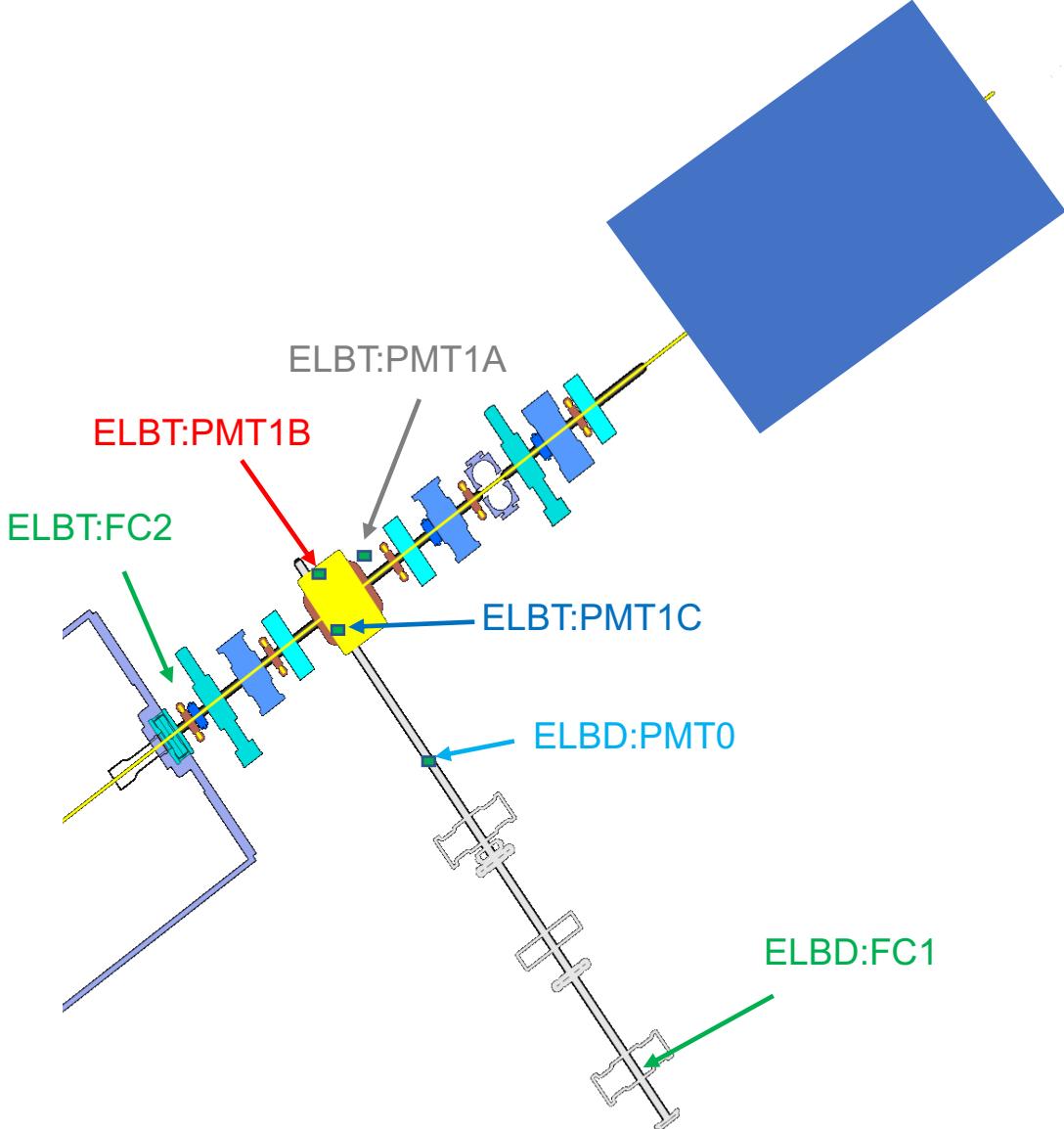
Features 8-channel BLM inputs, regardless of BLM type

- Dual switch integrators for continuous monitoring of integration
- 1 MHz digitization of integrators gives 1 μ s resolution of BLM current
- “100ms” trip threshold has 100 ms sliding integration window
- “Delta” trip threshold can be set to single BLM current pulse
- Trip signal uses fiber optic output to Fast Shutdown Board (FSD)
- Chronic loss displays 1 s of BLM integration
- Post-mortem to read out up to 1 s of each BLM

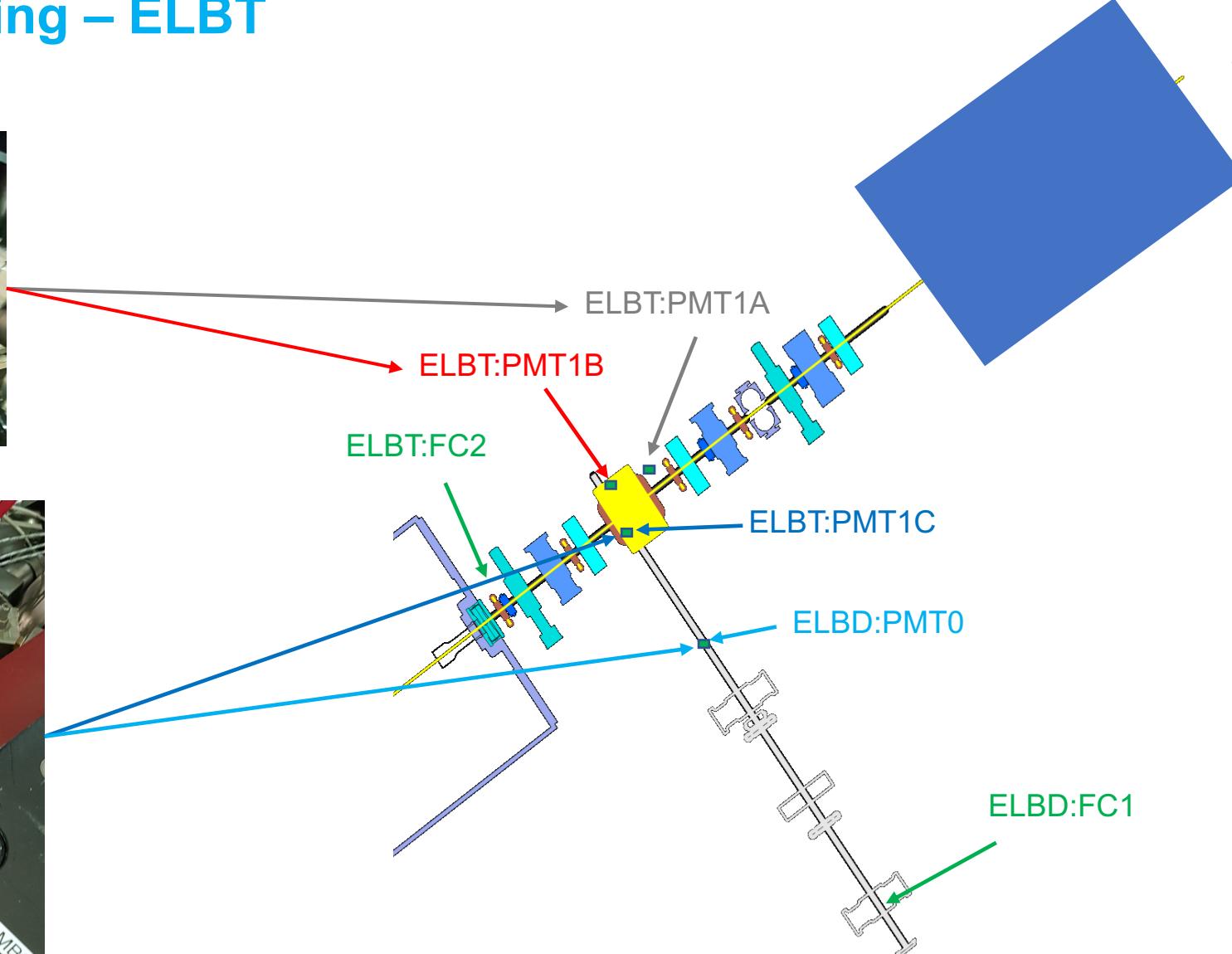
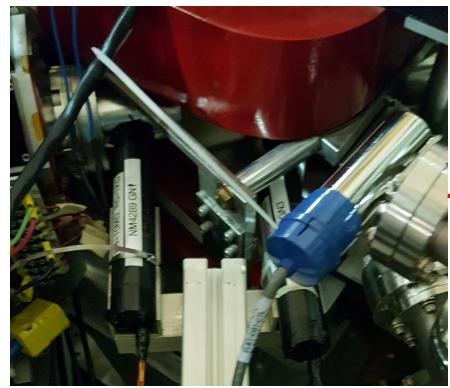
BLM Commissioning – ELBT

Low energy section

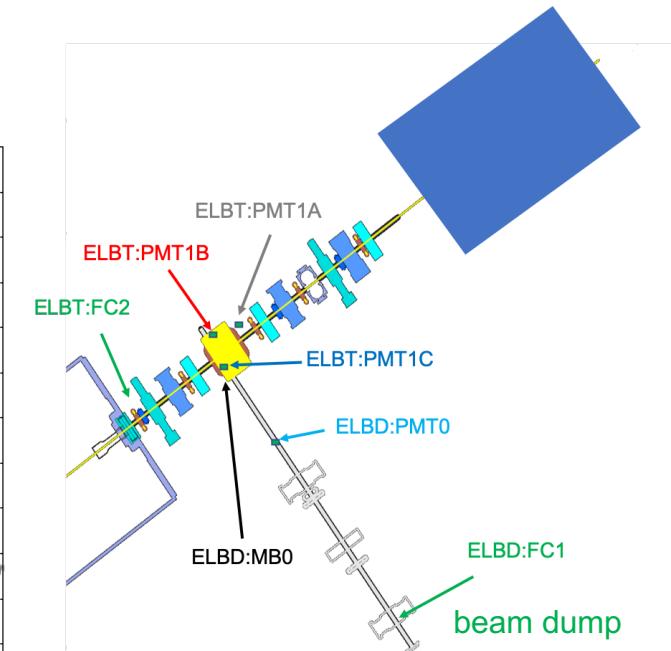
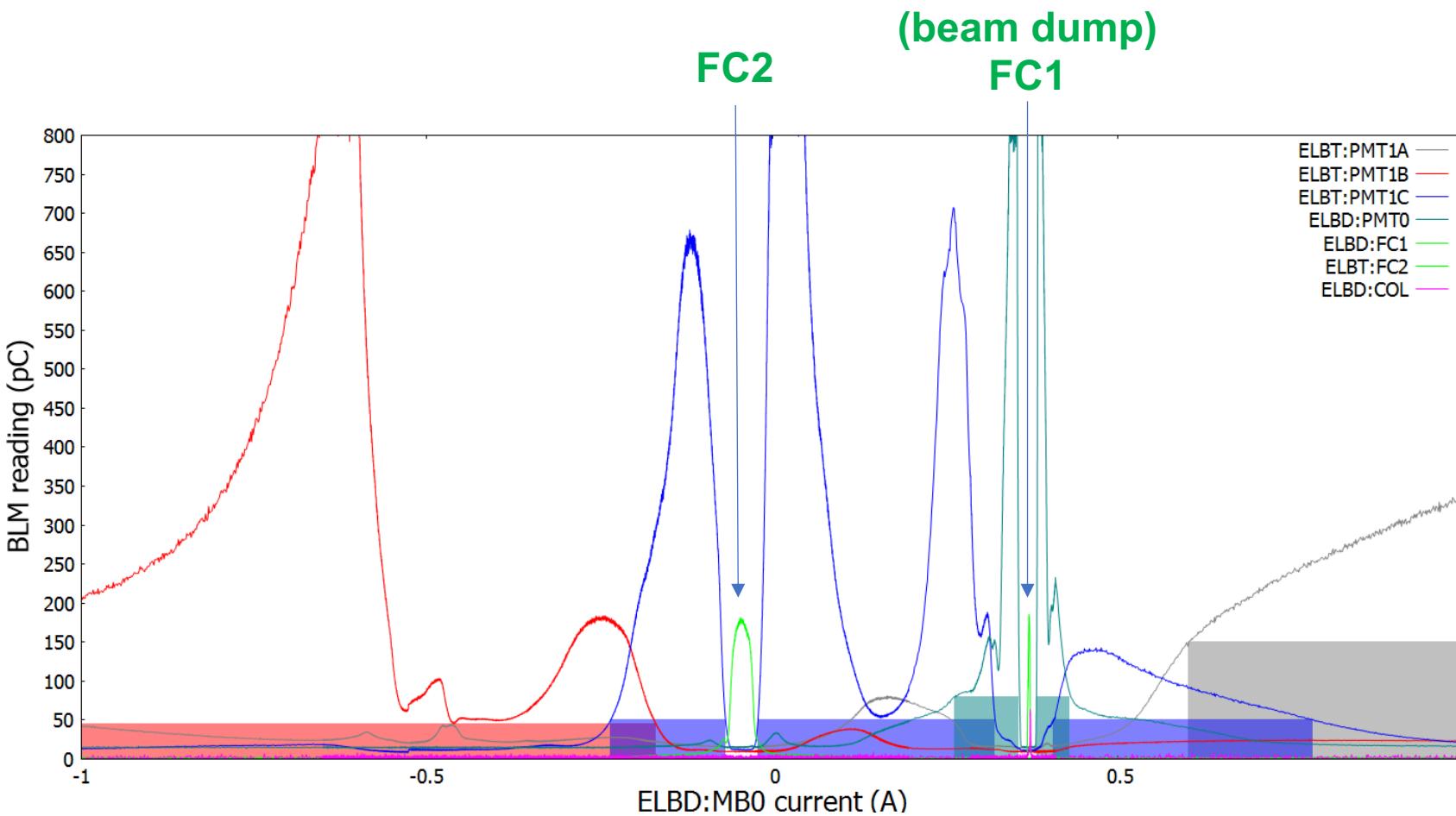
- 300 keV electron beam
- Beam spills using dipole, steerers, quadrupoles
 - Peak current of 200 uA
 - Duty factors ~0.5%
 - Different tunes used (transport and dump)
- Outfitted with four PMTs
 - Provides full coverage
- Dark current from downstream cryomodule
 - Up to 4.5 MeV electrons
 - Reduce gradient as temporary measure, though conditioning shows promise



BLM Commissioning – ELBT



BLM Commissioning – ELBT

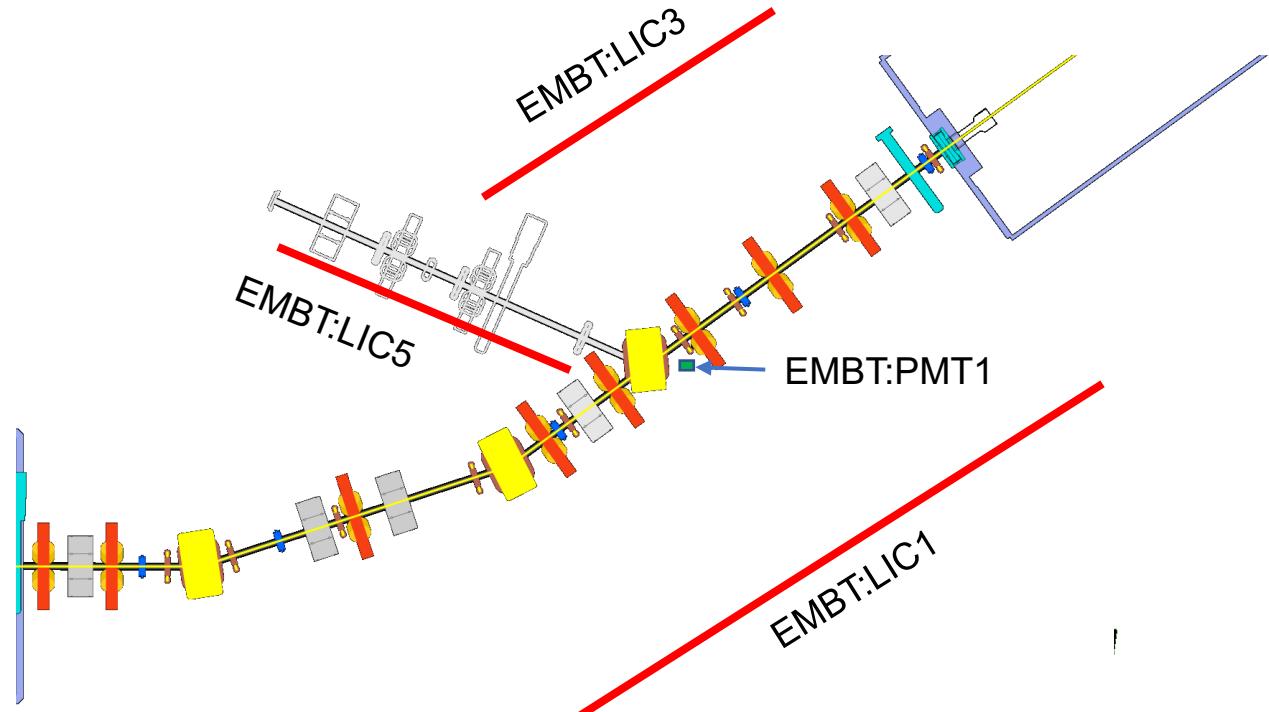


- Thresholds set to reduce “dark” spots
- FC1 located at 90°

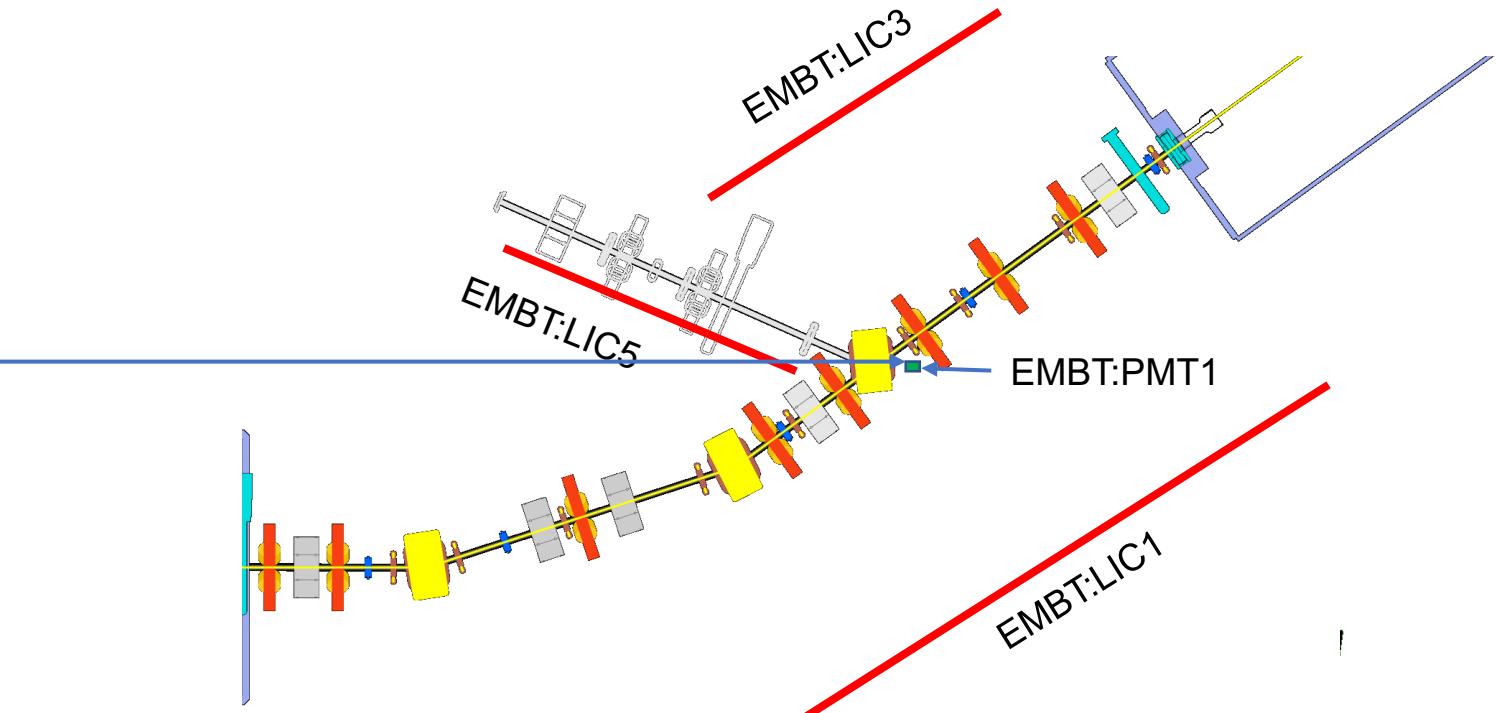
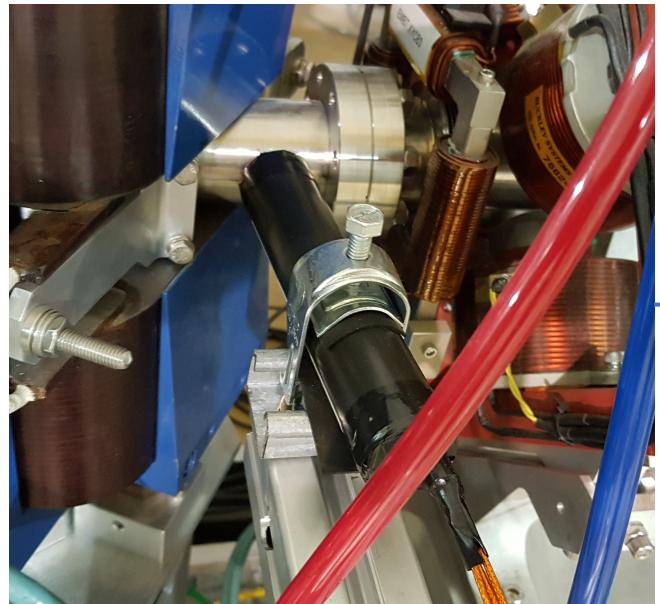
BLM Commissioning – EMBT

Medium energy section

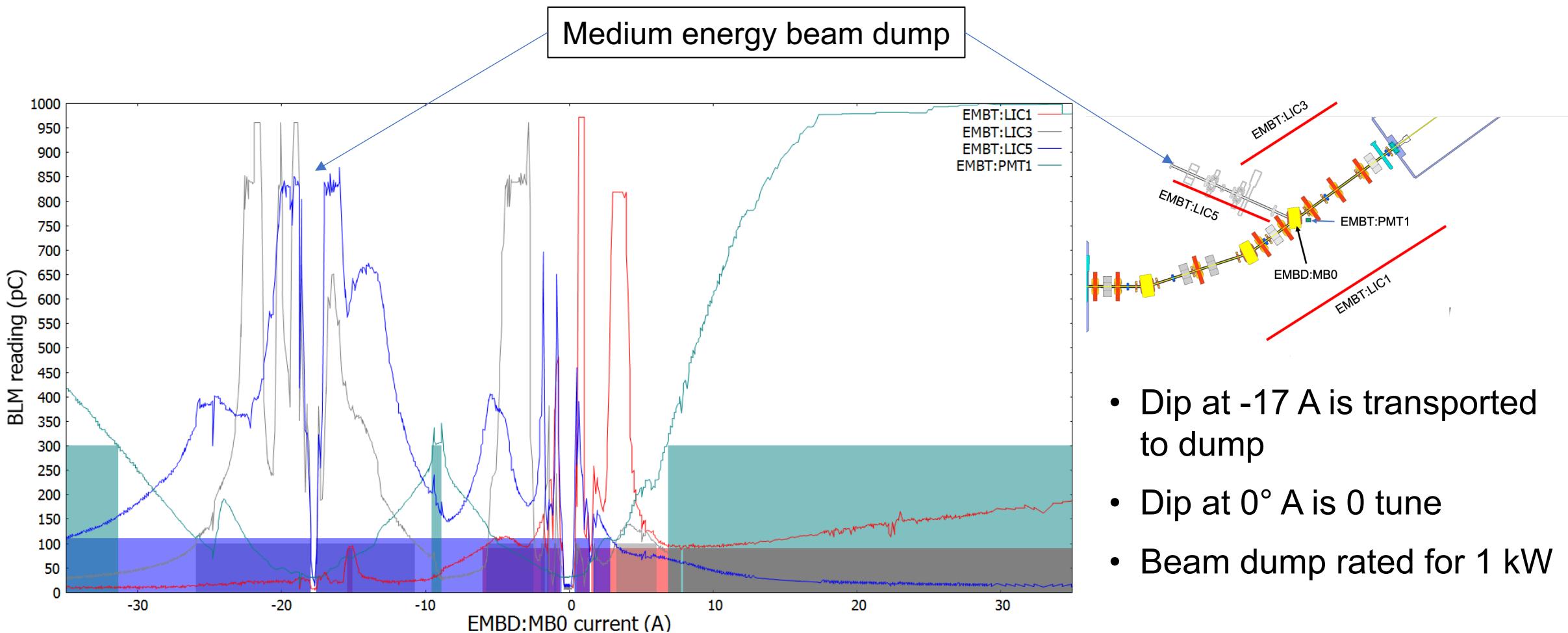
- ~10 MeV electron beam
- Beam spills in both vertical and horizontal direction with focused beam
 - 7 different spill scenarios generated due to more complicated geometry than ELBT
- Outfitted with four LICs, one PMT
 - Provides full coverage



BLM Commissioning – EMBT



BLM Commissioning – ELBT



Outlook

Current plans

- Complete commissioning in EHAT (30 MeV); send 1 kW to beam dump
 - Unknown what effect of shine from various beam dumps will have
- Develop post-mortem analysis
- Commission "delta" trip for high peak currents up to 10 mA
- Develop calibration routines for PMTs

Future challenges

- Transport tunnel to target station shared with 500 MeV proton beamline
 - Will have to differentiate spills between electrons at 30 MeV and protons at 500 MeV
- Integrate with other aspects of MPS
 - Target station, BPMs, Rastering, etc.

Thank you for your attention

...And thanks to my collaborators

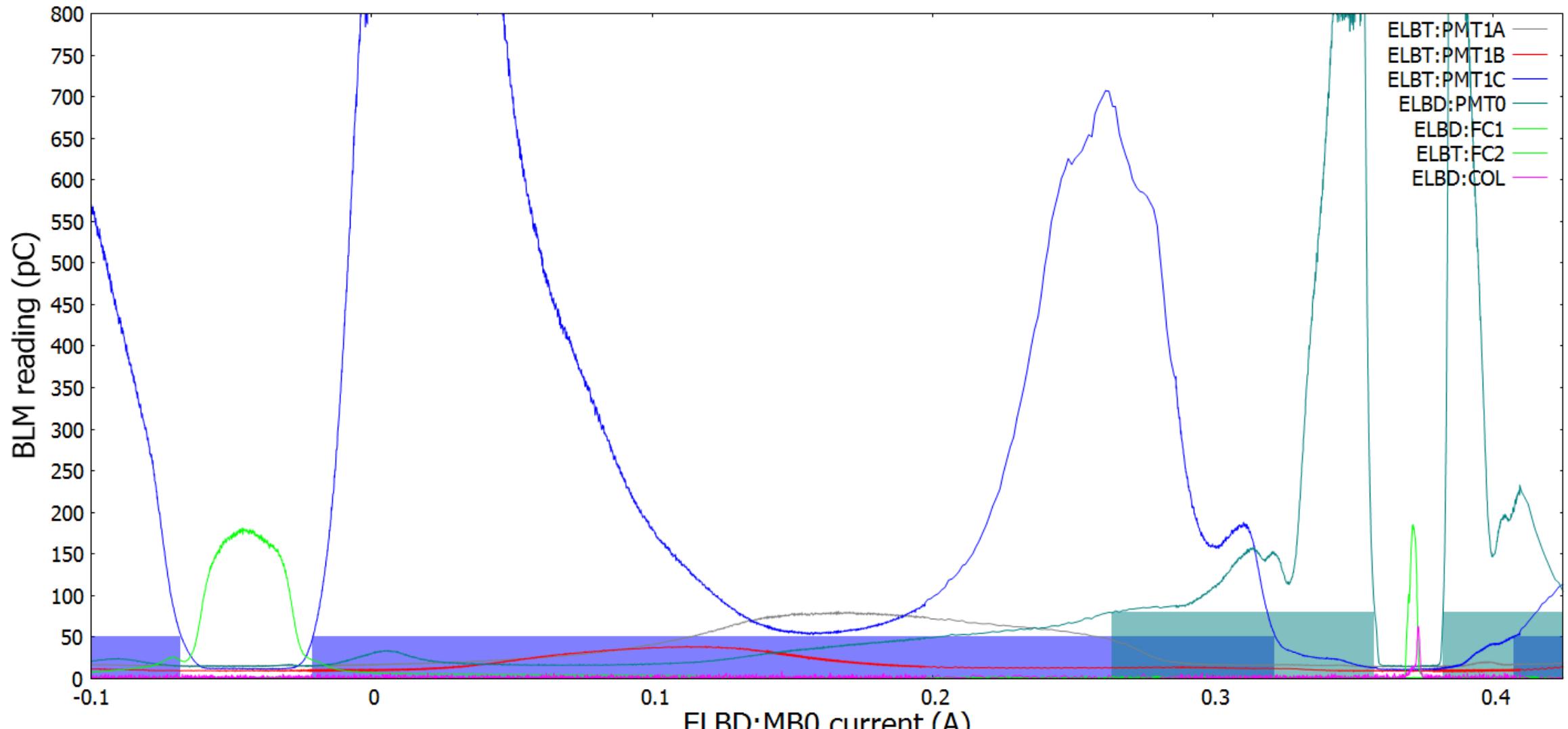
D. Dale, A.D. D'Angelo, H. Hui, B. Humphries, S.R. Koscielniak, K. Langton, A. Lennarz, R.B. Nussbaumer, T. Planche, S.D. Rädel, M. Rowe



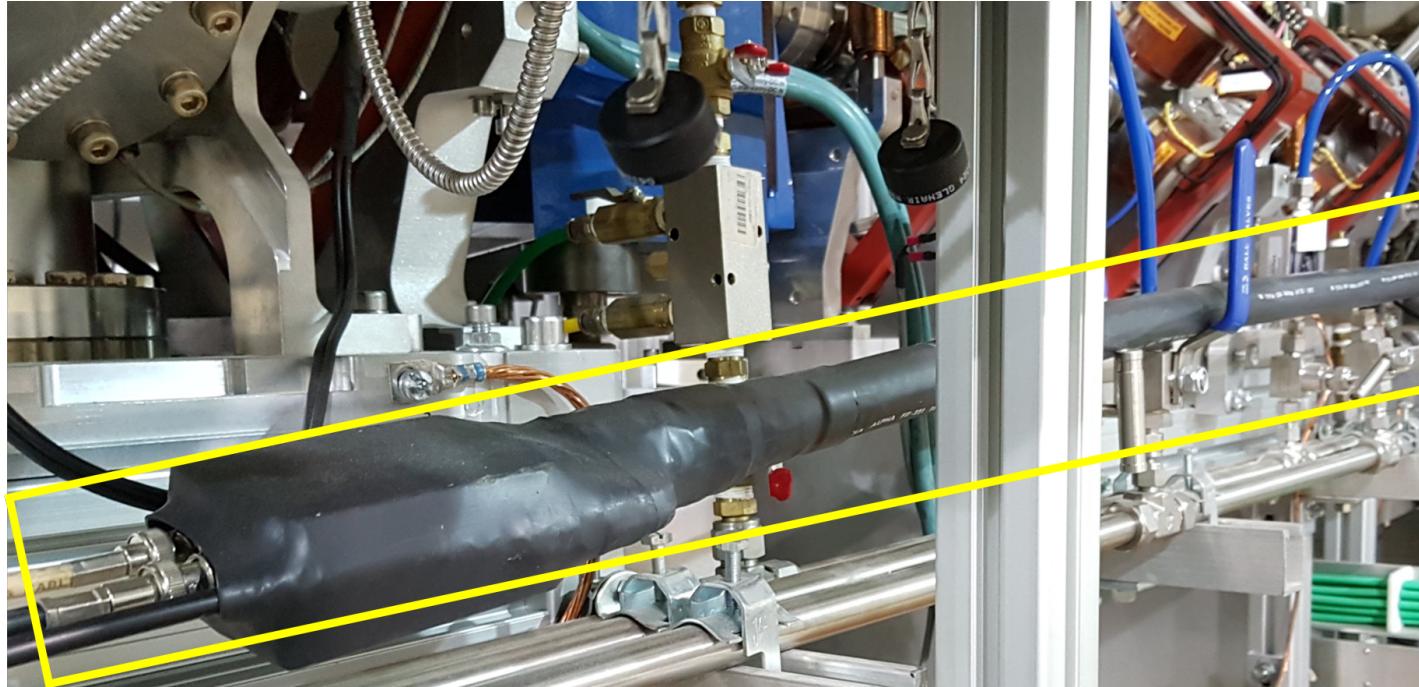
**Discovery,
accelerated**

EXTRAS

EXTRAS: ELBT beam spill plot ZOOMED

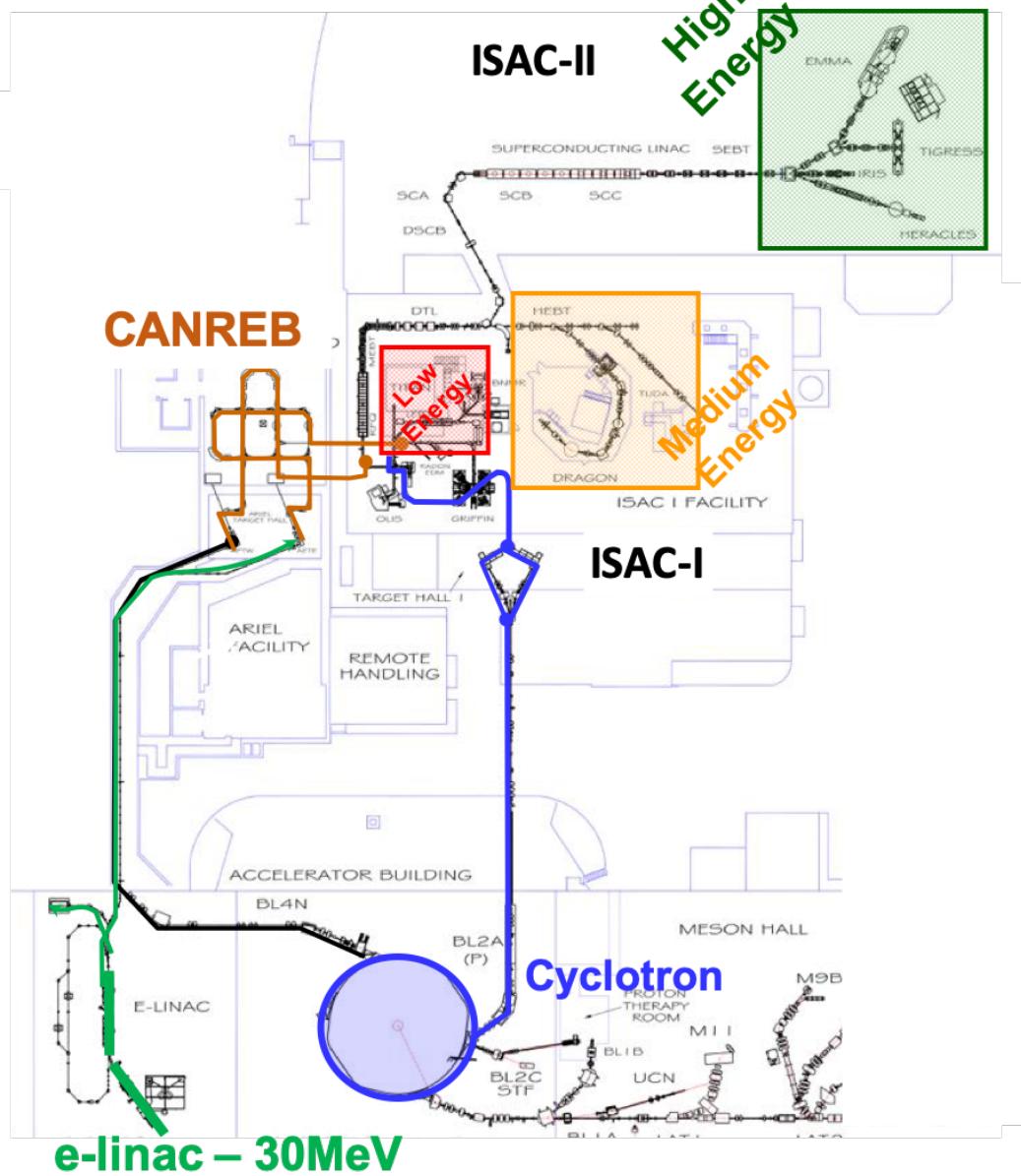


EXTRAS



LIC during
commissioning of EHAT

EXTRAS



ARIEL

- A new 30 MeV, 10 mA superconducting electron linac as driver for photo-fission to expand the rare isotope program.
- Two new high power rare isotope target stations
 - New 100 kW convertor target station
 - 50 kW proton target station (with symbiotic target for medical isotope production)
- Unique beam preparation and transport system (CANadian Rare isotope facility with Electron Beam ion source - CANREB)
 - High resolution separator
 - Beam preparation with RFQ and EBIS

ARIEL will triple ISAC's present rare isotope capabilities.