



**EUROPEAN
SPALLATION
SOURCE**



Beam Diagnostics Experience at ESS

Focus on recent commissioning

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Agenda



Layout and Strategy

Beam Accounting

Centroid Measurements

Distribution Measurements

Outlook Toward Future Commissioning

Layout for recent commissioning



Beam Accounting

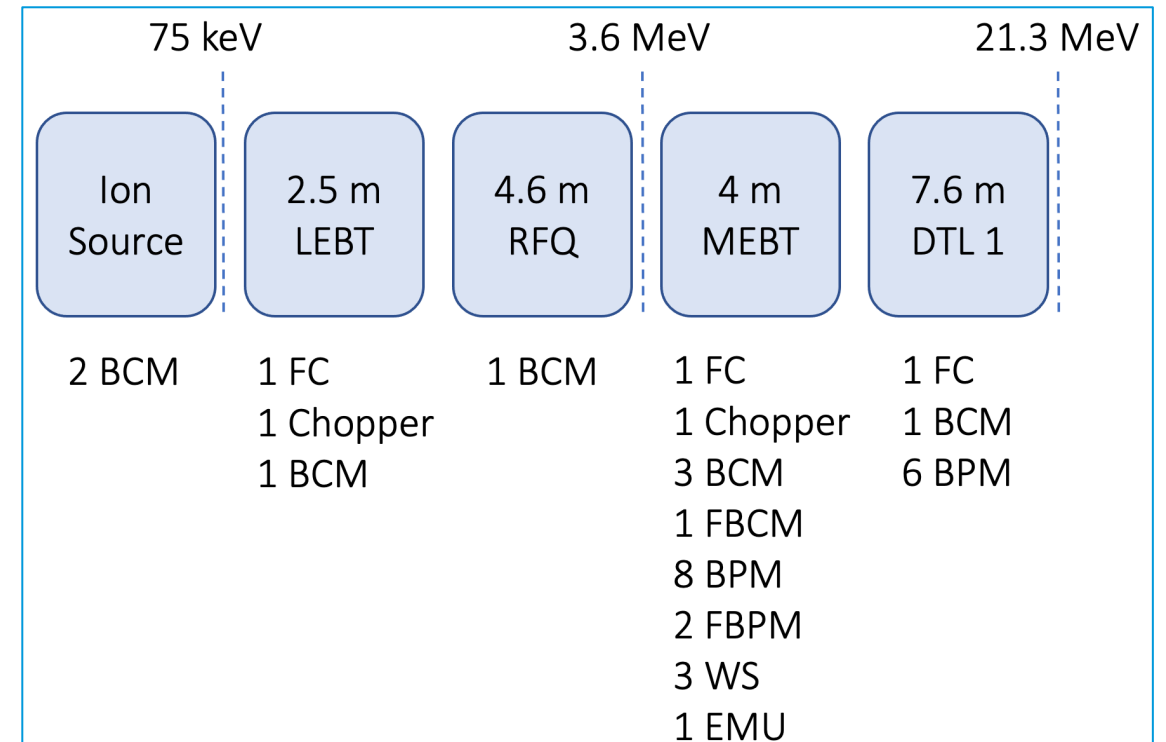
- **Choppers**
- Current (**BCM** and **FC**)
- Loss (nBLM)

Centroid Measurement

- Position (**BPM** and fBPM)
- Phase and Energy (**BPM** and fBPM)

Distribution Measurements

- Profile (WS)
- Emittance (slit and grid EMU)



Systems required for first protons in **bold**

Strategy

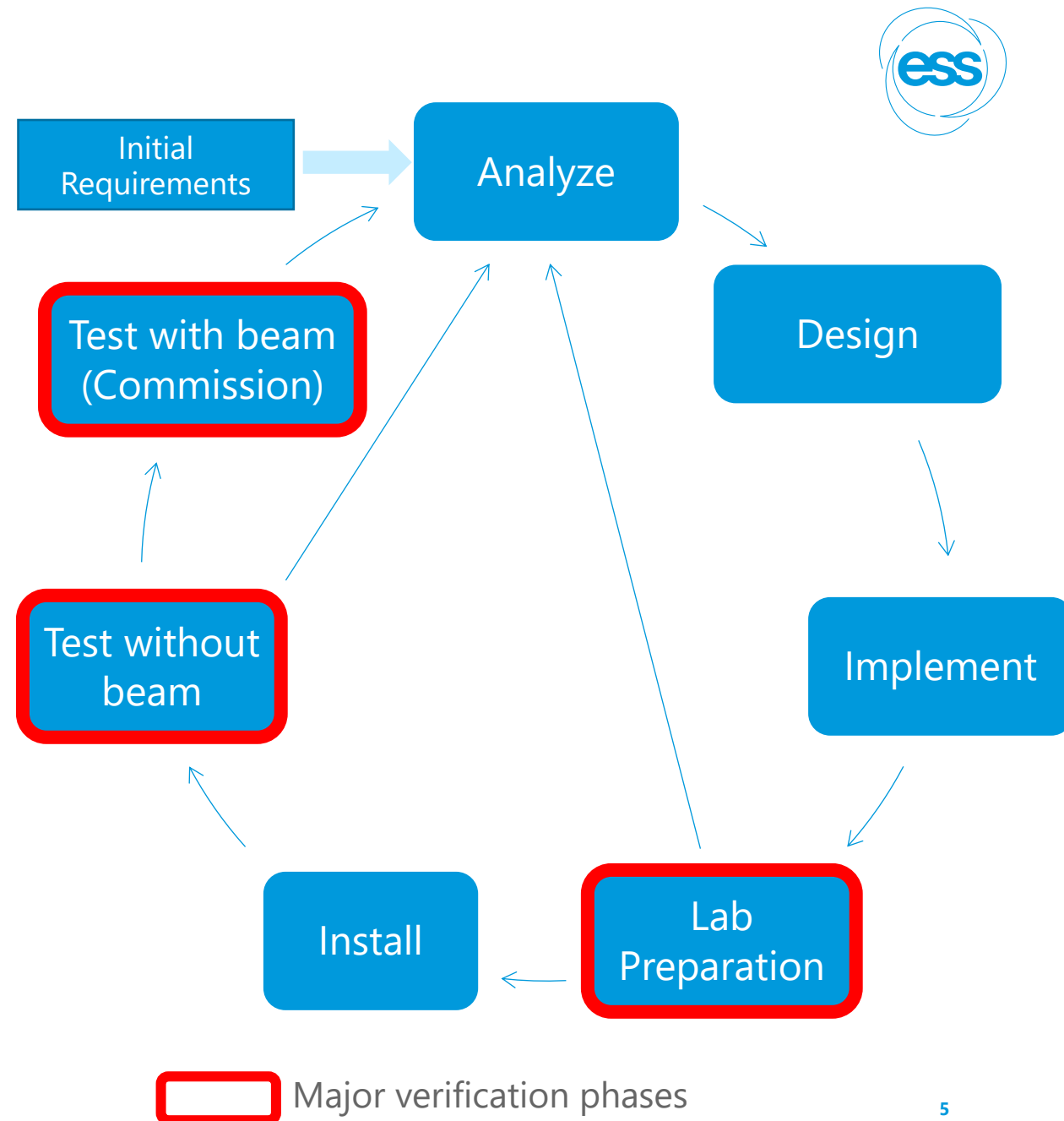
Once per commissioning run

For each commissioning milestone:

- Agree with stakeholders (Beam Physics, et. al.) on functionality **required for first protons** – after testing with beam, transfer control to operations
 - Determines the **required systems**
 - Focus limited Controls resources on these
 - Dedicate resources to support all ESS Engineering processes and Controls standards
- Use lighter processes to temporarily deploy systems for **diagnostic beam studies** – for expert use; control not transferred to operations

Toward beam on target (RBOT): Iterate to build out diagnostic capability and protection functions, typically by upgrading firmware and software.

Additional tests of multiple systems without beam could be beneficial

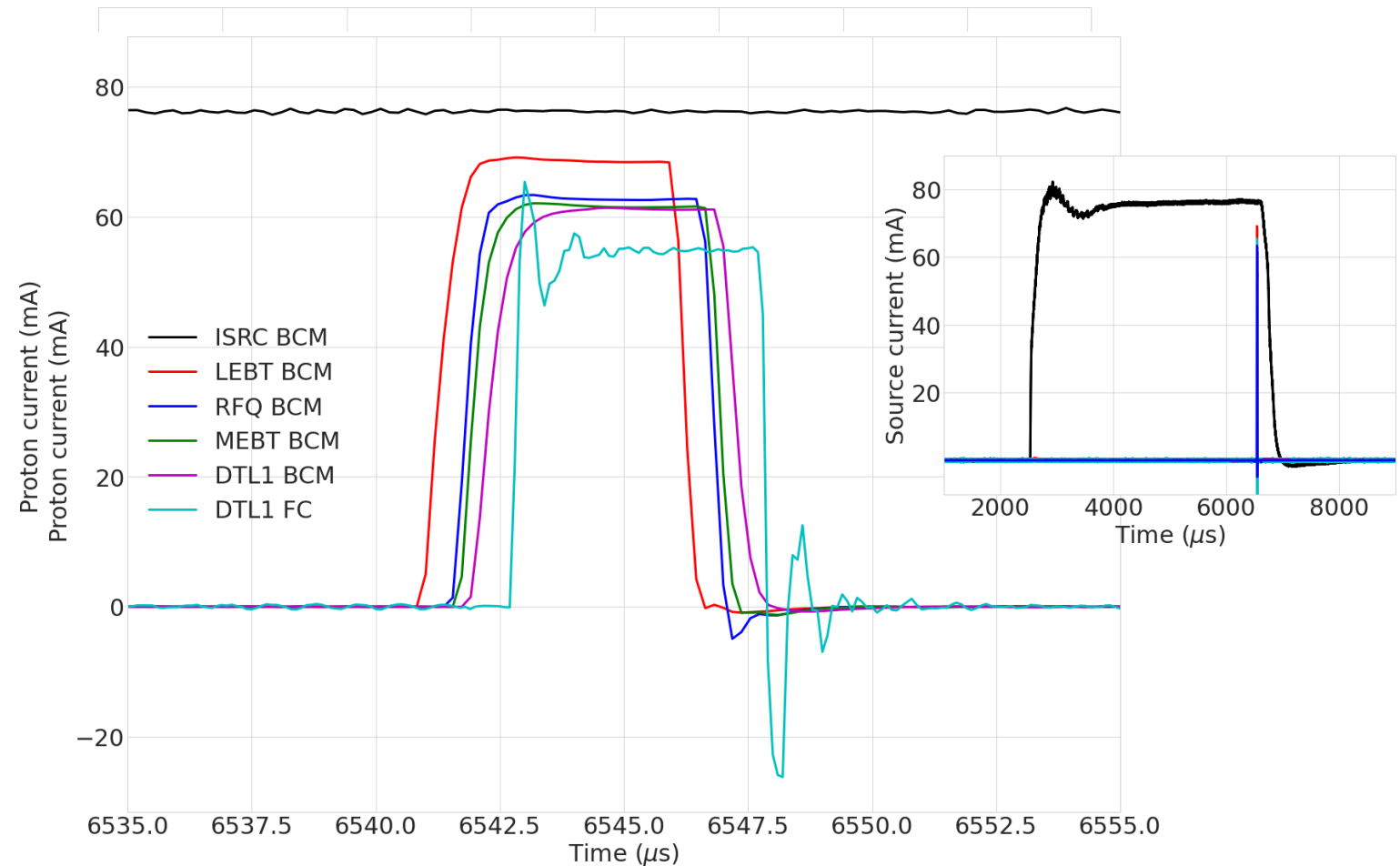


Beam Accounting - Beam Current



Current measurements from Toroids and Faraday cup readouts

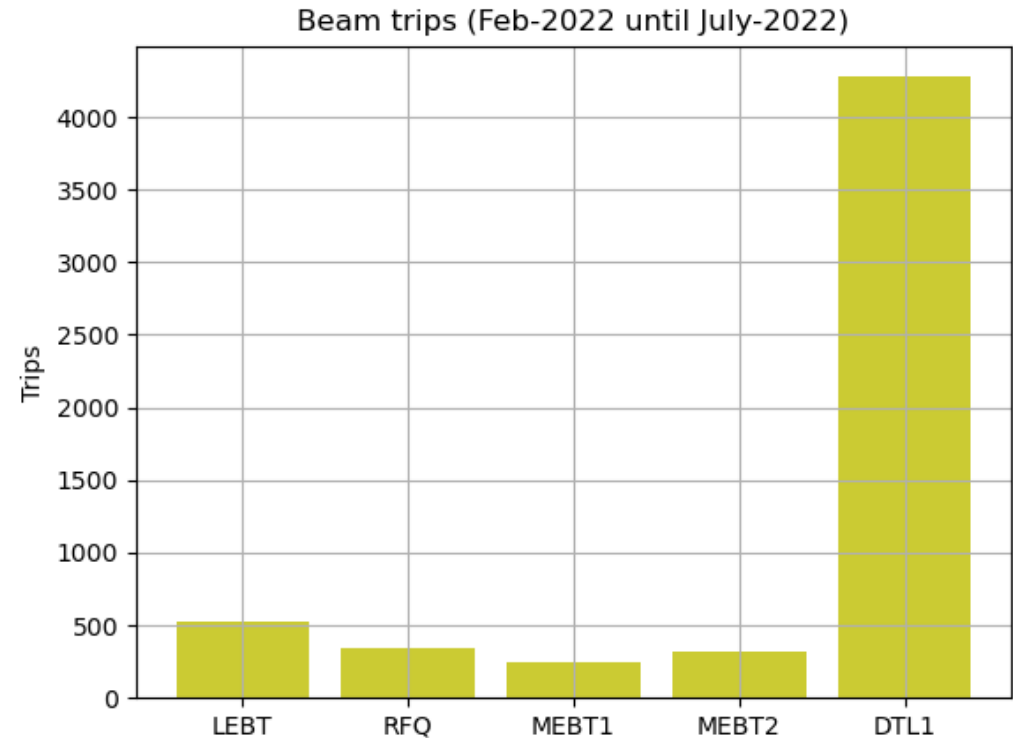
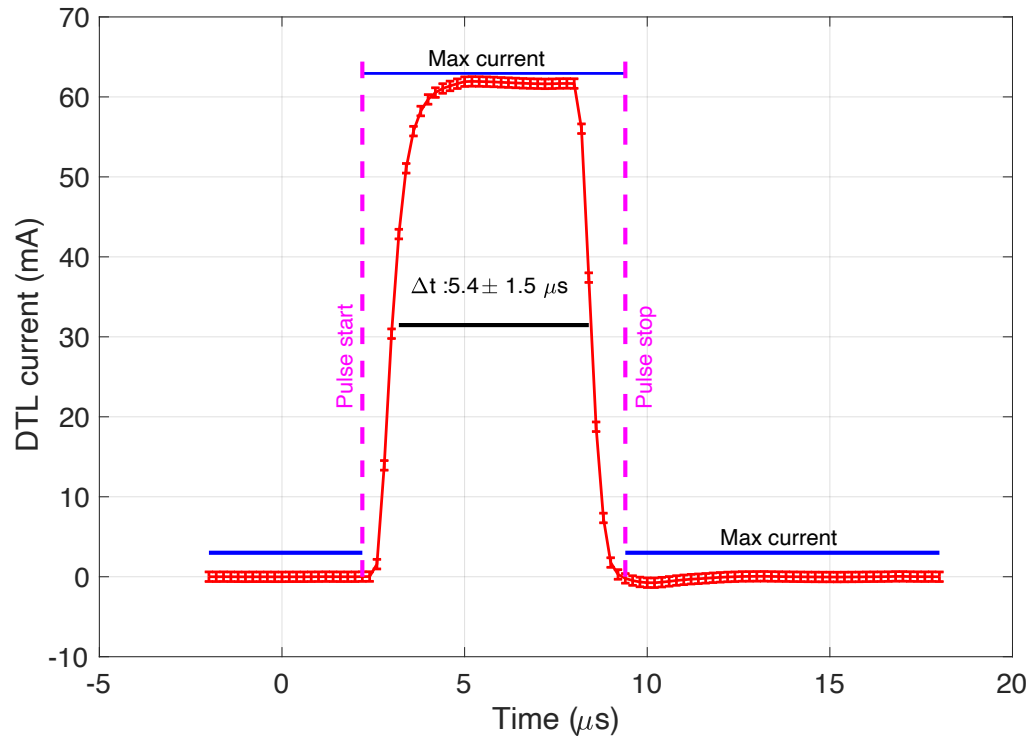
- Pulse shaping by LEBT and MEBT choppers
- Faraday Cups provide beam destinations for commissioning and also provide current measurement
- Beam Current Monitors are distributed throughout the linac and provide protection functions as well as current measurement



Beam Accounting – Protection Functions



Remove beam permit when unintended pulse properties are observed



Parameters to determine errant beam
(single channel function; differential current function also demonstrated)

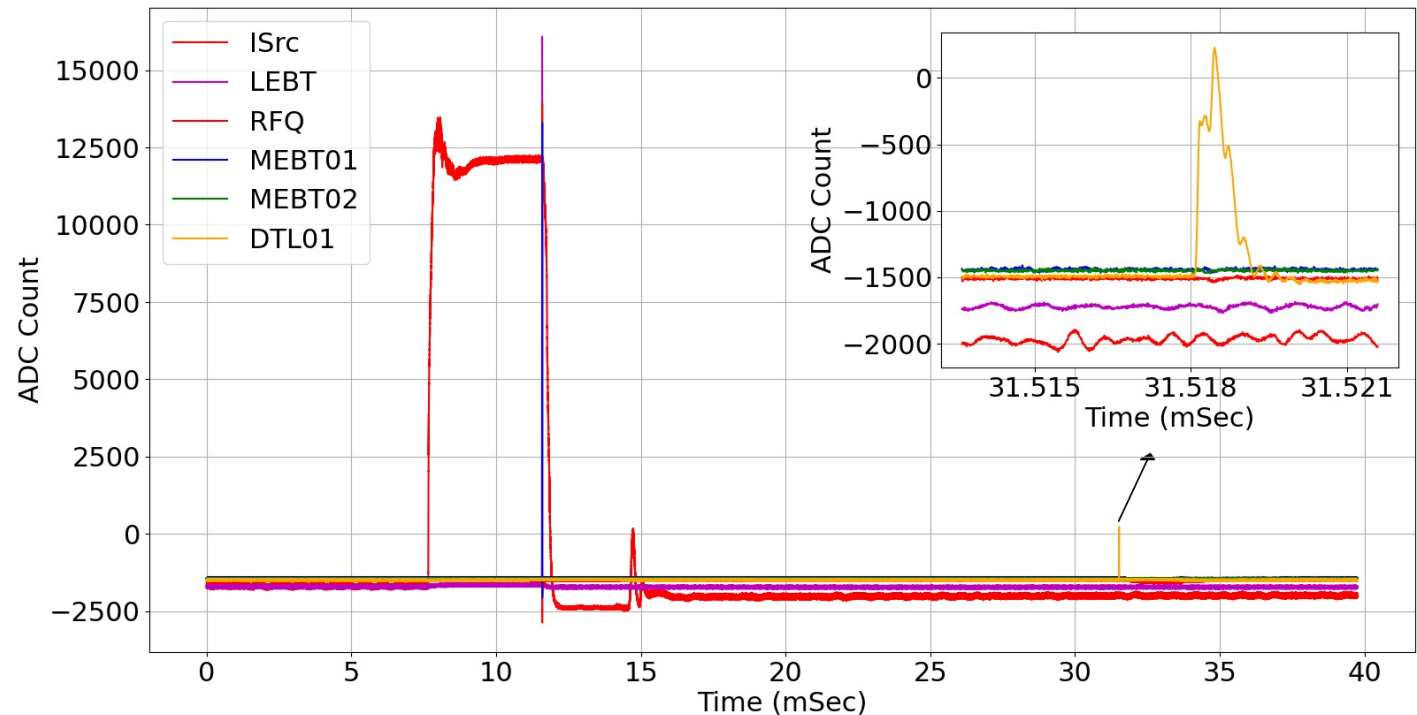
Trip statistics
~μs latency

Beam Accounting – Protection Functions



Post Mortem

- Most trips occurred during testing or were driven by signals other than errant beam
- Reconsider value of some redundant channels
- Will improve data acquisition and analysis capability (include RF waveforms, EPICS support for acquisition features, etc)



Utilized low-level acquisition features of FPGA framework

Beam Accounting – Beam Loss

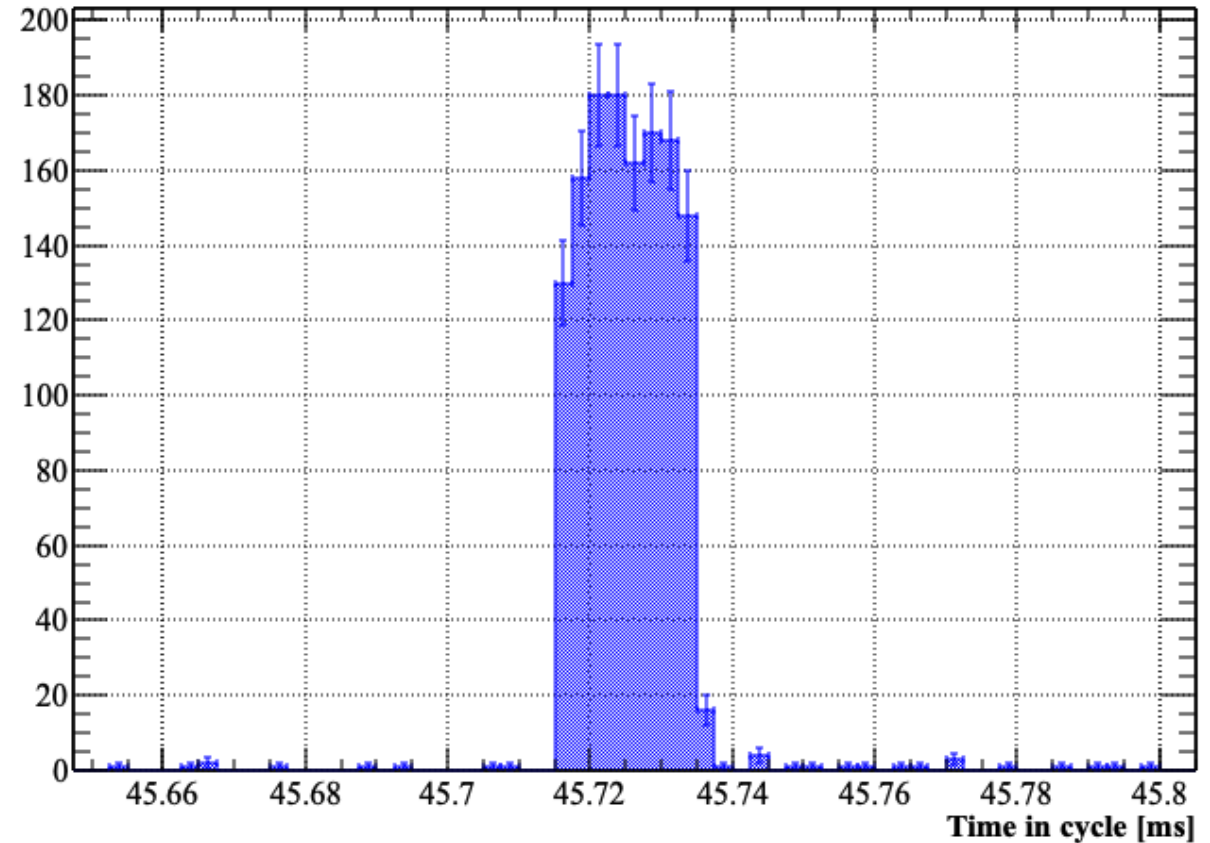


Fast neutron detector

Two detector types have been deployed:

- Slow: moderator, Boron capture reaction
- Fast: no moderator, n p recoil reaction

Intentional beam loss of 3.6 MeV protons on TZM chopper dump

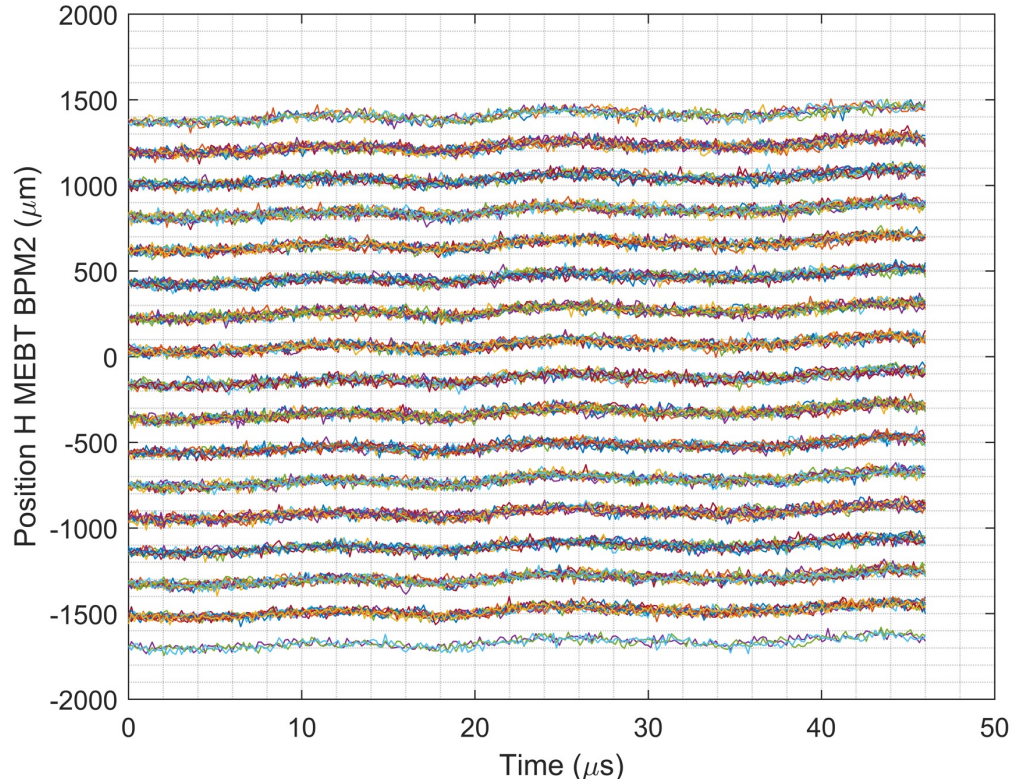


Demonstration of time response during loss of 20 μ s beam pulse

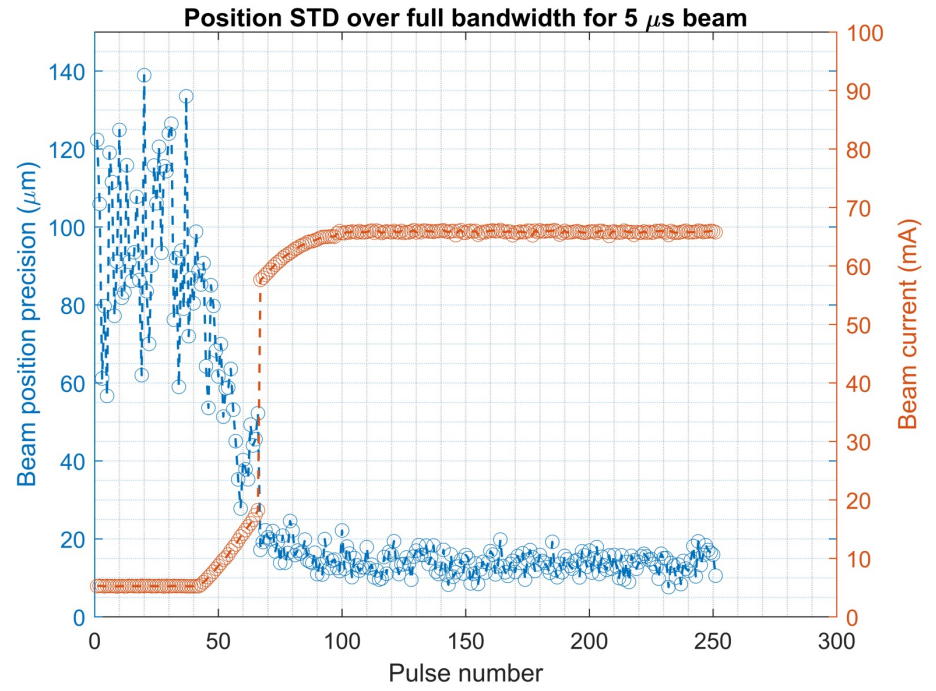


Centroid Measurements - Position

Stripline pickups in MEBT and in DTL drift tubes



- Scan of position using upstream corrector



- RMS of Position Measurements for varying peak beam current



Centroid Measurements - Phase

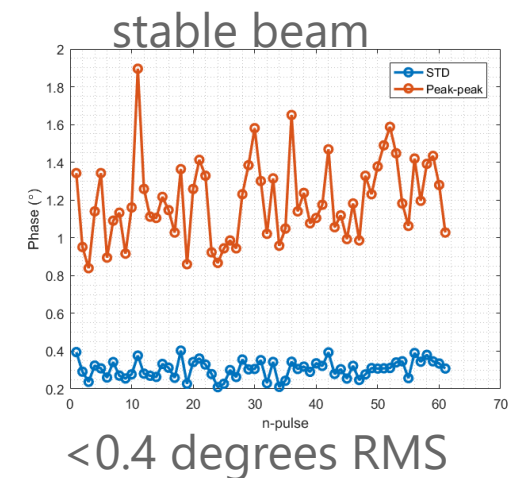
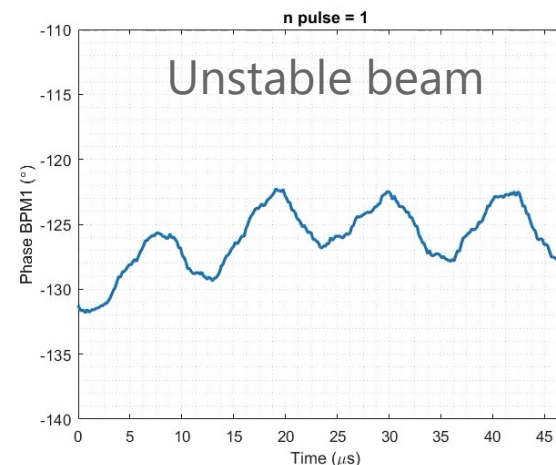
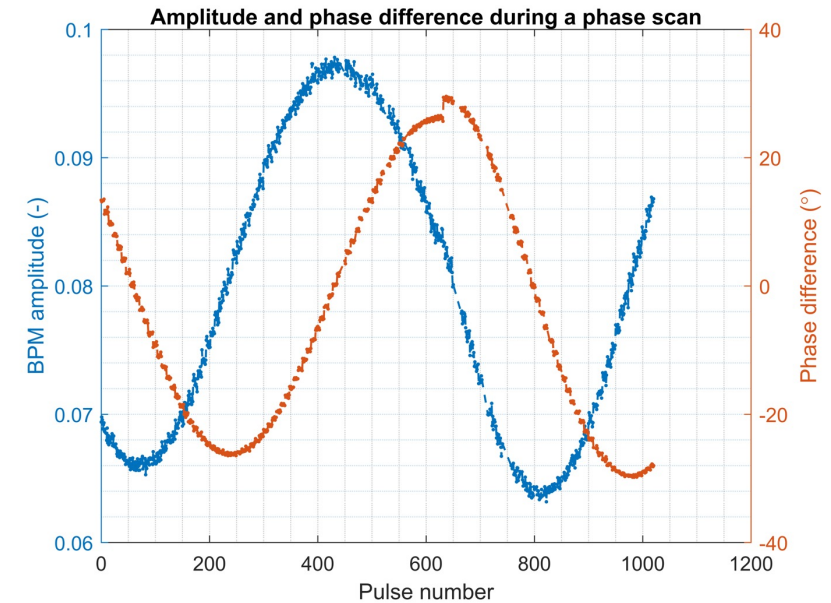
Provided by Beam Position Monitor System

Arguably more challenging than position measurements for linac setup and tuning

System supports measurements between multiple BPM pickups and with respect to phase-stabilized RF reference

Good performance even at low beam current

Phase within pulse

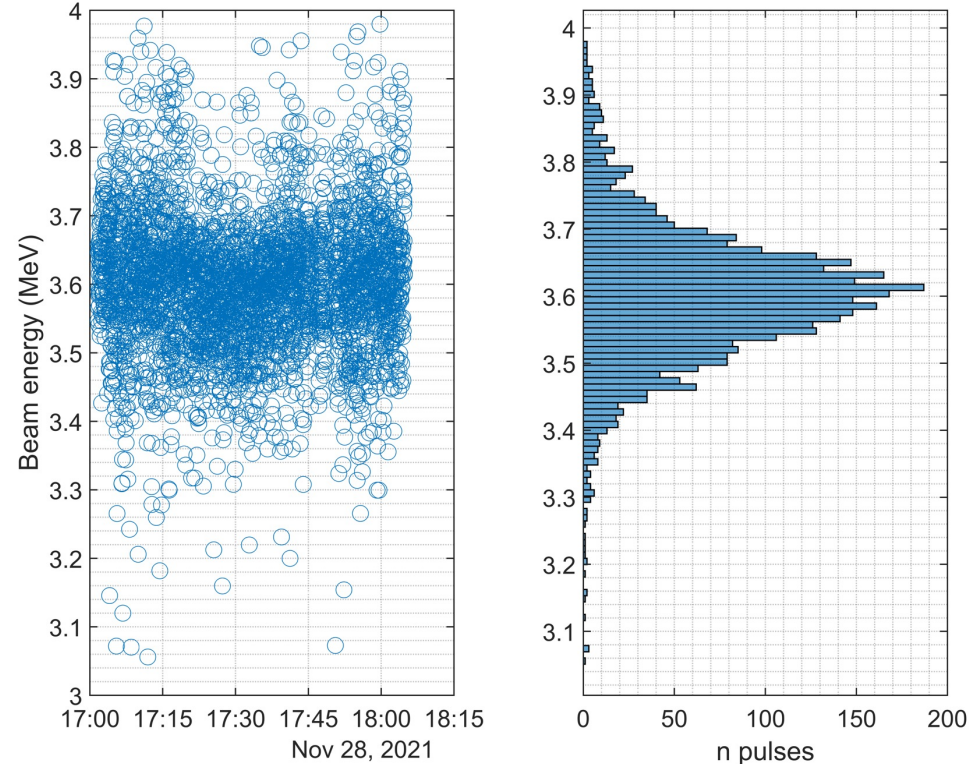
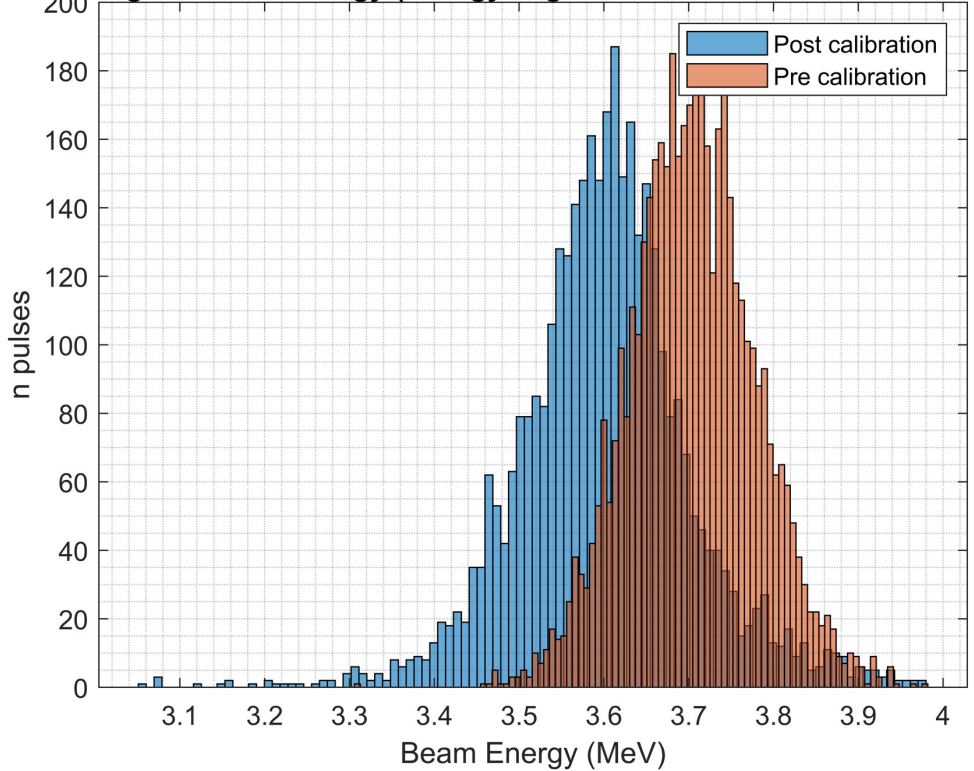




Centroid Measurements - Energy

Fast BPM

Histogram beam energy (Energy avg = 3.6015 MeV, STD=0.1032 MeV)



- Calibrating and trimming residual signal path difference

- Resulting distribution of energy measurements via time of flight



Distribution Measurements - Profile

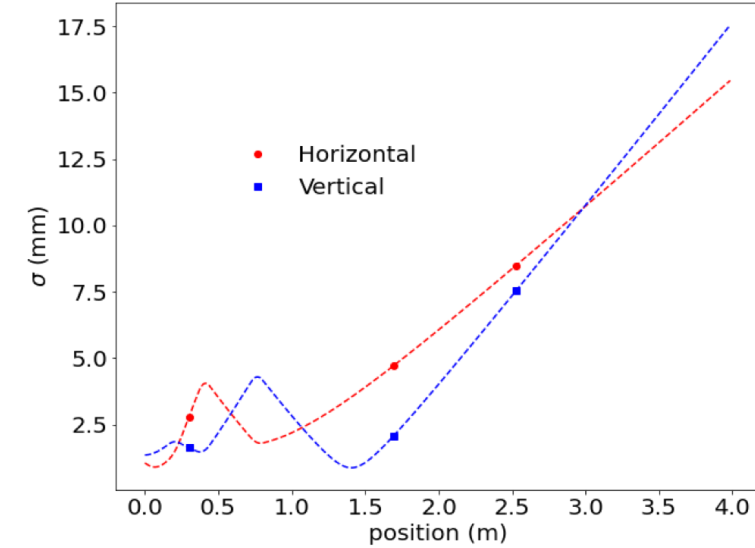
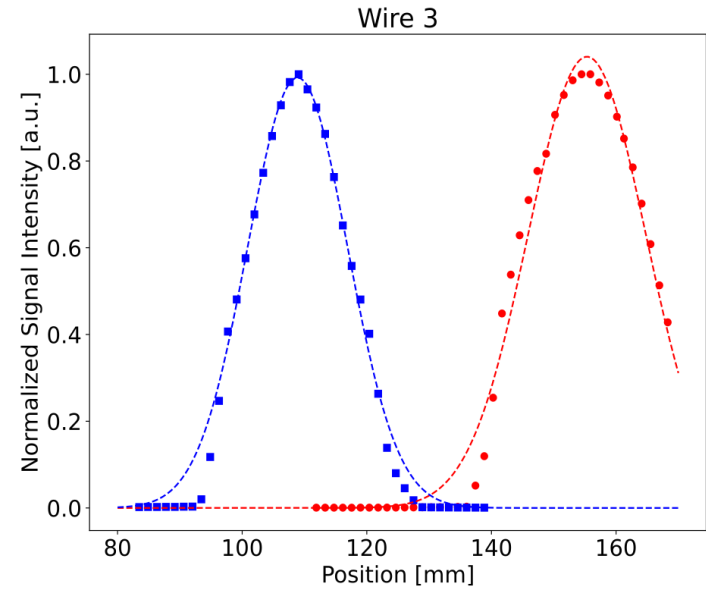
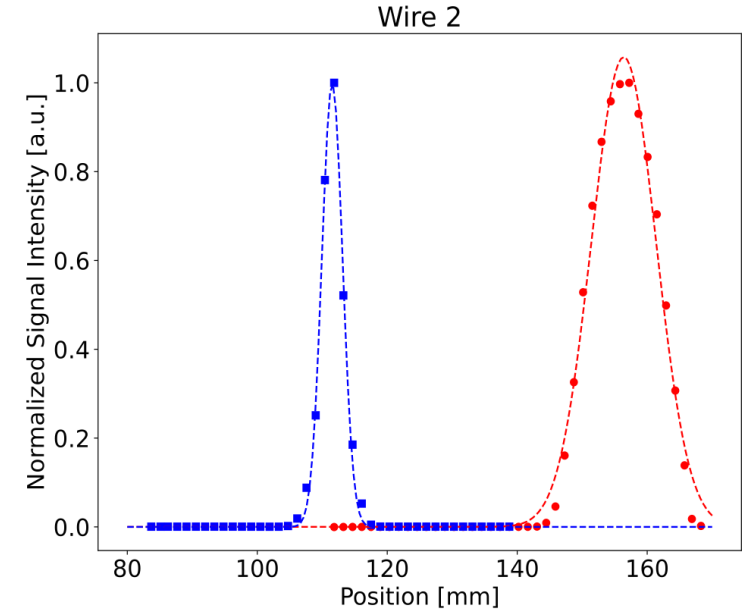
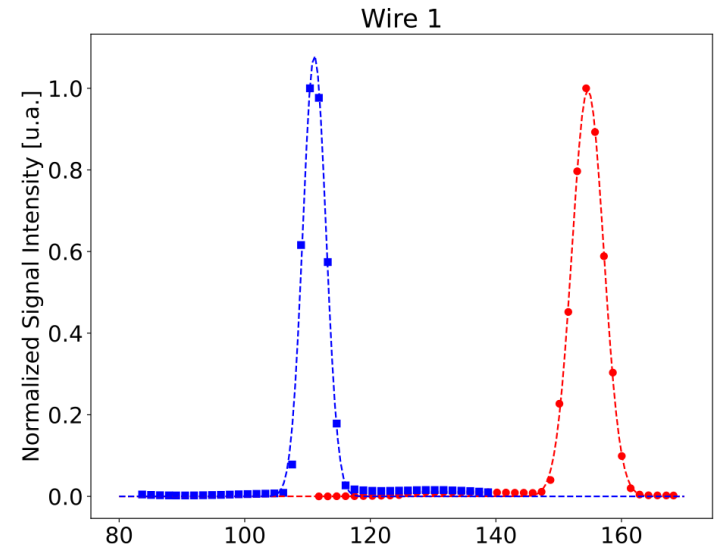
In the normal conducting linac, Wire Scanners are only located in the MEBT

3.6 MeV protons on carbon fiber

Secondary emission readout

Performance consistent with that observed in tests at Linac 4

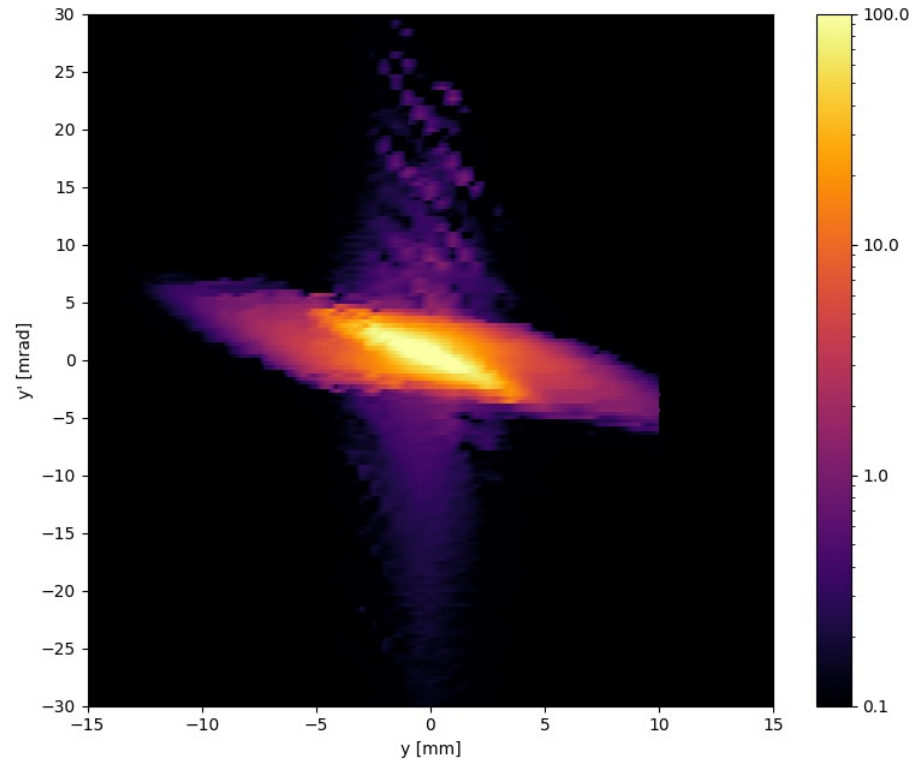
Effect of bias voltage is still being studied



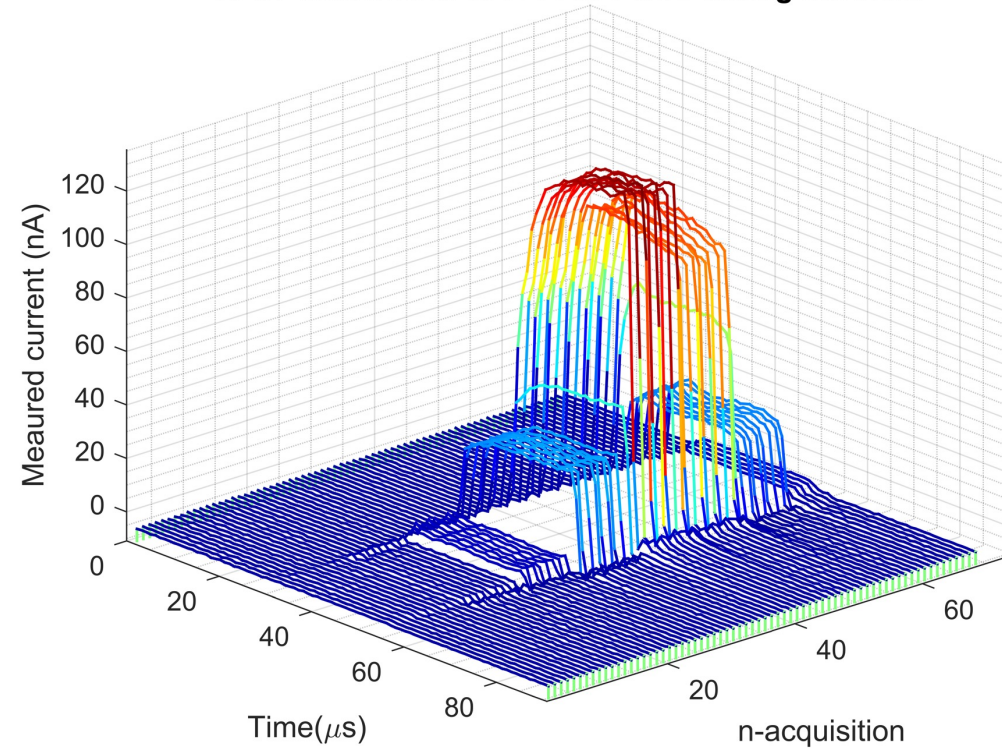
Distribution Measurements - Emittance



Slit and Grid device in MEBT



RAW data from a MEBT EMU wire during slit scan



- Successful initial scans
- Artifacts under study

- Slice emittance measurements are feasible
- Electromagnetic interference and dynamic range issues are being addressed

Toward Beam on Target

Build on lessons learned from NCL commissioning:

- Integrated testing
- Conduct of operations for high power ops

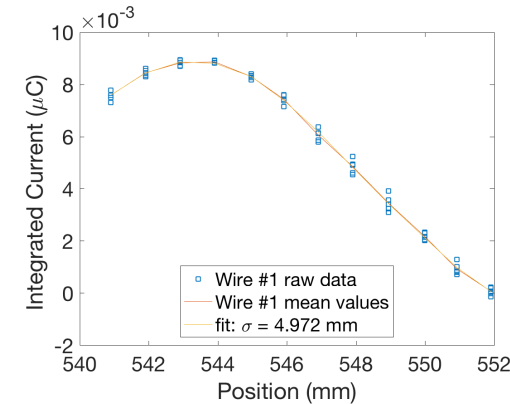
- Data acquisition and analysis tools

Combine with prior experience:

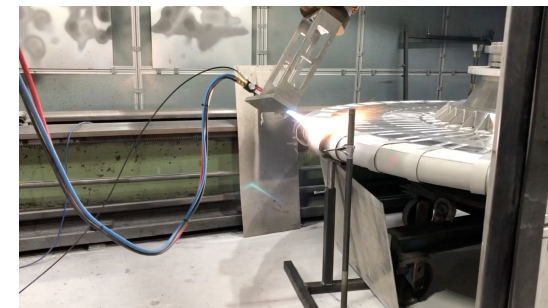
- Superconducting linac; spallation target commissioning and testing – SNS/ORNL, LANL, ...
- Target instrumentation studies – **J-PARC**, SNS/ORNL, DTU, OCL, ...



Fast Wire scanners for long pulse characterization



ESS target grid tested at J-PARC



Luminescent coating for imaging beam on target



Questions?