Summary WG-E: Beam Instrumentation and Intercepting Devices

Conveners: Peter Forck, Patrick Hurh & Kenichirou Satou

Very relevant talks: 10 invited speakers, 5 contributed speakers, good mixture of subjects

Relations between Working Group subjects:

- **Beam dynamics ↔ Instrumentation:**
  Modeling and tests ↔ Realistic instruments
- **Operation ↔ Instrumentation:**
  Reliability & safety ↔ Usability of instruments
- **Beam dynamics ↔ Material interaction:**
  Accelerator design ↔ Practical realizations
- **Operation ↔ Target & collimator:**
  Safety ↔ Simulations & installation requirements

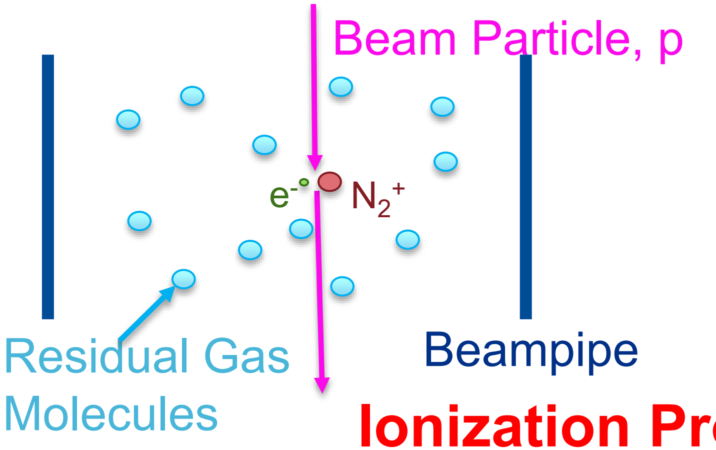
HB conference interactions:

- Best suited event for a discussion of those topics between experts of all fields
- Many thanks to the speakers and poster presenters for valuable contribution!

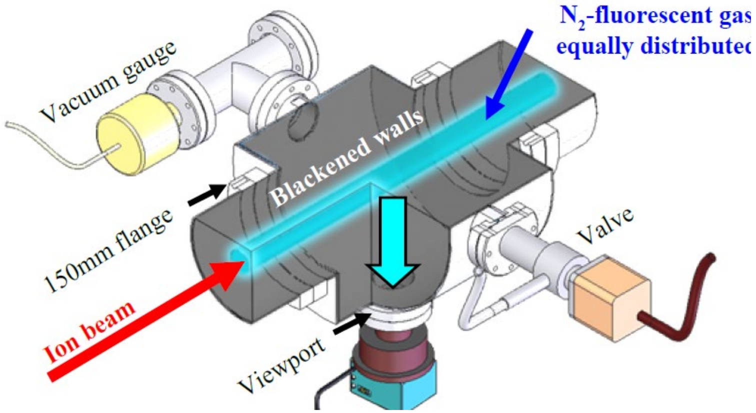
Randy Thurman-Keup: Non-Invasive Transverse Profile Measurement (Overview Talk)

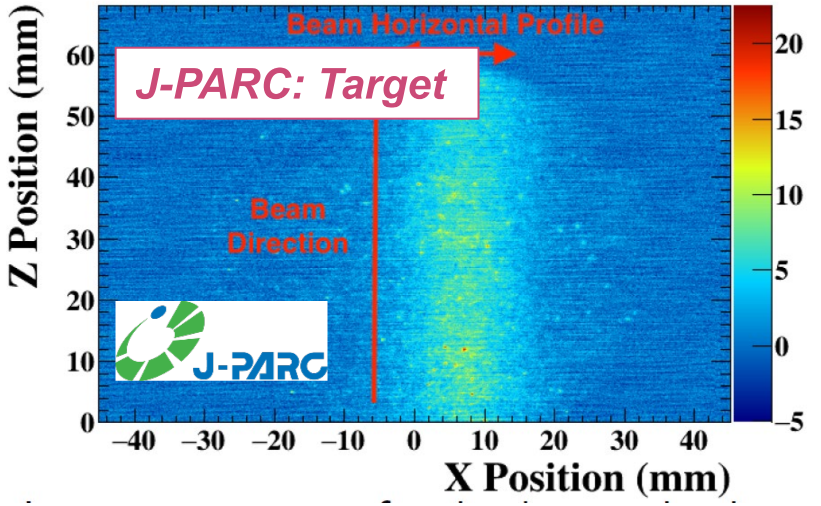
Fermilab

Signal from the residual gas or jet:

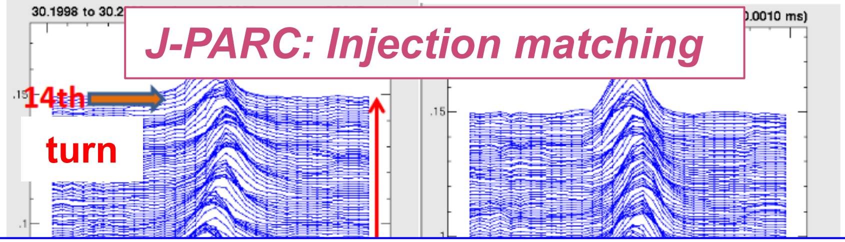


Beam Induced Fluorescence

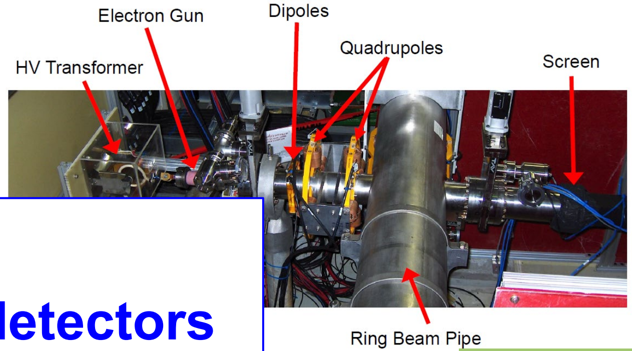




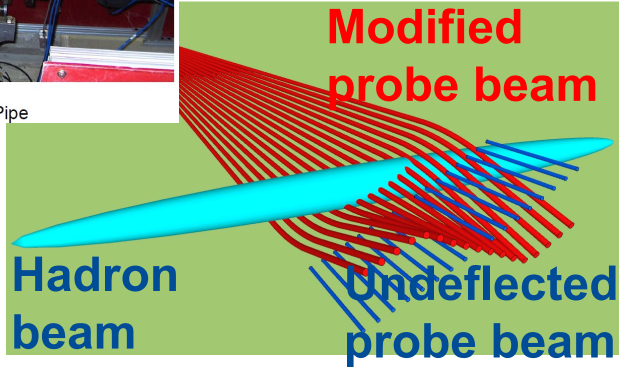
Ionization Profile Monitor



Deflection of electron beam



SNS & Fermilab



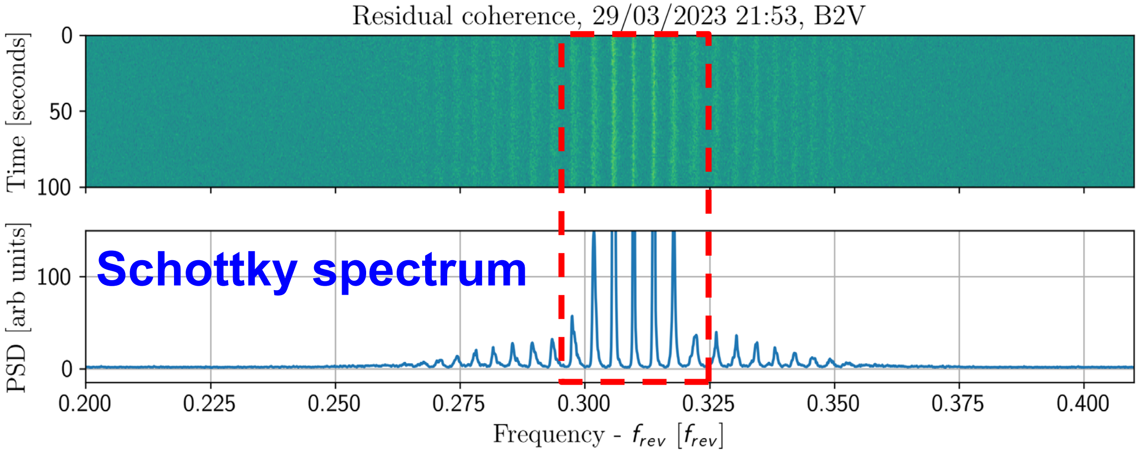
Trends:

- **Non-invasive profile measurement with innovative detectors**
- **Beam alignment with full power at LINACs, targets & rings**
- **Dedicated instruments with innovative concepts**

→ Permanent supervision possible

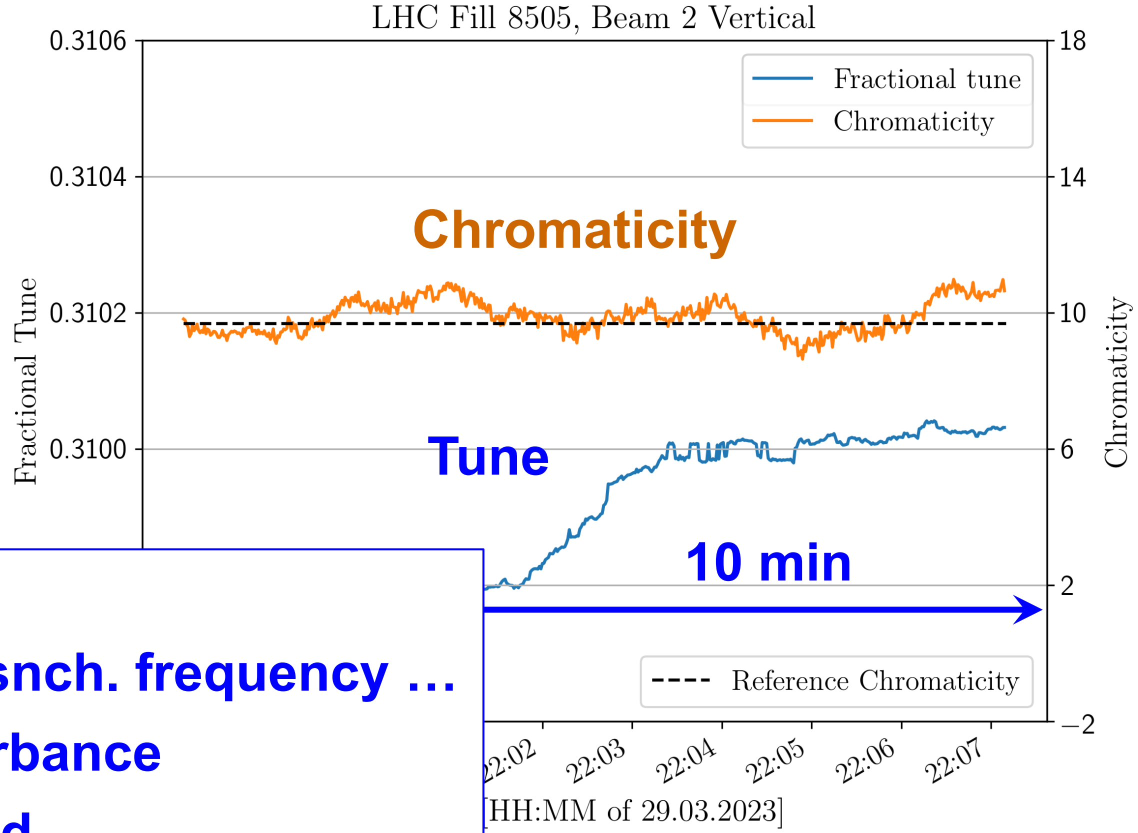
Extraction of beam parameters: tune & chromaticity

Example: Early proton fill in March 2023



Betatron tune

$$C_{MD}(k) = \sum^{i=N} \left| P_T^{\pm}(\omega_{k-i}) - P_T^{\pm}(\omega_{k+i}) \right|$$

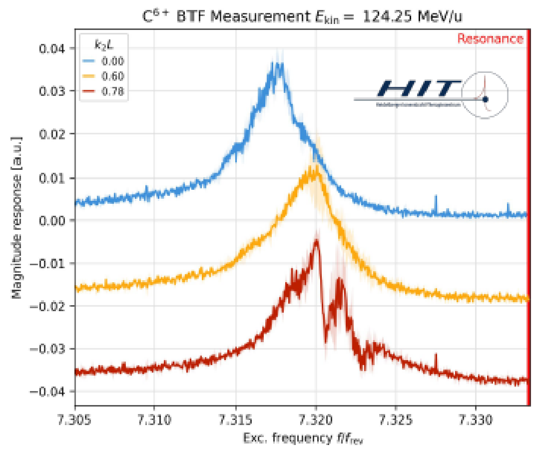


Trends:

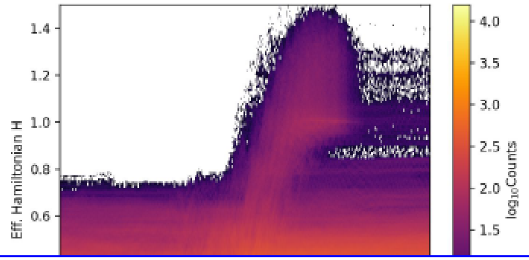
- **Non-invasive measurement: Tune, chromaticity, snch. frequency …**
- **Time-resolved determination without beam disturbance**
- **Exact mathematical analysis and fitting performed**

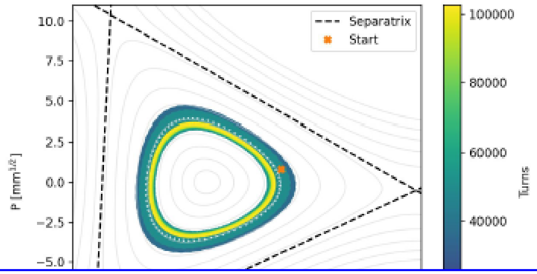
→ Required for improved operation

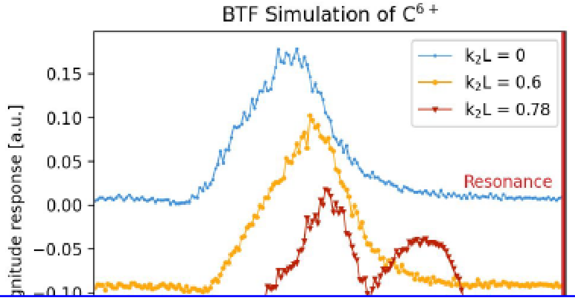
- The beam dynamics near the third integer resonance are well described by the Kobayashi Hamiltonian
- The measured BTF signal splits asymmetrically towards the resonance into two peaks
- The simulation shows that energy gain/loss induces a phase-amplitude detuning
- Initial conditions are key to understanding the underlying non-linear dynamics



Measurement







Simulation

Trends:

- **Non-invasive measurement: "Tune" modification**
- **Monitoring of non-linear processes**
- **Simulation with adequate tools (here XSuite)**

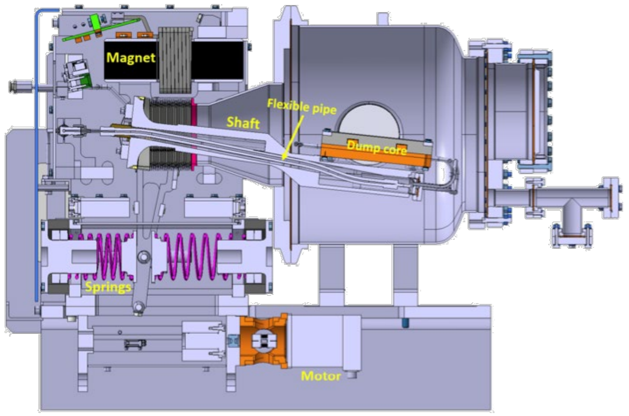
→ Improvements for understanding & operation achieved (here for slow extraction)

Samuel Niang: Shower simulations for the CERN PS Dump and Comparison to BLMs

Radiation from CERN-PS internal dump

Task:

- Comparison of measurement and simulation
- Radiation damage for upstream components calculated
- Head load of dump and nearby components



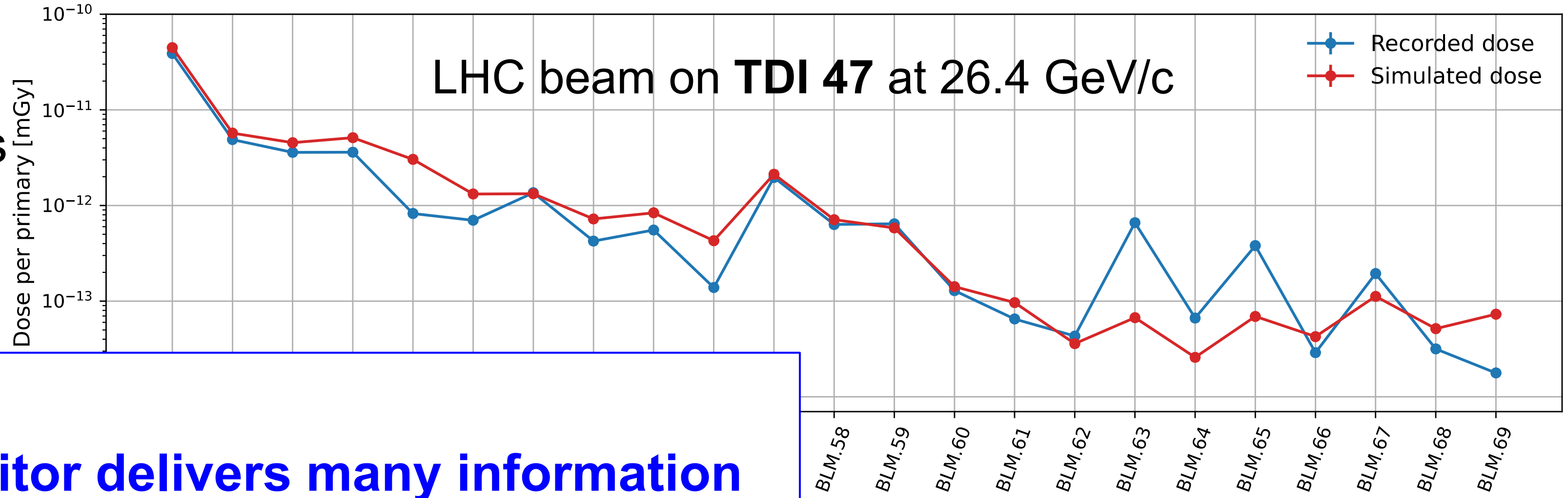
Results:

Good correspondence

Evaluation of hot-spots in magnets

Outlook:

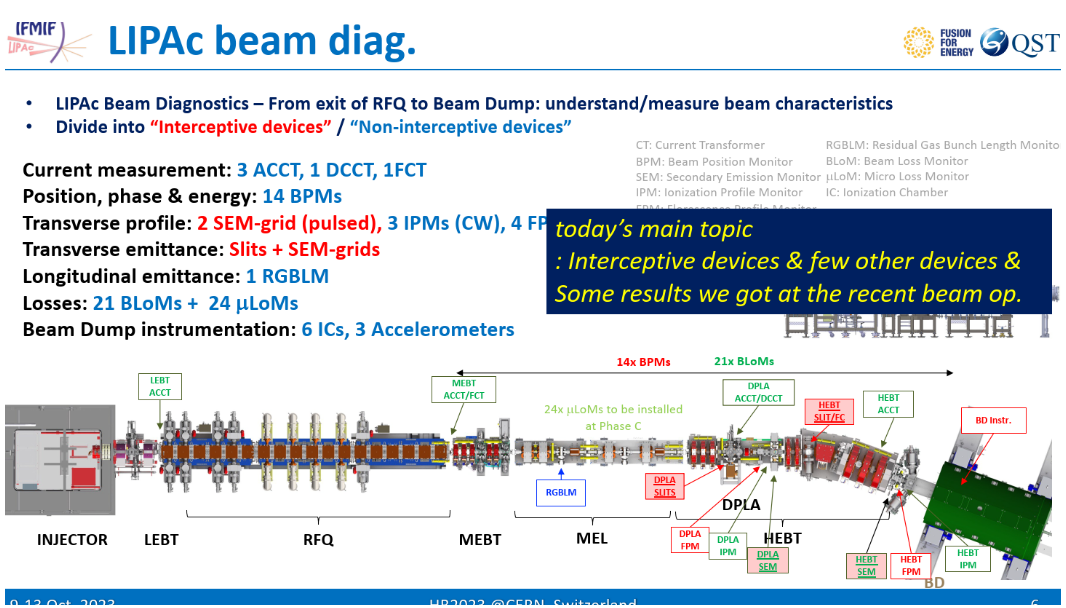
Error estimation of BLMs

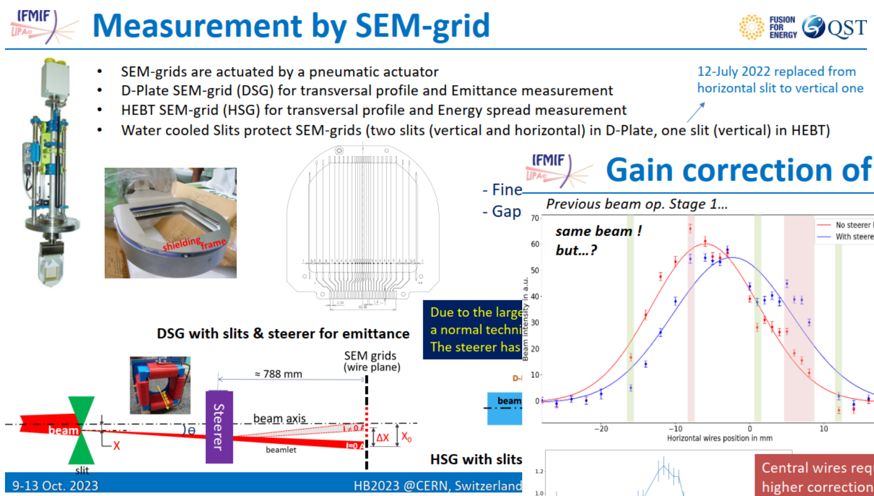


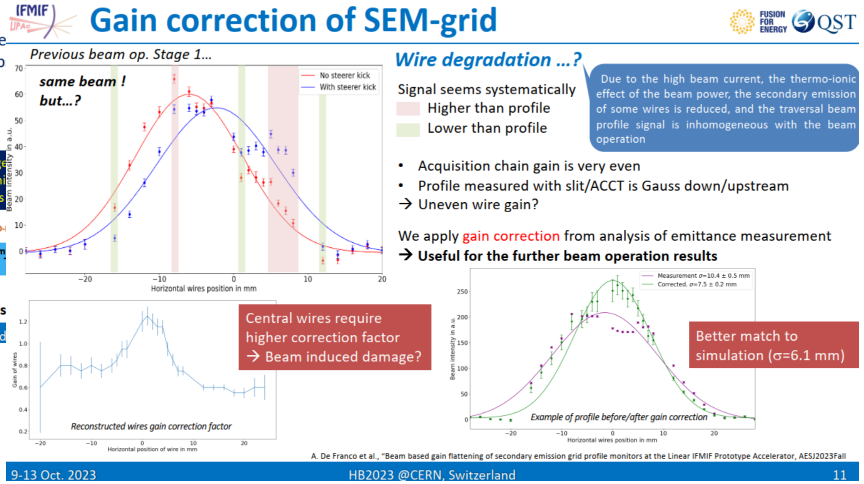
Trends:

- **Non-invasive beam loss monitor delivers many information**
- **Comparison measurement to simulation are enlightening**
- **Machine protection required for short and long term**

Searom Kwon: High beam current operation with beam diagnostics at LIPAc







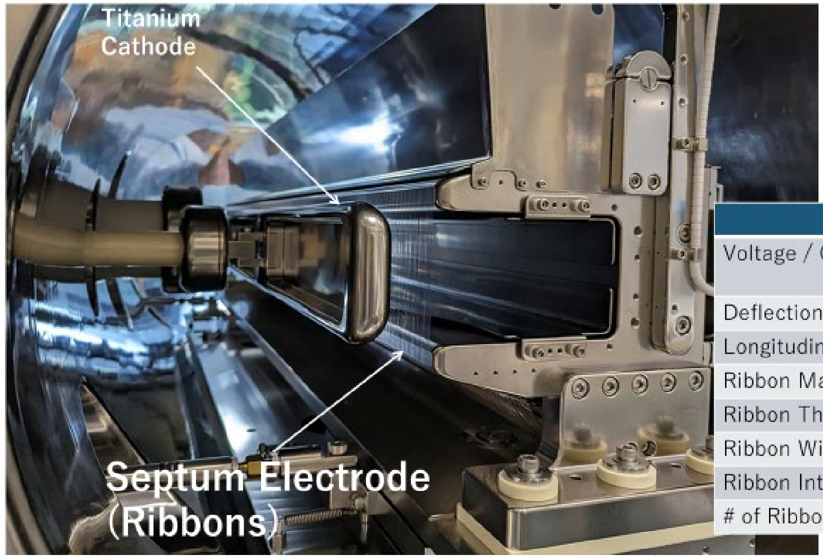
- Mainly introduces the performance and operational status of interceptive devices
  - SEM-grid, slits & faraday-cup,
- Several problems encountered during beam operation were reported
  - Wire gain flatness, wire damage due to gas pressure
- Beam position monitor, Beam dump monitoring system, non-interceptive profile monitor, CT, Beam loss monitor were also presented

➡ IPM and Beam gas fluorescence monitor are now partly ready for high-power beam tuning and operation

Look forward to the further report in the next HB

Ryotaro Muto: Devices for High-Efficiency Slow Extraction at J-PARC Main Ring

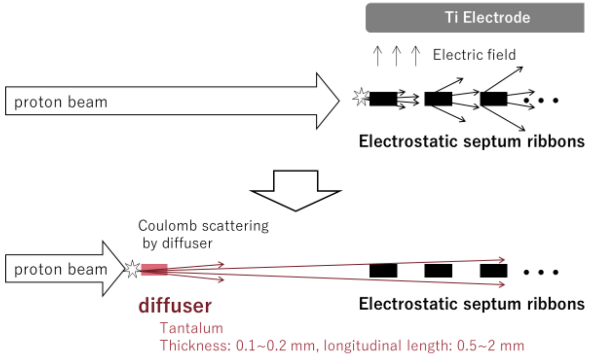
Electrostatic Septum (ESS)



	ESS1,2
Voltage / Gap	104 kV / 25 mm = 4.2 MV/m
Deflection Angle	- 0.2 mrad
Longitudinal Length	1.5 m
Ribbon Material	W-26 Re
Ribbon Thickness	30 μm
Ribbon Width	1 mm
Ribbon Interval	3 mm
# of Ribbons	495

15

Beam diffuser for loss reduction



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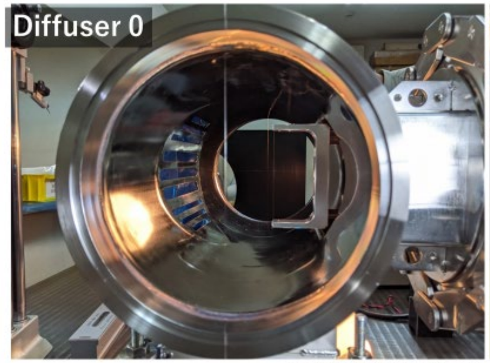
Installed Beam Diffusers



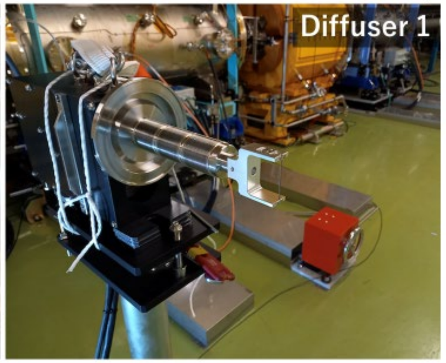


Photo from downstream

- Report on the slow extraction devices of J-PARC MR that achieved extraction efficiency of 99.5% with the help of dynamic bump scheme
- Introduction on the new devices of beam diffusers, bend silicon crystal for the beam loss reduction as well as collimator devices

Elena Donegani: Beam destinations Commissioning of the ESS normal conducting LINAC

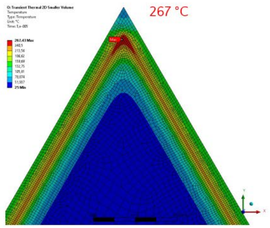
BEAM DESTINATIONS

GOALS:
- To safely absorb and dissipate the **ESS beam power**
- To measure the **proton current** in real-time
- To measure the **pulse length** in real time
- NO expensive/bulky test-benches
- To minimize the activation and residual dose rates

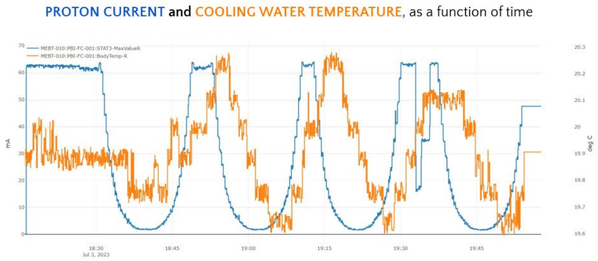
IN GENERAL:
- Designed for a specif
- Water cooling systen
- Pneumatic actuator for motion IN/OUT
- HV repeller bias (except the DTL4 FC)

→ EPICS for Timing, DAQ, HV, Motion, Cooling

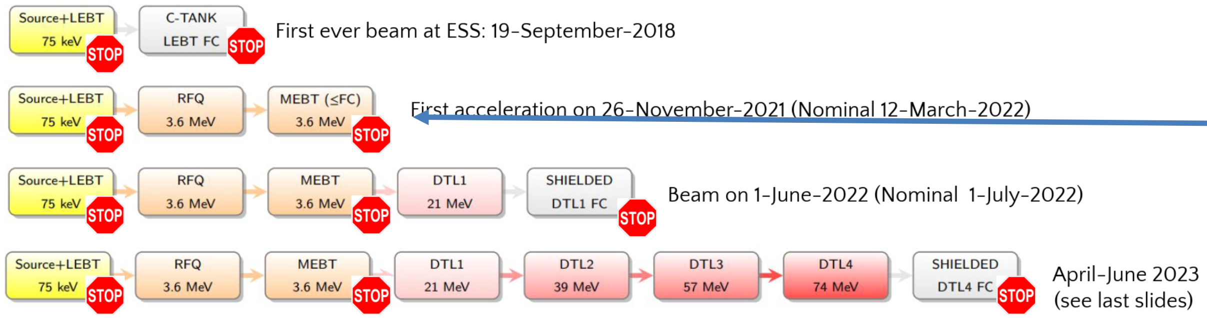
	E (MeV)	P (W)	T (℃)
LEBT FC	0.075	0.005	800
MEBT FC	3.6	16	960
DTL1 FC	21	170	620
DTL4 FC	[21, 74]	323	1010



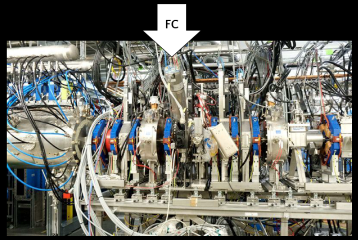
Courtesy of A. Olsson

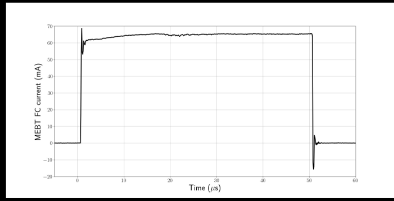


From the EPICS archiver-appliance at ESS



MEBT – 11/2021





MEBT = Medium Energy Beam Transport

[I.BUSTINDUY et al., LINAC2014]
[A.SOSA et al., LINAC2022]
[N.MILAS et al., IBIC2022]

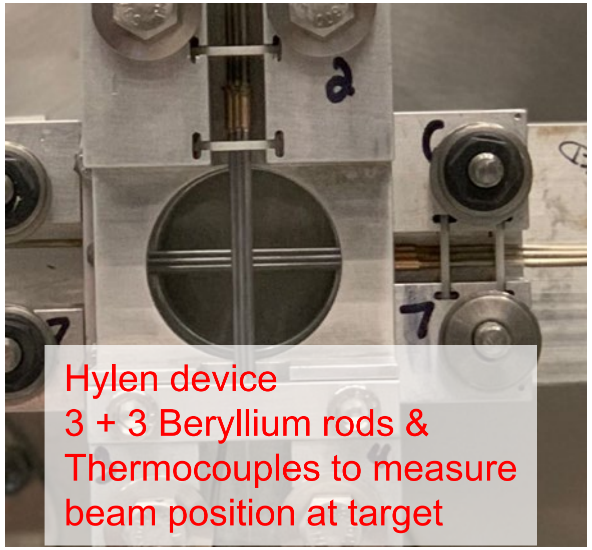
MEBT FARADAY CUP
Designed by ESS-Bilbao, manufactured by Pantechnik
11/2021 Probe beam successfully accelerated in RFQ

3/2022 Nominal current, 95% RFQ transmission (20 μs)
2023 Pulse cautiously increased up to 50 μs

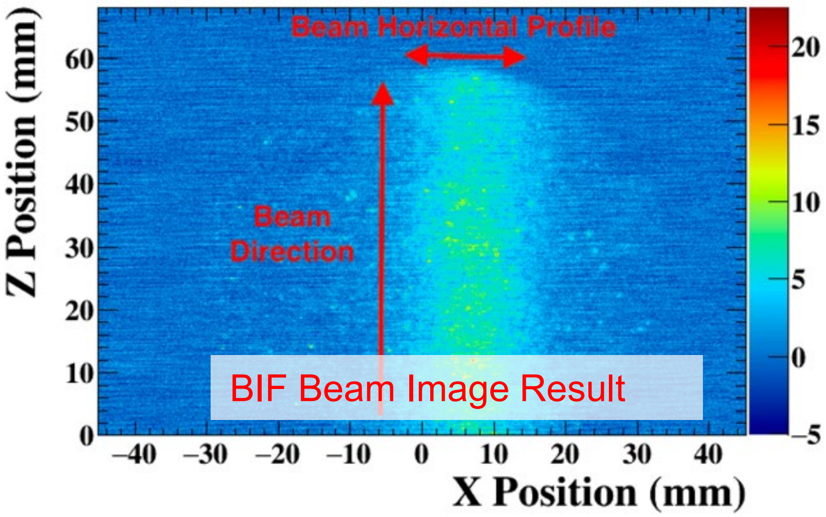
- Design and commissioning results of four different beam destinations (≒Faraday cups : FCs) at LEBT, MEBT, DTL1, and DTL4
  - Very high beam power density absorbed at CTs -> Heat and radiation issue
  - Different design for different beam destination, each has individual technical limitations
  - Thermal, cooling and activation simulations for each CT

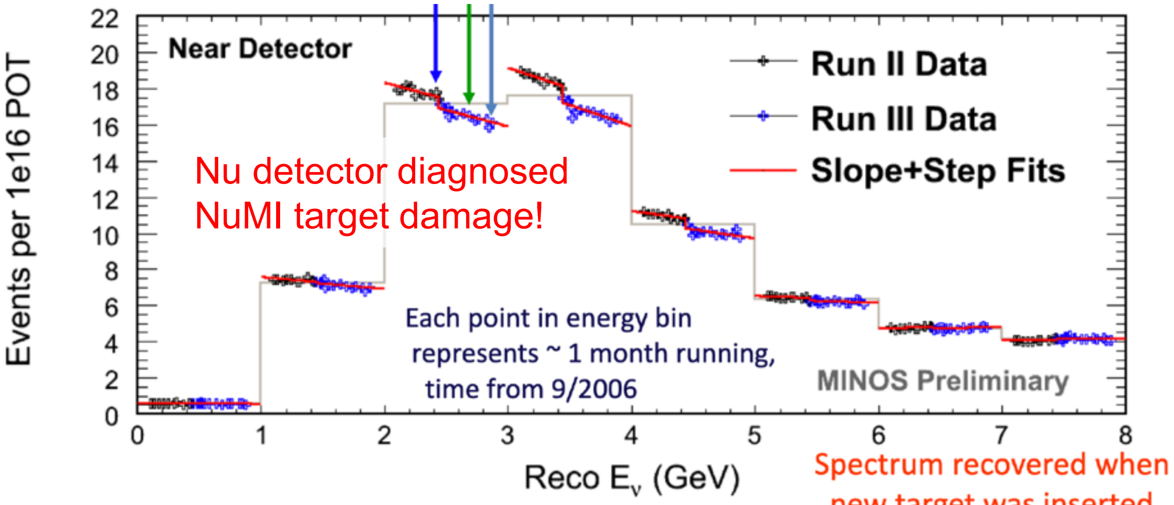
M. Friend: Beam Diagnosis and Soundness Check System for Neutrino Production Targets

- Similar set of diagnostic tools for reliable operations and monitor neutrino target health
  - Using both primary and secondary beam instrumentation
- Unique to Fermilab NuMI: "Hylen Device"
- Unique to J-PARC T2K:
  - Optical Transition Monitor
  - Beam Induced Fluorescence
- Lesson Learned: Instrumentation in high-power target facilities is critical to reliable operations and must be part of the accelerator facility design (incl MPS)



Beam image at camera (1 spill):



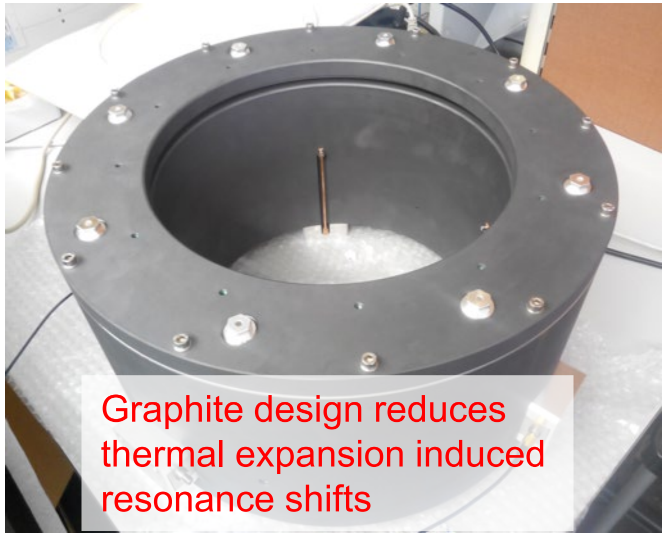


Spectrum recovered when new target was inserted

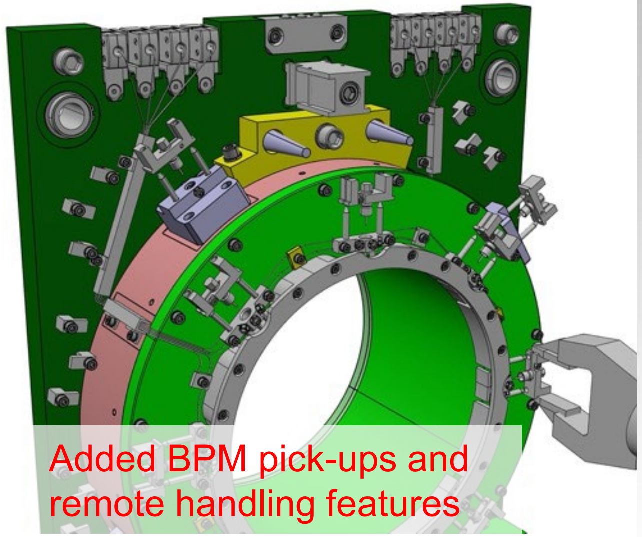
J. Sun: Improvement Design of a Beam Current Monitor based on a passive Cavity under heavy Heat Load and Radiation

PAUL SCHERRER INSTITUT

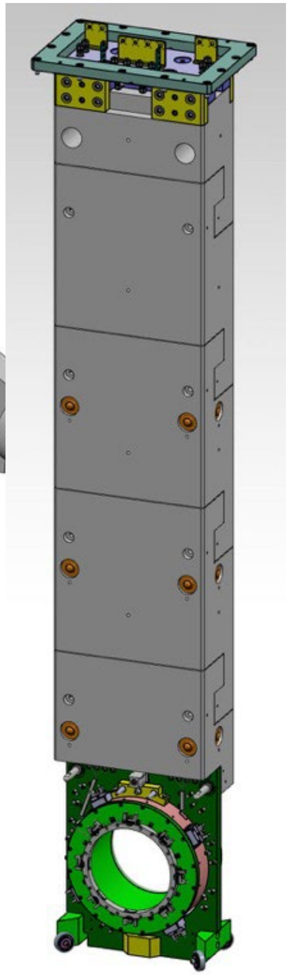
- The graphite resonator version of the MHC5 has been operated under heavy heat load and radiation since 2015.
- Beam current and position measurements are performing as expected.
- On-line current calibration method improves further the stability of the measurements.
- The new MHC5 design will:
  - further broaden the type of measurements performed
  - facilitate maintenance
  - minimize human radiation exposures and active wastes in case of replacement.
- Lab tests with the new system are expected to take place beginning of next year.
- *Bonus lesson: NuMI Hadron Monitor experience (Fermilab) with Kapton cable degradation caution to new cabling design



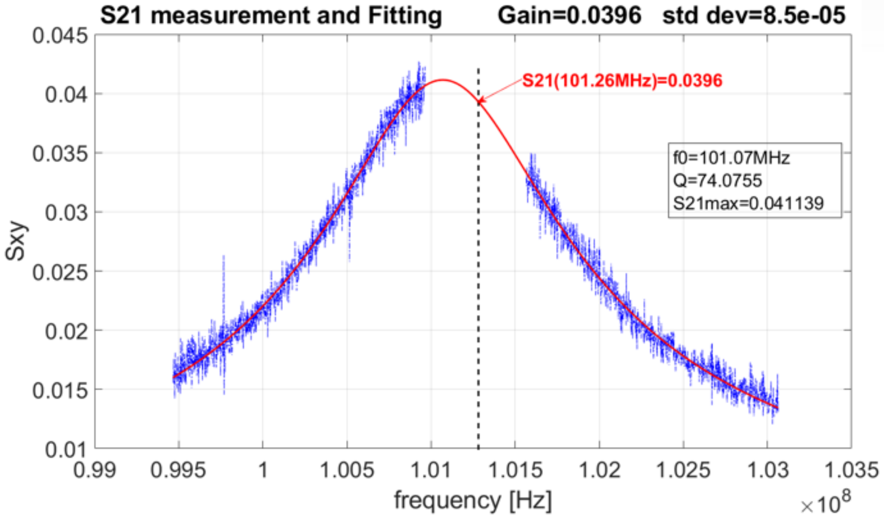
Graphite design reduces thermal expansion induced resonance shifts



Added BPM pick-ups and remote handling features

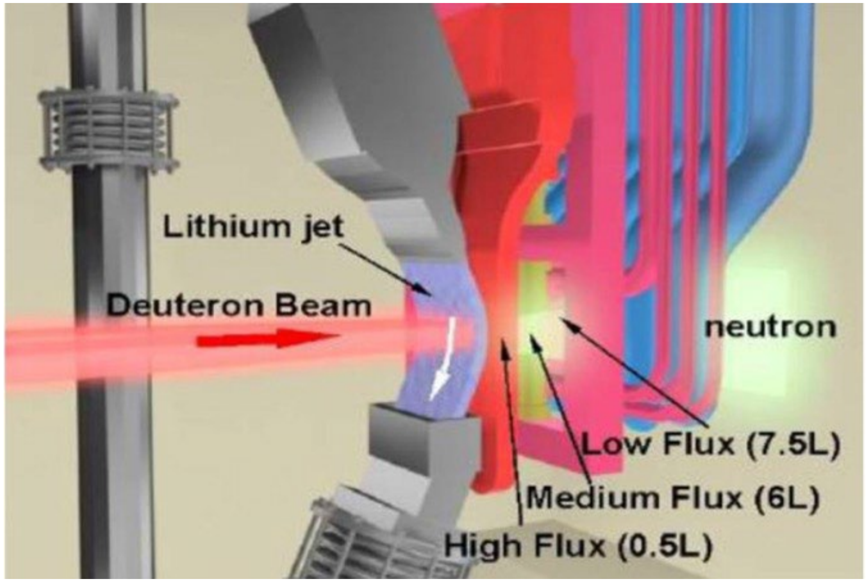


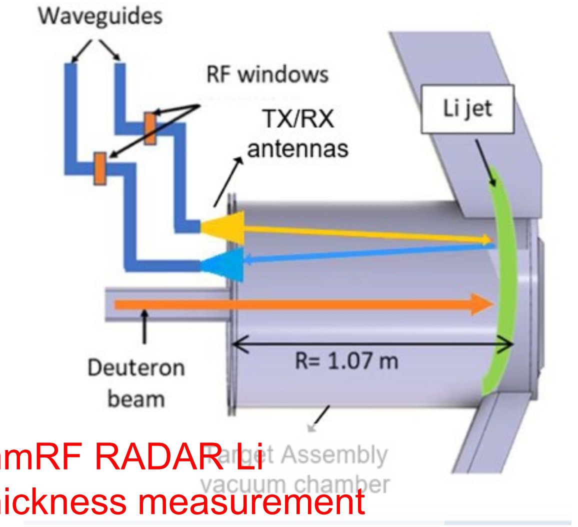
Kapton insulated cable for Remote Handling flexibility*



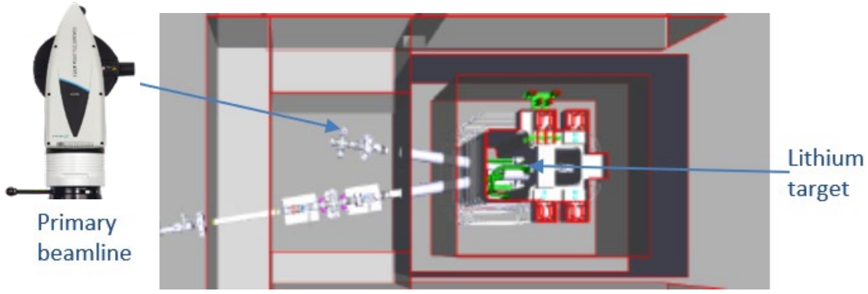
New Online Calibration Scheme improves accuracy and ease of use

- IFMIF-DONES will consist of a 5 MW, 40 MeV deuteron beam on a liquid lithium jet target (25 mm thick) to produce a 14 MeV neutron spectrum for fusion materials testing
- A Li thickness reduction > 3 mm would lead to power deposition in the Back-Plate
  - Failure/melting could take place in tens of milliseconds
- Thickness monitoring planned via optical LIDAR or mm RF (RADAR) techniques
  - Ultrasonic Transducer suggestion from HB participant
- Beam footprint obtained by beamline optics (not rastered) and monitored by thermal imaging
  - BIF possible technology suggestion
- Message: Diagnostics are critical to safe, reliable operations and need to work at all power levels (including low power)

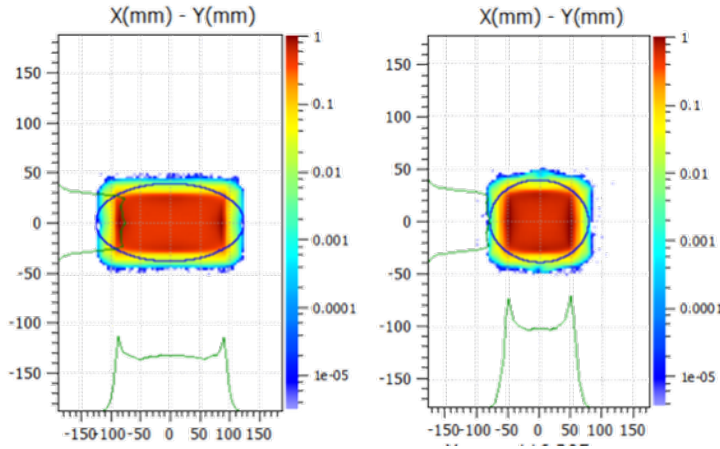




mmRF RADAR Li thickness measurement



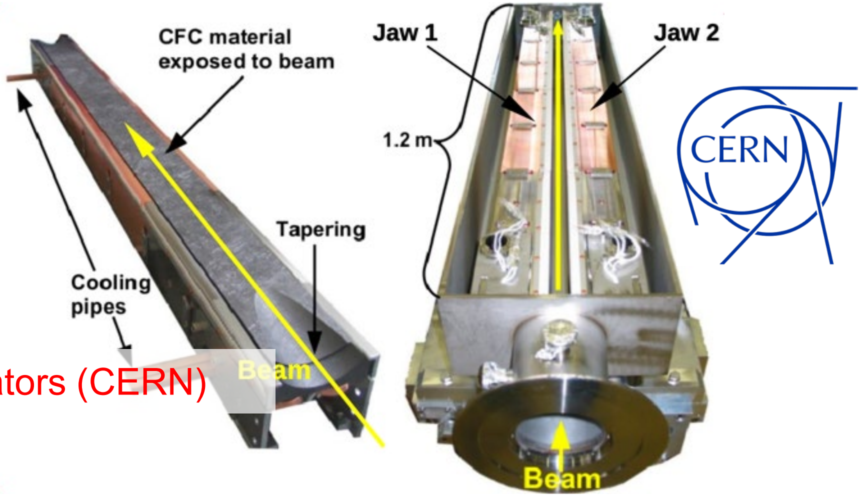
LIDAR Li thickness measurement through secondary beamline?



Beam footprint on Li target (5x20 cm^2) monitored by thermal imaging

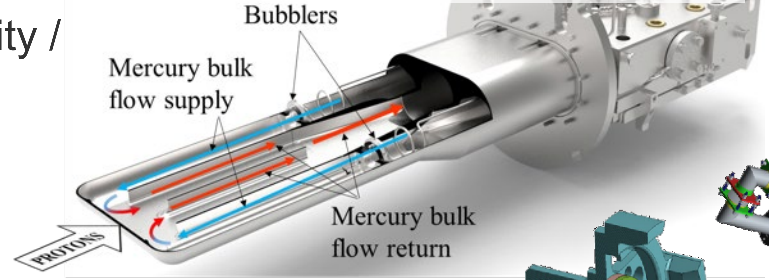
A. Perillo Marcone: **Beam Intercepting Device Challenges for High Intensity Accelerators - Global perspective**

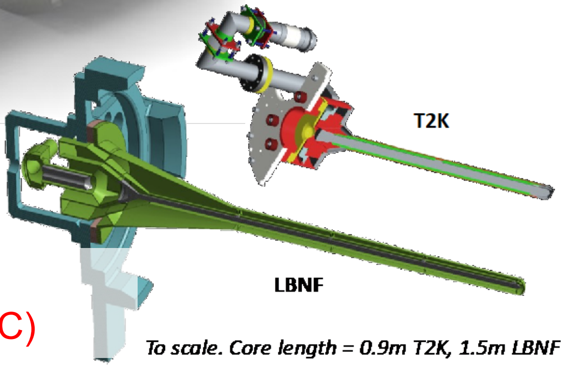
- Provided Global view of variety of Beam Intercepting Devices (BID) and associated challenges
- Wide variety of challenges found in BIDs
  - Material specification, characterisation, testing, simulation is critical
  - Instrumentation necessary to understand the behaviour of BIDs (but often a challenge itself)
  - Cooling
  - Manufacturing methods / reliability / fatigue
  - Operation in UHV
  - Impedance
  - Irradiation damage
- Near future applications are at the limit of engineering and materials capabilities/knowledge

LHC collimators (CERN)

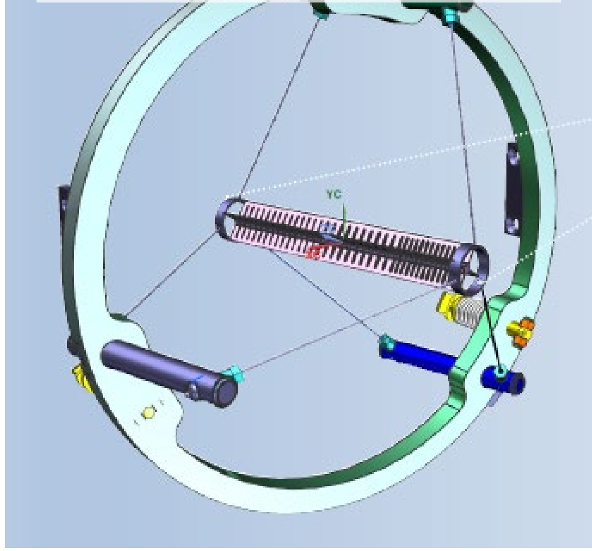
Spallation Neutron Source Targets (ORNL, J-PARC, RAL)



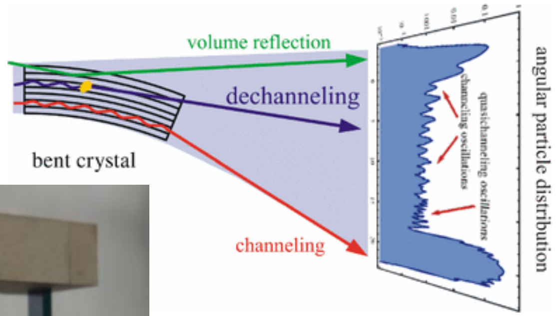


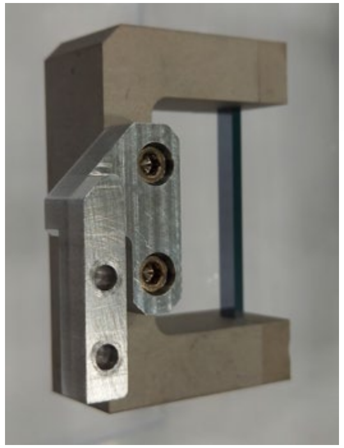
Neutrino Targets (FNAL/RAL, J-PARC)

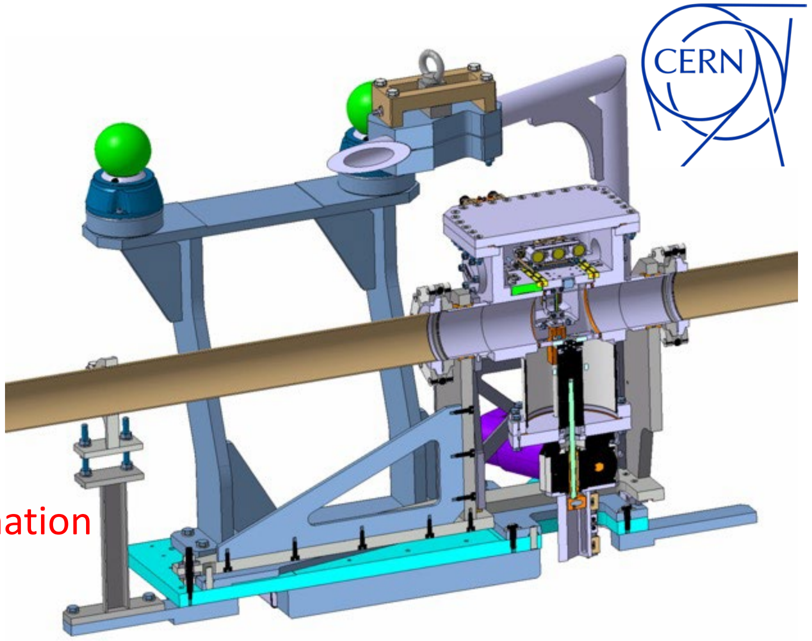
Mu2e Tungsten Target



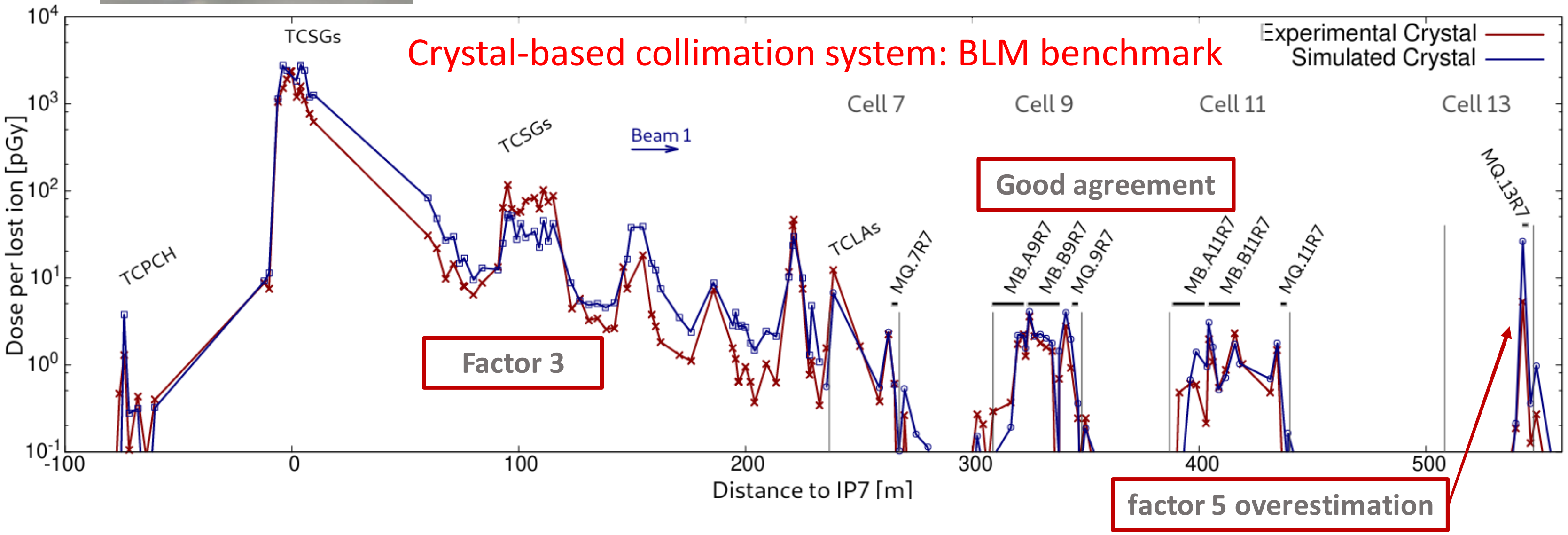
- Power deposition distributions in the superconducting magnets were obtained using FLUKA for the HL-LHC baseline configuration for Run3
- Satisfactory reduction of the power density in IR7 - DS magnets with crystal collimation even though there is some uncertainties about the actual quench levels.
- Power deposition in DS dipoles (~12 mW/cm3) from Beam 2 losses should remain below the expected quench limits in case of a lifetime drop . Much larger margin for quadrupoles.
- Losses in the DS are coming almost exclusively from inelastic/EMD interactions in the crystal/ primary collimators.
- A separate assessment for Beam 1 (crystal with different channeling efficiency) is ongoing.



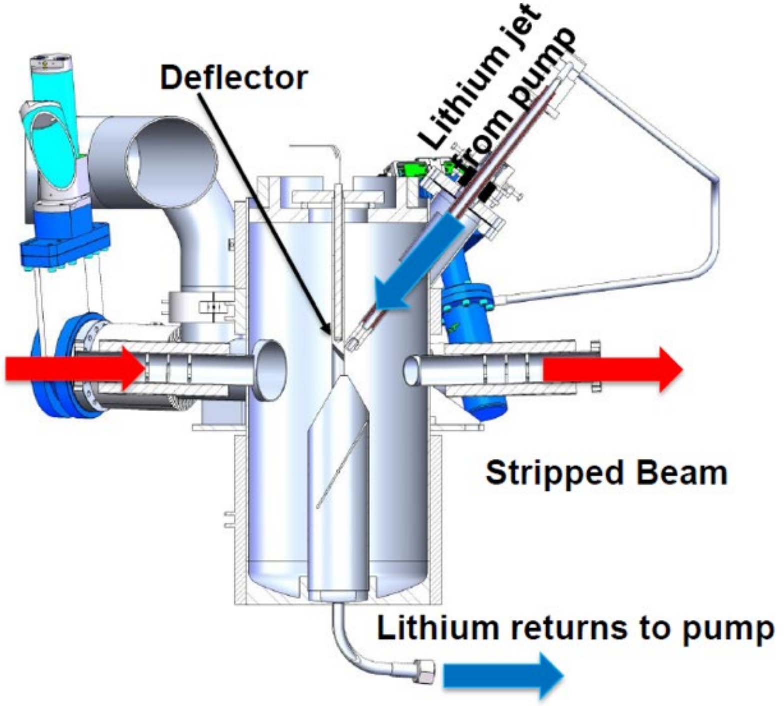


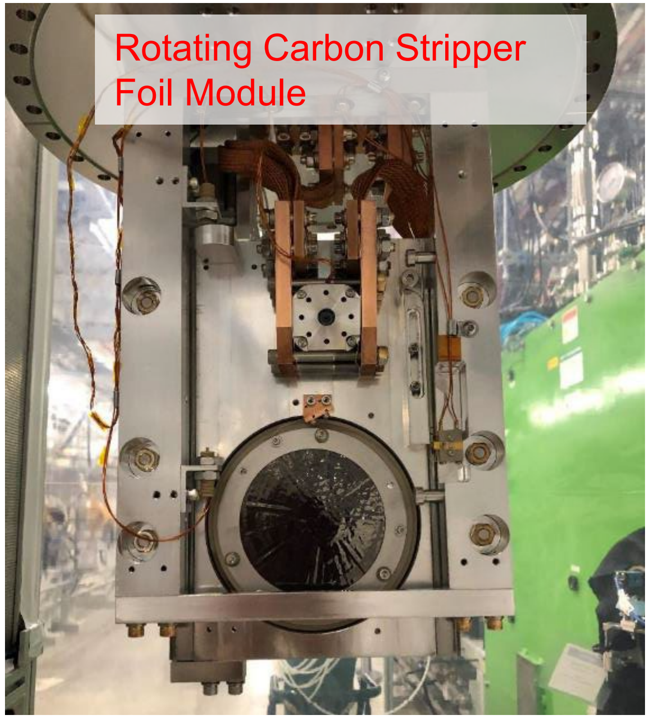


Crystal assisted collimation system in LHC Run 3

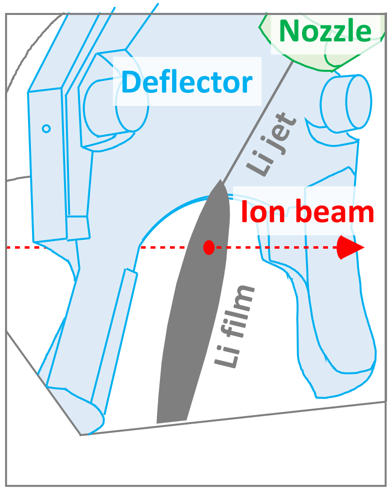


- FRIB has used two types of charge stripper
  - Liquid lithium charge stripper
  - Rotating carbon charge stripper
- Operational performance of liquid lithium charge stripper
  - Tested up to 5-kW-at-target Xe beams
  - Ready for higher power beams including uranium
- Operational performance of rotating carbon charge stripper
  - Two brands of graphene foils
  - Tested up to 5-kW-at-target Xe beams
  - Type A foil was damaged by ^{198}Pt most likely due to radiation damage
  - Type B foil has never been irradiated by ions heavier than Xe at FRIB
- Routine 10 kW operations will begin October 2023
  - Carbon stripper for ion species lighter than Xe
  - Lithium stripper for ion species heavier than Xe





Rotating Carbon Stripper Foil Module

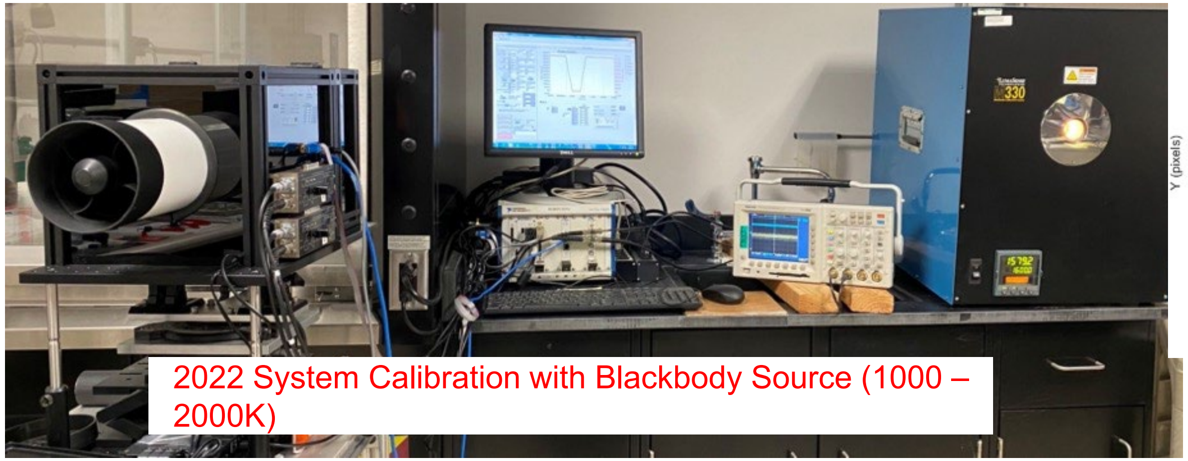


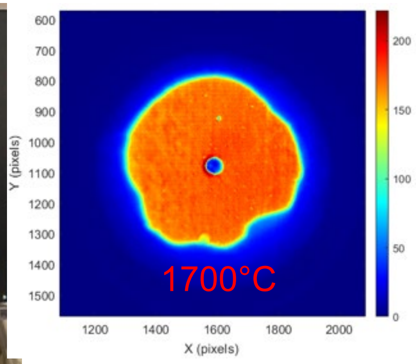
Damage with 198Pt beam at ~200 W (at stripper)

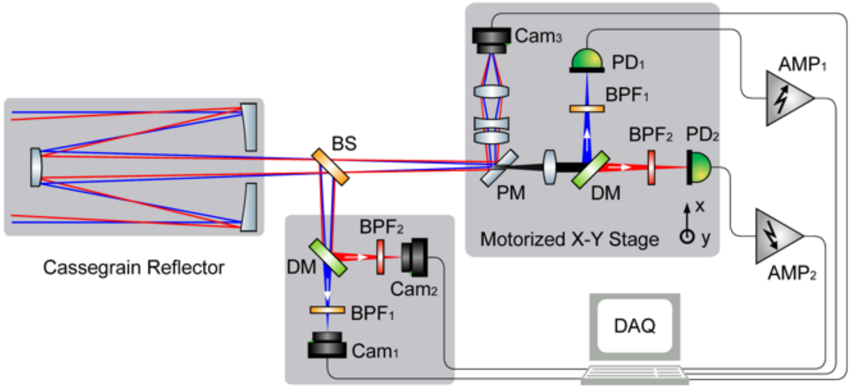
A. Oguz: 2-dim Temperature Measurements of nano-crys. Diamond Stripper Foils at SNS

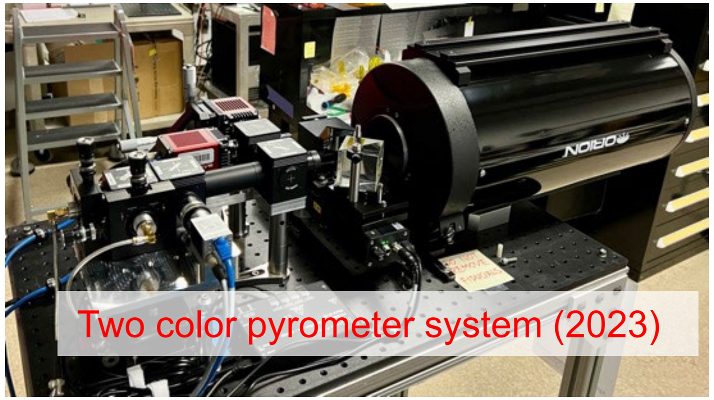
OAK RIDGE National Laboratory | SPALLATION NEUTRON SOURCE

- Designed, built & calibrated two-color imaging pyrometer with a wide working range (900 – 2000K).
- We have spatio-temporal measurements of foil temperature at various H– beam power (0.6 – 1.7MW).
- Developed an effective & reliable data analysis algorithm to extract foil temperature.
- Temperature measurement uncertainties:
- 2D Pyrometer Status:
  - Data is still being analyzed.
  - Optimization of filter choices will be next (SNR in shorter wavelength can be improved).
  - Thorough calibration and more studies will follow.


2022 System Calibration with Blackbody Source (1000 – 2000K)






Two color pyrometer system (2023)