JAPW workshop

Fixed target program – Beams and Areas
Instrumentation issues & requests

M. van Dijk (with input from many)

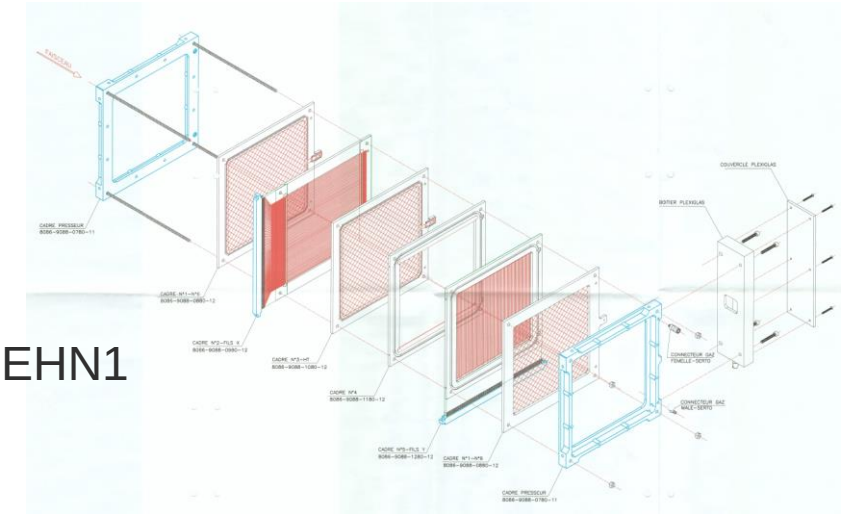
Resulting requests added to slides in red text

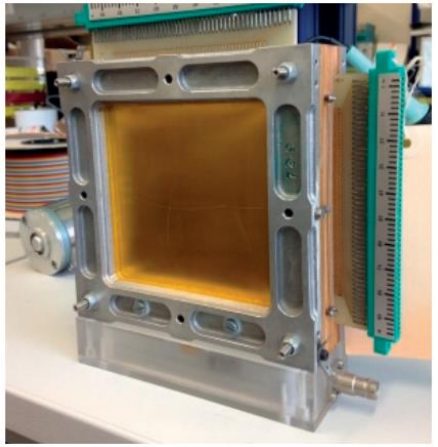
BPMs for FTN and FTA

- **Both FTN (from PS to nTOF) and FTA (from PS to AD) are limited by apertures**
  - FTN requires large beam size at new air-cooled target,
  - FTA requires very small beam size at target (requiring large beam in the line)
- **Lines are currently instrumented with mostly BTVs**
  - Cannot be used for continuous monitoring and affect the beam substantially
  - Further optics optimization would require precise and continuous monitoring using non-intercepting detectors
- **Upgrade would allow optics optimization leading to loss and activation minimization**
  - Could be used as input for YASP, possibly leading to automatic steering and drift compensation
- **Request for FTN: Five monitors providing continuous beam position measurement**
  - Suggested locations 400, 414, 434, 454 and 465, possibly using BPMs
- **Request for FTA: Four monitors providing continuous beam position measurement**
  - Suggested locations 9009, 9019, 9039, 9047, possibly using BPMs
- **Currently being followed in the BIFT meeting**
  - Activity not in MTP (currently no resources / budget), cost estimate being prepared

XBPF for NACONS and radiation hard profile monitors

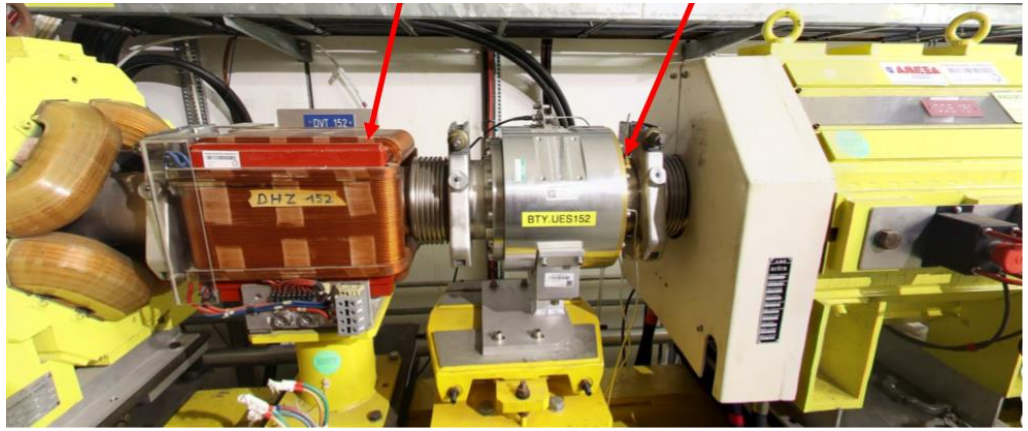
- **Multi-wire Proportional Chamber Refurbishment**
  - Critical number of spare XWCM & increasing failure rate
  - On-going MWPC refurbishment to ensure operation until LS3
- **NACONS Phase 1 – design and R&D**
  - Design of new North Area XBPF & production of 8 full (large) units for EHN1
    - Urgent new requests for upcoming NA-CONS C&S Review 2024:
      - Initiate procurement of XBPF parts for Phases 1 & 2 to optimise resources
      - Production of 8 large area XBPFs for Drell-Yan physics program in M2 beamline
  - R&D on a radiation-hard profile monitor for M2 and K12
    - Extensive prototyping on-going. Completion of final design during LS3.
- **NA-CONS Phase 2 – complete consolidation**
    - Production of rest of XBPFs ~ 40 units
    - Production of radiation-hard monitors.
- **Request 1: Accelerate timeline for XWCA/M replacement (BI)**
  Request 2: Production of large-area XBPFs for downstream part of M2 (BI)



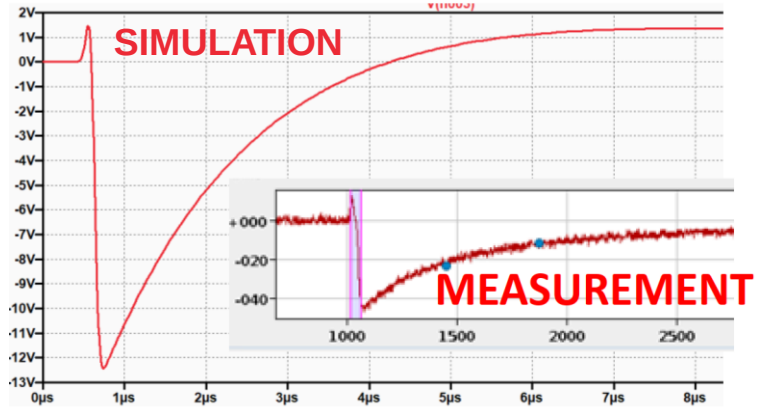


BTY line BPM issue

- **BTY.BPM152 in BTY line (from Booster to ISOLDE) suffers from electromagnetic pickup**
  - Problematic only in GPS cycles
    (for HRS, magnet current not enough to cause issues)
  - Good qualitative agreement between observed issue and SPICE simulation of pickup



- **Further steps are clear**
  - MSC team will measure stray field in YETS
  - EMI – fix: Reducing interference by grounding / shielding
  - Possible OP-side mitigation: Steer upstream so that this corrector can be used at low current



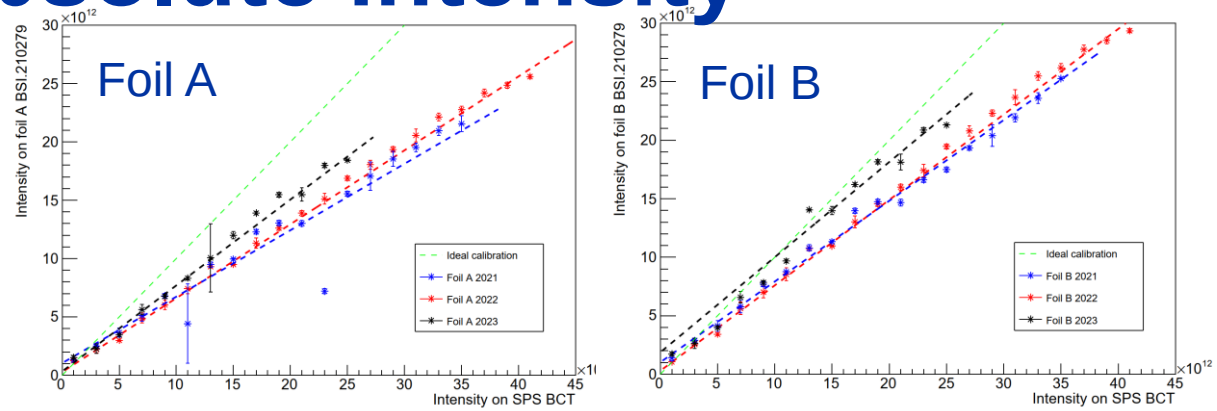
- **No request – follow issue to completion**

CEDAR issues

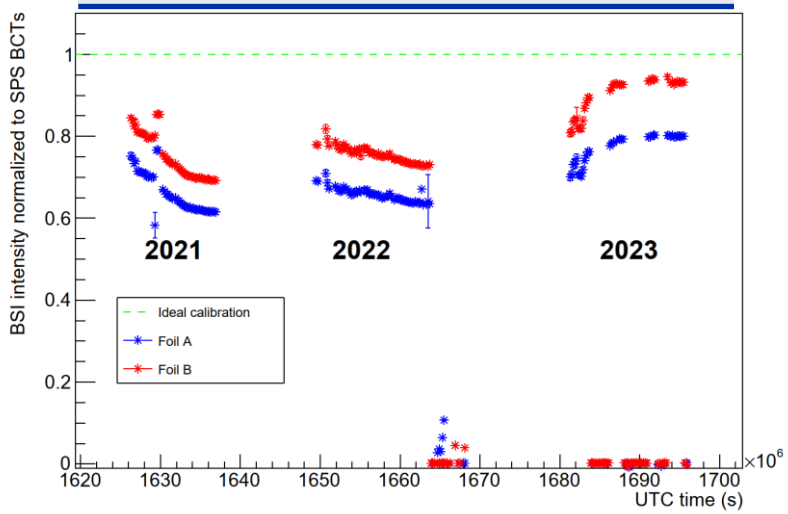
- **Some open issues remain (see backup slides for closed issues)**
  - H2 Difficult (noisy) opening of gas electrovalves June 2023
  - H2/H6 PMTs not 100% efficient with fully open diaphragm Summer 2023
  - H2 Unstable pressure August 2023
  - H6/M2 Diaphragm movement precision not adequate Summer 2023
  - M2/H2/H6 X-Y table movement precision not adequate Summer 2023
- **Program ongoing to address general ageing issues – selected issues, details in backup**
  - PMTs are becoming obsolete – model is going out of production
    - Mitigation: Buy PMTs of new model and modify CEDARs as soon as possible
  - Pressure sensors are losing precision, and no spares are available
    - Mitigation: Software modification to deal with current level of precision and deploy new pressure sensor
- **Consolidation budget likely to be advanced from NACONS Phase 2 to NACONS Phase 1**
  - To be approved at next NACONS Cost and Schedule Review (2024) – details in backup slide
- **Request: Follow to completion the remaining open issues (BI + EA)**

BSIs and the difficulty of absolute intensity

- **Long-standing uncertainty on NA intensity**
  - Last calibration >20 years ago (?)
  - Start with a request for calibration from NA62
  - Expected ~10%, to have a few % would be good
- **Observed since many years**
  - BSI intensity != SPS BCT intensity
  - Unstable over year and from year to year
  - Not clear what part is the monitor and what part is losses
  - Displayed most upstream monitor in TT20 (210279, two foils)
- **Gathering experience in diagnostics**
  - Analyze data from all BSI monitors in North Area
  - Compare monitors with each other
  - Develop the diagnostics that will lead to a strategy for addressing the issues



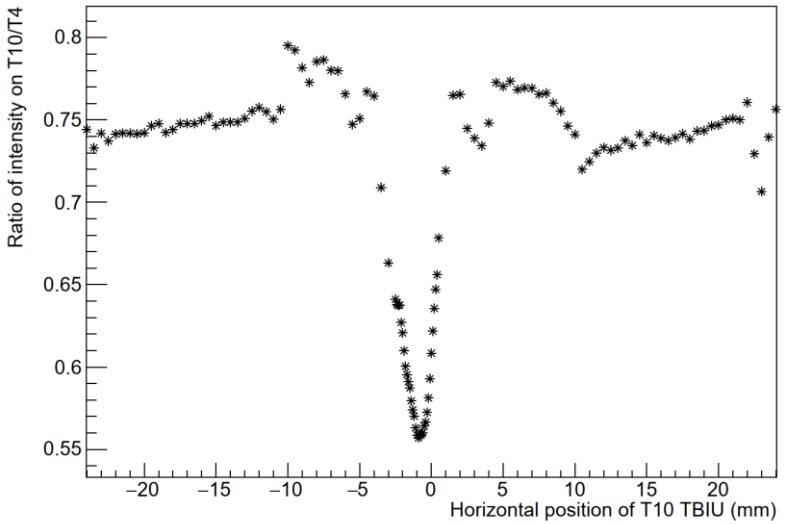
	Slope foil A	Slope foil B
2021	0.569 +/- 0.005	0.690 +/- 0.004
2022	0.634 +/- 0.003	0.731 +/- 0.003
2023	0.736 +/- 0.005	0.814 +/- 0.005



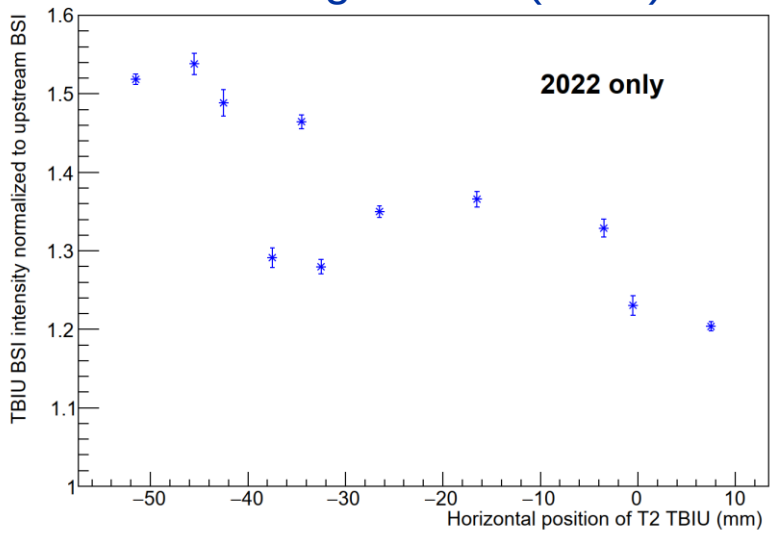
Damage to BSI foils

- **Year to year, the sensitivity of the foils seems to change**
  - Likely caused by small differences in hit position
  - Each part of the foil has a different history
- **BSI in TBIUs is too far (>12cm) from BSP**
  - Different wobbling has different horizontal angle on target
  - Changing wobbling horizontally displaces beam on BSI
  - Movement on BSI due to wobbling change can be ~2mm
  - Spotsize on T4 has σ_x ~0.4mm (T2 likely similar)
- **The BSIs in the target areas are likely giving an accurate assessment of intensity**
  - Foils in TBIU more problematic than upstream due to small spotsize (damage scales with area)
    - I am not yet certain of beam size in upstream region
  - SPS page 1 intensities could be wrong by >20%

T10 target TBIU scan

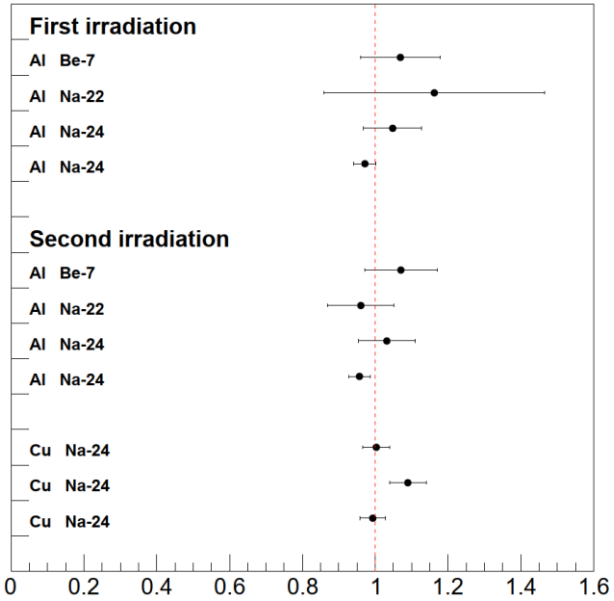


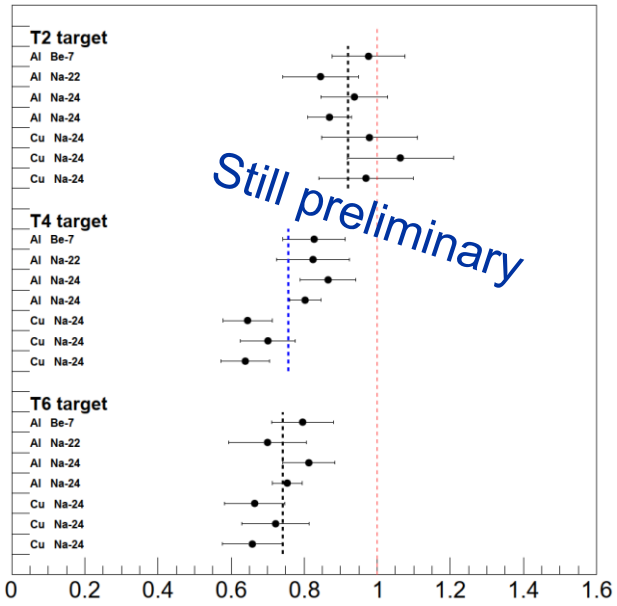
T2 target TBIU (2022)



Calibration of BSIs in North Area

- **Valuable experience gained in 2022 and 2023**
  - Put aluminium / copper foils in line (in this case, near target)
  - Expose to beam (~100-200 shots), sum up BSI signals
  - Divide activity by cross-section, and compare to BSI sum
- **First set of calibrations done with T10 target**
- **Second set of calibrations done for T2+T4+T6**
  - Measured fewer POT in activation foil than on BSI
- **Third set of foils measured in HiRadMat**
  - Not consistent with (inferred) cross-sections from T10
- **Aluminium foils can give different results than copper**
  - Implies impact of neutrons through auxiliary process
  - Present in both TCC2 and HiRadMat measurements – probably

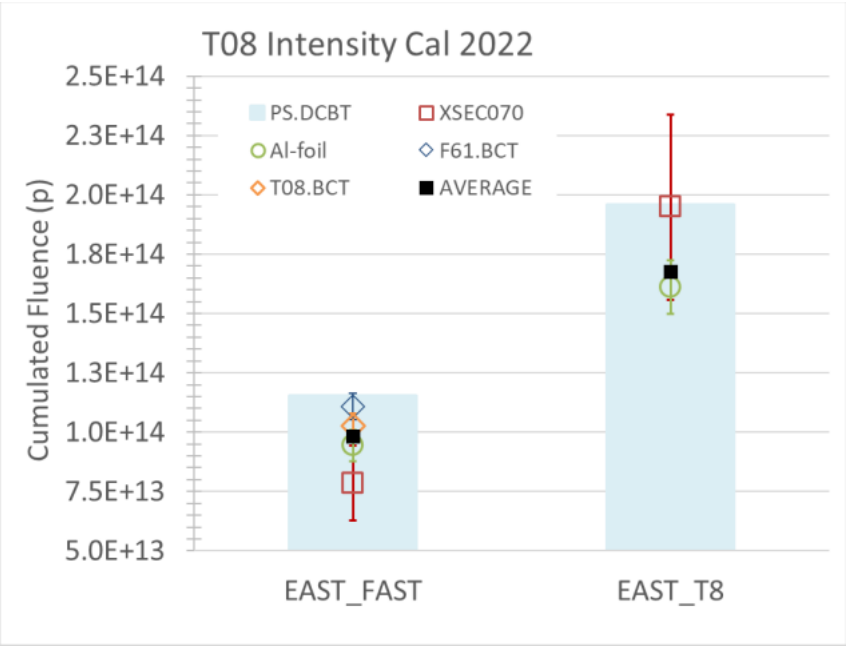




Calibration of XSECs in East Area

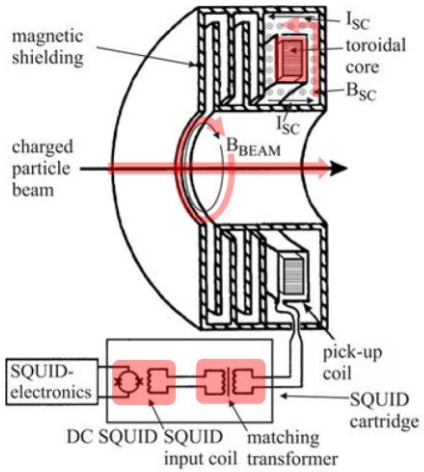
- **The XSECs are SEM-based intensity monitors**
  - Initial comparison between fast BCT and foil activity (2022)
    - Measurement based on single isotope (^{24}Na in aluminium foils)
    - Compared with fast extracted beam (few 10s of ns) onto fast BCT
    - Methods agree with absolute difference of 9.3%
  - Second irradiation with slow extracted beam (2022)
    - Measure XSEC signal & compare it with foils activity
    - XSEC signal calibration based on resulting measurement
  - Data collected also with copper foils in 2023
    - Analysis ongoing
- **Intensity calibration of T9/T10 primary lines not yet performed**
  - Possibly the factors of T8 can be reused – similar / same detectors
  - Will be assessed further once analysis of T8 foils is completed

F. Ravotti, EP-Tech-Note-2022-001



Intensity of DC beams in North and East – options

- **Three possible technologies under consideration: SEM, BCT and CCC**
- **Secondary Emission Monitors are the currently implemented technology**
  - BSI foils in North Area seem to get substantially damaged by beam – possibly even over a single run-year
  - Coupled to movement of the beam and vacuum history this gives a large (but slow) variations
- **Beam Current Transformers have been considered (but mostly ruled out)**
  - Ideally, measurement is “short” (1ms or less) – but even fast-pulsed slow extraction to TT20 is 10-20ms
  - Current lowest current is ~200µA in a ~200µs pulse (end of LINAC3)
  - Regular slow extraction is 4.8s (equivalent to 1.3µA with 4 10^{13} protons) – unfeasible
  - Fast extraction (using kickers) is limited in intensity allowed to be extracted to North Area
- **Cryogenic Current Comparator is an excellent candidate**
  - Magnetic field of beam induces screening current in superconducting shielding
  - Current is picked up by SQUID through pick-up coil and transformer
  - CCC’s features: non-intercepting & absolute current monitor, ~5nA resolution
  - Prototype deployed in the AD (cycle length 110s) and operational since Run 3



Next step for calibration of the BSIs

- **Observation: Continuous degradation of BSI monitors**
  - Consequence: uncertainty of 20% up to 50%, will grow in the future
  - Full impact on beam operation to be assessed
- **Available data far from fully analyzed**
  - Finalize, compare to simulation, condense into strategy
- **Study in more depth the BSI signals**
  - Archived data, and TBIU and “upstream” BSI scans in commissioning
- **Plan for the future – follow-up at BIFT**
  - BSIs are difficult, BCT not (very) possible, CCC for Run4 is technically feasible
    - Follow CCC also from NACONS perspective if and when fully justified
  - Continue calibration efforts until full consensus found, monitor degradation
  - Fast foil exchange is crucial for the activation foil calibrations
  - Investigate mitigation: motorize BSIs? (stepping motors instead of in/out)
  - Investigate mitigation: adapt BSI design for easier calibration?

Request for annual calibration plus 1-2 follow-ups in 2024 (~12h beamtime each)

Request for further study and additional personpower

Other issues

- **AD & ELENA**
  - AD – Ionization profile monitor (IPM) undergoing repairs (one plane not functional)
    - Will be operational for 2024
  - AD – Work ongoing for scraper (transverse profile measurement)
    - Further development of signal analysis is progressing well
  - ELENA – ring intensity measurement now fully established (~5%)
  - ELENA – SEM profile monitors will be installed in transfer lines
    - Missing monitors/spares and long-term maintainability are being addressed by BI with an in-house program to produce new BPMs
  - Main facility instrumentation is now operational, opportunities for further improvement are present in most detectors
- **Request for support of development and long-term consolidation/upgrade of the facility instrumentation**
- **XCETs of North and East Area: rescoping from NACONS under discussion (see backup)**
- **Number of new BLMs for North Area covered under NACONS (see backup)**

Collection of requests

- **FTN/FTA** — Request for 9 total BPMs
- **XBPF** — Accelerate timeline for XWCA/M replacement (BI)
  Production of large-area XBPFs for downstream part of M2 (BI)
- **CEDAR** — Follow to completion the remaining open issues (EA/BI)
- **BSI calibration** — Annual calibration plus 1-2 follow-up measurements in 2024 (EA/BI)
  Additional personpower to pursue study and calibrations (EA/BI)
- **AD/ELENA** — Request for long-term support for various instruments (BI)

Closing thoughts

- **Significant issues raised in many locations**
  - Goal is to identify the best path towards a good solution

Many thanks to the people who contributed, both to this talk and to future solutions!

D. Banerjee, A. Baratto Roldan, J. Bernhard, M. Bozzolan, M. Brugger, N. Charitonidis, S. Deschamps, W. Devauchelle, G-P. Di Giovanni, Y. Dutheil, L. Dyks, S. Erhard, M.A. Fraser, D. Gamba, M. Gasior, N. Menaa, L. Nevay, I. Ortega Ruiz, L. Parsons França, P. Podlaski, B. Rae, F. Ravotti, F. Roncarolo, J. Tan, F. Velotti.

Backup slides

CEDARs – closed issues

Fault	System	Beam line	When	Cause /comments	Assets
Switch's diaphragm broke	Mechanical	H2	2022		
Potentiometer XY table broke	Mechanical	H2		Wrong manipulation	
Link motorization/diaphragm broke	Mechanical	NA62	March 23	Wrong manipulation, Settings to be kept until LS3	SPXCEDH001-CR000001
Broke off the plastic gas pipe in the red feet	Gas	M2	April 23	Old connection with white plastic pipe exploded	SPXCEDN001-CR000020
Wrong pressure readings due to ground & impedance matching issue in the signal coming from the pressure sensor	Gas	M2	April 23	Signal impedance corrected. Old sensors, cables, electronics.	
Emptying He reserve due to degraded performance of pressure sensors. Resolution ~ 7-10 mbar instead of 1 mbar.	Gas control system	M2	April 23	Implemented XCET gas control regulation software. Need better resolution?	
Bad diaphragm reading.	Software	M2	May 23	FESA Class Modification	
Broken vertical switch	Mechanical	M2	April 23	Replaced. Ageing parts.	

CEDARs – general ageing issues

Fault	System	Consequences	Mitigation
Pressure sensors are losing precision	Gas	Unstable pressure regulation, gas losses	Software modification to account for new precision
Obsolete pressure sensors – no good spares available	Gas	Wrong pressure reading -> unstable pressure regulation, gas losses, no physics	Deploy new TERPS pressure sensor used in the East Area XCETs
Mechanical wear & tear of motors parts, including potentiometers and limit switches	Mechanical	Not achieving nominal precision	Produce new mechanical parts. Software algorithms to improve precision.
Ageing electronics	Control & acquisition	Wrong acquisition and control (pressure, PMTs, motors…)	New electronics being developed to be deployed during LS3
Obsolete Photomultipliers – current model, 9820 (19-pin), has been replaced by the 9829 (21-pin) -> requires mechanical changes on the CEDAR	Acquisition	Poor CEDAR efficiency	By 9829 PMTs and launch mechanical works to modify the CEDARs as soon as possible
Thermal insulation degradation	Gas	Unstable pressure regulation	Produce new thermal insulation

CEDAR advancement to NACONS Phase 1

- **Advancement of budget for consolidation from Phase 2 to Phase 1 will be discussed at the next NACONS Cost and Schedule Review (February 2024)**
  - Full details in EDMS 2742855

- **Brief overview of works under discussion**
  - Design of the new diaphragm motorisation, new thermal housing, gas control system or more general integration studies connected to beamline layout and/or specific test set-ups
  - Maintenance of the supports (supports + XY tables + jacks) starting with two unused sets in Phase I
  - Two sets of spare N and W optics would be produced during Phase I
  - Replace obsolete or damaged diaphragm system
  - Supply of 8 PMTs plus voltage dividers for one XCED spare
  - Design and supply of prototype thermal insulation
  - Design and supply of prototype gas system
  - Refurbishing of clean room for assembly works

XCET advancement to NACONS Phase 1

- **XCET is the family of Cherenkov Threshold Counters used in the North and East areas**
- **Advancement of budget for consolidation from Phase 2 to Phase 1 will be discussed at the next NACONS Cost and Schedule Review (February 2024)**
  - Full details in EDMS 2802361

BLMs for North Area under NACONS

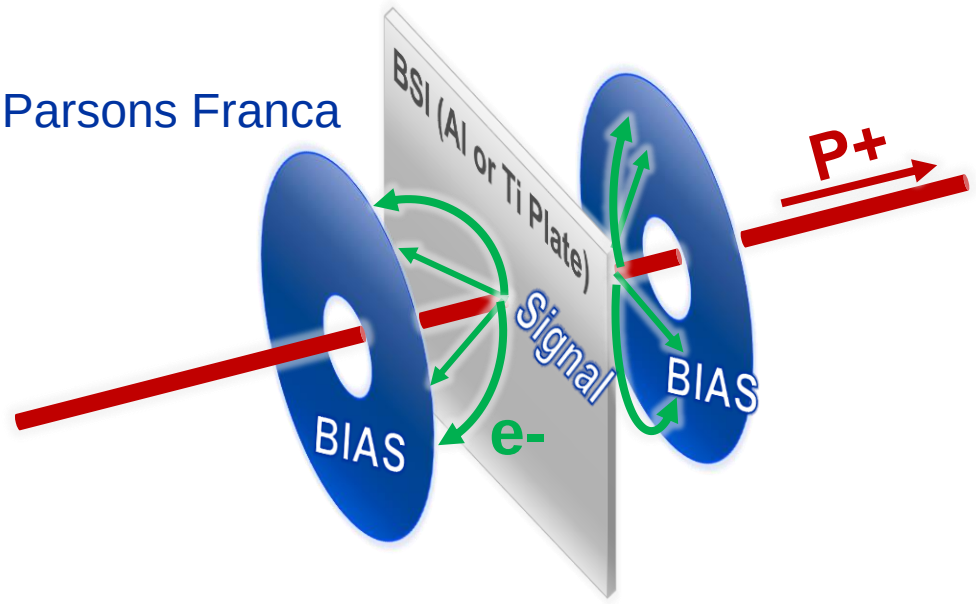
- **Roll-out of BLMs foreseen for primary lines**
  - 20 units to be exchanged by new units in TT20
  - 13 new positions in TT23/TT24/TT25
  - 13 units already installed in P42, 19 remaining units to be installed by LS3
  - 1 longitudinal BLM in LSS2 + 1 in TDC2 + 2 in TCC2

The intensity monitors of the North Area

BSI is a beam intensity monitor

- More versions available that do various jobs (BSG, BSP, BSM, ….) but here focus on intensity
- Monitor needs to give an ABSOLUTE number – so calibration is extremely important
- Basic operational mechanism is “Secondary Emission” – a small chance that a proton impinging on a metal foil will kick out a low-energy electron that you can collect, leading to a small current for a large beam

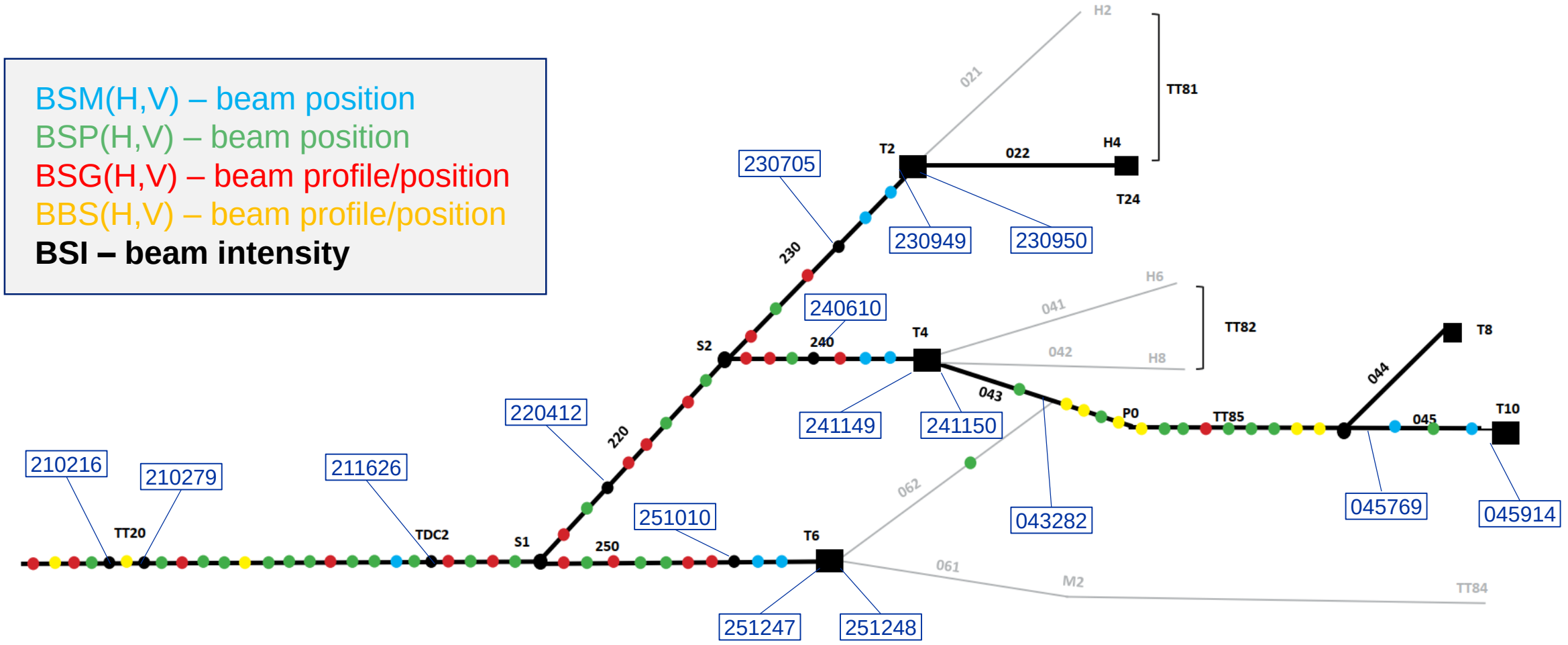
L. Parsons Franca



Map of SEM detectors in North Area

Labels given only for the BSIs

BSM(H,V) – beam position
BSP(H,V) – beam position
BSG(H,V) – beam profile/position
BBS(H,V) – beam profile/position
BSI – beam intensity



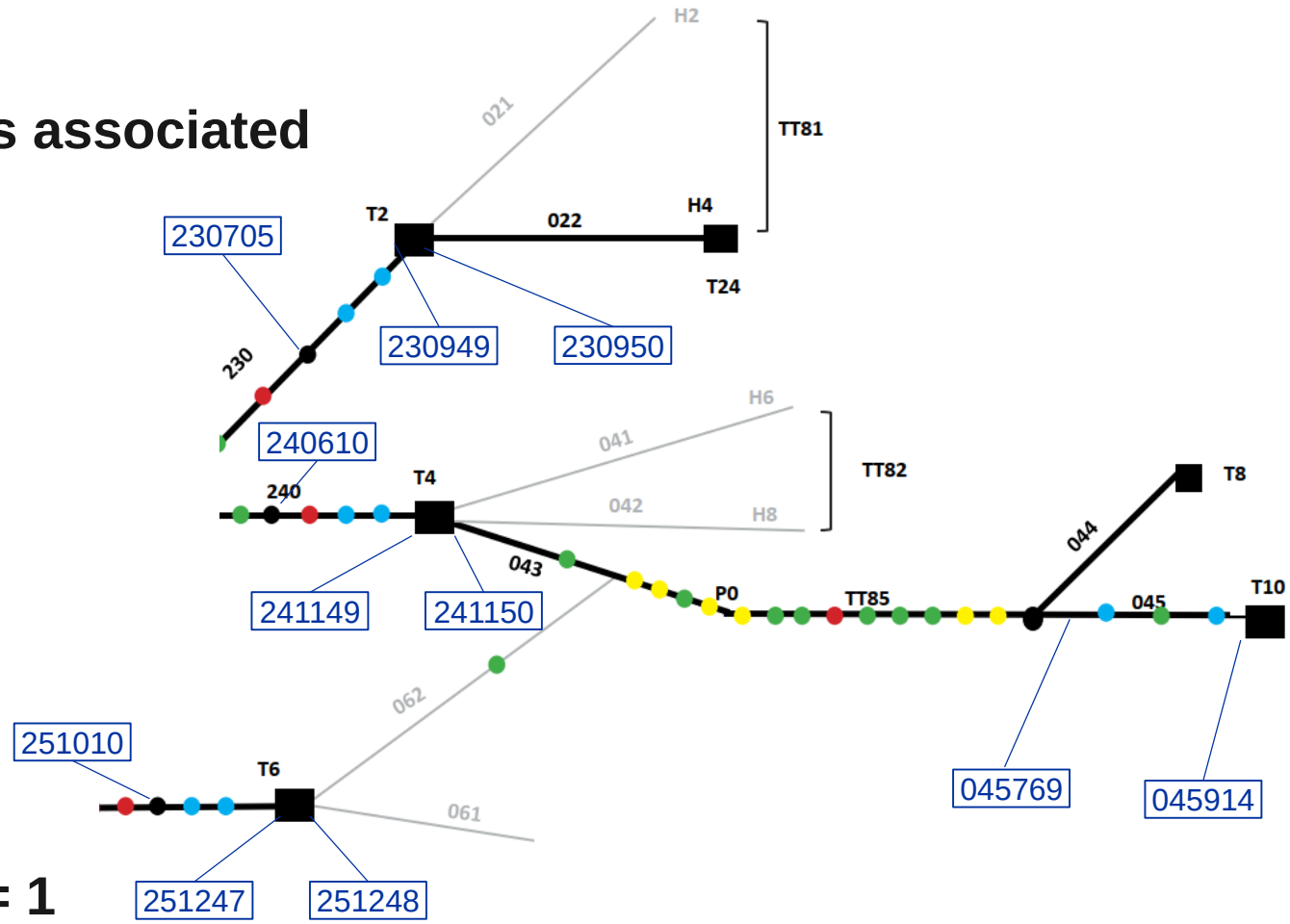
BSIs at the TCC2 targets (T2, T4, T6, T10)

Each target station has three BSI monitors associated

- 1x “Upstream”
- 2x target instrumentation (just before and after)
  - T10 has no TBID

The intensity reported on “page 1” comes from the “upstream” BSI

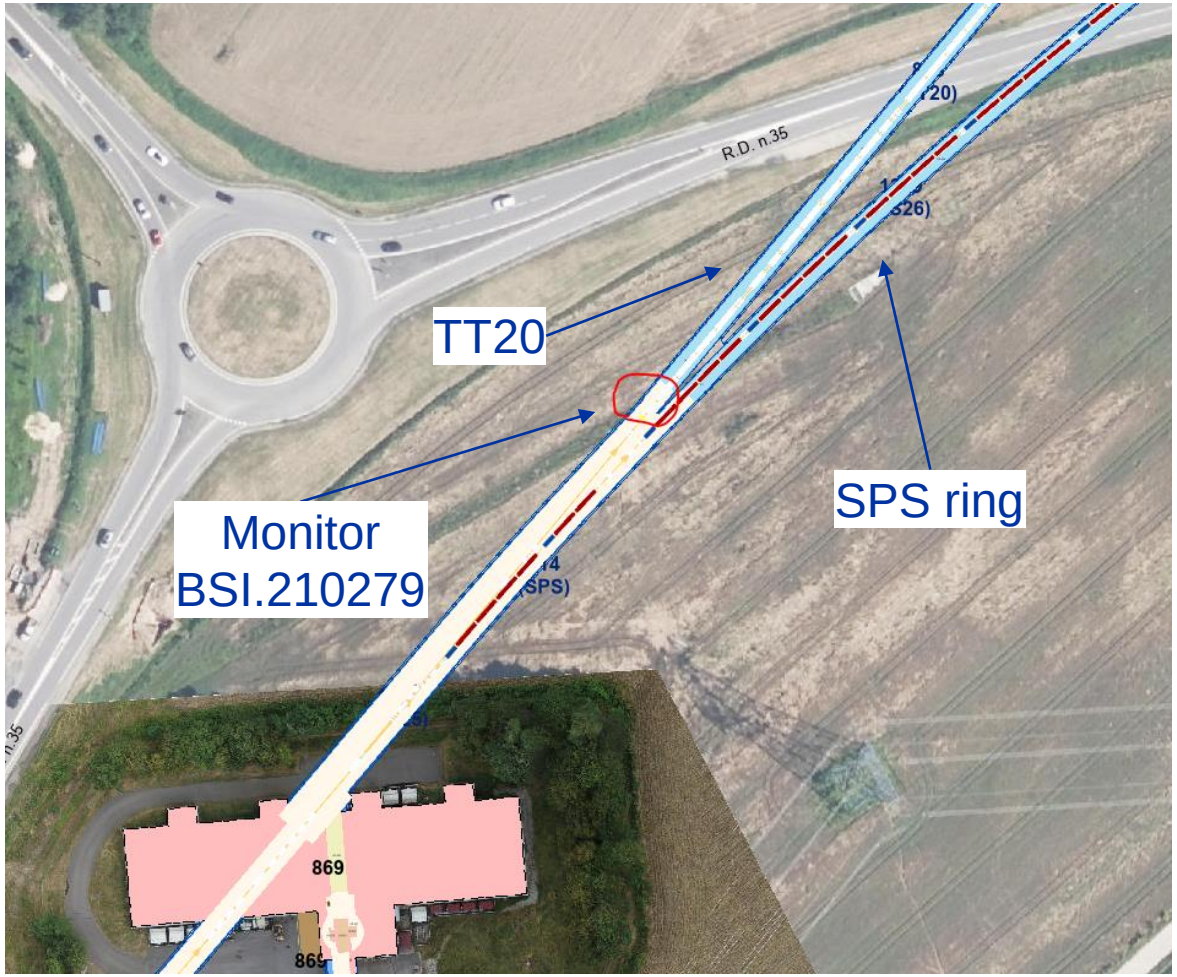
- 230705(T2), 240610 (T4), 251010 (T6)
- For T10, the page 1 intensity comes from the TBIU (045914)



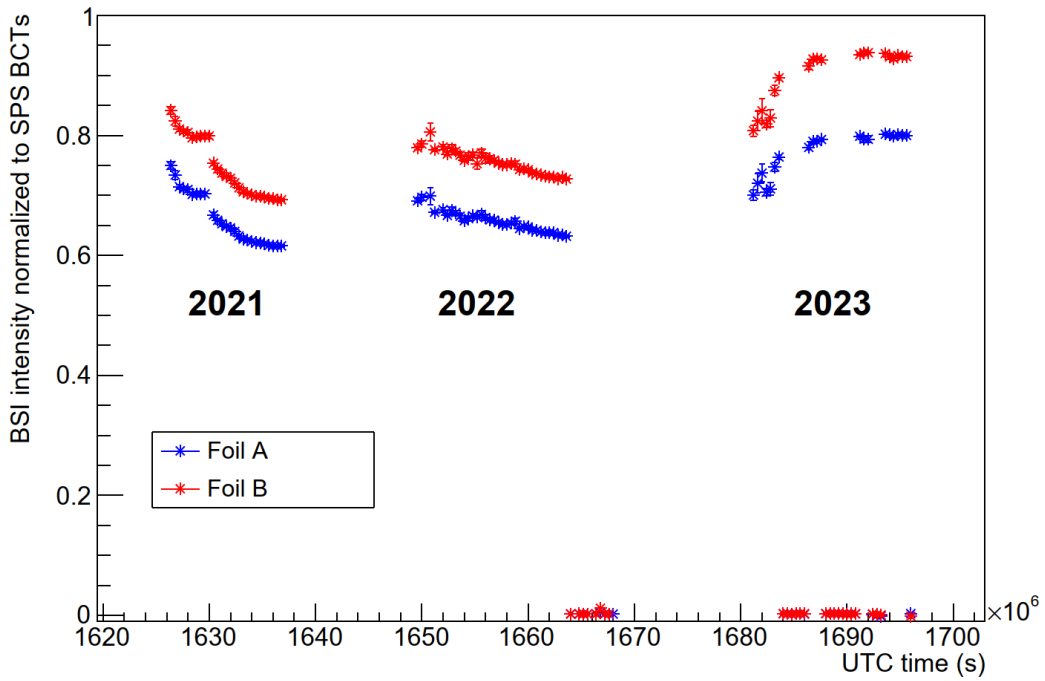
If all goes well, the ratio TBIU / upstream = 1

- Upstream monitors are only ~40-50m upstream

Monitor BSI.210279 (two foils)

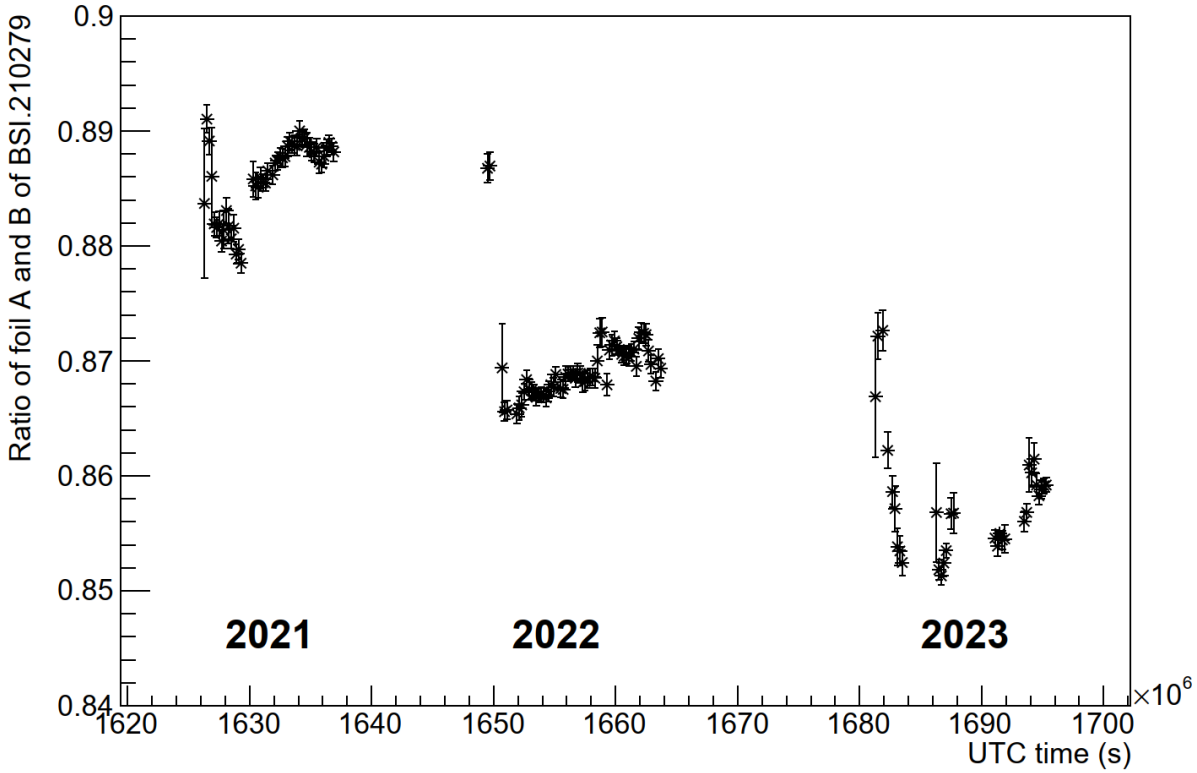


- **Monitor had some issue over part of 2023**



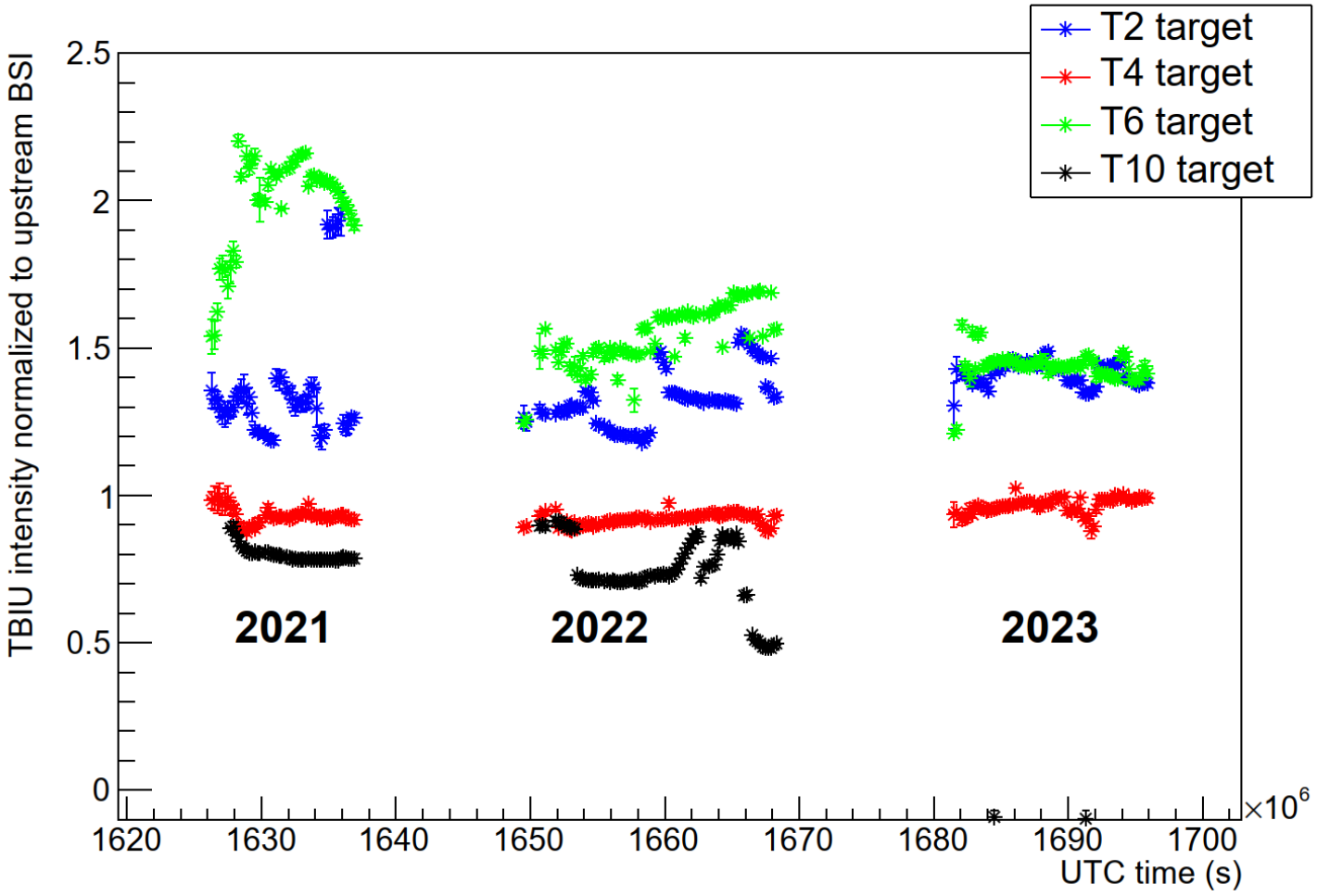
Monitor BSI.210279 (two foils)

- **Ratio of two foils in the same location**



Comparison TBIU and upstream BSI – T2, T4, T6, T10

- **Use ratio (TBIU / upstream BSI) as an indicator of stability**
  - Indication of good calibration: value equal to 1
  - Indication of stability: line is flat
- **Upstream monitor of T10 had some issue in 2023 (?)**



Additional notes to the BSI monitors

Monitor 210216 signal not accessible: “Utilisé par Ewald (…)”

Monitor 210279 has two foils (referred to as A and B)

Two additional sets of monitor signals found in data (210272 and 210278) not listed in documentation that are four-foil test tanks (type BSTL)

Data taken from TIMBER

- Seems to be by and large equivalent to direct data from NXCALS
- Data available as giant “SEM-concentrator-TT20:intensity” signal or a subset as individual signals
  - For some variables there is also a dedicated variable
    In some cases, these have different values and calibrations – not clear why
  - Follow advice from F. Roncarolo: use SEM-concentrator values

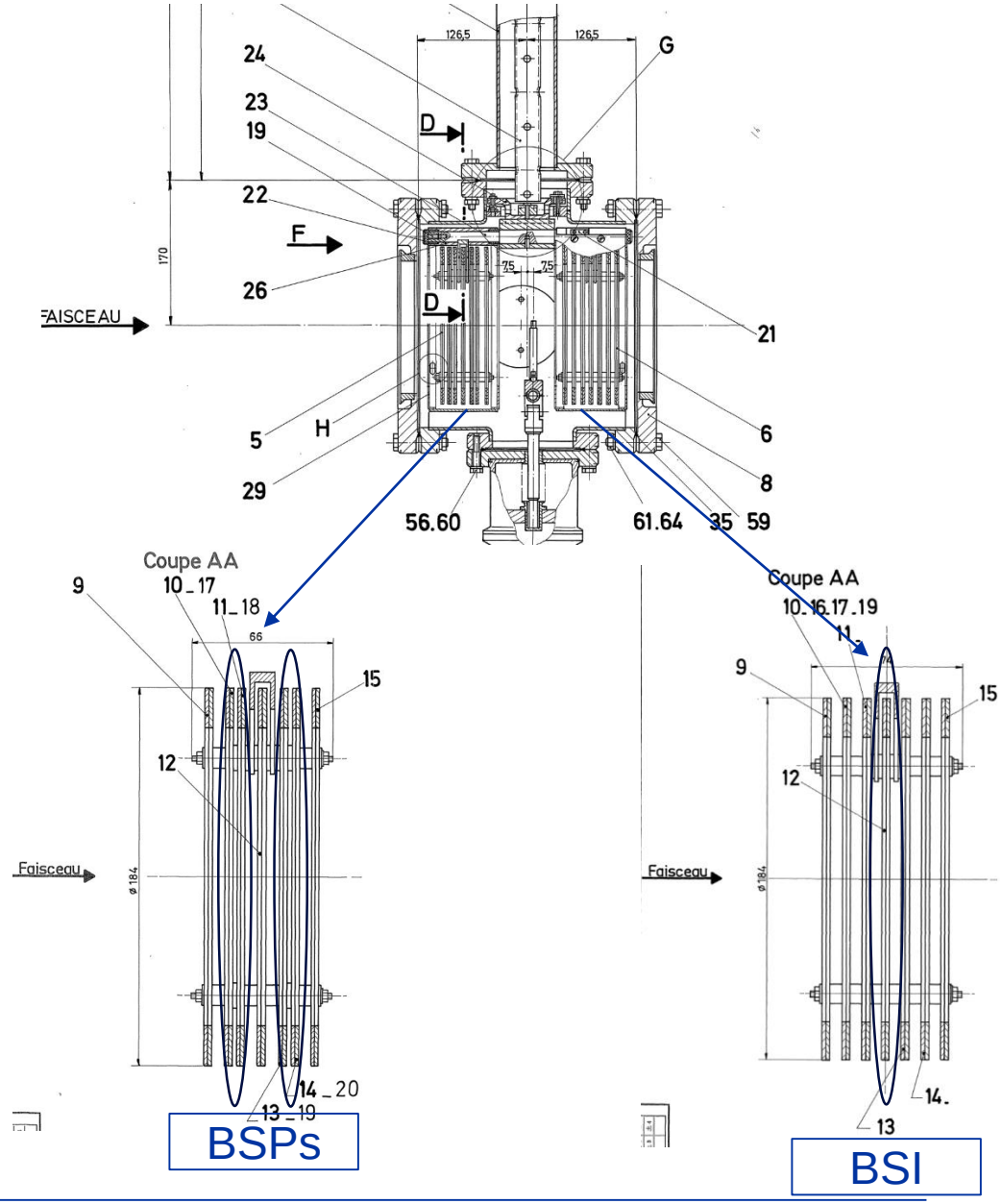
Layout of the TBIU

It was observed at the T10 target that the foils get damaged

- Scales with size of beam – more protons per mm2

TBIU has two “heads”, A and B

- Beam steering (symmetry) happens on two BSPs
- Both of these are located in head A
- Assume beam is centered perfectly on those
- However, the BSI is located in head B
- Distance between the two is around 12.5cm



Movement of the beam (example at T4)

Different wobbling settings give a different angle on the target

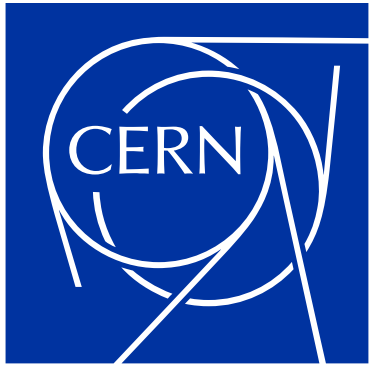
- The TBIU and TBID stations move with the wobbling setting
- The beam is then steered using the BSP settings
- However, lever arm of 12.5cm means beam is displaced on the intensity monitor
- Total difference (for two calculated wobblings) is ~15.7 mrad
- Absolute displacement of almost 2mm

Combine with beam size at T4 target

- In short, beam moves five sigma between these two settings

	Dedicated	Shared
$Particles$	50'000	7'382
$\sigma(x, y)$	(0.391,0.200) mm	(0.439,0.575) mm
$\sigma(px, py)$	(0.130,0.0618) mrad	(0.162,0.0480) mrad
$\sigma(pt)$	8.16e-04	8.70e-04

Primary beam size T4 (G. Mazzola)



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