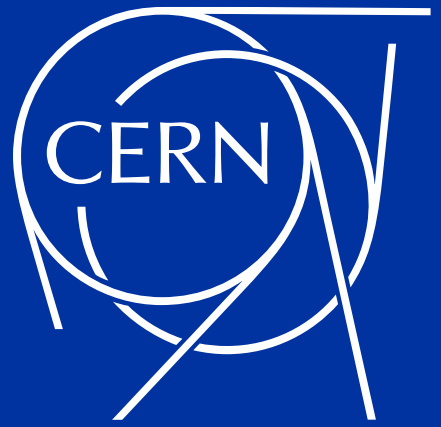


Beam instrumentation (present and short-term future)

Inaki Ortega (SY-BI), with input from operations and BI experts

Joint Accelerator Performance Workshop 2024 - Montreux

Beam Gas Curtain monitor

Status of existing BGC in P4 left

Successful data taking in 2024 both for Ions and Protons:

- Emittance measurement during the whole cycle
- Values consistent and reproducible
- No jet thickness effect for the horizontal
- OP-GUI implemented for live visualisation

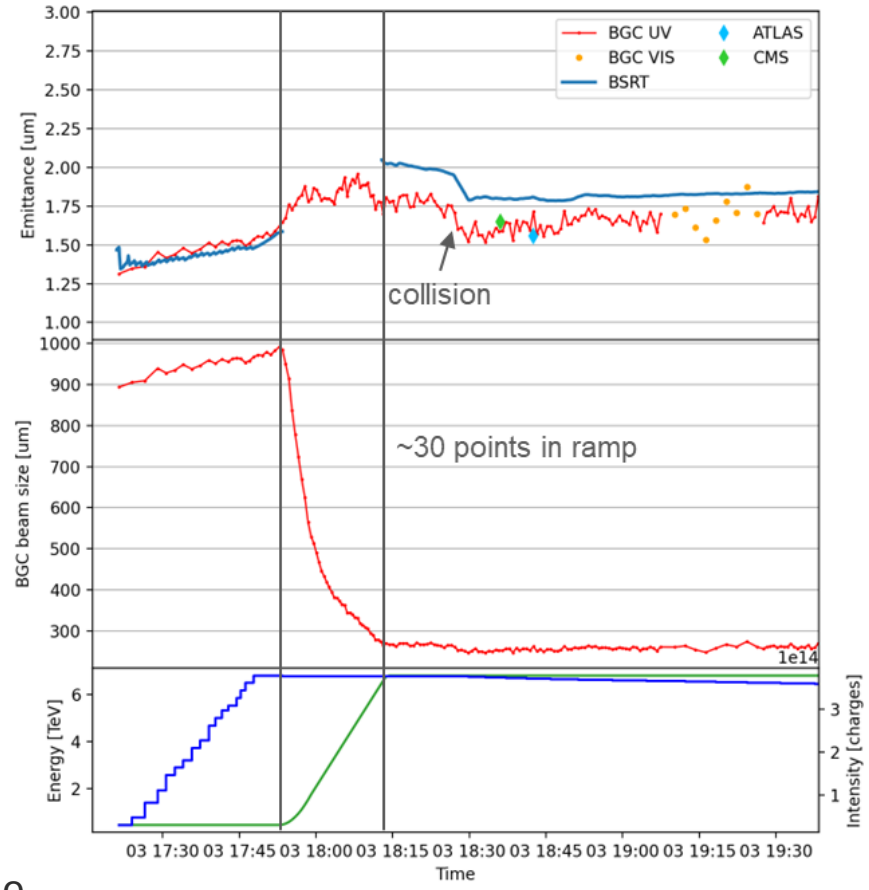
Known limitations:

- Not able to measure bunch by bunch
- Gas injection not implemented yet in the sequencer
- Optimisation of vertical BGC in progress – works during YETS24/25

YETS activities:

- Exchange of skimmers 3 and 4 to reduce curtain thickness and improve vertical profile measurement quality
- BLM installation to analyse gas injection-induced losses to study feasibility as halo monitor

Reference: BGC CM: https://indico.cern.ch/event/1468706/



BGC measurement through cycle

Injectors BWS Status & Plans

Current Status:

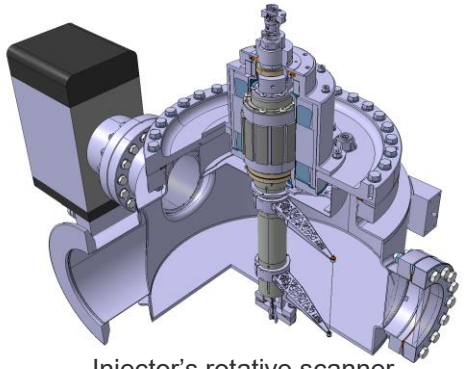
- 17 new rotary scanners installed in LS2: 214k scans since 2021
- All features implemented –including SPS intensity limits to be fully tested in 2025
- Impedance issues covered **by Chiara Antuono on Wednesday morning**

Main Challenge: Bearing Issues

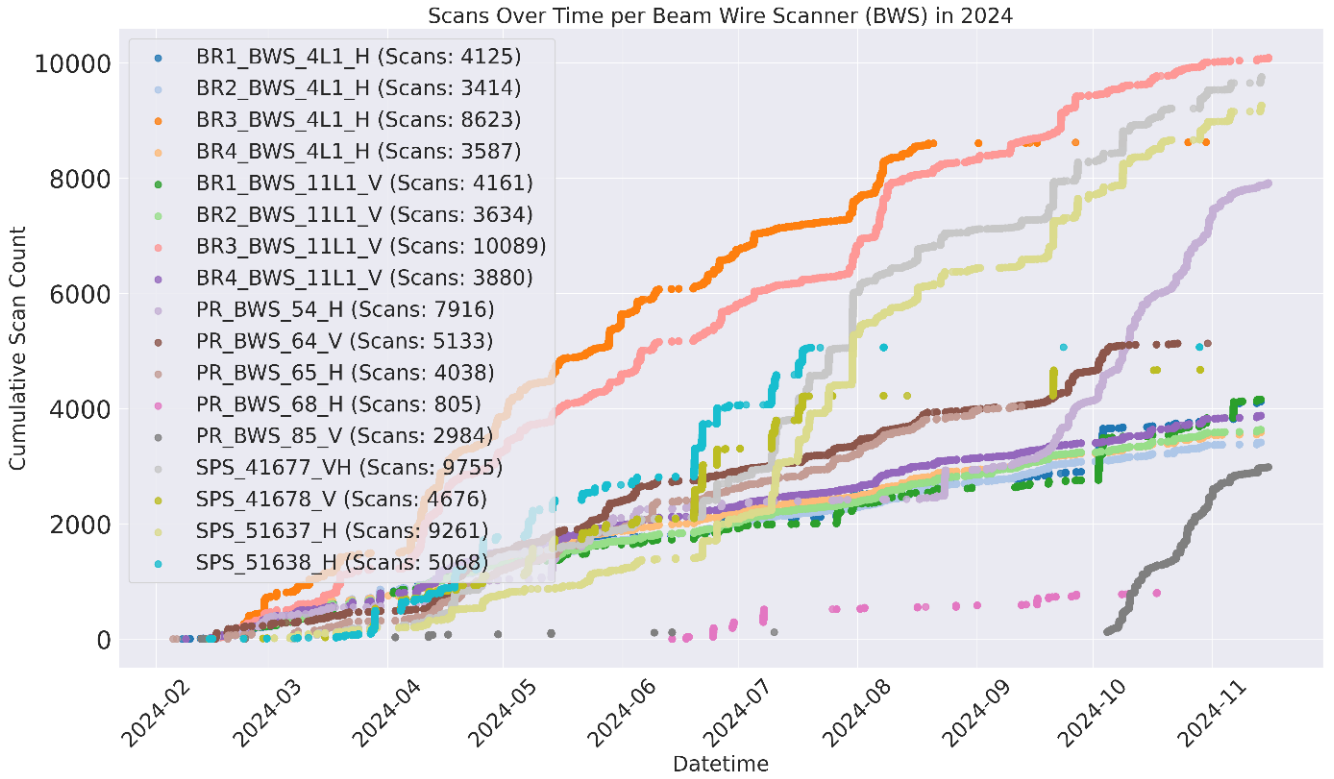
- Limited lifetime of the bearings –6 failures in 2024— with low impact on operation thanks to redundancy
- Bearings behaviour being tested at CERN: custom solution being studied together with the supplier

YETS 24/25 Actions:

- End-of-run inspection + IST procedure
- Replace 4 broken scanners (1xPSB, 2×CPS, 1xSPS)



Injector's rotative scanner



LHC BWS CONS

4 legacy units operational (10.3k scans in 2024)

- Uses obsolete electronics and old bellows

4 ‘Hybrid+’ units (legacy with improved mechanics and electronics)

- > 1k scans performed by BI experts
- HW: Beam 1 ready for OP. Beam 2 with DAQ issue generating ‘noisy’ profiles being investigated
- SW: FESA interface ready for integration in OP application
- Ensures operation up to LS3 – more cons needed for later

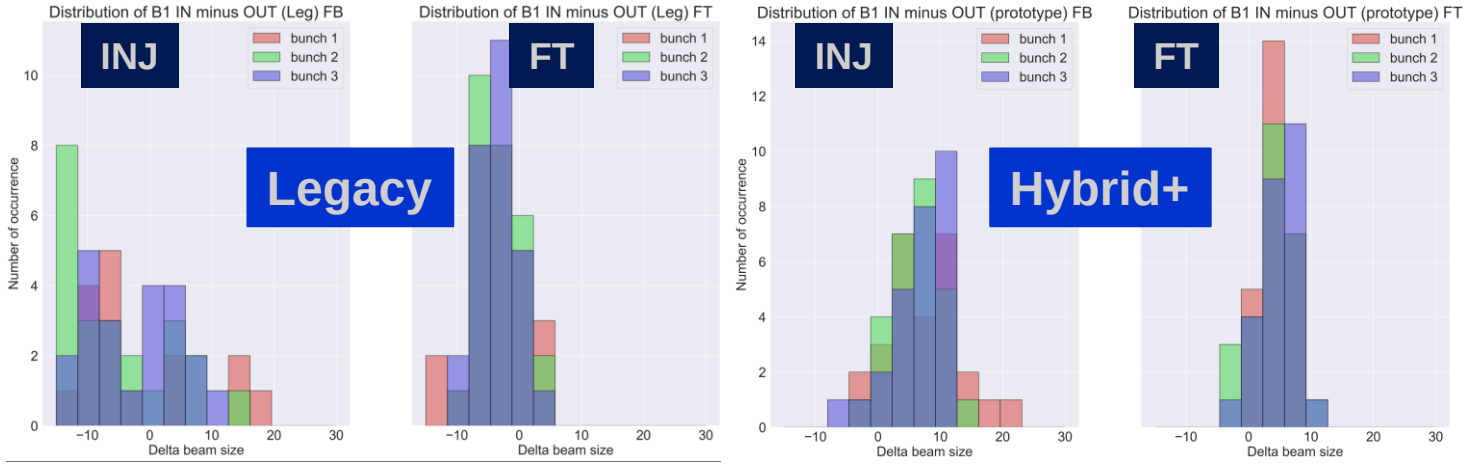
Lots of efforts on new generation of linear BWS

YETS 24/25:

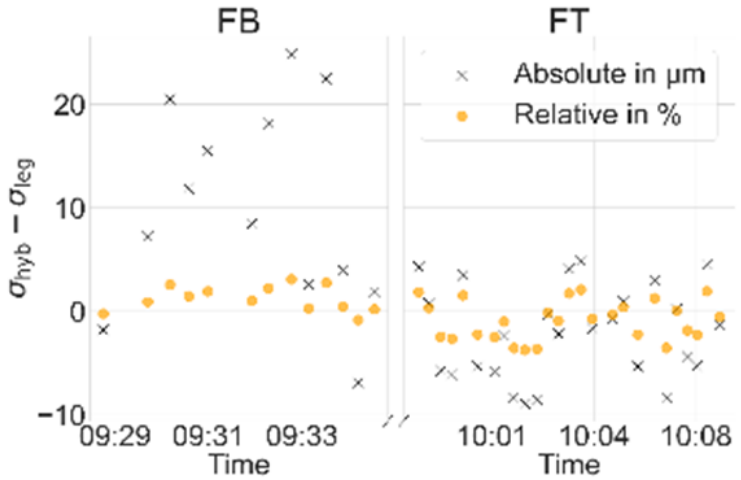
- Refurbish 3 Legacy scanners with improved bellows
- Fix Beam 2 Hybrid+ issue (likely related to DAQ FW)
- HW and Beam commissioning by BI experts. Plan: handover to OP 4 Hybrid+ after commissioning

YETS 25/26: new linear scanner prototype for beam tests in 2026 – confirm plans for LS3 CONS

Sigma IN – OUT [um]



Hybrid+ vs Legacy comparison in beam sigma measured on same bunches



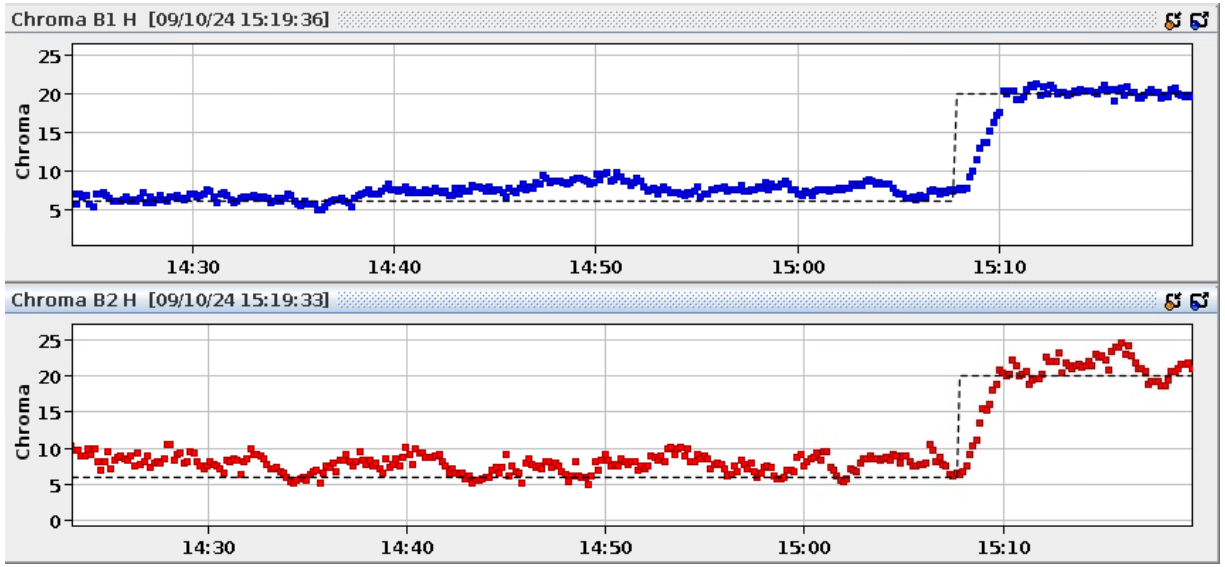
Injection energy
< +-20um in absolute
< +-2%in relative

Flat Top energy
< +-10um in absolute
< +-4 %in relative

LHC Schottky

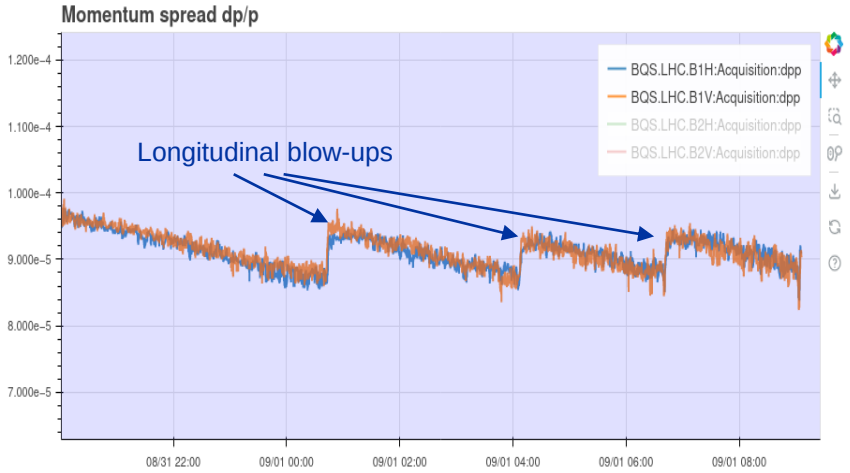
Schottky Monitor operational!

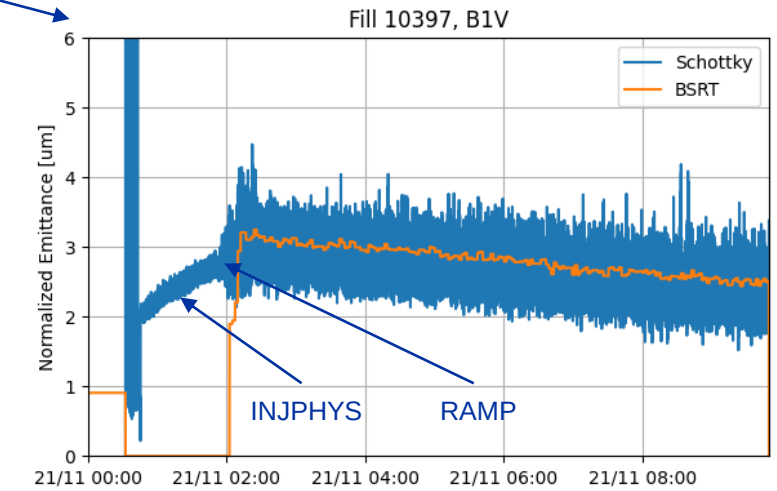
- Online Q' measurement with **proton** and **ion** beams
- Displayed in OP's LHC AccPit



Additional measurements:

- Betatron tune, RMS dp/p
- Transverse emittance of **ion** bunches along the whole cycle





Promising studies ongoing:

- Betatron coupling monitoring
- More realistic Schottky theory
- Machine-learning based analysis

K. Lasocha et al. PRAB 27 (11), 112801
C. Lannoy et al. JOI 19 (03), P03017
K. Lasocha et al., IPAC 2024, WEPG30
C. Lannoy et al., IPAC 2024, WEPG31
C. Lannoy et al., IPAC 2024, WEPG32
M. Bradicic, CERN-STUDENTS-Note-2024-224

Other LHC Diagnostics

BSRL 2024

- DAQ (TDC) failures: new TDC family being procured
- Degradation of signal on B1 due to limitation in collection options. Should be fixed during YETS 24

BRAN

- Motorisation issues under study, fix planned for LS3
- Improve calibration by performing systematic checks

BLMs

- Very good availability – keeps improving since LS2
- Several injection issues – more information on Sofia Kostoglou's presentation on Wednesday morning
- Extensive work on thresholds

Beam Secondary Emission Intensity foils (BSI) calibration

Absolute calibration studies

- Dependence on radiation and vacuum history: ongoing study
- Dependence on BSI bias voltage levels: study finished in 2024
- Effect of beam size on ‘hollow bias foil’: ongoing study

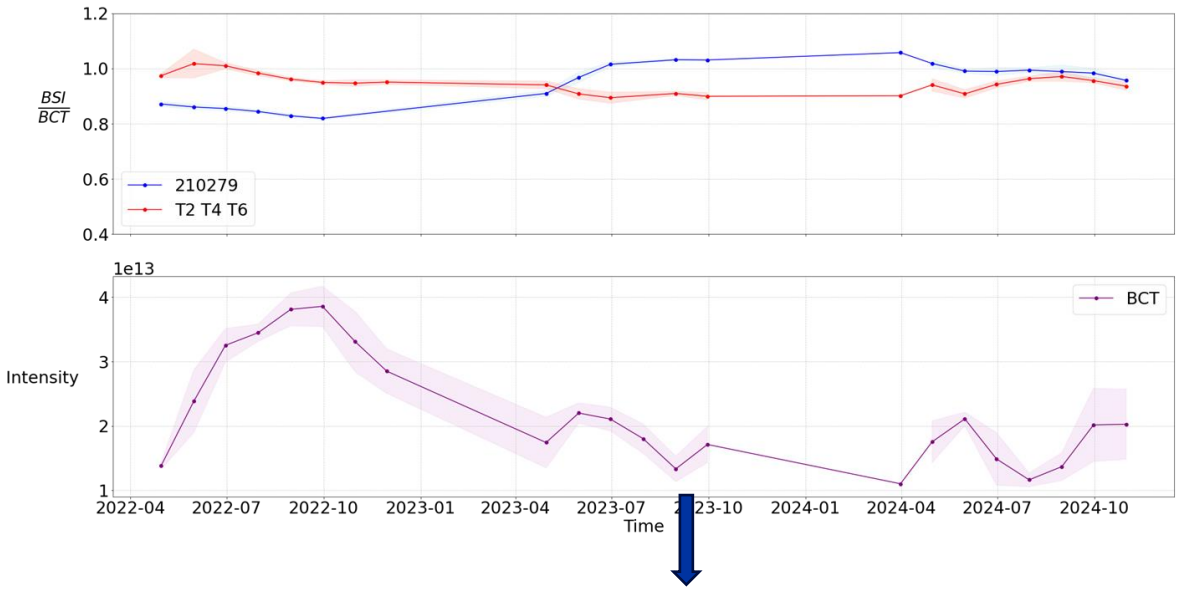
Calibration with activation foils

- Only available method at present for absolute calibration
- On-going analysis – see M. Van Dijk’s presentation on JAPW23 (https://indico.cern.ch/event/1337597)
- On-going studies on type of foil
- Request to establish systematic measurements at the beginning and end of the run

Outlook

- Proposal of new BSI design (e.g. no hole in bias foil) along with calibration procedures as part of NA-CONS
- Other options: BCT, CCC options discussed at BIFT and presented at 355th IEFC (https://indico.cern.ch/event/1460279/)
  - Cryogenic Current Comparator needs allocation of resources and R&D

Average signals per week



Comparison of BCT and BSI needs detailed study of losses at extraction and splitting. Improvements planned for 2025-2026.

TT20 SEM detectors with ions 2024

2024 measurements

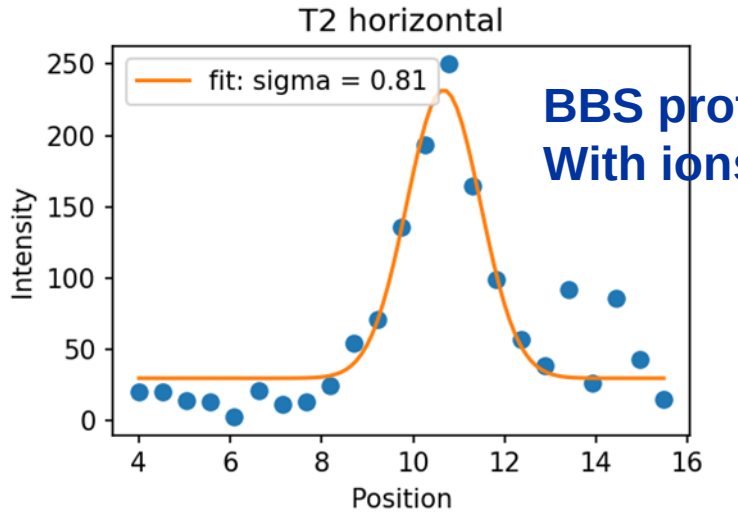
- 2024 Experience with ions: primary line SEMs could be used to steer the beam and validate optics despite ‘low’ signal
- BSGs (fixed bands) used in one-shot analysis
- BBS (scanning wire in TBIU) required multi-shots but allowed validating beam size at target expected by optics

Expected vs Measured BSI Signal Ratio (Ions/Protons):

- Expected: 10-15% (based on Z^2-scaling and BCT normalisation)
- Measured: ~8% (comparing integrated spills)
- Discrepancy: can be due to reduced beam transmission with ions?

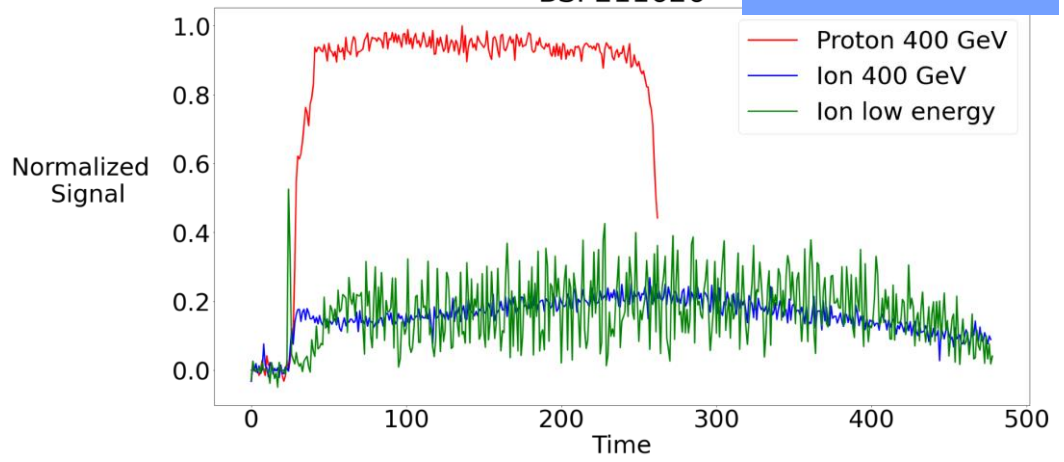
Outlook

- It is necessary to understand the limitations, particularly for low-intensity beams
- Find synergies with the upgrade project of the ion complex
- New BSGs for TBIUs funded by NA-CONS



BBS profile With ions

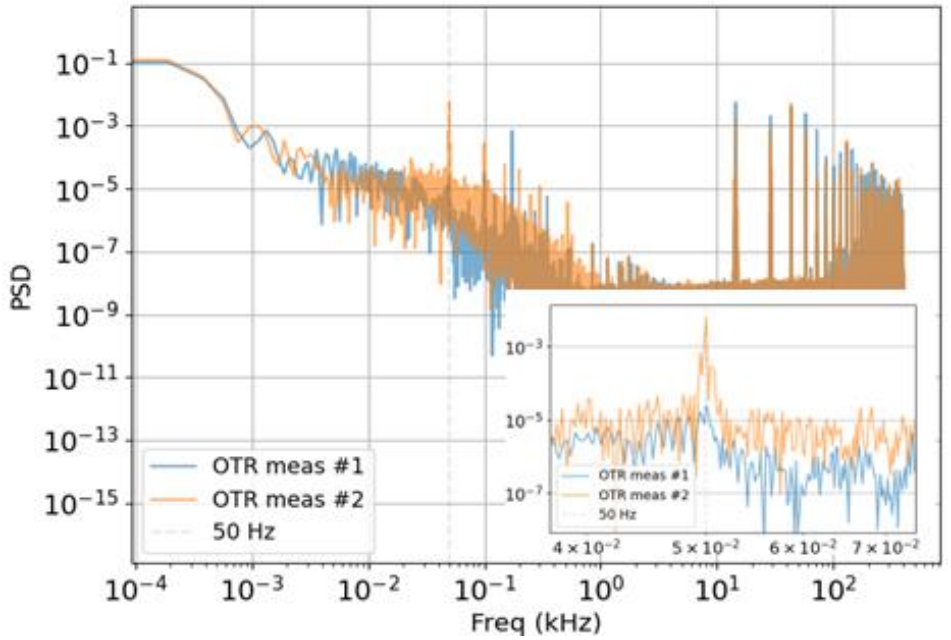
BSI 210279 showed same result



SPS Spill monitor

Spill monitor for NA-CONS

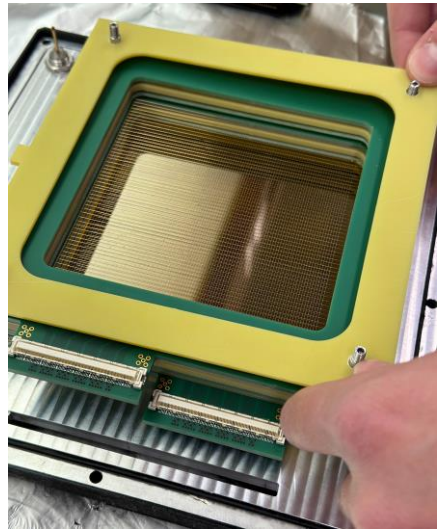
- System based on OTR screen + Photomultiplier tube: https://indico.jacow.org/event/80/contributions/5769/
  - Goal bandwidth of 800 MHz
- DAQ now ready for tracking 200MHz and 800MHz harmonics.
- Outlook for 2025:
  - Make the system fully operational and be an alternative to BSI
  - Reach maximum bandwidth



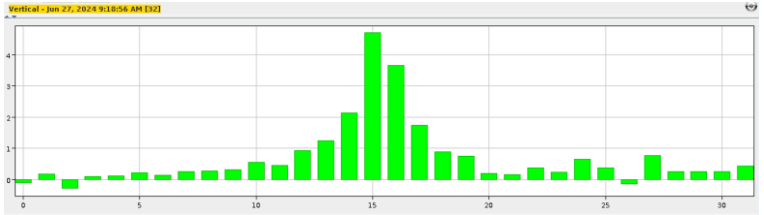
Plot courtesy of Pablo Arrutia

Experimental Areas - Secondary Beamlines

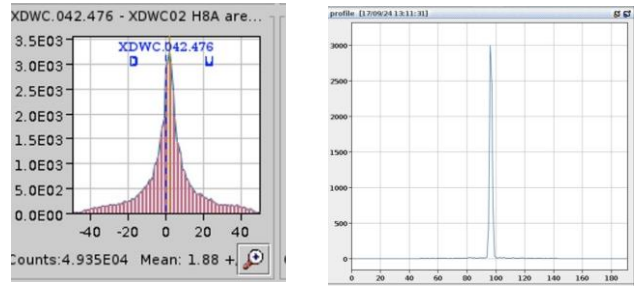
- **CEDAR (Cherenkov Differential Counter)**
  - Deployment of new pressure sensor
  - Improved precision of diaphragm and motor movements
  - Ongoing creation of a test bench for full detector characterisation
- **New Multi-Wire Proportional Chamber prototype**
  - Completed production and testing of new 10cm x 10cm prototype
  - Aiming to produce several 20cm x 20cm units for 2025
- **New scintillating fibre monitor (XBPF) and other R&D beam tests**
  - North Area XBPF with in-vacuum in/out motorisation successfully tested and validated with beam
  - Straw-tube detector for radiation-hard profile monitor and in-vacuum scintillator tile for North Area: several prototypes characterised with beam
- **New XCET (Cherenkov Threshold Counter) beam test**
  - New prototype produced and tested with beam – study still ongoing
- **FISC motor refurbishment**
  - Found replacement motor – integration work in progress



Assembly of the MWPC prototype



Profile from the first 10cm x 10cm MWPC prototype



Profile of a 10^6 hadron beam in the North Area measured by a DWC (left) and the XBPF (right)

Fixed target instrumentation: Limitations and future, feedback from BIFT on upcoming consolidation efforts and items not covered

- **AD-ELENA instrumentation issues and requests** presented at BIFT #10 and being followed-up
  - Examples: Ionisation Profile Monitors (IPM) refurbishment, Target BTV calibration issues (see Davide Gamba's presentation on Monday)

- **ISOLDE**: dedicated BIFT #16. Will need to clarify how to integrate ISOLDE requests and BI CONS plans in a common plan (schedule and resources)

- **ECN3 BI** requests presented at BIFT number #12, including ultra-fast spill monitor for SHiP, target instrumentation and other …

- **Other items not (yet) covered in BIFT and requiring follow-up:**
  - Upgrade Project of the Ion Complex recently discussed
  - Fully supported analytics tools to help improve performance

- **Feedback from EA operation**
  - Improve communication regarding HWC and IST completion
  - Expert availability needed during commissioning periods and outside working hours

BIFT (Beam Instrumentation for Fixed Targets Working Group)

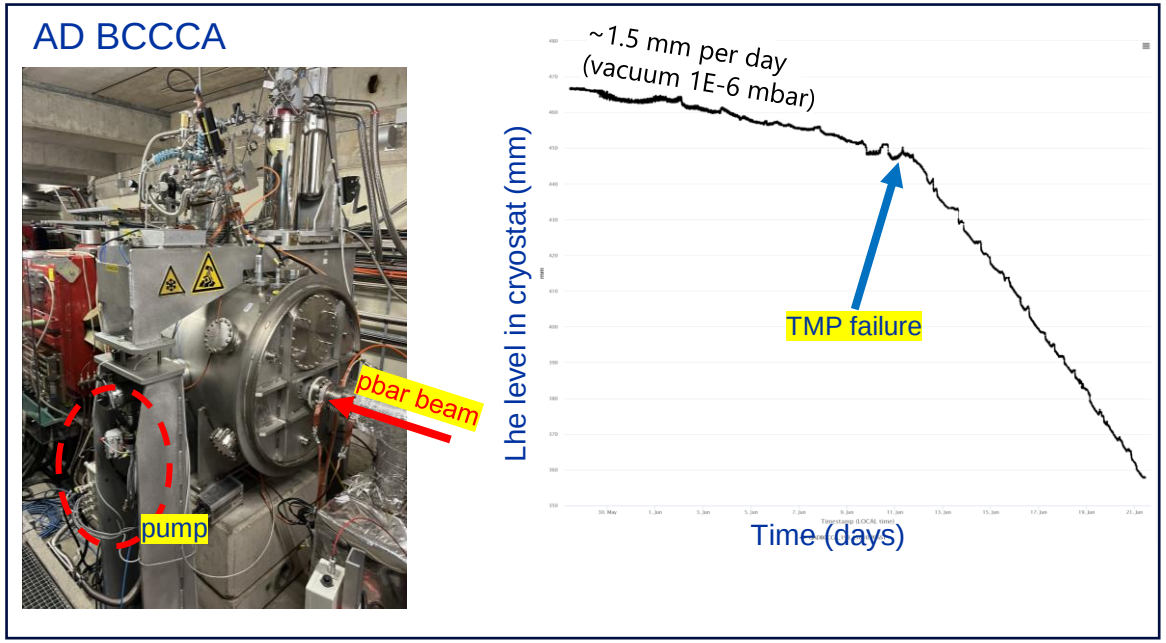
Indico: https://indico.cern.ch/category/16541/

Action list in Jira: https://its.cern.ch/jira/projects/BIFT/

AD Cryogenic Current Comparator (BCCCA) and E-coolers

AD E-cooler

- Cathode supply tripping issue
  - Mitigated by increasing collector voltage by 3%
  - Related to electron beam dynamics at entrance to collector
- Solenoid power supply issue
  - 7 trips in 2024, took 10 hours to repair on 1 occasion
  - CONS in LS3, until then a worrying trend...
- BPM reading drifts being investigated
- Good news: both H & V IPM working

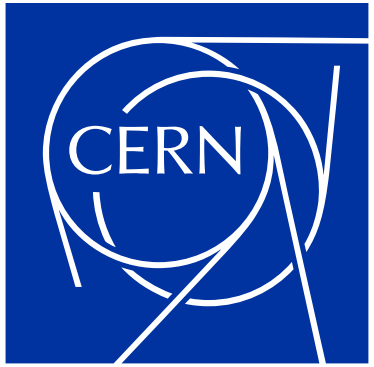


LEIR and ELENA e-Coolers

- Smooth pbar and Pb ion runs
- 1st time Mg ion cooling in LEIR

AD BCCCA (Cryogenic Current Comparator)

- Pump on insulation vacuum failed -> loss of He
- Temporary fix put in place. Definitive solution deployed during YETS24/25
- Good news: improved reading after applying real B-train signal



home.cern

Beam Gas Ionisation (BGI) Profile Monitor

Continuous transverse beam profile measurement based on detection of residual ionisation electrons

Instruments installed in the PS (LIU) and SPS (CONS)

Hardware issues:

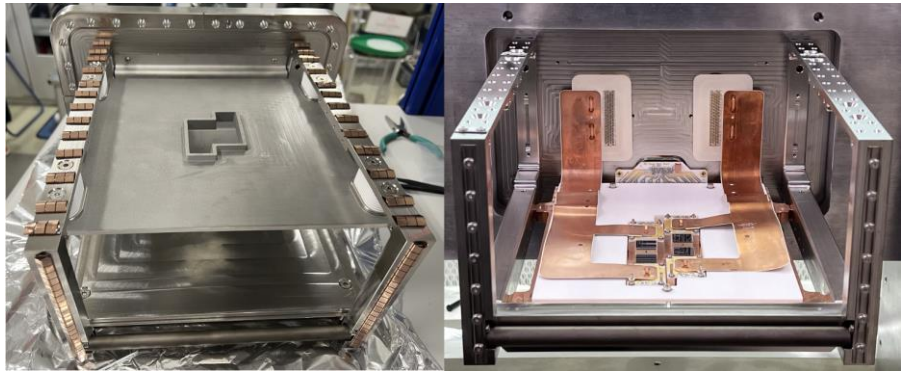
- **EMC issue** of SPS BGI instruments
- **Low gain** of PS BGI-Vertical at injection energy
- **Saturation of Timepix3** due to beam loss & noisy pixels

Software issues:

- **Stability & complexity** of current FEC + SoC readout system
- **Limited analysis** of Timepix3 data on SoC processor

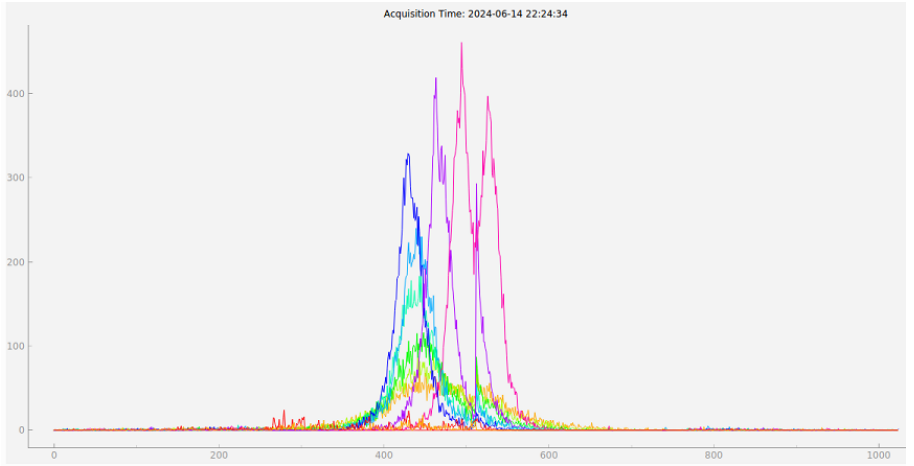
Summary of the BGI review

- Recommendation to proceed immediately to new Timepix3 readout architecture (ATS FESA-on-SoC + Server Event Processing), at the cost of reducing deliverables to OP in the short term -> ready by Q4 2025
- SPS EM issue is a significant problem, investigations underway with help of ATS EMC Lab -> SPS BGI-Vertical instrument to be installed in EYETS 24/25



BGI instrument - Field cage *BGI instrument - Timepix3 HPD's*

SPS BGI-H: Beam Profile Evolution of LHC3 Cycle



Transverse Position (Col. #)

SPS BGI's: Situation Today & After YETS 24/25

Situation Today

BGI Horizontal
- Instrument installed with "Diamond" RF shield
- Magnets in doublet configuration

BGI Vertical
- Prototype instrument installed
- Magnets in doublet configuration

After YETS 24/25

BGI Horizontal
- Same instrument with "Diamond" RF shield
- External HV countermeasures
- Magnets in triplet configuration (*)

BGI Vertical
- New instrument with "Denser" RF shield
- External HV countermeasures
- Magnets in triplet configuration (*)

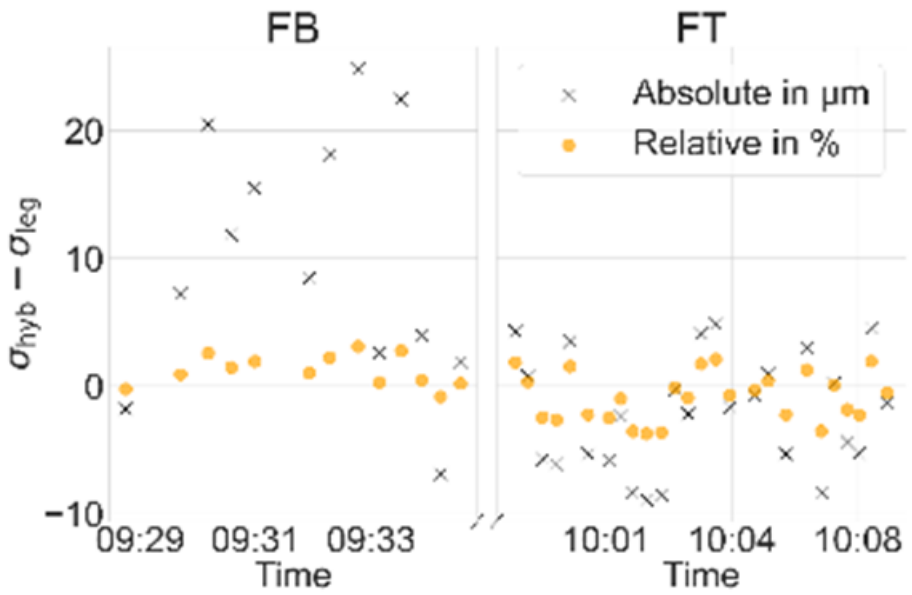
(*) ECR 3168184 "Modification of magnetic bump for operation of the BGI profile monitors in SPS LSS5.

LHC BLM Thresholds

- BLM Thresholds Working Group: https://indico.cern.ch/category/8964/
- 20 BLMTWG some combined with CollWG and/or MPP and13 ad-hoc meetings
  - 10 concentrated on ion run beam loss limitations
- BLM ECRs 2024:
  - LHC-BLM-ECR-0080 BLM thresholds for the new detectors in IP7 for Beam 1 on the passage wall
  - LHC-BLM-ECR-0081 BLM thresholds increase of RS12 for collimation losses
  - LHC-BLM-ECR-0082 BLM thresholds increase in IR3 at the start of beam energy ramp
  - LHC-BLM-ECR-0083 BLM thresholds for Proton Quench Test at 6.8 TeV
  - LHC-BLM-ECR-0084 BLM thresholds modifications for the proton-proton reference run at 2.68 TeV
  - LHC-BLM-ECR-0085 BLM thresholds for the LHC Pb-Pb ion run at 6.8 TeV in 2024

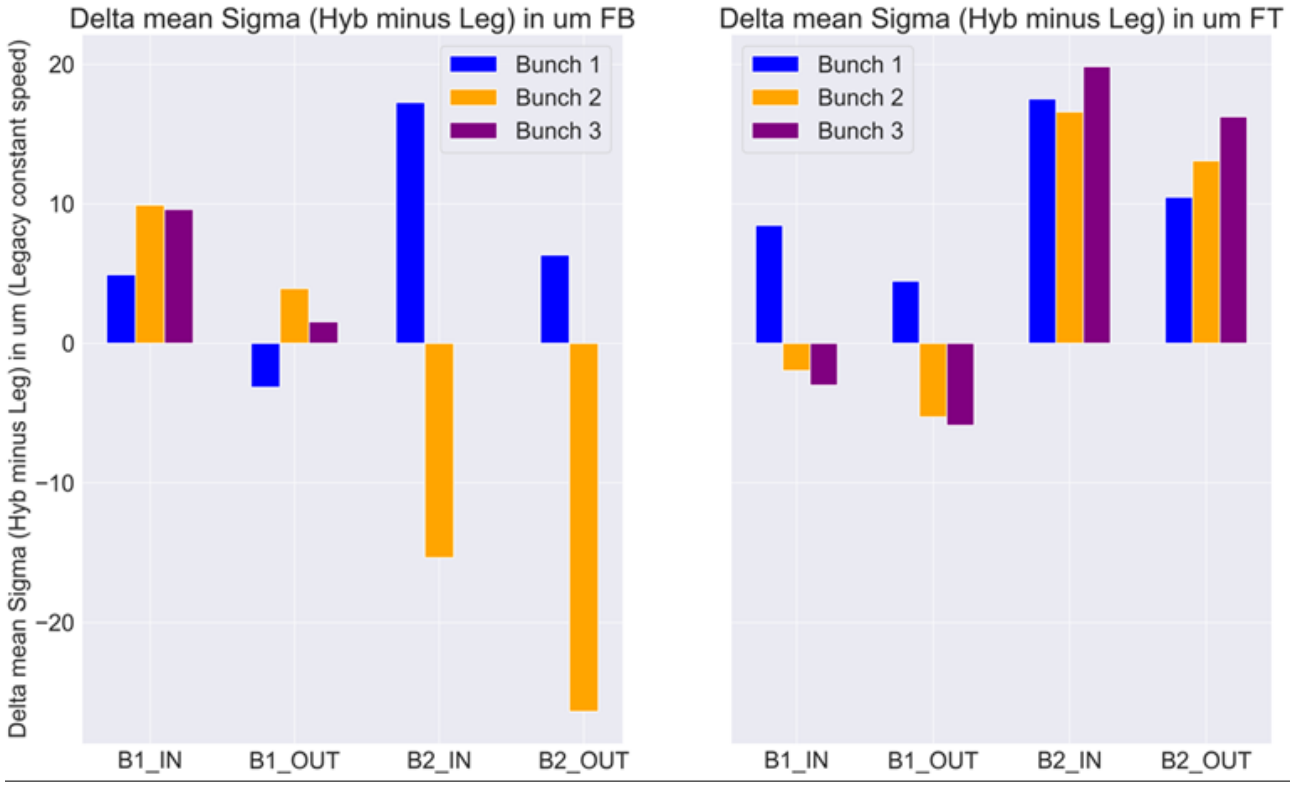
LHC BWS – Legacy vs Hybrid+

Hybrid – Legacy



Injection energy
< +-20um in absolute
< +-2%in relative

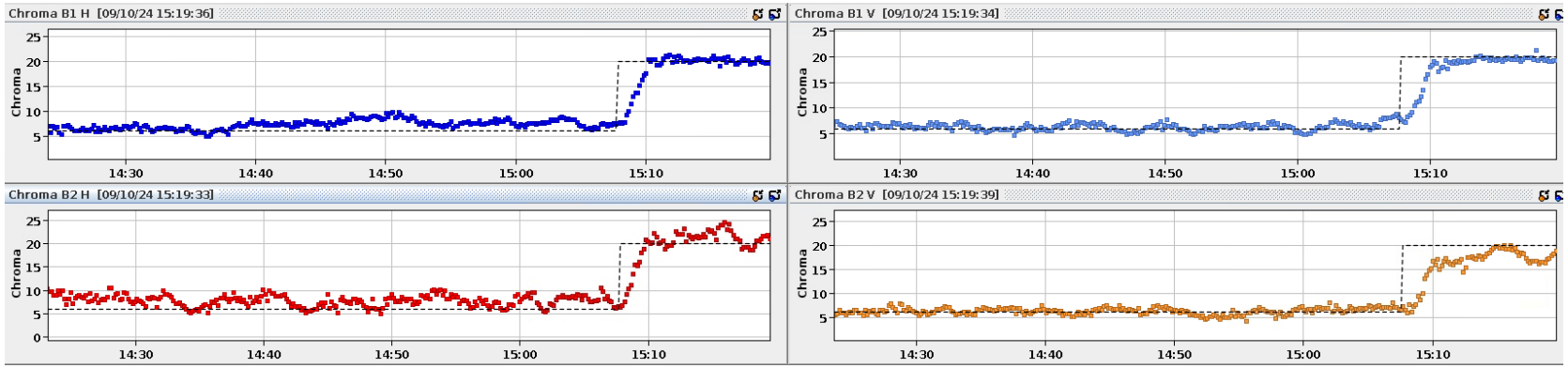
Flat Top energy
< +-10um in absolute
< +-4 %in relative



LHC Schottky

Schottky Monitor operational!

- Online Q' measurement with proton and ion beam
- Displayed in OP's LHC AccPit



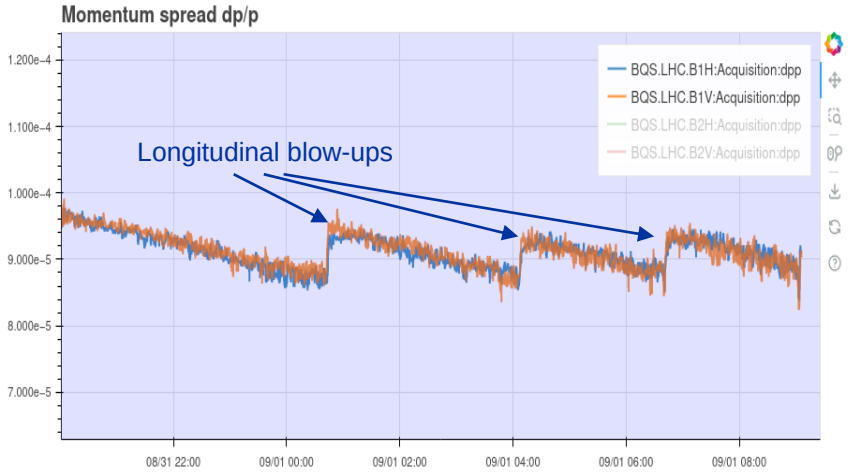
Additionally measuring:

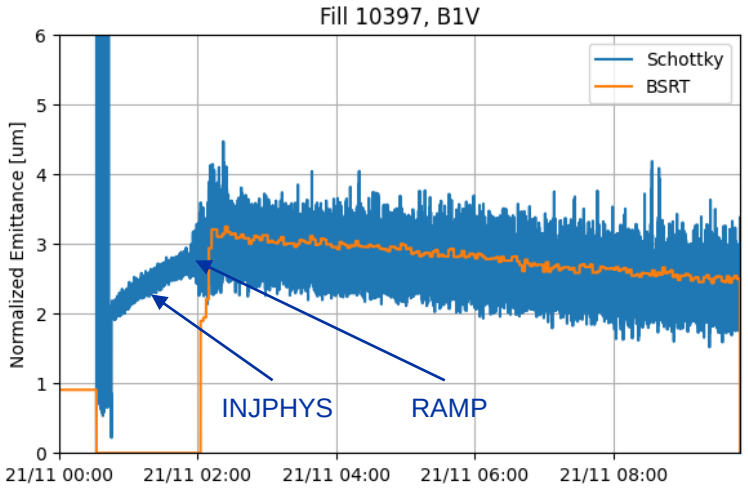
- Betatron tune, RMS dp/p
- Transverse emittance of ion bunches along the whole cycle

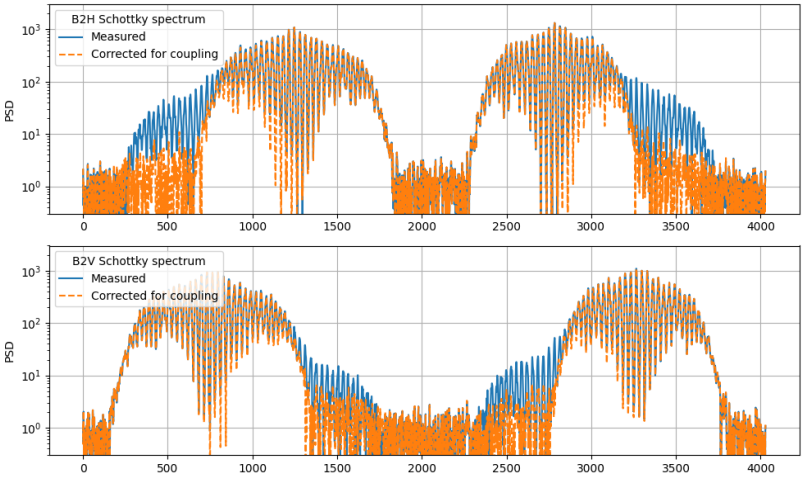
Promising studies ongoing:

- Betatron coupling monitoring
- More realistic Schottky theory
- Machine-learning based analysis

K. Lasocha et al. PRAB 27 (11), 112801
C. Lannoy et al. JOI 19 (03), P03017
K. Lasocha et al., IPAC 2024, WEPG30
C. Lannoy et al., IPAC 2024, WEPG31
C. Lannoy et al., IPAC 2024, WEPG32
M. Bradicic, CERN-STUDENTS-Note-2024-224







Original list of topics proposed by session chairs:

- **Focus up to 2026**
- **BSI measurement status & overview**
- **BGI plans after review**
- **Experimental Areas: Limitations and future, feedback from BIFT on upcoming consolidation efforts and items not covered**
- **Missing instrumentation (‘known unknowns’), where do we need R&D or resources?**
- **Compatibility with future beams? Ions? ‘Attention needed’?**

EA feedback to SY/BI (2024 + 2025)

- More clear HWC and ISTs completion
- XWCM spare strategy
- In case of planned comissioning in the weekend / days off, expert availability to be regulated.
- Strategy for intensity calibrations (include XSEC) - CCC (?)
- Test bench for CEDAR/XCET optics commissioning without beam --> On EA
- But for pressure and BI/related --> SY/BI
- Operational issues with XCEDs (pressure sensors …)
- Possibility of interventions outside working hours for critical equipments like CEDAR or XCET that experiments rely on. Piquet service ?
- Ion Beam Instrumentation for low-energy --> F. Roncarolo
- FISCs