Beam instrumentation studies

LSWG meeting on 2024 MD plans overview

Sara Morales Vigo on behalf of the SY-BI group

20/02/2024

Content

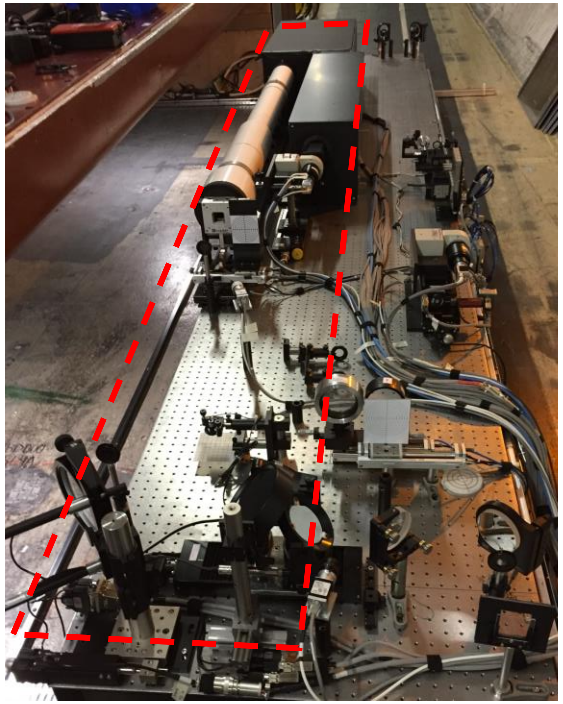
- **Characterization of the BSRH (beam halo measurements using a coronograph)**
  - Originally proposed in 2023 – MD10303
  - Slides slightly adapted from presentation at rMPP
- **Wire-scanners Hybrid+ and operational system beam size measures comparison in H and V**
  - Added on 22/01/2024 – MD11623
  - Follow up of MD9545
- **Schottky MDs**
  - MD requests not added yet
- **Beam scrapings for BLM calibration**
  - Originally proposed in 2023 - MD6950, MD9504, MD11067, follow up of these!

Characterization of the BSRH

Enrico Bravin, Daniele Butti, Federico Roncarolo, Georges Trad

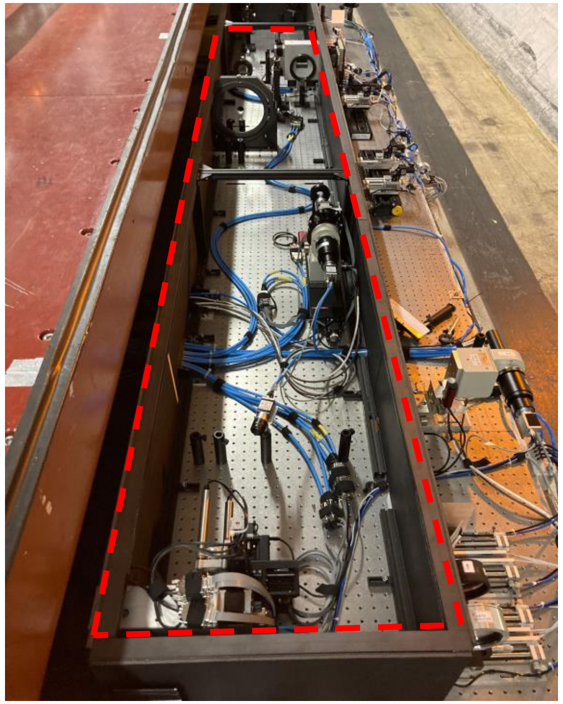
MD goal

- Synchrotron radiation (SR) halo monitor (BSRH) **refurbished for Run3**
- Extensive simulations carried out in LS2 provided **better understanding of LHC SR** source and its limitations



Run 2 setup
- proof of concept
- validated at injection (MD1900), discrepancies at flat-top (MD2243)

Run 3 setup:
- setup optimized for LHC parameters
- commissioning ongoing



- **Objectives:**
  - Is there a gain in contrast using a coronagraph instead of standard imaging (BSRT)?
  - What is the ultimate sensitivity of SR based diagnostics to halo population? (May require more MDs…)

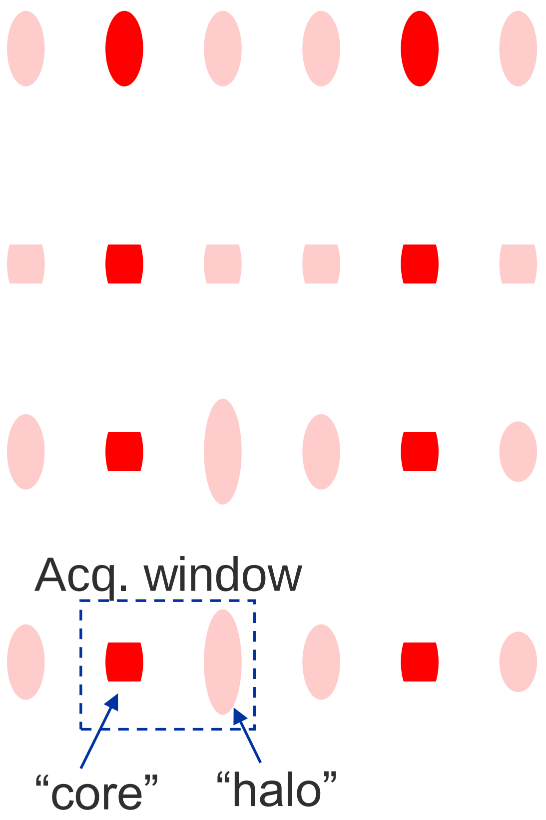
MD requirements

- **Two (4h + 4h) MD slots, optionally as floating MD**
- **Beam 2** only
- Work in **setup beam,** 2 nominals and a few pilots
- A filling scheme with **evenly spaced bunches** would help the measurements
- Ramp to **6.8 TeV**
- Frequent **wire scanner** measurements for reference
- Collimator **scraping** and ADT **blow-up** on both planes
- Perform **multiple ramps** to increase statistics (given the few bunches allowed by setup beam)

MD procedure (update)

Principle: scrape nominals to simulate a beam core and overlap blown-up probes to simulate the halo

1. Inject 2 nominals surrounded by a few probes (nominal 2.5 um emittance). Quick coronagraph check at injection and ramp
2. Scrape beam, ideally down to 3σ (HL reference, ~2.5σ LHC reference)
3. Open collimators >5σ, blow up probes to have several background levels. Take wire scanner reference profiles and reference images.
4. Take BSRH images overlapping nominal and probe(s) in the same acquisition window to assess the sensitivity to the fade background. Repeat blow-up / scraping sequence.



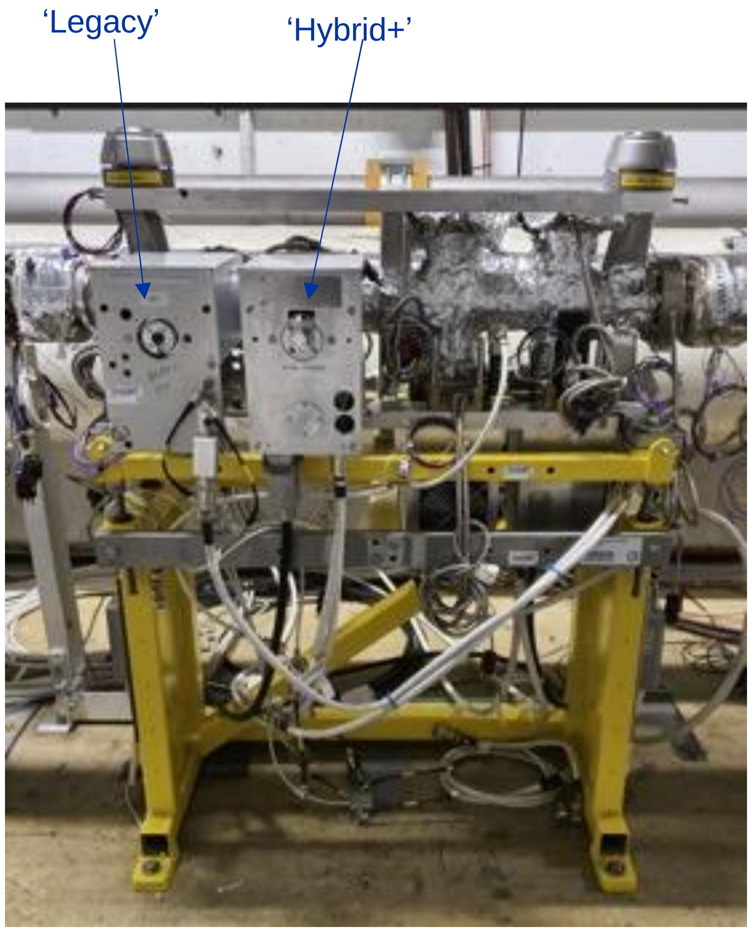
5. If possible, repeat entire cycle to increase statistics on both planes.

Wire-scanners Hybrid+ and operational system beam size measures comparison in H and V

Federico Roncarolo, Ana Guerrero Ollacarizqueta, David Belohrad, Jonathan Emery, Nabil El-Kassem, Daniele Butti, G. Trad

MD11623 - Wire-scanners Hybrid+ and operational system beam size measures comparison in H and V

- **Goal:** Assess Hybrid+ mechanisms (B1H2, B1V2, B2H2, B2V2) performance equipped with the acquisition based on injectors' system (electronics, control and acquisition)
- beam parameters of a BSRT calibration filling (12b, 4 Emittances) and measure alternatively with OP 'legacy' scanners and 'Hybrid+'
- The Hybrid+ mechanisms installed during the YETS23-24 are equipped with new bellows (with improved lifetime) and new electrical feedthrough compared to 'Legacy' (the OP system) and 'Hybrid' scanners (used in MD9545 in 2023).
- The goal of this 2024 MD is to finalise the comparison of the measurements with the two instruments in different conditions. Now we have both beams and both planes equipped with Hybrid+ (only 'Hybrid' version in B1 & B2 H in 2023).
- We will do repetitive wire scans with the Hybrid+ and operational scanners on both beams with a BSRT fill and compare the beam size measures statistics.
- We also need to study in detail the acquisition chain derivate from the injectors to:
  - find the working point to measure through the ramp using multi-channel capability of the new acquisition and PMT gain setting.
  - assess signal bandwidth and quantify crosstalk at different settings.



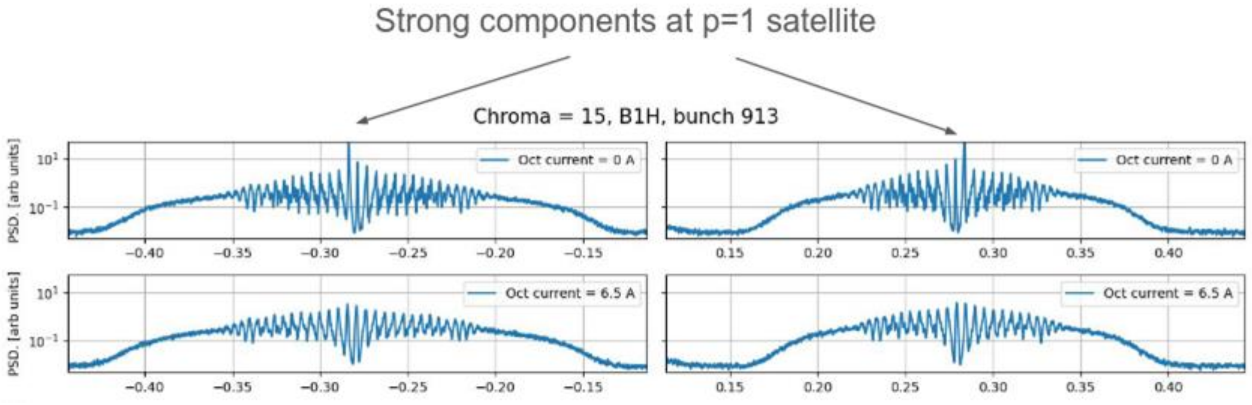
Schottky MDs

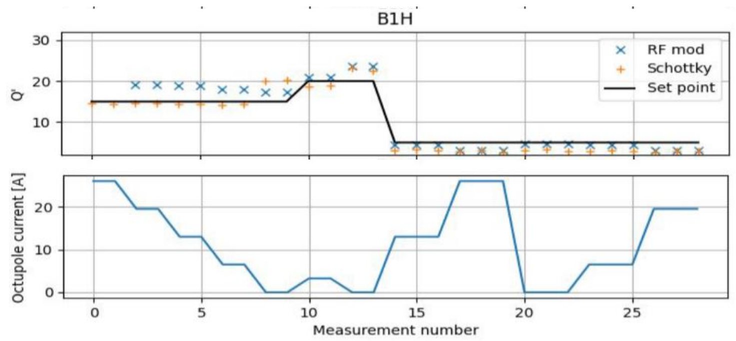
K. Łasocha, C. Lannoy, T. Pieloni, N. Mounet, D. Alves, T. Levens, O. Marqversen

MD: Schottky studies with proton beam

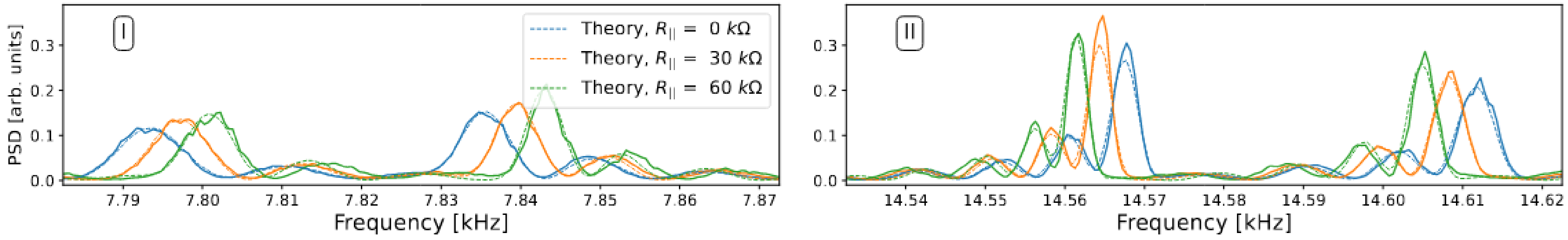
Motivation:

I. **Previous MD9263 (ions) has shown a positive impact of octupole magnets, which diminish coherent components and do not affect the chromaticity estimate. We would like to determine the magnitude of the octupole current needed to suppress all coherent components in proton spectra, and provide a reliable chromaticity estimate.**





I. **In the same measurement, using different bunch intensities we will also benchmark the new theory for the effect of the longitudinal impedance on the Schottky spectrum. Simulations suggest a visible, impedance-dependent shift of Schottky satellites for typical LHC conditions:**



MD: Schottky studies with proton beam

MD details:

<u>Species</u>: Protons

<u>Duration</u>: 8 hours

<u>Energy</u>: INJ+Flattop

<u>Bunches</u>: 3-6 bunches of different intensities

<u>Brief description</u>: For different chromaticity values we would like to perform an octupole current scan, and record Schottky spectra from all the bunches. Done twice, at INJ and flattop energy.

MD: Schottky-based coupling & emittance measurements

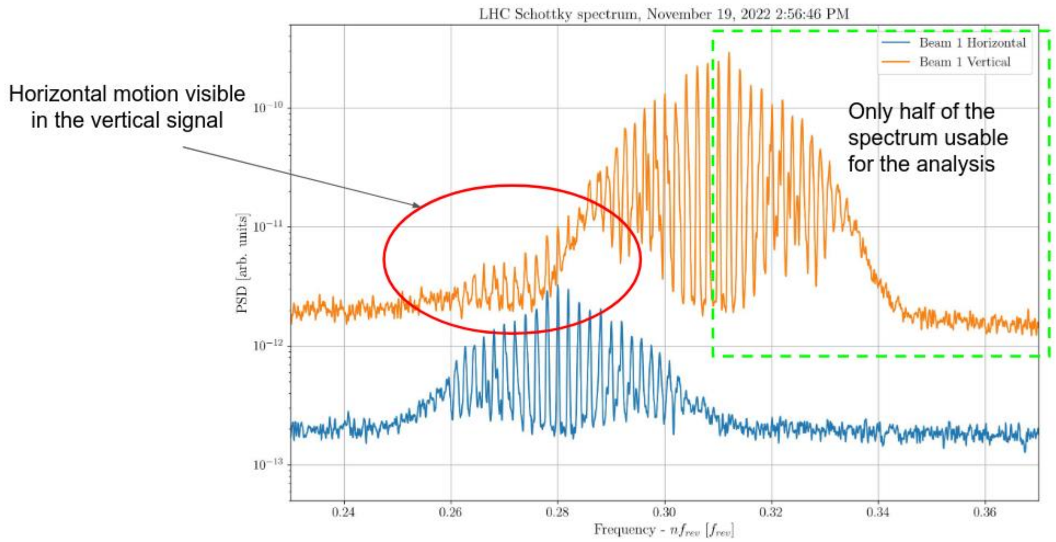
Motivation:

In day-to-day operation we have frequently observed the signatures of transverse coupling in the measured Schottky spectra.

The goal of this MD would be to acquire Schottky spectra for different values of the coupling constant. This data would then be compared to simulations and theoretical predictions, with the assessment of the coupling C^- coefficient measurement potential.

If successful, such an approach would allow for the non-invasive measurement of the coupling coefficient not only with the probe beams, but also for high-intensity beams at flattop energies.

In addition, we would like to revisit the potential of deriving the transverse emittance from Schottky spectra. The theory suggests that the presence of coherent components, which can be mitigated with increased octupole current, is the limiting factor for Schottky-based emittance measurements.



MD: Schottky-based coupling & emittance measurements

MD details:

Species: ions

Duration: 8 hours

Energy: INJ+Flattop

Bunches: 3-6 bunches of different emittance (ADT blow-up)

Brief description: We would like to sequentially change the coupling coefficient, and acquire the Schottky spectra for all the bunches present in the machine. In between, the standard measurements of the coupling coefficient and emittance (wirescanner) will be performed. Done twice, at INJ and flattop energy.

Beam Scraping MDs

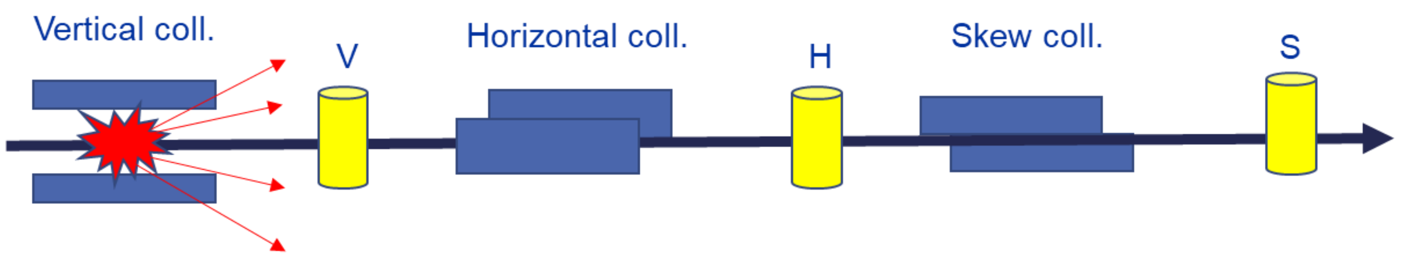
S.Morales[1], B.Salvachua[1], E.Calvo, S.Redaelli, P.Hermes, M.Rakic, C.Zamantzas

[1]Also part of beam scraping requests from RF and collimation

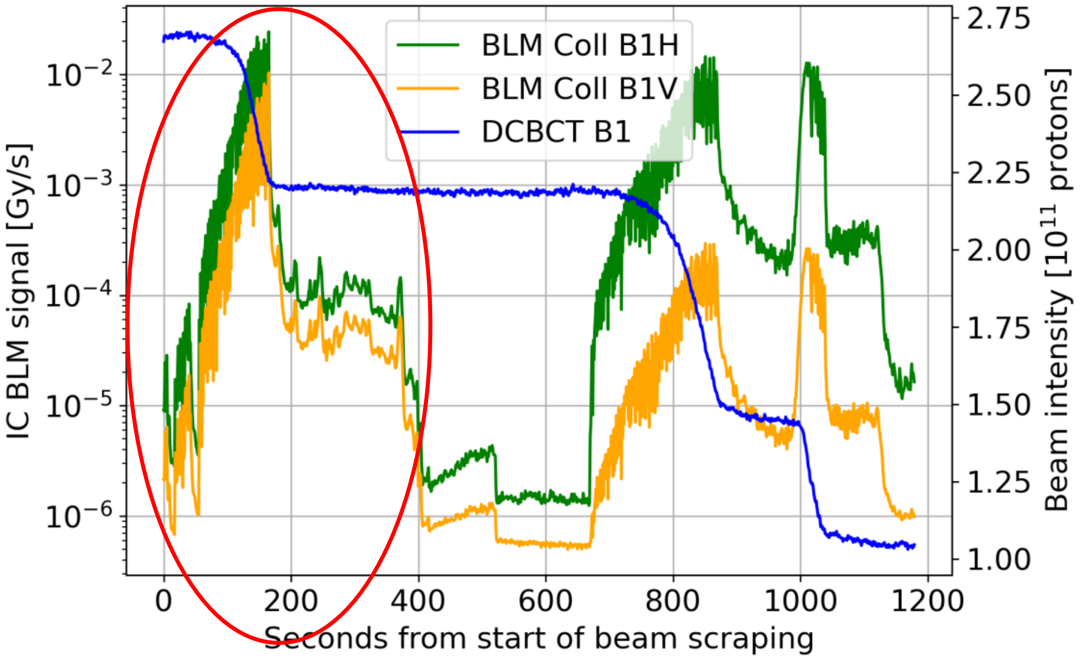
MD#6950 – Study of beam loss patterns for improving online BLM diagnostics – 2024 session

Calibration of the BLM system (Gy/s to protons/s)

- Based on the analysis of the BLM detector signals for different well-defined beam loss scenarios
- Proton impacts on the jaws of the primary B1 and B2 betatron and off-momentum collimators
- Beam loss scenarios reproduced by controlled beam scraping on single collimators
- To be repeated after every change in settings or long technical stop



From analysis of past beam scrapings, a dependence of the BLM response on the collimator jaw used was observed (especially in IR3!).
Check reproducibility of results and if changes are observed with the 2024 configuration



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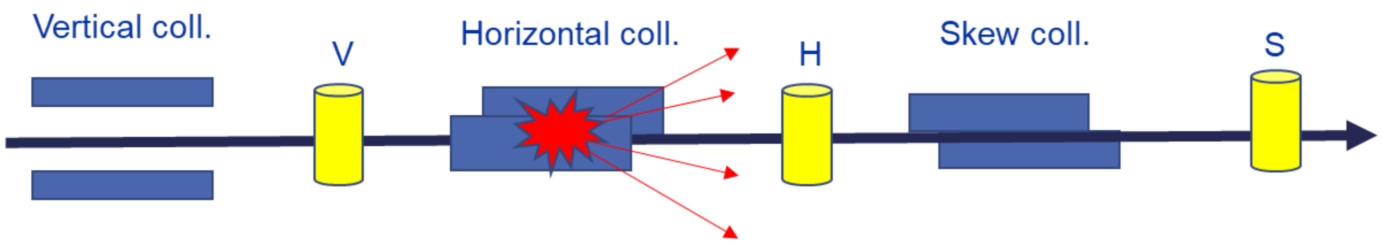
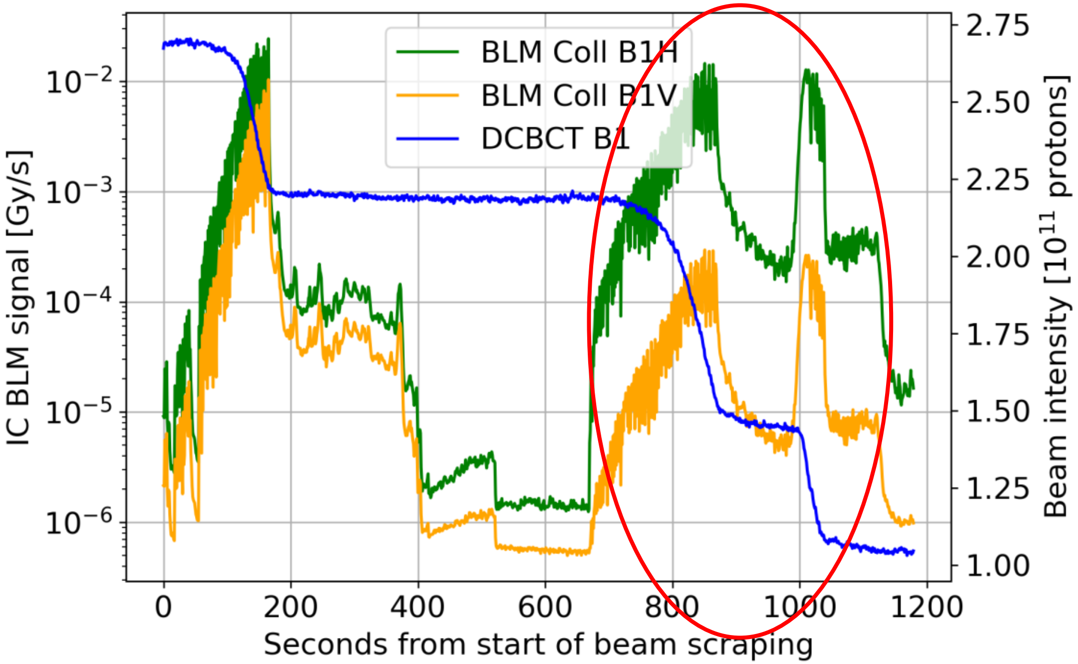


From analysis of past beam scrapings, a dependence of the BLM response on the collimator jaw used was observed (especially in IR3!).
Check reproducibility of results and if changes are observed with the 2024 configuration



MD#6950 – Study of beam loss patterns for improving online BLM diagnostics - 2024 session

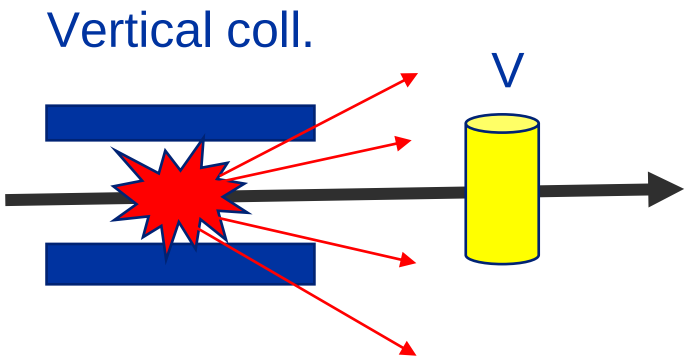
- Injection of 3 nominals (protons) per beam (to stay below SBF) and ramp to top energy
- BIC mask collimators, BLMs and BPMs
- BLM thresholds remain at the nominal settings in all the machine
- Correct beam orbit (if feedback is off)
- Check dBLM phasing
- Beam scraping with primary collimators in IR3 (off-momentum) and IR7 (horizontal, vertical and skew) with only left jaw, only right jaw, and both jaws
- Two sessions of 4 hours (or one of 8)
- Data useful for both IC BLM and dBLM calibrations

OK to do during beam commissioning once the final configuration of the machine is in place
–> collimation settings and optics
Possibility to check differences in FLATTOP, SQUEEZE, ADJUST? -> Request of 2 fills

MD#9504 – Diamond detector and ionization chamber BLM response studies at injection energy – 2024 session

- Calibration of the BLM system at injection energy (beam scraping)

- Study the dependence of the BLM response on the collimator jaw used for beam scraping



From analysis of past beam scrapings, a dependence of the BLM response on the collimator jaw used was observed (especially in IR3!).
Check reproducibility of results and if changes are observed with the 2024 configuration

- BLM thresholds remain at the nominal settings in all the machine

- Data useful for both IC BLM and dBLM response studies

- One session of 4 hours

MD#9504 – Diamond detector and ionization chamber BLM response studies at injection energy - 2024 session

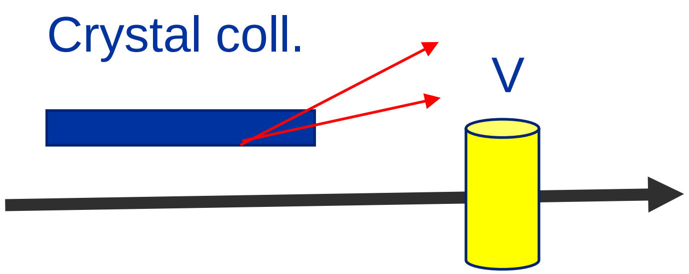
- Injection of 5 nominals (protons) per beam (to stay below SBF)
- BIC mask collimators, BLMs and BPMs
- Correct beam orbit (if feedback is off)
- Check dBLM phasing
- Beam scraping with left jaw of primary vertical collimators in IR3 and IR7
- Dump the beam and reinject
- Beam scraping with right jaw of primary vertical collimators in IR3 and IR7
- Dump the beam and reinject
- Beam scraping with both jaws of primary vertical collimators in IR3 and IR7

OK to do during beam commissioning once the final configuration of the machine is in place –> collimation settings and optics

MD #11067: Beam Loss Patterns with Ions and Crystal Collimation – 2024 session

Calibration of the BLM system (Gy/s to ions/s)

- Based on the analysis of the BLM detector signals for different well-defined beam loss scenarios
  - **Crystal collimator acting as primary now -> Completely different loss patterns!**
- Ion impacts on the jaws of the primary B1 and B2 off-momentum collimators in IP3
- Ion losses from crystal collimation in IP7
- Beam loss scenarios reproduced by controlled beam scraping on single collimators
- Exploration of beam loss patterns for crystal operational modes -> channeling, amorphous, VR



Could not finish MD as an electrical perturbation caused the beam dump!
Possibility to also perform at injection energy?

OK to do during beam commissioning once the final configuration of the machine is in place –> collimation settings and optics

MD #11067: Beam Loss Patterns with Ions and Crystal Collimation – 2024 session

- Injection of 20 nominals (ions) per beam (to stay below SBF) and ramp to top energy
- BIC mask collimators, BLMs and BPMs
- BLM thresholds remain at the nominal settings in all the machine
- Correct beam orbit (if feedback is off)
- Check dBLM phasing
- Beam scraping with primary collimators in IR3 (off-momentum) and crystal collimators in IR7 (horizontal, vertical)
  - First attempt optimizing the crystals at the start of the scraping, losing the channeling conditions at some point and scraping in amorphous or VR – Useful data as well for the calibration!
  - Second attempt optimizing the crystals at the start of the scraping, and every 0.5 sigmas scraped in order to keep the channeling conditions
- One session of 4 hours
- Data useful for both IC BLM and dBLM calibrations

home.cern

Spare slides

Comments

- **No need for Beam 1,** available for other (non-conflicting) activities
- Setup beam should allow **maximum flexibility on scraping / blow-up**.
  Discussions with BLM and collimation teams, no significant limitations in safe beam.
- First MD on the new BSRH setup. Exact data taking plan adapted to experimental findings.
- **Longer* allocated time** (8h-10h) would help to perform multiple ramps and increase statistics
  - If only one cycle available, check both planes with only one bunch

*w.r.t. to the initial request of a 6h slot with with many nominals

Basic requirements (BSRH)

- **Number of hours needed:** 8
- **Number of sessions:** 2
- **Ready?** Yes
- **Specie:** protons
- **Beam phase:** Flat-top
- **Beam:** beam 2
- **Total # bunches:** 20
- **Beam parameters:** INDIV
- **Non-standard parameters:** several PILOTs and INDIVs, about 10 pairs. PILOT and INDIV should be alternate so that gating can be made on one of each. Several pairs are needed to allow different blow-up configurations
- **Collimation change:** Yes
- **Need to mask detector BCM?:** Yes

Wire-scanner prototypes and operational system beam size measures comparison

Federico Roncarolo, Ana Guerrero Ollacarizqueta, David Belohrad, Jonathan Emery, Nabil El-Kassem, Daniele Butti, G. Trad

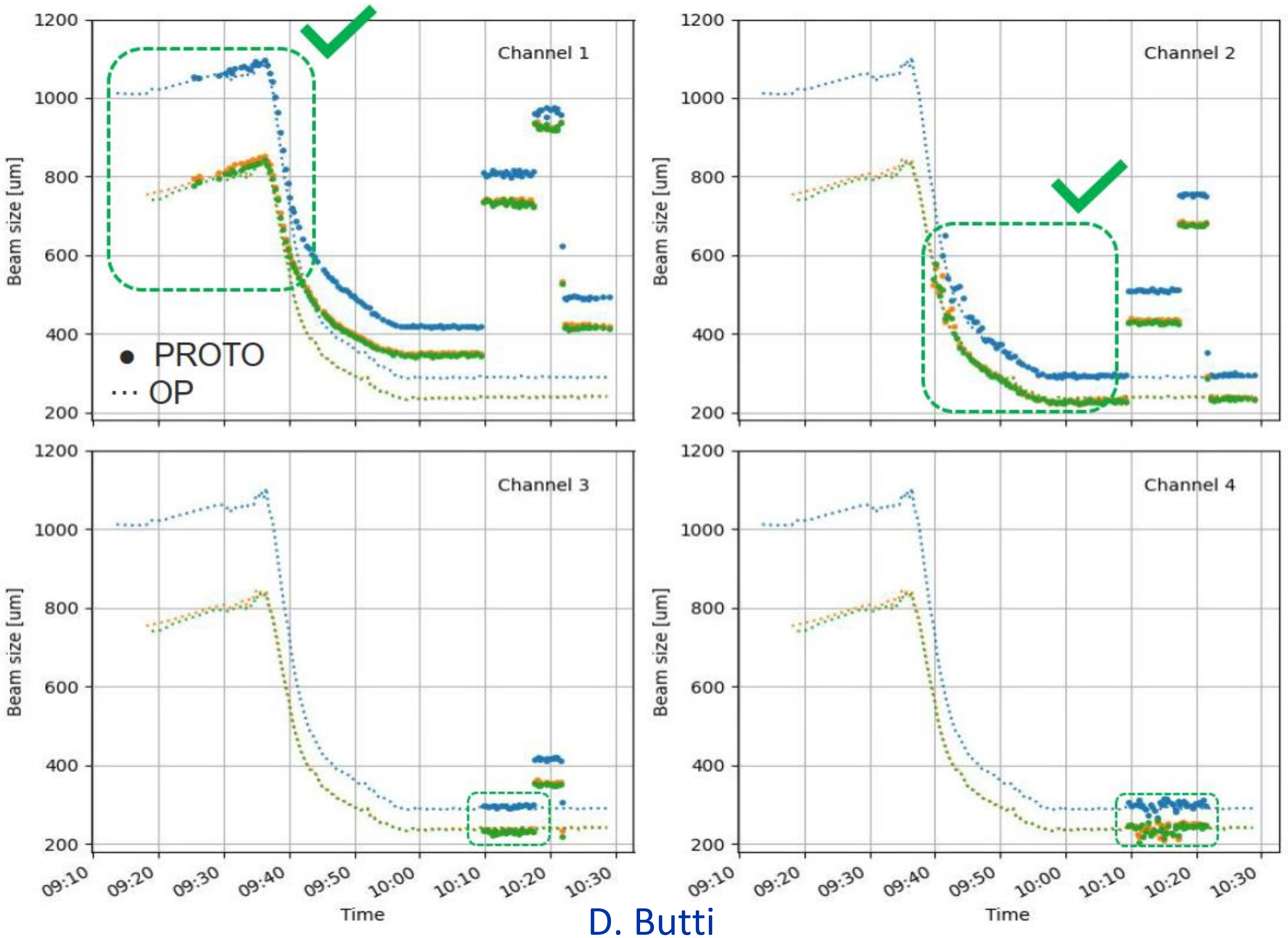
MD9545 - Wire-scanner prototypes and operational system beam size measures comparison (4h)

- **<u>Goal:</u> Assess prototypes (B1H2 & B2H2) performance equipped with the new injectors' electronics (control and acquisition) using BSRT calibration filling (12b, 4 Emittances)**
- **The legacy scanners B1H1 & B2H1 are the reference,
and we can compare directly the physical beam size (they are 30cm apart)**
- **After 2h30 of setting up -> refill for the ramp,
but due to B2 RF module trip, decision to ramp with 3b (1x2 ∝m & 2x1∝m)**
- **Many scans at FB, during the ramp and at FT, enough for a detailed analysis**
- **No vacuum level rise at all on VGPB.879.5L4.P.PR**
- **Different PMT voltage supply tested at FB to find the optimum
and at FT to measure with different PMT channels (CH3 and CH4).**
- **At FT with only 3b, we tried a slightly lower speed (0.833 m/s instead of 0.92 m/s),
losses went to 45% of the thresholds (40 us running sum).
16.05.2023: BSRT calibration with 12b and 0.92 m/s, losses were 36% of the threshold**

D. Belohrad, D. Butti,
N. El-Kassem, J. Emery,
A. Guerrero, F. Roncarolo,
G. Trad, and all BI BWS team

Scanner	Measures
Legacy beam B1H	134
Legacy beam B2H	158
Prototype B1H	172
Prototype B2H	196

MD9545 – Preliminary qualitative comparison Beam 1



D. Butti

The injector electronics uses 4 PMT with different filters in parallel supressing the need to change filter during the ramp

Using the OP scanner (small dots), we see sensible measurements of the prototypes (large dots) on CH1 at injection and CH2 from the middle of the ramp.

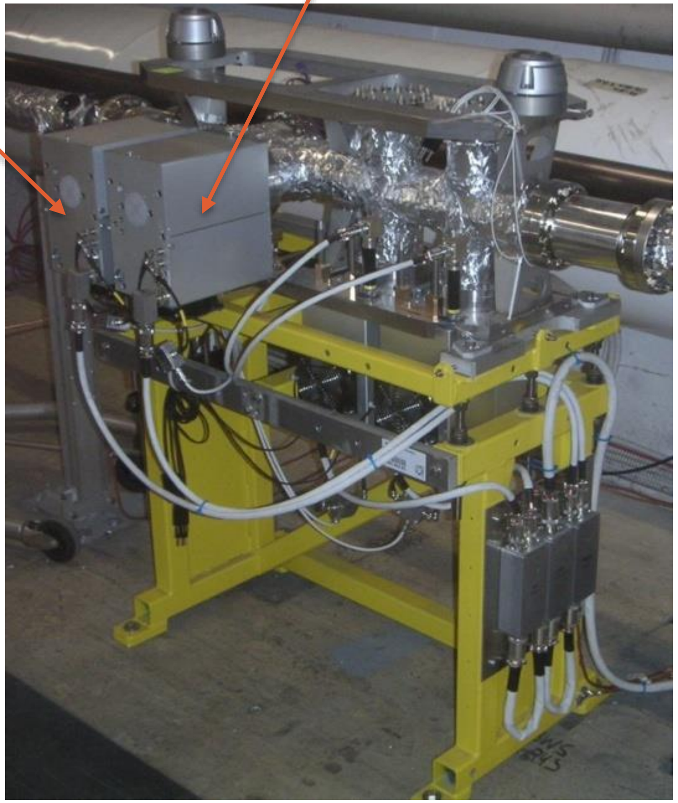
Changing the PMT supply, to change its gain, we can see that CH3 and CH4 can also measure sensible beam size at FT (tbc).

Next:
1) Detailed analysis to quantify precision and accuracy of the prototypes with the OP as reference
2) Verify the data fitting, channel automatic selection, internal FPGA and SW processing of the position and acquisition using RAW samples available on disk.

LHC wire-scanners setup

Operational mechanism

Prototype mechanism position



LHC BWS BEAM 1
MOTION PART

5m away

LIU based PMT assembly

Operational PMT assembly

LHC BWS BEAM 1
PMT PART