Beam Synchrotron Radiation Halo (BSRH) monitor: Implementation during LS3

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With precious input from:

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HL-LHC Beam Halo Monitor Review, 18-Dec-2024

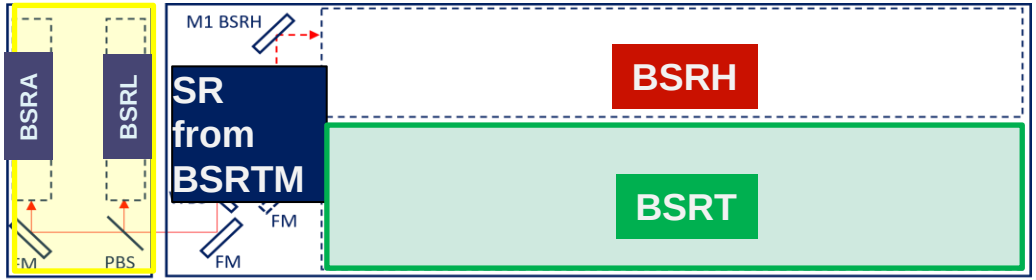
Contents

- Recall of present BSRs implementation
- BSR for beam halo (BSRH)
  - Pre-LS3 studies, achievements, plans
  - Possible LS3 implementations and dependencies
- Conclusions / Outlook / General Considerations

Present BSRs implementation

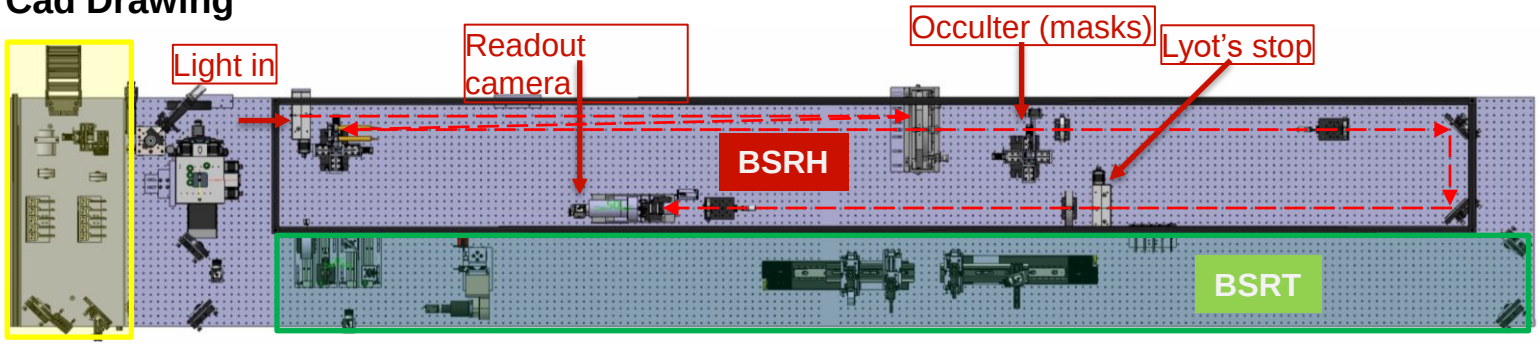
Optical Table Below Beam Pipe

Schematic Layout



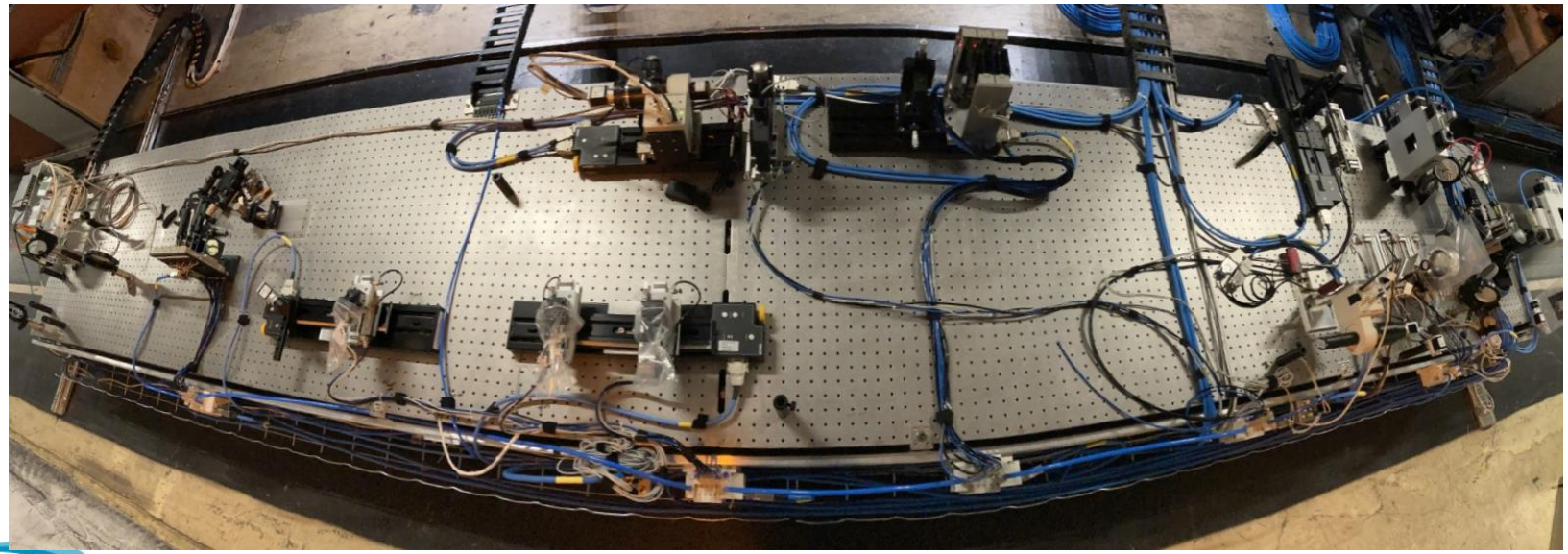
1 Beam Synchrotron Radiation Halo (BSRH) monitor (coronograph layout) system @ BSRTM 5L4 (Beam 2) , all details in previous talk by J.P.

Cad Drawing

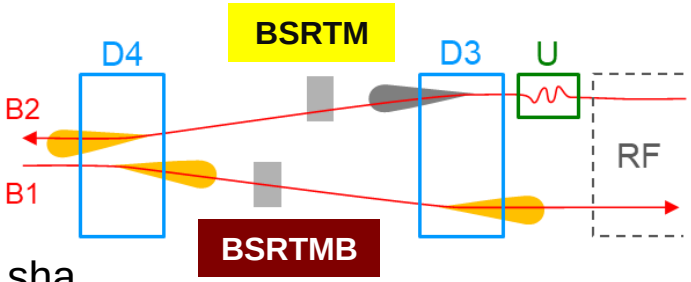


Present BSRs implementation

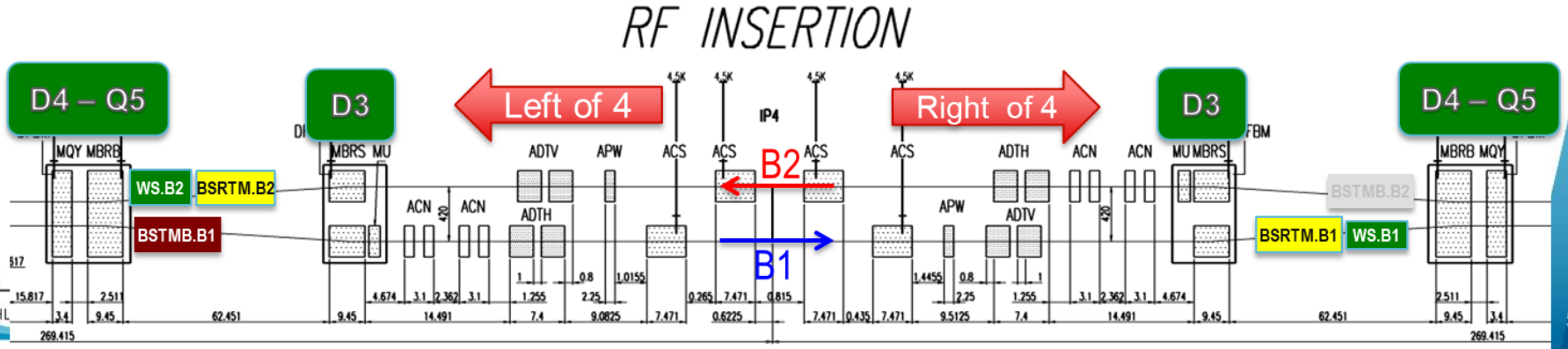
- Almost for every intervention the table below beam pipe must be ‘extracted’ via rails on passage area



Present BSRs implementation



- 2 (B1, B2) x BSRTM extraction systems
  - SR from Undulators and D3 dipoles. Layout and sha
  - Operational, evolved since LHC startup. Today serving transverse beam size (BSRT) and longitudinal (Abort Gap - BSRA, Longitudinal Density - BSRL) monitors
- 1 (B1) x BSRTMB extraction system
  - SR from D4
  - New extraction mirror design, movable with beam energy, see next slide



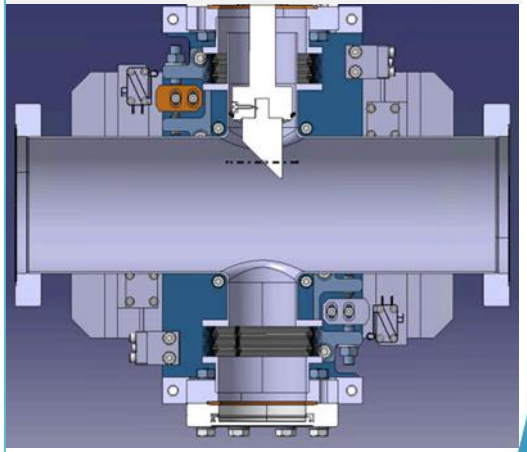
Pre-LS3 Development Phase

What is already designed (completed), installed, validated

- **BSRH prototype Beam2 @ BSRTM**. Two MDs 2024, all details in previous talk

- **BSRTMB (Second SR Source)** - HL-LHC baseline:
  - Completed design, RF studies, and lab measurements
  - Installed B1 system with movable mirror for aperture/impedance tests
    - Successfully integrated with LHC operations and interlocks
    - Confirmed no RF heating issues via temperature monitoring
  - Coated mirror installed B1, for 2025 beam tests
  - Infrastructure/integration:
    - Cables and fibers ordered for both beams
    - Space reserved for B1 and B2
    - Vacuum integration design ~complete
    - Schottky monitors (BQS) B1 and B2 swap to optimize future BSRTMB B2 upstream pipe aperture
    - D4-BSRTMB enlarged chambers in procurement

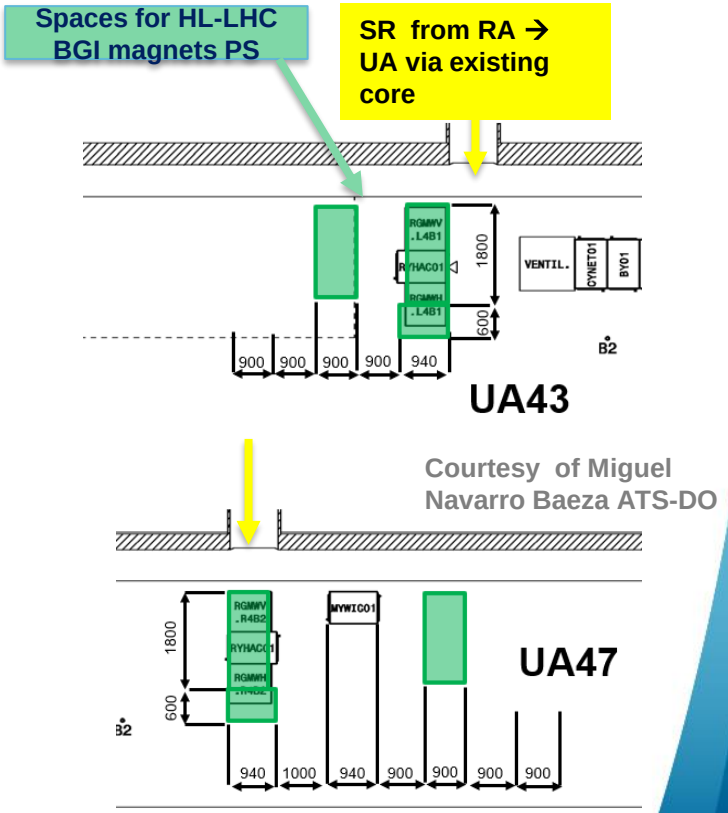
Movable mirror to optimize light collection at flat top and reduce effect of diffraction from edge



Pre-LS3 Development Phase

What is planned and expected to be implemented before LS3

- **BSRH prototype Beam2** studies:
  - systematic studies (2025: possible in parallel to BSRT), in MDs and normal operation.
  - propose / test simplified version (e.g. apodized occulter)
- **2025 BSRTMB B1** Testing Plan:
  - Light collection efficiency validation (Q1-Q2)
  - Parasitic SR impact assessment from upstream magnets (Q2)
- **BSRTMB-UA optical line**
  - ZEMAX simulations (by Q2 2025)
  - complete (ongoing) integration (by 2026), e.g. to allocate space for BSR optics as close as possible to UA wall



LS3 Implementation Phase

Context Recap

Current Setup:

- Located below beam pipe at BSRTM locations
- Used for multiple measurements:
  - Transverse (BSRT)
  - Longitudinal (BSRA - abort gap monitor, BSRL - density monitor)
  - R&D and prototype testing (BSRA, BSRI, BSRS)

Key Challenges:

- Tables are ‘overcrowded’, with SR shared among detectors via splitters/mirrors
- Access difficulties - maintenance
- Radiation concerns for detectors and electronics in Run3, expected to worsen in Run4

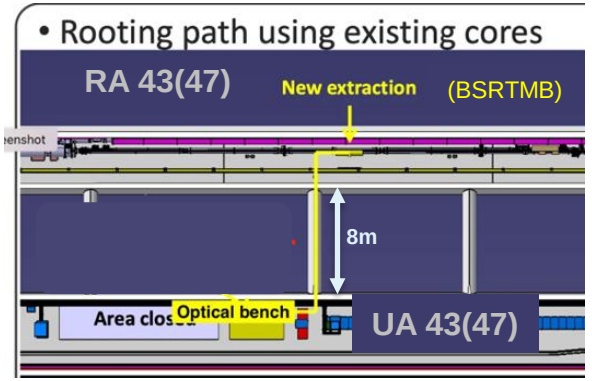
2024 SR sharing setup

Instrument	B1 Splitting Ratio	B2 Splitting Ratio
BSRT (Synchrotron radiation telescope)	0.35 (or 0.70 if BSRI splitter removed)	0.70
BSRA and BSRAN (Abort gap monitor)	0.15	0.15
BSRL (Longitudinal density monitor)	0.15	0.15
BSRI (Synchrotron radiation interferometer)	0.35	N/A (R&D on B1 only)
BSRH (Halo monitor)	N/A	0.7 (redirects BSRT light)
BSRS (Slit scanner)	0.35 (redirects BSRI light)	N/A (R&D on B1 only)

LS3 Implementation Phase

Option	Advantages	Disadvantages	Dependencies
1-BSRTMB with RA→UA Optical Lines	• Higher light collection • Less system interdependency • Redundant diagnostics • Immunity to radiation • Future-proof for LS4 (e.g. Undulator option)	• More systems to maintain, including +2 viewports • Longer outside vacuum (at optical line (see note** on the side) • SR only above xx TeV (no injection)	• Optics validation (Zemax simulations) (Q1-2 2025) • UA integration
2-BSRTMB without Optical Line	• Shorter outside vacuum optical line	• Difficult access • More shielding needed • Higher total cost	• Budget for shielding tbc
3-Upgrade Existing BSRT	• maintenance of 2 systems only	• Crowded tables, difficult access • BSRA-BSRT-BSRL systems intercedences • Radiation exposure	• RF impedance of present BSRTM with HL-LHC beam parameters to be re-checked

Option 1



** at least 8m to go to UA , detailed optics tbc

All options compatible coronagraph or other (simpler) SR based beam halo monitor. This can include

- More **standard 'occulting' imaging telescope**. No need for Lyot stops and related re-imaging present in coronagraph
- **HDR camera**: can re-iterate on ultimate performances reach (update survey made many years ago)
- **Slit Scanner**

LS3 Implementation Phase

About **non confirmed plan and open items requiring resolution/decision** (picking from previous slide and previous presentation), focusing on Option1:

Technical challenges:

- Ultimate reach of SR based BH monitor
- Bringing system to be operational

Resource gaps

- **HL-LHC GRAD : needed at least till end of commissioning Run4**

Approval/coordination needs,

- Big efforts in 2024 to include all possible options in the planning. See also next slide. All should be ~clear including support from integration, cabling, vacuum and other groups/teams/units.

From PLAN Tool

Activity 12854	BSRT Upgrade activities for HL LHC	SY-BI	FEDERICO RONCAROLO (SY-BI-PM)	3. HL-LHC project	HL-13

DOCUMENTS

Type	Description	Status	Information
ServiceNow	Cable installation, number of cables: 34, lenght: 3400, LHC, LS3	In progress	Open
ServiceNow	[HL-LHC] Fiber Optics installation: LHC - LS3	In progress	Open
EDMS	Installation of a Compact Imaging System on BSRTMB.5L4.B1 Device	Approval Accepted	Open
EDMS	HL-SRR - Beam Synchrotron Radiation Telescope (BSRT)	Approved	Open

Post-LS3 Phase

Here: **best estimate of the scenario**, always focusing on Option 1 (but most of this applies to any BSRH option). Based on pre-LS3 plan execution.

- Features/capabilities that
  - **Will be available after LS3**: Enhanced BSR-based halo monitor system with continuous relative halo integral monitoring. Aim at basic OP GUI.
  - **Will need to be developed/implemented after LS3**: Detailed performance characterization with HL-LHC beams and comprehensive reliability validation
- Expected **timeline for transition from expert to operational mode**
  - 1 year after LS3
- **Known risks** related to schedule and performance
  - risks: ultimate reach in terms of sensitivity and relative/absolute accuracy dependency on technical choices, implementation, learning curves
  - About schedule: what proposed = compatible with HL-LHC master schedule, tbc 2025

Budget (and Other General) Considerations

- Budget status:
  - Cost estimates for development and implementation phase vs available budget
    - Present budget ok. If Option 2: possible risk is additional radiation shielding
  - Funding gaps to be addressed ?
    - For ensuring GRAD till after LS3 ?
- Long-term budget considerations. Maintenance and operational costs, including manpower:
  - General (also for beam profile monitoring via BSR):
    - Need dedicated staff member for BSRs (currently vacant; Internal Mobility or LD position planned for 2026) + graduate student
    - Maintain adequate technical support from SY-PM team for ongoing maintenance and operations
    - Require expert SY-BI-SW staff support due to complex BSRs control architecture
  - If Option1: +2 systems to maintain, may need to re-allocate or add manpower
- Identify and anticipate potential future upgrade requirements:
  - Radiation potentially an issue for electronics and detectors left in the RAs (tbc)
  - New undulator ? (considered as option years ago, not in any plan now)

Outlook / Conclusions

- Present BSRH B2 prototype installed on optical table below BSRTM, with all others BSRs
- Present reach (e.g. absolute and relative resolution in measuring beam halo) discussed in previous talk
- 3 options presented for a BSR@HL-LHC with pro/cons/open questions
- 2025 fundamental to test present BSRH during physics + MDs and confirm optical line is a viable solution (optics simulations, lab tests)
- Second SR extraction systems: completing integration studies + keeping enlarged vacuum chambers in VSC procurement looks to be best (only?) option for not loosing LS3 implementation opportunity