Collimation MDs

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Proton collimation MDs

IR7 optics MD - 4+8 h

- **New IR7 optics reduces impedance, improves cleaning performance**
  - Important for ensuring HL performance
  - Will be put in HL baseline optics – important to properly test early in Run3
- **Planned for 2022 / 2023 – suffered heavily from unavailability**
  - 1 out of 20 measurements could be done
  - DS losses improved by 36 / 51 % in clusters 1 / 2!
- **Propose same program as previously planned:**
  - Part 1 (4 hours – 1 fill):
    - Set up and measure new IR7 optics at FT
    - Check collimator alignment
    - Preferably early in the block
  - Part 2 (8 hours – 1 fill):
    - Detailed measurements of cleaning performance and impedance
    - 2-3 days after part 1

same request as 2023

- **Follow-up MD (possibly together with Riccardo's MD on HL optics):**
  - IR7 squeeze during ramp – 1 fill

IR7 collimation quench test - 12 h

- **2022 collimation quench test successful**
  - 650 kW loss power without quench excellent control of losses with ADT, strong indication that there is no need for 11T upgrade

- **Remaining caveats/uncertainties:**
  - Difficult to reach design losses due to other constraints - BLM electronic limits and temperature interlocks
  - Quench limit scaling to 7 TeV uncertain
  - Symmetric response left / right of IR7?

- **Proposal for B1 test brought forward in 2023 (probe right side of IR7)**
  - Benefit from experience gained in 2022
  - Re-propose same test for 2024

same request as 2023

Impedance and stability with HL-LHC low-impedance collimators

- **First phase of low-impedance IR7 collimators installed in LS2**
  - 4 MoGr primary (TCPPM) collimators
  - 8 secondary collimator (TCSPM)
  - Second installation phase foreseen for LS3

- **Important to carry out measurements in Run 3**
  - Impedance and stability measurements
  - MDs carried out together with HL-LHC WP2
  - Possibly done as part of commissioning - in that case, no MD needed

HL-LHC collimation performance - 8h

- **More open collimator settings studied for HL-LHC**
  - “Relaxed” settings for reduced impedance - minor degradation of cleaning performance observed
  - “Tight” settings – still less tight than Run 3

- **MD goal**
  - Study IR7 cleaning performance for different settings considered for HL-LHC
  - Use setup beam, perform loss maps in different configurations
  - Combine with other MD to save a ramp? Combine with HL-LHC optics MD?

LHC proton collimation MDs

- **Placeholder: Alignment tools**
  - Development and tests of angular alignment of collimators, BLM vs BPM.
  - Some parts will be done in commissioning – to be seen what open questions remain afterward

- **Placeholder: Tighter collimation hierarchy**
  - Needed for extended β*-reach
  - First MD done in 2023, but not all measurements could be done
  - If this should be part of 2024 configuration, could also be commissioning

- **Controls test for crystal angle feedback in the ramp (for ions)**
  - CM to provide updated FESA class with real-time time channel by end of March, validate during TS1 – for MD4 or with ions
  - Move out of channeling, test if machinery can bring it back in optimal channeling, with and without excitation

PBC proton collimation MDs

- **Ramp in steps – stop intermediate energies (synergy with OP) - 6h**
  - Enables measurements at intermediate energies without pre-cycle.
  - PBC application: measurements of 7mrad crystal channeling efficiency (for 2025 PBC-FT proof of principle in IR3 - TWOCRYST)
  - special functions to be generated to resume the ramps after the stop points.
  - First tests proposed with two stops on the way to 6.8 TeV: 1 TeV and 3 TeV (4 energy values in one single ramp).

- **IR3 orbit bump for double-crystal PoP to be assessed with lossmaps –** ~4 hours

- **Align IR7 crystals with a proton secondary halo –** ~8 hours

Ion collimation MDs

ALICE background studies - 8h

- **Motivation**
  - Strong background observed in 2023 ion run – identified as Pb207 from IR7 hitting TCT in IR2, mitigated with on_disp knob
  - Some background remains – request from ALICE for further mitigation measures, but no showstopper for operation

- **MD idea**
  - Study background online with low intensity
  - Empirically identify residual background source (changing machine settings, in particular collimators) and try mitigtions
  - Simulations to be carried out over the year to identify candidate sources of remaining background
  - MD program to be detailed later in the year based on simulation outcomes

Understanding losses in the ramp - 8h

- **Motivation**
  - Strong losses in the ramp seen in 2023 – not strongly limiting in the end, after several BLM threshold updated, but could be worrisome at higher intensity
  - Mitigations considered for operation: more open collimators, take out part of the squeeze from the ramp to flat top, further BLM optimizations, turn on on_disp in the ramp
  - Would like to maximize chances of success in operation, but still interesting to understand which measures really help

- **MD idea**
  - Monitor losses in the ramp with and with full squeeze – if this is not the culprit, the full squeeze can be put back in the ramp
  - Do one test cycle at low intensity, followed by one ramp with the lowest intensity in intensity rampup – ideally need trains to see losses well
  - Optional (will take more time): qualify tighter collimator settings, compare ramp with tight and open settings

Ion collimation MDs

- **Use of TCLs to intercept collisional losses** 8h (less if combined)
  - Motivation
    - TCLs in IR1/5 normally not used with ions, but simulations indicate they could intercept some ion fragments from the collisions
    - Could decrease losses in region sensitive to R2E
  - Procedure:
    - Align TCLs, apply different TCL settings studied in simulations, observe loss pattern
    - Could be done with low-intensity setup beam (end-of-fill from other MD?) or end of fill in intensity rampup (but would then need qualification)

- **Crystal collimation quench test** 12h + recovery
  - Crystal collimation with ions : different physical processes at play than for protons
  - As for protons, need to quantify maximum power that can be deposited on the crystal-based collimation system without quench – compare with target from HL-LHC
  - Would allow further optimization of operational BLM thresholds

Placeholders - ion collimation MDs

- **Placeholder: Controls test for crystal angle feedback in the ramp** 8h
  - If not done already with protons, or if additional time is needed
- **Placeholder: Crystal collimation settings** 8h
  - Test collimation performance with different collimation settings – program to be defined based on first operational experience
- **Placeholder: Crystal alignment with bunch excitation**
  - In case natural losses are too low with more open collimators
  - Borderline with operation
- **Placeholder: Understand 10 Hz losses**
  - Possible correlation with cryo valve under investigation – can we provoke events?
  - Wait for vibration tests without beam to define strategy, and see if this MD makes is needed

Miscellaneous

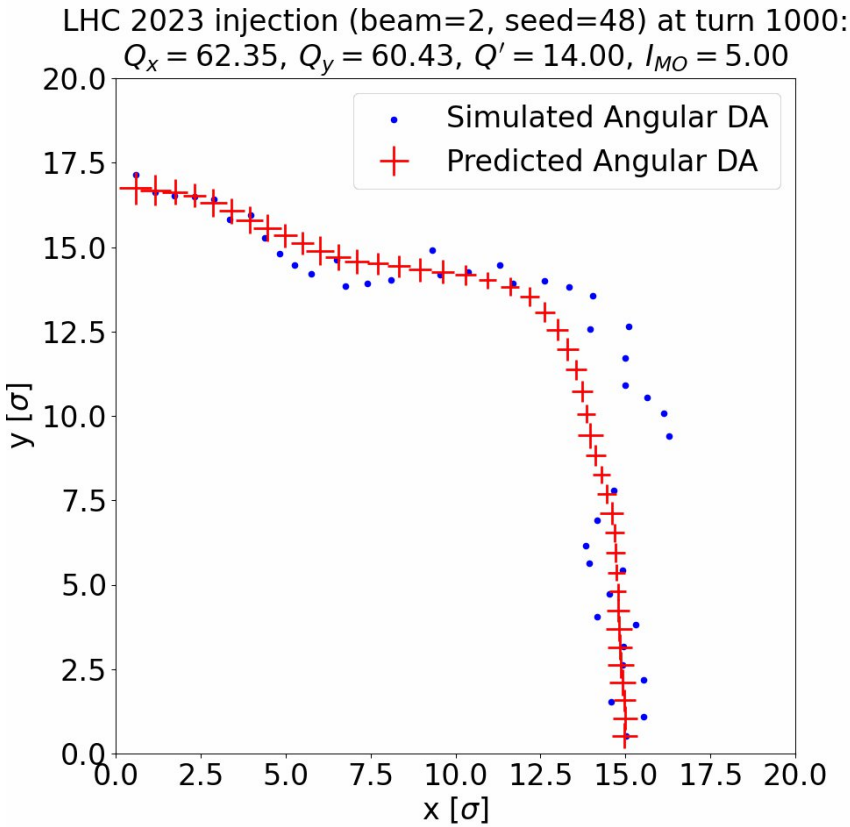
2025 ion configuration

Goes beyond collimation - includes also optics, beam-beam

- **OP configuration for 2025**
  - Targets not reached in 2023, and LHCb has increased their target
  - Need to study performance improvements, but without availability risk
  - MD idea: Test new optics/settings with smaller crossings (all IPs) and β* at IP8 (other IPs to be seen), with checks of aperture, collimation, beam losses, backgrounds, beam-beam
    - collaboration with collimation team, optics, beam-beam team

- **Procedure**
  - Optics commissioning - 8h
    - Possibly done with protons
  - Collimation fill with ions - 12h
    - Aperture measurement, quick collimation setup (TCTs with BPMs, crystal optimization) + loss maps, study backgrounds with colliding beams
    - Done with setup beam (ions)
  - Possible high-intensity follow-up:
    - Loss map qualification (+ 1 intensity rampup step?) + beam-beam study

Deep Learning for beam dynamics simulations



Developed and demonstrated active Learning framework to predict DA without full simulation (JACOW23):

- DA predictions **200 times** faster than MADX+XSUITE;
- Adaptability to **unseen** machine configurations

To enhance the practicality and reliability, combined theoretical calculations to estimate the intensity loss:

$$\mathscr{L} = N_P\left(1-4\int_0^{\frac{\pi}{2}}\int_0^{DA_\theta} r^3 e^{-r^2}\sin\theta\cos\theta\, dr\, d\theta\right)$$

Request 8h MD to link **predictions with real observables such as loss rates**

- At Injection, use single bunches
- Scan different settings of tune, chromaticity, and octupoles
- Observe beam lifetime and losses

Summary - proton MDs

- **HL-LHC**
  - IR7 optics: optics, cleaning and impedance measurements - 4+8 h
  - B1 collimation quench test with protons - 12h + recovery
  - Impedance and stability with HL-LHC low-impedance collimators – commissioning?
  - Study of Run 4 Commissioning Scenarios (performance with R4 collimator settings) - 8 h

- **LHC operation**
  - Placeholder: Alignment tools: angular alignment, BLM vs BPM. Open questions by commissioning?
  - Placeholder: Tighter hierarchy – see what is left to do after commissioning
  - Controls test for crystal angle feedback in the ramp (for ions)

- **PBC**
  - Ramp in steps – stop intermediate energies (synergy with OP) - 6 h
  - IR3 orbit bump for double-crystal PoP to be assessed with lossmaps – 4 h
  - Align IR7 crystals with a proton secondary halo – 8 h

- **Deep learning for beam dynamics simulations**

Summary - Ion MDs

- ALICE background tests – identify and mitigate remaining non-critical background 8h
- 2025 ion configuration 8+12h, + high-intensity beam-beam part
  - Including optics and collimation studies - more time if high-intensity beam-beam MD
- Understanding of losses in the ramp 8h
- Crystal collimation quench test 12h + recovery
- Placeholder: Controls test for crystal angle feedback in the ramp 8h
- Placeholder: Crystal collimation settings 8h
- Placeholder: Crystal alignment with bunch excitation
- Placeholder: Understand 10 Hz losses
- Use of TCLs to intercept collisional losses 8h (less if combined with other MD)