Update on HL-LHC studies on triplet aperture

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Outline

Motivation and set up

Interaction Region and the Final Triplet

Triplet scan

Global results

Conclusions
Motivation

- The HL-LHC based on the ATS scheme requires a new IR layout.
- The present IR protection of the incoming beam is based on one TCT.
- Final triplet must be protected.
- Aperture limitations might also appear upstream of the TCT.
- Both cleaning and machine protection aspects should be considered.
  - Here we cover the cleaning aspects.
- First step: assess cleaning losses at IR aperture bottlenecks without TCT
- Using SixTrack with collimation to simulate local losses at different apertures
- Open questions:
  - Another TCT further upstream?
  - How effective is the cleaning for the present TCT?
  - Minimal tolerable aperture before installing additional protection?
Introduction and setup of SixTrack simulations

HL-LHC lattice

- Lattice version: hllhcv1.11t
- Configuration: Squeezed $\beta^*$ ($\beta_{x,y}^*(\mathrm{IR1, IR5}) = 15 \, \text{cm}$).
- Perfect machine.

Collimator setup

- CollDB: CollDB.hllhcv1.11t.b1
- CollPositions: CollPositions.hllhcv1.11t.b1.b1.dat
- Tertiary collimators fully open (999$\sigma$).

Collimator configuration

- TCP IR7: 6$\sigma$
- TCSG IR7: 7$\sigma$
- TCLA IR7: 10$\sigma$
- TCP IR3: 12$\sigma$
- TCSG IR3: 15$\sigma$
- TCLA IR3: 17.6$\sigma$

Simulation parameters

- Beam 1 and 2.
- 6$\sigma$ horizontal beam halo of type 2 (no energy spread).
- $6.4 \times 10^6$ protons.
- 2000 jobs of $50 \times 64$ protons.
- 200 turns
Aperture scan

The triplet aperture has been scanned (reduced in steps with a cleaning simulation at each step) for different configurations.

- **HL-LHC**: IR1 upstream Q2, Q4 and Q5, horizontal and vertical halo, beam 1.
- **HL-LHC**: IR5 upstream Q2. horizontal halo, beam 1.
- **HL-LHC**: IR1 downstream Q2: horizontal halo, beam 1.
- **HL-LHC**: IR1 upstream Q2 beam 2.

The aperture has been reduced in steps of 2-4 mm.
IR5 and the Final Triplet: Beam envelope

## Optics in IR1 and IR5

<table>
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<tr>
<th>Name</th>
<th>$s$ [m]</th>
<th>$\beta_x$ [m]</th>
<th>$\beta_y$ [m]</th>
<th>$\sigma_x$ [mm]</th>
<th>$\sigma_y$ [mm]</th>
<th>$x$ [mm]</th>
<th>$y$ [mm]</th>
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</table>
Beam halo used as SixTrack starting conditions

- Example of vertical halo (the same for the horizontal halo).
- $6\sigma$ horizontal beam halo of type 2 (no energy spread).
- $6.4 \times 10^6$ protons (just a fraction represented in the plots).
Nominal loss map

- Tertiary collimators are in the nominal position.

- Keeping the nominal loss map in mind is a reference for future loss maps with reduced apertures.
Some examples: IR1 B1 Q2 Upstream, AP = 20 mm (4σ)
Some examples: IR1 B1 Q2 Upstream, AP = 32 mm (8\(\sigma\))
Some examples: IR1 B1 Q2 Upstream, AP = 36 mm (9.3\sigma)
Some examples: IR1 B1 Q2 Upstream, AP = 59 mm (17σ)
IR1 B1 Q2 Upstream: Spatial distribution of impacts

20 mm (4σ)

32 mm (8σ)

36 mm (9.3σ)

40 mm (10.7σ)

44 mm (12σ)

48 mm (13.3σ)
One more example: IR5 B1 Q2 Upstream, AP = 40 mm (7.7σ)
Some examples: IR5 B1 Q2 Upstream, AP = 40 mm (7.7σ)
History of the particles hitting the triplet

- We can extract the history of the particles that finally hit the magnets in the Interaction Region.
- That can explain the origin of these particles and might give information about how to mitigate them.

Example: IR5 B1 Q2R Horizontal Halo.

In that case, most of the particles hit just once a primary collimator and just a few hit a second primary collimator. A very few percentage hits also a secondary collimator before hitting the triplet.
We need to further investigate this.
Maximum losses as a function of the aperture in $\sigma$ units

- Aperture is calculated using the $\sigma$ where the losses are produced.

$$ Ap[\sigma] = \frac{Ap[mm] - x/y}{\sigma_{x,y}} $$
Maximum losses as a function of the aperture in mm
Conclusions and future prospects

The results shown are ongoing study to determine the aperture that can be tolerated without local protection.

- The scanning of the aperture of Q2 has been done for several cases including IR1 and IR5, upstream and downstream of the IP.
- Results show a qualitative approach of the impact of the triplet aperture on the collimation system.
- We have identified the positions where the aperture reduction causes a major impact (i.e. IR1 downstream and IR5 upstream.)

Next steps

- Clarify allowed local inefficiency.
- Assess machine protection aspects: aperture protection in case of asynchronous dumps.
- Detailed analysis of the history of the particles that hit the triplet aperture.
- Consider the impact of different error sources.
- Close TCT’s to verify the relation between the TCT setting and the aperture they protect. Are TCT’s in cell 5 sufficient?