Collimation cleaning with ATS optics for HL-LHC

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Introduction

- In the framework of the HiLumi studies for HL-LHC, the first cleaning simulations were set up for the "Achromatic Telescopic Squeeze" optics, including a first baseline for collimation settings
- Compare with standard optics: possible new limitations
- Address these new limitations
- Is there a solution that would solve both cases: standard optics + ATS new limitations
  - Make sure that only one intervention is needed (during LS2) avoiding another one in LS3
- Physics debris: preliminary results
Outline

- Introduction
- Presentation of ATS optics for HL-LHC
- Setup of collimation cleaning simulations
- Betatron losses without DS collimation
- Betatron losses with DS collimation
- Comparison with standard optics
- Preliminary thoughts about physics debris cleaning
- Ongoing HiLumi-related activities
- Conclusions
The ATS optics: Presentation

- Main characteristics: beta beating in the arcs adjacent to the low $\beta^*$ IPs
The ATS optics: Presentation

Different orbit

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A. Marsili, CERN, BE-ABP-LCU
The ATS optics: halo cleaning simulations

- Layout and optics version SLHCV3.1b (R. de Maria)
- IP1 & 5: $\beta^* = 0.15$ m; IP2 & 8: $\beta^* = 10$ m
- Crossing angles:
  - IP1 and 5: 295 $\mu$rad; IP2: 240 $\mu$rad; IP8: 305 $\mu$rad
- No separation (collision)
- New baseline recently defined for 10 cm with partial squeeze in IP8. Not yet taken into account: similar feature expected (triplet aperture follows optics)
- Perfect machine
The ATS optics: halo cleaning simulations

- Tracking 6.4 million particles around the ring for 200 turns with SixTrack; no initial $dp/p$
- Halo at 6 $\sigma$ (setting of the primary collimator) in the considered plan (H or V)
- Setting of the collimators:

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<th>Coll. setting</th>
<th>$\sigma$</th>
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<tr>
<td>TCP IR7</td>
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<tr>
<td>TCT IR2/8</td>
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Betatron losses simulations without DS collimation
Preliminary simulation results: Betatron losses with current coll.

- Horizontal halo, 6 σ, 3e7 protons, perfect machine
- Same limiting losses as standard: leakage downstream of IR7
- Additional limiting locations in arc 8–1
- Potentially serious issue as they have the same level as DS losses!
- Depends on the quench limit
Halo cleaning simulations: B2

- Reversed longitudinal positions
- Peaks in the arcs at the level of the DS peaks
- Same observations as for B1 (next slides)
- Optics matched less precisely
Loss peaks in arcs 7–8 and 8–1

Peaks appear at maximums of the dispersion and min. $dp/p > 0$.

⇒ Study the possibility to cure them with the DS collimation in IR7.
All peaks

$21 < \frac{dp}{p} < 155$  

$7.85 < \frac{dp}{p} < 10.2$  

$4.9 < \frac{dp}{p} < 8.72$  

$8.76 < \frac{dp}{p} < 24$  

$5.64 < \frac{dp}{p} < 9.38$  

$5.49 < \frac{dp}{p} < 8.14$  

$\frac{dp}{p}$ in units of $10^{-3}$
Characterisation of loss peaks

- Considering all particles lost downstream IR7
- All lost particles have a $dp/p$ above a given value
- All lost particles are lost at $y = 0$, $x = -0.022$ (apert.)
  $\Rightarrow$ dispersive losses
- Can DS collimators protect from them?

![Energy vs. # hits](Image1)

![Transversal distribution](Image2)
Collimators in the Dispersion Suppressors

- Longitudinal space created by the 11T dipoles
- Would protect locally from the loss peaks in the DS
- Importance of location (value of dispersion function):
- Could protect the arcs if their $\frac{dp}{p}$ cut is sufficient
Observations on $dp/p$ cut

- Majors peaks of arcs 7–8 and 8–1
- Min. $dp/p$ for all lost particles: 4.9e-3
- $dp/p$ cut $@10\sigma$ for particles at (0, 0, 0, 0) seems enough
- But secondary particles can have big position offsets!
- Only simulations can give full answer
Betatron losses simulations with DS collimation
Betatron losses with two TCRYO collimators

- The TCRYO.10 has a smaller $dp/p$ cut
- All particles are stopped, including further downstream in the arcs
- Also protected for 15 $\sigma$
Effect of the DS collimators

No TCRYO

TCRYO @10σ in cells 8 & 10
- No peak further than beginning of arc 7–8
- One collimator does not remove all peaks
- Two collimators in cells 8 and 10 provide protection.
  ⇒ DS collimators work in two cases
Physics debris simulations
Preliminary thoughts about physics

Debris cleaning

- Debris: products of p-p collisions simulated by FLUKA (F. Cerutti)
- Mainly protons with extra kicks $x'$, $y'$ and momentum offset $dp/p$
- Lost during the first turn
- Results cross-checked with FLUKA simulations
- Considering TCLs in cells 4, 5 and 6
- Different settings and position can be checked
Preliminary thoughts about physics debris cleaning

- Particles sorted by $dp/p$ (color scale)
- Dispersion is again the dominating effect
Preliminary simulations with physics debris

- Different positions provide different $dp/p$ cuts
- Has to be expressed in $p/m/s$ for comparison with FLUKA
- Differs from standard optics
Conclusion

- ATS scheme presents the same collimation issues than standard optics + extra limitations
- One extra collimator in DS is not enough
- **Two DS collimators** would provide a solution in both cases (including the extra loss locations of ATS)
- Debris: first results & comparison with FLUKA are very promising
- Full study with scans ongoing
- Other tasks
Ongoing HiLumi-related activities

- Update simulation models for latest ATS baseline (10cm)
- Add progressively error models (collimation + optics)
- Complete studies in IR1/5 for ATS vs STD layout
- Check the pre-squeeze ATS optics (halo + debris)

In parallel, other non-DS related studies of HL collimation upgrade are ongoing:
- background experiments from halo, new layouts in IR1/5, failure scenarios and impact on collimator loads, ...
Thank you.