Simulations of HL halo loss and IR losses

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Outline

- Introduction: SixTrack
  - Halo / debris tracking
  - Trajectories
  - Results validation with measurements
- Halo: ATS results
  - Comparison with 7TeV nominal
- Debris tracking
  - Loss maps
  - TCL scan
- Conclusion
Introduction: Simulation set-up

- **Collimation version of SixTrack**
  - Particles tracked around the ring
  - 6 dimensions: $x$, $x'$, $y$, $y'$, $l$, $E$
  - Records scattering / absorption by collimators
- **Post-processing: particles lost on aperture**
- **SixTrack was very succesfully used for system design. Very good agreement with measured loss maps.**
- **Final energy deposition studies rely on complete simulations by FLUKA**
- **Good experimental basis: validated results**
  - Comparison measurements / simulations
LHC & IR7: comparison measurement / simulation

- Very good agreement in the arcs
- Losses at collimators underestimated (secondary showers?)

R. Bruce, CERN.

A. Marsili, BE-ABP-LCU, CERN.
Halo / debris

- **Halo loss simulations** for collimation cleaning
  - Principal assessment of collimation performance
  - Limitations in dedicated betatron and momentum cleaning insertion regions (IR3 and IR7)
  - IR loads from incoming beams (tertiary collimators)
  - Multiturn simulations

- **Debris loss simulation**: tracking debris from Interaction Points (IPs) around the ring
  - Tracking of protons that experience collision
  - Two effects: shift in momentum, extra kicks ($x'$, $y'$)
  - Distributions simulated by the FLUKA team
  - Most particles lost immediately downstream of IP
Particle tracking: “flat” dp/p distribution

- **Dispersion suppressor**
- **Arc**
- **Warm and cold magnets**
- **Losses on collimators**
- **Losses on aperture**
- **Particles sorted by dp/p**
- **Aperture**

**Horizontal position [m]**

**Longitudinal position [m]**

A. Marsili, BE-ABP-LCU, CERN.
ATS halo tracking
First results for ATS optics

- ATS: $\beta^* = 15$ cm
- Preliminary results:
  - Collimator hierarchy not fully decided
  - Preliminary aperture for post-processing
  - Work still in progress
- Used for first comparison with nominal case
- Debris: evaluate the (specific) need for protection in dispersion suppressors.
ATS: Achromatic Telescopic Squeeze

Beta functions are already different in the arcs to achieve $\beta^* = 15$ cm.
## Collimator settings

- **Nominal settings at 7 TeV**
- **Note:** TCT partially closed in IR2/8 (to be reconsidered)

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<th>Coll. setting</th>
<th>$\sigma$</th>
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<td>TCP IR7</td>
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<td>TCT IR2</td>
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Preliminary loss maps
ATS / 7 TeV nominal

ATS, halo H, 6 $\sigma$

Losses in arc 81 at the level of the losses in the dispersion suppressor right of IR7 (detailed discussion tomorrow)

$7$ TeV nominal, halo H, 6 $\sigma$
Preliminary loss maps
ATS / 7 TeV nominal

ATS, halo H, 6 σ

Could be limiting
To be further investigated
(joint session with WP2 tomorrow)

Losses in arc 81 at the level of the losses in the dispersion suppressor right of IR7
(detailed discussion tomorrow)

7 TeV nominal, halo H, 6 σ
Debris tracking
4 TeV example: 6400 collisions first turn, sorted by $dp/p$

Protons of high $dp/p$ are absorbed by the TCL but some escape.

Risk for the magnets

TCL@10 $\sigma$
Preliminary loss map
ATS debris, 2 turns

Whole ring
lost particles
ATS debris checkturns

10^4
10^5
10^6
10^7

# hits
s [m]

Lost particles
ATS debris checkturns

ATS IR1
lost particles
ATS debris checkturns

10^2
10^3
10^4
10^5
10^6

# hits
s [m]

High losses in DS
TCLs open

4TeV IR1
lost particles
TCL@60°

10^4
10^5
10^6
10^7

# hits
s [m]

Cold lost p
Warm lost p
Lost on collimator

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Debris tracking benchmarking at 4 TeV: TCL scans
Measured losses at 4 TeV: TCL scan out

- Loss at TCL decrease: TCL retracting
- Losses downstream TCL increase: losing protection
- Different loss evolutions depending on the position
- Can we reproduce such behaviours?
At first turn
More and more particles survive TCL
Particles with higher dp/p
Lost closer to the TCL
Simulated TCL scan (4 TeV)

- Sum of aperture losses in Q7, cell 8, cell 9
- Work in progress: Trying to match these results to the measurements
- The furthest the losses are, the sooner they increase
- Very encouraging result
Conclusion

- First results, with halo and debris tracking, for different optics
- Halo tracking validated by loss maps
- Ongoing effort to understand in details TCL scan SixTrack simulations knowing the measurements
- Discovered possible new limitations: peaks in arc 81

Outlook

- Test different TCL settings for protection
- Still perfect machine. Add errors
- Only IP1: simulation from other IPs
- Simulate B2
Thank you for your attention
Effect of collisions: particles distribution

- Distributions of protons with $\theta$ and $dp/p$ from FLUKA
- Only inelastic contributions
- $x' = \tan(\theta) \sin(\varphi)$
- $y' = \tan(\theta) \cos(\varphi)$
- Distribution of $\theta$ is cut at the opening of the TAS
- Distribution of $dp/p$ is cut at 0.1

\[ \varphi \in [0 ; 2\pi] \]

![Diagram](image.png)
Distributions of $\theta$
(4 TeV)

- Effect of the cut
- Used to generate the extra kicks in $x'$ and $y'$
- These distributions are wider than the nominal ones.
Most protons with small $dp/p$, but long tail (cut)

Protons with higher $\theta$ or $dp/p$ would be lost anyway during tracking: momentum & betatron acceptance