Update on multi-turn particle debris tracking

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Outline

- Introduction
- Setup of the debris tracking simulations
- Losses at TCL
- TCL measures
- TCL scan
- Normalisation in physical units
- TCLP scan
Introduction

- **Goal**: study the losses due to debris from IPs (instead of regular beam losses) by tracking them around the ring
- Tools are set; first physical results
- Scan with TCL.5R1.B1;
- Comparison with measures;
Inputs:

- Generating the output of collisions:
  - Keeping only protons
  - Cut in $\Delta p/p < 0.1$ and kicks ($\theta < 0.85$ mrad)
  - Distribution (and help) courtesy of F. Cerutti
  - Tracking only perturbed particles

- Initial beam distribution is generated, then:

- Effect of the collisions is added:
  - Shift in momentum
  - Extra kicks

- Cf. ColUSM #3, ColUSM #11
The distributions of kicks due to collisions are wider than the original distributions of angles.

The kicks are cut at the opening of the TAS.
Initial distributions: positions

In meters

In sigma units

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Initial distribution: \( dp/p \)
Loss map

- 4 TeV, nominal settings
- 1.77e6 p (for 1e7 collisions, after cut)
- Tracking debris from IP1
- Highest losses at the TCP.6L3.B1 (momentum cleaning)
Loss maps 4 TeV nominal zooms
Particles lost per turn

- Most particles are lost in the first 2 turns
- Most likely first turn losses at TCL
Particles lost on TCL: horizontal phase space

- $\sigma_x = 359 \, \mu m$
- TCL setting: $10 \sigma$
- Most losses for $x > 0$
Initial distributions of particles hitting the TCL

- No obvious difference – just seem like scaled-down initial distr.
- 1/5 of total particles
TCL scan
Real TCL scans measurements were taken in the LHC earlier this year.

TCL starts at 10 $\sigma$, then is moved out to 60 $\sigma$ (and back in).

The losses at the TCL are decreasing, while the losses downstream are increasing (protection).

**Goal**: try to reproduce this effect with the simulations

Simulation setup: 10 $\sigma$ to 30 $\sigma$, steps of 2 $\sigma$

Before that, a reminder on the measures

**Movie**
Effect of the TCL in the LHC

![Graph showing the effect of TCL in and out on signal distribution across different DCUM [m] values.]

- TCL in
- TCL out

Signal [Gy/s]

DCUM [m]
Loss increase: $\times 4$

Loss decrease: $/50$
TCL scan 10 $\sigma$

- Cold lost p
- Warm lost p
- Lost on collimator

# hits

$s [m]$

0  50  100  150  200  250  300  350  400  450

$10^{-2}$ $10^{-1}$ $10^{0}$ $10^{1}$ $10^{2}$ $10^{3}$ $10^{4}$ $10^{5}$ $10^{6}$ $10^{7}$

Lost particles

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CoUSM #12, 05/10/2012
TCL scan 12 $\sigma$

lost particles

- cold lost p
- warm lost p
- lost on collimator

$\#$ hits vs $s$ [m]

Log scale from $10^{-2}$ to $10^{7}$
TCL scan 14 $\sigma$

![Graph showing lost particles with categories: cold lost p, warm lost p, and lost on collimator](image)
TCL scan 20 $\sigma$

![Graph showing the distribution of lost particles]

- **cold lost p**
- **warm lost p**
- **lost on collimator**
TCL scan 24 $\sigma$

lost particles

- cold lost p
- warm lost p
- lost on collimator

# hits vs. $s$ [m]
TCL scan 26 $\sigma$

lost particles

- cold lost $p$
- warm lost $p$
- lost on collimator

# hits vs. $s$ [m]

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TCL scan 28 $\sigma$

- cold lost p
- warm lost p
- lost on collimator

# hits vs. s [m]

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CoUSM #12, 05/10/2012
TCL scan 30 $\sigma$

lost particles

- blue: cold lost p
- red: warm lost p
- black: lost on collimator

# hits vs. s [m]

$10^7$

$10^6$

$10^5$

$10^4$

$10^3$

$10^2$

$10^1$

$10^0$

$10^{-1}$

$10^{-2}$

$0$ $50$ $100$ $150$ $200$ $250$ $300$ $350$ $400$ $450$

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Observations

- The loss at the TCL decreases with the increase of the gap (next slide)

- The losses downstream the TCL get closer to the TCL with the increase of the gap

- The highest loss downstream the TCL seems to increase with the increase of gap

- However, the sum of all losses downstream (up to 450 m) is actually decreasing (next slide).
Losses at TCL vs. TCL setting
Sum of losses downstream TCL (up to 450 m) vs. TCL setting
Normalisation factors

- \( L_{\text{LHC}} \simeq 6000 \, \mu\text{b}^{-1}\cdot\text{s}^{-1} = 6 \times 10^{33} \, \text{cm}^{-2}\cdot\text{s}^{-1} \)

- \( \sigma_p = 73.5 \, \text{mb} = 73.5 \times 10^{-27} \, \text{cm}^2 \, (\text{TOTEM}) \)

- \( L_{\text{LHC}} \times \sigma_p = 4.41 \times 10^7 \, \text{collisions/s} \)

- Simulations for \( 10^7 \, \text{collisions} \); bin width = 10 cm
  \( \Rightarrow \) normalisation factor of 44.1 for losses in p/m/s
TCLP scans

- Goal: see if the protection of the DS can be achieved by the TCLP.4R1.B1 (instead of TCL)
- \( \text{\textbackslash n} \) different optics sequence: V6.5.seq
- \( \text{\textbackslash n} \) Same procedure: 10 \( \sigma \) to 30 \( \sigma \), with 2 \( \sigma \) steps
- \( \text{\textbackslash n} \) The TCL was closed in this case
  (somehow defeating the point)
- Movie
Losses at TCLP vs. setting

Particles lost at TCLP.4R1.B1
Conclusions

- Whole debris tracking simulation chain is set-up.
- We managed to reproduce some observations;
- But some points are still not understood.
- New input distributions will be provided.
- B2 simulations seem OK as well.

Further work:
- Plot loss maps in physical units? [p/m/s]
- Start simulations at other IPs
Spare slides
Particles lost on TCL: horizontal phase space

- $\sigma_x = 359 \, \mu m$
- TCL setting: $10 \, \sigma$
- Most losses for $x > 0$
Particles lost on TCL: vertical phase space

- $\sigma_y = 82.8 \, \mu m$
- Usual asymmetric $y$ distribution
Particles lost on TCL

Physical space

- Seems to be made of two separated distributions
- Not centered around (0, 0)
Losses downstream of TCLP vs. TCLP setting