SPS-to-LHC Transfer Line Collimators and LHC Injection Protection System

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and thanks to: R. Bruce, R. De Maria, M. Giovannozzi, S. Redaelli

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
CERN
High Luminosity LHC

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Outline

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- failures of the injection kicker MKI.

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⇓

- Loss maps simulations needed to ease and improve the validation methodology;
- no ready-to-use simulation tools available for this kind of tracking ⇒ simple and easily usable for beam lines (target mainly single turn tracking);
- scattering routine developed in python ⇒ `pycollimate`;
- interfaced with both MADX-PTC and MADX (directly under the hood).

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  - modular;
- particles are sent back to MADX as lost and added to "trackloss" table or kept for further tracking.

HL-LHC Injection Protection System

- The change that will be introduced for HL-LHC in the injection protection devices (new TDI) and the new high-brightness beams needed to be simulated to understand if the protection was still sufficient and if the auxiliary collimators (TCLIA/B) needed to be upgraded as well;

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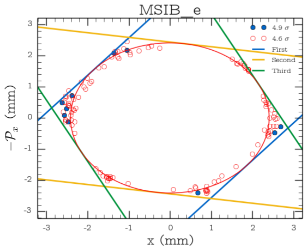
- good occasion to use the new simulation tool;
- gain more experience with it.

Procedure

- TCDIs centred using beam-based measurement ⇒ new operational tool does it automatically;



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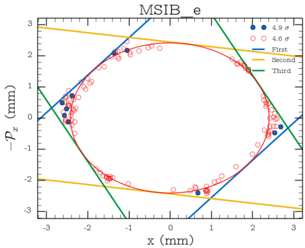

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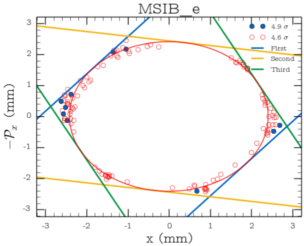

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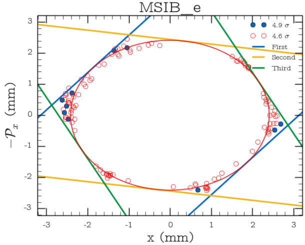

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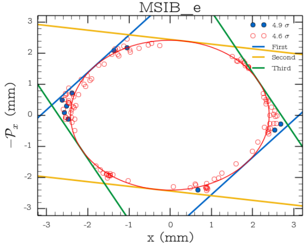

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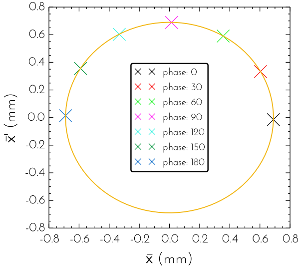

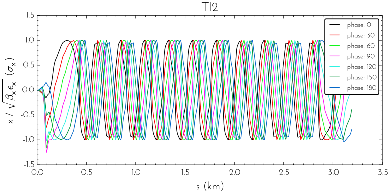

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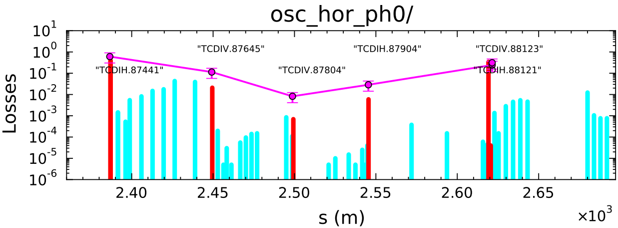

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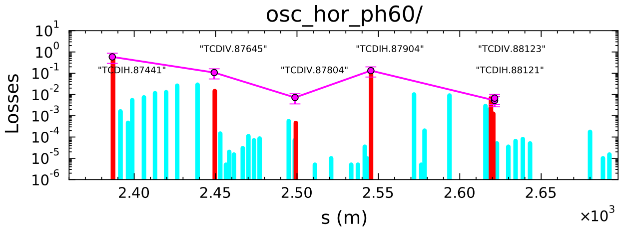

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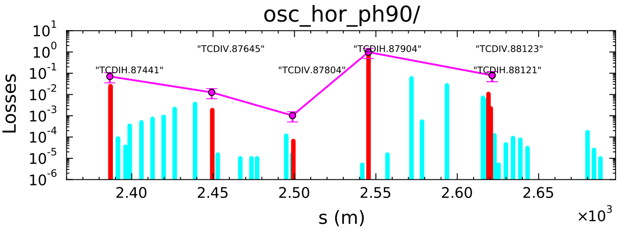

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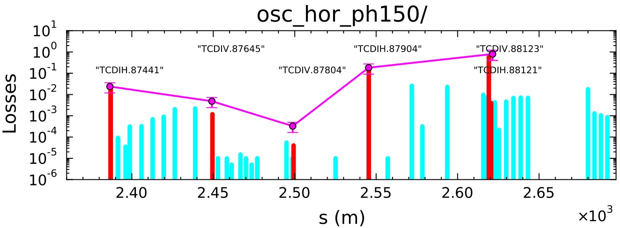
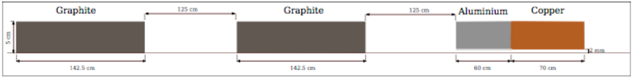


New TDI-S

- For HL-LHC a new TDI is foreseen to be installed;



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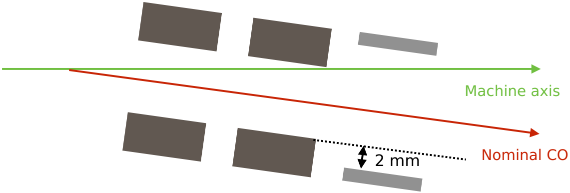

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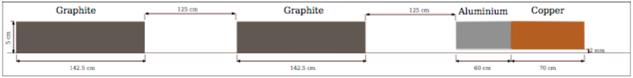

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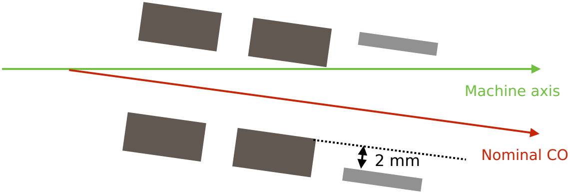

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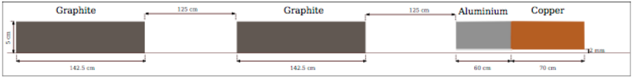
- the last block has 2 mm larger aperture than the others.



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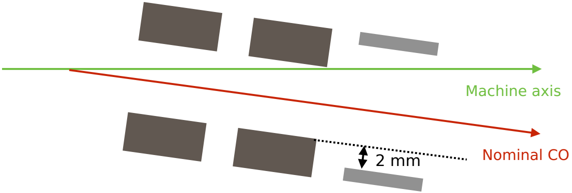

Assumptions

- The following studies are done using:
  - MKI strength of $\sim$11% of the nominal for B1 $\Rightarrow$ grazing (zero impact parameter);
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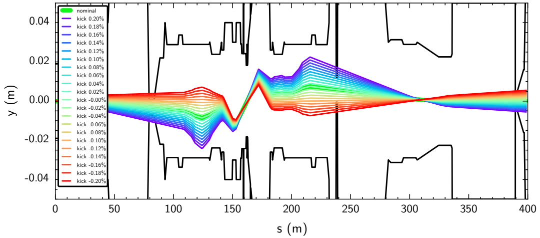

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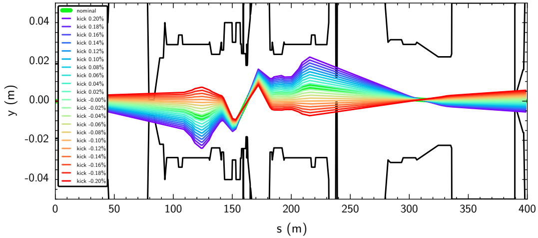

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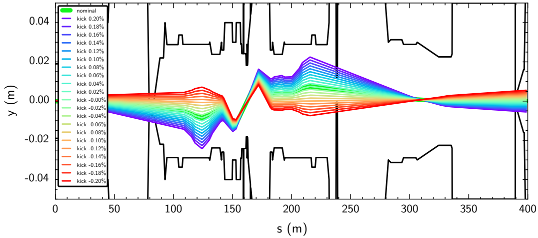

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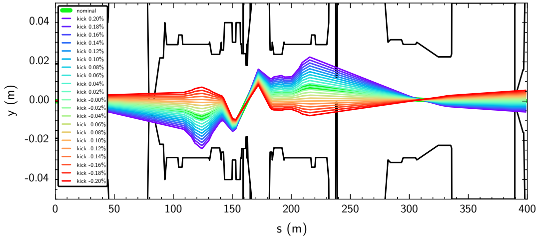

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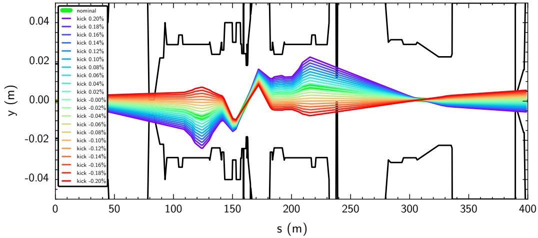

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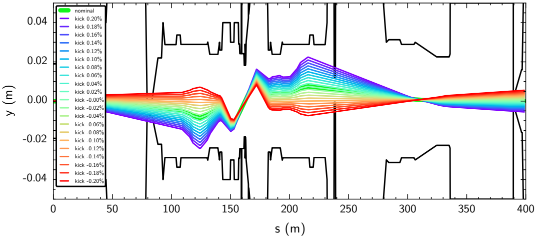

Loss maps at injection - Beam 1

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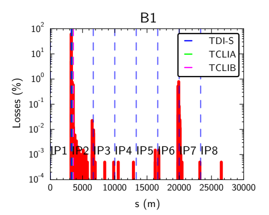
- tracking for 1 turn:



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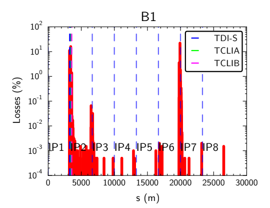

Scenario 2

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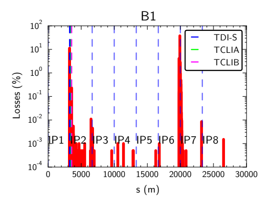

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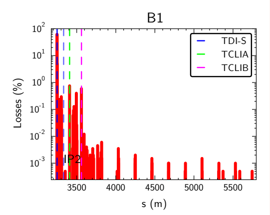

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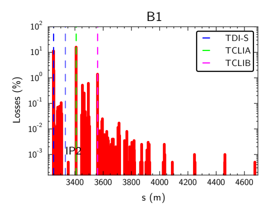

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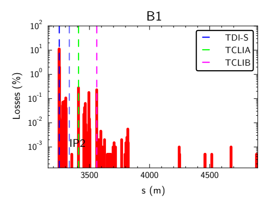

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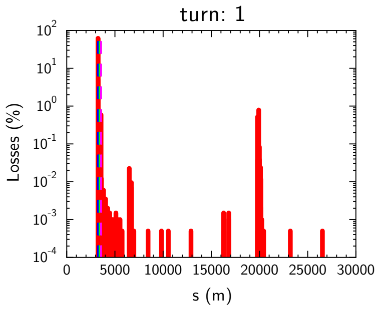

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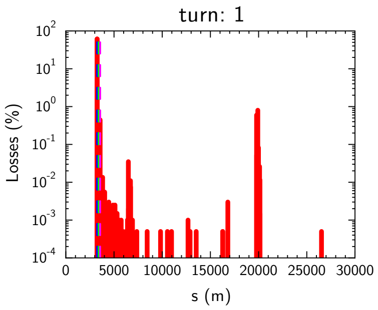

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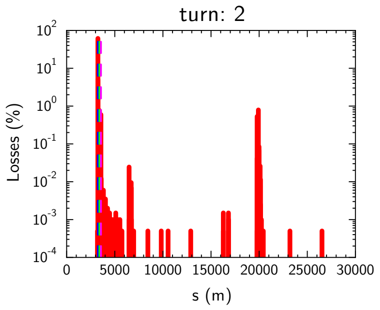

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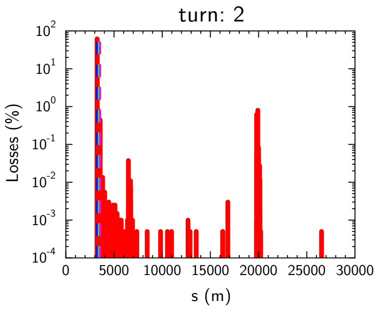

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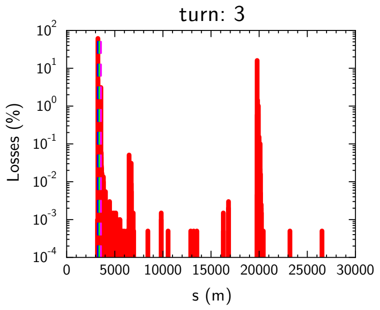

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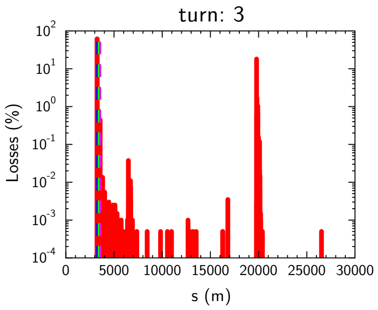

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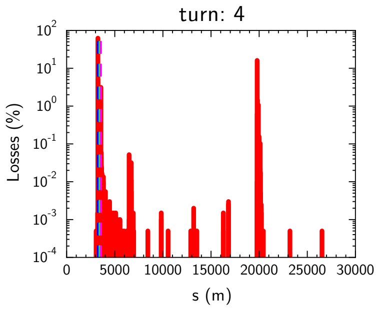

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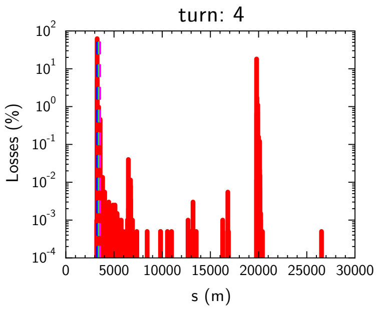

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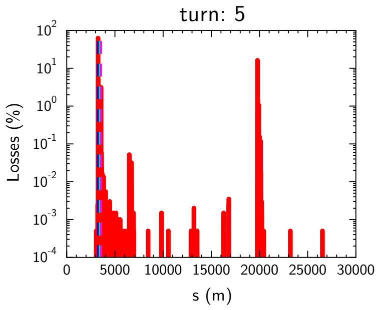

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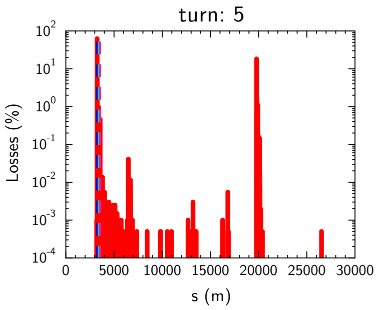

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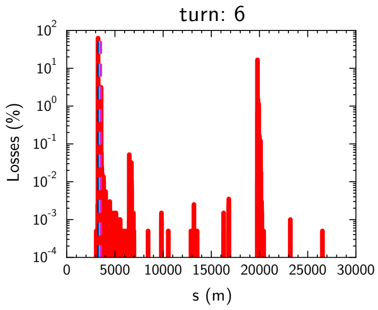

Scenario 0 ⇒ TCLIB @ 8.3 σ

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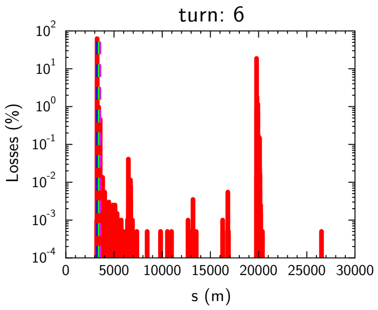
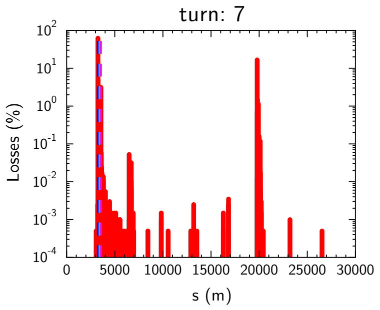


What happens to the surviving particles?

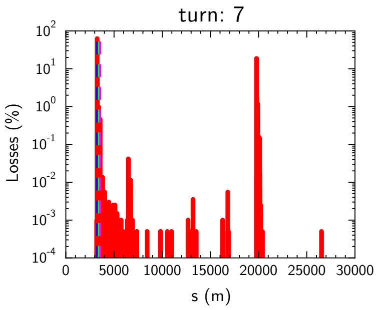
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

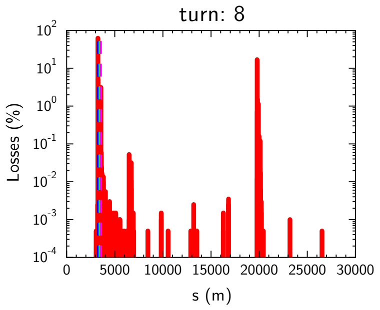
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

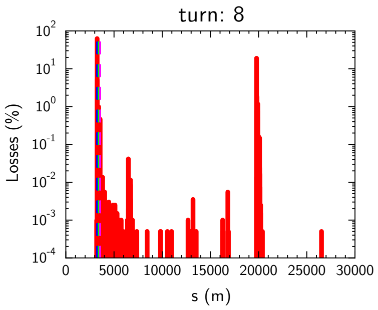
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

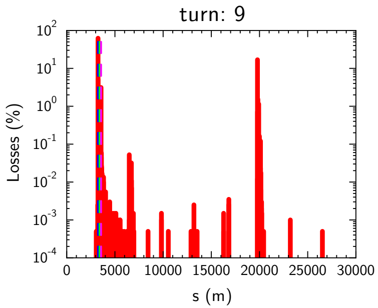
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

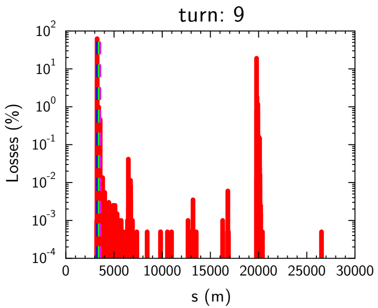
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 $\Rightarrow$ TCLIB @ 8.3 σ

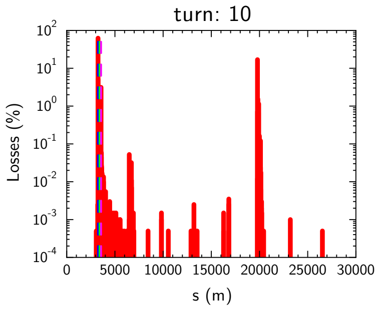
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

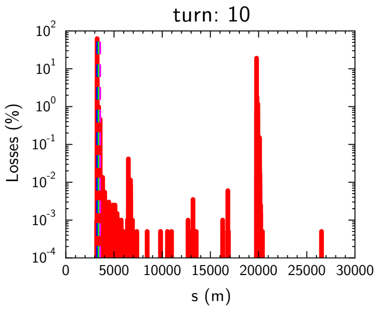
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



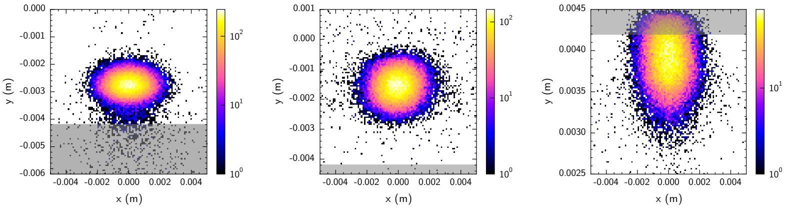
Scenario 0 ⇒ TCLIB @ 8.3 σ

- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



TCLIB - Zoom in

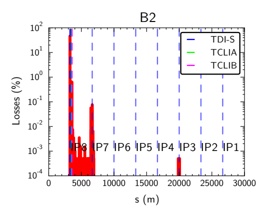
To be noticed that, when the TCLIB is at 6.8 σ, a quite significant part of the beam will intercept it at the third turn (just before dump)



Loss maps at injection - Beam 2

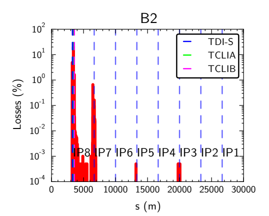
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S
- tracking for 1 turn:



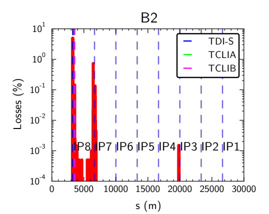
Scenario 1

- TDI-S at 7.8 σ_y, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S
- tracking for 1 turn:



Scenario 2

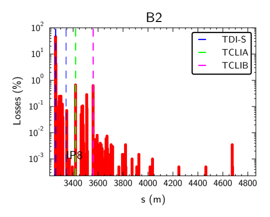
- TDI-S, TCLIA and TCLIB at 7.8 σ_y and 1 σ impact on the TDI-S
- tracking for 1 turn:



Loss maps at injection - Beam 2

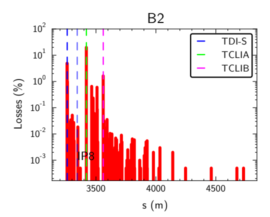
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S
- tracking for 1 turn:



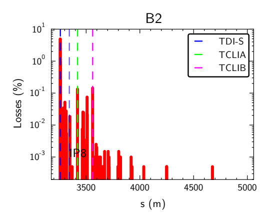
Scenario 1

- TDI-S at 7.8 σ_y, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S
- tracking for 1 turn:



Scenario 2

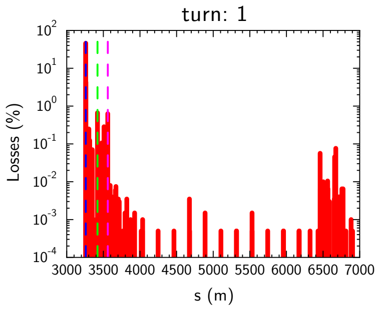
- TDI-S, TCLIA and TCLIB at 7.8 σ_y and 1 σ impact on the TDI-S
- tracking for 1 turn:



What happens to the surviving particles?

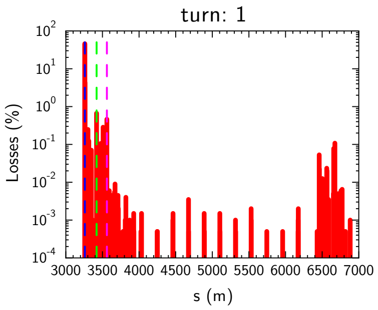
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

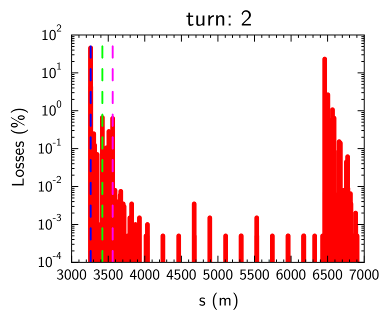
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

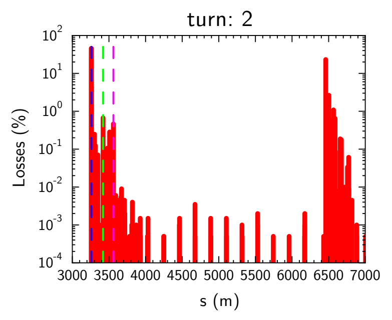
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

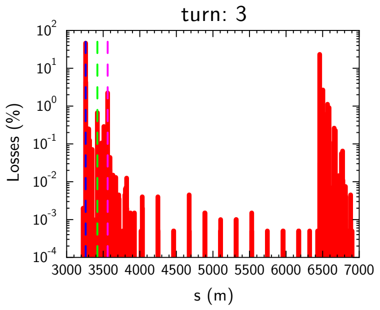
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

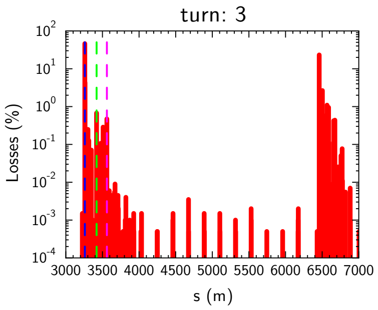
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 $\Rightarrow$ TCLIB @ 8.3 σ

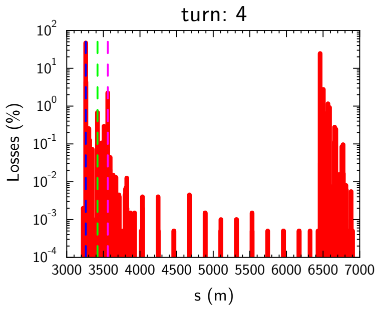
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

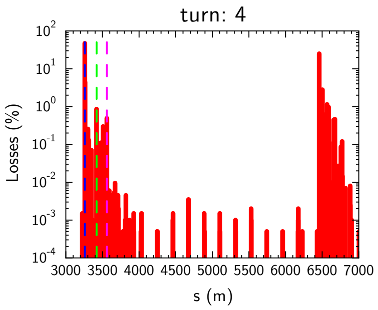
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

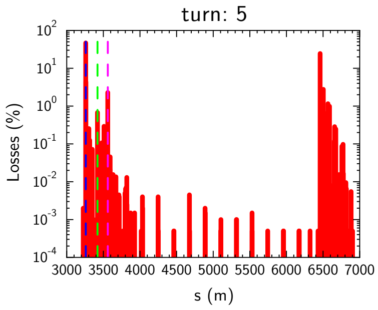
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

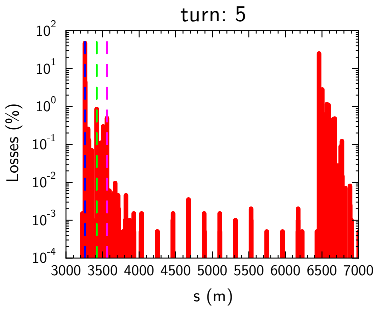
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

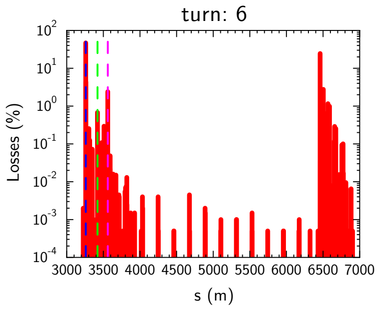
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

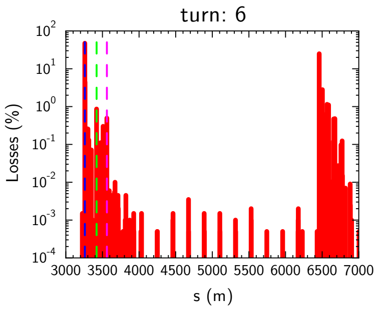
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

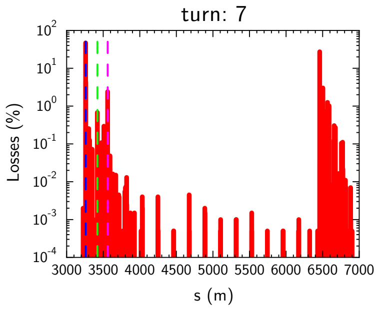
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

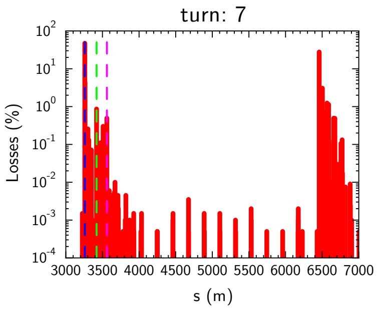
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

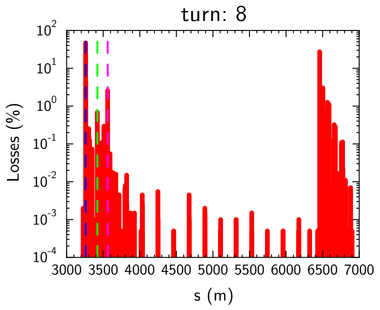
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

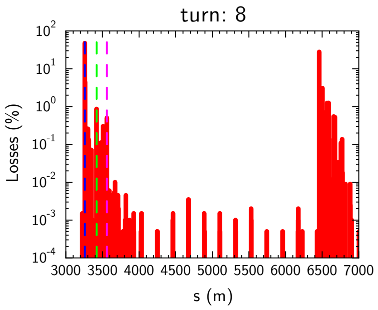
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

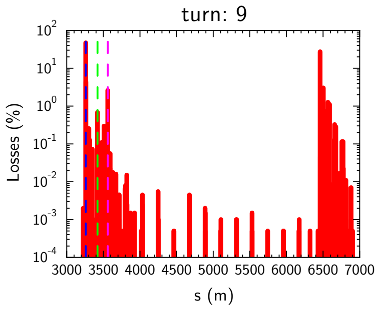
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

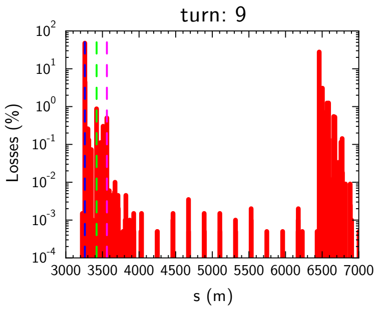
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

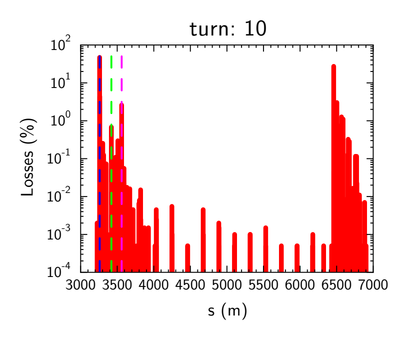
- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



What happens to the surviving particles?

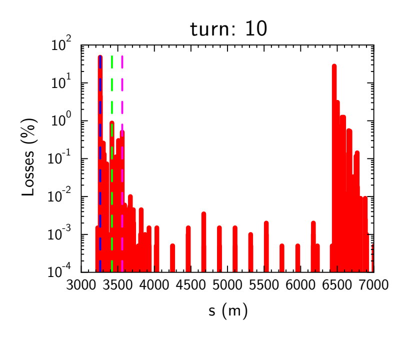
Scenario 0

- TDI-S, TCLIA and TCLIB at 6.8 σ_y and grazing impact on the TDI-S



Scenario 0 ⇒ TCLIB @ 8.3 σ

- TDI-S and TCLIA 6.8 σ_y and TCLIB 8.3 σ



Conclusions and Outlook

- To perform tracking of primary protons, taking into account also the ones scattered from collimators, in the SPS-to-LHC transfer lines a scattering routine has been implemented and interfaced with MADX and MADX-PTC;
- simulations of the expected loss maps for the TCDIs setup validation have been performed, as well as benchmarked with actual beam measurements;
- the same simulation tools have been used to evaluate the injection protection system with HL-LHC beams;
- studies to evaluate different settings of the injection protection absorbers are ongoing;
- the same tool will be also used to estimate the danger of an asynchronous extraction from the SPS for the TL elements (and injection into LHC as well) (M. Fraser);
- LHC asynchronous beam dump studies and benchmark calibration measurements for TCDQ re-qualification (C. Bracco).

Thank you!