Run III Layout and Performance for lead ions

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On behalf of the collimation team

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Outline

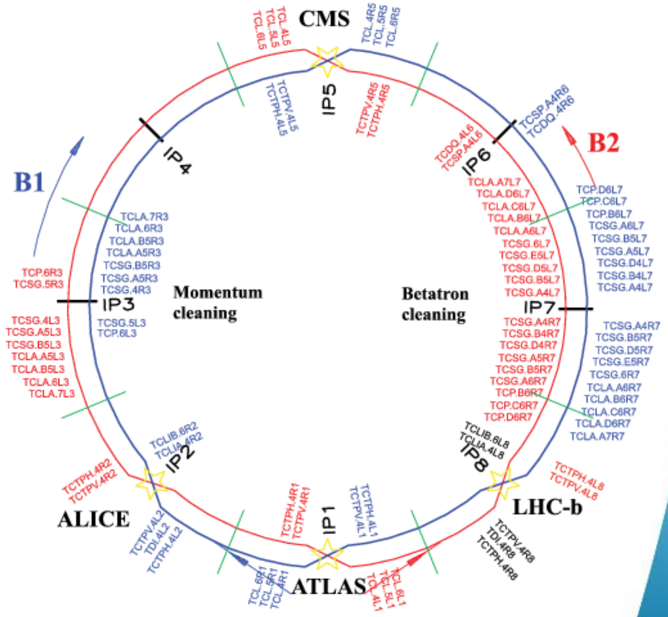
- Introduction
- Collimation system cleaning performance for ions with RunIII collimators
- Summary of new IR2 TCLD collimator performance
- Simulation studies of losses at TCTs due to fast failures dumps for RunIII ion configuration
- Conclusions

Introduction

- ❑ The **increase of store beam energy and beam intensity towards HL-LHC** poses serious challenges on the collimation system performance.
  - ✓ Even **more critical for heavy-ions** for which the cleaning performance is about a factor 100 worse than for protons **due to fragmentation processes**.

Main limitations for the heavy-ion performance addressed during LS2 :

- ❑ Losses of off-momentum and off-rigidity particles emerging from the collimators in IP7.
  - ✓ By the installation in IR7 of a single module **MBH(11T)+TCLD+MBH(11T)** per side.
- ❑ Losses due to heavy-ion collisions products around ALICE .
  - ✓ By the installation of a **TCLD in IP2**.



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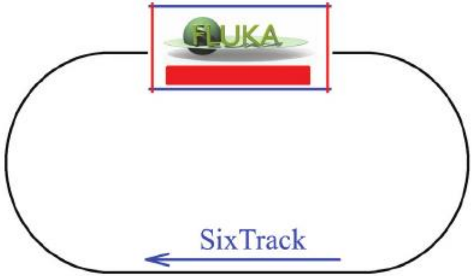
Introduction to the ion cleaning simulations



hiSixtrack-FLUKA coupling (FLUKA PRO and SixTrack v5)
(Thanks to FLUKA team and P. Hermes)

New 2018 ion optics (S. Fartoukh): potentially used in RunIII.

Beam: 7 Z TeV, N=6x10^6, $^{208}Pb^{+82}$ ions.

- Impact parameter at TCP: **1 μm** (max. ineff. in DS1/2 in the 2015 simulations).

New FLUKA collimator models per beam:

- 2 IR7 TCPs (60cm): from CFC to MoGr.
- 4 IR7 TCSs (1m): from CFC to Mo-coated MoGr.
- **A single module MBH(11T)+TCLD+MBH(11T) in IR7.**
- **A single TCLD in IR2.**

Twiss	IP1	IP2	IP5	IP8
β*	0.5	0.5	0.5	1.5
Ext. half-xing	+160	+137	+160	-170

Missing in these simulations:

Exchange MQWA.E5[L,R]7 with shielding:

- Small impact on the performance. Studied for HL-LHC proton optics.
  https://indico.cern.ch/event/713494/contributions/2931398/attachments/1618766/2576566/HL-LHC_MQW_study_15_3_2018.pptx

Collimator settings

Based on 2018 heavy-ion run configuration + TCLDs settings.
TCTs at 9σ to protect the smallest aperture in the machine expected about 11 σ in IP2.

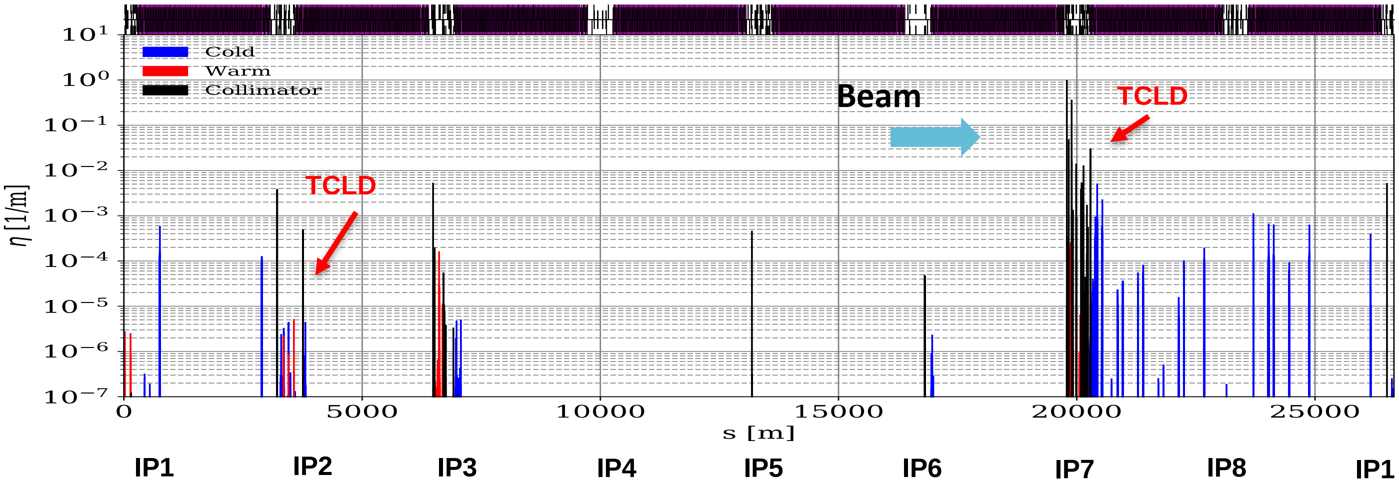
Coll.	Injection [σ, ε=3.5E-6]	Top energy [σ, ε=3.5E-6]	Physics [σ, ε=3.5E-6]
TCP/TCSG/TCLA IR7	5.7/6.7/10	5/6.5/10	5/6.5/10
TCP/TCSG/TCLA IR3	8/9.3/10	15/18/20	15/18/20
TCTs IR1/5	13	15	9
TCT IR2	13	15	9
TCT IR8	13	15	15
TCDQ/TCSP.6	8/7	7.4/7.4	7.4/7.4
TCL4/5/6 IR1/5	Open	Open	15/15/out
TCLD IR2	Open	Open	*25
TCLD IR7	14	14	14

* Preliminary value for this first simulation studies (collimator half gap range between 19-38)

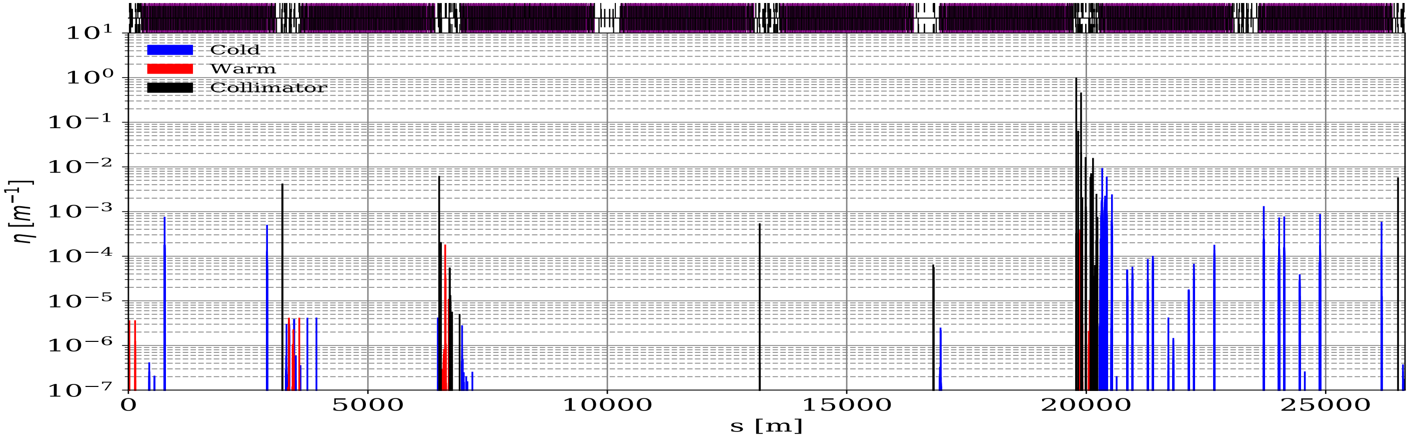
B1H Physics Loss map

RunIII layout: with TCLDs

Main differences in the new DS collimators. Almost no impact on the losses along the ring.

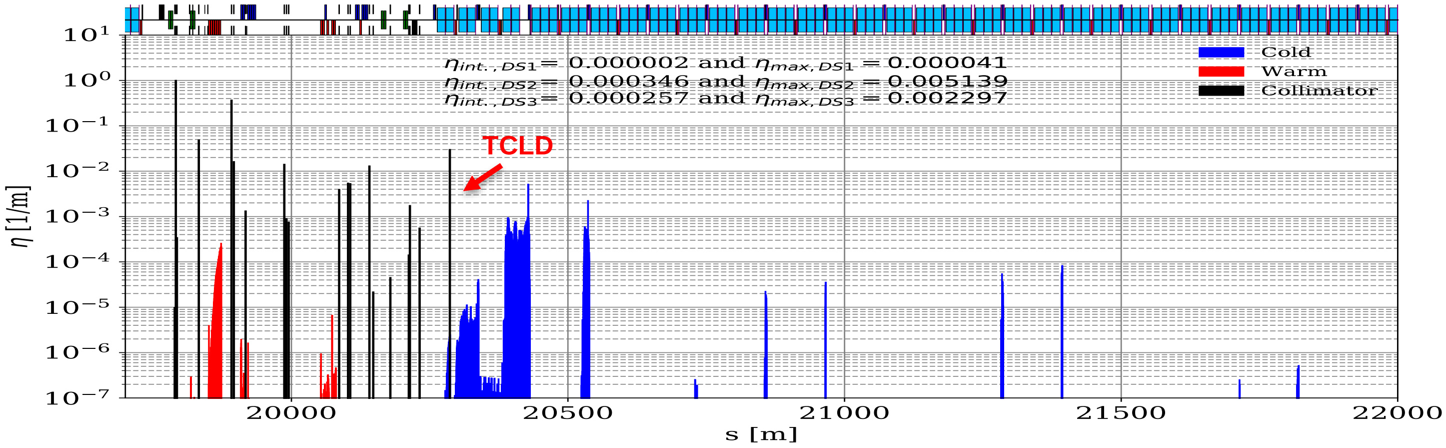


RunII layout: without TCLDs

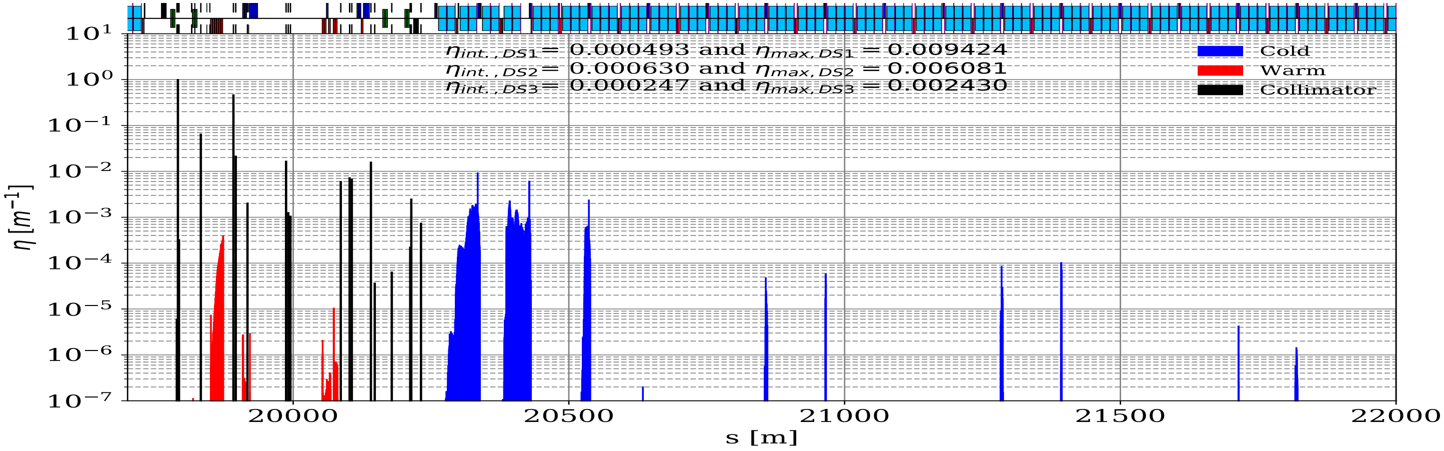


B1H Physics loss map zoom in IP7

RunIII layout: with TCLDs



RunII layout: without TCLDs



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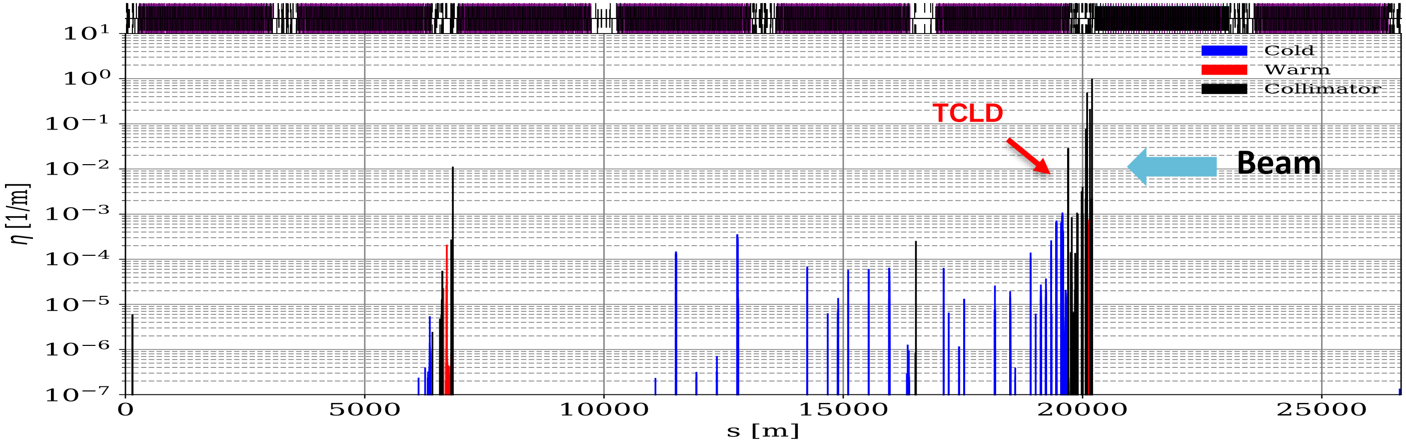
B2V Physics Loss map

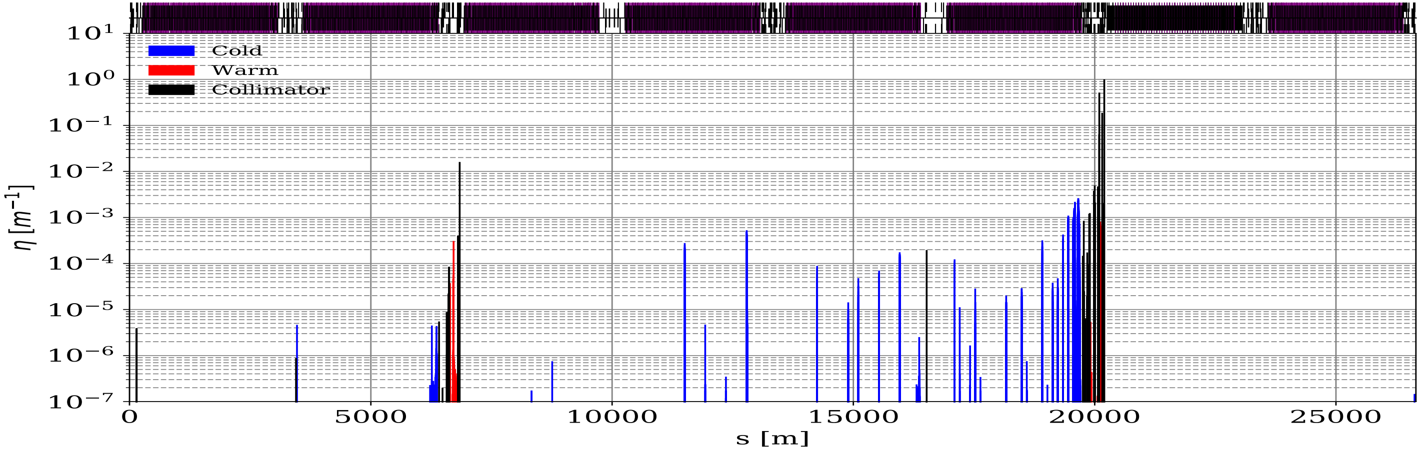
RunIII layout: with TCLDs

Main differences in the new DS collimator in IR7. Almost no impact on the losses along the ring.



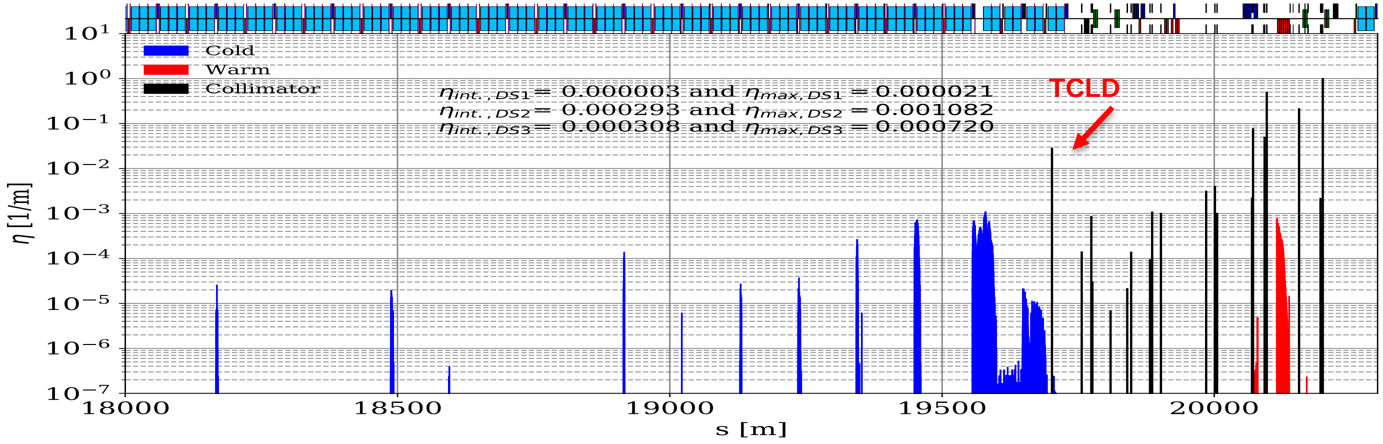
IP1 IP2 IP3 IP4 IP5 IP6 IP7 IP8 IP1

RunII layout: without TCLDs

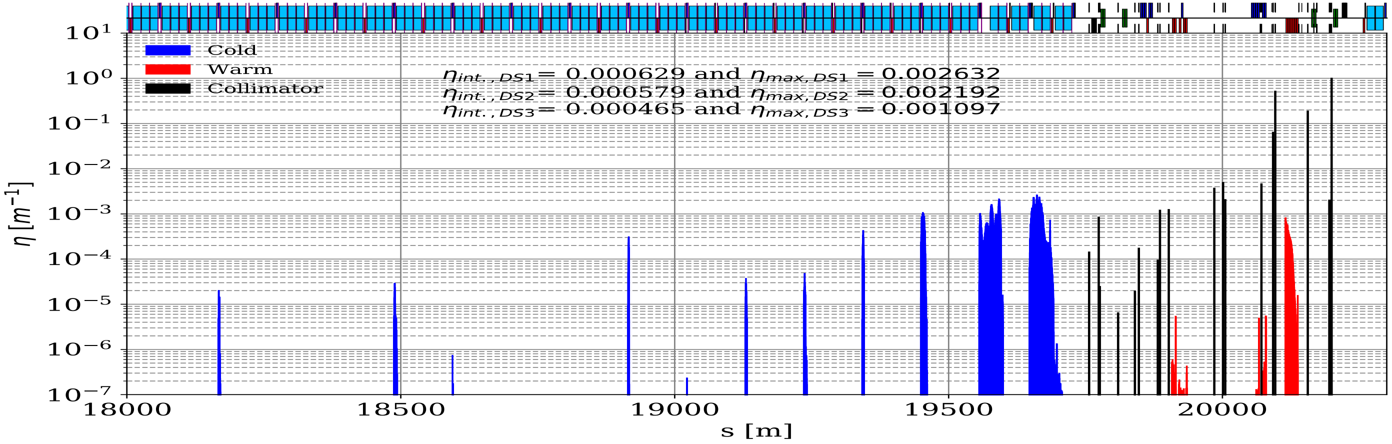


B2V Physics loss map zoom IR7

RunIII layout: with TCLDs



RunII layout: without TCLDs



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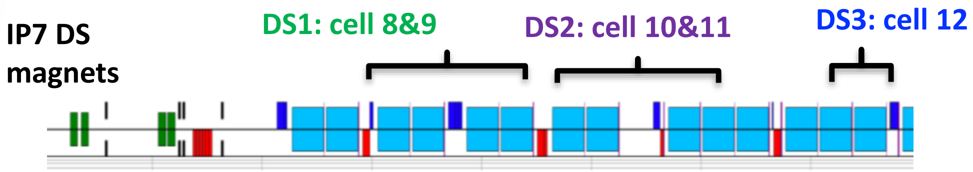
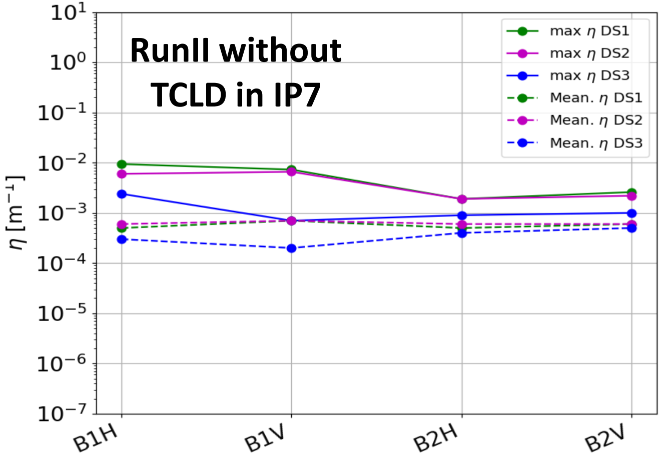
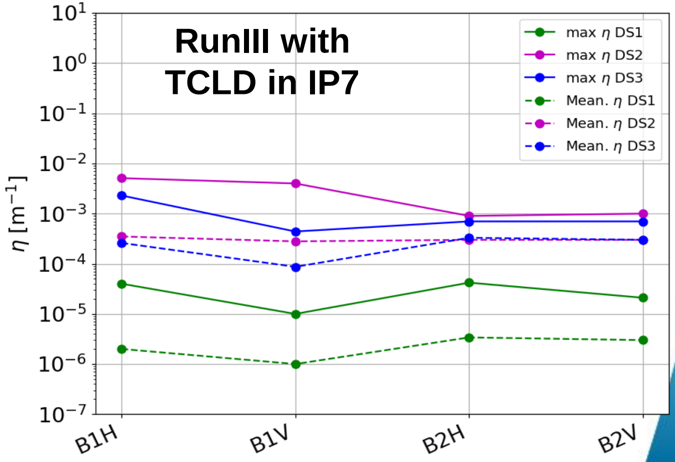
Summary of cleaning inefficiency in the IR7 DS magnets



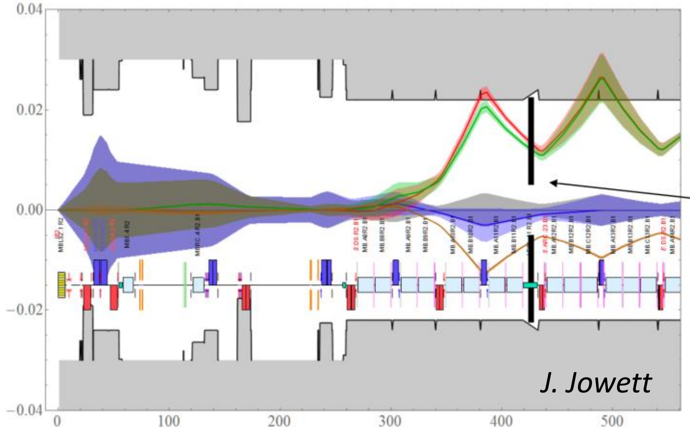
- The TCLD in IR7 reduces the losses in DS1 but losses in DS2 are still high.
- Pb ions (6.37 TeV) E_b^{max} < 10.8 MJ (P. Hermes, *Heavy-Ion Collimation at the Large Hadron Collider Simulations and Measurements)*
  - taking into account the 2015 maximum simulated inefficiency (DS1) quench test performed in 2015.
- Calculations performed for the RunIII and HL-LHC energy with reduction factor on quench limit shows intensity reach limitations with only 1 TCLD.
- **Input from 2018 run is crucial.**
- Possible improvement with crystal collimation. Good results were obtained in 2017 for Xe beams.



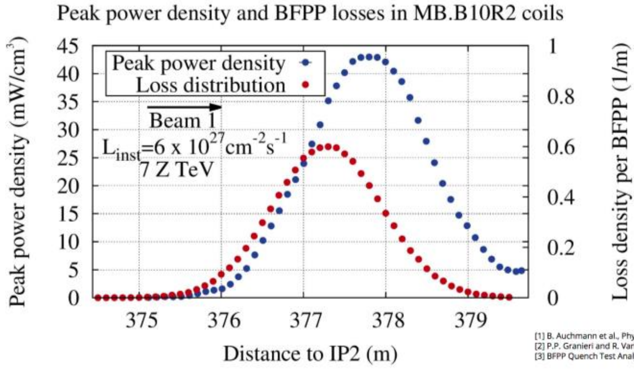


Summary of TCLD in IR2 expected performance

- Bound Free Pair Production (BFPP) losses in the downstream DS in IP2 limit ALICE luminosity.
- With luminosity levelling in ALICE quenches were not seen in 2015 (same solution for 2018).
- In RunIII after LS2 ALICE will be upgraded to increase the luminosity .
  - ✓ TCLD will be installed to reduce the risk of quenches.
- FLUKA team studied the BFPP energy deposition in the IR2 DS and the shower developed by TCLD.



C. Bahamonde, R. Garcia Alia, M. Brugger, F. Cerutti, A. Lechner



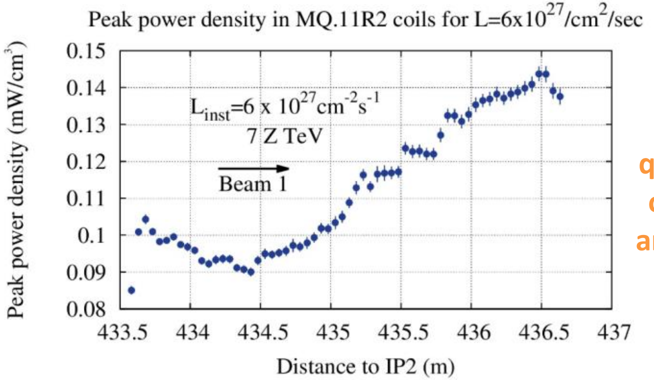
Peak power density in MB coils ~44 mW/cm³

Quench limit calculations [1,2] 27-49 mW/cm³

Quench risk in HL-LHC!

Remark → 2015 BFPP quench test shows quench limit could be as low as 15 mW/cm³ [3]

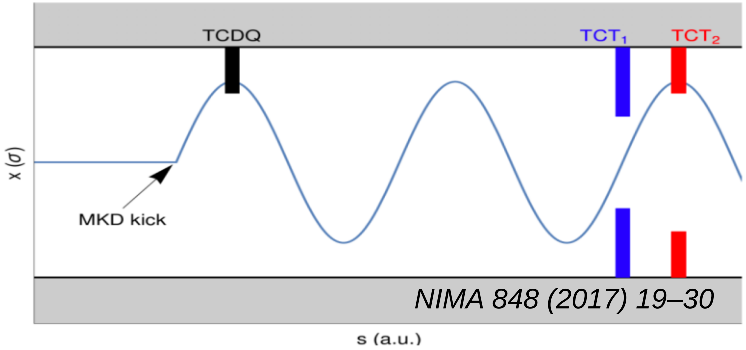
[1] B. Auchmann et al., Phys. Rev. ST Accel. Beams, 18, 061002, (2015).
[2] P.P. Granieri and R. Van Weelderen, IEEE Trans. Appl. Supercond., Vol 24 (2014).
[3] BFPP Quench Test Analysis Meeting https://indico.cern.ch/event/496892/



Far from estimated quench limit for other magnets and cryostat bus bars

Losses at the TCTs in case of dump fast failures for Run III

- **Dumps** of the beam **out of synchronization with the abort gap lead to miskicked bunches that** could cause fast high losses with consequent risk of **damage of sensitive components**.



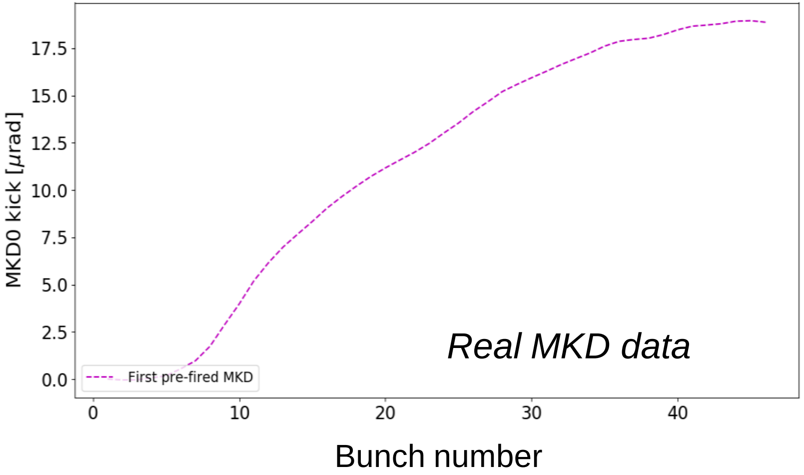
- **The most exposed elements** are the **tungsten TCTs (high absorption in favour of robustness) protecting the triplets.**
  - ✓ need to stay sufficient behind the dump protection (TCDQ and TCSP IP6).
  - ✓ Ideal MKDs-TCTs phase advance 0° and 180°.
  - ✓ Proton studies determined a 30° margin to have a safe operation.

- **For 2018 new ion optics some TCTs at the limit of accepted MKD-TCT phase advance (~43°/30° for B1/B2 in IP2).**

	$\Delta\mu_x$ (B1)	$\Delta\mu_x$ (B2)
MKD-TCTPH IR1	176°	151°
MKD-TCTPH IR2	223°	212°
MKD-TCTPH IR5	162°	176°

Fast failure dumps simulations method

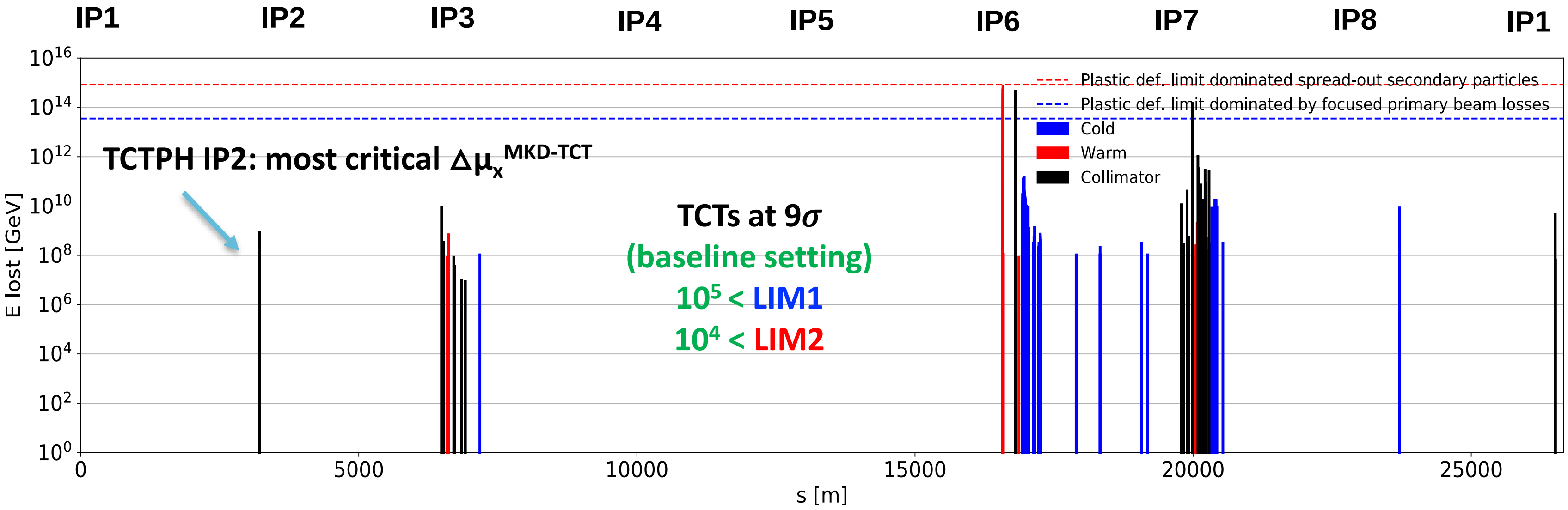
- **Simulations performed with hiSixtrack-FLUKA coupling.**
- **Tracking simulations of different bunches** receiving different MKDs kicks covering the rising field of kickers.
- **50 ns spacing between bunches (100/75 ns spacing for 2018 ion run).**
- **Real MKDs field data** (Matthew Fraser).
- **3 turns simulation**:
  - Kicks implemented with the **DYNK module** dynamically.
  - **First turn:** no kick is implemented.
  - **Second turn:** bunches are affected by the kicker field when it is still rising.
  - **Third turn:** maximum kick value of the MKDs is implemented.



- **Different dump failure modes** simulated.
  - ✓ **Single Module Pre-Fired (SMPF)** identified as the most critical one.

Fast failure loss map results for B1

- **Energy loss map normalized** to the full physics ion bunch energy (1.1×10^{14} GeV/bunch) and **summed for all bunches.**
- **TCTs damage limits estimated for protons** (*E. Quaranta et al., Phys. Rev. Accel. Beams 20, 091002 2017*)
  - ✓ Comparison valid for impact distribution dominated by secondary spread-out beam.

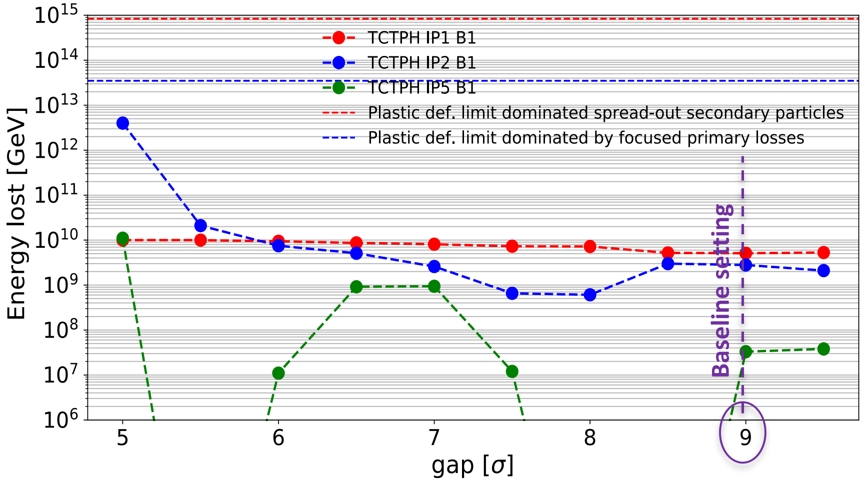


- TCLDs included, 50 ns filling scheme.
- **LIM1:Plastic deformation limit for primary and focused beam losses: 3.5×10^{13}GeV**
- **LIM2:Plastic deformation limit for secondary spread-out beam losses: 8.4×10^{14} GeV**

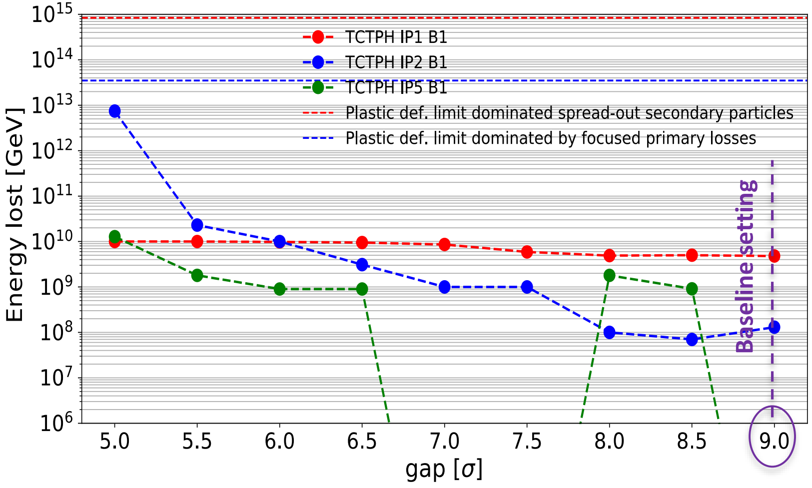
TCTs settings scan B1

- **Different TCTs settings (5-9.5 σ)** to study the sensitivity of the simulation results.

RunII layout (6.37Z TeV & 75 ns spacing)



RunIII layout (7Z TeV 50 ns spacing)

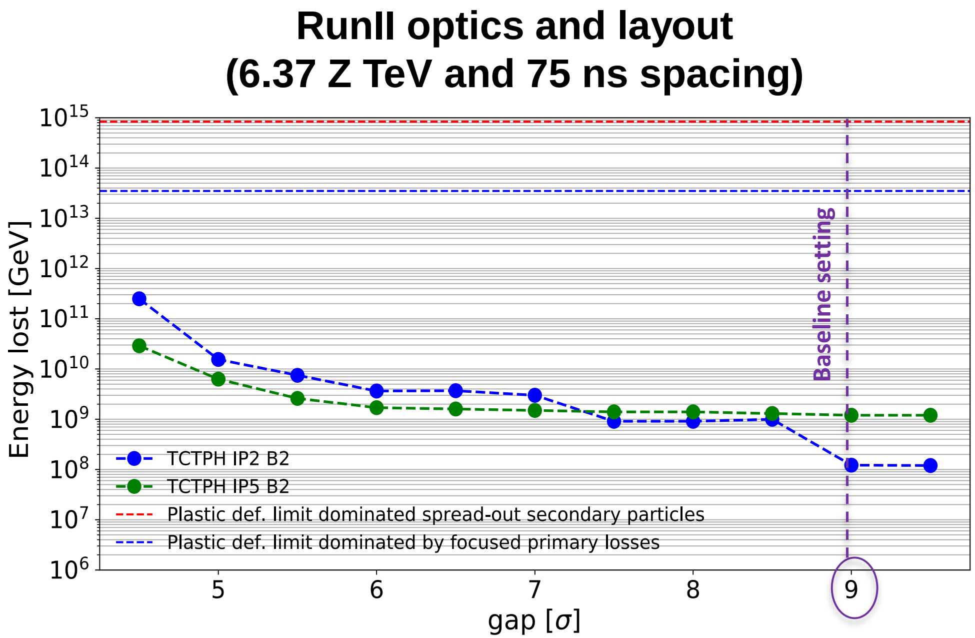


Conclusions:

- Losses at the TCTs below the damage limit for **baseline settings** with 3.5σ operation margin for B1.
- No significant differences on the results between 50 ns and 75 ns spacing.

TCTs settings scan B2

- **Different TCTs settings (4.5-9.5 σ)** to study the sensitivity of the simulation results.
- Simulations only performed for the **RunII layout.**
- For RunIII layout simulations are in progress.



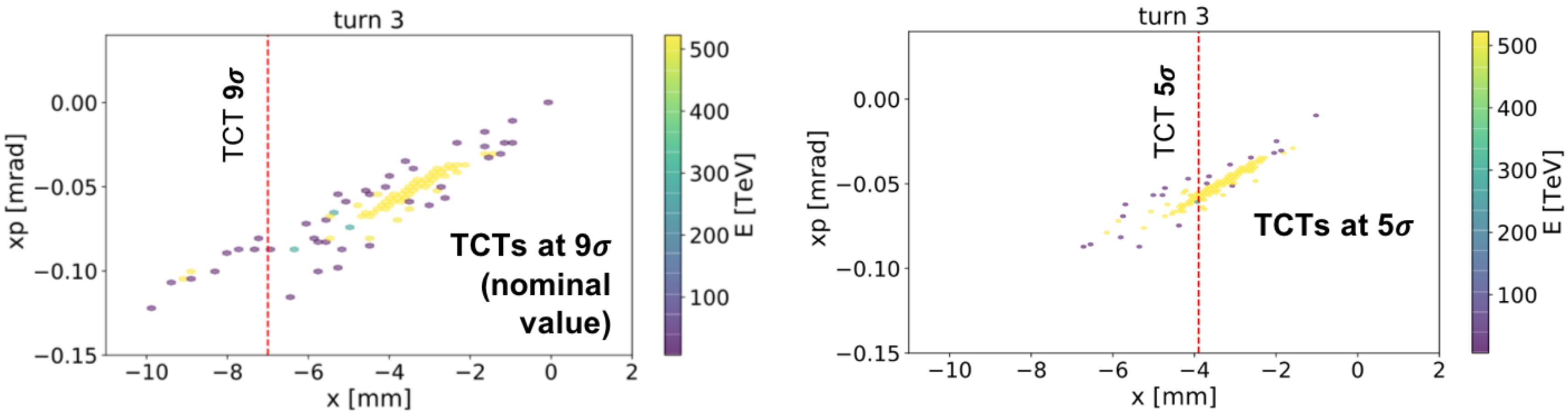
Conclusions:

- No big changes w.r.t. RunII layout results are expected. For RunII layout and baseline settings results indicate a safe operation with 4σ margin.

TCTs impact distribution for B1

Damage limits depends on impact distribution.
Presented conclusions valid for losses dominated by spread-out secondary beam.
For the most critical TCT and baseline settings losses are dominated by spread-out secondary beam.
Horizontal phase space at TCTPH in IR2.

✓ the most critical TCT with highest TCT-MKDs phase advance difference.



- Large margin, in principle no need to perform energy deposition studies but still can be interesting.

Conclusions

- **Collimation cleaning performance** for the **RunIII layout** studied with the recently developed simulation tool **hisixTrack-FLUKA coupling**.
  - **TCLD in IR7 reduces** the **losses in cell 8 and 9 by a factor 100**.
  - But we can not ensure with enough margins that the operation will be okay, unless the lifetime is better tan the design value (losses in DS2 and along the ring).
  - **Inputs from the 2018 ion run** could be crucial for a better understanding of the limitations and agreement with predictions.

- **Good performance of the TCLD in IR2** is expected with no issues concerning the collimator generated shower energy deposition in the surrounding elements.

- **From fast dump failure studies** we conclude that there is **no problem** on the TCTs losses for the **baseline settings** with a margin in operation of 3.5/4σ for B1/B2 respectively.

On going: Complete the studies also with optics changes in IR7.

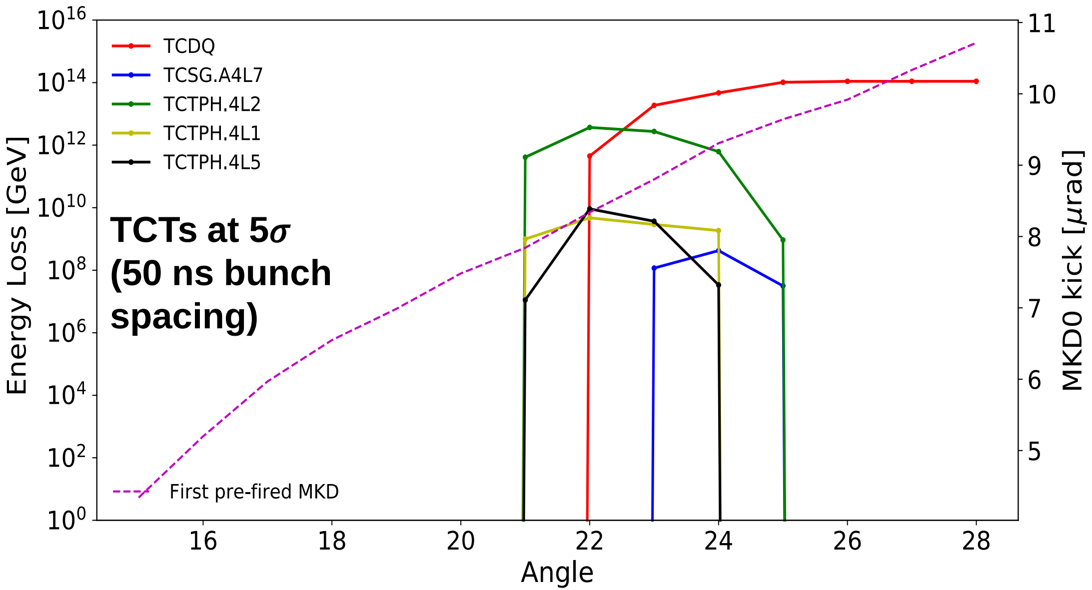
Thank you very much for your attention!

Collimator losses for different bunches for B1

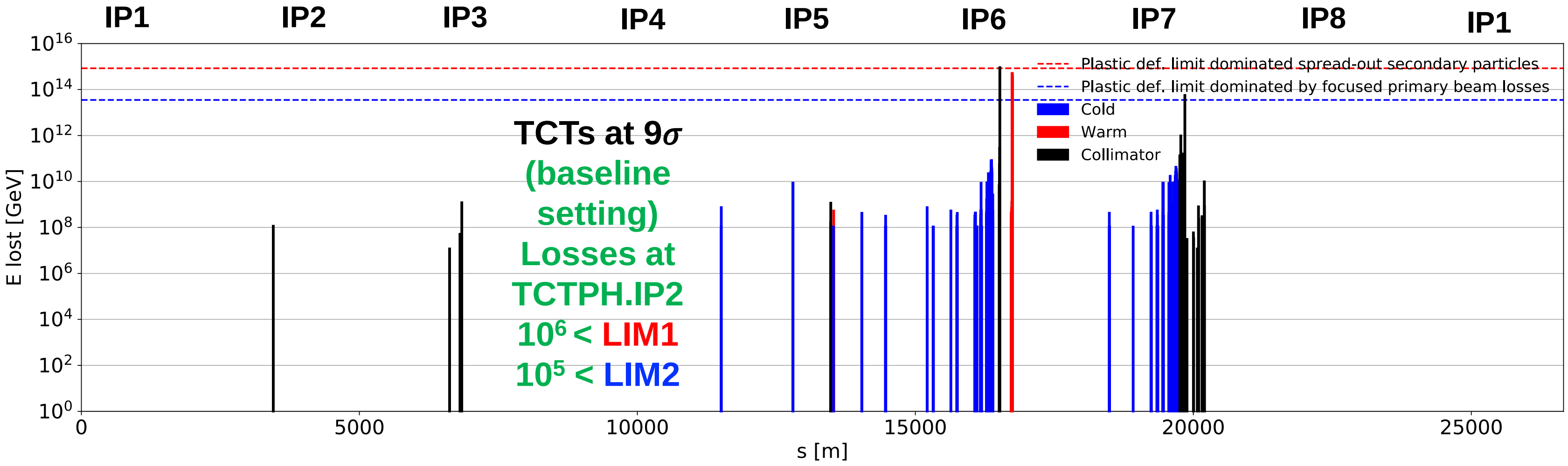
- Losses at the most critical collimators are shown for the different bunches.
- Different bunches will feel different kicks values covering the rising of the MKDs file with 50 ns spacing.

- **First bunches**: small kicks, pass through the whole ring.
- **Later bunches:** large kicks, hit TCDQ or are extracted.
- **Intermediate bunches:** risk to hit TCTs and aperture.

5 bunches contribute to losses in the TCTs.



SMPFA loss maps and collimator losses vs bunch number for B2



- Lower amount of losses w.r.t. B1 in TCTPH.IP2 (better TCTs-MKDs phase advances).
- Only 2 significant bunches contribute to losses in the TCTs.