Implications of Matching Section and Dispersion Suppressor losses for proton and ion operation

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WP10

Energy deposition & R2E

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OUTLINE

Continuation of the work presented in 9th HL-LHC Annual Meeting in 2019

https://indico.cern.ch/event/806637/contributions/3573645/attachments/1926897/3191739/2019_HL-Meeting_MGS_v2.pdf

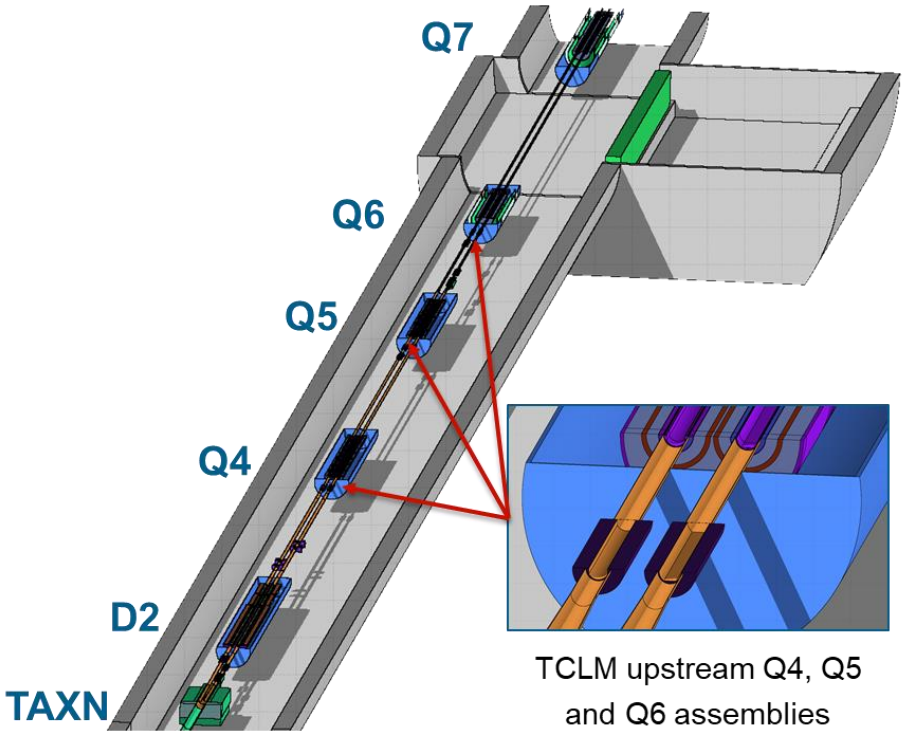
- ***Matching Section: collimation system.***
  - ***HL-LHC fixed masks.***
  - ***TID in cell 4 collimators.***
- ***Dipole correctors in the Matching Section (MS) and the Dispersion Suppressor (DS).***
- ***Losses in the DS for HL-LHC: p-Pb run.***

- p-p collisions at 7 TeV.
- HL-LHC optics v1.5 (May19).
- Half crossing angle: 250 μrad.

Matching section: *collimation system*

Layout of the matching section in IR1/5

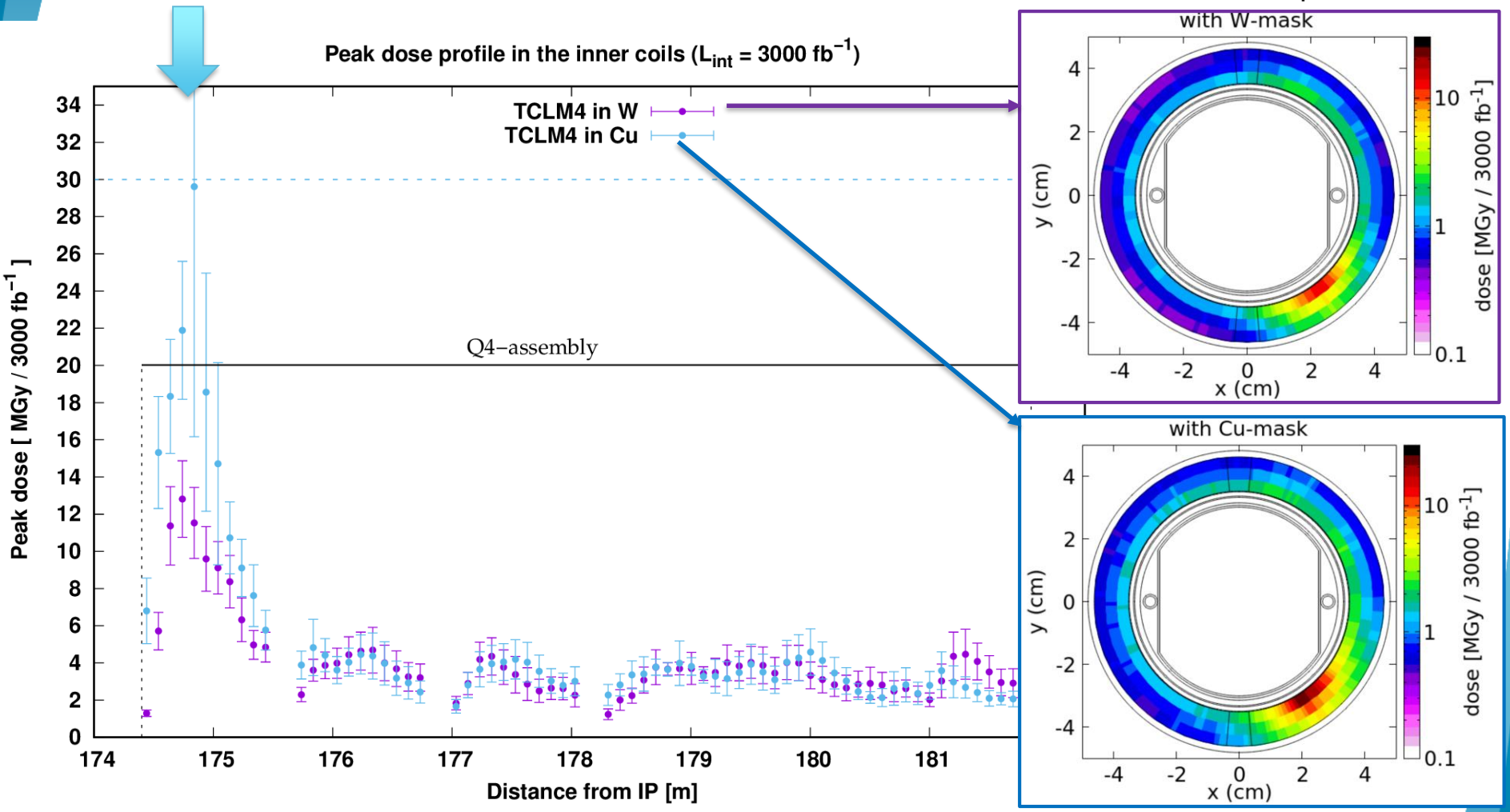
- Collimators:
  - *3 TCLs.*
  - *4 TCTs.*
- Masks (TCLMs):
  - ***In front of Q4, Q5 and Q6 assemblies*** *to further protect the magnets against collision debris.*
- ***Jaw material choice based on the protection effectiveness to the downstream magnet.***



TCLM upstream Q4, Q5 and Q6 assemblies

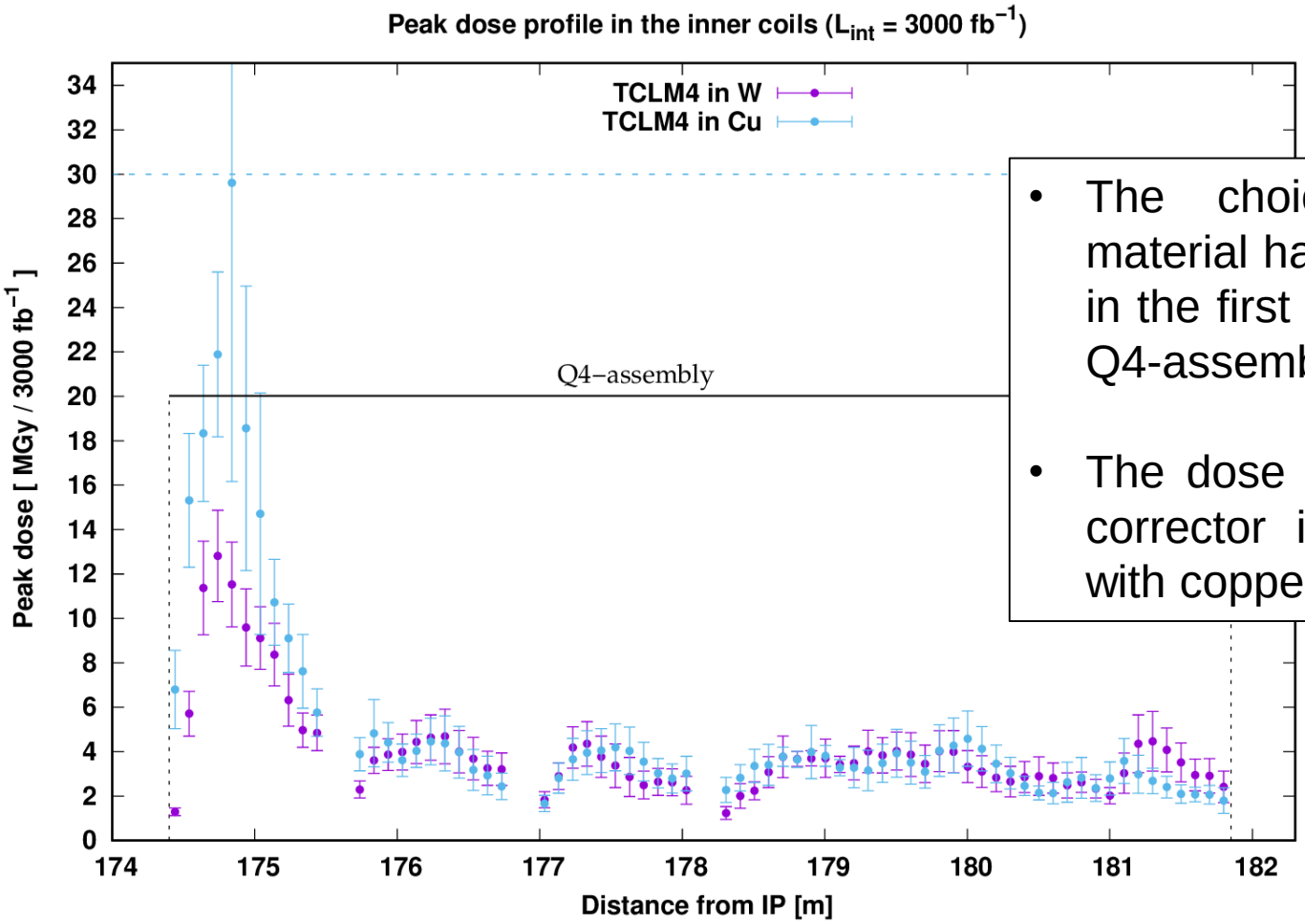
HL-LHC fixed masks: jaw material choice

Dose at the peak



*IR5-VC

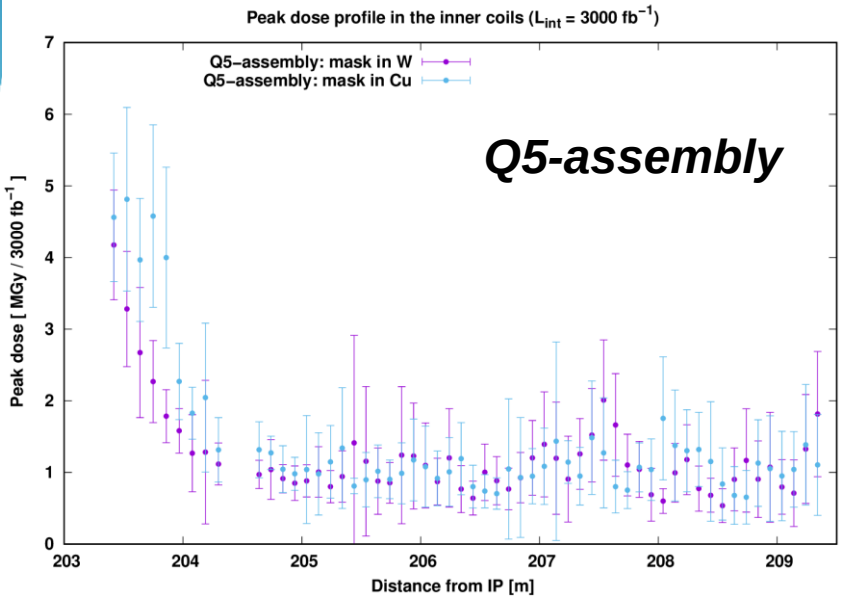
HL-LHC fixed masks: jaw material choice



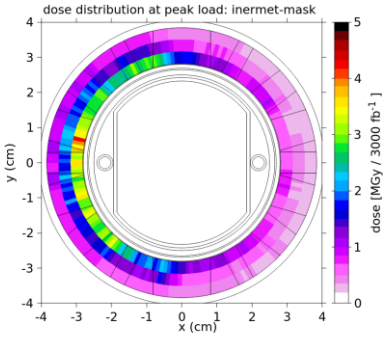
- The choice of the TCLM4 material has an important impact in the first dipole corrector of the Q4-assembly.
- The dose in the coil of the first corrector increases significantly with copper jaws.

*IR5-VC

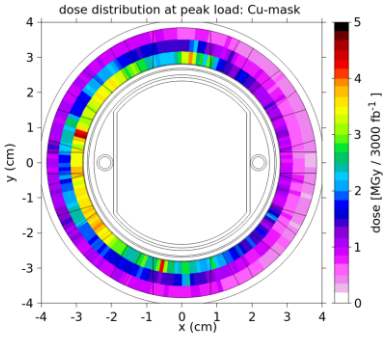
HL-LHC fixed masks: jaw material choice



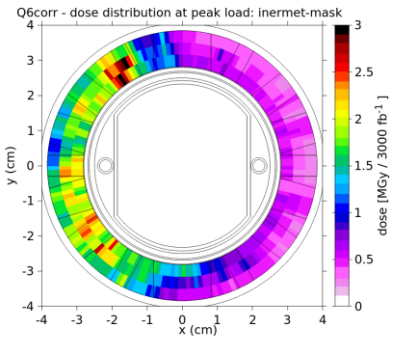
inermet



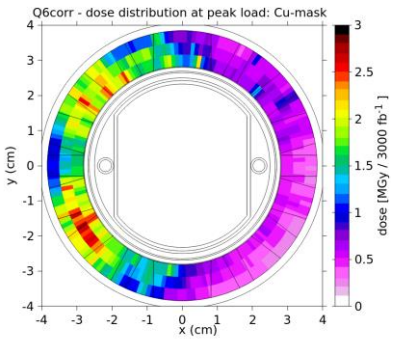
copper

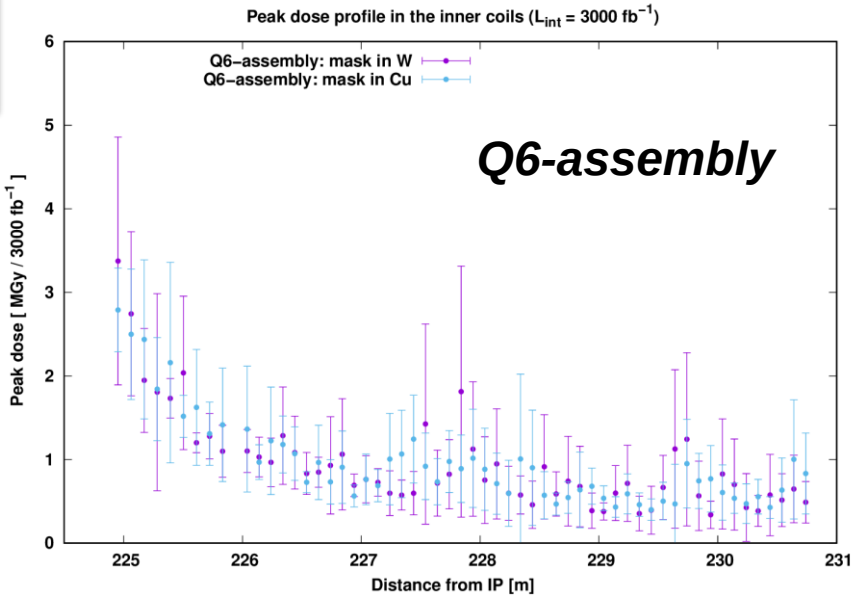


inermet



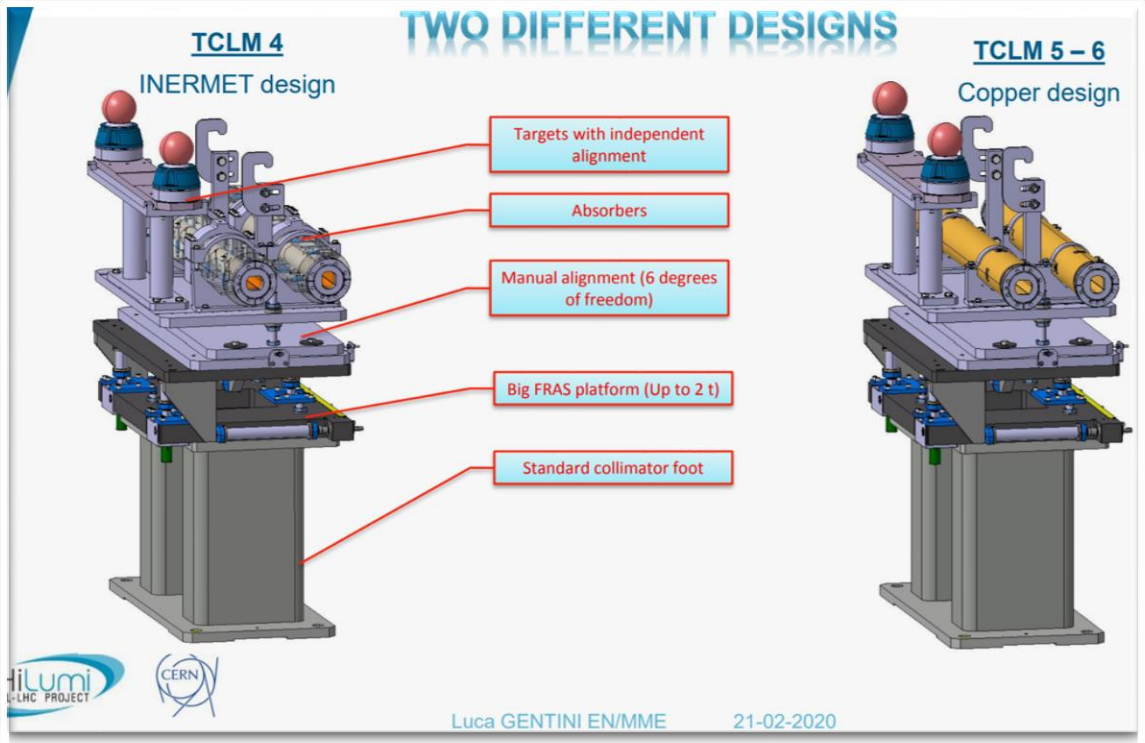
copper





*IR1-HC

HL-LHC fixed masks: jaw material choice



https://indico.cern.ch/event/883397/contributions/3722234/attachments/1992016/3321794/2020-02-21_ColUSM_124_TCLM.pdf

Cell 4: TCLM4

It is preferable not to replace the material jaw by copper.

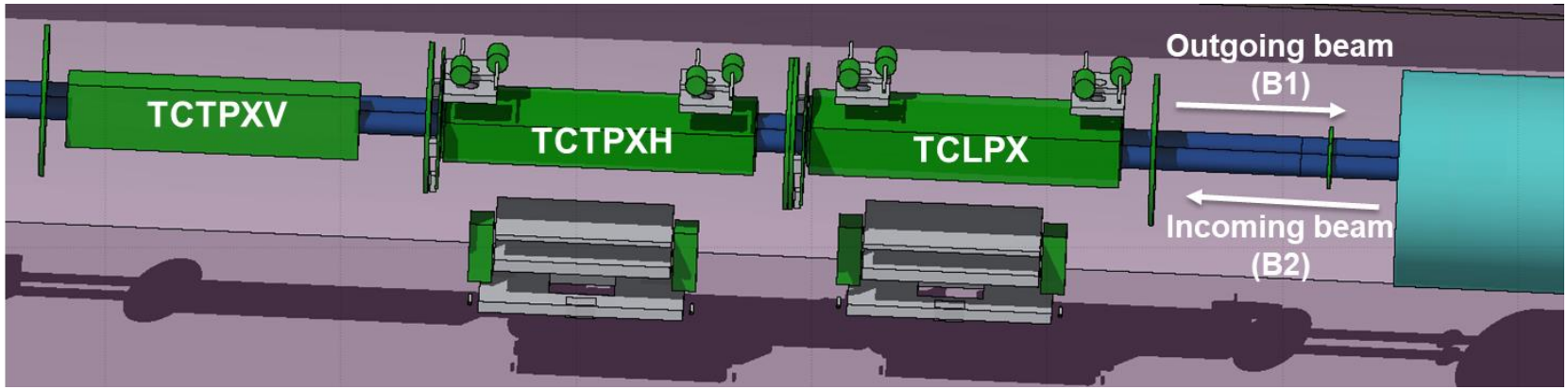
Cell 5/6: TCLM5/TCLM6

The replacement of inermet by copper (in order to reduce the cost of the masks) is possible, since the differences between the two materials are within uncertainties when looking at the dose and power density in the Q5/6-assembly.

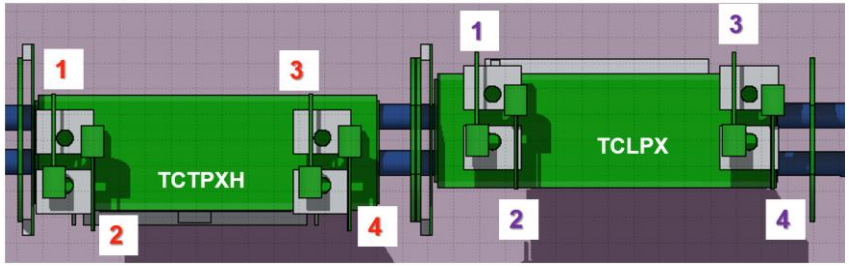
Total ionizing dose on cell-4 collimators and interconnecting elements

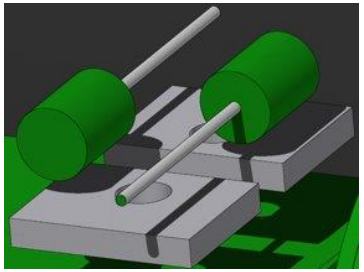
- FLUKA simulations were performed to extract the dose values in several positions of interest for the integrity of the grease used in the collimators and interconnect elements in cell-4.

- Worse case scenario for collimators in cell 4 under study: IR1 (HC).
  - The simulations presented here are performed for the right side of IR1.
  - The results also hold for IR1-left side due to the layout left/right symmetry.

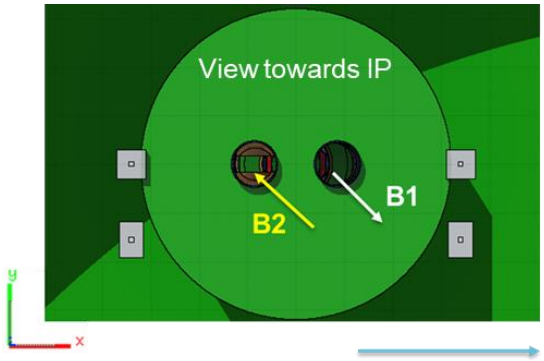


➢ Screws on the top motors of TCTPXH and TCLPX





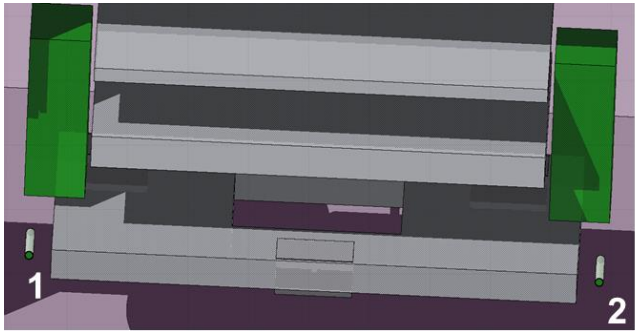
Grease 1 mm layer around the screws



X> 0 → External side of the ring

➢ TID in the vacuum interconnect gear boxes

➢ TID in the FRAS location

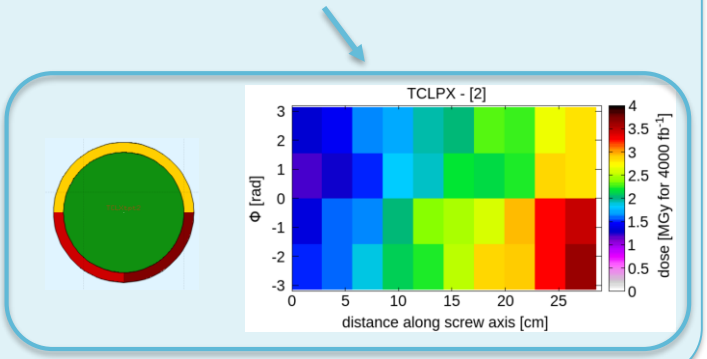


Grease 1 mm layer around the screws

Total ionizing dose on cell-4 collimators and interconnecting elements

- The maximum doses level at those locations for ultimate conditions, i.e., 4000 fb^{-1} integrated luminosity, are:

  - *4 MGy in the grease around the screws of the top motors.*
    - The dose distribution in the screws on the top motors is highly inhomogeneous.
  - *3 MGy inside interconnect gear boxes.*
  - *1 MGy in the FRAS region.*



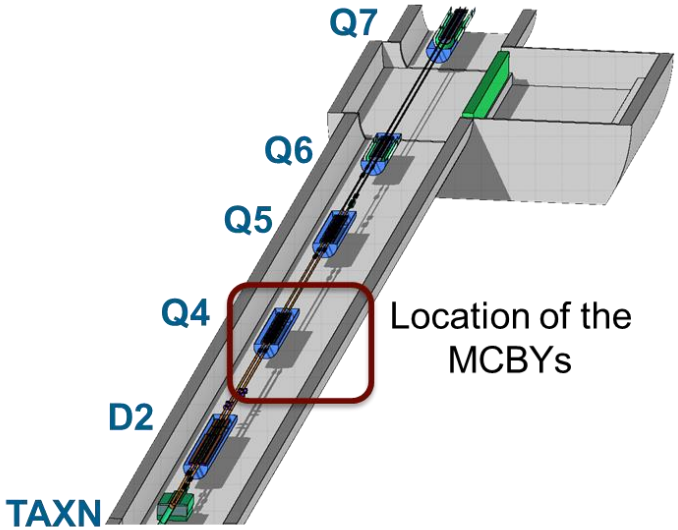
Correctors in the Matching Section and the Dispersion Suppressor:

Dose estimates on MCBYs, MCBCs and MCBH/V

Dose estimates on MCBY correctors in cell 4

- Cumulated dose up to Run 3 (360* fb^{-1}): ≤ 0.2 MGy.
- At the end of Run 4 (560* fb^{-1} integrated luminosity):

Horizontal Crossing		**1.1 MGy**
Vertical Crossing	Up	2.4 MGy
	Up/Down	**1.2 MGy**



The polarity inversion in VC is of importance to keep the cumulated dose in the MCBY < 1.5 MGy.

* https://edms.cern.ch/document/2364638/1.2

Dose estimates on MCBY correctors in cell 4

Run 4 560 fb^{-1}	Dose (MGy)
HC	1.1
VC Up/Down	1.2

---------- *LS4* ----------

Run 5 924 / **1465** fb^{-1}	Dose (MGy)
HC	1.8 / **2.9**
VC Up/Down	2.0 / **3.1**

---------- *LS5* ----------

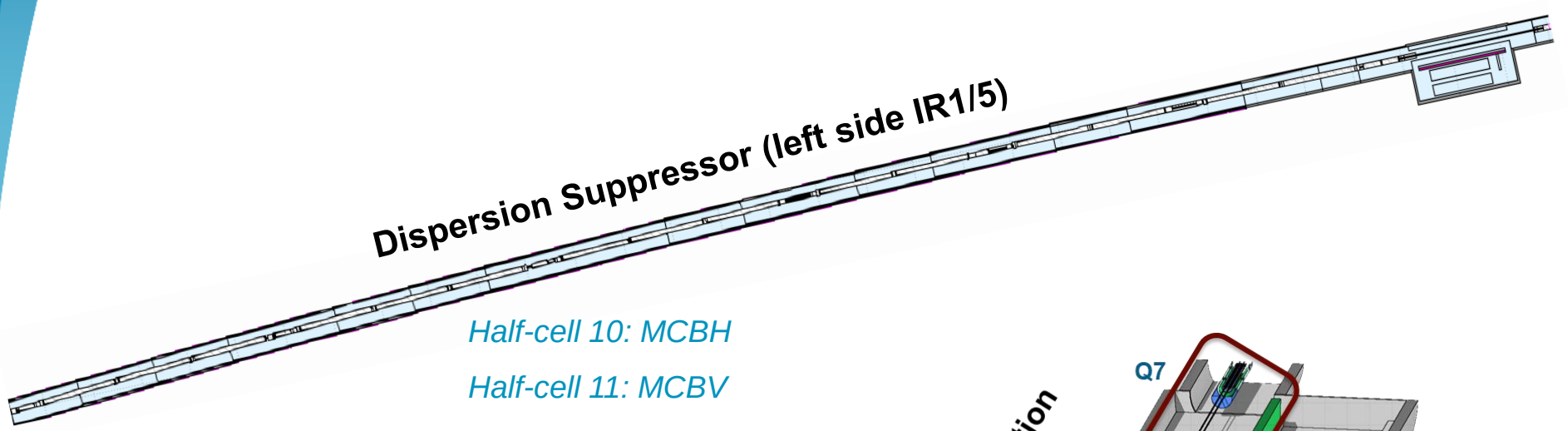
Run 6 1440 / **1780** fb^{-1}	Dose (MGy)
HC	2.8 / **3.5**
VC Up/Down	3.1 / **3.8**

---------- *LS6* ----------

HL-LHC 3000 / **4000** fb^{-1}	Cumulative dose (MGy)
HC	5.9 / **7.8**
VC Up/Down	6.4 / **8.6**

- The dose limit of the MCBYs is expected to be between 1 and 5 MGy.
- Therefore, MCBYs cannot handle the radiation levels in the present Q4-assembly configuration for the whole HL-LHC lifetime.
- Measures should be envisaged from LS4 onward.

Dose estimates on MCBC and MCB correctors



Half-cell 8: MCBC

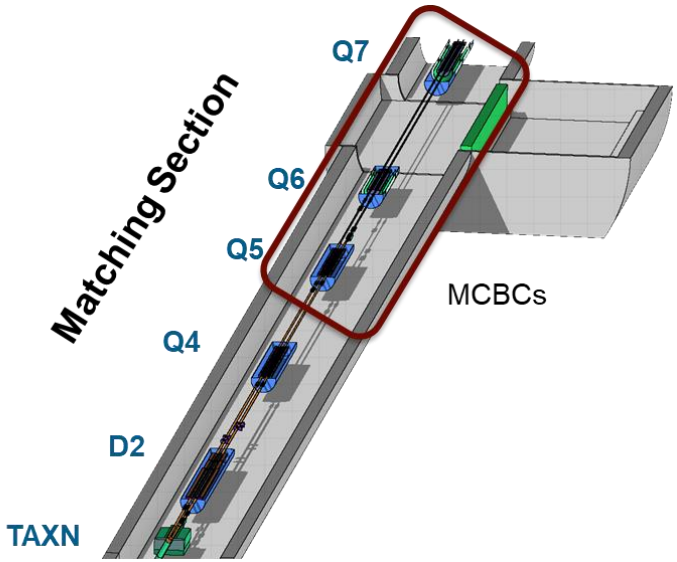
Half-cell 9: MCBC

Half-cell 10: MCBH

Half-cell 11: MCBV

Half-cell 12: MCBH

Half-cell 13: MCBV



Dose estimates on MCBC in the MS

- Worse case scenario: HC and IR1-right side, since the corrector of Q5/Q6 assemblies is facing the IP.

HC – IR1	***Q5 assembly***	***Q6 assembly***	***Q7 assembly***
Up to Run 3: 360 fb^{-1}	≤0.2 MGy	≤0.2 MGy	≤0.2 MGy
During Run 4: 560 fb^{-1}	0.7 MGy	0.6 MGy	< 0.01 MGy

(In case of VC in IR5, the maximum dose during Run 4 is 0.2 MGy)

- After LS4, **the additional contribution of Run 5 and Run 6** together on the most exposed MCBCs will be:

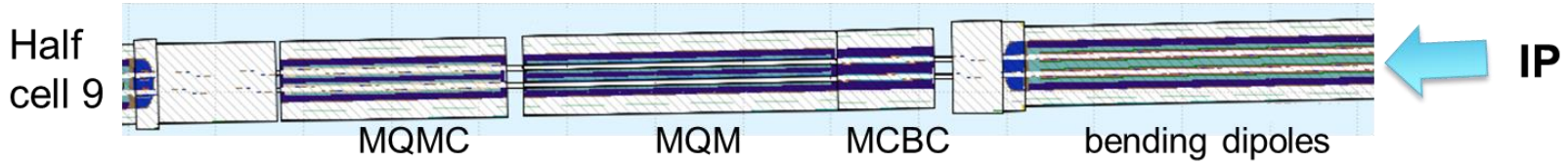
  - Nominal operation, 2364 fb^{-1} : 3 MGy
  - Ultimate operation, 3245 fb^{-1} : 4 MGy → approaching cumulatively 5 MGy

- The MCBC can be replaced by a shielded MCBY (see later).

Dose estimates on MCBC and MCB in the DS

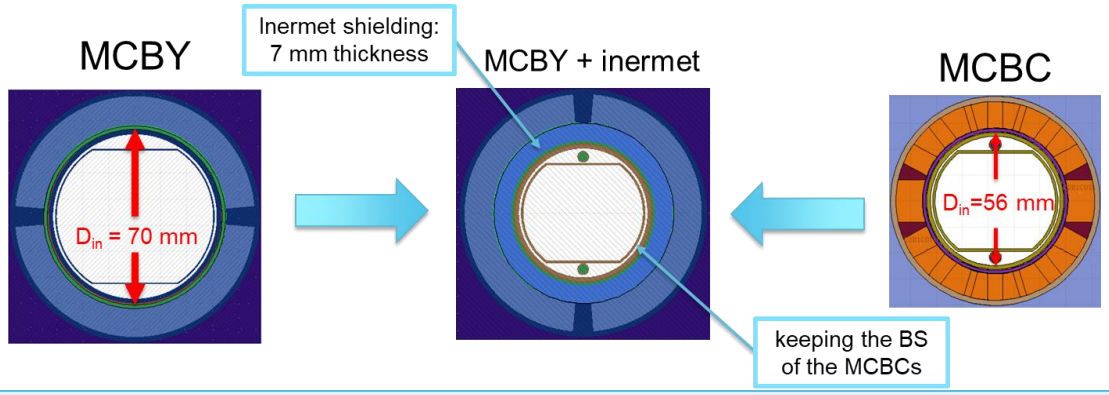
Half cell	Corrector type	**Cumulative** peak dose (MGy) up to LS4 *(360+560) fb^{-1}*	up to LS5 *1844 / **2385 fb^{-1}***	up to LS6 *3284 / **4165 fb^{-1}***
8	MCBC	1.6	3.2 / **4.1**	5.6 / **7.1**
9	**MCBC**	**3.8**	7.6 / **9.9**	13.6 / **17.2**
11	MCBV	1.8	3.6 / **4.7**	6.4 / **8.1**
13	MCBV	0.9	1.8 / **2.3**	3.2 / **4.0**

Worse case scenario is the left side of the IP since:



MCBCs and MCBs replacement by MCBYs + W-shielding

- Possible solution for the MCBC correctors



	Integrated luminosity	Replacement in LS3	Replacement in LS4	Replacement in LS5	NO Replacement
Up to LS3	360 fb^{-1}	1.5	1.5	1.5	1.5
Up to LS4	920 fb^{-1}	0.6	3.8	3.8	3.8
Up to LS5	1844 / **2385** fb^{-1}	1.6 / **2.1**	1.0 / **1.5**	7.6 / **9.9**	7.6 / **9.9**
Up to LS6	3284 / **4165** fb^{-1}	3.1 / **4.0**	2.5 / **3.4**	1.5 / **1.9**	13.6 / **17.2**

Color legend: cumulative dose on MCBC9 / on MCBY9+W

Dose in MGy

➢ Dose estimates on MCBC and MCB correctors

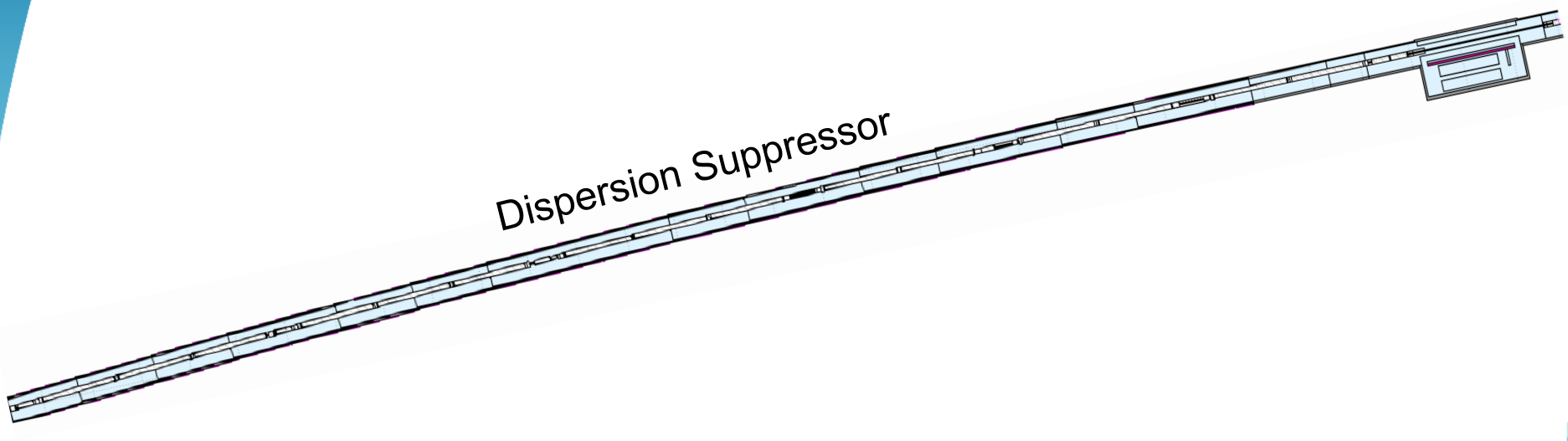
Half cell in DS	Location in the machine	Number of Corrector Magnet	Time scale to reach 4 MGy	Time scale to reach 5 MGy
8	IR1 and IR5 left side only	2	by LS5	during Run 6
9		2	by LS4	during Run 5
11		2	during Run 5	by LS5

Table 1: Number of correctors in the LSS and DS receiving more than 5 MGy. The last two columns provide the operation period within which 4 or 5 MGy will be reached.

Half cell	Location in the machine	Number of Corrector Magnet
5 (LSS)	IR1 right side and IR5 left side	2
6 (LSS)		2
8 (DS)	IR1 & IR5 right side	2
13 (DS)	IR1 & IR5 left side	2

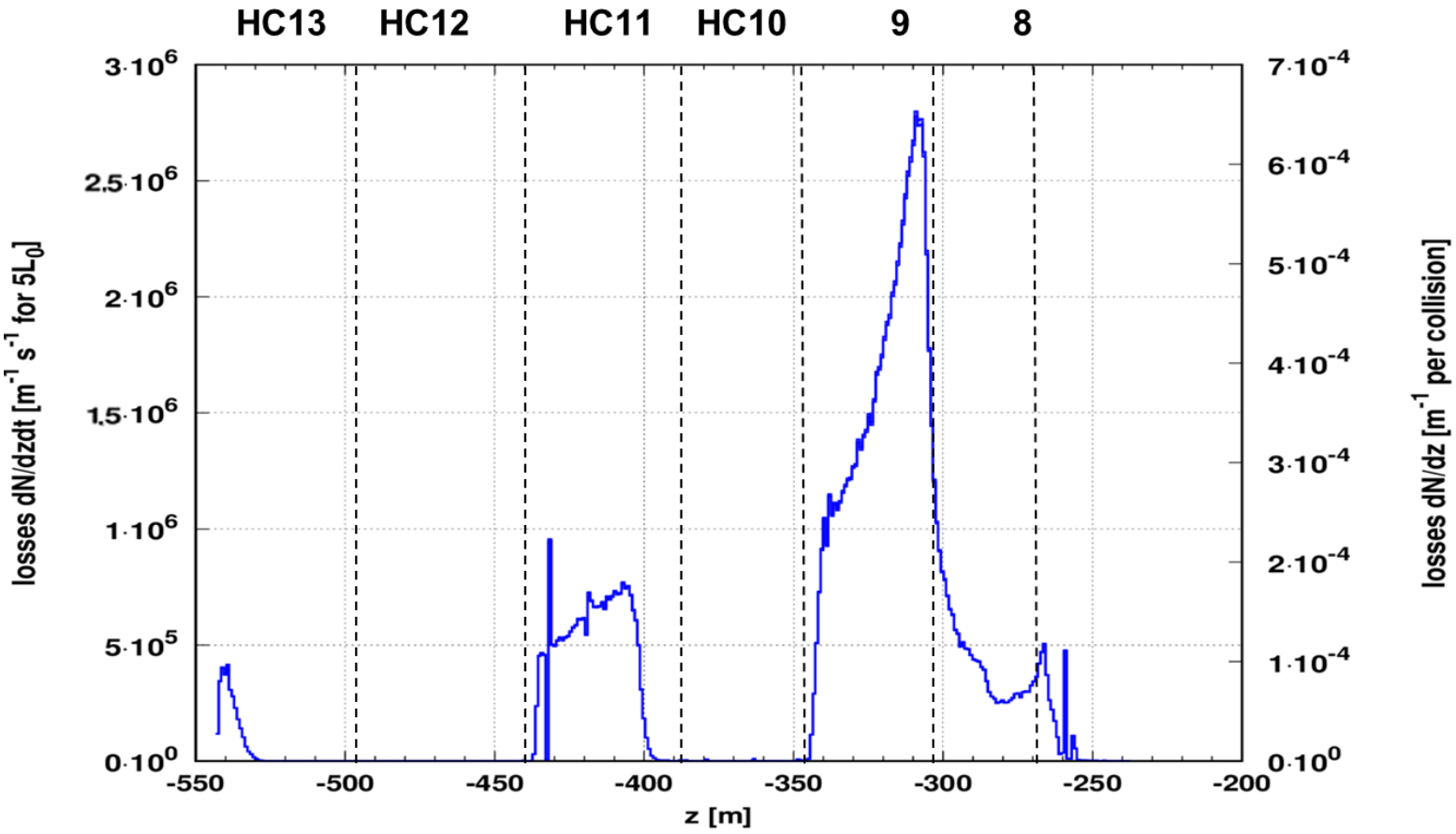
Table 2: The number of correctors in the LSS and DS receiving between 4 and 5 MGy by the end of HL-LHC operation, i.e., LS6.

The MCBH/V corrector magnets in cell 11 and 13 are shorter than the MCBCs thus the solution of replacing them by a MCBY + inner inermet shielding has to be carefully explored.



Losses in the DS during p-Pb run

Losses in the DS for p-p operation

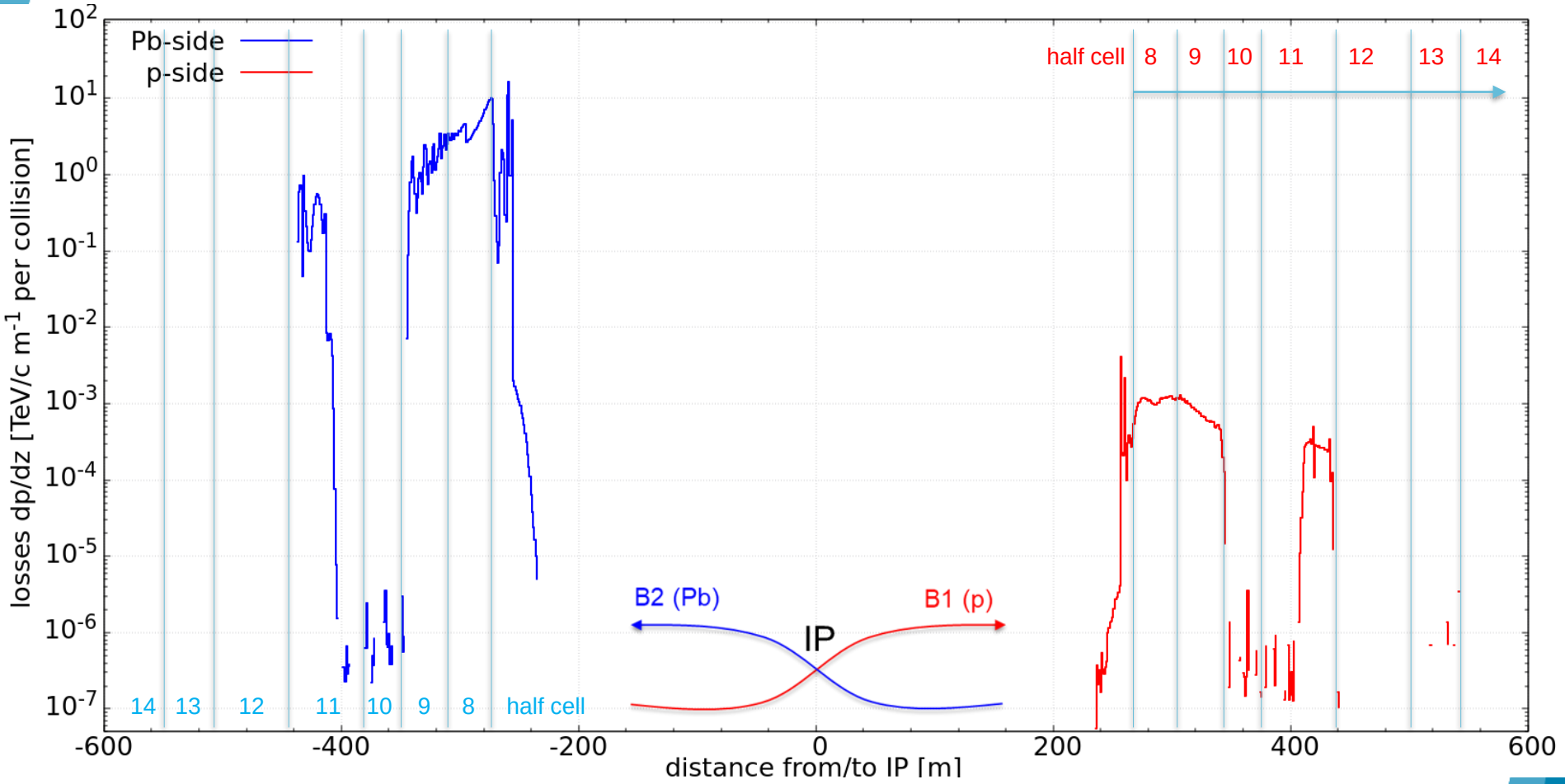


Baseline: TCL4, TCL5 and TCL6 are closed at 14σ

Losses in the DS for p-Pb operation

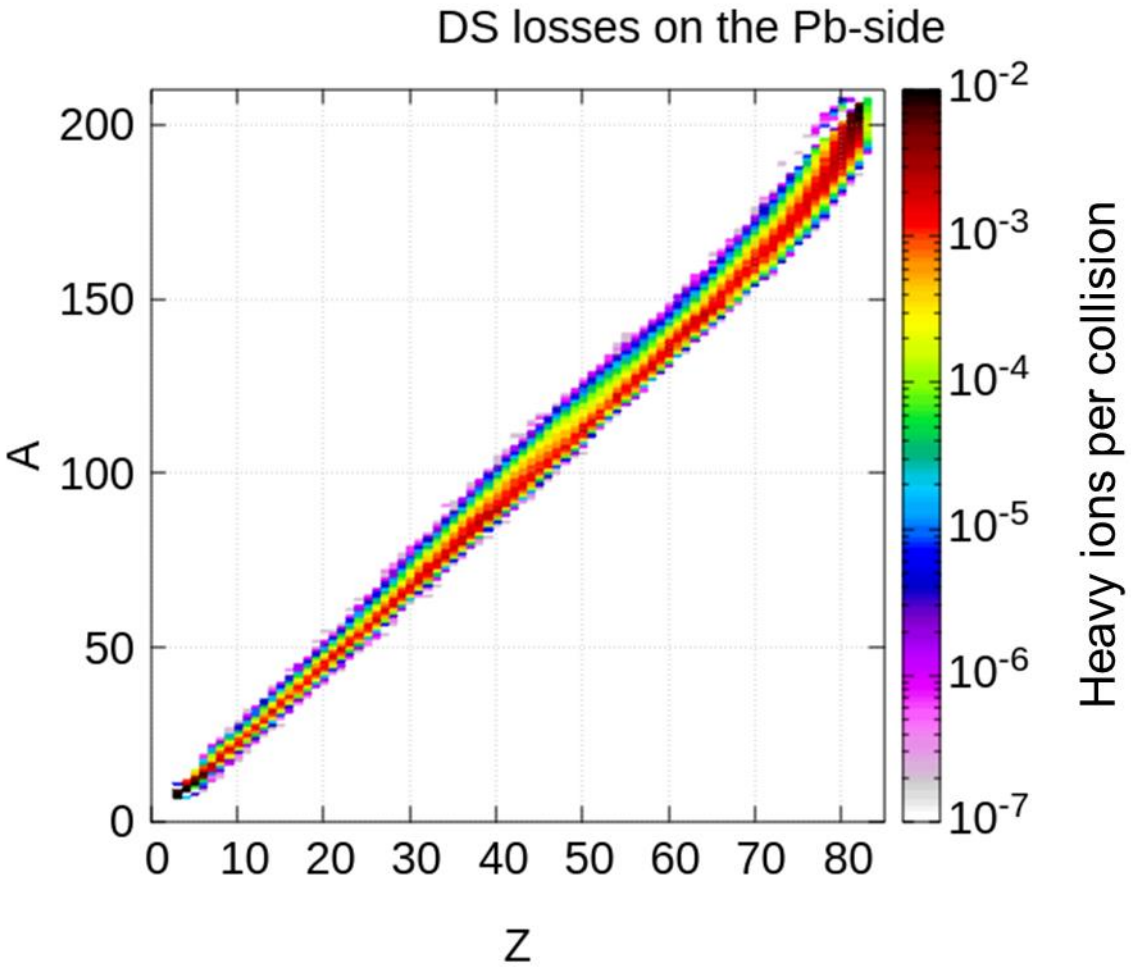
- HL-LHC optics v1.5 (May 2019):
  - IR1 right and left side.
  - $\beta^* = 0.5$ m
- p (B1) – Pb (B2) collisions:
  - +170 μrad half crossing angle in the vertical plane.
  - Energy per beam $7 \cdot Z$ TeV → $\sqrt{S_{NN}} = 8.8$ TeV.
- Collimators settings: assuming all TCLs open.
- Values normalized to 0.6 pb^{-1} integrated luminosity, for 1 month of operation.
- Instantaneous luminosity: 10^{30} cm^{-2} s^{-1}.
- Inelastic nuclear interactions are the dominant process in p-Pb collisions (σ = 2.11 b).

Losses in the DS for p-Pb operation

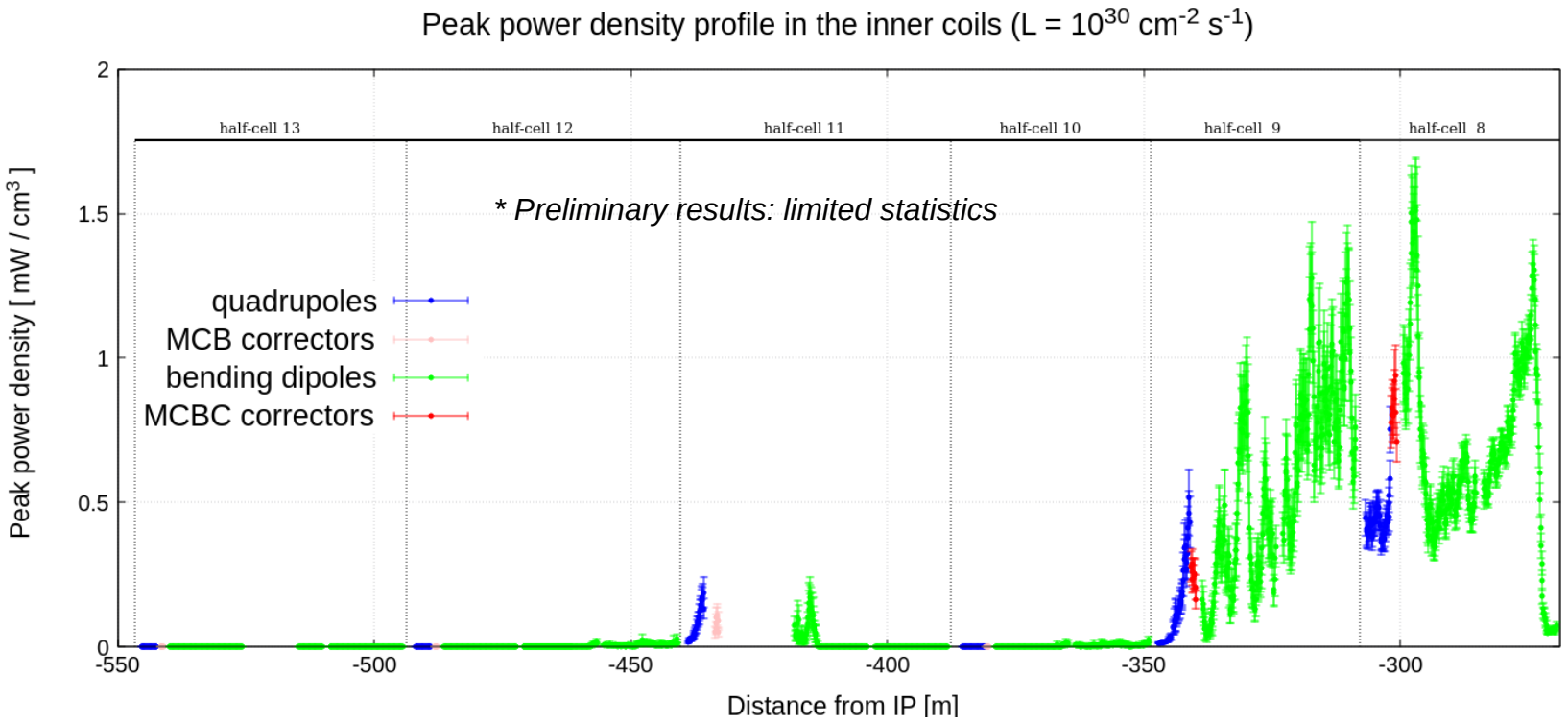


Losses in the DS for p-Pb operation

The most abundant species among the losses is **tritons**, which are not indicated in the plot.



Losses in the DS for p-Pb operation



- Closing the TCL6 will help cleaning the losses in half-cell 8 and 9.
- There is no threat for operation: peak power density below the quench limit for this L.
- The peak dose reaches 0.05 MGy in the MCBC9 coils and 0.15 MGy in the MCBC8 ones for an integrated luminosity of 0.6 pb^{-1}. The latter will be strongly reduced by closing the TCL6.

Outlook

- Background studies.
- Possible forward physics detector implications.

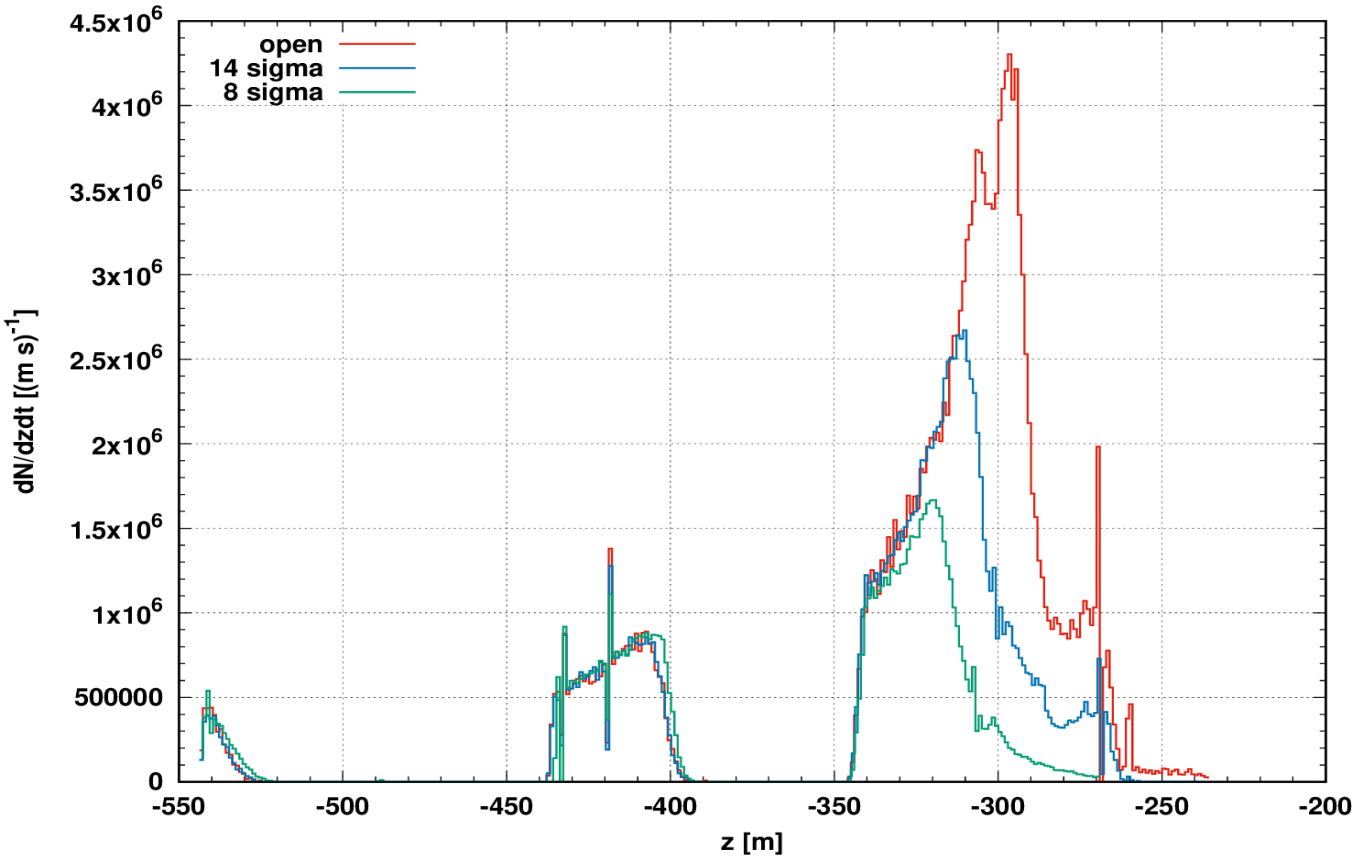
Thank you for your attention

Important input from:

R. Bruce, R. De Maria, M. Ferrari, P. Fessia, R. Garcia Alia, L. Gentini, A. Lechner, G. Lerner, F-X Nuiry, S. Redaelli, D. Senajova

Losses in the DS for p-p operation

Impact in the losses of different TCL6 aperture settings



Losses in the DS for p-Pb operation