HL-LHC radiation levels on alignment systems in the LSS of IP1-IP5
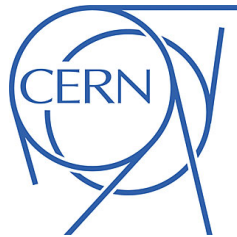
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With input from A.Tsinganis

EN-STI-BMI, HL-LHC WP10

27 August 2019

Content

- Expected HL-LHC radiation levels on alignment systems in the LSS of IP1-IP5.

- Results based on two versions of FLUKA simulations:
  - HL-LHC simulation by A.Tsinganis with **optics v1.3**, vertical/horizontal crossing plane in IP1/IP5 respectively, and TCL4-TCL5-TCL6 at 14σ.
  - HL-LHC simulation by M.Sabaté Gilarte with **optics v1.5** and many layout updates, only available for IP1 with horizontal crossing.

- The following equipment is examined:
  - Jacks for magnets/TAXN/crab cavities.
  - TCTPXV-TCTPXH-TCLPX collimator motors, Q4-Q5 masks, BPM after D1.
  - WPS-HLS systems, crab cavity reflectors.
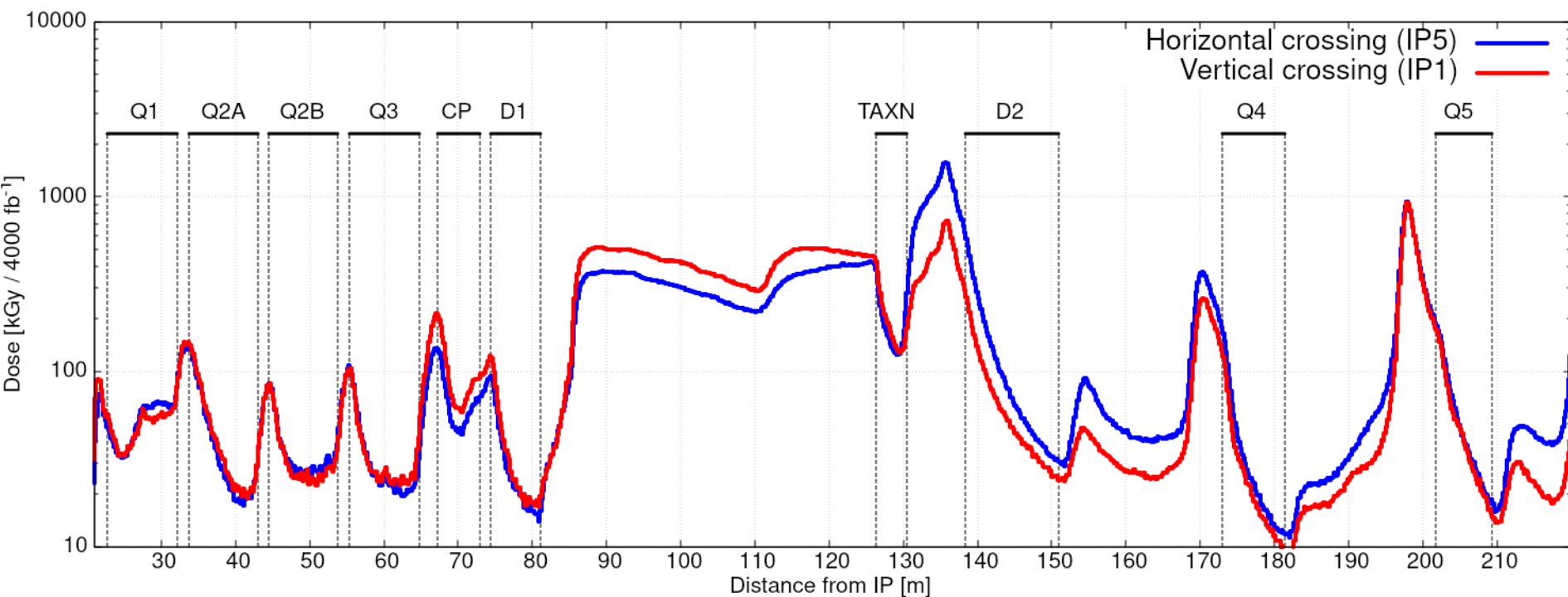
Jacks for magnets, TAXN, crab cavities

- Jacks located below the corresponding elements along the beamline.

- TID levels based on FLUKA simulation with optics v1.3, in a central x position ([-20,20] cm) below the beam (y range [-90,-70] cm).

- Results shown as TID profile as a function of the distance from the IP (see next slide).
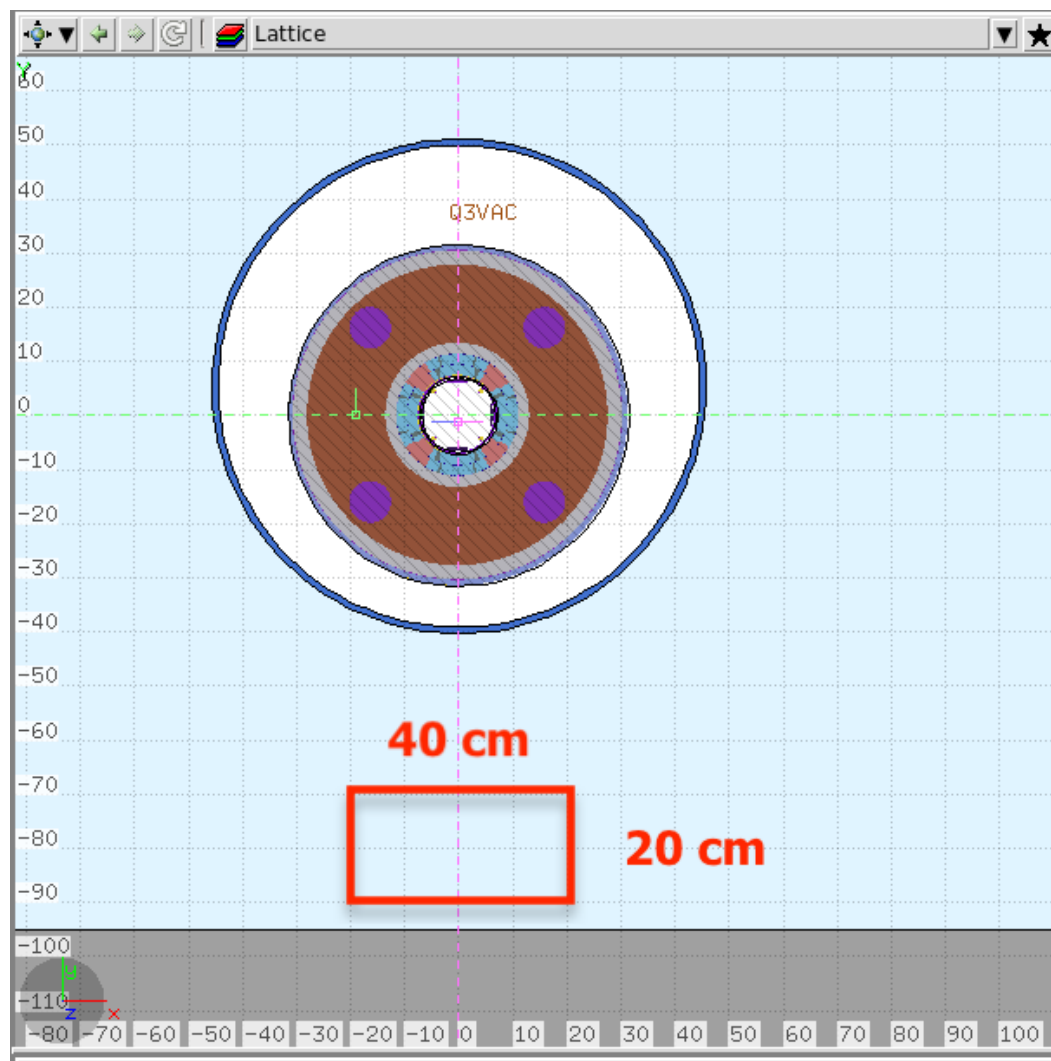
Jacks for magnets, TAXN, crab cavities

- Profile of TID vs distance from IP1-IP5 below the beamline, as shown in slide 3, for the ultimate HL-LHC scenario (4000 fb^{-1}).

- Irregular TID profile due to optics, absorbers, collimators, shielding of magnet cold masses, etc. Highest TID reached between TAXN and D2 for horizontal crossing.

Total HL-LHC dose 80cm below the beam in the LSS of IP1 and IP5

Jacks for magnets, TAXN, crab cavities

- Summary of HL-LHC TID levels on support jacks for 4000 fb^{-1}, obtained as the maxima below the corresponding elements.

Main element	Expected TID [kGy]	Main element	Expected TID [kGy]
Q1	80	TAXN	500
Q2A	150	D2	600**
Q2B	100	Crab cavities	90***
Q3	120	Q4	175
CP	220*	Q5	190
D1	120		

*220 kGy for vertical xing, 150 kGy for horizontal xing

**600 kGy for horizontal xing, 300 kGy for vertical xing

***90 kGy for horizontal xing, 50 kGy for vertical xing

- The TID levels can differ elsewhere (e.g. in the interconnections).

- For reference, higher TID levels on support jacks are expected in other areas, e.g. up to 10 MGy for the SPS dump TIDVG5 (see EDMS 2135822).
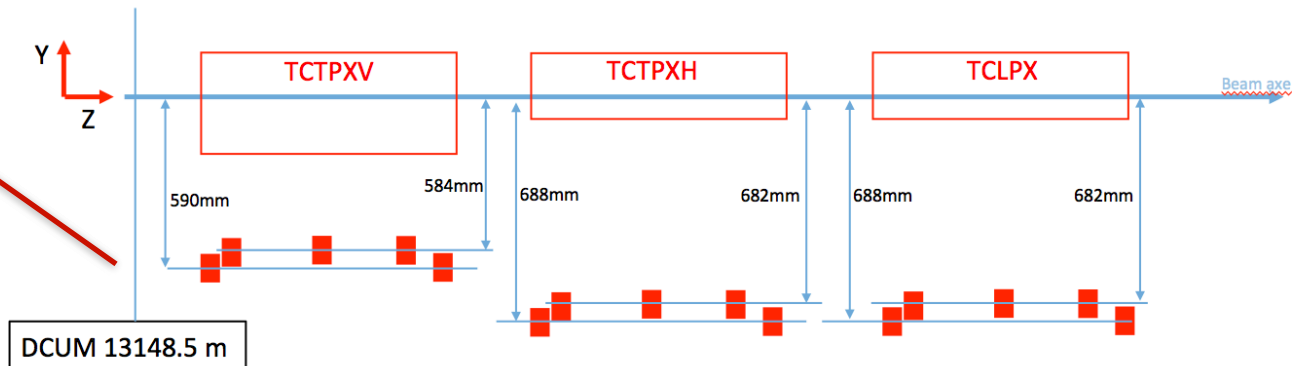
TCTPXV-TCTPXH-TCLPX collimators

- TCTPXV-TCTPXH-TCLPX collimator motors located between the TAXN and the D2. Layout and equipment location provided by Inigo Lamas García.
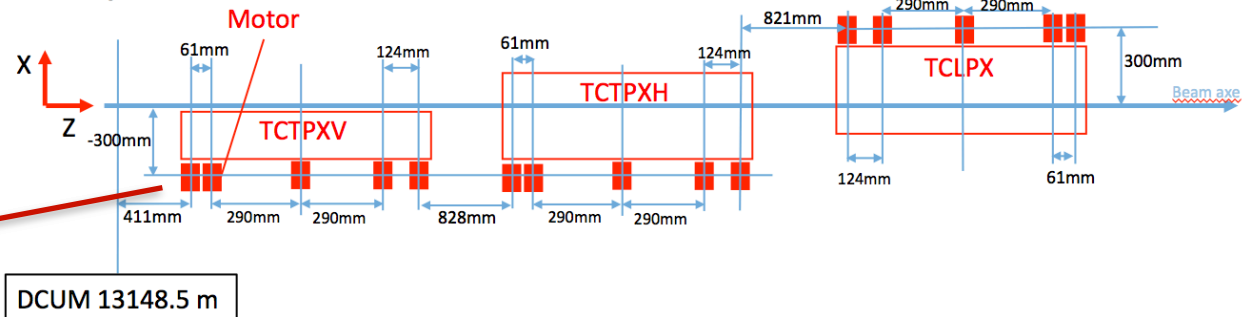

~30 cm on the two sides of the beam axis, ~60cm under it

FLUKA TID on collimators

- Profile of TID below the collimators from FLUKA with optics v1.5 (hor crossing) 60 cm below the beamline, with stainless steel collimator boxes (not present in the optics v1.3 simulation).

- Upper TID limit at collimator motor height: **1MGy** / 4000 fb^{-1}. Lower TID expected in IP5 (vertical crossing).

Total HL-LHC dose 60cm below the TCTPXV-TCTPXH-TCLPX collimators
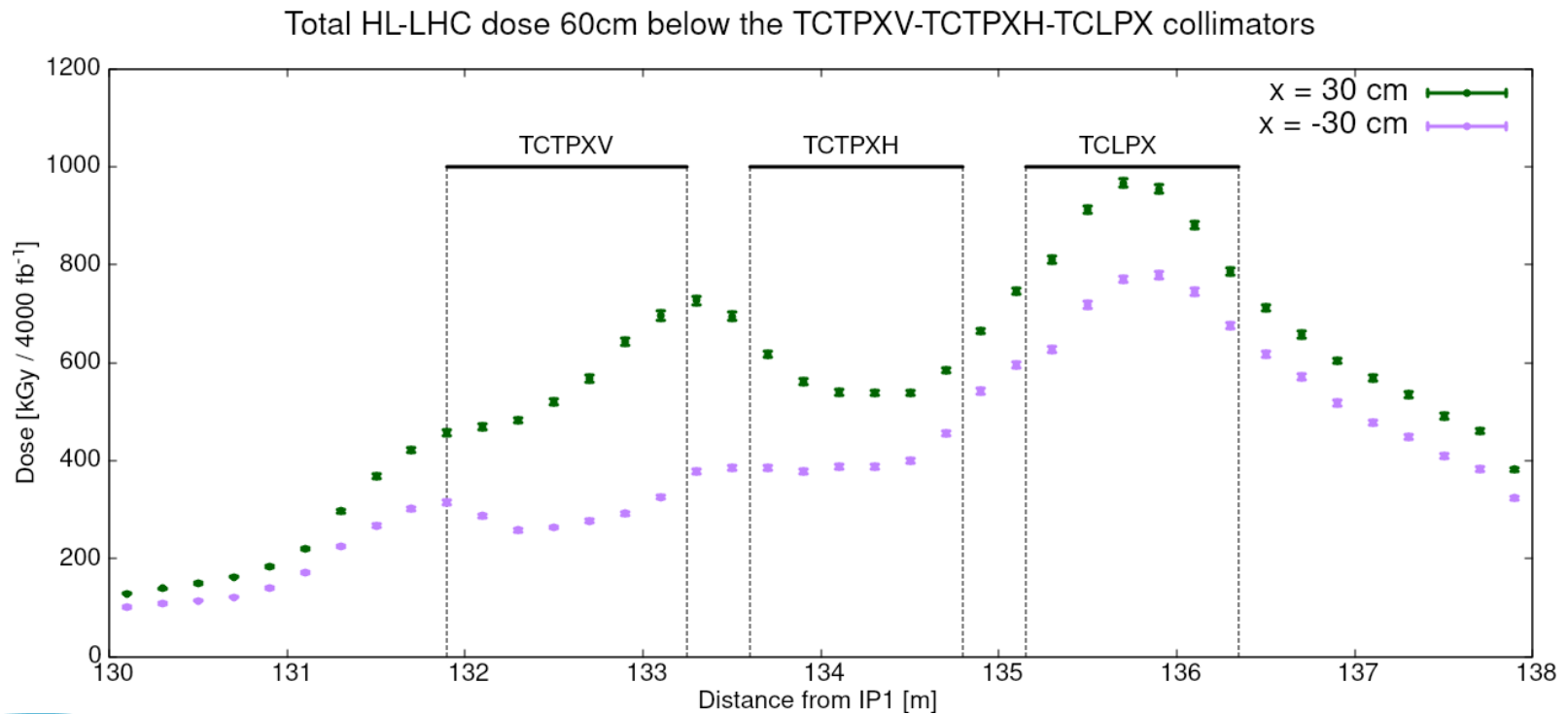
TID on Q4-Q5 mask alignment system

- Remote alignment systems for the masks located before Q4-Q5.

- No design available yet → 2D x-y profiles of TID at the position of the masks obtained with FLUKA with optics v1.3 for horizontal crossing (lower levels expected for vertical crossing).

- Higher levels for Q4, with strong radial gradient in both cases. Upper limit of **~700 kGy** / 4000 fb^{-1}, 40cm below the Q4 mask.

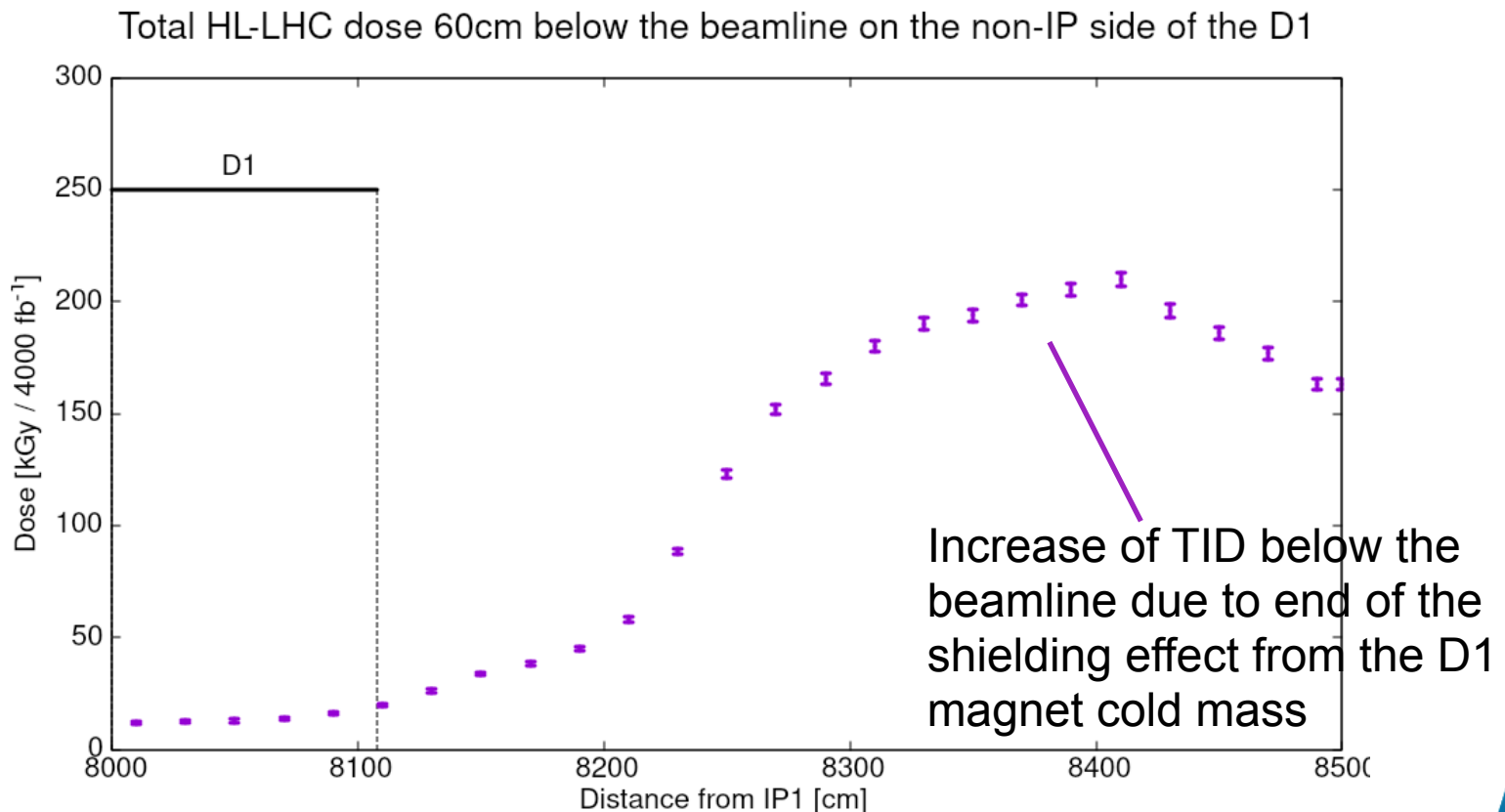x-y profile of the total HL-LHC dose at the position of the Q4 mask, hor crossing
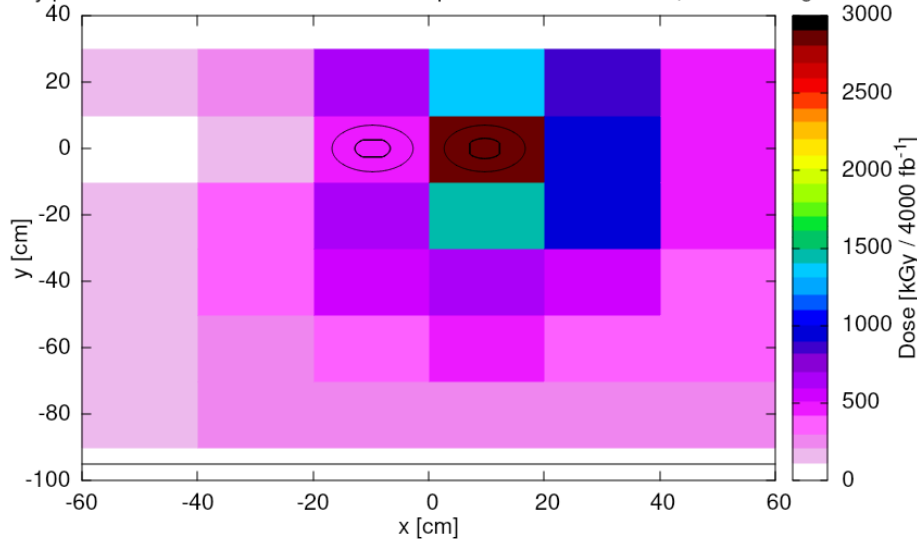
x-y profile of the total HL-LHC dose at the position of the Q5 mask, hor crossing
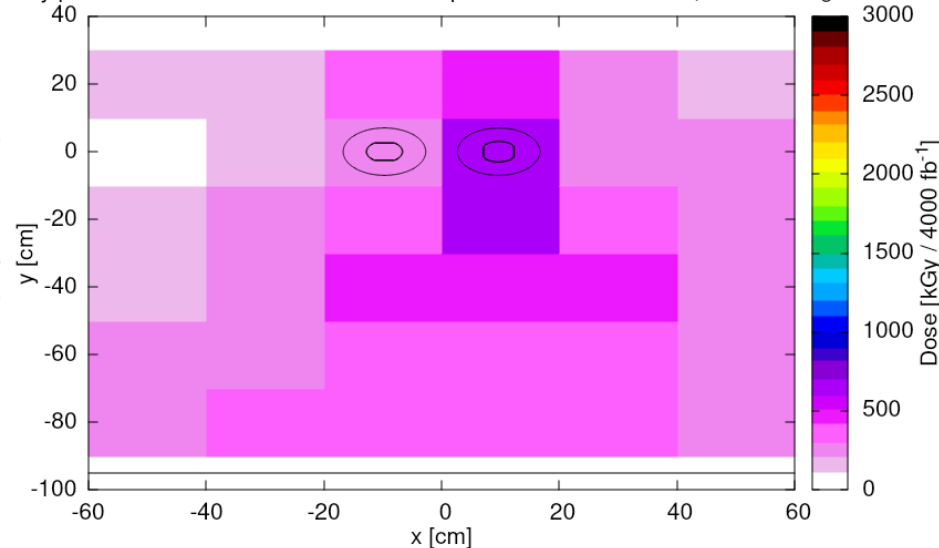
BPM after D1 - TID on alignment system

- The BPM located just after the D1 magnet could be remotely aligned (no official plan/design yet).

- FLUKA (optics v1.5) TID vs distance from IP1 at the end of D1 ~60cm below the beam. The TID grows rapidly with z reaching ~**200 kGy** / 4000 fb^{-1}.

Total HL-LHC dose 60cm below the beamline on the non-IP side of the D1

Increase of TID below the beamline due to end of the shielding effect from the D1 magnet cold mass

WPS and HLS systems

- The Wire Positioning System (WPS, shown in blue below) and Hydraulic Levelling System (HLS, in green) are located above the beamline all along the LSS.

- Peak TID of **~1 MGy** / 4000 fb^{-1} above TCL4, similarly to what seen below the beamline in slide 7. Details in backup.
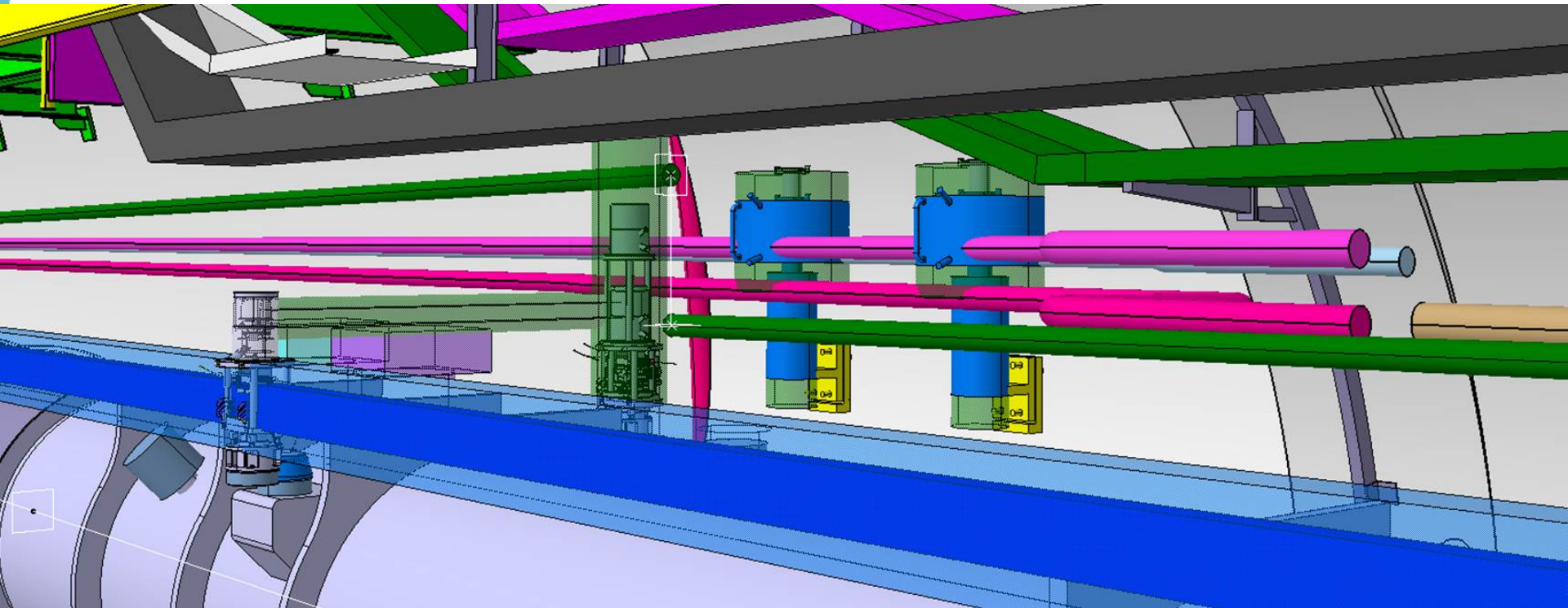
Reflectors on crab cavities

- Request by M.Sosin: crab cavity reflectors at ~10cm from the beam axis and ~5cm from the titanium surface of the He tanks.

- TID scoring available in the simulation with optics v1.5, on the x-y Titanium surfaces - good approximation of the reflector position.
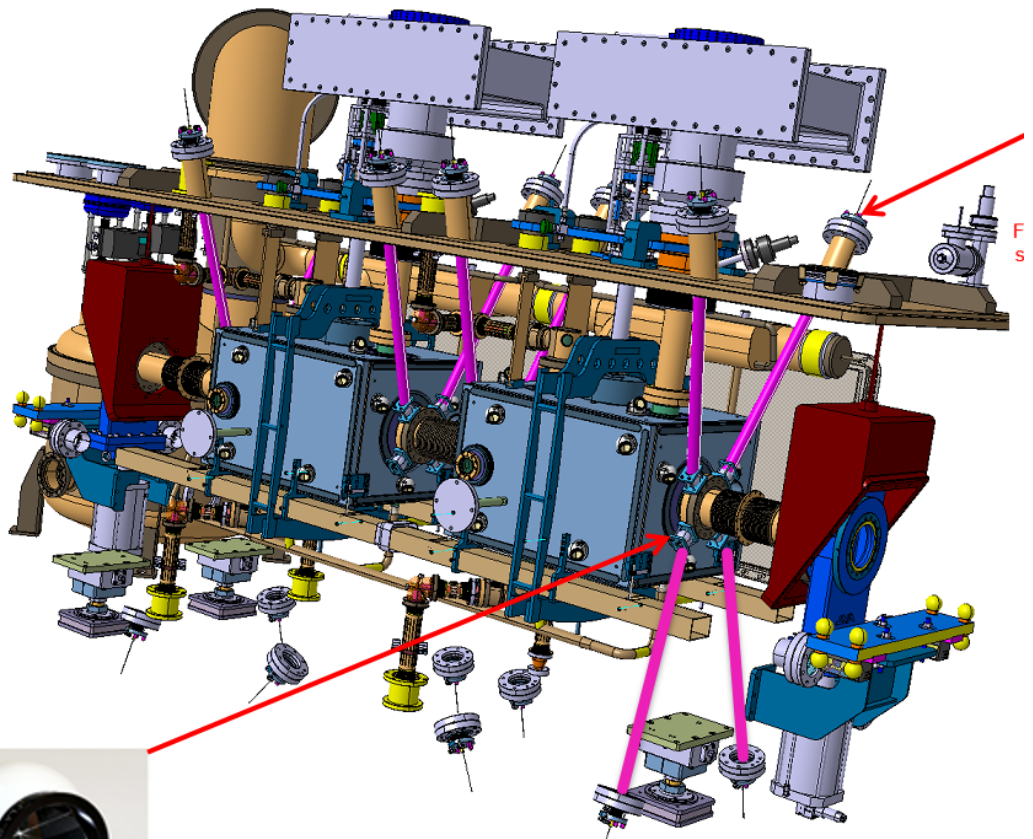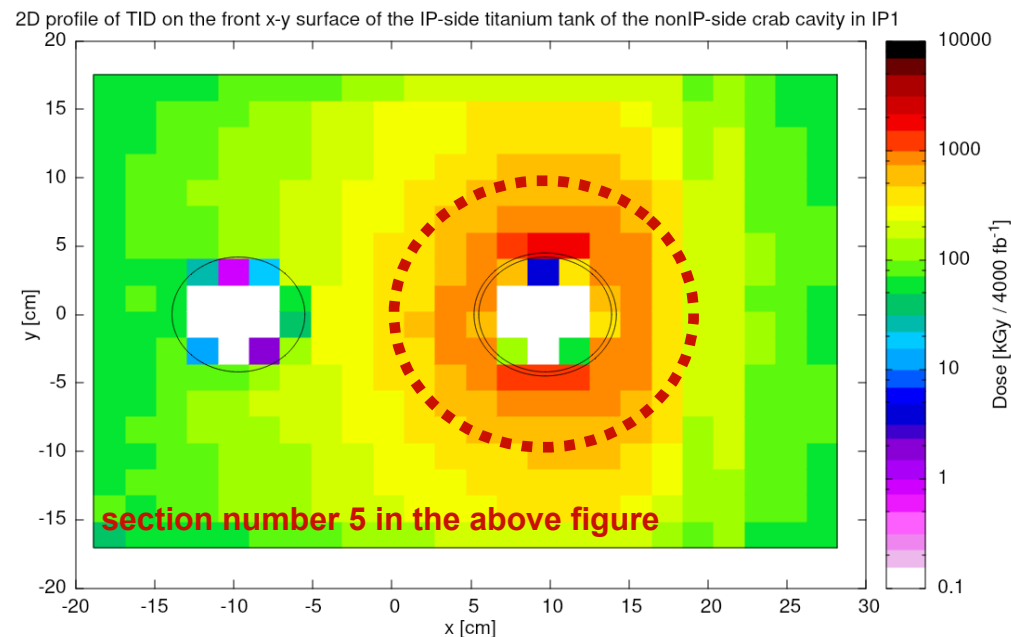

Input from M.Sosin

Reflectors on crab cavities: FLUKA results

- TID scored on the 8 x-y titanium surfaces of the two crab cavities.

Top view of the crab cavities in the FLUKA geometry
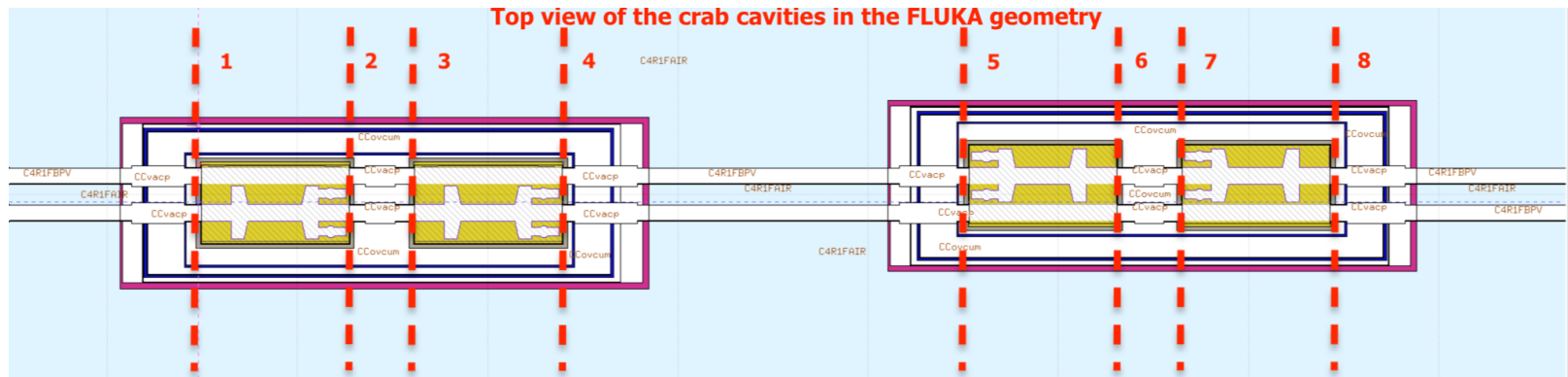
- Highest TID levels reached on faces 3 and 5 (shown on the right).

- Upper limit on the total TID at ~10cm from the beam pipe of interest: **~1 MGy** / 4000 fb[-1].

2D profile of TID on the front x-y surface of the IP-side titanium tank of the nonIP-side crab cavity in IP1

section number 5 in the above figure

Summary and R2E-R2M implications

- The peak TID levels on the alignment systems in the LSS of IP1 and IP5 are found to be in the **100 kGy - 1MGy range** for the ultimate HL-LHC scenario (4000 fb^{-1}).

- No active electronics is involved → the main concern is material degradation, e.g. polymers, grease.

- The Radiation to Materials (**R2M**) Work Package within the R2E project supports the evaluation and testing of radiation damage on materials for non-intercepting beam devices, including the coordination of irradiation campaigns at equipment and full system level:

  - *WP leader:* Marco Calviani.

  - *Activity supervisor:* Keith Kershaw.

  - *Technical Responsible:* Matteo Ferrari (as of September 1st).

  - *Contact e-mail:* r2m-radiationtomaterials-support@cern.ch

  - *Recent indico event:* https://indico.cern.ch/event/814752/

BACKUP

BPM after D1 - TID on alignment system

- Lateral view of FLUKA (optics v1.5) TID profile at the end of D1. Position of interest ~60cm below the beam. The TID level grows rapidly with z, reaching ~300 kGy / 4000 fb^{-1} at ~83m from the IP.

Side view of the region at the end of the D1 magnet, superimposed to FLUKA TID

Cold diode vacuum vessel

D1 cryostat
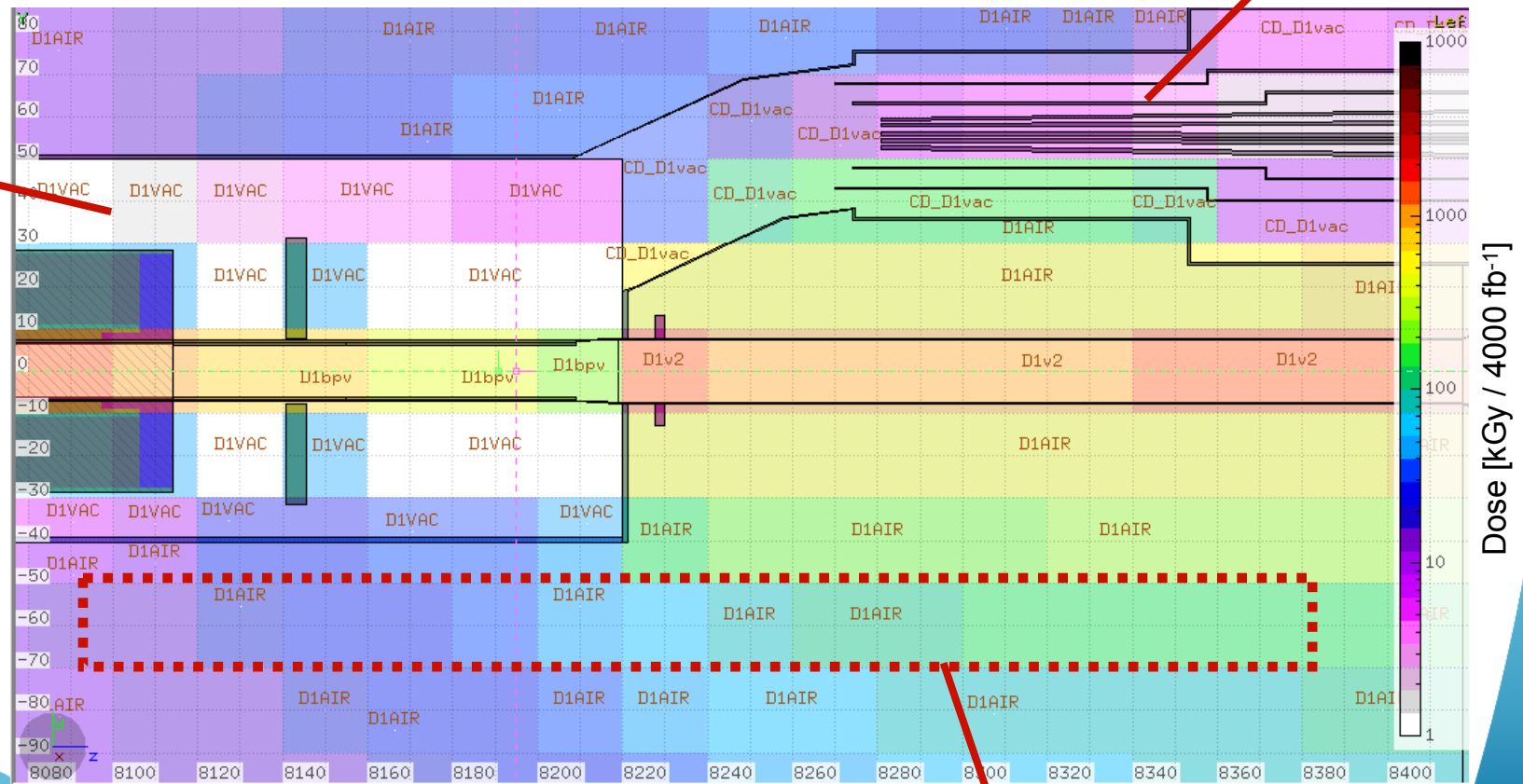
tentative longitudinal position of BPM

WPS and HLS systems: FLUKA with optics v1.3

- Optics v1.3, TID vs distance from the IPs, 60 cm above the beamline, to set upper limits on the levels on WPS-HLS systems.

- TID peak of ~2.5 MGy / 4000 fb^{-1} for horizontal crossing above TCL4, where the v1.3 simulation doesn't include the collimator box. A more accurate estimate can be obtained with the optics v1.5 simulation (next slide).

Total HL-LHC dose 60cm above the beam in the LSS of IP1 and IP5
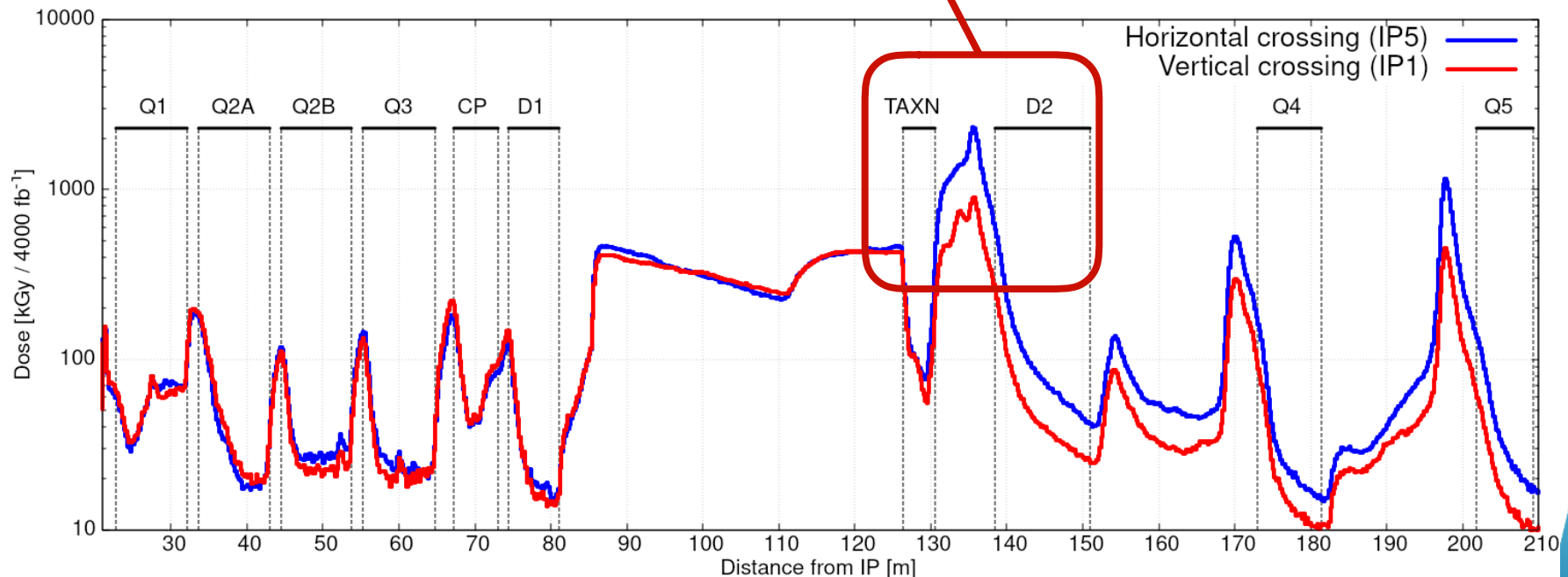
WPS and HLS systems: FLUKA with optics v1.5

- The optics v1.5 simulation includes the collimator box and allows to place an upper TID limit of ~**1MGy** / 4000 fb[-1] at the WPS-HLS position (~same pattern seen below the beam in slide 7).

Total HL-LHC dose 60cm above the beamline at the position of the TCTPXV-TCTPXH-TCLPX collimators