Radiation levels in the IR3-IR7 tunnel and shielded alcoves

WP10
Energy Deposition & R2E

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with input from C.Bahamonde Castro, K.Bilko

Review of HL-LHC radiation level specification document
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Introduction

- The IR3 and IR7 regions of the LHC host the momentum and betatron collimator systems.
- The levels are not anymore driven by the integrated luminosity: the primary source are the lost protons in the collimators, that can scale with different quantities.
- We normalise the levels in these regions with integrated beam intensity. Annual values for Run 2 and HL-LHC:

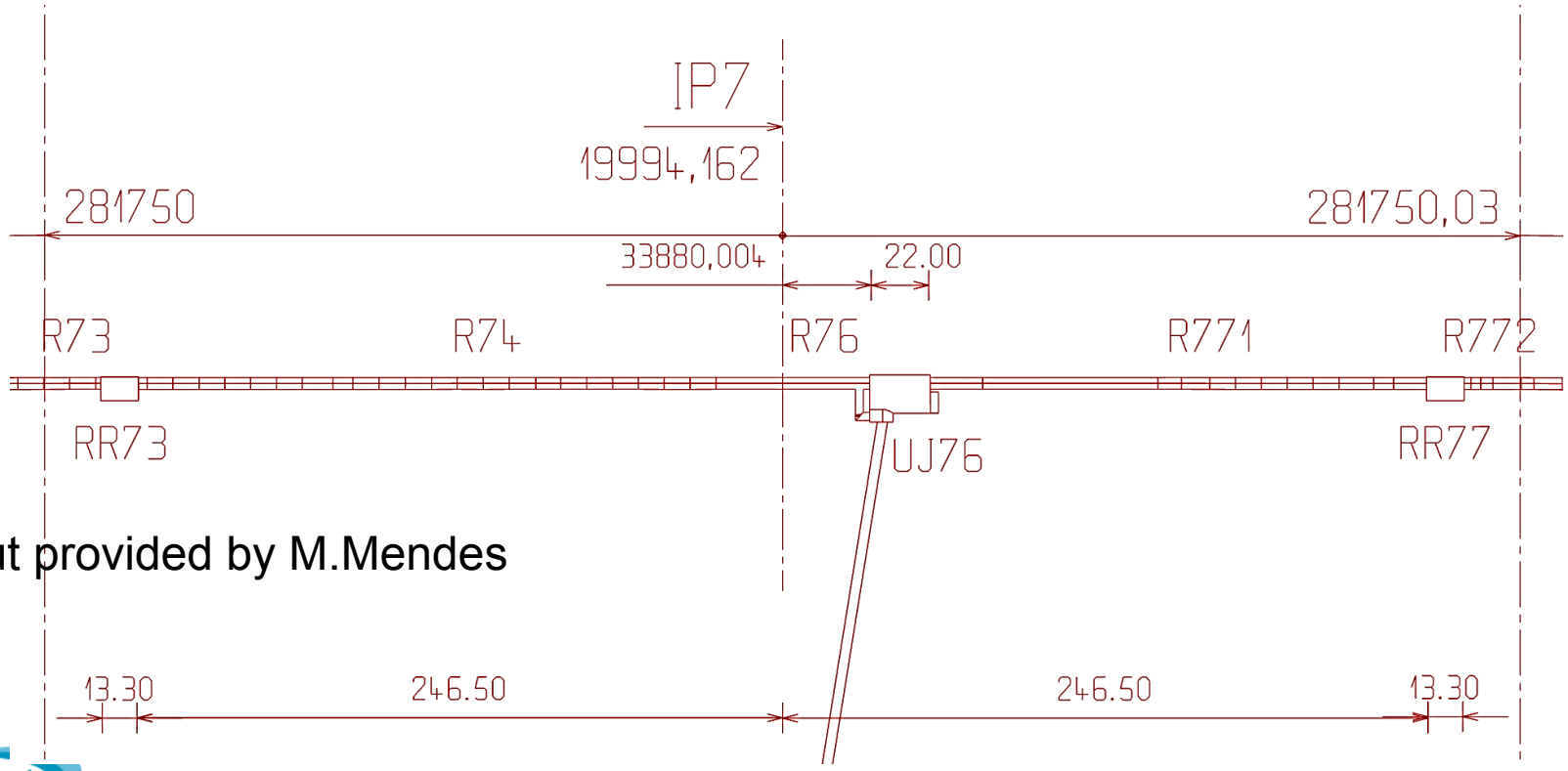
	Integrated beam intensity (beam 1 + beam 2)
2015	7.1×10^{20} ps/yr
2016	2.6×10^{21} ps/yr
2017	2.51×10^{21} ps/yr
2018	3.06×10^{21} ps/yr
HL-LHC	8×10^{21} ps/yr

IR7: loss scaling and post-LS2 layout

- From Run 2 measurements we know that the radiation levels in IR7 are dominated by proton runs.
- The number of lost protons in the primary IR7 collimators was measured to be ~1-2·10^{15} per beam in 2016 and 2017, and grew to ~5·10^{15} per beam in 2018 (see talk at 77th TCC).
- Assuming integrated intensity scaling, the number of lost protons per beam in IR7 ranges between ~5·10^{16} and ~2·10^{17}. At present we take **1·10^{17} lost protons per beam** as our baseline estimate for the **full HL-LHC**.
- Main layout update in IR7: installation of new TCLD collimators and 11T magnets in half-cell 9 (see talk by C.Bahamonde Castro at 62nd TCC).

IR7: HL-LHC radiation level specification strategy

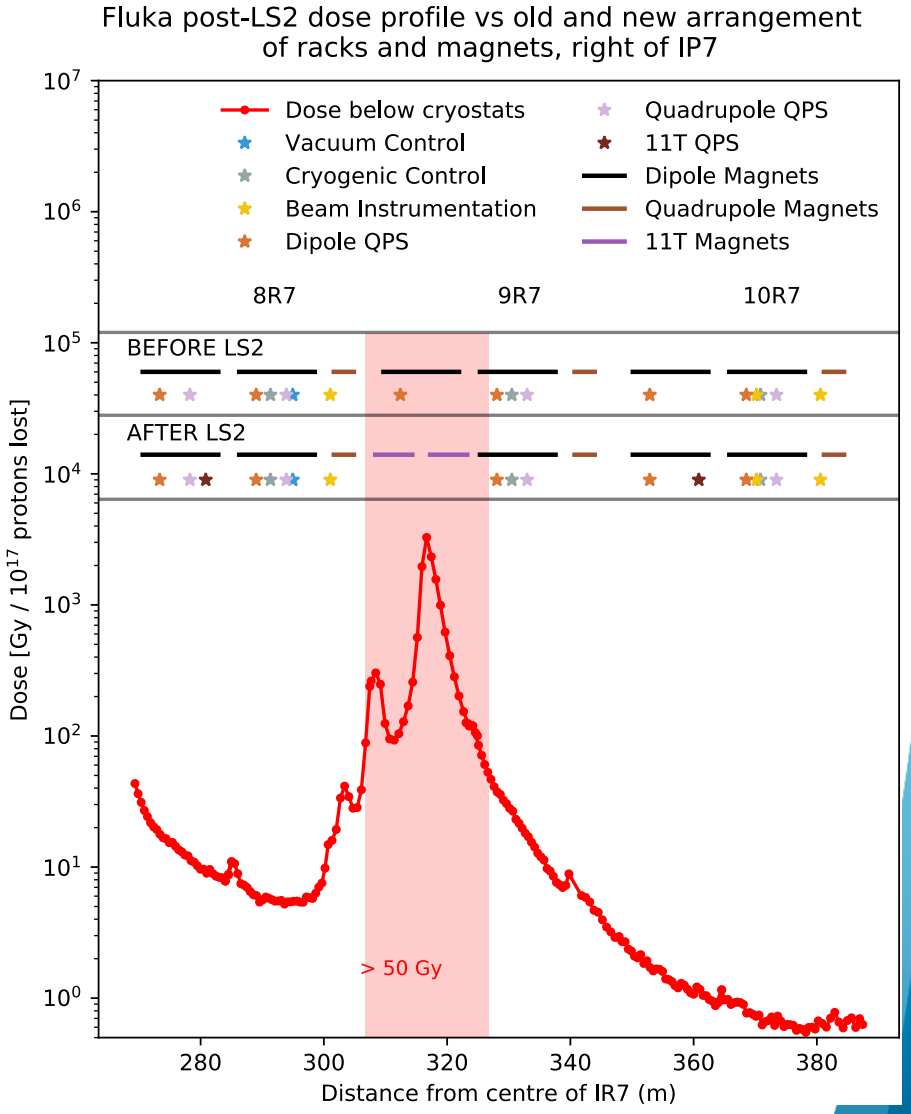
- Shielded alcoves (RR73-77, UJ76): RadMon measurements from Run 2 (2018) scaled with integrated beam intensity.
- DS: FLUKA simulation of TCLD losses normalised to $1 \cdot 10^{17}$ lost protons.



layout provided by M.Mendes

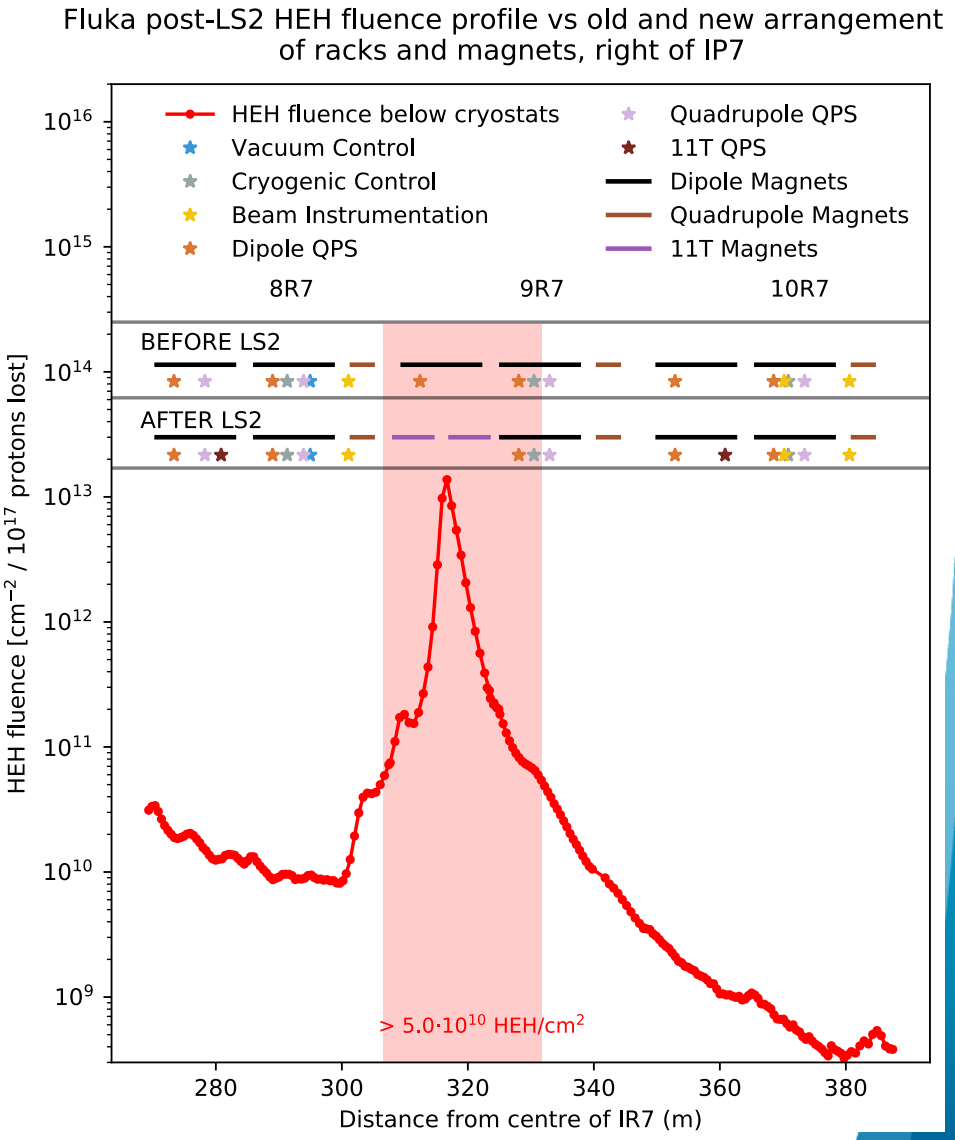
IR7 DS: FLUKA TID at floor level

- FLUKA simulation by C.Bahamonde Castro: TID at floor level in half-cells 8-10 for $1 \cdot 10^{17}$ lost protons in the primary IR7 collimators.
- Rack relocation strategy currently in place, taking into account an exclusion area around the TID peak.
- Left side of IR7 (same simulation, different rack positions) in backup.



IR7 DS: FLUKA HEH fluence at floor level

- The FLUKA simulation of HEH fluence shows a similar peak structure around the TCLD collimator, as expected.
- Compared to TID, the peak is slightly larger.
- Again, the left side of IR7 (with the corresponding rack relocation strategy) is shown in the backup.



IR7 DS: HL-LHC specifications

- The DS tunnel specifications are based on the A-B-C-D radiation level categories already used for IR1-IR5-IR8.
- They apply to both left and right of IR7.
- A safety margin is applied due to the uncertainty on the normalisation.
- Arc-like levels (i.e. negligible levels from TCLD losses) from z=365m onwards.

	z (distance from IP) range	Radiation level category
half-cell 8	$268 < z < 280$	B
	$280 < z < 300$	A
	$300 < z < 308$	B
half-cell 9	$308 < z < 312$	C
	$312 < z < 325$	D
	$325 < z < 328$	C
	$328 < z < 335$	B
	$335 < z < 348$	A
half-cell 10	$348 < z < 365$	A
	$365 < z < 387$	arc-like
half-cell 11	all	arc-like
half-cell 12	all	arc-like
half-cell 13	all	arc-like

IR7 shielded areas

- RR73-77 and UJ76 are located along the LSS of IR7, where the installation of the new TCLD collimators will not play a role
  → HL-LHC specifications can be extracted from Run 2 RadMon measurements scaled with integrated beam intensity.
- To be conservative, we use as reference the 2018 RadMon measurements (i.e. we select the year from Run 2 year with the highest number of lost protons, which translates in the highest radiation levels per unit integrated beam intensity).

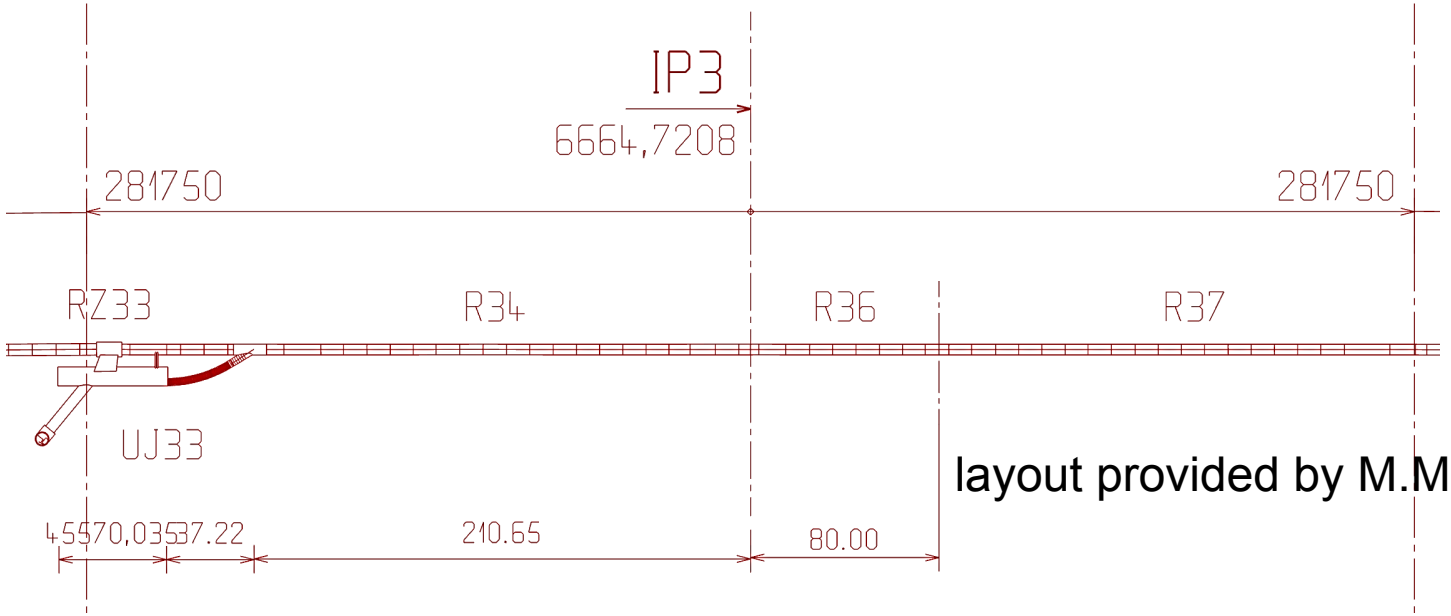
IR7 shielded areas: annual HL-LHC specifications

- Same specification for RR73-77, but different for L0 and L1 (similarly to what we did for the IR1-IR5 ones). Note that here the difference between L0 and L1 is larger (a factor ~10) due to more shielding at L0 (thicker wall with L-shape).
- From a standard conversion for mixed-field accelerator environments (1Gy ≈ 10^9 HEH/cm^2) with a safety factor of 2 we obtain **TID specifications: 400 mGy/yr in RR73-77 (L0), 4 Gy/yr in RR73-77 (L1), 1 Gy/yr in UJ76**.

	RadMon	2018 HEH (cm^{-2})	HL-LHC HEH (cm^{-2}/yr)
RR73-77 (L0)	SIMA.RR73.7LM05S	$6.6 \cdot 10^7$	$2 \cdot 10^8$
RR73-77 (L1)	SIMA.RR73.7LM21S	$6.4 \cdot 10^8$	$2 \cdot 10^9$
UJ76	SIMA.UJ76.7RM01S	$1.7 \cdot 10^8$	$5 \cdot 10^8$

IR3 layout and specification strategy

- From Run 2 we know that the levels in IR3 are generally lower than in IR7, and the scaling with integrated beam intensity worked well in the past years of operation.
- We extract HL-LHC specifications from Run 2 BLM and RadMon measurements scaled with integrated beam intensity, using the 2016 data as reference (as the levels per unit integrated beam intensity in 2016 were slightly higher than in 2017 and 2018).

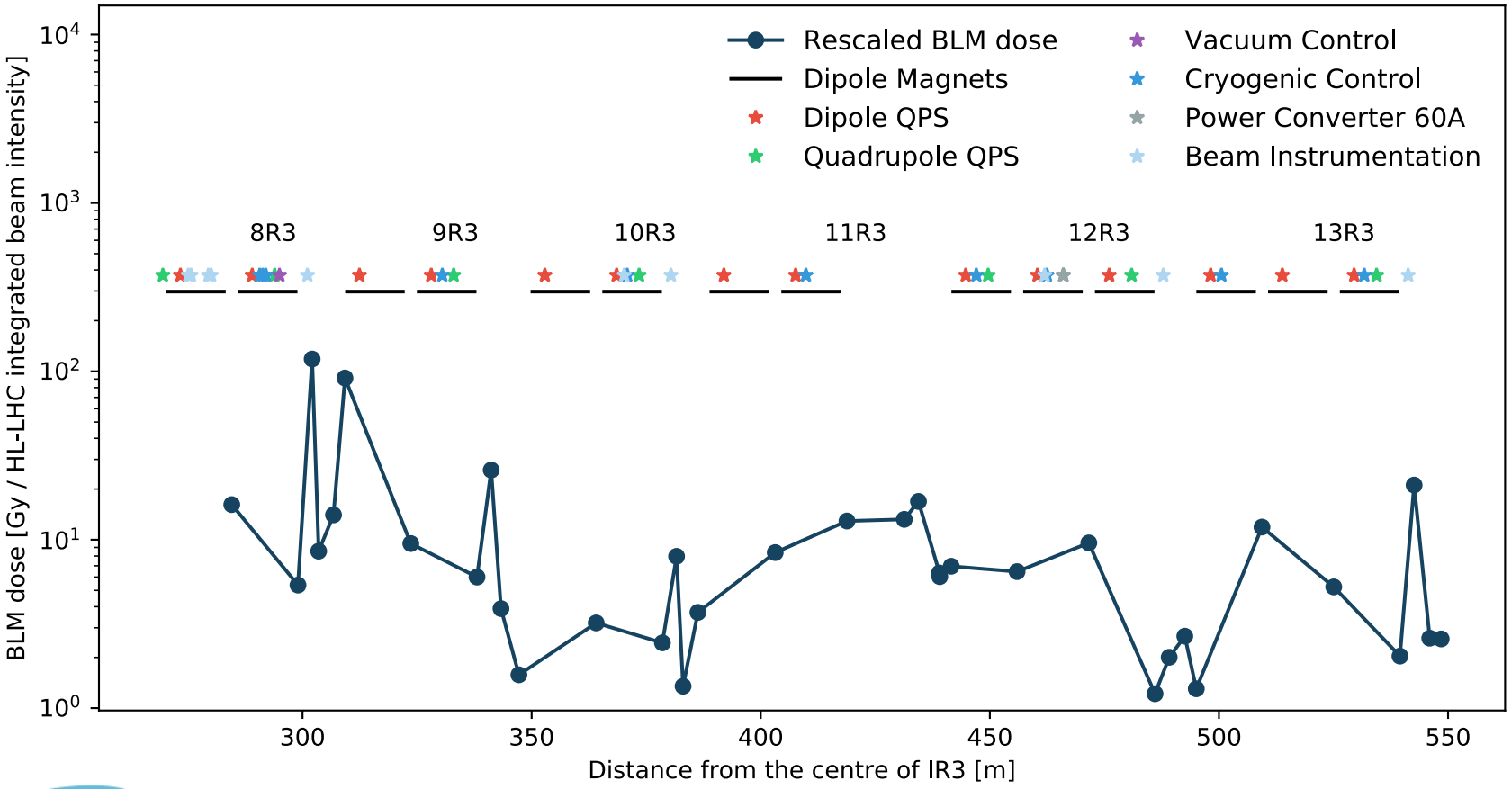


layout provided by M.Mendes

HL-LHC BLM TID profile in the DS of IR3

- BLM TID levels from 2016 in the DS of IR3, rescaled with integrated beam intensity to the full HL-LHC period (12 years).

BLM dose in proton runs in cells 8-13 right of IP3 in 2016 ($I_{tot}=2.6\cdot10^{21}$ ps) scaled to full HL-LHC ($I_{tot}=9.6\cdot10^{22}$ ps)



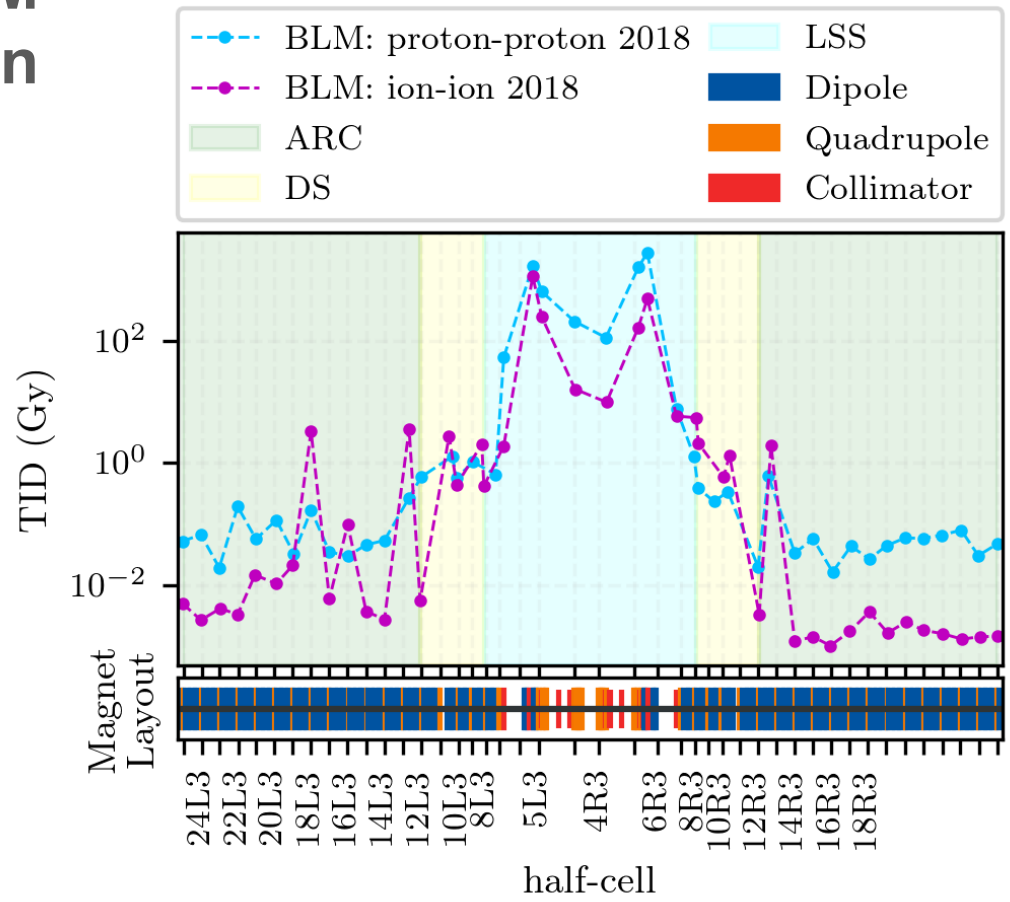
HL-LHC specifications in IR3

- HL-LHC specifications in the DS of IR3 (left-right) for the full HL-LHC period. Annual levels obtained by dividing them by a factor 12.
- Specifications derived from rescaled BLM TID levels and from RadMon HEH fluence measurements (one RadMon per DS half-cell, typically on the floor near the MB-MQ interconnection).
- No RadMon counts in Run 2 in **UJ33**→ we expect the area to be R2E-safe during HL-LHC operation.

	HL-LHC TID (Gy)	HL-LHC HEH (cm^{-2})
half-cell 8	100	$2 \cdot 10^{10}$
half-cell 9	50	$1 \cdot 10^{10}$
half-cell 10	20	$2 \cdot 10^{9}$
half-cell 11	30	$2 \cdot 10^{10}$
half-cell 12	20	$2 \cdot 10^{9}$
half-cell 13	40	$1 \cdot 10^{10}$

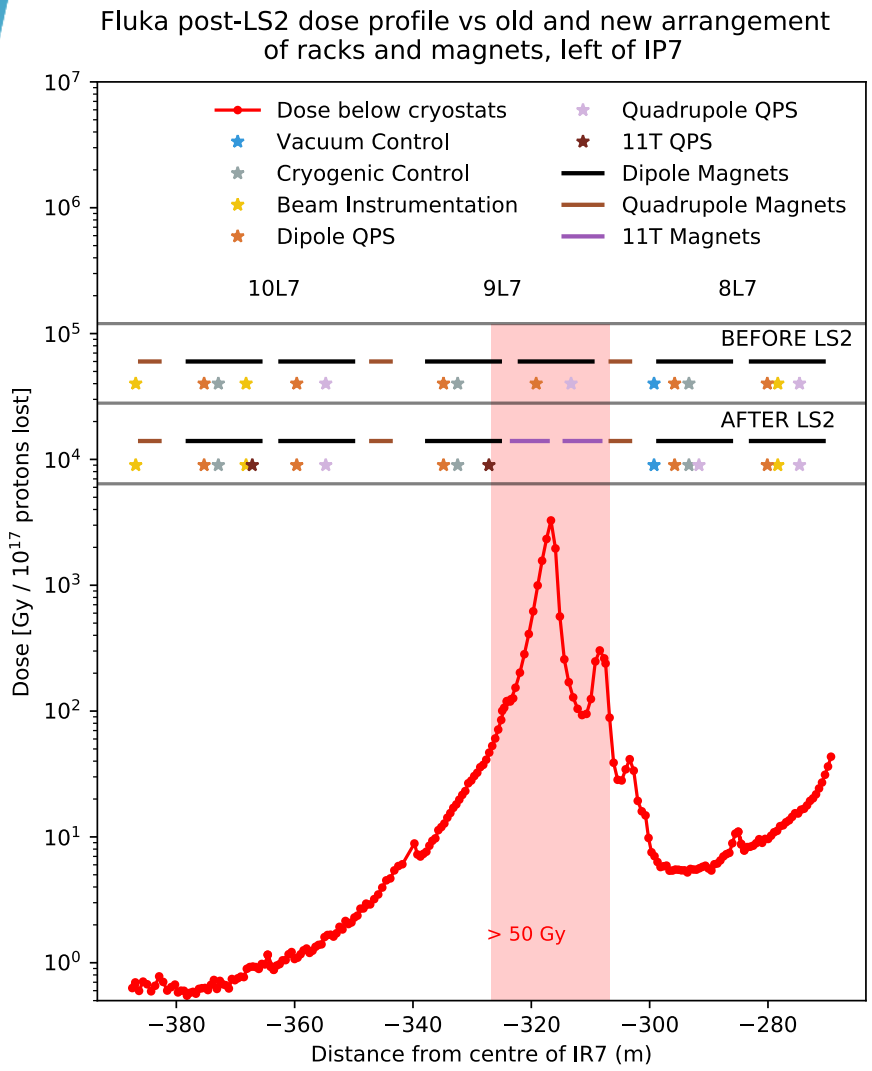
Final considerations on IR3 specifications

- So far we only considered proton runs, but it is not obvious that ion runs can be fully neglected: **in 2018 we observed similar BLM levels in IR3 in proton and ion operation** (possibly due to EMD beams reaching IR3).
- HL-LHC ion losses in IR3 are not trivial to estimate
  → further studies and considerations are needed.



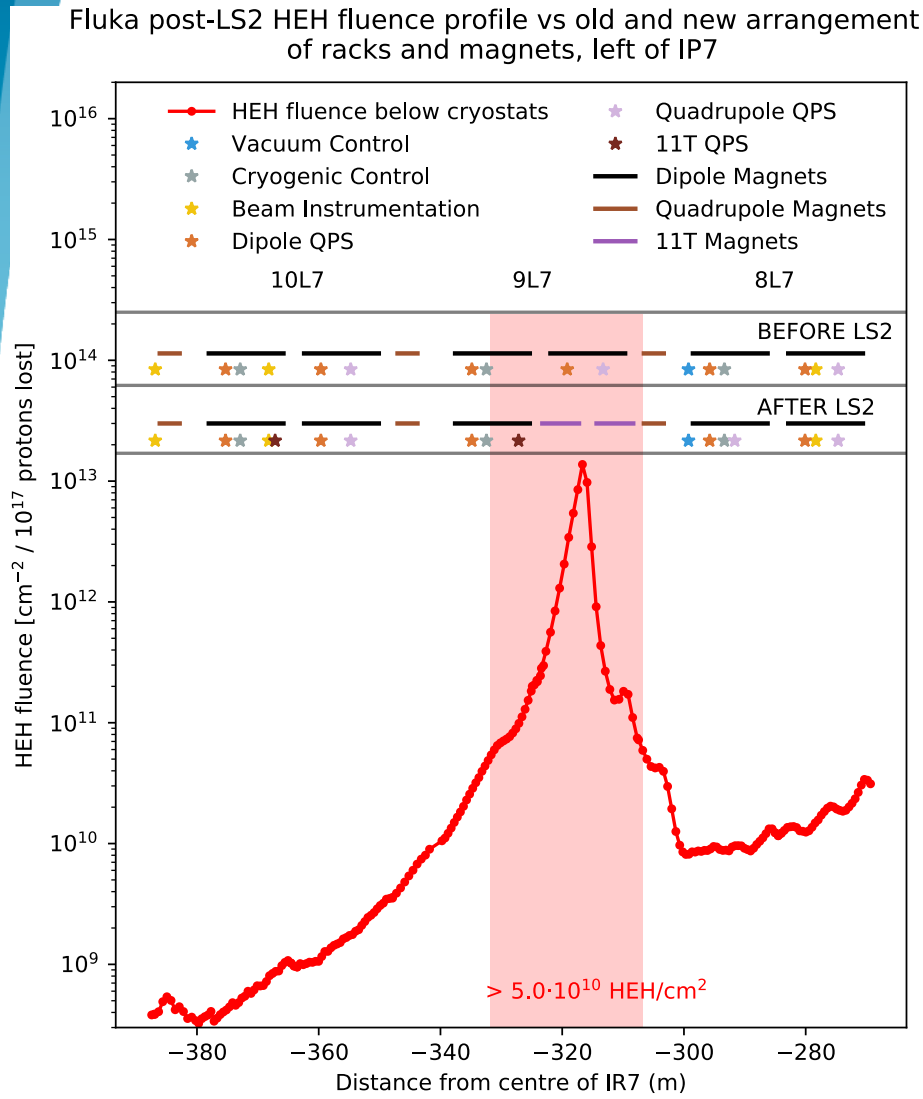
BACKUP

IR7 DS: FLUKA TID at floor level



- FLUKA simulation by C.Bahamonde Castro: TID at floor level in half-cells 8-10 for $1 \cdot 10^{17}$ lost protons in the primary IR7 collimators.
- Corresponding plot for the right side of IR7 shown in the main body of the presentation.

IR7 DS: FLUKA HEH fluence at floor level



- FLUKA simulation by C.Bahamonde Castro: HEH fluence at floor level in half-cells 8-10 for 1·10^{17} lost protons in the primary IR7 collimators.
- Corresponding plot for the right side of IR7 shown in the main body of the presentation.

IR3 BLM TID profile in the LSS

- BLM TID levels from 2016 in the LSS of IR3, rescaled with integrated beam intensity to the full HL-LHC period (12 years).