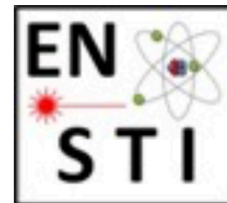
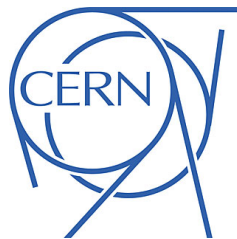




HL-LHC R2E levels in the DS areas of the high luminosity IRs (including option for shielding in LSS)

WP10
Energy Deposition & R2E



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with input from A.Tsinganis, A.Cerutti, A.Ciccotelli, L.Esposito

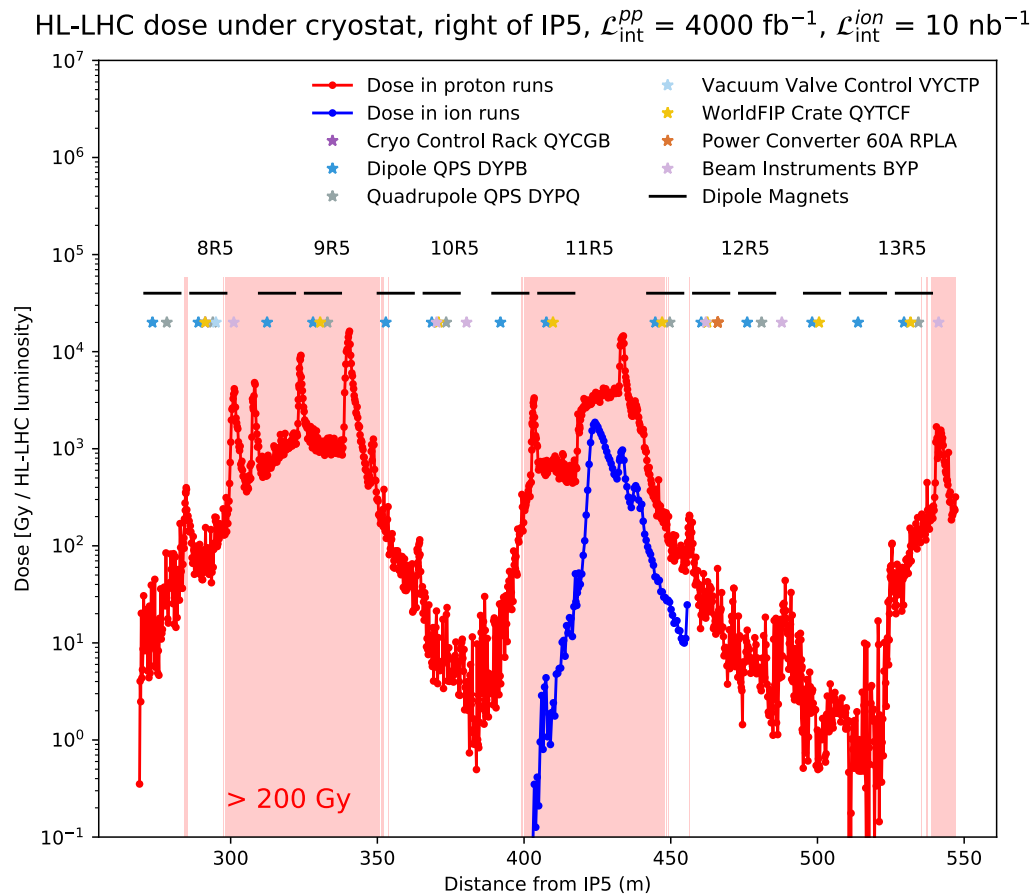
116th HL-LHC Integration Meeting, 30 November 2018

Outline

- Fluka simulations of DS radiation levels in the high-luminosity experiments (IP1-IP5) for the following scenario:
 - Integrated luminosity of 4000 fb^{-1} during proton operation (ultimate HL-LHC scenario).
 - Integrated luminosity of 10 nb^{-1} during lead ion operation, of which a large fraction will be delivered during Run 3.
- Shielding options for the IP1-IP5 RRs.
- Expected dose levels in the DS in IP8, based on current dose measurements with the BLM system rescaled to the HL-LHC integrated luminosity (100 fb^{-1}).

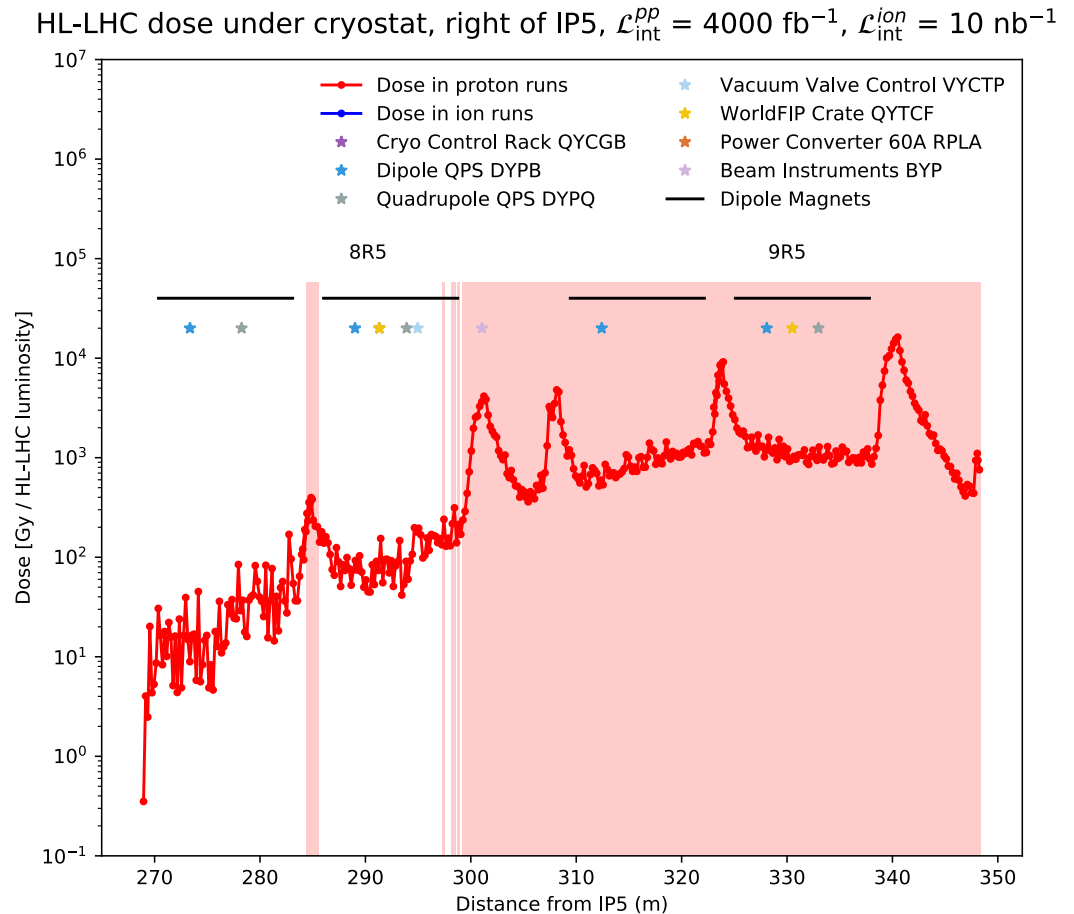
IP1-IP5 DS dose

- Fluka simulation for proton operation with TCL4, TCL5 and TCL6 closed @ 14σ , highlighting regions with dose > 200 Gy.
- Superimposed: Pb-Pb Fluka simulation, showing Bound Free Pair Production (BFPP) peak in cell 11.
- Right of IP5, valid reference also for left and IP1.
- The rack locations are purely indicative (present positions from layout database).
- Note: large fraction of ion dose to be received in Run 3, while the proton dose is for the entire HL-LHC period.



IP1-IP5 DS dose: zoomed view (1)

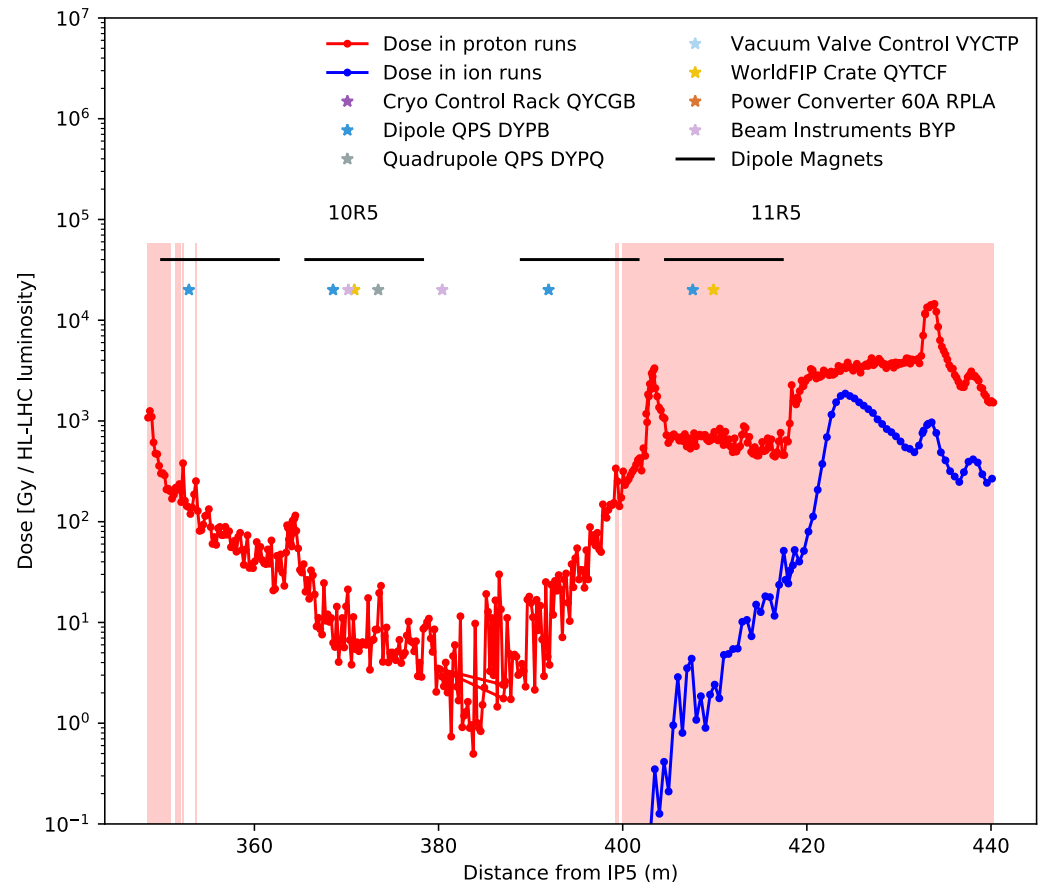
- Zoomed view of the plot in slide 3, showing cells 8-9:
- The dose in cell 9 is of the order of 1 kGy, with localised peaks higher than 10kGy.
- Cell 8 is instead significantly lower (~100 Gy with a small peak at the interconnection of the magnets).



IP1-IP5 DS dose: zoomed view (2)

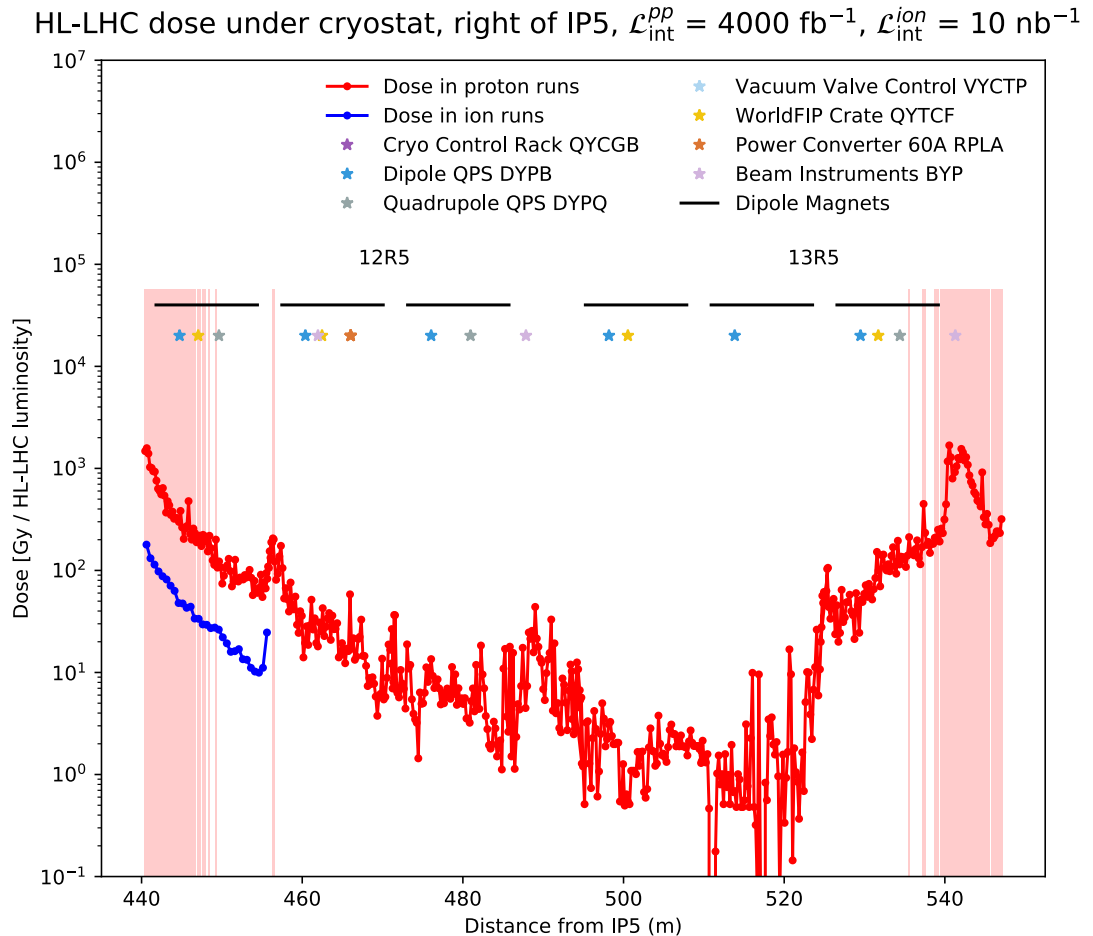
- Zoomed view of the plot in slide 3, showing cells 10-11:
- Dose > 1 kGy in cell 11, with important BFPP peak during ion operation already in Run 3.
- Again, lower levels in the even cell (cell 10).

HL-LHC dose under cryostat, right of IP5, $\mathcal{L}_{int}^{pp} = 4000 \text{ fb}^{-1}$, $\mathcal{L}_{int}^{ion} = 10 \text{ nb}^{-1}$



IP1-IP5 DS dose: zoomed view (3)

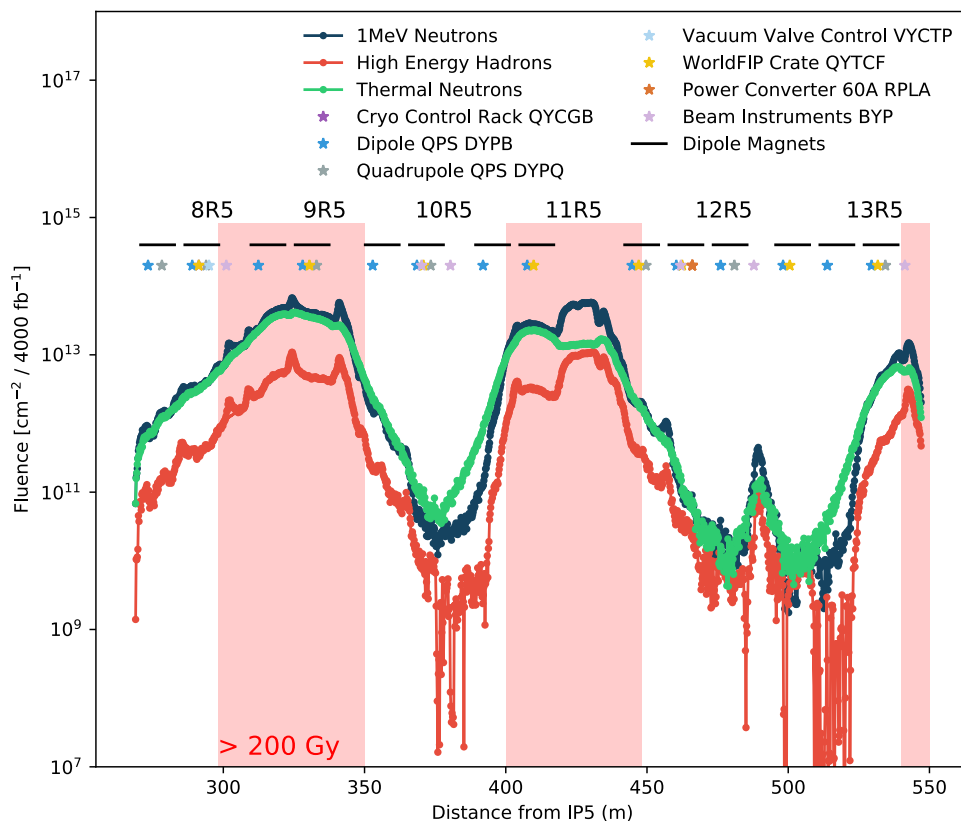
- Zoomed view of the plot in slide 3, showing cells 12-13:
- A 'tail' of the cell 11 dose peak impacts the initial part of cell 12, both during proton and ion operation.
- The peak in cell 13 is less critical, but still not negligible (> 1kGy at the top).



IP1-IP5 DS fluence

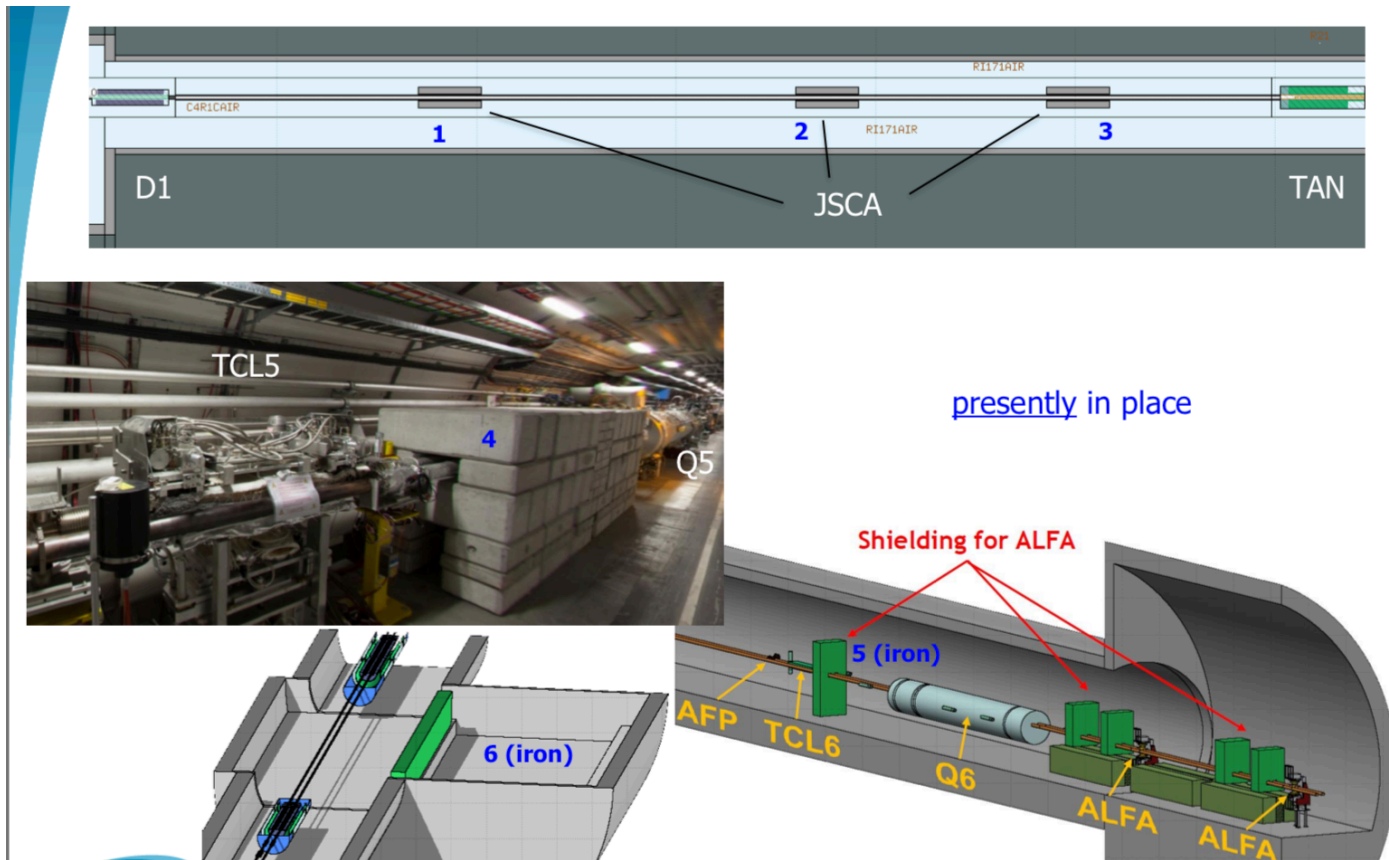
- Inclusive DS plot showing High Energy Hadron (HEH) fluence, 1 MeV neutron equivalent fluence and thermal neutron fluence.
- Only proton operation shown in the plot.
- Similar pattern as for the dose, with peaks in cells 9, 11, 13.
- The 1 MeV neutron equivalent fluence is relevant for equipment lifetimes. Typical qualification limit: $2 \cdot 10^{12} \text{ n/cm}^2$

HL-LHC fluences under cryostat, right of IP5, $\mathcal{L}_{\text{int}} = 4000 \text{ fb}^{-1}$



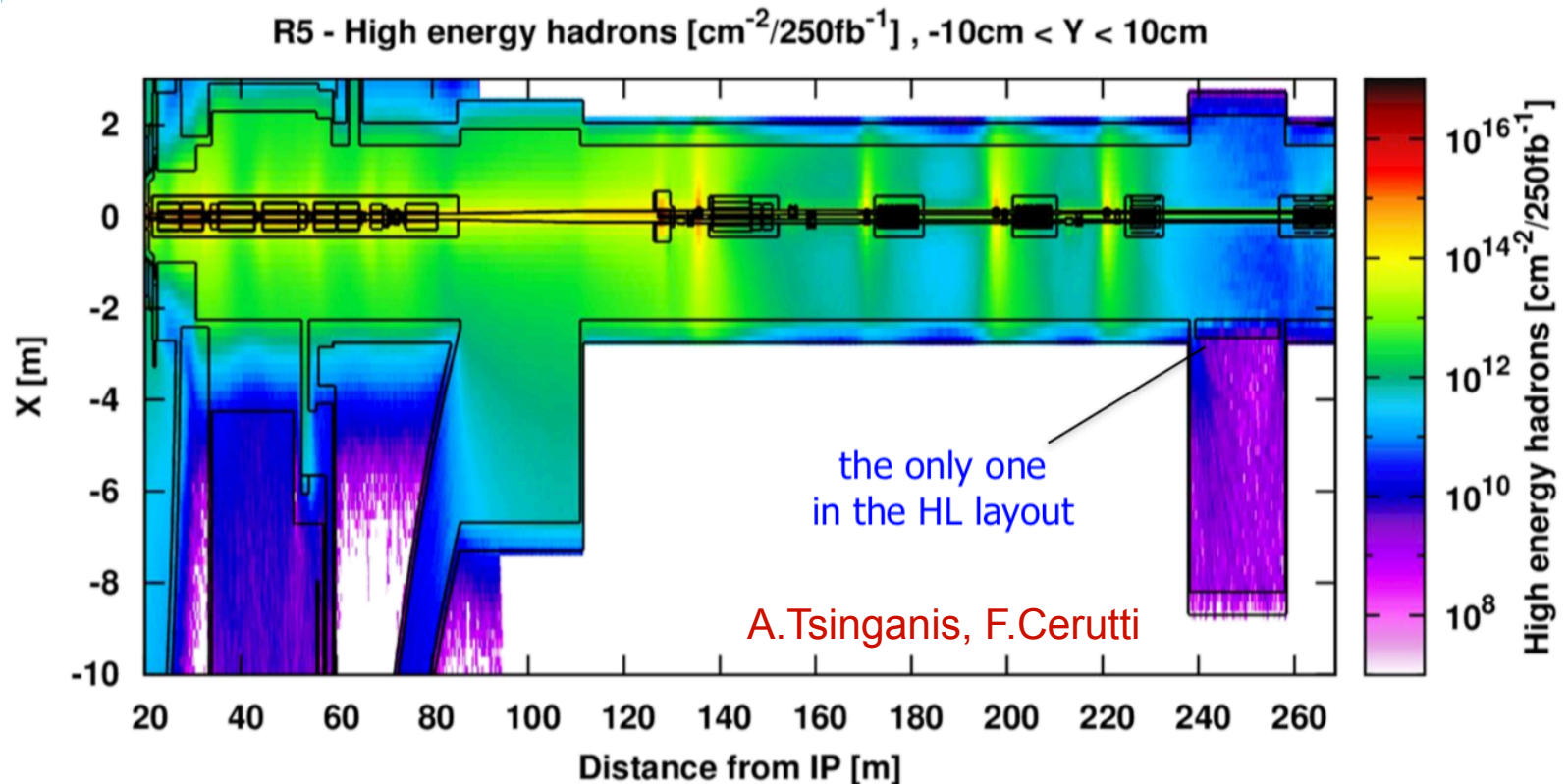
RR levels and shielding

- On top of the DS levels, another relevant topic is the shielding of the RRs in IP1-IP5.
- Current LHC shielding (from F.Cerutti's [CoUSM #107 talk](#)):



RR levels and shielding

- Present HL-LHC layout: only RR wall shielding defined.
- More shielding options to be considered, either at RR level or closer to the beam.



RR levels and shielding

- The RR levels per unit fb⁻¹ vary with TCL6 settings: in Run 2, the 2017 operation corresponds to the HL-LHC scenario (TCL closed).
- HL-LHC expected annual fluence: 3·10⁹ cm⁻²/y: factor ~10 higher than yearly Run 2 levels due to higher luminosity and reduced shielding.

LHC Run 2 RR levels (IN/OUT)

		HEH fluence in RadMONs (cm ⁻² /y)		
		2016	2017	2018*
RR13	OUT	1,4E+09	7,7E+09	1,9E+09
	IN	4,2E+07	2,4E+08	1,3E+08
RR17	OUT	1,0E+09	6,0E+09	2,0E+09
	IN	5,4E+07	3,9E+08	1,3E+08
RR53	OUT	2,9E+09	6,9E+09	5,3E+09
	IN	1,2E+08	3,5E+08	3,0E+08
RR57	OUT	4,5E+09	9,7E+09	4,3E+09
	IN	1,6E+08	3,5E+08	2,7E+08
RR73	OUT	2,0E+09	2,5E+09	7,6E+09
	IN	1,6E+07	1,8E+07	7,2E+07
RR77	OUT	8,5E+08	9,3E+08	2,4E+09
	IN	1,2E+07	1,4E+07	2,8E+07

*up to LS2 (mid-September)

- Note: in HL-LHC the RR levels may have implications also on the equipment lifetime (values below to be multiplied by ~16):

Yearly (250 fb⁻¹) HL-LHC levels

Location	HEH fluence	1 MeV n _{eq}	TID
	(cm ⁻²)		(Gy)
UJ	5 × 10 ⁹	5 × 10 ¹⁰	10
UL	10 ⁸	10 ⁹	0.2
RR	3 × 10 ⁹	3 × 10 ¹⁰	6
DS	5 × 10 ¹⁰	5 × 10 ¹⁰	100
ARC	10 ⁹	10 ⁹	2

Extra: levels in IP8 (LHCb)

- The radiation levels in IP8 are determined by the LHCb luminosity, with an extra contribution from the TI8 injection line, that merges into the LHC on the right of IP8 at the beginning of the DS (UJ87-UJ88).
- The BLM dose measured during pp operation in 2018 (up to 01/10 - 2.12 fb⁻¹) can be analysed with the tools from the Monitoring and Calculation Working Group (MCWG) and rescaled to the expected HL-LHC luminosity of LHCb.
- We considered 50 fb⁻¹ up to LS4 (baseline plan) plus an extra 50 fb⁻¹ after LS4 (could be more if further upgrades will take place). Total: 100 fb⁻¹.

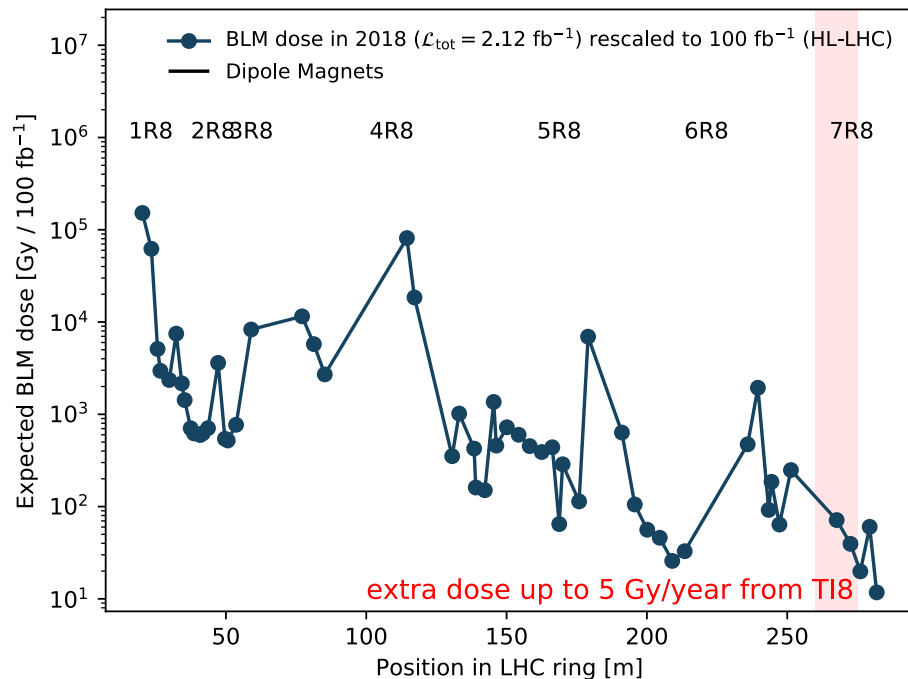
Dose levels on right of IP8 from TI8 injection

- Fluka simulation of losses at the end of TI8 have been performed (see [presentation](#) by A. Ciccotelli).
- The dose from TI8 is driven by the number of lost protons in the main post-LIU collimators (TCDIH.87822, TCDIH.87939).
- The results of the simulations allow to place conservative upper limits of 5 Gy per year in the vicinity of the two collimators:
 - Between 260m and 275m from IP8 (TCDIH.87939).
 - Between 315 and 335m from IP8 (TCDIH.87822).
- Elsewhere, the levels are expected to be negligible compared to luminosity-driven losses.

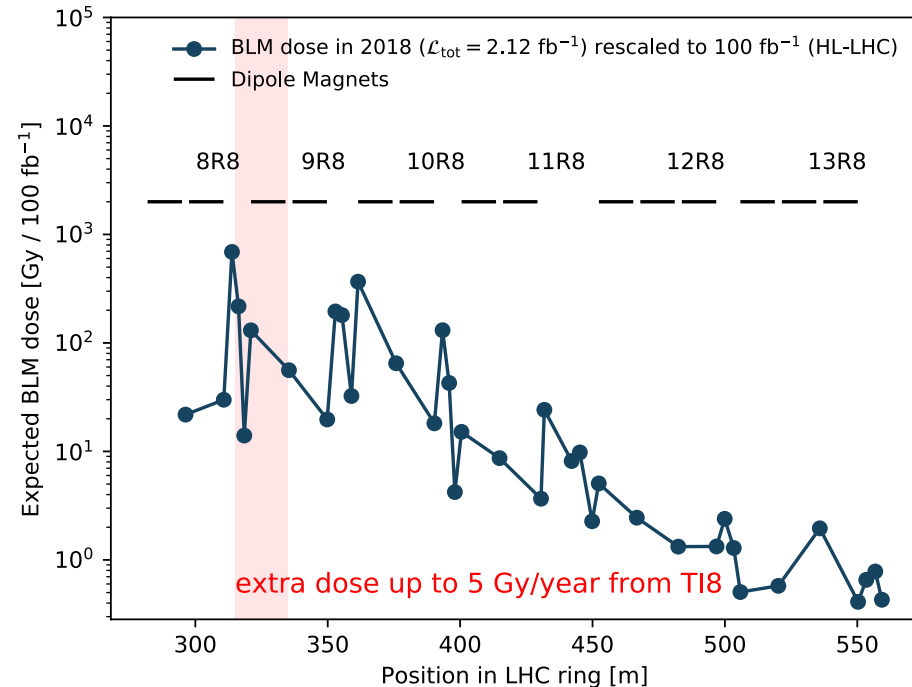
Dose levels on right of IP8

- 2018 BLM dose rescaled to 100 fb^{-1} in LSS and DS of IP8.
- The dose is significantly lower compared to IP1-IP5, but the DS levels (in cell 8-9) reach few hundred Gys.
- Levels may be a factor 2-3 lower under the cryostats.

BLM dose for 100 fb^{-1} in cells 1-7, right of IP8



BLM dose for 100 fb^{-1} in cells 8-13, right of IP8



Conclusions

- I presented the expected HL-LHC radiation levels in the most relevant collision IRs:
 - Dose and fluence profiles in the DS of IP1-IP5.
 - Expected levels in the IP1-IP5 RRs.
 - Expected levels in IP8 based on the rescaled BLM measurements and on end-of-TI8 Fluka simulation.
- As known the highest levels are expected in IP1-IP5, but also IP8 may start to cause R2E-related issues due to the significant increase in the luminosity.



BACKUP