

IP7 losses scaling and impact on forecast for HL-LHC era

Rubén García Alía, November 15th, 2017

HL-LHC annual meeting

Input from: Oliver Stein, Corinna Martinella, Yacine Kadi, Kacper Bilko, Markus Brugger, Salvatore Danzeca, Anton Lechner, Francesco Cerutti, Lefteris Skordis, Cristina Bahamonde, Stefano Redaelli, Simone Gilardoni, Andrea Apollonio, Paolo Fessia, Iñigo Sancho, Nicola Mariani, Philip Schwarz



Outline

- Introduction
- Run 2 IP7 loss scaling
- Other loss observations
- Scaling applications: 2016 and HL-LHC
- Conclusions & Outlook

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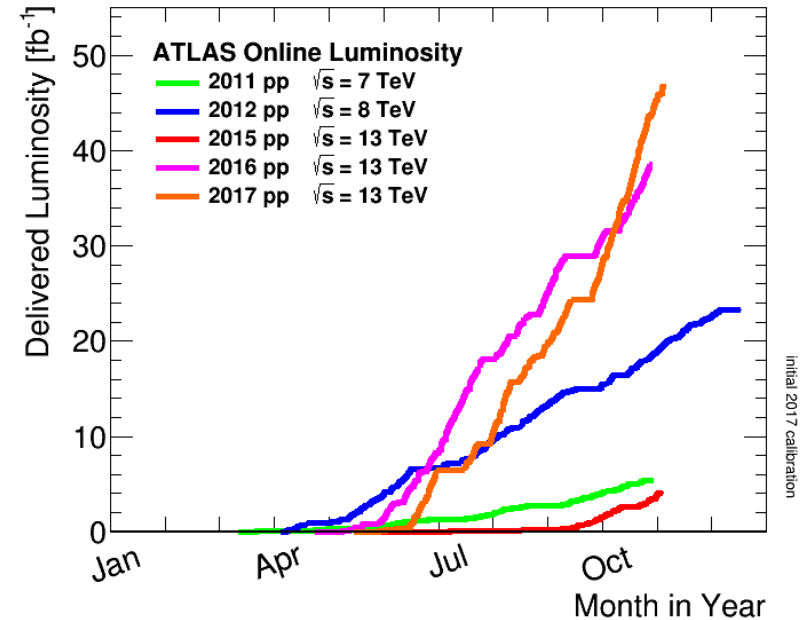
Integrated luminosity and intensity

Year	Integrated Lum. (fb ⁻¹)	Integrated Intensity* (ps)
2012	23	2.7×10^{21}
2015	4.2	7.6×10^{20}
2016	40	2.6×10^{21}
2017**	44	2.1×10^{21}
HL-LHC***	250	8.6×10^{21}

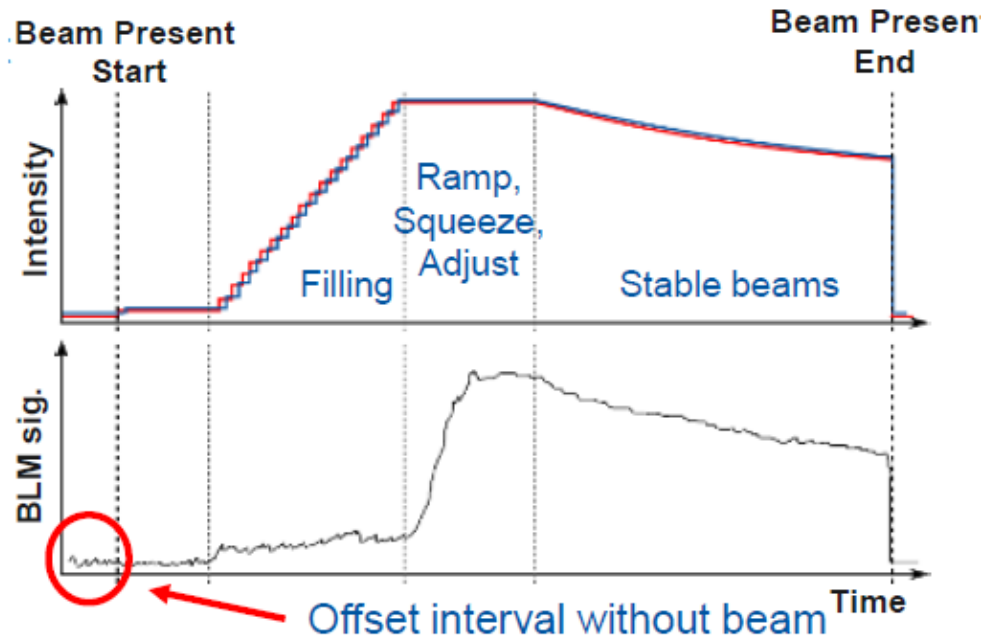
* *Integrated pp intensity considering both beams*

** *Analysis up to 25-10-2017*

*** *Estimated annual intensity calculation (Andrea Apollonio)*

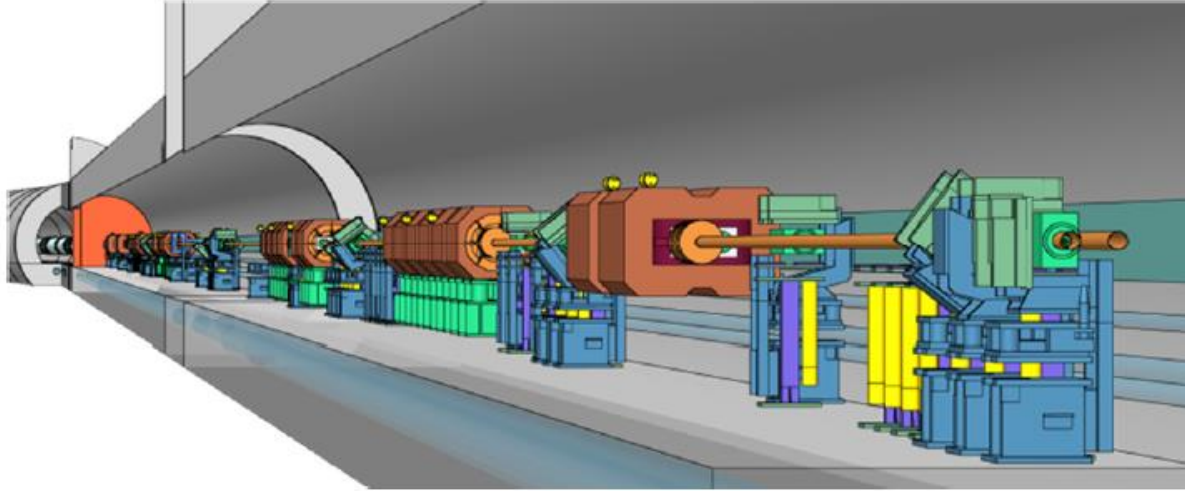


BLM and intensity calculations



- Contributors: Oliver Stein and Kacper Bilko (MCWG), with support from BLM team
- Dedicated Python workflow for data retrieval and analysis
- Main objective of calculating TID levels along the LHC and normalizing with integrated luminosity/intensity
- BLM offset subtraction, losses per beam mode/operational conditions (on-going), implications on equipment damage (R2E), etc.

FLUKA IP7 simulations: BLM benchmark



- FLUKA geometry and simulations for B2 (R7*): Lefteris Skordis (FLUKA team, with input from collimation team)

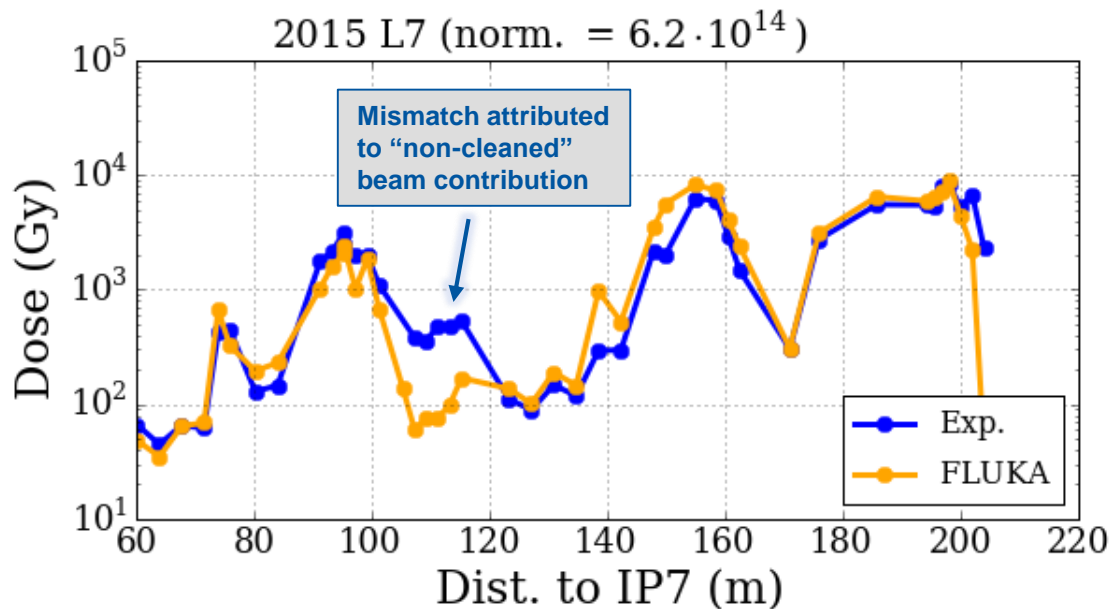
Impact of beam losses in the LHC collimation regions (IPAC 2015)

**Losses assumed to be symmetric*

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2015 BLM losses in IP7



*FLUKA simulations per lost proton scaled to best fit to data, yielding 6.2×10^{14} as estimation for number of **lost protons* per beam in IP7***

**Hereafter, 6.5 TeV equivalent protons*

Lost protons: intensity versus luminosity scaling

Year	Integrated Luminosity (fb ⁻¹)	Integrated Intensity* (ps)	Lost protons per beam	
			Luminosity	Intensity
2015	4.2	7.6×10^{20}	6.2×10^{14}	6.2×10^{14}
2016	40	2.6×10^{21}	5.9×10^{15}	2.1×10^{15}
2017**	44	2.1×10^{21}	6.5×10^{15}	1.7×10^{15}
HL-LHC***	250	8.6×10^{21}	3.7×10^{16}	7.0×10^{15}

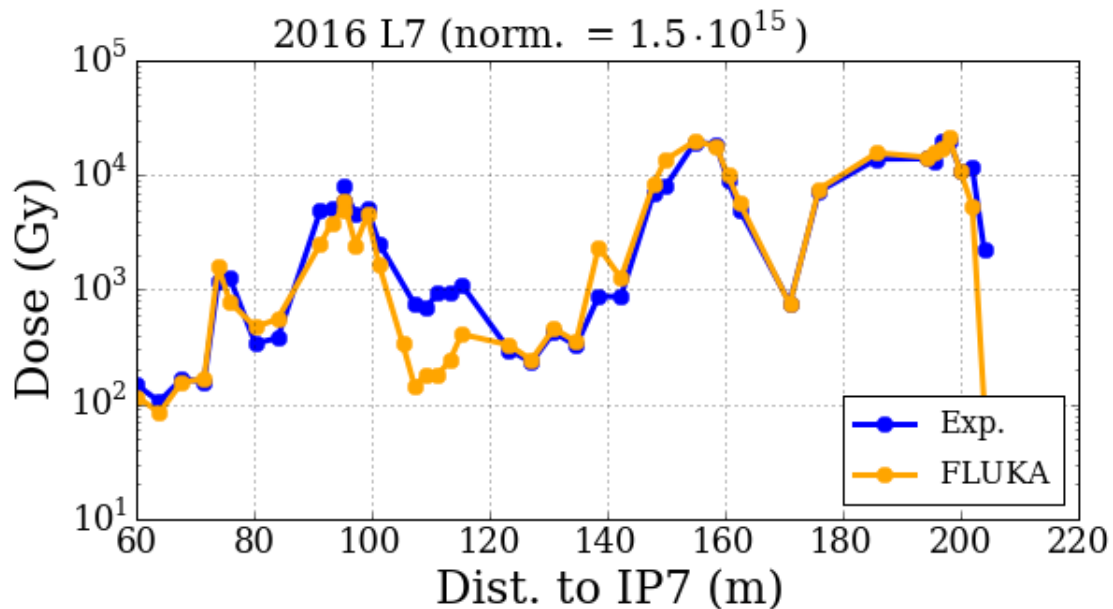
Predicted lost protons based on 2015 value, and scaled with integrated luminosity and intensity

* Integrated pp intensity considering both beams

** Analysis up to 25-10-2017

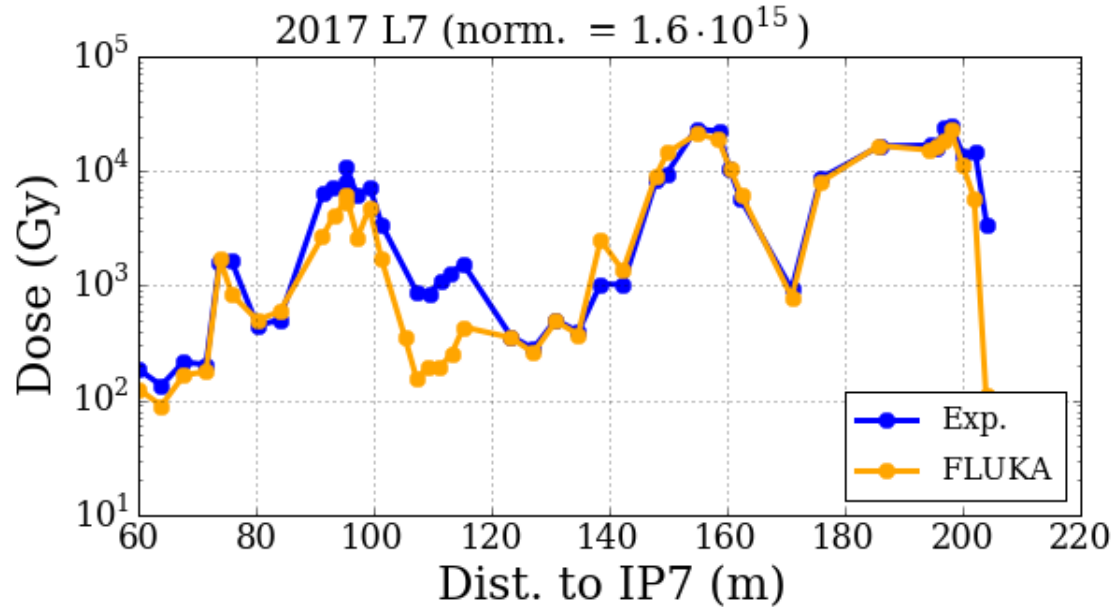
*** Estimated annual intensity calculation (Andrea Apollonio)

2016 BLM losses in IP7



*FLUKA simulations per lost proton scaled to best fit to data, yielding 1.5×10^{15} as estimation for number of **lost protons per beam in IP7***

2017 BLM losses in IP7



*FLUKA simulations per lost proton scaled to best fit to data, yielding 1.6×10^{15} as estimation for number of **lost protons per beam in IP7***

Lost protons: intensity versus luminosity scaling

Year	Lost Protons (FLUKA + BLM)	Lost Protons (2015 scaled)	Lost Protons (2015 scaled)
		Intensity	Luminosity
2016	1.5×10^{15}	2.1×10^{15} (1.4)	5.9×10^{15} (3.9)
2017	1.6×10^{15}	1.7×10^{15} (1.1)	6.5×10^{15} (4.1)
HL-LHC	-	7.0×10^{15}	3.7×10^{16}

L7 (beam 1) losses considered

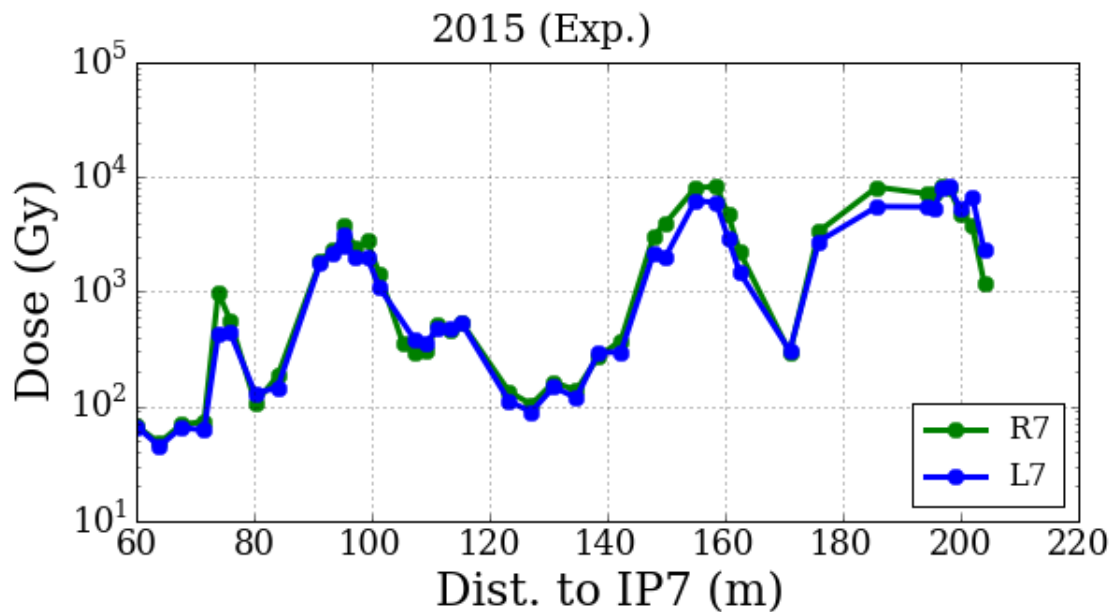
In brackets, ratio between scaled and measured protons lost

- Confirmation that despite the different operational scenario, integrated **intensity** scaled losses from 2015 are in **good agreement** (within **factor 1.5**) with 2016 and 2017 measurements
- When scaled with integrated **luminosity**, 2015 values result in **overestimation** of losses of roughly a **factor 4**

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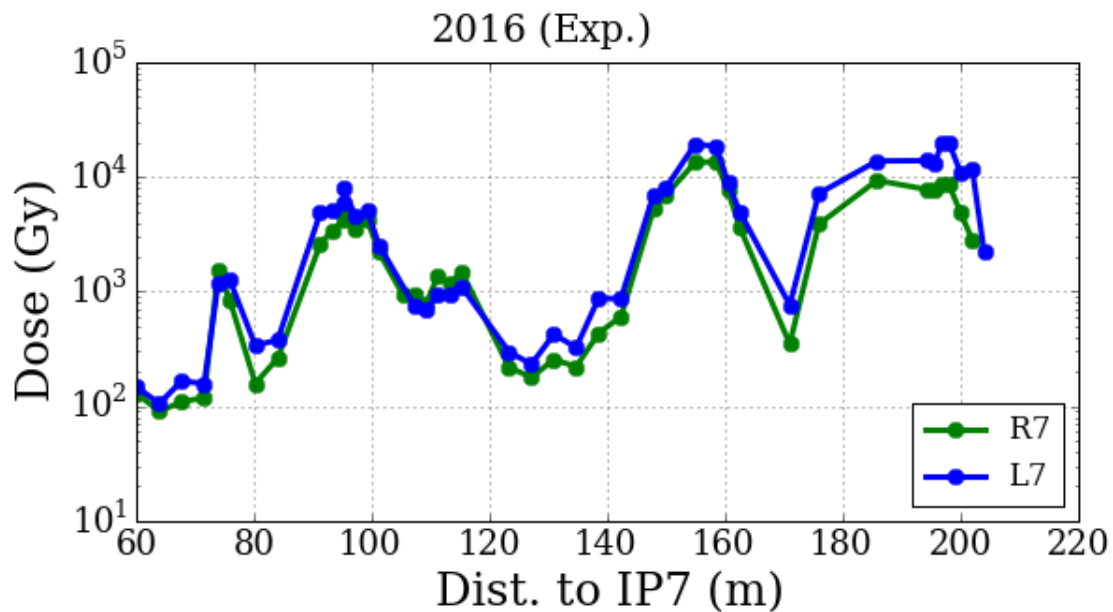
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2015: right versus left



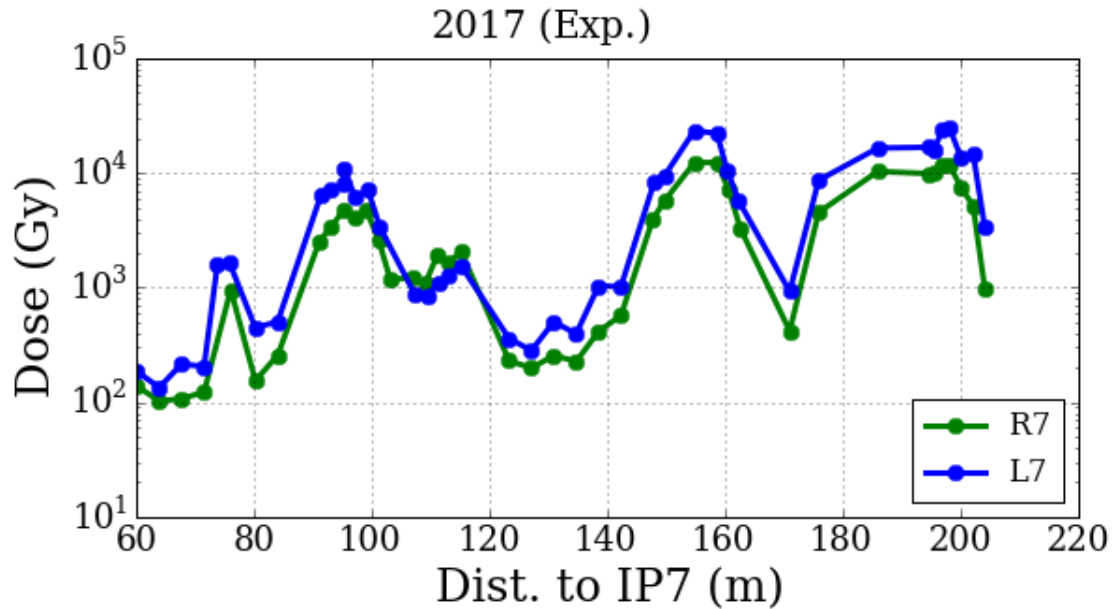
*Similar losses left
(beam 1) than right
(beam 2)*

2016: right versus left



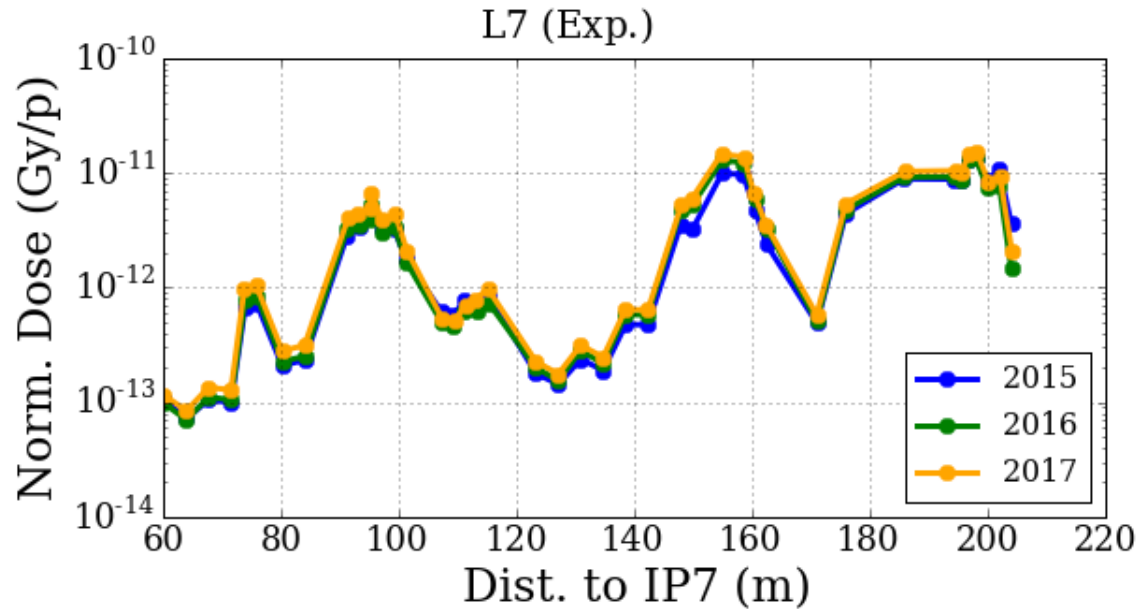
*Larger losses left
(beam 1) than right
(beam 2)*

2017: right versus left



*Larger losses left
(beam 1) than right
(beam 2)*

Normalized Run 2 BLM annual losses



Same absolute value by construction (as BLM levels used to derive lost protons) but highly reproducible patterns

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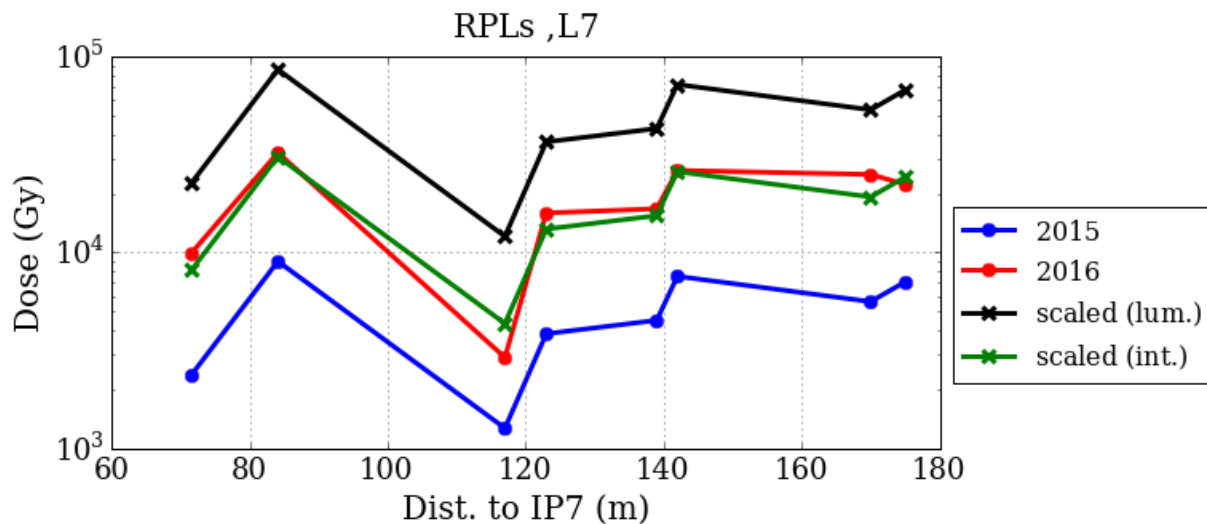
2016 scaling application: warm magnets

- RPL dosimeters to measure radiation levels in IP3 and IP7 warm magnets for long-term damage evaluation

(input: Paolo Fessia, Iñigo Sancho, Nicola Mariani, Philip Schwarz)



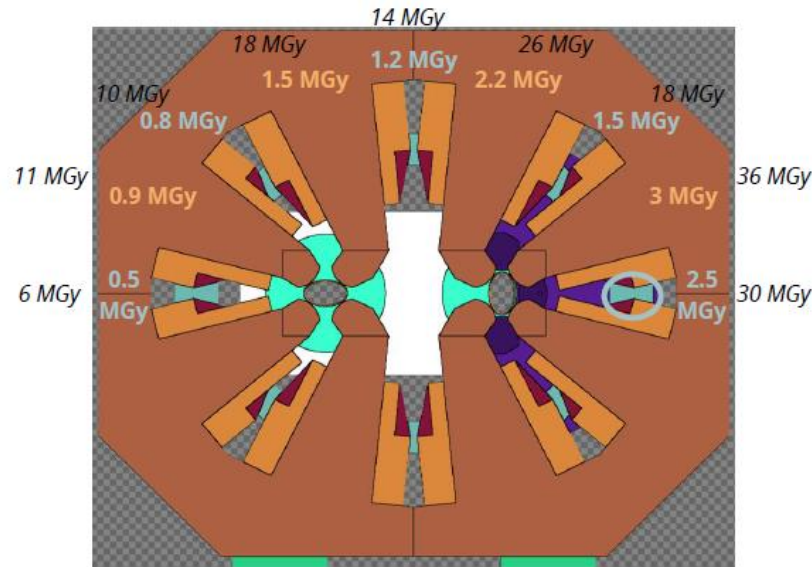
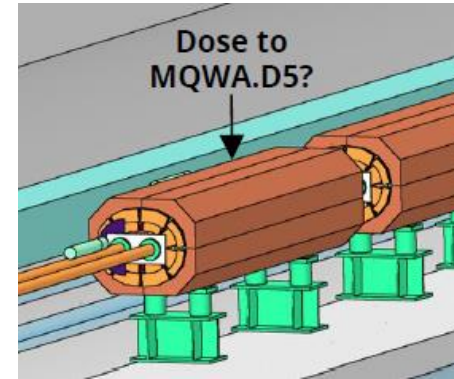
2016 scaling application: warm magnets



- As expected from BLM results, 2015 scaling with integrated intensity of provides a satisfactory agreement with 2016 experimental data
- Ratio between intensity scaled and measured values for dosimeters in L7: between 0.8 and 1.5
- Worst agreement (factor ~2) in R7 due to lower 2016 losses

HL-LHC application: warm magnets

- Estimation of dose accumulated in MQWA.D5 for full HL-LHC period, i.e. considering MQWA.E5 removal
- Despite expected reduction related to lost protons, reasonable to aim at maintaining relative levels similar to the case with MQWA.E5 in place (i.e. shielding)



■ New normalization 8.4×10^{16} protons lost

■ Old normalization 10^{18} protons lost *

C. Bahamonde, CoIUSM #95

**LHC Project Note 375 scaled with luminosity*

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Considered safety margins

- Integrated intensity scaling of 2015 IP7 primary collimation losses validated for 2016 and 2017, and expected to be valid also for HL-LHC beam conditions
- **Factor 2 safety margin** can be conservatively applied
- This factor relates only to the number of lost protons and does not include uncertainties linked to local radiation environment effects (e.g. shielding materials, exact equipment location...)

Conclusions and Outlook

- Run 2 analysis confirms that radiation levels in the IP7 collimation region scale with integrated intensity
- According to this and the FLUKA/BLM analysis for the present machine, the expected number of lost protons for a **nominal HL-LHC year** is **7×10^{15} protons/beam**, or 8.4×10^{16} for the full, 12-year operation
- This expected value is significantly lower than those scaled by luminosity assuming 1.15×10^{16} lost protons for $30\text{-}50 \text{ fb}^{-1}$ (LHC Project Note 375), or 6.2×10^{14} for 4.2 fb^{-1} (2015 values)
- Scaling with intensity expected to be valid for HL-LHC operational conditions (e.g. bunch intensity), factor 2 safety margin can be conservatively applied
- Further work will focus on loss patterns for different LHC beam modes