Review of the MQW and MBW lifetime taking into account results from the reading of the dosimeters collecting data in the 2016 RUN

Dosimeter (installation, reading, analysis): P. Schwarz, I. Brunner, I. Sancho Fernandez
FLUKA analysis: C. Bahamonde, F. Cerutti, E. Skordis, A. Lechner
R2E scaling: R. Garcia Alia
Shielding functional design C. Bahamonde, A. Lechner
Estimation of the integrated intensity for next year: A. Apollonio, R. De Maria
Magnet team: P. Fessia, N. Mariani [presently ITER] I. Sanchez Fernandez, P. Schwarz

PRELIMINARY RESULTS

Summary

- Recall of last year results from dosimeter reading
- This year dosimeter results
- New scaling
- New estimates
- Preliminary proposal for new action plan
- The design of the protection for LS2 for the elimination of the MQWE5.R(L)7

IMPORTANT

- THESE ARE PRELIMINARY DATA. FULL DISCUSSION AND VALIDATION WITH THE WP10 COLLEAGUE STILL TO TAKE PLACE

- THE NEW SCALING FOR LOSSES SHOWED HERE DOES NOT APPLY TO THE IP 1 AND IP 5. ALL CONSIDERATIONS APPLY ONLY AND EXCLUSIVELY TO THE CLEANING INSERTIONS

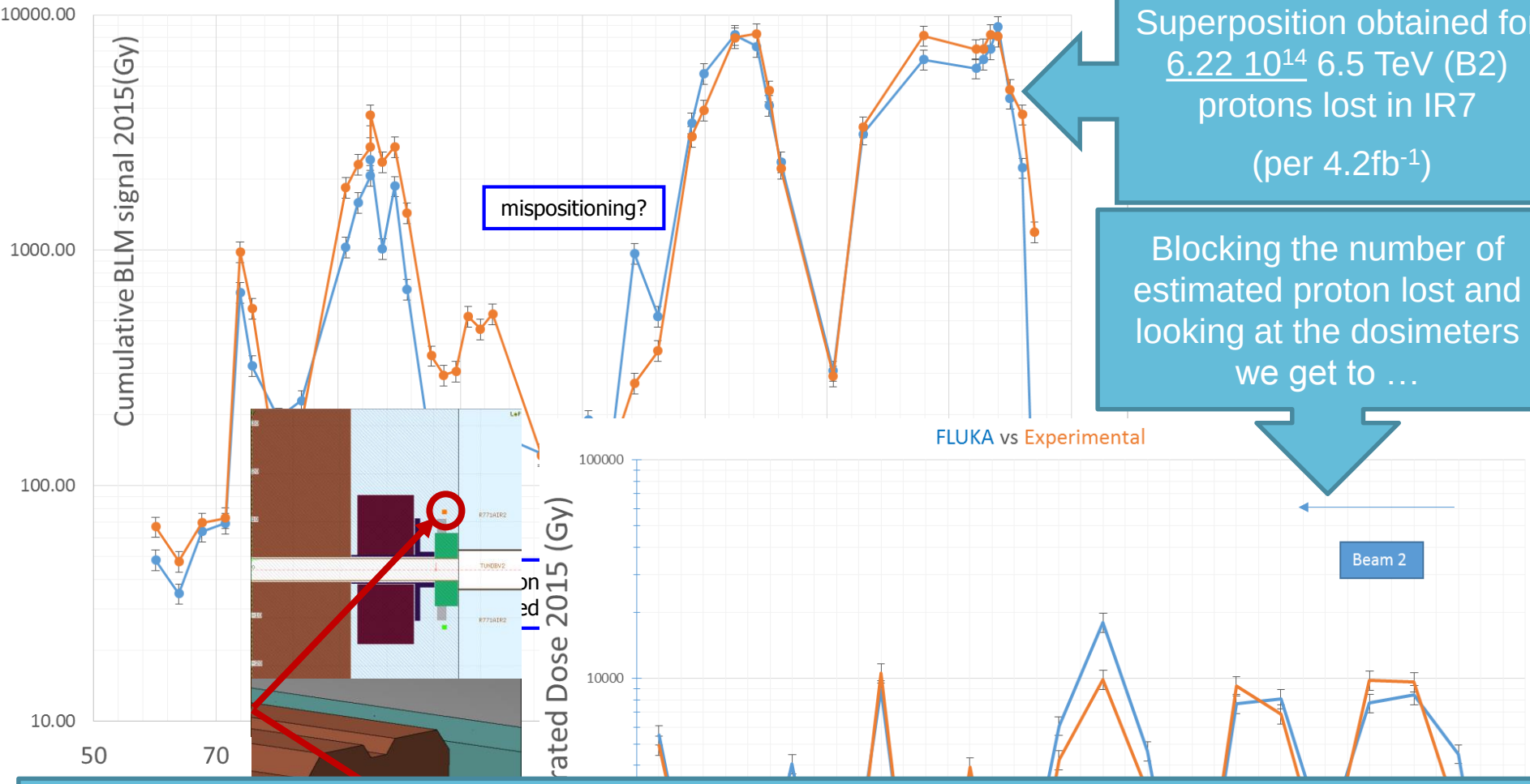
Recall of the analysis progress last year

Year	Direct experimental data	Dose repartition between magnets	Scaling	Material properties	Observations
2013	none	FLUKA analysis for the collimation nominal losses of 1.15 10^16 proton/(**30**-50 fb-1)	Luminosity following proposed scaling that was proposed at IPAC 2013	Extrapolation of previous experimental data of similar resins	
2016	Dosimeters from 2015 RUN	FLUKA analysis for the collimation nominal losses of 1.15 10^16 proton/(30-**50** fb-1)	Luminosity following proposed scaling that was proposed at IPAC 2013	Experimental data of really employed insulation system	Losses and doses lower then expected

Superposition obtained for 6.22 10^{14} 6.5 TeV (B2) protons lost in IR7

(per 4.2fb^{-1})

Blocking the number of estimated proton lost and looking at the dosimeters we get to …



6.22 10^{14} 6.5 TeV (B2) protons lost in IR7

(per 4.2fb^{-1}) corresponds to 7.5 10^{15} proton equivalent losses per 50 fb^{-1} (IR7 only, one beam only)

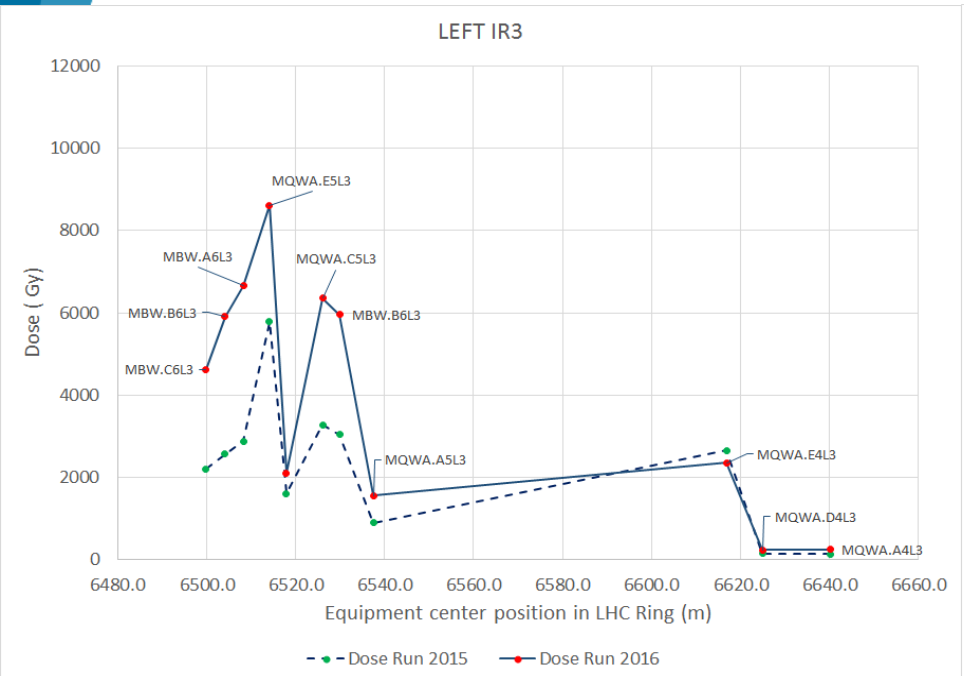
Previous assumption of 1.15 10^{16} proton (equivalent) losses per 50 fb^{-1} (IR7 only, one beam only) in line with the 2005 estimate of 1.15 10^{16} annual proton losses [M. Lamont, LHC Project Note 375]

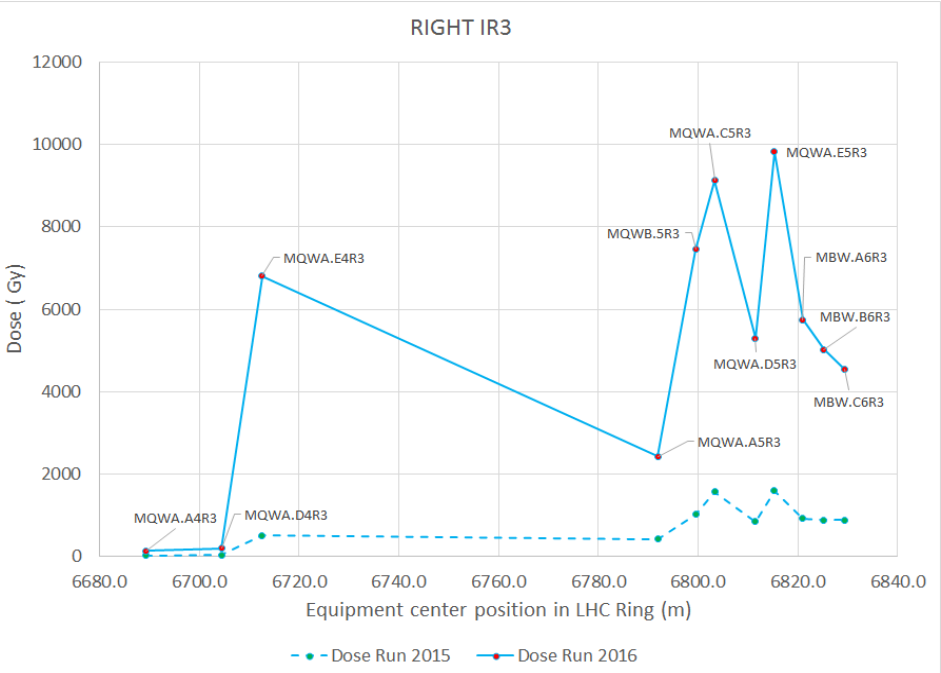
Based on the next slide, for lifetime projection purposes we conservatively stick to the old loss to lumi ratio for dose estimation

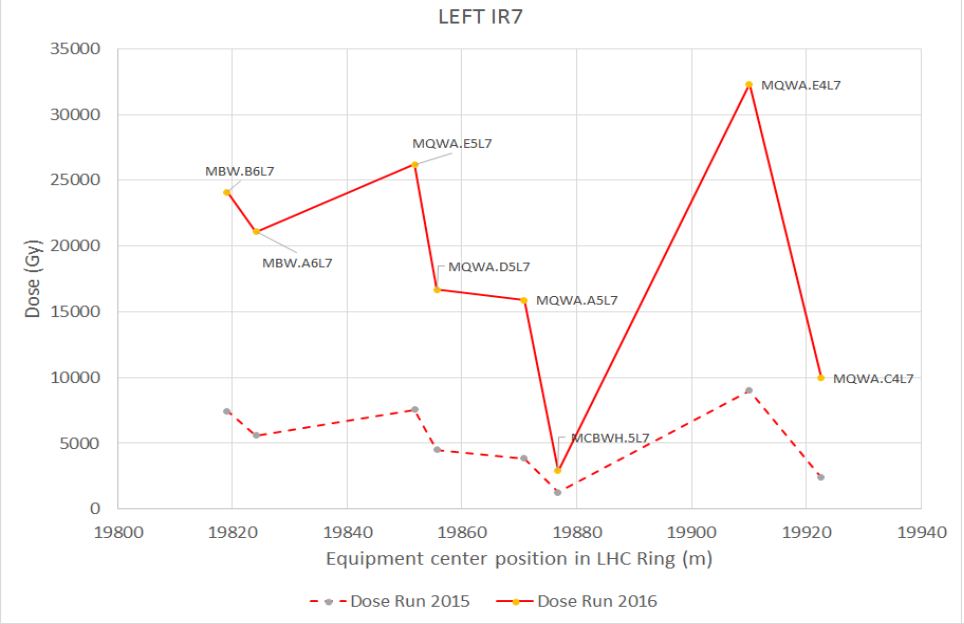
Recall of the analysis progress what is new

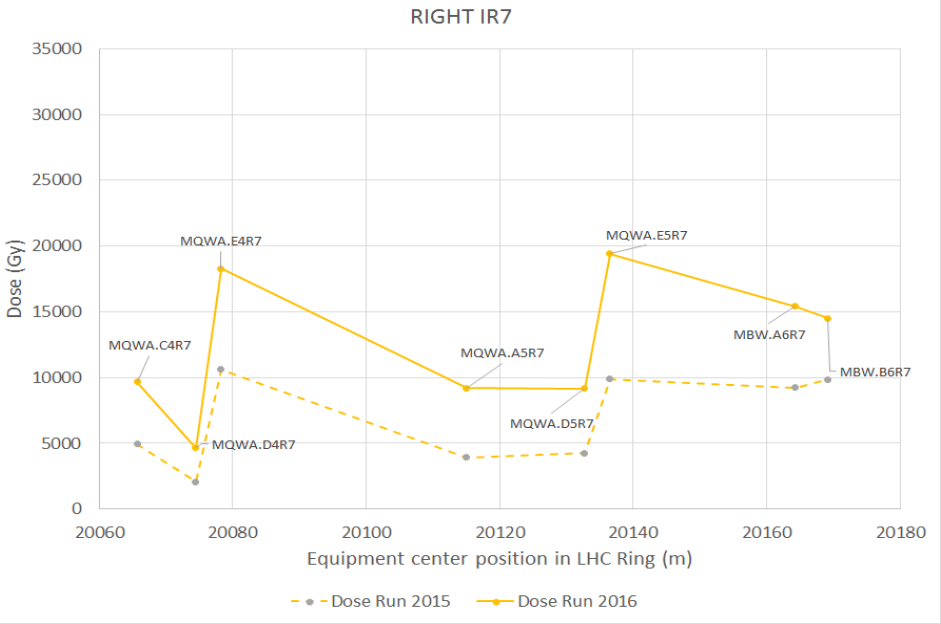
Year	Direct experimental data	Dose repartition between magnets	Scaling	Material properties	Observations
2013	none	FLUKA analysis for the collimation nominal losses of 1.15 10^16 proton/(**30**-50 fb-1)	Luminosity following proposed scaling that was proposed at IPAC 2013	Extrapolation of previous experimental data of similar resins	
2016	Dosimeters from 2015 RUN	FLUKA analysis for the collimation nominal losses of 1.15 10^16 proton/(30-**50** fb-1)	Luminosity following proposed scaling that was proposed at IPAC 2013	Experimental data of really employed insulation system	Losses and doses lower then expected
2017	Dosimeters from 2016 RUN	Based on dosimeters and FLUKA modelling	New scaling	Experimental data	It changes everything

Dosimeter 2015 Run vs. 2016 Run

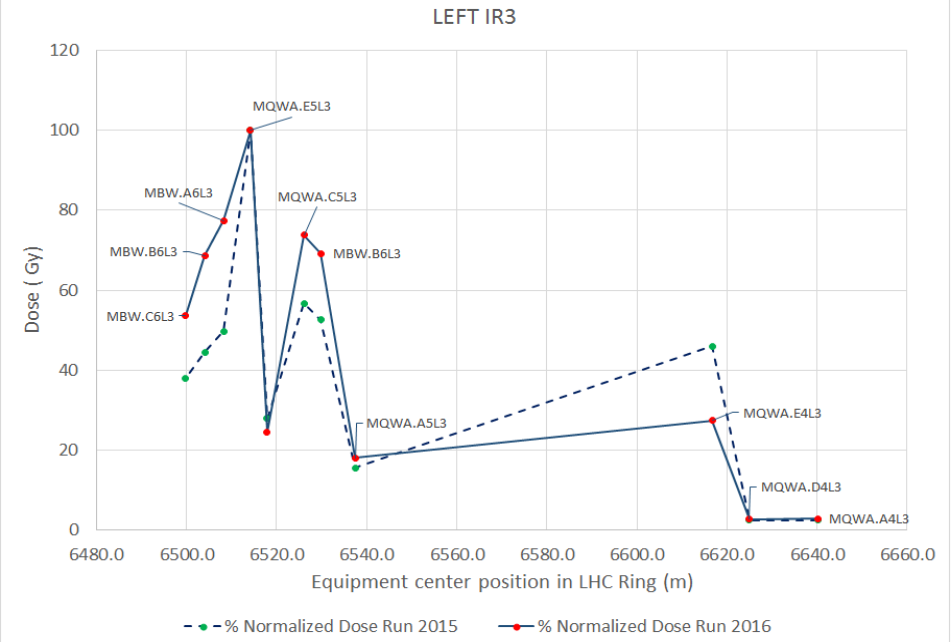


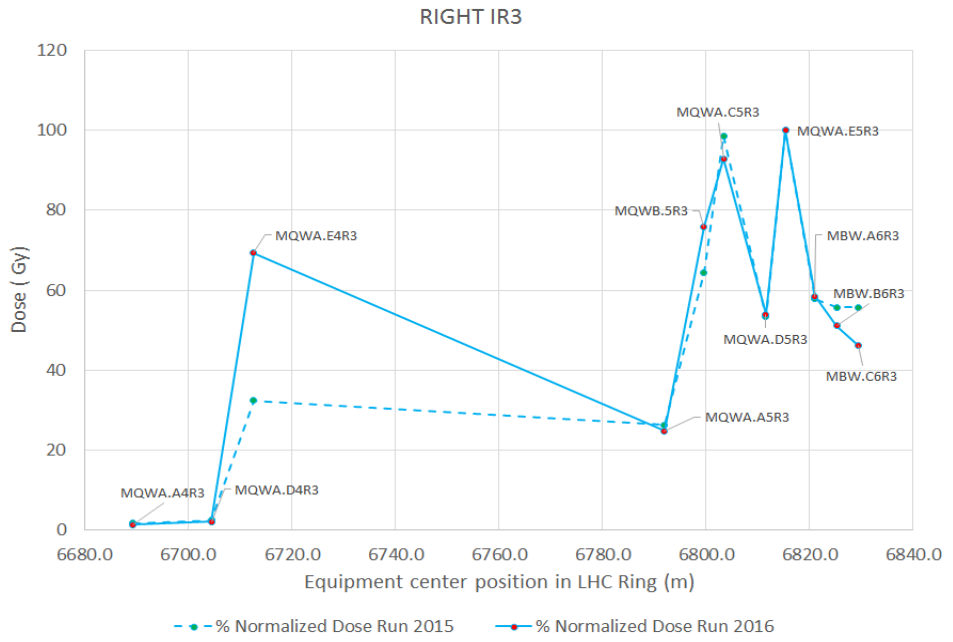


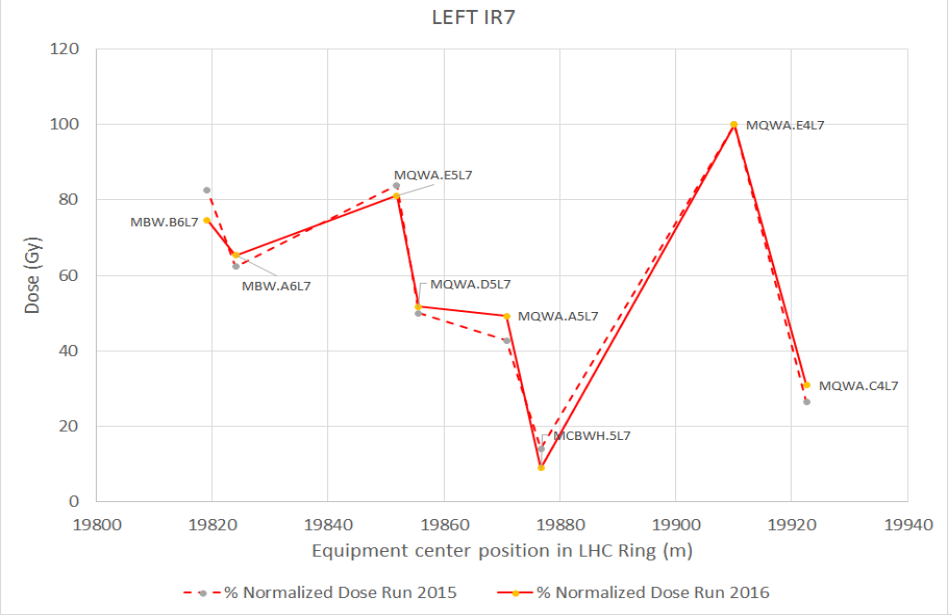


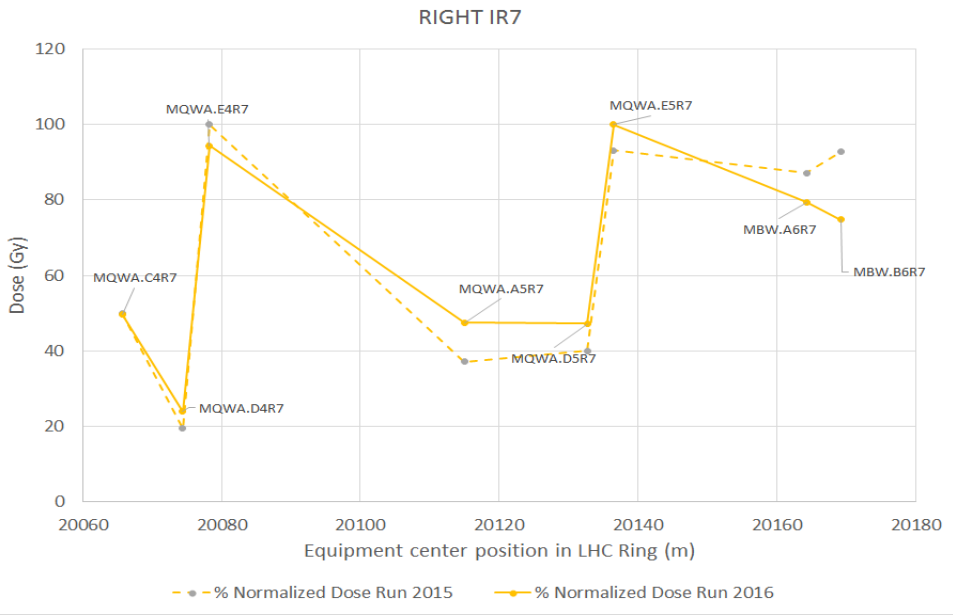


Dosimeter 2015 Run vs. 2016 Run: values normalised to the maximum of each measurement set

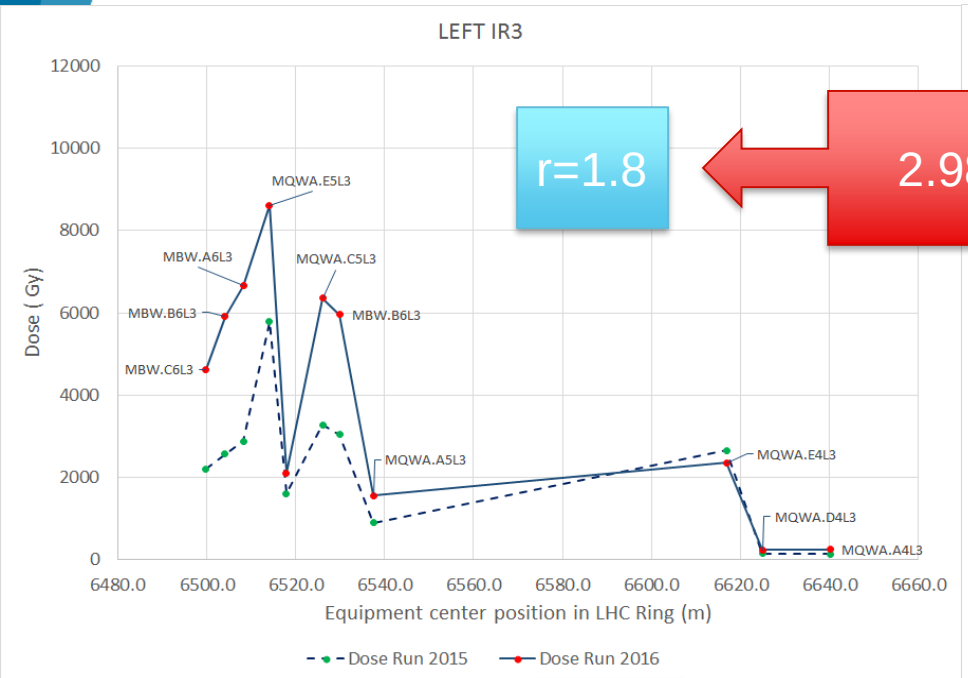




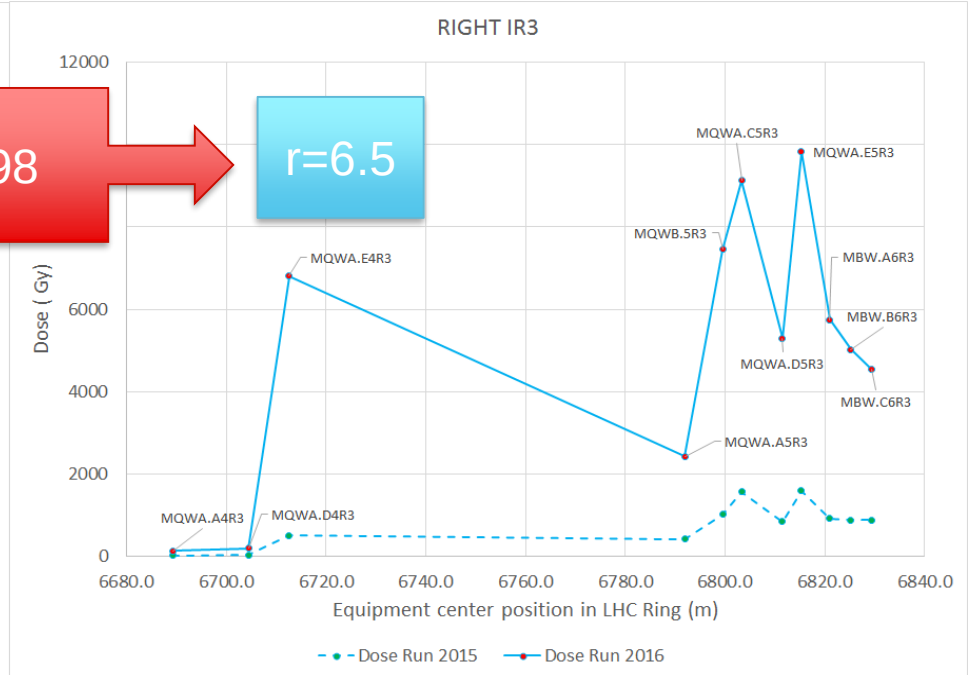


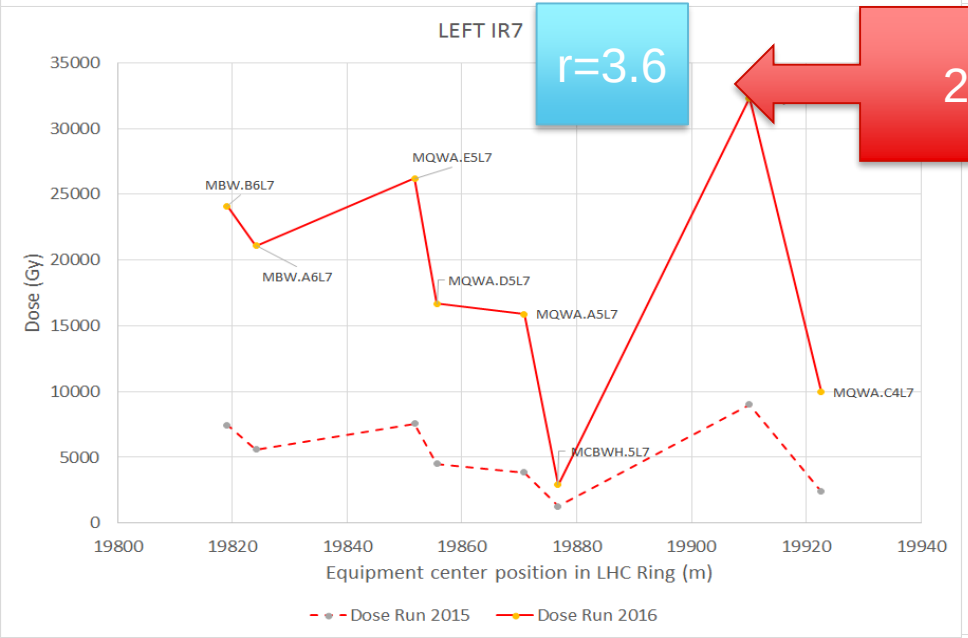


Dosimeter 2015 Run vs. 2016 Run with weighted ratio

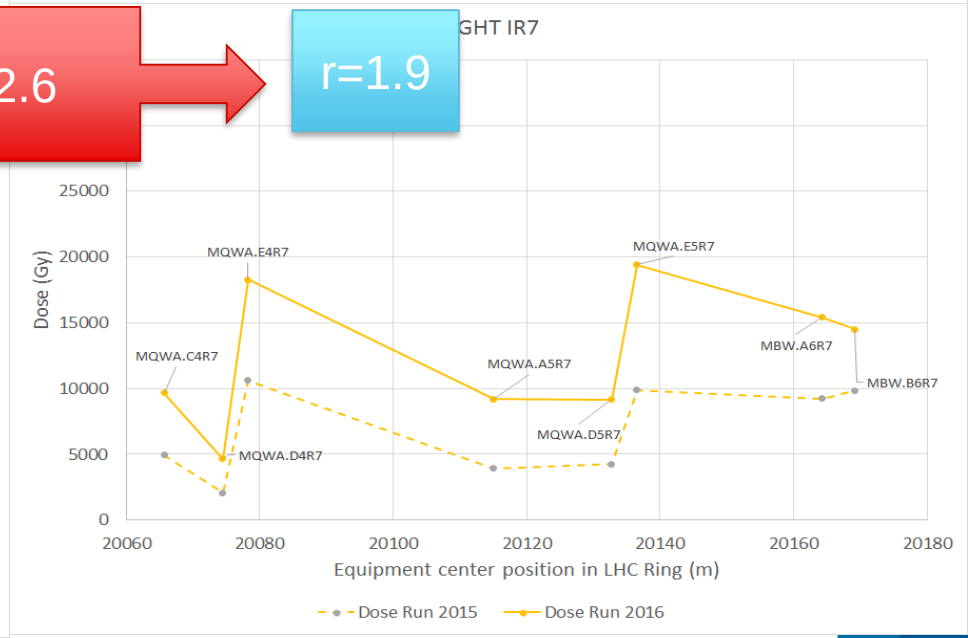


2.98

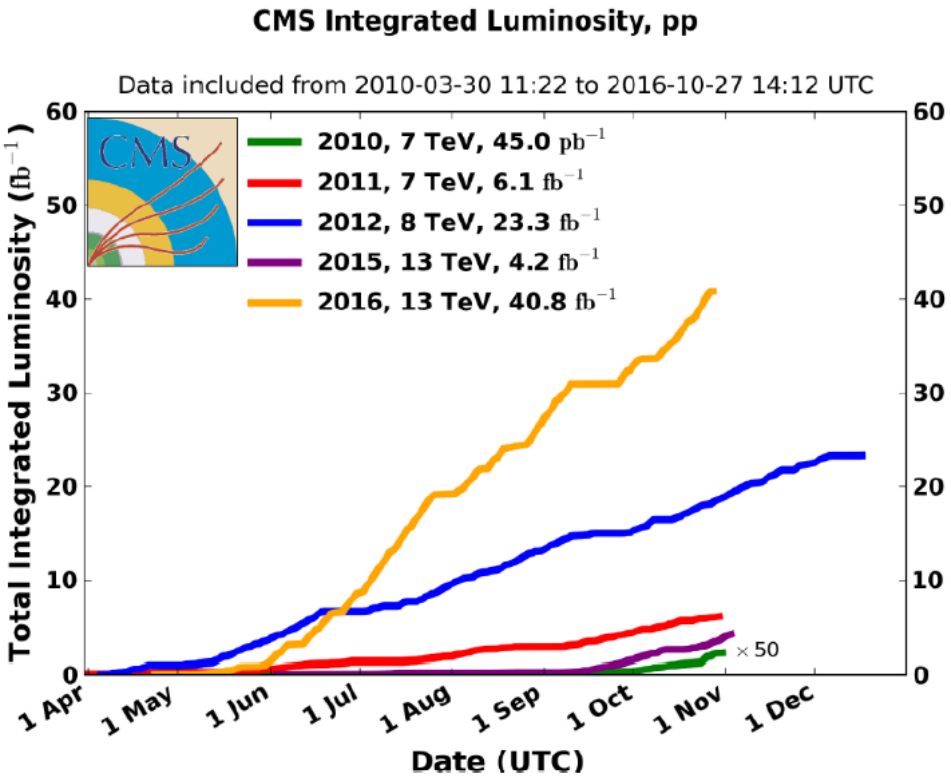




2.6



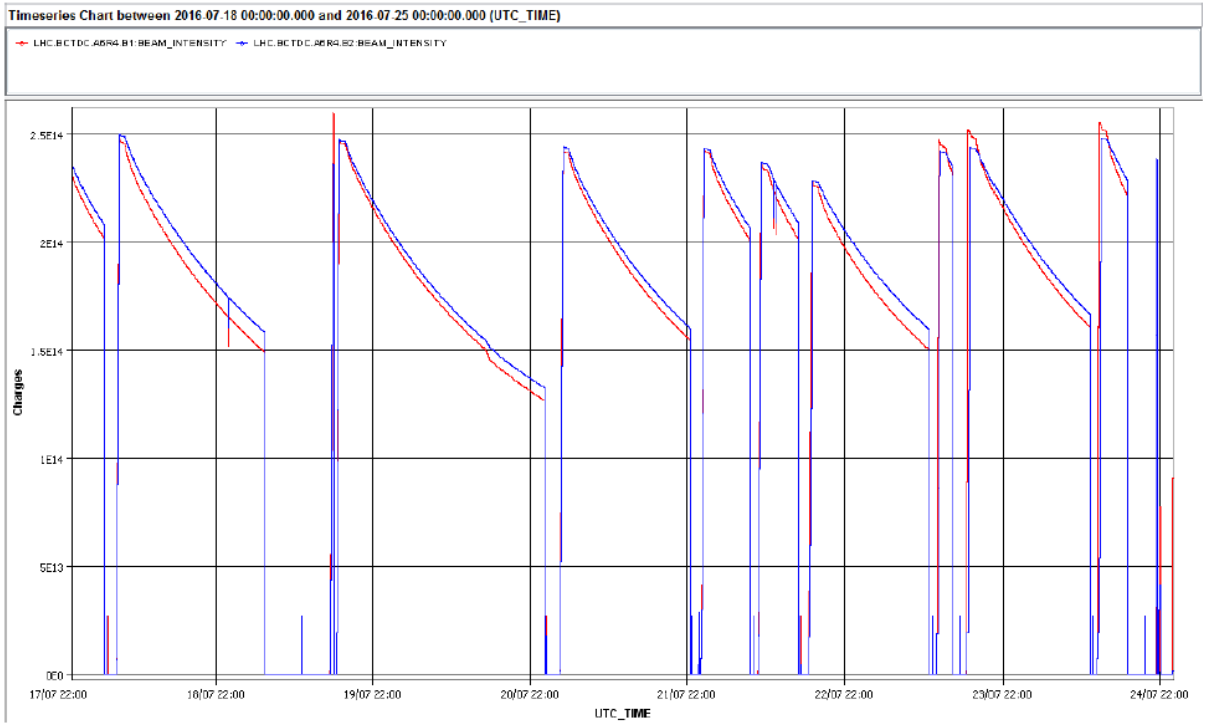
Integrated luminosity and intensity




```
#Integreated intensities (in ps)

int_2012 = 2.95e21
int_2015 = 7.61e20
int_2016 = 2.63e21

#Integrated luminosities (in fb-1)

lum_2012 = 23.3
lum_2015 = 4.2
lum_2016 = 40.8
```

EXPECTED ration on lumi scaling r=9.8

Intensity time integration



Integrated pp intensity in ps (in Stable Beam, SB):

2012: **2.95e21** (2.28e21)
2015: **7.61e20** (4.95e20)
2016: **2.63e21** (2.20e21)

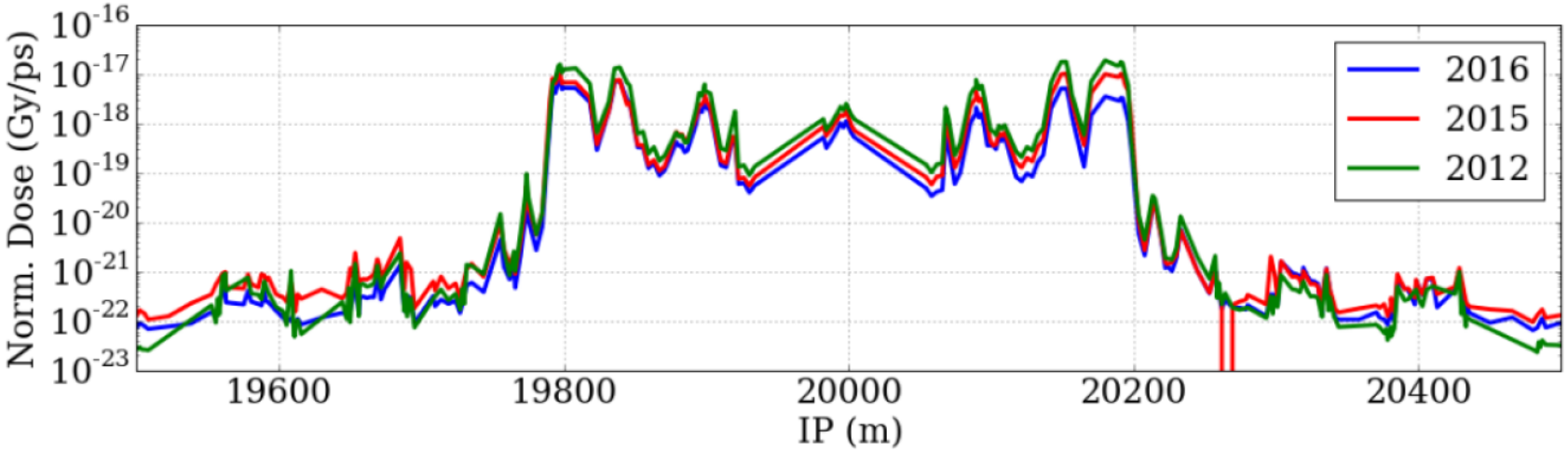
Total SB duration:

2012: 1814h
2015: 751h
2016: 1785h

Average intensity per beam during SB in p (A):

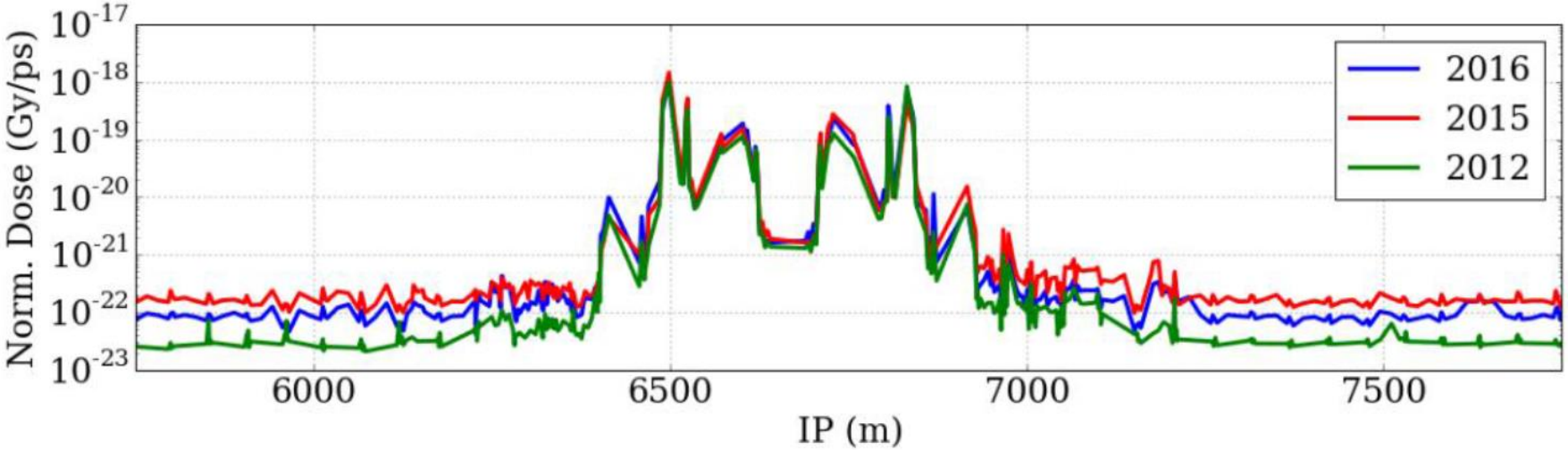
2012: **1.75e14** (0.31)
2015: **9.15e13** (0.16)
2016: **1.71e14** (0.31)

P7 integrated BLM losses per integrated intensity



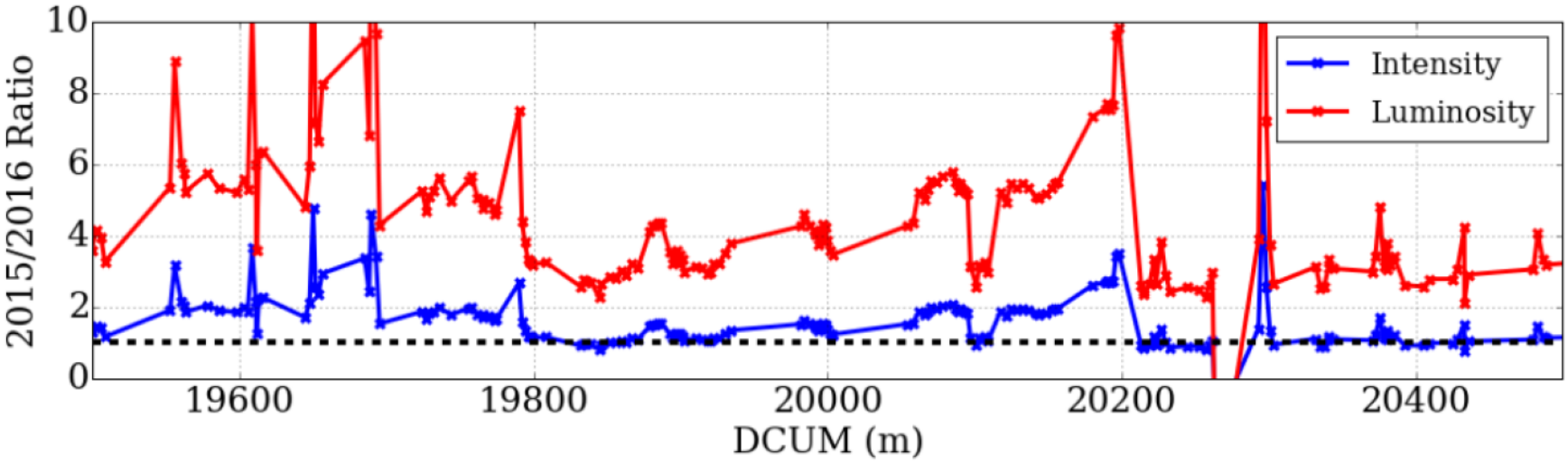
- Similar trend, but already visible that normalized 2016 values are lower

P3 integrated BLM losses per integrated intensity



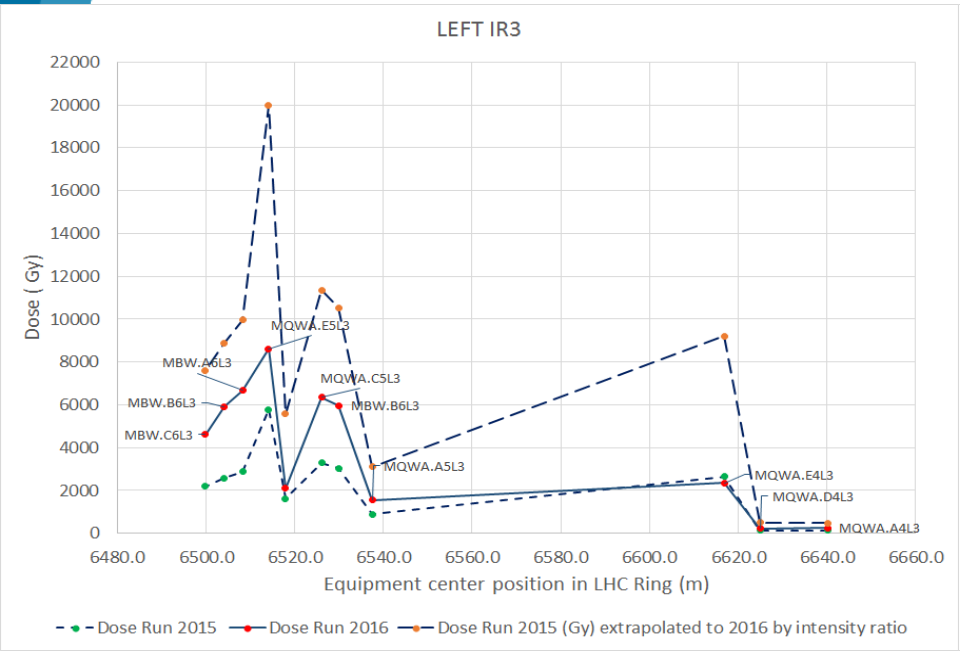
- Intensity scaling looks even better for P3 in high-loss region

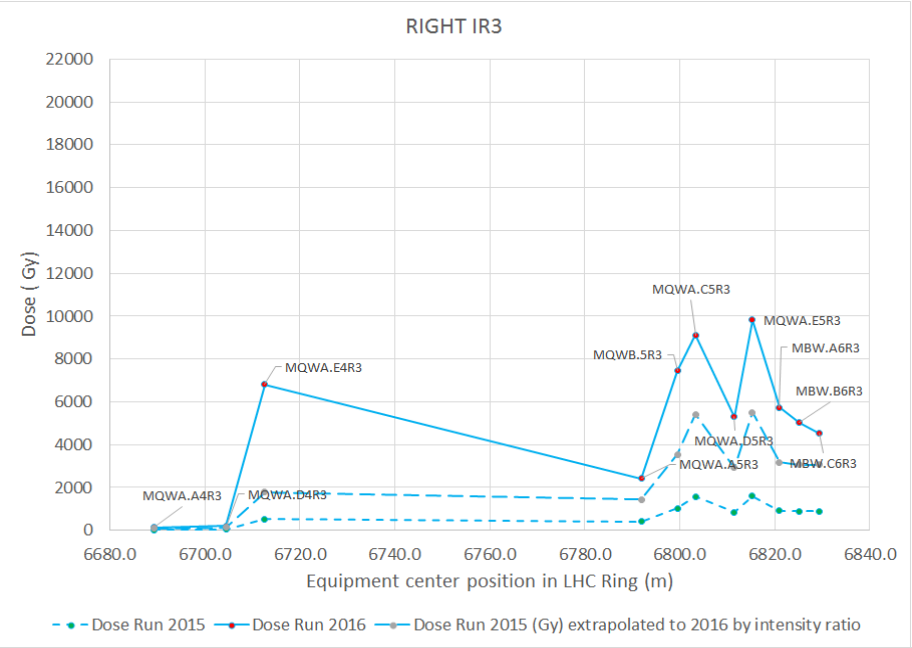
P7 scaling for 2015/2016

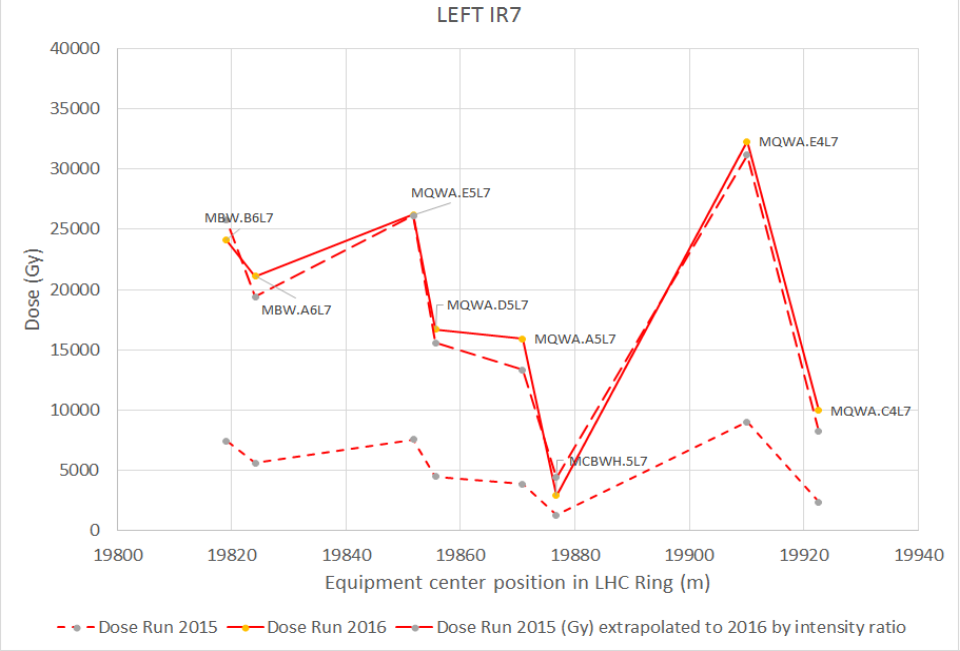


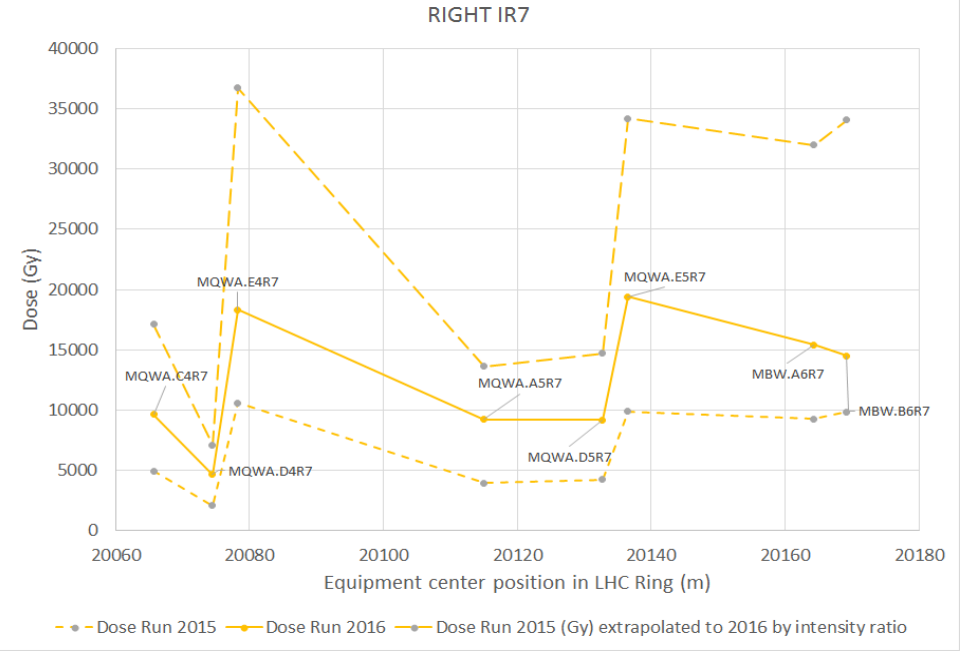
- Clearly better scaling with intensity, especially in high-loss region (19800-20200) where ratio is mostly near one
- Still, significant outliers (e.g. change in collimator settings?)

Scaling with integrated intensity





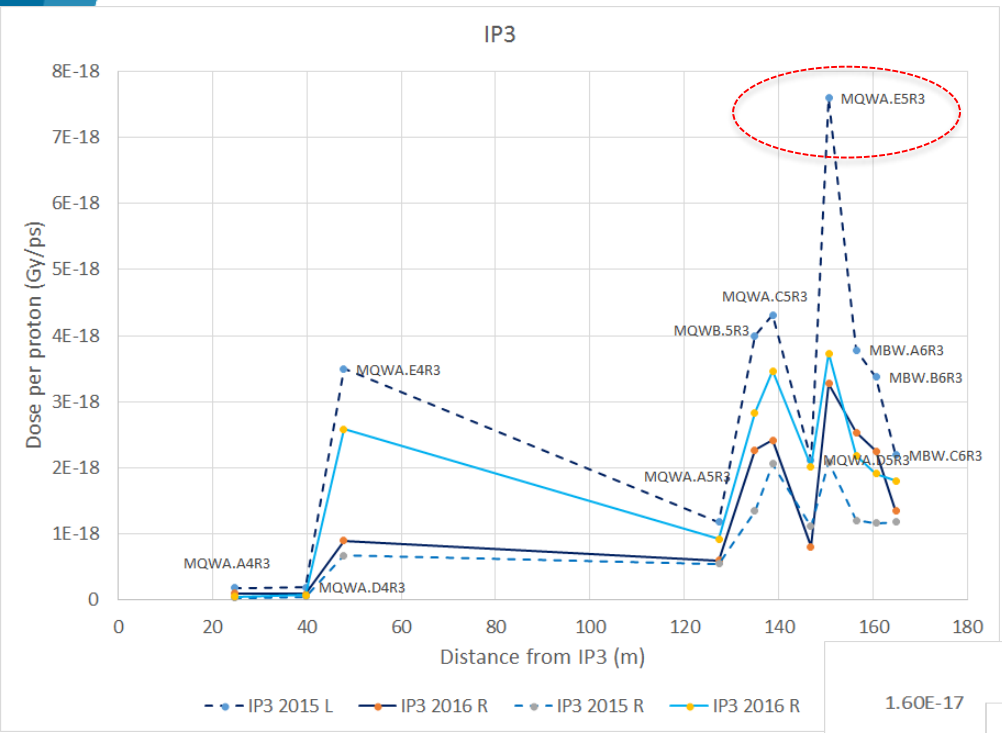


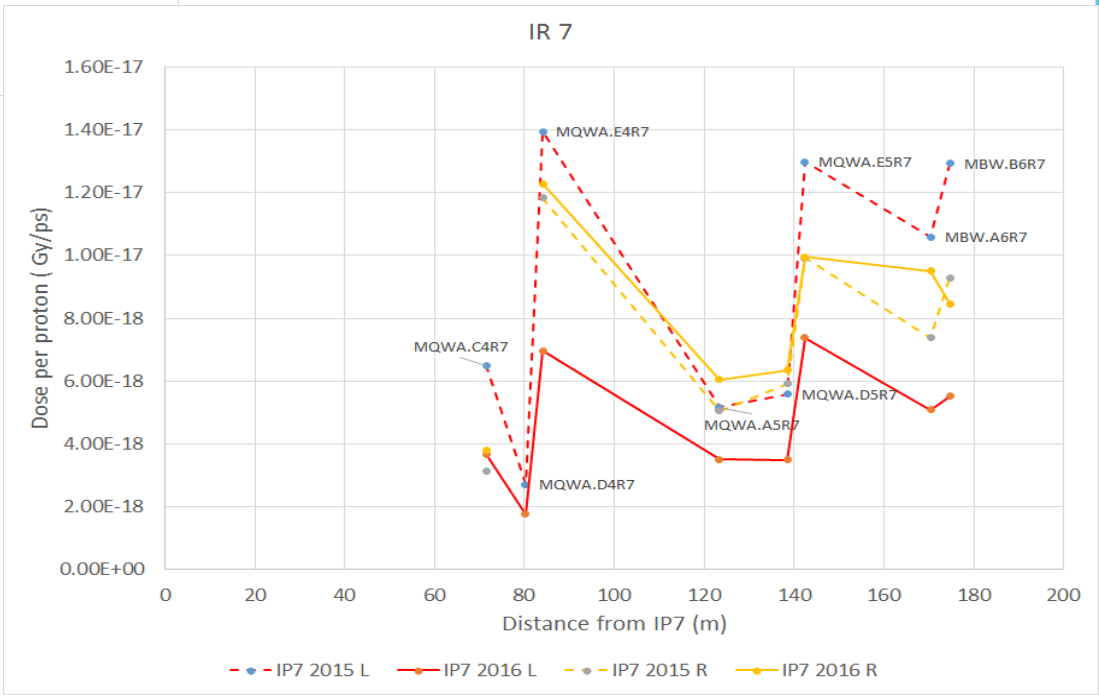


New procedure

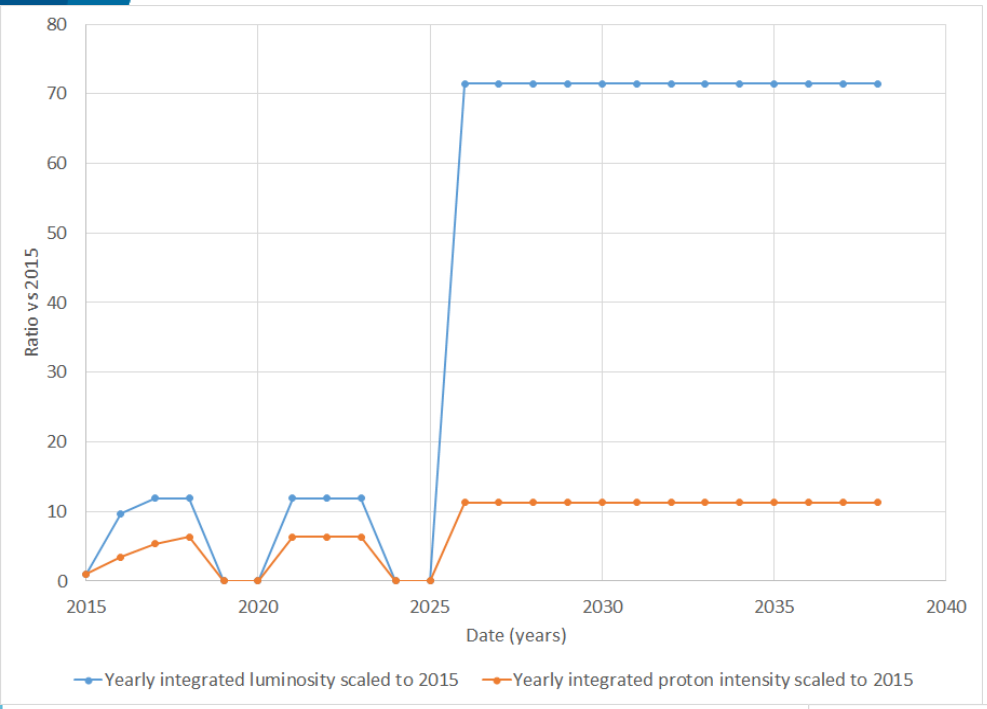
- Divide each dosimeter recorded dose by the integrated intensity recorded during the time of irradiation (value in Gy/ps)
- For each magnet take the maximum value in Gy/ps between 2015 Run and 2016 Run and between Left and Right (maximum among 4 values)
- Scale those values with the projected integrated intensity
- Thanks to FLUKA models transform the dose on the dosimeter to dose on the coil
- Thanks to FLUKA interpolate missing locations

Maximum in dose per p•s

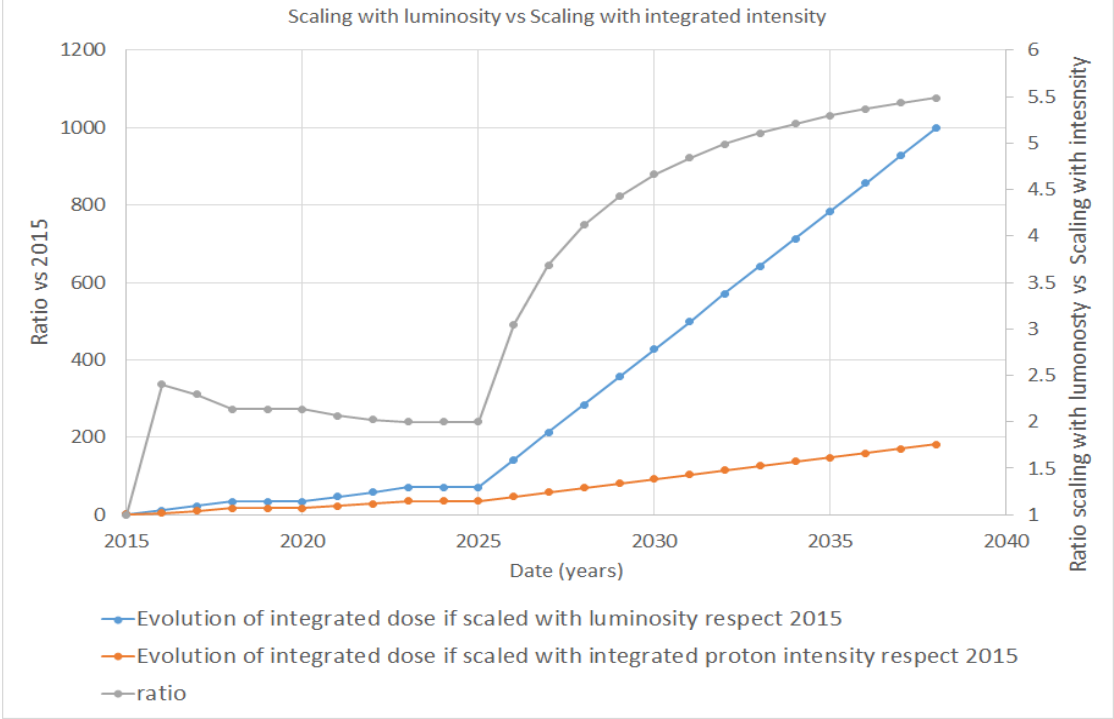




Projected intensity and luminosity evolution and effect on scaling a quantity respect one or the other (2015 equal 1)



Year	Measured Int P intensity 2 beams [p•s]	Estimated Int P intensity 2 beams [p•s]
2016	2.63 e21	2.98 e21
2017		4.1 e21
Typical LHC		4.82 e21
Typical HL-LHC		8.6 e21



Magnets Coil Dose/damage Forecast Update IR3

Updated values of foreseen peak dose for each involved magnet of IR3 **after shielding.**
NEW Materials Limits Applied: MQW: 10-50, 50-75, 75+ . MBW: 50-75, 75-90, 90+

IR3	*Dose [MGy] for integrated luminosity 150 fb^{-1} (LS2)*		*Dose [MGy] for integrated luminosity 350 fb^{-1} (LS3)*		*OLD forecast Dose [MGy] for integrated luminosity 350 fb^{-1} (LS3)- OLD LIMITS*		*Dose [MGy] for integrated luminosity 3000 fb^{-1} (LS6)*		*OLD Forecast Dose [MGy] for integrated luminosity 3000 fb^{-1} – OLD LIMITS*	
	R	L	R	L	R	L	R	L	R	L
MQWA.A4	0	0	0	0	0	0	3	3	1	3
MQWA.B4	0	0	0	0	0	0	3	3	1	3
MQWB.4	0	0	0	0	0	1	3	3	0	1
MQWA.C4	0	0	0	0	0	1	4	4	1	1
MQWA.D4	0	0	1	1	1	2	9	9	1	3
MQWA.E4	2	2	**3**	**3**	**2**	**5**	**15**	**15**	**7**	**14**
MQWA.A5	1	1	**2**	**2**	**2**	**3**	**10**	**10**	**5**	**10**
MQWA.B5	2	2	**3**	**3**	**2**	**4**	**12**	**12**	**6**	**12**
MQWB.5	4	4	**6**	**6**	**5**	**10**	**29**	**29**	**14**	**29**
MQWA.C5	10	10	**14**	**14**	**11**	**22**	Planned to be exchanged in LS3			
MQWA.D5	2	2	**3**	**3**	**3**	**5**	**16**	**16**	**7**	**15**
MQWA.E5	5	5	**6**	**6**	**5**	**10**	**30**	**30**	**14**	**27**
MBW.A6	4	4	**6**	**6**	**3**	**6**	**28**	**28**	**13**	**25**
MBW.B6	3	3	**4**	**4**	**3**	**7**	**20**	**20**	**9**	**18**
MBW.C6	3	3	**4**	**4**	**5**	**0**	**17**	**17**	**8**	**16**

MQW Spacers Dose/Damage Forecast in IR7

Values of foreseen peak dose for each involved MQW Spacer of IR7 **after shielding.**

NEW Materials Limits Applied: MQW: 5-10, 10-15, 15+ .

IR7	*Dose [MGy] for integrated luminosity 150 fb^{-1} (LS2)*		*Dose [MGy] for integrated luminosity 350 fb^{-1} (LS3)*		*Dose [MGy] for integrated luminosity 3000 fb^{-1} (LS6)*		*Dose [MGy] for integrated luminosity 4000 fb^{-1} (End of HL-LHC)*	
	R	L	R	L	R	L	R	L
MQWA.A4	0	0	0	0	2	2	3	2
MQWA.B4	0	0	0	0	3	2	4	3
MQWB.4	0	0	**0**	**0**	**2**	**1**	**2**	**2**
MQWA.C4	1	1	**1**	**1**	**5**	**4**	**7**	**5**
MQWA.D4	0	0	**1**	**0**	**3**	**2**	4	3
MQWA.E4	**1**	**1**	**3**	**2**	Exchanged in LS3			
MQWA.A5	1	0	**1**	**1**	**4**	**3**	**5**	**4**
MQWA.B5	1	1	**1**	**1**	**6**	**5**	**8**	**6**
MQWB.5	1	1	**1**	**1**	**6**	**5**	8	6
MQWA.C5	1	1	**2**	**1**	**7**	**5**	**9**	**7**
MQWA.D5	1	1	**2**	**1**	**9**	**7**	**12**	**9**
MQWA.E5	**2**	**2**	Removed in LS2 + Cell Reconfiguration					

MQW Spacers are critical only on magnets that were planned to be removed because of coils damage, however, it might be necessary to extend the shields and increase protection on C5 and D5 magnets spacers during LS2.

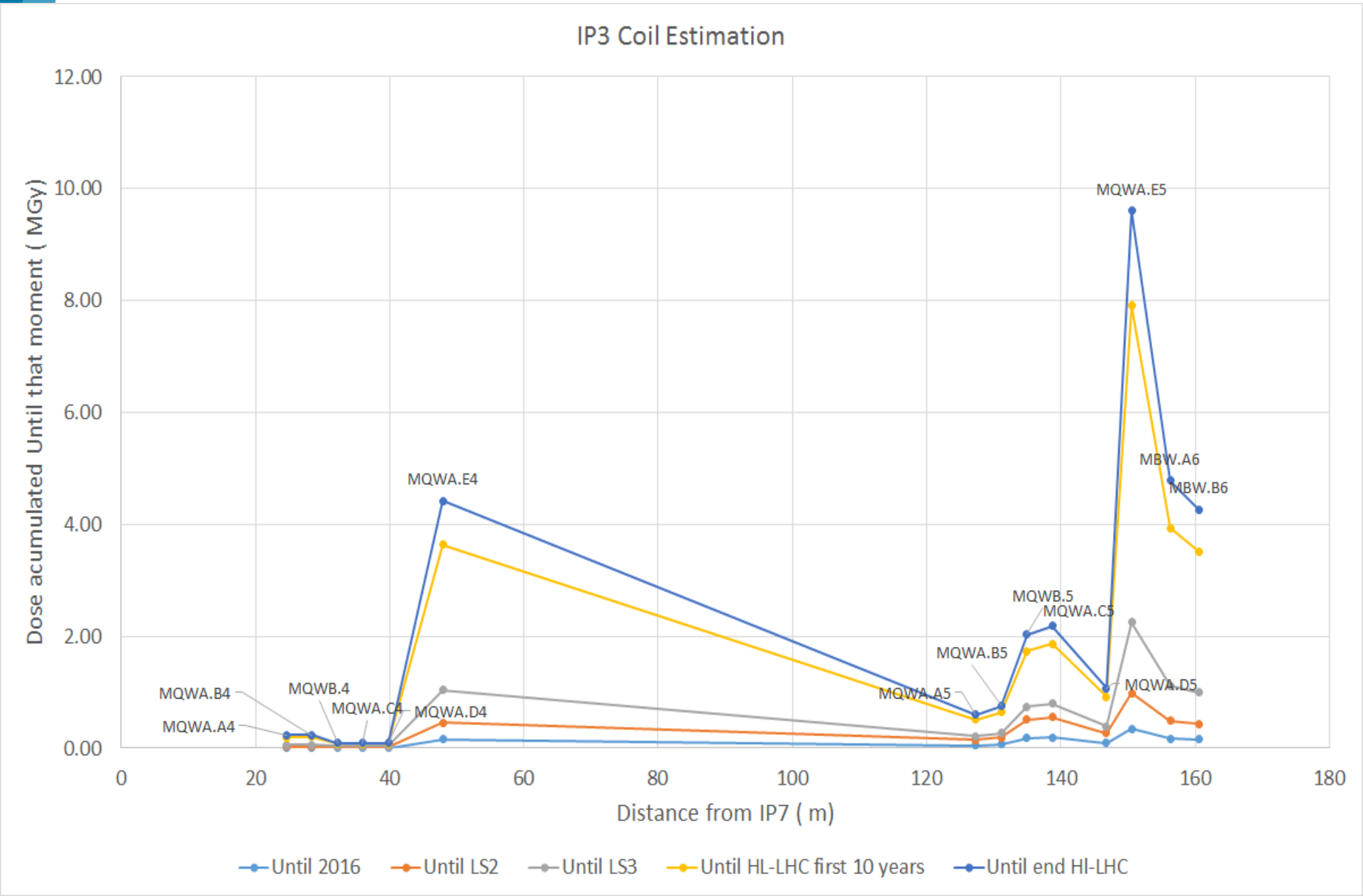
Magnets Coil Dose/Damage Forecast Update IR7

Updated values of foreseen peak dose for each involved magnet of IR7 **after shielding.**
NEW Materials Limits Applied: MQW: 10-50, 50-75, 75+ . MBW: 50-75, 75-90, 90+

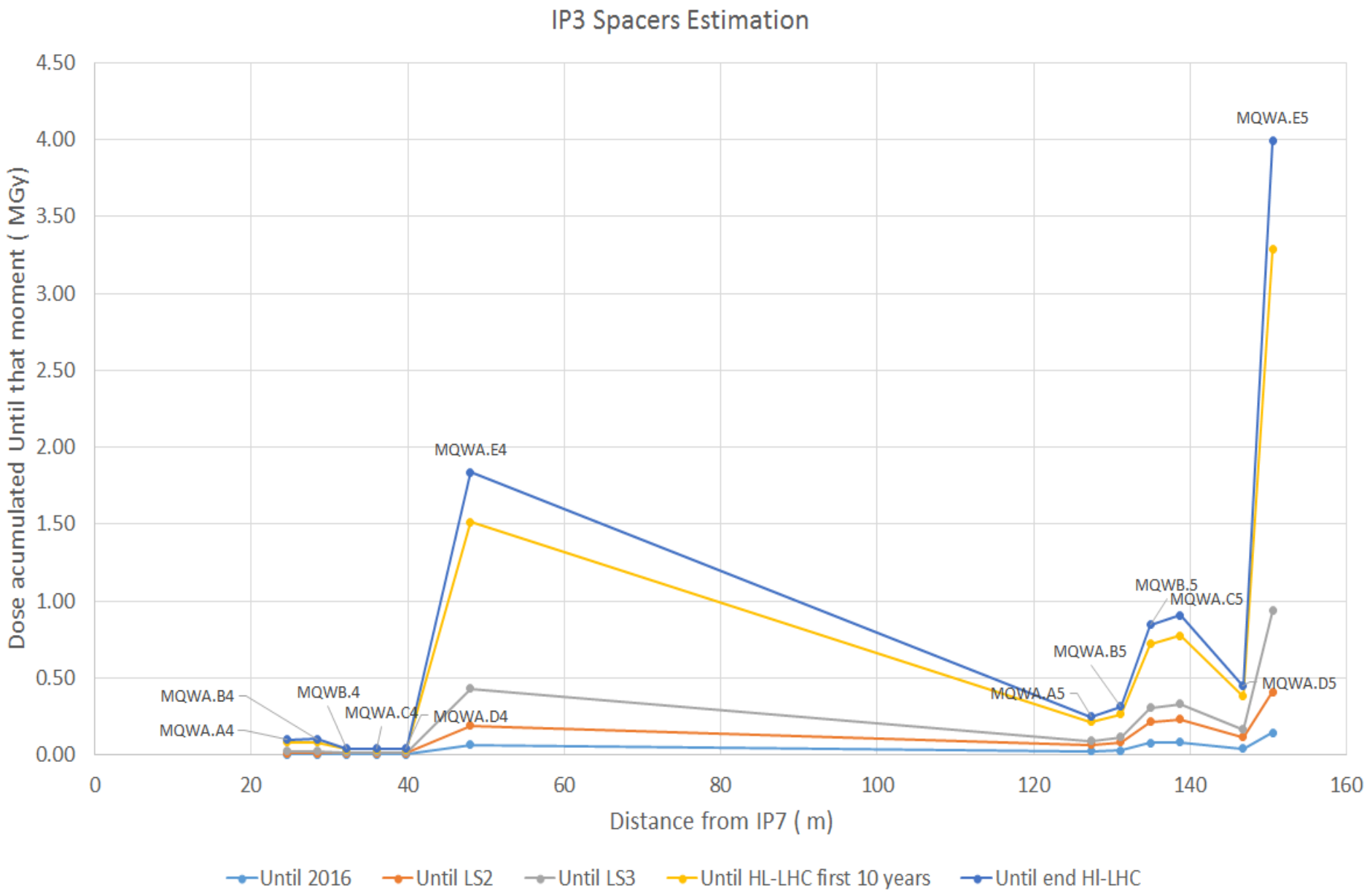
IR7	*Dose [MGy] for integrated luminosity 150 fb^{-1} (LS2)*		*Dose [MGy] for integrated luminosity 350 fb^{-1} (LS3)*		*OLD forecast Dose [MGy] for integrated luminosity 350 fb^{-1} (LS3)- OLD LIMITS*		*Dose [MGy] for integrated luminosity 3000 fb^{-1} (LS6)*		*OLD Forecast Dose [MGy] for integrated luminosity 3000 fb^{-1} – OLD LIMITS*	
	R	L	R	L	R	L	R	L	R	L
MQWA.A4	0	0	1	1	1	2	9	7	5	7
MQWA.B4	1	1	1	1	1	3	14	11	4	11
MQWB.4	1	1	**2**	**1**	**1**	**3**	**9**	**7**	**3**	**7**
MQWA.C4	4	3	**5**	**4**	**9**	**9**	**26**	**20**	**20**	**20**
MQWA.D4	2	1	**2**	**2**	**4**	**4**	**15**	**11**	**11**	**11**
MQWA.E4	**1**	**1**	**2**	**2**	**2**	**5**	Exchanged in LS3			
MQWA.A5	2	1	**2**	**2**	**4**	**4**	**13**	**10**	**10**	**10**
MQWA.B5	3	2	**4**	**3**	**6**	**6**	**18**	**14**	**14**	**14**
MQWB.5	3	2	**4**	**3**	**6**	**6**	**18**	**14**	**14**	**14**
MQWA.C5	3	2	**4**	**3**	**3**	**7**	**18**	**14**	**6**	**14**
MQWA.D5	3	2	**5**	**4**	**6**	**8**	**31**	**24**	**17**	**24**
MQWA.E5	**3**	**2**	Removed in LS2 + Cell Reconfiguration							
MBW.A6	**4**	**2**	**7**	**5**	**16**	**12**	Exchanged in LS3			
MBW.B6	**4**	**3**	**9**	**6**	**29**	**14**	Exchanged in LS3			

MQW: most exposed units see their estimated dose decreased while, low dose slightly increased
MBW: new forecasts are lower than previous estimations giving more margin.

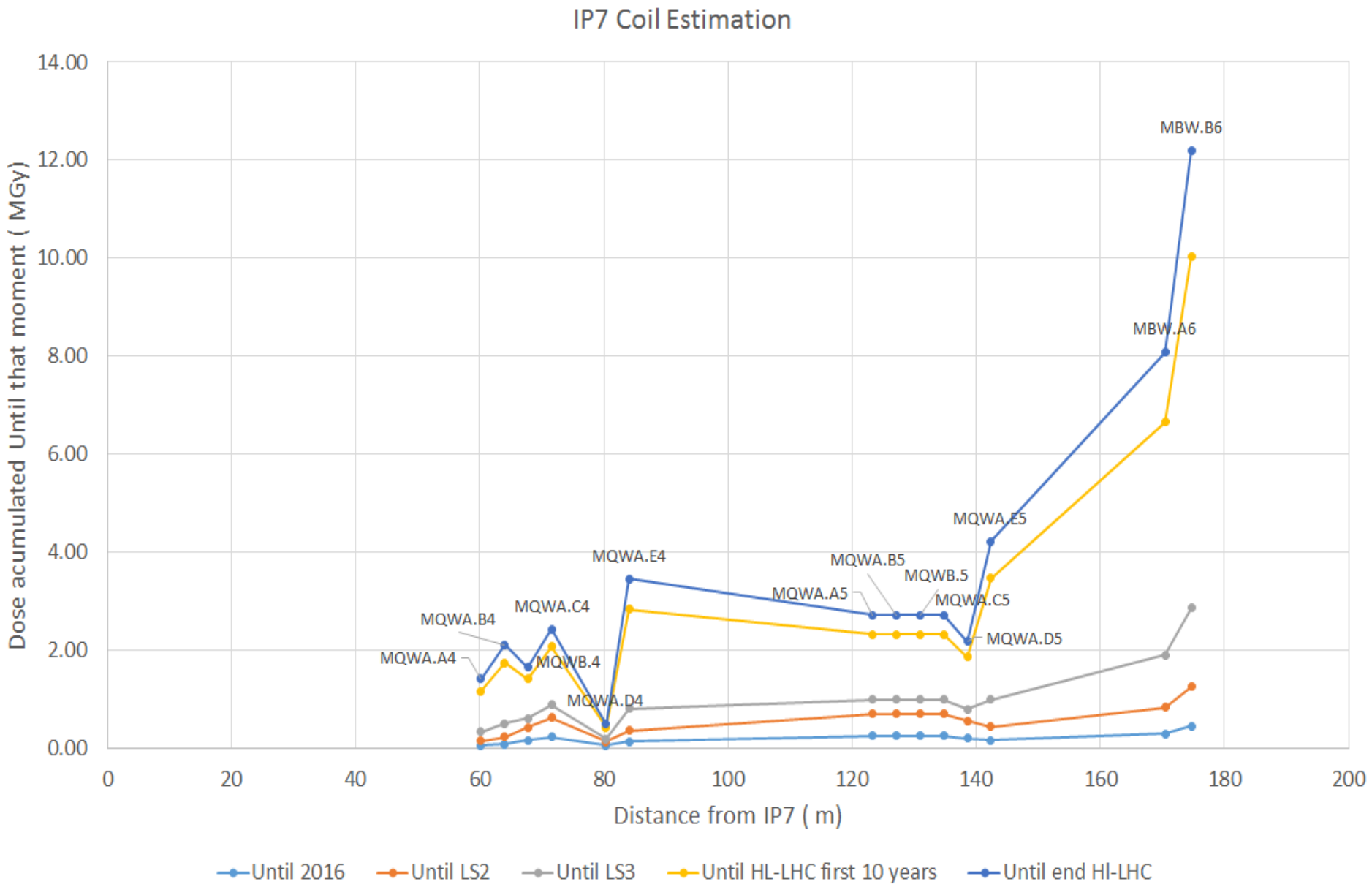
IP 3 coils


IP3 Coil Estimation
Dose acumulated Until that moment (MGy)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
20
40
60
80
100
120
140
160
180
Distance from IP7 (m)
MQWA.E5
MBW.A6
MBW.B6
MQWA.E4
MQWB.5
MQWA.C5
MQWA.B5
MQWA.A5
MQWA.D5
MQWA.B4
MQWB.4
MQWA.C4
MQWA.D4
MQWA.A4
Until 2016
Until LS2
Until LS3
Until HL-LHC first 10 years
Until end Hl-LHC

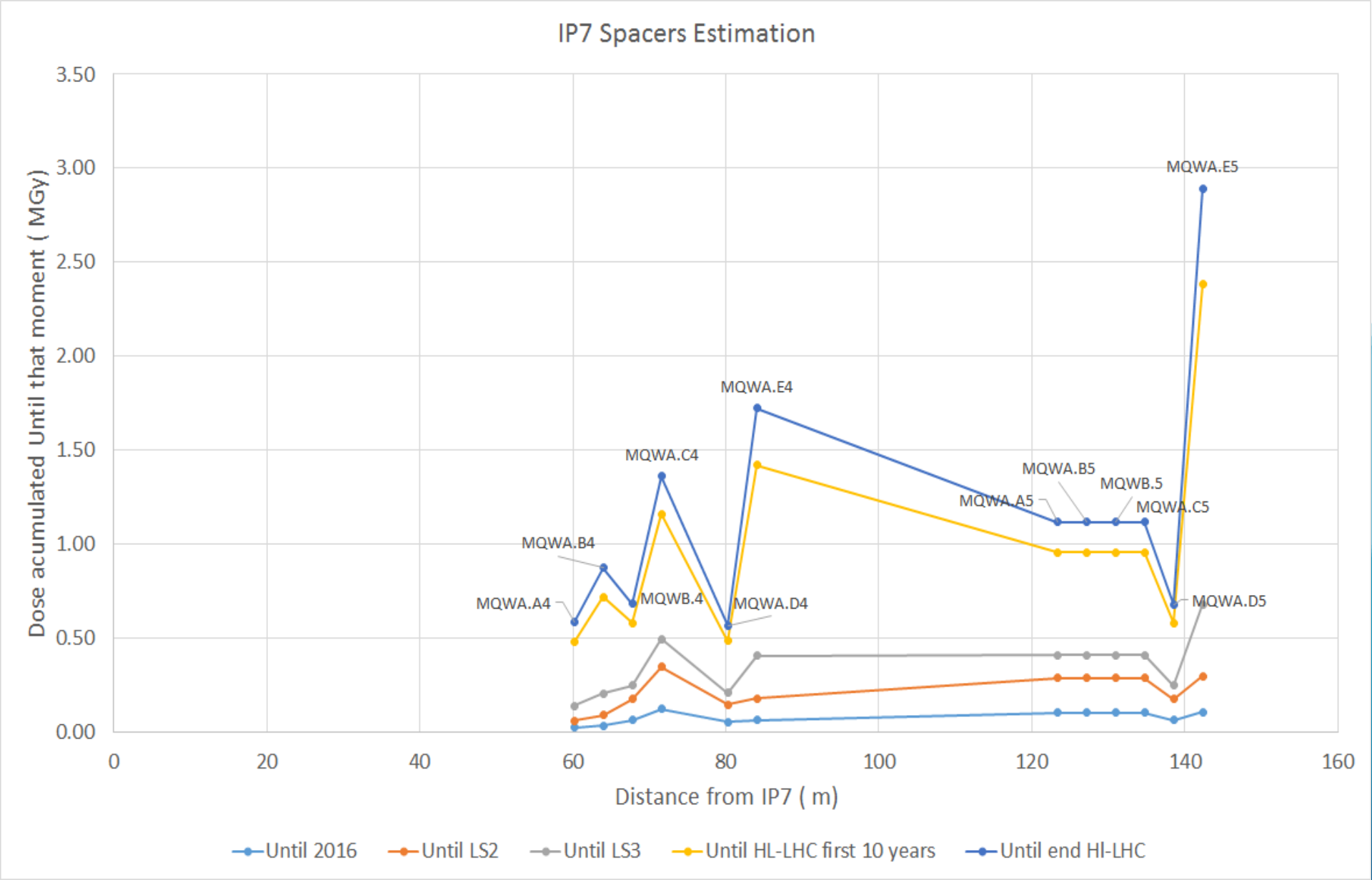
IP 3 spacers


IP3 Spacers Estimation
Dose acumulated Until that moment (MGy)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
120
140
160
Distance from IP7 (m)
MQWA.E5
MQWA.E4
MQWB.5
MQWA.C5
MQWA.B5
MQWA.A5
MQWA.D5
MQWA.B4
MQWB.4
MQWA.C4
MQWA.D4
MQWA.A4
Until 2016
Until LS2
Until LS3
Until HL-LHC first 10 years
Until end Hl-LHC

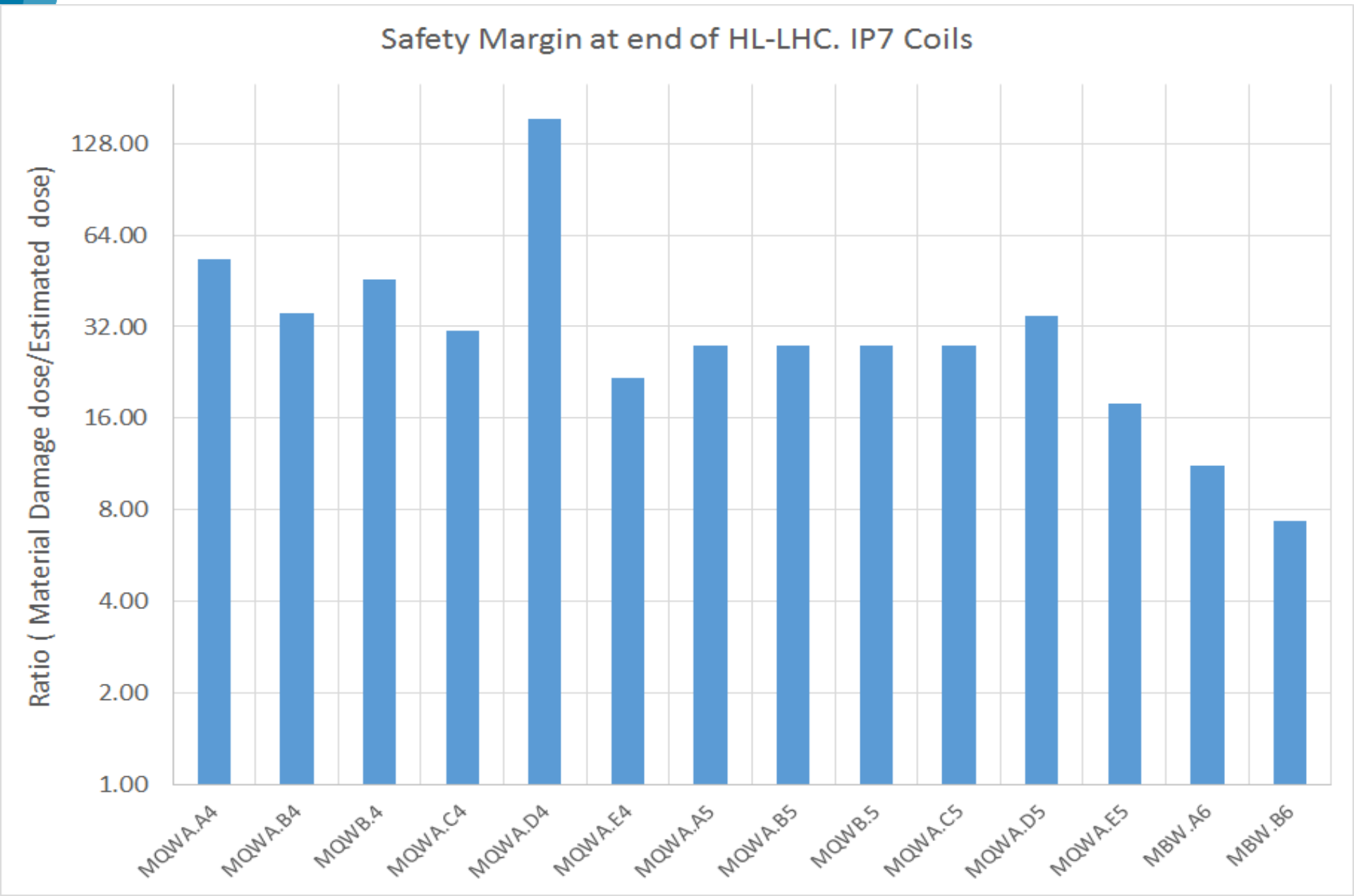
IP 7 coils


IP7 Coil Estimation
Dose acumulated Until that moment (MGy)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
20
40
60
80
100
120
140
160
180
200
Distance from IP7 (m)
MBW.B6
MBW.A6
MQWA.E5
MQWA.E4
MQWA.B5
MQWB.5
MQWA.A5
MQWA.C5
MQWA.D5
MQWA.C4
MQWA.B4
MQWA.A4
MQWB.4
MQWA.D4
Until 2016
Until LS2
Until LS3
Until HL-LHC first 10 years
Until end HI-LHC

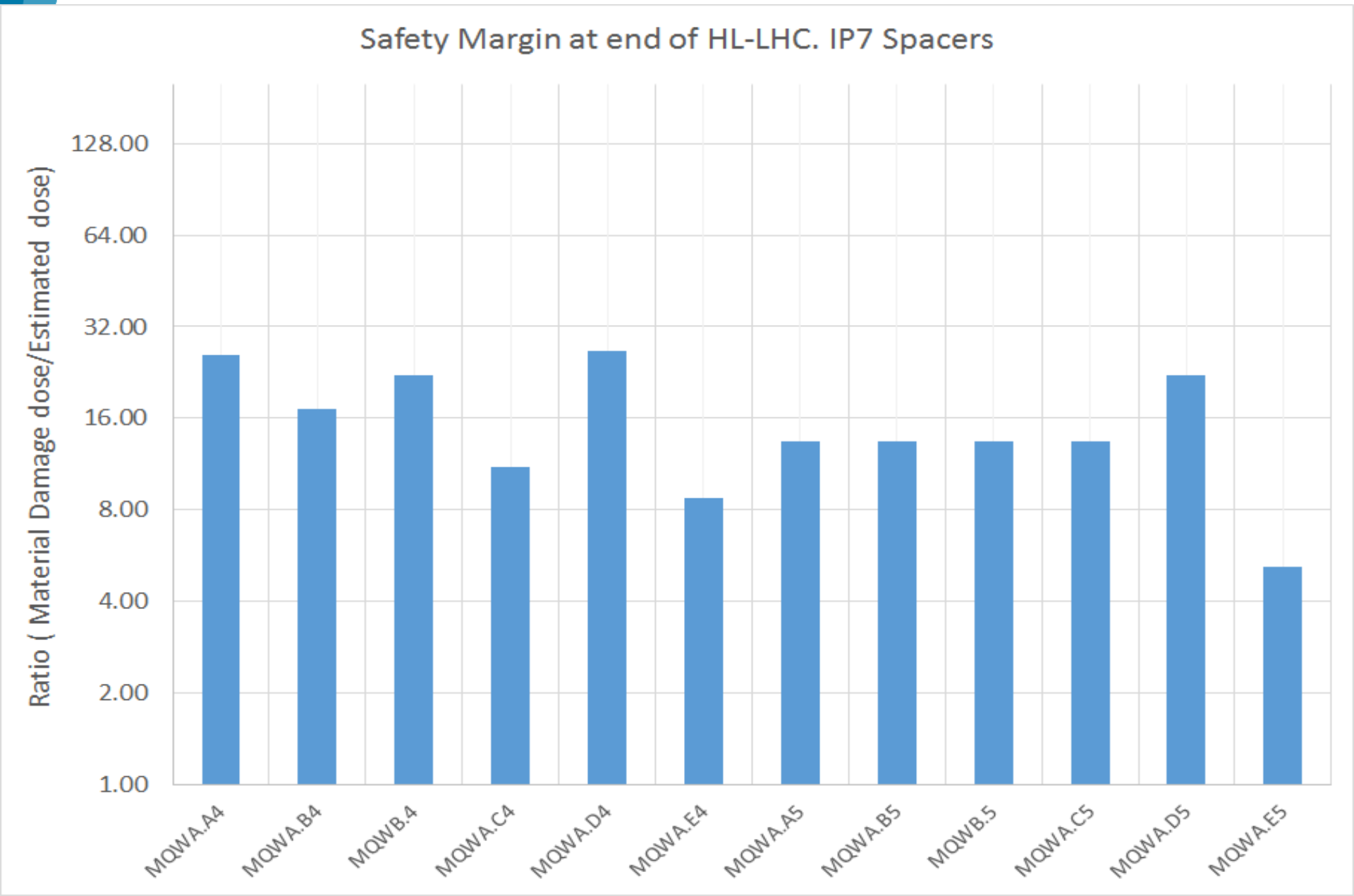
IP7 spacers


IP7 Spacers Estimation
Dose acumulated Until that moment (MGy)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
120
140
160
Distance from IP7 (m)
MQWA.E5
MQWA.E4
MQWA.C4
MQWA.B5
MQWB.5
MQWA.A5
MQWA.C5
MQWA.B4
MQWA.A4
MQWB.4
MQWA.D4
MQWA.D5
Until 2016
Until LS2
Until LS3
Until HL-LHC first 10 years
Until end Hl-LHC

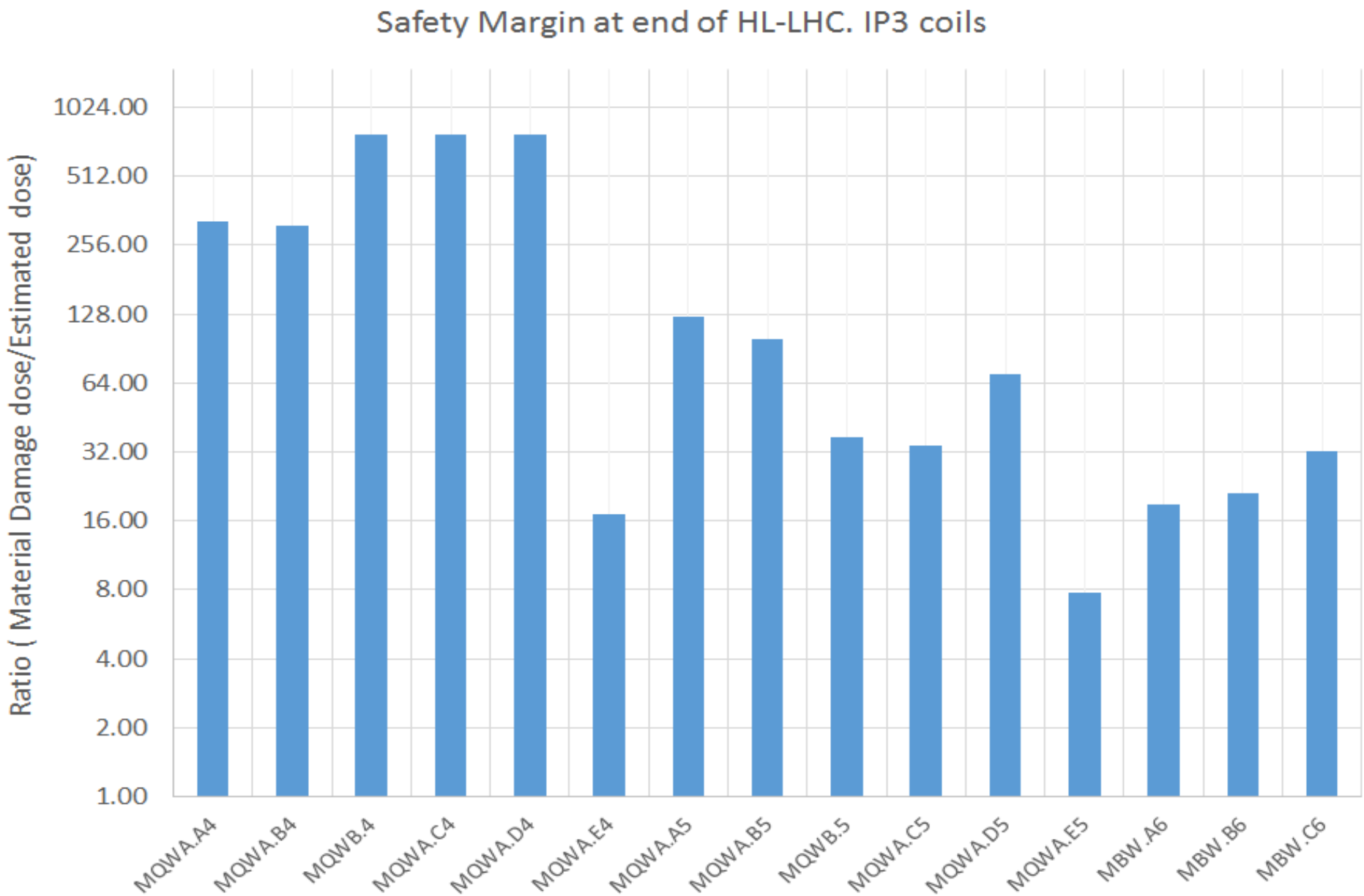
Material safety factor: coils in IP7



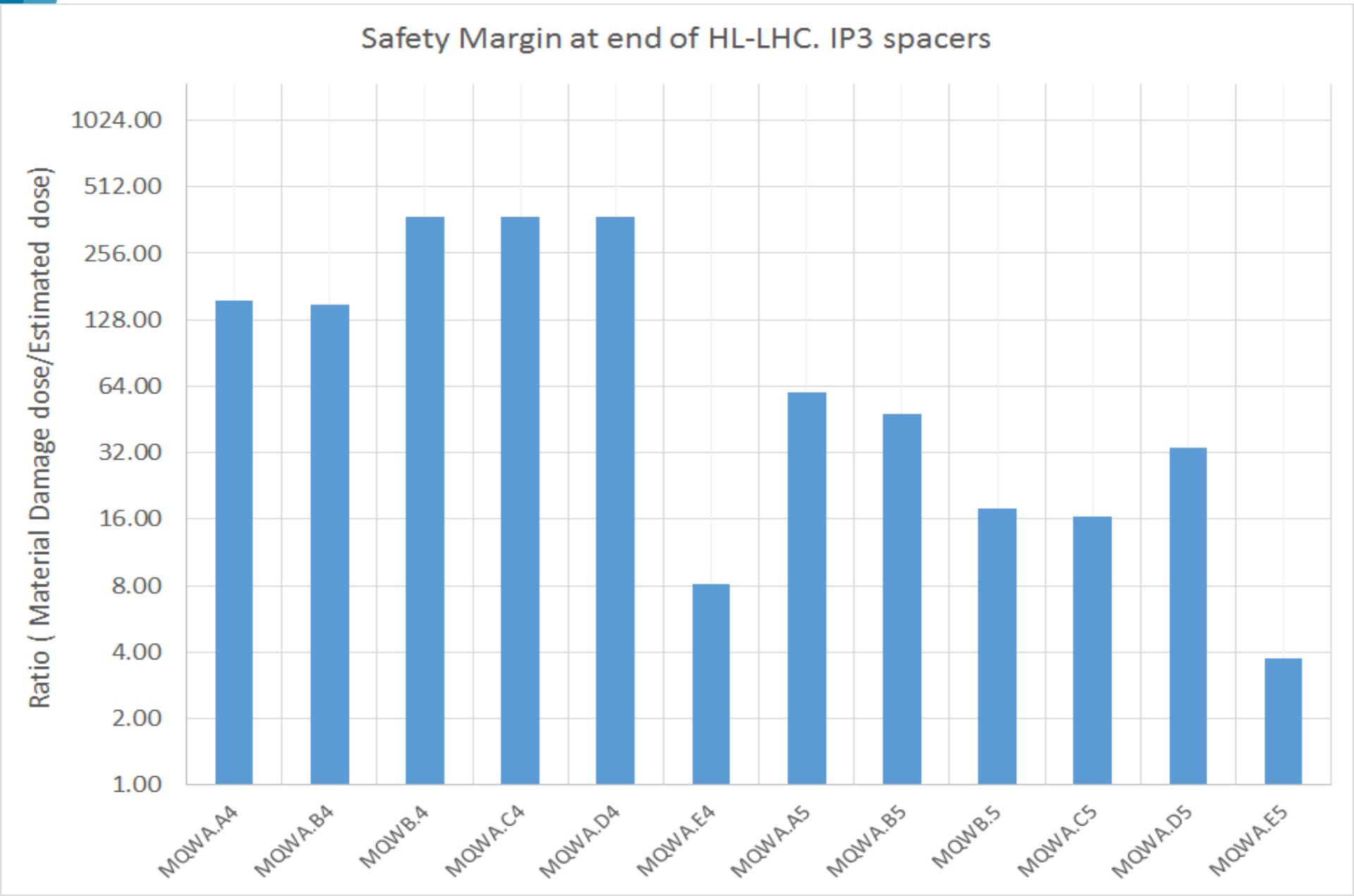
Material safety factor: MQW spacers in IP7



Material safety factor: Coils in IP3



Material safety factor: spacers in IP3



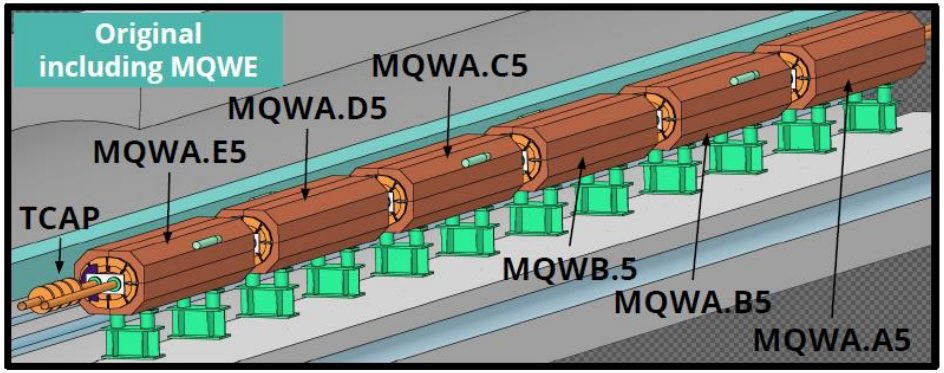
Proposal about what to do

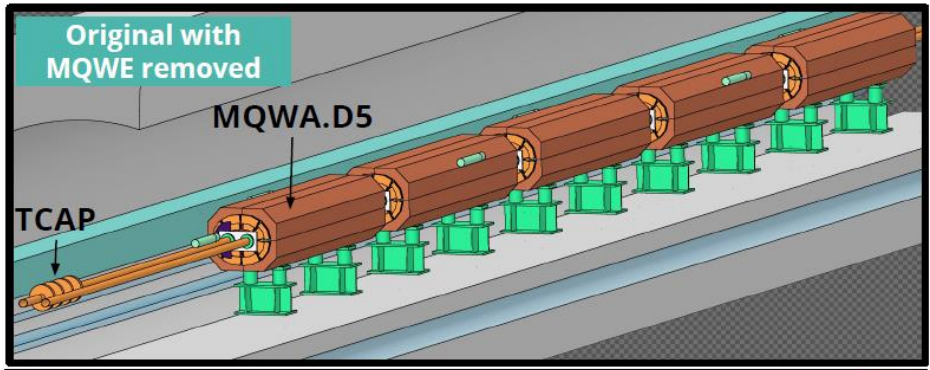
When	Action	Comment/Proposal
YETS 2017-2018	Reading of the dosimeter of 2017 run	Confirmed. Revaluation of scaling
LS2	Installation shielding IP3	Confirmed. Procurement placed. Delivery ongoing
	Installation shielding IP7	Confirmed. Procurement placed. Delivery ongoing
	Removal MQWA.E5 IP7	Confirmed. Recovery of 2 spares
RUN 3	Production of 4 sets of rad-hard coils for MBW.	Taking into account that 1) We have 4 spares 2) We have 2 sets of spare coils 3) That we could move magnet at dog leg start (before the primaries) to second part (after primaries) We propose not to procure these units and invest some money in having tooling to open these magnets

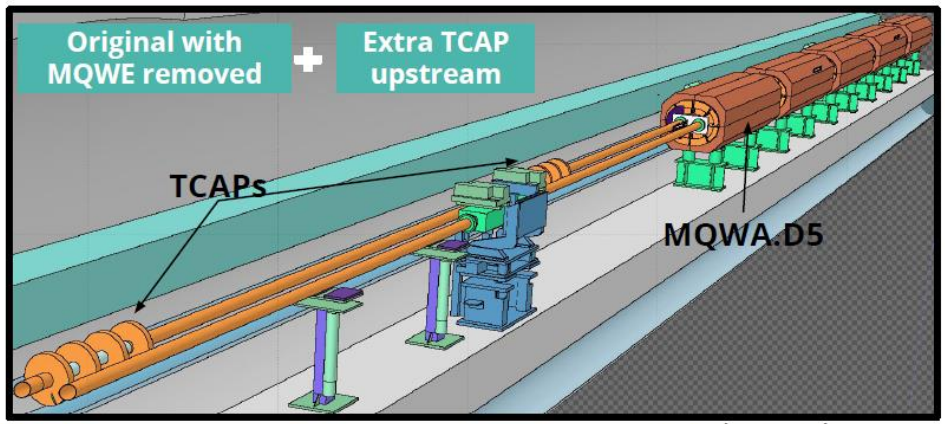
Proposal about what to do

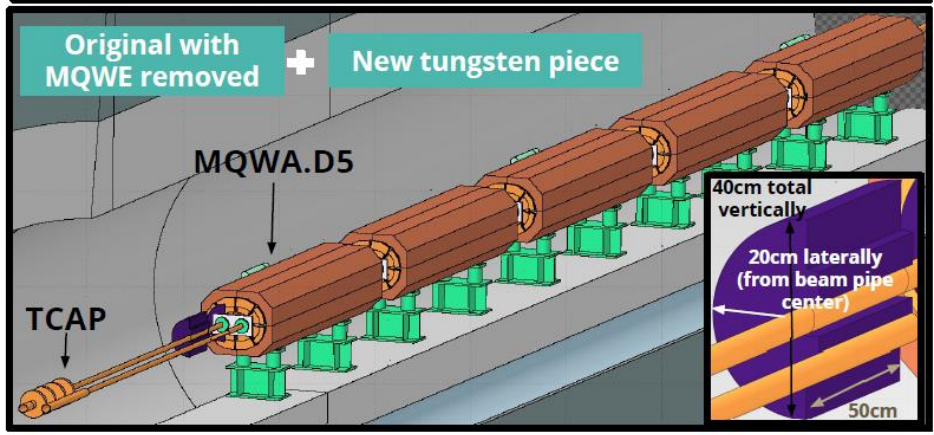
When	Action	Comment/Proposal
RUN 3	Production of 6+1 MQW magnets with rad hard coils.	Taking into account that 1) We have 4 spares 2) We have 10 of spare coils 3) We will have 2 spare magnets more from LS2 We have 2 proposals a) TRIUMF agrees to produce 4 sets of coils rad-hard. Replace coils in 4 spare magnets with rad-hard and decision if to change the magnets according to dosimeter reading 1-2 years before LS3 b) We do not find in kind contribution. We put baseline 4 sets of coils and we decided after 2017 RUN dosimeters data. We need to invest some money in being able to open and close MQWs

Cases studied









Peak dose the magnet coils and spacers