Update of the radiation levels in the LHC

O. Stein (EN-EA),
C. Martinella (EN-EA)

With input from the Monitoring Calculation Working Group

Outlook

1. Weekly reports of normalised data
2. Results of BLM and RadMon data of 2015/2016

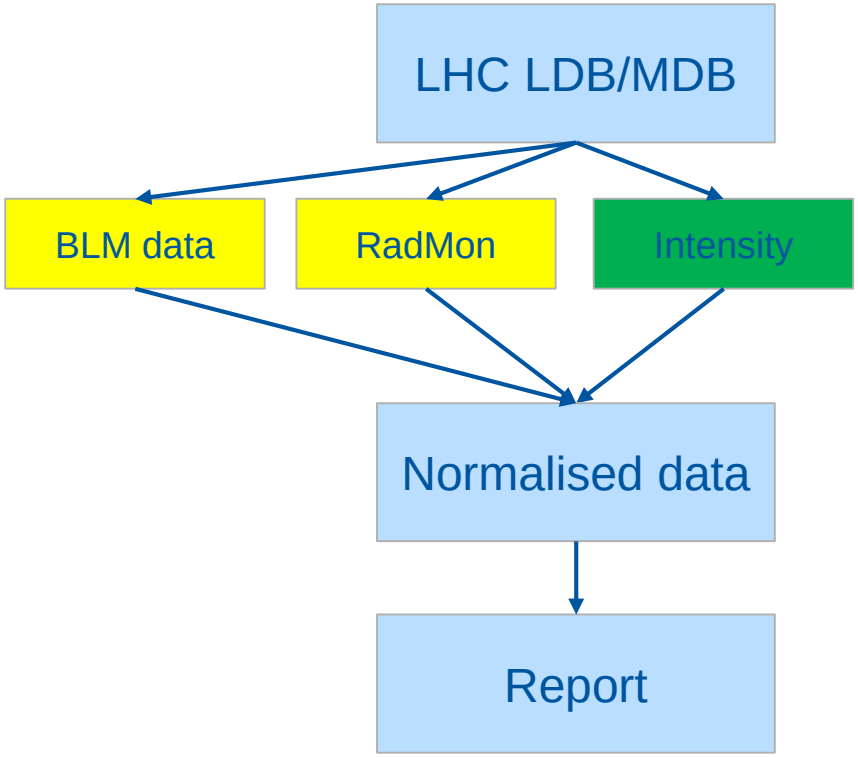
1. Weekly reports of normalised data

Normalising LHC BLM data with integrated intensity

Goal: Providing dose/integrated intensity (Gray/proton second)

Why: Normalised data independent of the intensities.

→ Better comparability of different intervals (weeks)*.



Ongoing work:

Creation of automated scripts

- Data retrieval
  - Intensities
  - BLM ← C. Xu BE-BI
  - RadMon
- Analysis scripts
- Plotting tools

Future:

Publish reports Weekly

* Comparability only for same machine conditions.

Data of 2015 and 2016 processed

BLM data integrated and corrected per week of operation

Data sets:

- Loss data (Gy), Integrated intensities (ps) and normalised losses with the integrated total intensities (all beam modes)

Data of 2015 and 2016 available for all 3590 BLMs at the LHC!

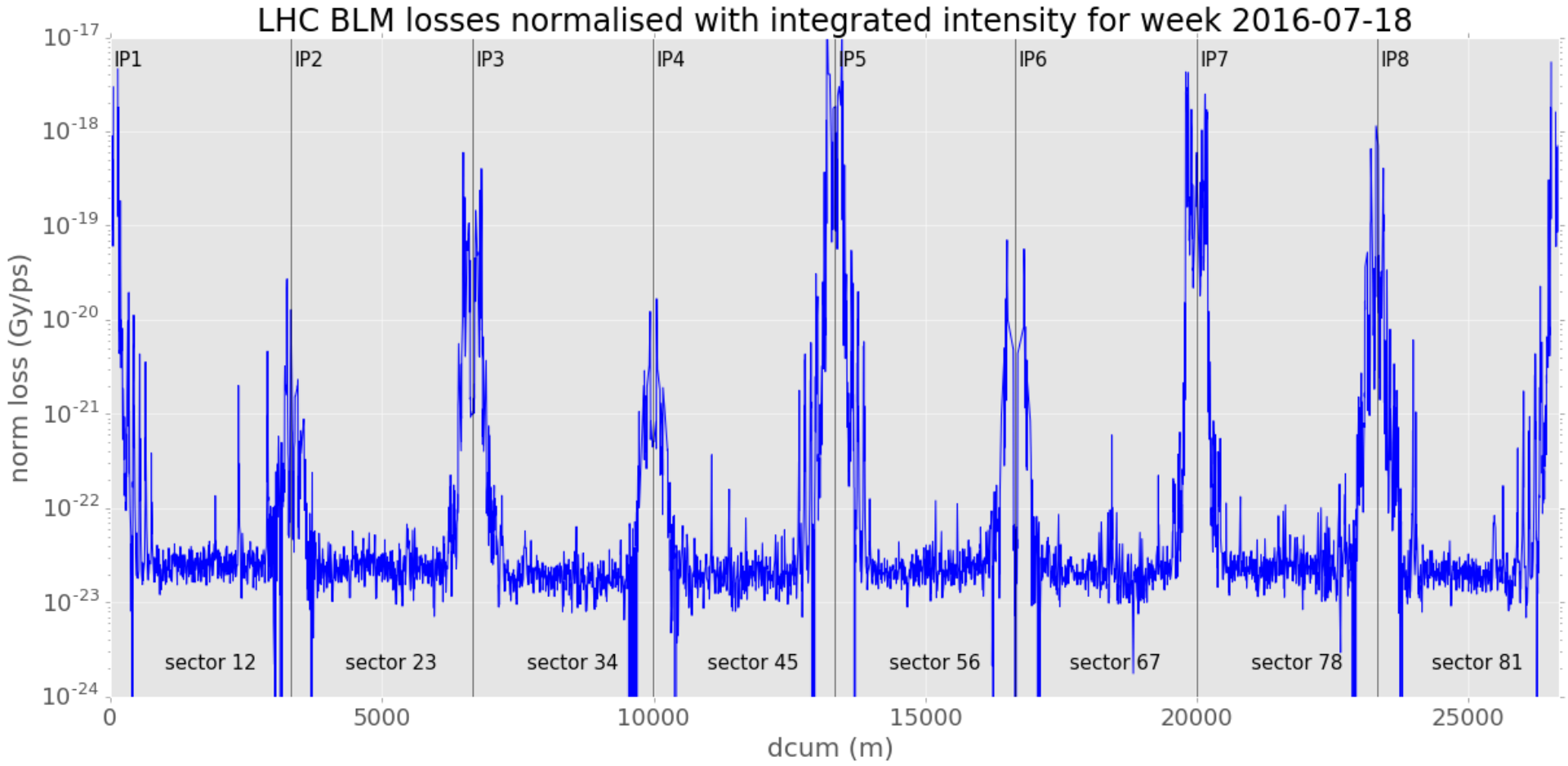
2015: 30 data points

2015: 34 data points

	blm name	dcum	dcum from ip	2015-04-06	2015-04-13	2015-04-20	2015-04-27	2015-05-04	2015-05-11	2
0	BLMQI.01R1.B2I30_MQXA	21.37	21.370	1.594589e-17	4.654897e-18	1.731151e-18	3.516724e-18	3.409768e-18	7.936476e-19	9
1	BLMQI.01R1.B1E10_MQXA	23.44	23.440	1.867354e-17	5.706843e-18	2.076363e-18	4.106782e-18	4.114847e-18	9.550038e-19	1
2	BLMQI.01R1.B2I20_MQXA	25.63	25.630	1.873511e-17	5.573024e-18	2.075854e-18	4.185523e-18	3.607686e-18	8.276182e-19	9
3	BLMQI.01R1.B1E20_MQXA	26.65	26.650	1.856513e-17	5.418976e-18	2.014801e-18	4.001047e-18	3.501402e-18	7.980867e-19	9
4	BLMQI.02R1.B2I30_MQXB	29.75	29.750	1.922588e-17	5.518053e-18	2.122477e-18	4.032909e-18	3.488507e-18	7.623808e-19	7
5	BLMQI.01R1.B1E30_MQXA	32.30	32.300	1.541087e-17	4.443677e-18	1.639020e-18	3.351011e-18	3.446716e-18	8.078491e-19	9
6	BLMQI.02R1.B2I23_MQXB	34.12	34.120	1.528528e-17	4.778259e-18	1.776972e-18	3.716738e-18	3.269234e-18	7.459077e-19	8
7	BLMQI.02R1.B1E21_MQXB	35.30	35.300	1.442561e-17	4.352919e-18	1.614500e-18	3.245779e-18	3.285424e-18	7.692748e-19	8
8	BLMQI.02R1.B2I22_MQXB	37.41	37.410	1.505508e-17	4.538577e-18	1.713883e-18	3.442820e-18	3.268782e-18	7.496519e-19	8

Normalised losses are dependent on the machine parameters.

Normalised loss data 2016, week 18.07.2016



Normalised loss data 2016, week 18.07.2016

Data from week: 18.07.2016

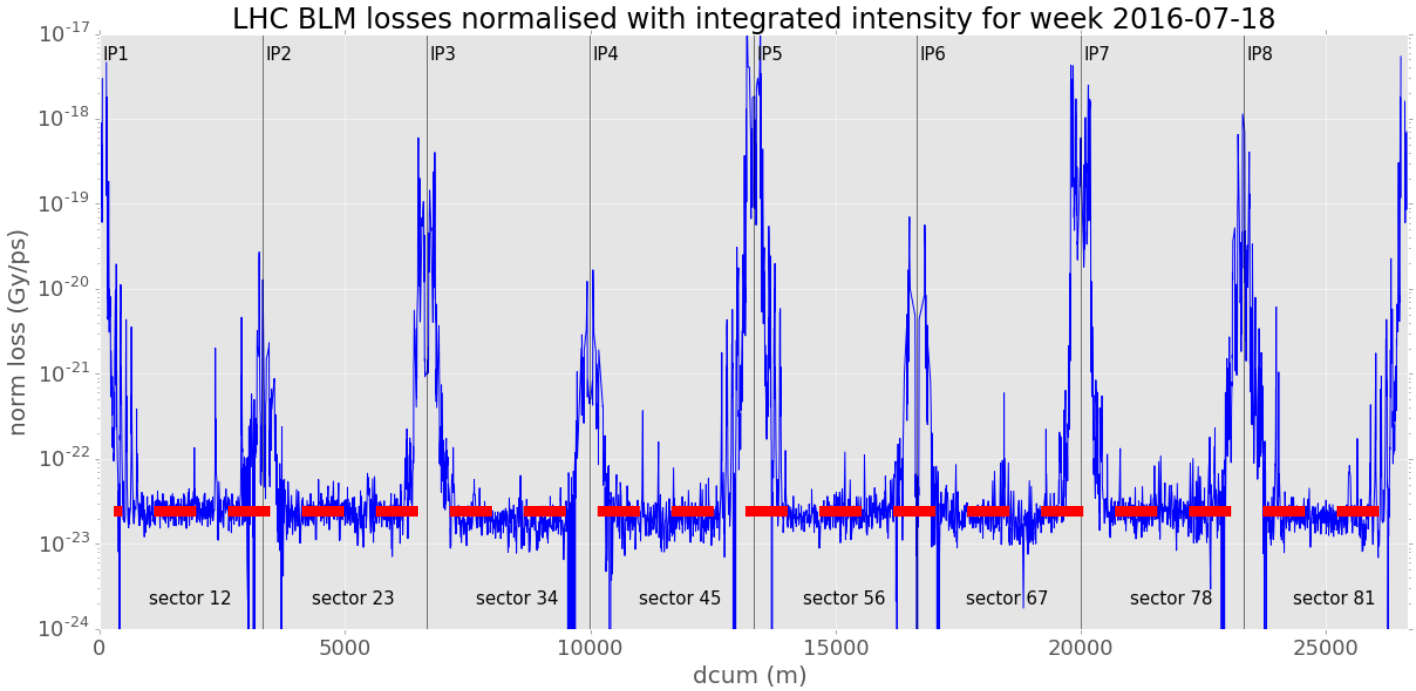
Integrated intensity: 3.37e20

Physics fills

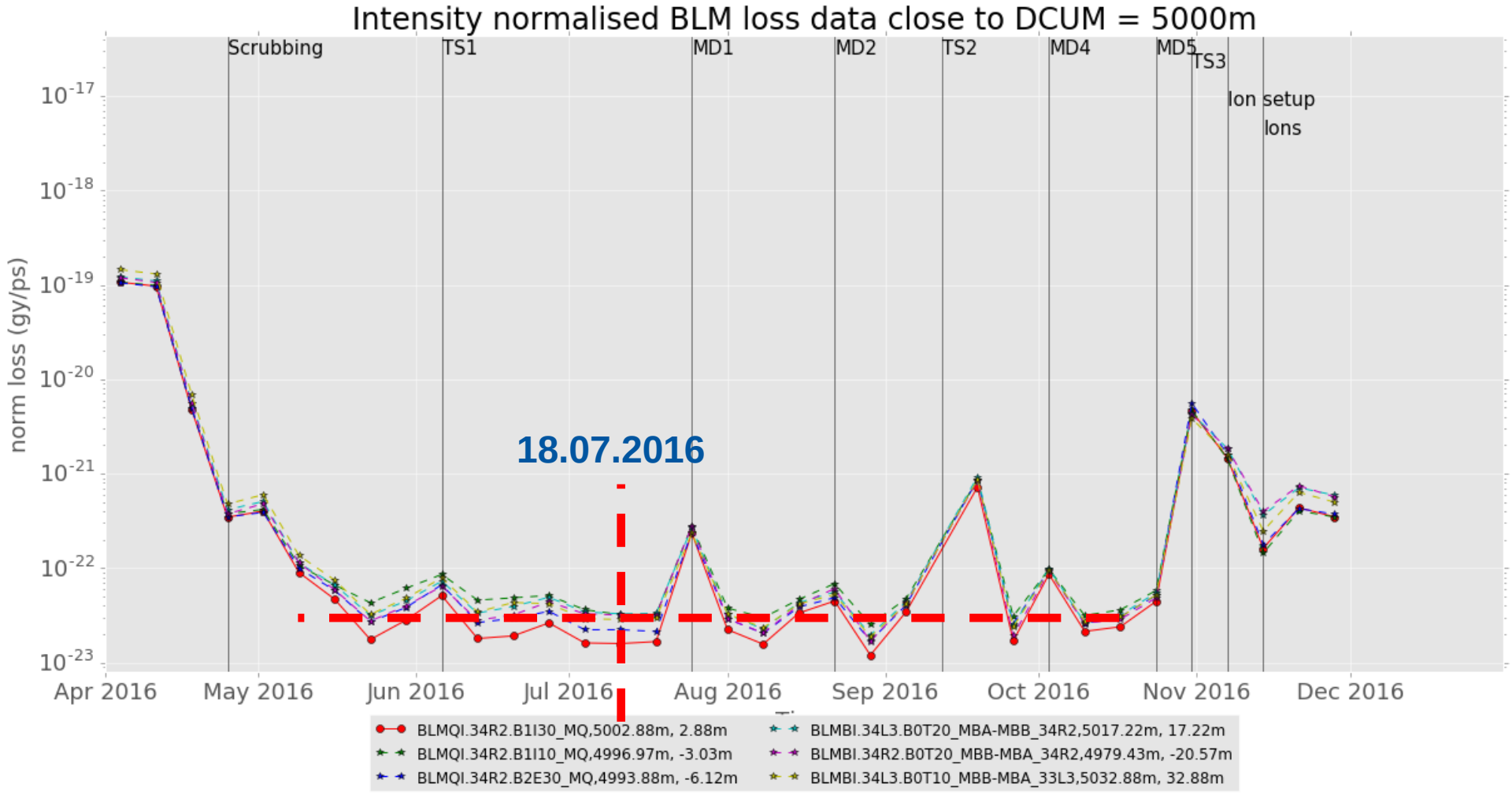
Data valid for 2016 machine parameters!

Loss spikes under investigation!

IP	Norm. loss
1	1e-17
2	1e-20
3	7e-19
4	1e-20
5	1e-17
6	8e-20
7	5e-18
8	1e-19
arc	3e-23



Loss data 2016, dcum 5000



Normalised loss data 2016, dcum 5000

Data from week: 18.07.2016 representative!

Integrated intensity: 3.37e20

Physics fills

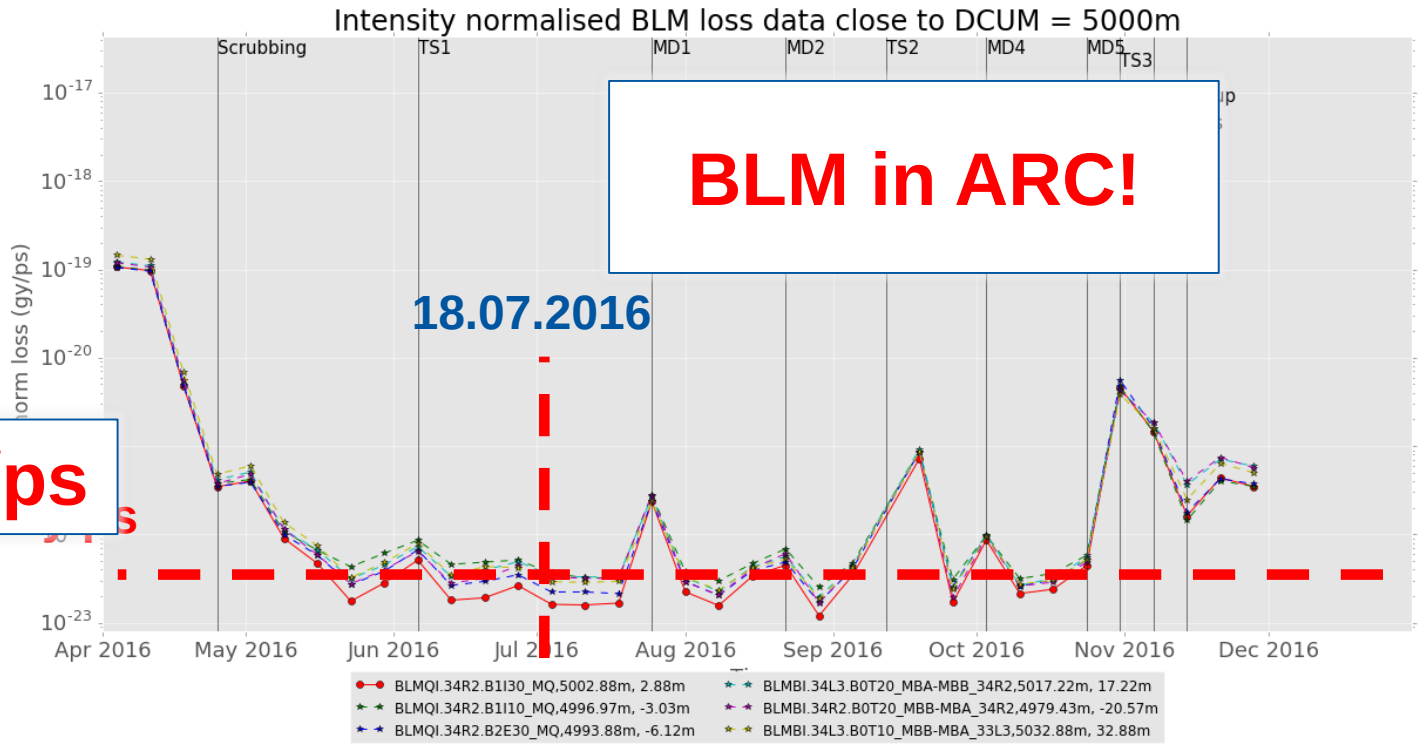
Data valid for 2016 machine parameters!

For physics fills low loss levels in the arcs.

Spikes: Special Fills MDs, TS, etc.

3e-23 Gy/ps

Losses in the IRs? Analysis ongoing!



Normalised loss data 2015, dcum 5000

Data from 2015, same location (dcum 5000)

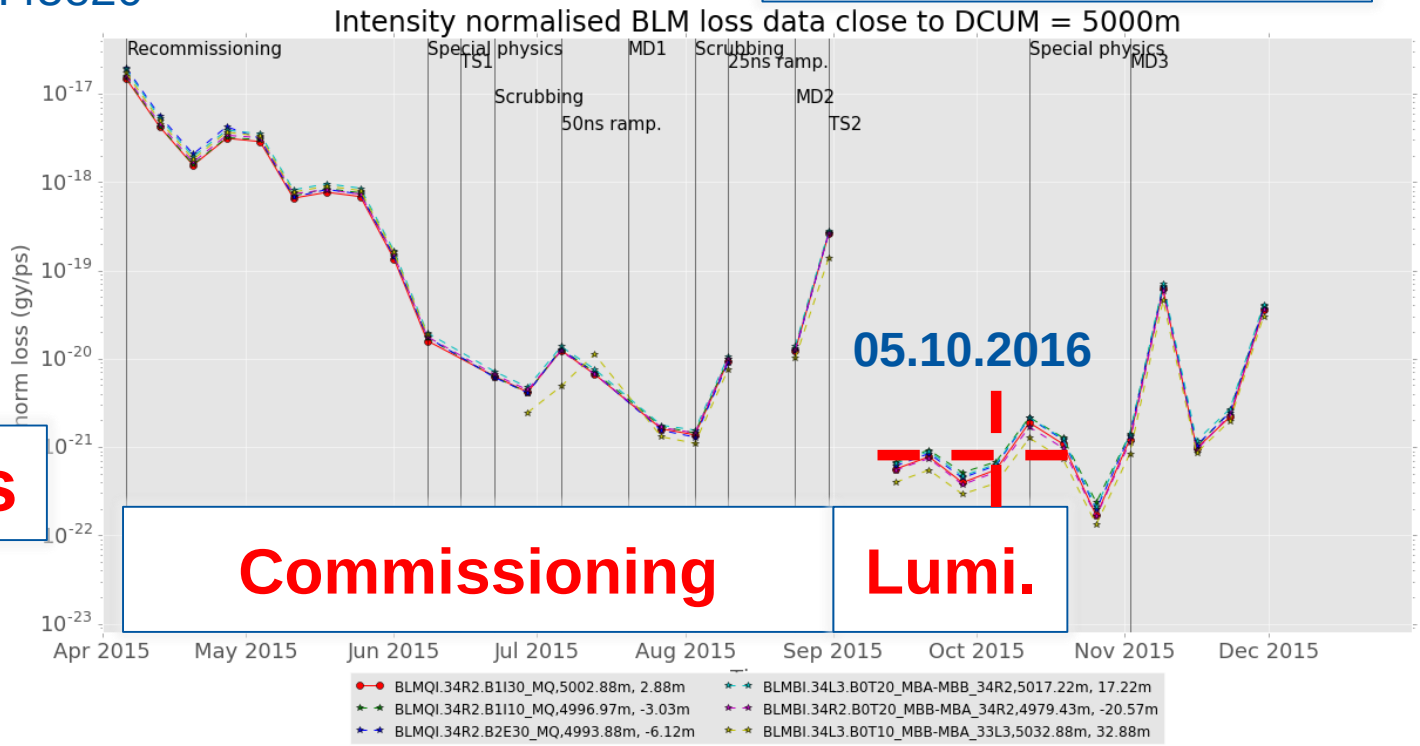
Until September 2015 LHC commissioning and ramp up.

Physics fills in October

Week: 05.10.2015

Integrated intensity: 1.45e20

BLM in ARC!

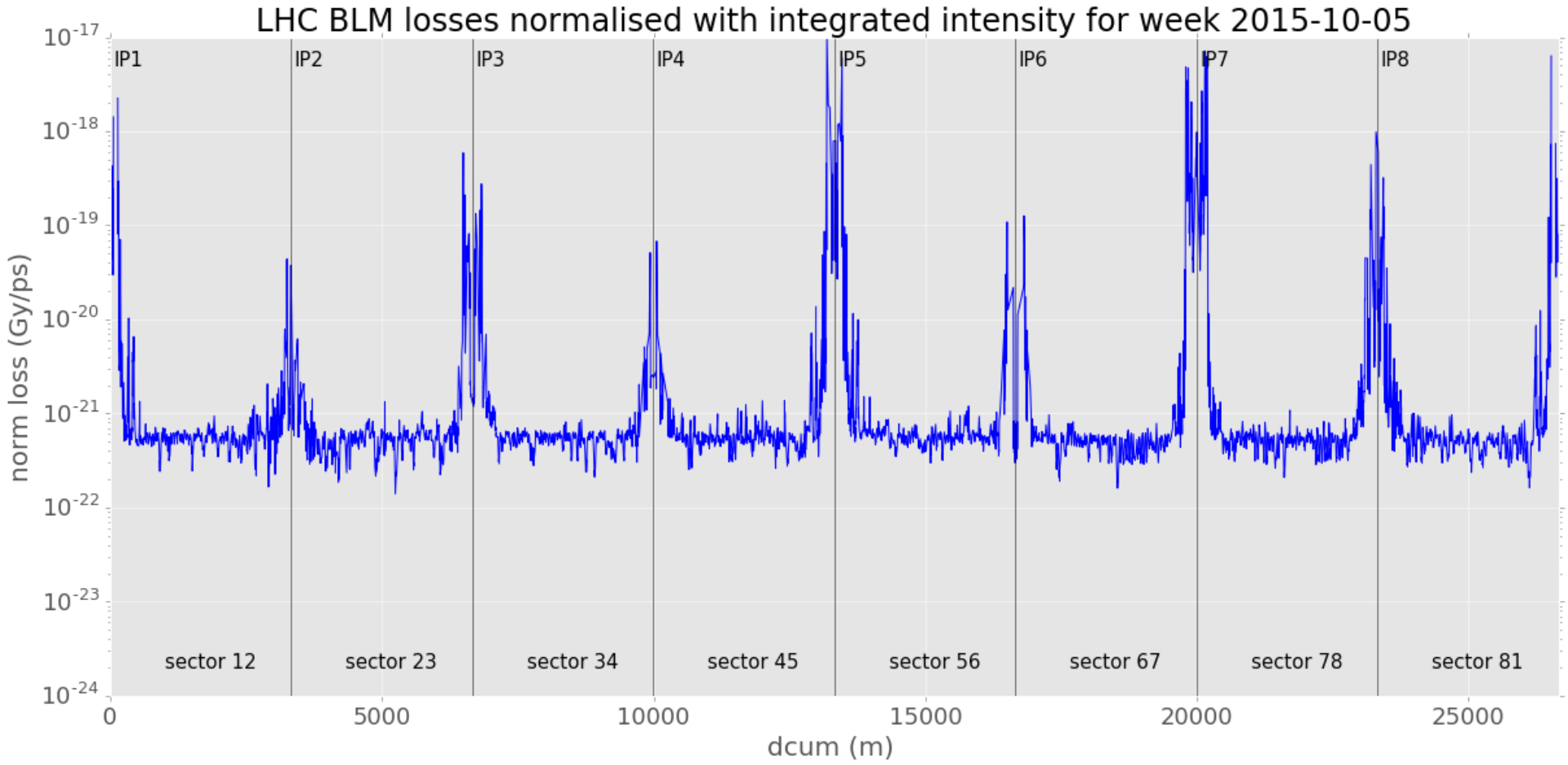


5e-22 Gy/ps

Commissioning

Lumi.

Normalised loss data 2015, week 05.10.2015



Normalised loss data 2015, week 05.10.2015

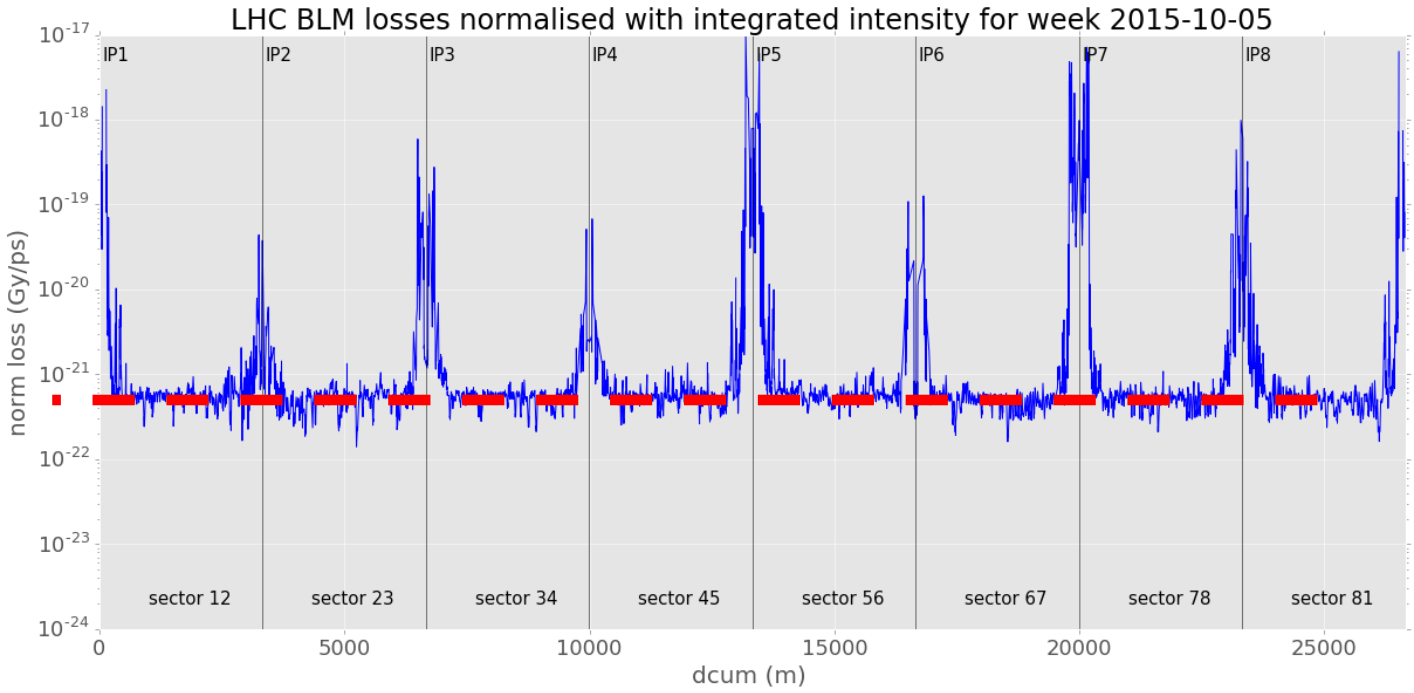
Data from week: 05.10.2015

Integrated intensity: 1.45e20

Physics fills

Data valid for 2015 machine parameters!

IP	Norm. loss
1	2e-18
2	5e-20
3	6e-19
4	6e-20
5	1e-17
6	1e-19
7	5e-18
8	1e-19
arc	5e-22



Weekly reports

Advantage of weekly reports:

- Distinction between weeks of physics and weeks with special fills
- Identification of loss driving machine conditions (scrubbing, re-commissioning)
- Monitoring of the loss evolution per week
- Normalised data allows direct comparison of different intervals (weeks).*
- Normalised loss data will allow prediction of future loss levels in dependency of the beam intensities.

Comparison of 2016 and 2015 data.

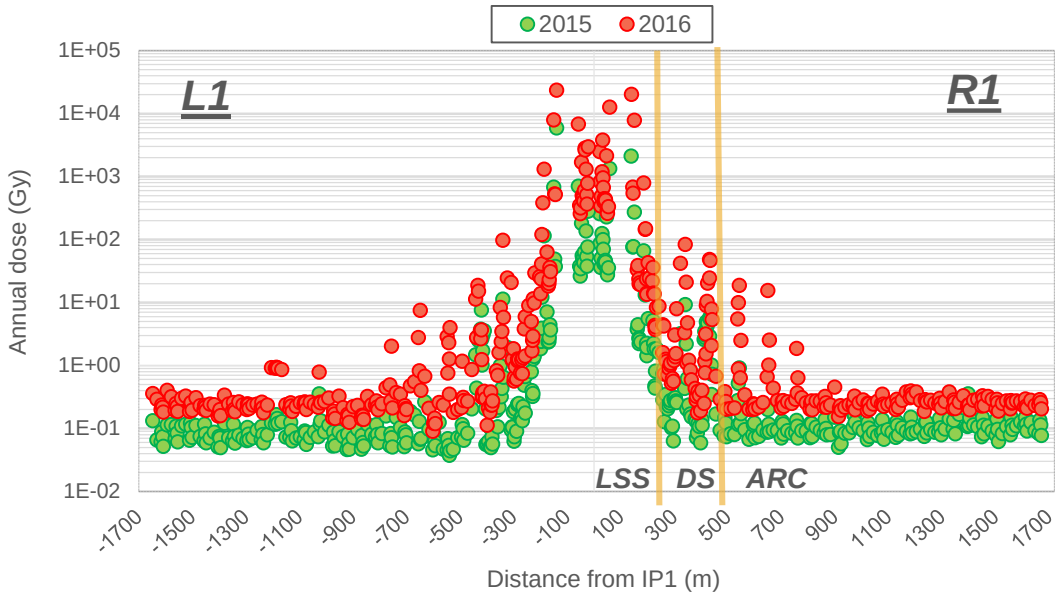
- Using data with same machine conditions (physics fills)
- **Normalised losses in the arcs factor 15 better in 2016!**
- **Losses in the IRs still under investigation (NOT a factor 15).**
  → Detailed analysis of local losses necessary.

2016 good year for physics. Data can be used as reference?
Predictions for 2017, work ongoing.

* Comparability only for same machine conditions.

2. Results of BLM and RadMon data of 2015/2016

Integrated Annual Dose P1 and P5

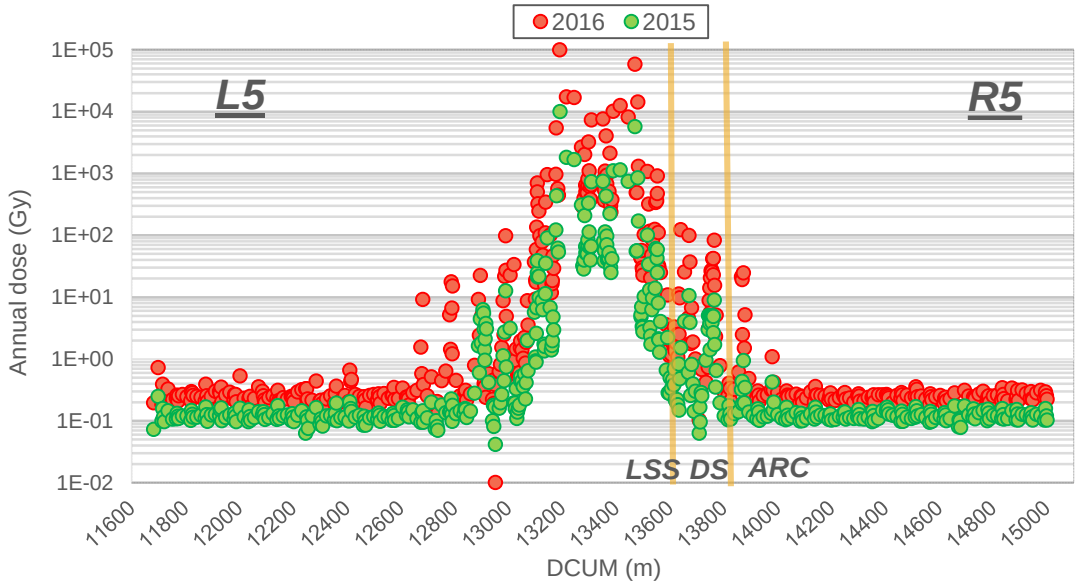


Annual dose measured from BLMs in Point 1 and Point5 during 2015 and 2016 (25 ns).

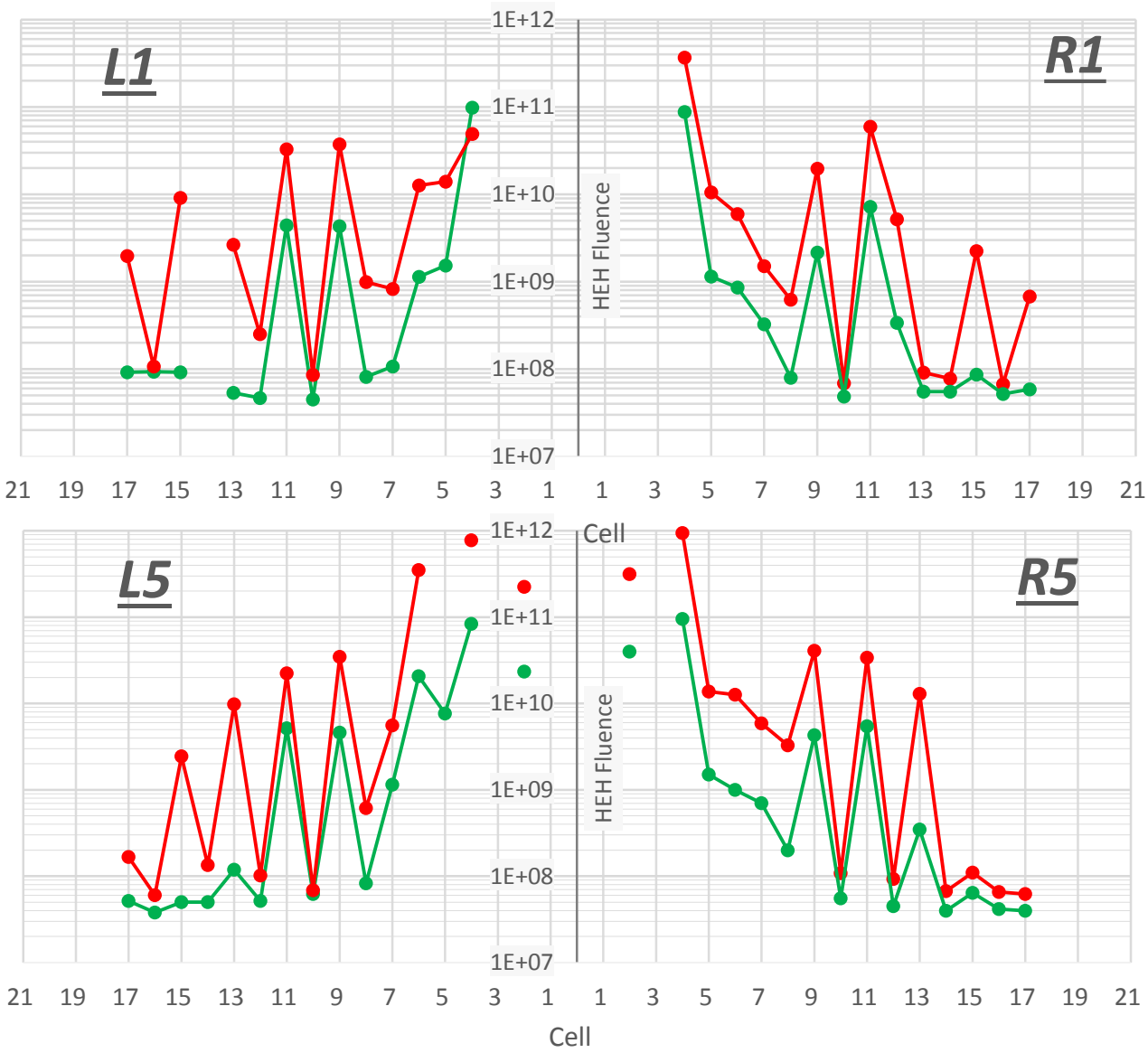
In 2016 (P5):

- **100 kGy in LSS**
- **124 Gy in DS**
- **<0.5 Gy in the ARC**

Localized losses in the ARCs up to 25 Gy



Integrated Fluence P1 and P5



- RadMon measurements of High Energy Hadron fluence during the entire 2015 and 2016 (25 ns).
- Cell close to ATLAS and CMS are luminosity driven (LSS, until cell 8).
- Peak in cell 9 and cell 11 (DS), dominated by losses in the collimators and absorbers.
- In the deep ARC (> cell 16) the radiation levels are proportional to the integrated intensity.
- Presence of localized losses confirmed with the RadMons.

Peaks in the LHC tunnel

Summary of the annual RadMon measurements for the localized losses in 2016 in IP1/5 L/R

Cells	max TID	max Fluence
8	0.78	3.29E+09
9	32.55	4.07E+10
10	0.11	1.08E+08
11	37.81	5.95E+10
12	1	5.18E+09
13	4.5	1.29E+10
15	3.13	9.11E+09

Impact of the luminosity under investigation.

Shielded Areas

Critical Areas	2012 HEH Measurements	2015 HEH Predictions	2015 Measurements (4fb-1)	2016 Predictions (35fb-1)	2016 Measurements
UJ14/16	1.10E+08	5.04E+07	6.82E+07	5.7E+08	5.85E+8 (30 fb-1)
RR13/17	1.80E+07	1.68E+07	1.44E+07	1.2E+08	5.37E+7 (39 fb-1)
UJ56	1.20E+08	4.24E+07	9.77E+07	8.1E+08	4.91E+8 (30 fb-1)
RR53/57	1.80E+07	2.64E+07	9.17E+06	7.6E+07	1.86E+8 (39 fb-1)
UJ76	5.50E+07	6.48E+06	9.75E+06	8.1E+07	3.41E+7 (39 fb-1)
RR73/77	3.00E+07	1.92E+07	1.57E+07	1.3E+08	1.57E+07 (39 fb-1))

Critical Areas	2017 Predictions (45fb-1) *
UJ14/16	8.78E+08
RR13/17	6.20E+07
UJ56	7.37E+08
RR53/57	2.15E+08
UJ76	3.93E+07
RR73/77	1.81E+07

Fluence in the RRs strongly dependent on the collimator (TCL) settings.

* The values are scaled with the luminosity

Thank you!

Backup

HEH Fluence 2016

RadMon measurements of SEU converted into HEH fluence

Cell\ Point	L1	R1	L2	R2	L3	R3	L4	R4	L5	R5	L6	R6	L7	R7	L8	R8
1															3.1E+11	4.9E+10
2									2.2E+11	3.2E+11						
3																
4	4.9E+10	3.7E+11	7.8E+09	2.1E+10	2.8E+10				7.8E+11	9.5E+11	4.4E+09	5.3E+09	1.9E+11	2.5E+10	2.1E+10	4.5E+10
5	1.4E+10	1.1E+10			9.9E+10			1.7E+09		1.4E+10	2.4E+09					
6	1.3E+10	5.9E+09			4.6E+09				3.5E+11	1.3E+10						
7	8.3E+08	1.5E+09					9.1E+09	3.8E+08	5.6E+09	5.9E+09					7.5E+09	
8	9.9E+08	6.2E+08		1.5E+08	9.8E+07	5.8E+08	3.1E+08	1.8E+08	6.2E+08	3.3E+09	1.8E+08	2.9E+08	1.6E+08	3.5E+08		
9	3.7E+10	2.0E+10	1.6E+08	9.6E+07	2.8E+08	2.0E+08	1.2E+08	1.3E+08	3.5E+10	4.1E+10	8.3E+07	7.4E+07	7.3E+08	6.5E+08		3.0E+09
10	8.6E+07	6.9E+07	1.4E+08	1.2E+08	6.0E+07	6.2E+07	9.6E+07	1.2E+08	6.9E+07	1.1E+08	8.8E+07	8.6E+07	2.6E+07	8.4E+07		1.5E+09
11	3.3E+10	6.0E+10	5.0E+09	1.4E+08	6.6E+08	2.8E+08	1.0E+08	2.4E+08	2.2E+10	3.4E+10	1.6E+08	1.5E+08	1.2E+09	2.1E+09		1.0E+08
12	2.5E+08	5.2E+09	9.8E+07	8.9E+07	4.8E+07	5.0E+07			1.0E+08	9.3E+07	8.4E+07	7.7E+07	4.6E+07	5.8E+07	1.3E+08	7.7E+07
13	2.7E+09	9.1E+07	8.3E+07	8.1E+07	1.2E+08	1.8E+08			9.8E+09	1.3E+10	1.9E+08	8.3E+07	8.6E+07	1.3E+08	9.2E+08	1.4E+08
14		7.7E+07	1.0E+08	8.4E+07	6.9E+07	6.0E+07			1.3E+08	6.7E+07	8.1E+07	7.9E+07	6.7E+07	4.5E+07	1.2E+10	1.5E+08
15	9.1E+09	2.2E+09	9.3E+07	7.2E+07	5.5E+07	8.6E+06			2.4E+09	1.1E+08	2.6E+08	5.2E+07	8.8E+07	9.6E+07	1.0E+08	3.0E+09
16	1.1E+08	6.7E+07	8.3E+07	4.3E+07	3.8E+07	4.0E+07			6.0E+07	6.5E+07	7.4E+07	5.2E+07	4.5E+08	6.1E+08	1.2E+09	9.8E+08
17	2.0E+09	6.7E+08	1.2E+08	6.2E+07	7.9E+07	5.8E+07			1.7E+08	6.2E+07	8.4E+07	0.0E+00	7.6E+07	9.3E+07	8.3E+08	6.9E+07
18			1.4E+08	7.1E+07		3.4E+07					4.8E+07	5.7E+07	5.3E+07	1.8E+09	1.5E+08	7.4E+07
19			2.5E+08	5.5E+07		6.2E+07					3.4E+07	5.3E+07	7.9E+07	8.4E+07	8.8E+07	9.6E+07
20			1.3E+08	7.7E+07		4.8E+07					4.8E+07	4.3E+07	3.6E+07	4.1E+07	7.1E+08	5.7E+07
21											1.2E+08	1.1E+08		5.0E+07		

HEH Fluence 2015

RadMon measurements of SEU converted into HEH fluence

Cell\Point	L1	R1	L2	R2	L3	R3	L4	R4	L5	R5	L6	R6	L7	R7	L8	R8
1															4.3E+10	9.9E+09
2									2.3E+10	4.0E+10						
3																
4	9.9E+10	8.8E+10	8.2E+09	1.2E+10	1.2E+10				8.4E+10	9.5E+10	3.9E+09	3.3E+09	1.2E+11	8.4E+09	3.9E+09	2.7E+10
5	1.5E+09	1.1E+09			3.9E+10			1.2E+09	7.7E+09	1.5E+09	1.2E+09					
6	1.1E+09	8.6E+08			5.0E+08				2.1E+10	9.9E+08						
7	1.1E+08	3.2E+08					8.7E+08	1.9E+08	1.1E+09	7.0E+08					3.7E+09	
8	8.1E+07	7.9E+07		6.9E+07	4.7E+07	3.5E+08	1.3E+08	1.3E+08	8.3E+07	2.0E+08	1.0E+08	1.4E+08	1.5E+08	4.2E+08		
9	4.3E+09	2.2E+09	1.2E+08	8.1E+07	8.3E+07	9.7E+07	8.8E+07	9.5E+07	4.6E+09	4.3E+09	5.9E+07	7.6E+07	4.5E+08	2.2E+08		5.8E+08
10	4.5E+07	4.8E+07	9.3E+07	1.2E+08	4.1E+07	5.0E+07	5.5E+07	8.8E+07	6.2E+07	5.5E+07	4.3E+07	5.0E+07	3.8E+07	4.0E+07		2.9E+08
11	4.4E+09	7.2E+09	6.1E+08	1.2E+08	1.7E+08	1.9E+08	7.1E+07	1.8E+08	5.2E+09	5.4E+09	1.1E+08	1.2E+08	5.8E+08	5.9E+08		7.6E+07
12	4.7E+07	3.4E+08	4.8E+07	4.3E+07	3.8E+07	3.5E+07			5.2E+07	4.5E+07	3.6E+07	6.9E+07	3.6E+07	4.3E+07	2.1E+08	6.6E+07
13	5.4E+07	5.5E+07	6.7E+07	4.3E+07	6.9E+07	9.7E+07			1.2E+08	3.5E+08	8.8E+07	2.6E+07	5.9E+07	6.9E+07	6.3E+08	5.7E+07
14		5.5E+07	8.5E+07	6.4E+07	5.4E+07	4.3E+07			5.0E+07	4.0E+07	2.9E+07	2.1E+07	2.2E+07	3.8E+07	1.5E+09	6.0E+07
15	9.2E+07	8.6E+07	6.9E+07	3.8E+07	7.6E+07	3.8E+07			5.0E+07	6.4E+07	1.3E+08	2.6E+07	5.7E+07	6.7E+07	8.3E+07	6.4E+07
16	9.3E+07	5.2E+07	6.4E+07	2.2E+07	3.1E+07	5.0E+07			3.8E+07	4.1E+07	4.7E+07	2.9E+07	3.1E+07	4.8E+07	1.2E+08	8.3E+07
17	9.2E+07	5.9E+07	5.9E+07	4.7E+07	2.8E+07	4.0E+07			5.2E+07	4.0E+07	4.3E+07		2.9E+07	7.9E+07	5.7E+08	5.7E+07
18			7.8E+07	3.8E+07		8.6E+06					2.2E+07	4.5E+07	1.9E+07	7.8E+07	5.0E+07	2.2E+07
19			6.2E+07	5.7E+07		7.3E+07					3.1E+07	4.0E+07	4.3E+07	8.5E+07	6.6E+07	4.5E+07
20			8.5E+07	5.7E+07		2.6E+07					2.6E+07	3.3E+07	2.1E+07	3.1E+07	6.5E+08	6.2E+07
21											5.2E+07	1.9E+07		6.6E+07		

Shielded Areas P1-P5

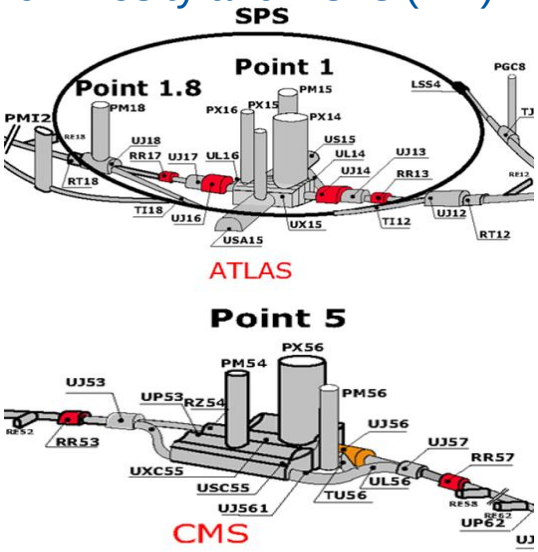
Shielded Areas: RRs				
Area	Name (S/T)	Φ_{2015}	Φ_{2016}	$\Phi_{2016}/\Phi_{2015}/\text{fb}^{-1}$
RR13	1LM10S (T)	$(1.34\pm 0.33)\times10^{8}$	$(1.36\pm0.30)\times10^{9}$	1.14 ± 0.38
	1LM11S (S)	$(1.44\pm0.51)\times10^{7}$	$(4.19\pm1.07)\times10^{7}$	0.33 ± 0.14
	1LM12S (S^1)	$(6.55\pm3.17)\times10^{6}$	$(5.37\pm1.30)\times10^{7}$	0.92 ± 0.50
RR17	1RM11S (T)	$(9.12\pm2.36)\times10^{7}$	$(9.96\pm2.22)\times10^{8}$	1.22 ± 0.42
	1RM12S (S)	$(1.05\pm0.41)\times10^{7}$	$(5.37\pm1.30)\times10^{7}$	0.57 ± 0.27
	1RM13S (S^1)	$(3.93\pm2.38)\times10^{6}$	$(2.88\pm0.81)\times10^{7}$	0.82 ± 0.55
RR53	5LM10S (T)	$(1.89\pm0.45)\times10^{8}$	$(2.85\pm0.62)\times10^{9}$	1.56 ± 0.51
	5LM11S (S)	$(9.17\pm3.86)\times10^{6}$	$(1.17\pm0.24)\times10^{8}$	1.32 ± 0.62
	5LM12S (S^1)	$(1.44\pm0.51)\times10^{7}$	$(1.65\pm0.34)\times10^{8}$	1.19 ± 0.49
RR57	5RM08S (T)	$(3.49\pm0.80)\times10^{8}$	$(4.53\pm0.99)\times10^{9}$	1.34 ± 0.43
	5RM09S (S)	$(9.17\pm3.86)\times10^{6}$	$(1.56\pm0.32)\times10^{8}$	1.76 ± 0.83
	5RM10S (S^1)	$(2.10\pm 0.65)\times10^{7}$	$(1.86\pm0.37)\times10^{8}$	0.92 ± 0.34

Shielded Areas: UJs **				
Area	Name (S/T)	Φ_{2015}	Φ_{2016}	$\Phi_{2016}/\Phi_{2015}/\text{fb}^{-1}$
UJ13/14	1LM03S (T)	$(3.48\pm0.76)\times10^{10}$	$(3.05\pm0.66)\times10^{11}$	0.98 ± 0.30
	1LM02S (S)	$(6.55\pm1.41)\times10^{7}$	$(5.85\pm1.06)\times10^{8}$	1.00 ± 0.28
UL14	1LM01S (S)	0.00	$(1.07\pm0.37)\times10^{7}$	-
UJ16/17	1RM02S (S)	$(5.28\pm1.18)\times10^{7}$	$(3.07\pm0.56)\times10^{8}$	0.65 ± 0.19
	1RM03S (T)	$(3.80\pm0.83)\times10^{10}$	$(3.28\pm0.71)\times10^{11}$	0.97 ± 0.30
UL16	1RM01S (S)	$(9.77\pm9.92)\times10^{5}$	$(1.37\pm0.43)\times10^{7}$	1.57 ± 1.67
UJ56	5LM01S (S)	$(3.81\pm0.76)\times10^{6}$	$(2.33\pm0.42)\times10^{7}$	0.63 ± 0.17
	5LM02S (S)	$(4.98\pm1.12)\times10^{7}$	$(2.85\pm0.53)\times10^{8}$	0.59 ± 0.17
	5RM01S (S)	$(8.99\pm1.85)\times10^{7}$	$(4.91\pm0.89)\times10^{8}$	0.56 ± 0.16

RadMon measurements of HEH fluence in the shielded areas close to ATLAS and CMS.

RadMon are placed in tunnel side (T), in the shielded side at the beam level (S) and at the first floor (S1).

RRs and UJs are affected by luminosity and TCLs (RR).



**Until September 2016 (30 fb-1)