Radiation To Electronics – 2016 Run

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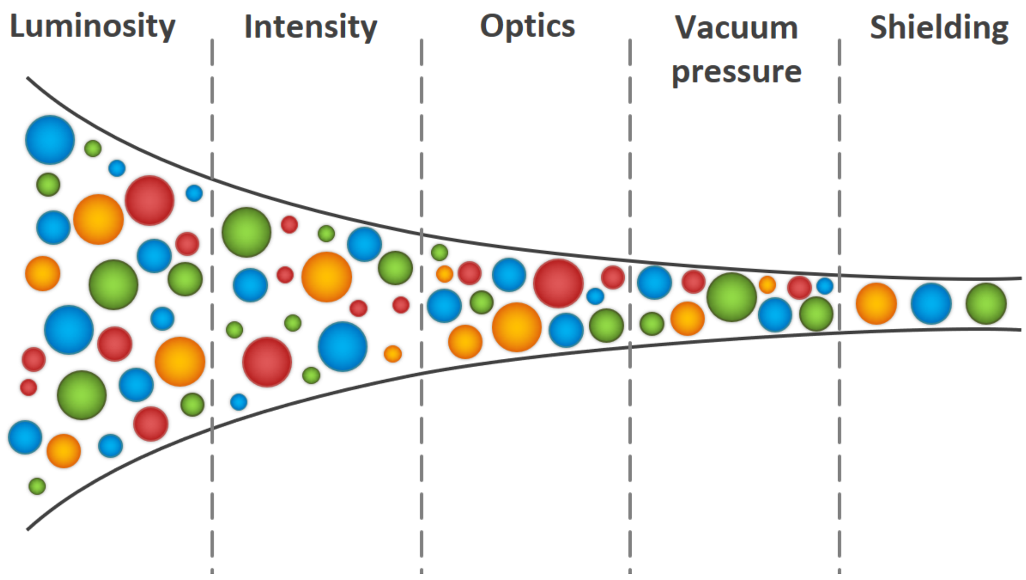
CERN | EN ENGINEERING DEPARTMENT

Overview

- Radiation levels in the 2015 vs 2016
  - Luminosity driven
  - Intensity driven
  - Shielded areas
- Failure analysis and expected failures
- Conclusions

Radiation Failures and radiation levels

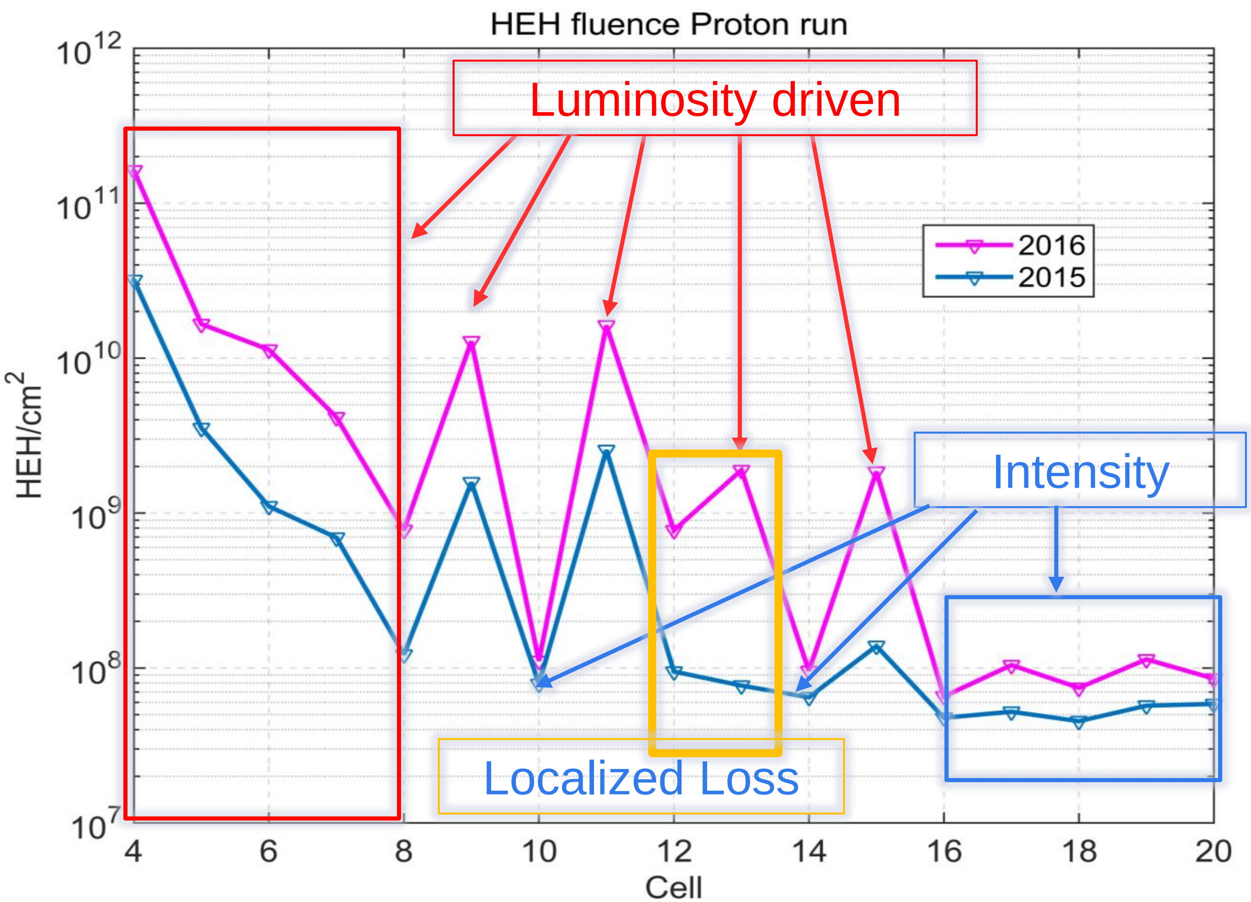
- Why we see so low failures radiation induced?
- **Failure rate is proportional to the radiation levels**
- The radiation levels are related to several factors:



Failure rate is proportional to the effort put in mitigation and prevention

Radiation Levels – Tunnel Areas

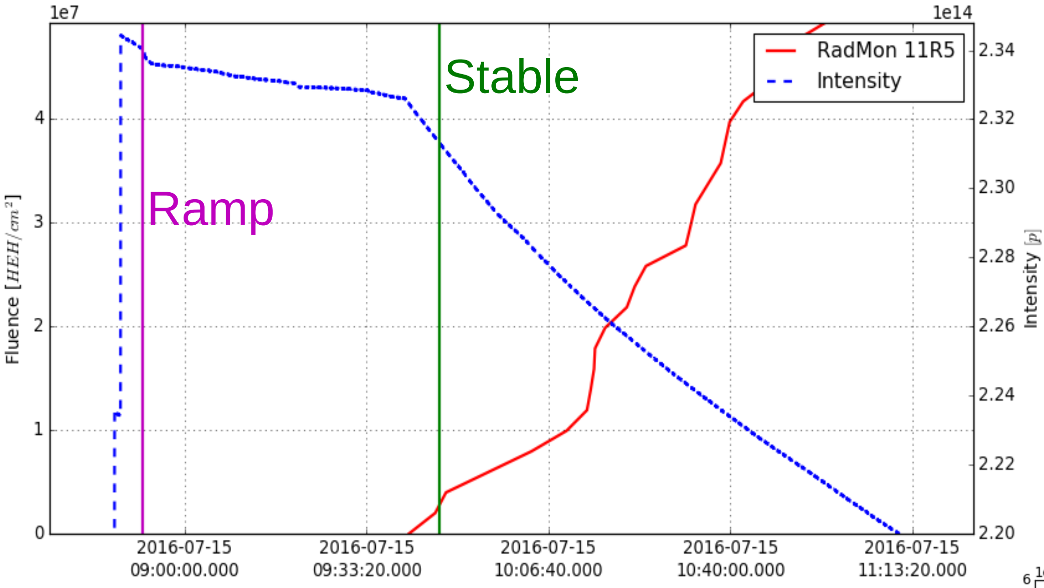
- **Tunnel areas – several equipment installed: QPS, EPC, Cryo**



- **Analysis based on the RadMon measurements for the entire proton run 2016 and 2015**
- **The average of all the points is computed (except point 7)**
- **Odd cells and LSS cells are luminosity driven for the interaction points**
- **In the deep ARC (> cell 16) and in the even cell the radiation levels are proportional to the integrated intensity**
- **Presence of localized losses**

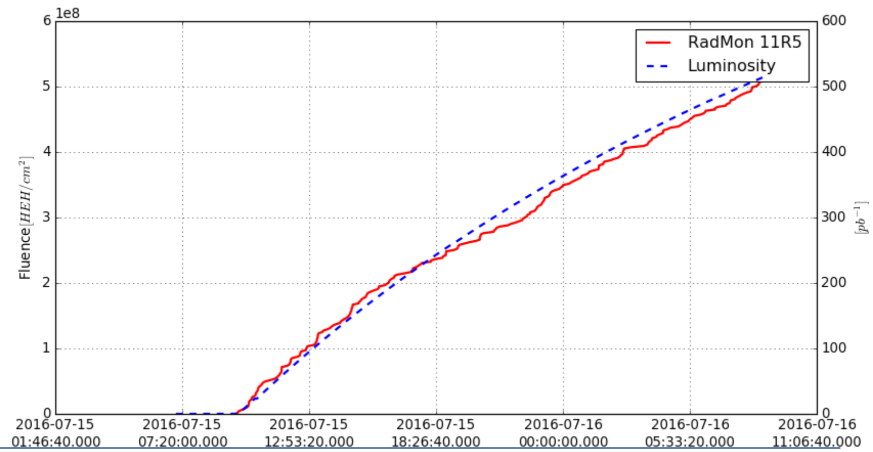
Tunnel areas – Luminosity driven

- Let's take the RadMon in 11R5 as a reference point and the fill 5096



- The RadMon starts to measure the HEH flux from the stable beam
- The fluence before the stable is lower than 1e5 HEH/cm2 (RadMon V5 resolution)

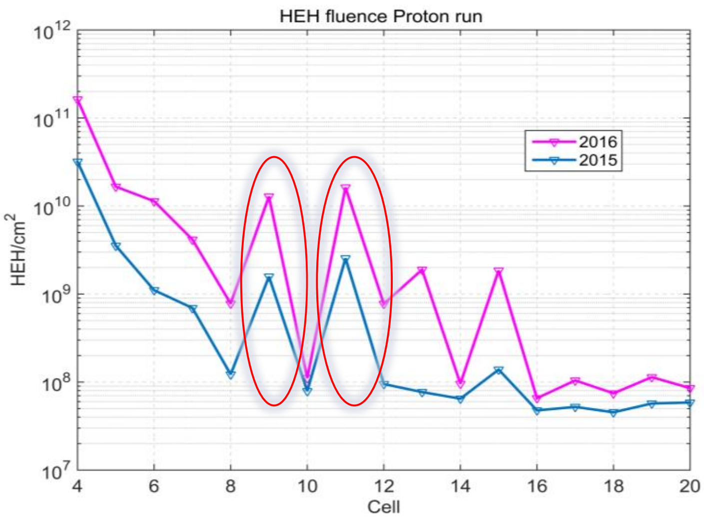
- The HEH fluence follows the Luminosity



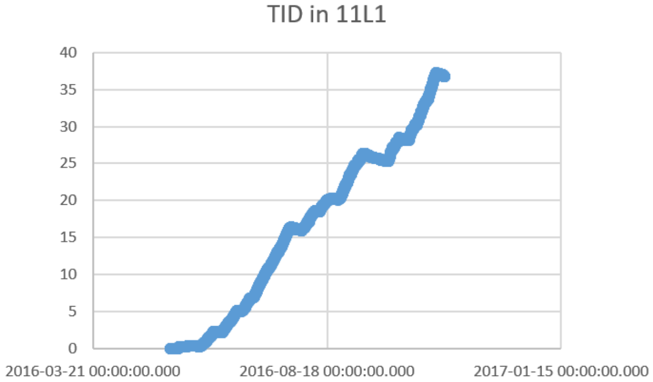
Tunnel areas – Luminosity driven

- We can normalize as function of the luminosity

Cell	HEH/cm2/pb-1
11L1	806.2
11L5	568.0
11R1	1590.5
11R5	963.8
9L1	945.5
9L5	846.5
9R1	516.7
9R5	1007.8

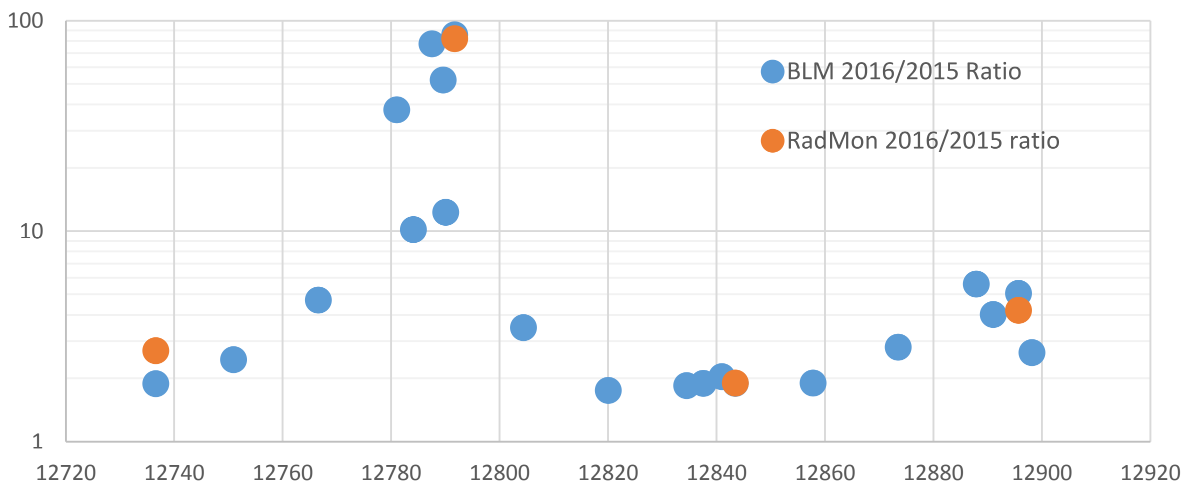


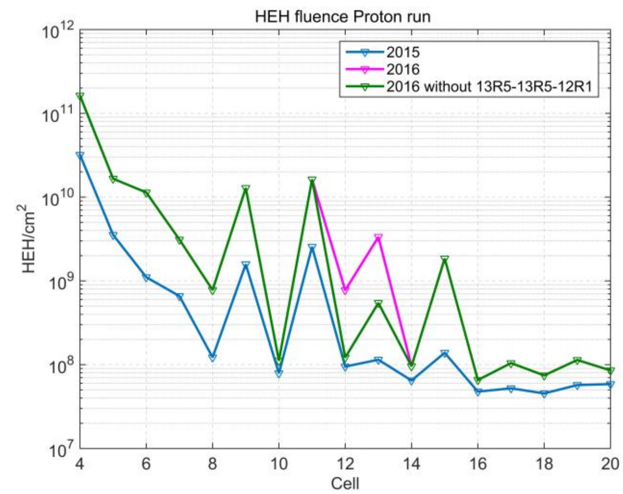
- Higher probability of events in these cells (but few systems compared to the total)
- Electronics however affected by TID degradation, risking complete system failure in the long-term
- The long term effects should be taken into account by a continuous monitoring and reporting.
- The strategy for the LS2 is to foresee a ‘chaise musicale’ substituting the equipment located in these cells with the ones located in the ARC



Localized high loss

- In cell 13L5 of Point 5 the levels are 80 times higher than the 2015 measured by both RadMons and BLMs



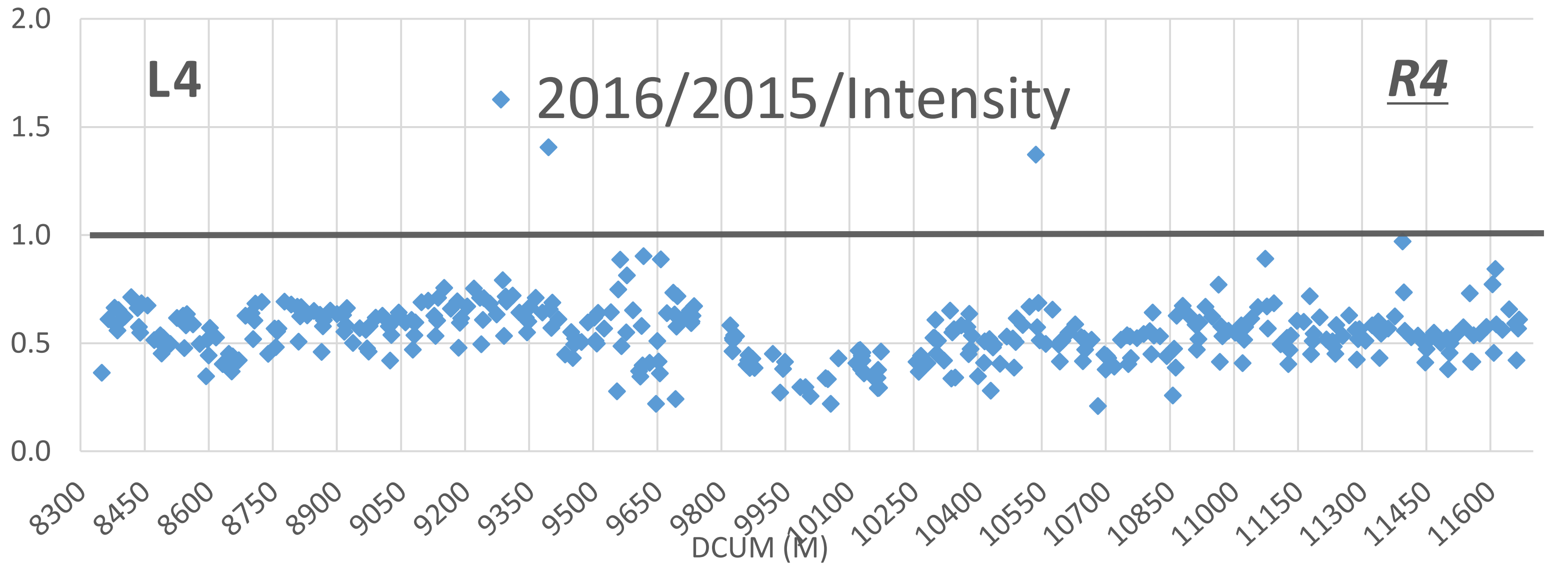


- Cell 13R5 is less charged than the left side
- 12R1 is the other hot spot for the proton Run in 2016
- This information are analysed by the MCWG and distributed to the equipment responsible through the RADWG

Tunnel areas – Integrated intensity

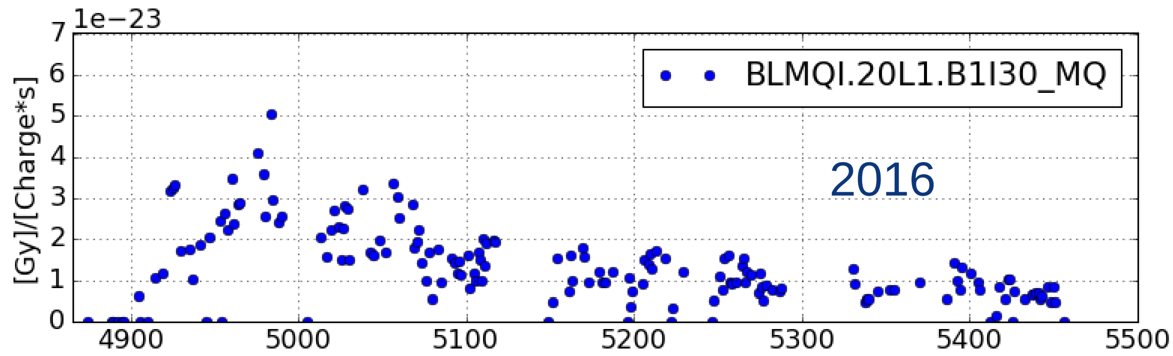
- Most of the electronic systems are located in the ARC

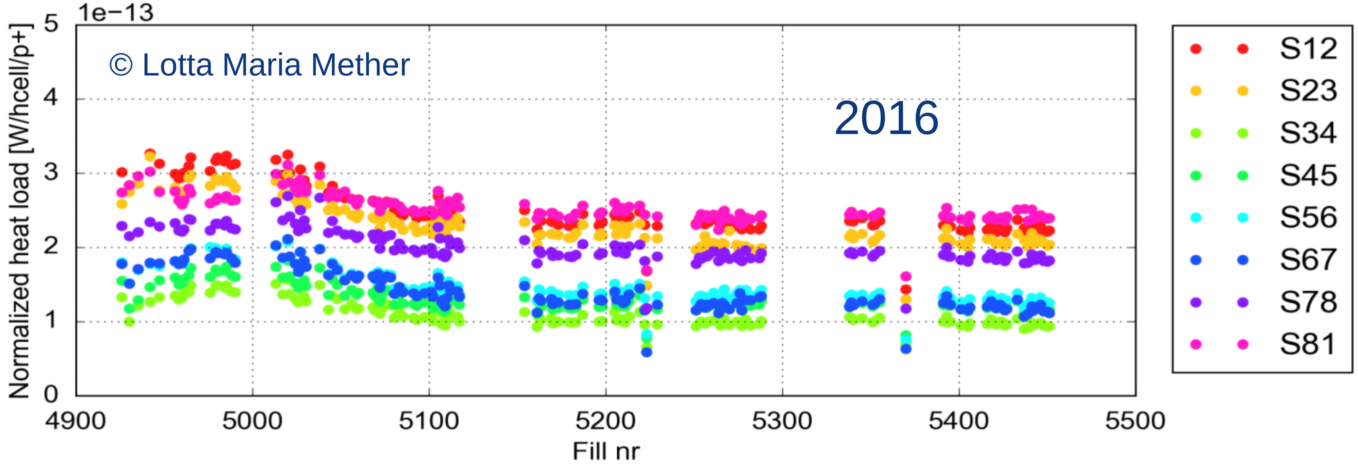
- 2016: **~2x less integrated intensity per integrated luminosity** (β^*, crossing angle, etc.)
- Observed levels were an **additional factor 2 smaller**
- Possible improvement in the vacuum levels reducing beam-gas interactions
- **This is one of the reason why we saw less events than expected**



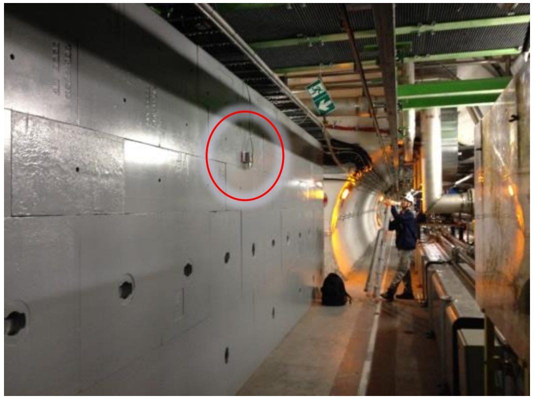
BLM normalized value in stable beam

- Integrated BLM dose in stable beam normalized by the integrated intensity
- The same pattern is found also in other sectors
- The BLM pattern is similar to the one of the heat load indicating a possible conditioning effect
- 2017 measurements to be used for final extrapolation

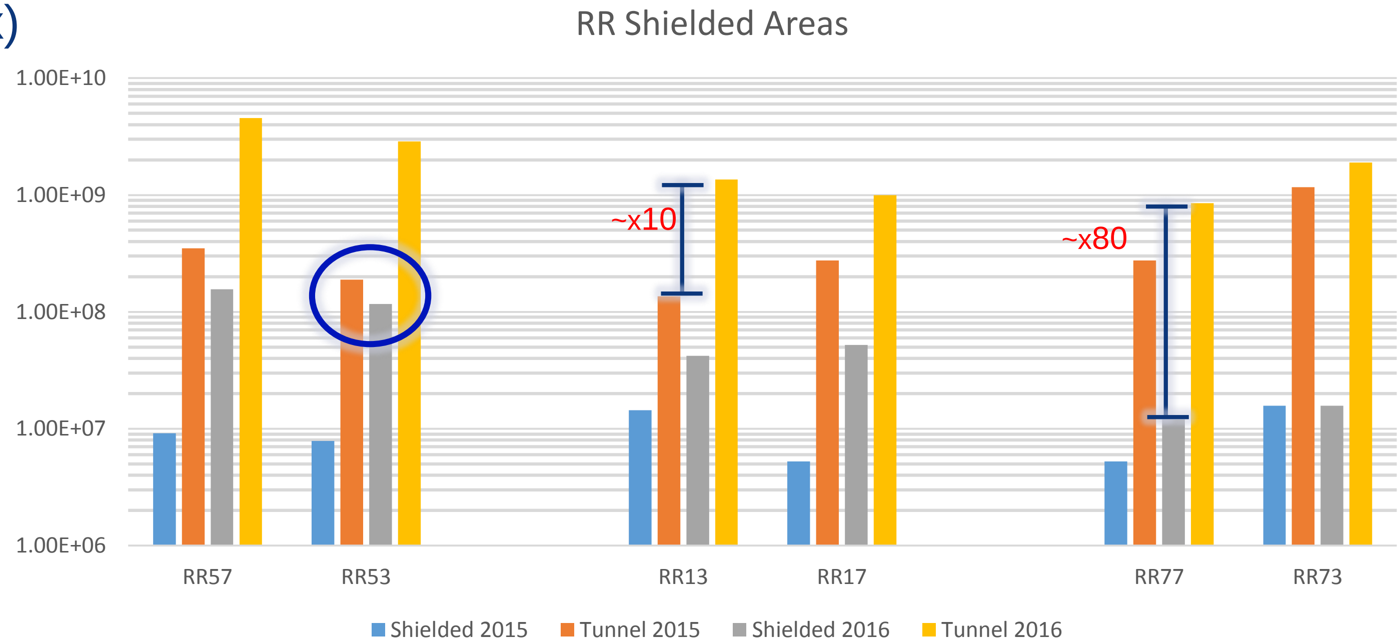




Shielded areas

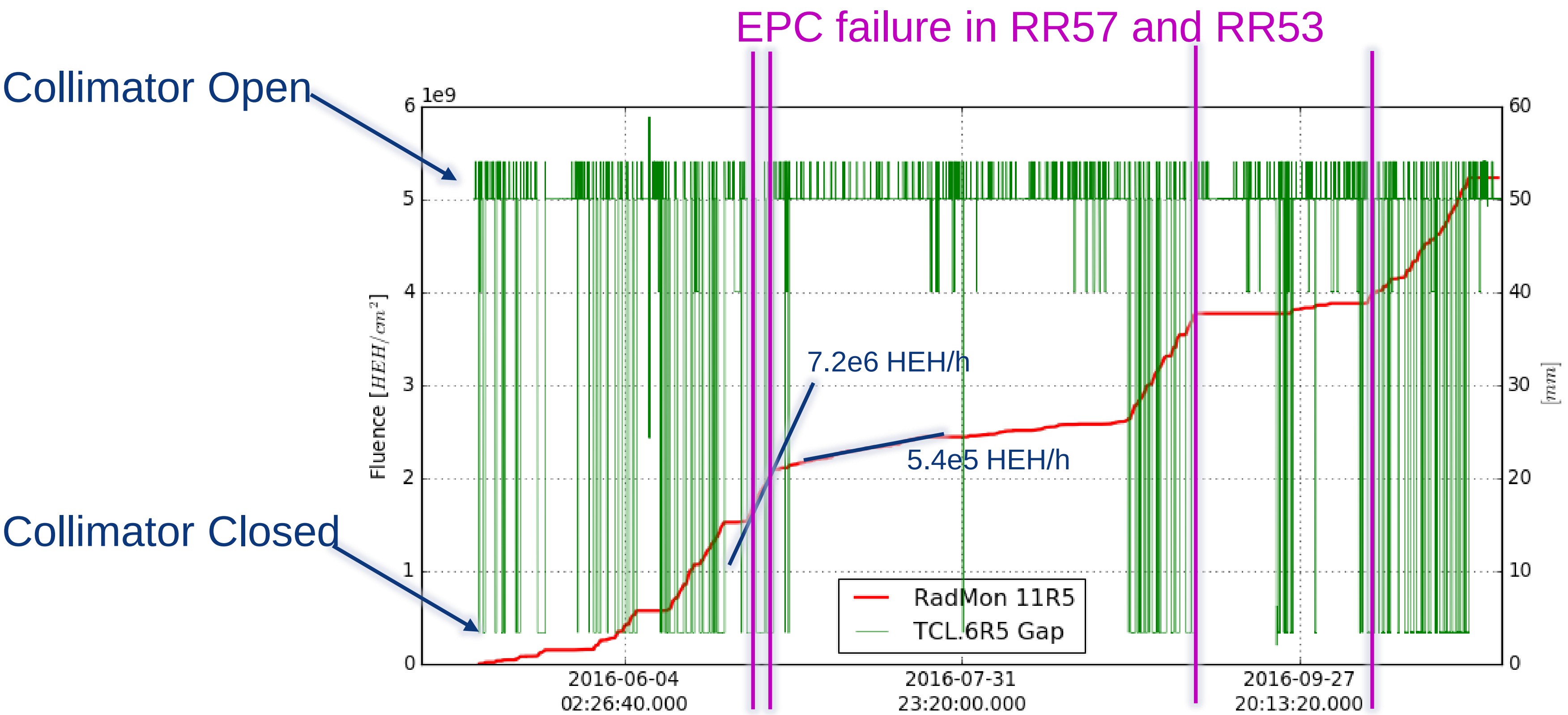


- RR13/17/53/57 shielded improvement during the LS1
- RadMon measurements cover the Tunnel side of the RR and the internal side of the RR
- HEH fluence in the RR areas scale with the luminosity apart from the RR73/77
- Operational parameters can have important impact (i.e TCL6 impact on the RR1x RR5x)



Impact on the RR of the TCL.6

- This year only in Point 5 the TCL.6 were closed (20 sigma) in most of the physic runs
- We can have an estimation of the impact of TCL.6 on the radiation levels comparing the closed and open operation
- The HEH flux increase of a factor 13 when the collimators are closed



EPC

	Power part	Control
	Dumps	Dumps
2012	15	10
2015	3	4
2016	3	4* (1 in Ion Run)

*To be confirmed

2015 Failures and strategies

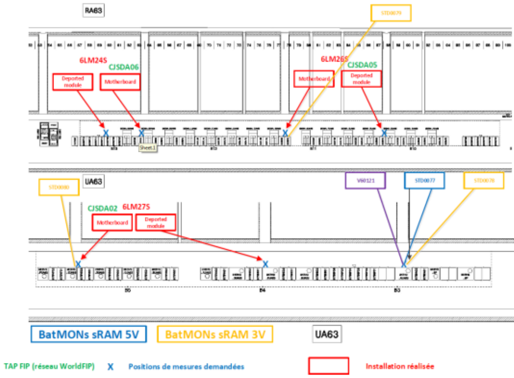
- **Locations in 2015:** ARC, RR77,RR57
- **Failure types in 2015**:
  - FGC2
  - 120A
- **Mitigations:**
  - WATCHDOG fault on the power converter should be corrected by a patch during this YETS
  - Start the deployment of the FGClite partially during the EYETS 2016

2016 Failures

- **Locations in 2016:** RR53,RR57, RR13
- **Failure types in 2015**:
  - 600A (power Mosfet)
  - FGC2 in the RR – Test in CHARM next year are planned
- **Actions :**
  - 752 FGClite will be installed in the tunnel in the even cells. ECR: https://edms.cern.ch/document/LHC-RF-EC-0001/0.1/TAB3
  - FGClite tested in CHARM showed no SEE up to a fluence of 4e12
  - No R2E failures expected $0.02<P_{event}<0.07$ /year (2e8 HEH/cm^2/year)
  - The RR FGClite replacement will be done in the YETS 2017-2018: the failures in the RR will still be present in 2017 (Power + Control)

QPS - TE-ABT and RF

- QPS only two failures during the ion run. Not yet confirmed
  - Deployment of the new Radiation Tolerand 600A QDS design in the RR during the YETS leads to no dumps.
- 2 events suspected to be radiation related on the MKBH but finally confirmed not to be (dust related)
- The monitor requirements are challenging
  - The expected hadron fluence is 5e4 HEH/cm2/year in UA63/67
  - The New York hadron fluence is 5e5 HEH/cm2/year
  - Currently we installed 11 RadMon
    - 0 Events recorded on all the detectors: <8e4 HEH/cm2/y



- No event on RF system thanks to the mitigation actions taken on the klystron : double AD channels + rad hard optical fiber

Failures Overview

Equipment	Dump 2012	Dump 2015	Dump 2016
QPS	32	2	0 + 2* ion
Power Converter	15	5	6+ 1* ion
Cryo	4	0	0
EN/EL	1	0	0
Vacuum	4	0	0
Collimation	1	0	0
TE/ABT		0	0
RF	1	4	0
Others (hidden)	-	-	-
Total	3 $/fb^{-1}$	3 $/fb^{-1}$ 1.2 $/fb^{-1}$	0.15$/fb^{-1}$ (proton run)

Conclusions

- Why we see so low failures radiation induced?
- In the luminosity driven cells, the radiation levels are higher this year compared to the 2015 but the system affected are few compared to the total number of systems. FGCs are not located in these cells
- We have to monitor continuously for long term degradation of electronics (TID effects)
- The radiation levels in the ARC did not scale with luminosity as conservatively assumed in 2015
  - Additional factor 2 of reduction scaling with the intensity could be due to a conditioning effect
- Increased radiation level in the shielded areas can lead to more failures (luminosity driven points)
  - If the TCL6 settings will change also in Point 1 we should expect a higher rate of failures
- Strategy:
  - Radiation level measurements and analysis on weekly basis
  - Follow-up the equipment failures
    - FGClite deployment in the ARC will keep the situation calm in the ARC
    - FGClite deployment in the RR is scheduled for the 2017-2018 YETS
    - Relocation/Shielding if needed
  - Follow-up the new development supporting the radiation tests and the correctness of the qualification process

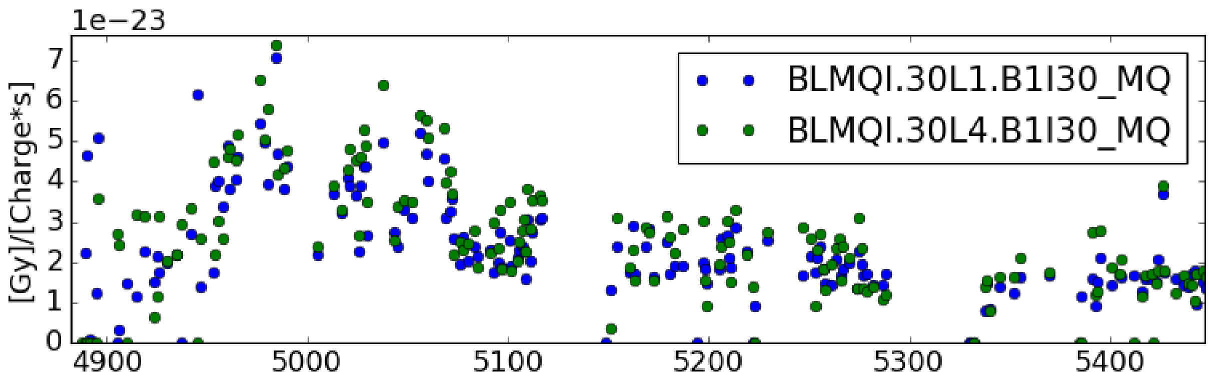
Thank you

Backup

EPC Failure 2016

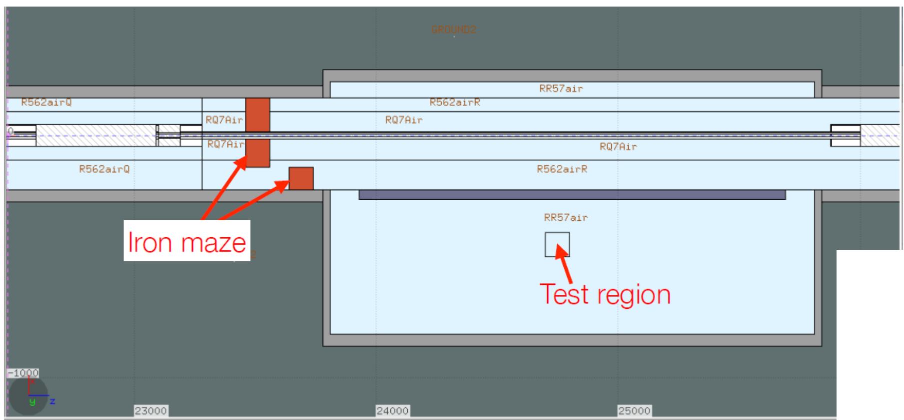
RPHGA.RR13.RQ10.L1 B2	31/05/2016	RR13	Voltage Source Electronics	CANDIDATE	1	TRIP / DUMP
RPMBB.RR57.ROD.A56 B2	24/06/2016	RR57	Aux Power Supply	CONFIRMED	1	TRIP / DUMP
RPMBB.RR53.ROD.A45 B2	28/06/2016	RR53	Aux Power Supply	CONFIRMED	1	TRIP / DUMP
RPMBB.RR53.ROF.A45 B1/B2	04/07/2016		FGC TRI VOLT PSU ?	CANDIDATE	1	TRIP / DUMP
RPMBA.RR17.RQT12.R 1B1	10/07/2016	RR17	FGC ?	NO DUMP	0	TRIP / NO DUMP
RPHGA.RR57.RQ7.R5B 2	19/07/2016	RR57	ADC Filter (FGC) *	NO DUMP	0	NO TRIP / NO DUMP
RPMBA.RR53.RQT13.L 5B1	10/09/2016	RR53	Converter internal Fault	CANDIDATE	1	TRIP / DUMP
RPLB.RR57.RCBCH6.R5 B2	12/09/2016	RR57	ADC Filter (FGC) *	NO DUMP	0	NO TRIP / NO DUMP
RPLB.RR57.RCBYH4.R5 B2	15/09/2016	RR57	DIM Card **	NO DUMP	0	NO TRIP / NO DUMP
RPLB.RR53.RCBCV5.L5 B1	28/09/2016	RR53	Voltage Source WatchDOG	NO DUMP	0	NO TRIP / NO DUMP
RPMBA.RR57.RQT13.R 5B1	09/10/2016	RR57	FGC – Com lost	CONFIRMED	1	TRIP / DUMP
RPMBB.RR13.RSS.A81 B2	19/11/2016	RR13	ADC Filter (FGC) *	NO DUMP	0	NO TRIP / NO DUMP
RPMBB.RR13.ROD.A81 B1	23/11/2016	RR13	FGC – Com lost	CANDIDATE	1	TRIP / DUMP

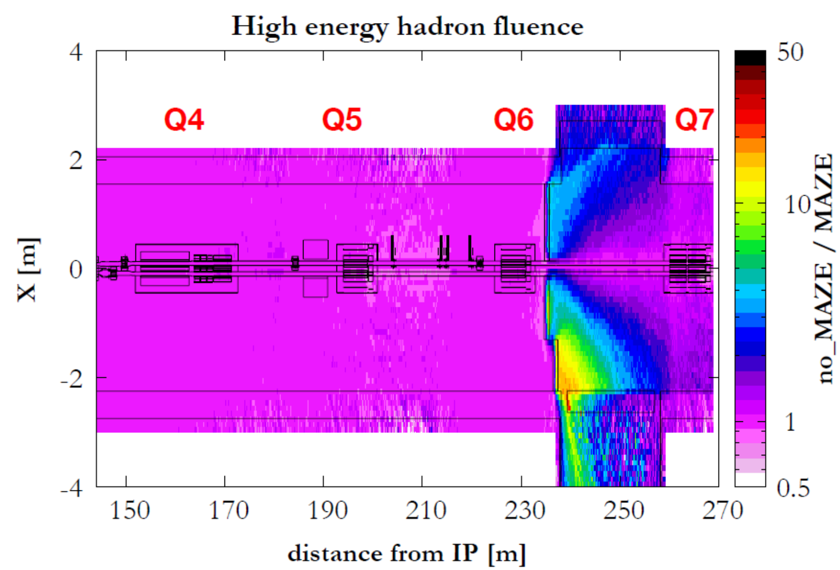
Sector Comparison



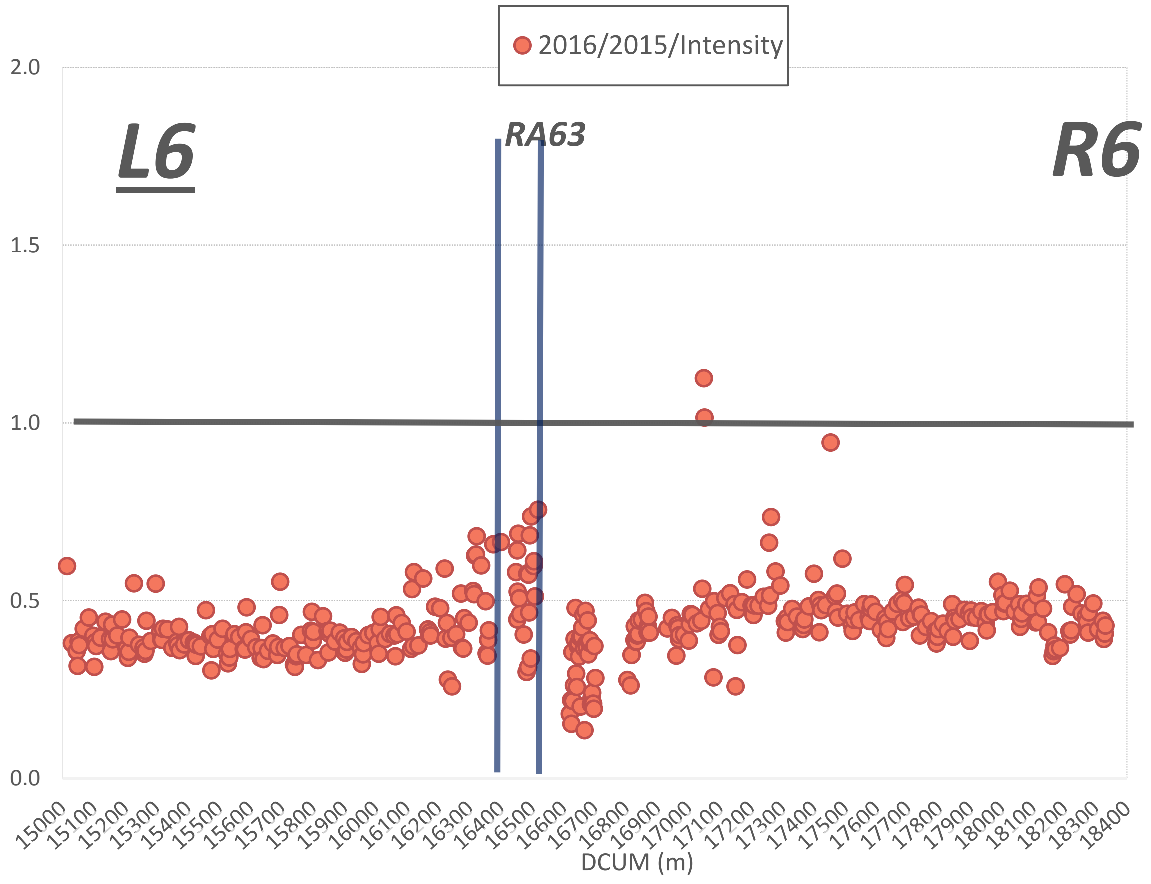
Shielding RR

- From: Collimation meeting: M. Brugger, F. Cerutti, L.S. Esposito FLUKA studies on the radiation in the Point 5 Q6-Q7 area: Roman Pots, TCL6 and RR



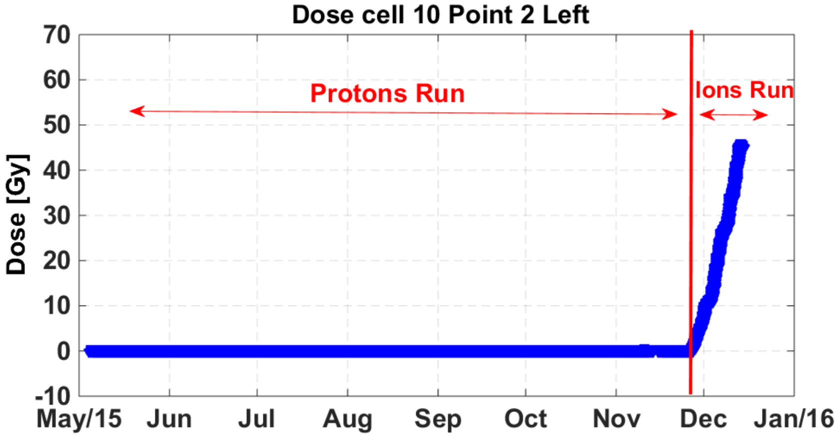


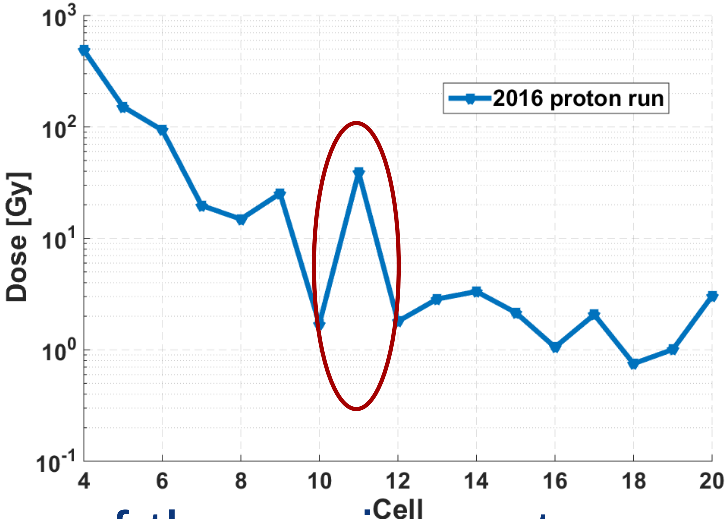
RA63 BLM intensity normalized



Looking at the future

- It is and it will be not only a question of SEE: long term TID effects will become an issue





- Ions run losses reduce the lifetime of the equipment
- The increase of the radiation levels due to higher luminosity (2016-2017) may lead to pre-emptive maintenance of several equipment