Radiation to electronics – R2E

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Many thanks to everybody but especially M. Brugger, S.Gilardoni, A.Masi

CERN | EN ENGINEERING DEPARTMENT

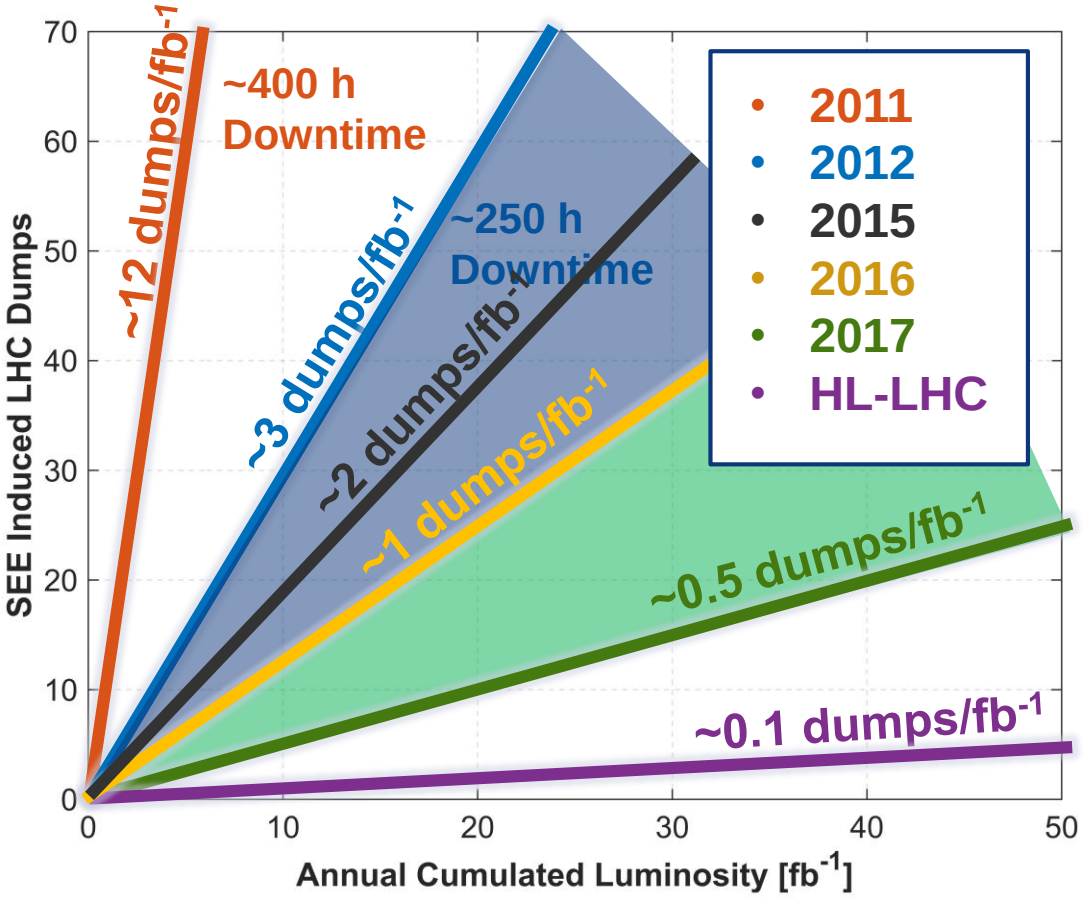
R2E

RADWG

Overview

- Summary of the 2015 run
  - 2015 radiation levels and failures in the LHC
  - Forecast for the future
  - TID issue with examples from 2015
- How to reach the nominal performances
  - Failures tracking and Radiation monitoring
  - Needs of tolerant hardware for LS2 and beyond
  - Radiation Hardness Assurance - RHA
  - How to approach the RHA: Guidelines Proposal

R2E and the Mitigation Strategy from 2011



Several shielding campaigns prior 2011 + Relocations 'on the fly' + Equipment Upgrades

2011/12 xMasBreak 'Early' Relocation + Additional Shielding + Equipment Upgrades

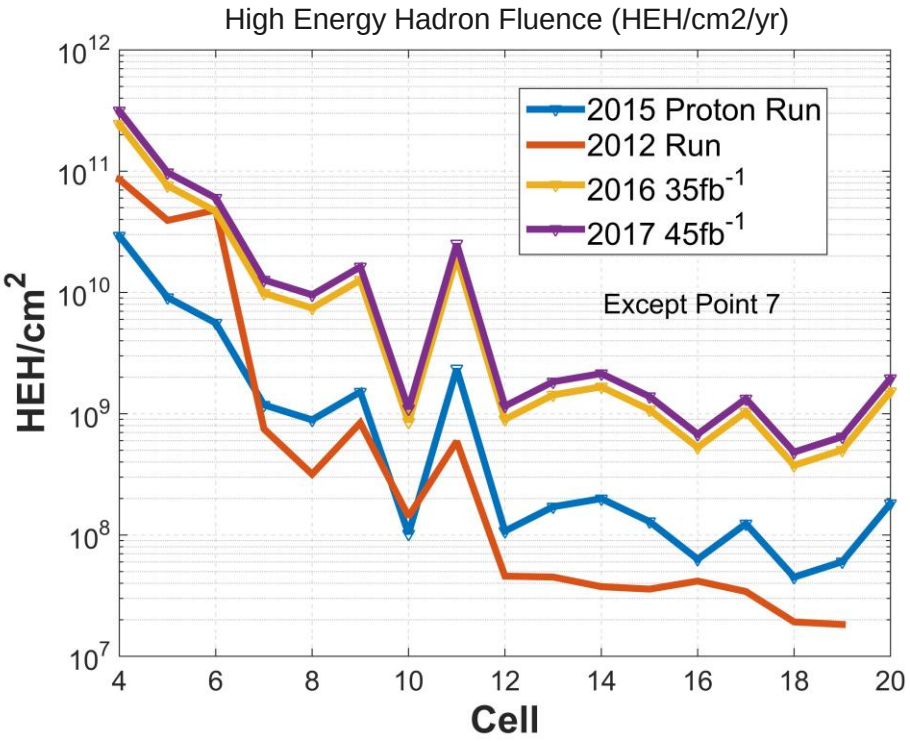
LS1 (2013/2014) Final relocation and shielding

LS1-LS2 (2015-2018) Tunnel equipment and power converters

LS3-HL-LHC Tunnel Equipment (Injectors + LHC) + RRs

Radiation Levels – Tunnel Areas

- **Failure rates are proportional to the radiation levels**
- **Tunnel areas – several equipment installed: QPS, EPC, Cryo**



- **Analysis based on the RadMon measurements up to end November**
- **2012 vs 2015 highlights the predicted impact of the 25ns operation**
- **2015 HEH fluence higher than 2012 in cells >8 due to the higher beam-gas interaction**
- **2015 low luminosity impacts the cell <8 with less fluence**
- **expected radiation level for 2016 and 2017 are ~8x and ~10x higher than the 2015 (scaling with the integrated luminosity)**

Failures Overview

Equipment	Dumps 2012	Dumps 2015 (After TS2)	Dumps 2016 35fb-1	Dumps 2017 45fb-1
QPS	32	2+1*	0-5	0-5
Power Converter	15	5+2*	~25	0-10
Cryo	4	0	0	0
EN/EL	1	0	0	0
Vacuum	4	0	0	0
Collimation	1	0	0	0
RF	1	4**	?	?
Others (hidden)	-	-	0-10	0-10
Total	3 /fb^{-1}	~3.4 /fb^{-1}** 2.3 /fb^{-1}	~1-1.5 /fb^{-1}	~0.5 /fb^{-1}

QPS strategy

EPC strategy

* Confirmed after Evian ** To be confirmed

EPC strategy: see V. Montabonnet talk
QPS strategy: see R. Denz talk

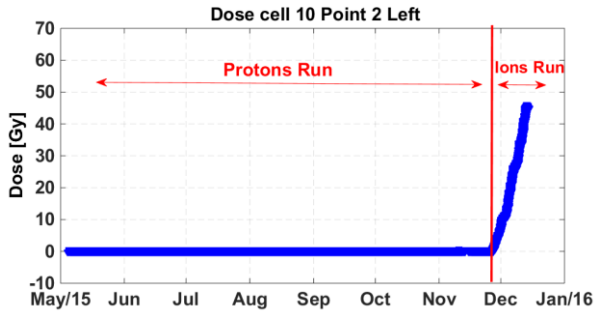
- **2015-2016 going in the right directions approaching ~1 dump/fb^{-1}**
- **2016 run will highlight if the RF failures are due to the radiation**
- **2016 other new failures can appear due to increase of the radiation levels**

The long term total ionizing dose TID problem

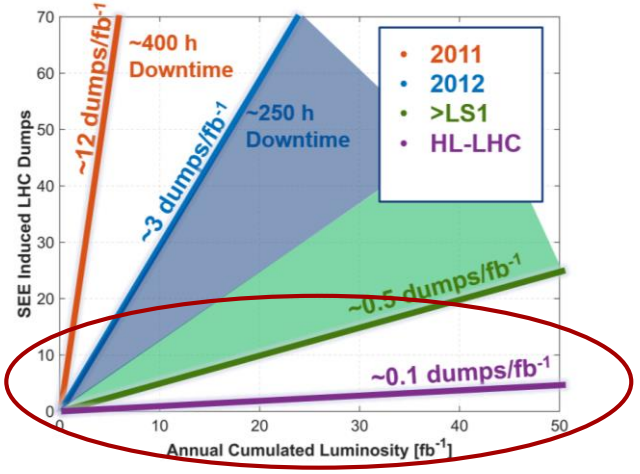
LHC Era	Machine Energy	Integrated Luminosity	Radiation Dose in Arc	Radiation Dose in DS
	[GeV]	[fb-1]	[Gy/year]	[Gy/year]
Run 1	3.5/4.0	~30	<<1	~10
Run 2	6.5/7.0	~100	~1	~20
Run 3	7	~300	~2-4	~40
HL-LHC	7	~3000	~4-8	~80-160

from R2E Availability workshop 2014

- We should **not forget the ions runs**
  - Due to the Bound-Free Pair Production (BFPP), even for short runs, radiation levels can be up to 50 times those of a proton run (Very localized)
- The solution before the HL is rotate/substitute the equipment where the level are too high (DS)

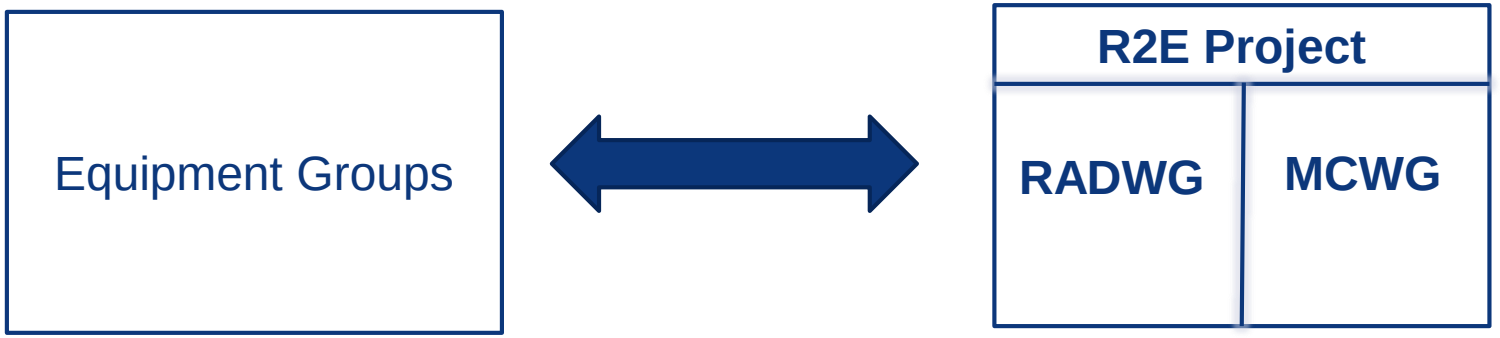


How to maintain and further improve the R2E failure rate?



- Recipe:
  1. Radiation Monitoring
  2. Equipment inventory
  3. Follow the new developments to be installed in radiation areas by means of dedicated guidelines

- Request a strong collaboration between the equipment groups and the Radiation Working group (RADWG) and the Monitoring and Calculation Working group (MCWG)



Radiation Monitoring and Equipment inventory

1. Equipment inventory

- Know what there is in the tunnel and in the critical areas
- Track the failures due to the radiation in the LHC and in the injector (collaboration with the AWG for the use of the AFT tool)
- Suggest and foresee mitigation actions
- Radiation testing coordination and supervision

RADWG
+
Equipment group

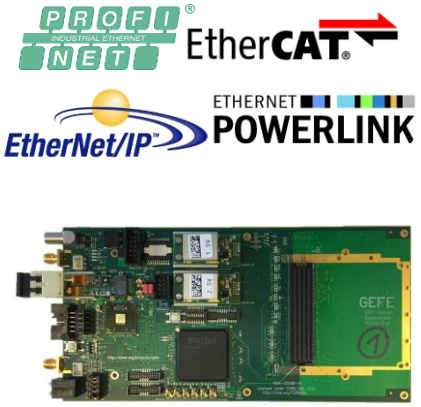
2. Radiation Monitoring

- Radiation levels in the entire accelerator (LHC and Injector) using RadMon, BLMs and passive dosimeters
- The radiation levels at the point of failures
- Radiation levels in the DS and in ARC in order to foresee an equipment rotation

MCWG
+
RADWG

New initiatives and developments

- RADWG is the interface with all the ATS equipment groups
  - BE-CO in view of the CO3 initiative for the new CERN fieldbus foreseen for the LS3
  - BE-BI in view of the upgrade of the BPM frontend
  - TE-MPE splice protection system for HL and consolidation of existing hardware
  - TE-VSC in view of the new readout of the pressure sensors
  - BE-RF for the pickup amplifier for the transverse feedback in the PSB

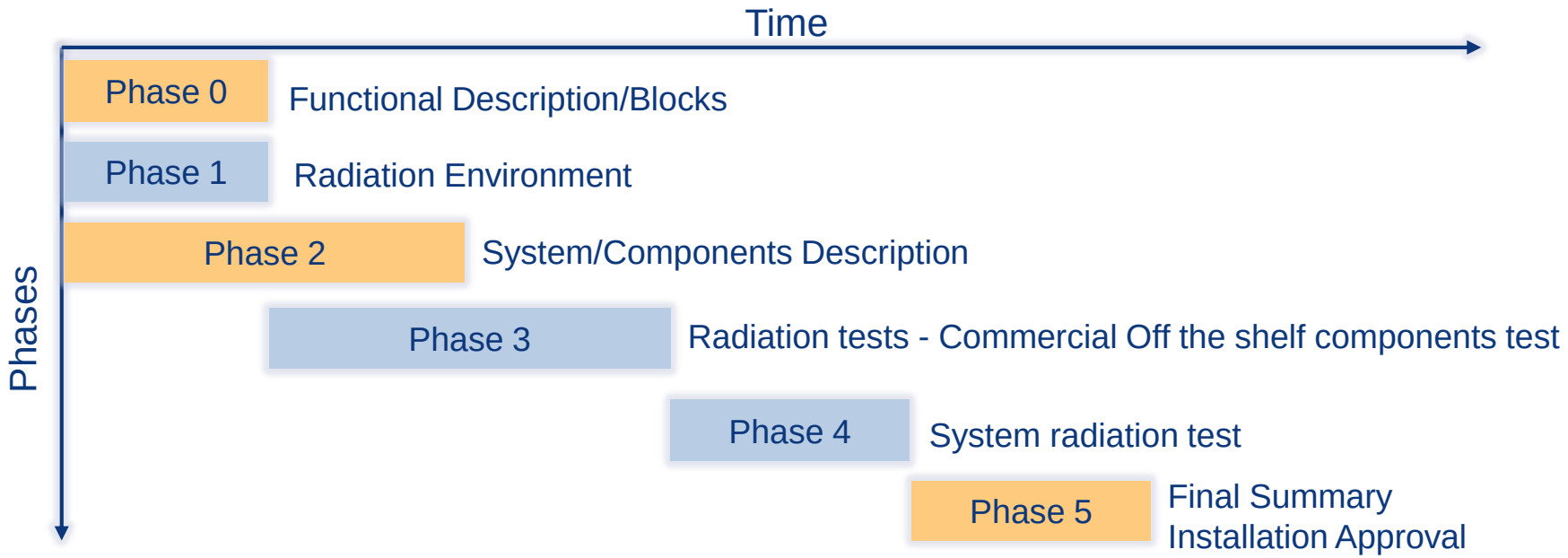


Radiation Hardness Assurance (RHA) guidelines

3. Follow the new developments to be installed in radiation areas by means of a dedicated guideline

- RHA consists of all activities undertaken to ensure that the electronics systems of the accelerator perform to their design specifications after exposure to the radiation environment.
- The RHA should be a part of the quality assurance of the hardware
- The RHA guidelines have to define the
  - **PROCESSES**
  - **ACTORS / RESPONSIBLE**

RHA guidelines for new developments



- A document has to keep track of all the phases and the results
- Proposal: A part in the ECR should be added to keep into account the RHA approval
- Follow-up action of the 227th LMC Meeting held on 22nd July 2015
- The R2E radiation test service has acquired a huge know-how on radiation testing and radiation effects which should be strengthened

Radiation tests – CHARM

Phase 3 Radiation tests

Phase 4 System radiation test

- CHARM is a mixed field radiation facility completely targeted at radiation tests on electronics system and components located at CERN in the East Area

- Electronics components
- New developed systems
- Evaluate the susceptibility of an existing system installed in critical areas.

→ Emulate the same radiation environment of the Tunnel areas and shielded areas

- 2015: 25 users in total from TE, EN and PH
- 2016: 10 users already scheduled
- RADWG gives the availability to test in several facility at CERN and outside CERN

Conclusions

- R2E made a very good work to reduce the number of failures
  - We will see failures in the coming years (around 1-2 dumps/fb^{-1})
    The latest EPC upgrade will pave the way for 0.5 dumps/fb^{-1} in 2017
  - Long term TID will become an issue for the equipment in the tunnel.
    The solution is to rotate/substitute the equipment with the help of monitoring and a correct development/qualification process
- Looking at LS3 and HL
  - RADWG and MCWG keep tracking the failures and the radiation levels
  - We proposed a Radiation Hardness Assurance (RHA) guidelines which should be integrated within the ECR to verify that the guidelines have been followed
  - The know-how on radiation testing and radiation effect should be strengthened in the future

Thank you

BACKUP Slides

QPS and EPC a closer look

QPS - Actions

Mitigations during LS1:

- Firmware upgrades
- Upgraded detection systems type nDQQDI
- Relocation

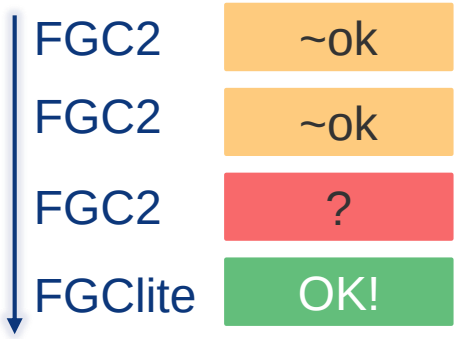
- **Mitigation during the YETS 2015**
  - Deployment of the new 600A design

QPS	Dumps
2012	32
2015 after TS2	2+1
2016	0-5
2017	0-5

EPC – Actions

Mitigation during the YETS 2015

- WATCHDOG fault corrected



EPC	Power part	Control
	Dumps	Dumps
2012	15	10
2015 after TS2	2+1	3+1
2016	0-5	~24
2017	0-5	0-5

Radiation Levels – Critical Areas

Critical Areas	2012 HEH Measurements	2015 HEH Predictions	2015 Measurements (4fb-1)	2016 Predictions 35fb-1	2017 Predictions 45fb-1
UJ14/16	1.10E+08	5.04E+07	6.82E+07	5.7E+08	7.3E+08
RR13/17	1.80E+07	1.68E+07	1.44E+07	1.2E+08	1.5E+08
UJ56	1.20E+08	4.24E+07	9.77E+07	8.1E+08	1.0E+09
RR53/57	1.80E+07	2.64E+07	9.17E+06	7.6E+07	9.8E+07
UJ76	5.50E+07	6.48E+06	9.75E+06	8.1E+07	1.0E+08
RR73/77	3.00E+07	1.92E+07	1.57E+07	1.3E+08	1.6E+08

- **UJ14/16 shielded 2011/2012**
- **Sensitive equipment relocated from the UJs during the LS1**
- **RR13/17/53/56 shielded improvement during the LS1**
- **HEH fluence in the critical areas scale with the expected luminosity (apart from the UJ76 and RR73/77)**
- **Operational parameters can have important impact (see UJ76)**
- **Some failures can appear in the RR during the next years**