EN Engineering Department

Session 7 – After LS1
Will we still see SEEs?

M. Calviani (EN/STI) for the R2E Mitigation Project

Thanks to the R2E Project team and RadWG members!

Introduction

- R2E Project mandate:
  - SEEs should allow LHC operation with **MTBF ≥ 1 week** for a peak luminosity of **$2*10^{34}$ $cm^{-2}s^{-1}$** and an yearly integrated luminosity of **~50 fb^{-1}**
  - **HL-LHC** performances in mind (**~$5*10^{34}$ $cm^{-2}s^{-1}$** for a yearly integrated luminosity of **~200 fb^{-1}**)
- Mitigation activities foreseen to reduce risk of radiation-induced failures:
  - Equipment relocation
  - Shielding
  - Hardware development

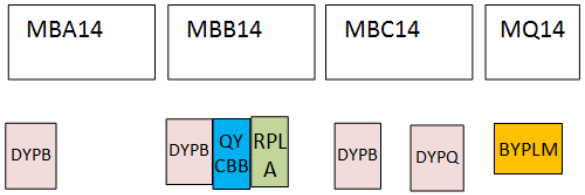
ONGOING process with major actions during and after LS1

YES, we will still see SEEs in the machine after LS1!!

- Why?
  - **Certain equipment will remain in tunnel/exposed areas**
- Mitigation!
  - Shielding/relocation **See A.-L. Perrot – S05**
  - Hardware developments
- How many?
  - We cannot give a reliable figure as of now (see later…)
  - Final goal to have MTBF ≥1 week due to SEEs in post-LS1 years

What will remain critical after LS1?

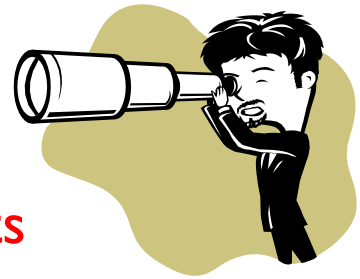
- No relocation/shielding is possible for several systems
  - Only rad-tol hardware modification or new developments
- Tunnel equipment
  - QPS protection (nQPS splice protection)
  - LHC60A PC
  - CRYO
  - Beam instrumentation



- RRs
  - QPS DQQDI/DG
  - LHC120A, LHC600A, LHC4-6-8kA PC

… how many?

- Difficult to quantify/predict precisely the number of events as they depends on:
  A. Evolution of radiation levels in critical areas
  B. Radiation tolerance of new hardware developments
  C. Appearance of additional failure modes



- How to improve prediction capability?
  - Follow-up 2012 operation (higher luminosity/intensity)
  - Radiation-testing campaigns
    - Testing at mixed-field facilities – LHC-type spectra
    - Test teams need to be properly manned
  - Improve radiation monitoring in LHC

Why?

Radiation level evolution

- Failure rates are proportional to the radiation levels
- Radiation levels for critical areas for which mitigation actions have been **already foreseen**

	Areas	High-Energy Hadron Fluence (/year) 2011	>LS1 (nominal)	Ultimate
Critical	UJ14/16	2.10E+08	6.30E+08	2.50E+09
	RR13/17	7.00E+06	**2.10E+08**	**8.40E+08**
	UJ56	3.50E+07	5.30E+08	2.10E+09
	RR53/57	1.10E+07	**3.30E+08**	**1.30E+09**
	UJ76	5.40E+06	8.10E+07	3.20E+08
	RR73/77	8.10E+06	**2.40E+08**	**9.70E+08**
	UX85b	1.70E+08	4.30E+08	4.30E+09
	US85	3.50E+07	8.80E+07	8.80E+08

- Shielding (2011/12) + full relocation (LS1)
- Shielding (LS1) + PC R&D (≥LS1)
- Full relocation (LS1)
- Relocation (LS1)
- PC R&D (≥LS1)
- Shielding and relocation (LS1)

Radiation level evolution

- Tunnel areas – no shielding/relocation possible

	Areas	High-Energy Hadron Fluence (/year) 2011	>LS1 (nominal)	Ultimate
Tunnel	DS (P1/5)	1.00E+10	1.50E+11	6.00E+11
	DS (3/7)	1.00E+09	1.50E+10	6.00E+10
	DS (other)	3.00E+08	1.40E+10	1.80E+10
	ARC	2.00E+08	9.00E+09	1.20E+10

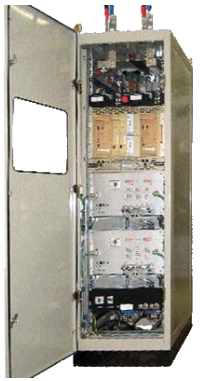
	Areas	High-Energy Hadron Fluence (/year) 2011	>LS1 (nominal)	Ultimate
Investigated	UA23 (maze)	3.40E+06	2.00E+07	2.90E+07
	UA87 (maze)	1.00E+06	6.00E+06	8.40E+06
	UJ23	2.00E+05	9.00E+05	1.20E+06
	UJ87	5.00E+05	2.30E+06	3.00E+06
	UX45	2.50E+06	1.50E+07	2.10E+07
	UX65	1.00E+06	6.00E+06	8.40E+06
	REs (entry!)	5.00E+05	2.30E+07	3.00E+07

- Dominated by leakage (luminosity or collimation)
- Beam-gas dominated
  - Large uncertainty due to 25ns operation vac pressure
  - Large number of exposed equipment → potentially more failures

- Beam-gas pressure (25ns operation)
  - PLCs most sensitive equipment

Power converters post-LS1

- Almost **~1700** equipment underground
  - UJ14/16, **RR** (P1/5/7), UJ/UA (P2/4/6/8) + **tunnel**
- Failure types (2011):
  - Auxiliary power supplies
  - Voltage source
  - Filter corruption on FGC ADCs
- Mitigation actions:
  - Digital filter improvem
  - Shielding UJ14/16 → **2**
  - Redesign and relocatio
  - SCL (**>LS1**)



An **aggressive hardware rad-tol R&D** is needed to guarantee minimum impact in terms of SEE in post-LS1 years

Q. King, Y. Thurel, TE/EPC

R2E-EPC project

- FGC replacement by FGClite
  - Main weakness is Xilinx 95000 CPLDs
  - Present in all PCs!
  - ~1050 devices, developed/tested towards installation **end of LS1**
- Patch solutions to be developed/applied on the AC-DC PSUs of LHC600A PCs
- Redesign and upgrade (RR equipment)
  - LHC600A & LHC4-6-8kA → complete redesign
  - LHC120A →

FGClite development is **crucial** for the R2E Project to guarantee the MTBF ≥ 1 week

Q. King, Y. Thurel, TE/EPC

Power converters failures post-LS1

Failures on 60A not necessarily lead to beam dump!

converter	failure per year 2011	2012	>LS1
LHC60A-8V	4	10 .. 30	60 .. 200
LHC120A-10V	1	2 .. 3	10 .. 30
LHC600A-10V	7	7 .. 10	1 .. 15
LHC4-6-8kA-8V	1	1 .. 3	1 ..45

- 2012:
  - Shielding improvemer
  - Digital filter improver
- **Post-LS1**:
  - Assumes EPC solved
  - Reduction of failure r LS1 years (*not include*

Uncertainties:
- Rad-failure cross-sections!
- Radiation levels in the ARC

→ **FGClite critical for R2E**
→ **PC patches for AC-DC**
→ **Radiation testing before installation required**

Q. King, Y. Thurel, TE/EPC + MCWG/R2E team

SCLs and outcome of the R2E review

I. **SCL technology** fully available by LS2

II. **PC R&D** needs to progress anyway for post-LS2

- Final solution (HL-LHC) might be an hybrid:
  - Horizontal SCLs in LS2 for P7 RR PCs
  - Radiation tolerant PC for other RRs in LS2
  - Vertical SC links in LS2/3?

- Review during 2012/13

A. Ballarino, R. Losito, R2E Review, November 2011

QPS upgrades

- Radiation-induced faults are responsible for most of the QPS trigger in stable beam during 2011

A. Macpherson S01
R. Denz – S06

- QPS equipment located in tunnel and critical areas
- Mitigation actions (**LS1**):
  - Relocation of equipment (IPQ/IPD/IT and 600A) in UJ14/16
  - Patches and hardware upgrades (new boards)

- Failure estimation post-LS1 not possible at the moment; likely good perspectives though (rad-tol developments)
- **Radiation/functional testing needed**

Other equipment in critical areas

- EN/EL (UPS)
  - Relocation from UJ56 (2011/2012) and US85 (**LS1**)
  - Radiation-sensitivity tests during 2012 at H4IRRAD
  - UPS will stay in the REs – ARC beam-gas
- CRYO (tunnel + shielded areas)
  - All known issues to be mitigated (hardware dev./relocation) during **LS1**
  - Follow-up needed on Siemens PLCs on compressors (rad-test at

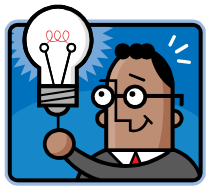
- No EN/EL or CRYO SEE-induced dumps expected after LS1 if all mitigation will be successful
- Follow-up still needed

See M. Brugger – S03, L. Tavian – S05

S. Claudet (TE/CRG), E. Blanco (EN/ICE)

Conclusions 1/3

- We cannot be more precise on the number of failures expected in post-LS1 years
  - Large uncertainty on radiation-induced **failure cross-section**
    - For existing equipment
    - …And for new hardware developments
  - Uncertainties on **radiation levels**
    - Vacuum pressure in the DS/ARC @25ns
    - Betatron/momentum collimation losses (total and sharing P3/7)
- Implementation of **on-fly patches** by equipment groups!



Conclusions 2/3

- We know what are the critical equipment and issues to address to **minimize SEE-induced dumps**!
- *Hardware developments:*
  - R2E-EPC power converter R&D program
  - FGClite development
  - QPS hardware modifications
  - Radiation testing campaigns before LHC installation!
- *Radiation levels:*
  - Scrubbing run 2012 to understand 25ns vac. – ARC/DS rad. levels
  - Tight collimation settings: radiation loading of RRs
- *SCLs:*
  - Development of horizontal/vertical SCLs + integration

Conclusions 3/3

- **SEE are still expected to be present after LS1**
- However:
  - Mitigation actions (developments/relocation/shielding) will allow to decrease their impact despite higher LHC performances
- Radiation level monitoring requires continuing effort
  - 2nd generation RadMons + BLM team support (!)
- R&D on rad-tol PC critical – perhaps joint with SCLs
- QPS developments in the tunnel critical for operation
- UX45/65 mitigation (other than PLCs) not in R2E baseline

MTBF ≥ 1 week feasible (with continued efforts)

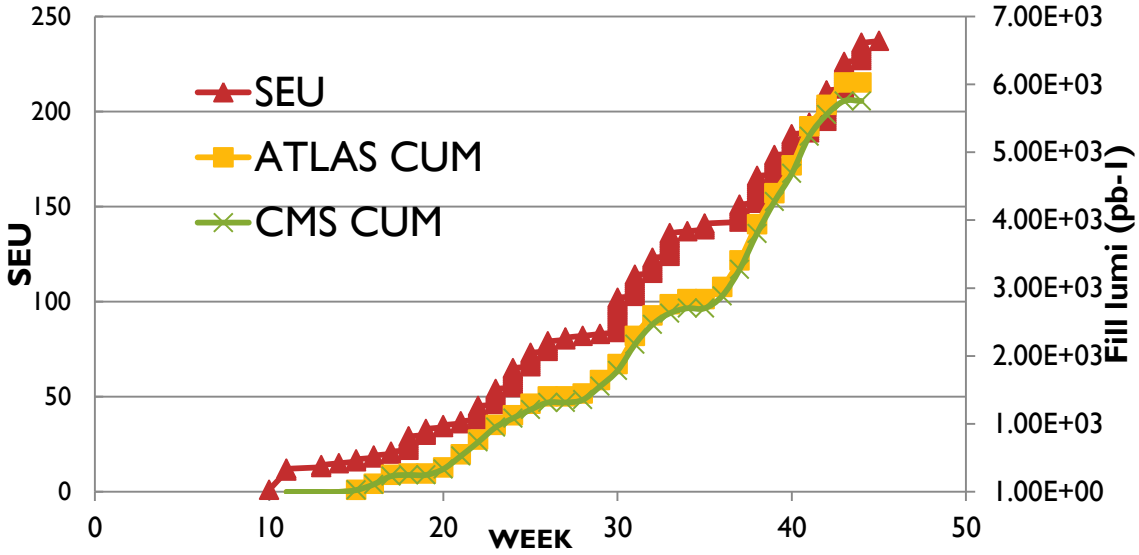
Thanks a lot for your attention!

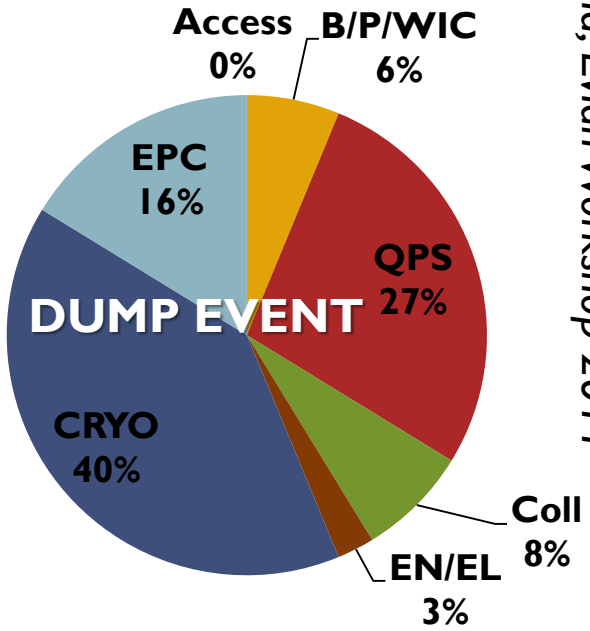
BACKUP

Summary of 2011 observations

- 70 dumps events induced by SEEs on LHC machine equipment
- ~400h total downtime

See M. Brugger – S03





G. Spiezia, Evian Workshop 2011