R2E – EXPERIENCE AND OUTLOOK FOR 2012

M. Brugger, M. Calviani, J. Mekki and G. Spiezia on behalf of the R2E Mitigation Project
CERN, Geneva, Switzerland.

Abstract

2011's very successful LHC operation has provided valuable input for the detailed analysis of radiation levels and radiation-induced equipment failures. Radiation levels around LHC critical areas and the LHC tunnel were studied in detail and compared to available simulation results, as well as put in perspective to LHC operation parameters. Observed radiation-induced failures were not only analyzed in detail, but already addressed through early relocation measures and patch-solutions on the equipment level. Both improvements continued during this Winter Break together with the installation of heavy shielding around the RBs and UJs in Point 1. Based on measured radiation levels, calculations for the shielding improvements, and expected operational parameters, this report provides an update on the expected radiation levels around LHC critical areas. It briefly summarizes the mitigation measures and equipment patches already performed and provides an estimate on the expected equipment failure rates during 2012 operation. Required beam and measurement studies are highlighted in order to further improve the predictions of both radiation levels and expected equipment failures, the latter driving the chosen mitigation actions for Long Shutdown 1 (LS1).

INTRODUCTION

Based on previous studies [1] and respective analysis, 2011's LHC operation provided key elements in analyzing radiation-induced failures on machine equipment. From early operation onwards, strong emphasis was put in the detailed analysis of equipment failures which could possibly be linked to radiation. To study in detail the latter correlation, a number of criteria were set, implying that one, several, or, ideally, all of the following conditions to be fulfilled:

- Equipment failure occurs during periods with beam-on/collisions/losses (i.e. the source of radiation being present);
- The failure(s) is/are not reproducible in a technical laboratory;
- The failure signature was already observed during radiation tests (CNRAD, H4IRRAD, and others);
- The frequency of the failures increases with higher radiation levels.

This obviously still includes remaining uncertainties which can lead to failures being attributed to radiation but which in reality they are not. However, as shown in this report, the detailed studies performed throughout the 2011 operation reduce these uncertain cases to only a few. On the contrary, there is also a limitation in the sense that the analysis is likely to miss radiation-induced failures which do not lead to a beam dump, as well as more complex cases where one piece of equipment is affected by radiation and indirectly causes a problem to another, thus leading to either longer downtimes or beam dumps.

In the following we provide a summary of the radiation levels and induced failures for the LHC operation in 2011, including an overall estimate of the respective machine downtime. The impact of performed countermeasures is highlighted and the conclusions for further mitigation measures are drawn. It is shown that the detailed monitoring of the radiation levels, as well as the detailed analysis of radiation-induced failures remains a high-priority for the upcoming years of LHC operation. It is the mandate of the R2E project [2] to minimize all radiation-induced failures in the LHC.

RADIATION LEVELS AND PARAMETERS SCALING

The radiation levels in the LHC tunnel and in the shielded areas have been measured by using the RadMon system [3]. The major radiation-induced failures observed during 2011 LHC operation are due to Single Event Effects (SEE) on electronic equipment. The probability of having an SEE is related to the accumulated High Energy Hadron (HEH) fluence (see [1] and references therein) which is summarized in Table 1 for the most critical LHC areas where electronic equipment is installed. The HEH fluence measurements are based on the reading of the Single Event Upsets (SEU) of SRAM memories whose sensitivity was previously calibrated in various facilities [3].

Table 1: Predicted and measured HEH fluence in LHC critical areas based on 2011 operation conditions.

Area	FLUKA 2011 (HEH/cm^2)	Measured 2011 (HEH/cm^2)
UJ14/16	~1.5*10^8	~2*10^8
RR13/17	~3*10^7	7.0*10^6
UJ56	5*10^7-10^8	3.5*10^7
RR53/57	~3*10^7	1*10^7
UJ76	~4*10^6	5*10^6
RR73/77	~2*10^6	~8*10^6
UX85B	~3*10^8	2*10^8
US85	~7*10^7	3.5*10^7

The results obtained during 2011 LHC proton operation show that the measurements equate FLUKA calculations. In addition, in the few areas where there is a greater difference, an actual explanation was found based on LHC operation conditions (e.g. the TCL collimators not being at nominal position for Points 1 and 5, and non-nominal collimation settings for Point 7).

Based on the results for 2011, the radiation levels can be scaled for the following years by using the expected machine parameters, chosen according to the main radiation sources for a given critical area. The latter can be grouped into three main categories:

a) Direct losses in collimators and absorber-like objects;
b) Particle debris from beam-beam collisions in the four main experiments; and
c) Inelastic interactions of the beam with the residual gas inside the beam pipe.

As far as the beam energy is concerned, according to calculations, the operation at 7 TeV will increase the radiation levels by a factor 1.5, while an increase to 4 TeV will only lead to a marginal increase of about 10%, thus largely within the overall uncertainties.

For the shielded areas close to the beam collision points, as well as for the Dispersion Suppressor (DS) zones, the radiation levels are scaled with luminosity which will increase for nominal operation by a factor of 10 for the ATLAS and CMS experiments and by a factor 2 for LHCb. For the arc of the LHC tunnel, the radiation levels depend on the beam-gas interaction the impact of which is related to beam-intensity, bunch spacing and conditioning of the vacuum (residual gas pressure). The scaling factor for the latter radiation source is affected by high uncertainties of the expected average residual gas pressure towards nominal LHC operation and can therefore vary between a factor of 10 and 100.

The expected scaling factors for the collimation areas also have associated uncertainties as both the absolute number of protons lost, as well as the loss distribution among the collimators depend on the collimator settings themselves and on operational parameters. Dedicated beam time should be reserved during 2012 operation to get a clearer understanding of the effects of the residual beam gas as well as the collimator settings on the resulting radiation levels. The scrubbing period during the start of 2012 operation will possibly help in clarifying the long-term impact of 25ns operation on the average pressure in the arc.

On the basis of the previously listed considerations, the expected HEH fluences for the next operational year (2012) can then be extrapolated from the radiation levels measured during 2011 and are reported in Table 2. It is important to note that the effective radiation levels for the UJ14/16 areas are less for 2012 due to the additional shielding put in place during the winter shutdown.

As far as the ion beam operation is concerned, a preliminary analysis shows that the losses significantly increased from 2010 to 2011 operation and are localised in the DS areas and in particular in the LHC tunnel cells from 9 to 13 (Points 1, 3, 5, 7), where, in a few weeks, the radiation levels reached the same levels as those accumulated throughout the year during proton beam operation. For 2012 ion operation, the impact is expected to be significantly reduced due to the proton/ion beam configuration.

Table 2: HEH fluence expected in LHC critical areas during 2012 LHC operation.

Critical LHC Areas	High-Energy 2011	High-Energy 2012
UJ14/16	2.1E+08	1.3E+08
RR13/17	7.0E+06	2.1E+07
UJ56	3.5E+07	1.1E+08
RR53/57	1.1E+07	3.3E+07
UJ76	5.4E+06	1.6E+07
RR73/77	8.1E+06	2.4E+07
UX85b	1.7E+08	2.1E+08
US85	3.5E+07	4.4E+07

MITIGATION MEASURES PUT IN PLACE PRIOR TO 2011 OPERATION

Following the list of critical areas based on FLUKA and early operation studies [1, 3, 4], a prioritization of mitigation measures was defined and followed throughout the R2E mitigation project:

- 1st Priority – critical safety: envisage/prepare for immediate relocation (performed at the earliest stage of all R2E related activities);
- 2nd Priority – shielding options: aim for fast and overall improvement of a large number of equipment (continuously performed taking into account the criticality of the concerned area and the time available during machine stops);
- 3rd Priority – most sensitive equipment and areas: relocation and shielding measures selecting the equipment/area with the highest impact on operation (as started during 2011 operation and continued during this Winter Break with a strong focus on radiation-tolerant patch-solutions for equipment design);
- 4th Priority – remaining critical equipment/areas: prepare long-term mitigation actions including additional shielding, consequent relocation and radiation-tolerant design for the remaining equipment.

Table 3 summarizes both the past and present mitigation measures leading to acceptable conditions for 2011 LHC operation and put in place prior to 2012 restart, as well as the global relocation and shielding measures foreseen for LS1. Additional design and development of radiation-tolerant equipment (for power converters, quench-protection systems and others) is, however, not listed in this summary table.

Critical LHC Area		Activity	Description	Reference	Time Frame	Gain
All	Tunnel + Shielded Areas	Upgrade	QPS Firmware Upgrade	ISO150	2010/2011	Transparent
Several	UJs, RRs	Upgrade	600A AC/DC Patch	TE/EPC PC R&D	2012/LS1	Robust
Several	RRs, (UJs, UAs)	Upgrade	Radiation Tolerant PCs	TE/EPC PC R&D	LS1 - LS2	Robust
Several	UJs, USs	Upgrade	Cryo ET200 Automatic Reset		2011	Transparent
Several	UJs, USs	Upgrade	Temperature Sensor	Mask partl. Manual	2011	More Robust
Several	UJs, USs	Upgrade	Temp.Sensor: Soft + Hardw.	ECR 1144903	xMas 2011/2012	Robust
Several	UJ14/16/56	Upgrade	Coll-Control	Watchdog for Controller	xMas 2011/2012	Robust
Point-1	UJ14/16	Relocation	P/W/BIC	PLC Part	2011	Safe
Point-1	UJ14/16	Relocation	Fire-Detectors	ECR 1053225	xMas 2011/2012	Safe
Point-1	UJ14/16	Shielding	UJ Junction	ECR 1182068	xMas 2011/2012	~5-10
Point-1	UJ14/16	Shielding	RR13/17	ECR 1182068	LS1	~3
Point-1	UJ14/16	Relocation	remaining relocations	PCs, etc...	LS1	Safe
Point-2	UJ22/23	Shielding	Injection		2009/2010	~10
Point-4	UX/US45	Relocation	Cryo-PLCs		xMas 2011/2012	Safe
Point-5	UJ56	Relocation	Fire/ODH Control	ECR 1053225	2010	Safe
Point-5	UJ56	Relocation	Fire-Detectors	ECR 1053225	LS1	Safe
Point-5	UJ56	Relocation	EN/EL RTU		2010	Safe
Point-5	UJ56	Relocation	P/W/BIC	PLC Part	xMas 2011/2012	Safe
Point-5	UJ56	Relocation	EN/EL UPS	to UL557	xMas 2011/2012	Safe
Point-5	UJ56	Shielding	RR13/17	ECR 1182068	LS1	~3
Point-5	UJ56	Relocation	remaining relocations	PCs, etc...	LS1	Safe
Point-6	RA/UA 63/67	Shielding	RA/UA Connection Ducts		2009/2010	~5-10
Point-6	UX/US65	Relocation	Cryo-PLCs		xMas 2011/2012	Safe
Point-7	UJ76	Shielding	Wall (esp. SafeRoom)	ECR 985313	2009/2010	~2-10
Point-7	UJ76	Relocation	Fire-Detectors	ECR 1053225	LS1	Safe
Point-7	UJ76	Relocation	EN/EL RTU		2010	Safe
Point-7	UJ76	Relocation	EN/EL UPS	ECR 985313	2010	Safe
Point-7	UJ76	Relocation	remaining relocations	PCs, etc...	LS1	Safe
Point-7	RR73/77	Shielding	Wall and Maze	ECR 985313	2009/2010	~10
Point-8	UX85	Upgrade	Cryo Valves		2009/2010	Safe
Point-8	UX85	Relocation	Cryo-PLCs		2009/2010	Safe
Point-8	US85	Shielding	SafeRoom		2010	~10
Point-8	US85	Shielding	US85/UW85	rel. equipment	LS1	~10
Point-8	US85	Replacement	Cryo Power-Supply	Old-Model	2011	Robust
Point-8	US85	Relocation	Fire/ODH Control	ECR 1053225	2010	Safe
Point-8	US85	Relocation	WIC & Timing Rack	to UA83	xMas 2011/2012	Safe
Point-8	US85	Relocation	Fire-Detectors	ECR 1053225	2010	Safe
Point-8	US85	Relocation	Cryo-PLCs		2011	Safe
Point-8	US85	Relocation	Ethernet (Starpoint)	to UL	xMas 2011/2012	Safe
Point-8	US85	Relocation	QURCb (EYQ)	Level-2 to Level-0	xMas 2011/2012	Better
Point-8	US85	Relocation	EN/EL UPS		LS1	Safe
Point-8	US85	Relocation	remaining relocations	PCs, etc...	LS1	Safe
Point-8	UJ88/87	Shielding	Injection		2009/2010	~10

FAILURES OBSERVED IN 2011 AND CORRESPONDING MITIGATION ACTIONS

Radiation-induced failures on the LHC equipment as observed during 2011 LHC operation were analysed in detail thanks to a weekly shift organization within a group of four R2E members. For the analysis, the main sources of information were the LHC e-logbook and the LHC operation follow-up meeting, held daily [6] and the direct and detailed interaction with the equipment groups. Throughout the year, the collaboration between TE-EPC, TE-MPE, TE-CRG, and EN-STI groups was highly appreciated and allowed the improvement of the failure analysis.

Once, a failure is suspected to be related to radiation effects, the following information is collected and stored on the web page of the <u>RAD</u>iation <u>W</u>orking <u>G</u>roup (RADWG) [7]:

a) Equipment type and system part/component;
b) Type of failure;
c) Location of the equipment;
d) Consequence of the failure;
e) LHC fill number.

In some cases, it is not so straight forward to understand whether a failure was actually caused by radiation. The event is then marked as '*to be confirmed*' and further analysis is required to understand exactly what happened. The number of the LHC fill is used as a direct link to insert information in the Post Mortem (PM) database and to track the beam dumps that were due, or possibly due ('*to be confirmed*') to radiation, and also enable respective analysis by the LHC operation team.

In addition, a dedicated tool was developed to easily retrieve statistics on the type of failures from the PM database [8]. Figure 1 shows the failures due to the SEEs throughout 2011. Four distinct failure cases are reported:

a) Events leading to beam dump;
b) Events leading to beam dumps which are possibly due to radiation;
c) Failures which did not lead to beam dump;
d) Failures which do not lead to beam dump and are possibly due to radiation.

It is important to note that the '*to be confirmed*' events only represent a small fraction and will therefore not affect the overall conclusion for the required mitigation measures. The increase of SEE failures starting from week 22 which did not lead to beam dump indicates the effectiveness of the mitigation solutions applied by the equipment groups as countermeasures to radiation effects. In fact, the active follow-up of the failures proved to be an effective and necessary task to reduce the total number of beam dumps encountered during the year.

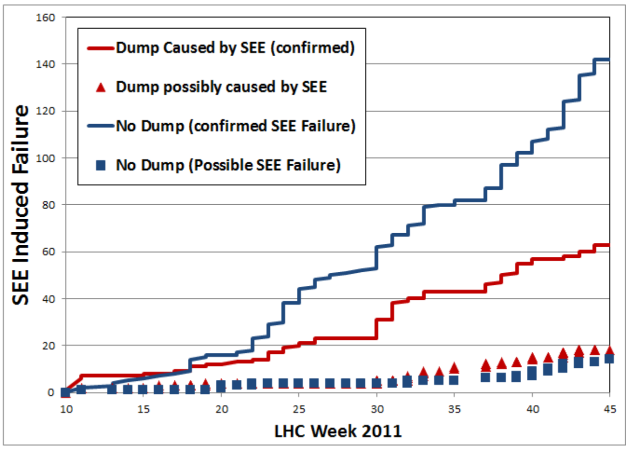

Figure 1: SEE failures along 2011 LHC operation.

Figure 2 shows the locations of the equipment affected by SEU radiation failures. The majority of the failures related to tunnel equipment were related to the Quench Protection System (QPS) electronics and happened in the Dispersion Suppressor (DS) areas (Fig. 2A). Mitigations at firmware level were already applied as from the 2010/2011 Winter Break in order to avoid a non-acceptable number of beam dumps [9].

A)

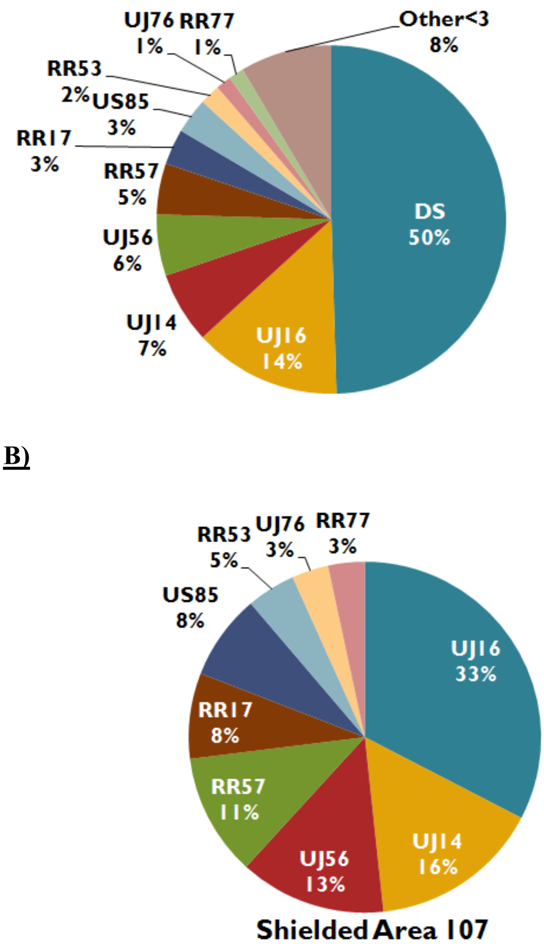

Figure 2: Locations of the equipment affected by radiation-induced failures. Figure A) reports all the cases for the tunnel and shielded areas; Figure B) shows the failure distribution in the so-called shielded areas (i.e., not LHC tunnel areas, thus RRs, UJs, UAs).

The shielded areas at Point 1, UJ14 and UJ16, resulted in being the most critical zones (Fig. 2B) both in terms of the number of failures as well as observed radiation levels. In summer 2011, it was decided to consider these areas of highest priority and to improve the shielding of equipment during the 2011/12 Winter Break. The proposed solution should enable the expected HEH fluence for 2012 to be reduced by a factor of 2 when compared to 2011 operation and this despite the expected luminosity for the ATLAS experiment to be increased by a factor of about 3 (Table 2). In the long-term, the relocation of the equipment will be the definitive mitigation action and is scheduled for LS1.

In addition to the shielding and relocation actions performed during 2010/2011 and during the upcoming Winter Break, additional effective countermeasures were applied by the groups in order to reduce the impact of radiation effects on machine operation. In the following subsections, the failure-analysis and envisaged mitigation actions for all the affected equipment groups are briefly summarized.

QPS

Failures on the QPS systems happened both in the tunnel and in the shielded areas. Most of the failures on the tunnel equipment are due to SEUs on an optical isolator (ISO150). An intermediate countermeasure at firmware level was designed to avoid beam dumps with a hardware change envisaged as a long-term possibility. Other sensitive parts of the QPS system are the communication and acquisition modules used for the protection of the magnets, splices and 600 A Power Converters (PC). It is important to note that all observed SEE-induced failures never compromised the safety of the machines. Various additional countermeasures are planned for the winter shutdown and for the technical stops programmed throughout 2012 to reduce the radiation-induced failures. The details of the actions are given in [9].

Cryogenics

The cryogenic equipment also suffered various types of failures. Both destructive and non-destructive SEU failures affected the PLC (Programmable Logic Counter) in Points 1 (UJs), 4 (UX), 6 (UX), and 8 (US). A false temperature reading on the current leads triggered unnecessary beam dumps in several shielded areas. In addition, power supplies failed due to destructive single events. The cryogenics group has therefore planned and integrated several mitigation actions. The most sensitive PLCs were or will be relocated in safer areas in the winter shutdown, the weaker power supplies were replaced with older models, more resistant to radiation. Patch solutions were applied at firmware levels to avoid non-destructive single events on the PLC system and on the temperature reading circuit which could trigger beam dumps. The details of those actions are given in [10].

Collimation equipment

Abnormal controller reboots, memory corruption and power supply failures affected the control equipment of the collimation system installed in UJ14, UJ16, and UJ56. As a countermeasure, the survey of critical registers will be implemented to increase the safety of the collimator operations. The failures of the power supply were investigated in detail and can be mitigated by applying a redundant system. However, this solution is not yet fully approved since the delivered monitoring card of the redundant power stage was found to be sensitive to radiation. Thus, for the 2012 restart no immediate mitigations are expected on this equipment which will mainly benefit from the shielding at point 1 to reduce radiation failures. Further mitigation actions will continue to be studied throughout 2012 operation.

Access System

During 2011 operation, the access doors and iris scan systems were blocked in many LHC Points, even at the surface. Therefore, in a general manner, replacing all the electronics for the access system has been programmed in order to change obsolete systems. However, the failure analysis showed that the fault cases which happened at UJ14 and UJ16 are higher in number and therefore expected to be partly related to radiation effects. The shielding of the UJ14 and UJ16 areas should reduce the number of these events by a factor 2 with the long-term relocation scheduled for LS1. It is important to note that newly installed system upgrades are not tested for radiation environments, thus a detailed failure-analysis during 2012 operation remains mandatory. A previously proposed mitigation measure to switch off the access control hardware during operation was not maintained since a possible failure of the equipment due to regular powering on and off could not be excluded by the equipment owner.

Beam/Power/Warm Interlock System

The PLC used for the Power Interlock Control (PIC) system was affected by the loss of communication with the respective remote Input/Output modules in the UJ14/UJ16 and UJ56 zones. Since, in view of possible SEE induced failures, the infrastructure for the relocation of this equipment was already prepared the previous year, the equipment owners decided to move its system from the critical UJ14/16 areas during a scheduled 2011 technical stop. No further failures happened after this relocation. The relocation of the equipment from UJ56 and US85 was performed during this winter stop. No respective radiation-induced failures are expected in the future. The VME-based part is known to be more robust, thus its relocation remains foreseen for LS1, with the required cabling already prepared during this Winter Break in order to allow higher reactivity in case an earlier need for relocation manifests itself during 2012 operation.

Power Converters

During 2011 operation, an auxiliary power supply of the 600 A Power Converters (PC) suffered 8 destructive events. In addition, the digital filter of the Function Generator Controller (FGC) was corrupted in several cases and did not ensure correct current measurements. These events mainly happened in the UJs of Point 1, RRs of Points 1, 5, and 7, and in the UJ and UA of Points 2 and 8. The affected auxiliary power supply will be tested under radiation early this year in order to find the weak component(s) and possibly prepare a mitigation action already in 2012. For the time being, the main benefit will be the shielding of the UJ14/16 (cumulative radiation levels reduced by a factor 2). In addition, the digital filter of the FGC has already been improved to avoid measurement corruption and neither the radiation failures nor the respective observed failure modes are expected in the future. In the long-term, both the power stage and the FGC of the PCs will be redesigned to be radiation-tolerant. Moreover, the relocation of the PCs will be carried out where it is feasible.

Electrical Distribution equipment

The Uninterruptible Power Supply (UPS) of the electrical network exhibited destructive events in the UJ56 and US85 areas. Although the failure analysis was inconclusive (dedicated tests could not be performed), the probability that these destructive faults were induced by radiation is considered as high, due to the observed failure mode, the affected locations, and the power components involved. On this basis, the UPS was already relocated during this winter stop from the UJ56 where the radiation levels are expected to increase by a factor 3 in 2012. The remaining relocation of the UPS from US85 is foreseen for LS1. It is important to note that additional UPS units are installed around the LHC in all the REs. As they will possibly be replaced by a new type of UPS, it was agreed that the power and control part will be qualitatively tested for radiation in order to avoid installing a very weak system even in areas where the radiation levels are still considered to be very low.

FAILURE SUMMARY AND 2012 OUTLOOK

Table 3 presents a summary of the number of dumps and failures for 2011 operation per equipment. The number of avoided dumps is also reported to underline the effectiveness of the mitigation actions taken throughout the year. The estimation of the machine downtime caused by the radiation-induced failures is presented in the before last column of Table 3. The latter analysis was performed by using the data collected on the RADWG website and PM database. A manual iteration of the data was required to take into account the downtime due to issues not related to SEEs which happened before or after the beam dump and led to longer downtimes than the radiation-induced failure itself. Although, the analysis is limited by the available details in the respective operation logbooks, it gives a fair indication of the operation time-loss due to radiation. The downtime for the cryogenics failures includes the recovery of the cryogenic temperatures, therefore clearly dominating the overall impact.

By knowing the integrated radiation levels in 2011, the number of occurred failures per equipment, and the expected HEH fluence for 2012, the failures for 2012 operation can be estimated as shown in Table 4. The analysis has been restricted to failures which lead to a beam dump. Without any additional mitigation actions, about 220 beam dumps would be caused by radiation effects.

Table 3: Summary of the SEU failures in 2011.

Affected Equipment Group	LHC Critical Areas	2011 #ofDumps	2011 #ofFailures	Estimated Downtime (partl. in shadow)	2011 Avoided SEE Dumps
QPS	Tunnel, UJs/RRs	23	140	~60 hours	150
Cryogenics	UJs	25	48	~250 hours	~25
Power-Converters	Tunnel, UJs/RRs, UAs	13	15	~30 hours	few (FGC)
Collimation Control	UJs (P1/5)	6	8	~20 hours	-
B/P/WIC	UJs, US85	3	4	~15 hours	1-2
Access	UJs	-	~4-8	~10 hours	-
EN/EL	UJ56, US85	2	3	~15 hours	-
	Totals	72	~220	~400h	~180

If one considers the improvement of the shielding in the UJ14/16, the additional mitigation actions (relocation and equipment patches) which have been applied towards the end of 2011 and the ones that will be applied in the winter shutdown, the total number of beam dumps is expected to be reduced to about 30-50. These figures show the importance of the winter shut-down operations, and suggest that each group must continue their efforts to apply new patch solutions during 2012.

Table 4: Expected SEU failures in 2012 with and without the mitigation actions.

Equipment	2012 #Expected Dumps (no additional mitigation)	2012 #Estimated Dumps (with mitigation)
QPS	~70	~20
Cryogenics	~80	1-2
Power Converter	~40	10-20
Collimation Control	~20	~5-10
B/P/WIC	~10	0
Access	-	-
EN/EL	~20	~1
Total	~240	~30-50

As a matter of fact, new failure signatures, which did not show up in 2011, might appear in 2012 and must be analyzed as they will dominate the failure scenario after LS1. It is important that a careful evaluation is performed in 2012 to ensure the mitigation measures planned for LS1 fully cover the latter failure scenarios.

CONCLUSIONS

A summary of the radiation levels and induced failures for the LHC operation in 2011 have been presented. About 70 beam dumps were provoked by radiation effects on electronic equipment causing a downtime for the machine of about 400 hours. The impact of the radiation effects would have been significantly higher without the countermeasures that were already applied in the past years. Furthermore, the prompt reaction of the LHC equipment groups to design patch solutions for mitigating radiation effects enabled the number of failures throughout 2011 which could have led to a beam dump to be reduced. The detailed failure analysis has permitted the UJ14/16 to be identified as the most critical shielded area already at an early stage and ensure that additional shielding will be installed during this winter shutdown. In addition, equipment groups have also programmed the implementation of additional mitigation actions during the winter technical stop to further improve the robustness of their equipment against radiation effects. Thanks to these efforts, the expected number of failures which can potentially dump the beam in 2012 is expected to be around 30-50, although the radiation levels will increase by a factor of 3 on average, with respect to 2011, in both the tunnel and shielded areas. The monitoring of the radiation levels will be a continuous job which aims at reducing uncertainty factors, mainly related to the beam gas effects and losses in the collimation areas. Dedicated beam time during Machine Development (MD) tests is required to better understand figures and, thus, increase confidence in the predications of the radiation levels in the following years. The detailed follow-up and analysis of equipment failures remains crucial to ensure a prompt reaction to possible new failure signatures which might appear in 2012.

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