ACTIONS TO MITIGATE THE RADIATION DAMAGE TO ELECTRONICS AT THE LHC

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Abstract

The level of flux of hadrons with energy in the multi MeV range expected from the collisions at the Large Hadron Collider (LHC) interaction Points 1, 5 and 8 and from the collimation system at Point 7 will induce Single Event Errors (SEEs) in the standard electronics present in many of the control equipment installed in LHC underground. Furthermore, a risk of SEEs induced by thermal neutrons cannot be excluded. Such events would perturb the LHC operation, possibly leading to a stop of the machine. Main mitigation actions will be implemented during the first LHC Long Shutdown of 2013/2014 (LS1) to reduce the SEE occurrence. This paper summarizes the mitigation measures and their associated foreseen improvements in terms of SEE. It presents the organization process and associated planning, highlighting the impacts on the overall LHC LS1 planning and the main concerns during implementation.

INTRODUCTION

The Radiation to Electronics (R2E) Project [1] is responsible for the development and the implementation of mitigation actions to minimize the radiation induced failures in the electronics and thus optimize the availability of the Large Hadron Collider (LHC). Three different types of actions were retained for the mitigation of the effects of radiation to electronics:

1. relocating the sensitive equipment located in areas where the High Energy Hadron (HEH) fluence exceeds ~10^7 HEH cm^{-2}/year into safer areas,
2. shielding when relocating is not possible due to technical or integration constraints
3. upgrading/re-designing equipment when both previous options are not possible due to technical or integration constraints.

It was decided to relocate, shield or upgrade all electronics systems/equipment

- where failures under radiation tests were observed;
- known to be radiation sensitive (e.g. complex control or powering systems);
- judged as sufficiently radiation resistant but where future replacements are likely to include commercial solutions prone for radiation induced failures;
- where relocation is necessary because of the relocation of other sensitive equipment (cabling, access, maintenance).

Ten areas located in four LHC points (Points 1, 5, 7 and 8–see Figure 1) were identified as critical in terms of hadrons fluence /SEE. These are located in services areas (UJ, UL, US, TZ) and in alcoves in the LHC tunnel (RRs) [2, 3].

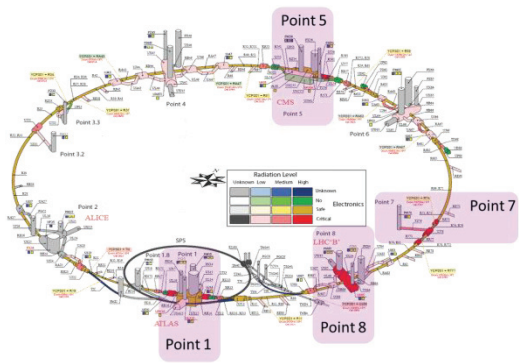

Figure 1: LHC critical areas in red considered by the R2E mitigation Project.

Figures 2 presents the layout with the reference names as used around LHC machine. The relocation areas were defined considering simulations or/and measurements in situ of radiation level. The choice between relocation and shielding options was a trade-off between the technical and integration constraints. In some cases, when possible and requested, both relocation and shielding were done to ensure long term protection.

The implementation of these mitigation measures was prioritized with first interventions during the 2011-2012 winter shutdown in Points 1 and 8 to ensure safe LHC operation in 2012. Because of the large amount of work, several activities were anticipated in LHC short technical stops during 2012. The remaining mitigation actions however will be performed during the LHC LS1 scheduled in 2013-2014.

This document reports the integration issues encountered for the R2E project. It presents the planning, organization process and main concerns linked to the implementation of these mitigation activities to be performed during the LHC LS1.

INTEGRATION STUDIES

The integration studies linked to the R2E project were very complex and challenging due to the large amount of equipment to be relocated and the lack of space available in an existing accelerator facility. The main issues were encountered in Point 5 and Point 7 where civil engineering works are needed to match the technical constraints of the equipment (e.g. removal of a 235 m long wall in Point 7, drilling of 16 m long ducts in Point 5). The tolerance in the final positioning of the relocated equipment is only of few centimetres (see Figure 3).

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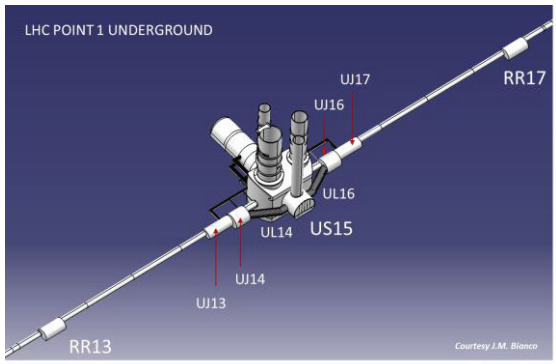

Figure 2: LHC Point 1 general layout.

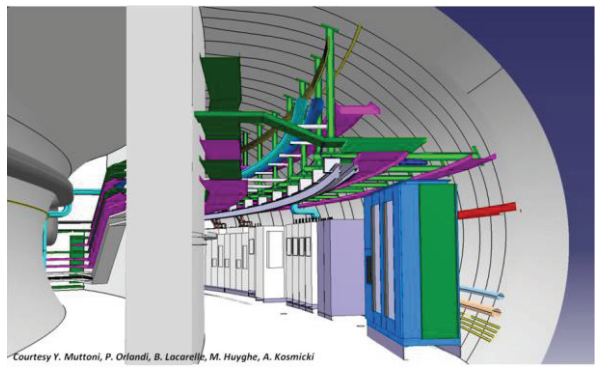

Figure 3: UL557 cross section after equipment relocation.

Two years were necessary to implement the new LHC 3D integration models linked to the R2E relocation and shielding activities. The electrical, transport, civil engineering and cooling and ventilation groups were involved in the implementation of these 3D models. An additional draughtsman was dedicated to the implementation and integration of all the new shielding walls. Finally, the LHC integration team merged all the models inside the LHC 3D modelling environment. The integration team provided dynamic 3D integration simulations for each integrated area that could be used for cross-checks in situ.

MITIGATION MEASURES AND ASSOCIATED IMPROVEMENTS

Overview of the Mitigation Activities

In Point 1, the sensitive equipment is located in the UJs and RRs on both sides of Point 1. The equipment located in UJ14/16 will be relocated in the adjacent ULs. A 28 m long cast iron shielding wall will be assembled in the RBs and UJs on the LHC tunnel side. The sensitive equipment located in the RRs will stay there (except smoke detectors electronics) but its shielding will be improved, replacing the current concrete walls by cast iron walls.

In Points 5 and 7, most of the equipment installed on the first floor of the services caverns (UJ56/UJ76) and a few racks located in ground floor were identified as sensitive. The majority of this equipment should be relocated inside the ULs in Point 5, and inside the adjacent TZ tunnel in Point 7.

The sensitive equipment located in the RRs will stay there (except fire detectors) but its shielding will be improved, replacing the current concrete walls by cast iron walls. Additional shielding walls will be implemented in UJ76 on the tunnel side.

In Point 8, equipment located in the first and second floors US85 was identified as sensitive. Most of this equipment will be relocated in the ground floor of US85, in the adjacent ULs and in other shielded areas located in the tunnels (UAs). An additional cast iron shielding wall with movable chicane will be installed in US85 on the ground floor to protect the near-by cooling and ventilation equipment and relocated cryogenics equipment.

Implementation of the Mitigation Activities

Several mitigation actions were performed during the 2011-2012 winter shutdown to ensure safe operation of the LHC during 2012. In Point 1, the shielding walls were installed in the RBs, UJs on the tunnel side (see Figures 2 and 3). The fire detectors were relocated in Points 1 and 7. In Points 4 and 6, sensitive cryogenics controls CPUs were relocated from UXs to ULs. In Point 5, the UPS units and Power Interlock Controllers were relocated in UL558 and USC55, respectively. In addition to parallel equipment upgrades, these activities reduced the expected number of beam dumps from 200 to 30-50 [4].

Other mitigation activities were anticipated to reduce the amount of work to be performed during the LS1; amongst them, electrical activities in all points, minor civil engineering activities and relocation of part of the cryogenics equipment in Point 5, the Warm Interlock Controllers, timing units and the Ethernet star point in Point 8.

However, the major part of the R2E mitigation activities will take place during LS1. Fifteen groups will be involved in the relocation of 90 racks, power converters, electrical equipment, safety control units and in the implementation of cast iron shielding walls. These mitigation activities will reduce the expected number of beam dumps (extrapolated from the measurements taken during the 2011 runs) from about 600 to less than 20 per year [4].

THE SCHEDULE

The R2E activities are one of the focal points of the LHC LS1, which will last around two years [5].

The preparation of the schedule involved 15 CERN groups, which met once a week for two years, to clearly define the tasks to be performed and to optimize the sequence of activities. The constraints of the LHC LS1 general schedule were always taken into account. For instance, the link between the cryogenic conditions and the R2E activities influenced drastically the length of the different activities. The R2E activities cannot start prior to the end of the warm-up, and the cool-down cannot start before the end of the R2E activities. Moreover, the logistic aspects for the R2E activities were taken into account while preparing the schedule.

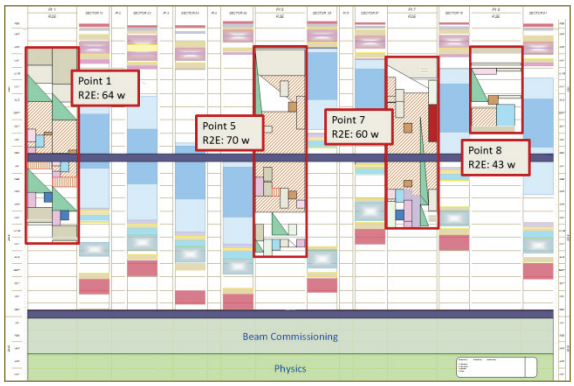

Figure 4: Long Shutdown Schedule in the LHC machine.

To fit within the LHC LS1 general schedule, the activities had to be scheduled in shifts or with extra working hours. This allowed both to reduce the duration allocated to R2E activities in each point and, to optimize the organisation of the logistics in the different worksites. For instance, at Point 7, during two months, the civil engineering activities will take place during the afternoon and night shifts, while the rest of the activities are scheduled during the morning shift. The current expected overall duration of the R2E activities extends over 64 weeks in Point 1, 70 weeks in Point 5, 60 weeks in Point 7 and 43 weeks in Point 8 (see Figure 4).

ORGANIZATION PROCESS

The first milestone was the completion of the integration studies in the four LHC points. This required the identification of all the equipment to be relocated and the definition of the new locations.

The second milestone was the completion of the R2E planning. This implied that all the activities to be identified and the detailed works sequences to be defined. At that stage, all the documentation required by LHC management team had been finalised.

The third milestone was the merging of the R2E schedule into the general LHC LS1 schedule. This implied all mutual constraints to be identified and optimized.

In view of the tight planning with respect to the non R2E activities, the main challenge will be to avoid delays during the procurement of materials and during the installation.

In addition, intermediate survey scans and cross-checks with the 3D models of the LHC integration will be carried out to avoid installation non conformities. In view of the stringent space constraints, it is clear that equipment not installed in the foreseen location will have to be removed, leading to delay of the overall project and thus possibly impacting the foreseen restart of the LHC.

The detailed installation planning with its critical path will be weekly updated to understand the impact generated on or by the non R2E activities.

SUMMARY

Ten areas located in four LHC points were identified as critical in terms of hadrons fluence/ SEE. During the LS1, in the framework of the R2E project, a large amount of electronics equipment considered as sensitive will be shielded or relocated outside these critical areas to optimize the LHC operation. The integration studies linked to the R2E mitigation project were very complex and challenging due to the large amount of equipment to be relocated and the lack of space in an existing machine. During LS1, 15 groups will work in parallel in four LHC points to carry out the R2E mitigation activities. The periods of planned intervention extend over a maximum of 70 weeks for Point 5. In view of the tight planning with respect with the non R2E activities, the main challenge will be to avoid delays that might impact the foreseen restart of the LHC.

ACKWOWLEDGEDMENT

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