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OPTIMISATION AND IMPLEMENTATION OF THE R2E SHIELDING AND RELOCATION MITIGATION MEASURES AT THE LHC DURING LS1

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Abstract

In the framework of the Radiation to Electronics (R2E) project, important mitigation actions are being implemented in the LHC during the first Long Shutdown (LS1) to reduce the Single Event Error (SEE) occurrence in standard electronics present in much of the equipment installed in the LHC underground areas. Recent simulations have motivated additional actions to be performed in Point 4, in addition to those already scheduled in Points 1, 5, 7 and 8. This paper presents the organisation process carried out during LS1 to optimise the implementation of the R2E mitigation activities. It reports the challenges linked to civil engineering and to safe room relocation in Points 5 and 7. It highlights the reactivity needed to face the new mitigation requirements to be implemented in Point 4 before the end of LS1. It presents the advancement status of the R2E mitigation activities in the different LHC points with the main concerns and impact with the overall LHC LS1 planning.

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 to optimize the availability of the Large Hadron Collider (LHC). Main shielding and relocation mitigation actions are being implemented during the first LHC Long Shutdown of 2013/2014 (LS1) in five LHC Points (Points 1, 4, 5, 7 and 8) [2] (see Figure 1). Their implementation involves fifteen groups across the different CERN Departments. They were scheduled to extend up to a maximum of 66 weeks in Point 5.

This document reports on the organisation process setup to implement the R2E mitigation activities. It further highlights the new requested mitigation activities to be carried out in Point 4. In more detail it presents the main challenges linked to civil engineering and safe room relocation in Points 5 and 7 and provides the overall advancement status of the R2E mitigation activities in the different LHC points together with the main concerns and possible impacts with the overall LHC LS1 planning.

ORGANISATION PROCESS

The R2E mitigation activities are coordinated by a team of six persons. Four point coordinators ensure the daily in situ coordination/follow-up and help in solving technical issues. One planning officer weekly performs the

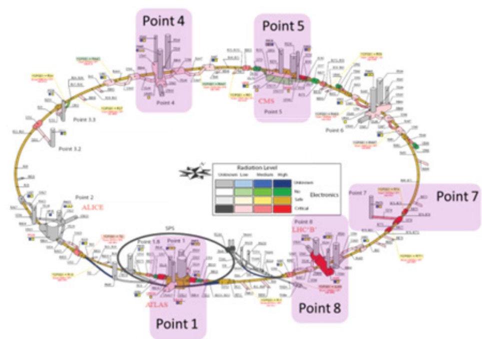

Figure 1: LHC critical areas considered by the R2E mitigation Project.

follow-up of the activities, the updates of the planning and redefines the associated critical path. She ensures the daily link with the LHC general planning/coordination team. The team leader supervises the overall coordination and works to solve the major issues linked to safety, integration, planning and technical points. A weekly coordination meeting is held in presence of the R2E coordination team, a representative of the LHC integration team and of the engineers in charge of the activities to be carried out. This meeting allows following and preparing all the current and forthcoming activities, solving technical and co-activity issues. Intermediate survey scans and cross-checks with the 3 D models of the LHC integration team are carried out to avoid the non-conformities in the installation. Each intervention is discussed in situ with the LHC safety coordinator to anticipate the safety issues. All activities are documented in a dedicated quality control report ('Engineering Change request') approved before implementation by all the stakeholders.

Four general major milestones were identified to keep the project on its baseline planning.

The first milestone was the start of the cabling campaigns. This required the completion of all the preparatory/dismantling activities including the civil engineering ones.

The second milestone was the completion of the cabling campaigns. About 210 kilometres of new cables were pulled for the R2E project with a maximum of 100 kilometres in Point 7. To fit within the time window allocated by the LHC general planning, it was mandatory to perform this work in two shifts per day or to double the number of teams working in a same point.

The third milestone was the start of the LHC cool-down sequence in May 2014. The cryogenics and part of the

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vacuum equipment had to be relocated and commissioned in Point 7 to allow starting the cool-down in sector 67.

The fourth milestone is the completion of the R2E mitigation activities before allowing the start of the cool-down in the adjacent sectors.

NEW MITIGATION REQUIREMENTS

During 2012 LHC operation, only very few failures were observed on the cryogenics equipment located in LHC Point 4. A possible future increase of the radiation levels could not be excluded during future changes in beam operation, however at first the relocation of the cryogenics equipment was put on hold, mainly due to the cable length limitation of special cables (15 metres) avoiding the equipment relocation outside the close surrounding area. In parallel, the cryogenics team (TE/CRG) successfully collaborated with firms to develop longer cables which resulted in the first production and test of longer cables (40 m) during the first semester of 2013. This provided us the opportunity to study together with the cryogenics team and other impacted equipment groups the relocation options for all critical equipment installed in Point 4. It turned out that several months were required for the relocation activities that could thus only be carried out during a Long Shutdown (LS). After a preliminary planning and the confirmation of the availability of required resources, at the end of May 2013 the LHC LS1 Committee gave its approval to perform these relocation activities during the LS1.

The work towards implementation followed three main phases.

The first phase was the identification/definition of the sensitive equipment to be relocated. In addition to one Personal Access Door (PAD) and one fire detection control unit the following cryogenics equipment was identified as equipment to be relocated: the cold compressor system, the cold box 1.8 K, the cryogenics distribution box 4.5 K, the associated SIPART valves positioners and the control system of the cryogenics RF cavities [3].

The second phase was the study of the activities to be performed with their associated technical and integration issues [4].

The third phase was the definition of the activities sequence and then the definition of the baseline planning. Three major constraints were identified to define the planning. The first constraint was the completion in Point 4 for mid-June 2014 of cryogenics activities needed for the cool-down preparation. The second constraint came from the cables delivery delay. The third constraint came from the manpower availability. These constraints defined a window of fifteen weeks for the cabling campaign. That was divided into sub-phases allowing the intervention of the cryogenics team in parallel to the cabling campaign. Only this scenario allowed fitting into the given tight time window.

The second and third phases were carried out in parallel to speed up the process and to allow starting as soon as possible the implementation. The mitigation activities started in January 2014. They were scheduled over 26 weeks with only two weeks of margin with the start of the 'flushing' activity in the adjacent sectors.

CHALLENGES

Civil Engineering Activities

Important civil engineering activities were required to allow the relocation of equipment in Points 5 and 7.

In Point 5 several ducts were required to minimise the cables length and to provide passageways for new cables and pipe work. The critical point was the relocation of the power converters and the rerouting of the four associated water cooled cables. Due to space and cables length constraints, it was not possible to reroute these cables within the existing galleries. The only alternative was to drill four ducts 14 metres long between the UJ56 level 1 and the UL557 (see Figure 2). Due to stringent integration constraints the ducts were spaced by only fifty centimetres allowing a maximal possible deviation angle of 2 degrees during the drilling process. The drilling activities included in total four 14 metres long ducts between UJ56 and UL557 and six 2 metres long ducts between the UJ56 service cavern and the LHC tunnel. They were carried out successfully during the summer 2013 within the space constraints and in only 6 weeks instead of the 9 allocated weeks.

In Point 7 the relocation of equipment in the TZ76 required to dismantle a wall and two surrounding ventilation ducts along 235 metres. The space constraints drove the choice of the dismantling procedure: wall and ducts were cut in small pieces that can be easily evacuated. Special care was taken to avoid dust propagation. This allowed parallel activities to be carried out in the TZ76. This scenario with co-activity was mandatory to be able to start the cool-down according to the LHC general planning. The dismantling activity was carried out successfully during the summer 2013 within the 9 allocated weeks.

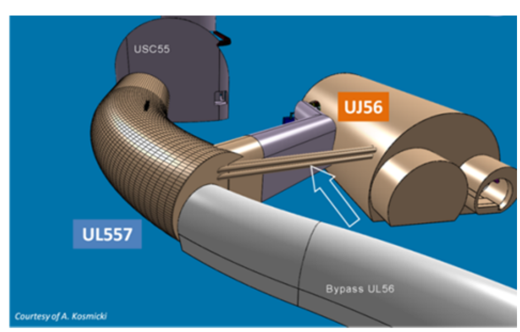

Figure 2: Four 14m long ducts for the R2E mitigation Project

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Safe Room Relocation

The electrical services dedicated to personal safety as general emergency stop, safety lighting etc., are installed underground in dedicated 'safe - rooms' ensuring the functionality of their inner equipment during two hours in case of external fire. Part of this equipment was found to be sensitive to radiation (Single Event Effects (SEE)) and in the Points 5 and 7 the 'safe - rooms' were located in areas identified as critical in terms of radiation, notably the annual high-energy hadron fluence. It was thus decided to relocate the sensitive parts respectively, in the UL557 and in the TZ76 galleries.

Due to space constraints, a classical implementation of a 'safe room' (constructed through walls, etc.) in the TZ76 gallery was not possible. The only respective way would have implied long and costly civil engineering work. The alternative solution was to relocate the equipment inside several individual and certified fire resistant enclosures with a dedicated and integrated ventilation system (see Figure 3).

In Point 5, due to safety constraints linked to the CMS experiment emergency exit path and due to integration issues, the optimal solution was to build a new 'mini safe room' in the UL557 with reduced dimensions. The associated ventilation system had to be located in the adjacent UL558 gallery. The design and implementation of this ventilation system were not trivial and required to solve several technical and safety issues (e.g., the respective ventilation control system allowing for highly reliable and fully redundant cooling during LHC operation).

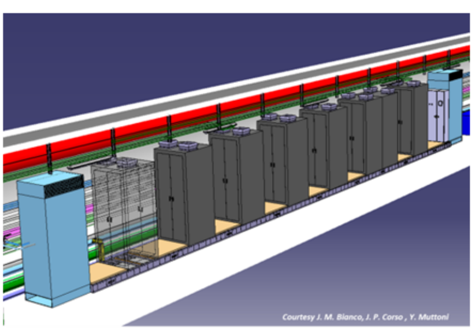

Figure 3: Relocation of Point 7 safe room equipment inside individual fire resistant enclosure.

ADVANCEMENT STATUS

Thanks to a very good preparatory work started three years before the LS1 and to the very efficient organisation process during the LS1 the R2E activities are progressing well without any impact on the other LHC activities. At the same time the needs of other LHC shutdown activities required rescheduling both in Points 7 and 8 several critical R2E activities. Thanks to the flexibility of the equipment groups and the reactivity of the R2E planning team, this resulted only in minor delays. In Point 7 it led to a delay of 2 weeks over 57 weeks mainly linked to the LHC electrical qualification tests (ELQA) and the start of the sector 67 cool-down. In Point 8, the cooling & ventilation group postponed one of the R2E activities to give priority to other more critical projects. This delayed the end of the R2E activities in Point 8 by two months but did not impact any other LHC activities. In Point 4 the R2E activities are progressing according to the schedule within the 26 allocated weeks. They are foreseen to be completed in Points 1 and 5 in advance of, respectively, three and two weeks over the 61 and 66 scheduled weeks.

The R2E activities were carried out in due time to allow in May 2014 the start of the LHC cool-down sequence. The end of the R2E activities in Points 1, 5 and 7 are on the critical path in the LHC general planning as there is only few days margin between them and the start of the cool-down in the adjacent sectors. Any delay in these R2E activities will generate a delay in the LHC re-commissioning process.

SUMMARY

The R2E mitigation activities are one of the focal points of the LHC LS1. Fifteen different equipment and service groups are working in parallel in five LHC points to carry out a long list of complex and lengthy activities that extend up to a maximum of 66 weeks in Point 5. A very efficient organisation process allowed the anticipation of the potential issues and required also a weekly update of the planning and its critical path. Thanks to a continuously fast reactivity of all equipment groups and the planning/coordination team, as well as a thorough optimisation during the preparatory phases the relocation and shielding work could be carried out in due time. Despite additional late requirements, the relocation of the cryogenics equipment in Point 4 will be completed during LS1 and only within tightly optimized 26 allocated weeks. Many challenges as underground drilling of 14 metres long ducts or 'safe room' implementation were faced to allow the R2E activities to progress well without any impact on the other LHC activities. In view of the tight margins between the end of the R2E activities in Points 1, 5 and 7 and the start of the cool-down in the adjacent sectors, the main challenge is to avoid any delays that might impact the foreseen restart of the LHC.

ACKNOWLEDGMENT

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