

# Radiation Damage to Electronics at the LHC –A First Analysis

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A large spectrum of equipment and electronics is exposed to radiation around the various underground areas of the CERN 'Large Hadron Collider'(LHC). In the current configuration, LHC alcoves equipped with commercial or not specifically designed electronics are mostly affected by the risk of 'Single Event Effects'(SEE), whereas electronics installed in the LHC tunnel will in the long-term also suffer from cumulative damage due to accumulated dose or displacement damage. While for the tunnel equipment radiation tests were performed and radiation tolerant design criteria were already taken into account during the LHC construction phase, most of the equipment placed in adjacent and partly shielded areas was not conceived nor tested for their current radiation environment. Given the large amount of electronics being installed in these areas, the risk of radiation-induced damage or malfunctioning has to be minimized as much as possible in order to allow for both safe and efficient LHC operation.

To carefully analyze the situation, in 2008 a 'Radiation Damage to Electronics'(R2E) study group was created, complemented by the R2E mitigation project in 2010 in order to mitigate all risks related to radiation induced failures and possibly limiting future LHC performance. The preparation, study and optimization of short/mid- and long-term mitigation actions require a careful analysis of the:

1. radiation levels and particle energy spectra, as well as their evolution with LHC operation based on both detailed Monte-Carlo simulations and dedicated measurements.
2. inventory of installed electronics (designed, COTS) and failure consequences
3. expected radiation sensitivity, failure cross-section and respective failure rates
4. early monitoring and optimization possibilities
5. evaluation of mitigation options, consisting of: • early actions • shielding (simple + complex) • relocation • radiation tolerant by design • civil engineering options • other options
6. analysis of early LHC operation
7. evaluation and comparison of required and available resources

This paper summarizes the chosen approach for the LHC, presents the encountered difficulties and summarizes the obtained experience concerning the main requirements: (a) the radiation field & related calculations, monitoring and benchmarking; (b) the particularity of commercial equipment/systems and their use for the accelerator; and (c) the required radiation tests, as well as respective test areas and facilities. A special focus will be put on the respective lessons learned, as well as on the observations made during early LHC operation.

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