DEFINITION OF REGULATORY FRAMEWORK, DESIGN LIMITS AND DOSE OBJECTIVES

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Abstract:
This document summarizes the Radiation Protection regulatory framework as well as the related design constraints and dose objectives to be followed by the HiLumi LHC upgrade.
The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404. HiLumi LHC began in November 2011 and will run for 4 years.

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Executive summary

This report summarizes the Radiation Protection regulatory framework applicable to the HiLumi LHC project including related constraints on the design as well as dose objectives to consider during upgrade and operation of the LHC.

1. INTRODUCTION

Design, operation and decommissioning of the LHC must follow CERN’s Radiation Protection (RP) rules and regulations. It includes upgrades such as studied within the HiLumi LHC Project where these rules may have substantial impact on design choices. Thus, the applicable regulations have to be known to all concerned parties from the beginning of the project and are summarized in the following report.
2. **SAFETY CODE F**

The CERN Radiation Protection legislation is detailed in the Safety Code F [1]. It stipulates that all activities involving ionizing radiation have to be *justified, optimized and limited* and defines respective limits:

- Any practice leading to an effective dose exceeding 100µSv per year for individuals working on the CERN site or 10µSv for members of the general public must be justified.
- It is obligatory to optimize radiation protection according to the As Low As Reasonably Achievable (ALARA) principle. Optimization can be considered as respected if the annual dose of a practice is below 100µSv for persons exposed because of their professional activity and 10µSv for members of the general public.
- The effective dose in any consecutive 12-months period is limited to 20mSv for Category A Radiation Workers, to 6mSv for Category B Radiation Workers and to 1mSv for not occupationally exposed personnel. The effective annual dose to any person outside of the CERN site boundaries must not exceed 300µSv.

3. **DESIGN CONSTRAINTS**

Design constraints for new or upgraded facilities ensure that the exposure of persons working on the CERN sites, the public and the environment will remain below the dose limits under normal as well as abnormal conditions of operation and that the optimization principle is implemented. In particular, the following design constraints apply:

- The design of components and equipment must be optimized such that installation, maintenance, repair and dismantling work does not lead to an effective dose exceeding 2mSv per person and per intervention [2]. The design is to be revised if the dose estimate exceeds this value for cooling times compatible with operational scenarios.
- The annual effective dose to any member of a reference group outside of the CERN boundaries must not exceed 10µSv. The estimate must include all exposure pathways and all contributing facilities.
- The selection of construction material must consider activation properties to optimize dose to personnel and to minimize the production of radioactive waste. In order to guide the user a web-based code (ActiWiz) is available for CERN accelerators [3].

4. **ALARA AND DOSE OBJECTIVES**

Detailed CERN-specific ALARA rules exist that apply to any work implying risks due to ionizing radiation [4, 5]. Procedures define the optimization process to follow based on a risk-dependent classification scheme. The estimated individual and collective dose equivalent determine the so-called ‘ALARA category’ (see Figure 1); the dose equivalent rate at the worksite as well as contamination risks might be used as additional criteria in the definition of the category (see Figure 2). Specific optimization procedures are associated with each ALARA category. For example, Level-II interventions require a detailed work-and-dose planning, a documented optimization process and a formal approval. In addition, Level-III interventions have to be reviewed by an ALARA committee.
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Table 1 Group 1 criteria that determine the optimization process [5].

<table>
<thead>
<tr>
<th>Individual dose equivalent</th>
<th>Level I</th>
<th>Level II</th>
<th>Level III</th>
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<tbody>
<tr>
<td>Level</td>
<td>100 µSv</td>
<td>1 mSv</td>
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<tr>
<td>Collective dose equivalent</td>
<td>Level I</td>
<td>Level II</td>
<td>Level III</td>
</tr>
<tr>
<td>Level</td>
<td>500 µSv</td>
<td>5 mSv</td>
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Table 2 Group 2 criteria that provide further guidance on the optimization process [5].

<table>
<thead>
<tr>
<th>Ambient dose equivalent rate</th>
<th>Level I</th>
<th>Level II</th>
<th>Level III</th>
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<tbody>
<tr>
<td>Level</td>
<td>50 µSv/hr</td>
<td>2 mSv/hr</td>
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<tr>
<td>Airborne activity in CA</td>
<td>Level I</td>
<td>Level II</td>
<td>Level III</td>
</tr>
<tr>
<td>Level</td>
<td>5 CA</td>
<td>200 CA</td>
<td></td>
</tr>
<tr>
<td>Surface contamination in CS</td>
<td>Level I</td>
<td>Level II</td>
<td>Level III</td>
</tr>
<tr>
<td>Level</td>
<td>10 CS</td>
<td>100 CS</td>
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</table>

In order to evaluate their later impact on the accelerator operation it is useful to consider these ALARA rules already during the design phase for interventions that may lead to considerable individual or collective doses.

Furthermore, the following personal dose objectives apply at CERN:

- Periods with accelerator operation for physics: 2mSv
- Long Shutdowns: 3mSv

The dose is to be counted for any consecutive 12-months period. As it is not a limit it can be exceeded. However, the latter requires the approval by the Radiation Protection (RP) group leader as well as the group leader responsible for the respective person.

5. CONCLUSIONS AND FUTURE PLANS

The upgrade to the LHC studied within the HiLumi LHC Project must be optimized according to CERN’s Radiation Protection rules and regulations. Thus, calculations of radiological quantities must accompany and validate every stage of the design. This is of particular importance for areas where elevated beam losses are expected.

All components in these areas must be optimized in order to minimize dose to personnel during interventions as well as the amount of radioactive waste created during final dismantling. As a guideline, the predicted individual dose for an intervention on a component must not exceed 2mSv. Any construction material should be validated with the ActiWiz code.

Furthermore, the radiological environmental impact of the LHC upgrade has to be studied. The annual effective dose to any individual residing outside of CERN’s site boundaries and must not exceed 10µSv.

The radiological constraints summarized in this report will be verified at each stage of the design before a final decision is taken.
6. REFERENCES


ANNEX: GLOSSARY

<table>
<thead>
<tr>
<th>Acronym</th>
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<tr>
<td>ALARA</td>
<td>As Low As Reasonably Achievable</td>
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<td>RP</td>
<td>Radiation Protection</td>
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