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Challenges and strategies in planning Long Shutdown 3 for the HL-LHC Upgrades of the LHC experiments at CERN: a comprehensive overview

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The CERN Large Hadron Collider (LHC) will undergo upgrades during the period of 2026-2028, known as Long Shutdown 3 (LS3) to become the High-Luminosity LHC (HL-LHC). These will allow for an increase in instantaneous luminosity by a factor from five to seven beyond the original LHC design value, thus allowing to increase almost tenfold the integrated luminosity by the early 2040s.

The four large LHC experiments will also be upgraded during LS3 accordingly to be able to cope with the increased collision rates and to withstand the harsher irradiation conditions posed by HL-LHC operation. These upgrades will entail the dismantling and decommissioning of large detector components, the refurbishment of existing ones, and the installation of new detectors and electronics. The execution of all these activities will require multiple and prolonged interventions in high-residual radiation environments and the handling of activated detector components of different nature. This poses complex radiological challenges that the CERN Radiation Protection group must address in a timely manner.

From an operational radiation protection point of view, the preparation of LS3 activities in the LHC experiments first requires a series of predictive studies aiming to estimate the residual radiation environment during interventions. This is necessary to preliminary estimate and then to properly reduce/optimize the dose to personnel for each intervention.

Furthermore, it is foreseen that a substantial amount of material will be removed from radiation areas during the shutdown. Detailed radiological characterization of evacuated equipment from the experimental caverns is essential for determining appropriate disposal paths and minimizing the duration of the dismantling activities as well as the waste disposal costs. It is also fundamental for ensuring and establishing the appropriate conditions for the transport off-site of activated components for their disposal or refurbishment.

This paper aims to provide a comprehensive overview of the challenges encountered in planning a long shutdown for the LHC experiments and the strategies employed to address these challenges, relying on advanced FLUKA Monte Carlo simulations. This will be illustrated by a series of case studies covering relevant applications at the LHC experiments.

Scientific Topic 1

Scientific Topic 2

Scientific Topic 3

Scientific Topic 4

Scientific Topic 5

Induced radioactivity and decommissioning

Scientific Topic 6

Scientific Topic 7

Scientific Topic 8

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