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Rad-Hard Fibre Optics Cabling Design for LHC Detectors Upgrades

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Upgrades over the next decades will enable LHC to operate at a higher luminosity (HL-LHC). Accordingly, the optical links designed to transmit collision data should be hardened against increased radiation levels, allowing for a reliable communication. This paper studies fibre cabling design of a generic link between the in-detector optical front-end and the counting room. The proposed solution concatenates radiation-resistant and conventional fibres using multi-fibre interconnections. The radiation penalty calculation considers a temperature of −30℃ inside the detector innermost part. The maximum link loss during HL-LHC lifetime is estimated to be 3.16dB, complying with predefined margins of Versatile Link system.

Summary

High speed optical links are critical building blocks of LHC detectors as they transmit particle collision data to the counting room immediately after detection. In this respect, the CERN Versatile Link (VL) project has been active since 2008 to provide point-to-point bi-directional links for upgrades of LHC experiments. The high radiation dose in proximity to these links necessitates special design and/or selection criteria for active and passive components to ensure their performance during the accelerator runtime. With the foreseen upgrades in HL-LHC the Versatile Link Plus (VL+) project was launched to target higher speed links and to provide the stringent design parameters for operating in a higher radiation dose. This paper studies the design of VL+ optical passive components including optical fibres and connectors to achieve the lowest possible link loss. The analysis considers a variable Radiation Induced Attenuation (RIA) model adapted to the dose map and variations of temperature along the designed fibre path.

A critical design criterion for the link loss is minimizing the aggregated RIA which is a function of accumulated dose, irradiation dose-rate, fibre temperature and transmitted power over the link path. The path studied in this work is designed to route the optical fibre inside the detector front-end to the intermediate patch panels through an existing cabling track. The path continues afterwards to the counting room passing through the standard cable trays. Once the link path is determined, the radiation penalty (P) is examined for three candidate multi-mode fibres by integrating the incremental RIA element $dP=f(\Gamma(\vec{r}),T(\vec{r}))d\vec{r}$ over the fibre path ($\vec{r}$). The f function (in dB/Km) approximates piecewise RIA given the accumulated dose (Γ) and fibre temperature (T) as the arguments. We evaluated this function experimentally for tested fibres at accumulated dose $\Gamma \leq 1$ MGy and for the temperatures set T={-30,25}℃ corresponding to the inner and outer detector ambient temperatures.

The RIA was evaluated for candidate fibres using the temperature and accumulated dose maps simulated for HL-LHC lifetime. Results show that a specific Radiation-Resistant (RR) fibre outperformed other tested fibres by more than 4.5dB in radiation penalty. Yet, inspecting the RIA distribution over the link path identifies high and low RIA zones respectively inside and outside the detector area for all tested fibres. Therefore as a cost efficient solution, the final design concatenates a RR fibre at the detector side to a conventional fibre at the counting room side with interconnection close to the detector outer volume. Given the new design the maximum RIA for a generic LHC cable path was calculated to be 1.4dB during the HL-LHC lifetime. Assuming a maximum 0.36dB propagation loss and an insertion loss of 1.4dB including four optical interconnections by 24-fibre MT and MPO ferrules, the resulting end-to-end link loss is strictly lower than 3.16dB which is below

the predefined link margin at 3.9dB. It is worth noting that optical connectors using multi-fibre MT and MPO ferrules are shown to have a negligible radiation penalty at the expected radiation levels.

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