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Development and prototyping of the Versatile Link+ fibre cabling plants for the HL-LHC upgrades of the ATLAS and CMS experiments at CERN

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With the foreseen upgrades in HL-LHC, the Versatile Link Plus project was launched to streamline the upgrade of the current optical fibre links between the experiments and the counting room in order to reach higher data rates.

New fiber cabling plants have been designed in this framework for tight integration in experiment front ends and operation at higher radiation doses. These make use of novel multi-fibre assemblies that are tailored to the specific experiment requirements and conditions.

This paper describes the design decisions that have led to the final production-ready prototypes and the related implementation of a large-scale procurement framework.

Summary (500 words)

During the Phase 2 upgrade of the ATLAS and CMS experiments at CERN's Large hadron Collider several detectors will be replaced or enhanced to improve their physics performance.

In this respect the CERN Versatile Link+ (VL+) project was launched to develop compact, low-mass and radiation resistant optical fibre links connecting the system front-ends to the counting room. These optical links aggregate multi-fibre assemblies with different designs, tailor-made to each specific system requirement.

Above all, the selection of radiation resistant fibres or conventional fibres is crucial in each of the assembly designs. The optimal fibre type is chosen based on the temperature and accumulated dose expected in the sub-detector, with the objective of minimizing optical attenuation in the link.

Different types of fibre cables and multi-fibre connectors are also proposed for the assembly design. Innovative lightweight solutions, employing solely unbuffered fibres terminated with multi fibre MT ferrules, are adopted for the assemblies close to the sensors where the available routing space is limited and a finely tuned signal distribution is key to reduce the number of dark fibres.
A more rugged construction is instead preferred outside the sub-detector volume where more robust designs are required to withstand the external mechanical stress.

Due to the complexity of the assemblies and to the specificity of their sub-components, the assembly manufacturing process has been organized in three sequential phases: the first phase is to manufacture the unbuffered optical fibres; the second is to bundle the unbuffered fibres in fibre cables; and the third is to manufacture the assembly by terminating the fibre with multi-fibre connectors.
At the end of each production phase quality control tests, such as radiation testing on fibres or insertion loss measurements on connectors, are undertaken to ensure conformity with the project standards. A traceability protocol has also been developed and implemented throughout the manufacturing phases in order to trace and document the origin and performance of each part making up the assembly.

In the framework of the tender for the supply of the assemblies, several specialized suppliers world-wide have been requested to manufacture and deliver prototypes. These have been extensively tested at CERN to explore commercial solutions available on the market and evaluate the suppliers'capabilities. These prototypes have also given the ATLAS and CMS collaborations an opportunity to test the assemblies in their own system,

demonstrating the validity of the proposed solutions to fulfil their requirements. Deviations and adaptations have been identified and taken into account in the specifications for the series production to be launched in September 2022.

This paper describes the development of the fibre cable plants, from the design to the prototyping phase, highlighting the innovative solutions implemented with respect to the legacy systems. It presents the process implemented to achieve large-scale assembly production while respecting the diversity of fibre plants and ensuring the quality of the final components. Finally, it shows test results from the first set of prototypes and provides a thorough analysis of the supplier's capabilities available on the global fibre market.

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