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

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Introduction

With the foreseen implementation of High Luminosity LHC (HL-LHC), the Versatile Link+ project was launched to streamline the upgrade of the current optical fibre links between the ATLAS and CMS experiments and their counting rooms. New fibre cabling plants have been designed in this framework for tight integration with the experiment front ends and operation at higher radiation doses.

Those plants make use of novel multi-fibre assemblies that are tailored to the specific detector requirements and conditions. This poster describes the design decisions that have led to the final production-ready prototypes and the related implementation of a large-scale procurement framework.

Challenges

Space constraints

The increased detector granularity, combined with the need to reduce passive material in the fiducial volumes, required the development of novel low-mass and high-density cable plants that could fit into the limited available space, while retaining the imposed optical and mechanical performance.

Customized design

The large number of different detectors, each with its own cable plant and requirements, necessitates the development of customized multi-fibre assemblies, making design, production, logistics and stock management extremely challenging and specific.

Harsh environment

The design and selection of the components are crucial due to the harsh environment in which the multi-fibre assemblies will operate during their expected lifetime, i.e. radiation doses up to 1MGy, temperatures ranging from −35°C to 60°C, magnetic fields up to 4T.

This is especially true for the optical fibres, which are meant to endure high radiation dose without jeopardizing the links' optical budget.

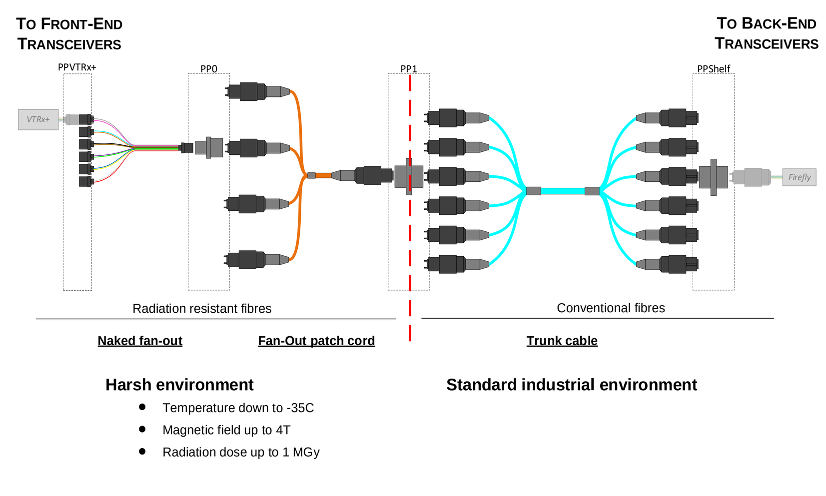

Figure 1: Example of cable plant

Strategy

Radiation resistant or conventional fibres?

The choice of OM2 radiation resistant fibre or OM3 conventional fibres is crucial for each of the multi-fibre assembly designs.

While radiation resistant fibres perform better in high radiation environments, the conventional fibres are preferable in very low radiation environments due to their intrinsic lower attenuation and production costs.

Therefore, the optimal fibre type was chosen on a case-by-case basis, depending on the temperature and radiation dose expected for each fibre assembly type of each detector, aiming at optimizing the link optical attenuation as well as the final costs.

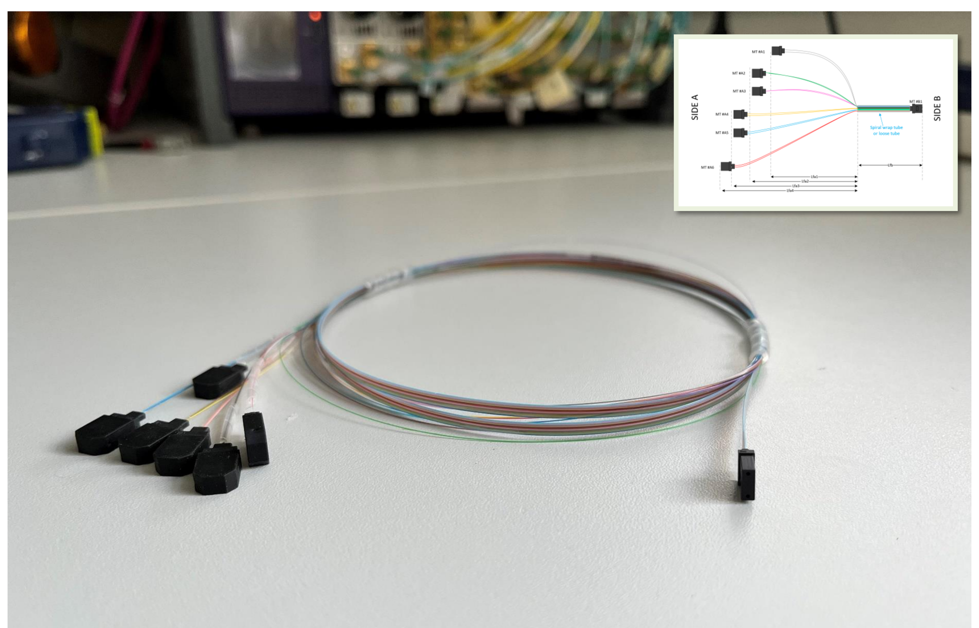

Figure 2: Example of assembly manufactured with unbuffered fibres and MT ferrules

Novel multi-fibre assembly designs

Innovative lightweight solutions, highly customizable, employing solely unbuffered fibres terminated with multi-fibre MT ferrules, were adopted for the multi-fibre assemblies closest to the sub-detector, where the available routing space is limited and a finely tuned signal distribution is key to reducing the number of dark fibres.

A more rugged construction with MTP connectors and multi-fibre jacked cables was instead preferred outside the sub-detector volume, where more robust designs are required to withstand the external mechanical stress.

Production

Manufacturing process

Due to the complexity of the assemblies and to the specificity of their sub-components, the assembly manufacturing process was organized in three sequential phases: manufacture the unbuffered optical fibres; bundle the unbuffered fibres into fibre cables; and manufacture the final assembly by fitting the fibres/cables with multi-fibre connectors.

Quality control tests were planned at the end of each production phase, such as radiation testing on fibres and insertion loss measurements on connectors, to ensure conformity with the project specifications.

Figure 3 shows the results of radiation tests performed to validate the produced 1300 km of radiation resistant fibres. Three fibre preforms (around 25 km) were rejected due to too high radiation induced attenuation (RIA).

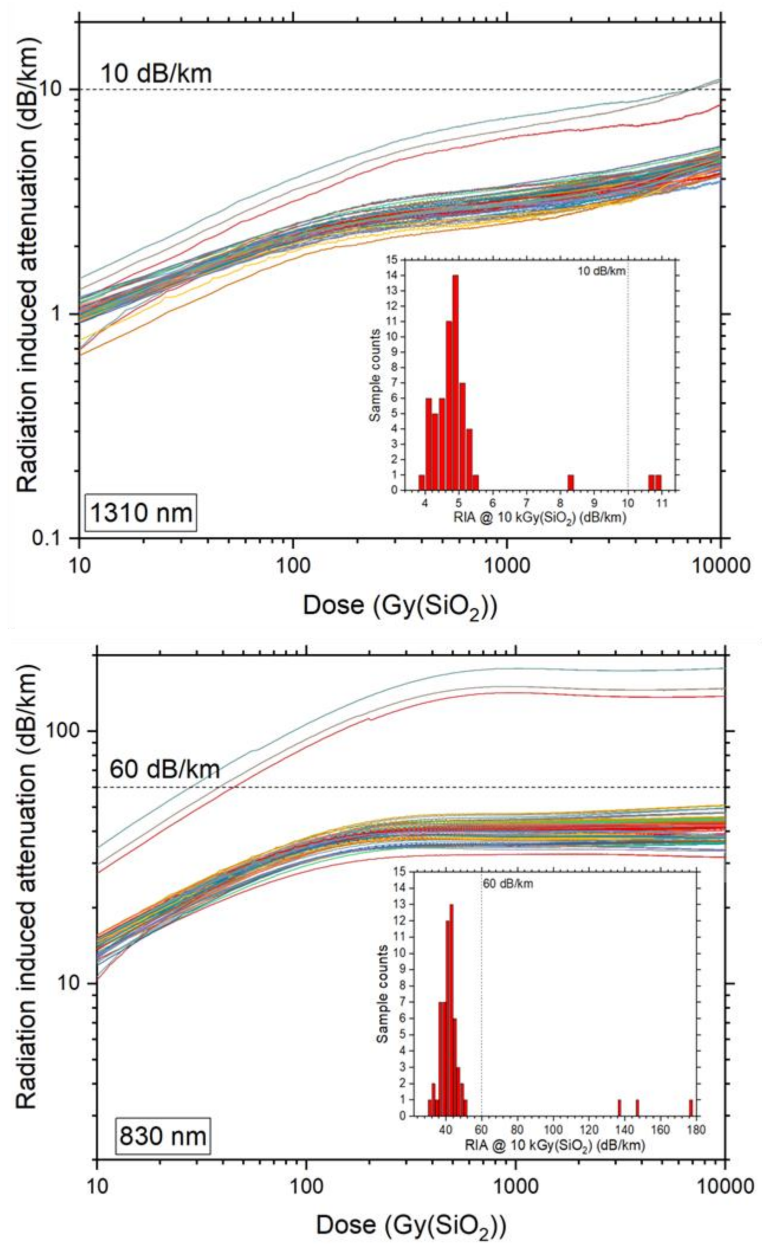

Figure 3: Results of radiation tests on radiation resistant fibres. The three lines above the threshold represent the 3 uncompliant spools

Prototyping

Prior to the series production, several qualified suppliers world-wide were requested to manufacture and deliver prototypes. Those were extensively tested at CERN to explore commercial solutions available on the market and evaluate the suppliers' capabilities to set up a mass production, while respecting the optical requirements set by the Versatile Link+ project.

Figure 4 shows the results of insertion and return loss measurements performed on 1400 connectors from 11 suppliers. The average results were largely within the imposed threshold (in red), with a rejection rate as little as 0.4%.

The prototypes gave the ATLAS and CMS collaborations also an opportunity to test the assemblies in their own systems, demonstrating the validity of the proposed solutions to fulfil their requirements.

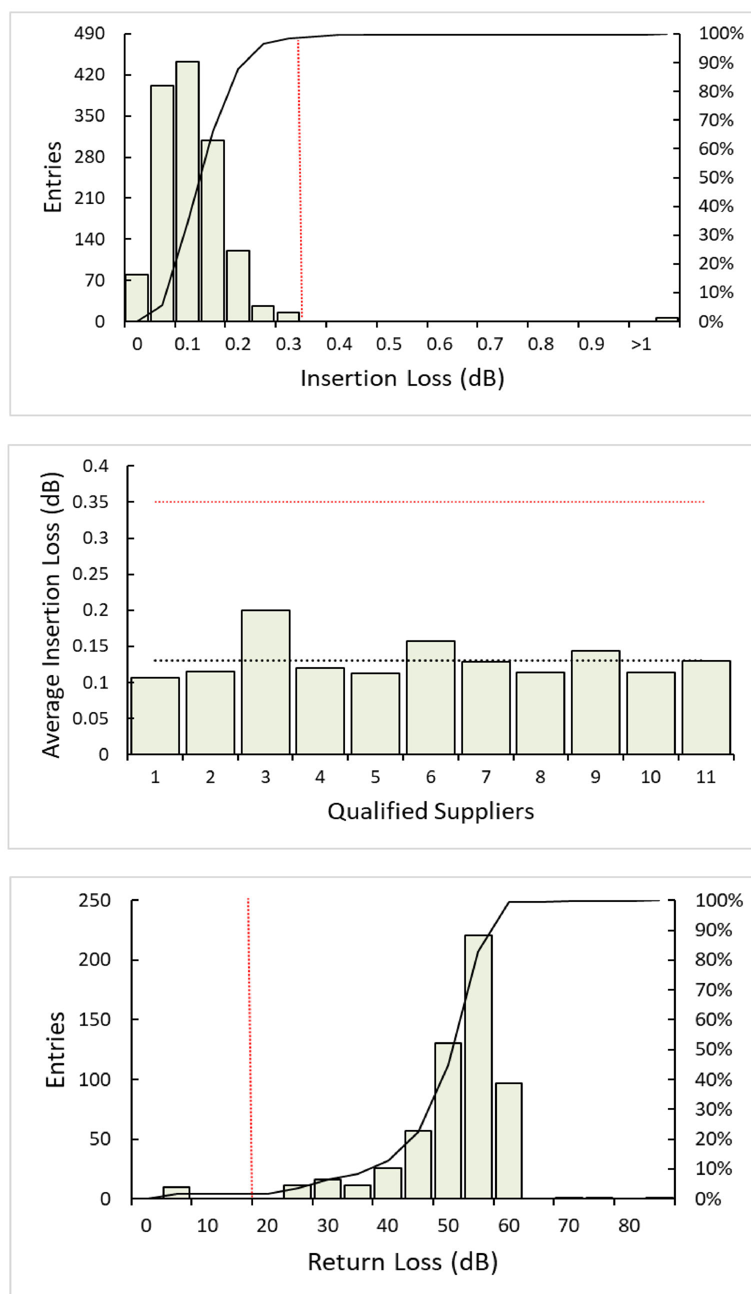

Figure 4: Insertion and return loss test on the prototypes.

Conclusions

Innovative customized, highly modular, multi-fibre assemblies, employing different designs and fibre components, were developed to fulfil the needs of the CMS and ATLAS experiments detectors. Tests on assembly prototypes were implemented to validate the proposed solutions and provided a complete overview on the expected capabilities of the surveyed suppliers from the global optical fibre market. A mass production is being launched aiming at manufacturing around ten thousand multi-fibre assemblies, as of January 2023, together with a thorough quality assurance plan ensuring a seamless production flow to build the different fibre plants and ensure the quality of the final components.

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TWEPP 2022, Topical Workshop on Electronics for Particle Physics
Bergen, Norway, September 19-23, 2022