Commissioning of the Test System for the Phase-2 Upgrade of the CMS Outer Tracker

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Abstract

The Phase-2 Upgrade of the CMS Outer Tracker requires the production of 8 000 *Strip-Strip and* 5 880 *Pixel-Strip modules, altogether incorporating* 47 520 *hybrid circuits of* 15 *variants. Module design makes the potential repairs unfeasible; therefore, performing production-scale testing of the hybrids is essential. Accordingly, a scalable, crate-based test system was designed and manufactured, allowing for parallel, high-throughput testing. To reproduce the operating conditions, the system was integrated within a climatic chamber, including the development of a remote control interface and the calibration of thermal cycles. The results and lessons learned from the system integration and commissioning will be presented.*

Summary

The Compact Muon Solenoid (CMS) Outer Tracker Phase-2 Upgrade for the High Luminosity Large Hadron Collider (HL-LHC) is composed of two main types of modules: the strip-strip (2S) and the pixel-strip (PS). The 2S modules contain two parallel strip sensors of $(10{\times}10)$ cm^2, two front-end hybrids and a service hybrid. The PS modules consist of a strip sensor and a macro-pixelated strip sensor of $(5{\times}10)$ cm^2, two front-end hybrids, power hybrid, and a data readout hybrid. Ten different front-end hybrid variants and five additional service, power, and readout hybrid variants have been designed. Currently 9 of those variants are in kick-off production at the manufacturer's premises, which will be followed up with pre-series and full production.

The modules constructed for the upgrade are permanently joining the components with gluing. Failure in any of the components would result in a discarded high value module. In order to reduce the losses at this level, it is fundamental to test the hybrids extensively. Given the large quantity of hybrids scheduled to be manufactured, a high-throughput testing system was required. Therefore, the test infrastructure was designed based on a 3U 19-inch sub-rack with custom-developed multiplexer backplanes, enabling the multiplexed testing of twelve hybrid circuits in one crate. The backplanes connect to FC7 data acquisition boards, which controls the selection of plug-in cards and processes the data.

Overall, six types of test cards were designed and produced. With the usage of interchangeable sockets and interconnection circuits, each card can accommodate all the hybrid variants from the same family. The total system quantity, accounting for spares, consists of 645 test cards. During the commissioning process, each card had to be inspected, assembled with mechanical sockets, and then fused with a serial number. After that, each card was fully tested and approved using reference hybrids. During the process, multiple problems arose and were solved before the final integration within the test system.

In order to integrate the test system within the climatic chamber, a custom-made frame was procured and mounted inside the chamber. To remove the necessity for supervision of a trained operator over the functioning chamber, a remote control interface was developed, allowing for partial control, monitoring, and error handling from within the test procedure.

Additionally, to protect the electronics from humidity condensation, external humidity and temperature probes were added. The supplementary sensors were used to obtain dewpoint characteristics of the test system during thermal cycling, which subsequently allowed for the calibration of temperature ramps and the utilization of additional protections.

In this contribution, the quantitative results of test system commissioning will be analyzed, including overall yield, test results, and common problems. Additionally, the process of safe-proofing and calibrating the climatic chamber will be presented, along with the capabilities of developed remote control interface. The conclusions presented could be exceptionally useful for future production-scale, reliability or lifetime-testing campaigns incorporating thermal cycling.