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CMS HCAL VTRx-induced communication loss and mitigation

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The Compact Muon Solenoid (CMS) Phase 1 Hadron Calorimeter Upgrade (HCAL) saw the first large-scale use of VTRx modules, optical transceivers designed to be radiation and magnetic field tolerant. During Run II of the Large Hadron Collider, the CMS HCAL experienced a short period of communication loss that revealed a manufacturing weakness in the VTRx affecting nearly half of the communication links. The CMS HCAL Team provided the first observation of this phenomenon, revealed its temperature dependence, and pioneered the mitigation tactic adopted by other LHC experiments. We will present these aspects of the larger VTRx investigation.

Summary (500 words)

During the 2018 data-taking period of Run 2 of the Large Hadron Collider (LHC), the Compact Muon Solenoid Experiment (CMS) experienced communication loss with the newly upgraded Hadron Calorimeter (HCAL) front end electronics. Installed in 2017, the new CMS HCAL Endcap front end incorporated the first large-scale use of the VTRx optical transceivers. These new radiation and magnetic field tolerant transceivers proved to be the origin of the communication loss, with symptomatic devices present in 45% of all HCAL Endcap control links. Anomalous features occur within the monitored Received Signal Strength Indicator (RSSI) current. Under normal operating circumstances, the RSSI should maintain a steady value, proportional to the level of received light. Before communication loss, slow losses in RSSI, termed "drift", were observed. Upon inspection, nearly half of all HCAL Endcap VTRxs exhibited some amount of drift at system power-on. The RSSI circuit itself is not involved in the communication pathway, and the transmitted backend power and optical fiber quality did not appear affected. Therefore, investigation was needed to understand the relationship between communication loss and RSSI. To decouple the VTRx from the rest of the CMS HCAL communication and control module, a custom Raspberry Pi-controlled multi-ADC system was developed. This autonomous setup, coupled with a custom VTRx mounting board, allowed for user friendly monitoring, and quickly tailorable test features. With the development of this simple to use system, multiple VTRx quantities could be read and studied, with minimal physical intervention to the VTRx. This system offered finely tuned temperature control and monitoring. With this, temperature was isolated as the cause of the VTRx communication loss. With the conversion of the test system, normally meant for in situ detector replication, to single-use application, we were able link the drift phenomenon to temperature gradients experienced between the VTRx module and the optical fiber plugged into the VTRx. The modular test setup allowed for the photographic capture of condensation on the fiber face, due to outgassing within the VTRx. While long term solutions are in development, for detector upgrades necessary for Run 3 operation, mitigation techniques are required. The CMS HCAL solution applies advancements used in the HCAL Barrel upgrade to the HCAL Endcap. The HCAL Barrel control electronics uses the VTRx as well, but drift is absent in the barrel. A rework of the HCAL Endcap Next Generation Clock and Control modules completed in winter 2020-2021 remedied the HCAL Endcap drift with the addition of copper heat sinks to the VTRx. The use of heat sinks to disperse heat generated by the VTRx serve as the first example of successful outgassing mitigation in situ.

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