Contribution ID: **101** Type: **Poster**

System Level and Production Tests of the CMS HCAL QIE10

Wednesday 25 September 2013 17:37 (1 minute)

The CMS Hadron Calorimeter (HCAL) is scheduled to be upgraded to increase longitudinal depth segmentation in the Barrel and Endcap regions and to improve anomalous signal rejection efficiency in the Forward Region. In order to achieve these goals, the phototransducers and the front-end and back-end electronics of the HCAL will be upgraded in stages over the next several years. New PMTs in the Forward Detector and silicon photomultipliers (SiPMs) in the Barrel and Endcap detectors will be read out with charge integrator and encoder (QIE) deadtimeless Flash ADCs operating at 40 MHz. During the HCAL Upgrade, the current QIE Version 8 (QIE8) chip will be replaced by the next generation QIE10 chip, which features a ten times greater dynamic range and the inclusion of TDC data with 0.5 ns resolution. The HCAL back-end electronics will be upgraded from a VME readout system to a micro-TCA achitecture. We present the results of system integration tests of the QIE10 chip's operation within the full front-end to back-end electronics chain. We also present the current progress of production chip testing of the QIE10, which involves the robotic ASIC tester at Fermilab.

Summary

The timetable of operation at the Large Hadron Collider (LHC) includes a number of upgrades which will increase its center of mass energy and integrated luminosity. These changes will also result in a higher fake rate in the Compact Muon Solenoid (CMS) tracking and a lower energy resolution due to signal overlap in the calorimeters. The purpose of the LHC Phase 1 Upgrade is to mitigate these effects by replacing the pixel detector of the CMS Tracker, improving the Level 1 Trigger, and upgrading the detectors and electronics of the CMS Hadron Calorimeter (HCAL).

During the HCAL Upgrade, the current hybrid photodiodes (HPDs) in the Barrel and Endcap calorimeters will be replaced with silicon photomultipliers (SiPMs) and the PMTs in the Forward Calorimeter will be replaced with multi-channel models. The performance of the SiPM detectors significantly exceeds the performance of the HPDs, which allows for a finer depth segmentation within the upgraded detector. To accommodate these improved detection capabilities and the corresponding increase in signal channels, both the front-end and back-end electronics also need to be upgraded.

In the HCAL, the signal from the phototransducers is integrated over 25 ns periods and digitized by a charge integrator and encoder (QIE) ADC. As part of the HCAL Upgrade, the current Version 8 (QIE8) chip will be replaced by the Version 10 (QIE10). The QIE10 is specifically designed to accommodate the increase in detector sensitivity by featuring ten times the dynamic range as the QIE8, from 3 fC to 330 pC. The QIE10 also provides previously unavailable TDC information which supplies signal arrival time information to the experiment with half-nanosecond resolution. This information is crucial for background reduction, distinguishing products from different bunch crossings in situations with high pileup, and identifying anomalous noise in the phototransducers.

Before the QIE10 can be implemented in the detector, the prototype chip's functionality needs to be demonstrated through system integration tests and all packaged chips need to be verified by production testing.

System integration testing focuses on the QIE10 chip's performance within the whole signal flow, from the phototransducer through the front-end and back-end electronics. A PMT is connected to a prototype QIE10 front-end electronics board which, in turn, communicates with a prototype HCAL micro-TCA back-end board. We flash the PMT with an LED to simulate in situ conditions and examine capacitor ID consistency, charge

bin widths, range and subrange overlap, charge calibration accuracy, timing measurements, and component cross-talk. These tests not only show that the QIE10 is operating correctly, but allow us to identify subtle hardware and software issues that are only revealed after the entire readout chain.

The purpose of production testing is to batch test all of the packaged QIE10 chips in order to determine which are of sufficient quality to send to the CMS detector. Every chip used in the CMS detector needs to pass a series of benchmarks, which we measure using Fermilab's robotic ASIC tester.

We present the results of these tests and argue that the QIE10 is ready for implementation in the HCAL Upgrade.

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Session Classification: Poster