Operational Experience with Radioactive Source Calibration of the CMS Hadron Endcap Calorimeter Wedges with Phase I Upgrade Electronics

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Abstract

The Phase I Upgrade of the CMS Hadron Endcap Calorimeters consist of new photodetectors (Silicon Photomultipliers in place of Hybrid Photo-Diodes) and front-end electronics (QIE11). The upgrade will allow the elimination of the high amplitude noise and drifting response of the Hybrid Photo-Diodes, at the same time enabling the mitigation of the radiation damage of the scintillators and the wavelength shifting fibers with a larger spectral acceptance of the Silicon Photomultipliers. The upgrade will also allow to increase the longitudinal segmentation of the readout to be beneficial for pile-up mitigation and recalibration due to depth-dependent radiation damage. As a realistic operational exercise, the responses of the Hadron Endcap Calorimeter wedges are being calibrated with a $^{60}$Co radioactive source both with current and upgrade electronics. The exercise will provide a manifestation of the benefits of the upgrade. Here we describe the instrumentation details and the operational experiences related to the sourcing exercise.

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Operational Experience with Radioactive Source Calibration of the CMS Hadron Endcap Calorimeter Wedges with Phase I Upgrade Electronics

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Abstract. The CMS Hadron Endcap Calorimeters will go through the Phase I upgrade which consists of new photodetectors (Silicon Photomultipliers in place of Hybrid Photo-Diodes) and front-end electronics. The upgrade will enable the mitigation of the radiation damage of the scintillators and the wavelength shifting fibers with the larger spectral acceptance of the Silicon Photomultipliers. As a realistic operational test, the responses of the Hadron Endcap Calorimeter wedges were calibrated with a 60Co radioactive source with upgrade electronics. The test successfully establishes the procedure for future source calibrations of the Hadron Endcap Calorimeters. Here we describe the instrumentation details and the operational experiences related to the sourcing test.

1 Introduction

The Compact Muon Solenoid (CMS) is a general-purpose detector designed to run at the highest luminosity provided by the CERN Large Hadron Collider (LHC) [1]. The hadron endcap calorimeter (HE) is a sampling calorimeter covering the pseudorapidity range $1.3 < |\eta| < 3$. The active medium of the HE is

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scintillator tiles placed in trays that are inserted between the absorber plates of cartridge brass. The scintillation light is collected by wavelength shifting (WLS) fibers, inserted in machined groves near the periphery of the scintillator tiles. One end of the WLS fibers is aluminized by sputtering to increase the light collection, and the other end is spliced to a clear fiber. The readout boxes (RBXs), which contain the photodetectors and front-end electronics, are located at the back of the calorimeter, near the edges. Multipixel hybrid photodiodes (HPDs) are used as photodetectors. Further information about HE can be found in [2].

The Phase I upgrade of HE consists of new photodetectors (Silicon photomultipliers - SiPMs) and upgraded front-end electronics (QIE11 - Charge Integration and Encoding [3]). The upgrade will allow the elimination of the high amplitude noise and drifting response of the HPDs, at the same time enabling the mitigation of the radiation damage of the scintillators and the wavelength shifting fibers with the larger spectral acceptance of the SiPMs. The upgrade will also have increased longitudinal segmentation of the readout, which is beneficial for pile-up mitigation and recalibration to correct for depth-dependent radiation damage [4].

As a realistic operational test, the responses of the Hadron Endcap Calorimeter test wedges were calibrated with a $^{60}$Co radioactive source with upgrade electronics. Here we describe the nature of the test, discuss the results and operational experience.

2 Description of the Test Setup and the Data Acquisition

The source calibration test was performed with two of the $\phi$ sectors of one of the permanently installed wedges in the CERN H2 test beam area [5], where test segments of the CMS hadron endcap, barrel and outer calorimeters are installed on a motion table.

Figure 1 (left) shows a sketch of the HE test megatile. The megatile consists of 16 scintillator tiles. The WLS fibers of the tiles are individually coupled to clear fibers which transport the light to the readout modules housing the 96 SiPMs. The RBX also houses the control and QIE11-based front-end electronics which are connected to the back-end electronics in the control room via control and data fibers. The back-end electronics is the current $\mu$TCA-based system of the CMS HE [6]. Figure 1 (left) also shows the locations of the source tubes inside the megatile as red lines. The source tube along $\phi=5$ sector goes across six scintillator tiles, and the one along $\phi=6$ sector goes across ten tiles. Also shown are the $\eta$ indices from 16 to 25. Various consecutive layers in the wedge were combined to form calorimeter towers. The towers with $\eta$ indices between 16 and 21 cover 5° in $\phi$ and those with $\eta$ indices between 22 and 25 cover 10° angles.

Figure 1 (right) shows a picture of the radioactive source driver, the indexer and the source tubes. The radioactive source is loaded at the end of the source wire that is wound around the source driver reel. The source tubes have unique indices. The particular source tube into which the radioactive source should be
inserted is selected by the data acquisition system, and this task is performed by the indexer. The radioactive source is then sent into the detector by the source driver.

The data acquisition system continuously records the location of the radioactive source and the data from the 96 SiPMs. The data from the SiPMs are histograms of ADC counts for a predefined number of time samples of 25 ns length each. The system can also take pedestal data, where the data from the SiPMs are randomly read out as ten consecutive time samples and can be used for calibration.

3 Results

Various measurements were performed during the sourcing tests. The efficiency of radioactive source tests in identifying possible issues in the optical paths as well as establishing the scintillating tile aging and radiation damage was studied by comparing the signals from different layers that form the same physical detector tower and are read out by the same SiPM. Figure 2 shows the responses measured in layers 7 and 8 when the radioactive source was moving in $\phi = 5$ (left) and $\phi = 6$ (right) sector. The deviations of the tile signals between layers 7 and 8 are minimal for $\phi = 5$ sector and is within 15% for $\phi = 6$ sector. The quality of the results obtained indicates that the correction factors at the per tile level obtained with the actual radioactive source calibration of the HE detector can be reliably implemented.

The default source wire speed in these tests was 2 cm/s. $\phi = 5$ sector was also tested at 1 cm/s to search for any improvements in the results due to higher statistics in data taking. The difference between the results of the two speed settings is minimal.
4 Conclusions

The test described here validates the radioactive source calibration operations of the actual CMS Hadron Endcap calorimeter wedges and provides insight about the effect of the source wire speed and the SiPM calibration on the quality and quantity of the data.

The prompt analysis methods developed during the test were successfully implemented at the actual sourcing campaign. This test also forms the basis of the techniques to be implemented in the radioactive source calibration of the Phase I upgrade of the Hadron Endcap Calorimeters during Year End Technical Stop 2017-2018. The test validates the automated radioactive source calibration concept for scintillator-based calorimeters and the efficient applicability of this concept to large scale detector systems.

References