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Phase 1 Front-End CMS Calorimeter (HE) Upgrade Preparation

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Abstract

Preparation of HE Phase 1 Front-End upgrade is shown. For the final quality control of the new generation HE front-end electronics components a Burn-in stand has been prepared. All electronics components are being tested on the burn-in stand and should pass through the burn-in QC before the installation on the CMS. First tests and results are presented.

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Phase 1 Front-End CMS Calorimeter (HE) Upgrade Preparation

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Abstract

Preparation of HE Phase 1 Front-End upgrade is shown. For the final quality control of the new generation HE front-end electronics components a Burn-in stand has been prepared. All electronics components are being tested on the burn-in stand and should pass through the burn-in QC before the installation on the CMS. First tests and results are presented.

Keywords: LHC; CMS; Hadron Calorimeter; Front-End electronics; Upgrade;

1. Introduction

The Hadron Calorimeter is an essential subsystem of the CMS detector [1]. The HCAL is organized into barrel (HB), outer (HO), endcap (HE) and forward (HF) sections. The HB and HE calorimeters were all originally fitted with hybrid photodiode (HPD) transducers. But for several reasons it was decided to replace all HPDs with silicon photomultipliers (SiPM), which are not sensitive to magnetic field. Radiation damage of HCAL is driving the need to modernize detector elements. Additional benefit is that SiPM gain is two orders of magnitude higher than the one of HPD and have higher efficiency. This allows to improve registration of weak light signals significantly due to improvement of signal to background ratio by a few orders in magnitude and improve longitudinal granularity of HE detectors.

2. FE HE upgrade phase 1 preparation

Despite the good performance of HCAL, showed in Run 2, there is a need to upgrade the readout electronics of CMS endcap hadron calorimeter (HE). The HB and HE detectors currently use Hybrid Photodiode transducers (HPDs). Each HPD is segmented and provides eighteen channels of optical-to-electrical conversion. During operation in the CMS magnet, a number of weaknesses have been identified, many of them related to the large electric field required for these devices. The most significant of these is the appearance of electrical discharges in the device when high voltage is applied. This effect is enhanced by particular orientations and strengths of the magnetic field relative to the HPD. While the discharge effect is much smaller in the HB/HE calorimeters, it is a significant source of high-amplitude noise and a risk to the longevity of the phototransducers.

Also there is the issue of radiation damage for the plastic scintillators of the CMS hadron calorimeter, especially in high pseudorapidity region. Due to above problems, the HE front-end electronics will be replaced during the 2016/2017 extended year-end technical stop. In particular, all hybrid photo detectors (HPD) will be replaced with silicon photomultipliers (SiPM) [2].

Beside of photodetectors replacement there will be front-end electronics components modernization. The upgrade front-end electronics design is similarly based on a number of common components. The electronics chain contains a number of new and common components: an enhanced integrator/ADC (QIE11), radiation-tolerant FPGAs for data alignment, a higher-bandwidth data link (GBT), and an improved control system (ngCCM/ngFEC).

Before the final installation of the electronics components on the detector, they should be tested in a long-term burn-in facility. Burn-In Stand is being assembled at CERN Building 904 for this purpose. There are 20 Readout Boxes (RBX) at Burn-In Stand (Fig. 1). The RBX teststand has individual powering line, dry gas and water-cooling loop, original slow control systems.

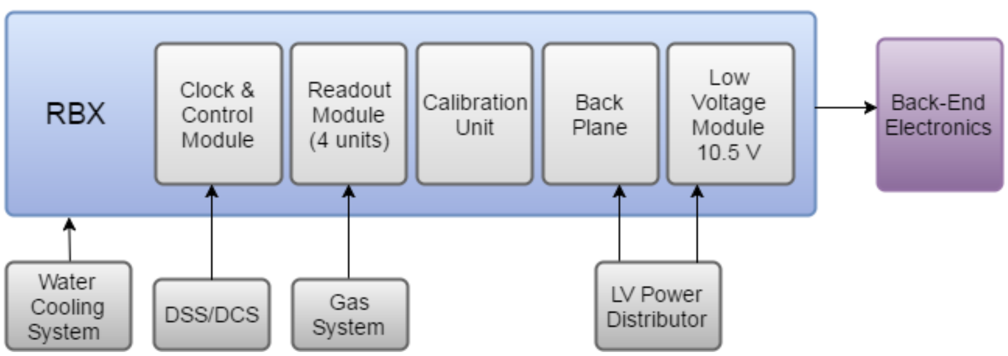

Figure 1. Scheme of individual RBX teststand.

New RMs are being assembled with QIE11, FPGAs and GBT. New ngCCM will be installed in RBX next to RMs. All electronics components have to pass initial quality check and long-term certification during 4 last months in 2016 and after that, certified components will be installed on the detector. In total, 180 readout modules have to pass through burn-in facility.

The HCAL upgrade back-end electronics use the μTCA standard. Each crate will typically include twelve μTCA HCAL Trigger/Readout (uHTR) cards. These cards are responsible for receiving the data links from the front-ends, calculating and transmitting trigger primitives, and holding the Level 1 readout pipeline. Each crate will contain one AMC13 card which will occupy the secondary MCH site and which will be responsible for data acquisition as well as distribution of the LHC clock and fast control signals. New generation back-end electronics already installed on the detector and commissioned.

At the b904 Burn-in facility, the following commissioning steps have been performed:

1) During the first initial tests the QIE11 showed the unexpected echo signal. The issue was in the 5V DC/DC Converters, which are powering QIE11s and installed in each individual RM. Performance of 48 channels of one readout module, were checked from 5.00V to 5.40V with step 0.05V. Our effort was to have target LED Signal in range ~300 000 fC < LED Signal < 370 000 fC (4 range of QIEs) in the Time Slice (TS) with maximum signal value. Signal profile is shown in Fig. 2a. We have noticed that there is a small jitter, so maximum LED Signal was from TS0 to TS2. We found a number of TS with maximum signal value and calculated the echo-to-signal ratio (echo from the same CapID) for this signal. In Fig. 2b the result of tests is presented. As a result of these tests, it was decided to rework DC/DC Converter output voltage from 5V to 5.3V. This choice is based on the fact that for voltage value 5.3V echo of signal disappears and capacitors are discharged completely (Fig. 3).

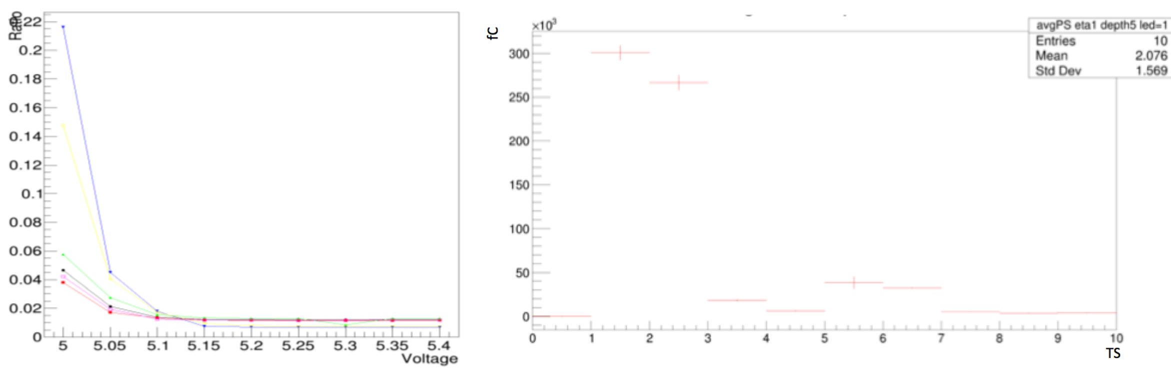

Figure 2. a) Signal profile; b) echo-to-signal ratio.

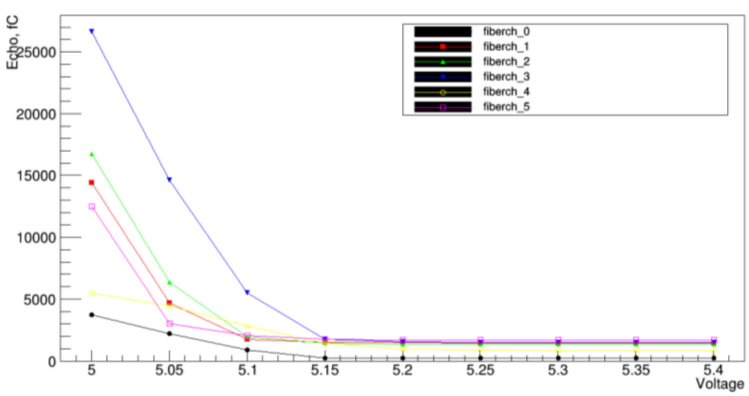

Figure 3. Echo-signal dependency of voltage

2) The QIE card shunt (signal divider) tests were performed. The data has been taken with LED signal from calibration module. Gsel value (shunt factor) was varied in order to obtain the following shunt factors: 1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 11.5. Charge dependencies on shunt factor was obtained (Fig. 4). The shunts were working as expected, the charge is going down with increasing of shunt factor.

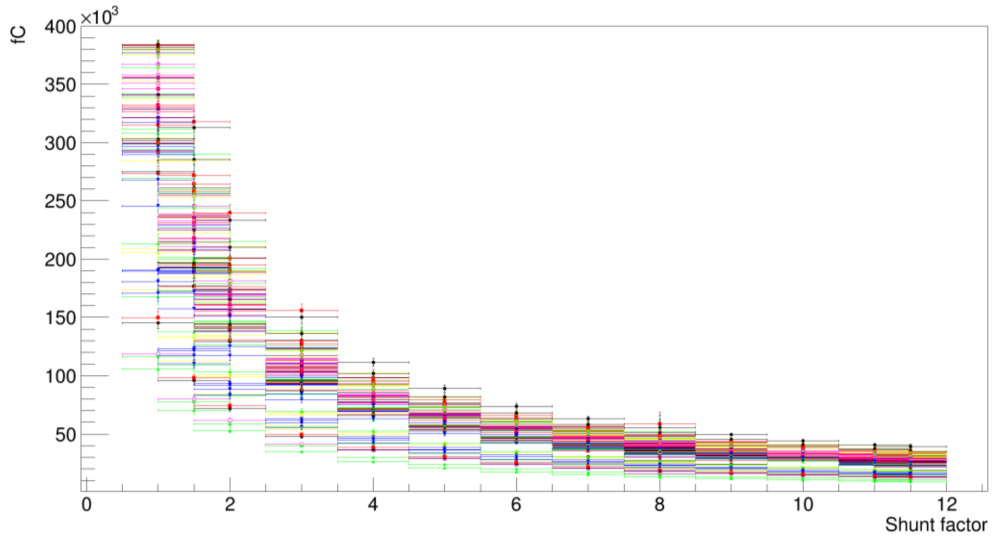

Figure 4. Maximum charge value vs shunt factor for all fibers. Each color corresponds to each group of fiber channels for every appropriate QIE

3) The very first pedestal data have been taken for the new generation electronics components. Normal and expected photoelectron peaks distribution is presented. Amplitude of signal from each photoelectron is ~50fC. (Fig. 5)

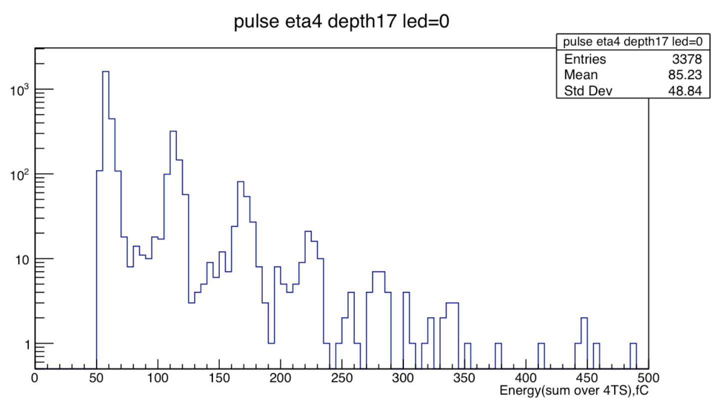

Figure 5. Photoelectron peaks distribution in individual SiPM+QIE11

The electronics components of the first bunch of assembled RM (27 readout modules) show normal and expected physics response with pedestal and LED data. 3 out of 27 RMs were kept from long-term certification due to failure of initial quality check and have been reworked and tested again. Then all RMs passed initial quality check are installed in the long-term burn-in stand.

3. Conclusion

27 readout modules successfully passed the first initial tests and installed on the burn-in stand for the long-term quality control. In total all 180 (144 + spares) readout modules will be tested on burn-in stand by December 2016. 144 readout modules will be installed on the Hardron Endcap by end of March 2017.

References

[1] The HCAL Technical Design Report (CERN/LHCC 97-31, CMS TDR 2, 20 June 1997)

[2] CMS Technical Design Report For The Phase 1 Upgrade of the Hadron Calorimeter (CERN-LHCC-2012-015, CMS TDR 10, 26 September 2012)