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CMS ECAL on-detector readout electronics radiation tests

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In preparation of the operation of the CMS electromagnetic calorimeter (ECAL) barrel at the High Luminosity Large Hadron Collider (HL-LHC) the entire on-detector electronics will be replaced. The new readout electronic comprises 12240 very front end (VFE), 2448 front end (FE) and low voltage regulator (LVR) cards arranged into readout towers (RTs) of five VFE, one FE and one LVR cards. The results of testing one RT of final prototype cards at CERN's CHARM mixed field facility and PSI's proton irradiation facilities are presented. They demonstrate the proper functioning of the new electronics in the expected radiation conditions.

Summary (500 words)

The electromagnetic calorimeter (ECAL) [1] barrel of the Compact Muon Solenoid (CMS) experiment [2] is made of 61200 lead-tungstate crystals read out by avalanche photodiodes (APDs). Its readout electronics are arranged into readout towers (RTs) of 5x5 channels, comprising five very front end (VFE) cards [3] one digital interface card (FE) and one low voltage regulator card (LVR) conditioning the power of one tower (Figs.1-3). Each VFE card hosts five channels of a pre-amplifier (CATIA) [4] followed by an analog-to-digital converter (LiTE-DTU) [5]. The FE card features four low power GigaBit Transceivers (lpGBT) [6], one slow control ASIC (GBT-SCA) [7] and one Versatile+ optical link module [8]. The LVR card hosts four DC-DC converters employing CERN's bPOL12V [9] and one linear regulator linPOL12V [10].
Operation at HL-LHC inflicts higher luminosity, resulting in higher radiation levels and more pile-up, increased leakage current in the APDs and more. To mitigate the related issues and maintain the desired ECAL barrel performance the entire on-detector electronics will be replaced [11].
Simulations predict a maximum total ionizing dose (TID) of 7650Gy (9.57x10-5Gy/s) and a neutron fluence of 4.7x1014cm-2 for 4000fb-1 integrated luminosity. We performed an irradiation test of one RT (Figs.4-5) at CERN's CHARM mixed field facility [12] followed by an irradiation at PSI's Proton Irradiation Facility (PIF) [13]. Two different versions of the VFE card, three employing CATIA v2.0 and two CATIA v2.1 were tested. The CATIA is a trans-impedance amplifier with ˜35MHz bandwidth and two differential gain outputs, gain 1 and gain 10. It features pedestal adjustment, ADC calibration signal output and an internal test pulse generation. Both VFE versions used LiTE-DTU v2.0, a two-channel 12bit 160MHz ADC with a 1.28Gbit/s data output. The LiTE-DTU employs a loss-less data compression scheme. The RT was completed with FEv3.2 (CHARM), FEv3.3 (PIF) and LVRv3. It was read out via prototype optical fiber cables by the barrel calorimeter processor (BCP) v1 [14].
At CHARM we accumulated a TID of 1380Gy (dose rate: 9.4x10-4Gy/s). This was followed by a TID of 5770Gy with an average dose rate of 9.9x10-2Gy/s at PIF. Throughout the tests the communication chain BCP-FE-VFE worked properly. The pedestal mean and RMS values and the amplitude of internal test-pulses were monitored. For CATIA v2.1 we measured a constant amplitude within ±1% for gains 1 and 10. CATIA v2.0 showed an amplitude drift of up to 12% in gain 10 (Fig.6). The RMS noise for CATIA v2.1 was stable within 5% (Fig.7). Moreover, at the PIF we noticed a drift in the pedestal values with respect to the dose, especially for channels with CATIA v2.0, even after the beam stopped. Monitoring the pedestals after the radiation at PIF, no drift was observed (Fig.8).
Our test showed that the RT is fully functional up to the expected radiation levels.

During the CHARM test, five APD capsules were attached to the inputs of one VFE card and their leakage currents measured using the GBT-SCA. This was working as expected (Fig.9).

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