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The Very-Front-End cards processing signal from photodetectors of the CMS electromagnetic calorimeter, have been put through extensive test program to guarantee their functionality and reliability. The characteristics of the VFE cards designed for the calorimeter barrel are presented. The results confirm the high quality of the cards production and show that the specifications are fully reached.

1. INTRODUCTION

The Very-Front-End (VFE) card is part of the on-detector electronics of the CMS electromagnetic calorimeter (ECAL) that will contains 75,848 radiation hard $PbWO_4$ scintillating crystals and will operate at the Large Hadron Collider at CERN. Almost 16,000 VFE cards amplify, shape and digitize signals from the photodetectors: Avalanche Photodiodes (APDs) in the barrel region and Vacuum Phototriodes (VPTs) in the end-cap regions. To obtain the best possible energy resolution, a precise calibration of all the VFE cards over their full dynamic range is essential.

2. VERY-FRONT-END-CARD

The VFE card comprises five identical and independent read-out channels which process the signal from five crystals simultaneously. Each read-out channel consists of a Multi-Gain Pre-Amplifier (MGPA), a multi-channel analog to digital converter (ADC) AD41240, and two level adapters LVDS-RX. The MGPA contains a preamplifier and three parallel amplifier stages with nominal gains 1, 6, and 12 that shape and amplify the photodetector signal. The three analog output signals of the MGPA are then digitized in parallel by the multi-channel 40 MHz 12-bit ADC AD41240. Digital logic internal to the ADC determines whether a gain is saturated and then outputs the data from the highest non-saturated gain. The MGPA chip also includes a test pulse unit with an integrated digital to analog converter (DAC) programed via an I^2C interface, which allows to check channel functionality by injecting a test charge directly into the input of the amplifier. In addition, the VFE card also incorporates a Detector Control Unit (DCU) chip for measuring the APD leakage current and the crystal temperature. All the chips are implemented in 0.25 μm IBM CMOS radiation-hard technology.

3. TEST AND CALIBRATION

Quality assurance of the VFE cards consists of several consecutive tests including: an automatic optical inspection performed by the manufacturer, a power-on test, a burn-in, and a complete calibration and characterization of each card

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and its 5 channels. The power-on test [1], performed at the manufacturer and at CERN by ETH Zürich, is the first electrical test that measures voltages, currents and performs a basic functionality test of the VFE card. The burn-in [2] test is carried out to find infant mortality failures and freak failures. The VFE burn-in system, designed and used at IPN Lyon can handle up to 300 VFE cards at once. The procedure consists of a run of 72 hours at a temperature of 60°C. During this procedure an active motherboard monitors the distributed clock (40 MHz) and total current consumption of each VFE card and checks if it remains in a predefined interval. From all the VFE cards produced for barrel, 109 cards were rejected during the power-on test and only 3 cards did not passed the burn-in.

3.1. Calibration bench

The main purpose of the calibration test [2] is to verify all the operational parameters of the VFE card and build calibration database for each card which will serve for the first calibration of all the channels of the CMS ECAL. For this purpose a complete calibration bench has been designed at IPN Lyon. In a 19 inches 6U crate, up to 6 test boards, which serves 6 VFE cards, can be installed and measured at the same time. An Altera FGPA placed on the test board sends data via a RS 232 bus to the master PC.

3.1.1. Slow Control

Slow control systems of the VFE card, such as tests of leakage current of the APDs and temperature read-out channel on its complete dynamic range, were performed. The DCU chip placed on the VFE card collects data and send them to the data acquisition system via the I^2C interface. For the temperature read-out channel, which is used for each 10^{th} crystal, the test board uses a digital potentiometer that changes its value to simulate a temperature variation of the crystals. The stability of the leakage current is tested using a current source which simulates a variation of the leakage current in a range between 0 - 200 nA to the input of the VFE.

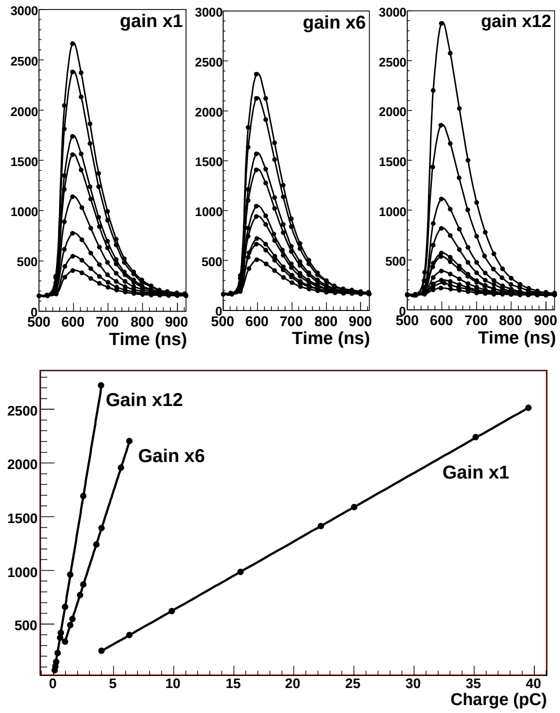

Figure 1. Top: Pulse shapes of VFE output Lines are to guide the eyes. Bottom: VFE output in ADC counts versus injected charge

3.1.2. Calibration

The calibration procedure includes an absolute calibration of each channel for the three gains in ADC counts versus pC, a channel-to-channel relative calibration, gain ratios and linearity studies. An Agilent square pulse generator and a attenuator are used to obtain different charges in a range from 0 up to 50 pC. The 10 ± 0.01 pF capacitor serve to reproduce the pulse shape. In order to check the linearity a set of pulses of precise charge are injected into the VFE card and a digital output of the card is recorded over the full dynamic range for all three gains and five channels. Injected charges were chosen to cover the whole range of each gain and to provide sufficient

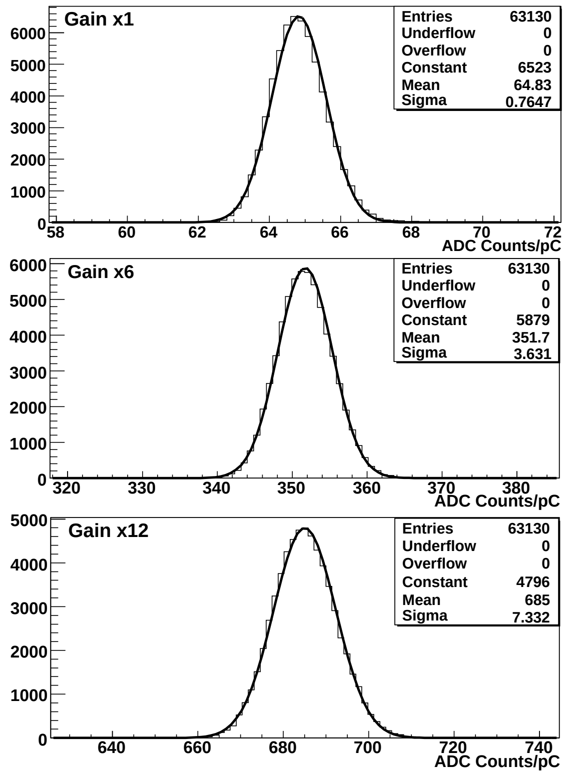

Figure 2. Slope distributions of the injected charges versus pulse height in ADC counts/pC.

amount of points for the calibration as well as for linearity studies. Therefore 8, 9, and 10 injected charges are used for gain 1, 6, and 12, respectively. The charge steps are not linearly spaced because of the logarithmic nature of the attenuator. Pulse shapes of the VFE output and linear dependence of the ADC VFE response on injected charges is shown for all the gains in Fig 1. The saturation level, which is not reached, is around 60, 10, and 5 pC for gain 1, 6, 12, respectively. Several charges were chosen as overlapping points to verify a good link between different gains. A charge of 4 pC is common for all three gains and allows to check the gain. To suppress instrumentation effects among test boards of the calibration system and variation during long period of calibration that lasts more than one year, an intercalibration between channels is applied. Since a pulse height temperature dependency and slope dependency of -0.2%/°C were observed, all the calibration measurement are performed in a temperature stabilized room (18±0.3°C).

4. RESULTS

All the 12,778 VFE cards needed for the barrel have been measured and calibrated. Fig. 2 displays the slope distributions of the injected charges versus pulse height in ADC counts/pC and their mean values for all the barrel VFE cards production which passed the tests. A slope dispersion of 1% for all three gains shows very small differences of the produced cards. The relative gain ratio is determined as a ratio of slopes between the gains. Its mean value over all the channels are 5.53 and 10.74 for gain 6/gain 1 and gain 12/gain 1 ratios, respectively. To identify the VFE cards with linearity problems, the acceptance threshold is set by coefficient of determination r^2 from a linear fit for the set of charges for each gain (VFE response vs. charge). This threshold must be higher then $r^2 = 0.9999$. 152 VFE cards were rejected during the calibration, for which mainly problems to set the pedestal value, a bad linearity, a wrong bit for gain determination were found.

5. CONCLUSIONS

At the present, all the VFE cards intended for barrel use underwent power-on test, burn-in and have been calibrated. Around 1% of them failed the test criteria and have consequently been rejected. The dispersion in the gains is found to be small (∼1%) complying with the CMS detector specifications. The VFE cards intended for the end-caps will be calibrated in the beginning of the year 2007.

REFERENCES

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2. J. Blaha et al.: Czech. J. Phys., Vol 56, 2006