In-situ performance of the CMS Preshower Detector

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Abstract

The CMS Preshower detector, based on silicon strip sensors, was installed on the two endcaps of CMS in March/April 2009. First commissioning showed that of the 137216 electronics channels almost all (>99.9%) are fully operational.

This report summarizes the electronics integration (on-detector) and in-situ performance in terms of noise (including common-mode pickup). First observations of in-situ cosmic-rays during CMS summer CRAFT program are presented.

I. Introduction

The CMS Preshower (ES [1]) is a fine-grain detector placed in front of the endcap Electromagnetic calorimeter. It's primary role is to detect photons with good spatial resolution in order to distinguish pairs of closely-spaced photons from single photons. Silicon sensors, measuring 63 x 63 mm^2 and 320 μm thick, divided into 32 strips are used as active elements. The complete Preshower detector contains 4288 sensors, mounted on 4 individual planes: two orthogonal planes form each CMS endcap Preshower. The location of the Preshower detector inside CMS is shown in fig. 1.

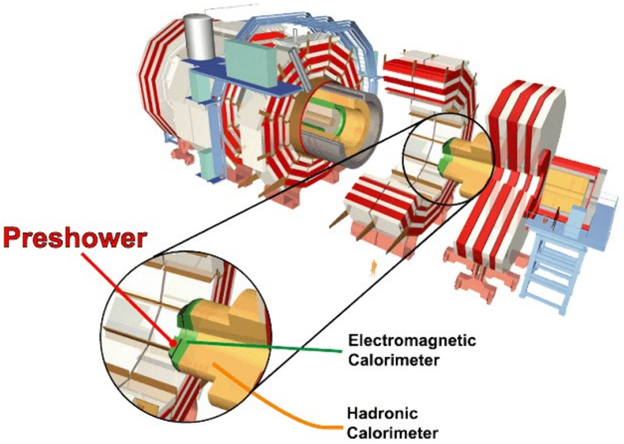

Figure 1: Location of Preshower detector in CMS.

The ES Control and Readout architecture can be divided into on-detector and off-detector parts. The on-detector part is based on 504 modules known as "ladders", each of which hosts 7-10 sensors and associated front-end electronics.

A. On-detector

Each silicon sensor was glued to a ceramic support, in turn glued to an aluminium tile (allowing sensor overlap in one dimension). The front-end hybrid, holding the PACE3 [2] chipset, is screwed through the ceramic to the tile and wire-bonded to the sensor. The resulting "micromodule" is shown in figure 2.

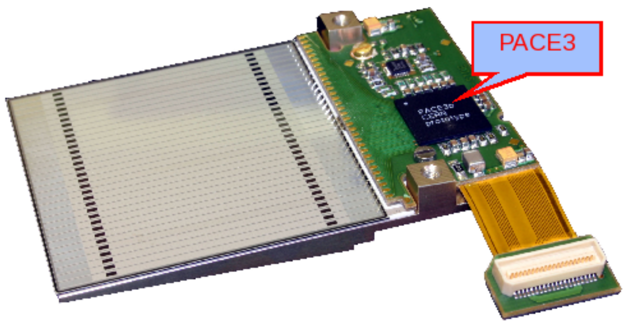

Figure 2: Preshower silicon sensor micromodule.

The role of the front-end readout chip - PACE3 - is to amplify, shape, sample (at 40MHz) and store voltage signals generated by charged particles passing through the sensor. Each channel of PACE3 contains charge amplifier, followed by switchable gain shaper and analog memory to store sampled data. Three consecutive voltage samples are stored per triggered event. The front-end can operate at two gains: High gain (HG) is mainly used for detecting minimum ionizing particles (MIPs) during calibration stage with a limited dynamic range of about 0-60 MIPs; Low gain (LG) is used for normal physics data taking operation with a high dynamic range of about 0-400 MIPs.

Micromodules were assembled into "ladders". On top of each ladder, a system motherboard (SMB) was installed. There are 4 types (shapes) of SMB in the Preshower to enable an approximately circular coverage of the endcap regions between $1.653 < \eta < 2.6$. This complex double-sided pcb contains voltage regulators, analog-to-digital converters, data concentrator chips, gigabit optical transmitters and slow control circuitry.

Analog time samples delivered by the front-end hybrids are digitized by the ADCs [3], then stored and reformatted to data packets in a data concentrator chip (K-CHIP) [4]. Finally, through a gigabit optical hybrid (GOH) mezzanine [5], data are pushed out to the counting room through optical fibers.

B. Off-detector

The Preshower off-detector electronics principal components are Clock and Control System (FEC-CCS) [6] and

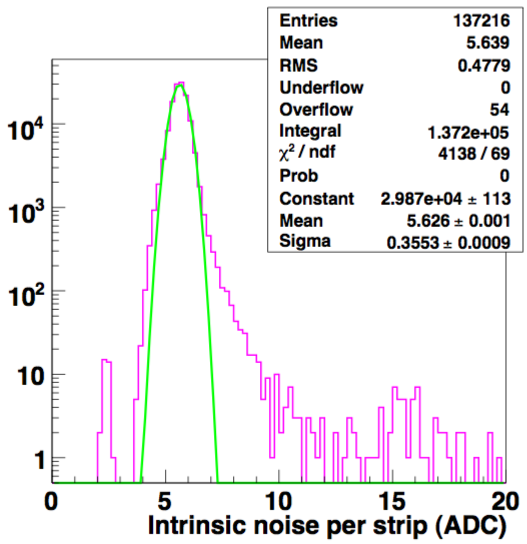

Figure 3: Intrinsic noise in ADC counts per sensor strip measured with detector operating in high gain (HG).

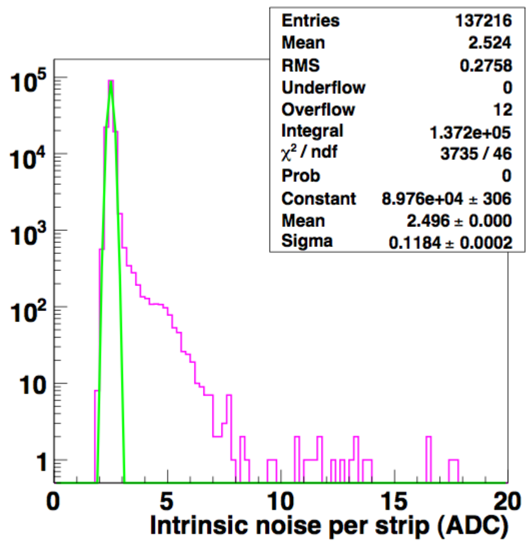

Figure 4: Intrinsic noise in ADC counts per sensor strip measured with detector operating in low gain (LG).

Preshower Data Concentrator Card (ESDCC) [7]. The role of the CCS is to redistribute clock and trigger information to the front-end electronics through ”control rings” and perform slow control of the on-detector system. It was implemented in 9U VME form factor as part of a common project for several other detectors present in CMS. The ESDCC card’s main objective is to acquire data from the front-end, process them to obtain a necessary data reduction of about a factor 20 and then send the sparsified data to the central CMS DAQ system via the S-LINK common interface. This 9U VME card performs pedestal subtraction, common mode noise rejection, signal reconstruction, bunch crossing assignment and threshold application [8]. Four VME 9U crates (one for each plane of each endcap) in the counting room host in total 16 CCS and 40 ESDCC cards.

II. Assembly and Installation

The Preshower detectors were assembled and tested on the CERN Meyrin site - starting from micromodule assembly and finishing with endcap ”Dees” (one Dee is an assembly of two half-planes). During this assembly process, each detector element underwent rigorous quality control/assurance checks, including detailed visual inspections, thermal shock/cycling and power-cycles, preceded and followed by functional tests . For example, vertical stacks of 6 ladders were placed in thermoregulated boxes and thermal cycles with power-cycles tests were performed (10 thermal cycles between -14°C and +15°C), followed by 24h continuous operation at -14°C (the nominal operating temperature of the Preshower). During this latter test cosmic muons passing through the sensors were detected and used to perform a first calibration [9].

The final assembly of the detector Dees was again followed by functionality and reliability tests at ambient and sub-zero temperatures, finishing in December 2008. In March and April 2009 the four Preshower Dees were transported to the CMS cavern. Before installing them in CMS all services needed were deployed and tested, including low and high voltage power, cooling and neutral gas flow systems. The Preshower is the only part of CMS that included a final assembly stage underground - attaching pairs of Dees together to form the full endcaps. This delicate operation took place with the beam-pipe in place, necessitating numerous safety precautions. The process went without any problems and according to schedule

The Preshower dectector was ready for first commisioning in-situ by the end of April.

III. Commissioning

After installation of the Preshower in CMS the most important thing to do was to check that all connectivity at the detector side for high and low voltage power lines, control cables and optical fibres was correct, prior to ”closing” CMS. The complete on and off-detector systems were used for this first commissioning, including all final power supplies and two crates of off-detector electronics (the other two crates were not available at that time).

Data were taken by means of a local DAQ system based on the XDAQ framework (CMS standard) [10][11]. The resulting data (pedestals runs mainly) were analysed using on-line Data Quality Monitoring (DQM) software tools, giving prompt feedback to cabling teams in case of connection problems. Just a few problems were in fact found, and these were mostly with optical connections that were quickly repaired. One sensor was found to have a short-circuit on its HV line inside the detector so it (and its neighbour) have been disconnected. A further 2 channels are also not functioning, bringing the total working channels down to 137150 from the nominal 137216. Thus after the first commissioning more than 99.9% of the ES was fully functional. Analysis of the noise performance in HG and LG modes was also performed. Figures 3 and 4 show noise distributions in ADC counts for HG and LG respectively (with 1 MIP being equivalent to about 50 ADC counts in HG and 9 ADC counts in LG). These noise figures agree with laboratory measurements and are within the detector design specification. In HG mode

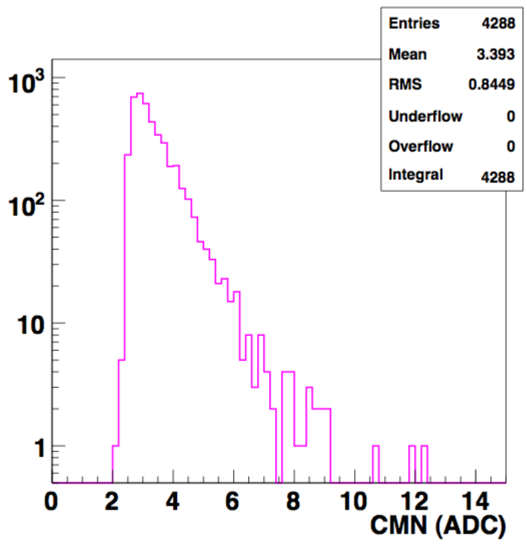

Figure 5: Common mode noise in ADC counts per sensor measured with detector operating in high gain (HG).

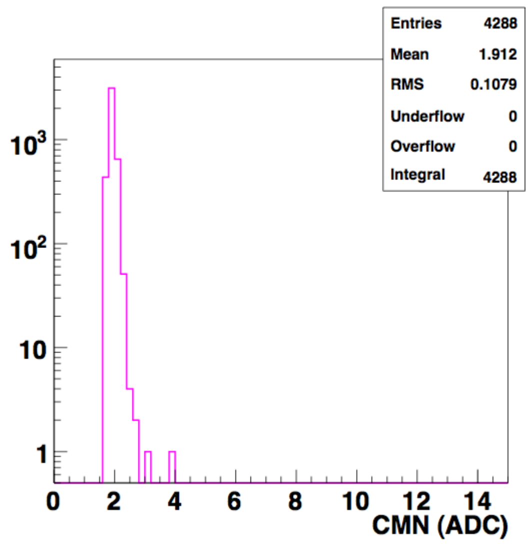

Figure 6: Common mode noise in ADC counts per sensor measured with detector operating in low gain (LG).

the typical noise is around 5.6 ADC counts, corresponding to a signal to noise ratio of 9 (for single MIPs), while in physics operating mode (LG) the noise average value is around 2.5 ADC counts and S/N ratio 3.5. In this latter mode of operation (fig. 4) one can see that a few hundred strips have noise above the norm, around 5 ADC counts. These strips were found to be located on specific micromodules on one type of ladder and the cause of the excessive noise traced to system clock crosstalk. This feature has no effect on overall performance of the detector itself.

Analysis of common mode (CM) noise gave reasonably low levels, reassuring us that the ES does not pick-up noise from neighbouring systems (through power lines etc.) nor from its own operation (see fig. 5 and 6). One can see that common mode noise values are bigger in HG than LG, which can be explained by PSRR ratio of charge preamplifier and switched gain shaper characteristics of the PACE3 front-end chip. Again these levels of CM noise do not affect the detector performance - indeed the ESDCC includes a CM correction algorithm.

IV. Cosmic data - CRAFT'09

With LHC machine operation announced for the end 2009, the CMS experiment began operating 24/7 for 6 weeks in the summer to test its readiness. During that time the magnet was switched on at full power. In the period of so-called CRAFT09 campaign (Cosmic Run At Four Tesla), the Preshower detector was included with one plane of one endcap. After an initial period of timing-in of the detector with particles, the Preshower delivered cosmic muon information to CMS. An example of a CMS event display showing muon hits in the Preshower is shown on figure 7. One specificity of CRAFT09 runs is that particles arrive asynchronously with respect to the system master clock. This feature brings obvious difficulties for precise timing-in of the detector for LHC machine operation. However, by fitting the front-end pulse shape to 3 data time samples one can reconstruct the particle arrival time and front-end signal amplitude. A preliminary plot of the energy spectrum in the Preshower due to incident muons is shown in figure 8. Note that this plot does not include a correction for the angle of incidence of the muons.

V. Summary

The CMS Preshower detector was assembled in the second half of 2008. It was installed and commissioned successfully in CMS in the first half of 2009. The results gathered from first check-out of the detector confirms all connectivity in place and expected noise performance. Virtually all channels (>99.9%) are operational, with just a small number of noisy channels observed. The average noise is 5.6 ADC counts in HG and 2.5 in LG operation mode. This leads to signal to noise figures of 9 for HG and 3.5 in LG for single MIP detector response, fully satisfying detector design specifications. Common mode noise was found to be at reasonable low level, confirming that detector is immune to outside environment. In summer 2009, CMS Preshower joined Cosmic Run At Four Tesla campaign, that resulted with successful timing-in in respect to whole CMS and measurements of energy deposit of cosmic rays in its silicon sensors.

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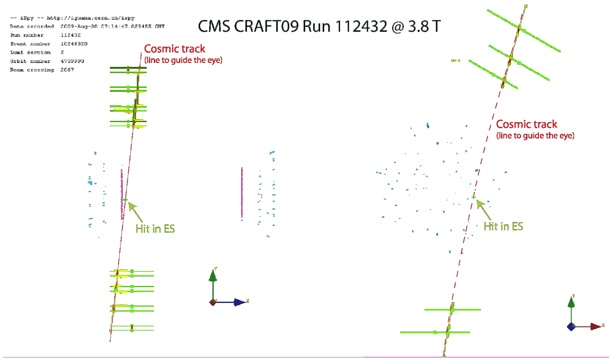

Figure 7: CMS Event Display. Example of Cosmic muon trace recorded in Preshower detector.

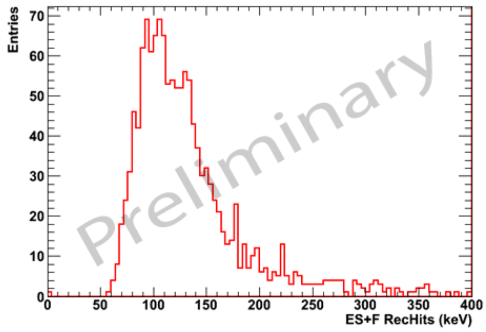

Figure 8: Energy deposit of minimum ionizing particles with Preshower sensors.

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