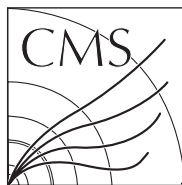


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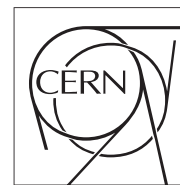
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The Compact Muon Solenoid Experiment

# Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland



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## Performance of CMS ECAL Preshower in 2007 test beam

Syue-Wei Li, Apollo Go, Chia-Ming Kuo

On behalf of CMS Preshower collaboration

National Central University, Taiwan

### Abstract

The Preshower detector is part of the CMS Electromagnetic Calorimeter, located in the endcap regions, in front of the lead tungstate crystals. It consists of two orthogonal planes of silicon strip sensors interleaved with two planes of lead absorbers. A combined beam test of close-to-final prototypes of the Hadron calorimeter, the crystal calorimeter and the Preshower detector was performed in the summer of 2007. Calibrations were made using electron and pion data. The combined crystal and Preshower energy resolution was studied using electrons. Good signal/noise performance was obtained in both sets of measurements.

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# Performance of CMS ECAL Preshower in 2007 test beam

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**Abstract.** The Preshower detector is part of the CMS Electromagnetic Calorimeter, located in the endcap regions, in front of the lead tungstate crystals. It consists of two orthogonal planes of silicon strip sensors interleaved with two planes of lead absorbers. A combined beam test of close-to-final prototypes of the Hadron calorimeter, the crystal calorimeter and the Preshower detector was performed in the summer of 2007. Calibrations were made using electron and pion data. Good signal/noise performance was obtained in both gains of measurements

## 1. Introduction

The CMS Preshower will be placed in front of endcaps of the electromagnetic calorimeter. The coverage of the Preshower is  $1.653 < |\eta| < 2.6$ . It consists of two lead absorbers (2 and 1  $X_0$  respectively) and two orthogonal planes of silicon strip sensors. The main purpose of the Preshower is to identify two closely spaced photons from  $\pi^0$  decays (background of  $H^0 \rightarrow \gamma\gamma$ ) in order to separate these photons from single photons [1].

There is a great need to understand the overall performance of the calorimeters, before CMS completes the installation and goes into operation. An effort was made in summer 2007 to bring together close-to-final prototypes of the Preshower, Electromagnetic Calorimeter (ECAL) and Hadron Calorimeter (HCAL) in the H2 test area at CERN.

## 2. Experiment setup and the Preshower signal reconstruction

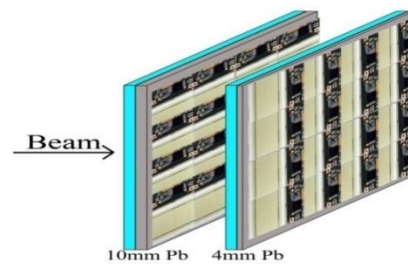
The setup including the 3 calorimeters HE (hadronic), EE (electromagnetic) and ES

(Preshower) is shown in Fig. 1. For the Preshower, it was the first time we had a full read-out chain (on-detector, off-detector integrated into the main CMS DAQ system for the combined beam test), DQM (Data Quality Monitoring) and DCS (Detector Control System). It proved that a small scale ES can operate successfully in realistic conditions.

The Preshower is a sampling calorimeter and consists of two orthogonal layers of silicon strip sensors positioned behind two planes of lead absorbers (Fig.2). Each silicon sensor measures  $63 \times 63 \text{ mm}^2$ , with an active area  $61 \times 61 \text{ mm}^2$  divided into 32 strips (1.9 mm pitch). The nominal thickness of the silicon is  $320 \text{ }\mu\text{m}$ . The thicknesses of two absorbers are nominally  $\sim 2 X_0$  and  $\sim 1 X_0$  [1].



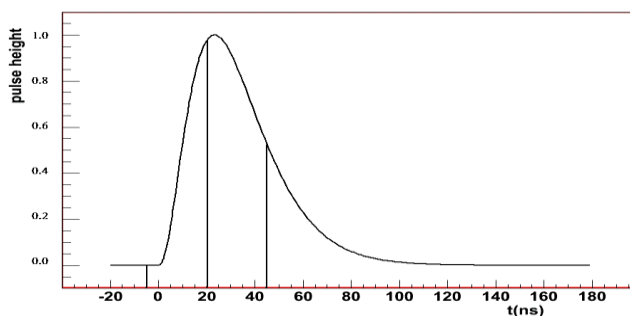
**Figure 1.** The picture of test beam setup in H2.



**Figure 2.** The setup of the ES in test beam.

The MIP is the energy unit in the Preshower and is defined as the deposited energy when a high energy pion/muon goes perpendicularly through the sensor. The Preshower absolute calibration can only be performed with MIPs.

Fig. 3 shows a typical pulse shape from a silicon strip. Three time samples are used to reconstruct the deposited energy in the silicon strip. The interval of each time sample is 25 ns. The total deposited energy in the silicon strip is given by  $E = W_1 * S_1 + W_2 * S_2 + W_3 * S_3$ , where  $W_i$  is a weight function for the  $i^{\text{th}}$  time sample and  $S_i$  is the signal in  $i^{\text{th}}$  time sample.

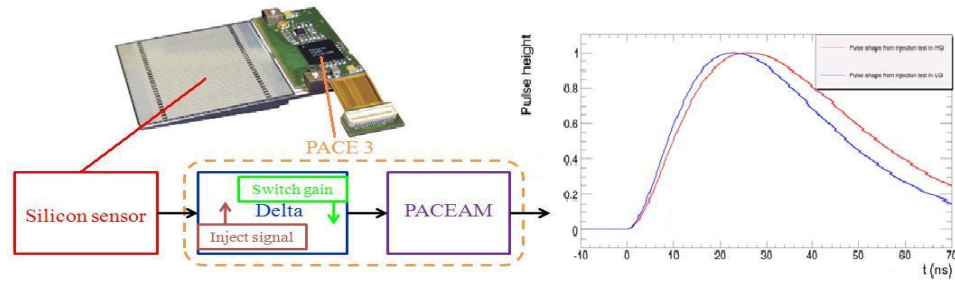


**Figure 3.** The typical pulse shape. The peak of the shape measures the total deposited energy in a silicon strip. Three time samples are used to reconstruct back to the total energy.

The standard operation of the Preshower is in “low gain (LG) mode”. It has then a dynamic range (0~400 MIPs). The Preshower is also designed to operate in “high gain (HG) mode” with limited dynamic range (0~50 MIPs) in order to calibrate precisely the MIPs with good S/N ratio.

An electronics test signal can be injected and can be used to measure the pulse shape in both modes. Fig. 4 shows the pulse shapes in both gains. There is an obvious difference in the

pulse shapes between HG and LG. It shows that MIPs need to be calibrated in HG and LG respectively, in order to obtain the corresponding weight functions.



**Figure 4.** Left plot shows the workflow of the injection test. Right plot indicates the pulse shapes in HG (in red) and LG (in blue) respectively. The pulse shapes are normalized to 1.

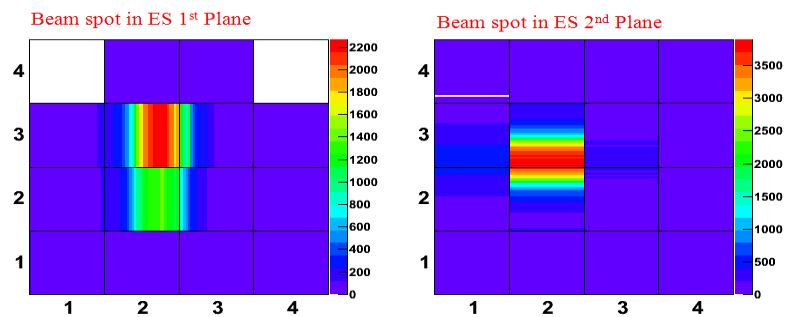
### 3. Preshower MIP calibration

#### 3.1. MIP calibration in HG

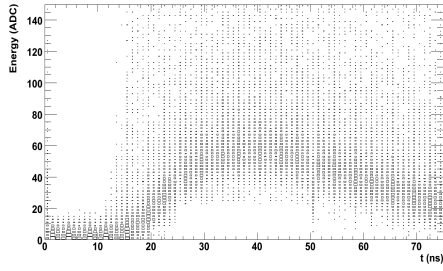
High energy (20 GeV/c) pion data was used to obtain the pulse shape, the weight functions and the MIPs, because the pulse shape from electronic charge injection may be different as the pulse shape observed with particle signals. Fig. 5 shows the image of the beam spot of pion data in the Preshower. The sensor in the 1<sup>st</sup> plane was used to obtain the pulse shape and the corresponding weight functions.

The data were divided in 1ns bins and fitted in each bin with a Landau distribution convoluted by a Gaussian to take the noise into account. The resulting pulse shape is shown in Fig. 7, and the corresponding weight functions were obtained using the method described in [2]. Fig. 8 shows the energy spectrum which is reconstructed using the weight functions. The signal to noise ratio is around 10.

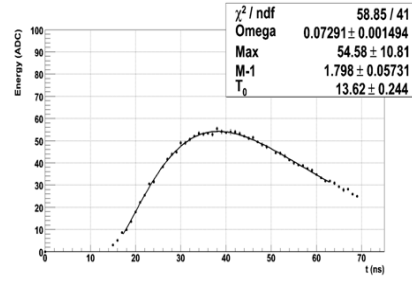
The data obtained with the 2<sup>nd</sup> plane was used to cross check the pulse shape. The difference in the pulse shapes between these two sensors is negligible. It proves that the pulse shape is universal.



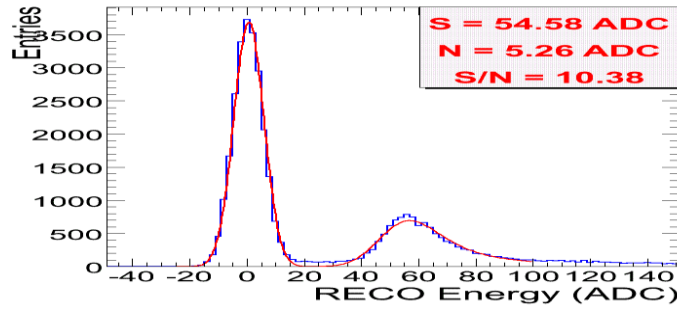
**Figure 5.** Beam spot in the 1<sup>st</sup> (left) plane and 2<sup>nd</sup> (right) plane of the Preshower.



**Figure 6.** The energy distribution as function of  $t_{TDC}$ .



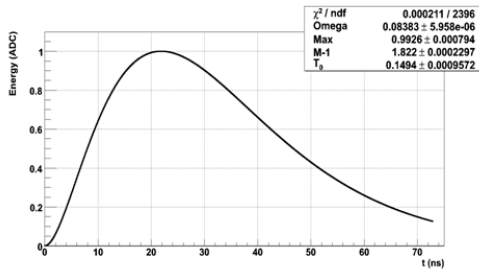
**Figure 7.** The pulse shape in HG.



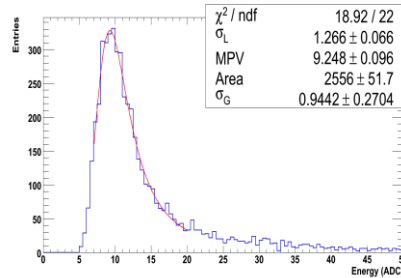
**Figure 8.** The reconstructed energy spectrum. The S/N ratio is around 10.

### 3.2. MIP calibration in LG

The MIP resolution in LG is not good enough to obtain the pulse shape directly, so electronics charge injection was used to deduce the pulse shape in LG (Fig. 9), and then to obtain the corresponding weight functions. Fig. 10 shows the MIP obtained from pion data.



**Figure 9.** The deduced pulse shape in LG.



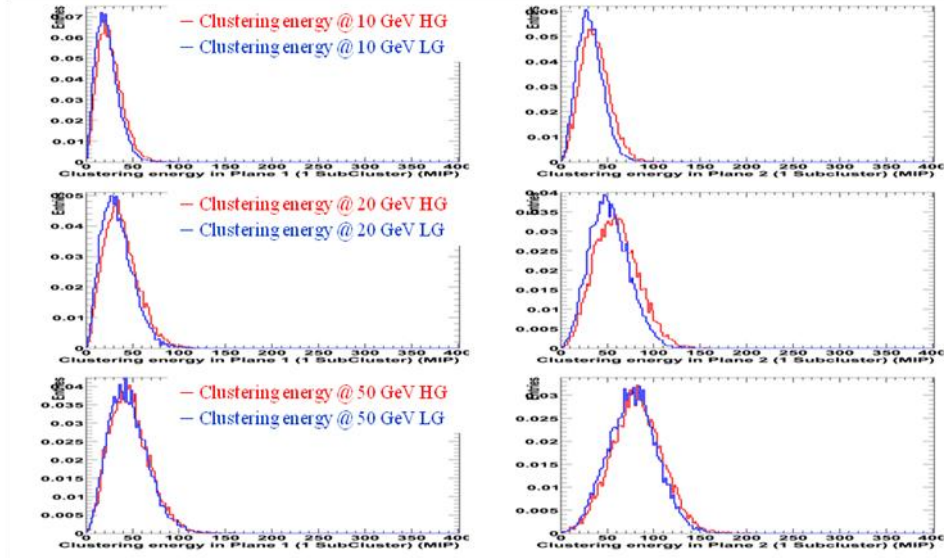
**Figure 10.** The MIP of the sensor. MIP is 9 ADC counts.

### 3.3. MIP cross check and additional correction

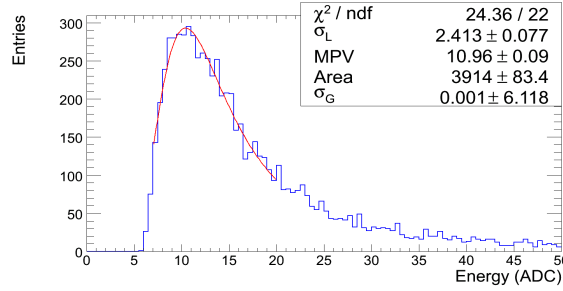
A cross check of the calibration in both HG and LG modes can be performed by measuring the energy deposited in the Preshower by electrons using data recorded with both gains. The distributions should be identical. The energy in the Preshower is defined as the sum of energies in a cluster containing the strip with highest deposit and 2 neighbors on each side. Fig. 11 shows the energy spectrum obtained in both gains with 10, 20, and 50 GeV electrons. The data of the two gains differ slightly, however in a consistent way.

Because the S/N ( $\approx 3$ ) is marginal in LG, the MIP value is shifted by the effect from the noise.

This effect is shown in Fig. 12 which is a result of a simulation where the MIP signal was set to 9 ADC counts and the noise to 2.5 ADC counts. The Most Probable Value of the distribution shifts from 9 to  $\sim 11$  ADC counts. Another effect is due to the fact that the pulse shape in LG was measured indirectly via charge injection.



**Figure 11.** Cluster energy in MIPs from electron data at 10, 20, 50 GeV in the 1<sup>st</sup> (left) plane and 2<sup>nd</sup> (right) plane of the Preshower. Blue line indicates the results in LG and red line indicates the results in HG.



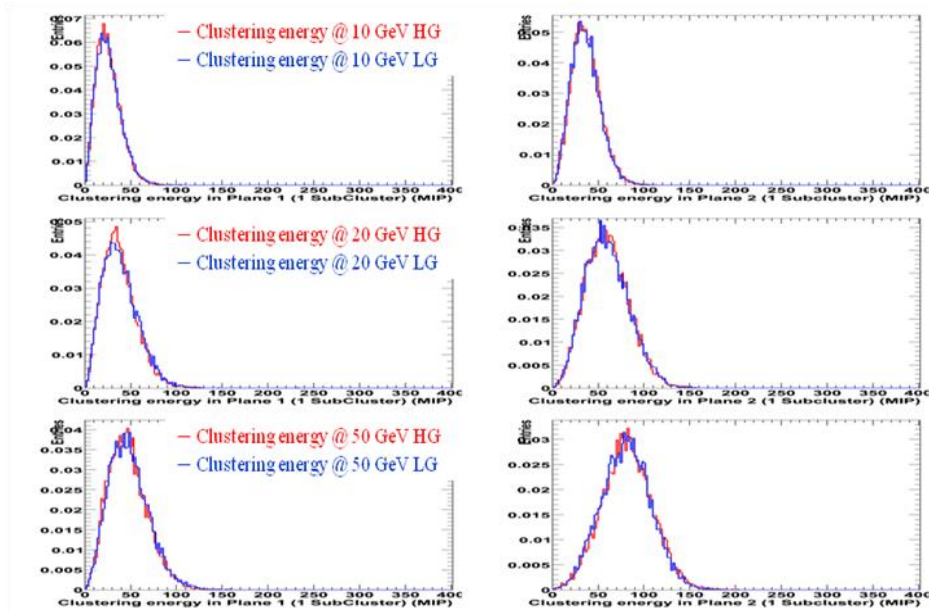
**Figure 12.** The fitting result from the simulation (see text).

By minimizing the  $\chi^2$  between the energy spectra in LG and HG, a global correction factor of 1.14 to be applied to the LG data was obtained. Fig. 13 shows the energy spectra after applying this correction factor to the reconstructed energy in LG. The distributions are in very good agreement for both planes and all energies. Fig. 14 shows the spectrum of the noise after applying correction and it implies that the S/N is around 3 in LG.

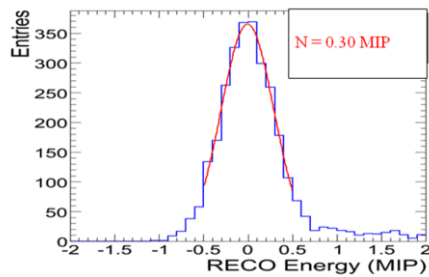
#### 4. Preliminary result of combined EE and ES energy

The total deposited energy in the electromagnetic calorimeters is given by  $E = E_{EE} + E_{ES}$ , where  $E_{EE}$  is the energy measured by EE and  $E_{ES} = \alpha(ES_1 + 0.7ES_2)$  is the energy measured by the Preshower.  $ES_{1,2}$  are the deposited energies in the 1<sup>st</sup> and 2<sup>nd</sup> plane of ES respectively. The coefficient 0.7 results from an optimisation study done in earlier work [3]. The coefficient  $\alpha$  is obtained from a linear regression fit of the correlation plot between  $E_{EE}$  and  $E_{ES}$ .

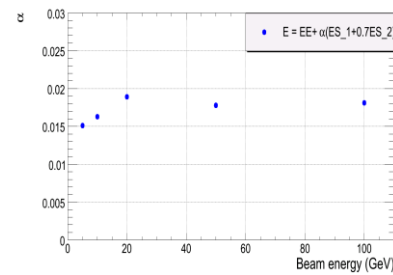
Fig. 15 shows value of  $\alpha$  for different beam energies. The coefficient,  $\alpha$ , is constant when the beam energy is above 20 GeV.



**Figure 13.** The energy spectrums after applying correction factor.



**Figure 14.** The spectrum of the noise in LG.



**Figure 15.** The Value of  $\alpha$  as function of the beam energy.

## 5. Conclusion

For the first time a small scale prototype of the CMS Preshower operated successfully in realistic conditions and then took useful data for calibration. We have shown that a reliable calibration using minimum ionizing particles can be obtained, allowing to calibrate the detector in-situ during operation.

## 6. References

- [1] CMS Physics TDR Vol. 1, CERN/LHCC/2006-001.
- [2] I. Evangelou, *Nuclear Instruments and Methods in Physics Research Section A*, Volume **572**, Issue 2, p. 624-632.
- [3] P. Aspell et al., CMS-NOTE 2000-001.