

## USING SINGLE PHOTOELECTRON SPECTRA IN THE CALIBRATION OF THE CMS-HF CALORIMETER

E. GÜLMEZ, M.DELIOMEROGLU, AND K. DINDAR

*Bogazici University, Bebek 34342 Istanbul, Turkey*

*E-mail: gulmez@boun.edu.tr*

U. AKGUN, A. S. AYAN, Y.ONEL, AND I.SCHMIDT

*University of Iowa, Iowa City 52242 IA, USA*

Relative gains of the PMTs installed in the CMS-HF calorimeter were measured at the University of Iowa PMT Test Station. Using the source data taken during the HF Test Beam period 2004 at CERN, PMT gains were determined from the single photoelectron spectra. Comparing these data provides an effective pedestal value and shows a very high correlation ( $r=0.994$ ). PMT gains obtained in this way can be used for final calibration of the HF calorimeter.

### 1. Introduction

Calibration of the HF Calorimeter requires the gains of the PMTs used in the calorimeter. One way of measuring the PMT gains would be to use the single photoelectron spectra. Such a set of data were taken during the test beam 2004 period with some of the HF wedges using a 5mCi  $^{60}\text{Co}$  source. The following is a report of the study made on the wedge 2-13 data to compare the relative gains obtained at the University of Iowa PMT test station and the gains obtained from the single photoelectron spectra. Then, these gains are used to calibrate the calorimeter with 100 GeV electron beam.

### 2. University of Iowa Measurements

As part of the quality control checks performed at the University of Iowa PMT test station, the relative gain of each tube was measured. The same reference tube was used throughout the measurements and the absolute gain of the reference tube was also measured accurately.<sup>1,2</sup> Even though all the measurements were performed at 1100 V, it was shown<sup>3</sup> that the

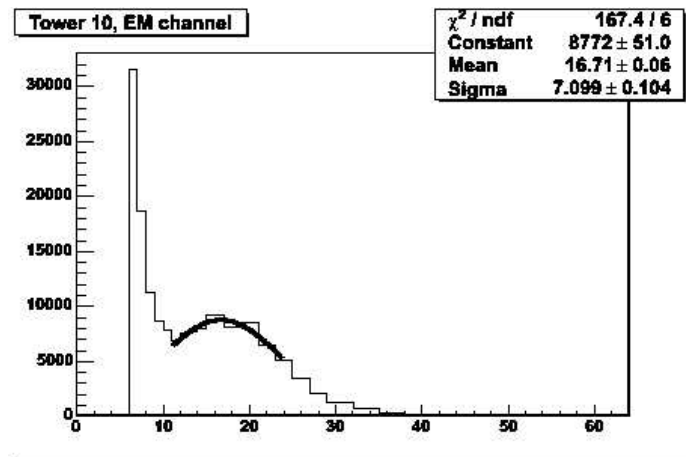


Figure 1. A sample fit of a single photoelectron spectrum at 1350V.

relative gains stayed flat as the HV increased.

Each HF wedge is divided into three sectors; inner, middle, and outer towers. PMTs are installed into each of these sectors according to their relative gains. Tubes with lower relative gains are installed in the inner sector (closer to the beam), medium gain tubes in the middle and the higher gain tubes in the outer sector. PMTs in each sector are also selected so that they have almost the same relative gains within a few percent. With three sets of PMTs in each wedge for both type of fiber lengths, EM and HAD, we have a total of six group of PMTs providing us with six different relative gain values.

### 3. CERN Measurements

During the test beam period at CERN in 2004, some of the wedges were tested under various beams and also with a  $^{60}\text{Co}$  source. The source was inserted into each tower one at a time and the pulse height histograms obtained through the QIE readout system were recorded. The histograms accumulated when the source was outside were used to determine the pedestals.

In this study, the source runs for the HF wedge 2-13 at three different HVs, 1150, 1250, and 1350 V, were used. For each run, pulse height histograms were fitted to a gaussian to determine the peak position corresponding to the single photoelectron distribution. Then the absolute gain

could be obtained from the single photoelectron peak position after correcting for the pedestals. The best results were obtained from the data taken with the 1350 V (Fig.1).

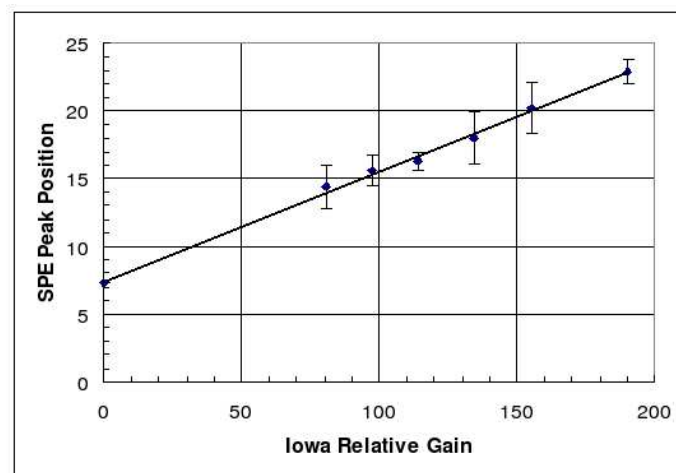


Figure 2. Single photoelectron peak positions or “uncorrected absolute gains in arbitrary units” (CERN) versus relative gains (Iowa). Intercept on the absolute gain axis is the effective pedestal value.

The single photoelectron peak positions were grouped according to the corresponding Iowa relative gains into six groups. When the peak positions are corrected for the pedestals, fitting the average of each group versus the Iowa relative gains to a straight line should yield a line passing through the origin. However, this does not happen when we determine the pedestals from the pedestal histograms. Instead of subtracting the pedestals obtained from the pedestal histograms, peak position versus the Iowa relative gain data were fitted to a straight line (linear correlation coefficient  $r=0.994$ ) (Fig. 2). The intercept on the peak position axis would be the effective pedestal value. At 1350 V, the effective pedestal value is higher than the average pedestal value obtained from the pedestal histograms (Table 1). At lower HVs, the effective pedestal gets closer to the value obtained from the pedestal histograms. The effective pedestal value at each HV was subtracted from the single photoelectron peak positions to obtain the corrected PMT absolute gains.

Table 1. Effective pedestal values obtained from the single photoelectron peak positions.

PMT HV	Pedestal from Histograms	Effective Pedestals
1150 V	$5.0 \pm 0.3$	not enough statistics.
1250 V	$4.9 \pm 0.2$	$4.1 \pm 1.1$
1350 V	$4.9 \pm 0.2$	$7.3 \pm 1.6$

#### 4. Energy response of the calorimeter

During the same test beam period, the HF wedges are exposed to several different beam types and energies. Response of the individual towers are determined by fitting the PMT pulse height distributions obtained with a 100 GeV electron beam. Since the PMTs in each of the three sectors have different gains, the PMTs show different responses. A simple approach to calibrate the calorimeter would be to correct the energy responses with the corresponding PMT gains. Figure 3 shows the individual response of the wedges corrected with the PMT gains obtained as explained above.

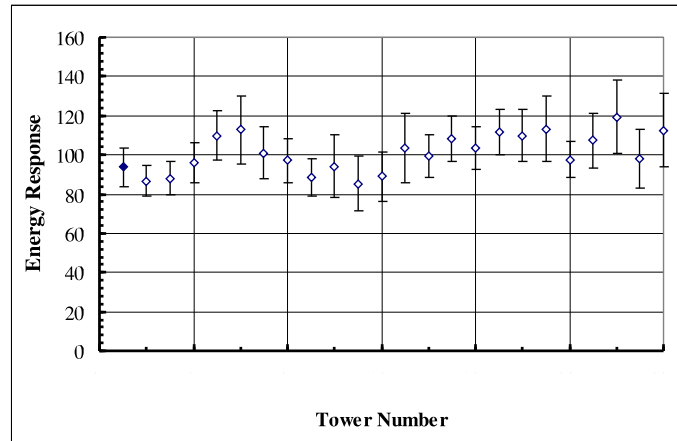


Figure 3. Energy response corrected with the PMT gains of towers versus the tower number

## 5. Conclusion

In this study, we show that we can calibrate the HF Calorimeter and monitor the calibration by using the PMT gains obtained from the single photoelectron spectra. Then the energy response of the individual towers to a specific beam energy can be corrected with these gain values. Such a simple method results in a calibration with an accuracy of about 10%. We also show that the relative gains measured at the University of Iowa PMT test station and the gains determined from the Test Beam 2004 source data are highly correlated ( $r=0.994$ ). However, determining the pedestal values seems to require a more careful study.

## Acknowledgements

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