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Comparison of PMT relative gains measured at the University of Iowa and at CERN

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Abstract

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 at CERN, PMT gains were determined from the single photoelectron spectra for the HF Wedge 2-13. Comparing these data provides an effective pedestal value and shows a very high correlation (r=0.994) between the Iowa and CERN data sets.

1 Introduction

Calibration of the HF Calorimeter requires the gains of the PMTs used in the calorimeter. Although the relative gains of all the PMTs were measured at the University of Iowa PMT test station prior to the installation as part of the quality control process, we should determine and monitor the gains continuously to keep the calibration of the calorimeter current. One way of measuring the PMT gains is to use 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}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.

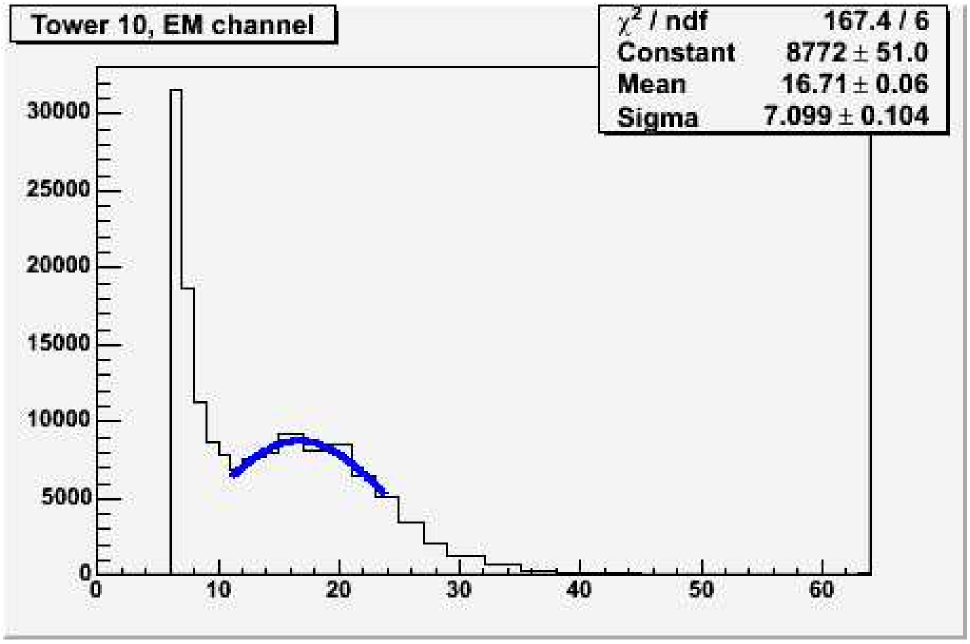

Figure 1: A sample fit of a single photoelectron spectrum at 1350V

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 were measured. The same reference tube was used throughout the measurements and the absolute gain of the reference tube was also measured accurately [1, 2]. Even though all the measurements were performed at 1100 V, it was shown [3] that the relative gains stayed flat as the HV increased.

Each HF wedge is divided into three sectors; inner, middle, and outer towers. PMTs were 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 were also selected so that they have almost identical relative gains within a few percent. In addition, each sector has fibers of two different length dividing each sector into a hadron (HAD) compartment and an electron/photon (EM) compartment. 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 (Table 1).

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}Co source. Source was inserted into each tower one at a time and the pulse height histograms obtained through the QIE readout system were recorded. The accumulated histograms for which the source was outside the HF wedge 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

Table 1: Average gains for the six groups of PMTs in Wedge 2-13 for 1350 V.

Group	Iowa Relative Gain	SPE Peak pos.[a]	Absolute Gain (CERN)[b] (in arbitrary units)	Rel. Gain (Iowa)[c] (renormalized)	Rel. Gain (CERN)[c]
HAD1	80.7	14.4±1.6	7.2±1.6	0.425	0.46±0.15
HAD2	97.5	15.6±1.1	8.4±1.1	0.514	0.54±0.07
HAD3	114.2	16.3±0.7	9.0±0.7	0.602	0.58±0.04
EM1	134.2	18.0±1.9	10.7±1.9	0.707	0.69±0.12
EM2	155.4	20.2±1.9	13.0±1.9	0.818	0.83±0.12
EM3	189.9	22.9±0.9	15.6±0.9	1.000	1.00±0.06

[a] SPE peak positions are obtained by fitting the single photoelectron distribution to a gaussian function.
[b] Effective pedestal value was subtracted from the SPE peak position.
[c] EM3 was chosen to be the reference group for the relative gains.

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 at 1350 V (Fig.1). For this data, the single photoelectron peak is easily identified. We were not able to get a good fit from four pulse height histograms corresponding to HAD PMTs only (Fig.2). The rest yielded good fits. However, at 1150V, we were able to get a good fit from only 11 histograms out of 48. We could not get a conclusive fit from some of the histograms because the single photoelectron peak overlapped with the pedestal as seen in Fig. 2. Mostly, this was the case when the gain was low.

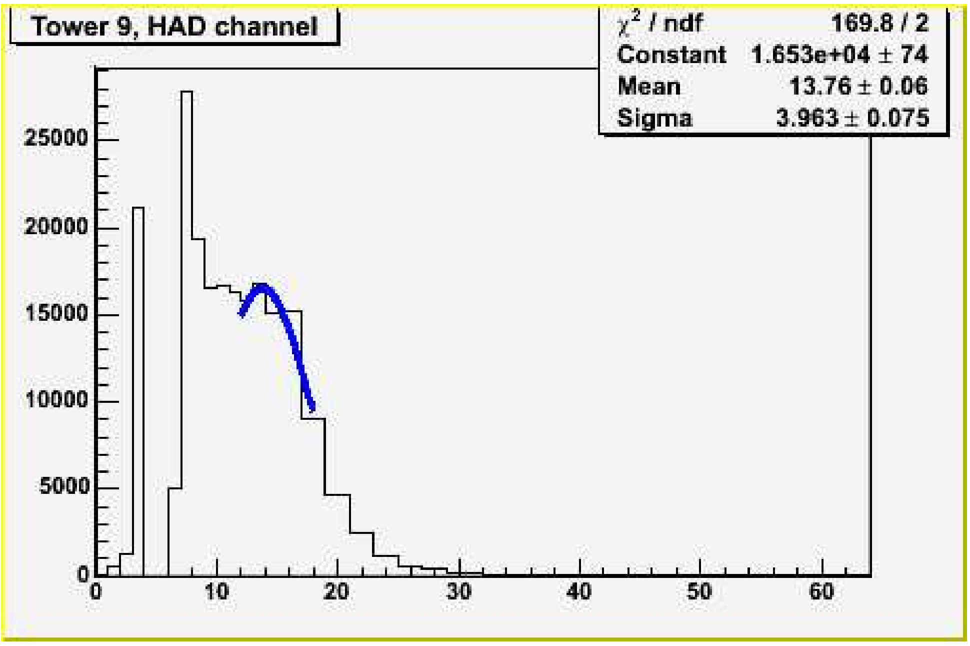

Figure 2: An example for an inconclusive single photoelectron spectrum at 1350V

4 Comparison of CERN and Iowa Relative gains

The single photoelectron peak positions were grouped according to the corresponding Iowa relative gains into six groups (Table 1). If the gains were corrected for the pedestals, fitting the average of each group versus the Iowa relative gains should yield a straight line and this straight line should pass 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 and an effective pedestal value were obtained (Fig. 3). 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 2). At lower HVs, 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.

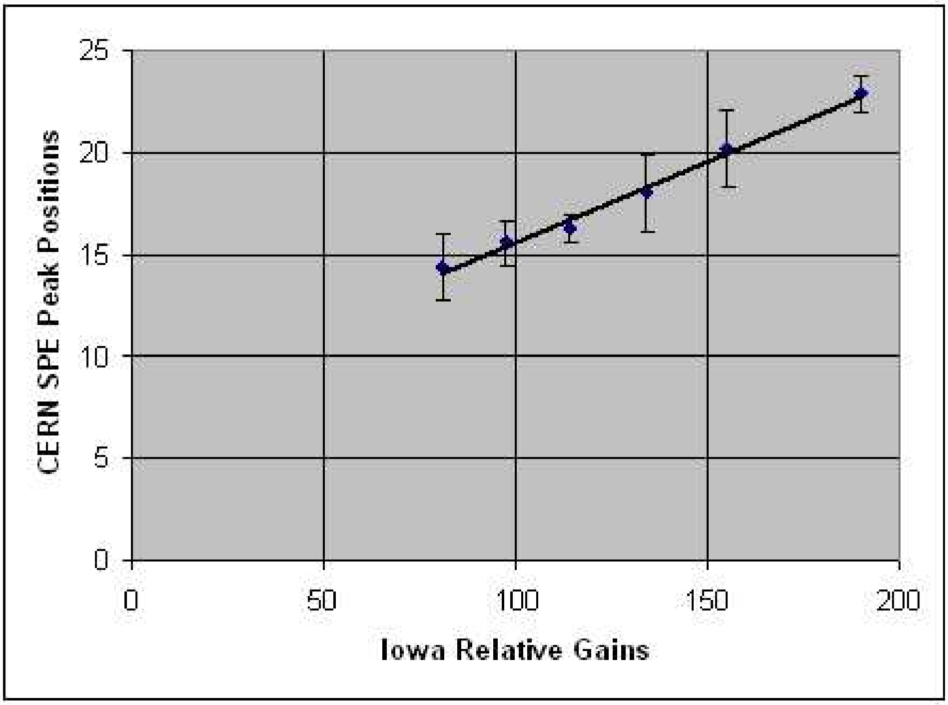

Figure 3: Single photoelectron peak positions or “uncorrected absolute gains (in arbitrary units)” (CERN) versus relative gains (Iowa). Intercept on the absolute gain axis is the effective pedestal value.

Table 2: Effective pedestal values obtained from the single photo electron peak positions.

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

To compare the Iowa relative gain measurements with the CERN measurements, the relative gains for each set have to be renormalized. This was done by taking one of the groups (EM3) as the reference and normalizing all the other gains or relative gains with respect to this group. In case of the Iowa relative gains, this means redefining our reference (Table 1). Fitting the CERN versus the Iowa relative gain values to a straight line yields a slope of almost one (0.99±0.15) with a linear correlation coefficient, r=0.994 (Fig. 4). Choosing a different set as the reference group yields slightly different slope in the fit. The value varies between 0.92 and 1.03 which is within the uncertainty (0.15). The linear correlation coefficient does not change.

5 Conclusion

In this study, we show that the relative gains measured at the University of Iowa PMT test station and the relative gains determined from the Test Beam 2004 source data are highly correlated. Because of the small number of PMTs in each sub-group, the uncertainty in the slope is somewhat larger than what is expected from the combination of Iowa and CERN measurements.

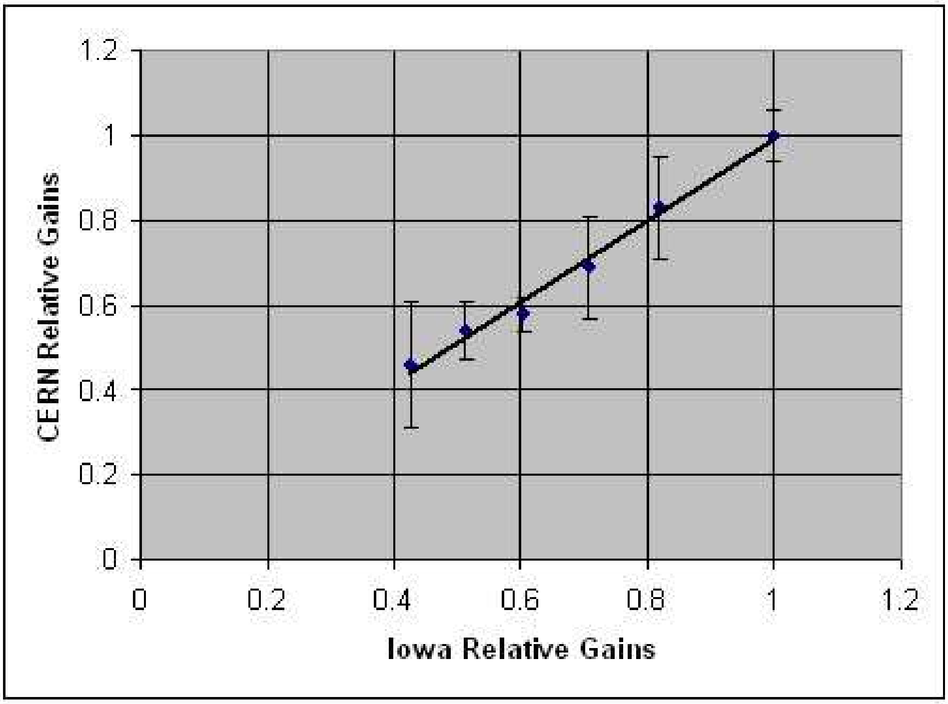

Figure 4: CERN relative gains versus Iowa relative gains.

Also, determining the pedestal values seems to require a more careful study.

References

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[2] U.Akgun, W.Anderson, A.S.Ayan, E.Gülmez, M.Miller, Y.Onel, I.Schmidt, D.Winn, Evaluation of PMTs from three different manufacturers for CMS-HF Forward Calorimeter, IEEE Tran. on Nuclear Science, **51**,(2004)1909.

[3] E.Gülmez, U.Akgun, Y.Onel, Variation of relative gains as a function of HV for the Hamamatsu R7525HA PMTs used in the HF Forward Calorimete, CMS Internal Report CMS IN-2005/006,(2005).