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Matching BCAL M.C. Energy Resolution to 2006 Beam Test

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Abstract

This note summarizes a Monte Carlo study to reproduce the resolutions of the 2006 BCAL Beam Test.

1 Introduction

In 2006 a prototype module of the BCAL detector was tested in a photon beam in Hall-B at Jefferson Lab. The results were published[1] for the configuration in which the beam was incident at 90° and centered on the BCAL module. A more recent Monte Carlo simulation[2] has been developed to study the BCAL performance. The Monte Carlo has been tuned to provide close agreement with the 2006 beam test results. This brief note documents the comparison and how the parameters of the final BCAL design differ from the prototype test.

2 Monte Carlo

Details of the GEANT3-based Monte Carlo are given in ref [2]. For the current comparison, a segmentation scheme of the existing light-guide + SiPM design was chosen to match the 2006 beam test as closely as possible. Figure 1 shows the chosen scheme with an outline of the prototype module over-layed. In the figure, the beam entered the module in the center of the bottom face. Most of the energy was deposited in the bottom 3 central sections where the cross-sectional area matches well.

There are a few major differences between the 2006 Beam test and the final BCAL design

- Fibers in prototype produced roughly half the light per MeV as those in the final design (75 photons/MeV/side vs 145 photons/MeV/side)
- SiPM readout will be used for the final design while phototubes were used for the beam test
- Different pre-amp circuits leading to different effective gains

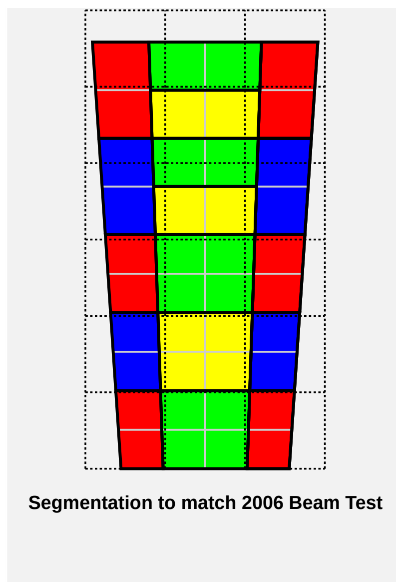


Figure 1: Segmentation used for the simulation study using the 2006 beam test configuration. The size and segmentation of the module in the 2006 test is shown by the dotted lines. The colored boxes indicate the segmentation used for the current study. In this picture, the beam enters from the center of the bottom edge.

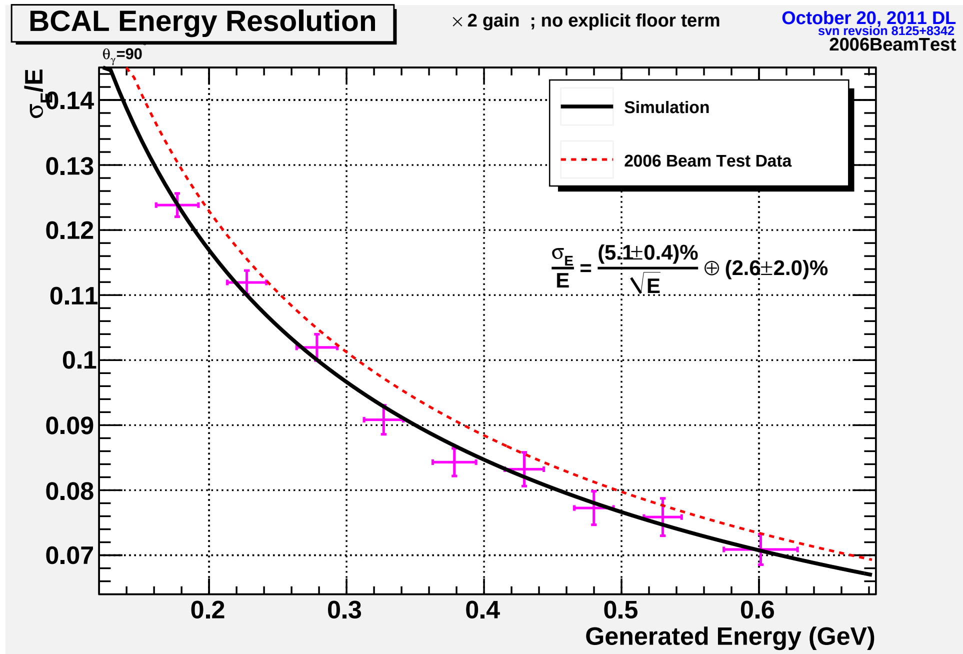


Figure 2: Energy resolution obtained from two different calibrations of the same dataset. The top two plots show the energy resolutions while the bottom two plots show the calibrations used to obtain the results. See text for more details.

The light output from the fibers will affect the contribution to the resolutions due to photostatistics. The SiPM's have dark hits not present in the PMTs. The SiPMs also use amplification on specially designed boards that includes 2 stages of gain for the TDC signal and 1 stage of gain for the fADC signal. For the PMTs used in the beam test, all amplification was done in the tube and the base included a splitter (50/50?) such that both the TDC and ADC signals were fed directly from it.

2.1 Energy Resolution

The energy resolution obtained from the current simulation study is shown in figure 2. The red, dotted curve in the plot indicates the parameters derived from analysis of the 2006 beam test data[1]. The black, solid curve represents a fit to the data points (shown) derived from the current Monte Carlo simulation study. The plot indicates good agreement between the beam test data and simulation.

2.2 Sensitivity to Calibration

Figure 3 shows the energy resolution obtained using two different calibrations of the same dataset. These illustrate the sensitivity of the total shower resolution to the calibration. The plot on the lower right is a fit using one parameter, the slope, while the plot on the lower left used two parameters, slope and intercept. Both fits are done to the same dataset. The top left and top right plots show the corresponding energy resolutions obtained using the two calibrations. Table 1 summarizes the χ^2 per degree of freedom for each of the two fits. The χ^2/NDF for both fits would indicate acceptable fit results.

Table 1: Fit quality for two calibration shown in fig 3 and described in the text.

	χ^2	NDF	χ^2/NDF
Fit1	23.9	26	0.92
Fit2	31.5	27	1.17

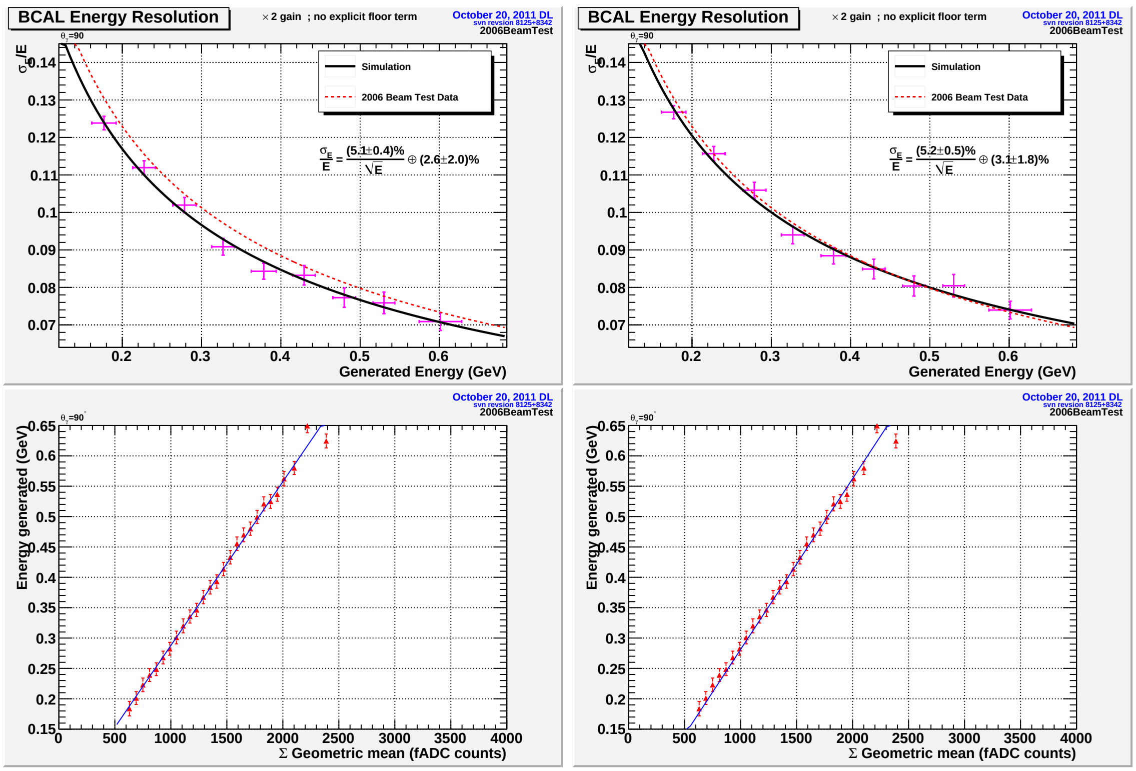
2.3 Time Difference Resolution

For the 2006 beam test, the gain of the signal was determined largely by the voltage settings of the PMTs. While effort was made to match the gains and the resulting voltages are known, the exact gain these correspond to is not easily determined. The time difference, $\Delta t/2$ was obtained from the same Monte Carlo dataset using multiple gains and the results shown in figure 4. The figure indicates that the ratio of gains between the actual beam test electronics and the simulated signal of the current Monte Carlo study may be between 1:1 and 2:1.

It can be seen that the shape of the curves indicated by the markers in figure 4 are not well matched to the functional form given on the figure. Specifically, $\sigma = A/\sqrt{E} \oplus B$ will not yield a good fit to this data. This may be due to threshold effects. To determine the timing, a threshold of 20mV was used as indicated in figure 8 of ref. [1]. By adjusting this threshold simultaneously with the gain, it is assumed one might achieve markers that more closely match the given functional form.

3 Summary

A comparison between the current Monte Carlo simulation and results reported from the 2006 beam test was made. These indicate good agreement between the two giving some confidence in the methods employed in the M.C. study.



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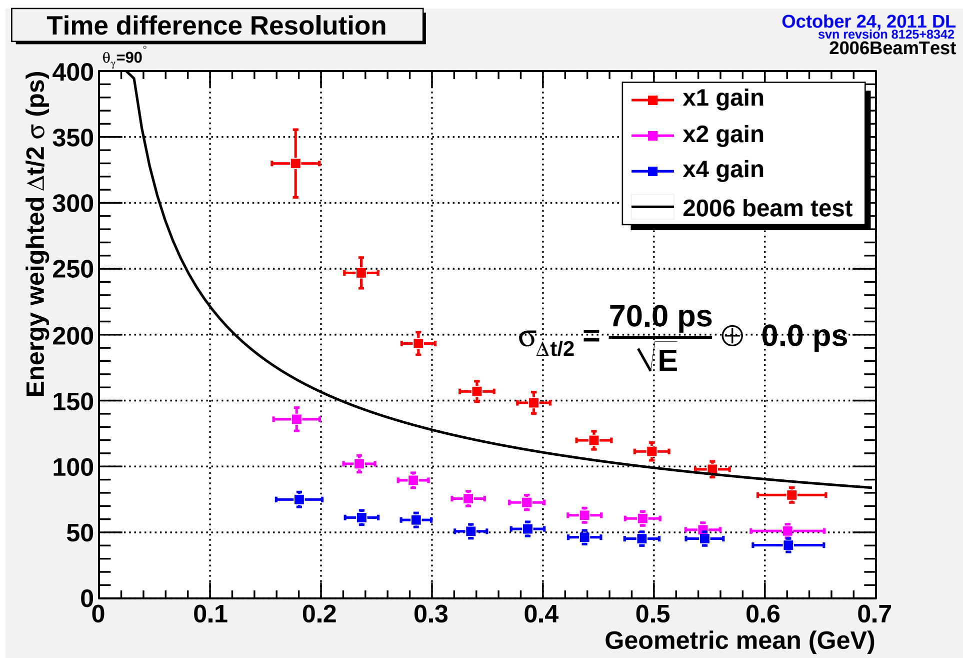

Figure 4: Time difference resolution ($\Delta t/2$) for fully reconstructed BCAL showers. The black curve represents the final resolution reported for the 2006 Beam Test data. The markers indicate the results from the current Monte Carlo study with various gain factors.

References

[1] B.D. Leverington, G.J. Lolos, Z. Papandreou, R. Hakobyan, G.M. Huber, K.L. Janzen, A. Semenov, E.B. Scott, M.R. Shepherd, D.S. Carman, D.W. Lawrence, E.S. Smith, S. Taylor, E.J. Wolin, F.J. Klein, J.P. Santoro, D.I. Sober, and C. Kourkoumeli. Performance of the prototype module of the gluex electromagnetic barrel calorimeter. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 596(3):327 – 337, 2008.

[2] David Lawrence. Bcal segmentation. Technical Report GlueX-doc-1801, JLab, 2011.