Understanding the BCAL Energy Resolution and Calibration

A Progress Report - Installment II

Alex R. Dzierba

Re-visiting the Calibration: In the previous note I looked at energy deposition in layers and compared that to the epected mean longitudinal profile in an electromagnetic cascade[1]:

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)} \tag{1}$$

where t is thickness in radiation lengths, E_0 is the energy of the particle initiating the shower, $b \approx 0.5$, and

$$\frac{a-1}{b} = t_{max} = \ln\left(\frac{E_0}{E_c}\right) + 0.5 \tag{2}$$

with $E_c \approx 800$ MeV$/Z_{eff}$. From the note by Zisis and others[2] we have $Z_{eff} \approx 73$ for the Pb/SciFi matrix and a radiation length of 1.3 cm. Equation 1 can then be used to compare the expected fractional energy deposition in each layer with data.

In the previous note I simply evaluated equation 1 at the center of each layer and multiplied by layer thickness to obtain the fractional energy deposition in the layer. I now integrate the function over the layer thickness. The total fractional energy integrated over six layers is 98% at the highest beam energy.

In calculating the energy deposition per layer for the normal incidence run (run 2334) I found the North-South geometric mean per segment and summed over segments for each layer. I then then tuned[3] the calibration constants for the first four layers to achieve reasonable agreement between data and the expected fractional energy deposition per layer – see the left panel of Figure 1. I then used these calibration constants in run 2363 (nominal beam incidence of 40°) and re-computed the expected deposition using equation 1. The results are shown in the right panel of Figure 1.

Note that the parameterization of equation 1 fails to describe the data below about 300 MeV. According to the reference cited in footnote 1, the parameterization was originally obtained by fitting energy deposition profiles for carbon through uranium from 1 to 100 GeV. However, there also seems to be a discontinuity in the data at around 300 MeV for the first three layers.

I also noticed that the nominal 40° data were better described by assuming an angle of incidence of 45°. Is is possible that there was some ambiguity in determining the angle for run 2363? For completeness, I show the expected energy deposition for the first four layers at 40°, 45° and 50° in Figure 2. Again, however, I do not know how reliable equation 1 is for our application and our range of energies.

It would be good to compare data with more detailed GEANT-based simulations of the BCAL module.

[1] See the *Passage of Charged Particles Through Matter* section of the Particle Data Booklet.
[2] *BCAL Radiation Length Calculations*, GlueX-doc-439.
[3] I tuned *by hand* - it took 3 iterations. The calibration constants for layers 1, 2, 3 and 4 are 0.83, 0.88, 1.22 and 1.73 with an overall calibration from ADC to energy to yield a mean beam to calorimeter energy ratio of unity.

Measuring Attenuation Length I used information from the North and South PMT's for segment 8 for runs 2334, 2335 and 2336 where the beam was positioned at 0, -50 and -100 cm with respect to module center. The result of a fit to an exponential is shown in Figure 3. The resulting attenuation length is 259 ± 8 cm[4].

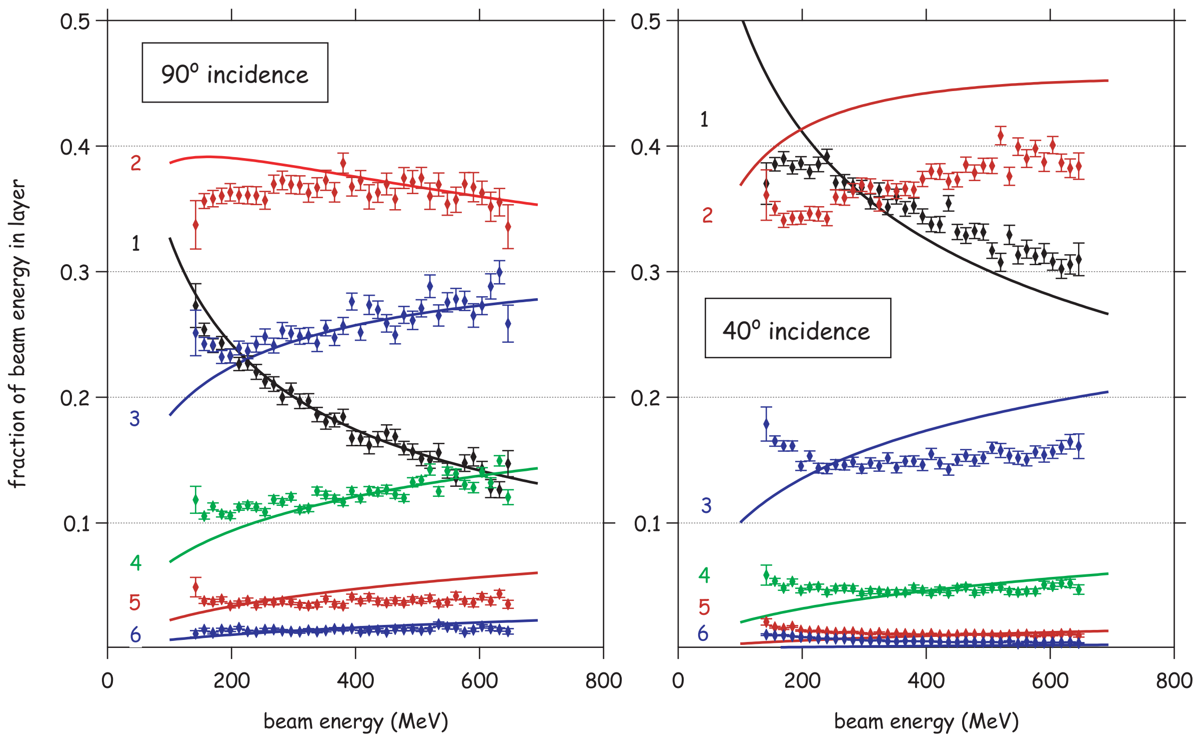

Figure 1: Left panel: Comparison of energy deposition in the six BCAL layers for run 2334 (normal incidence at the module center) with the expected deposition according to equation 1. The calibration constants for the layers were tuned to agree with expectations. Right panel: Comparison of data and expectations for run 2363. For the curves, an angle of incidence of 45° was assumed – see the text for more details.

[4] Christina Kourkoumeli reported an attenuation length measurement of 257 cm at the May 14-15 2007 PID Workshop.

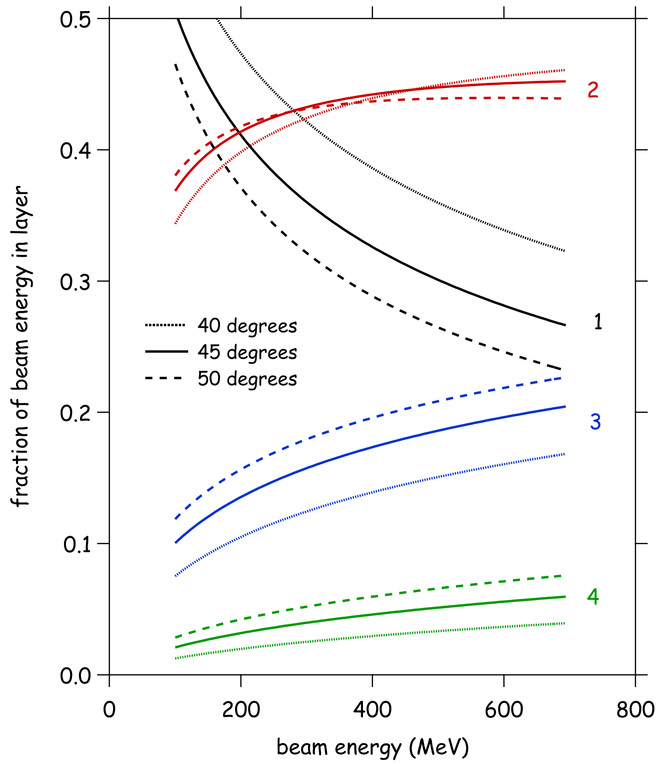

Figure 2: Expected energy deposition for the first four layers at 40°, 45° and 50° using equation 1.

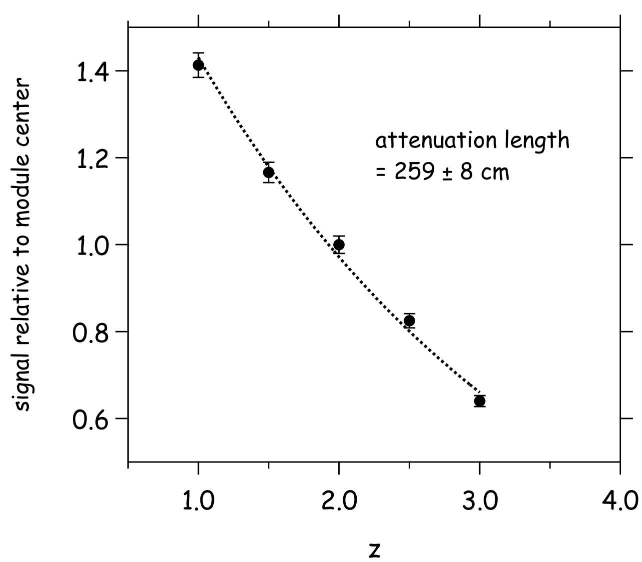

Figure 3: Attenuation length estimate using information from the North and South PMT's for segment 8 for runs 2334, 2335 and 2336 where the beam was positioned at 0, -50 and -100 cm with respect to module center. The result of a fit to an exponential is shown in Figure 3. The resulting attenuation length is 259 ± 8 cm.