Understanding the BCAL Energy Deposition per Layer

A Progress Report - Installment IV

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Summary of what follows: The goal is to use information about fractional energy deposition per layer in the BCAL test module as a constraint in calibrating the module. We have been using a parameterization of the longitudinal energy deposition in an electromagnetic shower to estimate the fractional energy deposited in each BCAL layer as well as a GEANT-based simulation (carried out by Blake) for photons incident at 90° and 40°. The analytical parameterization as given in the Particle Data book[1] depends on the critical energy, E_c, for which two approximations are given. The radiation length, X_0, of the lead/scintillating fiber matrix used in the test module is uncertain (Zisis is calculating it) ranging from 1.3 to 1.5 cm. In this note, we assume the results of the simulations, which seems to describe the data[2], is the *Gold Standard* and we compare these with the analytic parameterization under difference assumptions about E_c and X_0 to get some feel for how sensitive the analytical calculations are on these parameters.

Conclusions: For 90° incidence, varying E_c and X_0 can lead to a better agreement between analytic and simulation results for either layer 1 or 2 but not both. The differences between analytic and simulation results increase for 40° incidence. It is clear that the radial shape of the shower, and its longitudinal dependence, must be taken into account in trying to extend the analytical results to other than non-normal incidence. The radial dependence of the shower must also be taken into account for normal incidence – here we assume full containment transverse to the beam.

Results: The expression for the longitudinal energy deposition in an electromagnetic shower, as given in reference 1 is:

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

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 is the critical energy. Reference 1 cites two approximations for E_c, one (≈ 610 MeV$/(Z+1.2)$) from Rossi[3] and another (≈ 800 MeV$/(Z+1.2)$) from Berger and Seltzer[4]. I have been using the latter and Christine has been using the former in understanding test beam data with a pre-radiator.

[1] See the *Passage of Charged Particles Through Matter* section of the Particle Data Booklet.

[2] A. Dzierba, *Understanding the BCAL Energy Deposition per Layer - A Progress Report - Installment III*, June 7, 2007.

[3] B. Rossi, *High Energy Particles*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1952.

[4] M.J. Berger and S.M. Seltzer, *Tables of Energy Losses and Ranges of Electrons and Positrons*, National Aeronautics and Space Administration Report NASA-SP-3012 (Washington DC 1964).

Equation 1 is widely used. One relatively recent paper by Grindhammer and Peters[5] has a nice discussion of the use of the parameterization of longitudinal and radial profiles to describe showers in homogenous and sampling calorimeters.

Figures 1 through 4 show the fractional energy loss per BCAL layer as a function of incident energy E_γ. The solid curves are the results of Blake's simulations and are identical in all the figures. These curves are the results of second-order polynomial fits to Blake's results, as described in reference 2. The dashed curves are the result of using equation 1 with different values of E_c and X_0. In each case the left panel is for 90° incidence and the right panel is for 40° incidence.

Figure 5 shows the fraction of energy contained, as a function of E_γ, for different values of the radiation length, estimated by integrating equation 1 over the six layers of the BCAL module and assuming full containment transverse to the beam.

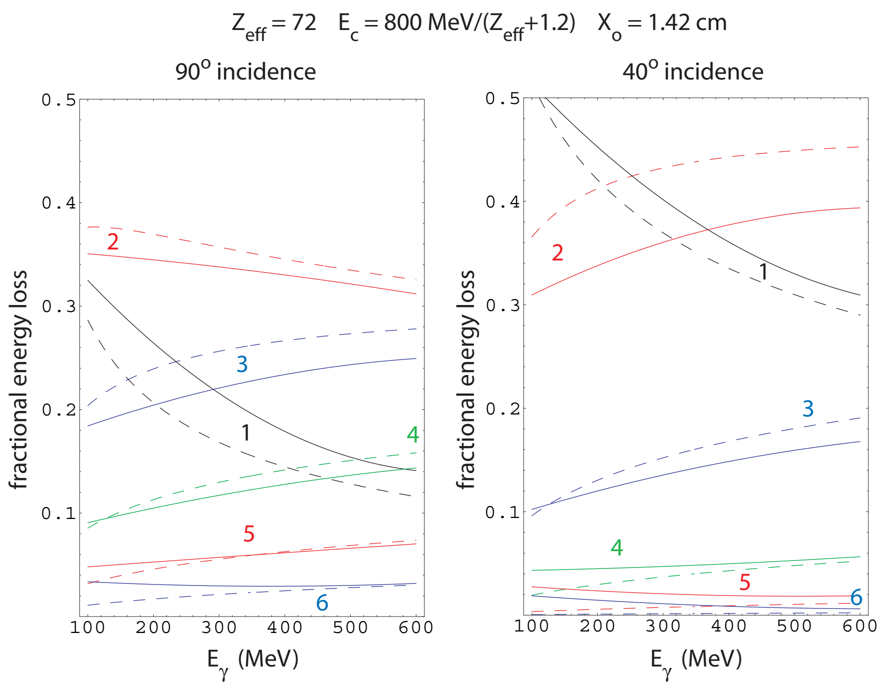

Figure 1: Fractional energy deposition for each BCAL layer, as a function of beam energy, using equation 1 (dashed curves) and simulations (solid curves). The left panel is for 90° incidence and the right panel is for 40° incidence.

[5]G. Grindhammer and S. Peters, *The Parameterized Simulation of Electromagnetic Showers in Homogeneous and Sampling Calorimeters*, hep-ex/0001020 (2000).

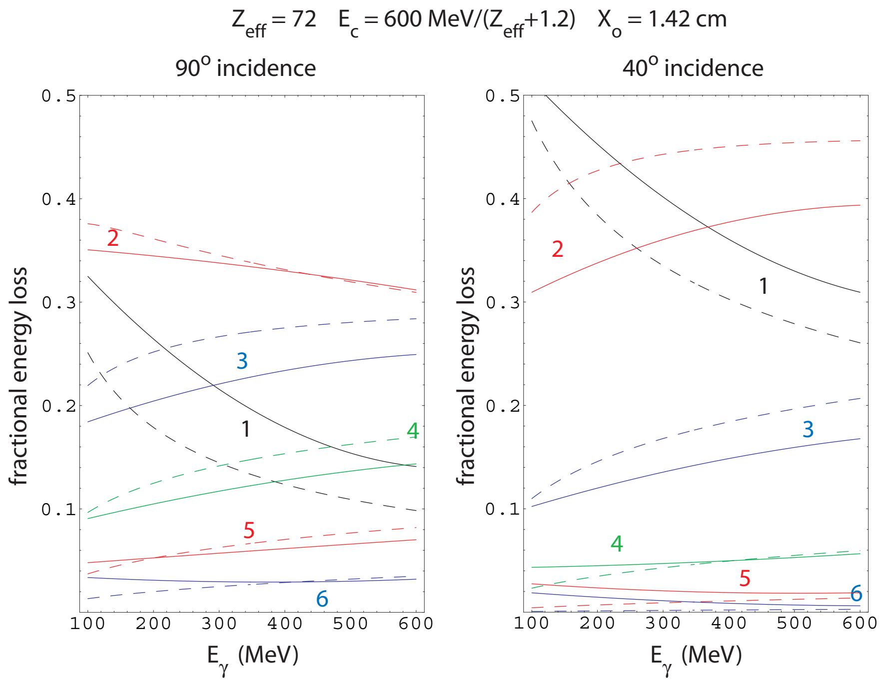

Figure 2: Fractional energy deposition for each BCAL layer, as a function of beam energy, using equation 1 (dashed curves) and simulations (solid curves). The left panel is for 90° incidence and the right panel is for 40° incidence.

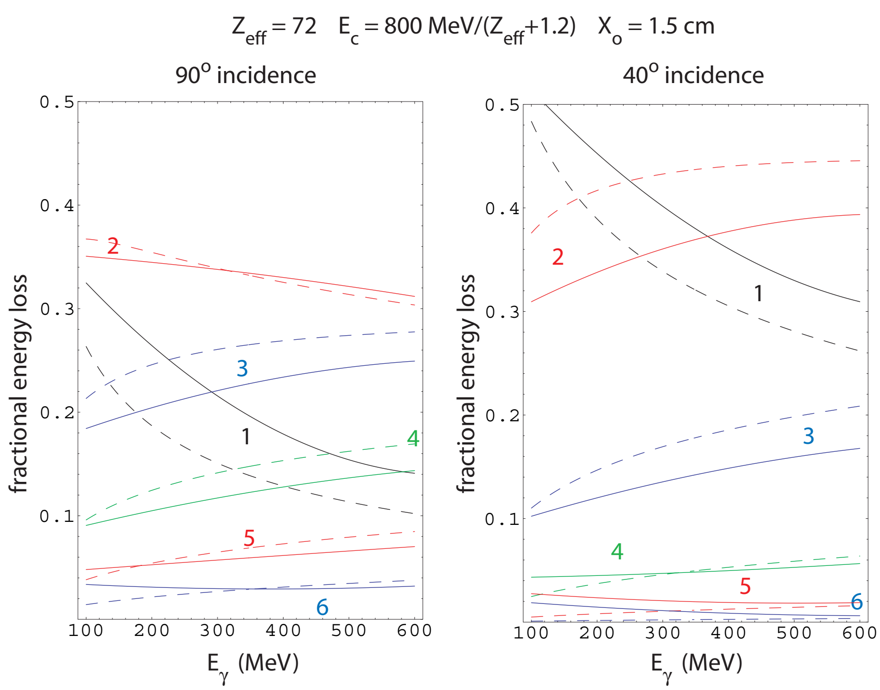

Figure 3: Fractional energy deposition for each BCAL layer, as a function of beam energy, using equation 1 (dashed curves) and simulations (solid curves). The left panel is for 90° incidence and the right panel is for 40° incidence.

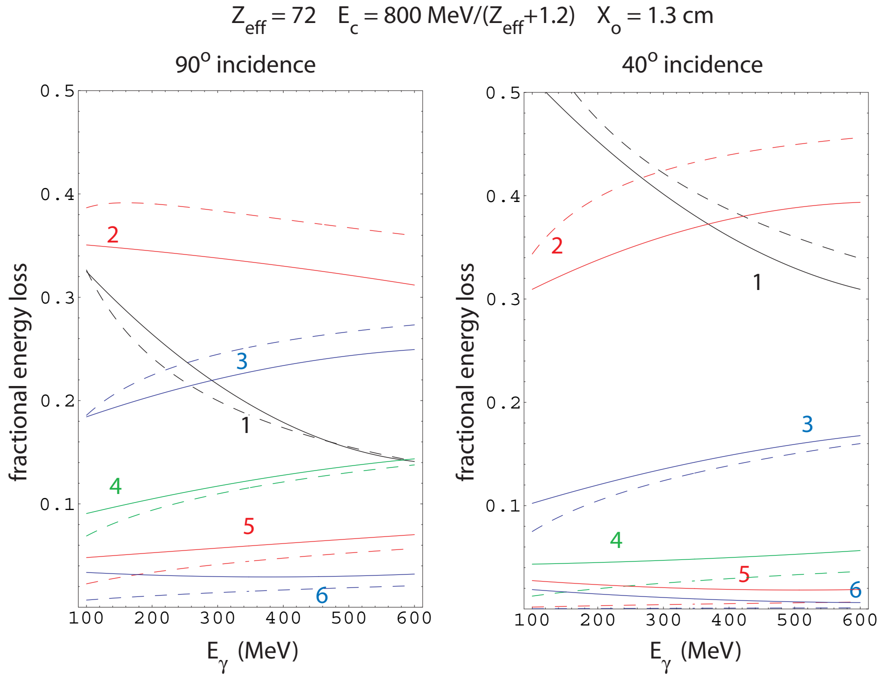

Figure 4: Fractional energy deposition for each BCAL layer, as a function of beam energy, using equation 1 (dashed curves) and simulations (solid curves). The left panel is for 90° incidence and the right panel is for 40° incidence.

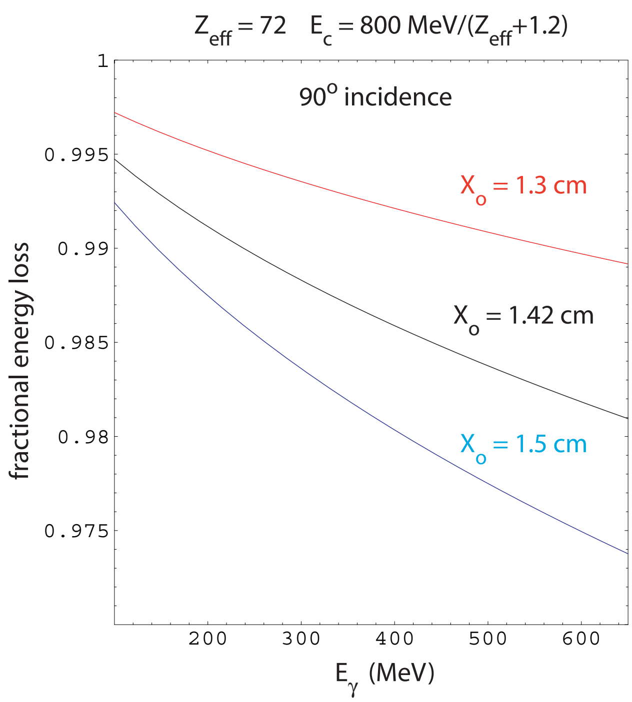

Figure 5: The fraction of energy contained, as a function of E_γ, for different values of the radiation length, estimated by integrating equation 1 over the six layers of the BCAL module and assuming full containment transverse to the beam.