BCAL Energy Deposition and Leakage

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Abstract

Simulations were carried out to study the response of the electro-magnetic barrel calorimeter of the GlueX Project. Specific issues that were investigated included the fraction of energy deposited in the scintillating fibers as well as the energy leakage from the sides of a single module. The results will be used as parameterized input to the full HDGEANT GlueX detector simulation package.

Key words: beam tests, scintillating fiber, barrel calorimeter, Monte Carlo simulations
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1 Introduction

The electro-magnetic barrel calorimeter, BCAL, for the GlueX Project consists of alternating layers of thin lead sheets and 1-mm-diameter scintillating fibers (SciFi). The BCAL is segmented into 48 modules with each module comprised of approximately 18,300 4-m-long fibers, thus requiring a total of over 3,500 km of fibers.

A 4m-long prototype module, termed Module 1, was constructed in 2004. Module 1, shown schematically in Figure 1, has a rectangular cross section of 13 x 23.0 cm^2. The scintillating fibers were made by PolHiTech and are blue emitting with a peak emission wavelength of 420 nm and an attenuation length of ~250 cm. The fibers have a diameter of 1 mm (with 3% and 1% being the thickness of the first and second cladding layers) and the thickness of the lead sheets is 0.5 mm. The module has 186 planes of Pb/SciFi. The composite has a Pb:SciFi:Epoxy ratio of 37:49:14 and an overall density of ~5 g/cm^3 and a radiation length X_0 of 1.5 cm. Each layer of the module to be tested has 96 SciFi's spaced 1.35 mm apart (center-to-center) with the layers being 1.18 mm apart so that a uniform SciFi density is presented across the shower path.

2 Simulations

Simulations were carried out for an individual module using a standalone version[1] of GEANT3. Select simulation results were already reported to the GlueX collaboration [1,2]. Herein, results are shown on the simulation of the energy deposited in the SciFi

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[1] The standalone Regina code that was used is termed *gbcal*.

and Pb as well as details on the energy leakage from all non-readout sides of the module. A typical shower profile in the PbSciFi matrix is shown in Figure 2.

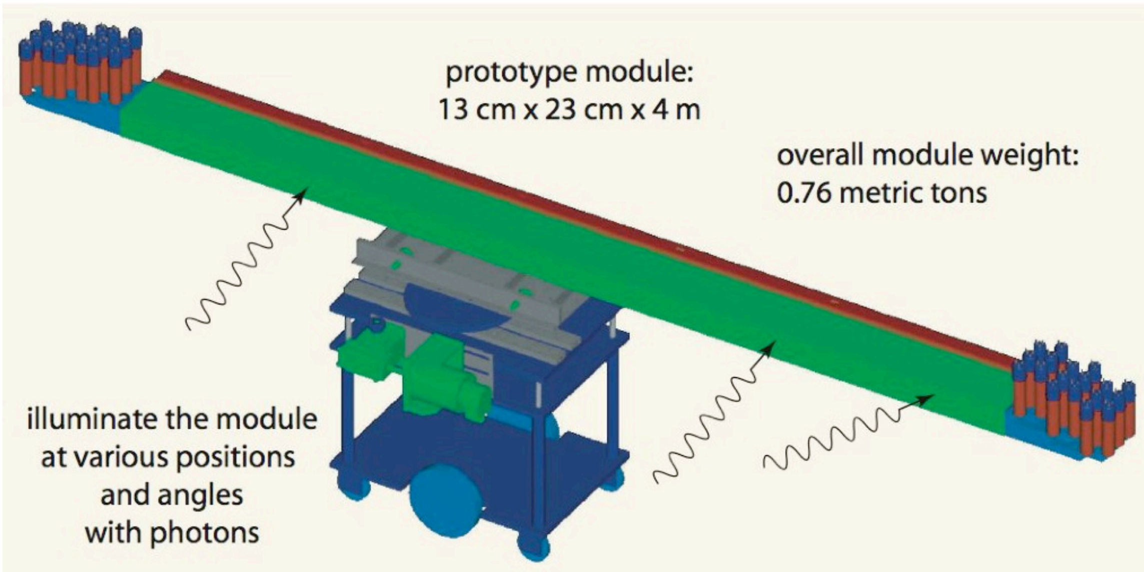

Fig.1. Schematic drawing of the prototype BCAL module with its readout on either end as deployed for the beam tests at Hall-B, Jefferson Lab. Eighteen photomultiplier tubes were attached to either end.

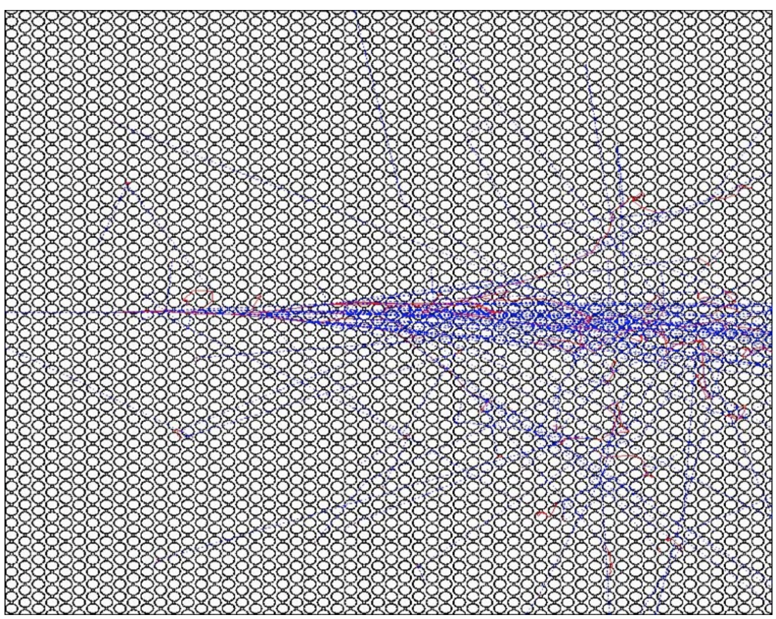

Fig.2. Shower profile in the PbSciFi matrix as generated by the *gbcal* simulation.

A uniform incident photon energy distribution was assumed for the initial simulations, in the range of 0 to 5 GeV. This spectrum and the distributions for the energy leaking out of all sides of the module and for that deposited in the Pb and SciFi are shown in Figure 3. The end point of the latter two spectra indicates the percentage of the energy deposited in the lead or fibers, respectively.

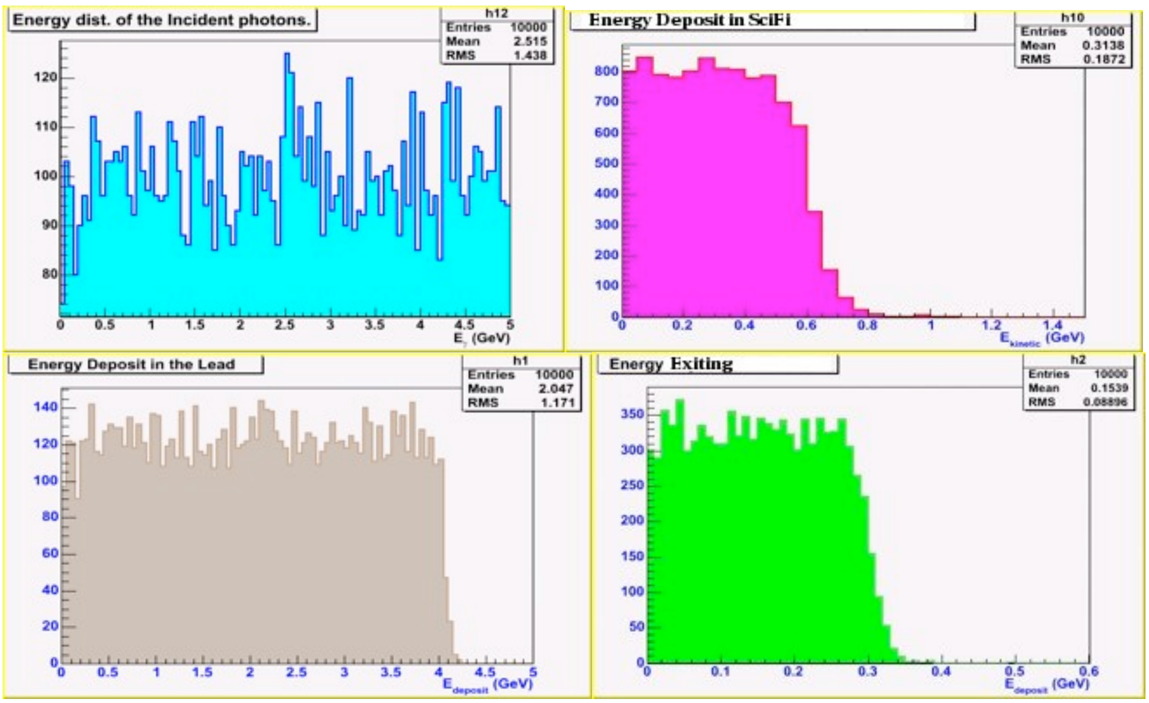

Fig. 3. The incident photon energy profile in the simulations (top left), energy exiting the rear of the module (bottom right), and energy deposited in the lead and scintillating fibers (bottom left and top right) are shown, respectively.

The simulated deposited energies in the lead and SciFi versus the photon energy are shown in Figure 4. The straight-line behaviour is indicative of the constancy of the fraction of energy deposition, and specifically for the fibers it shows the sampling fraction value of ~12%. The ratios of these deposited energies and the exit energy with respect to the photon energy, as a function of the latter, are presented in Figure 5. It should be noted that he distributions in Figure 4 broaden considerably at lower photon energies, specifically below 0.5 GeV, which is the range of the Hall-B beam tests. This effect will require further study.

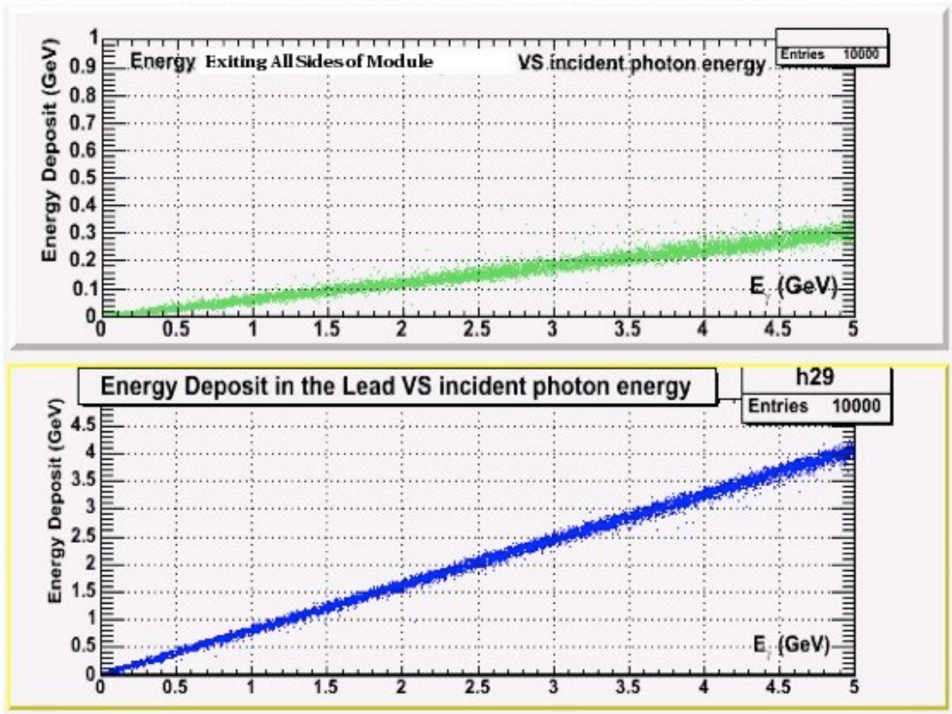

Figure 4: Energy deposit in the lead and exit energy as a function of photon energy.

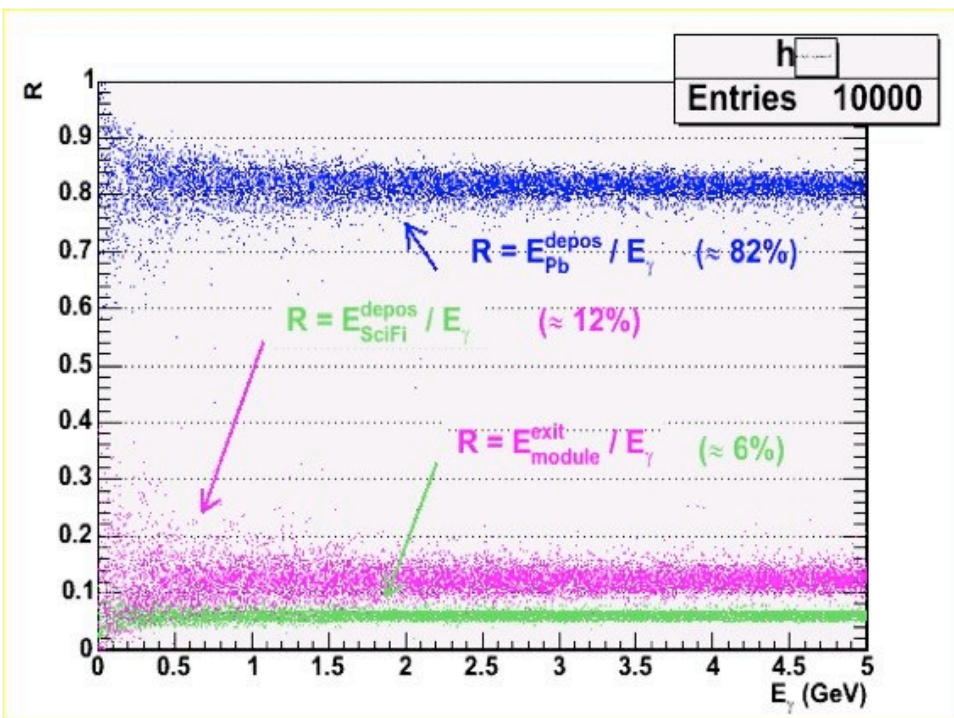

Figure 5: Energy deposit and energy leakage ratios to the photon energy as a function of the photon energy. Notice the broadening (along the y-axis) of the distributions, bellow 0.5 GeV.

The deposited energy spectra for three typical photon energies (650, 500 and 200 MeV) are shown in Figure 6 for the three available collimators in Hall-B. The beam tests were collected with the 2.6 mm collimator. The ratios of the RMS to mean for the three energies are 0.139, 0.089 and 0.86 for the 200, 500 and 650 MeV photons, respectively.

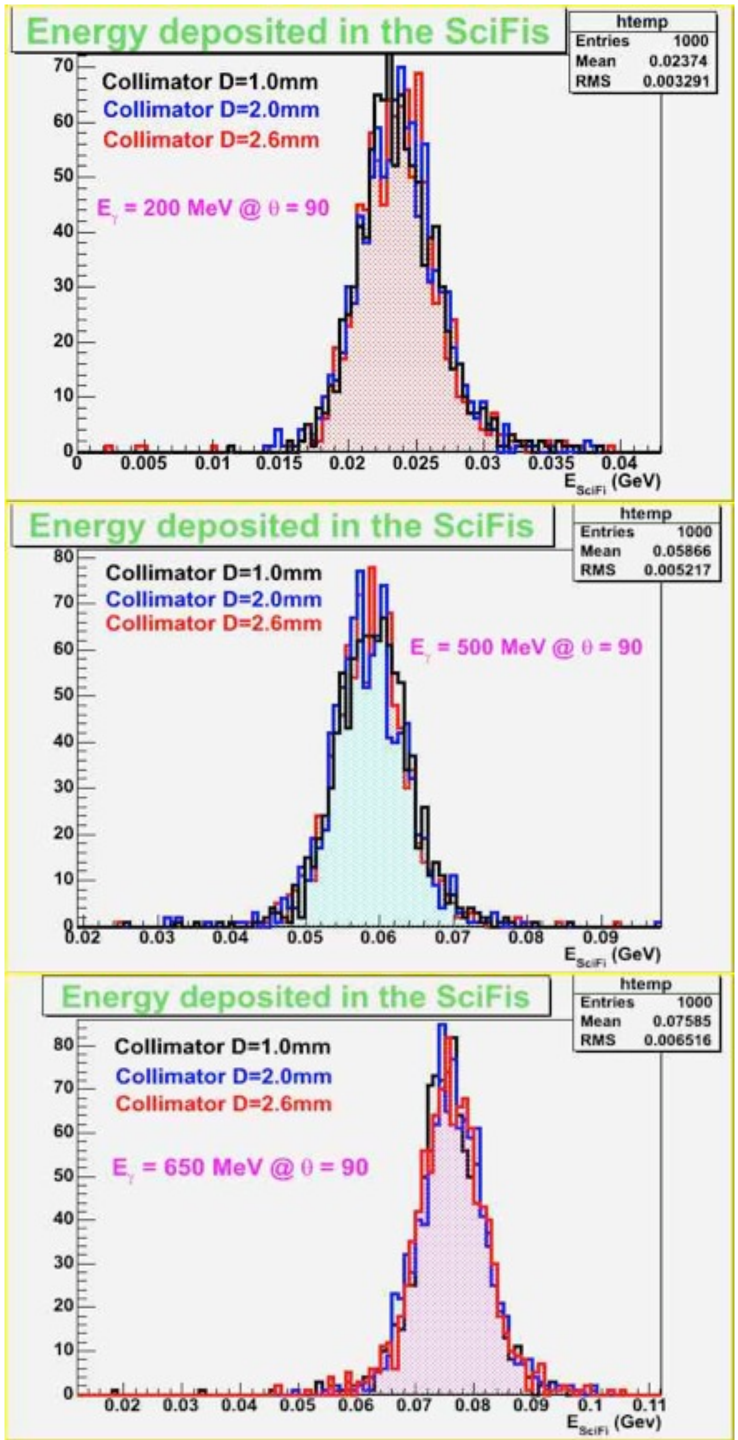

Figure 6: Energy deposition in the SciFi for three simulated photon energies.

A simulation study was carried out towards understanding the energy leakage from the four non-readout sides of the module, for three different collimator apertures in Hall-B. The leakage for the front, rear, top and bottom sides of the module is shown in Figure 7 for 650 MeV photon energy (the tagger's upper limit during these tests) and for 200 MeV energy (slightly above the tagger's lower limit of 150 MeV).

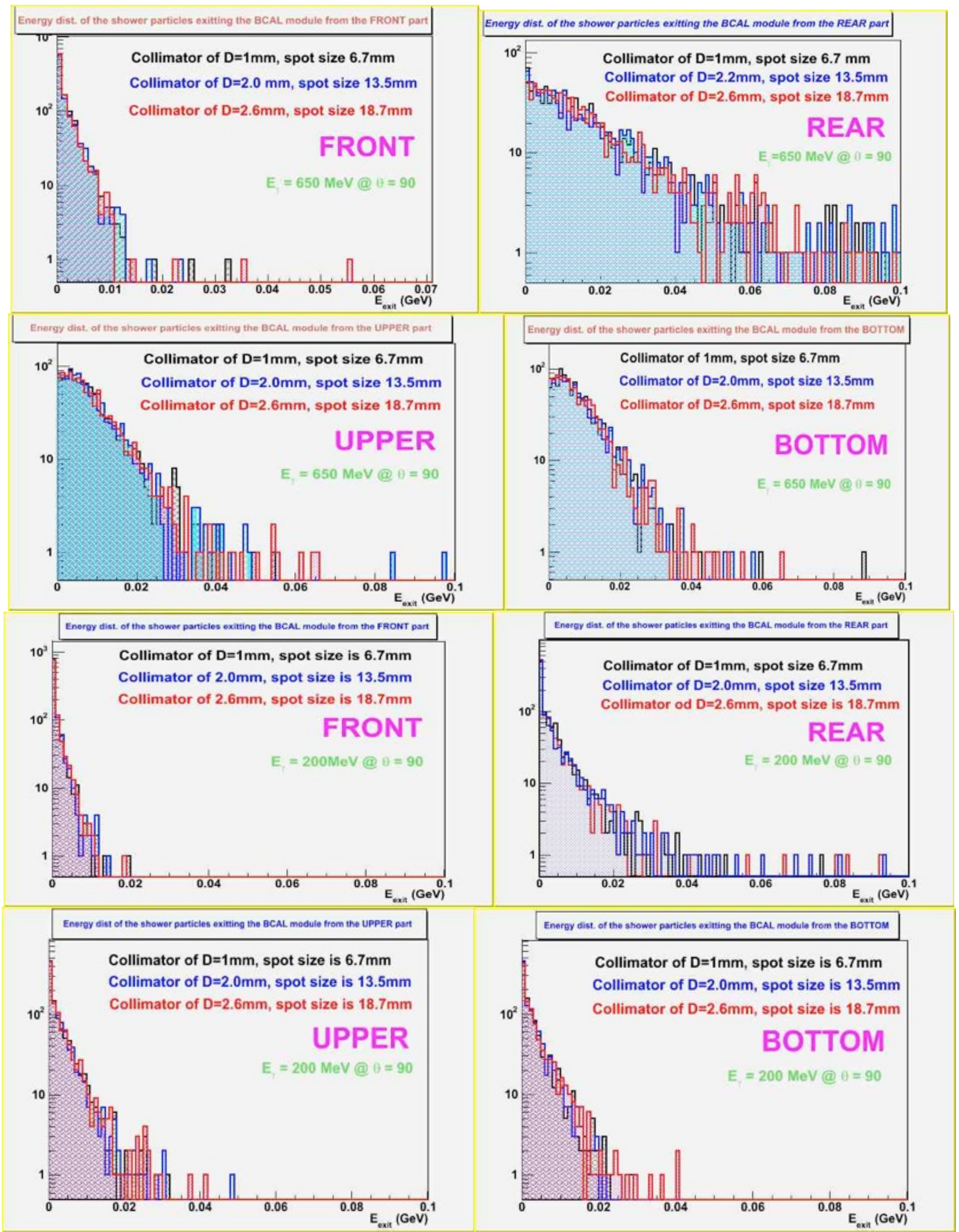

Figure 7: Energy leakage from each of the four sides at two different photon energies.

The leakage, for 500MeV photons for three different angles of the beam with respect to the long axis of the module, is shown in Figure 8.

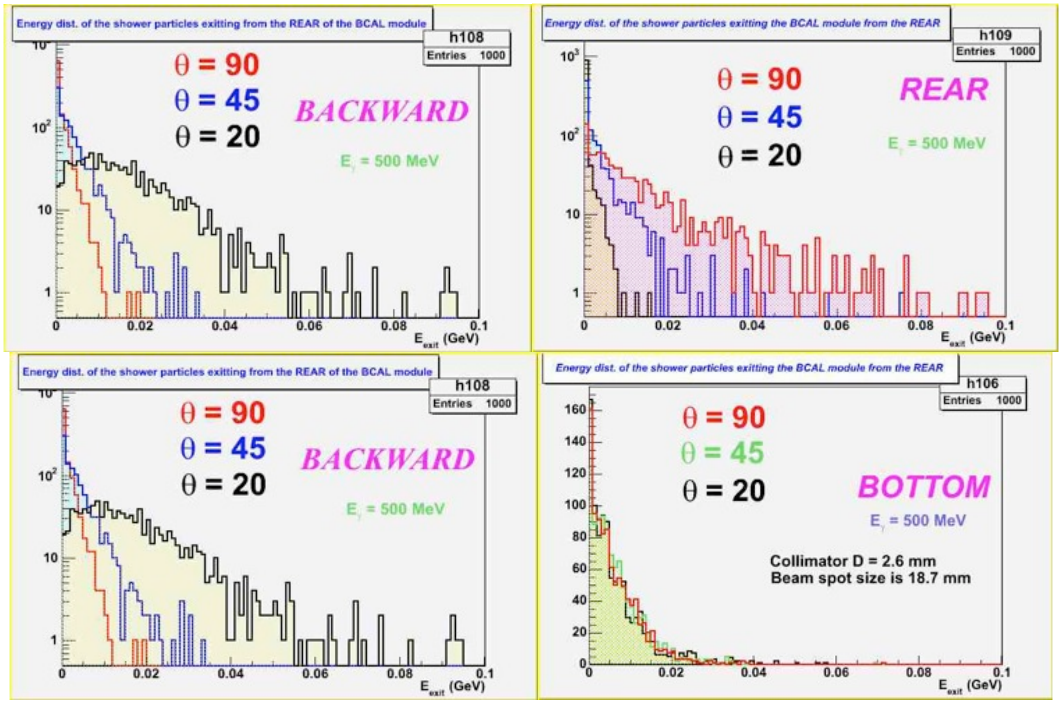

Figure 8: Energy leakage from each of the four sides for three different incident angles.

The energy leakage results are summarized in Figure 9. Once again the label 'backward' is synonymous to 'front' since it refers to events that 'bounce' off the front face of the module. Such events would strike a module on the opposite of the initially struck module, in the full 48-module configuration. The percentage of energy leaking out the sides is summarized in Table 1.

Eγ (MeV)	θ (degrees)	Eleak/Eγ (percentage)				
		Front	Rear	Top	Bottom	Total
650	90	0.56±0.02	3.42±0.15	1.37±0.04	1.33±0.04	6.68
	45	0.81±0.02	0.90±0.04	1.46±0.04	1.45±0.04	4.62
	20	3.13±0.08	0.51±0.01	1.39±0.04	1.34±0.04	6.37
500	90	0.56±0.02	3.13±0.15	1.37±0.04	1.37±0.04	6.43
	45	0.91±0.03	0.92±0.07	1.47±0.04	1.43±0.04	4.73
	20	3.50±0.09	0.52±0.01	1.35±0.04	1.44±0.04	6.81
200	90	0.73±0.02	2.01±0.12	1.68±0.07	1.74±0.07	6.16
	45	1.23±0.05	0.87±0.05	1.60±0.06	1.68±0.06	5.38
	20	4.42±0.16	0.52±0.01	1.51±0.06	1.52±0.08	7.97

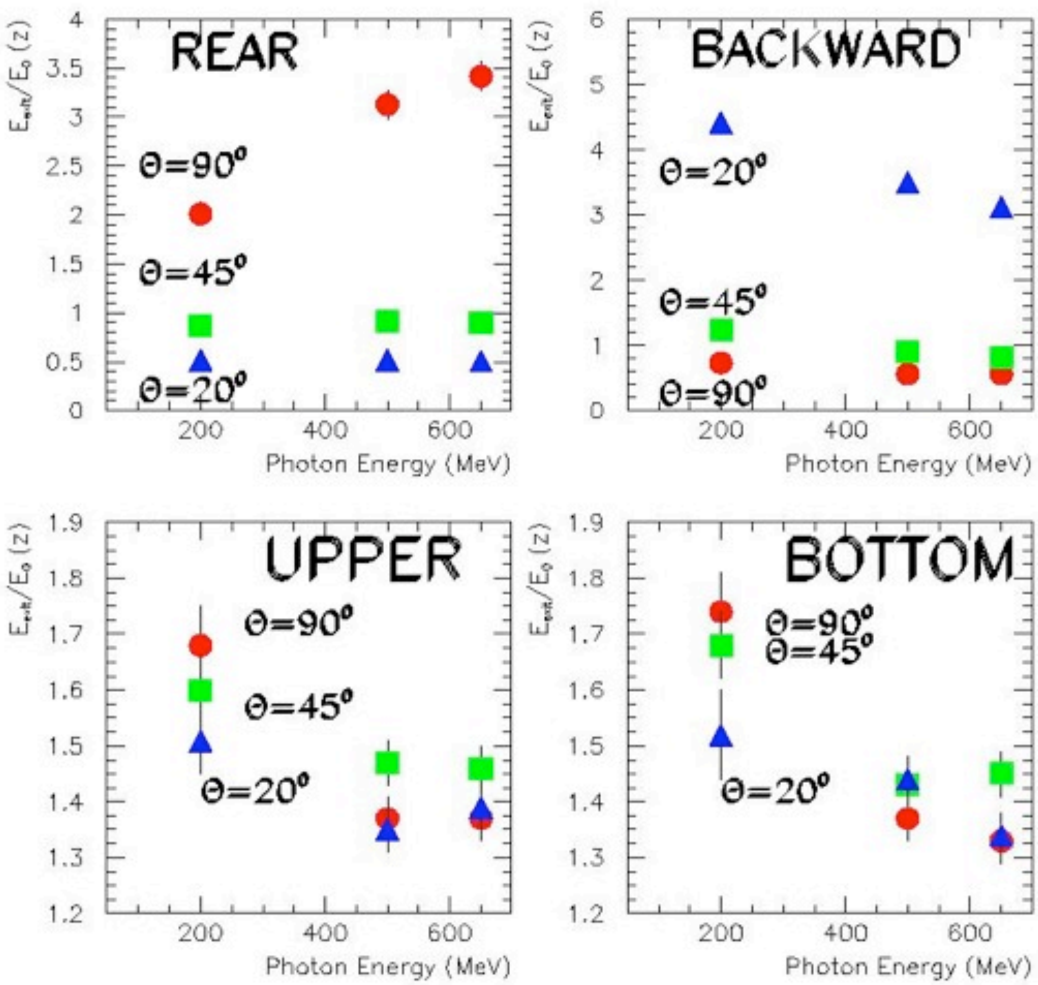

Figure 9: Energy leakage from the four sides of Module 1 as a function of incident photon energy and for three different incident angles; θ= 90^0 corresponds to the photons impinging perpendicularly to the module.

3 Summary

An initial set of simulations for a single BCAL module has been carried out. The results show a ~12% sampling fraction, an energy leakage of 6-7% at most angles and ~5% at 45^0 incidence. Clearly, the side losses are not an issue since adjacent modules in the production mode would capture these. New, more detailed simulations are under way.

4 References

[1] – R. Hakobyan and Z. Papandreou, 'BCAL Simulations for the Hall-B Tests', GlueX-doc-796 (2007).

[2] – R. Hakobyan, 'Energy Leakage Simulations', GlueX-doc-797 (2006).