GlueX Note - xxx
Issued: July 15, 2008

Non-linear photon energy corrections in the FCAL

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1 Introduction

This document describes a calibration procedure used to obtain photon momenta from reconstructed shower energy and position. For this study, photons were generated from the center of the GlueX target uniformly in azimuth and polar angle up to 12 degrees, using a grid that covered the range in photon energies from 50 MeV to 8 GeV. Deposited energy of shower particles in a single FCAL block was attenuated along the block with attenuation length of $L = 100$ cm. If deposited energy was over a threshold of 5 MeV it was recorded as a FCAL hit. The procedure to group hits into clusters was described in [1].

2 Energy reconstruction

Initial accounting for non-linear effects in shower detection in the FCAL was performed using simple power-law for the dependence of reconstructed cluster energy E_c on generated photon energy E_γ,

$$\frac{E_c}{E_\gamma} = N \cdot E_\gamma^\epsilon. \tag{1}$$

where A and ϵ are normalization and non-linear factors, respectively. In this approach, the energy dependence of non-linear factor was neglected.

A better agreement between reconstructed and generated photon energy up to 8 GeV can be achieved using the following equation

$$\frac{E_c}{E_\gamma} = A \cdot \left(1 + \frac{E_\gamma^\epsilon}{B + C \cdot E_\gamma}\right), \tag{2}$$

where a linear form $C + B \cdot E_\gamma$ was introduced to reduce the non-linear corrections for higher energy photons. Fig. 1 shows the distribution of mean fractional reconstructed cluster energy as a function of generated photon energy (dots). The black curve was obtained by fitting this distribution using Eq. 2. The red curve represents the fit with Eq. 1. The Eq. 2 is similar to the one used in Radphi [2] to account for angular-dependent nonlinear energy and depth correlations in the forward calorimeter. In the case of the GlueX forward calorimeter, there is no evidence that fitting parameters A, B, C and ϵ in Eq. 2 depend on polar angle.

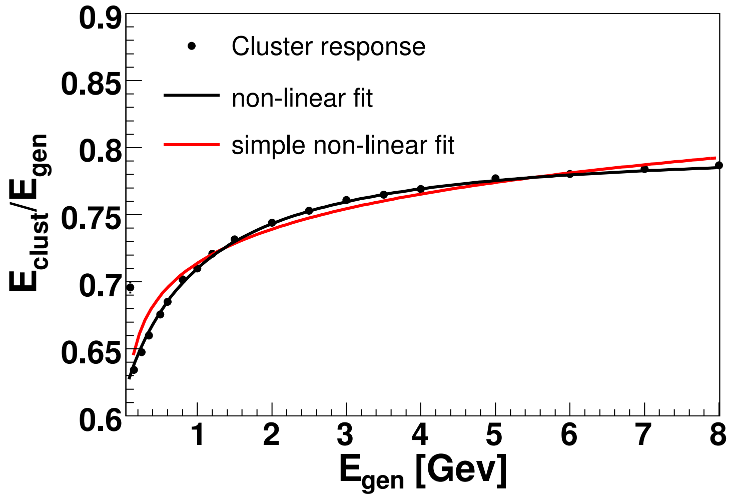

Figure 1: Reconstructed cluster energy normalized to generated photon energy (dots). Black line represents the fit by the function given in Eq. 2, while red line indicates simple power-law fit (Eq. 1).

3 Photon momenta reconstruction

Photon energy can be obtained from reconstructed cluster energy by solving equation

$$E_\gamma = \frac{E_c}{A} - \frac{E_\gamma^{1+\epsilon}}{B + C \cdot E_\gamma}, \tag{3}$$

iteratively. The number of iterations for the given precision increases with photon energy but does not exceed 10 for 0.1% accuracy. After the calibration given by above equation is applied to the cluster energy, reconstructed photon energy normalized to the generated energy becomes a flat function of generated energy (top plot in Fig. 2).

The average photon position in the FCAL along the beam axis depends on photon energy through the expression for the average shower depth at normal incidence in a electromagnetic calorimeter

$$z_A = X_0 \left[ln\left(\frac{E}{E_C}\right) + C_0 \right], \tag{4}$$

where X_0 is lead-glass radiation length, E_C is critical shower energy and C_0 is shower offset. Because the range of incidence photon angles in the FCAL is small, the photon z-position, $z = Z_0 + z_A cos\theta$, where Z_0 is the distance between the target and FCAL, can be obtained iteratively without taking into account energy-angle correlation. However, in order to reconstruct photon incident polar angle correctly for the current GlueX setup, values for critical shower energy and shower offset needed to be modified from values used in the Radphi experiment: $E_C 0.014 \rightarrow 0.035 GeV$ and $C_0 2 \rightarrow 1$. The bottom plot in Fig. 2 shows the difference between generated and reconstructed photon polar angle after shower-depth correction was taken into account.

Fig. 3 shows fractional energy resolution dependence on photon energy. The fit to standard expression for energy resolution

$$\frac{\sigma_E}{E} = \frac{A}{E} + B, \tag{5}$$

gives $A = 5.5\%$ for the statistical term and $B = 0.2\%$ for the floor term.

References

[1] M. Kornicer, Photon reconstruction in the FCAL, GlueX-Doc-823, (2007)

[2] R. T. Jones, at al. A bootstrap method for gain calibration and resolution determination of a lead-glass calorimeter, Nucl. Inst. and Meth. A 566 (2006) 366.

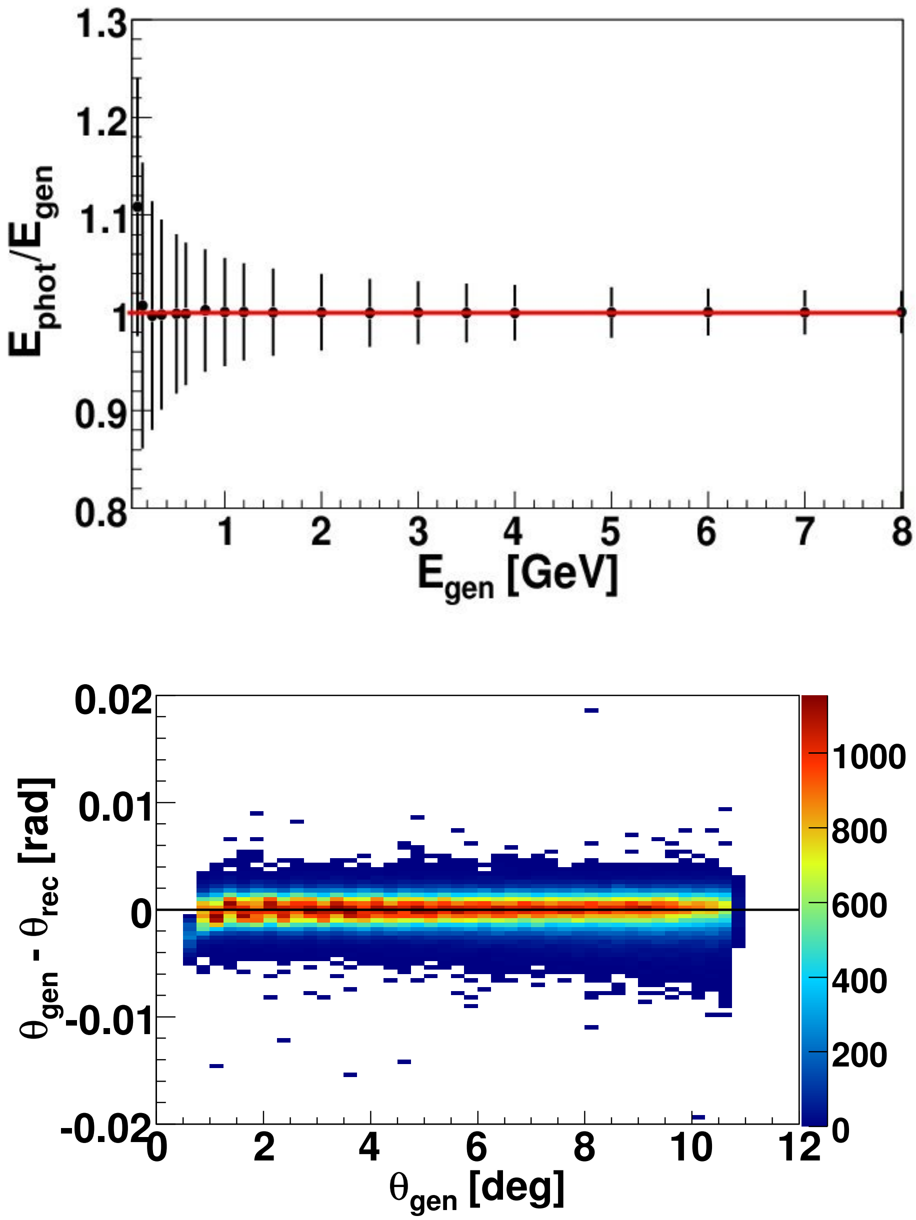

Figure 2: Normalized photon energy as a function of generated energy (top). The bottom plot shows the polar angle error as a function of generated photon angle.

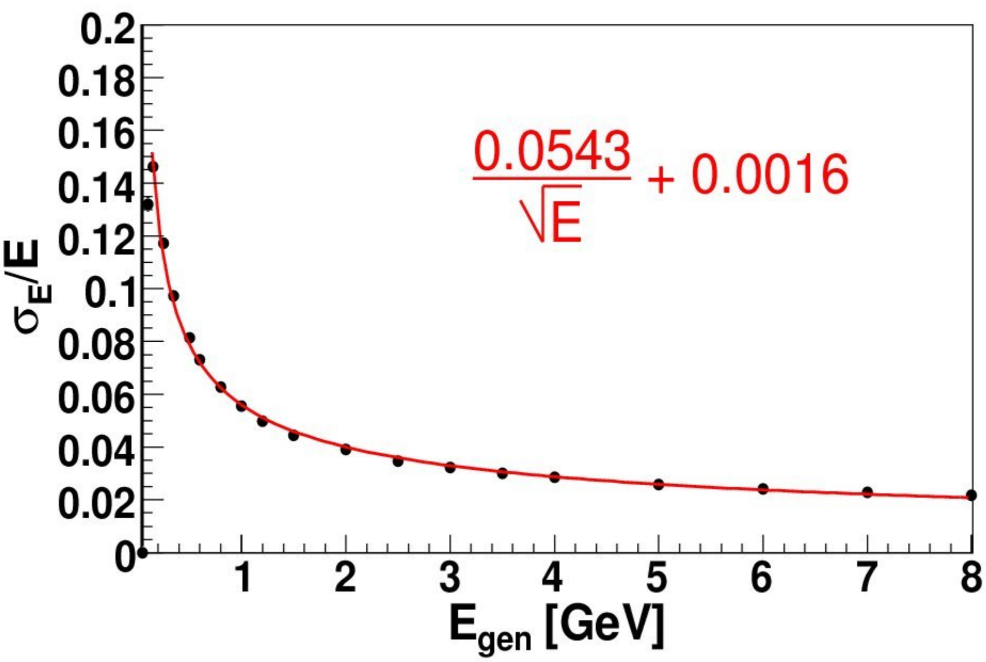

Figure 3: Fractional photon energy resolution fitted to the standard expression for calorimeter energy resolution.