Optimization of GEANT Tracking Cutoff Parameters for PbWO$_4$ and Lead – Glass

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1 Introduction

The PrimEx experiment is scheduled to take production data over a period of approximately one and a half months continuous beam time. This places great importance on having effective and accurate online monitoring of the data to ensure high data quality as it comes in. Since beam data for the full sized HYCAL will not exist prior to the commissioning run, we must make use of simulated data to develop online monitoring and analysis software. This makes it imperative that the simulated data represent the detector response accurately.

One of the key physical properties of the detectors in HYCAL is the Moliere Radius $R_M$. The value of $R_M$ is related to the transverse development of a shower created by an energetic particle in a material. $R_M$ is defined as the radius of a tube, whose axis is aligned with the direction of an incident particle, for which 90% of the shower is contained in a given material [1]. This property is often used to determine the optimal transverse dimensions of the detectors in a segmented calorimeter.

The transverse shower development has a significant impact on the position reconstructed from a segmented calorimeter. This becomes significant for simulated data since the effective $R_M$ varies strongly with the cutoff values. The cutoff values are used by GEANT to determine when a particle will no longer be tracked and its energy simply added to the current detector. GEANT has several cutoff values, but only two, the photon and electron/positron cutoffs are important here. Previous Monte Carlo studies have indicated there are different optimal tracking cutoffs for PbWO$_4$ and lead-glass detectors [2].

This short Monte Carlo study was done to determine the optimal cutoff energies for PbWO$_4$ and lead-glass as will be used in the construction of HYCAL. Values of the cutoffs will be determined by what corresponds to the $R_M$ values found in the literature [?]. A version of the primsim simulation code was modified for this study to replace the HYCAL detector with one PbWO$_4$
crystal and one lead-glass detector. Both detectors had the same geometry as shown in figure 1. Two sets of simulated data were produced. One in which energetic photons were thrown into the center of the PbWO$_4$ and the other into the lead-glass. The analysis results of these two sections are given in sections 2 and 3 respectively.

![Diagram of detector dimensions](image)

Figure 1: For the purposes of this study, PbWO$_4$ and lead-glass detectors were defined as blocks of dimension 1x1x2m$^3$. The incident photon momentum was along the 2m dimension.

For both sets of data, the incident photons were sampled evenly between 0.5 and 5.5GeV as shown in figure 2.

2 Lead-Glass Analysis

Figure 3 shows the energy distribution as a function of transverse distance from the beamline for 10,000 simulated showers developed in a large lead-glass block. This shows one example of the distribution for a specific cutoff energy. A set of 10,000 events was produced for 17 different values of the cutoff energy.

The value of $R_M$ was determined by finding the point on the x-axis for which the integral fraction was 90%. Figure 4 shows the calculated $R_M$ values plotted against the tracking cutoff value in MeV. The data were separated into 5 equal bins in incident photon energy between 0.5GeV and 5.5GeV. The plot indicates that $R_M$ has virtually no dependance on the incident photon energy.

Figure 5 shows a linear fit to the $R_M$ values for the lead-glass simulated data. The fit was done over a narrow range so that it covered the nominal value of $R_M$, 3.6cm.

The fit to the data in figure 5 yields a relation between $R_M$ and the cutoff value which is shown in equation 1.

$$R_M = 2.46 - 0.746 \times \text{cutoff}$$

(1)

where $R_M$ is returned in cm and cutoff is in MeV.
Figure 2: Incident photon energy distribution in GeV. Photon energies were randomly sampled evenly from 0.5 to 5.5 GeV.

Figure 3: Energy deposition in lead-glass as a function of distance from photon "beamline". Each entry in this histogram was weighted by the energy lost during the current step during tracking (DESTEP).
Figure 4: The Moliere radius as a function of electron and photon cutoff parameters in GEANT for lead-glass. This plot shows $R_M$ calculated for 5 separate energy bins. The points all line up on one another quite well indicating negligible energy dependance for $R_M$.

Figure 5: A linear fit to the data in figure 4 for all incident photon energies. The fit was done over a narrow range near the known Moliere radius for lead-glass.
3 \textit{PbWO}_4 \textit{ Analysis}

The analysis of the \textit{PbWO}_4 data was carried out in a similar fashion to the that of the lead-glass. Figure 6 shows the radial dependence of the shower in \textit{PbWO}_4 for a particular cutoff energy. Figure 7 shows the calculated $R_M$ values vs. cutoff energy for \textit{PbWO}_4. As for the lead-glass, there is apparently no dependence of $R_M$ on the incident photon energy.

Figure 8 shows a fit to the subset of data near the known value of $R_M$ for \textit{PbWO}_4, 2.0. The fit values give the relation in equation 2.

$$R_M = 4.53 - 0.097 \times \text{cutoff}$$

(2)

where $R_M$ is returned in cm and cutoff is in MeV.

![Figure 6: Energy deposition in \textit{PbWO}_4 as a function of distance from photon "beamline". Each entry in this histogram was weighted by the energy lost during the current step during tracking (DESTEP).]

4 \textit{Conclusion}

Two sets of simulated data were produced to determine the appropriate setting for the electron and photon energy cutoff parameters in GEANT such that the known values of the Moliere Radius are returned.

For the lead glass, this is approximately 1.1 MeV. For the \textit{PbWO}_4, this is approximately 630 keV.
Figure 7: The Moliere radius as a function of electron and photon cutoff parameters in GEANT for PbWO$_4$. This plot shows $R_M$ calculated for 5 separate energy bins. The points all line up on one another quite well indicating negligible energy dependance for $R_M$.

Figure 8: A linear fit to the data in figure 7 for all incident photon energies. The fit was done over a narrow range near the known Moliere radius for PbWO$_4$. 

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References
