A Study of photon sensitivity in the HALL D Detector at Jefferson Lab

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July 26, 2000

Abstract

Studies of photons in the HALL D detector have shown that steps are required to keep the photon sensitivity as high as possible. We found that it is important to achieve the lowest possible detectable energy threshold for the Barrel Calorimeter. It may also be necessary to add a backwards detector to keep the background noise as low as possible.

1 Introduction

Recent studies of the photon sensitivity of the Hall D detector design have shown interesting results. Exclusive reactions (see reactions 1 - 4) with photons in the final state were generated, tracked, and analyzed for three different regions of the detector: the Lead Glass Detector, Barrel Calorimeter, and the backward hole upstream of the target. In this study, loss due to the beam line hole in the LGD has been neglected. Our results show the importance of keeping the energy threshold of the Barrel Calorimeter and the Lead glass as low as possible. Analysis of reactions with photons originating at the baryon vertex have shown that current design configurations of the HALL D detector will miss approximately 10 percent in the backwards hole.

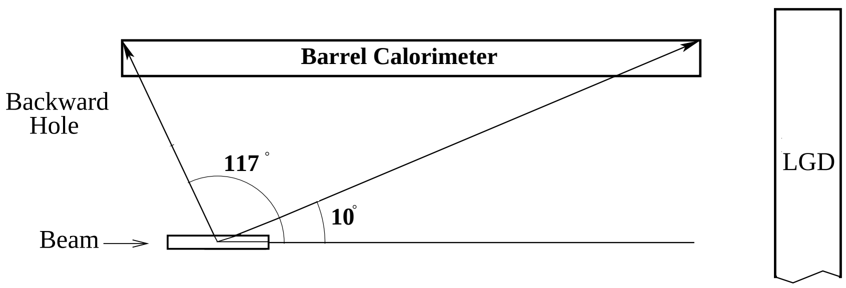


Figure 1: A figure showing angles in degrees from the center of the target to various reference points. Tracks more forward than 10° miss the Barrel Calorimeter and will hit the lead glass detector. Between 10° and 117° the photons will enter the Barrel Calorimeter. Photons produced at angles larger than 117° miss all current detectors.

1.1 Monte Carlo Events

In this study the GENR8 program was used to generate the events. We looked at four different exclusive reactions, two with photons produced at the baryon vertex:

$$\gamma p \to N^*(1500)\pi^+ \to (n\eta)\pi^+ \to n\pi^+\gamma\gamma \tag{1}$$

$$\gamma p \to X^+(1600)\Delta^o \to (\pi^+\pi^+\pi^-)(n\pi^o) \to \pi^+\pi^+\pi^- n\gamma\gamma \tag{2}$$

The Δ^o reaction (reaction 2) has a 3π-meson mass of 1600 MeV/c^2, and a width of 300 MeV/c^2. The two meson vertex reactions are:

$$\gamma p \to X^+(1500)n \to (\eta\pi^+)n \to n\pi^+\gamma\gamma \tag{3}$$
$$\gamma p \to X(1500)p \to (\pi^+\pi^-\pi^o)p \to p\pi^+\pi^-\gamma\gamma \tag{4}$$

The 3π reaction (reaction 4) has a meson mass of 1600 MeV/c^2. Both of these two reactions (reactions 3 and 4) have a width of 300 MeV/c^2.

Each of the above reactions were simulated using a beam energy of 8 GeV, and a t slope of 5. The production and decay vertex was assumed to be at the center of the target. For each system, 10,000 events were generated. The direction and energy of the photons were recorded and analyzed

2 Results

2.1 Detector energy resolution

The photons produced in the above decays were traced into the Barrel Calorimeter and the Lead Glass Detector. Figure 2 and 3 show the percentage of photons that would enter, but not be detected by the Barrel Calorimeter due to the minimum energy thresholds.

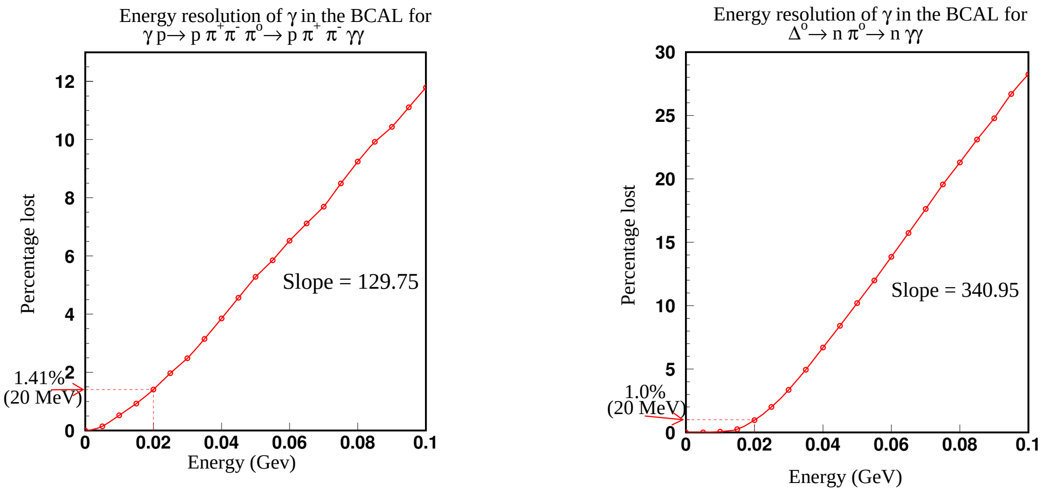


Figure 2: The percentage loss due to the energy threshold of the BCAL. Left is for reaction 4, while the right figure is for the Δ^o decay from reaction 2. The percent of the total photons entering the Barrel Calorimeter for reaction 4 is 57% and reaction 2 is 87%.

Currently, the design calls for the energy sensitivity of 20 MeV for the Barrel Calorimeter. One can see that this results in around a 1% loss of

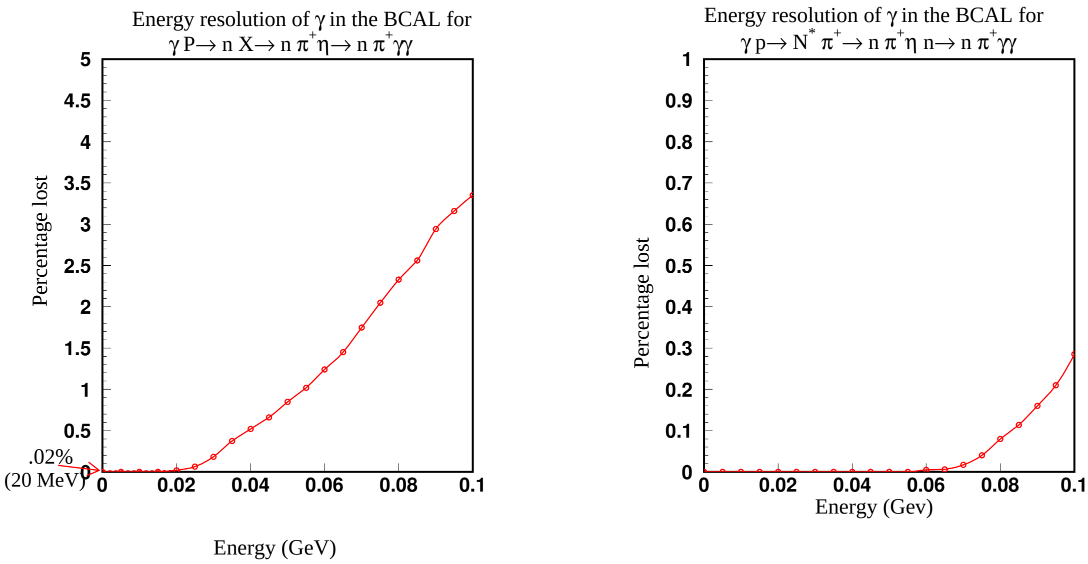


Figure 3: The percentage loss due to the energy threshold of the BCAL. The left plot is for reaction 3, and right is for reaction 1. The percent of all the photons entering the Barrel Calorimeter for the η X (reaction 3) and the η N^* (reaction 1) are 55% and 88% respectively.

photons which is quite acceptable. However, if this energy can not be met, the percentage of photons lost rises rapidly with the increased energy threshold, especially for the Δ^o (reaction 2) decay. For example, if the threshold is 50 MeV, then 5% of the 3π reaction is lost, and 10% of the Δ^o reaction is lost. The situation for the η reactions is not so severe, as would be expected from the higher energy photons in the η decay (figure 3).

The results for the Lead Glass Detector is similar, but the percentage rise is not so significant at higher energy thresholds. The only system with significant loss in the Lead Glass Array is the 3π (reaction 4) decay. At the sensitivity threshold of 100 MeV, the Lead Glass Detector will no see .718% of the photons. The design calls for a 150 MeV detection minimum in the LGD. At this energy, the detector will miss 1.86% of the photons (figure 4).

2.2 Backwards photons

During these studies, it was found that in reactions where photons were produced at the baryon vertex a significant amount were traveling in the negative $\hat{z}$ direction (positive $\hat{z}$ is defined along the beam), and missing the detector. This corresponds to an angle greater than 117° (figure 1). The N^* η and the Δ^o reactions (reaction 1 and 2) produced around the same amount of backwards going photons which are not covered by photon detectors. For both reactions, approximately 10% of all the photons produced

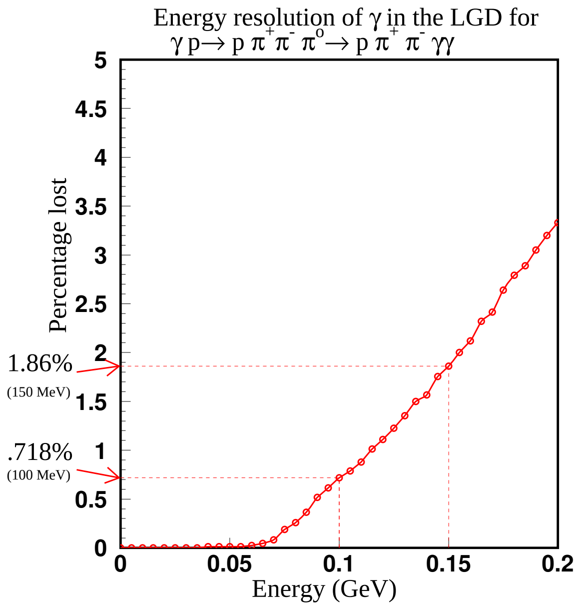


Figure 4: The percentage of undetected photons for a given energy threshold of the Lead Glass Detector. From reaction 4.

in the decays will not be detected with the current design configurations. Figure 5 shows this loss as a function of the angle. For example, to recover half of the lost photons, an additional detector would have to cover angles up to approximately 130°.

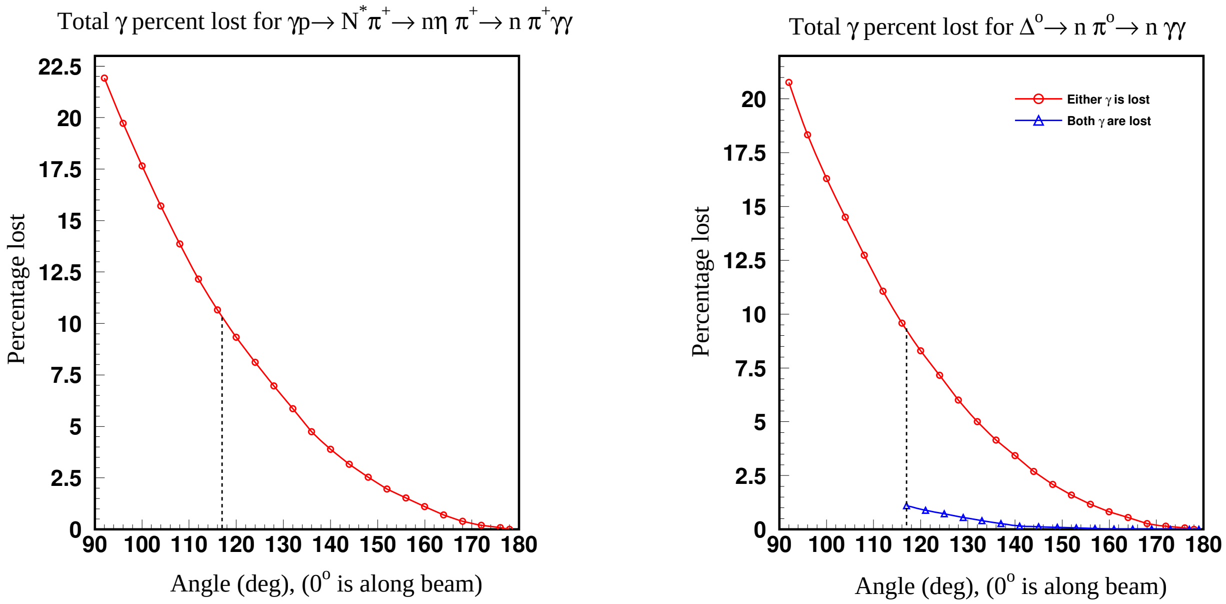


Figure 5: The Percentage of photons that would be lost at various angles from the target. The Current Barrel Calorimeter limit of 117° is marked with a dotted line.The "o" marker indicates that at least one γ is lost, the "Δ" line shows when both photons are lost (both were never lost in reaction 1).

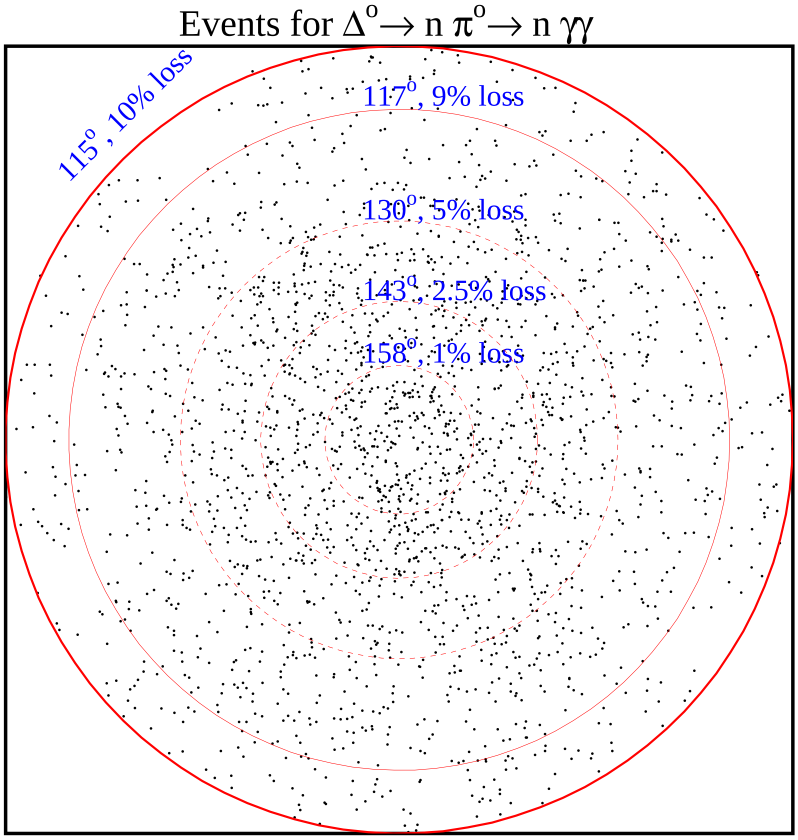


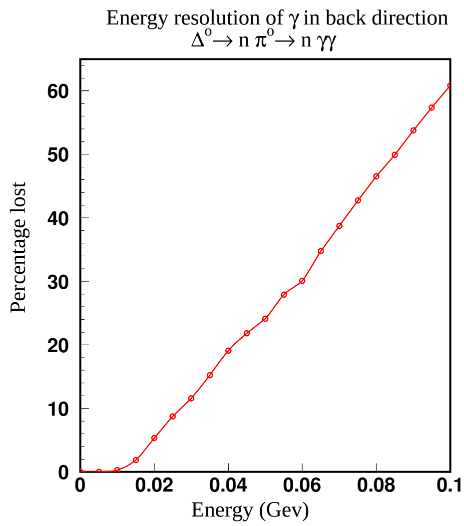
Figure 6: The traced photon locations on the x-y plane at the upstream end of the Barrel Calorimeter. The 117° circle is the end of the Barrel Calorimeter. Various other percentages, and their corresponding angles are plotted as well.

Figure 6 shows where these lost photons would hit a hypothetical backwards detector at z = -50cm. The ring at 117° is the current detector limit. Several rings are shown at other angles, indicating the geometrical losses from each.

The energy of these backwards going photons was examined. If a backwards photon detector were to be built, figure 7 shows the percentage of the photons that would be lost at various energy thresholds.

2.3 Summary of Photon Sensitivity

The total loss of the photons originating at the baryon vertex (reactions 1 and 2) is around 11%. The largest cause of this loss is the backwards going photons at 10%, with the sensitivity of the Barrel Calorimeter adding the



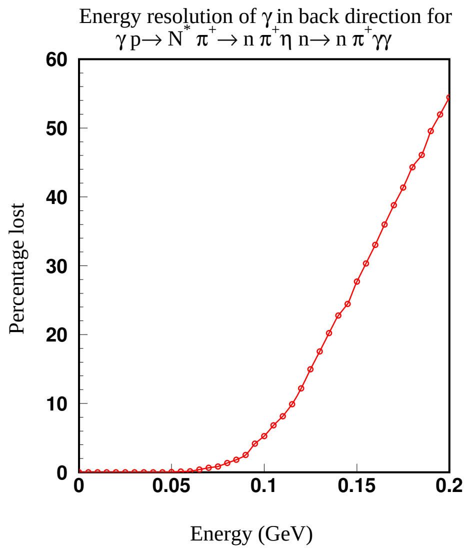


Figure 7: The percentage of those photons that would hit a backwards detector, but be lost due to the indicated energy threshold.

extra 1%. However, this total percentage could easily rise to 14% or higher if the Barrel Calorimeter does not reach the 20 MeV energy threshold goal. For photons originating at the meson vertex fewer are lost. The total percent of photons lost for the η X (reaction 3) system is less than 1%. Even at higher thresholds, this percentage loss does not rise beyond 1%. For the 3π system (reaction 1), the total percentage loss is higher at around 4%. In order to keep the detection of photons at a maximum it is important that the Barrel Calorimeter's energy threshold be kept as low as possible. It may also be necessary to build an upstream detector to catch the escaping photons.

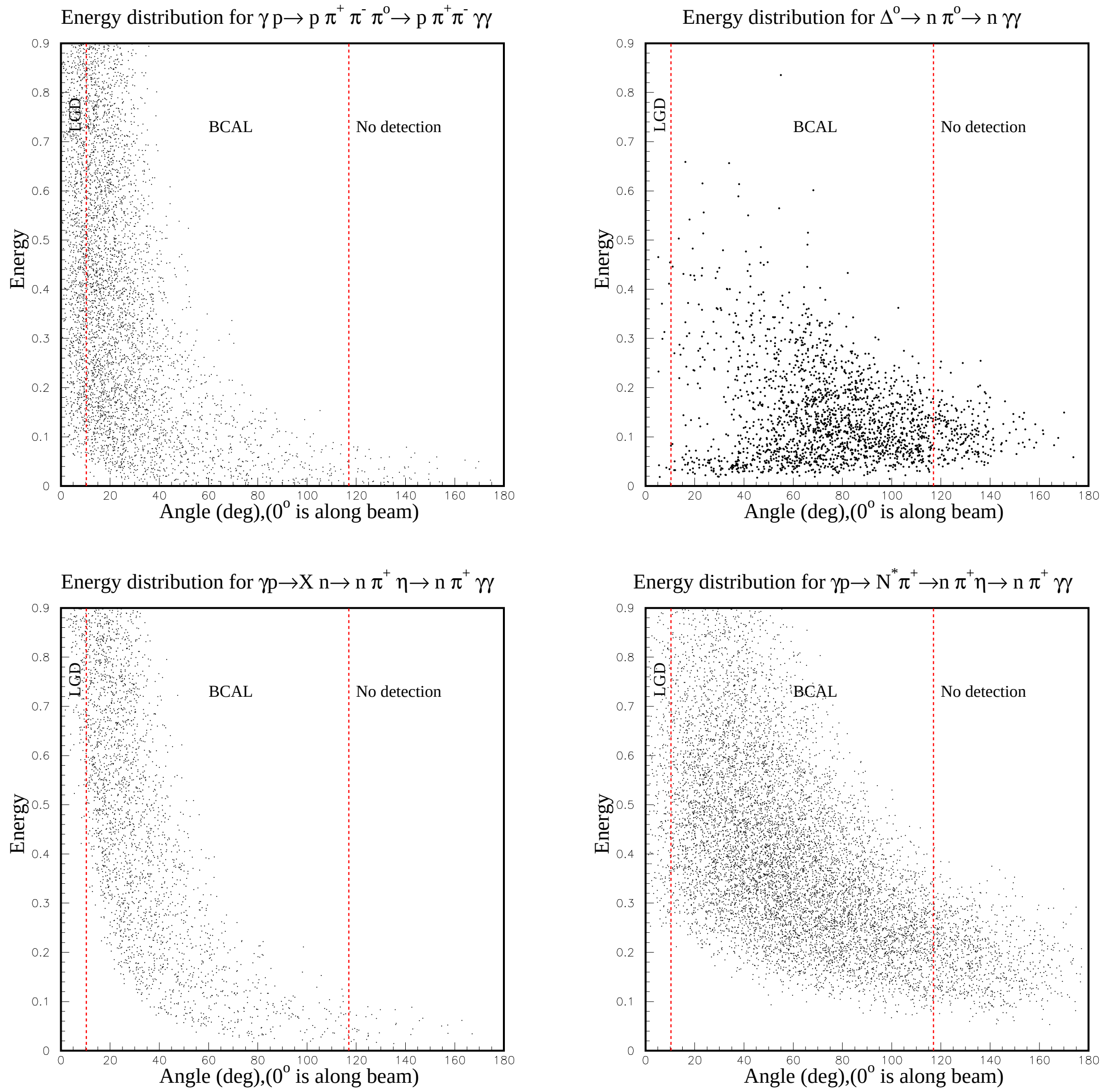


Figure 8: Photon energy versus photon direction for the four reactions studied. Energies are in GeV.