Brief GlueX Note
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How Photons Illuminate GlueX Calorimeters

With an Emphasis on UPV

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Introduction

This note summarizes information about which calorimeter elements are struck by photons from photoproduced events at 9 GeV using events simulated by Pythia and also by looking at events from the exclusive process $\gamma p \to X\Delta$ where X is a forward-produced meson and the Δ is produced with a $|t|$ distribution that follows $e^{-5\cdot|t|}$. One million events were generated in each of these two categories. Which calorimeter element was struck by an individual photon was determined by looking at the radial distance (r) of the photon from the beam line at a particular z position along the beam line where the target center is at $z = 65.0$ cm. The calorimeter elements thus defined at listed in Table 1. The calorimeter elements are listed starting with the most upstream element (the hole in UPV) to the most downstream (the hole in FCAL). In the current geometry there is a gap between the upstream end of BCAL and the UPV in which photons are undetected. Event vertices were distributed uniformly over the 30-cm target.

Calorimeter Element	Condition on photon radial distance (r) in cm at z in cm
Upstream Hole	$r < 10.0$ at $z = -50.8$
UPV	$92.5 < r < 10.0$ at $z = -50.8$
Gap Between BCAL and UPV	Between previous and following element
BCAL - Upstream End	$92.5 < r < 65.0$ at $z = 17.0$
BCAL	Between previous and following element
BCAL - Downstream End	$92.5 < r < 65.0$ at $z = 407.0$
FCAL	$120.0 < r < 10.0$ at $z = 670.3$
Downstream Hole	$r < 10.0$ at $z = 670.3$

Table 1: Determining Which Calorimeter Element is Struck

Monte Carlo Samples

The current version of Pythia, as tuned for 9 GeV photoproduction, was used to generate the event sample that is meant to represent photoproduced hadronic events. That sample has been compared[1] against existing data of photoproduction at 9 GeV[2]. Overall, the simulated Pythia data describe existing published data rather well, in terms of overall multiplicity distributions and relative cross sections among important exclusive reactions. The photon multiplicity distribution for the sample of 1M Pythia events is shown in Figure 1. Table 2 shows the fraction of these photons in each of the calorimeter elements.

In addition to looking at Pythia simulations, events corresponding to the exclusive process $\gamma p \to X\Delta$ where X is a forward-produced meson and the Δ is produced with a $|t|$ distribution that follows $e^{-5\cdot|t|}$. For these events the $\Delta \to \pi^0 N$ followed by $\pi^0 \to 2\gamma$ was assumed. So this process would include $\Delta^+ \to \pi^0 p$ and $\Delta^0 \to \pi^0 n$. Table 2 shows the fraction of photons from Δ decays in each of the calorimeter elements.

[1] A. Dzierba, *Comparing Pythia Simulations with Photoproduction Data at 9 GeV*, GlueX-doc-856-v4 (2007).
[2] A. Dzierba, *A Summary of Photoproduction Data in the GlueX Energy Regime*, GlueX-doc-835-v1 (2007).

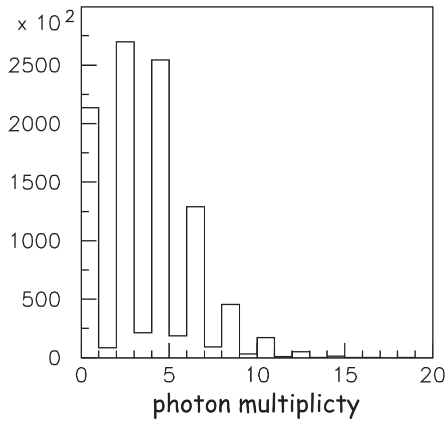

Figure 1: Photon multiplicity distribution for 1M Pythia events at 9 GeV.

Referring to Table 2 for the recoil Δ events, note that the percentages quoted are for the total number of photons and for these events there are always two photons per event. Also for these events, 71% of the events have both photons from the π^0 fully contained in BCAL (not including the upstream or downstream ends of BCAL) and 28% of the events have one fully contained photon. So information from BCAL can be used to tag the vast majority (99%) of Δ events with a π^0.

The cross section measurements near GlueX energies show significant Δ^{++} production in the 3-prong and 5-prong topologies but little Δ^+ or Δ^0 production. For example, in the 3-prong topology, the cross sections for $\rho^-\Delta^{++}$, $\rho^0\Delta^+$ and $\rho^+\Delta^0$ are 1.1 ± 0.2 μb, 0.3 ± 0.2 μb and 0.2 ± 0.2 μb respectively. The cross sections for $n\rho^0\pi^+$ and $\Delta^-\pi^+\pi^+$ are 2.0 ± 0.6 μb and 0.2 ± 0.2 μb respectively. In the 5-prong channel with a single π^0, reactions with a Δ^{++} account for nearly 75% of that channel but no reactions with Δ^+ are quoted. So, although measurements are based on low statistics, there appears to be little Δ^+ or Δ^0 production.

Calorimeter Element	All (Pythia) Events	Recoil Δ Events
Upstream Hole	0.01	0.06
UPV	0.83	3.43
Gap Between BCAL and UPV	0.91	3.61
BCAL - Upstream End	0.71	2.78
BCAL	58.4	84.5
BCAL - Downstream End	10.1	2.46
FCAL	28.6	3.14
Downstream Hole	0.44	0.02
Any Element	100.0	100.0

Table 2: Percentage of Photons in GlueX Calorimeter Elements

Energy Spectra in UPV and the Gap

In Figure 2, the energy spectra of photons hitting UPV and the gap between UPV and BCAL are shown for Pythia events and for events with recoil Δ. The distributions for Pythia and Δ events are normalized to the same integral. The integral distributions are also shown. Using the Pythia spectra, we see that about 40% of the photons have energies less than 50 MeV and this increases to about 75% at 100 MeV. This holds true for both UPV and the gap which intercept a total of 1.7% of the photons.

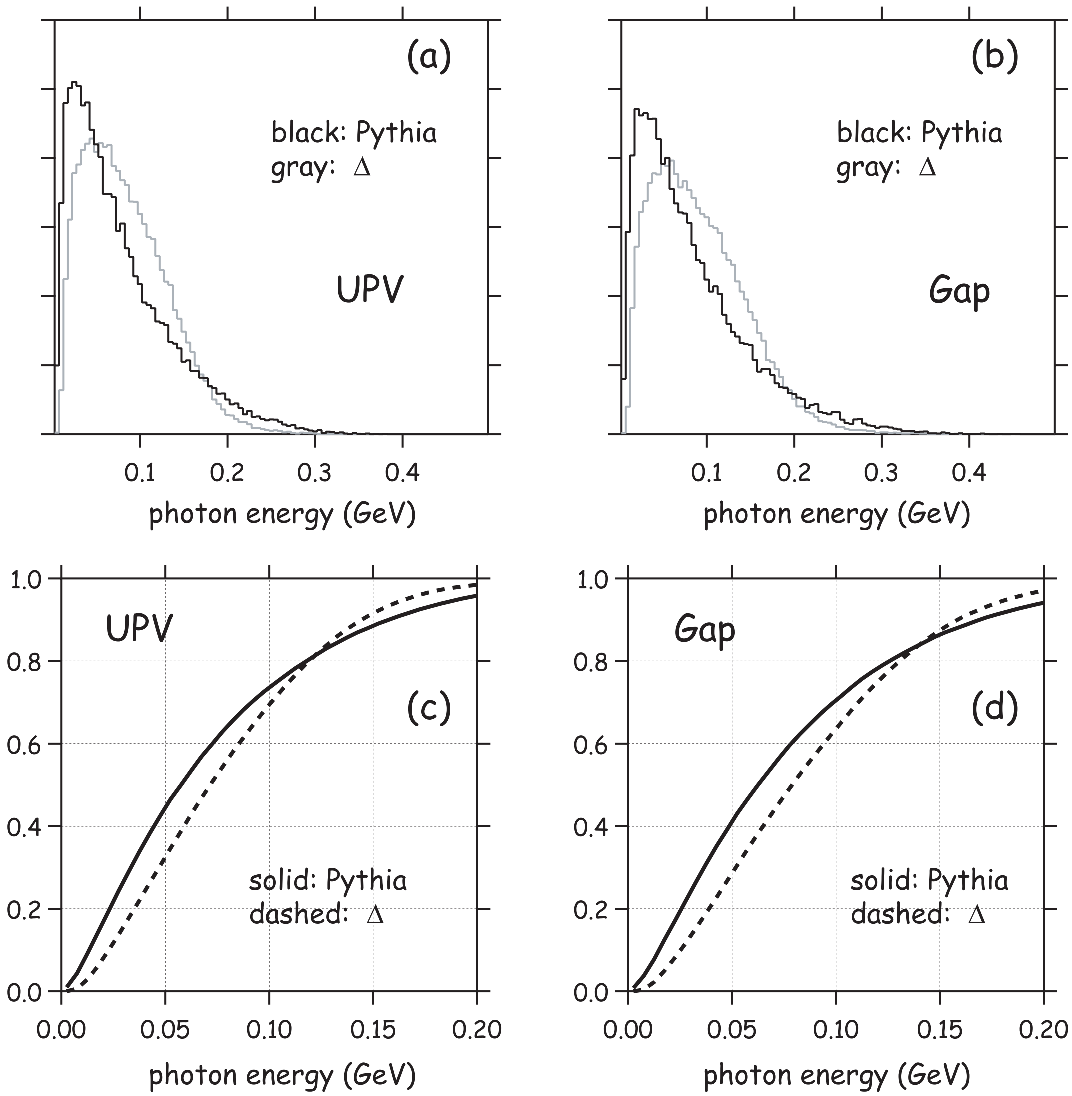

Figure 2: (a) Photon energy spectrum for photon hitting UPV for Pythia events (black histogram) and Δ events (gray histogram); (b) Same for photon in the GAP between UPV and BCAL; (c) Integral distributions corresponding to the histograms in panel (a); and (d) Integral distributions corresponding to the histograms in panel (b).

Conclusion

Given the dearth of manpower, it may be good to revisit the cost/benefit of instrumenting the UPV and Gap regions. The number of photons populating these regions is small and their energies are low presenting a real challenge for detection. The numbers in Table 2 also underscore the importance of BCAL.