UPV veto efficiency for soft photons

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In this Monte Carlo study, we consider the efficiency of the Upstream Photon Veto (UPV) in detecting photons originating from decays of soft π^o's coming from excited baryons produced in γp collisions at 9 GeV.

Events of the type $\gamma p \to X(1600)N^*$ were generated at the center of the GlueX target for different masses of excited baryons N^* or Δ, different slopes b of momentum transfer distribution e^{-bt}, and for one- or two-pion decays of a baryon: $N^* \to N\pi^o$, $N^* \to N\pi^\pm\pi^o$, and $N^* \to N\pi^o\pi^o$.

The analysis is based solely on the lab angle θ of the produced photons. We assumed that the FCAL covers the angular range from 0^o to 10^o and has a 100 MeV energy threshold and the BCAL covers angles from 10^o to 117^o with a 40 MeV threshold for detecting photons.

Two UPV configurations were studied. In Design A, UPV has a rectangular shape and is located upstream of the magnet. Due to the aperture of the magnet, this design covers photon lab angles θ above 135^o only. This creates a gap from 117^o to 135^o in photon coverage. In Design B, UPV has a circular shape and is positioned inside the magnet right next to BCAL. UPV outer radius is equal to the inner radius of BCAL. Therefore, the photon coverage continues at 117^o. The inner UPV radius (i.e., the maximum covered angle θ) is a compromise between UPV size and cost on one hand and its efficiency as an upstream photon veto on the other hand. To determine the later, we studied the angular dependence of the photons from the reaction $\gamma p \to X(1600)N(1535)$, $N(1535) \to N\pi^o$, $\pi^o \to \gamma\gamma$ with slope of t-distribution $b = 5$ (GeV)$^{-2}$. This reaction was chosen because it is more likely to get a backward-going photon from decay of a higher mass baryon produced at higher value of t.

First, we consider the case when an upstream photon hits in BCAL and is above threshold to veto the event. As shown in Fig. 1, up to 14% of such events will have a photon at the lab angle of more than 117^o. Note that this distribution barely plateaus near full backward direction. A near full photon coverage of the upstream angular range is necessary to reject 14% of excited baryon events in this scenario.

In addition to the UPV detection of photons, events with unpaired photons detected in either the BCAL or FCAL can be vetoed. The emphasis

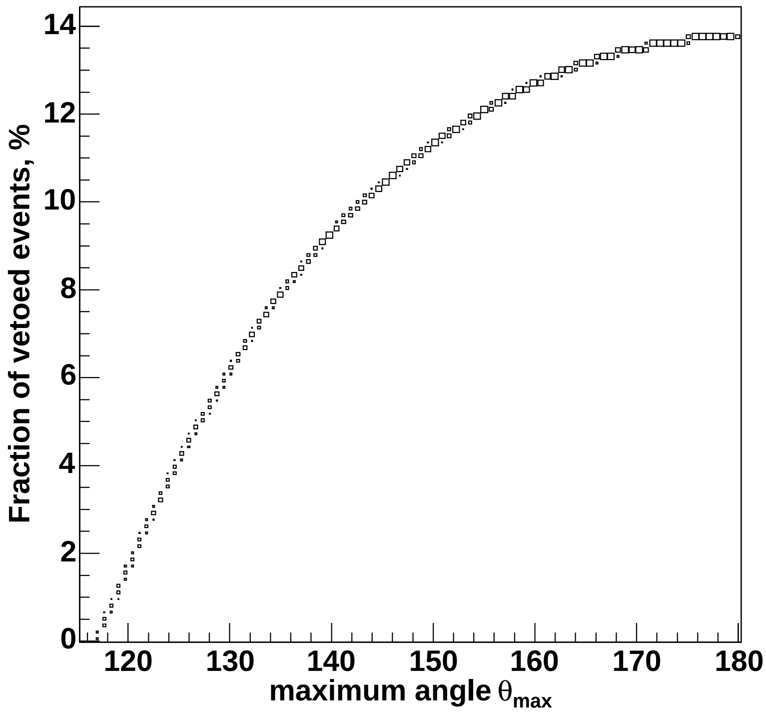

Figure 1: Fraction of events $\gamma p \rightarrow X(1600)N(1535),\ N(1535) \rightarrow N\pi^o,\ \pi^o \rightarrow \gamma\gamma$ vetoed by UPV for the range of lab angles from θ_{min} to 180^o as a function of θ_{min} (Design A).

here is to use these detectors in an energy threshold veto mode (which includes calorimeter hits that are not reconstructed as photons) as opposed to a full photon energy-direction measurement.

To study the case of unpaired photons in the UPV, only events with no above-threshold photons in the BCAL or FCAL detectors and at least one photon in UPV were considered.

First, a fraction of the generated events which can be vetoed only by UPV is given in Fig. 2 for the Design A. The plot shows a fraction of events with at least one photon in the range $\theta_{min} < \theta < 180^o$ and nothing detected in BCAL, as a function of θ_{min}. At $\theta_{min} = 135^o$, about 2.3% of generated events will be vetoed solely by UPV only. It is interesting to note that covering the whole backward angular range from 117^o to 180^o will increase this fraction only to approximately 3.2%. Many of the events with a photon in the direction of the present $117^o - 135^o$ gap will have the second photon already detected

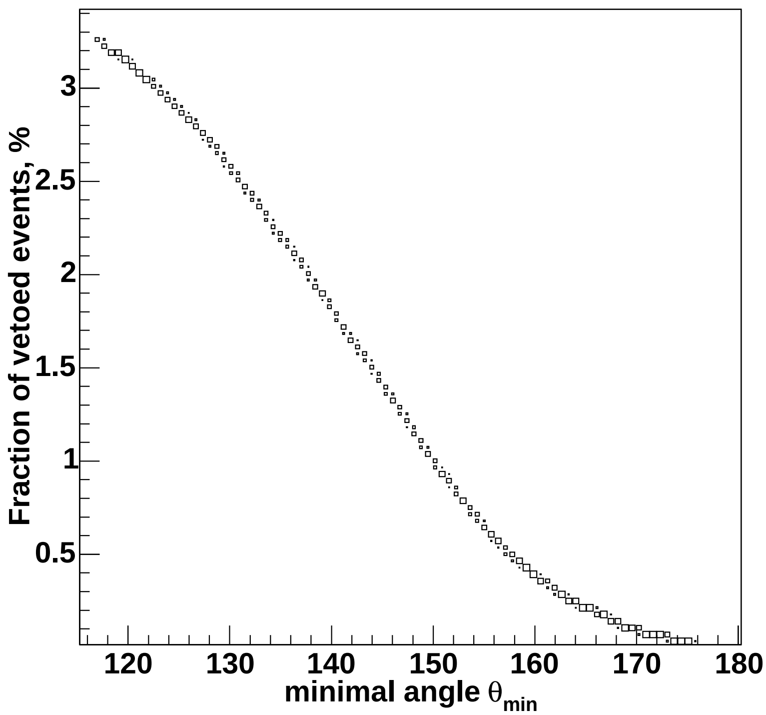

Figure 2: Fraction of events $\gamma p \to X(1600)N(1535),\ N(1535) \to N\pi^o,\ \pi^o \to \gamma\gamma$ vetoed by UPV after using BCAL to veto single-photon events for the range of lab angles from θ_{min} to 180^o as a function of θ_{min} (Design A).

by Design A UPV and, therefore, will not increase the single-photon veto efficiency.

The last conclusion may be interpreted in a different way. If no photons below 117^o are detected in BCAL and there is a photon coverage upstream of 117^o with a new UPV than they may be no need to extend this coverage all the way to 180^o. Doing so will increase the number of 2-photon events detected by UPV but it will not contribute to its efficiency as a single-photon veto. This is shown in Fig. 3 in which a fraction of events vetoed solely by UPV is given as a function of the maximum covered angle θ_{max} directly related to the inner UPV radius in Design B. Covering only the $117^o - 135^o$ gap will give the same 2.3% fraction of vetoed events as in Design A. By extending the coverage a little further to 150^o, this fraction will increase to 3%, with only about 0.2% of total N^* events escaping potential detection by UPV.

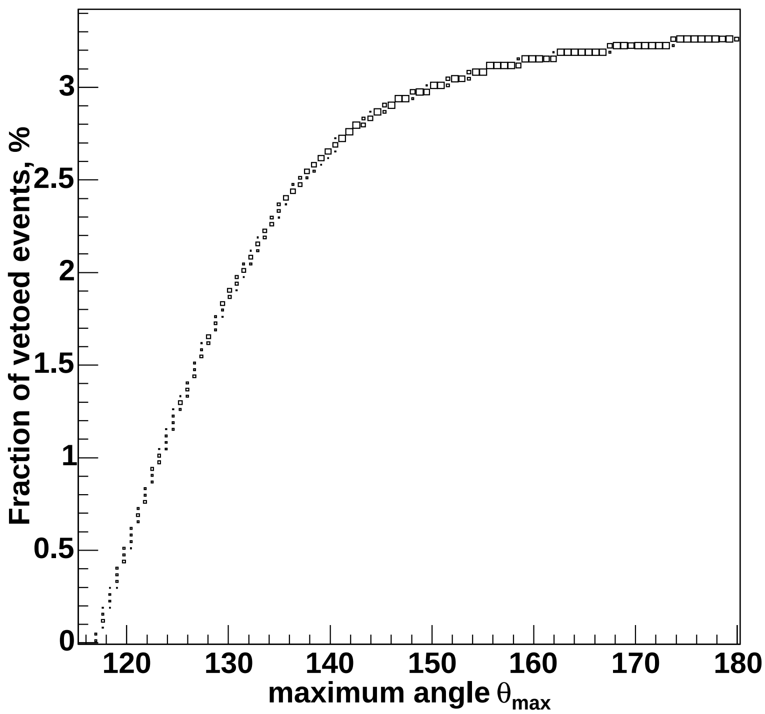

Figure 3: Fraction of events $\gamma p \rightarrow X(1600)N(1535),\ N(1535) \rightarrow N\pi^o,\ \pi^o \rightarrow \gamma\gamma$ vetoed by UPV only for the range of lab angles from 117^o to θ_{max} as a function of θ_{max} (Design B).

Other excited baryon reactions have qualitatively similar angular dependencies of the fraction of events with soft photons detected in UPV. The absolute values of this fraction, however, are somewhat different. Table 1 lists the fraction of UPV-vetoed events for a few studied reactions.

Table 1: Fraction of UPV-vetoed events

Reaction	No hits in BCAL A ($135^o - 180^o$)	No hits in BCAL B ($117^o - 150^o$)	Regardless of BCAL B ($117^o - 150^o$)
$\gamma p \rightarrow X(1600)\Delta(1232)$			
$\Delta(1232) \rightarrow N\pi^o$			
$b = 1.5$	0.7%	1.4%	12.3%
$b = 3.0$	1.0%	2.0%	14.9%
$b = 5.0$	1.3%	2.4%	16.6%
$b = 7.0$	1.4%	2.2%	15.9%
$\gamma p \rightarrow X(1600)N^*(1535)$			
$N^*(1535) \rightarrow N\pi^o$			
$b = 5.0$	2.2%	3.0%	14.3%
$\gamma p \rightarrow X(1600)N^*(1535)$			
$N^*(1535) \rightarrow N\eta$			
$b = 5.0$	0.8%	1.4%	11.4%
$\gamma p \rightarrow X(1600)\Delta(1620)$,			
$\Delta(1620) \rightarrow \pi^o\pi^o$			
$b = 5.0$	0.1%	0.1%	20.2%
$\gamma p \rightarrow X(1600)\Delta(1620)$,			
$\Delta(1620) \rightarrow \pi^\pm\pi^o$			
$b = 5.0$	0.7%	1.3%	10.5%