PrimEx Note for Estimating Veto Counter Hole Size

Author: Eric Clinton

Abstract

An ongoing concern of the PrimEx collaboration is proposed hole to be cut into the two central veto counter paddles located in front of HyCal. This Note addresses that concern by presenting Monte Carlo data and recommending a radius for the hole. The hole size is constrained by a few parameters, namely acceptable rate, light propagation, and HyCal coverage. A hole of radius 2.26 cm meets these requirements and is our recommendation.

One of the lingering questions concerning major PrimEx hardware is determining what size the hole should be cut out from the active veto counter array. The hole would obviously be centered on the beam path, but must be as small as practical. The hole itself will be cut from the two central veto counters. A smaller hole size will minimize light propagation losses in the scintillator material and maximize HyCal surface coverage. Various hole sizes were studied, and a case for a radius of 2.26 cm will be presented.

The biggest issue is one of rate. We want to cut away as much of the non-interacting photon beam as possible without losing physics events. It is also important to confirm that rates over the whole array and per veto counter will be acceptable. The veto counters are plastic scintillators. As such, they are very fast and can easily handle a rate of 1 MHz.

In this Monte Carlo, a bremmstrahlung photon generator [Figure 1] was used for an event source. The photons were thrown down the beamline with an angular distribution of $1/E_{beam}$ and allowed to interact in the defined experimental structures. These structures included the beam pipe, the PrimEx target ladder, dipole magnet, pair spectrometer, helium bag with Mylar windows, the veto counters, and HyCal. The only major change to the standard release in CVS was the omission of the previously defined veto counter hole. The coordinates of each interaction in the veto counter array were recorded, as well as the energy of the created photon.

The first step in the analysis was to compute rate as a function of distance from the beam path [Figure 2]. As expected, there is a large rate in the first few centimeters, a slow decrease in rate from roughly 4 cm to 60 cm, a quickening decrease in rate as the radius extends to roughly 85 cm, and no rate past 85 cm. We expect a very high rate close to beam center due to a large number of photons interacting and scattering charged particles to very small angles. Some larger angle scattering occurs and this illuminates the range from 4-85 cm. The slowly decreasing rate in the 4-60 cm range is what we expect to see since fewer interactions scatter particles to larger angles. This range also defines the largest circular area of HyCal the veto counter array covers, so we expect a much quicker decrease in rate in the 60-85 cm region since the percentage of solid angle coverage the veto counter array provides approaches zero. We are projecting a growing circular area over a fixed square area, and so the largest radius we should see events is 85 cm ($60\sqrt{2}$ cm).

A bremmstrahlung beam is not a mono-energetic beam, so it was decided to break up the beam into six distinct energy bins. As expected, the largest rate contribution is from the lowest energy spectrum since this is the most highly populated part of the photon energy spectrum (Figure1). Energy deposition is not a limiting factor, as both the Bethe-Bloch formula and simulation (Figures 3 & 4 & 5) give a maximum energy deposition of roughly 1 MeV. The two peaks in Figures 3 & 5 correspond to single and double charged particle energy depostion from Compton, pair production, and photo_electric processes. Figures 6 and 7 show the rates for the 0.0 to 0.5 GeV and 0.5 to 1.5GeV spectrums. It is clear from these figures and Figure 8 how much the lowest energy spectrum dominates rate. A lower limit of 1 MeV photons was set to fully determine low energy rate behavior, maximize computer time, and is commensurate with the Bethe-Bloch energy deposition. This gives us great confidence in our rate calculations.

Finally, we put all of the information we have together in a graph Rate (Hz) vs. Hole Radius size (cm) for all energy spectrums [Figure 8]. Figure 9 zooms in to look at the structure of the smaller rates. In Figure 9, it is seen that the two lowest energy photon bins have a large gradient. The other bins show little variation past with a hole size greater than 2 cm All we must now do is decide where the rates have flattened out enough for us. It is also easy to see from Figures 8, 9, and 2 that the veto counter array is essentially uniformly illuminated in the 2-60 cm range.

Up to this point, rates in individual veto counters have not been calculated. It would be very useful to know what rate can be expected in an individual counter. Figure 10 shows the rate/veto counter paddle. Only six paddles are shown since the illumination of the array should be symmetric about the lab frame X-axis. The highest rate is predictably in the inner most paddle, and its rate is a manageable 700 KHz. Figure 10 was generated by considering only where the interaction took place, and not the energy of the initial photon. As such, it's a good check of our data in Figures 8, 9, and 11.

A brief point to make involves the photon angular distribution of the created photons. Figure 12 shows the Hall B X-axis transverse momentum of the bremmstrahlung photons. The distribution in the code goes as $\theta^2/(\theta - \theta_c{}^2)^2$ where θ_c is a cut-off angle. Figure 12 shows a smoothly varying distribution, consistent with our expectations of small transverse momentums.

It is the recommendation of the author to cut a circular hole of radius = 2.26 cm. This is radius matches the circular area of the hole with the beam pass thru hole built into HyCal. At a radius of 2.26 cm, the veto counter array can also catch any backwards scattered electrons from the non-fiducial part of HyCal that could cause a false signal. Figure 11 is a re-plotting of total rate, but now with the proposed 2.26 cm radius hole. We can see that the total rate summed over all energies is roughly 150 kMz. Tallying up both sets of numbers from Figure 8 and 10, the rate for the whole veto counter Array is about 150 kMz. These consistent numbers are well within our bandwidth limitations and hardware specifications.

Figures

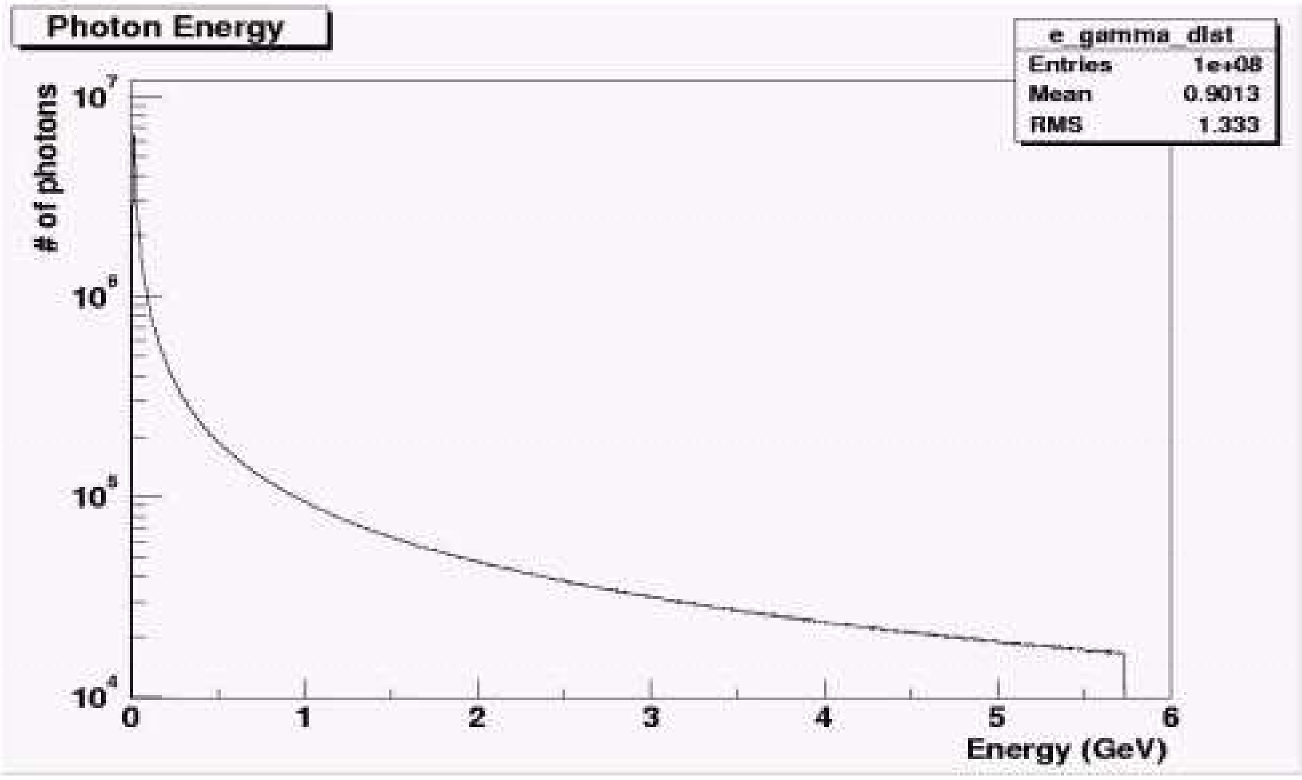

Figure 1: Incident photon energy spectrum.

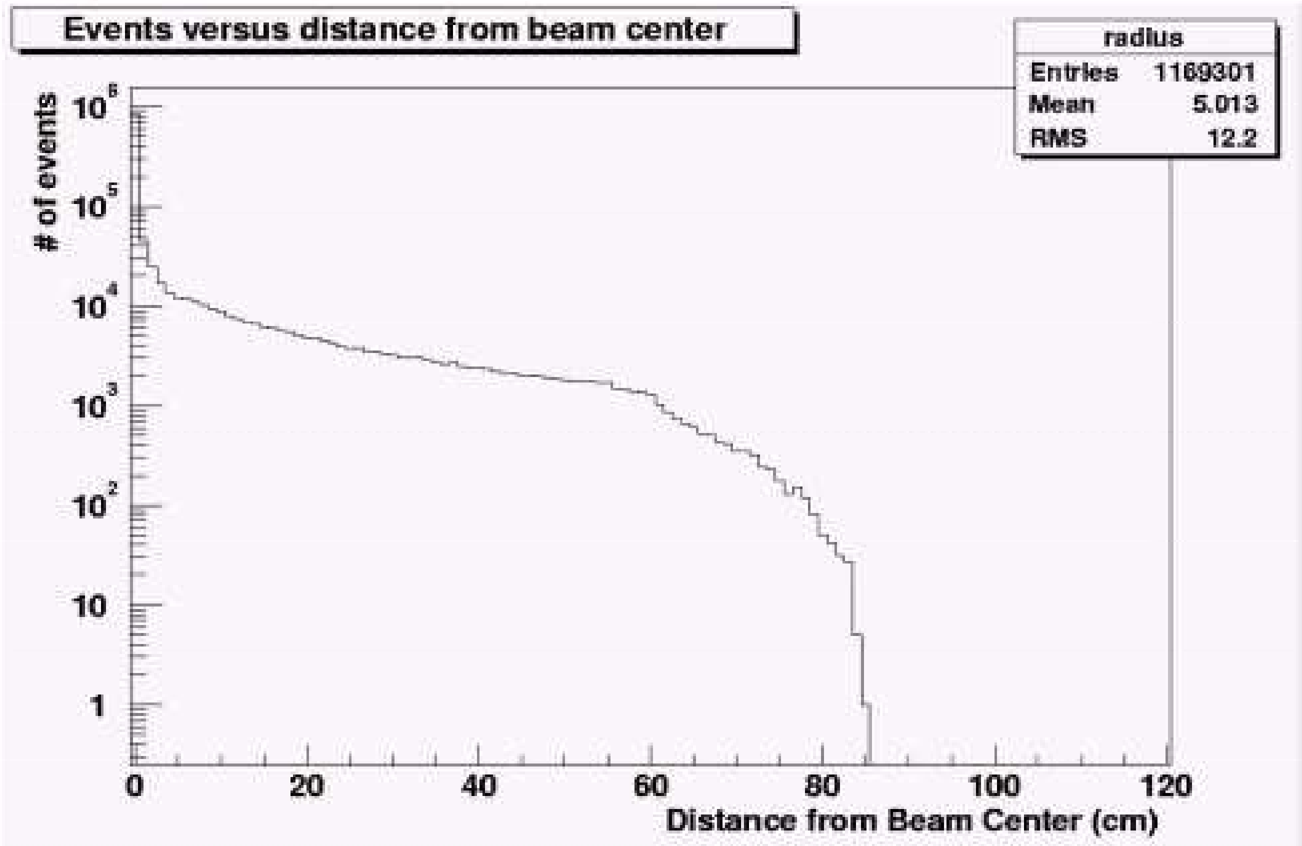

Figure 2: Events versus Distance from Beam Center.

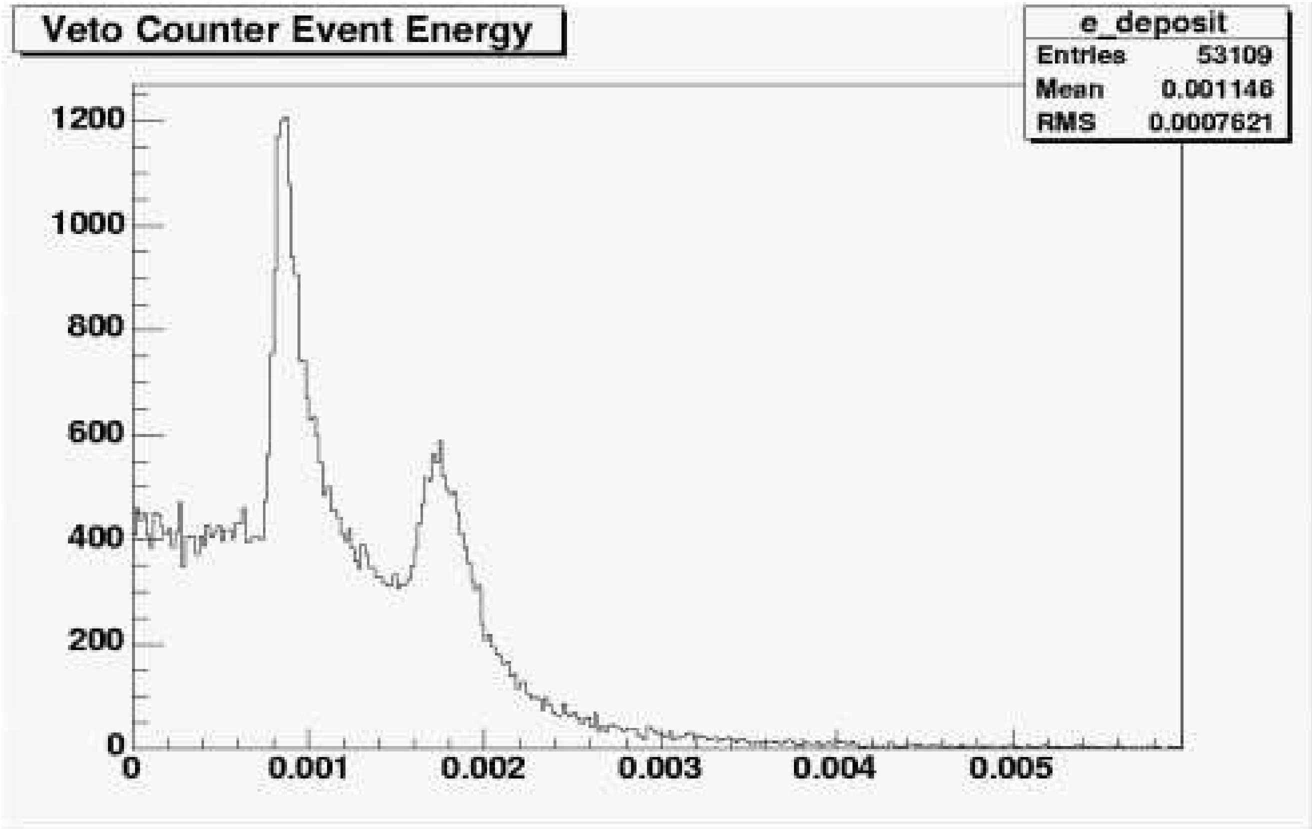

Figure 3: Total Energy deposition in Veto Counters.

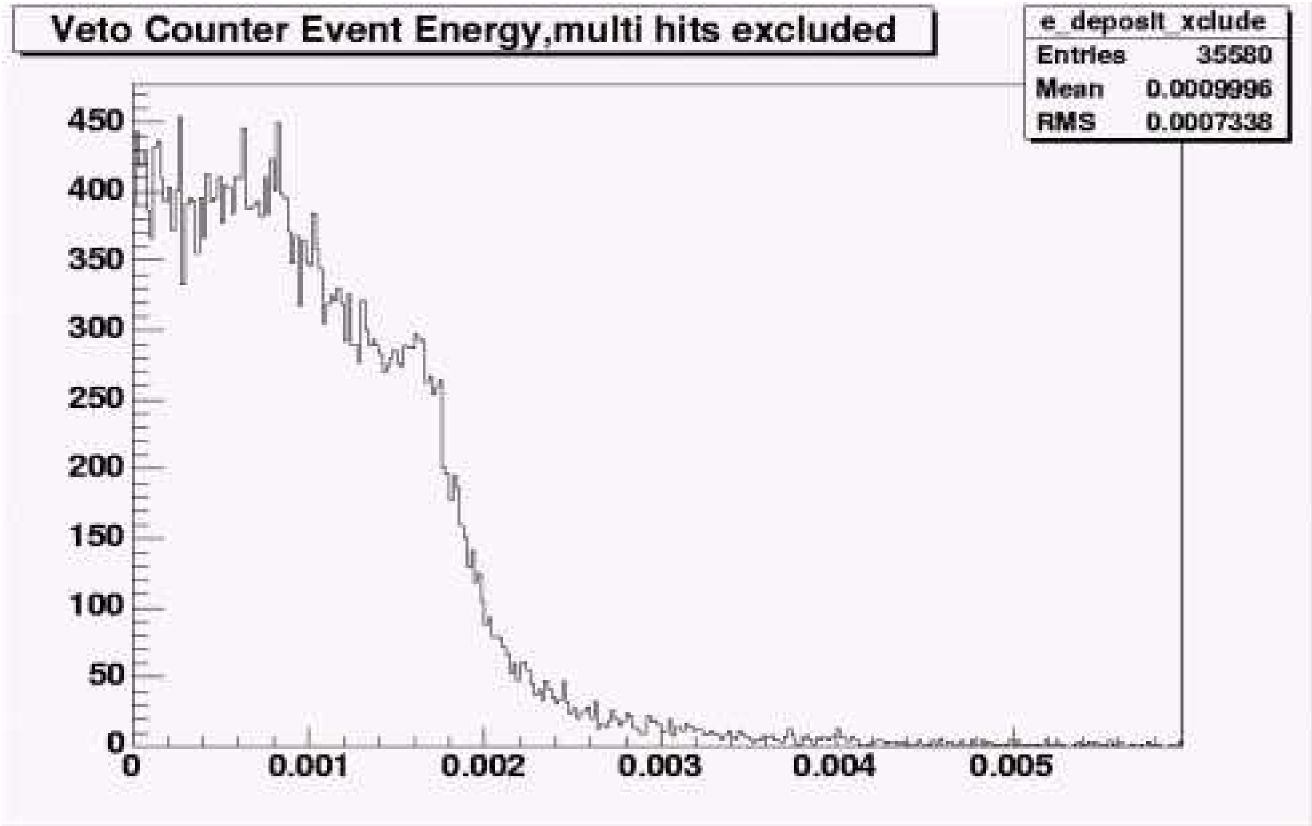

Figure 4: Photon Energy depostion in Veto Counters.

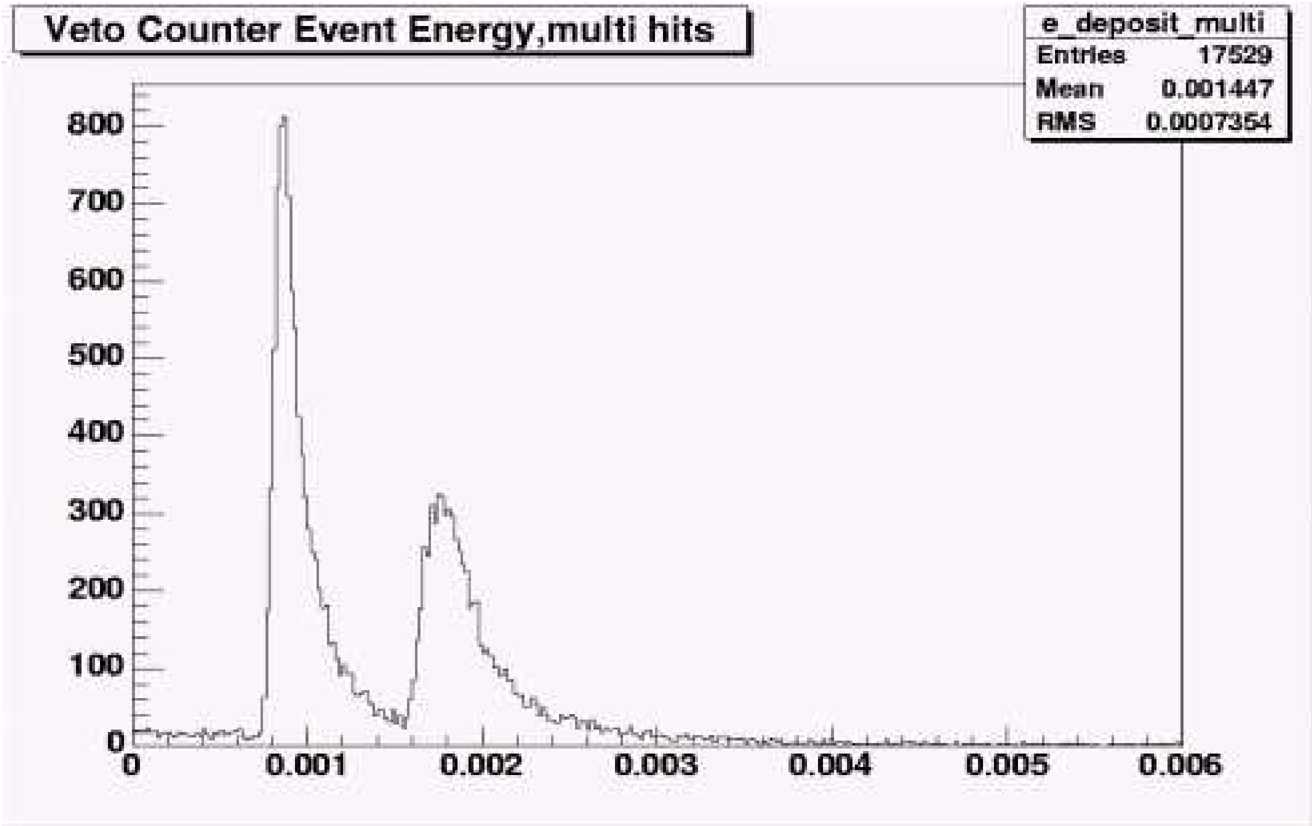

Figure 5:Secondary charged particle energy deposition in Veto Counters.

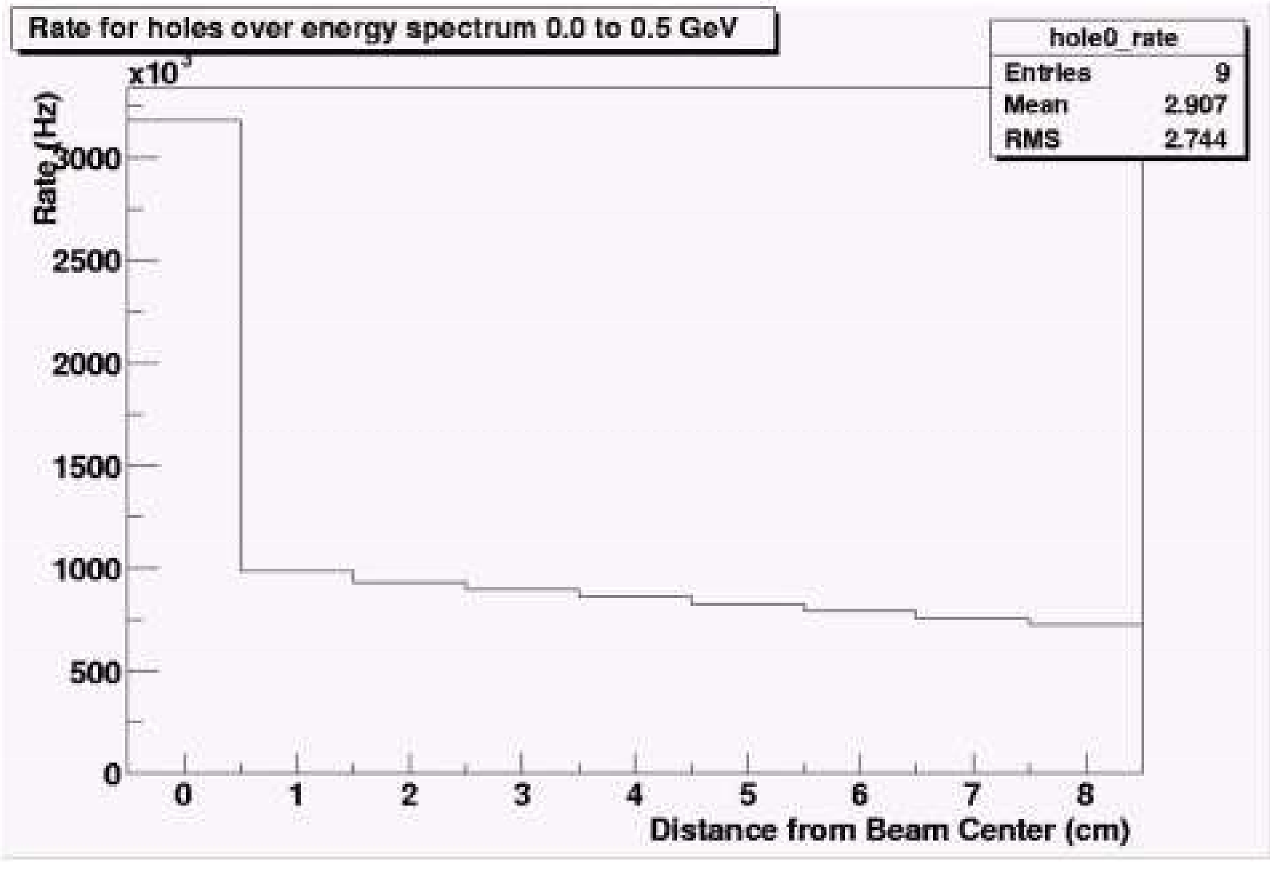

Figure 6: Rate versus Distance from Beam Center for 0.5 to 1.5 GeV photons

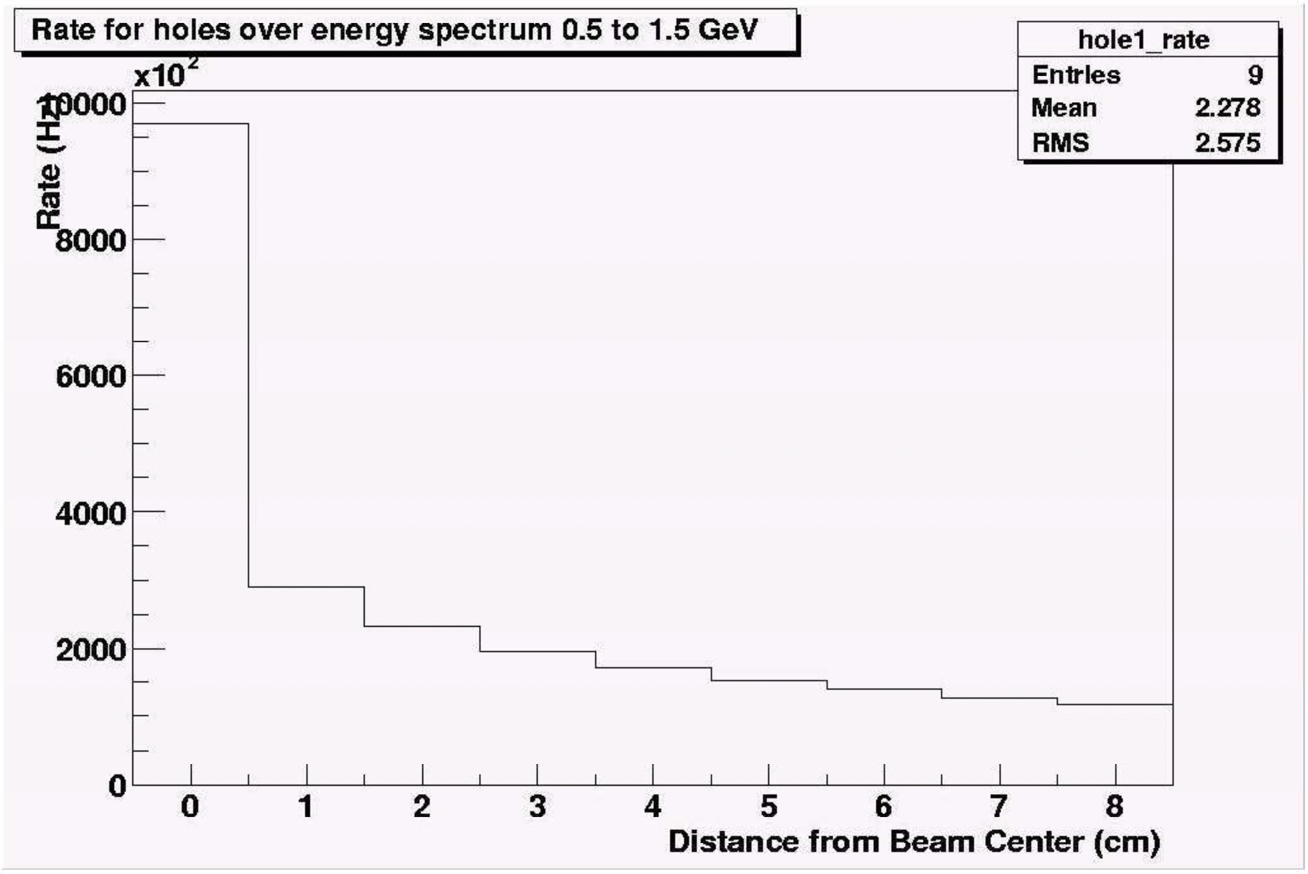

Figure 7: Rate versus Distance from Beam Center for 4.5 to 5.5 GeV photons

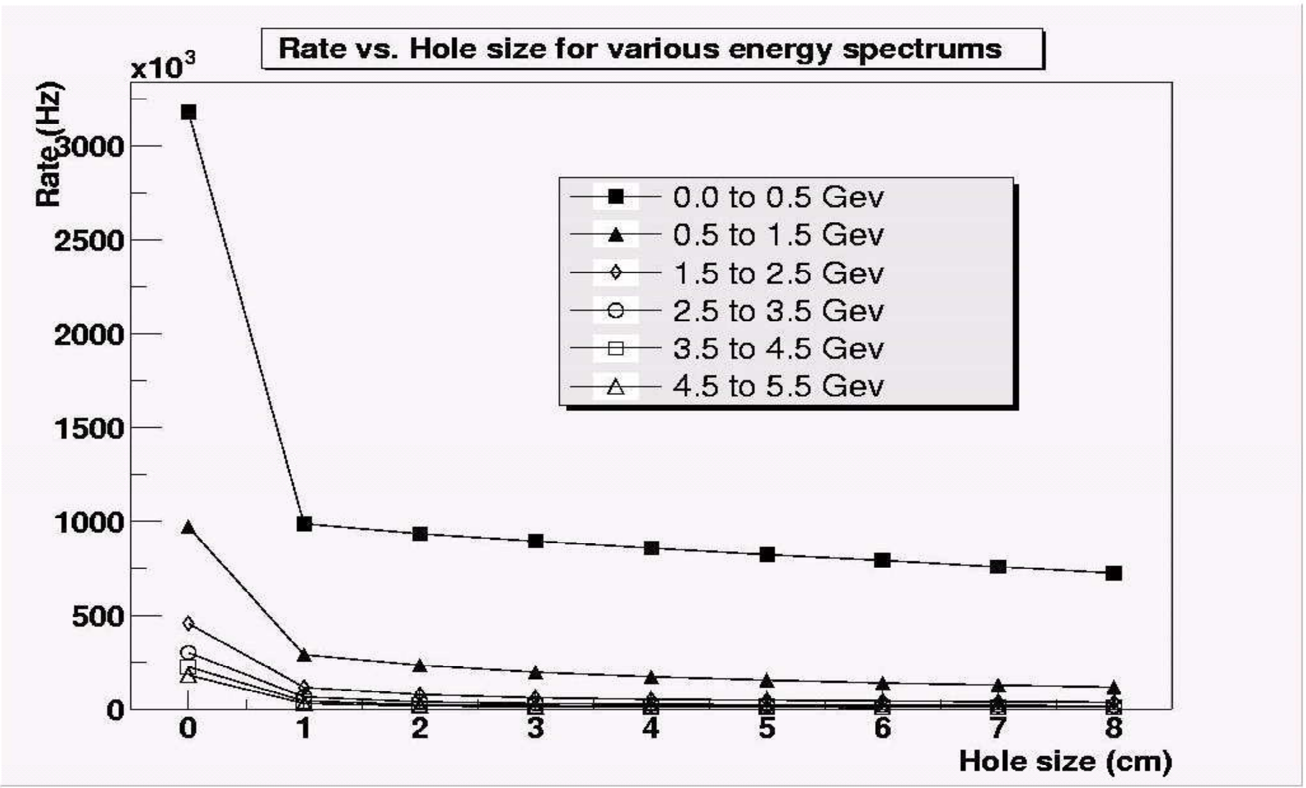

Figure 8: Rate versus Hole Size for all energy spectrums.

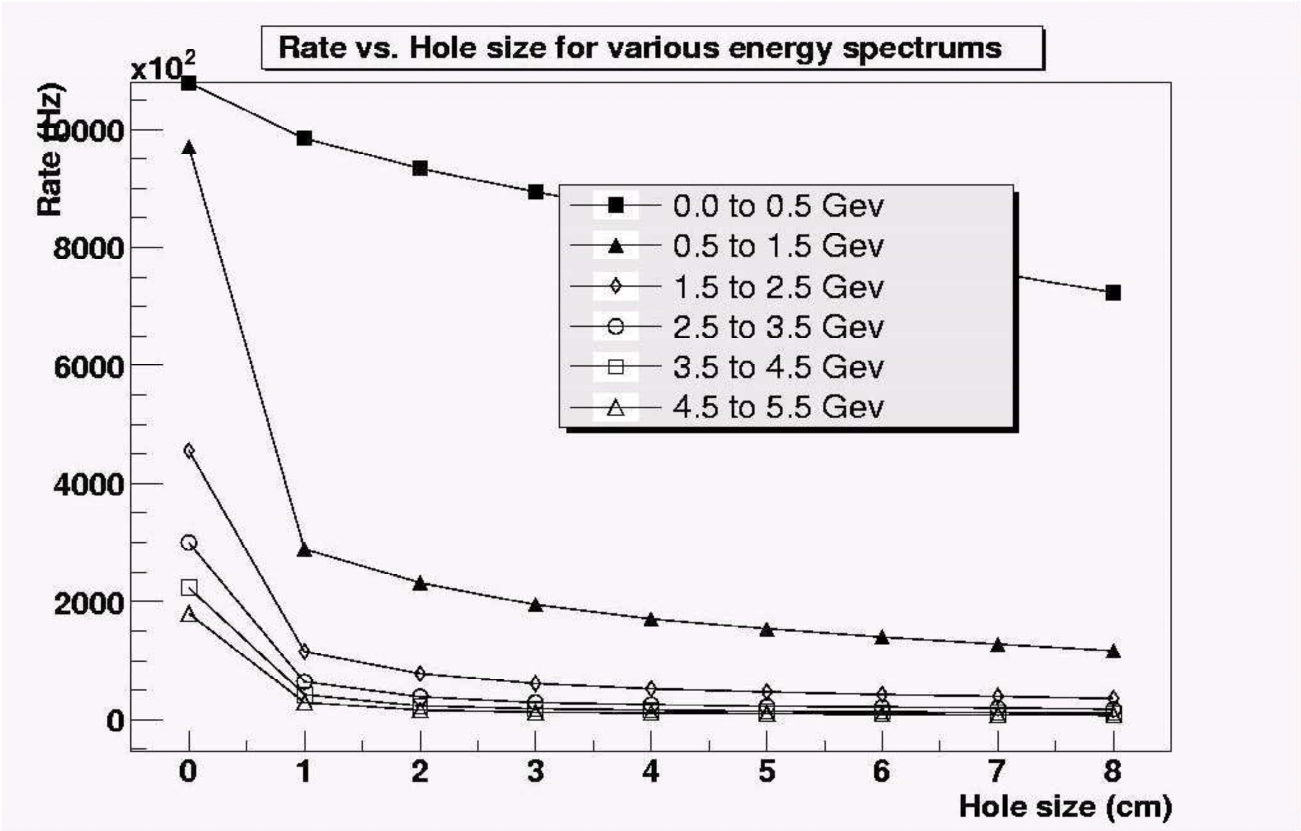

Figure 9: Zoom of Figure 5-Rate versus Hole Size.

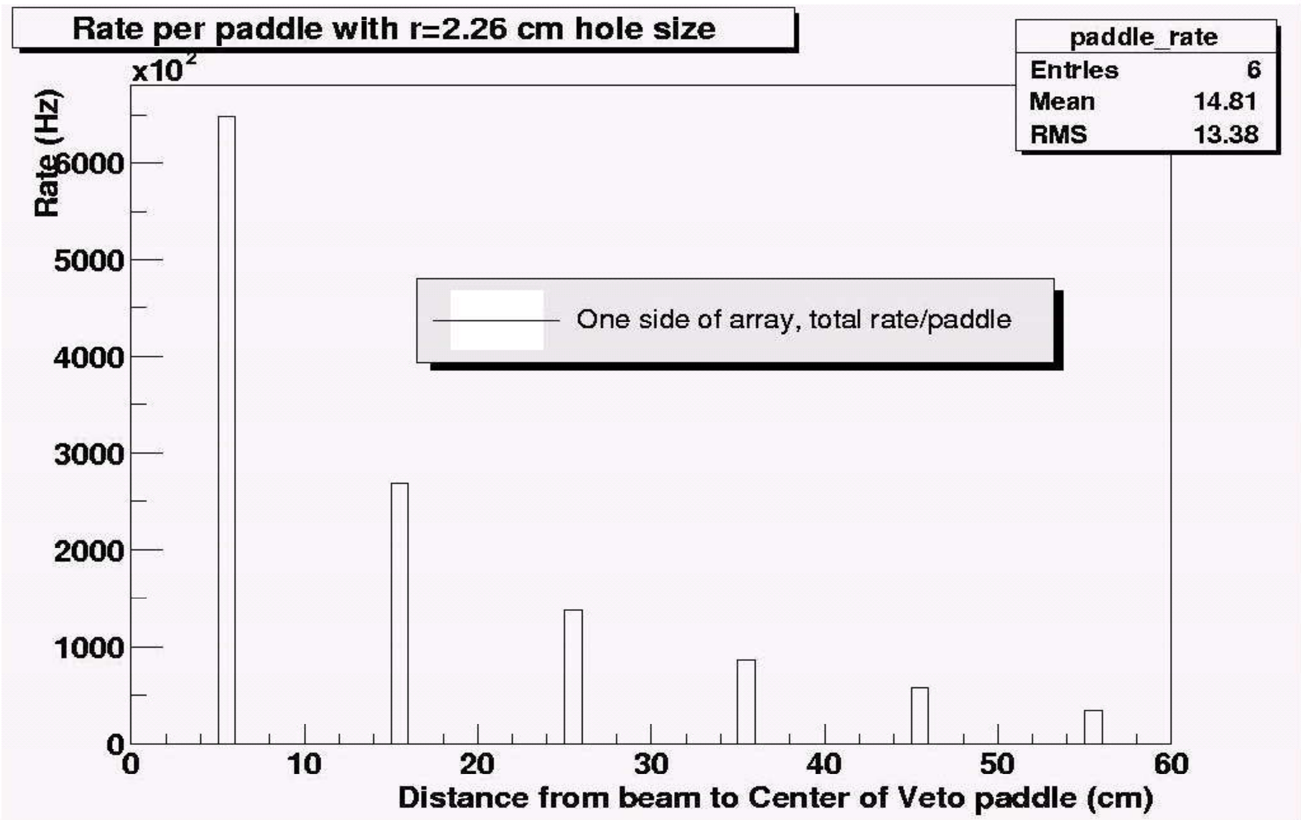

Figure 10: Rate per paddle, plotted at the center of the paddle.

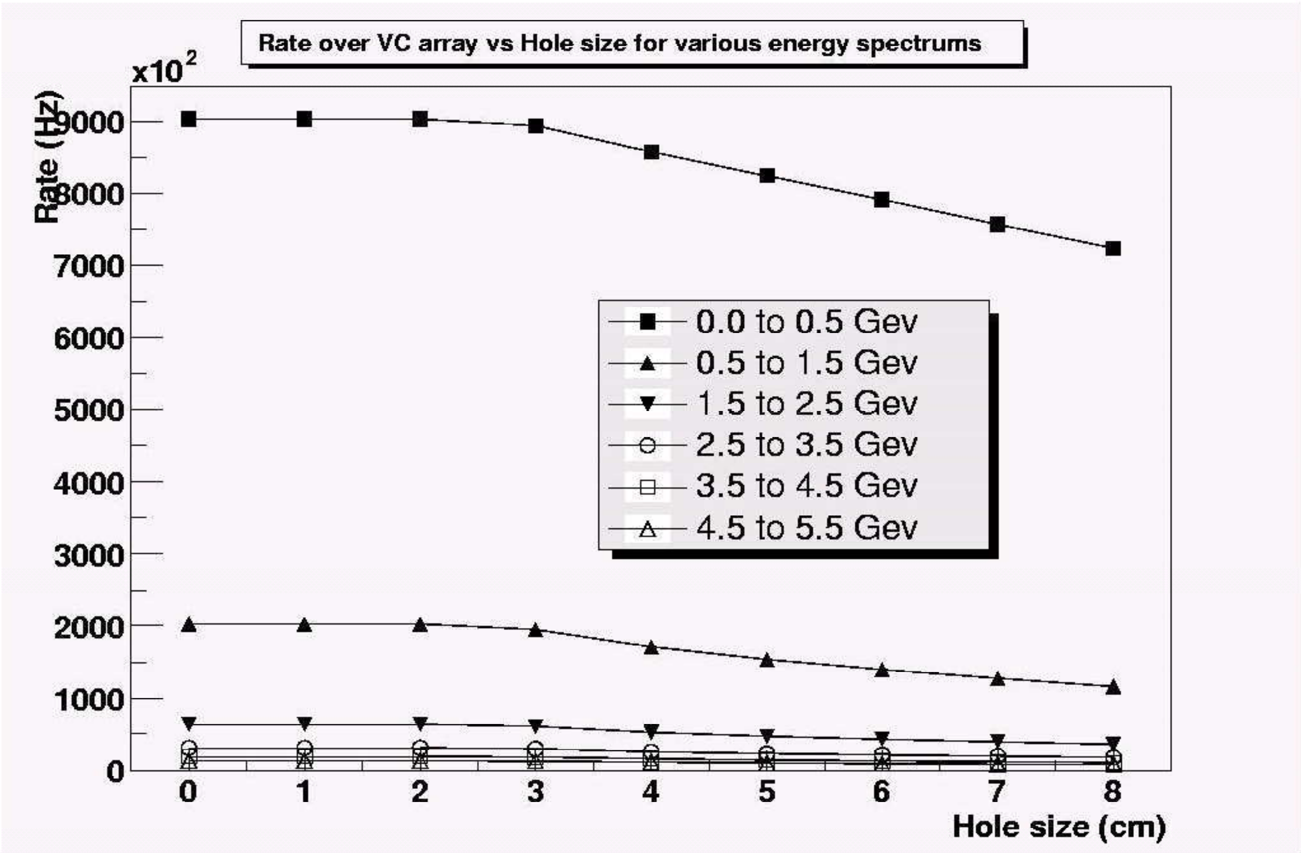

Figure 11: Rate versus Hole Size, all events less then 2.26 cm from Beam Center excluded.

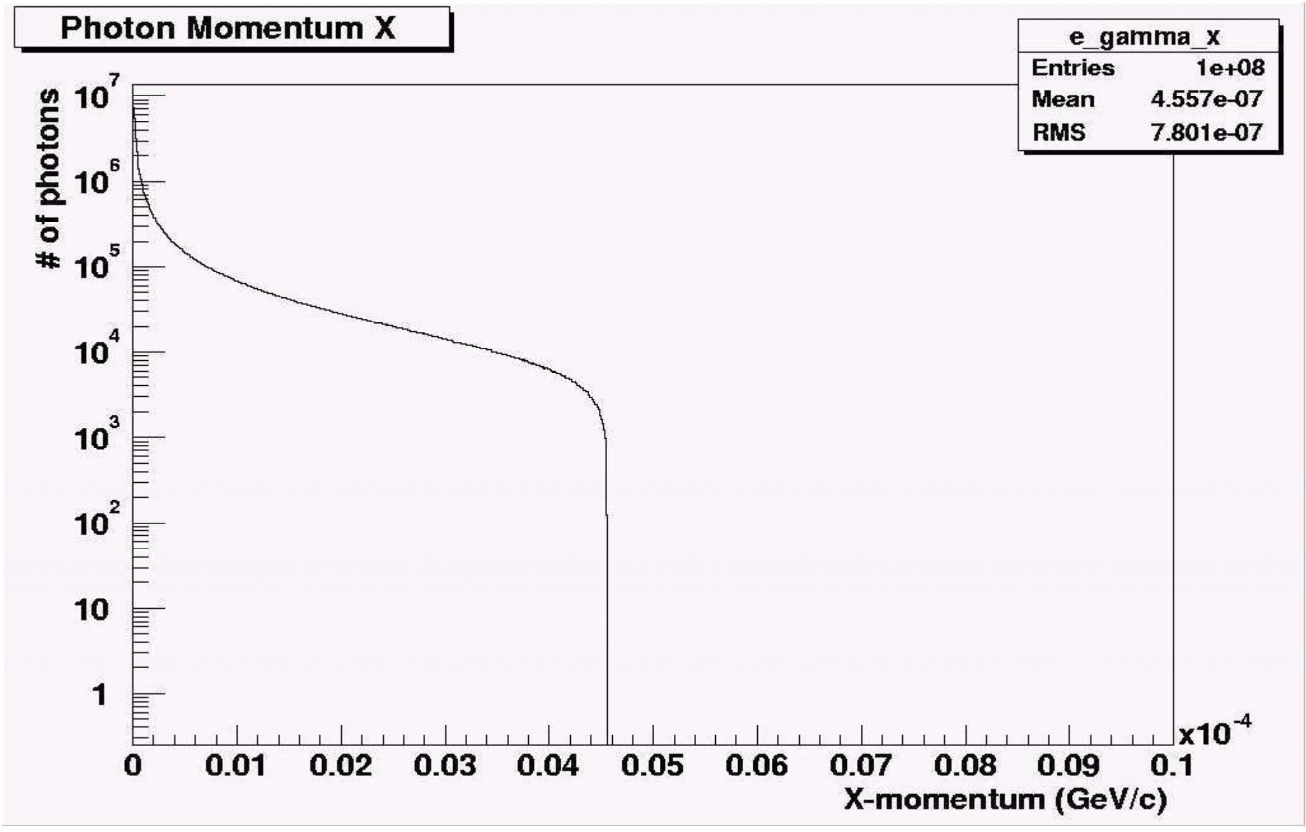

Figure 12: Transverse momentum of the creation bremmstrahlung photons