HYCAL $PbWO_4$ $PbGlass$ Offset Optimization From Simulation

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1 introduction

The HYCAL detector being constructed for the PrimEx experiment (TJNAF E99-014) will be made from 2 different types of detectors: $PbWO_4$ crystals and lead-glass Cherenkov detectors. These two detectors have different physical properties (e.g. density) which affect the development of electromagnetic showers from energetic photons incident upon them. This led to differing designs for the two detectors types. The $PbWO_4$ crystals are $2.05x2.05x18cm^3$ while the lead-glass are $3.84x3.84x45cm^3$. Since the $PbWO_4$ detectors are significantly shorter than the lead-glass, showers which develop in a detector near the border between the two detector types may lose shower particles in a way which depends on the relative positions. Figure 1 shows a diagram of the border region which illustrates the geometry.

2 Showers originating in $PbWO_4$

For the first set of simulations, a simple photon generator was used which sampled photons from a bremstrahlung energy distribution (see fig. 2). The photons were thrown at an angle normal to the front face of the calorimeter and centered on a $PbWO_4$ crystal which bordered the lead-glass detectors. Figure 3 indicates the point at which the photons entered the detector.

The energy deposited in the detectors contained in the black outline in figure 3 was combined and divided by the incident photon energy. Figure 4 shows a typical distribution of the energy fraction contained in the cluster for a specific $PbWO_4$ offset.

Data were simulated for 25 different values of the $PbWO_4$ offset ranging from 0.0 cm to 24.0 cm in 1 cm intervals. For each value 10,000 events were generated. Figure 5 shows the energy fraction contained in the cluster as a function of the $PbWO_4$ position. This shows two things: 1.) The effect is very

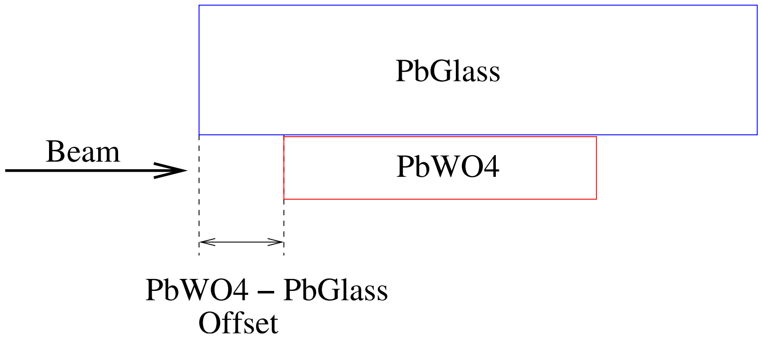

Figure 1: Side view of the border between the $PbWO_4$ and lead-glass detectors. The beam represents the direction of the "thrown" photons for part of the simulation. Simulations were run for 25 different values of the offset ranging from 0.0 cm to 24.0 cm.

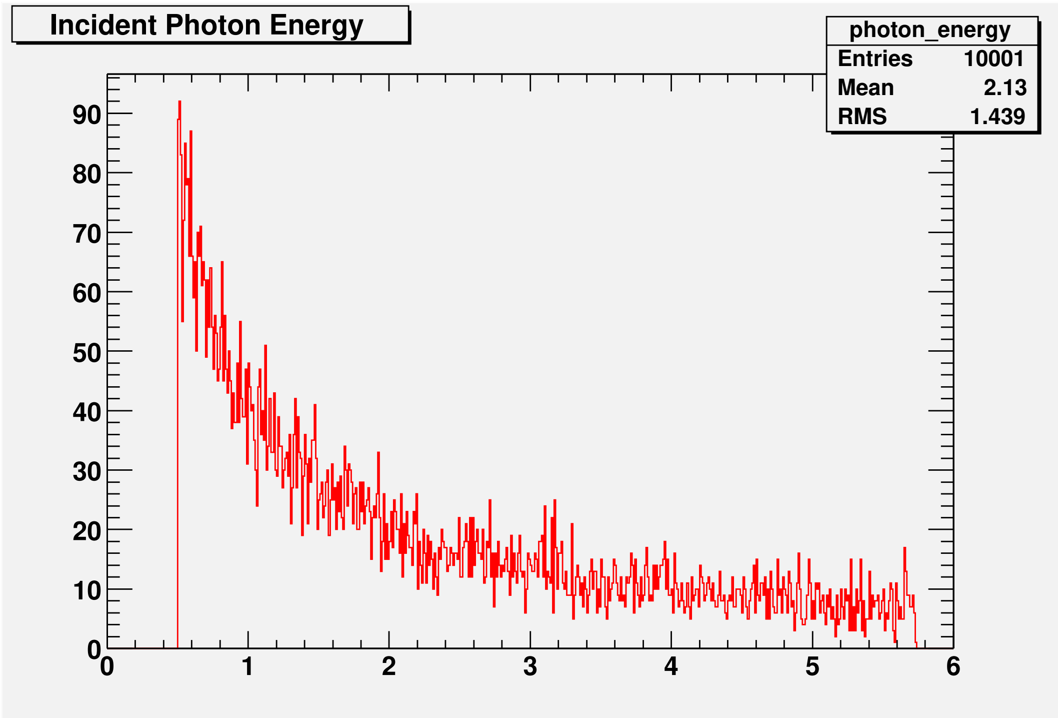

Figure 2: Incident photon energy distribution. This photons were sampled from a 1/E bremstrahlung distribution with energies between 0.5GeV and 0.95*5.734 = 5.44GeV. This does not include the distribution of photons from π^o decays and includes some photons of higher energy than our fiducial acceptance.

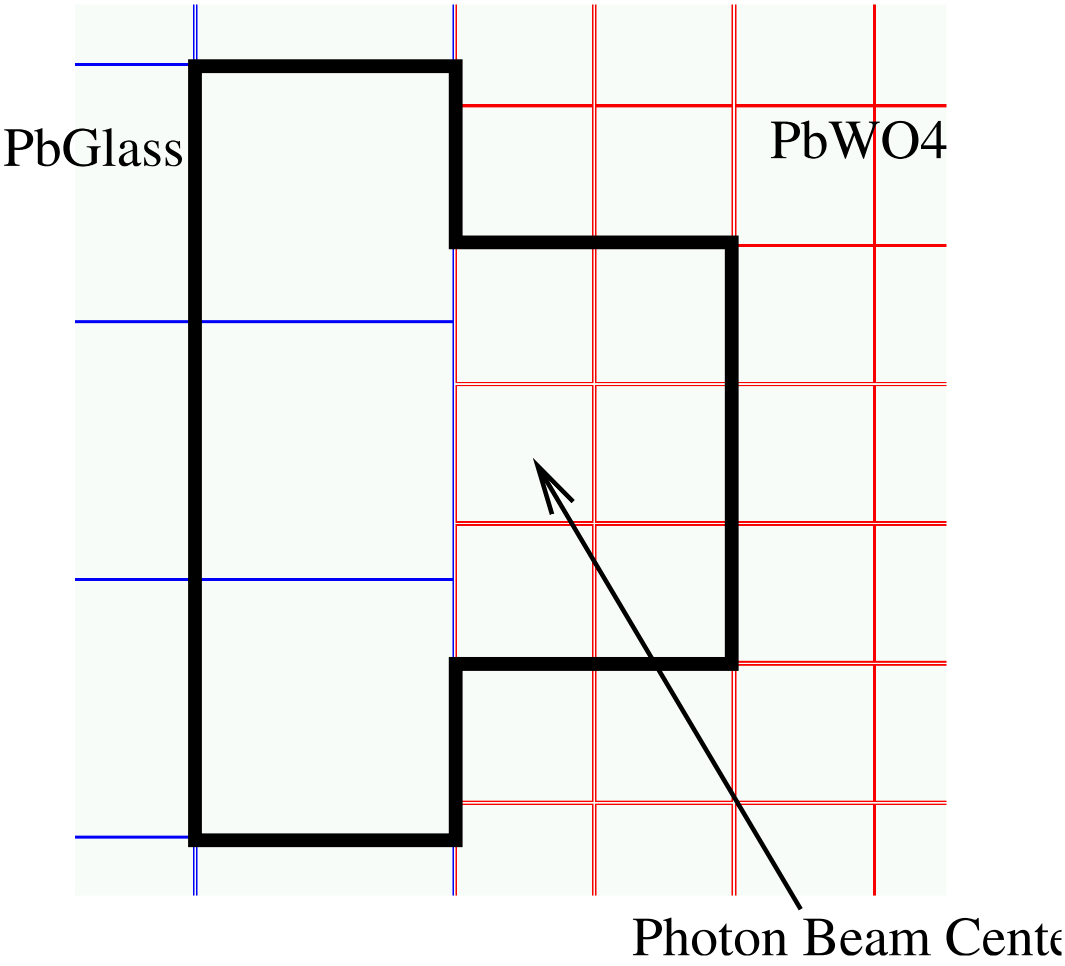

Figure 3: For the first set of simulated data, the photons were were incident on the center of a $PbWO_4$ detector which bordered lead-glass detectors. The black outline shows the detectors whose energy was added for the determining the cluster energy.

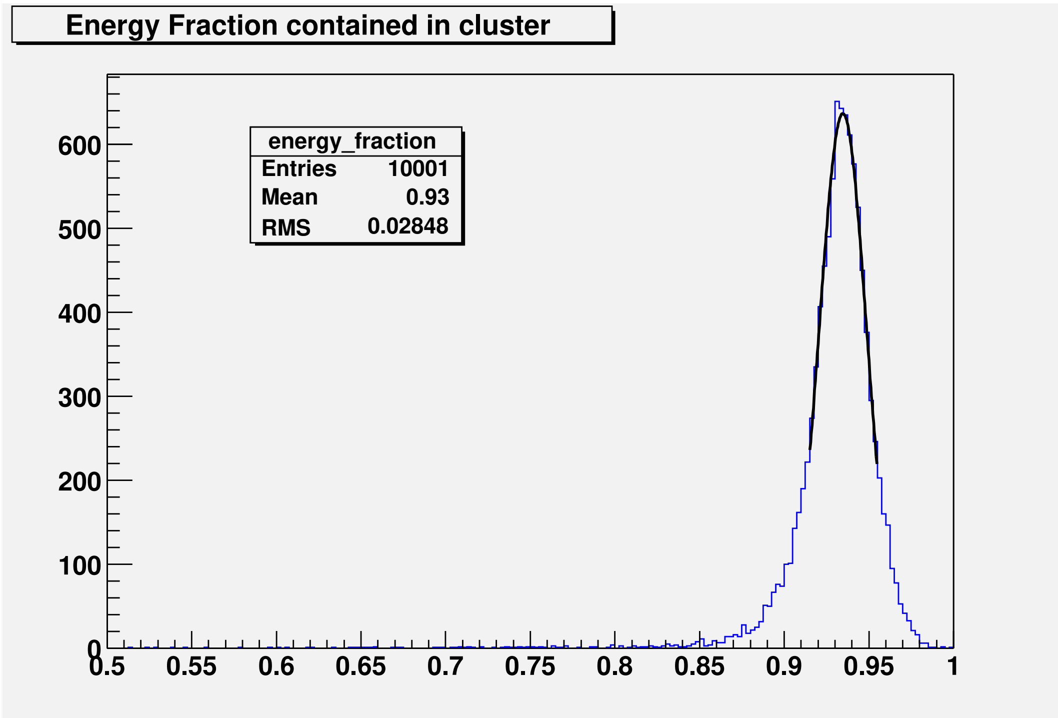

Figure 4: Fraction of the incident photon energy deposited in the cluster shown in figure 3. The black curve at the top of the distribution is the result of a gaussian fit to the peak.

small for photons incident on the $PbWO_4$. and 2.) The energy loss does increase as the $PbWO_4$ is moved back. This is what one might expect given the angular range of shower particles exiting the back of the $PbWO_4$ which do not hit the lead-glass increases with the z-position of the $PbWO_4$. Also, given the longer raditation length of the lead-glass [1] shower particles entering near the back of the detector will be more likely to escape through the back.

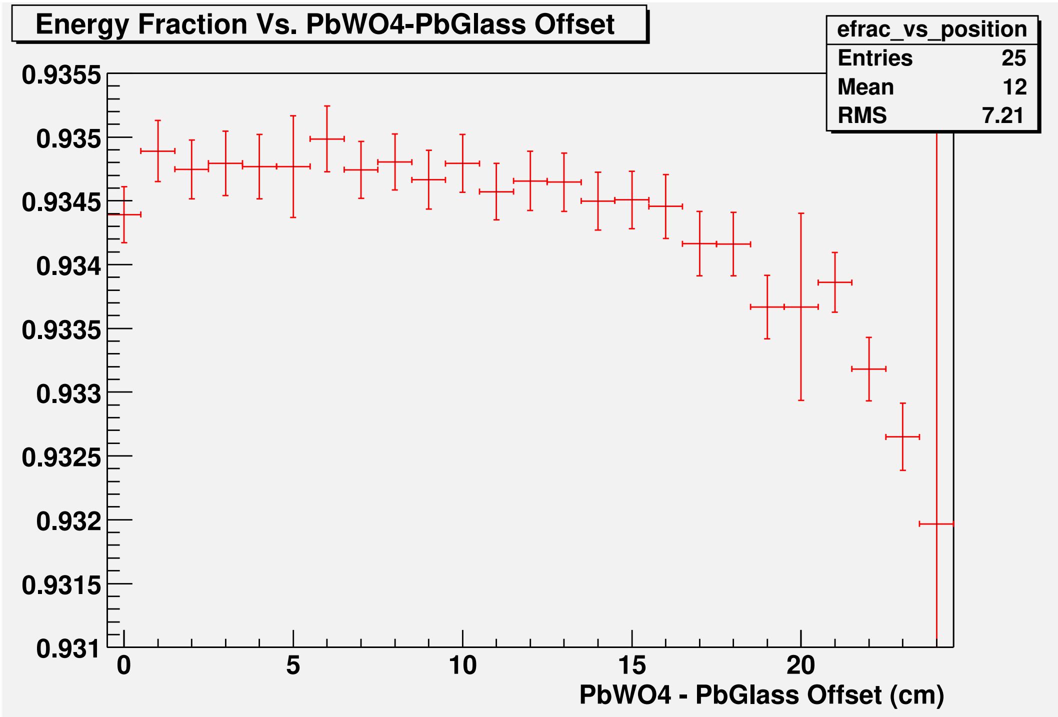

Figure 5: Fraction of the incident photon energy deposited in the cluster shown in figure 3 as a function of the z-offset of the $PbWO_4$ relative to the lead-glass.

3 Showers originating in $lead-glass$

A second set of simulations were done but with the photon beam incident on a lead-glass detector which bordered the $PbWO_4$ detectors. Figure 6 indicates the lead-glass detector on which the photon beam was centered. Once again the $PbWO_4$ z-offset was varied from 0.0 cm to 24.0 cm in 1 cm steps. For each point, the energy deposited in the cluster indicated in figure 6 was added and divided by the incident photon energy.

[1] 2.9 cm for lead-glass as opposed to 0.89 cm for $PbWO_4$

Figure 7 shows the energy fraction contained in the cluster as a function of $PbWO_4$ position for photons incident on the lead-glass. The effect here is much larger than for the $PbWO_4$ case (see figure 5). The shape is again what one might expect. For the $PbWO_4$ close to the front of the lead-glass, shower particles are lost which come out of the lead-glass downstream of the $PbWO_4$. As the $PbWO_4$ is moved downstream, it catches more and more of the leaked shower from the lead-glass. Eventually, however, it starts to miss some of the shower particles upstream of the front of the $PbWO_4$. The curve in 5 indicates the optimal position of the $PbWO_4$ is approximately 12 cm downstream of the lead-glass.

A further analysis was made of the simulated data where the beam was incident on the lead-glass. In this analysis, the number of detectors contributing to the cluster was increased and the data were split into 3 bins in initial photon energy. Figure 8 shows the larger cluster while figure 9 shows plot of energy fraction vs. z-position of the $PbWO_4$. The black points represent all incident photon energies while the blue, red, and green points represent energy ranges centered at 0.8GeV, 1.82GeV, and 4.0GeV respectively. The amplitude of the curves are as expected with lower energy showers being more completely contained in the cluster. The general shape, however, shows only a slight dependance on the optimal z-position of the PbW_4 as a function of energy.

4 Conclusion

A simulation study was performed to determine the optimal position of the $PbWO_4$ crystals relative to the lead-glass detectors in HYCAL. The optimal position maximizes the shower which is caught by neighboring $PbWO_4$ detectors, but orginates in lead-glass. This study shows the optimal position to be such that the front face of the $PbWO_4$ is approximately 12 cm downstream of the lead-glass with only a slight dependance on energy over the range 0.5GeV to 5.44GeV.

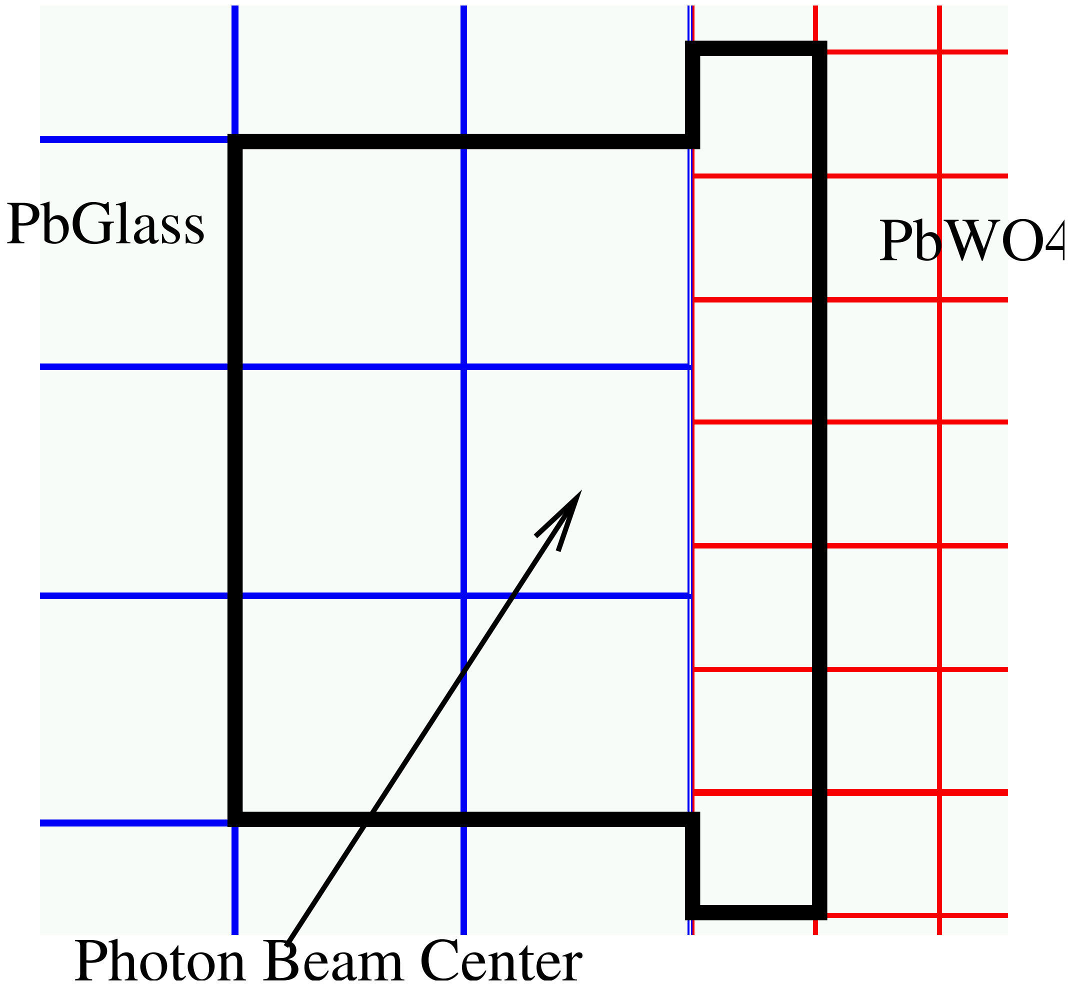

Figure 6: For the second set of simulated data, the photons were were incident on the center of a lead-glass detector which bordered $PbWO_4$ detectors. The black outline shows the detectors whose energy was added for the determining the cluster energy.

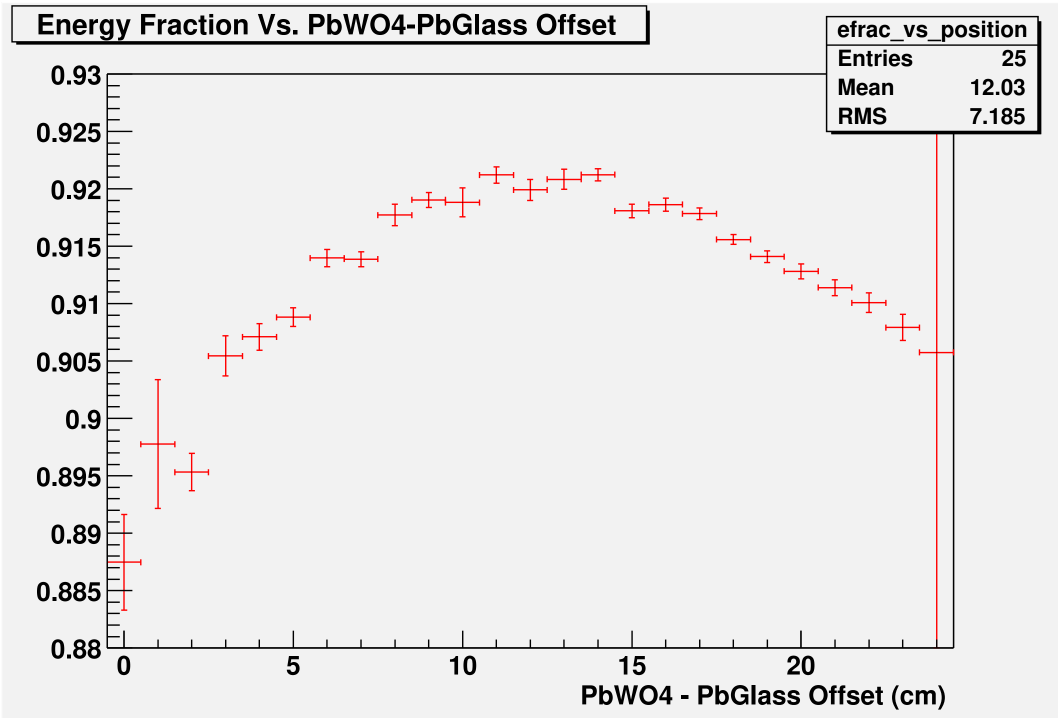

Figure 7: Fraction of the incident photon energy deposited in the cluster shown in figure 6 as a function of the z-offset of the $PbWO_4$ relative to the lead-glass.

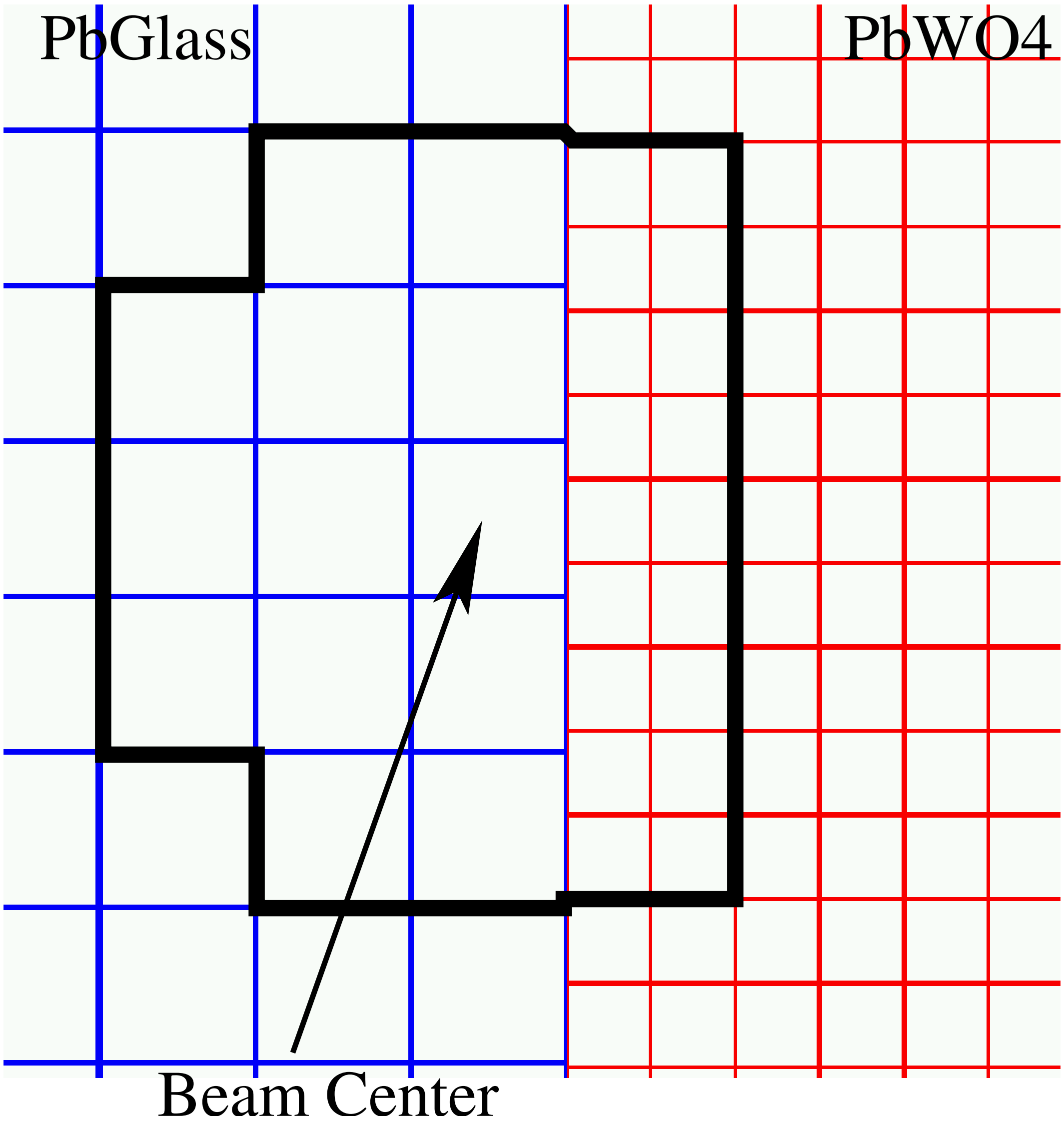

Figure 8: The second data set was also analyzed for a larger cluster size. The black outline shows the detectors whose energy was added for the determining the cluster energy used in figure 9

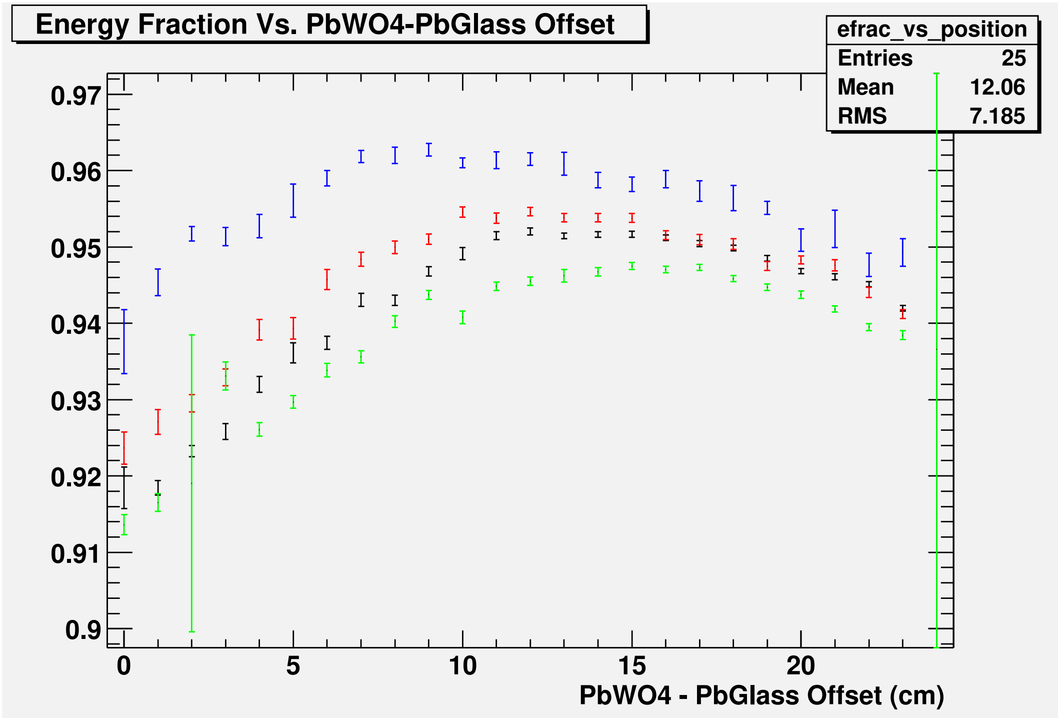

Figure 9: Fraction of the incident photon energy deposited in the cluster shown in figure 8 as a function of the z-offset of the $PbWO_4$ relative to the lead-glass. The curves represent the following energy ranges for the incident photon: $Blue = 0.5 < E < 1.1GeV; Red = 1.1 < E < 2.5GeV; Green = 2.5 < E < 5.4GeV; Black =$All photon energies.