$K_l \to \pi^0 \nu \overline{\nu}$ Simulation Analysis 1

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ABSTRACT

Monte Carlo produced data for $K_l \to \pi^0 \nu \overline{\nu}$ decays were studied in order to decduce acceptable showers in the endcap preradiator. Results for the acceptance and shower characteristics are presented.

1. Introduction

A study of the KLOE type endcap preradiator using events from the GEANT MONTE CARLO written by P Gumplinger with the geometry of run 12 is described below. This run generated 5000 $K_l \to \pi^0 \nu \overline{\nu}$ decays in a 4m diameter endcap with 1cm wide (y) bundles (slices) of fibers. Otherwise the run parameters are standard and here we are not concerned with the endcap calorimeter.

2. Method

The scintillator hits are examined without regard to which π^0 photon caused the hit. The latter is known to GEANT, but not to the experiment.

Each of the 45 preradiator layers is examined in order of increasing layer number. On each layer the scintillator hits are examined. Only unused hits from the endcap and the layer in question are accepted. Once such a hit is found it is classified as used. This hit can become part of an old shower or start a new shower. The decision is made by examining all showers, if any. For each shower all the previous points on the shower are examined and the values of minx, maxx, minslice, and maxslice are found for the layer in question or 1 layer back. If the hit x is between maxx+20cm and minx-20cm, the hit slice is between maxslice + 2 and minslice - 2, and the hit time within 1ns of that of any point on these layers, then the hit can become part of the shower. If the hit cannot become part of any previous shower it starts a new shower. Note that changing 20cm to 30cm, 1ns to 2ns or 2 to 3 (slices) had very little effect (<1%) on the final acceptance. With good timing 20 cm resolution in x from a scintillator should be possible.

After all layers are examined all possible showers (NS) have been found. If there are less than 2 showers the event is cut. If there is more than 3 MeV deposited in the upstream crystals the event is cut. The barrel scintillators can veto events also, however, for now I only veto events if the hits in the barrel are upstream of the endcap. Then if there is more than 3 MeV deposited in the surrounding barrel or more than 10 barrel scintillators have hits the event is cut. These are respectively failure codes 5,1,2 when discussing the results below. These are the pass0 cuts.

For each shower the following quantities are accumulated for each layer with hits: average x, average y, layer gives z, mint, Edep. Also the first and last layers in the shower and the id are obtained. The shower id can be 0,1,2 if the shower contains hits from both photons, photon 1 only, photon 2 only. We can't get id in the experiment, but the simulation can show us the probability for id=0 (which leads to presumably worse fits).

Next the pass1 cuts are obtained. First sum up the number of showers with less than 2 layers hit=m. The id of each shower contributing to m is incremented by 3 to 3,4,5. If NS-m is less than 2 cut the event because you can't obtain a direction from a shower with less than 2 layers. This is failure code 8. Next sum up the showers with 2 layers such that the last layer is not layer 45 = n. The id of each shower contributing to n is incremented by 3 to 3,4,5. Such showers do not have mwpc data for mwpcs sandwiched by scintillators. If NS-m-n is less than 2 cut the event. This is failure code 9.

For the remaining events we seek mwpc coordinate information. This is the information which will be used to find the photon direction. For each layer on any of the showers with id less than 3 examine all mwpc points. For endcap mwpc hits on the same layer average the x and y coordinates that are within 20cm of the averaged scintillator coordinates for that layer. Variation of the 20cm between 1-30cm had very little effect on the overall acceptance. This is expected as the mwpcs just mirror the scintillators. These become the shower coordinates for this layer in any subsequent fit. The number of showers with fewer than 2 layers of mwpc information are summed = k. For each shower contributing to k the id is incremented by 3 to 3,4,5. The event is cut if NS-m-n-k is less than 2. This is failure code 10. The events passing these cuts are the ones from which fits for the π^0 vertex,energy and direction will be obtained (in a later note).

3. Results

There were 5000 events generated and 4837 output records written. Thus in 163 events there were no scintillators with any deposited energy. Figure ID 21 shows the energy (KeV) deposited in a scintillator for any hit. It is typically 125 KeV. Below you will see that for good events there are about 75 scintillator hits on average or about 37 per shower. So each shower will deposit about 4.6 MeV in the preradiator (a small fraction of the total photon energy). Thus a mistake in measurement of preradiator energy doesn't affect measurement of the π^0 energy very much. In order to get an idea of how much the shower spreads, I calculated maxx-minx for scintillator hits from photons 1 and 2. These are plotted in figure ID 101 for all events and in ID 103 for those events passing the pass1 cuts. Here maxx-minx (cm) is horizontal and Ephoton(MeV) is vertical. There is a great deal of shower spreading and so, splashing, but with these statistics it is difficult to see the functional dependence on photon energy. The horizontal and vertical projections of these scatter plots are shown in figures IDs 101(103)x and y. The long tail in maxx-minx is apparent even for good showers. It is interesting to note that the good events favor lower photon energies.

In figure ID 2-6-10 the number of endcap scintillator hits is shown for the various cuts. In the leftmost panel, ID 2, there are 1300 underflows. These are the events with no hits in the scintillators and they will be cut in pass0. In the rightmost panel is the spectrum for good events. Note this panel shows that about 75 scintillators are hit in a good event, as noted above. However, there are only 642 such events, which means at most, an acceptance of about 13%. Presumably the fitting will introduce other cuts. This acceptance is smaller than that estimated at TRIUMF for the same geometry, so that just how we decide on acceptable showers is important.

In figure ID 5-9-13 the number of shower points are shown. The rightmost panel, ID 13, shows the spectrum for good showers. One would hope that there were 2(642)=1284 entries in this spectrum, however, because of shower splashing there are 1399 entries. There are even more showers from splashes, but these have id=3,4,5 and don't enter the spectrum.

In figure ID 3-7-11 some scintillator statistics are shown. In channels 1-9 are the hits/layer. Any layer with more than 9 hits appears in channel 10. There are typically 2 and usually less than 4 hits/layer. The next 45 channels show the hit layers. Note there is a slow rise and then a leveling off as most showers tend to hit the downstream most (higher) layers and enter the calorimeter. Channels 56-65 show the number of hits per slice, which is 1 or 2, but mostly 1. Channels 66-75 show the number of slices per layer hit.

In figures ID 4, ID 8 the shower statistics are shown for all, pass0 events. The first 20 channels show the failure code. Note in ID 4 there is no failure code 1 so that a 3 MeV cut in the upstream crystals will not cut events due to splashing. Changing to 0 MeV would cut a large number of events. Failure code 2 the barrel veto eliminates about 2350 events, while failure code 5 cuts about 600 events. In the latter case there is nothing in the barrel veto, but less than 2 showers in the endcap. In ID 8 you see the failure codes after pass0 cuts. Failure codes 8,9,10 cut about 850,450,50 events respectively.

Channels 29-39 ID 4,30-39 ID 8 show the number of showers with the lowest channel indicating 0 and for ID 4 channel 39 indicates more than 9 showers. Those events surviving pass0 have at least 2 showers. Channels 40,41,42 show the number of showers with id=0,1,2. Thus in ID 8 the number of mixed showers id=0 (contains information from both photons) is quite small (about 375/8700 = 4%). Channels

51-95 show the first layer in the shower and channels 101-145 show the last layer which is mainly 45. So we will know where the shower enters the calorimeter.

In figure ID 12 the shower statistics for the good events are shown. The underflow and channels 1,2 show the showers with id=0,1,2. Now the id=0 showers are slightly more likely. These events have alot of activity. The fraction of good showers (id=0,1,2)is about 125/1350 = 9%. Channels 3,4,5 show the showers with id=3,4,5 in these events. These are showers widely separated from the main shower due to splashing and contain less than 3 layers of information. Channels 6-50 show the number of layers in the shower, channels 51-95 show the first layer in the shower and channels 101-145 show the last layer in the shower (typically 45).

Two last figures are of interest. I picked out a good event (the first I encounted) and plotted the mwpc x and y values of the hits versus layer or z. You can see the difficulty in fitting by drawing straight lines through some of the points and seeing where the tracks intersect. In general the intersection of the yz fit doesn't yield the same z as the xz fit. However, one event doesn't answer any resolution questions, which will be contained in following notes.