A Plan for Calibration

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Abstract

A proposed method for calibating the LGD and the trigger processor is given. A brief description of the calibration algorithm is included.

The calibration method used for this experiment depends on obtaining a set of events where photons can be identified as being the decay products of a narrow, massive parent with a precisely known mass. The π^0 and the η are examples. The decay $\omega \rightarrow \pi^0\gamma$ can also provide photons suitable for calibration.

Given such a data set, constrained fits can be performed to determine an improved estimate of the actual energy of the photons causing the clusters observed in the detector. These improved estimates can, in turn, be used to improve the calibration of the detector. The calibration algorithm is discussed in appendix A.

The difficulty with this calibration method is twofold:

- Triggering the detector on well contained events is difficult because the trigger processor algorithm depends on the values of the calibration constants which are unknown before calibration

- Identifing a set of events where a massive parent produced the clusters in the detector is complicated because the constants that convert ADC signals to energies are, again, unknown.

Neither of these problems can be solved directly but, both can be solved approximately and, by iteration, as accuarately as desired. I discuss them separately below.

1 The trigger problem

The pre-trigger for this experiment is not sufficiently selective to produce a useful data sample for calibration. It is essential that some higher level trigger be used in addition to the pretrigger to produce the calibration data set. Unfortunately, the only such trigger is the LGD trigger processor which depends on knowledge of the calibration constants.

Two observations will make clear how this problem can be solved. The rate for real $\gamma N \rightarrow \mathrm{Hadron} N$ events is small compared to our typical pretrigger rate, and, given a real $\gamma N \rightarrow \mathrm{Hadron} N$ event, the probability that the produced hadron has a π^0 among its decay products is large. This probability is made near 1 by the further requirement that the hadron have no charged particles among its decay products.

If a trigger can be found that reduces the rate sufficiently that data can be taken without a very large deadtime and this trigger has *some* efficiency for selecting hadronic events, these events are useful for calibration. Given this data set, the calibration can be improved, which, in turn, improves the efficiency of the trigger.

Craig Steffan has shown that there is a resolved signal in the E-counters of the RPD due to a recoiling proton. He has also shown that, by selecting on events with a large signal in an RPD E-counter, a relatively background free π^0 signal can be extracted. This fact can be exploited at the trigger level by increasing the discriminator level for the RPD E-counters.

Another way to increase the trigger efficiency is to use the uncalibrated trigger processor. Assuming there is not a huge variation in the gains of the phototubes, the gain of any individual tube can be approximated as some constant independent of the cell address. The trigger processor would be initially loaded with EPROMS reflecting this approximate calibration. The threshold for the trigger processor would be increased until the trigger rate was acceptable, data collected, and a new set of calibration constants determined. In principle, either the energy or effective mass output of the processor could be used for this purpose but, because the effective mass calculation depends on the energy calculation, it would probably be most useful to use only the energy output during calibration runs.

Since it is unlikely that we will have easy access to the detector, it will not be possible to replace the EPROMS with a new set reflecting the new calibration constants. It will, however, be possible (see appendix B) to adjust the gain of the phototubes so that the "constant gain" approximation made above is closer to correct. After this adjustment is made, the efficiency of the trigger processor will improve and the data taken will improve the calibration.

The above observations lead to a plan for the calibration trigger:

1 establish a two level trigger using the LGD trigger processor

2 determine the trigger rate as a function of the required threshold for the trigger processor.

3 choose a threshold that gives a trigger rate acceptable for the DAQ system and that approximates the expected neutral hadronic rate

4 take sufficient data to determine a set of calibration constants. Since the yeild of "good" hadronic events is not known at this time it is not possible to define "sufficient" but 500 $\pi 0 \rightarrow \gamma\gamma$ events is adequate for the next step [1]

5 determine a new set of calibration constants

6 adjust the gain of the LGD based on the new calibration constants

7 iterate to step 2

If it turns out not to be possible to extract an acceptable set of calibration events using the trigger processor, it has already been shown that such a data set can be extracted (very inefficiently) using only the pretrigger. (recall that during the last run the energy sum trigger had failed but it was still possible to isolate the π^0) This process could be improved by adjusting the thresholds of the RPD E-counters until an enhanced data set was obtained.

2 The analysis problem

As stated above, given a real $\gamma N \rightarrow (\mathrm{Hadron} \rightarrow \mathrm{Neutrals})N$ event, the probability that the produced hadron has a π^0 among its decay products is large. Because of this, isolation of a π^0 signal is possible even if an uncalibrated detector is being used. The procedure is:

- select all events with exactly two photon clusters
- calculate the effective mass of these photon pairs under the assumption that all calibration constatns are equal. (the assumed value is arbitrary but should be chosen for histogramming convienence)
- plot the distribution of obtained effective masses

[1] 500 $\pi^0 \rightarrow \gamma\gamma$ events give 1000 photons which illuminate 8000 cells of the detector which works out to 20 "hits" per cell, a typical minimum value for calibration

- assume the peak of the distribution is due to the π^0 and rescale the arbitrary calibration constant to map the location of the peak onto the known π^0 mass.
- select events with a mass near the π^0 mass and fit them to the π^0 hypothesis
- use these events for calibration
- iterate. The selection defining "near the π^0 mass" will have to be refined as the π^0 peak becomes more and more resolved.

This procedure was carried out during the last two runs and the π^0 peak was successfully isolated both times.

A The calibration algorithm

A "good" set of calibration constants minimizes the difference between the observed energy in a photon cluster and the actual energy of the photon that caused it. The energy of a photon cluster is given by

$$E = \sum_j C_j P_j \tag{1}$$

where the sum is over the blocks in a cluster, C_j is the calibration constant of the $j'th$ module and P_j is the pedestal subtracted pulse height in the $j'th$ module. Suppose there exists data with known energy photon clusters. (This data set is produced by constrained fitting of two photon events to the π^0 hypothesis, for example) The difference between the observed energy and the actual enegy for the $i'th$ photon is given by

$$\delta = E_i - \sum_j C_j P_{ji}. \tag{2}$$

A good set of calibration constants can be determined by minimizing the quantity

$$\chi^2 = \sum_i \frac{\left[E_i - \sum_j C_j P_{ji}\right]^2}{\sigma_i^2} \tag{3}$$

where the index i runs over some large set of photons and σ_i is the expected energy resolution for the $i'th$ photon . Imposing

$$\frac{\partial \chi^2}{\partial C_l} = 0 \tag{4}$$

gives

$$\sum_i \frac{E_i P_{li}}{\sigma_i^2} = \sum_j \left(\sum_i \frac{P_{li} P_{ji}}{\sigma_i^2} \right) C_j, \tag{5}$$

a system of linear equations that can be solved for the calibration constants. Treating the calibration constants as parameters in a χ^2 minimization, the estimated error in the "parameters" is determined by the error matrix. The error matrix is the inverse of the covarience matrix. The $(l, m)'th$ element of the covarience matrix is

$$U_{lm} = \frac{\partial^2 \chi^2}{\partial C_l \partial C_m} = -\sum_i P_{li} P_{mi} \tag{6}$$

so the error in the $j'th$ calibration constant is given by

$$\delta_j = \sqrt{E_{jj}} \tag{7}$$

where

$$E = U^{-1}. \tag{8}$$

B Phototube gain as a function of voltage

The gain of a phototube varies with the applied voltage as

$$G \propto V^K \tag{9}$$

where K is a constant that depends on the tube. For this experiment it has been shown that K is equal to 10 and depends only slightly on the individual tube, that is, K can be approximated as 10 for all the tubes in the LGD. Since

$$G \propto 1/C \tag{10}$$

where C is the calibration constant, the gains of the tubes can be equalized once a set of calibration constants is known. In particular, if it is desired to force all calibration constants to equal the fixed value C_0, a cell with a calibration constant C_i and voltage V_i should be given a new voltage V_n such that

$$V_n = V_i \left(\frac{C_i}{C_0} \right)^{1/10}. \tag{11}$$