SASY Technical Note # 17

π^0 Reconstruction — EXP vs MC

M. Lucas and M. Blecher

June 1, 1998

Version 1.1

1 Introduction

This technical note presents an initial look at the reconstruction of π^0's in the XTAL box. We find good agreement between Monte Carlo (MC) and experimental (EXP) data. We present an overview of this analysis and preliminary spectra.

EXP data used in this note are from April 1997 scattering from hydrogen. Specifically, runs 3851–3854 have been used. The calibration from previous work on Compton separation was used with some small refinement of the XTAL Box calibration. See SASY Tech Note 16 for details of the calibration.

Raw data was filtered with two major criteria: there was a neutral hit in a 25-pack of crystals in a given face of the XTAL Box (XT), and a proton was identified in the first layers of bars (B) in the endcap (EC). We looked at the top and bottom faces, since these corresponded to full bars above and below the center of the bar. This avoided the need to calibrate the half-bars.

This note briefly describes the preparation of the experimental data, the filtering of the data, the π^0 reconstruction analysis and the comparison of MC and EXP results.

SASY Tech Notes can be found in postscript form on the LEGS VMSCluster and on the Web. On the cluster, notes are located in `DISK$USER09:[LUCAS.SASYTECH]`. The files are labelled `SASYNOTExx.PS`. The file `INDEX.TXT` gives the titles and a brief description of the notes. On the Web, notes are located `http://legsux1.phy.bnl.gov/~lucas/L10/` (e-mail lucas@bnl.gov for user and password).

2 Calibration of Experimental Data

The calibration is roughly the same as for the Compton-separation analysis (see SASY Tech Note 16). A survey of the 4 XTAL Box faces found a couple of crystals requiring adjustment. Most crystal gains are matched to MC to within 2–3%. A couple crystals may be off as much as 5%, but not many. Gain offsets for the XTAL box were forced to 0. The XTAL Box corners were not calibrated. For the purpose of analysis, the corners were ignored both in EXP and MC.

Several MC runs were processed investigating the concern of gain matching. As stated the calibration of the crystals is not perfect. Before analyzing a MC run, each crystal was assigned a random correction factor distributed about a mean of 1 with a given sigma. Before each event was analyzed, the energies were thus 'smeared' to represent imperfect gain matching. We realized that when the opening angle is included in the reconstruction of the pion mass and energy, the spectra are not very sensitive to mismatching. Deviations as mentioned above of order 5% are not an issue.

Four crystals were functioning poorly during the run of interest. Three crystals had pulse height spectra but were not functioning in the trigger (this meant they could not be gain matched in the standard manner). A fourth crystal was simply not providing any signal. These four crystals were not used in the analysis of the EXP or MC data. Two of these crystals were FBL 6-4 and FTR 6-4 and reside squarely in the region of interest in the top and bottom faces.

The top bars retained their calibrations from previous analyses. The bottom set of PN vetos and bars were matched in gain to the top half using protons and assuming symmetry between the two sets. This provides quite sufficient alignment to identify protons in the PN Bars. The quadratic transformation was again applied to the upper vetos. I realize now that this was not applied to the lower vetos. This will only affect lower energy protons.

3 Filtering of Experimental Data

The EXP data were filtered directly from the raw runs resident on disk. The follow requirements were applied to the data before passing it through to the analysis machinery:

- Only 1 tagging counter had a hit in the TA peak (this guarantees knowledge of the photon energy).
- 'mono-energetic' photons — selected events on a single tag counter. The counters used in different runs were tag counter 20 [1] (E_γ = 300 MeV) and tag counter 40 (E_γ = 256 MeV) [2].
- A summed energy of 30 MeV or greater was required in the 25-pack of crystals bounded by FBL 3-3 and FBL 7-7 (or FTR 3-3 and FTR 7-7 in the case of the top face).

[1] Tag counters range from 0–63

[2] Energies represent central energy of tag counter. Each counter has a spread of roughly 5.5 MeV FWHM.

- A ΔE-E Cut for protons in bars was placed on the sum of the signal in the veto paddles versus the sum of the signals in the bars.
- No charged hits in XTAL Box.

Four passes were made down the EXP data.

AG: E_γ = 300 MeV; Bottom Face; Run 3854.

AH: E_γ = 256 MeV; Bottom Face; Runs 3851–3854.

AK: E_γ = 256 MeV; Top Face; Runs 3851–3854.

AL: E_γ = 300 MeV; Top Face; Run 3854.

4 Generation of MC Data

MC runs were created for all 4 of the above scenarios distributing π^0's throughout the box. XTAL box cuts were placed similar to the filters placed on the EXP data.

5 Analysis

Both EXP and MC data are then passed to the analysis routine. Corner energies and the four questionable XTAL Box Face crystals have their energies set to 0. Hits in the box are clumped and hits in the bars are analyzed for particle id.

At this point, the energy of the EXP XT clumps is increased by a factor of 14% to compensate for the difference in calibrations between pions and photons.

Having identified a proton in the bars and two clumps in the XTAL Box, the π^0 properties are reconstructed. A 1988 NIM article by Hans Ströher, et.al. [3] provides a good reference for this work. Below are several equations of interest from this paper.

The total energy of the π^0 ($E_{\pi^0} = E_{\pi^0}^{kin} + m_{\pi^0}$) can be determined in a variety of ways. If one has very good energy resolution, the energy of the two photons can be used.

$$E_{\pi^0} = E_{\gamma 1} + E_{\gamma 2} \tag{1}$$

One can also use the energy of one photon and the opening angle:

$$E_{\pi^0} = E_{\gamma i} + \frac{m_{\pi^0}^2}{2E_{\gamma i}\,(1 - \cos\Phi_{\gamma\gamma})} \tag{2}$$

[3] H. Ströher, et.al., NIM **A269** (1988) 568–579.

A third technique uses the opening angle in conjunction with the two photon energies:

$$E_{\pi^0} = \sqrt{\frac{2m_{\pi^0}^2}{(1 - X^2)(1 - \cos\Phi_{\gamma\gamma})}}, \tag{3}$$

where

$$X = \frac{(E_{\gamma 1} - E_{\gamma 2})}{(E_{\gamma 1} + E_{\gamma 2})} \tag{4}$$

The invariant mass of the pion can likewise be obtained using the two photon energies and the opening angle.

$$m_{\pi^0}^2 = 2E_{\gamma 1}E_{\gamma 2}(1 - \cos\Phi_{\gamma\gamma}) \tag{5}$$

6 Comparison of Experiment and MC

The following figures provide a comparison of MC and EXP data. They also show the comparison of the top and bottom faces.

When Equation 3 is referenced, E_{π^0} has actually been calculated in the following manner: (I) Calculate using Equation 3, (II) if provides a non-physical (negative) kinetic energy, then use Equation 2, (III) if this provides a negative kinetic energy, use Equation 1.

When Equation 1 is reference, E_{π^0} has been calculated using Equation 1 first, Equation 3 second, and Equation 2 third.

Figure 1 provides a comparison of EXP and MC for the bottom face at two different incident photon energies. The top panels show the kinetic energy as derived from the total energy as calculated using Equation 3. The bottom panels show the difference between the calculated π^0 invariant mass and the accepted value of 135 MeV. EXP curves are shown as solid lines, MC as dashed. The spectra have been normalized to the same number of counts. The lefthand panels present the spectra for E_γ =300 MeV, the righthand panels for E_γ =256 MeV.

The comparison between MC and EXP is very favorable. The widths of the peaks are comparable (EXP only slightly wider at the level of a couple of percent). The means are slightly different, but it should be noted that the measured value is really E_{π^0}, and $E_{\pi^0}^{kin} = E_{\pi^0} - m_{\pi^0}$. A 5 MeV deviation at 80 MeV is a 2% error in E_{π^0}. The most striking difference between EXP and MC is the high energy tail in the energy spectra. Amusingly enough it is *present* in MC and missing the EXP data. This is probably the result of events with protons that are not being processed properly in the bars (the half-bars are not yet calibrated properly).

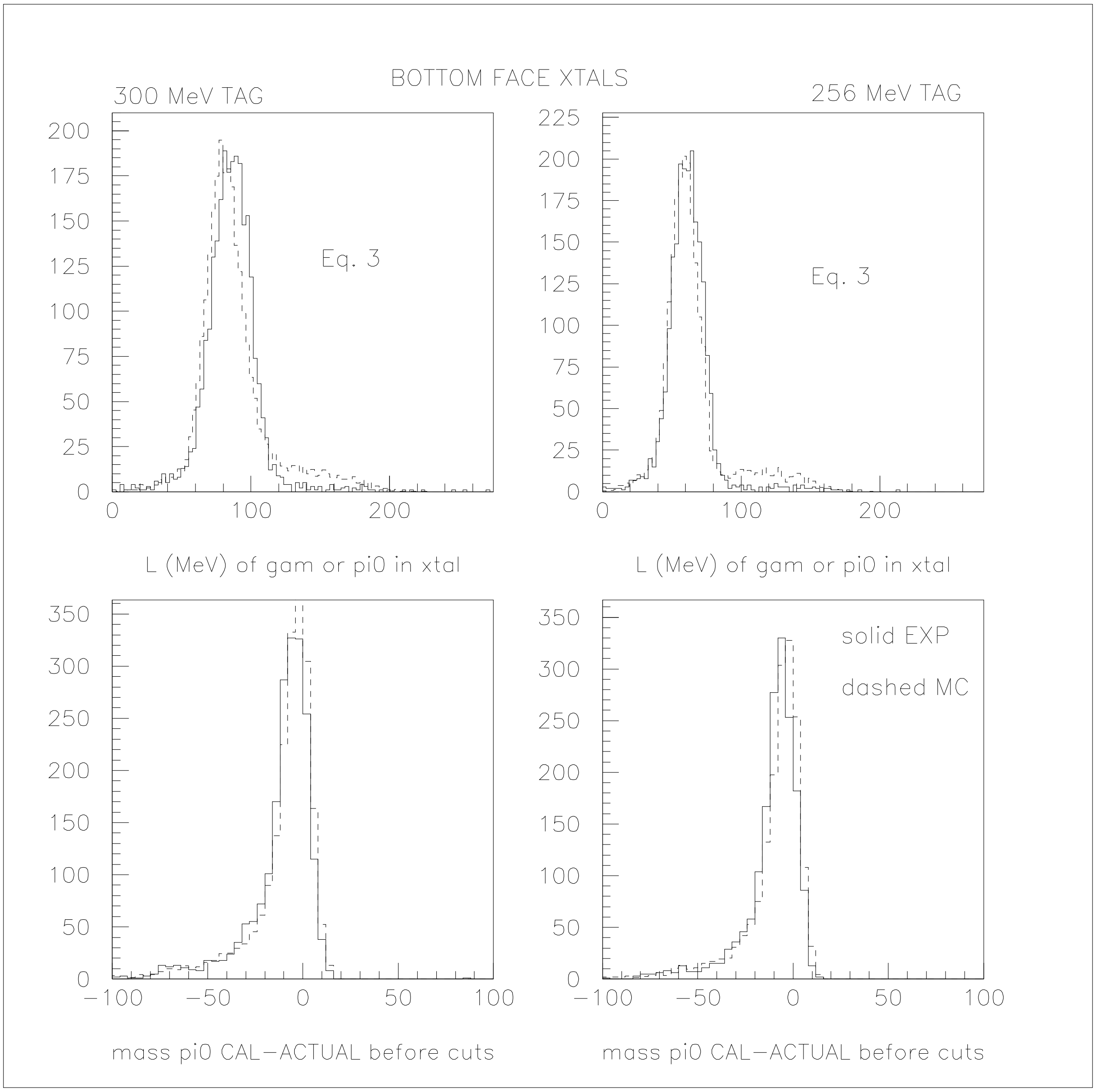

Figure 1: EXP (solid) and MC(dashed) π^0 spectra for E_γ =300 MeV and E_γ =256 MeV. The top panels show $E^{kin}_{\pi^0}$. The bottom panels plot the difference between the reconstructed invariant mass and accepted value of m_{π^0}.

Figures 2 and 3 present a comparison of the bottom and top faces at photon energies of 256 and 300 MeV. The top left panel is $E_{\pi^0}^{kin}$ as calculated from Equation 3. The top right is the same as calculated from Equation 1. This shows the effect of removing the opening angle from the reconstruction and relying solely on the photon energies. The bottom left panel is the deviation of the reconstructed invariant mass relative to the accepted value.

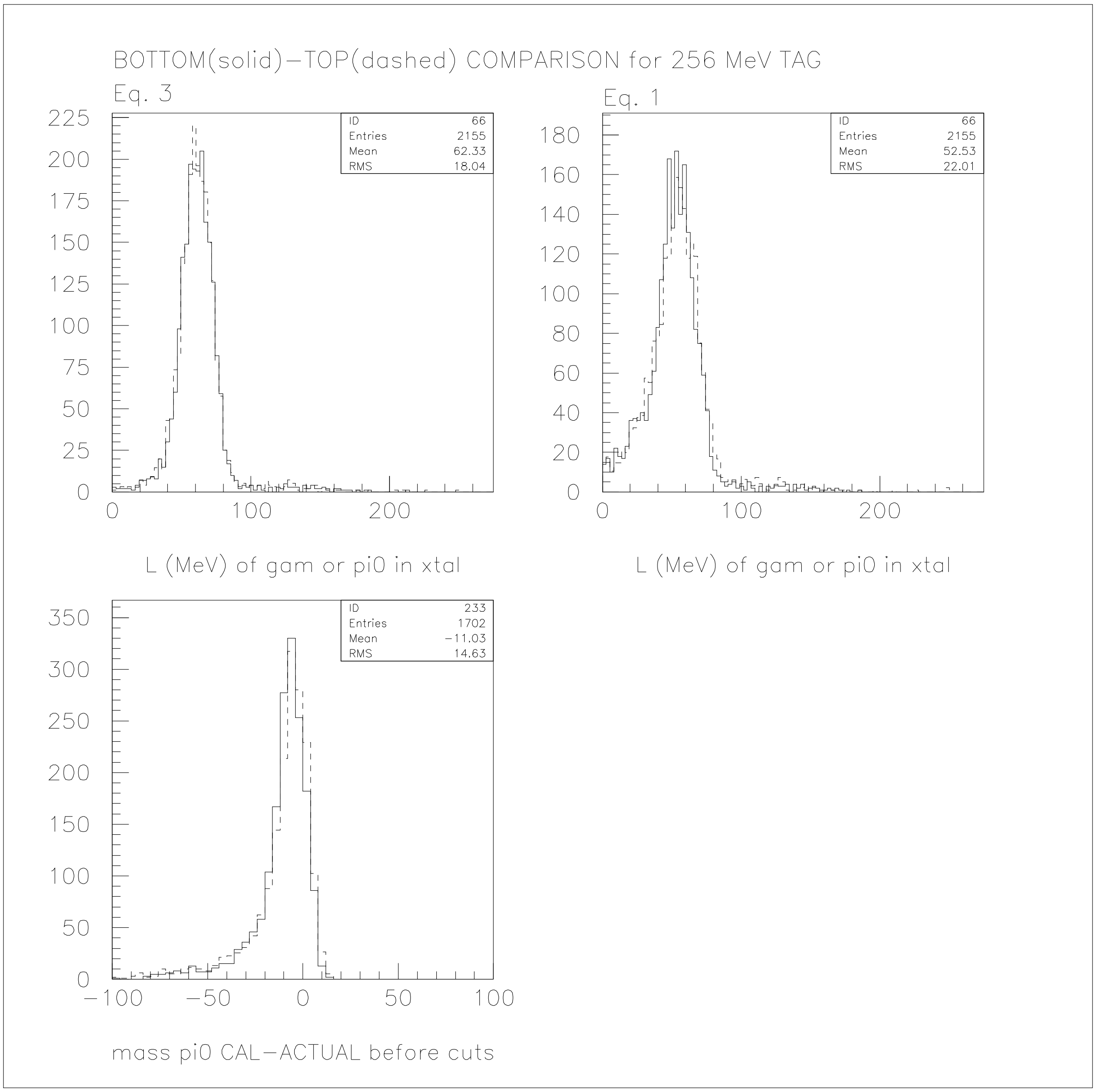

Figure 2: Comparison of bottom (solid) and top (dashed) faces for $E_\gamma = 256$ MeV. Top left: $E_{\pi^0}^{kin}$ using opening angle (Equation 3). Top right: $E_{\pi^0}^{kin}$ without opening angle (Equation 1). Bottom left: reconstructed π^0 mass minus accepted value.

The plots show that the top and bottom faces are essentially identical at this point.

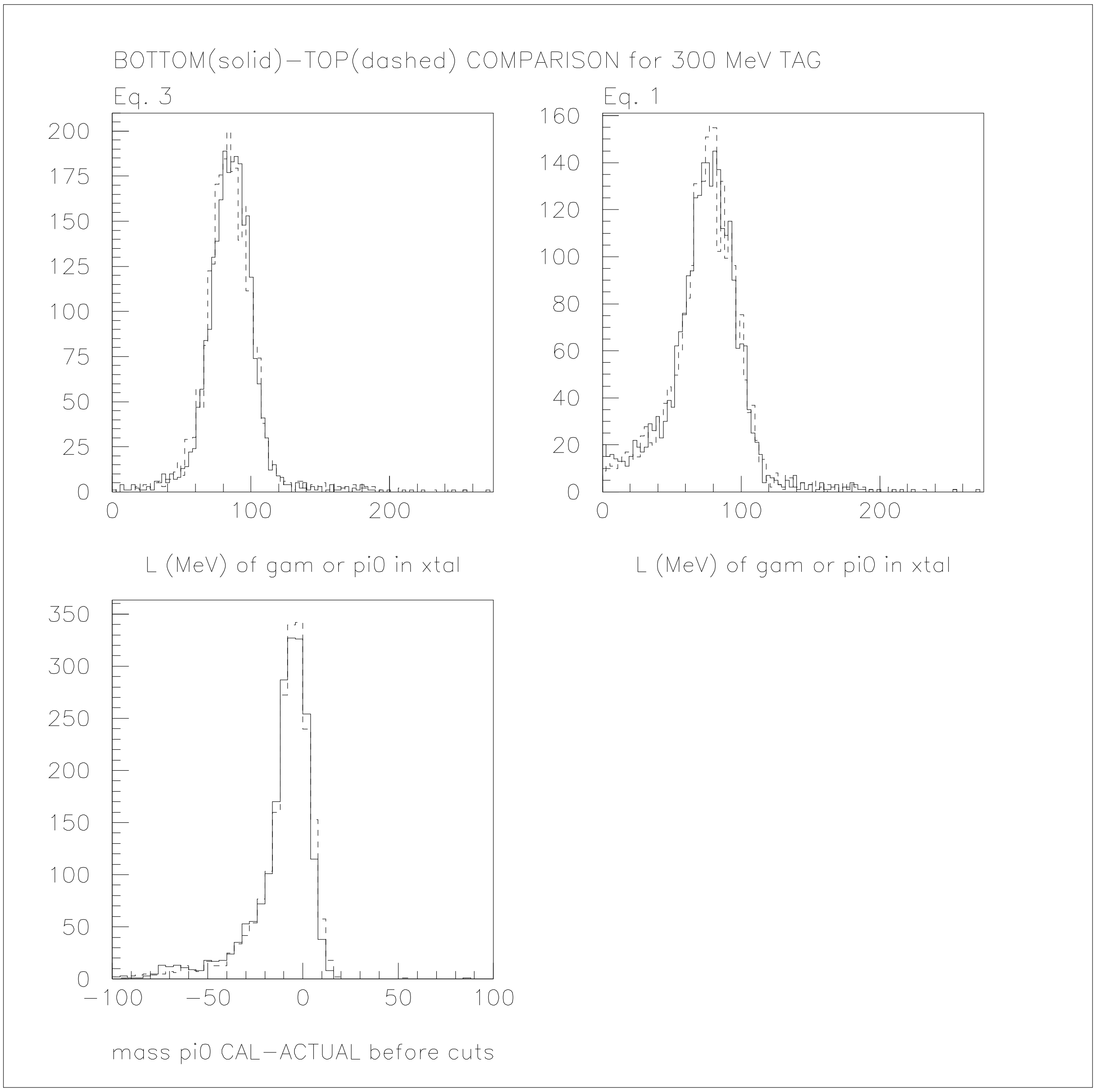

Figure 3: Comparison of bottom (solid) and top (dashed) faces for $E_\gamma = 300$ MeV. Top left: $E^{kin}_{\pi^0}$ using opening angle (Equation 3). Top right: $E^{kin}_{\pi^0}$ without opening angle (Equation 1). Bottom left: reconstructed π^0 mass minus accepted value.

7 Conclusions

We have reconstructed the energy of the π^0 in MC and EXP and have shown that there is good agreement between the two in two different energy regimes. There are slight differences in the peak energies which may be reduced by further iterations in calibration. Most notably there is a high energy tail in the MC not present in the EXP data that is probably the result of slightly different acceptances with the present calibration. The top and bottom faces behave quite similarly.