PE and TPed Calibration with the data

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1 Introduction

Presented here is a new method for (TOT-PE) calibration and a data based timing pedestal calibration. With these new calibrations DELEO is reduced by about 30%. There is also a discussion of possible systematics associated with this calibration method.

2 The Baseline Calibration

To date, the only calibration publicly available is a very crude calibration that I compiled last spring. These calibrations have been used for all the online reconstruction done to date. Online reconstruction began in June of this year (or last year depending on when you are reading this).

For these calibrations, I took the slewing corrections for a single Milagro PMT calibrated by Roman and Lazar and applied that calibration for all the PMTs. Naturally, all the PMTs have unique slewing curves, but I recalled from Milagrito that the slewing curves for the vast majority of PMTs were very similar for pulse heights used in the angle reconstruction, above 2 PEs.

The Pulse Height calibration was obtained with the ADC using the same method as used to calibrate Milagrito, which was described in a previous memo. 360 of the 450 AS Layer PMTs were calibrated. The 90 PMTs that were not calibrated were either dead, were associated with a dead ADC channel, or had poorly resolved 1 PE peaks.

The timing pedestals were estimated with a quick look at the t-Chi (time-time$_{predicted}$), where the predicted time from the angle reconstruction of large air-shower events. Looking back, there was a bug in the code that estimated the t-Chis that caused the timing correction for a given PMT to be associated with the next highest number PMT. This effectively amounts to no TPeds for this calibration.

3 PE Spectrum Calibration

A new method was developed to provide TOT-PE calibrations. The method is quite simple, and can be easily implemented on any data set. The method works like this: If you know the expected PE spectrum for a PMT, and you can measure the TOT spectrum for a PMT, then there is a one-to-one correspondence between PEs and TOT. I simply assign the value of the x percentile TOT (the value in TOT for which 100-x% of the hits are above and x% are below) with the x percentile value for the PE spectrum. In this analysis I "force" the PE spectrum to look right.

For the analysis presented here the PE spectrum was obtained from the a sample of simulated proton events with greater than 150 PMTs hit. Hits from all 450 Air

Shower layer PMTs were combined to produce a single PE spectrum for the top layer and likewise the PE spectra for the 273 muon layer PMTs were combined. The data from a recent "Save" file were used to produce the TOT spectrum for each PMT separately. The "Save" files are generated by applying a software cut of 150 PMTs hit in the air shower layer. In producing the TOT spectra, the high TOT hit are assumed to be greater than all the low TOT hits. Figure 1 shows the PE spectrum used for the air shower layer and the TOT spectrum for a typical air shower layer PMT.

It would be better to obtain the PE spectrum from a few well calibrated PMTs, leaving out all the systematic effects associated with MC/data matching. But, for this memo I only have the data from the simulation to work with. In defense of the simulation, Stefan has showed that the PE spectrum for Milagrito and the Milagrito Monte Carlo simulation agree quite well.

Figure 2 shows core position distribution for the standard offline and the new pulse height calibrations. In the data displayed here patch 24 was off, but one can see none the less that the cores are distributed smoothly over the pond without the hot spots and gaps that populate the standard calibration.

Figure 3 shows DELEO with the old and new calibrations. A substantial improvement is observed.

3.1 PMT Quantum Efficiency

Using this calibration method, unlike others, the PMT Quantum Efficiency (QE) plays a role. If a PMT has a different QE as assumed for the source of the PE spectrum, then the expected PE spectrum for that PMT is different than the distribution used to calibrate it. For example, assume a target PMT has a QE of 10% and a neighboring PMT that was well calibrated using another method a QE of 20%. The spectrum of the neighboring PMT is used to calibrate the target PMT. If the neighboring PMT observes 1% of the showers have pulse heights above 100 PEs, then because the efficiency for detecting photons is smaller for the target PMT, that PMT will observe 1% of the showers to have greater than 50 PEs. But this calibration method would assign an amplitude of 100 PEs to the target PMT none the less.

One could think of simple ways of correct of this effect. The target PMT's lower quantum efficiency could be measured by the reduced hit rate. Measurement of the hit rate could be used to estimate the QE of the target PMT, and knowing the QE, the PE spectrum could be corrected to reflect the correct spectra for that PMT. However, one should think about weather this is the right thing to do. In core fitting, energy estimation, and to a lesser extent in shower angle fitting, we think of "PEs" as being synonymous with light intensity, but if the QE varies from PMT

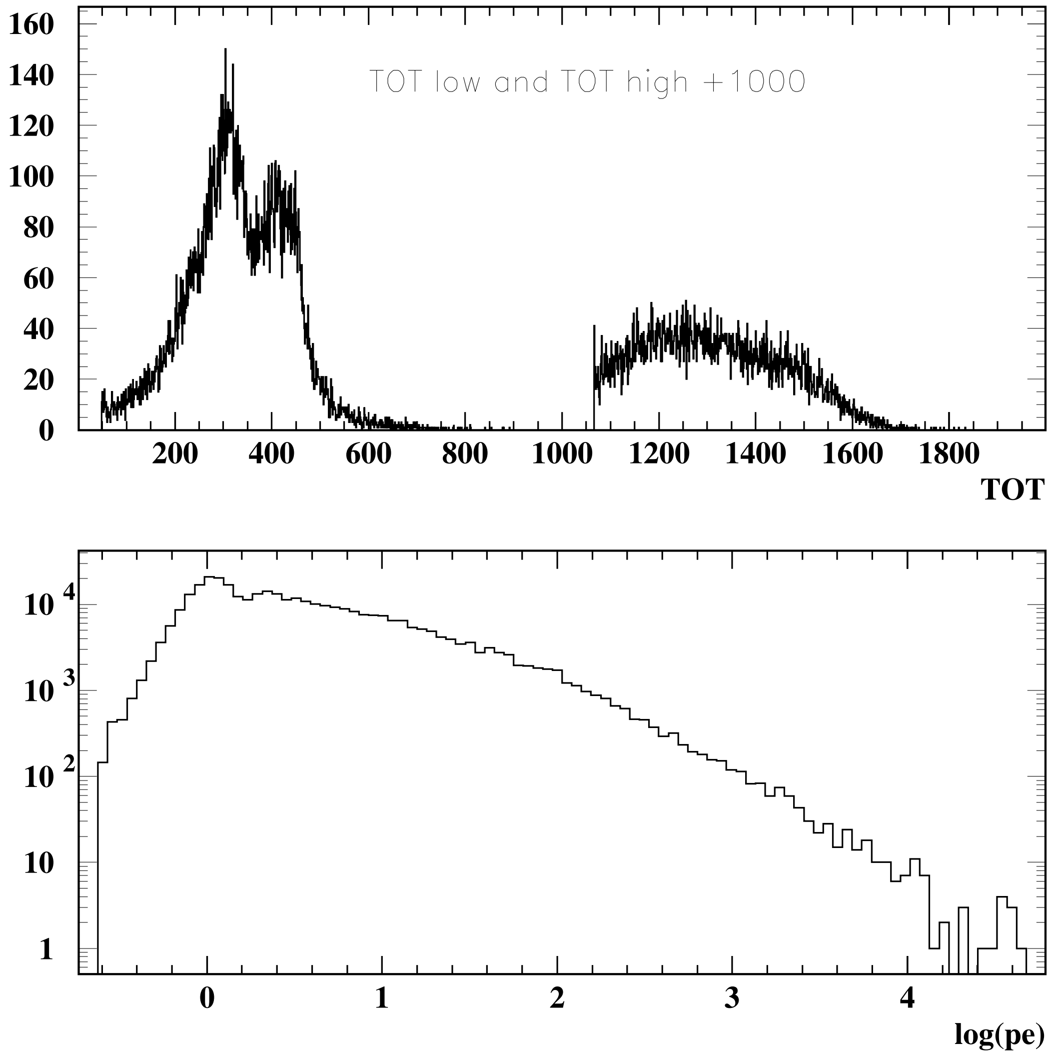


Figure 1: PE spectrum from MC protons with NHIT>150 for the Milagro air shower layer PMTs and TOT distribution (in counts) for a typical PMT. Measured hi-TOT values have been increased by 1000 to avoid overlap with lo-TOT.

to PMT then clearly it is not. Assume that the two PMTs described above both register 100 PEs as calculated from a laser calibration or a calibration that corrected for saturation. That is to say, in both cases the charge measured was equivalent to

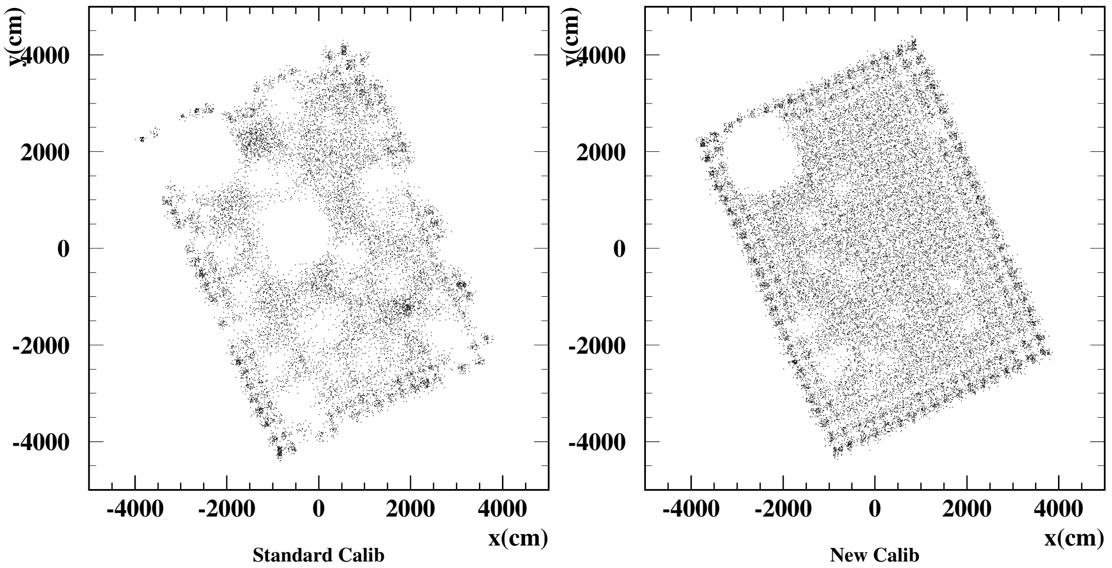


Figure 2: Center of Mass core fitter core position distribution for the standard TOT-PE calibration and the spectrum calibration.

the charge of 100 electrons being freed from the photo cathode of each PMT. For the PMT with QE=20%, the light level is $\frac{100}{0.2} = 500$ photons striking the photon cathode. For the PMT with QE=10%, the light level is 1000 photons. As the light level is higher for the PMT with the lower QE, the core estimation algorithm should identify the core position as closer to that PMT, however, as the have identical PE levels, the core locator will weight both PMTs the same. So, it is not clear that correcting the spectra for PMT quantum efficiency is the right thing to do.

4 Timing Pedestal Calibration

The timing pedestals were recalculated by fitting the t-Chi distribution for each PMT for hits with large pulse heights to a Gaussian and shifting the timing pedestals by the observed offset in the t-Chi distribution. The process was iterated 4 times, but by the 4th iteration the corrections were small.

Figure 3 shows the improvement in deleo when the new T-Peds were used. Figure 4 is a plot of the NFIT distribution for these calibrations and the standard calibrations. Figure 5 is a plot of the CHISQ distribution for these calibrations and the standard calibrations. Figure 6 is a plot of the ϕ distribution for the standard

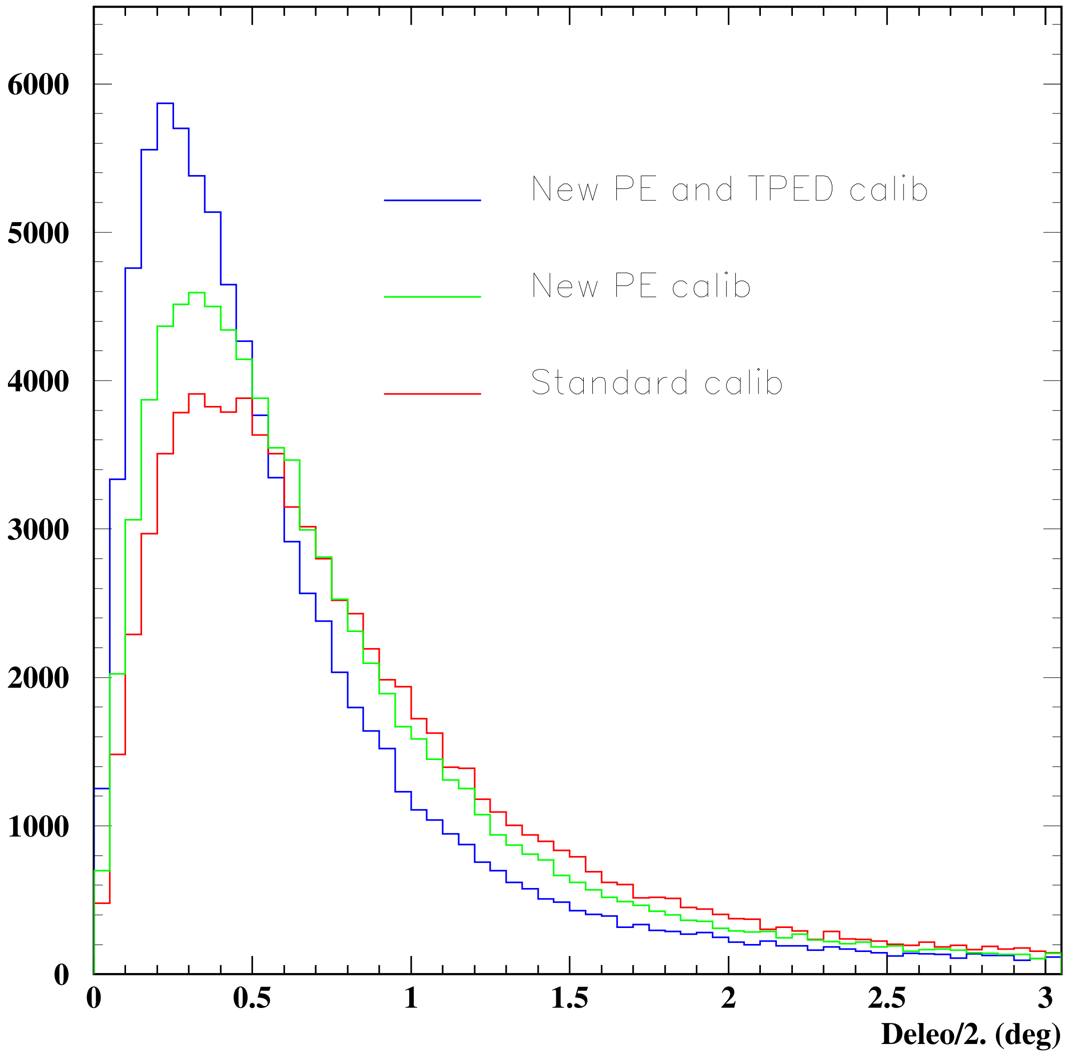


Figure 3: Deleo for the standard calibrations, the new PE calibration and the new PE and TPED calibrations

calibrations and these calibrations.

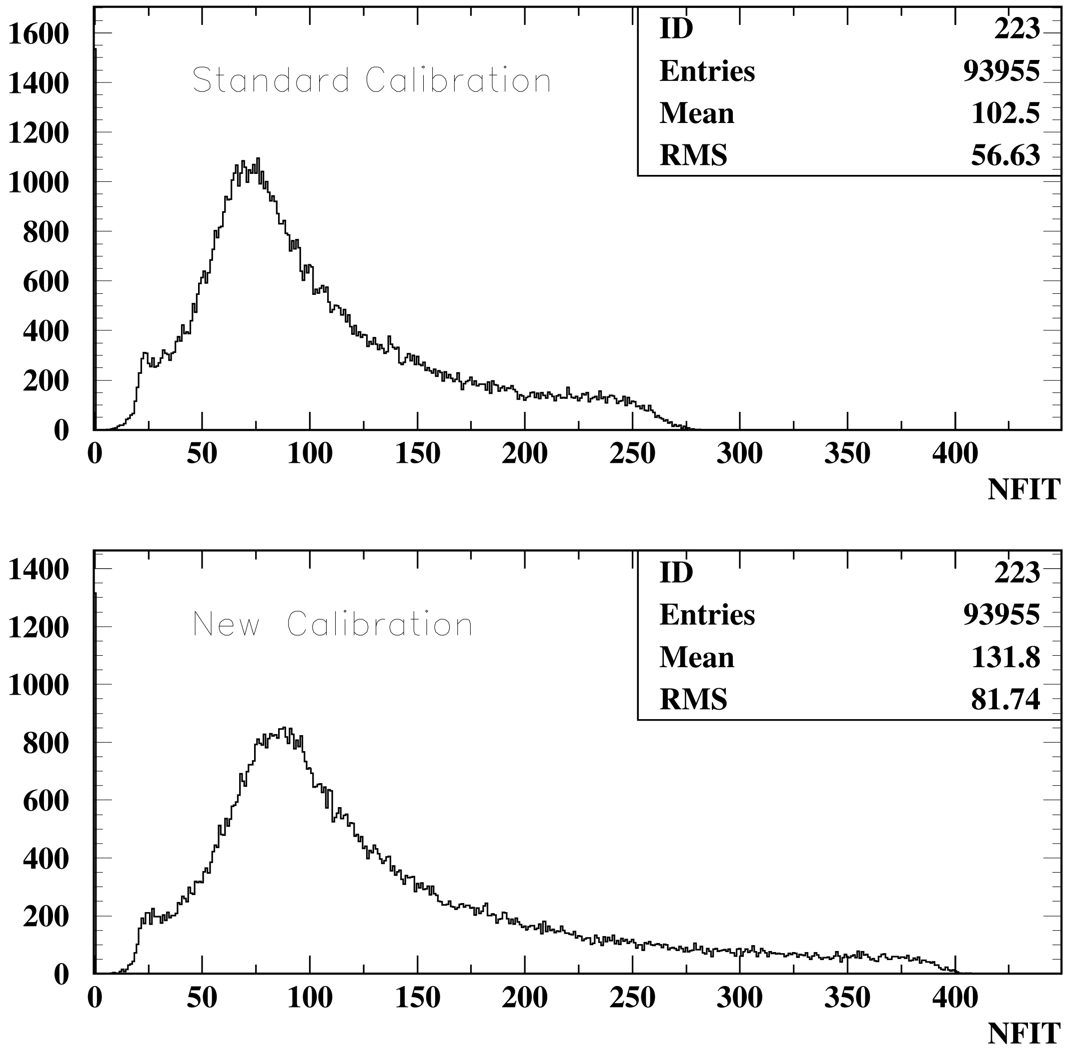


Figure 4: NFIT.

5 The Crab

The events on 5 tapes(SA035-SA039) containing raw Crab data were reconstructed using these new calibrations. The tapes contained approximately 2 weeks of data collected with a trigger rate of about 1000 Hz prior to the repairs. Figure 7 shows the significance map in the vicinity of the Crab for the new calibrations.

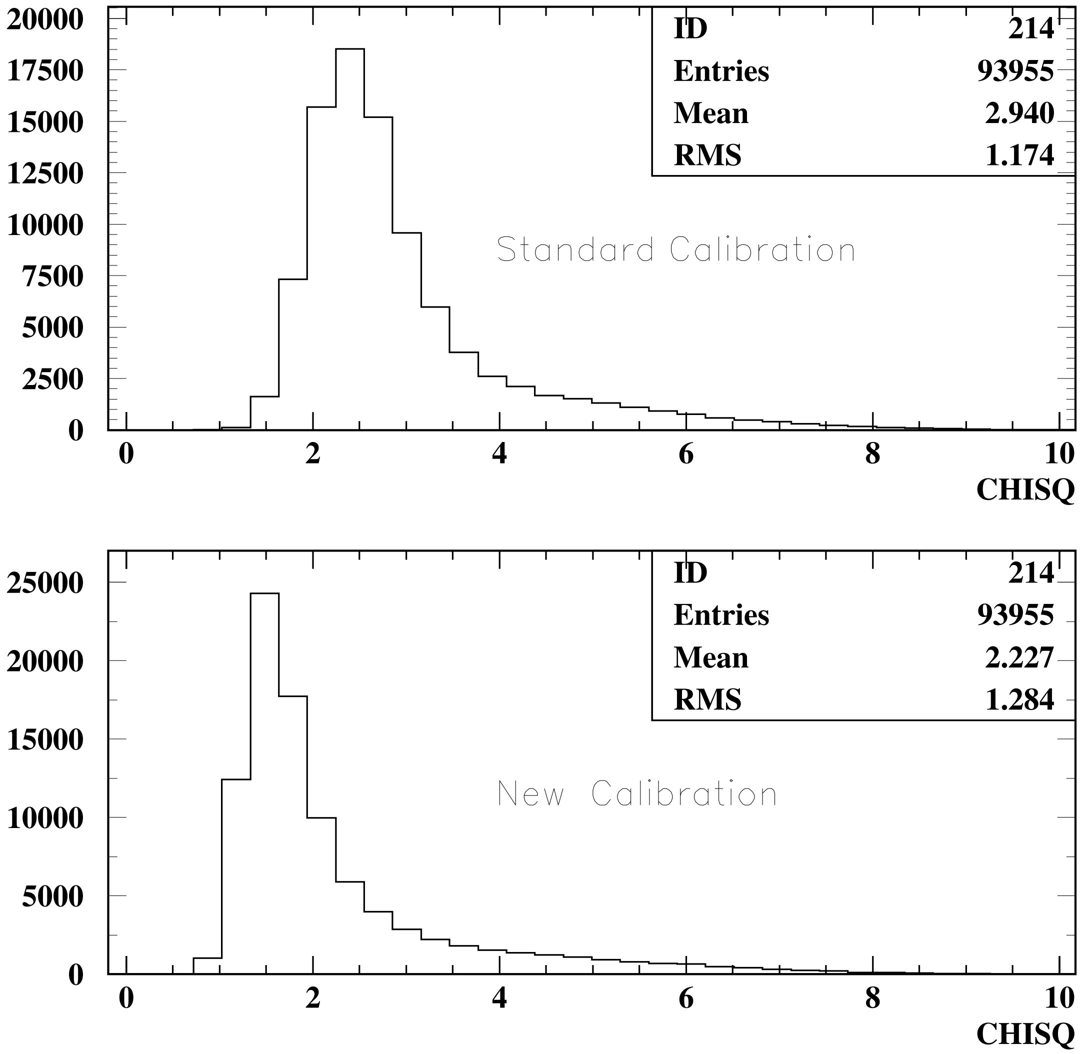
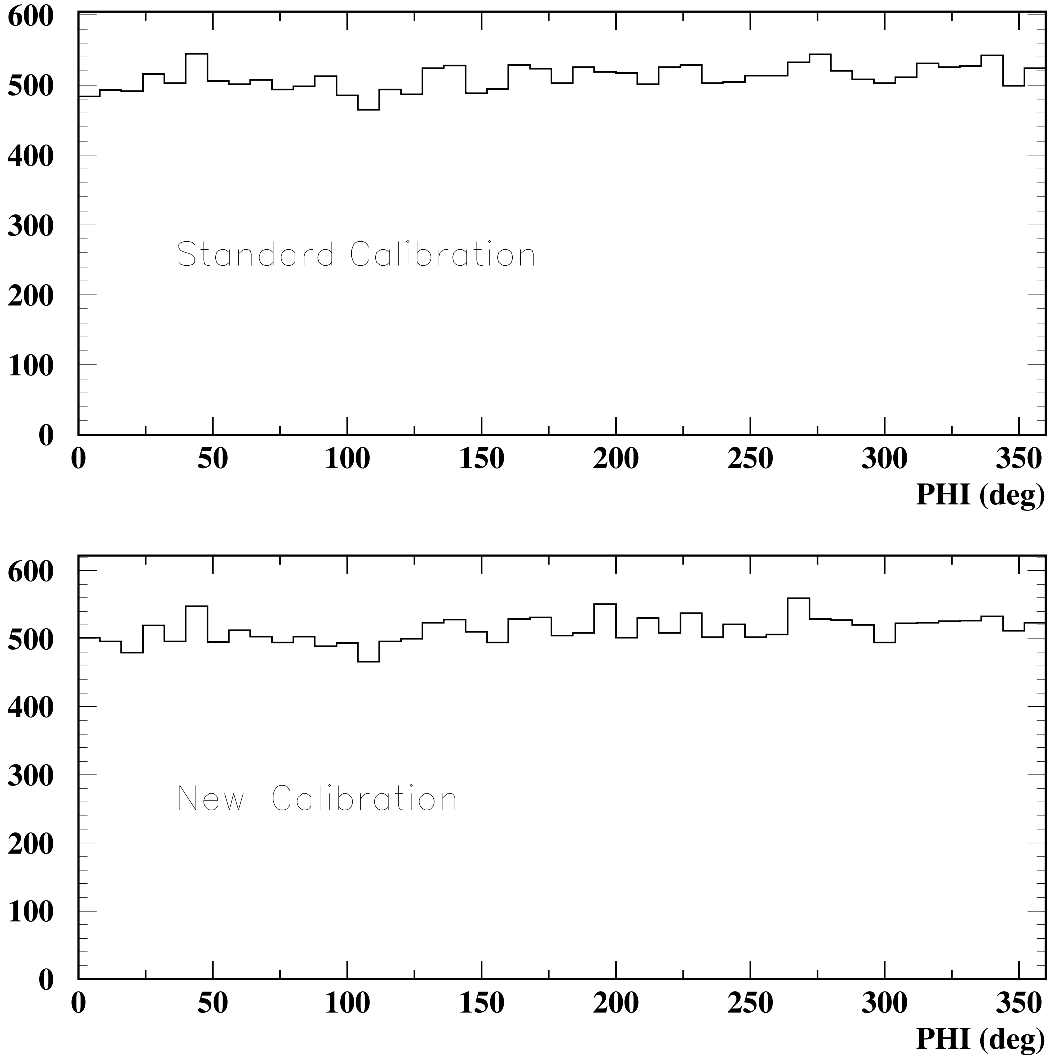


Figure 5: CHISQ.

6 Conclusion

The calibrations described here are located in the Milagro reconstruction code area at Los Alamos (/disk02/Milagro/analysis/offline_v32). These calibrations reside in the directory "config_milagro2" and can be used with the existing Milagro reconstruction software by setting the CONFIG_MILAGRO environment variable.



600
500
400
300
200
100
0
Standard Calibration
0 50 100 150 200 250 300 350
PHI (deg)
600
500
400
300
200
100
0
New Calibration
0 50 100 150 200 250 300 350
PHI (deg)

Figure 6: ϕ.

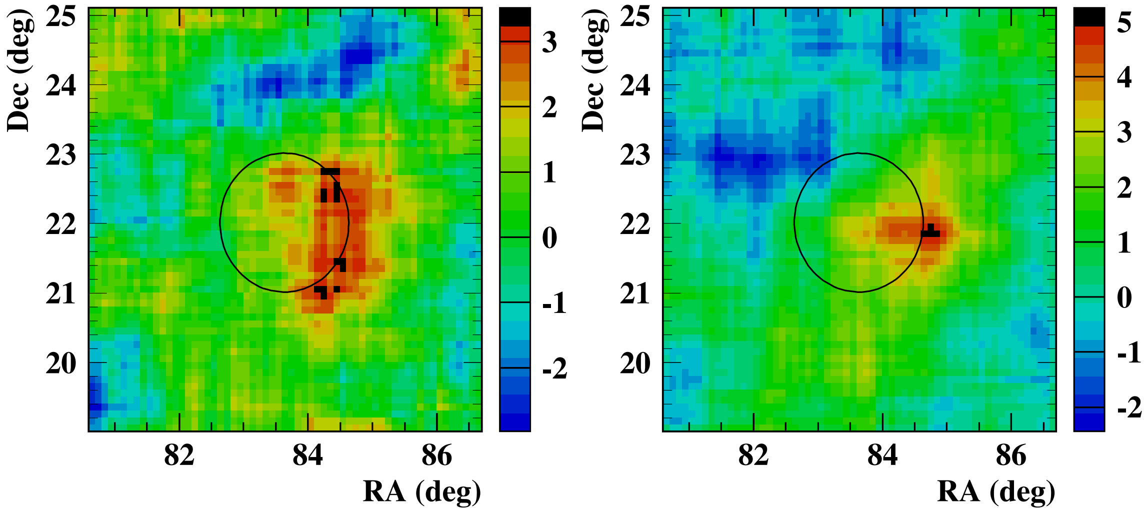


Figure 7: Significance of the excess in the vicinity of the Crab. The panel on the left uses an NFIT>40 cut and 1.5^o square bins. The panel on the right uses an NFIT>20 cut and 2.5^o square bins.