Data and Monte Carlo - PE distributions

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1 Introduction

There were some concerns raised at the last collaboration meeting about the poor match between data and Monte Carlo. In particular, we were/are concerned about photoelectron distributions. This is a quick note to document some things I have been looking at recently. In case you don't want to read the memo; the conclusions are that based on the locations of the muon peak in MC and data, that the number of PEs actually recorded by a PMT is about a third less than predicted by the Monte Carlo. Since the muon peak is produced by local particles

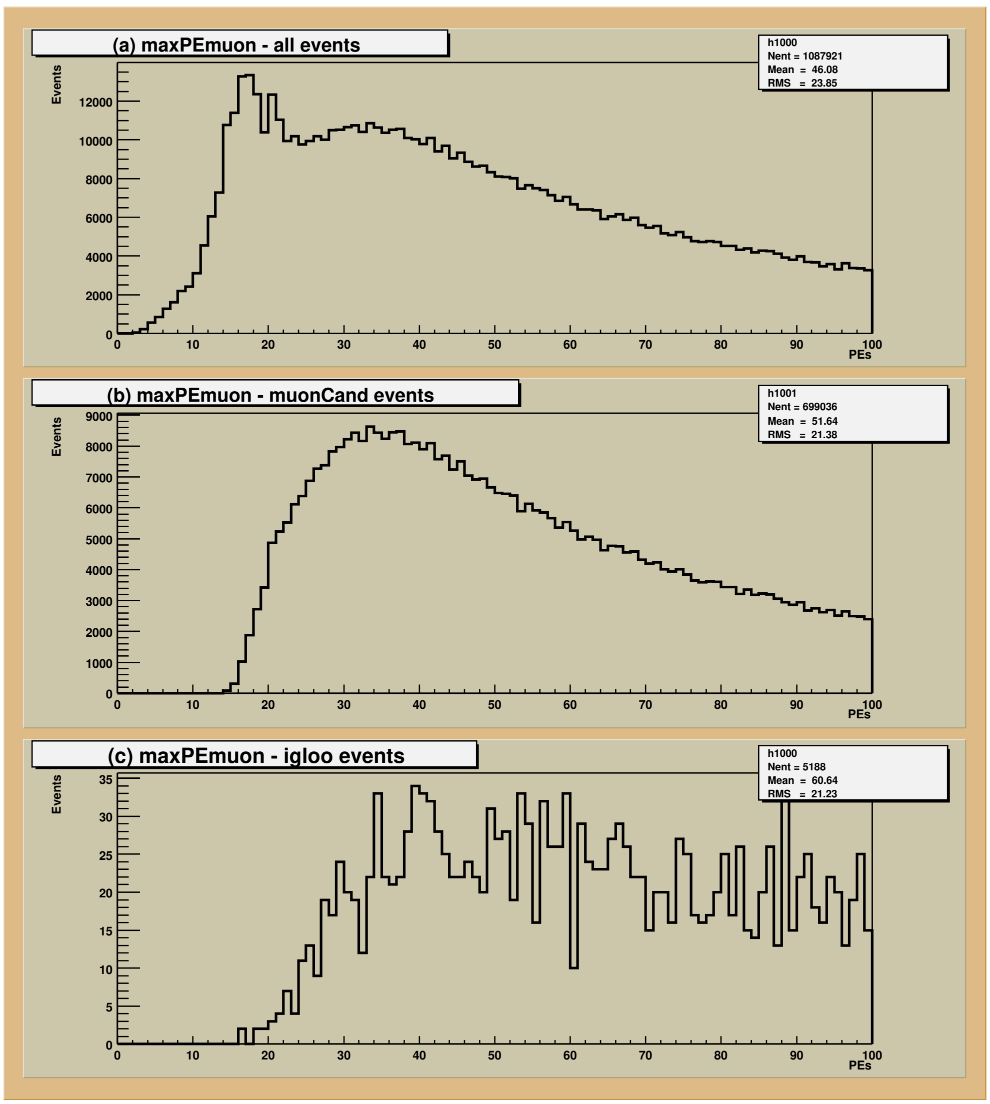

Figure 1: Some distributions of maxPEmuon in data

we assume that this is not related to photon propagation in the pond (water quality, cover reflectivity etc). We investigated the effect of this shift by lowering the QE of the

PMT by 33%. We made a bunch of plots which indicate that this rescaling gives better agreement between MC and data and finally you can move right to the last plot to see the effect on our gamma-ray sensitivity calculations.

2 Looking for muons in the data

I looked at GRB_2278_0012.dat, GRB_2278_0039.dat and GRB_2278_0040.dat. These runs were taken in June 2000 shortly after Andy plugged the remaining working igloo into channel 900. I looked at the distribution of the pulse height of the brightest tube in the muon layer (maxPEmuon) in several ways. (a) maxPEmuon for all events. (b) maxPEmuon for all events where David Williams modified muonCand (presented at the Wisc. collaboration meeting) identified at least one muon. and (c) maxPEmuon for all events which produced a 4 edge event in the igloo. These distributions are shown in figure 1. The maxPEmuon distribution for all events shows two peaks; one at 15 pes and a second much broader peak at 35 pes. The maxPEmuon distribution for events flagged as containing at least one muon by muonCand rises smoothly from about 15 pes to a broad peak at 35 pes. The final panel show the maxPEmuon distribution for events with an igloo hit shows a distribution rising from 15 pes up to a max at 30 - 40 pes and remaining fairly flat thereafter. There are not really enough events. I think that a muon peak, if there is one, is not a sharp feature and is somewhere between 30 and 40 pes.

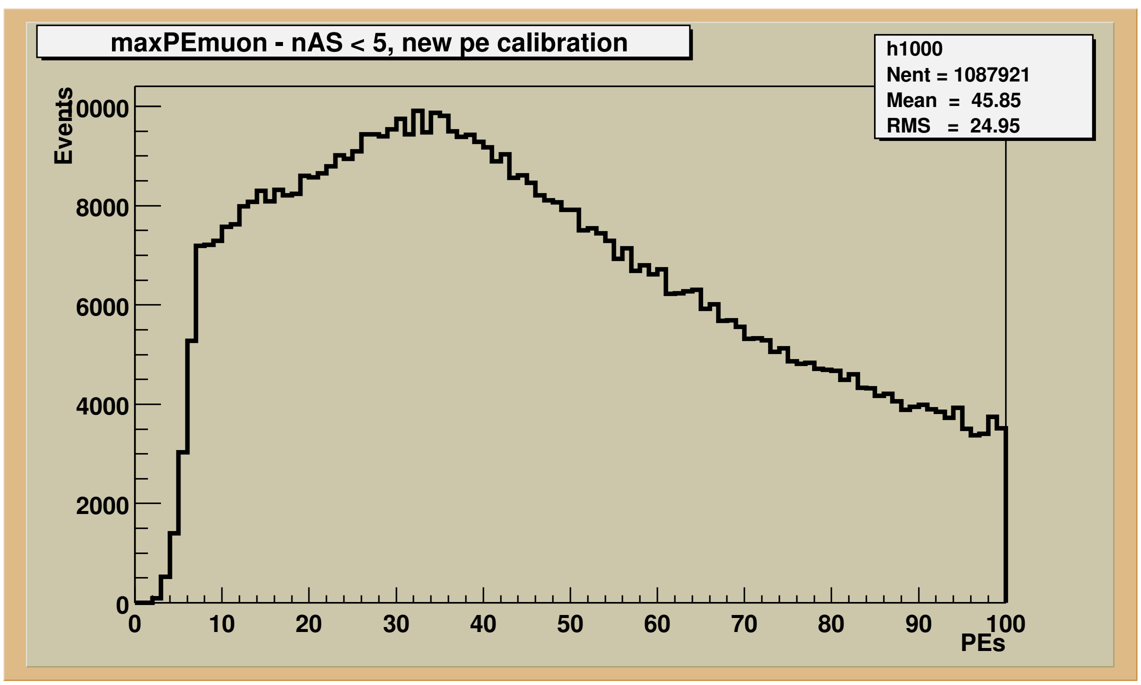

Figure 2: maxPEmuon for data calibrated with Eriks new pe calibrations

The sharp peak at 15 pes seems quite likely to be due to mis-calibration. There is a peak in the Monte Carlo at 6-8 pes, this is just where we think we may have some problems with the pe calibration. To investigate this we used the new calibrations presented by Erik at the collaboration meeting and looked at the distribution of maxPEmuon for all events. This is shown in Figure 2. The sharp peak at 15 pes disappears, but the broad peak at 30-40 pes remains.

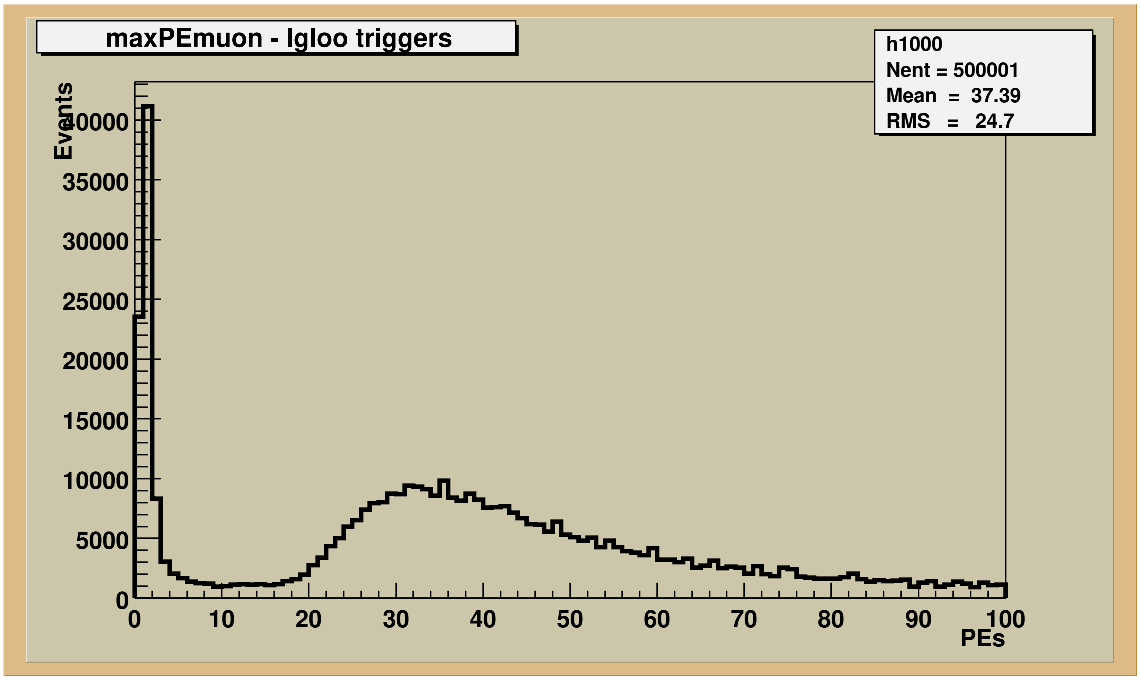

Figure 3: maxPEmuon for data triggered by the igloo

I also looked at an 'igloo run' taken by Gus and Greg last Summer. This was a run where the trigger was a high threshold hit in the igloo. I required that the number of air-shower tubes hit be less than five in an effort to isolate single muons. The distribution of maxPEmuon for these events is shown in Figure 3. I think that this confirms that we really do have a peak caused by muons/local particles at around 30-35 pes.

3 Looking for muons in the Monte Carlo

This is easy. We can just pick out events in which an actual muon hits the pond. I have taken v2.6 proton simulations (/data01/sim/milagro/proton2.6 in Wisconsin) and made some similar plots to those I made for the data. Again I looked at maxPEmuon and made three plots: (a) the maxPEmuon distribution for all events. (b) the maxPEmuon distribution for events with at least one muon identified by muonCand and (c) the maxPEmuon distribution for events where an actual muon hit the pond. These distributions are shown in

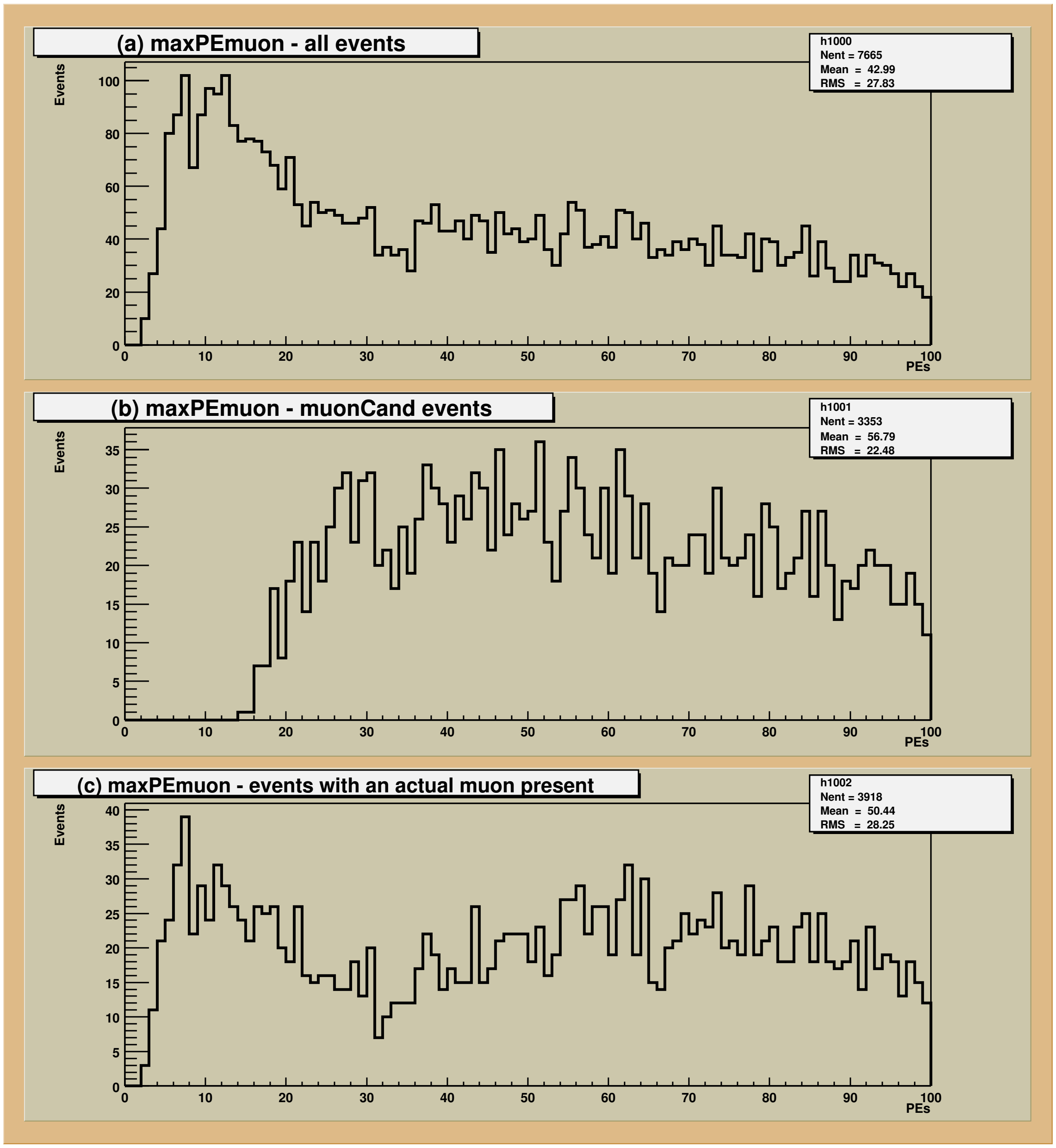

Figure 4: Some distributions of maxPEmuon in Monte Carlo

Figure 4. The plot of maxPEmuon looks quite different to that seen in the data. The first peak begins at 5-8 pes, and the ratio of the amplitude first peak to the amplitude of the high pe part of the distribution is much greater than seen in the data. However, this ratio is very sensitive to the trigger threshold which has not really been tuned to the data we are comparing it to. It is difficult to compare the maxPEmuon distribution in

the Monte Carlo to the data. Our trigger threshold (in data) has varies significantly which affects this distribution. The large differences in the maxPEmuon distribution with different calibrations implies that we may not understand our data very well. However, we can probably usefully compare the location of the muon peak in data and MC. It is not easy to see if there is a peak due to muons (lack of statistics does not help), but there is a hint of a broad peak at 50-60 pes.
It is possible to select events to get mostly single muons. We required that there be a muon in the pond and that there be less than five air-shower layer tubes hit. This should give us events similar to those found in the igloo file. The maxPEmuon distribution is shown in figure 5. A clear peak can be seen at 50 pes, which is not consistent with the peak at 35 pes seen in the igloo data.

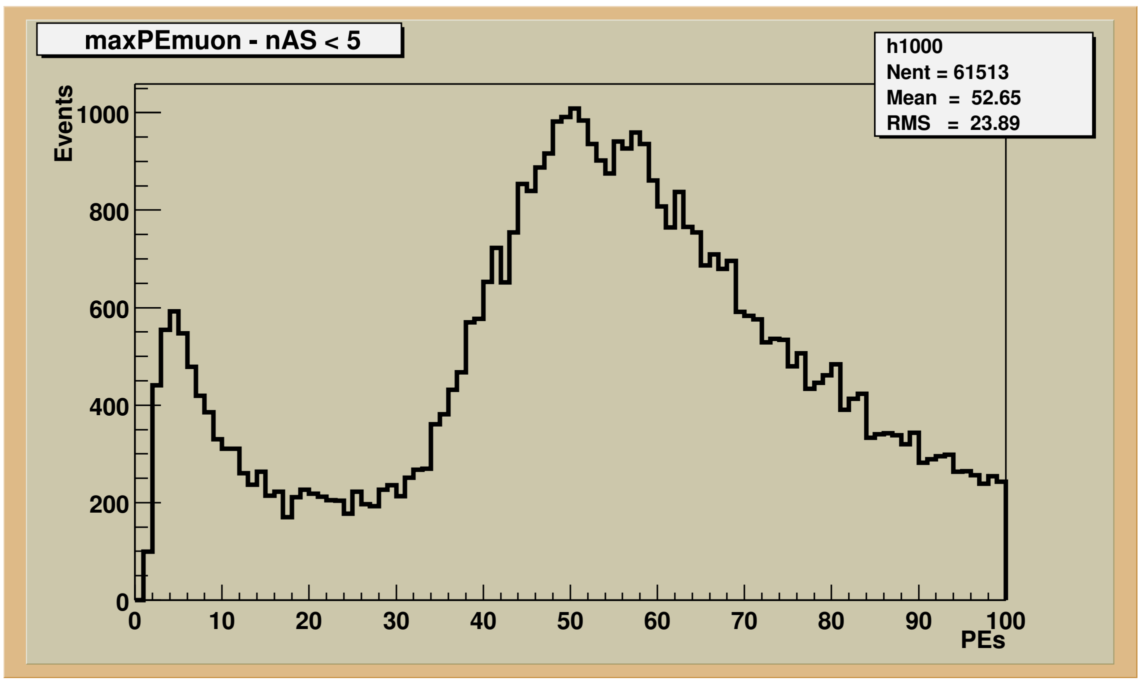

Figure 5: Distribution of maxPEmuon in Monte Carlo for events with a muon in the pond and less than 5 hit air-shower tubes.

Since the muon bump is due to local particles, the properties of our water are unlikely to cause the observed discrepancy. Instead it is presumably something more local to the PMT (qe?, baffle reflectivity?...). I checked that the ADC -pe calibration puts the muon peak in the data at 30 -35 pes as well, so a systematic miscalibration is unlikely. To look at the effect of this shift, we reduced the quantum efficiency of the PMTs by 33%. Figure 6 shows some of the resulting maxPEmuon distributions. For these plots the tubes which were dead in the data were switched off in the MC. These distributions are a much better match to the data.

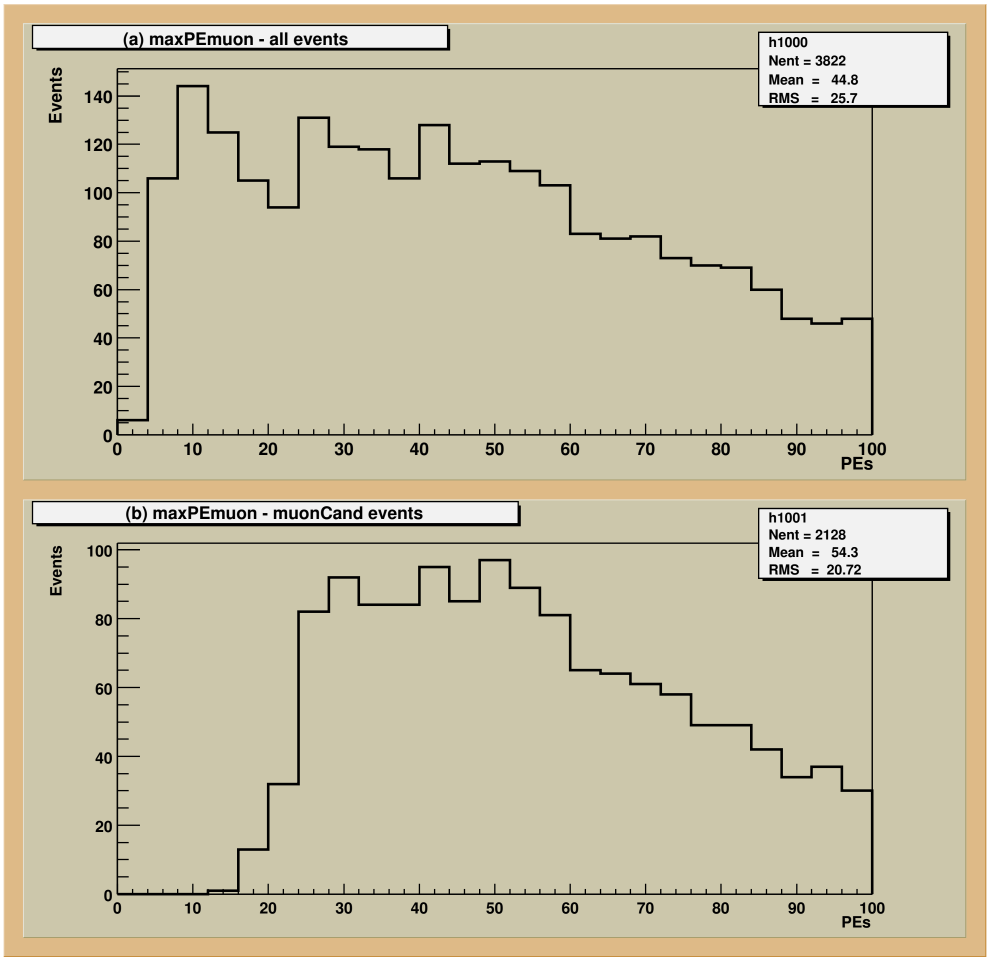

Figure 6: Distributions of maxPEmuon in Monte Carlo after the quantum efficiency has been reduced by 33%. This looks very similar to the data in Figure 2.

3.1 Some other comparisons between data and MC

Figure 7 shows the ratio of the number of air-shower layer tubes to the number of muon layer tubes. The MC is offset to slightly higher values relative to the data. There is no significant difference in the MC distributions before and after rescaling.
Figure 8 shows the distribution of the number of PMTs (>2 pe) in the muon layer. The data are drawn with a black line and the (rescaled) simulations are indicated by the blue line and the original simulations are in red. The peak in this plot for the Monte Carlo data moves from about 70 tubes to 50 tubes after rescaling by 33%. This is consistent with the data.
Figure 9 shows the X2 distribution. Again the MC agrees more closely with the data after the pes have been rescaled by 33%.

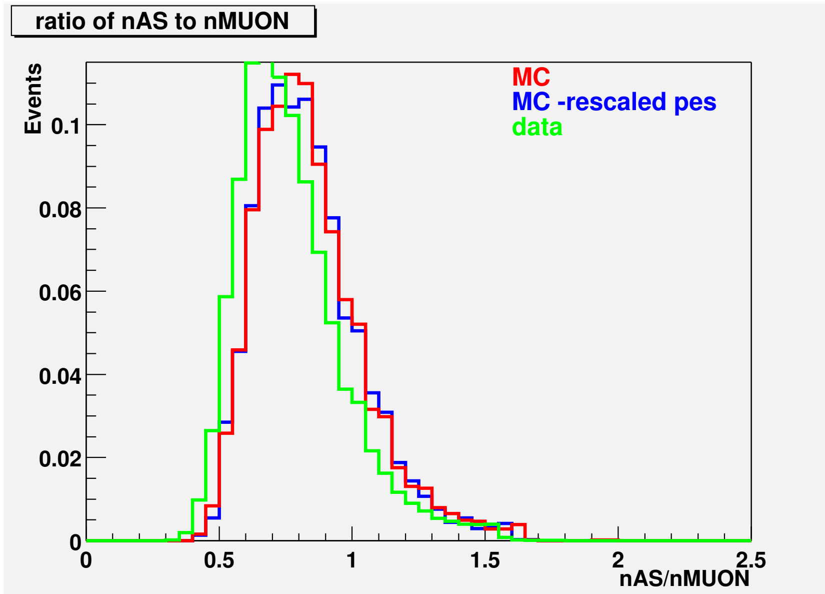

Figure 7: Ratio of nAS to nMUON for data (green) and mc before (red) and after(blue) rescaling by 33%.

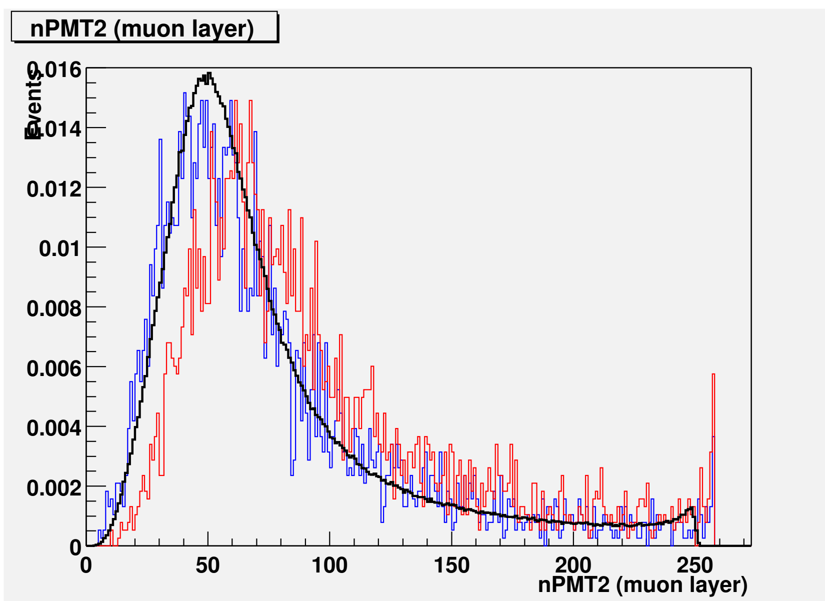

Figure 8: nPMT2 for data (black) and mc before (red) and after (blue) rescaling by 33%.

The discrepancy between data and MC in the first bin, noted by Gus at the last collaboration meeting, is not so large.

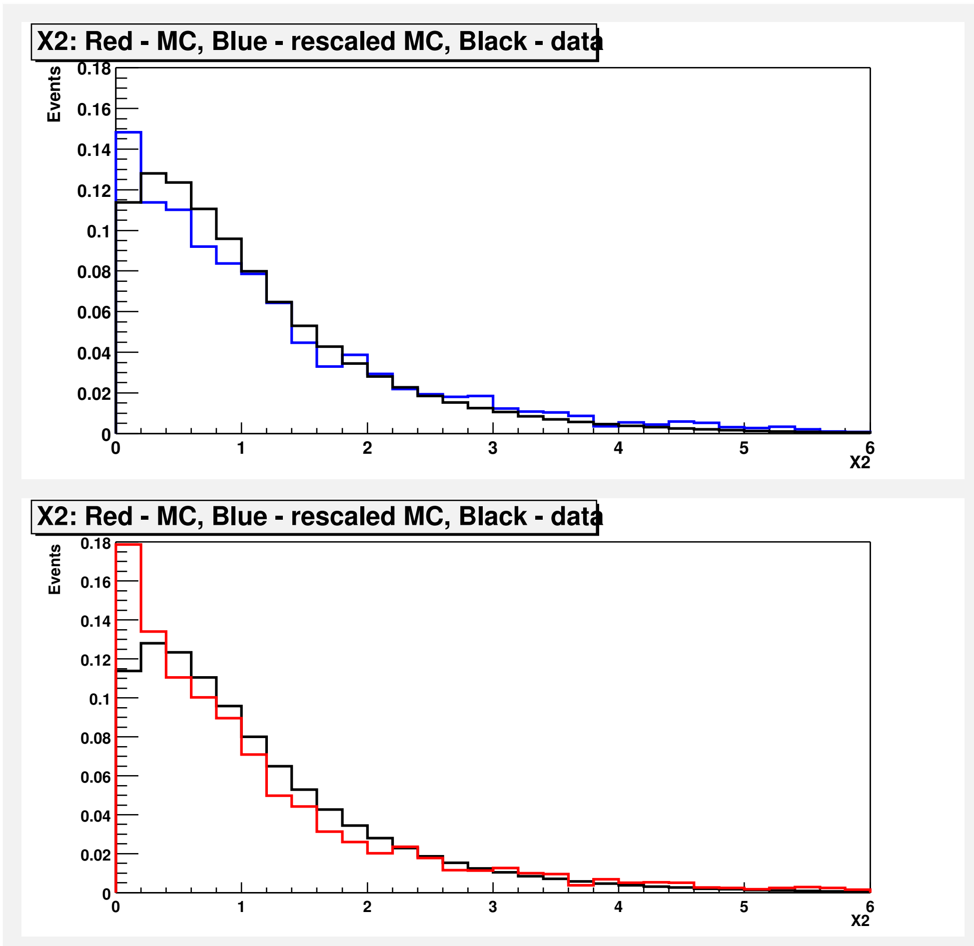

Figure 9: X2 for data (black) and mc before (red) and after (blue) rescaling by 33%.

3.2 Sensitivity to trigger threshold

I had a quick look at how the nAS/nMUON and maxPEmuon distributions vary with trigger threshold. Figure 10 shows these distributions for data (black), 50 tube trigger (green), 60 tube trigger (blue) and 70 tube trigger (red). As the trigger threshold is increased the peak in the nAS/nMUON distribution moves to higher values (not surprisingly as we are requiring nAS to be bigger). In the maxPEmuon plot as we increase the threshold the height of the muon peak increases relative to the height of the first peak at 6-8 pes.

3.3 The disappearing MC muon bump

What about the infamous 'muon peak' which dissappeared in the most recent proton simulations? This is probably best illustrated in the gamma-ray simulations. In Figure 11

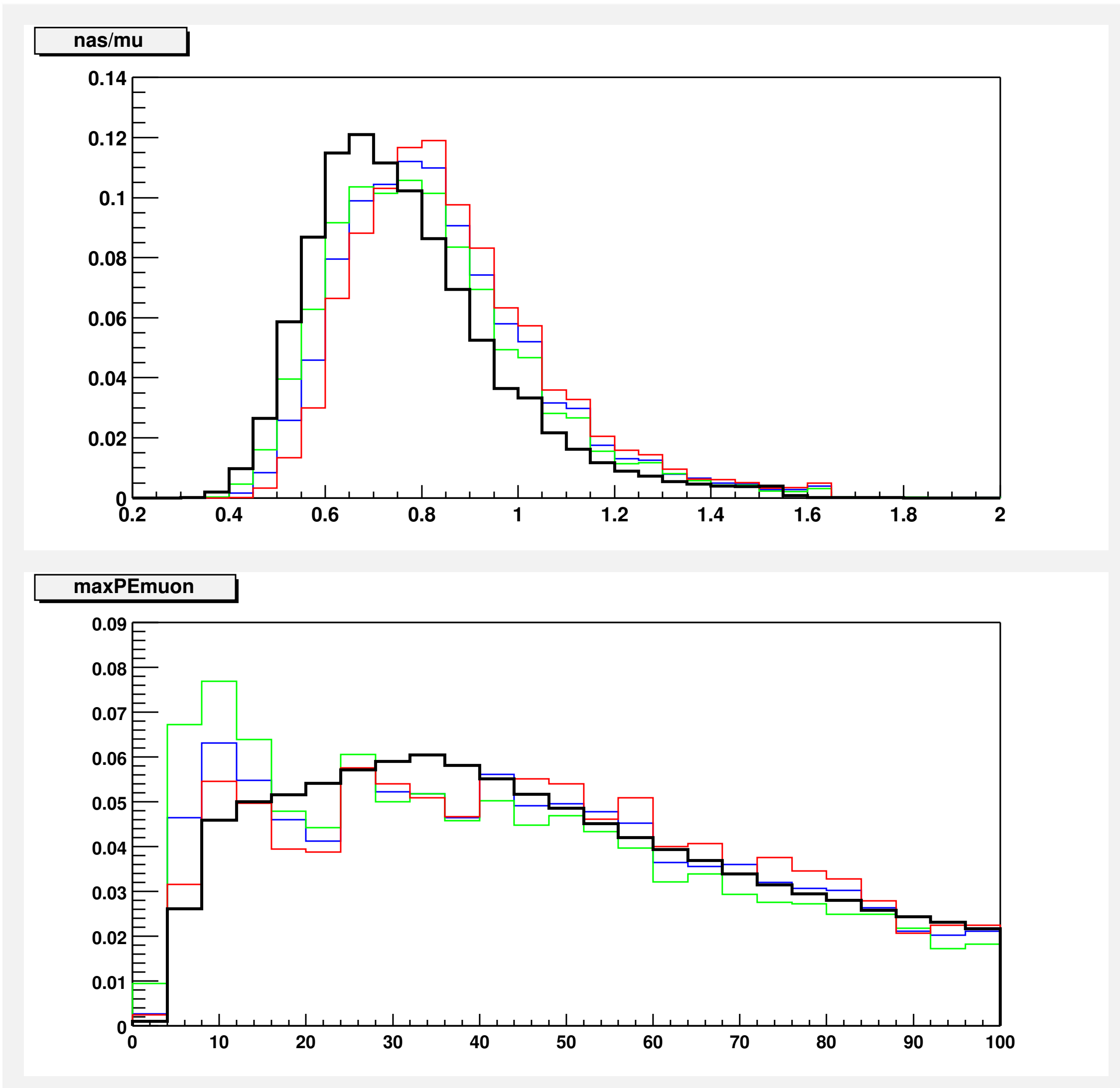

Figure 10: nAS/nMUON and maxPEmuon as a function of trigger threshold. The plot contains data (black), 50 tube trigger (green), 60 tube trigger (blue) and 70 tube trigger (red)

shows the maxPEmuon distribution for all events, and for events selected by muonCand. The plots on the left are for v23 of the MC and the plots on the right are for v26 of the code. Note the discontinuity at 40 pes in the v23 simulations. This is caused by the saturation correction function which corrects for adc saturation. We don't use the ADC to calibrate, so we should not have been making this correction. It switches on at 40 pes. The saturation correction was applied (in error) to all versions of the Monte Carlo before v26. For proton simulations the maxPemuon disribution has much more events at large pes. The discontinuity at 40 pes becomes much more pronounced and looks like a peak.

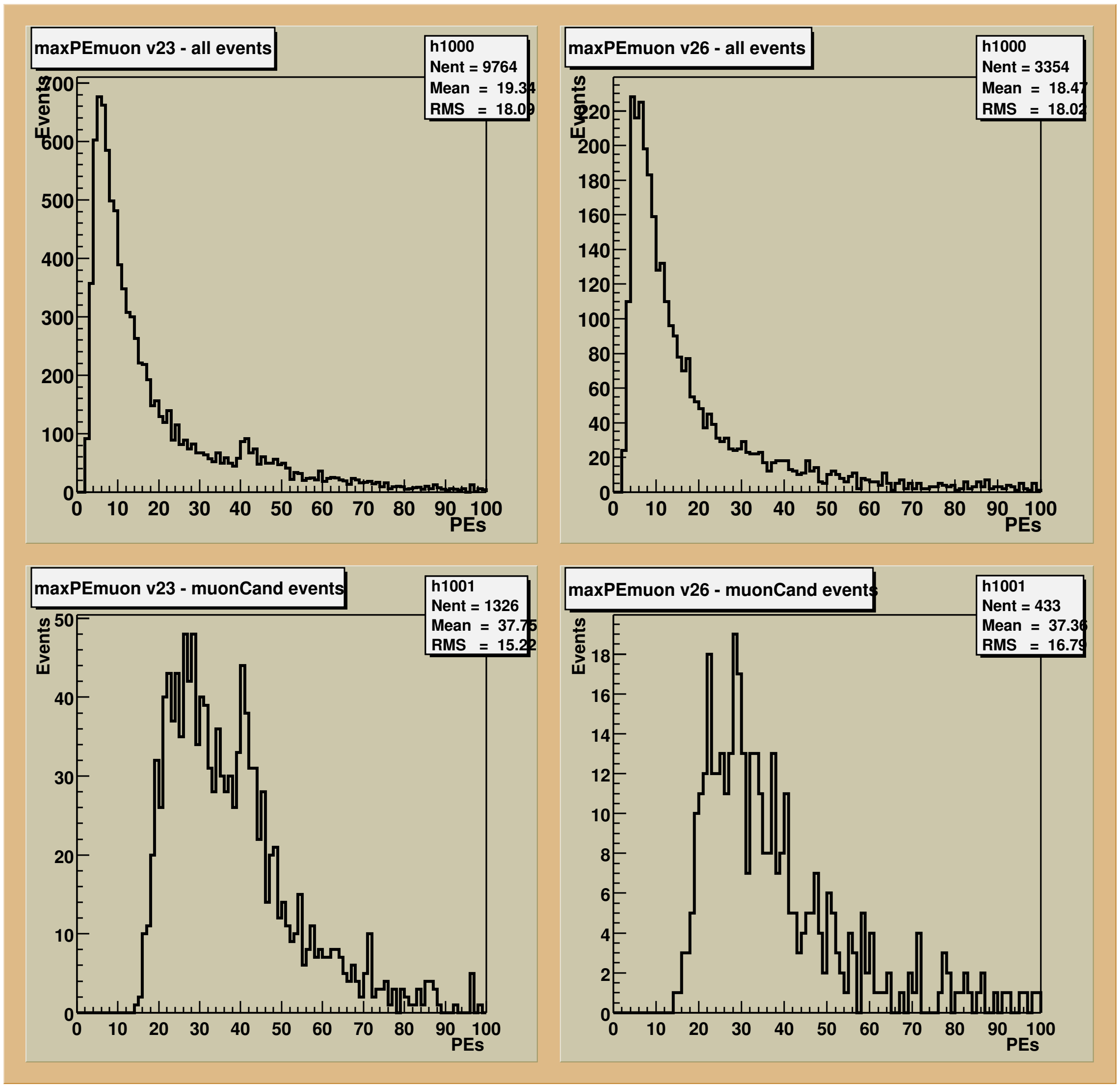

Figure 11: Distribution of maxPEmuon in gamma-ray Monte Carlo for v26 and v23. The discontinuity at 40 pes in the v23 gamma-rays is an artifact of the saturation correction.

4 Effect of rescaling on Milagro sensitivity

Obviously one of the more important implications of this study is the effect on our sensitivity to a gamma-ray signal. I looked at the v26 gamma-ray simulations. I selected events (N_{pass} which triggered us, were fit to within 1.6 degrees of the true direction and had X2 >2.5 (the same as our analysis) out of the total number of events (N_{tot}). I then calculate the a modified effective area as

$$A_{eff} = \frac{N_{pass}}{N_{tot}} \times 1000 \times 1000 \tag{1}$$

The simulations were thrown over a 1000 m X 1000 m area (in case you were wondering about the factors of 1000). There is no significant difference in our sensitivity after reducing the number of pes seen at each PMT by 33%.
Reducing the number of pes detected will degrade the timing somewhat. This has not been considered here. You will have to wait for the next memo.

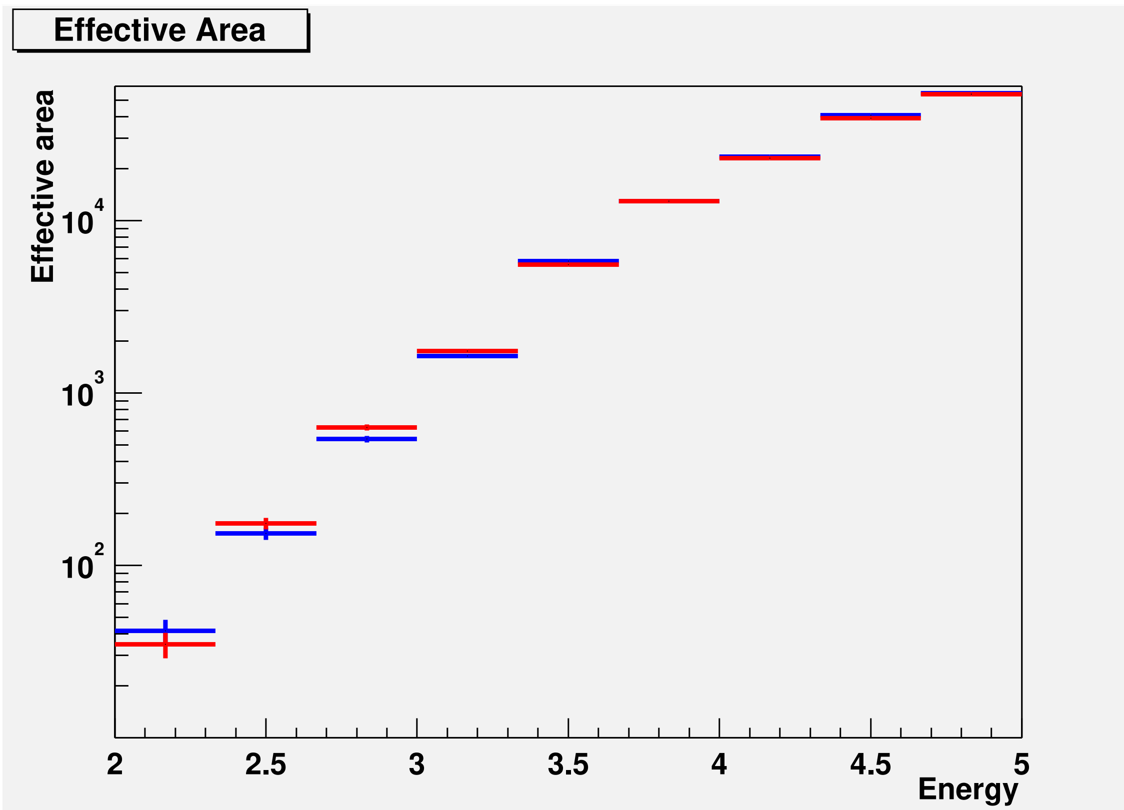

Figure 12: Effective area vs. energy before (red) and after (blue) rescaling