Exploring the Effects of Timing Cuts at Low Trigger Thresholds

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1 Introduction

In a previous memo (Motivation for Lowering Milagro's Trigger Threshold, 9/9/00) David Noyes and I discussed the need to run at lower trigger thresholds in order to extend Milagro's viewing range to include more GRB's. Recall that an energy cutoff in the TeV range due to photon scattering from extragalactic background light makes high energy sources invisible above some energy. For Milagro to be more sensitive to energies below 1 TeV, a lower trigger threshold is necessary. However, there are problems with lowering the trigger threshold. At lower trigger thresholds the rate increases and the rate of no fits increases substantially. Can the high rate be handled? At lower thresholds random hits become a concern. Can gamma events still be fit? To attempt to reduce the rate we consider the effect of a timing cut in the trigger on the rate of fits and no fits in data and on gamma MC. The same cut is applied to proton MC as a check on the gamma result. In most of the results shown, random hits are included in the Monte Carlo events.

2 Timing Cuts in the Trigger

2.1 Why Time?

At lower trigger thresholds high angle muons hit enough PMTs to be a factor in the no fit rate. Although I have not included it here, at the Wisconsin meeting I showed distributions of theta for proton MC events that indicated a contribution from large angles as the trigger threshold was lowered. While particle showers from overhead travel through the pond at approximately the speed of light, c, light from muons travels at c/n where n is the index of refraction. These two types of showers differ in how they develop in time. Because of the difference in speed, single muon showers take longer to hit

Table 1: Ungated Rates for Low Trigger Thresholds

Threshold (PMTs)	Total (Hz)	Fit Rate (Hz)	Not Fit Rate (Hz)
56	2047	1638	409
46	3309	2250	1059
37	6203	3350	2853
27	14612	5699	8913
17	44169	10159	34010

the tubes that will be included in the event. These events fail the fitter and cause an increase in no fits at lower thresholds. This difference in time development can be exploited in the trigger to reduce rates by getting rid of the no fits.

2.2 Risetime

Risetime is defined as the time it takes for 10-90 percent of the tubes in the shower to be hit. When events with risetimes shorter than a risetime cut are kept, this parameter excludes some events that fail to fit because of their shower development time lag while keeping the more quickly forming gamma showers. For this note risetime cuts are applied to data sets taken at low trigger thresholds (50 , 100, 150, 200, and 250 mV). According to Andy (see the June 2000 collaboration meeting notes) the voltage thresholds correspond to 17, 27, 37, 46, and 56 PMTs respectively. Table 1 lists the ungated data rates for these thresholds. When the risetime distribution is split by fit and not fit events there is a peak separation. We also need to know how the cut affects gammas, so we apply it to gamma MC (version 2.3) events and can see the that the gamma risetime distribution peak is also separated from the no fit data peak (figure 1).

This looks good, but as a reality check the cut is applied to proton MC (version 2.3) events and compared to the data. The match is not terrible at higher trigger thresholds but degrades as the threshold is lowered. For the proton MC the risetime histogram peaks at a lower risetime for all trigger levels. When high angle protons (45-70°) are added to the mix, the no fit peaks improve but the fit event distributions are mostly unaffected. Another effect must be considered. It seems likely that adding random hits to the MC events will shift the risetime peaks to higher values for both proton and gamma events. For the risetime cut to work, the separation between the data and gamma MC peaks must remain. To believe the gamma result, the proton MC distributions should look more like the data distributions.

3 Random Hits

When an event is recorded not all the tubes hit are part of the actual shower. These extra tubes are mostly excluded from the fit, but at lower trigger thresholds, 17 PMTs, for example, they can cause events with a small number of tubes in the shower to pass the nHit cut. The small showers may not fit, so this lowers the fit efficiency. Since the random tubes cannot be discarded before reconstruction, they can interfere with the effectiveness of a risetime cut. To include random hits in the Monte Carlo data, I use raw data taken by Miguel with a 1kHz clock trigger. The random hit events from this file are calibrated and then pasted into each Monte Carlo event before reconstruction.

When the random hits are combined with the Monte Carlo data a time shift is neccesary to bring the random hits within the same time window as the MC events. As it turns out, the risetime, parameter is somewhat sensitive to this time shift. To get a sensible result I required the PMT time distribution for the MC data to fall in the middle of the PMT time distribution for random hits (figure 2). In addition, the proton MC risetime distribution can be checked against the data result. Since these are close, I believe the gamma result can be trusted.

4 Results

With the inclusion of random hits, the fit efficiency drops and the risetime distributions move out. The risetime distributions for proton MC including random hits are closer to the distributions for data (figure 3). The risetime distributions for gamma MC can still be separated from the data though not quite as nicely as before. The fractions retained for gamma MC, data, data fit, and data not fit can be compared for different trigger thresholds in figures 4 and 5. Tables 2, 3, and 4 show the effects of various risetime cuts on gamma events and the corresponding data rates. Even including the effects of random hits, the risetime cut can be used to lower the data rate. For the curious, I have also included some plots that give an indication of how well we do as the trigger threshold is lowered. The fraction fit (figure 6), mean delAngle (figure 7), and nHit for fit events (figures 8 and 9) are shown for gamma MC with random hits.

Table 2: Effects of risetime cuts on MC gammas (ver. 2.3 including random hits) and data taken at 250mV (56 PMT) trigger threshold. Note that the cut excludes events with risetimes higher than the cut value.

Risetime Cut (ns)	% Gammas Kept	% No Fits Rejected	% Data Rejected	Ungated Rate (Hz)
75	44	99.9	89	225
100	73	99	65	716
125	88	91	44	1146
150	94	67	25	1535
175	97	35	12	1801

Table 3: 150mV (37 PMT) trigger threshold.

Risetime Cut (ns)	% Gammas Kept	% No Fits Rejected	% Data Rejected	Ungated Rate (Hz)
75	40	99	91	558
100	68	97	77	1427
125	84	86	60	2481
150	91	61	38	3846
175	94	32	20	4962

Table 4: 100mV (27 PMT) trigger threshold.

Risetime Cut (ns)	% Gammas Kept	% No Fits Rejected	% Data Rejected	Ungated Rate (Hz)
75	39	99	93	1023
100	66	94	82	2630
125	81	82	66	4968
150	89	58	45	8036
175	93	34	26	10812

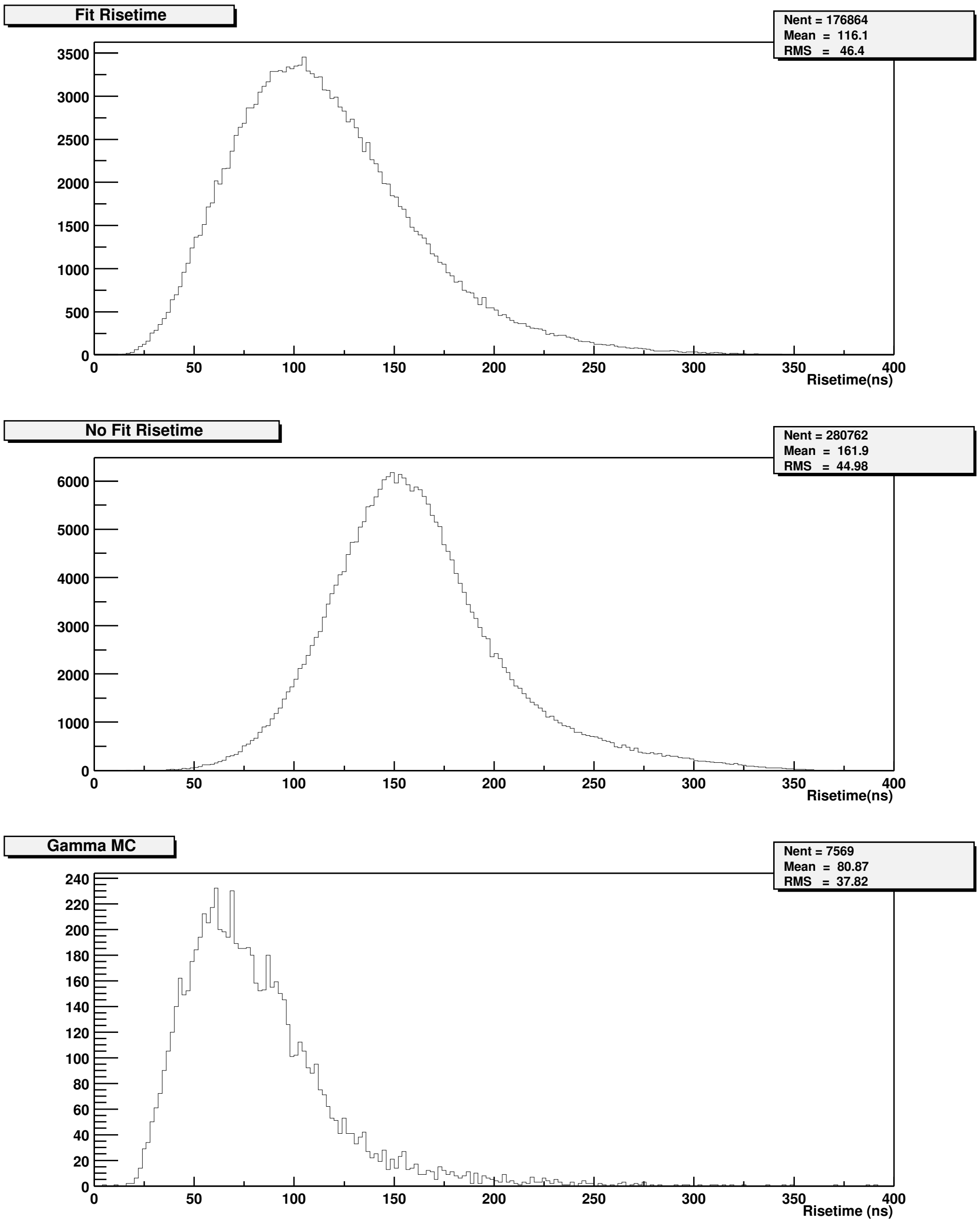

Figure 1: The top two risetime distributions are for data taken at 100 mV (27 PMT) threshold. At this threshold 39% of the events fit. The bottom risetime distribution is for gamma MC events without random hits.

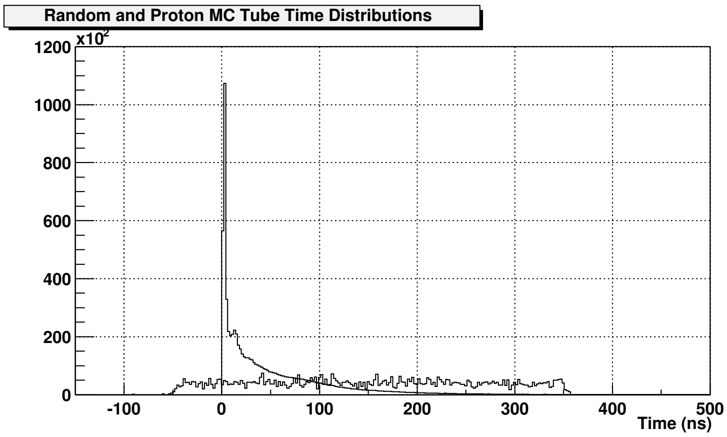

Figure 2: The sharply peaked distribution is the proton MC tube times. The random hits distribution has been shifted to overlap with the proton distribution. The same thing was done for gamma MC analysis.

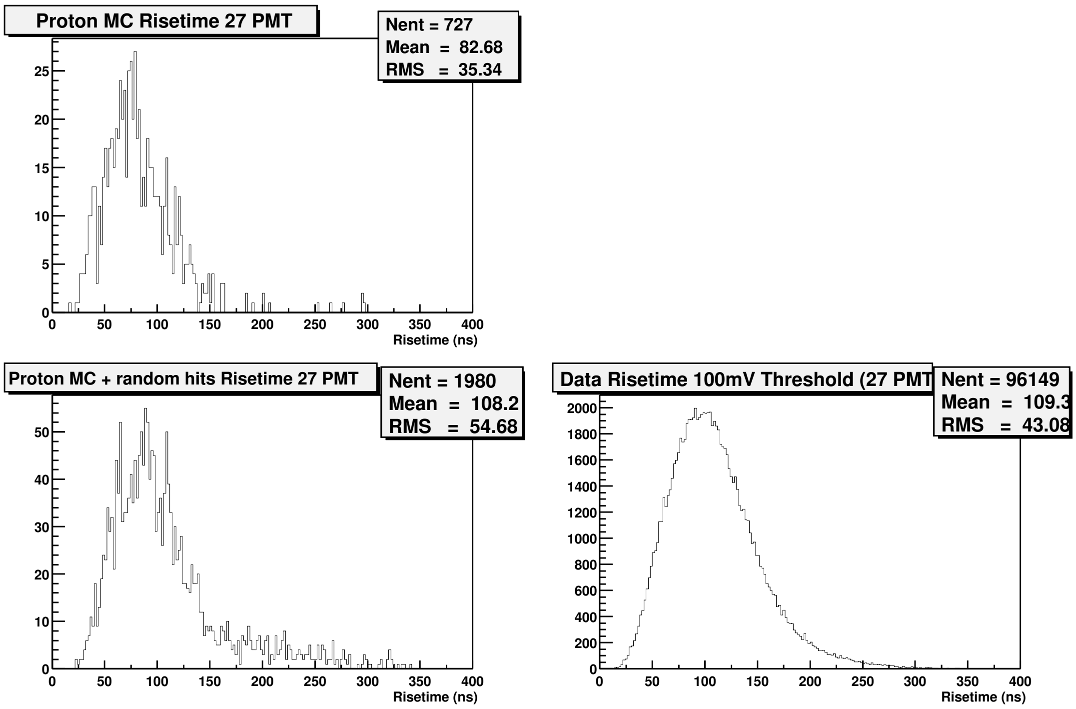

Figure 3: This is intended to show that after adding random hits, the proton MC risetime distribution matches the data somewhat better. All distributions are for events passing an nFit cut of 10 PMT's.

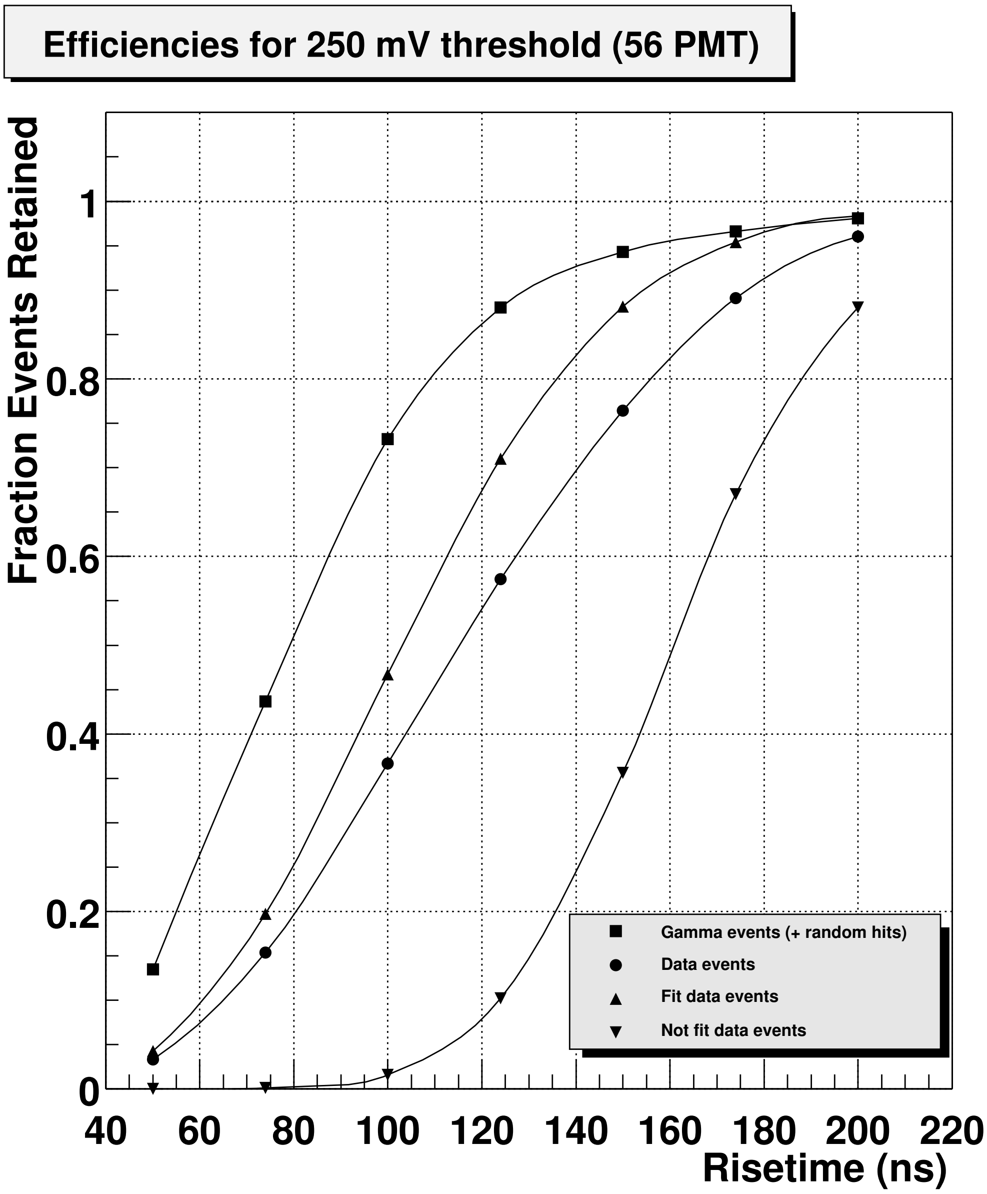

Figure 4: The fraction of events retained for a risetime cut are plotted for gamma MC events (including random hits, for data taken at this threshold, and for that same data split by fit or not fit where the nFit cut is 10 PMT's. The cut was made for seven risetimes and the connecting lines are a simple fit to those points.

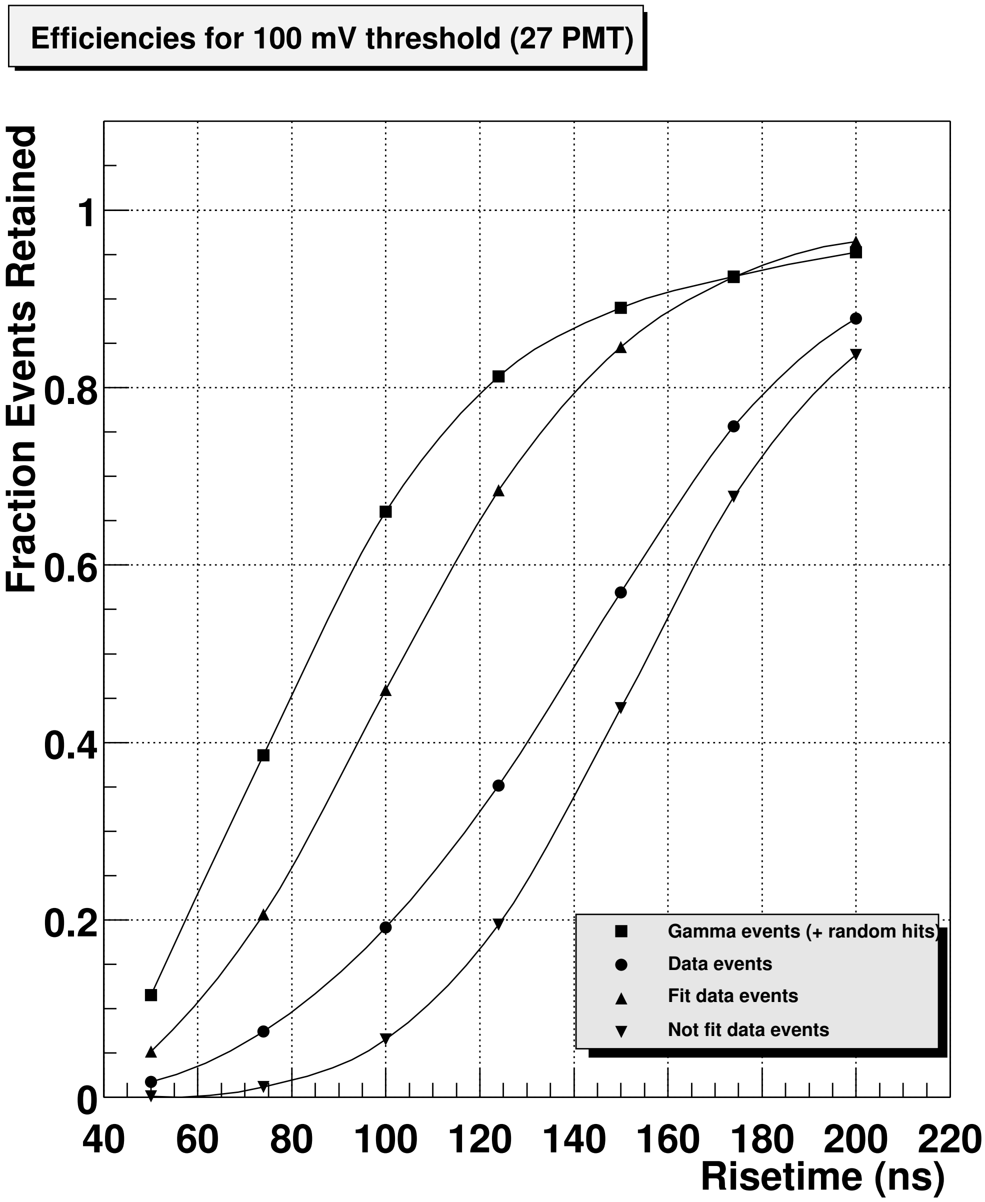

Figure 5: The same as figure 4 but for a 100 mV (27 PMT) trigger threshold.

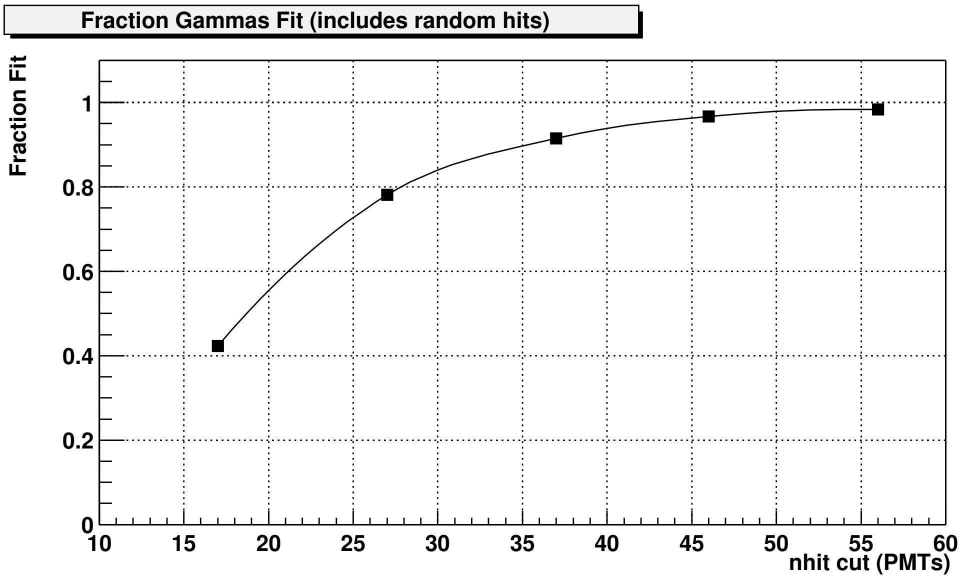

Figure 6: The fraction of gamma events that pass an nFit cut of 10 PMT's against PMT threshold. The gamma events include random hits.

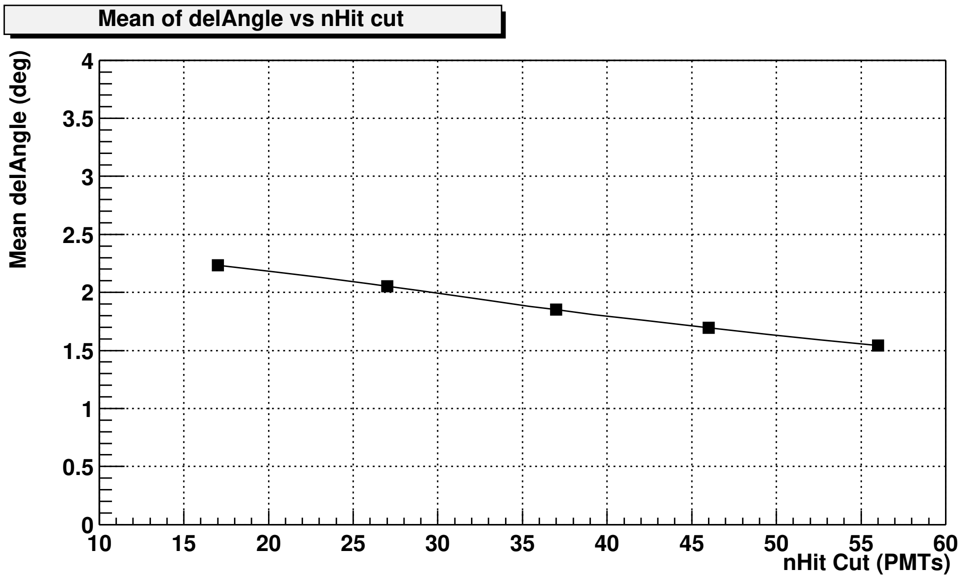

Figure 7: The mean of delta angle is plotted against PMT threshold for gamma MC events. The gamma events include random hits.

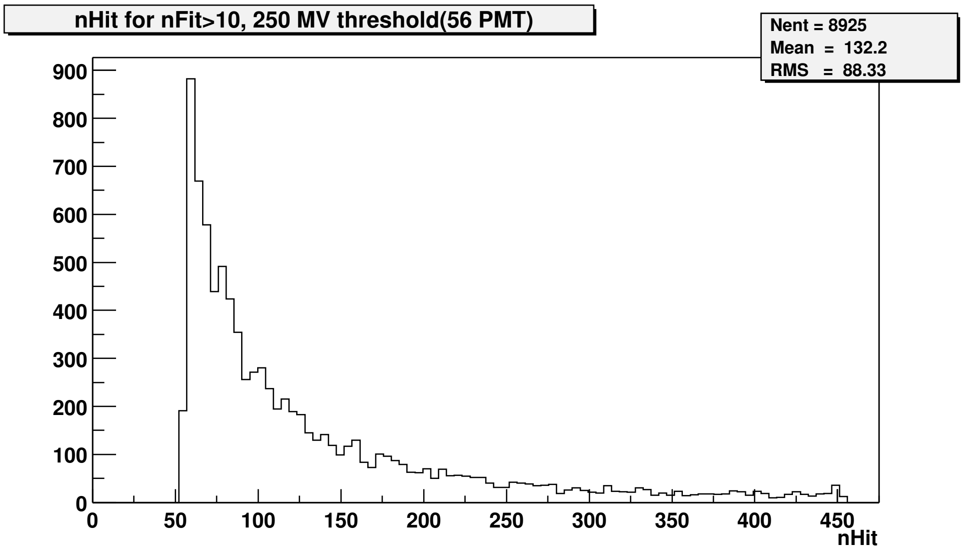

Figure 8: The nHit distribution of gamma MC events that pass an nFit cut of 10 PMT's for a 56 PMT threshold. The gamma events include random hits.

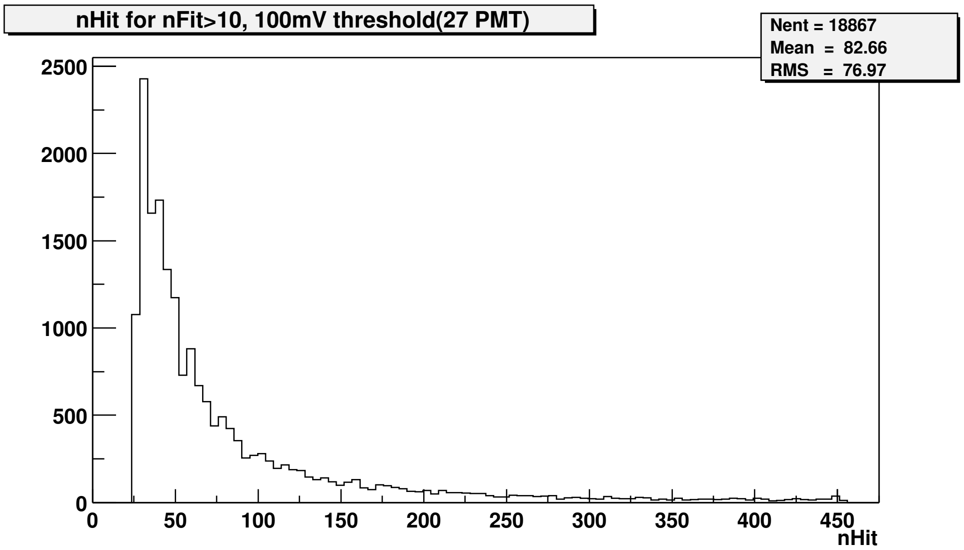

Figure 9: Same as figure 8 but for a 27 PMT threshold. See figure 6 for corresponding fit efficiencies.