A preliminary study of flashers and their effect on Milagrito GRB analyses

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1 Introduction

We have been studying the effect of flashers on the Milagro/Milagrito GRB analysis. The impetus for this study was the detection of a second "burst" (please note the quotes) during the reanalysis of the Milagrito all-sky search for short timescale transients (ie. blind search). We have rejected this second "burst" as a GRB candidate since it is dominated by a high pulse-height flasher which generated *fake* events in the pond. The transient nature of the flasher caused these events to be identified as a potential GRB-like event.

Using this false burst as a tool, in addition to information provided by the scaler system, we have made preliminary identifications of **at least** 7 high pulse-height flashers and perhaps 2 mis-calibrated PMTs in Milagrito. We have also performed a *preliminary* analysis to understand how these 9 questionable tubes affect reconstruction.

2 Flashers: The Bane of Water Cherenkov Detectors

Flashers have always been a problem in water Cherenkov detectors[1]. Experience with large volume detectors such as IMB, Kamiokande, and SuperKamiokande has shown that the same flasher can produce events with varying morphologies: sometimes events with identical pulse-height and timing distributions are produced by a flasher, and sometimes the flasher generated events are completely unique. In addition, it is quite common that the flashing character of a PMT is transient, with PMTs going through alternating periods of normal and flashing operation. Because of these strange and often unpredicatble characteristics, identification of flashers is difficult.

2.1 The Second "Burst"

Shortly after the last collaboration meeting, a reanalysis of the Milagrito untriggered burst search was begun. This reanalysis incorporated the results from the study of the optimal binsize and nfit cut. To summarize, the search looked for 10s bursts using an nfit cut of 30 and a variable binsize dependent upon the number of background events. This search indicated that there were five burst candidates all with approximately the same RA and Dec, and all within 100s of one another. Upon a more careful examination, it looked as though we had two very intense bursts separated by about 30s. Figure 1 shows the time history for a 10 degree square region of the sky centered on this "burst" position; a sky plot of these events is shown in Figure 2.

A further analysis of the "burst" events showed that 87 (of 101 total) events had their fitted cores within approximately 8 m of each other (Figure 3). Figure 4 shows the sky locations of these clustered events and the sky location of all other events. Digging deeper into the cause of these events we found that a number of PMTs in the pond appear to be high pulse-height flashers. In fact, most of the fit cores for the clustered events of Figure 3 are centered on one of the identified flasher PMTs. Below we describe the techniques used to identify flashers and their implications.

2.2 Identification of Flashers in Milagro/Milagrito

We have made an attempt at flasher identification using 2 different approaches. The first method uses the recorded scaler data. Here the high-threshold OR'd scaler rates (measured for each patch) are checked visually for *unusual* behavior. There is some subjectivity in determining what is unusual; fortunately (or unfortunately) there are some PMTs with scaler rates so bizarre that there is no question that they are problematic. Figure 5 shows the scaler rates for PMTs 109 and 111 during subrun MGT0140-0070.dat, one

[1]We will not try to explain the cause of flashers here

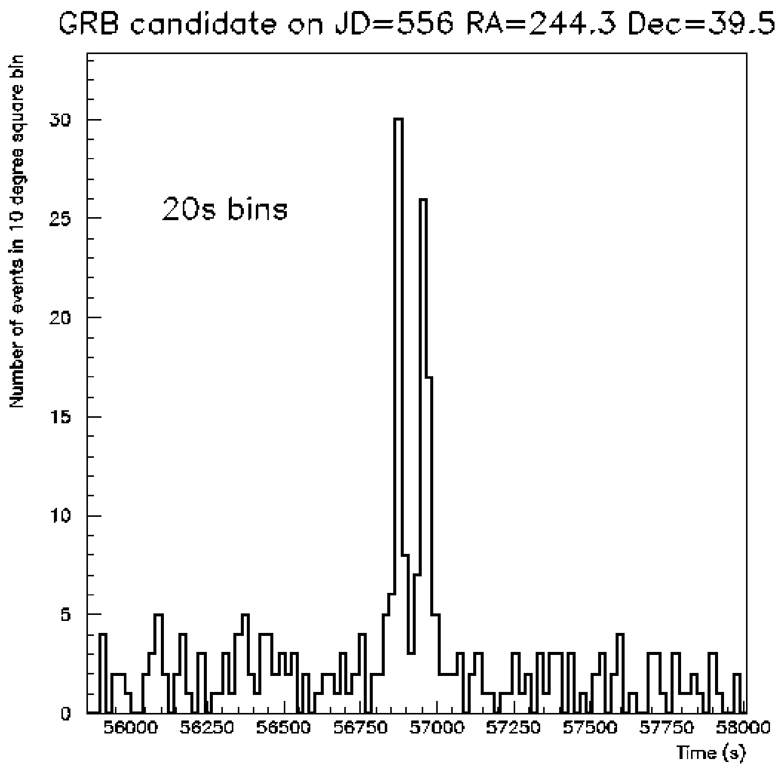

Figure 1: Lightcurve of the second "burst".

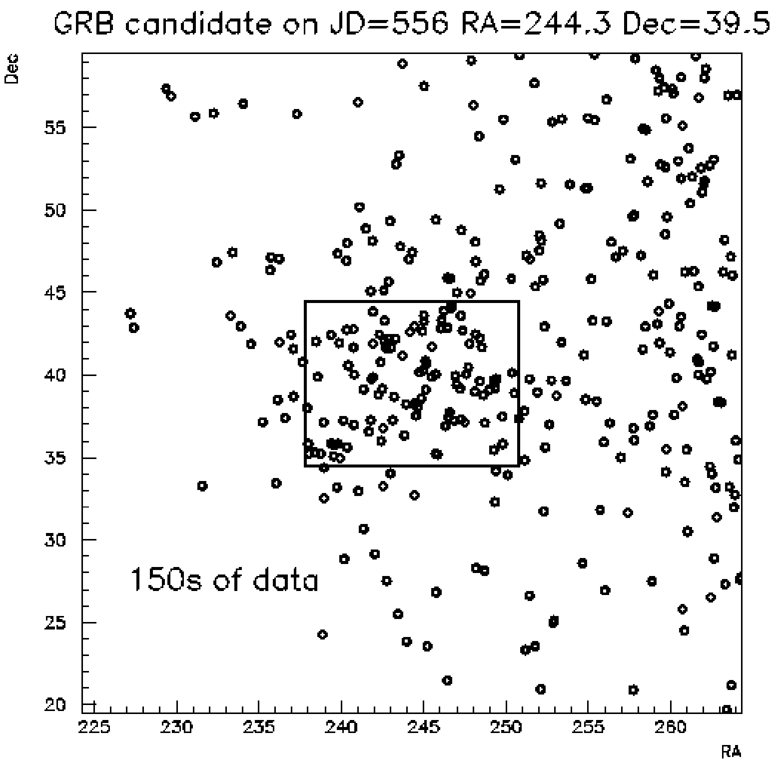

Figure 2: Sky plot of events from the second “burst”.

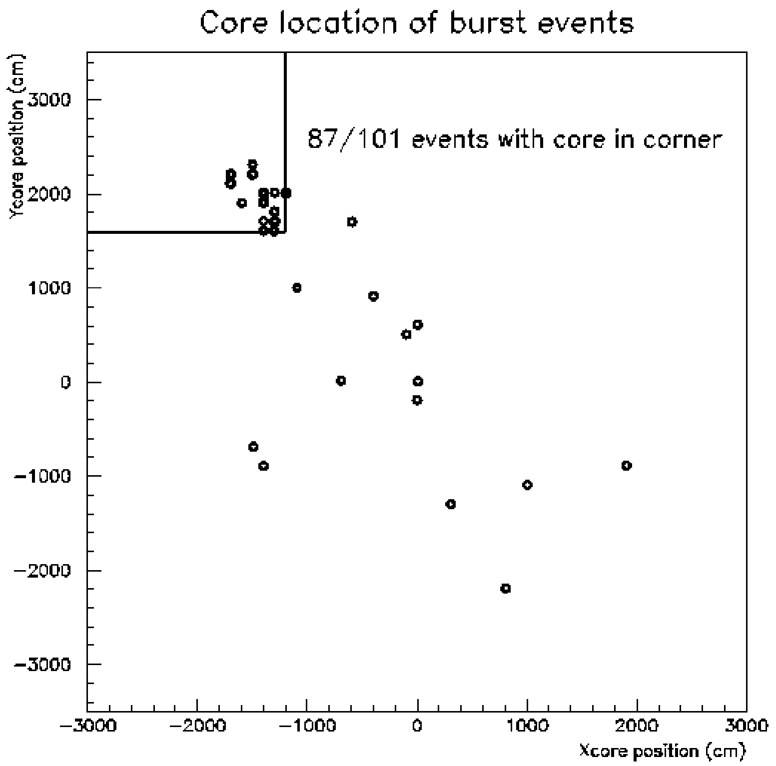

Figure 3: Fitted core positions of events in the second "burst". Note that more than one event can be represented by the symbol.

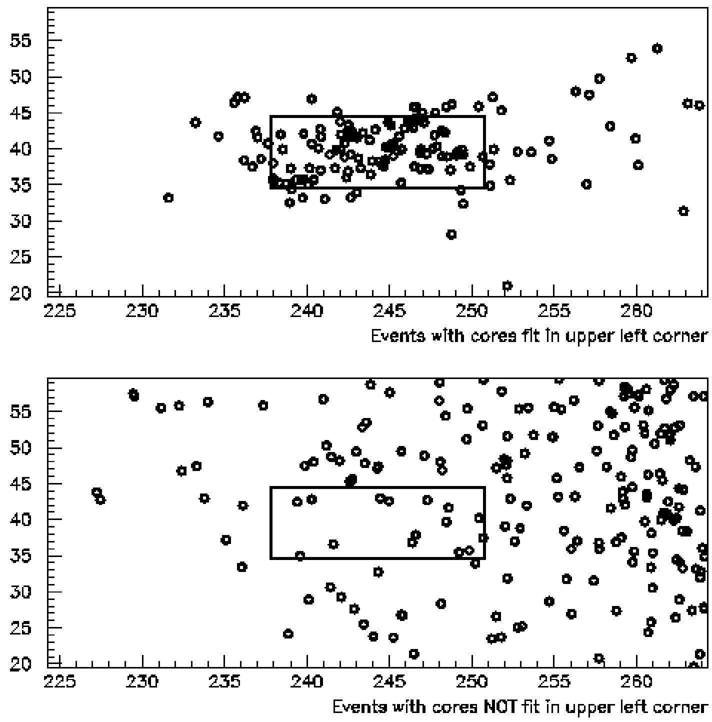

Figure 4: Sky locations of events from the second "burst". The top plot shows locations for the "clustered" events. The bottom plot shows locations for all other events.

of the subruns during which the second "burst" was detected. The behavior of these tubes is the most unusual of all Milagrito PMTs. These tubes also happen to be in Patch 7, which was known to show unusual behavior from Abe's solar analysis. Also shown in Figure 5 is PMT 134 which is representative of the more standard scaler behavior, and the high-threshold scaler rate for patch 7. This final plot shows that the flashing is indeed at high pulse-heights.

Looking at scaler rates is adequate for identifying high-rate flashers. However, the most difficult flashers to identify are low-level flashers. These tend to flash at relatively low rates and can be quite transient in nature, thereby requiring a different technique to weed them out.

A simple criteria to find low-level flashers is to measure the fraction of events in which a given PMT is the hottest PMT. Figure 6 shows histograms of this measure for 3 different nFit cuts, for subrun MGT0140-0070.dat. Figure 7 shows the same measure but for the 3 hottest tubes in an event[2]. Using Figures 6 & 7 it is clear, for this subrun, that PMTs 63, 109, 154, 157, 159, 175, 211, 225, 226 are much more likely to be "hot" than the average tube. PMTs 109 & 111 were also identified as questionable via scalers, as noted above.

2.3 An Algorithm for Low-Level Flasher Identification

A less subjective approach (compared to a visual judgement call) for flasher identification should be developed. As a first attempt in developing such an algorithm we note that in Figures 6 & 7 all of the *obvious* flashers are "hot" at least 1.5% of the time they are hit. Therefore we will identify a PMT as a flasher if it has a $\geq 1.5\%$ chance of being hot in any of the six plots of Figures 6 & 7. This threshold could be made more restrictive but we take the conservative approach here. We have also looked at multiple subruns to determine if PMTs are true flashers or simply mis-calibrated tubes. For some of the PMTs we find that there may indeed be mis-calibrations, ie. PMTs show the same high probability of being "hot" across runs separated by months. For this preliminary analysis we identified PMTs as mis-calibrated if they do not show variabilitiy in time, but are still more likely to be hot than the average PMT.

3 Implications for BATSE 6188

In the previous sections we showed the relatively simple procedure we developed for identifiying the cause of the false burst detected during the blind GRB search. For the relevant subruns 8 flashers (109, 111, 154, 157, 159, 175, 225, 226) and 2 mis-calibrated (63 & 211) PMTs were identified. Since this subrun was recorded only 1 day after BATSE 6188, we felt it was prudent to perform a similar analysis to see if the Milagrito "burst" was affected. The purpose of this analysis is not to reanalyze the burst search, but merely to show that contamination of events by flashers (or mis-calibrated PMTs) can have an important impact on event reconstruction.

Figures 8 & 9 show the low-level flasher detection plots for subrun MGT0139-0058.dat, the subrun during which BATSE trigger 6188 occurred. Using the flasher detection criteria described above, 3 flashers (PMTs 109, 111, 175) and 2 mis-calibrations (PMTs 63 & 211) were identified for this subrun. Note that these were also identified during subrun MGT0140-0070.dat. Using the identified flashers and mis-calibrations, we will now try to study impact on the 18 events detected during the T90 (7.9 seconds) of BATSE trigger 6188.

3.1 Refitting Events

In order to get a quantitative measure of the effect of flasher/mis-calibration contamination, the 18 burst events have been refitted with the identified PMTs removed. Table 1 shows the difference between the fit parameters with and without the inclusion of the 5 questionable PMTs identified in subrun MGT0139-0058.dat.

We have not removed any additional PMTs from the events that may have been affected by the flasher (ie. PMTs that neighbor identified flashers)so this refit analysis is meant only to get a "feel" for the contamination effect. These refit parameters are presented here to show that changes in the fit parameters (primarily angle fits) can occur due to potential flasher contamination. In Figure 10 we show the event locations on the sky for

[2]We choose to check the 3 hottest PMTs because these are the tubes used as the starting points for core position determination

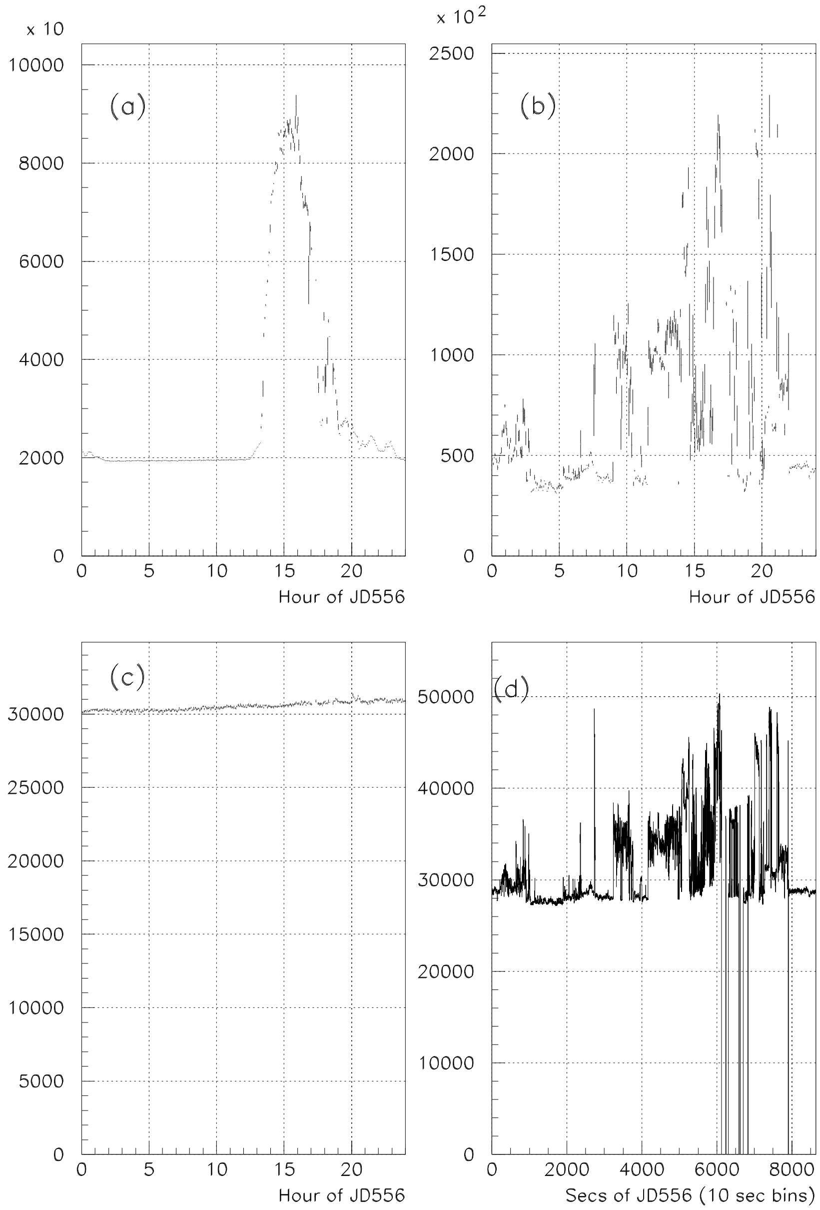

Figure 5: Scaler rates during MGT0140-0070.dat. (a) MASKED scaler rate for PMT 109, (b) MASKED scaler rate for PMT 111, (c) MASKED scaler rate for PMT 134, (d) High-threshold scaler rate for Patch 7 which includes PMTs 109 & 111.

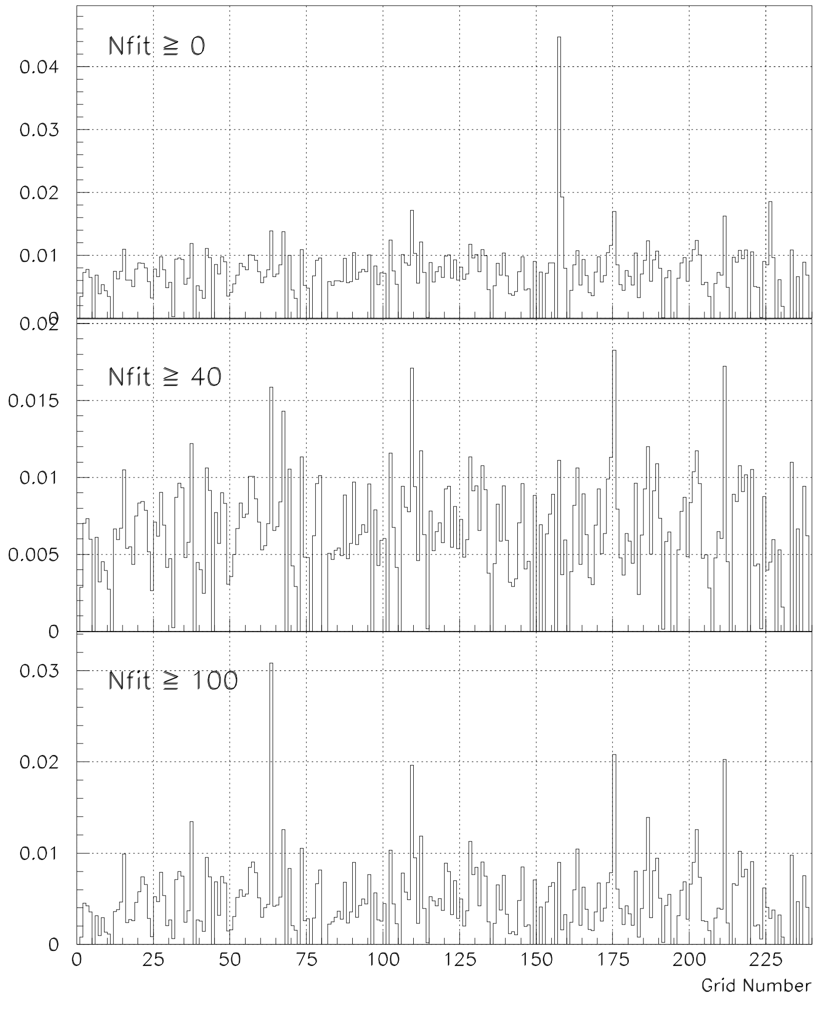

Figure 6: Low-level Flasher Identification in Subrun MGT0140-0070.dat. Plotted is the fraction of times each PMT (grid number) is the hottest tube (assuming it was hit) for three values of nFit cut (0, 40, 100).

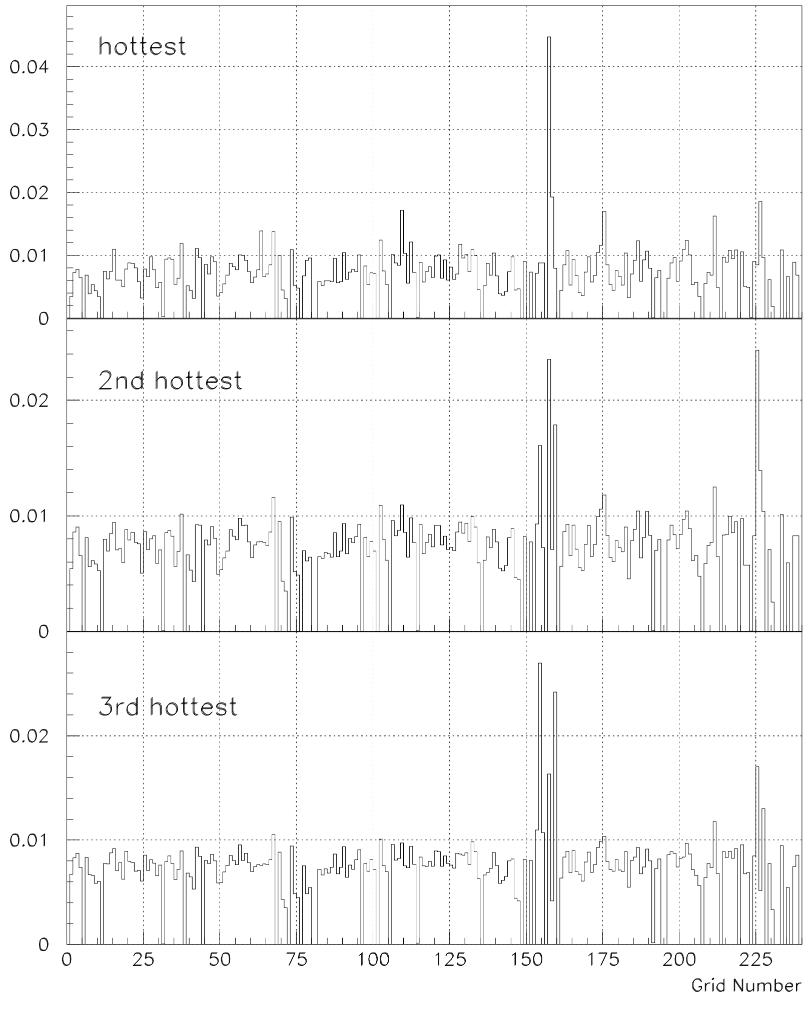

Figure 7: Low-level Flasher Identification in Subrun MGT0140-0070.dat. Plotted is the fraction of times each PMT (grid number) is one of the 3 hottest tubes (assuming it was hit) for an nFit cut of 0.

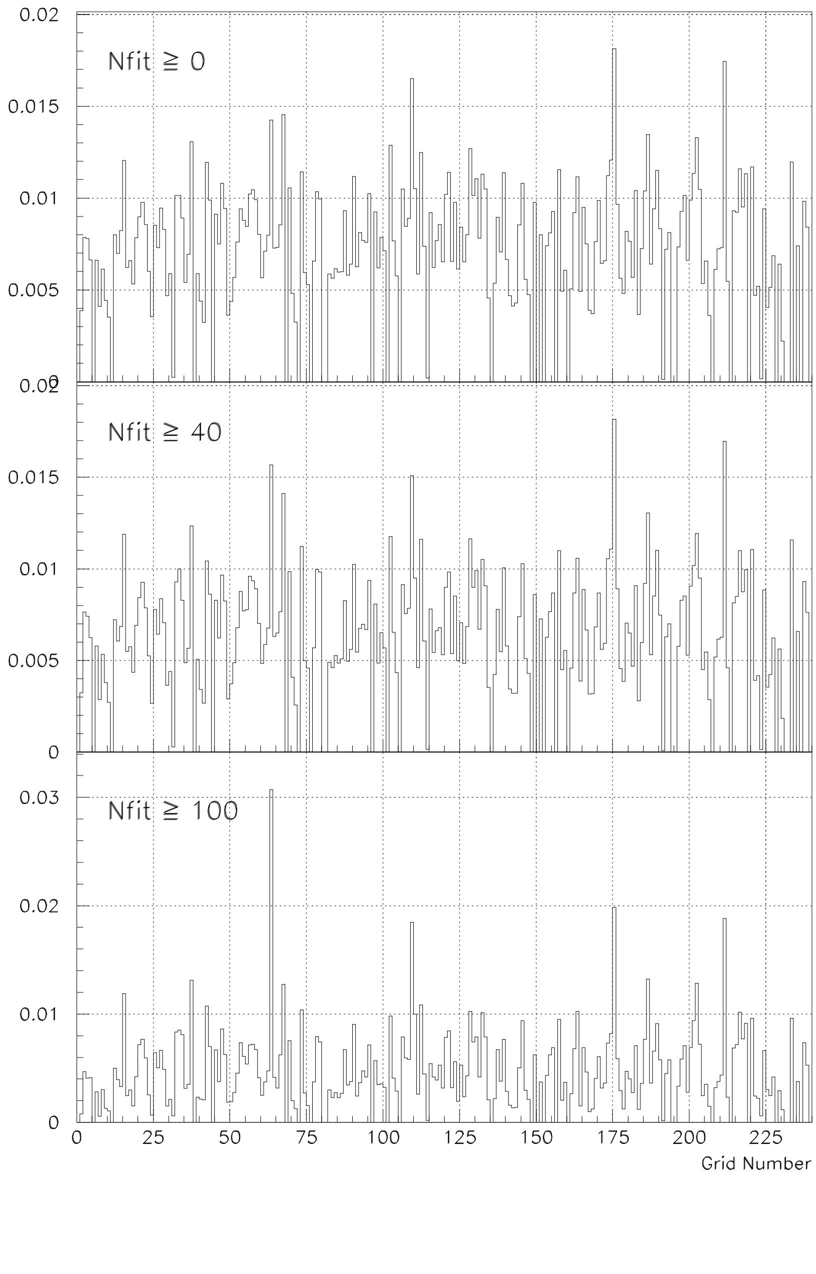

Figure 8: Low-level Flasher Identification in Subrun MGT0139-0058.dat. Plotted is the fraction of times each PMT (grid number) is the hottest tube (assuming it was hit) for three values of nFit cut (0, 40, 100).

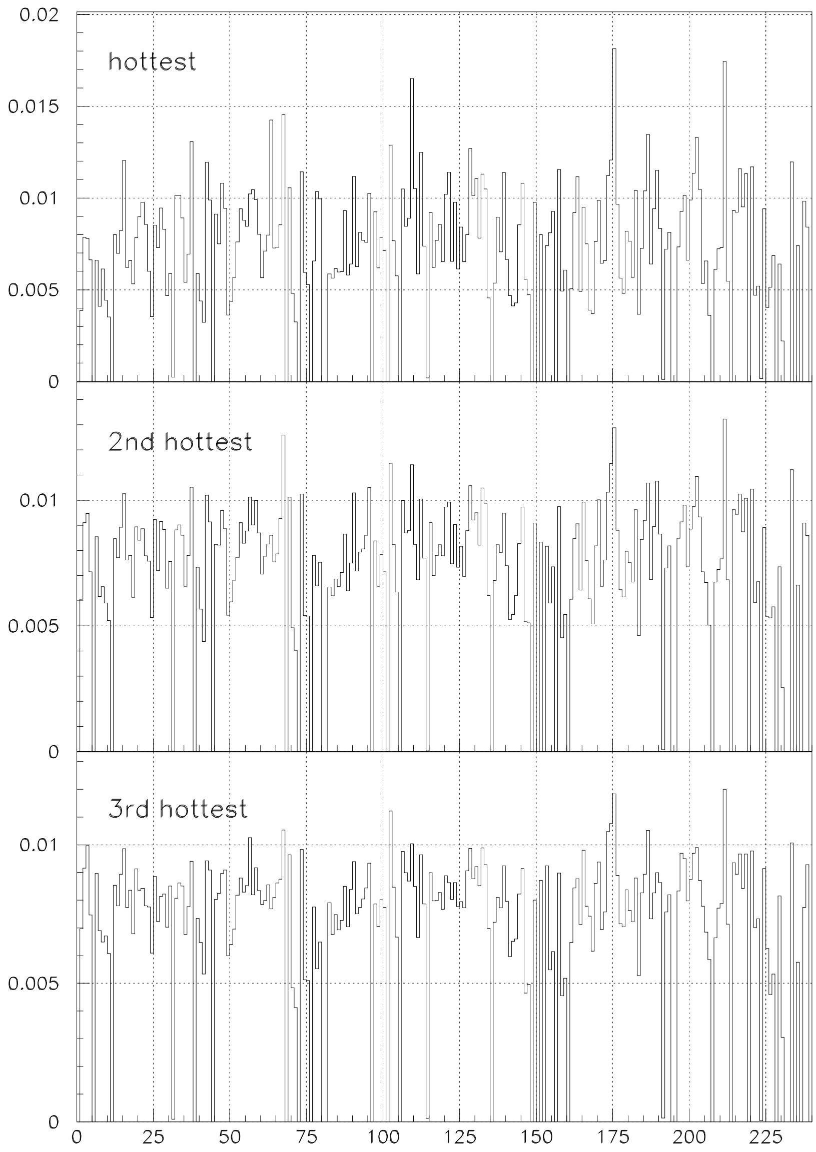

Figure 9: Low-level Flasher Identification in Subrun MGT0139-0058.dat. Plotted is the fraction of times each PMT (grid number) is one of the 3 hottest tubes (assuming it was hit) for an nFit cut of 0.

GRB 6188 Event No.	ΔCore position (m)	(θ, ϕ) Space Angle Difference (deg.)	New RA (deg.)	New Dec (deg.)
1	0.0	0.0	291.4	53.0
2	4.20	0.7	289.7	55.6
3	0.0	0.1	290.4	54.9
4	0.0	0.2	291.0	53.2
5	0.0	0.0	290.1	53.6
6	0.0	0.2	290.7	55.3
7	0.0	0.5	291.0	52.8
8	2.79	0.4	287.7	52.6
9	0.0	0.0	290.1	53.4
10	0.33	0.1	291.2	54.8
11	0.0	0.3	291.7	54.5
12	0.10	0.1	292.1	54.4
13	0.0	0.1	290.9	55.6
14	0.03	0.2	289.0	52.9
15	0.11	1.5	292.0	52.9
16	0.0	0.1	289.3	52.5
17	22.32	1.0	288.2	54.1
18	0.10	0.0	290.5	55.3

Table 1: 18 Refitted Milagrito Events Coincident with BATSE 6188

both fits. The removal of the questionable PMTs has caused perhaps 3 events to fall outside the previously determined 1.6^o signal bin for BATSE 6188. It is also possible, and likely, that after removal of PMTs, that other events move *into* the burst signal bin.

3.2 Hot Flasher Discussion

If a PMT has a high measured pulse-height then it, along with its neighbors, can affect the (center-of-gravity) core position fit and/or the angle fit. From Table 1 it appears that 3 of the 18 events have an affected core fit, with only one event being severely affected. Table 2 shows the distance between the fitted core position and the *nearest* identified questionable PMT, for each of the 18 events currently identified as coincident with BATSE 6188.

The next three columns of Table 2 list the hottest 3 PMTs for each of the 18 burst events. In four cases (events 1, 8, 13, & 17) one of the identified flashers/mis-calibrations was hot (rank 1, 2, or 3). It should be noted that in two of these events (8 & 13) the *hottest* PMT is one of the identified flashers/mis-calibrations, and in 2 events (2 & 17) the fitted core position was within 1 grid spacing of a questionable PMT. Considering the patchy nature of operating PMTs in Milagrito (dead PMTs, etc.) more work is necessary to determine if this is a non-random result. The last two columns of Table 2 show the nFit and nFit/nHit ratio for the events prior to removing the identified PMTs. Our expectation is that flasher dominated events will have a low nFit/nHit ratio - how low is a task for future study. Future work will also need to address how the χ^2 of the events can be affected by flashers. Although most of the clustered flasher events identified in subrun MGT0140-0070.dat and associated with the second fake "burst" would have been eliminated with a nFit cut of $\geq$40 (ie. events supposedly generated by PMT 225) the same is not necessarily true here. Figure 8 shows that the flashing PMTs are still detectable even with large nFit cuts for this subrun.

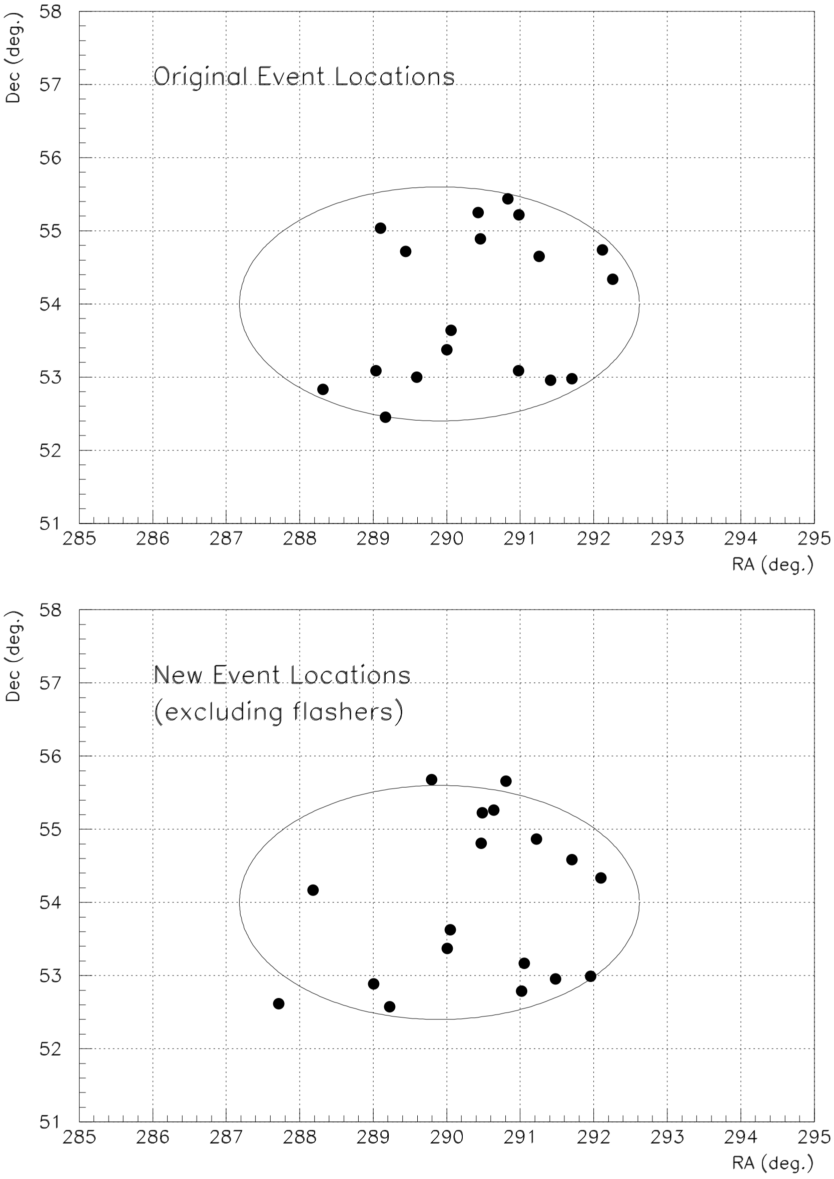

Figure 10: Sky plots for 18 events detected during the T90 of BATSE 6188. The top plot shows the event locations using the original fits, the botton plot shows the event locations fit after 5 flasher/mis-calibrated PMTs were removed.

GRB 6188 Event No.	core-questionable PMT dist (m)	nearest questionable PMT	hottest PMT	2nd hottest PMT	3rd hottest PMT	nFit	nFit/nHit
1	17.3	63	151	211	37	14	0.13
2	1.95	111	180	66	110	49	0.33
3	8.65	111	161	185	188	72	0.49
4	17.76	111	23	179	127	40	0.40
5	10.41	109	217	14	90	55	0.44
6	5.96	111	26	51	102	66	0.45
7	10.56	63	47	120	75	34	0.37
8	3.68	175	175	165	174	32	0.34
9	8.74	111	99	186	89	30	0.33
10	8.95	63	65	56	205	36	0.36
11	9.04	63	53	2	51	53	0.43
12	6.14	109	128	87	168	34	0.35
13	16.43	63	63	67	7	34	0.30
14	6.14	211	113	139	201	73	0.47
15	4.13	211	139	143	45	22	0.22
16	12.02	109	15	170	216	157	0.82
17	0.40	211	69	106	211	65	0.44
18	5.81	111	125	95	33	91	0.54

Table 2: 18 Milagrito Events Coincident with BATSE 6188

4 Summary

We have preformed a preliminary study of flashers in Milagrito. The original motivation of this study was the observation of unusual events that produced false burst detections, the cause of which appear to be flashing PMTs. Using simple criteria to identify potential flashing PMTs, both high-level and low-level (rates) flashers, we have identified 8 flashers, 3 of which were *active* during subrun MGT0139-0058.dat, which contains the 18 events detected in coincidence with BATSE trigger 6188. We have also identified at least 2 mis-calibrated PMTs that may tend to have higher than average measured pulse-heights.

We have used 2 criteria to identify flasher PMTs. Removal of questionable tubes from event reconstruction, both core and angle fits, leads to significant changes in the sky position determination of events. We find that perhaps 3 of the 18 events previously identified as coincident with BATSE 6188 are no longer within the 1.6^o signal bin. It is, of course, true that other events are likely to move into the signal bin after removal of questionable PMTs and refitting. The purpose of this analysis was not to reanalyze the burst search, but merely to show that contamination of events by flashers/mis-calibrations can have an important impact on event reconstruction, and hence astrophysics - particularly in the case of small number of events.

We recommend the following steps be taken:

- A systematic study of flashers and their potential effects on event reconstruction be performed ASAP.
- That additional, more sophisticated algorithms for flasher identification be developed.
- That additional work be performed to identify mis-calibrated PMTs.
- A determination as to what degree the baffles in Milagro reduce the effect of flasher PMTs.
- That the analysis of BATSE 6188, and all other burst searches, be redone with the removal of identified flashers and mis-calibrations.

It is our feeling that without additional information and an understanding of flasher and mis-calibrated PMTs in Milagrito, our ability to address transient searches with low number of events may be impacted.