A proposal to change the Milagro Trigger

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Abstract

We present a proposal to change the Milagro trigger setup to increase our sensitivity to gamma rays, especially below 300 GeV. The trigger would have a risetime cut that increases in strength as the size of the analog sum pulse decreases. This trigger should be implemented immediately to increase our chances of seeing a GRB.

1 Motivation

A primary physics goal of Milagro is the detection of GRBs.

The distribution of GRBs is extragalactic in nature. Figure 1 shows the distribution of GRBs that have had redshifts found for the host galaxies. This distribution is filled with objects near and beyond z=0.5.

High energy gamma rays can be absorbed by electron-positron pair production on the diffuse background of infrared photons as they propagate to the Earth. Figure 2 shows the survival probabilities after IR absorption is considered as a function of gamma ray energy. Higher energy gamma rays(>300 GeV) are strongly attenuated and will not make it to our detector.

The best chance Milagro has to see GRBs is to maximize the sensitivity of the detector to gamma rays below ~300 GeV. Our current high trigger threshold makes it difficult to trigger on many of these lower energy events, since they do not generate many hits in the pond AS layer. This memo proposes a trigger which lowers the trigger threshold and increases the number of events from these low energy gamma ray showers.

This memo builds on the work presented in memos and talks by Liz Hays and David Noyes (Memos dated: 9-9-00,2-15-01).

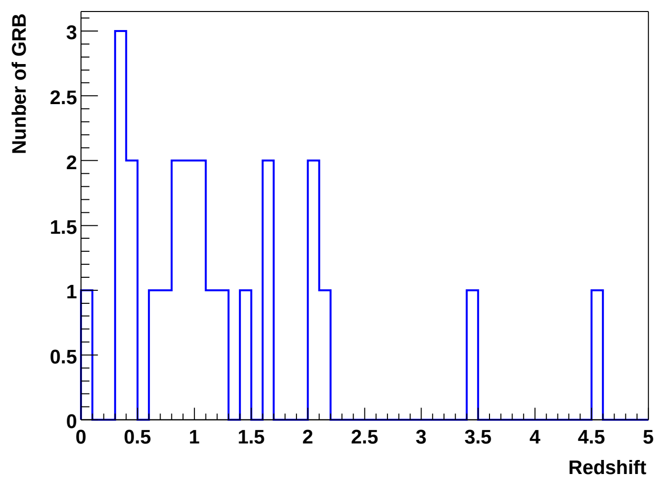

Figure 1: Distribution of gamma ray bursts in redshift.

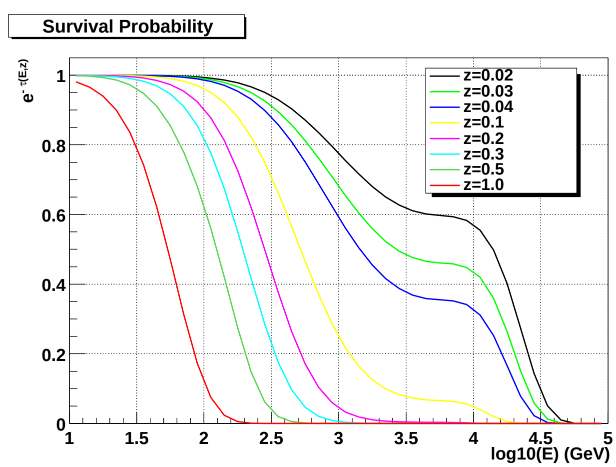

Figure 2: Survival probabilities after IR absorption as a function of gamma ray energy for sources at different redshifts. For a source at z=0.5, no gamma rays above ∼300 GeV survive.

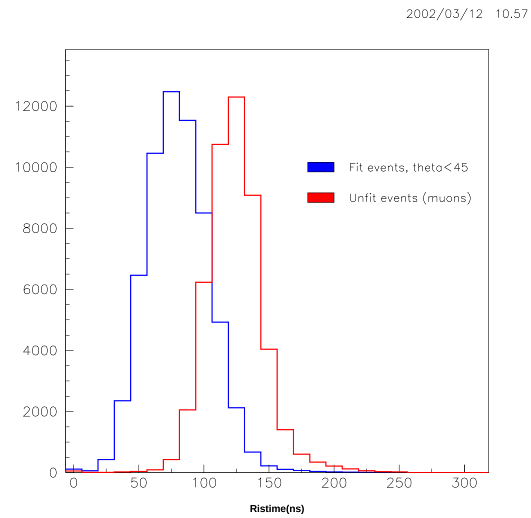

Figure 3: Risetime distributions for fit events (blue curve, zenith angles < 45 deg.) and for unfit events (red curve). Unfit events have longer risetimes.

2 Risetime cuts

The newly installed VME trigger card allows us to make trigger decisions based on the risetime and size of the analog sum pulse. Figure 3 shows the risetime distributions for data events that fit with zenith angles less than 45 degrees and unfit events. Unfit events, events which do not fit well to a plane shower are assumed to be near-horizontal muons, which we wish to reject. As the trigger threshold is lowered, the contribution from this unfit (long risetime) sample increases dramatically. A cut on the risetime for lower nhit events would help reduce the rate from this unfit sample.

The risetime of MC gamma rays seems to be even more concentrated at short risetimes. Figure 4 shows the risetime distribution for gamma MC events (version 3.2, no simulated noise included here) as well as unfit events. Additional study was performed on the MC samples (both gamma and proton showers). Figure 5 has the risetime distributions for gamma and proton showers, including simulated noise. Noise was added to these simulations by combining hits from clock triggers with the MC hits. Protons are v3.2 of the simulation, 50 GeV-100 TeV, and events with at least 20 hits in the detector. Gammas are also v3.2 of the simulation, 50 GeV-300 GeV primary energy,

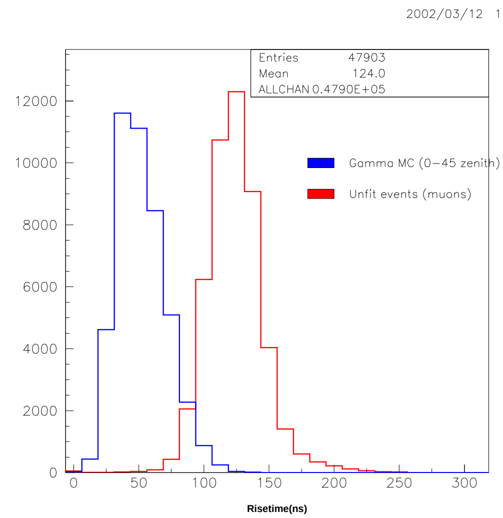

Figure 4: Risetime distribution for gamma MC (blue) and unfit data (red). Gamma MC events are V3.2, 0-45 zenith angles, and require Delangle<2.5 degrees. The MC gammas do not include simulated noise here. Unfit events are the same as Figure 3.

delangle <2.5 deg., and events with at least 20 hits in the detector. These gamma rays have a preferentially shorter risetime than proton showers, as the gamma rays that trigger the detector in this energy range are mostly from near zenith.

3 Proposed Trigger

To be able to take the additional rate needed to acquire these fast risetime and low nhit sample, we need to cut into our current trigger with a modest risetime cut. The following trigger setup has been studied and is being proposed:

- Trigger 1: NPMT>74 (450mV), with no risetime cuts, no prescale.
- Trigger 2: NPMT>53 (320mV), risetime ≤87.5 ns, no prescale.
- Trigger 3: NPMT>20 (125mV), risetime ≤50 ns, no prescale.

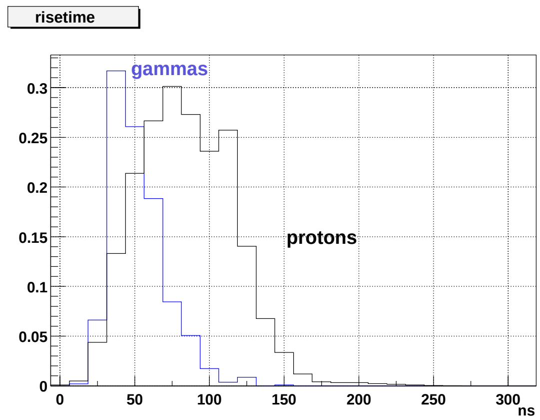

Figure 5: Risetime distribution in blue for gamma MC (v3.2 of the simulation, 50 GeV-300 GeV primary energy, delangle <2.5 deg., and events with >20 hits) and proton MC (v3.2 of the simulation, 50 GeV-100 TeV, and events with >20 hits). Both of these simulations include noise hits.

- Trigger 4: NPMT>20 (125mV), no risetime cuts, prescaled for low rate.

The muon layer veto, for reasons to be shown soon, has been ignored for all these triggers. The prescale rate for Trigger 4 will be determined so that a few Hz of this sample is collected to ensure the stability of the trigger cuts. This trigger arrangement has been tested, and runs stably at ~1800 Hz, with 8.3% deadtime, and a VME DMA rate of 5.16 M/s. Adding the risetime cut in Trigger 2 also helps to reduce the trigger rate variations due to temperature variations in winter, as I presented in the February 2002 LANL collaboration meeting.

The efficiency for the $\leq$50 ns cut for the gamma rays shown in Figure 5 is 65%. The effective area as a function of primary energy for events that fit with a 2.5 degree bin, presented here relative to the effective area with a standard 55 tube, no risetime cut trigger for this proposed trigger is shown in Figure 6. The increase in effective area below 300 GeV is about 4 times the standard effective area. The same plots were made for the current trigger including the muon layer veto, and are shown in Figure 7.

This risetime cut value of 50 ns was chosen so that the trigger rate with the lowest possible threshold (20 pmts) was below the DAQ limitation of 2000 Hz.. An alternative set of triggers would rise the threshold on Trigger

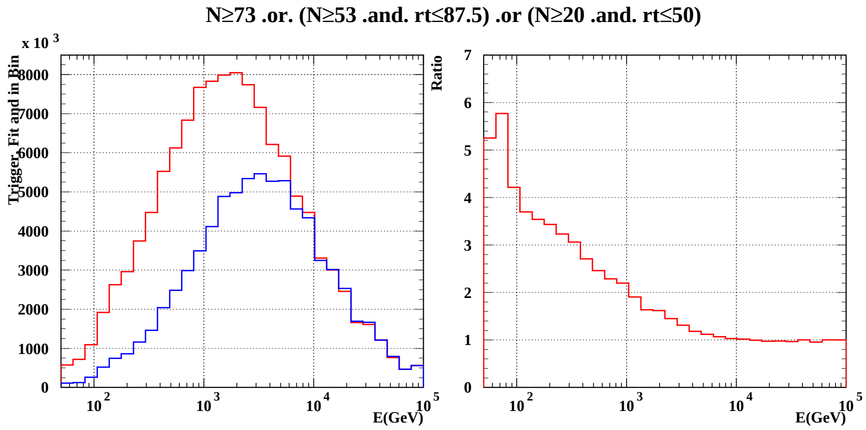

Figure 6: (Left) The number of triggers that fit within a 2.5 degree bin passing the standard 55 tube requirement (blue) and passing the proposed trigger (red). (Right) The ratio of these two represents the increase in effective area for the detector. The increase in effective area below 300 GeV is about 4 times the standard effective area.

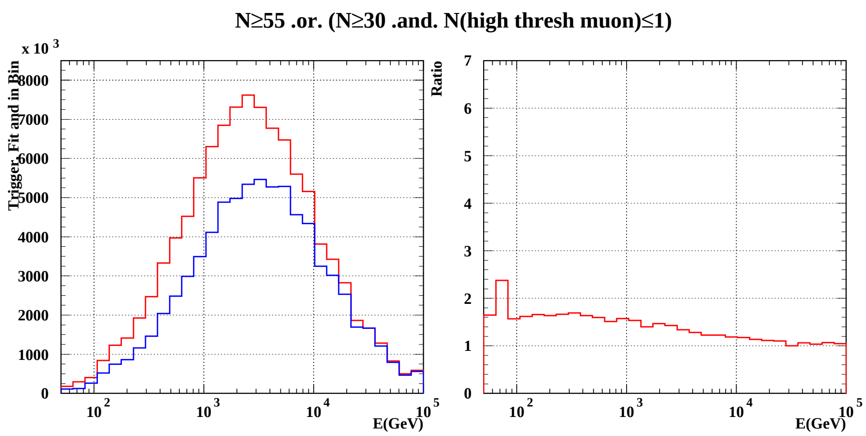

Figure 7: Analysis of Figure 6 repeated for the current trigger settings, including the muon layer veto.

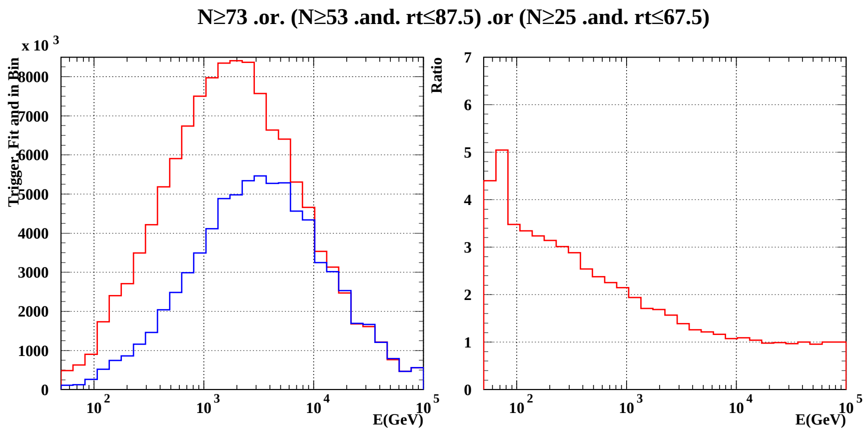

Figure 8: Analysis of Figure 6 repeated for an alternative trigger 3, with NPMT> 25 pmts and risetime ≤62.5 ns. The increase in effective area below 300 GeV is about 3 times the standard effective area.

3, and allow longer risetime values. An alternative trigger setting was also considered, with Trigger 3 set to (Trigger 1 and 2 were unchanged):

- Trigger 3: NPMT>25 (125mV), risetime ≤62.5 ns, no prescale.

This trigger setting and the proposed trigger setting listed above yield about the same trigger rate in the detector. The effective area increase relative to the 55 tube trigger is shown in Figure 8. The increase in the effective area for this case is not as high in the lower gamma ray energy range (<300 GeV) as the proposed trigger, even though the increase in gamma MC efficiency is higher (83% versus 65%). The gain in the number of low energy gamma rays by reducing the trigger threshold to 20 pmts more than offsets the reduced efficiency.

4 Sensitivity to the Crab/MRK421

You might wonder if the proposed trigger, since it does use a risetime cut on events that previously had none applied (Trigger 2), would decrease our sensitivity for objects like the Crab. In fact, the opposite is true, the proposed

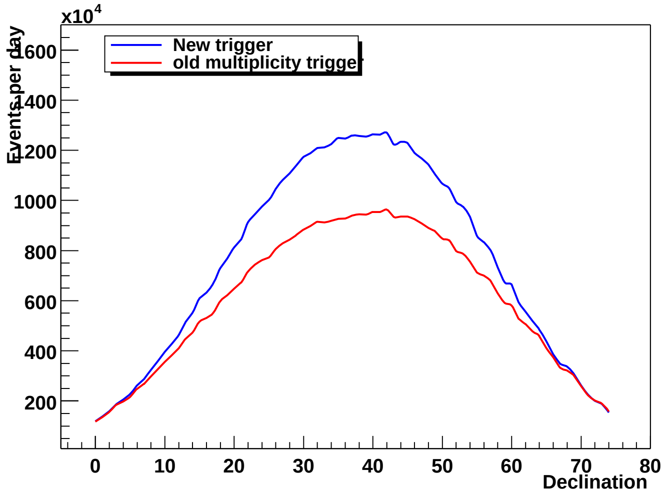

Figure 9: Number of events triggering Milagro for a source day as a function of declination. Blue curve is the new proposed trigger setting and red curve is the 55 tube standard trigger.

trigger actually increases the sensitivity to these objects. Figure 9 shows the number of triggered events for the new proposed trigger settings and the standard 55 tube trigger for a source day as a function of declination, assuming a Crab-like spectrum and an arbitrary normalization. Figure 10 is the same figure with an X2 cut of 2.5 and an Nfit cut of 20 applied (standard crab cuts). In both cases, a clear increase in the number of triggers is seen, especially for source that transit near zenith. It would probably be good to readdress the set of cuts used in the Crab analysis after the new trigger is implemented.

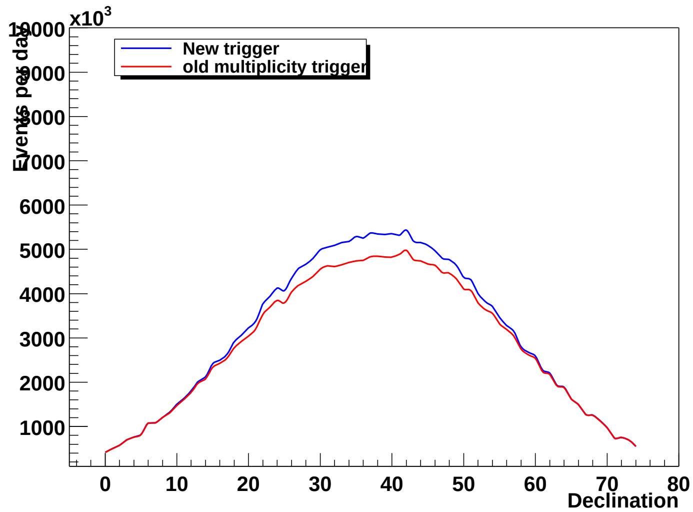

Figure 10: Number of events triggering Milagro for a source day as a function of declination. Additionally an X2 cut of 2.5 and a nfit cut of 20 have been applied here. Blue curve is the new proposed trigger setting and red curve is the 55 tube standard trigger.

5 Conclusion

A set of proposed trigger setting has been presented which increases our sensitivities to GRBs below 300 GeV by a factor of 4. These trigger settings would reduce the trigger rate variations seen in the winter due to ice formation. These trigger setting would increase our sensitivity to objects like the Crab and MRK421. The hardware to implement this trigger has been running successfully at the site for a couple of months now, and works well. It would be silly not to implement this trigger setup immediately.