LAT Onboard Science: Gamma-Ray Bursts Identification

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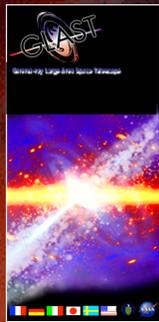
Abstract

The main goal of the Large Area Telescope (LAT) onboard science program is to provide quick identification and localization of Gamma Ray Bursts (GRB) onboard the LAT for follow-up observations by other observatories. The GRB identification and localization algorithm will provide celestial coordinates with an error region that will be distributed via the Gamma ray burst Coordinate Network (GCN).

We present results that show our sensitivity to bursts as characterized using Monte Carlo simulations of the GLAST observatory. We describe and characterize the method of onboard track determination and the GRB identification and localization algorithm. Onboard track determination is considerably different than in the on-ground case, resulting in a substantially altered point spread function. The algorithm contains tunable parameters which may be adjusted after launch when real bursts characteristics at very high energies have been identified.

Algorithm Overview

The current onboard GRB detection algorithm capitalizes on both temporal and spatial characteristics of GRBs. It works by associating a probability for a cluster of events/tracks to be located in a small part of the sky during a short interval of time.

A list of the most recent 40 events (a free parameter) that have 3D onboard tracks is maintained. The algorithm searches this list for the cluster of events that has the smallest probability of occurring in time and space. When the associated spatial and temporal probabilities pass a threshold we have a trigger (see Figure 1). Events from this cluster and all clusters within the next 10 seconds that pass our cut get added to a list used to obtain a localization. For our parameter choices clusters typically have more than 10 photons

Figure 1
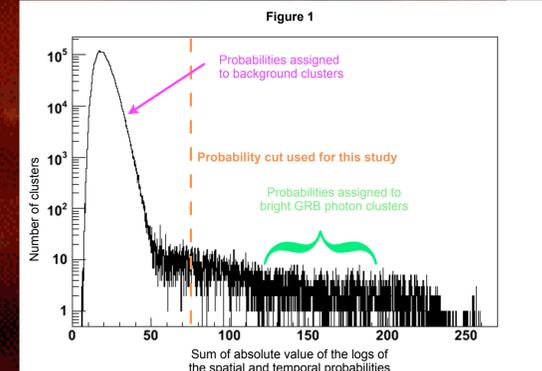
Onboard Quantities

The quantities available to the onboard algorithm differ substantially from the on-ground information. While there are 3D tracks onboard, the true gamma direction is currently measured much better by the ground reconstructed variables. Figure 3 shows the 68% containment PSF for the onboard and on-ground cases. Black points represent the current onboard filter 3D tracks, in red the on-axis best ground reconstruction, in blue the best ground track (no multiple track combining/vertexing) and in green a proposed improvement to the onboard 3D tracks.

The distribution of angles between the track direction and the incoming photon true direction is highly non-Gaussian. This poses a challenge to our localization scheme where we need to consider how we can eliminate these tracks from our list of candidate tracks. Another enhancement that we are investigating may alleviate this issue by having the algorithm focus on a region of the sky, rather than its entirety (see the section "Future Improvements").

Efficiencies and False Trigger Rates

We measure the trigger efficiency using GRB photons interleaved with background events (see section "Implementation and Validation"). Figure 4 shows the efficiency for triggering on a GRB given a probability cut (represented by a value on the x-axis). To study the localization we set the estimated false trigger rate at once every 35 days which corresponds to a cut of 75. Our trigger efficiency is ~6% of all our bursts, ~16% of the subset in our field of view, or 18 GRBs. It is ~34% of the burst with at least than 10 photons.

Implementation and Validation

GRBs and background are generated separately using the Monte Carlo LAT simulator GLEAM[1]. For this study we focused on 70 out of 290 bursts with 5 or more photons with onboard 3D tracks placed from 0° - 70° relative to the LAT z-axis. The brightest burst has ~1000 photons with onboard 3D tracks (see Figure 2). The bursts were generated with a high energy spectral index (β) distribution derived from BATSE bursts.

The algorithm was originally written in IDL. It has been translated from IDL into C, the language used by the LAT. A large fraction of the code has already been implemented into the onboard environment.

Limited onboard computational resources limit the complexity of the algorithm. The current algorithm appears implementable without overtaxing the system. Nevertheless, we are investigating options for speed enhancements (see the section "Future Improvements") .

Figure 2

Figure 3

Figure 4
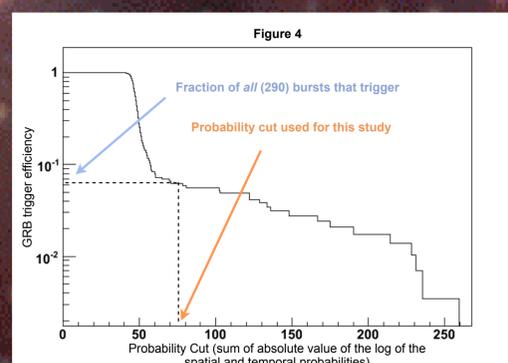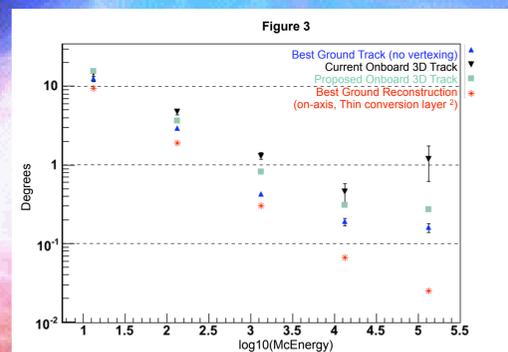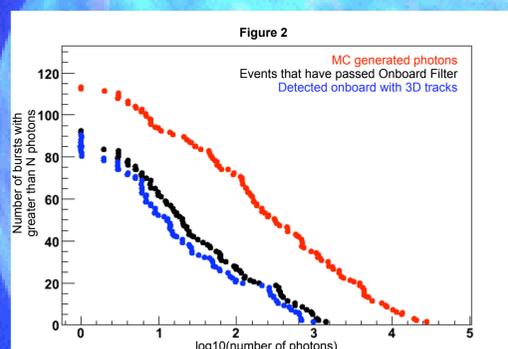
Localizations, Estimated Errors and Purity

Once a burst has triggered we maintain a list of all photons passing our cuts during the next 10 seconds and localize on this list. As a result, some long bursts have multiple triggers and localizations. We plan on reporting one localization per burst to the community, however.

Figure 5 shows the resolution obtained for our localizations and when we choose the best localization for each burst. It also shows the corresponding estimated error. We aim to identify bursts to better than 1 degree of accuracy onboard.

With the cuts used in this analysis the list of photons that we use for localizations is, on average, 97% GRB photons.
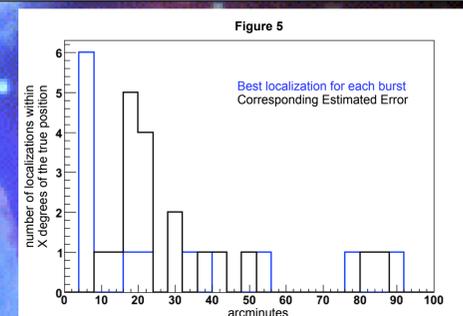
Figure 5

Future Improvements

We are currently investigating multiple avenues for improvement. Implementing a histogramming front-end for the trigger gives similar localization results (Figure 6) while significantly reducing computational overhead. It allows the extension of the localization time window to more than 10 seconds without an impact on performance.

We are improving the quality of the 3D onboard tracks to obtain results as close to the ground tracks as possible (see Figure 3).

We are studying the effect of onboard filter veto bits on background and signal events so as to help reduce the background rate we have to contend with.

In the long term we will explore how to communicate with the GBM so that we can narrow our field of view when they trigger and help us reduce the background in our search window. We aim to maintain a separate trigger and localization in the case that there are new types of high energy bursts that will only trigger the LAT.

Figure 6
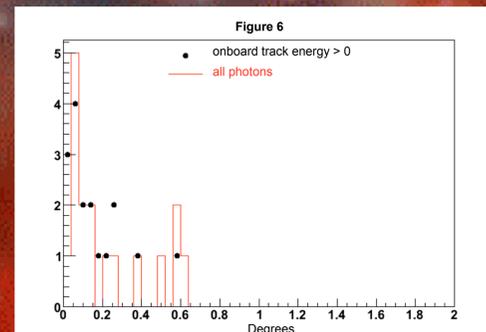
References

1. astro-ph/0308120

2. http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance-2007jan.htm

3 Credit for background: Dana Berry SkyWorks Digital