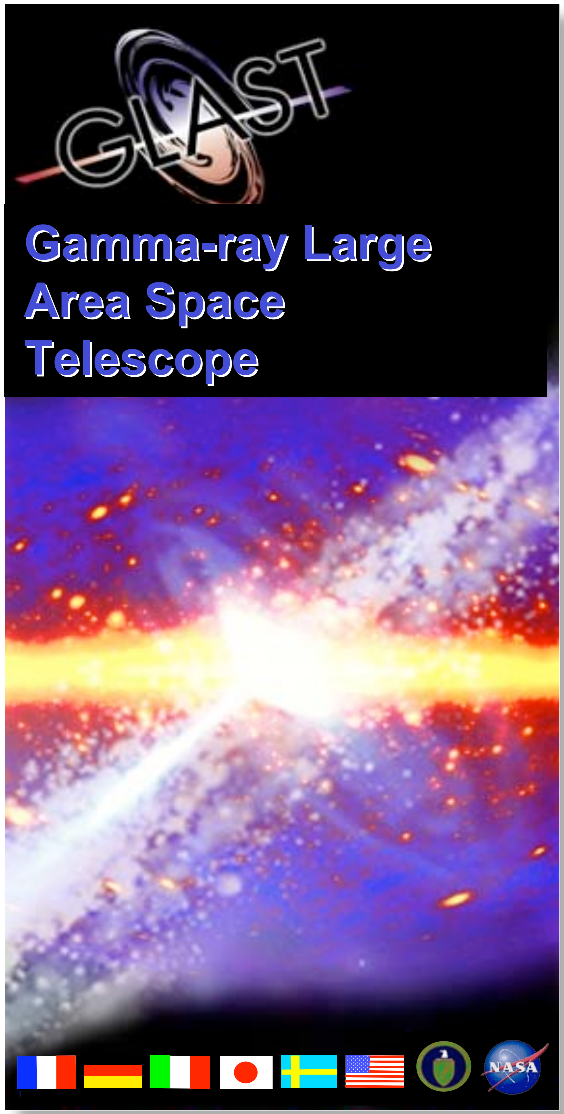


GLAST Large Area Telescope

LAT Science Working Group Review

GRB Onboard Analysis

Jay Norris

GRB Onboard Analysis: Outline

- Implementation Status — Progress on implementation of FSW algorithm for GRB trigger / localization
- Onboard performance
- Summary

Implementation Status 1

- Background
  - ✓ Original IDL trigger algorithm — tested/refined over ~ 7 years: Utilizes the unbinned 2D spatial & 1D temporal coordinates and energy of detected event to generate probabilities for 2D+1D clusters of events, as function of time.

    An N-event "sliding window in time" is searched for significant 2D+1D event clusters.
  - ✓ Upon significant trigger, IDL localization algorithm assembles all events between first & last significant cluster — that are mutually consistent with one position — in a T_{max} window of ~ 150 s.

    << Weight these photons by PSF(E) → Localization & Error >>
  - ✓ Notably, the mechanics of Onboard filters and knowledge of Onboard PSF(E) were not included.

Implementation Status 2

- Onboard Simulations in C++

  ✓ IDL trigger & localization algorithms implemented into C++ code, with extensive verification of C++ code in Gleam environment.

  Flavor of studies described here: Onboard filters, Onboard PSF(E)

  ✓ Specifically, the Onboard PSF(E) results from combining 2D track information to make 3D tracks. This additional "filter" reduces background rate ~ factor of 2 (375 Hz → 210 Hz).

  ✓ Refinement: In selection of best spatial cluster in a given "N-event sliding window ", highest spatial probability cluster rather than tightest cluster is chosen — increases cluster size.

  ✓ For ease of storage / retrieval: events in a histogrammed map of the sky is maintained over a relatively long window in time —

  Allows possibility of accumulating GRB photons over longer than fixed ~ 10-s window, for localization algorithm.

Implementation Status 3

- Conversion to FSW "C"
  - ✓ Anticipated "C" code necessary to realize original algorithms into FSW is 80-90% implemented.

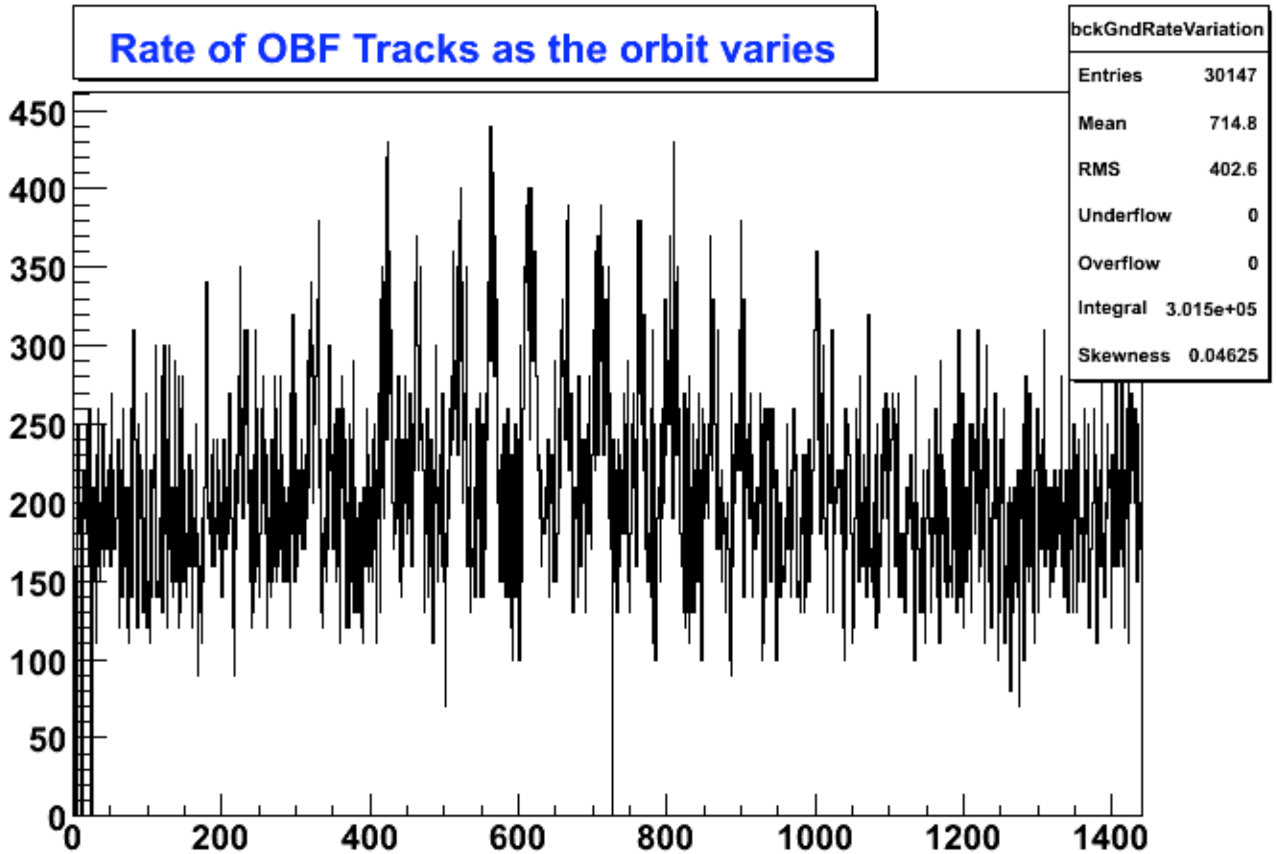
    No problem forseen in completing implementation.

    No "performance wall" for reasonable parameter choices.
  - ✓ Computational intelligence:
    - Number of loops reduced — maintenance of prior computations: by adding effect of newest event, dropping oldest event.

      Trig formulae allowed separation of Event{i} from Event{i+k}

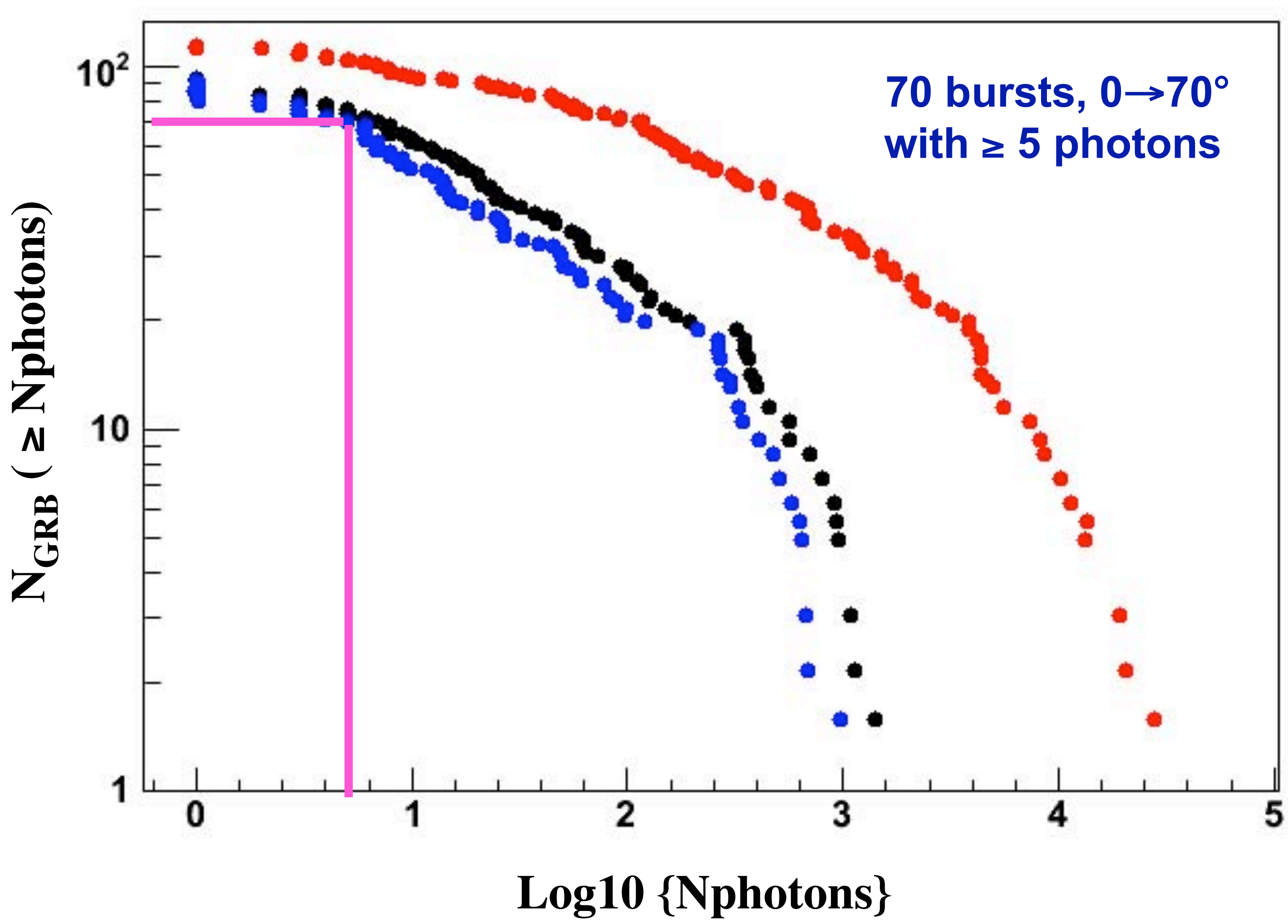
      << Renders probability computation order N instead of N^2 >>
    - "Modularized" temporal structures, reducing number of transcendental computations from 3 to 2 per event.
    - Lists kept, storing transcendental computations that would have been done more than once.

Background Rate for 3D Tracks



Average upon requiring 3-D track ~ 210 Hz, down from average "input" rate of ~ 375 Hz.

Sample with 3D tracks in LAT FOV



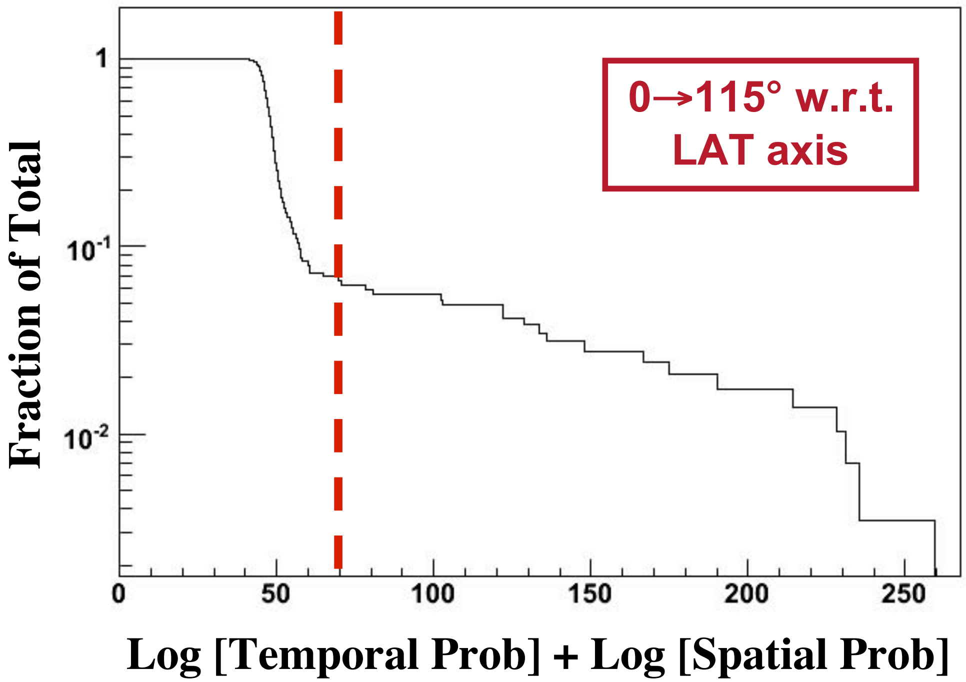
MC photons
pass OBF
have 3D track

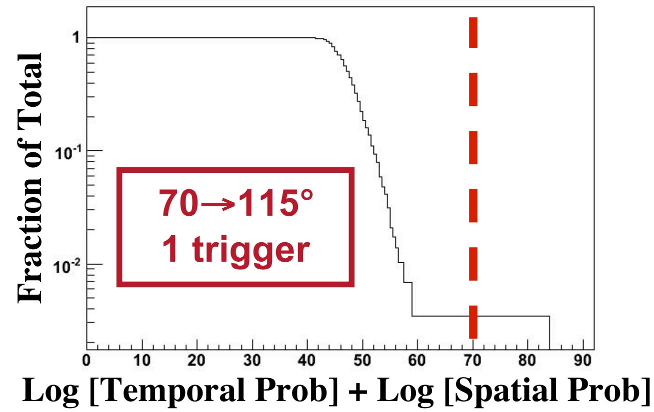
Input: 290 bursts, isotropic
0→115° w.r.t. LAT axis

Measure trigger efficiency with:

Fixed background rate = 210 Hz,
Threshold ~ 1 false trigger/week
…

GRB Trigger Efficiency

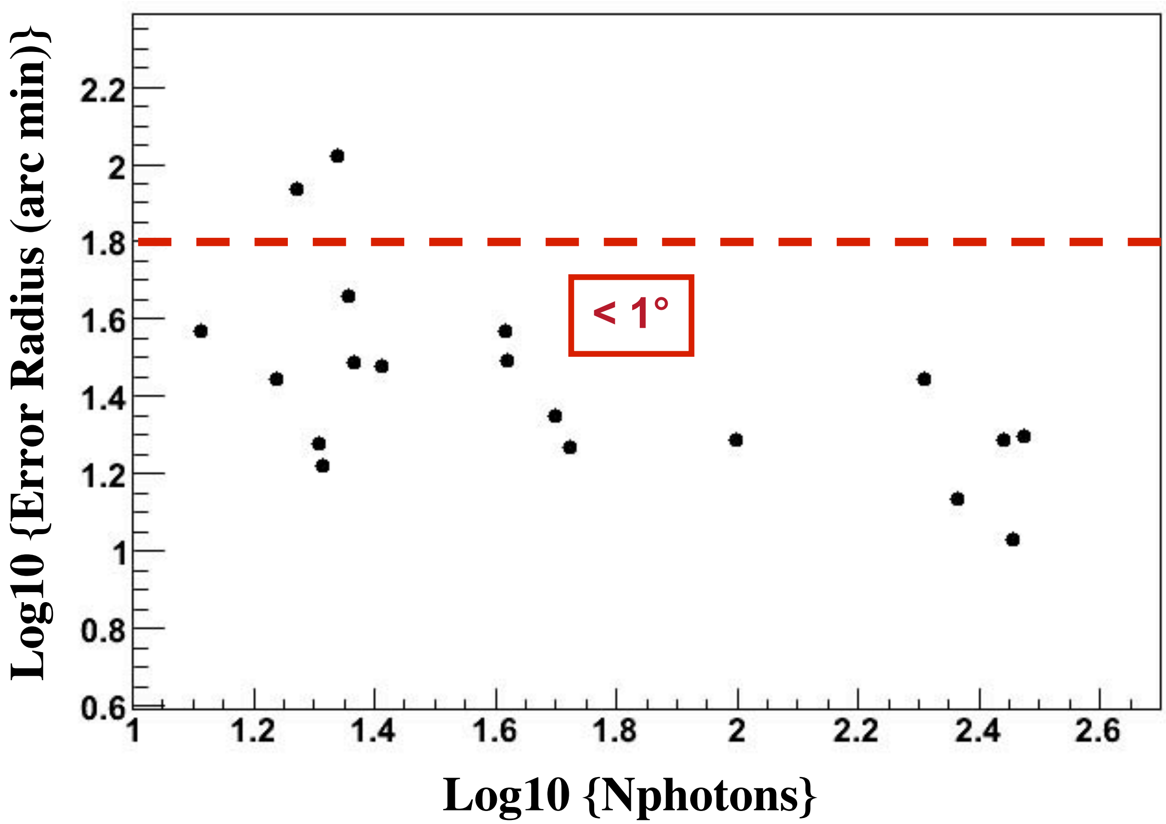




Roughly, Current Threshold:
LAT: 0.025 phot cm^{-2} (> 30 MeV)
(for 10-s localization list, E^{-2})
Corresponding BATSE threshold
F_p ~ 5 phot cm^{-2} s^{-1}

- **With Log{Prob} Threshold = 70, efficiency (0→70°) is ~ 16% — 19 bursts trigger.**
- **Plateau on left hand side is due to background clusters.**
- **Fraction of GRBs with ≥ 5 detected photons in this sample is ~ 25% (~ 70 bursts).**

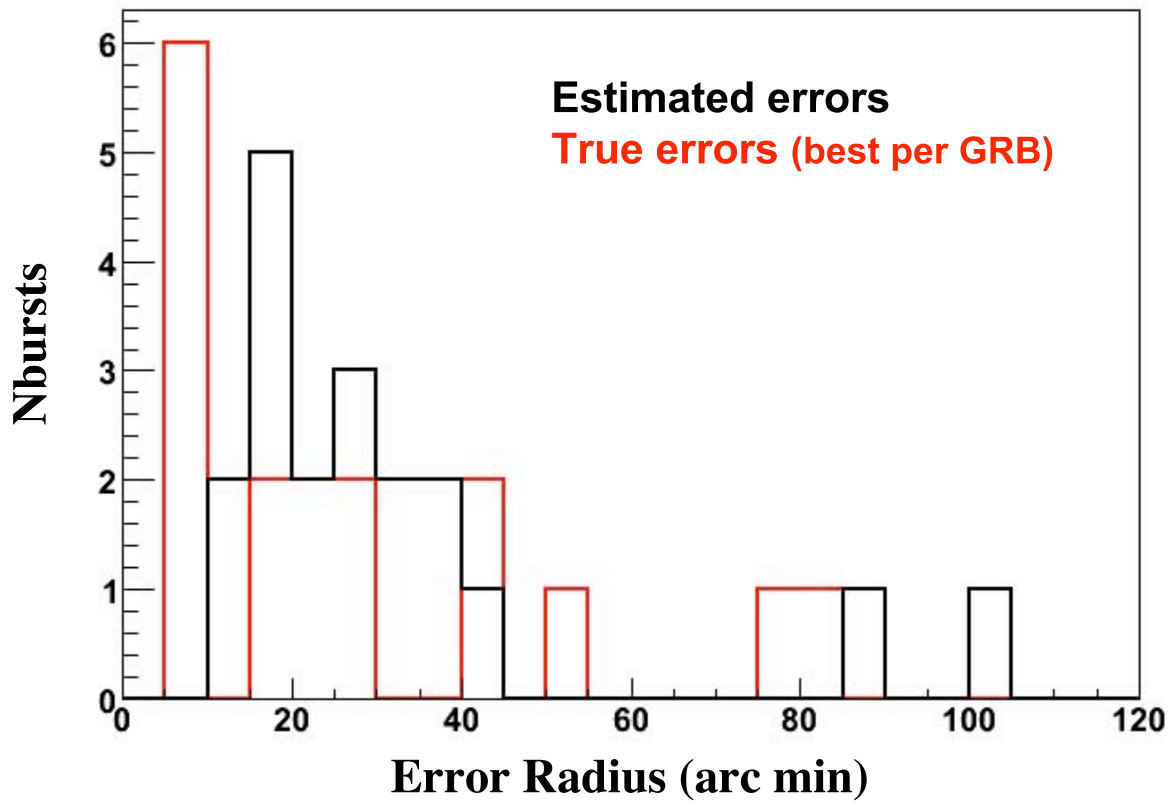
OnBoard Estimated Errors, Triggered Bursts



- Clusters formed from 40 most-recent events with 3D tracks
- Localization list < 10 s (but often, more photons available per burst)

From 116-burst sample in 0→70° FOV:
~ 19 trigger, ~ 17 with Errors < 1°

Estimated vs. True Error, Triggered Bursts



[True errors are often smaller than estimated, due to: non-Gaussian statistics of steep number spectra, and PSF(E)]

Summary: GRB Onboard Analysis

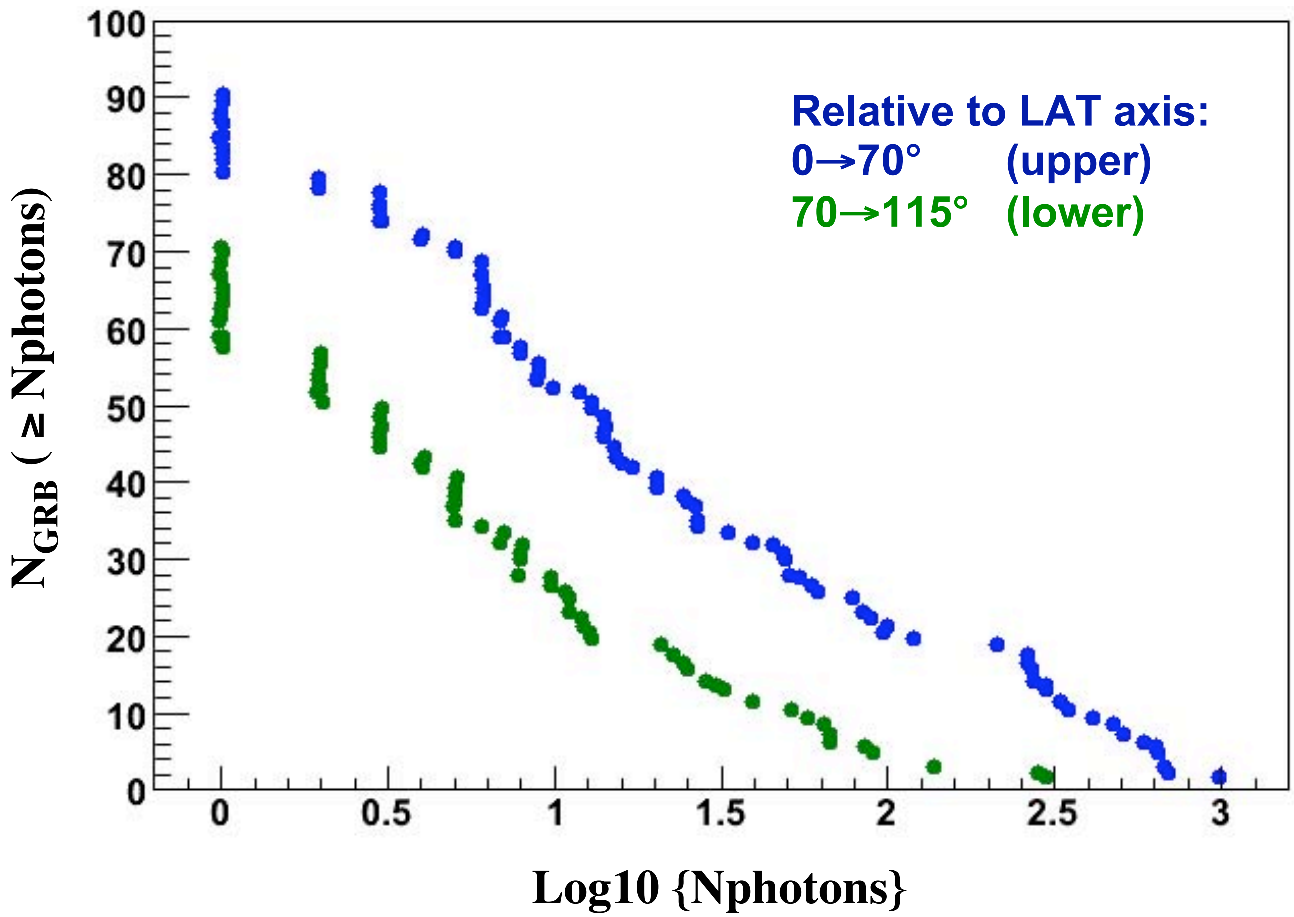
- Implementation has been rigorous reproduction of original algorithm over 9 months (IDL → C++ → "C"), with fixes and well-considered improvements.
- FSW implementation is ~ 80-90% done. Several optimizations. Remainder is simple: We see no problem expediently completing algorithm.*
- Currently demonstrated $PSF_{OnBoard} \sim 2\times PSF_{OnGround}$, ~ independent of energy.
- GRB yield ~ 16%, with threshold set for ~ 1 false trigger / week.
- Current Onboard localizations: ~ 17 (per half year) with error radii < 1°.
- If there were a burst with 100 γ's with E's > 1 GeV, Onboard error radius would be < 5 arc minutes — that meets the SRD. This is modern estimate, in line with current LAT performance characterization, and modified for Onboard PSF.
- <u>Expected Improvements</u>. PSF: by improving quality of Onboard 3D tracks. Background Rate: Further study of filter veto bits (only to reduce background entertained by GRB algorithm).

* Testing is acknowledged to be far and away the larger effort. Note: Testing in a hardware mockup is virtually independent of specific trigger and localization algorithm —which again, is nearly in place.

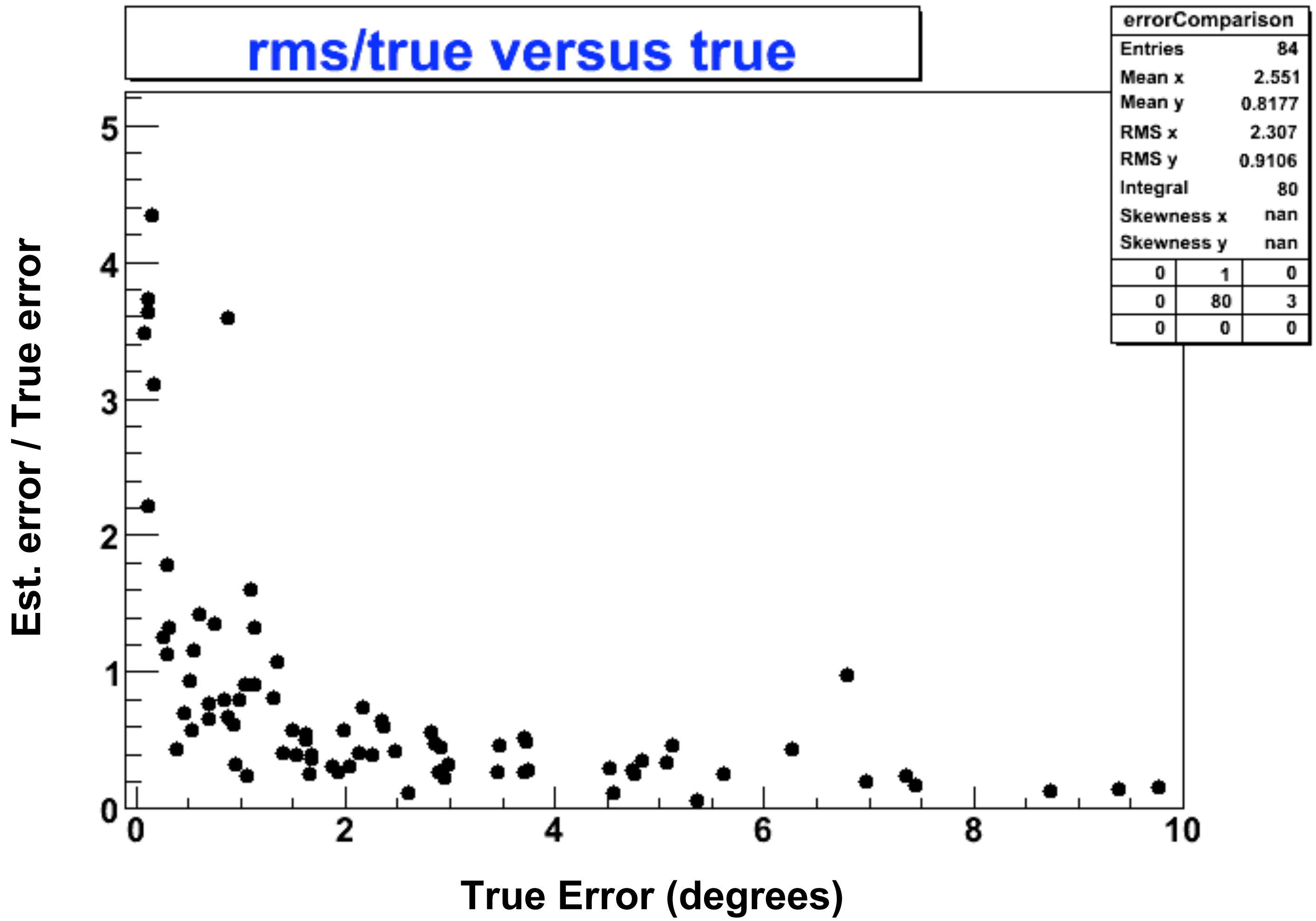
GRB Onboard Analysis

Backups

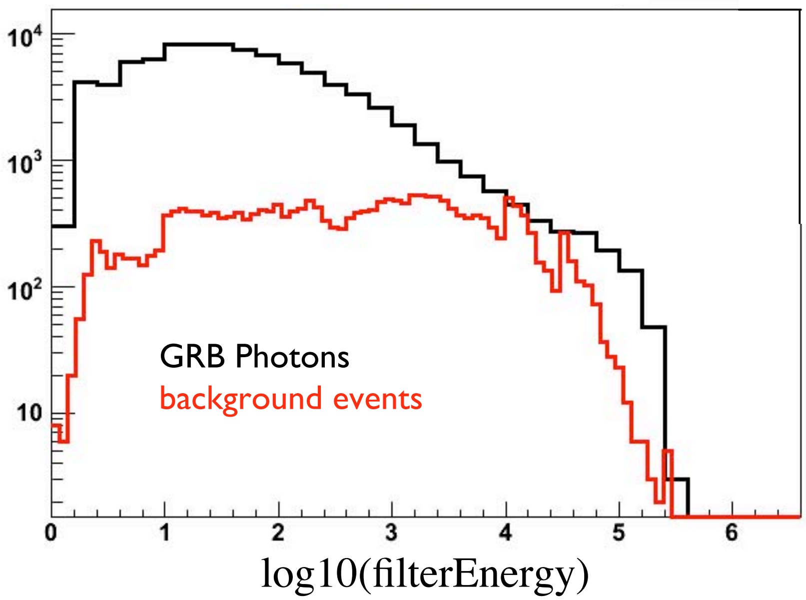
Sample with 3D tracks, 0→115°

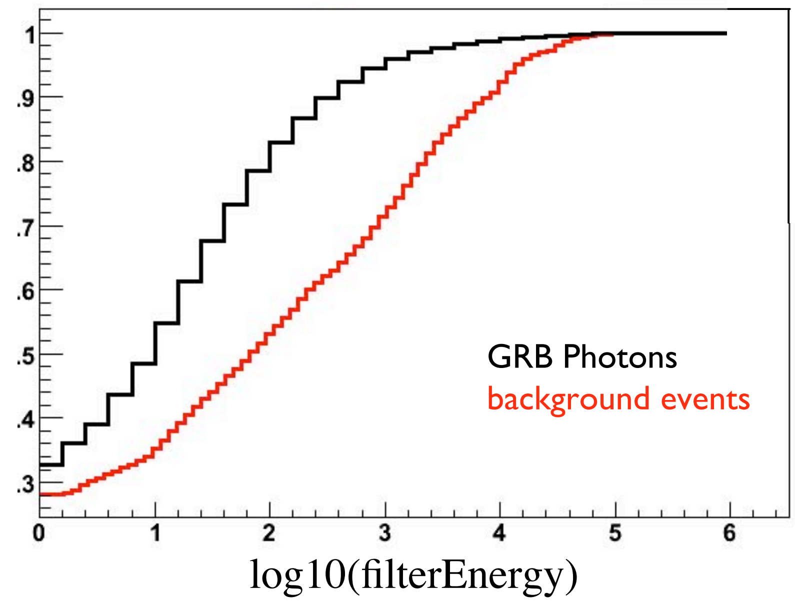


Estimated vs. True Errors



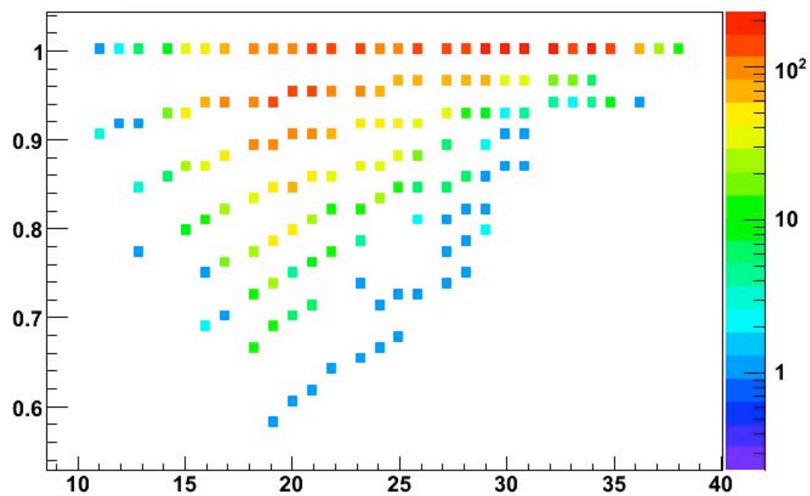
Filter Energy: Signal vs. Background

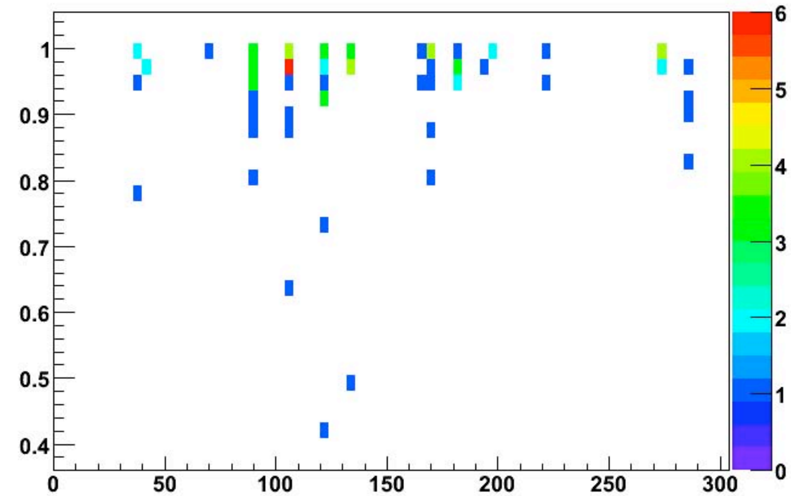




- **Left (right) plot: differential (integral) E distributions of GRB γ's and background.**
- **~33% of GRB γ's have zero filter energy (~28% of the background events).**
- ***If the PSF were energy-independent*, then with an energy cut we would always lose a larger fraction of GRB photons than background events.**

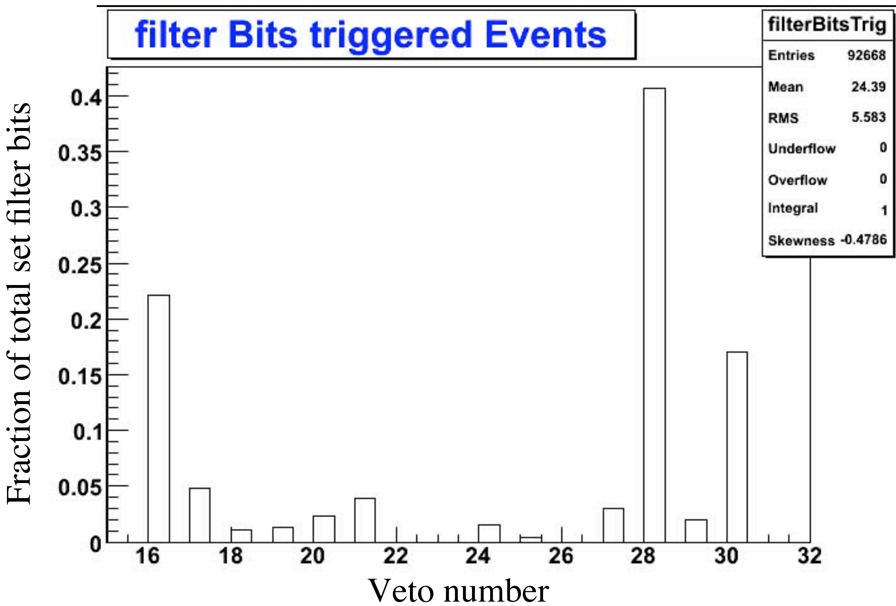
Purity of Clusters and Localization List

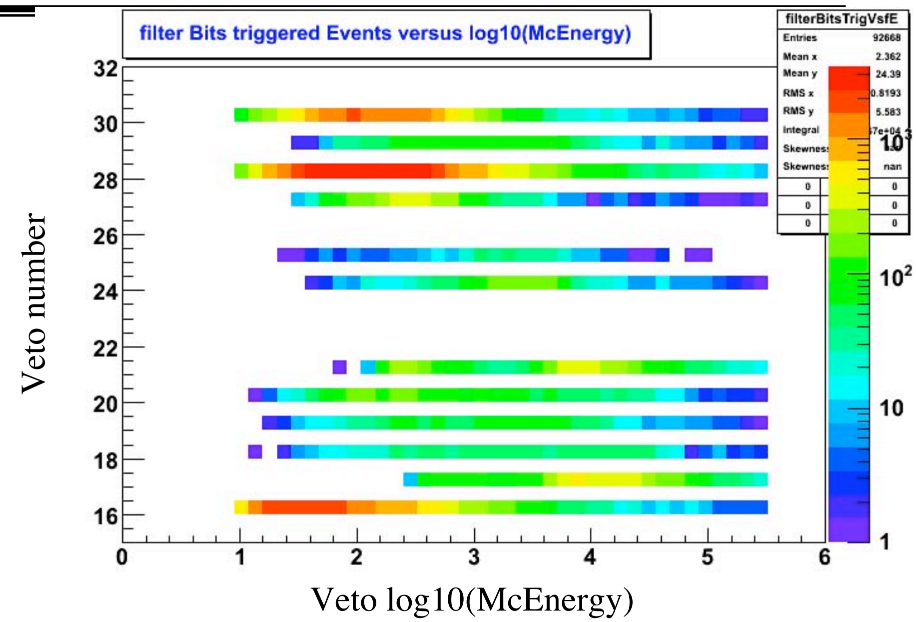


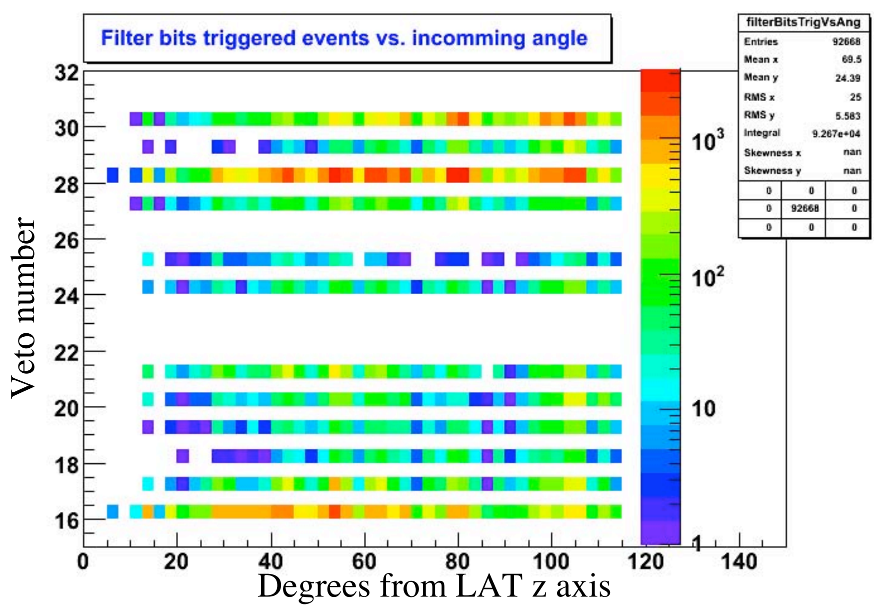


- All clusters have ≥ 10 events — no GRB trigger occurs with < 10 photons.
- Clusters are created from most-recent 40 events with OBF 3D tracks.
- Median purity of Clusters (localization photon list) is ~ 95% (96%) GRB photons.
- Threshold: 1 false trigger/week. Increasing threshold to one/35 days does not significantly change trigger efficiency (Log{Prob}: 70 → 75).
- **Bottom Line: We have a relatively clean sample with the probability cut used.**

OnBoard Filter: Effects on GRB gammas







- Vetoes 28 and 30 are set (roughly) when the ACD is over threshold and there is no energy in the CAL
- Veto 16 is set when a projection passes through the space between the CAL and the ACD (the "skirt")
- We are loosing gammas that come from the side or below the LAT or are at low energies
- The 3D track filter is 77% efficient at retaining GRB gammas that trigger
- Vetos with no entries are currently turned off