



Fermi

Gamma-ray Space Telescope



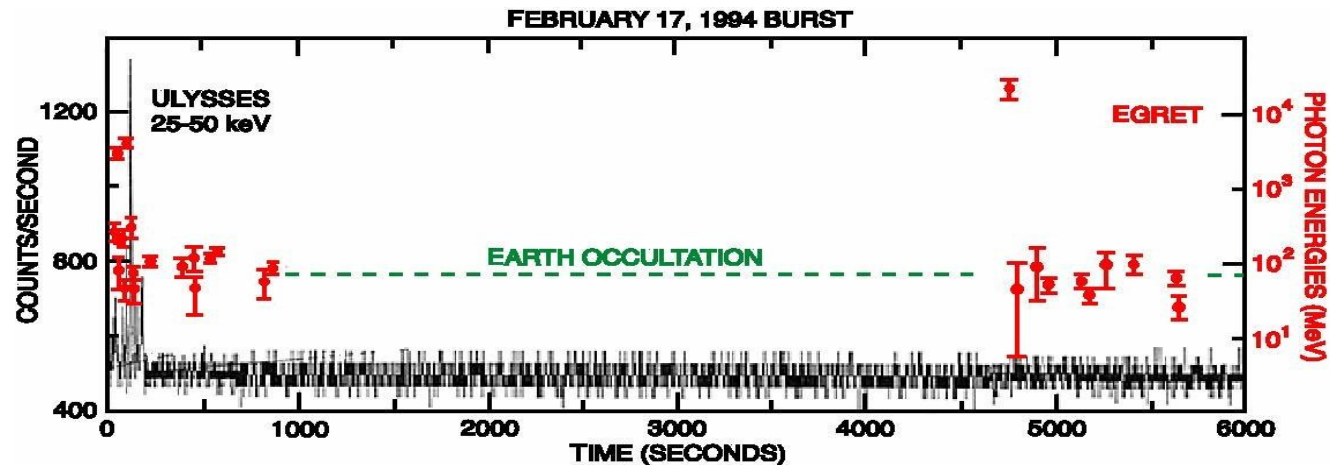
GRB observations with Fermi

Luca Baldini (INFN-Pisa)
luca.baldini@pi.infn.it

On behalf of the Fermi LAT and GBM
collaborations

Rencontres de Moriond
La Thuile, February 02, 2009

GRBs at high energy before Fermi

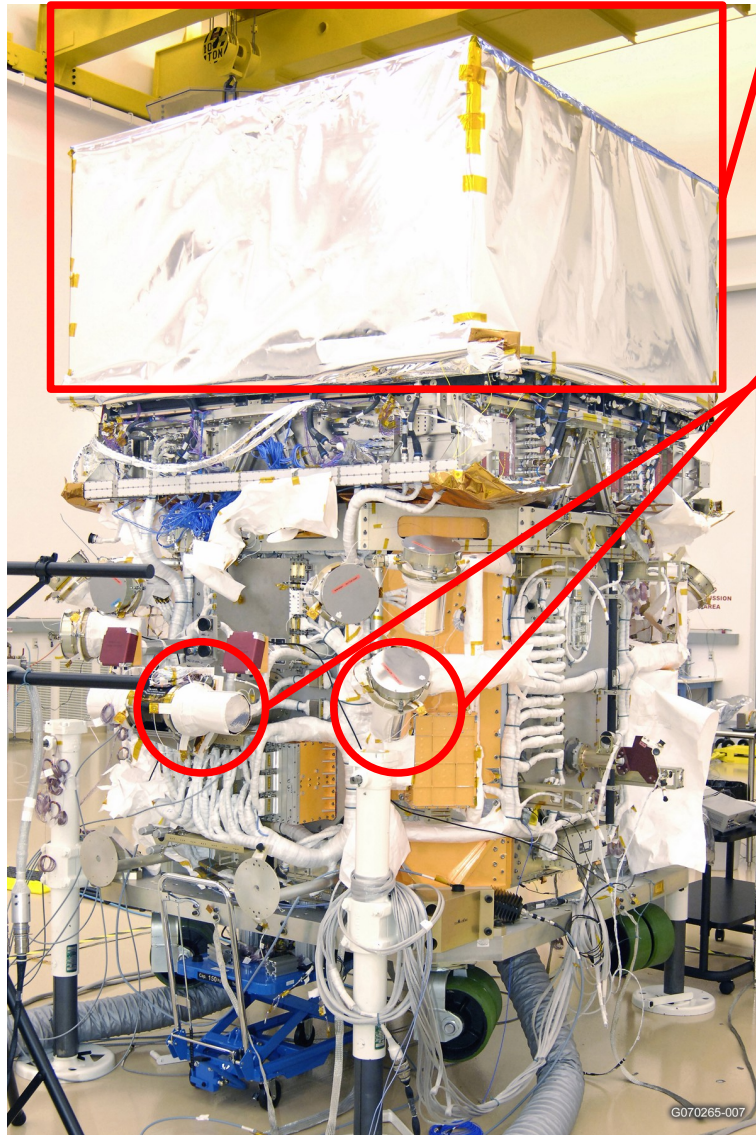


- ▶ A few GRB detected by EGRET
 - ▶ GRB940217 (Hurley et al. 1994): 18 GeV photon 90 minutes after the trigger.
 - ▶ GRB941017 (Gonzalez et al. 2003): HE extra component with different time evolution.
- ▶ Recent AGILE observation
 - ▶ GRB080514B (Giuliani et al. 2008).
- ▶ Limited knowledge of emission processes above 100 MeV.

Outline

- ▶ The Fermi Observatory
 - ▶ GRB observation capabilities.
 - ▶ Sensitivity
 - ▶ Localization performance
 - ▶ Reaction to alerts
- ▶ Fermi GRB observations (mostly LAT)
 - ▶ Establish the context for the illustration of the actual results (introduced in the following talks).
- ▶ Stay tuned for:
 - ▶ R. Preece, *The Gamma-Ray Burst Monitor on Fermi*
 - ▶ V. Pelassa, *Observation of GRB high-energy properties with Fermi*
 - ▶ J. Granot, *GRB Theory in the Fermi era*

The Fermi Observatory

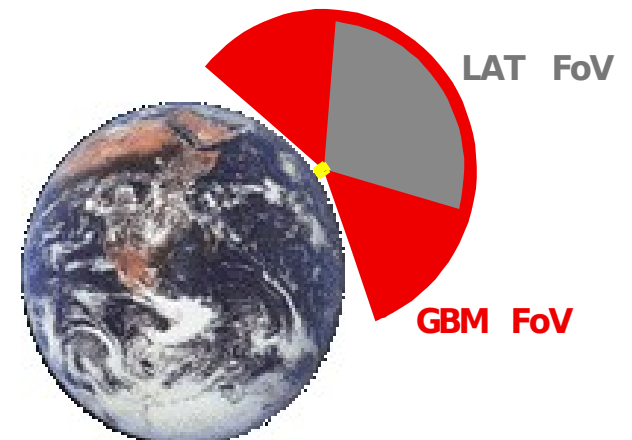


▶ Large Area Telescope (LAT)

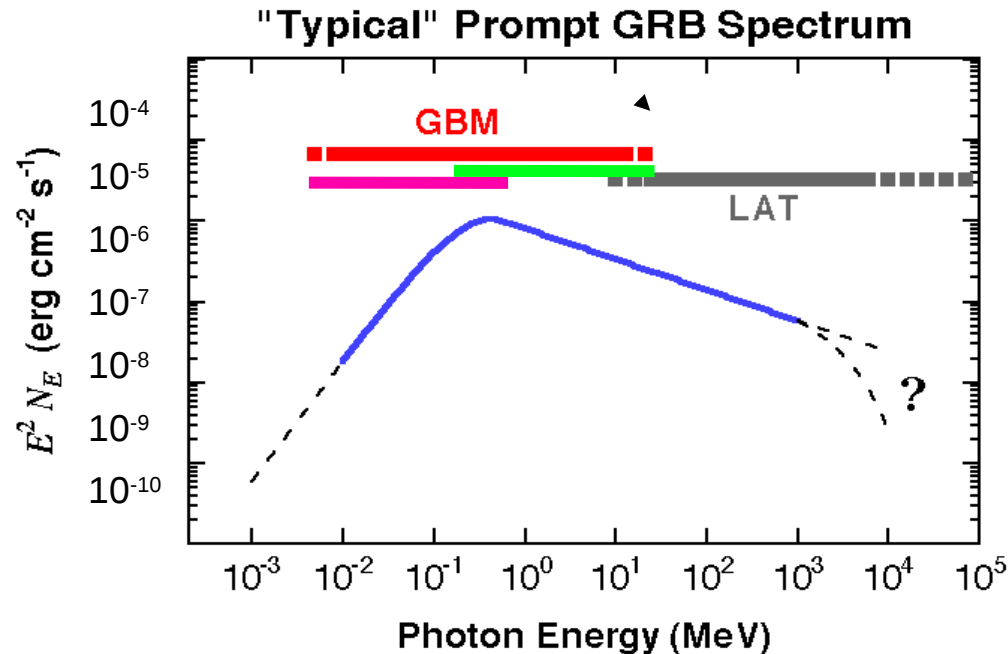
- ▶ Pair conversion telescope.
- ▶ Independent on-board and ground burst trigger, spectrum from 20 MeV to 300 GeV.

▶ Gamma-ray Burst Monitor (GBM)

- ▶ 12 NaI detectors, 2 BGO detectors.
- ▶ Onboard localization over the entire unocculted sky, spectrum from 8 keV to 40 MeV.



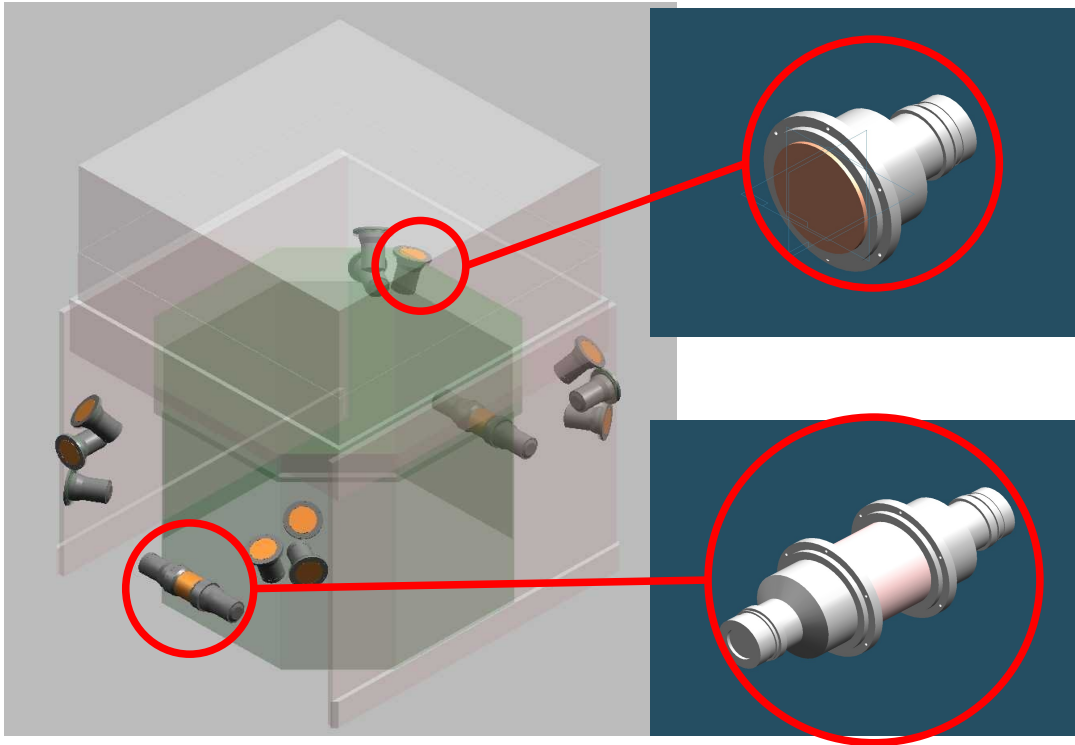
Fermi and GRBs



► GBM-LAT synergy for GRB studies

- Spectral coverage of more than 7 decades (8 keV--300GeV).
- Matching the typical energy spectrum of the GRB prompt emission.
- LAT observations would be difficult to interpret in the context of the current knowledge of GRBs without the GBM information (measure α and E_{peak} , correlate low-energy and high-energy time variability).

GBM performance



- ▶ 12 NaI detectors
- ▶ Onboard trigger, onboard and ground localization.
- ▶ Spectroscopy between 8 keV and 1 MeV (8% $\Delta E/E$ @ 100 keV)
- ▶ 2 BGO detectors
- ▶ Spectroscopy between 150 keV and 30 MeV (4.5% $\Delta E/E$ @ 1.0 MeV)

- ▶ Spectra from 8 keV to 40 MeV with high time resolution
 - ▶ 2 μs time resolution, 2 μs dead time.
 - ▶ Measures E_{peak} for most the burst detected.

GBM trigger and data flow

▶ Trigger

- ▶ Two or more NaI detector over threshold with respect to background rate.
- ▶ Flexible on-board trigger algorithm, enhanced sensitivity to very short GRBs and long, soft GRBs.
- ▶ On-board trigger classification, re-point recommendation to LAT (forwarded to the spacecraft), rapid alerts via GCN.

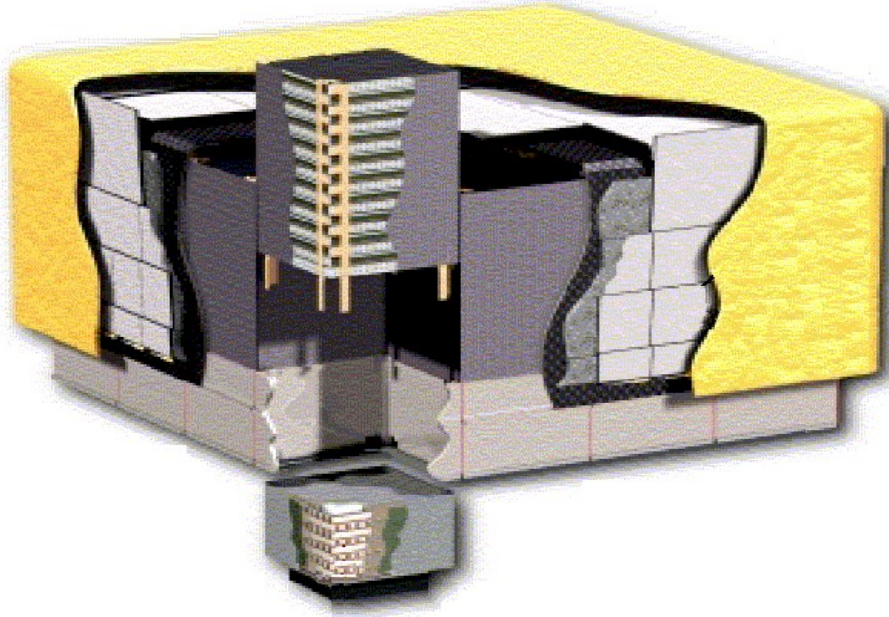
▶ Localization (see Rob's talk)

- ▶ Better than 15° (onboard within 2s) .
- ▶ Automatic refinement to better than 10° within few minutes on the ground.
- ▶ Final human-in-the-loop localization.

▶ Data products

- ▶ Two different types of histogram (optimized for timing and spectroscopy, respectively) acquired continuously
- ▶ Time tagged events during the bursts.

LAT performance



- ▶ Precision Si-strip Tracker/Converter
- ▶ Hodoscopic CsI Calorimeter.
- ▶ Segmented Anti-Coincidence Detector

	Field of view (sr)	Effective area (cm ²)	PSF @ 100 MeV (deg)	PSF @ 10 GeV (deg)	Dead time	Energy range
EGRET	0.4	1500	4.7	0.2	100 ms	30 MeV—10 GeV
Fermi LAT	2.5	9000	3.5	0.1	25.6 μ s	20 MeV--300 GeV

Many GRBs

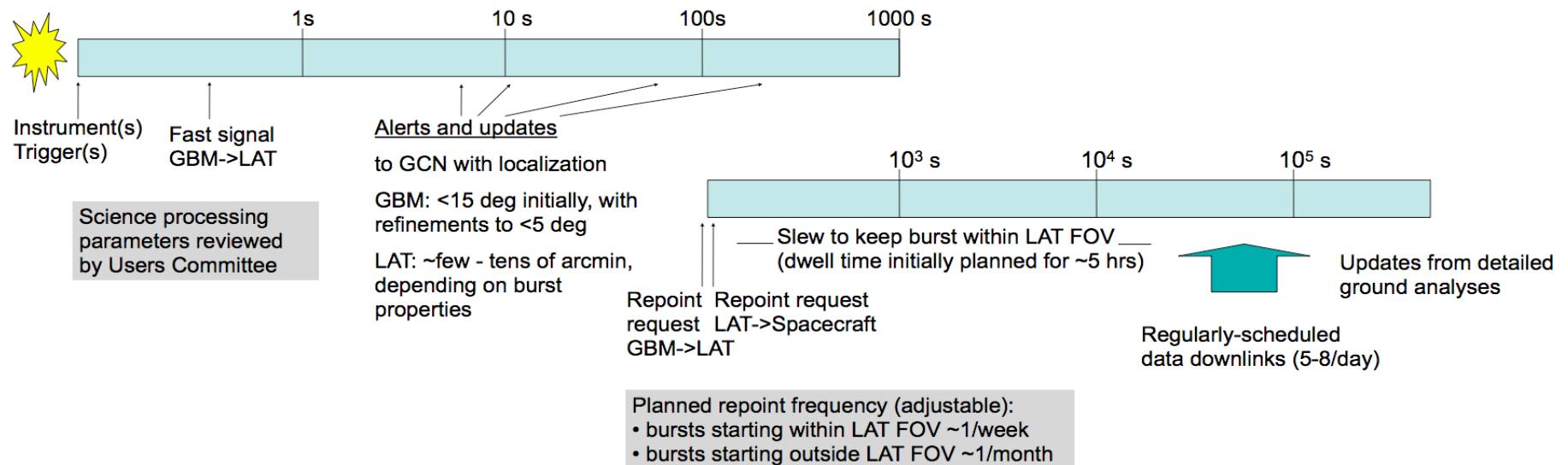
Localization

Unexplored time and energy scales

LAT trigger and data flow

- ▶ Background rejection on an event-by-event basis
 - ▶ Most of the events downlinked to ground are background (few hundreds:1)
 - ▶ Three “standard” event classes (transient, source, diffuse) with progressively less background contamination (event rate reduced from ~400 Hz to ~2 Hz or less).
 - ▶ Transient class appropriate for the study of the prompt emission (long lived emission and afterglow need diffuse class).
- ▶ On-board GRB search
 - ▶ 3D track reconstruction with raw TKR information, search for clustering in time and space.
 - ▶ On-board track efficiency and angular resolution slightly worse than ground counterparts.
 - ▶ On-board search intrinsically limited by the background (full background rejection machinery only available on the ground), see slide 16.
 - ▶ Right now in diagnostic mode.

Alerts and notices

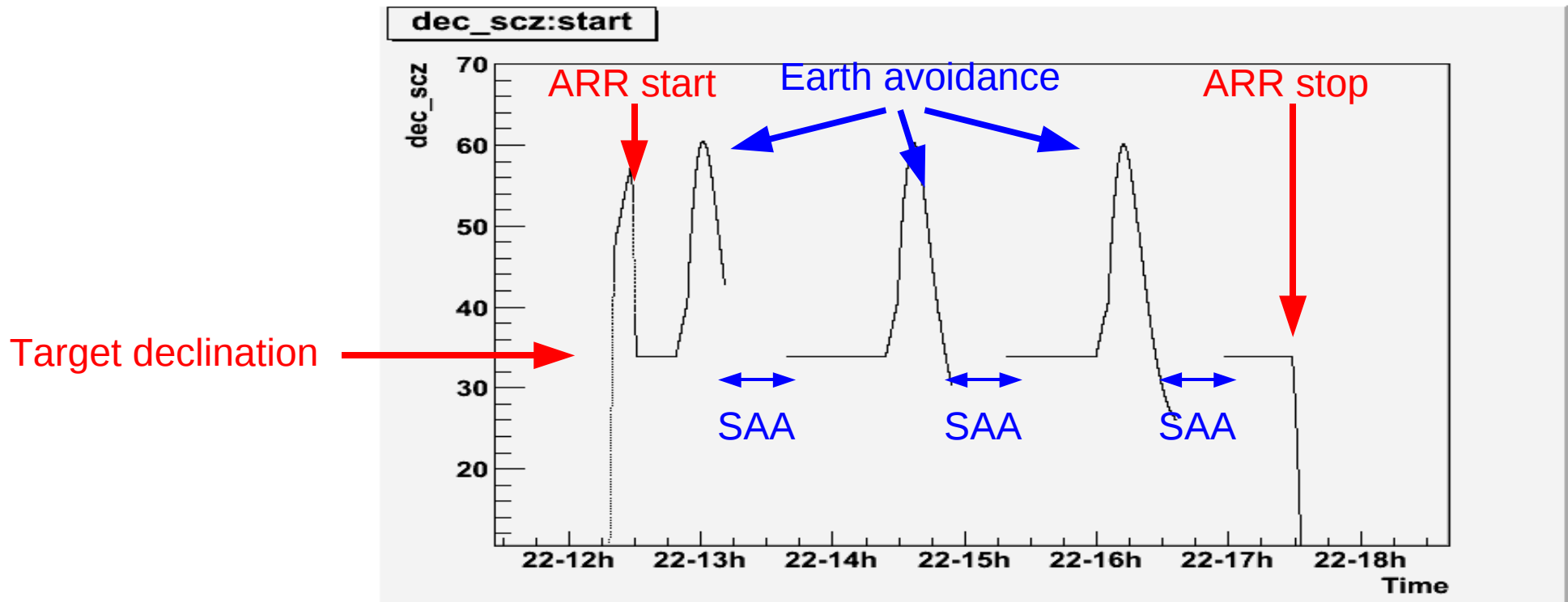


- ▶ GBM/LAT on-board processing (10—15 s):
 - ▶ GCN alert within 10—15 s from the trigger time through TDRSS (alert, location).
- ▶ GBM ground processing of prompt data (few minutes):
 - ▶ Updated GBM position, preliminary light curve.
- ▶ LAT GBM ground processing
 - ▶ Final location, spectrum (circular).
 - ▶ Final location, high-energy flux and spectrum, afterglow search results (circular).

ARR

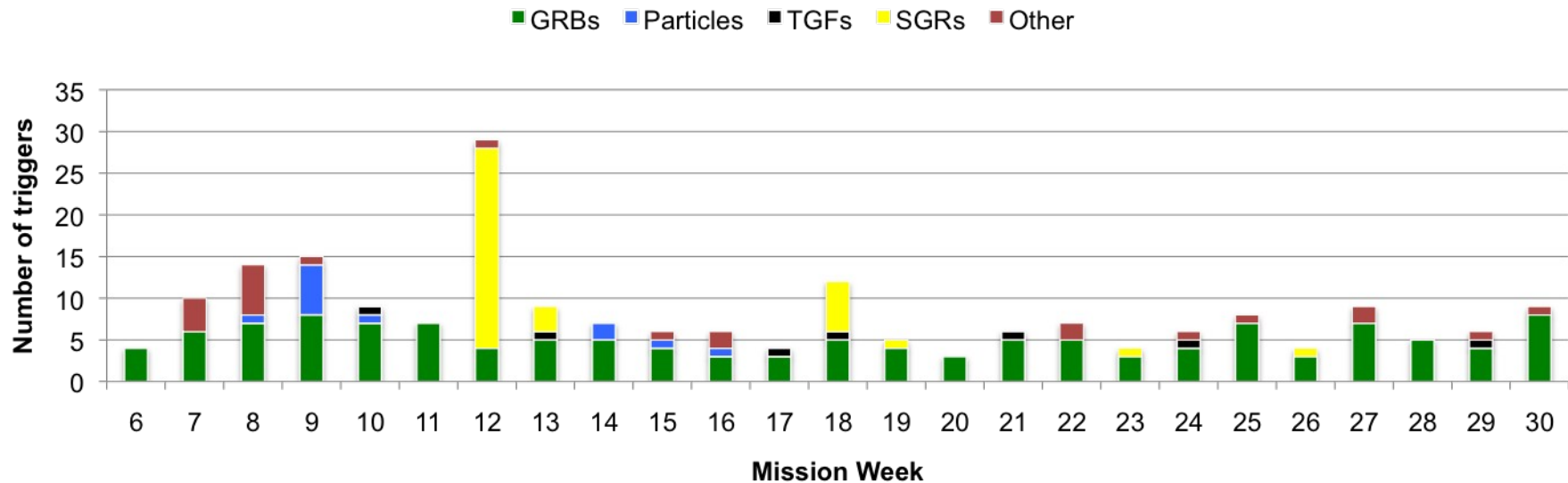
- ▶ Autonomous Repoint Recommendation
 - ▶ Initiated by either the LAT on-board trigger or by a bright GBM trigger (the GBM sends the ARR to the LAT, which in turn sends it to the spacecraft).
 - ▶ Can be either within or outside the LAT field of view (with different thresholds for the definition of “bright burst” in the GBM).
- ▶ Result of accepted ARR is 5 hours (nominal) of uninterrupted observation of the GRB location.
 - ▶ Track the target direction while above the horizon by at least the Earth Avoidance Angle (20° nominal), then slew at constant angle from the Earth limb until the the target rises on the other side.
 - ▶ Impacts the nominal science data taking in survey mode.
- ▶ Spacecraft response to ARRAs enabled on October 8, 2008 at 14:11:08
 - ▶ Three ARRAs accepted by the spacecraft, so far.
 - ▶ Not for the GRB detected by the LAT.

The first ARR (November 22, 2008)



- ▶ GBM triggered on a bright GRB.
 - ▶ This triggered an ARR at ra, dec = (339.150, 33.85)
 - ▶ Observation not very efficient (SAA passages while the target was not occulted by the Earth).
 - ▶ Earth limb within the LAT field of view for a considerable fraction of time.

Fermi GBM detections



▶ GBM is operating well

- ▶ Backgrounds and performance consistent with expectations.
- ▶ As of yesterday night 119 GRBs detected (200—250 per year).
- ▶ ...and two SGRs, two AXP, a few TGFs and a solar flare.

Fermi LAT detections

GRB080916C

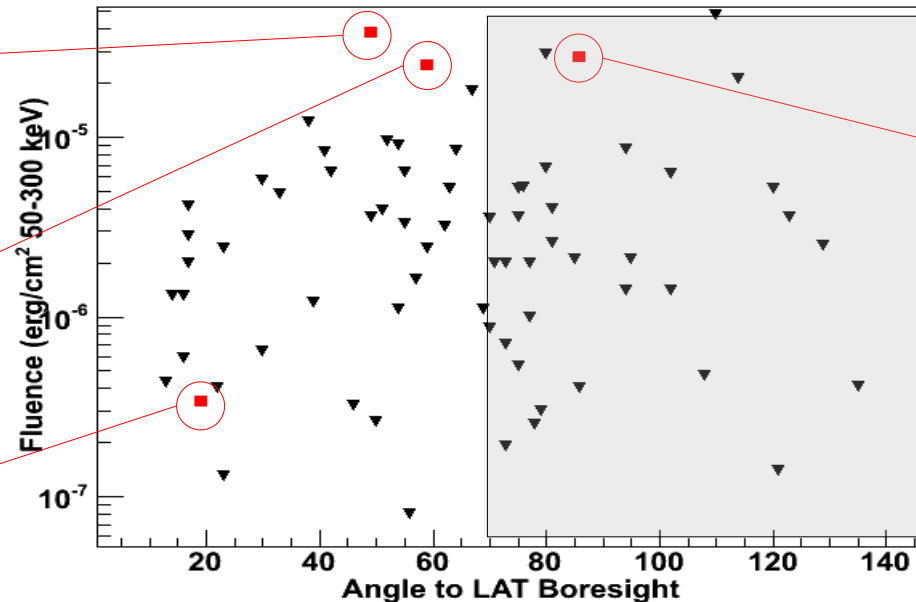
GCN 8246, Tajima, H. et al.; GCN 8245, 8278, Goldstein A. et al.

GRB080825C

GCN 8183, Bouvier, A. et al.; GCN 8141, 8184, van der Horst, A. et al.

GRB081024B

GCN 8407, Omodei N. et al.; GCN 8408, Connaughton, V. et al.



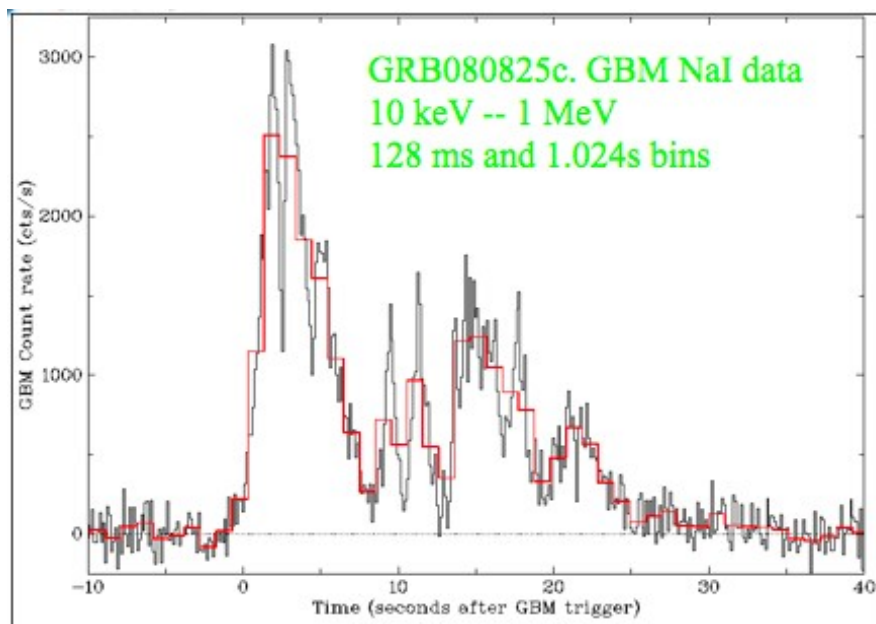
GRB081215A

GCN 8684, McEnery, J. et al.; GCN 8678, Preece, R. et al.

► Four LAT detections

- GRB080825C, more than 10 events above 100 MeV.
- GRB080916C, more than 145 (14) events above 100 MeV (1 GeV).
- GRB081024B, first short GRB detected above 1 GeV.
- GRB081215A, outside the LAT field of view, excess seen in the raw counts.

First LAT GCN: GRB080825C



TITLE: GCN CIRCULAR
NUMBER: 8183
SUBJECT: GRB080825C: Fermi-LAT observations
DATE: 08/09/05 17:45:46 GMT
FROM: Aurelien Bouvier at Stanford <bouvier@stanford.edu>

A. Bouvier (SLAC)... on behalf of the Fermi LAT team:

We report a detection by the Fermi Large Area Telescope (LAT) of emission from GRB080825C, which was triggered by the Fermi Gamma-ray Burst Monitor (GBM) at 14:13:48 UT on August 25th 2008 (GCN 8141 by Van der Horst et al.). The angle of the GBM best localization (ra, dec=232.2,-4.6) with the LAT boresight was 60 deg at the time of the trigger which is on the edge of our field of view.

The data from the Fermi LAT shows a significant increase in the event rate within 10 degree of the GBM localization and up to 35 seconds after the GBM trigger that is spatially and temporally correlated with the GBM emission with a significance of more than 5 sigma. All the LAT events detected during the GBM emission have energies below 1 GeV.

The best LAT on-ground localization is found to be RA,DEC=233.96,-4.72 deg with a 90% containment radius of 1.5 deg (statistical+systematics; 68% containment radius: 0.95 deg) which is consistent with the GBM localization...

TITLE: GCN CIRCULAR
NUMBER: 8184
SUBJECT: GRB 080825C: Fermi GBM Spectral Analysis
DATE: 08/09/05 18:01:27 GMT
FROM: Alexander van der Horst at NASA/MSFC <avdhorst@science.uva.nl>

A.J. van der Horst (NASA/ORAU) ... on behalf of the Fermi GBM Team:

"We have performed time-resolved spectroscopy of GRB 080825C (GCN 8141, GCN 8183). The main emission up to 23 seconds is best fit by the Band function. Time-resolved spectra of this emission period display the commonly observed hard-to-soft spectral evolution, with E_{peak} decreasing from 170 to 110 keV, while the spectral indices remain roughly constant at $\alpha \sim -0.4$ and $\beta \sim -2.4$, consistent with the time-averaged spectral result (GCN 8141). Weaker emission following this period lasts a further 11 seconds and deviates from this spectral behaviour. The spectrum of this tail over the energy range 8-900 keV is best fit by a single power law with index -1.41 ± 0.09 .

- ▶ >10 photons above 100 MeV
- ▶ Over the whole duration of GRB, as detected by the GBM.
- ▶ No photons above 1 GeV.
- ▶ No follow-up possible due to the large error bars (see the following).

Second LAT GCN: GRB080916C



TITLE: GCN CIRCULAR
NUMBER: 8278
SUBJECT: GRB 080916C: Fermi GBM Spectral Analysis
DATE: 08/09/20 23:41:31 GMT
FROM: Alexander van der Horst at NASA/MSFC <avdhorst@science.uva.nl>

Alexander van der Horst (NASA/ORAU) and Adam Goldstein (UAH) report on behalf of the Fermi Gamma-ray Burst Monitor Team:

"We have performed spectral analysis of GRB 080916C (GCN 8245, 8246). The time averaged spectrum, from 8 keV up to 30 MeV, of the main emission up to 66 seconds after the burst is best fit by a Band function with $E_{\text{peak}} = 424 \pm 24$ keV, $\alpha = -0.91 \pm 0.02$, and $\beta = -2.08 \pm 0.06$. The fluence (8 keV - 30 MeV) is 1.9×10^{-4} erg/cm²...

TITLE: GCN CIRCULAR
NUMBER: 8246
SUBJECT: GRB 080916C: Fermi LAT observation
DATE: 08/09/16 18:25:23 GMT
FROM: Nicola Omodei at INFN(Pisa)/GLAST <nicola.omodei@pi.infn.it>

H. Tajima (SLAC)... on behalf of the Fermi LAT team:

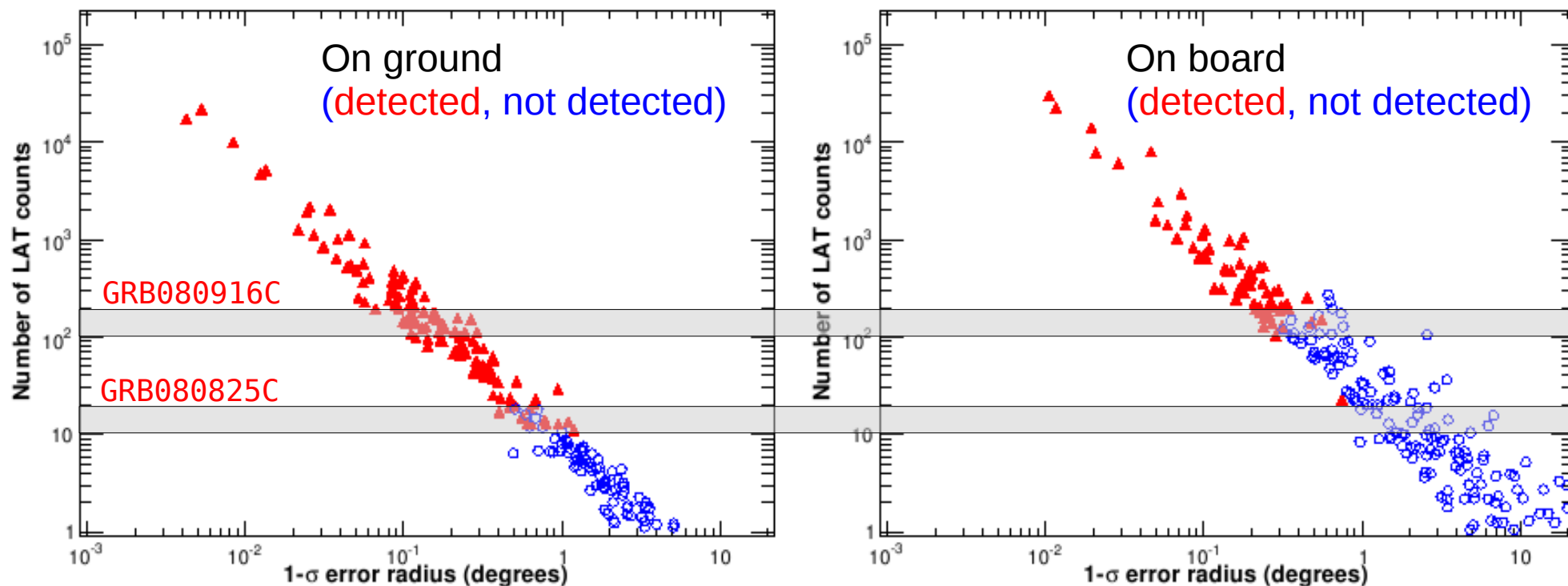
We report a detection by the Fermi Large Area Telescope (LAT) of emission from the long GRB 080916C, which was triggered by the Fermi Gamma-ray Burst Monitor (GBM) at 00:12:45 UT on September 16th 2008 (GCN 8245). The angle of the GBM best position (RA, Dec=121.8,-61.3) with respect to the LAT boresight was 52 degrees at the time of the trigger, which is close to the edge of our field of view.

The data from the Fermi LAT shows a significant increase in the event rate within 10 degrees of the GBM location after the GBM trigger that is spatially and temporally correlated with the GBM emission with high significance. More than 10 photons are observed above 1 GeV during this time.

The best LAT on-ground localization is found to be (RA,Dec=119.88, -56.59) with a 90% containment radius of 0.13 deg (statistical; 68% containment radius: 0.09 deg, preliminary systematic error is less than 0.1 deg) which is consistent with the GBM localization...

- ▶ 145 photons above 100 MeV.
- ▶ 3 photons above 10 GeV (highest energy photon is 13.2 ± 0.7 GeV).
- ▶ Good localization, follow up by Swift/XRT (X-rays) and GROND (optical).
- ▶ Photometric redshift of $z=4.35 \pm 0.3$

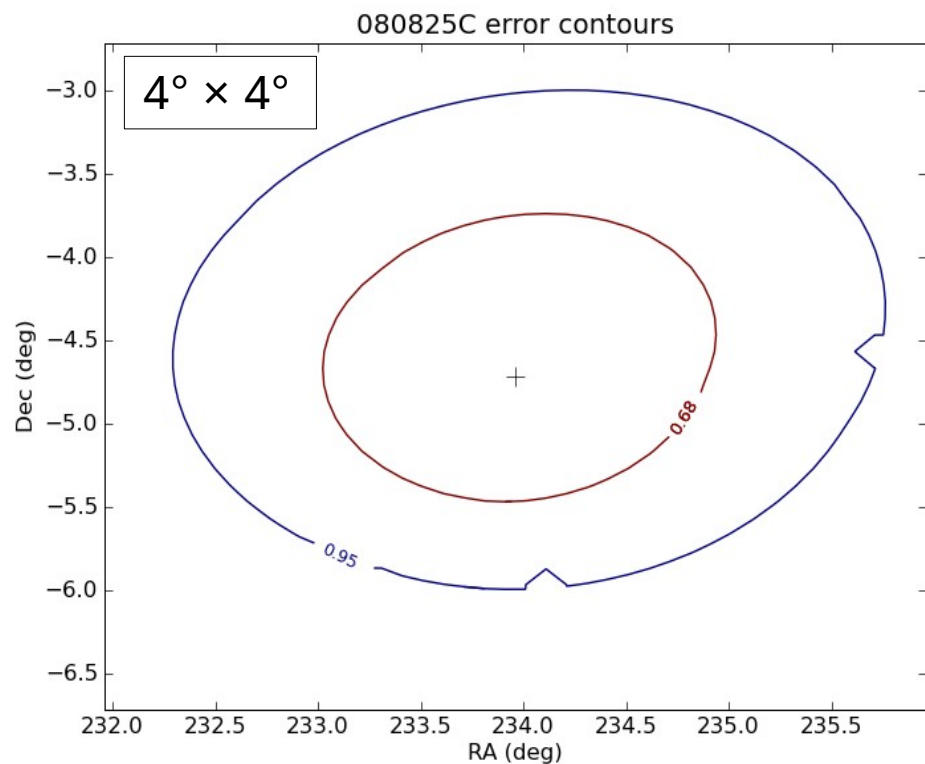
LAT localization accuracy



► Localization accuracy (simulation on the GRB grid):

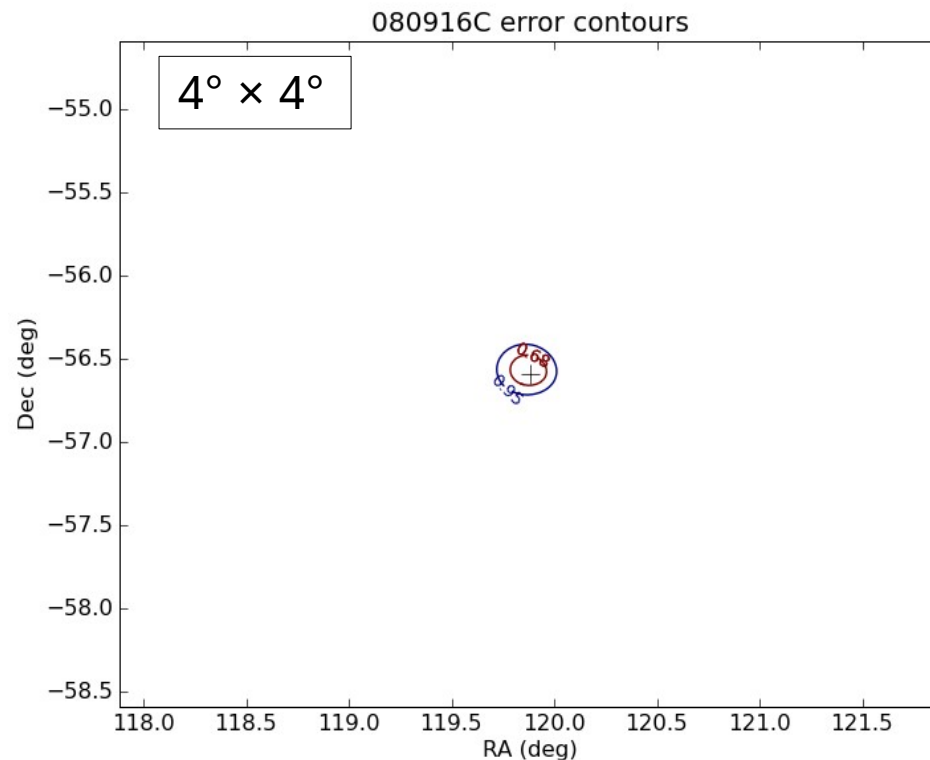
- Depends on beta, angle to boresight, fluence, duration.
- LAT angular resolution strongly energy-dependent, even a single high-energy photon can make a big difference.
- Lower detection threshold and localization error on the ground.

LAT localization accuracy



▶ GRB 080825C

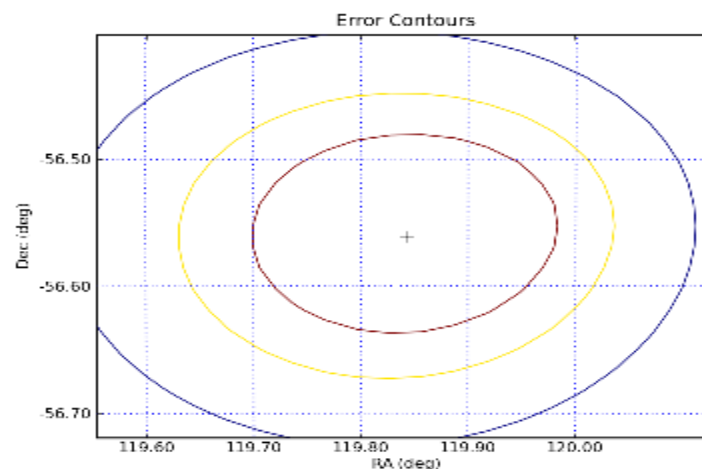
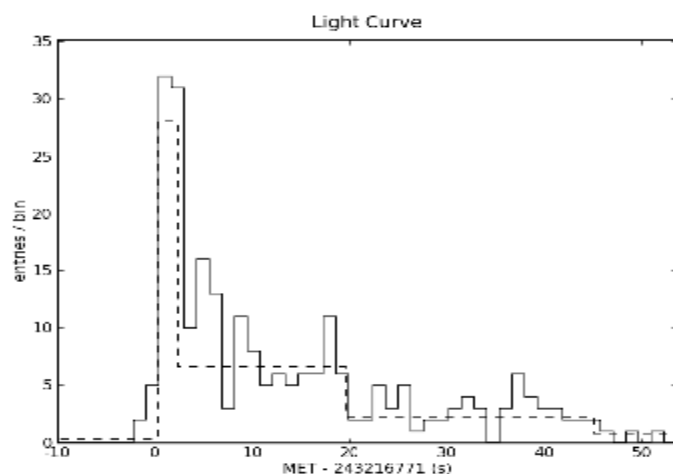
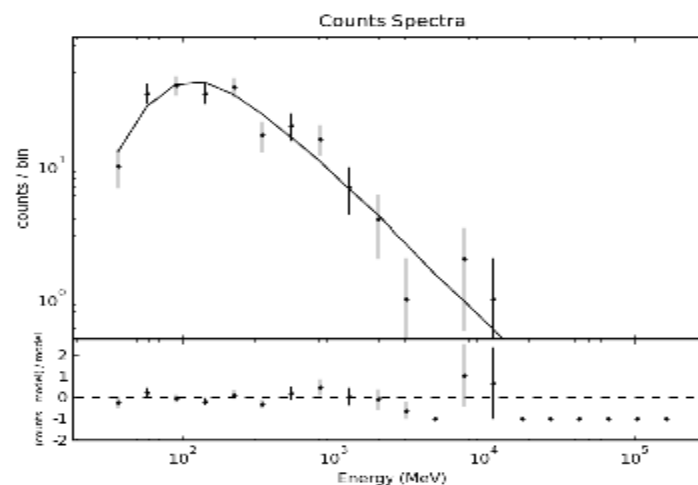
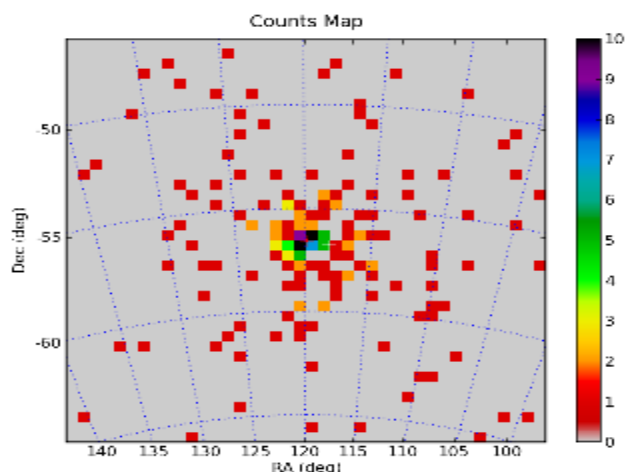
- ▶ ~10 evts above 100 MeV, 60° off-axis
- ▶ GBM: $(232.2^\circ, -4.9^\circ) \pm 1.5^\circ$ (68%)
- ▶ LAT = $(233.96^\circ, -4.72^\circ) \pm 0.95^\circ$ (68%)



▶ GRB 080916C

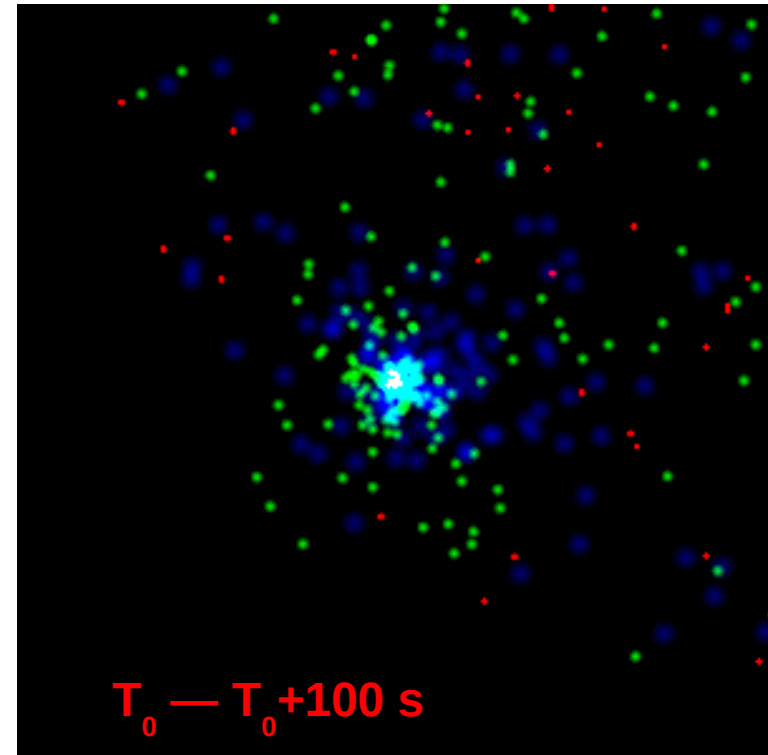
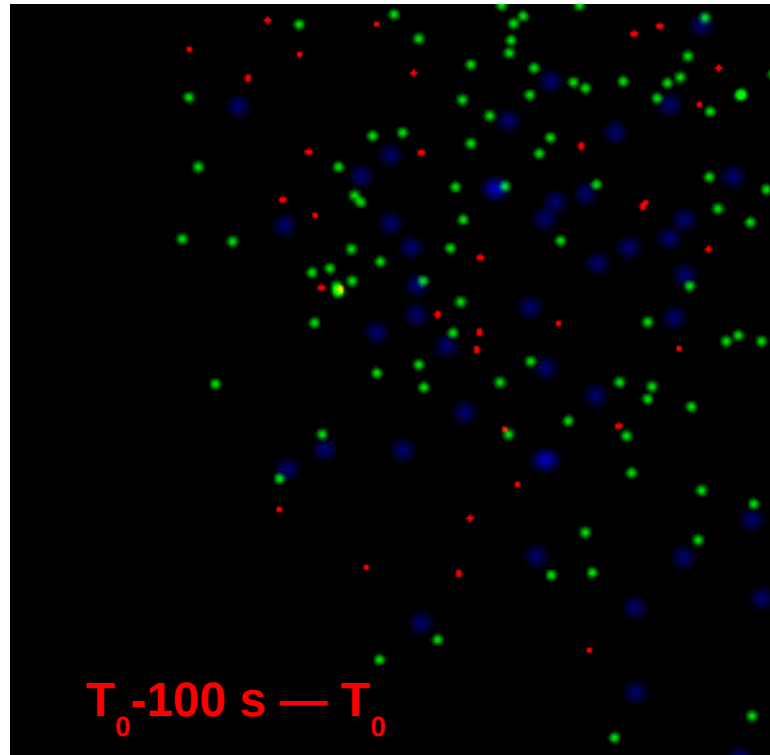
- ▶ 145 evts above 100 MeV, 52° off-axis
- ▶ GBM: $(121.8^\circ, -61.3^\circ) \pm 1.0^\circ$ (68%)
- ▶ LAT : $(119.88^\circ, -56.59^\circ) \pm 0.09^\circ$ (68%)

Automated Science Processing



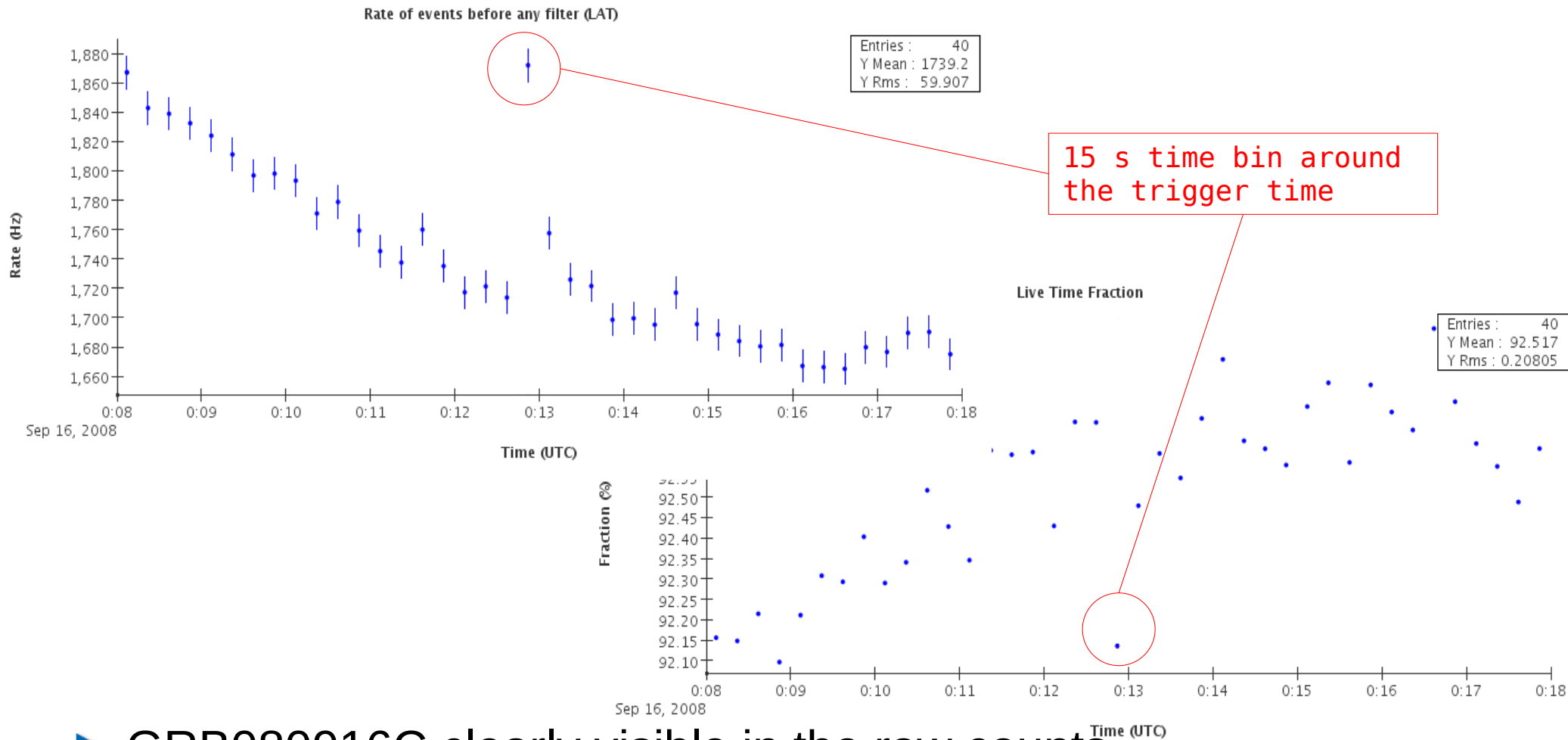
- ▶ Automatically run in the data processing pipeline for each GCN.
 - ▶ Available to the BA typically ~8--10 hours after the data have been acquired

GRB 080916C skymap



- ▶ 30° region around the GRB location
 - ▶ RGB: below 100 MeV, 100 MeV—1 GeV, above 1 GeV.
 - ▶ Black region is out of the field of view.

GRB 080916C “lightcurve”



- ▶ GRB080916C clearly visible in the raw counts.
 - ▶ Noticeable increase in the rate before the on-board filters on top of the bkg.
 - ▶ Livetime still above 90%.

Conclusions

- ▶ GBM and LAT are both working well:
 - ▶ GBM GRB detection rate is ~250/year.
 - ▶ LAT GRB detection rate is ~10/year (4 detections, so far).
- ▶ GRB 080916C:
 - ▶ 145 photons above 100 MeV, highest energy photon 13 GeV.
- ▶ Fermi is living up to its expectations.
- ▶ And that's just the beginning...