

# GRB Studies with ~~GLAST~~ Fermi

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for the Fermi GRB Team

see <http://www.nasa.gov/glast> and  
links therein



# The Fermi Observatory



## Large Area Telescope (LAT)

- Large Field of View ( $>2.4$  sr)
- views entire sky every 3 hrs
- 20 MeV - 300 GeV



## Gamma-ray Burst Monitor (GBM)

- Views entire unocculted sky
- **NaI**: 8 keV - 1 MeV
- **BGO**: 150 keV - 30 MeV



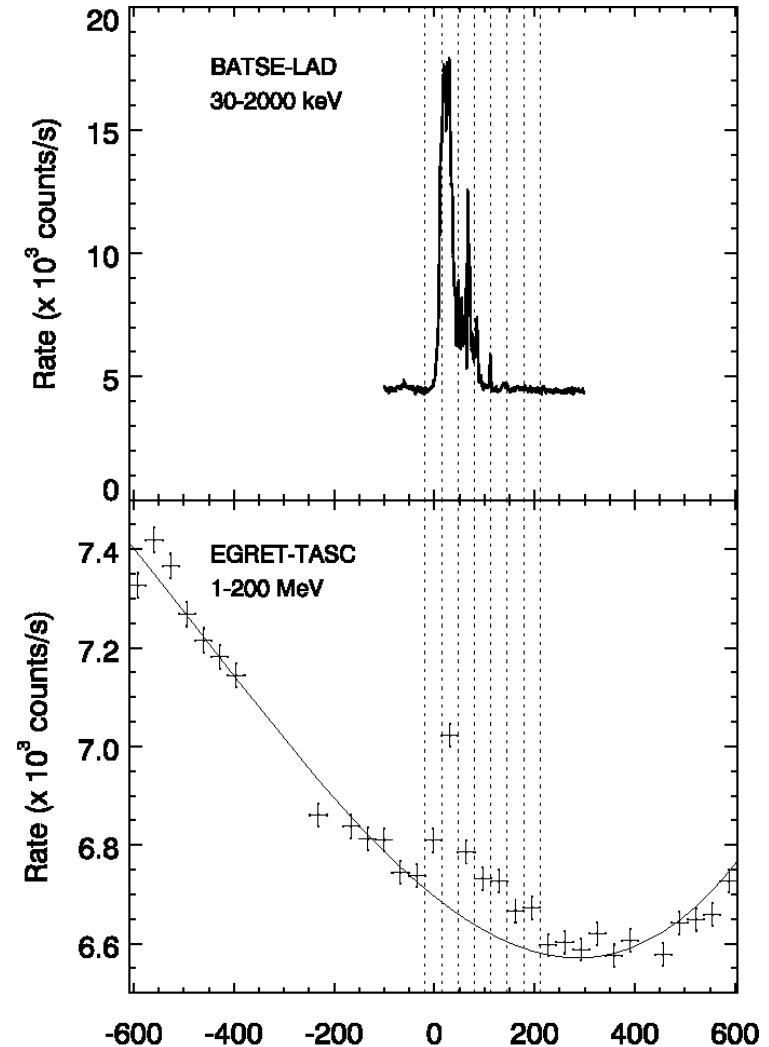
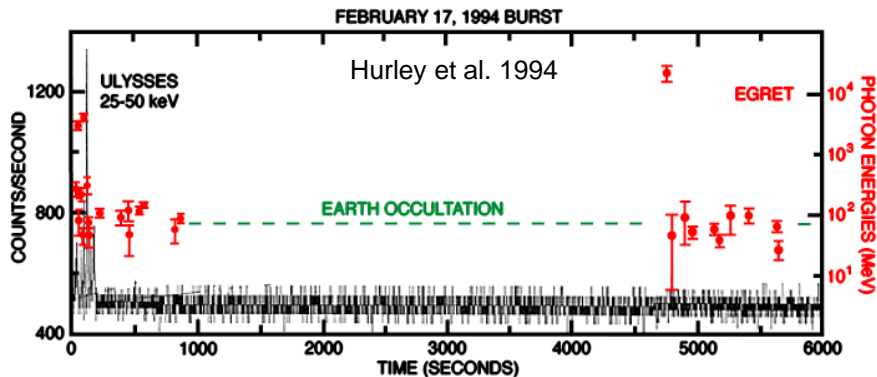
SESAPS



- ✦ Launch from Cape Canaveral Air Station 11 June 2008 at 12:05PM EDT
- ✦ Circular orbit, 565 km altitude (96 min period), 25.6 deg inclination.
- ✦ Communications:
  - Science data link via TDRSS Ku-band, average data rate 1.2 Mbps.
  - S-band via TDRSS and ground stations



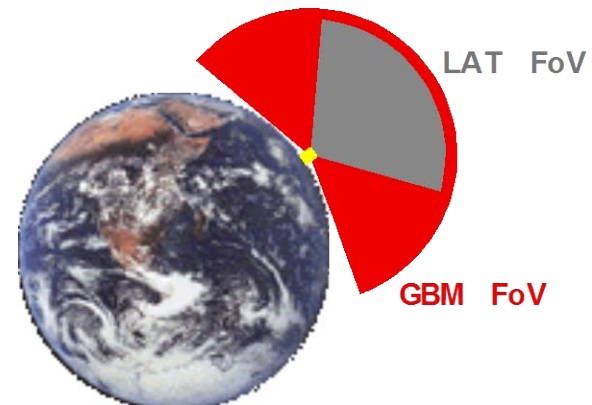
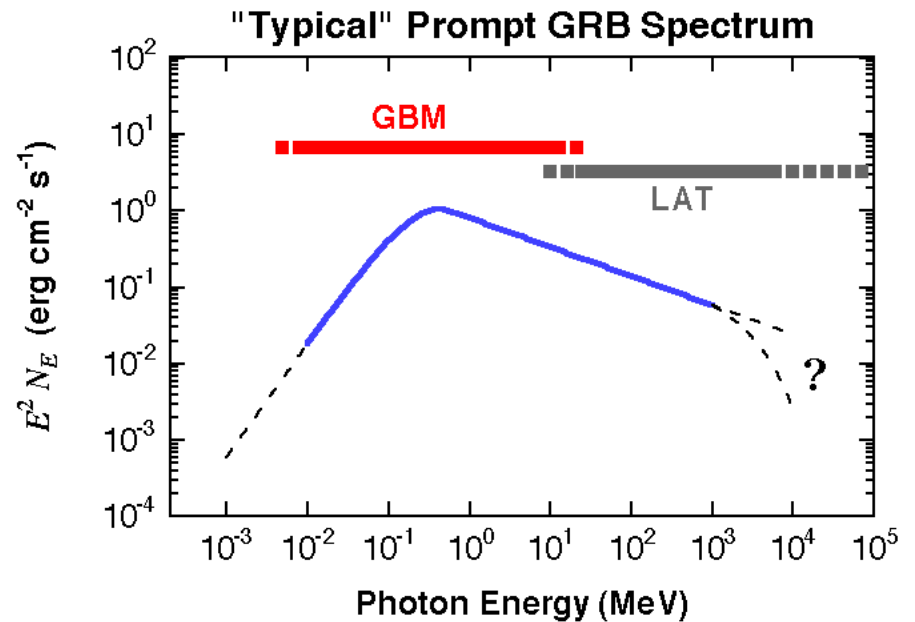
- ◆ Delayed emission
- ◆ SSC component
- ◆ Absorption
  - Internal
  - External
- ◆ Thermal + non-thermal spectra
- ◆ Quantum Gravity



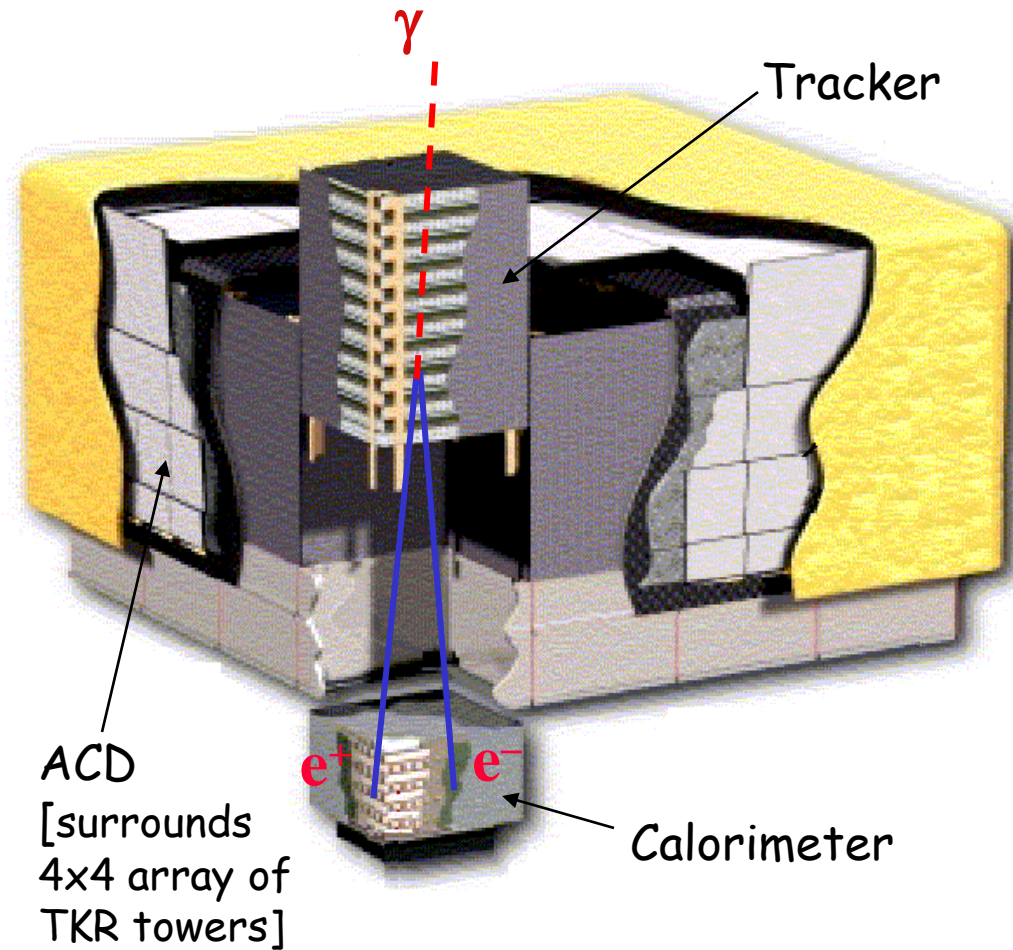
Gonzalez et al. 2003



- ★ LAT + GBM cover 6 decades in energy
- ★ GBM provides full sky coverage
- ★ Autonomous repointing for strong bursts
- ★ Synergy with Swift



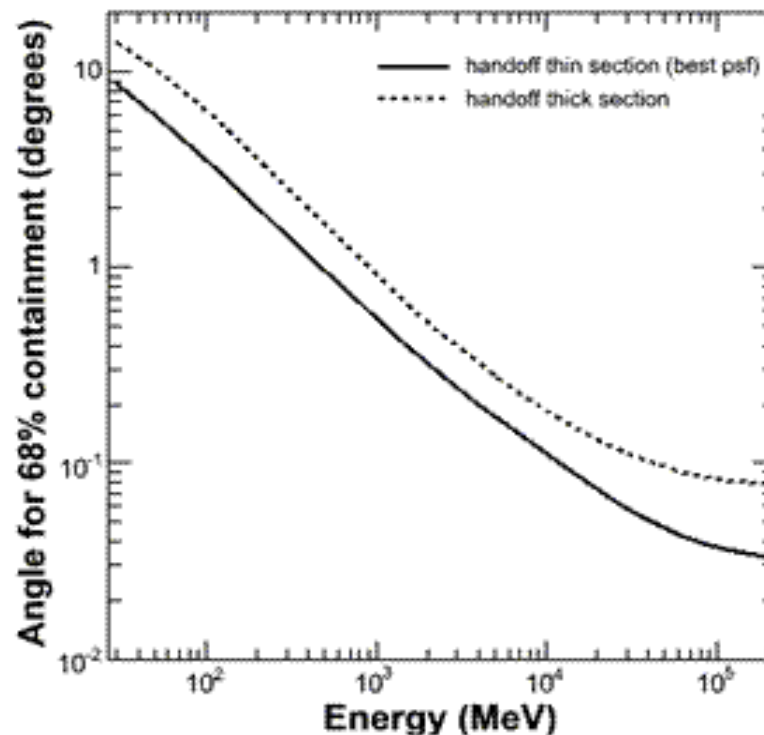
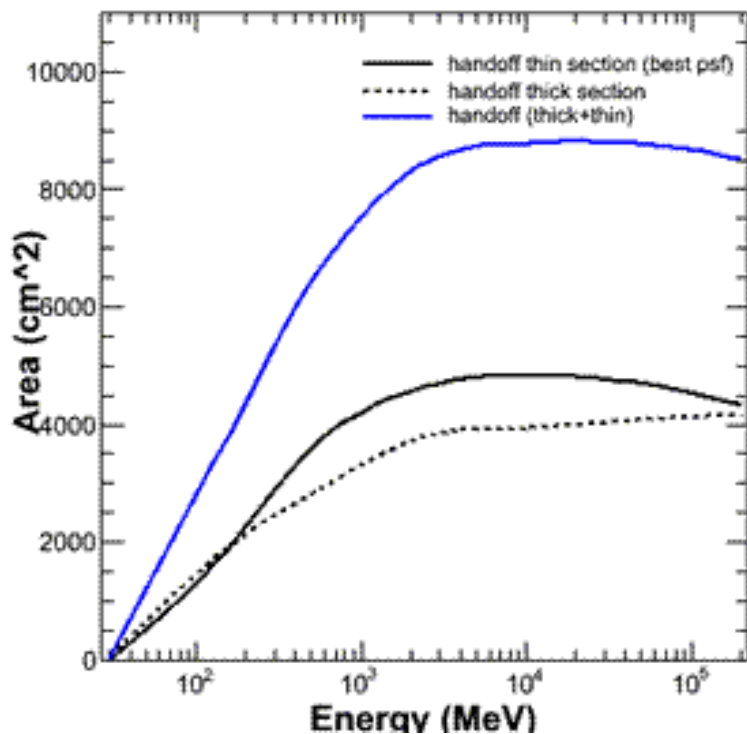
- ✦ Precision Si-strip Tracker (TKR)  
70 m<sup>2</sup> of silicon detectors  
arranged in 36 planes.  
880,000 channels.
- ✦ Hodoscopic CsI  
Calorimeter(CAL) 1536  
CsI(Tl) crystals in 8 layers, total  
mass 1.5 tons.
- ✦ Segmented Anticoincidence  
Detector (ACD) 89 plastic  
scintillator tiles.
- ✦ Electronics System Includes  
flexible hardware trigger and  
onboard computing.



# LAT Capabilities



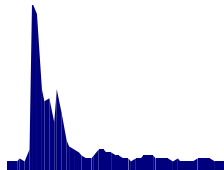
- ◆ Effective Area  $>8000 \text{ cm}^2$  above 10 GeV (10 x EGRET)
- ◆ Field of View: 2.4 sr
- ◆ PSF  $<10$  arcmin above 10 GeV (5 times better than EGRET)
- ◆ Very low background for GRBs
- ◆ Deadtime per event  $\sim 26 \mu\text{s}$  ( $10^4$  better than EGRET)







- ✦ Onboard (150 Hz background rate, simplified direction/energy reconstruction)
  - Standalone search: look for spatially and temporally clustered events in a blind search
  - GBM seeded search: Look at the location and time of a GBM burst
  - Currently in a “diagnostic” mode where the thresholds for the standalone search are set very high (so we will rarely trigger) and the thresholds for the GBM seeded search are set very low (so that we always send LAT alert messages)
- ✦ Ground search (5 hz background rate, sophisticated direction/energy reconstruction)
  - Standalone/blind search
  - Follow up of all GRB within LAT FoV
- ✦ GRB 080916C
  - LAT onboard (ra, dec): 119.3, -56.7
  - LAT ground (ra, dec): 119.88, -56.59
  - GROND (ra, dec): 119.85, -56.63



# Gamma-Ray Burst Monitor

## ✦ 12 Sodium Iodide Detectors (NaI)

- 5" x 1/2", 8 keV – 1 MeV

## ✦ 2 Bismuth Germanate detectors (BGO)

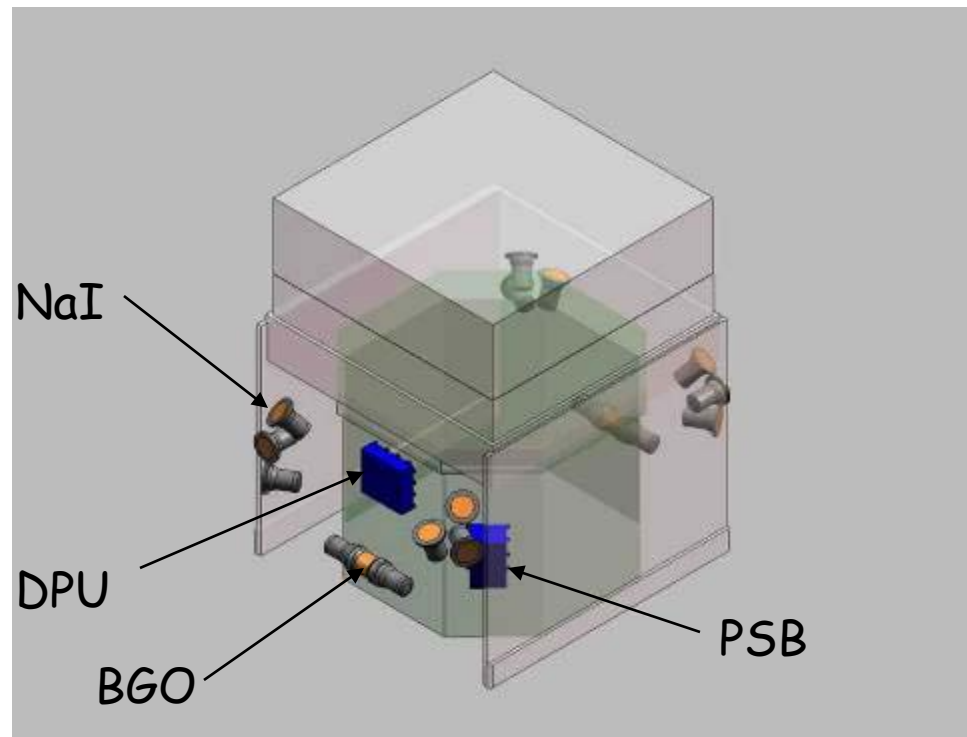
- 5" x 5", 150 keV – 30 MeV

## ✦ Data processing Unit (DPU)

- Command, telemetry, flight software.

## ✦ Power Supply Box (PSB)

- HV and LV to DPU and detectors

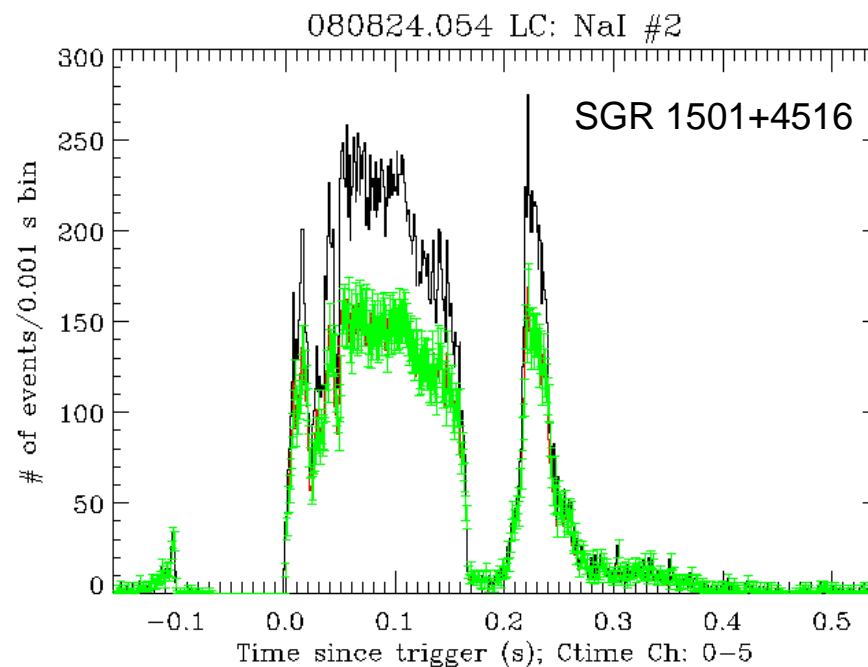
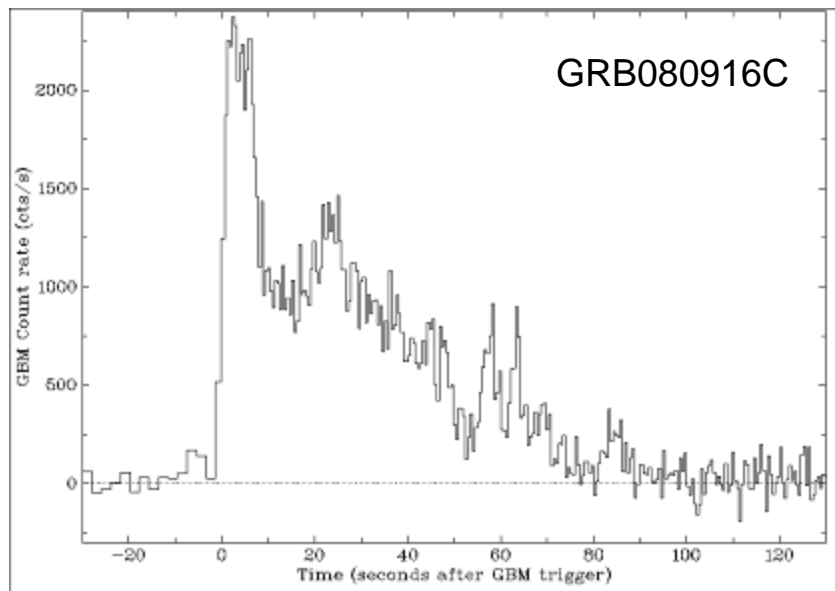




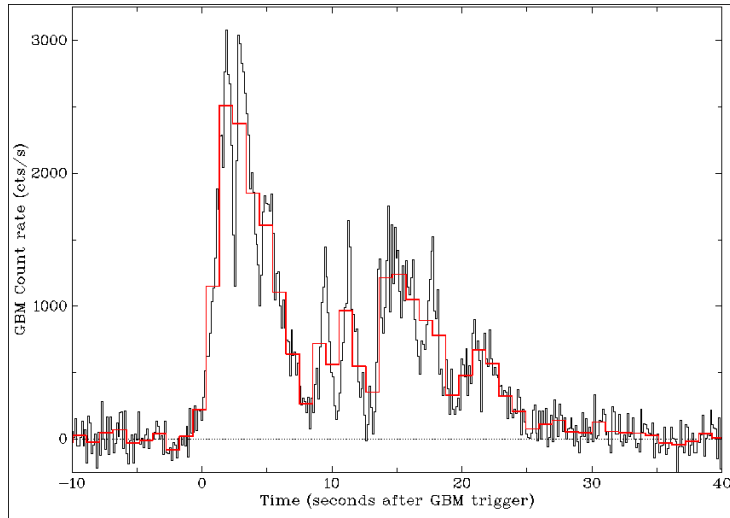
- ✦ Energy Range: 8 keV to 30 MeV
- ✦ On-Board Trigger
  - Up to 5 energy ranges
  - Timescales 16 ms to 16 sec
  - Classification
  - Localizations to  $<8$
- ✦ Trigger sensitivity:  $0.7 \text{ photons cm}^{-2} \text{ s}^{-1}$
- ✦ Rapid GCN notifications
- ✦ Data:
  - 8 channel spectra every 256 ms
  - 128 channel spectra every 8 s
  - Time-tagged events during bursts
- ✦ Expect  $\sim 280$  GRB triggers/year

## ◆ 141 triggers in 94 days

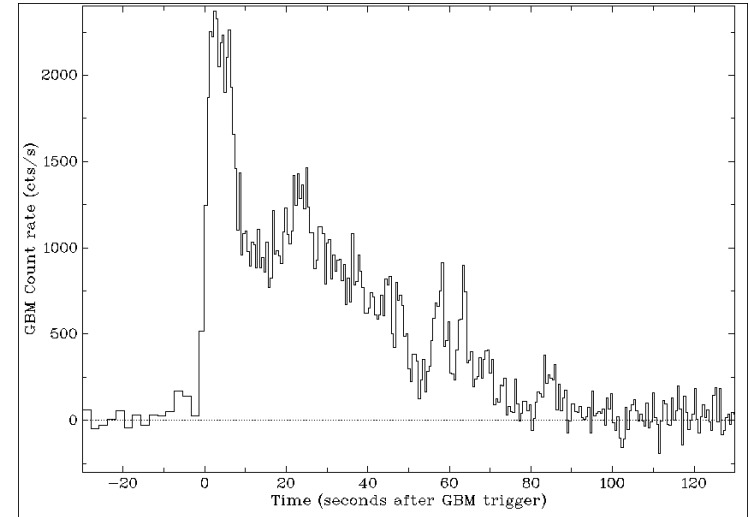
- 72 GRBs – 280 per year
- 27 SGR 1501+4516
- 7 AXP 1E1547.0-5408
- 5 TGF
- 29 Other (particles, Cyg X-1, accidental, unknown)



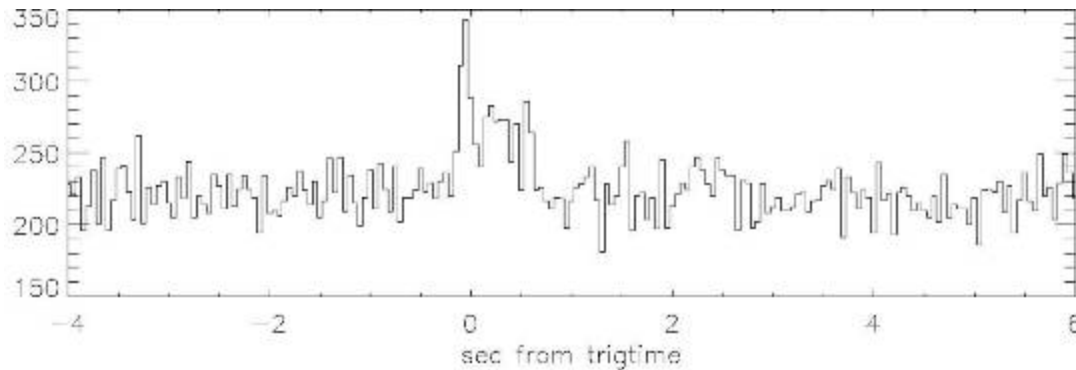
# 3 LAT/GBM Detections of GRBs



GRB080825C: ~13 LAT photons



GRB080916C: >200 LAT photons



GRB081024B: ~20 LAT photons

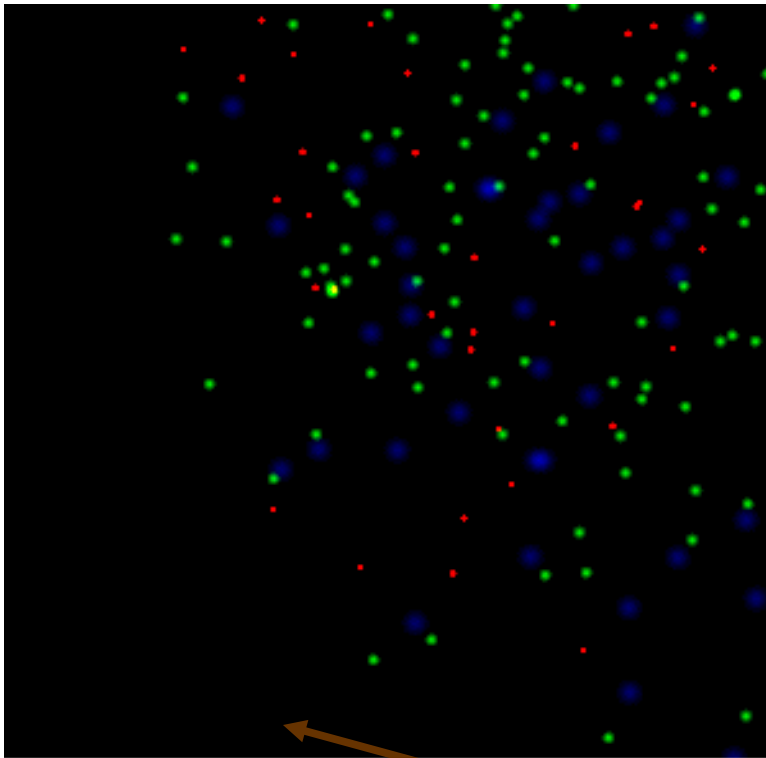
# GRB 080916C LAT skymap



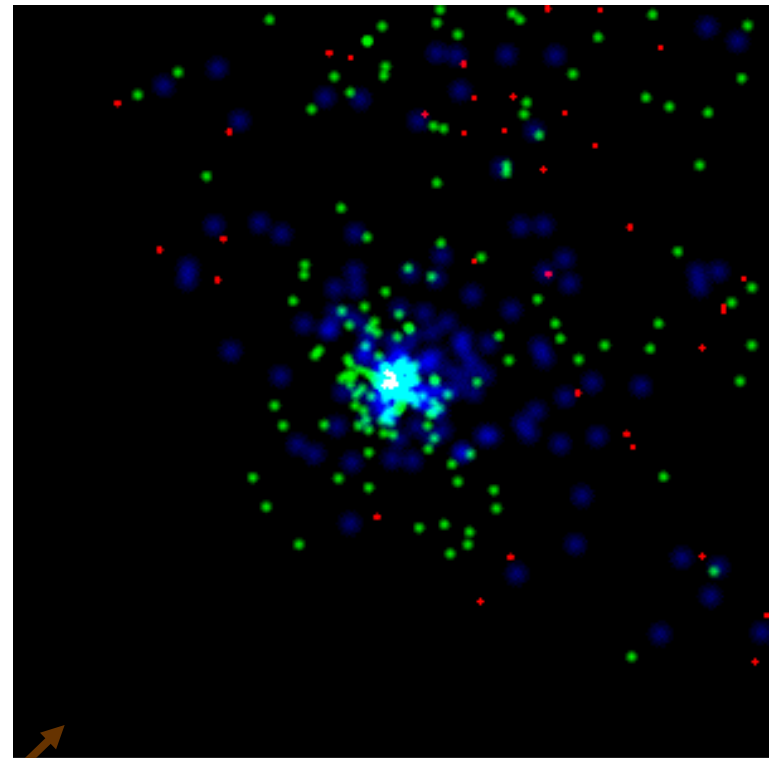
30 deg region around GRB 080916C

- GRB at  $48^\circ$  from the LAT boresight at  $T_0$
- **RGB** = **<100 MeV**, **100 MeV - 1 GeV**, **>1 GeV**

*Before the burst ( $T_0 - 100$  s to  $T_0$ )*



*During the burst ( $T_0$  to  $T_0 + 100$  s)*

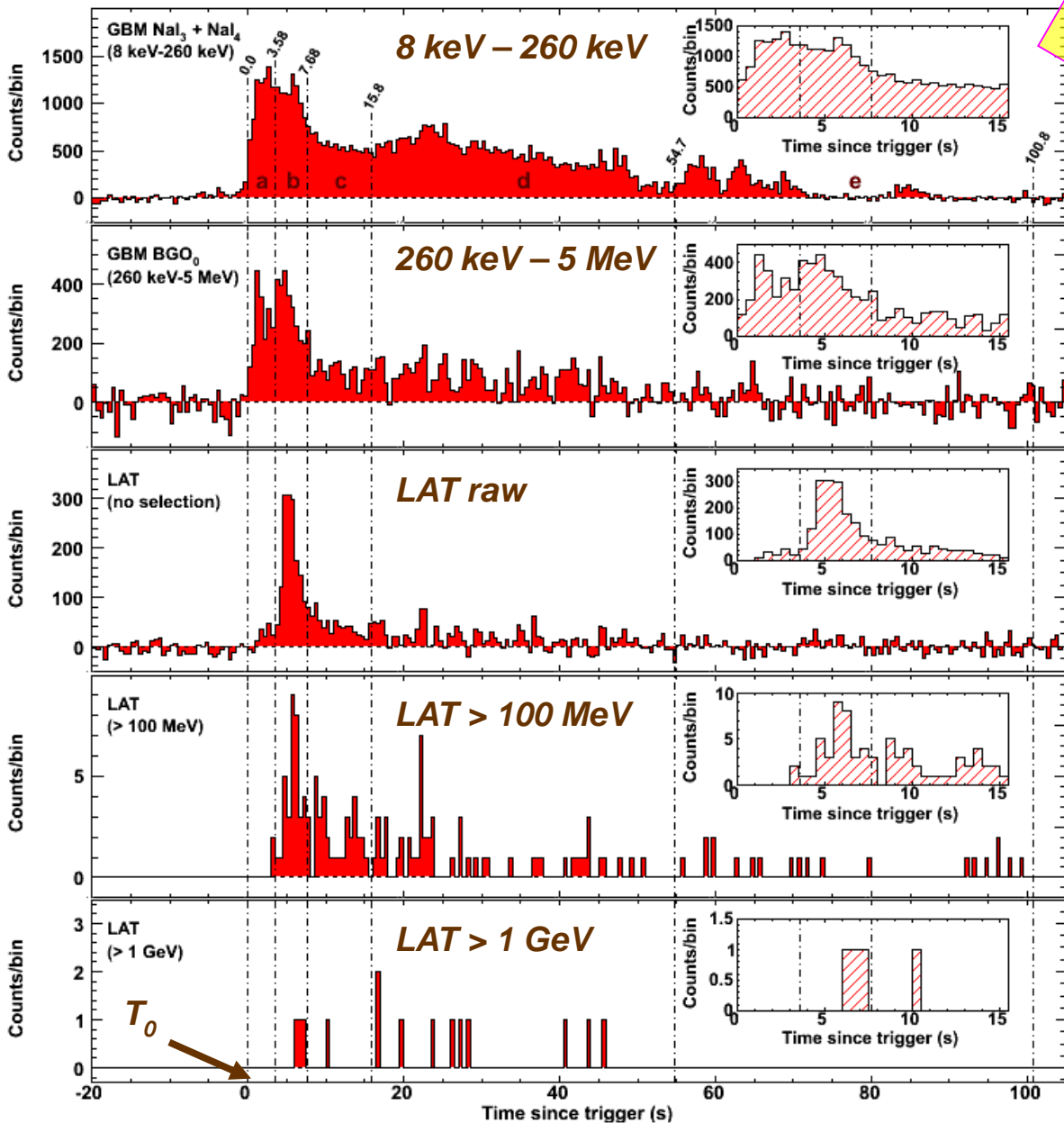


*Black region = out of FoV*

# Multiple detector light curve



**PRELIMINARY!**



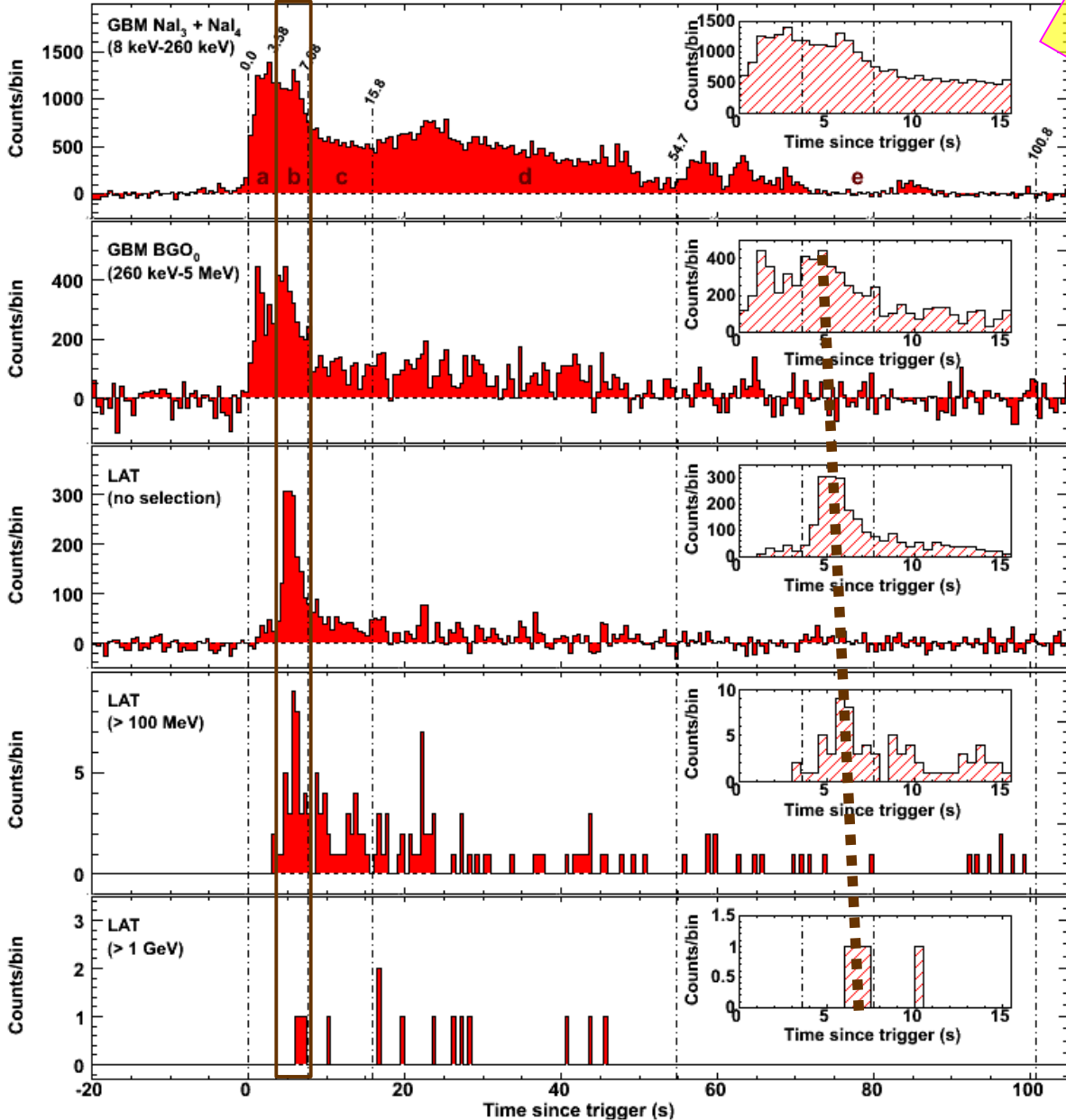
*First 3 light curves are background subtracted*

- The LAT can be used as a **counter** to maximize the rate and to study time structures above tens of MeV
  - The first low-energy peak is not observed at LAT energies
- **Spectroscopy** needs LAT event selection (>100 MeV)
  - 5 intervals for time-resolved spectral analysis:  
0 – 3.6 – 7.7 – 16 – 55 – 100 s
  - 14 events above 1 GeV

# Multiple detector light curve



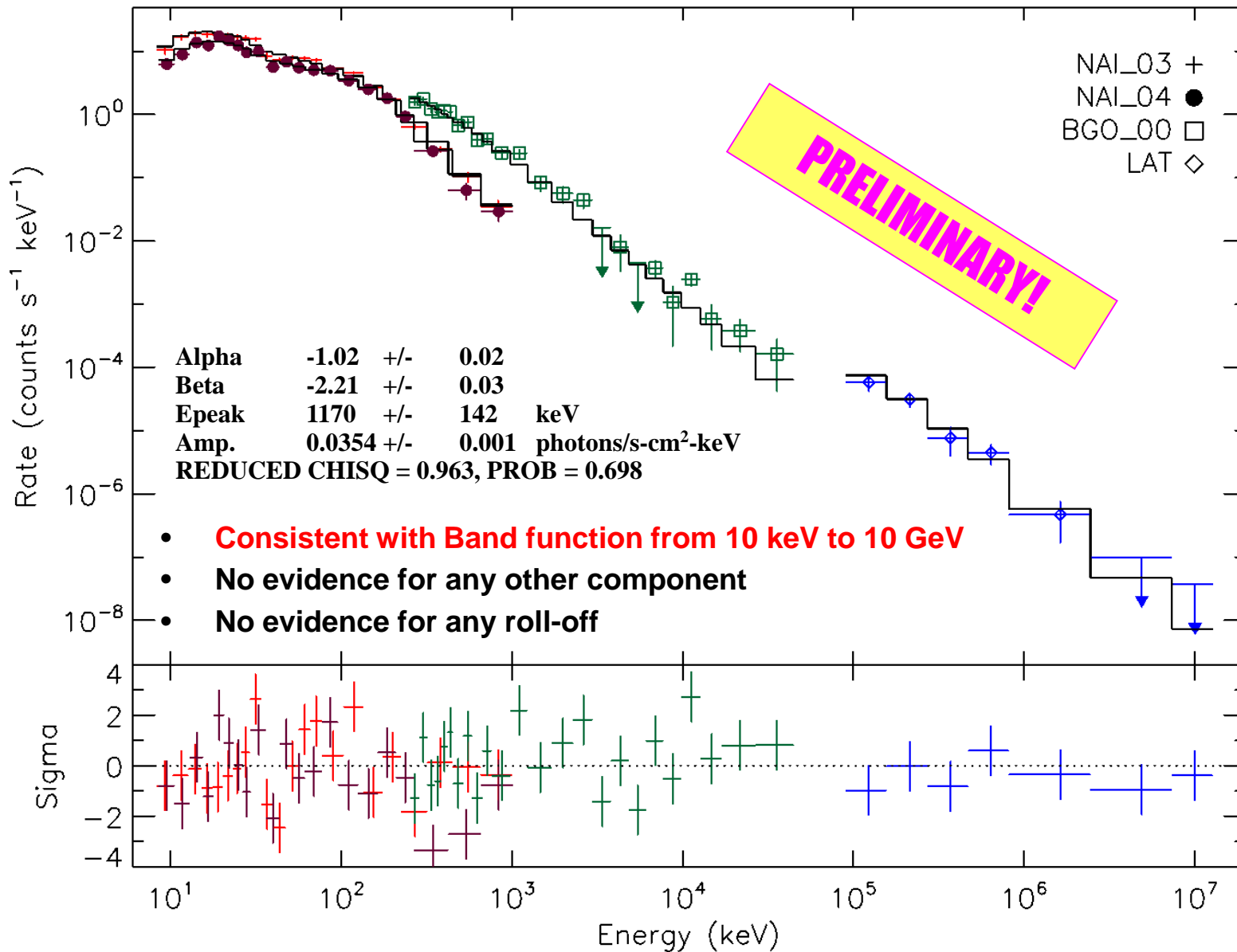
**PRELIMINARY!**



- The bulk of the emission of the 2<sup>nd</sup> peak is moving toward later times as the energy increases
- Clear signature of spectral evolution



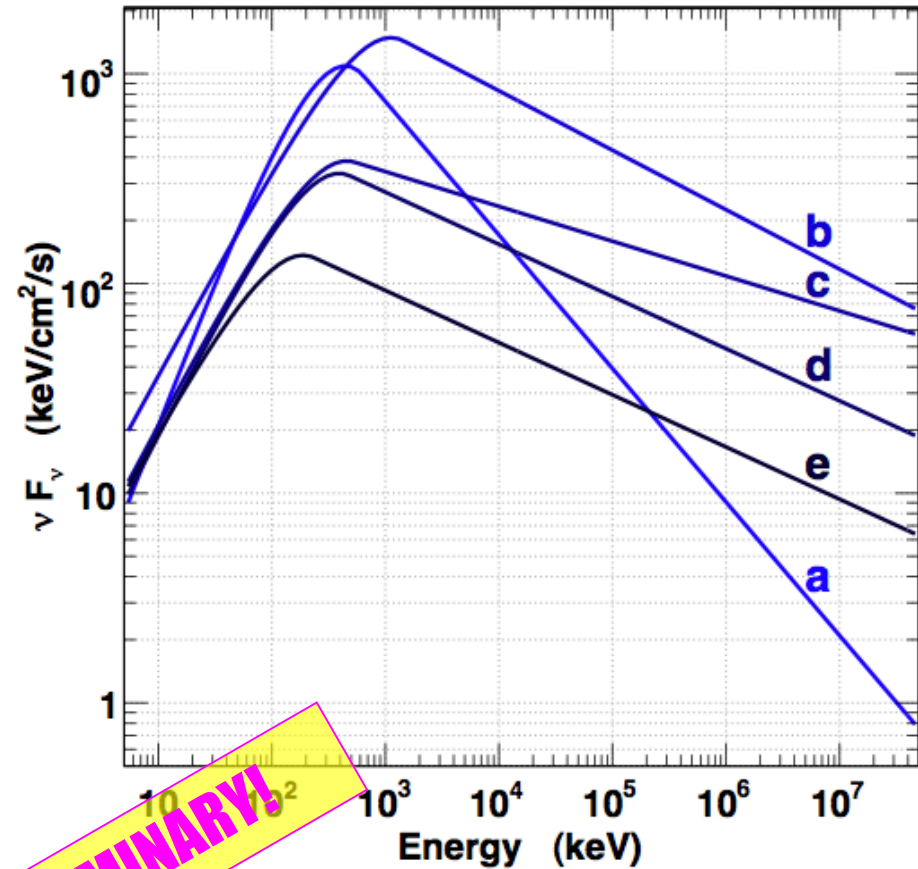
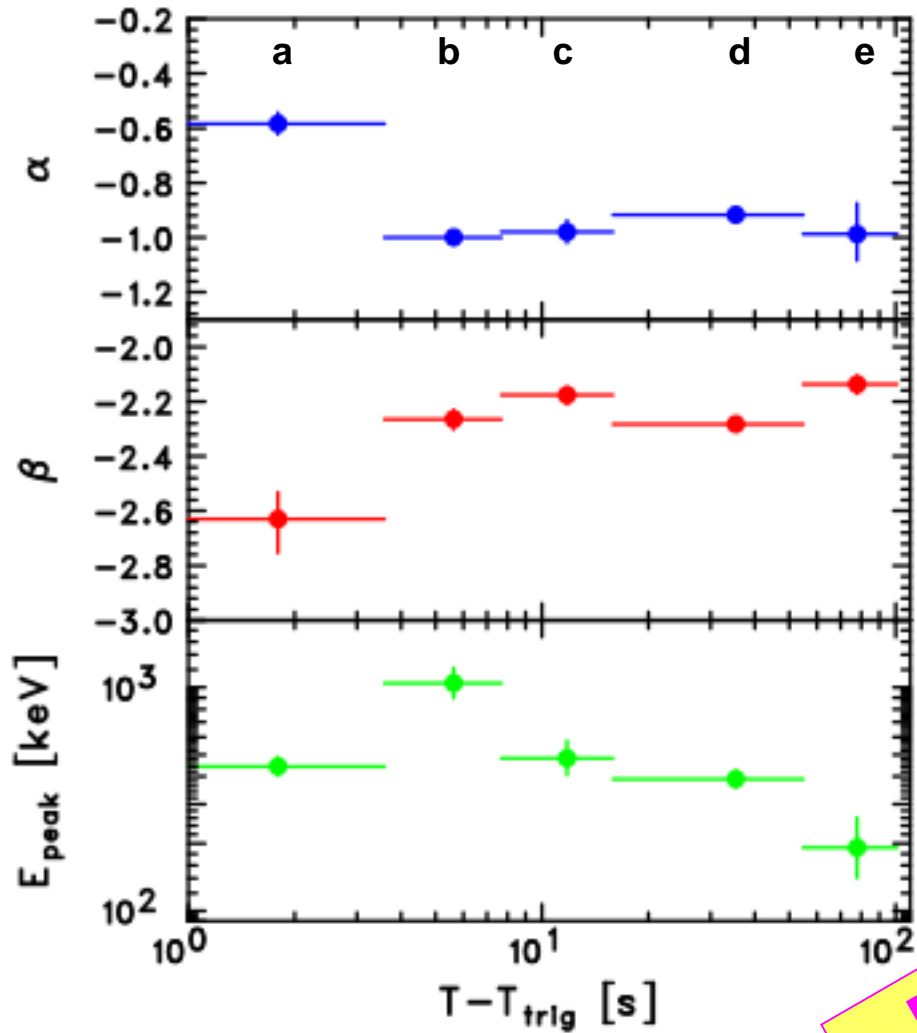
# Spectroscopy of the main LAT peak



# GRB 080916C Spectral evolution

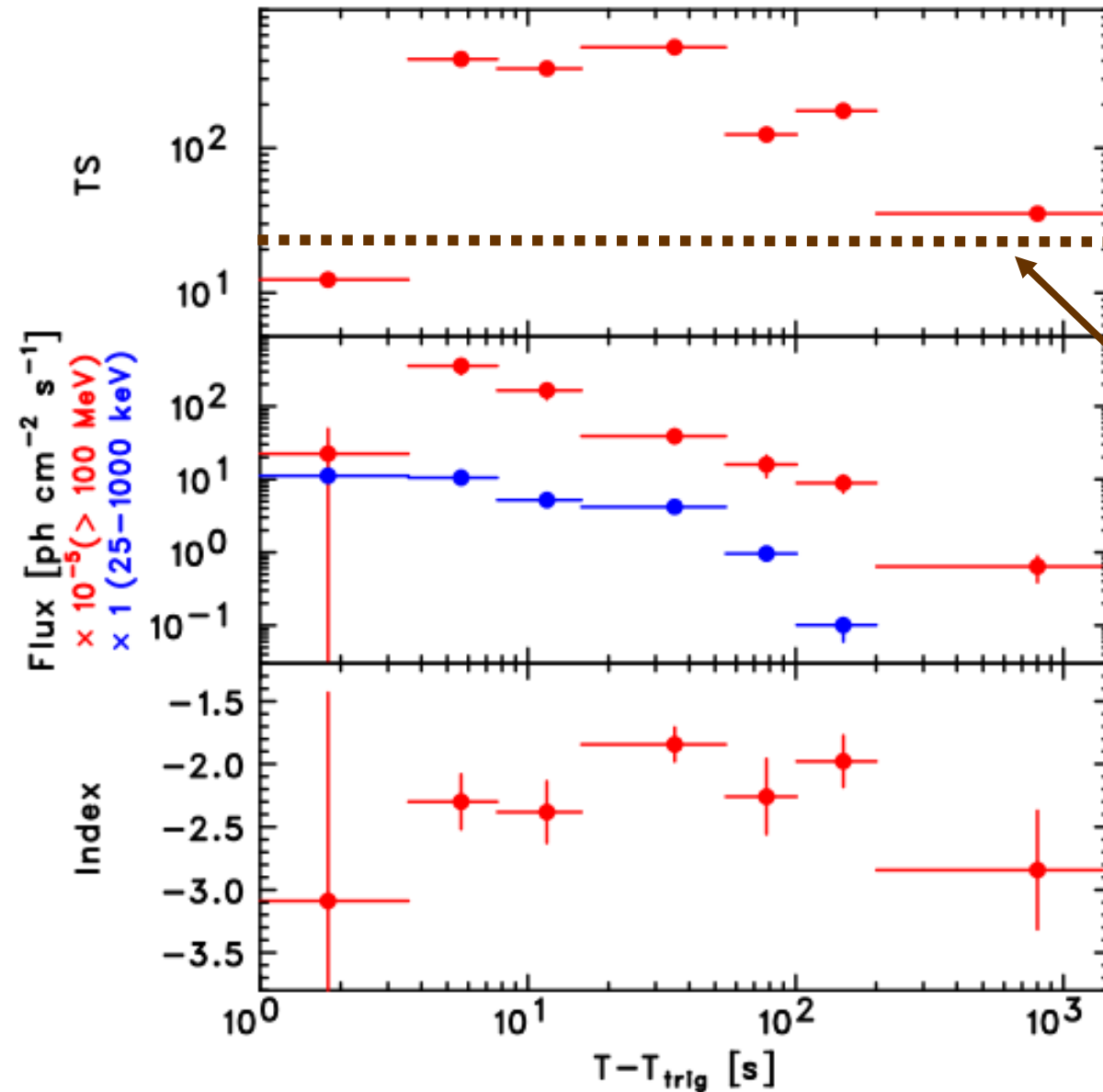


Soft-to-hard, then hard-to-soft evolution



**PRELIMINARY**

# Temporally-extended LAT emission




- GBM emission drop-off ~55 seconds after  $T_0$
- Significant LAT emission from  $T_0+3.6$  s to  $T_0+1400$  s
  - Tighter event selection cuts, optimized for weak sources
  - **Test Statistics** with position fixed at GROND location:  $TS > 25$  (square of significance)
  - **Still significant ( $5.9\sigma$ )** between  $T_0+200$  s and  $T_0+1400$  s, and consistent with the trend from the prompt emission

**PRELIMINARY!**

# GRB 080916C Summary



- **After only 2 months of the Fermi mission!**
  - **Second burst detected by the LAT after GRB 080825C [GCN 8183 – A. Bouvier]**
  - **The first GRB since EGRET epoch with imaged photons and energies > 1 GeV !**
- **Prompt emission**
  - **A long bright GRB**
    - **First GBM burst in fluence ( $4.0 \cdot 10^{-5}$  erg/cm<sup>2</sup> in 50 – 300 keV) and in the LAT FoV**
    - **More than 140 LAT events for spectral analysis (> 100 MeV)**
    - **More than 3000 LAT photons in the first 100 seconds**
  - **Time-resolved spectroscopy over 6 decades in energy (10 keV to 10 GeV)**
    - **Joint analysis of GBM and LAT data works very well !**
    - **All spectra are consistent with a Band function**
  - **Soft-to-hard (up to  $E_{\text{peak}} = 1.2$  MeV) then hard-to-soft spectral evolution**  
  
**The high-energy emission peaks at later times**
- **High-energy continued emission up to 23 min after the trigger time**
  - **Constantly declining flux**

All detailed analyses in upcoming article!

- ✦ Fermi Large Area Space Telescope is operational and working well.
- ✦ Three bursts detected by both LAT and GBM
- ✦ Wide spectral range shows great promise
- ✦ Still to come:
  - Automatic repoints
  - GBM/LAT/Swift bursts

# Backup Material



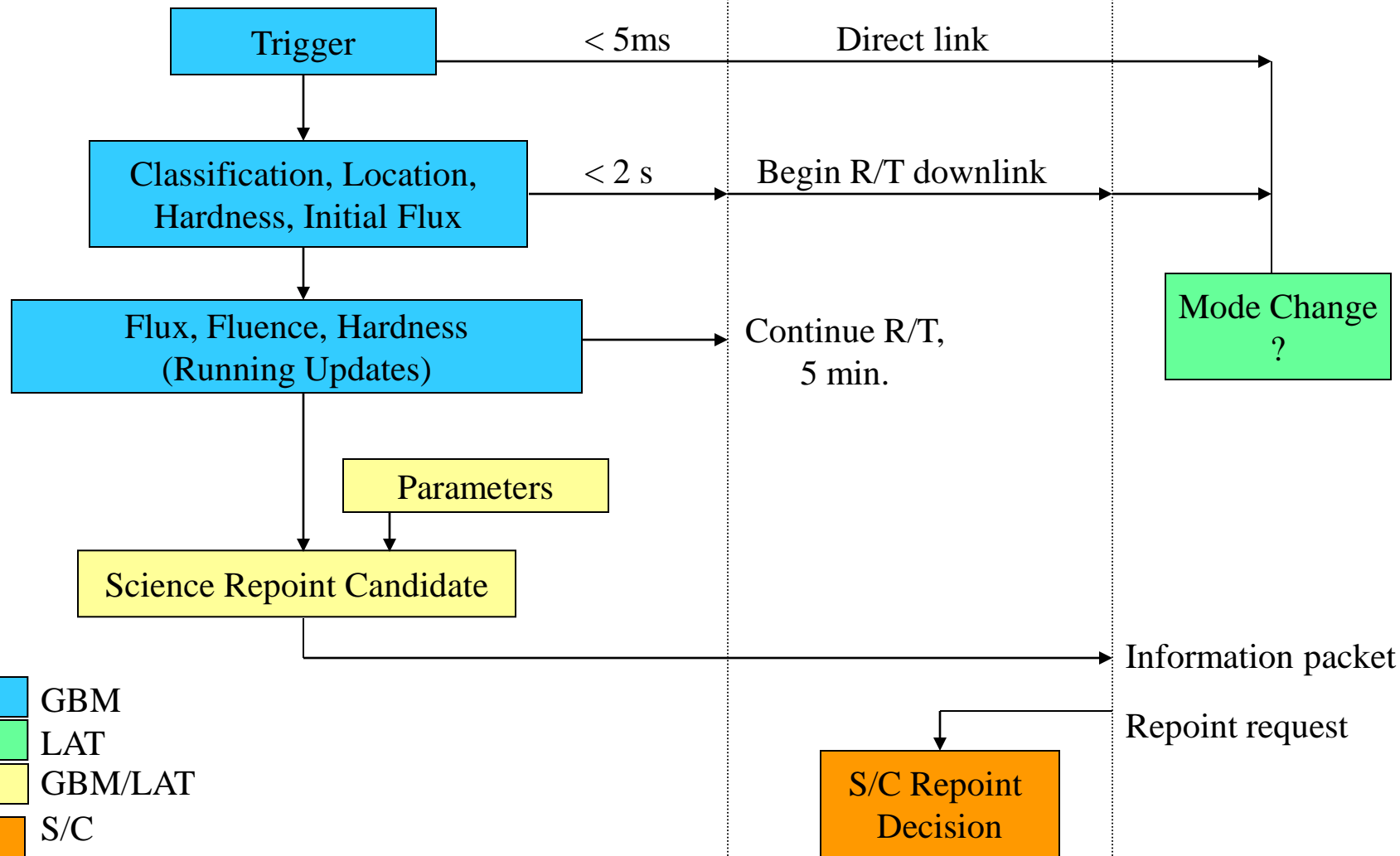


# GBM Burst Alerts

**GBM**

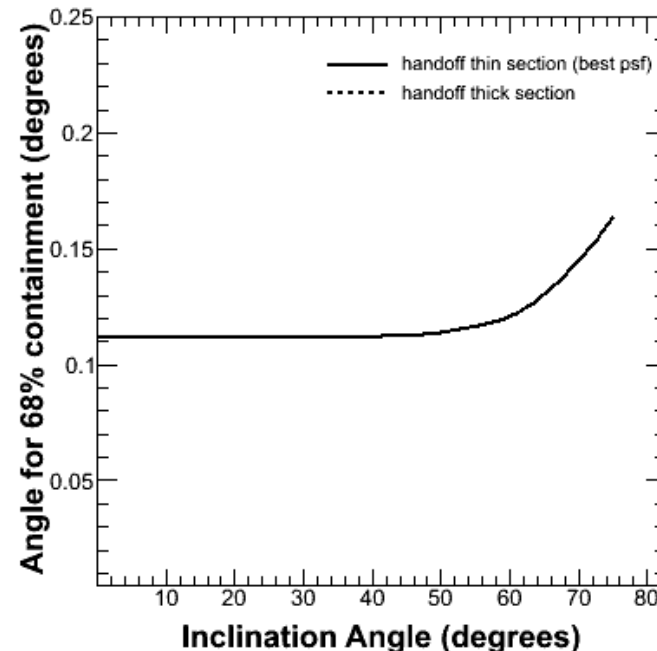
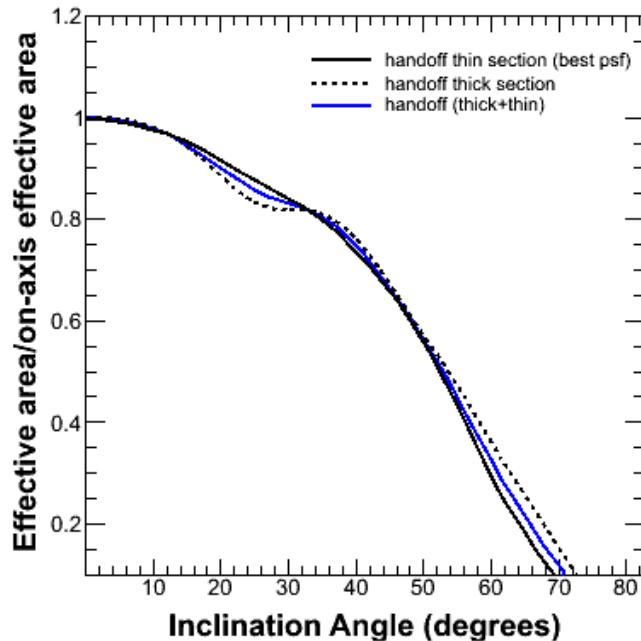
**S/C**

**LAT**





[http://www-glast.slac.stanford.edu/software/IS/glast\\_lat\\_performance.htm](http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm)



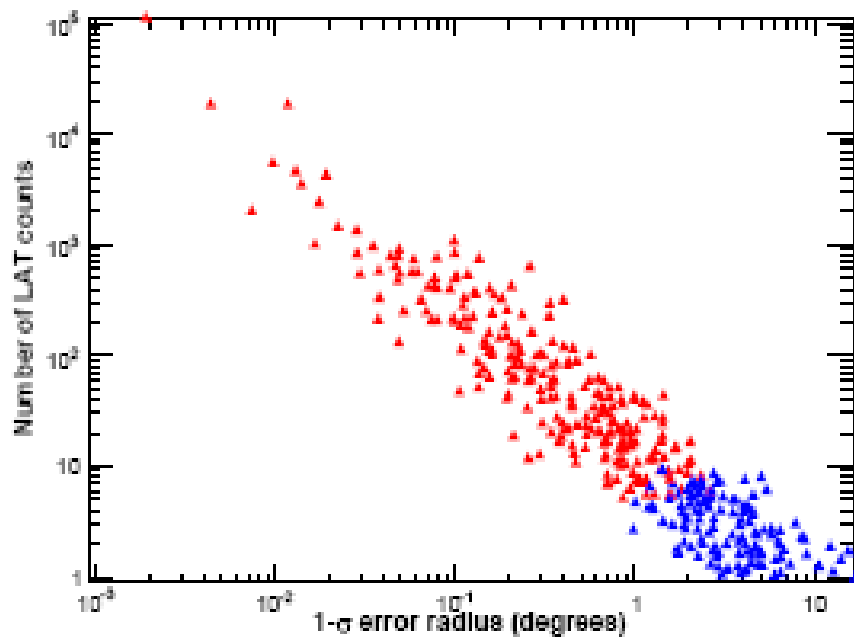
- ✦ The LAT Field of view is huge! (>55 deg half angle)
- ✦ Increases total exposure (because more of the sky is exposed at any instant)
- ✦ Superb for “catching” transients



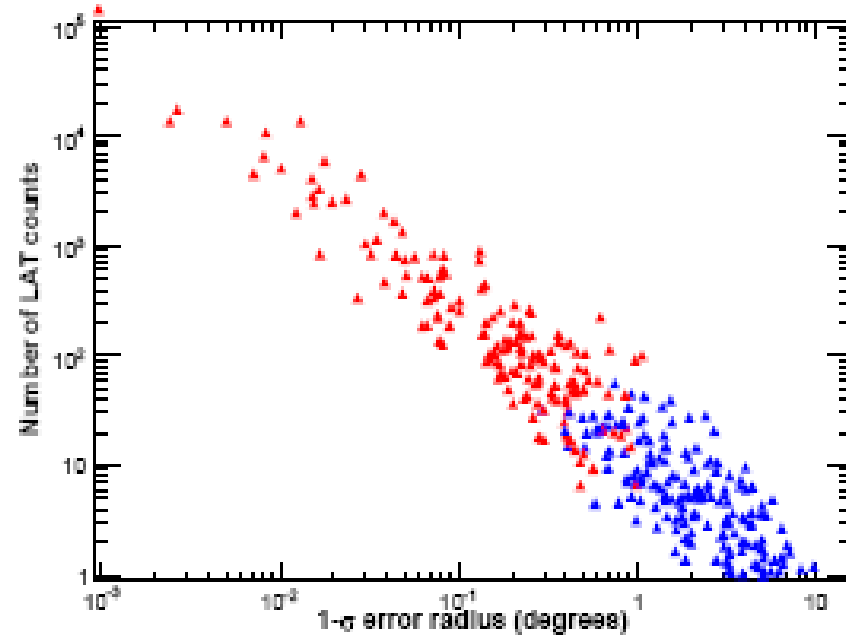
# LAT Burst Localization



LAT will routinely localize GRBs to  $<1^\circ$



Low background



High background



# GBM On-board Trigger Algorithm

- ✦ Four energy ranges: 25-50, 50-300, >100, >300 (keV)
- ✦ Eleven integration times: 16 ms – 8 s.
- ✦ Two timing phases
- ✦ Threshold of 4.5 sigma for 50-300 keV, 64 ms – 4 s
- ✦ Background rate 50-300 keV is ~320 counts/s
- ✦ Flux threshold for 1 s burst, 50-300 keV: ~0.75 photons/cm<sup>2</sup>/s
- ✦ Prediction of 200 bursts/year with BATSE-like trigger