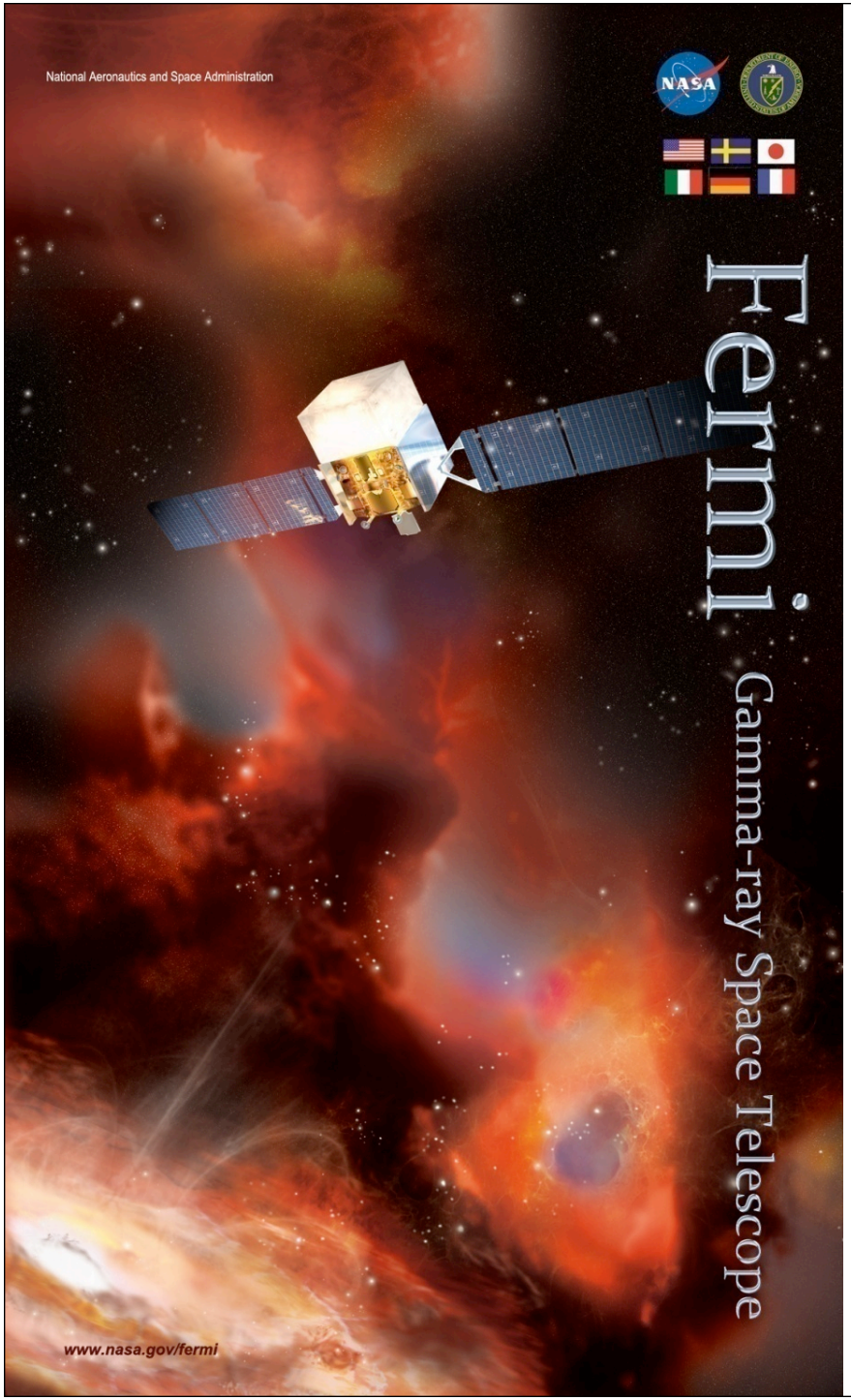



Fermi Gamma-ray Space Telescope

# Fermi/LAT GRB catalog

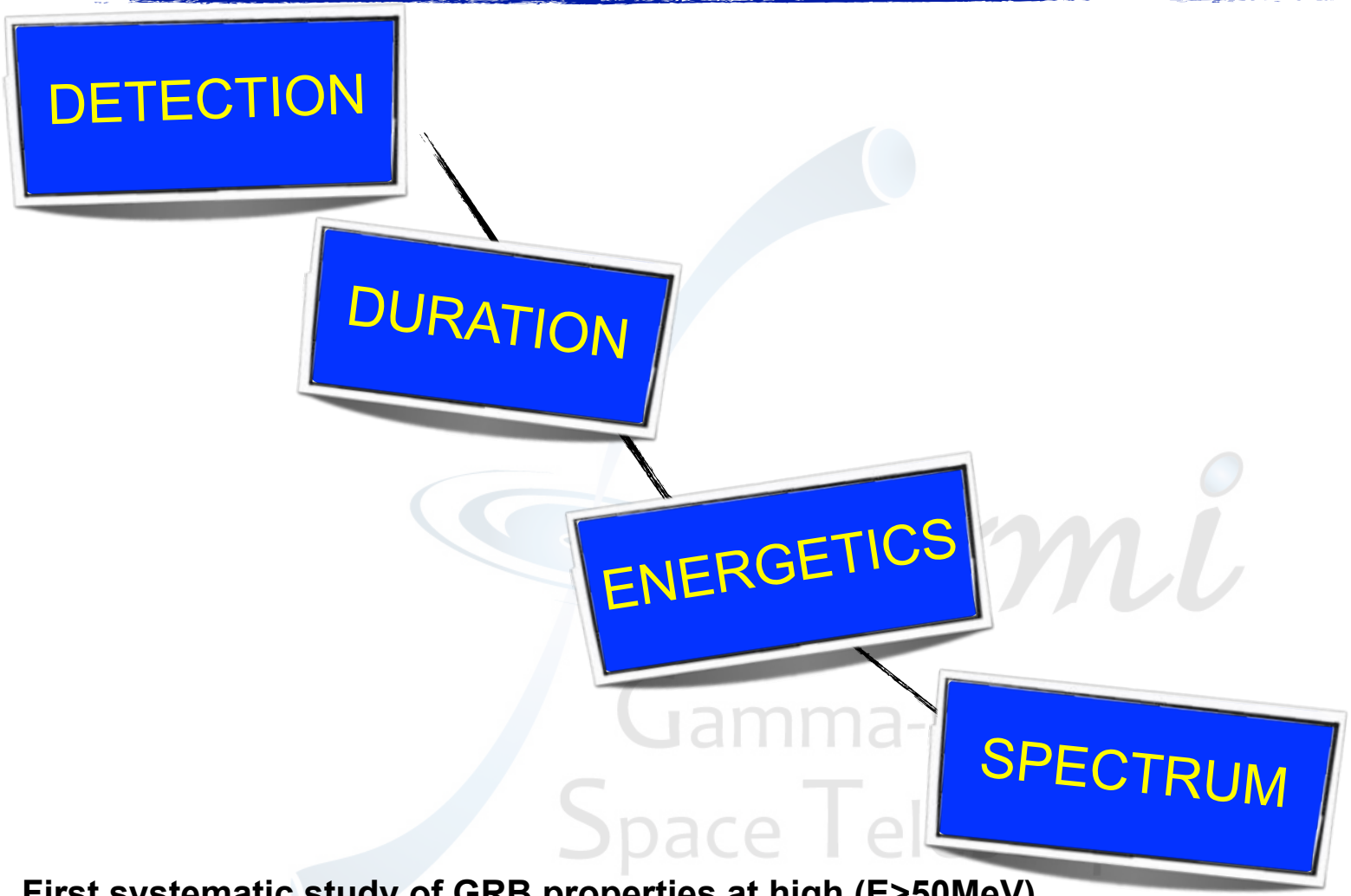
**Nicola Omodei (Stanford University)**

**Fred Piron, Vlasios Vasileiou, Giacomo Vianello**

**on behalf of the**

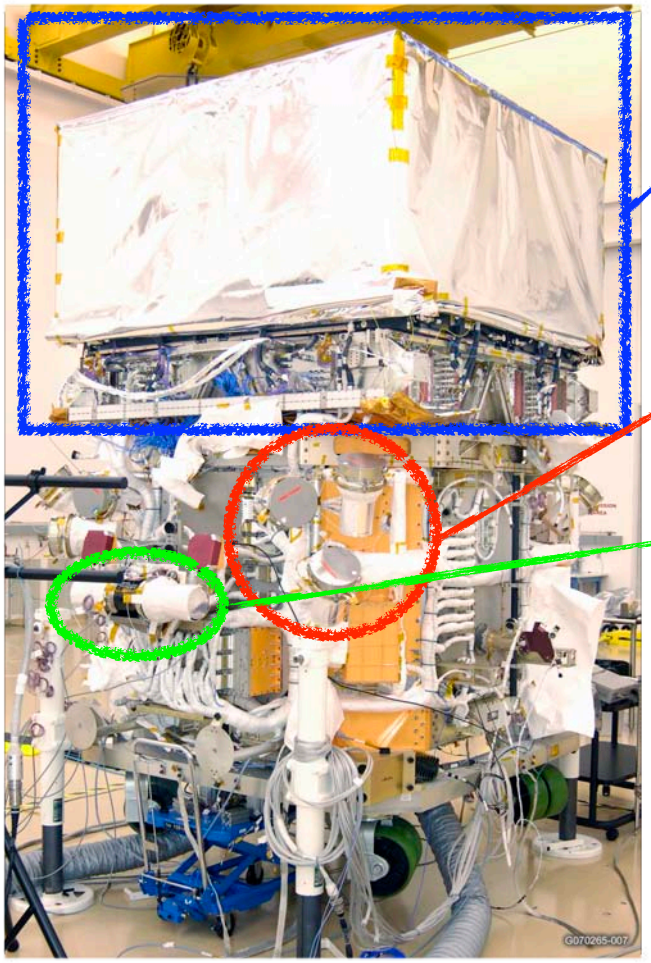
**Fermi Large Area Telescope collaboration**

# First LAT GRB catalog




- **First systematic study of GRB properties at high (E>50MeV) energies.**
  - **Covers bursts starting August 2008 – Feb 2011 (2.5 yrs).**

# The Fermi observatory

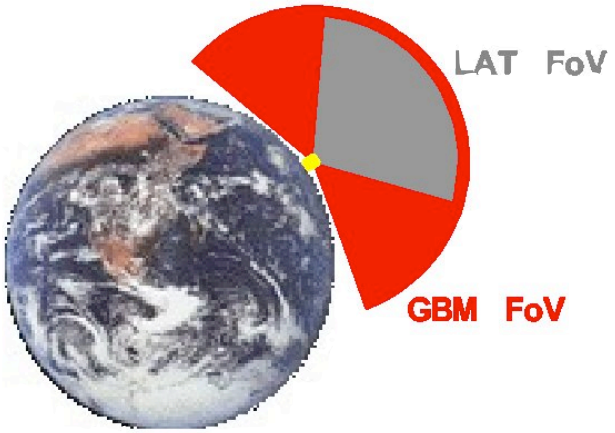


LAT : Pair conversion telescope
Trigger, localization, spectroscopy
20 MeV – > 300 GeV

GBM 14 PMT
12 NaI
Trigger, localization, spectroscopy
8 keV – 1 MeV
2 BGO
Spectroscopy
150 keV – 40 MeV

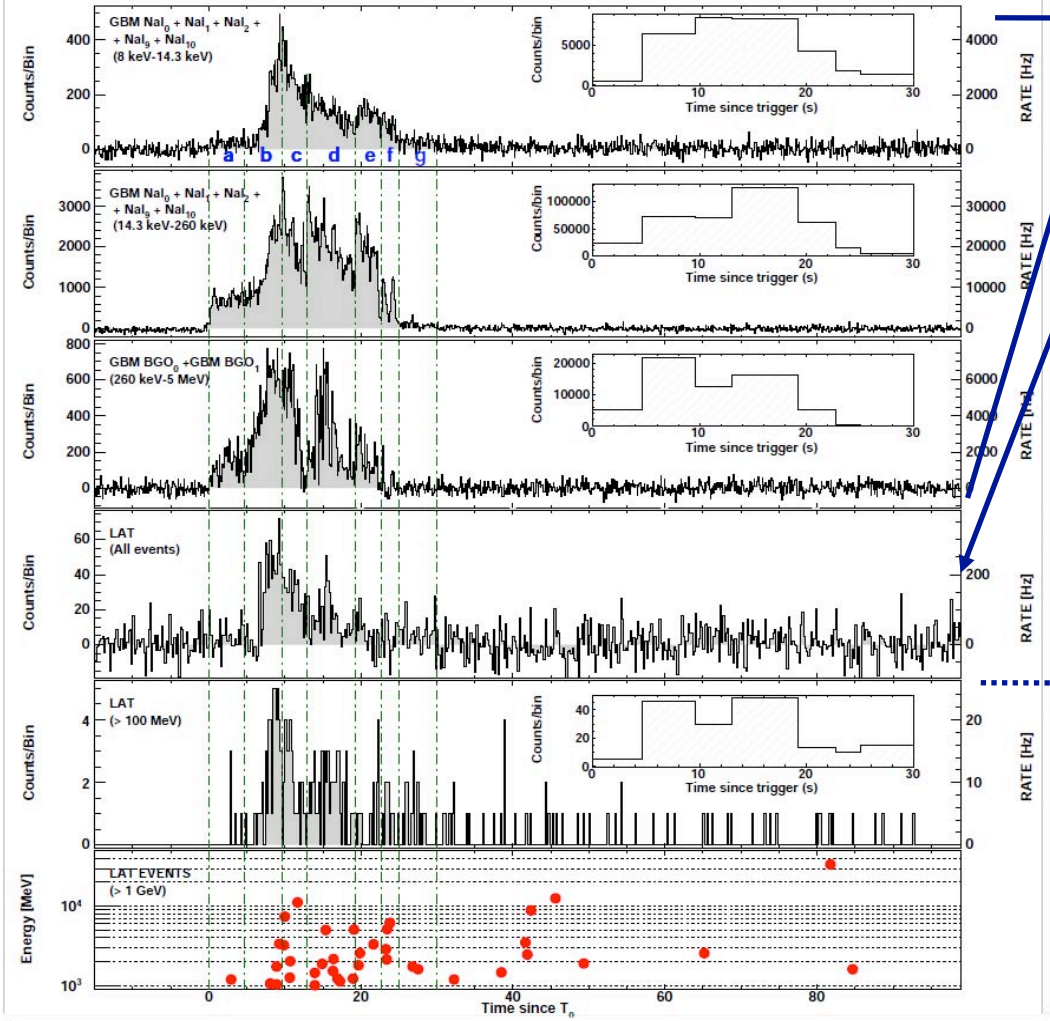
Fermi Spacecraft can **Repoint** to keep/bring GRB in the LAT FoV

Both GBM and LAT can *trigger* onboard on GRBs



# GRB data

**GRB 090902B**
**Abdo, A. A. et al. 2009, ApJL, 706, L138**




GBM data

**LAT Low Energy Event (LLE)**

On-board photon selection
One track required

V. Pelassa's talk in the "Analysis Methods" session

✓ High statistics
➢ Timing and spectral analyses (yet unpublished)
× High background rates
➢ (energetically) binned analyses of bkg-subtracted data

**LAT standard "transient" data**

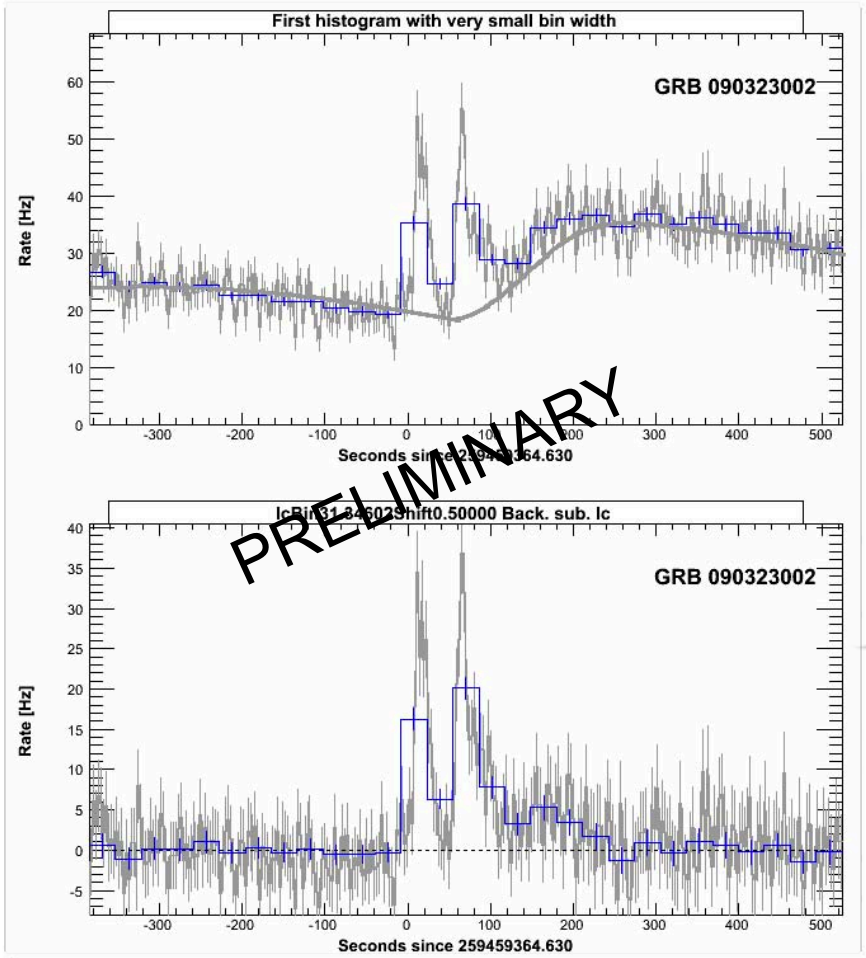
Tight quality cuts > 100MeV in ROI
➢ (very) low background
➢ (published) likelihood analyses :
spectra, localization
Even tighter cuts used for long-lived emissions (faint)

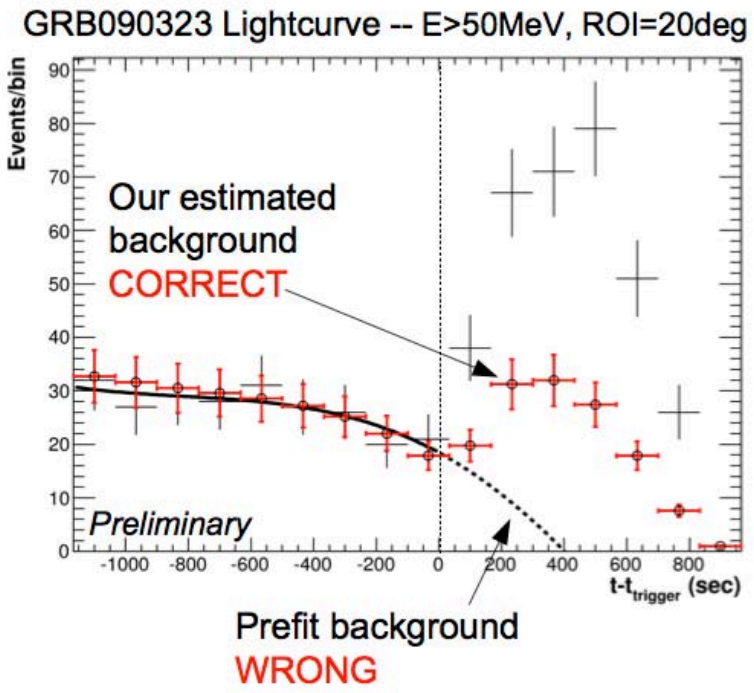
# Backgrounds

- The background in the LAT for GRB studies:
  - charged cosmic rays (dominant in “transient” class and “LLE” data);
    - geomagnetic coordinates of the spacecraft,
    - burst position in instrument coordinates (since the LAT’s acceptance varies with the incidence angle),
    - azimuthal angle of the burst position in Earth coordinates (East-West effect);
  - galactic, extra-galactic gamma rays, sources;
    - burst position in the celestial sphere
  - Earth’s albedo;
    - burst zenith angle, (highest towards the Earth’s limb);
- **Background varies with time!**
- **Transient** class events: Background estimator (BKGE):
  - Use first 2+ years of data to build up the statistics needed to estimate the background in **any position of the orbit, in any position of the sky, for any time interval**;
  - We **remove** the Earth Limb (zenith cut)
- **LLE data**:
  - Broad PSF: cannot remove the contamination from Earth Limb;
  - Background is modeled by a phenomenological function (poly in cos(theta(time)));
  - “Fit” the pre-burst and post burst intervals;

# Detection criteria

## LLE Data



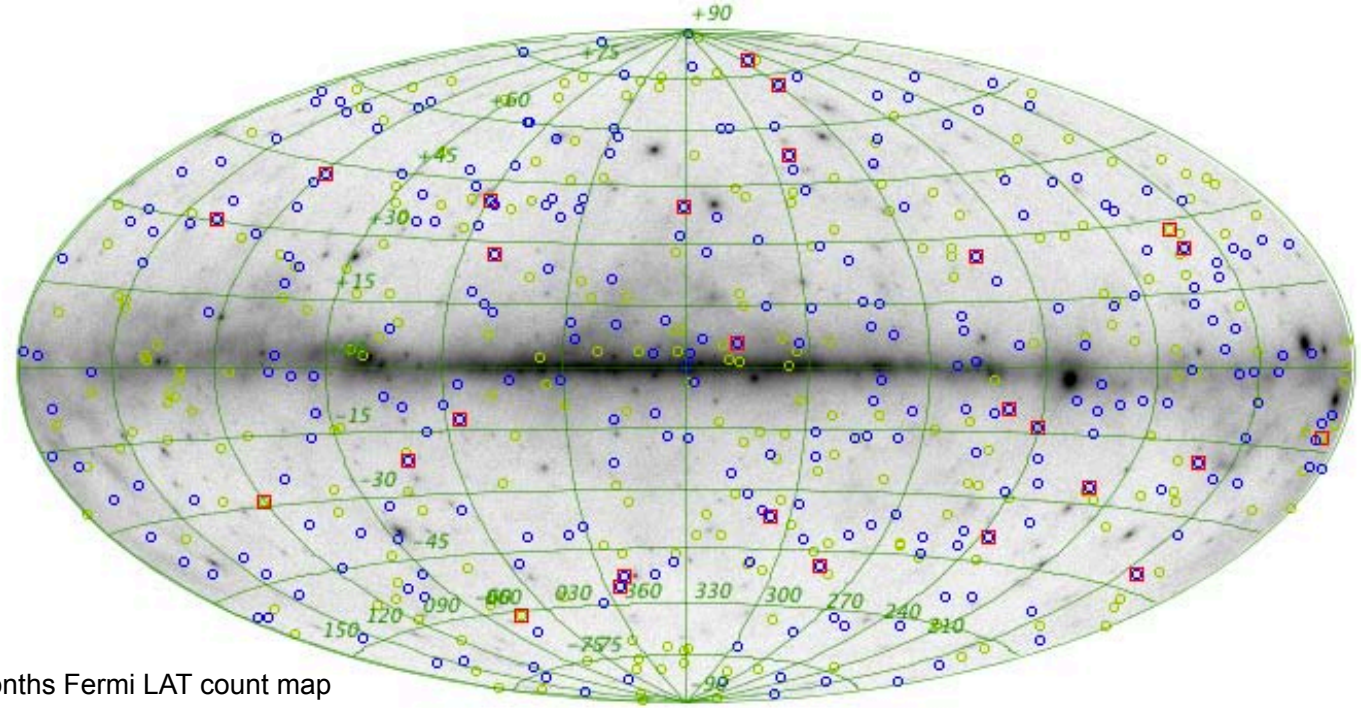




- **Starting from:**
  - **ALL GCN messages (and updated positions)**
  - **We look for GRB in LAT only data (Blind search analysis runs continuously)**
- **Two ways to look for detections:**
  - **LLE data, significant excess over the background level (above 4 sigma)**
  - **Transient-class Data >100MeV: Standard Likelihood analysis (TS>16)**

# Fermi detections as of 2011-01-20

~550 GBM GRB (since Aug 2008)
27 LAT GRB (7 LAT LLE-only GRB)

Circles:
In Field-of-view of LAT (<70˚): 275
Out of the FOV
Squares:
LAT detections




11 months Fermi LAT count map

PRELIMINARY

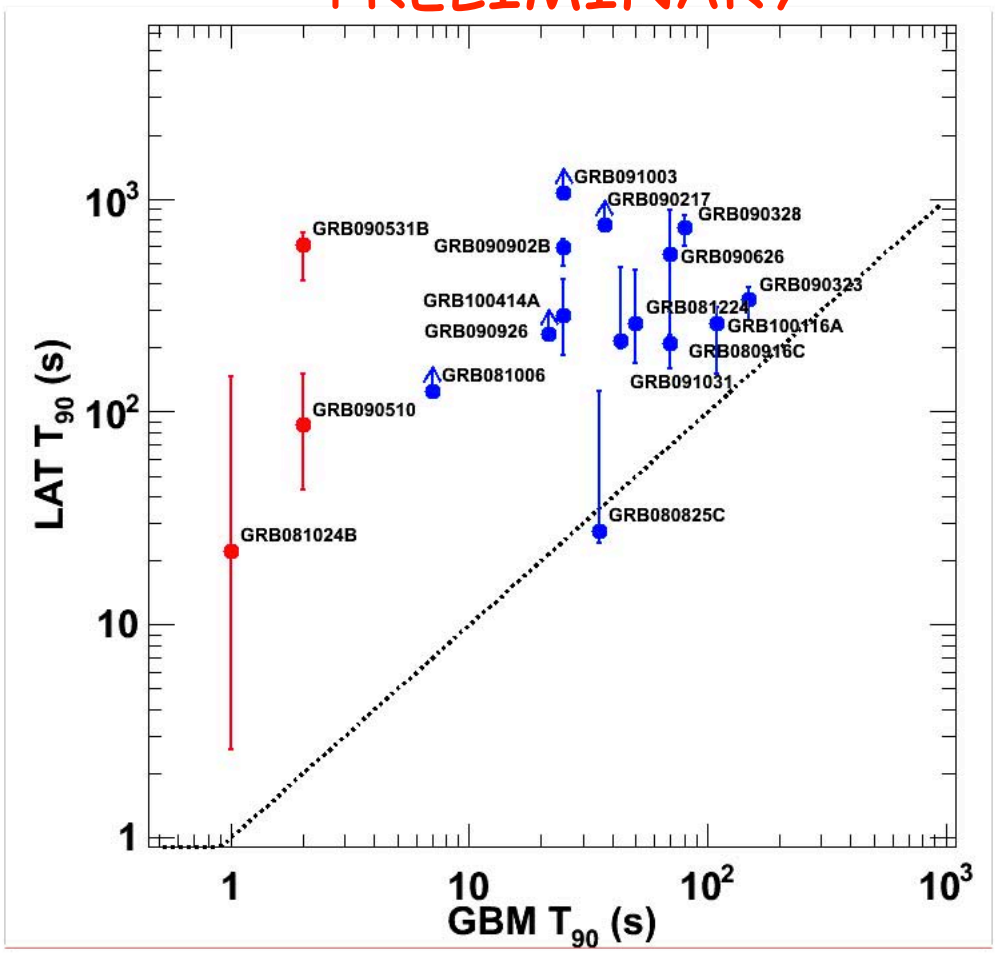
# Duration: Study of the extended emission

All about estimating the background!

$T_{90}$: time between the 5% and the 95% of the integrated signal above background;

Estimation of the errors done running simulations (Upper and lower bounds)

PRELIMINARY

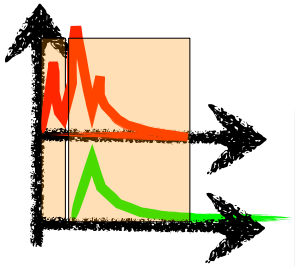



- **We measure a systematically longer duration in the LAT**
  - **Emission at GeV energy lasts longer than the emission at MeV energy**
    - **Different component?**
  - **OR, better sensitivity of the LAT detector (low background) than the GBM detector (background dominated)**
- **We also systematically measure a delayed onset between the GBM and the LAT emission**

# Spectrum & energetics

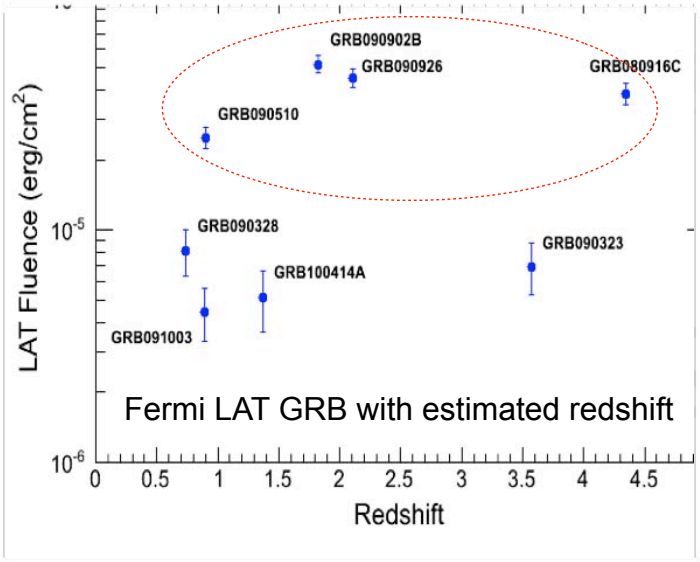
- **For Each GRB, we perform complete Un-binned Likelihood analysis;**
  - **We use transient event class, >100 MeV**
  - **We assume isotropic background in each ROI**
    - **Estimate the background using the background estimator**
- **GRB is modeled with a simple powerlaw**
  - **Integrated flux, spectral index,...**
  - **Time-resolved spectral analysis**
- **We also include results from GBM joint spectral fit:**
  - **Does the LAT show significant excess over the Band function?**
  - **Persistency of the power law component with time;**

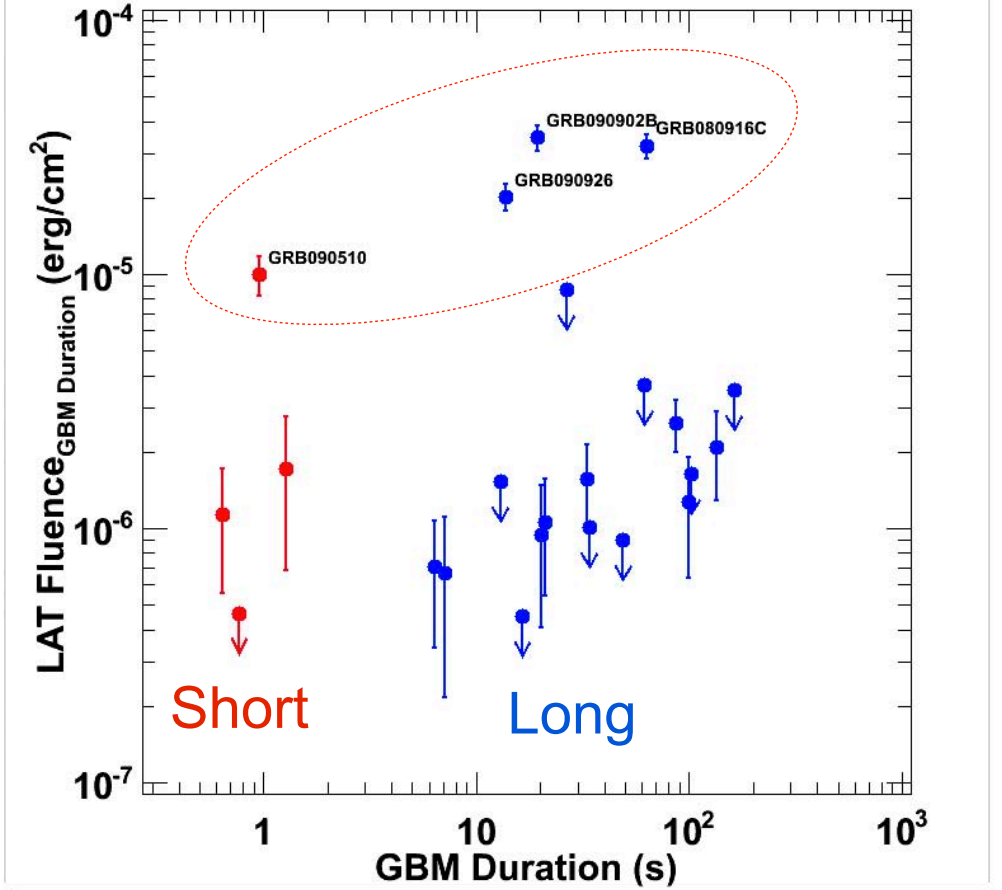
# The Fantastic 4 !



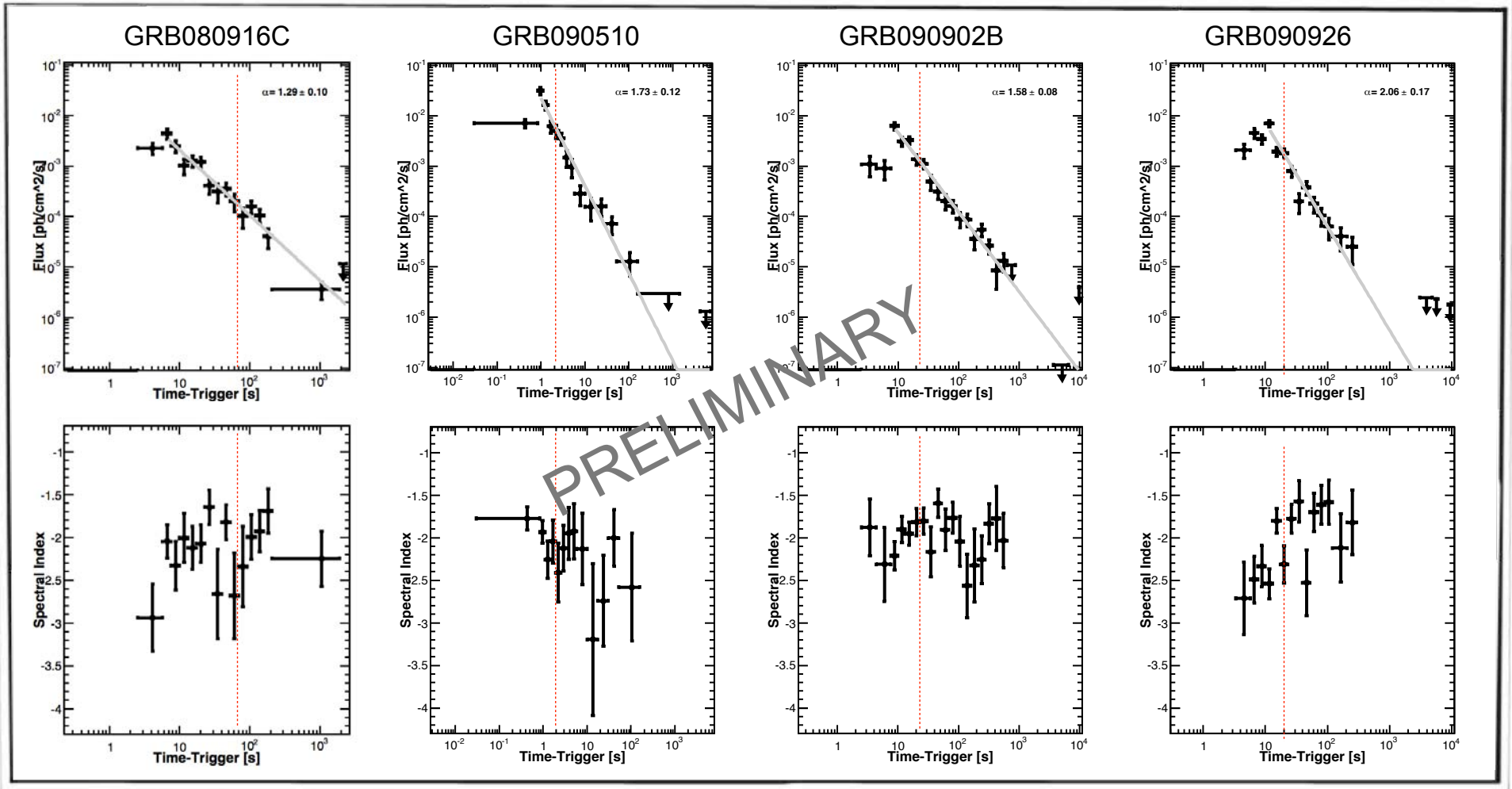
- **Four bursts show an exceptionally high fluence (100 MeV - 10GeV)**
- **These bursts are not the closest to us**

PRELIMINARY



# Extended Emission as seen by the LAT

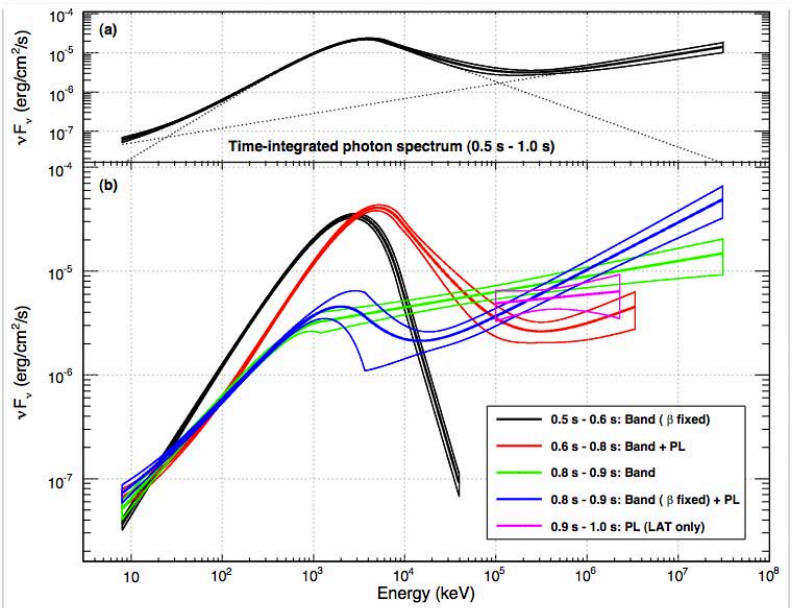



- **Red lines: GBM T90 durations**
- **Flux decays as a power law in time ($t^{-\alpha}$), $\alpha \sim 1 — 2$**
- **No clear breaks. Different type of spectral evolutions.**
- **Radiative vs Adiabatic fireball *(Ghisellini et al. 2009)***

# Evidence of the "extra components"

## GRB 090510

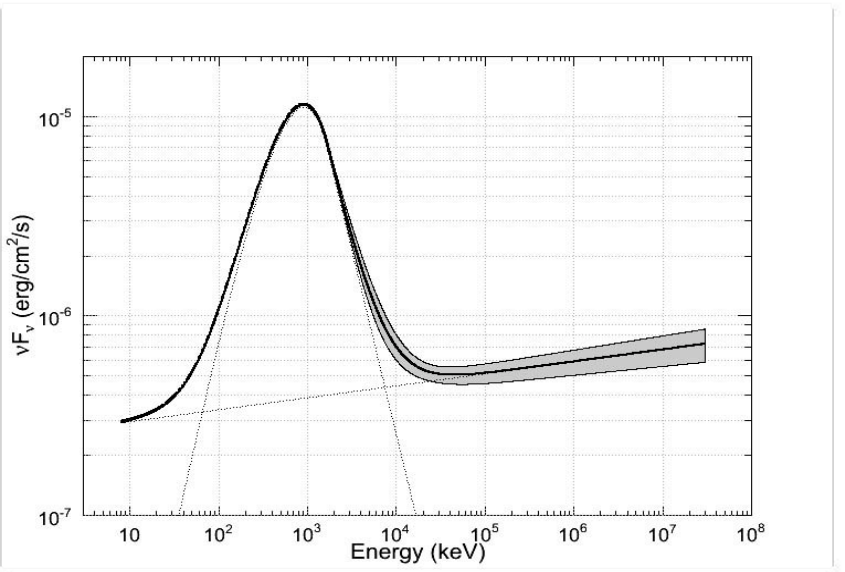
*Ackermann, et al. 2010, ApJ, 716, 1178*




Joint spectral fit (of binned data) :
GBM<40MeV
standard LAT data>100MeV

## GRB 090902B

*Abdo et al. 2009,ApJ, 706L, 138A*




- Constrains main keV-MeV component
- Spectral evolution during prompt phase
- **Additional PL component seen at high and low energies**

# Summary Table & Highest Energy Events compatible with the GRB position

| GRB Name | Likelihood Detection >100 MeV | LLE Detection | LAT off axis angle at $T_0$ (degrees) | GBM $T_{90}$ | N Pred. Events (>100MeV, Trans.) | HE Delayed Onset? | Long Lived HE Emission? | Maximum Energy (GeV) meas. during the LAT detection | Arrival time of the highest events (seconds since trigger) | Redshift |
|---|---|---|---|---|---|---|---|---|---|---|
| GRB080825C | √ | √ | 60.3 | 21 | 10 | √ | √ | 0.6 | 28.3 | - |
| GRB080916C | √ | √ | 48.8 | 63 | 211 | √ | √ | 13.2 | 16.5 | 4.35 |
| GRB081006 | √ | x | 10.7 | 6.4 | 13 | - | √ | 0.6 | 1.8 | - |
| GRB081024B | √ | √ | 18.6 | 0.6 | 11 | √ | √ | 3.1 | 0.6 | - |
| GRB081215 | x | √ | 97.1 | 5.6 | - | - | - | - | - | - |
| GRB081224 | x | √ | 17 | 16.4 | - | √ | √ | - | - | - |
| GRB090217 | √ | √ | 34.5 | 33.3 | 17 | √ | √ | 0.9 | 14.8 | - |
| GRB090227B | √ | √ | 70.1 | 1.3 | 3 | - | - | - | - | - |
| GRB090323 | √ | √ | 57.2 | 135.2 | 39 | √ | √ | 7.5 | 195.4 | 3.57 |
| GRB090328 | √ | √ | 64.6 | 61.7 | 58 | √ | √ | 5.3 | 698.3 | 0.736 |
| GRB090510 | √ | √ | 13.6 | 1 | 183 | √ | √ | 31.3 | 0.8 | 0.903 |
| GRB090531B | x | √ | 21.9 | 0.8 | - | - | - | - | - | - |
| GRB090626 | √ | √ | 18.2 | 48.9 | 30 | √ | √ | 2.1 | 111.6 | - |
| GRB090902B | √ | √ | 50.8 | 19.3 | 323 | √ | √ | 33.4 | 81.7 | 1.822 |
| GRB090926 | √ | √ | 48.1 | 13.8 | 252 | √ | √ | 19.6 | 24.8 | 2.106 |
| GRB091003 | √ | √ | 12.3 | 20.2 | 33 | √ | √ | 2.8 | 6.5 | 0.897 |
| GRB091031 | √ | √ | 23.8 | 33.9 | 16 | √ | √ | 1.2 | 79.7 | - |
| GRB100116A | √ | √ | 26.6 | 102.5 | 21 | - | √ | 2.2 | 105.7 | - |
| GRB100225A | x | √ | 54.9 | 13 | - | - | - | - | - | - |
| GRB100325A | √ | x | 7.4 | 7.1 | 5 | - | √ | 0.8 | 0.4 | - |
| GRB100414A | √ | √ | 69 | 26.5 | 28 | √ | √ | 4.3 | 39.3 | 1.368 |
| GRB100707A | x | √ | 90.3 | 81.8 | - | - | - | - | - | - |
| GRB100724B | √ | √ | 48.8 | 87 | 24 | - | - | 0.1 | 15.4 | - |
| GRB100728A | √ | x | 59.9 | 162.9 | 17 | - | √ | 1.7 | 709 | - |
| GRB101014A | x | √ | 54.1 | 450.9 | - | - | - | - | - | - |
| GRB101123A | x | √ | 84.2 | ~160 | - | - | - | - | - | - |
| GRB110120A | √ | x | 13.7 | ~20 | 9 | - | √ | 1.8 | 72.5 | - |

Last bright GRB: Sept 2009!

PRELIMINARY

# Summary

- **First Fermi/LAT catalog of GRBs on its way!**
  - **Systematic study of LAT GRBs**
    - **First catalog of GRB at high energy;**
    - **Also includes methodology to reproduce the analysis;**
  - **Using both LLE data + standard transient class data**
  - **27 GRB (7 LLE only, 4 likelihood only, 4 very bright bursts)**

- **Common observed properties:**
  - **Temporal extended emission (long lasting);**
  - **Delayed onset between LAT and GBM emission;**
  - **"Extra component"**
- **All numbers here are <u>preliminary</u>, a paper will come out soon!**