On the origin of the high-energy emission from short γ-ray bursts observed by *Fermi*

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On behalf of the *Fermi*
GBM and LAT teams

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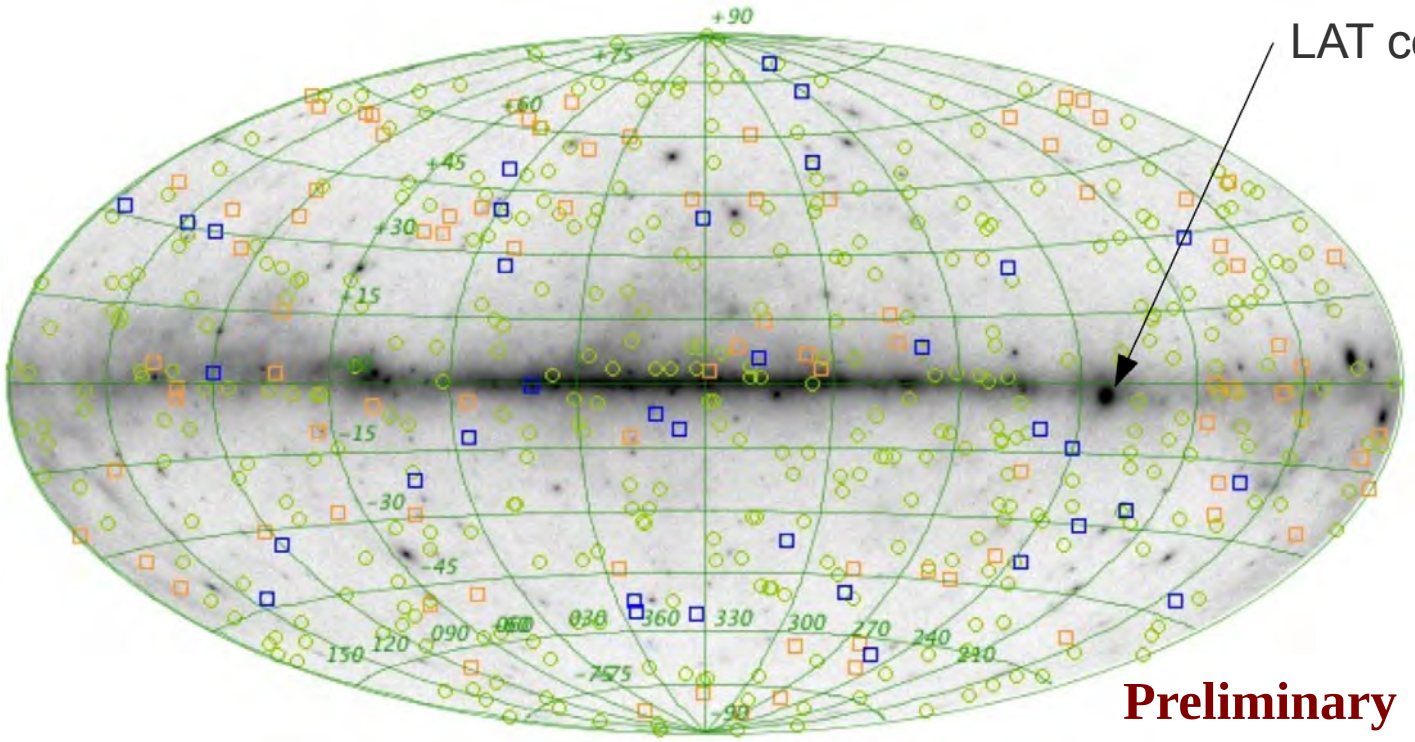
UAHuntsville
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Outline

Gamma-Ray Bursts observed by Fermi
Properties of short GRB detected by the LAT
Prompt emission properties of the short GRB observed by the GBM

First Fermi GRB catalogs



LAT count map : first 11 months

GBM catalog (07/08 –07/10)
Green circles : long GRB
Orange squares : short GRB
trigger cat : Paciesas et al. 2012
spec cat : Goldstein et al. 2012
(ApJS 199, articles 18 & 19)
http://fermi.gsfc.nasa.gov/ssc/

Blue squares : LAT GRB from in prep. catalog (08/08 – 08/11)

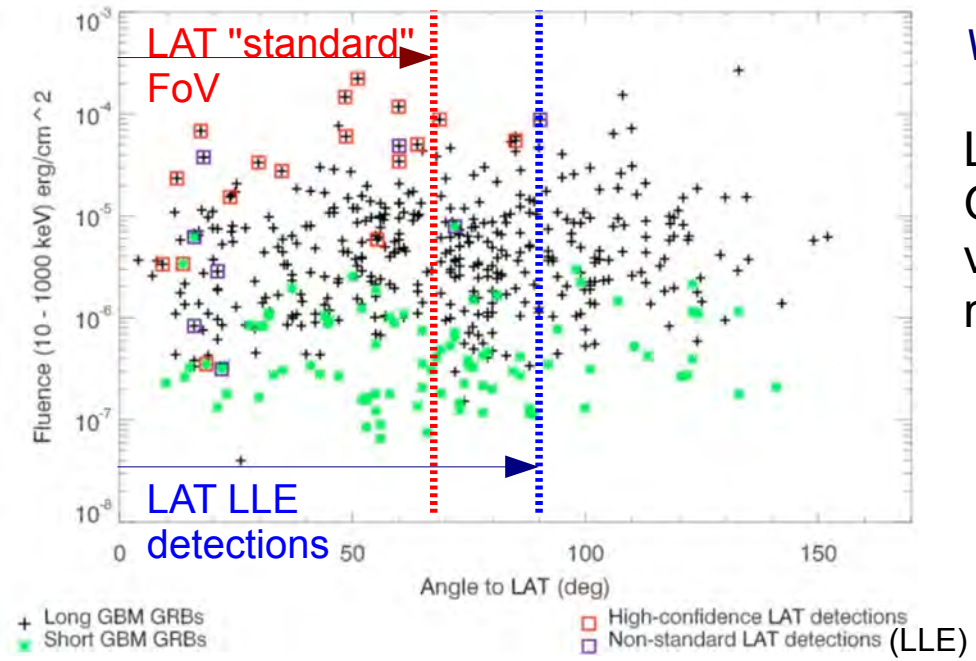
Preliminary

GBM (8keV – 40MeV) : ~250 GRB/yr, ~45/yr are short.
~1/2 GRB occur within the LAT FoV
LAT (20MeV – 300GeV) : ~10 GRB/yr, i.e. ~8% of GBM GRB located in the LAT FoV.

5 short GRB in 4yrs
→ 2 high-confidence detections (likelihood analyses of LAT "standard" data >100MeV)
→ 3 LLE-only detections ("LAT Low-Energy" = bkg-limited event class, incresing γ statistics esp. <100MeV ; suitable for transient sources)

Why are short GRB (not) detected at high energies (i.e. in the LAT) ?

LAT detections among GBM GRB



V. Connaughton et al, 2012

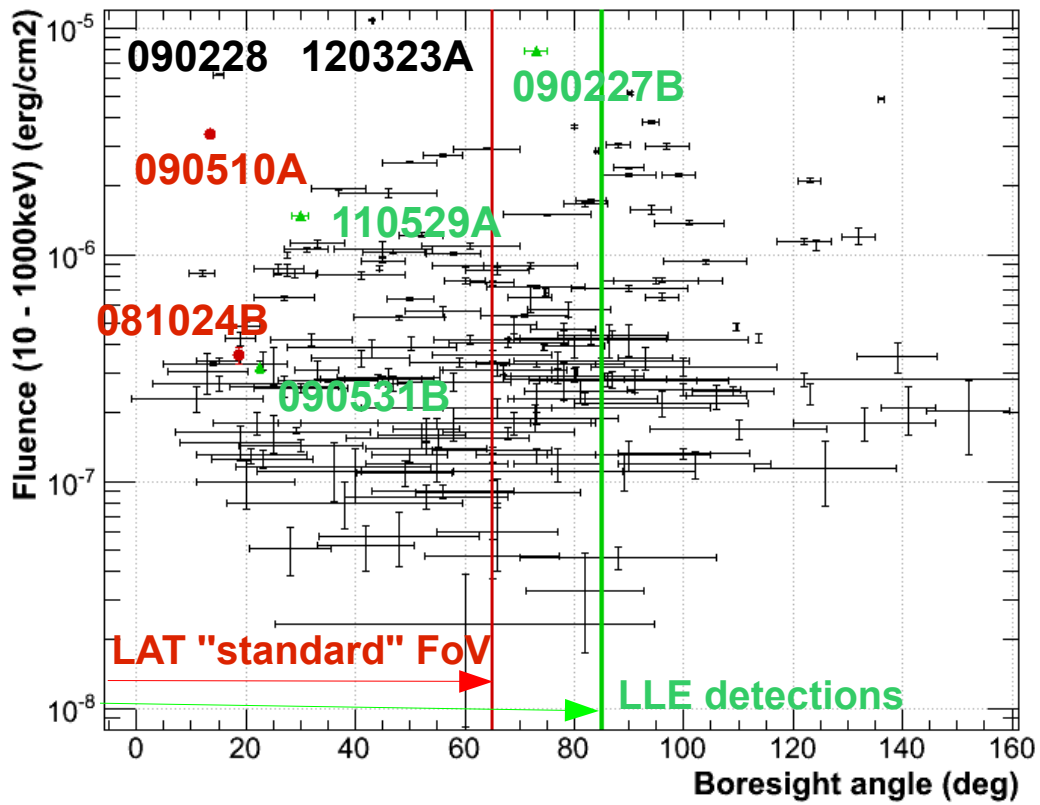
LAT detected bursts are a sub sample of bright GBM GRB. Except well within the LAT field-of-view (angle to LAT boresight <~40°) where it is most sensitive.

179 GBM sGRB (07/2008 – 07/2012)

2 High-confidence (likelihood) detections

3 LLE-only detections (LLE)

→ Fluence and location in the LAT FoV are not the only criteria.



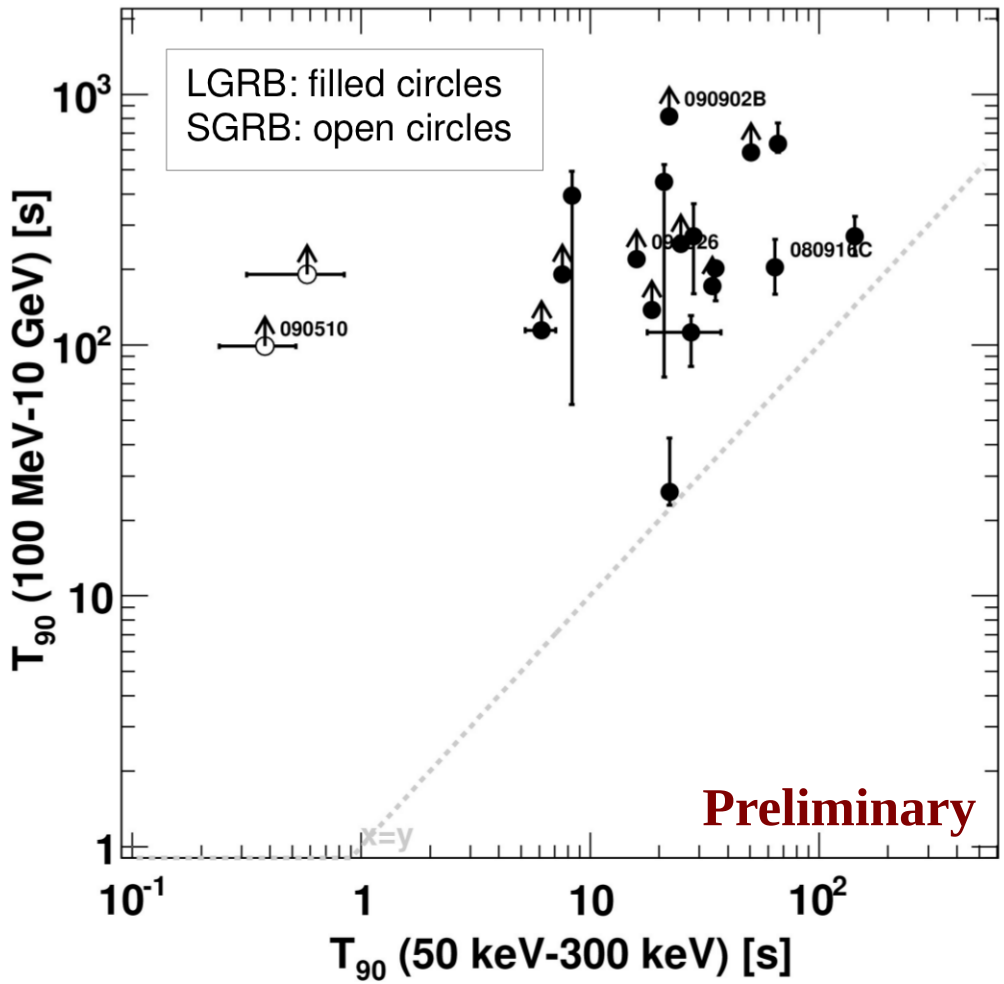
Fluences and locations from:

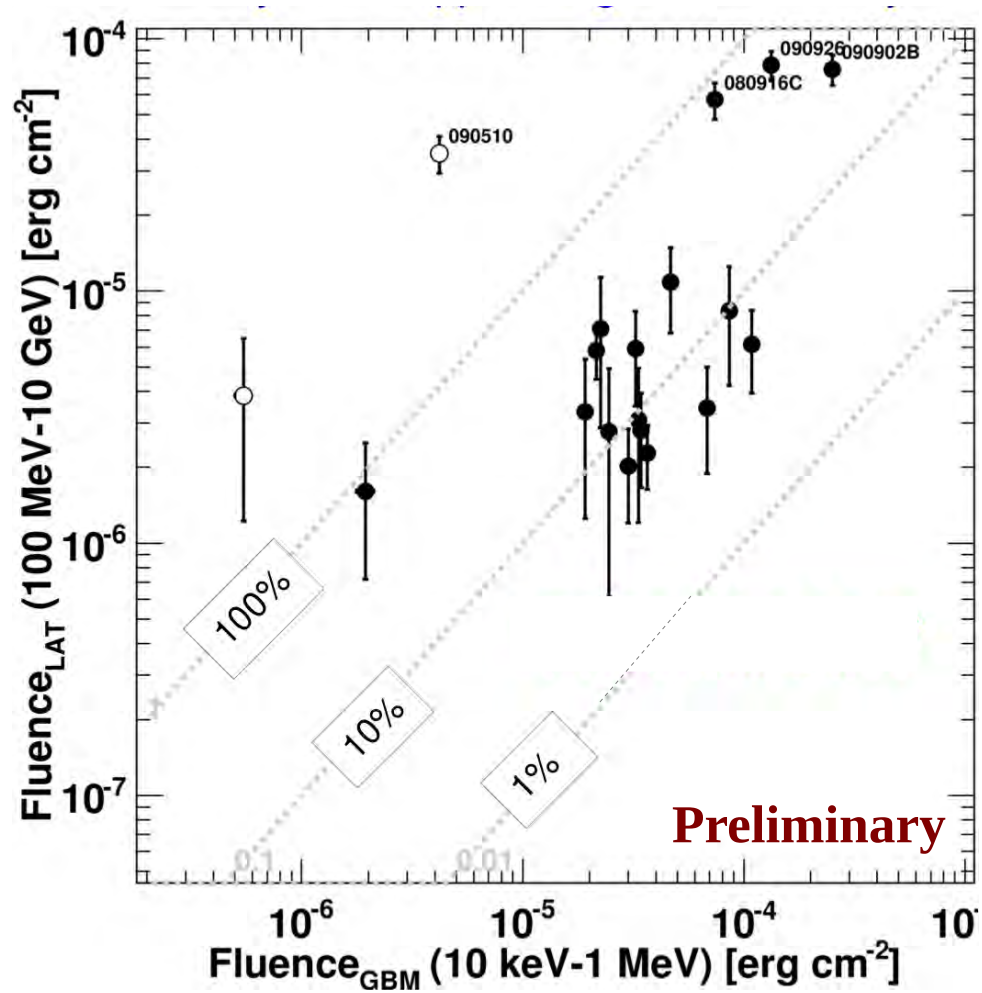
1st GBM catalog (<08/10) *(Paciesas et al, 2012)*

2nd GBM catalog (<08/12) *(von Kienlin et al, in prep)*

(see A. von Kienlin's talk)

Long-lived emissions at high energies

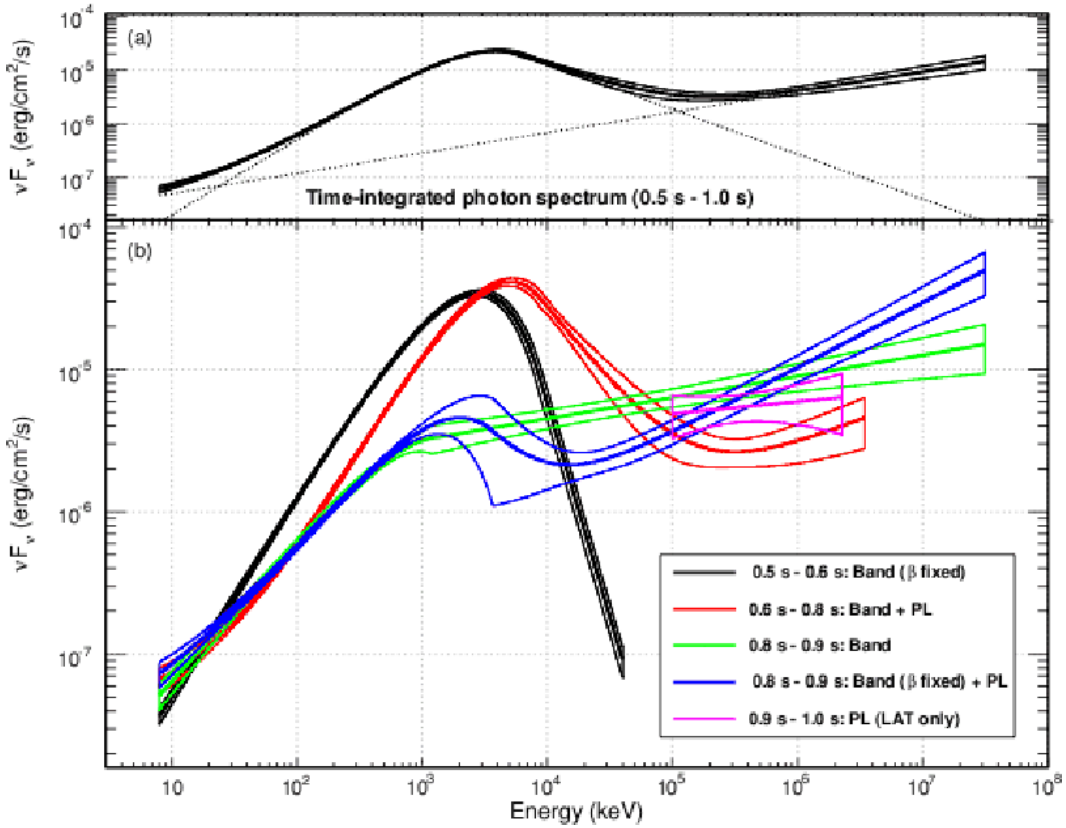




(LAT GRB catalog, in prep) ***(also see G. Vianello's talk)***

Both sGRB detected above 100MeV in the "standard" analysis exhibit a high-energy emission lasting much longer than the prompt emission observed by GBM.

Additional power law component



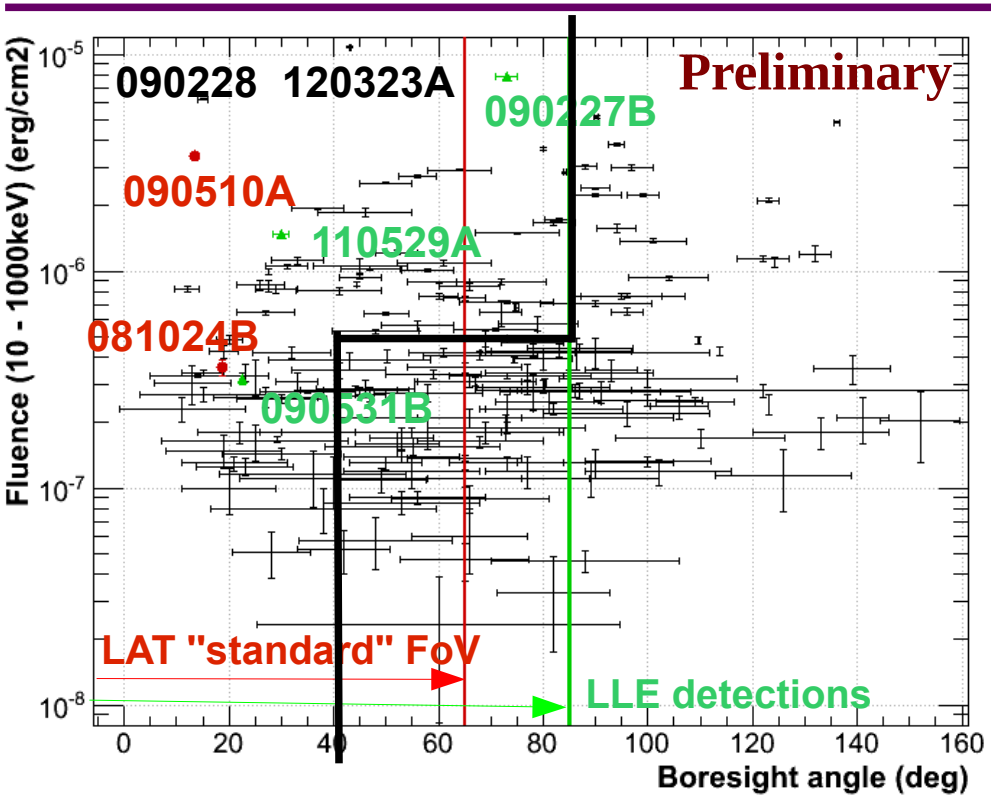
GRB 090510
Averaged & time-resolved spectra
M. Ackermann et al. 2010

This additional power law was can also be found in bright GRB 090227B and GRB 090228A *(Guiriec et al, 2010)*. An excess is found at low energies, aligned with this hard component.

Bright short GRB120323A ***(see S. Guiriec's talk)*** does not show this hard component, neither does (somewhat dimmer) LAT-detected GRB 081024B.

Why are short GRB (not) detected at high energies (i.e. in the LAT) ?
Is it due to overall brightness, this additional spectral component, the high energy extended emission ?
Does it relate to the prompt emission observed in the keV – MeV range ?

Prompt emissions of a subsample of sGRB



Total population : 179 sGRB

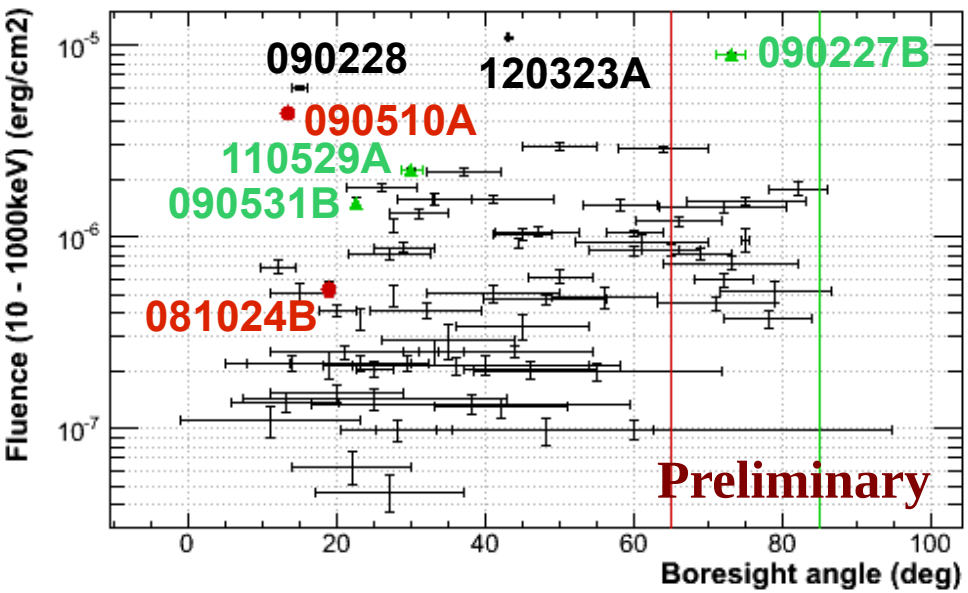
Selection :

1/ θ<42°: LAT standard eff. area ~flat, or

2/ Fluence >5e-7erg/cm² and θ<85°

3/ In spectral catalog (constrained spectra)

Study sample : 71 sGRB
(LAT or LLE detections and non-detections observed under similar conditions)

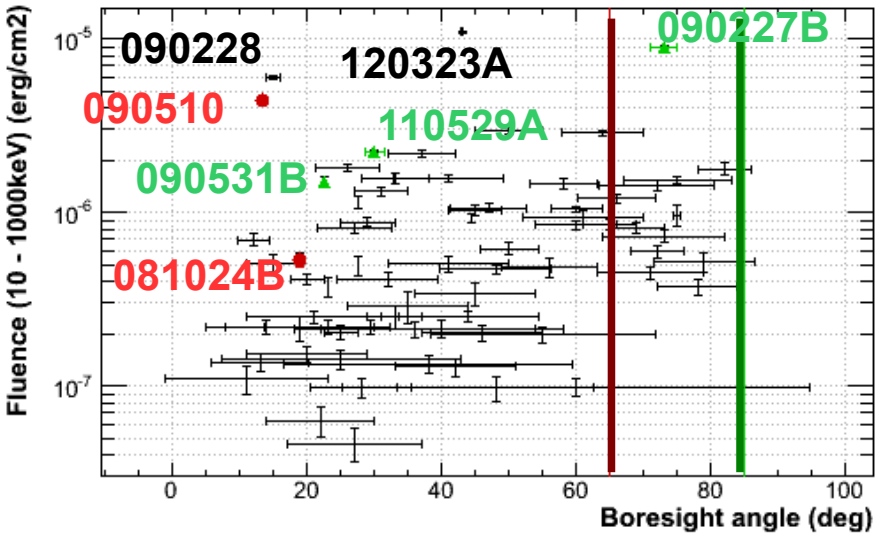


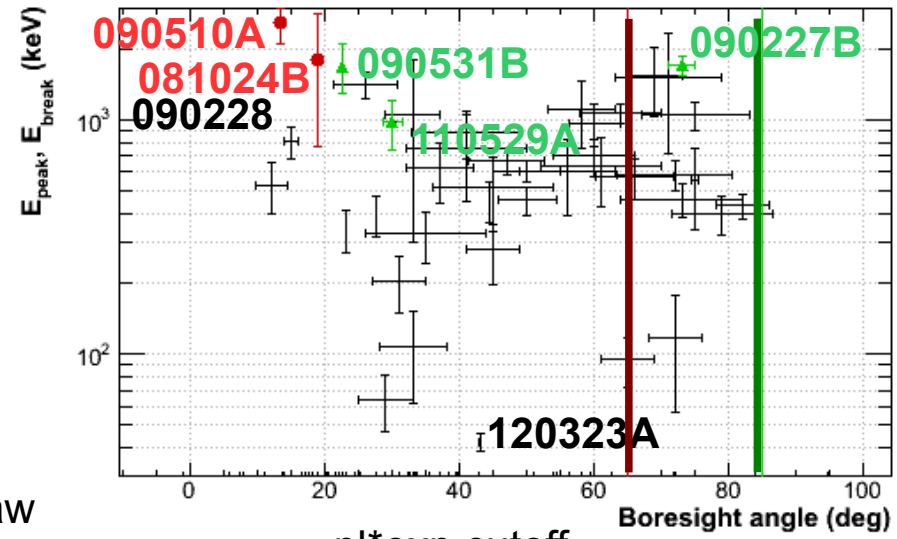
Fluences and spectral parameters from:
1st GBM spectral catalog *(Goldstein et al, 2012)*
2nd GBM catalog *(von Kienlin et al, in prep)*

Time interval for spectral analysis not strictly equal to T_{90} → fluences change a little

Spectral parameters (vs boresight angle)

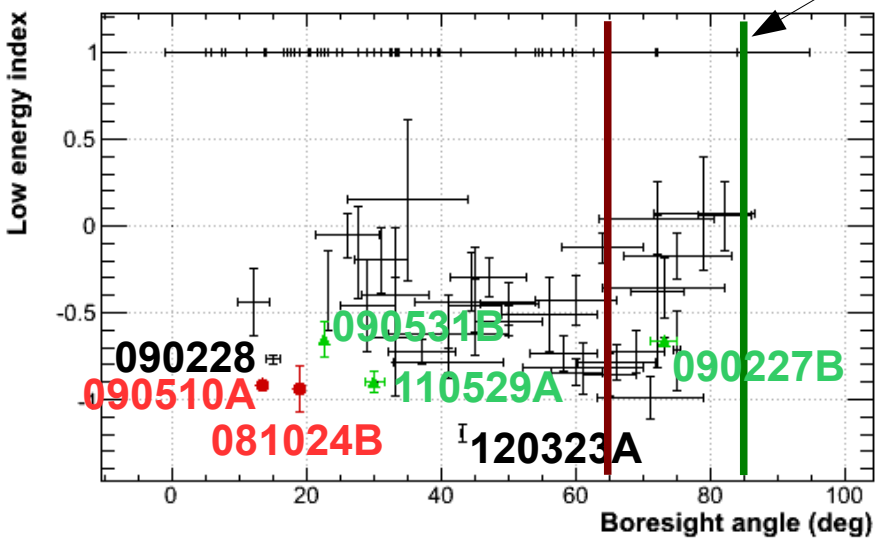
Spectral fits : power law (low counts), power law*exp cutoff,
Band function *(D. Band et al, 1993)*, smoothly broken power law
(all plots preliminary)

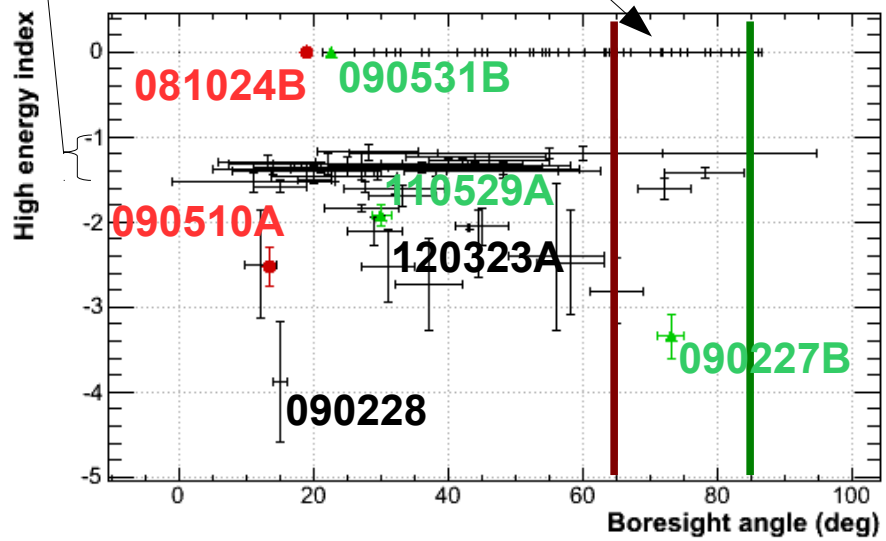




Powerlaw
(too few counts)

pl*exp cutoff





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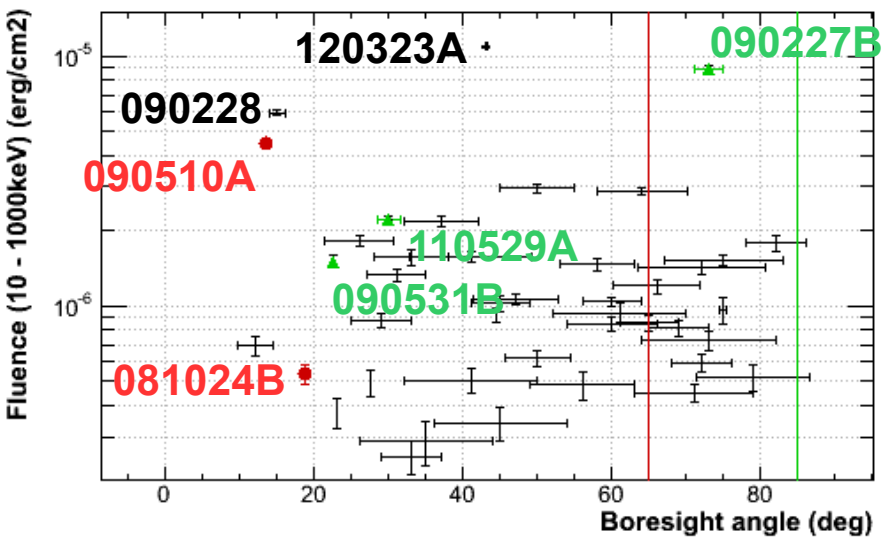

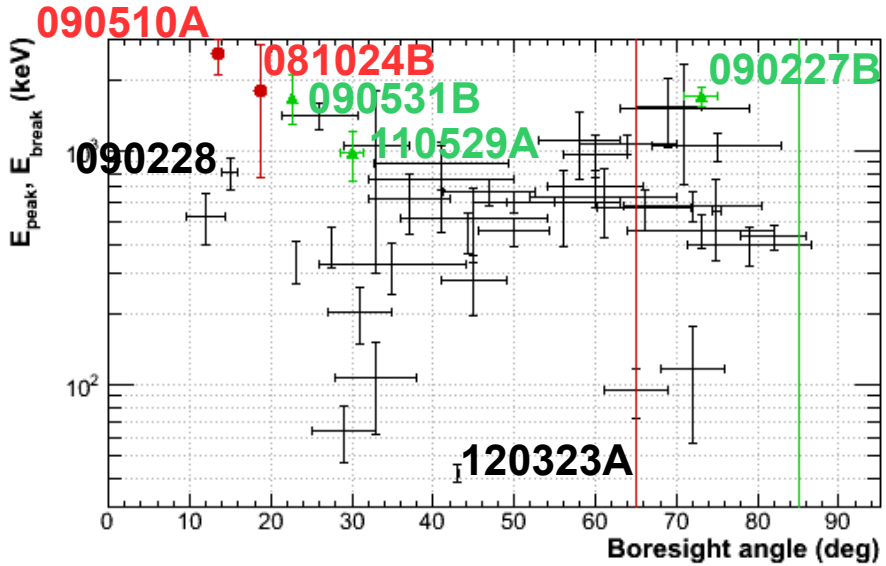

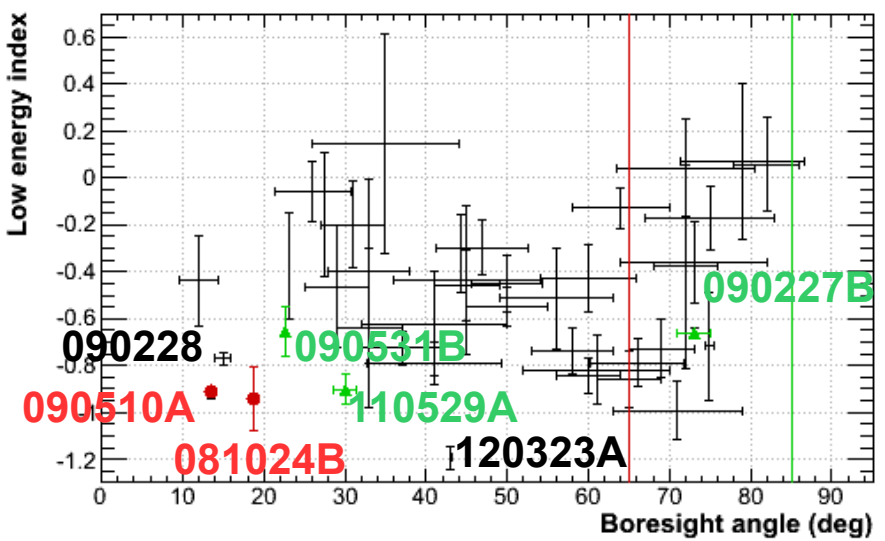

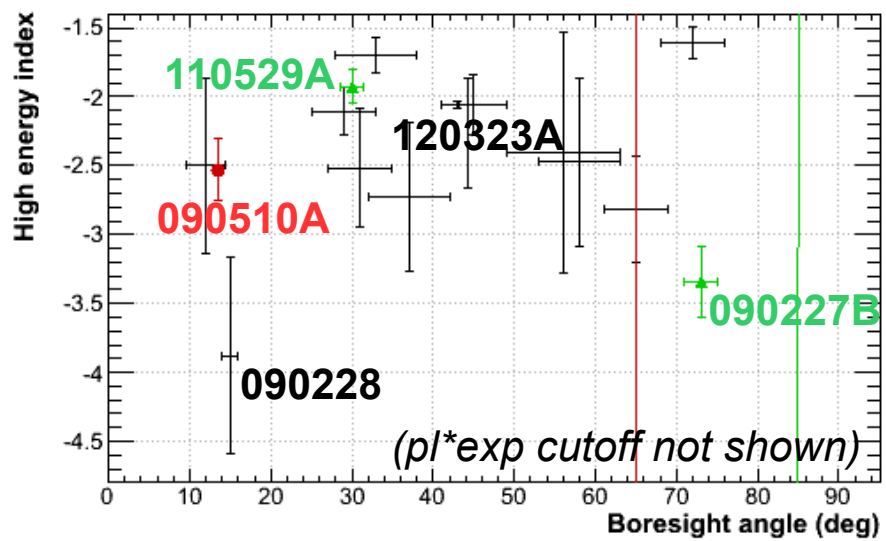

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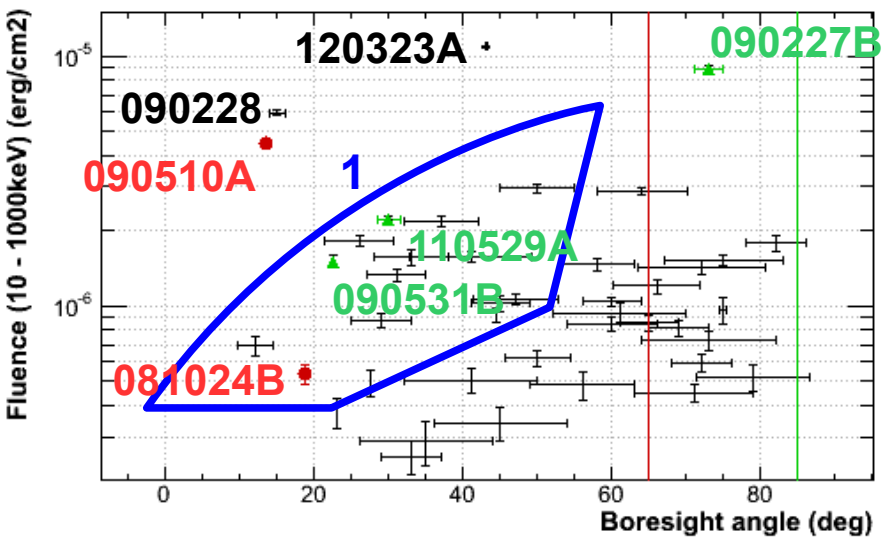
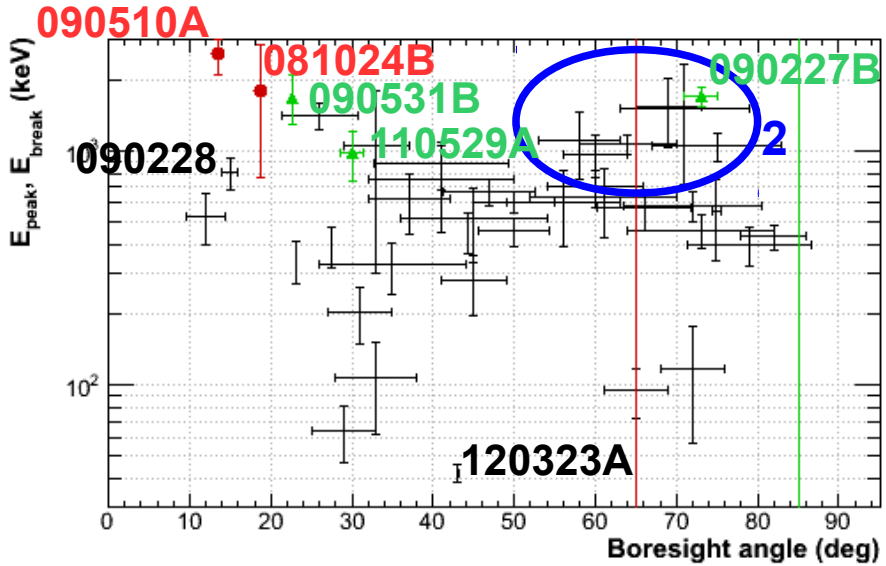
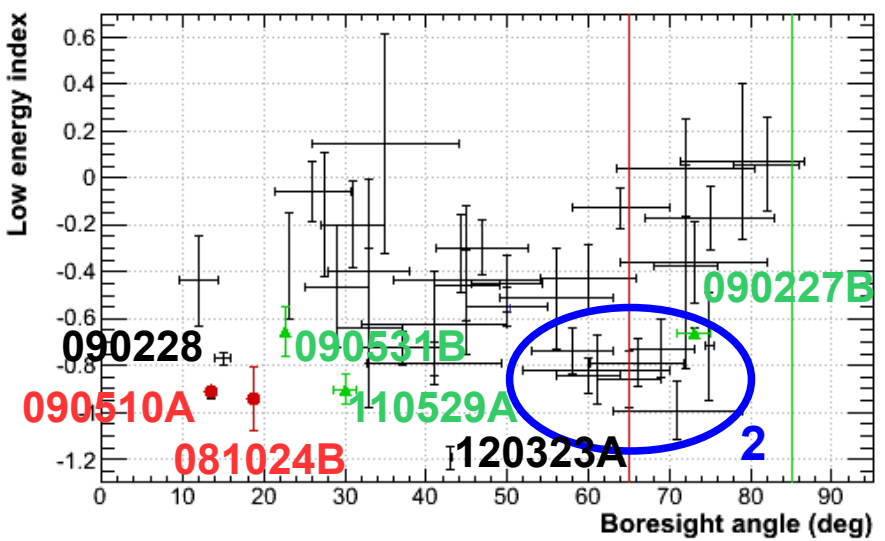
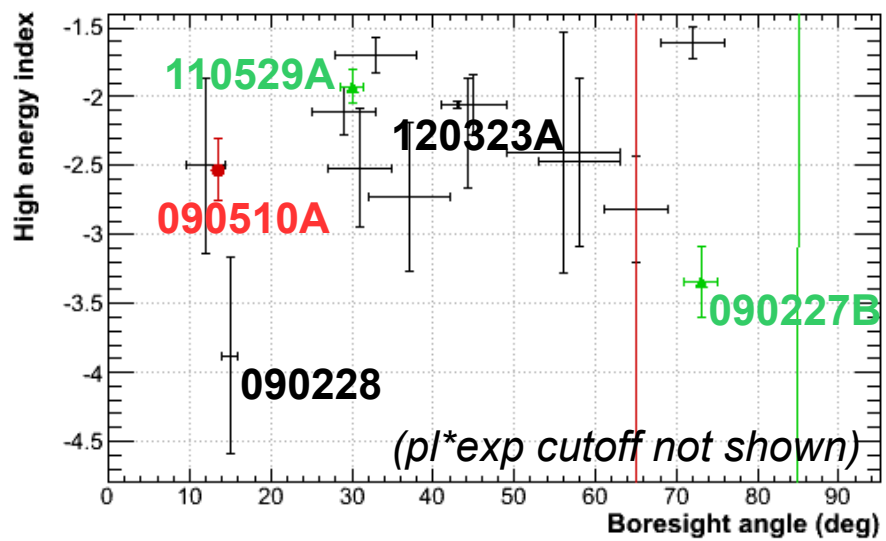








Trends and correlations

LAT (likelihood) and LLE detections :
Enough counts to be fit by better than a simple power law
Soft low energy index (relatively to other short GRB)
And Band E_{peak} or SBPL E_{break} ~MeV

Other bursts with "similar" observation conditions (boresight angle) :

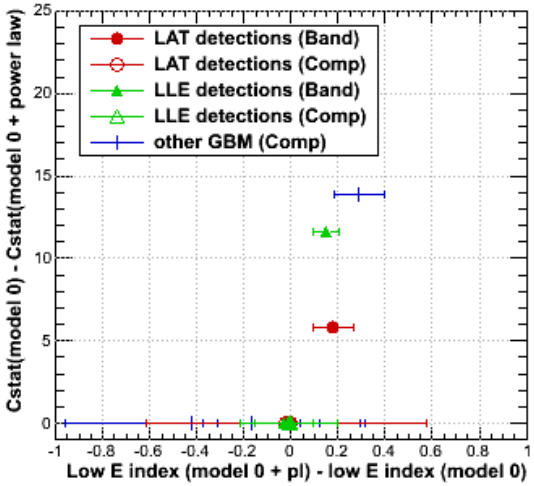
High fluence bursts (090228, 120323A and cluster 1)
E_{peak} <1MeV

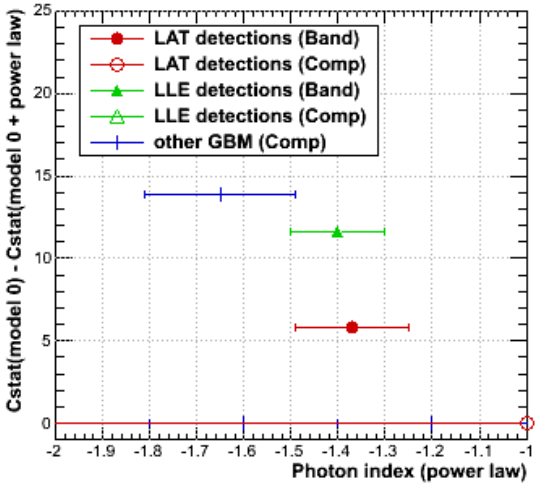
Bursts with a high Epeak and a soft low energy index (cluster 2)
At large boresight angles : fluences significantly lower than GRB090227B's.

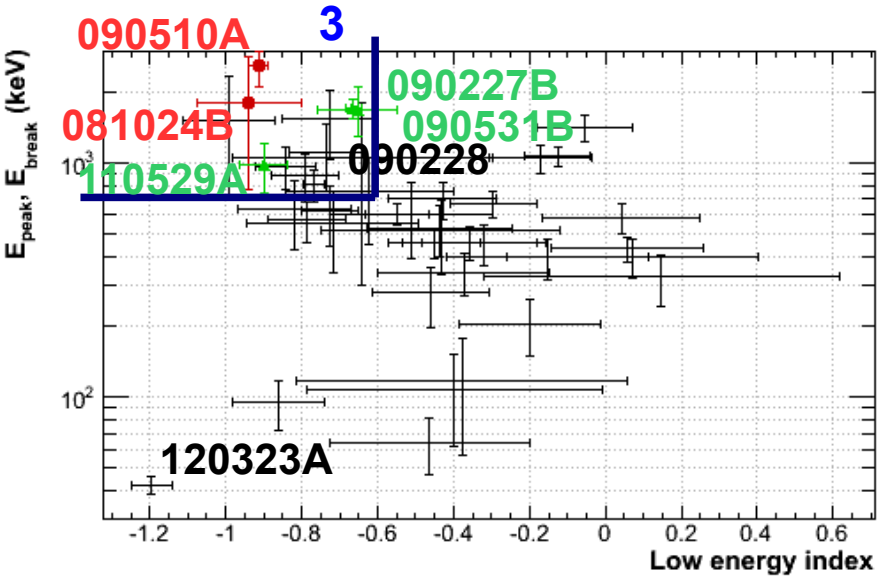
→ **possible link between the high-energy emission and the keV – MeV component's peak energy (in the FoV) and fluence (out of FoV).**

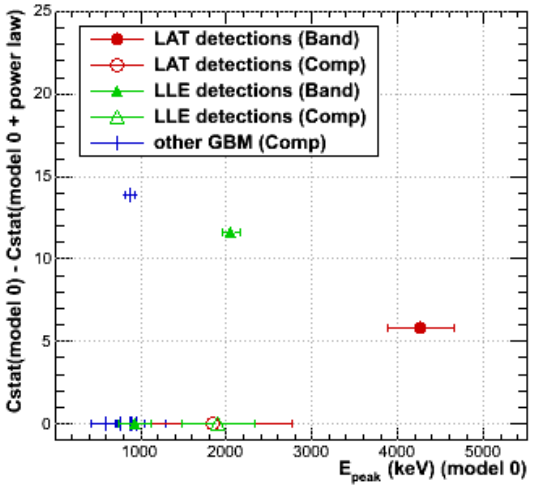
E_{peak} and the detection at high energies

Investigation of cluster 3 :
E_{peak} or E_{break}> 700keV and low energy index < -0.6
(plots preliminary)









Testing the significance of a power law component added to a Band function or a powerlaw with exponential cutoff ("Comp").

→ **several types of LAT-detected bursts**
→ **low-E deviation and hard component do not evolve together**
→ **E_{peak} drives the behaviour of the hard component**

GBM data used only. Fluence spectra : do not account for (strong) spectral evolution *(Guiriec et al, 2010)*

Summary

– *Fermi* GBM observations yield a large sample of short GRB, and the broad energy range covered by both *Fermi* instruments together allows the identification of multiple spectral components.

– A (relativeley) soft negative low energy index can hide an additional spectral component but no obvious correlation to the HE emission's properties is found.

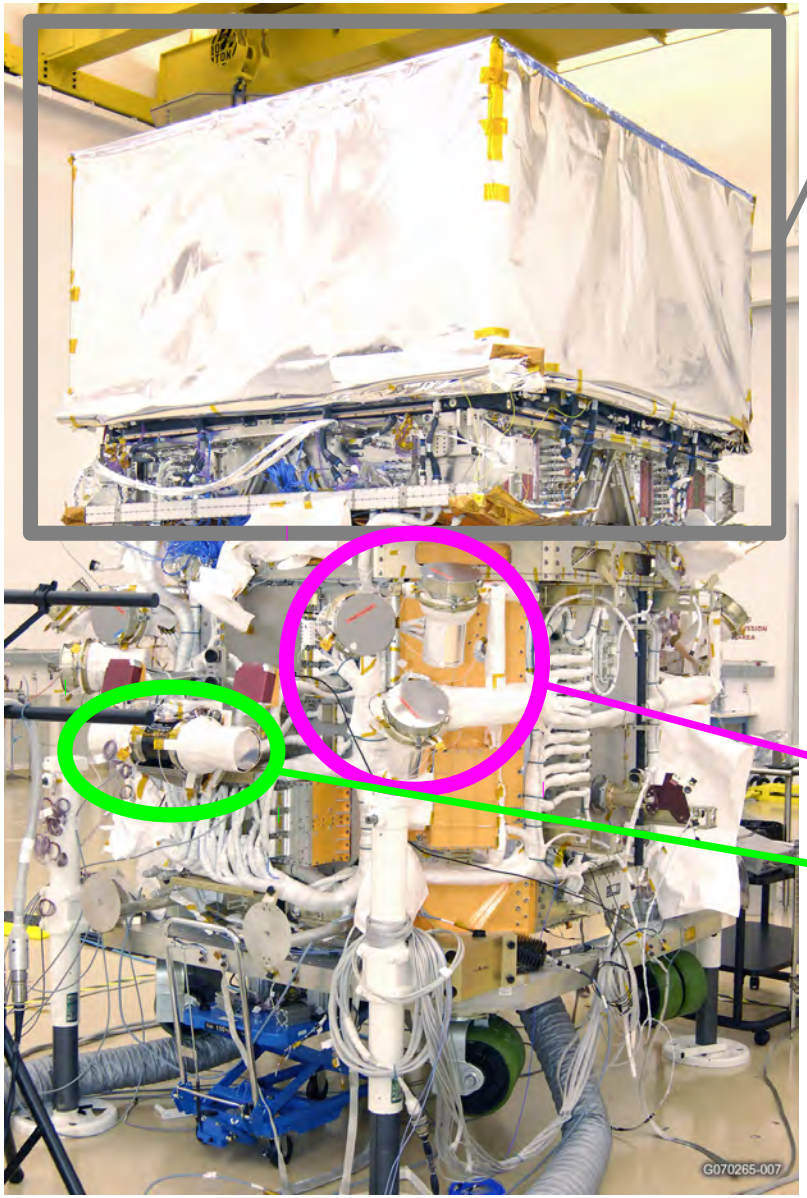
– The presence or luminosity of the additional power law component may relate to the "main" component's fluence.
→ (at least) two types of LAT detections

– The energy where this hard component rolls off may relate to the main component's peak energy.
→ Using LLE data for spectral analyses can help answering this point.

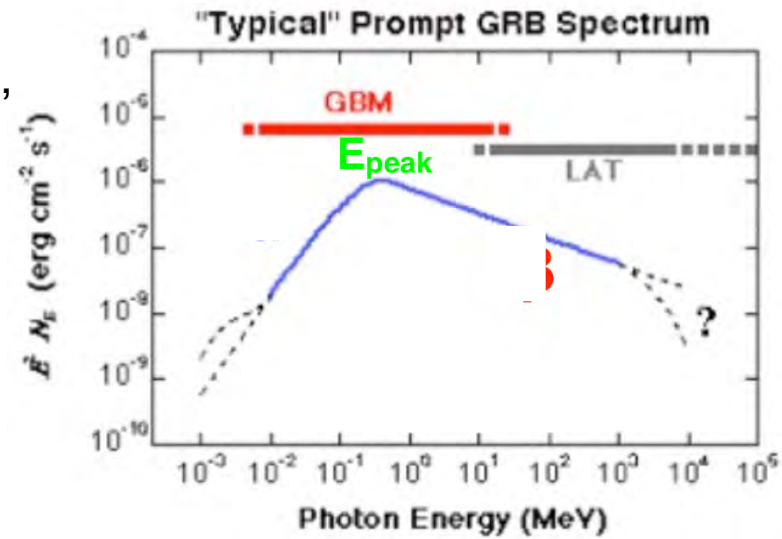
– The possible relation between the temporally extended emission and the additional power law component requires further investigation.

– ***Thank you for your attention !***

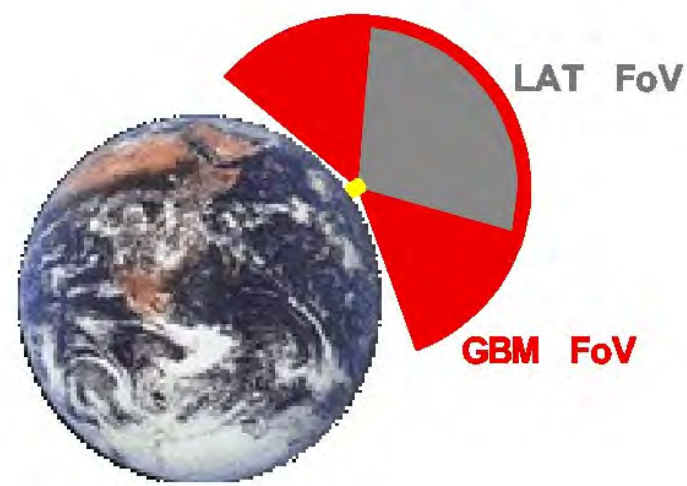
The Fermi observatory



Large Area Telescope :
Pair conversion
Trigger, localization,
spectroscopy
20 MeV – 300 GeV
W. Atwood et al 2009

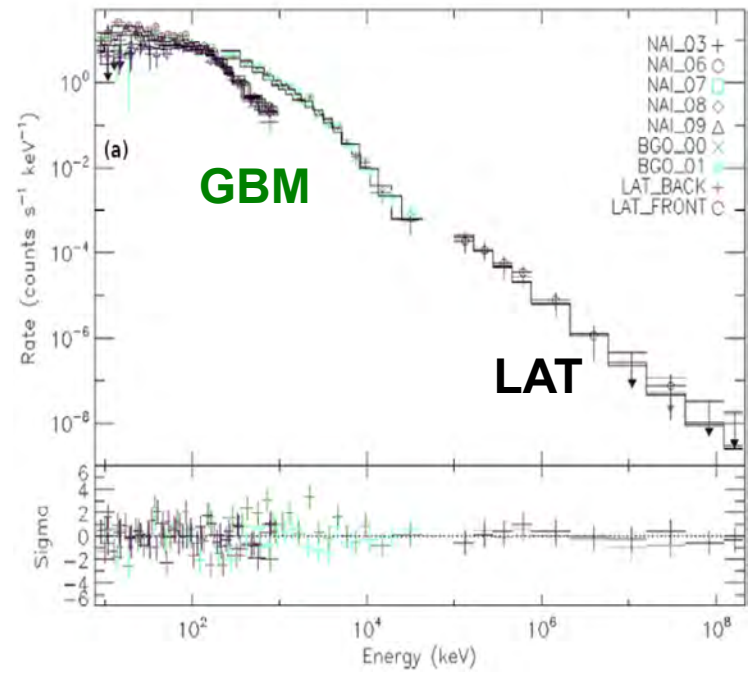


Gamma-ray Burst Monitor :
12 NaI PMT
8 keV – 1 MeV
2 BGO PMT
200 keV – 40 MeV
Trigger, localization,
spectroscopy
C. Meegan et al 2009

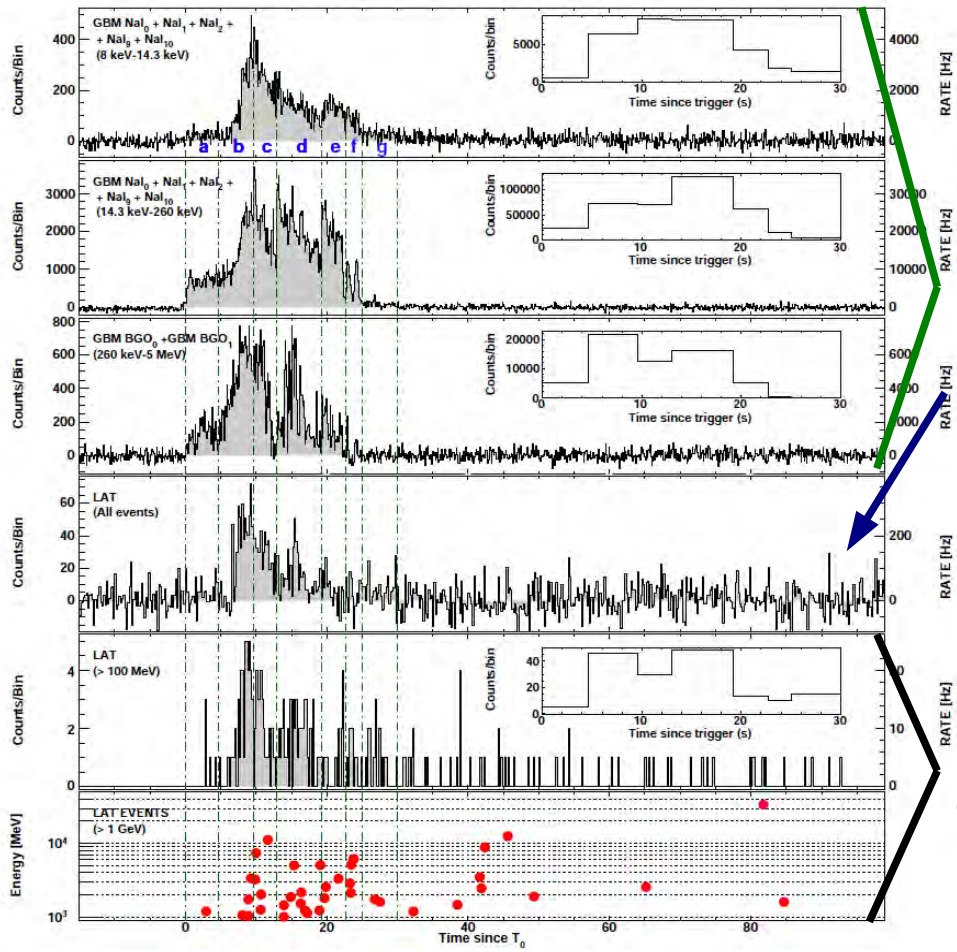


2 types of LAT data for transients studies

GRB 090510
integrated counts spectrum
M. Ackermann et al. 2010



GRB 090902B
A.A.Abdo et al. 2009

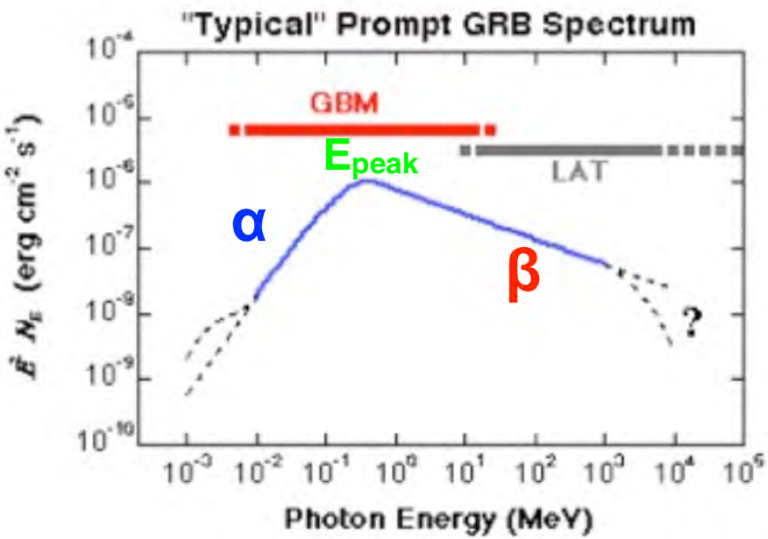


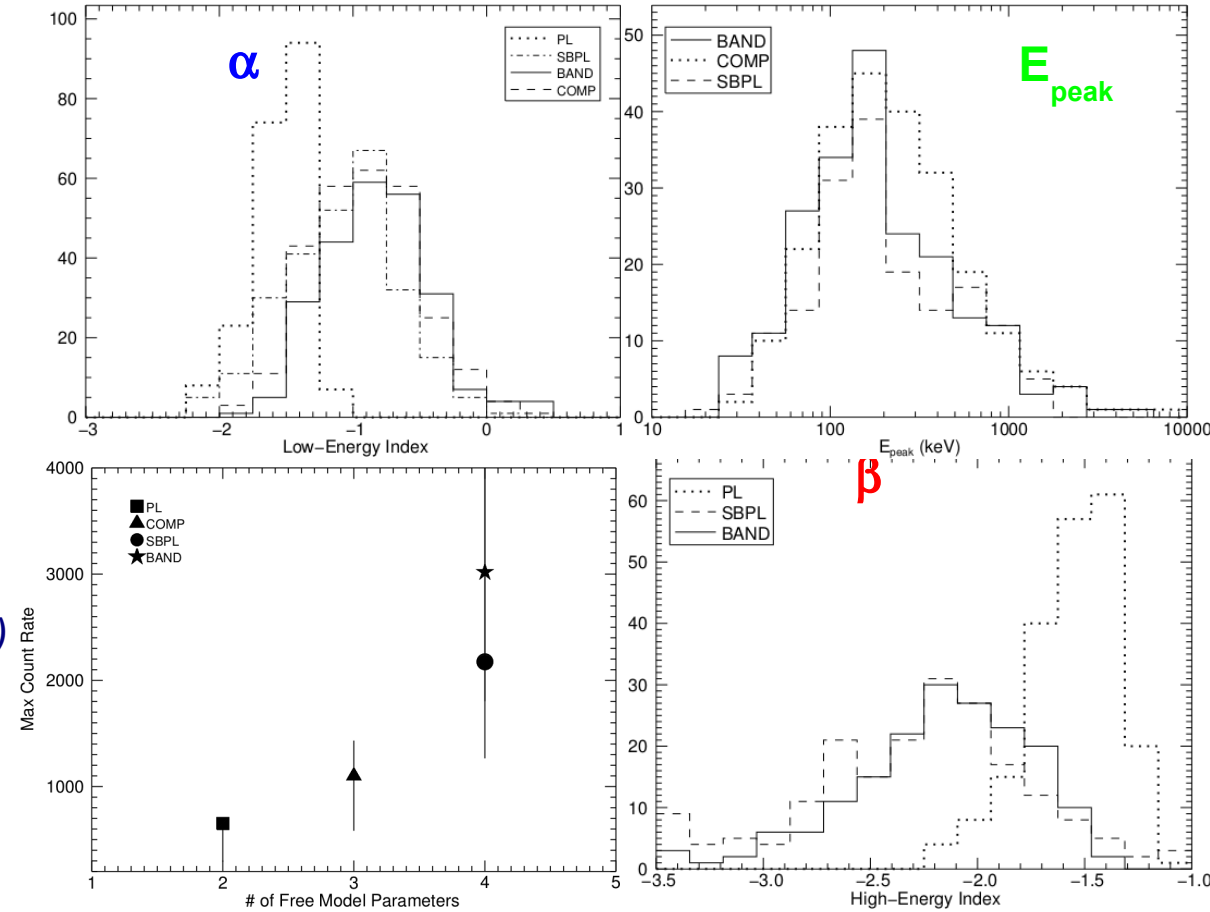
GBM (bkg-limited)

LLE = "LAT Low Energy" (bkg limited)
On-board photon selection + 1 track
First LAT GRB catalog : detection & duration
Spectral analyses of impulsive Solar Flares
Data to be released soon for GRB and solar flares

LAT standard data
Tight quality cuts > 100MeV in ROI : very low bkg.
Event by event likelihood analyses :
spectra, localization

Empirical fits of GBM spectra





Band function
(Band et al, 1993)

1. A = amplitude in photons s^{-1} cm^{-2} keV^{-1},
2. E_{peak} in keV,
3. low-energy index α,
4. high-energy index β.

$$f_6^A = A(E/100)^\alpha \exp\left(-E(2+\alpha)/E_{peak}\right) \quad (12)$$

if

$$E < (\alpha-\beta)E_{peak}/(2+\alpha), \quad (13)$$

and

$$f_6^A = A\{(\alpha-\beta)E_{peak}/[100(2+\alpha)]\}^{(\alpha-\beta)} \exp(\beta-\alpha)(E/100)^\beta \quad (14)$$

if

$$E \geq (\alpha-\beta)E_{peak}/(2+\alpha) \quad (15)$$

Comp:
β infinite

Smoothly Broken Power Law ~ ch(log E)

1. A = amplitude in photons s^{-1} cm^{-2} keV^{-1},
2. E_{piv} = pivot energy in keV,
3. λ_l, lower index,
4. E_b, break energy in keV,
5. Δ, break scale in decades of energy,
6. λ_2, upper index.

$$m = \frac{\lambda_h - \lambda_l}{2} \quad (5)$$

$$b = \frac{\lambda_l + \lambda_h}{2} \quad (6)$$

$$\alpha_{piv} = \frac{\log_{10}(E_{piv}/E_b)}{\Delta} \quad (7)$$

$$\beta_{piv} = m\Delta \log_e \frac{\exp(\alpha_{piv}) + \exp(-\alpha_{piv})}{2} \quad (8)$$

$$\alpha = \frac{\log_{10}(E/E_b)}{\Delta} \quad (9)$$

$$\beta = m\Delta \log_e \frac{\exp(\alpha) + \exp(-\alpha)}{2} \quad (10)$$

$$f_4^A = A(E/E_{piv})^b 10^{(\beta-\beta_{piv})} \quad (11)$$

PL *square*	SBPL *circle*	BAND *star*	COMP *triangle*
Fluence Spectra			
113 (23%)	67 (14%)	75 (15%)	231 (48%)
Peak Flux Spectra			
152 (31%)	48 (10%)	69 (14%)	214 (44%)

GBM spectroscopic catalog