Uncovering the low energy emission of Fermi LAT transients

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http://fermi.gsfc.nasa.gov/ssc/library/austinaas2012.html

Fermi Large Area Telescope (LAT) standard science analyses are restricted to well-reconstructed events, with energies above 100 MeV. Applying a less restrictive selection allows one to recover the high photon statistics between 30 MeV and 100 MeV in the prompt emission from Gamma-Ray Bursts (GRB) and Solar Flares (SFL), thus filling the gap between the Fermi Gamma-ray Burst Monitor (GBM) and the LAT in standard analysis mode. We present here results showing the power of this technique to extract both lightcurves and energy spectra of the transients in this energy range. GRB and SFL data (event histories, spectra, responses) will be released soon.

Motivation

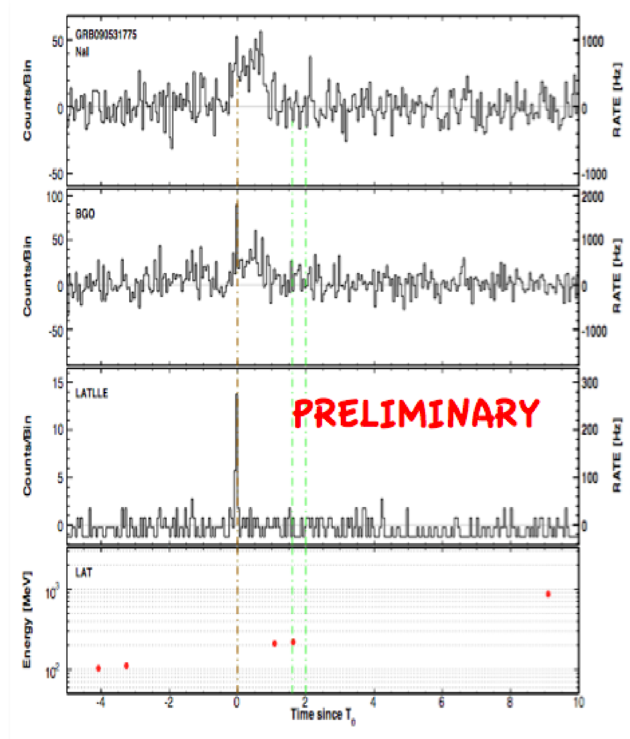
Energy "gap" in standard analysis
GBM data: 8 keV – 40 MeV
LAT transient data: >100 MeV

LAT Low-Energy (LLE) selection
On-board photon selection
1 track found in the LAT tracker
No veto signal in the ACD
(Anti-Coincidence Detector)

High photon statistics <100 MeV
Fill the energy "gap"
Better constraints on spectra
Studies of temporal properties

High particle background
Not an event-by-event technique
"ON - OFF", energy binned
Not suitable for steady sources.

Gamma-Ray Bursts(GRB)

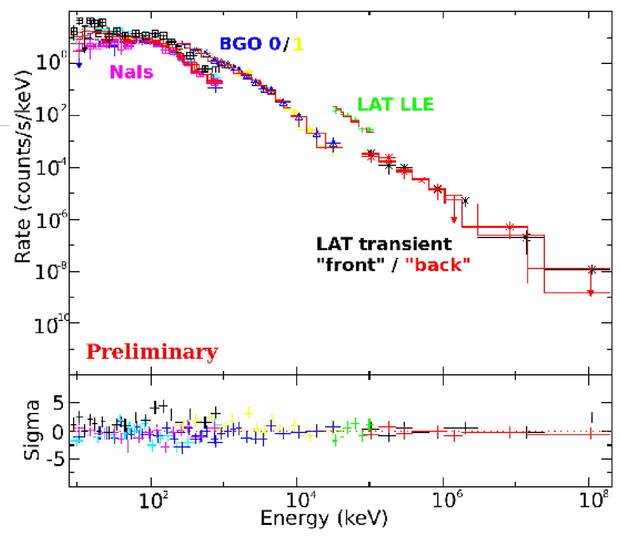


GRB 090531

30 LAT GRB between June 2008 and July 2011, 7 in LLE only [2].

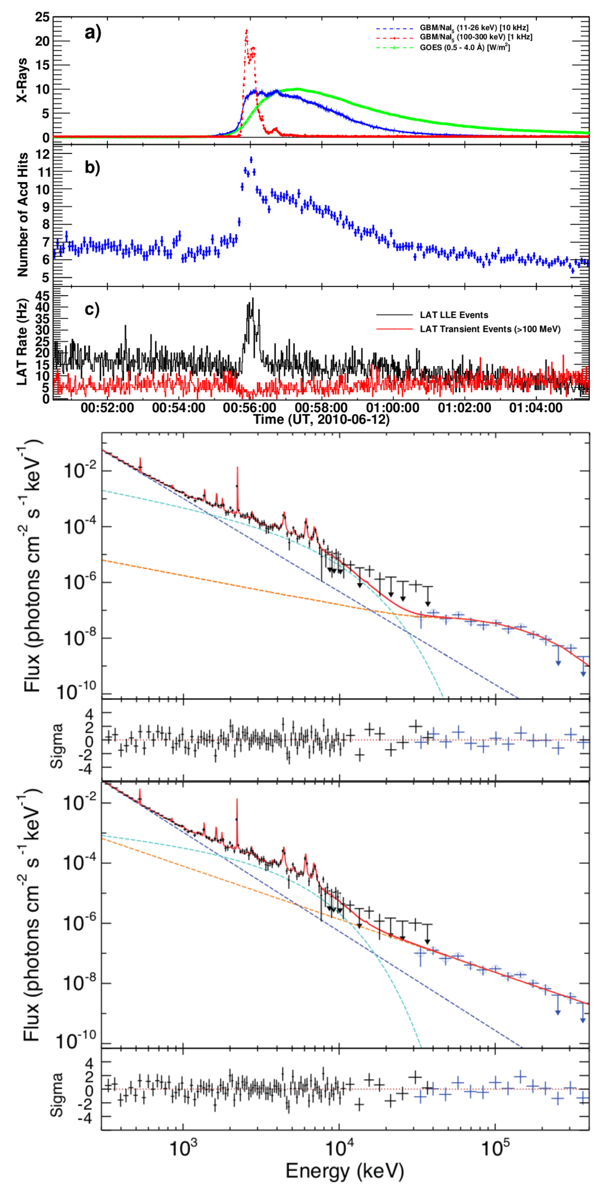
Durations for all GRB prompt emissions [2, 1].

Further analyses (spectra and temporal properties) ongoing.



Bright short GRB090510
Fit GBM+LLE+LAT
Good residuals
Additional PL component: N_σ=8.9 (instead of 5.6)

Solar Flares



SOL2010-06-12T00:57 (M2-class) in LLE [3]
High X-ray flux causes ACD pile-up ⇒ Photons treated as cosmic rays in standard classes and rejected
LLE ok (no ACD veto)

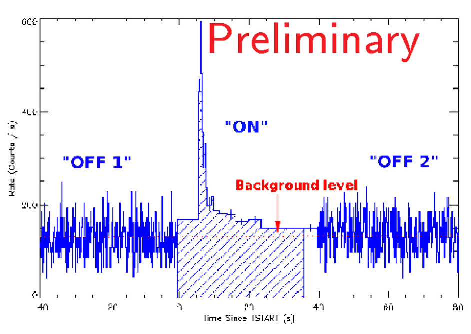
Accumulated spectrum
fit GBM + LLE

e^- Bremsstrahlung
+ nuclear de-excitation
+ 0.511 & 2.223MeV lines
+ HE component

HE comp. (LLE)
Top: Pion decay
Bottom: PL (Bremss.)

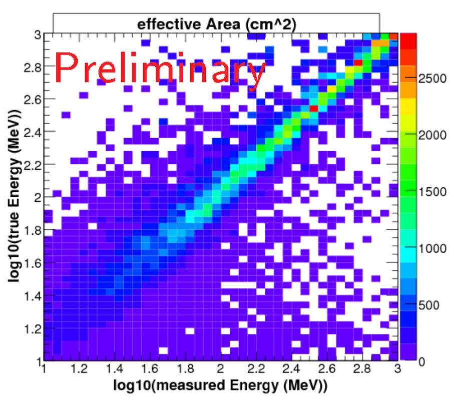
Both fit well the data.

LLE Analysis Procedure

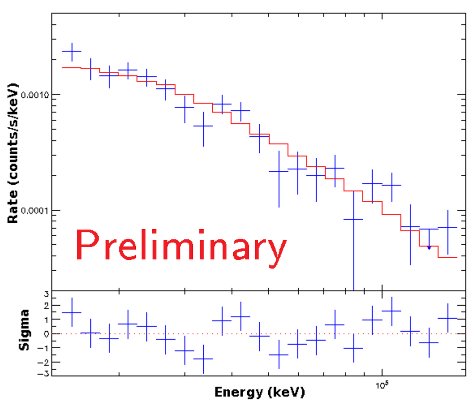


LLE+spatial selection
Bin count rate in energy
Extrapolate bkg rate to "ON" (in each energy bin)

Detector Response Matrix (DRM)
Extensive photon sim. in `gleam` (LAT `geant4`)
Same θ and livetime as GRB observation
LLE+spatial selection
Bin: true and measured energy
Convert to area units



Spectral analysis
Convolve a photon model to the DRM to fit the "ON - OFF" counts spectrum (forward-folding).

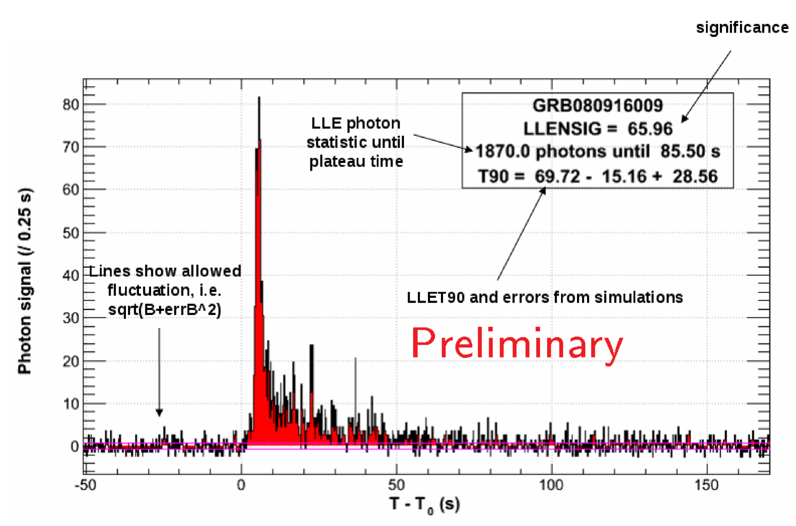


Background subtraction: the tricky step

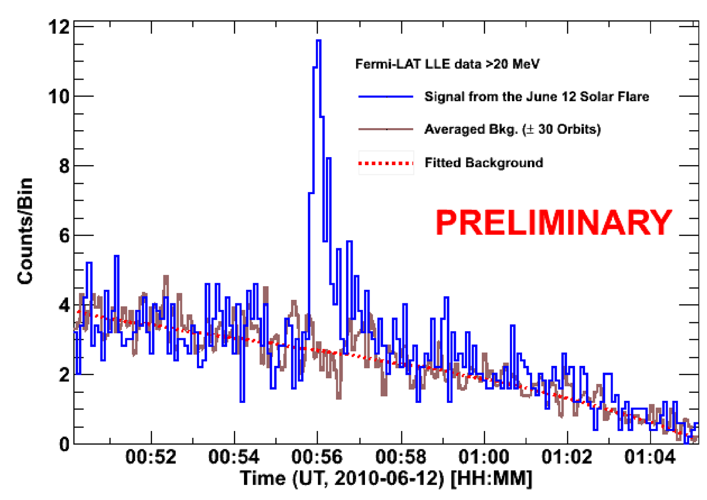
Bkg rate is fit as B(t) in each energy bin (for spectral analyses) or the whole considered energy range (for duration measurements)

Method 1: B(t) = $pol(t)$, "OFF" before and after "ON"
Spectral analyses and calculation of detection signifcance [1].
Good results in most cases (except if repoint occurs).

Method 2: B(t) = $pol(cos(\theta(t)))$, "OFF" before and after "ON"
θ is the inclination of the source in the field of view
Measurements of detection significance and duration.
Simulations are used to determine the duration [1].



GRB 080916C (method 2)



SOL2010-06-12T00:57 (method 3)

Method 3: orbital subtraction (under development: non-public)
Average orbits N-n and N+n to reproduce same background history as in orbit N of the flare/burst, and fit B(t) = $pol(t)$.
Choice of n: same position of the source in the field of view and above horizon as in orbit N, same position of the spacecraft in the Earth magnetic field (high cosmic ray bkg).

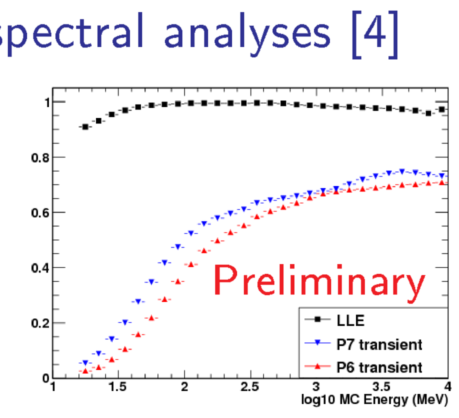
Performance

A_{eff} (wrt Pass6 transient)
$\theta < 30°$: ×10 @30MeV, x2.5 @100MeV
$60° < \theta < 80°$: x40 @30 MeV, x9 @100MeV

Energy res: 0.4 @30MeV, 0.3 @100MeV

68% PSF: 20° @30MeV, 6° @100MeV

Extensive validation studies have shown a good agreement between the response functions derived from simulations and real efficiencies, and small systematic errors for spectral analyses [4]



Selection efficiency / on-board photon filter efficiency (simulations)

Conclusions

The LLE data selection brings high photon statistics for the studies of *Fermi* transients, filling a former energy gap (40 – 100MeV), but also increasing the background rate. Performance validation studies show these data can be used for spectral analyses. Using LLE already allowed to detect several GRBs and Solar flares which were not seen in the LAT standard data. Preliminary spectral analyses show promising results, further analyses (both temporal and spectral) are ongoing. LLE data for detected GRB and SFL will be released soon via the FSSC.

References

[1] F. Piron (LAT coll.) "Event counting methods for detection and study of the temporal profile of *Fermi*-LAT GRB", 3rd Fermi symposium (2011)
[2] N. Omodei (LAT coll.) "*Fermi*-LAT GRB catalog", 3rd Fermi symposium (2011)
[3] M. Ackermann et al "*Fermi* detection of γ-ray emission from the M2 Soft X-ray Flare on 2010 June 12", *ApJ, accepted* (astro-ph/arXiv:11.7026)
[4] V. Pelassa (LAT coll.) "Recovering LAT transients signal below 100 MeV: LLE performance and validation", 3rd Fermi symposium (2011)

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