Spectral features of *Fermi* Gamma-Ray Bursts revealed by the LAT Low-Energy technique

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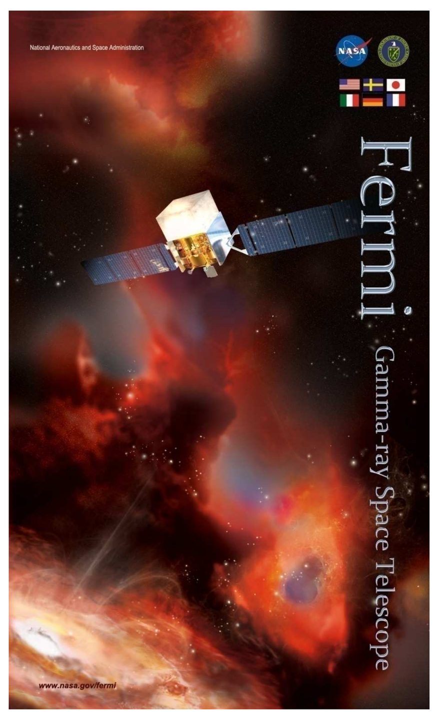
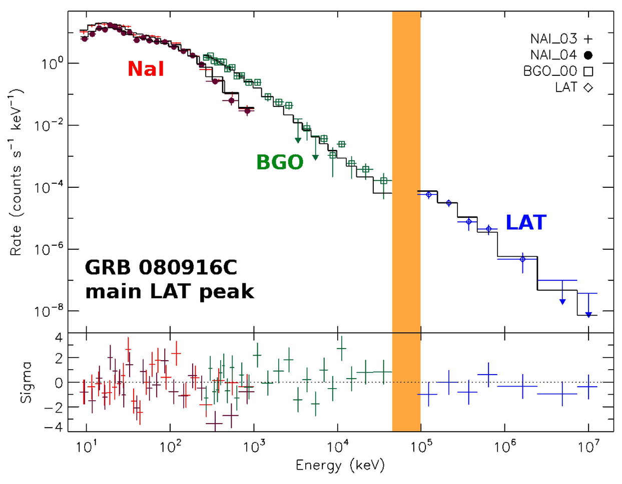
on behalf of the *Fermi* LAT and GBM collaborations



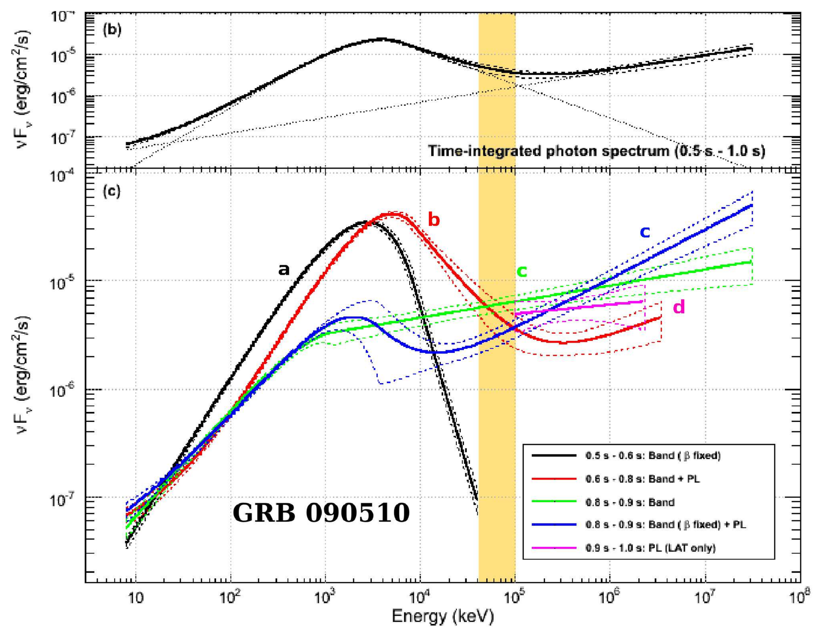
Abstract

Fermi Large Area Telescope (LAT) data analyses based on event reconstruction and classification are so far restricted to events of measured energy larger than 100 MeV. We present a new technique to recover the signal from Gamma-Ray Bursts' (GRB) prompt emission between ∼30 MeV and 100 MeV, which differs from the standard LAT analysis. Filling the "gap" between Gamma-ray Burst Monitor and LAT observations allows to better constrain the high-energy spectra of GRB. The LAT Low-Energy (LLE) technique is described, first performance studies are presented, and preliminary spectral re-analyses of two *Fermi* GRBs are presented.

The 40 MeV – 100 MeV gap



LAT standard event-by-event analysis starts at 100 MeV since detector response and background rejection are not fully understood yet below 100 MeV.



Why looking there ?

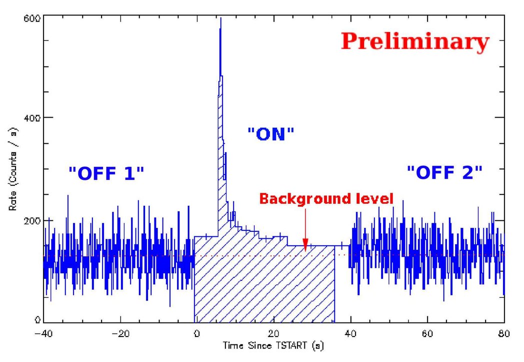
Faint/soft spectra (e.g. GRB 090510 bin a : soft)

no signal > 100 MeV, or very faint
⇒ killed by the usual event selection
⇒ few information on spectrum > 40 MeV

Bright spectra (e.g. GRB 090510 bins b, c, d, e)

- better spectral constraints
- e.g. additional power-law component takes over the Band spectrum at ∼100 MeV

LAT Low-Energy (LLE) analysis procedure



"ON" - "OFF"

- not an event-by-event technique
- LLE data sample used
- no direction selection
- temporal selection of "ON" and "OFF" regions
- "ON" and "OFF" binned in measured energy
- background time profile polynomial fit in each energy bin
- "OFF" subtracted to "ON"

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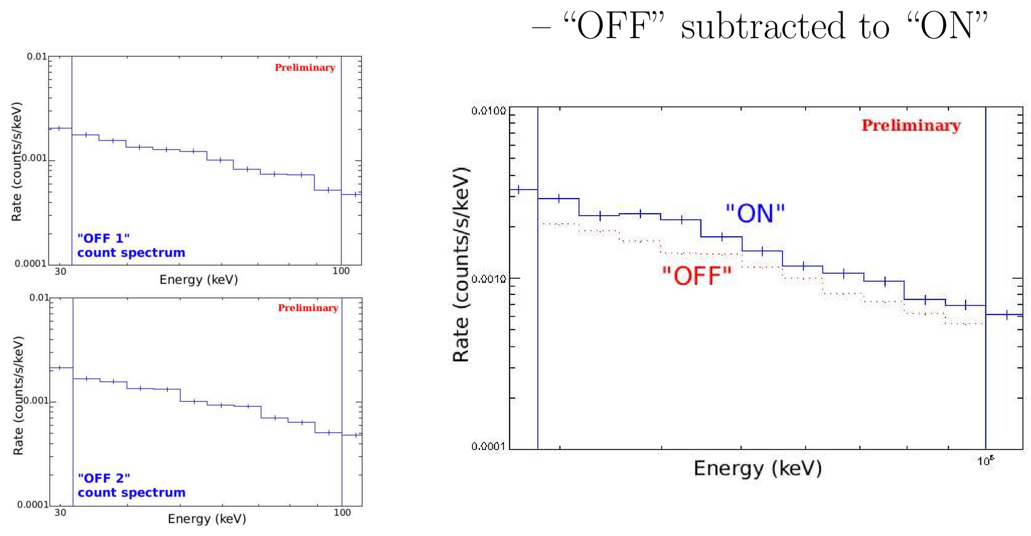

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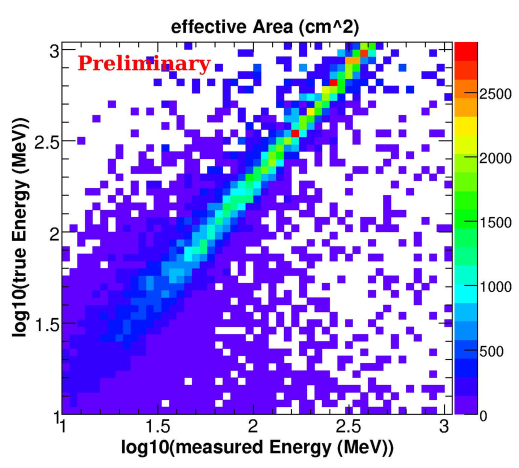

Detector Response Matrix (DRM)

- extensive γ simulation with GLEAM (GEANT4)
- observation conditions of the GRB : same inclination angle and livetime over time
- LLE selection is applied
- distribution binned in true (Y-axis) and measured (X-axis) energy
- converted to area units

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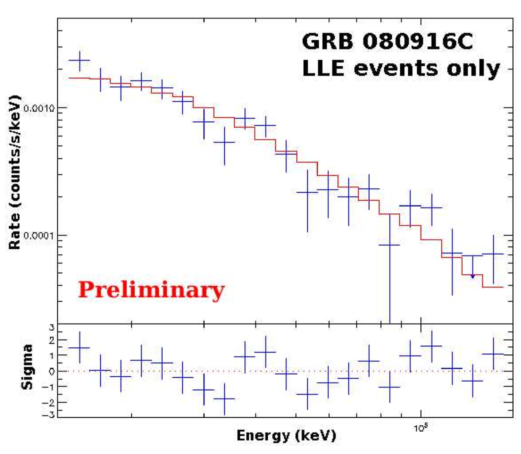
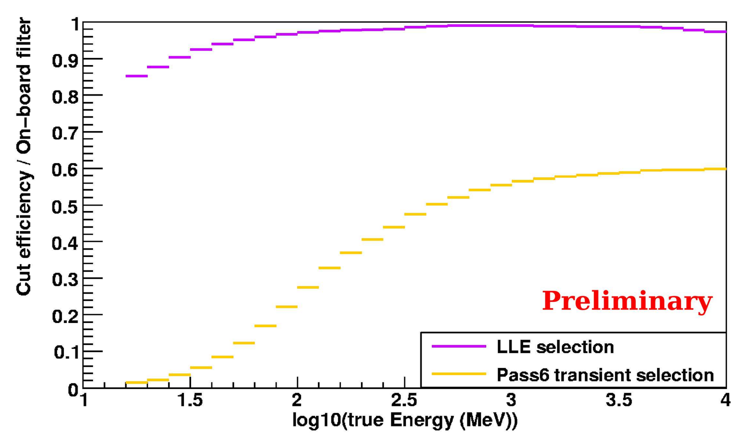


Spectral analysis (RMfit)

The "ON"- "OFF" spectrum is fitted using the DRM (forward-folding).

LLE selection

- on-board photon filter
- at least one associated track
⇒ many more possible photons than the standard selection
⇒ much more background too
- cuts efficiency compared to standard Pass6 transient class, from GLEAM photon simulations



LLE vs standard P6 transient class :

$A_{eff} \times 50$ at 30 MeV
$A_{eff} \times 4.5$ at 100 MeV
$A_{eff} \times 2 > 1$ GeV

⇒ photon statistics greatly improved at low energies, and may improve at high energies too

Energy measurement

- based on tracker and calorimeter
- not the same variable as in standard analysis
- good correlation for events with at least one track (see DRM)
- resolution study from GLEAM photon simulations
⇒ no very large bias, reasonable energy resolution (under improvement)

incoming photon inclination : $\theta < 40°$

E_{MC} (± 2 MeV)	$< E_{mes} >$ ± RMS (MeV)	RMS/$< E_{mes} >$	($< E_{mes} >$ - E_{MC})/E_{MC}
30	27 ± 10	37%	-10%
50	45 ± 16	36%	-10%
100	90 ± 27	30%	-10%
500	490 ± 70	14%	-2%

incoming photon inclination : $40° < \theta < 70°$

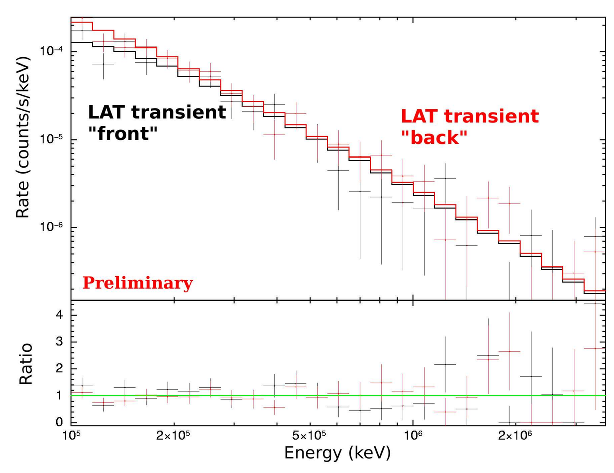
E_{MC} (± 2 MeV)	$< E_{mes} >$ ± RMS (MeV)	RMS/$< E_{mes} >$	($< E_{mes} >$ - E_{MC})/E_{MC}
30	30 ± 14	47%	0%
50	44 ± 18	41%	-12%
100	85 ± 34	40%	-15%
500	470 ± 80	17%	-6%

Reconstruction capabilities

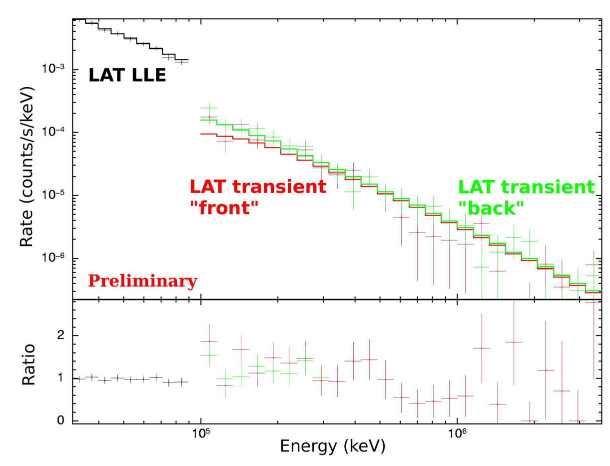
- simulated GRB
- spectrum :

$N(E) = N_0(E/E_0)^{-\beta}$
$E_0 = 1$ GeV
$N_0 = 1.19 \times 10^{-9}$ ph.cm^{-2}.s^{-1}.keV^{-1}
$\beta = 2.1$

- no background added
- LAT-only reconstruction : with and without LLE
⇒ similar results are observed, with a smaller uncertainty on β when using LLE events, yet with a systematic error which will be investigated after the technique has been fully calibrated.



$N_0 = 1.36 \pm 0.13 \times 10^{-9}$
$\beta = 2.21 \pm 0.06$



$N_0 = 1.60 \pm 0.12 \times 10^{-9}$
$\beta = 2.02 \pm 0.02$

(statistical errors)

Conclusions

- very promising technique for GRB studies
- can be used also for other sources (see poster P2-96 by J.M. Burgess)
- **this is a non-standard analysis, which uses non-public information**
- **validation and improvement still ongoing (acceptance, energy calibration, systematics studies)**

References

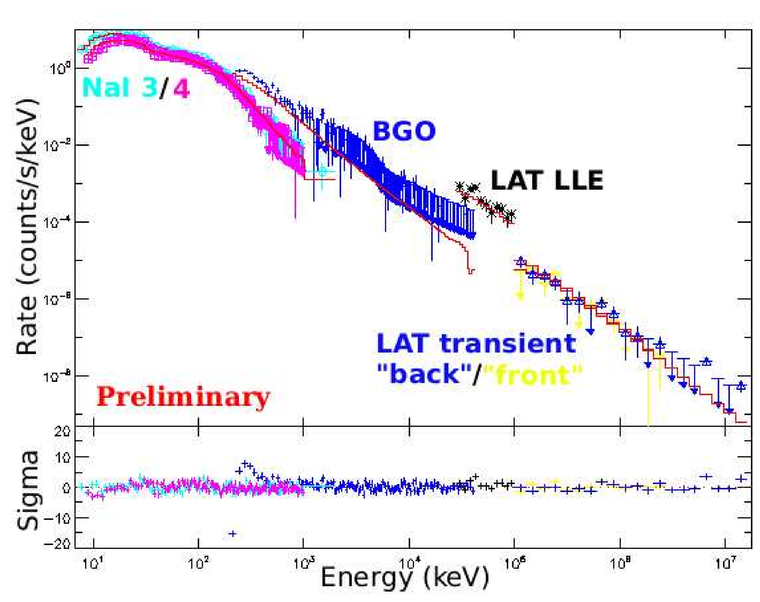
W.B. Atwood et al., "The Large Area Telescope on the *Fermi* Gamma-ray Space Telescope", *ApJ*, 697, 1071 (2009) (arXiv : 0902.1089)

A.A. Abdo et al., "*Fermi* observations of high-energy gamma-ray emission from GRB 080916C" *Science*, 323, 1688 (2009)

A.A. Abdo, et al. "*Fermi* Observations of GRB 090510 : A bright, short burst with a hard power-law component above 100 MeV", *ApJL, in prep.*

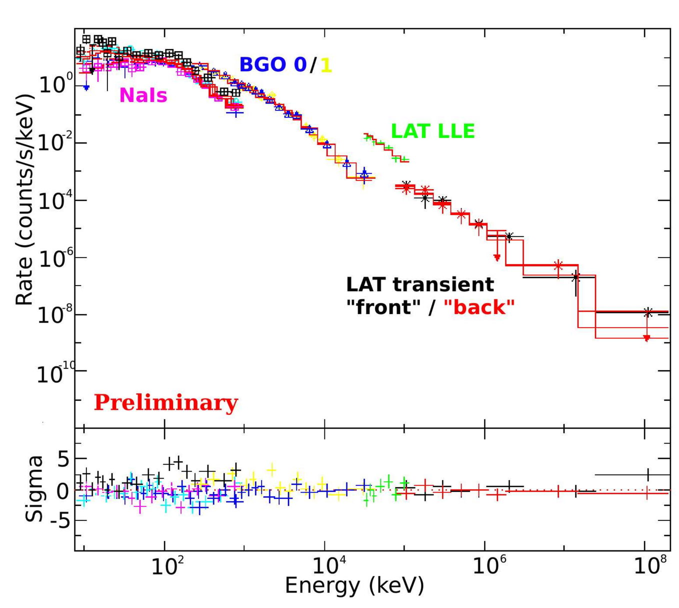
Preliminary re-analyses of real *Fermi* GRBs

bright long GRB 080916C



- time integrated spectrum, Band function fit
- LLE data superimposed to other datasets but not fitted
⇒ good residuals
⇒ consistent with the standard analysis

bright short GRB 090510



- time-integrated spectrum, Band + power-law fit
- LLE and other data fitted together
⇒ high-energy additional component even more significant : $N_\sigma = 8.9$ (5.6 without LLE)
⇒ spectral evolution may better show up if using the LLE data in the time-resolved spectroscopy