Performance of the GLAST/LAT for the Observation of GRB Spectra

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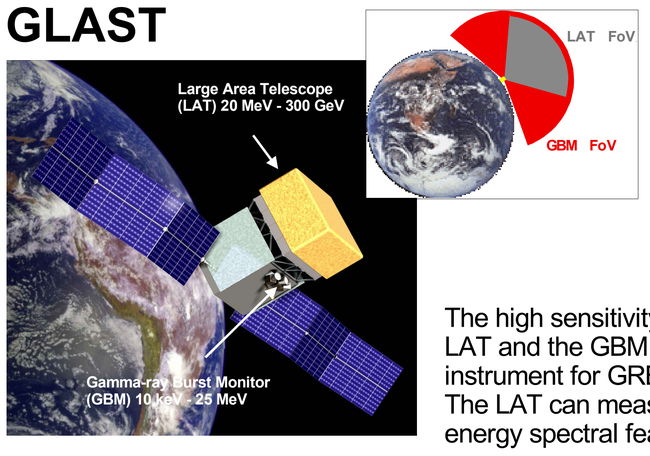
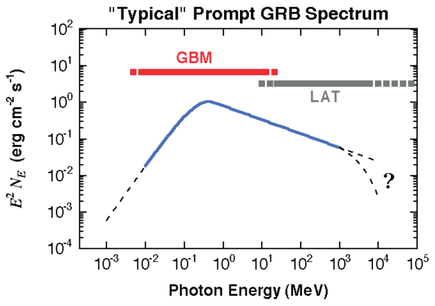
Abstract

GLAST is a gamma-ray mission which will be launched in autumn 2007. It is equipped with the GLAST Burst Monitor (GBM) which detects GRBs with high reliability and provides a position and energy spectrum in the range between 10 keV and 25 MeV. The Large Area Telescope (LAT) will observe photons with energies from 20 MeV up to more than 300 GeV.

Here we present a systematic study of the performance of the LAT for the reconstruction of the energy spectrum of Gamma-Ray Bursts (GRBs), based on the simulation of 1 year of data taking. We focus on deviations from a pure power-law photon spectrum (exponential cut-offs). This feature can provide insight in the particle acceleration mechanisms at work in GRBs; and it can be used to probe the Extra-Galactic Background Light.

GLAST





The high sensitivity and large field of view of the LAT and the GBM makes GLAST an ideal instrument for GRB observation (Band 2007). The LAT can measure currently unknown high-energy spectral features.

Scientific Motivations

(Very) High-Energy GRB detections

- EGRET detection of GeV prompt and delayed emissions from GRB940217 (Hurley et al. 1994)
- Evidence for a second component from BATSE + EGRET/TASC analysis (González et al. 2003)
- GRB970417a detection above 600 GeV by Milagrito during BATSE T90 (Atkins et al. 2003)

GeV photons can tell about:

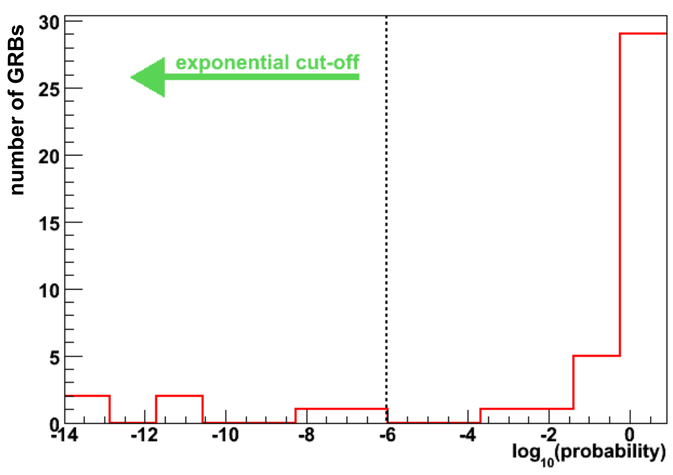
- bulk Lorentz factor Γ, IC components, acceleration physics, UHECRs and hadronic processes (π^0 cascades, synchrotron), extragalactic background light (see below)

Simulations

- simulation of 1 year of GLAST operation using the fast simulator (parametrization of LAT response functions)
- ~430 simulated bursts using a physical and a phenomenological model (see Omodei & Norris 2007)
- simulations of LAT photons contain synchrotron emission, inverse Compton emission and attenuation due to EBL
- 42 bursts with >20 photons in the LAT

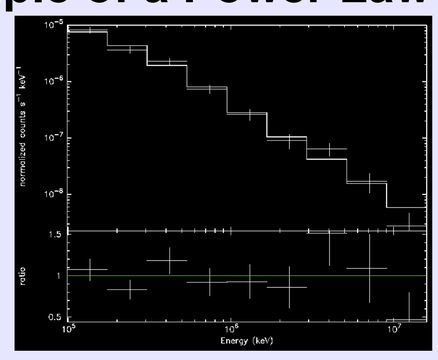
Analysis Procedure

- standard GLAST event selection, energy threshold 100 MeV
- perform a spectral fit using XSPEC
- fit of a power law: $\frac{dN}{dE} = N_0 \left(\frac{E}{10\,MeV}\right)^{-\beta}$
- χ^2/dof (degrees of freedom) quantifies the goodness of the fit
- search for a cut-off in the spectrum: add exponential cut-off as additional parameter: $\frac{dN}{dE} = N_0 \left(\frac{E}{10\,MeV}\right)^{-\beta} e^{-E/E_{cut}}$
- The fits are performed as Likelihood-Fits using Cash statistics. The difference of the fit statistics (at their respective minimum) follows a χ^2-distribution with 1 dof and determines the improvement of the fit by adding the cut-off parameter. A probability of less than ~10^{-6} corresponds to a 5σ detection of a cut-off.



No intrinsic cut-off was simulated. Thus, cut-offs are due to EBL attenuation and are expected for distant and bright bursts only.

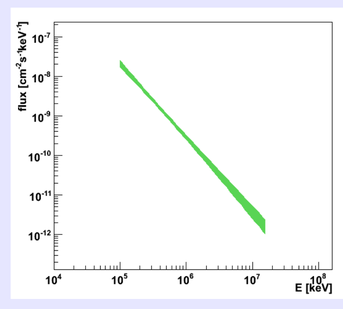
Example of a Power Law



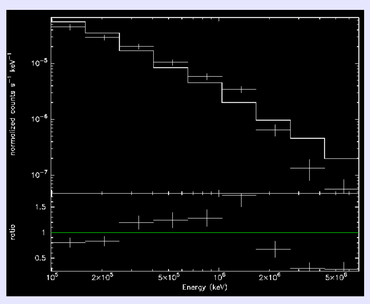
χ^2/dof = 8.1/7

Likelihood-Test for exp. cut-off probability = 0.6

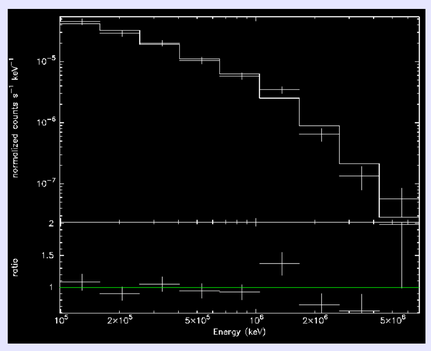
95% Conf. Region of Best Fit



Power Law with Exponential Cut-Off



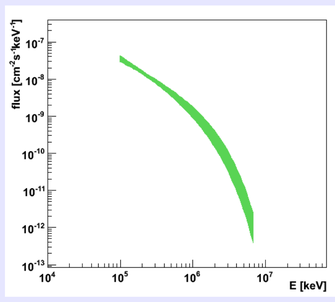
χ^2/dof = 62.7/7

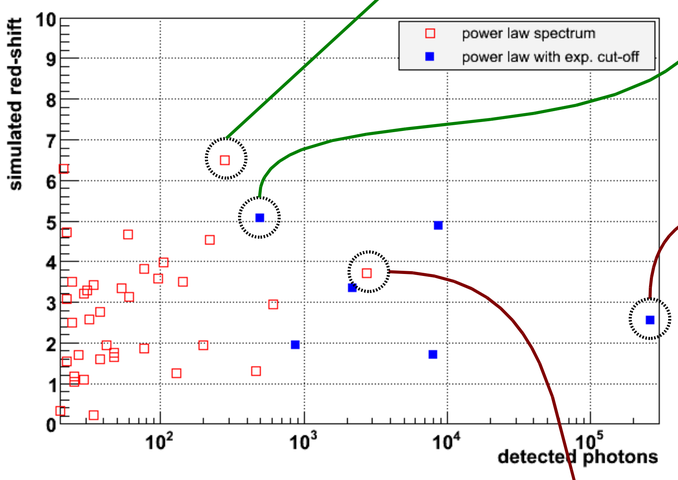


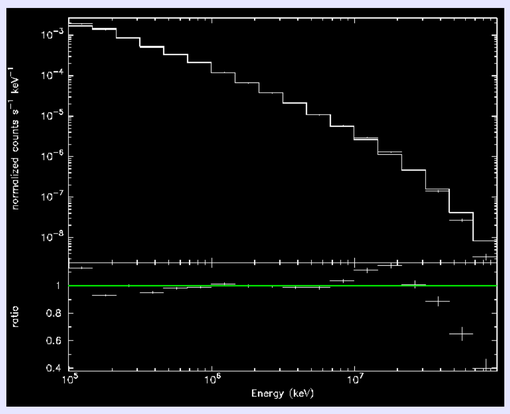
Fit with exp. cut-off
Likelihood-Test
probability = 10^{-11}

χ^2/dof = 10.7/7

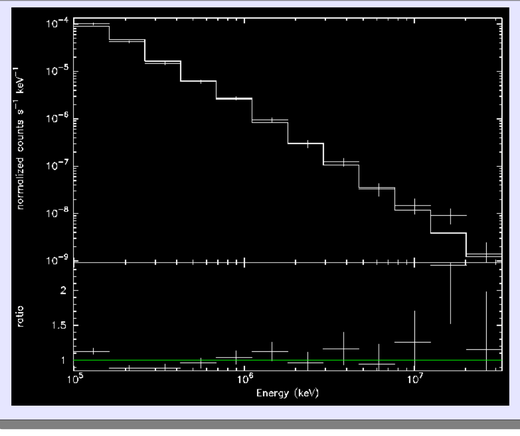
95% Conf. Region of Best Fit







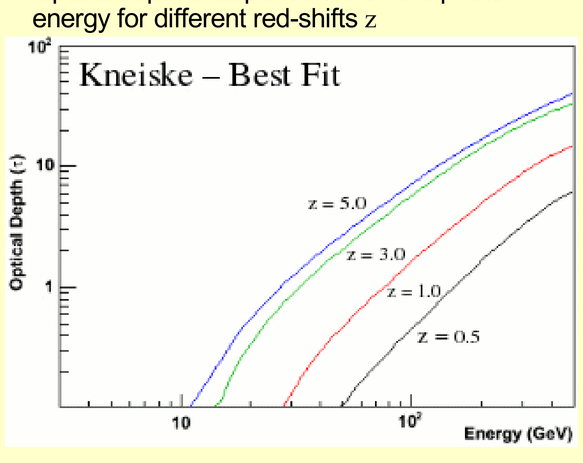
- clear cut-off due to EBL attenuation
- model does not describe data properly
- additional parameters needed



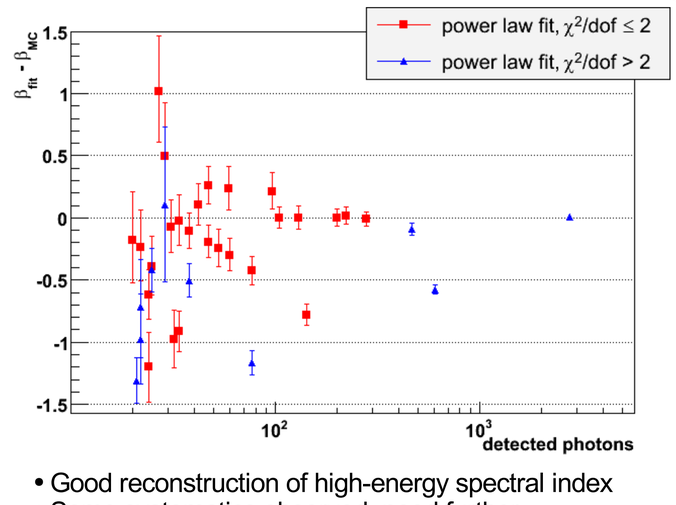
- no obvious attenuation
- For the simulated red-shift (z=3.7) a cut-off due to EBL attenuation is not expected to be very prominent below 30 GeV.

EBL Attenuation

- attenuation due to pair-production in interactions with the extra-Galactic background light (EBL)
- see (Reyes & Carson 2007) for details
- Optical depth in dependence on the photon energy for different red-shifts z



Comparison of spectral index from a power-law fit with simulated value for the bursts without a cut-off



- Good reconstruction of high-energy spectral index
- Some systematics observed, need further investigation

Summary

- Tools for systematic search detect high-energy cut-offs with high reliability.
- Fit is performed using XSPEC. Any XSPEC model can be used.
- Future work will be dedicated to the search for inverse Compton peaks and other high-energy components.
- Could be used for population studies and for prompt analysis.

Bibliography

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- González et al. 2003, *Nature* **424**, 749-751
- Atkins et al. 2003, *ApJ* **583, *824-832***
- Band 2007, poster on "The Synergy Between the LAT and GBM in GLAST's Study of Gamma-Ray Bursts"
- Omodei & Norris 2007, poster on "LAT observations of GRBs, simulations and sensitivity studies"
- Reyes & Carson 2007, poster on "Detecting the EBL attenuation of Blazars with GLAST"

1st GLAST Symposium, 5 – 8 February 2007, Stanford University