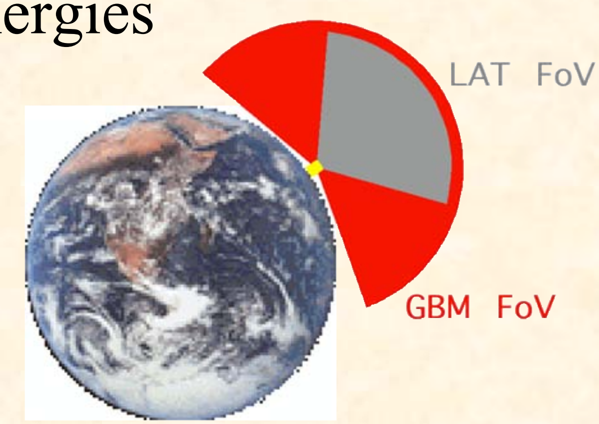
Burst Capabilities of the GBM

by
Giselher Lichti
MPE Garching

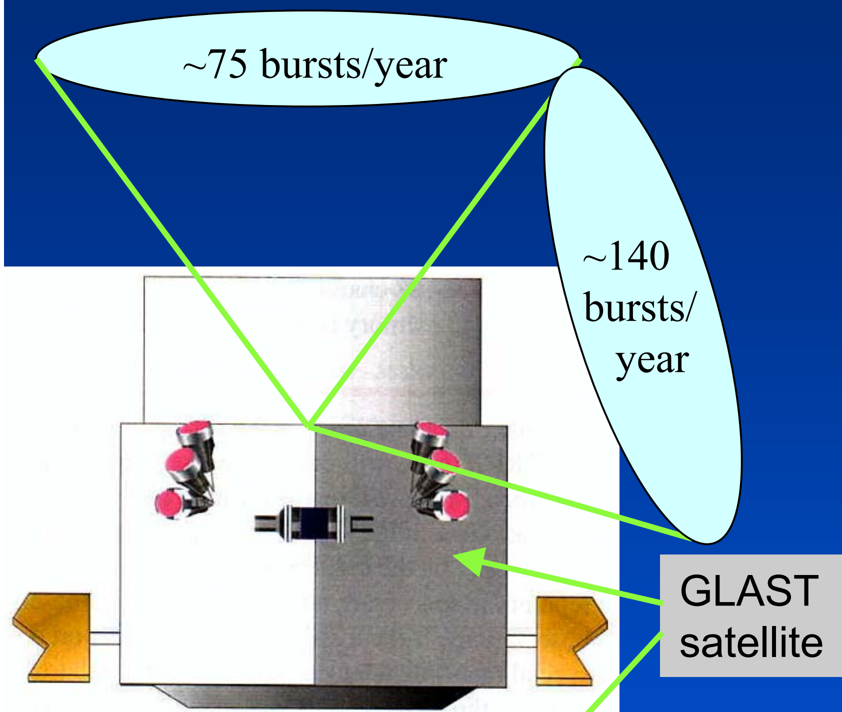
GLAST Burst-Monitor Approach

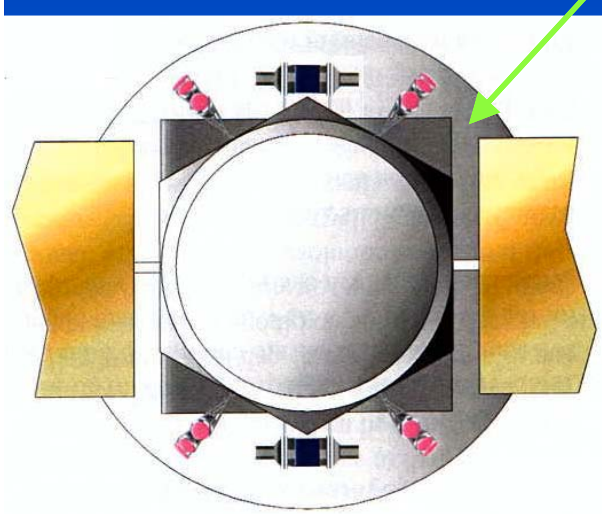
- **Main goals of the GBM**
  - measuring γ-rays from GRBs at low energies
  - having a larger FoV than the LAT to allow repointing of the LAT
  - localizing bursts in this FoV
  - allowing time-resolved spectroscopy.

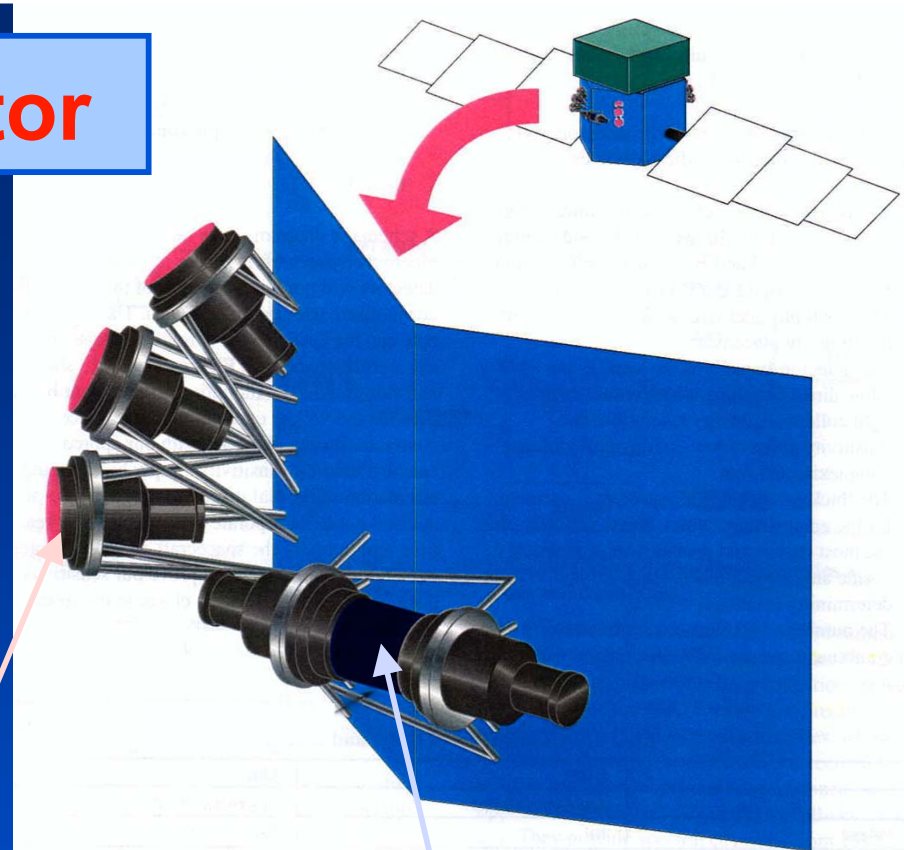


- **These goals can be achieved by**
  - an arrangement of 12 thin NaI detectors to locate GRBs (as with BATSE) and get low-energy spectrum.
  - use of two BGO detectors to get spectral overlap with the LAT.

The GLAST Burst Monitor







4 × 3 NaI-detectors:
∅: 12.7 cm, thickness: 1.27 cm
E-range: 5 keV - 1 MeV

2 BGO-detectors:
∅: 12.7 cm, thickness: 12.7 cm
E-range: 150 keV - 30 MeV

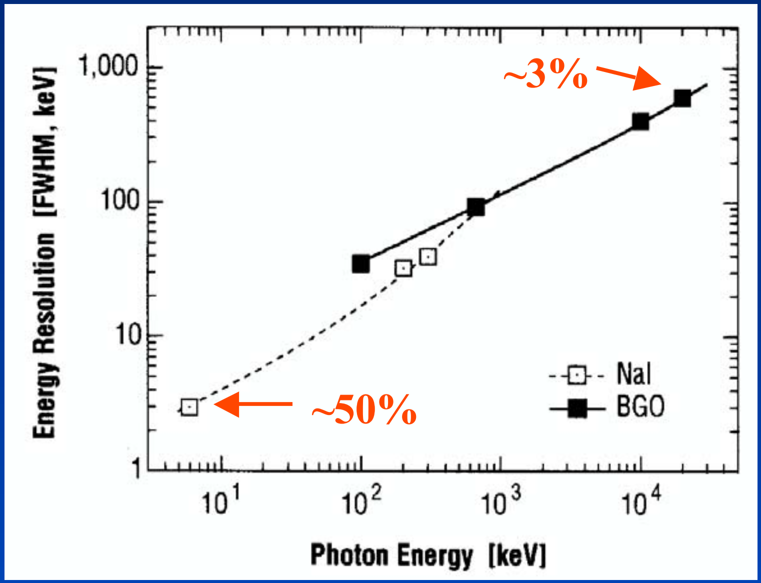
GLAST Burst Monitor:
overlapping energy ranges
LAT / BGO / NaI

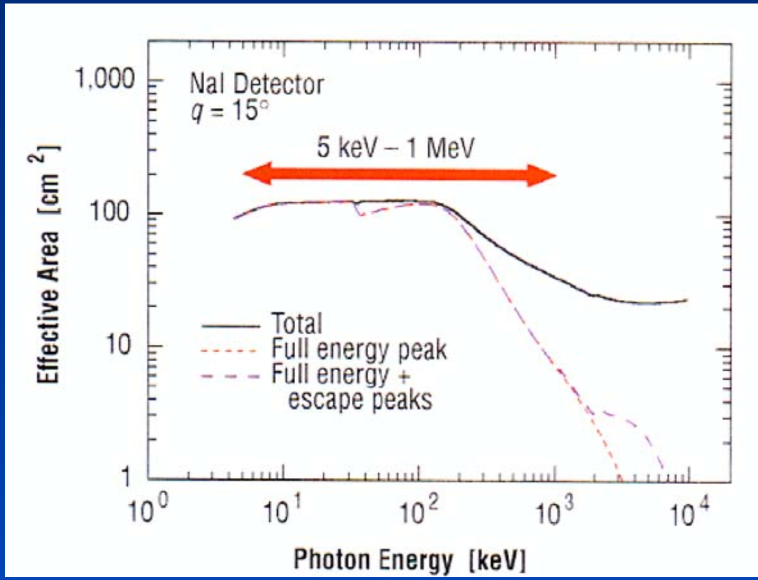
Burst localisation via count-rate comparison of different NaI-detectors (BATSE - principle)

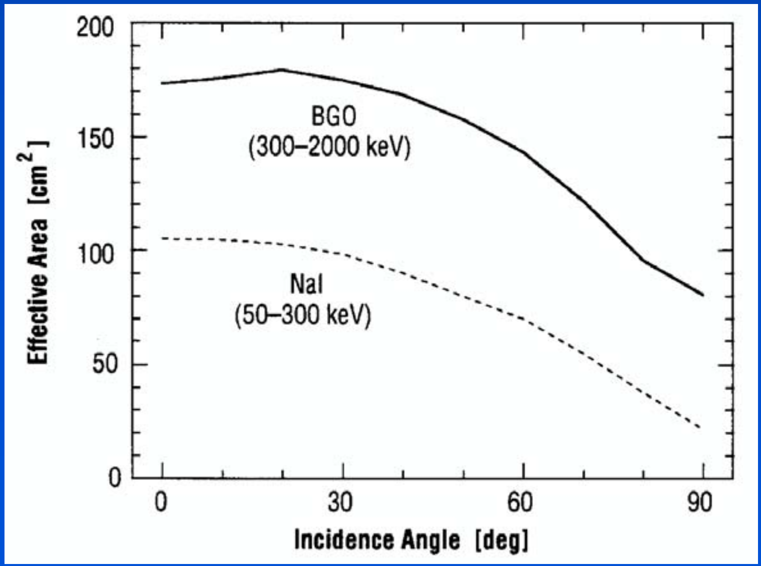
Burst-Monitor Performance

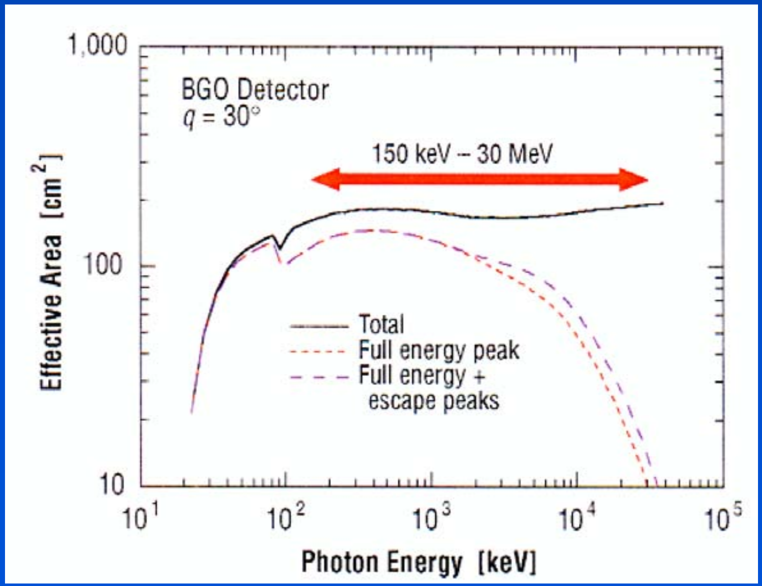
- spectral coverage from ~5 keV to ~30 MeV (goal) (overlap with LAT: 15 - 30 MeV)
- field of view: 8.6 sr (LAT only 2-3 sr)
- sensitivity:
  - ~ 0.57 photons/(cm^2 s) for nominal on-board trigger [BATSE: ~ 0.2 photons/(cm^2 s)]
  - ~ 0.35 photons/(cm^2 s) for ultimate 5σ sensitivity
- on-board location accuracy: < 15^{O} for most bursts
- ultimate on-ground location accuracy: <1.5^{O}
- ~215 bursts/year will be detected

Energy Resolutions and Effective Areas









Scientific Goals of the GBM

- continuous measurements of energy spectra for determination of spectral parameters (peak energy & power-law indices)
- measurements of light curves with high time resolution (in the ms-range)

- sensitive trigger for the main instrument of GLAST
- rapid localisation (within few seconds) of γ-ray bursts (~15^{O})

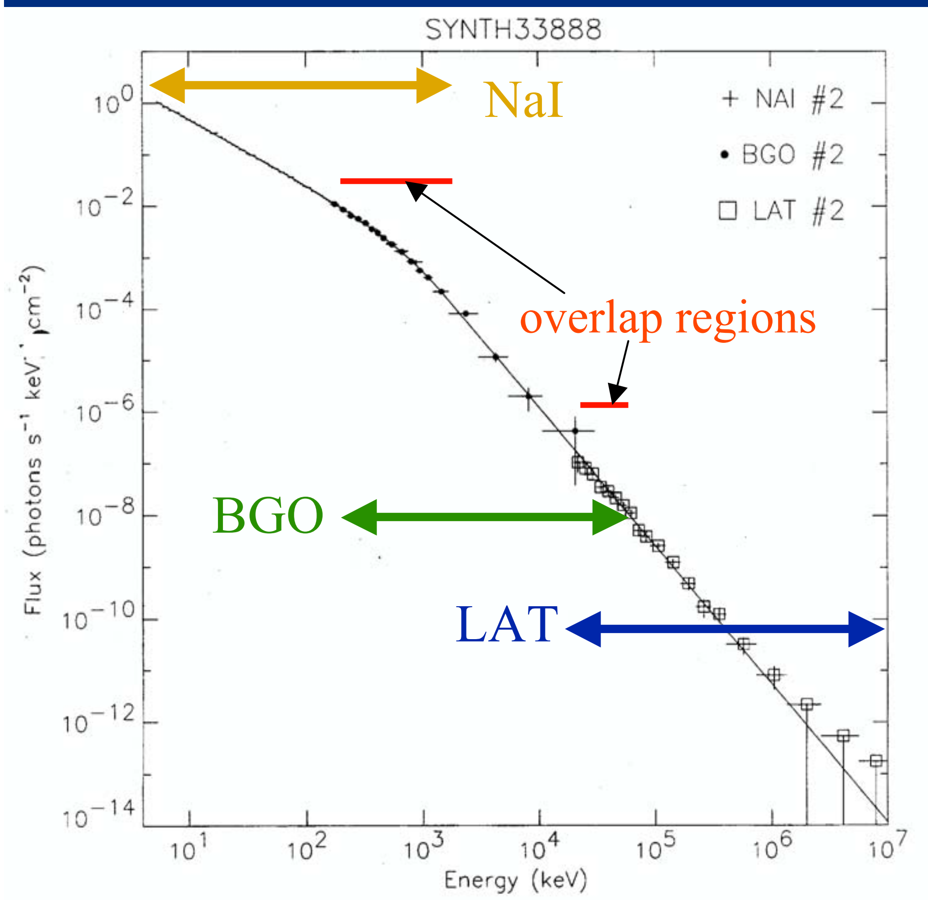
➡ initialization of data-reduction modes in the LAT
➡ preciser localisation (arcminutes) of the bursts by the LAT
➡ search for objects at other wavelength regions

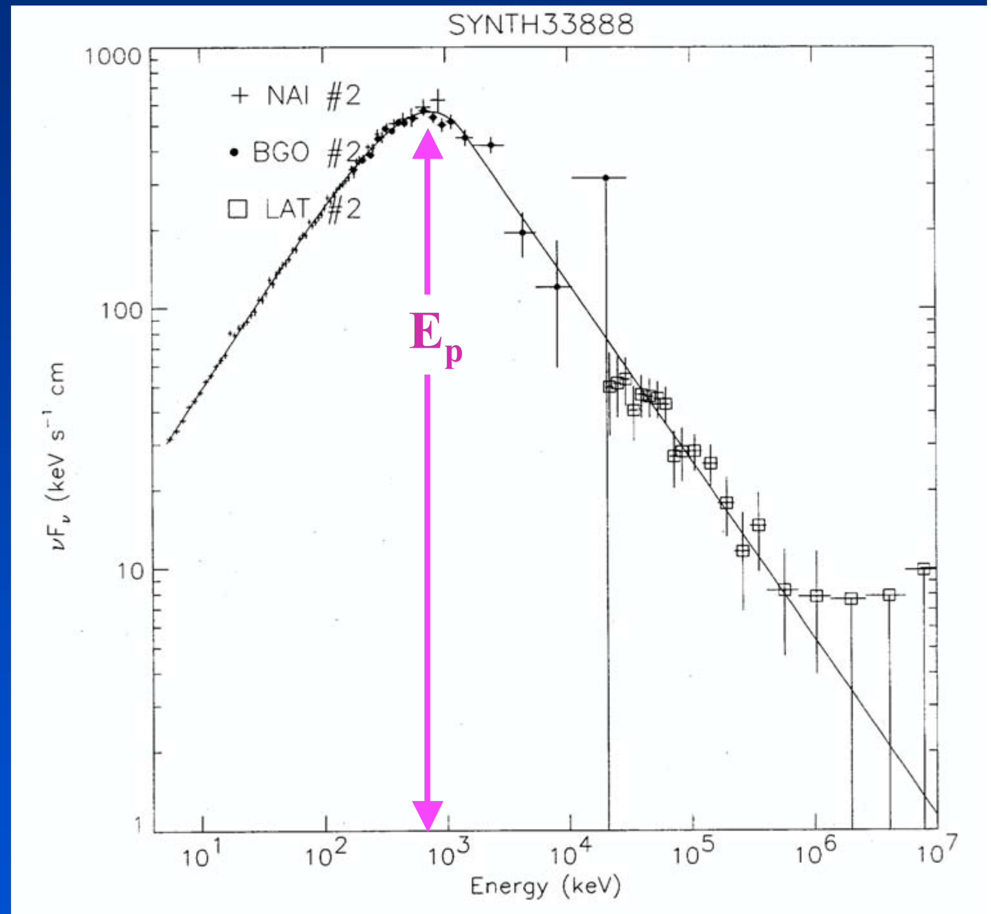
- preservation of the continuity to the BATSE-data
- participation in the 4th Interplanetary Network as earth-bound burst detector
- all-sky monitor for transient sources

Trigger Criteria & Interaction with LAT

- Rates are searched for sudden increases with 1.024 s resolution in energy interval 50-300 keV.
  Trigger criteria:
  - >4.5σ in 2 neighbouring NaI crystals
  - similar lightcurves in both detectors
  - calculation of an unambiguous position
- Trigger signal to LAT within 5 ms
- Position to the LAT for repoint within 2 s
  - if LAT repoints, then burst-location determination to <10 arcmin (goal: 3‘)
  - communication of this position to other observatories within ~10 s
- Initiation of fast transfer of GBM data to ground
- Calculation of a refined position on ground within few minutes
- Distribution of this position to the GCN

Simulated γ-ray burst spectrum of GRB 940217

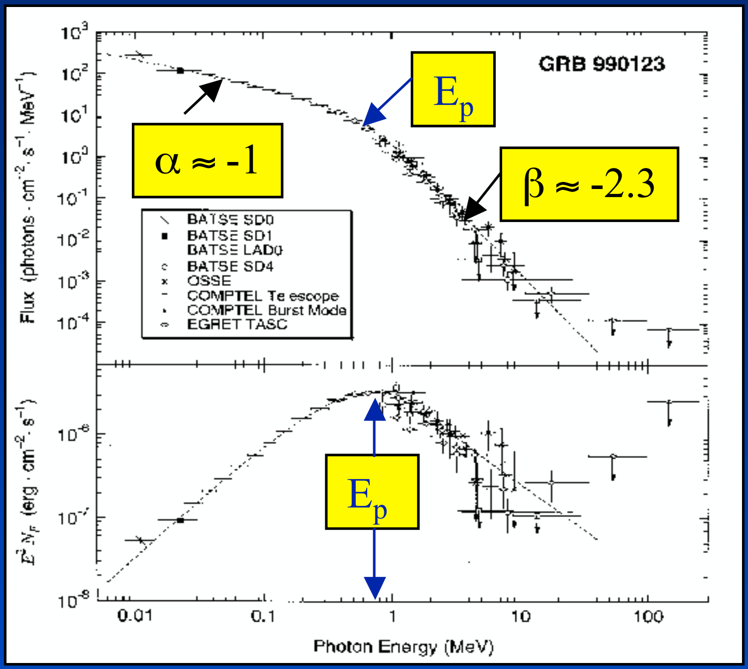


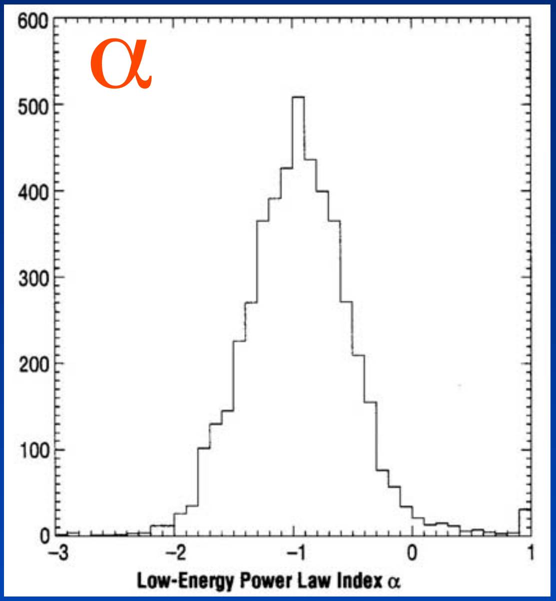


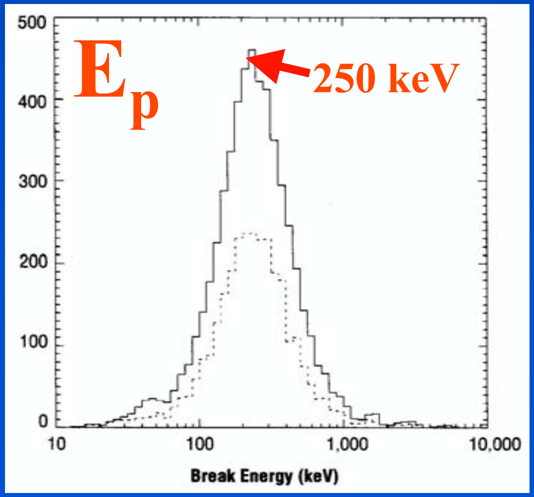
Measurement of a burst spectrum over 6 energy decades!

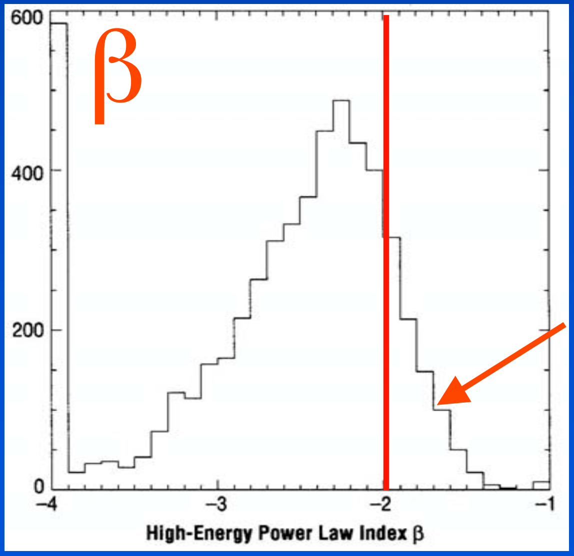
GBM needed for determination of E_p!

Spectral Characteristics of GRBs



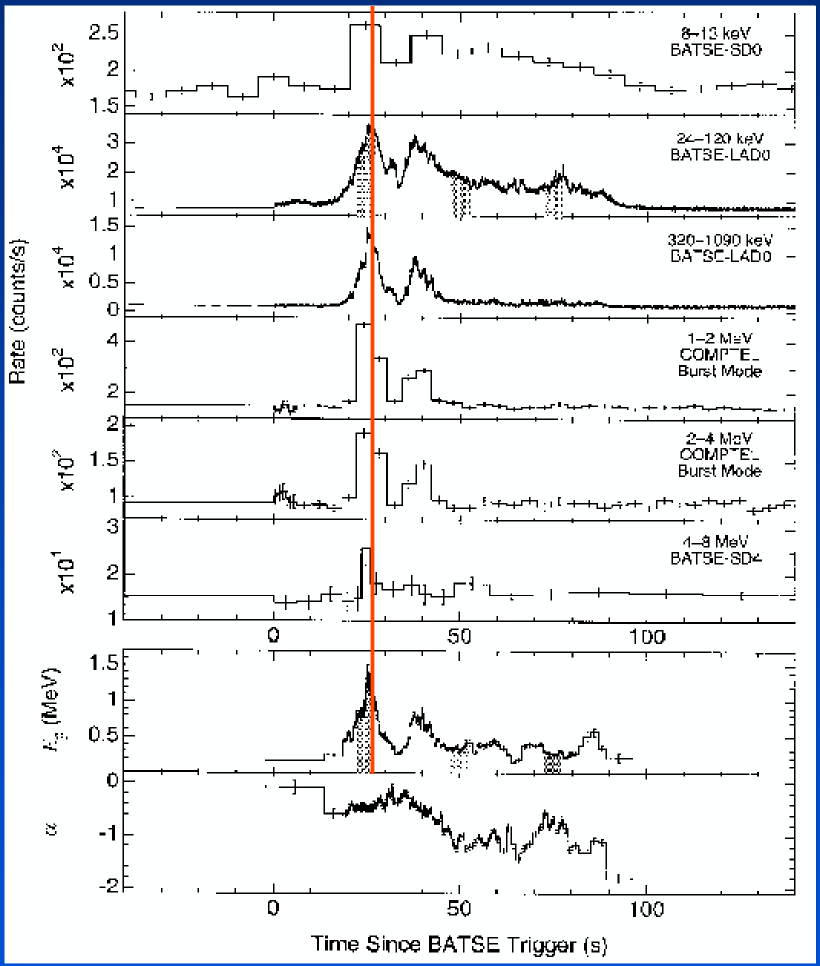






Energy-Resolved Lightcurves

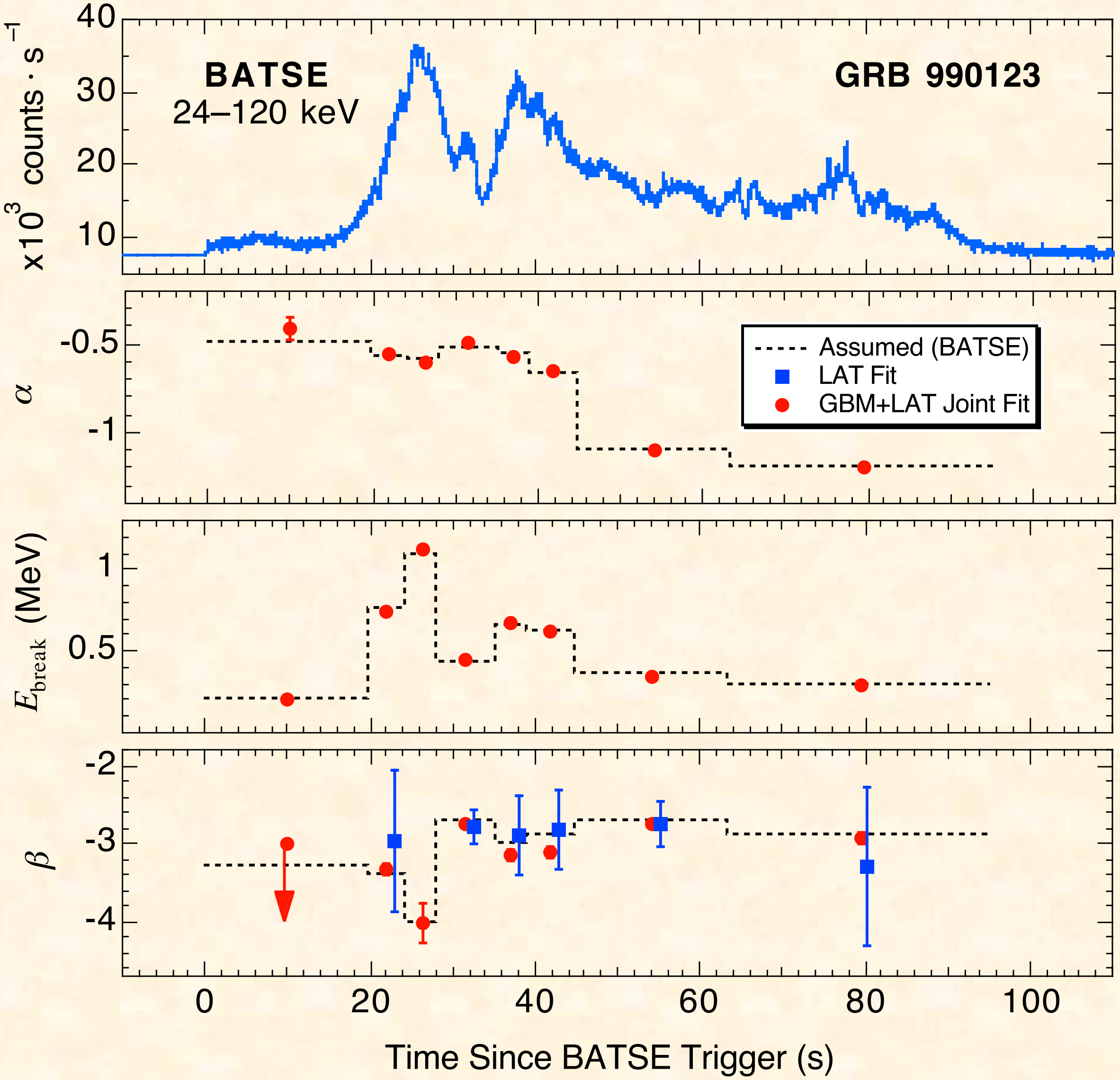
GRB 990123



CGRO results

- So-far obtained results of the observations:
  - low-energy emission lasts longer than high-energy emission
  - E_p correlates with the lightcurves (high E_p at large intensity and vice versa)
  - power-law index α shows hard-to-soft evolution
  - narrowing of the peaks with energy
  - high-energy peaks precede low-energy peaks
- With GLAST it will be possible, to investigate these correlations to high energies (evolution of power-law index β)!

Simulation of GRB 990123 for LAT + GBM



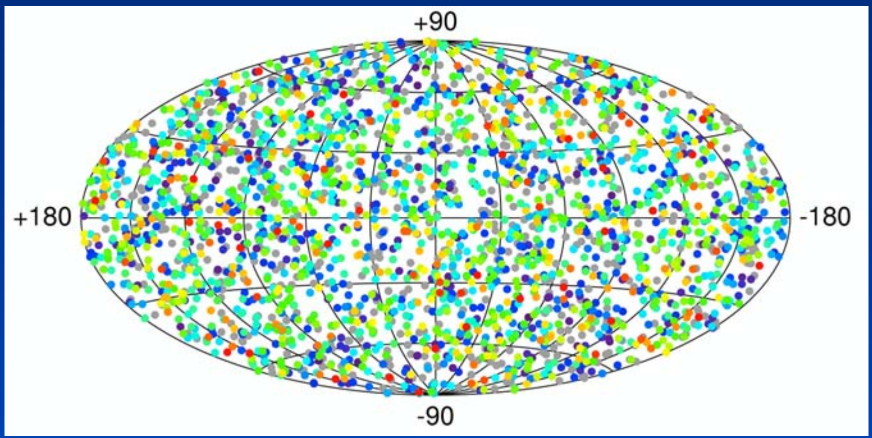
α hard-to-soft evolution

E_p correlates with intensity

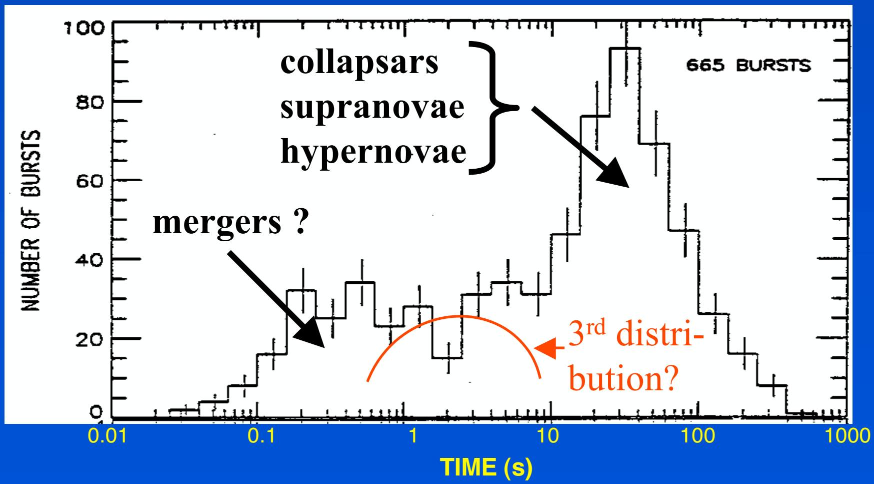
β anti-correlation with intensity?

Global Properties of GRBs (BATSE Results)

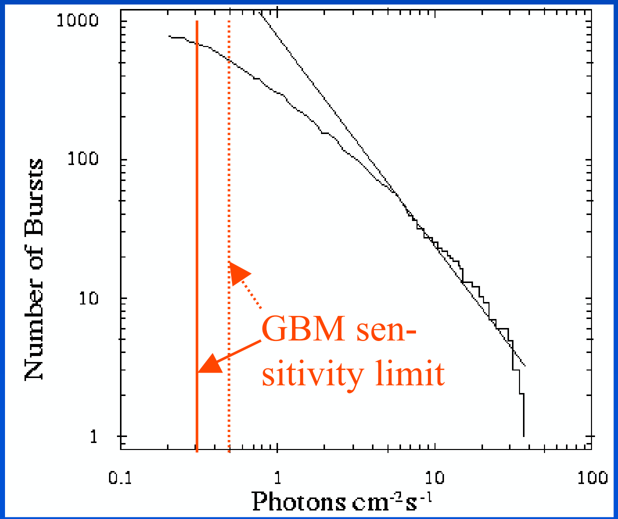
Isotropic distribution



Bimodality



Non-homogeneous distribution

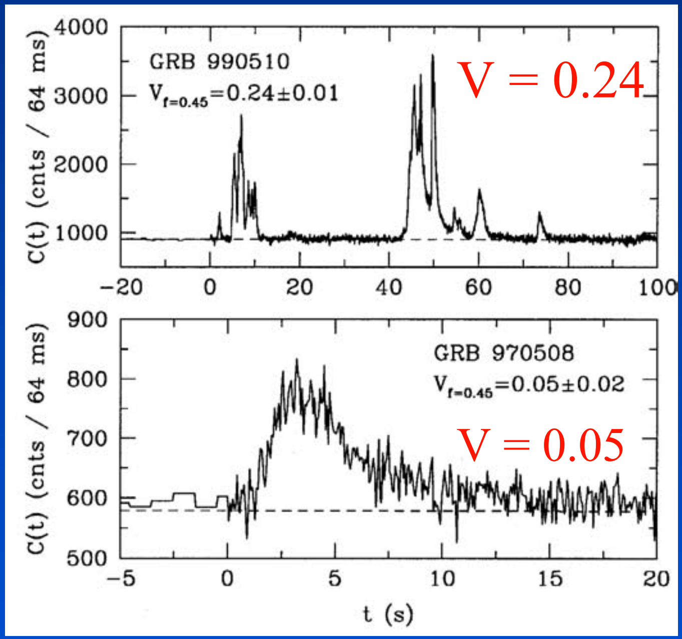


Prove or disprove of newly-discovered correlations

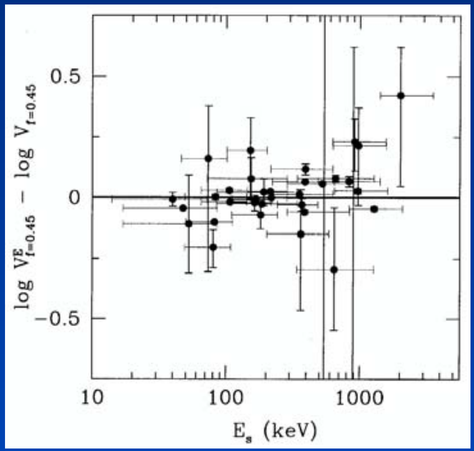
- In recent years correlations have been found which allow distance estimates of GRBs from measured burst parameters alone:
  - variability measure (Reichart et al. 2000)
  - spectral time lag (Norris et al. 2000)
  - gamma-photometric redshift determinations (Bagoly et al. 2002)
- With the data from GLAST (LAT & GBM) these correlations can be proved or disproved.

Luminosity Determination by means of a Variability Measure V (Cepheid-like Luminosity Determination?)

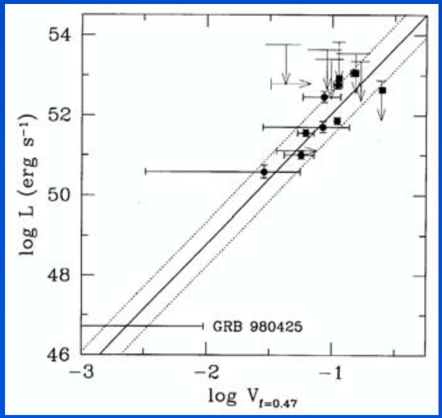
Introduction of a “robust” variability measure V



V is not depending on energy:



Calibration of the L(V)-Relation by means of 13 measured redshifts:

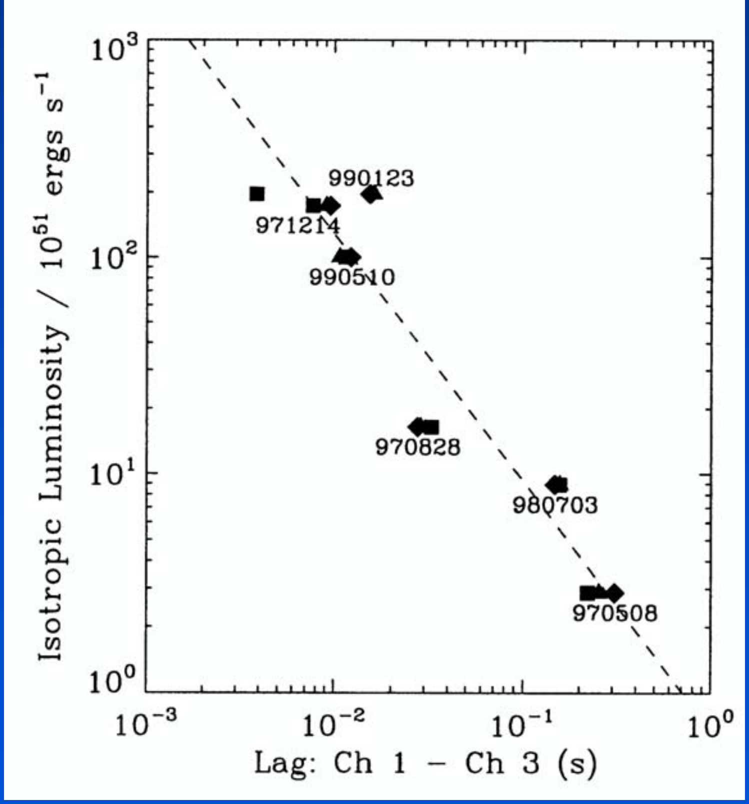


$L \sim V^{3.3}$

The more variable the lightcurve, the larger the luminosity (e. g. Reichart et al. 2001).

Luminosity-Time-Lag Relation of GRBs

Norris et al. (Ap. J. 534, 248, 2000) correlated the peak luminosity with the measured time lag for bursts with known redshifts:



$$L \sim \tau^{-1.1}$$

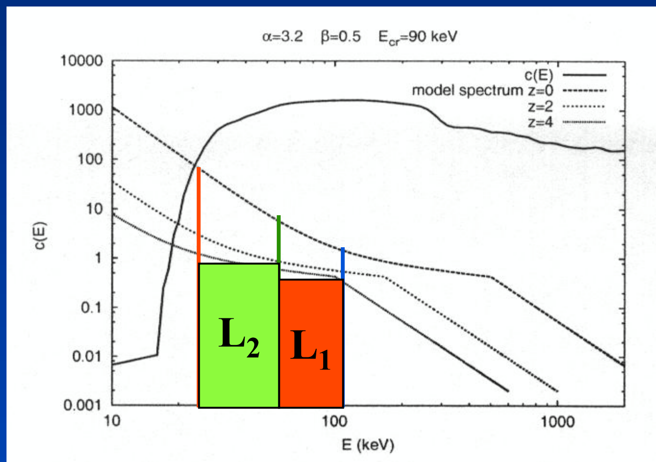
τ = time delay of the peak position with energy: 25-50 keV & 100-300 keV

measurement of τ with GBM possible

Determination of a Gamma-Photometric Redshift?

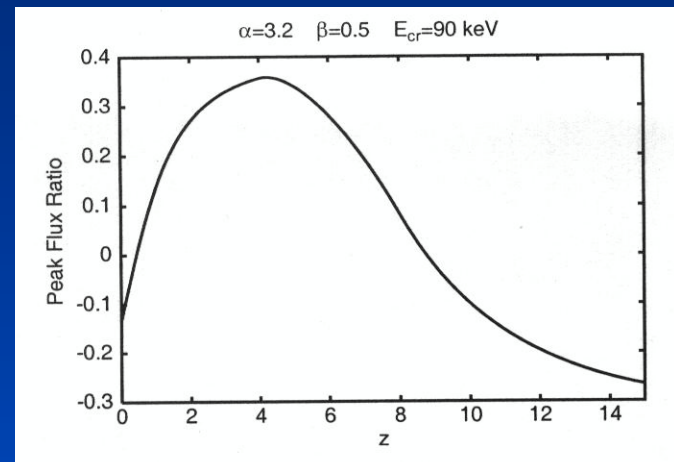
Definition of a peak-flux ratio:

$R = (L_1 - L_2)/(L_1 + L_2)$

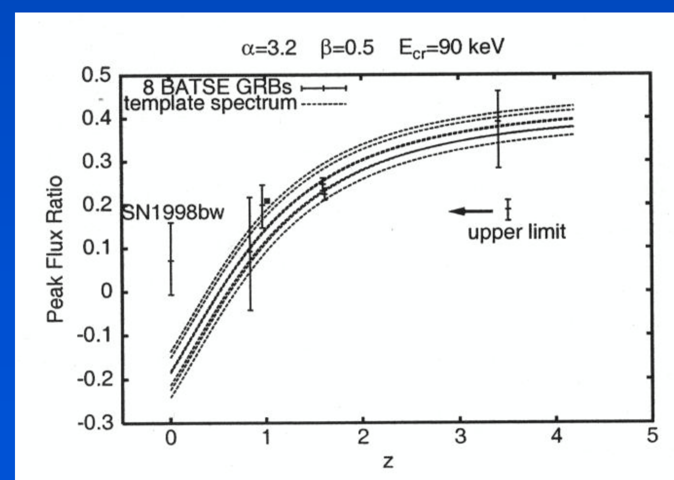


25 55 100 keV

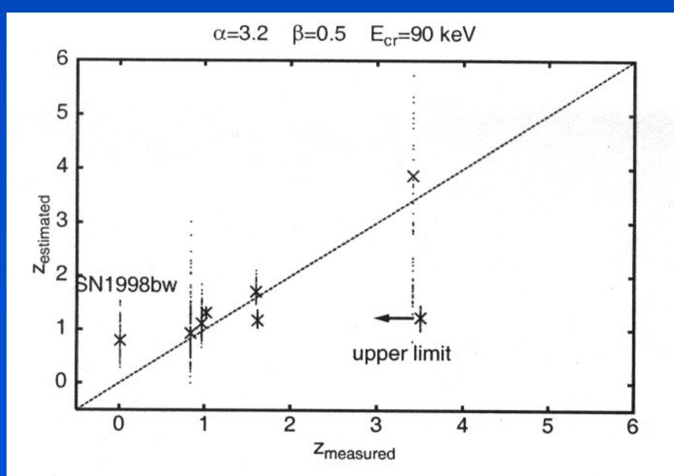
Dependence of R on z



Tested with 6 BATSE bursts with known redshifts



Comparison of measured and determined redshifts



Conclusion or Expected Results of the GBM

- Investigation of the relation between keV-MeV-GeV emission
- Measurement of
  - time-resolved energy spectra (time-resolved spectroscopy) and
  - energy-resolved lightcurves
- Final determination of the position of γ-ray bursts ($\sim 1.5^{O}$)
- Production of a burst catalog with
  - position
  - duration
  - integrated fluxes (fluences)
  - maximal energy flux (energy flux at E_p)
- GRB trigger with location
  - for the main instrument (LAT) within seconds for repointing
  - for the interplanetary network
- Investigation of behaviour of spectral parameters E_p, α, β with respect to
  - correlation with high-energy emission
  - dependence on time
  - overall distribution
- Creation of transient alerts

The End

Pulse Narrowing and Time Lags

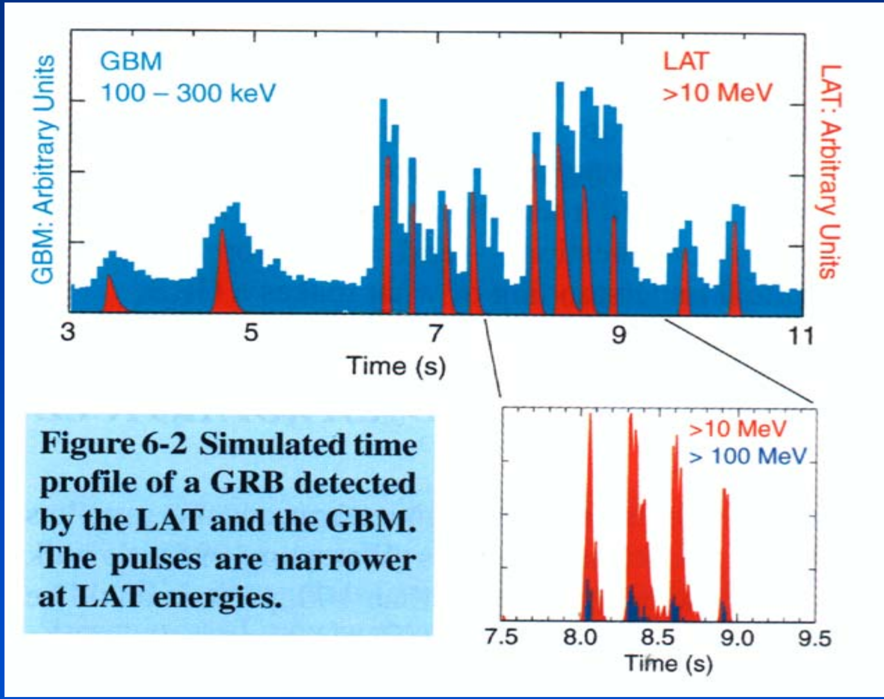


Figure 6-2 Simulated time profile of a GRB detected by the LAT and the GBM. The pulses are narrower at LAT energies.