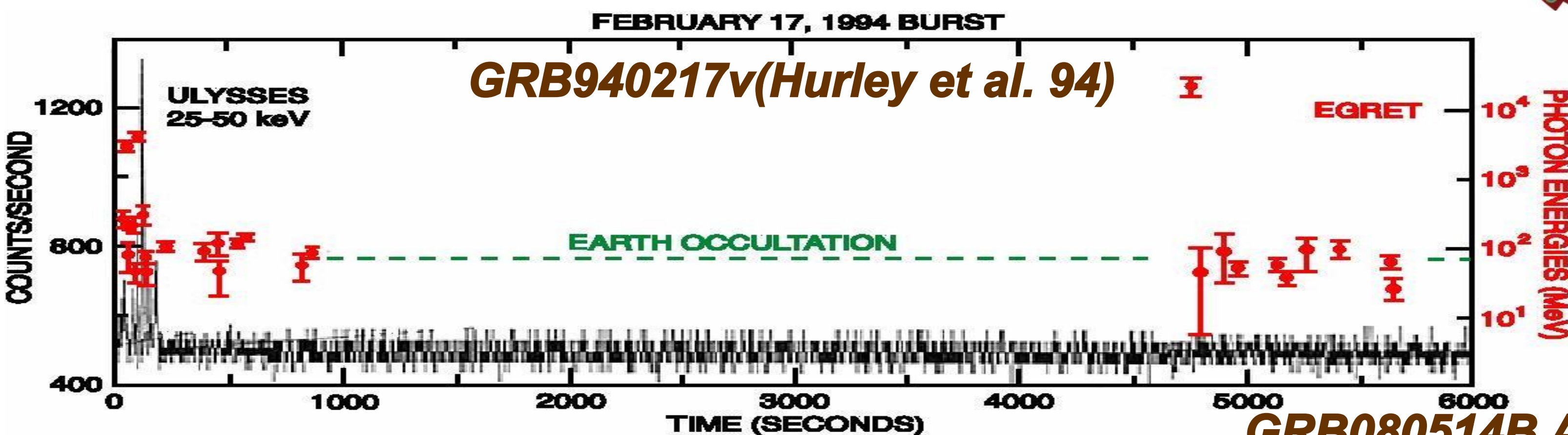
DETECTION OF A SPECTRAL CUTOFF IN THE EXTRA HARD COMPONENT FROM GRB 090926A

Ackermann +10 (submitted)

Takeshi Uehara (Hiroshima Univ.)
on behalf of the Fermi LAT and GBM Collaborations

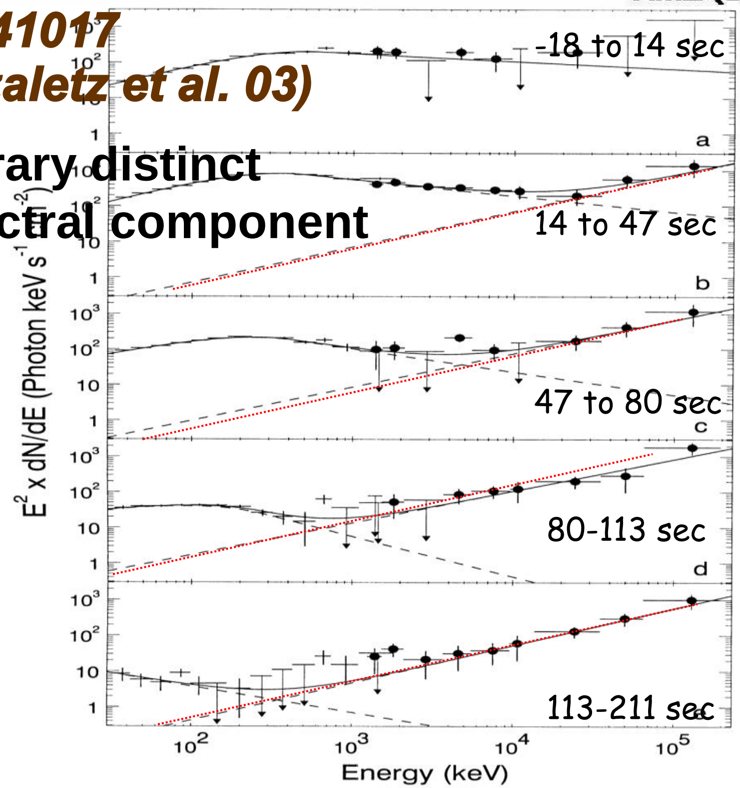
HE emission from GRBs : Pre-Fermi Era

GRB940217v(Hurley et al. 94)



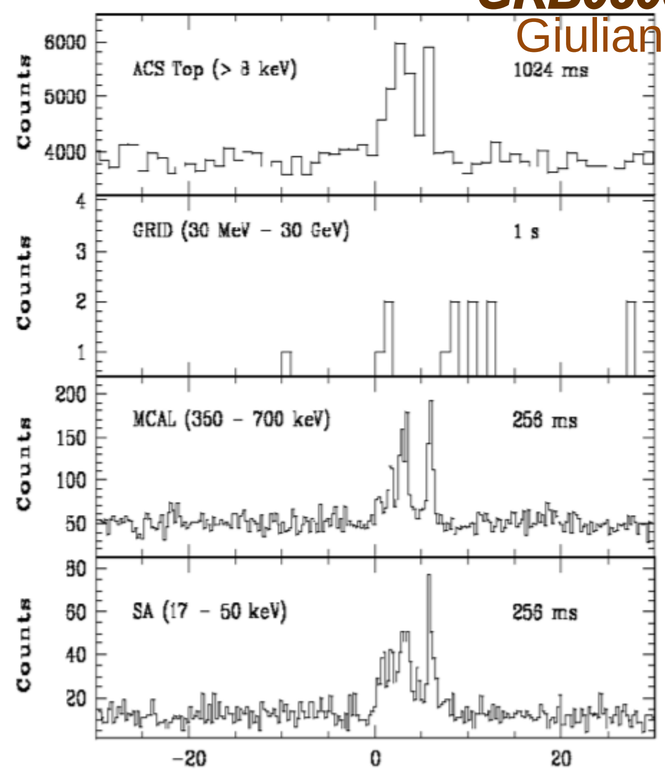
GRB941017
(Gonzaletz et al. 03)

Temporary distinct
HE spectral component



GRB080514B AGILE
Giuliani et al. 08

Long-lived
HE emission



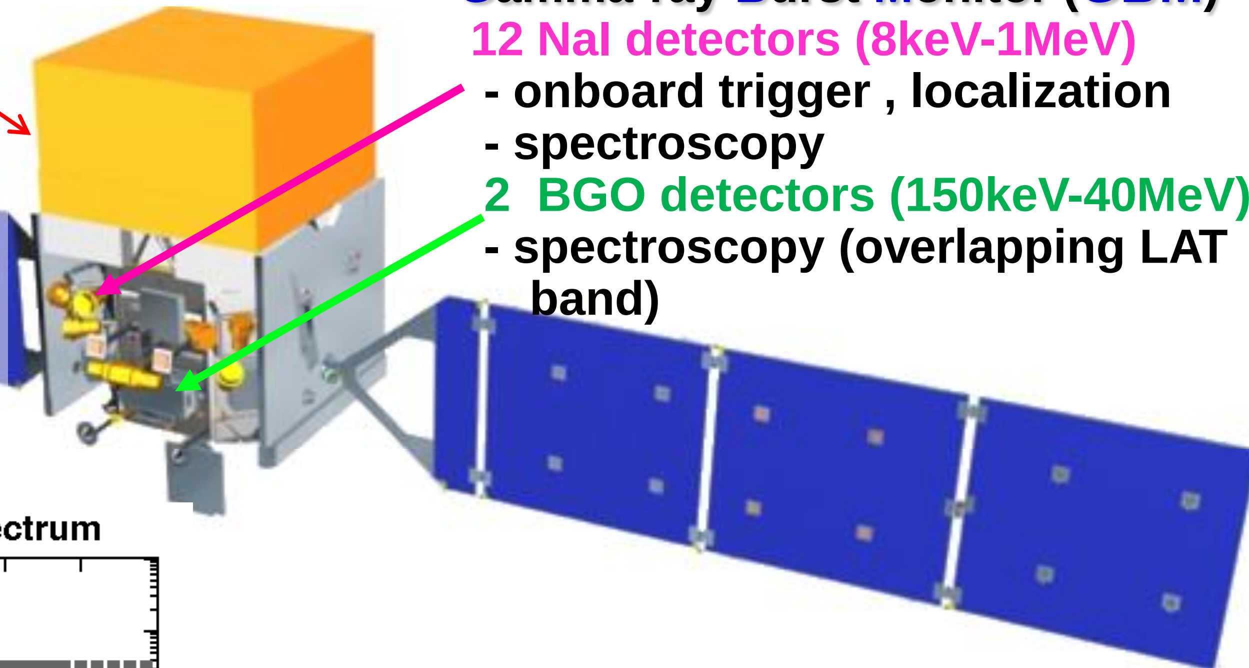
Fermi Gamma-ray Space Telescope

LAT
(80MeV-300GeV)

Silicon-Strip detectors
- **Identification &direction measurement of γ-rays**

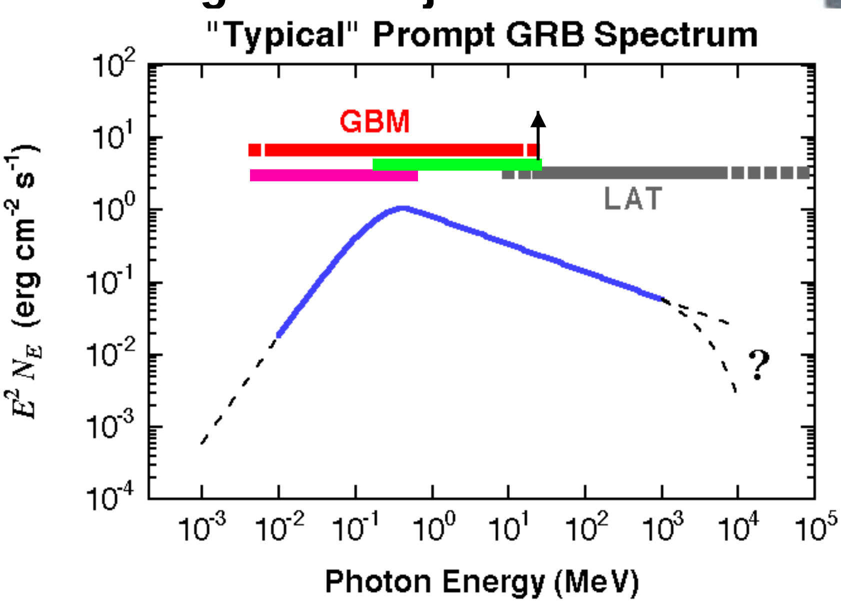
CsI calolimetor
- **Energy measurement**

ACD (plastic scintillators)
- **background rejection**



Gamma-ray Burst Monitor (GBM)
12 NaI detectors (8keV-1MeV)
- **onboard trigger , localization**
- **spectroscopy**

2 BGO detectors (150keV-40MeV)
- **spectroscopy (overlapping LAT band)**



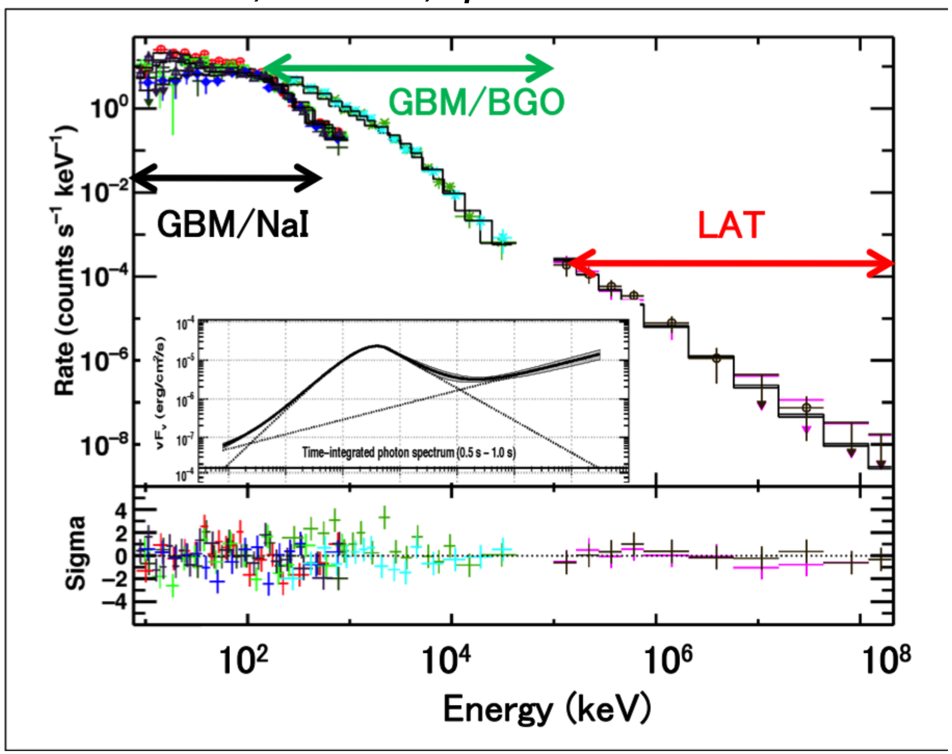
- **Efficient observing mode**
- **Wide FoV**
- **Low deadtime**
- **Large effective area**
- **Good angular resolution**
- **Energy coverage**

More photons from Many GRBs

GRB high energy spectrum

GRB 090510 (short)

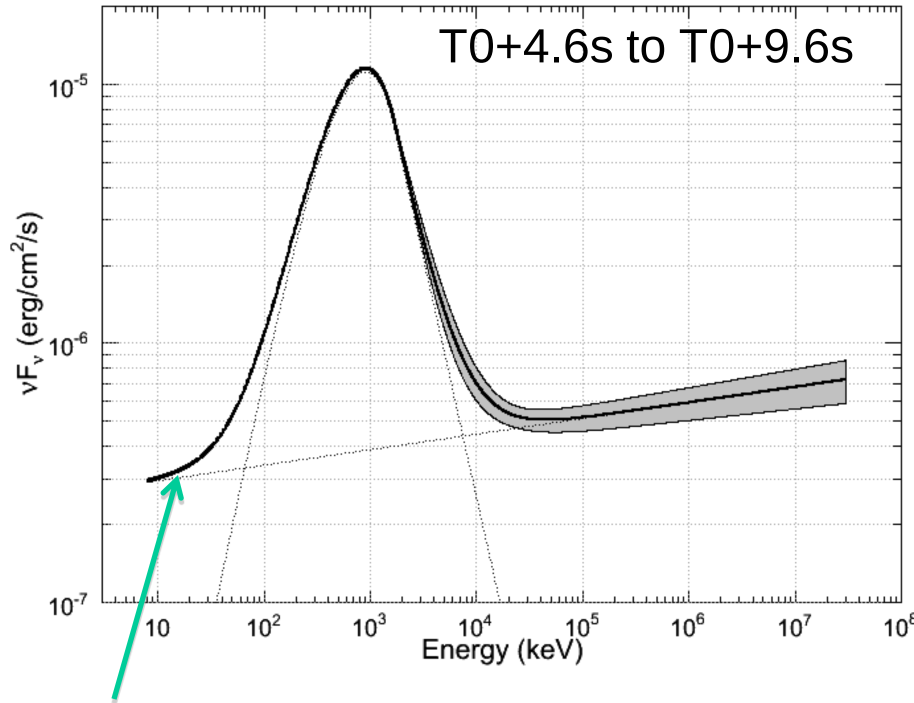
Abdo, A. A. et al., ApJ submitted



First extra component by Fermi
At > 5 sigma level

GRB 090902B (long)

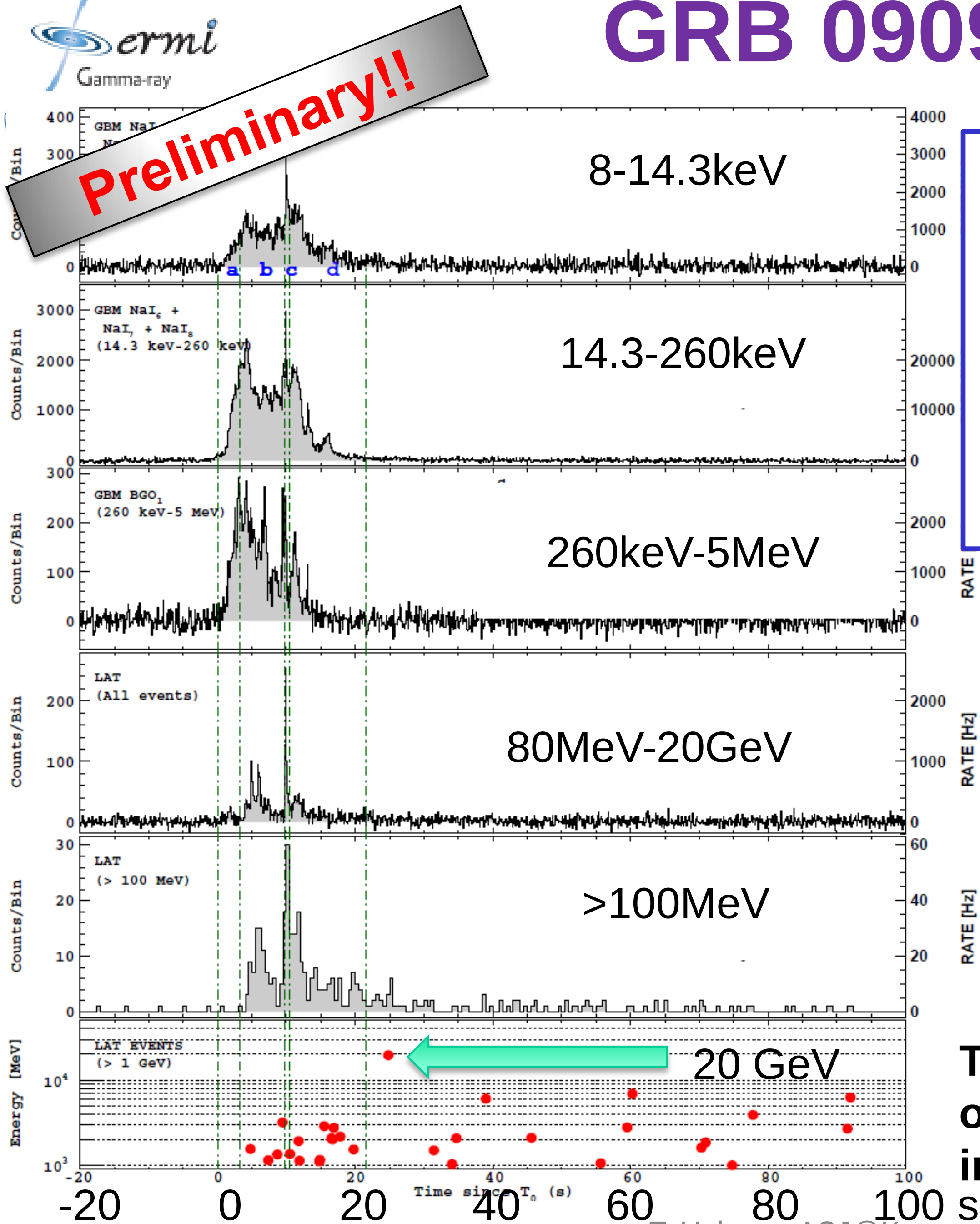
Abdo, A. A. et al., ApJL 706, 138 (2009)



- First time a low-energy extension of the PL component has been seen

CGRO reported a PL extra-component in a few GRBs.
LAT have detected ~14 GRBs above 80 MeV in 2 years, and extra PL component is significantly detected from two bursts.

GRB 090926A



- **Long GRB(T90=21 s)**
- **One of the brightest LAT GRB**

(199/29 photons above 100MeV/1GeV)

Uehara +09 GCN 9934

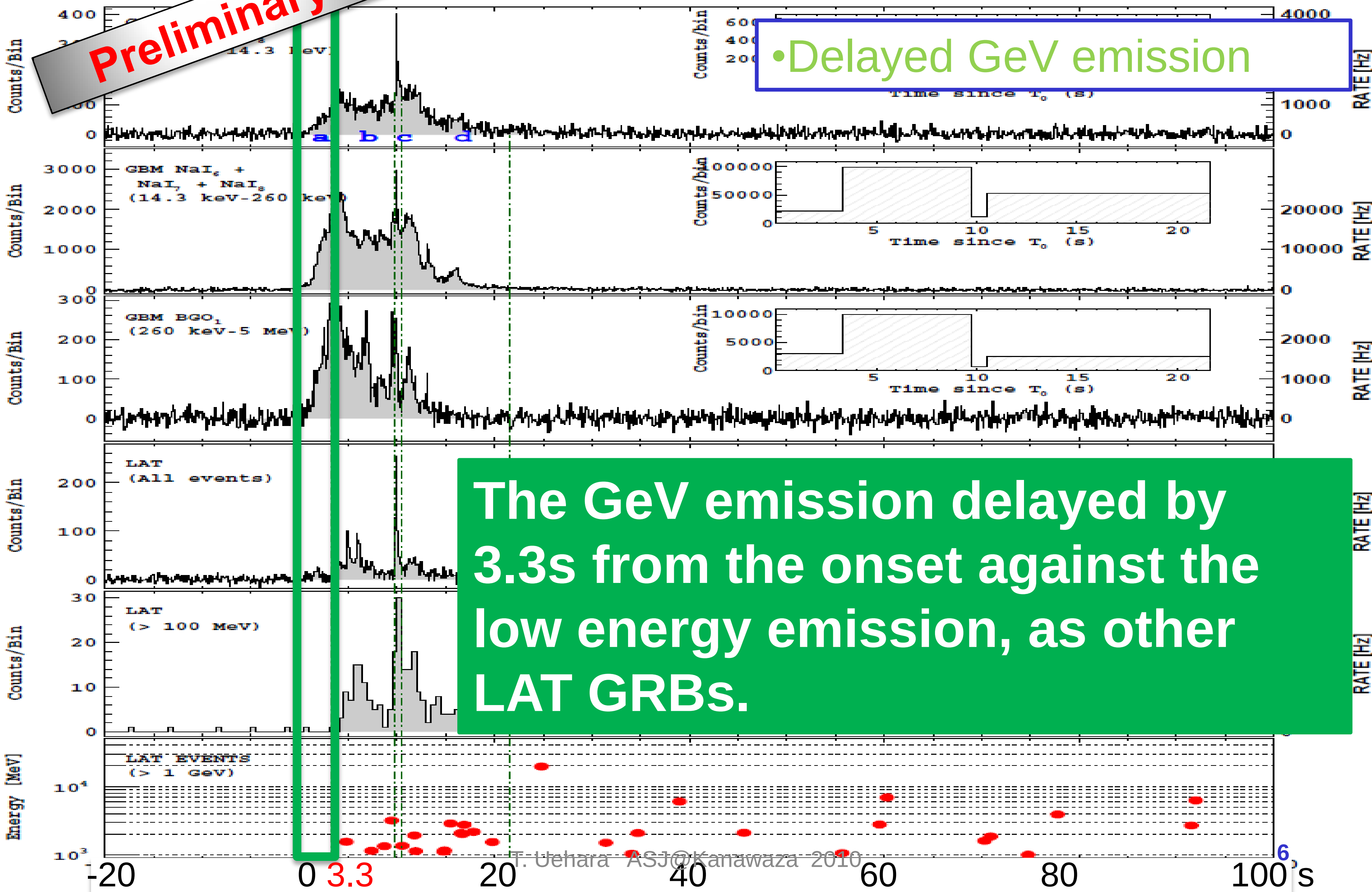
- **z=2.1062**

The bottom panel plots an energy of gamma-rays above 1 GeV in the LAT transient class data.

Light curves

Preliminary!!

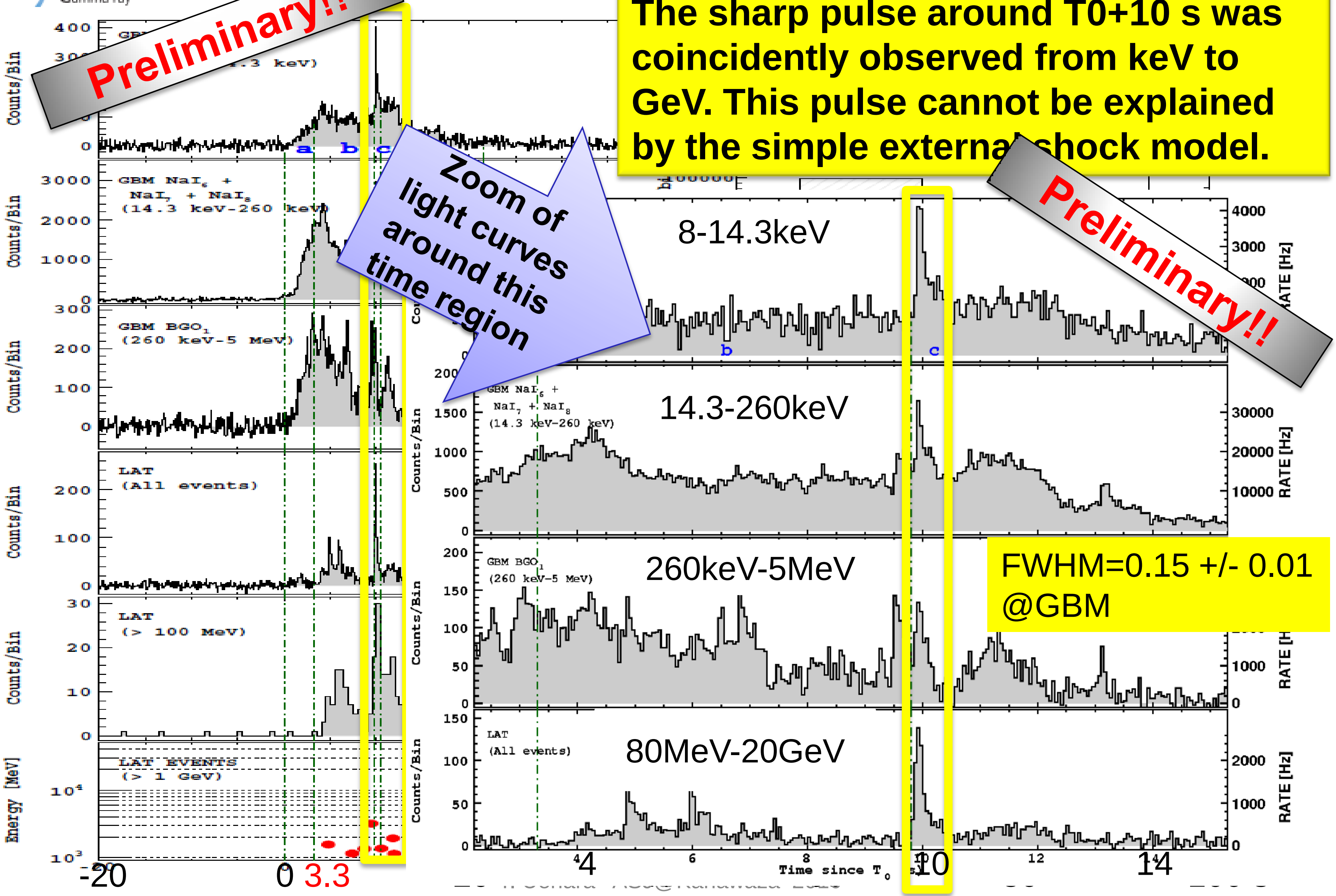
•Delayed GeV emission



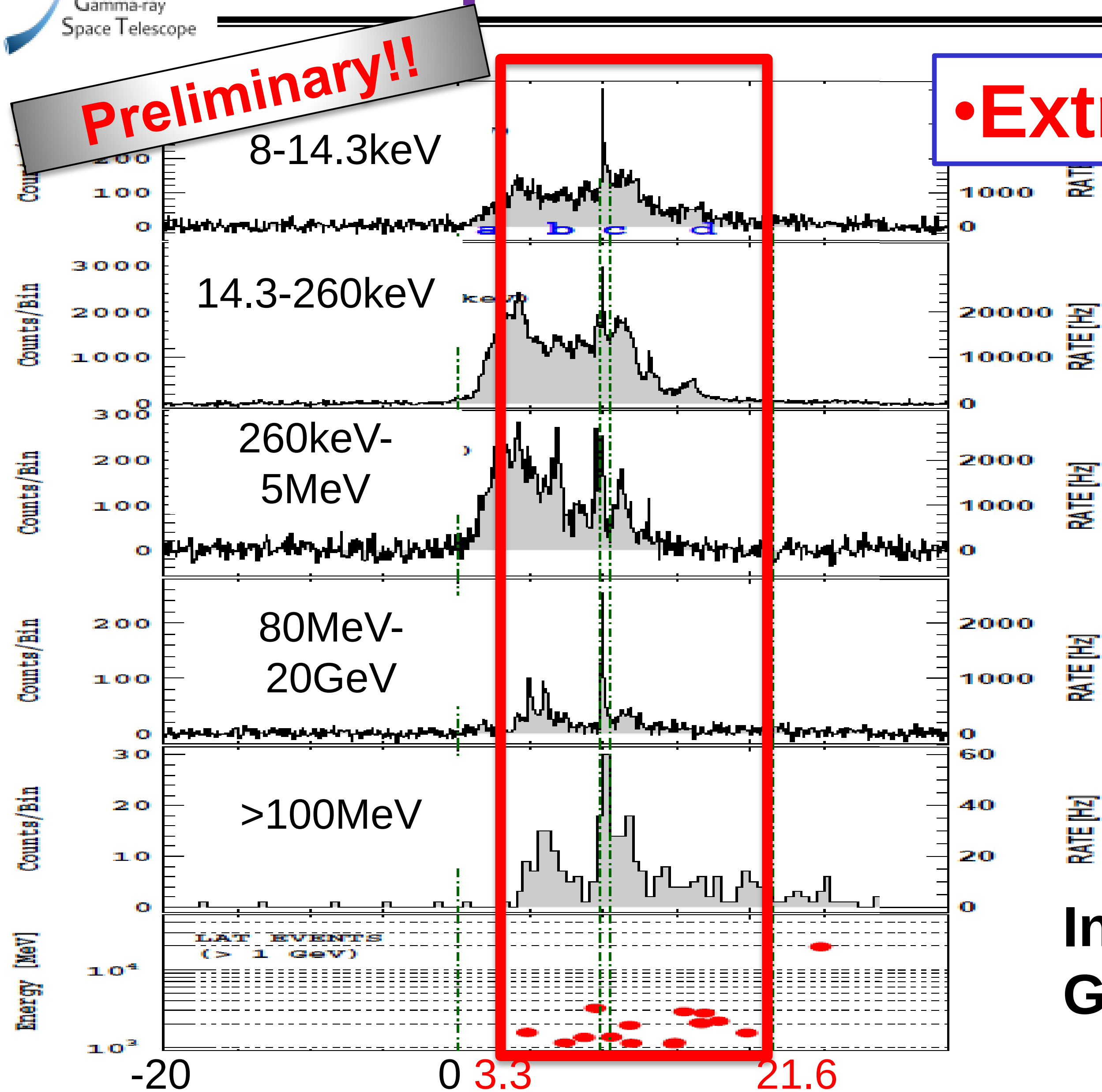
The GeV emission delayed by 3.3s from the onset against the low energy emission, as other LAT GRBs.

Light curves

The sharp pulse around T0+10 s was coincidently observed from keV to GeV. This pulse cannot be explained by the simple external shock model.



Spectrum on 3.3-21.6 s

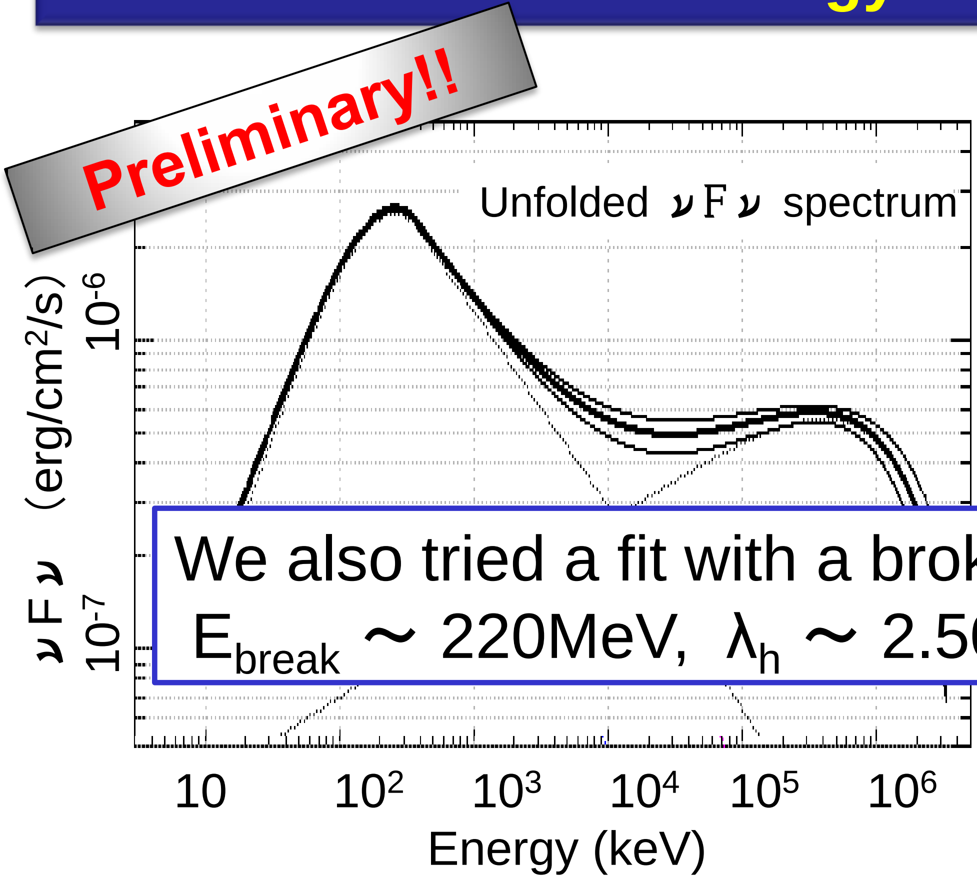


•Extra-component

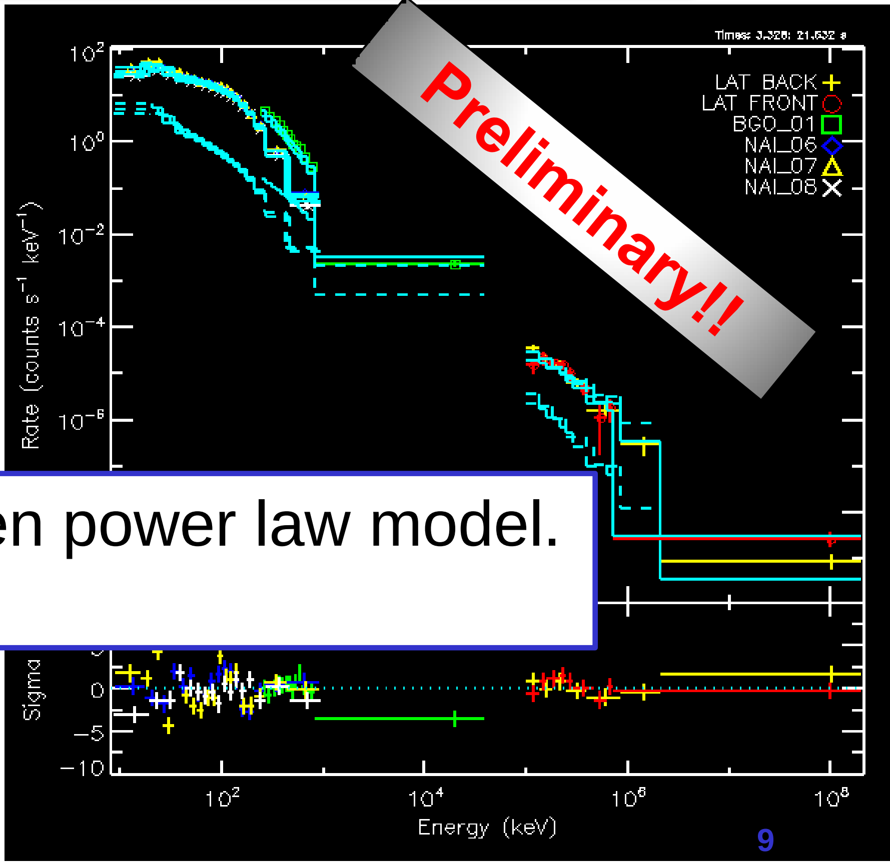
In this time region, GeV emission is bright.

Spectrum on 3.3 — 21.6 s

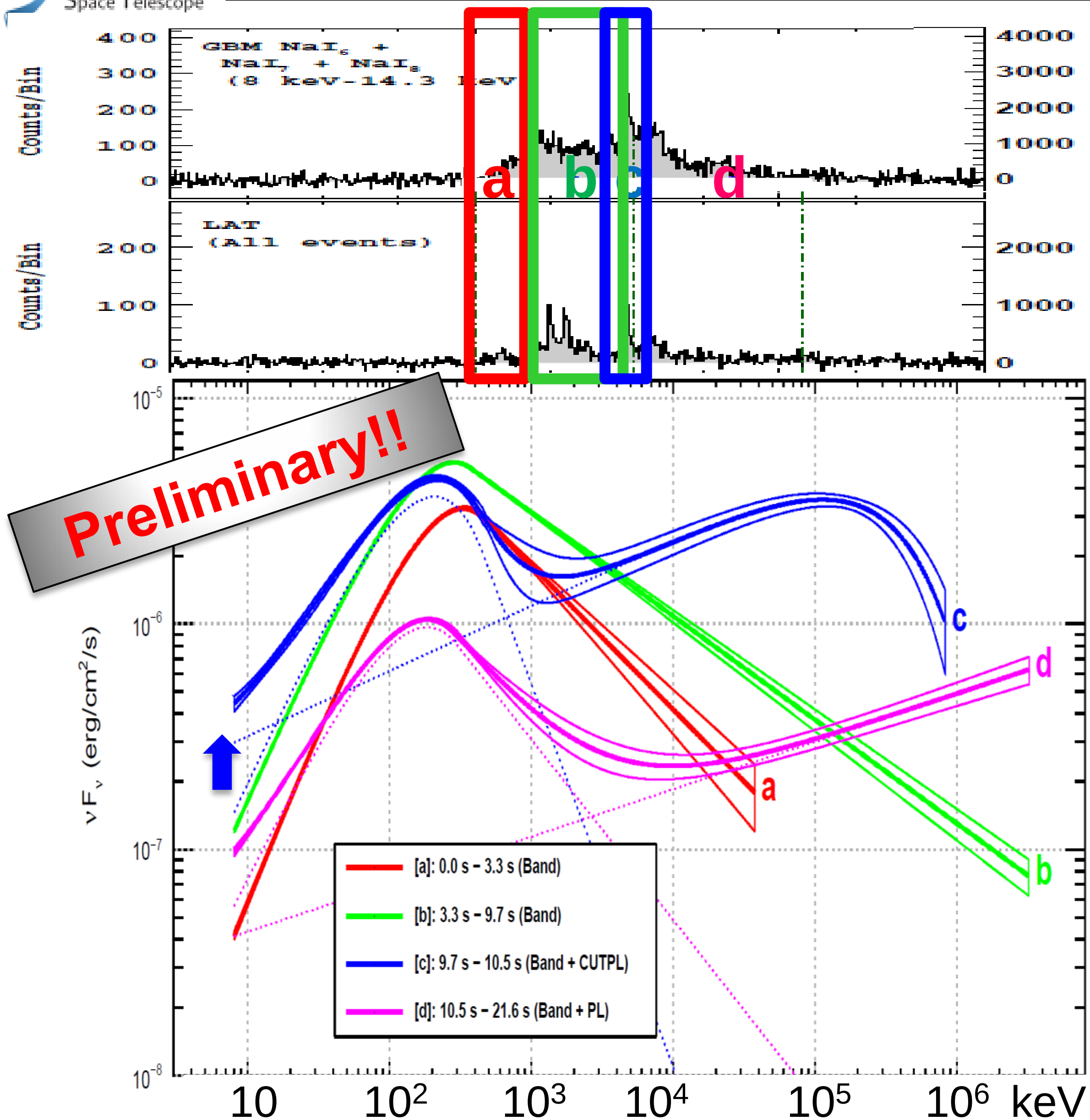
Since the LAT spectrum shows a signature of the spectral break, we include the high energy cut-off for the extra PL component. Then, the fit improves rather than 4 σ. The cut-off energy is around 1.4 GeV.



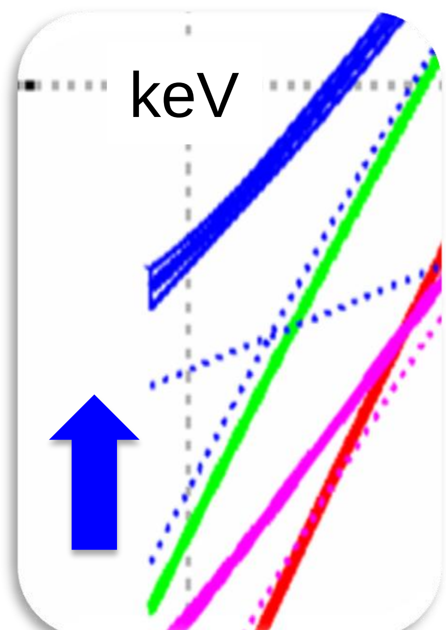
We also tried a fit with a broken power law model.
E_{break} ~ 220MeV, λ_h ~ 2.50.



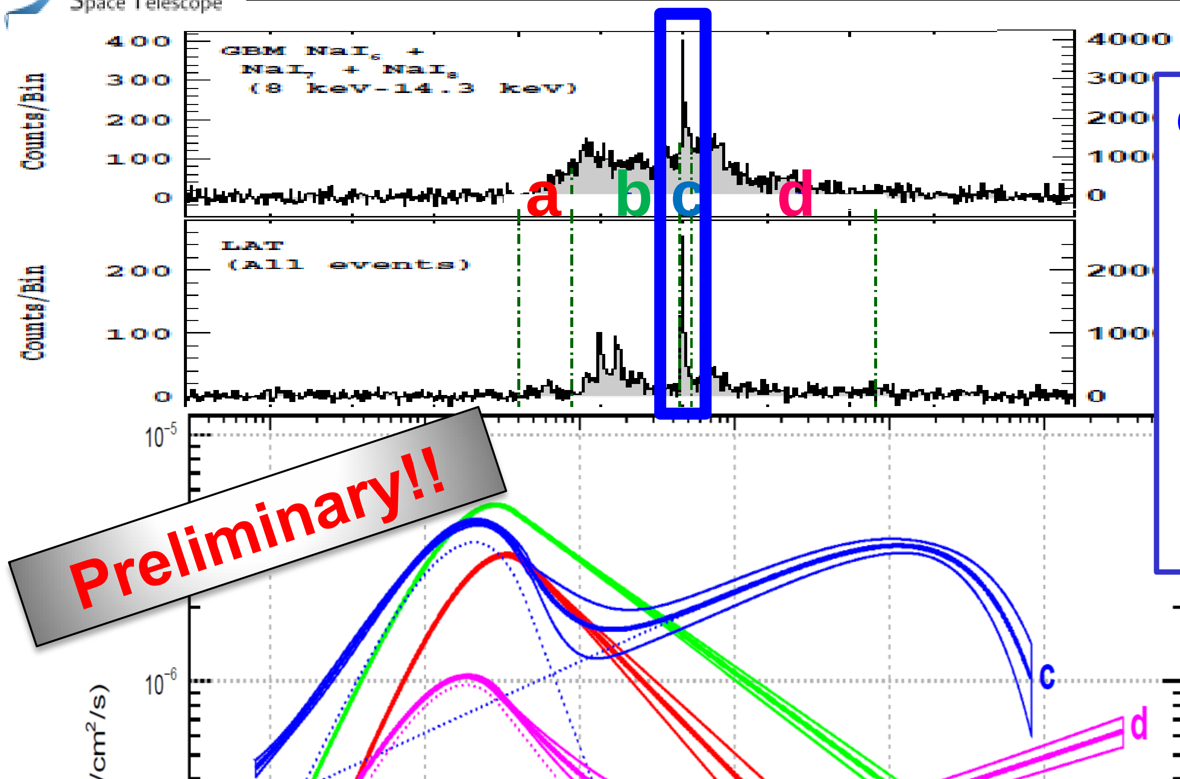
Time resolved spectra



a: Band
Ep~340keV, α~-0.4, β~-2.6
b: Band
Ep~290keV, α~-0.6, β~2.5
c: Band + Cutoff-PL
Ep~210keV, α~0.6, β~3.7
Ef~400MeV, λ~1.70
d: Band + PL
Ep~190keV, α~0.7, β~2.8
λ~1.80



Time resolved spectra



c:

Band + Cutoff-PL

Ep∼210keV, α∼0.6, β∼3.7

Ef∼400MeV, λ∼1.70

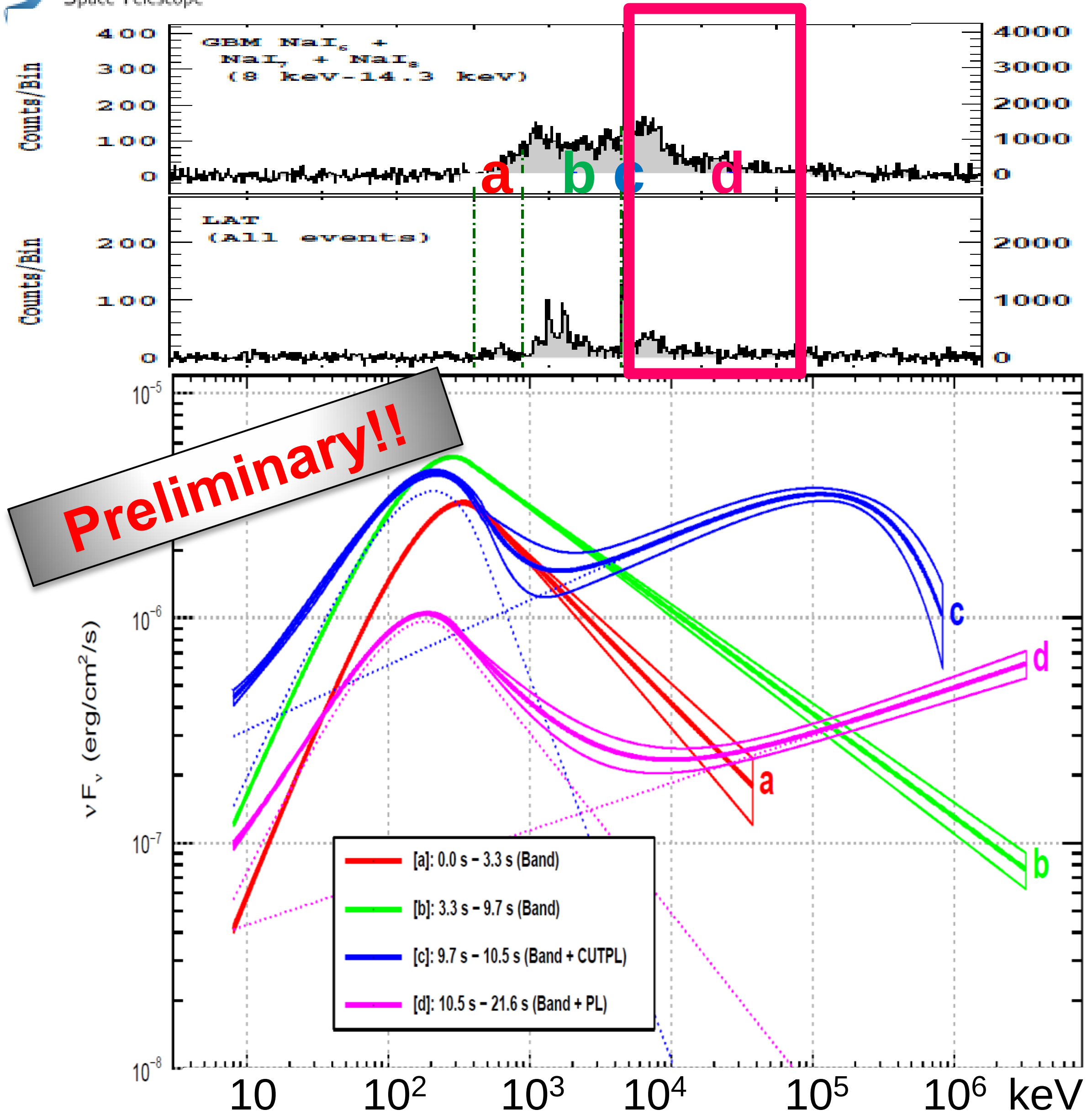
Band + Broken PL

E_{break}∼260MeV, λ_h∼3.6

The extra component has a **spectral break around ~0.4GeV, with > 4 σ significance in time bin c.**

The cutoff gives constraint on the **bulk Lorentz factor to be Γ ~720** for the first time, if the spectral break is due to the gamma-gamma absorption.

Time resolved spectra



a: Band
Ep~340keV, α~-0.4, β~-2.6

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Ep~290keV, α~-0.6, β~2.5

c: Band + Cutoff-PL
Ep~210keV, α~0.6, β~3.7
Ef~400MeV, λ~1.70

d: Band + PL
Ep~190keV, α~0.7, β~2.8
λ~1.80

Summary of GRB090926A

- ✓One of the brightest LAT GRB
- ✓Delayed GeV emission
- ✓A sharp pulse coincidently in GBM and LAT
- ✓Extra PL component with spectral break for the first time in integrated spectrum
- ✓Spectral break in 0.4 GeV and excess extra PL in keV at the sharp pulse $\rightarrow \Gamma \sim 720$

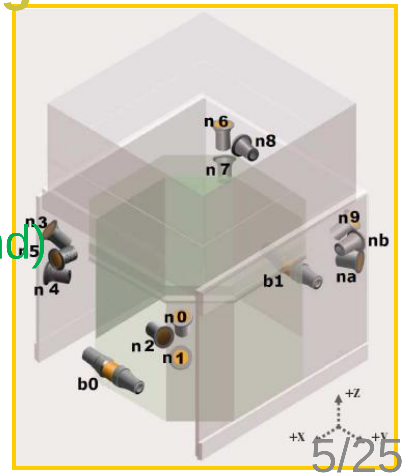
Extras

The Fermi Observatory

- **Spacecraft :**

  Low-Earth Circular Orbit (altitude 550 km) with 28.5° inclination

- **Large Area Telescope (LAT) :**
  - Energy range : 20 MeV to >300 GeV
  - Large field of view : ~2.4 sr at 1 GeV
  - Full sky coverage every 3 hours
  - Localization, spectroscopy and GRB trigger capabilities (on board and ground)
- **Gamma-ray Burst Monitor (GBM):**
  - Full unocculted sky coverage : >9.5 sr
  - On board triggers
  - 8 keV to 40 MeV
  - 12 NaI (8 keV to 1 MeV)
    - Localization (on board & ground)
    - Spectroscopy
  - 2 BGO (200 keV to 40 MeV)



Spectrum on 3.3 — 21.6 s

•Extra-component

1, Band function: There is a residual @~GeV.
2, Band + PL component:
Improving significantly (> 10σ)
(GRB 090510 and GRB 090902B)

Limit on bulk Lorentz factor

Due to large luminosity and small emitting region, optical depth for the γ-γ -> e+e- pair production is too large to observe the non-thermal emission from GRB → compactness problem.

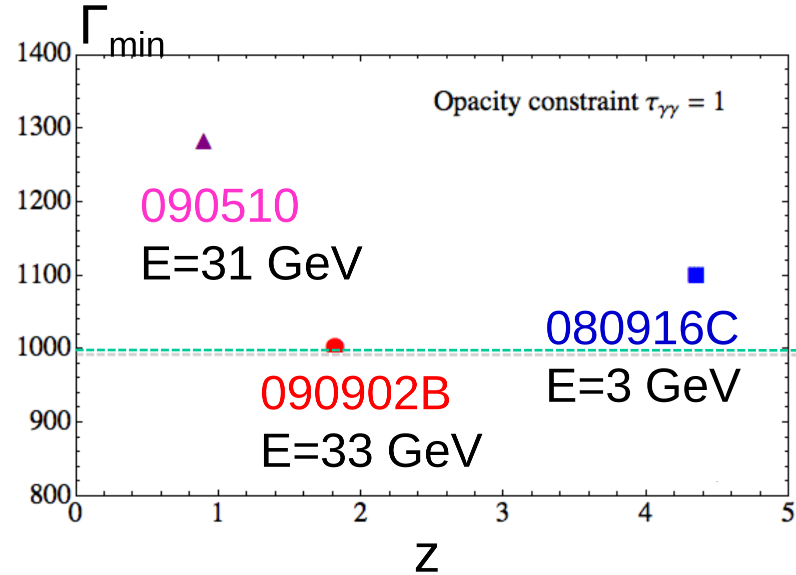
Relativistic motion (Γ>>1) could avoid this compactness problem

$$\tau_{\gamma\gamma}(E) = \frac{3}{4}\frac{\sigma_T d_L^2}{t_v \Gamma}\frac{m_e^4 c^6}{E^2(1+z)^3}\int_{\frac{m_e^2 c^4 \Gamma}{E(1+z)}}^{\infty}\frac{d\epsilon'}{\epsilon'^2}\, n\left(\frac{\epsilon'\Gamma}{1+z}\right)\varphi\left[\frac{\epsilon' E(1+z)}{\Gamma}\right]$$

Γ_{min} can be derived using observed highest energy photon

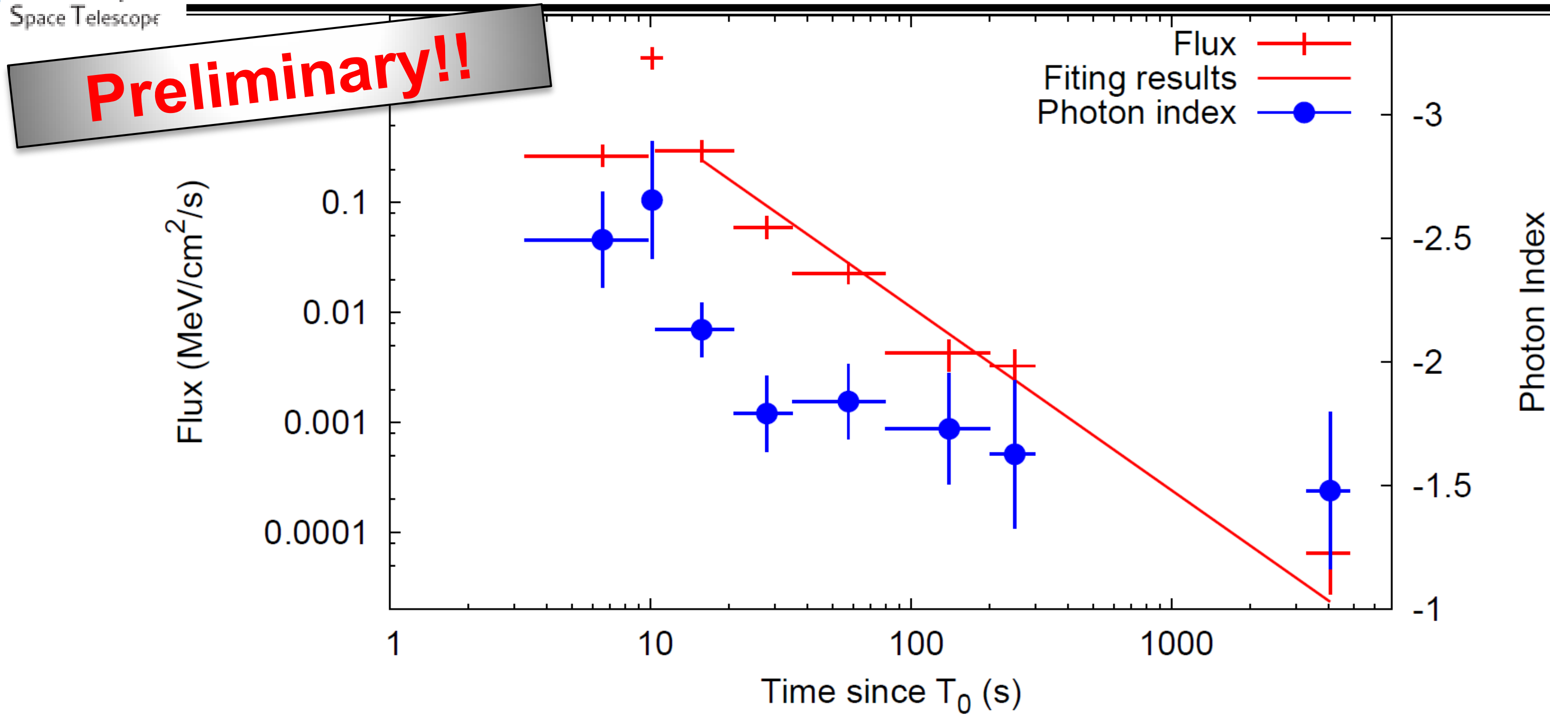
$$\Gamma_{\rm min}(E_{\rm max}) = \left[\frac{4 d_L^2 A}{c^2 t_v}\frac{m_e^2 c^4}{(1+z)^2 E_{\rm max}} g \sigma_T\right]^{\frac{1}{2-2\beta}}\left[\frac{(\alpha-\beta)E_{\rm pk}}{(2+\alpha)100\ {\rm keV}}\right]^{\frac{\alpha-\beta}{2-2\beta}} \times \exp\left(\frac{\beta-\alpha}{2-2\beta}\right)\left[\frac{2 m_e^2 c^4}{E_{\rm max}(1+z)^2 100\ {\rm keV}}\right]^{\frac{\beta}{2-2\beta}};$$

$$\text{for}\quad \Gamma_{\rm min} > \sqrt{\frac{(1+z)^2 E_{\rm max} E_{\rm pk}(\alpha-\beta)}{2 m_e^2 c^4 (2+\alpha)}},$$



Γ_{min}~1000 for short and long GRBs

Extended emission



The LAT flux follows a power-law. The decay index is −1.69±0.3 after T0 + 20 (~T90)s. This behavior is similar to other cases, such as GRB 090510 and GRB 090902B. This is expected by standard external shock model.

The spectral photon index largely varies before T0 + 20 s from 2.5 to 1.7, while it is almost constant around 1.5–1.9.

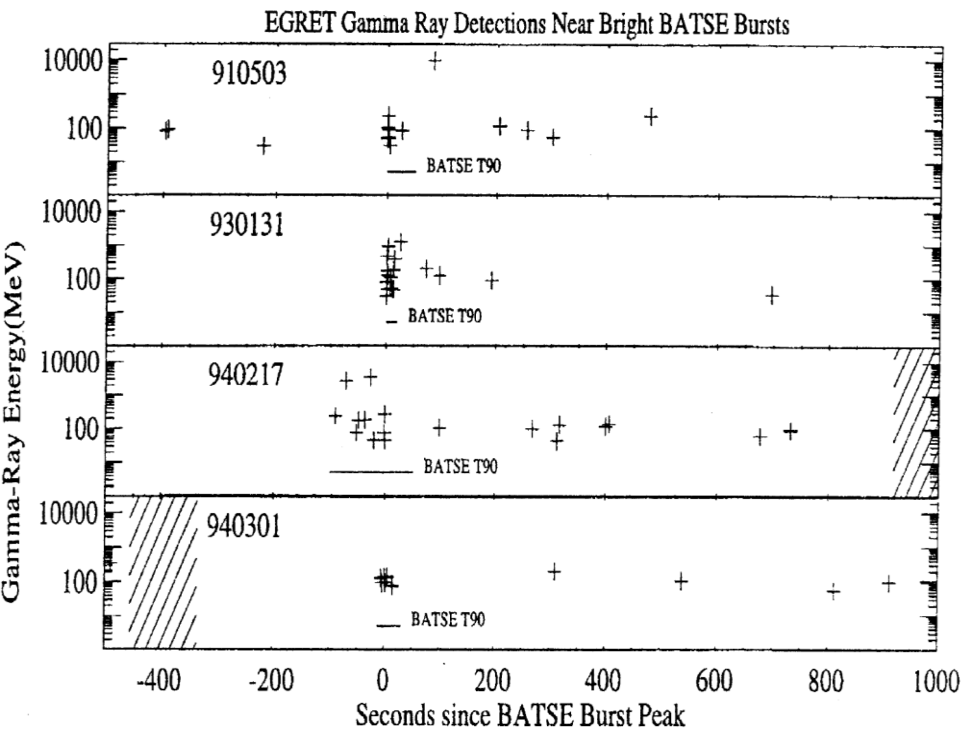
How to require Γ

$$\tau_{\gamma\gamma}(E'_c) = \sigma_T \left(\frac{d_L}{R}\right)^2 \frac{\Gamma E'_{\rm piv} f(E_{\rm piv})}{(1+z)^3} \left(\frac{E'_c E'_{\rm piv}}{m_e^2 c^4}\right)^{-\lambda-1} F(\lambda) = 1$$

$$\Gamma \simeq \left[\sigma_T \left(\frac{d_L}{c\Delta T}\right)^2 E_{\rm piv} f(E_{\rm piv}) F(\lambda)(1+z)^{-2(\lambda+1)} \left(\frac{E_c E_{\rm piv}}{m_e^2 c^4}\right)^{-\lambda-1}\right]^{\frac{1}{2(1-\lambda)}}$$

HE emission from GRBs : Pre-Fermi Era

- **5 EGRET bursts with >50 MeV observations in 7 years**
  - **No evidence of cutoff in the summed spectrum**
- **Evidence for extended emission**
  - **>hour (afterglow?) GeV emission**
  - **Extra component at 100 s**



Composite spectrum of 4 EGRET Bursts