



# Fermi

Gamma-ray Space Telescope



## The Fermi LAT observations of the gamma ray bursts

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On behalf of the Fermi GBM/LAT  
Collaborations

# Outline



- GRBs: general properties and the inheritance from the past;
- The Fermi observatory: instruments, capabilities and responses in the case of a GRB trigger;
- The sample: GBM and LAT detected bursts;
- Temporal properties of the LAT detected bursts;
- Spectral properties of the LAT bursts;
- Not detected bursts: flux upper limits;

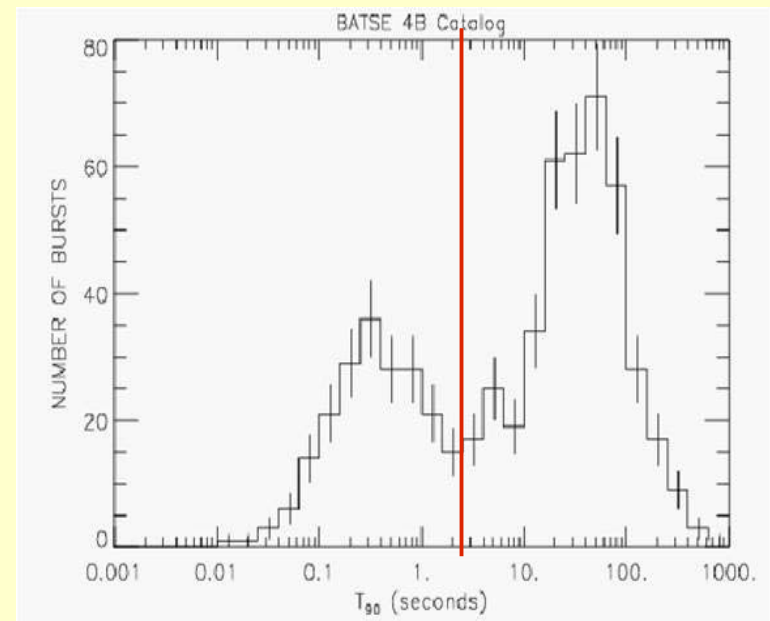
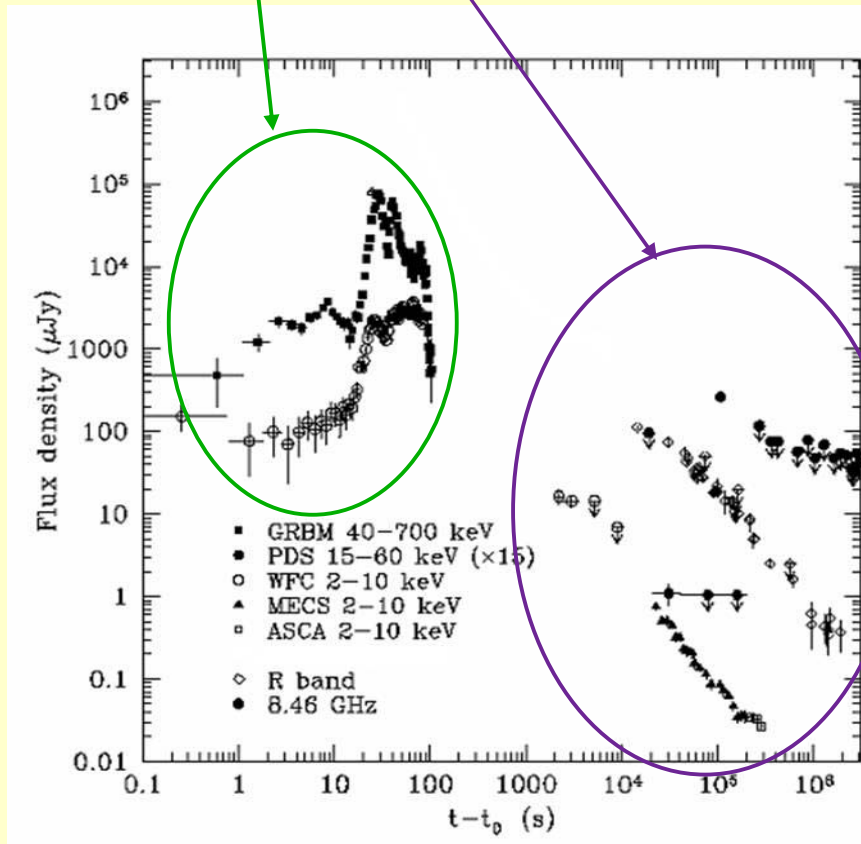
# GRBs: general properties

Two phases:

- The **PROMPT** phase: lasting ~ 100s main in the keV-MeV band;
- The **AFTERGLOW** phase lasting >3000s;

Two populations in time duration:

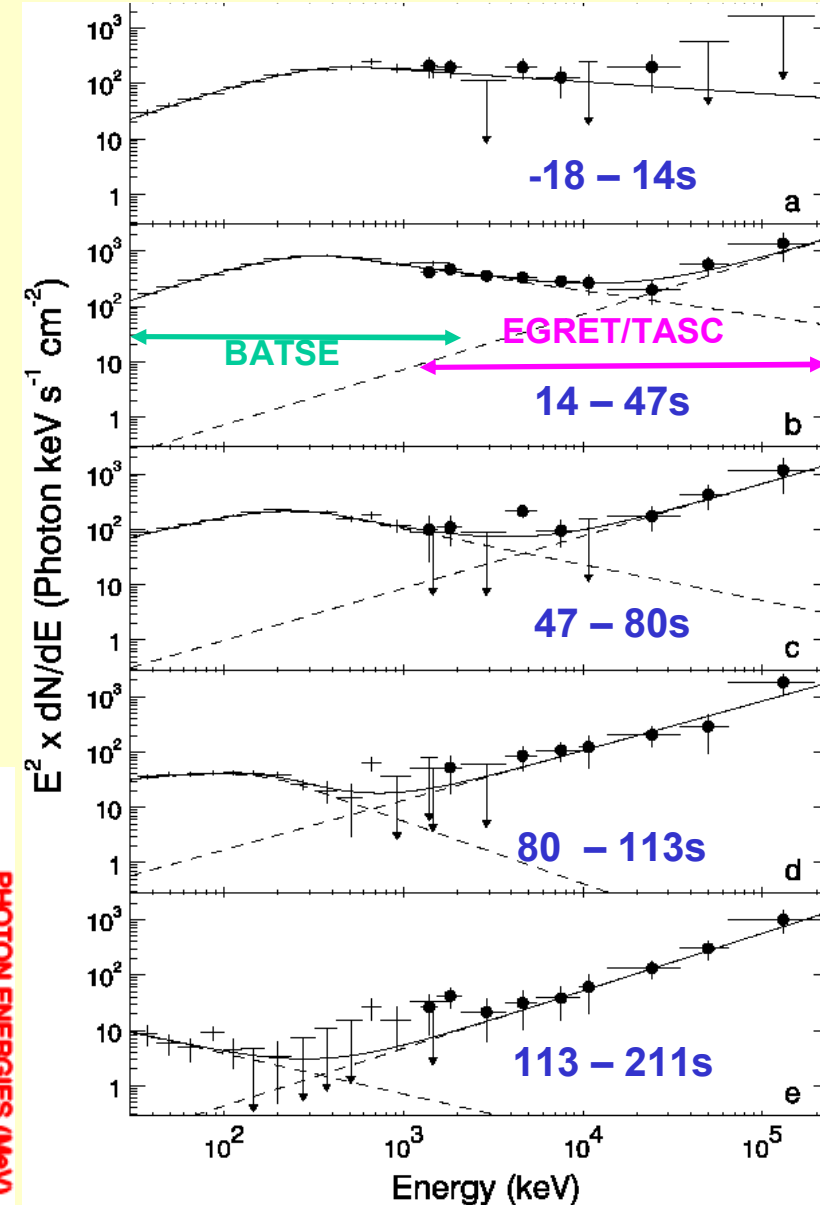
- **SHORT**: duration of the prompt phase <2s;
- **LONG**: duration of the prompt phase >2s;



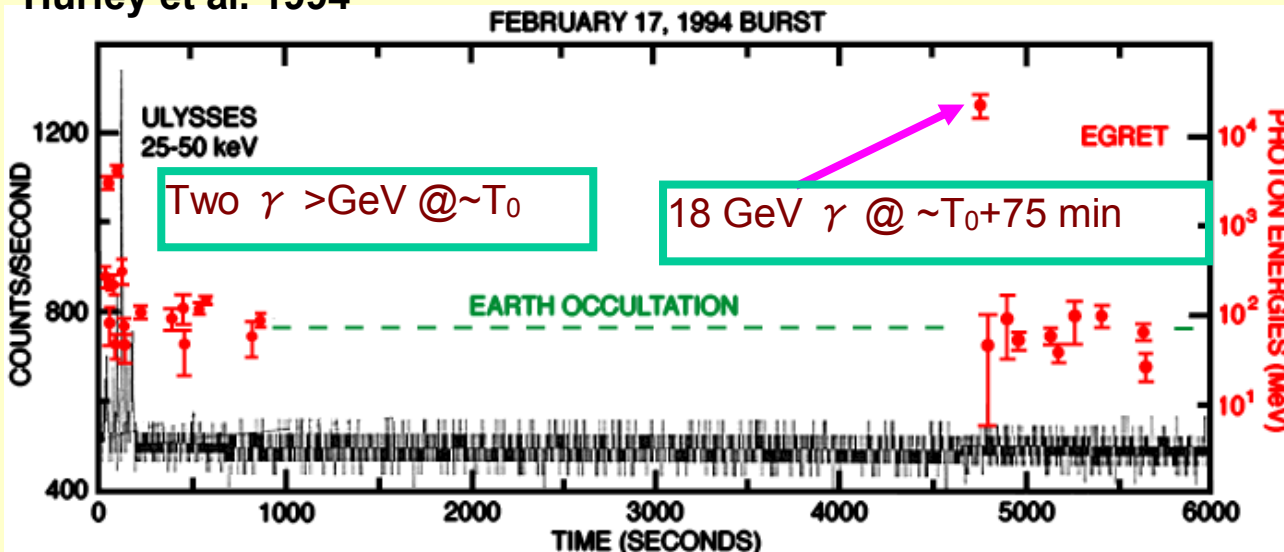
# High-Energy Emissions from GRB (Past)

- EGRET observations of delayed HE gamma-ray emissions
  - It is not straightforward to explain by conventional electron synchrotron models
  - Proton acceleration?
- Extra components?
- 5 EGRET bursts with  $>50$  MeV observations in 7 years
  - No evidence of cutoff or extra HE component in the summed spectrum

Gonzalez, Nature 2003 424, 749

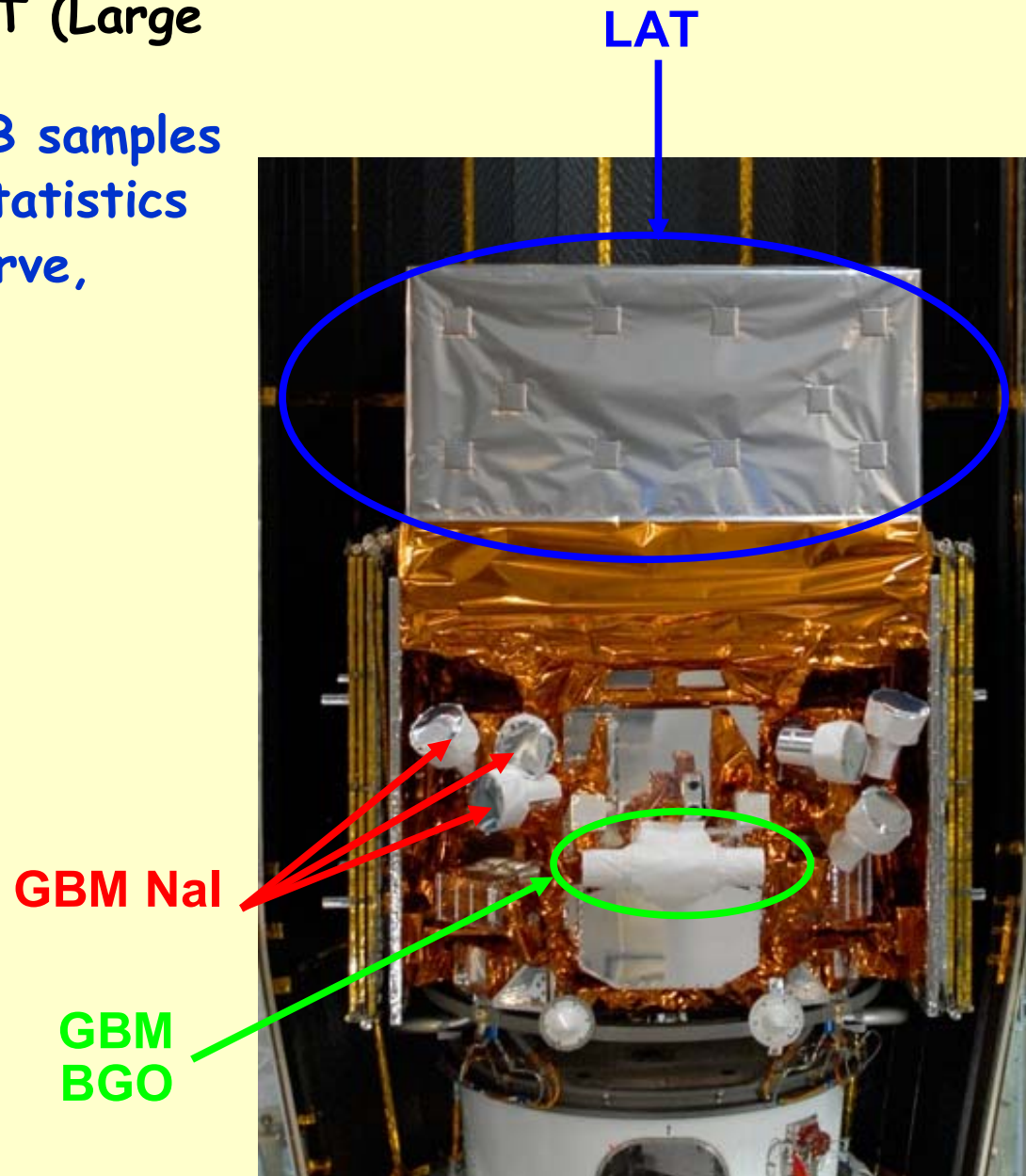
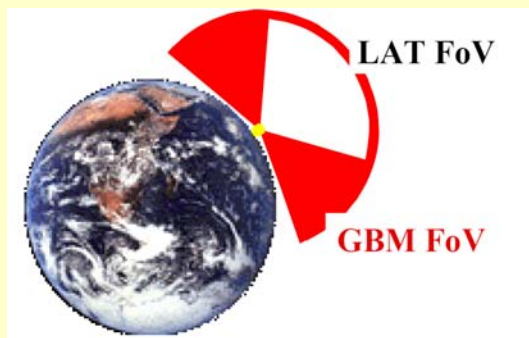


Hurley et al. 1994

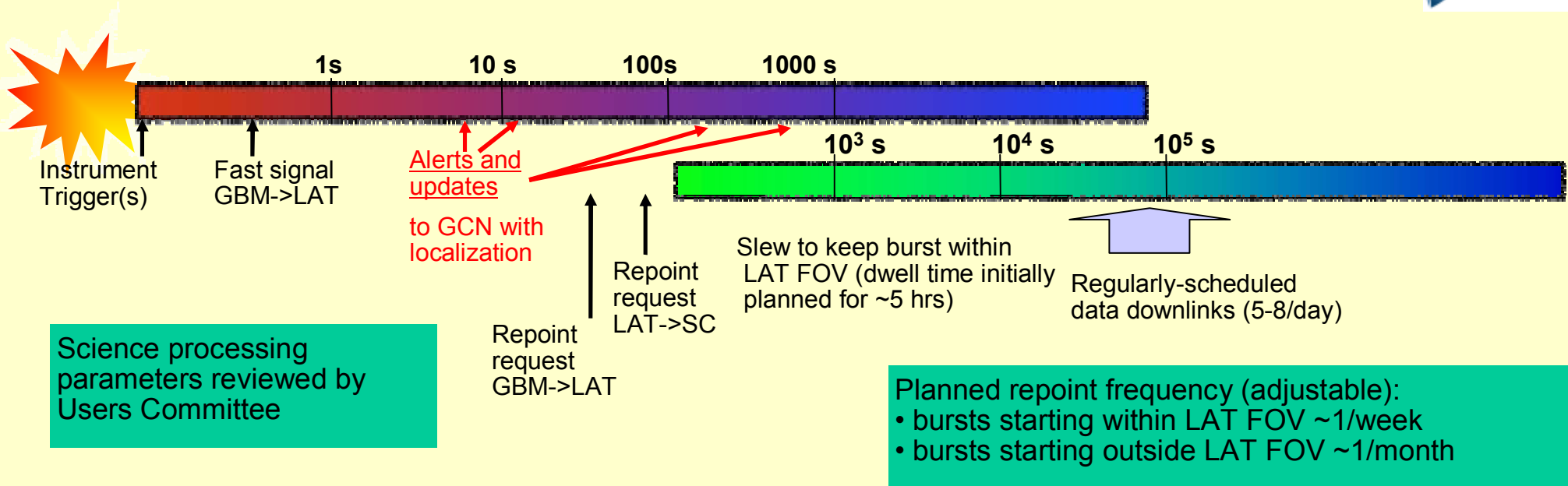


# The Fermi observatory instruments

- Improved performance of Fermi LAT (Large Area Telescope)
  - Larger FOV ( $>2.4$  sr): more GRB samples
  - Larger effective area: better statistics
  - Less dead time: detailed lightcurve, time-resolved analysis
  - Wider energy coverage: up to  $>300$  GeV
- Fermi Gamma-ray Burst Monitor
  - Views entire unocculted sky
  - NaI: 8 keV - 1 MeV
  - BGO: 200 keV - 40 MeV



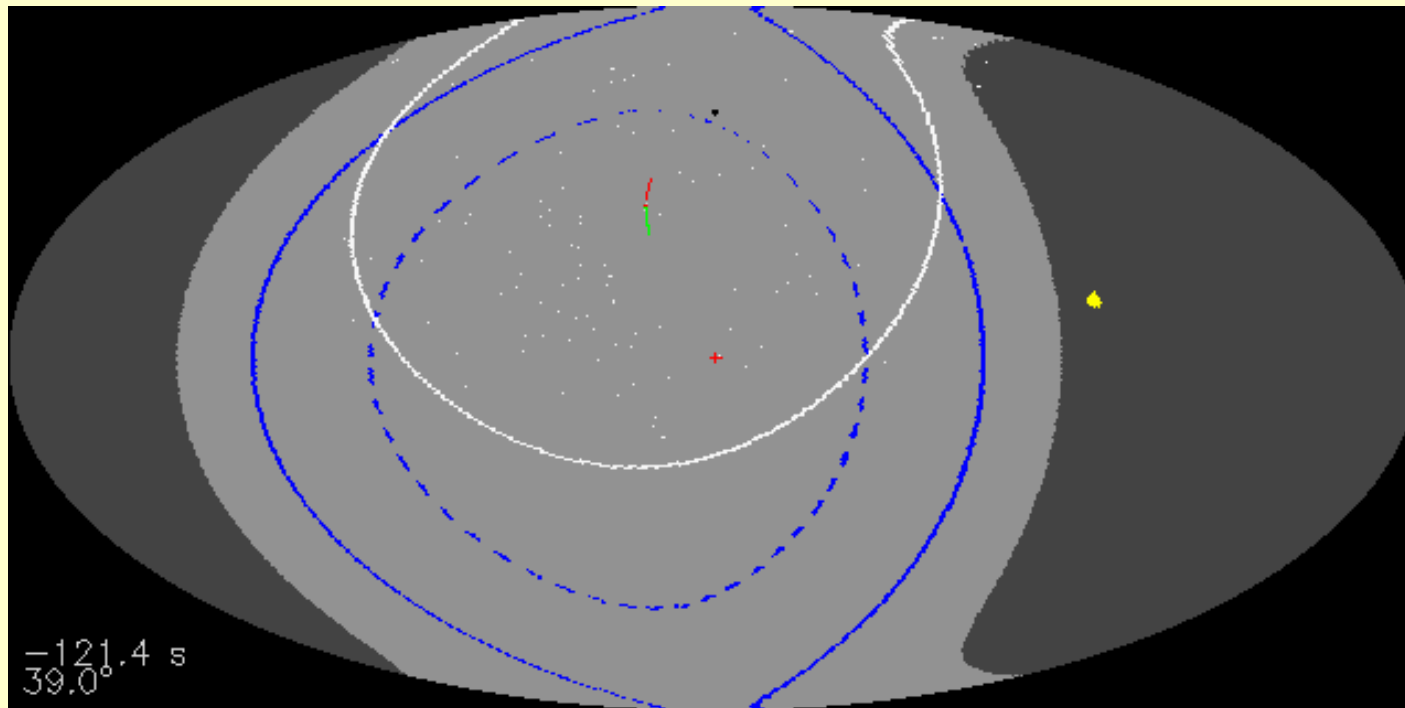
# Alerts and Data Flow



- Onboard processing (both LAT and GBM) - GCN alerts: location, intensity (cnts), hardness ratio, trigger classification etc  
[http://gcn.gsfc.nasa.gov/fermi\\_grbs.html](http://gcn.gsfc.nasa.gov/fermi_grbs.html)
- LAT ground processing (5-12 hours): updated location, high energy spectrum, flux (or upper limit), afterglow search results
- Final ground processing (24-48 hours): GBM model fit (spectral parameters, flux, fluence), joint LAT-GBM model fit, raw GBM data available.
- 1 or 2 circulars are sent in case of LAT detection

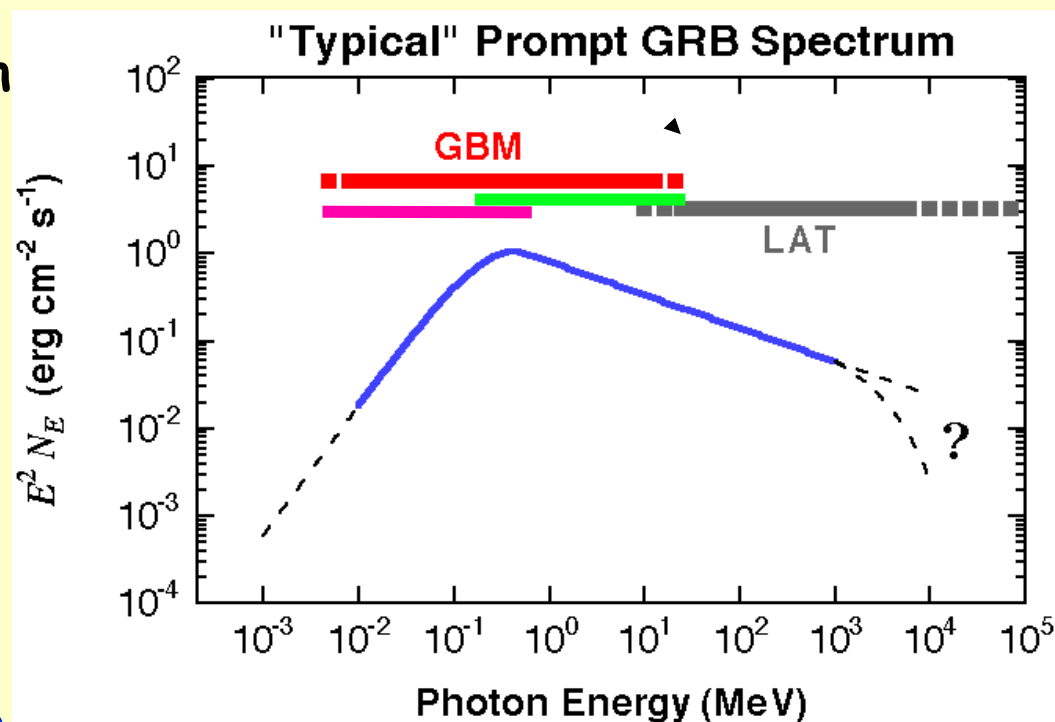
# An example of ARR

- LAT pointing in celestial coordinates from -120 s to 2000 s
  - Red cross = GRB 090902B
  - Dark region = occulted by Earth ( $z > 113^\circ$ )
  - White line = LAT FoV ( $\pm 66^\circ$ )
  - Blue lines =  $20^\circ$  (Earth avoidance angle) /  $50^\circ$  above horizon
  - White points = LAT transient events (no cut on zenith angle)



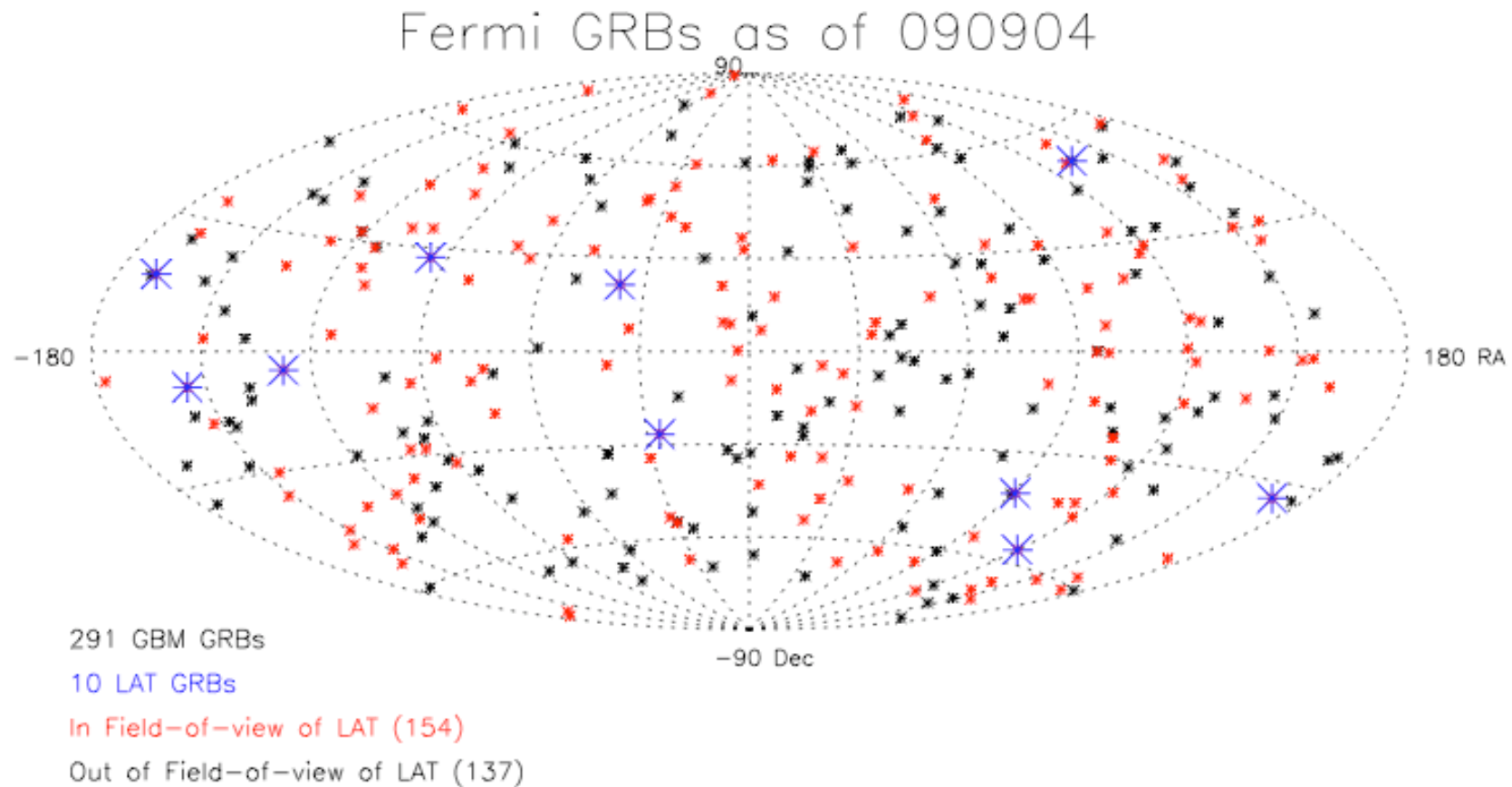
# GBM-LAT synergy for GRB studies

- ✓ Both LAT and GBM can independently trigger
- ✓ Spectral coverage of more than 7 decades (8keV- $\rightarrow$ 300GeV)
  - Bright burst: study of the cut-off, if any.
- ✓ Detailed temporal/spectral resolution:
  - Is there any "extra component"?
  - How common is the extended/delayed GeV emission?
  - Intrinsic lag because cosmological effects?





# Fermi GRBs



- 1 year from GBM turn on: 252 GRBs, 138 in the LAT FoV
- 12 GRB detection at high energy so far (9 in the first year)

# The first 10 Fermi GRBs



GRB	duration	# of events > 100 MeV	# of events > 1 GeV
080825C	long	~10	0
080916C	long	>100	>10
081024B	short	~10	2
081215A	long	—	—
090217	long	~10	0
090323	long	>10	>0
090328	long	>10	—
090510	short	>150	>20
090626	long	—	—
090902B	long	>200	>30

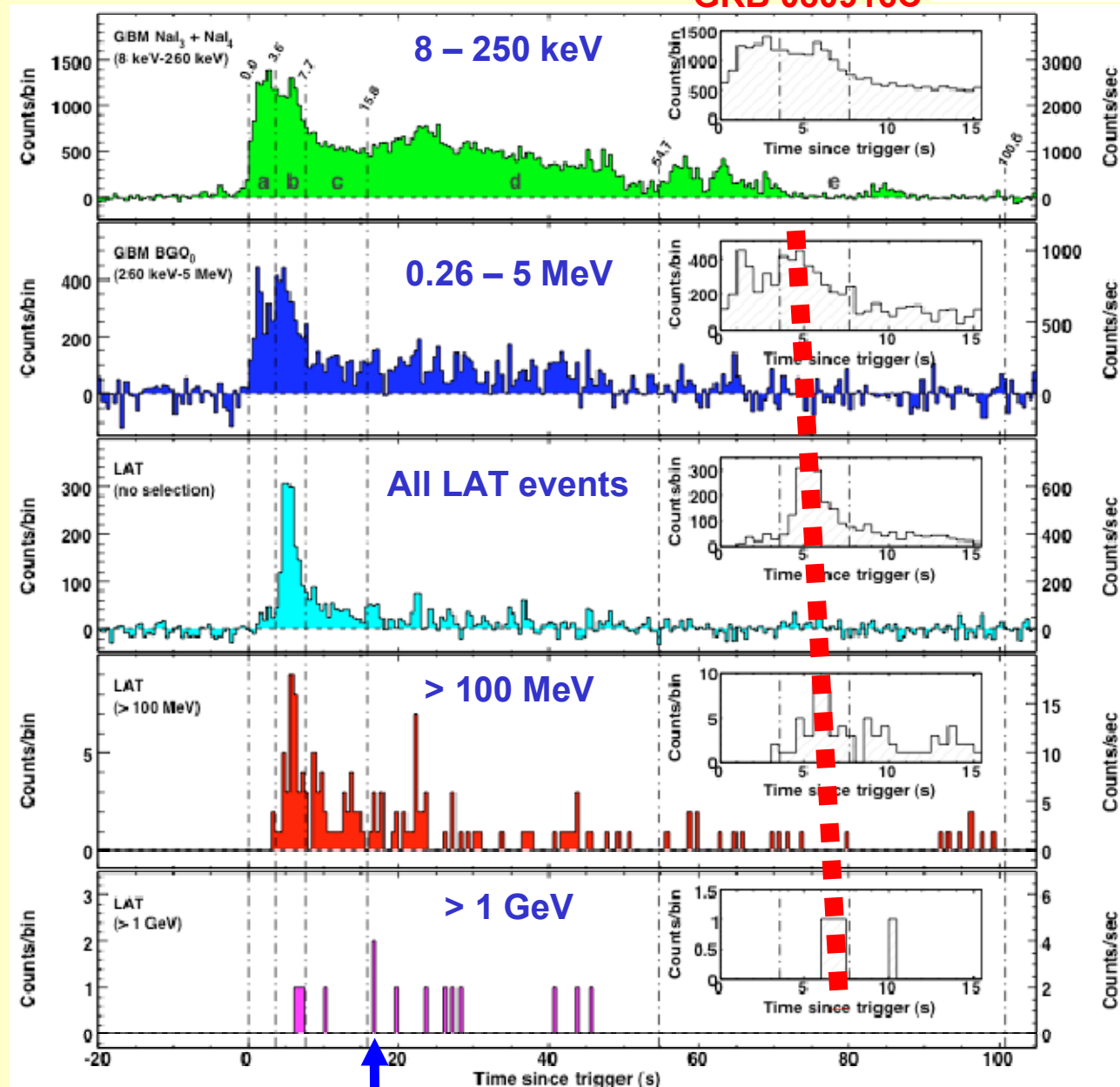
See Cutini's poster!

See de Palma's talk!

# Delayed HE Emission from 080916C

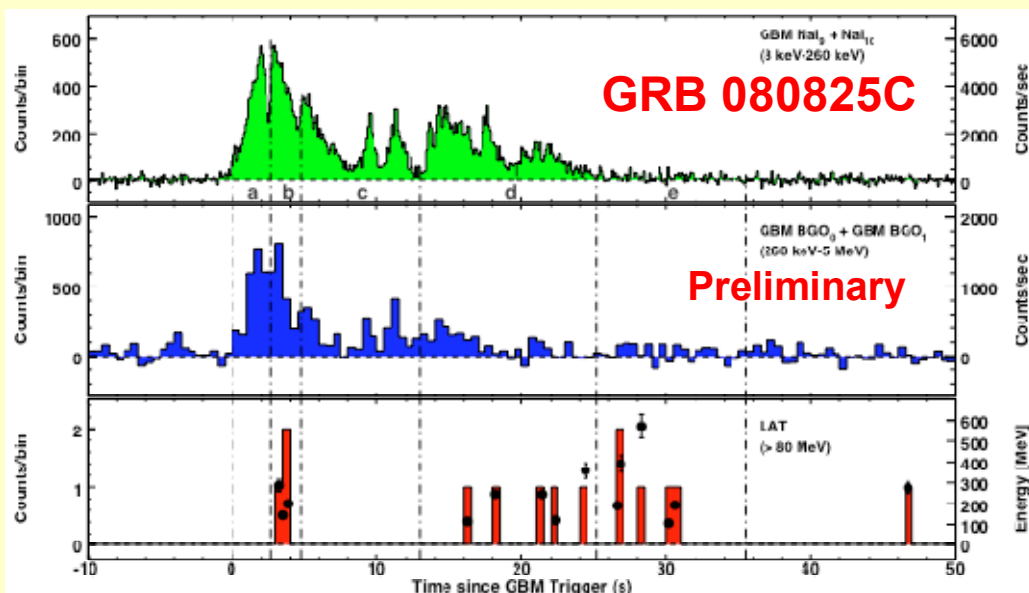
GRB 080916C

- The “lack of the first peak”
  - Opacity due to  $\gamma\gamma \rightarrow e^+e^-$  in the first peak?
- Delay onset of the second peak
  - Lorentz invariance violation?
  - Synchrotron proton emission? (Razzaque 2009)

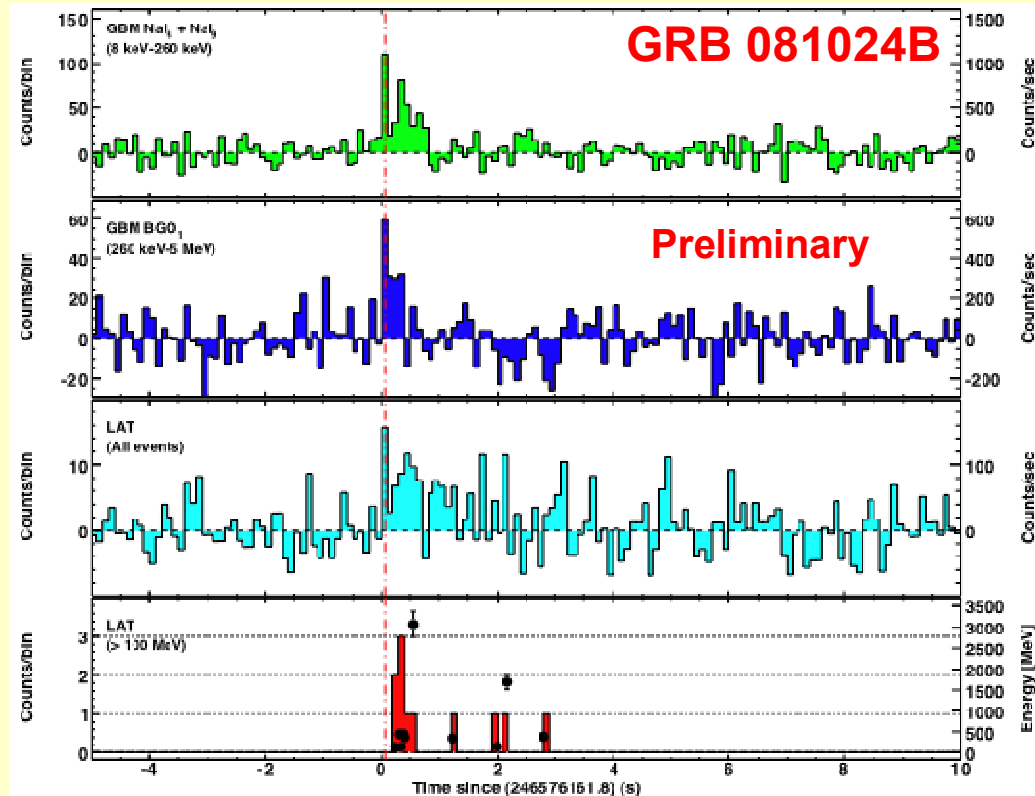


# Delayed HE Emission from Other LAT GRBs

- Apparent temporal onset of high-energy emissions (coincident with 2nd GBM pulse)
  - Common origin for this emission in low and high energies
  - Separate region from initial GBM emission
- Highest energy is very late (GRB 080825C)
  - No detectable low energy emission
- Similar template seen in short bursts
- Delayed emission also detected by Agile (080514B, Giuliani '08, 090510, Giuliani '09)

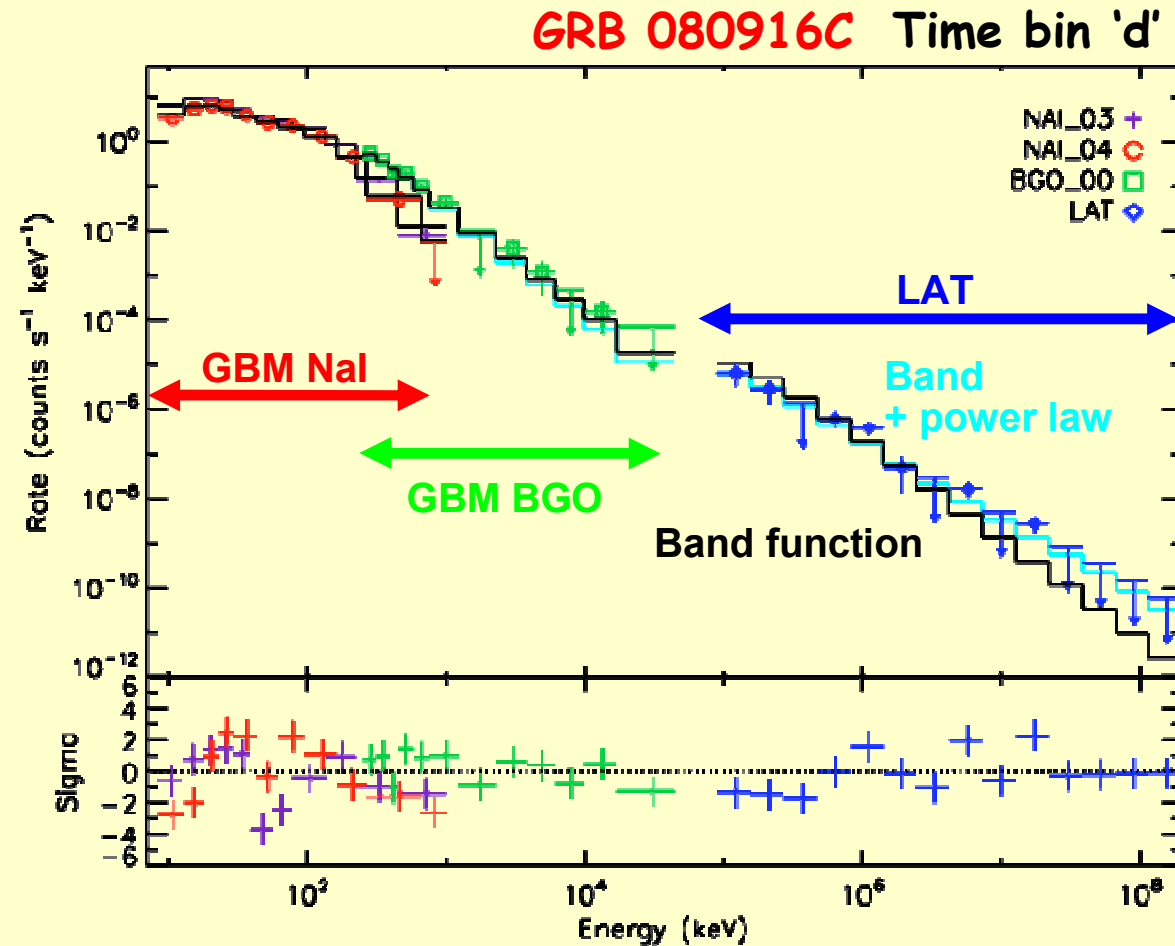
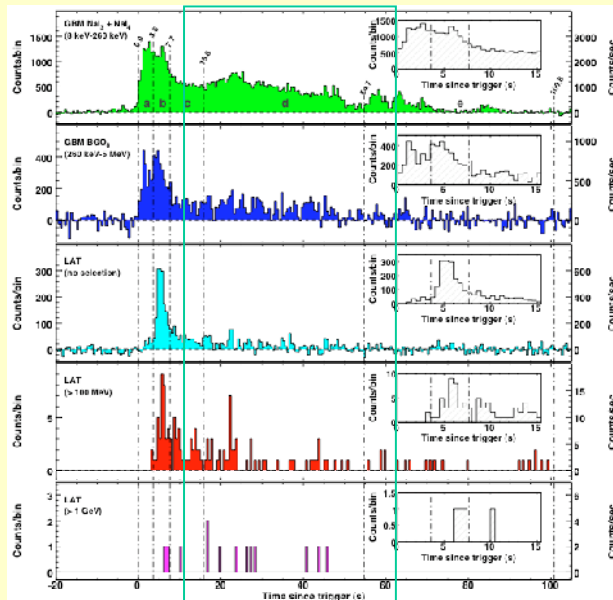


SciNeGHE - Assisi 2009 -Elena Moretti



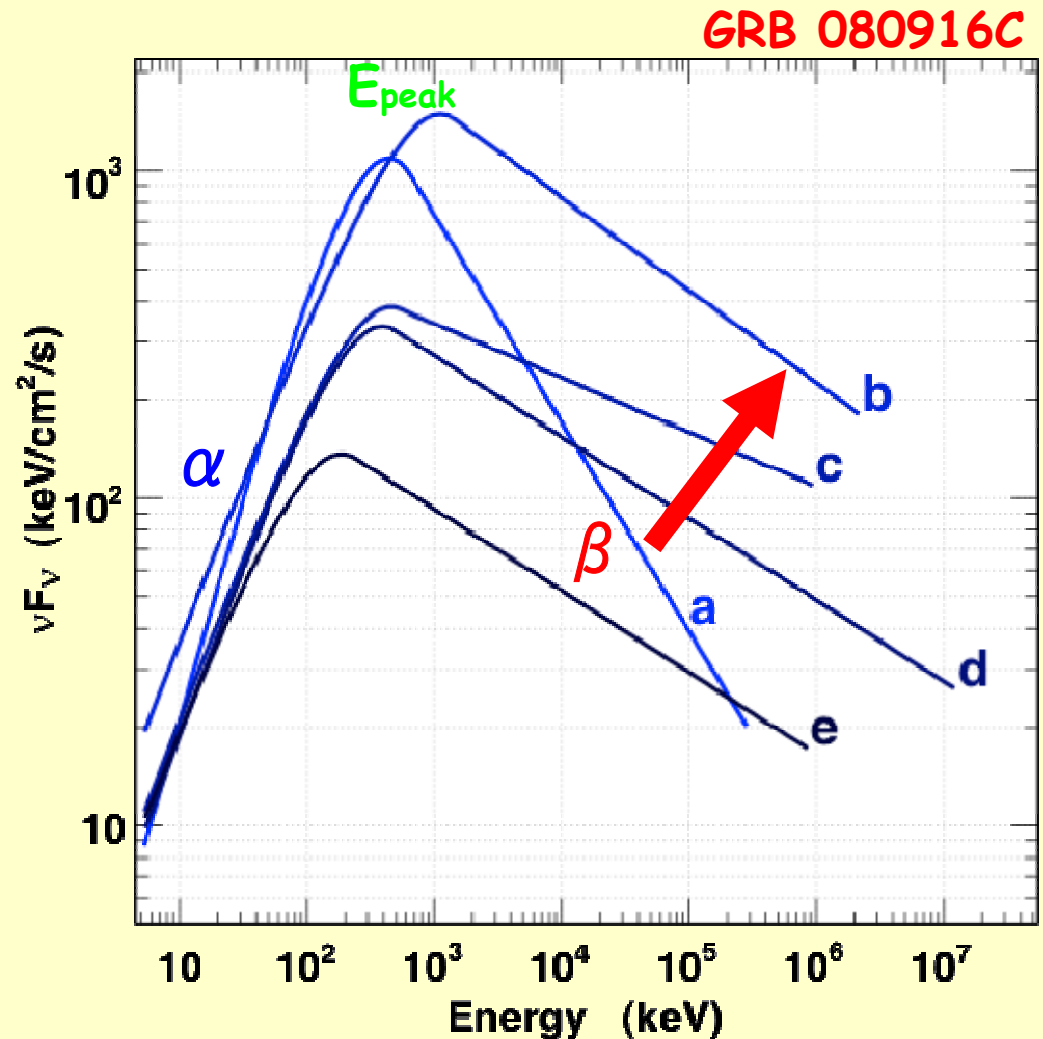
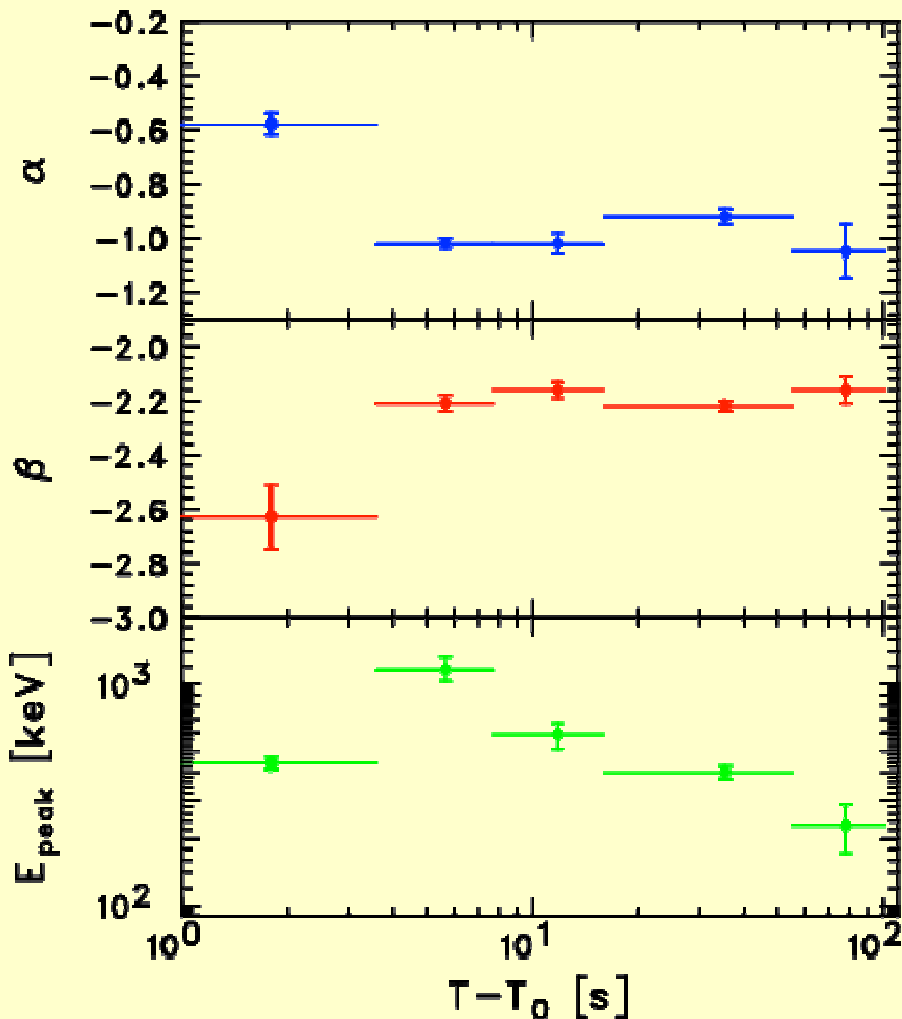
# Extra Component in GRB 080916C?

- Single Band-function dominant for 6 decades of energy band!
- No conclusive evidence of extra HE component



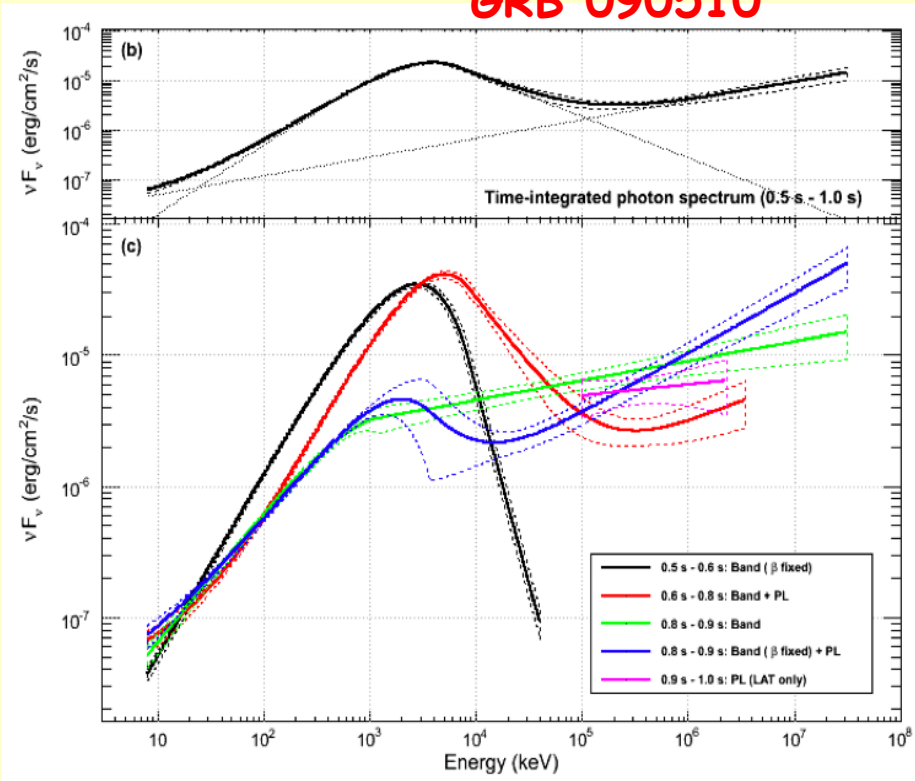
# Spectral Evolution of GRB 080916C

- Rapid soft to hard evolution in (a) to (b)
- Gradual decrease of  $E_{\text{peak}}$  from (b) to (d)

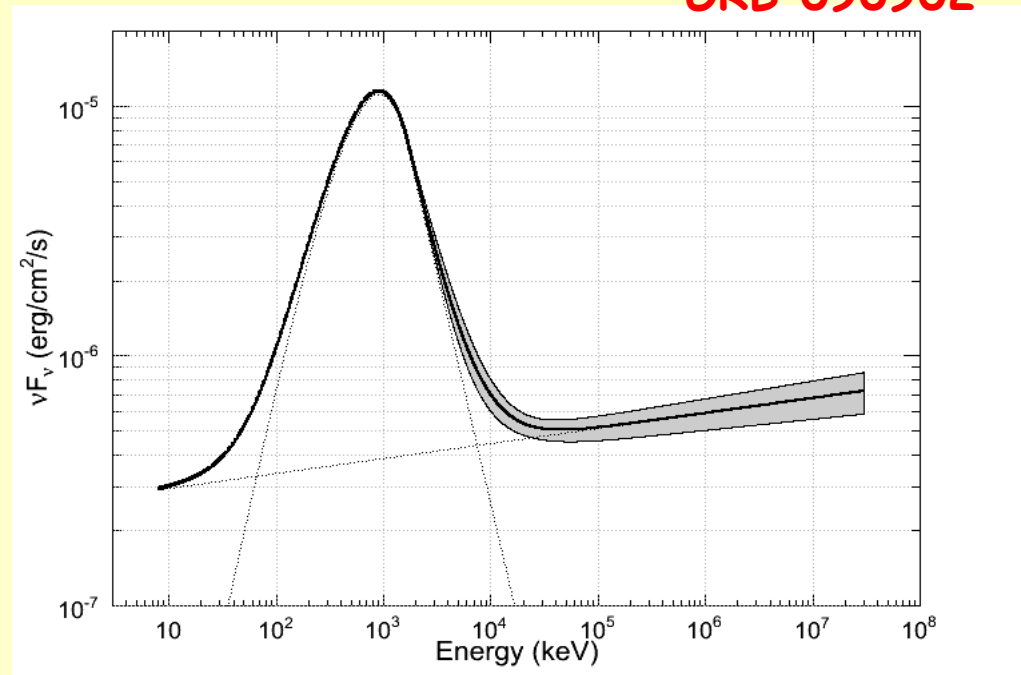


# Extra component?

## GRB 090510



## GRB 090902

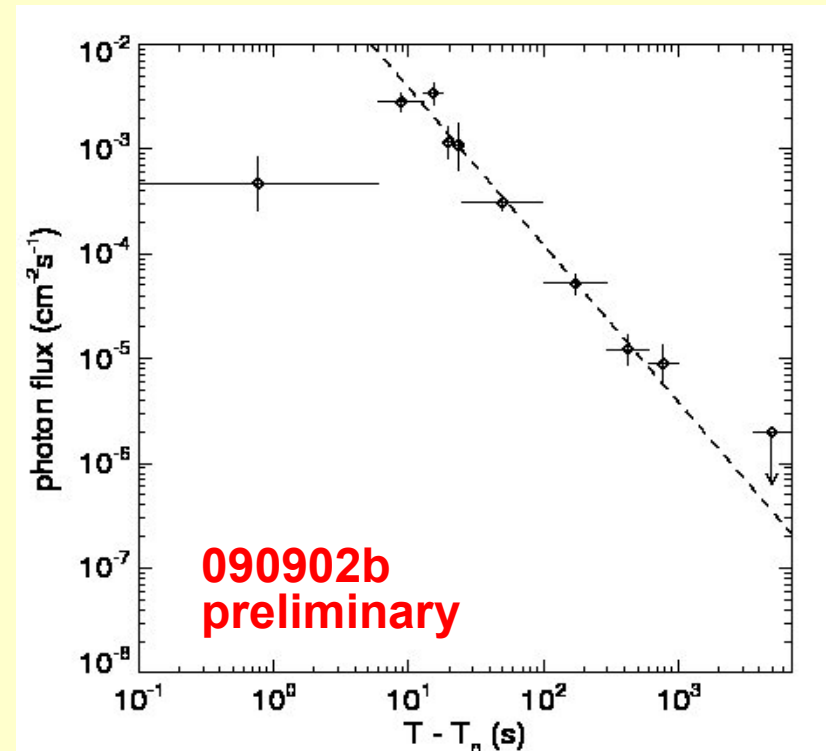
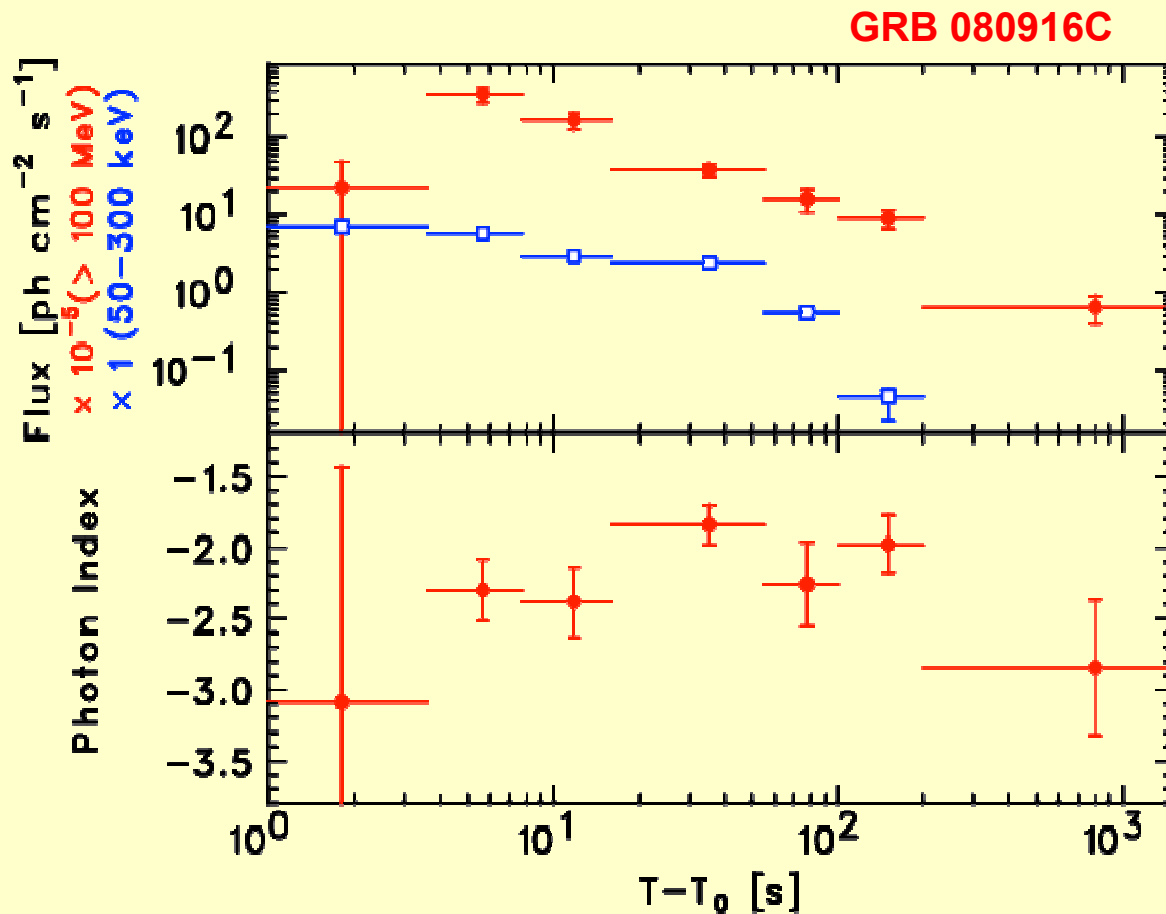


See de Palma's talk on 090510!!!

- **Some trends**
  - Soft to hard evolution
  - Long-lived HE emission
  - "Extra component" @ HE
- **Few events in GRB081024B, not possible discriminate models**
- **Evidence in GRB090510, GRB090902**

# Long-Lived HE Emission in 080916C

- HE (>100 MeV) emission shows different temporal behavior
  - Temporal break in LE emission while no break in HE emission
    - Indication of cascades induced by ultra-relativistic ions?
    - or angle-dependent scattering effects?

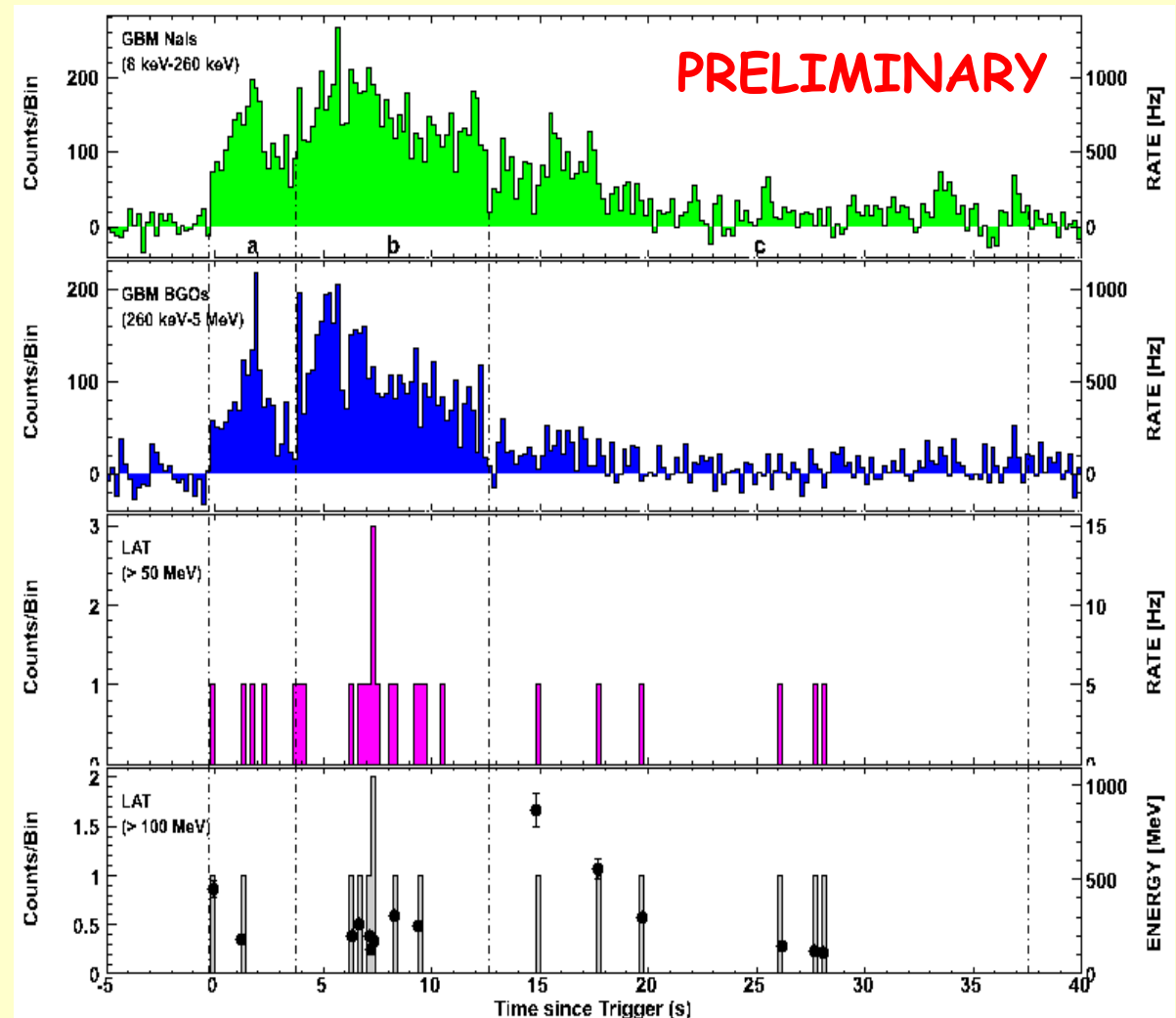




# GRB 090217: a featureless burst

See Sara Cutini's poster!

- >100 MeV events detected from the trigger time
- No delay in HE emission, and different event accumulation



# The first 10 Fermi GRBs: summary of the characteristics



GRB	duration	# of events > 100 MeV	# of events > 1 GeV	delayed HE onset	Long-lived HE emission	Highest Energy	Redshift
080825C	long	~10	0	?	✓	~600 MeV	
080916C	long	>100	>10	✓	✓	~ 13.2 GeV	4.35
081024B	short	~10	2	✓	✓	3 GeV	
081215A	long	—	—	—	—	—	
090217	long	~10	0	x	—	~1 GeV	
090323	long	>10	>0	—	✓	—	3.57
090328	long	>10	—	—	✓	—	0.736
090510	short	>150	>20	✓	✓	~31 GeV	0.903
090626	long	—	—	—	✓	—	
090902B	long	>200	>30	✓	✓	~ 33 GeV	1.822

# Non-detected GRBs: flux Upper Limits

- Only ~52% of Fermi GRBs are in LAT field of view

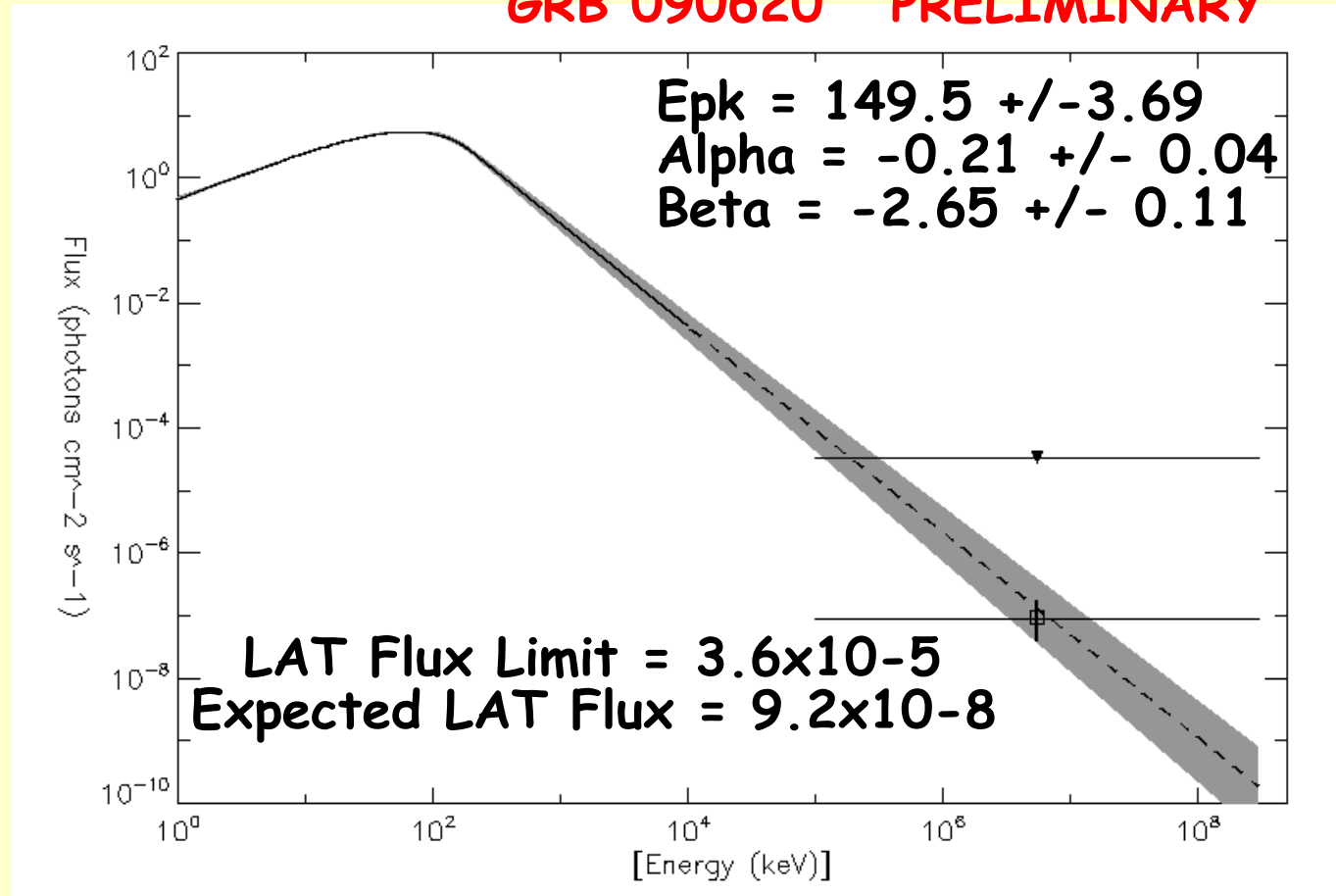
Flux limit ~ few  $\times 10^{-5}$  photons  $\text{cm}^{-2} \text{s}^{-1}$

- Bright BGO Sample

- ~80% of "Gold" sample do not predict LAT counts;

- ~20% do show discrepancies and hint at spectral curvature;

## GRB 090620 PRELIMINARY



# Summary



- Fermi is performing extremely well, the LAT already doubled the number of GRBs detected above 100 MeV
- Some observed properties
  - High energy emission (>100 MeV) observed in both long and short bursts
  - Delayed onset between LAT and GBM (“the missing peak”)
    - Characteristic Spectral evolution
    - Separate region from initial GBM emission (Internal Shocks?)
    - Not seen in 090217
    - Both in long and short bursts
- Single Band-function dominates 6 decades of energy band
  - Extra component dominates in few cases (both in long and shorts)
- Long lived high-energy emission detected both in Long and Short bursts
- Fundamental physics tested (LIV, Gamma min)

**Thank you!**