The 50 Brightest and Hardest GRBs Detected with the Gamma-ray Burst Monitor on Fermi

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On behalf of the Fermi GBM Team

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I. Predictability of LAT-detected events

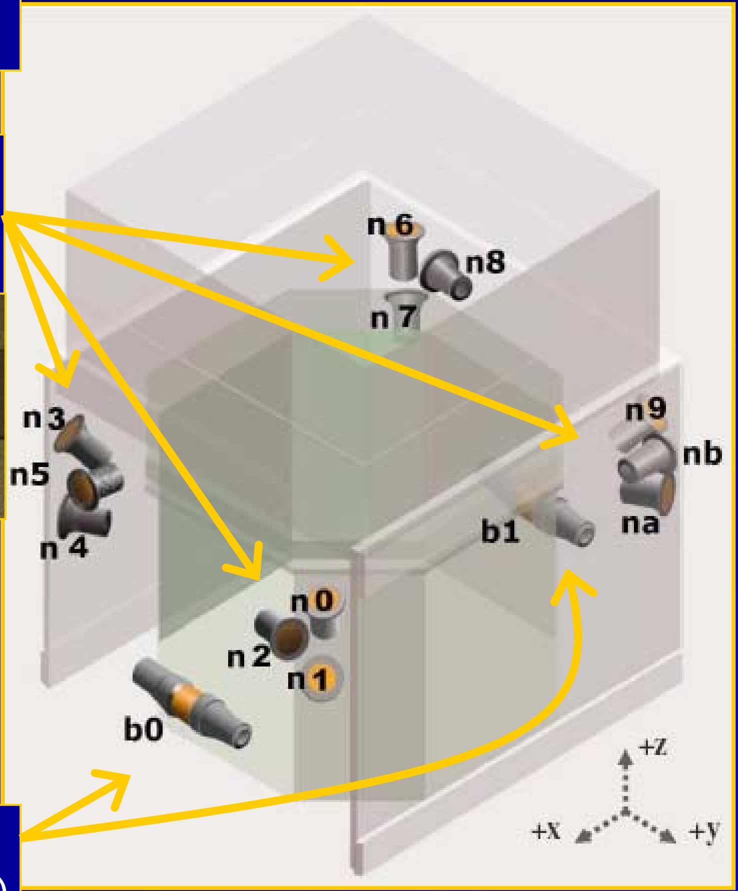
II. High-energy temporal analysis

III. High-energy spectral analysis and comparisons

The GBM-BGO detectors

GBM

12 NaIs
(location & low-E spectrum)



2 BGOs
(mid-E spectrum)

LAT
(high-E spectrum)

The GBM-BGO detectors

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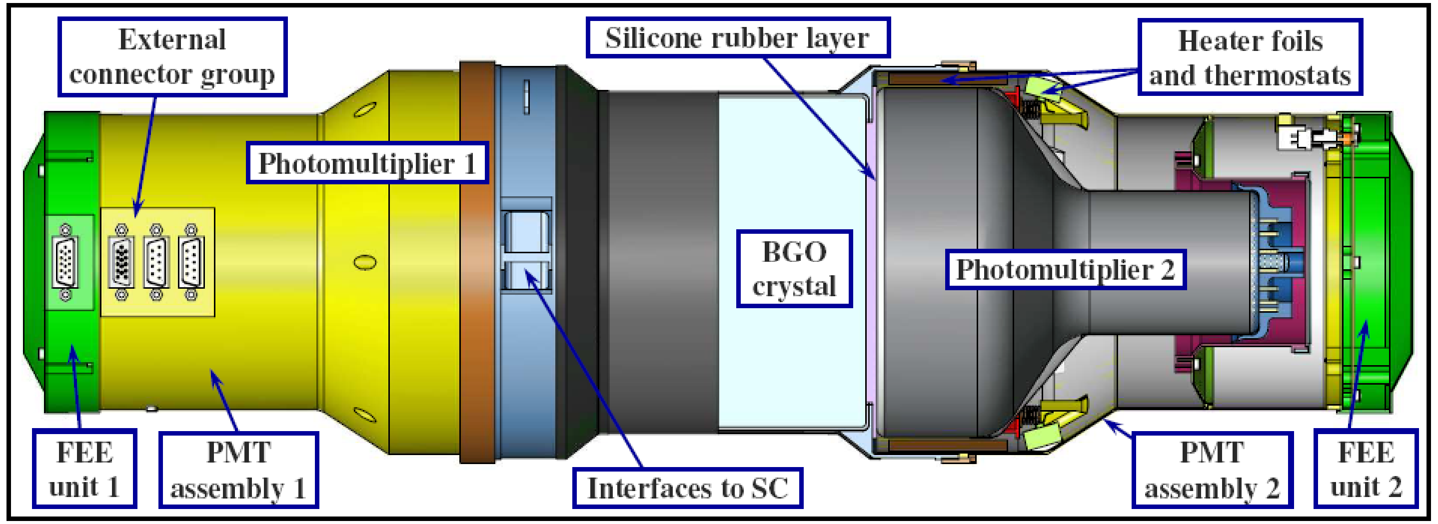


2 BGOs
(mid-E spectrum)

2 Bismuth Germanate Detectors

- **Diameter:** 12.7 cm (5” x 5”)
- **Thickness**: 12.7 cm (5”)
- **Energy range:** ~200 keV – ~40 MeV

BGO bright bursts selection criteria (1)

- Selection from the set of 253 GRBs collected during the first year of GBM operation

1. First (coarser+automated!) selection
   - Bursts with more than 80 counts/s over background in at least one BGO detector over the full energy range (250 keV–40 MeV)
2. Second (refined!) burst selection
   - Bursts with signal above 3 σ in the BGO CTIME light curves
     - [CTIME data have a 64 ms temporal resolution during burst–mode and spectral resolution of 8 energy channels]

Example of BGO CTIME energy channel boundaries for GRB 090227B

BGO Ch. #	Energy Interval Start (keV)	Energy Interval Stop (keV)	
0	113.25	451.60	150-500 keV
1	451.60	973.33	0.5-1 MeV
2	973.33	2119.65	1-2 MeV
3	2119.65	4591.62	2-5 MeV
4	4591.62	9757.00	5-10 MeV
5	9757.00	21463.0	10-20 MeV
6	21463.0	37989.0	20-40 MeV
7	37989.0	50000.0	Overflow

BGO bright bursts selection criteria (2)

- **Total number of GRBs included in this analysis: 52**
  - ~20% of all bursts detected during the first year of GBM operation
  - All LAT detected burst (in the first year!) are in the sample

Abdo et al. ApJ,707,580 (2009)

Science,323,1688 (2009)

ApJ,712,558 (2010)

McEnery et al. GCN 8684 (2008)

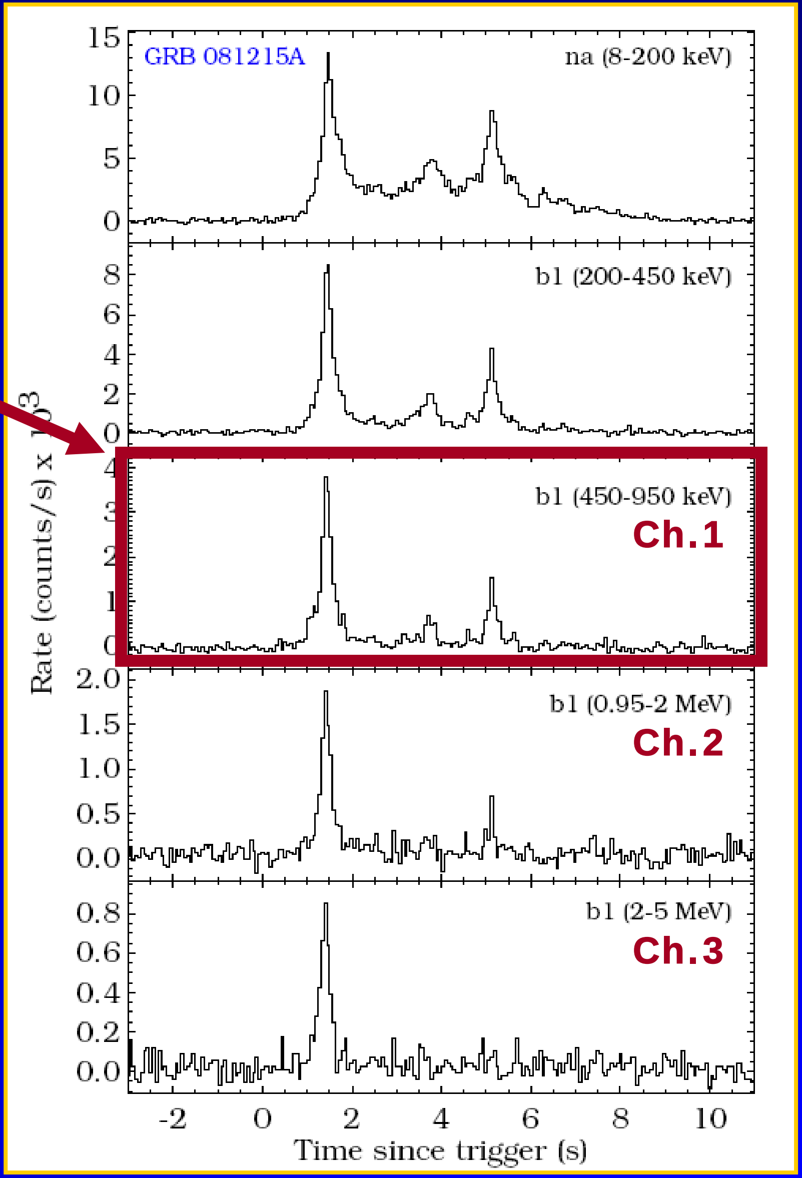
TABLE 1
BASIC PROPERTIES OF 52 BRIGHT GRBs

GBM Trig. # (1)	GRB Name (2)	Trig. Time (T_0, MET) (3)	NaI Det. (4)	BGO Det. (5)	LAT Angle (deg) (6)	Data Type (7)	Time Interval[a] Start (8)	Stop (9)
080723.557	080723B	238512142	4	0	107	CSPEC	0.004	60.161
080723.985	–	238549063	5,2	0	113	CSPEC	-2.304	50.945
080725.541	–	238683564	6,7	1	50	TTE	-0.064	0.384
080802.386	080802	239361311	4,5	0	125	TTE	-0.064	0.448
080807.993	080807	239845833	0,1,2	0	74	CSPEC	-1.376	21.152
080816.989	080816B	240623035	b,7	1	70	TTE	-0.064	4.480
080817.161	080817A	240637931	2,5	0	80	CSPEC	0.004	60.417
080825.593	080825C	241366429	9,a	1	60	CSPEC	0.004	25.216
080905.499	080905A	242308736	6,7	1	28	TTE	-0.064	1.024
080906.212	080906B	242370312	0,1,3	0	32	CSPEC	0.004	3.712
080916.009	080916C	243216766	3,4	0	52	CSPEC	0.004	70.145
080925.775	080925	244060556	6,7	1	38	CSPEC	0.004	25.856
081006.604	081006	244996175	0,3	0	16	TTE	-0.384	3.392
081009.690	–	245262818	8,b	1	96	CSPEC	-2.688	40.321
081012.045	081012B	245466323	9,a	1	66	TTE	-0.128	0.768
081024.891	081024B	246576161	6,9	1	16	TTE	-0.128	0.128
081101.532	081101B	247236325	5,2	0	116	CSPEC	0.003	8.704
081110.601	081110	248019944	7,8	1	67	TTE	-0.192	12.096
081121.858	081121	248992528	a,b	1	140	CSPEC	0.003	21.504
081122.520	081122	249049693	0,1	0	21 (ARR)	CSPEC	0.002	25.600
081125.496	081125	249306820	a,b	1	126	CSPEC	0.003	10.368
081126.899	081126	249428050	0,1	0	18	CSPEC	-12.160	40.065
081129.161	081129	249623525	a,b	1	118	CSPEC	-2.944	28.800
081207.680	081207	250359527	9,a	1	56	CSPEC	0.003	100.354
081209.981	081209	250558317	8,b	1	107	TTE	-0.056	0.256
081215.784	081215A	251059717	9,a	1	89	CSPEC	0.004	7.424
081216.531	081216	251124240	8,b	1	99	TTE	-0.128	0.960
081224.887	081224	251846276	6,9	1	17 (AAR)	CSPEC	0.002	16.544

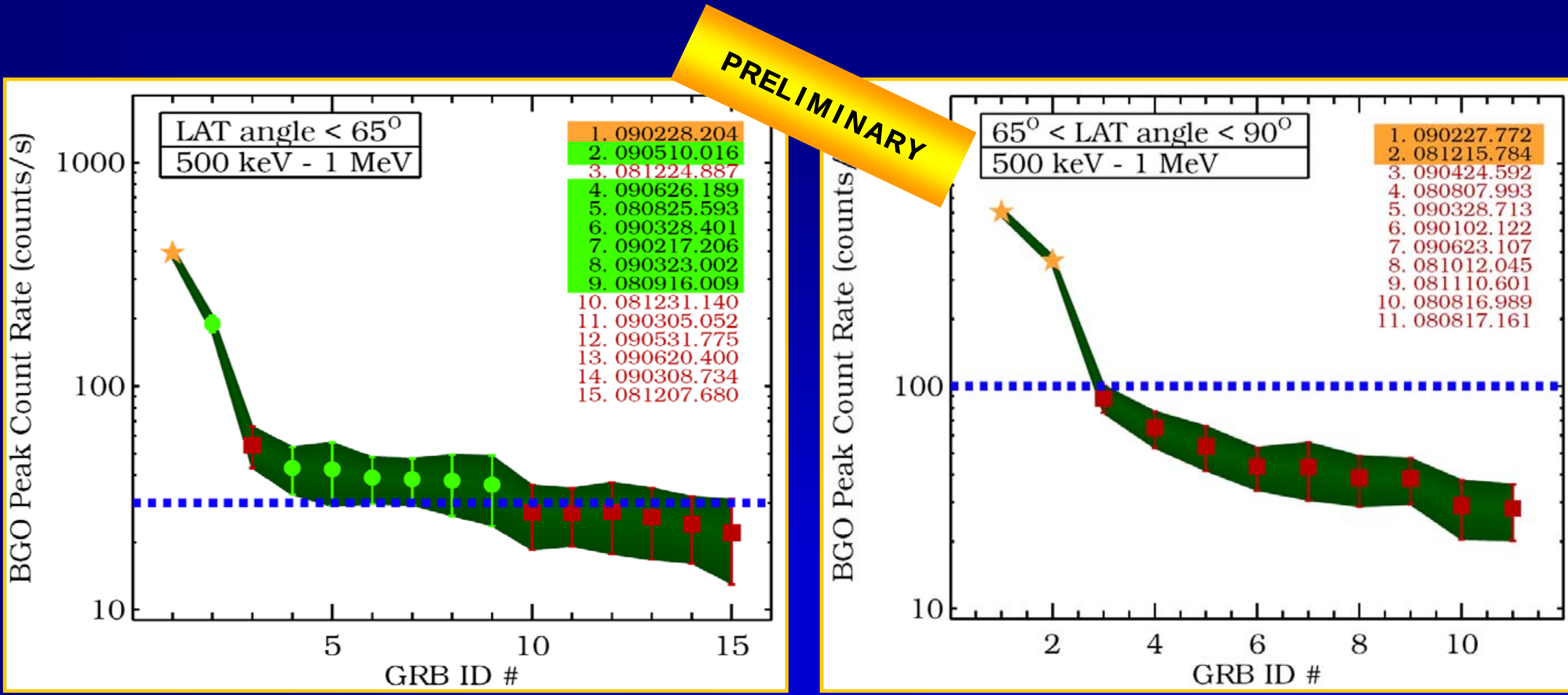
BGO bright bursts selection criteria (3)

- Further subdivision according to the detection significance in different energy channels
  - 52 GRBs in Ch.1 (~0.5 – 1 MeV)
  - 19 GRBs in Ch.2 (~1 – 2 MeV)
  - 10 GRBs in Ch.3 (~2 – 5 MeV)
  - 6 GRBs in Ch.4 (~5-10 MeV)

- GRB 081215A: Example light curve
  - Top panel: 8–200 keV band (NaI detector)
  - Other four panels: BGO light curves in different energy ranges
  - Marginally detected by the LAT (86° to the boresight)
  - No directional nor energy info



LAT predictability



- BGO peak count rate measured in channel 1 (~500 keV - ~1 MeV)
  - 15 GRBs inside the LAT FoV
  - 11 GRBs at the edge of the LAT FoV
  - Green circles, orange stars and red squares represent firm, marginal or missing LAT detections
  - Blue dotted line marks a "detection limit" which was arbitrarily placed at 30 and 100 counts per second in the measured peak count rate.
- This analysis enables selection of good candidates for potential LAT detections
  - Project is ongoing to implement the code into the GBM FSW

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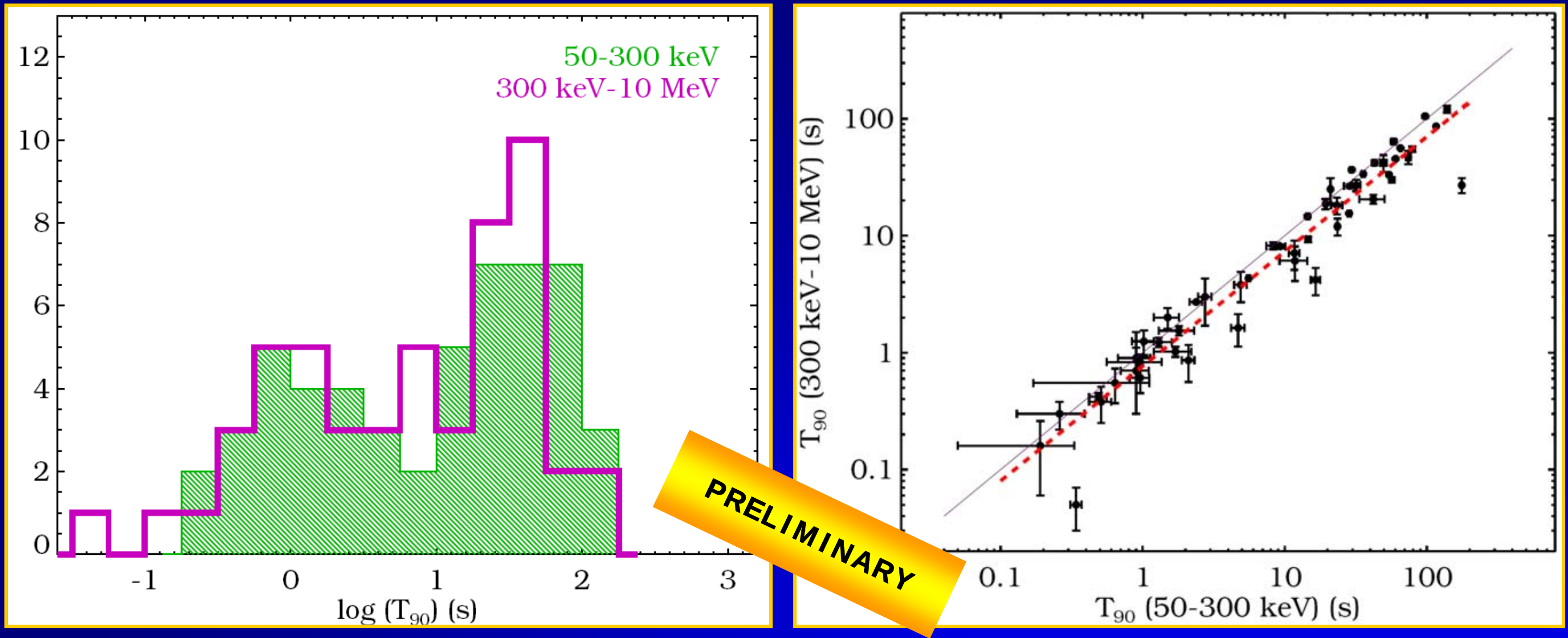
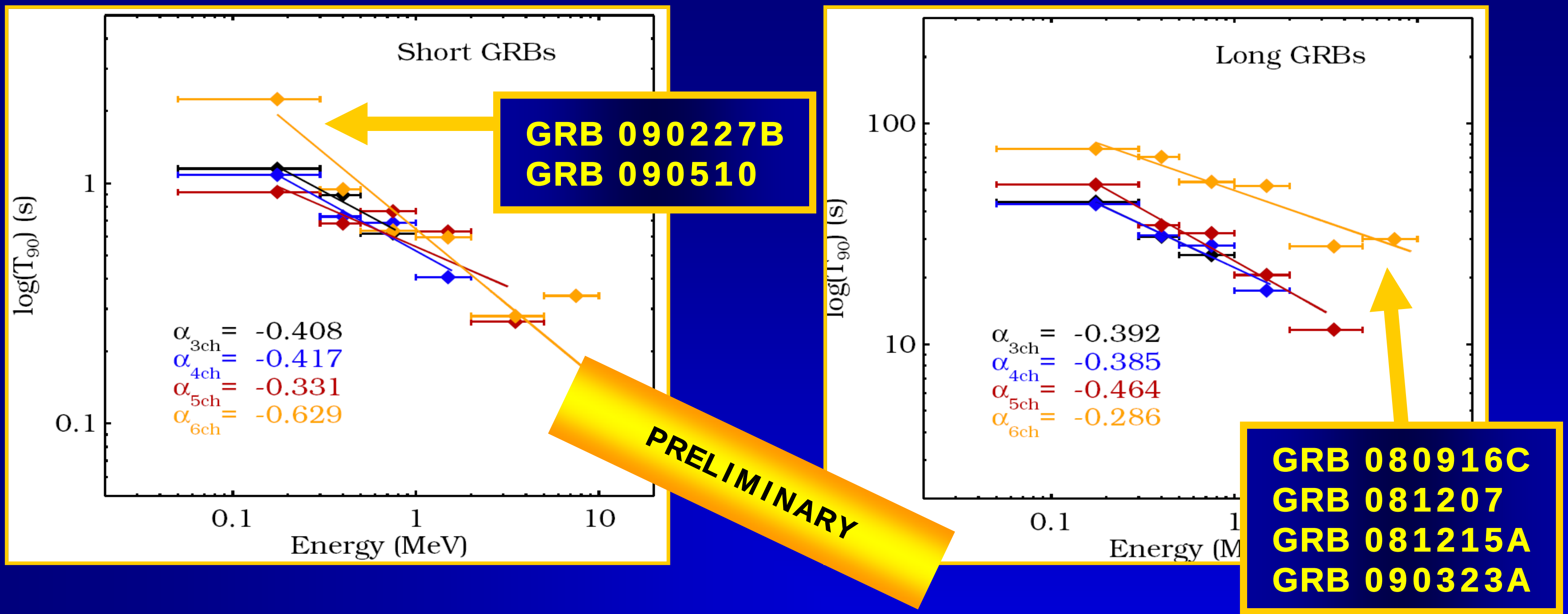
Duration distributions

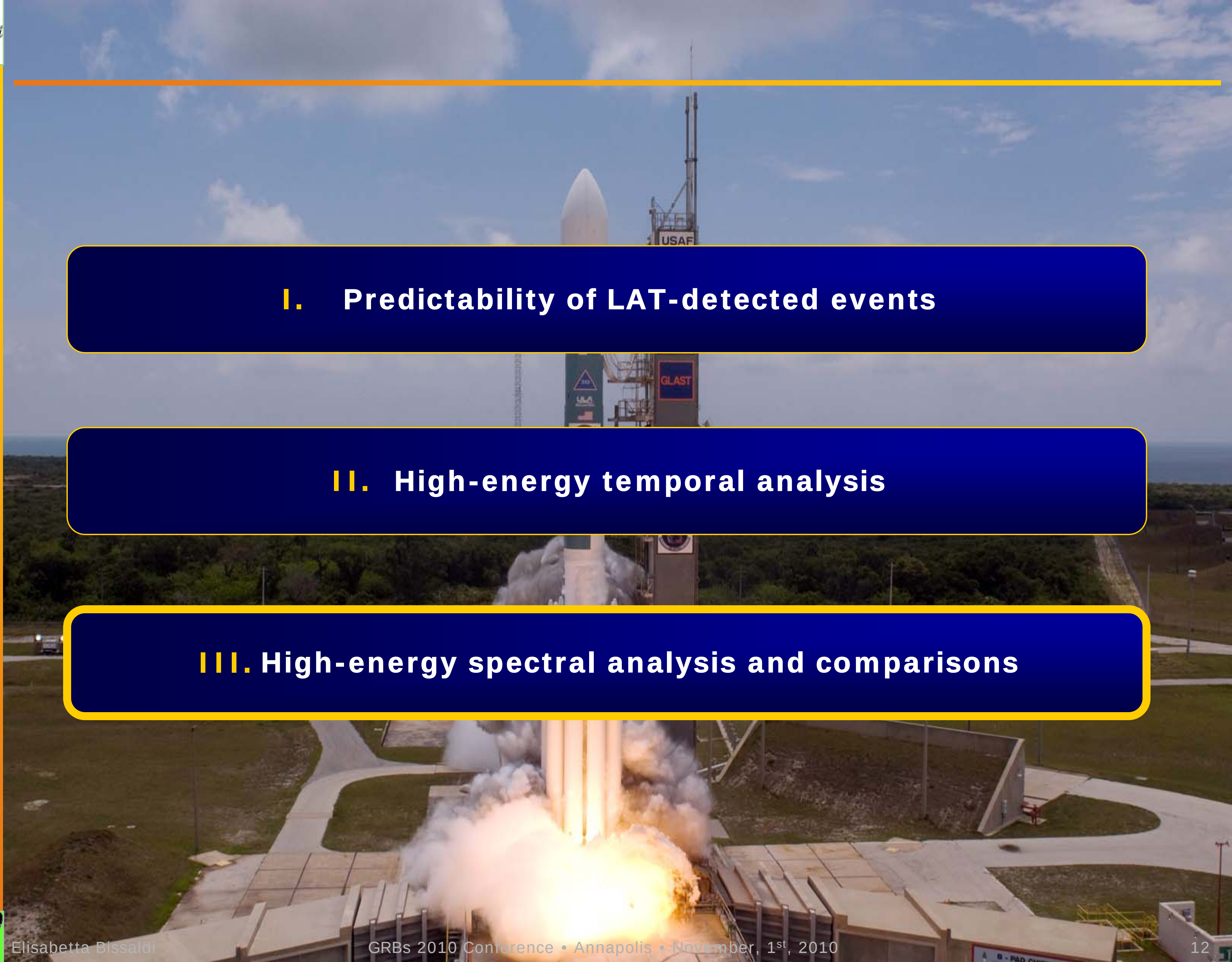


- **17 short, 35 long bursts in the sample**
- **Duration bimodality in the 50-300 keV distribution is clear**
- **T90 (50–300 keV): Short bursts: ~1.2 s, Long bursts: ~33 s**
- **T90 (300 keV–10 MeV): Short bursts: ~1.0, Long bursts: ~25 s**
  - **Narrower distribution**
  - **Bursts at higher energies tend to be shorter**

Evolution of duration with energy



- **Followed the approach described by Richardson et al. (1996)**
  - **BATSE 3B, 72 bursts, 25-50 keV, 50-100 keV, 100-300 keV, and >300 keV.**
- **Utilized broader BGO energy coverage: adding five energy channels, namely 300-500 keV, 500 keV-1 MeV, 1-2 MeV, 2-5 MeV, and 5-10 MeV**
- **Power law fit ($T90 = AE^{\alpha}$)**
  - **Central energy value used to represent each energy channel in the fit**
- **Results for long and short bursts computed separately**
- **Fit performed for the mean T90 values computed from subsets of bursts detected in 3–6 energy channels**



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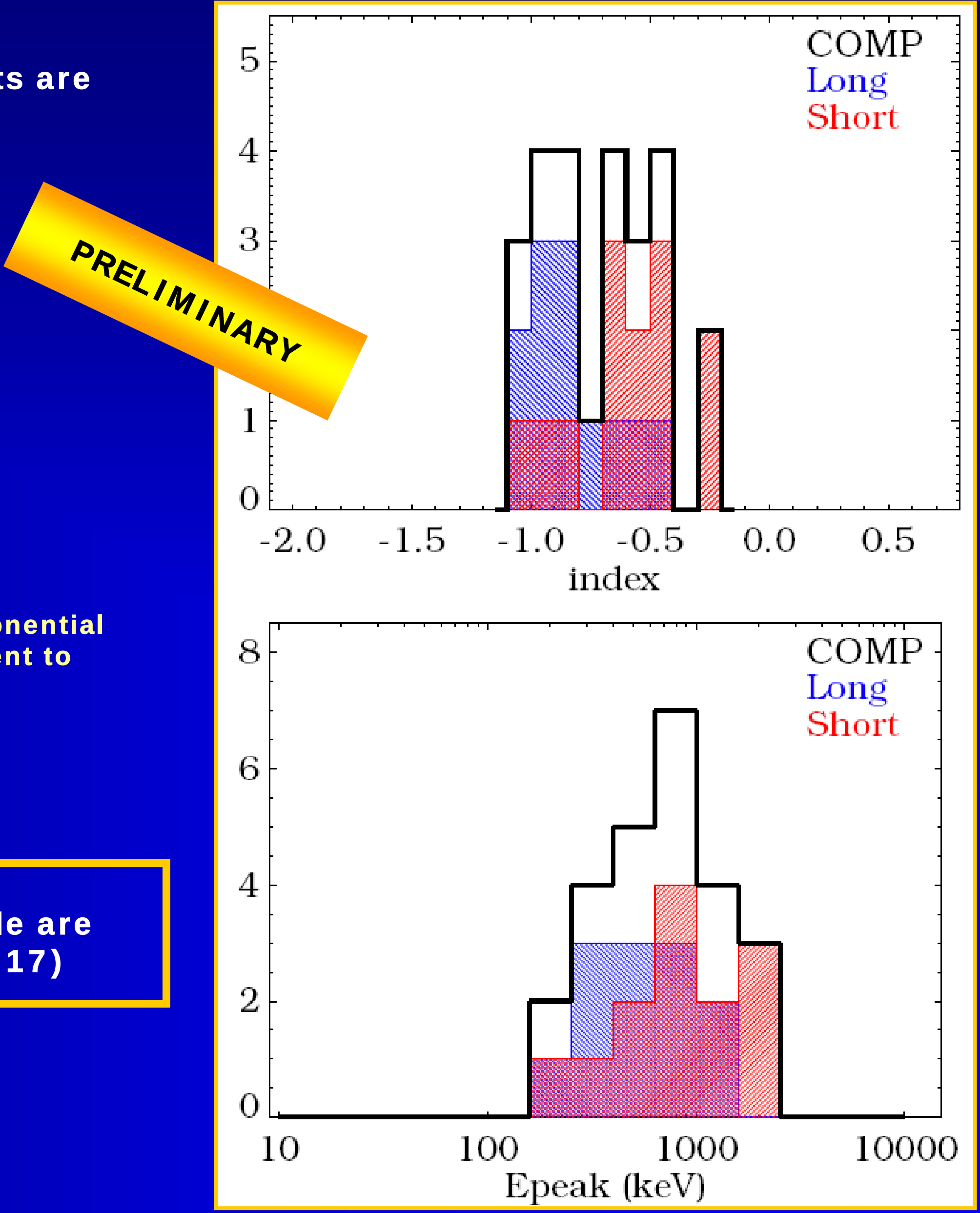
Comp results

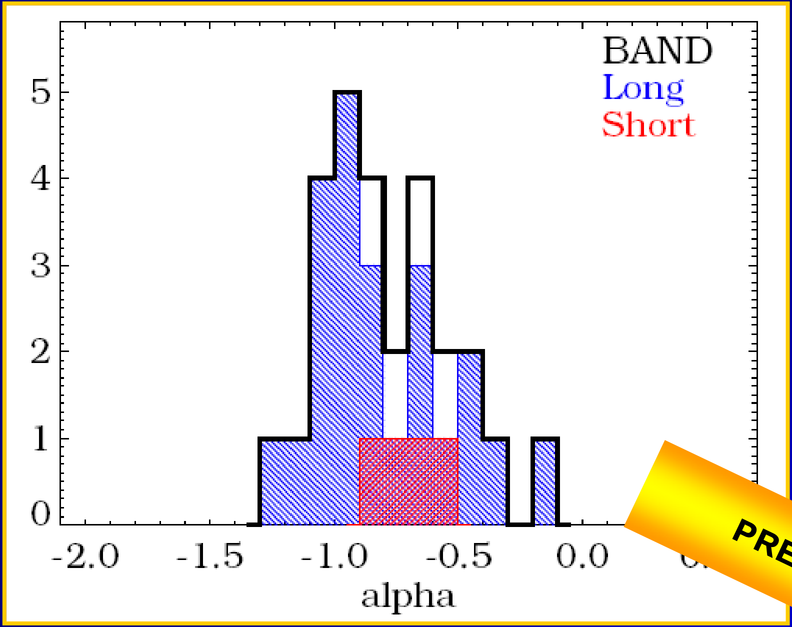
- Time–integrated spectra of 25 bursts are best fit with a Comp model!

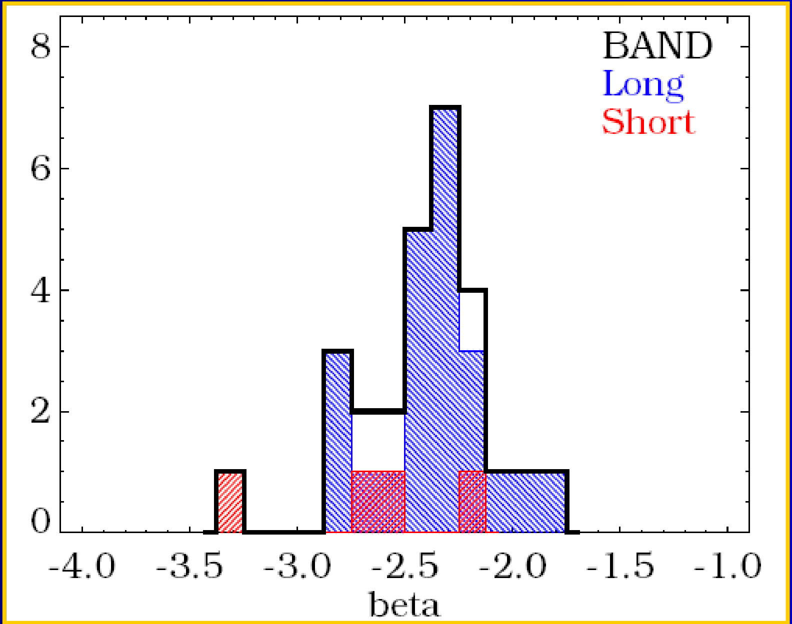


- Comptonized (Comp) model
  - Low–energy power–law with an exponential high–energy cutoff, which is equivalent to the Band function with $\beta \rightarrow$ -inf

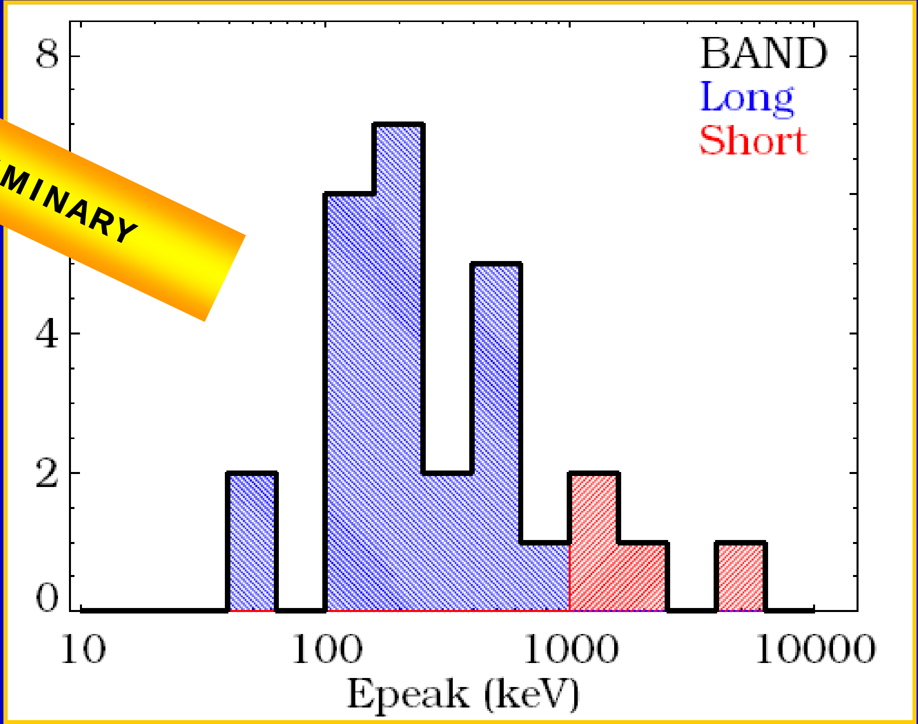
→ 75% of all short bursts in the sample are best fit by a Comp model (13 out of 17)

Band results



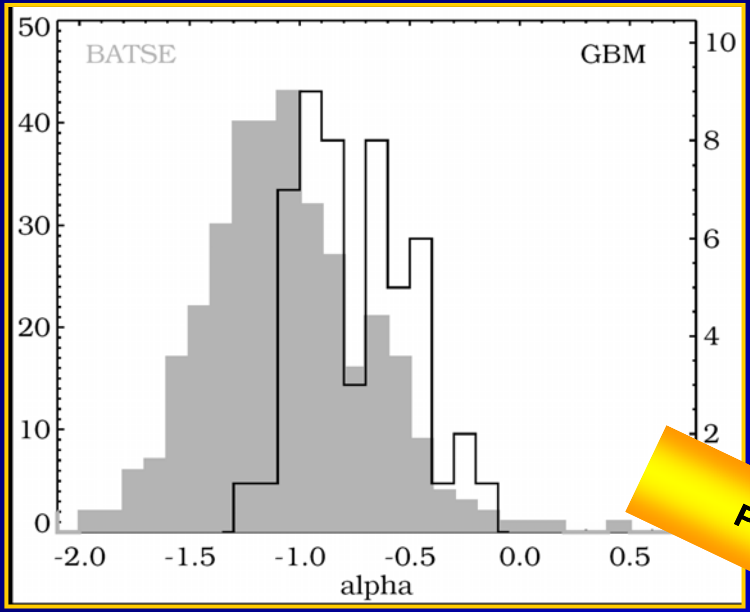


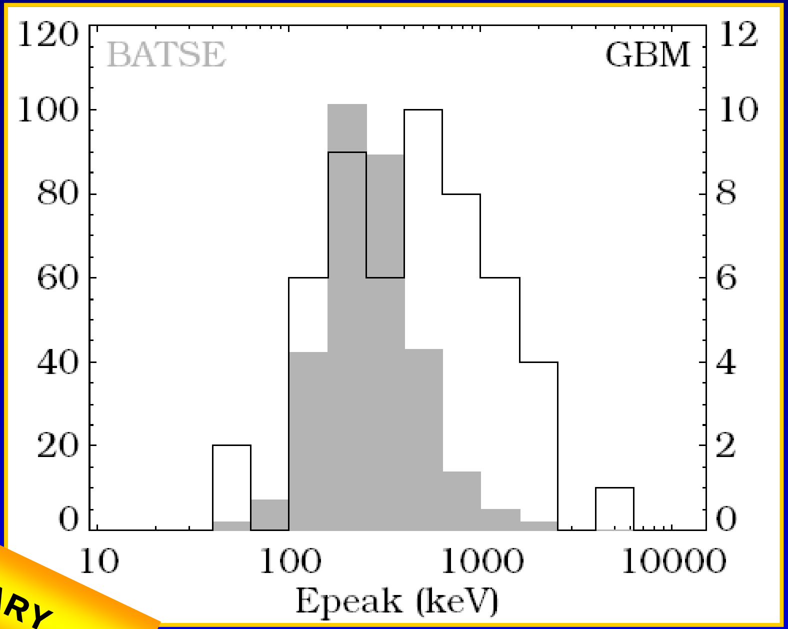
- **Time–integrated spectra of 27 bursts are best fit with a Band function**
- **Only 4 out of 17 short GRBs are best fit by Band (+evidence for extra component!)**
  - **Softer beta values**
  - **Higher Epeak values**



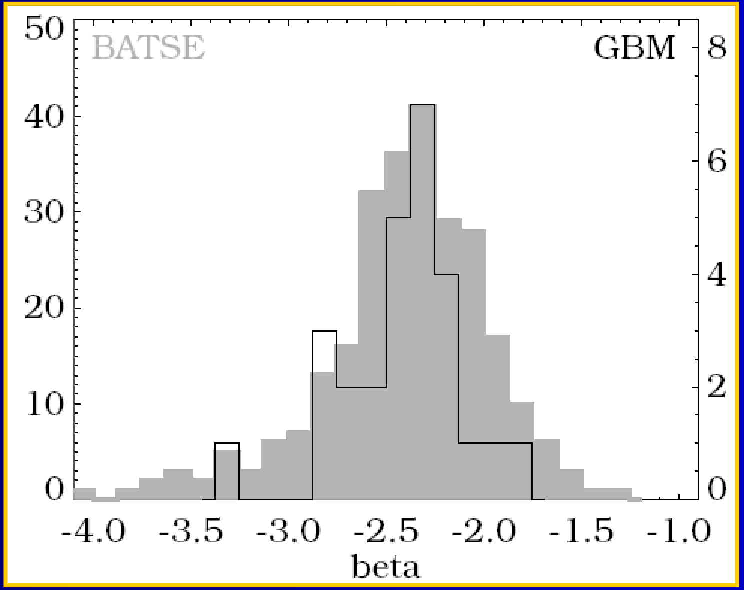
PRELIMINARY

GBM vs. BATSE comparison





PRELIMINARY



- **Comparison with BATSE bright bursts results (Kaneko et al. 2006)**
- **Increasing the space of study towards short and hard bursts with higher Epeak values (by selection!)**
  - **30% of the sample are short bursts, unlike the Kaneko sample (only 4%!)**
  - **See Guiriec et al., Ghirlanda et al., Nava et al. (2010)**

Summary

- GBM is an excellent tool to study in detail bright shorter and harder GRBs as well as longer ones
- We can use the GBM data to predict LAT detections
  - Peak count rate measured between 500 keV and 1 MeV with the mostly illuminated BGO detector
- We have extended the duration vs energy relationship up to ~10 MeV; we confirm the earlier trend of T90 α E^-0.4
- Most Integrated spectra of bright short GRBs are best fit with a comptonized model. We find that the ones associated with an extra component are best fit with a Band function.
- The hardness selected sample of GBM differs from the BATSE bright burst sample.