The Fermi Gamma-Ray Burst Monitor: Results from the first year+

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1) The Gamma-Ray Burst Monitor

The GBM Collaboration

National Space Science & Technology Center

University of Alabama in Huntsville

NASA Marshall Space Flight Center

Los Alamos National Laboratory

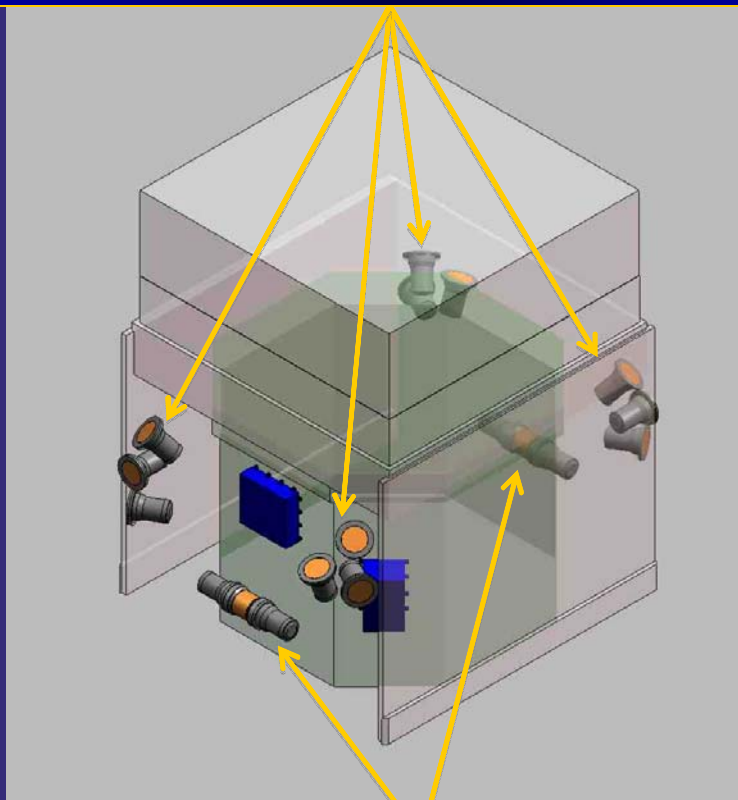
Max-Planck-Institut für extraterrestrische Physik

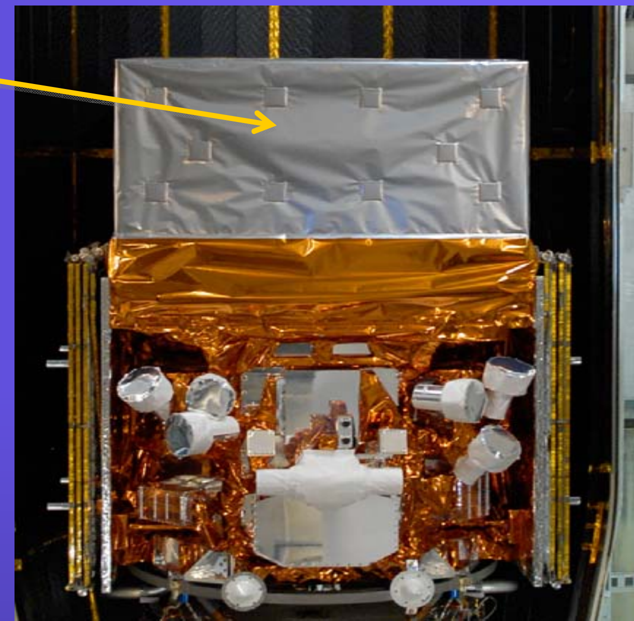
Bill Paciesas (PI)
Jochen Greiner (Co-PI)

The Fermi Gamma-Ray Burst Monitor

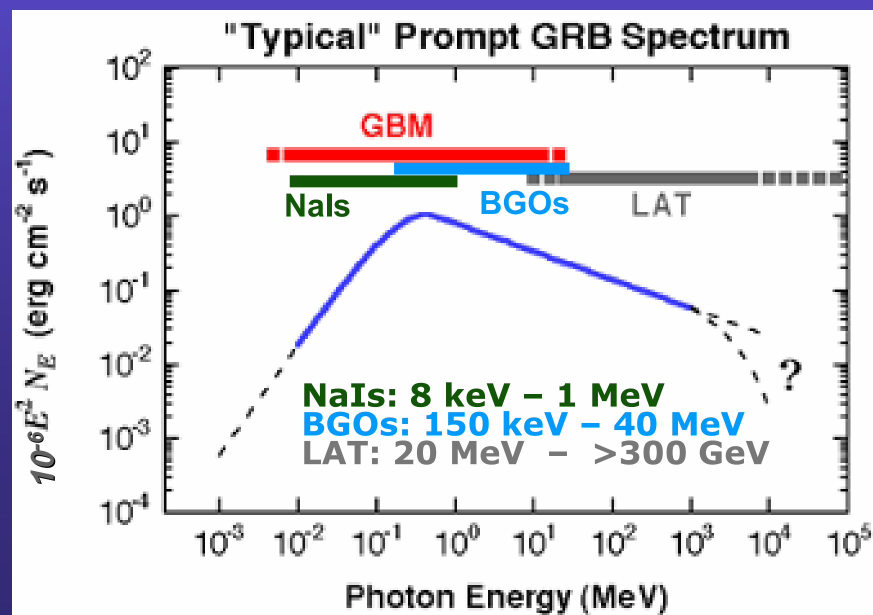
LAT (high-E spectrum)

NaIs (location & low-E spectrum)

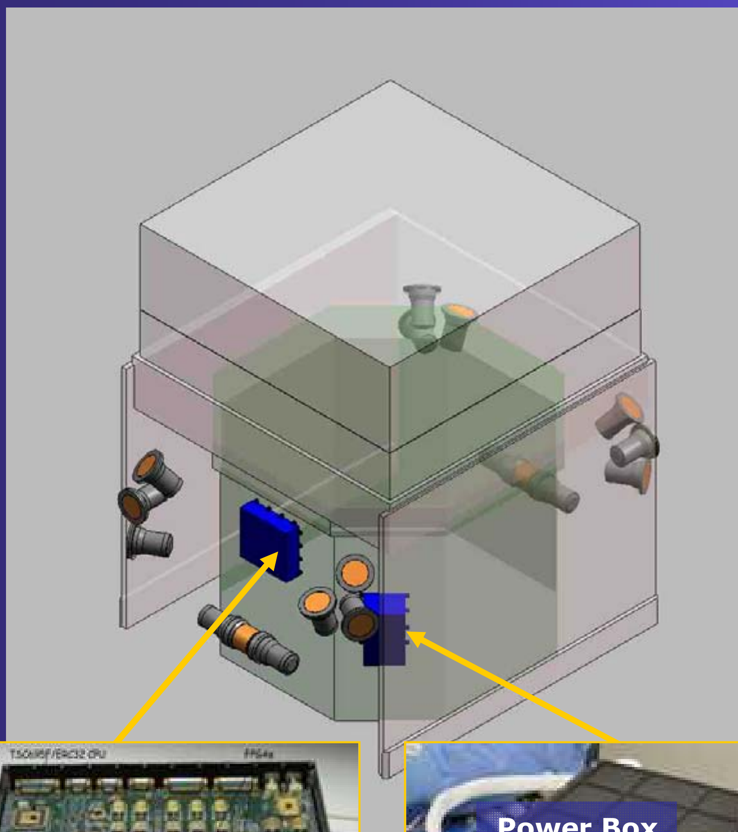


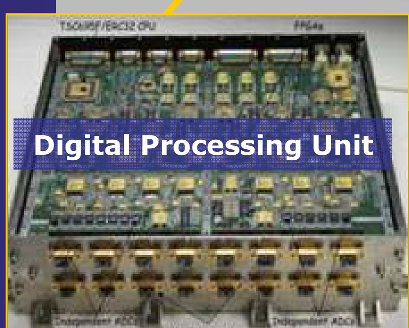


BGOs (mid-E spectrum)



The Fermi Gamma-Ray Burst Monitor

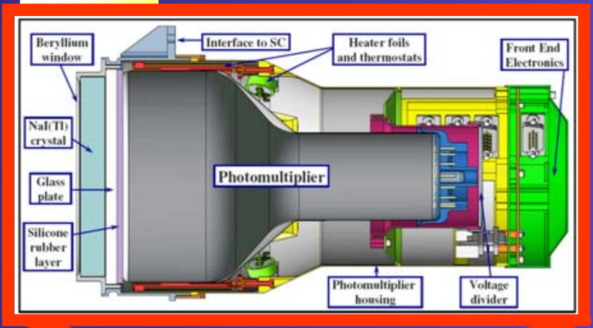




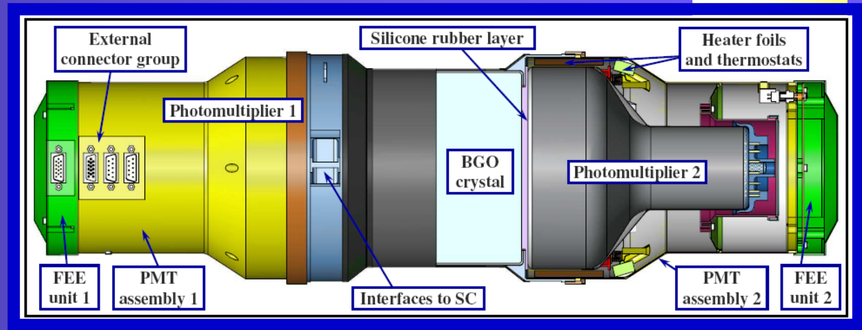
- **12 Sodium Iodide NaI(Tl) scintillation detectors**
  - **∅: 12.7 cm (5” x 5”)**
  - **Thickness: 1.27 cm (0.5”)**
  - **Energy range: 8 keV – 1 MeV**
  - **Wide Field of View**
  - **Burst Trigger**
- **2 Bismuth Germanate (BGO) scintillation detectors**
  - **∅: 12.7 cm (5” x 5”)**
  - **Thickness: 12.7 cm (5”)**
  - **Spectral overlap with the LAT: 200 keV – 40 MeV**
- **1 Power Box (PB)**
- **1 Digital Processing Unit (DPU)**

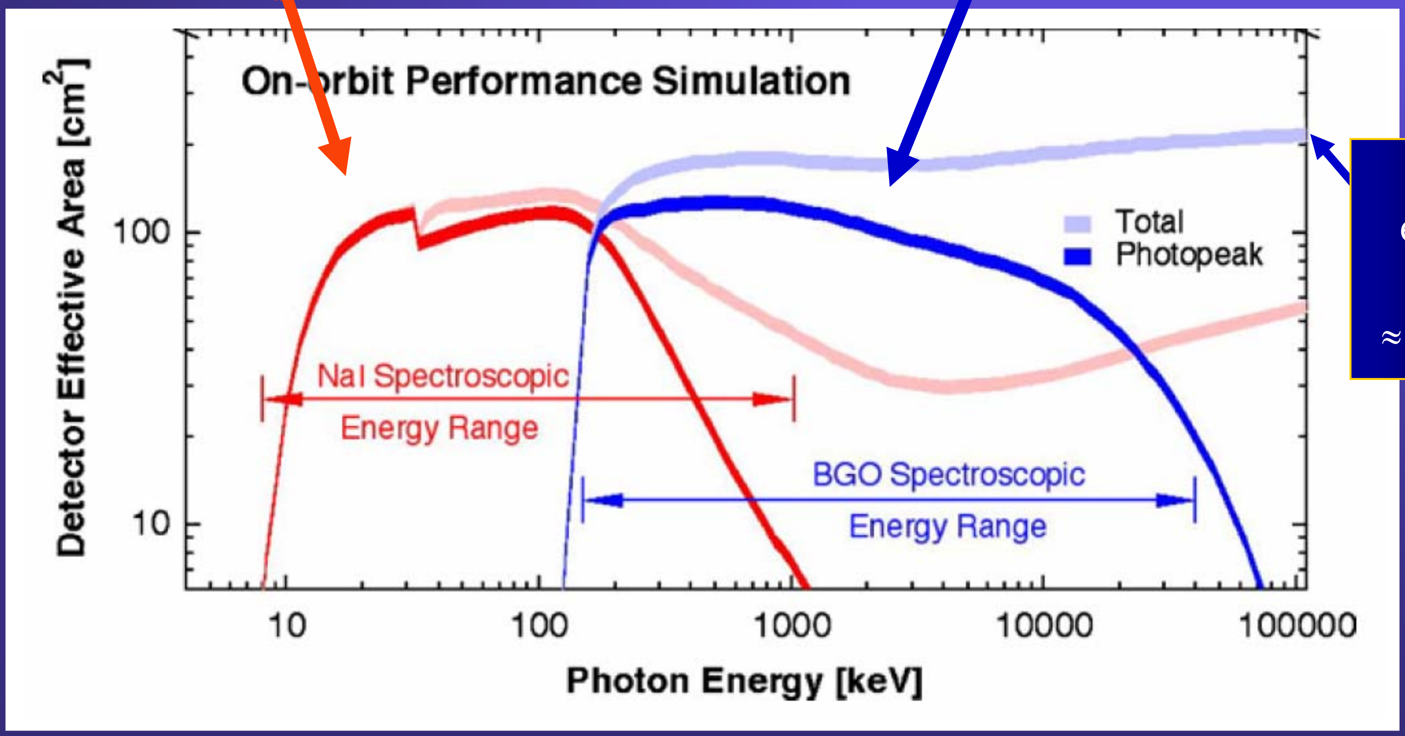
The Fermi Gamma-Ray Burst Monitor

NaI



BGO





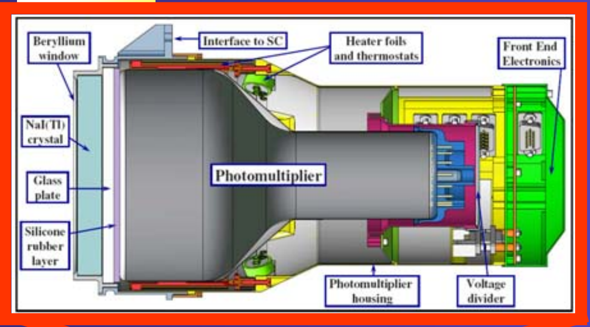
On-axis effective area

$\approx$ 120 cm^2

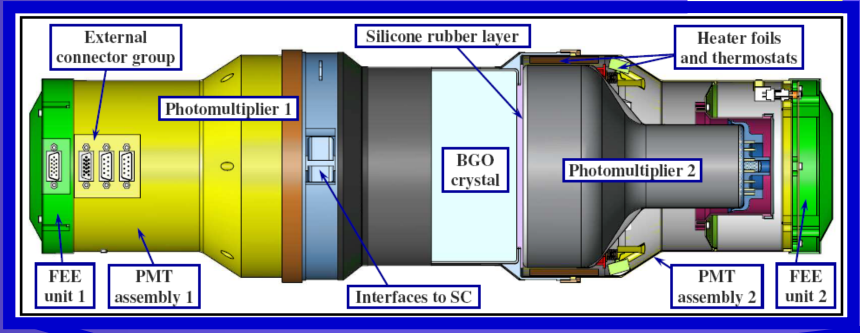
C. Meegan et al. 2009, ApJ, 702, 791

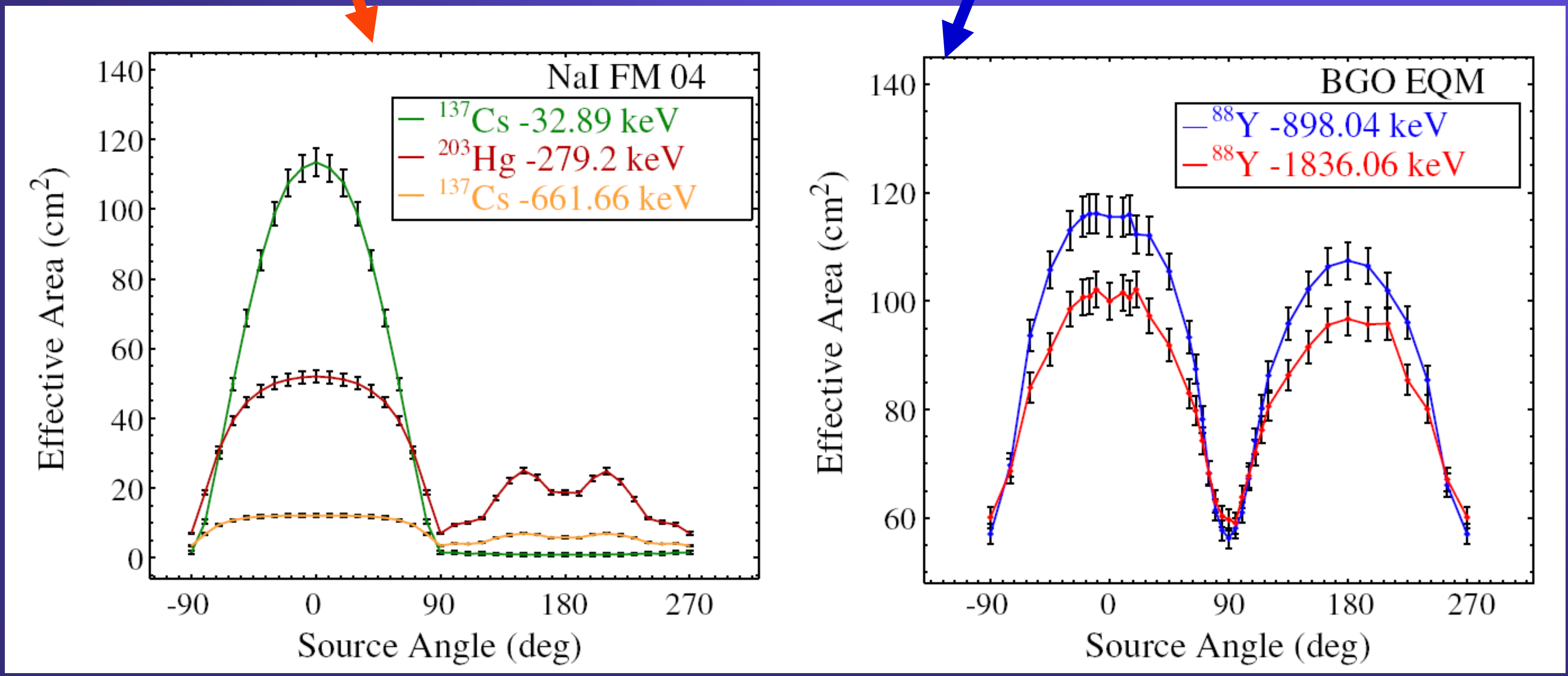
The Fermi Gamma-Ray Burst Monitor

NaI



BGO



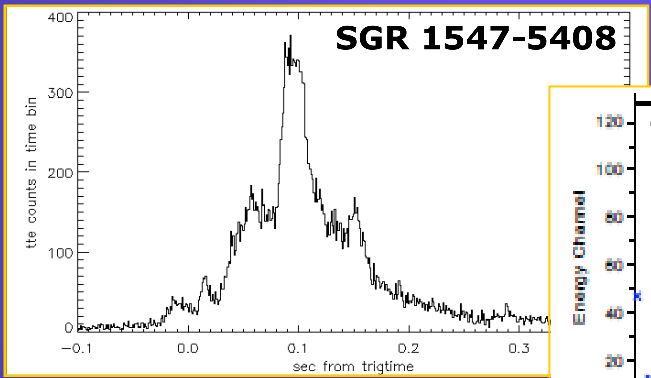


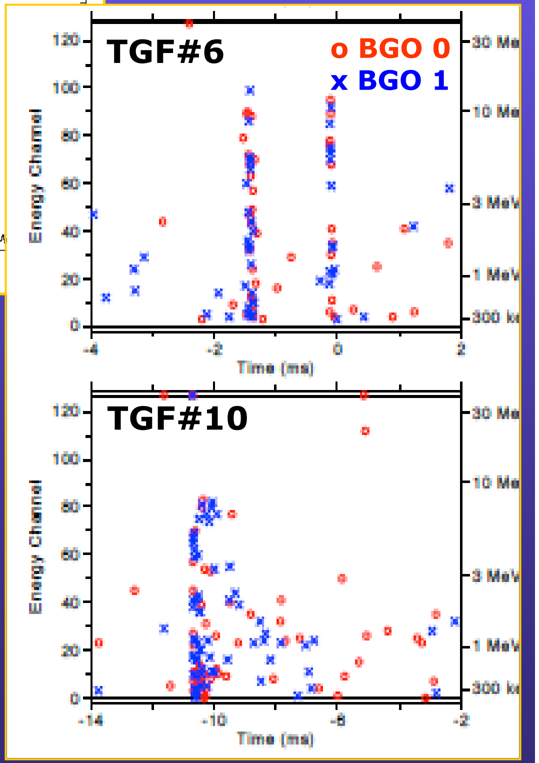
E.Bissaldi et al. 2009, ExpAstr, 24, 47

2) GBM Science

GBM Science

- **Techniques**
  - **Short transients detected by on-board trigger algorithm**
    - **trigger timescales 16 ms – 16 s (currently longest is 8 s)**
  - **Pulsed sources detected by power spectral analysis and/or epoch folding**
  - **Longer-term transients and persistent sources detected by Earth occultation**



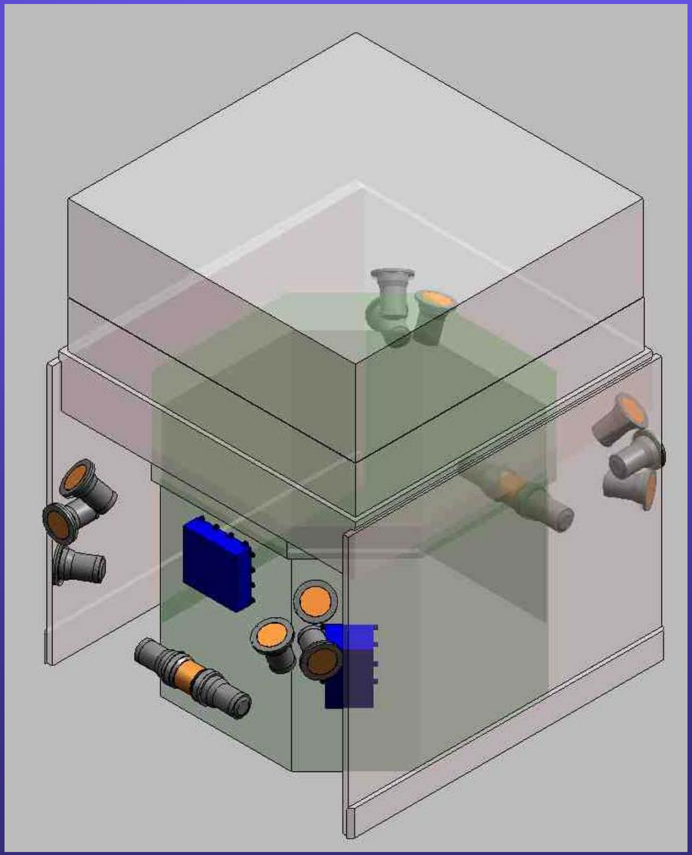


- **Triggered Sources**
  - **Gamma-ray bursts (GRBs)**
  - **Soft Gamma Repeaters (SGRs)**
  - **Terrestrial Gamma Flashes (TGFs)**
  - **Solar flares**
- **Non-triggered Sources**
  - **AGNs**
  - **X-ray binaries: HMXBs, LMXBs, Be binaries, microquasars**

GBM triggering

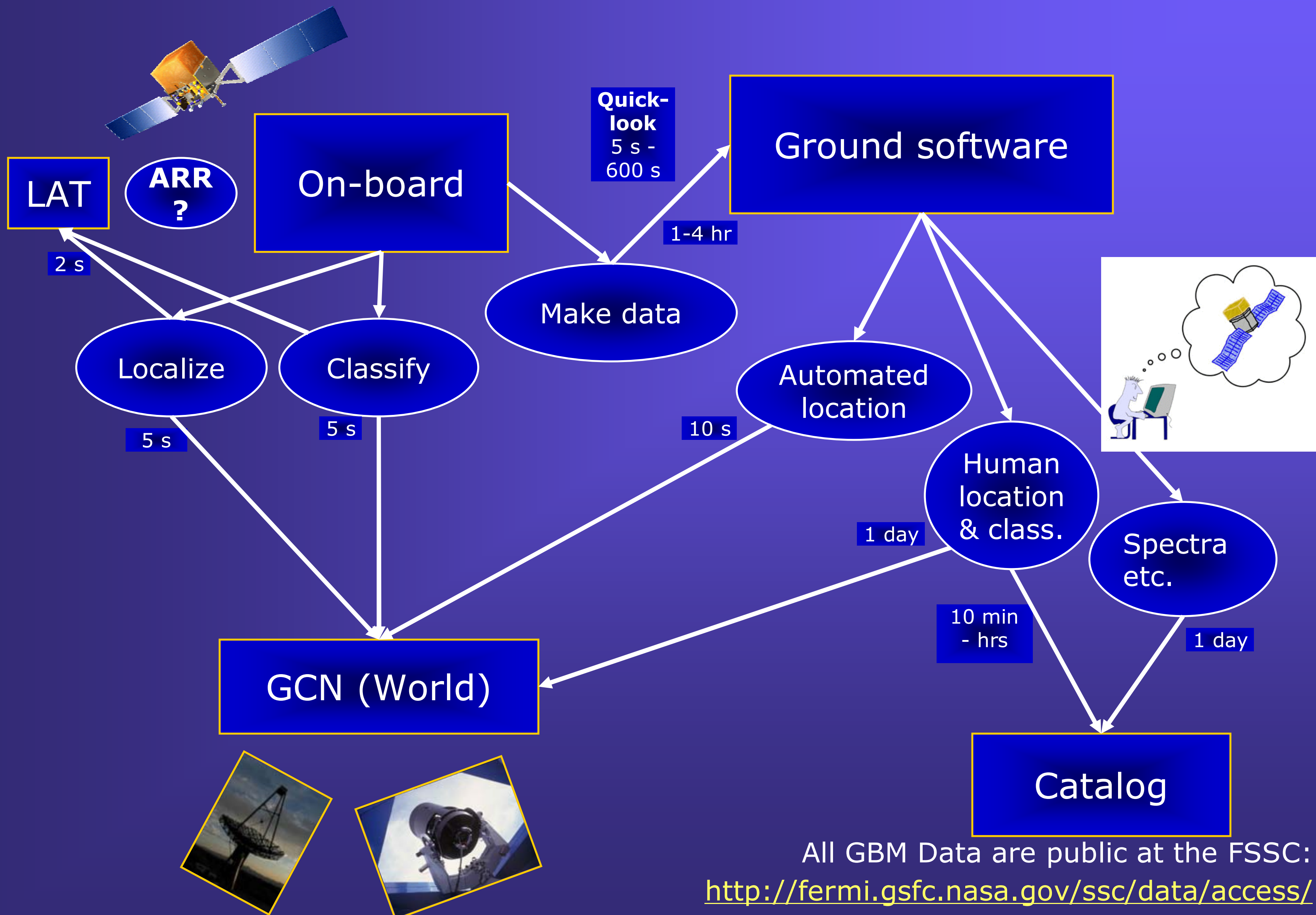
- GBM triggers when 2 or more detectors exceed background by n sigma over t timescale in e energy band

- 62 algorithms operating simultaneously:
  - $4.5 \leq n \leq 7.5$
  - $16 \text{ ms} \leq t \leq 8.096 \text{ s}$
  - E
    - 25 - 50 keV
    - 50 - 300 keV
    - 100 - 300 keV
    - > 300 keV



- What happens when GBM triggers?
- What does GBM trigger on?

GBM Actions on Triggering

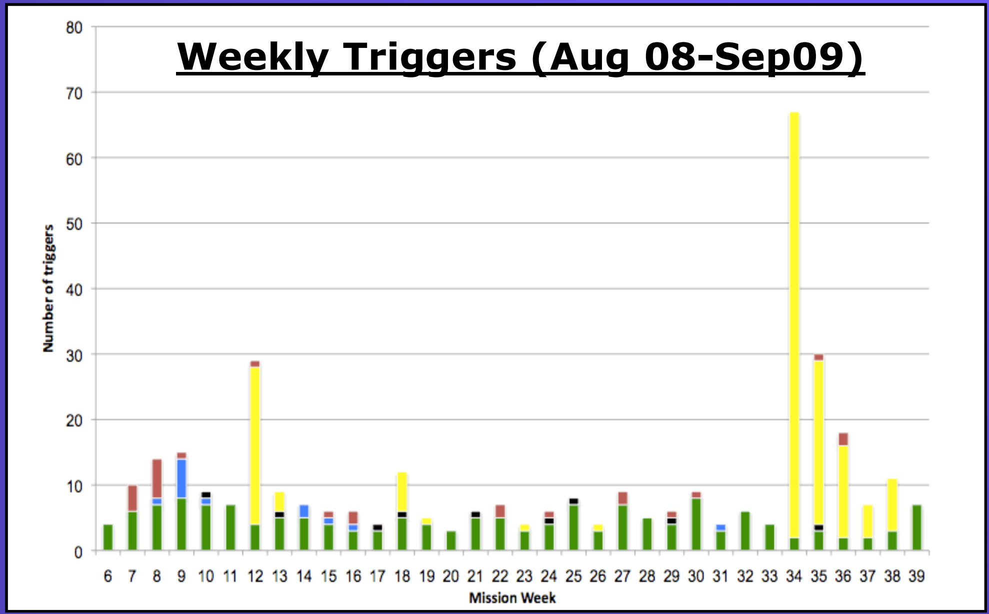


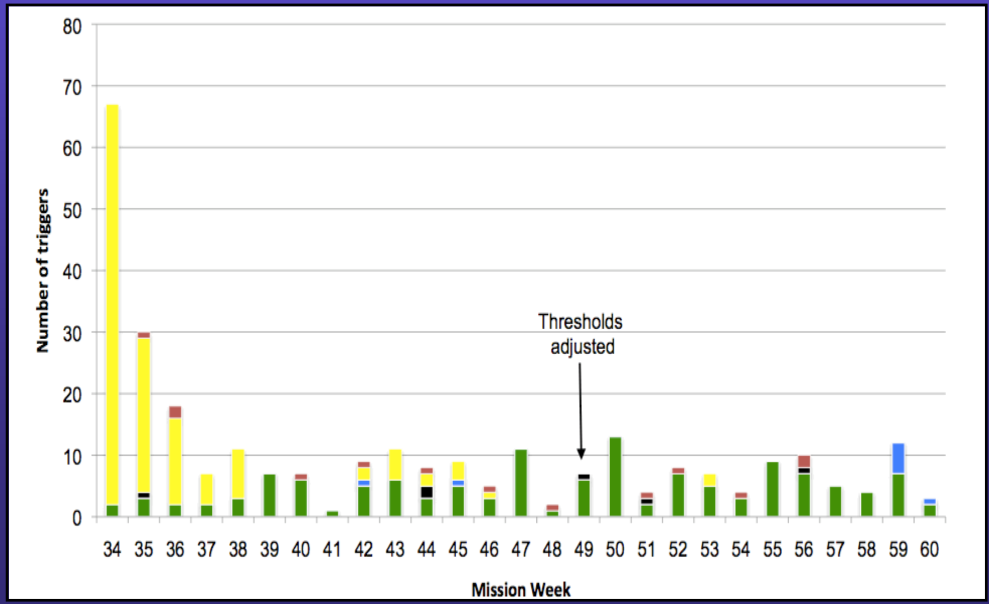
All GBM Data are public at the FSSC:
http://fermi.gsfc.nasa.gov/ssc/data/access/

GBM First Year Trigger Summary

■	GRBs	>250
■	TGFs	14
■	SGRs	~170
■	Particles	
■	Other	

- **253 GRBs**
  - **242 between 50–300 keV**
    - **11 between 25–50 keV**
    - **No GRB triggered on hard energy ranges**
    - **i.e. 212 BATSE-like GRBs in 1 year**
- **62 commanded (test)**
- **168 SGRs – most on soft, short trigger algorithms.**
- **14 TGFs – all on hard, short trigger algorithms.**
- **1 solar flare**
- **Others are Cyg X-1 rises, accidentals, and particle events**





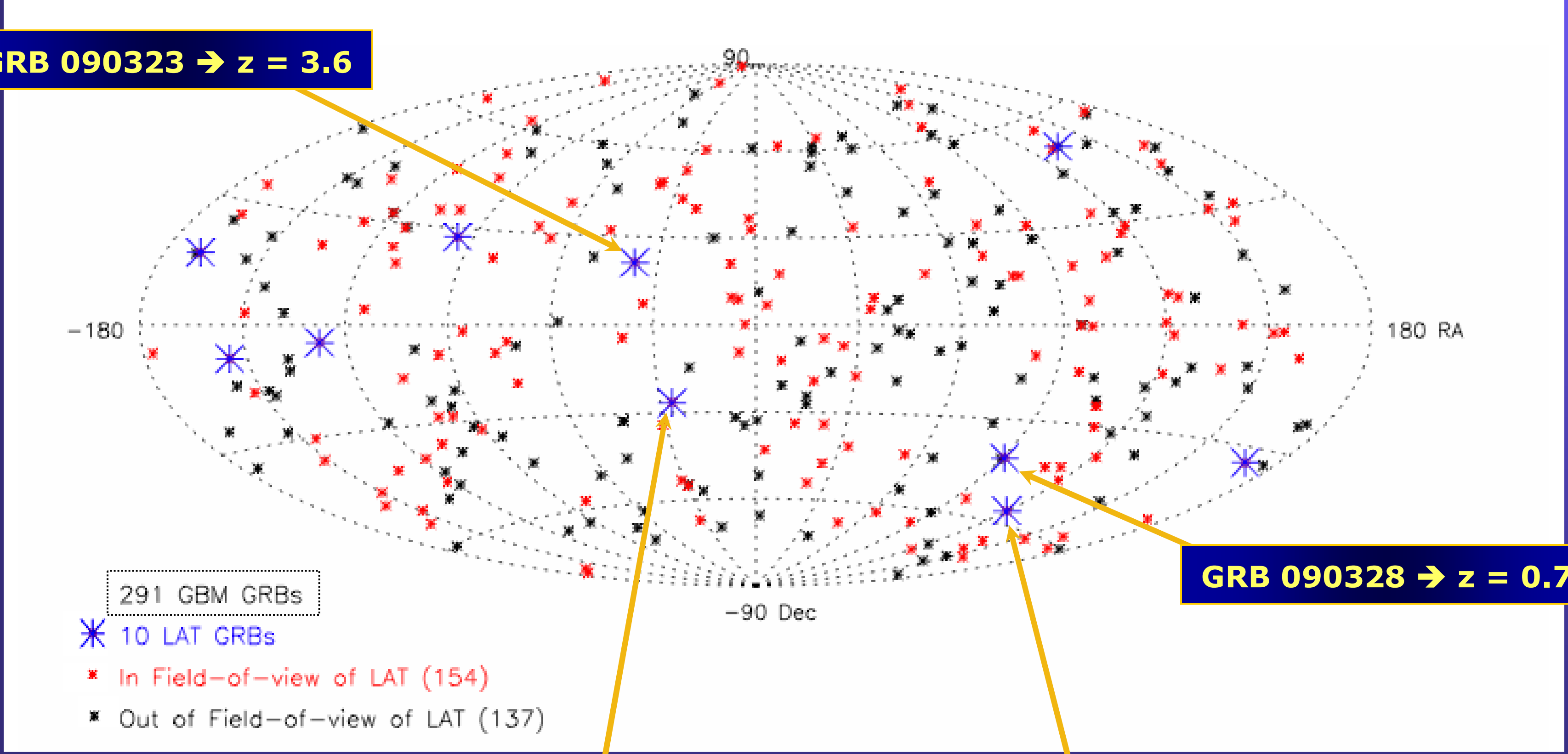
Localization Accuracy

- Determined using GBM GRBs which have accurate locations from other instruments
  - Swift, IPN, Integral and ground-based
  - Bayesian method (Briggs et al., ApJSS, 1999)
- Systematic error (to be added to the stat. error) :
  - FSW automatic: 3 degrees, consistent with zero
  - Human-in-the-loop: 3.8 +/- 0.5 degrees
- FSW and ground-automatic locations are sent as GCN Notices
  - Ground-automatic more accurate!
  - Recent improvement (by ~20 s) in the speed of the ground-automatic locations
- Human-in-the-loop locations are currently sent within GCN Circulars.
  - Plan to switch to Notices & speedto make these locations more accessible to robotic telescopes!
- First optical afterglow detection using GBM automatic location:
  - GRB090902B using ROTSE-IIIa & IIIc (Pandey et al, GCNC 9878); 15.9 mag after ~1.4 hours
- Algorithm improvements are under development to improve the localization accuracy of the ground-automatic and human-in-the-loop locations

GBM Gamma-Ray Bursts

Fermi Gamma-ray Bursts – First Year+

Detections as of 090904



GRB 090323 → z = 3.6

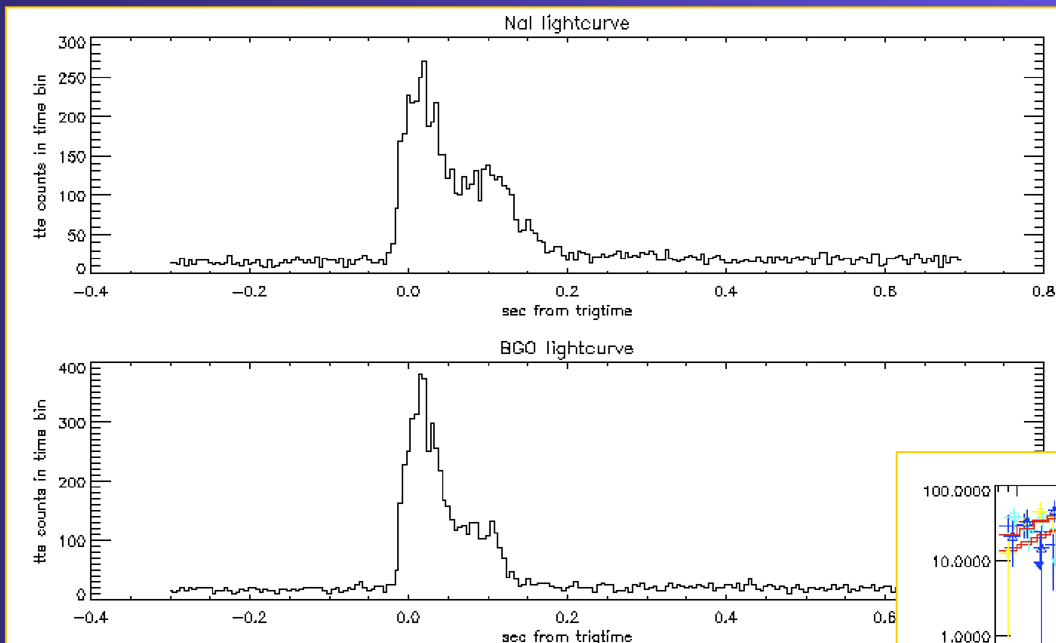
GRB 090328 → z = 0.7

GRB 090510 → z = 0.9

GRB 080916C → z = 4.4

V. Connaughton

What can GBM GRBs add?

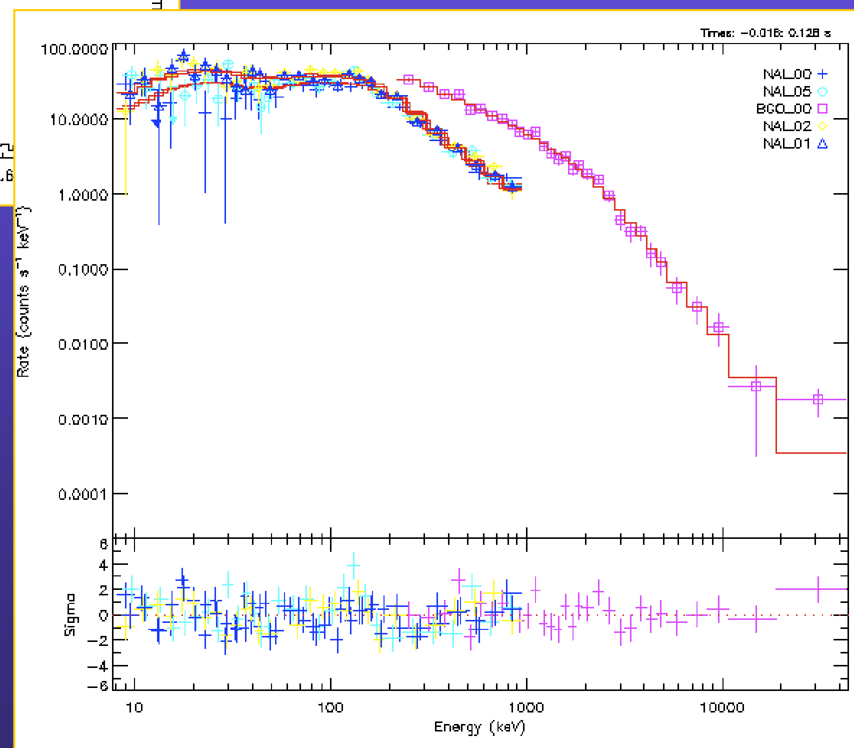


GRB 090227B

Short GRB

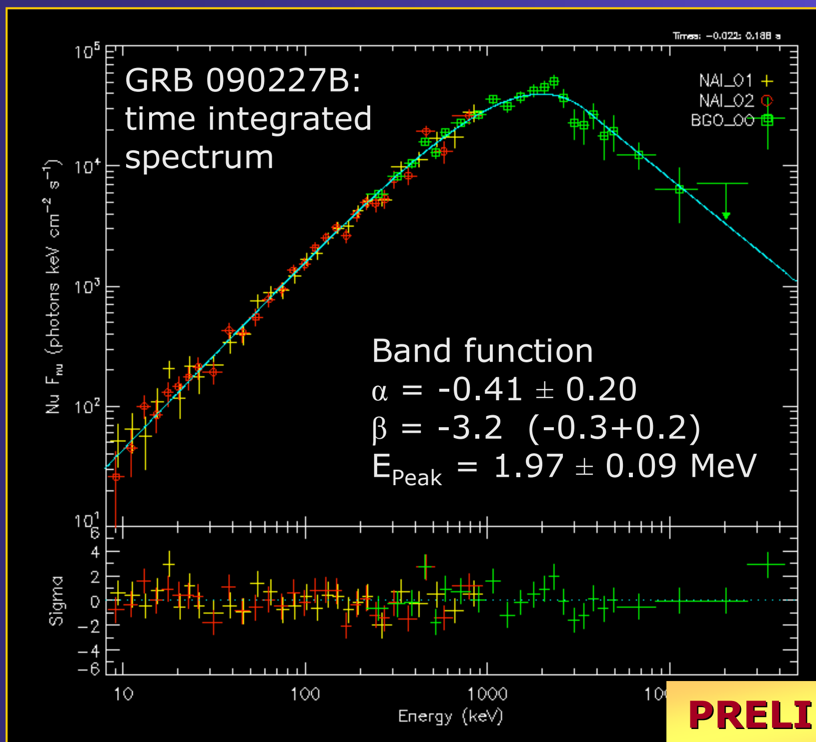
$E_{Peak} \approx$ 2 MeV

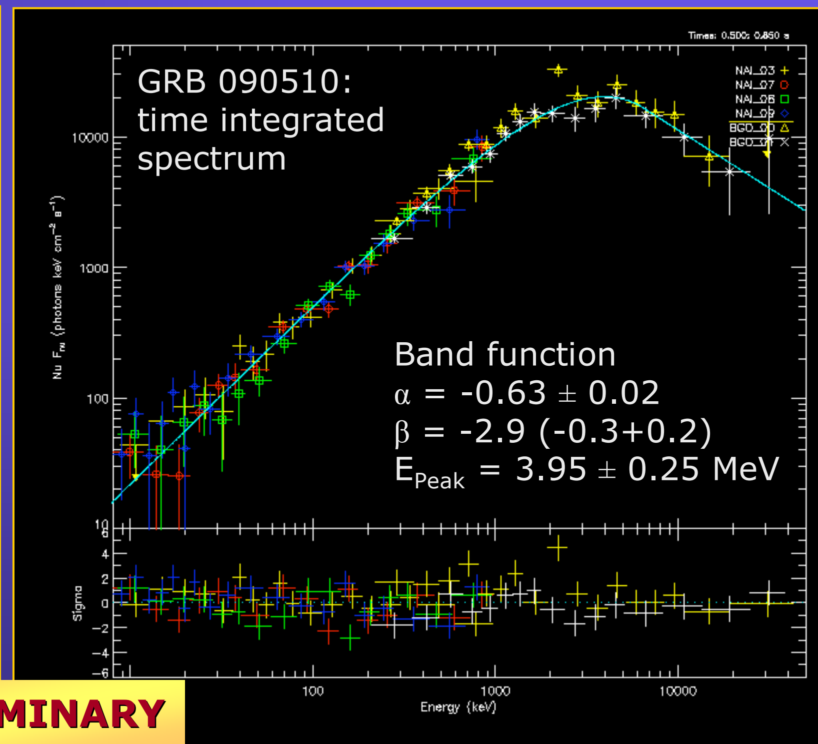
- **Source of E_{Peak} for Swift bursts**
  - **Spectroscopy from 8 keV - 40 MeV**
- **Time-resolved spectra for under-standing central engine of GRBs**
- **Trigger for LAT → Joint spectral fits**



GBM Observation of Short GRBs

- **Short & Bright GRB Sample:**
  - **t_{50} < 1 s**
  - **Fluence > 2E–6 erg/cm^2 (8-1000 keV)**
  - **3 GRBs: 090227B, 090228, 090510**



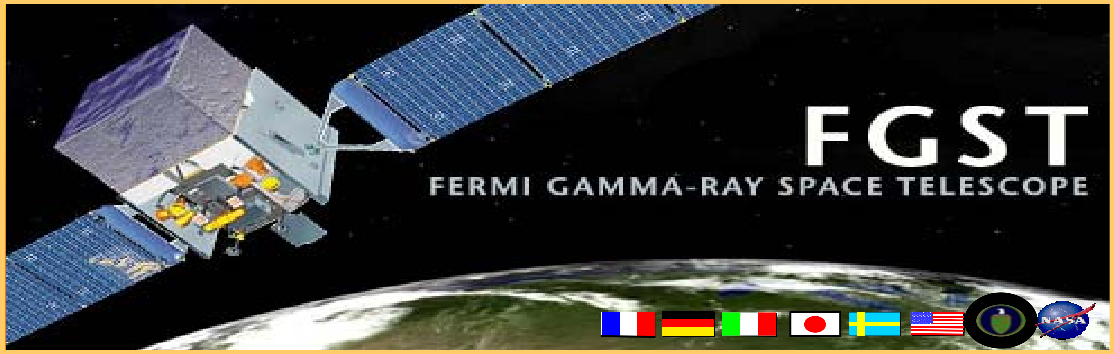


PRELIMINARY

- **GBM Results:**

S.Guiriec et al. 2009, in preparation

  - **short GRBs have very high E_{peak} values, with modestly steep β values**
  - **Band function preferred in 2 of the 3 GRBs over cutoff power law**

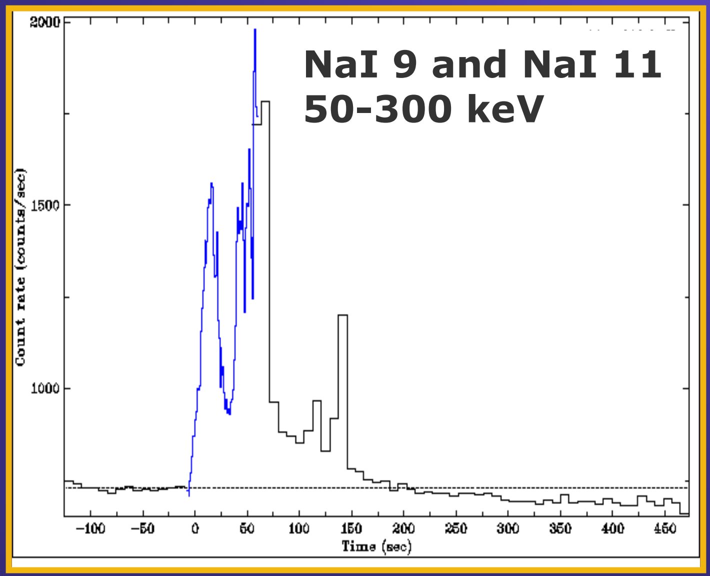


GRB 090323 and GRB 090328

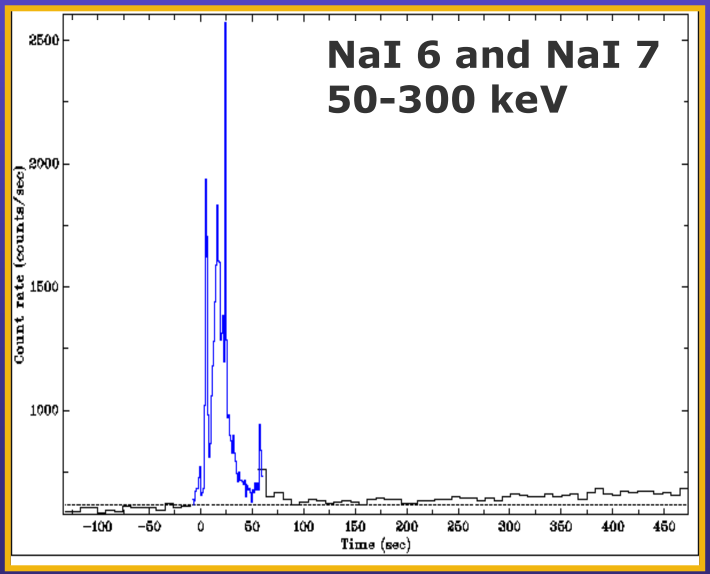
Items in common

- Long duration GRBs
  - Detection up to much, much later times than GBM duration
  - Careful evaluation of the LAT background as a function of time
- ARR issued
  - Significant impact on the Fermi analysis (especially for GBM)
  - Responses change while the observatory is slewing
- Superb afterglow observations from X-ray to radio
- Spectroscopic redshifts were determined

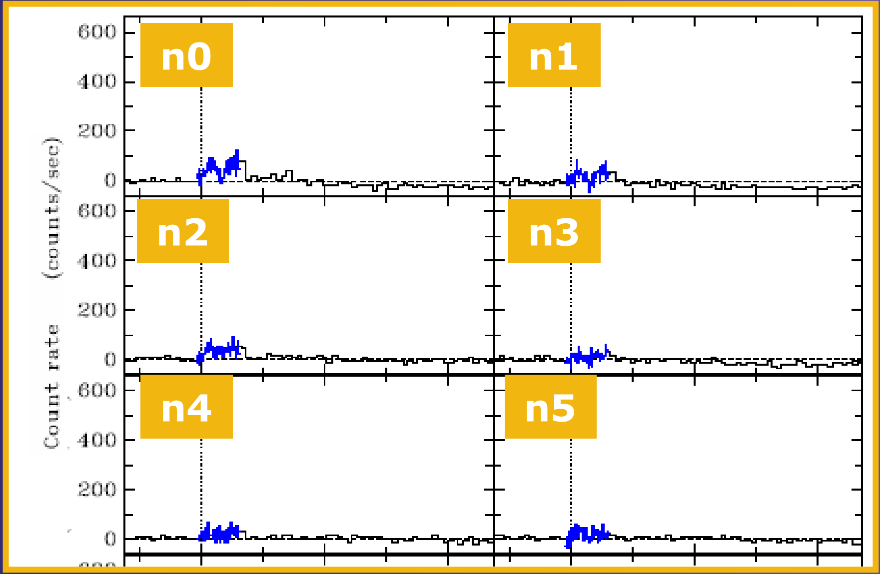
GRB 090323 is at z = 3.6



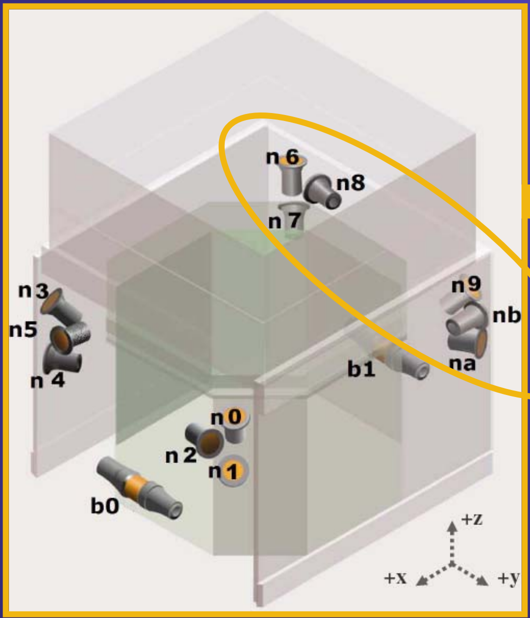
GRB 090328 is at z = 0.736

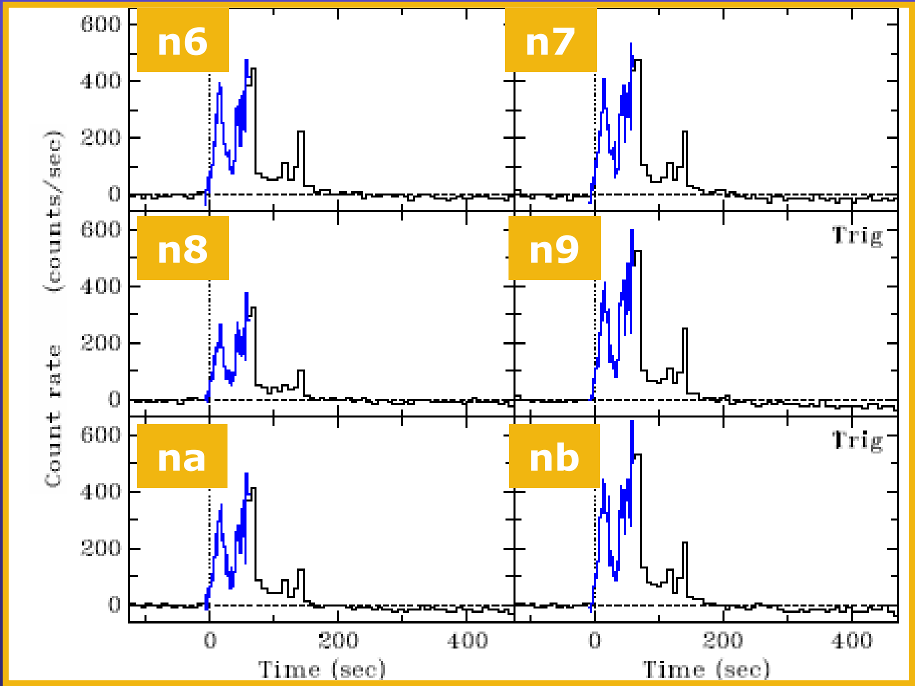


GRB 090323: GBM detectors

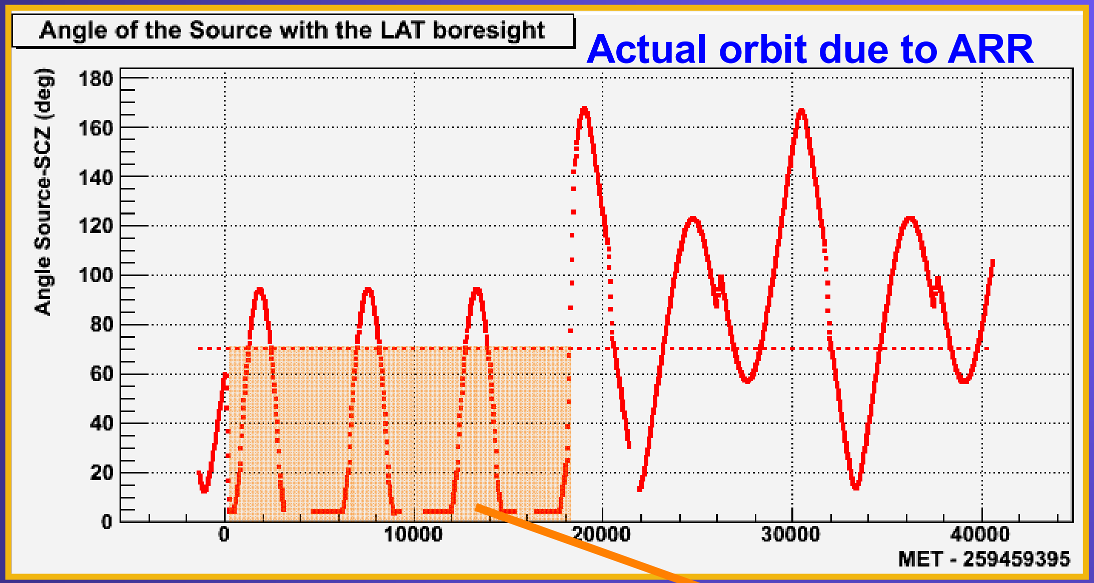


- First quick-look data analysis of the NaI detectors (50-300 keV band)
- Temporal resolution:
  - Blue line: 1 s resolution
    - 70 s, covering ~8 s pre-burst and ~60 s post-burst.
  - Black line: 8 s resolution

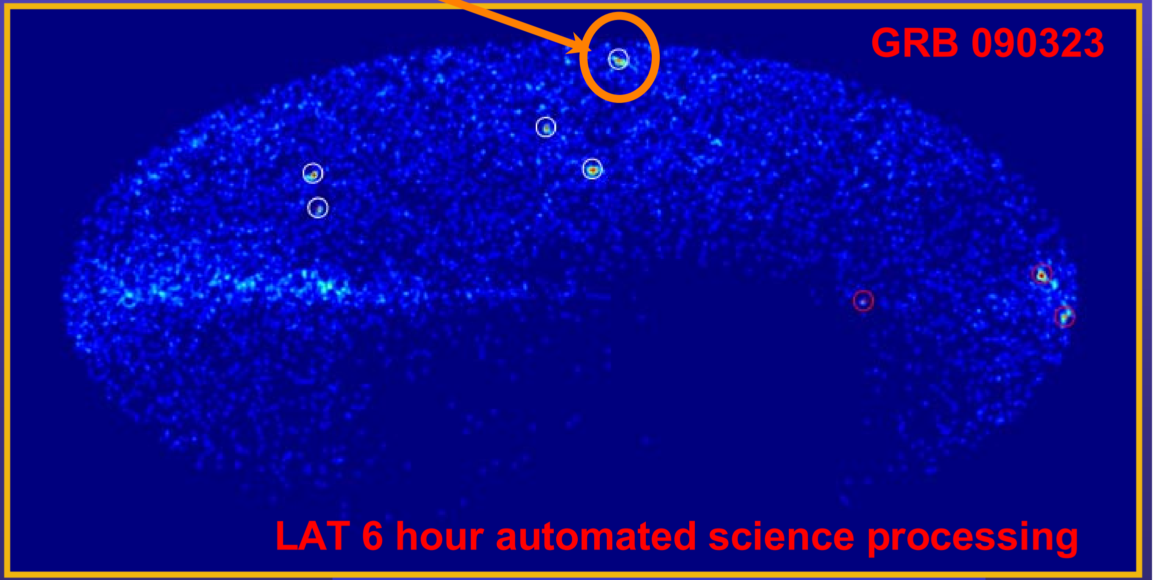




Autonomous Repoint Recommendation (ARR)

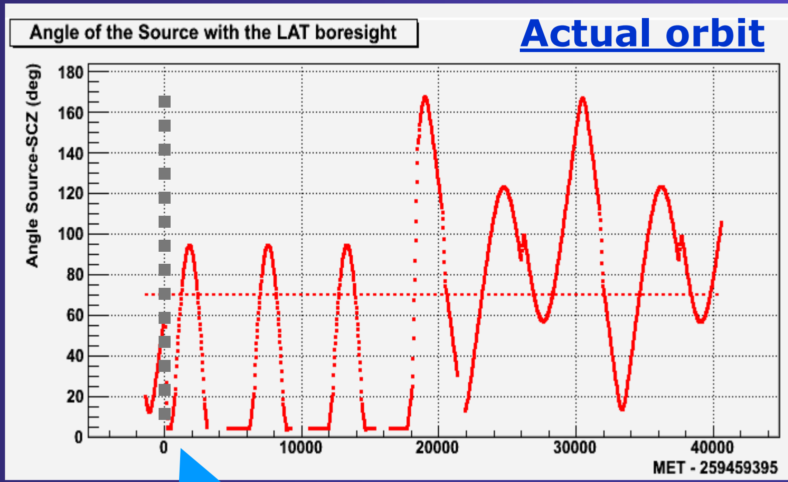


- **The high energy emission detected by the LAT was made possible by the ARR sent from GBM**
  - **Otherwise GRB would have been out of FOV!**



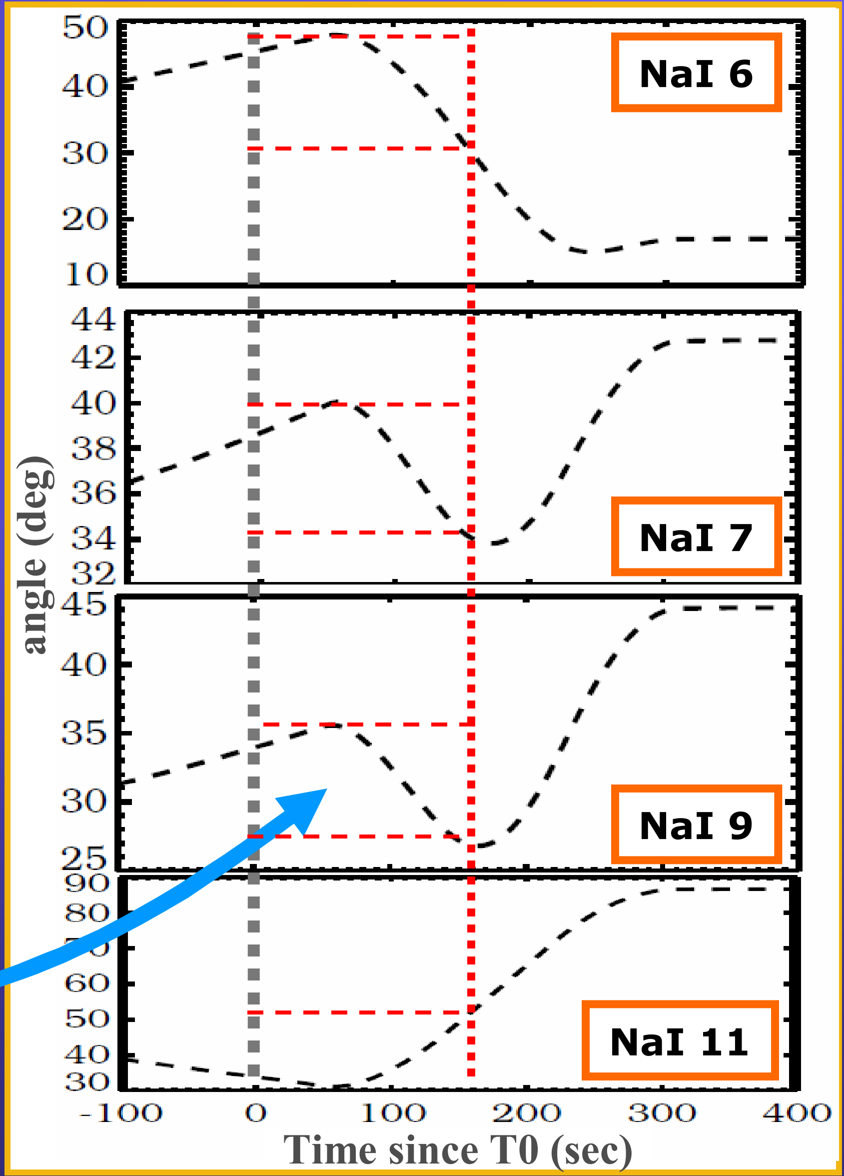
GBM orientation evolution

In GBM, the effect of the ARR is particularly visible after T0+60 s, where the detectors orientation changes with incredible rapidity, making the spectral analysis a delicate issue



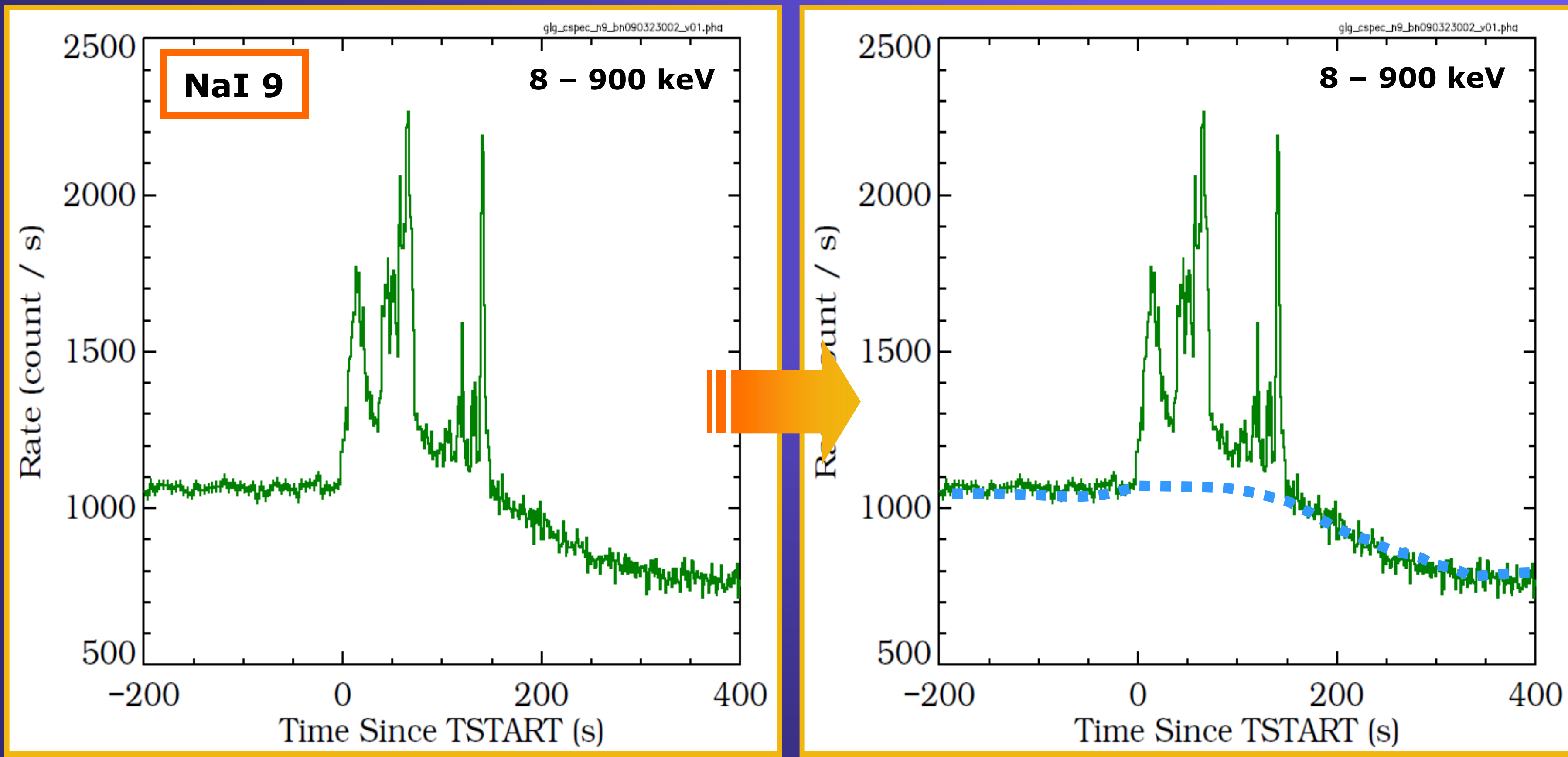
ARR

GRB 090323



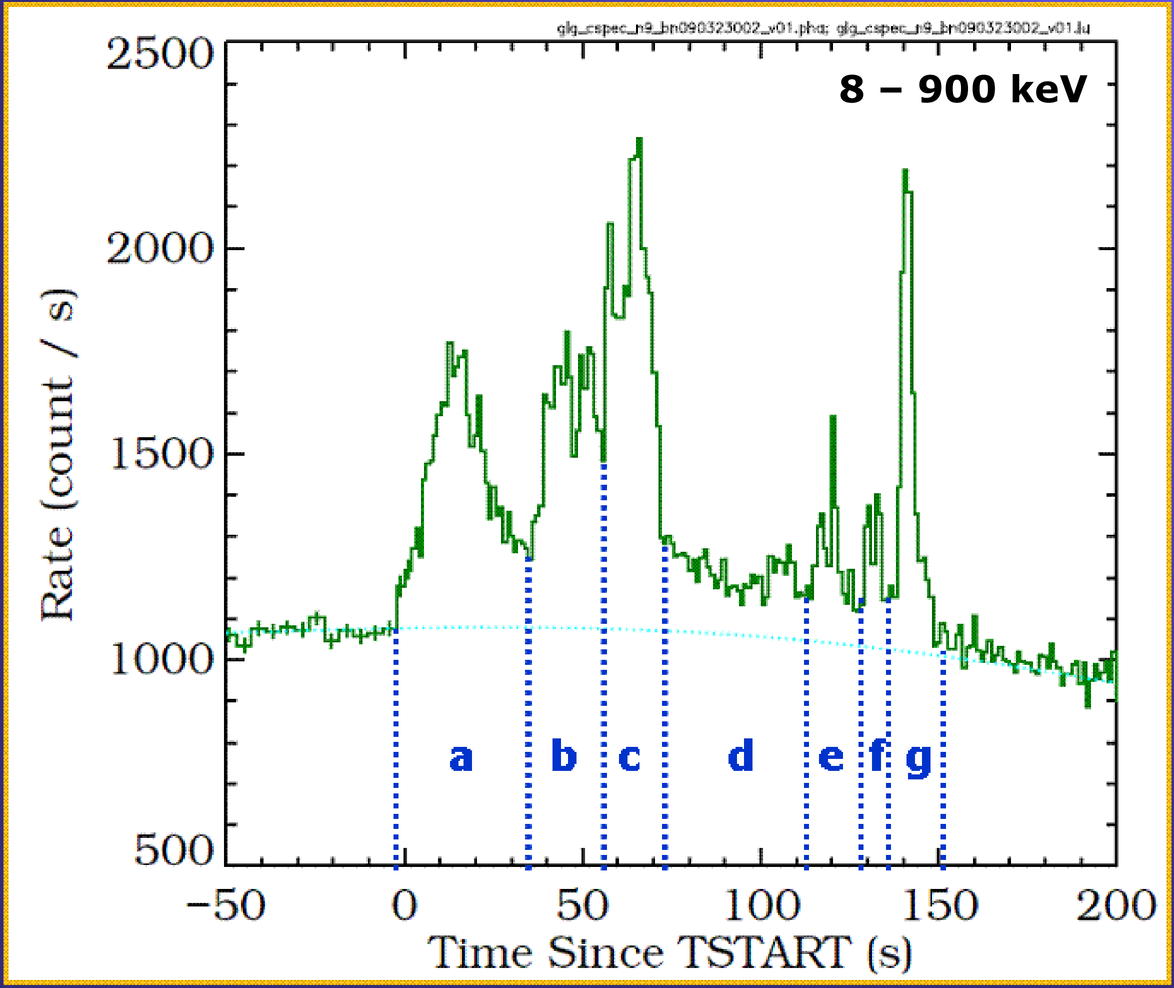
NaI background subtraction

GRB 090323



Time interval selection

GRB 090323



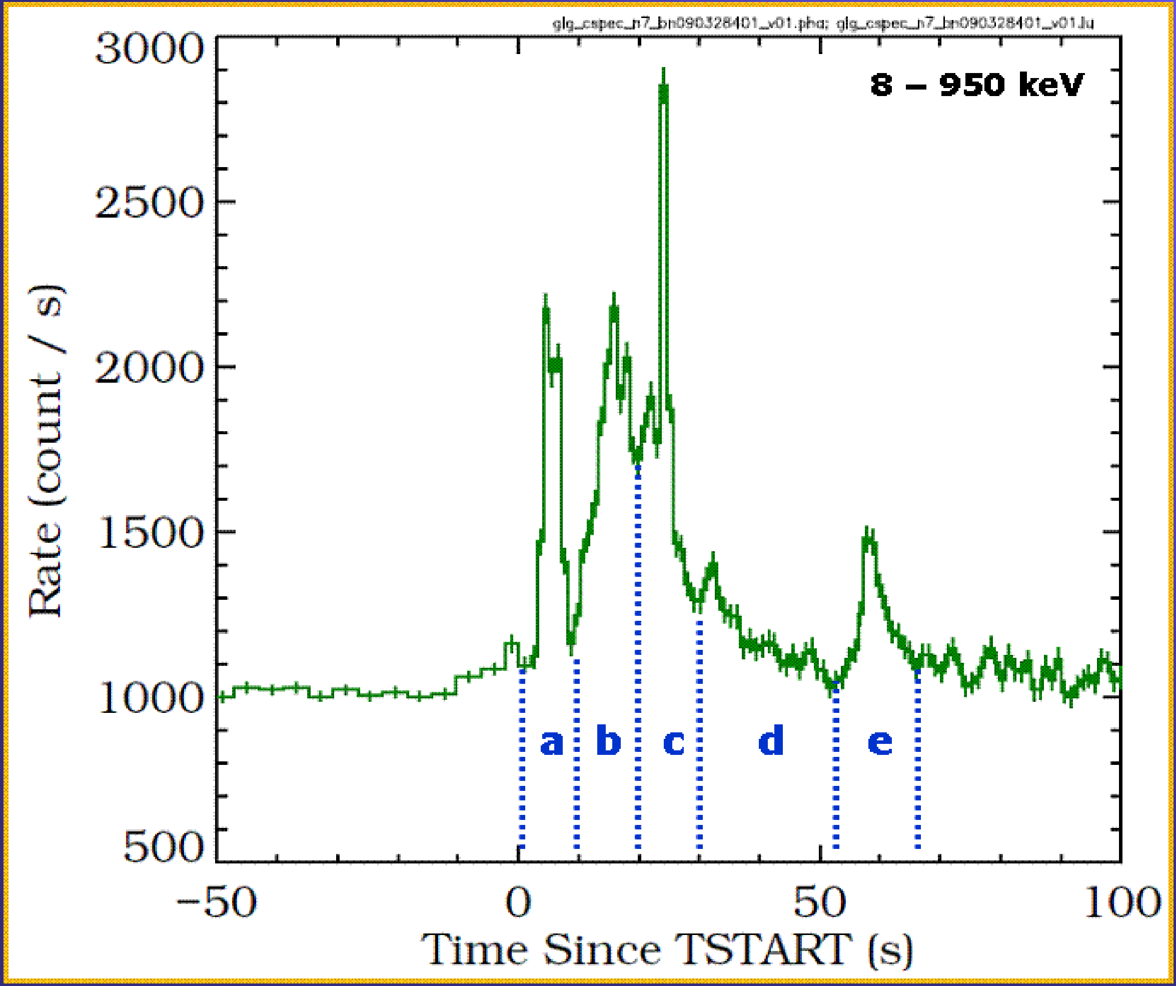
E.Bissaldi et al. 2009, in preparation

Because of the slewing due to the ARR, we need to select the best NaI detector combination for each time interval!

- **T90 ~ 140 s**
- **Fluence = (1.23 ± 0.02)E-04 erg/cm²**
- **1-sec Peak Flux = 12.3 ± 0.4 ph/s/cm²**

Time interval selection

GRB 090328

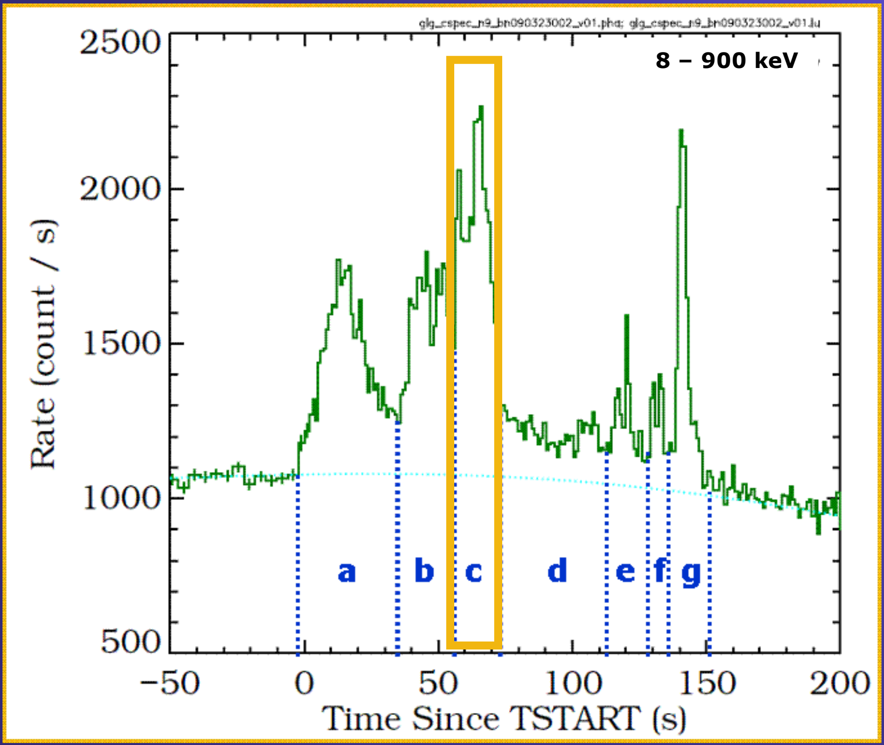


E.Bissaldi et al. 2009, in preparation

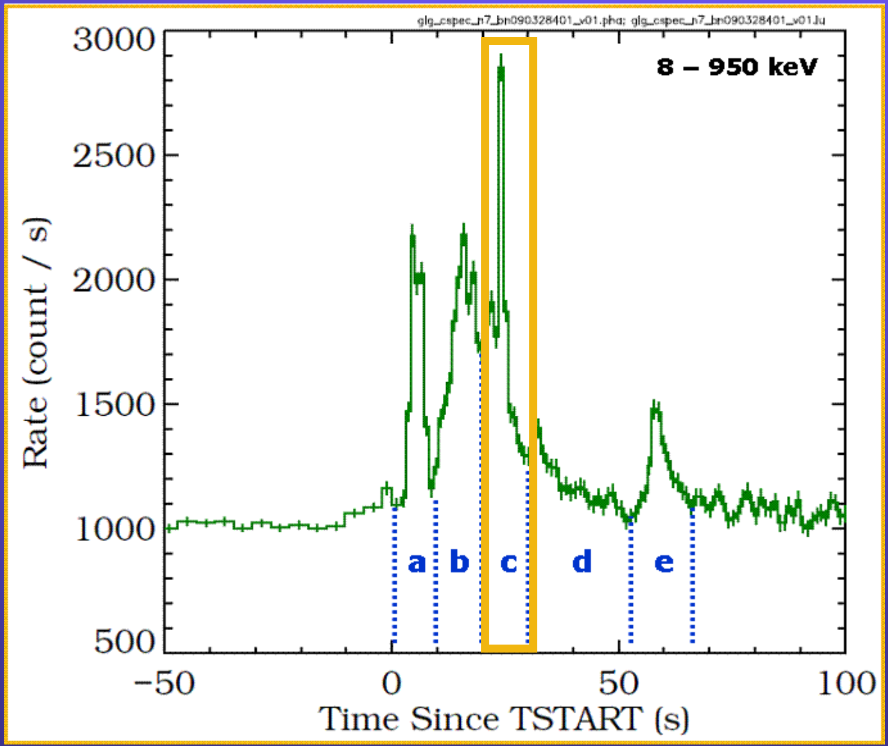
- **T90 ~ 60 s**
- **Fluence = (5.2 ± 0.7)E-05 erg/cm^2**
- **1-sec Peak Flux = 22.6 ± 0.8 ph/s/cm^2**

Spectral analysis of the brightest interval

GRB 090323



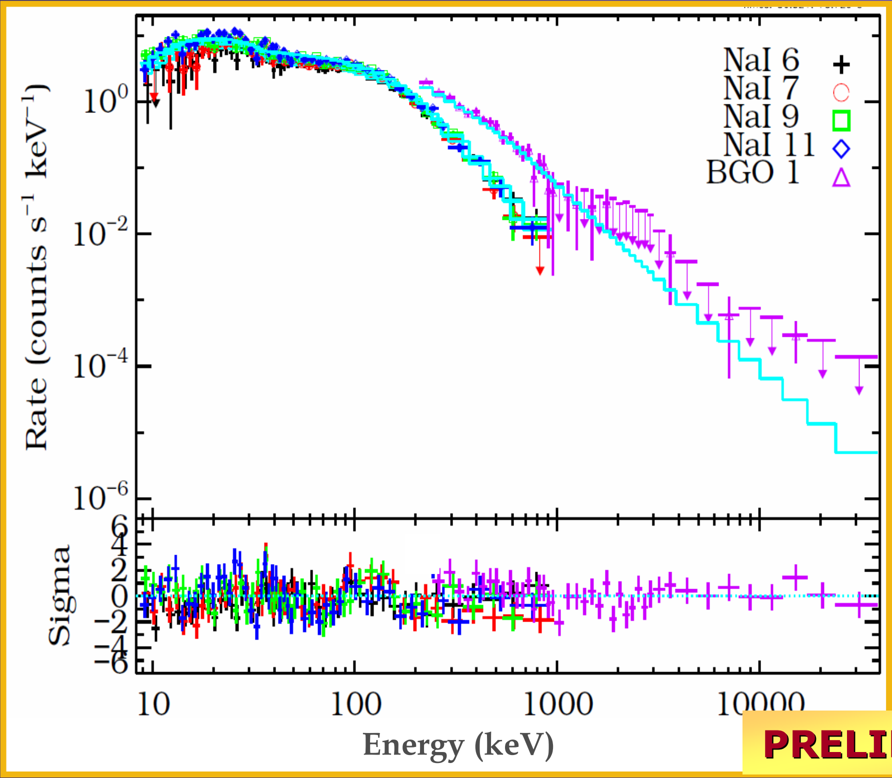
GRB 090328



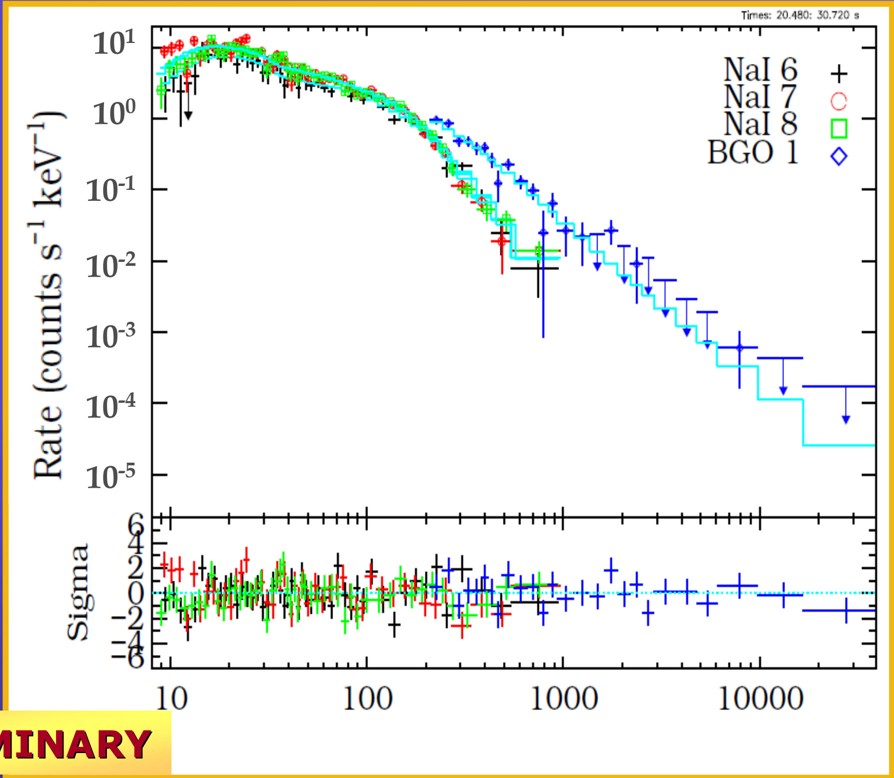
Spectral results brightest interval

GBM only Band fit

GRB 090323



GRB 090328



PRELIMINARY

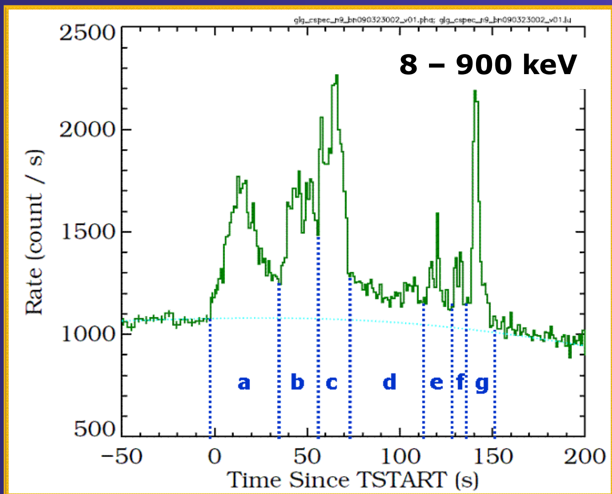
- Epeak = 536 (+25-24) keV
- alpha = -0.80 (± 0.02)
- beta = -2.8 (+0.2-0.4)

- Epeak = 479 (± 58) keV
- alpha = -1.08 (+0.04-0.03)
- beta = -2.3 (+0.2-0.3)

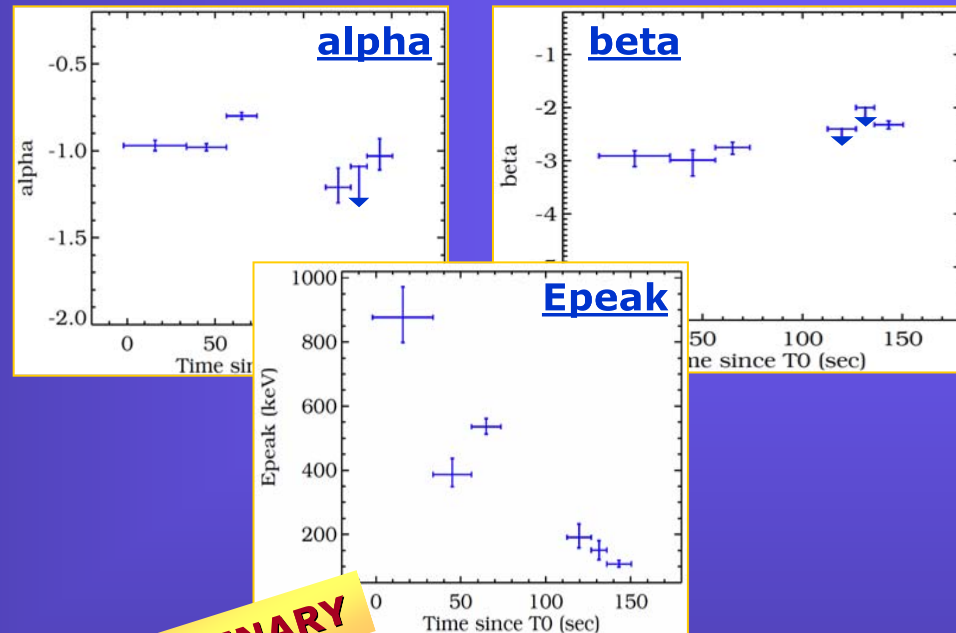
E.Bissaldi et al. 2009, in preparation

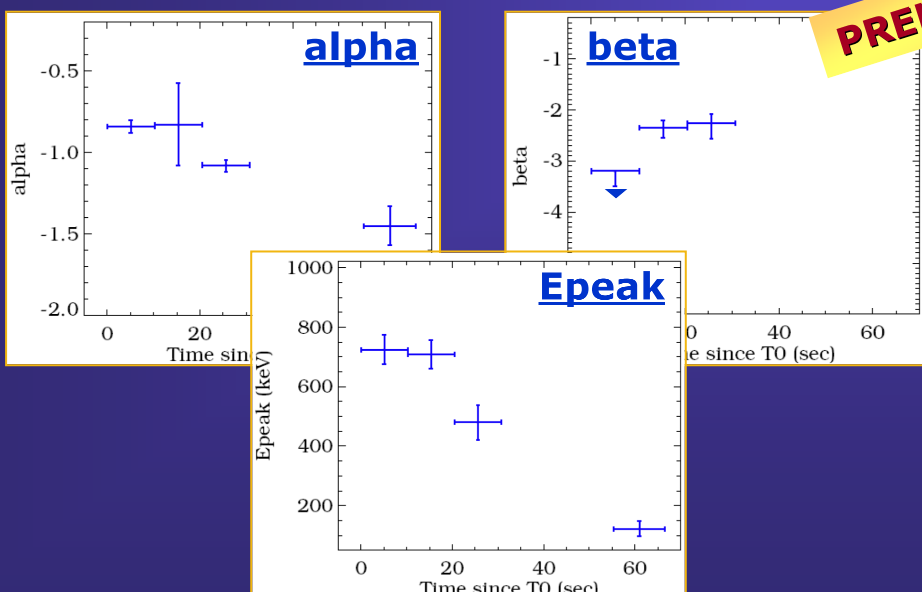
Spectral parameter evolution

GRB 090323

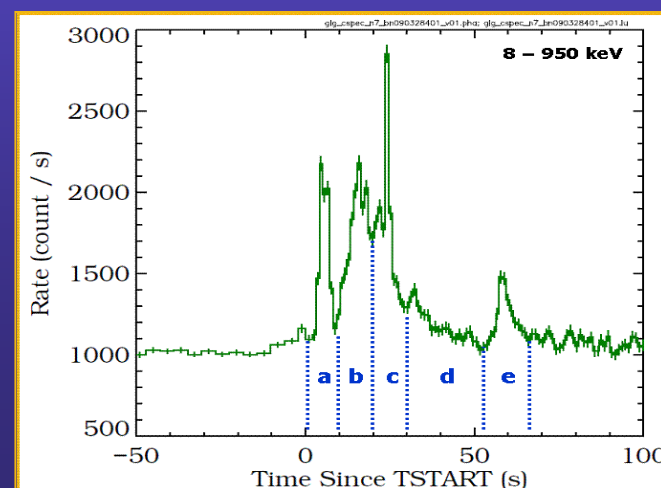


E.Bissaldi et al. 2009, in preparation



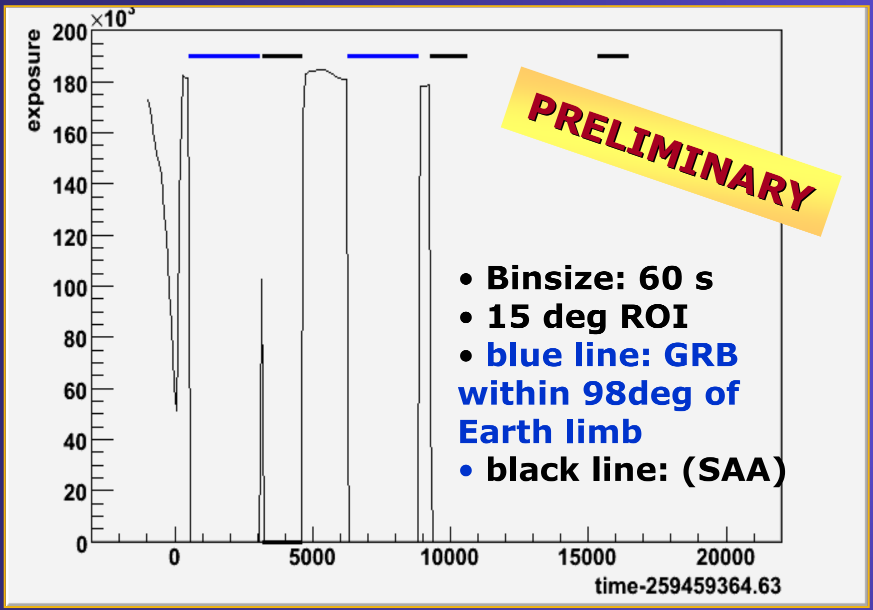


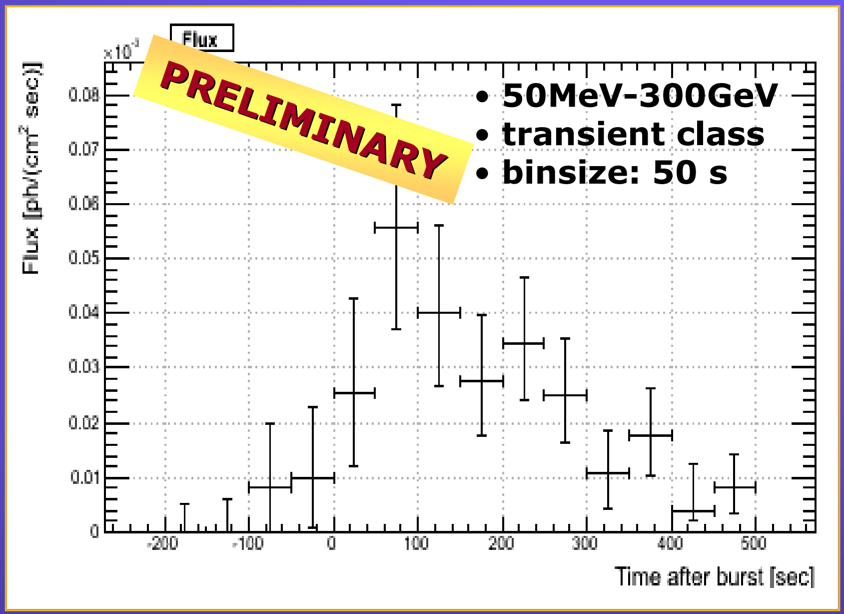
GRB 090328



LAT extended emission

GRB 090323



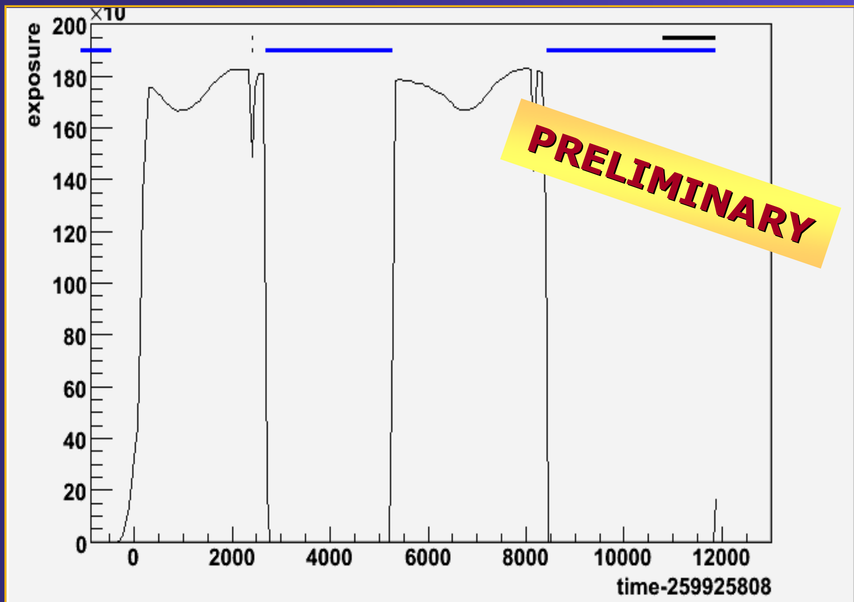


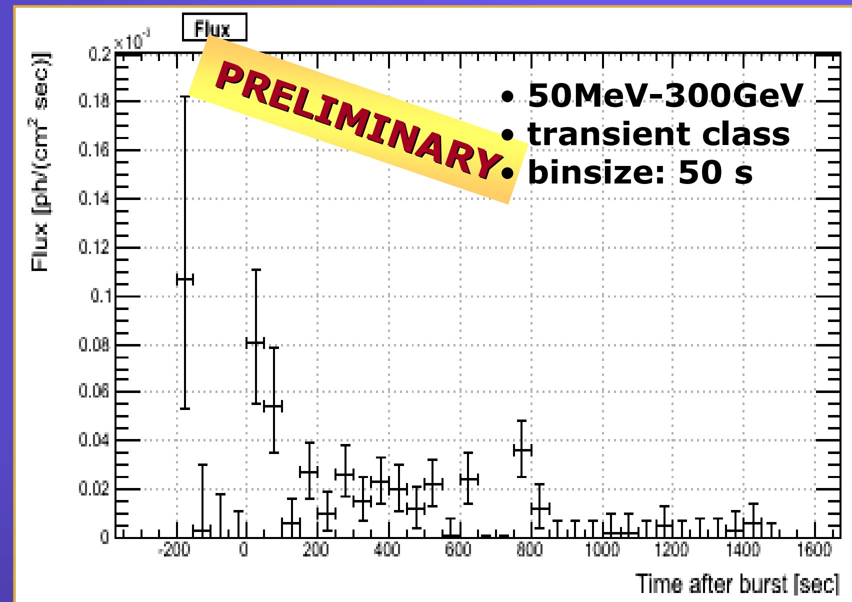
Abdo et al. 2009, in preparation

- **LAT detections above 100 MeV:**
  - **During GBM time (0 – 160 s): ~25 events**
  - **From 0 to 400 s: ~60 events**
  - **From 0 to 17 ks: ~80 events**
    - ▶ **High detection significance**

LAT extended emission

GRB 090328





- Binsize: 60 s
- 15 deg ROI
- blue line: GRB within 98 deg of Earth limb
- black line: (SAA)

Abdo et al. 2009, in preparation

- **LAT detections above 100 MeV:**
  - **During GBM time (0 – 70 s): ~18 events**
  - **From 0 to 6.8 ks: ~60 events**
    - **High detection significance!**

Conclusions

- **GBM is healthy!**
  - **More than 300 GRBs up to now**
  - **Flexible triggering**
    - **SGRs**
    - **TGFs**
    - **Extra GRBs that are long but weak**
  - **Better localization**
    - **More follow-up observations**
  - **Good spectral capabilities for short burst**
  - **Source of E_{Peak} for Swift bursts**
    - **Spectroscopy from 8 keV - 40 MeV!**

- **LAT observations are providing surprises!**
  - **Fermi analysis of two long bursts**
    - **~150 s and ~60 s in GBM**
    - **Extended emission is detected to much longer time in the LAT**
    - **ARR enabled the detection!**
  - **…Papers coming soon!**