Fermi LAT observations of long-lasting high-energy emission from GRB090323 and GRB090328

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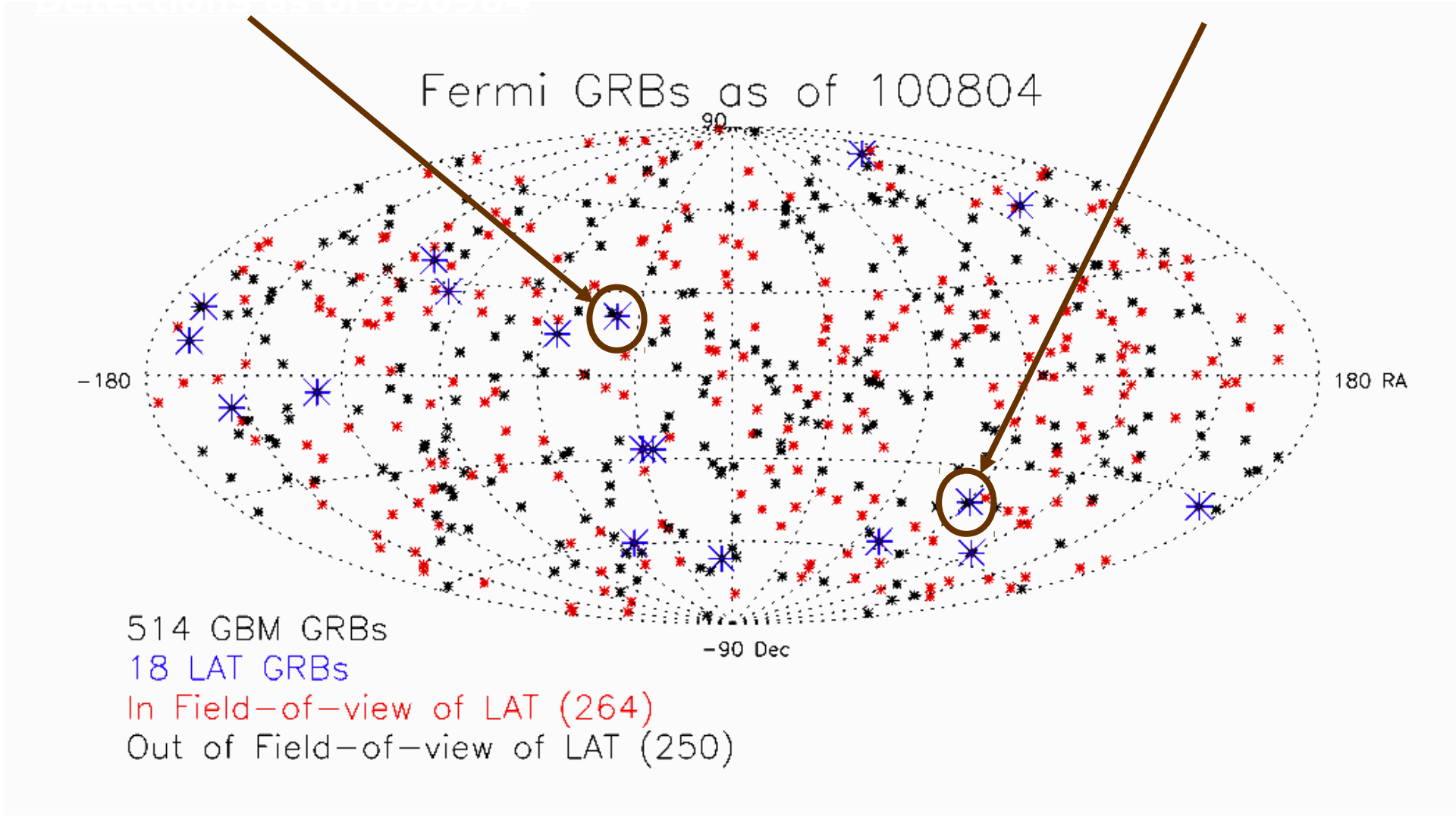
on behalf of the *Fermi* LAT and GBM Collaborations

The 2009 March bursts

GRB 090323 (z=3.6)

GRB 090328 (z=0.7)

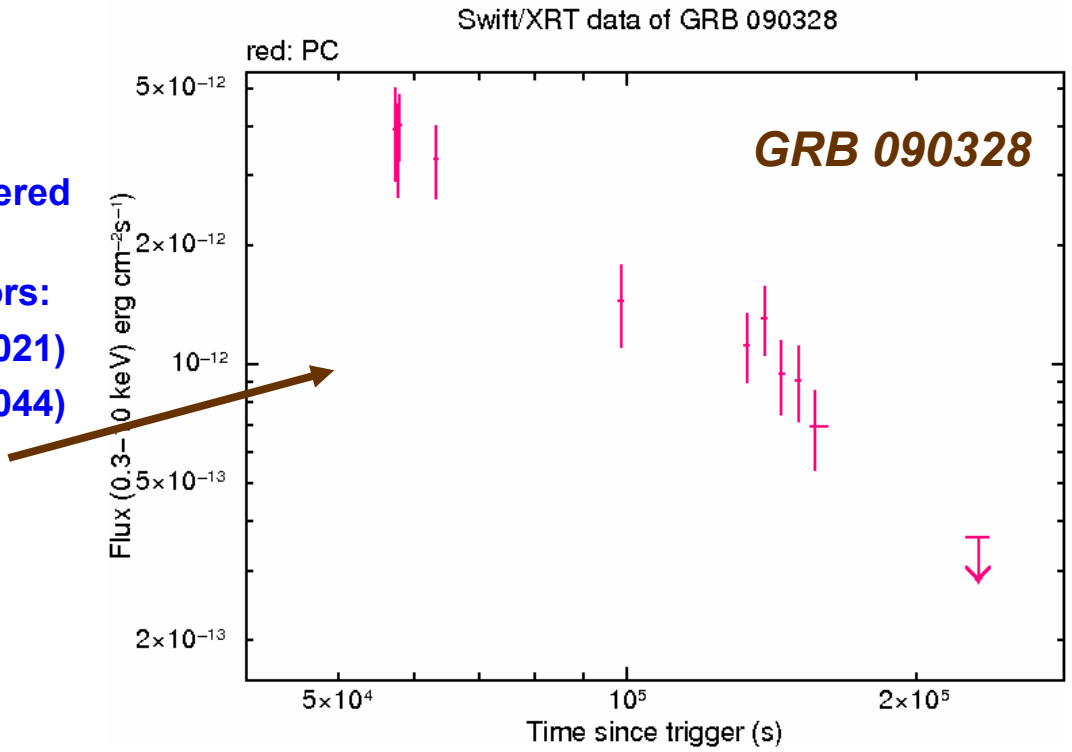


Observation sequence

- **GRB 090323**
  - GBM Trigger time: 00:02:42.63 UT on March 23, 2009
  - Triggered detectors: NaI 9 and NaI 11 (also seen in NaI's 6, 7, 8 and 10)

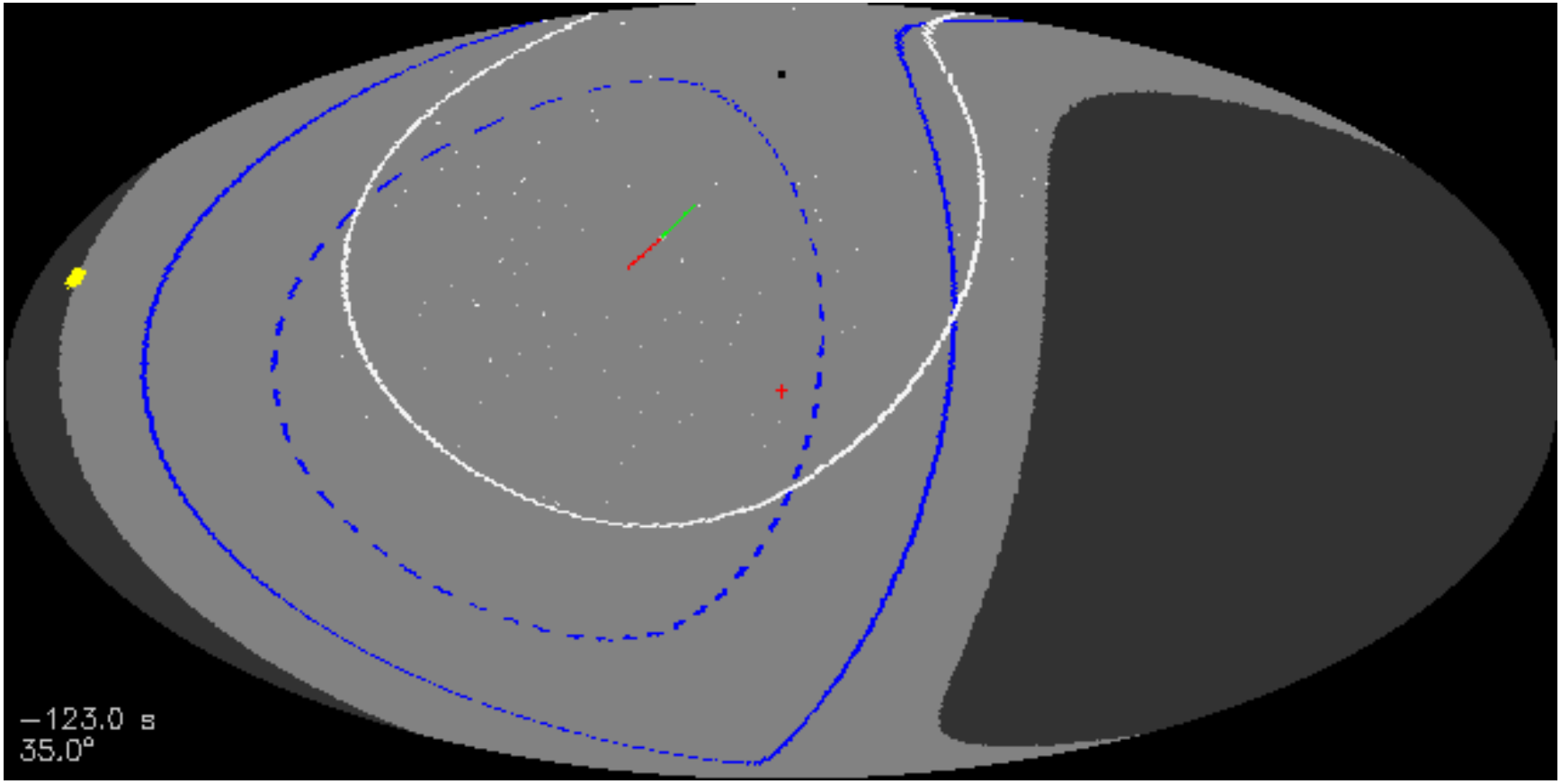
- **GRB 090328**
  - GBM Trigger time: 09:36:46.51 UT on March 28, 2009
  - Triggered detectors: NaI 6 and NaI 7

- **In both cases**
  - ~60 deg from the LAT boresight at trigger time (T0)
  - Autonomous Repoint Request triggered by the GBM
  - LAT improved localization, 68% errors:
    - GRB 090323: 0.09 deg (GCN 9021)
    - GRB 090328: 0.11 deg (GCN 9044)
  - Follow-up observation by Swift in the X-ray and optical
  - Follow up observation by ground-based telescopes
  - Spectroscopic redshifts (Gemini South, GCN 9028 & 9053)

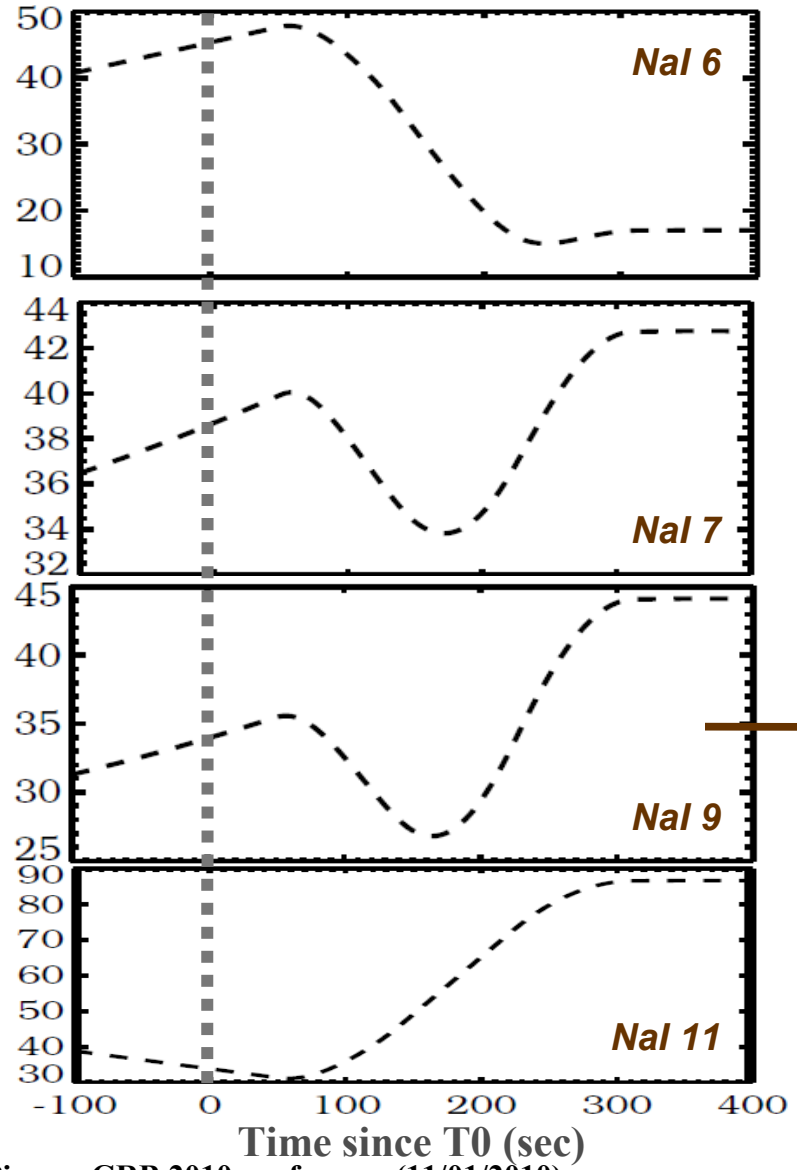


GRB 090323 ARR

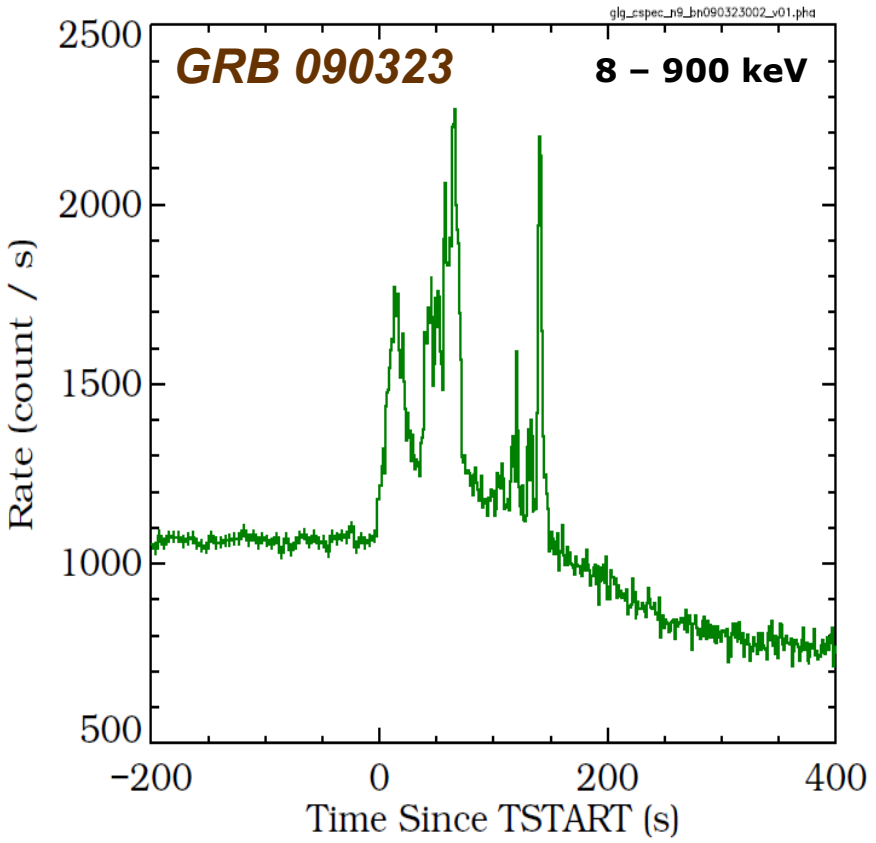
- **LAT pointing in celestial coordinates from -120 s to 6000 s**
  - **Red cross = GRB 090323, dark region = occulted by Earth (θ_z>113°)**
  - **Blue lines = 20° (Earth Avoidance Angle) / 50° above horizon**
  - **White line = LAT FoV (±66°), white points = LAT TRANSIENT events (no cut on zenith angle)**



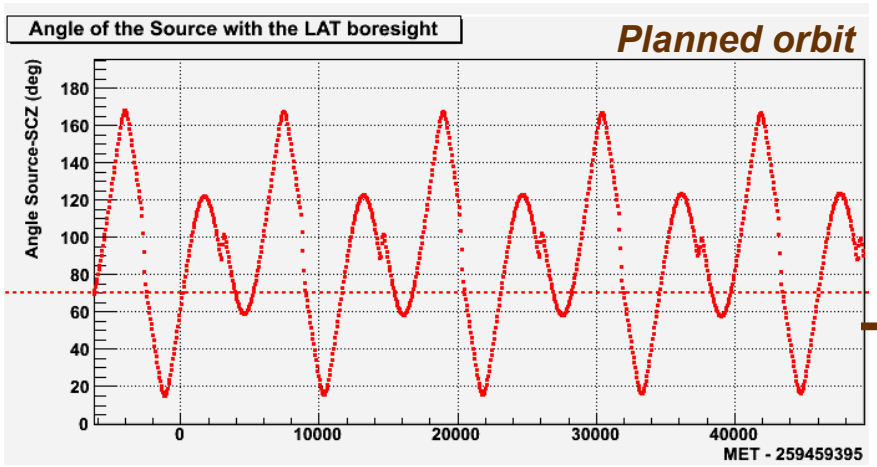
ARR and background in the GBM



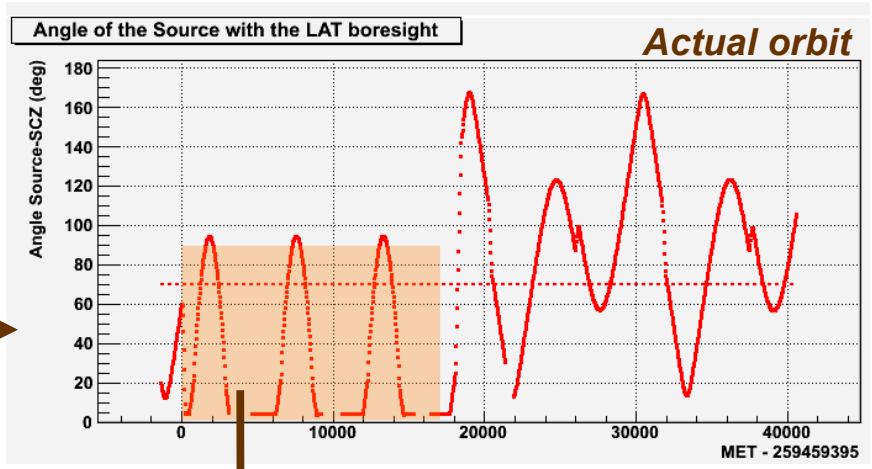
- The effect of the ARR is particularly visible in the GBM after ~50 s
- The detectors orientation and the background change very rapidly
- Introduces complications for GBM analysis



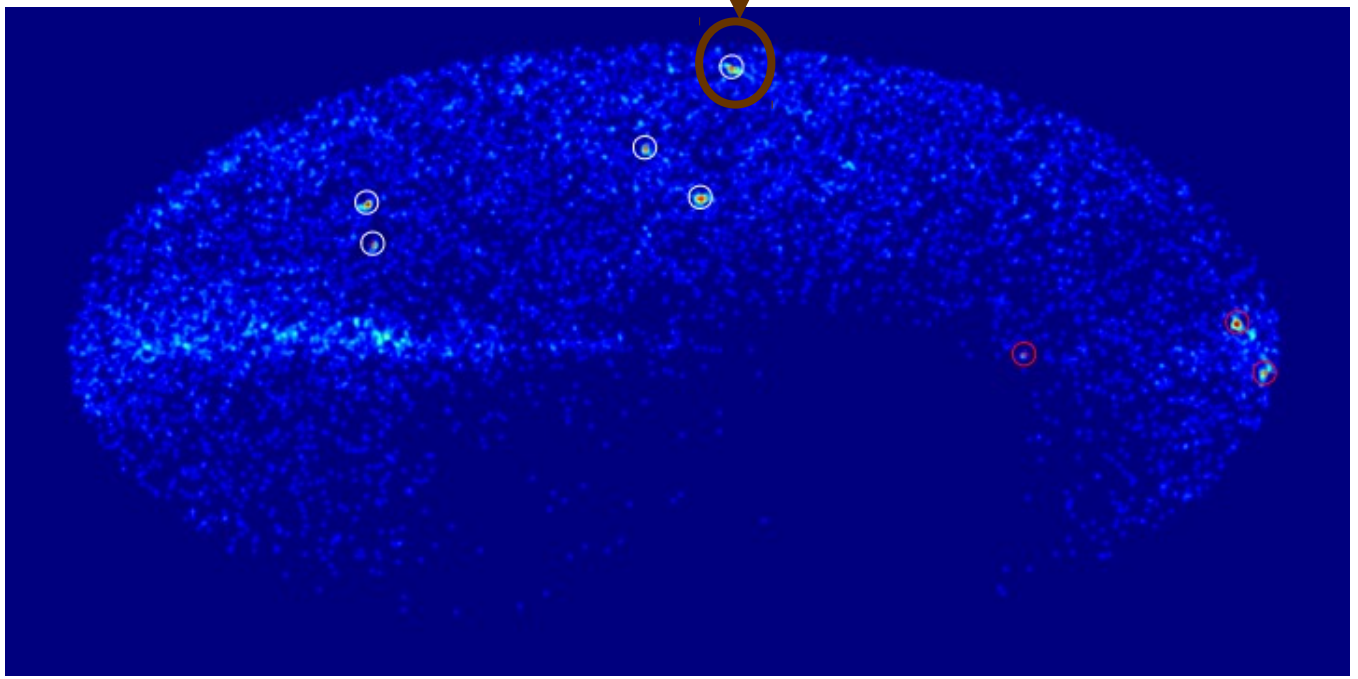
Initial detection of GRB 090323 by ASP



ARR

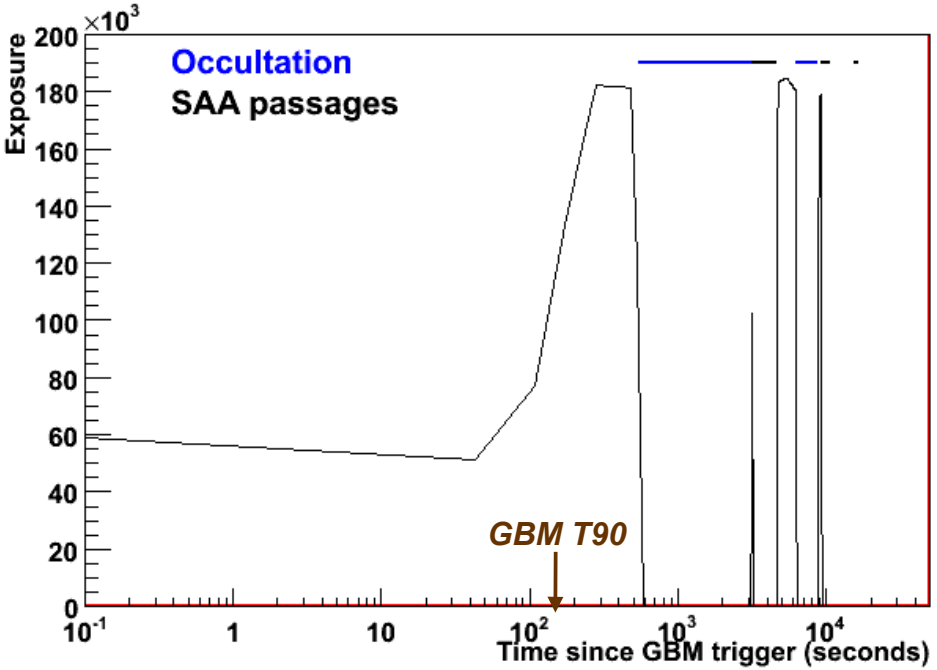


6-hour Automated Science Processing of LAT data

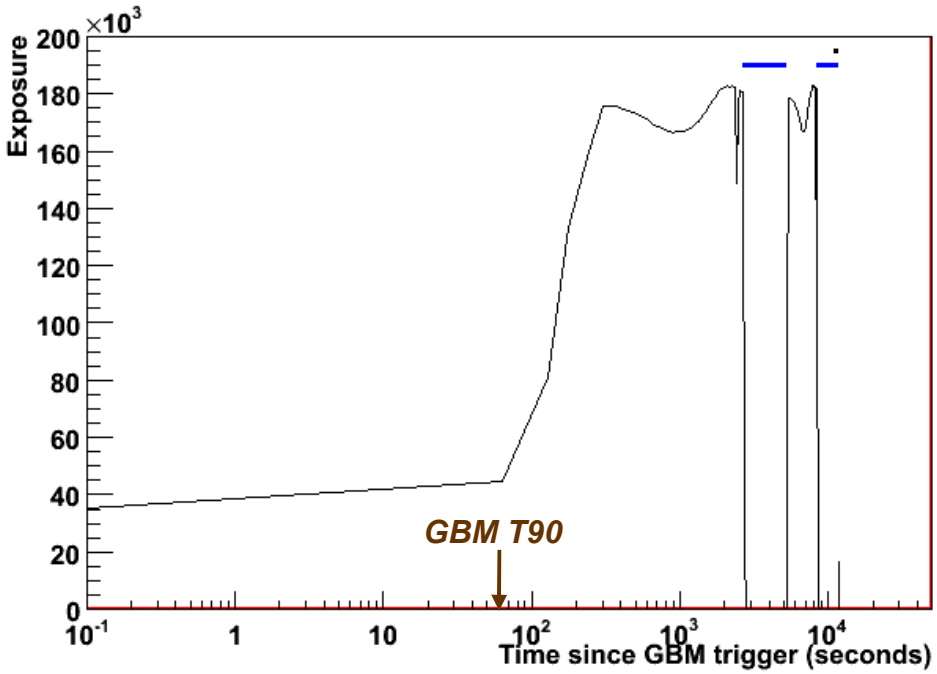


LAT exposure during the first orbits

GRB 090323

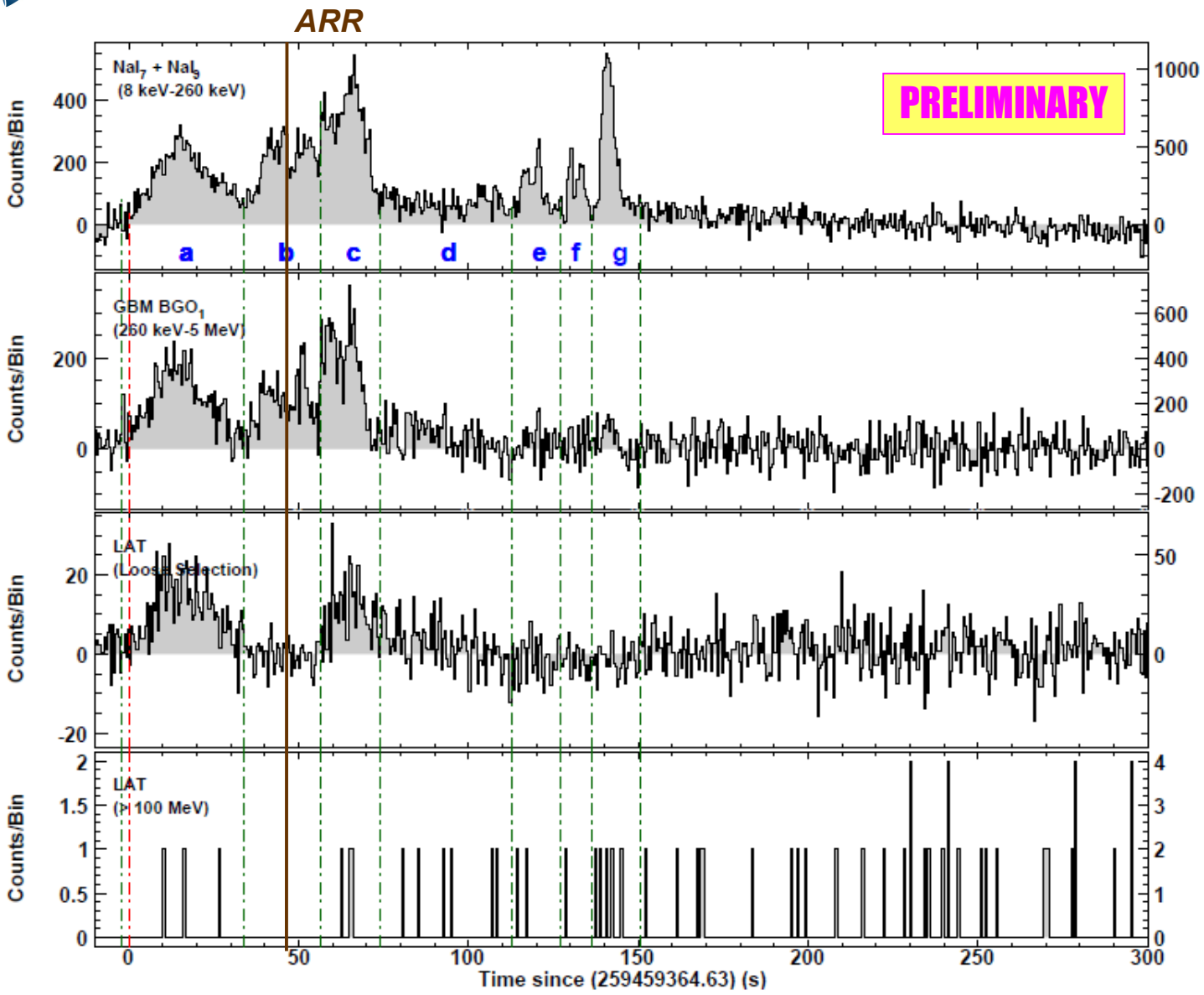


GRB 090328



- GRB 090323 ARR not especially fantastic
  - ARR initiated at T0+46 s, but GRB location became occulted after 573 s
  - S/C entered SAA 47 s after the GRB exited occultation
- GRB 090328 ARR was beautiful
  - ARR initiated at T0+37 s (triggered on the GRB just after it exited occultation)
  - No SAA passage for the next two orbits (observations only interrupted by occultations)
- ARR for all later LAT detected bursts have been initiated within 10 s (with updated criteria)

GRB 090323 multi-detector light curve



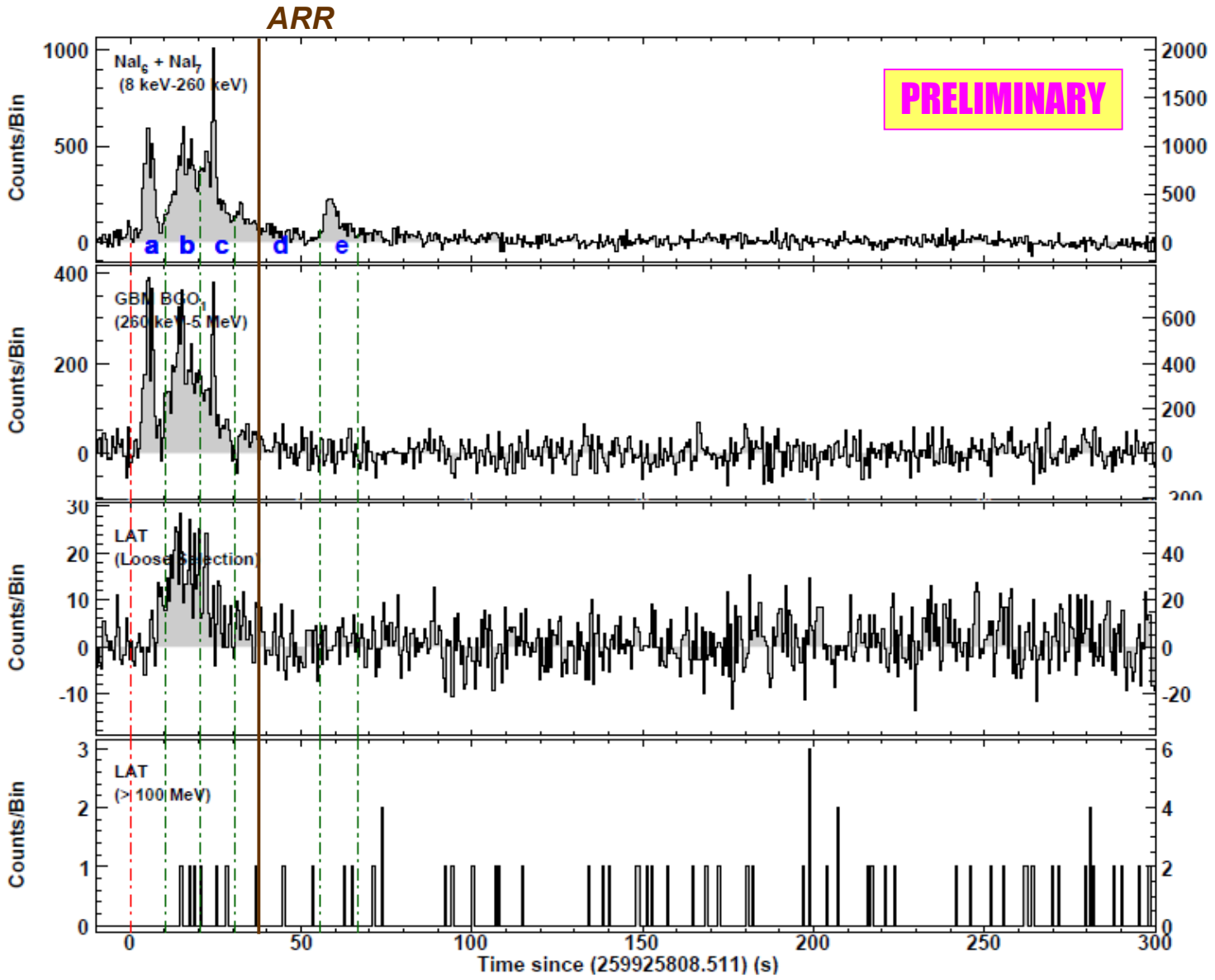
Multiple peak structure in the GBM

Very long burst T90=(133+-1) s

LAT loosened selection provides very high statistics

Poor statistics with TRANSIENT events for spectral analysis above 100 MeV

GRB 090328 multi-detector light curve



Multiple peak structure in the GBM

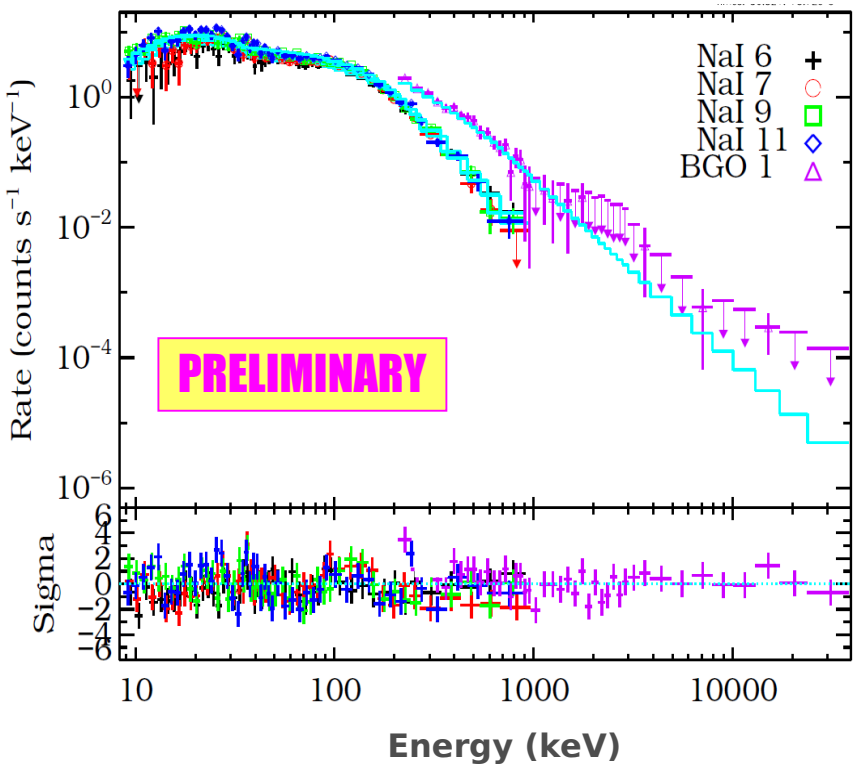
Long burst T90=(58+-7) s

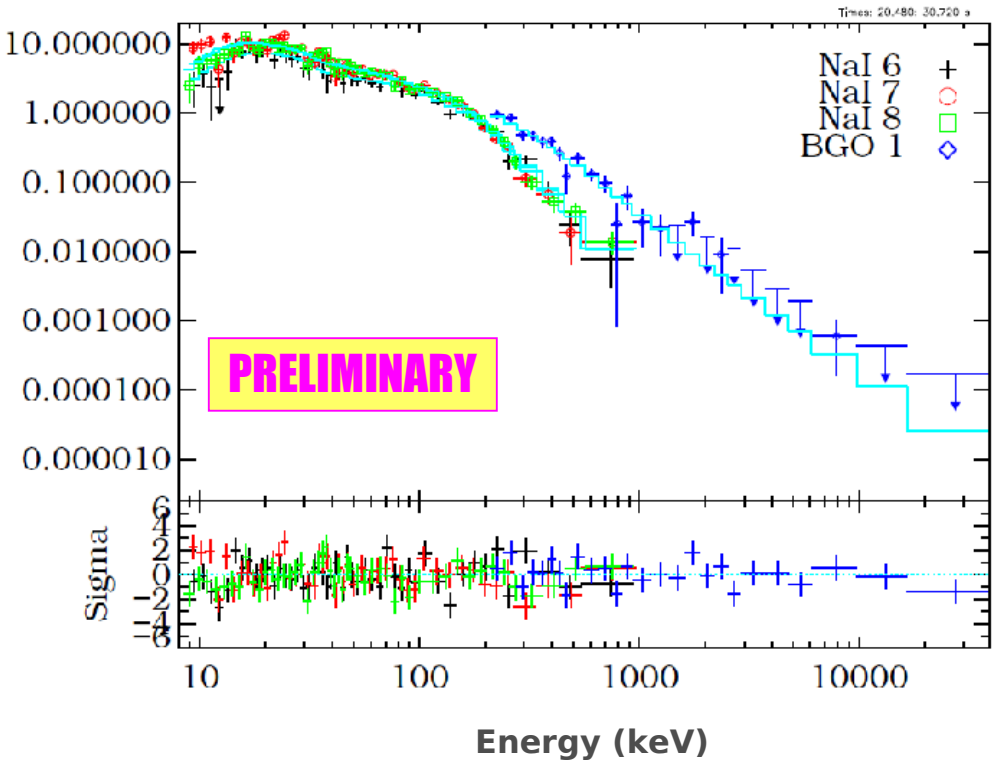
LAT loosened selection provides very high statistics

First GBM peak missing in the LAT data

Poor statistics with TRANSIENT events for spectral analysis above 100 MeV

GBM spectral results (brightest intervals)





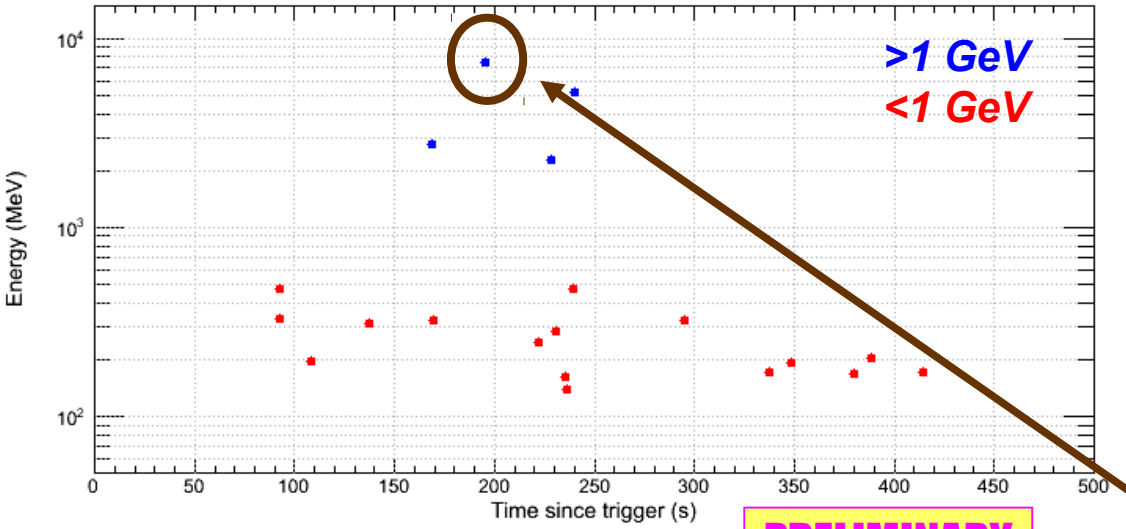
- **GRB 090323 (interval 3)**
  - E_{peak} = 525 (+ 25 - 22) keV
  - α = -0.84 ± 0.02
  - β = -3.1 (+ 0.3 – 1.7) – needs LAT data
- **GRB 090328 (interval 3)**
  - E_{peak} = 451 (± 66) keV
  - α = -1.07 (+ 0.05 - 0.04)
  - β = -2.2 (+0.2 - 0.3)

GBM/LAT joint spectral analysis is ongoing

Highest-energy detected photons

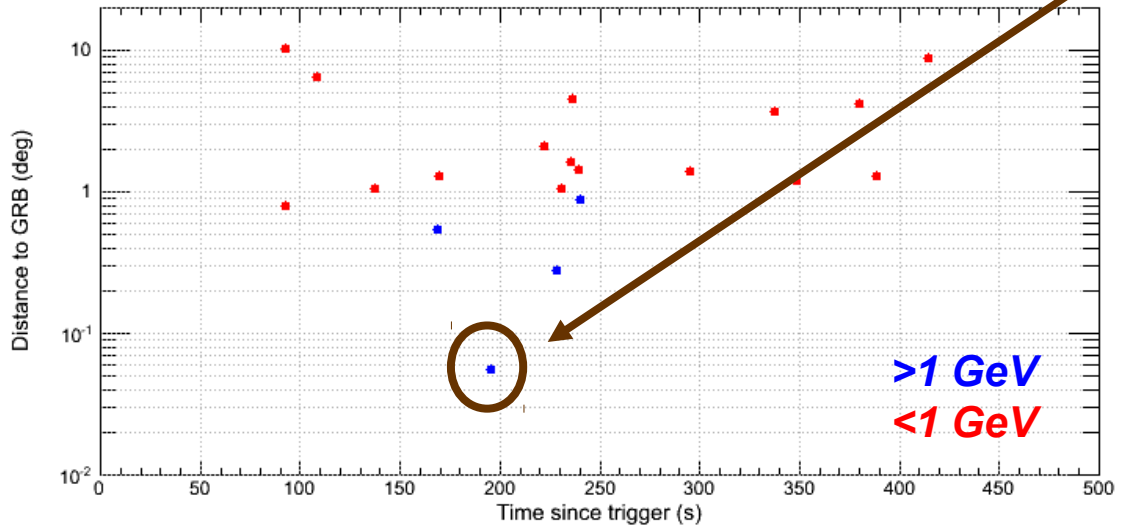
Energy

GRB 090323



PRELIMINARY

Distance to GRB



- **>GeV events are observed closer (<1º) to the GRB position**
- **Highest energy emission peaks late (but acceptance increases after start of ARR at T0+~50s)**
- **GRB 090323: 7.5 GeV event detected at T0+195.4 s (space prob. 0.815)**
- **GRB 090328: 24.5 GeV event detected at T0+262.2 s (space prob. 0.075)**

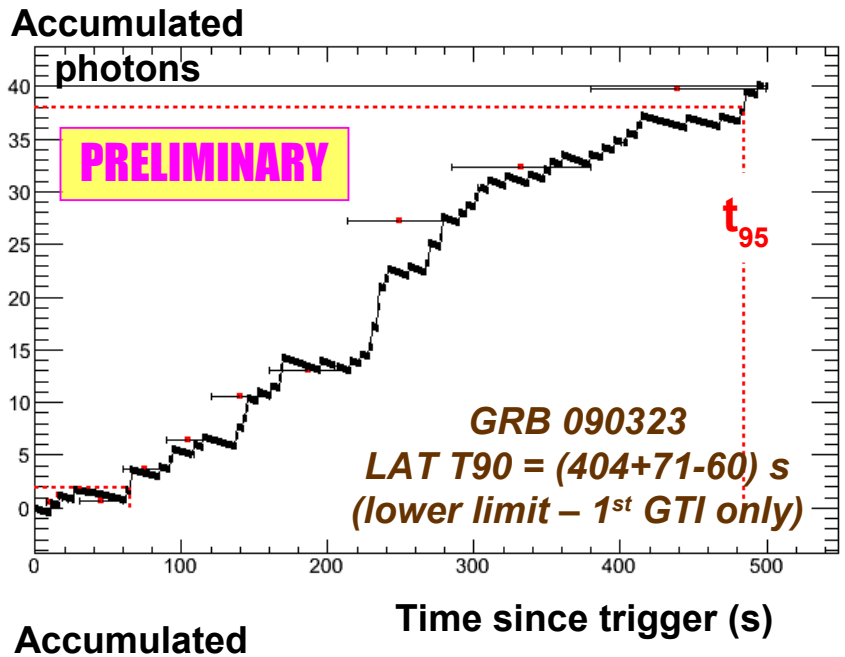
Search for high-energy extended emission

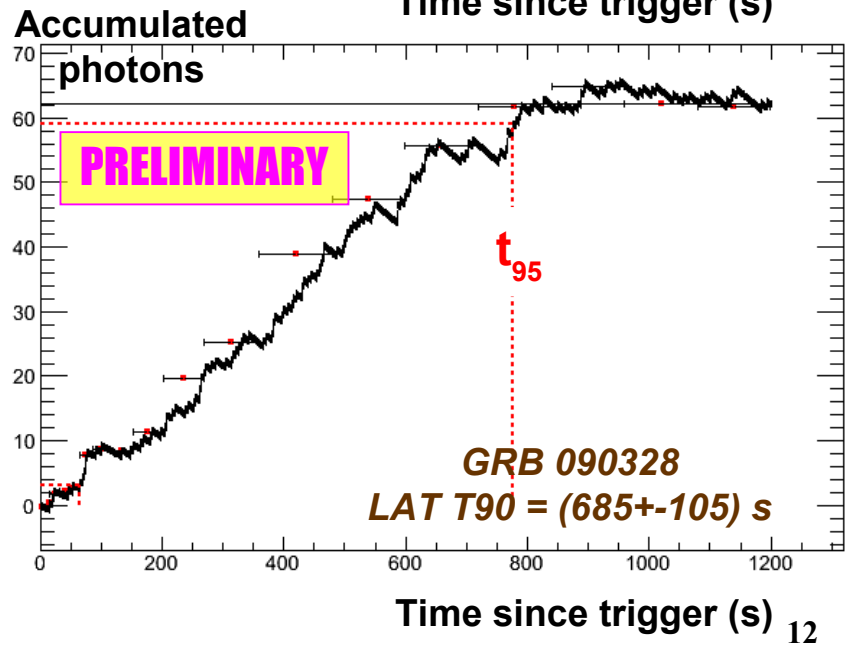
- Two complementary techniques are used

- [1] Event counting in an energy-dependent ROI using TRANSIENT class events
  - Background estimator tool developed by the collaboration: estimates backgrounds at any time and for any S/C orientation, and yields background-subtracted light curves and signal significance (Poisson)
  - Final duration and error (here >100 MeV) are computed through simulations: (LAT T90) (see also V. Vasileiou's talk)

- [2] Unbinned likelihood analysis above 100 MeV (gtlike in Science Tools) using a 10º ROI and DIFFUSE class events (Pass_V3_DIFFUSE IRFs) – see next slide

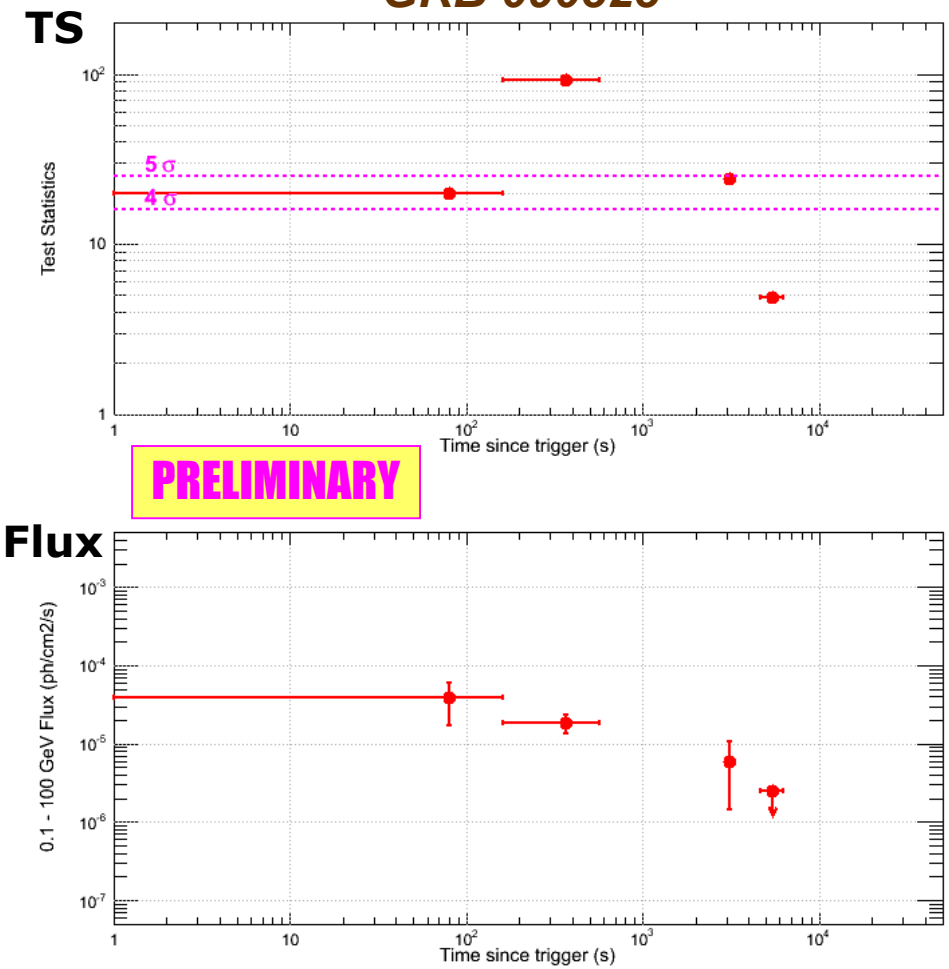
- The background estimator is simpler, can include lower energy events (>50 MeV), but can be less sensitive than gtlike (which makes use of the PSF)



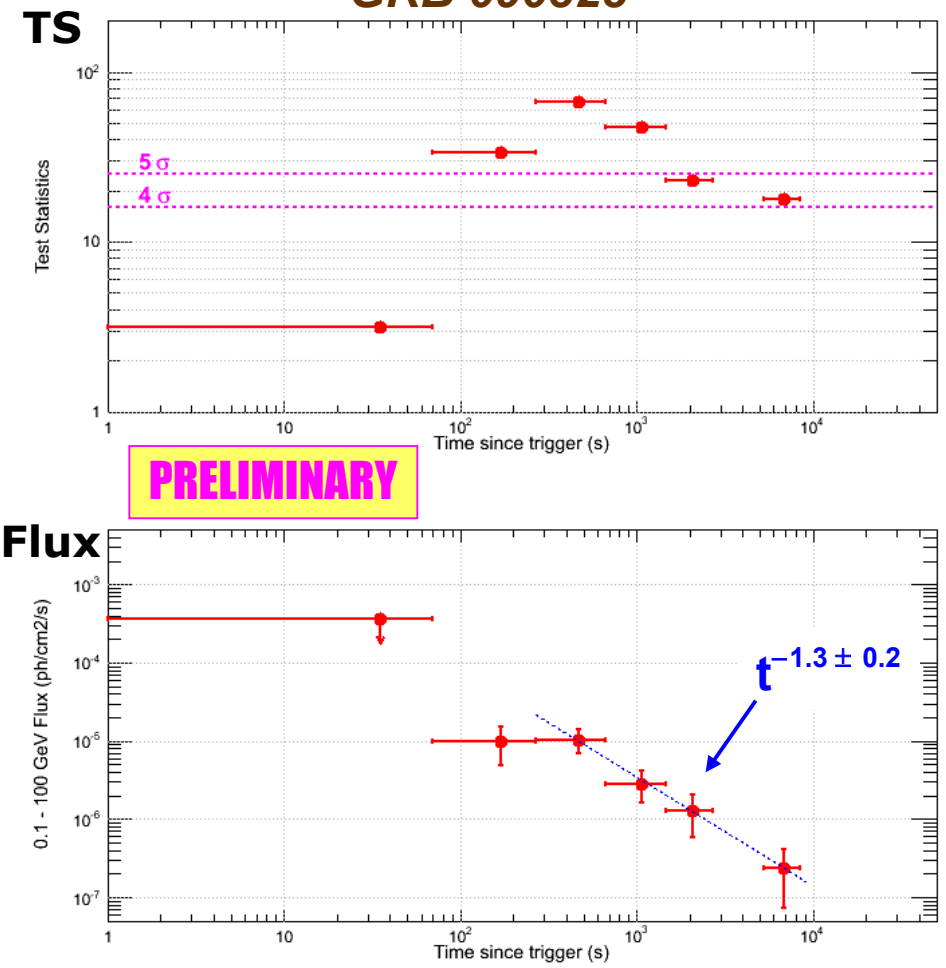


Unbinned likelihood analysis

GRB 090323



GRB 090328



- GRB 090323 flux decay is badly sampled, clear detection up to T0+3.2 ks
  no significant spectral evolution (mean spectral index of -2.1+-0.2)
- GRB 090328 continuously detected up to T0+8.4 ks
  no significant spectral evolution (mean spectral index of -1.79+-0.14)

We checked possible systematics in the case of "marginal" detections: very stable results under different configs (ROIs, bkg model)

Summary

- Two long bursts GRB 090323 and GRB 090328
  - GBM T90: 133 s and 58 s, respectively
  - LAT T90: >~400 s and ~700 s, respectively
  - LAT loosened selection provides high photon statistics when standard acceptance is low
  - Spectroscopy did not reveal any notable feature so far

- ARRs greatly improve the search for GRB HE extended emission in the LAT
  - Responses change while the observatory is slewing
  - Careful evaluation of the backgrounds vs. time is required by the spectral analyses (GBM, LAT) and for the search of HE emission in the LAT
  - Multi-GeV events are detected by the LAT well after the GBM prompt emission
  - GRB 090323 ARR was not optimal, but firm detection up to 3.2 ks
  - GRB 090328 has the longest extended emission in the LAT, up to 8.4 ks