Fermi observations of long-lasting GRB emission at high energies

Frédéric Piron

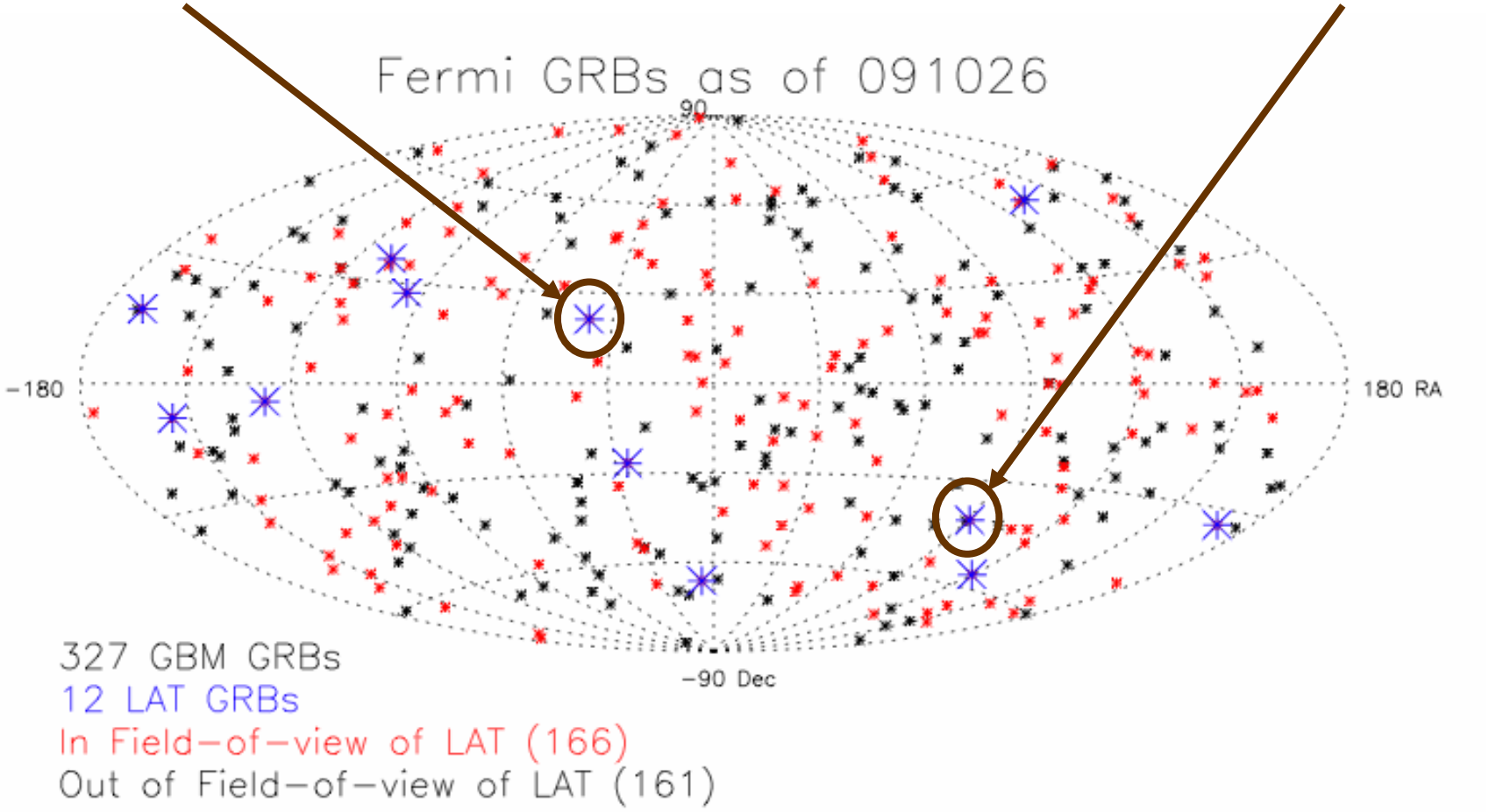
(IN2P3/LPTA, Montpellier)

on behalf of the *Fermi* LAT and GBM Collaborations

The *Fermi*-LAT March bursts

GRB 090323 (z=3.6)

GRB 090328 (z=0.7)

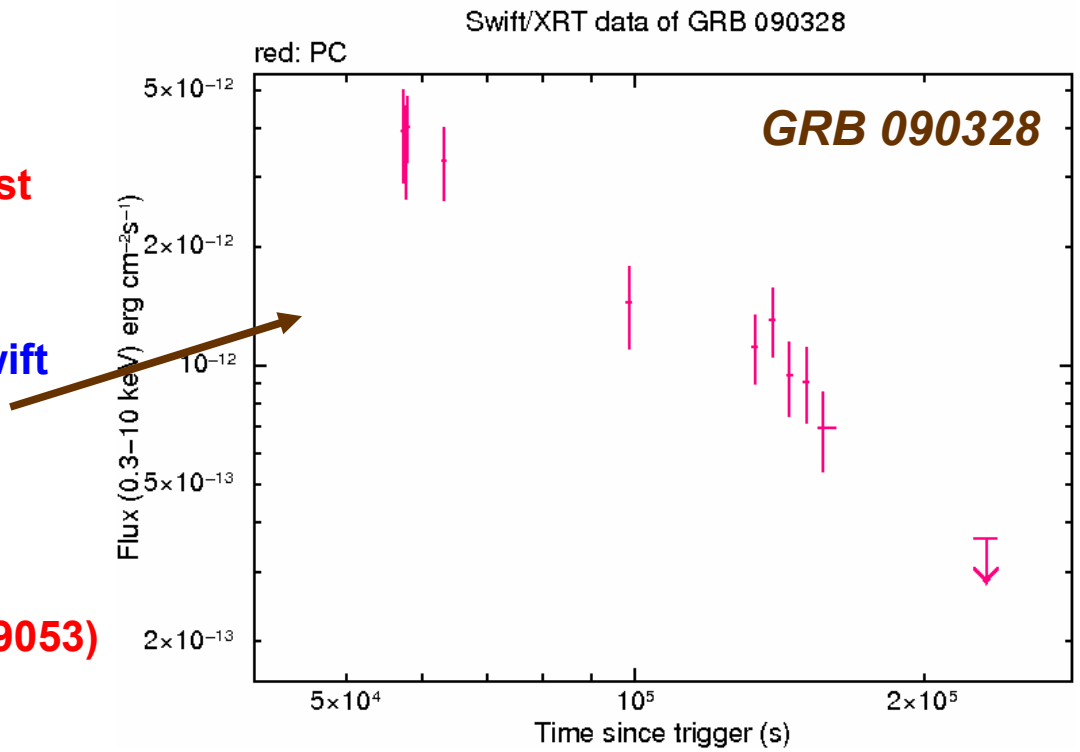


Observation sequence

- **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)

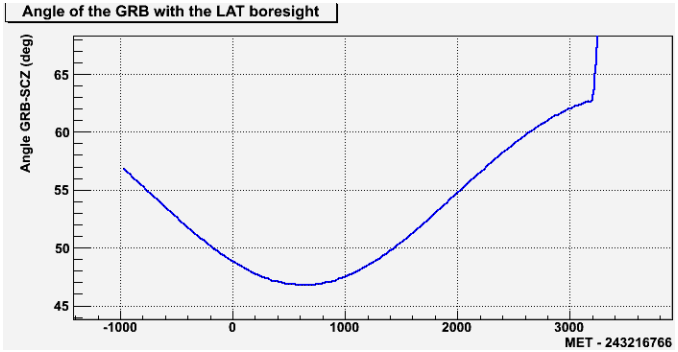
- **GRB 090328**
  - GBM Trigger time: 09:36:46.51 UT on March 28, 2009
  - Triggered detectors: NaI 6 and NaI 7

- **In both cases**
  - Autonomous Repoint Request triggered by the GBM
  - LAT improved localization
  - 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)

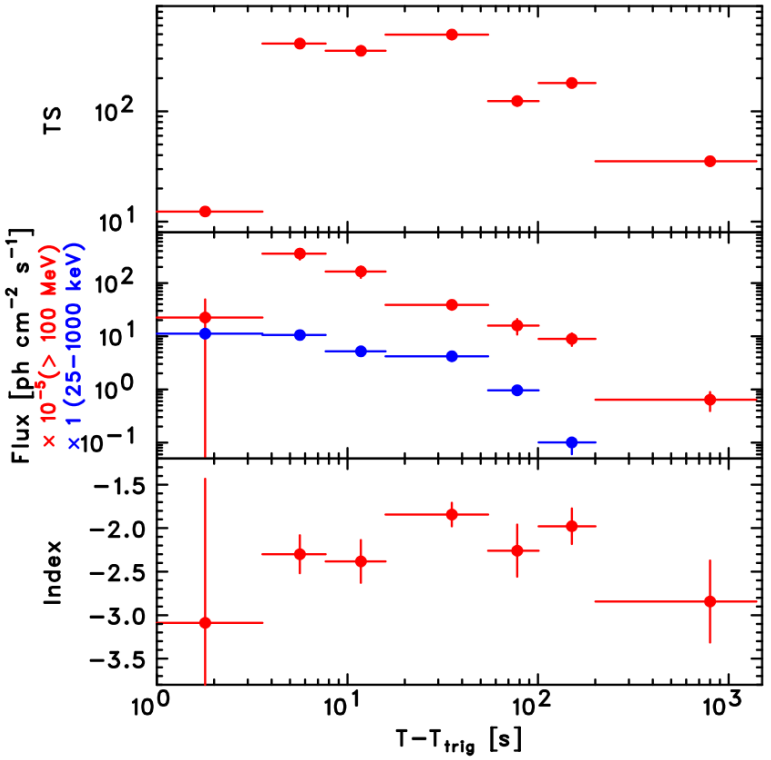


Autonomous Repoint Request (ARR)

- The S/C can be repointed for LAT observations of extended emission from strong bursts
  - Since Oct. 8, 2008 at 14:11:08
  - Triggered either by the GBM or by the LAT
  - Dwell for (nominally) 5 hrs
    - Target monitored while >20º ("Earth avoidance angle") above the horizon
    - Otherwise the LAT z-axis remains at 50º above the horizon until the target rises



GRB 080916C extended emission



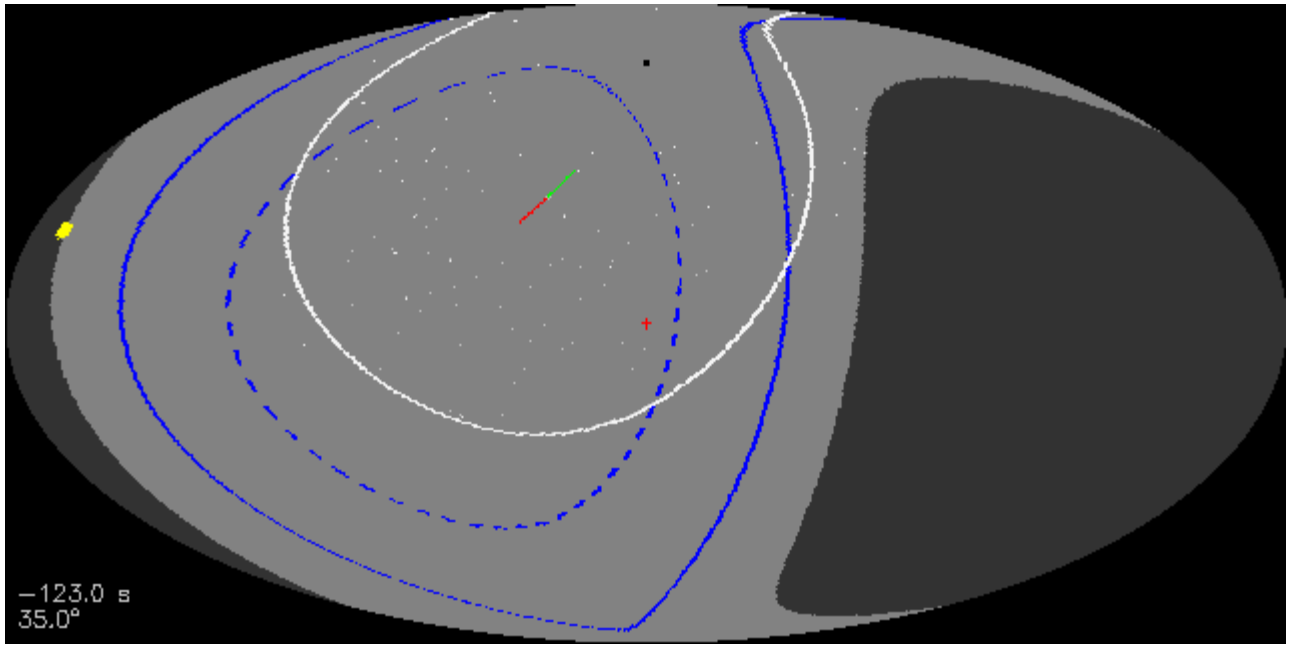
- GBM ARR if the trigger exceeds a specified threshold for peak flux or fluence
  - Thresholds reduced spectrum exceeds a specified hardness ratio

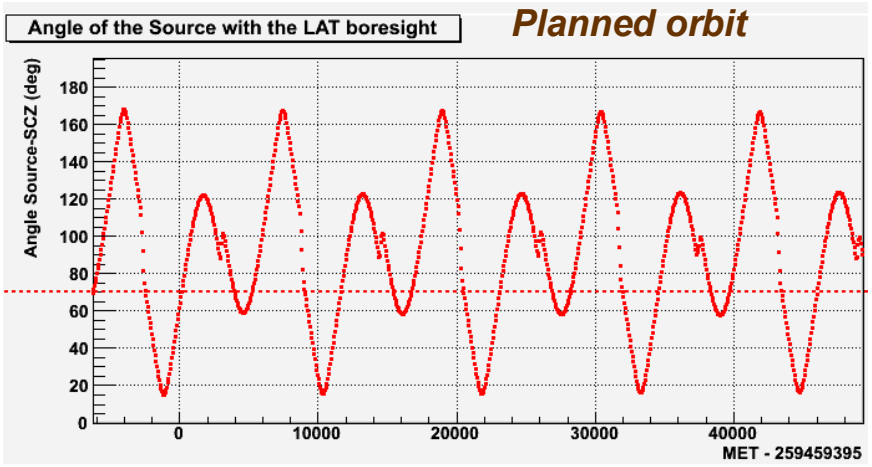
- GBM positions are used as cluster seed positions by the LAT onboard algorithm
  - The LAT recalculates the position
  - If no LAT detection, the recommendation is forwarded as an ARR to the S/C

- ~2/month for bursts within the LAT FoV
  ~2/year if not already in the LAT FoV

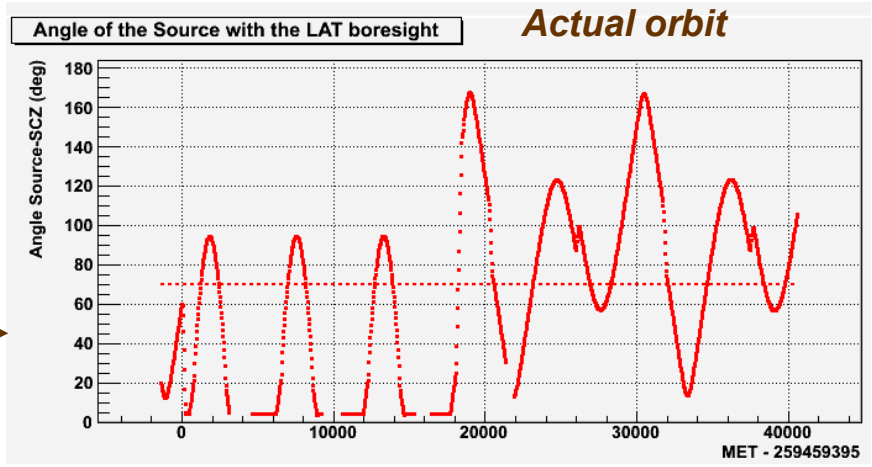
GRB 090323 ARR

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

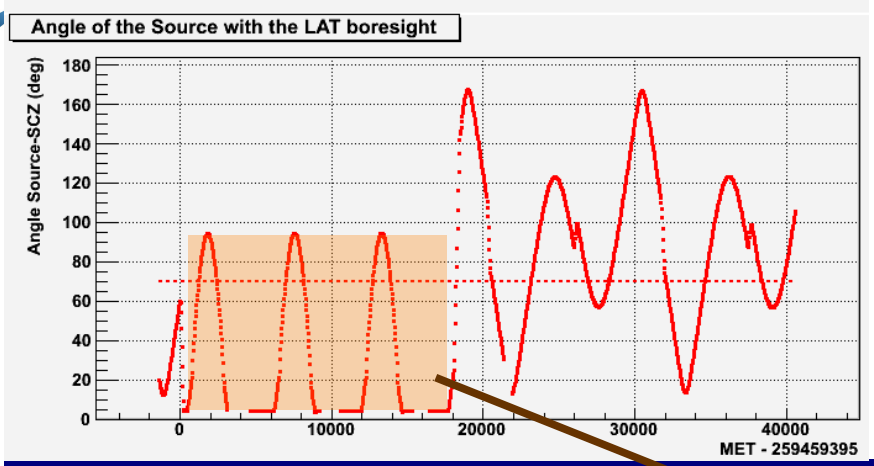




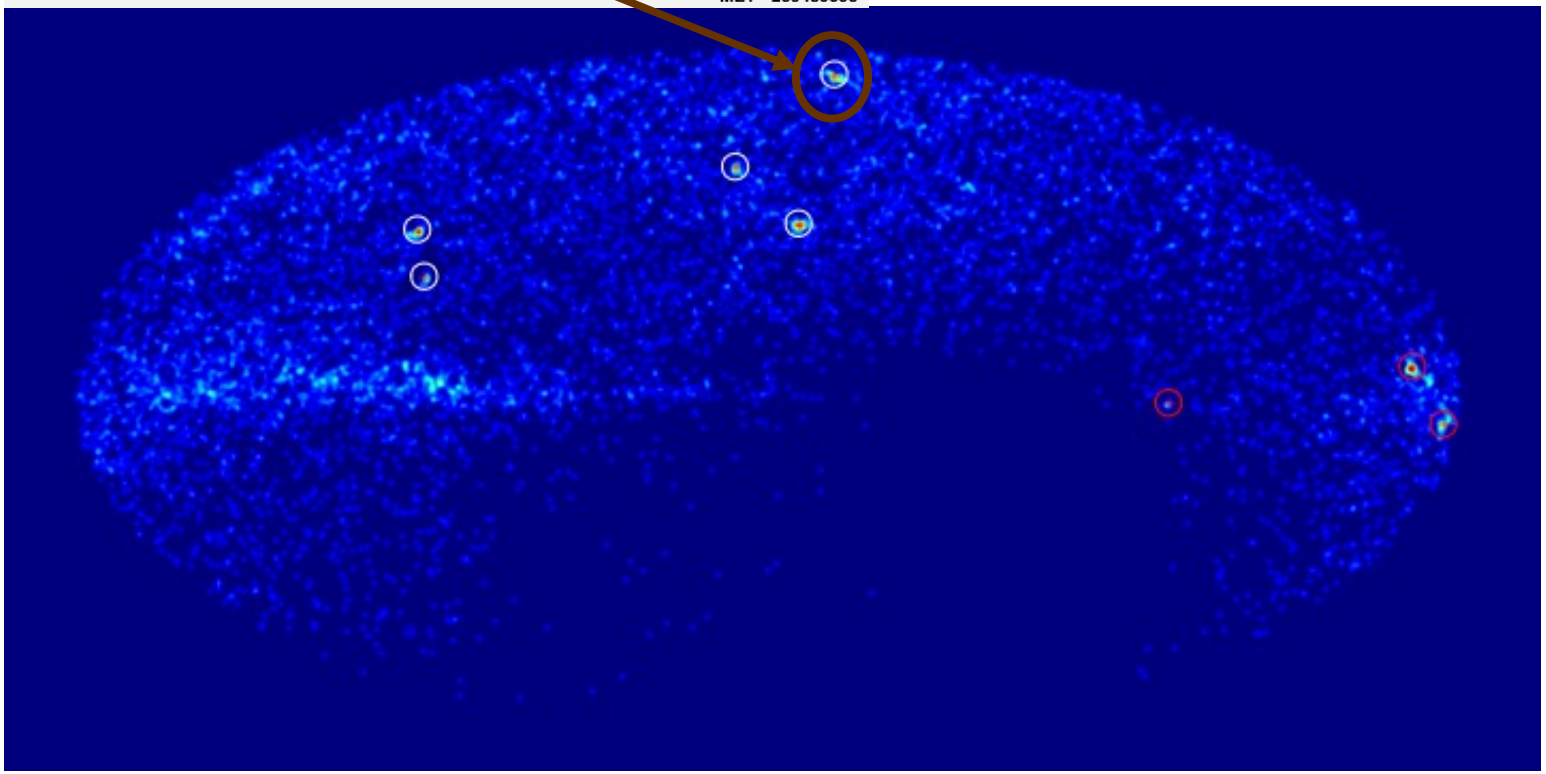
ARR



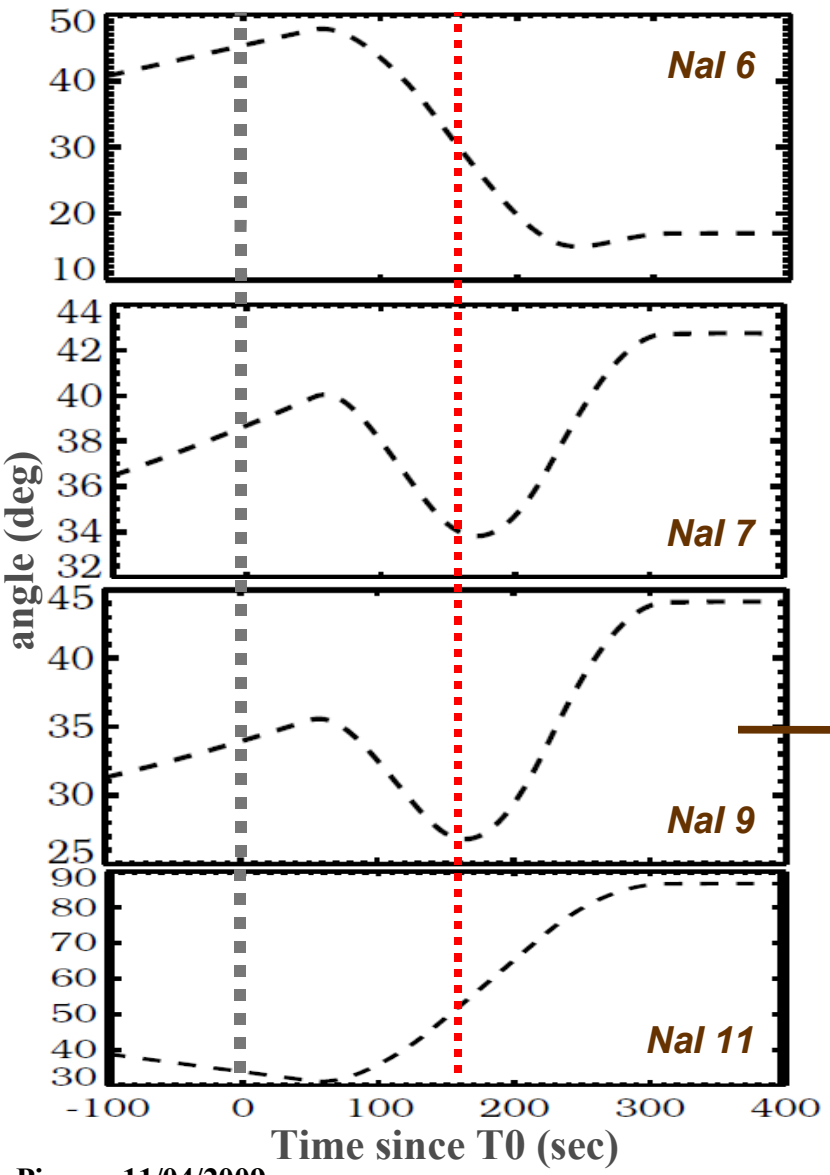
ARR and Automated Science Processing



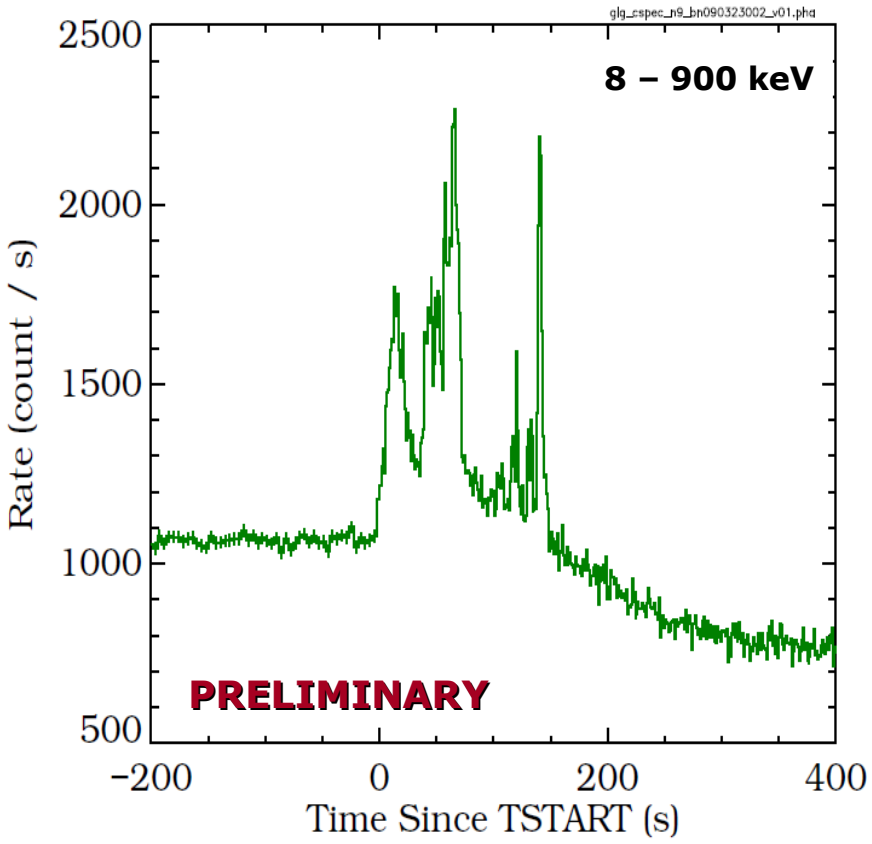
- **Initially detected by ASP**



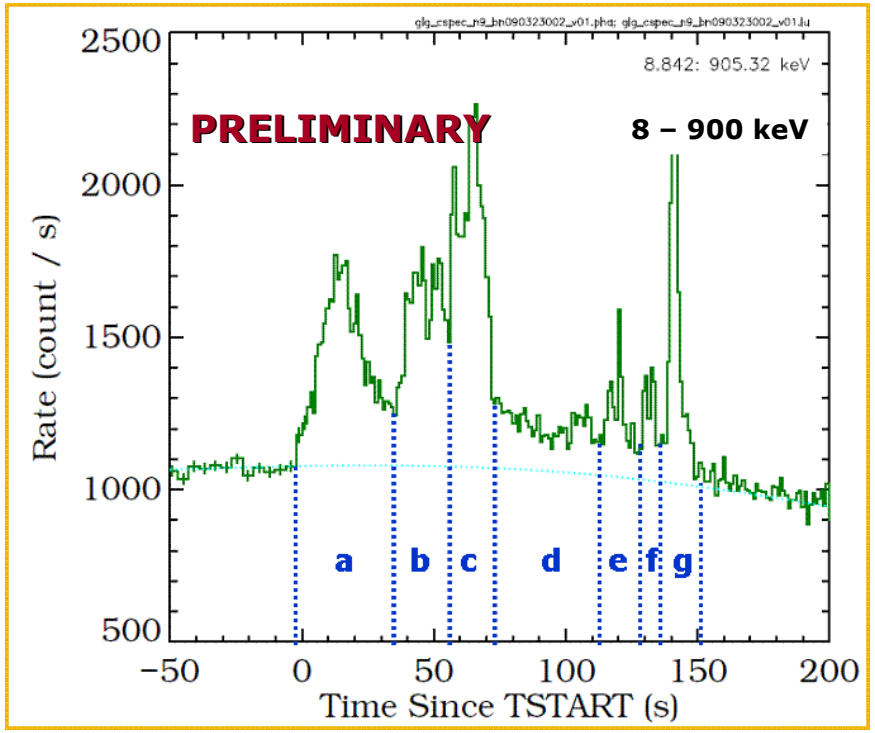
ARR and background in the GBM

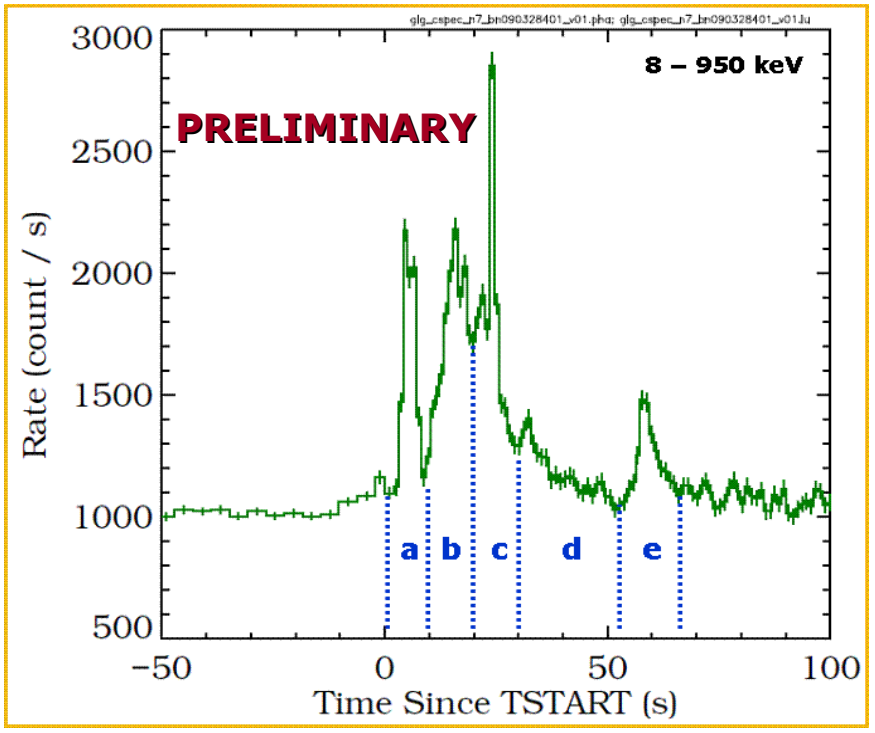


- **The effect of the ARR is particularly visible in the GBM after 60 s, where the detectors orientation changes very rapidly**



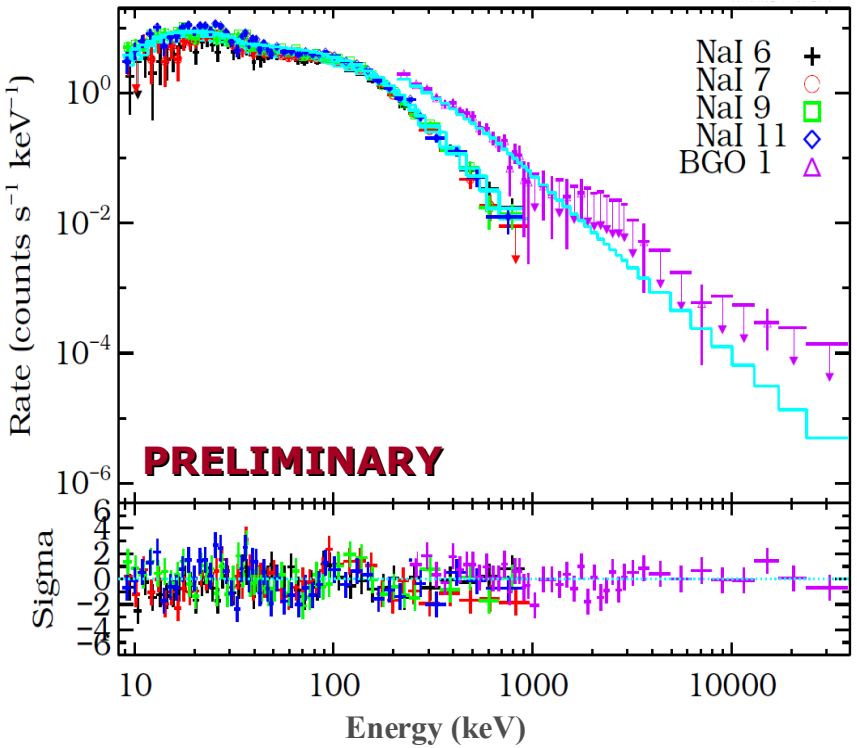
GBM lightcurves

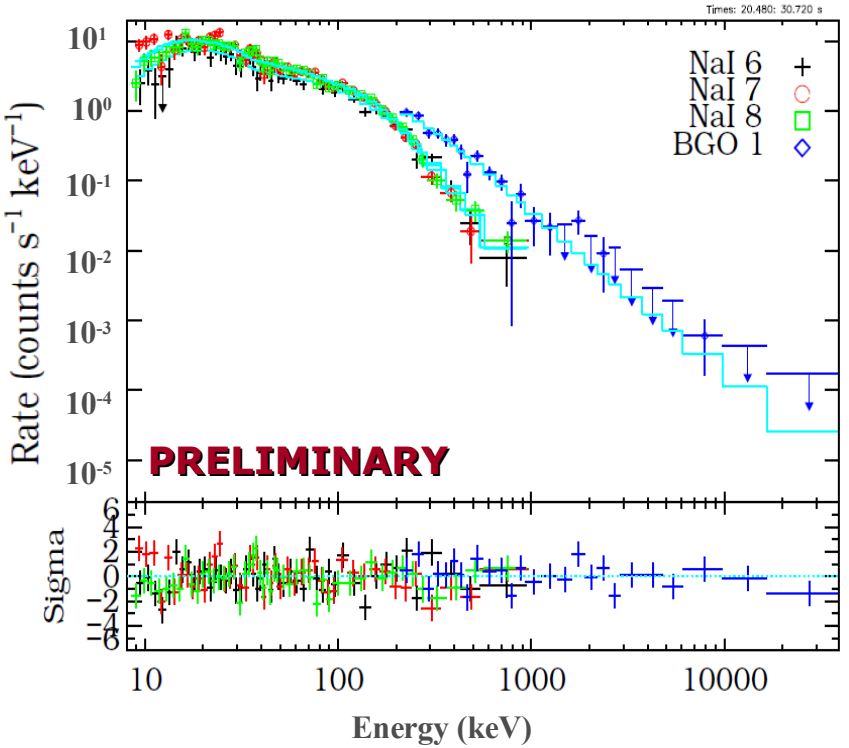




- **GRB 090323**
  - **T90 ~ 140 s**
  - **1-sec peak flux = 12.3 ± 0.4 ph/s/cm2**
- **GRB 090328**
  - **T90 ~ 60 s**
  - **1-sec peak flux = 22.6 ± 0.8 ph/s/cm2**

GBM spectral results (brightest intervals)





- **GRB 090323**
  - E_{peak} = 536 (+ 25 - 24) keV
  - α = -0.80 ± 0.02
  - β = -2.8 (+ 0.2 - 0.4)
  - Fluence = (1.23 ± 0.02) E-04 erg/cm2
- **GRB 090328**
  - E_{peak} = 479 (± 58) keV
  - α = -1.08 (+ 0.04 - 0.03)
  - β = -2.3 (+0.2 - 0.3)
  - Fluence = (5.2 ± 0.7) E-05 erg/cm2

Search for HE extended emission in the LAT

- **Two complementary techniques are used**

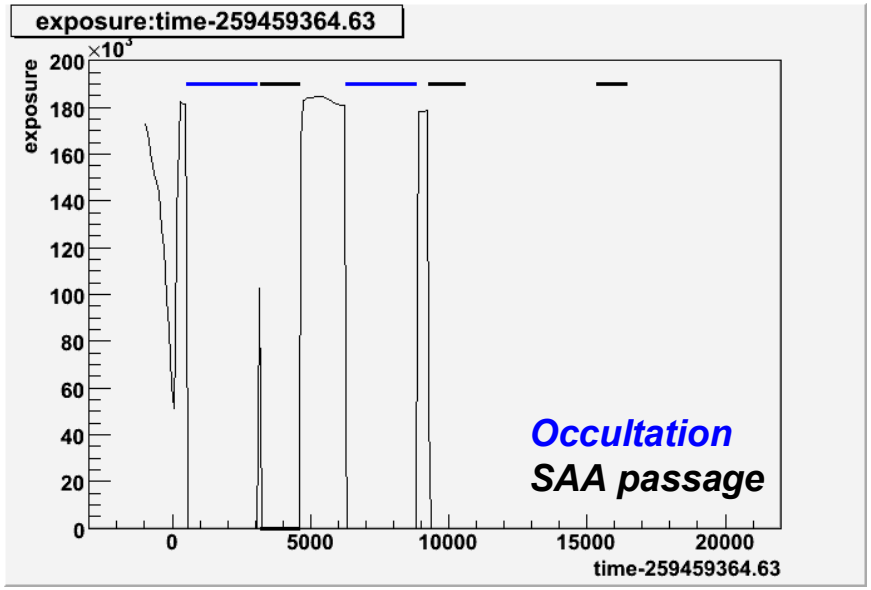
- **Event counting in an energy-dependent ROI**
  - **Background estimator, see V. Vasileiou's poster (P5-207)**
  - **Time history of estimated background and background-subtracted lightcurve above 50 MeV for any orientation**
  - **First look at signal accumulation, quick search for bright time intervals**
  - **Signal significance through simple Poisson probability**

- **Unbinned likelihood analysis (gtlike in Science Tools) in a 12º ROI**
  - **Final analysis above 100 MeV on various time scales**

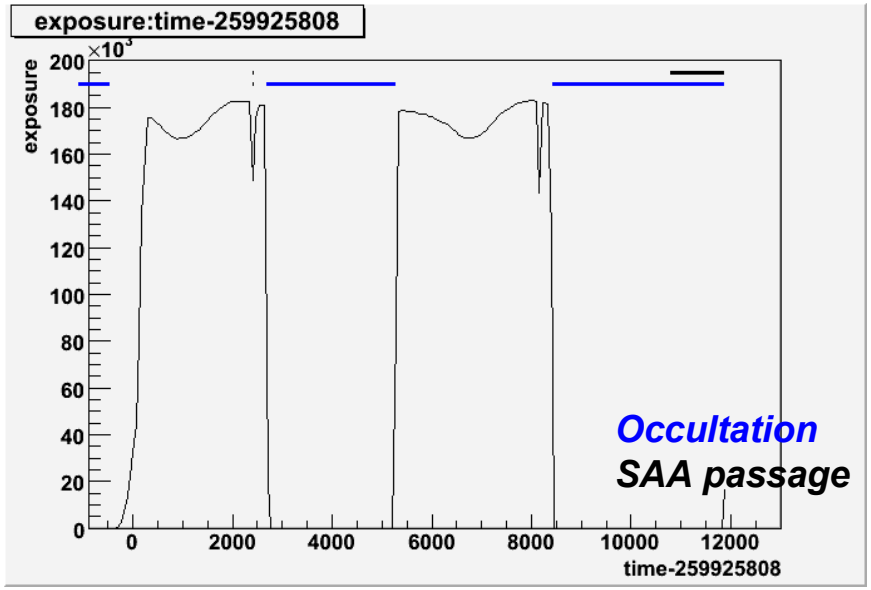
- **Gtlike is sensitive but maybe complicated in case of an ARR, while the background estimator is simpler, includes event at lower energies, but can be less sensitive (no spatial information)**

LAT exposure during the first orbits

GRB 090323

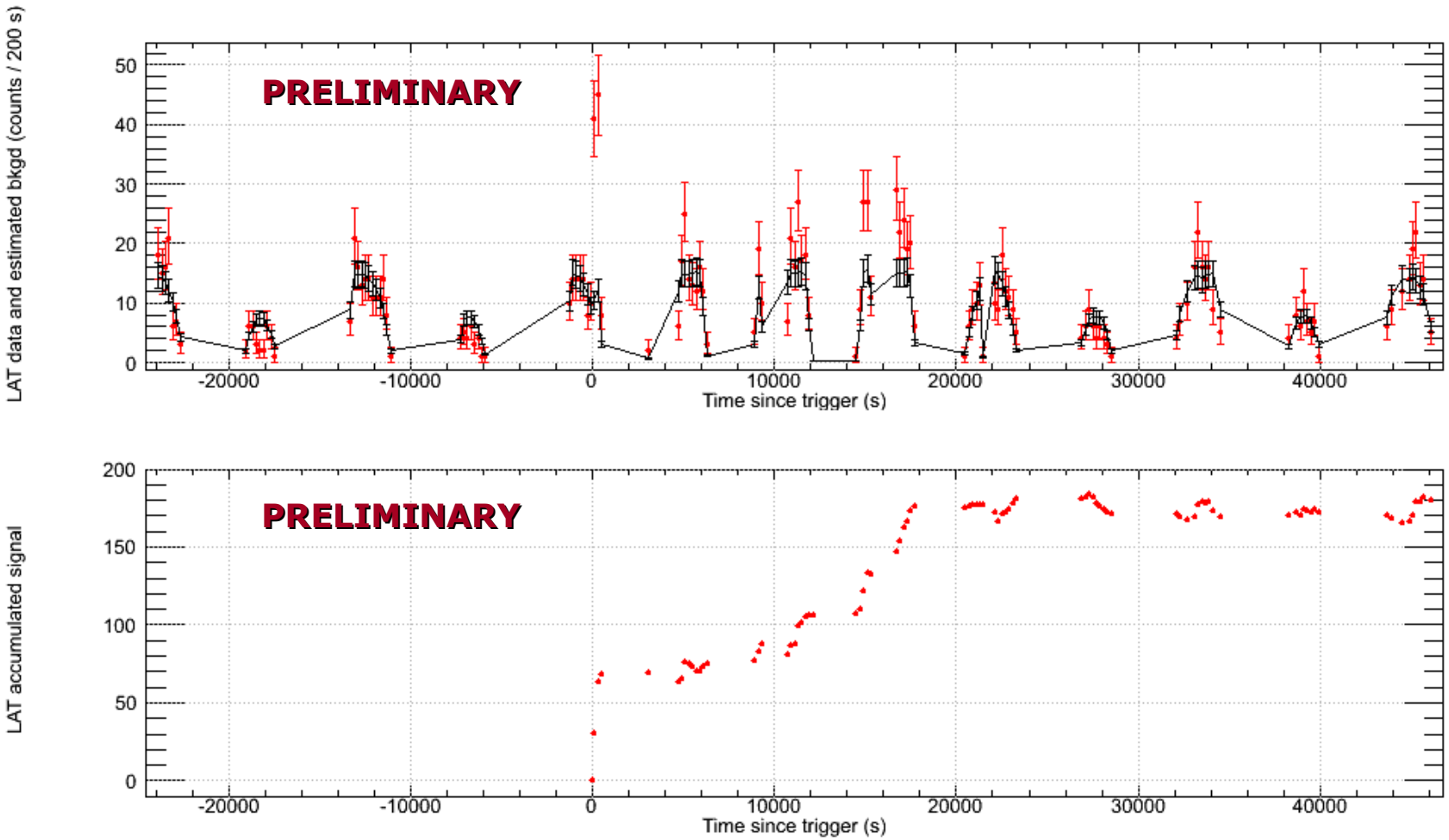


GRB 090328



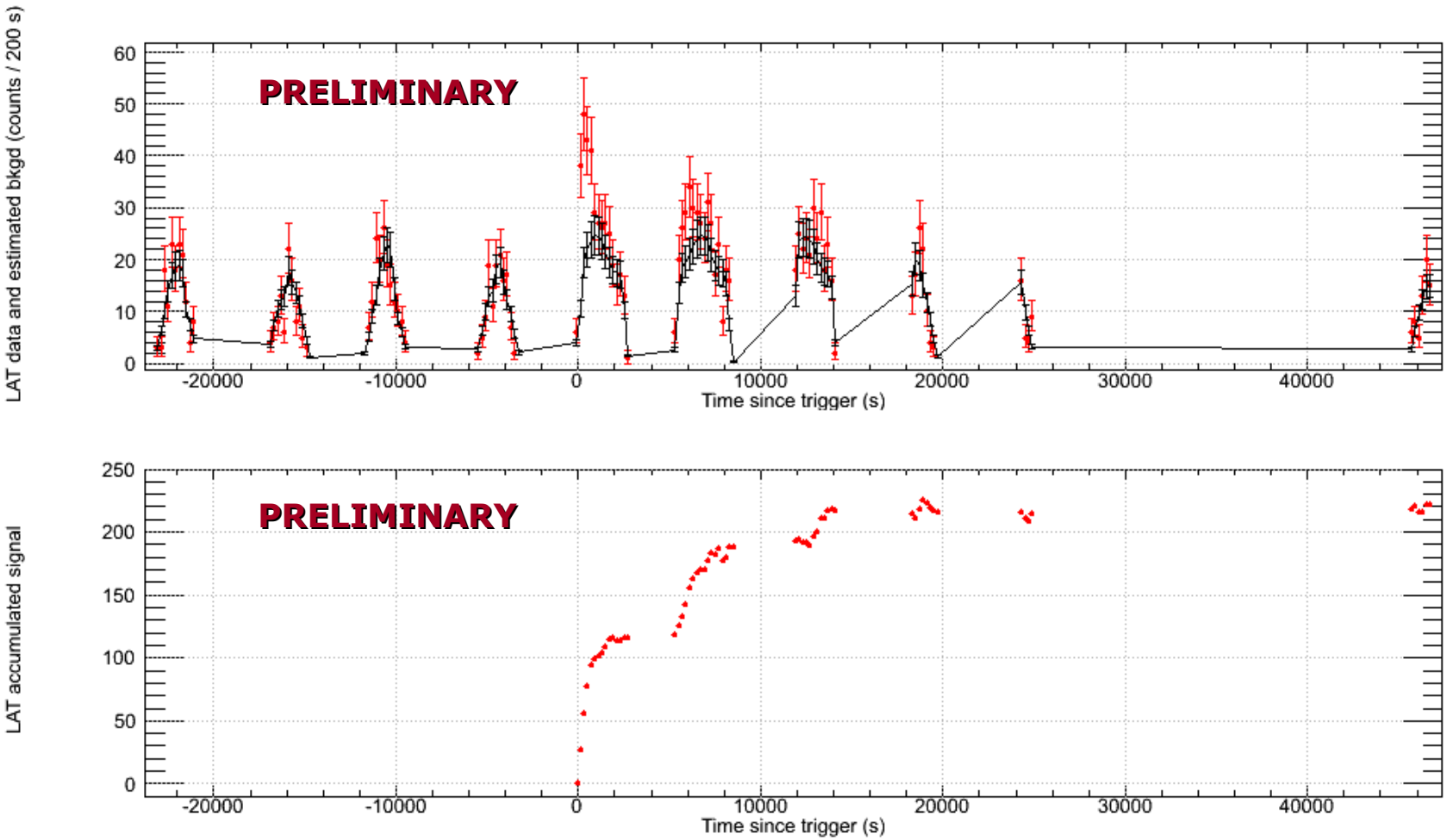
- **GRB 090323 ARR not especially fantastic**
  - The LAT exposure varies by a factor ~2 (~3) during the first ~180 s (~300 s)
  - GRB location became occulted after 539 s
  - S/C entered SAA 47 s after the GRB exited occultation
- **GRB 090328 ARR was beautiful**
  - The LAT exposure varies by a factor ~2 (~6) during the first ~120 s (~300 s)
  - Triggered on the GRB just after it exited occultation
  - No SAA passage for the next two orbits (observations only interrupted by occultations)

LAT count lightcurve of GRB 090323



- **Background varies by a factor ~2 within the ARR**
- **Very rapid rise of accumulated signal in 1st orbit, faint signal in next orbits up to a plateau observed after 17.8 ks (end of the ARR) – photon signal or systematics in BKG subtraction during ARR?**
- **BKG-subtracted counts = 106 from 3.8 ks (2nd orbit) to 17.8 ks (461 events for 355 BKG expected, P=0.10)**

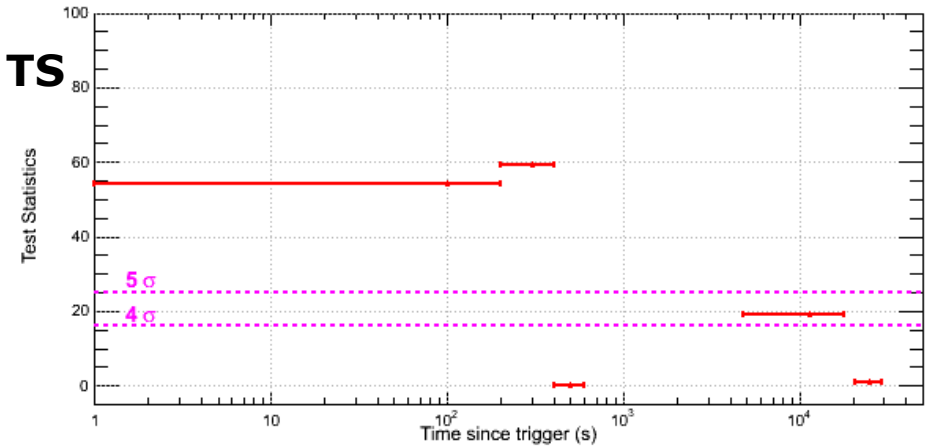
LAT count lightcurve of GRB 090328

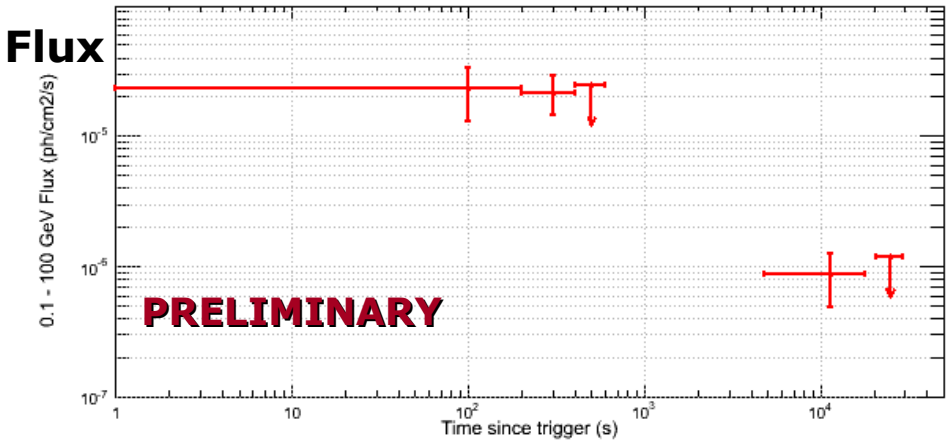


- **Very rapid rise of accumulated signal in 1st orbit, faint and decreasing signal in next orbits up to a plateau observed after 14.2 ks (end of the ARR in next orbit)**
- **BKG-subtracted counts = 101 from 5.2 ks (2nd orbit) to 14.2 ks (617 events for 516 BKG expected, P=0.20)**

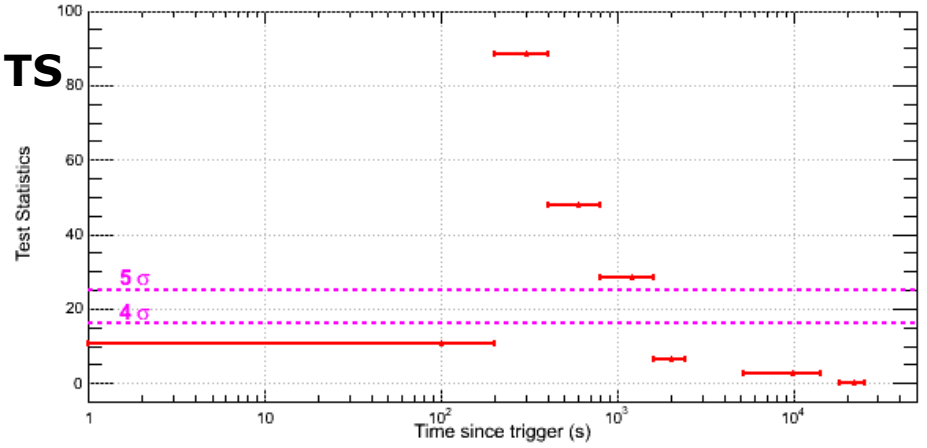
Unbinned likelihood analysis

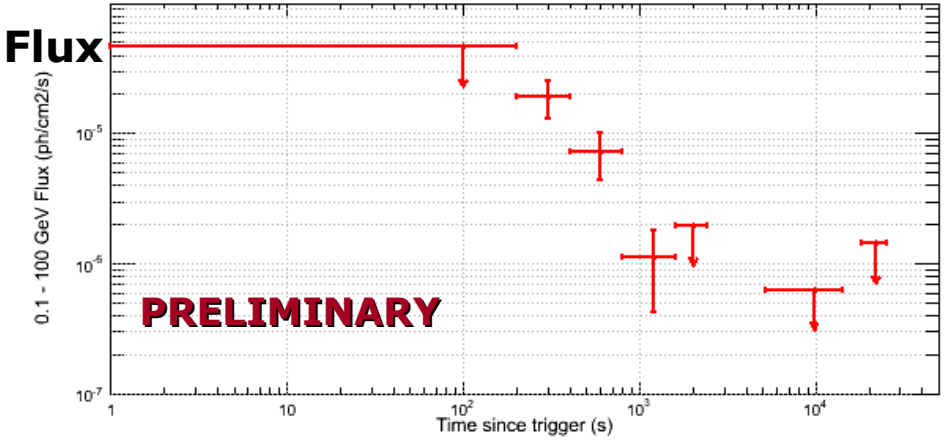
GRB 090323





GRB 090328



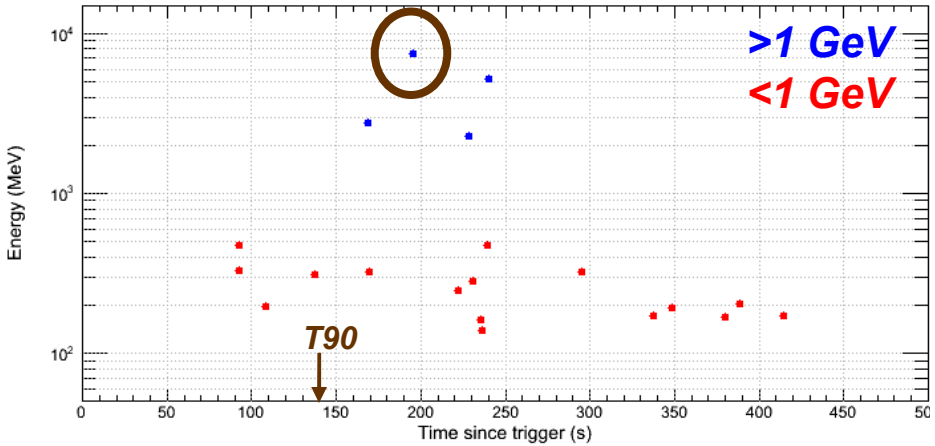


- GRB 090323 flux decrease is badly sampled, clear detection up to 400s after trigger
  very late (~10 ks) 4-sigma detection to be confirmed (careful study of systematic effects)
- GRB 090328 continuously detected up to 1600 s

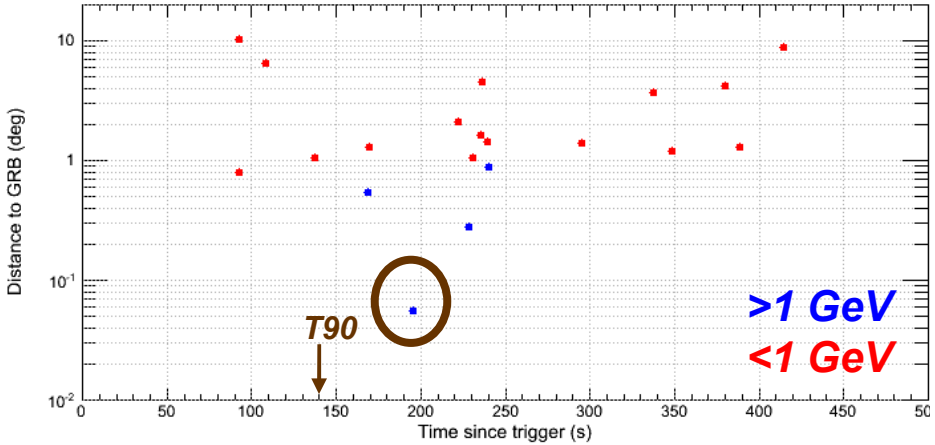
Energy (and distance to GRB) vs. time

GRB 090323

Energy

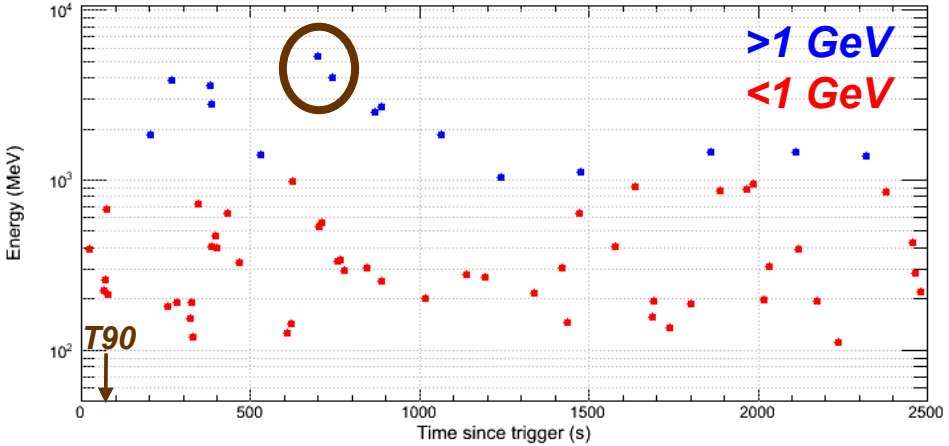


Distance to GRB PRELIMINARY

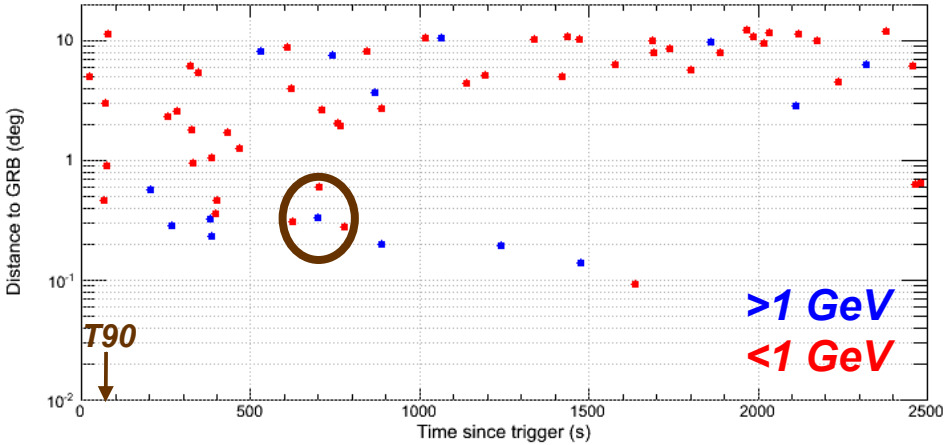


GRB 090328

Energy



Distance to GRB PRELIMINARY



- **>GeV events are observed closer (<1º) to the GRB position**
- **Highest energy emission peaks late (but acceptance varies!):**

7.5 GeV event @ T0+195s (GRB 090323, T90 ~ 140s)
5.3 GeV event @ T0+698s (GRB 090328, T90 ~ 60s)

Conclusions

- Two long bursts GRB 090323 and GRB 090328
  - ~140 s and ~60 s in GBM, respectively
  - Prompt emission well reproduced by a Band model (GBM only)

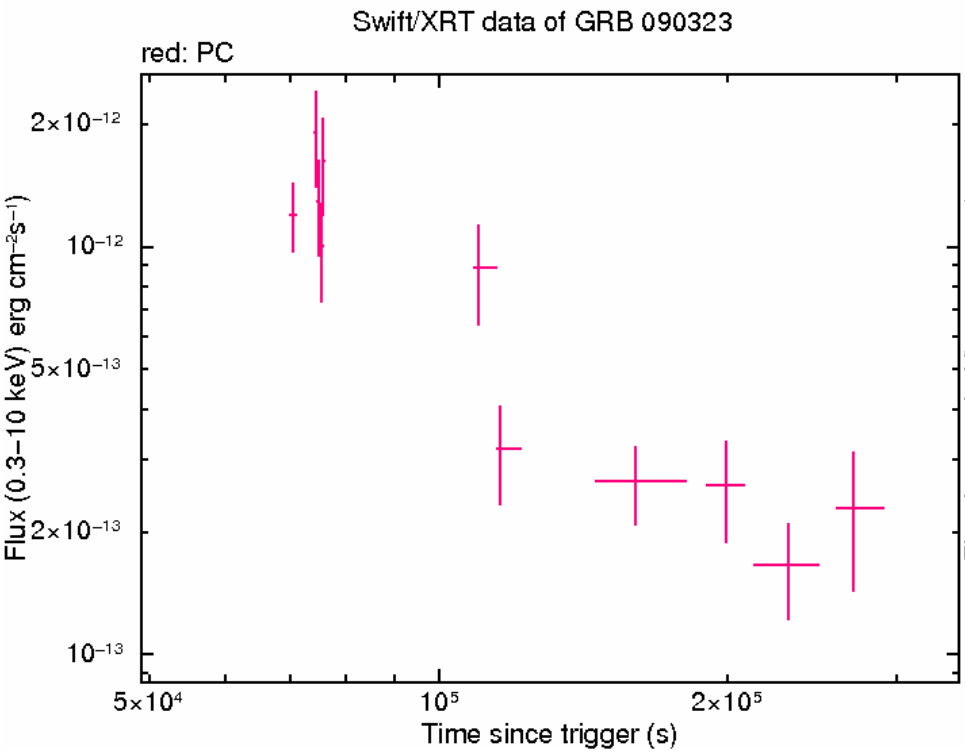
- ARRs greatly improve the search for GRB HE extended emission, but:
  - Responses change while the observatory is slewing
    - Possible delay of high-energy photons is difficult to measure
  - Careful evaluation of the backgrounds vs. time is required by the spectral analyses (GBM, LAT) and for the search of HE emission in the LAT

- High-energy events are observed (up to ~8 GeV) well after the prompt emission seen in the GBM
  - GRB 090323 ARR not optimal, but firm detection up to 400 s
  - GRB 090328 has the longest extended emission in the LAT, up to 1600 s
  - See J.Chiang's talk and V. Pelassa's poster (P3-153) for other LAT detections of GRB extended emission

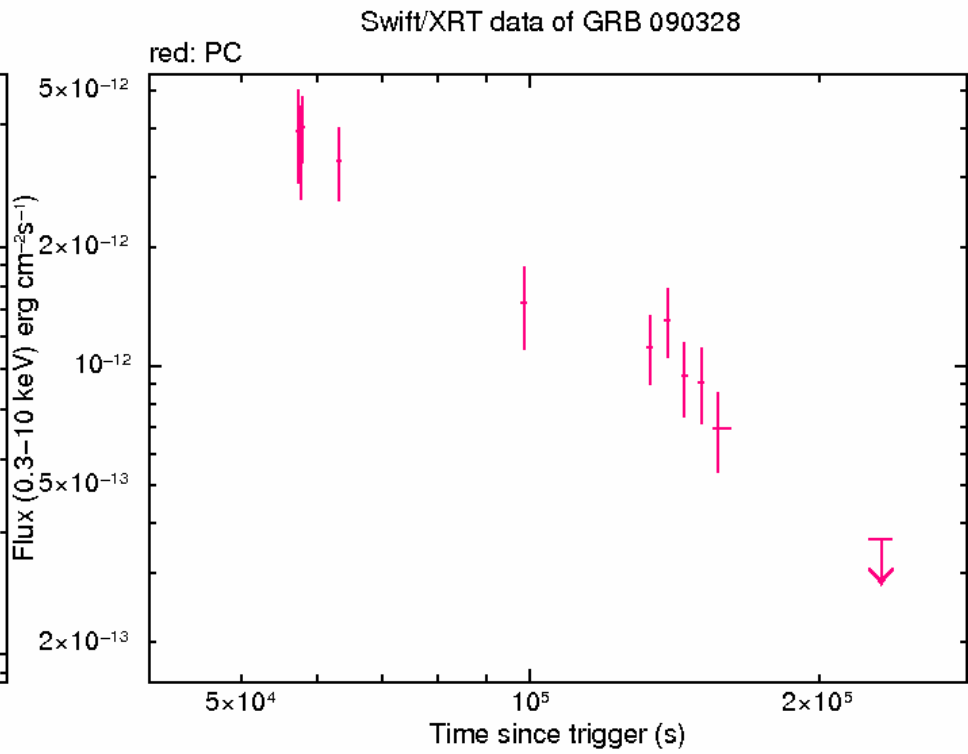
Backup slides

Swift/XRT follow up observations

GRB 090323



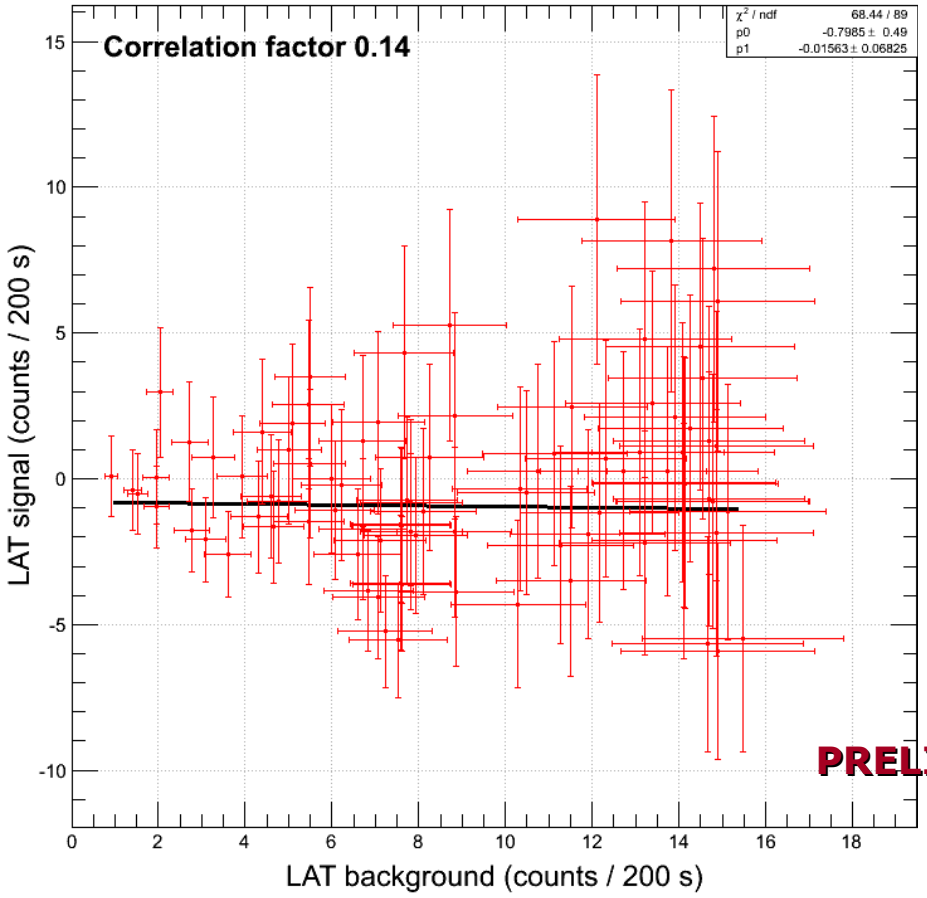
GRB 090328



Background estimation in OFF periods

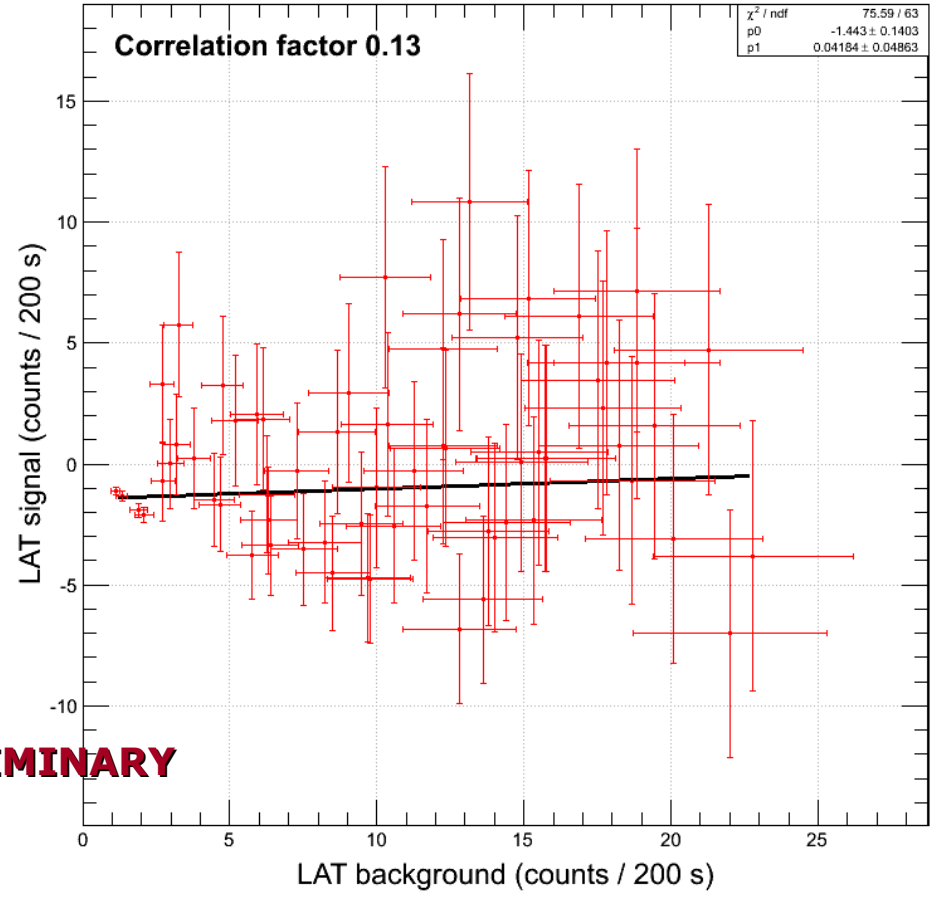
GRB 090323

OFF region before -100 s and after 20000 s



GRB 090328

OFF region before -100 s and after 18000 s



PRELIMINARY