Fermi Gamma-ray Space Telescope

Fermi-LAT Observation of High-energy Gamma-ray Bursts

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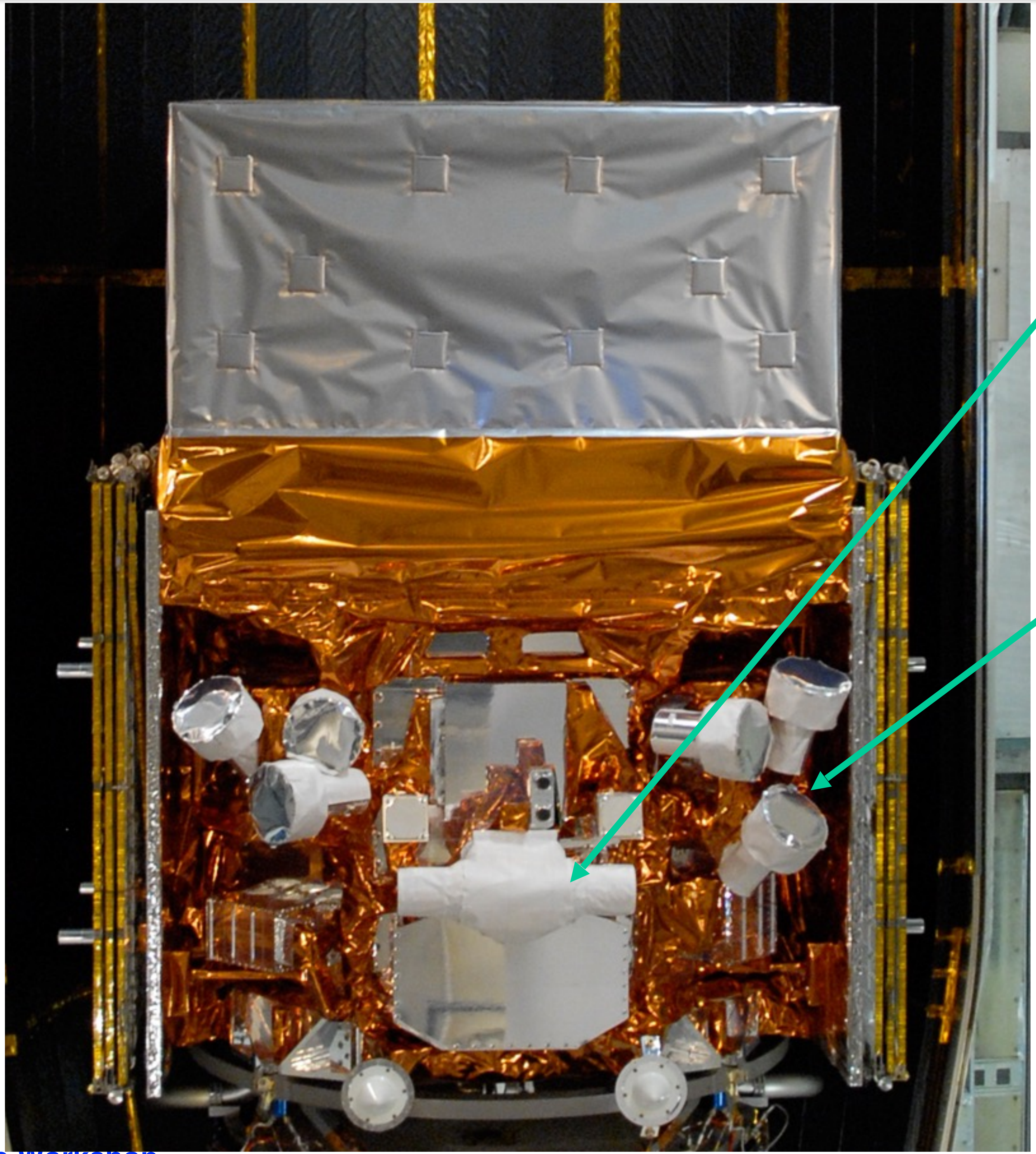
<u>on behalf of the Fermi LAT collaboration</u>

HEPL

The Fermi Gamma-Ray Space Telescope



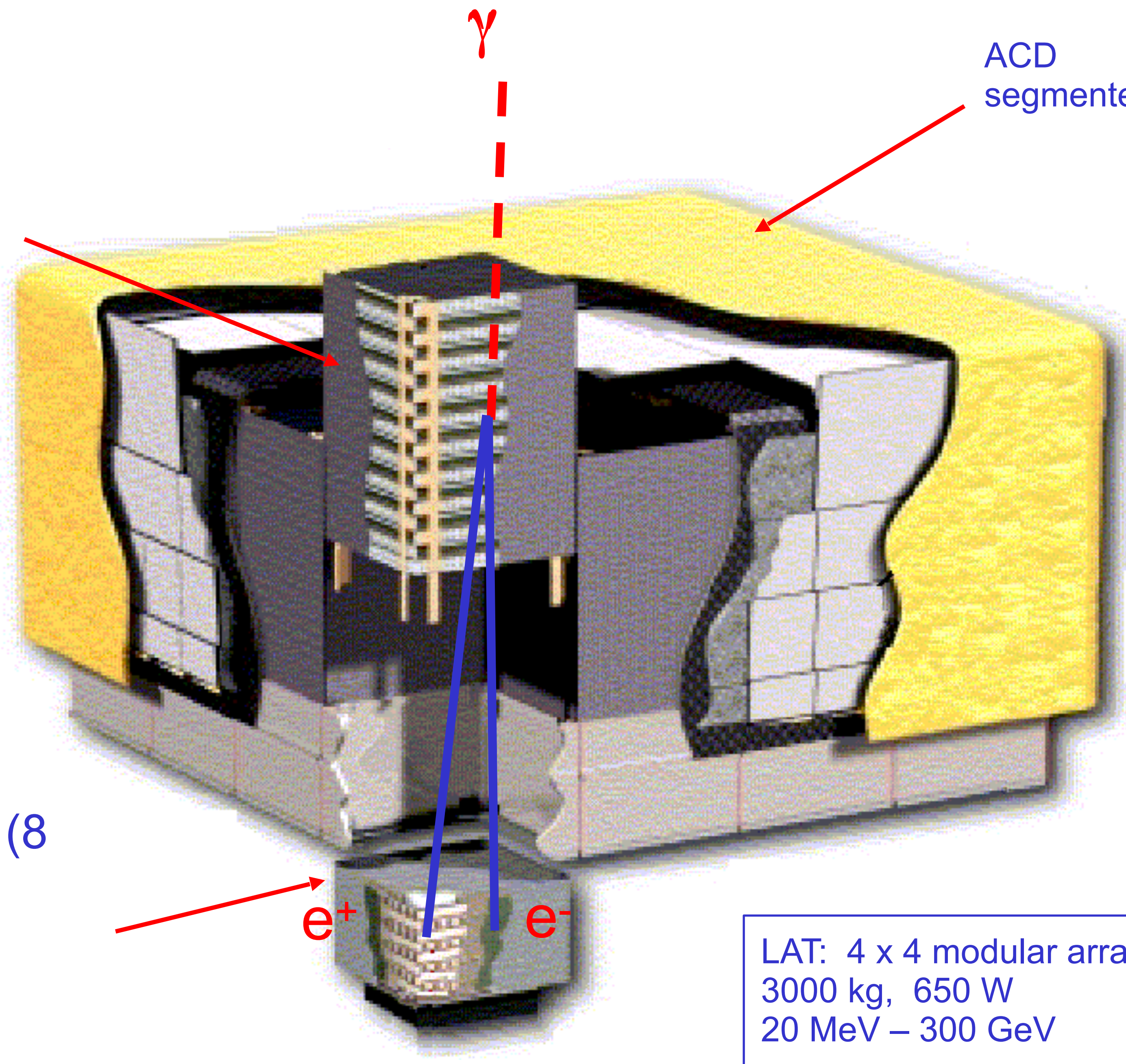
Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 40 MeV

The Fermi Gamma-Ray Space Telescope

Large AreaTelescope (LAT)
20 MeV - >300 GeV

Si Tracker
pitch = 228 µm
8.8 10^5 channels
18 planes

ACD
segmented scintillator tiles

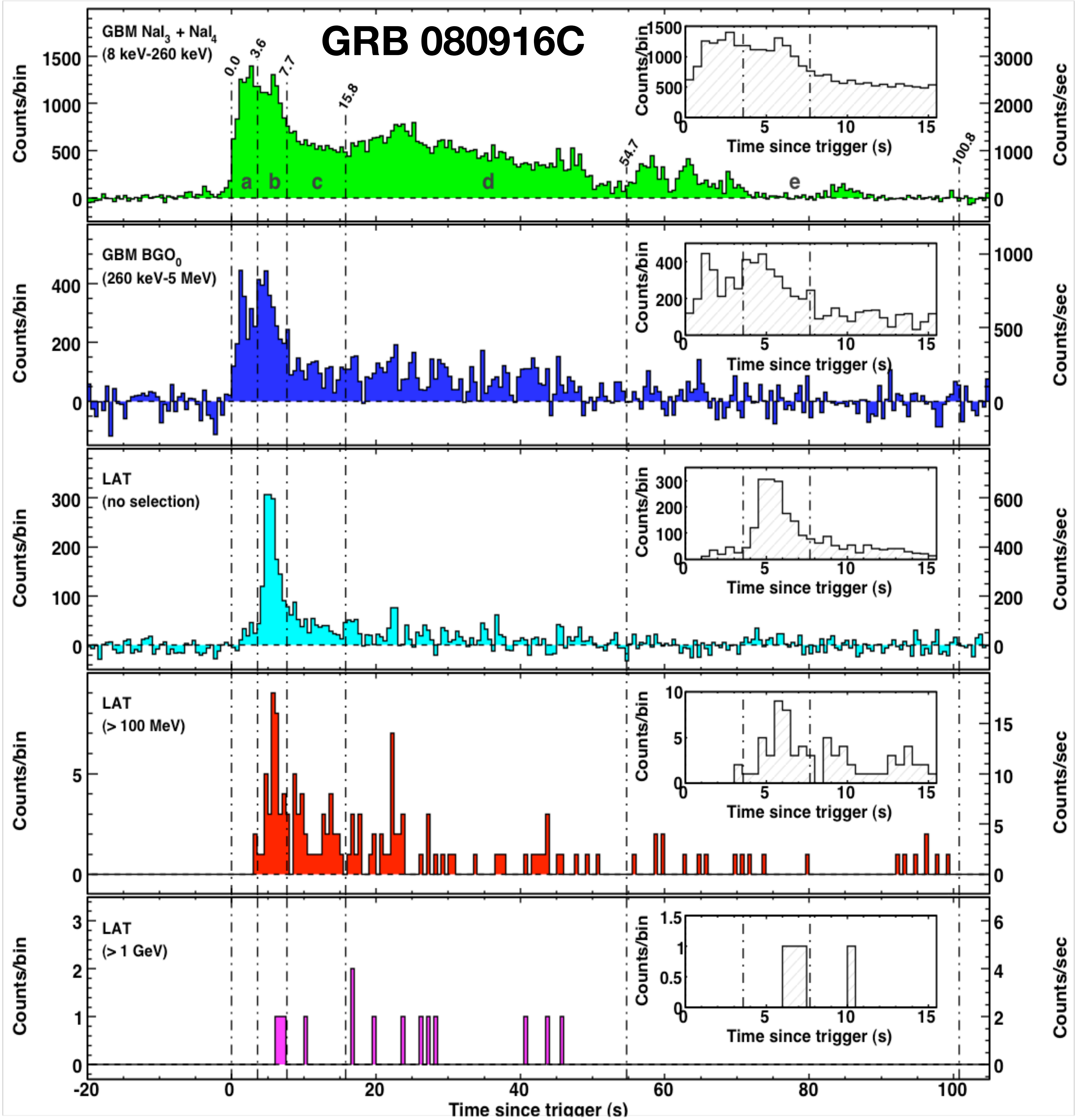


CsI Calorimeter
hodoscopic array (8 layers)
6.1 10^3 channels

LAT: 4 x 4 modular array
3000 kg, 650 W
20 MeV – 300 GeV

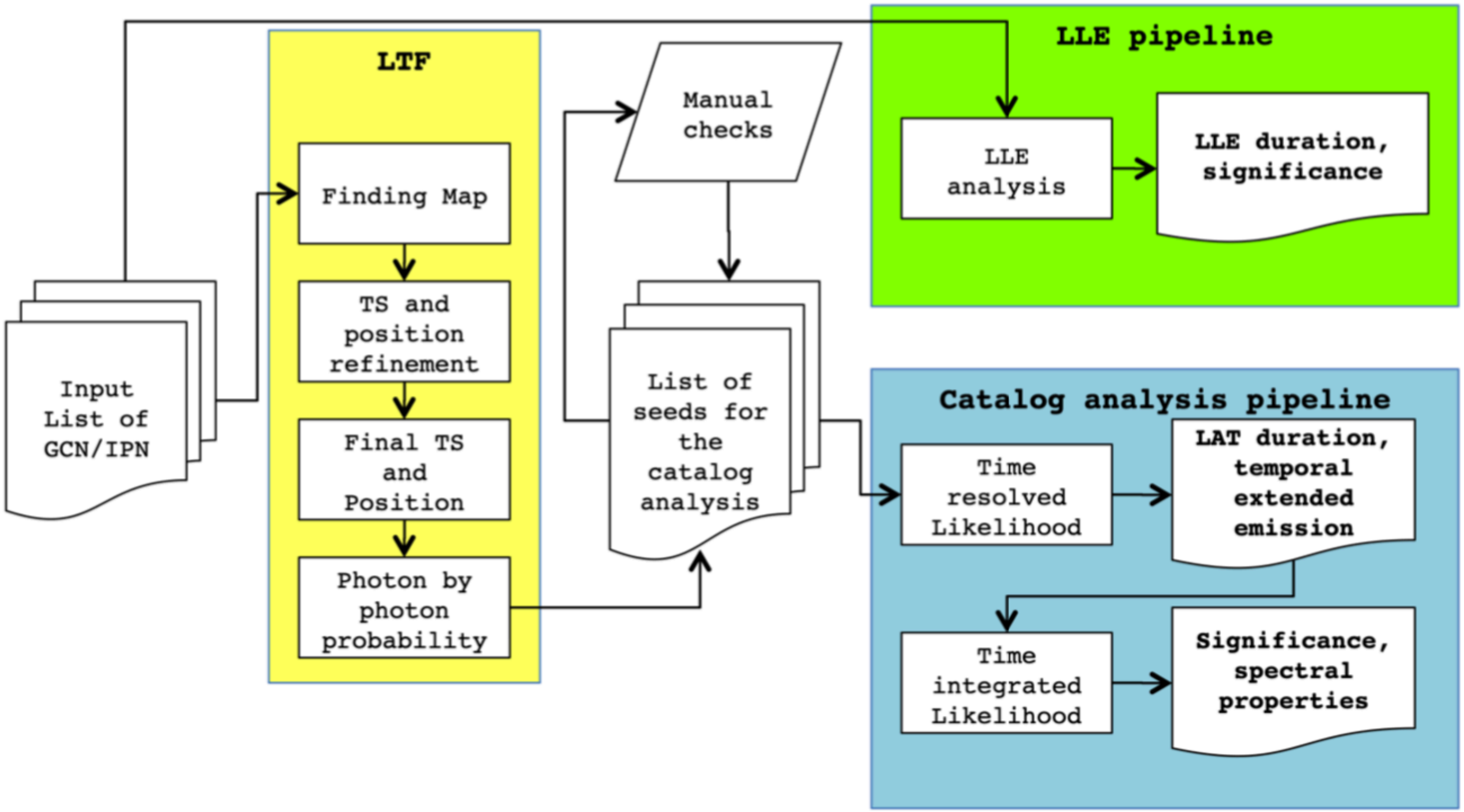
International collaboration

Gamma Ray Burst at High Energy



- Since its launch in 2008, LAT has detected >150 GRB at high energy (>100 MeV) announced via GCN thanks to the work of Burst Advocates that continuously monitor our data looking for high-energy emission associated with GBM (and other detectors) GRBs
- LAT Low Energy events (LLE) have been developed by the LAT team to study rapid transients down to 30 MeV, and are available online at the Fermi Science Support Center.
- First LAT catalog (3 years, 35 GRBs) published in 2013 (Ackermann et al.)

10 years of data: The second Fermi-LAT GRB catalog



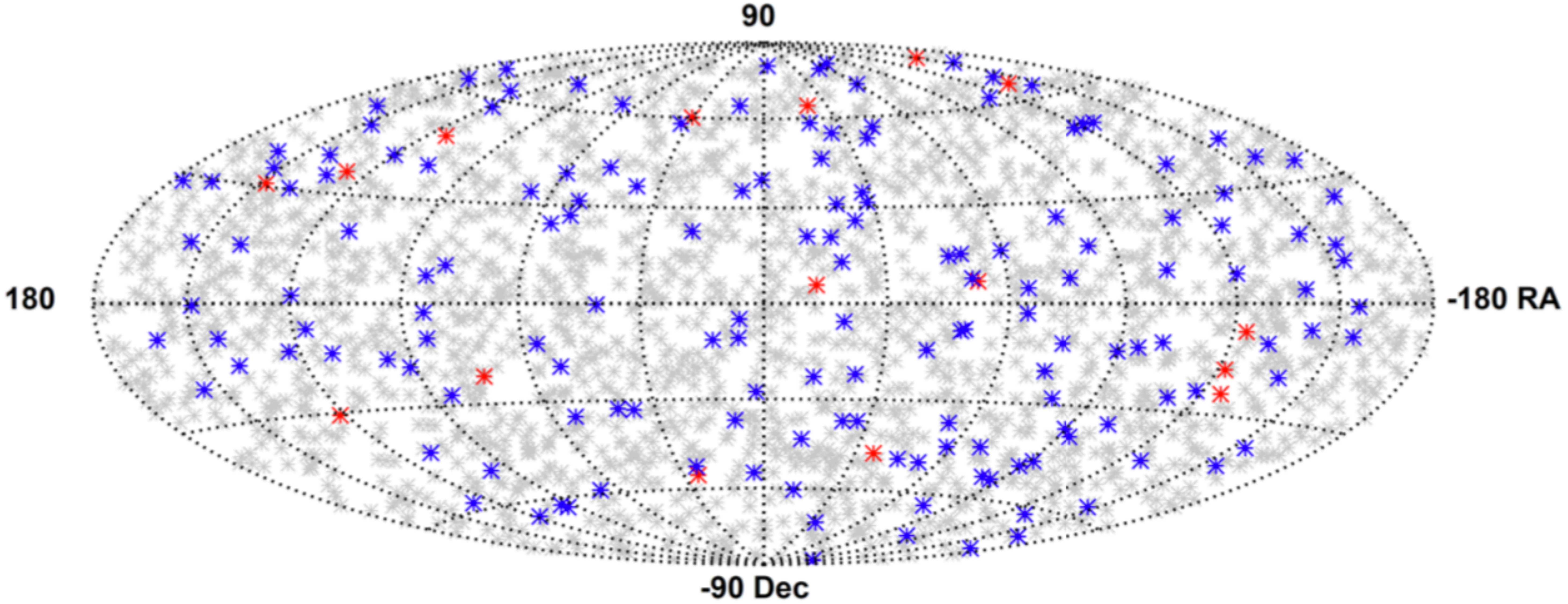
In 10 years: 186 GRBs, 169 above 100 MeV, 17 LLE only

Expectations surpassed !

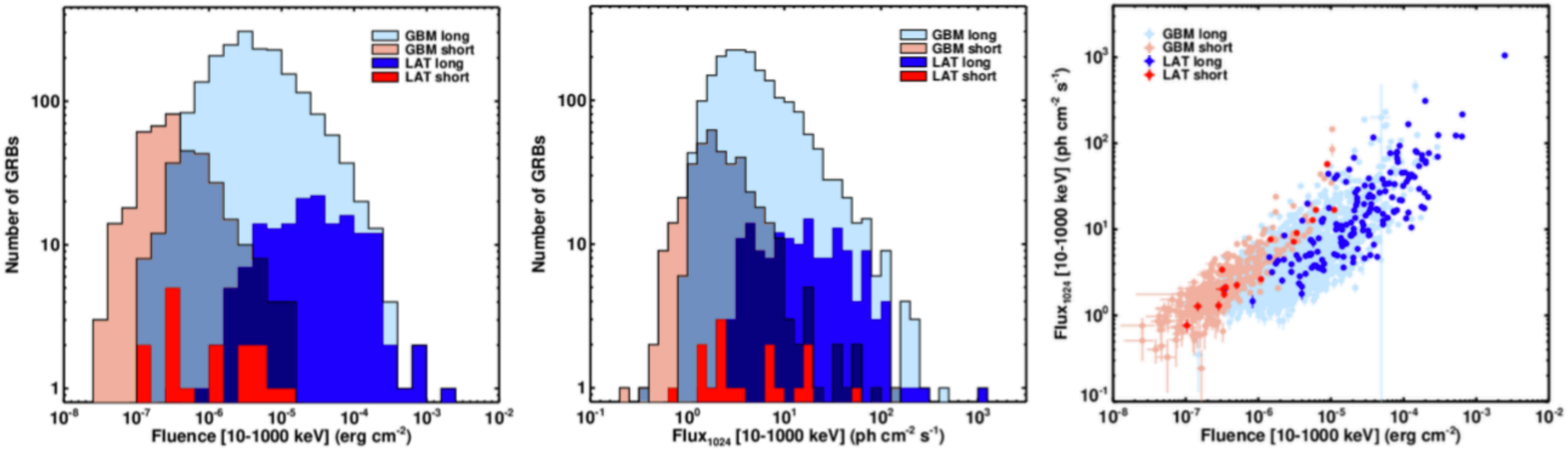
New detection algorithm and better detector performances (Pass8)

several time scales

Which GBM GRBs does the LAT detect?



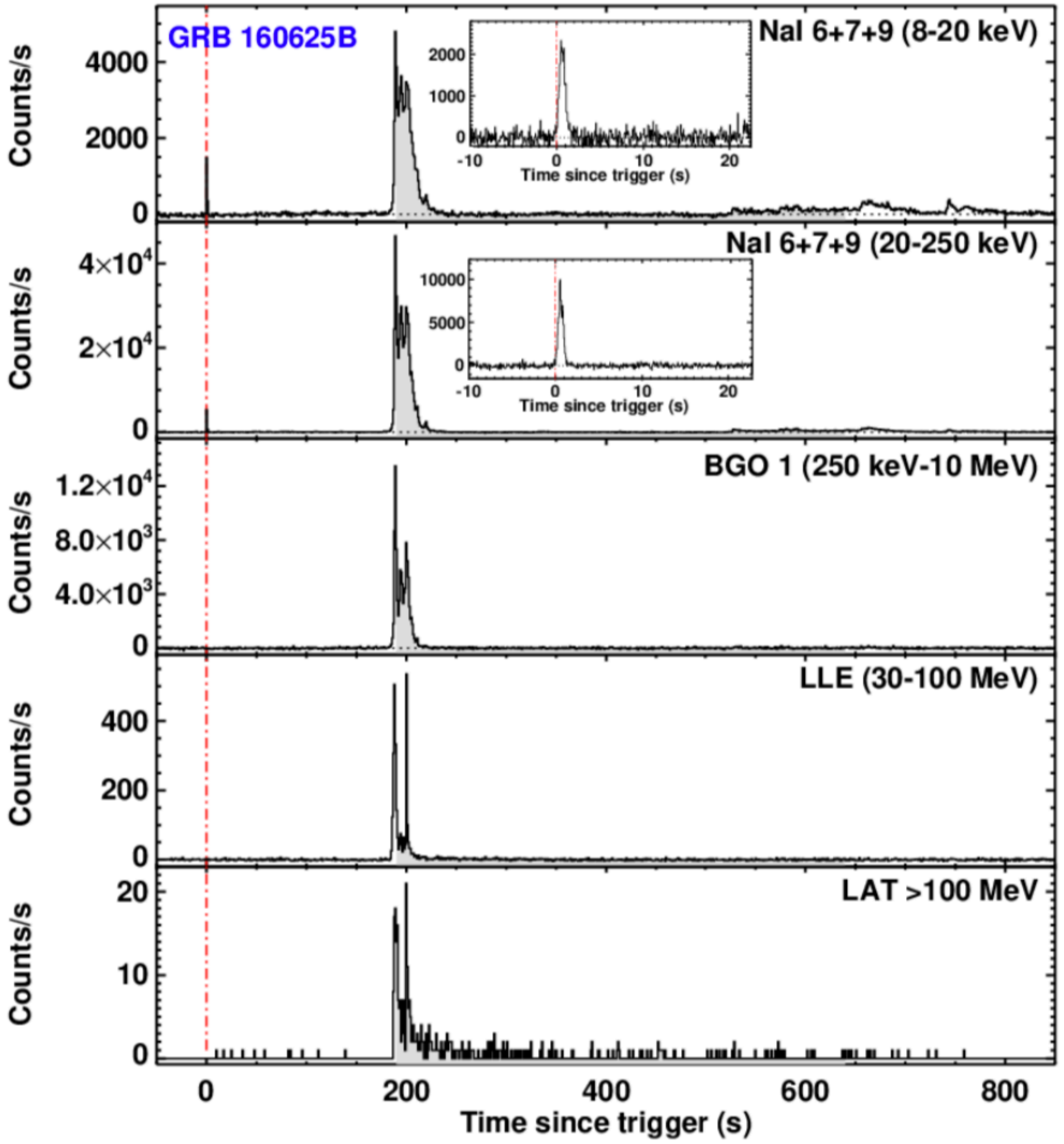
PRELIMINARY

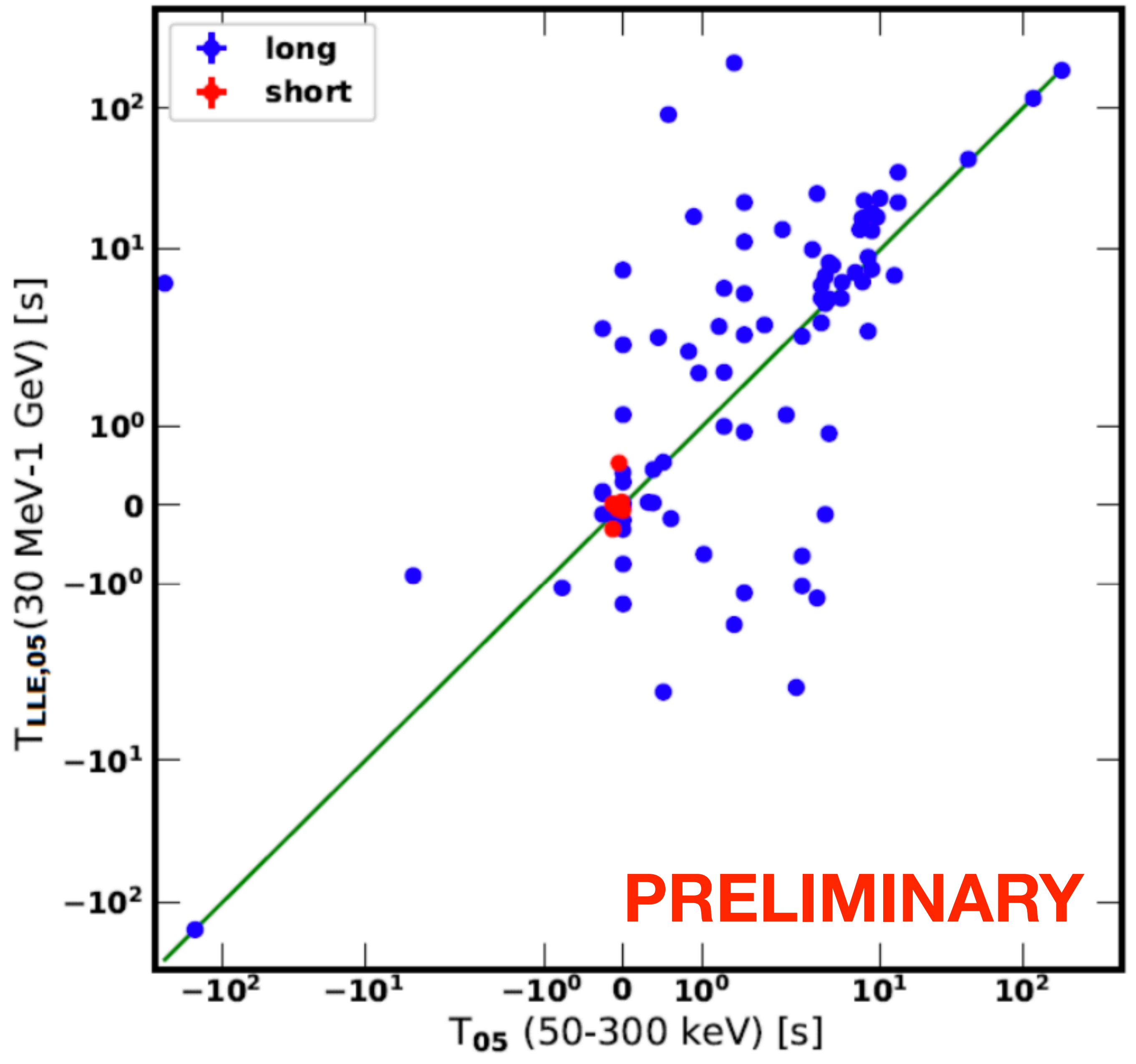


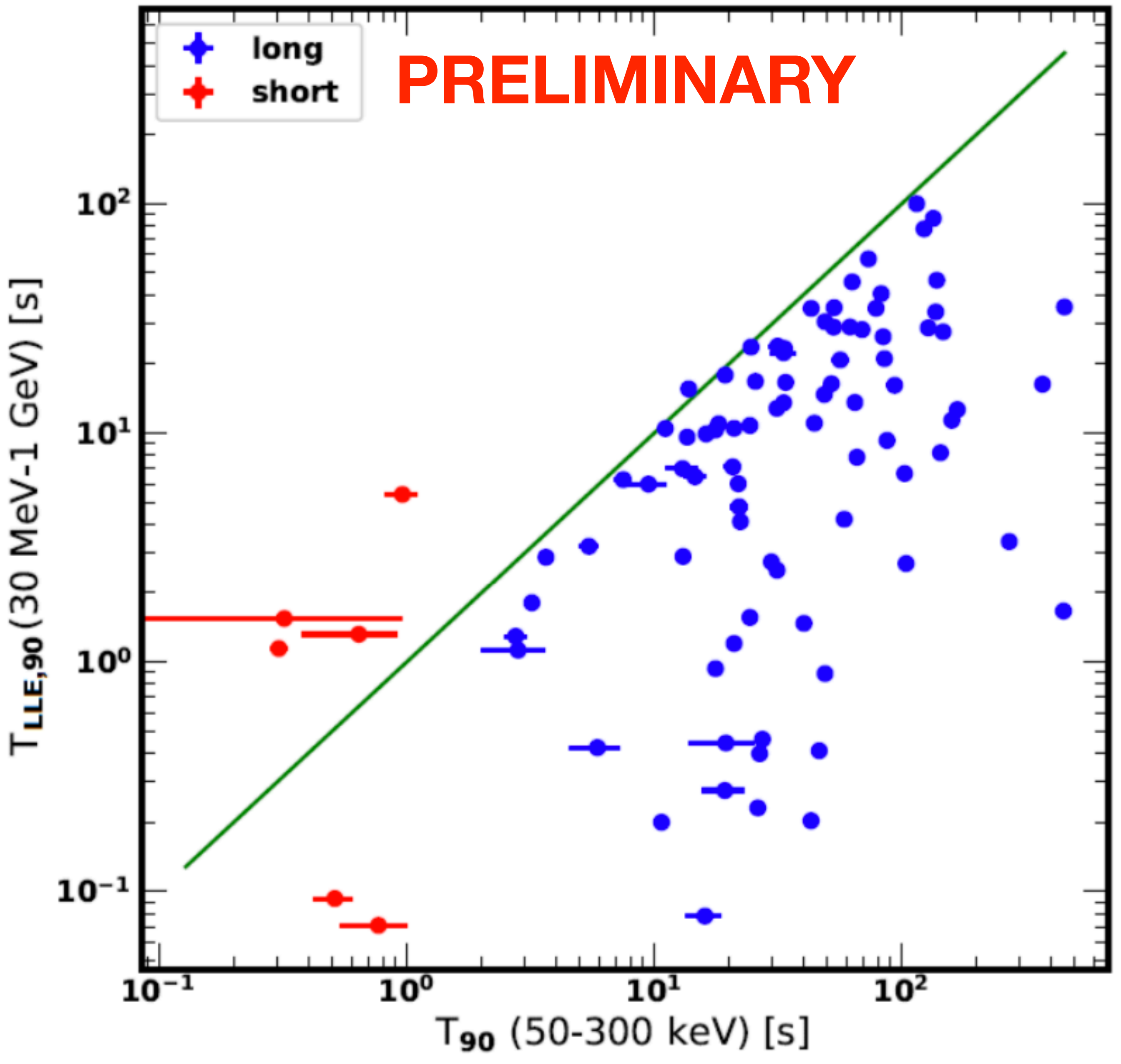
- **LAT detects slightly brighter GBM bursts (especially for the long ones), but not necessarily the closest ones;**

GBM, LLE and LAT

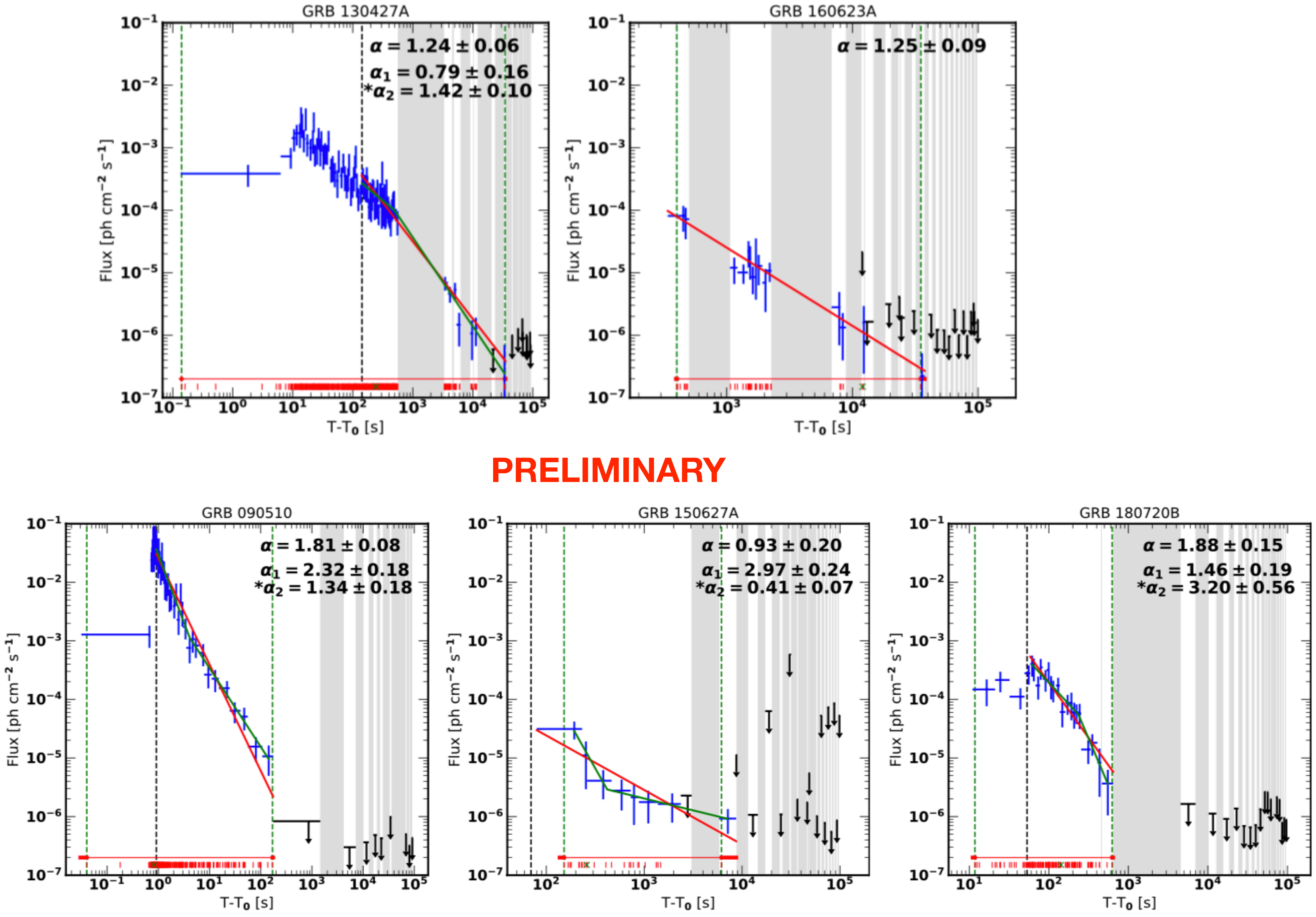
- **LLE is an analysis technique that extends LAT data down to 30 MeV**
- **Large effective area, large field of view, poor localization higher background**
- **Onset time similar to GBM, but shorter emission (Pulse paradigm Norris et al.)**





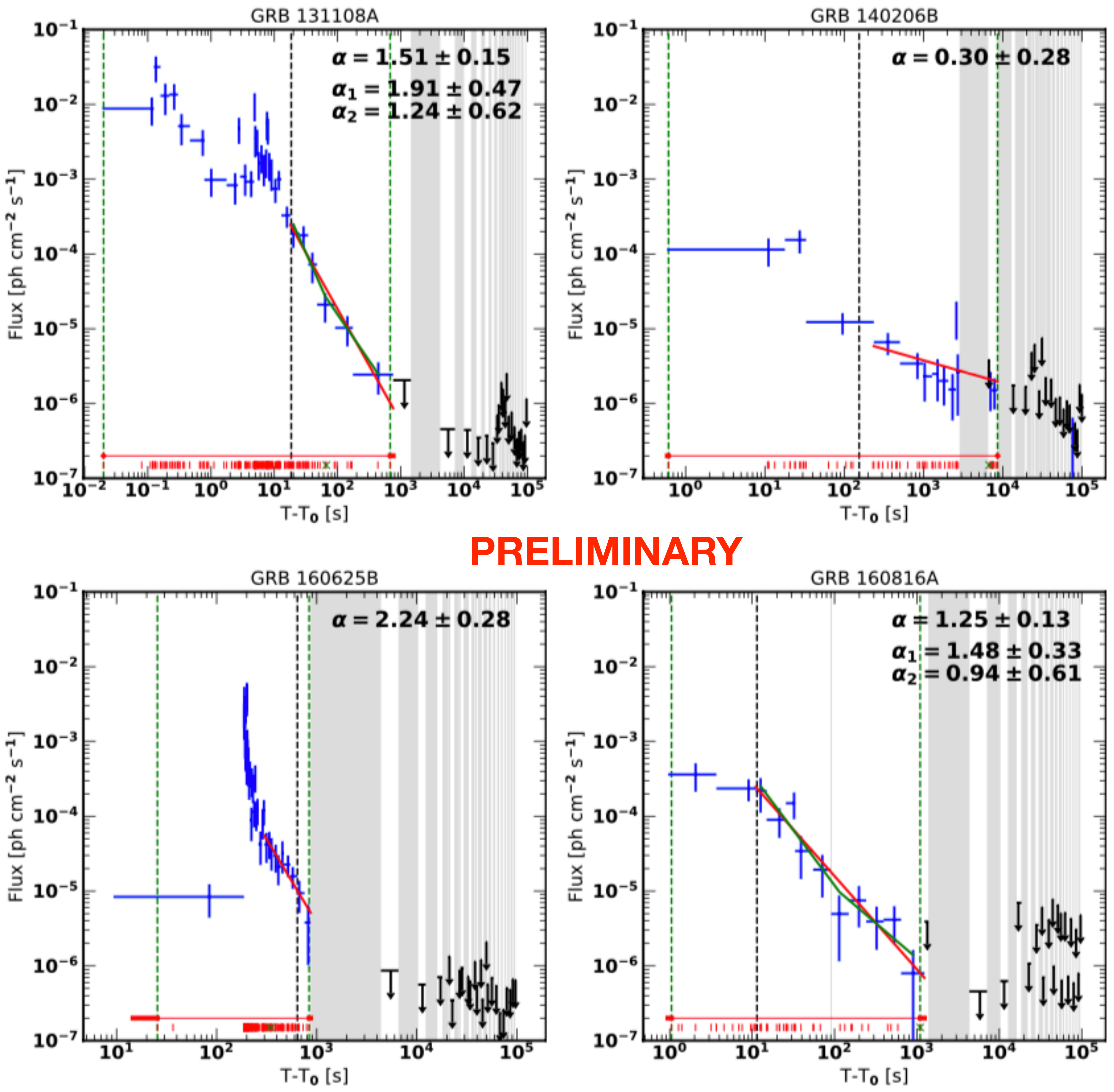


Characterizing the LAT emission >100 MeV



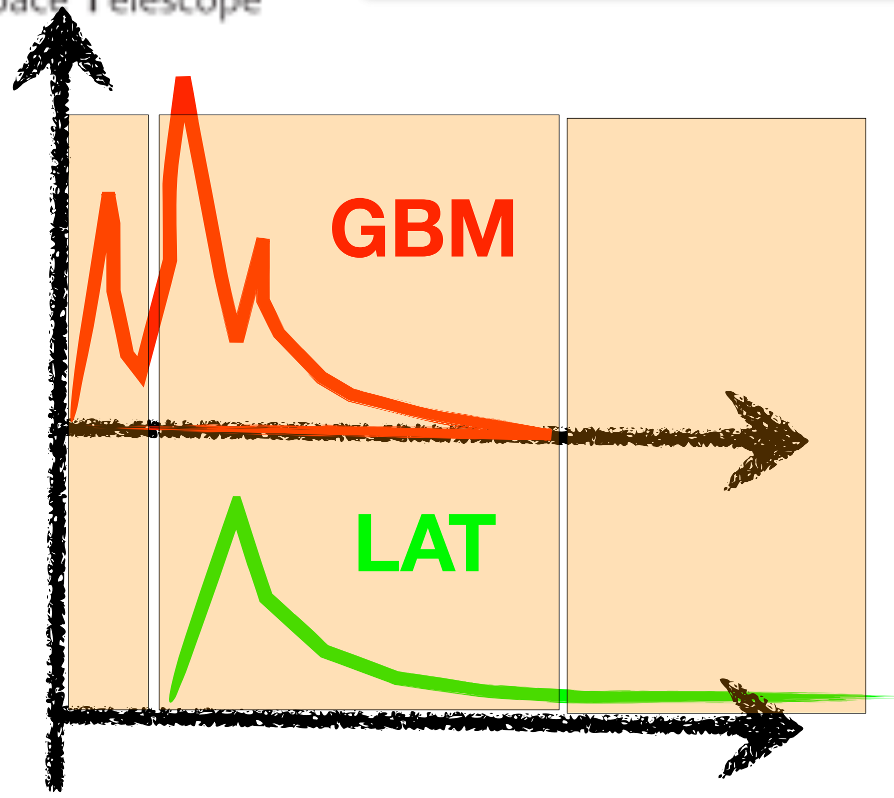
- **Full likelihood analysis (unbinned) in different tome bins (adaptively chosen)**
  - **Spectrum of the source is described by simple power law**
- **Temporal decay fitted with simple power law or with a broken power law.**
- **Test closure relation (see later)**

Peculiar LAT light curves



- **There are also cases where we clearly see variability, spikes, and possible late time flares in the LAT Lightcurves**

Onset and duration of >100 MeV



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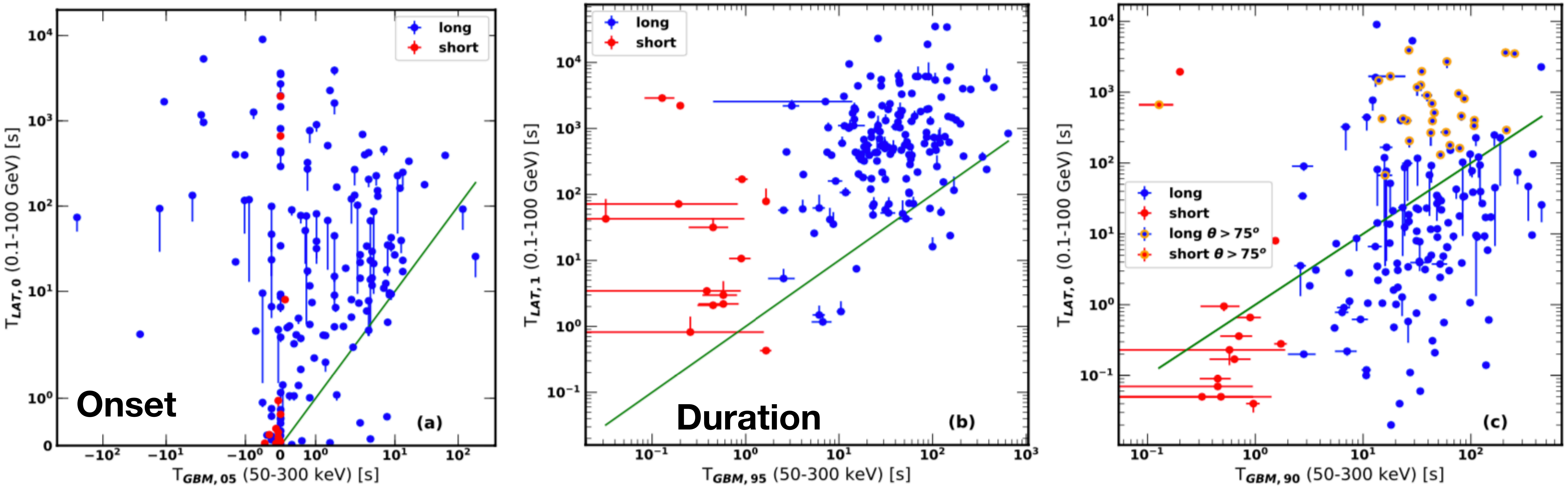
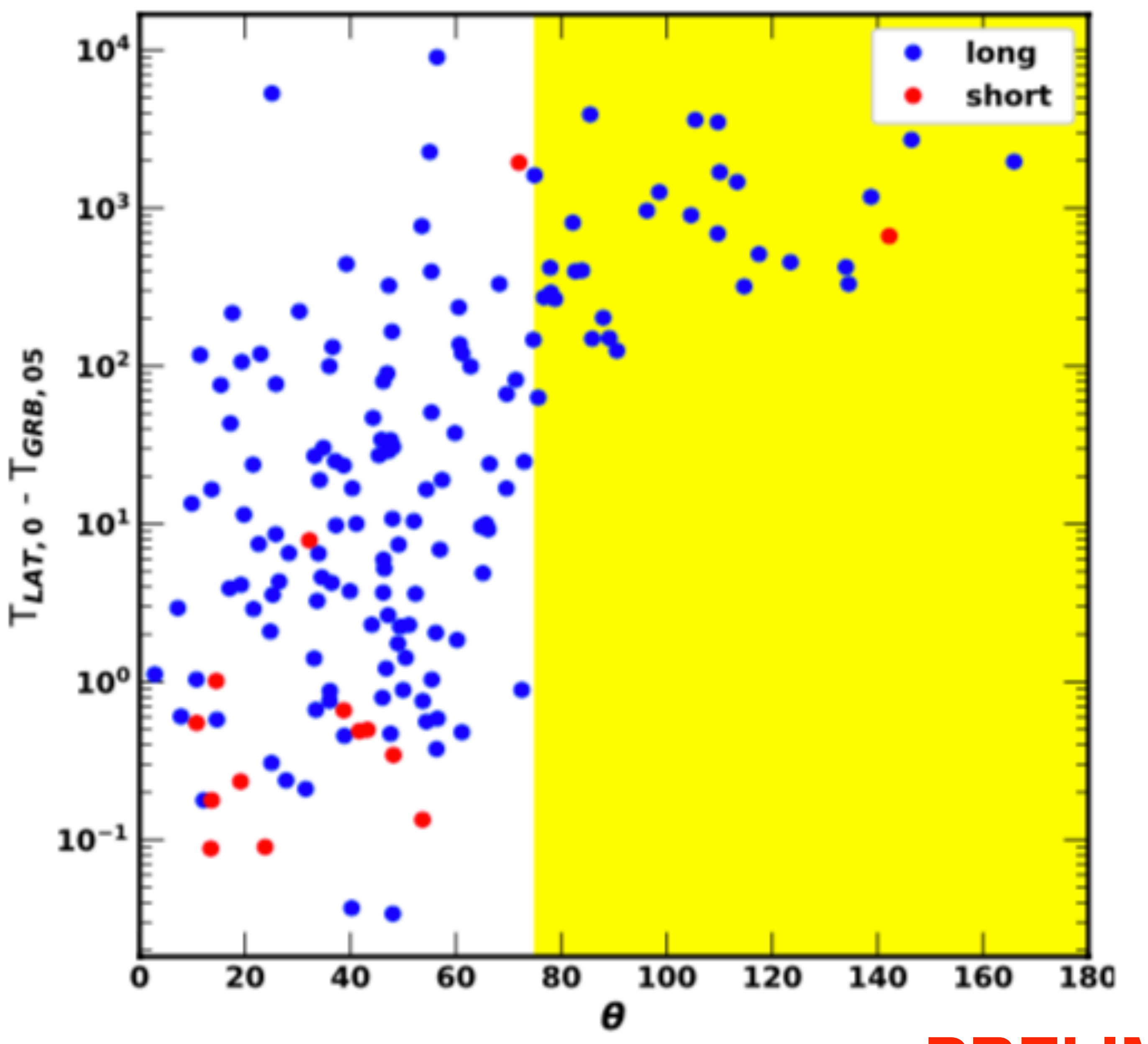
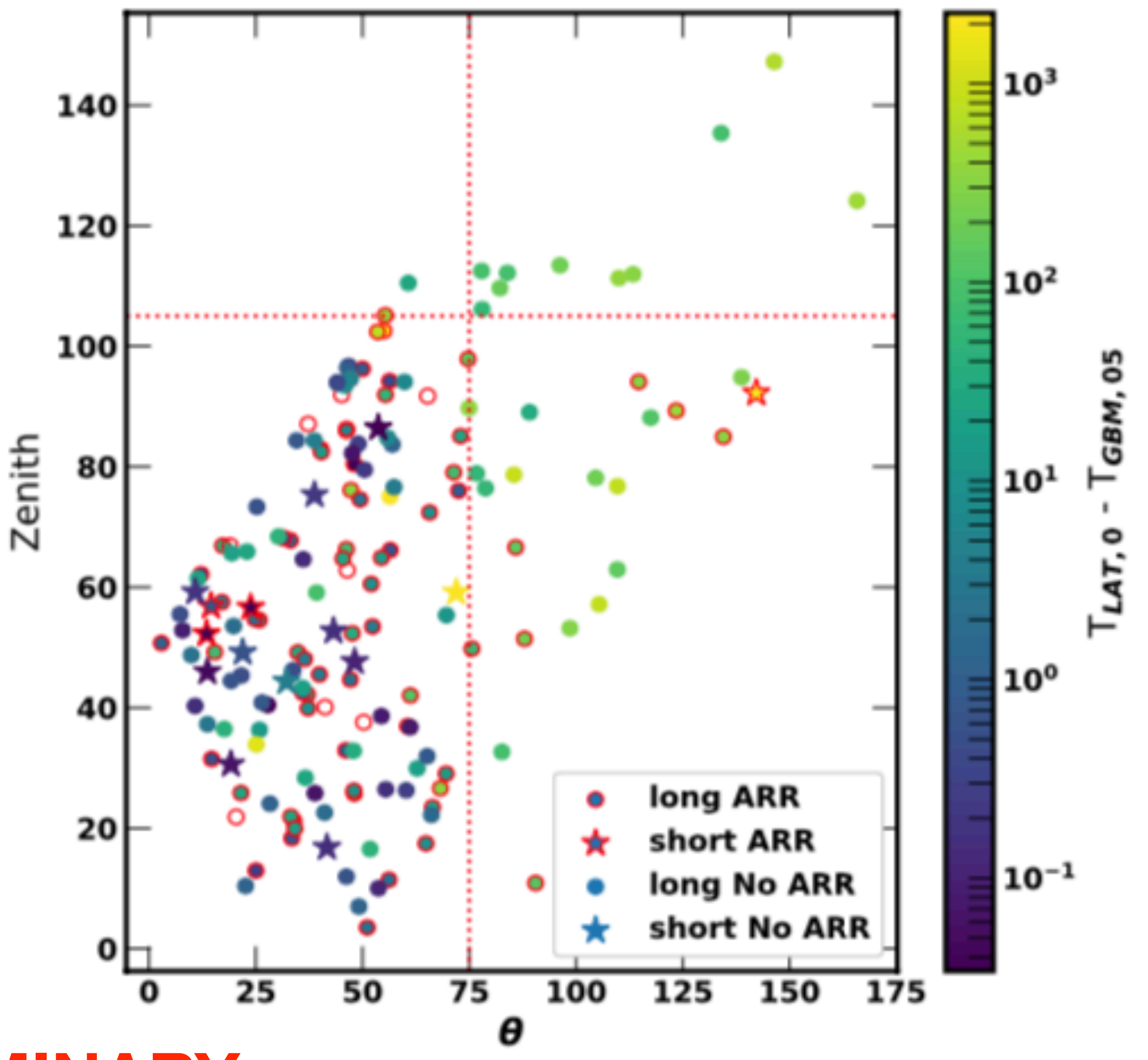


- High-energy emission (LAT) starts significantly after, and lasts significantly longer than lower-energy emission (GBM)
- The jet is "fast" for much longer than the prompt emission.

Effect of the rocking





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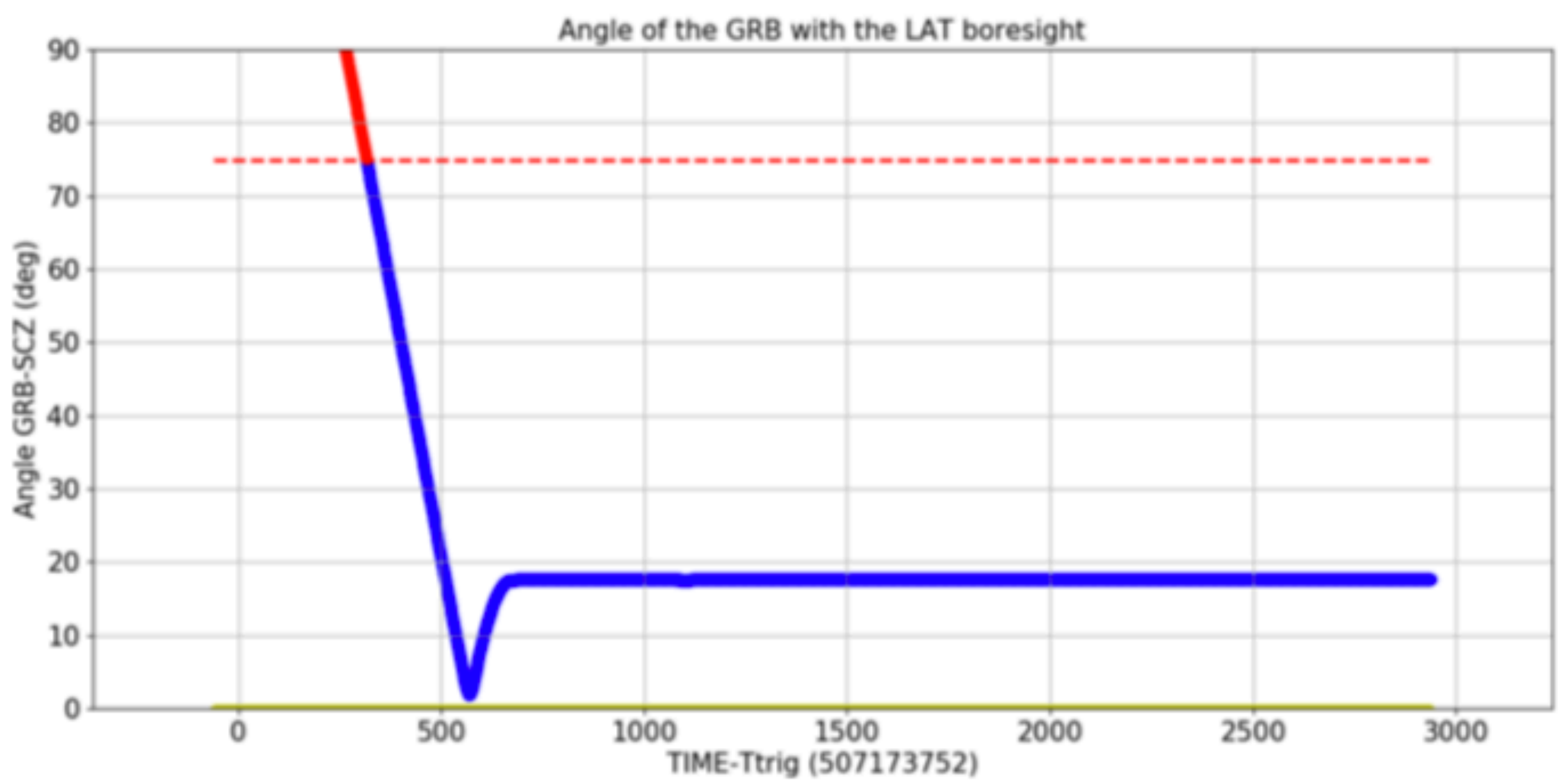
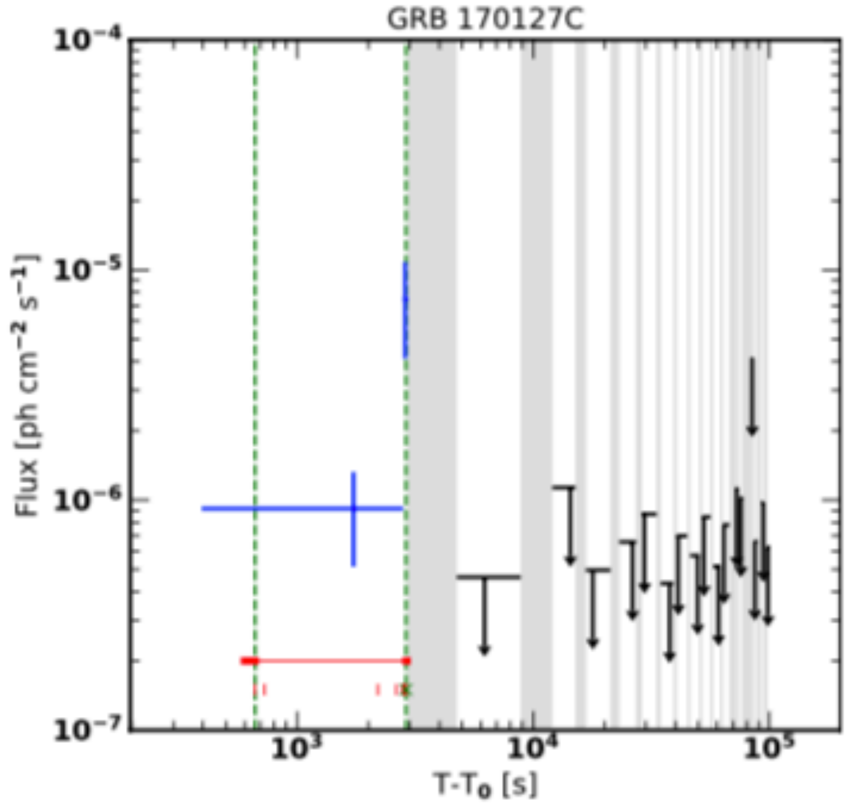
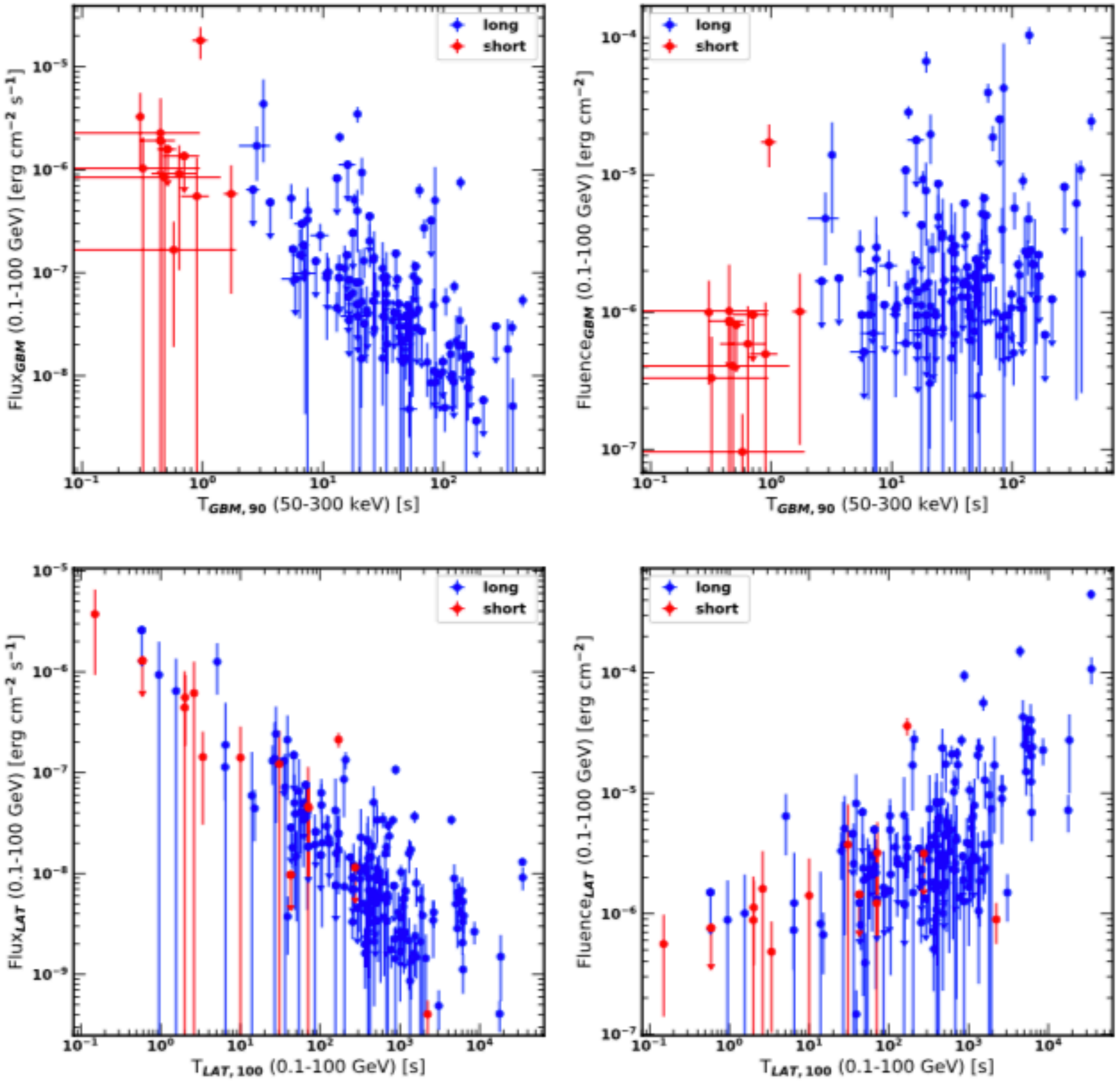




- **Some GRB were outside the LAT field of view, and reentered at later times**
  - **Onset is expected, but due to a biased observation;**
  - **ARR helps to detect these GRBs**
- **In most of the cases, the high-energy emission is “genuinely” delayed**
  - **GRB was in the LAT field of view at the time of the trigger;**

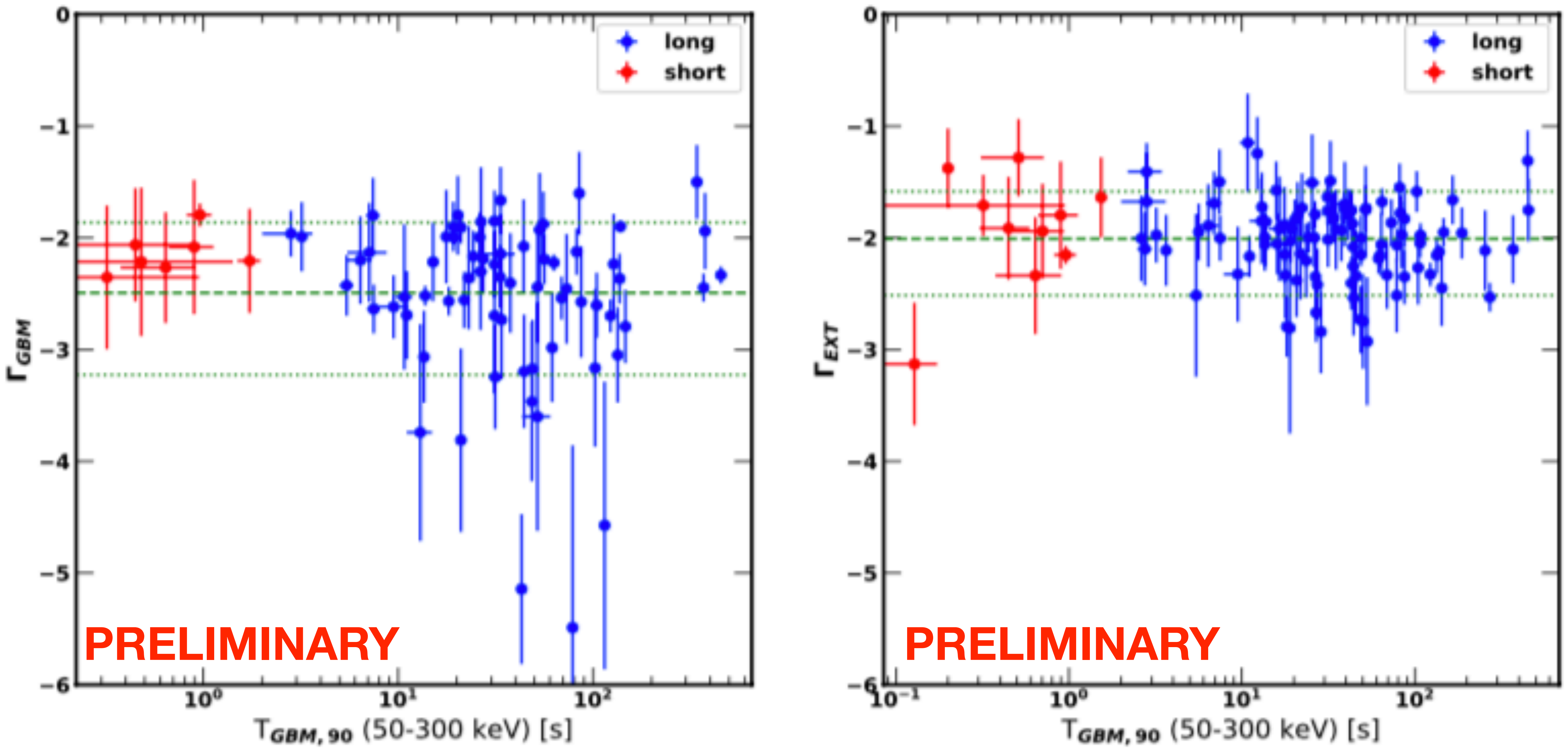
Fluxes & fluences

PRELIMINARY



- Some exceptionally bright GRB: also one short (090510), but all compatible with one class (no more super-GRBs);
- At high-energy: longer GRB are also the most energetic
  - Sustained jet emission? Environment?

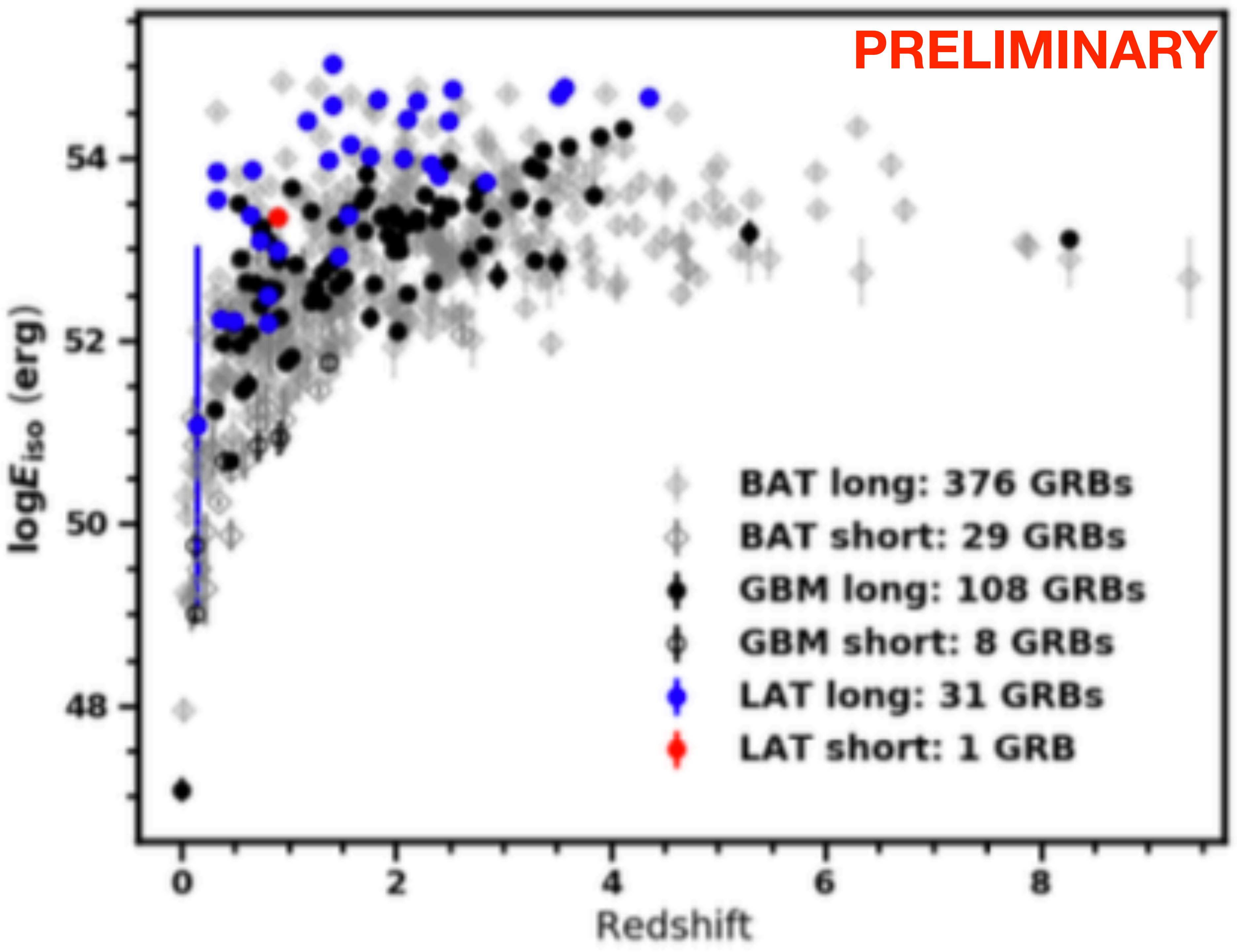
Spectral variability during the prompt phase vs late times

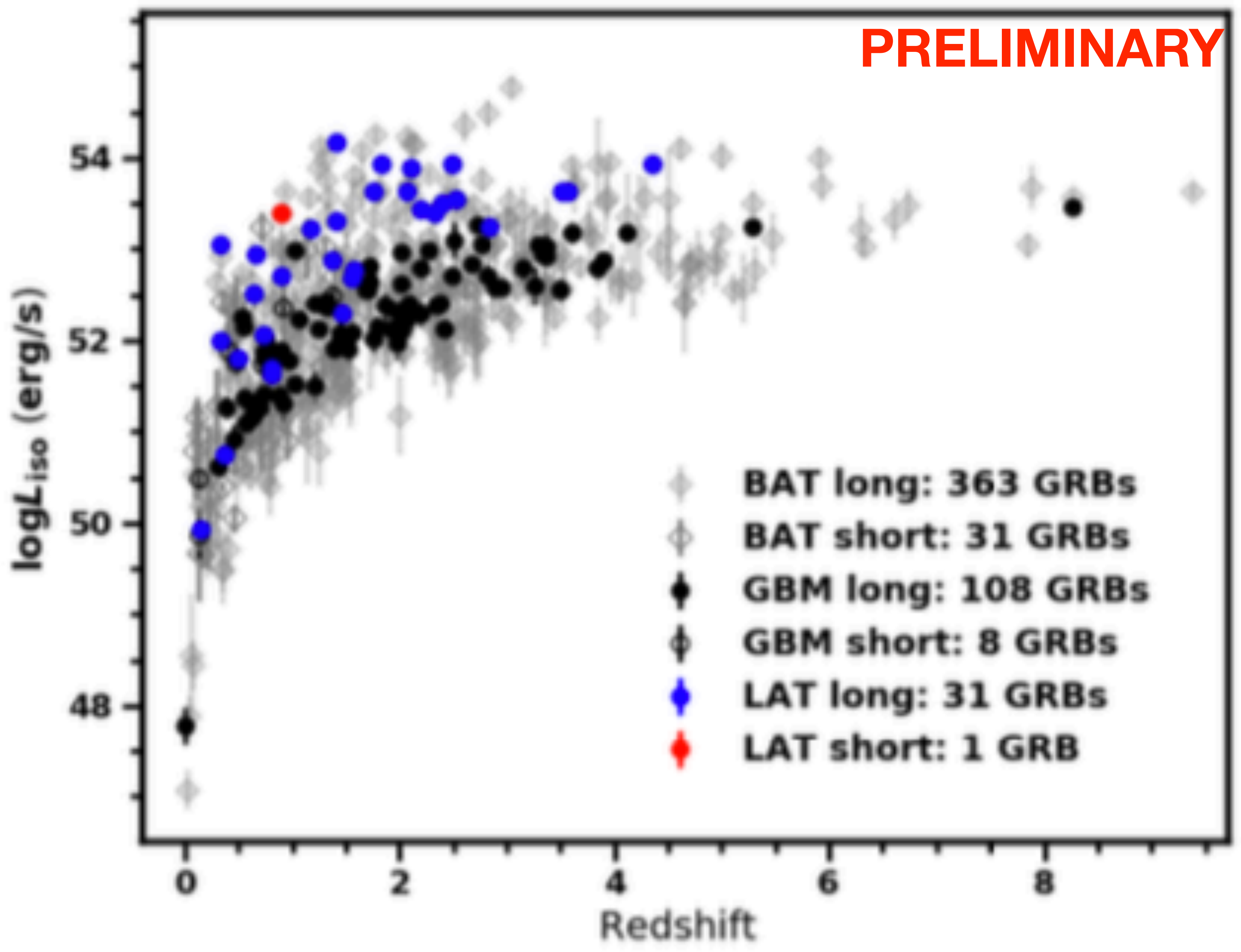


- **Larger burst-to-burst spectral variation during the GBM prompt emission**
- **At later time, quite consistent with photon index gamma^-2**
- **Combining spectral information (gamma) with decay index (alpha) we can test closure relations:**
  - **81% of the LAT GRB can be classified using a particular closure relation**
  - **2/3 prefers ISM model**
  - **1/3 either wind or ISM**
  - **GRB that can't be classified with closure relation tend to show a slower decay (continuous energy injection?)**

Intrinsic properties

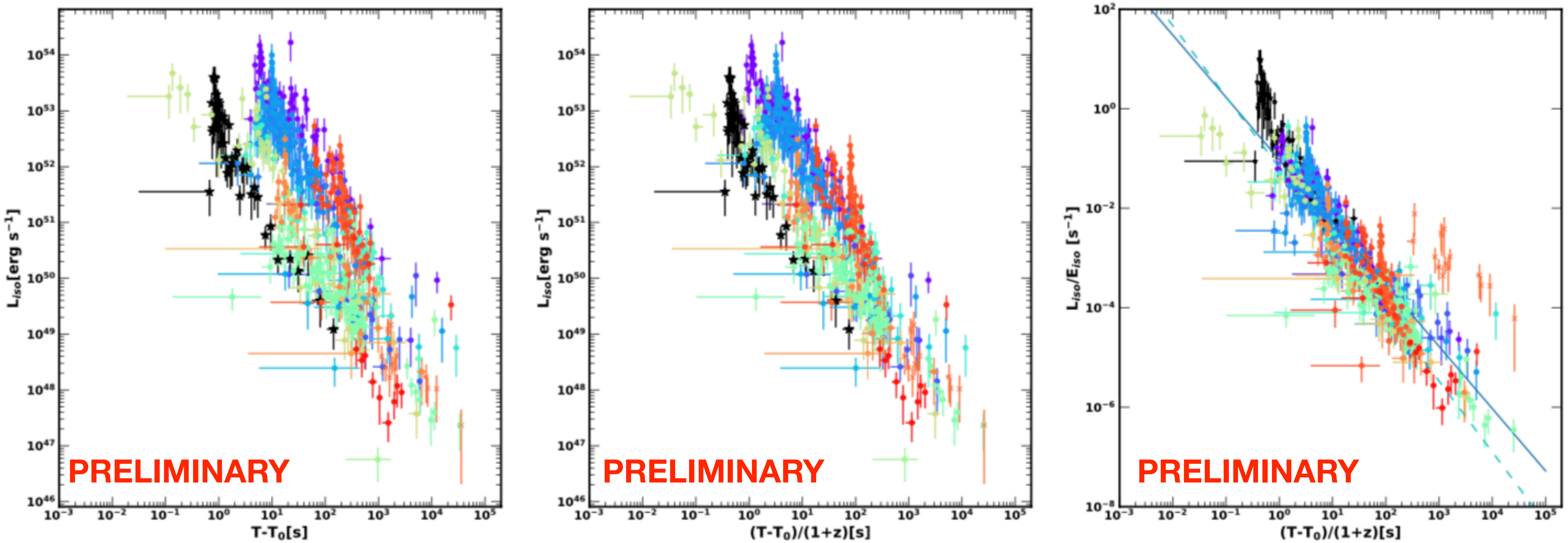
1keV - 10 MeV intrinsic





- **35 GRB have redshift informations:**
  - **LAT detects the intrinsically most energetic GRB**
  - **Not necessarily the closest one (GRB080916C at z=4.35)**

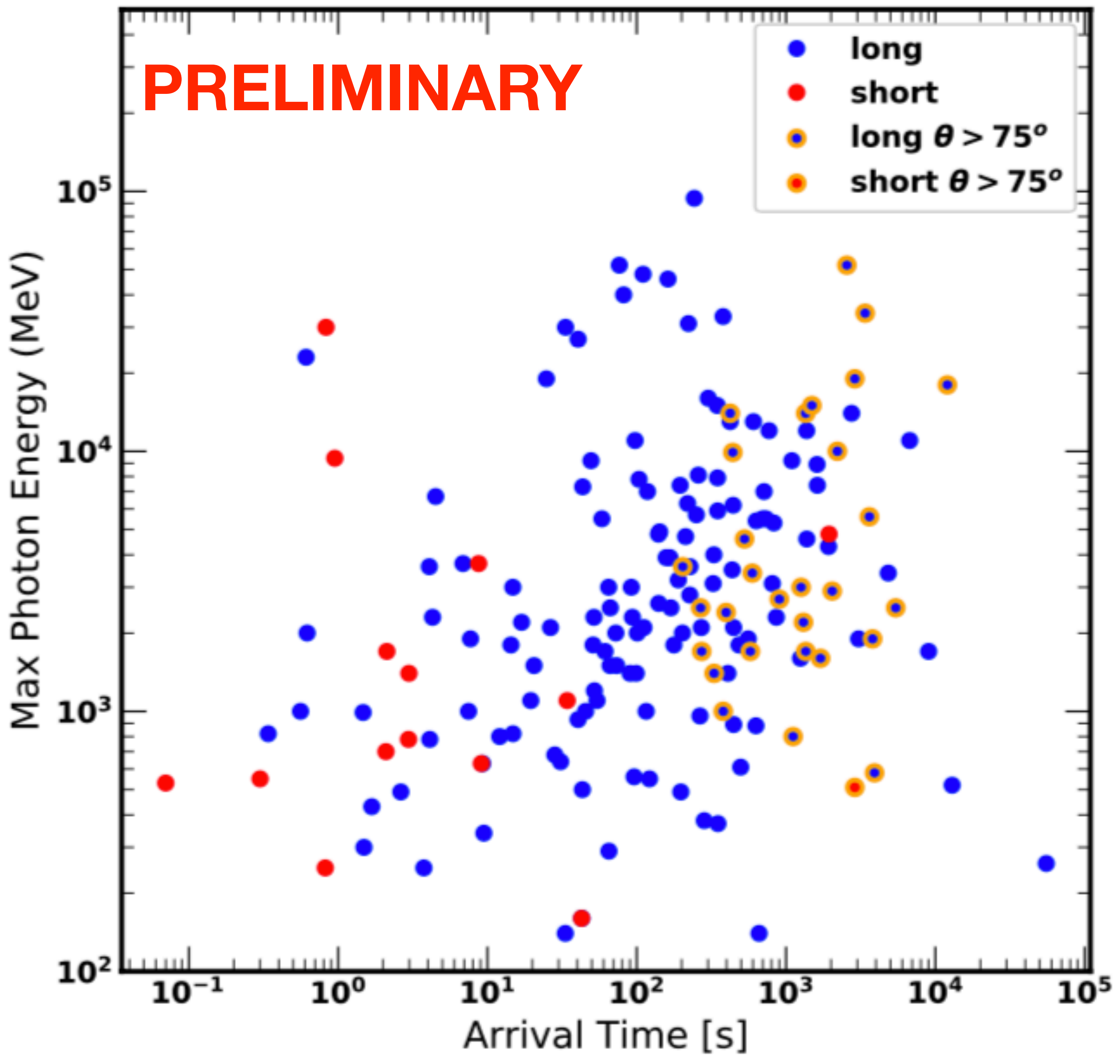
Rest frame high energy light curves

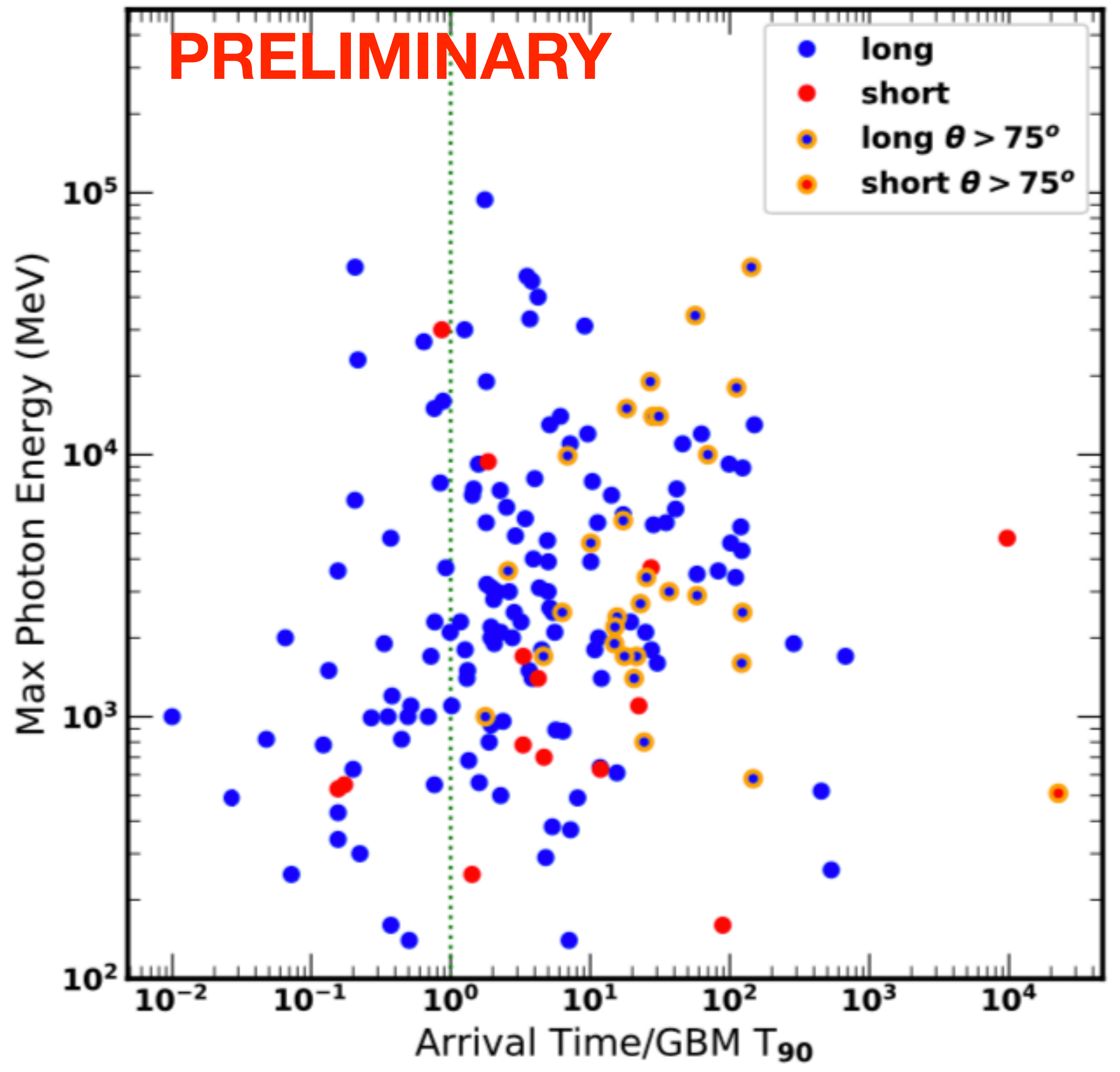


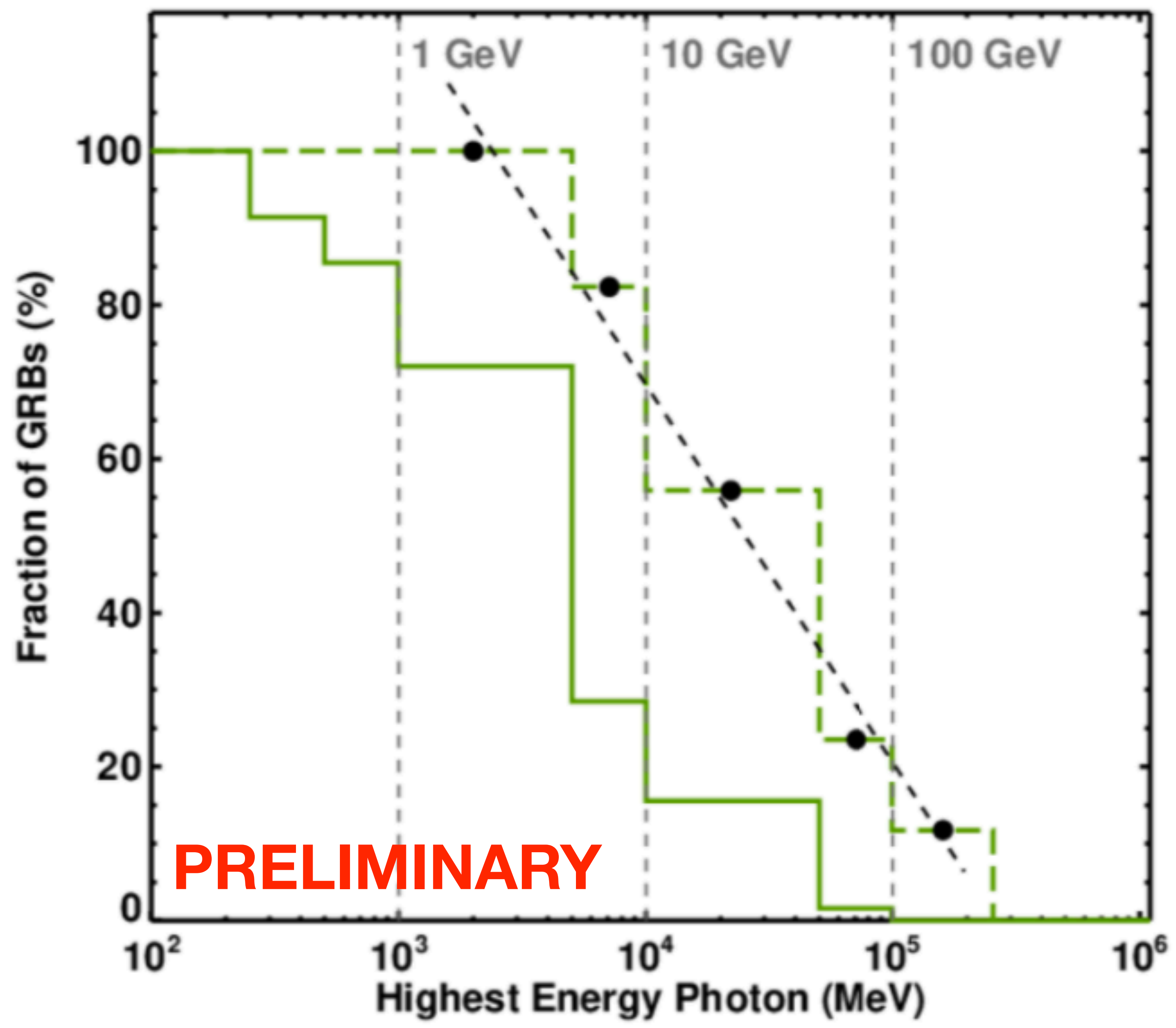
- Observed clustering of the light curves when divided by the isotropic energy in the GBM emission (repeating the Nava et al. 2014)
  - Solid blue line: best fit model with alpha=1.25
  - Dashed line: alpha=10/7: Fast cooling from a radiative fireball in a constant density environment (Sari 1997; Katz & Piran 1997; Ghisellini et al. 2010).

High-energy events and prospects for Cherenkov telescopes

- LAT detected events up to 100 GeV, and most of them arrived after the end of the GBM emission
- Source-frame-corrected: 10% of the GRB emitted events >100 GeV



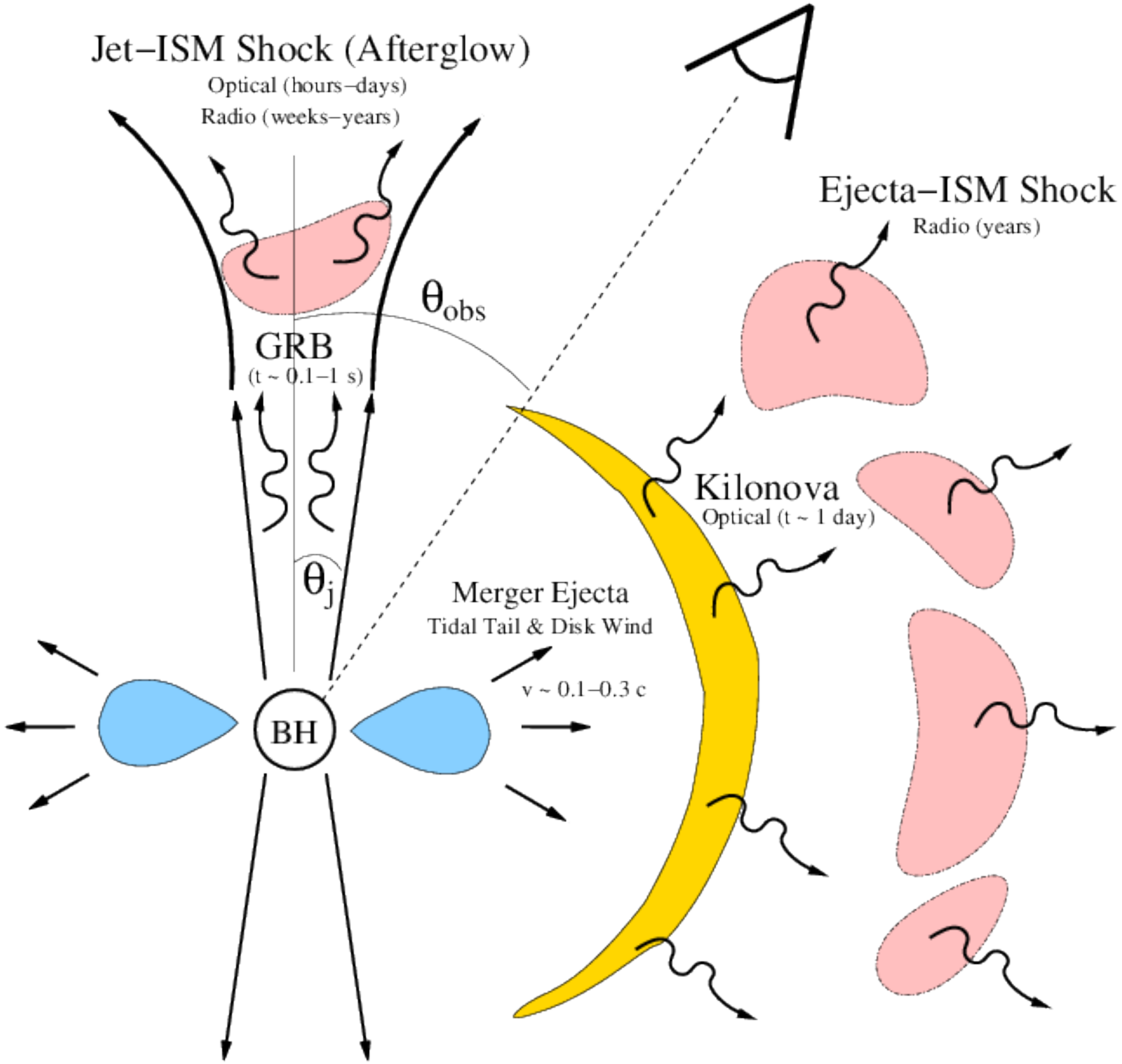




- Efficient acceleration of particles at later times: good case for CTA (see also MAGIC detection of GRB190114C at 300 GeV)

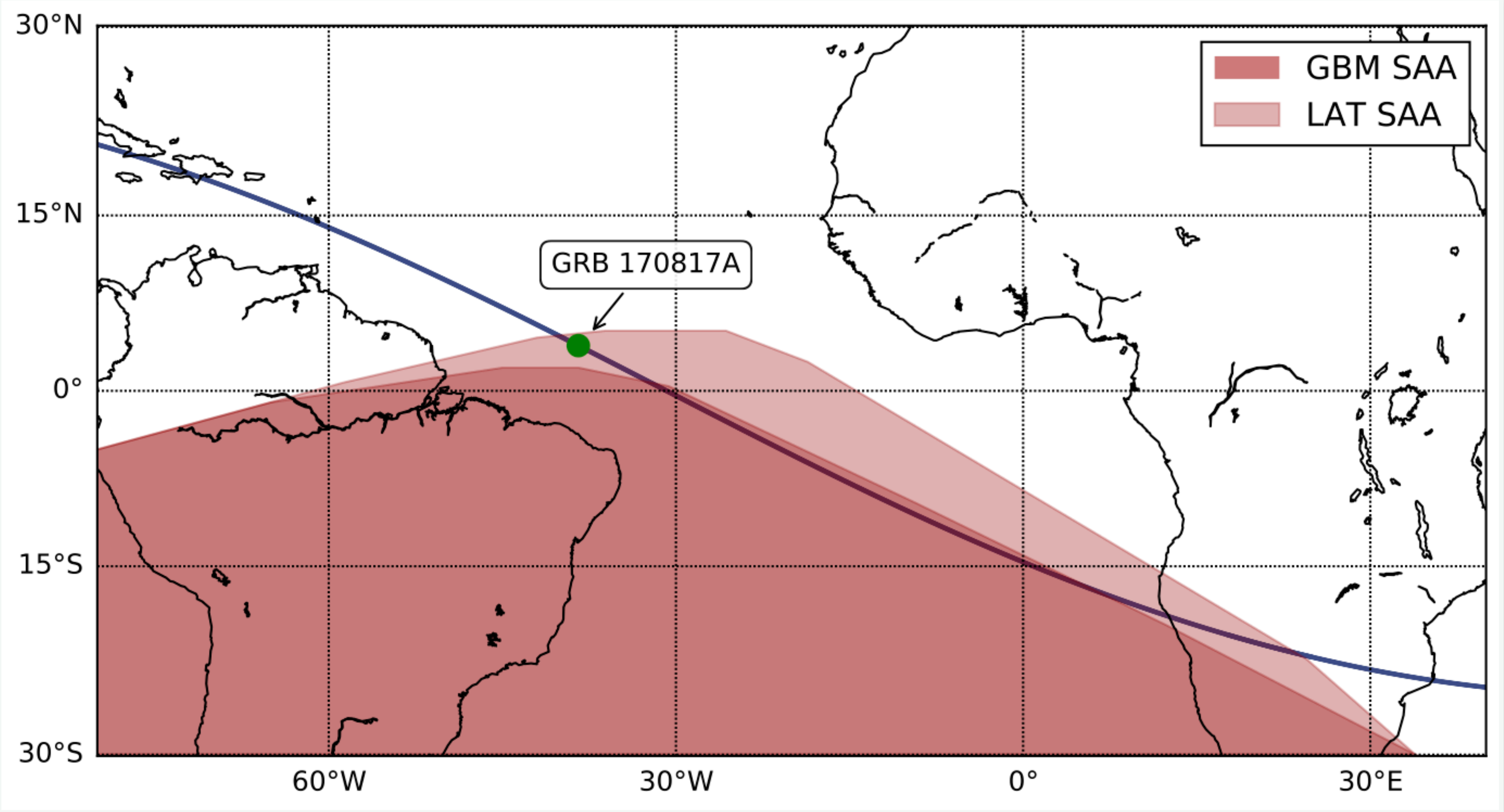
Short GRB associated with GW events

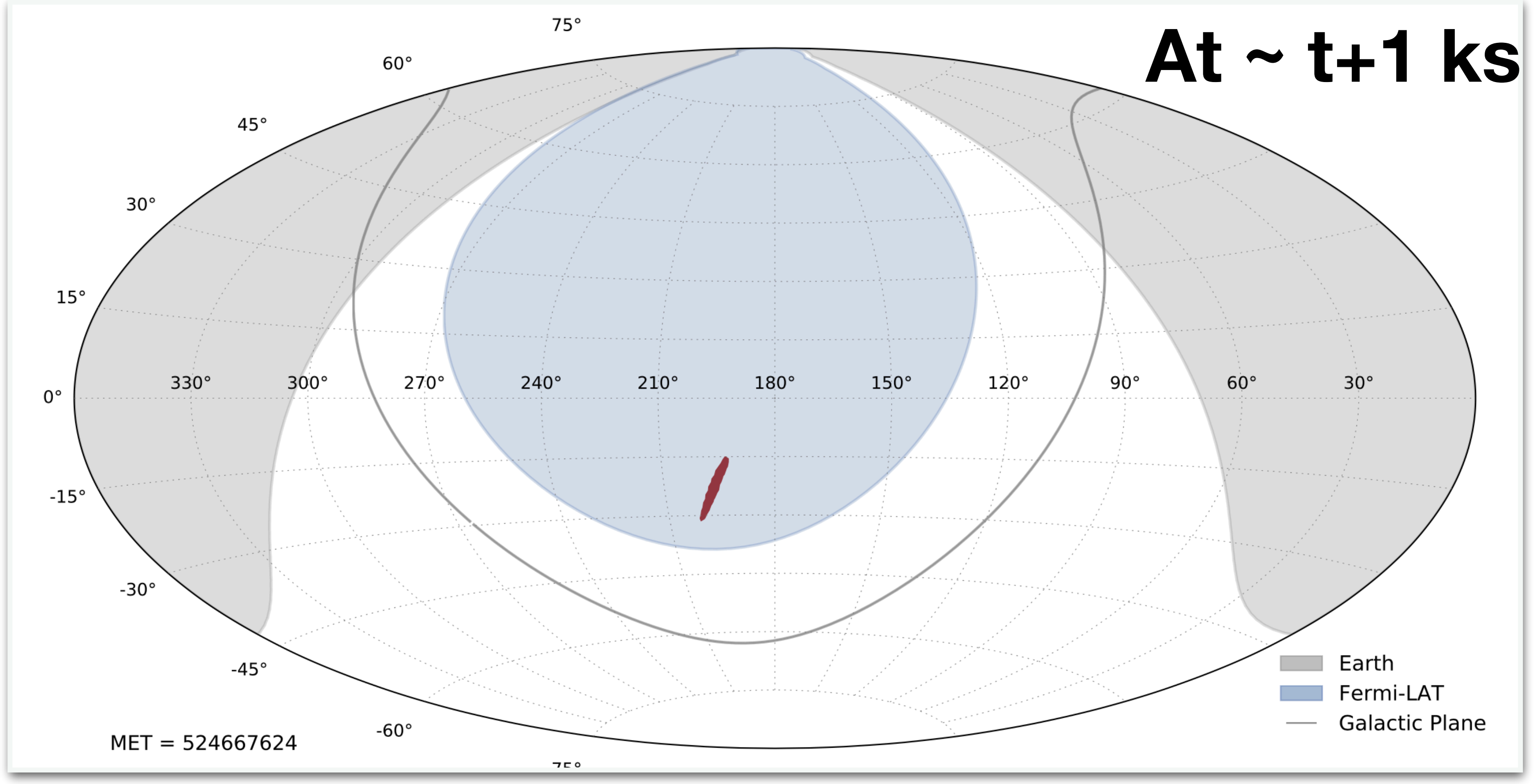
- **Short GRB in a nutshell:**
  - **Progenitors: NS-NS, NS-BH -> BH**
  - **On-axis sGRB:**
    - **More rare (needs to point toward us);**
    - **“Standard” afterglow due to the Jet-ISM interaction**
    - **Observed at high-energy by the LAT (17 sGRB detected by the LAT so far);**
    - **Temporally extended emission detected up to ~100 seconds after the trigger;**
  - **Off-axis:**
    - **No prompt or weak emission (GRB 170817) in <MeV (due to the beaming);**
    - **Isotropic optical bump (“kilonova”);**
    - **Late “orphan” X-ray afterglow (when the beaming decreases);**
    - **At high-energy: little is know…**



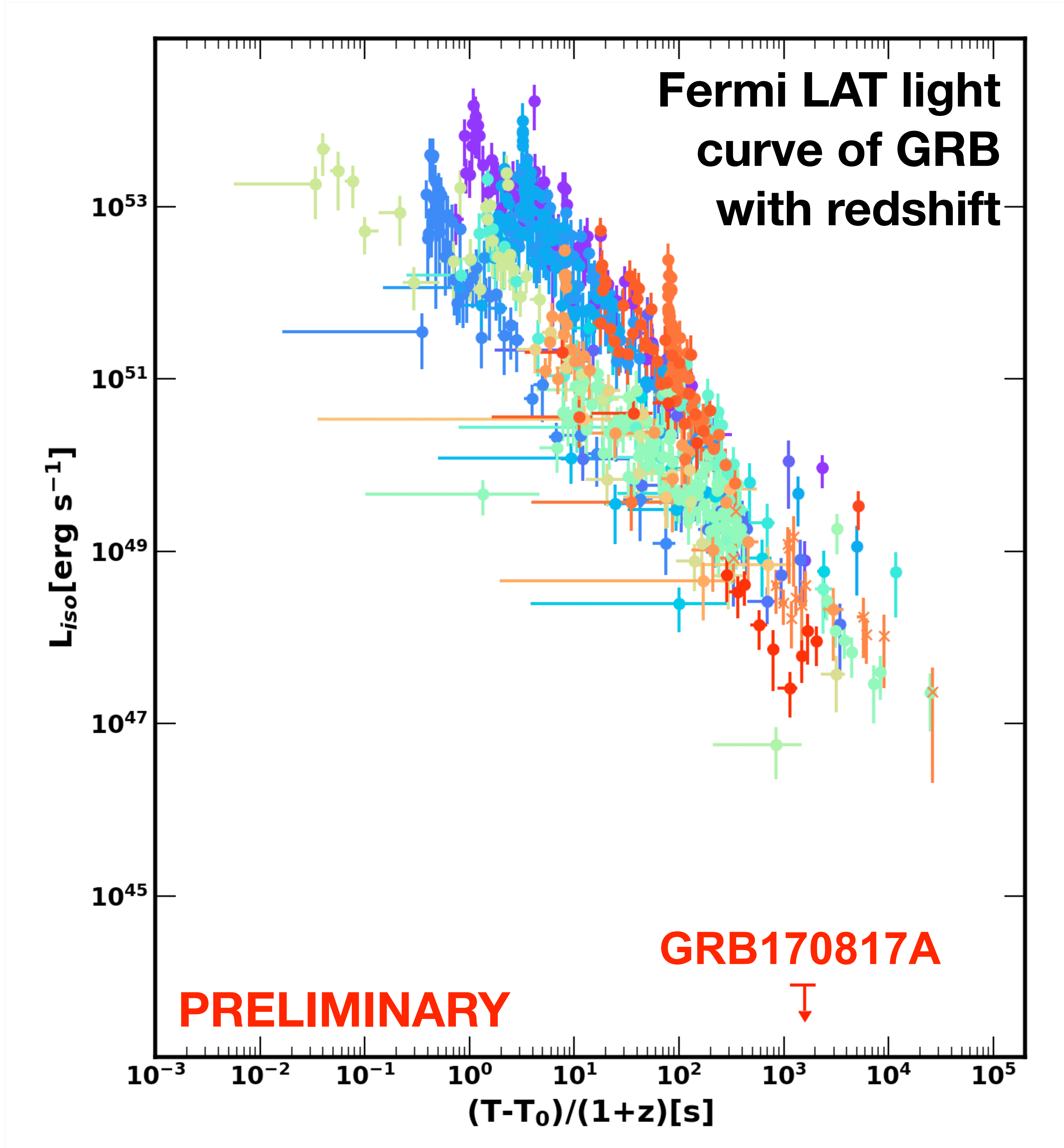
Metzger & Berger.

NS-NS merger GW/GRB170817A: an unlucky event for the LAT





- The LAT and the GBM do not collect data when in the SAA
  - For different instument requirements, the SAA definition for the LAT is slightly larger (14%) than the GBM one;
  - At the time of the GW event (and GBM trigger), the LAT was in the SAA;
  - We observe the entire region between t_{GW}+1153 – t_{GW}+2017;
  - Upper bound (0.1–1 GeV):
    - F < 4.5×10^{-10} erg cm^{-2} s^{-1}
  - At the distant of GW170817:
    - $L_{iso} < 9.3 \times 10^{43}$ erg s^{-1}



★ Very strong constrain on the luminosity of GRB170817A at high energy

Summary and conclusions

- LAT detects GRBs at high energy with an unprecedented sensitivity
- A 10-year catalog has been accepted for publication by ApJS, containing more than 180 GRBs, exceeding the expectations
  - Focused on observational features, it provides a lot of material to be used within the scientific community;
- High-energy GRBs are likely associated with the early afterglow phase of the expanding blast wave;
  - Delayed onset, temporally extended emission, adiabatic expansion (in the context of the fireball model).
  - Highest energy events arrive late, typically after the prompt emission: good news for CTA!

- Short GRBs also detected at high energy, and also exhibit temporally extended emission
  - Looking forward for more NS-NS events and their association with LAT GRBs: constrain on the geometry of the jet and on the energetic of the blast wave;
  - Even upper limits are very constraining (due to the proximity of these events).