Terrestrial Gamma-Ray Flashes
(TGFs)

G. J. (Jerry) Fishman
NASA-Marshall Space Flight Center
Huntsville, AL USA

Thunderstorms and Elementary Particle Acceleration
(TEPA 2010)
Nor Amberd, Armenia
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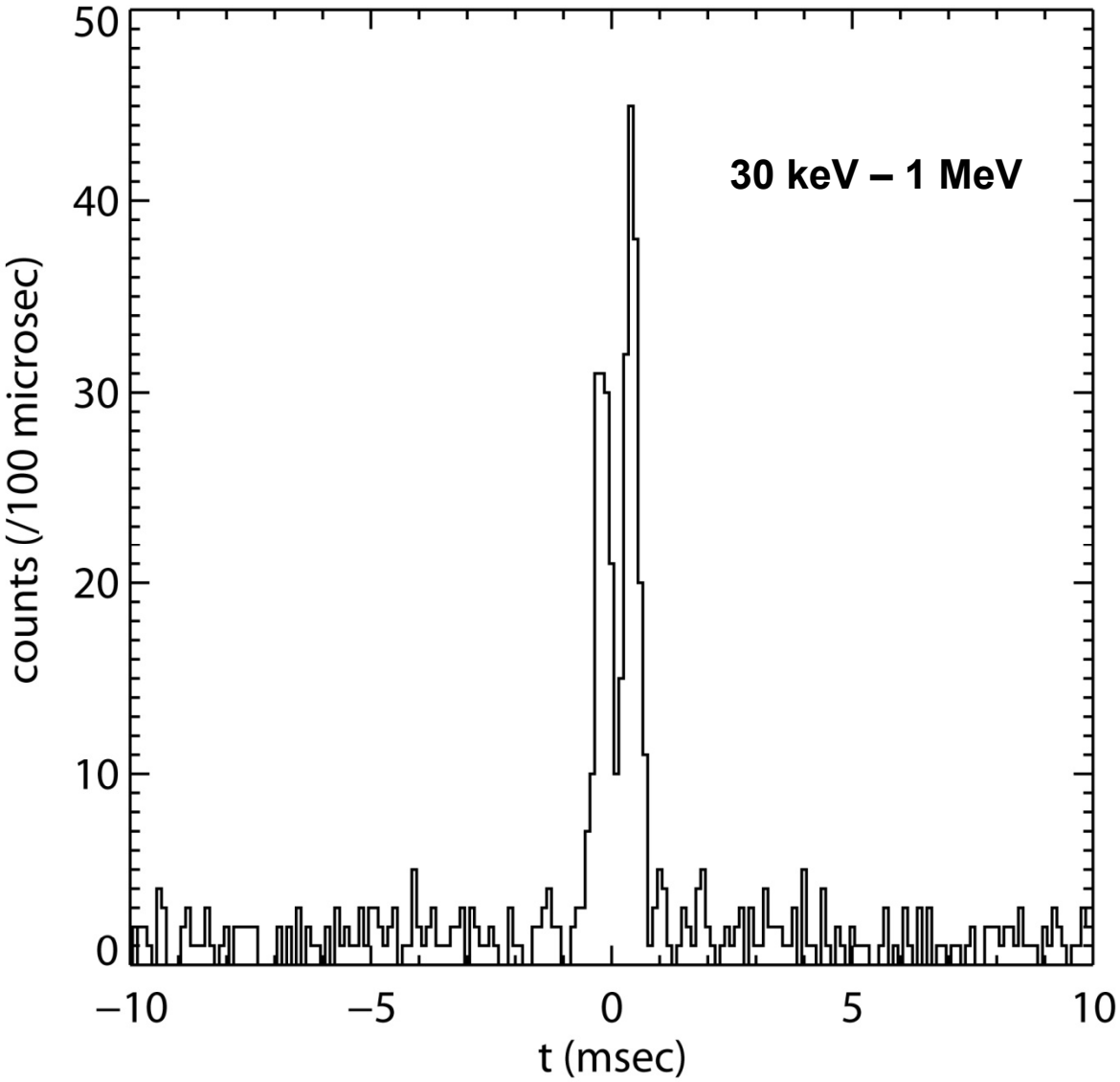
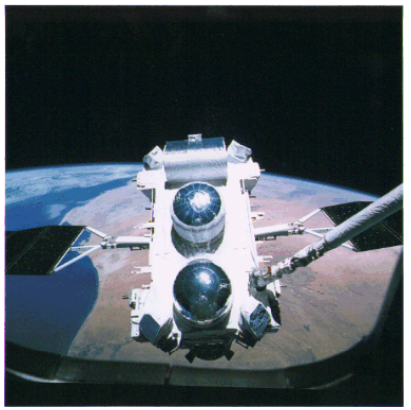
TGFs - Overview & Some New Results

- **History; Spacecraft observations**
- **Observations from Fermi-GBM**
- **Future Space Missions**

CGRO/BATSE Terrestrial Gamma-ray Flash (TGF)



Observations of TGFs with Four Spacecraft:



I. BATSE /Compton Observatory: 1991-2000

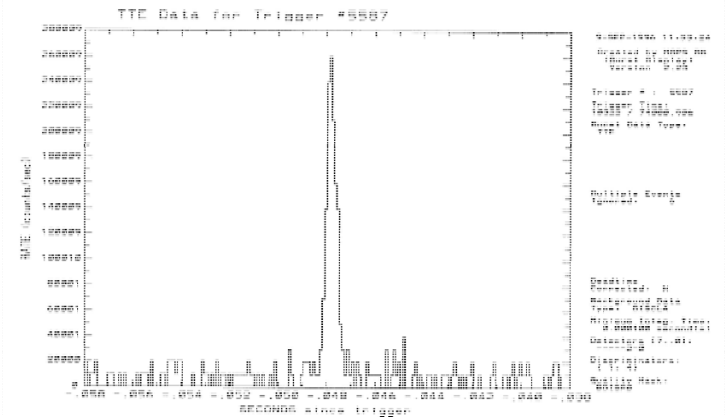
II. Solar Spectroscopic Imager

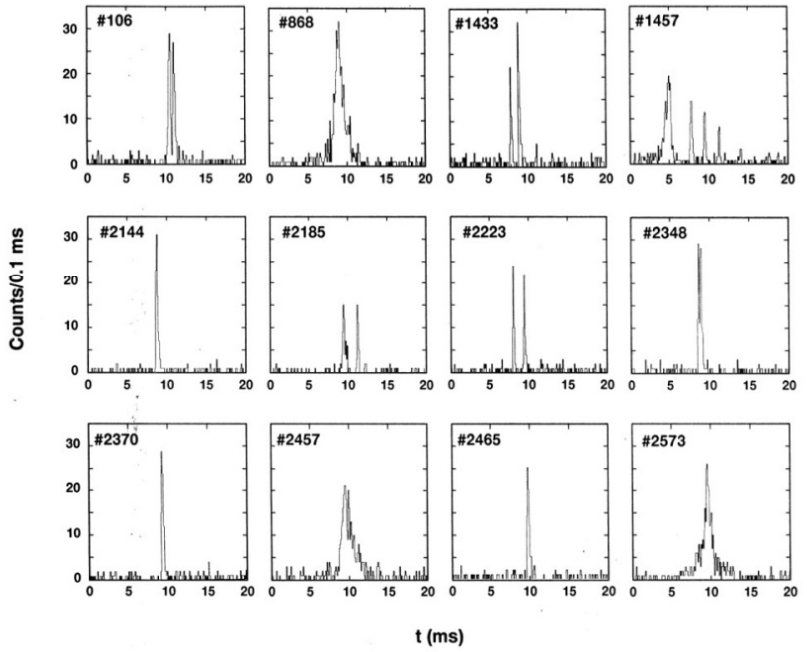
III. AGILE Gamma-ray Telescope

IV. <u>Gamma-ray Burst Monitor (GBM) on the Fermi Gamma-ray Space Telescope</u>

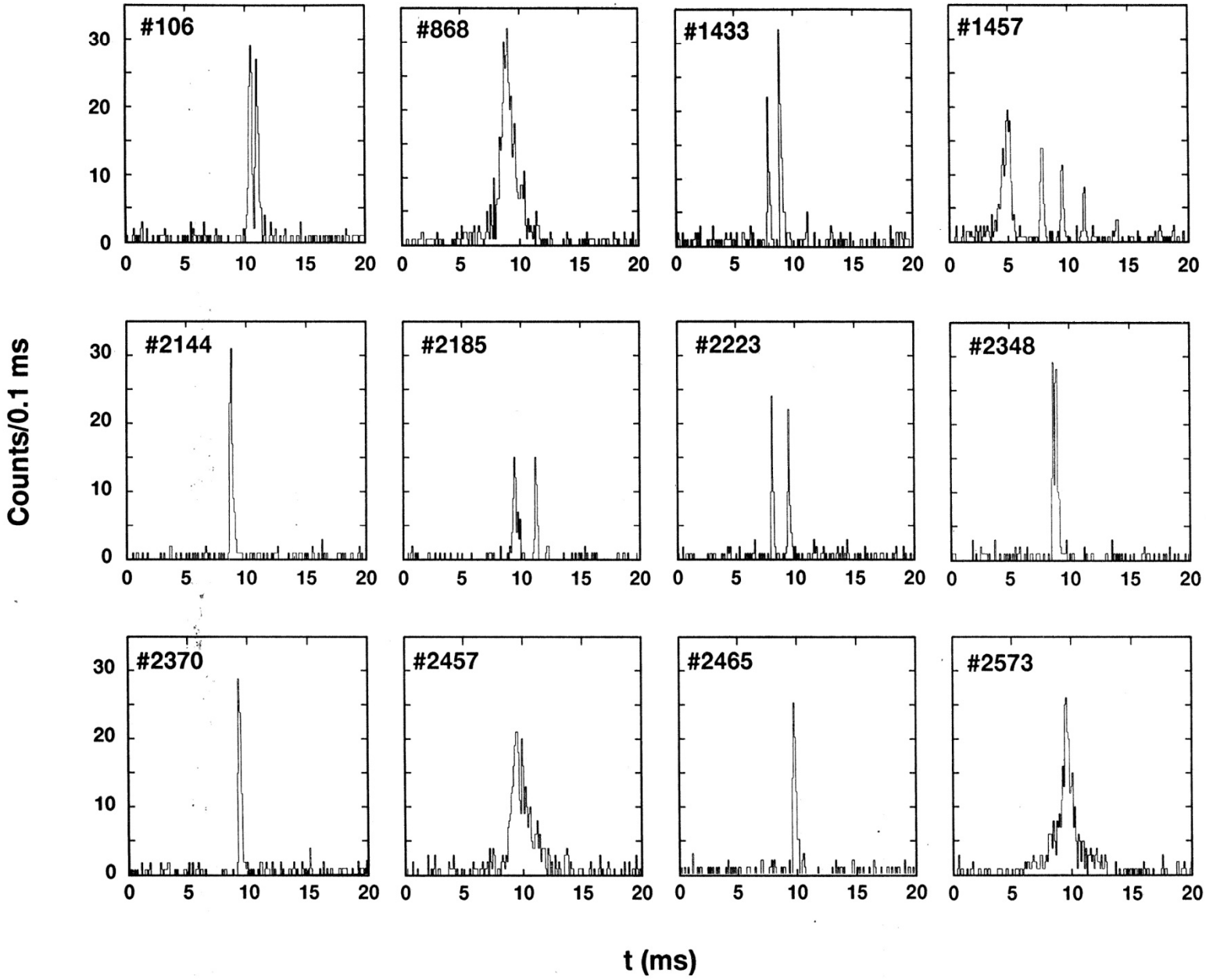
BATSE TGFs:

- Determined rough spectral properties (extremely energetic)
- Associated with thunderstorms
- Observed 78 in 9 years





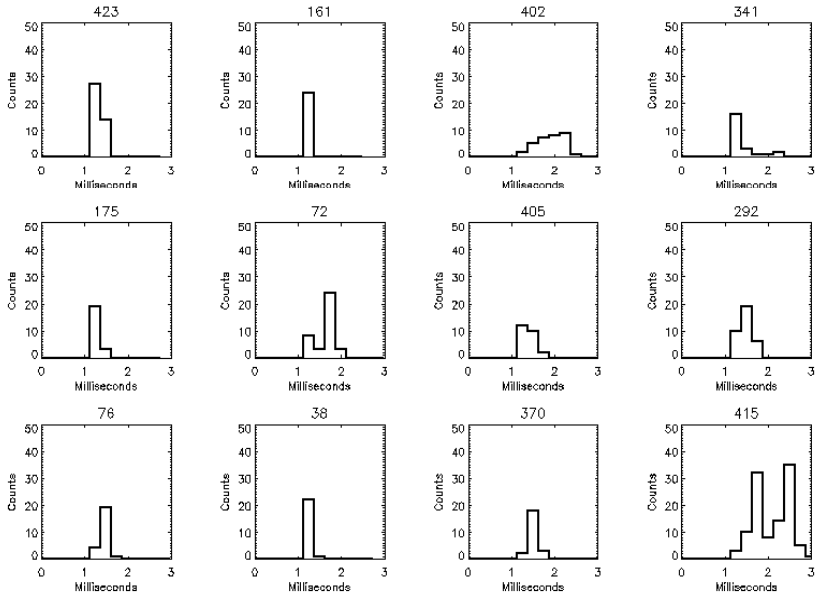
TGFs from BATSE (showing saturation at ~300,000 cps)

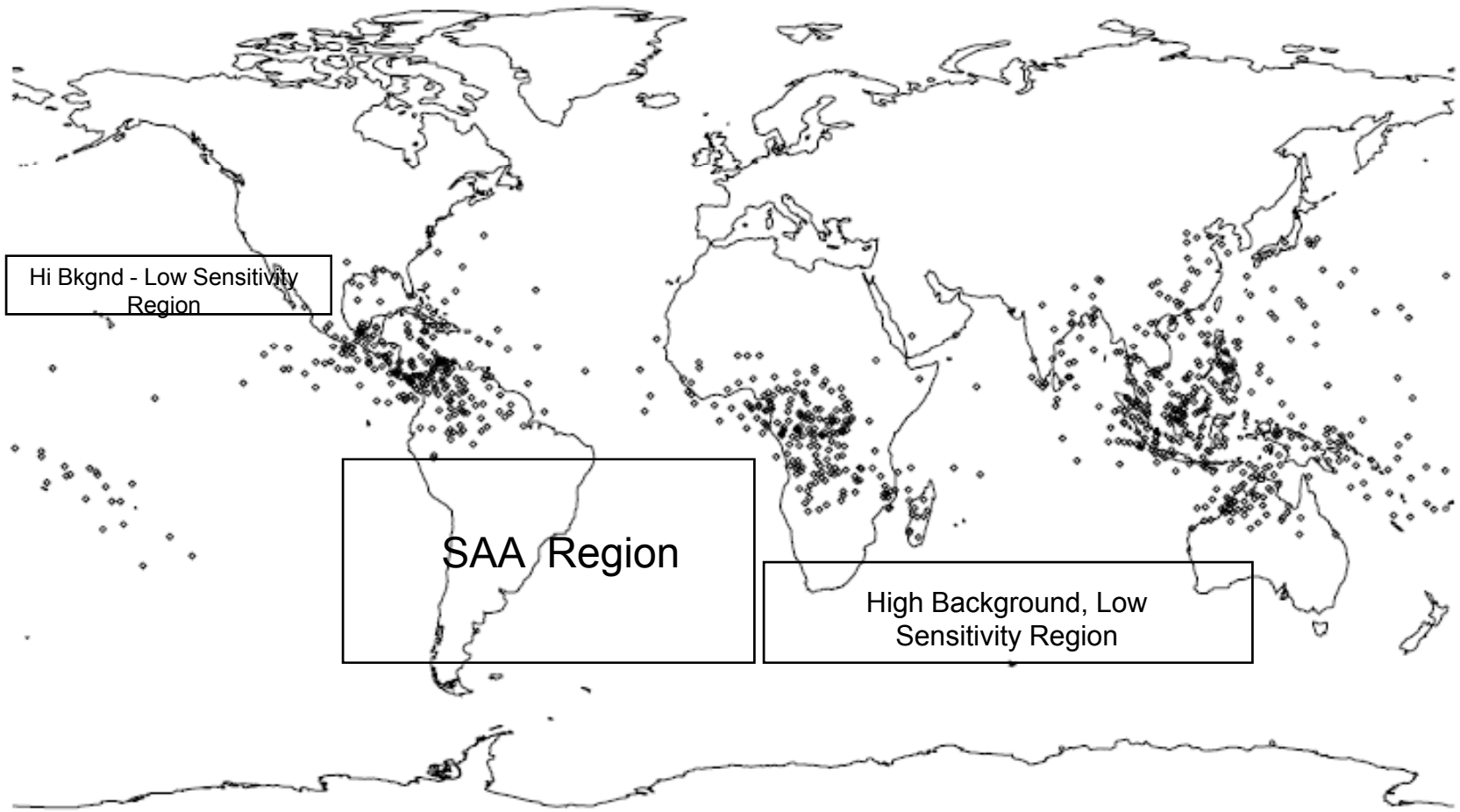


RHESSI Observations:

- Doesn't require trigger; all data are transmitted
- Detected many more TGFs than BATSE, but they were much weaker
- Determined very hard spectra (> 20 MeV)

Time Profiles of some RHESSI TGFs:

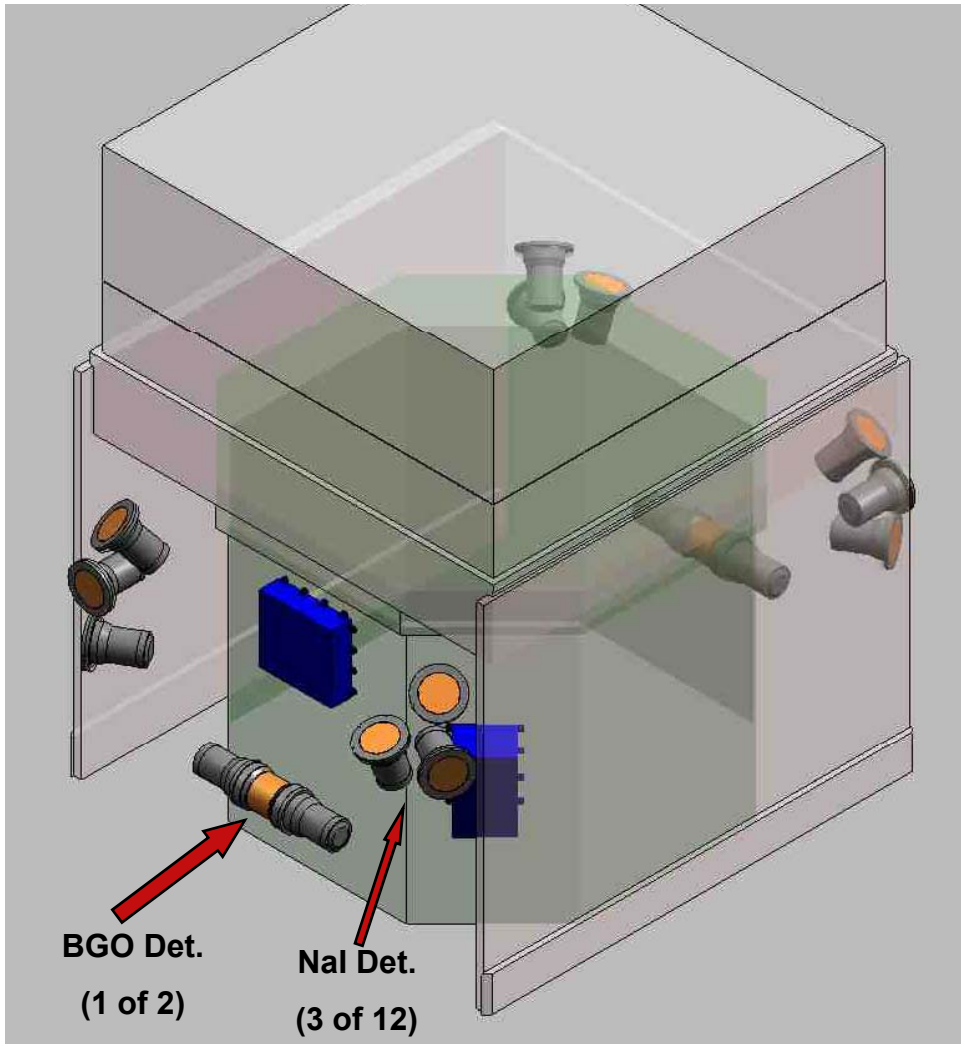




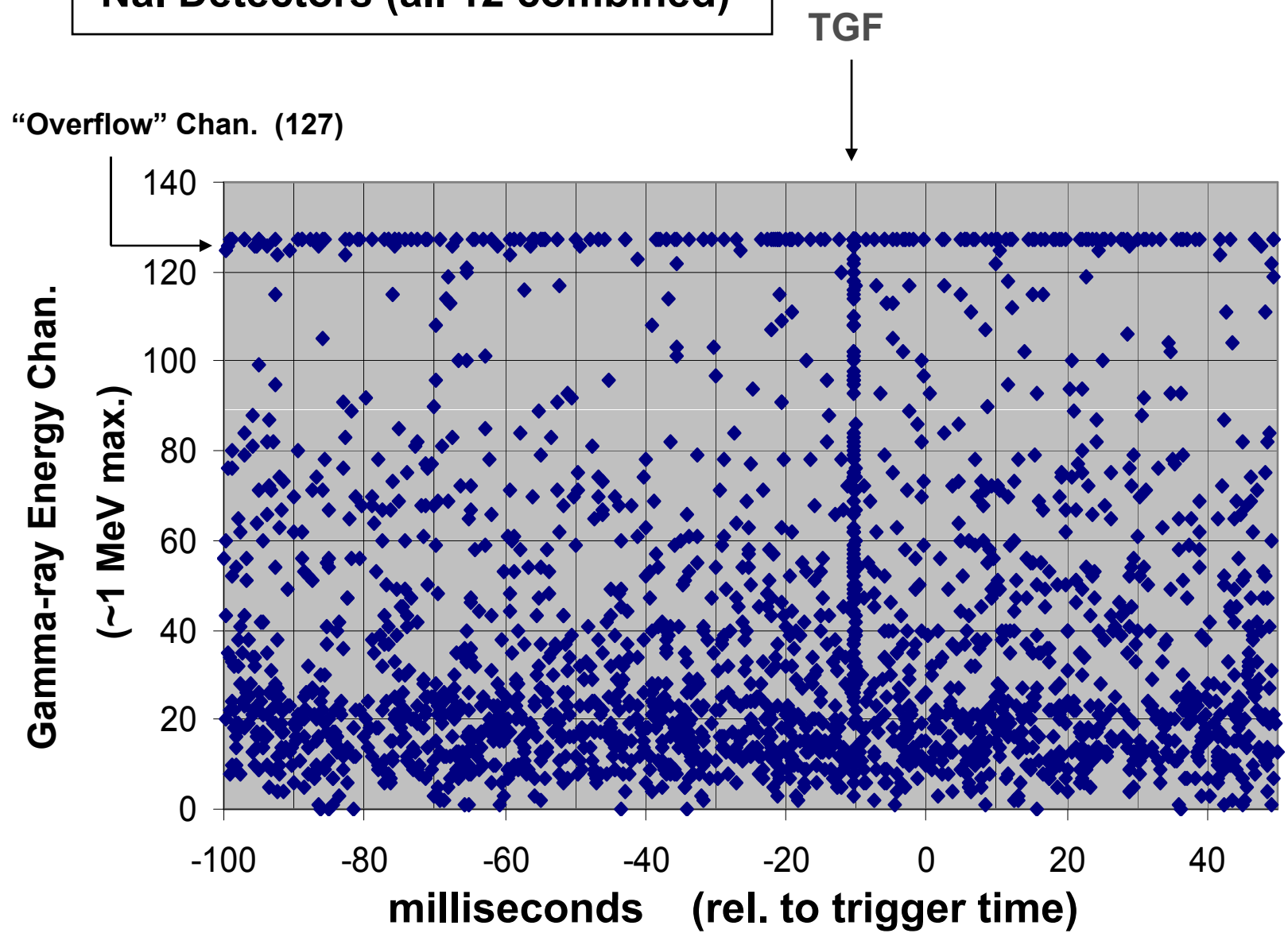
Map of RHESSI TGFs (820 events)

Gamma-ray Burst Monitor (GBM)

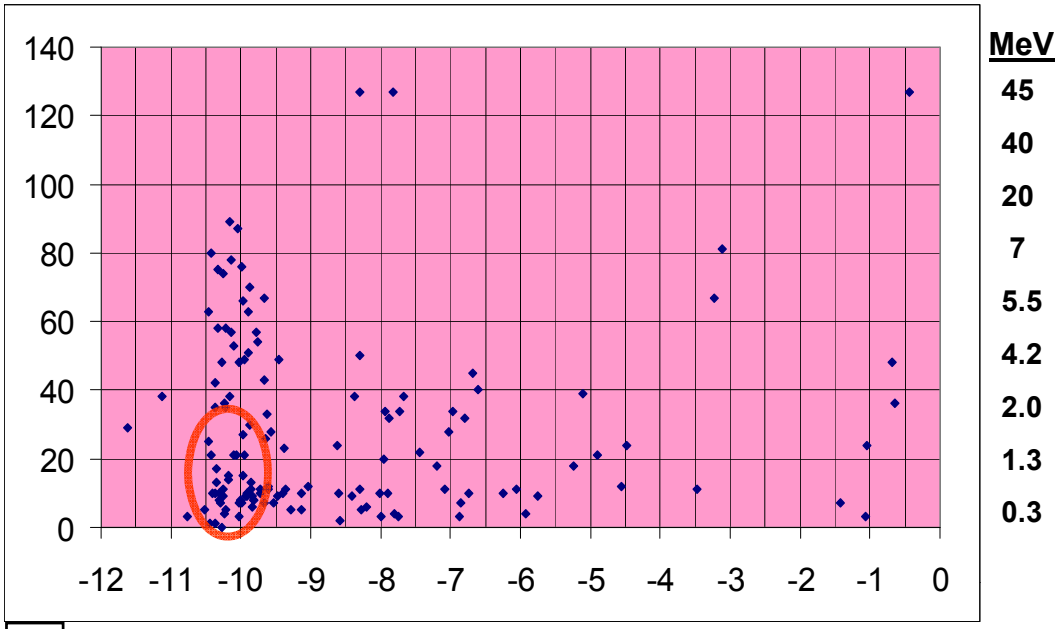
Detector Locations on the Fermi Spacecraft – Launched June 2008



NaI Detectors (all 12 combined)



Spectral Differences



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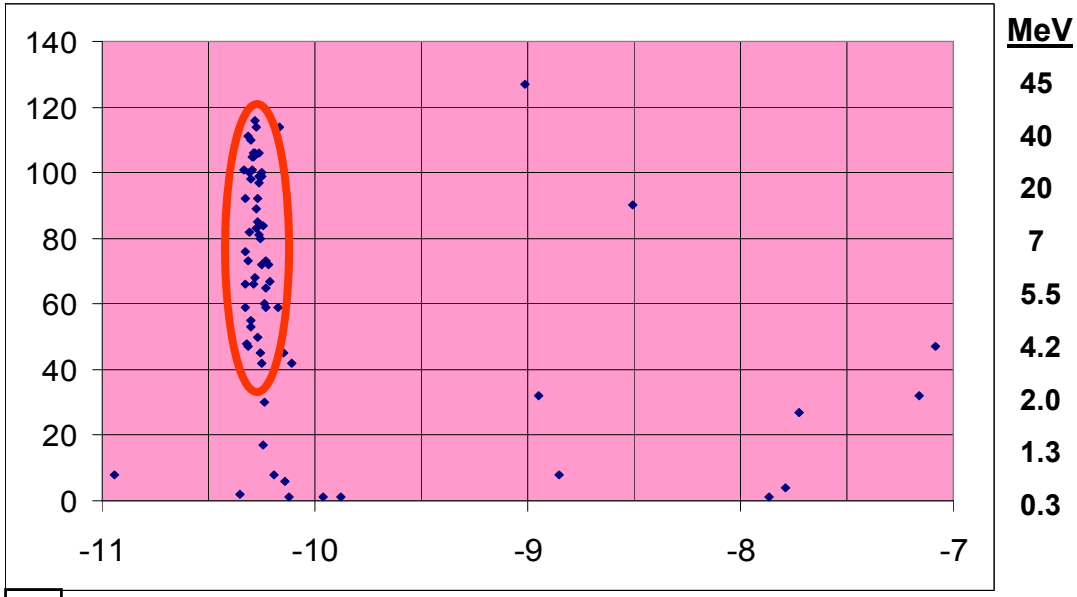
TGF #1:

Low energies dominate



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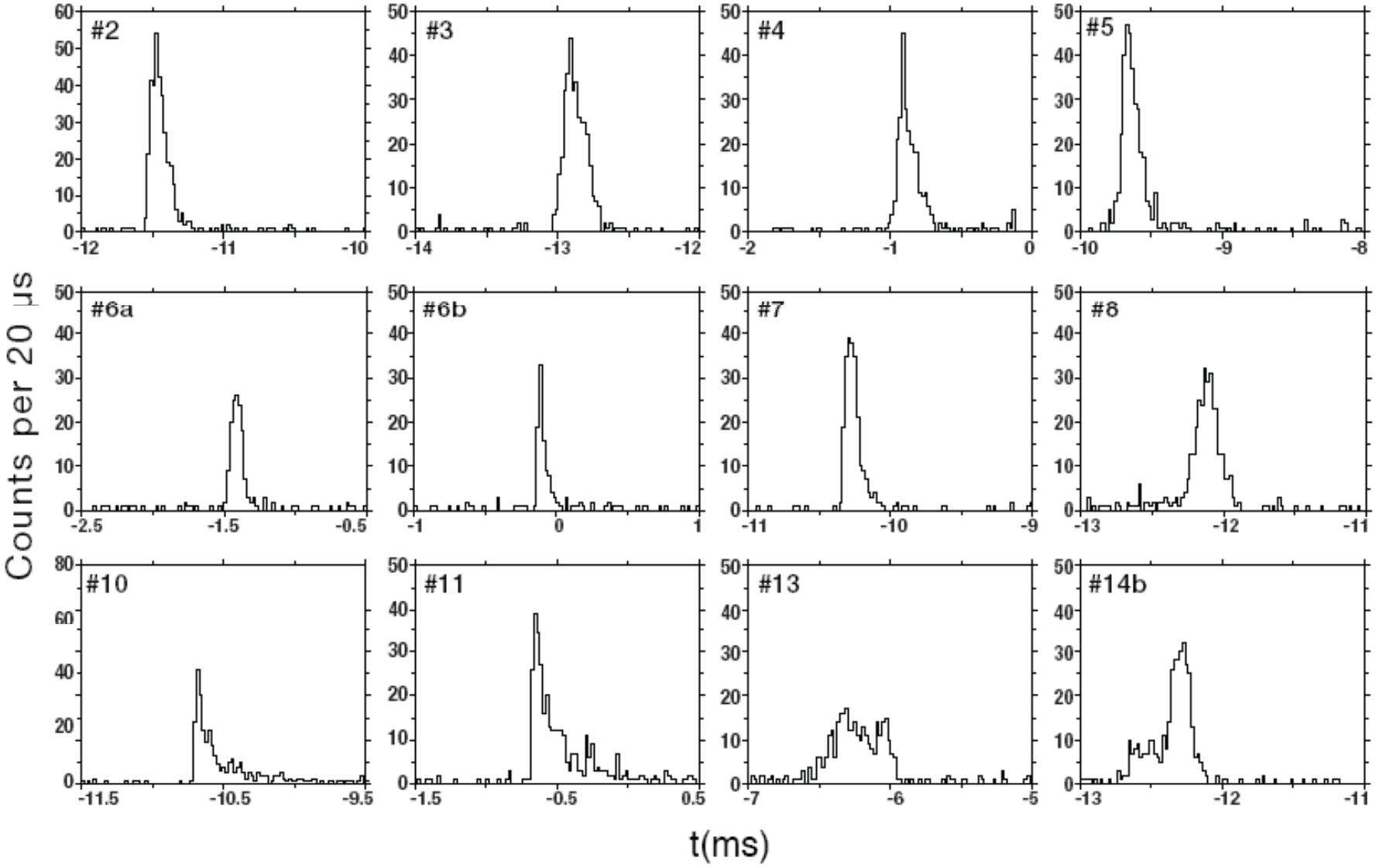
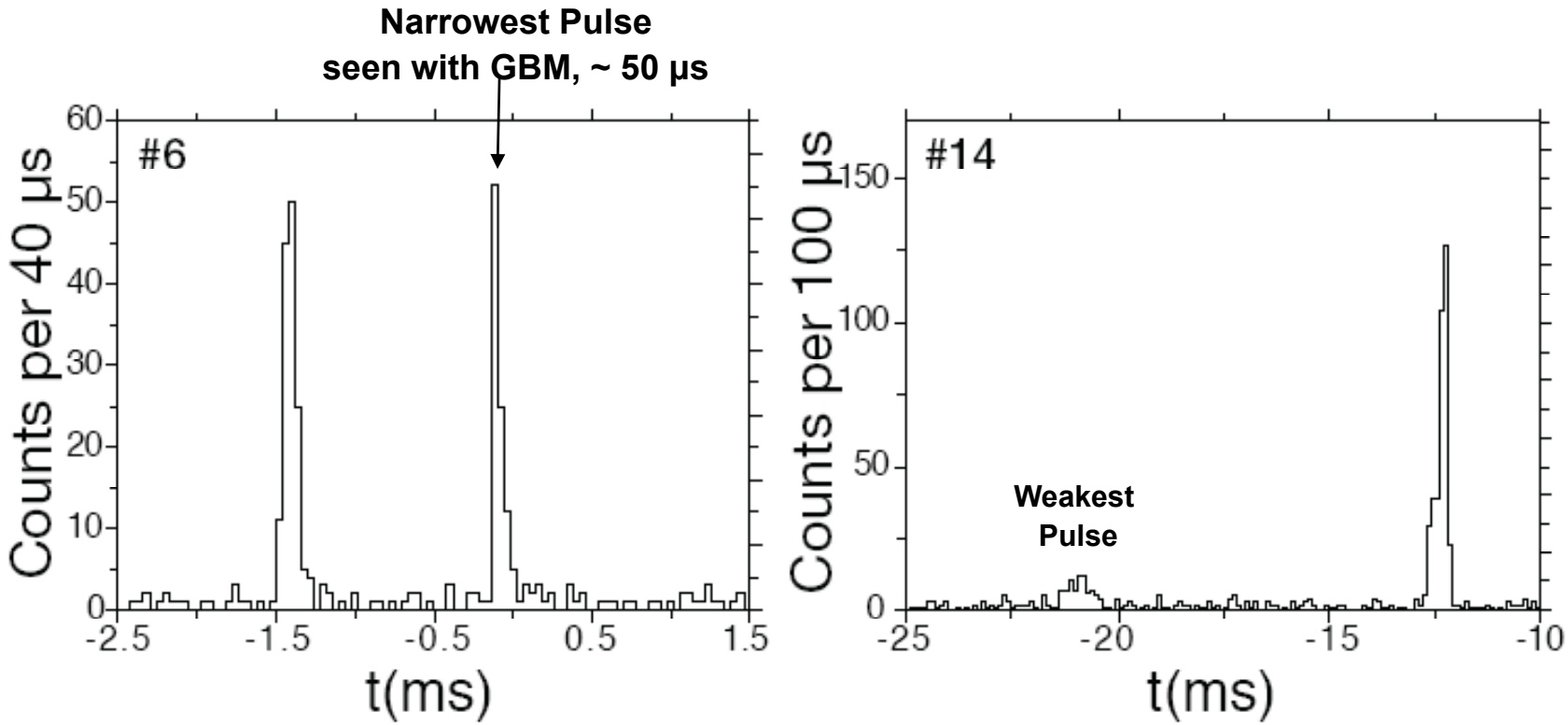
TGF #7:

High energies dominate

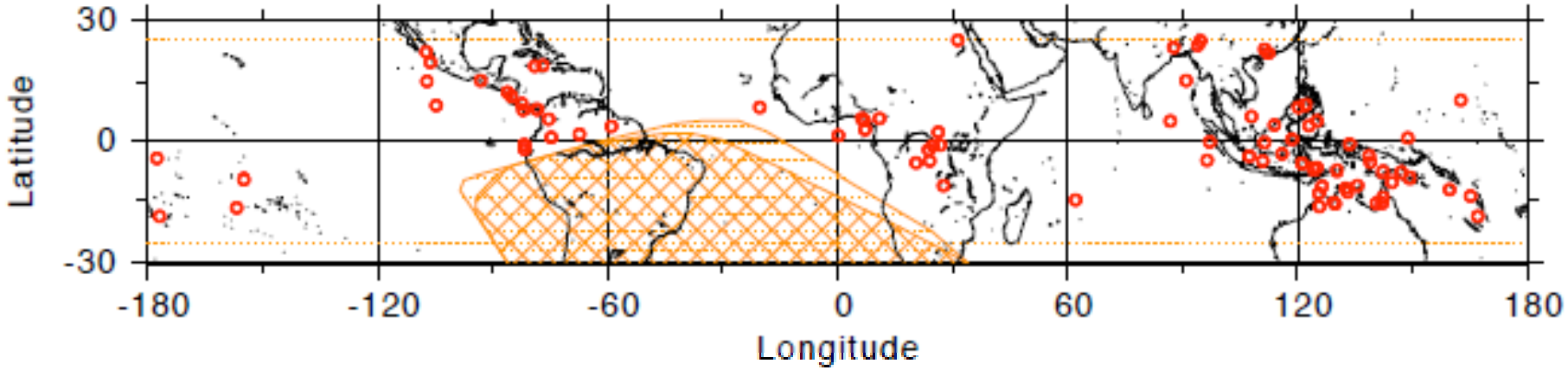
Fermi – GBM TGFs (all Detectors)



Two Well-separated, Double-Pulse TGFs seen with GBM, All Detectors – Time Profiles

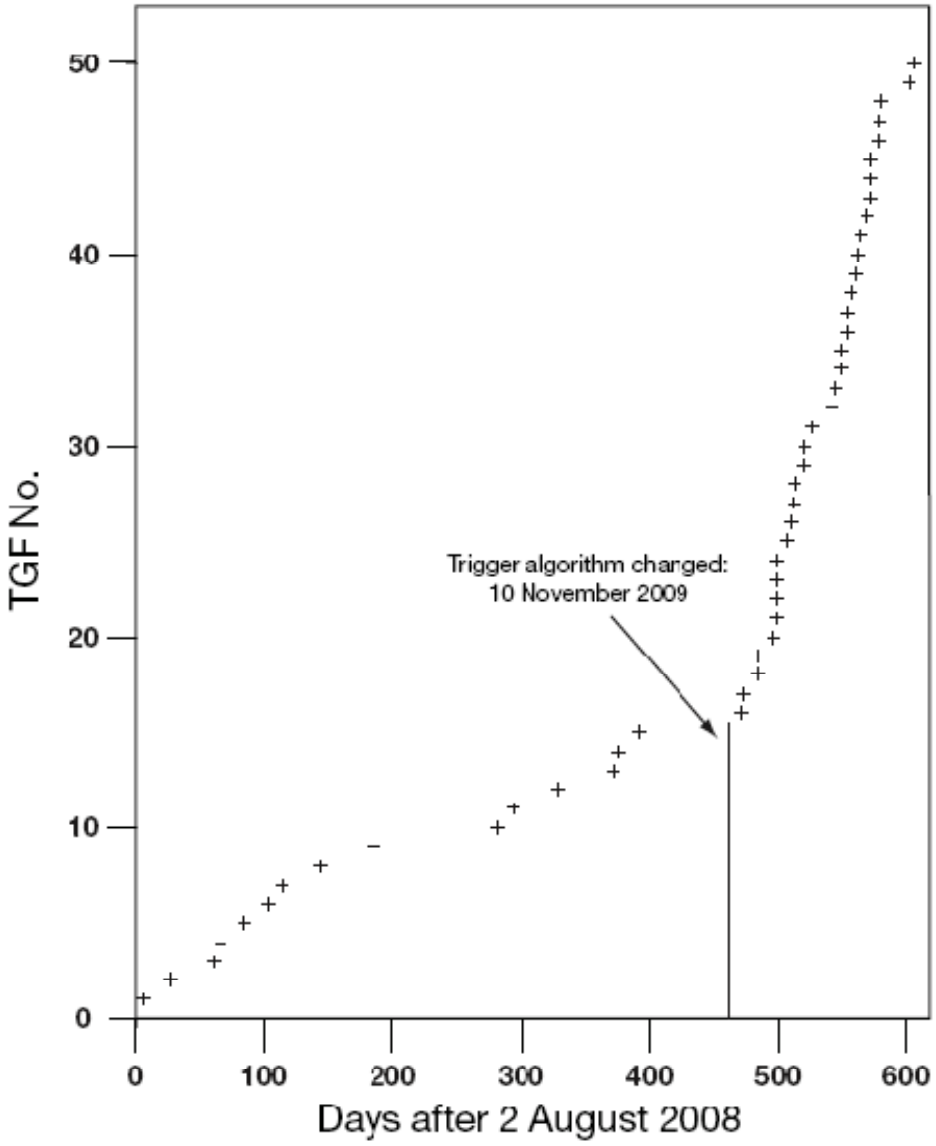


Fermi – GBM
Locations of 85 TGFs



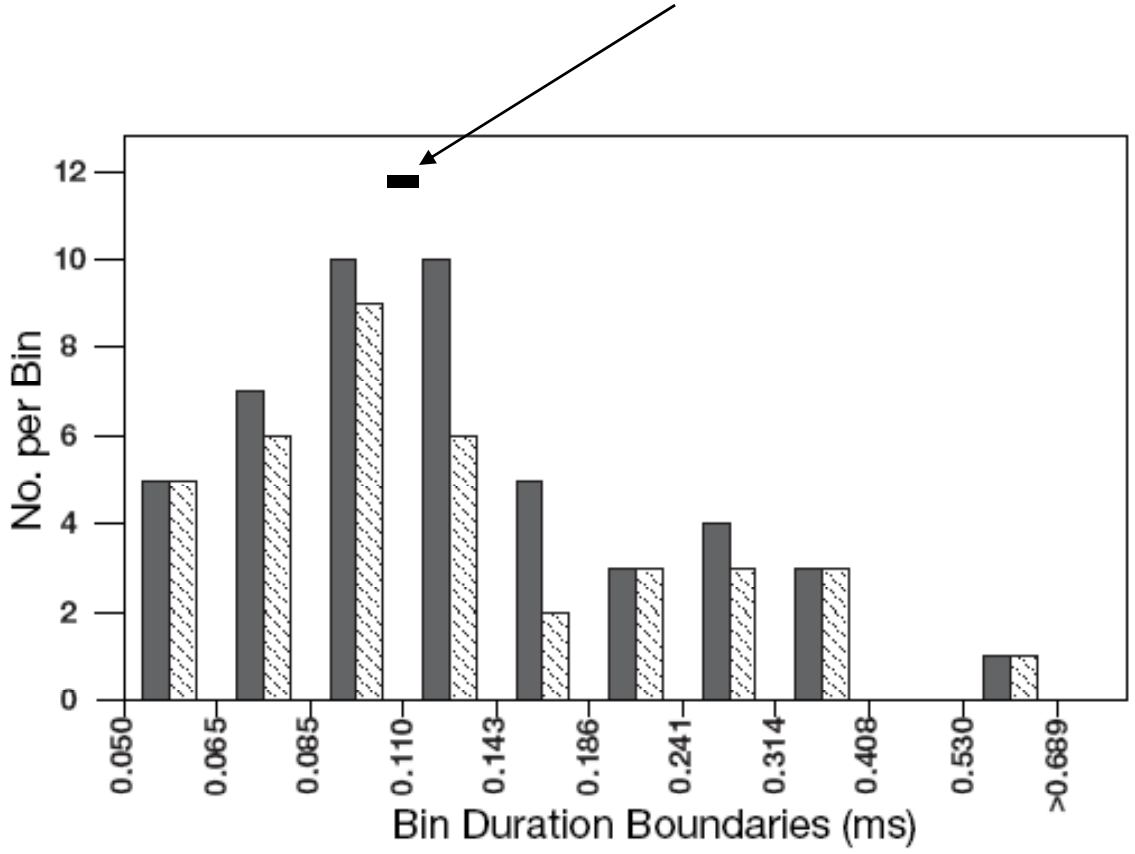
Triggered TGF Rate in GBM: ~1/mo., prior to 11 Nov. 2010

~8/mo., after " "



First 50 GBM TGFs

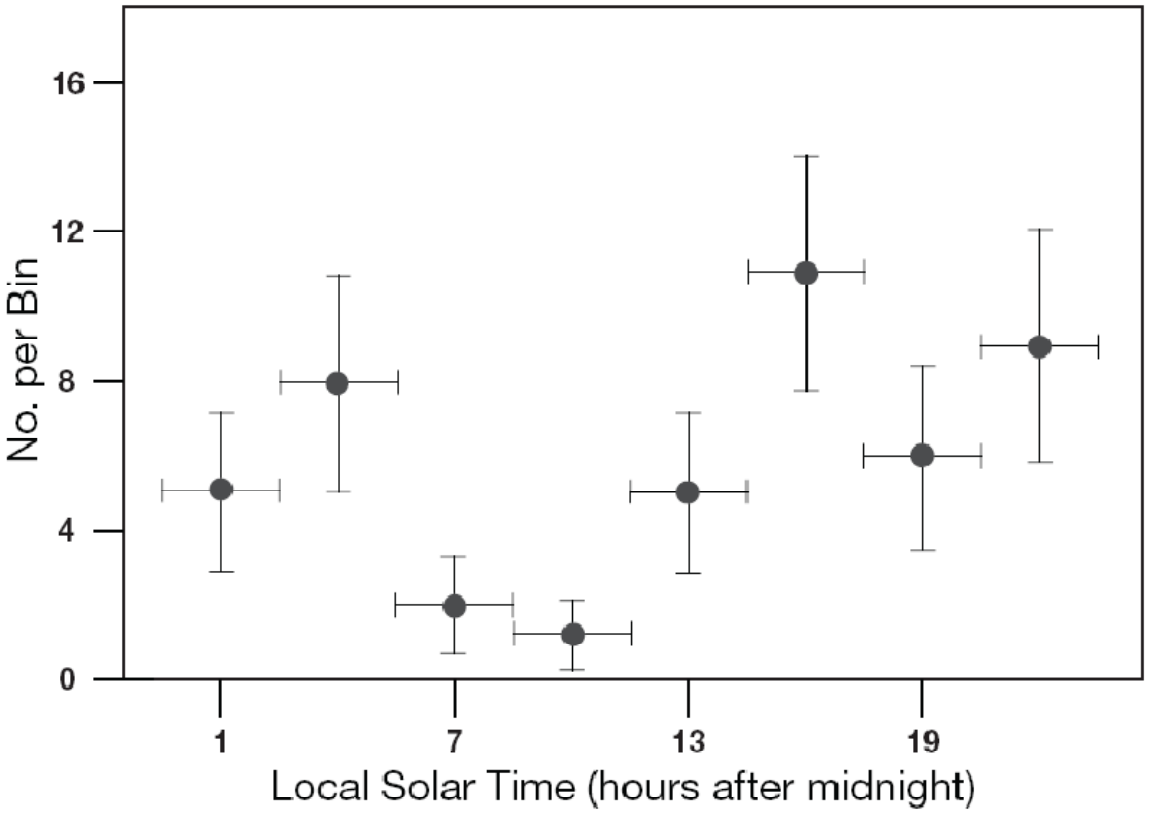
Media TGF Pulse Duration = 0.11ms

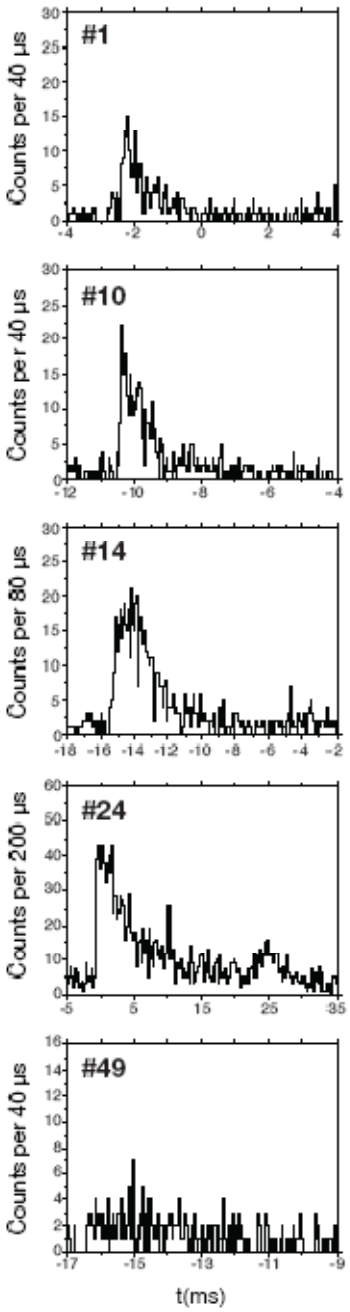


- Does not include 5 longer “electron” TGFs
- Solid column – includes 10 possible un-resolved pulses

Time-of-Day Occurrence of TGFs

- shows afternoon enhancement



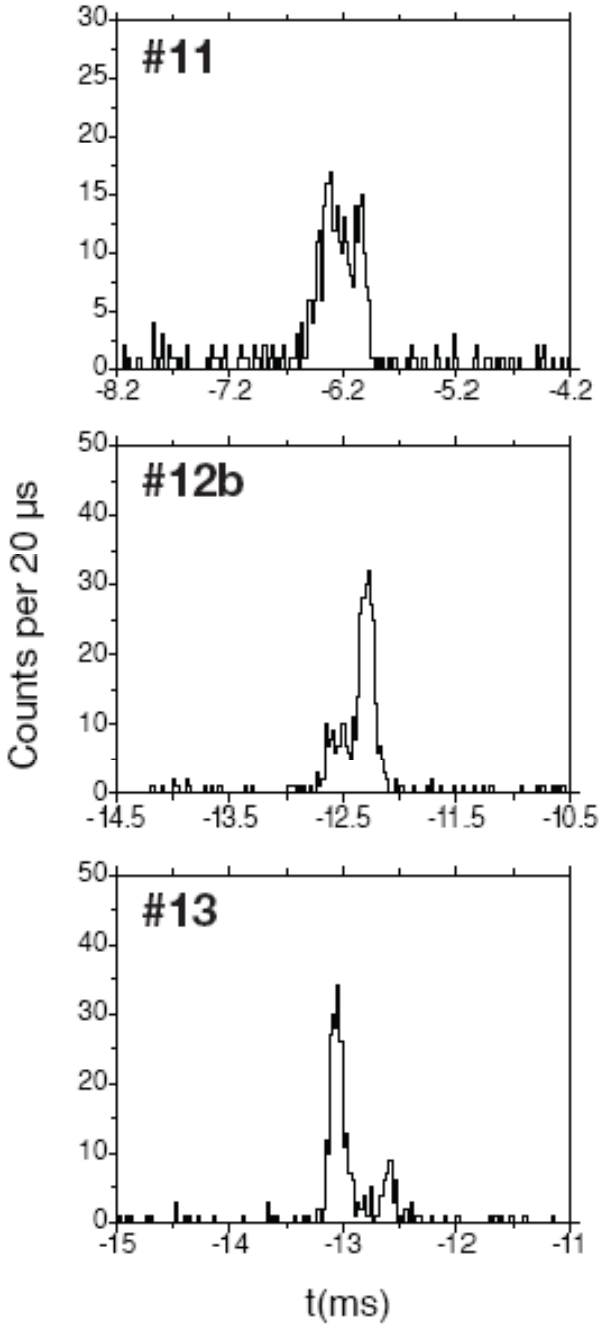


Five "Electron" TGFs

(in the first 50)

Characteristics:

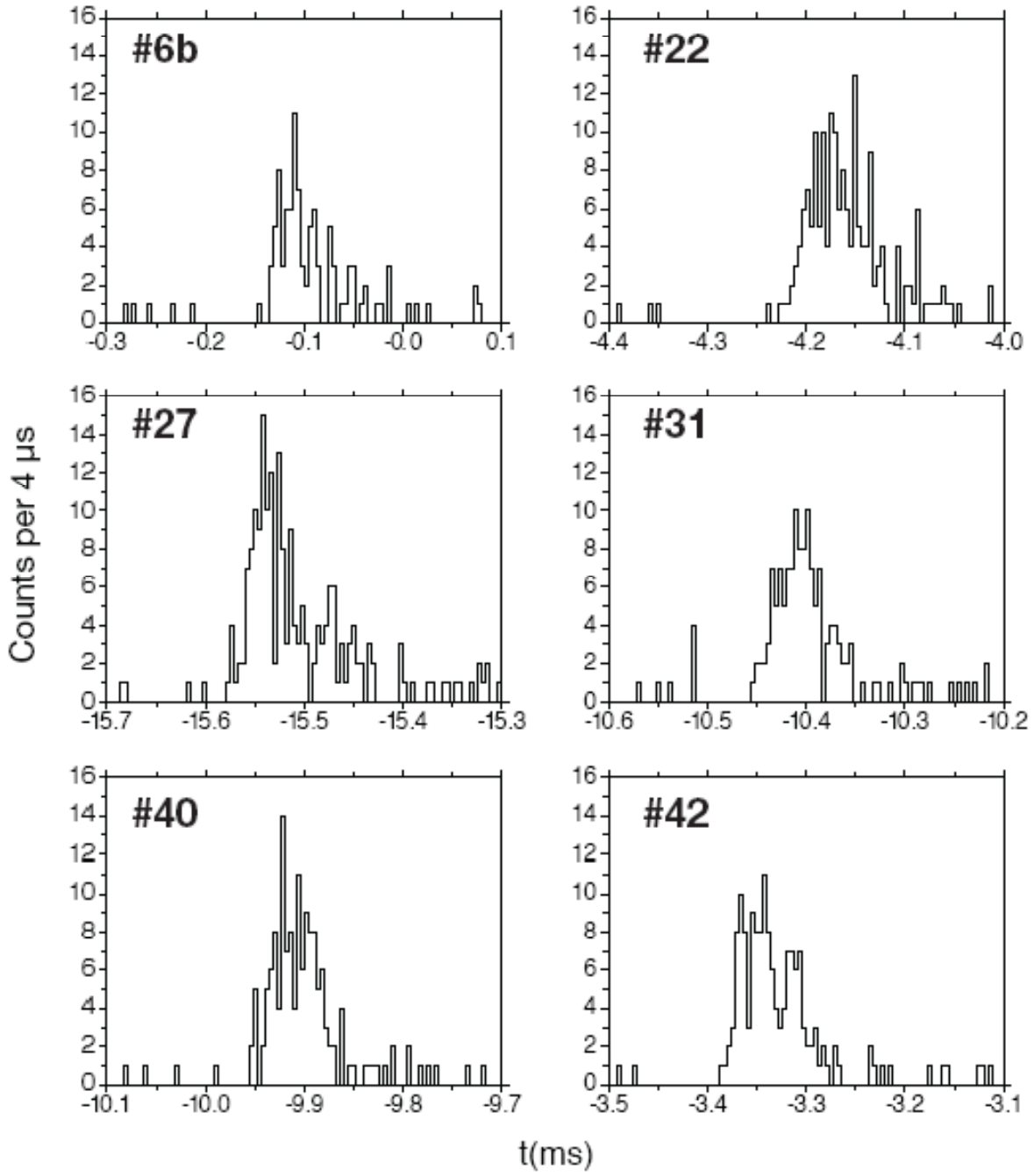
- Longer than usual
- Fast rise, then decaying
- Some are <u>not</u> over thunderstorms



Overlapping Double Pulses

- 3 in the first 50 TGFs

(~7 others are less obvious)



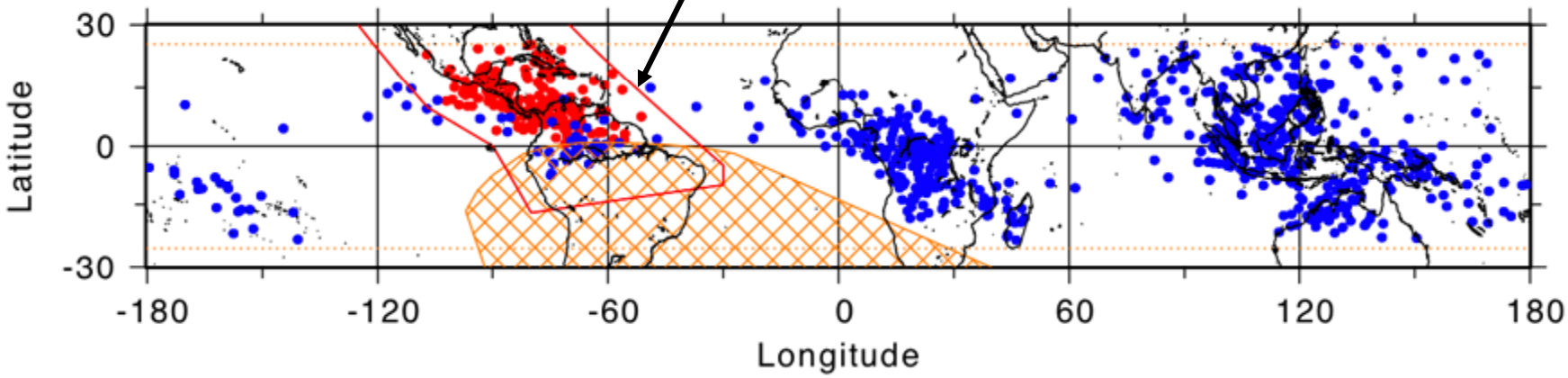
6 of the fastest TGFs

Show variations (risetimes & falltimes) of

~7 to 15µs

July 2010 – Implemented “un-triggered” TGF capability

Over selected “America’s Region”:

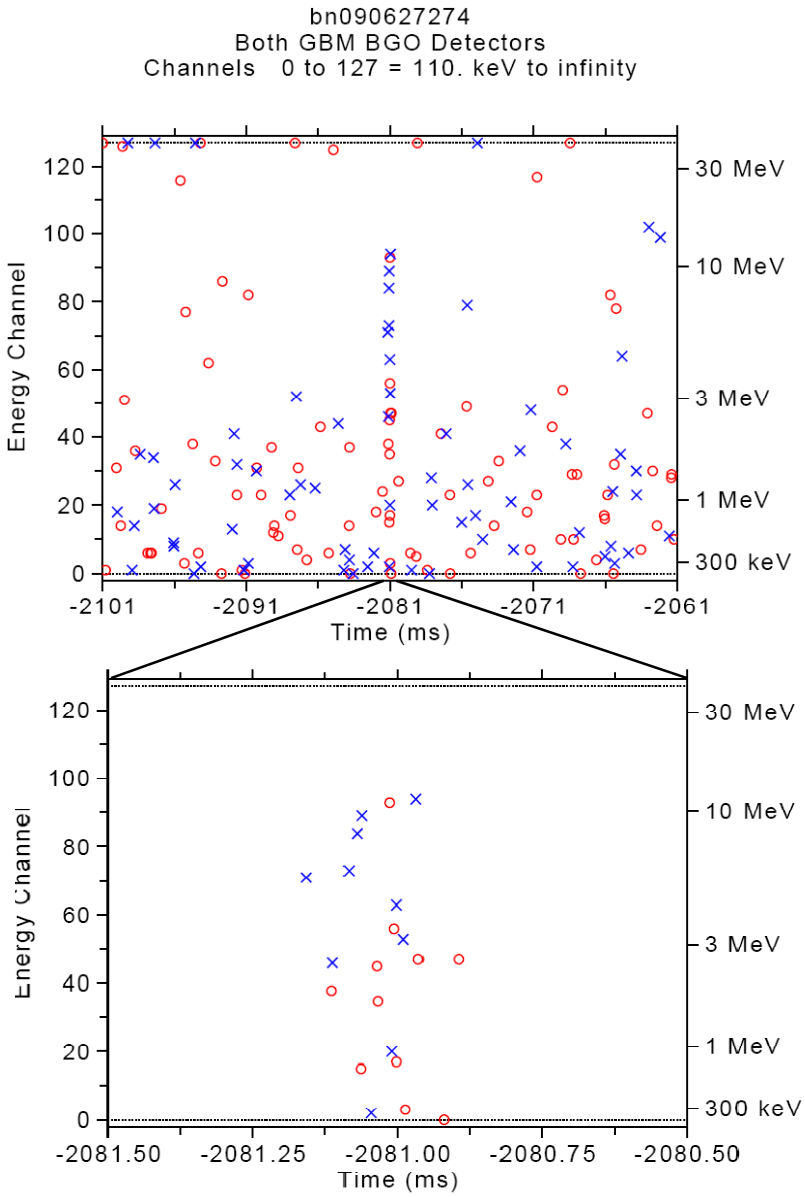


● - RHESSI TGFs

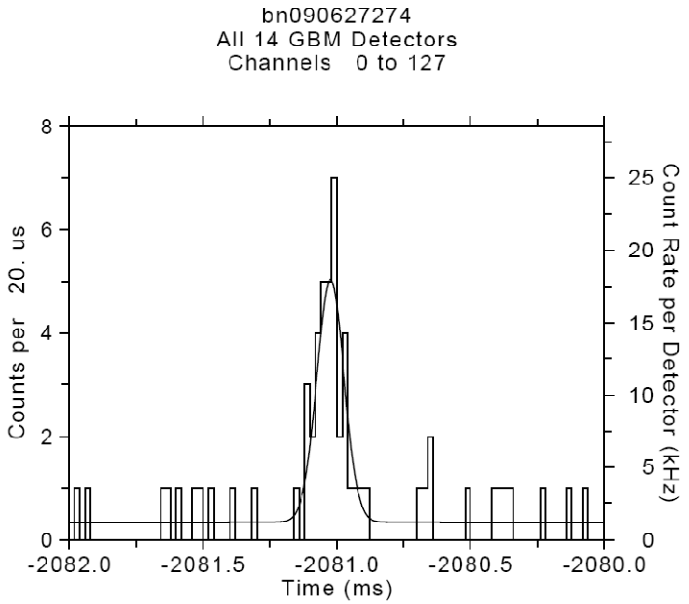
● - RHESSI TGFs, May-November

est.: ~several TGFs per day in this Reion

First look at a GBM an Un-triggered TGF



Binned Data 20μs/bin



TGF

Full-Width: ~0.25ms

Total cts above bkgnd: ~35 cts

Peak ct. rate: ~20kcps

(Spectrum appears similar to strong TGFs)

TGFs –

Major Observational Questions:

- **Altitude of origin?**
- **Extent & volume of the emitting region?**
- **Beaming properties of the emission?**
- **What is the intensity distribution of TGFs ?**
- **Are TGFs related to Gigantic Blue Jets ?**

What Causes TGFs?

Ans.: ***Relativistic Runaway ElectronAvalanche***

What is their physical relationship to storm systems & lightning?

- ***Temporal?***
- ***Spatial?***

- to be covered by V. Connaughton

Future Spacecraft to Study TGFs:

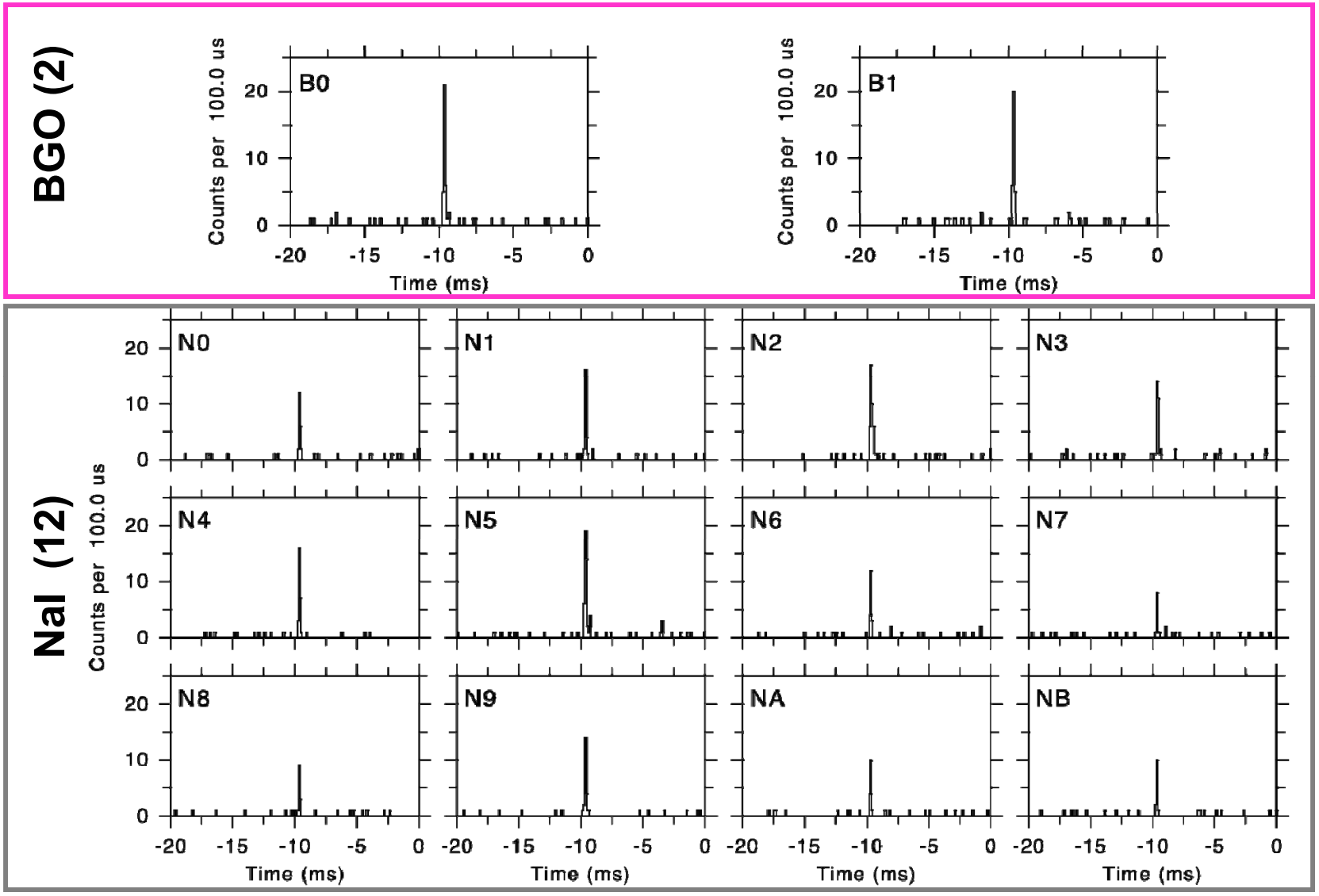
- **Firefly – NSF cubesat; GSFC; Siena Coll.**
- **ASIM – on ISS; ESA, led by Danish**
- **TIRANIS – French & others**
- **CHIBIS-M – Russian (IKI) & others**

End

Back-up

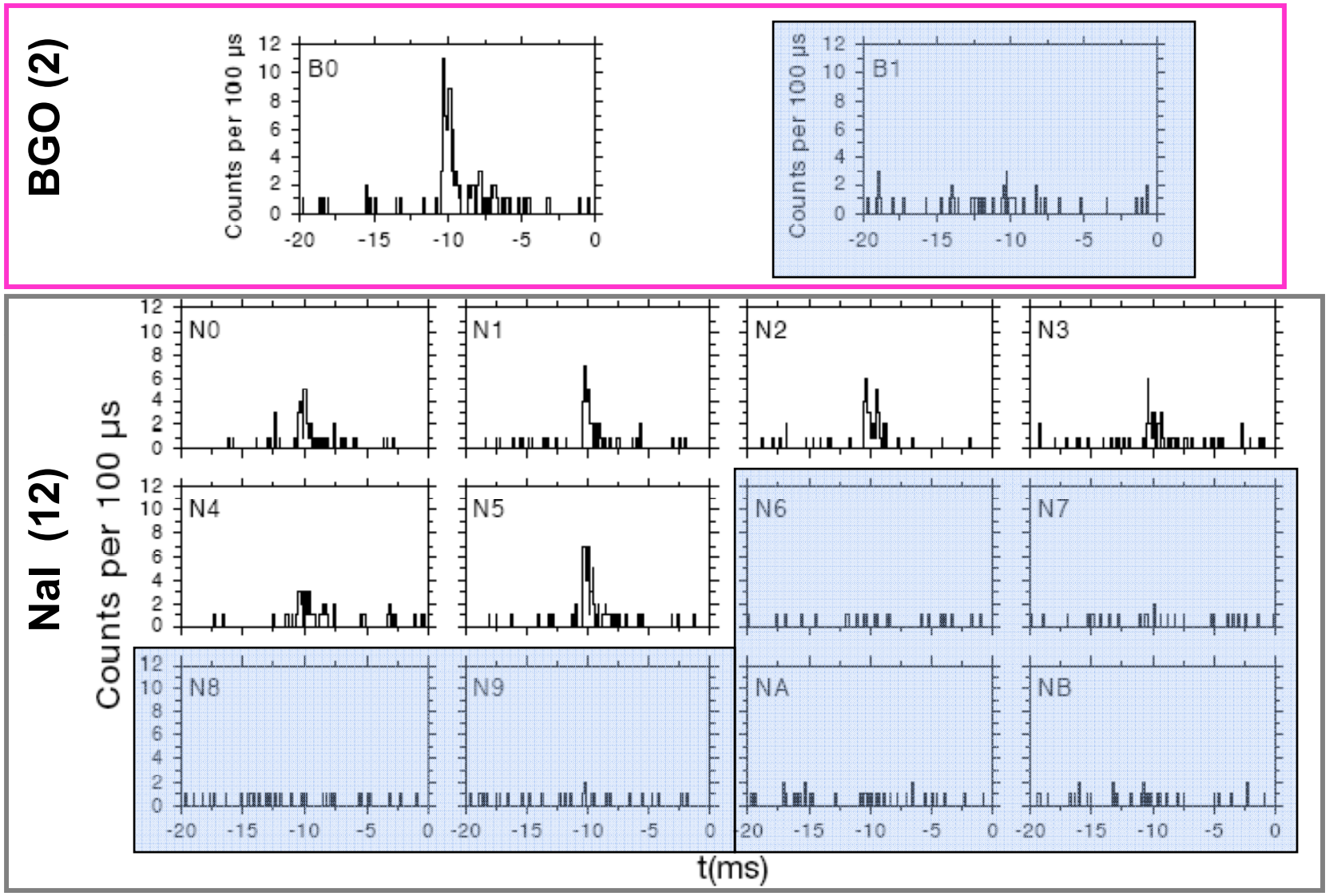
Slides

TGF #5 , Individual Detectors, 0.1ms bins



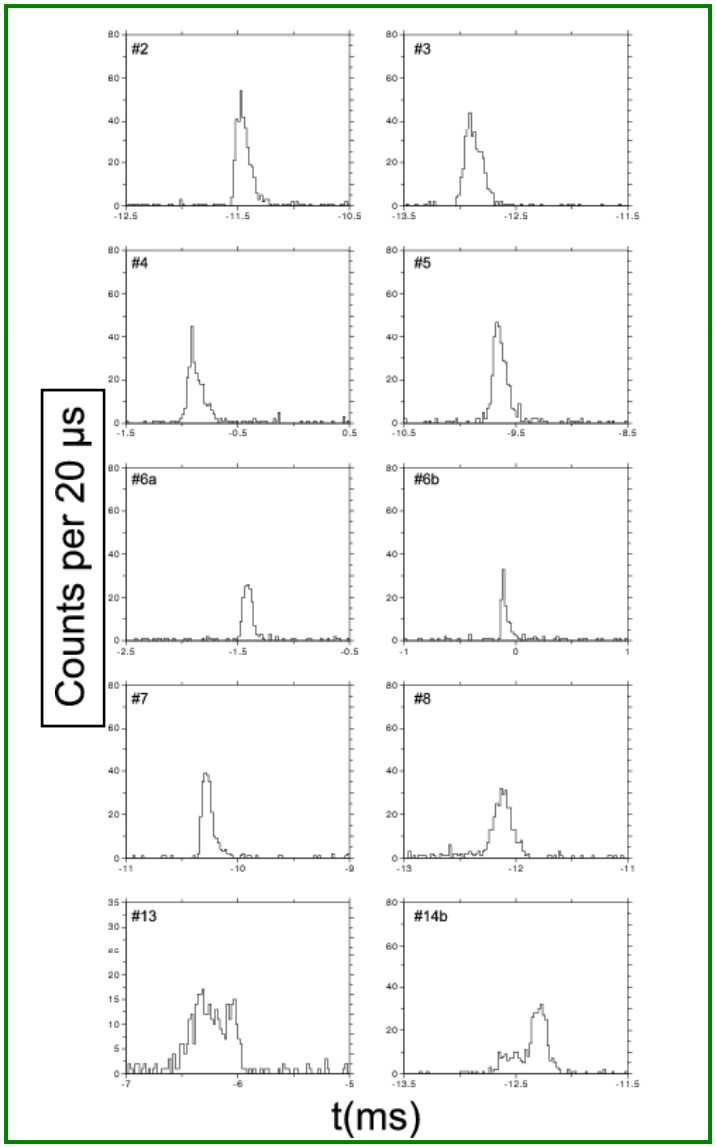
Plot by M. Briggs

TGF #1 , Individual Detectors, 0.1ms bins

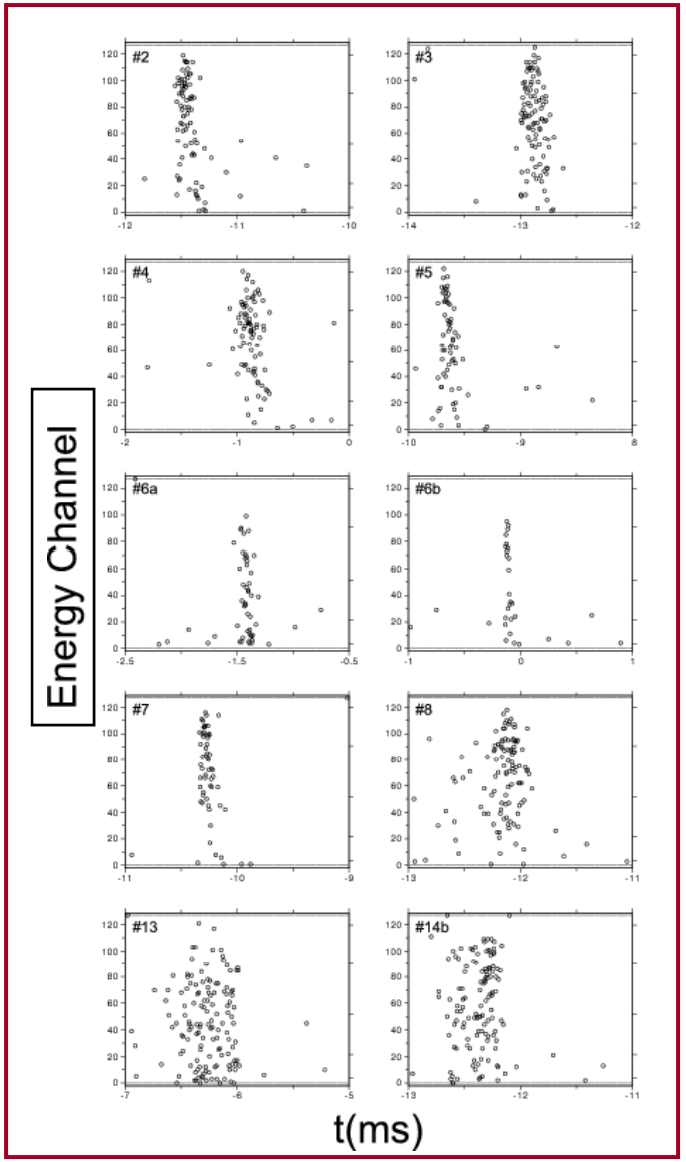


Properties of 10 Short TGF Pulses

Time Profiles – All Detectors Combined

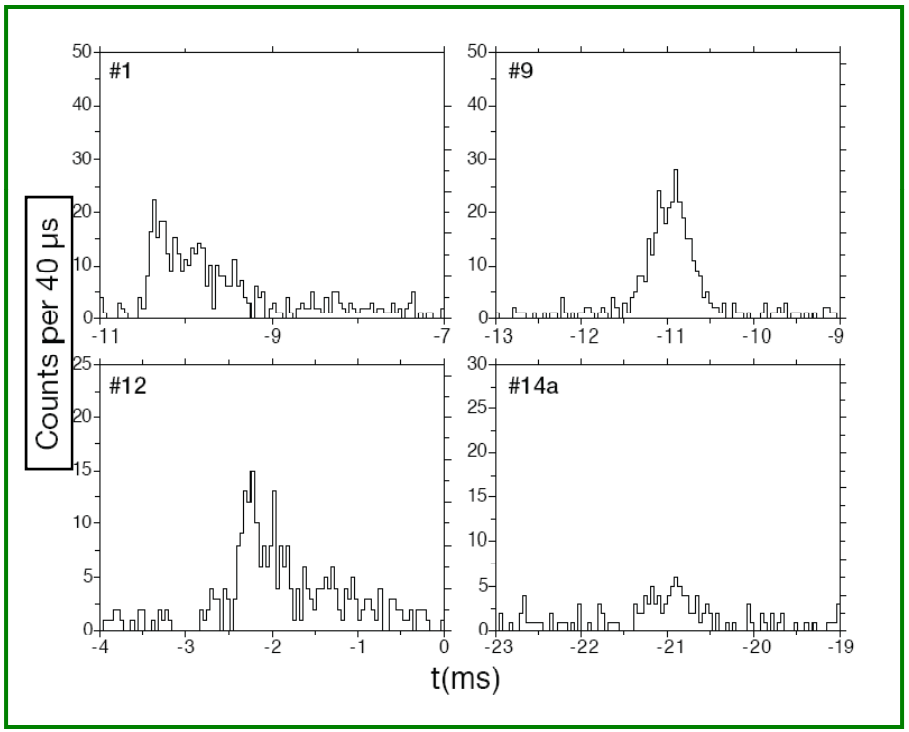


Energies of Single Counts - BGO Detectors Only



Four Longer TGF Pulses (~1-3 ms)

Time Profiles –
All Detectors Combined



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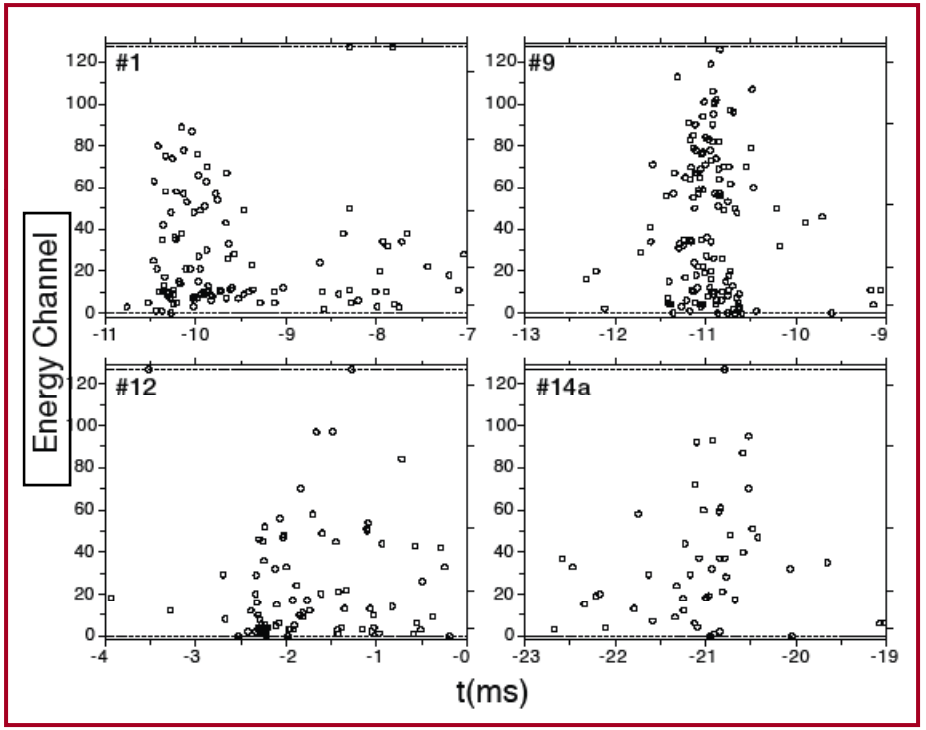
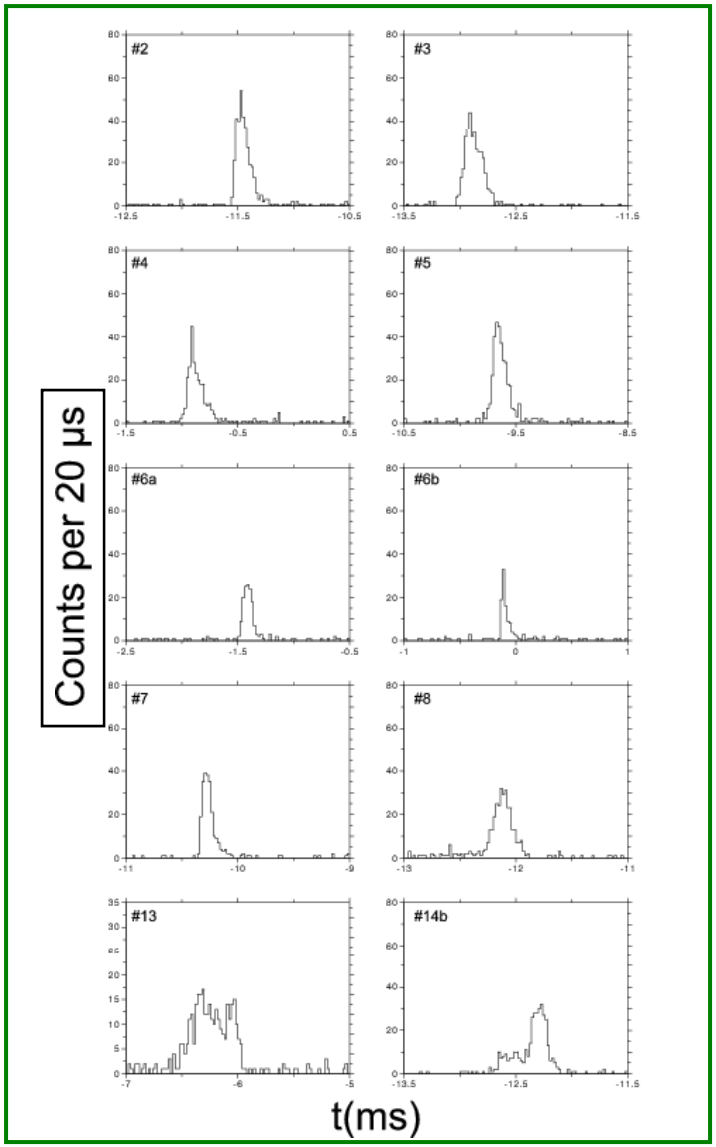
BGO Detectors Only



Properties of 10 Short TGF Pulses

Time Profiles – All Detectors Combined



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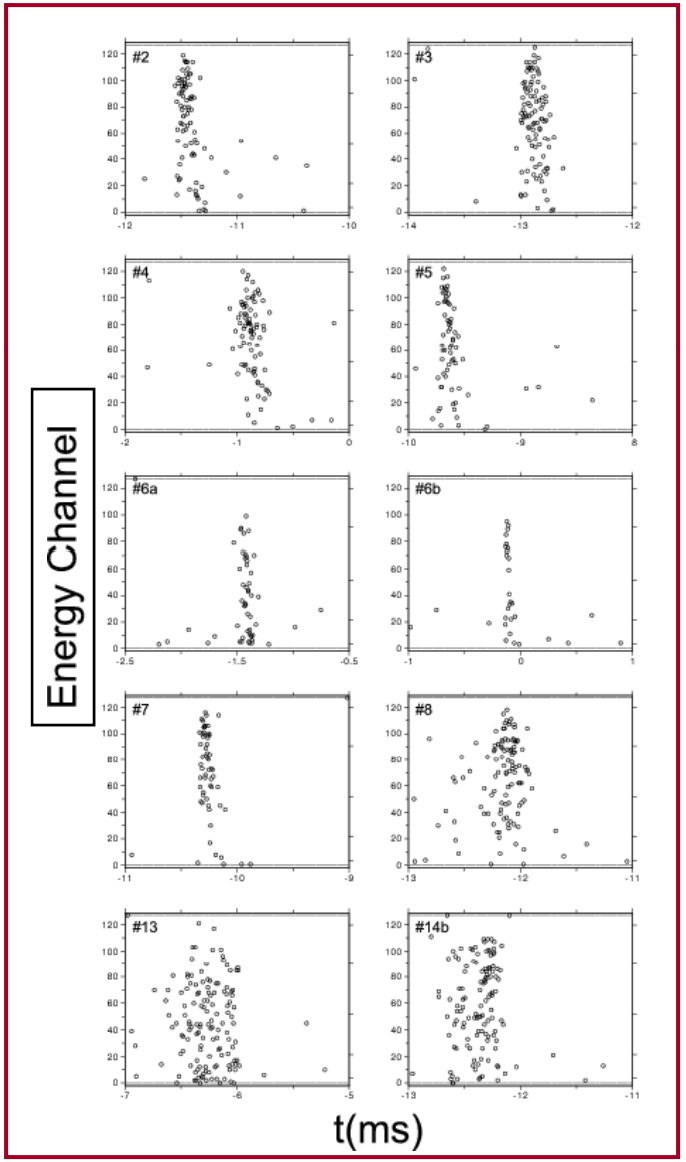

Four Longer TGF Pulses (~1-3 ms)

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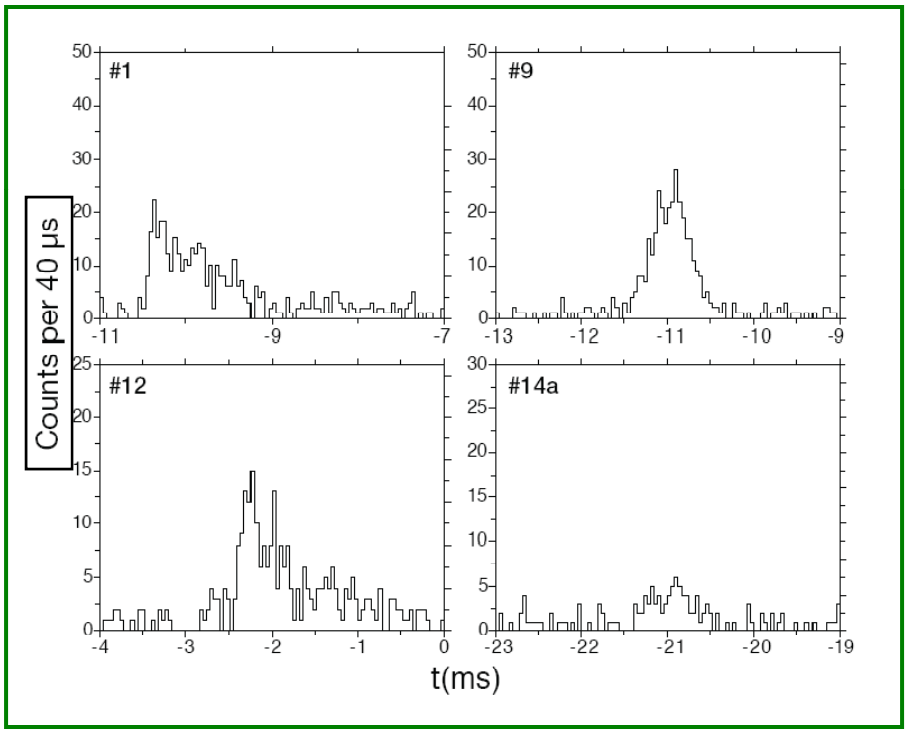

Energies of Single Counts -
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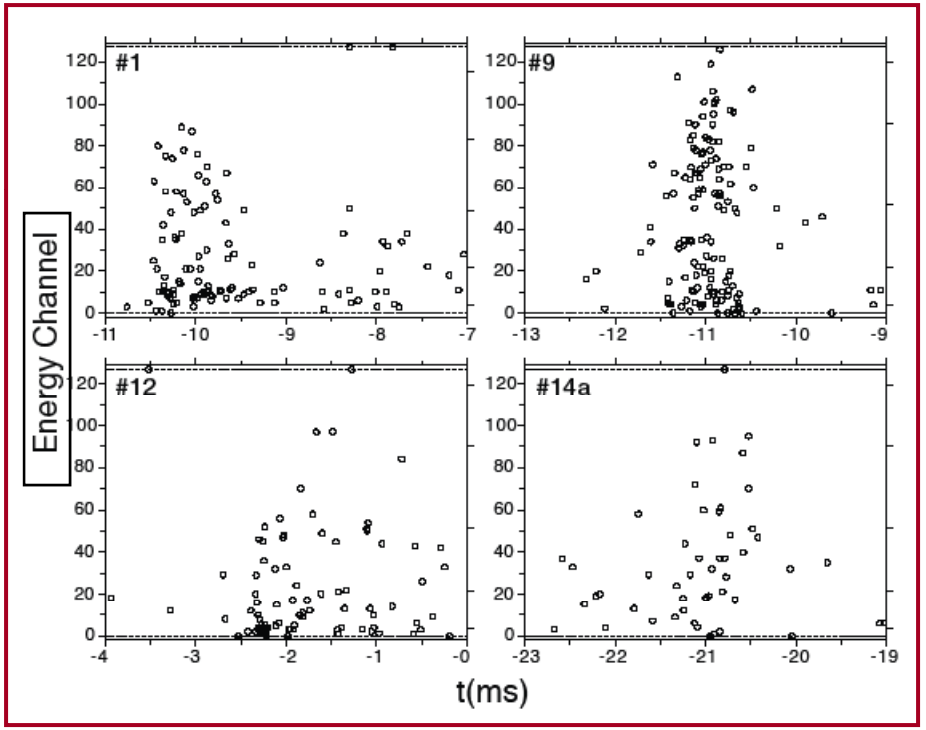
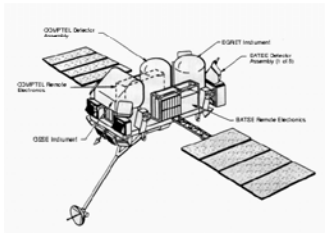


Four Orbiting Spacecraft Have Observed TGFs:

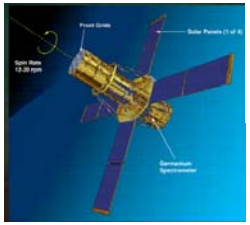
BATSE on the Compton Gamma-ray Observatory

- **Discovered TGFs ; publ. in 1994**
- **Operational 1991-2000**



RHESSI - Solar Spectroscopy Spacecraft

- **Comprehensive TGF Observations**
- **On-line Catalog Available; still in-orbit**



AGILE

- **Italian Gamma-ray Astronomy Mission**
- **Detects TGFs in calorimeter, still operational**

The Gamma-ray Burst Monitor, "GBM" on the Fermi Gamma-ray Space Telescope, "Fermi"

- **This talk and the next one**