

# Terrestrial Gamma-Ray Flashes (TGFs)

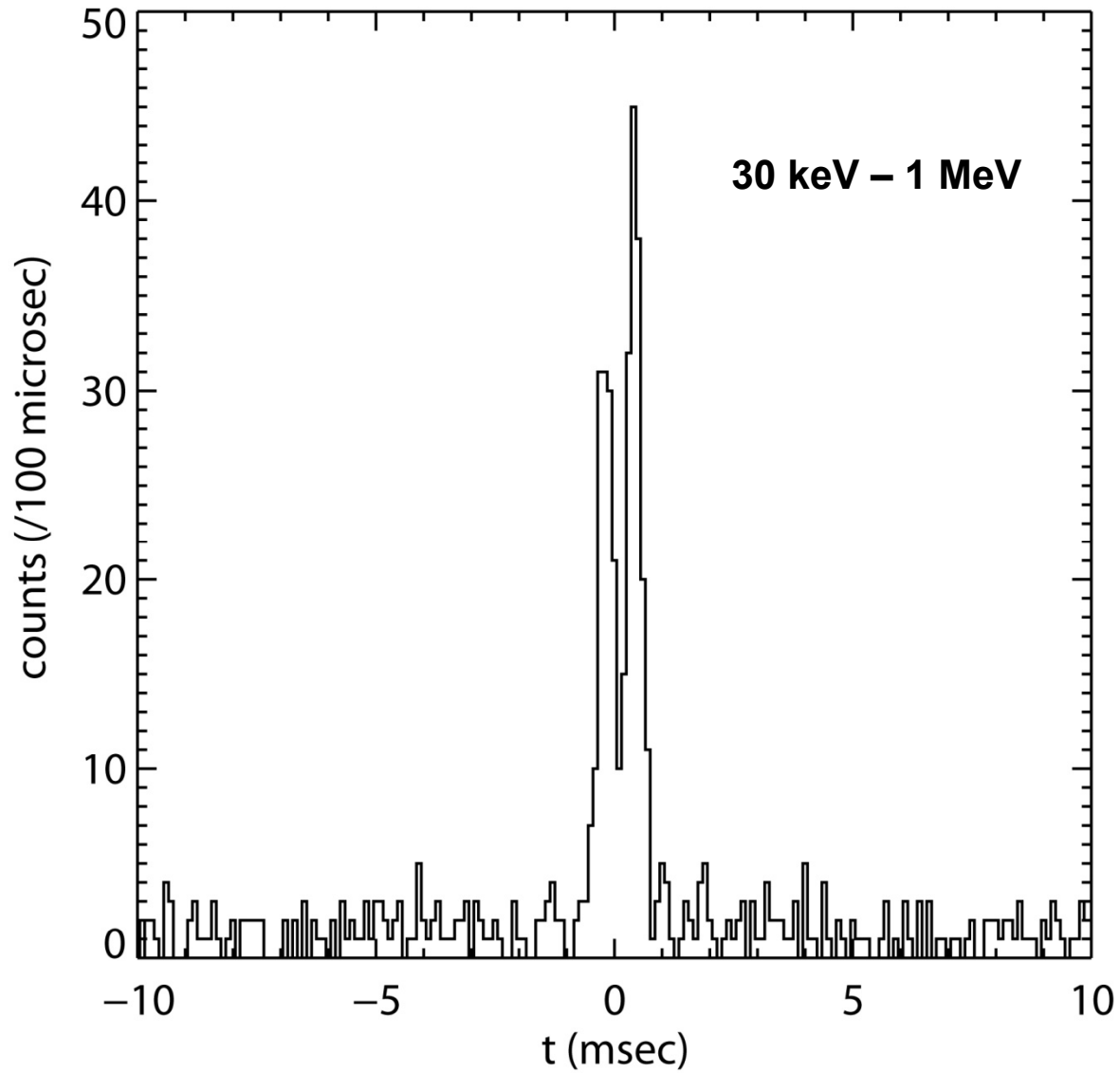
**G. J. (Jerry) Fishman**  
NASA-Marshall Space Flight Center  
Huntsville, AL USA

*Thunderstorms and Elementary Particle Acceleration  
(TEPA 2010)  
Nor Amberd, Armenia  
6-11 September 2010*

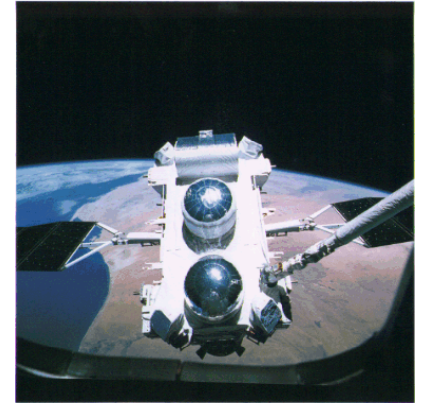
# TGFs - Overview & Some New Results

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

# CGRO/BATSE Terrestrial Gamma-ray Flash (TGF)

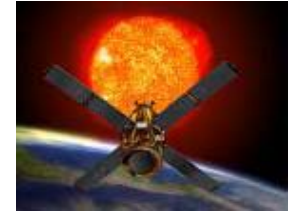


# Observations of TGFs with Four Spacecraft:



I. BATSE /Compton Observatory: 1991-2000

II. Solar Spectroscopic Imager



III. AGILE Gamma-ray Telescope

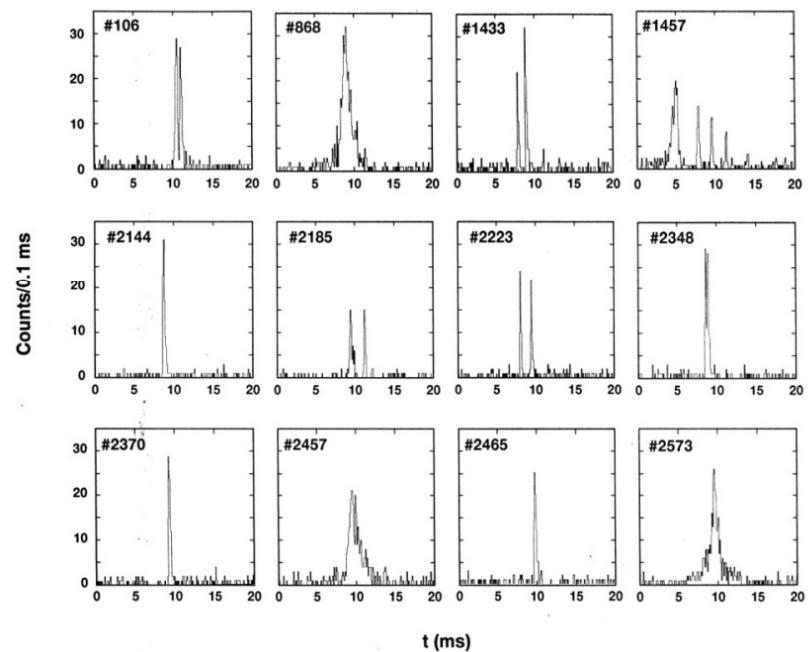
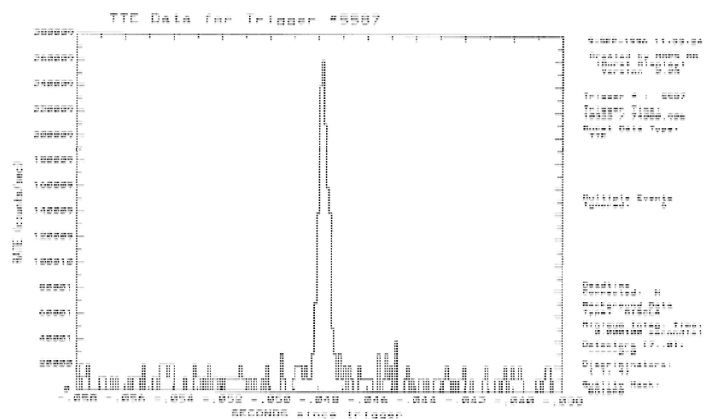


IV. Gamma-ray Burst Monitor (GBM) on the  
Fermi Gamma-ray Space Telescope

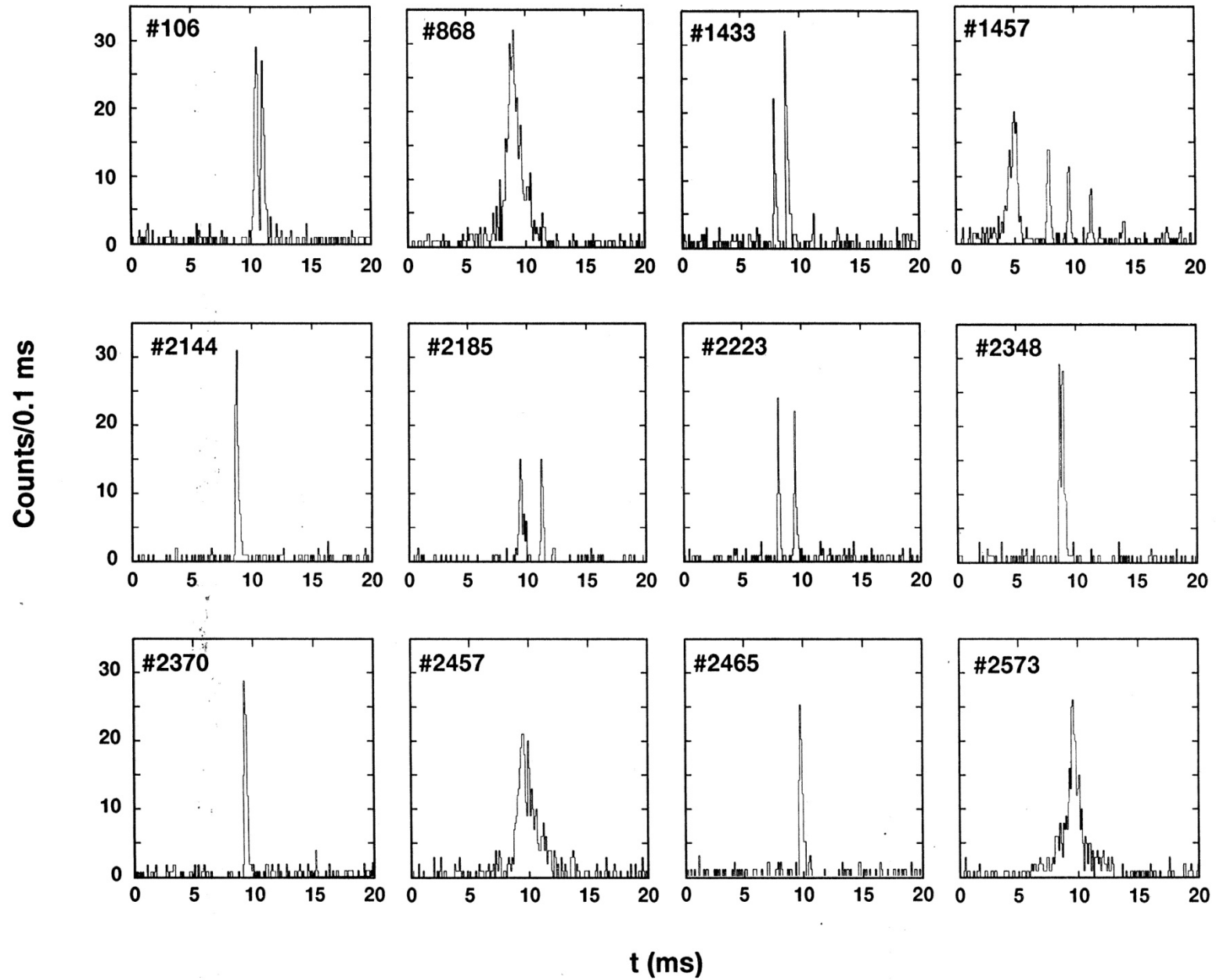


# BATSE TGFs:

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



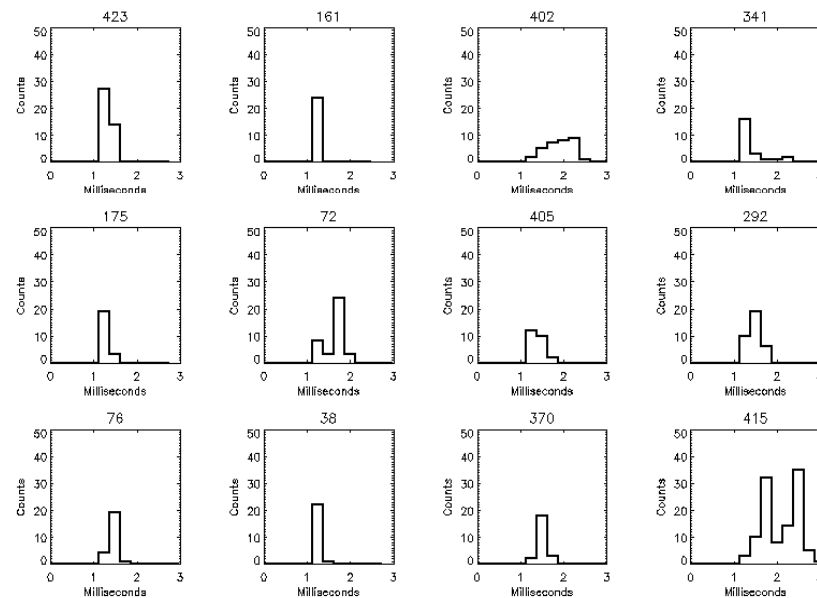
# TGFs from BATSE (showing saturation at ~300,000 cps)

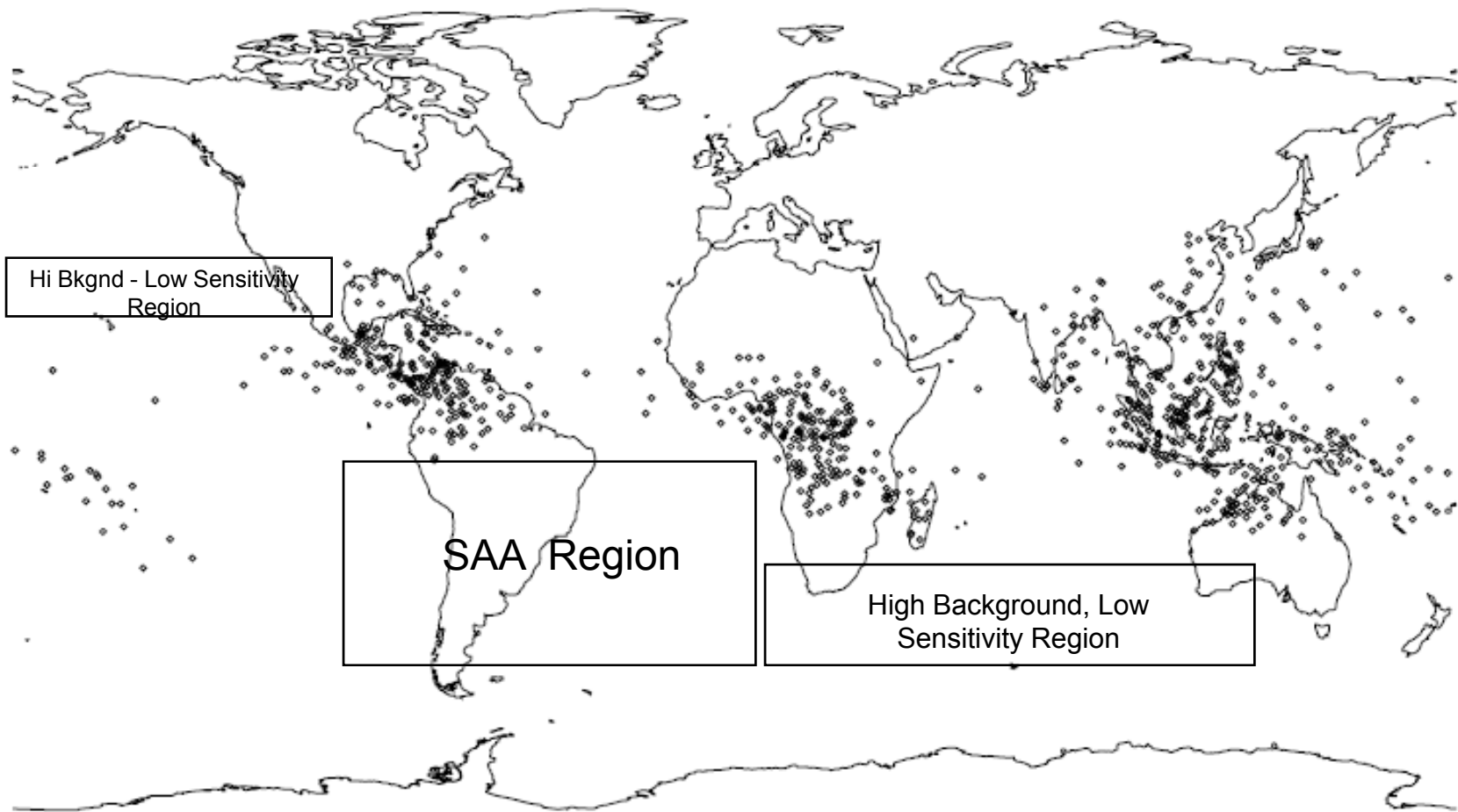


# RHESSI Observations:

- 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:



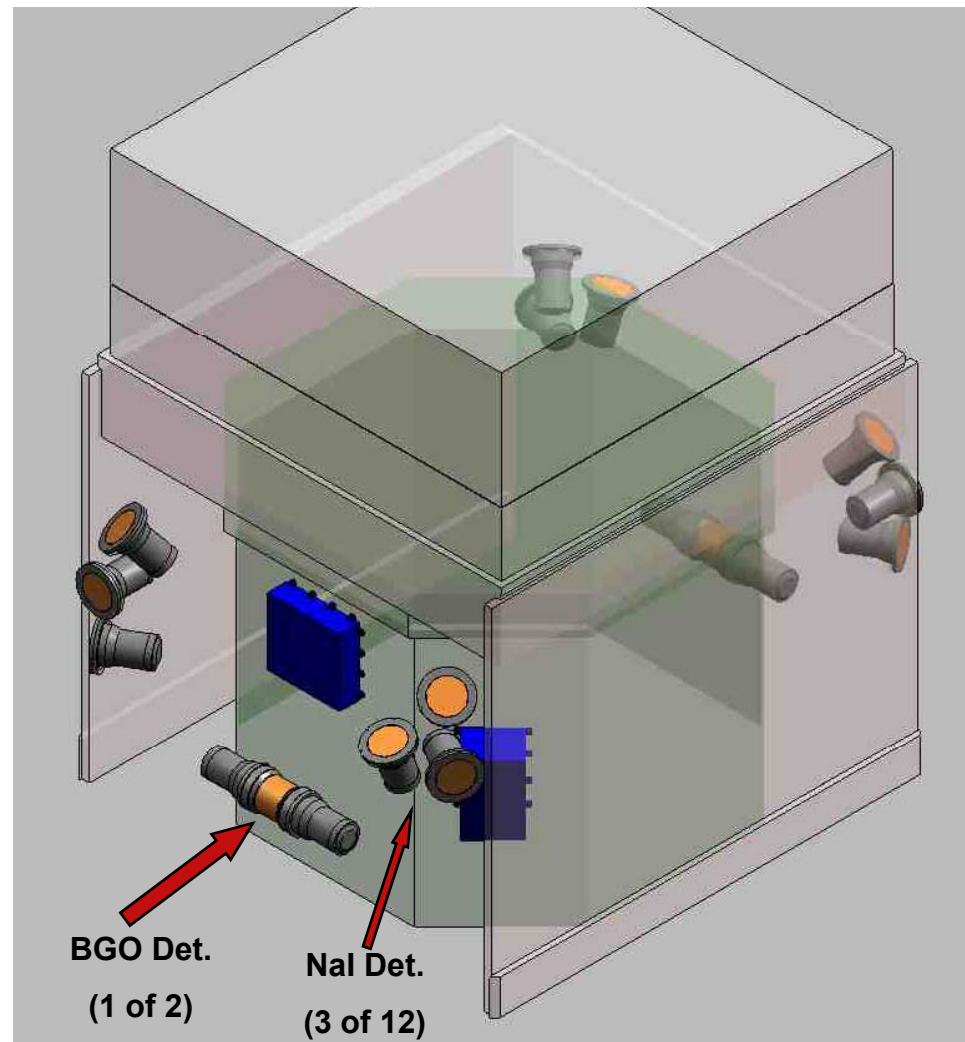


**Map of RHESSEI TGFs (820 events)**



# Gamma-ray Burst Monitor (GBM)

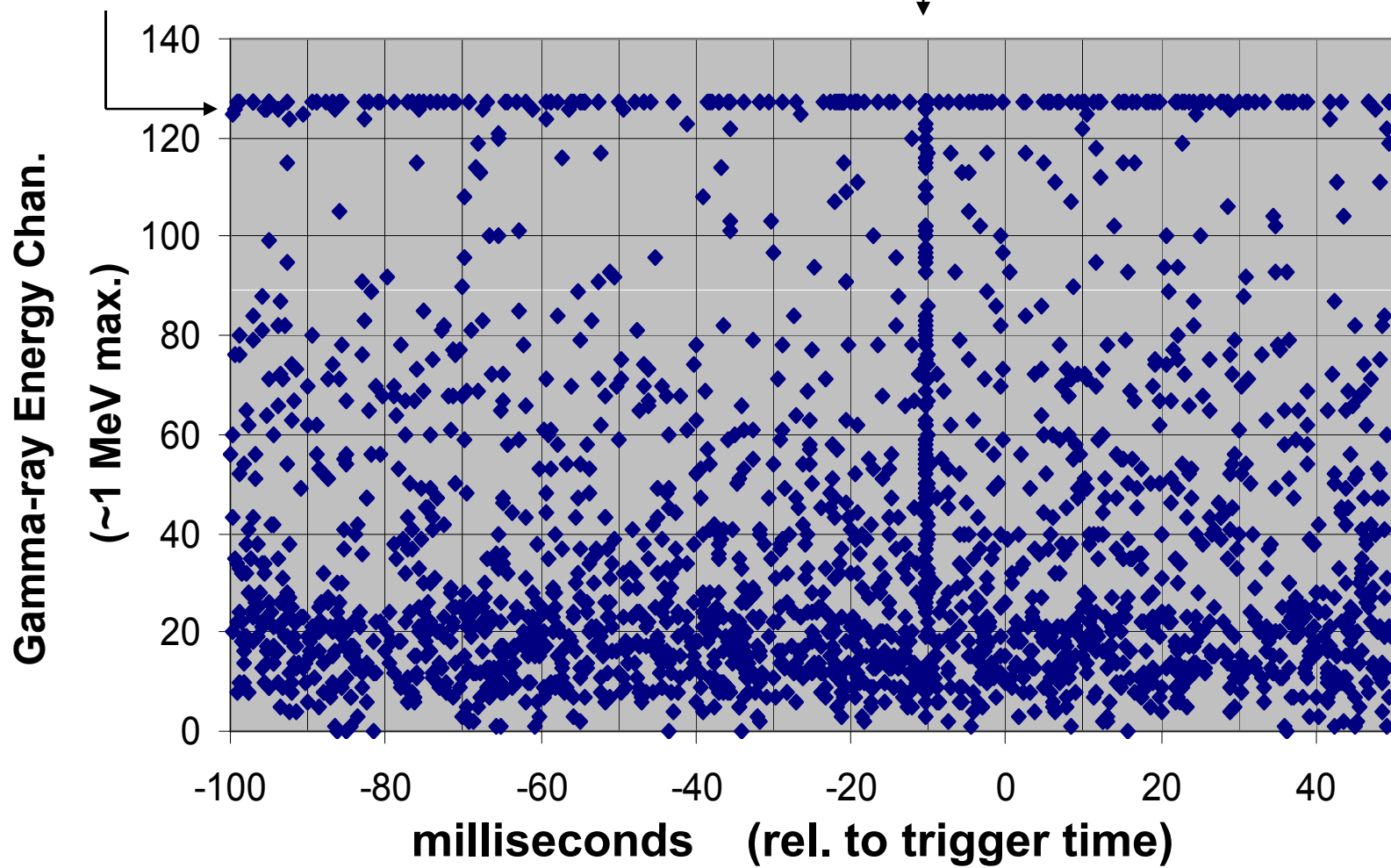
Detector Locations on the  
Fermi Spacecraft – Launched June 2008



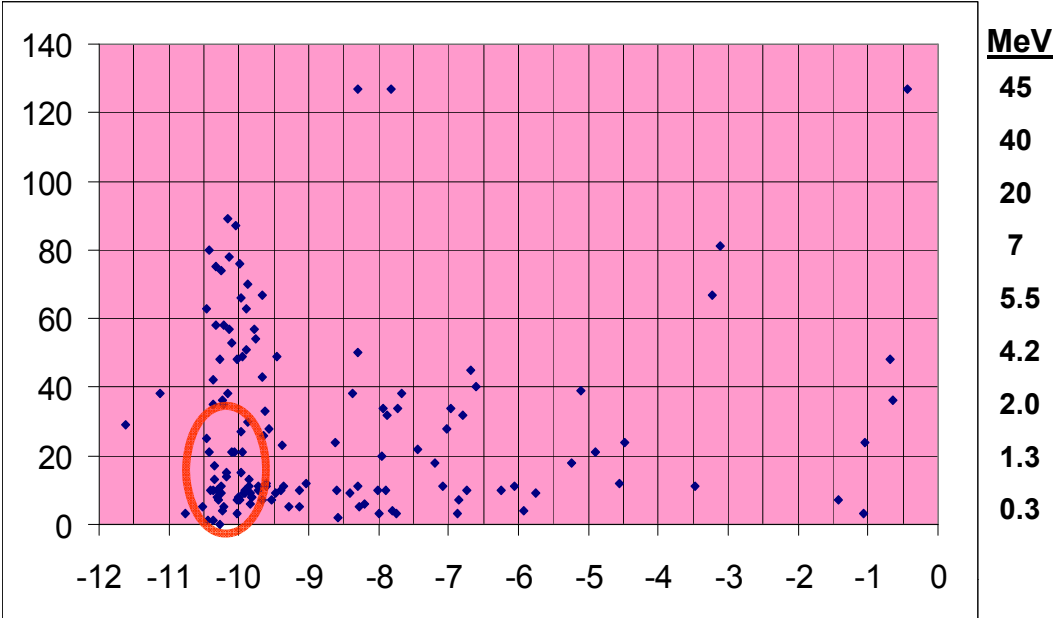
**Nal Detectors (all 12 combined)**

“Overflow” Chan. (127)

TGF

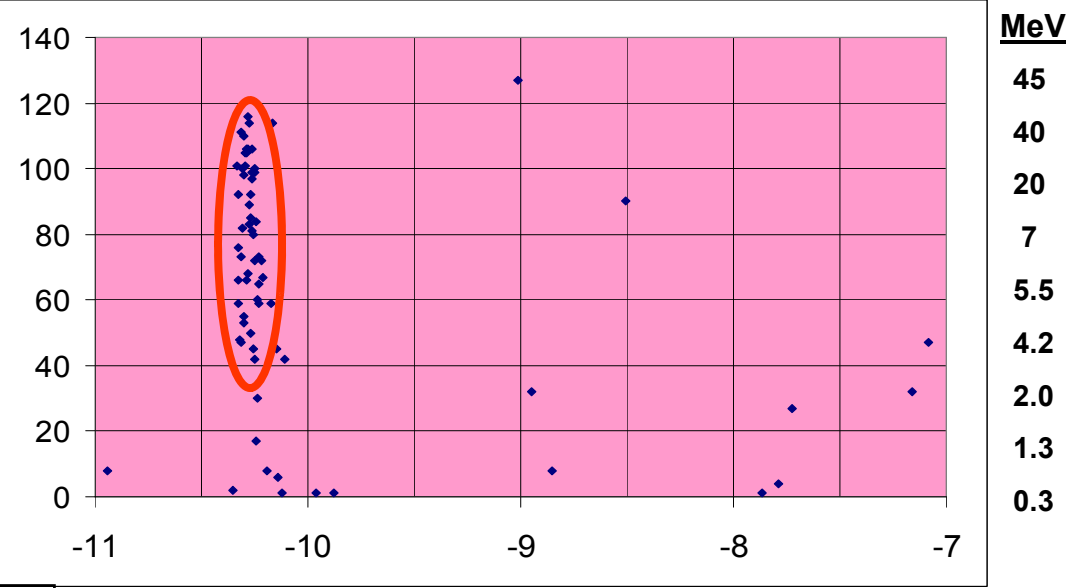


# Spectral Differences



1

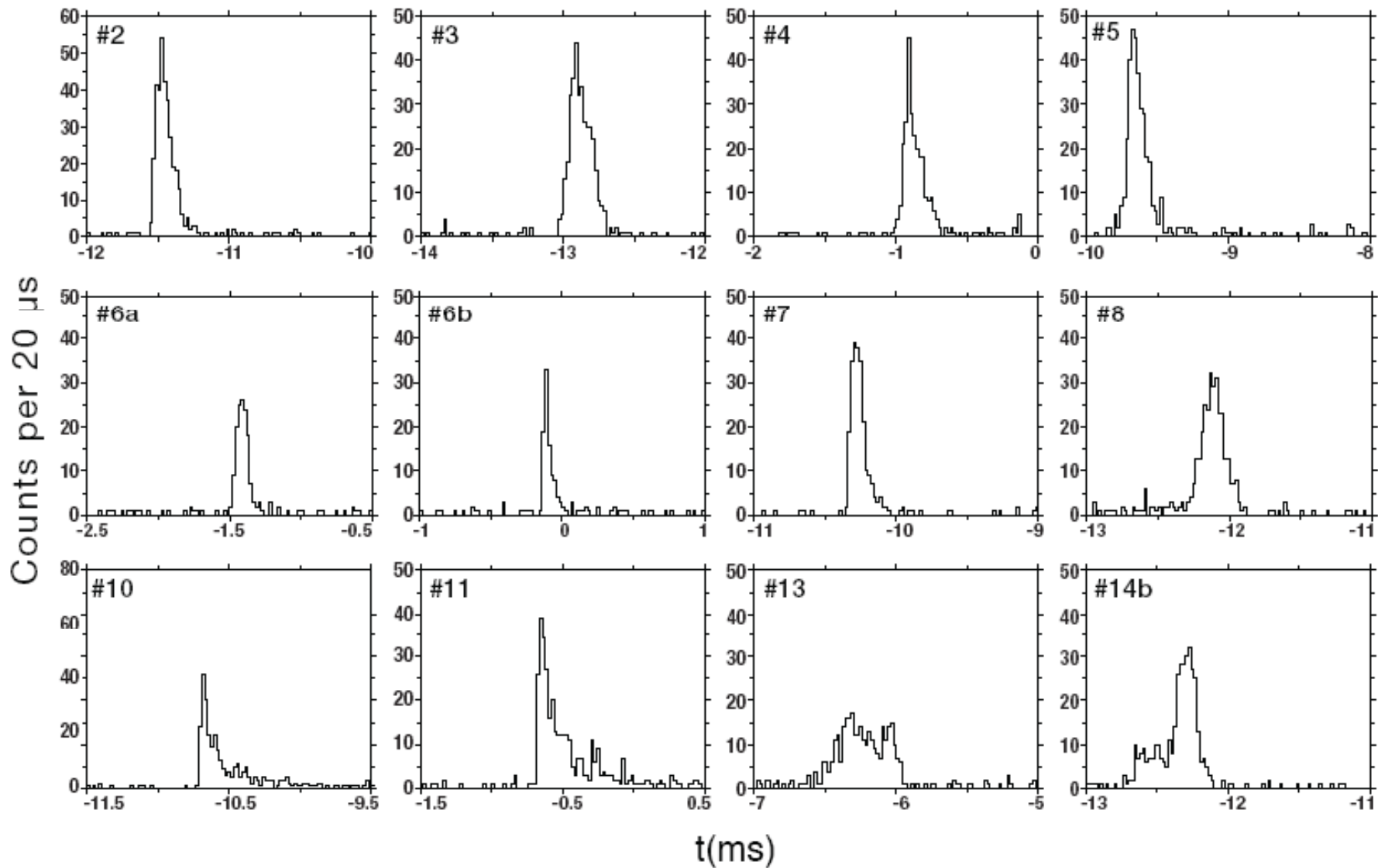
**TGF #1:**  
**Low energies dominate**



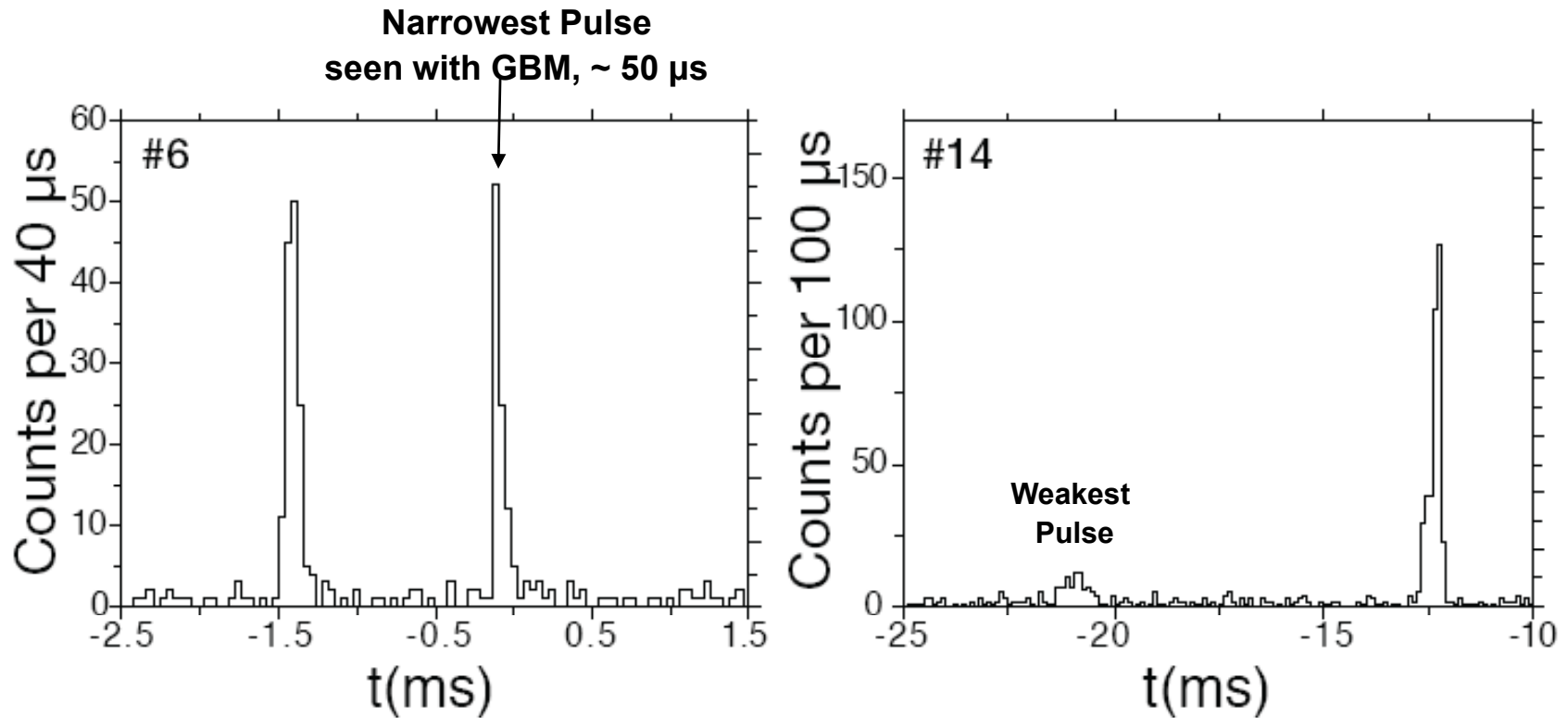
7

**TGF #7:**  
**High energies dominate**

**Fermi – GBM TGFs (all Detectors)**

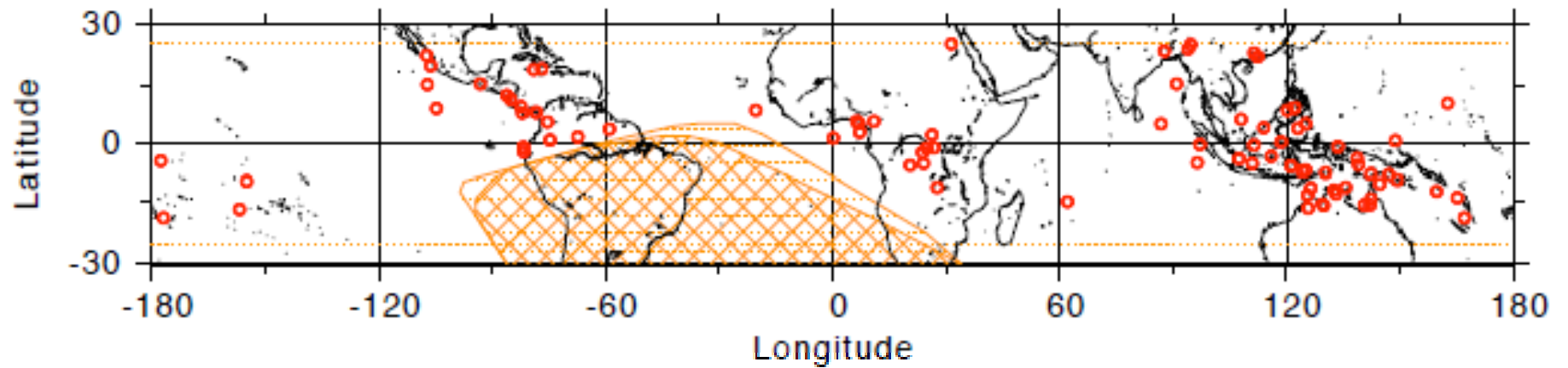


## Two Well-separated, Double-Pulse TGFs seen with GBM, All Detectors – Time Profiles



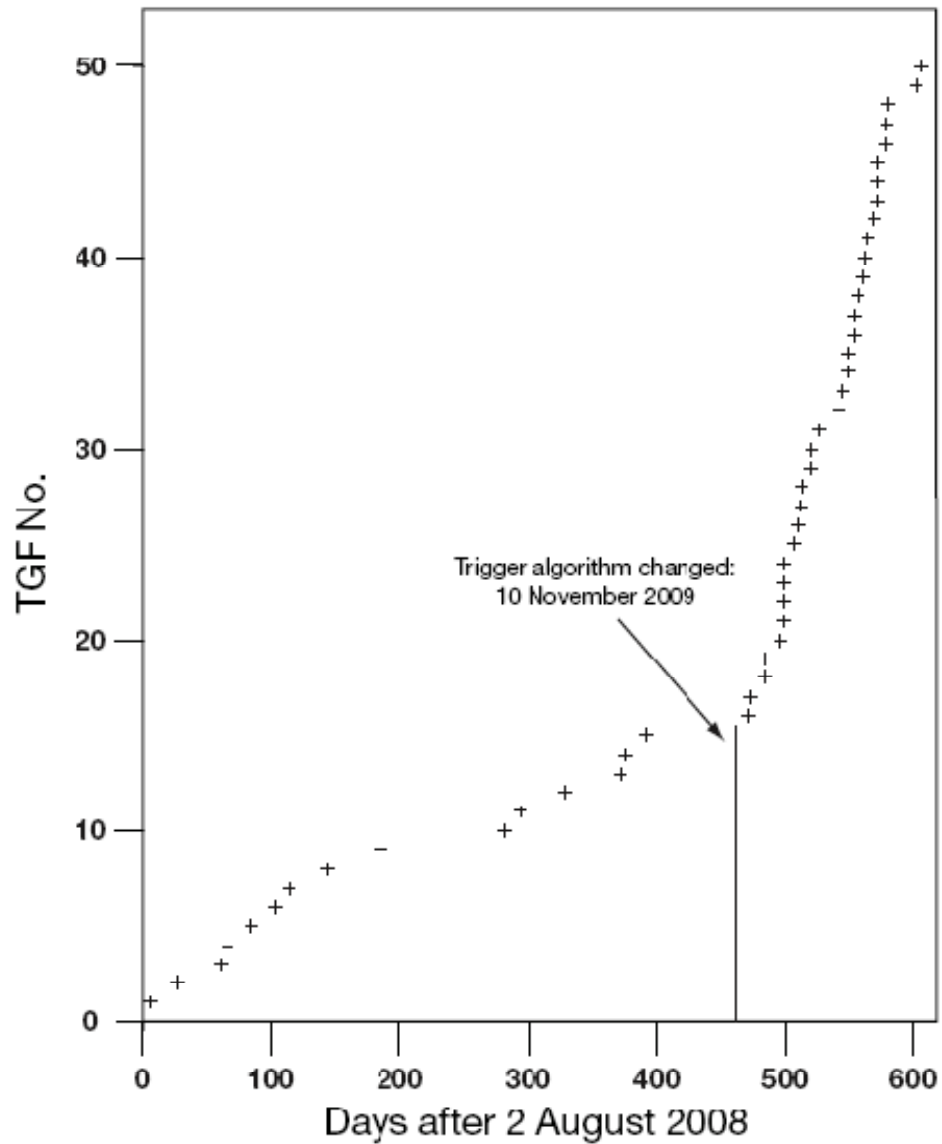
# Fermi – GBM

## Locations of 85 TGFs



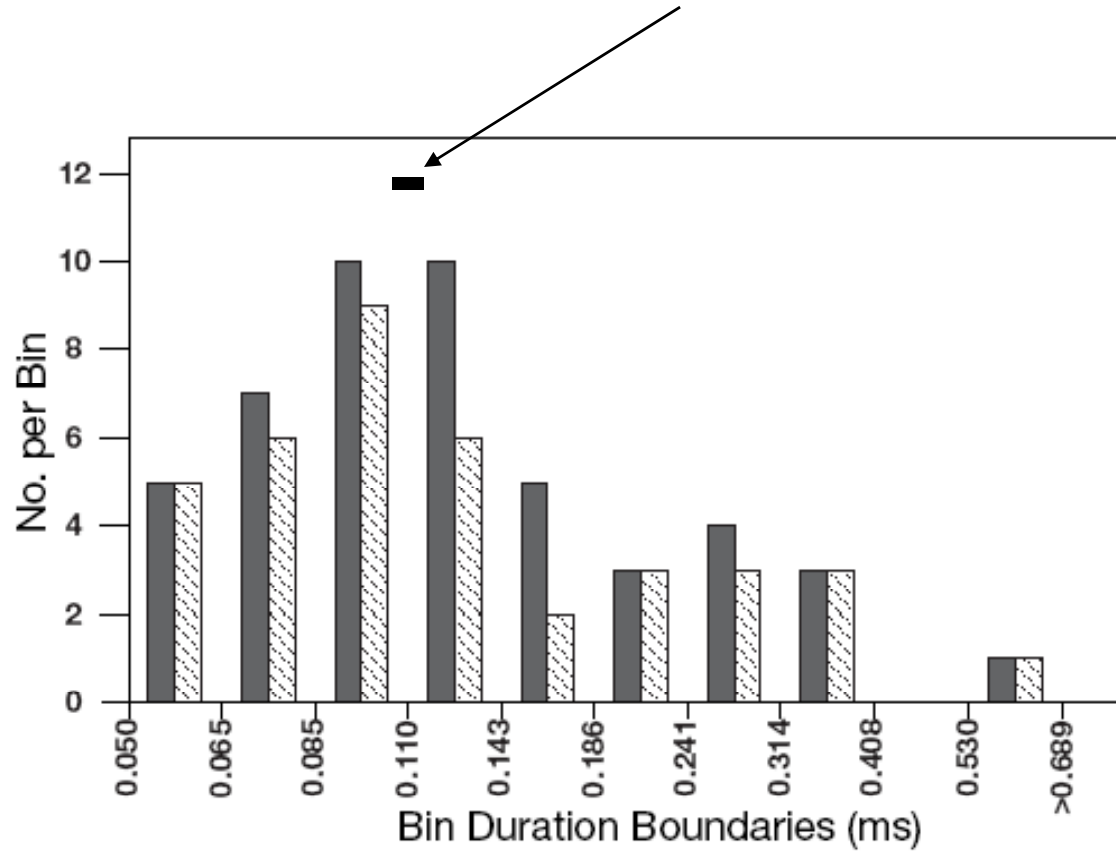
Triggered TGF Rate in GBM: ~1/mo., prior to 11 Nov. 2010

~8/mo., after “ “



# First 50 GBM TGFs

Media TGF Pulse Duration = 0.11ms

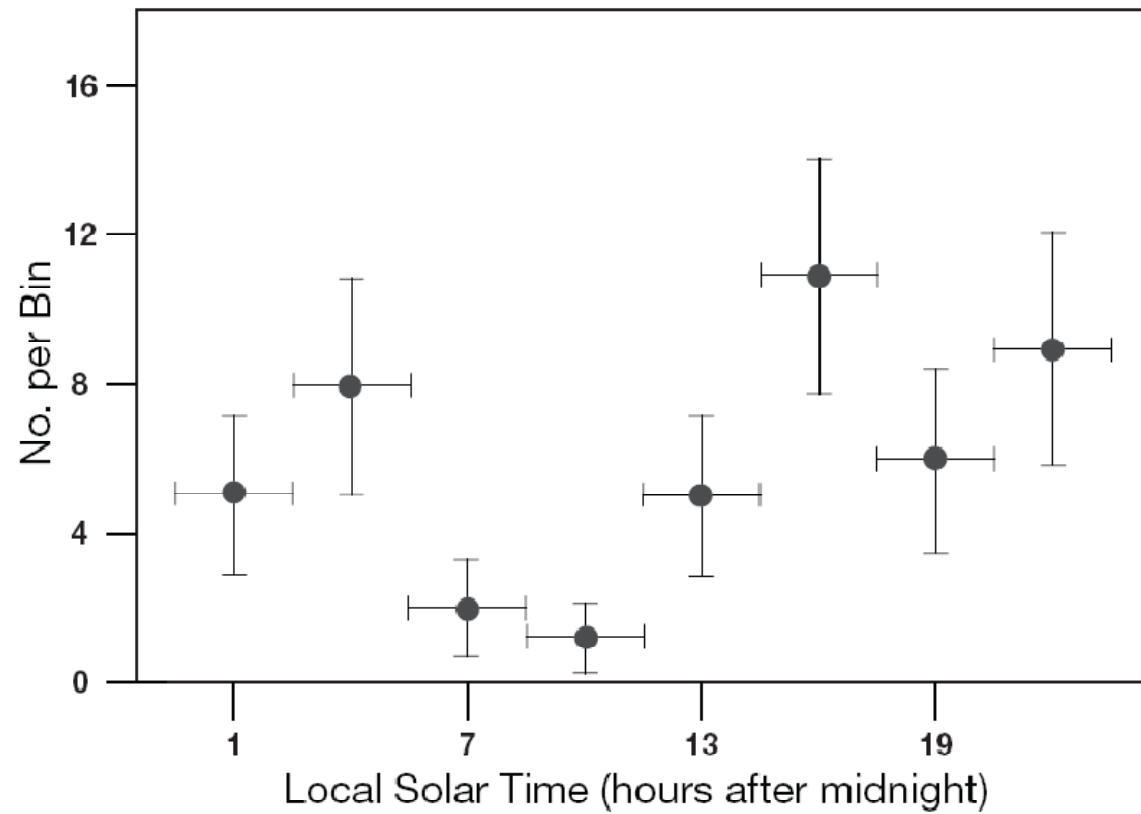


- Does not include 5 longer “electron” TGFs
- Solid column – includes 10 possible un-resolved pulses



## Time-of-Day Occurrence of TGFs

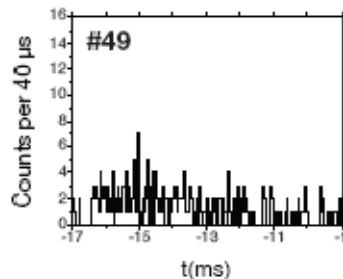
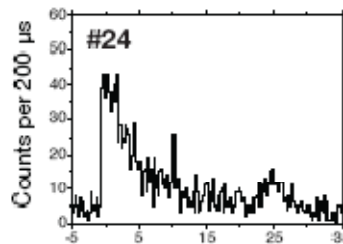
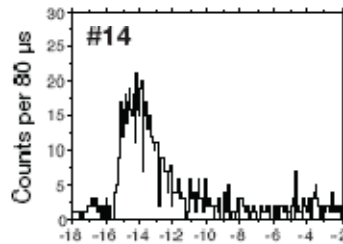
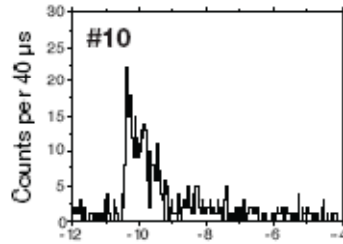
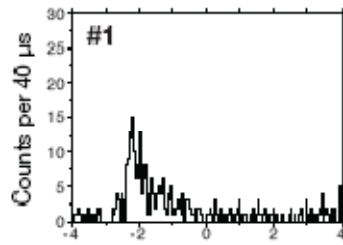
- shows afternoon enhancement



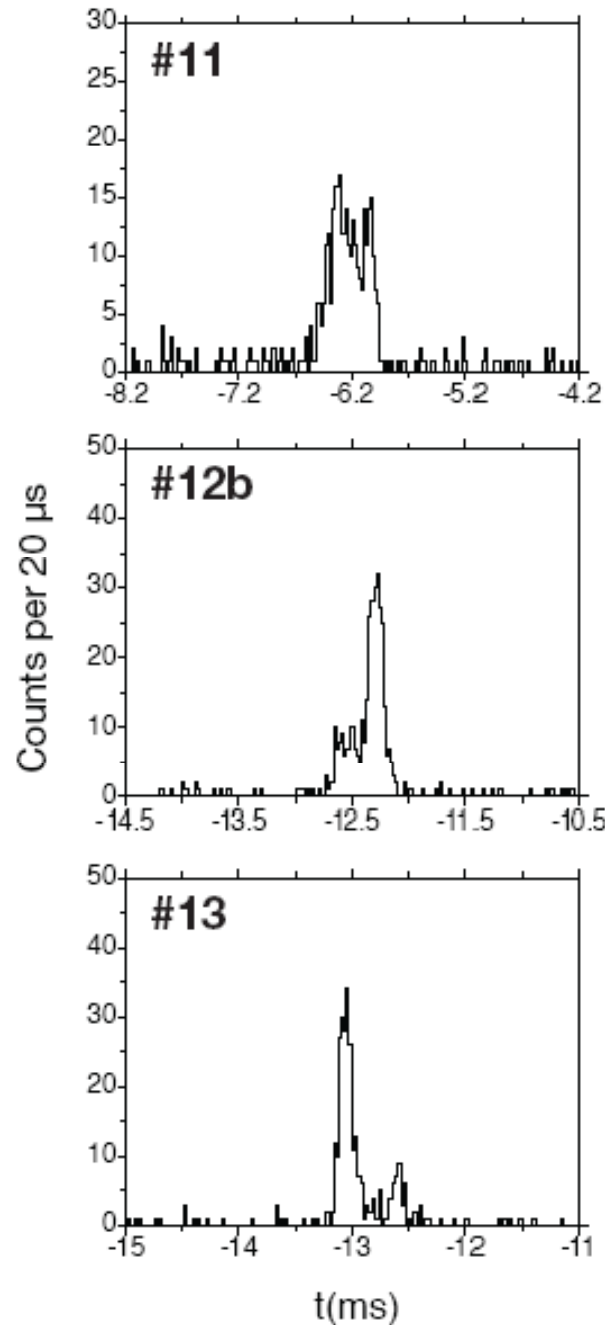
# Five “Electron” TGFs (in the first 50)

## Characteristics:

- Longer than usual
- Fast rise, then decaying
- Some are not over thunderstorms



# Overlapping Double Pulses

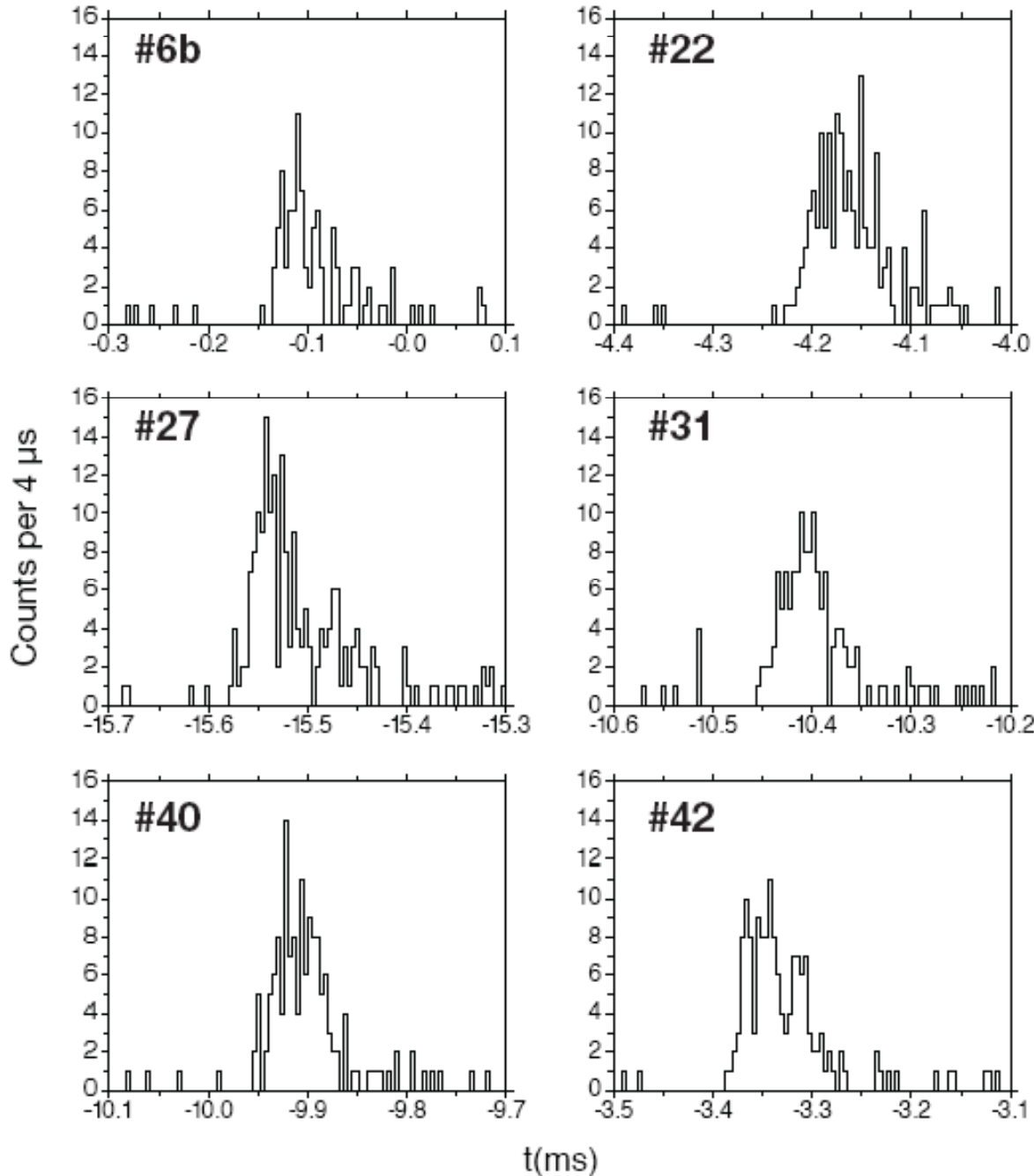


- 3 in the first 50 TGFs

(~7 others are less obvious)

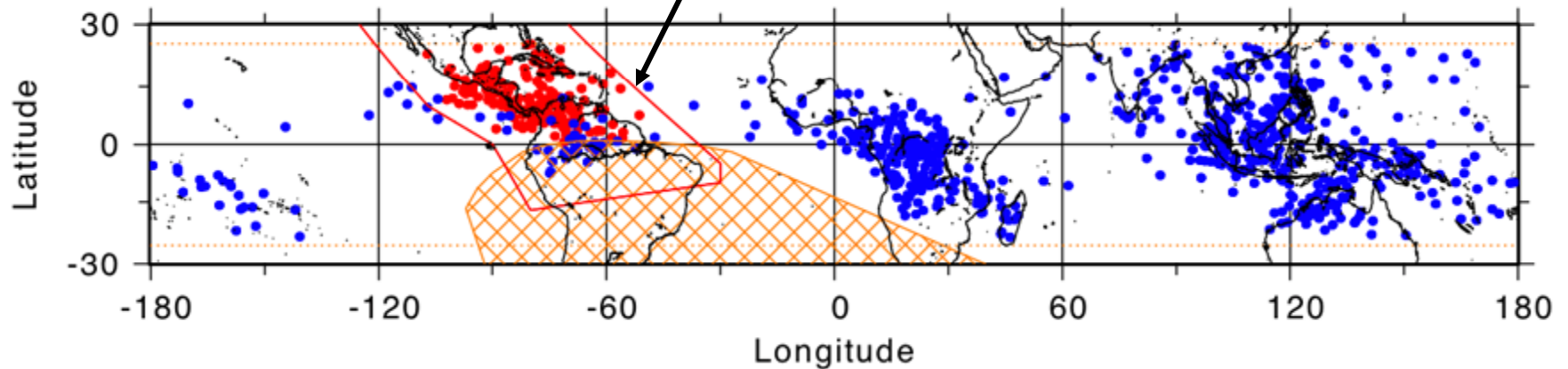
# 6 of the fastest TGFs

Show variations  
(risetimes & falltimes)  
of  
~7 to 15 $\mu$ s



# July 2010 – Implemented “un-triggered” TGF capability

Over selected “America’s Region”:

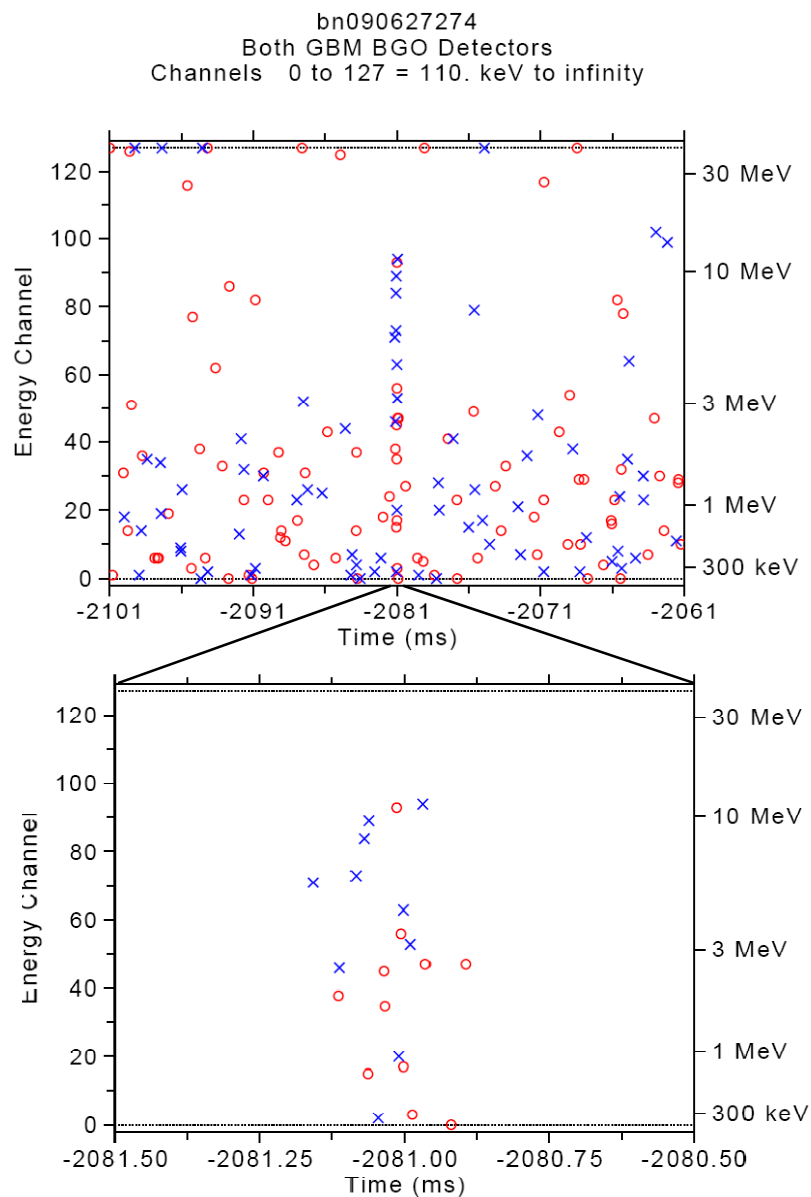


● - RHESSI TGFs

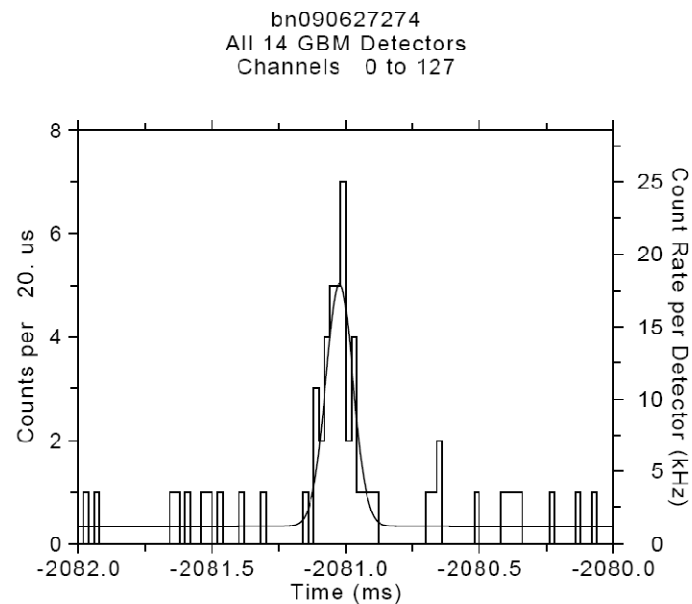
● - RHESSI TGFs, May-November

est.: ~several TGFs per day in this Reion

# First look at a GBM an Un-triggered TGF



Binned Data 20 $\mu$ s/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  
Electron Avalanche*

**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**

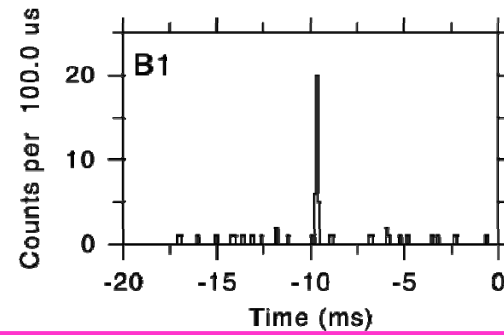
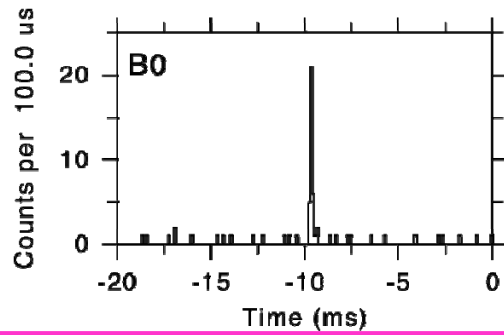
**End**

**Back-up**

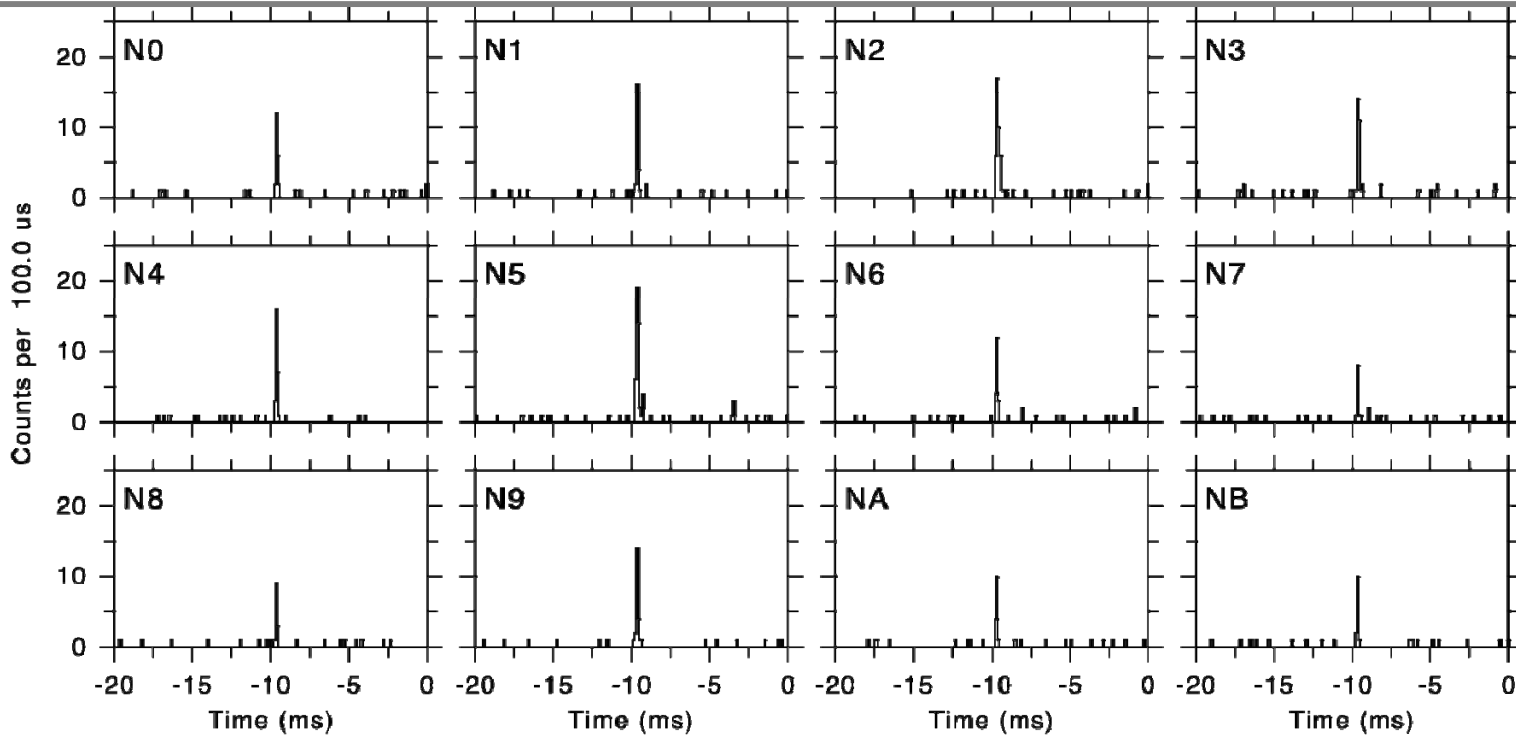
**Slides**

# TGF #5 , Individual Detectors, 0.1ms bins

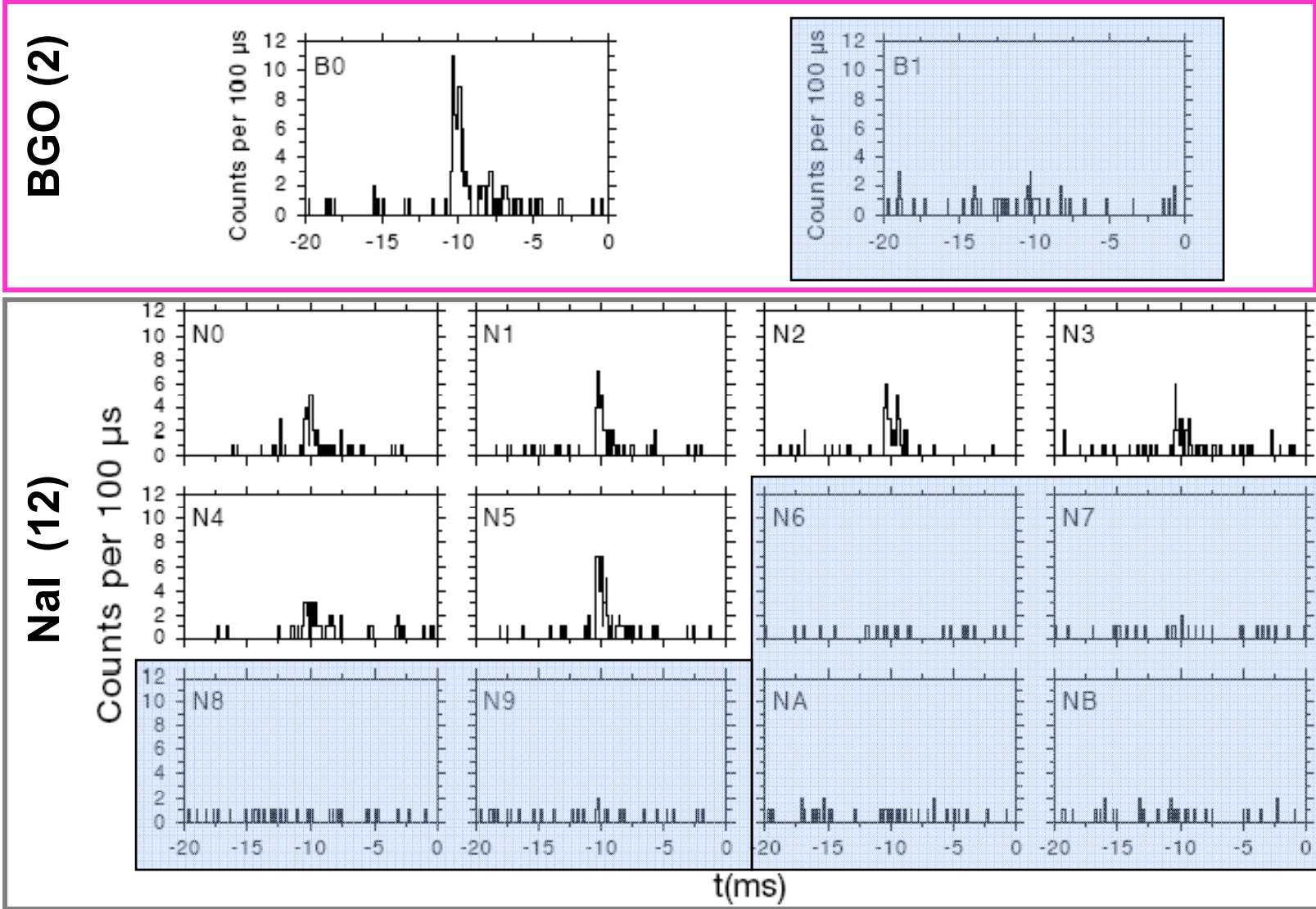
**BGO (2)**



**NaI (12)**

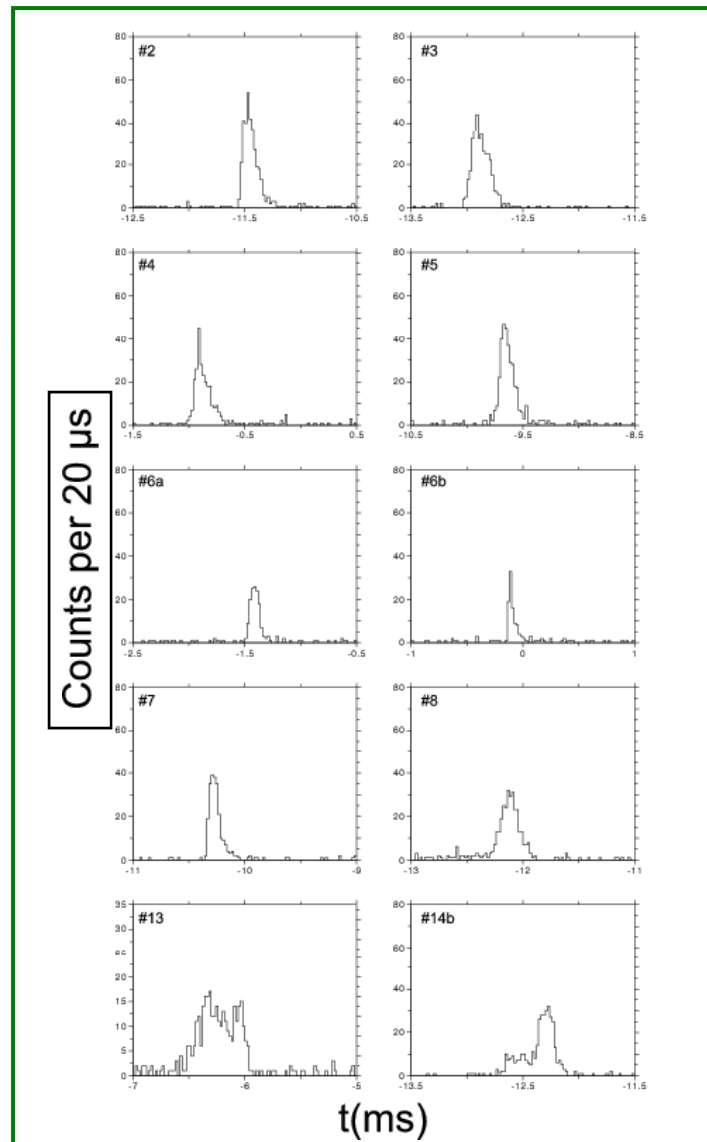


# TGF #1 , Individual Detectors, 0.1ms bins

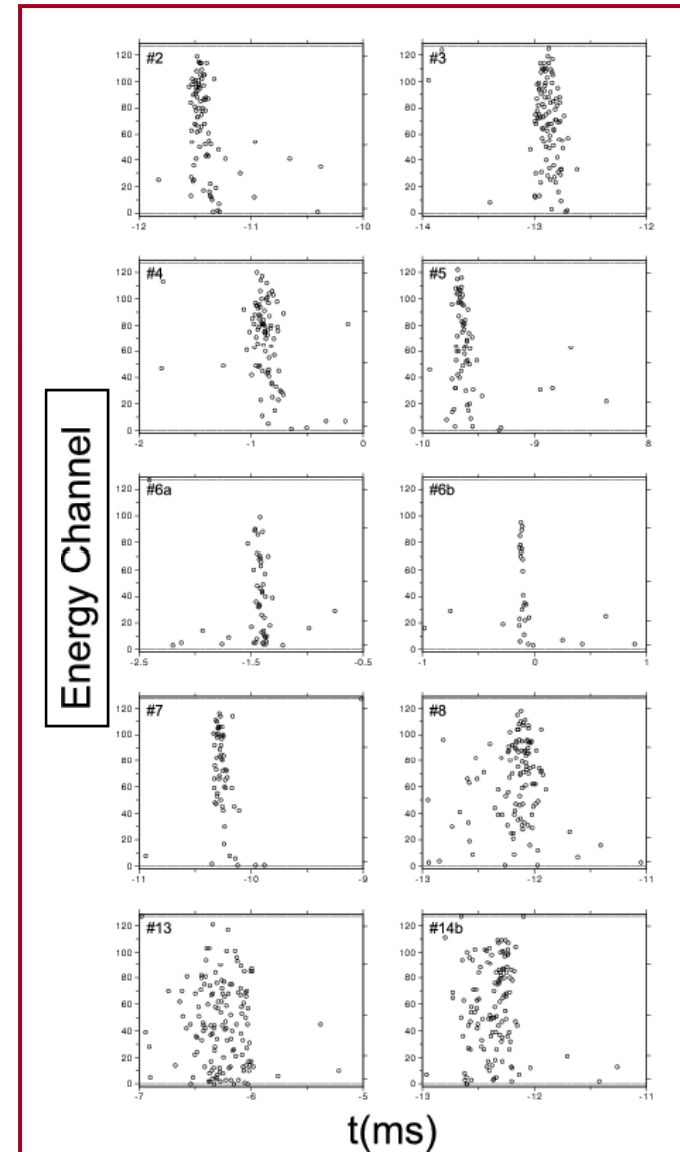


# Properties of 10 Short TGF Pulses

## Time Profiles – All Detectors Combined

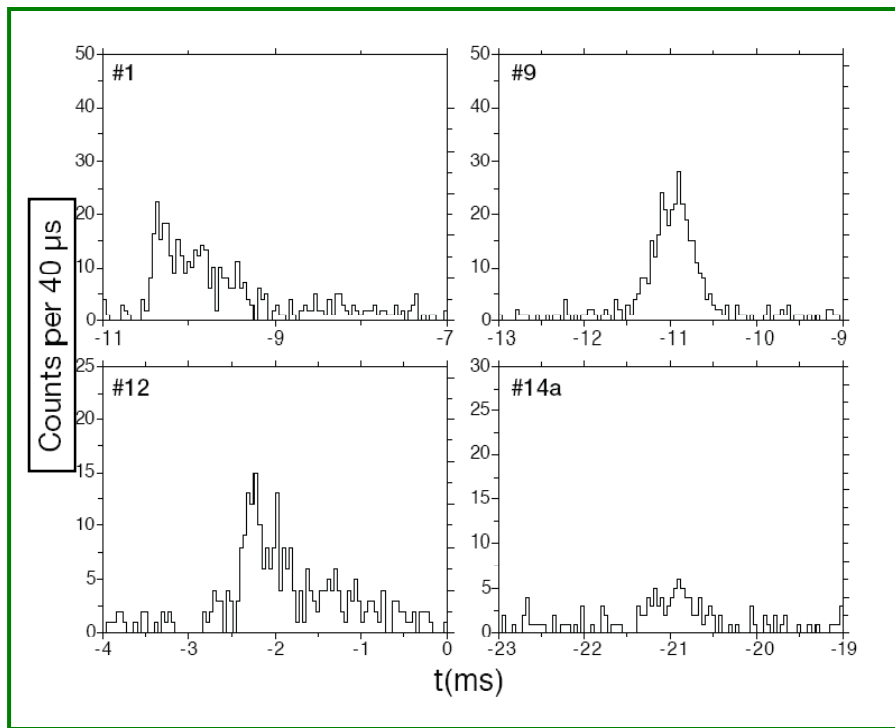


## Energies of Single Counts - BGO Detectors Only

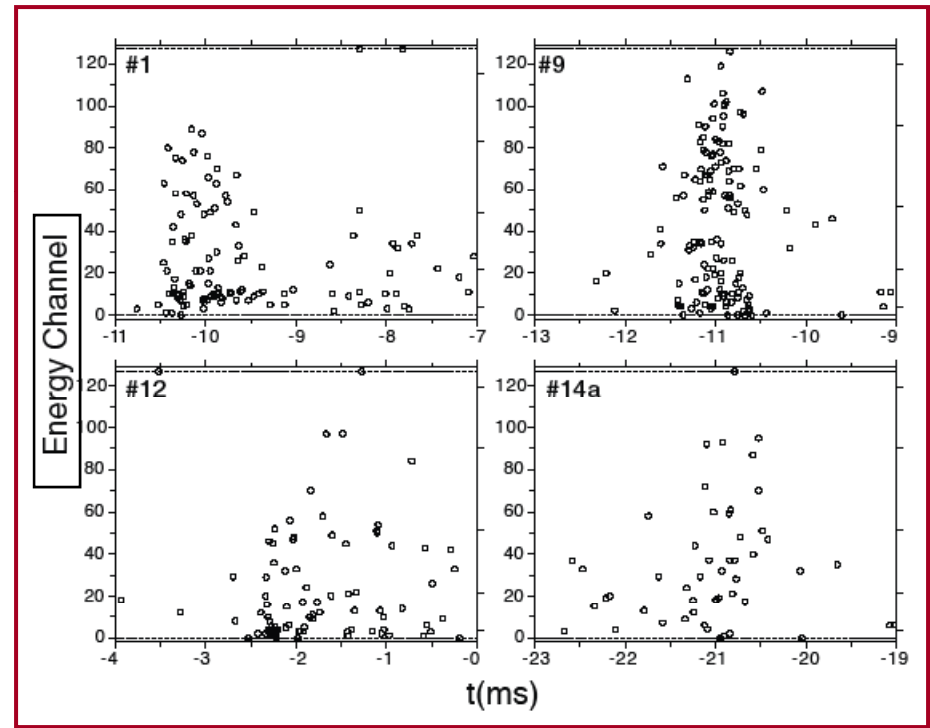


# Four Longer TGF Pulses (~1-3 ms)

Time Profiles –  
All Detectors Combined

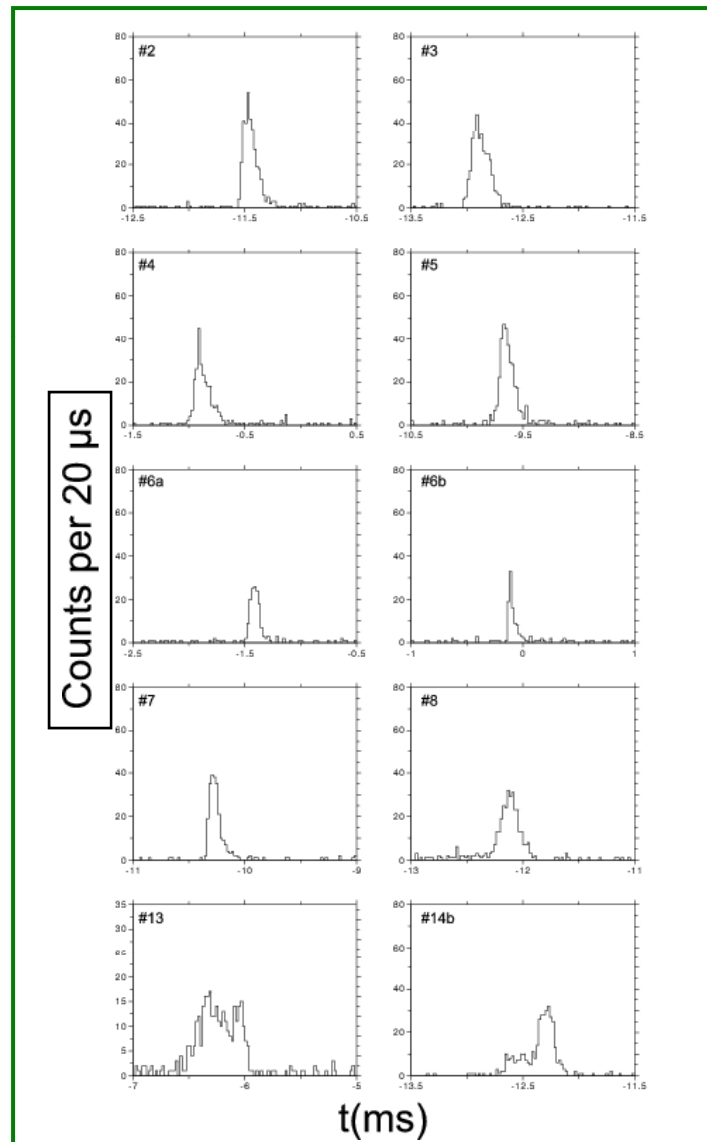


Energies of Single Counts -  
BGO Detectors Only

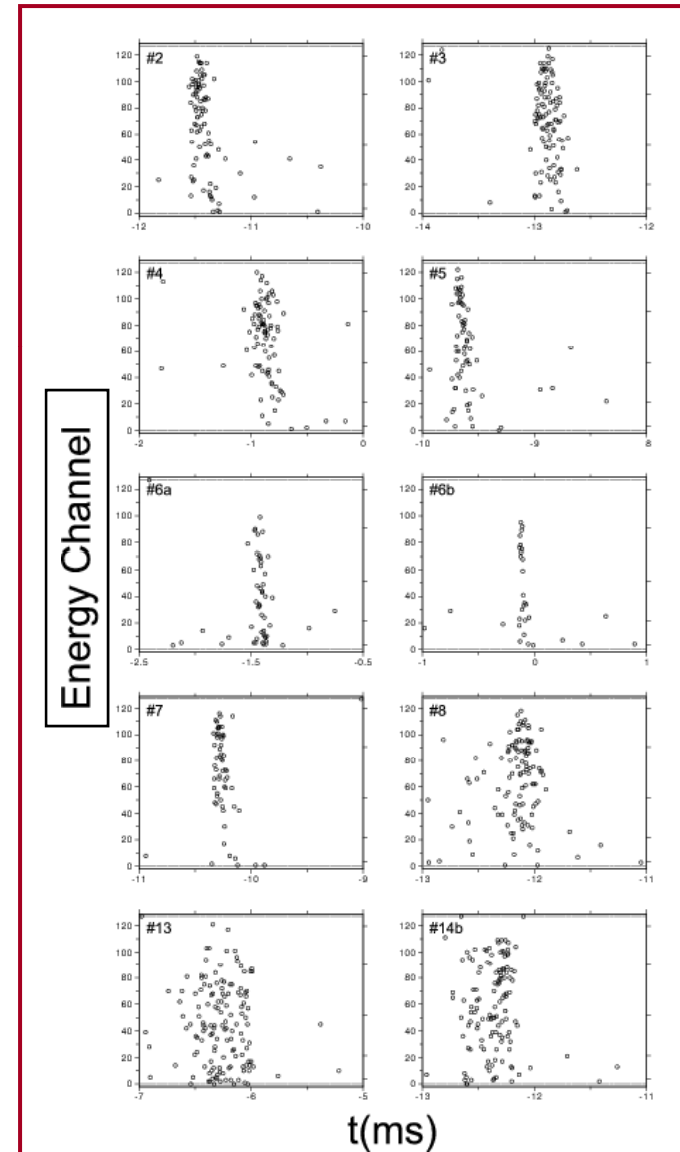


# Properties of 10 Short TGF Pulses

## Time Profiles – All Detectors Combined



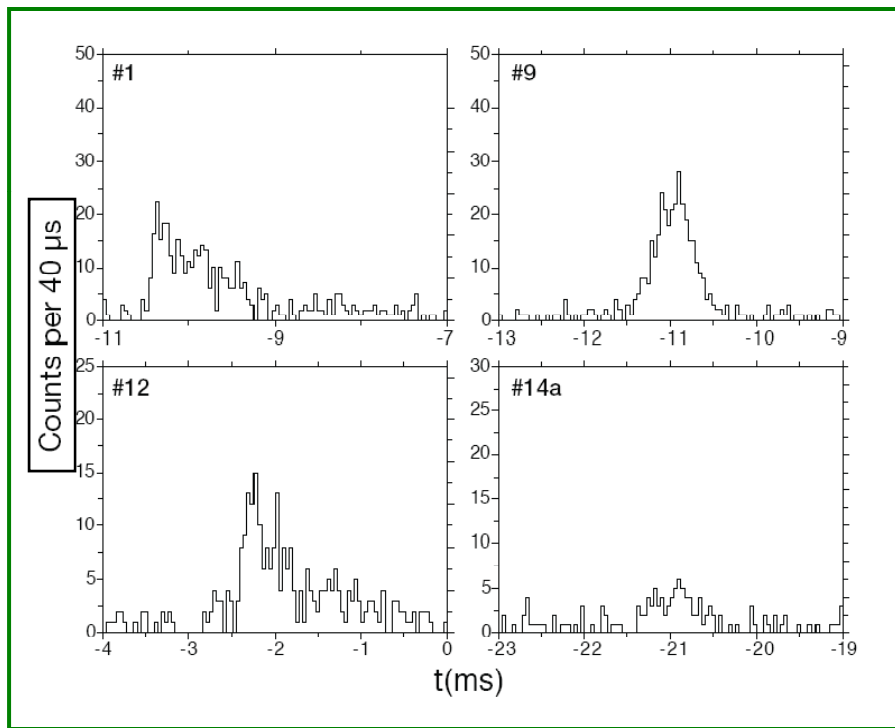
## Energies of Single Counts - BGO Detectors Only



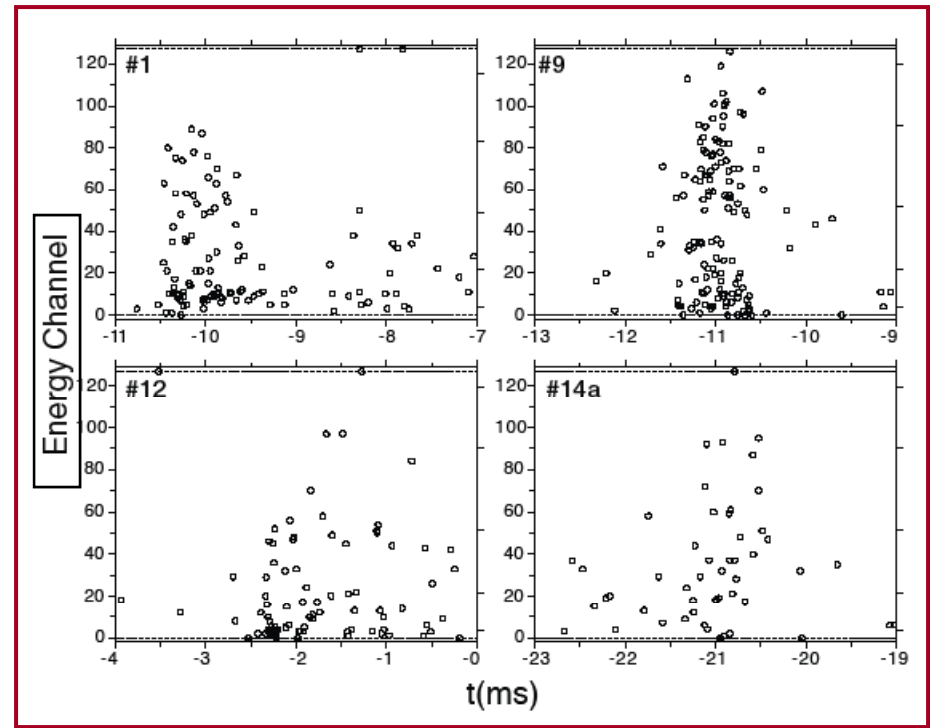


# Four Longer TGF Pulses (~1-3 ms)

Time Profiles –  
All Detectors Combined



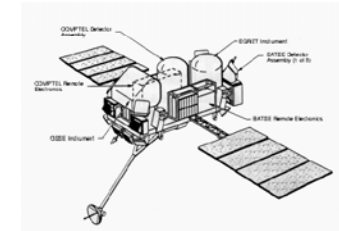
Energies of Single Counts -  
BGO Detectors Only



# Four Orbiting Spacecraft Have Observed TGFs:

## BATSE on the Compton Gamma-ray Observatory

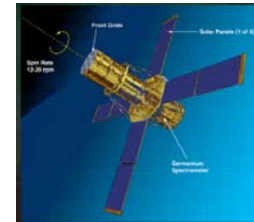
- Discovered TGFs ; publ. in 1994
- Operational 1991-2000



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## RHESSI - Solar Spectroscopy Spacecraft

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



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## AGILE

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



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## The Gamma-ray Burst Monitor, “GBM” on the Fermi Gamma-ray Space Telescope, “Fermi”

- This talk and the next one

