GLAST: A GeV All Sky Monitor

Interdisciplinary Scientist Proposal of
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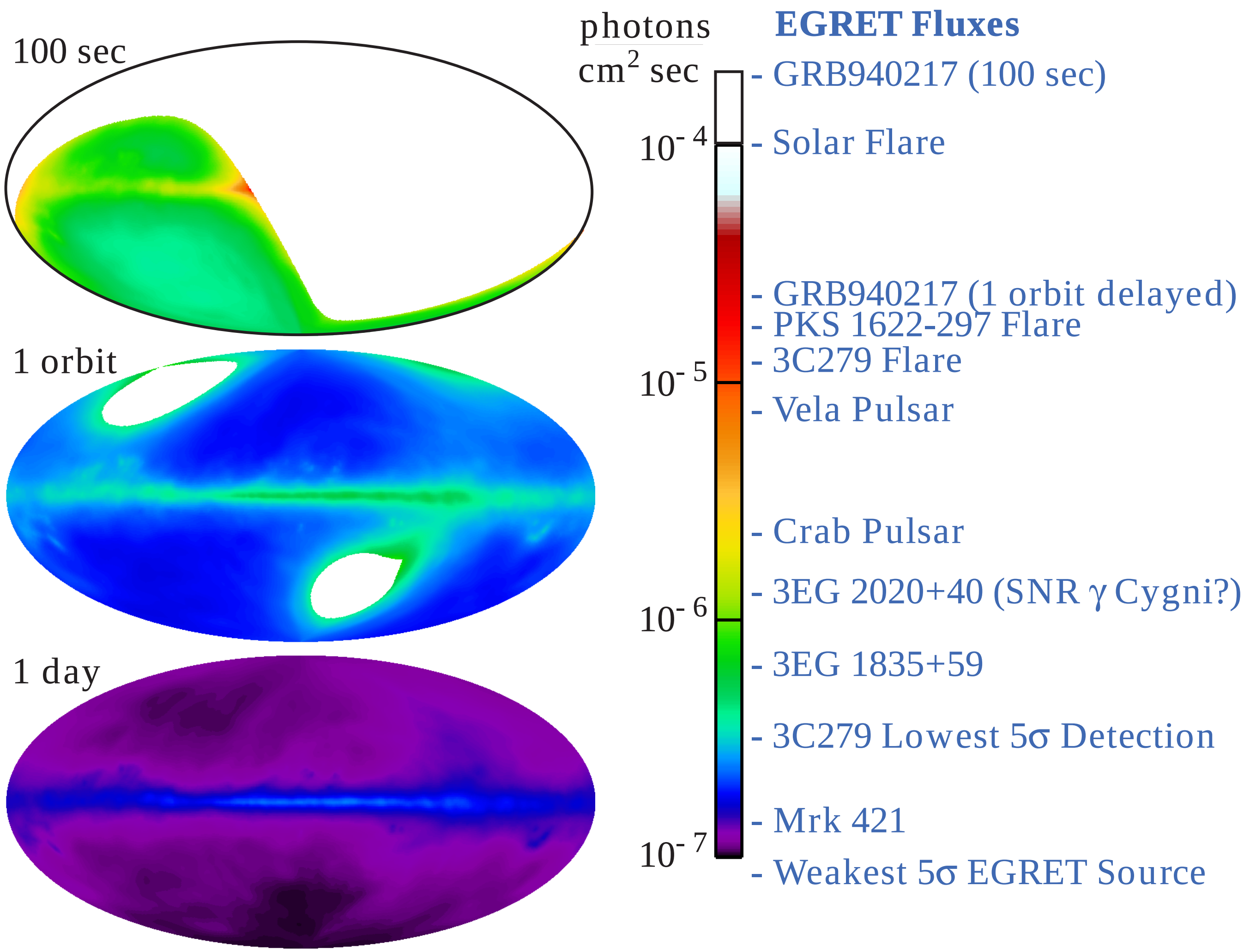
GLAST Sensitivity



IDS Proposal

GLAST GRB Research

- **GRB Spectral Evolution**
- **GRB GLAST Sim ulations**
  - **< 30 MeV to resolve fastest time variability at highest E**
    - **Probe Quantum Gravity**
  - **> 10 GeV to extend spectra to highest E**
    - **Constrain Bulk Lorentz factor and Intergalactic absorption**
- **GRB Analysis Software**

TeV Rapid Notification Service

- **Develop algorithms to promptly search for highest E transients**

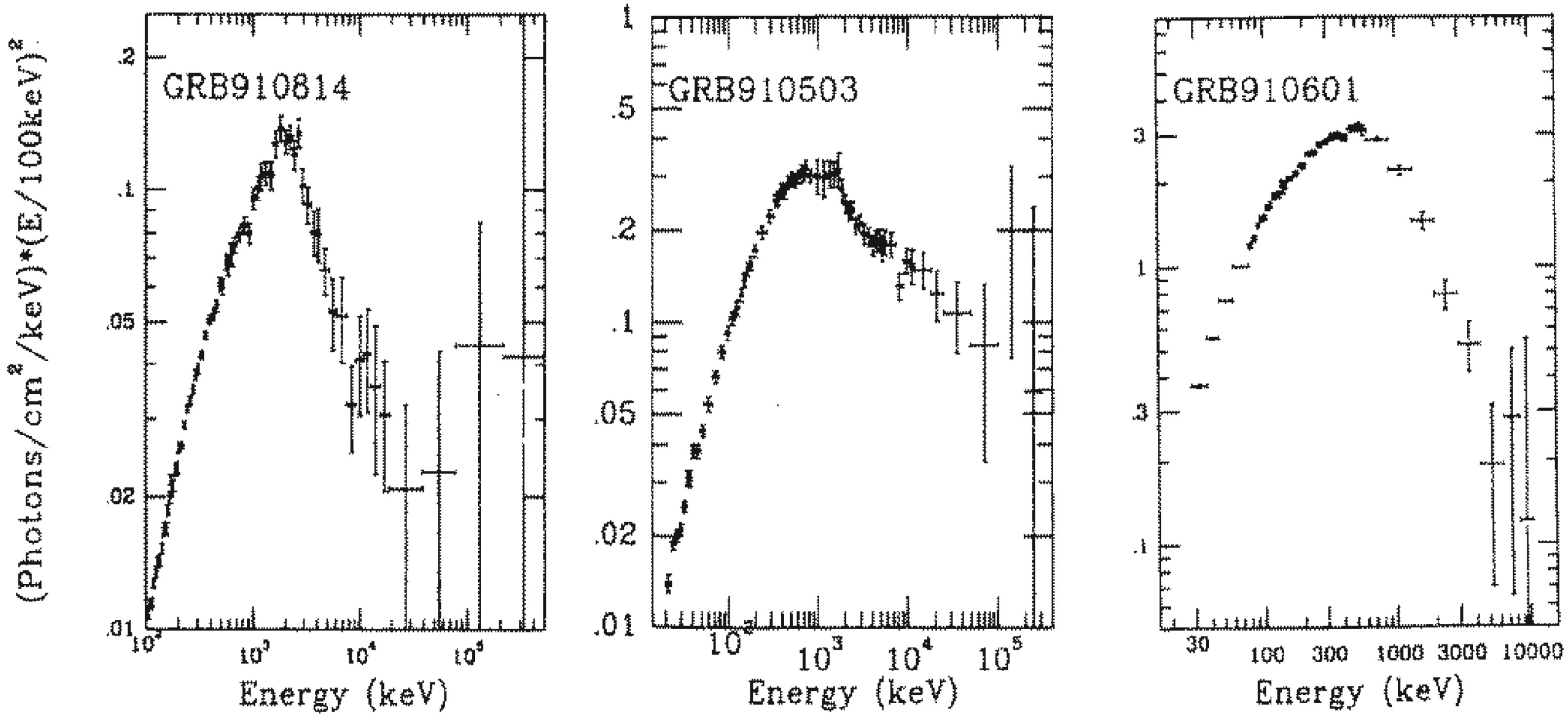
Interdisciplinary Research

- **EGRET analysis**
- **Milagro: A TeV All Sky (northern hemisphere) Monitor**

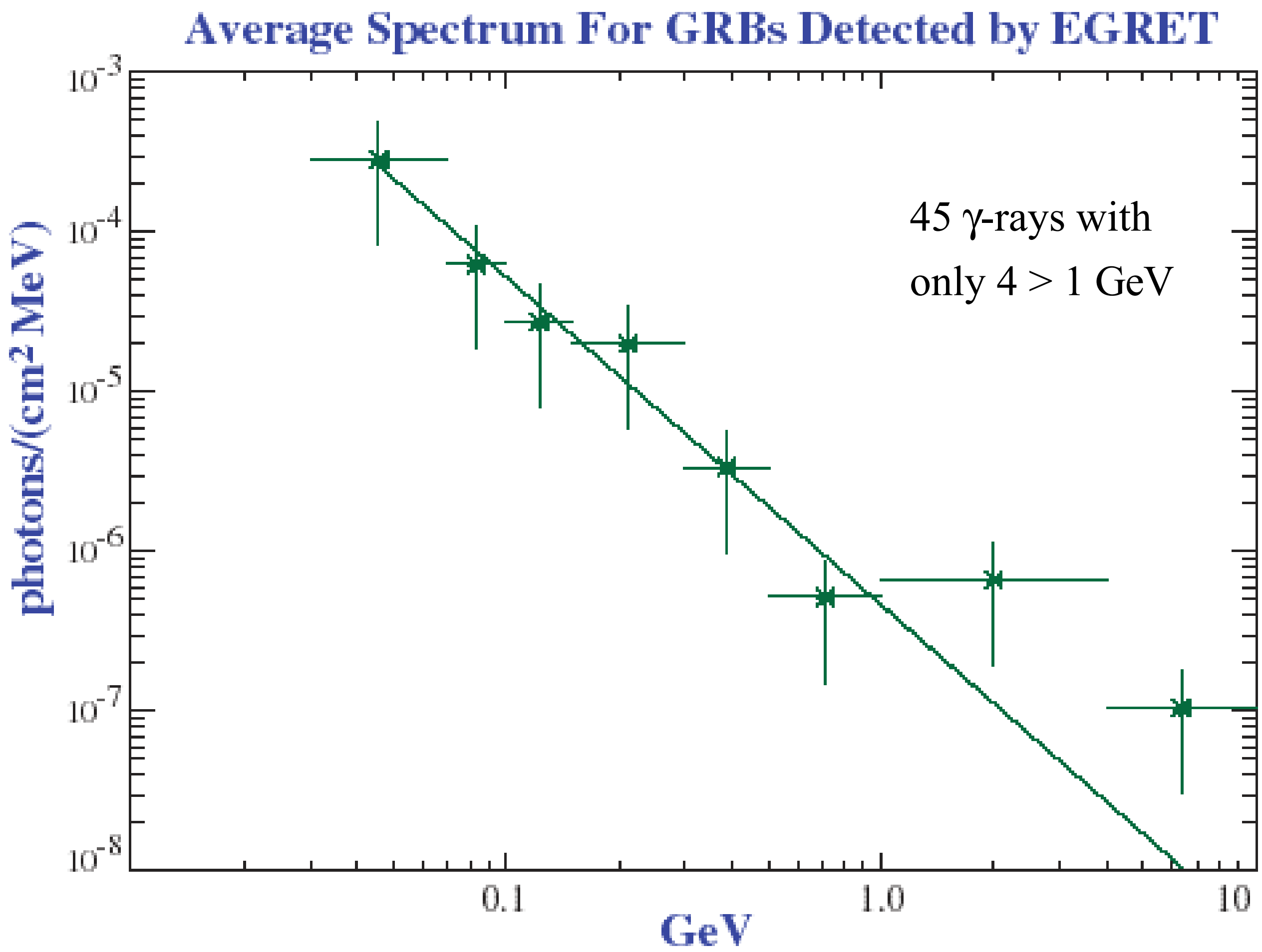
EPO and SWG

Energy Spectra of GRBs

Spectra of bursts have peak fluence in narrow range of energy as seen in these 3 bright bursts

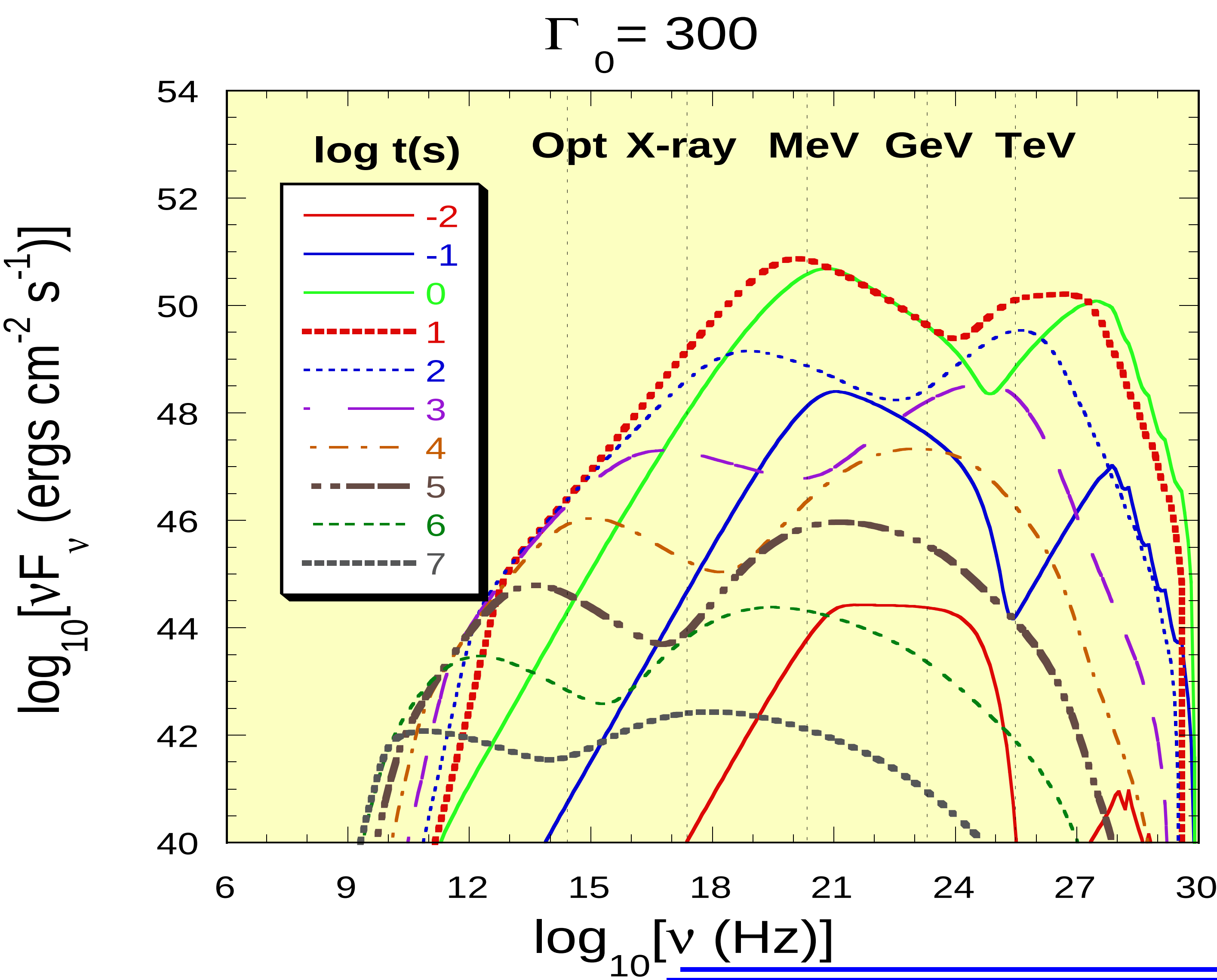


Highest Energy Spectrum from GRB



$dN/dE \propto E^{-1.95\pm0.25}$ or $E^2\, dN/dE \propto E^{0.05\pm0.25}$

Higher E γ-rays Predicted



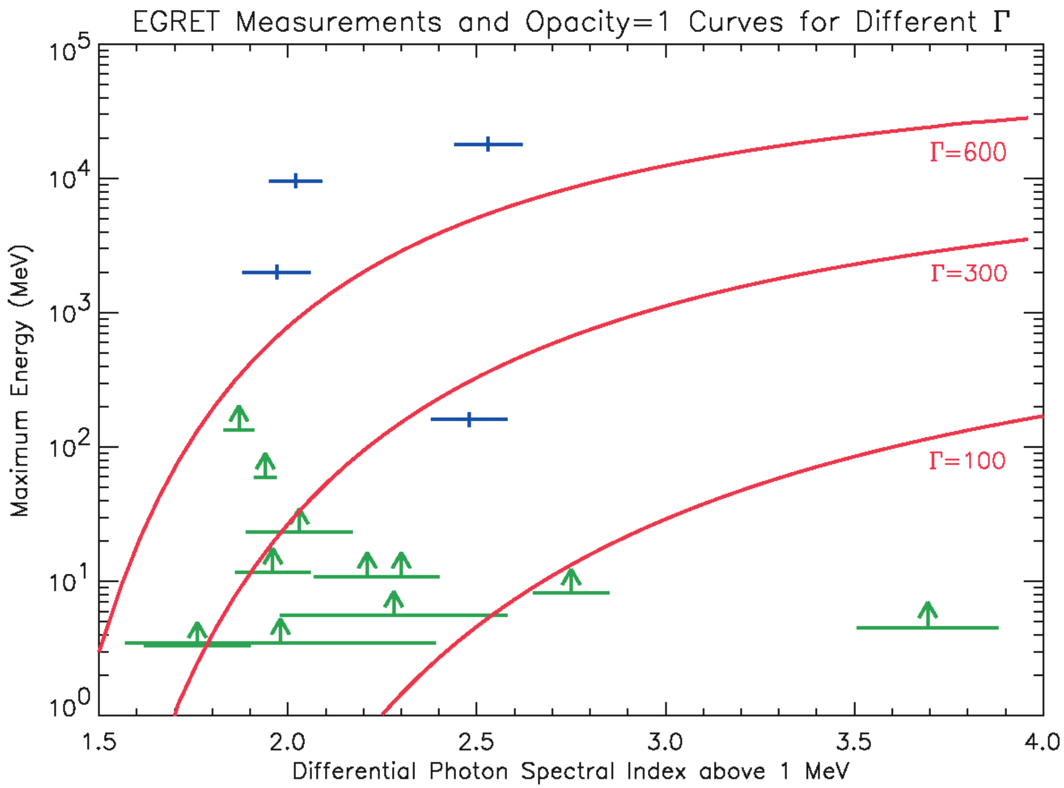
Dermer, 1999

Importance of Highest Energy Observations

•Gamma Rays attenuated by γ (GeV) + γ (keV) --> $e^- + e^+$

•Density of keV photons high is inferred by rapid variability and source distance

•No attenuation if emission is from fireball with LARGE bulk Lorentz factor--peak cross section if $E_1 E_2 \sim 4 m_e^2 c^4 / (1\text{-}\cos \vartheta)$

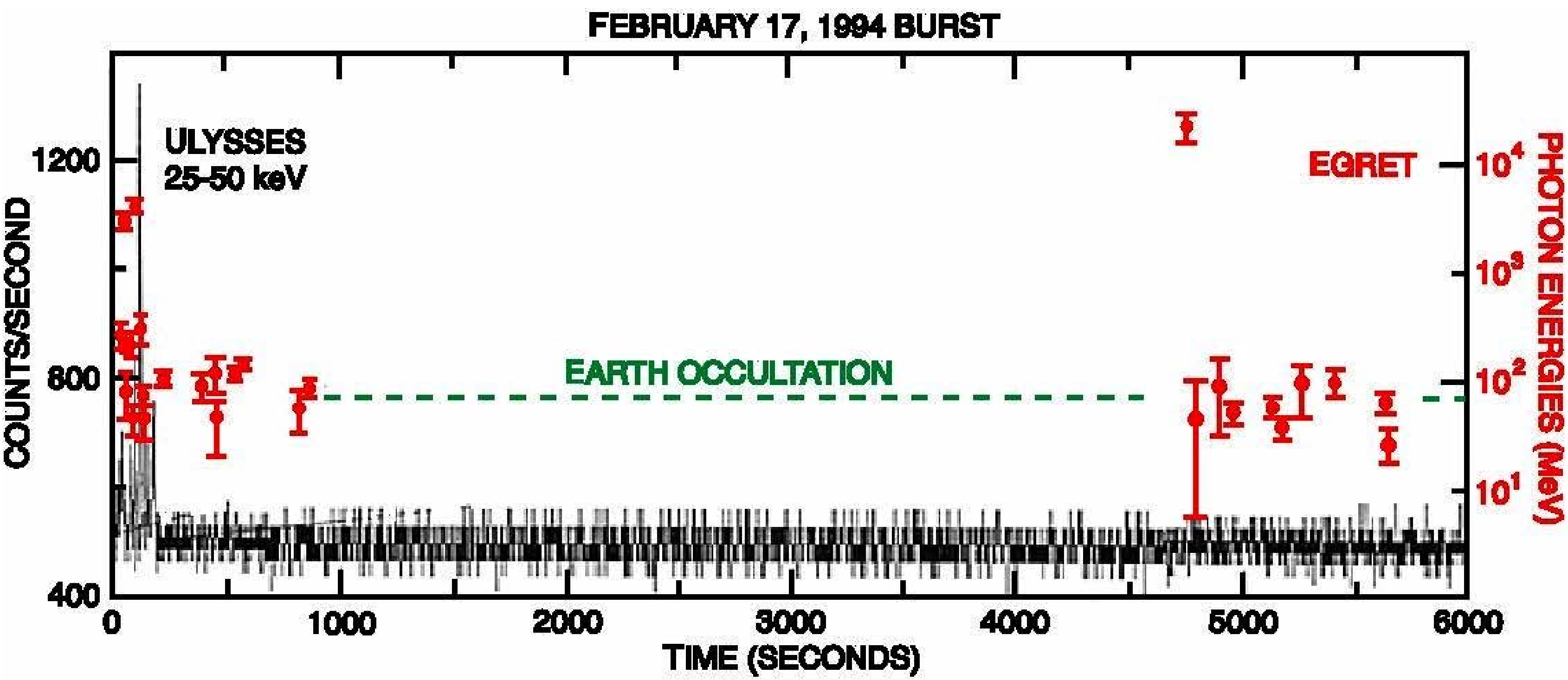


Bulk Lorentz factor, Γ, required for opacity, τ =1, and for parameters of typical bright burst detected by EGRET (Baring & Harding, 1997)

GeV Afterglows

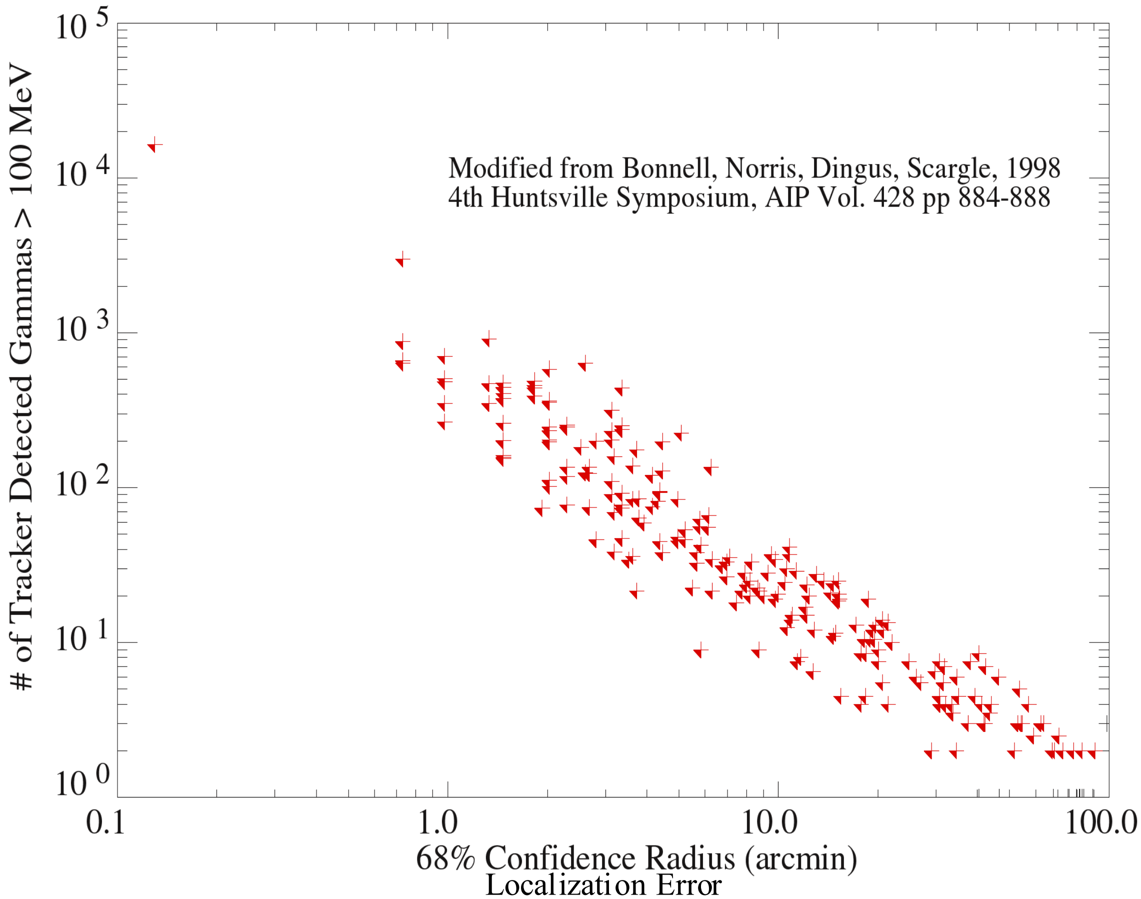
Longer duration emission at GeV than MeV

- **Due to external shocks which cause lower energy afterglows?**
- **Significant fraction of the energy released?**



GLAST GRB Capabilities

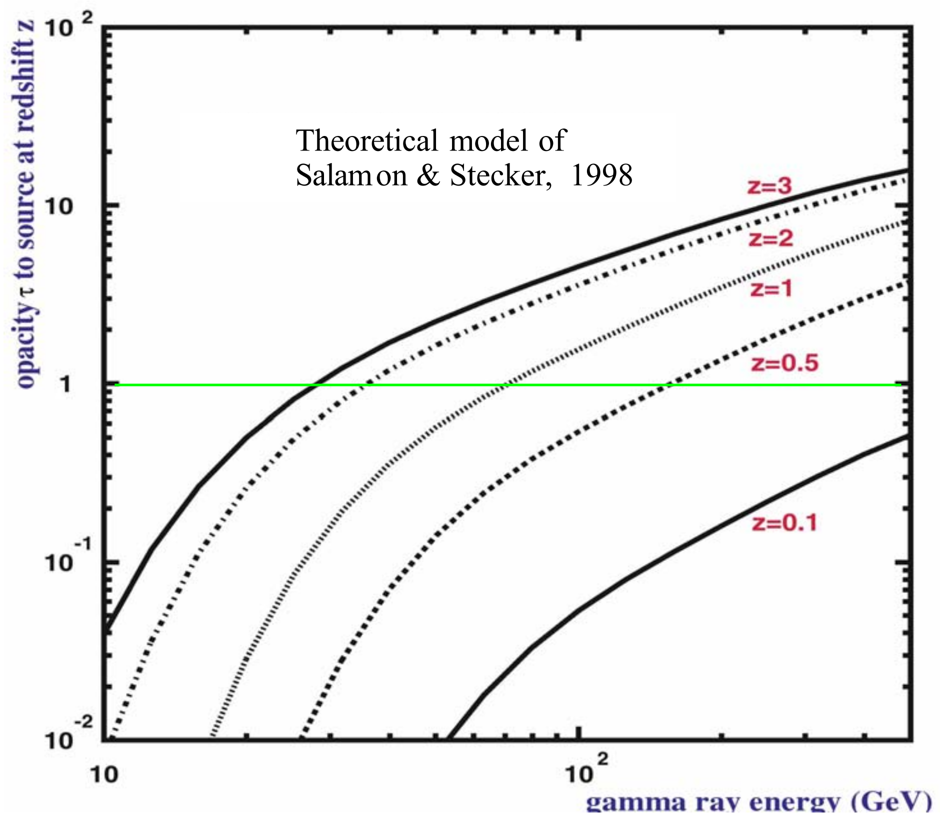
Simulation of Bursts Detected in One Year of Observation assuming extrapolation of EGRET power law spectra (for which no high energy cut off have been observed)



- > 50 bursts per year with > 100 γ-rays detected
  - Sufficient to measure spectral indices to ± 0.1 up to > 1 GeV
- > 10 bursts per year with > 100 GeV γ- rays and multiple spectra

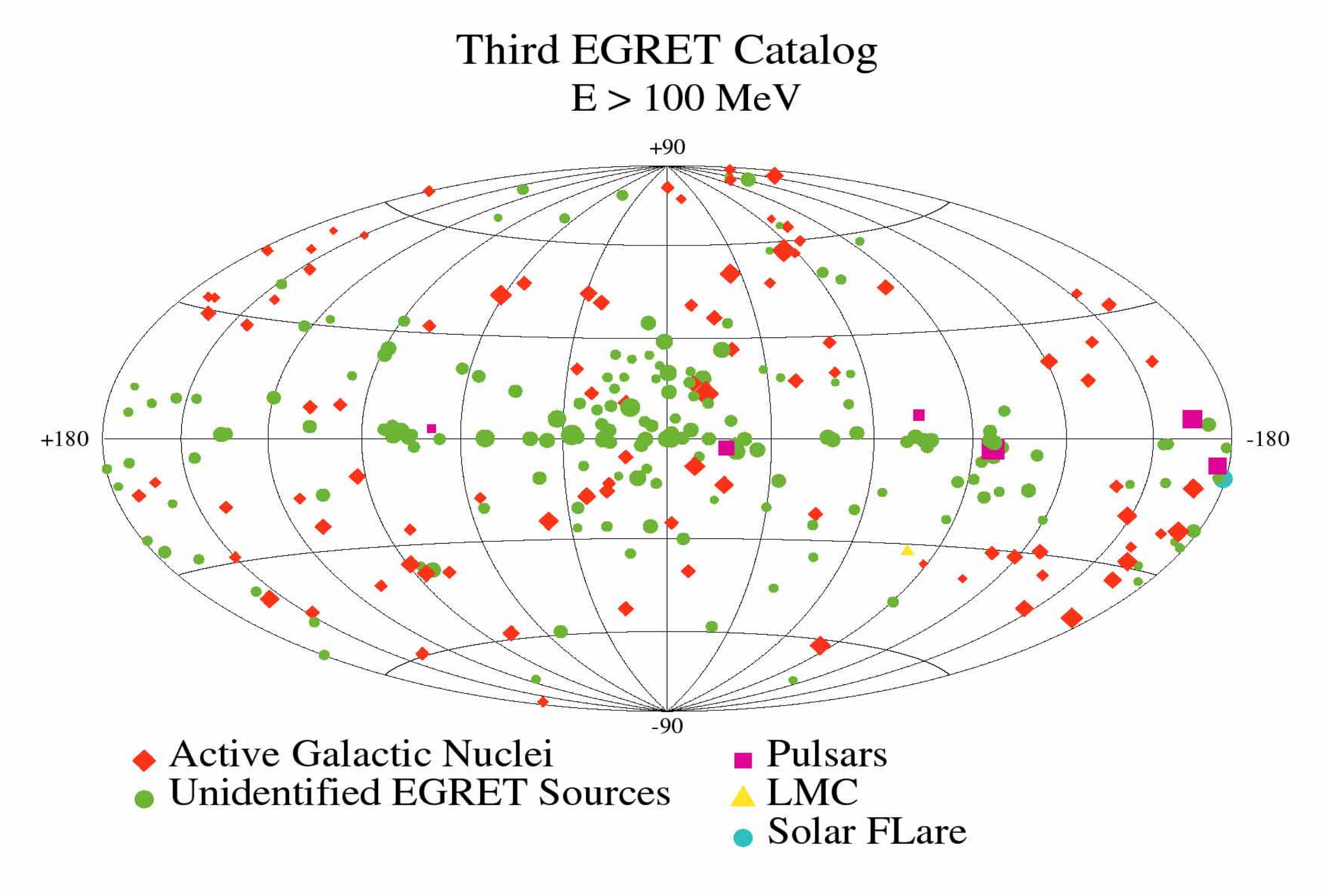
Extragalactic Background Light Absorption

- γ (10-100 GeV) + γ (100-10 eV) --> $e^- + e^+$
- Ultraviolet to optical photon density probes stellar initial mass function (IMF) at high redshifts

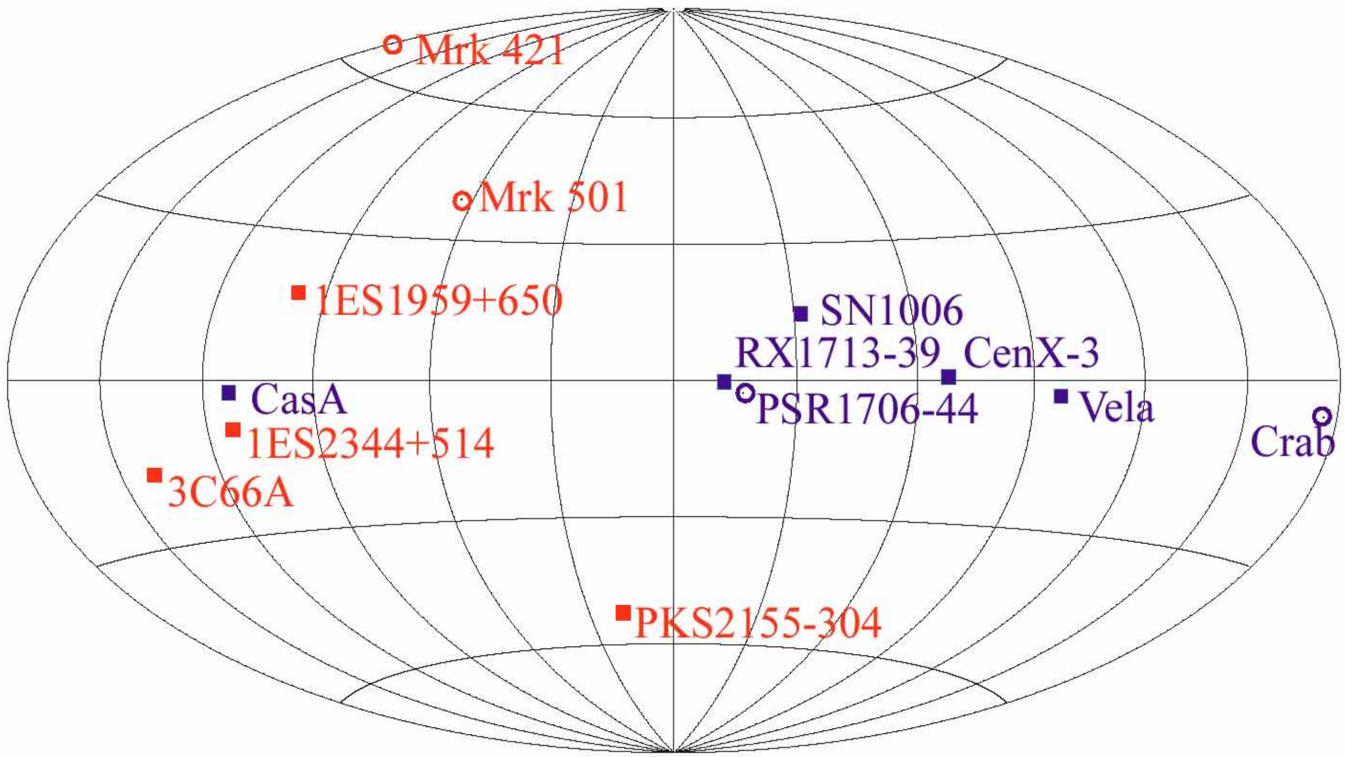


- UVto IR photon density at large redshifts is difficult to determine
- Theoretical calculations differ considerably!
- Ramifications to stellar and galaxy formation in the early Universe

GeV Astrophysical Sources



TeV Astrophysical Sources



Active Galactic Nuclei
Galactic Sources (all supernovae remants, except CenX-3)
Confirmed Detection
Unconfirmed Detection

Why so Few Observed TeV Sources?

Fewer TeV Accelerators, but

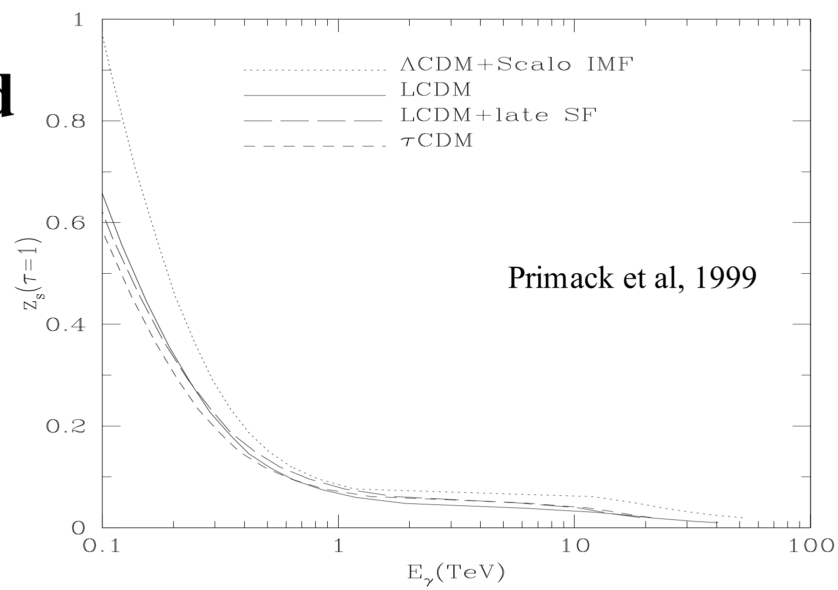
- **X-ray emission from supernova remnants and active galactic nuclei => TeV electrons**
- **Sources of >10^{19} eV cosmic rays likely to emit TeV γ-rays**

TeV γ-rays are Attenuated

$\forall \gamma\,(\text{TeV}) + \gamma\,(\text{eV})$

$\longrightarrow e^- + e^+$

- **Attenuation can be internal to the source or in transit**



TeV sources are Variable

- **Long term monitoring is needed to catch flares**

Better TeV Observatories are Being Built

Improved Flux Sensitivity to Detect Weaker Sources

- **VERITAS, HESS, MAGIC, CANGAROO**

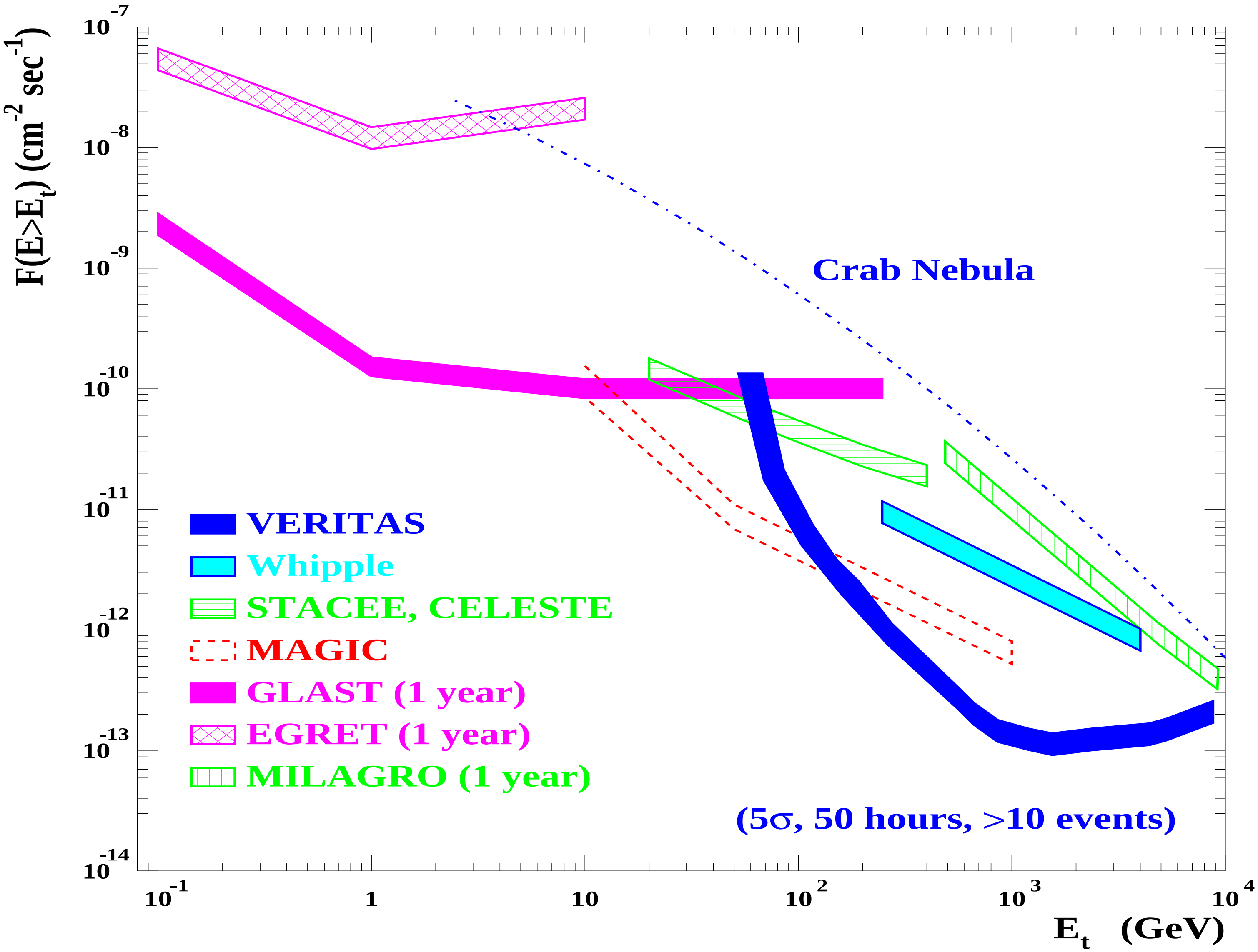
Lower Energy Threshold to Detect Distant Sources

- **STACEE, CELESTE, Solar 2**

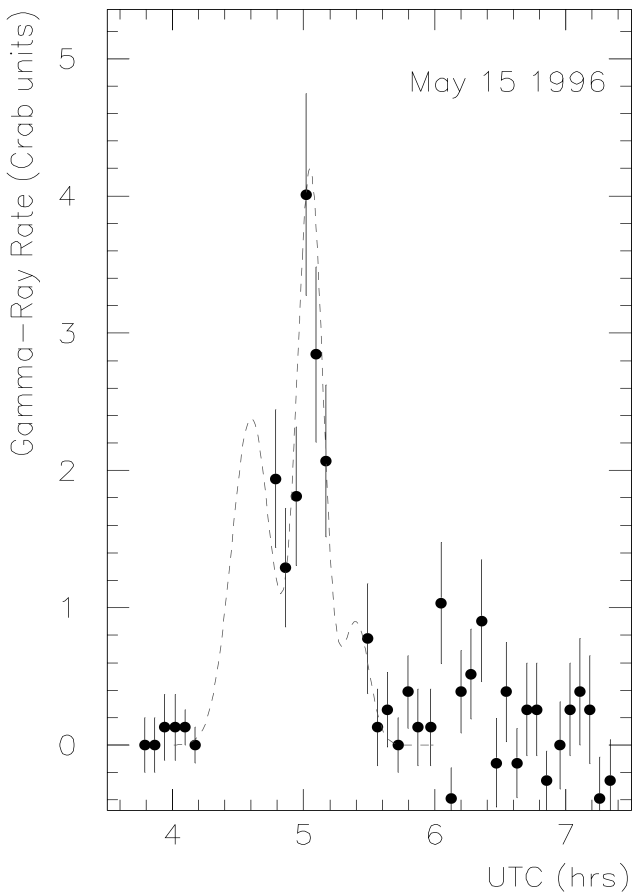
Large Field of View, High Duty Factor to Identify New and Flaring Sources

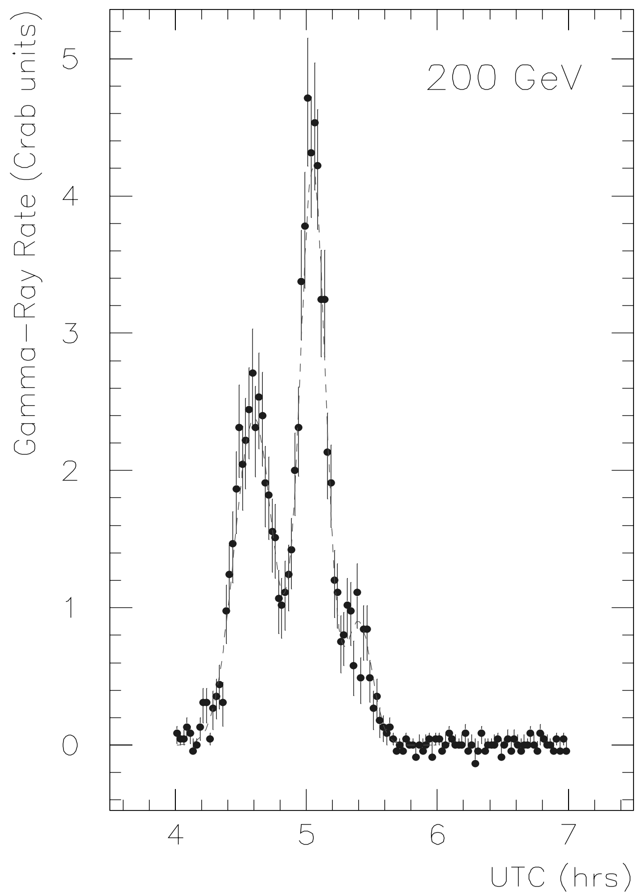
- **MILAGRO, Tibet EAγ, ARGO**

Improved Observatories



TeV Capabilities for Variability Studies





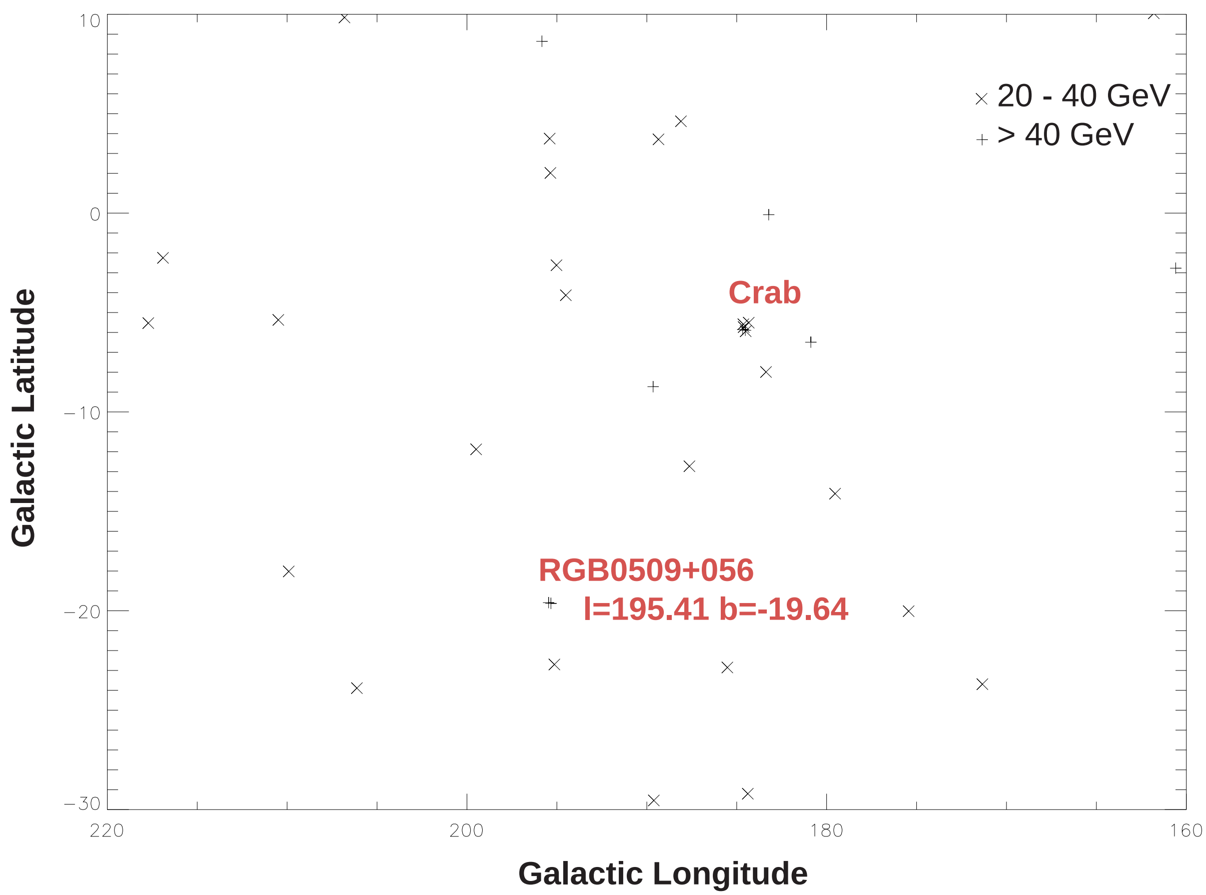
Whipple Observation **VERITAS simulation**

The Highest E γ-rays

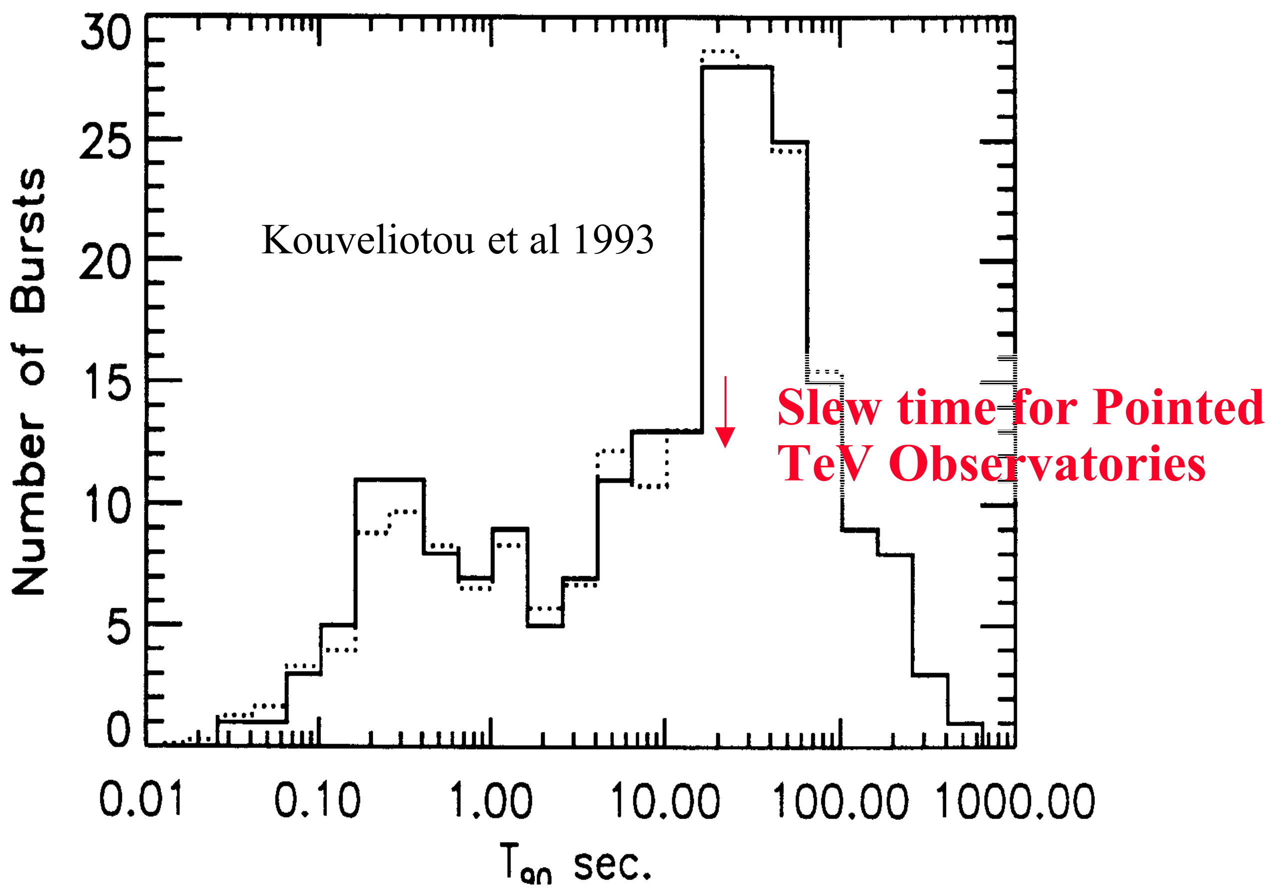
- **Due to huge collection area TeV observers can detect rapid variability but need rapid notification**
- **GLAST p.s.f ~5’ @ 10 GeV**

EGRET data has ~3 σ detection of RGB0509+056 (ROSAT detected BL Lac with 1 Jy radio flux) with only 2 γ-rays

Date	GeV	Ang. Dist.
940214	45±25	4’
940825	66±29	5’

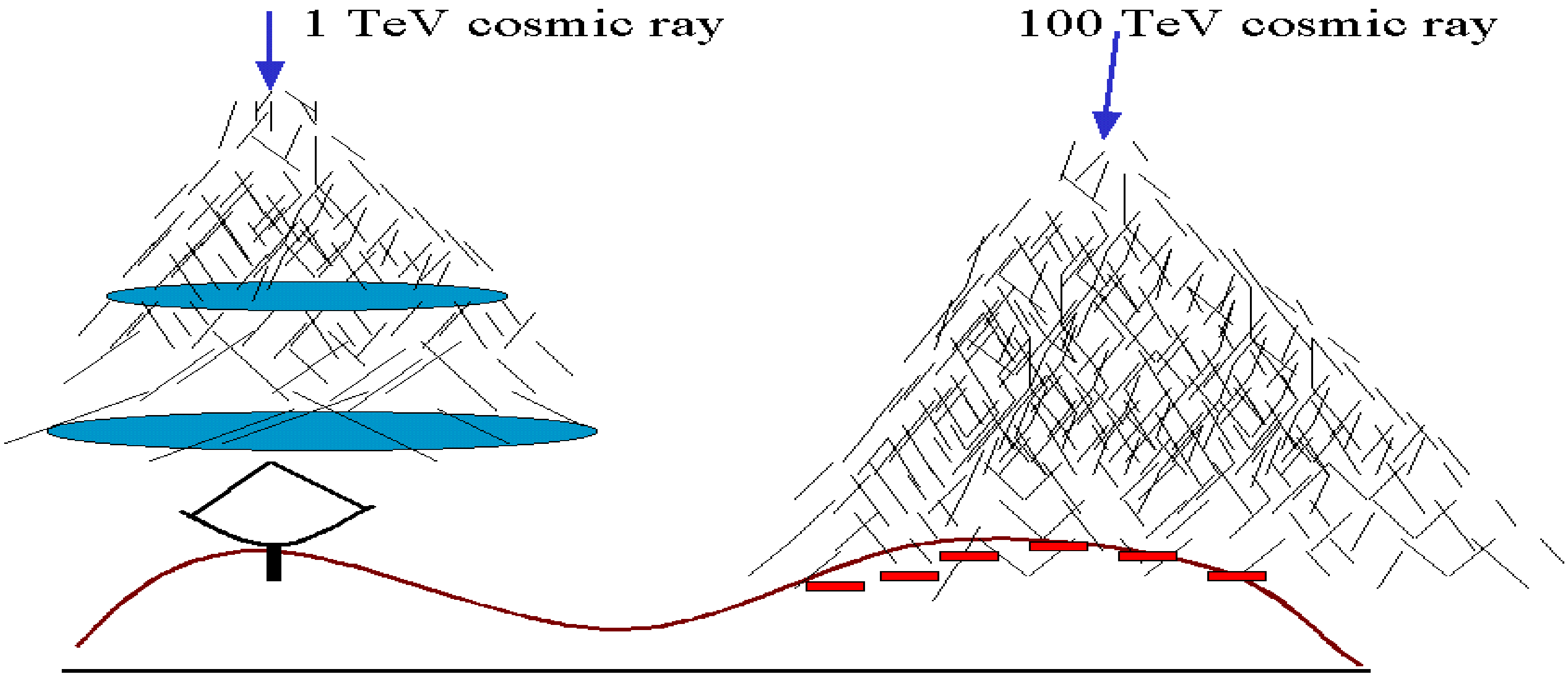


GRB Phenomena



Detecting TeV Gamma Rays

Air Cherenkov Telescope | Extensive Air Shower Array



Air Cherenkov Telescope

Low energy threshold (300 GeV)
Good background rejection (99.7%)
Small field of view (2 msr)
Small duty cycle (< 10 %)

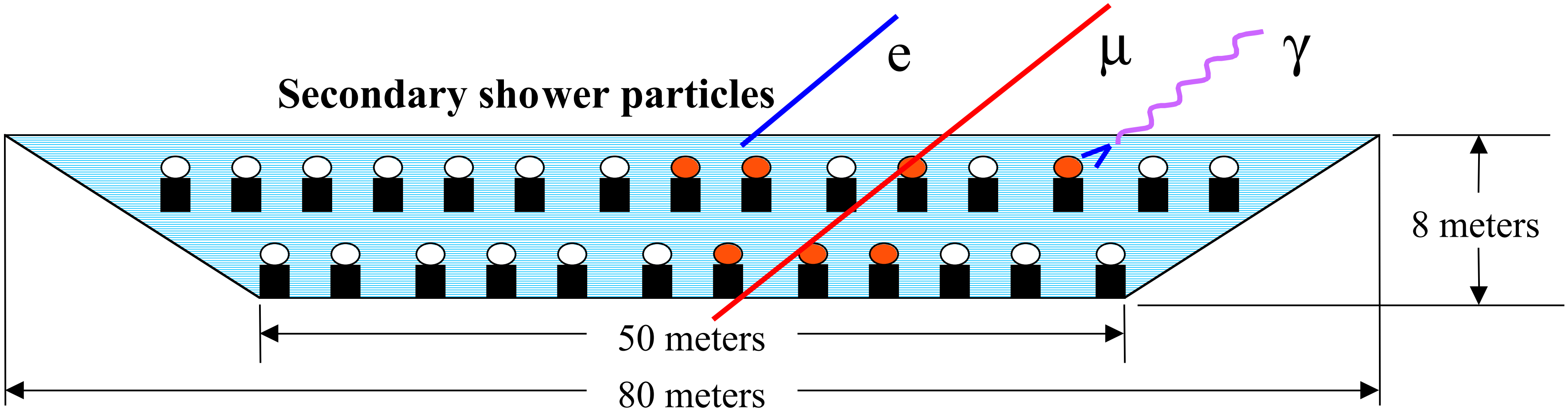
Extensive Air Shower Array

High energy threshold (100 TeV)
Moderate background rejection (50%)
Large field of view (~2 sr)
High duty cycle (>90%)

Milagro: The Best of Both Worlds

Use water instead of scintillators to detect EAS particles

100% of the area is sensitive (instead of 1% with scintillator)

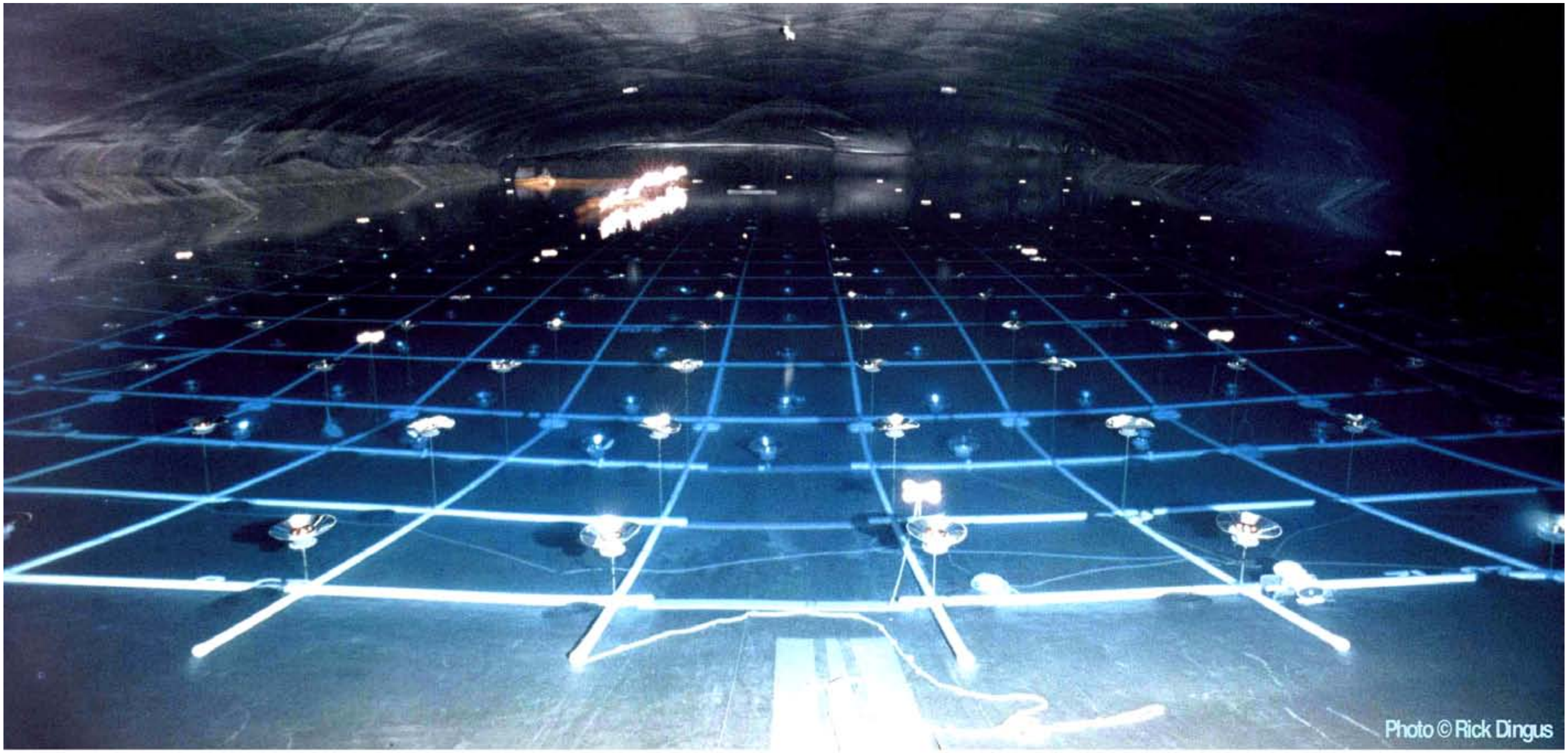


Low energy threshold (300 GeV)
High duty cycle (>90%)
Large field of view (~2 sr)
Moderate background rejection (~75%)

Milagro is in the Jemez Mountains 35 miles west of Los Alamos at an elevation of 8500’

Pond previously used by LANL geothermal project

Milagro Completed



Current Status

Milagro physics runs began 12/99

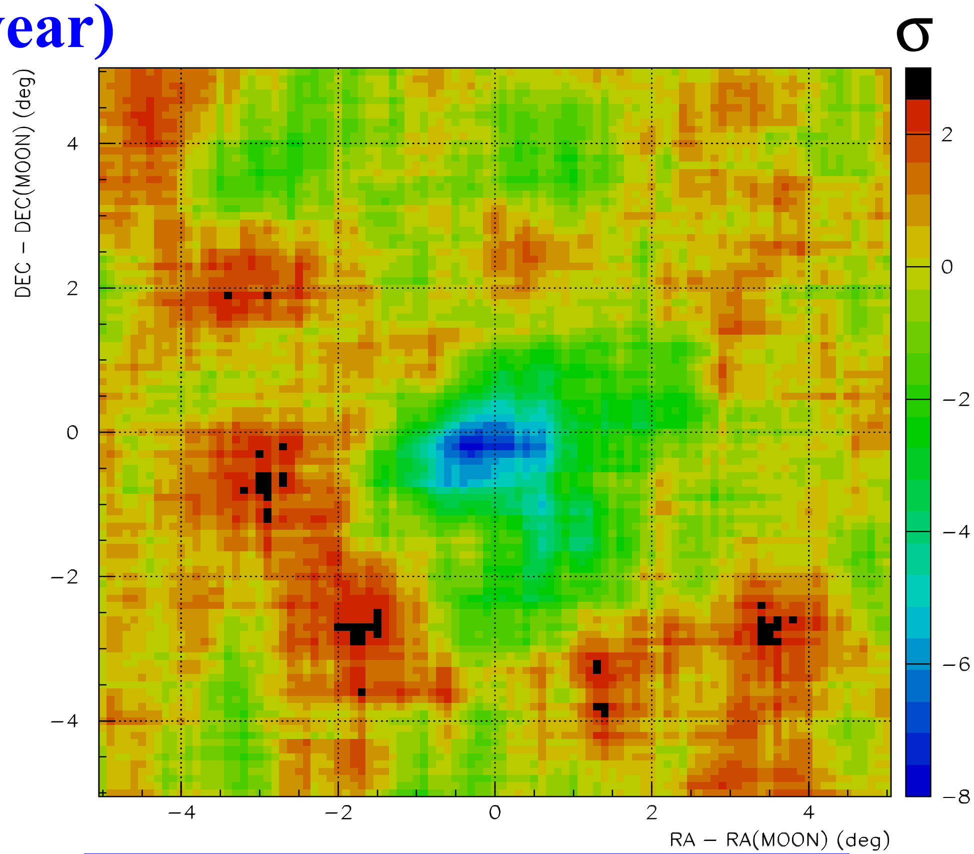
Current event rate ~1500 Hz

- **Raw Data Rate ~ 5 MBytes/sec**
- **Reconstructed Data ~ 80 kBytes/sec (2 TBytes/year)**

Duty factor >90%

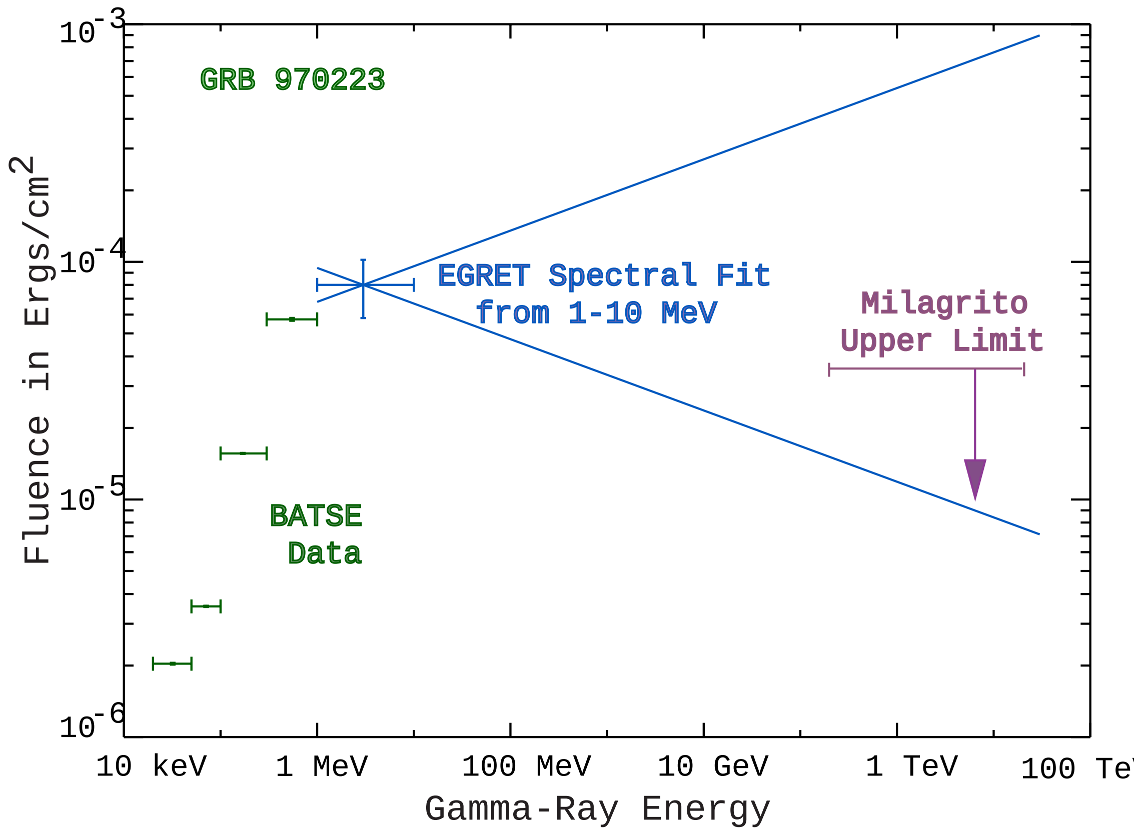
Angular resolution ~ 0.5°

Detect shadow of Moon in cosmic-rays



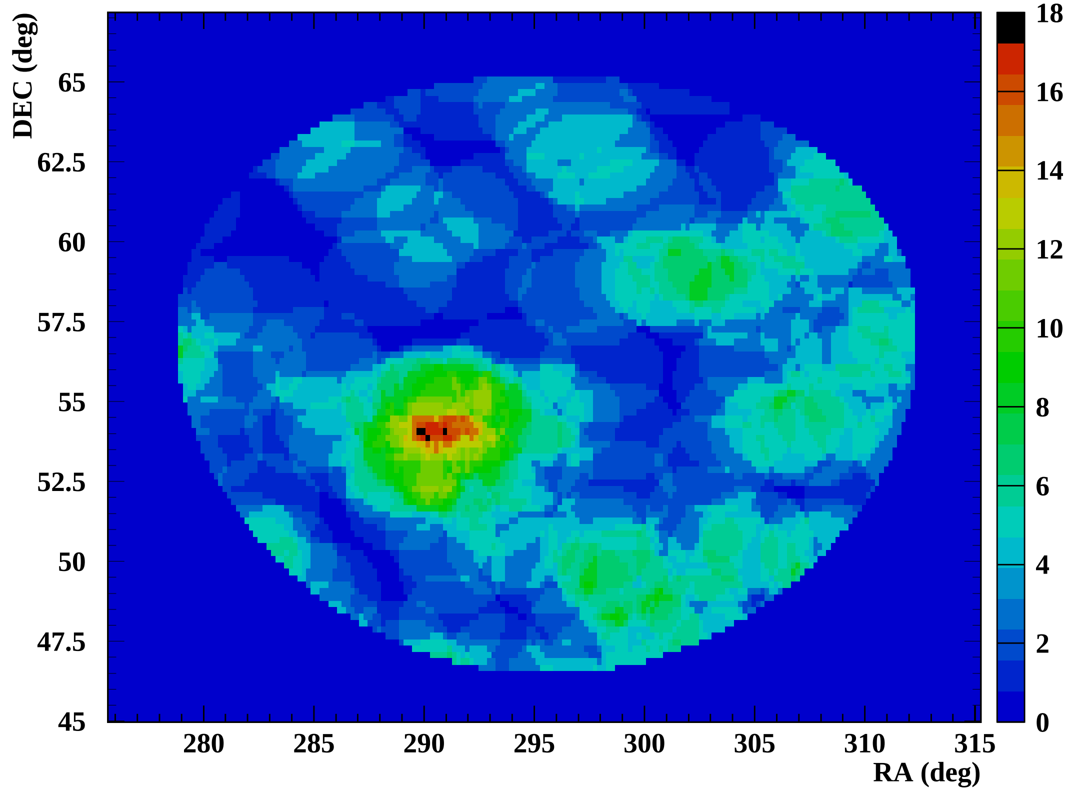
Milagrito GRB Observations

- 54 satellite-detected GRBs in Milagrito's field of view (zenith angle < 45^o)
- GRB970223 brightest burst at few 100 keV



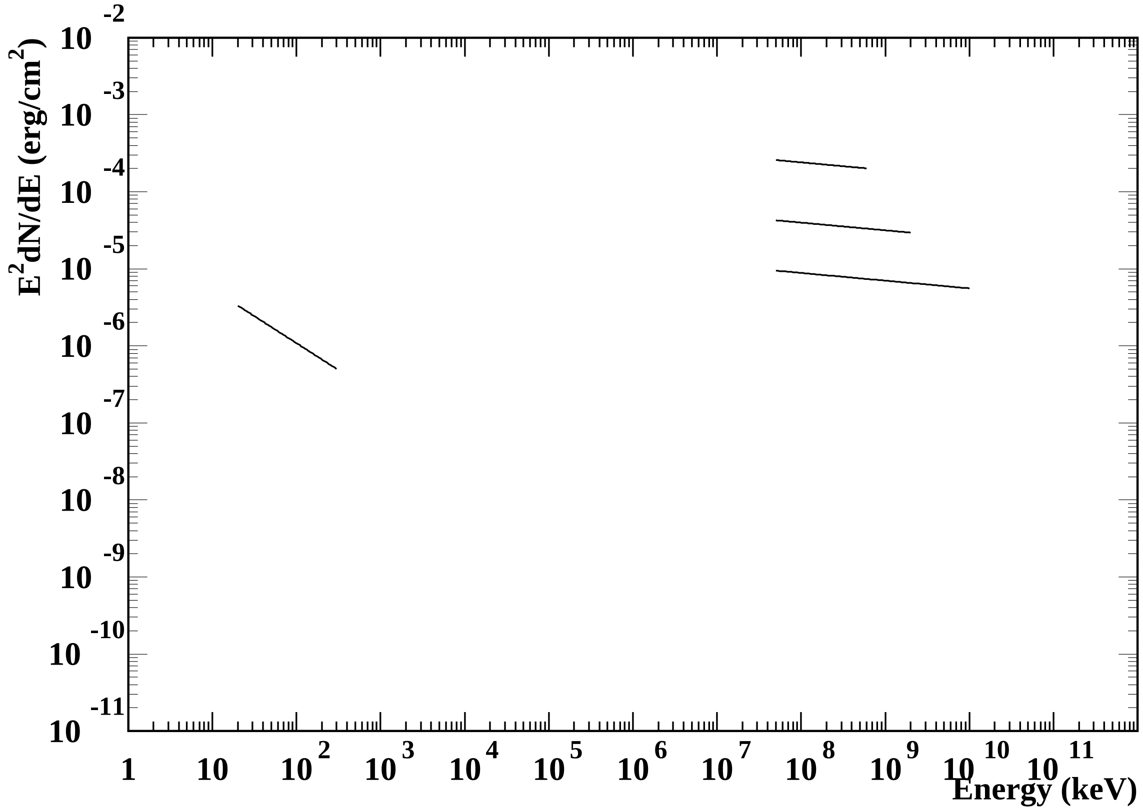
GRB 970417A

- 18 events detected when 3.46 expected
- Probability of this excess within the satellite-determined positional error box is 2.8×10^{-5}
- Probability that one of 54 bursts has such an improbable excess is $54 \times 2.8 \times 10^{-5} = 1.5 \times 10^{-3}$



- Atkins, et al. ApJ Lett 533 L119 April 2000

Luminosity of GRB90417a



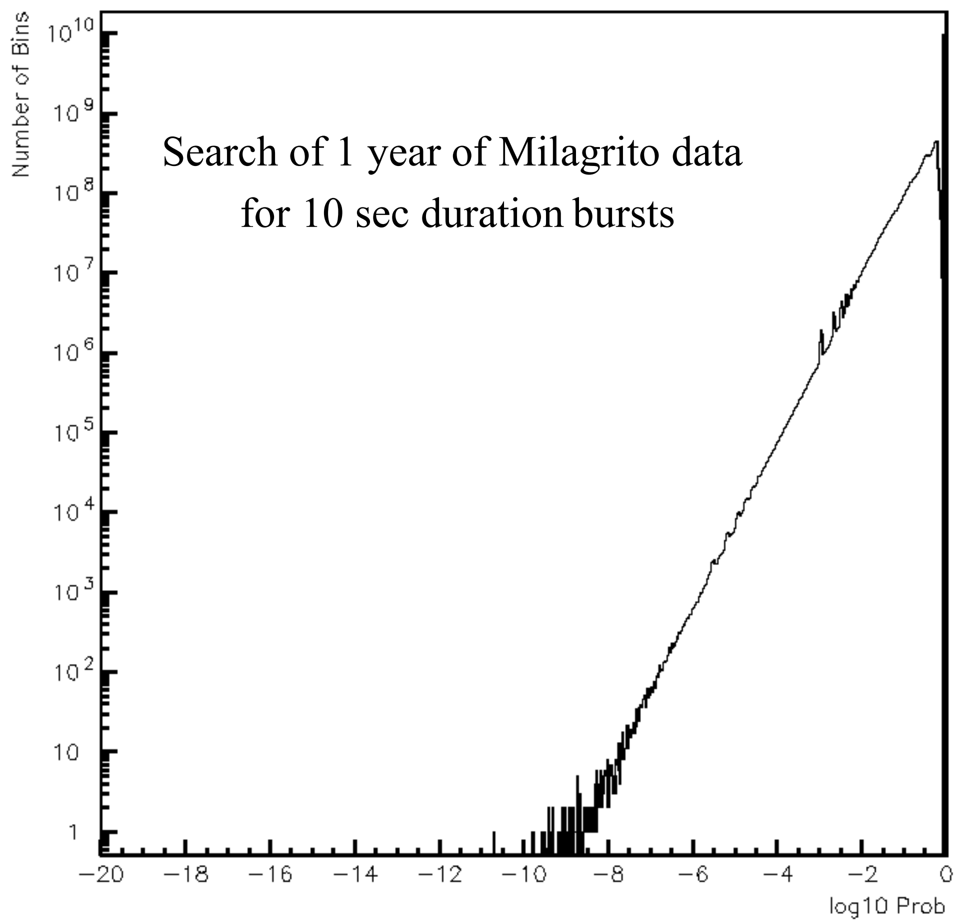
- **Distant sources are attenuated by γ (TeV) + γ (eV) -> e^- + e^+**

z~0.1 => Eγ < 700 GeV so L < 5 x 10^{51} ergs

z~0.03 => Eγ < 10 TeV so L < 1 x 10^{49} ergs

Milagro and GRBs

- **Improved Sensitivity**
- **Energy Resolution**
- **Background Rejection**
- **If GRB970417a had been observed by Milagro, then 72 events with 13.8 background => chance prob. 10^{-27} so satellite notification is NOT required**



3 June 2000
Compton Gamma-Ray Observatory RIP