Gamma Ray Bursts with GLAST

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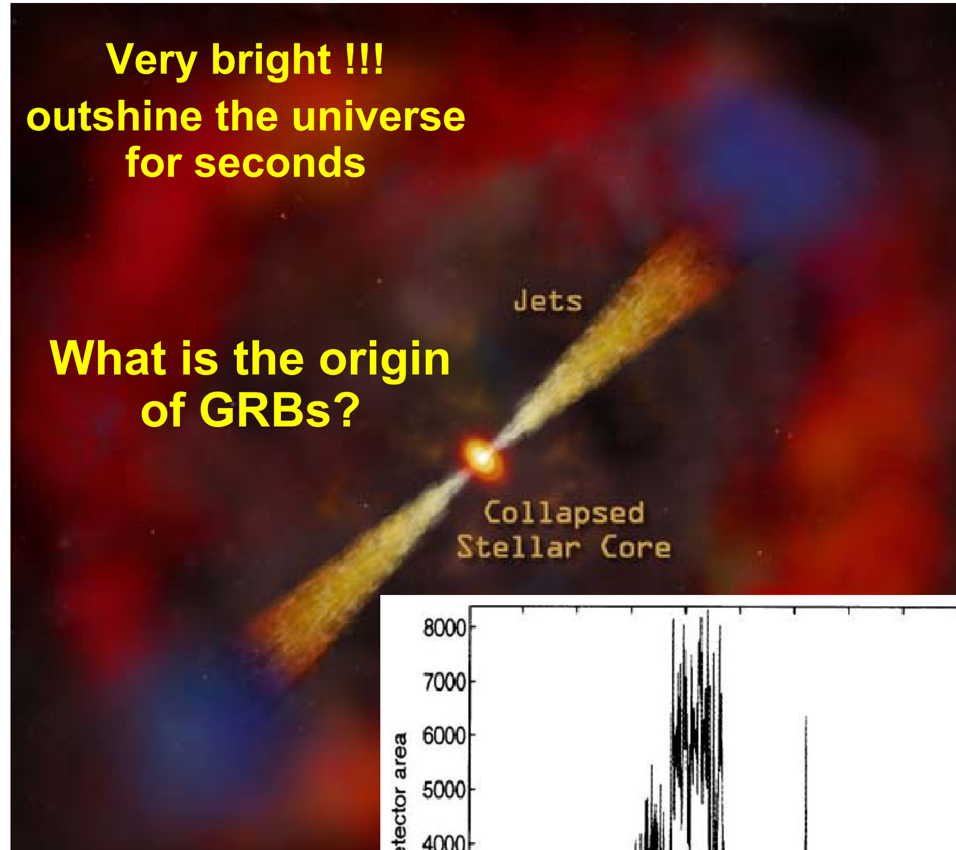
Overview

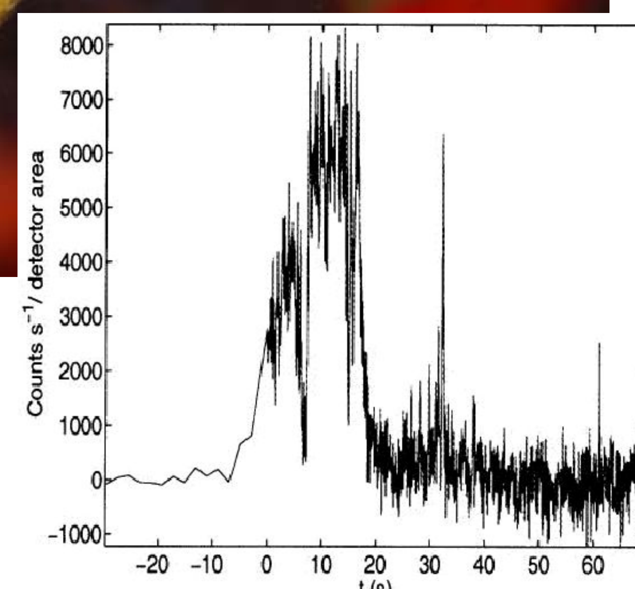
* Introduction to Gamma Ray Bursts
  – Science Motivation
  – Expectations for GLAST
* GLAST Capabilities
  – Synergy with other missions
* Summary

Gamma Ray Bursts

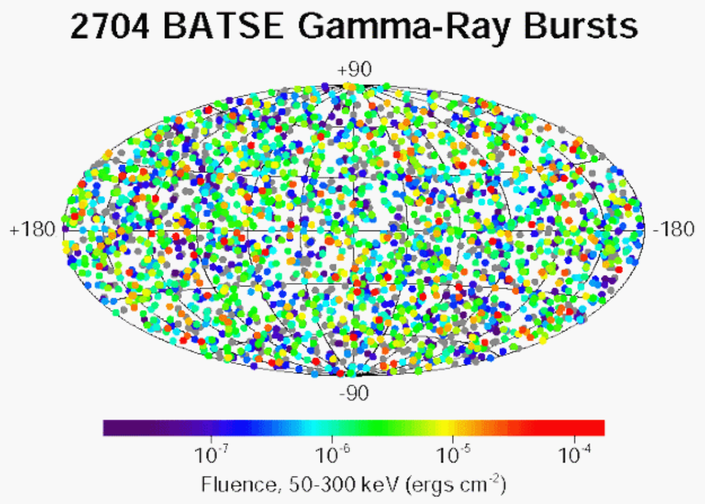
* What do we know ?
  - Typical fluences
    - $10^{-4 \text{ to } -7}$ ergs cm^{-2}
  - Cosmological distances
    - z ~ 1-2
  - Rate
    - 1 /Myrs/galaxy
  - Non-thermal emission
    - up to γ rays
    - Peak photon energy ~ 0.1-1 MeV

* Temporal properties
  - Rapid flux variations
    - miliseconds
  - Range of burst durations
    - few seconds to hours



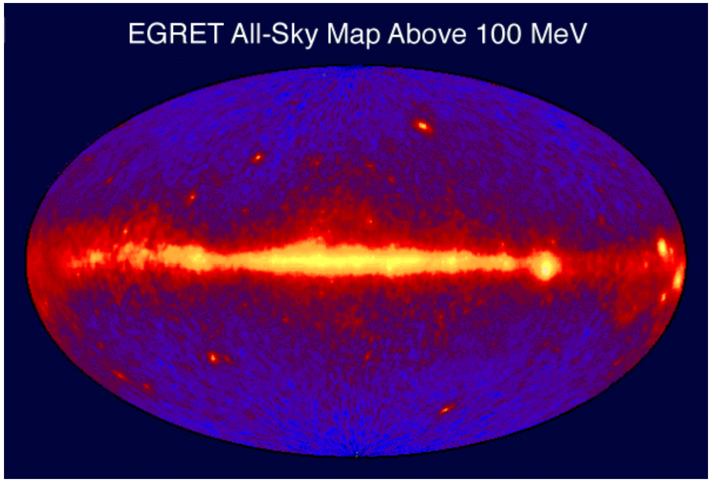


There was CGRO before GLAST…



* BATSE
  – 25 KeV – 2 MeV
  – Thousands of bursts

* Low energy emissions only !!!!!



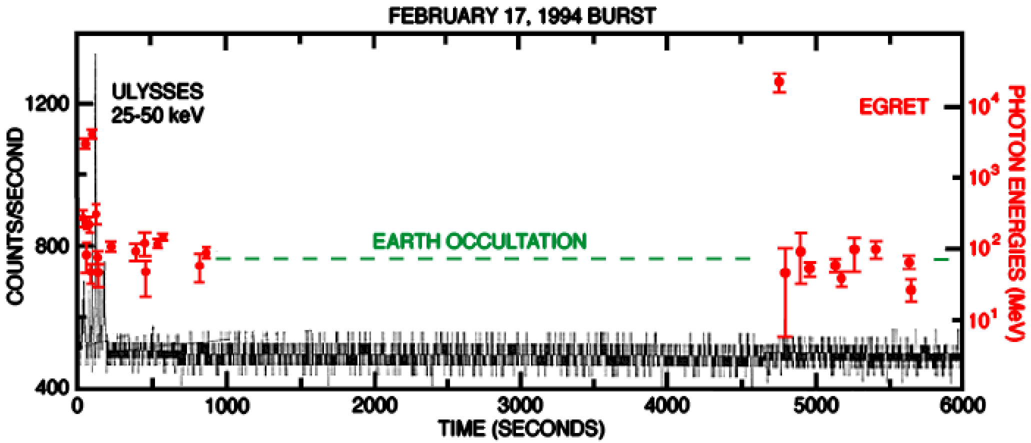
* EGRET
  – 20 MeV – 30 GeV
  – 5 bursts

* BATSE + EGRET (spark chambers and calorimeter)
  – Only 4 coincident bursts !!!!

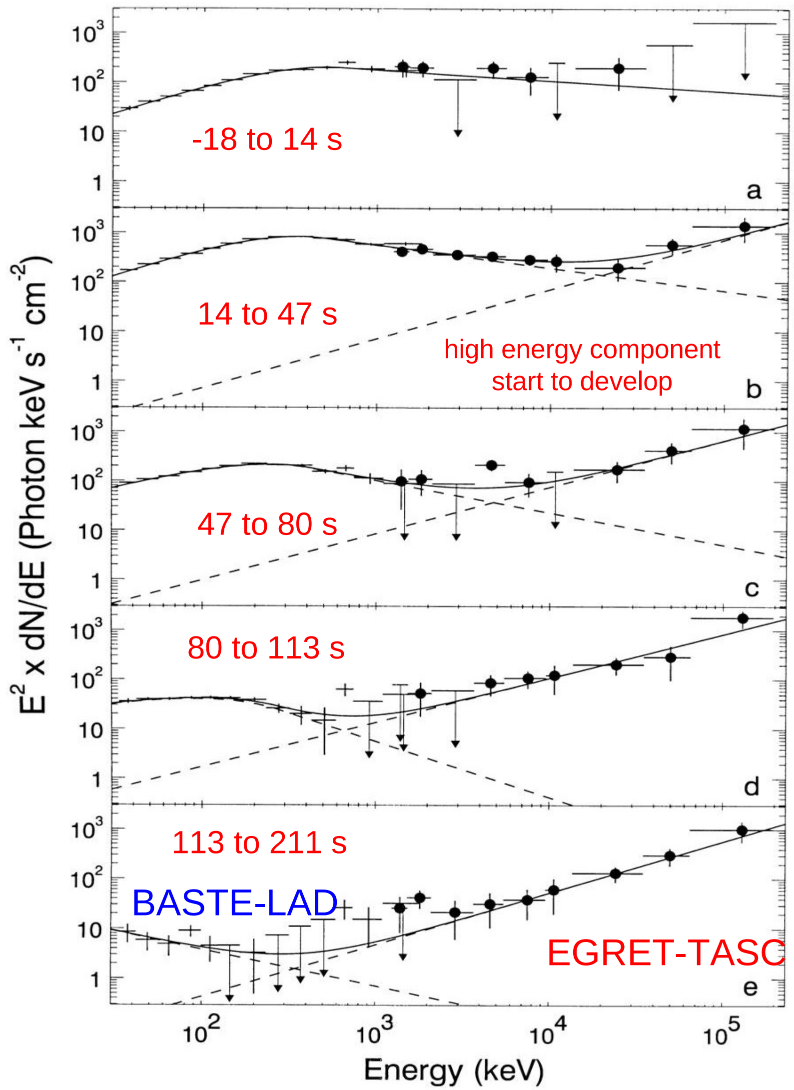
* EGRET fluences are between 1 to 2 orders of magnitude lower that that of BATSE

Expect high energy emissions based on EGRET data

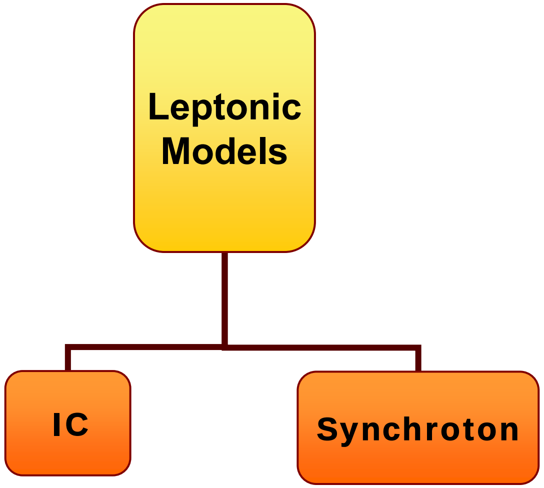
* Extrapolated spectra suggest high energy component continues after low energy ends
  - GRB930131, GRB940217
    - With spark chamber
  - GRB941017, GRB980923
    - Without spark chamber

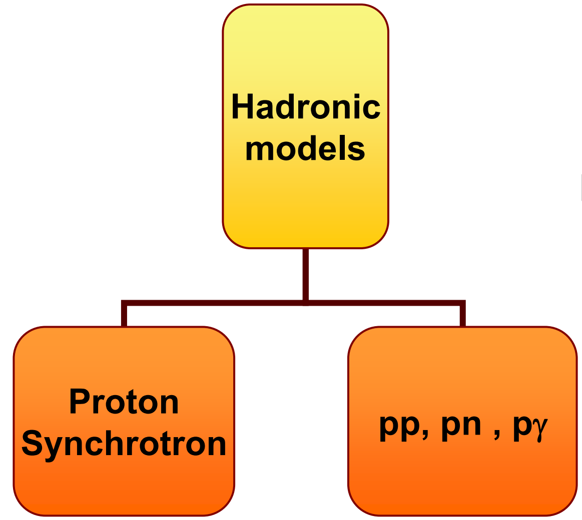


An afterglow at high energies



Expect high energy emissions from theory

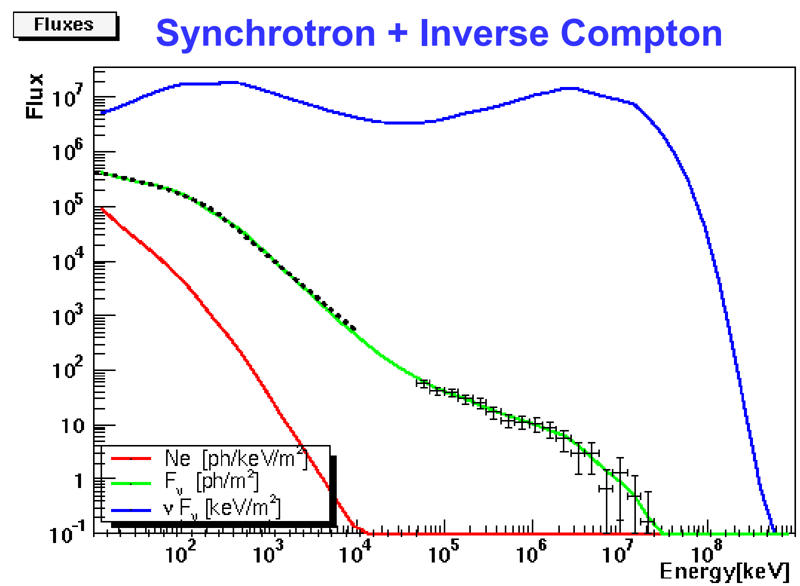




Photons from pion decays

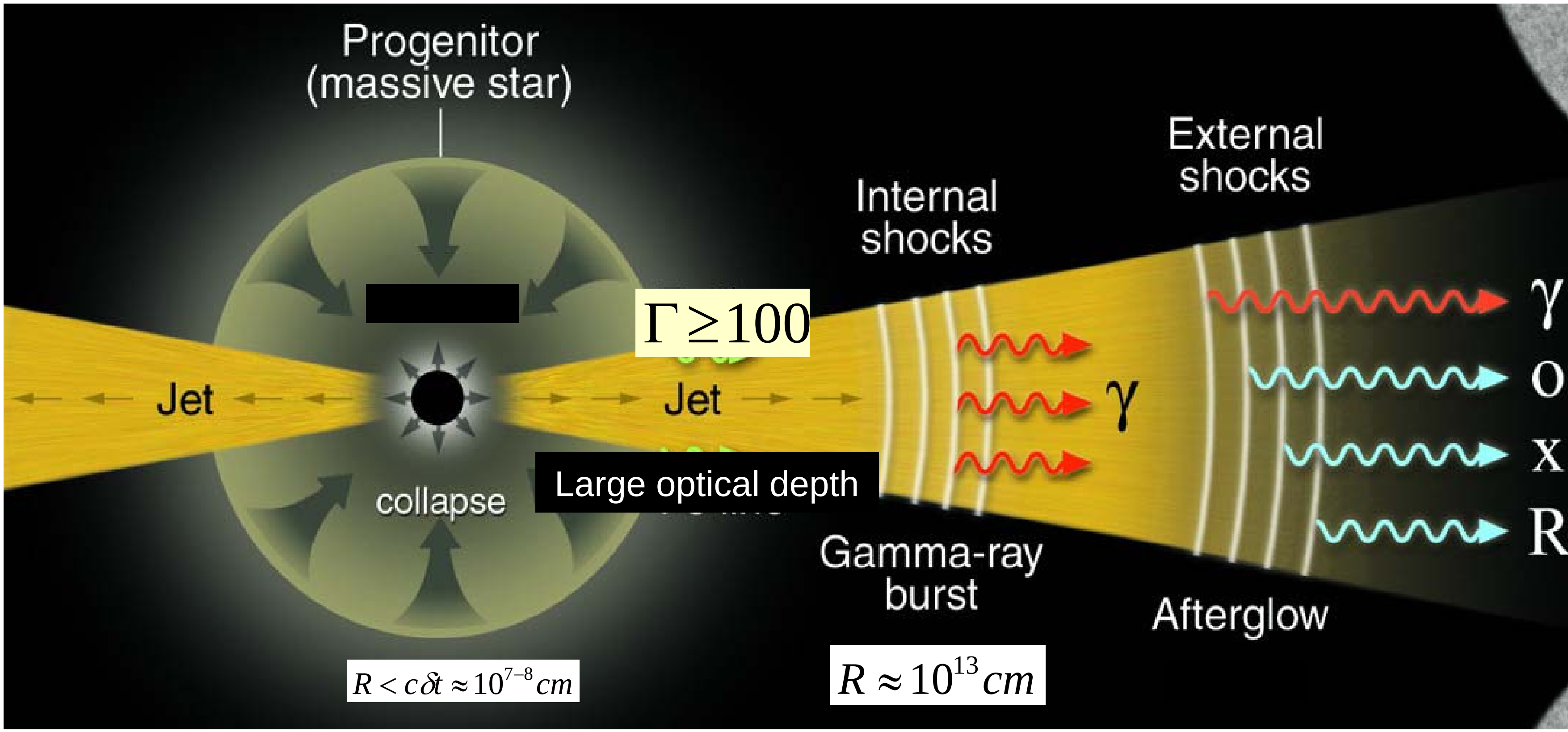
– Relativistic electrons scatter off photons to GLAST energies (IC)
  - Photons from synchrotron emission
  - Photons from photospheric thermal emission at low energies
    – so far undetected at low energies and maybe visible at higher energies

Synchrotron + Inverse Compton



A Gamma Ray Burst Model

When the optical depth falls below unity , γ rays can escape the source



How large is the <u>bulk</u> Lorentz factor (Γ)?
From which radii is the prompt gamma ray emission coming from?
What is the role of B fields (see S. Akiyama's talk in the theory session)

Potential GRB Science Topics for GLAST

* Physical Properties of the Relativistic Outflow in GRBs
  - Measurement of the bulk Lorentz Factor
  - Estimation of the radii of emission
    - provide input to the role of B fields
* Particle Content in the Relativistic Outflow
  - Delayed high energy emission
  - High energy afterglows
  - hadronic processes
    - connections to extreme particle acceleration
* GRBs as cosmological probes
  - redshift indicators
* New Physics
  - Test of Lorentz invariance with high energy GRBs
    - models of quantum gravity

Observing GRBs involves two of SLAC's GLAST science thrusts (relativistic outflows and particle acceleration)

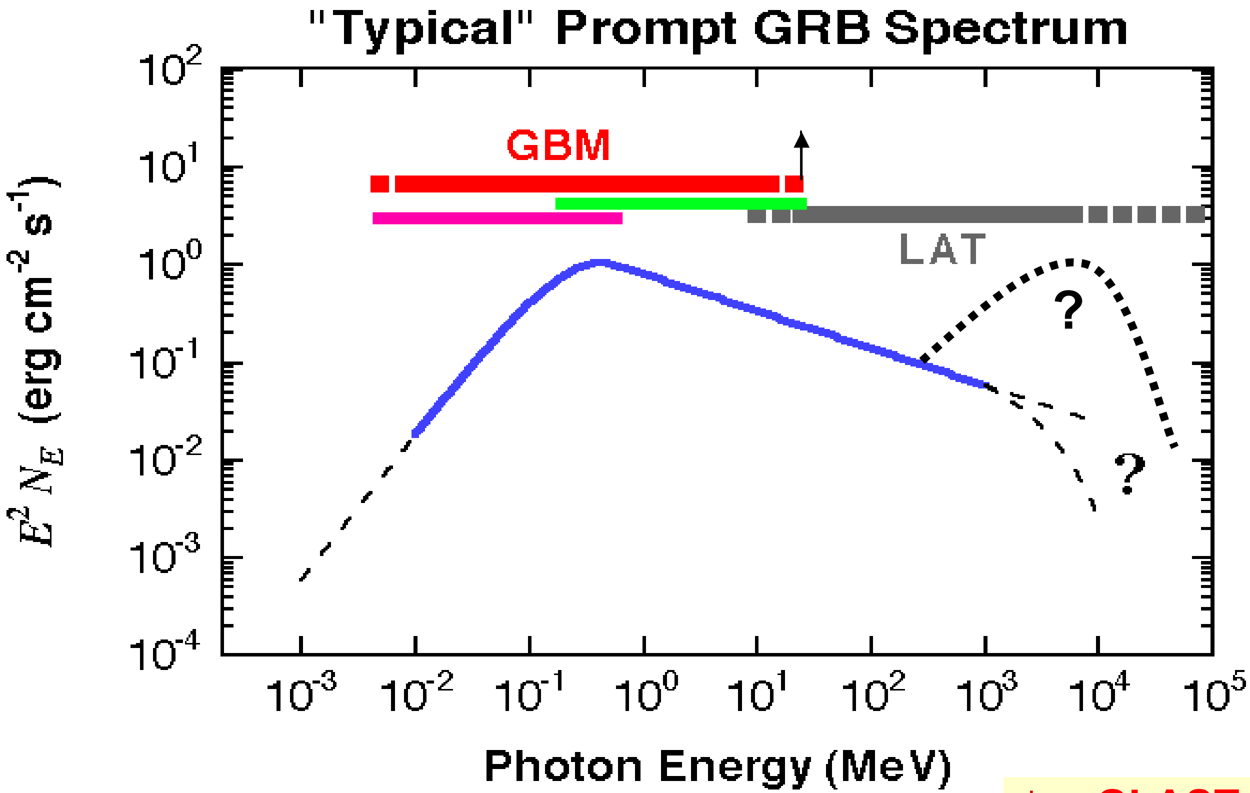
LAT is a Particle Physics Detector to Explore New Frontiers

* LAT is a superior particle physics detector
  - deadtime is 3 orders of magnitude smaller than that of EGRET
  - energy range is at least 1 order of magnitude higher than that of EGRET

* It will do the following measurements
  - Time correlations in the prompt phase of the GRB
  - Widths of spikes in the GRB light curves
  - Spectral breaks and corresponding time evolution

* to address fundamental scientific questions
  - Total energy reservoir of the GRB source
  - Size of the GRB emission region
  - Lorentz factor of the GRB relativistic outflow
  - Energy dependence of speed of light
    - test Quantum Gravity theories

GRB Capabilities of GLAST



* A window into the unexplored high-energy behavior of GRBs
  – from few MeV to > 300 GeV

* Unprecedented energy coverage during GRB <u>prompt</u> phase
  – 8 keV to >300 GeV

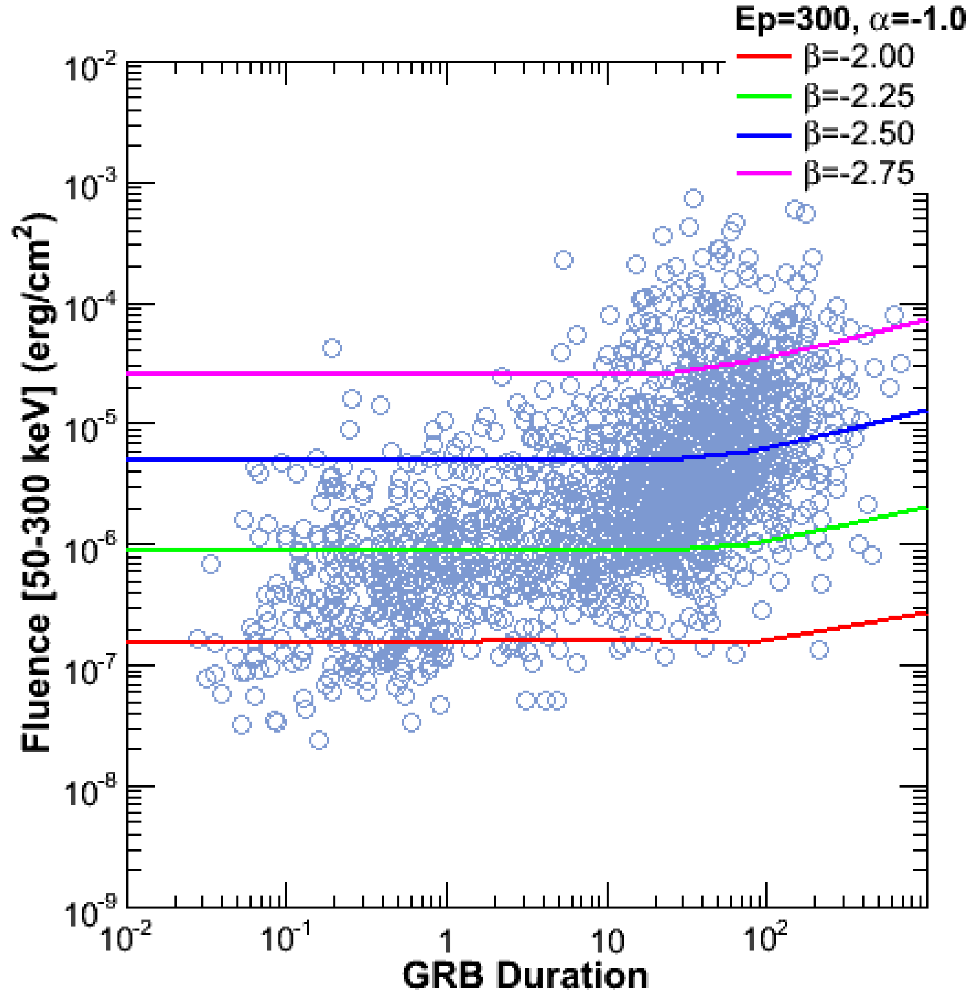
Energy measurements
7 orders of magnitude !

* **GLAST highlights**
  – **Larger Effective Area**
  – **GBM and LAT with wide field-of-view**
  – **Autonomous repoint capabilities**

LAT Sensitivity to GRBs

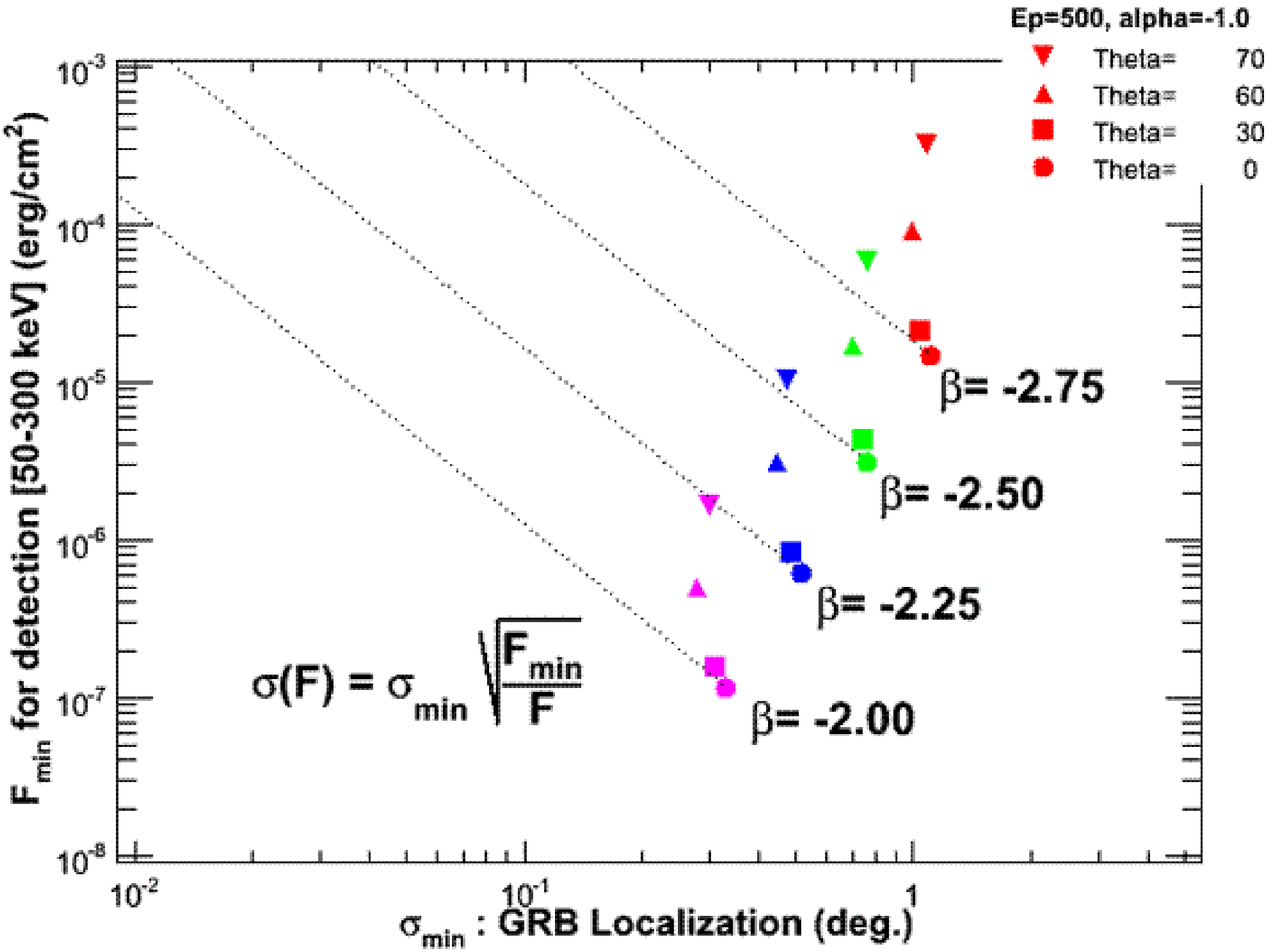
* In blue is the GRB dataset from BATSE

* LAT sensitivity curves are shown for different spectral hardness

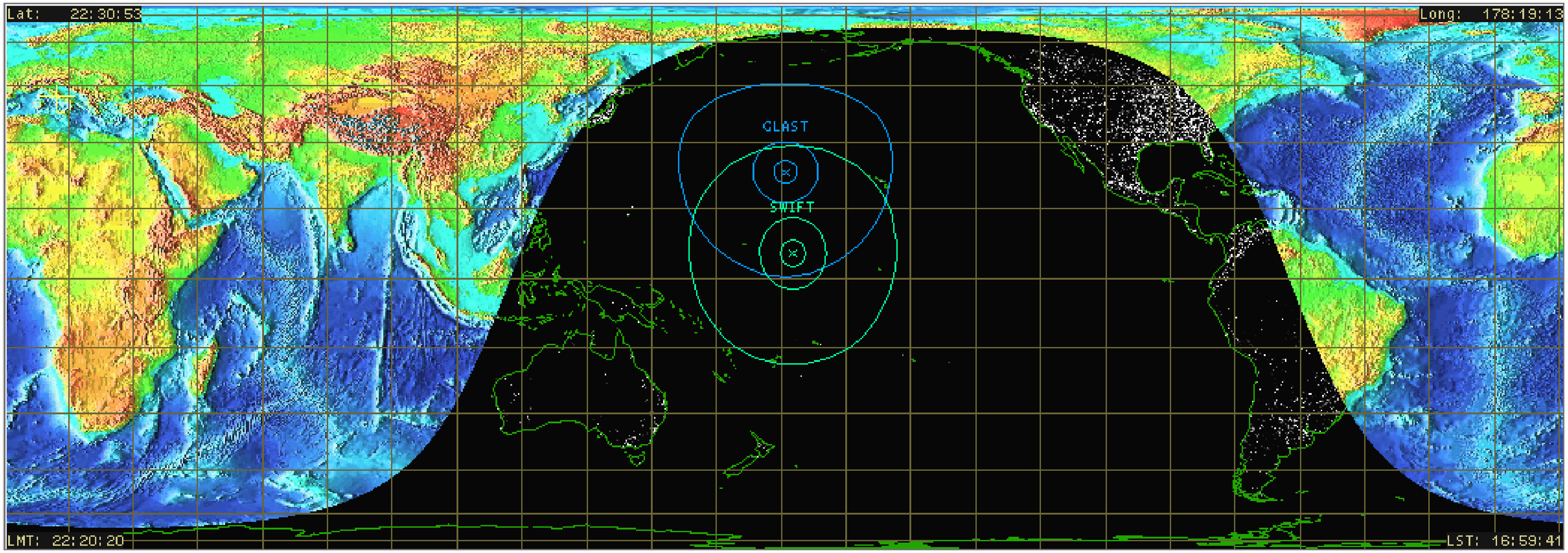


GBM Fluence vs LAT Localization on the GND

* Minimum fluence which corresponds to a detection (y-axis) vs the 68% localization accuracy



Combine GLAST Data with Those from Other Telescopes



* Combining data from different wavelengths will provide answers to fundamental questions in GRB science
  – We will perform joint fits to the GLAST/Suzaku/Swift and GND based telescope data
    • Improve efficiency below 100 MeV to increase acceptance to short GRBs (Tajima, Bouvier)
    • Probe the GRB relativistic outflows via time dependent opacity effects (do Couto e Silva)
    • Study structure of GRB jets and connections with ground based observations (Kocesvski)

Summary

* Particle physicists, with their unique experience, were essential to build a detector with unprecedented capabilities.

* The complex international interagency collaboration was crucial for the successful launch and remarkable turn-on of GLAST

* GLAST will probe unexplored time and energy regimes to address fundamental questions in GRB science
  – discovery potential

* We will soon enter the GRB commissioning phase of Launch and Early Orbit Operations
  – We can't wait to find the first GRB with high energy emission…

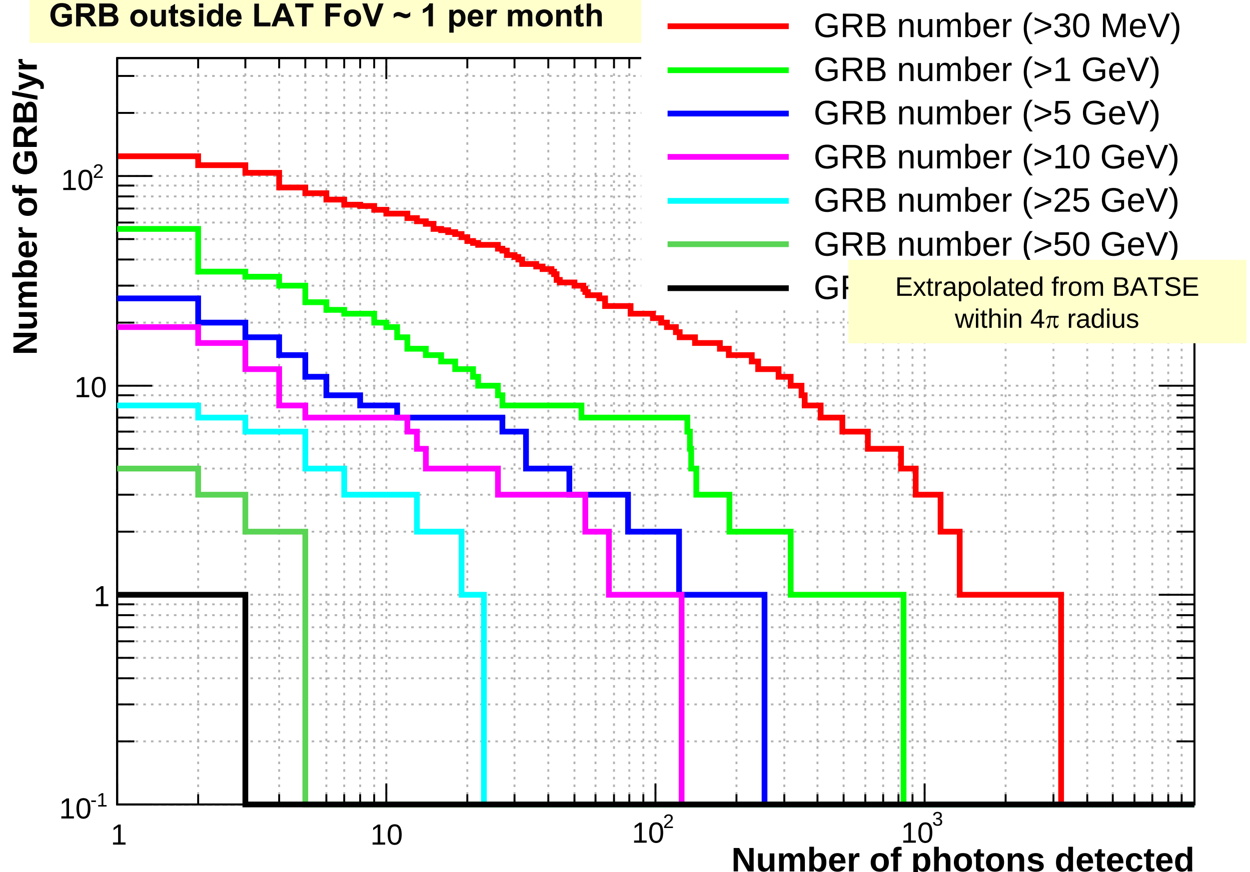
back-up

Number of GRBs with GLAST (Simulations)

GRB inside LAT FoV ~ 1 per week
GRB outside LAT FoV ~ 1 per month

10 photons @ 100 MeV
3.5/√10 ~ 1° loc. accuracy

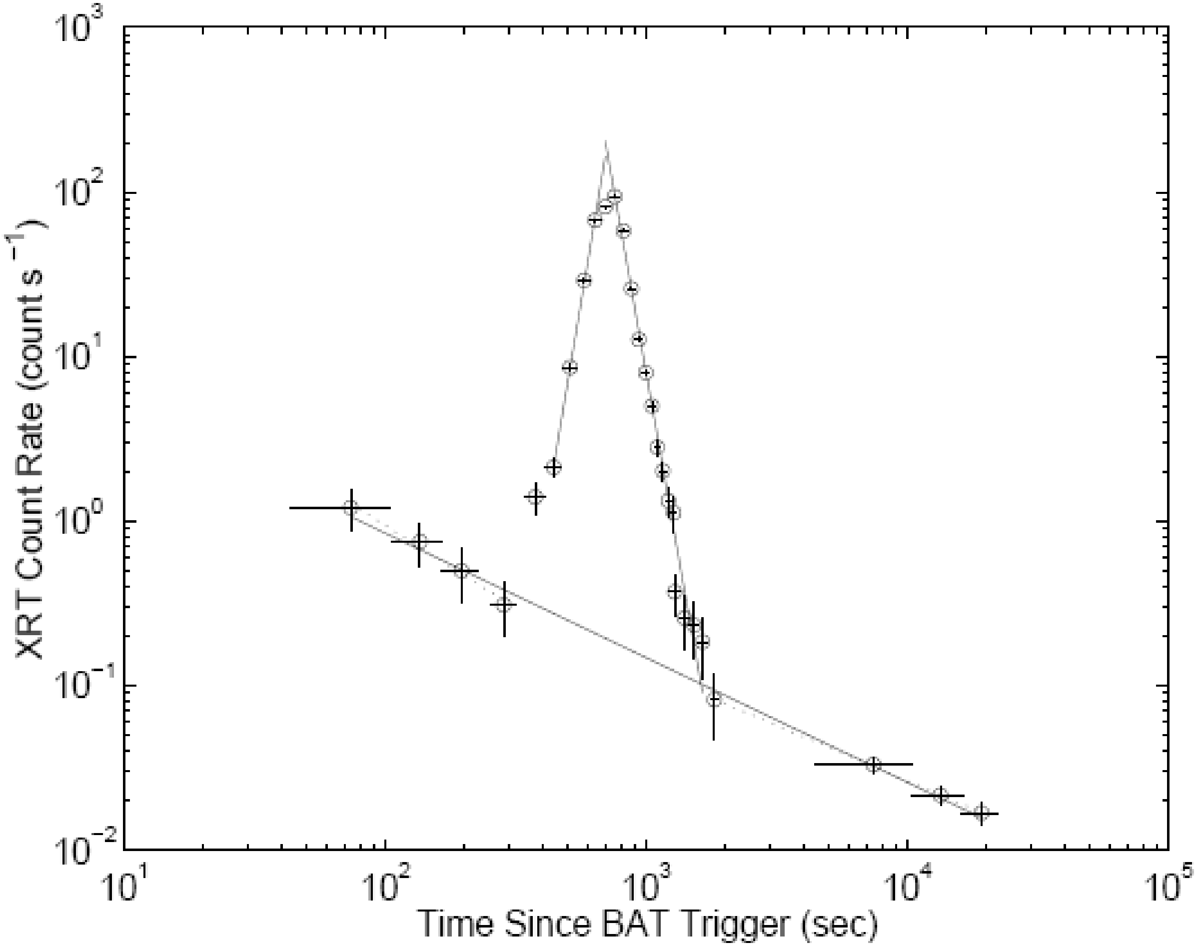
10 photons @ 10 GeV
0.1/ √10 ~ 1' loc. accuracy



~ 70 GRB/year (LAT) : 10 photons for E> 30 MeV

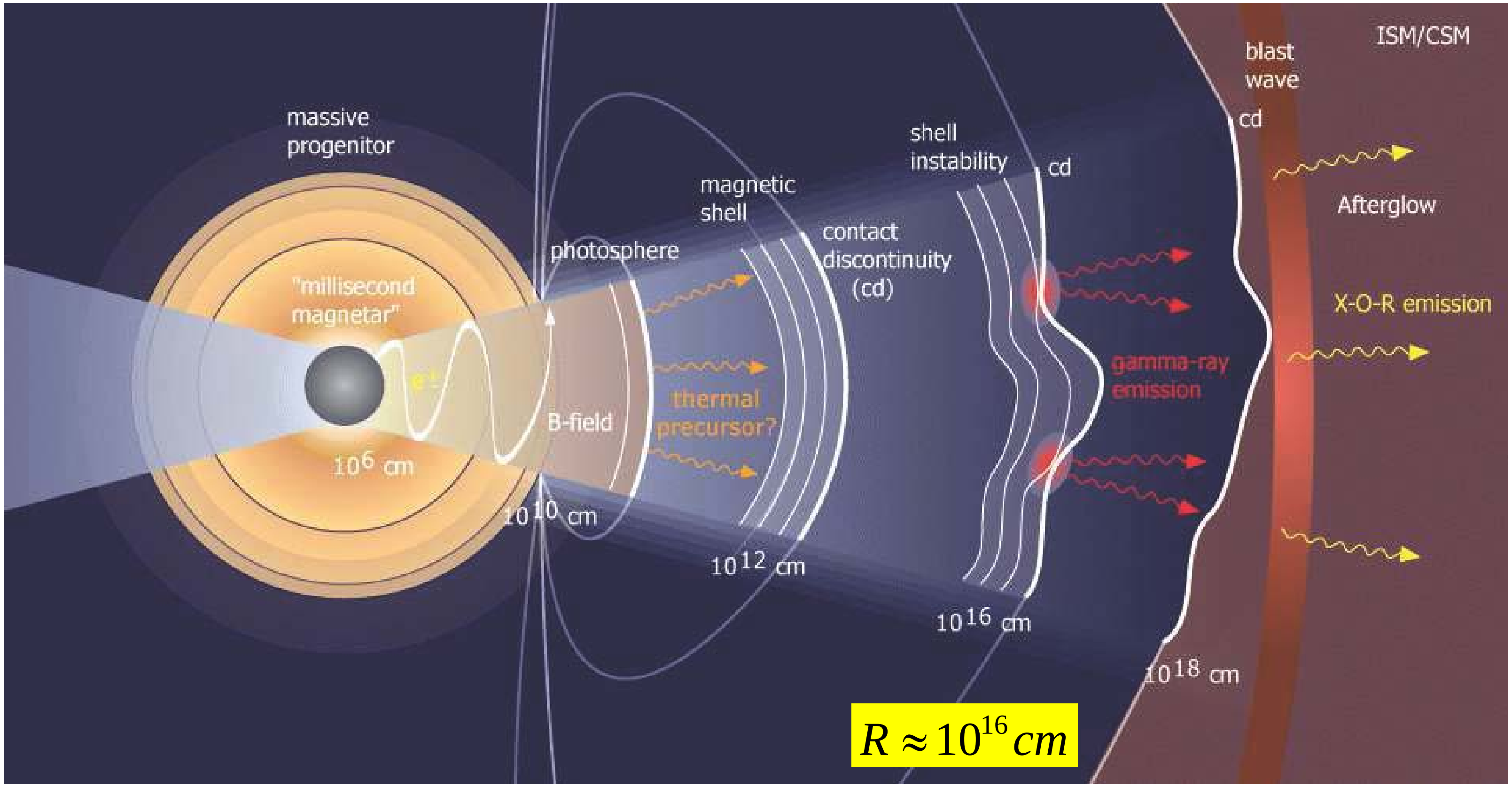
X -ray flares scattered to GeV energies?

X ray flare photons can be scattered to
high energies GRB05052B (Falcone 2006)



Late flare activity?
Magnetic processes?

Electromagnetic Model



Prompt emission happens at a radii which are ~ 1000 times larger than those predicted by fireball models

Determination of Radius of Prompt Emission

* Predict signatures for pair production at GeV energies
  - see next slides

* Measure pair-opacity cut-off in the spectrum with GLAST data
  - Determine $\Gamma^{2\alpha}R$
    - not the lower limit on Γ!

* Measure onset of X-ray Afterglow with Swift
  - Additional constrain on Γ

* Combine GLAST and X-ray results
  - Constrain radius of emission
    - role of B fields?

* Buon appetito…

La Riceta

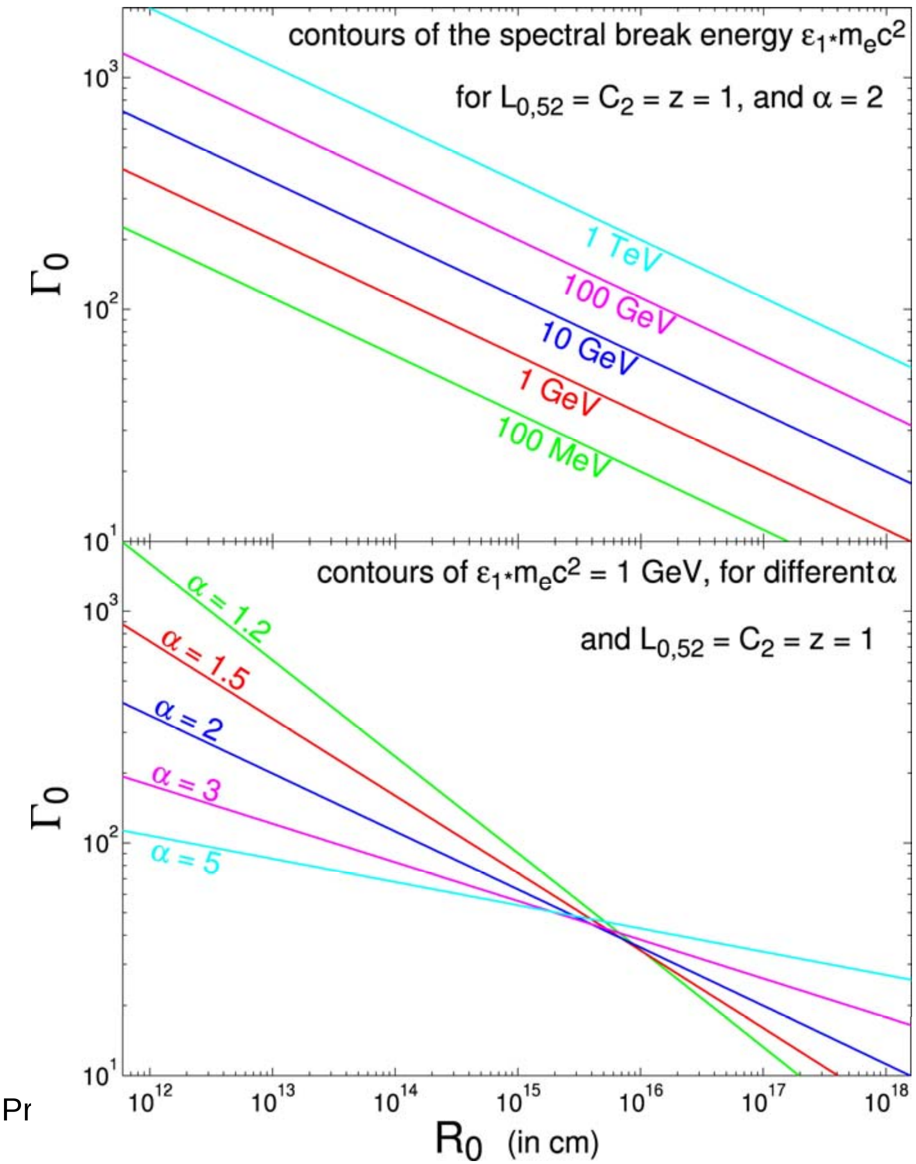
Lorentz Factor and Emission Radius

* From the time integrated spectrum we can measure $\Gamma^{2\alpha} R$
  – Not only a lower limit on the Lorentz factor

* Combine this data with Swift observations and we can determine the radius of emission

$$(\Gamma_{0,2})^{2\alpha} R_{0,13} = C_2^{-1} 40.2^{2-\alpha} \left(\frac{\alpha}{2}\right)^{-5/3} L_{0,52} \left[\frac{(1+z)\varepsilon_{1*} m_e c^2}{127 \text{ MeV}}\right]^{\alpha-1}.$$

(J. Granot, J. Cohen-Tanugi, and EdCeS ApJ 677. 97, 2008)



How long it takes to see a source?

* Minimum time necessary to detect a source at high galactic latitude with a 5-sigma significance (thick solid curve), to measure its flux with an accuracy of 20% (thin solid curve) and its spectral indew with an uncertainty of 0.1 (dashed curve), as a function of the source flux.

* A photon spectral index of 2.0 is assumed.
* The steps at shorts times are due to the discontinuous coverage related to the survey mode.