LAT observation of GRBs: simulations and sensitivity studies

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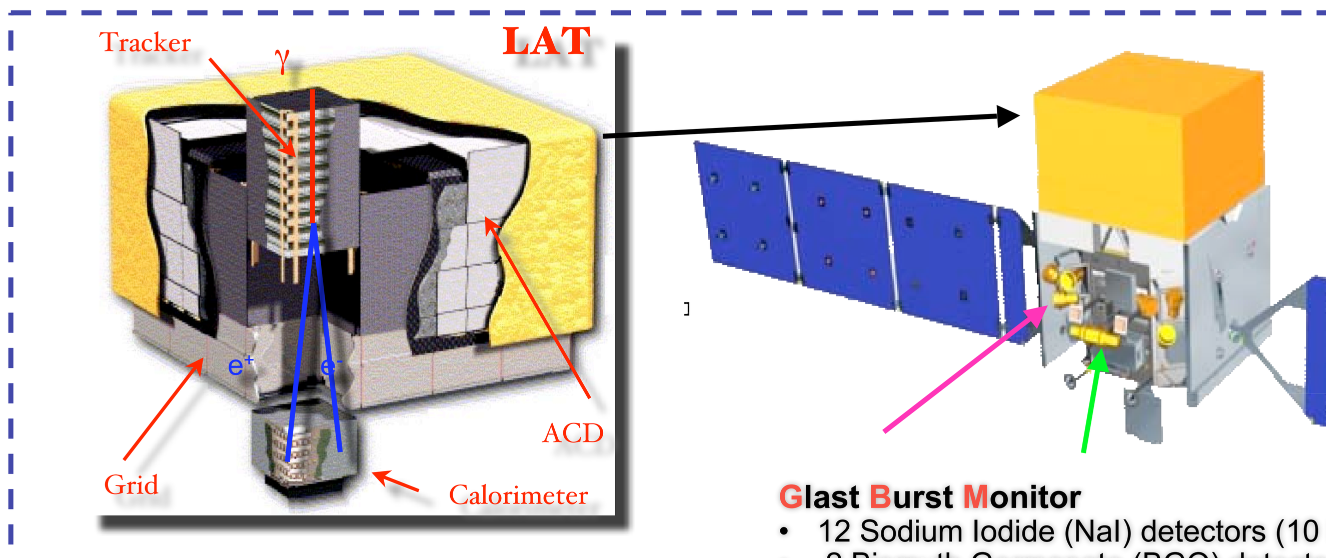
on behalf of the GRB Working Group

Abstract:

The GLAST Large Area Telescope (LAT) is the next generation satellite experiment for high-energy gamma-ray astronomy. It employs a pair conversion technique to record photons in the energy range from 20 MeV to more than 300 GeV. Its modular design consists of sixteen towers made of silicon trackers followed by segmented CsI electromagnetic calorimeters. Towers are surrounded by plastic scintillators acting as an anticoincidence shield that rejects unwanted charge particle background. The LAT will follow the steps from its predecessor, EGRET, and will explore the high-energy gamma-ray sky with unprecedented capabilities. The observation of Gamma-Ray Bursts is one of the main science goal of the LAT: in this contribution we compute an estimation of the LAT sensitivity to GRB, adopting a phenomenological description of GRBs, where the high-energy emission in GRB is obtained extrapolating the observed BATSE spectrum up to LAT energies. The effect of the cosmological attenuation is included. We use the BATSE current catalog to build up our statistics.



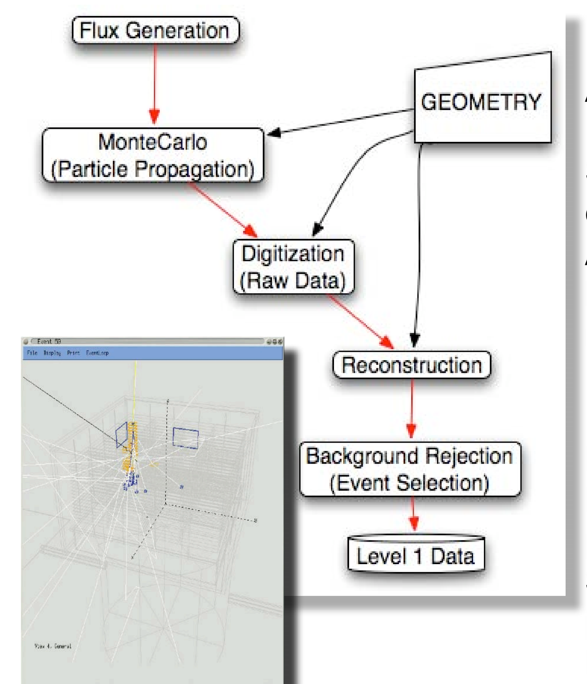
Orbit: 565 km Circ, 25.3° inclination
Launch Vehicle: Delta 7920H-10
Launch Site: Kennedy Space Center
Telemetry: TDRSS S-Band, Ku-Band

Glast **B**urst **M**onitor
- 12 Sodium Iodide (NaI) detectors (10 keV-1 MeV)
- 2 Bismuth Germanate (BGO) detectors (150 keV-30 MeV)

	LAT	EGRET
Energy range	20 MeV – >300 GeV	20 MeV – 30 GeV
Energy resolution (on axis, 100 MeV – 10 GeV)	<10%	10%
Peak effective area	9000 cm²	1500 cm²
Angular resolution (single photon, 10 GeV)	0.15°	0.54°
Field of view	2.2 sr	0.5 sr
Deadtime per event	27 us	100 ms

	GBM
Energy range	~8 keV – 30 MeV (measured)
Energy resolution	15% FWHM at 0.1 MeV (measured) 8% FWHM at 1.0 MeV (measured)
On-board GRB locations	<15° for any pointing <8° for S/C zenith angle < 60°
GRB sensitivity (5σ, on ground)	0.47 ph cm⁻² s⁻¹ (peak flux, 1 s, 50-300 keV)
GRB on-board trigger sensitivity	0.71 ph cm⁻² s⁻¹ (peak flux, 1 s, 50-300 keV)
Field of view	9.0 sr

Simulation framework



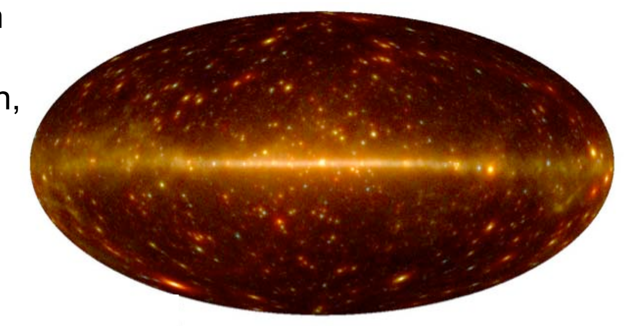
GLEAM

A full Montecarlo is available, based on *Geant4*
Same detector geometry in propagation, digitization and reconstruction.
Actual Level 1 data and simulated data have the same format, and the same reconstruction algorithm is applied.

ObservationSim

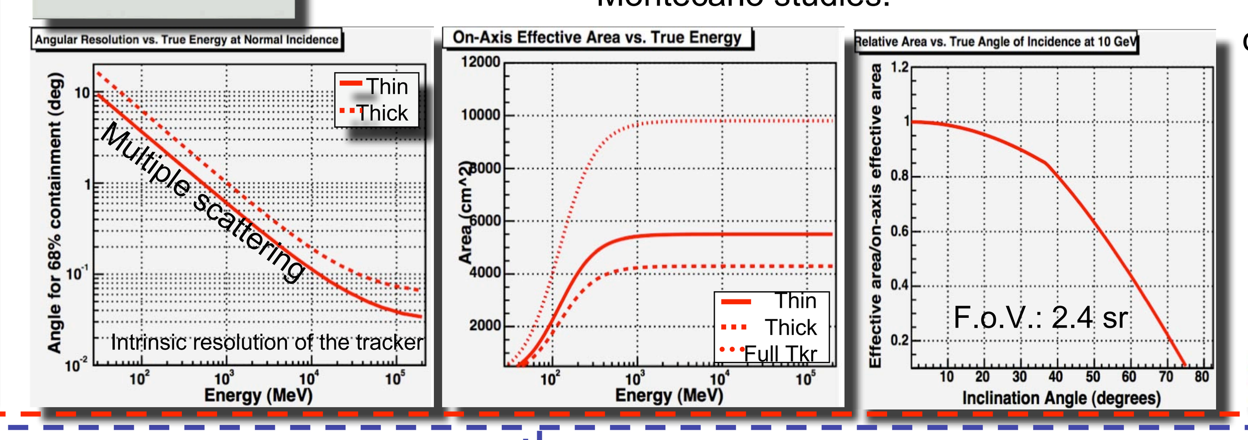
Is a fast simulator that makes use of the Instrument Response Function as parameterization of the instrument.
Suitable for simulating long observation periods. IRF derived from detailed Montecarlo studies.

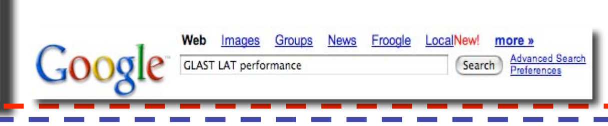
The Sky model(s)



1 yr simulated sky: ~7596 "realistic" sources, (stationary and transient)
Galactic and extragalactic diffuse + Dark Matter sources,…

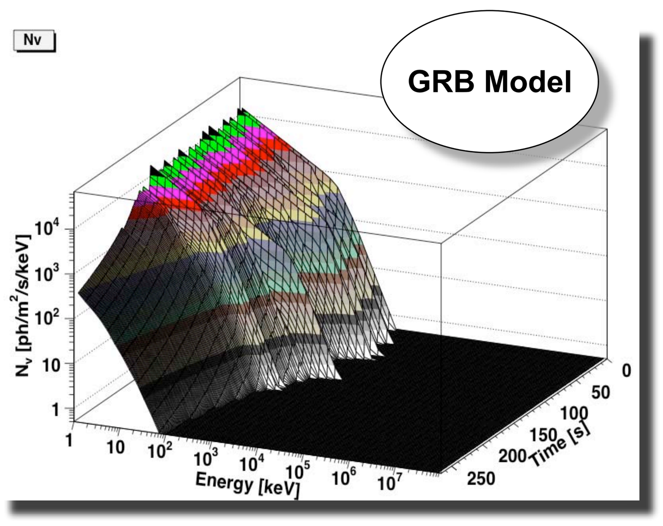
This is just an example, several different "realizations of the sky" can be tested: **first time in gamma-ray astronomy**!



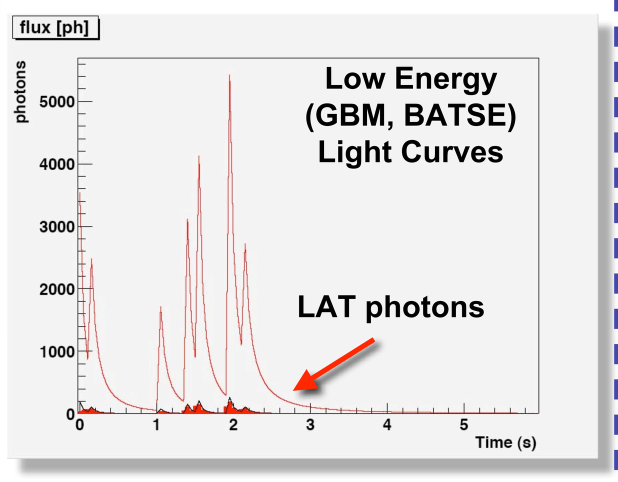


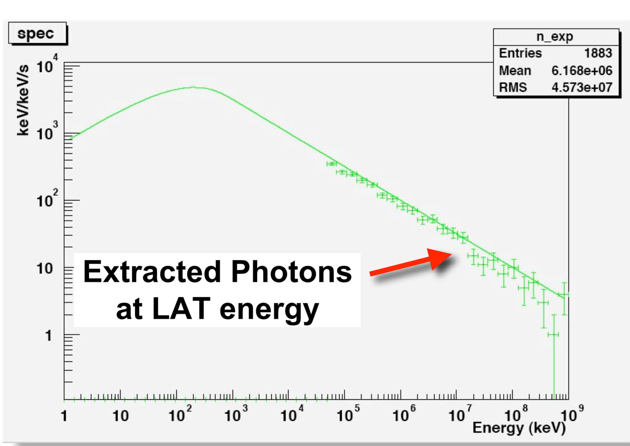
GRB Models

GRBs are described with **spectral-temporal** models.
Different models can used in our framework: they share the same infrastructure (**SpectObj**) that interfaces the GRB simulator with **GLEAM** and **ObservationSim**.
- GRB Physical Model: based on the fireball model in the internal shock scenario (relativistically colliding shells)
- Phenomenological model: the BATSE catalog is used to sample parameters for the spectral -temporal shape. The high energy emission is obtained extrapolating to LAT energies.
- GRBtemplate: reads the spectrum from an ASCII file.



A model produces a 2 dimensional histogram that stores the flux N(e,t) (ph/keV/cm²/s) as a function of energy and time.



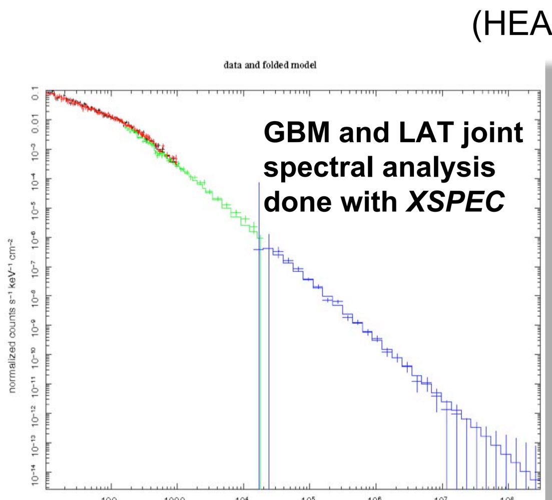


The photons are sampled from the histogram and the spectral-temporal evolution is reproduced.

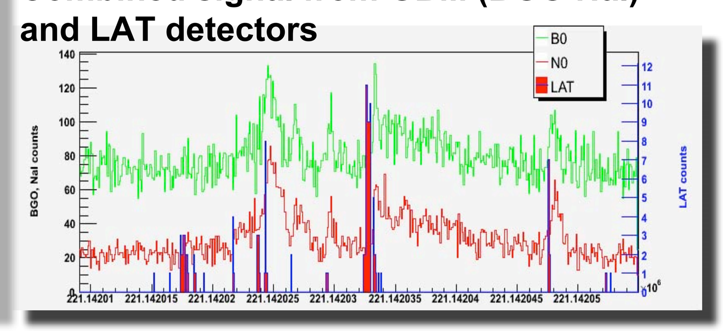
Photons feed the MC simulator or the fast ObservationSim simulator.

GBM data for the same burst are also available (from the GBM simulator).

GBM and LAT simulated data are ready to be analyzed as real data!
(HEASARC tools)

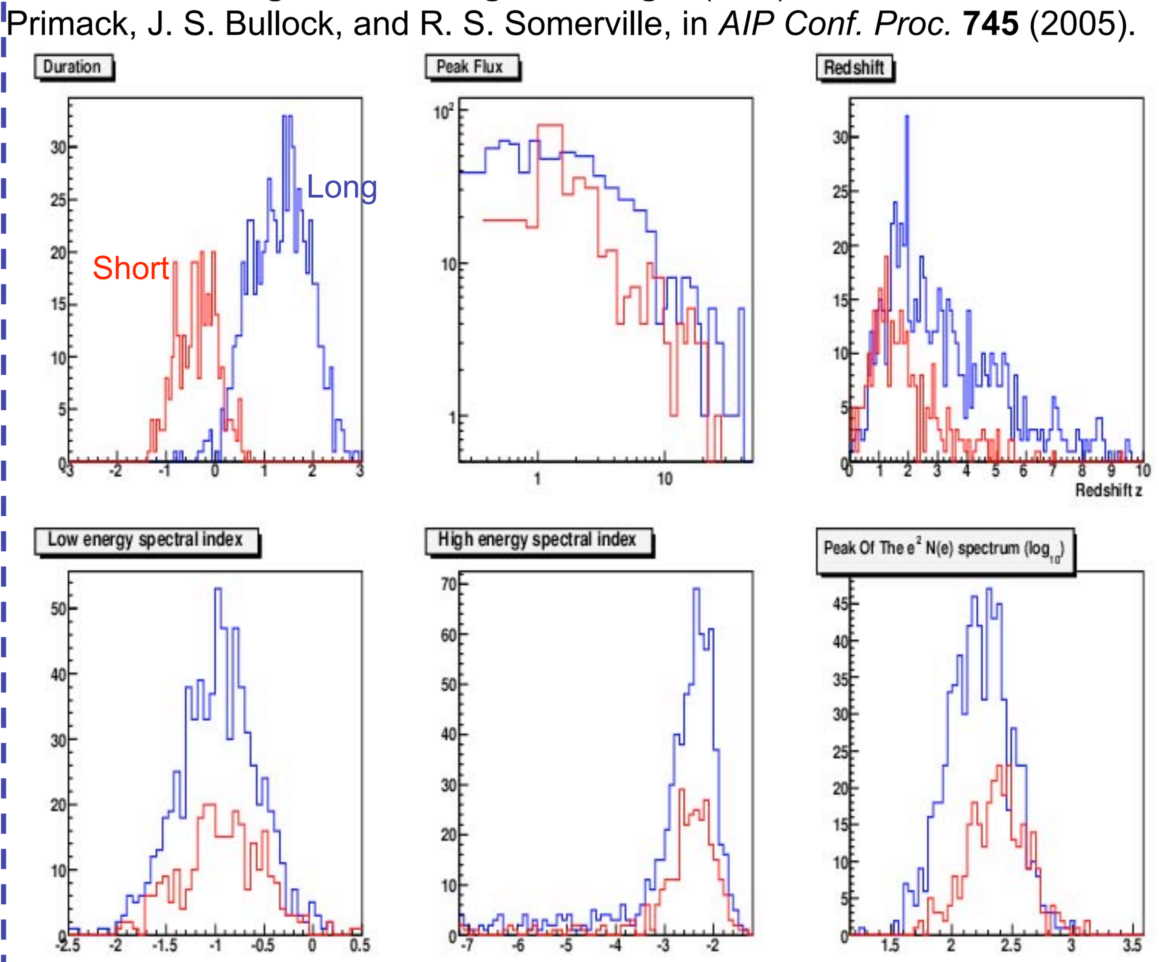


Combined signal from GBM (BGO NaI) and LAT detectors

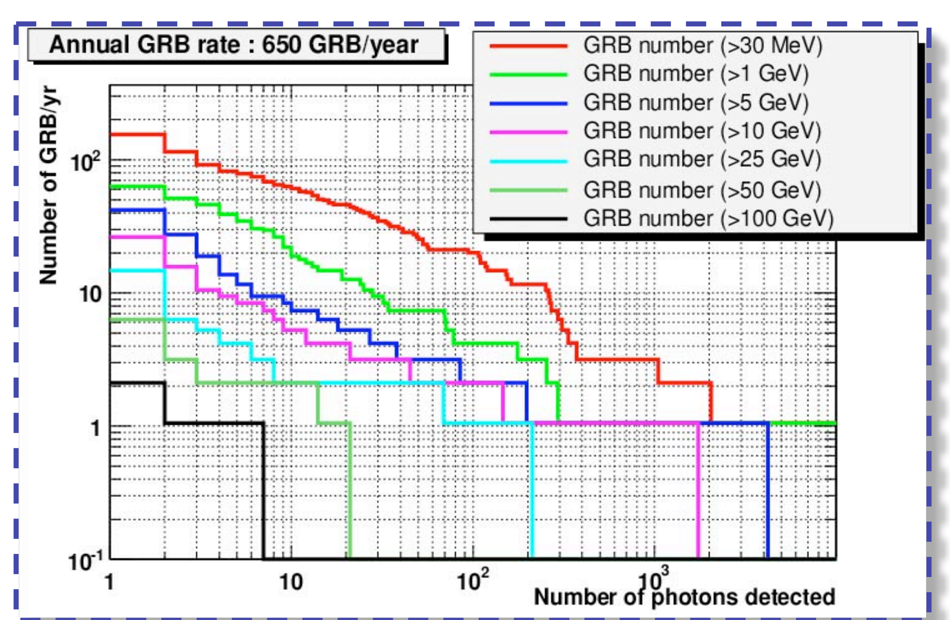


Study the GLAST sensitivity: from BATSE to GLAST

Using the phenomenological model with the pulse shape proposed by J. P. Norris et al., *Ap. J.* **459** (1996): high energy pulses are narrower than low energy pulses (see also E. E. Fenimore, et al. Ap. J. Lett., **448** (1995)).
Time dependent spectrum is a Band function, as well as the time integrated spectrum. Model from D. Band et al., *Ap. J.* **413** (1993), parameters distribution from Preece et al., *Ap. J. Supp.* **126**, (2000).
At high energy it is also important to consider the attenuation of the GRB spectrum due to the cosmological absorption. We have adopted for short bursts the redshift distribution proposed by D. Guetta, and T. Piran, *Astron. & Astrophys.* **435** (2005), while for long burst we adopt the Star Formation Rate from C. Porciani, and P. Madau, *Ap. J.* **548** (2001).
For the the **Extragalactic Background Light** (EBL) model, see J. R. Primack, J. S. Bullock, and R. S. Somerville, in *AIP Conf. Proc.* **745** (2005).



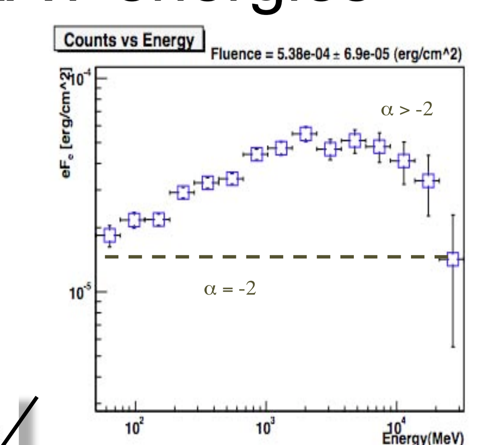
From the Current BATSE catalog: estimated number of burst per year over 4 pi: **~650 GRB/yr**

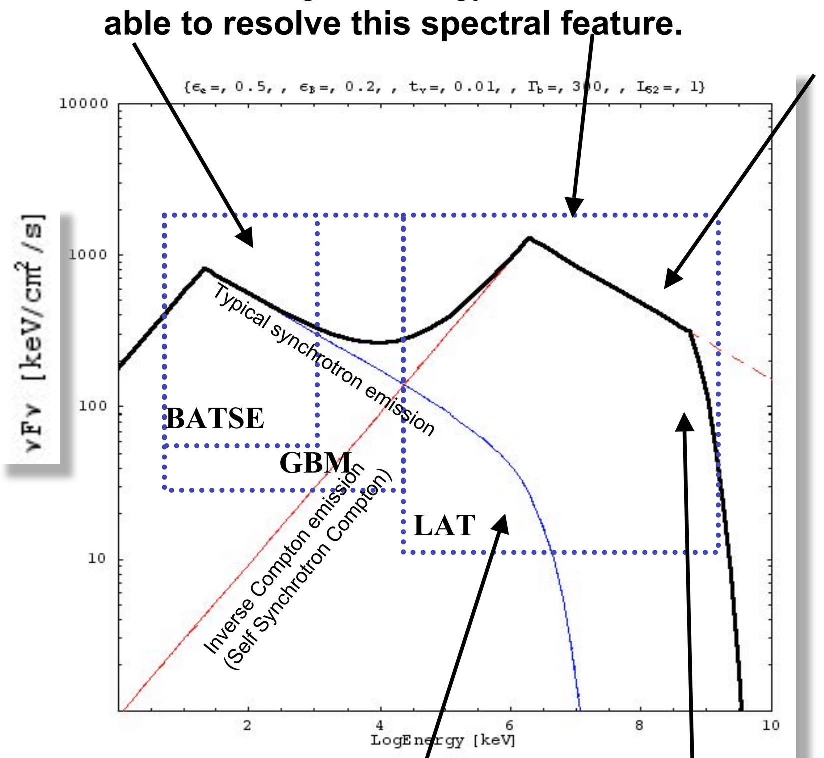


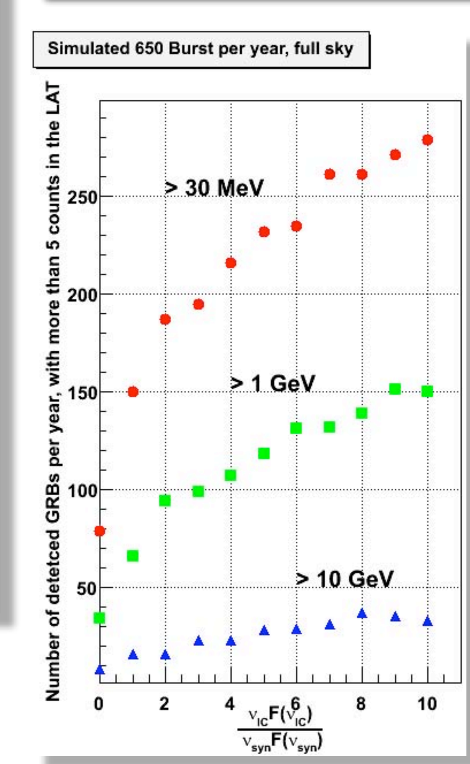
Alert algorithms are sensitive down to **5 GRB photons**, under this conditions, and with the assumed model, the GRB yield per year **for the LAT** would be **~ 60-70 bursts/yr.**
Similar computations show that **GBM will detect 200 burst/yr, 60 of which will be in the LAT f.o.v.**

Spectral Features at LAT energies

The **Inverse Compton** (**IC**) emission **was undetectable by BATSE**!
GLAST/LAT will be able to study this high energy radiation mechanism and, thanks to its large effective area and good energy resolution, **will be able to resolve this spectral feature.**



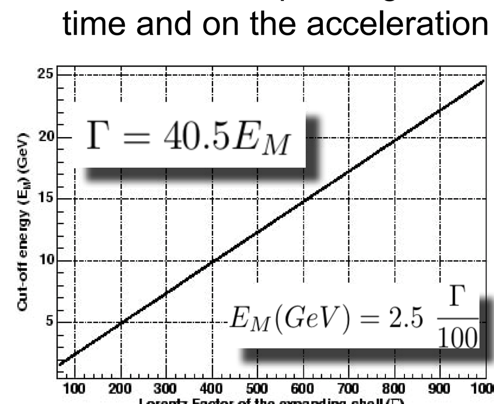




Variation of the **GRB yield** as a function of the **IC Emission.**

Cut-off due to synchrotron cooling:

Electrons are accelerated up to a certain Lorentz factor, depending on the cooling time and on the acceleration time.



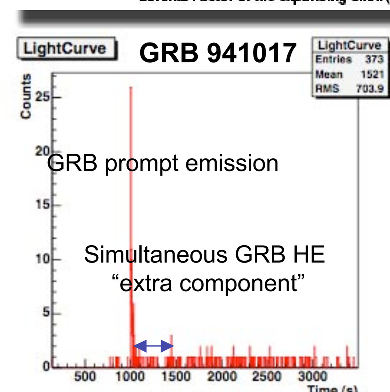
γγ ⇒ e+ e- internal attenuation:

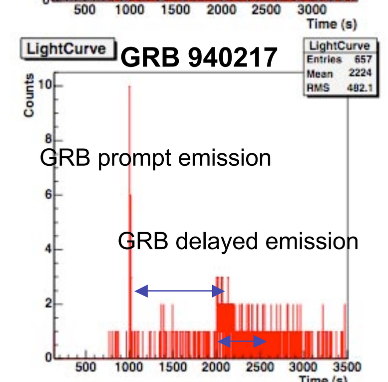
Observation of high energy photons is mainly limited by the opacity of two-photons annihilation into an electron positron pair. (Razzaque, Meszaros, Zhang 2004)

For relatively moderate Γ factors, this turn over should be accessible to GLAST energy range (Baring 2006)

$$E_{\gamma,\mathrm{pk,th}} = \frac{m_e^2 c^4 \Gamma_b^2}{2\epsilon_{\gamma,\mathrm{pk}}} \approx 26 \Gamma_{b,2.5}^2 \epsilon_{\gamma,2.7}^{-1}\ \mathrm{GeV}$$

EBL attenuation:
Important only for distant (z~6) and bright burst





Simulations of extended emission (top) and delayed emission (bottom).

High energy delayed/extended emission
At least in two cases a very hard extra component has been observed.
The delayed/extended emission is very interesting for GLAST, and represents one of the most interesting point left open by its predecessor EGRET.

More Info:
http://www-glast.stanford.edu/
http://glast.gsfc.nasa.gov/
http://glast.pi.infn.it/