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Abstract. The Gamma-ray Large Area Space Telescope (GLAST), scheduled to be launched in fall of 2007, is the next generation satellite for high-energy gamma-ray astronomy. The Large Area Telescope (LAT) is a pair conversion telescope built with a high precision silicon tracker, a segmented CsI electromagnetic calorimeter and a plastic anticoincidence shield. The LAT will survey the sky in the energy range between 20 MeV to more than 300 GeV, shedding light on many issues left open by its highly successful predecessor EGRET. LAT will observe Gamma-Ray Bursts (GRB) in an energy range never explored before; to tie these frontier observations to the better-known properties at lower energies, a second instrument, the GLAST Burst Monitor (GBM) will provide important spectra and timing in the 10 keV to 30 MeV range. We briefly present the instruments onboard the GLAST satellite, their synergy in the GRB observations and the work done so far by the collaboration in simulation, analysis, and GRB sensitivity estimation.

Keywords: Gamma-ray:bursts; Gamma-ray:telescopes
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INTRODUCTION

GLAST[1] is an international mission that will study the gamma-ray Universe (for more details, see the GLAST website at: `http://glast.gsfc.nasa.gov/`). It will be launched aboard a Delta 2920H-10 from Cape Canaveral, on a 565 km circular orbit at 28.5^o inclination. The heart of GLAST is the LAT, a pair production telescope sensitive to gamma rays in the energy range between 20 MeV-300 GeV and above. The LAT is an array of 4×4 identical towers, each made by a tracker of silicon strip planes with slabs of tungsten converter, followed by an hodoscopic calorimeter. The array of towers is surrounded by an anticoincidence detector (ACD) which identifies charged cosmic rays. The LAT's energy range, effective area, field-of-view (FoV) and angular resolution are vastly improved in comparison with those of its highly successful predecessor EGRET (1991-2000), so that the LAT will provide a factor 30 or more advance in sensitivity[1].

[1] see http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm for the LAT performances

This improvement should enable the detection of several thousands new high-energy sources and allow the study of GRBs and other transients, the search for dark matter, the detection of active galactic nuclei, pulsars, supernova remnants and the study of the extragalactic diffuse gamma-ray emission. The second detector onboard the GLAST satellite is the GLAST Burst Monitor (GBM)[2], which consists of 12 NaI detectors for the 10 keV to 1 MeV range and two BGO detectors for the 150 keV to 30 MeV range. It covers the entire visible sky not occulted by the Earth, extending the spectral coverage of GRBs down to the tens keV range, where most of GRB phenomenology is known since the BATSE instrument. GBM and LAT data will be jointly fitted providing spectral information over more than seven energy decades.

GAMMA-RAY BURSTS AND GLAST

GRBs are still a puzzling topic and few observations are nowadays available above 50 MeV. EGRET detected only a few high-energy bursts[3], and did not detect the high energy cutoff or rolloff that must exist for some hard spectra to keep the energy flux finite. Surprisingly, GeV emission was found to last up to 90 minutes after the 150 keV emission[4]; in addition, an extra spectral component was observed at 100 MeV in GRB941017[5]. GLAST will be a real breakthrough in the observation of GRBs; in the first year it will operate in scanning mode, providing uniform full sky coverage every three hours, with each region viewed by 30 minutes (the orbital period is 90 minutes). Starting from the second year of operations, and depending on the Guest Investigator program, GLAST may also be used in pointing mode. In case of an intense burst, GLAST will also be able to repoint to maintain the GRB in the LAT FoV during the prompt emission phase or to search for delayed emission. The GBM and LAT will independently trigger on GRBs: the first on a rapid increase of the count rate, and the second considering spatial and temporal clustering of counts. The GBM's threshold flux in the 50-300 keV range, along the LAT's axis, is 0.8 ph s^{-1} cm^{-2}. According to this, and by assuming a BATSE-like population of bursts, the GBM will detect $\sim$200 bursts per year, of which more than 60 will fall in the 2.4 sr field of view of the LAT[6], allowing joint observations. In case of a GRB trigger, an alert message will be sent to ground in near real-time via TDRSS (a communications satellite system). This will provide basic information for follow-up observations. The initial on-board GBM localization accuracy is $\sim$15 degrees (within 1.8 s). Updates will come later, reducing the GBM localization error box up to $\sim$3 degrees for a bright burst. The LAT detector can provide better accuracy, of the order of ten arc minutes or less, depending on the burst intensity. A full downlink of all the data will be performed via TDRSS $\sim$ 6 times a day and the scientific data, after a first analysis done by the LAT collaboration, will be delivered to the user community (LAT event data will be public after the first year of scientific operations). GLAST will cooperate with other telescopes (like Swift [7]) and ground based detectors in studying bursts. For a few bursts per year the LAT will localize them to sufficiently small error boxes (0.1 degrees) that medium field-of-view instruments can point for follow up observations, providing a more precise measurement of the GRB position. On the other hand, GLAST will frequently scan the burst position in the hours after a burst detection, searching for delayed high-energy emission. Finally, simple computations show that ∼20 Swift-detected GRBs per year will also be in the LAT FoV, hence connecting the well known soft-gamma ray emission with the still unknown high-energy emission from gamma-ray bursts. GLAST will be able to investigate the emission processes that are present in GRB phenomena and scan the most energetic region where particles are accelerated, probably reaching their highest energy.

GRB SIMULATORS

The basic idea is to develop a general interface to accommodate different models based on different approaches. In general we consider a GRB flux as a two dimensional histogram, where the flux (as $N_{ph}/cm^2/s$) is described as a function of energy and time. Different simulators[12] can produce such a histogram, here we will focus our attention on a phenomenological approach. A physical model is also available, where the GRB is described starting from the emission of shells of matter and is produced by the synchrotron emission of shocked accelerated electrons in internal magnetic fields (the so-call standard *fireball* scenario[8]). A different approach is followed in the phenomenological model, where the GRB behavior is based on observed quantities. In this model, firstly developed by Norris et al.(1996) [9], the pulse shape is described by a universal family of functions of equation:

$$I(t) = A \begin{cases} \exp[-(|t-t_0|/\sigma_r)^\nu], & t \le t_0 \\ \exp[-(|t-t_0|/\sigma_d)^\nu], & t > t_0 \end{cases} \quad (1)$$

Each pulse is divided in a rise phase (for $t < t_0$), and a decay phase (for $t > t_0$), σ_r and σ_d are the rise time and the decay time respectively (from data, $\sigma_r \sim 0.33\ \sigma_d^{0.86}$). The Full Width at Half Maximum (FWHM) is related to the rise and decay time through the following relation:

$$W = (\sigma_r + \sigma_d)\ln(2)^{1/\nu}. \quad (2)$$

Moreover, an important observed feature of GRB pulses is that the pulse width is narrower at higher energy [10, 9, 11]. This law has been observed in the BATSE energy range, while there is not enough statistics to observe a similar behavior at EGRET energies. In the phenomenological model, this scale law is extrapolated to GLAST/LAT energies, obtaining pulses which are narrower than the pulses in the BATSE (or GBM) energies. Adopting the results from [9] and [11] we define the quantity:

$$W(e) = W_0 \left(\frac{e}{20keV}\right)^{-\xi}, \quad (3)$$

where ξ is around 0.4 in value [9]. Thus, we can rewrite the pulse shape as a function of the energy and time:

$$I(t,e) = A \begin{cases} \exp[-(|t-t_0|/\sigma_r(e))^\nu], & t \le t_0 \\ \exp[-(|t-t_0|/\sigma_d(e))^\nu], & t > t_0 \end{cases} \quad (4)$$

with $\sigma_r(e)$ and $\sigma_d(e)$ given by:

$$\begin{cases} \sigma_d(e) = 0.75 \times \ln(2)^{-1/\nu} W_0 (e/20keV)^{-\xi} \\ \\ \sigma_r(e) = 0.25 \times \ln(2)^{-1/\nu} W_0 (e/20keV)^{-\xi}. \end{cases} \quad (5)$$

GRB spectra are very well described by a double power law function, smoothly joined (also known as “Band” function) [15]:

$$Band(e, e_b, \alpha, \beta) = N_0 \begin{cases} e^{\alpha} \exp[-e(2+\alpha)/e_p], & e < e_b \\ \\ e_b^{(\alpha-\beta)} \exp[\beta - \alpha] e^{\beta}, & e > e_b, \end{cases} \quad (6)$$

here α and β are the low and high energy index, and e_b is the “break energy”; $e_p = (2+\alpha)/(\alpha-\beta)e_b$ is the “peak energy” which corresponds to the maximum of $e^2 Band(e, e_b, \alpha, \beta)$ function. Some interesting features of the GRB spectrum are that they can be well described with a Band function both if they are integrated and instantaneous (notice that instantaneous naturally means integrated on time scale shorter then the pulse width). In order to build up the model, we have to consider the energy dependence of the pulse shape as introduced by Eq.3. The temporal-spectral function $f(t, e)$ is the product of a Band function (with spectral indices α' and β') and a pulse shape $I(t, e)$, whose width varies with the energy:

$$f(t, e) = I(t, e)\; Band(e, e_b, \alpha', \beta') \qquad [ph/cm^2/s/keV], \quad (7)$$

The *integrated spectrum* has to be itself a Band function (Eq. 6), with different spectral indices α and β:

$$\int_0^{\infty} f(t, e) dt = Band(e, e_b, \alpha, \beta) \qquad [ph/cm^2/keV] \quad (8)$$

Inserting Eq. 7 into Eq. 8 and integrating, we get that the integrated spectrum $Band(e, e_b, \alpha, \beta)$ is basically represented by the product of the terms: $Band(e, e_b, \alpha', \beta') \times W(e)$ which is, considering that $W(e)$ is a power law with slope -ξ, equal to a Band function with the modified spectral index:

$$\begin{aligned} \int_0^{\infty} f(t, e) dt &= Band(e, e_b, \alpha, \beta) = A_0 \times Band(e, e_b, \alpha', \beta') \times W(e) \\ &= A_0\; Band(e, e_b, \alpha' - \xi, \beta' - \xi) \end{aligned} \quad (9)$$

where A_0 contains all the numerical constants. A single GRB is built by adding many pulses; for each pulse we can then rewrite the phenomenological model function $f(t, e)$ as:

$$f(t, e) = I(t, e) Band(e, e_b, \alpha + \xi, \beta + \xi), \quad (10)$$

where e_b, α and β are the observed spectral indices for the integrated spectrum (of the burst), which are parameters of our model, while the amplitude, the width and the

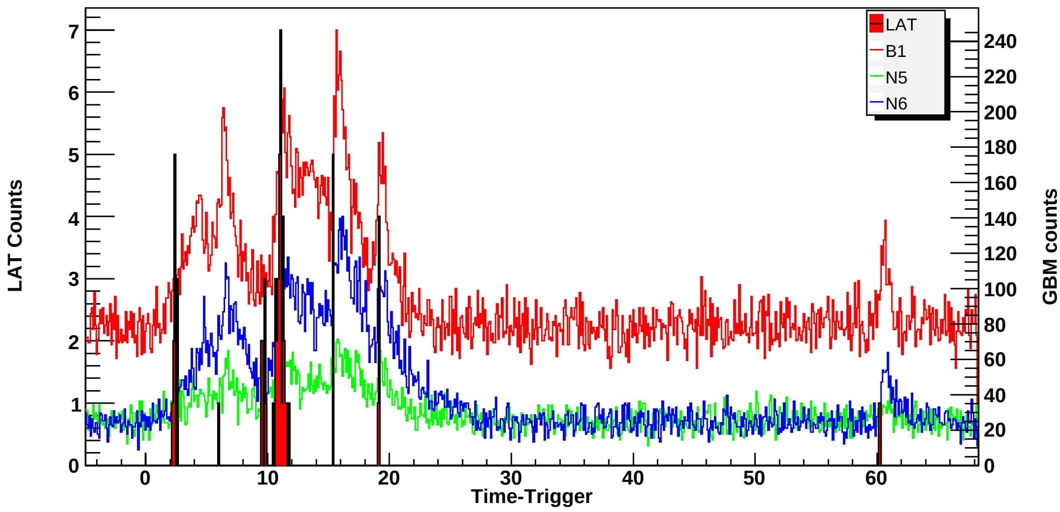

FIGURE 1. Combination of the simulated counts rate of the BGO (B1), two NaI detectors (N5 and N6) of the GBM experiment, over-imposed with the LAT light curve. LAT will have enough temporal resolution to correlate low energy spikes with high energy temporal profiles, understanding details of the emission process. In the figure is well visible the 'time-lag' between low energy and high energy temporal structures as well as the characteristic 'pulse paradigm', for which high energy pulses are narrower than low energy pulses.

peakedness of each pulse are randomly sampled from pulse to pulse, from the observed distributions [9]. Alternative spectral models have also been simulated. Battelino et al. (2007)[12] describe simulations with emission containing a strong photospheric component. They also discuss the framework Simple Burst Modeler (SBM) in which such simulations are made (see also [13]).

The GRB simulators are inserted in the framework of the official GLAST/LAT ground software and for each burst a sequence of photons is sampled, in agreement with the spectral-temporal development of the flux. Each photon is than processed by a Monte Carlo simulator, based on GEANT4 toolkit, which follows the propagation of particles in the detector. Another (faster) approach is to use the parameterized response of the instrument, using the Instrument Response Function (IRF). Even in this case the followed approach is photon-by-photon, and the output format is the same as in the case of the full Monte Carlo approach. GRBs can be combined with other classes of sources, (stationary and flaring AGN, solar flares, SNR, Pulsars,...), building a very complex and, possibly realistic, picture of the gamma-ray sky.

The GRB simulators are also able to interface the GBM software providing correct input files for the detector simulators. In this case the approach is slightly different. The GRB simulators produce a temporal series of Band parameters, fitting continuously the GBM counterpart of a LAT bursts. These parameters are then used to compute the GBM response and the final output is a series of *fits* files, containing background data, response data and counts (i.e. these files are ready to be analyzed by xspec). For the LAT side, *Science Tools* have been developed by the LAT team, and will be distributed to the user community as soon as GLAST will be launched. *Science Tools* are a general set of tools

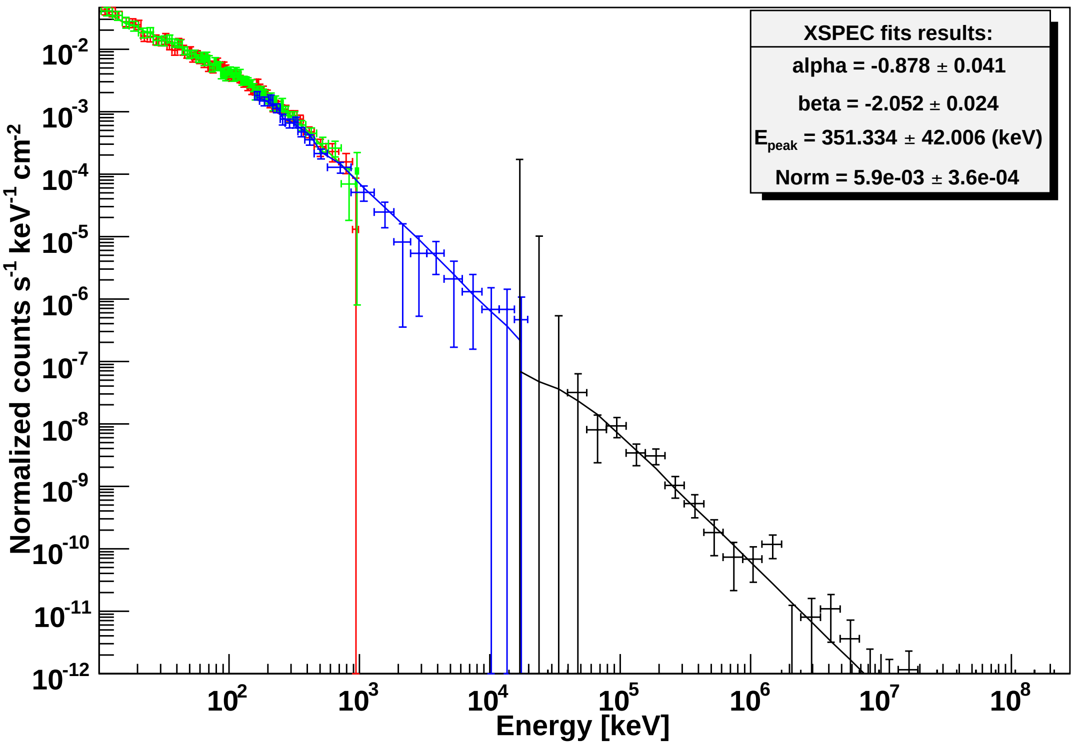

FIGURE 2. A simulated GRB as viewed by the two experiments onboard the GLAST satellite. The simulated data are from 2 NaI (GBM) detector, the BGO (GBM) detector and the LAT detector. With GLAST, GRBs will be observable simultaneously on more than seven decades in energy.

that are used to manipulate the data files. Data can be binned in time producing light curves (see, for example, Fig.1), or can be analyzed using xspec[2] combining GBM and LAT data: in this case a GRB can be simultaneously studied in an energy band larger than seven orders of magnitude (see Fig. 2), making GLAST a very powerful tool for understanding the correlation between the low-energy and high-energy spectra in GRBs.

STUDY THE LAT'S GRB SENSITIVITY

We used the BATSE catalog for building up our statistics. Considering the flux threshold (0.3 ph/cm^2/s) and the field of view of the BATSE instrument, the expected number of bursts per year over the full sky is 650. Each of these bursts is randomly sampled from the BATSE catalog, and its emission is extended up to high energy with the model described in the previous section. Long bursts and short bursts are treated separately (on average, short bursts are *harder*). For each simulated burst the duration is drawn from the observed T_{90} distribution and its flux is sampled from the BATSE peak flux

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[2] *PHA* files and *RSP* files are the only needed since LAT is "background free" considering an integration time that lasts the typical duration of a burst.

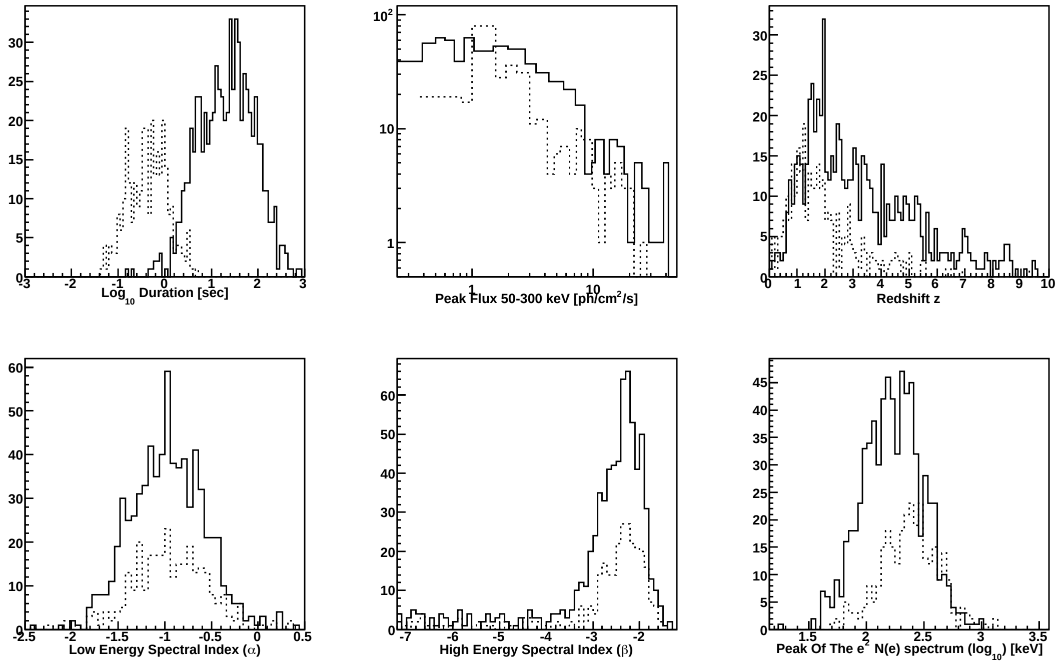

FIGURE 3. Simulated distributions of parameters for short bursts (dashed lines) and for long bursts (solid line). The distributions shown the logarithm of the duration, the peak flux the redshift distribution, the low and high energy spectral indexes and the logarithm of the energy of the peak of the νF_ν spectrum. Each entry corresponds to a simulated burst.

distribution in the 50-300 keV energy range[14]. The number of pulses is fixed by the total burst duration. Pulses are combined together in order to obtain a final T_{90} duration. The peak energy e_p and the low and high energy spectral indices α and β are sampled from the observed distributions[15, 16]. High-energy emission (>10 GeV) is also sensitive to cosmological attenuation due to pair production between the GRB radiation and the Extragalactic Background Light (especially with optical-UV photon). The uncertain EBL spectral energy distribution resulting from the absence of high redshift data provides a variety of theoretical models for such diffuse radiation. Thus the observation of the high-energy cut-off as a function of the GRB distance can, in principle, constrain the background light. In our simulation we have included this effect, adopting the EBL model proposed in[17]; short bursts are thought to be the result of the merging of compact objects in binary systems, so we adopted the short burst redshift distribution from [18], while long bursts are related to the explosive end of massive stars, whose distributions are well traced by the Star Formation History [19]. In Fig. 3 the sampled distributions are shown, for long and short bursts separately.

The burst sensitivity strongly depends on the GRB high-energy emission where little is known. In our computations we have adopted the simple assumption of merely extrapolating the BATSE observations to the LAT energies, with the model described above. We simulate one year of observations in scanning mode. The orbit of the GLAST satellite, the South Atlantic Anomaly (SAA) passages and the Earth occultations are correctly considered. In Fig.4 we plot the number of expected bursts per year as a function of the number of photons per burst detected by the LAT, where different lines refer to different energy thresholds. The EBL attenuation affects only the high-energy curve, as expected from the theory, leaving the sensitivities almost unchanged with thresholds less than 10 GeV. Table 1 shows some useful numbers. In this calculation, LAT will independently detect 50-70 burst per year, depending on the sensitivity of the detection algorithm; few bursts per month have more than a hundred counts in the LAT detector: these are the bursts for which a detailed spectral or even time resolved spectral analysis will be possible. With the assumed high-energy emission model, few bursts per year will show high-energy prompt emission, with photons above 50 GeV.

TABLE 1. Estimated sensitivity to GRB, for the given model.

Energy threshold	Number of photons per Bursts	Number of Burst per year
30 MeV	1 counts	100 Bursts per year
30 MeV	5 counts	50 Bursts per year
30 MeV	1000 counts	1-2 Bursts per year
1 GeV	1 count	50 Bursts per year
1 GeV	100 counts	10 Bursts per year
10 GeV	1 count	20 Bursts per year
50 GeV	1 count	1 Bursts per year

CONCLUSION

GLAST is the new generation of high-energy gamma-ray satellite. It is close to being launched (late 2007), and will follow the path opened by its predecessor EGRET. GLAST will observe GRBs with highly improved performances: here we computed the sensitivity of the LAT to GRBs, showing that, by assuming a simple model that extrapolates the BATSE flux to high-energy, the LAT will be able to detect 50-70 bursts per year, some of these with enough counts for a detailed spectral study. Bright GRBs will be detected by the GLAST satellite, providing a spectral coverage of more than seven orders of magnitude: in this case a broadband study comparing the low energy emission with the high energy emission will allow the study of the still puzzling emission mechanism in GRBs. LAT has a much smaller dead time with respect to its predecessor EGRET, which, also thanks to its larger effective area, allows the detailed study of the substructure of the pulses in GRB lightcurves. Nevertheless, intrinsic absorption can affect the high-energy spectrum[20] as well as different emission mechanisms that can enhance the spectrum at the LAT energies increasing the GRB yield. Further studies will consider this effects in detail.

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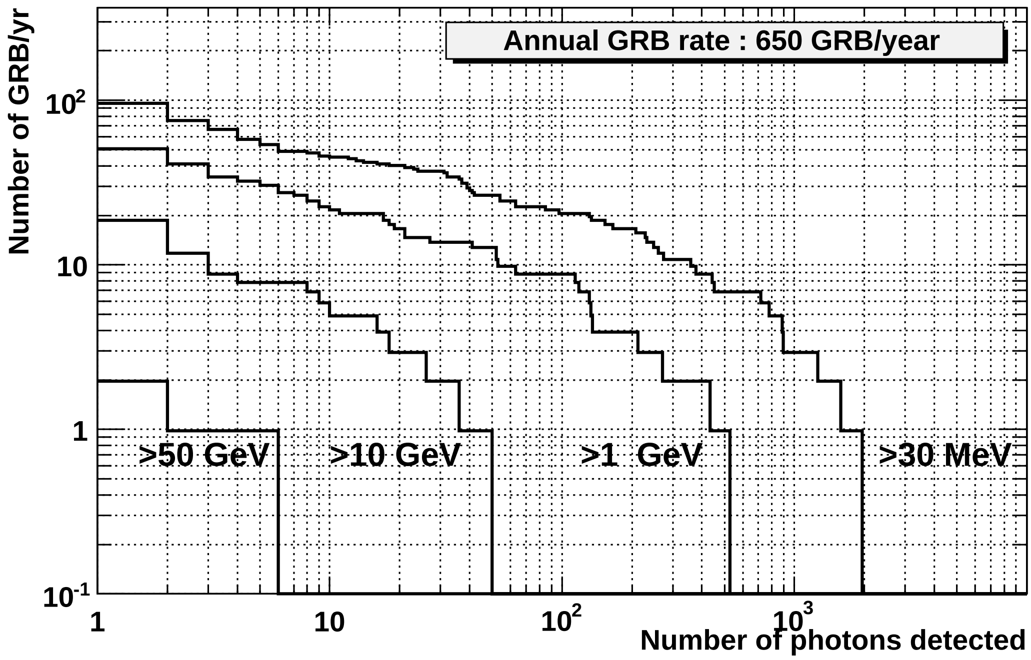

FIGURE 4. Model-dependent LAT GRB sensitivity. The GRB spectrum is extrapolated from BATSE to LAT energies. The burst rate in the 4π sphere is assumed to be 650 GRB/yr (above 0.3 ph s^{-1} cm^{-2} in the 50-300 keV band), in agreement with BATSE statistics. The effect of the EBL absorption is included. Different curves refer to different energy thresholds.

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