ELSEVIER

Proceedings of ICHEP 2002, pp. 122–125
S. Bentvelsen, P. de Jong, J. Koch and E. Laenen (Editors)

31st INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS AMSTERDAM

The Gamma Ray Large Area Space Telescope - an astro-particle mission to explore the high energy gamma ray sky

L. Latronico[a] *

[a]Istituto Nazionale di Fisica Nucleare, Sez. Pisa,
Via Livornse 1291, 56010 S. Piero a Grado (Pisa), Italy

The *Large Area Telescope (LAT)*, the main instrument on the *Gamma-ray Large Area Space Telescope (GLAST)* mission under development for launch by NASA in 2006, will survey the sky in the rich yet poorly explored high-energy band between 20 MeV and 1 TeV with unprecedented resolution and sensitivity. The LAT, which benefits from the application of particle physics detection technologies to astrophysics instrumentation, has a pair-conversion silicon-strips tracker and an imaging CsI calorimeter to measure the direction and energies of gamma rays. The relatively very intense background of charged particles will be rejected primarily by an anticoincidence shield of segmented plastic scintillators. In this paper we give an overview of the many physics goals and potential reach of the LAT, describe the instrument design and performance, and report on the status of the tracker construction.

1. Motivation and instrument design

The first complete survey of the sky in high-energy (30 MeV-10 GeV) γ-rays was performed by the Energetic Gamma Ray Experiment Telescope (EGRET, [1]), which was launched in 1991 on board of the Compton Gamma Ray Observatory. It showed the high energy γ-ray sky to be surprisingly dynamic and was able to detect a few hundred γ-ray point sources, most of which still remain unidentified. The GLAST mission ([2]) has been conceived to answer many of the important questions in high energy astrophysics raised by the EGRET results. Like EGRET, the Large Area Telescope, the main instrument on-board GLAST, will be a pair conversion telescope with a tracker, calorimeter, and an anticoincidence shield. But the latest-generation technology applied to the design of the LAT results in a remarkable advance in performance. EGRET had a gas-filled spark chamber tracker, and monolithic calorimeter and anticoincidence shield. The LAT will have a very large (83 m^2 total area in 36 layers) silicon strip tracker with fine detector pitch (228 μm), a hodoscopic, 8-layer calorimeter that will permit shower profiling, and an anticoincidence shield that is segmented to minimize self-veto from high energy electron backsplash from the calorimeter.

*on behalf of the GLAST-LAT collaboration

The performance of the LAT relative to EGRET is compared in Table 1. The result is that the LAT will have unprecedented resolution and an advance in sensitivity of a factor 20 or more with respect to EGRET.

2. GLAST Science Program

2.1. Sky map and unidentified sources

A full-sky survey with the LAT is planned for the first year of the GLAST mission. The excellent angular resolution and sensitivity of the LAT telescope will provide high-quality data with large statistics for detailed sky mapping, with source localization to the level of arc-minutes. The LAT will also offer dramatic improvements in ability to detect γ-ray flares and perform direct pulsation searches and critical spectral measurements.

Most of the 271 γ-ray sources in the EGRET catalog are unidentified; the large error boxes in the localization do not allow unambiguous association of these sources to known objects in the optical, radio, or X-ray bands. Moreover the distribution of the sources on the sky and their variable temporal properties suggest that more than one source class is required.

doi:10.1016/S0920-5632(02)02106-0

Table 1
GLAST LAT performances compared to EGRET

Quantity	EGRET	LAT(minimum spec.)
Energy range	20MeV - 30 GeV	20MeV - 300 GeV
Peak effective area[1]	1500 cm^2	8000 cm^2
Field of view	0.5 sr	$> 2sr$
Angular resolution[2]	5.8^o (100MeV)	$< 3.5^o$ (100MeV)
		$< 0.15^o$ ($>$ 10GeV)
Energy resolution[3]	10%	10%
Dead time per event	100ms	$< 100\mu s$
Source location determination[4]	$15^{'}$	$< 0.5^{'}$
Point source sensitivity[5]	$\simeq 10^{-7}cm^{-2}s^{-1}$	$< 6x10^{-9}cm^{-2}s^{-1}$

[1]After background rejection. [2]Single photon, 68 % containment, on-axis. [3]1-σ, on-axis. [4]1-σ radius, flux $10^5cm^2s^{-1}(> 100MeV)$, high $|b|$. [5] $> 100MeV$, at high $|b|$, for exposure of one-year all sky survey

While there are indications that many of these sources belong to well established classes like blazars, radio-quiet pulsars, or binary systems, some of them may very well be examples of previously undetected γ-ray emitters, like forming clusters of galaxies or the recently discovered Galactic microquasars.

2.2. Active galactic nuclei

A large fraction of the known high-energy sources is represented by AGNs, most of them belonging to the blazar class and characterized by jet-like emission and broadband spectra peaking at gamma rays and between radio and X-ray.

The high sensitivity and large effective area of the LAT will be crucial for testing different models proposed for the central engine of blazars. Detailed spectral studies of gammas emitted should allow distinction between pure leptonic and hadronic particle acceleration mechanism.

The two models can be identified by tracking time variation of AGN spectra and studying the decay characteristics of the synchrotron and γ-ray components during flares, which usually occur on time scales of the order of minutes. Flaring states, when the most energetic phenomena occur inside the cores of AGNs, are in fact closely related to the nature of AGNs central engine, and more information can be obtained after correlation with observations at other wavelength, which will be done exploiting a network of other satellite and ground-based experiments alerted by the LAT.

Extrapolation of the log N-log S relation ([3]) for AGNs suggests that thousands will be detected by the LAT. With such a large population, the redshift dependence of the γ-γ attenuation of AGN spectra by the infrared-UV Extragalactic Background Light may be useful for measuring this cosmic background.

2.3. Pulsars

It is widely projected that GLAST will discover $\simeq$ 250 new pulsars. The high time resolution and detection efficiency of the LAT will in fact allow direct pulsation searches in the γ-ray band, with a possible identification of many Galactic, bright, unidentified sources with X or radio-quiet pulsars like Geminga ([4]). The very high photon statistics provided by the LAT large effective area will bring accurate spectra, opening the way to a clear discrimination between the *outer gap* and *polar cap* models of γ-ray production for rotation-powered pulsars.

2.4. Diffuse background and dark matter

An apparently isotropic background of high-energy gamma rays was confirmed by EGRET data. However, the relatively poor angular resolution and photon statistics has left open the possibility that the isotropic background is unresolved emission from AGNs. A truly diffuse background could instead have a more exotic interpretation, such as relic radiation from some very high energy primordial process in the early universe. The LAT will resolve a large fraction of the AGN component of the high-energy, diffuse background, and spectral and fluctuation analyses should permit sensitive limits to be determined for any cosmic diffuse background.

A similar excess was found in the emission from the galactic centre ([5]), suggesting a possible connection with the existence of dark matter at the centre of the galaxy. The most promising candidate process is neutralino (χ) decay, as foreseen by supersymmetric extensions of the elementary particles standard model ([6]). Besides theoretical reasons, the hypothesis of neutralinos as the main dark matter constituents in galaxies is particularly attractive as searches for supersymmetric particles can be correlated to current limits from accelerator and underground experiments as well as from other space missions.

Figure 1 shows a simulation of the galactic centre spectrum obtained with standard propagation models and a contribution from neutralino decay. GLAST will have enough sensitivity to disentangle the two contributions.

The supersymmetric phase space that GLAST will be able to probe is model-dependent. In the context of the Minimal SuperGravity Model, recent preliminary calculations for the $\chi\chi \rightarrow \gamma\gamma$ or $\chi\chi \rightarrow \gamma Z$ cross sections, which would produce a spectacular monochromatic line as distinctive signature, indicate that a large region in the $m_0 - M_{1/2}$ space will be accessible to GLAST ([7]), providing an alternative test field for the supersymmetric hypothesis.

2.5. Gamma-ray bursts

In recent years, Gamma-ray bursts (GRBs) have been shown to be immensely energetic (10^{54} erg) outbursts that occur at cosmological distances. Bursts have highly variable temporal structures (~ms) and typical durations of seconds. The large effective area and field of view of the LAT, together with the unprecedently short instrumental deadtime, will greatly advance knowledge of GRBs at high energies. The highest-energy emissions constrain the acceleration processes and the bulk motions within the fireballs. LAT data will permit distinguishing between internal and external shock models for the production of gamma rays, and evaluation of the baryon fraction in the fireballs.

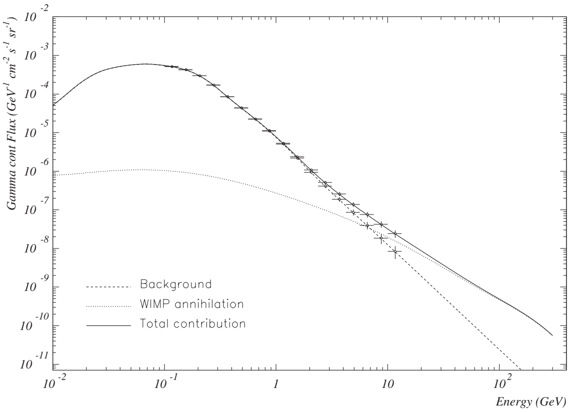

Figure 1. Simulation of the GLAST sensitivity to neutralino decay contributions to the total photon spectrum from the galactic centre

2.6. Cosmic rays

Cosmic rays (CR) have been known and measured for a long time. A fundamental outstanding question is the origin of the hadronic CRs, which is widely believed, but not yet proven to be supernova remnants (SNR). The SNR origin for nucleons would have a signature in a broad peak at 68 MeV from by the decay of π^0 produced by the interaction of freshly-accelerated CR nucleons with interstellar gas in the vicinity of an SNR. The LAT should be able to spatially resolve several SNR with degree-scale angular extents and spectrally resolve the π^0 decay peak from other γ-ray components.

3. Status of the LAT tracker construction

In order to maximize production efficiency with constrained cost, the LAT tracker is organized in a highly modular structure of $4x4$ identical towers of $37x37$ cm^2 area, each composed of a stack of 19 composite panels (*trays*) equipped with silicon-strip layers on both sides and a thin W converter, for a total of 18 bidimensional detection planes and an overall number of channels approaching 10^6(see fig.2). When a high energy gamma crosses the tracker, it produces an e^+e^- pair after interacting with one of the converters, and the direction of the incoming photon can be evaluated by reconstructing the leptons tracks. Construction

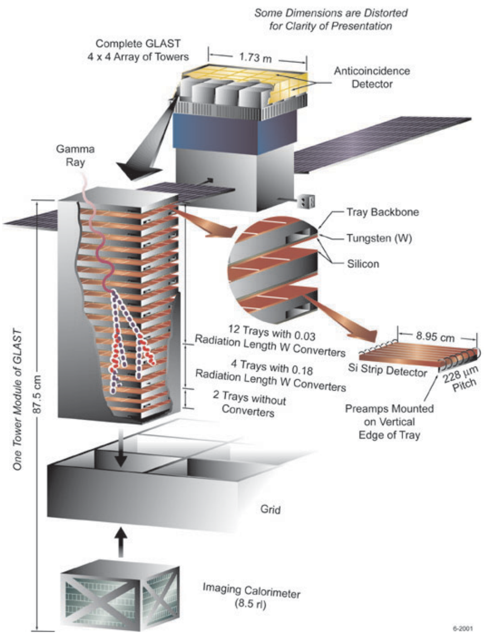

Figure 2. The GLAST-LAT detector

of the LAT tracker has begun with procurement and test of more than 3000 6" silicon sensors, representing more than 25% of the whole production. The electrical tests performed on the sensors show a high uniformity across the production (see table 2).

Construction of the baseline detector, obtained by wire bonding 4 silicon sensors together, has finished the prototyping phase with excellent results, while the engineering of the tray structure was confirmed after thorough qualification tests([8]).

4. Conclusions

The LAT is the product of a partnership of HEP and Astrophysics communities that will explore the high-energy γ-ray sky. Diverse astrophysical objects like AGN, GRBs, pulsars, and SNR, radiate in this energy range, and observations in this regime are key to understanding the nonthermal processes involved. Observation of the diffuse γ-ray halo of the Milky Way will also allow testing the hypothesis of a supersymmetric origin of dark matter, probing a large part of the supersymmetric phase space. Today only a little is known about the γ-ray sky, mainly because of technological limitations of previous missions. GLAST will be equipped with state of the art particle detectors, resulting in greater than an order of magnitude advance in sensitivity and resolution.

Table 2
Test results from the first 3000 silicon sensors

Measurement	average	RMS
Leakage current[1] (nA)	115	50
Depletion voltage (V)	70	20
Bulk capacitance[1] (pF)	1800	10
Wafer cut alignment (μm)	0	2
Broken strips (overall rate)	10^{-4}	

[1] measured at a bias of 150V

Acknowledgements

I want to thank the GLAST-LAT collaboration for the material provided. Special aknowledgements to Seth Digel for his precious suggestions.

REFERENCES

1. P. Nolan et al. IEEE Trans., Nucl. Sci.,39, 993-996
2. E. Bloom et al.,*Proposal for the Gamma-ray Large Area Telescope*, SLAC-R-22.February 1998
3. Stecker F.W., Salamon M.H. 1996, ApJ 464, 600
4. McLaughlin M.A. et al., 2000, ApJ 538, 818
5. H. Mayer-Hasselwander et al., Astron.Astrophys. 335, 161 (1998)
6. Bergstrom L. et al. Astropart. Phys. 1998, 9, 137
7. Morselli A. et al., *Search for Dark Matter with GLAST*, submitted to Nucl. Phys. B (*SpacePart* Conference Proceedings, Elba Island, 14/19 May 2002)
8. Bellazzini R. et al., *The GLAST Tracker design and construction*, submitted to Nucl. Phys. B (*SpacePart* Conference Proceedings)