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STATUS OF THE GLAST LARGE AREA TELESCOPE

Richard Dubois

Stanford Linear Accelerator Center, Stanford University, PO Box 20750, Stanford, CA, USA

Abstract

The GLAST Large Area telescope is a modular 4x4 tower pair conversion telescope with field of view greater than 2 steradians and energy coverage from 20 MeV to 300 GeV. The observatory is scheduled for launch in September 2006. A status of the instrument construction is presented here.

1 Introduction

GLAST is a next generation high-energy gamma-ray observatory designed for making observations of celestial gamma-ray sources in the energy band extending from 20 MeV to more than 300 GeV. It follows in the footsteps of the Compton Gamma Ray Observatory EGRET experiment, which was operational between 1991-1999. The GLAST Mission is part of NASA's Office of Space and Science Strategic Plan, with launch anticipated in 2006. The principal instrument of the GLAST mission is the Large Area Telescope (LAT) that is being developed jointly by NASA and the US Dept. of Energy (DOE) and is supported by an international collaboration of 26 institutions lead by Stanford University.

The GLAST LAT is a high-energy pair conversion telescope that has been under development for over 7 years with support from NASA, DOE and international partners. It consists of a precision converter-tracker, CsI hodoscopic calorimeter, plastic scintillator anticoincidence system and a data acquisition system. The design is modular with a 4x4 array of identical tracker and calorimeter modules. The modules are approximately 38 x 38 cm. Figure 1 shows the LAT instrument concept.

The LAT science instrument (Figure 1) consists of an Anti Coincidence Detector

(ACD), a silicon-strip detector Tracker (TKR), a hodoscopic CsI Calorimeter (CAL), and a Trigger and Data Flow system (T&DF). The principal purpose of the LAT is to measure the incidence direction, energy and time of cosmic gamma rays while rejecting background from charged cosmic rays and atmospheric albedo gamma rays and particles. The data, filtered by onboard software triggers, are

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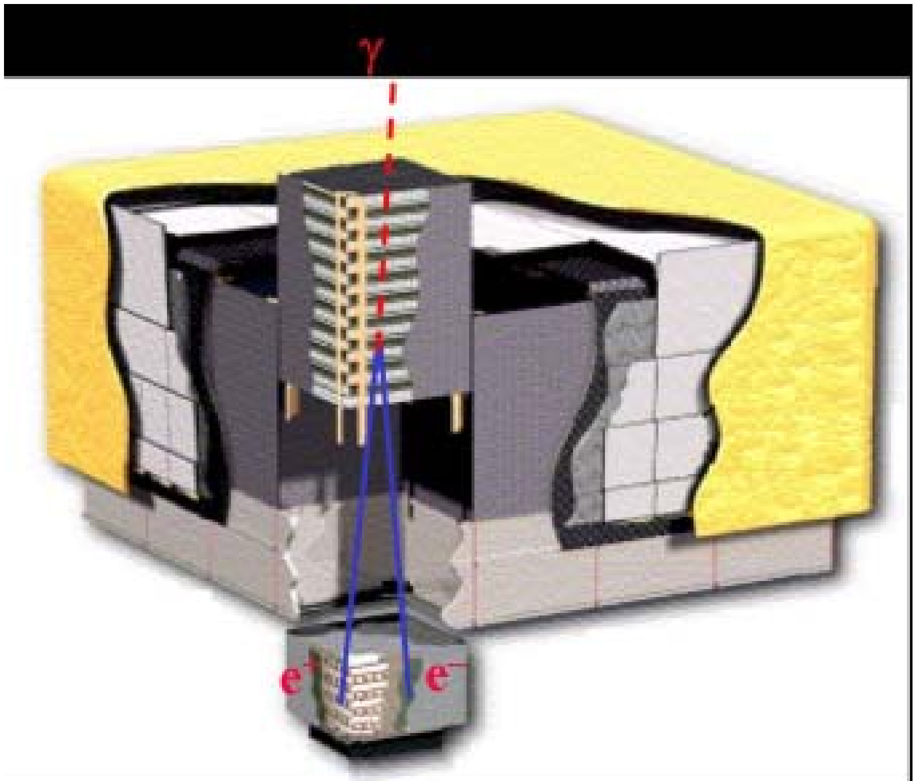

Figure 1: Large Area Telescope. Composed of 16 modules containing Tracker and Calorimeter elements, all surrounded by a scintillator anti-coincidence shield.

streamed to the spacecraft for data storage and subsequent transmittal to ground-based analysis centers. The Tracker provides the principal trigger for the LAT, converts the gamma rays into electron-positron pairs, and measures the direction of the incident gamma ray from the charged-particle tracks. It is crucial in the first levels of background rejection for providing track information to extrapolate cosmic-ray tracks to the ACD scintillator tiles, and it is important for further levels of background analysis due to its capability to provide highly detailed track patterns in each event.

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The primary tasks of the GLAST calorimeter are to provide accurate measure of the energy of the shower resulting from pair conversion of incident gamma rays in the tracker, and to assist with cosmic-ray background rejection through correlation of tracks in the silicon tracker with the position of energy deposition in the calorimeter. The calorimeter also provides triggers to the LAT, particularly for very large energy depositions.

The primary task of the GLAST ACD is to detect energetic cosmic ray electrons and nuclei for the purpose of removing these backgrounds. It is the principal source for detection of other than gamma ray particles. This detector element covers the Tracker. It consists of an array of 89 plastic scintillator tiles (1 cm thick, various sizes), plus eight scintillating fiber "ribbons" that cover the gaps between the tiles. Signals produced by the ACD are used by the T&DF system to identify cosmic ray electrons and nuclei entering the instrument.

See the LAT Peer Design Review reports for more details [1, 2, 3].

1.1 The LAT Tracker

The Tracker converts gamma rays to charged particles and measures with good precision the path of the charged particles within the Tracker. Fast signals from tracks are examined in the T&DF system for likely gamma ray candidates. Once identified and at the request of the trigger system, data are read out via the dataflow system. The dataflow system uses the data to assemble particle tracks and, coupled with the ACD and CAL, identify gamma rays. The Tracker consists of 16 modules arranged in a four-by-four square array. Each module is mounted via flexures to the aluminum Grid, which also supports a Calorimeter module directly below each Tracker module. The Tracker modules are enclosed under the ACD.

Silicon-strip detectors are used as the charged particle detection element within the Tracker. Briefly, silicon-strip technology provides excellent intrinsic resolution and high, nearly 100%, efficiency in a thin detector plane, all of which gives optimal resolution performance in a wide field of view. This technology is also robust, highly stable, has been used extensively in space applications, and requires no consumables.

1.2 The LAT Calorimeter

The Calorimeter (CAL) subsystem consists of 16 identical modules arranged in a 4x4 array that is defined by the LAT support grid structure. As a result of the LAT technology development program, we selected a segmented thallium-doped cesium iodide, CsI(Tl), scintillation crystal calorimeter. This technology is well established in both laboratory and space experiments and can meet or exceed all of the identified requirements for the GLAST mission. It provides excellent intrinsic energy resolution at modest cost, provides a fairly fast signal, and is reasonably radiation hard. CsI(Tl) is also a much more rugged material than NaI(Tl) and is comparatively not hygroscopic, greatly reducing the cost and complexity of construction and handling. To achieve the required energy coverage and resolution, the calorimeter is 8.5 radiation lengths (8.5 X0) deep. An additional depth of 1.5 X0 resides in the tracker. To assist in track correlation for background rejection and to improve the energy measurement by shower profile fitting, the calorimeter is segmented into discrete detector elements and arranged into a hodoscopic or imaging configuration and read out using PIN photodiodes. Each CAL module contains 96 crystals of size 26.7 mm x 19.9 mm x 333 mm. The crystals are individually wrapped for improved light collection and optical isolation, and are arranged horizontally in 8 layers of 12 crystals each. Each layer is aligned 90° with respect to its neighbors, forming an x-y array. (See Figure 6 for clarity.) The spectral response of the PIN photodiodes is well matched with the scintillation spectrum of CsI(Tl), which provides for a large primary signal (5,000 electrons collected in 1.5 cm2 diode per MeV deposited), with correspondingly small statistical fluctuations and thereby high intrinsic spectral resolution. The PIN photodiodes are mounted on both ends of a crystal and measure the scintillation light at each end of a crystal from an energy deposition in the crystal. This provides a redundancy in the energy measurement. However, the difference in light levels seen at the two ends of the crystal also provides a determination of the position of the energy deposition along the CsI crystal. The position resolution of this imaging method ranges from a few millimeters for low energy depositions (10 MeV) to a fraction of a millimeter for large energy depositions (¿1 GeV).

The size of the CsI crystals has been chosen as a compromise between electronic channel count and desired segmentation within the calorimeter. The indicated size is comparable to the CsI radiation length (1.86 cm) and Moliere radius (3.8 cm) for electromagnetic showers. The size of the crystals is not the dominant factor in determining the imaging capabilities of the calorimeter; most of the positional information is provided by the light-difference measurement.

2 Reconstructing LAT Data

The pair-converted daughters of the gamma, are tracked through the silicon and tungsten of the tracker with the goal of find the best one or two trajectories, depending on the incident energy. Multiple scattering is key to this analysis, in that it is the dominant error contribution below a few GeV.

A Kalman filter technique is used in the tracker to account for this effect. It basically follows trajectories, accounting for energy-dependent error introduced by material in the tracker and predicting a cone in which to look for hits to associate in the next layer.

At present, energy in the calorimeter is lumped together into a single cluster from whose moments are derived the energy and direction. The energy is used to seed the track finding, since the multiple scattering errors are energy dependent. The calorimeter is not thick enough to contain all the shower energy above a couple of GeV. Corrections are required to estinmate the leakage energy. This has been done in two ways: correlating the total energy with the energy measured in the last layer; and by fitting the expected shape of the shower against a standard function.

Tracks are extrapolated back to the anti-coincidence device to help distinguish background events.

Figure 2 shows a typical gamma conversion at 100 MeV. The severe multiple scattering is quite apparent. Below 100 MeV, in fact, only the first two tracker layers after the interaction contribute to measuring the direction; the remaining layers are used in pattern recognition to find the first two.

The estimated performance of the LAT is shown in Table X, along with the Science requirements.

3 Project Status

As of the time of this writing, the LAT Instrument had just completed its Critical Design Review for approval to begin flight hardware construction. It is expected to take some 18 months, with integration into the 16 tower LAT beginning in mid 2004, and handoff to the spacecraft for integration into the Observatory in late 2005. All this leading to a launch scheduled for fall 2006.

4 Summary

GLAST will be the follow-on project to EGRET in gamma ray observations, but with 30-100 times its sensitivity. GLAST should allow detailed understanding of many of the new source classes that EGRET found with the advent of much larger source samples. It is a unique fusion of particle physics and particle astrophysics.

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References

[1] N.Johnson et al, *LAT Calorimeter Peer Design Review Report* , GLAST Document LAT-TD-0242, 2002

[2] D.J.Thompson et al, *LAT ACD Peer Design Review Report* , GLAST Document LAT-TD-0429, 2002

[3] R.Johnson et al, *LAT Tracker Peer Design Review Report* , GLAST Document LAT-TD-0156, 2002

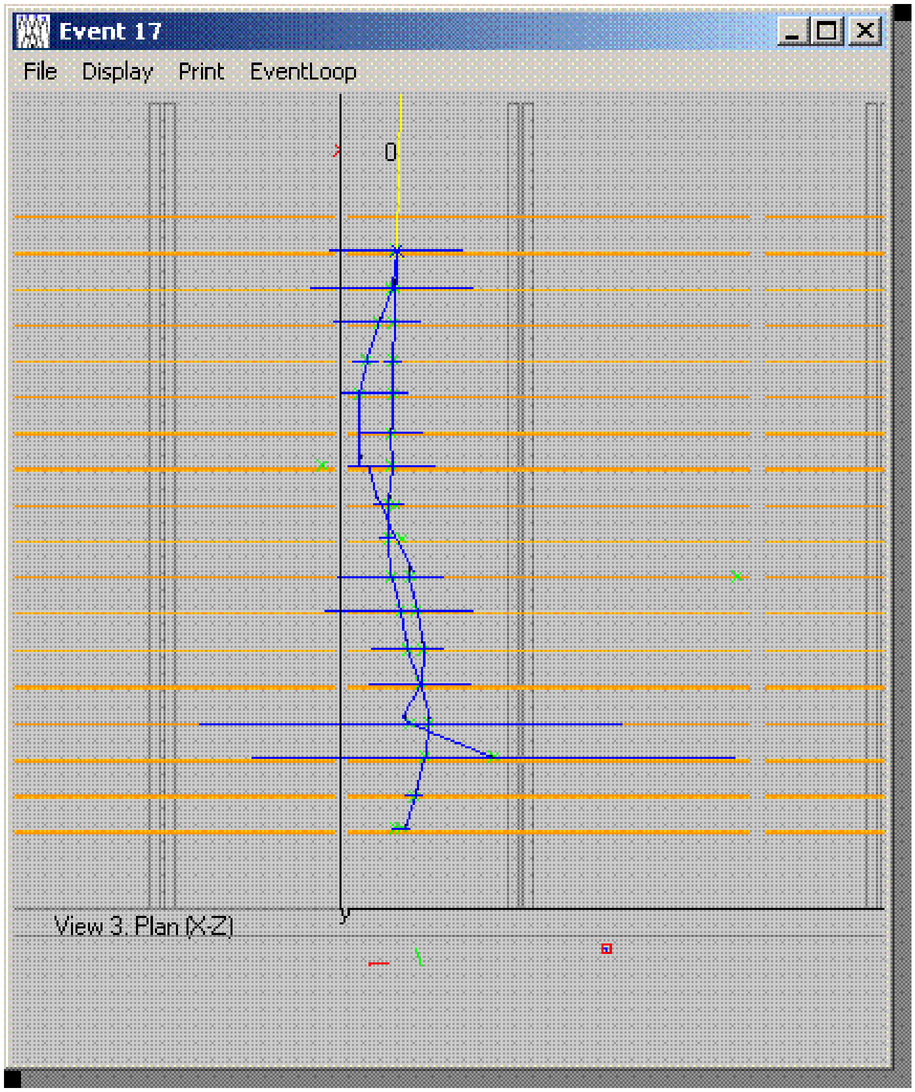

Figure 2: Simulation of 100 MeV gamma