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THE STATUS OF GLAST CSI CALORIMETER

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GLAST is a gamma-ray observatory for celestial sources in the energy range from 20 MeV to 300 GeV. This is NASA project with launch anticipated in 2006. The principal instrument of the GLAST mission is the Large Area Telescope (LAT), consisting of an Anti Coincidence Detector (ACD), a silicon-strip detector Tracker (TKR) and a hodoscopic CsI Calorimeter (CAL). It consists of 16 identical modules arranged in a 4×4 array. Each module has horizontal dimensions $38 \times 38cm^2$ and active thickness 8.5 radiation length. It contains 96 CsI (Tl) crystals arranged in 8 layers with 12 crystals per layer. The scintillation light is measured by PIN photodiodes mounted on both ends of each crystal. The sum of signals at the two ends of the crystal provides the energy measurement. The difference in these signals provides the position measurement along the crystal. The calorimeter was designed to meet the goals of good energy resolution (better than 10% for photon energies 100 MeV - 100 GeV), position resolution of $\sim 1mm$ for photon energies $> 1GeV$, and a rejection factor of > 100 for charged cosmic rays, under limitations on calorimeter weight (95 kg per module) and power consumption (6 W per module). The Monte Carlo simulation and prototype beam test results confirm that proposed design meets the requirements. Calorimeter production is planned to start in 2003.

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. 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[1] is a high-energy pair conversion telescope. It 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 design is modular with a 4×4 array of identical tracker and calorimeter modules. The modules are $\sim 38 \times 38cm^2$. Figure 1 shows the LAT instrument concept.

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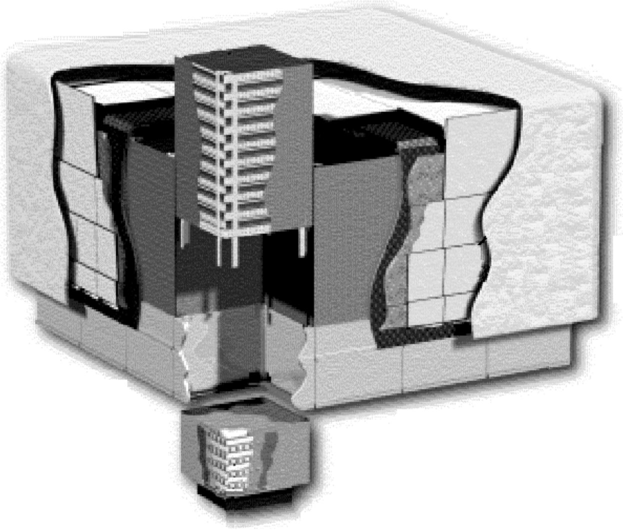

Figure 1. View of the LAT Science Instrument with one Tracker tower module and one Calorimeter module pulled away from the Grid. GLAST is a 4×4 array of identical Tracker and Calorimeter modules.

2. LAT technical description

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 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.

The primary tasks of the GLAST calorimeter[2] are to provide an 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.

3. Calorimeter design overview

The calorimeter is comprised of a segmented thallium-doped cesium iodide, CsI(Tl), scintillation crystal array.

To achieve the required energy coverage and resolution, the calorimeter is 8.5 radiation lengths ($8.5X_0$)deep. An additional depth of $1.5X_0$ 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. The design of a single calorimeter module is shown on Figure 2.

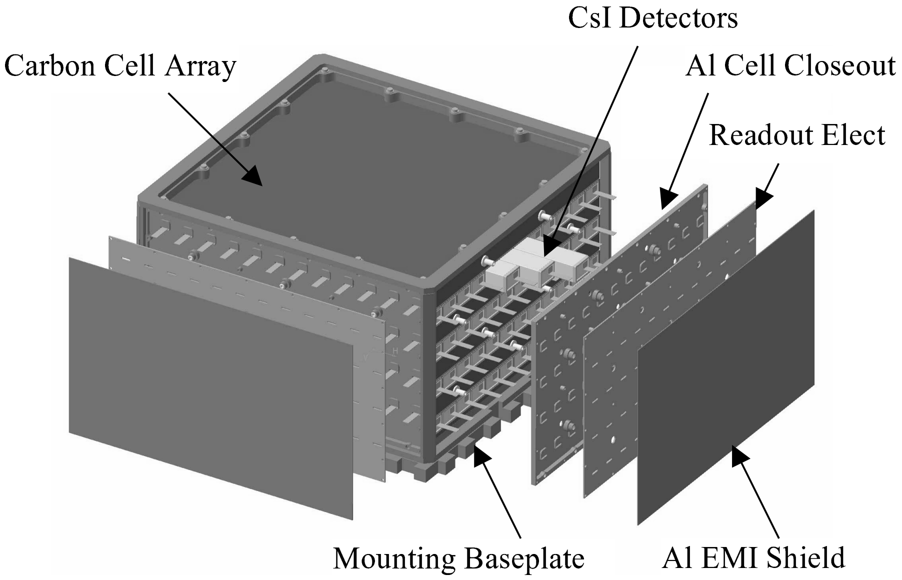

Figure 2. Exploded view of a single Calorimeter module. Eight layers of 12 CsI Crystals are readout by PIN photodiodes and electonics on the four module sides

Each CAL module contains 96 crystals of size $26.7 \times 19.9 \times 326mm^3$. 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 degrees with respect to its neighbors, forming an x-y array. The spectral response of the PIN photodiodes is well matched with the scintillation spectrum of CsI(Tl), which provides for a large primary signal (~ 5000 electrons collected in $1.5cm^2$ diode per MeV deposited), with correspondingly small statistical fluctuations and thereby good 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 ($\sim 10 MeV$) 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 hodoscopic array of CsI crystals is installed in a carbon composite cell structure. Aluminum side panels hold the CsI crystals in the cells, provide mounting space for the readout electronics printed circuit cards, and provide EMI shielding. A baseplate provides for mounting of the calorimeter module to the LAT GRID structure and is integral to the strength of the GRID.

As shown in Figure 2, the readout electronics for the calorimeter are mounted on the four sides of the module where they attach to the PIN photodiodes. The major design challenges for the calorimeter electronics were

- dynamic range of 5×10^5
- reduced power consumption per CsI crystal

The large dynamic range is supported by using two independent signal chains. A custom dual PIN photodiode assembly is used at each end of the crystals. The active areas of the two diodes have a ratio of 6 to 1. The larger area diode covers the low energy band (2 MeV - 1.6 GeV), while the smaller diode covers the higher energy band ($\sim 15 MeV$ to $100 GeV$). The significant overlap between the two ranges permits cross-calibration of the electronics. Each diode has dedicated preamp and shaping amplifiers that are part of a custom application specific integrated circuit (ASIC). The power for the readout electronics has been reduced by the development of analog and digital CMOS ASICs that are optimized to the performance requirements of the calorimeter.

The mechanical structure is designed to have the structural stiffness to withstand environmental loads without requiring any contribution from the crystals. The honeycomb geometry of the structure, combined with light, high strength material ensures the required mechanical properties, while minimizing the amount of passive material between the CsI logs. The thickness of the wall within a layer is less than 0.4 mm and from layer to layer less than 0.8 mm. The outer walls are thicker since metallic inserts are embedded in the composite material to provides attachment point for the aluminum parts.

A wrapped CsI crystal with bonded photodiodes is called Crystal Detector Element (CDE). The wrapping material - non-metalic reflector film VM2000 from 3M - was chosen to maximize the light yield. The wide qualification temperature range (from -30C to +50C) and the significant mismatch of thermal expansion coefficients of CsI and photodiode carrier require a chareful choice of adhesive to bond photodiodes to crystals. After a substantial test program, we have selected a Dow Corning silicone elastomer (DC93-500) and primer (DC92-023). These materials have excellent optical and mechanical properties and provide bonds that readily survive the mechanical stresses.

The CDEs are mounted independently inside the composite cells and access is granted to each of them until the close out plates are assembled. A clearance of 0.3 to 0.5 mm allow their integration inside the cells. A silicone elastomeric cord is placed between each the corners of the cells and the chamfers of the crystals to provide a support distributed along the full length of the logs and center the CDE in the cell. The cords are stretched to reduced their diameter and allow the insertion of the log. Transverse vibrations of the CDE are damped by the elastomeric cords. Longitudinal motion is damped by elastomeric pads in the cell closeout.

Table 1 shows the sharing of the responsibilities of collaboration countries in calorimeter manufacturing.

Table 1. The manufacturing responsibilities of collaborating countries.

Sweden	- Acceptance and verification of crystals from vendor - Acceptance, verification
France	- Assemble Crystal Detector Elements (CDEs) - Manufacture mechanical structure
USA	- Manufacture front-end electronics - Integrate CDEs with structure and electronics - Test and calibration

4. Calorimeter status

The CsI crystal production contract with Amcrys (Kharkov, Ukraine) is in place for more than 2000 prototype and flight crystals. 240 crystals have been received in Sweden. Minor adjustments have been made in crystal length, chamfer size, and tolerance since the original specification.

650 custom prototype Dual Photodiodes (DPDs) have been received from the vendor, Hamamatsu. The photodiodes have excellent optical and electronic characteristics. Radiation testing in France indicates no problem with

the GLAST environment. Thermal cycling tests show small cracks within the optical epoxy, with no degradation of optical or electrical performance. We expect that this problem will be readily solved by the vendor before procurement of flight DPDs.

The bonding material and processes have been tested over 90 sample bonds of PIN diodes to CsI crystals. Bond strength is measured to be the same ($\sim 250N$) before and after thermal cycling, significantly exceeding the tensile and shear strength requirements. Light yield tests on sample CDEs manufactured by the proposed bonding process indicate an expected yield of 7500 e/MeV for the final dimensions, which exceeds the requirement by 25The first two copies of bonding tools have been fabricated, and the first CDEs have been bonded.

The prototype mechanical structure has successfully undergone vibration and thermal cycling.

The calorimeter analog front-end ASIC design have evolved through 6 fabrication iterations. Essentially all required performance parameters have been demonstrated. Minor remaining issues will be tested in parts delivered in August.

The first version of digital readout controller ASIC was received in March 2002 and demonstrated full functionality. Minor improvements and adjustments have been incorporated in parts to be received in August 2002.

Two prototype versions of front end printed circuit board have been fabricated for testing of calorimeter readout components. The final version of PCB is currently in layout design.

An Engineering Model calorimeter module is planned to be assembled and tested in late 2002 and early 2003. The modified production schedule includes following milestones:

- CsI crystal production: Oct 2002 - Oct 2003
- Calorimeter modules integration and tests: May 2002 - June 2004
- Instrument integration and test: June 2004 - Sep 2005
- Spacecraft integration and test: Sep 2005 - Sep 2006
- Launch: Nov 2006

References

1. P. E. Michelson, "GLAST: A detector for high-energy gamma rays" *Proc. SPIE Conf. Gamma-Rays and Cosmic-Ray Detectors, Techniques and Missions* **2806**,B.D.Ramsey and T.A.Parnell, Eds., Denver,CO, pp.31-40 (Aug,1996).
2. W.N.Johnson, J.E.Grove, B.F.Phlips,J.Ampe, S.Singh, E.Ponslet, "The construction and performance of the CsI hodoscopic calorimeter for the GLAST beam test engineering module", *IEEE Trans. on Nuc. Sci.* **48**, 1182 (2001).