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Construction, test and calibration of the GLAST silicon tracker

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Abstract

The Gamma-ray Large Area Space Telescope represents a great advance in space application of silicon detectors. With a surface of 80 m^2 and about 1 M readout channels it is the largest silicon tracker ever built for a space experiment.

GLAST is an astro-particle mission that will study the mostly unexplored, high energy (20 MeV–300 GeV) spectrum coming from active sources or diffused in the Universe. The detector integration and test phase is complete. The full instrument underwent environmental testing and the spacecraft integration phase has just started: the launch is foreseen in late 2007. In the meanwhile the spare modules are being used for instrument calibration and performance verification employing the CERN accelerator complex. A Calibration Unit has been exposed to photon, electron and hadron beams from a few GeV up to 300 GeV. We report on the status of the instrument and on the calibration campaign.

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Keywords: Gamma-ray; Silicon; Tracker; Calibration; Beam test

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1. Introduction

The Large Area Telescope (*LAT*) of the Gamma-ray Large Area Space Telescope (*GLAST*) mission [1] is the next generation pair conversion gamma-ray telescope dedicated to the exploration of the high energy sky. It is designed to cover the energy band from 20 MeV up to more than 300 GeV with sensitivity at least 30 times better than its predecessor, EGRET. The great improvement in performance will allow the solution of the several mysteries left by past experiments. The scientific case of the mission is indeed vast and goes from traditional astrophysical topics (like understanding the emission models of celestial sources) to fundamental physics (like searches for dark matter).

The LAT comprises three detector subsystems. A tracker/converter made of XY layers of Silicon Strip Detectors (*SSDs*) and tungsten conversion foils wherein the incident gamma-ray converts into an electron–positron pair. An electromagnetic calorimeter composed of CsI logs in hodoscopic configuration allows the reconstruction of the photon energy. The whole system is surrounded by a segmented anticoincidence shield (composed of plastic scintillator tiles) to veto the charged particles. The LAT is composed of a 4×4 array of identical modules called towers. Each tower has a tracker, a calorimeter and an electronic module for triggering and data handling. A very aggressive mechanical design was required to minimize the dead areas between detector planes: the gaps between towers, only a few millimeters wide, are used to accommodate the front-end electronics. The GLAST mission is planned to operate in orbit for about 10 years. The space environment poses major constraints on total weight and power budgets, moreover the hardware survival to launch and operations has to be proved with specific tests: all the instrument building blocks, from the single detector element to the complete satellite, have to pass such environmental tests.

2. Tracker construction and test

The active sensor of the tracker is a SSD: 400 μm thick with strips at 228 μm pitch. About 11500 detectors have been produced by Hamamatsu and tested by INFN and only 0.5% were rejected. The SSDs were glued and bonded in groups of four to form a ladder: a single detector with 36 cm long strips. Each of the 2700 flight ladders produced was fully tested by repeating the IV and CV scan performed on single SSDs and verifying insulation and continuity at the strip level.

The tracker tower building block is the tray [2,3]. It is a lightweight carbon-composite panel with sensors bonded on both sides (four ladder per side). The conversion foil is placed in the bottom part of the tray just above the silicon layer while the front-end electronics [4] is placed on two sides of the tray at 90° with respect to the detector planes. Both the mechanical panel and the fully equipped tray are qualified for space operation with a series of vacuum and thermal cycles. Full functional tests are performed before and after the cycles to investigate any damage. Trays are then stacked to form a tracker tower whose supporting structure is composed of four carbon fiber sidewalls (Fig. 1).

During the assembly each tower undergoes comprehensive performance tests before and after final closure of the structure with the sidewalls. The environmental test for a tracker tower comprises vibration tests (to measure proper resonance frequencies and to ensure that the structure will survive the launch) and a thermal–vacuum (*TV*) test: tower performance is continuously monitored while the temperature cycles from −15 to +45 °C. About 360 trays have been produced and tested and a total of 18 towers were assembled in 10 months during 2005. All tracker modules satisfy the requirements in terms of detector performance [5]: the average layer efficiency (within the active area) is more than 99.4% (Fig. 2) with a strip noise occupancy lower than 10^{-6}.

2.1. LAT status

The LAT construction phase has been successfully completed. All the tracker and calorimeter modules have

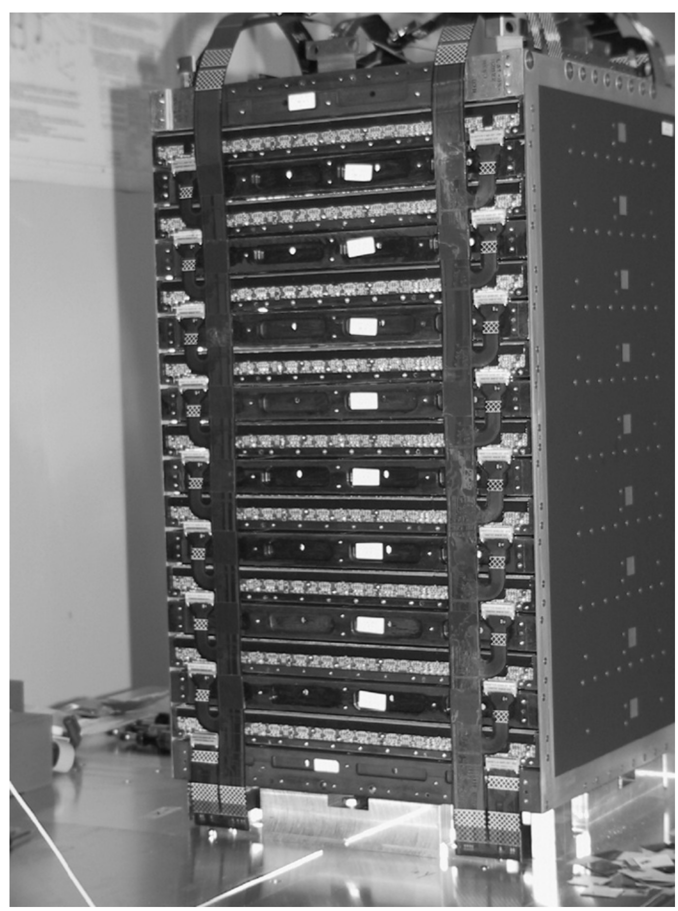

Fig. 1. A tracker tower during the assembly. The trays structure and the front–end electronic boards are visible.