GLAST beam tests at CERN-PS and SPS

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The Gamma-ray Large Area Space Telescope (GLAST) is a multi-agency satellite mission with a vast and ambitious physics program in gamma-ray astronomy, particle astrophysics and cosmology. The Large Area Telescope (LAT) is the main instrument onboard GLAST, and will detect photons from the whole sky in a very broad, mostly unexplored, energy band (20MeV->~300GeV); LAT data are expected to boost our knowledge of the physics of Active Galactic Nuclei, Pulsar, Super-Novae Remnants, the Sun, Gamma-Ray Bursts, Dark Matter, interstellar medium and sources of cosmic rays.

The LAT detector is a modular array of 4x4 identical elements, called towers, each composed by a heavy tracker (TKR), equipped with 18 XY silicon-strip tracking planes interleaved with tungsten layers for photon pair-conversion, an imaging CsI electromagnetic calorimeter (CAL) and a readout electronics module for trigger and data flow. All the towers are surrounded by an anticoincidence detector (ACD) built with plastic scintillator tiles to reject the charged-particle cosmic-ray background. Several modules of on-board electronics combine trigger signals from the self-triggering subsystems and issue common readout strobes, merge data streams from the single modules, apply software algorithms for second level trigger and background rejection.

The LAT calibration is based on a combination of cosmic ray data analysis and particle beam test results from a Calibration Unit (CU), a smaller detector built with 2 complete flight spare towers, a third calorimeter module, five ACD tiles and flight-like readout electronics. It is in fact not practical to expose the whole LAT to a beam for direct calibration, and most of the events on orbit will be contained within 2 towers; an extensive beam test campaign was therefore performed on the CU in 2006, in parallel to the completion of the LAT integration and test, thus also improving on the overall project schedule that indicates november 2007 for the satellite launch. The CERN accelerator complex was chosen as the only facility that can provide electrons and hadron particle beams ranging over the whole LAT energy acceptance. The good reproduction of both directly-measured parameters (energy deposits, hit multiplicities) and quantities resulting from a high-level analysis (reconstructed energy and direction) at both ends of the LAT energy band must be investigated, each being important in its own right. Most photons detected by the LAT will have low energy, since typical gamma-ray sources are associated with power-law photon distributions with indices close to (-2). On the other hand, the coverage of the energy band 1-300 GeV is of prime scientific importance and constitutes one of the major breakthroughs with respect to the LAT predecessor, EGRET. The extinction of most EGRET sources takes place within this energy band, the precise high-energy cut-offs remaining unknown so far.

A sophisticated Monte-Carlo simulation of the LAT, based on the Geant4 package, was developed to reproduce the detector response to radiation. This simulation is of paramount importance for the LAT as it will benchmark the instrument performance during flight operation and will be used to optimize filters for background rejection. The validation of the LAT MC simulation, through comparison with directly measured response, was the primary goal of the GLAST CU beam test campaign. To achieve this result many measurements were required, exposing the CU to many different particle beams hitting the detector in many impact point and under different angles, in order to finely sample the instrument performance over the CU acceptance and extrapolate to the whole LAT phase space using simulation.

The GLAST beam test at CERN was organized in two different runs, one at the PS accelerator and a second one at the SPS. The T9 line at PS offers beams with energy in the few GeV range, where the LAT will collect most of its photons. Many different setups were used during our PS run taking advantage of the different particle types available in the beam (e,p,π). In addition, gamma-rays up to 2.5 GeV were produced and tagged in a spectrometer composed of a 0.7 Tm magnet provided by CERN (MNP17) and a set of silicon detectors. The H4 line at SPS, which provides well defined, clean particle beams (0-mrad wobbling mode) allowed us to explore the maximum energy reach of the LAT. Table 1 summarizes the run conditions. Low rates of 0.1-5KHz/cm^2 were used in the different test phases.

The PS run was hampered by several technical stops of the facility and the beam line (CERN power outage, main PS quadrupole failure, loss of several line magnets), but a prompt support from the CERN accelerator team increased our duty cycle sending more spills to our area, therefore enabling us to recover and collect enough statistics for the different target studies. The SPS run was smooth, and the excellent CERN support for both installations helped in minimizing the setup time. A total of 100M events was collected and processed by our farm.

The main goals of both experiments were reached, with almost real-time analysis confirming the general validity of our MC simulation (see figure 1) and a wealth of excellent data now being analyzed to fine-tune the MC and cross check the reconstruction algorithms at the % level. Some discrepancies have been found in the number of hits in the TKR from secondary particles (which does not compromise tracking reconstruction and resolution), and in the energy deposited in the CAL at very high bombarding energy, both effects being under investigation.

Test Area	Particles	Energy	Mode and purpose
PS-T9	e, p, π	1-5 GeV	CAL calibration, hadronic interaction in the CAL, ACD backsplash
PS-T9	e^+,e	1 GeV	Background from e^+ annihilation
PS-T9	γ	0.05-2.5 GeV	Tagged photons-general validation of MC
SPS-H4	e, p, π	10-280 GeV	CAL calibration, hadronic interaction in the CAL, ACD backsplash studies

Table 1: Summary of run conditions

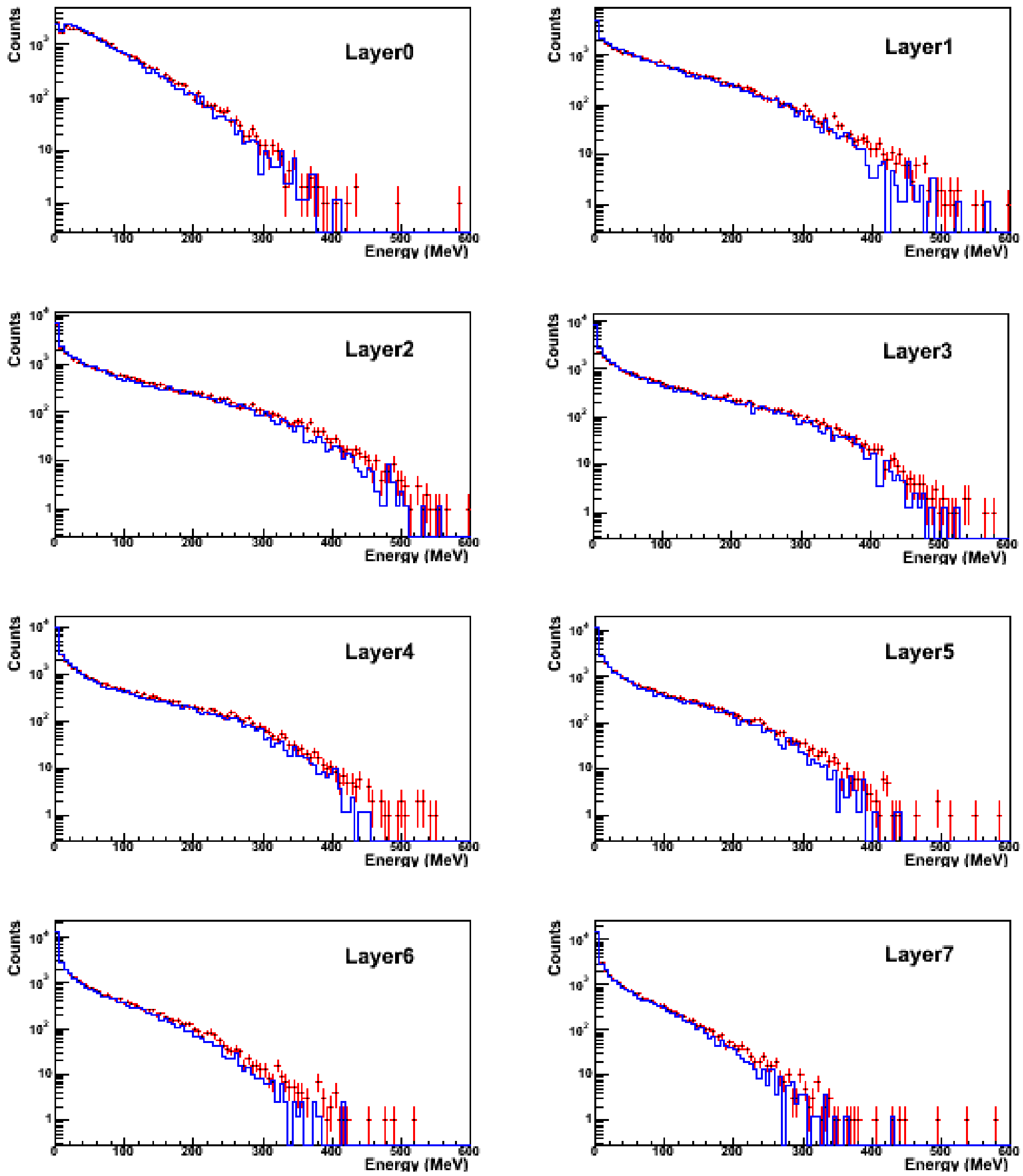

Figure 1: Data (symbols)-MC comparison (histogram) - energy deposited in the 8 CAL layers for a bremsstrahlung spectrum obtained from a 2.5GeV primary electron.

Additional information

Institutions involved: all the collaborating countries involved in the GLAST project (France, Italy, Japan, Sweden, US), in particular CENBG-Bordeaux, LLR-Paris, LPTA-Montpellier, INFN-Bari, INFN-Padova, INFN-Perugia, INFN-Pisa, INFN-Roma2, INFN-Trieste, Hiroshima University, KTH-Stockholm, SLAC, GSFC, NRL, UCSC.
People involved 60
Thesis that will benefit from beam test data: 1 diploma (Emanuele Bonamente, INFN-PG), 3 PhD (Claudia Monte, INFN-BA; Carmelo Sgro, INFN-PI, Tomi Ylinen, KTH)
Conference contributions: 6
- Particle beam tests for the GLAST-LAT Calibration, submitted to Glast Science Symposium, Stanford 5-8 February 2007
- Response of the GLAST-LAT Calibration Unit to sources of background, submitted to Glast Science Symposium, Stanford 5-8 February 2007
- Instrument design, construction, test and calibration of the GLAST Large Area Telescope, Luca Latronico (INFN-PI), submitted to VCI2007, 11th Vienna Conference on Instrumentation, Vienna 19-24 February 2007
- Construction, test and calibration of the GLAST silicon tracker, Carmelo Sgro (INFN-PI), RESMDD06, 6th International Conference on Radiation Effects on Semiconductor Materials Detectors and Devices, Firenze 10-13 October 2006
- First results from GLAST-LAT beam test at CERN-PS and SPS, Monica Brigida (INFN-BA), IPRD06, 10th Topical Seminar on Innovative Particle and Radiation Detectors, Siena 1-5 October 2006
- GLAST Silicon Tracker beam test results, Stefano Germani (INFN-PG), Vertex06, 15th International Workshop on Vertex Detectors, Perugia 25-29 September 2006)