PARTICLE BEAM TESTS FOR THE GLAST-LAT CALIBRATION

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The calibration strategy of the GLAST Large Area Telescope combines analysis of cosmic ray data with accelerator particle beams measurements. To validate the LAT simulation and to study its performances, a massive campaign of particle beam tests was performed, in parallel with the LAT integration and test, on the LAT Calibration Unit (CU). This is a detector built with two complete flight spare modules, a third spare calorimeter module, five anticoincidence tiles located around the telescope and flight-like readout electronics.
The CU was exposed to different kinds of beams, representing the whole spectrum of the signal that will be detected by the LAT, using the CERN and the GSI accelerator facilities. Beams of photons (0-2.5GeV), electrons (0.5-300GeV), hadrons (pions and protons, 6GeV-100GeV) and ions (C, Xe, 1.5GeV/n) were shot through the CU to measure the physical processes taking place in the detector and eventually fine-tune their description in the LAT Monte Carlo simulation. This talk describes the motivations and goals of the test runs, the many different experimental setups used to select the required particles and trigger the CU, the measured performance of the CU and the results of the LAT Monte Carlo validation.

1. Introduction

The Gamma-Ray Large-Area Space Telescope (GLAST) is a next generation high-energy observatory, to be launched by NASA in early 2008 with a lifetime of five years. The payload includes two different instruments: the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). The LAT is sensitive to photons in the energy range between 20 MeV ad 300 GeV and consists of three subsystems: a solid state detector tracker (TKR), a CsI calorimeter (CAL), and a plastic scintillator anticoincidence system (ACD). The GMB is optimized for the detection of transients photon events at low energy (10 keV – 20 MeV). The combined detectors will observe the entire sky not occulted by Earth in all-sky survey and pointing model.

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2. Goals of beam tests for GLAST

After LAT integration, dedicated tests must be performed in order to study the instrument response, to test the calibration procedures and to improve the predictions of the current Monte Carlo simulation, based on GEANT4.
The whole LAT, now integrated and delivered for launch, was not available for these tests. However, since most laboratories do not provide beams facilities to irradiate the full instrument and the simulation shows that most of events in orbits will be contained in two towers, a test on a smaller unit (Calibration Unit" or CU) of the full LAT has been performed. The CU is composed of two complete LAT tower modules (TKR and CAL) and one additional CAL module, integrated in a 1·4 aluminum grid, identical for all practical purposes to a one-row slice of the actual LAT flight grid. Five flight-like ACD tiles complete the assembly. A mechanical interface with the remotely controlled *XY* table was used to set the CU position and orientation with respect to the beam line [1].
In this paper we will discuss the main features of the beam test set-ups ans the low level performance.

3. Beam test setup

The CU was exposed to different kinds of beams, representing the whole spectrum of the signal that will be detected by the LAT, using the CERN and the GSI accelerator facilities. Beams of photons (0-2.5GeV), electrons (0.5-300GeV), hadrons (pions and protons, 6GeV-100GeV) and ions (C, Xe, 1.5GeV/n)

3.1 Cern PS set-up

The T9 line of the CERN-PS provides a mixed beam of electrons, positrons, pions and protons between 500 MeV/c and 10 GeV/c. Figure 1 shows a schematic view of the experimental setup.

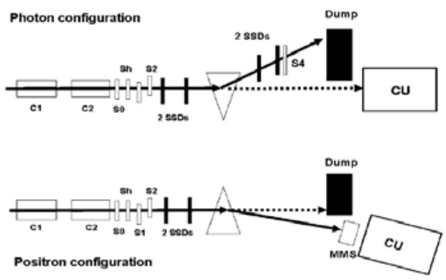

Figure 1. Schematic view of the experimental setup at the CERN PS-T9 line.

Two gas threshold Cherenkov counters (*C*1 and *C*2) were used for particle identification, while a set of plastic scintillators (S_0, S_h, S_1, S_2, S_4) provided the external trigger/veto signal for the different data acquisition configurations. S_0 was used to monitor the total number of particles in the beam; S_h had a hole of 2.4 cm diameter in the center and was used as a veto to reject the halo beam; S_1 and S_2 had a small cross-section to select a small area of the beam; S_4 was used to select electrons inside the spectrometer acceptance.

Bremstrahlung photons are produced by electrons in matherials through the beam line. The photon tagger is a two-armed spectrometer composed of two Silicon Strips Detectors (SSDs) hodoscopes with two XY detection planes each: it is used to evaluate the photon momentum by mesuring the charge particle deflection in a magnet (triangle in the picture).

The dipole magnet had a maximum bending power of 50cm·1T and deflected electrons into the second arm of the spectrometer and eventually onto the beam dump. The curved tracks measured by the spectrometer provide the energy of the deflected electron and, by difference with the nominal beam energy, that of the photon hitting the CU.

Different electron beam momenta (0.5; 1; 1.5; 2.5 GeV/c) were required to cover the photon bremsstrahlung spectrum between 50 MeV/c and 1.5 GeV/c, required for the CU calibration. Runs with $e+/e^-$, π and protons have been also performed to ensure the instrument calibration and a proper ovelap with SPS data.

3.2 Cern SPS setup

The high-precision H4 line has been used for CERN SPS tests. This line provides secondary beams (e^+, e^-, p, π) with momenta from 10 GeV/c until 300 GeV/c , corresponding to the high-end domain covered by the LAT, with low hadron contamination (lower than 1% beyond 50 GeV). The discrimination between electron and hadron has been performed by two Cherenkov counters and a set of three plastic scintillators has been also placed upstream to provide the trigger/veto signal.

3.3 GSI setup

The CU was exposed to heavy ion beams (${}^{12}_{6}C$ and ${}^{131}_{54}Xe$), with energies of 1 and 1.5 *GeV/n*, and impacting the detector at 0, 30 and 60. Various rates were explored (10-1000 Hz/cm^2) around the expected average ion rate inorbit to make sure that test results were not influenced by rate effects such as event pileup. Given the purity of the beam line, which provides a well defined ion species with no contamination at any beam rate, the CU was in fact mostly operated in self-trigger mode.

4. The CU Performance

4.1 Tracker

The TKR trigger efficiency, hits and clusters have been analyzed to study the low level performance of the TKR and to compare experimental and simulated data. Figure 2 left shows the TKR trigger efficiency as a function of the beam electron energy and incident angle for real data and MC simulations. The agreement between data and MC is quite good, and the small discrepancies at normal incidence are due to the differences in the impact point. In fact, at normal incidence the gaps between the ladders introduce dead regions in the TKR. Figure 2 right shows the multiplicities of fired strips in the TKR planes for electrons with momenta ranging from 1 GeV/c to 280 GeV/c and for 6 GeV/c protons, all at normal incidence. The beam direction is from the top plane (35) to the bottom one (0). The hit strip multiplicity is roughly constant for non-interacting protons, but it increases along the beam direction for electrons, following the development of the electromagnetic shower in the tracker.

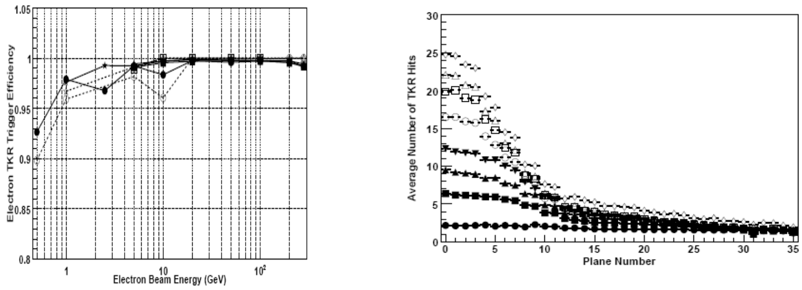

Figure 2. *Left*: Tracker electron trigger efficiency vs beam energy and incident angle. Real data: solid line and full symbols, MC data: dashed line and empty symbols. Circles: beam at normal incidence; squares: beam incidence 10 deg; triangles: beam incidence 20 deg; stars: beam incidence 30 deg. *Right*: Average number of TKR hits as function of the plane number: full circles: 6 GeV/c protons; other symbols: electrons of different momenta, from the bottom to the top 1; 2.5; 5; 20; 50; 100; 280 GeV/c.

4.2 Calorimeter

To calibrate the CU calorimeter the following procedure has been followed. The pedestals in all channels were measured using random trigger events, when no energy is deposited in the calorimeter crystals. The non-linearity of each channel was measured using the charge injection system. The energy scale of each channel was calibrated using the signals produced by cosmic muons. After path-length correction, the energy deposits of cosmic muons in a single crystal have the peak with most probable value of 11.2 *MeV*. To see this signal in the high energy ranges a special muon gain setting was used providing an output signal ten times bigger than for normal flight gain. The exact ratio between the flight and muon gains was calibrated using charge injection. At the beginning of each beam test data taking period the calorimeter was exposed to the electron beam (5 *GeV* for the PS and 100 *GeV* at the SPS) and a set of runs was collected with four-range readout and different incident points in order to provide a broad spectrum of energy deposits in all crystals.

Figures 3 show the energy distributions measured by the CU and by the tagger with 2.5 *GeV/c* electrons. In the left plot, the blu line shows the energy distribution of photons measured with the CU, the red line shows the energy distribution of deflected electrons measured with the spectrometer tagger, and the white line shows the distribution of the sum of photon and electron energies. As expected, the total energy distribution is peaked around the nominal energy of the incoming beam. Figure 3-right shows a linear dependence beteewn the photon energy mesured by the CU and the energy mesured by the tagger spectrometer.

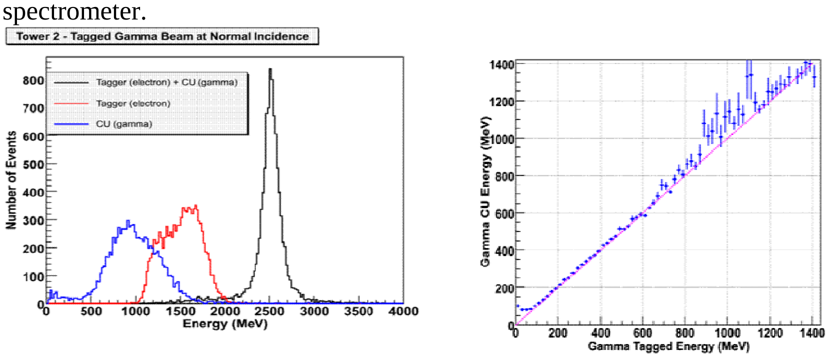

Figure 3. *Left*: Energy distributions: photon energy measured with the CU (blue); deflected electron energy measured with the tagger spectrometer (red); total energy (white). *Right*: The energy mesured in the CU vs energy mesured by the tagger spectrometer.

5. Conclusion

A massive beam test campaign on a GLAST Calibration Unit made with spare flight modules was performed in 2006 to validate the LAT Monte Carlo simulation and to verify the actual response of the whole detector. In particular the angular dispersion of the TKR and the energy resolution of the CAL fulfil the requirements of the missions and are in good agreement with the simulation.

References

1. L.Baldini et al., “Preliminary results of the LAT Calibration Unit beam tests”, Proceedings of the first GLAST symposium, AIP Conference Proceedings Vol. 921 (2007) 190-204