Heavy ion beam tests for the preparation of the LAT on-orbit calibration

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on behalf of the GLAST LAT CU Beam Test Team

Abstract

The calorimeter (CAL) and the AntiCoincidence Detector (ACD) of the GLAST LAT telescope will be calibrated in flight with cosmic-ray heavy ions. A dedicated high level threshold in the ACD will trigger heavy ion events, and the pulse amplitude in the CAL and the ACD will be used to identify different ion species and calibrate the readout electronics. Tracker (TKR) information will be used to precisely identify the impact point and the path length of the ions in the plastic scintillators of the ACD and the CsI logs of the CAL. Such mode of operation was successfully tested in a heavy ion beam test carried out on the LAT Calibration Unit (CU) with Carbon and Xenon ions from the GSI synchrotron. The CU is a detector built with two complete flight spare modules, a third calorimeter and 5 ACD tiles which underwent a major beam test campaign in 2006 to validate the LAT MonteCarlo simulation with different particle beams.
The behaviour of all the three subsystems (TKR, CAL, ACD) under heavy ion irradiation is discussed in this poster, as well as the results that provide the necessary input for the optimization of the strategy for on-orbit calibration.

1. On orbit calibration with heavy ions

- Instrumental calibration of the LAT in orbit will be based on irradiation from primary cosmic rays. While MIPs are ideal for checking the status of TKR strips and the efficiencies of all subsystems, ionization losses from heavy ions provide the necessary dynamic range to determine the energy scale to calibrate the CAL and the ACD subsystems
- In orbit, heavy ion events will be collected in parallel to photons for science data, thanks to a flexible trigger logic that is able to select different type of events and activate specific readout modes. Heavy ions will be triggered by a special high level discriminator in the ACD and followed to the CAL using TKR information
- The LAT response to heavy ions in orbit will be compared to MonteCarlo simulations and used to calibrate the response and trend the performance of the subsystems

2. Calibration Unit beam test program

- In 2006 a Calibration Unit was built integrating spare flight modules (2 TKR, 3 CAL, 5 ACD tiles) into a flight-like mechanical grid with flight readout electronics. The CU was exposed to a variety of beams to directly measure its performance and validate the MC simulation
- A beam test with heavy ions from the GSI (Darmstadt) accelerator facility was performed on the CU. Beams of 12C and Xe, with energy of 1.5GeV/n were shot through the CU at 0, 30 and 60 degrees incoming angle. Various rates were explored (10-1000Hz/cm^2). The trigger and readout configuration were the same that the LAT will use in orbit

2. CAL response: quenching

Heavy ions irradiation in CsI produces non linear response to ionization energy losses due to large ionization densities. The deviation from the calculated behaviour in unit of MIPs is called quenching factor and must be measured and incorporated in the simulation to correctly model the Csi response

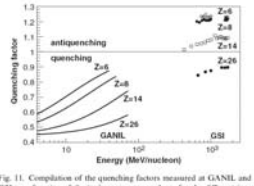
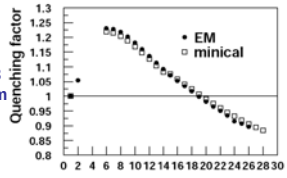


Fig. 11. Compilation of the quenching factors measured at GANIL and GSI as a function of the ion's energy per nucleon, for the different ions relevant to the on-orbit calibration of GLAST's calorimeter.

- Quenching factors measured on CsI in previous heavy ion beam test on the GLAST CAL (NIMA 560-2006). A lower response wrt to a MIP is measured at low ion energy, while at high energy the behaviour is reversed

- Quenching factors measured for different ion species in the 2003 GSI heavy ion beam test of the GLAST CAL



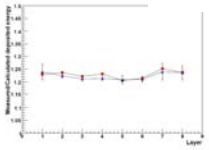
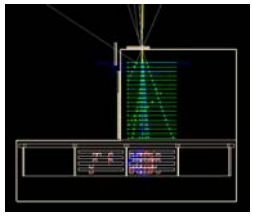


Fig. 4 - Ratio of the mean energy measured over the calculated deposited energy (i.e quenching factor) in the eight EM layers for 1.5 GeV/nucleon Carbon ions for events with $\Delta t < 5 \times 10^{-9}$s in red squares and events with $\Delta t > 4 \times 10^{-8}$s in blue triangles.

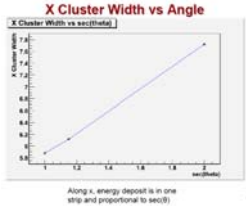
- Quenching factors measured for C ions in the 2006 heavy ion beam test of the GLAST CU for high and low beam rate. THe quenching factors are the same of those measured in 2003

3. TKR response: cluster size

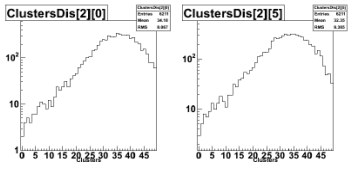


- A C ion event reconstructed in the CU. THe high multiplicity of hits and tracks does not hamper the tracking capabilities of the detector and the reconstruction software

- Average cluster widths for C measured in the TKR. The dependence from the incoming angle is well reproduced, but the average values are twice those expected by current simulations

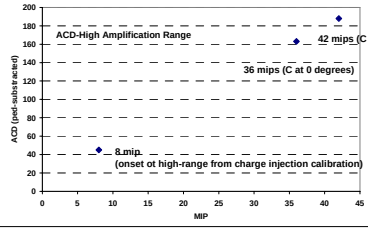


- Average cluster widths for Xe measured in the TKR. Cluster sizes become very high and a special (mention FIFO full issue and add a Xe event with tracks?)



4. ACD response:

- The plot below show a linearity curve for the ACD in the high amplification range. The Xe signal is still within the range but appears in the non-linear part of the range



5. Conclusions

- A GLAST-LAT Calibration Unit was exposed to beams of C and Xe ions at the GSI accelerator facility to test the calibration strategy of the LAT in orbit and the instrument response
- The run was a successful system test as the whole detector was operated and readout in the same configuration that will be used for the LAT
- The CAL subsystem response confirmed the already measured quenching factors that were already included in the MC simulation
- The TKR subsystem response showed that the average cluster size for C ions is two times the expected value from simulation. This feature does not hamper the tracking capabilities of the detector. A new MC algorithm is under development for an accurate description of such large cluster
- The ACD efficiently triggered on heavy ions. A linear response was recorded in the initial part of the high amplification range