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

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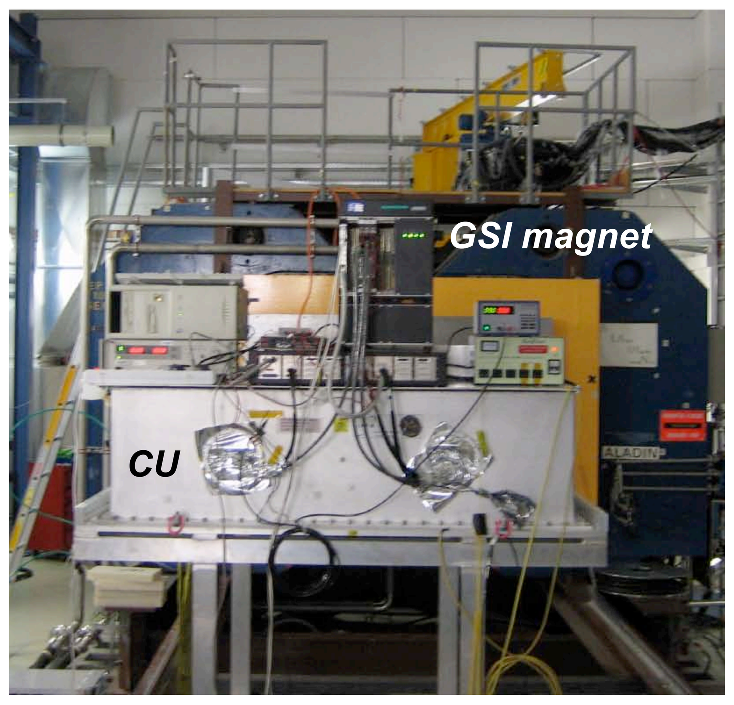
Abstract

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.

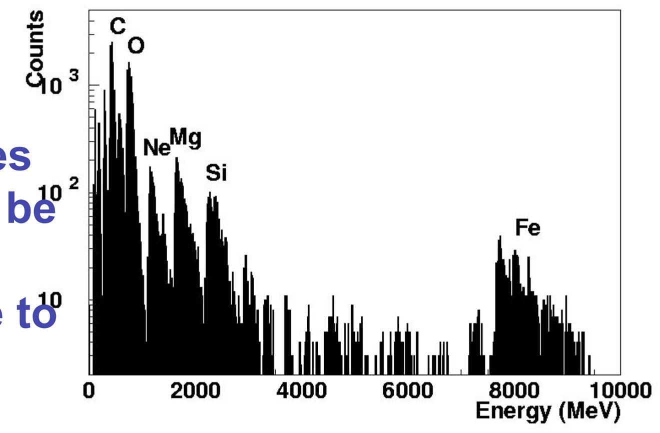
The behaviour of all the three subsystems (TKR, CAL, ACD) under heavy ion irradiation is discussed in this poster, as well as the results that provide the necessary input for the optimization of the strategy for on-orbit calibration.



The CU and readout electronics in the GSI experimental area. The detector, which represents 1/8 of the LAT, has more than 110k silicon strip active sensors, 288 CsI crystals, and more than 2k FE readout ASICs. The CU is protected by a closed, N^2-flushed Al container that ensures proper environmental conditions for flight hardware. The overall weight of the CU and its container exceeds 1300Kg

1. On orbit calibration with heavy ions

- Calibration of the LAT instrument in orbit will be based on irradiation from primary cosmic rays. While Minimum Ionizing Particles (MIP) are ideal for monitoring the status of TKR strips and the detection efficiency of all subsystems, ionization losses from heavy ions provide well identified peaks over the whole dynamic range of the CAL and ACD detectors, and can therefore be used to determine the energy scale to calibrate these 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 Monte-Carlo simulations and used to calibrate the response and trend the performance of the detectors subsystems



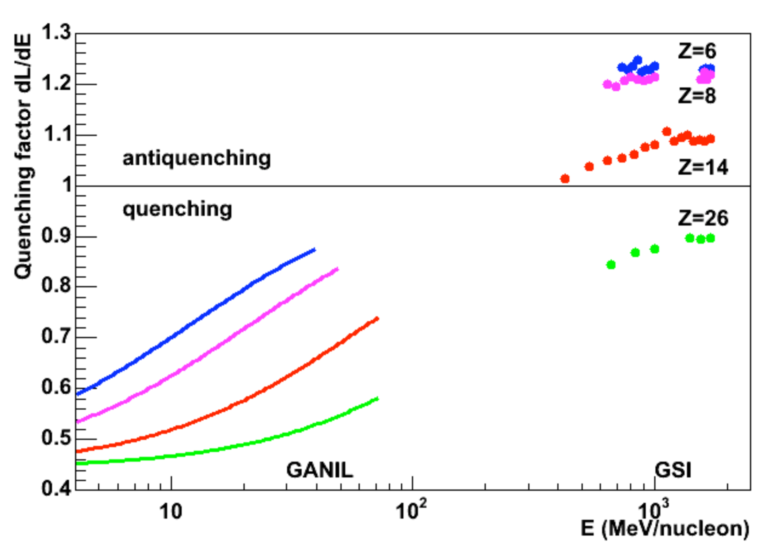
Expected distribution of ionization energy deposited by CR ions in one CsI crystal of the LAT CAL

2. Calibration Unit beam test program

- In 2006 a Calibration Unit (CU) was built integrating spare flight modules (2 TKR, 3 CAL, 5 ACD tiles) into a flight-like mechanical grid and readout with flight electronics. The CU was exposed to a variety of beams (γ, e, p, π from 100MeV to 300GeV from CERN, heavy ions from GSI) to directly measure its performance and validate the MC simulation
- A beam test with heavy ions was performed using beams of $^{12}_{6}C$ and $^{131}_{54}Xe$, with energy of 1.5GeV/n. Ions were shot through the CU at 0, 30 and 60 degrees incoming angle and various rates were explored (10-1000Hz/cm²). The trigger and readout configuration were the same that the LAT will use in orbit

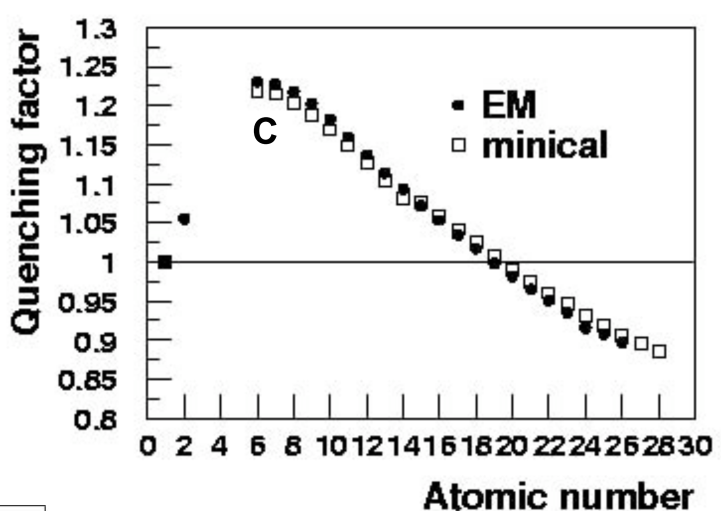
3. CAL response: quenching

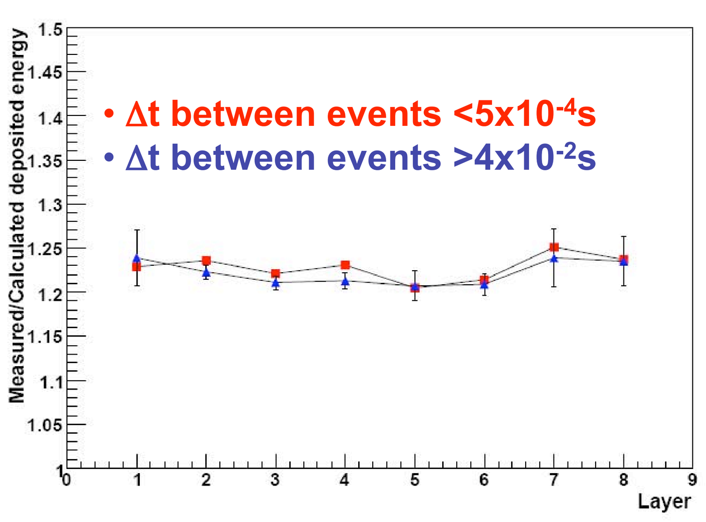
Heavy ion irradiation in CsI(Tl) produces non linear response due to large ionization densities. The deviation from the calculated behaviour is called Quenching Factor (QF), and is defined as $\alpha S/E_{dep}$, where S is the measured ionization signal, E_{dep} the calculated ionization energy deposit, and α a constant such that the QF=1 for Z=1 particles. The QF must be measured and incorporated in the simulation to correctly model the CsI response



- QF measured on CsI in previous heavy ion beam test on a prototype of the GLAST CAL (NIMA 560-2006). A lower response wrt to a MIP was measured at low ion energy at GANIL, while an anti-quenching effect was recorded at high energy at GSI

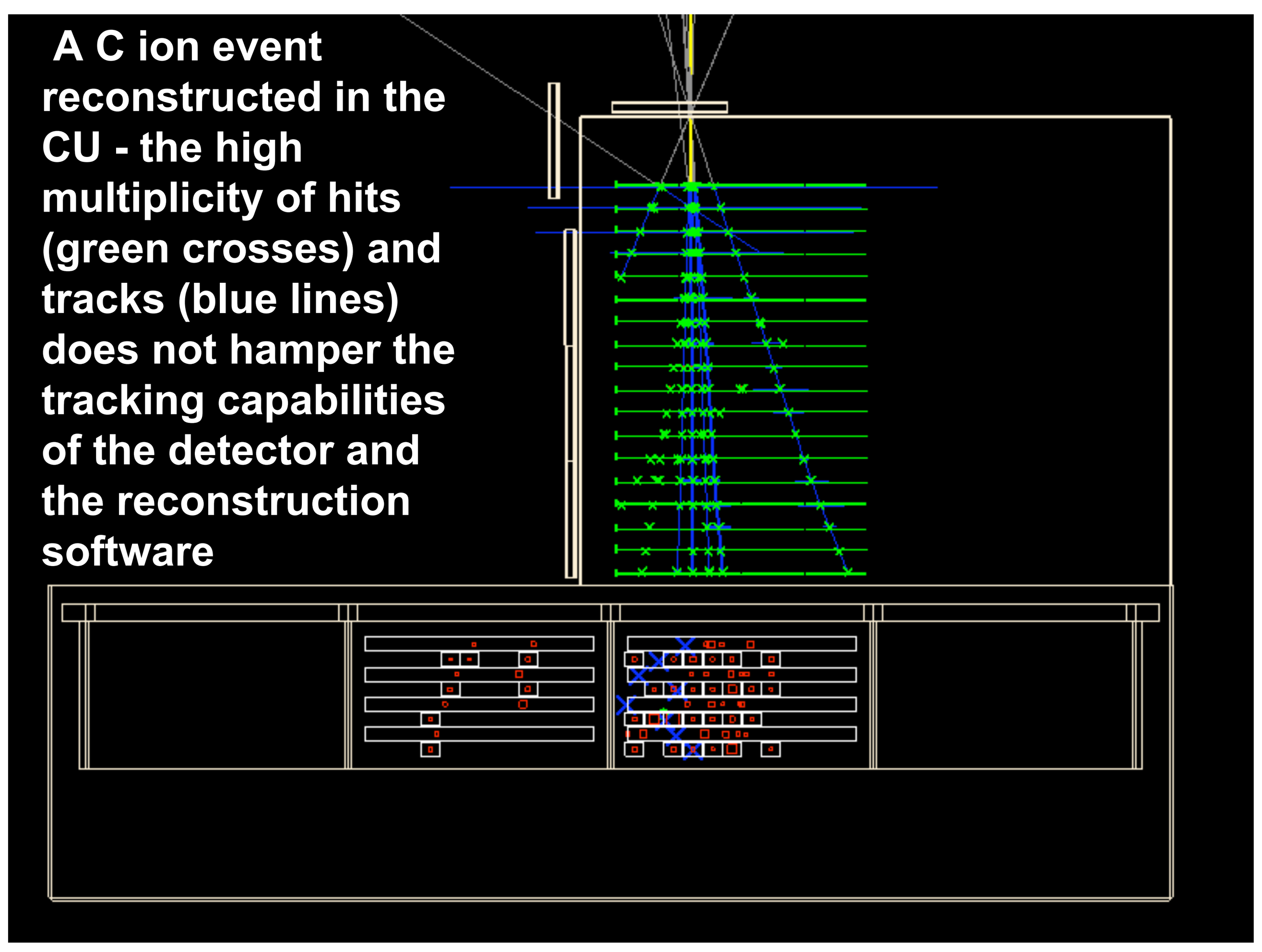
- QF measured for different ion species at high energy in the 2003 GSI heavy ion beam test of the GLAST CAL prototype, which was later integrated in the CU and tested in 2006. The antiquenching effect decreases as Z increases





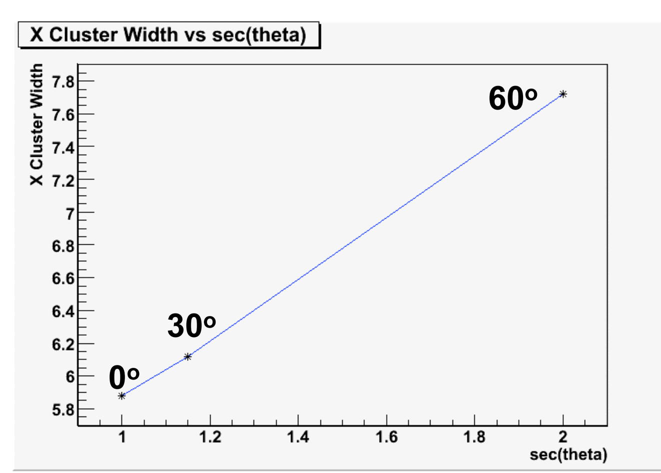
- QF for C ions measured in the 8 layers of the CAL modules of the GLAST CU tested in 2006 - the QF is the same as that measured in 2003
- No rate effect was recorded, as can be seen from the two curves

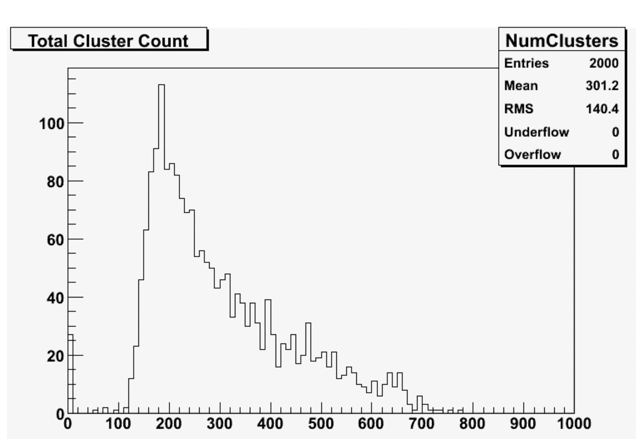
4. TKR response: cluster size



All the CU elements are shown in the reconstructed event: one TKR tower, 2 CAL modules and the top ACD tile are hit by ions while 4 ACD tiles and a complete TKR+CAL tower are not activated; the external container is also visible

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

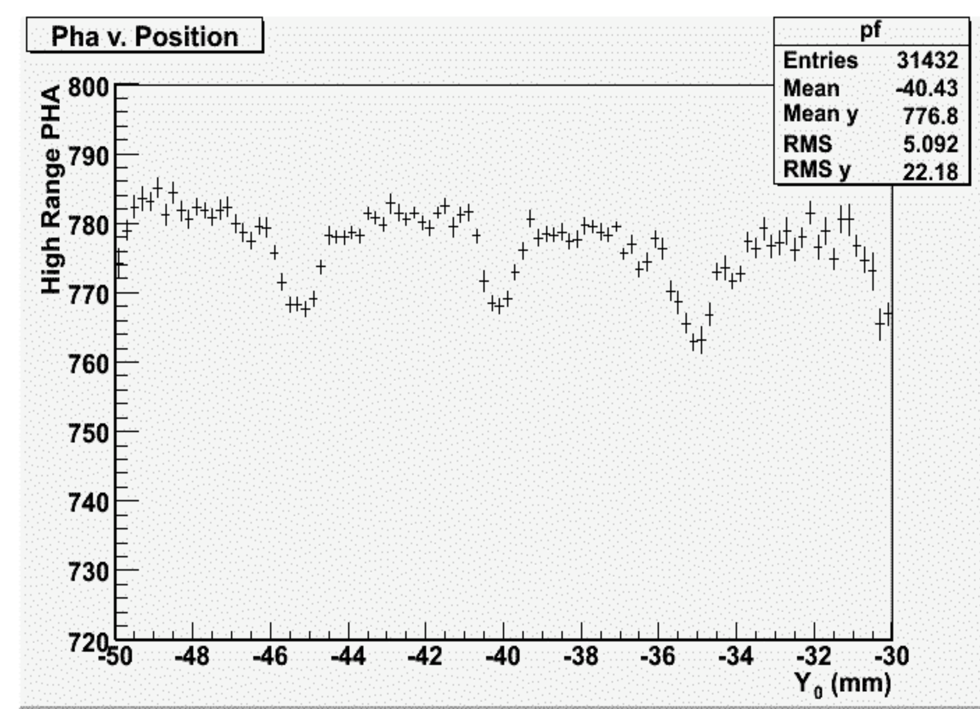




- A special run with a Xe beam made available by GSI was performed. The number of TKR clusters becomes very high and the cluster size increases up to 15 strips. A dedicated analysis to identify secondary fragments at lower Z is underway

5. ACD response:

- The high gain range of the ACD for heavy ions triggering was successfully tested for the first time
- The very large signal induced by C ion events was used to perform a *radiographic* image of the ACD tiles, showing the location of the WLS fibers that bring the light to the readout electronics



6. Conclusions

- The GLAST-LAT Calibration Unit was exposed to beams of C and Xe to test the calibration strategy of the LAT in orbit
- 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 ACD efficiently triggered on heavy ions and a linear response was recorded in the initial part of the high amplification range
- The TKR subsystem was able to reconstruct ion tracks even in a high density radiation environment. A new simulation algorithm that describe the unexpectedly measured large cluster is under implementation
- The CAL subsystem response confirmed the already measured quenching factors already included in the MC simulation