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Pre-flight Performance Studies of the Anticoincidence Systems of the PAMELA Satellite Experiment

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The PAMELA satellite experiment will be launched on-board a Resurs DK1 earth observation satellite towards the end of 2005. During the three year mission, the primary objective of PAMELA is to measure the flux of antiprotons (80 MeV - 190 GeV) and positrons (50 MeV - 270 GeV) in the cosmic radiation. The wide energy range and large statistics, $\sim 10^4$ antiprotons and $\sim 10^5$ positrons, will allow sensitive tests of cosmic ray propagation models and searches for exotic sources of antiparticles, such as the annihilation of dark matter particles. The PAMELA experiment contains two anticoincidence systems built from plastic scintillators read out by photomultipliers. One system surrounds the permanent magnet spectrometer and the other surrounds the volume between the first two time-of-flight layers. The pre-flight performance of both anticounter systems has been studied using data from ground tests of PAMELA.

1. Introduction

PAMELA [1][2] is built around a permanent magnet silicon spectrometer (tracker), surrounded by a plastic scintillator anticoincidence shield. The electromagnetic calorimeter, mounted below the tracker, is used for particle identification and energy measurements. The time of flight system (TOF) consists of scintillator planes (S1-S3), which provide the main trigger to the experiment. Simulations have shown that the majority ($\sim 75\%$) of triggers in space are expected to be false triggers [3], i.e. where the coincidental energy deposits in the TOF scintillators are generated by secondary particles, produced in the mechanical structure of the experiment. Figure 1 (left) shows a schematic view of the PAMELA experiment and a false trigger: a proton interacts with the magnet and generates a shower of particles which fulfill the trigger condition. The aim of the anticoincidence (AC) systems is to identify these events during offline data analysis. A second level trigger [4] based on information from the AC detectors and from the calorimeter provides an online identification of false triggers and is capable of reducing the data downloaded to Earth by 60% (figure 1, right). The second level trigger can be enabled via uplink commands from ground.

The performance and stability of the AC detectors and of the electronic read-out system has been investigated and is discussed in section 3.

2. The Anticoincidence System

The main AC system [5] consists of 4 plastic scintillators (CAS) surrounding the sides of the magnet and one covering the top (CAT). The second AC system consists of 4 scintillators (CARD) covering the sides of the volume between the first two time-of-flight layers. Each scintillator (Bicron BC-448M) is coupled via a 7 mm thick optical pad to 2 (8 for CAT) photomultiplier tubes (Hamamatsu R5900 PMT), operated at 800 V and read-out by to 2 independent data acquisition boards, for a total of 24 electronic channels. For each channel binary hit information is generated indicating whether the deposited energy exceeds 0.5 mip. The hit information is recorded in a time window of length 1.28 μs centred on the trigger time. Within this window, the hit can be located with an accuracy of 80 ns. Hits coincident with the trigger are registered in the central 2 bits, while the first (last) bit refers to particles interacting ~ 600 ns before (after) the trigger. The time window has been

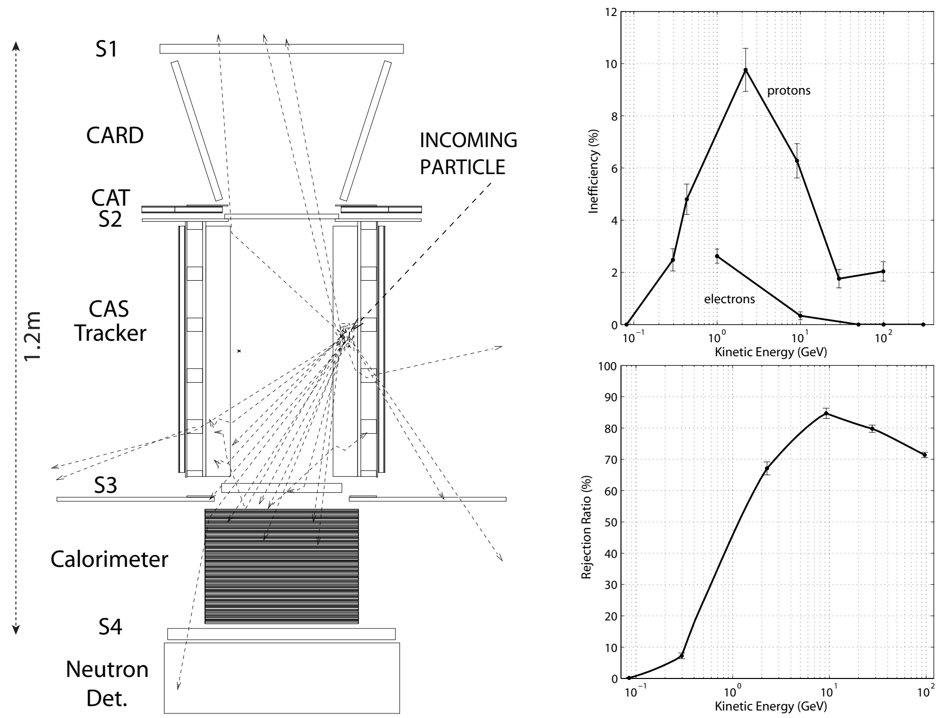

Figure 1. (left) A proton entering from the side generates an hadronic shower and triggers the experiment (false trigger). (right) The inefficiency of the second level trigger (top) is shown for electrons and protons. The rejection ratio (bottom) is the fraction of false proton triggers correctly identified. The total data reduction is $\sim 60\%$. Adapted from [4].

chosen to allow an overlap with the calorimeter self trigger [6], which is issued a few hundred of ns after the interaction of a particle.

A miniature low intensity light emitting diode (LED) is glued directly onto each scintillator (2 for CAT). The LEDs are placed far away from the PMTs, in order to provide a long path for the photons to reach the PMT, which increases the sensitivity to opacity. The LEDs allow the functionality and stability of the AC systems to be verified in-flight [5]. Once per orbit, on the ascending node, the data acquisition is stopped and a calibration procedure is performed. All PAMELA detectors are calibrated, sequentially and independently. Each LED emits short light pulses ($\lambda \simeq 640$ nm), that reproduce mip-generated pulses inside the scintillator with respect to pulse height, shape and timescale. The monitoring procedure requires less than one second to be performed and provides an integral spectrum with statistical errors of the order of 1% (to be discussed in section 3 and figure 4).

3. Performance of the System

In 2004 and 2005, extended acquisitions of cosmic particles at ground level with PAMELA detectors and read-out system in flight configuration have been performed in the laboratory in Rome (Italy) and in Samara (Russia). The AC system performances have been investigated on ground using a ‘QuickLook’ package, a

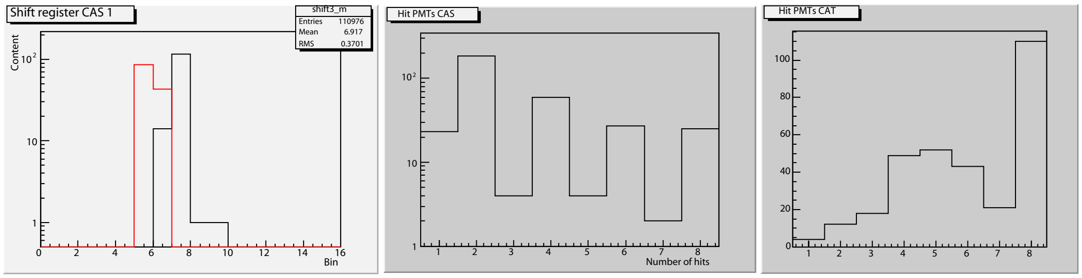

Figure 2. (left) The 'time window' of 1.28 μs for the 4 CAS detectors during a data acquisition in the laboratory with cosmic particles. Hits simultaneous with the trigger are in the centre, while the first (last) bin corresponds to hits $\sim$ 600 ns before (after) the trigger. The two distributions correspond to different read-out boards and are shifted due to differences in the timing of the trigger signals sent independently to each board. (centre) The number of PMTs hit in CAS (histogram) per trigger for a given run with cosmic rays. The CARD detectors show a similar behaviour. (right) The number of PMTs hit in CAT per trigger for the same run.

ROOT based tool which will be used during flight to monitor the PAMELA apparatus almost[1] in real time. Quicklook (QL) has been successfully used for the study of cosmic ray data taken on ground with PAMELA in flight acquiring data in flight configuration. The Quicklook software provides detailed performances analysis specific to each of the PAMELA subdetectors in the form of histograms or plots.

Apart from monitoring error flags that indicate system anomalies (parity errors in data transmission, regulator latch-ups, high temperature warnings, ...), the QL software checks the stability of the AC systems monitoring the time variation of specific parameters. Figure 2 (left) illustrates the stability of the shift register: the temporal distribution of hits for a specific run with cosmic particles is shown. The majority of hits occupy 2 bins at the centre of the time window, i.e. in time with the trigger, as expected (section 2). The histogram in the centre (right) shows the number of PMTs hit in the CAS (CAT) detector per cosmic ray trigger. The read-out redundancy is clearly illustrated. Each electronic channel records the detector singles rate between two consecutive triggers. This allows to monitor the 'singles rate' in each channel. Figure 3 (left) shows the 'singles rate' for a typical run ($\sim$ 2 h) with cosmic particles measured in Rome. The two distributions refer to the 2 PMTs facing the same scintillator. Since the sensitive area and the thresholds are the same, the histograms almost overlap and show a peak around 60 Hz. The plots in the centre and right show the stability of the 'singles rate' for the same detector over a period of $\sim$ 5 months, where the x-axis displays the days elapsed since the 1^{st} January 2005. On the y-axis are shown the mean of the peak (centre) and its RMS (right). At the end of March (day 90) PAMELA was transported from Rome to Samara, where the different laboratory set-up (taller building, i.e. larger amount of concrete placed above PAMELA) caused a significant singles rate decrease in all scintillators.

During data acquisition in the laboratory, the AC detectors have been monitored several times each day with the LED-based monitoring system. Figure 4 (left) shows a typical result from the monitoring procedure, i.e. the number of LED-generated pulses above threshold, where the threshold varies from 0 to 1 V (0 to several mips). The QL software shows the stability of the plateau at low thresholds (centre) and of the falling edge (right). The characteristics of the AC detectors have not changed since the first measurements were taken with the AC system integrated on PAMELA in flight configuration. The LED data allows to determine that the singles rate decrease is not due to a degradation of the system.

[1] As soon as data are downloaded to Earth (few times a day), the QuickLook software checks PAMELA stability and performances.

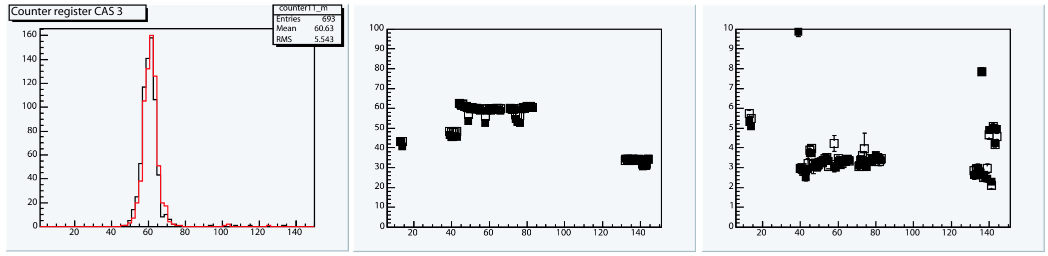

Figure 3. The 'singles counters' monitor the hit rate between consecutive triggers in a CAS detector. The filled and empty squares refer to the 2 PMTs facing the scintillator. The hit rate distribution for one run is shown as function of the frequency (Hz) (left). The position (RMS) of the peak shown in the left is shown in the centre (right). In the central plot, the first gap (day ∼ 20) is due to the vibration test. The rise (day 45) is due to the increased high voltage to the flight value. The second gap is the transport to Samara. The RMS jumps are due to commissioning tests.

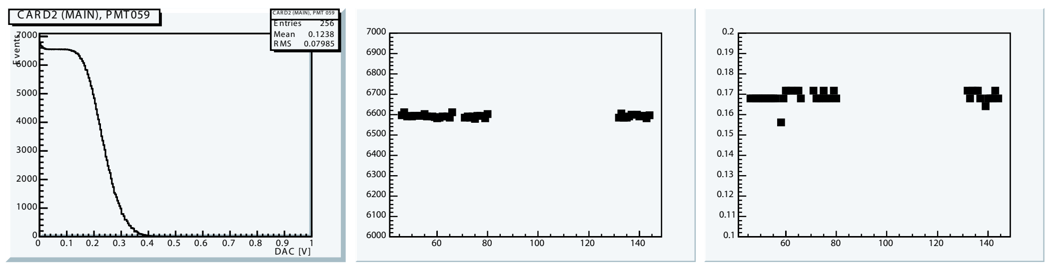

Figure 4. The LED-based monitoring system provides a mean of monitoring the system independent of cosmic ray particles hitting the detectors (section 3). The number of LED pulses above the discriminator threshold is shown as function of the threshold (left). The time stability of the height of the plateau shown in the left figure is shown in the centre (x-axis in days). The edge (defined as the voltage corresponding to 90% of the plateau) is shown on the right.

4. Conclusions

The performance of the PAMELA anticounter systems has been monitored using cosmic ray and LED monitoring runs during the commissioning of the experiment. No significant changes in the performance of the systems was observed.

References

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