30TH INTERNATIONAL COSMIC RAY CONFERENCE

The First Year in Orbit of the PAMELA Experiment

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Abstract: On the 15th of June 2006, the PAMELA experiment mounted on the Resurs DK1 satellite, was launched from the Baikonur cosmodrome and it has been collecting data since July 2006. PAMELA is a satellite-borne apparatus designed to study charged particles in the cosmic radiation, to investigate the nature of dark matter, measuring the cosmic-ray antiproton and positron spectra over the largest energy range ever achieved, and to search for antinuclei with unprecedented sensitivity. The PAMELA apparatus comprises a time-of-flight system, a magnetic spectrometer, a silicon-tungsten electromagnetic calorimeter, an anticoincidence system, a shower tail catcher scintillator and a neutron detector. We will present the status of the apparatus after one year in orbit. Furthermore, we will discuss the PAMELA in-flight performances.

Introduction

The PAMELA (a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) experiment was launched into space on June 15th 2006 from the Baikonur cosmodrome in Kazakhstan. The apparatus is installed inside a pressurized container attached to the Russian Resurs DK1 earth-observation satellite. The satellite orbit is elliptical and semi-polar, with an altitude varying between 350 km and 600 km, at an inclination of 70° . The mission is foreseen to last for at least three years.

A description of the scientific goals are presented elsewhere at this conference[11], here we present the status of the apparatus after one year in orbit.

The PAMELA apparatus

The apparatus is composed of the following sub-detectors, arranged as in Figure 1, from top to bottom:

- a time of flight system (ToF (S1,S2,S3));
- a magnetic spectrometer;
- an anticoincidence system (CARD, CAT, CAS);
- an electromagnetic imaging calorimeter;
- a shower tail catcher scintillator (S4);
- a neutron detector.

More technical details about the instrument and its preparation for the launch can be found in reference [10] and references therein.

In-flight operations and performance

On June 21st 2006 PAMELA was switched on for the first time. After a few weeks of commissioning, during which several trigger and hardware configurations were tested, PAMELA has been in a nearly continuous data taking mode since July 11th. Until May 2007, the total acquisition time has been ~270 days, for a total of ~570 million collected events and 4.6 TByte of down-linked raw data.

All in-flight operations are handled by the PSCU (PAMELA Storage and Control Unit). The PSCU manages the data acquisition and other physics tasks and continuously checks for proper operation of the apparatus. The data acquisition is segmented in runs, defined as continuous period of data taking with constant detector and trigger configurations. The duration of a run is determined by the PSCU according to the orbital position. Two acquisition modes are implemented, for high- (radiation belts and polar regions) and low- (equatorial region) radiation environments. The run configuration, in both acquisition modes, and the criterion to switch between low- and high-radiation environments can be varied from ground. The main PAMELA trigger conditions are defined by coincident energy deposits in the scintillator ToF layers. The high-radiation trigger environment uses only information from the S2 and S3 scintillators while the low-radiation one also from the S1 scintillators. Figure 2 shows the PAMELA trigger rate as a function of orbital position obtained after a few months of data taking (see also [3, 8]). From the figure it can been seen that the average trigger rate of the experiment is ~ 25 Hz, varying from ~ 20 Hz at the equatorial region to ~ 30 Hz at the poles. Furthermore also the region where the satellite crosses the inner proton radiation belt, i.e. the South At-

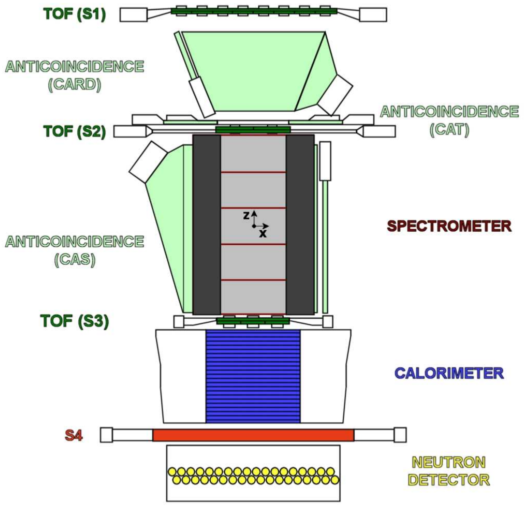

Figure 1: Schematic overview of the PAMELA apparatus. The detector is approximately 1.3 m high, has a mass of 470 kg and an average power consumption of 355 W. The magnetic field lines inside the spectrometer cavity are oriented along the y direction. The average value of the magnetic field is 0.43 T.

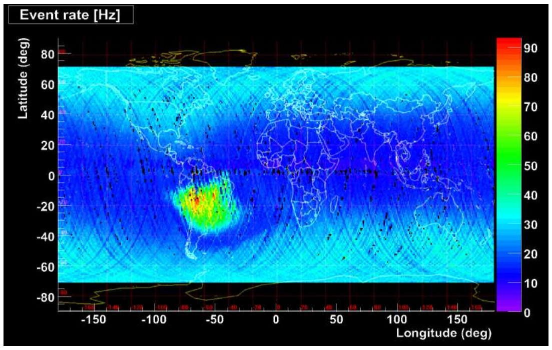

Figure 2: The PAMELA trigger rate shown as a function of orbital position. The high trigger rate region above Argentina and Brazil corresponds to the so-called South Atlantic Anomaly.

lantic Anomaly, can be clearly seen as a significant increase in the trigger rate. The average fractional live time of the experiment exceeds 70%.

During this time some error conditions (approximately one per week) occurred, mainly attributable to anomalous electronics conditions in the detector electronics. Every time the PSCU was able to recover the system functionality and continue the acquisition.

The thermal profile of the instrument has been very stable and no power-off due to over-temperature occurred. Furthermore, no radiation dose effects have been observed in the PAMELA sub-detectors. Indeed, all sub-detectors are behaving nominally. Additional information about sub-detectors is presented elsewhere at this conference [2, 4, 5, 7, 12].

Data handling and analysis

About 14 GB of PAMELA data are transfered to ground via a few down-link sessions every day. The main receiving station is located at the Research Center for Earth Operative Monitoring (NTs OMZ) in Moscow, Russia. After receiving the data, a dedicated computer facility unpacks and transfers them to various institutions for further data processing and analysis [6].

Particles trigger the instrument when crossing the ToF scintillator paddles. The ToF system also measures the absolute value of the particle charge and

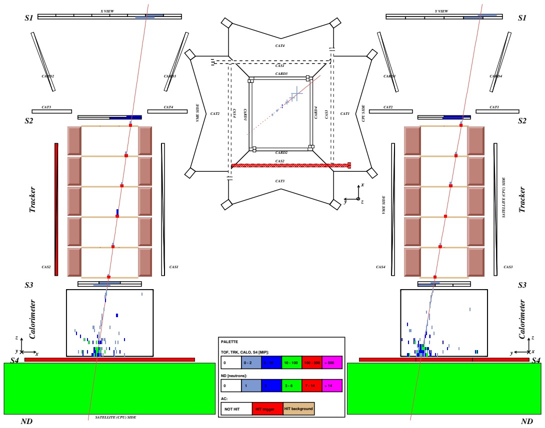

Figure 3: The event display a ∼41GV interacting antiproton. The bending (x) and non-bending (y) views are shown on the left and on the right, respectively (plane 19 of the calorimeter x-view was malfunctioning.). A plan view of PAMELA is shown in the center. The signal as detected by PAMELA detectors are shown along with the particle trajectory (solid line) reconstructed by the fitting procedure of the tracking system.

flight time crossing its planes. In this way down-going particles can be separated from up-going ones. Particles not cleanly entering the PAMELA acceptance are identified by the anticounter system. Then, the rigidities of the particles are determined by the magnetic spectrometer. Thus, positively and negatively charged particles can be identified. The final identification (i.e. positrons, electrons, antiprotons, etc.) is provide by the combination of the calorimeter and neutron detector information plus the velocity measurements from the ToF system and ionization losses in the tracker system at low momenta.

Electrons and protons are distinguished by comparing the particle patterns and energy losses inside the calorimeter. From test beam data, the calorimeter has been proven to provide a proton rejection factor of about 10^5 in selecting positrons and electrons and, from simulations, an electron rejection factor of about 10^5 in antiproton measurements, while keeping in both cases about 90% efficiency [1]. The calorimeter in-flight performance as well as its particle identification ca-

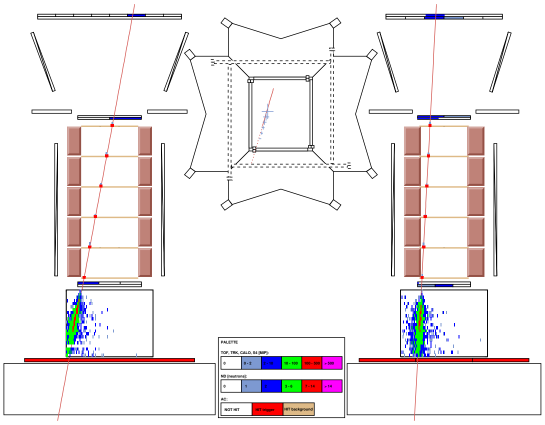

Figure 4: The event display a ∼70 GV positron. The bending (x) and non-bending (y) views are shown on the left and on the right, respectively (plane 19 of the calorimeter x-view was malfunctioning.). A plan view of PAMELA is shown in the center. The signal as detected by PAMELA detectors are shown along with the particle trajectory (solid line) reconstructed by the fitting procedure of the tracking system.

pabilities are consistent with design and ground tests [7]. Several thousand events have been identified as positrons and hundreds of events as antiprotons. As an example, figure 3 shows a ∼41 GV negatively-charged interacting hadron identified as an antiproton and figure 4 shows a ∼70 GV positively-charged electromagnetic particle identified as a positron.

In figure 3 and figure 4 a different signature in the neutron detector can be clearly noticed. Indeed, additional hadron-rejection power is provided by the neutron detector and this increases as the energy increases.

Besides selection of charge one particles, PAMELA is able to identify light nuclei particles, up at least to Oxygen, using the ionization losses in the calorimeter, ToF and tracker systems [9].

Conclusions

The PAMELA satellite experiment was successfully launched on the 15^{th} of June 2006. Detectors did not suffer any damage due to the launch and the experiment has been continuously taking data since then. Individual detectors are performing nominally allowing for precise measurement of cosmic-ray spectra over a wide energy range.

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