LAUNCH IN ORBIT OF THE SPACE TELESCOPE PAMELA AND GROUND DATA RESULTS

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PAMELA is a satellite-borne experiment that aims to measure the antiproton and positron spectra in the cosmic radiation over the largest energy range ever achieved, and to search for antinuclei with unprecedented sensitivity. In addition, it will measure the light nuclear component of cosmic rays and investigate phenomena connected with Solar and Earth physics. All detectors have been successfully integrated in the apparatus that has been installed on-board the Russian Resurs-DK1 satellite. In the first months of 2006 PAMELA will be launched from the Baikonur cosmodrome in Kazakhstan, for a 3 year long mission. In this paper an overview of the mission and the instrument will be presented, along with results of cosmic ray muons recorded at ground during the final integration phase.

1. Experiment overview

The PAMELA[a] apparatus is designed to study charged particles in the cosmic radiation. It will be hosted by a Russian Earth-observation satellite, the Resurs-DK1, that will be launched into space by a Soyuz rocket in 2006 from the Baikonur cosmodrome. The orbit will be elliptical and semi-polar, with an inclination of 70.4° and an altitude varying between 350 km and 600 km. The mission will last at least three years.
The main scientific goal of the experiment is the precise measurement of the cosmic-ray antiproton and positron energy spectra. The satellite orbit and mechanical design of the apparatus will allow the identification of these particles in an unprecedented energy range (between 80 and 270 MeV for positrons and between 80 and 190 MeV for antiprotons) and with high statistics ($\sim 10^4$ $\overline{p}$ and $\sim 10^5$ e^+ per year). The importance of these measurements stems from the information that they can provide about solar modulation effects (below a few GeV), cosmic-ray propagation and primary production from exotic sources such as primordial black holes, annihilation of supersymmetric particles or Kaluza-Klein particles. Almost

[a]a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics.

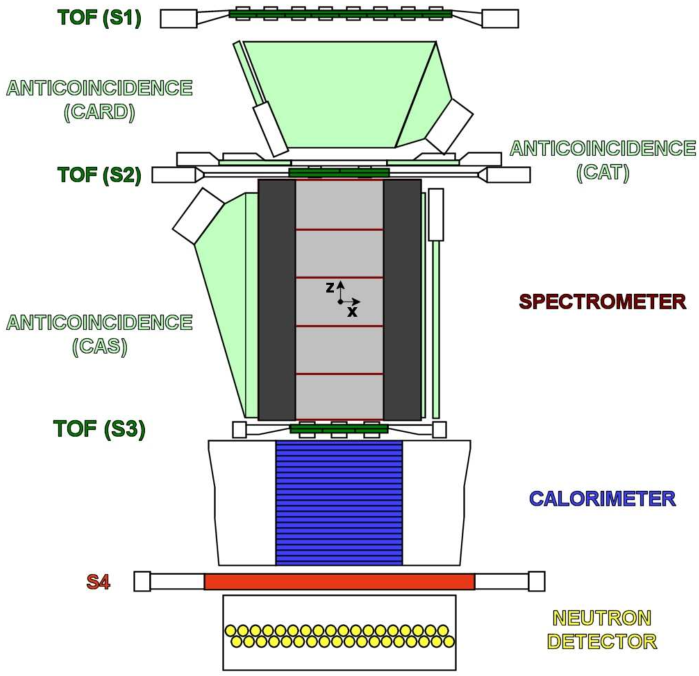

Figure 1. A sketch of the PAMELA apparatus.

all data available so far have been obtained by balloon-borne experiments. New and extensive measurements with high statistics are strongly needed.

Additionally, PAMELA will search for antimatter in the cosmic radiation (sensitivity to the $\overline{He}/He$ of $\sim 10^{-8}$), it will measure the light nuclear component of cosmic rays and investigate phenomena connected with Solar and Earth physics.

2. The apparatus PAMELA

The apparatus [1] 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)), an *anticoincidence system* (CARD, CAT, CAS), a *magnetic spectrometer*, an *electromagnetic imaging calorimeter*, a *shower tail catcher scintillator* (S4) and a *neutron detector*.

Particles trigger the experiment via the main trigger[b] provided by the ToF system [2] composed of 6 layers of segmented plastic scintillators

[b]Additional triggers can be provided by the calorimeter and S4.

arranged in three planes (S1, S2, S3). The ToF system also measures the absolute value of the particles charge and flight time crossing its planes. In this way downgoing particles can be separated from upgoing ones. Furthermore, the acceptance of the apparatus can be varied by changing the configuration of the ToF layers used to form the trigger. Particles not cleanly entering the PAMELA acceptance are rejected by the anticounter system [3]. The rigidities of the particles are determined by the magnetic spectrometer [4] consisting of a permanent magnet and a silicon tracking system. 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 (see [5]) and neutron detector information plus the velocity measurements from the ToF system at low momenta.

The detector is approximately 120 cm high, has a mass of about 450 kg and the power consumption is 360 W.

A daily amount of about 10 GByte of data from the instrument are expected. The main downlink center is located at the Research Center for Earth operative monitoring "Nts-OMZ" in Moscow (Russia); an average of 8 passages per day over the station are foreseen, during which PAMELA will download all scientific data along with telemetry data about the status of the detector (temperatures, power consumptions, voltage levels, ..). An additional station, located in Khanty-Mansiisk (Siberia, Russia), is under consideration, but has not been officially established yet.

3. Ground data results

Prior to the delivery to Samara (Russia), where the spacecraft is built, the PAMELA apparatus was assembled at the laboratories of the University of Rome "Tor Vergata", Italy. Here the system was tested with ground muons over a period of several months, in order to calibrate the sub-detectors and check the overall performance of the instrument. As a whole, a total of about 480 hours of ground cosmic rays have been collected.

Figure 2 shows an event recorded in Rome. The event is a 1.5 GeV/negatively charged particle, with high probability of being a μ^- considering the clean non-interacting pattern in the calorimeter. All PAMELA detectors are shown in the figure along with the signals produced by the particle in the detectors and derived information. It can be clearly seen the highly detailed information provided for each cosmic-ray event. The solid line indicates the track reconstructed by the fitting procedure of the

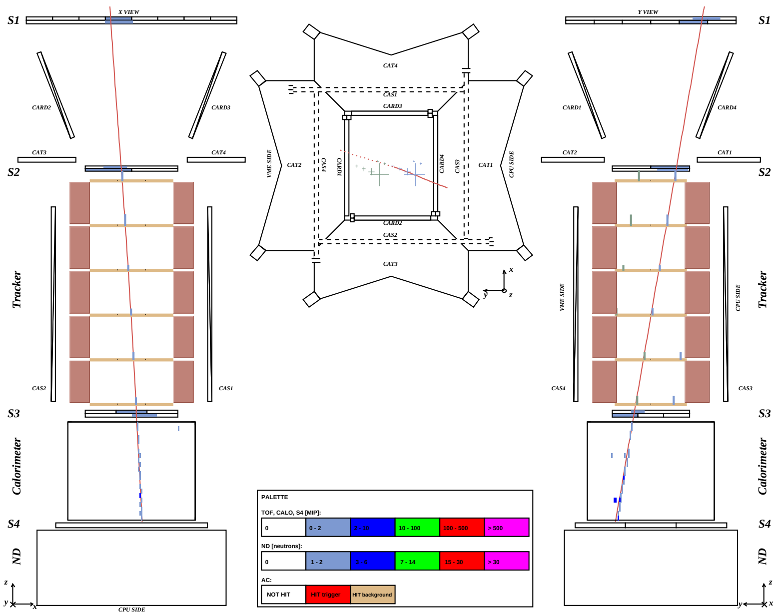

Figure 2. A muon track in PAMELA.

tracking system. From this information the muon charge ratio measured at ground in Rome (50 m a.s.l.) has been obtained and shown in Figure 3. Muons were selected as non interacting particles in the calorimeter and charge one in the ToF scintillators. Their momenta were determined by the tracking system. In the figure PAMELA data are compared with other experimental results [6,7,8]. A good agreement can be seen.

Once PAMELA reached Samara, it was extensively tested again before being integrated inside the spacecraft. As a result, about 140 hours of cosmic ray acquisition have been recorded. Analysis of Samara data is in progress.

4. Status of the mission

Extensive space qualification tests of PAMELA detectors, electronics and mechanical structures have been performed. Furthermore, the detectors were tested at test beam facilities at CERN and shown to comply with their design specification.

Three models of the PAMELA apparatus were developed: a mass/thermal model, a technological model for electrical and compatibil-

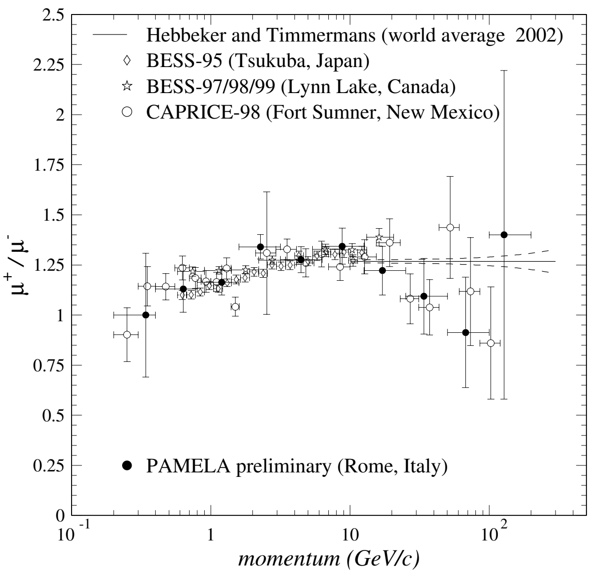

Figure 3. μ^+/μ^- ratio as measured by PAMELA during ground data acquisition - preliminary results.

ity tests with the satellite, and the flight model for actual data taking in space [9]. All these models were delivered for testing to Samara, and shown to be fully compliant with the requirements of the Resurs-DK1 spacecraft environment. Specifically, the flight model underwent incoming and acceptance tests in April/May 2005 and was integrated with the satellite in September 2005. Electrical and data transmission tests of the integrated PAMELA-spacecraft system are still taking place.

Subsequently, PAMELA and the satellite will be transported to Baikonur for the launch into space, foreseen for the beginning of 2006 after about two months of tests in-situ.

References

1. M. Bongi et al., IEEE Trans. Nucl. Sci. 51, 854 (2004).
2. D. Campana et al., 28th ICRC, Tsukuba, 2141 (2003).
3. S. Orsi et al., 35th COSPAR, Paris, to appear in Adv. Sp. Res. (2004).
4. O. Adriani et al., Nucl. Instr. & Meth. A 511, 72 (2003).
5. M. Boezio et al., Nucl. Instr. & Meth. A 487, 407 (2002).
6. T. Hebbeker and C. Timmermans, Astropart. Phys. 18, 107 (2002).
7. M. Motoki et al., Astropart. Phys. 19, 113 (2003).
8. M. Boezio et al., Phys. Rev. D 67, 072003 (2003).
9. R. Sparvoli et al., 35th COSPAR, Paris, to appear in Adv. Sp. Res. (2004).