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The Space Experiment PAMELA

M. Boezio on behalf of the PAMELA Collaboration

INFN, Structure of Trieste, Via Valerio, 2 I - 34127 Trieste, Italy

Presenter: M. Boezio (Mirko.Boezio@trieste.infn.it), ita-boezio-M-abs1-og15-oral

We present a status report of the space experiment PAMELA. PAMELA is a satellite-borne experiment which aims primarily 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 polar orbiting Resource DK1 satellite. Before the end of 2005 it will be launched from the Baikonur cosmodrome in Kazakhstan, for a 3 year long mission. Details of the integration phase and detectors performances will be presented along with results of ground data taking and expected scientific output from the mission.

1. Introduction

The PAMELA apparatus (a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) is a satellite-borne experiment designed to study charged particles in the cosmic radiation. It will be hosted in a pressurized vessel attached to a Russian Earth-observation satellite, the Resource DK1, that will be launched into space by a Soyuz TM2 rocket in 2005 from the Baikonur cosmodrome, in Kazakhstan. 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, during which time PAMELA will measure the cosmic-ray composition and energy spectrum.

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 (~ 80 MeV – ~ 270 MeV for positrons and ~ 80 MeV – ~ 190 MeV for antiprotons) and with high statistics ($\sim 10^4$ $\overline{\mathrm{p}}$ 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 (e.g. see [1]), annihilation of supersymmetric particles (e.g. see [2] or Kaluza-Klein particles (e.g. see [3, 4]). Almost all data available so far have been obtained by balloon-borne experiments. The short data-taking time (approximately 24 hours) and the presence of a residual overburden of atmosphere above the detecting apparatus at the altitudes that a balloon can reach (around 40 km, ~ 5 g/cm^2 of residual atmosphere) are the main limits of such kind of measurements.

Additionally, PAMELA will search for antimatter in the cosmic radiation (sensitivity to the the $\overline{\mathrm{He}}/\mathrm{He}$ of $\sim 10^{-8}$), it will measure the light nuclear component of cosmic rays and investigate phenomena connected with Solar and Earth physics (e.g. see [5]).

2. The PAMELA apparatus

The apparatus [6] is composed of the following subdetectors, arranged as in Figure 1, from top to bottom:

1. a time of flight system (ToF (S1,S2,S3));

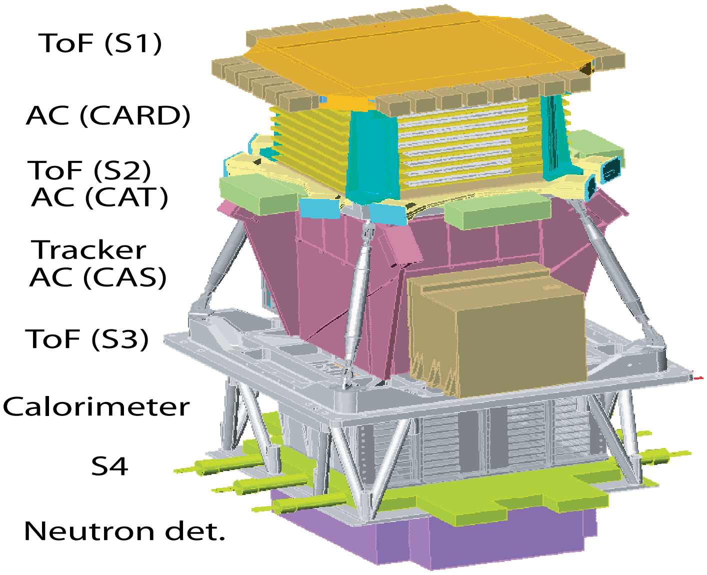

Figure 1. The PAMELA telescope. The apparatus is $\sim$ 1.2 m high, weighs $\sim$ 450 kg and has a power consumption of $\sim$ 360 W.

2. a magnetic spectrometer (Tracker);
3. an anticoincidence system (CARD, CAT, CAS);
4. an electromagnetic imaging calorimeter;
5. a shower tail catcher scintillator (S4);
6. a neutron detector (ND).

Particles trigger the experiment via the main trigger[1] provided by the ToF system [7] composed of 6 layers of segmented plastic scintillators arranged in three planes (S1, S2, S3). The ToF system also measures the absolute value of the particles charge Z 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 [8]. The rigidities of the particles are determined by the magnetic spectrometer [9] 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 [10]) and neutron detector information plus the velocity measurements from the ToF system at low momenta.

Three models of the PAMELA apparatus were developed: a mass/thermal, a technological model for electrical and compatibility tests with the satellite and the flight model for actual data taking in space. All these models were delivered for testing to the TsSKB–Progress factory in Samara, Russia and shown to be fully compliant with the requirements of the Resurs DK1 spacecraft environment. Specifically, the flight model underwent

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

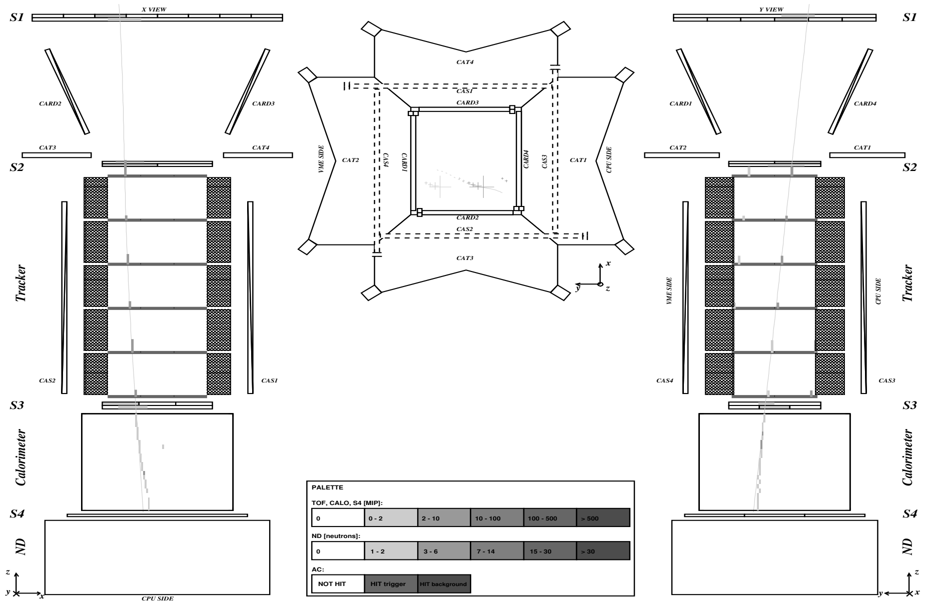

Figure 2. The event display of a 1.5 GeV/c μ^- from ground data in the PAMELA apparatus.

incoming and acceptance tests and is going to be integrated with the satellite by August 2005. Subsequently, PAMELA and the satellite will be transported to Baikonur for the launch into space foreseen for the end of 2005.

3. Ground data

Prior to the delivery to Russia, the PAMELA apparatus was assembled at the INFN laboratories of RomaII, Rome, Italy. Here the system has been tested with ground muons over a period of several months. Figure 2 shows an event recorded in Rome. The event is a 1.5 GeV/c 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 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 [11, 12, 13]. A good agreement can be seen.

4. Conclusions

PAMELA is a powerful instrument that will give results of great scientific relevance in several fields of cosmic ray research. The PAMELA flight model has been extensively tested on ground and shown to perform as required to meet the scientific goals of the mission. The model was delivered to Russia for integration with the

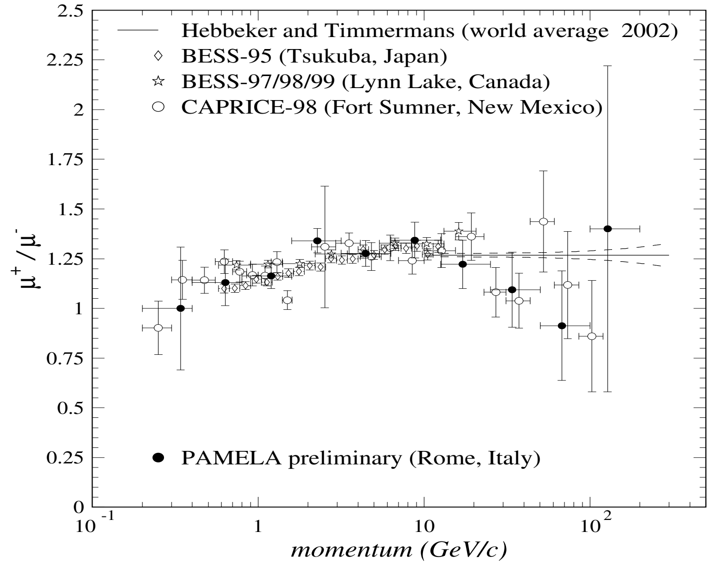

Figure 3. The muon charge ratio at ground measured by PAMELA compared with the global fit of experimental data by Hebbeker and Timmermans [11] and subsequent experimental results [12, 13].

satellite in March 2005. Incoming and acceptance tests are underway and by end of Summer 2005, PAMELA will be moved to Baikonur for the launch into space scheduled for the end of 2005.

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