Status of the PAMELA Experiment On-board of the Resurs DK-1 Spacecraft

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Abstract

This paper presents the current status of the PAMELA magnetic spectrometer. The experiment is devoted to the investigation of the origin of the Universe baryon asymmetry, of the dark matter, of processes of cosmic rays generation and propagation in Galaxy and solar system, as well as of processes of solar modulation and interaction of cosmic rays with Earth's magnetosphere. This will be achieved by means of precision measurements of the fluxes of cosmic antiparticles, electrons and light nuclei in the energy range $10^2 - 10^6$ MeV.

In the second part of 2003 the assembly of PAMELA and of the Russian Resurs DK-1 spacecraft will be finished, and complex integration tests will start. The launch of PAMELA will take place in early 2004.

1. The physics of the experiment

The primary objective of PAMELA is to measure the energy spectrum of antiprotons and positrons in the cosmic radiation. Per year, at least 10^5 positrons and 10^4 antiprotons are expected. Almost all measurements of antiprotons and positrons available so far originate from balloon-borne experiments operating at altitudes around 40 km for approximately 24 hours. There is still a residual amount of the earth's atmosphere above the detecting apparatus at this altitude (~ 5 g/cm^2) with which cosmic rays can interact. A satellite-borne experiment benefits from a lack of atmospheric overburden and a longer data-taking time. The PAMELA data sets expected after three years of lifetime exceed what is available today by several orders of magnitude and will allow significant comparisons between competing models of antimatter production in our galaxy.

Distortions to the energy spectra are very interesting because of possible contributions from exotic sources, such as the annihilation of supersymmetric neutralino particles - candidates for the dark matter in the universe [5]. Sensitivity to the low energy part of the spectrum is a unique capability of PAMELA and arises because the semi-polar satellite orbit overcomes the earth's geomagnetic cut-off. Another PAMELA goal is to measure the antihelium/helium ratio with a sensitivity of 10^{-7}, a factor of 50 improvement on the current limits [1, 7].

Although optimised for the detection of antimatter, PAMELA will also study protons, electrons and light nuclei up to Z=6. Since PAMELA will carry

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Particle	Number (3 years)	Energy Range
p	3×10^{8}	80 MeV - 700 GeV
$\bar{p}$	$>3\times10^{4}$	80 MeV - 190 GeV
e^{-}	6×10^{6}	50 MeV - 2 TeV
e^{+}	$>3\times10^{5}$	50 MeV - 270 GeV
He	4×10^{7}	80 MeV/n - 350 GeV/n
Be	4×10^{4}	80 MeV/n - 350 GeV/n
C	5×10^{5}	80 MeV/n - 350 GeV/n
$\bar{H}e$ limit (90% C.L.)	7×10^{-8}	80 MeV/n - 30 GeV/n

Table 1. Expected particle samples after a three year PAMELA mission.

out its observations during the transition to the minimum of the 23rd solar cycle, and will stay in orbit for at least three years, the effects of long and short term solar modulation on the fluxes of electrons, positrons, protons and nuclei can also be studied. The expected particle samples after three years of operation are summarized in table 1.

PAMELA is a natural progression from the WiZard balloon flights [2 and references therein] and forms part of the RIM (Russian Italian Mission) framework, which has also generated the successful series of Sil-Eye [3] and NINA [4] space experiments.

2. The spectrometer PAMELA and the Resurs DK-1 satellite

The PAMELA* spectrometer will be launched into space by a Soyuz rocket. PAMELA will be mounted in a pressurised vessel attached to a Resurs DK-1 earth-observation satellite, as shown in figure 1 (left). During launch and orbital manoeuvres the pressure vessel is secured against the satellite's body. During data-taking the pressure vessel is swung up to give PAMELA a clear view into space (red position in the figure). The satellite will execute a semi-polar (70.4° inclination) elliptical orbit with an altitude varying between 300 km and 600 km. Three years of data-taking are expected.

An overview of the instrument is given in figure 1 (right). PAMELA is built around a 0.4 T permanent magnet spectrometer ('tracker') equipped with double-sided silicon detectors which will be used to measure the sign, absolute value of charge and momentum of particles. The tracker is surrounded by a scintillator veto shield ('anticounters') which is used to reject particles which do not pass cleanly through the acceptance of the tracker. Above the tracker is a transition radiation detector based around proportional straw tubes and carbon fibre radiators. This allows electron-hadron separation through threshold velocity measurements. Mounted below the tracker is an imaging silicon-tungsten calorimeter. This measures the energies of incident electrons and allows topological discrimi-

*Payload for AntiMatter Exploration and Light-nuclei Astrophysics.

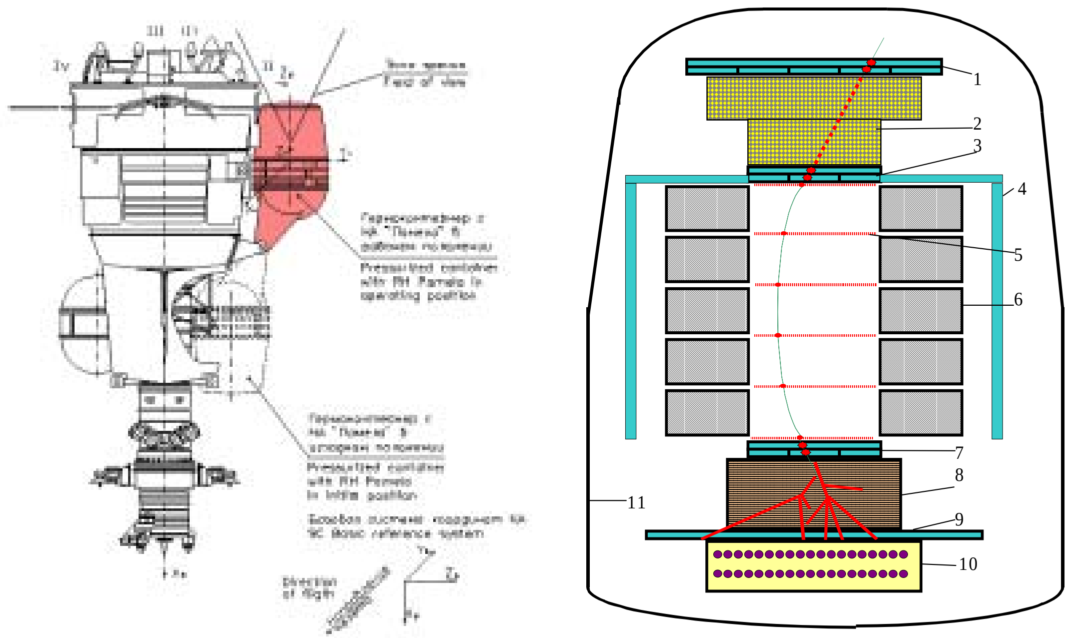

Fig. 1. Left: A schematic view of the Resurs DK-1 satellite on which PAMELA will be located inside a pressure vessel. The pressure vessel is shown in both the 'parked' and 'data-taking' (red) orientations. Right: The PAMELA instrument. **1, 3, 7:** ToF scintillators; **2:** transition radiation detector; **4:** anticoincidence system; **5:** silicon tracker; **6:** magnet; **8:** silicon-tungsten calorimeter; **9:** bottom scintillator; **10:** neutron detector; **11:** pressure vessel.

nation between electromagnetic and hadronic showers (or non-interacting particles). A scintillator telescope system provides the primary experimental trigger and time-of-flight particle identification. An additional scintillator (Bottom Scintillator) is mounted beneath the calorimeter to provide an additional trigger for high energy electrons (>100 GeV). This trigger will register particles arriving from everywhere - thus, the geometrical factor will be increased allowing the registration of particle fluxes with incoming energies up to several TeV. Finally the data obtained from the neutron detector, right at the bottom of the PAMELA detector, will provide additional information to separate hadronic from electromagnetic showers.

PAMELA stands approximately 1.2 m high, has an overall mass of 450 kg and a power consumption of 350 W. Detailed description of the PAMELA spectrometer is given in a sizeable number of publications (see the link "Publications" in [6]). In addition, several presentations about PAMELA will be given at this Conference [F. Cafagna et al., D. Campana et al., M. Casolino et al., J. Lund et al., J. Lundquist et al., G. Osteria et al., M. Pearce et al.].

3. Data Processing and Downlink Stations

Each PAMELA subdetector has its own data acquisition board which is read out by the central DAQ processor. Here, the subdetector data are packed for storage in the Resurs hard-disk array prior to downlinking to earth.

Technically, the spacecraft allows to store and dump about 20 GB of data per day to ground. A daily data bulk of around 10 GB is to be expected however. Two downlink stations are currently foreseen for PAMELA: one near Moscow at the NTsOMZ centre (where there is also a command uplink) and one in Sturup, south of Sweden.

4. Status of the mission

During 2000 and 2001, engineering models of the PAMELA subdetectors were qualified during vibration, thermal, irradiation, testbeam and laboratory studies. Integration of the flight model versions of all subdetectors is now underway. A preliminary integrated flight model set-up consisting of the tracker and anticounter systems and calorimeter was exposed to protons (200 GeV - 300 GeV) and electrons (40 GeV - 300 GeV) at the CERN SpS in June 2002. Testbeam studies of a completely integrated PAMELA are planned for later in the year.

Parallel to the calibration and integration of the flight model components of PAMELA, a dimensional and thermal model of the full instrument has been undergoing dynamical and thermal tests, both standalone and in conjunction with the pressure vessel and a model of Resurs DK-1, since early 2002. Such operations are the necessary steps for the qualification of the whole structure prior the flight. In August 2003 an electrical model of PAMELA will be delivered to Russia (TsSKB-Progress factory in Samara) for electro-diagnostic tests of the compatibility between PAMELA and the spacecraft power supply.

PAMELA in its final flight configuration will be shipped to Russia for integration with the Resurs DK-1 satellite towards the end of this year. Once integration tests are complete and the functionality of PAMELA is verified, the satellite will be moved to the Baikonur launch site (Kazakhstan) for launch preparations. The launch is scheduled for early-2004.

5. References

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