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The PAMELA space mission

O. Adriani^a, G. C. Barbarino^b, G. A. Bazilevskaia^c, R. Bellotti^d, M. Boezio^e, E. A. Bogomolov^f, L. Bonechi^a, M. Bonghi^a, V. Bonvicini^e, A. Bruno^d, F. Cafagna^{d*}, D. Campana^b, P. Carlson^g, M. Casolino^h, G. Castelliniⁱ, M. P. De Pascale^h, G. De Rosa^b, N. De Simone^h, V. Di Felice^h, A. M. Galper^j, P. Hofverberg^g, S. V. Koldashov^j, S. Y. Krutkov^f, A. N. Kvashmin^c, A. Leonov^j, V. Malvezzi^h, L. Marcelli^h, W. Menn^k, V. V. Mikhailov^j, E. Mocchiutti^e, S. Orsi, G. Osteria^b, P. Papini^a, M. Pearce^g, P. Picozza^h, M. Ricci^l, S. B. Ricciarini^a, M. Simon^k, R. Sparvoli^h, P. Spillantini^a, Y. I. Stozhkov^c, A. Vacchi^e, E. Vannuccini^a, G. Vasilyev^f, S. A. Voronov^j, Y. T. Yurkin^j, G. Zampa^e, N. Zampa^e, V. G. Zverev^j

^a INFN, Structure of Florence and Physics Department of University of Florence, Via Sansone 1, I-50019 Sesto Fiorentino, Florence, Italy

^b INFN, Structure of Naples and Physics Department of University of Naples Federico II^o, Via Cintia, I-80126 Naples, Italy

^c Lebedev Physical Institute, Leninsky Prospekt 53, RU-119991 Moscow, Russia

^d INFN, Structure of Bari, V. Amendola 173, I-70126 Bari, Italy

^e INFN, Structure of Trieste, Padriciano 99, I-34012 Trieste, Italy

^f IOFFE Physical Technical Institute, Polytekhnicheskaya 26, RU-194021 St. Petersburg, Russia

^g KTH Department of Physics, Albanova University Centre, SE-10691 Stockholm, Sweden

^h INFN, Structure of Rome Tor Vergata^o and Physics Department of University of Rome Tor Vergata^o, Via della Ricerca Scientifica 1, I-00133 Rome, Italy

ⁱ IFAC, Via Madonna del Piano 10, I-50019 Sesto Fiorentino, Florence, Italy

^j Moscow Engineering and Physics Institute, Kashirskoe Shosse 31, RU-11540 Moscow, Russia

^k Universitat Siegen, D-57068 Siegen, Germany

^l INFN, Laboratori Nazionali di Frascati, Via Enrico Fermi 40, I-00044 Frascati, Italy

The PAMELA (a Payload for Antimatter-Matter Exploration and Light-nuclei Astrophysics) space mission has been launched on-board the Resurs-DK1 satellite on June 15th 2006 from the Baikonur cosmodrome, in Kazakhstan. PAMELA is a particle spectrometer designed to study charged particles in the cosmic radiation with special focus on the investigation of the nature of dark matter, by mean of the measure of the cosmic-ray antiproton and positron spectra over the largest energy range ever achieved.

1. Introduction

PAMELA is a particle spectrometer housed inside a pressurized container attached to the Russian satellite Resurs-DK1. It was launched into

space on the 15th June 2006, by a Soyuz-U rocket, from the Baikonur cosmodrome in Kazakhstan, and deployed in a semi-polar (70°) elliptical orbit at altitude in the range 350–600 km. PAMELA was switched on for the first time on 21st June 2006 and has been in a nearly continuous data

*E-mail: francesco.cafagna@ba.infn.it

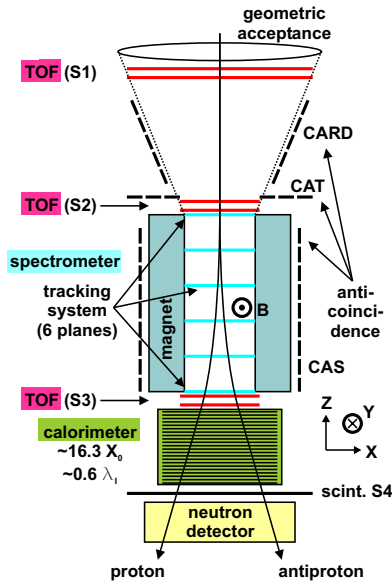


Figure 1. Sketch of the PAMELA apparatus.

taking since 11th July 2006.

PAMELA has been designed to measure in detail the spectra of primary and secondary components of the cosmic radiation. Its major scientific goal is the indirect detection of dark matter by means of the precise measurement of antiprotons and positrons spectra in cosmic rays, over the largest energy range ever achieved. The long term period of data taking provides unprecedented statistics with no atmospheric overburden reducing the systematic uncertainties of previous measurements obtained by balloon-borne experiments.

2. PAMELA apparatus

The PAMELA apparatus is composed of the following sub-detectors stacked, as in Fig. 1, from top to bottom: a time of flight system (ToF) (S1,S2,S3), a magnetic spectrometer, an anti-coincidence system (CARD, CAT, CAS), an electromagnetic imaging calorimeter, a shower tail

catcher scintillator (S4), and a neutron detector [1].

The ToF is made out of 3 double-layer plastic scintillator paddles. It provides the first-level trigger and helps in particle identification, for rigidity (R) < 1 GV, and in rejecting albedo particles by measuring particle β and dE/dx .

Particle rigidity and charge sign are determined by the spectrometer. Six layer of double-side silicon sensors are stacked in between five permanent magnet modules. Thanks to spatial resolution of $3 \div 4 \mu\text{m}$ and $8 \div 13 \mu\text{m}$, in bending and not bending view respectively, it is possible to reach a maximum detectable rigidity (MDR) of ≈ 1 TeV/ c .

A plastic scintillator anti-coincidence system shields the spectrometer, covering the magnet top (CAT), lateral sides (CAS), and the upper part of the detector (CARD).

The electromagnetic imaging calorimeter comprises 44 single-sided silicon sensor planes, orthogonally arranged, interleaved with 22 plates of tungsten absorber. With a total depth of $16.3 X_0$ and 0.6 nuclear interaction lengths, combines the topological information of the two views with the dE/dx , achieving proton rejection factor of at least 10^5 above 10 GeV while maintaining an electron selection efficiency of $\sim 90\%$.

The neutron detector consists of 36 ^3He counters, inserted into a polyethylene moderator. It helps in hadrons and leptons discrimination in the high energy events along with the shower tail catcher scintillator, that is attached at the calorimeter bottom above the neutron detector.

PAMELA overall size is about $130 \times 70 \times 70 \text{ cm}^3$, corresponding to a geometric factor of $21.5 \text{ cm}^2\text{sr}$ (for $R > 1$ GV), for a total mass of ~ 470 kg, and a maximum power consumption of 360 W.

3. Data analysis and results

Since the first days of operation, PAMELA, is transmitting to ground about 16 GB of data every day. After a quick look, to check the status of the detector, data are reduced and calibrated.

Using the ToF and AC, only down-going particles, cleanly entering the PAMELA acceptance, are selected. Then the charge sign is identified and the rigidity determined, using the spectrom-

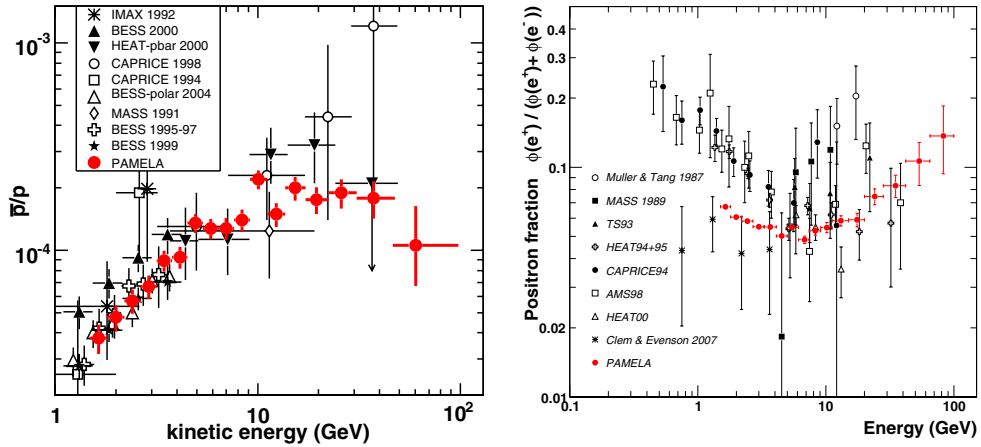


Figure 2. Antiproton to proton ratio between 1 and 100 GeV (left)[3]. Positron to electron ratio between 1.5 and 100 GeV (right)[4]. Both ratios are compared to recent measurements, see [3,4] for references

eter. The final identification is provided by the calorimeter, combining dE/dx with the topological information, the β measurements from the ToF and ionization losses in the tracker system at low momenta.

A full detector simulation has been used to estimate or cross validate selection efficiencies and detector acceptance as well as possible backgrounds from secondary particles produced in the material surrounding the detectors.

The fluxes of proton and antiproton, electron and positron have been calculated and charge ratio estimated. Results are shown in Fig. 2 where the antiproton to proton ratio is shown along with the one of the positron to electron. For the first time these charge ratios have been investigated at energy larger than 50 GeV. Antiproton results are compatible with earlier data and do not show any clear deviation from a secondary production.

Positrons, instead, clearly show an excess at high energy; this can be due to dark matter particle annihilation in the galactic halo or to nearby sources, such as pulsar [4].

4. Conclusions

PAMELA is smoothly collecting data recording the largest antiparticle statistic in the energy range up to 100 GeV. So far $\sim 8 \times 10^9$ triggers have been registered allowing for precise measurement of cosmic-ray spectra over a wide energy range, candidating PAMELA to be a permanent cosmic ray laboratory in space.

REFERENCES

1. Picozza, P. *et al*, *Astropart. Phys.* **27**, 296–315 (2007).
2. Casolino, M. *et al*, *Two years of flight of the Pamela experiment: results and perspectives*, preprint at arXiv:0810.4980v1 [astro-ph].
3. Adriani, O. *et al*, *A new measurement of the antiproton-to-proton flux ratio up to 100 GeV in the cosmic radiation*, preprint at arXiv:0810.4994v1 [astro-ph], accepted for publication in *Phys. Rev. Lett.*
4. Adriani, O. *et al*, *Observation of an anomalous positron abundance in the cosmic radiation*, preprint at arXiv:0810.4995v1 [astro-ph], submitted to *Nature*.