The PAMELA Experiment on Satellite and its Capability in Cosmic Rays Measurements

The PAMELA collaboration [a]

[a] *Contact person: Samuele Straulino, INFN Florence, e-mail: straulino@fi.infn.it*

Abstract

The PAMELA equipment will be assembled in 2001 and installed on board of the Russian satellite *Resurs*. PAMELA is conceived mainly to study mainly the antiproton and positron fluxes in cosmic rays up to high energy (190 GeV for $\overline{\mathrm{p}}$ and 270 GeV for e^{+}), and to search antinuclei, up to 30 GeV/n, with a sensitivity of 10^{-7} in the $\overline{\mathrm{He}}$/He ratio. The PAMELA telescope consists of : a magnetic spectrometer made up of a permanent magnet system equipped with double sided microstrip silicon detectors ; a transition radiation detector made up of active layers of proportional straw tubes interleaved with carbon fibre radiators ; a silicon-tungsten imaging calorimeter made up of layers of tungsten absorbers and silicon detector planes. A time-of-flight system and anti-coincidence counters complete the PAMELA equipment. In the past years, tests have been done on each subdetector of PAMELA ; the main results are presented and their implications on the anti-particles identification capability in cosmic rays are discussed here.

1 Introduction

The PAMELA telescope, on board of the Russian satellite Resurs DK, will be launched in December 2002, and will enter a orbit at $350 \div 600$ km of altitude and 70.4° of inclination. These orbital characteristics will allow a mission life more than two year long, and will enable the telescope to investigate the Galactic component of cosmic rays close to poles, where the geomagnetic cut-off is lower. During its mission, PAMELA will detect positrons and antiprotons, allowing the measurement of the ratios $\overline{\mathrm{p}}\,/\,\mathrm{p}$ and $\mathrm{e}^{+}/\,(\mathrm{e}^{+}+\mathrm{e}^{-})$ with statistics never reached in balloon-borne experiments, which are limited by the effects of the overlying atmosphere and by the short duration of the flights. PAMELA should detect more than $10^4\ \overline{p}$ per year and more than $10^5\ \mathrm{e}^{+}$ per year. The information coming from all the sub-detectors is used to identify the particles and to measure their energy. Several beam tests have been done on PAMELA , the last one in July 2000 ; the main results of these tests, concerning the performance of each detector, are briefly presented in the following section.

2 Description of the apparatus and results obtained during beam tests

***Magnetic spectrometer*:** the magnetic system consists of five modules (up a total height of 445 mm) made of a magnetic material (a Nd-Fe-B alloy) with a high value of residual magnetic induction ($\sim$ 1.3 T). These modules have an internal rectangular cavity (132$\times$162 mm^2) that allows the passing of the particles; the field inside the cavity is $\sim$ 0.48 T at the centre. The total geometrical factor (or acceptance) of the instrument is 20.5 cm^{2}sr. The five magnetic modules are interleaved with six planes of double-sided silicon detectors, 300 μm thick. Six basic detecting units (53.3×70 mm^2) form each plane; each detector is segmented in microstrips on both sides and consists of a high resistivity $n-$type silicon wafer provided with p^+-type strips implanted on the junction side (X view) and n^+-type strips on the ohmic side (Y view). On the X view of the silicon wafer the strips direction allows to determine the particle position along its bending coordinate. Here the implantation pitch is 25 μm and the read-out pitch is 50 μm; however one can take advantage of the capacitive coupling between two adjacent strips to get a high resolution. In the magnetic field direction the strips are 67 μm apart. The decoupling capacitors are integrated directly on the silicon sensors. This geometry implies a total number 6144 electronics channels per plane. The signal–to–noise ratio, measured on several detectors, varies from 48 to 51 on the X view (see fig. 2) and from 23 to 24 on the Y view. The two components of the spatial resolution are $\sigma_X = 3.0 \pm 0.1$ μm (fig. 3), and $\sigma_Y = 11.5 \pm 0.6$ μm, and they allow to measure the charged particles up to a maximum rigidity of $\sim$ 800 GV/c. Actually the proton and electron spillover background sets an energy limit value of $\sim$ 200 GeV in antiproton and $\sim$ 300 GeV in positron measurements. A non–gaussian tail can be observed in figure 3: it is associated with high multiplicity events and could be explained with the emission of δ–rays.

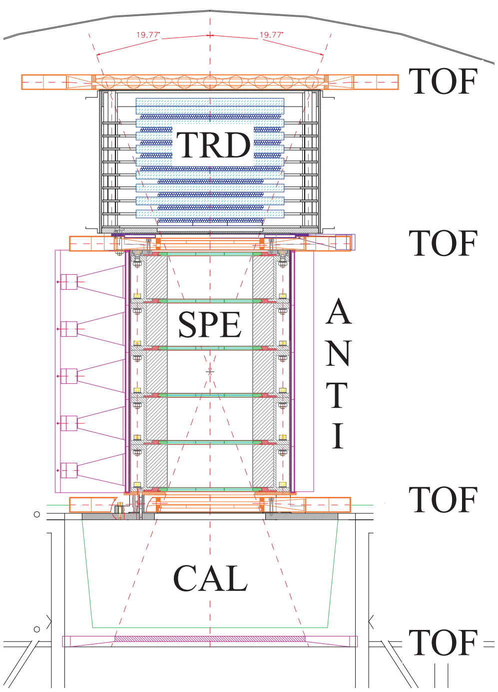

Fig. 1. *The* PAMELA *telescope (1050 mm high) consists of a transition radiation detector (TRD), a magnetic spectrometer equipped with silicon micro-strip detector (SPE), a silicon/tungsten calorimeter (CAL), a time-of-flight detector (TOF), and an anti-coincidence system (ANTI).*

***Electromagnetic imaging calorimeter*.** It is a sampling calorimeter, which utilizes silicon sensors planes, 240×240 mm^2 wide, and tungsten layers as absorber. Each detector plane consists of nine single-sided detectors 80×80 mm^2 wide and 380 μm thick, segmented in strips whose implantation

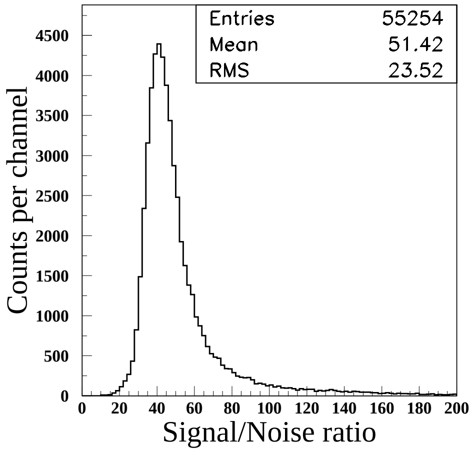

Fig. 2. *S/N ratio of the X tracker view.*

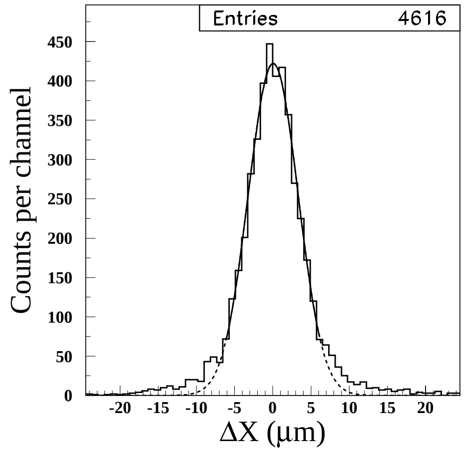

Fig. 3. *Spatial resolution of the X view.*

pitch is 2.4 mm. Two sensors provided with perpendicular strips and a 2.3 mm thick absorber layer are the basic elements that, in number of 22, form the sequence that constitutes the calorimeter. The total thickness of the calorimeter corresponds to 0.9 interaction lengths and 16 radiation lengths.

The front–end electronics is based on a chip, whose linear dynamic range is from 0.4 to 1200 MIP ; the total number of channels is 4416. The high granularity of this calorimeter allows a very good reconstruction of the particle shower in the sensitive volume, and allows to distinguish leptons from hadrons; this kind of detectors have been already tested and used for the WiZard collaboration's balloon flights (the last one was CAPRICE98). In July 2000 at SPS a test has been done, using an electron and pion beam. A prototype of the calorimeter, consisting of 5 views only, has been used. Figure 4, based on data gathered at SPS, shows the separation of electrons and pions at momentum 100 GeV/c, determined on the basis of the total number of hit strips and the total energy deposition. Doing an extrapolation of these results for the final configuration of the calorimeter, these performances are obtainable: an energy resolution better than 5 % in the range $20 \div 100$ GeV (and ~ 6.5 % at 250 GeV); a rejection power of 10^4 for protons and electrons in antiproton and positron measurements (selection efficiency 95 %).

Transition Radiation Detector : This detector can select different types of particles, providing high speed particles' identification. The TOF of PAMELA can separate $p(\overline{p})$ from $e^+(e^-)$ up to ~ 1.5 GeV. The TRD is able to increase the energy range of hadrons and leptons separation up to energies of several hundreds GeV. The PAMELA TRD has a modular structure, formed by 9 radiator fibre planes interleaved with straw tubes. The radiators are cushions of carbon fibre, whose density of 60 g/l has been considered suitable to optimize the radiation yield. 1024 straw tubes in proportional regime ($\oslash$ 4 mm), 280 mm long and filled with a gas mixture (80% Xe, 20% CO_2) are the sensitive element. An on–board storage of 1500 l of gas has been planned, to ensure the TRD a life as long as the duration of the flight. The pulse–height measurement technique has been used to measure the transition

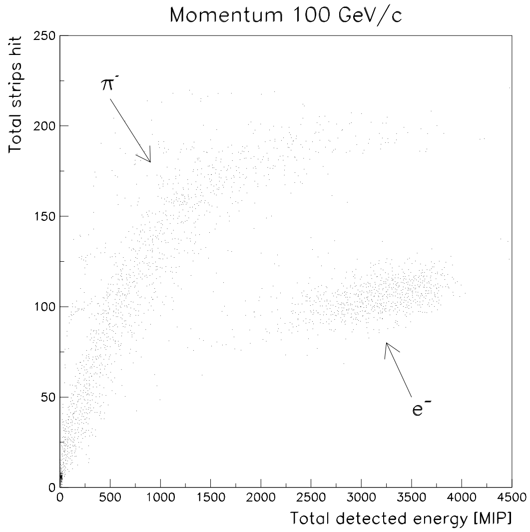

Fig. 4. *Separation between electrons and pions (both with momentum 100 GeV/c) in the calorimeter, obtained reporting the number of hit views as a function of the total energy deposition.*

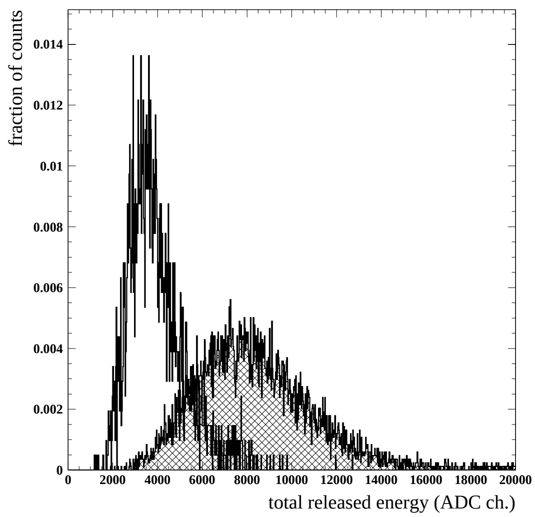

Fig. 5. *Distributions of total energy released in the TRD for electrons (shaded region) and pions, both with momentum of 40 GeV/c.*

radiation.
At Cern a pion and electron beam has been used to study the detector's capability to identify the particles. The results obtained for 40 GeV/c e^- and π are shown in fig. 5, where distributions of the energy released in TRD by these particles are reported. When the electrons selection efficiency is 90 %, the $\pi-$contamination is about 7 % at this value of the momentum.

3 Conclusions

The PAMELA apparatus is completely designed and will be assembled in the next months. Tests have been done in order to study both the physical performance of the detectors and the adequacy of the system to a mission on a satellite.
The results of the tests are encouraging and the observed capability meets the scientific requirements for observations of antiparticle and particle spectra.

References

The PAMELA collaboration 1999, Proc. 26th ICRC (Salt Lake City), OG.4.2.04
M.L. Ambriola et al. 1999, Proc. 26th ICRC (Salt Lake City), OG.4.1.05