STATUS OF THE PAMELA EXPERIMENT FOR THE STUDY OF COSMIC ANTIMATTER IN SPACE

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ABSTRACT

The PAMELA experiment is mainly devoted to the antiproton and positron flux measurements in cosmic rays, with large statistics in an energy range between 100 MeV and 100 GeV, and to the search for antinuclei, up to 30 GeV/n, with a sensitivity better than 10^{-7} in the $\overline{\mathrm{He}}$/He ratio. The PAMELA telescope will be installed on–board of the russian Resurs–Arktika satellite to be launched in the 2000 for a mission at least 3 years long. The orbit satellite is polar, sun–synchronous and 700 km high: the peculiarity of this orbit will allow also to study several items in Astrophysics, Solar–Physics and Earth–Physics. In this paper the status report of the PAMELA project is presented.

INTRODUCTION

The PAMELA experiment (Adriani, 1995) is a part of the Russian Italian Mission (RIM) which consists of several space missions for different researches. The first step (RIM–0/1 and RIM–0/2) is the Si–eye–1/2 experiment, on board of the russian MIR Station, consisting of silicon sensors to study the particles producing light flash seen by astronauts. The RIM–1 studies low energy cosmic rays, by means of a telescope (called NINA, Barbiellini, 1995) made by 32 silicon detector planes, and it will fly in 1997 as "piggy–back" of the Resurs–4 russian polar orbit satellite. The RIM–2 mission is the PAMELA experiment and the RIM–3 project, called GILDA (Morselli, 1995), is also foreseen to study cosmic gamma rays at high energy.

The PAMELA telescope will be installed on board of the russian Resurs–Arktika satellite and will be launched in the 2000. The 700 km high and sun-synchronous polar orbit allows a long life of the satellite and, close to the poles, permits also the study of cosmic rays at low energy.

are the accurate measurements of the antiproton and positron fluxes from 100 MeV to energies above 100 GeV and the search of antihelium with a sensitivity better than 10^{-7} in the $\overline{\mathrm{He}}$/He ratio. In Table 1 are reported the expected rates in about 3 years. Profitting of the peculiarity of the orbit before and after the maximum of the 23rd solar activity cycle, additional research objectives can be addressed: solar modulation of cosmic rays in the heliosphere; solar flare particle spectra; distribution and acceleration of solar cosmic rays; stationary and disturbed fluxes in the Earth's magnetosphere; anomalous component of cosmic rays.

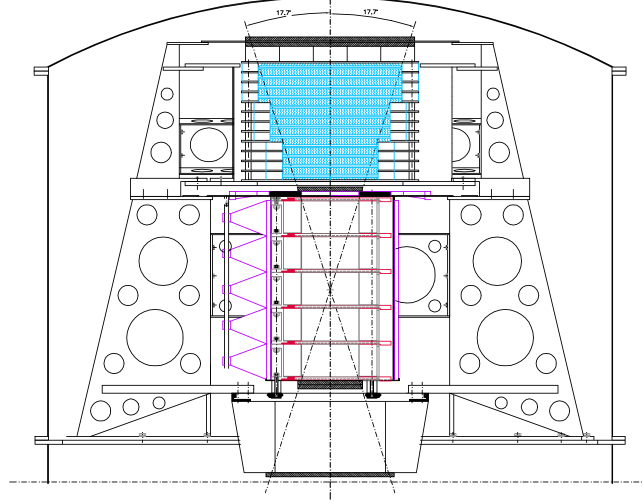

Fig. 1: The PAMELA telescope.

protons	3×10^8	antiprotons	$\geq3\times10^4$	electrons	6×10^6
positrons	$\geq3\times10^5$	He nuclei	4×10^7	Be nuclei	4×10^4
C nuclei	4×10^5	antinuclei limit	7×10^{-8}		

Table 1: Expected rates in PAMELA in 10^8s

THE PAMELA TELESCOPE

The PAMELA telescope (see Figure 1) is about 1 m high and consists of:

- a permanent magnet equipped by a tracker based on microstrip silicon detectors to measure the particle momentum;
- an imaging calorimeter based on silicon detectors and tungsten absorbers to measure the energy released by the particles and to identify their nature by their interactions inside the calorimeter volume;
- a Transition Radiation Detector (TRD) to identify electrons and positrons;
- a plastic scintillator system to give the first level trigger and the time of flight of the particles through the telescope;
- several scintillation anticoincidence counters surrounding the magnet for a better magnet entrance definition and for shielding the tracker from particle showering in the magnet itself.

The Maximum Detectable Rigidity (MDR) is 400 GV/c, the acceptance of the experiment is about 21 cm^2 sr, the weight is less than 400 kg and the electrical consumption less than 300 W.

PRESENT STATUS OF THE PAMELA PROJECT

The realization of prototypes are foreseen for each sub–detector and for the mechanical structure of PAMELA, to verify performances and space qualification requirements (vibrational, thermal and EMI/EMC tests). Some of these prototypes and tests has been already realized and other are in progress.

Magnetic spectrometer

The general scheme of the magnet system consists of five modules, each one 81 mm high, interleaving six frame 8 mm high, in which the silicon sensors are accommodate. The total height of the spectrometer results 445 mm with a rectangular cavity 130×160 mm^2 corresponding to a geometrical factor of induction ($\sim$ 1.3 T). The field inside the spectrometer results 0.4 T in the center, and outside the spectrometer the field is screened by a ferromagnetic shield. At the present one magnetic module has been built as prototype and tested. Both mechanical and magnetic performances gave results in agreement with expectations and in the next future the whole magnetic system will be manufactured. A view of the magnetic spectrometer is shown in Figure 2.

Inside the spectrometer are inserted six detector planes composed by 3 ladders, each made by 2 silicon sensors, 70×53.33 mm^2 and thickness of 300 μm, and by an aluminium oxide hybrid 5 cm long, containing the front end electronics. Each ladder is stiffened by means of 2 carbon fiber bars, precisely glued on the lateral sides of the ladder. This mechanical configuration minimize the thickness of material crossed by the particles, reducing the effect of the multiple scattering in the momentum measurement, consisting only by the silicon sensor thickness. The mechanical simulation of vibration and shock on this structure during the launch phase shows a good behaviour and laboratory tests are in progress to confirm these calculations.

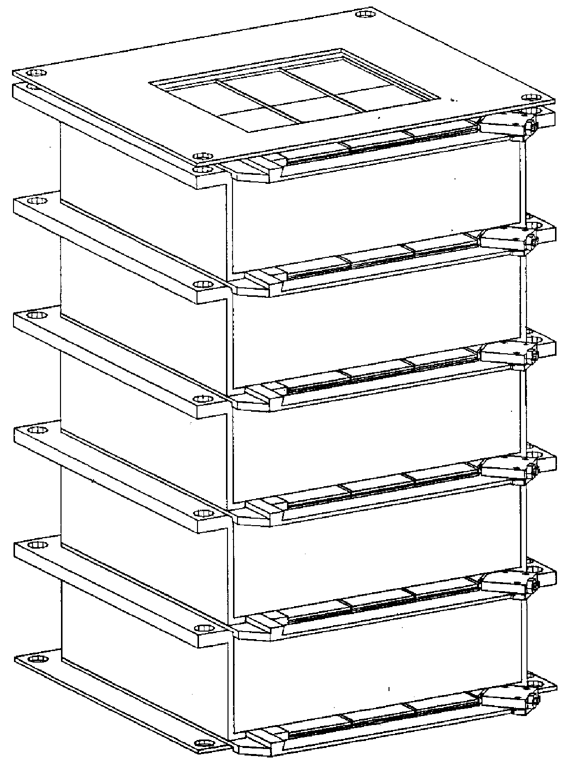

Fig. 2: The PAMELA spectrometer.

The silicon sensors are double sided double metal AC coupled, to avoid the use of external decoupling capacitors and kapton fanout. The p^+ strips are used to measure the X coordinate to have the best spatial resolution on the bending plane; the implantation pitch is 25 μm, and the readout pitch 50 μm, taking advantage of the capacitive coupling between adjacent strips. On the ohmic side the implant pitch is 67 μm with the doyble metal strips parallel to the junction's ones. The total number of readout lines in one ladder is 2048 and, for the whole tracker, we have $2048\times3\times6$=36864 channels.

As a preliminary study, during november 1996, a system composed of three ladders completed by their electronics was exposed into a beam test at the PSI using MIP pions and non–MIP protons. The measured performances results well inside the requirement of the PAMELA experiment. In particular the signal to noise ratio is about 30 in the bending view and 20 in the non–bending view. With these detector characteristics the spatial resolution in the bending view will be equal or better than 7 μm (value required by the PAMELA project) resulting in a MDR larger than 400 GV/c.

The Transition Radiation Detector

The TRD consists of 9 layers of straw tube modules interleaving carbon fiber radiators which fill completely the gaps between the tubes. The whole detector is 270 mm high with 1024 total number of channels. The carbon fiber density is fixed to 60 g/l and the straw tubes are 300 mm long, with a diameter of 4 mm, filled with Xe/CO_2 gas mixture. The tests on the gas leakage show that a total storage of 1500 l of Xe/CO_2 gas ensures a TRD life at least 3 years. In a beam test at the CERN with four modules of straw tubes and carbon fiber radiators, the processing signals from the detectors with analog readout has been compared with the cluster counting technique. The analog readout showed a better discriminator capability between "fast" and "slow" particles. The rejection power of the PAMELA

The calorimeter

It is a sampling calorimeter made by silicon sensor planes interleaved by tungsten absorbers. In the Figure 3 is shown the modularity configuration of the PAMELA calorimeter. The external calorimeter dimensions are 484×483×204 mm^3. The sensitive area of one detector plane is 240×240 mm^2 and it consists of a 3×3 matrix of single sided silicon detector 80×80 mm^2, each one divided in strips with a pitch of 3.6 mm. This high granularity permits a very good path reconstruction of the particle energy released in the calorimetric volume. The thickness of the silicon sensors is 380 μm and that of the absorber tungsten layers is 2.3 mm corresponding to 0.7 X_0. The whole calorimeter is made by 46 detector layers (23 for the X view and 23 for the Y view) and 22 absorber layers. The performances of this kind of calorimeter in particle identification and energy measurement is well studied using both beam test and balloon flights experiments in the context of the WIZARD balloon program (Bocciolini, 1996). An accurate simulation of the described calorimeter has been performed tuning the simulated parameters with the real data. The main results of this simulation are a resolution in the electron and positron energy measurement better than 5% in the range 20–100 GeV (and ~6.5% at 250 GeV) and a rejection power of protons and electrons in the positron and antiproton identification better than 10^4.

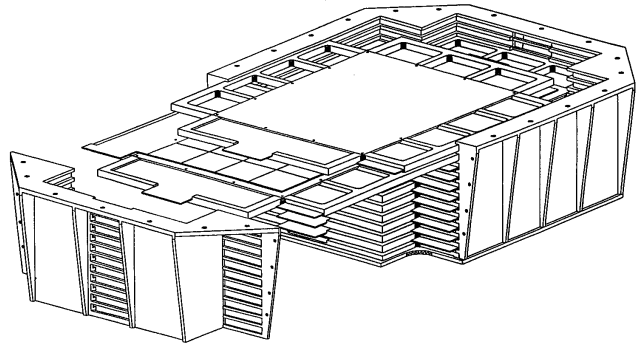

Fig. 3: Main structure of the calorimeter

CONCLUSIONS

The work for the PAMELA telescope construction is in progress and the flight is already scheduled and guaranteed by agreement. The characteristics of the experiment and of its orbit give a good opportunity to study many items of cosmic rays physics and in particular to study accurately the positron and antiproton fluxes in a large energy range. In Figure 4, as an example, is shown the antiproton identification capability of PAMELA compared with the main background duo to electrons. Analogous situation exist for the rejection of protons in the positron identification. The 3 years flight duration foreseen for the Resurs–Arktika satellite should allow to gather enough statistics to measure the antiproton and positron fluxes up to energies larger than 100 GeV.

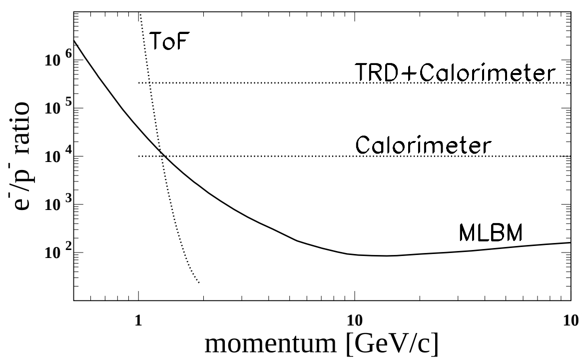

Fig. 4: PAMELA electron rejection power in the $\overline{p}$ measurement compared with the expected cosmic ray ratio of $e^-/\overline{p}$ from the Modified Leaky Box Model. The PAMELA apparatus is enable to well discriminate the antiproton component in all the energy range.

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