Secondary electron and positron fluxes in the Earth magnetosphere near the geomagnetic equator

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Abstract— **Measurements of electron and positron fluxes in energy range from 80 MeV to several GeV (below the geomagnetic cutoff rigidity) were performed using the PAMELA spectrometer onboard the Resurs-DK satellite. It has been launched on June 15th 2006 on an elliptical orbit (the inclination is 70.4°, the altitude is 350-600 km). The main goal of the experiment is precise measurements of an antiparticle component: antiprotons (in energy range 80 MeV-190 GeV) and positrons (in energy range 50 MeV-270 GeV). Particle rigidity, charge and type are determined with the three main detectors of the spectrometer - the silicon tracker with a permanent magnet, the time-of-flight system based on scintillation detector and the electromagnetic calorimeter. The work presents measurements of secondary electrons and positrons in the Equatorial region. These results are particularly interesting for more precise definition of electron/positron flux model in the Earth magnetosphere.**

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1. Introduction

First papers concerning electrons and positrons in the near Earth space appeared in scientific journals more than 50 years ago. Since then numerous experimental results onboard different satellites have been obtained and flux forming mechanism was discussed. In particular in [1] it was suggested that electrons and positrons under the radiation belt have a secondary origin. Namely cosmic ray protons interact with the Earth atmosphere and produce pions that decay throw $\pi^{\pm}\rightarrow\mu^{\pm}\rightarrow e^{\pm}$ chain. Production cross-section of π^{+} is 1.5 – 2 times more than π^{-}, so we should observe a positrons prevalence in the equatorial region. Numerous experimental works [2,3,4,5 and references therein] confirmed the main conclusions of the model.

This work presents some results of the PAMELA experiment obtained within the first three months of its working.

2. The PAMELA Instrument

The spectrometer [6] consists of a Time-of-Flight system (TOF), an anticoincidence system (CAS, CARD, CAT), a magnetic spectrometer, an electromagnetic calorimeter, a shower tail catching scintillator (S4) and a neutron detector (fig. 1). The main trigger system is TOF composed of 6 layers of segment plastic scintillators.

An acceptance is about 21.6 cm^{2}sr (in case of S1×S2×S3 trigger configuration), a magnetic field intensity is 0.4 T, a position track determination accuracy is about 4 μm, a time-of-flight accuracy is about 350 psec. The instrument is approximately 120 cm high, has a mass of about 470 kg and power consumption 355 W.

Using of the TOF system, the magnetic spectrometer (composed of a permanent magnet and a set of silicon plaines)

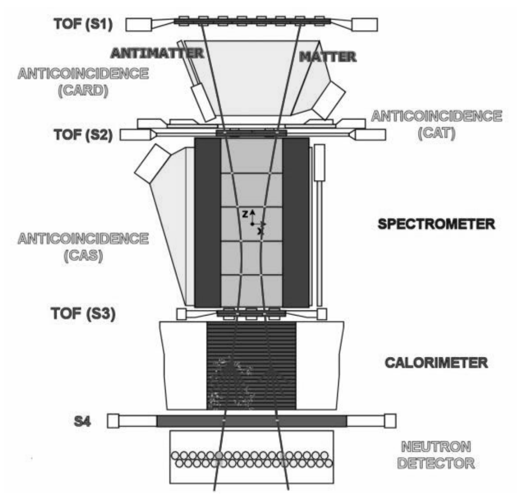

Figure 1. Sketch of the PAMELA instrument

and additional analysis of the calorimeter information allows extracting leptons and measuring their energy (from 50 MeV to several hundred GeV) effectively.

The spectrometer is set onboard a Resurs-DK1 satellite with elliptical orbit (altitude is 350-600 km, inclination is 70^0). The main axis of PAMELA points to a local zenith. Such an orbit characteristics allow measuring particles with pitch angles about 90^0 in the equatorial region.

3. DATA ANALYSIS

For each trigger event the following parameters were measured or calculated: number of tracks and energy losses in the magnetic spectrometer; rigidity and the track length (by fitting the track in the magnetic field [7]); time of flight. A particle velocity (β) was calculated using the time of flight and the track length.

As the first step of our analysis so-called "good" tracks were extracted from all scientific information. The following rules were applied:

1. A single track in the magnetic spectrometer;
2. The particle should move in the forward direction (from S1 to S3).

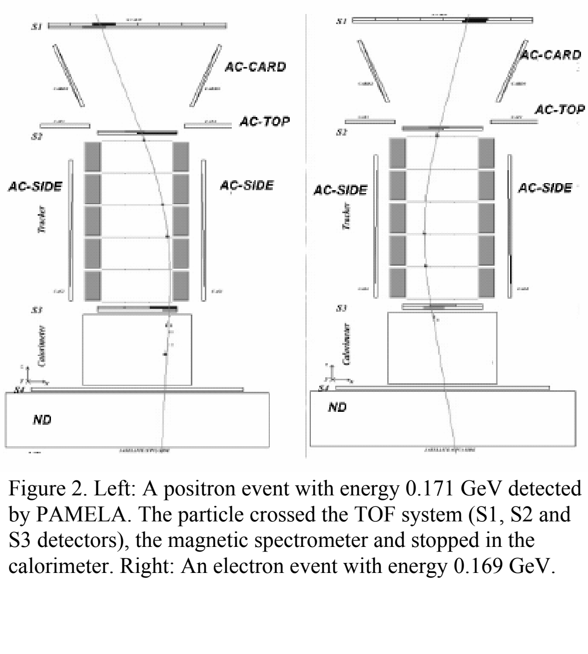

Figure 2. Left: A positron event with energy 0.171 GeV detected by PAMELA. The particle crossed the TOF system (S1, S2 and S3 detectors), the magnetic spectrometer and stopped in the calorimeter. Right: An electron event with energy 0.169 GeV.

Then electrons and positrons were identified using information about energy losses in the spectrometer and the electromagnetic calorimeter, particle velocity and a rigidity sign. The pions contamination for the selection is less than 1%.

Examples of events extracted in this way are in the Figure 2 (a positron event with energy 0.171 GeV and an electron event with energy 0.169 GeV). Note the opposite curvatures that allow identifying a charge sign of a particle.

Using known geographical coordinates and PAMELA orientation in each point the geomagnetic coordinates were calculated for every registered events. For the calculation the model IGRF'05 of the Earth magnetic field was used. We analyzed electron and positron fluxes in the equatorial region (L<1.2 and B>0.23). The South Atlantic Anomaly was rejected.

4. RESULTS

In the article preliminary results of the PAMELA experiment are presented. The only data from August till September 2006 were proceeded.

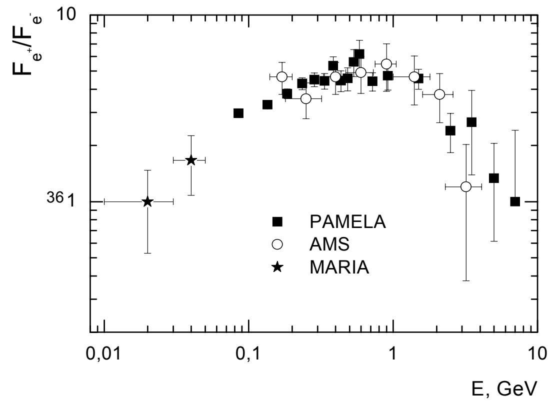

Figure 3. Positron to electron ratio in the equatorial region (L<1.2 and B>0.25)

In the Figure 3 dependence of e^+/e^- ratio on particle energy for the equatorial region below the Earth radiation belt is presented. We can see that e^+/e^- ratio depends on particle energy and reach to about 5 for energy region from 300 to 800 MeV. So in the region positrons predominate over electrons.

This result is in a very good agreement with the AMS [5] and MARIA [3] data. But the statistics and wide energy range of the PAMELA's data allow detailing of obtained energy dependence.

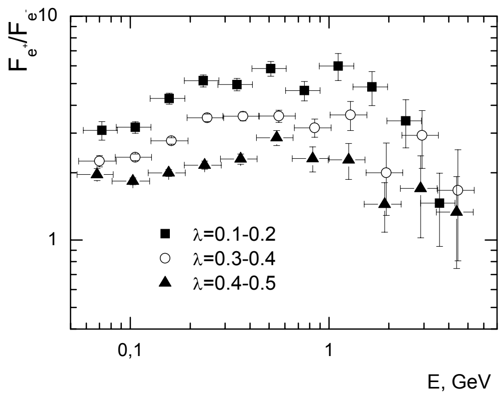

Figure 4. Positron to electron ratio for different geomagnetic latitudes

In the Figure 4 a detail dependences of positron to electron ratio for different geomagnetic latitudes are presented. Analysis of this latitudinal dependence shows that positron to electron ratio decreases for high latitudes. Such results can be explained by different conditions of particle creation and propagation in the different regions of the near Earth space [8].

6. CONCLUSION

In spite of the fact that the experimental results presented in the paper has been obtained using only the first three months of PAMELA working, they can be used to detail electron and positron generation model for particle energy range from 100 MeV to several GeV in the equatorial region due to a very good statistics.

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