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The high energy cosmic ray particle spectra measurements with the PAMELA calorimeter

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Abstract

Up until now there has been limited, contradictive data on the high energy range of the cosmic ray electron-positron, proton and helium spectra. Due to the limitations of the use of a magnetic spectrometer, over 8 years experimental data was processed using information from a sampling electro-magnetic calorimeter, a neutron detector and scintillator detectors. The use of these devices allowed us to successfully obtain the high energy cosmic ray particle spectra measurements. The results of this study clarify previous findings and greaten our understanding of the origin of cosmic rays.

Keywords: Cosmic ray; electrons and positrons; protons, helium, calorimeter

1. Introduction

Study of high energy cosmic ray particles in satellite experiments is one of the main tasks in modern astrophysics. Cosmic ray electrons with energy more than 10 GeV carry important information about their origin and propagation through interstellar space. The energy spectra of cosmic ray electrons is known to be

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affected by the inverse inverse Compton effect, synchrotron emission and possible dark matter particles. During propagation the time of energy losses for 1 TeV electron is about 10^5 years corresponding to 1 kps. Due to these significant energy losses the electrons are not able to cover distant areas from their sources. The direct measurement of positron and electron spectra in cosmic ray with satellites in space should help to improve existent models as well as create a new one that describes the processes of electron-positron generation and propagation. Today just 3 satellites are taking measurements of electron-positron fluxes - they are Fermi [1], AMS-02 [2] and PAMELA [3]. In ground based experiments (HESS [4], Kabayashi et al. [5]) the abrupt falling or cutoff in the electron-positron spectrum have been demonstrated at energies higher than few hundred GeV. But resent satellite experiments Fermi [6] and AMS-02 [7, 8] do not show this behaviour.

Up to now experimental results of proton and helium energy spectra measurements agree that proton and helium spectrum slopes are different [9, 10, 11, 12, 13, 14], that became more obvious in TeV region, but different experiments disagree in the value of this difference. Regardless of the value of the difference, the nature of such a difference remains unknown.

The use of a calorimeter would extend the measured energy range in the PAMELA experiment. Thus allowing for the clarification of previous studies.

2. The PAMELA experiment

The PAMELA experiment was put into space on board of the Resurs DK1 satellite from the Baikonur Cosmodrome on June 2006. It was designed to study the composition and energy spectra of cosmic ray particles in a wide energy range in near-Earth space. The PAMELA instrument (a total mass is 470 kg) consists of several specialized detectors as shown in Fig.1: a permanent magnet equipped with the silicon tracking system, a time of flight (ToF) system made of three double planes, anticoincidence counters, a neutron detector (ND), a bottom shower scintillator detector and a tungsten/silicon sampling electromagnetic calorimeter.

The sensitive elements in the ND [15] are the He^3 neutron counters 18.5 mm in diameter and 200 mm sensitive length. The counters recording neutrons by a reaction $He^3 + n \longrightarrow H^3 + p$ are mainly sensitive to the thermal neutrons (cross section more than 5000 barns). Two layers of 18 counters (36 pieces in total) are placed into the polyethylene moderator. One polyethylene block 2 g/cm^2 thick is above the upper layer of counters, similar block is between the upper and the bottom layer of

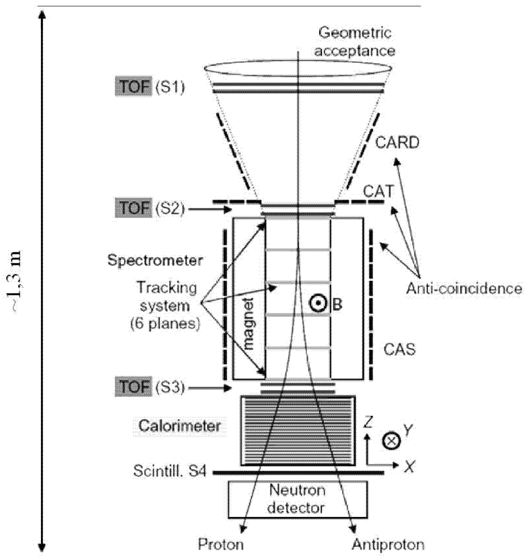

Figure 1: The PAMELA instrument.

counters, and 6 g/cm^2 of polyethylene are beneath. The Cd shield 0.5 mm in thickness envelopes the ND from the bottom and the sides. The ND is mounted under the S4 scintillator.

The total calorimeter [16] thickness is 16.3 radiation lengths and 0.6 nuclear interaction length. The calorimeter is composed of 44 silicon layers (SSD)interleaved by 22 tungsten plates with a thickness of 0.26 cm thick. Each silicon plane is 380μm thick and segmented in 96 strips with a pitch of 2.4 mm. 22 planes are used for the X view and 22 for the Y view in order to provide topological and energetic information about the showers produced inside the calorimeter. The ToF system [17] comprises six layers of fast plastic scintillators arranged in three planes (S1, S2 and S3). Each detector layer is segmented into strips, placed in alternate layers orthogonal to each other. The distance between S1 and S3 is 77.3 cm.

The magnetic spectrometer allows the energy of incident protons and helium nuclei to be precisely measured up to about 1 TeV/nucleon while the energy of electrons up to 600 GeV. However, the measurements of the spectra can be extended to higher energies by using the calorimeter information.

3. The method for electron-positron spectrum measurement

The electron-proton separation method for the calorimeter depends on an incident angle. It has been