Galactic deuteron spectrum measured in PAMELA experiment

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Abstract. Results of galactic deuteron spectrum measurement by means of PAMELA apparatus are described. PAMELA is an international experiment developed for antimatter search and measurement of p, He, electron and positron spectra in wide energy range. In addition, PAMELA allows to identify and measure deuteron spectrum at low energies. In this paper deuteron-to-proton ratio and deuteron spectrum are presented.
1. INTRODUCTION
The PAMELA detector [1] is a magnetic spectrometer equipped with a time-of-flight (TOF) system and a calorimeter. It also comprises a shower tail catcher scintillator and a neutron detector. The active volume of the spectrometer is covered with an anticoincidence system.

![Figure 1. Schematic view of PAMELA apparatus.](image)

The permanent magnet produces a homogeneous magnetic field with an average induction of 0.43 T inside the work space with dimensions of $13.1 \times 16.1 \times 43.7$ cm [2].

Tracker is installed in the magnetic field. It consists of six position-sensitive detectors in the form of thin (300 $\mu$m thick) double-sided microstrip silicon wafers used to measure both the particle trajectory in the magnetic field and ionization losses dE/dx. The coordinate accuracy is 3.0 $\mu$m for the bending view and 12 $\mu$m for the perpendicular view. Based on the measured curvature of the particle trajectory in the magnetic field, the particle rigidity is reconstructed. Rigidity is the ratio of particle momentum to its charge.

The TOF system consists of three scintillator detectors: S1 is at the top of the instrument, S2 is above the magnetic spectrometer, and S3 is at the top of the calorimeter. Each detector consists of two detecting planes consisting of paddles by such a way that the strips of adjacent planes are orthogonal. The end faces of the paddles are viewed by photomultiplier tubes. The thickness of detectors S1 and S3 is 7 mm, the thickness of S2 is 5 mm, and the spacing between detectors S1 and S3 is 77.3 cm [1]. The TOF system is used to measure the time of flight and arrival direction of particles in the instrument, and its time resolution is 250 ps. Each scintillator detector is capable to measure the ionization losses of particles passing through it.

The anticoincidence system rejects the events when particle passes beyond the magnetic spectrometer aperture.

Detection of events and recording of data into the memory are triggered by the signal produced when the signals of three TOF detectors coincide. The detectors of the PAMELA spectrometer are described in more detail in [1–3].

In this paper, deuteron identification method and results of galactic deuteron spectrum reconstruction in energy range 50 - 650 MeV/n are shortly described.

2. IDENTIFICATION
Responses of different detectors, which depend on the characteristics of detected particles, are used in the PAMELA experiment to discriminate deuterons from other particles.
For deuteron identification the special method was developed. It was described in detail in [4]. Some improvements of this method were implemented and are presented here. This improvements allows to enhance proton suppression and decrease systematic errors in calculation of number of deuterons.

First of all, truncated mean value of energy losses in tracker was used for deuteron separation instead of usual mean value. Truncation of energy measurements (vetoing of few maximum values) allows to make distribution of energy losses more “Gaussian” and more narrow and therefore to improve the different particles peaks separation.

Secondly, dE/dx values from six detectors of TOF system were used (instead of one value in original methodic [4]). This addition gives an opportunity to improve proton suppression.

At last, 1/β distributions (instead of mass to charge square distributions) for calculation of number of deuterons is preferable to use because it is “more” Gaussian than for other variables.

3. EFFICIENCY CALCULATION
It’s important to know the efficiency of particle selection to reconstruct spectrum. Efficiency was calculated using flight data by following way. Since few detectors were used for particle identification it is possible to use cross-detector efficiency determination. It means that, for example, the efficiency of TOF system can be calculated by analysis of tracker and AC system data. Some particles (e.g., deuterons) were selected from full data sample with help of procedure as described above, but with important addition: selection was made only by tracker and AC system, TOF system basic criteria and particle selection were discarded. The last steps were the implementation of TOF system basic separation criteria and efficiency calculation.

Efficiency of tracker system and AC system were calculated by in a similar manner.

Final apparatus efficiency was calculated by multiplication of AC, TOF and tracker systems efficiencies.

4. RESULTS
Finally, galactic deuterons spectrum and deuteron to proton ratio were reconstructed (Figure 2 and Figure 3, respectively). It can be seen the good agreement between the data obtained by PAMELA experiment and the results of some other experiments.
Figure 3. Galactic deuteron to proton ratio.

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