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Energy characteristics of Forbush decreases for different types of heliospheric disturbances according to muon hodoscope URAGAN

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Abstract

Experimentally obtained energy characteristics of the muon flux during Forbush decreases registered by means of the muon hodoscope URAGAN at different phases of 23rd and 24th solar cycles are studied. To obtain the energy spectra of Forbush decrease amplitudes in the flux of the primary particles, coupling functions of the primary and the secondary cosmic ray fluxes for five zenith-angular intervals of the muon hodoscope URAGAN were used. It is shown that the energy characteristics of Forbush decreases, caused by heliospheric disturbances of different types, significantly differ on phases of maximum and minimum of the solar cycle.

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Keywords: Forbush decrease, muonhodoscope,cosmic rays ;

1. Introduction

Forbush decrease (FD) represents a sharp decrease in the intensity of cosmic rays (CR), caused by deviation of the charged particles by interplanetary magnetic field in homogeneities associated with the shock wave in the solar wind. FD is a shining example of the impact of solar activity on the CR and can serve as a good tool for the study of the processes occurring in the interplanetary space. Studies of the energy characteristics of Forbush decreases are mainly conducted via a network of neutron monitors with different geomagnetic rigidities, positioned at different points of the globe. The possibility to solve this problem by using a single installation is provided by the muon

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hodoscope (MH) URAGAN [1], which has a wide aperture and a high angular resolution (~ 1°) and is able to detect muons at different zenith angles, enabling to conduct research in a wide range of primary particle energy (at energies above 10 GeV). Studies of the FD energy characteristics in the 24th solar cycle are relevant in connection with the unusually low solar activity during this period.

In this work we investigate the temporal changes of the energy characteristics of the amplitude spectra of Forbush decreases obtained according to the muon hodoscope URAGAN data for different types of heliospheric disturbances during the period of 2007 – 2013, covering in part 23rd and 24th solar cycles. An earlier research method was tested by Yakovleva E.I. *et al.* [2].

2. Experimental data of the muon hodoscope URAGAN

MH URAGAN design and data collection system allow measuring nearly continuous zenith-angular distribution of the muon flux at the Earth's surface with a sufficiently small sampling interval of time (1 minute). Fig. 1 shows the dependence of the number of registered events on the zenith angle, normalized to the total number of events for all zenith angles for the three supermodules (SMs) of the muon hodoscope URAGAN. As can be seen from the graph, the functions for all SMs are almost identical. Detector counting rate per interval of zenith angle increases to 30° (although the flux is reduced, but the solid angle increases), and then decreases.

For the analysis of the amplitude spectrum index of FD it is necessary to split the total range of zenith angles into several intervals. They must have approximately the same statistical reliability. Selected five zenith-angular intervals are [0° - 17°), [17° - 26°), [26° - 34°), [34° - 44°) and more than 44°. Corresponding areas are shown in Fig. 1 by the vertical lines and marked by the numbers.

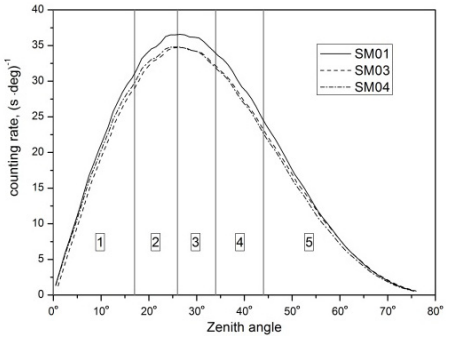

Fig. 1. The dependence of the SM URAGAN counting rate on zenith angle ($\Delta\theta = 1°$).

Fig. 2 shows the time dependence (2007 - 2013) of the integrated counting rate of three SMs for the five selected intervals of zenith angle. For the analysis of FD, muon flux data corrected for the barometric and temperature effects [3] are used.

Fig. 3 shows an example of registration of FD in two extreme ranges of zenith angles, changing the counting rate in other three intervals lie between them. We see a good similarity of dependences for different angles, and the amplitude of FD with increasing zenith angle decreases, due to an increase in the effective energy of the primary particles. This enables to study the dependence of the amplitude drop of the detector counting rate during the FD on the primary particle energies.

The sensitivity of the data obtained by the muon hodoscope to the index of the CR energy spectrum is explained by the fact that the primary particles with different effective energies are responsible for the production of muons recorded at different zenith angles. Thus, by selecting a few ranges of zenith angle and defining for them the appropriate energy of the primary protons and amplitudes of the Forbush decrease it is possible to estimate the slope of the energy spectrum of the counting rate reduction in the analyzed period. This paper analyzes the 10-minute data for integral counting rate and for the five selected ranges of zenith angles. From an analysis of the integral counting