Analysis of Continuous Cosmic-Ray Measurements in Belgrade

J. Puzović,[1] A. Dragić,[2] V. Udovičić,[2] D. Joković,[2] R. Banjanac[2] and I. Aničin[1]
(1) Faculty of Physics, University of Belgrade, Belgrade, Serbia and Montenegro
(2) Institute of Physics, Belgrade, Serbia and Montenegro

Abstract

The two identical plastic scintillator detectors were used for continuous monitoring of cosmic-ray intensity during the whole of the last year. Muon ΔE spectra were obtained simultaneously from the first detector situated on the ground level and from the second one at the depth of 25 m.w.e. in the underground laboratory.

1. Introduction

In the present paper preliminary results of cosmic-ray muon intensity measurements for year 2002 in Belgrade (44.8^{o}N, 20.4^{o}E) laboratory are reported. Muons are detected with two identical plastic scintillator detectors. One of them is situated on the ground level, while the other is in the underground laboratory at the depth of 12m (25 m.w.e.)[1].

Fluctuations of muon intensity during the year 2002 are studied. Autocorrelations of the data from both detectors, as well as their cross-correlations are calculated. Also, power spectra analysis in the frequency region $3.2 \cdot 10^{-8} Hz < \nu < 1.4 \cdot 10^{-4} Hz$ is performed. Comparison of cosmic ray fluctuations with data from some neutron monitors is given.

2. Experimental setup

Cosmic-ray muons are detected by two identical plastic scintillator detectors of prismatic (50cm x 23cm x 5cm) shape. Detectors are produced by the High Energy Physics Laboratory of JINR, Dubna, and are similar to NE102. Each detector lies horizontally on its largest side and single 5 cm photomultiplier watches its long side (50cm x 5cm) via a correspondingly shaped light guide. Recorded spectrum is thus mainly the muon ΔE spectrum. At the conversion gain of 4K ground level detector has a well defined maximum around the 180$^{\text{th}}$ channel at about 11 MeV, and assuming linearity, stretches to about 200 MeV of deposit energy. Monte Carlo simulation of this ΔE spectrum, assuming $\cos^2\theta$ distribution and a specific energy loss of 2 $MeV g^{-1} cm^{-2}$, as well as the Landau treatment of

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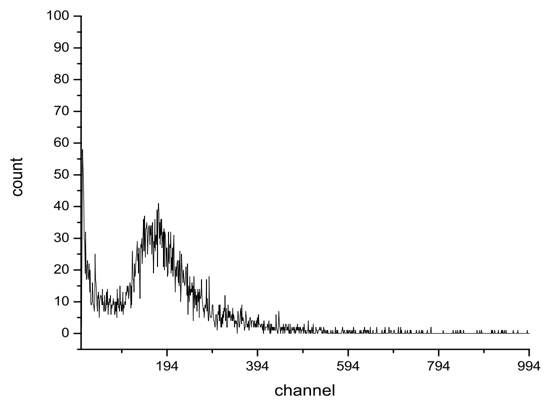

Fig. 1. A typical 5 min spectrum of the underground detector.

energy loss fluctuations, agrees very well with the experimental spectrum. The simulated spectrum differs from the experimental one only at high energies, where the experimental spectrum is seen to be richer. The reason for this is most likely the simultaneous detection of several shower particles, a process not included in the simulation. Also, departure of muon distribution from the $\cos^2\theta$ law at large zenith angles might contribute to some extent.

The integrated counting rate is about 18 *cps*, corresponding to a muon flux of 160 $m^{-2}s^{-1}$. At the same time the counting rate of underground detector is about 5 *cps* (muon flux 45 $m^{-2}s^{-1}$).

The 4K channel spectra are registered every 5 *min*, with 270 *sec* dedicated to measurements and 30 *sec* being allowed for the recording of the spectrum and some quick interventions on the system. A typical spectrum of the underground level detector is presented in Figure 1.

The problem of long term stability of high voltage (and temperature in the ground detector environment) makes it difficult to take full advantage of spectral energy loss measurements. For that purpose, the optical pulsing system for regular checking of the calibration is under construction.

3. Results and Discussion

The data from the two detectors for the year 2002 are studied for fluctuations in muon flux intensity. In Figure 2 data from both detectors, averaged over period of 8 hours, for entire year 2002 are plotted in form of deviation from the mean value. For comparison, data from Oulu neutron monitor station are also plotted.

Typical intensity change is smaller than the one observed in neutron monitors and it is on the level of 1-3 %. The change of intensity is bigger in the data

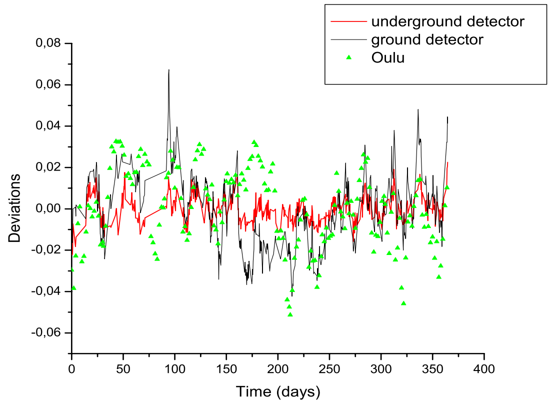

Fig. 2. Annual intensity variations of muons (Belgrade) and neutrons (Oulu) for the year 2002.

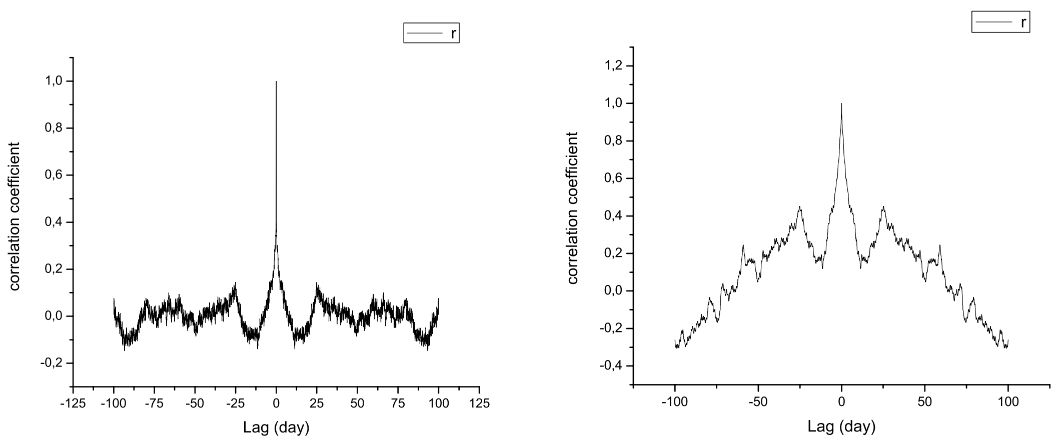

Fig. 3. Autocorrelogram for underground (left) and ground (right) detectors.

from the ground detector. Cross-correlation coefficient between data from the two detectors, also averaged over 8h period, is r=0.67.

Although our measurements are continuous, some data are missing due to electric power or computer system failures, etc. This problem introduced difficulties in the analysis, especially in comparison of different observation periods.

After eliminating suspicious data (for instance artificially low recorded intensity due to instability in electronics), we calculated auto-correlations for both detectors for different values of time shift (Figure 3(a) and 3(b)).

Most evident in the Figure is the increase of autocorrelation coefficient after shifting spectrum for about 25-26 days. However, this periodicity is not very sharp, and calculation of correlations is plagued by missing data.

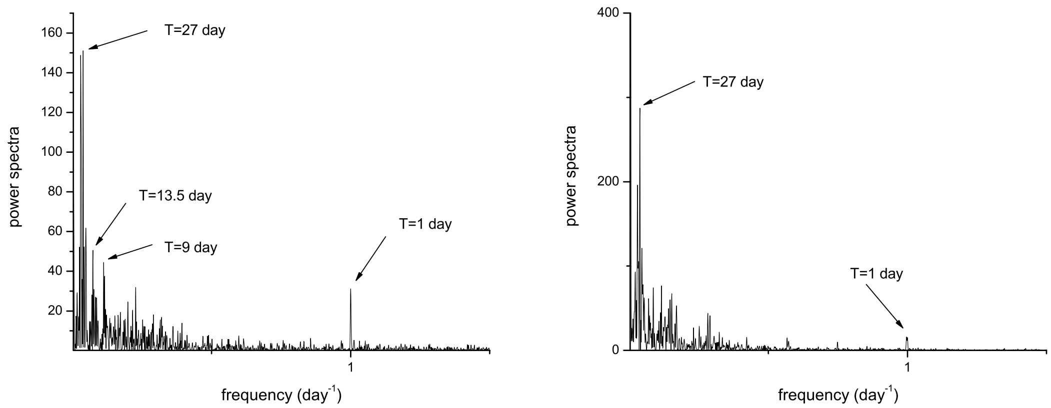

Fig. 4. Lomb periodogram for underground (left) and ground (right) detector.

To study eventual periodicity, we have performed spectral analysis of recorded data by implementing the Lomb method [2]. The technique is designed for treating unevenly sampled data, and in our case it is more suitable than the Fourier transformation. The cosmic-ray muon power spectra we calculated in the frequency range $3.2 \cdot 10^{-8} Hz < \nu < 1.4 \cdot 10^{-4} Hz$ and results are presented in Figure 4.

For both detectors the most prominent is the 27 days periodicity, corresponding to period of solar rotation. In the power spectrum of the underground detector data, higher harmonics of solar rotation T=13.5 days and T=9 days are also present. The one day periodicity is seen in both spectra but it is by far more significant for the underground detector. This periodicity might be attributed to daily temperature variations which were not corrected for. In the low frequency region both spectra have a significant peak (T=250 days for underground detector and slightly longer for the ground detector). Other peaks are not consistent in both data sets. This difference might be caused by the fact that raw data are used in this analysis. Data are not previously corrected with respect to the atmospheric pressure, and pressure variations could contribute to harmonic content.

The measurements continue and the raw data are available online at http:\\ www.phy.bg.ac.yu\~cosmic.

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2. Press W.H. et al. 1995, Numerical recipes