Effect of Disturbed Electric Field of the Atmosphere on Cosmic Rays: 2. Hard Component

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Abstract

The results of studying the correlation of the hard component of cosmic rays with the electric field of the atmosphere during thunderstorm periods are presented. The data at several energy thresholds are examined using the liquid scintillators of the Baksan air shower array and the plastic scintillators of the muon detector with a threshold of 1 GeV. It is demonstrated that the quadratic effect (changing intensity of muons at the electric field of any sign) is the most pronounced for soft muons.

1. Introduction

The influence of the electric field on the intensity of muons was first detected in the experiment with the Baksan air shower array in the beginning of 1980s, and in [1] a calculation of the so-called muon mechanism was performed. According to this calculation the effect is negative (net reduction of the intensity at the field of any sign) and quadratic with respect to the field strength. In the new experiment with the same array we have already published [2] a curve that generally confirmed this behavior. In this paper we present the data of a similar analysis for muons of various energies. The Baksan air shower array (BASA) includes the Carpet of thick (30 cm) scintillators with an area of 200 m^2, six huts with 54 m^2 of liquid scintillators of the same type, and the muon detector with plastic scintillators of 175 m^2 area and the energy threshold 1 GeV. We analyze the intensity of muons in three energy ranges: the counting rate in the muon detector (energy range $>$ 1 GeV, counting rate is 19000 s^{-1}), the difference of counting rates of the Carpet and the muon detector (energy range (70 MeV - 1 GeV, counting rate 4900 s^{-1}), and the intensity of stopping muons in scintillators of one hut (estimated energy range 15 - 90 MeV). Stopping muons were detected searching for a single pulse within the time gate of 3 μs after each pulse. Since the counting rate is high even for one hut, the random coincidences prevail in thus selected trigger (estimated rate is 21 s^{-1}). The real counting rate measured is 30 s^{-1}, so that the counting rate of stopping muons is 9 s^{-1}.

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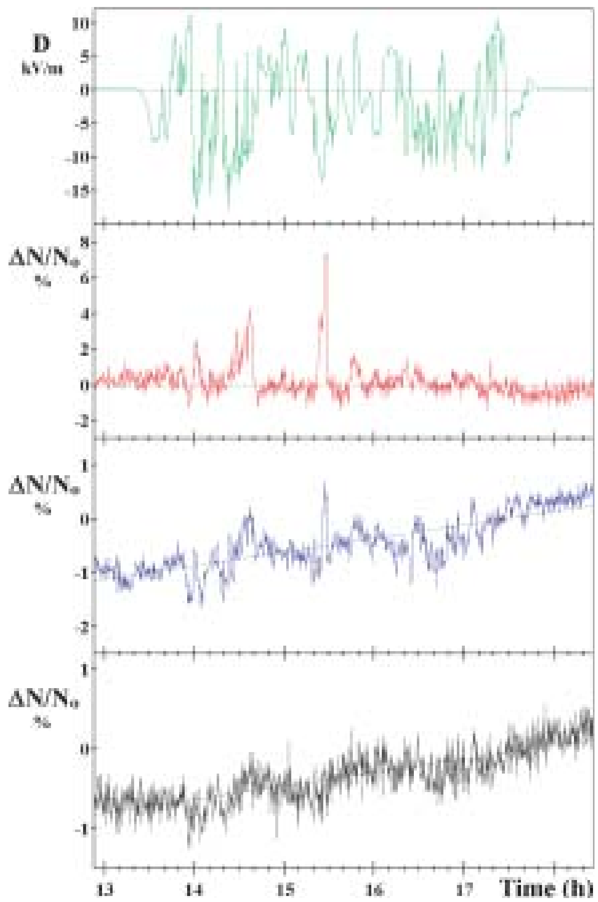

Fig. 1. Thunderstorm on September 26, 2001. The panels present the records (from top to bottom) of electric field, soft component, hard component > 70 MeV, and hard component > 1 GeV.

2. Results

Figure 1 presents the example of one thunderstorm (September 26, 2001) in its entirety: the electric field disturbance begins approximately at 13:30 and ends at 17:40 (the top panel). The next panel shows the disturbance in the soft component (the largest increase is the same that was analyzed as a bright pre-lightning enhancement in [2]). Two bottom panels present the counting rates of the Carpet and muon detector (energy thresholds are 70 MeV and 1 GeV, respectively). Slow trends in these data are, presumably, due to temperature variation at large altitudes. Short variations are in obvious connection with the electric field strength. It is interesting that some of them are nearly identical in shape, in spite of large difference in energy thresholds.

Figures 2, 3, and 4 present the results for three above described components. The correlation analysis was made for each thunderstorm event individu-

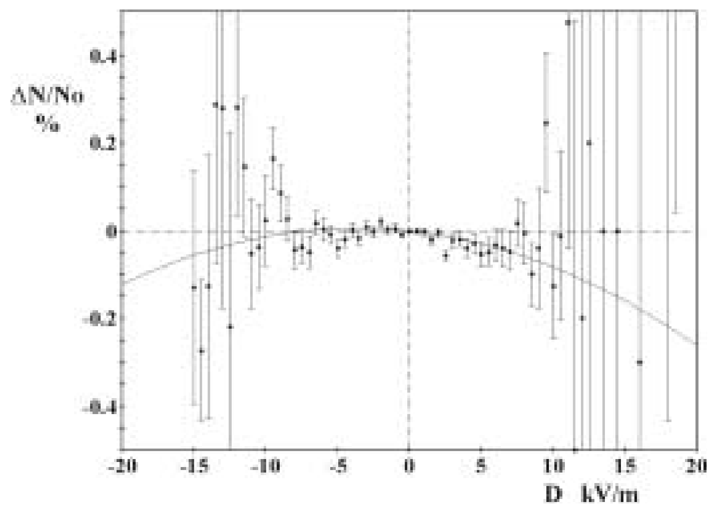

Fig. 2. The variation of the intensity of muons with energies above 1 GeV versus the electric field near the ground level. The data include 60 thunderstorm events (3.59 days of live time).

Table 1. Electric field dependence of the cosmic ray intensity. Weighted mean linear and quadratic regression coefficients for different components.

Component	Linear, % per kV/m	Quadratic, % per $(kV/m)^2$
Muons > 1 GeV	-0.0035 ± 0.0007	-0.00048 ± 0.00013
Hard component	-0.0175 ± 0.0015	-0.00262 ± 0.00026
Stopping muons	-0.0246 ± 0.0156	-0.00602 ± 0.00183

ally. Table 1 presents the weighted mean coefficients (linear and quadratic) for all events, and solid curves in Figs. 2, 3, and 4 are the functions corresponding to the tabulated coefficients.

It is clearly seen that the quadratic effect is substantial for low energies. At GeV energies (Fig. 2) this effect (if it exists at all) is not significant. This is reasonable since we study correlations with local field that cannot influence the muon spectrum at these energies strongly. For intermediate energies (Fig. 3) the experimental data have rather complicated structure, though the quadratic term is certainly present, especially at low field intensities. For stopping muons the statistical significance of our result is also not high, but these data confirm the conclusion that the variations of muon intensity with local electric field are concentrated in the low energy part of the spectrum.

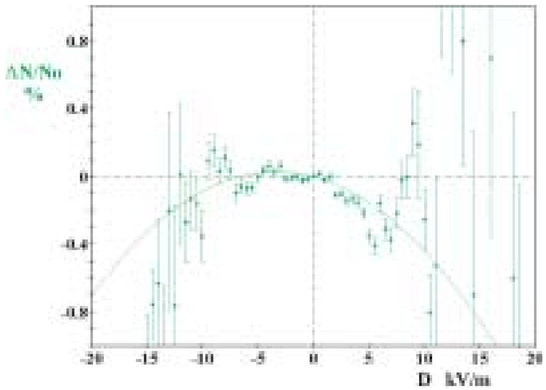

Fig. 3. The variation of intensity of the hard component with energies in the interval 70 MeV - 1 GeV versus the electric field near the ground level. The data include 56 thunderstorm events (3.40 days of live time).

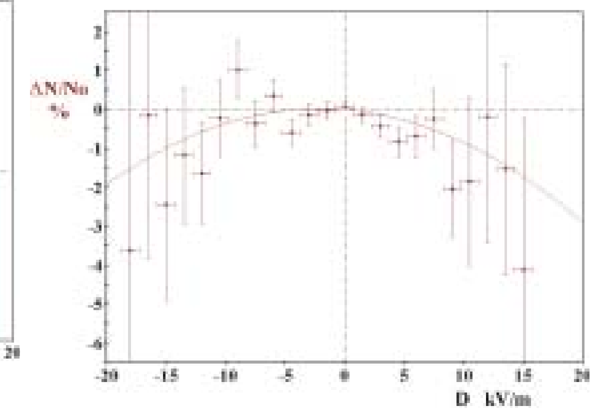

Fig. 4. The variation of the intensity of the soft muons with energies in the interval 15 - 90 MeV versus the electric field near the ground level. The data include 87 thunderstorm events (7.67 days of live time).

3. Acknowledgments

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4. References

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