Effect of Disturbed Electric Field of the Atmosphere on Cosmic Rays: 1. Soft Component

N. S. Khaerdinov, A. S. Lidvansky, V. B. Petkov, and Yu. P. Surovetsky
Institute for Nuclear Research, Russian Academy of Sciences,Moscow, Russia

Abstract

The results of studying the correlation of the soft component of cosmic rays (10-30 MeV) with the electric field of the atmosphere during thunderstorm periods are presented.

1. Introduction

The relation between disturbances in the intensity of secondary cosmic rays and the electric field strength during thunderstorms was first established in [1]. Recently, we started a more sophisticated version of the same experiment with a higher time resolution and with separation of the effects for the soft and hard components of cosmic rays. Some results of these observations were reported at the previous ICRC [2] and published in [3]. Here we present more data accumulated for three seasons of observations (2000-2002) and the results of more careful analysis of the regression curve 'the intensity versus field strength'.

2. Data selection and corrections

The raw data included the periods of disturbances of the electric field of the atmosphere selected with the following criterion: it was required that the electric field measured by the field meter on the roof of the experimental building in the center of the array would exceed 2 kV/m for at least 15 min. The total number of such thunderstorm events (events should be separated from one another by an hour interval, a thunderstorm can consist of several events) observed for three seasons is 108. These data contain variations due to different factors. In order to isolate the dependence on the electric field, we use a special procedure of data selection and filtering. The data were analyzed using several periods of sliding average procedure: 10 s, 2 min, 20 min and 3 h. Each time, after subtraction of sliding average curve the data were analyzed for time homogeneity. The points with small significance (approximately at 3σ level) were excluded from the analysis (successively 1 s, 10 s, 2 min, and 20 min 'bad' intervals). Some thunderstorm events become shorter than 15 min after this analysis and were eliminated so that the sample for further analysis included 88 events.

pp. 4169–4172

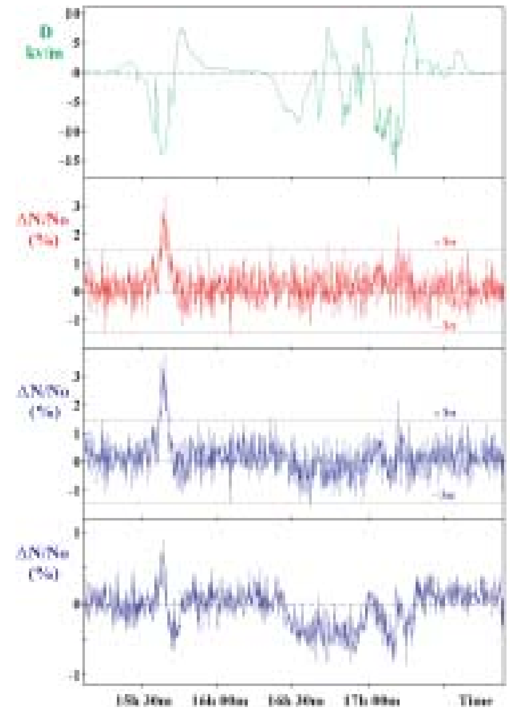

Fig. 1. A thunderstorm event on September 24, 2000. The records shown from bottom to top are as follows: hard component, soft component corrected only for pressure, fully corrected soft component, and the electric field strength.

In order to exclude pressure and temperature variations the regression coefficients of multiple correlation were calculated. The ratio of two halves of soft component detectors (odd and even huts) was used to eliminate periods with spurious data and electronic drift applying criteria of homogeneity. The live time included in the final analysis was about 100 days; pressure, outdoor temperature, and detector temperature were used at first as regression parameters. The soft component barometric coefficient was determined to be equal to -0.597 ± 0.002 % per mm of Hg, which is consistent with the absorption of electromagnetic component at these energies. A considerable part of the soft component at our observation level originates from muon decays. This equilibrium component contains variations related to muon intensity behavior. Therefore, simple barometric correction is not enough, as is well seen in Fig. 1, where a short interval of thunderstorm on September 24, 2000 is presented as an example. The bottom panel of this figure presents the variation of the hard component. The next panel from bottom shows the soft component corrected with the barometric coefficient given above. One can clearly see that some part of the hard component variation in the right part of the figure is conserved after correction. This is the reason why the variation of the hard component was used as an additional regression parameter.

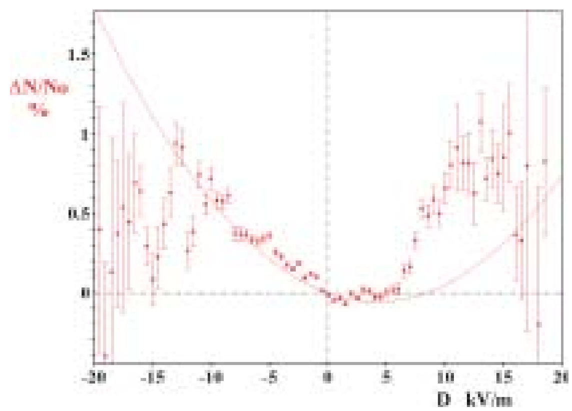

Fig. 2. The regression curve of the soft component intensity versus electric field after corrections. The data include 88 thunderstorm events detected in 2000-2002.

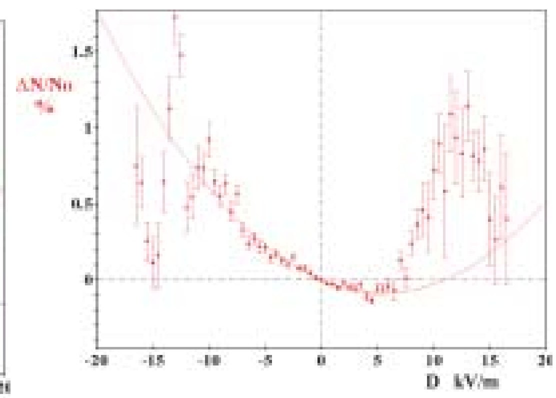

Fig. 3. The regression curve of the soft component intensity versus electric field after the additional selection of data (see text for explanation). The data include 52 thunderstorm events.

Then the correction coefficients become equal to -0.300 ± 0.003 % per mm of Hg and $0.996 \pm 0.005\%/\%$. The intensity of the soft component after these corrections is presented in the second panel from above. Now no traces of the hard component variation are seen in the right part of the plot.

3. Results

The full live time of observation for 88 thunderstorm events selected as described above is equal to 7.76 days. The corrected data were correlated with the electric field intensity using a second-order polynomial. The linear and quadratic coefficients were calculated separately for each thunderstorm event. The weighted mean values of these coefficients for all 88 events are equal to (-0.0267 ± 0.0008) % per kV/m and (0.00317 ± 0.00009) % per $(kV/m)^2$, respectively. The curve corresponding to these values is presented in Fig. 2 together with the total distribution of the soft component intensity versus the electric field strength. The bin width in Fig. 2 is equal to 0.5 kV/m. The errors given above are statistical, and the scatter of experimental points is larger than these errors. In order to reduce the influence of possible unknown variations, unrelated to the electric field, we performed further selection of data with the aim of optimization of the sample.

We excluded those events in which the residual dispersion was statistically distinct at a certain significance level from the theoretical dispersion, thus reducing contribution of variations, which are not related to measured parameters. The particular value of the level of significance is determined as optimum at which the difference of weighted mean value of the remaining ratios of residual dispersions to their theoretical values is as close to unity as possible. This value turned out to be $\alpha = 0.03$. After this procedure 52 out of 88 thunderstorm events survived with corresponding live time of 3.75 days. For these 52 events the weighted mean values of the linear and quadratic coefficients are equal to (-0.0315 ± 0.0012) % per kV/m and (0.00287 ± 0.00019) % per $(kV/m)^2$, respectively. Figure 3 presents the new thus corrected distribution of the soft component intensity versus the electric field strength.

4. Discussion and conclusion

Thus, after several steps of successive selection of data, we obtained a fairly regular curve at the moderate electric field strength. This regular part is obviously connected with acceleration of electrons. There is a strong asymmetry between electrons and positrons in the soft component at low energies: electrons prevail, since the knock-on process (by both muons and electrons) and Compton effect yield no positrons. Hence the curve of Fig. 3 is asymmetric too.

However, there is a strong bump in the right part of the figure, which apparently suggests even stronger acceleration of positrons. We can assume that this bump (very stable since it survived all the cuts) is also due to acceleration of electrons, but at a higher level, where the field is stronger than near the ground and often has the opposite sign. On the one hand, the absorption and deceleration in a weaker field can be not sufficient to compensate the gain of energy and multiplication. On the other hand, gamma rays produced by these accelerated electrons are not subject to deceleration and can contribute to the increase of counting rate directly. In any case, this bump is obviously connected with the active phase of thunderstorms, as is proved in [4], where it is shown that exclusion of around-lightning intervals reduces this effect nearly completely.

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5. References

1. Alexeyenko V.V., Chudakov A.E., Sborshikov V.G., and Tizengauzen V.A. 1985, Proc. 19th ICRC, La Jolla, 5, 352
2. Alexeenko V.V., Khaerdinov N.S., Lidvansky A.S., and Petkov V.B. 2001, Proc. 27th ICRC, Hamburg, SH-250, 4161
3. Alexeenko V.V., Khaerdinov N.S., Lidvansky A.S., and Petkov V.B. 2002, Phys. Lett. A301, 299
4. Khaerdinov N.S., Lidvansky A.S., Petkov V.B., and Surovetsky Yu.P. 2003, This conference