Proceedings of ICRC 2001: 885 © Copernicus Gesellschaft 2001

ICRC 2001

The Cherenkov Track Detector Consisting of the Yakutsk Complex EAS Array

G. K. Garipov[1], V. M. Grigoryev[2], N. N. Efremov[2], B. A. Khrenov[1], M. I. Pravdin[2], A. A. Silaev[1], and I. Ye. Sleptsov[2]

[1] Skobeltsyn Institute of Nuclear Physics of Moscow State University (Moscow)
[2] Institute of Cosmophysical Research and Aeronomy (Yakutsk)

Abstract.
Characteristics of the Cherenkov detector on the basis of the camera obscura as part of the Yakutsk complex EAS array are given. We discuss the possibility for direct measurement of the shower development maximum depth by the single detector of same construction. A shower core is determined by data of the operating EAS array: at $> 10^{17}$ eV according to a trigger-500 for the charged EAS component; at E $\sim 10^{16}$ eV with the autonomous Cherenkov installation.

1 Introduction

In (Garipov and Khrenov, 1994) it was stated for the first time about the possible using of the camera obscura to observe of EAS image in Cherenkov light. In (Garipov and Khrenov, 1995; Garipov and Khrenov , Rome, 1995) the study of the longitudinal and lateral development of showers by means of the Cherenkov detector network on the basis of the camera obscura was substantiated.

In those works it was particularly emphasized that unlike the typical integral Cherenkov detectors the camera obscura considerably quenched the background of night sky light and, thus, it increased the observation time including twilights and moon nights. The use of the photo-mosaic in a detector allows to obtain information on the differential flux of the EAS Cherenkov light, i.e. in substance the direct measurement of the longitudinal shower development is provided.

At the Yakutsk EAS complex array the measurement of the shower Cherenkov light is carried out by typical wide-angle detectors. By data obtained with these detectors two methods for recovering of the shower longitudinal development (of the cascade curve) have been realized: the first method (Fomin et al., 1971; Kalmykov et al., 1979) - by the profile of the EAS Cherenkov light impulse; the second one (Dyakonov et al., 1979; Dyakonov et al., 1986) - by the shape of the measured lateral distribution function of the EAS Cherenkov light flux density.

Both methods although they are somewhat mutually supplementary, have some limitations. First of all, these methods are based not on the direct measurements and their possibilities are limited by the necessity of assumption of some suppositions on the picture of the EAS development. Besides, the recovery accuracies of the cascade curve parameters by these methods are not sufficient to study characteristics of their fluctuations.

In the present paper the project of addition of the EAS Yakutsk array by the principally new optical Cherenkov radiation detector on the basis of the camera obscura - the Cherenkov track detector (CTD) is discussed. It will allow to carry out the direct measurements of the longitudinal and lateral development of the shower cascade.

2 Design and parameters of the detector

The detector camera represents the lightproof shed, the roof of which consists of two-tier hexahedron dome (Fig. 1). The diameter of the upper tier slit (the slit A) is 100 cm and its width is 10 cm. The diameter of the lower tier slit (the slit B) is 160 cm and its width is 10 cm too.

The photo-mosaic of the detector is of 19 photo-multiplier tubes (PMT) with the photocathode 10 cm diameter. PMT are located on the horizontal plane along 6 directions in groups of 3 close to each other and there is one PMT in the center. The angle between neighboring radiates is the same and accounts for $60°$. The photo-mosaic is located strictly horizontally and the axis of the dome coincides with the axis of the central PMT.

Due to such a construction of the dome, the detector photo-mosaic and geometry of their mutual location, the detector aperture is azimuth- symmetrical and is of 6 identical view sectors. The last circumstance substantially simplifies and reduces a body of calculation when the measurement modeling by the present detector is carried out. Besides, two detector functions is provided using one common photo-mosaic.

Correspondence to: I. Sleptsov (i.ye.sleptsov@ikfia.ysn.ru)

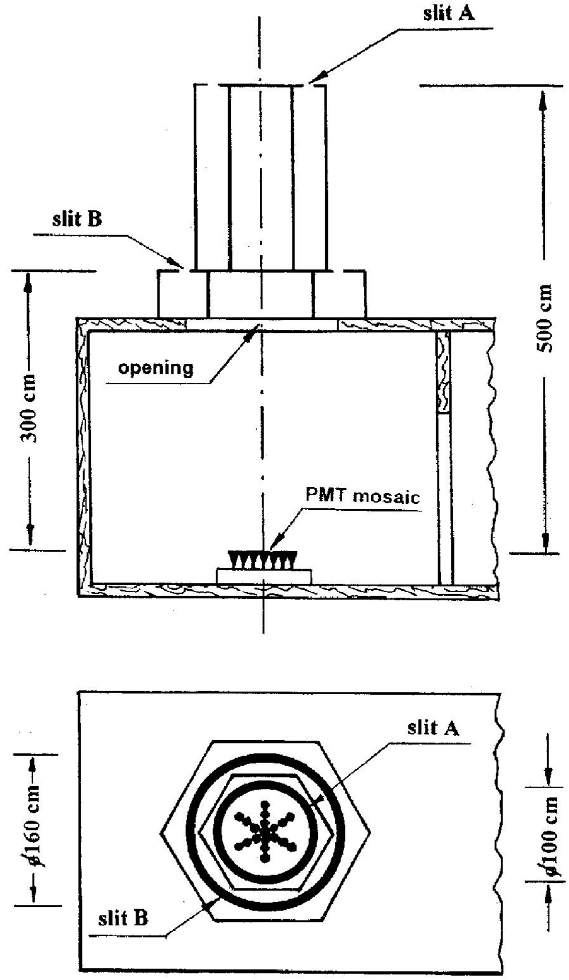

Fig. 1. Design of the Cherenkov track detector: the upper part is a view from the side; lower part is a view from the top.

The single detector of the above-described design is located at a distance of 400 m from the center of the operating Yakutsk EAS array. Such a location gives the possibility to the detector to operate as a part of the array and to use the registration data according to the basic program. Thus, the localization of the shower core in space (the determination of a zenith angle θ, an azimuth φ and coordinates of intersection place of the core with the array plane) is carried out by the data of the operating installations. In this case, for energies above 10^{17} eV the information from the scintillation counters of the main array and in the energy range of 10^{16} eV the autonomous Cherenkov array data are used (Afanasiev et al., 1997).

Fig.2 presents the dependence of the average depth of the atmosphere controlled by the photo-mosaic separate PMT (along the radiate, without accounting of the lateral PMT) on the distance to the shower core. The figures near the curves stand for the PMT numbers in order of moving to the slit. From Fig.2 it is seen that fuller information on the longitudinal development of the showers with the maximum depth 600 g/cm^2 and more can be obtained by registration data at the distance of 300 m and father from the shower core.

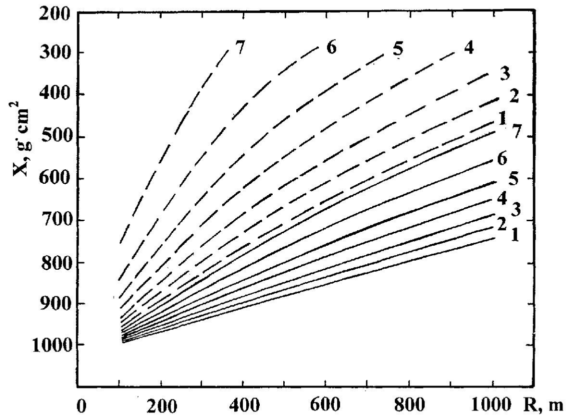

Fig. 2. The average depth of the atmosphere observed by the separate PMT of the detector photo-mosaic versus the distance to the vertical shower core. The dashed lines are through the slit A. The solid lines are through the slit B.

As compared with the typical integral Cherenkov detector (for example, at the Yakutsk array) the CTD considerably suppresses the background light. The detector has the summarized aperture for two slits A= 8.2·10^{-2} sr., and the integration time can be chosen T= 50 ns because the detector is differential. Then, at the flux of night-sky light (from the data at the Yakutsk array) q = 1 photon/cm^2·ns·sr the mean number of photoelectrons produced by one mosaic PMT is equal to

n = q·A·T·S·p = 64 photoelectrons,

where S = 78.5 cm^2 is the PMT photocathode area and p = 0.2 is quantum effectiveness of photocathode. Thus, the background signal from the PMT will be equal to 8 photoelectrons. Starting from these estimations one can take for the proposed detector the threshold density of the level of the triplet background signal which is equal to 120 photons for one PMT or

$Q_{treshold}$ = 1.5·10^4·photons·m^{-2}.

3 The calculation of the lateral spread of the Cherenkov light impulse.

If the CTD parameters are known then every mosaic PMT will have its own view boundaries, defined by the PMT photocathode sizes, slit width and distance from the slit to the PMT.

The total number of photons fallen on the photo-cathode of the separate PMT is determined by summing of photons from the whole region viewed by the PMT. For this purpose the density of the photon fluxes radiated by a shower from the every observed region of the atmosphere towards the detector is calculated. The calculation of the photon flux density has been carried out in the axial approach of a shower developing according to the QGS-model with the account of the age

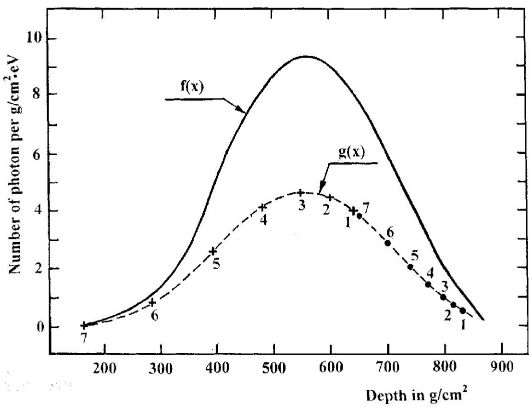

Fig. 3. The number of photons radiated towards the detector, f(X), and fallen on the separate PMT (simbols as in Fig.2) of the detector photo-mosaic, g(X), versus the atmosphere depth.

parameter and for the exponential angular distribution of the cascade electrons.

Fig.3 presents the calculation results for the vertical shower with E = 10^{17} eV and at a distance of 500 m from the shower core. Here f(X) is the number of photons radiated by the shower at a depth X at a length of 1 g$\cdot$cm^{-2} towards the detector on the photo-cathode of one PMT , i.e. a given Cherenkov cascade and g(X) is the total number of photons led to 1 g$\cdot$cm^{-2} of the observed region length and fallen on the separate mosaic PMT, i.e. a measured Cherenkov cascade. At approximation of dependencies f(X), g(X) by the Gaussian distribution we have obtained the following estimations of the maximum depth and distribution width:

Xf = 562.2 g$\cdot$cm^{-2} DXf = 299.0 g$\cdot$cm^{-2}

Xg = 555.1 g$\cdot$cm^{-2} DXg = 302.3 g$\cdot$cm^{-2}

The comparison of plots f(X) and g(X) shows that a form and parameters of these functions are practically identical. Such a coincidence denotes that experimentally by means of the suggested detector one can really obtain the nonshifted estimation of location in the atmosphere of the maximum intensity point of the Cherenkov cascade for the given distance from the shower core.

4 Conclusion

The maximum depths of the electromagnetic and Cherenkov cascades for different distances from the shower core, generally speaking, don't coincide but they are genetically associated with each other. The finding of these dependencies is the subject of our further investigations.

Acknowledgements. This work is supported by the Russian Fundation for Basic Research (grants 99-02-16022 and 00-15-96787).

References

Garipov, G. K. and Khrenov, B. A., J. Phys. G: Nucl. Part. Phys., 20, 1981-1988, 1994.

Garipov, G. K. and Khrenov, B. A., J. Phys. G: Nucl. Part. Phys., 21, 879-887, 1995.

Garipov, G. K. and Khrenov, B. A., Proc. 24-th ICRC (Rome), v. 1, 491-497, 1995.

Fomin, Yu. F. and Khristiansen, G. B., Yadernaya fizika, v. 41, 642, 1971.

Kalmykov, N. N., Nechin, Yu. A., Prosin, V. V. et al., Proc. 16-th ICRC (Kyoto), v. 9, 73-78, 1979.

Dyakonov, M. N., Knurenko, S. P., Kozlov, V. I. et al., Proc. 16-th ICRC (Kyoto), v. 8, 174 -179, 1979.

Dyakonov, M. N., Knurenko, S. P., Kolosov, V. A. et al., Nucl. Instr. and Methods in Phys. Research, Amsterdam, A248, 224-226, 1986.

Afanasiev, B. N., Knurenko, S. P., Kolosov, V. A. et al., Proc. 25-th ICRC (Durban), v.7, 217-220, 1997.