

ON THE DETERMINATION OF THE DEPTH OF EAS DEVELOPMENT  
MAXIMUM USING THE LATERAL DISTRIBUTION OF CERENKOV LIGHT  
AT DISTANCES  $< 150$  m FROM EAS AXIS

N. Aliev, T. Alimov, M. Kakhkharov, B.M. Makhmudov,  
N. Rakhimova, R. Tashpulatov  
Samarkand State University, Samarkand, USSR

N.N. Kalmykov, G.B. Khristiansen, V.V. Prosin  
Institute of Nuclear Physics, Moscow State University,  
Moscow 119899, USSR

ABSTRACT

The Samarkand EAS array was used to measure the mean and individual lateral distribution functions (LDF) of EAS Cerenkov light. In the interval of distances  $r = 20-150$  m, the functions are approximated to take the form  $q(r) \sim \exp(b \cdot r/10^4)$ . The analysis of the individual parameters  $b$  has shown that the mean depth of EAS maximum and the variance of the depth distribution of maxima of EAS with energies of  $\sim 2 \times 10^{15}$  eV can properly be described in terms of Kaidalov-Martirosyan quark-gluon string model (QGSM).

The Samarkand EAS array has been described in detail in /1/. The present work uses the experimental data obtained in 1983 when the EAS array consisted of 13 Cerenkov light detectors, each of which included from 7 to 10 FEU-49 photomultiplier tubes, arranged at distances of 15-120 m from the array center and 18 scintillators of  $0.5-2$  m<sup>2</sup> area each arranged at distances of 15-60 m from the array center. The showers were selected on the basis of their Cerenkov light. The events were selected for the analysis in which  $\theta \leq 30^\circ$  and the Cerenkov light flux density  $q \geq 8$  photon/cm<sup>2</sup>·eV in 6 detectors located at 60m and  $q \geq 5$  photon/cm<sup>2</sup>·eV in 3 detectors at 120 m.

The EAS axis positions and sizes were inferred from the scintillator data. The shower energy was derived from the Cerenkov light flux density at a 100-m distance from EAS axis. The analysis were made for the showers whose

axes fell within a 60-m radius circles and the selection probability was  $> 90\%$ .

During 45 hours of the array operations, 500 showers satisfying the above requirements were selected. The shower energies were from  $10^{15}$  to  $10^{16}$  eV.

Fig. 1 shows the mean LDF for  $E_0 = 3 \times 10^{15}$  eV. Fig. 2 exemplifies the individual LDF of Cerenkov light.

The LDF at small distances was proposed in /2,3/ to describe by the function of the form

$$g(z) \approx \exp(bz/10^4) \quad (1)$$

We used this approximation with one parameter  $b$  to describe the mean and individual LDF. From Figs 1 and 2 it is seen that the approximation (1) can properly describe the experimental functions at distances of 20-150 m from EAS axis.

The Samarkand EAS array permits from 8 to 12 dots to be obtained in an individual shower at the above mentioned distances. In such a way, individual parameter  $b$  was found in each of 500 showers.

The results were interpreted quantitatively by mathematical simulation of experimental data. The EAS axis position and direction, energy, and depth of maximum were simulated as main parameters. The rest parameters, namely, EAS size  $N_e$ , the LDF parameters of Cerenkov light and charged particles, and densities in individual detectors, were treated as functions of the main parameters. The calculations allowed for the errors in measuring the angles and the flux densities of Cerenkov light and charged particles. The relationship of LDF to EAS maximum depth was taken from the calculations made in terms of the supracritical pomeron model described in detail in /4/. The parameter of the maximum depth distribution were taken from the calculations made in terms of the same model for mixed chemical composition of primary cosmic rays (40% of p and 15% of nuclei with  $A = 4, 15, 31$ , and 56 each):

$$\begin{aligned} \bar{X}_m &= 504 + 75 (\lg E_0 - 15) \text{ g/cm}^2 \\ G(X_m) &= 85 \text{ g/cm}^2 \end{aligned}$$

640 artificial showers were simulated. The simulation has shown that the accuracy of determining  $b$  in individual cases is  $\Delta b = 18$ .

To make sure that the LDF form reflects the depth of the maximum of an individual shower, we examined the correlation of the parameter  $b$  with the independent parameter, the particle number-to-energy ratio, which must also be sensitive to the depth of EAS maximum. Fig. 3 shows the experimental dots of the dependence  $b$  on  $\lg(N_e/E_0)$ . The correlation coefficient is  $0.55 \pm 0.03$ . The curve in the figure is the regression line:

$$b = 153 + (102 \pm 7) \cdot (\log_{10}(N_e/E_0) + 9.7)$$

Fig. 4 shows the  $b$  distribution of individual showers with  $E_0 = 2 \times 10^{15}$  eV. In the distribution,  $\bar{b} = 154 \pm 2$  and  $\sigma(b) = 35 \pm 1$ . The dashed line is the distribution obtained by simulating experimental data. In the distribution,  $b = 154 \pm 2$  and  $\sigma(b) = 33 \pm 1$ . The experimental data coincide in practice with the calculation results for the above mentioned parameters of the maximum-depth distribution.

To test the sensitivity of the  $b$  distribution to the fluctuations of the maximum depth, the experimental data were repeatedly simulated at  $\zeta(X_m) = 65 \text{ g/cm}^2$ , but at the same shape of the cascade curve. In this case  $\sigma(b) = 26 \pm 1$ , i.e. is much different from the experimental value.

It should be noted in conclusion that the procedure of finding  $X_{\max}$  from LDF of Cerenkov light is in principle dependent on the model determining the cascade curve shape in the lower atmosphere.

#### References

1. Kalmykov et al. (1983), Proc. 18th ICRC, Bangalore, 11, 383
2. Kuhlmann J. Det al. (1981) J. Phys. G, 7, 183.
3. Petterson J.R., Hillas A.M. (1983), J. Phys. G. preprint
4. Kalmykov N.N., Kristiansen G.B. (1983) Proc. 18th ICRC Bangalore, 11, 330.

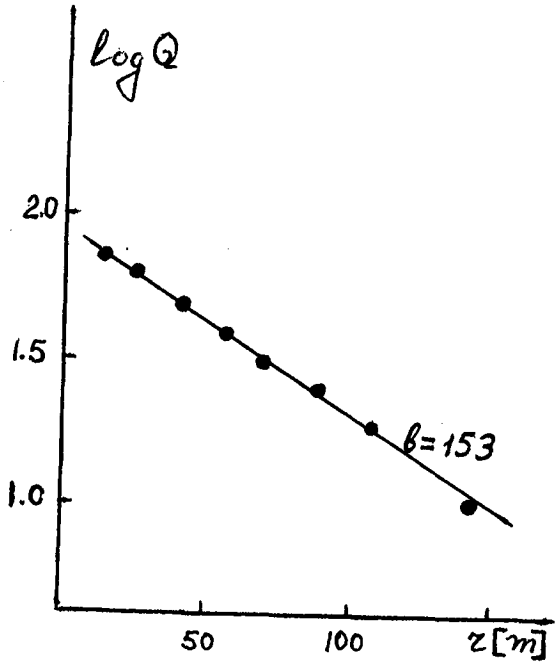


Fig 1.

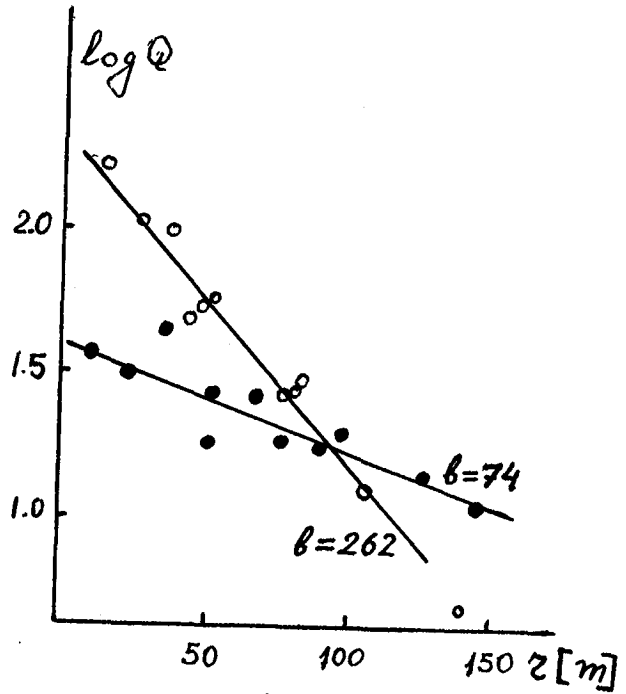


Fig 2.

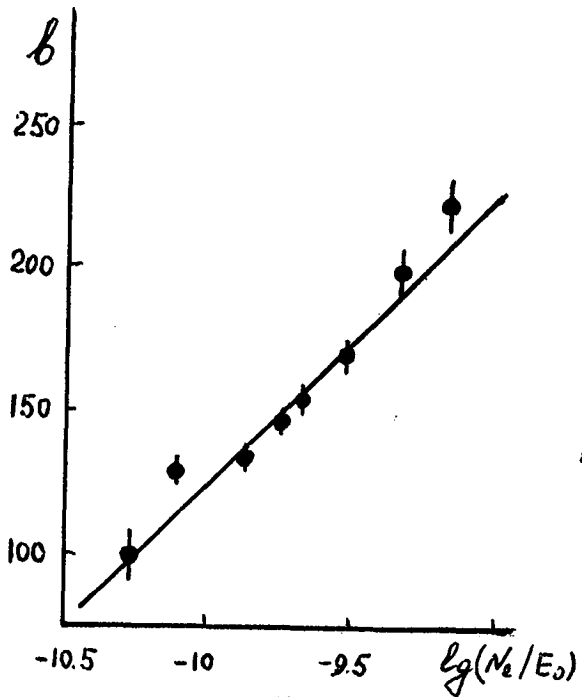


Fig 3.

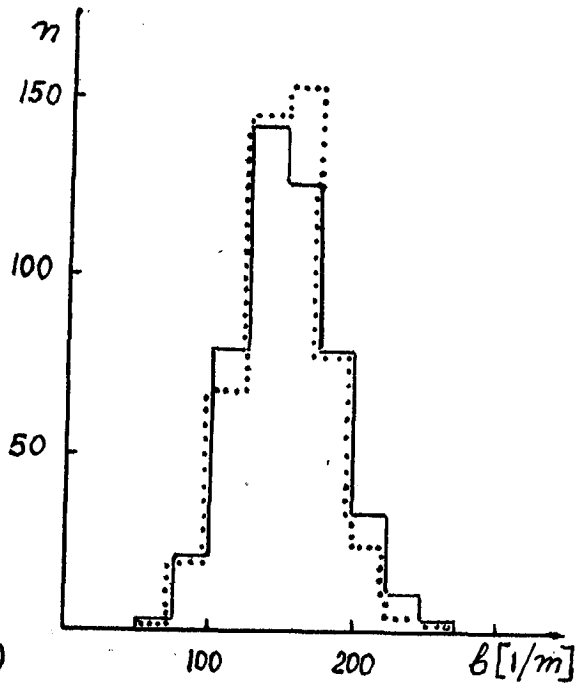


Fig 4.