STUDY OF THE ENERGY SPECTRUM OF PRIMARY COSMIC RAYS; EAS SIZE FLUCTUATIONS AT A FIXED PRIMARY ENERGY

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During the initial period of the Samarkand EAS array operations (1981) the ahowers were selected on the basis of charged--particle flux density /1/, and during the subsequent periods (1982-1983) the showers were selected on the basis of Cerenkov light flux density /2/. Such a procedure has made it possible to measure the shower energy, to estimate the EAS size fluctuations at a fixed primary energy, and to experimentally obtain the scaling factor K(Ne, Eo) from the EAS size spectrum to the primary energy spectrum. In 1983 six scintillators of area S= 2 m^2 each were added to the array. The scintillators were placed at the verteces of a right hexagon at 60-m distances from the EAS array center. The fluctuations of EAS sizes in the showers of fixed primary energies and the scaling factors K(Ne,Eo) were inferred from the data obtained in 1983.

The showers with zenith angles $<30^\circ$ were selected. The EAS axis positions were inferred from the amplitude data of the scintillators. The primary energy Eo was determined by the method of least squares for the known EAS axis position (inferred from the scintillator data) using the data of the Cerenkov detector located at 80-150 m (100m on the average) from EAS axis. In this case the NKG function was taken to be the mean lateral distributions function (LDF) of charged particles, while the Cerenkov light LDF was assumed to be of the form proposed in /3/ with the parameters found using the Samarkand EAS array.

The calculations /4/ have shown that the Cerenkov light flux fluctuations at 100 m from EAS axis, q_{100}, do not exceed 10% at a fixed EAS energy, so the parameter q_{100} may be used to estimate the EAS-generating primary particle- energy.

Fig. 1 compares between the calculated and experimental data on the fluctuations of sizes Ne of EAS with fixed Eo. The mean energy of such showers is 3×10^{15} eV. The standard deviation lgNe is $\sqrt{D(\lg Ne)} = 0.31 \pm 0.02$. The figure also shows the distribution calculated in terms of the supracritical pomeron model (SPM) allowing for the difference between the hadron-nucleon and hadron-nucleus interactions (the solid line). The calculations were made in case of mixed chemical composition (40% of p and 15% of nuclei with A= 4, 15, 31, and 56 each) distributed through the $0^{o} - 30^{o}$ zenith angles. To imitate the instrumental errors, each values of Ne was added a random number distributed normally with a variance equaling the squared instrumental error. The instrumental error in the values of Ne, σ_{Ne}, was taken to be 0.15 Ne .

The so obtained distribution shows the stardard deviation $\sqrt{D(\lg Ne)} = 0.31 \pm 0.01$ (for the pure proton composition of primary cosmic rays, $\sqrt{D\ (\lg Ne)} = 0.34 \pm 0.01$.

Fig. 2 shows the Ne dependence of the scaling factor from Ne to (Ne, Eo) in the showers with fixed values of Eo and Ne, Also shown are the results of the model calculations of the scaling factors in case of complex chemical composition for various models of EAS development. The SPM gives a good agreement with experimental data.

The Ne spectrum was scaled to the primary spectrum using the K(Ne,Eo) approximation of the form

$$K\ (Ne,Eo) = Eo/Ne = (0.57)0.06) \times 10^{6} (Ne/10^{6})^{-0.1 \pm 0.02}$$

The approximation was obtained as follows. Experimental data were used to find only the absolute value of K(Ne,Eo), while the Ne dependence of K(Ne,Eo) was inferred from the SPM calculations.

During 160 hours of its operations (at clear moonless nights), the EAS array detected 10240 showers which gave 7-fold coincidences in the scincillators located at 30 m (see / 1/)from the array center. Out of the events detected, the showers were selected in which the charged-particle density was at least 2 particle/m^2 in the scintillators at 30 m from the array center. A 6 particle/m^2 density was required in the central scintillator. After such a selection, 7233 showers remained. Of them, 3380 showers were with zenith angles $\leqslant 30^{\circ}$. For the purposes of final analysis the showers were selected whose detection probability is > 0.9 within a 20-m circle for Ne = $(2.5-4.0)\times10^5$ and within a 30-m circle for Ne 4×10^5. Such showers amounted to 920 and were used to construct the EAS size spectrum. This spectrum can be approximated by the the functions

$$F(>Ne) = (3.45 \pm 0.20)\times 10^{-10}(Ne/10^5)^{-1.47\pm0.05}\ cm^{-2}s^{-1}sr^{-1}$$

for $2.5\times10^5 \leqslant Ne < 6\times10^5$ and

$$F(>Ne) = (1.15 \pm 0.30)\times 10^{-9}(Ne/10^5)^{-2.10\pm0.09}\ cm^{-2}s^{-1}sr^{-1}$$

for $9.0\times10^5 \leqslant Ne < 3.2\times10^6$.

The experimental scaling factor found in the showers with fixed Ne was used to scale from the measured EAS size spectrum to the primary EAS energy spectrum which can be approximated by the functions.

$$F(>Eo) = (1.9\pm0.3)\times 10^{-10}(Eo/10^{15})^{-1.63\pm0.09}\ cm^{-2}s^{-1}sr^{-1}$$

for $1.5\times10^{15} \leqslant Eo < 3.5\times10^{15}$ eV and

$$F(>Eo) = (5.2\pm0.8)\times 10^{-10}(Eo/10^{15})^{-2.30\pm0.12}\ cm^{-2}s^{-1}sr^{-1}$$

for $5.2\times10^{15} \leqslant Eo < 2.0\times10^{16}$ eV.

Fig. 3 shows the primary cosmic ray spectra obtained with the Samarkand EAS array and elsewhere /5-8/.

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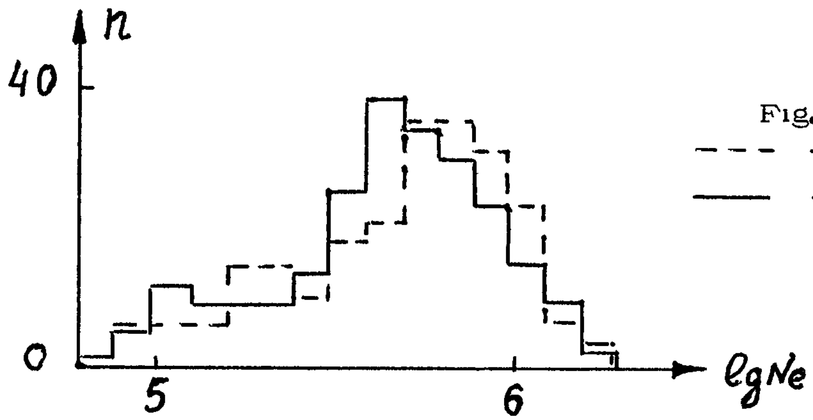

Fig. 1.
- - - — experimental data
——— — SPM calculations

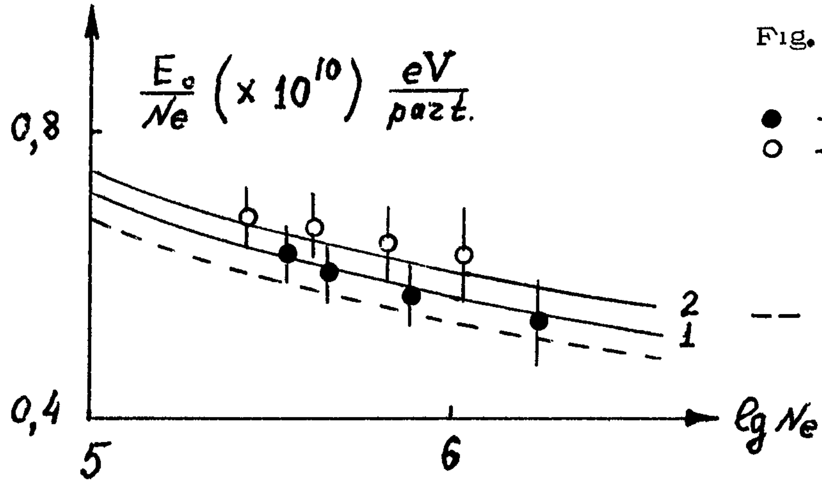

Fig. 2.
experimental data
● — fixed Ne
○ — fixed Eo
SPM calculations
1 - fixed Ne
2 - fixed Eo
- - CKP calculations

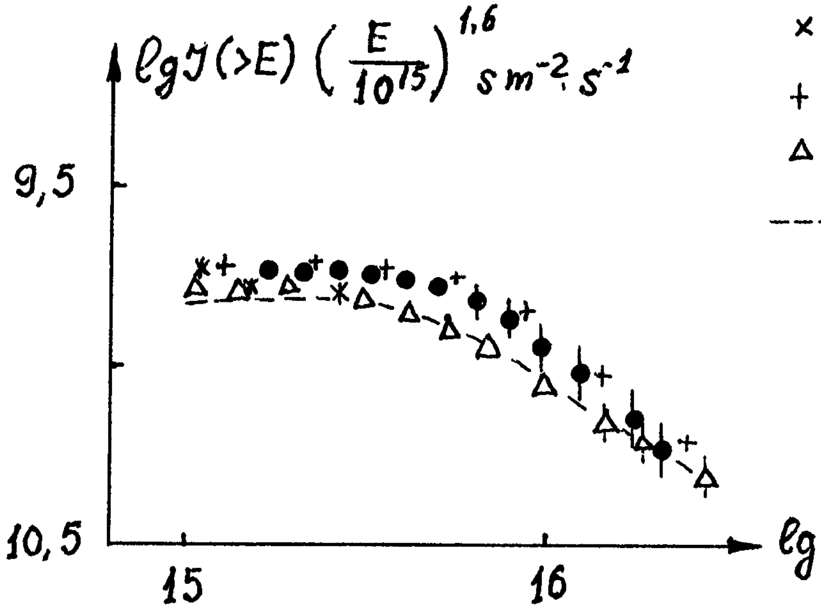

Fig. 3.
● — the present work
× — /5/
+ — /6/
△ — /8/
- - - - /7/