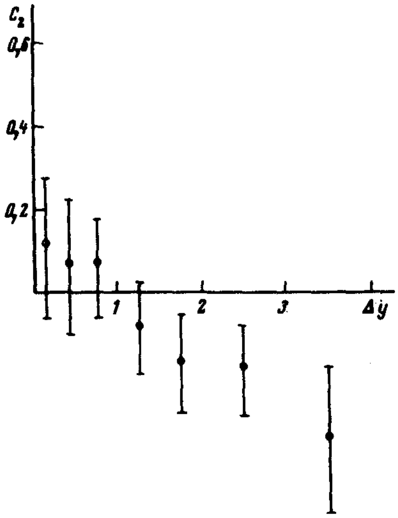

Fig. 1

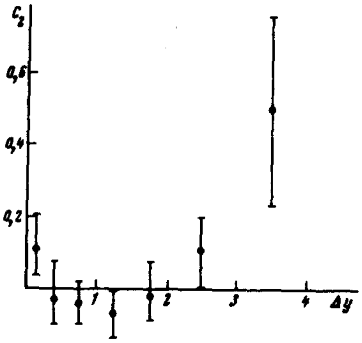

Fig. 2

Fig. 1. Correlation function C_2 in C-system vs Δy.

Fig. 2. Correlation function C_2 in S-system vs Δy.

(in the C-system), integrated over all values of y_1. Figure 2 shows the function C_2 determined in the rest system of the charged particles (the S system). There is an evident difference between the correlation functions determined in different reference frames. The function C_2 in the S system (Fig. 2) shows an appreciable positive correlation for particles with a large difference Δy, i.e., the particles with highest energy move apart in opposite directions in this system. This interesting physical regularity is completely erased in the C system because of the difference in the relative motions of the S and C systems in the individual interactions. Unfortunately, the statistics of this result is adequate only to call attention to the importance of complete investigations of this type, and does not make it possible to assess its physical meaning.

[1] W. E. Shephard, J. T. Powers, N. N. Biswas, N. H. Cason, V. P. Kenney, and D. W. Thomas, Phys. Rev. Lett. 28, 703 (1972).
[2] Winston Ko, Phys. Rev. Lett. 28, 935 (1972).
[3] E. Berger, B. J. Oh, and G. A. Smith, Phys. Rev. Lett. 29, 675 (1972)
[4] M. Jacod, Review, International Conference in Batavia, 1972.

PARTICLE-NUMBER SPECTRUM OF EXTENSIVE AIR SHOWERS AT SEA LEVEL

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Submitted 30 July 1973
ZhETF Pis. Red. 18, No. 6, 353 - 356 (20 September 1973)

Experimental results are presented on the investigation of the spectra of extensive air showers with respect to the number of particles N in the interval 10^6 - 10^8. The data indicate that the particle-number spectrum experiences a change in the region $N > 10^7$.

The possibility of a change in the spectrum of extensive air showers (EAS) with respect to the number of particles N in the region $N > 10^7$ was first noted in [1]. The N-spectrum analyzed there was that obtained in [2] in the interval $N = 10^6 - 10^8$. The spectrum of [2], however, was not investigated with sufficient accuracy, since the setup used in [2] and [3] had too small a number of detectored distributed over a large area.

The N-spectrum was subsequently investigated in [4, 5]. The results of [4] have low statistical accuracy, and the results of the Yakutsk installation [5] pertain to the interval $N = 10^7 - 10^{10}$. To investigate the features of the N spectrum in the region $N \geq 10^7$ it is apparently necessary to record the shower spectrum approximately in the interval 10^6 - 10^8, and in one and the same installation.

For a more detailed study of the EAS structure and of the form of the spectrum in the region N ≥ 10 , the installation at the Moscow State University was modernized in 1967; the effective registration areas for the EAS axes were enlarged and the number of detectors was increased.

Characteristic features of the new installation are (i) the possibility of registering showers in a wide range of particle numbers, $N = 10^5 - 10^8$, and (ii) measurement, in each shower, of the charged-particle flux densities in the distance interval where the majority (60 - 80%) of the total particle flux in the shower is concentrated.

A detailed description of the installation is given in [6]. We present here only a brief description.

The value of N is determined with a surface installation consisting of 6000 hodoscopic counters. The total counter area is $\sim 100\ m^2$.

Groups of hodoscopic counters, each of area σ, serve as charged-particle detectors. The charged-particle flux density is determined directly from the ratio of actuated counters to the total number of counters.

The charged-particle detectors are placed in 53 points symmetrically about the center of the installation, in a cricular area of radius 200 m^2(Fig. 1).

The use of counters with different areas σ and the use of a large number of counters at each registration point make it possible to determine the particle flux density with good accuracy in the range 0.5 - 1500 particle/m^2.

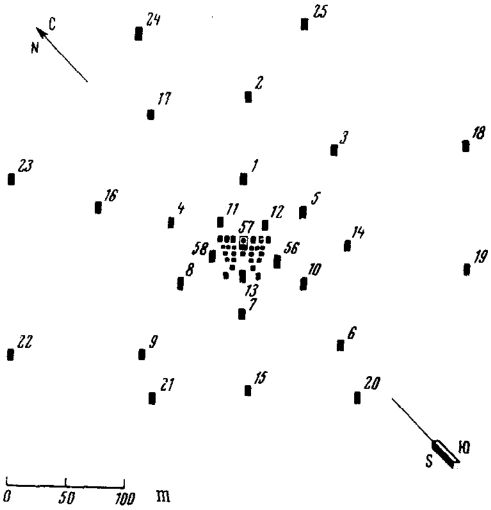

Fig. 1

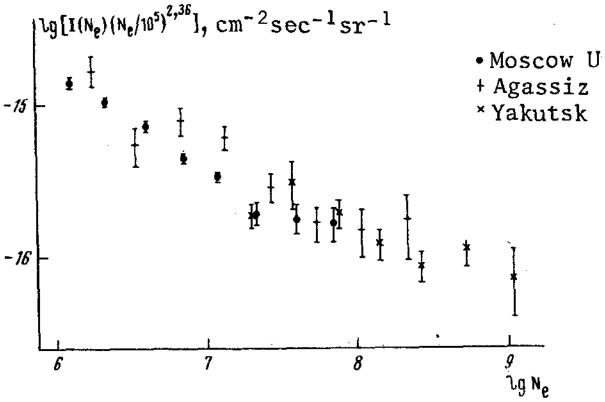

Fig. 2

The installation includes also a system of fast scintillators to determine the inclination of the shower axis (the zenith angle θ and the azimuthal angle ϕ [7]. When an individual shower is registered, the particle flux density is distributed over an area of 120 000 m^2, where the registration points are located.

To determine the axis coordinates x_0 and y_0 and the total number N of the shower particles, we seek the minimum of the following expression as a function of x_0, y_0, and N:

$$\sum_{c=1}^{n} [\rho_e(x_j, y_j) - \rho_c(N, r_{j,0})]^2,$$

where $\rho_e(x_j, y_j)$ is the density of the particles registered at point j with coordinates x_j and y_j; $\rho_c(N, r_{j0})$ is the particle density calculated from the central function for a shower with N particles and axis coordinates x_0 and y_0 for the j-th point, $r_{j0} = [(x_j - x_0)^2 + (y_j - y_0)^2]^{1/2}$, and n is the number of registration points.

The central function $\rho_c(N, r_{j0})$ was chosen by us to be the function obtained in [8]. The choice of this function was governed by the fact that it was demonstrated in [9] that the central function of the lateral distribution of the particles cannot be described by the function of Nishimura and Kamata with a single parameter s, but is a superposition of two functions with different s, namely $s \sim 1.20$ at distances $r < 100$ m from the axis and $s = 1.30$ at $r > 100$ m. This result was subsequently confirmed in theoretical calculations of the lateral distribution functions of the particles in nuclear-cascade processes [10].

The total number of shower particles N, determined with the aid of the function $\rho_c(N, r_{j0})$, differs by not more than 10% from the value of N calculated from the central function of [9].

The accuracy with which the shower parameters are determined by inducing artificial showers, with allowance for the fluctuations of the lateral distribution function of real showers, amounted to 20% for N and 10% for x_0 and y_0. The spectrum obtained by determining N from the standard function retains the same shape if N is determined with allowance for the fluctuations of the lateral distribution functions; allowance for the fluctuations merely decreases somewhat the absolute shower intensity [11].

Figure 2 shows the differential shower spectrum obtained in the present study for the interval $N = 10^7 - 10^8$. The same figure shows experimental data obtained by us earlier with the same installation in the interval $N - 10^6 - 10^7$ [12].

As seen from the figure, the spectrum has a power-law form and its exponent changes its value, from 3.00 ± 0.10 for $N = 10^6 - 10^7$ to 2.60 ± 0.15 for $N > 10^7$. The same figure shows the data of [2] and [5]. As seen from the figure, these experimental data confirm the change occurring in the spectrum in the region $N \geq 10^7$.

As is well known, study of the particle-number spectrum is one of the methods used to investigate primary cosmic radiation. The obtained change in the N-spectrum is connected with a change in the spectrum of the primary cosmic radiation. This is confirmed by study of the dependence of the muon fluxes N_μ on N. In the investigated interval of N this dependence is described by a single power law $N_\mu \sim N^\alpha$, where α is constant [9]. The change of the primary spectrum can be attributed to the fact that metagalactic particles begin to predominate in the cosmic radiation, which is a superposition of particles of galactic and metagalactic origin.

[1] G. V. Kulikov and G. B. Khristiansen, Zh. Eksp. Teor. Fiz. 35, 635 (1958) [Sov. Phys.-JETP 8, 441 (1959)].
[2] G. Clark, J. Earl, W. Kraushaar et al., Nature 180, 406 (1957).
[3] G. Clark, J. Earl, W. Kraushaar et al., Phys. Rev. 122, 637 (1961)
[4] G. B. Khristiansen, Dissertation, 1964; S. N. Vernov, G. B. Khristiansen, A. T. Abrosimov et al., Izv. AN SSSR, ser. fiz. 24, 1876 (1965).
[5] T. A. Egorov, Dissertation, Yakutsk, 1973.
[6] S. N. Vernov, G. B. Khristiansen, A. T. Abrosimov, et al., Izv. AN SSSR, ser. fiz. 32 458 (1968).
[7] S. N. Vernov, G. B. Khristiansen, A. T. Abrosimov, et al., ibid. 28, 2087 (1964).
[8] A. T. Abrosimov, N. N. Goryunov, V. A. Dmitriev, et al., Zh. Eksp. Teor. Fiz. 34, 1077 (1958) [Sov. Phys.-JETP 7, 746 (1968)].
[9] G. B. Khristiansen, O. V. Vedeneev, G. V. Kulikov, et al., Proc. ICCR, Hobart, 6, 2097 (1971).
[10] L. G. Dedenko, I. A. Dymova, G. B. Khristiansen, Izv. AN SSSR ser. fiz. 37, No. 7 (1973).
[11] S. N. Vernov, G. B. Khristiansen, A. T. Abrosimov, et al., Can. J. Phys. 66, 197 (1967).
[12] G. B. Khristiansen, A. T. Abrosimov, V. B. Atrashkevich, et al., Izv. AN SSSR ser. fiz. 28, 1935 (1964).

INTERFERENCE PHENOMENA IN TRANSITION RADIATION

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Submitted 27 June 1973; resubmitted 13 August 1973
ZhETF Pis. Red. 18, No. 6, 356 - 359 (20 September 1973)

Many recent experimental and theoretical studies have been devoted to x-ray transition radiation [1 - 9]. Although it has been shown theoretically that under certain conditions an interference picture should be produced in the spectral distribution of x-ray transition radiation formed in a stack of plates [2, 9], this phenomenon has not yet observed in the emission spectra.

We present here the results of an investigation of transition radiation produced by 3.0-GeV electrons in the photon frequency range 5 - 100 keV, for radiator consisting of 230 aluminum foils each of thickness a = 8 microns, as a function of the distance b between the foils, which ranged from 50 to 1000 microns.

The measurements were performed on a previously described setup; the spectra in the 5 - 20 keV range were investigated with a multisection proportional counter with energy resolution ±10% at the 13.8 keV line, while for photon energies above 20 keV we used a scintillation