Number of showers having N electrons with energy > E at depth t

$t = 0.5$					$t = 1.5$				
N	E, ev				N	E, ev			
	10^{10}	$4\cdot10^{9}$	10^{9}	$4\cdot10^{8}$		10^{10}	$4\cdot10^{9}$	10^{9}	$4\cdot10^{8}$
0	1	0	0	0	0—5	103	76	46	41
1	102	94	84	83	6—10	45	57	49	44
2	24	23	14	9	11—15	4	18	35	29
3	16	24	38	41	16—20	1	2	14	21
4	7	6	4	6	21—25	0	1	6	14
5	4	5	9	8	26—30	0	0	3	0
6	0	2	0	2	31—35	0	0	0	3
7	0	0	4	4	36—40	0	0	1	1
8	0	0	1	0					
9	0	0	0	0					
10	0	0	0	1					

1.0, 1.5, and 4 cascade units, and the solid curves represent the spectra calculated using the usual values of the cross-sections.[6] It is evident that the energy spectrum calculated accounting for multiple scattering is different: there are more high-energy particles and less low-energy particles ($< 10^9$ ev) present than in the usual spectrum.

The distribution of showers with respect to the number of particles with energy > E at two depths is given in the table. It can be seen that the fluctuations of $\overline{N}(>E)$, of the order of $\pm 0.7\,\overline{N}(>E)$, occur in about 30% of all cases at the depth of one cascade unit. Fluctuations of $\overline{N}(>E)$ in showers calculated using the usual values of the cross sections are, evidently, of similar magnitude. Great statistical accuracy is, therefore, needed for a confirmation of the effects predicted in references 1 to 4 by a measurement of the energy spectrum of electrons with energies 4×10^8 ev in showers initiated by 10^{12}-ev particles.

The authors thank V. Ia. Pivkin for help in the reduction of data.

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INCREASE OF THE BAROMETRIC EFFECT WITH THE ENERGY OF EXTENSIVE AIR SHOWERS

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Two series of observations of the time variations of extensive air showers frequency were carried out in 1954 through 1956 in Yakutsk, latitude 62° N, longitude 129° E, elevation 100 m. The measurements covered a range of mean shower densities and arrays of self-quenching Geiger-Müller counters were used.

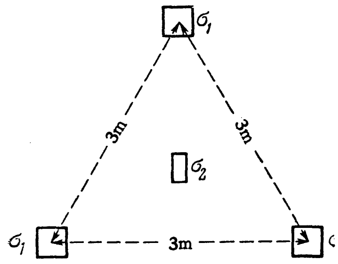

FIG. 1. Diagram of the position of counter trays under 60 g/cm² of matter. Effective counter tray area: $\sigma_1 = 0.1$ m², $\sigma_2 = 0.033$ m².

In the first series (Fig. 1), triple coincidences of counter trays of area σ_1 and fourfold coincidences C_3 and C_4 were recorded under 60 g/cm² of matter. In the second series (Fig. 2), the thickness was reduced to 2.5 g/cm² of a light substance. Six-fold coincidences C_6 of counter trays of area σ_1, eight-fold coincidences C_8 and, independently, coincidences C_3 not accompanied by a six-fold coincidence were recorded in the second series besides the coincidences C_3 and C_4 in the two independent arrays.

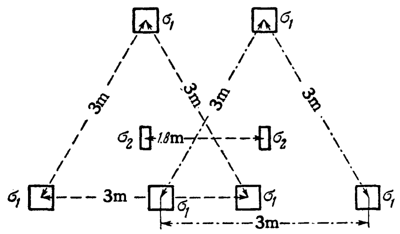

FIG. 2. Diagram of the position of counter trays under 2.5 g/cm² of matter. Effective counter tray area: $\sigma_1 = 0.1$ m², $\sigma_2 = 0.033$ m².

A statistical analysis of the variation of the mean daily number of showers, correlated with the variations of the mean daily values of the temperature and pressure at the point of observation, revealed a marked increase of the barometric coefficient with increasing mean particle flux density $\overline{\rho}$ in the showers. The measured partial coefficients of the barometric effect, in percent per millibar of pressure variation, are given below for different densities $\overline{\rho}$ (particles/m^2).

	$\overline{\rho}$	Under 60 g/cm^2	Under 2.5 g/cm^2
$A_3 = C_3 - C_6$	15		−0.55±0.05
C_3	26	−0.68±0.07	−0.58±0.04
C_4	50	−0.76±0.11	
C_6	53		−0.70±0.05
C_8	100		−0.73±0.07

Assuming that $\overline{\rho}$ equals the particle flux density in recorded showers at a certain distance from shower axis, and using the energy estimate given by Greisen,[1] it is possible to estimate the mean energy of the primary particles initiating the showers. We found that the energies are 1×10 and 2×10^{15} ev for coincidences C_3 and C_6 respectively.

The observed increase of the barometric effect with energy can be explained on the lines of the theory proposed recently by Nikol'skii, Vavilov, and Batov.[2]

The author would like to thank S. I. Nikol'skii for a discussion of the work and to N. N. Efimov, N. P. Emel'ianov, and T. F. Panfilova for help in reducing the data.

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A CONTRIBUTION TO NEUTRINO THEORY

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WE show in the present article that all the experimental results which can be explained by a two-component neutrino theory[1] can also be explained without introducing a longitudinal (asymmetric) neutrino. We suggest replacing this longitudinal-neutrino assumption by the assumption that in β, μ, and π decays there is emitted a quantum mechanical mixture of two light neutral Dirac particles of opposite parity, each being the antiparticle of the other, and for this purpose we introduce a possible new particle-antiparticle conjugation rule.

We shall, for simplicity, consider only β decay, given by a Hamiltonian of the form

$$H = \sum_{i=1}^{5} c_i (\overline{\psi}_n O_i \psi_p)(\overline{\psi}_e O_i \Phi). \qquad (1)$$

Before the work of Lee and Yang[2] the symbol Φ stood either for ψ_ν or $\psi_{\overline{\nu}}$, which is equivalent to postulating the possibility of experimentally differentiating between ν and $\overline{\nu}$. The possibility that a quantum mixture $\nu \pm \overline{\nu}$ may be emitted was not considered, i.e., the number of leptons assumed to be conserved. In the two-component theory, however, we write

$$\Phi \to \Phi^{(\pm)} = (1 \mp \gamma_5)\psi_\nu/\sqrt{2} = (\psi_\nu \mp \gamma_5 \psi_\nu)/\sqrt{2}. \qquad (2)$$

Let us write, to be specific, $\psi_\nu = \psi_{+\uparrow}$ (the explicit form for the solutions to the Dirac equation are given by Schiff;[3] we write everywhere $E = E_+ = -E_-$). Then

$$\gamma_5 \psi_{+\uparrow} = \begin{pmatrix} 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \\ -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{pmatrix} \begin{pmatrix} -p_z/E \\ -(p_x + ip_y)/E \\ 1 \\ 0 \end{pmatrix} e^{i(pr - Et)}$$

$$= \begin{pmatrix} -1 \\ 0 \\ p_z/E \\ (p_x + ip_y)/E \end{pmatrix} e^{i(pr - Et)} = -\psi_{-\uparrow}(-E).$$

Our hypothesis is equivalent to the assumption that

$$\psi_{\overline{\nu}}(E) = \psi_-(-E) = -\gamma_5 \psi_+(E) \qquad (3)$$

behaves like the wave function of $\overline{\nu}$, while $\psi_\nu = \psi_+(E)$ is the wave function of ν.

Usually the wave function of a particle and an antiparticle (such as, for instance, the electron and positron) are related by

$$\psi_n = C\psi_-^*(-\mathbf{p}). \qquad (4)$$

This relation is necessary, and is the only possible one because in the negative-frequency equation

$$[\boldsymbol{\alpha} \cdot (\mathbf{p} - e\mathbf{A}) + \beta m + eA_0 + E]\psi_- = 0$$

it is necessary, on going over to the antiparticle equation

$$[\boldsymbol{\alpha} \cdot (\mathbf{p} + e\mathbf{A}) + \beta m - eA_0 - E]\psi_n = 0,$$

to change the sign of both the energy and the charge.