the existence of type III states was studied by measuring the temperature dependence of the intensity J of the (100) and (001) magnetic reflections (Fig. 3). The transition point, determined by extrapolating the curves, is at 78.5°K. According to specific-heat data, the transition point is at 73.2°K.[6] The curves are in general smooth. The difference $J_{He} - J_T$ varies approximately as T^2. The crystal does not change in magnetic structure as the temperature is reduced from T_N down to helium temperature. Had there been a change in magnetic structure, the temperature-dependence curve of J_{001} would have had a maximum.

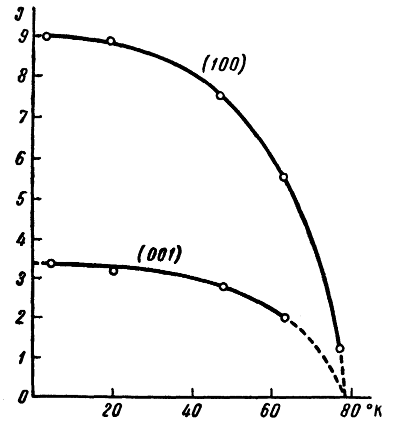

FIG. 3

I wish to thank Academician P. L. Kapitza for continuous interest in this work. I am grateful to A. S. Borovik-Romanov for much advice and to I. E. Dzyaloshinskiĭ for valuable discussion. I am indebted to Yu. G. Abov for his constant cooperation in the work. I also thank N. N. Mikhaĭlov for furnishing the sample.

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ON CERTAIN SINGULARITIES IN THE INTERACTION WITH LIGHT NUCLEI OF PARTICLES WITH ENERGIES $E \geq 2 \times 10^{12}$ ev

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In a previous paper[1] we have shown, by assuming the existence of large fluctuations in the fraction of energy transferred to π mesons when a high-energy nucleon interacts with a light nucleus, that all the observed basic characteristics of extensive atmospheric showers can be easily explained without resorting to the hypothesis that the shower development is influenced by the nuclear cascade.[2] This paper presents experimental data demonstrating the existence of interactions in which the primary particle loses almost all its energy (to the production of π^0 mesons), and estimates the probability of this process.

The experimental array, shown schematically in Fig. 1, consisted of four mutually perpendicular rows of pulse ionization chambers. Each row contained 33 chambers 330 cm long and 10 cm in diameter. The effective area of the array was 10 m^2. Each of the 132 chambers was connected to its own amplifier, which measured the pulses with 300 to 400-fold range of amplitudes. Pulse registration occurred whenever the ionization in any two or more chamber rows exceeded a given value. Part of the time the array operated with a hodoscope of 250 counters located at various distances from the array. This work was performed in Moscow during 1959. E. S. Loskevich and A. A. Oles' took part in the task.

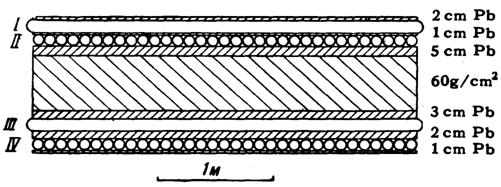

FIG. 1. Schematic array

During the operation of the array, there were observed in chamber rows I and II impulses for which almost all the ionization was confined to a circle of ~ 20 cm radius. In subsequent data proccessing, those events were selected in which more than 70% of all ionization was concentrated in not more than four chambers (in a circle of 20 cm radius), and the energy of the soft component falling on the array was $E \geq 2 \times 10^{12}$ ev. The ionization distribution in one of these impulses is shown in Fig. 2. There were 27 such events recorded during 800 hours of array operation. Hence their frequency is $\sim 9 \times 10^{-11} \text{cm}^{-2} \text{sec}^{-1}$. If the integrated spectrum of these impulses is represented by an exponential function, the exponent is $\gamma = 1.5 \pm 0.5$.

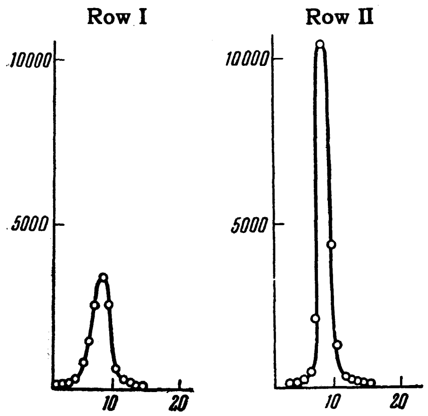

FIG. 2. Example of an event in which a newborn shower impinges on the array. Abscissa – chamber numbers; ordinate – ionization in each chamber, expressed in terms of the number of recorded particles.

It can easily be shown that μ mesons cannot contribute more than 10% of the selected events. One can therefore assert that those impulses, for which almost all the ionization occurring in the upper rows of chambers is concentrated within a circle of ~ 20 cm radius, are produced by newborn electron-photon showers generated by the interaction of particles of $E \geq 2 \times 10^{12}$ ev with the nuclei of atmospheric atoms located not far above the array. The concentration of 70% of the shower energy within a radius of 20 cm shows that shower generation occurs within an atmospheric layer ~ 100 g/cm^2 above the array. In those cases when the hodoscope was operating, the number of particles in the atmospheric shower accompanying such an impulse in the upper chamber rows comprised $\lesssim 5\%$ of the number of particles in an extensive atmospheric shower, for which the energy of the electron-photon component $\geq 2 \times 10^{12}$ ev was contained in a circle of 20 cm radius. This circumstance also furnishes direct proof that the recorded shower is newborn.

The two lower rows of chambers in the array permit determination of the energy of the nuclear-active particles accompanying newborn electron-photon showers. (Counting efficiency for individual nuclear-active particles was 70%.) According to the experimental data, impulses produced in the lower chamber rows III and IV, by nuclear-active interactions in the filtering array are observed in only 30% of the events (8 occurrences out of 27). During such occurrences, as a rule, not one but several nuclear-active particles fall on the array, generating impulses of commensurate magnitude (from which it follows that the counting efficiency of the nuclear-active component in the selected events approaches 100%). For the 30% of events in which newborn showers are accompanied by nuclear-active particles, the pulse amplitude in the lower rows averages 40% of the pulse amplitude in the upper rows. We conclude that in these events the energy of the nuclear-active particles equals the energy of the electron-photon component.

The fact that a significant fraction of the newborn showers, generated not far above the array, does not contain high-energy nuclear-active particles, indicates the existence of processes in which the primary particles transfer almost all their energy to the electron-photon component. If a given process in which 100% of the nuclear-active particle energy goes to the soft component occurs via π^0-meson production, then it follows from our data that the number of π^0 mesons thus created is small ($\ll 10$), and indeed it is possible that almost all the energy is transferred to a single π^0 meson.

The probability of such interactions, in which almost all the primary-particle energy is transferred to the soft component, can be determined by comparing our count of such events in an atmospheric layer ~ 100 g/cm^2 thick with the absolute flux of nuclear-active particles having $E \geq 2 \times 10^{12}$ ev (nuclear-active particle flux data were taken from reference 3). Comparison of the experimental data indicates that the probability of complete energy transfer to the soft component is $\sim 10\%$.

If one assumes that the basic characteristics of the interaction do not change materially as the particle energy increases to $10^{13} - 10^{14}$ ev, then it can be shown, from the frequency of newborn showers registered, that 25 – 50% of the observed extensive atmospheric showers containing 10^4–10^5 particles can be produced merely by those interactions in which almost all the primary-particle energy is transferred to the soft component. In these showers the energy of the nuclear-active component will be significantly lower than the energy of the electron-photon component.

Since as a rule a newborn shower is accompanied by a very weak atmospheric shower, it follows that nuclear-active particles with $E \geq 2 \times 10^{12}$ ev, which have interacted not far above the array, have passed through almost the entire atmosphere without taking part in any interactions involving a large energy loss. Hence, along with the interactions associated with almost 100% energy loss, there must also be weak interactions which involve little energy loss, and which occur with significantly higher probability.

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PHOTOPRODUCTION OF π^0 –MESONS FROM CARBON NEAR THRESHOLD

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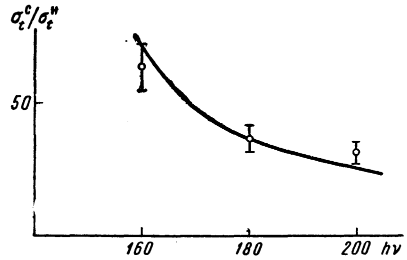
IT has been shown[1,2] that in the photoproduction of π^0 mesons from helium at energies between threshold and ~ 200 Mev, the elastic production dominates. To investigate the role played by the elastic process in the photoproduction of π^0 mesons from more complex nuclei, we measured in the present work the ratios of the total cross sections for photoproduction from carbon and from hydrogen at primary photon energies of 160, 180, and 200 Mev. The geometry and the experimental method for the carbon measurements, which were made on the 265-Mev synchrotron of the P. N. Lebedev Physics Institute of the U.S.S.R. Academy of Sciences, are similar to those previously described[3] for hydrogen experiments.

Curves were obtained for the energy dependence of the emerging γ rays from the decay of the π^0 mesons from carbon, for three angles. The emerging decay γ rays were measured to within 1 or 2%. The energy dependence of the cross section for producing the decay γ rays was calculated by the method of "photon differences" from the corresponding measured energy-dependence curves. The angular distributions of the decay photons obtained in this way were then integrated to obtain the total cross sections for the photoproduction of π^0 mesons from carbon (σ_t^C) in relative units.

The ratios of the number of decay γ rays emerging from carbon and hydrogen at angles of less than 90°, obtained by measuring the counting rate of decay photons from hydrogen and styrofoam (C_8H_8) targets with the same geometry, were used to determined the ratio of the total cross sections σ_t^C/σ_t^H. The measured values of these ratios are shown in the figure.



The results obtained were compared with the predictions of the theory of elastic photoproduction of π^0 mesons from nuclei.[1] According to the theory, the differential cross section for π^0-meson photoproduction from a nucleus with nucleon number A and spin zero can be expressed in the form

$$(d\sigma(k)/d\Omega)_A = A^2 (d\sigma(k)/d\Omega)_H F_A^2(qR)/F_H^2(q), \quad (1)$$

where q is the nuclear recoil momentum, while $F_A^2(qR)$ and $F_H^2(q)$ are the nuclear and proton form factors; the second can be set equal to unity. From electron scattering experiments on carbon[4] it is known that the form factor for the carbon nucleus is expressed as follows

$$F_C^2(qR) = \left\{\left[1 - \frac{\alpha a^2 q^2}{2(2+3\alpha)}\right] e^{-q^2a^2/4}\right\}, \quad (2)$$

where $\alpha = 4/3$, $a = 1.635 \times 10^{-13}$ cm, $(d\sigma(k)/d\Omega)_H$ is the spin-independent differential cross section for π^0-meson photoproduction from hydrogen. From the form of the matrix elements for π-meson photoproduction from nucleons one can easily get

$$(d\sigma(k)/d\Omega)_H = (3/8\pi)\,\sigma_t \sin^2\theta_\pi, \quad (3)$$

where θ_π is the angle of emission of the π^0 meson in the center-of-mass system, and σ_t is the spin-independent part of the total cross section for π^0-meson photoproduction from protons.

Substituting (3) into (1) and integrating over the solid angle, we obtain

$$\sigma_t^C = 17.2 \cdot \sigma_t \int_0^\pi F_C^2(qR) \sin^3\theta_\pi \, d\theta_\pi .$$