could possibly be a proton, so that we would have nonmesonic decay of $_{\Lambda}Be_4$ accompanied by neutron emission.

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STUDY OF HIGH-ENERGY NUCLEAR-ACTIVE PARTICLES WITH IONIZATION CHAMBERS

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Nuclear-active particles with energy $> 10^{11}$ ev were studied at an altitude of 3860 m above sea level by means of ionization chambers placed under absorbers of various thickness and of a counter hodoscope. Integral spectra of ionization bursts in the chambers are presented, and conclusions are drawn regarding the absorption mean free path in air and in lead of nuclear-active particles with energy $> 10^{11}$ ev.

HIGH-ENERGY nuclear-active particles ($E > 10^{11}$ ev) were studied in Autumn 1955 at 3860 m elevation by means of an array consisting of six pulse ionization chambers placed under lead absorbers of varying thickness (20, 50, and 80 cm, Fig. 1). The ionization chambers were constructed of brass cylinders with walls 3.8 g/cm^2 thick and an internal diameter of 22.5 cm. The effective area of each chamber was 0.22 m^2. The chambers were filled with argon at 4 atmos.

The electronic system made it possible to record the ionization pulse heights in each of the six chambers. The interval of recorded pulses ranged from that due to the passage of a single relativistic particle to that due to 1.5×10^4 particles, assuming the trajectories to lie on the mean chord of the chamber. A hodoscope consisting of 972 counters with total area of ~ 10 m^2 was used in conjunction with the ionization chambers. Alternate triggering was provided: the array was operated whenever

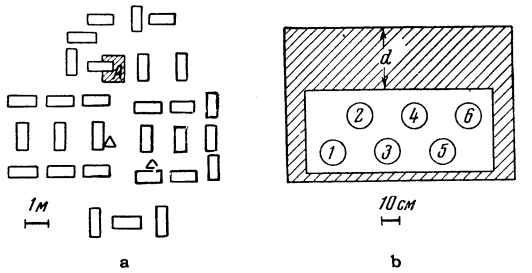

Fig. 1. a – position of the nuclear-active particle detector A with respect to hodoscope counter groups (rectangles). Δ indicates the position of the trigger counters (fourfold coincidence). b – position of the six ionization chambers in the nuclear-active particle detector A. d – variable thickness of lead (20, 50, or 80 cm)

either the total pulse in the ionization chambers was greater than the equivalent of 600 relativistic particles, or the occurrence of an air shower was recorded by a fourfold coincidence of discharges in unscreened counters each 0.05 m^2 in area. The hodoscope made it possible to detect the presence of an air shower associated with an ionization burst, even when the shower was small ($\rho \gtrsim 0.5\,m^2$), and to determine the total number of particles for showers with $n > 10^3$.

Frequency distribution of ionization bursts with respect to their size under different absorbers is shown in Fig. 2, where the x axis represents, in

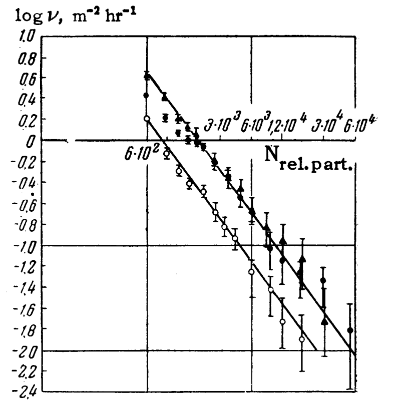

Fig. 2. Frequency distribution of ionization bursts with respect to their size. Absorber thickness: ▲ – 20, ● – 50, ○ – 80 cm Pb.

logarithmic scale, the sum of the bursts in the six chambers, expressed in the corresponding number of relativistic particles N, and the y axis represents the absolute frequency $\nu(> N)$ of bursts greater than N.

Integral spectra of bursts corresponding to N > 2000 relativistic particles can be expressed by a power law $\nu(N) = A/N^{\gamma}$, where γ, within statistical accuracy, is the same for all three spectra (20, 50, and 80 cm Pb) and on the average equal $\overline{\gamma} = 1.5 \pm 0.16$. Absolute frequencies of ionization bursts under 20 and 50 cm Pb are, within the accuracy limit, identical. Absorption mean free path for 50 to 80 cm Pb is $\lambda = (340 \pm 60)$ g/cm^2.

Comparison of the frequency of observed ionization bursts with the number of bursts observed at sea-level[1] leads to the conclusion that the absorption mean free path for the nuclear-active component in air amounts to ~ 120 g/cm^2.* Comparison of the absolute intensity of the primary cosmic radiation with the frequency of the observed nuclear-active particles leads also to a value which does not contradict the above result, provided reasonable assumptions concerning the energy are made (an ionization burst due to 10^3 relativistic particles corresponds according to our estimates to a primary particle of 10^{12}ev).

In the study of correlation between ionization bursts and air showers, the events were divided into two groups: (1) ionization bursts accompanied by low-density air showers, when it was not possible to locate the shower axis and to determine the total number of particles in the shower, and (2) ionization bursts accompanied by extensive showers with more than 10^3 particles. The results are given in the table.

Absorber	50 cm Pb			80 cm Pb		
Size of the burst (number of relativistic particles)	600	6000	18000	600	6000	18000
Total number of bursts	360	27	5	266	9	2
Number of bursts accompanied by an air shower	190	18	4	80	7	2
Number of bursts accompanied by an extensive air shower	43	5	3	35	6	2

It can be seen that the probability of the presence of an associated air shower increases with the size of burst.

Bursts which could be interpreted as due to simultaneous incidence of at least two high-energy nuclear-active particles were observed in 25% of cases. Those bursts (> 600 relativistic particles) were accompanied in 70% of cases by air showers.

Just as the spectrum of ionization bursts represents the energy spectrum of all nuclear-active particles at the observation level, so does the spectrum of ionization bursts under more than 20 cm of lead, due to extensive air showers, represent

*It was taken into account in the comparison that the experiments of Ref. 1 were carried out under a thick roof and that a part of the bursts recorded at sea level is due to μ-mesons.

the energy spectrum of the nuclear-active component in extensive air showers when the following three conditions are met: (1) only one nuclear-active particle of the shower falls upon the detector, (2) the shower-detecting system does not introduce any bias for different distances between the core and the nuclear-active particle detector, and (3) the interval of the sizes of observed showers is sufficiently narrow so that the energy spectra of nuclear-active particles in the showers are similar.

We examined showers of $7 \times 10^4 - 7 \times 10^5$ particles. It was found from the measured distribution of axis positions of showers associated with ionization bursts, corresponding to > 600 particles, that in more than 90% of the events the axis was less than 20 m from the detector of nuclear-active particles. For such distances, errors introduced into the shower axis distribution by the four-fold coincidence system were negligible.

The frequency distribution of ionization bursts due to nuclear-active particles of air showers, with respect to their size, is shown in Fig. 3. The frequency of bursts accompanied by extensive air showers decreases with the thickness of absorber, varying from 20 to 80 cm Pb (mean free path $\lambda = (570 \pm 120)\ \mathrm{g/cm^2}$.

The size distribution of bursts accompanied by extensive air showers can be represented by a power law with an exponent $\gamma = 0.9 \pm 0.2$. If we assume that only a single nuclear-active particle arrives at the detector each time then the spectrum of the nuclear-active component in an extensive air shower of $\sim 10^5$ particles can be expressed as $E^{-0.9 \pm 0.2}$ in the energy region $5 \times 10^{11} - 10^{13}$ ev.

The probability of simultaneous incidence of two

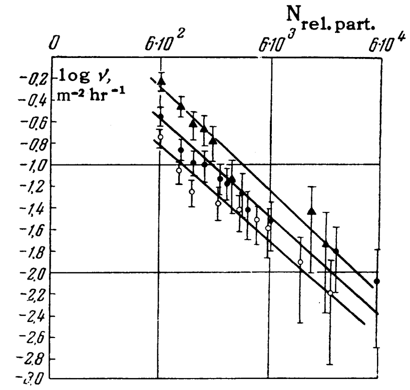

Fig. 3. Frequency distribution of ionization bursts due to nuclear-active particles of extensive air showers with 7×10^4–7×10^5 particles. Absorber thickness: ▲ – 20, ● – 50, ○ – 80 cm Pb.

nuclear-active particles upon a detector may be rather high for extensive showers. The true spectrum of nuclear-active particles in extensive air showers can, therefore, be different from the expression given above. The role of this effect is at present unknown.

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