Brief Communications

STUDY OF NEUTRAL PION GENERATION AT PARTICLE ENERGIES $5 \times 10^{12}-10^{13}$ eV

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OUR studies of the formation of large ionization bursts [1] and young air showers [2,3] have shown that in both cases the mechanism for the generation of the electron-photon component is the same, and differs essentially from the mean interaction characteristics by having a large interaction inelasticity coefficient K and an anomalously large fraction K_{π^0} of the energy transferred to the π^0 mesons; the average values of K and K_{π^0} for these processes turned out to be $\bar{K} \geq 0.8$ and $\bar{K}_{\pi^0} = 0.6-0.8$.

In order to clarify the mechanism of the large fluctuations, we used our previously developed [4-6] method of "controlled nuclear photoemulsions." The gist of the method consists in placing the nuclear photoemulsions, interleaved with lead filters, over an array containing a large number of ionization chambers. The array is shown schematically in Fig. 1. When the nuclear-active particle interacts in the generator (layer of graphite 20 g/cm² thick) located 150 cm above the nuclear emulsions, the π^0-meson decay produces γ quanta which strike the lead filters with the emulsions, and which have time to move hundreds of microns apart. As a result, the electron-photon cascades produced in the lead by the γ quanta are recorded in the emulsions as individual lines.

With the aid of the ionization chambers in rows 3 and 4 we have located the passage of these cascades through the emulsion and determined their total energy, while ionization chambers in rows 1 and 2 have made it possible to determine the energy E_2 of all the secondary nuclear-active particles left after the first interaction, and to estimate the primary-particle energy $E_0 = \sum_i E_\gamma^i + E_2$.

The energy E_γ^i of the individual γ quanta generated in a given interaction was determined from the number of shower particles produced by the given γ quantum and registered by the emulsion. To this end, the showers found in the emulsion were traced with the aid of a projection microscope MBI-8, and the energy E_γ of the γ quantum producing the given shower was determined from the formula $E_\gamma = a/R$, where R—radius of the circle containing 40 particles (under a layer of 3 cm of lead) and a—a coefficient having a theoretical value $a = 1.0 \times 10^{13}$ eV·μ; the experimental value obtained for a was found to be $(1.03 \pm 0.13) \times 10^{13}$ eV·μ.

In this installation we used NIKFI-R emulsions 15 microns thick. The photographic plates with the emulsions were placed under the chambers—four rows between three 1-cm layers of lead.

During the course of the investigation, the ionization chambers yielded six showers with

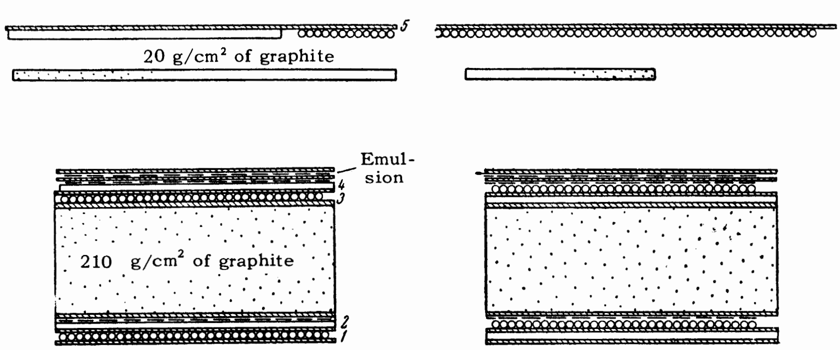

FIG. 1. Diagram of array in two projections: 1 – 5) rows of ionization chambers (area of array 10 m²)

Event	E_0, 10^{12} eV	$\sum_i E^i_\gamma$, 10^{12} eV	$K_{\pi^0} = \sum_i E^i_\gamma / E_0$	$n_{\pi^0} = n_\gamma/2$	$E_{\pi^0 max}/E_0$, %
1	6.0	4.8	0.81	5	48
2	5.9	4.5	0.78	5	25
3	10.0	7.5	0.75	3	61
4	8.9	5.5	0.62	3	59
5	2.9	2.6	0.90	3	49
6	11.7	3.1	0.26	10	4

$\Sigma_i E^i_\gamma \geq 2 \times 10^{12}$ eV. For each shower we determined the fraction of the energy transferred to the neutral pions $K_{\pi^0} = \Sigma_i E^i_\gamma / E_0$, the number of neutral pions n_{π^0}, and the energy of the neutral pion with maximum energy $E_{\pi^0 max}$. The results obtained are listed in the table.

The table shows that:

1. Most ionization bursts result from interactions in which the inelasticity coefficient K is close to unity and the neutral pions received in the mean about 80% of the primary-particle energy.

2. In these interactions the multiplicity of the generated neutral pions is $n_{\pi^0} \cong 4$, which is much lower than the average multiplicity at the corresponding primary-particle energy.

3. One π^0 meson receives in these interactions an average of approximately 50% of the primary-particle energy.

The mean value of the perpendicular component of the γ-quantum momentum, averaged over all the showers (58 γ quanta), was found to be

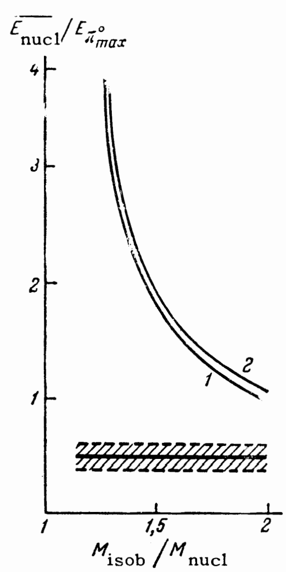

FIG. 2. Dependence of the average energy ratio of the nucleon and pion produced by isobar decay on the isobar mass M_{isob}: 1 – for $\gamma = 2.9$ (γ – exponent of the differential energy spectrum of nuclear-active particle); 2 – for $\gamma = 2.7$. The shaded area shows the maximum possible experimental values of the ratio $\langle E_{nucl}/E_{\pi^0 max}$.

$(1.71 \pm 0.11) \times 10^8$ eV/c. The mean perpendicular pion momentum component, recalculated from this quantity, turned out to be $(3.2 \pm 0.2) \times 10^8$ eV/c, that is, the transverse component of the momentum of the generated pions remains unchanged up to primary-particle energies $\sim 10^{13}$ eV.

To ascertain whether the appearance of an energetically singled-out π^0 meson is due to the decay of a baryon isobar, we determined the average ratio E_2 to $E_{\pi^0 max}$. It was found that $\langle E_2/E_{\pi^0 max}\rangle = 0.5 \pm 0.7$. Since the energy of all the secondary nuclear-active particles is $E_2 = \Sigma E_{mes} + E_{nucl}$, where ΣE_{mes} —energy of all the mesons and E_{nucl} —energy of the fast nucleons, we should have for the averages

$$\langle E_{nucl} / E_{\pi^0 max}\rangle \leqslant \langle E_2 / E_{\pi^0 max}\rangle.$$

If the energetic π^0 meson were to result from isobar decay into a π^0 meson and a nucleon (with isotropic scattering in the proper coordinate system), then the ratio $\langle E_{nucl}/E_{\pi^0 max}\rangle$ would depend on the isobar mass in the manner shown in Fig. 2. According to our data, this ratio is $\leq 0.5 \pm 0.1$, that is, the appearance of high-energy pions as the result of the decay of known baryon isobars has low probability.

We can therefore conclude that the large fluctuations in the value of K_{π^0} are due essentially to the transfer to one π^0 meson of approximately 50% of the primary-particle energy, and that this meson is apparently not the product of the decay of isobars with mass $M \leq 2M_{nucl}$.

[1] Babayan, Babecki, Boyadzhyan, Buja, Grigorov, Loskiewicz, Mamidzhanyan, Massalski, Oles, Tret'yakova, and Shestoperov, Izv. AN SSSR ser. fiz. **26**, 558 (1962), Columbia Tech. Transl. p. 558.

[2] Babayan, Boyadzhyan, Grigorov, Mamidzhaniyan, Tret'yakova, and Shestoperov, JETP **46**, 1525 (1964), Soviet Phys. JETP **19**, 1032 (1964).

[3] Babayan, Boyadzhyan, Mamidzhanyan, Grigorov, Tret'yakova, and Shestoperov, JETP **46**, 110 (1964), Soviet Phys. JETP **19**, 80 (1964).

[4] Brikker, Grigorov, Kondrat'eva, Podgurskaya,

Savel'eva, Sobinyakov, and Shestoperov, Nuovo cimento Suppl. 8, 733, (1958).
[5] Grigorov, Kondrat'eva, Savel'eva, Sobinyakov, Podgurskaya, and Shestoperov, Trans. Intern. Conf. on Cosmic Rays, Moscow, 1, 122 (1960).
[6] Grigorov, Podgurskaya, Shestoperov, and Sobinyakov, Proceedings of Conference on Thick Emulsion Procedures, JINR, 1, 168 (1957).

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53