JOINT INSTITUTE FOR NUCLEAR RESEARCH

Laboratory of High Energies

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P-211

NEUTRAL PION PRODUCTION IN 9 BEV PROTON INTERACTIONS WITH EMULSION NUCLEI

Dubna, 1958

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A b s t r a c t

The value of the average energy of π^0 -meson appeared in ~ 9 BeV proton interactions with emulsion nuclei has been determined. This value $\bar{E}_{\pi} = 750 \pm 180$ MeV has been obtained for average energy of neutral pions. The energy carried away by pions in these interactions is within the limits 0,33 ± 0,08 to 0,27 ± 0,07.

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The problem of the value of the energy K transferred into secondary pions is of great interest for studying the mechanism of high energy interaction. The investigation of this question for the interactions due to cosmic ray particles with light nuclei in the energy region $E \sim 10^{10}$ ev indicates that the value of K is approximately 30% [1] . It seems useful to estimate the value of K under the conditions when the energy and nature of primary particles are exactly known.

In this paper an average energy of π^0-mesons appeared in ~ 9 BeV proton interaction with emulsion nuclei was determined.

An analysis of electron-positron pairs due to γ -quanta arising as a result of neutral pion decay was made in an emulsion stack exposed to the internal proton beam of the Joint Institute synchrophasotron. The emulsion used in this stack were NIKFI type "P" 450 microns. The pairs were found by following separate relativistic tracks chosen in the band perpendicular to the beam direction at a distance of 30 mm from the stack edge. The tracks having the projected angle φ with the beam direction $1^\circ < \varphi \leq 30^\circ$ and the projection length in one plate $\ell \geq 1600\,\mu$ were selected. Those tracks which satisfied the above conditions were followed backward to the point of the pair production, or to a star or to an escaping from the stack. A similar scanning was suggested by King [2] . It is convenient for the purpose of the present research since it excludes the possibility of pair bias by energies.

To determine the average energy of γ-quanta due to neutral pion decay it is necessary to eliminate the background of bremsstrahlung. With this aim the area near the top of each pair was scanned to find an electron track parallel to the pair. The pairs having such tracks were considered as secondary ones and omitted. Their number is $\sim 10\%$ that agrees with the number of secondary pairs expected under our conditions and estimated according to the cascade theory [3] . Besides, a background of γ -quanta incident on the stack from outside was evaluated and found to be negligible. The number of pairs was equal to 93 after excluding the secondary ones. The number of relativistic tracks leading to stars was 116.

In both cases the distributions of the angles of emission against the primary beam were plotted (see Fig. 1). In the same figure is given the angular distribution of relativistic particles tracks in stars which were found by scanning along the primary proton tracks. All three distribution coincide within the error. As the angular distributions of γ-quanta and π^0-mesons coincide approximately in the studied energy region^x) one may consider the angular distributions of neutral and charged pions to be similar.

The estimation of the ratio $R = \frac{n_{\pi^0}}{n_s}$ with account of the geometrical conditions and probability of γ-quantum conversion gives the value $R \sim 0,5$. An exact determination of R may be made if better statistics is available.

The values $\bar{n}'_s$ and $\bar{N}_h$ found to be $4,3 \pm 0,2$ and $7,8 \pm 0,7$ accordingly were determined for the stars obtained by following secondary relativistic tracks. Using such a method of scanning one should expect a certain increase of $\bar{n}'_s$ in comparison with the $\bar{n}_s$ corresponding to the stars obtained by following along the track of primary protons, i.e.

$$\bar{n}'_s = \bar{n}_s + \frac{\mathcal{D}}{\bar{n}_s},$$

where $\mathcal{D}$ is the dispersion of star distribution by n_s. According to [4] $\bar{n}_s = 3,21 \pm 0,1$, $\mathcal{D} = 3,64 \pm 0,15$, that leads to the value $\bar{n}'_s = 4,3$. A good agreement with the observed value of $\bar{n}'_s$ points out the absence of a bias when choosing relativistic tracks. The estimation of the average energy of γ-quanta $\bar{E}_\gamma$ can be made by the distribution of the angles of divergence ω between the components of a pair since $E_\gamma = \varkappa\,(\overline{\frac{1}{\omega}})$. The calculation of the coefficient $\varkappa$ was made using the theoretical distribution of the angles of divergence at the given energy of γ-quantum [5]. The probability of energy distribution between an electron and positron was taken into account [6]. The numerical value of the coefficient $\varkappa$ is 4,15, if ω is expressed in radians, and the energy in MeV.

The measurement of the space angles ω for the narrow pairs was found under ours conditions practically impossible. Therefore, the measurements of the projected angles of divergence were made by the method, suggested in [7] which allowed to decrease the influence of multiple scattering. The error in the determination of the angle of divergence of a separate pair, including the error due to multiple scattering and the error of a scanner is about 25%. The distribution of the projected angles of divergence, shown in Fig. 2, was approximated by a linear combination of two Gauss distributions. Then, the transition from this distribution to that of space angles ω was made and the quantity of $(\overline{\frac{1}{\omega}})$ was calculated. It was found to be equal to 102 ± 10^xx). So, the mean value of the energy of γ-quanta is $\bar{E}_\gamma = 420 \pm 100$ MeV. The given error includes an error in the measurements, an inaccuracy in the determination of the coefficient $\varkappa$, an inaccuracy of the approximation and a statistical error in the determination of $(\overline{\frac{1}{\omega}})$.

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x) The estimation which were made confirm this assumption (See, also [2]).

xx) The statistical error is given.

To obtain the value of the average energy of π^0-meson $\bar{E}_\pi$. it is necessary to estimate the ration $f = \frac{\bar{E}_{\pi^0}}{\bar{E}_\gamma}$, where $\bar{E}_\gamma$ the average energy of γ-quanta, emitting into the solid angle under observation. The quantity f depends slightly on the type of a pion energy spectrum. The upper limit of f under reasonable assumptions on the spectrum is 1,8. Hence the upper limit of the average energy of π^0-mesons emitting in the considered solid angle is 750 ± 180 MeV.

The average energy transferred to $\pi^{\pm 0}$-mesons in one disintegration is

$$\bar{E}_\pi = (\bar{n}_s - \alpha)\cdot \frac{3}{2}\bar{E}_\gamma.$$

where α is the average number of fast protons. It was taken to be equal to 0,5. Substituting the oorresponding value of $\bar{n}_s$ and supposing that the average energy of pions is independent of the emission angle, we obtain the upper limit of the value of $\bar{E}_\pi$ equal to 3,0±0,7.

The more precise estimation of $\bar{E}_\pi$ = 2,5±0,6 oan be made under the assumption of constancy of the transverse momentum of the secondary pairs[x)] (See e.g. [8]).

Since the value of $p_\perp$ somewhat inoreases with the increase of the emission angle, the given value gives a lower limit of the pion average energy.

Thus, a part of energy carried away by pions in the proton interaction at ~ 9 BeV with emulsion nuclei is in the limits from 0,33±0,08 up to 0,27±0,07.

The authors express theirs gratitude to M. Danysz for the discussion of the results and to N.L. Solomakhina who soanned the emulsions.

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x) The average value of the transverse momentum $p_\perp$ under ours conditions is equal to $(1\div 2)\mu_\pi c$.

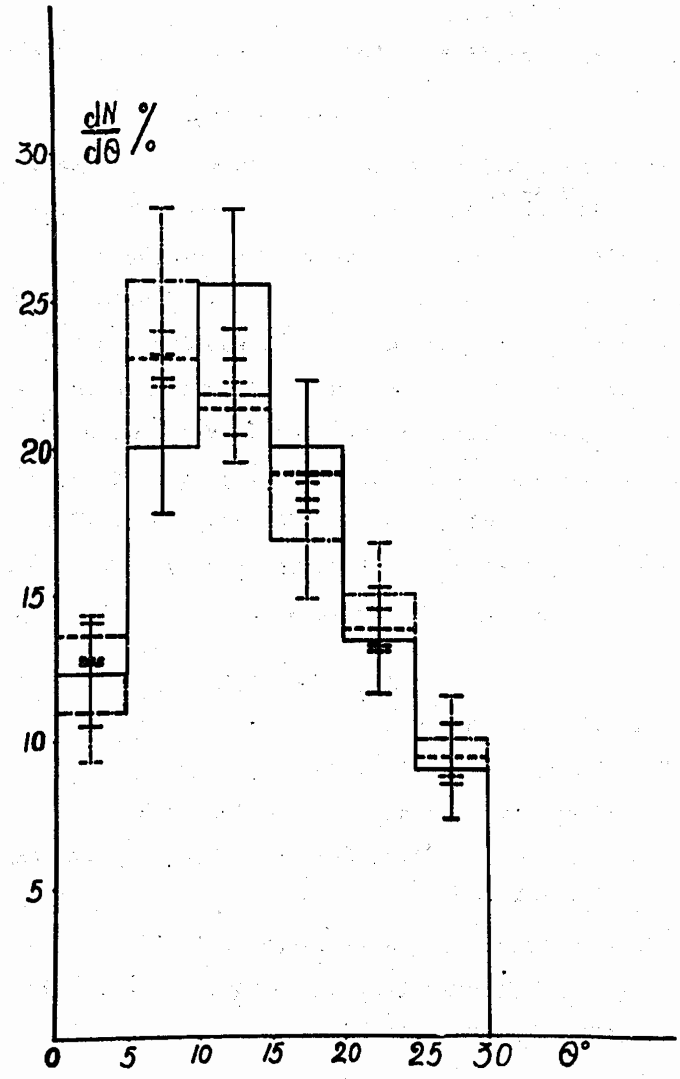

Fig.I. Distribution of the emission angles of electron-positron pairs(continuous line), distribution of the fast charged particles from stars, found by following the tracks of the primary protons (dotted line) and from stars found by scanning of secondary fast particles (dash-dotted line).

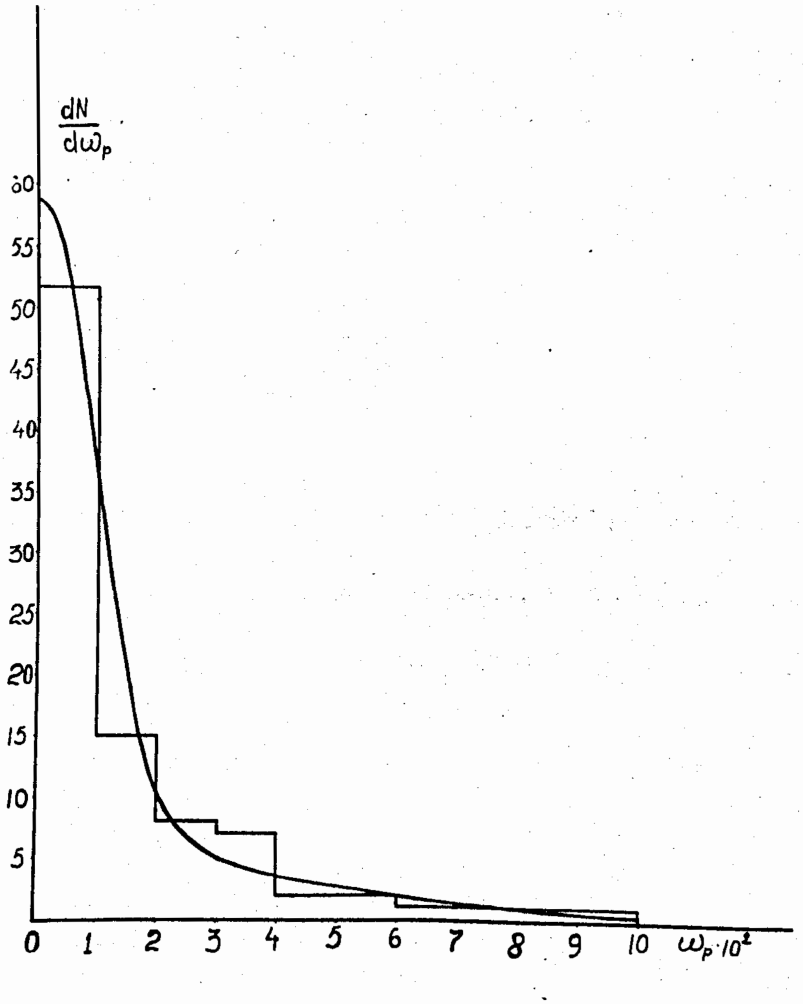

Fig.2. Distribution of the projected angles of divergence of the pair components.