Spectra of $\pi^{\pm}$ mesons in an inclusive reaction $\gamma C \to \pi X$ induced by bremsstrahlung γ quanta with a maximum energy of 4.5 GeV

K. V. Alanakyan, M. Dzh. Amaryan, R. A. Demirchyan, K. Sh. Egiyan, Dzh. V. Karumyan, Zh. L. Kocharova, M. S. Ogandzhanyan, and Yu. G. Sharabyan

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The heretofore unavailable experimental energy and angular distributions of the inclusive-photopion yields over a broad range of energies and angles of secondary π mesons are presented.

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In our preceding work,[1-4] we investigated many aspects of the inclusive photoproduction of protons by different nuclei irradiated by high-energy, bremsstrahlung, γ quanta with an energy up to 4.5 GeV, which showed that the main systematic features of the cumulative effect[5,6] and of the nuclear scaling[7,8] in the interaction of electromagnetic radiation with the nuclei are correct.

The photoproduction of inclusive π mesons by nuclei, especially at high energies of primary γ quanta and at large angles of secondary π mesons, has not been sufficiently investigated.

In particular, the photoproduction of cumulative π mesons, i.e., π mesons whose production by free nucleons is kinematically forbidden, to our best knowledge, has not been investigated.

We present here the spectra of $\pi^{\pm}$ mesons produced by C^{12} nuclei at a 20°–120° angle, which were irradiated by bremsstrahlung quanta with a maximum energy of 4.5 GeV.

2. We investigated the reaction

$$\gamma + C^{12} \to \pi^{\pm} + X, \qquad (1)$$

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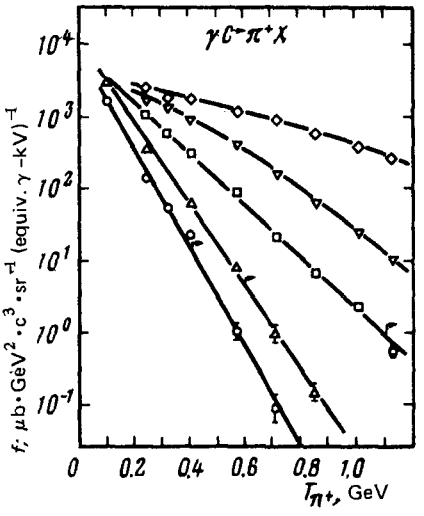

FIG. 1. Energy spectra of π^+ mesons. The experimental points are as follows: ◇, the π-meson angle $\theta_\pi = 20^\circ$; ▽, 40°; □, 60°; △, 90°; and ○, 120°.

where X is a residual system. According to the kinematics, the π-meson spectra belong both to the cumulative and noncumulative regions.

The measurements were performed using the "Deuteron" apparatus that was placed in the beam of the G-3 Erevan Electron Synchrotron. This apparatus was described in detail in Ref. 9.

The π mesons were identified[9] by a magnetic spectrometer using the time-of-flight method.

This spectrometer made it possible to measure the particle momentum in the range $p = 0.18-1.4$ GeV/c with a relative error $\Delta p/p = \pm 6.5\%$ (at $p \geqslant 1$GeV/c) and the

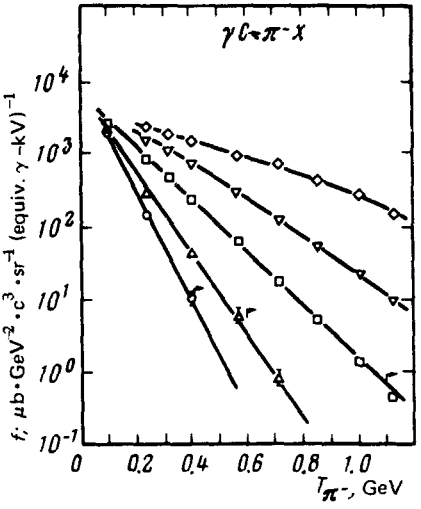

FIG. 2. The same as in Fig. 1 for π^- mesons. The symbols are the same as in Fig. 1.

TABLE I

Values of $T_0 \pm \Delta T_0$ (MeV)

	π^+ mesons	π^- mesons
60°	124 ± 2	121 ± 2
90°	76.2 ± 2.6	78.3 ± 1.5
120°	65.1 ± 3.1	57.1 ± 1.8

particle velocity in the range $0.4 \leqslant \beta \leqslant 1$ sec with a spread $\Delta\beta/\beta \leqslant 5\%$. The solid angle of the spectrometer, which was calculated by using the Monte Carlo method, was $\Delta\Omega = 1.26$ msr (at $\Delta p/p = \pm 6.5\%$).

The invariant cross section was determined from the measured yields of the reaction (1).

$$f = E\frac{d^3\sigma}{d^3 p\, Q} = \frac{E}{p^2} C \frac{N_\pi}{\Delta\Omega\,(\Delta p/p) p\, N_n Q}, \qquad (2)$$

where N_π is the measured yield of the reaction (1), E and P are the total energy and momentum of recorded π mesons, N_n is the number of nuclei on the γ-quanta path, and C takes into account the corrections due to nuclear absorption and multiple scattering in the detector and target and paraproduction in the target due to in-flight decay and finite efficiency of particle recording.

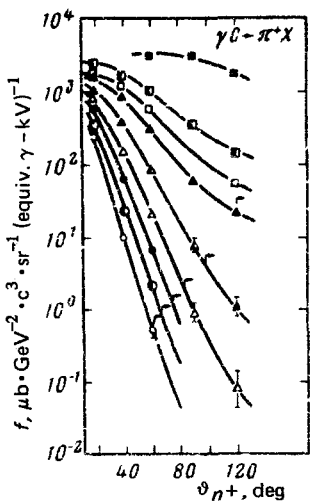

FIG. 3. Angular dependences for π^+ mesons. The experimental points are as follows: ■, (for the kinetic energy of π mesons) $T_\pi = 0.094$ GeV; ●, 0.239 GeV; □, 0.318 GeV; ▲, 0.399 GeV; ▲, 0.567 GeV; △, 0.712 GeV; ●, 0.851 GeV; ●, 1.00 GeV; ○, 1.12 GeV.

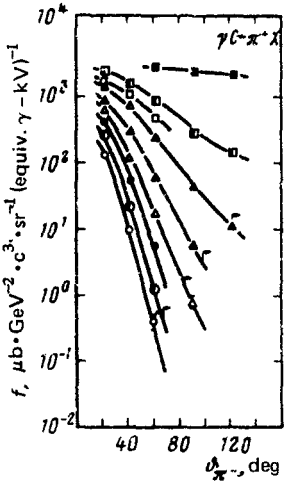

FIG. 4. The same as in Fig. 3 for π^- mesons.

Figure 1 shows the energy spectra of positively charged π mesons. Only statistical errors are shown. The estimates show that the systematic errors do not exceed 20%. The lines were drawn through the experimental points for $\theta_\pi = 60°$, 90°, and 120° by using the least-squares method and they were drawn approximately for $\theta_\pi = 20°$, and 40°. The errors indicate the beginning of the cumulative region.

As we can see, the spectra for $\theta_\pi \geqslant 60°$ and $T_\pi \leqslant 1.1$ GeV are well described by a single exponential curve. At $\theta_\pi \leqslant 40°$ we can see a deviation from the exponential curve (the spectrum drops off more sharply at high energies).

Figure 2 shows analogous data for π^- mesons. As we can see, the spectrum of negatively charged π mesons is identical to that of positively charged mesons.

The invariant cross section for $\delta_\pi \geqslant 60°$ can be represented as follows:

$$f = C \exp(-T/T_0), \tag{3}$$

where C and T_0 are constants and T is the kinetic energy of π mesons.

Table I gives the values of T_0 determined for different angles from the experimental points by using the least-squares method. As we can see, T_0 decreases with increasing angle and at $\theta_\pi = 120°$ reaches a value $T_0 = 65$ MeV, which is in good agreement with the value $T_0 = 60$–65 MeV determined in analogous processes induced by hadrons.[5,6]

We must emphasize an important fact: the spectra show no singularities when we go from a noncumulative region to a cumulative region. The spectra behaves similarly in the case of photoproduction of protons by nuclei.[1-4]

4. Figures 3 and 4 show angular dependences of π^+ and π^- mesons, respectively.

As we can see, these dependences have a strongly forward direction that increases with increasing energy.

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