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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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K.V.ALANAKIAN, M.Dj.AMARIAN, R.A.DEMIRCHIAN,
K.Sh.EGIYAN, Dj.V.KARUMIAN, Zh.L.KOCHAROVA,
M.S.OGANDJANIAN, Yu.G.SHARABIAN

$\pi^{\pm}$-MESON SPECTRA IN THE INCLUSIVE REACTION $\gamma C \to \pi X$ CAUSED BY BREMSSTRAHLUNG γ-QUANTA WITH THE MAXIMUM ENERGY 4.5 GEV

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К.Ш.ЕГИЯН, Дж.В.КАРУМЯН, Ж.Л.КОЧАРОВА,
М.С.ОГАНДЖАНЯН, Ю.Г.ШАРАБЯН

СПЕКТРЫ $\pi^{\pm}$-МЕЗОНОВ В ИНКЛЮЗИВНОЙ РЕАКЦИИ $\gamma C \to \pi X$, ВЫЗВАННОЙ ТОРМОЗНЫМИ γ - КВАНТАМИ С МАКСИМАЛЬНОЙ ЭНЕРГИЕЙ 4,5 ГЭВ

Приведены экспериментальные энергетические и угловые распределения выходов инклюзивных $\pi^{\pm}$-мезонов, образованных на ядре C^{12} под действием тормозных γ-квантов с максимальной энергией 4,5 Гэв. Показано, что в случае $\vartheta_{\pi} \geq 60^{0}$ энергетические спектры хорошо описываются одной экспонентой, тогда как при $\vartheta_{\pi} \leq 40^{0}$ это не представляется возможным. В тех случаях, когда спектры переходят из кумулятивной области в некумулятивную, никаких особенностей не наблюдается. Угловые зависимости фотомезонов имеют остронаправленный вперед характер.

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The experimental energy and angular distributions of inclusive $\pi^{\pm}$-mesons produced on C^{12} by bremsstrahlung γ-quanta with a maximum energy 4.5 GeV are presented. It is shown that at $\vartheta_{\pi} \geq 60^{\circ}$ the energy spectra are well described by one exponential, whereas at $\vartheta_{\pi} \leq 40^{\circ}$ this is impossible. On the boundary of cumulative and noncumulative regions no singularities in the spectra are observed.

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K.V.ALANAKIAN, M.Dj.AMARIAN, R.A.DEMIRCHIAN,
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Yerevan 1981

1. In our previous works [1-4] we investigated a number of aspects of the inclusive photoproduction of protons on different nuclei irradiated with the high-energy bremsstrahlung γ -quanta with the energy up to 4.5 GeV. These investigations confirmed the validity of the basic rules of the cumulative effect [5,6] and nuclear scaling [7,8] in photofragmentation of nuclei with production of backward fast protons.

The inclusive π -meson pfotoproduction on nuclei, particularly at high energies of primary γ -quanta and at large angles of secondary π -mesons is studied insufficiently. In particular, as far as the authors know, the photoproduction of cumulative π -mesons, i.e. the ones whose production on free nucleons is kinematically forbidden, is not investigated at all.

In this work we present the spectra of π -mesons produced at 20° - 120° on C^{12} nuclei irradiated with bremsstrahlung quanta with the maximum energy 4.5 GeV.

2. We have investigated the reaction

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

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

The measurements were done with a "Deuteron" experimental setup [9] placed on the Γ -3 beam of the Yerevan electron synchrotron.

π -mesons were identified by a magnetic spectrometer using the time-of-flight measurement.

The spectrometer allows to measure the particle momentum P with the relative errors $\Delta P/P = \pm 6.5\ \%$ (at $P \geq 1$ GeV/c) as well as the particle velocity β with the spreads $\Delta\beta/\beta \leq 5\%$. In Fig.1 are given some time-of-flight spectra of positive (a) and negative (b) charged particles produced at $\vartheta_\pi = 40^\circ$ with momenta up to 1.4 GeV/c. As one can see, in the region $P \leq 1.4$ GeV/c π^+ -mesons (the right-hand peaks in Fig.1a) separated with high efficiency from protons and the other positive particles. For π^- -mesons with the same momenta the separation is nearly trivial, since a more or less intensive flux of the other negative particles is absent.

The solid angle of π -meson detection was calculated with the Monte-Carlo technique and was $\Delta\Omega = 1.26$ millisterad (at $\Delta P/P = \pm 6.5\ \%$). The particle detection efficiency, the contributions of multiple scattering and nuclear absorption of detected particles in the target and in the whole matter of the spectrometer counters, as well as the contribution of the pairproduction effect by γ -quanta in the target were determined by the analogous calculations.

3. In Table 1 the values of the invariant cross sections (yields)

$$f = E\frac{d^3\sigma}{d^3p}\cdot\frac{1}{Q} = \frac{E}{p^2}\cdot C\,\frac{N_\pi}{\Delta\Omega\,(\Delta p/p)\,p\,N_я\,Q} \qquad (2)$$

are given, where N_π is the number of π -mesons (the area under pion peaks in Fig.1), $\Delta\Omega$ and Δp are respectively the solid angle and momenta spreads, E and p are the total energy and momentum of the detected particles, respectively, $N_я$ is the number of nuclei, C takes into account the contributions of all the above effects. Only statistical errors are given. As the estimates show, the systematical errors do not exceed 20 %.

In Fig.2 the energy spectra of positive π -mesons are given. The lines are drawn through the experimental points by the least squares method in the case of $\vartheta_\pi = 60^\circ$, 90°, 120° and "by eye" in the case of $\vartheta_\pi = 20^\circ$, 40°. The arrows indicate the beginning of the cumulative region.

As is seen, for $\vartheta_\pi \geq 60^\circ$ and $T_\pi \leq 1.1$ GeV the spectra are well described by one exponential. At $\vartheta_\pi \leq 40^\circ$ the deviation from the exponential is observed (the spectrum falls more rapidly at high energies).

The analogous data for π^- -mesons are given in Fig.3. One can observe the identical character of the spectra behaviour with negative and positive charged π -mesons.

For the cases $\vartheta_\pi \geq 60^\circ$ the invariant cross section can be presented as

$$f = C\cdot\exp\left(-T/T_0\right) \qquad (3)$$

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

In table 2 are given the values of T_0 as found by experimental points with the least squares method for different angles. It is evident that with increase of the angle T_0 decreases and at already $\vartheta_\pi = 120^0$ gets the value $T_0 = 65$ MeV, which coincides well with the value $T_0 = 60 \div 65$ MeV as found in the analogous investigations with hadrons [5,6].

One important circumstance should be emphasized: the spectra characters do not change at transition from the noncumulative region to the cumulative one. The same behaviour is observed for the photoproduction of protons on nuclei [1-4].

In Figs 4 and 5 the angular dependences of π^+ and π^- mesons are given.

One can see that these dependences are of forward sharply directed character and as the energy grows this tendency increases.

The authors should like to thank A.Ts.Amatuni for his interest in the work, S.G.Matinian for support, T.G.Mkrtchian and A.V.Kirakosian for assistance in the work and also the staff of the Yerevan synchrotron for providing a beam.

Invariant cross sections of reactions $\gamma C \to \pi^+ X$ and $\gamma C \to \pi^- X$ at E_γ^{max} =4.5 GeV, $\mu b \cdot GeV^{-2} \cdot c^3 \cdot sterad^{-1}$ (equ. γ -quants)$^{-1}$

Table 1

ϑ_π / Gev	20°		40°		60°		90°		120°	
	π^+	π^-	π^+	π^-	π^+	π^-	π^+	π^-	π^+	π^-
,094	-	-	-	-	2980 ± 150	2680 ± 118	3060 ± 140	2310 ± 167	1690 ± 80	2130 ±227
),239	2550 ± 80	2415 ± 85	1690 ± 70	1637 ± 67	1050 ± 40	879 ± 38	359 ± 21	295 ± 22	142 ± 7	148 ± 22
),318	1890 ± 80	1837 ± 77	1340 ± 60	1183 ± 74	575 ± 28	485 ± 22	-	-	53,9 ± 4,7	-
),399	1730 ± 70	1472 ± 64	877 ± 35	762 ± 33	311 ± 21	247 ± 11	59 ±10,8	45 ± 4	21,7 ± 2,4	11 ± 2,1
0,567	1110 ± 50	931 ± 44	392 ± 20	303 ± 17	86,1 ± 7,1	64 ± 2,9	8,02 ±1,44	5,6 ± 0,8	1,07 ±0,27	-
0,712	873 ± 33	716 ± 30	159 ± 10	126 ± 9,1	21,8 ± 2,0	18 ± 1,1	0,940 ± 0,243	0,79 ± 0,094	0,0851 ± 0,0425	-
0,851	547 ± 20	425 ± 20	64,1 ± 4,7	54 ±4,3	6,50 ± 0,64	5,4 ± 0,45	0,142 ± 0,047	-	-	-
1,00	353 ± 13	264 ± 12	23,2 ± 2,0	22,3 ± 1,9	2,21 ± 0,31	1,35 ± 0,14	-	-	-	-
1,12	244 ± 9	143 ± 7,1	9,91 ± 0,88	9,5 ± 0,85	0,525 ± 0,124	0,43 + 0.057	-	-	-	-

Table 2

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

ϑ_π	π^+ - mesons	π^- - mesons
20°	388 ± I4	335 ± I5
40°	I76 ± 8	I74 ± 4
60°	I24 ± 2	I2I ± 2
90°	76,2 ± 2,6	78,3 ± I,5
I20°	65,I ± 3,I	57,I ± I,8

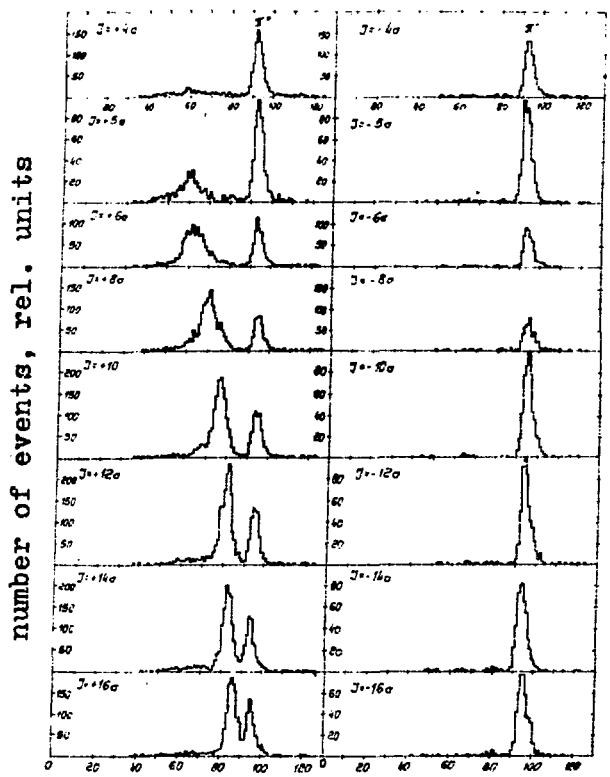

Fig.1

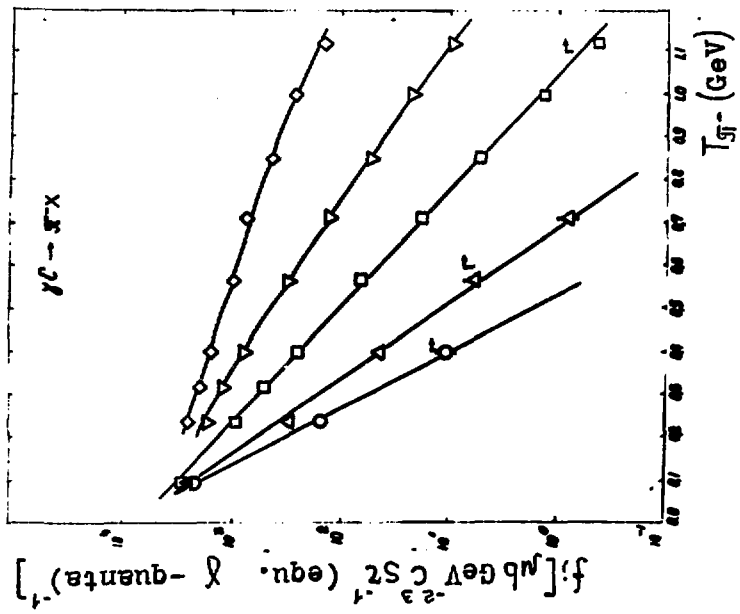
f_i[μb GeV^{-2} c^3 sr^{-1} (equ. γ -quanta)$^{-1}$]
T_{π^-}(GeV)
$\gamma C - \pi^- X$

Fig.3

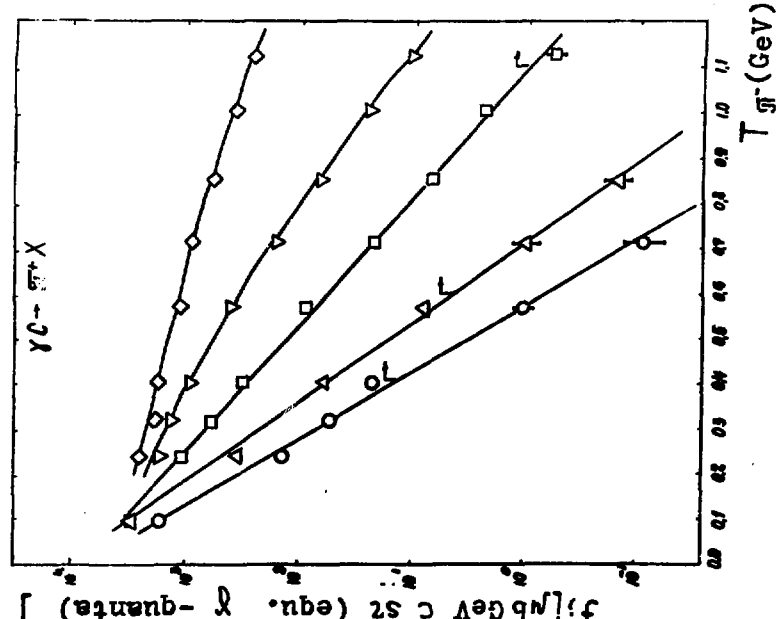
f_i[μb GeV^{-2} c^3 sr^{-1} (equ. γ -quanta)$^{-1}$]
T_{π^-}(GeV)
$\gamma C - \pi^- X$

Fig.2

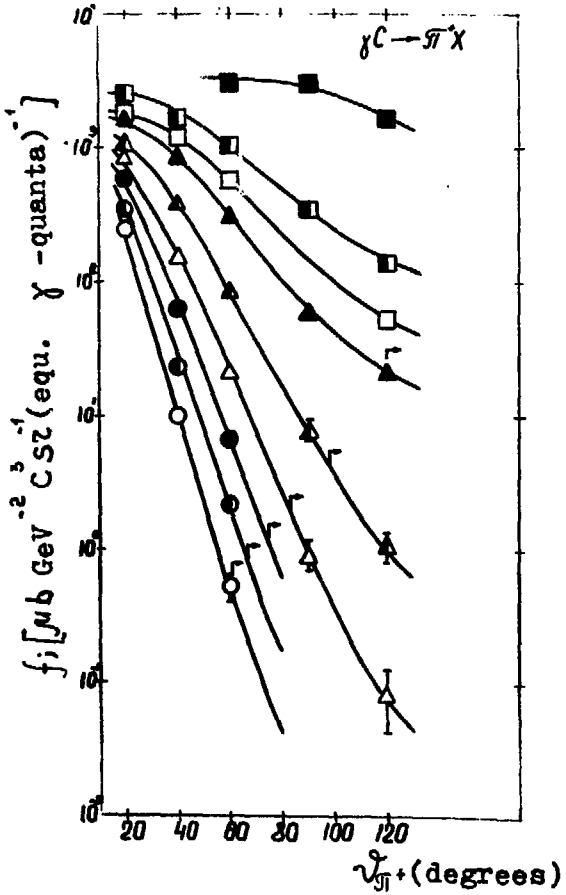
γC → π⁺X
f; [μb GeV⁻² C sr³]⁻¹ (equ. γ -quanta)⁻¹]
20 40 60 80 100 120
ϑπ⁺ (degrees)

Fig.4

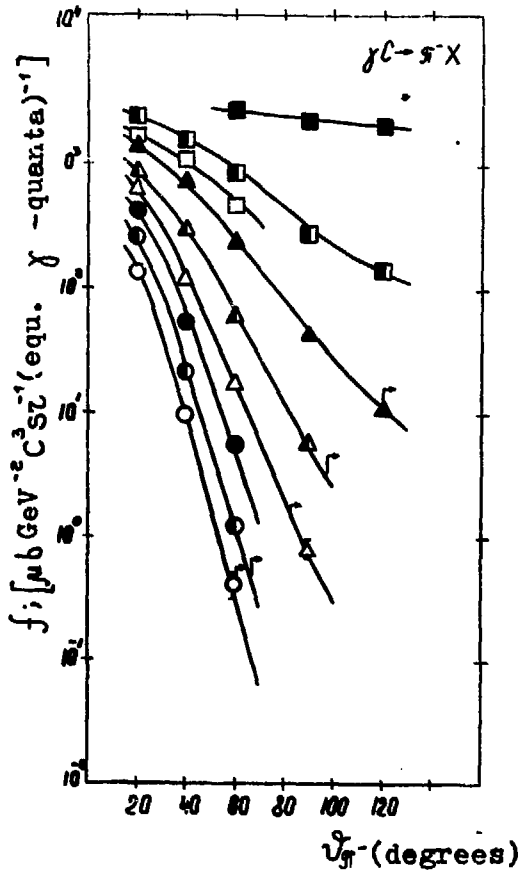
γC → π⁻X
f; [μb GeV⁻² C sr³]⁻¹ (equ. γ -quanta)⁻¹]
20 40 60 80 100 120
ϑπ⁻ (degrees)

Fig.5

CAPTIONS

Fig.1 Time-of-flight spectra of positive (a) and negative (b charged particles.

Fig.2 Energy spectra of π^+ -mesons. Experimental points: ◇ - π -meson angle ϑ_π = 20°, ▽ - 40°, □ - 60°, △ - 90°, ○ - 120°.

Fig.3 The same as in Fig.2 for π^- -mesons.

Fig.4 Angular dependences for π^+ -mesons. Experimental points: ■ - at π -meson kinetic energy T_π = 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.5 The same as in Fig.4 for π^- -mesons.

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К.В.АЛАНАКЯН, М.Дж.АМАРЯН, Р.А.ДЕМИРЧЯН,
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