ЛАБОРАТОРИЯ ЯДЕРНЫХ ПРОБЛЕМ

ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

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D – 548

DETERMINATION OF THE CHARGE–EXCHANGE CROSS SECTION OF π-MESONS INTO π-MESONS FROM THE ANALYSIS OF THE REACTION $\pi^- + p \rightarrow \pi^- + \pi^+ + n$ AT 290 MEV

ЖЭТФ, 1960, т 39, в2, с 506-508.

Дубна 1960

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Submitten to JETP.

The importance of the study of (π-π) interactions is evident and was often stated[1,2]. However, the experimental methods of obtaining data on (π-π)-scattering are very difficults because there are no direct ways of preparing targets of unstable particles yet, and one has to use only indirect methods. All the informations on (π-π)-interaction available at present are given in Table I. It should be pointed out that in[1-3] (see Table 1) attempts were made to evaluate only the order of magnitude of the (π-π)-interaction cross section.

In the present paper we made use of the data obtained by the authors from the study of the reaction $\pi^- + p \rightarrow \pi^- + \pi^+ + n \; (I)$ in photoemulsions (200 events). The emulsion stacks were irradiated at the negative pion beam of the Laboratory of Nuclear Problems (JINR) synchrocyclotron. The average energy of the primary pions was found to be (290 ± 15) MeV, the slowing down in the emulsions being taken into account. The preliminary results on the energy and angular distributions of the secondary particles from reacction (1) were reported at the Kiev Conference on High Energy Physics in July, 1959, and are to be published[3].

As a theoretical basis for the treatment of experimental data we used the paper of A.A. Anselm and V.N. Gribov[4] in which it is shown that the amplitude of the charge-exchange of charged mesons into neutral ones in the process $\pi^- + \pi^+ \rightarrow \pi^0 + \pi^0$ at zero energy can be determined by the energy distribution of the secondary particles, in particular, in reaction (1) near the threshold. The account of the particle interaction in the final state, under the assumption that the interaction is non-resonant, permits one to write the energy distribution of the secondary particles within the accuracy of terms linear on kr_0 in the following way: (where K is the meson momentum in the order of magnitude corresponding to the total kinetic energy of the three particles in the centre of mass system and r_0 is the reaction radius)

$$\frac{d\sigma}{d\Gamma} = A\left(1 + c k_{12} + d k_{13}\right) . \qquad (2)$$

Here A is the constant determined by the total cross section of reaction (1). The coefficients c and d are connected with the charge-exchange amplitudes (π-π) and (π-n) at zero energy, K_{12} and K_{13} are the absolute values of the relative momenta (π^+-π^-) and (π^+- n), respectively; $d\Gamma$ is the element of the phase volume. Making use of the isotopic invariance one can write:

$$\frac{c}{d} = \frac{(a_2 - a_0)}{\sqrt{3}\,(b_{1/2} - b_{3/2})} \qquad (3)$$

where a_2 and a_0 are the amplitudes of pion-pion scattering at zero energy in states with isotopic spin 0 and 2, $b_{1/2}$ and $b_{3/2}$ are the amptitudes of pion-nucleon scattering at zero energy in states with isotopic spin ½ and 3/2. Since the difference ($b_{1/2} - b_{3/2}$) is known[5] one can find the difference of the amplitudes $a_2 - a_0$ and, hence, the amplitude of the charge-exchange $a_{12} = 1/3\,(a_2 - a_0)$ determining the ratio of the coefficients c/d experimentally. However, the applicability of this theory to the experiment at 290 MeV can turn out to be not quite correct. The matter is that the theory takes into consideration only those terms which are linear on kr_0. So it is necessary that the terms quadratic on kr_0 should be small comparing to the linear ones, and hence, it is required that the P-phases of the pair $(\pi - n)$ and $(\pi - \pi)$ scattering should be small. In our case the kinetic energy in the centre of mass system is about 90 MeV. The average scattering energy of the particles in the final state is about 40 MeV. At this energy one of the P-phases of the $(\pi - n)$scattering δ_{33} is comparable with the S -phases δ_3 and δ_1 .

Nevertheless, we made an attempt to perform the treatment of the experimental data and find out to what degree formula (2) describes the experimental situation. With this aim the whole kinematically available region on the plane K_{12} and K_{13} was divided into districts so that each of them had not less than 13 points and the densitv of the points within the same district was approximately constant. Thus, the whole region was divided into 9 parts. Due to the spread on energy (± 15 MeV) only those events were chosen which were situated in the region restricted by the internal limit values (see Fig. 1). If formula (2) is correct, the points having the coordinates x_i, y_i, z_i should lie on the plane. Here x_i and y_i are approximately equal to the average values of K_{13} and K_{12} for each district and z_i is equal to the total number of points in each district divided by the average values of the phase volume. The analysis carried out with the V^2 distribution/6/ has shown that within errors experimental points lie on the plane. The ratio c/d obtained from the equation of the plane is equal to $-(0.76 \pm 0.65)$. It should be pointed out that other divisions analogous to that shown in Fig. 1 lead to the same value of c/d. From relation (3) for the difference $(a_2 - a_0)$ one obtains the value $-(5 \pm 4).10^{-14}$cm; this corresponds to the charge-exchange cross section $\sigma_{\pi^+ + \pi^- \to \pi^0 + \pi^0} = 4\pi a_{12}^2 = (4^{+6}_{-4})$ mb. Here experimental errors are given which are determined by statistics and no accuracy of the theory at our energy is taken into account.

All the data available at present concerning the amplitudes of S-wave $(\pi - \pi)$-scattering are enlisted in Table 2. As is seen from the Table, the results of various authors differ both by the absolute value and by the sign. In such a situation it is of great interest to obtain more accurate data. Since in our treatment the accuracy of the theory is the main problem, it is more useful to run an experiment at lower energies where the theoretical assumptions are more correct. At present such an experiment is being performed at an energy of 240 – 250 MeV (40 – 50 MeV in the centre of mass system).

The authors are grateful to Prof. V.P. Dzhelepov for interest and attention shown to the work and also to A.A. Anselm and V.N. Gribov for valuable discussions and advice and to S.N. Sokolov for help in the treatment of the results.

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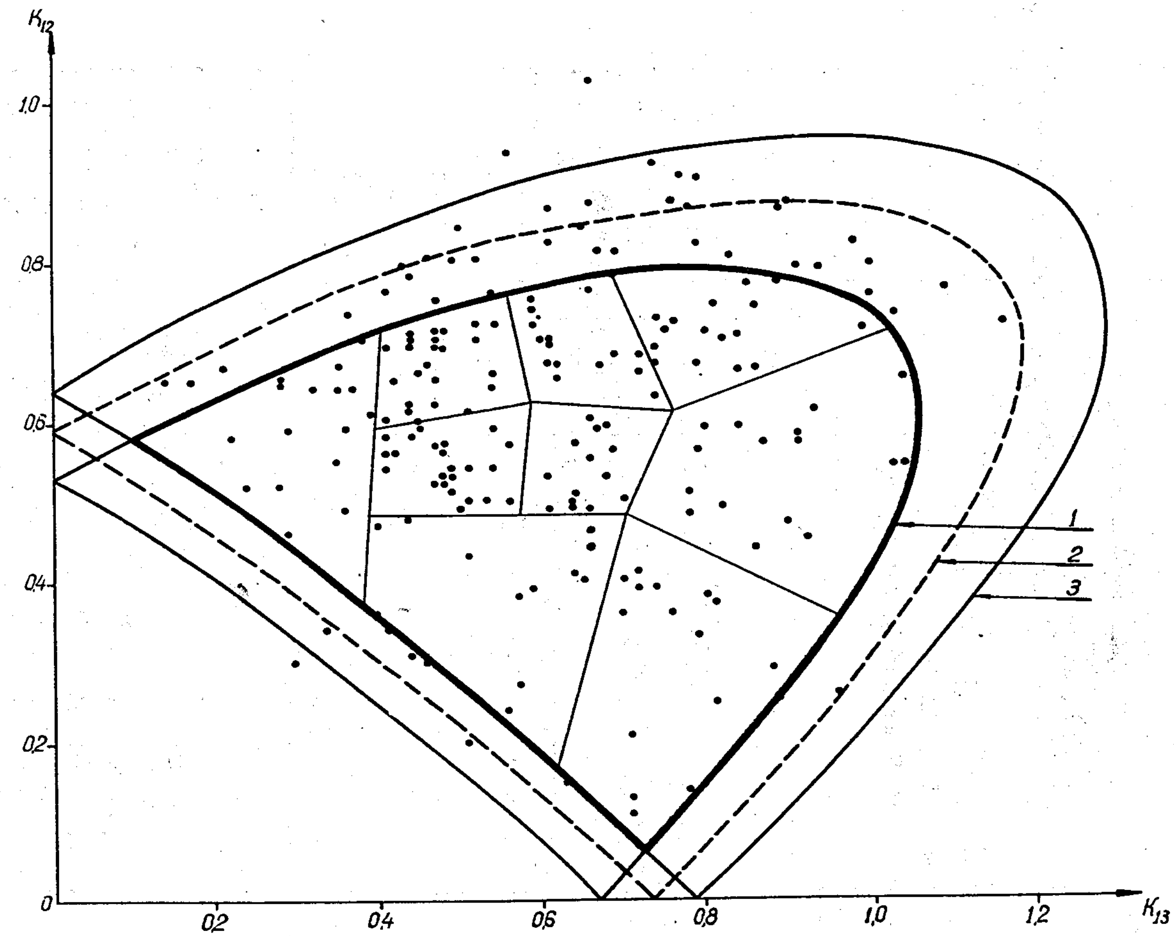
Recieved by Publishing Department
on May 31, 1960.



F i g. 1. Distribution of the events of the reaction $\pi^- + p \to \pi^- + \pi^+ + n$ at (290 ± 15) MeV in the plane K_{12} and K_{13}. K_{12}, K_{13} are the relative momenta $(\pi^+ - \pi^-)$ and $(\pi^+ - n)$ in the units $\mu_\pi \cdot c$. Curves 1,2,3 restrict the regions available kinematically on K_{12} and K_{13} at 275, 290, 305 MeV.

Data on $(\pi - \pi)$ Interaction Cross Sections

Table 1.

NN	References	Process	The value of $(\pi-\pi)$-Interaction cross section (mb)	Initial reaction
1	B.S. Thomas and W.G. Holladay (Tennessee) Phys. Rev. 115, 1329 (1959)	$\pi^+ + \pi^+ \to \pi^+ + \pi^+$	~ 250 (the relative nesons energy is egual to zero)	$\tau^+ \to \pi^+ + \pi^+ + \pi^-$
2	F. Bonsignori and F. Selleri (Bologna) Nuovo Cimento, 15, 465 (1960)	$\pi^+ + \pi^- \to \pi^+ + \pi^-$	~ 20 (averaged on meson energies)	$\pi^- + p \to \pi^+ + \pi^- + n$ (960 MeV)
		$\pi^- + \pi^0 \to \pi^- + \pi^0$	~ 40 (averaged on meson energies)	$\pi^- + p \to \pi^- + \pi^0 + p$ (960 MeV)
3	J. Derado (CERN - Geneva) Nuovo Cimento, 15, 853 (1960)	$\pi^- + \pi^0 \to \pi^- + \pi^0$	~ 30 (averaged on meson energies)	$\pi^- + p \to \pi^- + \pi^0 + p$ (1 BeV)
4	The present paper Yu. A. Batusov, S.A. Bunyatov, V.M. Sidorov, V.A. Yarba (JINR - Dubna)	$\pi^+ + \pi^- \to \pi^0 + \pi^0$	(4^{+6}_{-4}) (the relative mesons energy is egual to zero)	$\pi^- + p \to \pi^+ + \pi^- + n$ (290 MeV)

Data on the S-Wave of $(\pi-\pi)$-Scattering length. (in units of $\frac{\hbar}{\mu_\pi c}$)

Table 2

NN	References	a_2	a_0	$a_2 - a_0$	Initial reaction
1	B.S.Thomas and W.G.Holladay (Tennessee) Phys. Rev., 115, 1329 (1959)	~ 1			$\tau^+ \to \pi^+ + \pi^+ + \pi^-$
2	Yu.A.Batusov, S.A.Bunyatov, V.M.Sidorov, V.A.Yarba (JINR - Dubna) The present paper			$-(0,35 \pm 0,30)$	$\pi^- + p \to \pi^+ + \pi^- + n$
3	A.V.Efremov, V.A.Mescheryakov, D.V.Shirkov (JINR - Dubna) JETP (in press, 1960)		~ 1		$\pi + N \to \pi + N$
4	R.F. Sawyer and K.C.Wali (Wisconsin) Preprint (1960)	-0,48	-0,8	0,3	$K^\pm \to 3\pi$
5	N.N.Khuri and S.B.Treiman (Princeton) Preprint (1960)	-0,3	-1	0,7	$K^\pm \to 3\pi$
6	K. Ishida, A. Takahashi and Y. Ueda (Sendai) Preprint (1960)		~ 1		$\pi + N \to \pi + N$