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np INELASTIC INTERACTIONS AT ENERGIES FROM 2 TO 10 GEV

III. STUDY OF $N\Pi\Pi$-COMBINATIONS IN THE REACTION: $np \to np\Pi^+\Pi^+\Pi^-\Pi^-(m\Pi^0)$

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From 22000 pictures of a 24-litre propane bubble chamber exposed to neutrons with energies from 2 to 10 GeV, 730 events of the type $np \rightarrow np\ \pi^+ \pi^+ \pi^- \pi^- (m\ \pi^0)$ were selected. The separation methods of the channels of the reactions in this exposure are described in /1/.

The momentum spectrum of the incident neutrons (spectrum multiplied by the magnitude of the channel cross section) is shown in Fig.1. By means of γ-quanta the production of one π^0-meson consisting of 30% of the events, and two π^0-mesons - of 20% is determined. Since a part of the 5-prong events (≈ 25%) is not measurable, a special investigation for establishing the absence of bias was carried out. For this purpose the angular and momentum distributions of protons and neutrons in c.m.s. were compared. Within the errors, no bias was observed. The contribution of nC-interactions to the events is practically negligible since they were rejected by the kinematic analysis /1/. The error of the effective mass determination is equal to ≈ 30 MeV/c^2.

The effective mass of the $p\pi\pi$-combinations in the 5-prong interactions was studied.

All events were separated into 4-momentum groups, and in each of them the production rate of isobar $N^{*++}_{(1236)}$ was determined. The results are presented in Table I.

Table I

P_n (GeV/c)	3–6	6–8	8–10	>10
% $N^{*++}_{(1236)}$	58.6 $\pm$14.8	47.2$\pm$9.4	49$\pm$8	35$\pm$8.4

With the increasing of the incident neutron energy there was a slight tendency for the $N^{*++}_{(1236)}$ production rate to fall, but within the errors, this rate is constant and the average value of the production rate of the $N^{*++}_{(1236)}$ over the whole spectrum is equal to (44$\pm$5)% . Similarly, the value for the N^{*0} (1236)$\to p\,\pi^-$ –decay is (10+4)%.

Let us consider the following reaction channel:

$$np \to p\,\pi^+\pi^+\pi^-\pi^- n\ (m\,\pi^0)\ , \tag{1}$$

$$np \to N^{*++}_{1236}\,\pi^+\pi^-\pi^- n\ (m\,\pi^0)\ , \tag{2}$$

$$np \to p\,\pi^+\pi^+\pi^-\,N^{*-}_{1236}\ (m\,\pi^0)\ , \tag{3}$$

$$np \to N^{*++}_{1236}\,\pi^+\pi^-\,N^{*-}_{1236}\ (m\,\pi^0)\ . \tag{4}$$

As was mentioned above, the isobar production in the $p\,\pi^-$, $n\,\pi^+$ systems form a small part of all interactions of this type. No essential contribution of the heavier isobars was observed.

Each of the reactions (1–4) gives a contribution to the effective mass distribution of $p\,\pi^+\pi^+$ –combinations (Fig.2). It was found by the χ^2 –method that the best description of the experimental spectrum of the $p\,\pi^+\pi^+$ effective mass was a curve of the type (0.20$\pm$0.13) F_1 + (0.80$\pm$0.13) $(F_2 + F_3)/2$. Here F_i were the statistical effective mass distributions of the $p\,\pi^+\pi^+$ –combinations from the i –channel. F_2 , for example, describes the spectrum of the effective mass of the $(N^{*++}_{1236}\,\pi^+)$ –system. It should be noted that the equality of the cross sections of the (2) and (3) channels follows from isotopic invariance and therefore curves F_2 and F_3

must be taken with the same statistical weight. In all descriptions the theoretical curves are taken in the form

$$F(x) = \text{const}\; x^{\frac{1}{2}(3\nu-5)} (1-x)^{3/2(n-\nu)-1},$$

where $$x = \frac{M\nu - (m_1 + m_2 + \dots + m_\nu)}{E^* - (m_1 + m_2 + \dots + m_n)},$$

n is the particle number in the final state of the reaction, ν is the number of the particles entering into the resonance, E^* is the total energy in c.m.s. This form of phase space curves was suggested by G.I.PKopylov /2/ and is quite an accurate approximation of the real phase space curves. All curves are weighted using the incident neutron spectrum and the production rate of π^0 -mesons. The $N^{*++}_{(1236)}$ production rate is considered to be the same in all momentum intervals. The $N^{*++}_{(1236)}$ width was taken everywhere in the form given by Jackson /3/. As is seen, the best description (the solid curve of $p\pi^+\pi^+$ distributions) is in agreement with the value (44±5)% of the $N^{*++}_{(1236)}$ production rate.

Let us consider the effective mass distributions of $p\pi^-\pi^-$-combinations (Fig.2). In channel (1) it must be described by curve F_1. In channel (2) a proton from $N^{*++}_{(1236)}$ nust be bound with two π^--mesons. In the presence of multiparticle final states (as in our case) all kinematic "traces" of the $N^{*++}_{(1236)}$ production are lost, and a proton from the isobar may be considered as a free proton in the combination construction. Therefore the theoretical description from process (2) for $p\pi^-\pi^-$-combinations must be taken in the form of F_1. The same applies to processes (3) and (4). Consequently, $p\pi^-\pi^-$-combinations in channels (1)-(4) must be described by curves F_1 only. The result of this description is presented in Fig.2 (dotted line). The χ^2 value for such a description is equal to 36 for 30 degrees of freedom. Therefore one can say that our prediction agrees well enough with experimental results. The best fit gives the distribution (79±13) F_1 + (21±13) $\left(\frac{F_2 + F_3}{2}\right)$, it does not contradict the magnitude of the $N^{*0}_{(1236)} \to p\pi^-$-production.

By similar considerations in the case of $p\pi^+\pi^-$ systems one may notice that there are 4 $p\pi^+\pi^-$ -combinations in each event and so the $M_{eff}(p\pi^+\pi^-)$ distribution is to be taken in the form:

a_1	$p\pi^+\pi^+\pi^-\pi^- n\ (m\ \pi^0)$	$F_1, F_1, F_1, F_1,$
a_2	$N^{*++}_{(1236)}\pi^+\pi^+\pi^- n\ (m\ \pi^0)$	$F_1, F_1, F_2, F_2,$
a_3	$p\pi^+\pi^+\pi\ N^{*-}_{1236}\ (m\ \pi^0)$	$F_1, F_1, F_3, F_3,$
a_4	$N^{*++}_{1236}\ \pi^+\pi^- N^{*-}_{1236}\ (m\ \pi^0)$	F_1, F_2, F_3, F_4 .

Letters a_i to the left of the reactions represent the probability of each reaction. It is necessary to remember that $a_2 = a_3$.

Let us for the present neglect reaction (4) and see what predictions can be obtained for the $p\pi^+\pi^-$ -combination description. According to Table 2 the effective mass distribution of $p\pi^+\pi^-$-combinations is to be described by the combination of the curves:

$$a_1F_1 + 0{,}25\, a_2 F_1 + 0{,}5\, a_2 F_2 + 0{,}5\, a_3 F_1 + 0{,}5\, a_3 F_3 =$$

$$= [\, a_1 + 0{,}5\,(a_2 + a_3)\,]\, F_1 + a_2 (F_2 + F_3)/2$$

The following relation between different rates can be obtained from this expression:

$$\frac{I\,(F_1)}{I\,((F_2 + F_3)/2)} = \frac{a_1 + (a_2 + a_3)\ 0{,}5}{a_2}$$

Taking into account that $a_1 = 0.2$ and $a_2 = a_3 = 0.4$ from the description of $p\pi^+\pi^+$ -combinations, we obtain:

$$\frac{I(F_1)}{I((F_2+F_3)/2)} = \frac{0,6}{0,4}$$

The best agreement with the experiment gives the curve $(0.53\pm0.06)\ F_1 + (0.47\pm0.06)\left(\frac{F_2+F_3}{2}\right)$. As is seen, the agreement with our prediction is good enough. A small disagreement is explained by our neglect of reaction (4).

Thus all three effective mass distributions of $p\pi^+\pi^-$, $p\pi^-\pi^-$ and $p\pi^+\pi^-$ -combinations are satisfactorily explained by the effect of the $N^{*++}_{(1236)}$ and $N^{*-}_{(1236)}$ isobar production in reactions (2), (3), (4). If the isobar with T=5/2 decaying into $p\pi^+\pi^+$ exists, its cross section does not exceed 30 μb in the region of masses from 1400 to 1700 MeV/c^2.

We can also explain the deviations from phase space in $p\pi^+\pi^+$ -combinations in the reactions $pp \to p\pi^+\pi^+\pi^- n$ /4,5,6/ by taking into account the fact that the reaction $pp \to p\pi^+\pi^+\pi^- n$ mainly goes through the channels $pp \to N^{*++}_{(1236)}\pi^+\pi^- n$ and $pp \to p\pi^+\pi^+ N^{*-}_{(1236)}$. It is in agreement with the results of the papers indicated. It should be noted that in the case of the distributions of $M_{eff}(p\pi^+\pi^+)$ it is also necessary to take into account the isobar width. The data of Refs. /4,5,6/ is presented in Fig.3, where the solid curves are our curves with the best χ^2.

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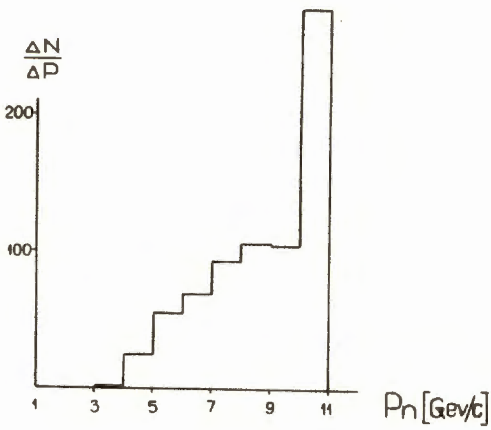

Fig. 1.

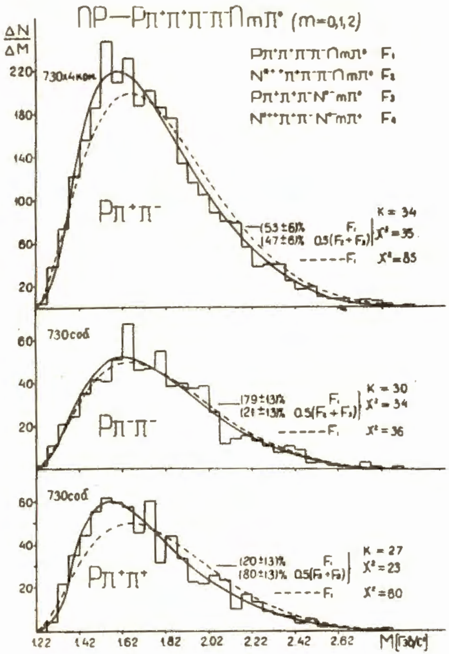
np—pπ⁺π⁺π⁻π⁻n mπ° (m=0,1,2)
ΔN/ΔM
pπ⁺π⁺π⁻π⁻n mπ° F₁
pπ⁺π⁻
pπ⁻π⁻
pπ⁺π⁺
K = 34
K = 30
K = 27
M [Gev/c²]

Fig. 2.

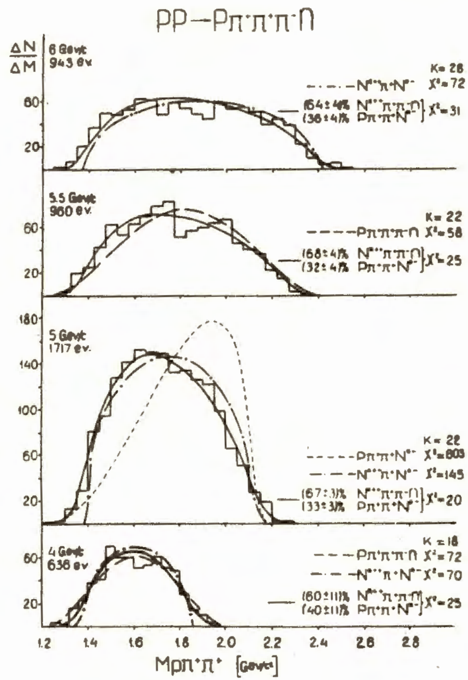
pp—pπ⁺π⁺π⁻n
ΔN/ΔM
6 Gev/c
5.5 Gev/c
5 Gev/c
4 Gev/c
K= 28
K= 22
K= 22
K = 18
Mpπ⁺π⁺ [Gev/c²]

Fig. 3.