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SEARCH FOR A $\Delta\Delta$(1236) COMPONENT IN THE DEUTERON

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Dubna-Warsaw Collaboration

1. Introduction

In the last few years several authors [1,2] have considered the possibility of a marked (~1%) admixture of the lowest mass baryon resonances in the deuteron wave function. It has been suggested [3,4] that the presence of nuclear isobars in the deuteron may manifest itself through observable effects in certain nuclear reactions, especially when the high energy incoming particle does not hit one of the virtual nuclear isobars which is going off in the direction it has been moving just before the collision. Recently, M.Godhaber [5] has presented some preliminary bubble chamber results on $\pi^+ d$ interactions at 15 GeV/c which may support the above picture. They concern the observation of the $\Delta^\circ(1236)$ spectator originating from the $\Delta^\circ\Delta^+$ deuteron configuration. Further experimental results [6,7] confirm the data of [5] but there still exists ambiguity in the interpretation.

In this paper we report on an analogous obsevation of three different pion-nucleon systems emitted backwards in the deuteron rest frame. The effect is analysed from the point of view of the $\Delta\Delta$ admixture in the deuteron.

2. Experiment

The experiment has been performed with the JINR 1 m hydrogen bubble chamber exposed to the deuteron beam with a momentum of 3.33 ± 0.08 GeV/c [8].

We present here the data collected from the following channels:

$$dp \rightarrow d\pi^+ + \text{neutrals} \qquad (1)$$

$$dp \rightarrow pp + \text{neutrals} \qquad (2)$$

$$dp \rightarrow ppp\pi^- \qquad (3)$$

The cut on missing mass and the fit to the reaction $pp \rightarrow pn\pi^+$ allow one to eliminate in channel (1) the admixture of pp events ($5 \pm 2\%$ of the total sample) due to the proton contamination in the beam. The use of the deuteron beam provides no losses in the spectators and unambiguous identification of the reaction (3). At the energy considered the cross section for two pion production is still very low [9] (e.g., we have found the cross section of $\approx 50\ \mu b$ for the $dp \rightarrow ppp\pi^-\pi^o$ reaction), and the channels (1) and (2) contain almost exclusively $dp \rightarrow p\pi^+nn$ and $dp \rightarrow ppn\pi^o$ events. The number of the events found in channels (1) - (3) is presented in table I. The weights 1/2 and 1/3 were ascribed to the events with two and three ambiguous hypotheses. More details about the experiment can be found in ref. [8] .

3. Results and discussion

The aim of this work is to search for a Δ-spectator from the hypothetical $\Delta\Delta$-configuration in the deuteron since at our energy (E^{kin}_{cms} = 440 MeV in the proton-nucleon cms at 1.66 GeV/c) we cannot observe both of the Δ's on the mass shell.

The possible processes which correspond to reactions (1) - (3) involving the $\Delta\Delta$ deuteron component are shown in fig.1. Since it is unlikely for kinematical reason to produce Δ's backward in a single nucleon-nucleon interaction, the presence of the nucleon-pion systems emitted in the backward hemisphere in the deuteron cms having their masses in the Δ-band may be due to the $\Delta\Delta$ admixture in the deuteron. Fig.2 displays the pion-nucleon mass versus the emission angle of the pion-nucleon system in the deuteron rest frame. Events from channels (1)-(3) are plotted together: $p\pi^+$ and $p_s\pi^-$ are the effective mass for channels (1) and (3) and missing mass for channel (2), respectively. Each event in channel (3) is represented by one combination only of a spectator proton with a pion because no proton except the slowest one contributes to the $p\pi^-$ systems emitted in the backward hemisphere. The pion-nucleon effective mass distribution (fig.3) exhibits a maximum with a width close to that expected for Δ (1236) but shifted towards a value lower than the Δ (1236) mass. This shift is also present for Δ's produced in the forward direction (fig.4) but amounts to about 20 MeV*), whereas in the backward hemisphere it is equal to about 100 MeV.

According to the diagrams shown in fig.1, we may observe Δ-spectators from both possible deuteron configurations, namely:

*) See next page

$\Delta^{++}\Delta^{-}$ channel (I)

Δ^{o} Δ^{+} channels (2) and (3)

Assuming that all the observed pion-nucleon systems emitted backwards in the deuteron rest frame originated from a Δ -spectator decay, one can check the two following predictions which should occur if the assumption were correct:

1. Deuteron is composed of Δ^{++} Δ^{-} and Δ^{+} Δ^{-} configurations with equal probability, and therefore the number of the events emitted backwards in reactions (2) and (3) to that in reaction (I) is expected to be equal to 1.

2. The branching ratio of a Δ^{o} decay into charged and neutral particles must be equal to

$$R_2\ (B) = \frac{\Delta^{o} \longrightarrow p\,\pi^{-}}{\Delta^{o} \longrightarrow n\,\pi^{o}} = 0.5\ .$$

The experimental ratios are respectively,

$$R_1\ (B) = \frac{N(2) + N(3)}{N(I)} = 0.37 \pm 0.16\ ,$$

$$R_2\ (B) = \frac{N(3)}{N(2)} = 0.67 \pm 0.13\ .$$

The obtained value of $R_1(B)$ differs significantly from the expected one whereas the $R_2(B)$ ratio is consistent with the expected branching ratio. However the value of $R_2(B) = 0.5$ also holds if pions are due to the produced Δ's and are combined accidentally with the spectator nucleons. To examine this possibility, let us assume now that the observed pions in channels (I)-(3) are due to the production process on a nucleon target via Δ's in the following reactions:

x) A similar effect is always present in the production experiment (see, e.g., refs. [9] and [10]).

$$pn\ (p_s) \longrightarrow n\ \Delta^{+}\ (p_s) \longrightarrow nn\ \pi^{+}\ (p_s) \qquad (4)$$
$$pp\ (n_s) \longrightarrow p\ \Delta^{+}\ (n_s) \longrightarrow pp\ \pi^{o}\ (n_s) \qquad (5)$$
$$pn\ (p_s) \longrightarrow p\ \Delta^{o}\ (p_s) \longrightarrow pp\ \pi^{-}\ (p_s) \qquad (6)$$

and that in each of the channels (I) and (3) only the slowest nucleon spectator gives the pion-nucleon system emitted backwards in the deuteron cms as it does take place in channel (3). The charge independence and the assumption that at our energy all the pions originated from the produced Δ's [9] give the following branching ratios:

$$\sigma(4)\ :\ \sigma(5)\ :\ \sigma(6) = 1 : 2 : 1$$

and therefore $R_1 = \sigma(4) / (\sigma(5) + \sigma(6)) = 0.33$ is in good agreement with the obtained experimental value of R_1 (B). The corresponding R_2 (F) value for the pion-nucleon systems emitted in the forward direction in the deuteron cms is 0.38 ± 0.02.

The obtained $R_1(B)$, $R_2(B)$ and $R_2(F)$ experimental values indicate that the majority of the pion-nucleon systems emitted backwards may be due to the accidental pion-spectator-nucleon correlation. To check this possibility more carefully, the Monte Carlo simulation of the events was done with the momentum and angular distributions of pions and spectator-nucleons taken from hydrogen data [9] and channel (3), respectively. The results are shown in figs. 3,5-7 and compared with the experimental data. It is seen that the Monte Carlo events reproduce rather well the main features of the experimental distributions. The backward-to-forward ratio for Monte Carlo events is 0.125. The corresponding experimental value for channel (3), where the spectator distributions for Monte Carlo simulation were taken from, is 0.16 ± 0.02.

If the nucleon-pion systems emitted backwards result from the Δ's decaying outside of the interaction region, the $(1 + 3\cos^2\theta_N)$ symmetric angular distribution of protons with respect to the laboratory Δ direction is expected [7]. Fig.8 shows the experimental results for reactions (I) and (3). A strong asymmetry in the angular distribution is observed. A similar result is presented in ref. [7] where a part of the effect was ascribed to the losses in non-stopping protons. In our experiment, we overcome this difficulty using the deuteron beam providing no losses of this sort. Within the assumptions that the backwards emitted Δ's decay after leaving the interaction region and that the events in the 0.5–1 $\cos\theta_N$ interval are due to the $\Delta\Delta$ component in the deuteron, an estimate of the cross section for Δ-spectator observation can be obtained. Thus an upper limit of this cross section is equal to ≈ 100 μb while the total dp cross section is 82.9 ± 0.1 mb.

Summarizing we would like to point out that there exist the sources, other than $\Delta\Delta$, leading to the backward emission of the pion-nucleon systems. On the other hand, the expected Δ-spectator momentum and angular distribution are close [11,12] to those observed in the experiment.

It is worth noting that the existence of the $\Delta\Delta$ component in the deuteron leads to the definite ratios between the different charge states; due to the conditions of our experiment we have been able to present some results concerning this point.

The authors wish to thank the staffs of the Laboratory of High Energies and the Laboratory of Computer Technique and Automatization (JINR) and of the Warsaw University and the Institute of Nuclear Research (Warsaw) for their help in scanning and measurements.

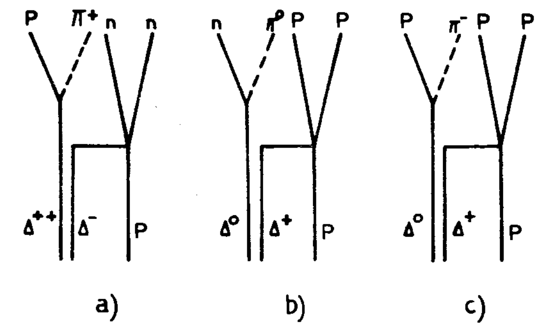

Fig.1. Diagrams involving different $\Delta\Delta$ components in the deuteron: a), b) and c) correspond to reactions (I), (2) and (3) respectively.

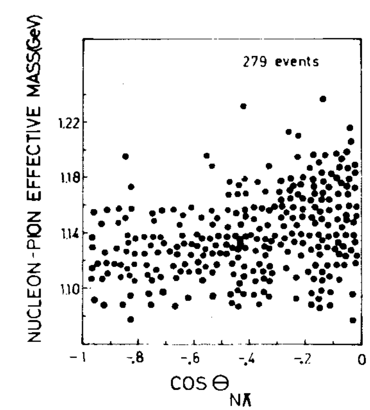

Fig.2. The (π-N) effective mass distribution versus $\cos\Theta_{\pi N}$ in the deuteron rest frame.

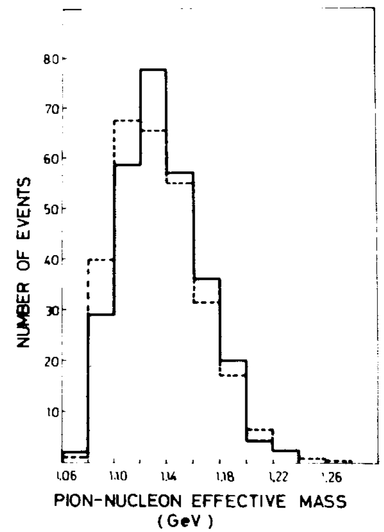

Fig.3. The (π -N) effective mass distribution for the (π -N) system emitted backwards in the deuteron rest frame. The dotted line corresponds to the Monte Carlo events.

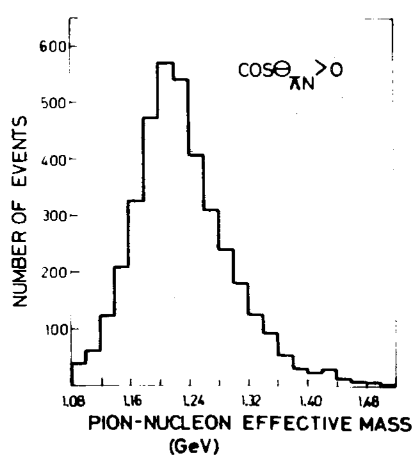

Fig.4. The pd $\longrightarrow$ p π^+ nn reaction; (p-π^+) systems emitted forwards in the deuteron rest frame.

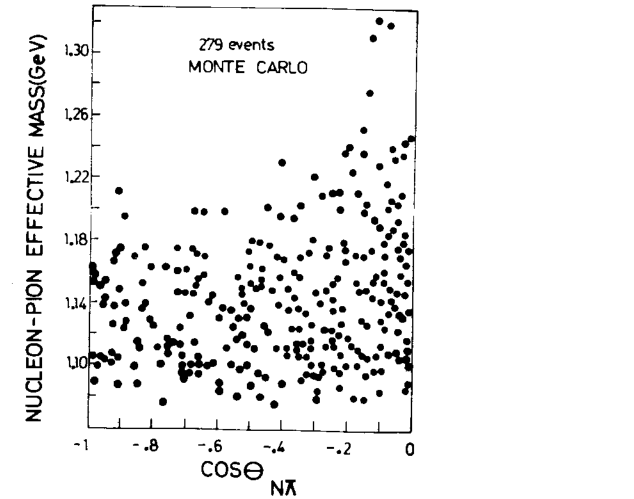

Fig.5. The (π -N) effective mass distribution versus cos $\Theta_{N\pi}$ in the deuteron rest frame for the Monte Carlo events.

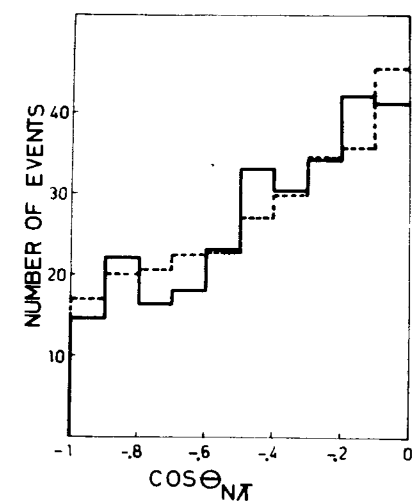

Fig.6. The angular distribution of the (π -N) system in the deuteron rest frame. The dotted line corresponds to the Monte Carlo events.

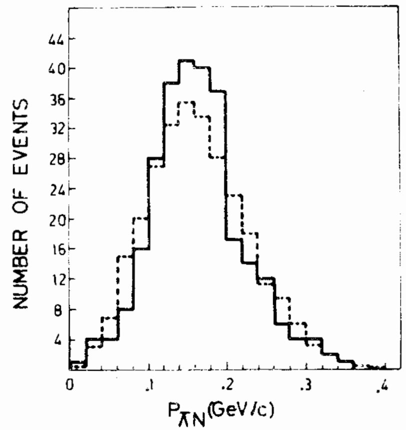

Fig.7. The momentum distribution of the (π -N) systems emitted backwards in the deuteron rest frame. The dotted line corresponds to the Monte Carlo events.

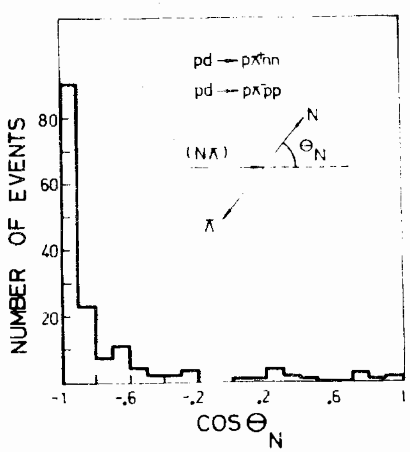

Fig.8. The nucleon angular distribution in the (π-N) rest frame for reactions (I) and (3); Θ_N is the angle between the nucleon direction in the (π -N) rest frame and the direction of the (π -N) combination in the deuteron rest system.

Table I

Reaction	Number of the (N-π) systems emitted backwards in the deuteron rest frame	
	unweighted	weighted
pd —— p π^+nn	84	75
pd —— ppn π^0	122	112
pd —— ppp π^-	82	82

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