Краткие сообщения ОИЯИ №5-84 JINR Rapid Communications №5-84
УДК 539.172.13

ENHANCEMENTS OBSERVED IN THE TWO-PROTON EFFECTIVE MASS DISTRIBUTION IN THE PIONLESS DEUTERON BREAK-UP AT 3.3 GeV/c

V.V.Glagolev, A.K.Kacharava*, G.I.Lykasov, M.S.Nioradze*, Z.R.Salukvadze*, J.Urban

A sample of "non-spectator" events in the pionless break-up at a 3.3 GeV/c deuteron momentum has been investigated by means of a 1 m HBC at the Dubna synchrophasotron. The two-proton effective mass spectrum in the charge exchange channel exhibits two enhancements at masses M_{pp} = 2010 and 2160 MeV/c^2. The experimental results are compared with theoretical calculations supposing virtual π-meson production and absorption by a nucleon pair.

The investigation has been performed at the Laboratory of High Energies, JINR.

Наблюдение особенностей в спектре эффективных масс двух протонов в безмезонном развале дейтрона при 3,3 ГэВ/с

В.В.Глаголев и др.

Исследовались "неспектаторные" события из безмезонного развала дейтрона при импульсе 3,3 ГэВ/с, полученные на 100 см водородной пузырьковой камере ЛВЭ ОИЯИ. В спектре эффективных масс двух протонов в канале с перезарядкой наблюдаются два максимума при значениях M_{pp} = 2010 и 2160 МэВ/с^2. Экспериментальные результаты сравниваются с теоретическими расчетами, учитывающими рождение и поглощение виртуального π-мезона на паре нуклонов.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

In the last few years in two-nucleon systems produced in nucleon-nucleon and hadron-nucleus collisions new

* High Energy Physics Institute, Tbilisi, USSR.

effects have been observed, which may be treated as dibaryon states. A search for such states is particularly interesting in connection with the existence of six-quark bags predicted previously. A detailed account of experimental results and their theoretical treatment have been published in a number of reviews, e.g., [1,2]. However, we should remark that not in all cases the resonance behaviour in cross sections or two-baryon effective mass distribution may be identified as a manifestation of dibaryon resonances [2].

Using a 1m HBC exposed to light nucleus beams, such enhancements have been recently observed in two-nucleon effective mass distributions at 2.040 GeV/c^2 and 2.140 GeV/c^2. Besides, these peaks have been observed in proton-proton combinations [3,6] of the ^{4}Hep→dppn reaction, in proton-neutron [4] combinations of the dp→ppn reaction and in neutron-neutron combinations of the dp→pπ^+nn reaction [5]. The question arises whether such a structure exists in proton-proton combinations of the dp→ppn reaction. It should be stressed that in all the noted cases of the deuteron break-up only those events have been taken into account which cannot be classified as quasi-nucleon ones, i.e., events without spectator nucleons. The ^{4}Hep→dppn reaction proceeds mainly via the mechanism in which two nucleons participate from ^{4}He and the remaining deuteron is a spectator [6] The situation is quite different in the dp→ppn channel where quasielastic neutron-proton or proton-proton scattering takes place in the overwhelming majority of events. In this case the events, in which the momentum of the slowest nucleon ("spectator") in the deuteron rest frame is large enough, have been conditionally regarded as spectatorless ones. A few boundary cuts have been taken as 300 MeV/c [5] or 350 MeV/c [4]. If one applies a cut at too low momentum values, the hypothetical structure may be hidden due to a large quasielastic background. On the other hand, a too high boundary impoverishes event statistics in the region of our interest.

One of the ways of choosing the cut boundary may result from the following considerations. Let us try to select the class of inelastic scattering, e.g., with virtual π-meson production and absorption [7,9]. Due to kinematical constraints on π-meson absorption with a single nucleon, the overwhelming majority of these events occurs on a nucleon pair. Figure 1 shows a plot of the effective mass of two slow nucleons versus four-momentum transfer squared from the incident proton to the leading particle. In our terminology charge retention and charge exchange channels mean the leading proton and neutron in the final state, respectively. It can be seen that the events are intensively grouped according to the quasi-elastic nucleon-nucleon kinematics. An analogous plot in the $dp \to ppp\pi^-$ channel is demonstrated in fig.2.

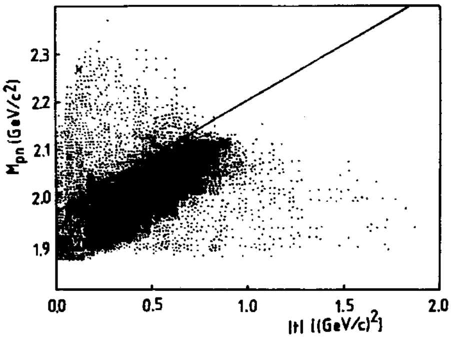


Fig.1. Slow proton and neutron effective mass versus four-momentum transfer squared for the charge retention part of the $dp \to ppn$ *reaction.*

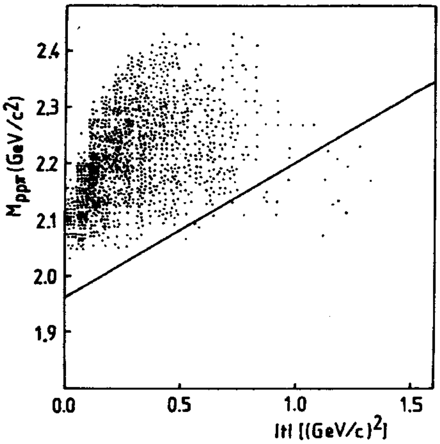


Fig.2. $pp\pi^-$ *effective mass, without the leading proton, versus four-momentum transfer squared for the* $dp \to ppp\pi^-$ *reaction.*

It should be noted that from the kinematical constraint for the quantities put on the axes x and y such a plot reflects only the incident proton momentum loss. Supposing that in the $dp \to ppn$ channel the produced π-meson is almost on-mass-shell, the comparison of these two plots allows us to select the sample of wanted events. They will lie above the line presented in figs.1 and 2. Such a procedure has been also applied to the charge exchange channel. The momentum distributions for the selected groups of events are demonstrated in figs.3a and 3b for the charge retension and charge exchange channels, respectively. In the momentum distribution of the slowest nucleon in the charge retension channel figure 3a shows two maxima which are well divided at a momentum of ≈200 MeV/c. The first of them corresponds to a part of quasi-elastic NN scattering owing to the conditionality of the lines in figs.1 and 2. The second maximum corresponds to the events with π-meson absorption.

Previous studies of the $dp \to ppn$ reaction at 3.3 GeV/c have shown that a high momentum tail in the charge exchange channel substantially exceeds that of the retention one. This phenomenon is explained by contributions

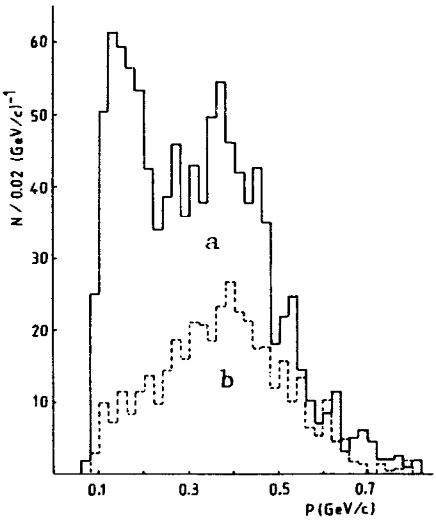


Fig.3. Momentum distribution of the slowest nucleon in the deuteron rest frame: (———) for the charge retention and (- - - -) for the charge exchange channels. The events are taken from the "pion absorption region".

of inelastic processes such as Δ-isobar exchange or virtual π-meson production and absorption [8,7] considering the corresponding isospin states. Involving the above mechanisms has been also necessary in the analysis of ^{4}Hep → dppn at 8.6 GeV/c [6,9]. According to the foregoing, it is not surprising that the second maximum preponderates over the first one in the slowest proton momentum distribution of the charge exchange channel (fig. 3b).

Applying the cut at p = 200 MeV/c for the slowest nucleon momentum, the effective mass distribution of two slow protons is histogrammed in the charge exchange channel. The result is shown in fig.4a. Two maxima can be seen at approximately the same mass values as in pn and nn combinations [3,4,5,6]. The admixture of the second-order polynom and two Breit-Wigner functions has been fitted to the experimental distribution with the following results for maxima and widths:

$M_1 = 2014 \pm 10$ MeV/c^2, $\Gamma_1 = 63 \pm 28$ MeV/c^2,

$M_2 = 2162 \pm 10$ MeV/c^2, $\Gamma_2 = 18 \pm 26$ MeV/c^2.

A cut boundary of 350 MeV/c has been applied in ref. [4]. This choice is justified whereas the admixture of quasi-elastic events to the charge retention channel at p = = 200 MeV/c is fairly large as shown in fig.3a.

The authors of ref. [10] have not observed the quoted enhancements. This is connected with the following fact: the effective mass distribution M_{pn} contains both combinations in the charge retention part of the dp→ppn reaction, and, owing to the high cut value for the M_{pp} distribution in the charge exchange channel, statistics becomes insufficient.

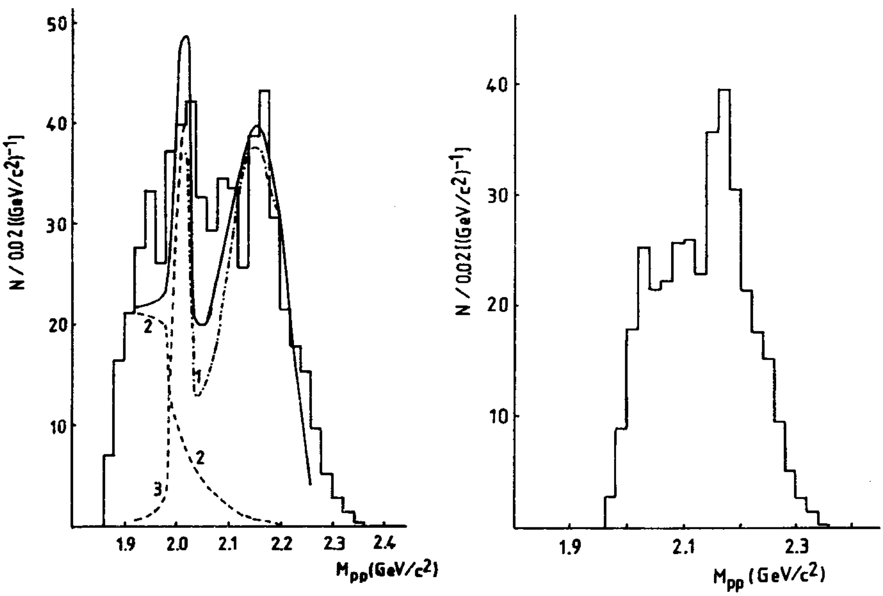
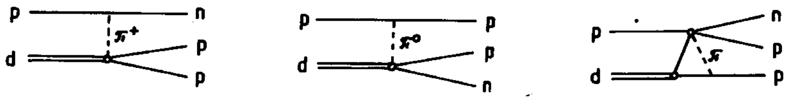


Fig.4. a) Two-proton effective mass distribution from the charge exchange channel for both protons with momenta over 200 MeV/c: histogram - experimental results, full curve - calculated result. Curves 1 and 3 correspond to diagrams 5a and 5c, respectively. Curve 2 corresponds to elementary p-n *charge exchange. b) Two-proton effective mass distribution for the charge exchange channel for both protons with momenta over 200 MeV/c. Only events from the "pion absorption region" are taken.*

It should be pointed out that ref./11/ confirms the observed enhancement in the M_{pn} distribution at 2.140 GeV/c^2.

The resonance behaviour of the effective mass distribution of two protons (fig.4a) suggests the question if they can be treated as an evidence for dibaryon resonances. The $dp \to ppn$ reaction, in principle, may proceed via virtual π-meson production in the intermediate state and its further absorption by the deuteron as displayed in fig.5. Then the analysed two-nucleon distribution is mainly determined by the behaviour of the $\pi d \to NN$ process cross section. This cross section has a strong resonance-like character observed at $M_{NN} \simeq 2.160$ GeV/c^2 /12/ and theoretically found by Δ-isobar production in the intermediate state/13/. At $M_{NN} \simeq 2.020$ GeV/c^2, what means a π-meson almost with zero kinetic energy, strong π-meson absorption by the deuteron is expected according to the



a) b) c)

Fig.5. Diagrams used in the calculation.

1/v law, where v denotes the π-meson velocity, i.e., at these values of M_{NN} the cross section $\sigma(\pi d \to NN)$ has to grow [12-14]. The effective mass distribution at $M_{NN} <$ < 2.020 GeV/c^2 should be decreased because of the behaviour of the studied $dp \to ppn$ reaction phase space. Thus, the observed peaks in the effective masses of proton-proton and proton-neutron systems in $dp \to ppn$ and also in a neutron-neutron system in $dp \to p\pi^+nn$ [4,5] can be due to the mechanism of virtual π-meson absorption by a nucleon pair. The M_{pp} distribution of the charge exchange channel is mainly determined by the contribution from the diagram 5a and the M_{pn} distribution of the charge retention channel from the diagram 5b.

The two-proton effective mass has been calculated taking into account the diagram 5a for $M_{pp} \geq 2.020$ GeV/c^2, the diagram 5c for $M_{pp} < 2.020$ GeV/c^2, and the contribution from elementary p-n charge exchange in both regions. The detailed calculations are published separately. The final results are shown in fig.4a.

Figure 4b displays the two-proton effective mass distribution from the charge exchange channel with the cut on "spectator" momentum for the events lying above the same line as presented in fig.1 for the charge retention channel. As is clearly seen, only one of the enhancements remains in the region of masses 2.160 GeV/c^2.

The proton-proton effective mass distribution, produced in the pionless deuteron break-up on proton target at 3.3 GeV/c ($dp \to ppn$) in the charge exchange channel, can be qualitatively described by virtual π-meson absorption on the deuteron. However, the disappearance of the first maximum in the "pion absorption region" (fig.4b) may show evidence that the observed structure is connected with a more virtual π-meson or if it is of a deeper physical origin.

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Received on December 28,1984.