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NARROW SIGNALS IN THE TWO-NUCLEON EFFECTIVE MASS SPECTRUM AND SPIN EFFECTS IN THE pn→np CHARGE EXCHANGE PROCESS

By B. S. Aladashvili*, B. Badełek**, V. V. Glagolev*, R. M. Lebedev*, M. S. Nioradze*, I. S. Saitov*, T. Siemiarczuk***, J. Stepaniak***, V. N. Streltsov* and P. Zieliński***

Dubna—Warsaw Collaboration

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Narrow signals are observed in the effective mass spectra of "pp" and "pn" systems at $Q \approx 0$ MeV in the deuteron break up reaction. Experimental evidence is presented for a spin-dependent interaction in the elementary pn→np charge exchange process.

In recent years growing interest has been focused on the nucleus fragmentation process initiated by high energy projectiles. The main effort was devoted to the inclusive studies and little is known about the correlations between nuclear fragments which are still calling for a more systematic approach. The present work is concerned with the study of two-nucleon correlations in the break up of the deuteron on the proton target. This process, which may be considered as one of the simplest fragmentation processes, can be used as a tool for studying the elementary pn → np charge exchange reaction.

Several years ago, a narrow signal has been reported at $Q \approx 0$ MeV in the effective mass distribution of two slow proton fragments emitted in the fragmentation of the xenon nuclei induced by 9 GeV/c negative pions [1, 2]. This observation of the "diproton" has been confirmed lately by Azimov et al. [3, 4] who have been studying the fragmentation of carbon nuclei by negative pions at 4.5 and 7 GeV/c. Some evidence for the frequent emission of two protons with a small relative angle was also found in the emulsion experiment [5].

The aims of the present work are: (a) to search for a similar correlation in the neutron proton system ("quasideuteron"); (b) to use the incoming deuteron as a kind of spin-analyzer for seeking the spin-dependent interaction in the elementary pn→np charge

* Joint Institute for Nuclear Research, Dubna, USSR.

** Warsaw University, Warsaw, Poland.

*** Address: Institute for Nuclear Research, Warsaw, Poland. Mailing address: Instytut Badań Jądrowych, Hoża 69, 00-681 Warszawa, Poland.

exchange process; the latter is possible since the deuteron (being the triplet spin state of the n–p system) selects the spin and, for the low four-momentum transfer to the struck proton, also the orbital momentum of the two protons in the dp → (pp)n charge exchange reaction.

The experiment was performed by exposing the JINR one metre hydrogen bubble chamber to a deuteron beam of 3.3 GeV/c momentum. The analysis of about 20000 events of dp→ppn deuteron break up is reported here.

The break up events can be distinctly separated into two processes: the charge exchange reaction

$$\mathrm{dp} \rightarrow (\mathrm{pp})\mathrm{n} \tag{1}$$

corresponding to the configuration when the neutron momentum is higher than that of any proton in the deuteron rest system, and the remaining charge retention events proceeding without charge exchange between the projectile and the target:

$$\mathrm{dp} \rightarrow (\mathrm{pn})\mathrm{p}. \tag{2}$$

The following advantages of using the deuteron beam, which make the present study possible, should be pointed out:

(*i*) No mixing takes place between elastic and break up channels; this mixing is common for the deuterium target experiments, where the conservation laws' requirements are not sensitive to the substitution of a slow deuteron by a slow proton, and do not allow one [6] to study the low Q part of the two-nucleon effective mass spectrum. In our beam-target configuration the curvature of the fast outgoing proton is twice as large as that of the deuteron from the elastic event provided that the energy-momentum conservation distinguishes unambiguously between the elastic and break up events. The competition of the break up and elastic events does not occur in our GRIND results.

(*ii*) There is also very distinct separation between the dp → ppn and dp → ppn + neutrals channels (see Fig. 3 in our previous work [8]), since the σ(MMIS) = 32 MeV is much less than the mass of π^0 meson.

(*iii*) No losses occur in the proton spectators, whereas when the deuterium target is used, the protons with momentum $p_s < 80$ MeV/c are invisible.

For further details of the experimental procedure, the reader is referred to Refs [7, 8].

Figure 1a shows the $Q_{pp} = M_{pp} - 2m_p$ distribution of a pair od two slow protons in the deuteron rest system for the charge exchange channel. A narrow signal is observed at $Q_{pp} \approx 0$ MeV. The peak is associated mainly with low spectator[1] proton momenta ($p_s < 100$ MeV/c) and low four-momentum transfer ($|t| < 0.1$ (GeV/c)^2) from the proton target to the fastest nucleon in the deuteron rest system. The smaller the momentum of the spectator proton, the lower is the four-momentum transfer associated with the Q_{pp} contribution to the "diproton" peak. The picture changes when we consider the charge retention channel. Figure 1b shows the neutron-proton Q_{pn} distribution for different intervals of the spectator nucleon momentum. The signal at $Q_{pn} \approx 0$ MeV is present for $p_s > 100$ MeV/c,

[1] The slowest nucleon in the deuteron rest system is referred to as "spectator".

whereas the events with low spectator nucleon momentum ($p_s < 100$ MeV/c) exhibit a dip at $Q \simeq 0$ MeV. The experimental Q resolution is obtained by using the GRIND programm and is equal to 1 and 2 MeV for the two first bins of the Q_{pp} and Q_{pn} distributions, respectively[2]. For larger Q the $\sigma(Q)$ increases and amounts to about 10 — 15 MeV around $Q \simeq 300$ MeV.

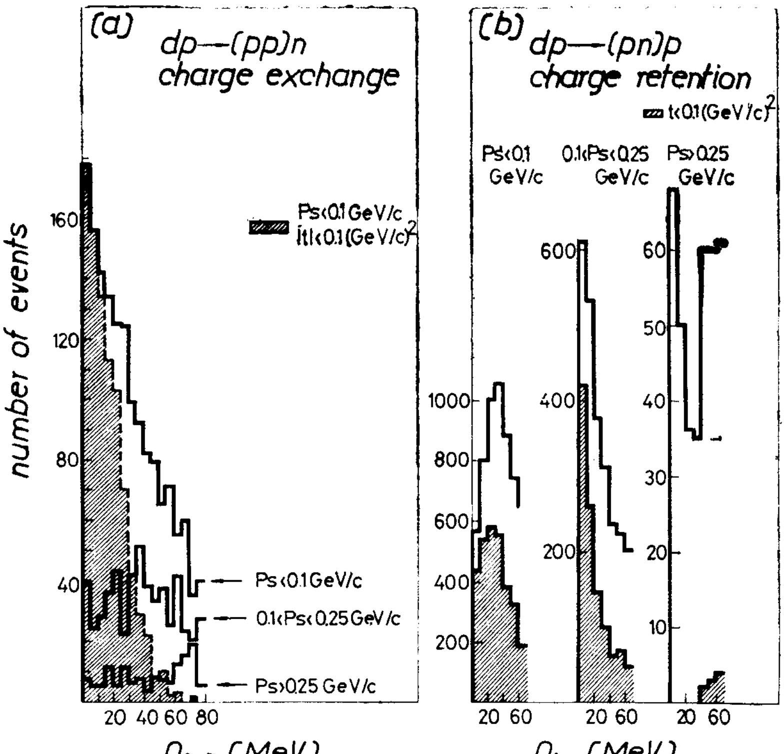

Fig. 1. a — The two-proton $Q_{pp} = M_{pp} - 2m_p$ distribution for different intervals of the spectator proton in reaction (1). The shaded area corresponds to the events with $|t| < 0.1$ (GeV/c)^2 (t being the four-momentum transfer from the proton target to the neutron); b — The proton-neutron $Q_{np} = M_{pn} - m_p - m_n$ distribution for different intervals of the spectator nucleon in the charge retention channel. The shaded area corresponds to the events with $|t| < 0.1$ (GeV/c)^2 (t being the four-momentum transfer from the proton target to the fastest proton in the deuteron rest frame)

The presence of the peak in the charge exchange channel for the low spectator momentum events and its absence in the charge retention case can be understood when we examine the

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[2] It is worth noting that we report here the first experimental data on the *low Q part* of the two-nucleon effective mass spectrum in the deuteron break up and no such results so far are available at high energy. This is due to the fact that in the deuterium bubble chamber experiments, the low Q events are usually excluded from the analysis because of the ambiguity which occurs with other competing channels (see e.g. Ref. [6] and references contained therein).

four-momentum transfer distributions for both channels presented in Figs 2a and 2b. The curves represent the Glauber model prediction calculated according to Refs [9, 10], the spin being neglected. In the calculations we used the closure approximation and the

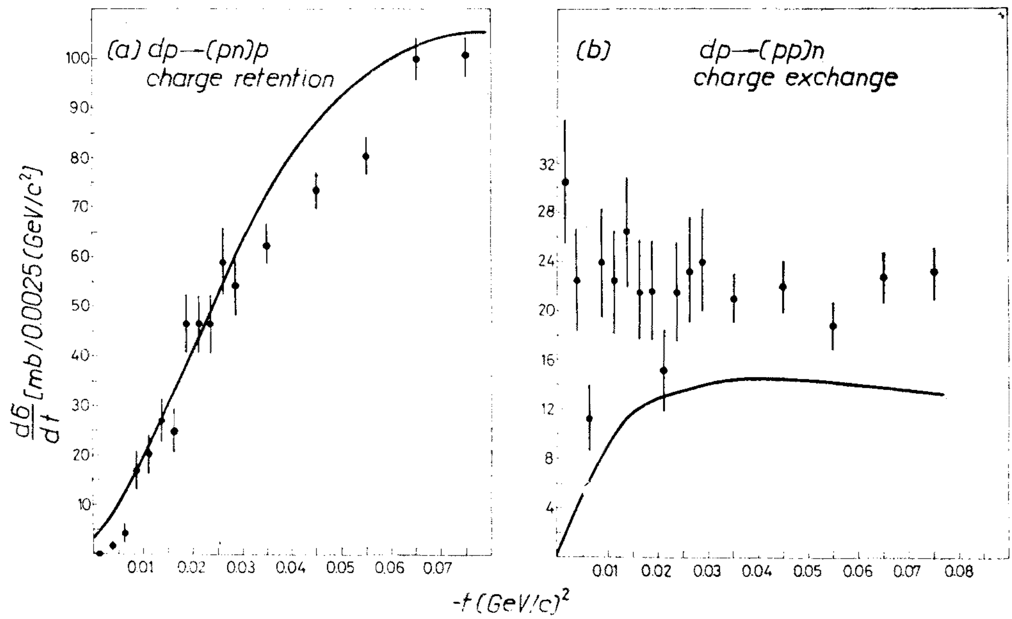

Fig. 2. The four-momentum transfer distribution for charge exchange and charge retention channels. The curves represent the Glauber model prediction with spin effects neglected

Bressel–Kerman deuteron wave function. The parametrization of the elementary proton--nucleon and elementary charge exchange amplitudes were taken in the form:

$$f_{pN} = A_N(i+\alpha_N)\exp\left(\tfrac{1}{2}b_N t\right),$$

$$f_{ch.ex.} = A_1\exp(b_1 t)+iA_2\exp(b_2 t).$$

The latter amplitude was fitted to the experimental data by Bizard et al. [11].

The shapes of the experimental $d\sigma/dt$ distributions for charge exchange and charge retention channels exhibit a completely different behaviour in the low $|t|$ region. A strong dip and fairly good agreement with the Glauber model prediction is observed for the charge retention channel, whereas the charge exchange reaction shows significant disagreement between the experiment and Glauber model calculations neglecting the spin. The observed shapes of the $d\sigma/dt$ distribution for channels (1) and (2) can be related to the presence and absence of the peaks at $Q \approx 0$ MeV for low spectator momenta ($p_s < 100$ MeV/c) in the charge exchange and charge retention reactions, respectively. In the former case the low momentum spectator has frequently a partner (struck nucleon) with small relative momentum providing the low Q_{pp} contribution, whereas in the latter case the partner which could give low Q_{pn} is absent due to the fact that the neutron-proton pairs corresponding to low $|t|$

values, being in the triplet spin state, form a deuteron and pass to the elastic channel. The picture is different, however, when the charge exchange process is considered. The low $|t|$ events[3] correspond to the S state of two protons which are not allowed to remain in the triplet spin state unless the spin-dependent interaction occurs in the elementary pn → np process. The narrow peak at $Q \approx 0$ MeV provides, therefore, evidence of the presence of a spin-dependent interaction in the elementary pn → np charge exchange process.

In conclusion, we should like to point to the following experimental findings:

(*i*) The presence of "diproton" production at high energy, observed previously in the pion interaction with heavy nuclei, is confirmed.

(*ii*) Evidence is presented for the similar signal in the proton-neutron system at $Q \approx 0$ MeV.

(*iii*) Evidence is reported for occurence of the spin-dependent interaction in the elementary pn → np charge exchange process.

Analysis of the nature of the signals observed in the Q_{pp} and Q_{pn} distributions at $Q \approx 0$ MeV is the subject of a forthcoming study.

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[3] About half of the events in the first bin of the Q_{pp} distribution corresponds to four-momentum transfer smaller than 0.01 $(\mathrm{GeV}/c)^2$. The experimental t resolution in the (0 — 0.03) $(\mathrm{GeV}/c)^2$ interval of the four-momentum transfer is 0.0015 $(\mathrm{GeV}/c)^2$.