Singlet-to-triplet ratio in the deuteron breakup reaction pd → pnp at 585 MeV *

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Recent analyses of experimental data on $\pi-$meson production, employing the largely model-independent approach of Ref. [1], show that the formation of the final spin-singlet np-pair is strongly suppressed in the $pp \to pn\pi^+$ reaction at proton kinetic energies between 300 and 800 MeV (see [2, 3] and reference therein).

The measured pion-production cross section in pp collisions allows one to estimate the singlet-to-triplet (s/t) ratio in the deuteron breakup reaction $pd \to \{pn\}p$, when the quasi-bound $\{pn\}$ pair is observed in the final-state interaction (fsi) region at high momentum transfer. If one assumes that the triangle diagram of one-pion exchange with the subprocess $pp \to d\pi^+$ [5] dominates in the $pd \to \{pn\}p$ reaction at large scattering angles, one would expect in this reaction a similar s/t ratio of a few percent. For the Δ mechanism in the $pd \to pnp$ reaction, which dominates the one-pion exchange triangle diagram, the product of spin and isospin factors yields a s/t ratio of $\frac{1}{27}$ [6]. In contrast, one should expect the s/t ratio of about $\frac{1}{3}$ for the one-nucleon exchange mechanism of the deuteron breakup.

Available data on the formation of a singlet $(np)_s$ pair were obtained in a few semi-inclusive measurements of the reaction $dp \to pnp$. The only exclusive $pd \to pnp$ experiment has been performed in Virginia [7] at a proton beam energy of $T_p = 585$ MeV and with a low relative energy of the final neutron-proton pair ($E_{np} = 0 - 5$ MeV) and a large scattering angle of the second proton ($\theta_{cm} \sim 90°$). The data from Ref. [7] are shown in Fig. 1 as a function of the momentum of the detected proton. At energies E_{np} of about 1 MeV the cross section is strongly influenced by the np fsi. The shape of this peak is well described by the Migdal-Watson formulae [4], which take into account the nearby poles in the fsi triplet (t) and singlet (s) $pn-$scattering amplitudes

$$d\sigma_{s(t)} = FSI_{s(t)}(k) \cdot K \cdot |A_{s(t)}|^2. \qquad (1)$$

Here $A_{s(t)}$ is the production matrix element for the singlet (triplet) state, K is the kinematical factor, and $FSI_{s(t)}$ is the well known Goldberger-Watson factor. Important new information on the mechanism of $pd \to pnp$ and off-shell properties of the NN system is hidden in the matrix elements $A_{s(t)}$, in particular in the ratio $\zeta = |A_s|^2/|A_t|^2$. One can find the following parametrization for the full singlet plus triplet cross section

$$d\sigma_{s+t} = \left(1 + \zeta \frac{FSI_s}{FSI_t}\right) d\sigma_t, \qquad (2)$$

where $d\sigma_t$ is the triplet cross section. The second term in the brackets of Eq. (2) corresponds to the singlet contribution.

Using the Fäldt-Wilkin extrapolation [1], which relates bound and scattering S-wave functions in the triplet state at short pn distances $r < 1$ fm, and by taking into account the short-range character of the interaction mechanism, one can find a definite relation between the matrix elements of the $pd \to \{pn\}_t\, p$ and $pd \to dp$ reactions [1]. Thus, the triplet cross section can be calculated in a largely model-independent way in terms of the large angle proton-deuteron elastic scattering. This approach was employed in Ref. [8] to reanalyze the data of Ref. [7]. The result is shown in Fig. 1. After smearing over the experimental resolution we obtain good agreement both in the shape and in the absolute value between the data and a pure triplet contribution of the final pn pair with $\chi^2 = 0.7$. A small singlet contribution, corresponding to $\zeta = 0.02$, does not contradict the data ($\chi^2 = 0.9$), whereas the assumption of Ref. [7] about the statistical weight of the singlet $\zeta = \frac{1}{3}$ results in a too large cross section in the vicinity of $E_{np} = 0$.

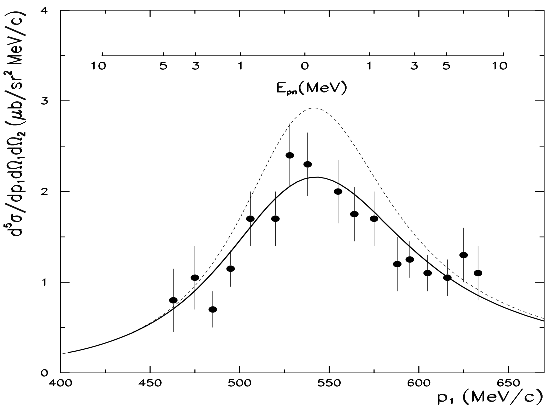

Fig. 1: Experimental cross section (points) of the $pd \to pnp$ reaction from Ref.[7] at a beam energy 585 MeV and proton laboratory scattering angles $\theta_1 = 41°$, $\theta_2 = 61°$ as function of the momentum of proton 1 measured at θ_1 in comparison with our calculations. The pure triplet contribution is calculated with corrections taking into account the experimental resolution (full line) and without (dashed). The upper scale shows the relative energy of the pn pair for $\theta_1 = 41°$.

The direct measurement of the singlet channel in the reaction $\vec{p}\vec{d} \to (pp)n$ is in progress at ANKE, COSY (Exp. No. 20).

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* Supported by BMBF, Germany (WTZ grant KAZ 99/001 and Heisenberg-Landau program)