Mechanisms of $^1S_0$ diproton formation in the $dp \to \{pp\}_s N\pi$ reaction in the Δ-isobar region

Yu. Uzikov

The charge exchange reaction $dp \to \{pp\}_s n$ at small transferred momenta, where $\{pp\}_s$ denotes the two-proton system at low excitation energy ($E_{pp} < 3$ MeV), allows one to study the spin-flip amplitudes in the $pn \to np$ process [1]. This reaction has been investigated at ANKE in both single [2] and double-polarized [3] experiments.

Also of interest is the $dp \to \{pp\}_s N\pi$ reaction, with the invariant mass M_x of the non-observed $\pi^0 p$ and $\pi^+ n$ systems being in the Δ-isobar region, i.e. $M_x = 1.1 - 1.3$ GeV/c^2. It is expected that at low transferred momenta this channel would be dominated by the direct (D) one-pion exchange mechanism depicted in Fig.1a. This mechanism is sensitive to the spin-flip part of the $NN \to N\Delta$ amplitude. Knowledge of this spin dependence is important in many tasks, in particular in resolving the so-called T_{20} puzzle in proton-deuteron backward elastic scattering (see Ref. [4] and references therein). The preliminary ANKE data [5] consist of the unpolarized cross sections and the tensor analyzing powers A_{xx} and A_{yy}. An important point is that the measured A_{xx} and A_{yy} differ in sign from the corresponding observables in the "ordinary" $dp \to \{pp\}_s n$ charge-exchange reaction.

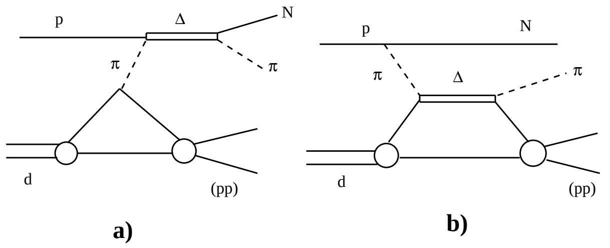

Fig. 1: a) The direct (D) and b) exchange (E) mechanisms for the $dp \to \{pp\}_s N\pi$ reaction with Δ excitation.

In order to understand the dominant mechanisms of this reaction, estimates of the D-mechanism in the analogous $p(^3\text{He}, t)\Delta^{++}$ reaction [6] were made in Ref. [5]. The results obtained explain well the shape of the measured spectra at $M_x \sim 1.2 - 1.35$ GeV/c^2. However, this model strongly underestimates the $dp \to \{pp\}_s X$ experimental data [5] at low missing masses, $M_x \sim 1.1 - 1.2$ GeV/c^2. It was suggested [7] that this deficit was caused by the another type of OPE mechanism, called here exchange (E), where a nucleon in the deuteron is excited into the Δ-isobar (Fig.1b). According to Ref. [8], this mechanism dominates the $dp \to dX$ reaction in the Δ-region. In the present work we consider the contributions of the E and D mechanisms to the $dp \to \{pp\}_s N\pi$ reaction.

We use the Feynman diagram technique with relativistic πNN vertices and pion propagator but treat the $\pi N \to \Delta \to \pi N$ transition non-relativistically. Values $f_{\pi NN} = 1.08$ and $f_{\pi N\Delta} = 2.15$ were taken for the coupling constants. Monopole form factors $F_{\pi NN}(k^2{}_\pi) = (\Lambda^2 - m_\pi^2)/(\Lambda^2 - k_\pi^2)$, where m_π is the pion mass, k_π the pion 4-momentum, and Λ the cut-off parameter, were introduced at the πNN and $\pi N\Delta$ vertices. The dependence of the width of the Δ-isobar on the relative momentum in the πN system was taken into account. The transition form factor $d \to \{pp\}_s$ was calculated using the CD Bonn potential.

The numerical results illustrated in Fig. 2 show that the D-

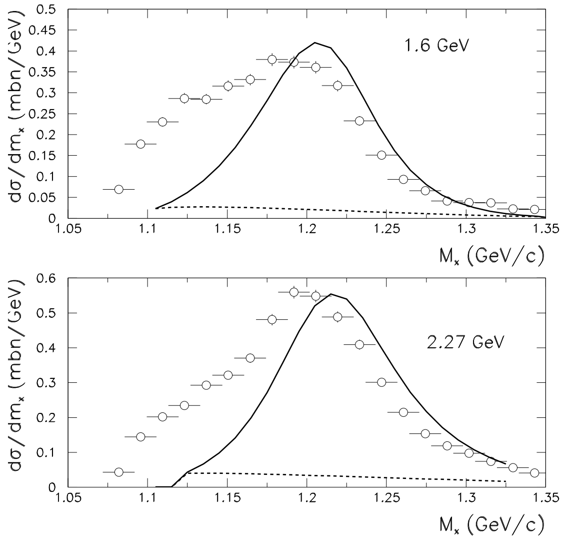

Fig. 2: The differential cross section of the $dp \to \{pp\}_s N\pi$ reaction in terms of the invariant mass of the πN system M_x at beam energies $T_d = 1.6$ GeV (upper panel) and $T_d = 1.6$ GeV (lower). The preliminary ANKE data [5] ($\circ$) are compared with the results of calculations based on the D mechanism (full line) and E-mechanism (dashed) in impulse approximation. At 2.27 GeV the full line is normalized to the data by a factor 1/1.56.

mechanism can explain the shape of the $d\sigma/dM_x$ distribution for $M_x > 1.2$ GeV/c^2 at 1.6, 1.8 and 2.27 GeV [5]. With a cut-off parameter $\Lambda = 0.5$ GeV/c, the absolute value of the cross section is also well described for $M_x > 1.2$ GeV/c^2 at $T_d = 1.6$ and 1.8 GeV, while at 2.27 GeV a normalization factor $\approx 1/1.5$ is required. This slight discrepancy might be connected with the non-relativistic treatment of the $\pi N \to \Delta \to \pi N$ sub-process, where one has to evaluate the scalar product of the 3-momenta of the initial ($\mathbf{k}$) and final ($\mathbf{k}'$) pions in the cms of the Δ-isobar. At lower missing masses, $M_x < 1.2$ GeV/c^2, the D-mechanism fails to explain the measured cross section, as already found in Ref. [5].

The E-mechanism is calculated in a similar way. Due to the spin-flip in the $d \to \{pp\}_s$ transition, the vector product $[\mathbf{k} \times \mathbf{k}']$ of the pion momenta appears in the reaction amplitude. The E-contribution has a maximum at $M_x \approx 1.1$ GeV, but it is much smaller in absolute value than the D-contribution and so does not explain the measured shape of the cross section. The reasons for this are (i) the smallness of the Δ propagator for the E-mechanism as compared to the D-mechanism, and (ii) the smallness of the vector product $[\mathbf{k} \times \mathbf{k}']$ for E-kinematics compared to the scalar product $(\mathbf{k} \cdot \mathbf{k}')$ for the D-kinematics.

In order to control these calculations, we estimated within the same approach the cross section for the $dp \to dX$ reaction. The E-mechanism in this case has a different spin structure as compared to the $dp \to \{pp\}_s N\pi$ reaction whereas the D-mechanism is forbidden by isospin conservation. We found a reasonable agreement with the data on this reaction and with

the associated model calculations [8].
Further investigations are therefore in progress in order to try to describe the data in the $dp \to \{pp\}_s X$ reaction for $M_x < 1.2$ GeV/c^2 [5].

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* Joint Institute for Nuclear Research, Dubna, Russian Federation