NN ($^1S_0$) pairs in ^{3}He and in p^3He backward elastic scattering

Yu. Uzikov[a,*], J. Haidenbauer

p^3He backward elastic scattering has been investiged [1] on the basis of the DWBA method using a trinucleon bound-state wave function obtained from solving the Faddeev equations for the RSC nucleon-nucleon (NN) potential. Those studies suggest that this process at beam energies $T_p > 1$ GeV can give unique information about the high momentum component of the ^{3}He wave function $\varphi^{23}(\mathbf{q}_{23}, \mathbf{p}_1)$, and specifically for high relative momenta, $q_{23} > 0.6$ GeV/c, of the nucleon pair $\{23\}$ in the $^1S_0$ state and low momenta of the nucleon "spectator" $p_1 < 0.1$ GeV/c. Here φ^{23} is the first Faddeev component of the full wave function of ^{3}He, $\Psi(1,2,3) = \varphi^{23} + \varphi^{31} + \varphi^{12}$. The calculations presented in Refs. [1] demonstrate a dominance of the mechanism of sequential transfer (ST) of the proton-neutron pair (Fig.1a) in this process over a wide range of initial energies $T_p = 0.1-2$ GeV, except for the region of the ST dip at around 0.3 GeV. Other mechanisms of two-nucleon transfer, such as the deuteron exchange, non-sequential np transfer [1], and direct pN scattering involve very high internal momenta in the ^{3}He wave function in q_{23} as well as in p_1 and, in sum, give much smaller contributions. We show here (Fig.2, line 4) [2] that the above conclusion is valid for the CD Bonn ^3H wave function too [6]. We found also that in the region of the ST dip at 0.4-0.7 GeV the triangle diagrams of the one pion exchange (OPE) with the subprocesses $pd^* \to {}^3\mathrm{He}\,\pi^0$ and $p(pp) \to {}^3\mathrm{He}\,\pi^+$ (Fig. 1b-d) dominate, where d^* and pp are the $^1S_0$ np pair and diproton, respectively.

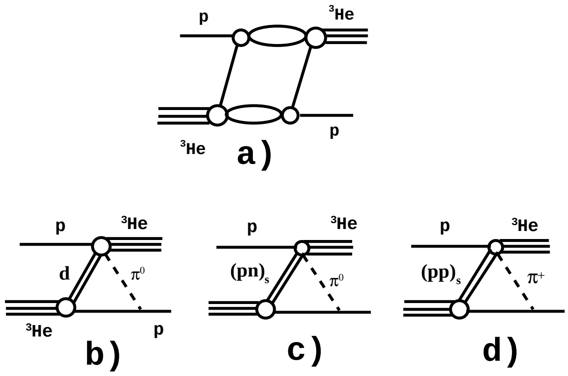

Fig. 1: The sequential transfer (ST) (a) and one pion exchange (OPE) (b-d) mechanisms of p^3He backward elastic scattering with intermediate deuteron (b), singlet pn pair (d^*) (c), and singlet pp pair (diproton) (d).

When considering the OPE diagrams, we assume for the subprocess p(NN)$\to$ $^3He\pi$ the spectator mechanism, dominating in the $pd \to$ $^3He\pi^0$ at energies $T_p < 1$ GeV [3], and neglect the spin-singlet $(NN)_s$ pair in the one-pion producton $pN \to (NN)_s\,\pi$ in the Δ-region [4]. With these approximations, the obtained cross section for the reaction p$d^* \to$ $^3He\pi$ is in agreement with the experimental data on the reaction $\pi^+\,{}^3He \to ppp$ [5].

Summarizing our results (see Fig.2), we can conclude the following. (i) The OPE mechanism in the plane wave approximation with the subprocess $pd \to$ ^{3}Heπ^0 describes well the energy dependence of the p^3He $\to$ ^{3}Hep cross section, but underestimates its absolute value by a factor of 2–3.5, depending on the cut-off mass used in the form factor at the πNN vertex. (ii) The contribution of the $d^* + pp$ is enhanced by isospin relations and provides about 90% of the OPE cross section whereas the deuteron alone gives the rest 10%. At higher energies, $T_p > 1$ GeV, the spectator mechanism of the subrocess $pd \to$ $^3He\pi$ fails, therefore this correlation may be changed. The total $d + d^* + pp$ contribution overestimates the measured cross section. (iii) Distortions in the initial and final states [2] reduce the $d + d^* + pp$ contribution by the factor about of ten and bring the OPE cross section in qualitative agreement with the data.

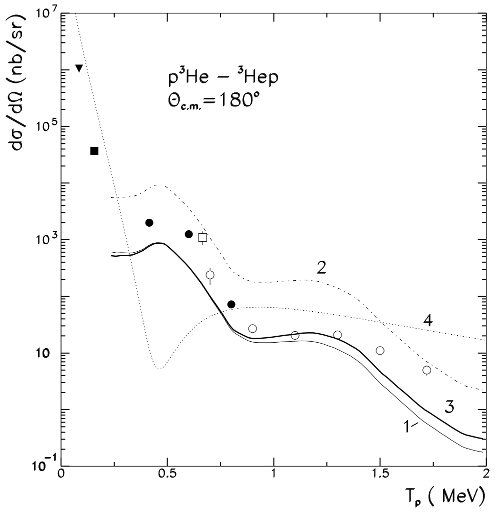

Fig. 2: The cms differential cross section of the process $p^3He \to$ ^3Hep versus the beam energy. Calculations on the basis of the OPE model: 1 – only d in the intermediate state, 2 – $d + d^* + pp$; 3 — $d + d^* + pp$ with distortions taken into account. 4 – the non-distorted ST mechanism with the S-component of the CD Bonn trinucleon wave function [6]. Experimental data are taken from literature cited in Ref. [2]).

A more detailed discussion can be found in Ref. [2].

References:

[1] L.D. Blokhintsev, A.V. Lado, Yu.N. Uzikov, Nucl. Phys. **A597**, 487 (1996); Yu.N. Uzikov, Nucl.Phys. **A644** (1998) 321.
[2] Yu.N. Uzikov, J.Haidenbauer, Phys. Rev. **C 68**, 014001 (2003).
[3] J.-F. Germond, C. Wilkin, J. Phys. G **14**, 181 (1988).
[4] Yu.N. Uzikov, C. Wilkin, Phys. Lett. **B545**, 191 (2001).
[5] H. Hahn *et al.*, Phys. Rev. **C 53**, 1074 (1996).
[6] V. Baru, J. Haidenbauer, C. Hanhart, J.A. Niskanen, Eur. Phys. J. **A 16**, 437 (2003).

---

[a] JINR, Dubna, Russia

[*] Supported by BMBF (Heisenberg-Landau program)