TWO-STEP MECHANISM OF MESON PRODUCTION IN $pd \to ^3\mathrm{He}\, X$ REACTION*

L.A. KONDRATYUK

Institute of Theoretical and Experimental Physics
B.Cheremushynskaya 25, Moscow 117259, Russia

AND

YU.N. UZIKOV

Laboratory of Nuclear Problems
Joint Institute for Nuclear Research, Dubna
Moscow reg. 141980, Russia
e-mail address: uzikov@nusun.jinr.dubna.su

(Received October 9, 1996)

It is shown that the two-step model of the reaction $pd \to ^3\mathrm{He}\, X$ ($X = \eta,\ \eta'\ , \omega,\ \phi$), involving the subprocesses $pp \to d\pi^+$ and $\pi^+ n \to Xp$ allows to explain the form of energy dependence of experimental cross sections above the thresholds under assumption that the singlet part of the $pp \to d\pi^+$ amplitude dominates in collinear kinematics. The spin-spin asymmetry for the reaction $\vec{d}\vec{p} \to ^3\mathrm{He}X$ has been found to be ~ -1 in the forward-backward approximation.

PACS numbers: 25.10. +s, 25.40. Qa, 13.60. Le, 14.40. Aq

Reactions $pd \to ^3\mathrm{He}X$, where X means a meson heavier than the pion, are of great interest for several reasons. Firstly, high momentum transfer (~ 1 GeV/c) to the nucleons takes place in these processes [1]. Secondly, the possible existence of quasi-bound states in the $\eta-^3$He system is discussed in the literature [2, 3]. Thirdly, production of the η, η', ϕ mesons, whose wave functions contain valence strange quarks, raises a question concerning strangeness of the nucleon and the mechanism of Okubo-Zweig-Iizuka rule violation [4]. The experimental investigation of the reaction $\vec{d}\vec{p} \to ^3\mathrm{He}\phi$ is proposed [5] in Dubna to check the hypothesis of polarized strangeness

* Presented at the "Meson 96" Workshop, Cracow, Poland, May 10–14, 1996.

content of nucleon [4]. The investigation of conventional (nonexotic) mechanisms of this reactions seems to be of great importance.

The two-step model of the $pd \to ^3$ Heη reaction including two subprocesses $pp \to d\pi^+$ and $\pi^+ n \to \eta p$ was developed in Refs. [3, 6, 7]. In Ref. [8] the cross section of the reaction $pd \to ^3 H_\Lambda K^+$ was predicted in the two-step model in spinless approximation.

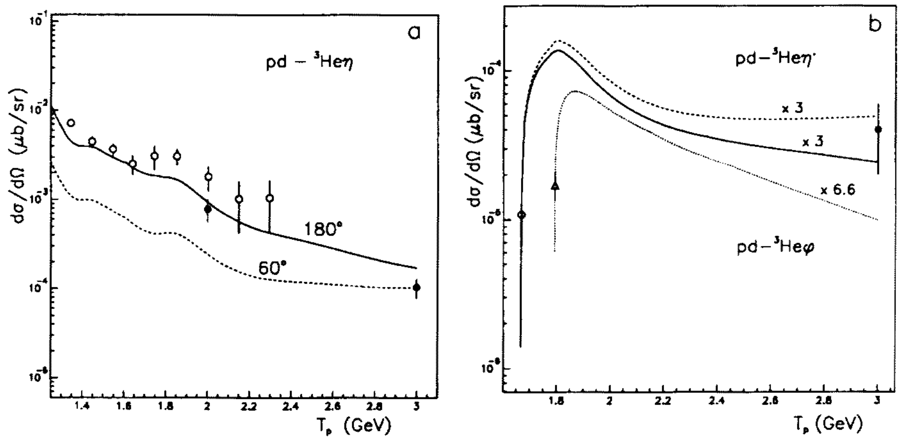

Fig. 1. Differential cross sections of the $pd \to ^3 He\eta(\omega,\ \eta',\ \phi)$ reactions as a function of lab. kinetic energy of proton T_p. The curves show the results of calculations for different angles $\theta_{\rm c.m.}$ multiplied by the appropriate normalization factor N. a — $pd \to ^3 He\eta$: 180° (full line, $N = 3$), 60° (dashed curve, $N = 3$), circles are experimental data: ∘ - $\theta_{\rm c.m.} = 180^0$ Ref.[1] ; • - $\theta_{\rm c.m.} = 60^0$ Ref.[10]; b — $pd \to ^3 He\eta'$ at $\theta_{\rm c.m.} = 180^0$ (full, N=3) and $\theta_{\rm c.m.} = 60^0$ (dashed, N=3); the circles are experimental data for the η' production: ∘ -$\theta_{\rm c.m.} = 180^0$ Ref. [11]; • - $\theta_{\rm c.m.} = 60^0$ Ref. [10]; the dotted line shows the results of calculation for the $pd \to ^3 He\phi$ reaction at $\theta_{\rm c.m.} = 180^o$ normalized by factor $N = 6.6$ to the experimental point (△) from Ref.[11].

In this work (see Ref. [9]) the two-step model [3] is extended for the production of η, ω, η' and ϕ mesons above the thresholds and spin observables are calculated [9]. The results of calculations performed under assumption that singlet part $\mathcal{A}$ of forward-backward amplitude of $pp \to d\pi^+$ dominates and triplet part, $\mathcal{B}$, is negligible ($|\mathcal{A}| \gg |\mathcal{B}$), are presented in Figs.1 and 2 in comparison with the experimental data. One can see that the two-step model *(i)* describes the shape of the energy dependence of the observed cross sections for the η, η', ω meson production (see Figs.1, 2); *(ii)* predicts the ratio of modules of the threshold amplitudes squared $R(\phi/\omega) = |f(pd \to ^3$ He$\phi)|^2/|f(pd \to ^3$ He$\omega)|^2 = 0.52$ in agreement with the experimental value $R^{exp} = 0.07 \pm 0.02$; *(iii)* does not contradict within the experimental errors

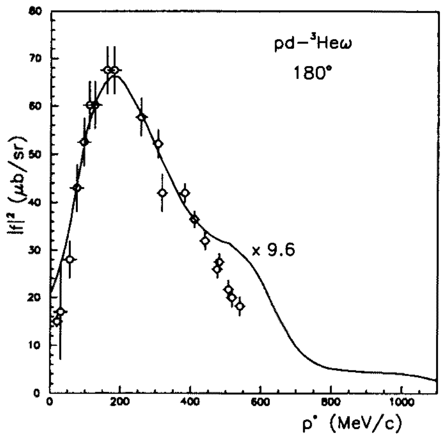

Fig. 2. The modulus squared of the amplitude of the $pd \to^3 He\omega$ reaction as a function of the c.m.s. momentum of the ω meson, p^*. The curve is the result of calculation at $R_1 = \frac{1}{3}$ multiplied by factor $N = 9.6$, the circles (○) are experimental data [12].

to the experimental data [10] on the absolute value of the cross section of η' production at $T_p = 3$ GeV, $\theta_{\text{c.m.}} = 60^0$ (this kinematical region corresponds to the matching condition).

Under the same assumption $|\mathcal{A}| \gg |\mathcal{B}|$ we give the definite prediction for spin-spin correlations in the reaction $\vec{p}\vec{d} \to^3$ HeX with polarized deuteron and proton defined as $\Sigma_X = d\sigma(\uparrow\uparrow) - d\sigma(\uparrow\downarrow)/d\sigma(\uparrow\uparrow) + d\sigma(\uparrow\downarrow)$ where $d\sigma(\uparrow\uparrow)$ and $d\sigma(\uparrow\downarrow)$ are the cross sections for parallel and antiparallel orientation of the polarization vectors of the proton and deuteron. We have found numerically that near the threshold $\Sigma_{\phi,\omega} \sim= -0.95$ and $\Sigma_{\phi,\omega}$ very fast goes to -1 above the threshold. The positive value for Σ_ϕ is expected on the basis of $s\bar{s}$ hypothesis [4].

In conclusion, keeping in mind that the cross section of η' and ϕ meson production differs from that for $\eta-$ meson by three orders of magnitude we can conclude that the two-step model in collinear approximation allows to understand the main features of the reactions $pd \to^3 He\eta(\eta', \omega, \phi)$. Nevertheless absolute value of the cross section for vector mesons is too small in comparison with the experimental data. To describe the absolute magnitude of the cross section of $\omega-$ meson production in the range of 100 MeV/$c \leq p^* \leq 400$ MeV/c one needs the normalization factor $N = 9.6$ that is essentially larger than the corresponding value for pseudoscalar mesons $N_{\eta,\eta'} = 3$ or $N_\omega = 2.4$ found in Ref. [7] at the threshold. The experimental data on spin structure of the $pN \to NN\pi$ amplitude are necessary to resolve this problem.

This work was supported in part by grant N^o 96-02-17458 of the Russian Foundation for Fundamental Researches.

REFERENCES

[1] J. Berger et al., *Phys. Rev. Lett.* **61**, 919 (1988); P. Berthet *et al.*, *Nucl. Phys.* **A443**, 589(1985).
[2] C. Wilkin, *Phys. Rev.* **C47**, R938 (1993).
[3] L.A. Kondratyuk, A.V. Lado, Yu.N. Uzikov, Yad. Fiz. **58**, 524 (1995) (*Phys. At. Nucl.* **58**, 473 (1995)).
[4] J.Ellis, M.Karliner, D.E.Kharzeev, M.G.Sapozhnikov, *Phys.Lett.* **B353**, 319 (1995).
[5] B. Khachaturov *et al.*, Talk in Int. Symp. DEUTERON-95, Dubna, July 4-7, 1995.
[6] G. Fäldt, C. Wilkin,*Nucl. Phys.* **A587**, 769 (1995).
[7] G. Fäldt, C. Wilkin, *Phys. Lett.* **B354**, 20 (1995).
[8] V.I. Komarov, A.V. Lado, Yu.N. Uzikov, *J. Phys. G* **21**, L122 (1995).
[9] L.A. Kondratyuk, Yu.N. Uzikov, *Pis'ma Zh. Eksp. Teor. Fiz.* **63**, 3 (1996) (*JETP Lett.* **63** 1 (1996)).
[10] H.Brody *et al..*, *Phys. Rev.* **D9**, 1917 (1974).
[11] R. Bertini *et al.*, Preprint LNS/Ph/94-16.
[12] R.Wurzinger *et al.*, *Phys. Rev.* **C51**, R443 (1995).