Formation of the $^1S_0$ diproton in the reaction $pp \to \{pp\}_s\pi^0$ in the Δ isobar region

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The reactions with the diproton $pp(^1S_0)$ in the final or initial state can give more insight onto the short-range dynamics of the reaction and the nucleon-nucleon interaction in addition to the corresponding reactions with the deuteron. Indeed, the contribution of non-short range mechanisms related to excitation of the Δ-isobars in intermediate states of the considered reactions is expected to be considerably suppressed for the case of the diproton (or the spin-singlet deuteron), as compared to the deuteron case due to isospin symmetry and conservation of angular momentum and parity [1, 2].

According to ANKE-COSY measurements [3], the cross section of the reaction $pp \to \{pp\}_s\pi^0$, where $\{pp\}_s$ is the proton pair in the $^1S_0$ state at small excitation energy $E_{pp} < 3$ MeV, demonstrates a clear bump at beam energy $\sim 0.6-0.7$ GeV for the cms diproton scattering angle $\theta_{cm} = 0°$. The microscopical model [4], which includes $\Delta(1232)$-isobar excitation via coupled channel and the s-wave πN-rescattering and successfully applied to the $pp \to d\pi^+$ reaction, fails to describe the data [3]. In view of this failure, a more simpler approach that is the one pion exchange model (OPE) which includes the on-mass-shell subprocesses $\pi^0 p \to \pi^0 p$ and accounts for the final state pp-interaction, was used in theoretical analysis of this reaction [5]. It was found that the OPE model fairly well explains the shape of the observed bump and suggests that it is related the $\Delta(1232)$ isobar excitation [5].

Here we present results of calculations [6] performed using the box diagram (Fig. 1) with explicite consideration of the Δ-isobar. The direct term (Fig. 1a) can be written as

$$A^{dir}_{\sigma_1\sigma_2} = -8m_p^2 m_\Delta \left(\frac{f_{\pi NN}}{m_\pi}\right)\left(\frac{f_{\pi N\Delta}}{m_\pi}\right)^2 \int \frac{d^3q}{(2\pi)^3} \frac{4\pi f(q,k_{pp};E_{pp})}{k_{pp}^2 - \mathbf{q}^2 + i\varepsilon} \frac{F_{\pi NN}(t)}{m_\pi^2 - t - i\varepsilon} \frac{F_{\pi N\Delta}(t)}{m_\Delta^2 - P_\Delta^2 - im_\Delta\Gamma} \Re_{\sigma_1\sigma_2}(\mathbf{k},\mathbf{k}',\mathbf{Q}), \quad (1)$$

where $f(q,k_{pp};E_{pp})$ is the half-off-shell amplitude of the pp-scattering in the $^1S_0$ state at on-shell momentum $k_{pp} = \sqrt{E_{pp}m_p}$, $t = k_\pi^2$ is the squared 4-momentum of the intermediate pion, P_Δ, m_Δ and Γ_Δ are the 4-momentum, mass and the full energy-dependent width of the Δ-isobar, respectively; $f_{\pi NN}$ and $F_{\pi NN}$ are the πNN coupling constant and the πNN form factor, respectively; $f^2{}_{\pi NN}/4\pi = 0.0796$, $F_{\pi NN}(k^2{}_\pi) = \frac{\Lambda^2 - m^2{}_\pi}{\Lambda^2 - k^2{}_\pi}$; $f_{\pi N\Delta} = 2.15$ is the $\pi N\Delta$ coupling constant; the 3-momentum $\mathbf{Q}$ is determined by the πNN vertex, the spin-tensor $\Re_{\sigma_1\sigma_2}$ is related to the amplitude of the subprocess $\pi^0 p \to \Delta \to \pi^0 p$ and depends on the spin-projections of the intial protons σ_i and 3-momenta of the intermediate ($\mathbf{k}$) and final ($\mathbf{k}'$) π-mesons.

One can see from Fig. 2 that an explicite consideration of the Δ-isobar contribution within the box-diagram model is less succesfull in explanation of the data [3] than the OPE model [5, 6]. We found that neither energy and angular dependencies of the cross section are reproduced. However, for energy dependence the agreement becomes better if the Δ-propagator is taken off the loop integral. In this approximation the box-diagram is close to the OPE model and provides a similar agreement with the data.

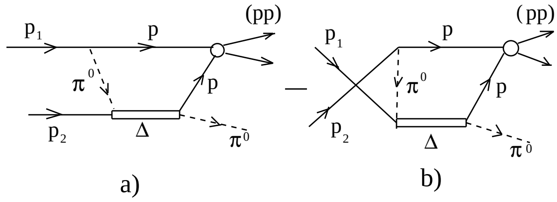

Fig. 1: The box-diagrams of the Δ mechanism: direct (a) and exchange (b) terms.

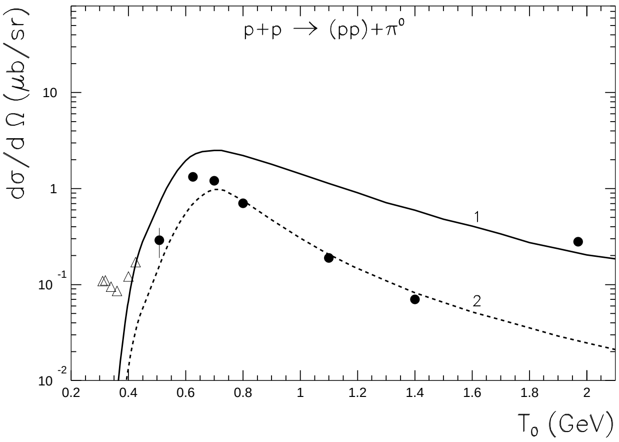

Fig. 2: The forward differential cross section of the reaction $pp \to \{pp\}_s\pi^0$ versus the beam energy. The curves show the box-diagram calculations with the Δ-propagator being under the loop integral (1) and outside the integral (2). The curve 2 is multiplied by the factor 0.2. Data (•) are taken from Ref. [3].

Very similar result we have got when applying the box diagram to the $pp \to d\pi^+$ reaction at beam energies 0.5-1.5 GeV.

References:

[1] O. Imambekov, Yu.N. Uzikov, Yad. Fiz. 52 (1990) 1361

[2] Yu.N. Uzikov, Pis'ma v ZHETF, **75** (2002) 7.

[3] V. Kurbatov et al., Phys. Lett. **B 661**, (2008) 22.

[4] J.A. Niskanen, Phys. Lett. **B 642**, (2006) 34.

[5] Yu.N. Uzikov, in Proc: 19th International Baldin Seminar on High Energy Physics Problem, (September, 2008, Dubna), Eds. A.N. Sissakian et al. (JINR, Dubna, Russia, 2008), v. 2 p. 307; arXiv:0803.2342 [nucl-th]

[6] O.Imambekov, Yu.N. Uzikov: In proc. of XX Int. Baldin Seminar on High Energy Physics Problem (September, 2010, Dubna) (in press).

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