One-loop contribution of the Δ-isobar mechanism to the reaction $pp \to \{pp\}_s\pi^0$ near the Δ-threshold region

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Single pion production in NN-collision is the simplest inelastic process in the NN scattering which is used at rather low energies as a testing ground for the chiral perturbation theory of nucleon-nucleon interactions. At higher energies the resonance structure observed in the total cross section of the reaction $pp \to d\pi^+$ with the maximum at about 600 MeV is explained by the Δ(1232)-isobar excitation in the intermediate state via the subprocess $NN \to N\Delta$ (see Ref. [1] and references therein). Within the same approach based on the method of coupled channels differential cross section and several spin observables were explained reasonably [1, 2]. Another channel of this reaction is the process $pp \to \{pp\}_s\pi^0$ with formation of the diproton $\{pp\}_s$ in the final state with small excitation energy $E_{pp} < 3$ MeV providing a dominance of the $^1S_0$ state. It is interesting to consider the reactions $pp \to d\pi^+$ and $pp \to \{pp\}_s\pi^0$ together at similar kinematical conditions. The point is that due to zero spin of the $^1S_0$ diproton $\{pp\}_s$ the reaction $pp \to \{pp\}_s\pi^0$ is described only by two independent spin amplitudes in contrast to six amplitudes for the $pp \to d\pi^+$. This fact allows one to perform a complete polarization experiment for the reaction $pp \to \{pp\}_s\pi^0$ using few differential spin observables. In part this was done at ANKE@COSY for the $pp \to \{pp\}_s\pi^0$ and $pn \to \{pp\}_s\pi^-$ reactions at 353 MeV. Furthermore, the isospin T=1 of the diproton differs from the deuteron isospin T=0. In total, the transitions allowed by the angular-momentum and P-parity conservation are essentially different in the diproton case as compared with the deuteron channel. Therefore, the reaction $pp \to \{pp\}_s\pi^0$ provides a strong test for the models developed for the reaction $pp \to d\pi^+$.

According to [3], the coupled channels approach [1] which explains the reaction $pp \to d\pi^+$ semi-quantitatively, completely fails to describe the data on the reaction $pp \to \{pp\}_s\pi^0$ obtained by ANKE@COSY [4, 5]. A simpler model based on the triangle diagram of the one-pion exchange with the subprocess $\pi N \to \pi N$ turned out to be more successful [6]. In this work we study the reaction $pp \to \{pp\}_s\pi^0$ using (antisymmetrized) on-loop diagrams with the subprocess $\pi N \to \Delta \to p\pi^0$ (Fig.1). For the coupling constants and vertex form factors are used the same parameters as in [7]. The CD Bonn model is used for the $^1S_0$ NN. The penetrate Z-factor is introduced to account the momentum dependence of the Δ-isobar width. The numerical results show (see Fig.2) that the energy dependence of the differential cross section at zero angle of the pion is qualitatively explained in the energy interval 0.4 -1.4 GeV. However, the calculated angular dependence of the differential cross section and A_y is in contradiction with the ANKE data at 0.35 -0.8 GeV [8]. The partial wave amplitude analysis is performed for this mechanism using the Jacob-Wick formalism. The obtained numerical results show that the following three partial waves ^3P_0s, ^3P_2d and ^3F_2d are important in the energy interval 0.35-0.8 GeV, whereas the $^3F_4g - ^3H_4g$ amplitude and other amplitudes with higher orbital momenta are negligible.

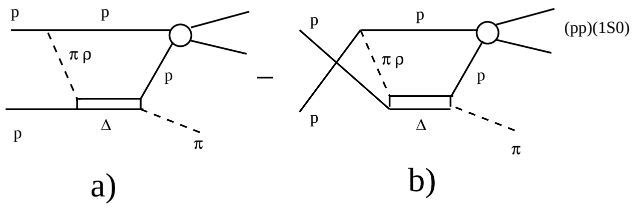

Fig. 1: The one-loop Δ-mechanisms of the $pp \to \{pp\}_s\pi^0$ reaction: a) – direct term, b) – exchange term.

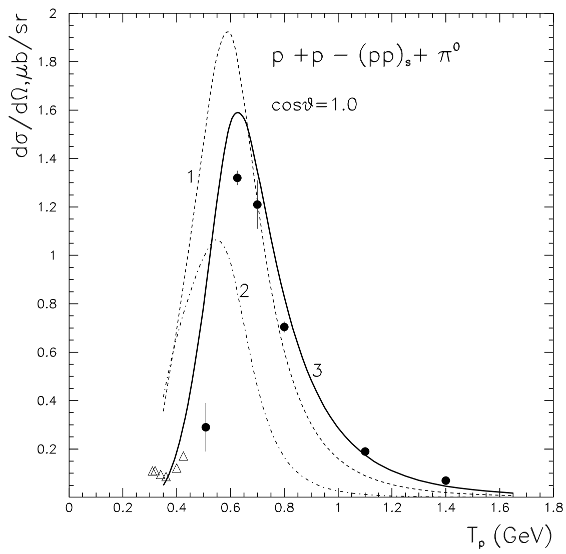

Fig. 2: Differential cross section of the reaction $pp \to \{pp\}_s\pi^0$ at $cos\theta = 1$ versus the proton beam energy. The curves are results of calculations for the one-loop mechanism with the Δ-isobar excitation with the cutoff parameter $\lambda_\pi = 0.65$ GeV/c, $\lambda_\rho = 0.7$ GeV/c, and $Z^{3/2}$ factor in both $\pi N\Delta$-vertexes as defined in Ref. [7]:1 – the direct mechanism with normalization factor $N = 0.55$, 2 – the exchange mechanism (with $N = 1$), 3 – total result with $N = 1$. Experimental data (•) are taken from [4],[5].

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