Forward cross section energy dependence of the $pp \to \{pp\}_s\pi^0$ reaction at COSY energies*

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One of the means to investigate the underlying dynamics of NN interaction is single pion production in nucleon-nucleon collisions, $NN \to NN\pi$. The $pp \to d\pi^+$ reaction is the most thoroughly studied one, while little was known so far about its spin-isospin partner, $pp \to \{pp\}_s\pi^0$, where $\{pp\}_s$ is a proton pair in $^1S_0$ state. Since these channels involve different quantum numbers and transition matrix elements, their combined study may provide deeper understanding of the process dynamics.

The reaction $pp \to \{pp\}_s\pi^0$ in the $\Delta(1232)$ resonance region was studied for the first time at ANKE [1], allowing to obtain the forward differential cross section at several energies. The experimental results have shown complete disagreement with the theoretical model considering the NN and $N\Delta$ intermediate states in the coupled channels approach [2], though this model described perfectly the $pp \to d\pi^+$ reaction. The experiment [1] gave a hint at the existence of a broad peak in the energy dependence of the cross section at small angles, while the theory [2] predicted a fine structure of the cross section energy dependence and values much smaller than observed experimentally (see figure 1). Since the known data seemed not convincing enough to prove the absence of the narrow structure, some additional measurements were performed in order to improve our knowledge on the forward cross section energy dependence and cover the poorly known region of the 450–600 MeV.

The experiment was carried out with the ANKE spectrometer [3] at COSY-Jülich with the proton beam interacting with the hydrogen cluster-jet target. Data were taken in October 2007 with unpolarized beam at energies T_p = 353, 500 and 550 MeV and in April 2009 with the transversely polarized beam at energies T_p = 353, 500, 550 and 700 MeV. The setup and procedure for data handling are described in detail in [1].

When observing the $pp \to \{pp\}_s\pi^0$ reaction, two final protons were registered with the ANKE forward detector system. Proton pairs were selected from all the observed double–track events using the time-of-flight difference criterium. ANKE resolution on the pair excitation energy E_{pp} is less than 0.6 MeV in the worst case, that allows us to apply the $E_{pp} < 3$ MeV cut to select the set of events where the $^1S_0$ state of the pair dominates.

The kinematics of the $pp \to \{pp\}_sX$ process was reconstructed event–by–event and a missing–mass spectrum was obtained. The main sources of the background are random coincidences and a contribution from the $pp \to \{pp\}_s\gamma$ channel. Both are small compared to the π^0 signal and finding the number of $pp \to \{pp\}_s\pi^0$ events does not pose any difficulty. For the polarized beam case the event numbers were polarization-averaged.

The setup acceptance was found by simulation using the GEANT3 framework, and events were corrected by acceptance on event–by–event basis. The integral luminosity was estimated from pp elastic scattering, measured concurrently with $\{pp\}_s\pi^0$, and normalized using SAID [4] predictions.

The setup covers the angular range $10° < \theta_{pp}^{cm} < 120°$ at 353 MeV and about $2° < \theta_{pp}^{cm} < 30°$ at 500, 550 and 700 MeV. The cross section at 0° is found by extrapolating $d\sigma/d\Omega$ angular dependence linearly over $\cos^2\theta_{pp}^{cm}$. New data allow to detalize the energy dependence of $d\sigma/d\Omega(0°)$ obtained earlier [1].

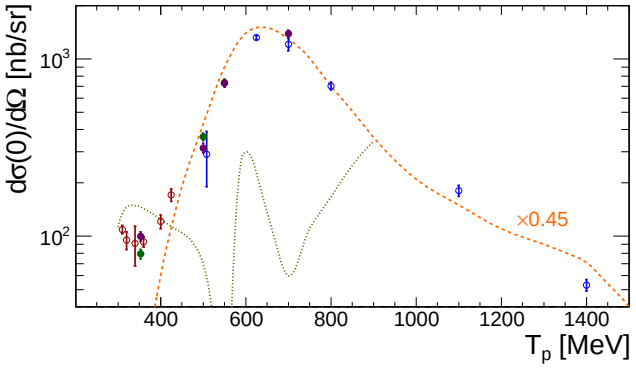

Fig. 1: Energy dependence of the forward differential cross section for the $pp \to \{pp\}_s\pi^0$ reaction. The points stand for: ○ — ANKE data [1], ○ — WASA data [5], ● — new ANKE data, unpolarized beam, ● — new ANKE data, polarized beam. The lines represent theoretical predictions: - - - — impulse approximation model [6], · · · — coupled channels approach [2].

With the new data points obtained, we can definitely state that $d\sigma/d\Omega(0°)$ has a broad peak in the region of $\Delta(1232)$-excitation with no signs of fine structure. The shape of the forward cross section may be qualitatively described in the impulse approximation model [6], but it overestimates its absolute value by a factor of 1/0.45, that could be due to rescattering not taken into account. A more developed theoretical description would be useful.

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