Differential cross section and vector analysing power of the $p_{\rm pol}p \to \{pp\}_s\pi^0$ reaction at 353–700 MeV

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Abstract

The reaction $p_{\rm pol}p \to \{pp\}_s\pi^0$ was studied with the ANKE spectrometer at COSY-Jülich using a polarized beam with energies 353, 500, 550 and 700 MeV. The proton pairs $\{pp\}_s$ were detected at low excitation energy $E_{pp} < 3$ MeV, where S-wave dominates. The angular dependences of vector analysing power A_y and differential cross section $d\sigma/d\Omega$ of the reaction have been obtained for the most of the angular range at 353 MeV and forward angles at the higher beam energies. The partial wave amplitude analysis, done with the 353 MeV results, is important for Chiral Perturbation Theory tests at this energy. The data at higher energies detalize the energy dependence of $d\sigma/d\Omega(0^\circ)$ obtained earlier. It allows to learn about the dynamics of the $\Delta(1232)$ resonance excitation in two-nucleon systems.

1 Introduction

Use of the $^1S_0$ state proton pairs $\{pp\}_s$, emerging from a short-range interaction, simplifies significantly a theoretical description of single pion production in proton-proton collisions due to a spinless character of this state and binary type of the process.

The data on $d\sigma/d\Omega$ and A_y for $p_{\rm pol}p \to \{pp\}_s\pi^0$ at $T_p = 353$ MeV may be used to get information about $NN \to NN\pi$ contact term in the chiral perturbation theory approach and thus to check its ability to describe the pion production in NN collisions at energies close to the production threshold [1].

ANKE allows also to measure the forward differential cross section and vector analyzing power in the $\Delta(1232)$-resonance energy range. These data could help to get better understanding of the short-range NN and $N\Delta$ dynamics.

2 Measurement, analysis and results

The experiment was carried out with the ANKE magnetic spectrometer [2] positioned inside the ring of the synchrotron COSY–Jülich. The current data were taken in two beam times. The first measurements were made using the unpolarized beam at beam energies 353, 500 and 550 MeV. During the second beam time the transversely polarized beam was used, with polarization changing up and down and the beam energies the same with addition of 700 MeV. In the both cases the hydrogen cluster-jet target was used, and the positively charged products of the reaction, deflected by the spetrometer magnet, were registered by the ANKE forward detector system. The detailed description of the experimental conditions can be found in papers [3, 4] and refs. therein.

The procedure used at 353 MeV [4] to identify the $pp \to \{pp\}_s\pi^0$ reaction and estimate the analysing power A_y and the differential cross section $d\sigma/d\Omega$ remained the same for the higher energies as well.

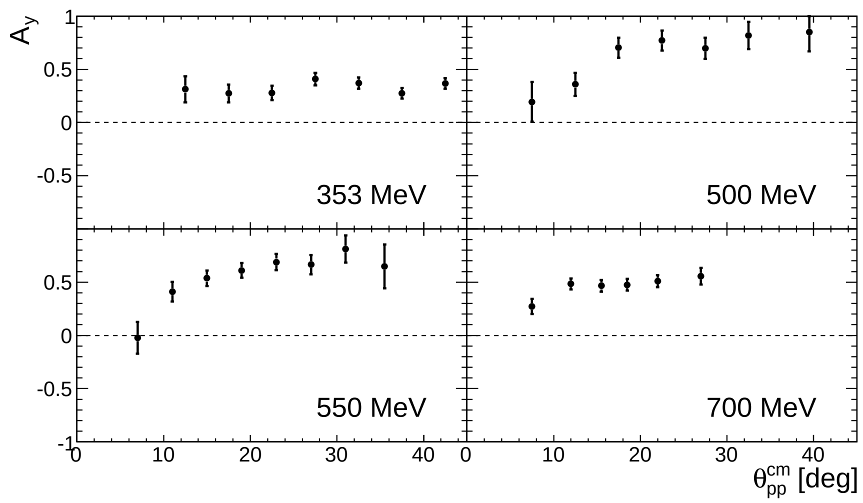

Figure 1: The vector analysing power A_y vs. the proton pair polar angle in the center mass system $\theta_{pp}^{\rm cm}$ for the beam energies 353, 500, 550 and 700 MeV. Errors shown are pure statistical.

The obtained A_y angular dependences for the forward angles are shown in fig. 1, the full angular dependence at 353 MeV can be found in [4]. Rather high analysing power of about 0.7–0.8 is seen in the 20°–35° angular interval for 500 and 550 MeV energies.

The $d\sigma/d\Omega$ results for the beam energies used in both the beam time

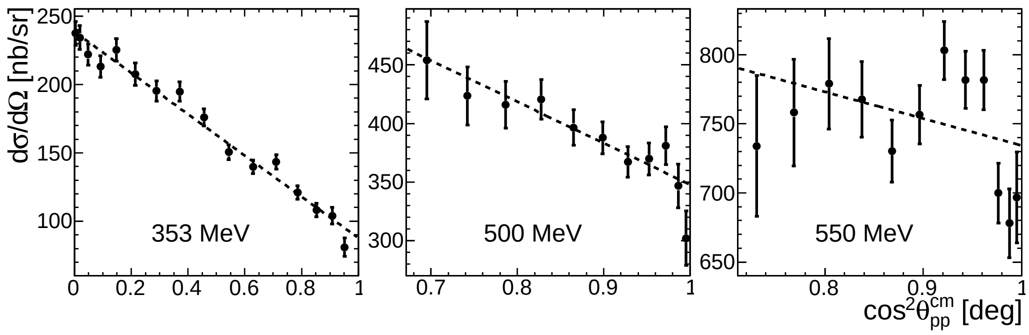

Figure 2: The dependences of differential cross section $d\sigma/d\Omega$ on cosine squared of the proton pair polar angle $\cos^2\theta_{pp}^{\rm cm}$. The lines are linear fits.

expositions are consistent with each other within the measurement errors, so a weighted average has been obtained. The differential cross section results are presented in fig. 2 with the exception of those for the 700 MeV beam energy, where the analysis is not finished yet. The angular dependences are linear over $\cos^2\theta_{pp}^{cm}$, and the extrapolation allows to determine the differential cross sections at $\theta_{pp}^{cm} = 0°$.

3 Discussion

From the results at 353 MeV one can extract information on the pion s- and d-wave contributions to the reaction amplitudes. Using it and the phase information from the elastic pp scattering, unique solutions can be obtained for the corresponding amplitudes [4]. This information is needed for the test of the chiral perturbation theory applicability at this energy [1].

The found energy dependence of the 0° differential cross section (fig. 3 a) exhibits a clean peak in the $\Delta(1232)$ excitation region. The amplitude squared spectrum (fig. 3 b) was parametrized by expression

$$\frac{d\sigma(0°)}{d\Omega} = \left(\frac{k_\pi}{k_\pi^\mu}\right)^m \frac{N\cdot\Gamma^2/4}{(x-\mu)^2+\Gamma^2/4} + a\times(k_\pi)^n, \quad (1)$$

where the first term is a Breit-Wigner dependence modified to account for the peak being close to the pion production threshold and the second describes a contribution of the near-threshold s-wave pion production. The mean value μ of the peak was obtained at 2180 ± 3 MeV, close to the position 2172 MeV of the ^3F_3D transition peak in the $pp \to d\pi^+$ cross section found in the SAID

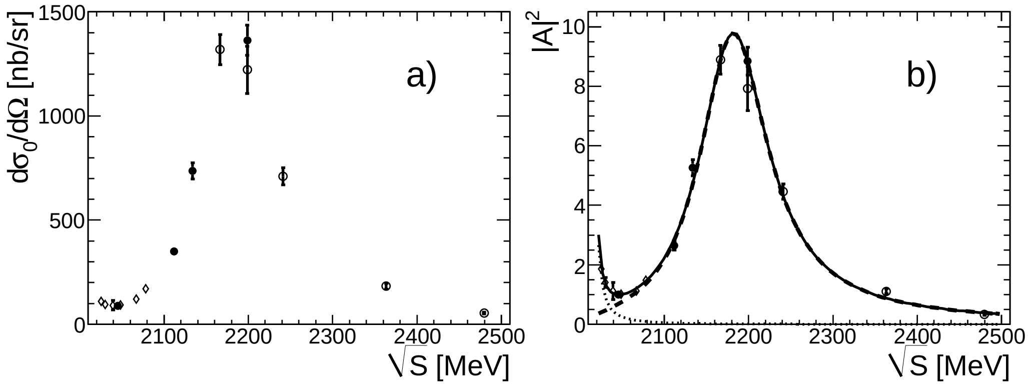

Figure 3: The energy dependence of a) differential cross section $d\sigma/d\Omega$ at $\theta_{pp}^{\rm cm} = 0$ and b) the corresponding amplitude squared $|A|^2$. The dots $\bullet$ show the new values, the open circles $\circ$ — the earlier ANKE measurements [5], the diamonds $\diamond$ — the WASA-PROMICE [6] results. The lines show a fit by function (1).

partial wave analysis [7]. The most prominent feature of the $pp \to \{pp\}_s\pi^0$ peak is its small width $\Gamma = 99 \pm 5$ MeV, definitely less than the width 117 MeV [8] of the free $\Delta(1232)$ resonance. It can be treated as an indication of a significant $\Delta N \to N\Delta$ intraction in the p-wave state of the intermediate ΔN pair.

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