

Measurement of the spin-correlation coefficients $A_{x,x}$ and $A_{y,y}$ in the quasi-free $np \rightarrow \{pp\}_s \pi^-$ reaction near threshold at ANKE-COSY.

V. Shmakova^{1,2,a} and the ANKE collaboration

¹ Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, 141980 Dubna, Russia

² Institut für Kernphysik, Forschungszentrum Jülich, 52425 Jülich, Germany

Abstract. A kinematically complete double-polarization measurement of the quasi-free $np \rightarrow \{pp\}_s \pi^-$ reaction near threshold has been performed using the ANKE spectrometer at COSY-Jülich. Here $\{pp\}_s$ represents a two-proton system with an excitation energy less than 3 MeV. The transversely vector polarized deuteron beam and the internal polarized ANKE hydrogen target were used to determine the spin-correlation coefficients $A_{x,x}$ and $A_{y,y}$. Events from the quasi-free $np \rightarrow d\pi^0$ reaction were recorded simultaneously and used for both beam and target polarimetry. In addition, the product of the beam and target polarizations could be estimated from the $A_{y,y}$ coefficient. The storage cell within the polarized target was the main source of background events. Dedicated runs, with no gas in the cell and with the cell filled with N_2 gas, were taken to study the backgrounds. The data analysis procedure and the initial results of the experiment are presented.

1 Introduction

Chiral perturbation theory (χPT) allows accurate calculations for hadronic reactions but its extension to the $NN \rightarrow NN\pi$ reactions requires new high precision experimental information in the near-threshold region. Of particular interest are the $np \rightarrow \{pp\}_s \pi^-$ and $pp \rightarrow \{pp\}_s \pi^0$ processes in the 350 MeV region, with the formation of a 1S_0 proton pair (diproton) in the final state, here denoted by $\{pp\}_s$. Measurements of the spin-correlation coefficients $A_{x,x}$ and $A_{y,y}$, taken in conjunction with values of the vector analyzing power A_y and the differential cross section $d\sigma/d\Omega$, will promote further development of χPT in this sector and lead to the determination of the strength parameter d , the so-called low energy constant (LEC) of the $4N\pi$ contact operator [1].

The most direct way to access the LEC is by measuring the cross section and spin-correlation coefficient $A_{x,x}$ in the $np \rightarrow pp_s \pi^-$ process. At low energies

$$(1 - A_{x,x}) d\sigma/d\Omega \sim |a|^2 \sin^2 \theta \quad \text{and} \quad A_{y,y} = 1, \quad (1)$$

where a is a p -wave amplitude involving the $4N\pi$ contact interaction [2]. Given that the angular dependence is known in Eq. (1), only the value of $(1 - A_{x,x})d\sigma/d\Omega$ at 90° has to be extracted from the measurements.

^a e-mail: v.shmakova@fz-juelich.de

2 Experimental setup

The experiment was performed in 2011 at the Cooler Synchrotron (COSY) of the Forschungszentrum Jülich. The synchrotron produced a vector polarized deuteron beam with kinetic energy 706 MeV which interacted with the internal polarized hydrogen cluster target. This target consisted of an Atomic Beam Source (ABS), a storage cell, and a Lamb-shift polarimeter [4]. The density of the polarized hydrogen gas in the cell was $1.34 \times 10^{13} \text{ cm}^{-2}$. The cell material (20 μm of aluminium and 5 μm of teflon) gave rise to the most significant background, the shape of which in the missing-mass spectra was obtained from dedicated measurements with N_2 in the cell and with the empty cell. The reaction products were registered with the Forward and Positive Detectors (FD and PD) of the ANKE magnetic spectrometer [3].

3 Polarimetry

Polarimetry was done using the quasi-free $np \rightarrow d\pi^0$ reaction. For independent determination of the beam and target polarizations for spin orientation up and down, samples of data were taken with unpolarized beam or target. The process was selected by demanding a deuteron and proton spectator in the FD. These pairs were identified on the basis of the TOF differences [5] and the process confirmed through the missing mass in the reaction. Scaling the SAID A_y predictions [6] to fit the experimental asymmetries of Figs. 1 and 2, values for the ABS and beam polarizations could be deduced.

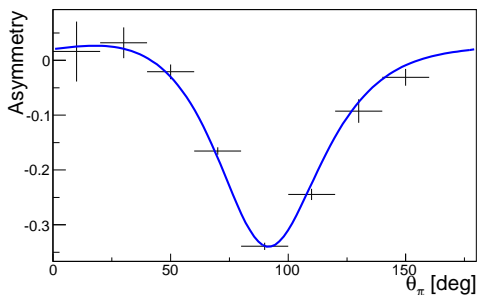


Fig. 1. Determination of the ABS polarization, $P_{\text{ABS}} = 69 \pm 2\%$

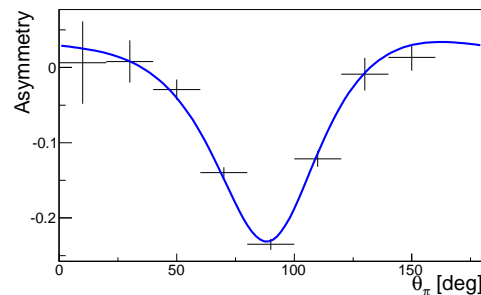


Fig. 2. Determination of the beam polarization, $P_{\text{beam}} = 50 \pm 2\%$

4 Experimental results

The final diprotons from the $dp \rightarrow \{pp\}_s p_{\text{spec}} \pi^-$ process were detected in the PD and the spectator proton (p_{spec}) in the FD. The reaction was selected from the missing mass of the three protons and a cut of $E_{pp} < 3 \text{ MeV}$ was imposed on the diproton excitation energy.

The asymmetry can be written in terms of $\Sigma_1 = N_{\uparrow\uparrow} + N_{\downarrow\downarrow}$ and $\Sigma_2 = N_{\uparrow\downarrow} + N_{\downarrow\uparrow}$ as

$$\xi = \frac{\Sigma_1 - \Sigma_2}{\Sigma_1 + \Sigma_2} = PQ(A_{xx} \sin^2 \phi + A_{yy} \cos^2 \phi) \quad (2)$$

and this was fitted to the experimental data to yield $A_{y,y}$ and $A_{x,x}$.

Quite generally $A_{y,y} = 1$ for all θ_π and our results shown in Fig. 3 are consistent with a constant. Equating this constant to unity gives an independent determination of the product PQ . $A_{y,y} = 1$ was then imposed on the fit to get more precise values of $A_{x,x}$.

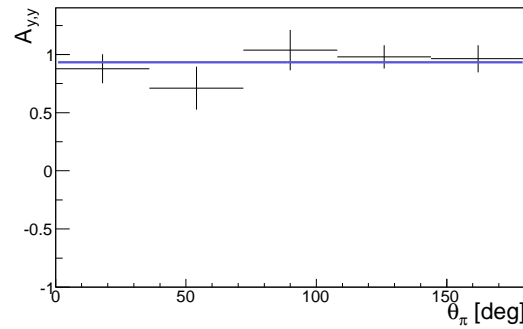


Fig. 3. $A_{y,y}$ as a function of θ_π in the $pn \rightarrow \{pp\}_s \pi^-$ process at 353 MeV.

The results for $A_{x,x}$ are presented in Fig. 4. Using the cross sections determined earlier [7], the values of $(1 - A_{x,x}) d\sigma/d\Omega$ are shown in Fig. 5 as a function of θ together with the $\sin^2 \theta$ fit of Eq. (1). This gives $|a|^2 = (0.077 \pm 0.025) \mu\text{b/sr}$, to be compared to a model-dependent value of $0.052 \mu\text{b/sr}$ obtained by fitting cross section and analyzing power data [7].

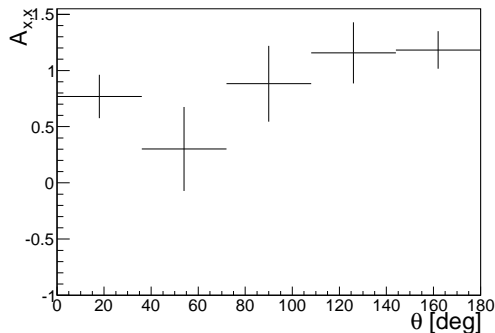


Fig. 4. $A_{x,x}$ for the $pn \rightarrow \{pp\}_s \pi^-$ process at 353 MeV.

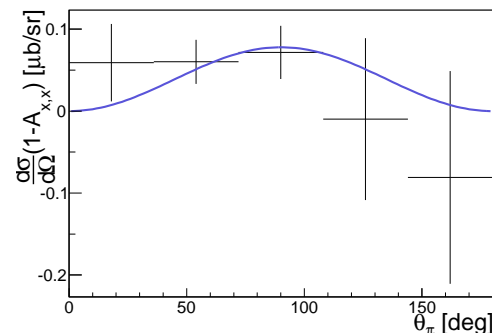


Fig. 5. $(1 - A_{x,x}) d\sigma/d\Omega$ for the $pn \rightarrow \{pp\}_s \pi^-$ process at 353 MeV fitted with $\sin^2 \theta_\pi$.

Acknowledgements

The results presented here would not have been possible without the efforts of the COSY machine crew and other members of the ANKE collaboration. The work was supported in part by the COSY-FFE programme.

References

1. C. Hanhart, Phys. Rep. **397** (2004) 155.
2. V. Baru et al., Phys. Rev. C **80** (2009) 044003.
3. S. Barsov et al., Nucl. Instr. Methods Phys. Res. A **462** (2001) 364.
4. S. Dymov et al., COSY proposal #205 (2010), available from www.fz-juelich.de/ikp/anke/en/proposals.shtml
5. S. Dymov et al., Phys. Rev. C **81** (2010) 044001.
6. SAID data base, available from <http://gwdac.phys.gwu.edu>
7. S. Dymov et al., Phys. Lett. B **712** (2012) 375.