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Analyzing Power in Quasi-Elastic Proton-Proton Scattering at 500 and 650 MeV/nucleon

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Abstract. Analyzing power in elastic proton-proton scattering was obtained at the Nuclotron Internal Target Station using a polarized deuteron beam and a polyethylene target. The selection of useful events was performed using the time and amplitude information from scintillation counters. The asymmetry on hydrogen was obtained by the subtraction of the carbon background. The obtained analyzing power values are compared with the predictions of the partial-wave analysis SAID at the beam energies of 500 and 650 MeV/nucleon.

INTRODUCTION

Elastic pp-scattering experiments are the fundamental to understand of the NN interaction. For kinetic energies below 1 GeV a precise database of the differential cross sections and different polarization observables has been accumulated. These data are well reproduced by the phase-shift analysis (PWA) [1]. Modern phenomenological potential models provide a good description of the data up to the pion threshold. Extension of the meson-exchange models to the higher energies requires the inclusion of the inelastic channels contributions via baryonic resonances excitations. On the other hand, elastic pp-scattering is well suited to study the short range part of NN interaction. Precise knowledge of the analyzing power at the energies above the pion threshold provides a focus on heavy-meson exchanges with respect to the spin-orbit forces.

Here the results on the vector analyzing power of the dp-scattering reaction in pp-quasi-elastic kinematics at the energies of 500 MeV/n and 650 MeV/n are presented. These results were obtained using polarized deuteron beam from new source of polarized ions (SPI) [2] at internal target station at Nuclotron-JINR.

EXPERIMENTAL SCHEME

The scheme of the experiment was as follows: the deuteron beam was provided by the source of polarized ions (SPI) [2], polarized deuterons were accelerated by RFQ and the linear accelerator LINAC-20, and then they were injected into the Nuclotron ring. When the required energy was reached, the target disc rotated to the path of the beam.

The internal target station (ITS) of the Nuclotron is a spherical vacuum chamber and a target change system [3]. The disk with the target (CH_2, C, W, Cu, etc.) was fixed inside the chamber. A polyethylene film and a carbon filament were used as the targets to obtain the effect on hydrogen via CH_2-C subtraction.

The particles obtained during the interaction of the beam with the target entered the scintillation detectors settled around the scattering chamber in the primary beam direction (see Fig. 1). They detect the products of the pp-quasi-elastic scattering reaction. 11 detectors were used in the experiment to register protons scattered on the left. The same number of detectors and in the same geometry were located for the scattering on the right. Two separate detectors were located symmetrically with respect to the beam direction at about 90° in c.m.s.

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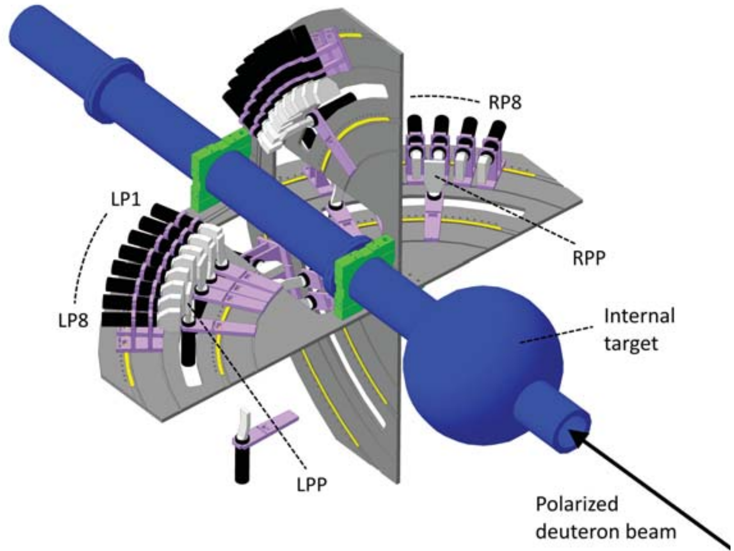

FIGURE 1. Internal target station setup.

DATA ANALYSIS

The polarization of the beam has been measured from the dp-elastic scattering at the beam energy of 270 MeV/n [4]. This procedure was carried out regularly throughout the experiment. Thus, the averaged values of the beam polarization were used to obtain the analyzing power values of the pp-quasi-elastic reaction at deuteron beam energies of 500 MeV/n and 650 MeV/n.

The useful data were selected using the cuts for the event interaction point, for the time-of-flight difference and for the energy losses correlation of the signals from the kinematically coupled scintillation counters. During the experiment the target position was recorded to the data accordingly for each event. Therefore, the position of the target relative to the center of the ion tube is known for each event, which makes it possible to ignore events that take place far from the main array of events. Time-of-flight difference shows the time difference between the signals for two kinematically coupled detectors. Events that have large difference are highly likely not useful.

Due to the fact, that the deuteron beam interacts not with a polyethylene target, carbon events inevitably appeared in the data. It leads to the need to remove the carbon background. The yield from the carbon content of the CH_2-target is estimated in separate measurements using several carbon wires. It was assumed, that the shape of the carbon spectrum is the same for scattering on the polyethylene and carbon targets (Fig. 2). The present procedure for subtracting the carbon background consists of determining the coefficient by which the carbon spectrum must be multiplied to the carbon spectrum in the data on polyethylene. For subtracting were used the following formula:

$$N_p = N_{CH2} - kN_C, \tag{1}$$

where N_p is the number of proton events, N_{CH2} is the number of events on polyethylene, N_C is the number of events on carbon, k is the coefficient that needed to be found.

The coefficient k can be found as follows: a clearly visible proton peak marked out on the histograms of energy losses correlations for the polyethylene target; this selection is also transferred to the histogram of the energy losses correlation for the carbon target; according to the data outside the range between the criteria, the carbon spectrum is fitted to the polyethylene spectrum using the least squares method; as a result, k is the coefficient by which the carbon spectrum must be multiplied to obtain the least squares minimum for the data outside the cut.

The analyzing power values can be calculated using the data of the pp-quasi-elastic reaction, found by subtracting the carbon background from the data on polyethylene target. The following formulas were used:

$$N_L = 1 + P_z A_y, \tag{2}$$

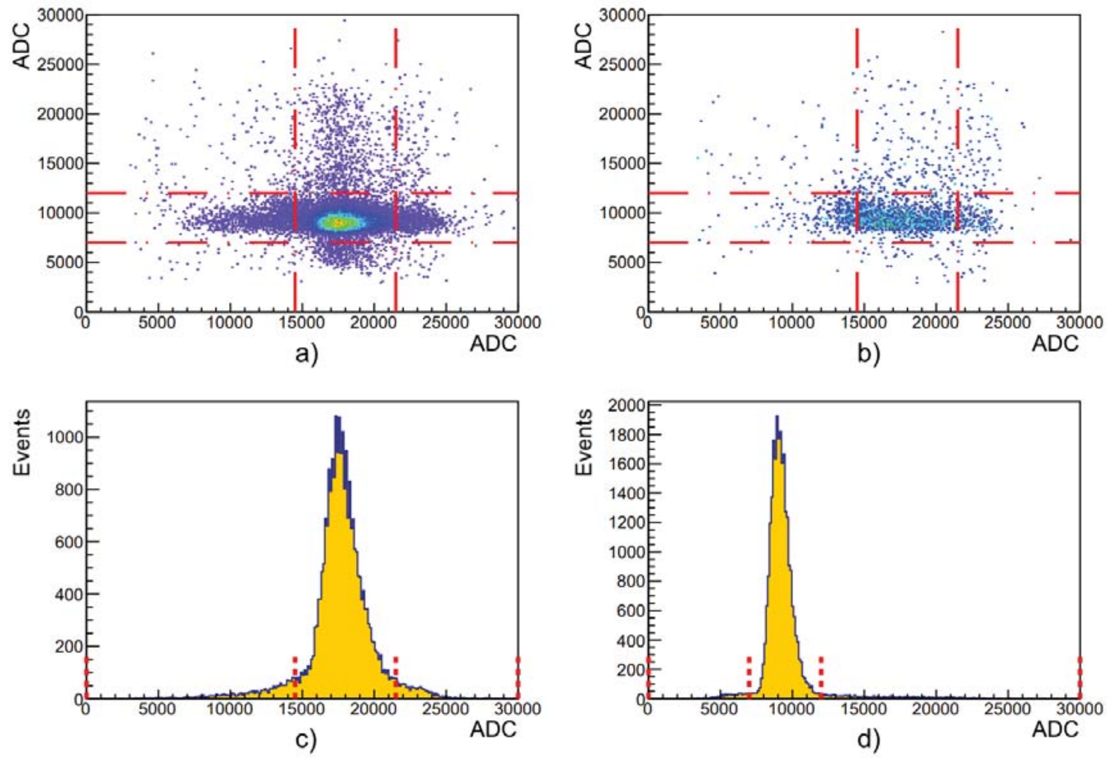

FIGURE 2. The process of setting up cuts for the CH_2-C subtraction procedure: a) ADC-correlation for the polyethylene target; b) ADC-correlation for the carbon target; c) Deuteron detector ADC; d) Proton detector ADC. Dotted lines are the cuts for the background subtracting procedure.

$$N_R = 1 - P_z A_y, \tag{3}$$

where N_L, N_R are the reaction yields for the left and right, respectively, P_z is the vector polarization value, A_y is the vector analyzing power of the reaction. Using the above equations (2, 3), the following formulas were obtained to calculate the vector analyzing power of the reaction:

$$A_{yL} = \frac{\frac{N_L^+ M^0}{N_L^0 M^+} + \frac{N_L^- M^0}{N_L^0 M^-} - 2}{P_z^+ + P_z^-}, \tag{4}$$

$$A_{yR} = -\frac{\frac{N_R^+ M^0}{N_R^0 M^+} + \frac{N_R^- M^0}{N_R^0 M^-} - 2}{P_z^+ + P_z^-} \tag{5}$$

where A_{yL} and A_{yR} are the vector analyzing powers of the reaction for the left and right scattering, respectively. N_L^+, N_L^- and N_L^0 are the numbers of events of a particular left pair for 2 polarized and unpolarized modes, respectively. N_R^+, N_R^- and N_R^0 are the numbers of events of a particular right pair for 2 polarized and unpolarized modes, respectively. M^+, M^- and M^0 are the monitor numbers for corresponding spin modes. P_z^+ and P_z^- are the vector polarization values of the beam for polarized SPI modes, respectively. To determine A_y were used thirty different pairs: six pairs to the left, six pairs to the right and one pair at 90° in c.m.s.

The obtained analyzing power values can be compared with the data obtained in other experiments with the same or close energies, as well as with the results of the partial-wave analysis SAID.

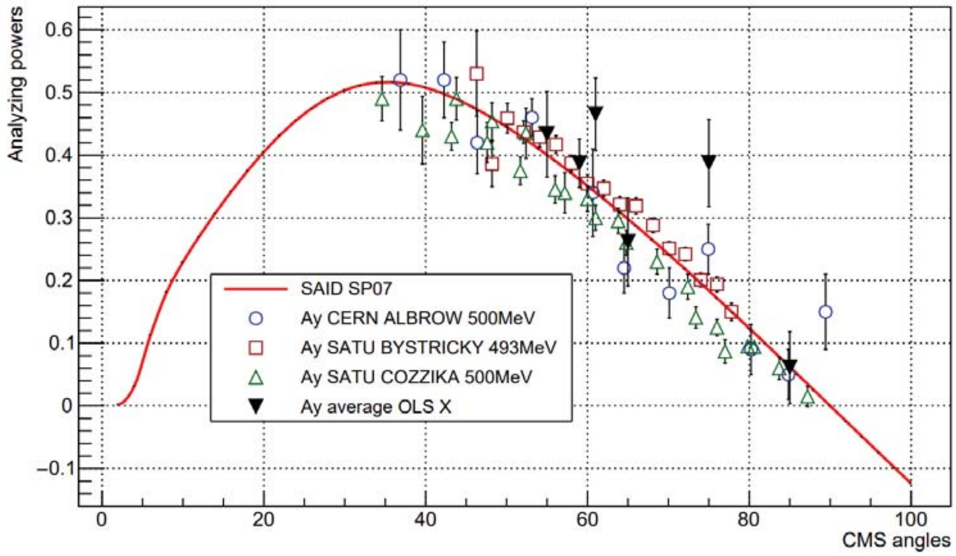

FIGURE 3. Comparison of the analyzing powers of the pp-quasi-elastic scattering reaction at the energy of 500 MeV/n with the world data and the results of the SP07 solution for the SAID partial-wave analysis. Full symbols are the results of the present experiment. Open symbols are the world data [5, 6, 7]. A solid line is the SAID predictions [1].

RESULTS

The angular dependencies of the proton vector analyzing power A_y in pp-quasi-elastic scattering at the deuteron beam energies of 500 and 650 MeV/n are presented in Figs 3 and 4 respectively. The full symbols are the results of the present experiment at ITS at Nuclotron. Open symbols are the data obtained in the other experiments [5, 6, 7, 8, 9]. The analyzing power values were also compared with SP07 SAID PWA predictions [1]. One can see good agreement of new Nuclotron data with the results obtained earlier within achieved error bars as well as with the SAID SP07 solution. Therefore, one can conclude also that the medium effects are insignificant for Nuclotron data.

CONCLUSION

The vector analyzing power A_y for the deuteron-proton scattering reaction in pp-quasi-elastic kinematics at the deuteron beam energies of 500 MeV/n and 650 MeV/n is obtained using polarized deuteron beam and the internal target of Nuclotron-JINR. The analyzing power pp-quasi-elastic scattering was measured at these energies at large angles in c.m.s for the first time.

The results is the vector analyzing powers were compared with the data obtained at other laboratories, and also with the results of the partial-wave analysis SAID SP07 solution. The comparison showed that the results obtained in this work, in general, correspond to the world data and the results of the SAID within the obtained experimental accuracy limits. This indicates that the proton binding effect in a deuteron and the possible rescattering effect are small. Therefore, using of pp-quasi-elastic scattering in the long term makes it possible to measure the vector polarization of the deuteron beam.

The rather large statistical measurement errors are due to the fact that the experiment was carried out in a test mode. Future researches with polarized proton and deuteron beams are planned to increase the accuracy of the analyzing power measurements.

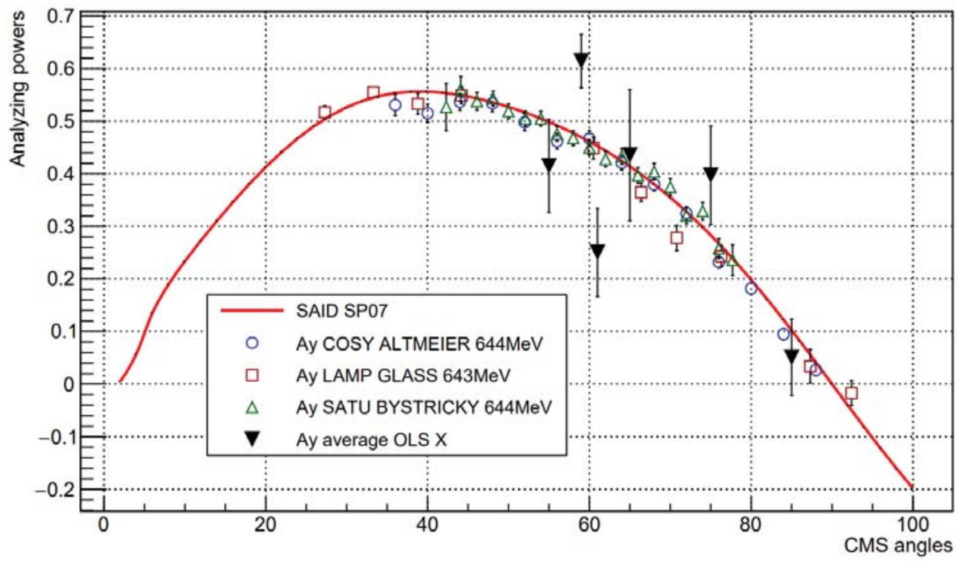

FIGURE 4. Comparison of the analyzing powers of the pp-quasi-elastic scattering reaction at the energy of 650 MeV/n with the world data and the results of the SP07 solution for the SAID partial-wave analysis. Full symbols are the results of the present experiment. Open symbols are the world data [6, 8, 9]. A solid line is the SAID predictions [1].

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