Study of the deuteron analyzing powers in dp elastic scattering at the energy of 800 MeV

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Abstract. Preliminary results on the angular distributions of the vector A_y and tensor A_{yy}, A_{xx} analyzing powers in dp elastic scattering at the energy of 800 MeV are presented. The measurements have been performed on Internal Target Station of the JINR Nuclotron using polarized deuteron beam from new source of polarized ions. The experimental data are compared with the preliminary calculations obtained within framework of relativistic multiple scattering approach.

1 Introduction

The main activity in the spin studies at the Laboratory of High Energy Physics of the Joint Institute for Nuclear Research (LHEP-JINR) at the Nuclotron is related to the short range correlations (SRCs) in nuclei. The physics of SRCs deals with the understanding of the role of the QCD in the formation of nuclear forces at short distances and with the understanding of the dynamics of the super-dense cold nuclear matter. The study of the SRCs gives information about the equation-of-state (EOS) of dense nuclear matter. One of the simplest and most extensively studied reactions in spin physics are dp elastic scattering and dp breakup. Despite the fact that spin physics is being studied rather actively still many open problems exist both in experimental and theoretical aspects.

New generation of the nucleon-nucleon (NN) potentials e.g. CD-Bonn [1], AV18 [2], Nijmegen [3] has been obtained. At energies below the π production threshold (E = 210 MeV /nucleon), these potentials provide rigorous description of the experimental data. However these NN forces fail to recreate experimental binding energies of few-nucleon systems. Inclusion of the three-nucleon forces (3NFs), mostly based on a 2π exchange between three nucleons with Δ-isobar excitation, into the calculations, can remedy the discrepancies between the set of experimental data and the theoretical approach [4]. Nevertheless, the universal theory

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that provide a good agreement with polarization observables in various kinematic conditions does not exist, so these studies turn out to be very important. The Nuclotron facility allows

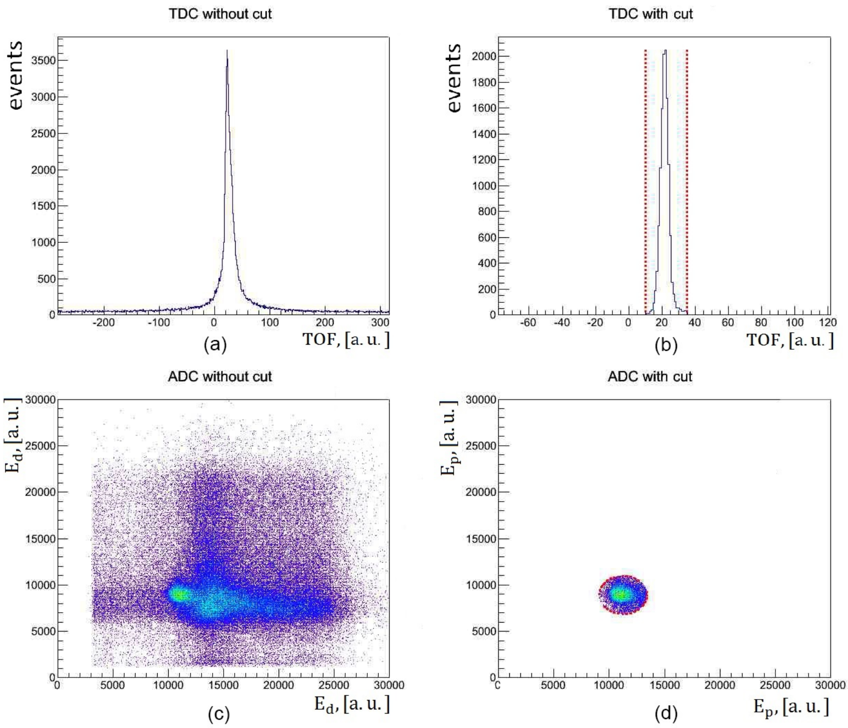


Figure 1. Selection of the dp elastic events by the time-of-flight difference (TOF) and the correlation of the energy-losses signals for a pair of the deuteron and proton detectors at 95° in the center-of-mass system. a) and c) (b) and d)) panels show the TDC and ADC spectra without (with) graphical cut

one to investigate the spin effects of 2N and 3N SRCs in a wide energy range. The spin structure of the np SRCs has been investigated at the Nuclotron via the measurements of vector A_y and tensor A_{yy}, A_{xx} analyzing powers in reactions with deuteron beam. One of the simplest composite particle scattering processes is the nucleon–deuteron elastic scattering. During the last several years polarization observables in Nd elastic scattering have been studied in a number of experiments at RIKEN [5], IUCF [6], KVI [7, 8] and RCNP [9].

In the present work new results on the analyzing powers A_y, A_{yy} and A_{xx} for dp elastic scattering measured at T_d^{lab} = 800 MeV and in angular range from 60° to 135° are reported. They are compared with the results of theoretical models.

2 Experimental procedure

The experiment was performed at the Internal Target Station (ITS) [10] at Nuclotron, Laboratory of High Energy Physics of Joint Institute for Nuclear Research. The ITS consists of a spherical scattering chamber and a target sweeping system. The scattering chamber is fixed on the flanges of the Nuclotron ion tube. The actual target used for the measurement is moved to the centre of the ion tube when the particles are accelerated up to the required energy. A

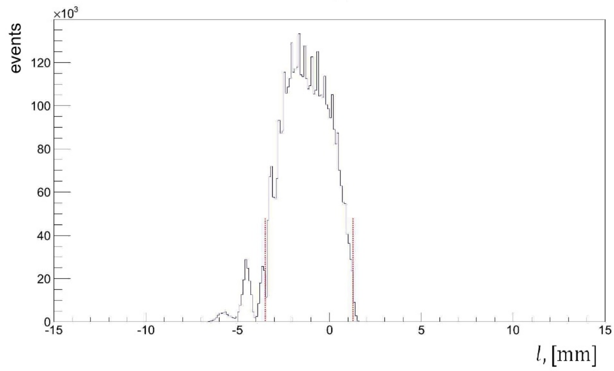


Figure 2. Position of the interaction point of the beam in the target. The solid line represents a graphical cut for the selection of dp-elastic scattering events

CH_2 film has been used as a proton target and in order to evaluate the background originating from the CH_2 Carbon wire measurement was used.

The polarized deuteron beam has been provided by the new polarized ion source PIS. Nuclear polarization is provided via radio-frequency (RF) hyperfine transitions. Ideal values of polarization were: (p_z,p_{zz}) = (0,0), (-1/3,1) and (-1/3,-1). The spin modes have been changed cyclically and spill-by-spill. The detection system for deuteron-proton elastic scattering events consists of 39 plastic scintillation counters, located downstream near ITS hemisphere. The setup covers angular range is from 60° to 135° in the center-of-mass system. There are eight proton detectors placed on the right, left and up side with respect to the ITS and only four detectors are placed on the bottom side, due to the space limitations. One pair of detectors has also been used for pp quasi-elastic scattering as an intensity monitor. The detection of the dp elastic scattering events has been carried out by the coincident measurement of deuteron and proton at several angles in the center-of-mass system.

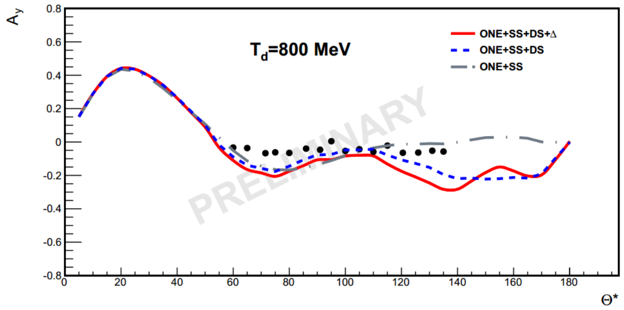
The analyzing power determination procedure consists of two steps. In the first one the elastic dp events are selected. The calculation of the tensor and vector analyzing powers is performed in the second step. The selection of the dp-elastic events is done by the correlation of the energy losses in plastic scintillators for deuteron and proton and their time-of-flight difference, see Figs. 1(a,b). Cuts on TDC and ADC signals from deuteron and proton detectors are applied to obtain the true number of the deuteron–proton elastic events, see Figs. 1(c,d).

The information about the position of the interaction point between the beam and the target has also been used. The distribution of the position of interaction point in *mm* is shown in Fig. 2. The analyzing powers A_y, A_{yy} and A_{xx} for the dp-elastic scattering at T_d^{lab} = 800 MeV are measured simultaneously. They are defined using the normalized yields $n(\Theta^*, \Phi) = \frac{N_{pol}(\Theta^*,\Phi)}{N_0(\Theta^*,\Phi)}$ using values of vector and tensor polarization calculated as follows [11]:

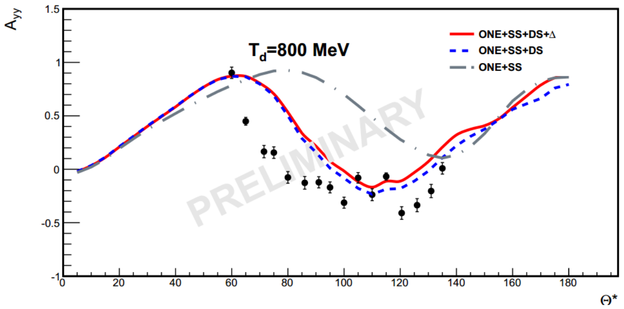
$$A_y(\Theta^*) = \frac{n(\Theta^*, 0) - n(\Theta^*, \pi)}{3p_z},$$

$$A_{yy}(\Theta^*) = \frac{n(\Theta^*, 0) + n(\Theta^*, \pi) - 2}{p_{3z}},$$

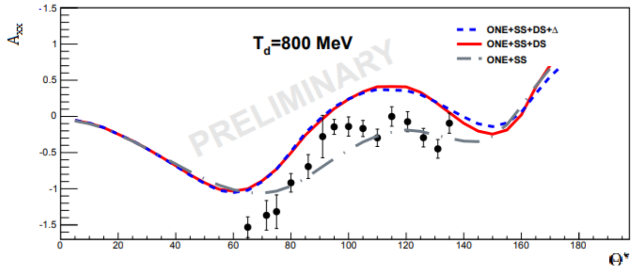
$$A_{xx}(\Theta^*) = \frac{n(\Theta^*, -\frac{\pi}{2}) - n(\Theta^*, \frac{\pi}{2})}{p_{zz}},$$



a)



b)



c)

Figure 3. Angular dependencies of the vector A_y and tensor A_{yy}, A_{xx} analyzing powers for the dp-elastic scattering at 800 MeV. The curves are described in the text

where $N_{pol}(\Theta^*, \Phi)$ and $N_0(\Theta^*, \Phi)$ are the yields corrected using information about beam luminosity and dead–time for polarized and unpolarized case, Θ^* is the scattering angle in the center-of-mass system, Φ is the azimuthal angle in the plane perpendicular to the beam direction. The azimuthal angles Φ for the detectors placed at left, right, up, and down are 0, π, $-\pi/2$, and $\pi/2$ radians, respectively. All analyzing powers were averaged over two different polarized mode of PIS.

3 Results

The angular dependencies of the vector A_y and tensor A_{yy}, A_{xx} analyzing powers in dp elastic scattering at 800 MeV are shown in Fig. 3. The error bars are the statistical only.

The results obtained at Nuclotron denoted by the full symbols are compared with the theoretical calculations performed within the relativistic multiple scattering expansion formalism. The dot-dashed (gray) curve corresponds to the results of those calculations which takes into account one-nucleon exchange (ONE) and single scattering (SS) term, while the dashed (blue) curve is obtained using a double scattering one [12]. The calculation with Δ-isobar excitation included is given by red curve [13]. It can be seen in Fig. 3(a), that the angular dependence of the vector A_y analyzing power is almost constant in the whole angular range and the theory describes the experimental data reasonably well in the angular range from 85° to 115° in the center-of-mass system. Tensor A_{yy} analyzing power have large values at small angles (Fig. 3(b)). Full calculation which includes SS, DS and Δ-isobar excitation (red curve) fails to reproduce these data, while the calculations, which take into account ONE and SS (dot-dashed gray curve) and calculation including DS term (dashed blue curve) describe the behavior of A_{yy} in the middle of the angular range. The angular dependence of the tensor A_{xx} analyzing power is presented in Fig. 3(c)). The values of the experimental data increase approximately linearly in the angular range from 65° to 90° in the center-of-mass system. One can see that theoretical approach based on ONE and SS (dot-dashed gray line) provides good agreement with the experimental data, while other mechanisms fail to reproduce the behavior of A_{xx}.

4 Conclusions

The vector A_y and tensor A_{yy}, A_{xx} analyzing powers for the dp elastic scattering have been measured for the first time on Internal Target Station of the JINR Nuclotron at T^d_{lab} = 800 MeV and in the angular range from 60° to 135° in the center-of-mass system. The obtained data are compared with theoretical predictions obtained using relativistic multiple scattering model. The data favour results of the calculation using the ONE and SS terms only, with the exception of the behavior of the A_{yy} at the middle angular range.

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