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# Study of the polarization observables in $dp \rightarrow dp$ reaction at the deuteron energy of 800 MeV

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**Abstract.** The polarization observables are sensitive to the two nucleon (2NF) and three-nucleon structures (3NF) of the nuclei. The aim of the deuteron spin structure (DSS) experiment is to obtain polarization observables in dp elastic scattering at large CMS angles ($> 60^\circ$) and in dp breakup. Of great importance is the study of polarizations observables in these reactions at intermediate energies because the experimental and theoretical data are very scarce. In this review, results of vector and tensor analyzing powers obtained at JINR Nuclotron at 800 MeV will be presented.

## 1. Introduction

Understanding the nature of the nuclear force is one of the most important questions in nuclear physics. A detailed knowledge of the nuclear force provides description of the nuclear properties and their reactions. Nowadays, from experimental side, high precision data on nucleon - deuteron (Nd) scattering process exsist in a large energy range [1, 4]. From theoretical side, different theoretical models, such as meson-exchange potentials, chiral perturbation theory, etc. provide good descriptions of the few nucleon forces phenomena. At present,the two nucleon force (2NF) models provide a good description of the experimental data of proton-proton and neutron-proton scattering and of the properties of the deuteron, such as the binding energy and D wave content. For the three nucleon (3N) system, the use of only 2NF is not enough. The presence of a third nucleon in a 3N system can influence the characteristic of all three nucleons. This effect which exists in the 2N interaction is called three nucleon force (3NF). Measurements of diffential cross sections in NN elastic scattering process is a tool to study the 3NF. For istance, the spin-depent part of the 3NF can be studied by measuring the vector and tensor analyzing powers using polarized deuteron or proton beams.

During the last several years, polarization observables in Nd elastic scattering have been studied in a number of experiments at RNCP [1], KVI [2], RIKEN [3], IUCF [4] etc. These experiments were stimulated by the observed discrepancy beetween differential cross section data at the energies of 65-135 Mev/nucleon [5, 6] and theoretical calculations. Many of the descrepancies for the differential cross section and vector analyzing powers at these energies are remedied by the inclusion of the 3NFs such as TM-3NF [7], Urbana IX-3NF [8] or TM99 [9]. However, theoretical models with 3NFs still have difficulties in reproducing polarization observables, e.g. tensor analyzing powers. At energies 200-600 MeV/nucleon, large discrepancies between the experimental data and theoretical predictions in the minimum of the differential cross section are persistent after inclusion of 3NFs [10, 11]. It has been found that when only NN forces are included into the calculations, the relativistic effects are significant only at backward scattering angles. They are relatively small in the minimum of the differential cross section [12]. However, inclusion 3NF into theoretical models does not allow to get an agreement with the polarization observables experimental data obtained at 400-1800 MeV [14]. The reason of the deviation can be associated with the neglected 3N short range correlation [15]. Despite of significant progress in the development of theoretical calculations which include 3NF and relativistic effects into the investigation of few nucleon systems at intermediate energies still many open questions persist. The main goal of the Deuteron Spin Structure (DSS) experimental program at the Nuclotron internal target station (ITS) [19] is to obtain information about on the spin-dependent parts of 2NF and 3NF in two processes: dp-elastic scattering in a wide energy range and dp-breakup at energies $300-500$ MeV [16–18] .

In the present work new results on the analyzing powers $A_y$, $A_{yy}$ and $A_{xx}$ from dp elastic scattering measured at the incident deuteron energy of 800 MeV and in angular range from $60^\circ$ to $135^\circ$ obtained by DSS are reported. They are compared with the results of theoretical prediction.

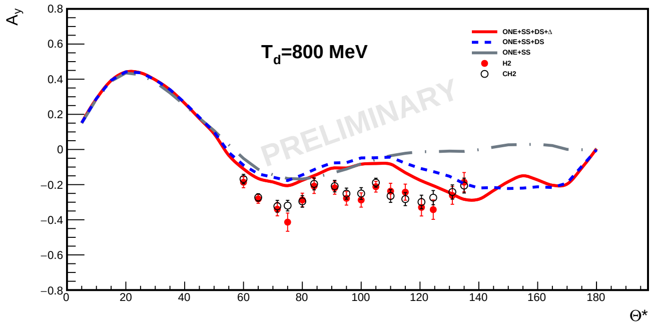
## 2. Experimental setup

The experiment was performed in Laboratory of High Energy Physics of Joint Institute for Nuclear Research on DSS ITS at the Nuclotron. The setup is well suited for the study of the dp reactions at large scattering angles in the center-of-mass system (CMS). In the current experiment polyethylene target of $10\mu$m was used for the measurements. The yield from Carbon content of the $CH_2$ is estimated in separate measurements using several twisted $8\mu$m carbon wire.

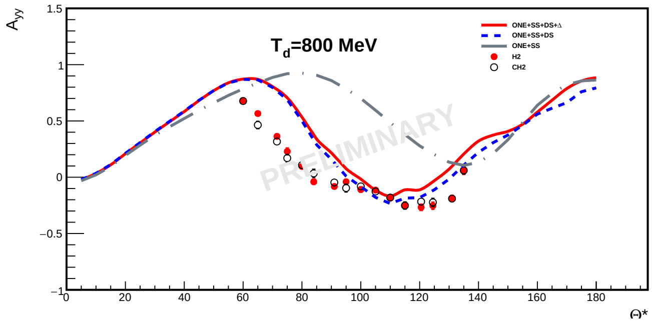
Polarized deuterons were provided by polarized ion source SPI [20] at the energy of 270 MeV [22]. In the current experiment the spin modes with the maximal ideal values of $(p_z, p_{zz}) = (0,0), (-1/3,+1), (-1/3,-1)$ were used. The typical values of beam polarization differ from ideal values about 65-75% [21]. The detection of the dp elastic scattering events has been done by deuteron and proton registration in coincidence. Selection of the dp elastic scattering events has been done by the kinematical coincidence of the scattered deuterons and recoil protons. The same method was used to obtain the polarisation observables data in elastic scattering reaction at 880 MeV [23], 2000 MeV [24] and in energy range 400-1000 MeV [14].

## 3. Measurements of analyzing powers

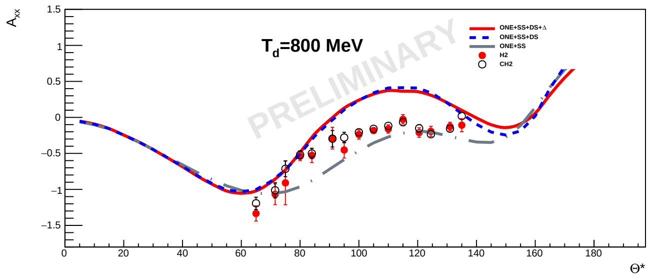
The selection of the dp-elastic scattering events is done by the correlation of the energy losses in plastic scintilation counters and their time-of-flight difference [25]. The normalized number of useful events is used for analyzing power calculations. The $CH_2 - C$ subtraction procedure is performed to obtain the reaction on Hydrogen.




a)




b)




c)

**Figure 1.** 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.

The angular dependencies of the vector $A_y$ and tensor $A_{yy}$, $A_{xx}$ analyzing powers in deuteron-hydrogen reaction at the energy of 800 MeV are presented in Fig.1. The results obtained at polyethylene are denoted by open black symbols, hydrogen analyzing powers presented by full red symbols. It shoud be noted, that the discrepances between $CH_2$ and $H_2$ data are about 10%. The dashed-dotted, dashed and solid curves are the calculations performed within the relativistic multiple scattering expansion formalism [26] considering one nucleon exchange (ONE) and single scattering (SS) terms, with the double scattering (DS) contribution and Δ-isobar exitation, respectively. It is shown that the model which includes only one-nucleon exchange and single scattering is suitable for describing the behavior of tensor analyzing power $A_{xx}$ in all angular range but does not reproduce the behavior of $A_y$ and $A_{yy}$. Inclusion of the double scattering and Δ-isobars improves the description of $A_{yy}$ experimental data obtained at the central scattering angles.

## 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 at 800 MeV over the c.m. angular range from 60° to 135°. New results on the vector analyzing power $A_y$ and tensor analyzing power $A_{yy}$, in contrast to tensor analyzing power $A_{xx}$, indicate strong deviations from the predictions of the relativistic approaches based on the nucleon-nucleon forces only.

Some differencies in the description of the analyzing powers require consideration of additional mechanisms, e.g. 3NFs. Since the present 3NFs models cannot improve the agreement with the data obtained at this energies, new models of 3NFs should be considered.

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