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INFLUENCE OF THREE-NUCLEON FORCE EFFECTS ON POLARIZATION OBSERVABLES OF THE $^1H(\vec{d},pp)n$ BREAKUP REACTION AT 130 MEV*

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High-precision vector and tensor breakup analyzing powers for the reaction $^1\mathrm{H}(\vec{d},pp)n$ at 130 MeV were evaluated for a large phase space region. Results are compared with rigorous theoretical calculations based on realistic nucleon–nucleon potentials as well as on chiral perturbation theory approach. Theoretical predictions generally describe data quite well, only in a few cases influence of three-nucleon forces is significant.

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1. Introduction

Three-nucleon (3N) system is the simplest testing ground for probing the basic nucleon–nucleon (NN) interaction in a non-trivial environment. Properties of the 3N systems are determined mainly by pairwise NN interaction. However, also additional dynamics related to the presence of the third nucleon is expected, a so-called 3N force (3NF). Nowadays precise predictions for observables in the 3N system can be obtained via exact solutions of Faddeev equations with NN potentials and with inclusion of three nucleon force.

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The nuclear dynamics is modeled in different ways: in form of a realistic potential and a phenomenological 3NF (TM99) [1] or obtained within the chiral perturbation theory [2] (results obtained at N2LO and N3LO are presented in this paper). In the first stage of data analysis the cross sections have been evaluated [3, 4]. They showed clearly that the calculations including 3NF better reproduce the data than those based on NN potentials only.

2. Experimental setup

Vector and tensor polarized deuteron beam from the AGOR cyclotron of KVI Groningen, with the energy of 130 MeV, was focused on the liquid hydrogen target. Charged reaction products were passing a three-plane multiwire proportional chamber (MWPC) and were detected in a scintillator hodoscope (SALAD) consisting of 24 horizontal transmission detectors (ΔE) and 24 vertical stopping detectors (E). The detection system covered laboratory polar angles between 10° and 40° and the full range of azimuthal angles. More details can be found in Refs. [3, 4].

3. Data analysis

The registered events of interest are coincidences of two charged particles: proton–proton pairs from the $^1\mathrm{H}(\vec{d}, pp)n$ breakup process or deuteron-proton pairs from the $^1\mathrm{H}(\vec{d}, dp)$ elastic scattering reaction. For each telescope, formed by an overlap of one ΔE strip with one E slab, spectra of energy loss *versus* energy deposited in the stopping detector were built. Very good separation between protons and deuterons was observed over the whole energy and angular ranges. Emission angles of the reaction products were determined on the basis of the MWPC information, with the precision of 0.5°. Kinematical configurations for the breakup channel were defined by polar angles, θ_1, θ_2, of the two outgoing protons and their relative azimuthal angle, φ_{12}. Energies of the protons were determined on the basis of comparisons of the special calibration runs, in which protons from the elastic scattering process were passing degraders of precise thicknesses, with accurate Monte Carlo simulations. For every chosen configuration events were projected on the kinematical curve S, given by E_2 *versus* E_1 dependence and defined as the distance along the kinematic curve from the point of minimal E_2 value. Intensity of the events for a given polarization P is expressed by:

$$\begin{aligned} I_P(\xi) = I_0(\xi) \big[1 + P_Z \left(-\tfrac{3}{2} \sin\varphi A_x(\xi) + \tfrac{3}{2} \cos\varphi A_y(\xi) \right) \\ - P_{ZZ} \left(\cos\varphi \sin\varphi A_{xy}(\xi) \right) + P_{ZZ} \left(\tfrac{1}{2} \sin^2\varphi A_{xx}(\xi) + \tfrac{1}{2} \cos^2\varphi A_{yy}(\xi) \right) \big] \,, \quad (1) \end{aligned}$$

where $\xi = (\theta_1, \theta_2, \varphi_{12}, S)$, $I_0(\xi)$ is the intensity of the events with unpolarized beam, P_Z, P_{ZZ} are vector and tensor polarization respectively, A_x, A_y —

vector analyzing powers, A_{xx}, A_{yy}, A_{xy} — tensor analyzing powers. Elastic scattering events, measured simultaneously with the breakup process, were used for determining the vector and tensor polarizations of the deuteron beam. The method of the polarization evaluation is described in Ref. [5]. Quality of this procedure has been verified by precise results obtained for the elastic scattering analyzing powers [6]. In determining the analyzing powers the breakup events belonging to a given configuration were sorted with respect to the S value and the azimuthal angle of the first proton. Rates were normalized to the collected charge and a ratio $f = \frac{I_P - I_0}{I_0}$ was constructed. For a given bin in S the dependence of the ratio f on the azimuthal angle was fitted with the analyzing power values as parameters (see Fig. 1).

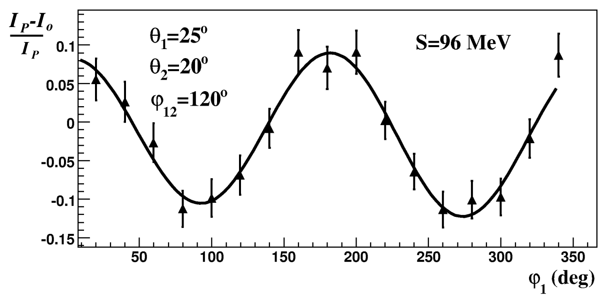

Fig. 1. An example of the asymmetry for one configuration and one bin in S. Solid line shows a fit of function resulting from Eq. (1) to the ratio $f = \frac{I_P - I_0}{I_0}$ with analyzing powers as parameters.

4. Results

High precision vector and tensor analyzing power values were obtained for 72 kinematical configurations. In total nearly 1000 data points for each observable $(A_x, A_y, A_{xx}, A_{yy}, A_{xy})$ were obtained. The data are compared with the theoretical predictions based on realistic NN potentials only and including TM 3NF. A comparison is done also for the chiral perturbation theory predictions, at N2LO and N3LO. In this later case only 2N dynamics is at present available. An example of such comparison is given in Fig. 2. While in general the data are well described by the predictions, there is still room for possible improvements in modeling the interaction dynamics. No large effect of 3N forces are visible in many configurations, although in some cases they are manifesting themselves clearly (see Fig. 3 as an example). More detailed global comparisons are currently underway.

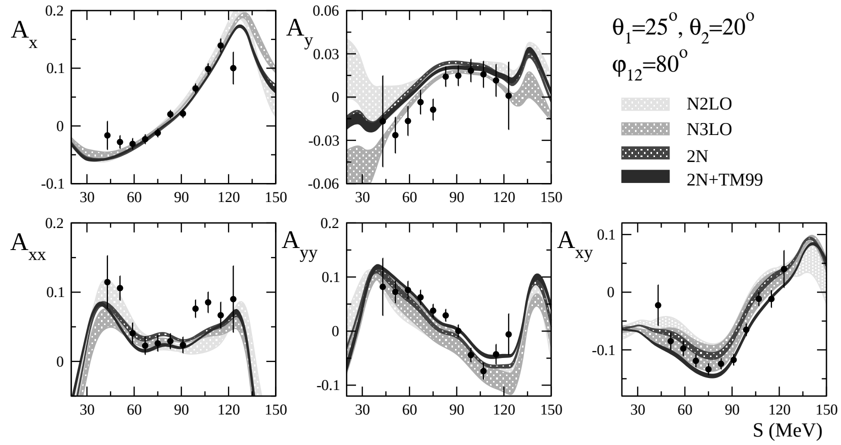

Fig. 2. An example of all five breakup analyzing powers measured in the presented experiment, for one selected kinematical configuration. Gray bands show the results of various theoretical calculations, as specified in the legend.

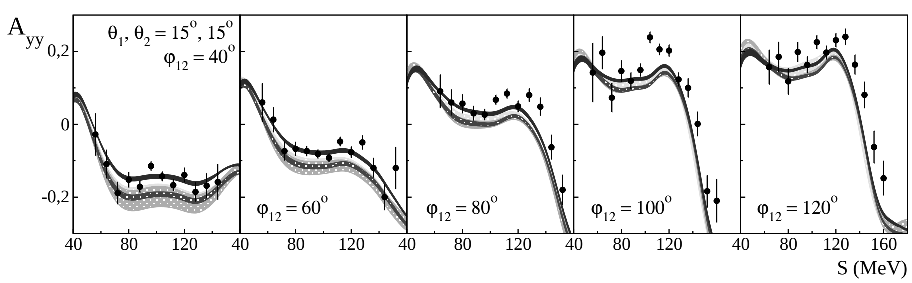

Fig. 3. The breakup tensor analyzing power A_{yy} for one pair of proton polar angles and several relative azimuthal angles (as given in the panels). The meaning of the bands as in Fig. 2.

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