COULOMB FORCE EFFECTS IN DEUTERON–PROTON BREAKUP REACTION*

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A large set of cross-section data for the $^1\mathrm{H}(d,pp)n$ breakup reaction was measured at 130 MeV deuteron beam energy with the Germanium Wall setup covering the range of very forward polar angles. In the investigated part of the phase-space, the dynamics is dominated by the Coulomb force influence. The data are compared with results of theoretical calculations based on the realistic Argonne V18 potential supplemented with the long-range electromagnetic component. The predictions also include the Urbana IX three nucleon force model. The cross-section data reveal seizable Coulomb force effects.

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1. Introduction

New-generation experiments dedicated to investigations of the $p(d, pp)n$ breakup reaction in a large phase-space region were performed with the use of the SALAD and BINA detectors at KVI [1–4]. They revealed for the first time large Coulomb force effects in the breakup cross-section data [2]. The first calculations with the electromagnetic long-range force included were performed within the coupled-channel formalism [5]. Then, the Coulomb force was also implemented into calculations with the realistic Argonne V18 (AV18) nucleon–nucleon (NN) potential combined with the Urbana IX (UIX) three nucleon force ($3N$F) model [6]. To test the predictions, a dedicated experiment [7] was performed at the Research Center in Jülich (FZJ) aiming at investigation of the Coulomb force effects at the very forward angular region. The results confirmed the importance of the Coulomb interaction in the selected region of the breakup phase-space. In the present paper, the results of the following experiment at FZJ dedicated to cross-section measurement are presented.

2. Experiments and results

The experiments at FZJ was conducted with the Germanium Wall (GeWall) setup [7] at the deuteron beam energy of 130 MeV. GeWall consisted of three high-purity germanium position sensitive detectors. Two different types of the detectors were used: a thin transmission detector *Quirl* with an excellent spatial resolution for determining the position and energy loss (ΔE detector) of the passing charged particles, and two thick detectors E1 and E2 for measurement of particle energies with an excellent resolution. The angular acceptance of the apparatus was $5°$–$14°$ for the polar and 2π for the azimuthal angles

The data collected with GeWall were analyzed for about 145 kinematical configurations, defined by the polar angles of the two outgoing protons, θ_1, θ_2, and their relative azimuthal angle φ_{12}. Then, the results were quantitatively compared with the available predictions for the $3N$ systems demonstrating a crucial role of the electromagnetic component in the data description. An example of effects of the Coulomb force action between the two breakup protons is presented in Fig. 1. The data were integrated over energy and studied in a function of the φ_{12} variable. The results are well reproduced by the model predictions with the Coulomb force taken into account (AV18+UIX+C, AV18+C). For very small relative azimuthal angles, the calculations without the Coulomb interaction included (AV18+UIX) overestimate the data, whereas for higher ones the data are underestimated. Such behavior is consistent with a naive picture — the Coulomb repulsion decreases the number of protons in configurations characterized by small relative energies. That is why with increasing φ_{12} discrepancies change sign. At a certain point, the theoretical curves cross. This refers to a situation when number of "incoming" and "outgoing" protons is balanced and the net effect of the Colomb force is equal to zero. Comparing the predictions for AV18+UIX+C and AV18+C, one can conclude on the 3NF influence. The UIX 3NF effects are rather small in the investigated part of the phase-space, in contrast to the seizable Coulomb force contribution.

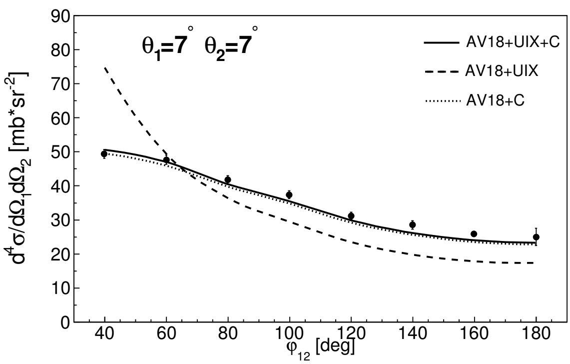

Fig. 1. Differential, integrated over energy, cross-section values presented as a function of the relative azimuthal angle φ_{12}, for a given θ_1, θ_2 combination. The data are compared with the calculations indicated in the legend.

3. Further studies

A new possibility of continuation of few-nucleon dynamics studies at medium energies has appeared together with a new facility at the Institute of Nuclear Physics PAN in Kraków — Cyclotron Center Bronowice (CCB). The BINA detector was brought to CCB and currently is operating with the new cyclotron PROTEUS. The apparatus [3, 4] is composed of the two main parts called Wall and Ball. Wall, covering the angular range from 15° to 37°, is built of the MWPC for momenta reconstruction, ΔE (24 strips) and E (10 slabs) scintillator detectors. The ΔE and E create virtual matrix of 120 hodoscopes. The backward part is ball-shaped and consists of 149 phoswich detectors which cover polar angles between 40° and 160°. The Ball plays two roles: of the particle detector and scattering chamber. The BINA detection system was already tested with respect to the detector symmetry, energy and angle reconstruction. The first data obtained look very promising. Proton beam with the energy of 108 MeV was impinging on the solid CH_2 and C_2D_4 targets. Figure 2 presents sample kinematical spectrum for protons. The energy was reconstructed from the thick E detector, whereas the polar θ angles with the use of the MWPC. The particle identification was done on the basis of the ΔE–E spectra by applying of graphical cuts defined separately for proton and deuteron branches. The energy calibration was performed based on events identified as protons elastically scattered from deuterons present in C_2D_4 target. The particles seen in Fig. 2 originate from the elastic scattering on ^{12}C, ^{4}He, d and the deuteron breakup processes.

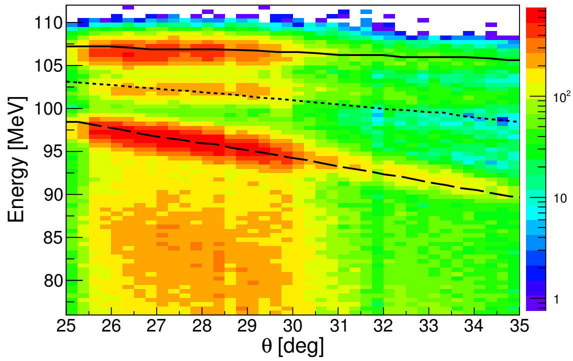

Fig. 2. Kinematical relation for protons scattered from a C_2D_4 target. Presented data were registered in one E-slab. The lines represent the kinematics calculated for the following elastic scattering processes: $p+{}^{12}$C (solid), $p+{}^4$He (dotted), $p+d$ (dashed).

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