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Investigation of the dp-non-mesonic breakup reaction at 300-500 MeV at Nuclotron

S.M. Piyadin*, M.Janek[1,2], G.Tarjanyiova[2], Yu.V. Gurchin[1], A.Yu. Isupov[1], J.-T. Karachuk[1,3], A.N. Khrenov[1], A.K. Kurilkin[1], P.K. Kurilkin[1], V.P. Ladygin[1], A.N. Livanov[1], G. Martinska[4], S.G. Reznikov[1], A.A. Terekhin[1].

[1] *Joint Institute for Nuclear Research, Dubna 141980, Russian Federation*
[2] *Physics Department, University of Žilina, Žilina 010 26, Slovak Republic*
[3] *Advanced Research Institute for Electrical Engineering, Bucharest 030138, Romania*
[4] *P.J.Šafarik University, Košice 041 80, Slovak Republic*
E-mail: piyadin@jinr.ru

The first results on the study of the dp-breakup reaction with 300-500 MeV unpolarized deuteron beam at Internal Target Station at Nuclotron are discussed. Selection procedure of useful events for the $dp \to ppn$ reaction with the registration of two protons is shown.

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1. Introduction

The purpose of Deuteron Spin Structure experimental program is to obtain the information on the spin - dependent parts of 2-nucleon and 3-nucleon forces from two processes[1],[2]: dp-elastic scattering in a wide energy range [3],[4],[5],[6] and dp non-mesonic breakup with two protons detection at energies 200 - 500 MeV[7].

Properties of few-nucleon system at moderate energies are determined mainly by pairwise nucleon-nucleon interactions. Models of NN forces describe the long range interaction part according to the meson-exchange, while the short range is based on phenomenology, adjusted by fitting a certain number of parameters to the NN scattering data. Nowadays a new generation of the NN potentials (AV-18[8], CD-Bonn[9], Nijmegen[10] etc.) was obtained. They reproduce data on the nucleon nucleon scattering up to 350 MeV with very good accuracy. However, these modern $2N$ forces fail to provide the experimental binding energies of few-nucleon systems. Moreover, the data on the dp- elastic scattering and deuteron breakup are not described properly.

Precise predictions for observables in the $3N$ system can be obtained via exact solutions of the $3N$ Faddeev equations for any nucleon-nucleon (NN) interaction, even with the inclusion of a $3NF$ model [11]. Incorporation of the $3N$ forces makes it possible to reproduce the binding energy of the three-nucleon bound systems and also data on unpolarized dp- interaction. Nevertheless, polarization data for the reactions with participation of three and more nucleons are not described even with inclusion of $3NF$. Therefore, the obtaining of the additional polarization data in the dp-interaction in the wide energy range more is very desirable for the study of the spin structure of $2N$ and $3N$ forces [12]. To investigate the details of the dynamics of the $3N$ system, in addition to elastic Nd scattering data, reliable deuteron breakup data sets, covering large regions of the available phase space, are needed.

The experimental data on the deuteron analyzing powers for dp-breakup for large phase space were obtained at 130 MeV at KVI [13]. A_y, A_{yy} and A_{xx} analyzing powers in dp-breakup will be investigated at Internal Target Station at 200-500 MeV. The predictions for analyzing powers and differential cross section in the selected dp-breakup configurations at 200 MeV were obtained in [14]. It was shown large sensitivity of these observables to the model of $3NF$.

In this report the status of the experiment at internal target station (ITS) at Nuclotron preparation and first beam results are presented.

2. The experimental setup

The first stage of the DSS experimental program[2, 15, 16] is the beam energy scan of dp- elastic scattering cross section at the deuteron energies from 400 up to 2000 MeV and measurements of dp- non-mesonic breakup at 300, 400 and 500 MeV in different kinematic configurations. These measurements will be performed using ITS[17] with new control and data acquisition system[18].

The dp breakup reaction will be investigated using ΔE-E techniques for the detection of protons. 8 detectors of this kind are planned to use in the experiment. The details of the ΔE-E detector construction are presented in [7],[19].

Each detector consists of two scintillators ΔE and E. The first scintillator has the cylindrical form with the height 10 mm and the diameter 80 mm. Two PMTs-85 view through given scintillator

and they are located the friend opposite to the friend. Two planes have been made on the scintillator to increase the area of the optical contact between the scintillator and photocatode of the PMT-85. These planes have been polished. ΔE scintillator is covered by a white paper. Digital dividers of the high voltage are used for PMT-85.

E scintillator also has the cylindrical form with height 200 mm and diameter 100 mm. PMT-63 view through this scintillator. Given PMT has been chosen because of the suitable size of the cathode (100 mm) with both good time and amplitude properties. E scintillator has been wrapped by a white paper. The part which is located to ΔE scintillator has been covered by a black paper. It is made to exclude possibility of hit the light from one plastic scintillator to another. The calibration for ΔE-E counters were performed with cosmic muons and pp-quasi elastic scattering.

3. The simulation results

The simulation results on the energy losses of the protons which passes through the scintillators are presented in Fig. 1. In (b) figure the energy losses of the proton in thin scintillator are plotted versus ones of the thick scintillator. The events were selected in the region of approximate linear dependence of the energy losses in the scintillator versus the incident proton energy[20]. Therefore the following conditions on the ΔE and E information were imposed:

5 MeV $< \Delta E <$ 35 MeV and 0 MeV $< E <$ 180 MeV.

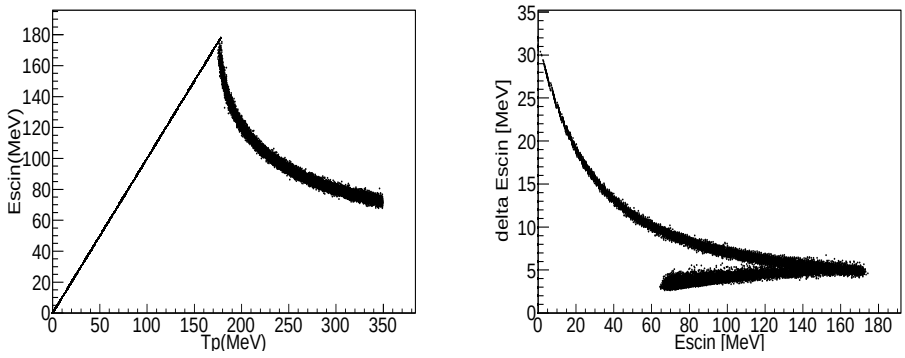

Figure 1: (a) Simulation results of the energy losses of the protons passed through ΔE and E scintillators when the length of a scintillator is 21 cm (ΔE + E) (b) Simulation results of the energy losses of the protons passed through ΔE and E scintillators in thin scintillator versus thick.

4. Results obtained at Nuclotron.

The missing mass has been calculated using the kinematic formulas (Fig. 2). Histogram was obtained for the kinematical configuration Θ_1=25^o, Θ_2=43.6^o, Φ_{12}=178.5^o and deuteron energy of 400 MeV. One can see clearly the allocated the dp-breakup reaction and dp-elastic scattering. Useful events were obtained with the cut on missing mass: less than 950 MeV for the configuration register dp-elastic scattering and dp-breakup are detected; 940 MeV $\pm$ 10 MeV for the configuration when only dp-breakup events are registered.

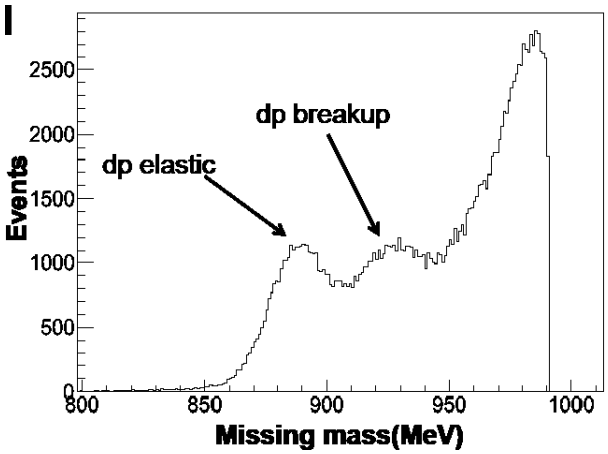

Figure 2: The missing mass for the kinematical configuration Θ_1=25^o,Θ_2=43.6^o,Φ_{12}=178.5^o.

Correlations of the detected proton energies with the cut on the neutron missing mass obtained at 300 MeV, 400MeV and 500MeV on CH_2 target are presented in the left, middle and right panels of Fig. 3.

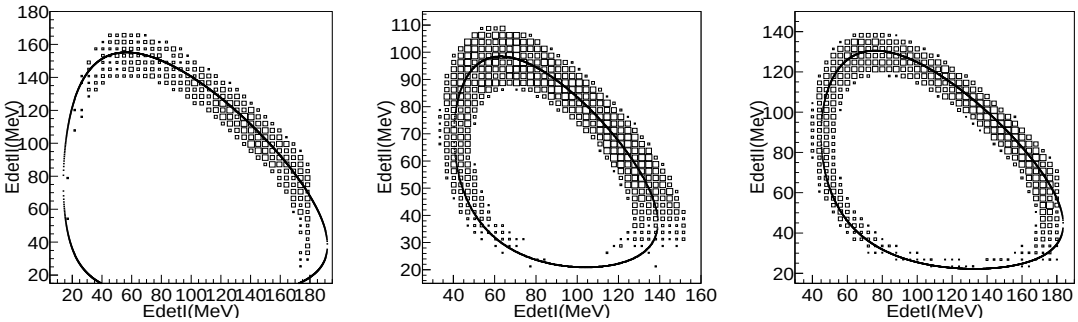

Figure 3: The missing mass for the kinematical configuration Θ_1=25^o,Θ_2=43.6^o,Φ_{12}=178.5^o.

The spectra correspond to the detected protons kinematical configuration Θ_1=25^o, Θ_2=43.6^o, Φ_{12}=178.5^o. Black curve is the kinematic locus for deuteron breakup reaction at 300-500 MeV energy of deuteron for different angle configuration. The correlation of the proton energies were ploted with the cut on mass of neutron ($\pm$ 10 MeV).

5. Conclusion

The preliminary results for $dp \rightarrow ppn$ reaction at 300-500 MeV for different geometry at Internal Target Station at Nuclotron are obtained. The procedure of selection of events relating to the dp-breakup reaction is established. The setup for the studies of deuteron non-mesonic breakup reaction was put into operation.

The future plans are to continue to process the obtained data and to estimate a contribution of background events to these results for the study of dp-breakup reaction. We are going to take the

data on dp - breakup using with polarized deuteron beams at Nuclotron. New source will provide up to $2*10^{10}$ ppp and higher values of polarization than POLARIS. Part of the IUCF source is used for the construction. The putting into operation of new PIS is planned in 2016.

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