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THE SELECTION OF THE dp BREAKUP EVENTS FROM d CH_2 REACTION AT 500 MeV

The simulations of dC and dCH_2 (CH_2 - polyethylene) reactions for different detector configurations were performed at 500 MeV of deuteron energy. We present method by means of which the signal from dp breakup reaction can be separated from the background that mainly comes from the carbon content of the target.

Keywords: *dp breakup, energy deposit, missing mass distribution, nucleon-nucleon correlations.*

1. Introduction

The results obtained at BNL [1], SLAC [2] and JLAB [3 and 4] clearly demonstrate that more than 90% of all nucleons with internal momenta k>300 MeV/c belong to 2N (2 nucleon) short range correlations; probability for a given proton with momenta 300 MeV/c < k < 600 MeV/c which belongs to pn correlation is ~18 times larger than for pp correlations; probability for a nucleon to have momentum k>300 MeV/c in medium nuclei is ~25% and 3N (3 nucleon) short range correlations are present in nuclei with a significant probability [5]. However, still many open questions persist and further investigations are required both from the experimental and theoretical sides. For instance, the experimental data on the spin structure of 2N (I=1) and 3N short range correlations are practically absent. The study of short range correlations can be realized via study of deuteron structure at large internal momenta of nucleons, ^{3}He structure, nuclei breakup reaction A(p, pp)X, A(p, pn)X, A(p, ppp)X etc. with the detection of few nucleons in the final state.

The great importance is the study of the spin effects in these reactions because the data on the spin structure of these correlations are scarce. Nuclotron allows to investigate the spin effects for multi-nucleon correlations in a wide energy range. The model of 2N and 3N correlations at low and intermediate energies (below pion threshold production) can be built from the boson-nucleon picture of strong interaction. During last several years a new generation of nucleon-nucleon potentials are built (Nijmegen, CD- Bonn, AV-18 etc.). These potentials reproduced the nucleon-nucleon scattering data up to 350 MeV with very good accuracy. But these potentials cannot reproduce triton binding energy (underbinding is 0.8 MeV for CD-Bonn potential), dp → dp elastic scattering and breakup reactions [6]. Incorporation of three nucleon forces (3NF), when the interaction depends on the quantum numbers of the all three nucleons, allows reproducing triton binding energy and unpolarized dp → dp elastic scattering and breakup data. The contribution of 3NF is found to be up to 30% in the vicinity of Sagara discrepancy for deuteron-proton elastic scattering at intermediate energies [7 and 8]. However, the use of different 3NF models in Faddeev calculations cannot reproduce polarization data intensively accumulated during last decade at different facilities [7 - 11].

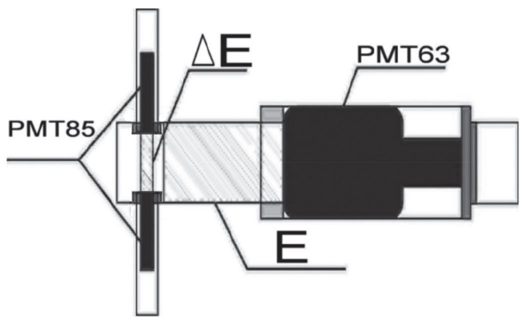

Fig. 1 Sketch view of ΔE-E detector

The dp breakup possesses rich phase space. The effects originating from the 3NFs can dominate in some regions of the phase space, the relativistic effects in other ones. Thus, to obtain data for a large region of the phase space it is desirable to get complementary information about the reaction mechanism and

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the structure of the objects involved in the dp breakup. Large discrepancies between experiment and theoretical calculations based on various NN and 3N potentials have also been found in case of the dp breakup measured at 130 MeV [12]. The main goal of this study is to present method for selection of dp breakup events. Obtained results will be used in the experimental deuteron spin structure program at the Nuclotron in Dubna.

2. Experiment and simulation

The dp breakup reaction is detected by the simultaneous registration of two protons by two detectors in coincidence. Deuteron energies range from 300 MeV up to 500 MeV. Eight ΔE-E scintillation detectors are used. Both scintillators are of a tube shape, the thin one of a height of 1 cm, the thick one of a 20 cm height, with the diameter of the cross section 8 cm and 10 cm, respectively. Two Photomultiplier tubes PMTs-85 are positioned opposite to each other at the outside cylindrical surface of the thin scintillator as shown in Fig. 1. The ΔE scintillator surface was polished in order to increase the area of the optical contact between the scintillator and the photocatode of the PMT-85. This scintillator is covered by white paper and digital dividers of high voltage are used for the PMT-85. At the free bottom of the E scintillator a photomultiplier tube PMT-63 is positioned. The E scintillator is also covered by white paper. The contact area of the two scintillators is covered by black paper in order to exclude the possibility of the transfer of light between them. The details of the ΔE–E detector construction can be found in [13]. Each detector is positioned at a distance of 99.6 cm from the target so that the angle whose vertex is the target subtended by the diameter of the thin scintillator is 4.6°.

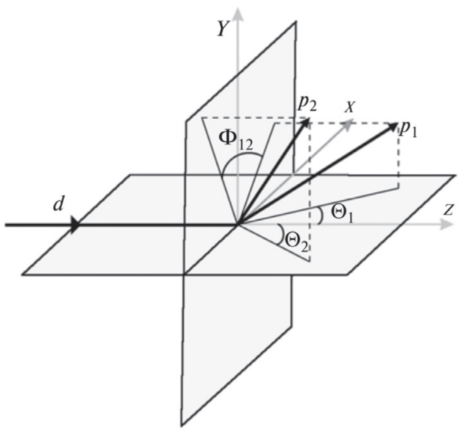

Fig. 2 Kinematic variables for the deuteron breakup reaction

Targets from carbon and CH_2 are enclosed in a spherical hull made from stainless steel with an external diameter of 160 mm and a thickness of 0.5 mm. To produce collisions of the deuteron with hydrogen, CH_2 target is used. When the CH_2 target is bombarded with deuterons, large background originates. Hence, ways must be found for selecting our signal events out of all detected events and this should be done for various detector configurations.

To accomplish this goal we performed computer modeling using the GEANT4 toolkit [14] with Liege intranuclear cascade model included. From simulation comes that when bombarding the CH_2 target with deuterons in the vast majority of cases the two detectors detect in one event two protons and very rarely other particles or more than two particles obviously mostly coming from the collisions of the deuterons with the carbon nuclei. The events represented by the collisions of deuterons with the carbon nuclei form the dp breakup background that we simulated by the collisions of the deuterons with a carbon target, i. e. by the dC events. Then by subtracting the dC events from the dCH_2 events the signal events can be selected.

Deuteron beam with energy of 500 MeV hits the target. The types of the outgoing particles, their energy and their scattering angle, i. e. the angle made by the trajectory of the outgoing particle and the direction of the deuteron beam, were recorded only if this angle is greater than 17°. The reason for this cut is that roughly for scattering angles smaller than 17° the collisions of the deuterons with the CH_2 target produce large background that is mainly due to the carbon content of the target. Energies deposited by particles in ΔE and E detector were also recorded. The longitudinal axes of scintillation detectors pass through the target and make angles that we designated Θ_1 and Θ_2 with the trajectory of the incoming deuterons. The angle between detectors in plane perpendicular to the direction of the deuteron beam is denoted by Φ_{12}. The three angles Φ_{12}, Θ_1 and Θ_2 (see Fig. 2) specify a detector configuration. The simulation was performed for 20 various detector configurations. They were selected according to experimental ones. Characteristicconfigurations for which we present our results are given in Table 1. As you can notice, the angles Θ_1 and Θ_2 appear as an interval of angles, which is due to the finite size of the detectors' cross section.

Detector configurations description Table 1

Configuration	Θ_1	Θ_2	Φ_{12}
2 – Fig. 3a	22.400° - 27.000°	31.015° - 35.615°	40°
5 – Fig. 3b	22.400° - 27.000°	40.901° - 45.501°	180°
7 – Fig. 3c	22.400° - 27.000°	50.983° - 55.583°	140°
19 – Fig. 3d	31.015° - 35.615°	40.901° - 45.501°	130°

3. Results

To analyze our data we calculated the missing mass distribution of the two particles that hit the detectors in one event. We used as the particles' kinetic energy (incoming energy)

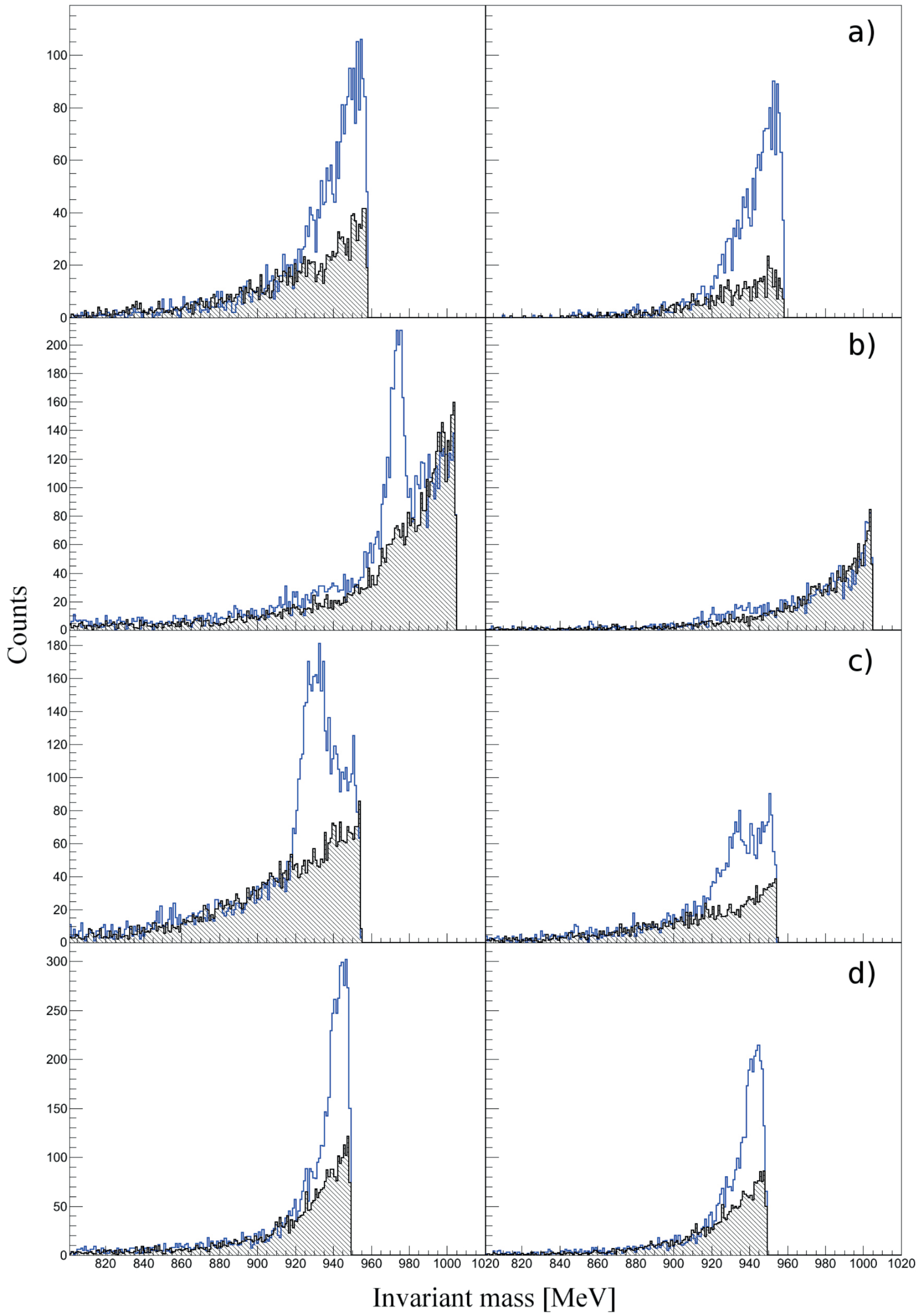

Fig. 3 Missing mass distribution of two charged particles obtained for CH2 (non-shaded spectra) and carbon (shaded spectra) target that were bombarded by deuterons of energy 500 MeV; the detector configurations are 2 (first row), 5 (second row) 7 (third row) and 19 (fourth row), respectively. First (second) column corresponds to the cut1 (cut2).

the energy deposited by them in the detectors and the mean value of the range of angles Θ_1 and Θ_2 for the relevant detector configuration as the directions of the particles momenta.

Two cuts were applied on missing mass distributions. The choice of energy ranges for ΔE and E detectors of these cuts were determined in the separate simulation in which protons with energies between 1 and 500 MeV hit the detector at various angles. First cut designated as "cut1" contains particles with deposited energy ΔE between 1 and 35 MeV and E less than 180 MeV. Cut1 contains also particles which not all their energy deposit in detector even if they passed along detectors main axis. It happens when particles have energy above 180 MeV due to insufficient length of the detector. Second cut designated as "cut2" contains particles with deposited energy ΔE between 5 and 35 MeV and E less than 180 MeV. The purpose of cut2 is to cut out mostly the particles which pass through the detector basically along its longitudinal direction and then leave it, thus depositing only a part of their kinetic energy there. However, in order not to suppress the signal significantly cut2 can contain a part of these particles. Hence the calculation of the missing mass for these particles does not give its correct value as well, which means that these events should also contribute to the background in the missing mass spectra. It will be shown below, however, that a part of this background are actually our signal events. Another contribution to the background is constituted by the events in which the particles registered by the detectors are not protons since in the calculation of the missing mass we assume that two protons are detected, i. e. we use the rest mass of protons in the missing mass formula. The main part of the background in the missing mass plots is due to the protons that come from the collision of the deuteron with the carbon nuclei.

Fig. 3 depicts the missing mass distribution of two charged particles registered by the detectors at deuteron energy of 500 MeV. The non-shaded spectra represent the dCH_2 simulations and the shaded ones the dC simulations. The dC spectra are normalized against the dCH_2 spectra according to the regions where only the carbon content is expected. Fig. 3 contains eight plots arranged in four rows and two columns. The rows correspond to the four detector configurations given in Table 1, the first column represents the spectra calculated using the cut1 events, in the second column are depicted spectra calculated using cut2 ones. The a), b) and d) spectra in Fig. 3 exhibit clear peaks at about 940 MeV, i. e. at the value of the rest mass of neutron.

From Fig. 3 we can see that the events corresponding to this peak are mostly our dp breakup events and calculating the missing mass is a good means of how to separate them from the rest of the events. The effect of using the cut2 selection of events is visible in Fig. 3 in all detector configurations. The calculation of the missing mass spectra for the cut1 case actually enabled us to localize in the spectra those events in which the energy of the incoming protons is larger than about 180 MeV. As can be seen, these events are shifted towards the right part of the spectra. Since GEANT4 gives the incoming energies of the particles, we could calculate the missing mass for these events with the correct value of their kinetic energy (that should be ideally whole deposited in the detectors) and we found that these events are also the dp breakup events, i. e. the signal events. Especially marked is the cut2 effect on the signal for detector configuration b) when a large part of the signal is cut out.

The main reason of the peak spreading in the missing mass spectra is connected with using in the calculation of the missing mass of a pair of charged particles instead of the actual value of the scattering angle of the particles hitting the detector the angle at which the detector is placed, i. e. the angle the longitudinal axis of the detector makes with the direction of the incoming deuterons. In this way we simulate the real experimental conditions at which the scattering angles of the detected particles will not be known. Other reasons of the peak spreading are associated with the detector response. The spherical hull affects the scattering angle and causes energy losses only at very low energies of scattered particles which are cut out by the ΔE and E coincidence condition.

Hence, we conclude that two methods of reconstructing the signal events are possible. The first one is based on the localization of the dp breakup events by means of the GEANT4 simulation that uses cut1 selections of events with the subsequent subtraction of the C spectra from the CH_2 spectra. The second one is calculating the CH_2 and C spectra using only the cut2 selection of events and subsequently applying the above described subtraction procedure. The spectra in the second row and second column in Fig. 3 shows that for this case the yield is low. One can see that the subtraction procedure can be used for selecting the signal events in the missing mass spectra but the yield varies with the detector configuration.

4. Conclusion

We present results of the GEANT4 simulations of the $dp \rightarrow ppn$ reaction at deuteron energy of 500 MeV for some configurations of two ΔE-E detectors. To separate the signal from the background we calculated the missing mass distributions of two charged particles assuming that these two particles are protons. The events that form the background of the missing mass spectra can be largely removed by means of the subtraction procedure, i. e. by simulating collisions of the deuterons with a target made from carbon and subsequent subtraction of the dC missing mass spectra from the dCH_2 ones.

Two variants of subtraction procedure were presented. First one uses cut1 which leads to results with higher statistics, but some part of signal is shifted to higher values (above 940 MeV) of the missing mass spectra. Second one uses cut2 which caused lower statistics, but events are localized in the vicinity of the rest mass of neutron.

It was noted that the simulated missing mass spectra on CH_2 are normalized according to those of their regions where only carbon content is located. However, the normalization is questionable if the region with only the carbon content is very narrow, which can be also due to a large content of the misplaced dp breakup events, i. e. the signal events with the incorrect value of the missing mass. To conclude, our GEANT4 modeling suggests that the subtraction procedure may be a useful tool for separating the dp breakup events from the rest of the events originating in the deuteron collisions with the CH_2 target.

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