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# COMPARISON OF THE JISP16 AND THE AV18 FORCES-BASED PREDICTIONS FOR THE DIFFERENTIAL CROSS SECTION AND THE NUCLEON ANALYSING POWER IN $d(n, nn)p$ REACTION*

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The JISP16 nucleon–nucleon potential has been applied to explore the nucleon-induced deuteron breakup process at the incoming nucleon laboratory energy $E = 65$ MeV. We have found that the JISP16 model generally gives predictions for the differential cross section and the nucleon analysing power, which are similar to the ones obtained with the standard realistic nucleon–nucleon AV18 potential. However, there are some regions of the phase space, for which the cross section and the analysing power differ by approximately 50%. These kinematical configurations could be used to refit the JISP16 potential parameters.

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## 1. Introduction

The JISP16 potential [1] is a contemporary model of the nucleon–nucleon ($NN$) interaction derived within the inverse scattering method. Its free parameters have been fixed by fitting to the $NN$ phase shifts, bound and excited states of nuclei up to oxygen-16. This unusual method of fixing parameters allows one to study many-nucleon systems without using many-nucleon interactions. It was shown that the JISP16 model works well in the nuclear structure calculations [2]. Nevertheless, we have recently found [3] that the JISP16 potential fails in the description of some observables in the elastic nucleon–deuteron scattering process. The reason for the behaviour

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was traced back to the P-wave components of the JISP16 potential. In this contribution, we explore the usefulness of the nucleon–deuteron breakup process in more detailed investigations of this $NN$ force model.

The final-state kinematics for the nucleon–deuteron breakup reaction is specified by five variables, for example by the polar and azimuthal angles corresponding to the momentum of nucleon 1 ($\theta_1$,$\varphi_1$) and the momentum of nucleon 2 ($\theta_2$,$\varphi_2$) as well as the energy of nucleon 1 ($E_1$). In some cases, this set gives two physical solutions for the energy of nucleon 2, so the arc length $S$ for the kinematical locus in the $E_1-E_2$ is used instead of $E_1$ to yield a unique definition of the three-body kinematics. Various dynamical and kinematical aspects dominate the cross section in different parts of the three-nucleon phase space and this allows one for more systematic and detailed studies of the nucleon–nucleon interaction than these available *e.g.* in the elastic scattering process [4].

## 2. Formalism and methods

We use the framework of the Faddeev equations to compute the transition amplitude and, consequently, the differential cross section and the nucleon analysing power. In this approach, the Faddeev equation for an auxiliary state $T|\phi\rangle$ plays a central role. It reads in our case [4]

$$T|\phi\rangle = tP|\phi\rangle + tPG_0T|\phi\rangle \,, \tag{1}$$

where the initial state $|\phi\rangle$ is composed of a deuteron and a relative momentum eigenstate of the projectile nucleon, $P$ is a permutation operator, $G_0$ is the free $3N$ propagator, and $t$ is the solution of the Lippmann–Schwinger equation for the two-nucleon t-matrix for the $NN$ interaction $V$.

In order to investigate the properties of the JISP16 potential, we chose the incoming nucleon energy to be $E_{\rm initial} = 65$ MeV. For this energy, we have solved Eq. (1) twice, once using the JISP16 interaction and then employing the AV18 potential [5]. Next, we scanned the whole phase space using a grid of 45 points for the $\theta_1$ and $\theta_2$ polar angles in the range of (0°, 180°), 45 points for the relative azimuthal angle $\varphi_{12} = |\varphi_2 - \varphi_1|$ in the range of (0°, 180°) for the cross sections and in the range of (0°, 360°) for the nucleon analysing power, and a fine step of 0.1 MeV along the arc length $S$ parameter. At each point on this four-dimensional grid, we evaluated the transition matrix elements and finally the selected exclusive observables both with the JISP16 and AV18 $NN$ potentials. The results for the AV18 force are used as reference values. In our calculations, we applied additional threshold cuts, skipping configurations (in practice immeasurable) with very low energies of the outgoing nucleons and/or very small cross sections. In order to quantify the discrepancy between the predictions based on the two different models of the $NN$ interaction, we calculated a relative difference for the cross sections and the analysing power, using the following formula:

$$\varDelta \equiv \varDelta(\theta_1,\theta_2) = \max\left[\frac{\mathrm{Obs}_{\mathrm{JISP16}} - \mathrm{Obs}_{\mathrm{AV18}}}{\frac{1}{2}\left(\mathrm{Obs}_{\mathrm{JISP16}} + \mathrm{Obs}_{\mathrm{AV18}}\right)}\right]_{\{\phi_1,\phi_2,S\}}, \tag{2}$$

where $\mathrm{Obs} = \frac{\mathrm{d}^5\sigma}{\mathrm{d}\varOmega_1\mathrm{d}\varOmega_2\mathrm{d}S}(\theta_1,\phi_1,\theta_2,\phi_2,S)$ or $A_y(\theta_1,\phi_1,\theta_2,\phi_2,S)$ and $\mathrm{d}\varOmega_1 = \sin\theta_1\mathrm{d}\theta_1\mathrm{d}\varphi_1$, $\mathrm{d}\varOmega_2 = \sin\theta_2\mathrm{d}\theta_2\mathrm{d}\varphi_2$.

Extreme values of $\varDelta$, shown in Figs. 1 and 2, allow one to identify phase-space regions with a strong deviation between the JISP16- and AV18-based predictions. The data taken in these areas could be used to refit the JISP16 parameters. The following maps enable, in the convenient way, the identification of regions which might be of interest in this context.

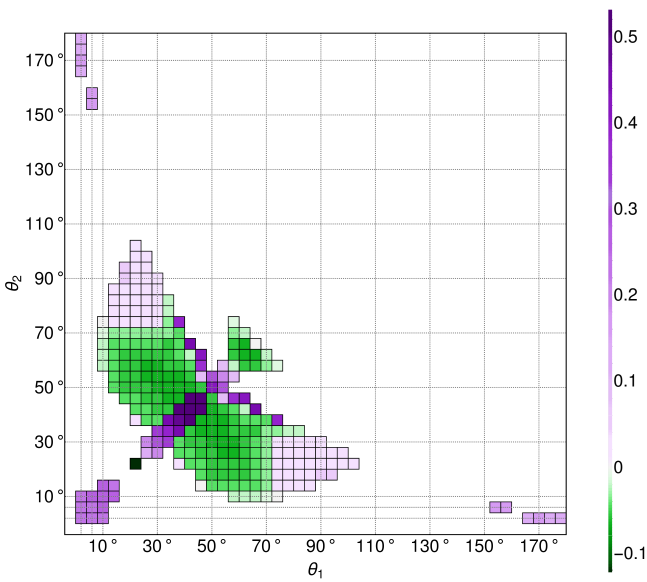


Fig. 1. The distribution of $\varDelta_{\text{cross section}}$ for the deuteron breakup at $E_i = 65$ MeV.

## 3. Conclusions

We have found kinematical configurations of the nucleon–deuteron breakup for which the difference between predictions for the exclusive cross section and for the nucleon analysing power obtained with the JISP16 and with the AV18 force amounts up to 50% for nucleon-induced energy of 65 MeV. Such configurations can be identified with maps, such as those presented in this paper. Many of these interesting configurations seem to be experimentally accessible.

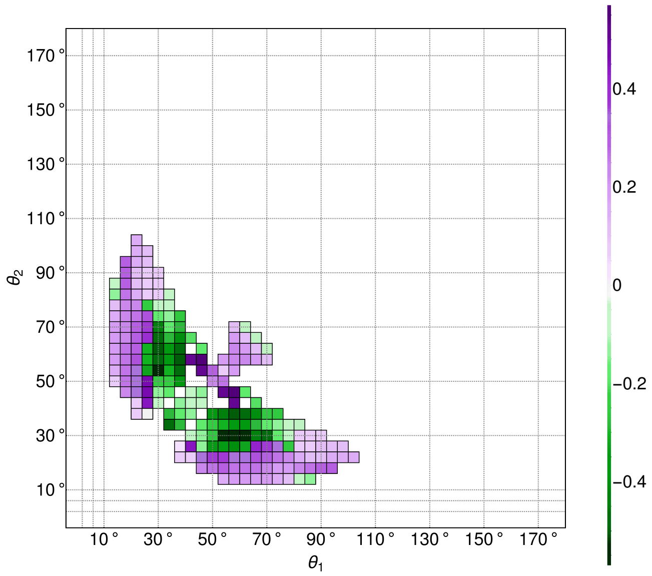


Fig. 2. The distribution of $\Delta_{\text{analys power}}$ for the deuteron breakup at $E_i = 65$ MeV.

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