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The differential cross section for the dp-elastic scattering at 500 to 900 MeV/nucleon

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Abstract. The results of the differential cross section measurements of dp-elastic scattering at energies from 500 to 900 MeV/nucleon at Nuclotron JINR are reported. The data were obtained for the angular range of 70-120° in the center-of-mass (c.m.s.). The results are compared with existing world data.

1 Introduction

The dp-elastic scattering is the simplest reaction to study the deuteron structure. The experimental material for this reaction covers the energy range from tens to thousands MeV/n [1]-[9]. The theoretical approaches based on the solution of the three-particle Schroedinger equation [10–12] and on the Faddeev calculations [13, 14] are described of the three-nucleon scattering with high accuracy at energies below 200 MeV/n [15, 16]. The theoretical calculations using not only 2N forces but also different 3N forces [17, 18] give the best agreement with experimental data. However, the discrepancy between the theory and experiment increases with the energy increasing. The Glauber scattering theory which takes both single and double interactions is a classic approach at the energies higher than 400 MeV/n. [19, 20]. The experimental data can be fitted with a relativistic multiple-scattering theory which uses off-mass-shell extrapolations of the nucleon-nucleon amplitudes suggested by the structure of derivative meson-nucleon couplings [21, 22].

The new differential cross section data were obtained at internal target station ITS [23] at Nuclotron at the energy of 1000 MeV/n [6]. Recently, the deuteron vector and tensor analyzing powers have been obtained at 440 MeV/n [25]. The preliminary data on the differential cross section for dp-elastic scattering at energies from 500 to 900 MeV/n, obtained at ITS at Nuclotron are presented in this paper.

2 Experiment and data analysis

The measurements were performed at ITS [23] at Nuclotron JINR by using new ITS DAQ system [26]. Two pairs of scintillation detectors placed symmetrically with respect to the beam direction

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Table 1. Characteristics of detectors.

Detector	Size,mm^3	Distance from target,cm	Angular span,deg	
			lab.sys.	c.m.s.
P	20x60x20	58	2	4
D	10x40x24	56	1	2
PP	50x50x10	56	5	10

were used to register the elastically-scattered deuterons and protons. Also two scintillation counters (PP-detectors) were used to register the quasi-elastically scattered protons. All counters based on the Hamamatsu H7416MOD PMT were used previously in the experiment [25]. The DP-detectors were rotated to give an angular range of the θ_{lab} = 19° to 50° ($\theta_{c.m.}$ = 70° to 120°). The PP-detectors were mounted at the angle corresponding to quasi-elastic scattering at $\theta_{c.m.}$ = 90° and remained stationary throughout the experiment at each energy. The size of the scintillation detectors, distances to the target, angular spans in the laboratory system and c.m.s. are shown in table 1. The layout of the counters with respect to the beam direction is shown in figure 1.

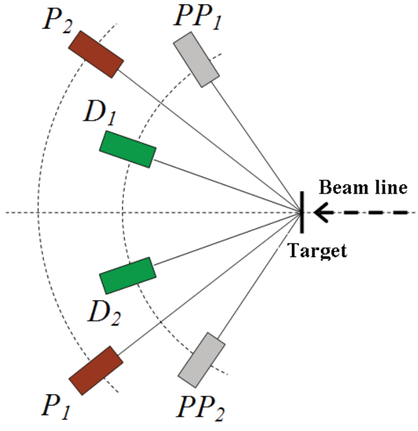

Figure 1. Layout of the counters with respect to the beam direction. $D_{1,2}$, $P_{1,2}$- deuteron and proton detectors, $PP_{1,2}$- detectors to register the pp-quasi-elastic scattering.

The procedure to obtain differential cross section data was realized by analysis of the amplitude and timing spectra. The estimation of the background in the amplitude data was performed by using the temporary gates on the deuteron and proton time difference spectra. The subtraction of the timing signal from deuteron- and proton- counters for 650 MeV/n is shown in figure 2. In this distribution the dp - elastic scattering events (I domain) and the background (II and III domains) are selected so that the widths of both domains are equal. The amplitude distribution for proton counter obtained by using these timing gates is shown in figure 3 A. The subtraction of the resulting spectra allows to reduce the background (figure 3 B).

The next stage is the CH_2-C subtraction procedure. The carbon background subtraction normalization coefficient k is deduced from the interval $a_{min} < a < a_{max}$, where a - channels of CH_2- and

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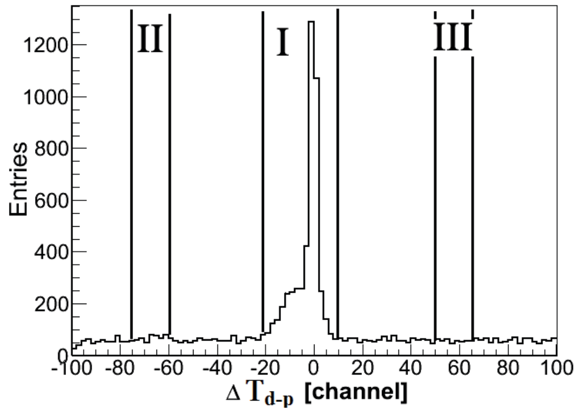

Figure 2. The time difference of signals arrival from the deuteron and proton counters for $\theta_{c.m.}$ = 73° at 650 MeV/n.

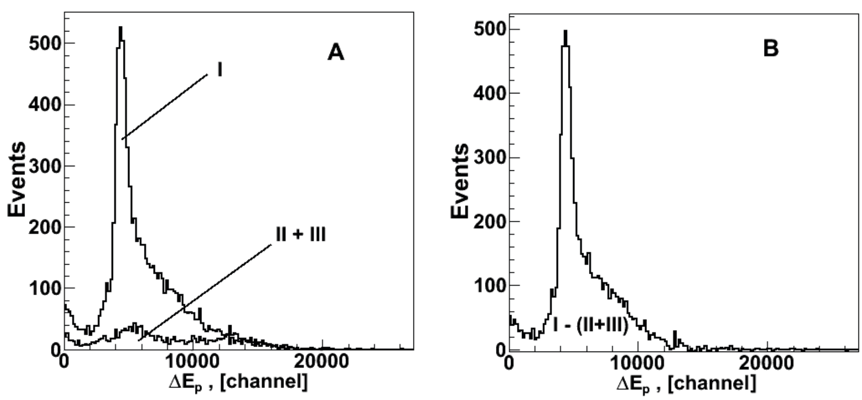

Figure 3. The background subtraction procedure for the amplitude spectrum of proton counter for $\theta_{c.m.}$ = 73° at 650 MeV/n.

C-amplitude distributions:

$$k = \frac{N_{CH_2}|_{a_{min}<a<a_{max}}}{N_C|_{a_{min}<a<a_{max}}}. \tag{1}$$

Here N_{CH_2} and N_C - CH_2 - and C - amplitude distributions integrals in a - interval within the window shown in figure 4 A by the solid lines. The carbon background can be then subtracted as:

$$N_{dp} = N_{CH_2} - kN_C, \tag{2}$$

where N_{dp} is the resulting dp - elastic scattering distribution, N_{CH_2} is the total CH_2 - distribution, kN_C is the normalized C - distribution within the window shown in figure 4 B by the dotted lines.

In figure 4 A the CH_2 - distribution is shown by the solid line. The normalized C - spectrum is shown by the dotted line. In figure 4 B the result of subtraction is demonstrated. Such procedure was performed for proton amplitude spectra for each $\theta_{c.m.}$.

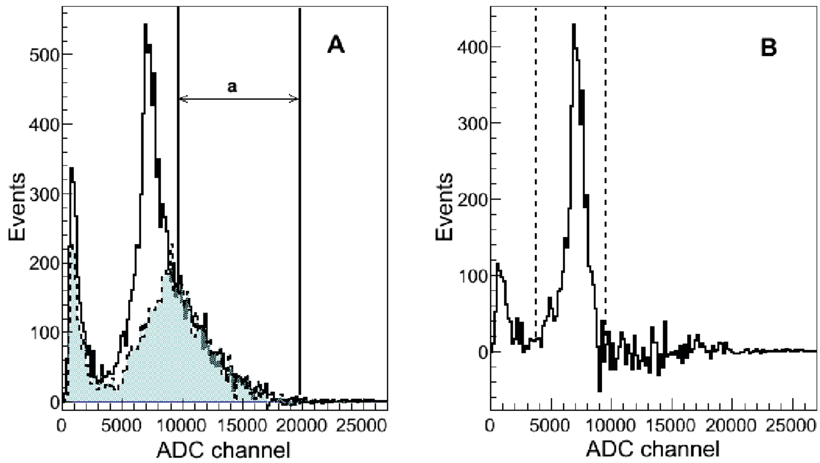

Figure 4. The procedure of CH_2 - C subtraction for $\theta_{c.m.} = 73°$ at 650MeV/n. A - is the CH_2- and normalized C- distributions given by the solid and dotted histograms, respectively, vertical solid lines - is the interval of the normalization. B - is the result of $CH_2 - C$ subtraction, vertical dashed lines are the gates indicating the domain of the dp-elastic scattering events.

3 Differential cross section

The experimental data for 650 MeV/n were normalized to the data [5]. The normalization factor for this energy was used to obtain the differential cross section for other energies. The differential cross section angular dependence [5] was approximated by the function $f(\theta_{c.m.}) = P_0 exp(P_1 \theta_{c.m.})$ in angular range $71° < \theta_{c.m.} < 108°$. The obtained parameters P_0 and P_1 were fixed. After this our data at 650 MeV/n was approximated by the function $C^{650}_{norm} f(\theta_{c.m.})$. The calculated value is equal to $C^{650}_{norm} = 79.98 \pm 5.29$ mb. The obtained differential cross section angular dependence at 650 MeV/n is shown in figure 5. The normalization factor C^{700}_{norm} at 700 MeV/n was calculated as composition $C^{650}_{norm} R$, where R - ratio of the pp – elastic cross section at 650 MeV and at 700 MeV in the PP – monitor counter angular span in the c.m.s. which is equal to $R = 1.22 \pm 0.05$. Analogous procedure was performed for 500 and 900 MeV/n. The differential cross section for 700,500 and 900 MeV/n are shown in figure 6,7,8.

One can see, that the new results are in agreement with the behavior of the world data.

4 Conclusion

The procedure on the dp-elastic scattering differential cross section at high energies at ITS at Nuclotron using CH2 - C subtraction is established.

The preliminary differential cross section data for dp - elastic scattering at 500, 700 and 900 MeV/n are obtained. New results are compared with the existing data for similar values of energies. The data are in reasonable agreement.

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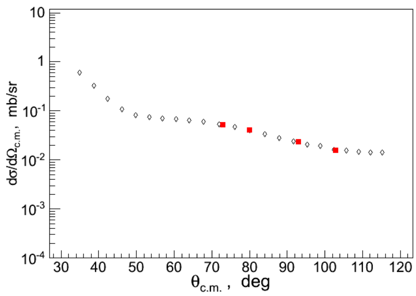

Figure 5. The differential cross section for dp-elastic scattering at 650 MeV/n. Squares - the results of this work, triangles - data from [5].

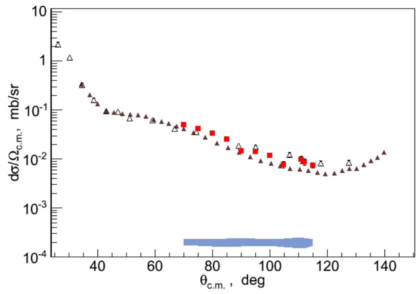

Figure 6. The differential cross section for dp-elastic scattering at 700 MeV/n. Squares - the results of this work, solid band - the systematic errors, open triangles - data from [5], solid triangles - data from [7].

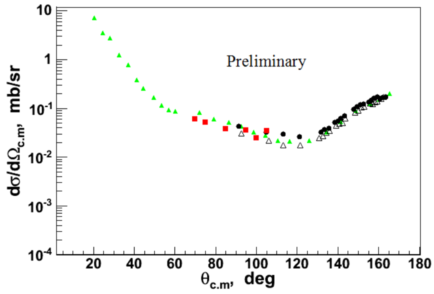

Figure 7. The differential cross section for dp-elastic scattering at 500 MeV/n. Squares - the results of this work, circles – data at 470 MeV/n [3], open triangles – data at 590 MeV/n [3], full triangles – data from 580 MeV/n [4].

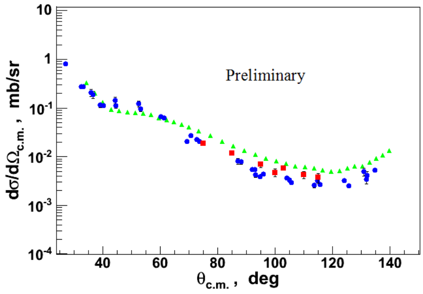

Figure 8. The differential cross section for dp-elastic scattering at 900 MeV/n. Squares - the results of this work, circles – data at 1000 MeV/n [8], triangles - data from 800 MeV/n [7].

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