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ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА. ЭКСПЕРИМЕНТ

THE CROSS-SECTION IN dp-ELASTIC SCATTERING AT THE ENERGIES OF 500, 700 AND 880 MeV OBTAINED AT THE INTERNAL TARGET STATION OF NUCLOTRON

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The results on the cross-section of dp-elastic scattering reaction obtained at 500, 700 and 880 MeV at the internal target of Nuclotron are presented. The measurements have been performed using CH_2 and C targets and kinematic coincidence of signals from scintillation counters. The cross-section data are compared with theoretical predictions and results of previous experiments.

Представлены результаты получения сечения реакции dp-упругого рассеяния на внутренней мишени нуклотрона. Измерения были выполнены с использованием CH_2- и C-мишеней и кинематического совпадения сигналов со сцинтилляционных детекторов. Проведено сравнение сечения с теоретическими предсказаниями и результатами предыдущих экспериментов.

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INTRODUCTION

The study of the deuteron–proton elastic scattering has a long history. The first nucleon–deuteron experiments were already performed in the fifties of the last century [1–7]. Differential cross-section and nucleon analyzing powers [5–7] were measured at few hundred MeV. Nowadays this reaction is still subject to investigation [8–10].

The purpose of DSS (Deuteron Spin Structure) project is the broadening of the energy and angular ranges of measurement of different observables in processes, including 3-nucleon systems. The main aim of offered experiment program is to obtain information on the spin depending part of 3-nucleon forces. DSS project experimental program includes 2 experiments, one of which is the experiment on dp-elastic scattering study. It includes measurement of cross-section, vector A_y, tensor A_{yy}, and A_{xx} analyzing powers in dp-elastic scattering in the range from 300 to 2000 MeV of the deuteron kinetic energy [11].

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The goal of present investigation is to measure the cross-section of dp-elastic scattering at the energies of 500, 700 and 880 MeV using the kinematic coincidences of deuteron and proton with plastic scintillation counters. Measurements were performed using polyethylene and carbon targets and procedure of CH_2–C time difference spectra subtraction [12, 13]. The data are compared with the calculation of relativistic multiple scattering model [14].

1. EXPERIMENT AT INTERNAL TARGET STATION OF NUCLOTRON

The schematic view of the experiment on dp-elastic scattering study at Internal Target Station (ITS) of Nuclotron is shown in Fig. 1. The setup consists of 4 proton and deuteron scintillation detectors (P and D) based on FEU-85 photomultiplier tubes. The amplitudes of the signals and timing information from both the P and D detectors were recorded for each event. Each detector (Fig. 2) consists of 2 scintillation counters and has geometric acceptance 20×30 mm. Scintillators have thickness 4 mm (first) and 20 mm (second), respectively. Coincidences of the signals from both counters are used as a trigger. Information about particle energy losses was obtained using second counter (thick plastic scintillator).

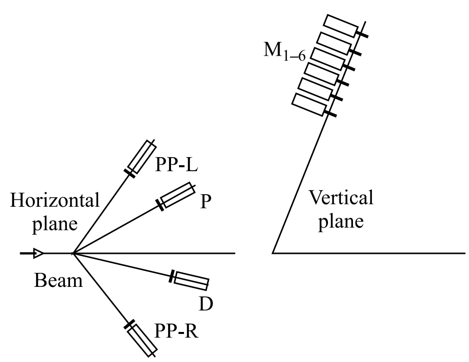

Fig. 1. Scheme of the experimental setup at the internal target station: P — proton detector; D — deuteron detector; PP-L and PP-R are the detectors for pp-quasi-elastic scattering; M_{1-6} — monitor counters

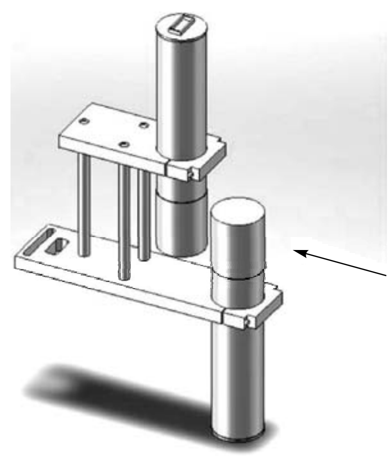

Fig. 2. Detector for registration of protons and deuterons

The signals from the P and D detectors give coincidences for dp-elastic and quasi-elastic reactions, PP-L and PP-R register protons from pp-quasi-elastic reaction. This reaction is used as the relative intensity monitor of the interaction between the beam and the target for calculation of cross-section of dp-elastic scattering reaction. This monitor can be also used for polarization measurements because PP-detectors are located at 90° in c.m.s. and are nonsensitive to the beam polarization.

Measurements were performed using the 500-, 700- and 880-MeV deuteron beam, polyethylene and carbon targets. Deuteron and proton detectors were placed in the kinematic coincidence.

2. DATA ANALYSIS

The distributions of the amplitudes for scattered deuterons and recoil protons for polyethylene target at 880 MeV are presented in Fig. 3, *a* and *b*, respectively. The correlation of the amplitudes and time difference between signals for proton and deuteron detectors are shown in Fig. 3, *c* and *d*. One can see clean correlation between the amplitudes from P and D detectors and well-pronounced peak in time difference spectrum corresponding to the *dp*-elastic scattering events. The measurements on carbon target were also performed to estimate the carbon contribution from the polyethylene target.

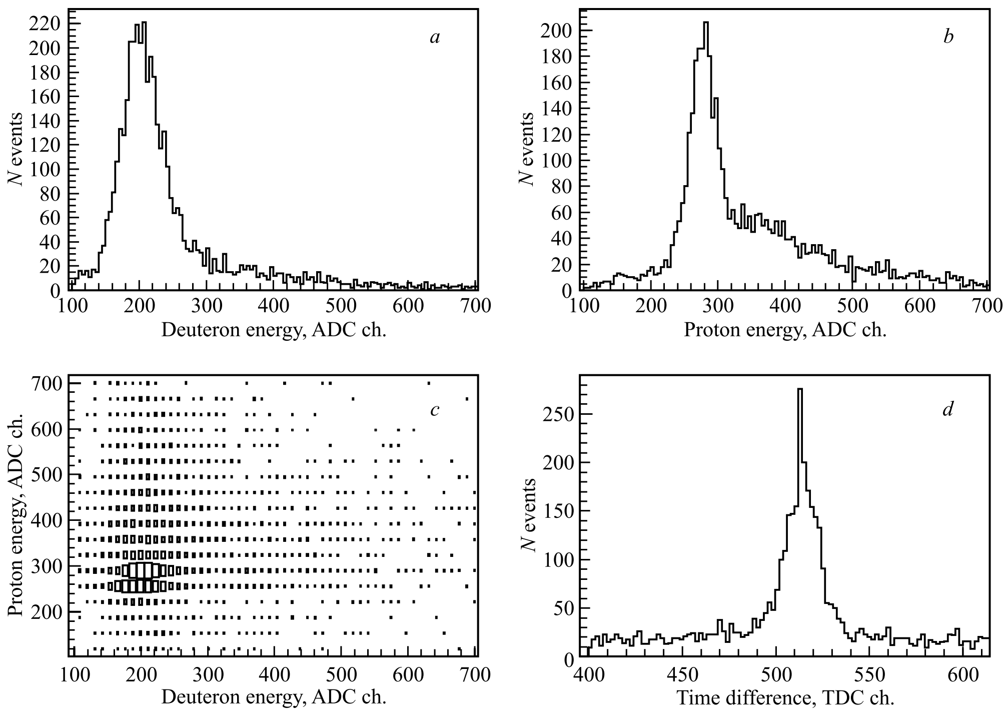

Fig. 3. Data obtained with polyethylene target at 880 MeV: distributions of the amplitudes for scattered deuterons (*a*) and recoil protons (*b*). The correlation of the amplitudes (*c*) and time difference between signals for proton and deuteron detectors (*d*)

The first stage of *dp*-elastic scattering events selection is the application of temprorary gates on the deuteron and proton time difference spectra to see the behaviour of the ADC data (Fig. 4). ADC correlation with and without TDC gates is shown in Fig. 5, *a* and *b*, respectively. The second stage of the analysis is the application of the criteria on the signal amplitudes correlation from the deuteron and proton detectors (Fig. 5, *b*). This allows significant reduction of the background in the time difference spectrum shown in Fig. 4, *a*. The same graphical cut was imposed for the data obtained with the carbon target. The graphical criteria for PP

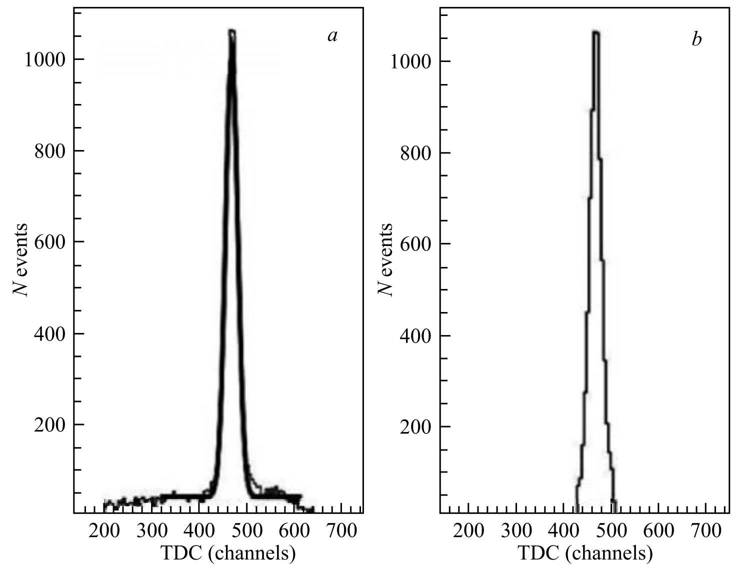

Fig. 4. Application of the gates on deuteron–proton time difference spectra: *a*) spectra without gates, *b*) spectra with gates. The fit is presented by the solid line

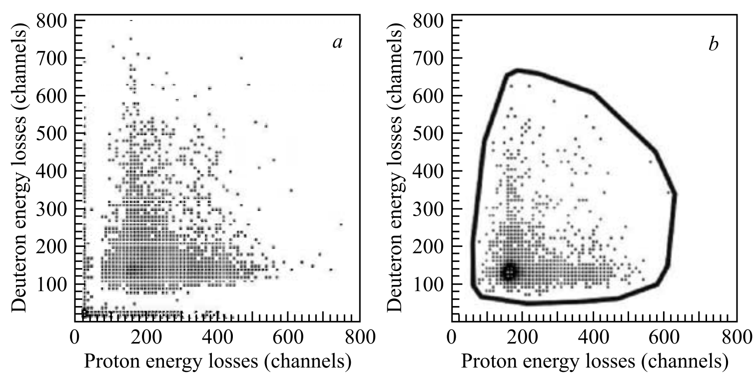

Fig. 5. Correlations of proton and deuteron energy losses: *a*) without TDC gates, *b*) with TDC gates. ADC criterion is presented by the solid line

detectors are the same for each angle because PP detectors were not moved. The graphical criteria for D and P detectors are different depending on the scattering angle. The time difference for polyethylene and carbon targets after application of the graphical cut on the amplitudes correlation are shown in Fig. 6, *a* and *b*, respectively. The relative normalization of the spectra was obtained from the ratio of the background events placed to the left and right from the peak. It is posible because background in CH_2 spectra corresponds to carbon contribution in CH_2 data. It should be noted that as the energy increases, the carbon contri-

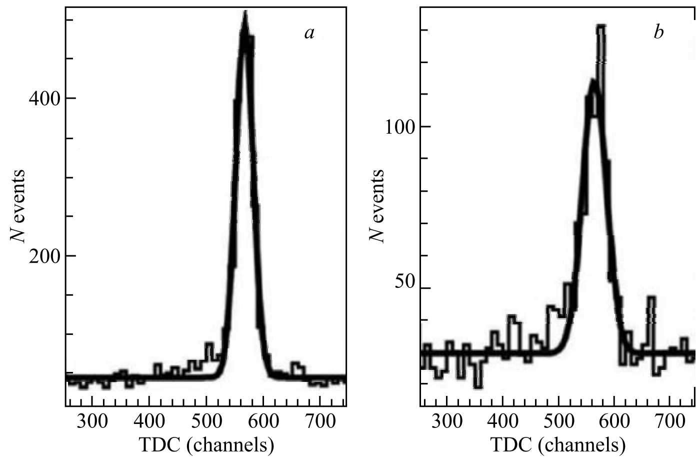

Fig. 6. Normalization of TDC spectra: *a*) polyethylene data; *b*) carbon data

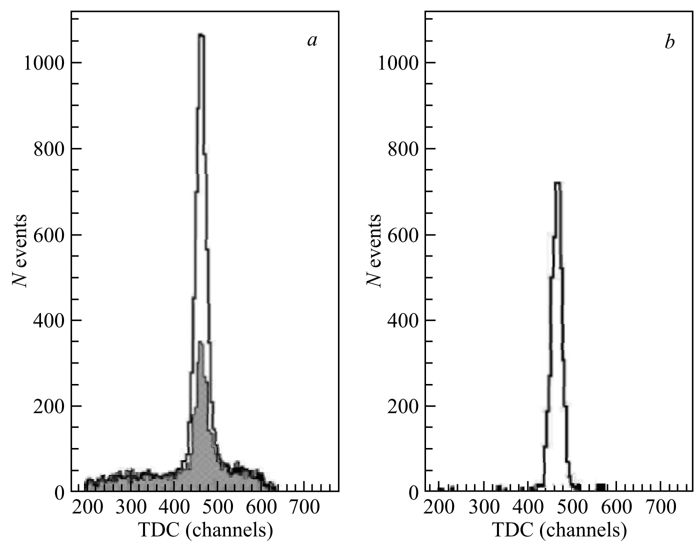

Fig. 7. Procedure of CH_2–C subtraction (*a*) and result of subtraction (*b*). White spectra are CH_2 data, gray spectra are C data

bution increases as well. The time difference spectra in Fig. 6, *a* and *b* were fitted by the sum of Gaussian and constant. The ratio of the obtained constants was considered a normalization factor.

The procedure of the CH_2–C normalized time difference spectra subtraction [12, 13] for 880 MeV is presented in Fig. 7. The relative normalization of the *d*p-elastic scattering data was performed using *pp*-quasi-elastic scattering data.

3. RESULTS OF THE CROSS-SECTION MEASUREMENTS

Angular dependences of the dp-elastic scattering cross-section obtained at 500, 700 and 880 MeV are represented by solid symbols in Figs. 8–10, respectively. The experimental data obtained at Nuclotron are normalized to the theoretical calculation performed within relativistic multiple scattering model [14] at the 60° c.m.s. These calculations take into account the single scattering one-nucleon exchange and double scattering terms. The dashed curves are obtained by the consideration of only single scattering and the nucleon exchange. One can see that the contribution of the double scattering at the angles larger than 70° c.m.s. increases as the energy grows. The shape of the angular dependence of the relatively normalized data

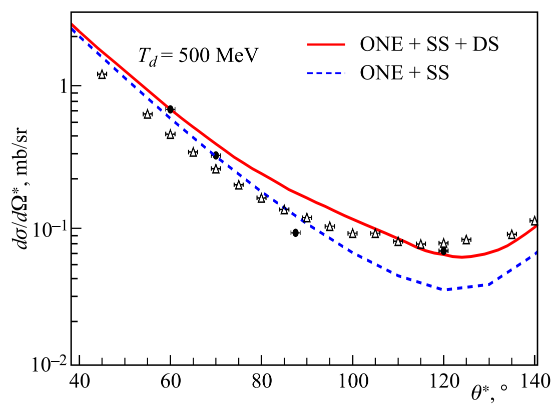

Fig. 8. The differential cross-section of dp-elastic scattering at the deuteron energy of 500 MeV obtained at Nuclotron and RCNP [8] is depicted by solid and open symbols, respectively. The solid and dashed curves are the results of the calculations within relativistic multiple scattering model [14] with and without taking into account the double scattering term, respectively

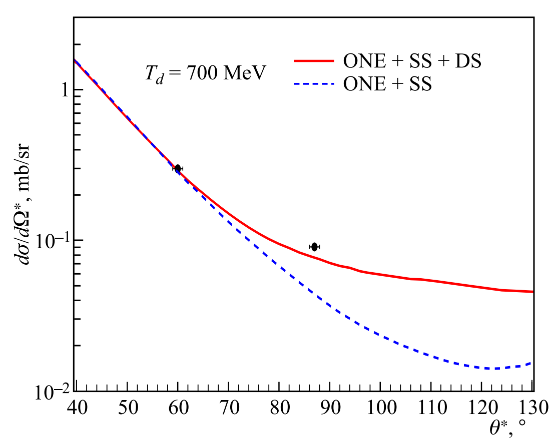

Fig. 9. The differential cross-section of dp-elastic scattering reaction at the deuteron energy of 700 MeV obtained at Nuclotron. The lines are the same as in Fig. 8

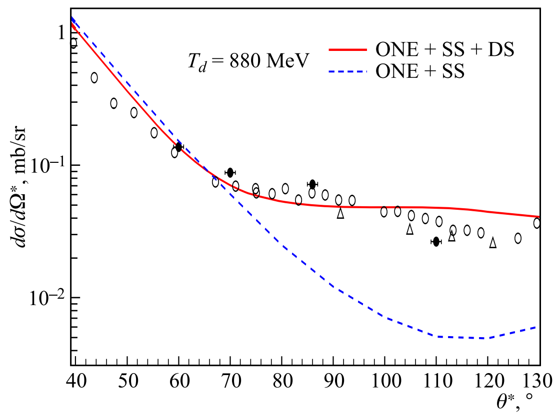

Fig. 10. The differential cross-section of dp-elastic scattering reaction at the deuteron energy of 880 MeV obtained at Nuclotron is shown by solid symbols. Open circles and triangles are the data from [16] and [15], respectively. The lines are the same as in Fig. 8 in relative normalization on degrees in c.m.s. (solid symbols)

obtained at Nuclotron at the energies of 500 and 880 MeV agrees with the behaviour of the previously obtained data [8, 15, 16].

CONCLUSION

The following results have been obtained:

• The results of the cross-section measurement using CH_2–C subtraction in dp-elastic scattering at the energies of 500, 700 and 880 MeV have been obtained. The angular dependence has been obtained using relative normalization to pp-quasi-elastic scattering at 90° c.m.s. The data demonstrate good agreement with results of previous experiments at all deuteron scattering angles. The deviation of theoretical predictions (relativistic multiple scattering model) with the experimental data is observed at the deuteron scattering angles above 100° c.m.s.

• The goal for the nearest runs is to measure the cross-section of dp-elastic scattering reaction in wide deuteron energy range with the step not more than 100 MeV in the region from 500–1000 MeV. This is needed for an experiment to measure analyzing powers for the dp-elastic scattering [11].

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REFERENCES

1. *Schramberger R. D.* // Phys. Rev. 1952. V. 85. P. 424.
2. *Chamberlain O., Stern M.O.* // Phys. Rev. 1954. V. 94. P. 666.
3. *Chamberlain O., Clark D. D.* // Phys. Rev. 1956. V. 102. P. 473.
4. *Creve A. V. et al.* // Ibid. V. 114. P. 473.
5. *Marshall L. et al.* // Phys. Rev. 1954. V. 95. P. 1020.
6. *Marcowitz S.* // Phys. Rev. 1960. V. 120. P. 891.

7. *Postma H., Wilson R.* // Phys. Rev. 1961. V. 121. P. 1229.
8. *Hatanaka K. et al.* // Phys. Rev. C. 2002. V. 66. P. 107.
9. *Ersmish K. et al.* // Phys. Rev. C. 2005. V. 3. P. 044002.
10. *Kurilkin P. K. et al.* // Eur. Phys. J. ST. 2008. V. 162. P. 137.
11. *Uesaka T. et al.* // Phys. Part. Nucl. Lett. 2006. V. 3. P. 305.
12. *Gurchin Yu. V. et al.* // Phys. Part. Nucl. Lett. 2011. V. 8. P. 571.
13. *Gurchin Yu. V. et al.* // Ibid. P. 566.
14. *Ladygina N. B et al.* // Eur. Phys. J. A. 2009. V. 42. P. 91.
15. *Alder J. C. et al.* // Phys. Rev. C. 1972. V. 6. P. 2010.
16. *Booth N. E. et al.* // Phys. Rev. D. 1971. V. 4. P. 1261.

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