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THE INVESTIGATION OF SHORT-RANGE ^{3}He, ^{3}H, AND DEUTERON SPIN STRUCTURE VIA THE MEASUREMENT OF THE ANGULAR DISTRIBUTIONS OF THE ANALYZING POWER IN THE $\vec{d}d \to {}^3\mathrm{He}n$ AND $\vec{d}d \to {}^3\mathrm{H}p$ REACTIONS AT 140, 200, AND 270 MeV

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The data on the vector A_y and tensor A_{yy}, A_{xx}, and A_{xz} analyzing powers of the $\vec{d}d \to {}^3\mathrm{He}n$ and $\vec{d}d \to {}^3\mathrm{H}p$ reactions obtained at intermediate energies at RARF (RIKEN, Japan) are presented. The high-precision experimental data are compared with the theoretical calculation within the one-nucleon exchange model by using the standard ^{3}He, ^{3}H, and deuteron wave functions. The data demonstrate the sensitivity to the short-range ^{3}He, ^{3}H, and deuteron spin structure.

Представлены данные по векторной A_y и тензорным A_{yy}, A_{xx}, A_{xz} анализирующим способностям реакций $\vec{d}d \to {}^3\mathrm{He}n$ и $\vec{d}d \to {}^3\mathrm{H}p$, полученные при промежуточных энергиях в RARF (RIKEN, Япония). Высокоточные экспериментальные результаты сравниваются с теоретическими расчетами, основанными на модели однонуклонного обмена при использовании стандартных волновых функций ^{3}He (^{3}H) и дейтрона. Экспериментальные данные демонстрируют чувствительность к спиновой структуре ^{3}He, ^{3}H и дейтрона на малых межнуклонных расстояниях.

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INTRODUCTION

The spin structure of light nuclei has been extensively investigated during the last decades. The main purpose of the studies at intermediate and high energies is to obtain the information on the high-momentum components of the light nuclei and to search for the manifestation of the non-nucleonic degrees of freedom. The essential amount of the experimental data sensitive to the structure of light nuclei have been accumulated. Large discrepancies between the Nd data and theoretical predictions based on exact solution of the Faddeev equations with modern NN potential are reported [1,2]. The inclusion of the 2π-exchange 3NF models into theoretical calculations removes many of them. In contrast, theoretical calculations with 3NFs still meet difficulties in reproducing data of some spin observables [3, 4]. In this respect, the study of the ^{3}H and ^{3}He is particularly interesting, because these nuclei represent an important testing ground for models of the NN interaction and for studies of the many-body aspects of the strong interaction in nuclei. The $\vec{d}d \to {}^3\mathrm{He}n$ ($^3\mathrm{H}p$) reactions with large momentum transfer can be used as an effective tool to investigate the structure of ^{3}H and ^{3}He at short distances.

The experiment on the measurement of the analyzing powers for these reactions has been performed at RIKEN. Physics motivation of experiment at RIKEN is the investigation of the spin structure of the ^{3}H, ^{3}He, and a deuteron at the energies 140, 200, and 270 MeV.

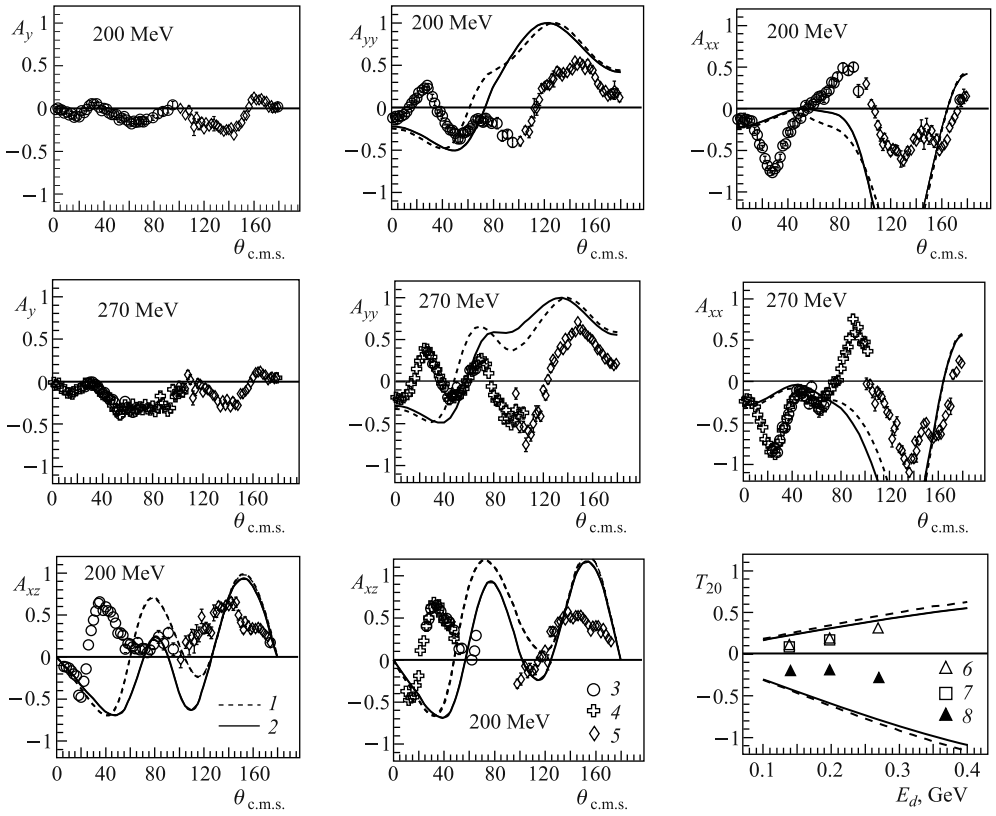
1. EXPERIMENT

Experiment on the measurement of the vector A_y and tensor A_{yy}, A_{xx}, A_{xz}, T_{20} analyzing powers for the $\vec{d}d \to {}^3\mathrm{H}p$ ($^3\mathrm{He}n$) reactions was performed at RARF (RIKEN Accelerator Researh Facility). The polarized deuteron beam was accelerated by AVF and Ring Cyclotrons up to the energies of 140, 200, 270 MeV and was transported to the target. The measurement of the beam polarization was carried out with the help of Swinger and Droom polarimeters. The scattered particles (^{3}He, ^{3}H, p) were registered by the spectrometer SMART. The identification of the particles was based on the time of light and on the value of ionization losses in the plastic scintillator detectors. Further details on the experiment are described elsewhere [5, 6].

2. RESULTS

The experimental results on the vector and tensor analyzing powers of the $\vec{d}d \to {}^3\mathrm{H}p$ ($^3\mathrm{He}n$) reactions are presented in the Figure. The errors of the experimental values include both the statistical and the systematic ones. The systematic errors were derived from the errors of the beam polarizations measurements. The dashed curves in the Figure are the results of ONE [7] calculations using Paris deuteron and ^{3}He wave functions [8]. The solid curves are the results of ONE calculations using CD-Bonn deuteron and ^{3}He wave functions [8].

One can see that ONE calculations are in qualitative agreement with the data on the T_{20} in the collinear geometry. But they don't reproduce the behavior of the tensor A_{yy}, A_{xx}, and A_{xz} analyzing powers in the full angular range. ONE model calculation reproduces only the signs of the tensor analyzing powers at forward and backward angles. Some structures in



Analyzing powers of the $\vec{d}d \to {}^3\text{He}n$ and $\vec{d}d \to {}^3\text{H}p$ reactions: *1* — predictions of ONE model by using Paris deuteron and ^{3}He wave functions; *2* — predictions of ONE model by using CD-Bonn deuteron and ^{3}He wave functions; *3, 4, 5* — values of analyzing powers in the cases when ^{3}H, ^{3}He, and a proton were registered; *6, 7, 8* — correspond to the $\vec{d}d \to {}^3\text{He}n$ (0°), $\vec{d}d \to {}^3\text{H}p$ (0°), and $\vec{d}d \to {}^3\text{H}p$ (180°) reactions, respectively

the experimental results on A_y indicate the possibility of other mechanisms in these reactions since the vector analyzing power A_y equals zero in ONE model.

The reason of such discrepancies can be both in the inadequate description of the 3N-bound state spin structure and/or in more complicated reaction mechanism. These high-precision experimental data are important for the development of the theoretical description of the short-range spin structure of the light nuclei and mechanisms of these reactions.

CONCLUSION

• The results on the vector A_y and tensor A_{yy}, A_{xx}, and A_{xz} analyzing powers of the $\vec{d}d \to {}^3\text{H}p$ ($^3\text{He}n$) reactions at the energy of initial deuterons of 200 and 270 MeV have been obtained. The data demonstrate large values of the analyzing powers.

• The experimental data were compared with the ONE calculations using ^{3}He and deuteron wave functions derived from CD-Bonn and Paris potentials. The deviations between the data

and theoretical calculations indicate the possibility of other mechanisms in these reactions. Also, problem may be in inadequate description of the spin structure of ^{3}He and ^{3}H. The obtained experimental data require further development of the theoretical approaches.

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REFERENCES

1. *Sekiguchi K. et al.* Resolving the Discrepancy of 135 MeV pd Elastic Scattering Cross Sections and Relativistic Effects // Phys. Rev. Lett. 2005. V. 95. P. 162301.
2. *Stephenson E. J. et al.* Indications on Three-Nucleon Force Effects in the Proton Analyzing Power for 70–200 MeV $\vec{p} + d$ Elastic Scattering // Phys. Rev. C. 1999. V. 60. P. 061001(R).
3. *Maeda Y. et al.* Differential Cross Section and Analyzing Power Measurements for $\vec{n}d$ Elastic Scattering at 248 MeV // Phys. Rev. C. 2007. V. 76. P. 014004.
4. *Hatanaka K. et al.* Cross Section and Complete Set of Proton Spin Observables in $\vec{p}d$ Elastic Scattering at 250 MeV // Phys. Rev. C. 2002. V. 66. P. 044002.
5. *Janek M. et al.* Analyzing Powers A_{yy}, A_{xx}, A_{xz}, and A_y in the $\vec{d}d \to {}^3\mathrm{He}n$ Reaction at 270 MeV // Eur. Phys. J. A. 2007. V. 33. P. 39.
6. *Ladygin V. P. et al.* Measurement of the Tensor Analyzing Powers in the $\vec{d}d \to {}^3\mathrm{He}n$ and $\vec{d}d \to {}^3\mathrm{H}p$ Reactions at RIKEN // Part. Nucl., Lett. 2000. No. 3[100]. P. 74.
7. *Ladygina N. B.* Private commun.
8. *Baru V. et al.* New Parameterization of the Trinucleon Wave Function and Its Application to the $\pi\,{}^3$He Scattering Length // Eur. Phys. J. A. 2003. V. 16. P. 437.