MEASUREMENT OF THE TENSOR A_{yy} AND VECTOR A_y ANALYZING POWERS FOR THE $\vec{d}d \to p\ ^3H$ AND $\vec{d}d \to pX$ REACTIONS AT 270 MEV

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Abstract

The experimental results on the tensor A_{yy} and vector A_y analyzing powers at $E_d = 270\ MeV$ for the $\vec{d}d \to\ p\ ^3H$ reaction in the angular range from 90° to 180° in c.m.s. are presented. The $\vec{d}d \to\ p\ X$ data near breakup threshold are also obtained.

The experimental data for these reactions are sensitive mostly to the spin structure of the deuteron.

Introduction

The light nuclei structure has been extensively investigated during the last few decades using both electromagnetic [1, 2] and hadron probes [3]. A significant amount of the data devoted to the investigations of the deuteron spin structure at short distances are accumulated in the last years [4, 5, 6, 7]. The tensor analyzing T_{20} and polarization transfer coefficient k_0 in backward elastic scattering, $dp \to pd$ have been measured at Saclay [4] and Dubna [5]. Later, the set of polarization observables was also obtained in dp-elastic scattering in over wide angular range at intermediate energies at RIKEN [8, 9] and KVI [10].

Measurements of the polarization correllation coefficients $C_{//}$ in the $d\ ^3He \to\ p\ ^4He$ reaction have been performed at RIKEN [7].

All the data show the sensitivity to the deuteron spin structure at short distances. However, the remarkable deviation of the polarization observables from the One Nucleon

Exchange (ONE) predictions using standard deuteron wave function occurs even at relatively small internal momenta of $\approx 200\ MeV/c$. Such a discrepancy can be due to the non-adequate description of the light nuclei structure at short distances, as well as to the importance of the mechanisms in addition to ONE.

The $\vec{d}d \rightarrow\ p\,{}^3H$ and $\vec{d}d \rightarrow\ p\,X$ process concern to the ONE reactions. These reactions are the simplest processes with a large momentum transfer, so they could be used as a tool to study the deuteron structure at short distances. The polarization observables of these reactions are sensitive to the D/S wave ratio in the deuteron.

In this report the data on the tensor and vector analyzing powers, A_{yy} and A_y, for the $\vec{d}d \rightarrow\ p\,{}^3H$ reaction obtained in R308n experiment at RIKEN [11] are presented. Also the data for the breakup reaction near threshold $\vec{d}d \rightarrow\ p\ X$ are shown.

The relative momenta of nucleons in deuteron achieves $\approx\ 400\ MeV/c$ at initial deuteron kinetic energy $E_d = 270\ MeV$.

Experiment

The experiment was performed at RIKEN accelerator Reseach Facility shown in Fig.1A. A polarized deuteron beam extracted from polarized ion source was accelerated with the AVF and the Ring cyclotrons up to energy 270 MeV. The accelerated beam was transported to a spectrometer SMART (see Fig1B) and injected onto a target placed in the scattering chamber. Scattered particles were momentum analyzed with three quadrupole and two dipole magnets in QQDQD configuration and then detected with a Multi Wire Drift Chambers (MWDC) and three plastic scintillators at the focal plane FP2. The magnitude of the beam polarization have been measured with two beam-line polarimeters based on dp-elastic scattering. Deuterated polyethylene was used as the deuteron target [12]. Measurements with a carbon target was also performed to substract the contribution of carbon nuclei in CD_2 target. For the $\vec{d}d \rightarrow\ p\ {}^3H$ reaction the detected protons scattered in the backward angles in the c.m.s..

Information from MWDC was transformed to the scattering angles and the momenta of the particle using the optical matrix of the spectrometer. The particle identification procedure was performed using the correlation between the ADC signals from scintillators and time of flight of particle.

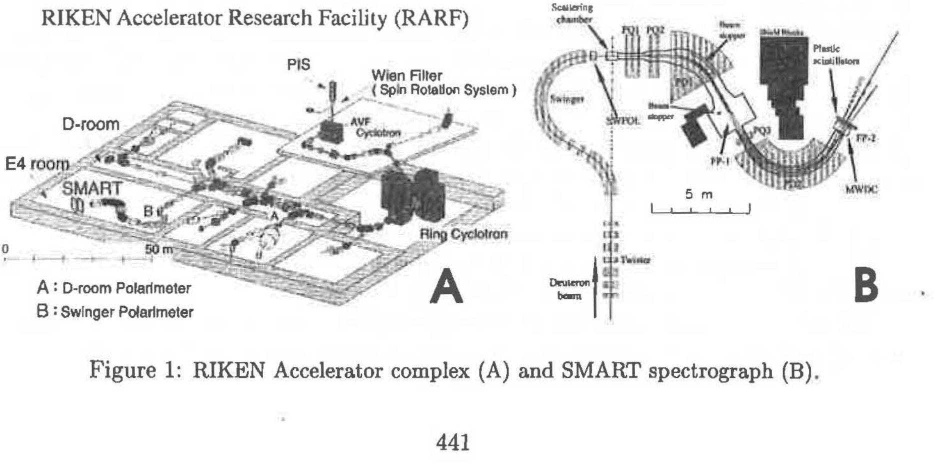


Figure 1: RIKEN Accelerator complex (A) and SMART spectrograph (B).

Results and discussion

The experimental results on A_{yy} and A_y analyzing powers of the $\vec{d}d \to p\ ^3H$ reaction at $E_d = 270\ MeV$ are presented by the filled symbols in Fig.2. The solid, long-dashed and dotted curves are the results of ONE calculations using Paris [13], Bonn B [14], and Bonn C [14] deuteron wave functions, respectively. Urbana ^3He wave function [15] was used in the calculations.

ONE calculations predict that the tensor analyzing power at the backward angles is sensitive to the structure of the deuteron. So, they reproduce the global feature of the experimental data at the backward angles. The sign of the tensor analyzing power A_{yy} near 180° in the c.m.s. is positive in accordance with the sign of the deuteron wave function. However there is quantitative difference between the experimental and the predicted data. ONE calculation near 90° in the c.m.s. are sensitive to the both deuteron and ^3He wave functions. The experimental data strongly disagree with the calculations in this region.

Monte Carlo (MC) simulation was performed for the $\vec{d}d \to p\ X$ reaction at 270 MeV initial deuteron energy and small proton emission angles in accordance with 2 and 3 particle phase space. MC calculations and a typical example of the obtained energy spectra of $\vec{d}d \to p\ X$ reaction at the emission angle of $\Theta_{cm} = 8°$ are presented in the same plot (see Fig.3).

The solid line is the experimental data for the $\vec{d}d \to p\ X$. The dot-dashed line and the shadowed area are the events generated by Monte Carlo for the $\vec{d}d \to p\ dN$ and $\vec{d}d \to p\ pnn$ reactions, respectively.

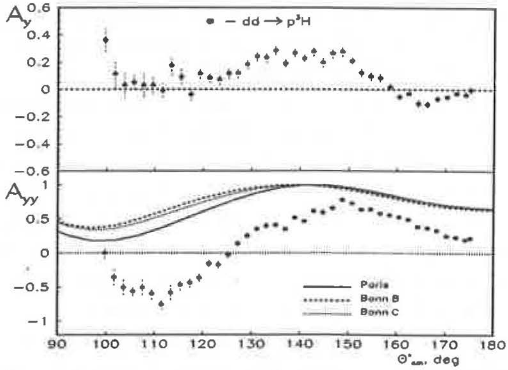


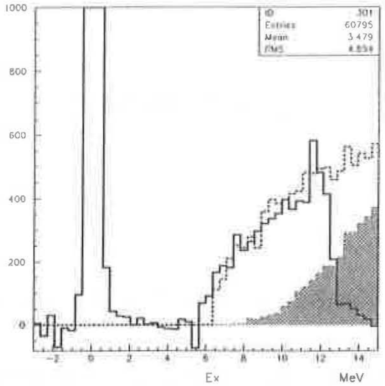
Figure 2: The experimental results on A_{yy} and A_y analyzing powers of the $\vec{d}d \to p\ ^3H$ reaction at $E_d = 270\ MeV$.

The peak near 0 MeV corresponds to the binary reaction, the plateau begining from 6 MeV corresponds to the breakup reaction near threshold. It is shown that MC simulation for 2 particle phase space ($p - dn$ in the final state) reproduces well the excitation energy spectra near threshold. The calculations in accordance with 3 particle phase space is quite small within the acceptance of the spectrometer. A peak obliged to the Final State Interaction (FSI) near breakup threshold is not observed for the 3-nucleon unbounded state in contrast with np state [5]. Thus, it gives the opportunity to conclude that FSI for the dn system is insignificant or much weaker than for the np one.

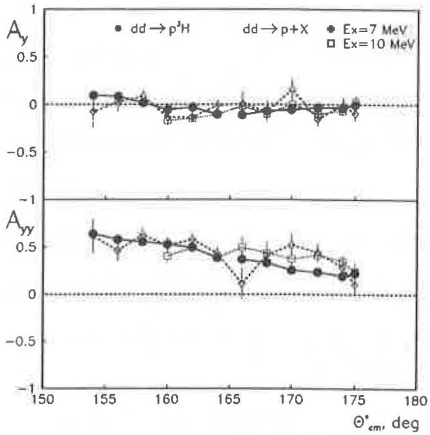
The experimental results on A_{yy} and A_y analyzing powers for $\vec{d}d \to p\ X$ reaction at $E_d = 270\ MeV$ are presented by the filled symbols in Fig.4.

The comparison of the polarization observables of the breakup and the binary reactions gives an opportunity to conclude that they are in an agreement within achieved errors.

The distributions of the tensor and vector analyzing powers of the breakup and the binary reactions are approximately the same within achieved experimental errrors.



Fugure 3: The excitation energy spectra for $d+d$-scattering, see text for the explanations.



Fugure 4: The experimental results on A_{yy} and A_y analyzing powers of the $\vec{d}d \to p\,X$ reaction at $E_d = 270\ MeV$.

Summary

The experimental data on the tensor and vector analyzing powers A_{yy} and A_y for the $\vec{d}d \to p\,^3H$ is obtained at $E_d = 270\ MeV$ in the angular range $90° - 180°$ in the c.m.s. The experimental data on A_{yy} for this reaction shows the sensitivity to the spin structure of the deuteron. The angular distribution of A_y indicates the necessity to take into account mechanisms beyond the ONE. The experimental data of the tensor and vector analyzing powers A_{yy} and A_y for the $\vec{d}d \to p\,X$ breakup reaction is obtained. The experimental data on A_{yy} for this reaction also shows the sensitivity to the spin structure of deuteron. The obtained experimental data require further development in theoretical approaches either for adequate description of the light nuclei structure at short distances and (or) taking into account mechanisms in addition to ONE.

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New Technical Developments