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TITLE: Special Features of the Alpha Induced d and $\vec{d}$ Breakup

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SPECIAL FEATURES OF THE ALPHA INDUCED d AND $\vec{d}$ BREAKUP

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Summary

The alpha induced deuteron breakup reactions have been of interest since the three-nucleon, nucleon induced deuteron breakup, problem was addressed with tractable and predictive codes based on the Faddeev formalism and with appropriate nucleon-nucleon forces. In this paper we discuss a few special features of the alpha induced deuteron breakup reactions. Specifically, we point out the importance of the n-p tensor force in the predictions of the three-body model that fit the tensor analyzing powers better and the concommittent deterioration of the fit to the vector analyzing power caused by the inclusion of the tensor force. We suggest that there exists evidence for the $^1S_0$ n-p interaction, which is isospin forbidden, in both the cross section and spin observables data. Finally, we discuss certain characteristics of the p-α quasifree-scattering and n-α final-state-interaction processes.

Introduction

Alpha induced deuteron breakup has been studied over wide range of energies, 4 - 55 MeV, for p-α quasifree scattering (QFS) and p-α, n-α and n-p final-state interaction (FSI) kinematic conditions[1-3]. Data recently have been compared with the predictions of the three-body model[4] which assumes that the alpha particle is a structureless boson and which uses separable potentials for the input N-α and n-p forces. Specifically, the model employs N-α $s_{1/2}$, $p_{3/2}$ and $p_{1/2}$ forces with Yamaguchi form factors. The Coulomb force is not explicity included in the three-body equations, but only in the two-body p-α t-matrix so as to reproduce experimental p-α phase shifts. For then-p system only a $^3S_1$ rank-one Yamaguchi potential is used. While the three-body model provided satisfacory fits to most of the data, some significant discrepancies exist. Therefore, it is necessary to investgate whether, and in which way, more realistic forces affect the predictions from the model. This paper discusses some special features of the alpha induced deuteron breakup and information derived from these features.

Quasifree Scattering

The importance of the two-particle input force for the QFS is well established from the D(p,pp)n studies[5]. Similarly, in order to fit the p-α QFS data it is necessary to employ a good p-α input force[1]. However, even at the c.m. energy of 47 MeV, though the impulse approximation term, $I_{\alpha p}$, is the largest one, other terms in the multiple scattering series, particularly those which terminate in the n-p FSI, are very important.

The inadequacy of the plane-wave-impulse-approximation (PWIA) approach is dramatically demonstrated through the study of polarization observables. For the incident deuteron energy of 17 MeV, the measured A_y of the p-α QFS is 0.50 ± 0.03, while at the corresponding conditions, i.e., $T_p^{lab} = 5.7$ MeV and $\theta_{c.m.} = 45^o$, the A_y measured for free p-α scattering is -0.4. However, in the QFS kinematic region the measured tensor-analyzing powers are consistent with zero as intuitively expected from the QFS picture.

This information is useful when one plans to use the $^4He(\vec{d},ab)cd$ reactions to st two-spectator QFS processes.

Tensor n-p Interaction

The tensor n-p force recently has been included in the three-body model[6]. The comparison of the three-body model predictions, when the tensor force is included, with our 17 MeV $^4He(\vec{d},p\alpha)n$ data[2] shows that the inclusion of the tensor force which predicts a deuteron D-state probability of 7% significantly improves the fit to the tensor-analyzing power data, as shown in Figure 1. On the contrary, the fit to the vector-analyzing power, A_y, becomes somewhat worse. We also have done the calculation with the tensor force which results in D-state probability of 4% and, as expected, the results are in between those for 7% and 0% D-state probabilities. Similar indications have been obtained from the kinematically incomplete measurements of the $^4He(\vec{d},p)^5He$ reaction at 21 MeV[7]. Thus, we conclude that the tensor-analyzing powers are sensitive to the n-p tensor force. The vector-analyzing power is influenced by the hitherto unincluded forces. Thus, it is worthwhile to investigate whether modifications of the N-α force, notably the $P_{1/2}$ force, would restore agreement between the predictions of the three-body model and the data. Likewise, it is important to investigate the effect of the tensor force at higher energies.

The $^5He_{gs}$ FSI Structure

The cross section enhancements due to the n-α, FSI, $^5He_{gs}$, seems to vary rapidly as a function of the relative n-α c.m. angle. Figure 2 shows that the inclusion of the tensor force modifies the predicted $^5He_{gs}$ spectral structures rather significantly and in different ways, i.e., one peak increases in magnitude while the other decreases. With the limited data available, we suggest that alpha induced deuteron breakup spectra which include the $^5He_{gs}$ structure should be acquired.

This should be done for both low and high energies.

The $^1S_0$ n-p Force

The $^1S_0$ n-p FSI is isospin forbidden in the d-α breakup. The present three-body model ignores the $^1S_0$ n-p force. The possible contribution of the $^1S_0$ n-p interaction has been studied experimentally[8] and theoretically in the framework of the impulse approximation[9].

Our 17 MeV data[2], analyzed in a higher resolution mode than previously considered, are shown in Figure 3 (3a: $\Theta_\alpha = 20^\circ$, $\Theta_p = 120^\circ$ and 3b: $\Theta_\alpha = 30^\circ$, $\Theta_p = 82.8^\circ$) and are compared with the three-body model predictions. First, we note that there was an error in our code related to the n-p FSI enhancement. The error has been corrected[6] and, in order to illustrate its effect we show the old incorrect calculation the new correct, but not including the tensor force, calculation, and the new calculation which includes the tensor force. The error appreciably influenced only the region where the n-p relative energy is close to zero. In the region far from the n-p FSI the inclusion of the tensor force improves the fit to the cross section as shown in Figure 3a. However, in the n-p FSI region, as shown in Figure 3b, the inclusion of the tensor force makes the fit worse, underlining the need to incorporate the $^1S_0$ n-p force also. The effect is not large, but it is apparent. The discrepancy at E_p approximately 4 MeV could be a reflection of the same $^1S_0$ n-p impurities or of an inadequate $P_{1/2}$ n-α force.

More insight into the role of the $^1S_0$ n-p force can be obtained from the spin observables. In Table I we compare our measurements at 17 MeV for the reaction $^4He(\vec{d},d^*)\alpha$ at $\Theta_{c.m.} = 116.5^\circ$ with the previously measured elastic scattering data[10].

Table I

Comparison between $^4He(\vec{d},d)\alpha$ and $^4He(\vec{d},d^*)\alpha$ data

Observable	$^4He(\vec{d},d)\alpha$, ref. 10	$^4He(\vec{d},d^*)\alpha$, ours
A_y	-0.40	-0.3 ± 0.1
A_{xx}	+0.25	+0.6 ± 0.1
A_{yy}	-0.65	-0.8 ± 0.1

The good agreement for the A_y and A_{yy} suggests that the $^3S_1$ n-p force dominates the n-p FSI interaction. However, the fact that the A_{xx} results differ markedly suggest that this observable may be sensitive to the details of the n-p force, particularly to the $^1S_0$ component.

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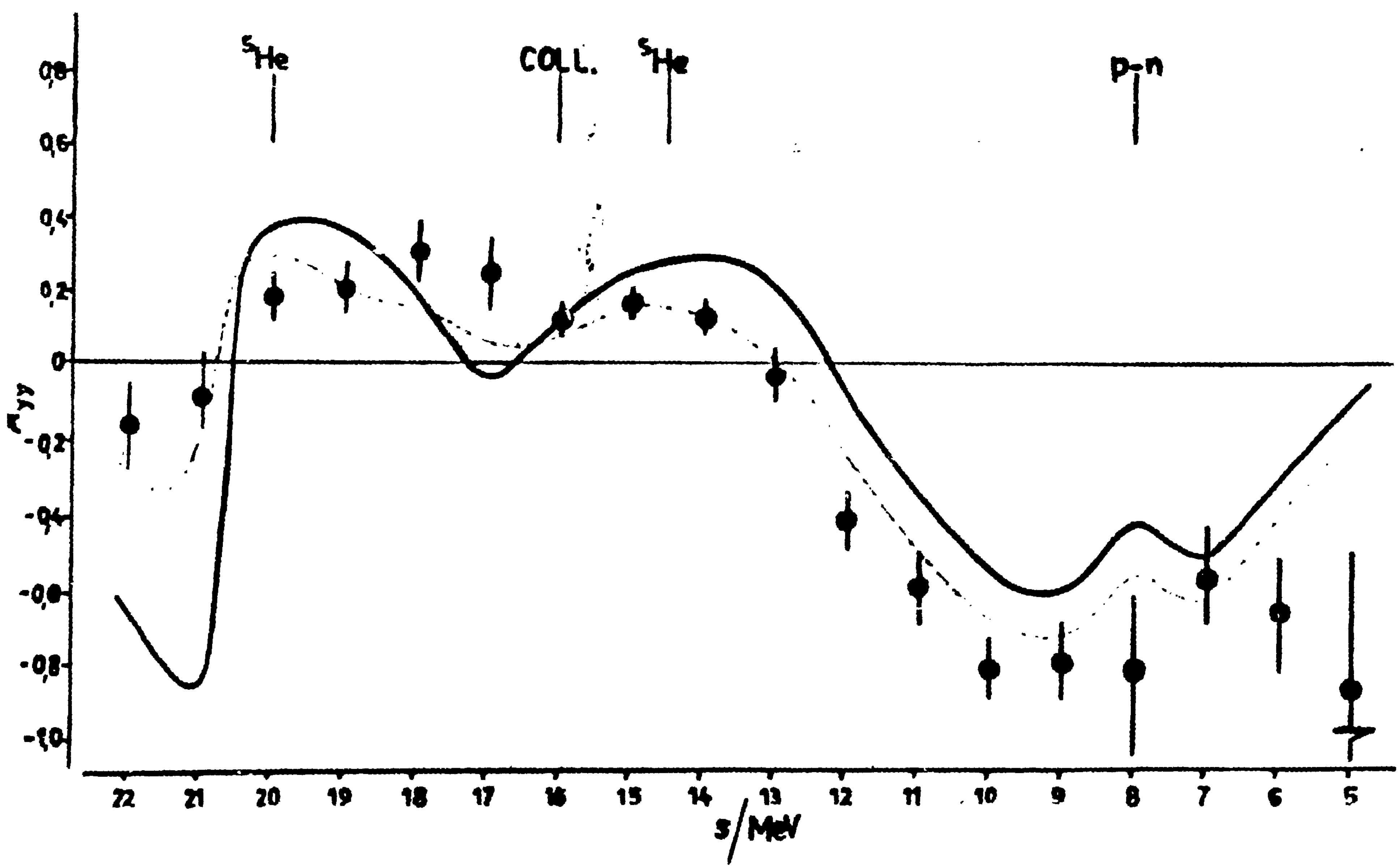
Figure Captions.

1. The tensor analyzing power, A_{yy}, for the reaction $^4He(\vec{d},p\alpha)n$ at 17 MeV and $\theta_\alpha = 30^o$, $\theta_p = 82.8^o$. The solid curve is for the three-body model prediction with no n-p tensor force and the dashed curve is for the three-body model prediction including the n-p tensor force with the deuteron D-state probability of 7%. Kinematic conditions for the n-p and $^5He_{gs}$ FSI, as well as for collinearity, are indicated.

2. The cross section for the reaction $^4He(\vec{d},p\alpha)n$ with $\theta_\alpha = 20^o$, $\theta_p = 120^o$, and $E_d = 17$ MeV. The curves are: W = a previous calculation[2)] without the n-p tensor force and with an error in the n-p FSI enhancement region; C = no tensor force and no error; and C-T = with the tensor force and P_d=7%, and no error.

3. The cross section, in the higher resolution mode, for the $^4He(\vec{d},p\alpha)n$; (a) $\theta_\alpha = 20^o$, $\theta_p = 120^o$, and (b) $\theta_\alpha = 30^o$, $\theta_p = 82.8^o$. The curves are labeled as in Figure 2.



^{5}He
COLL.
^{5}He
p-n
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1,0
A_{yy}
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
s/MeV

Figure 1.

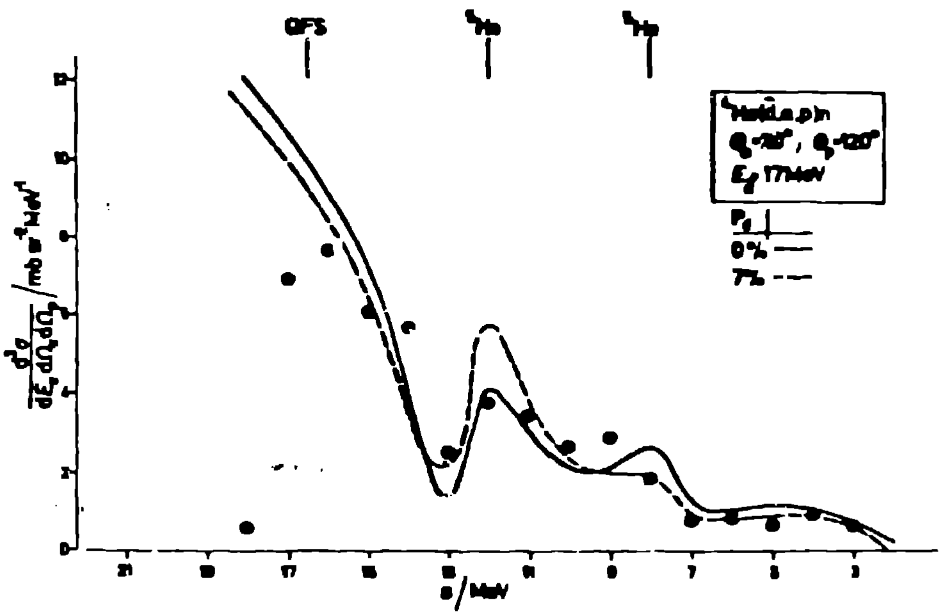


Figure 2.

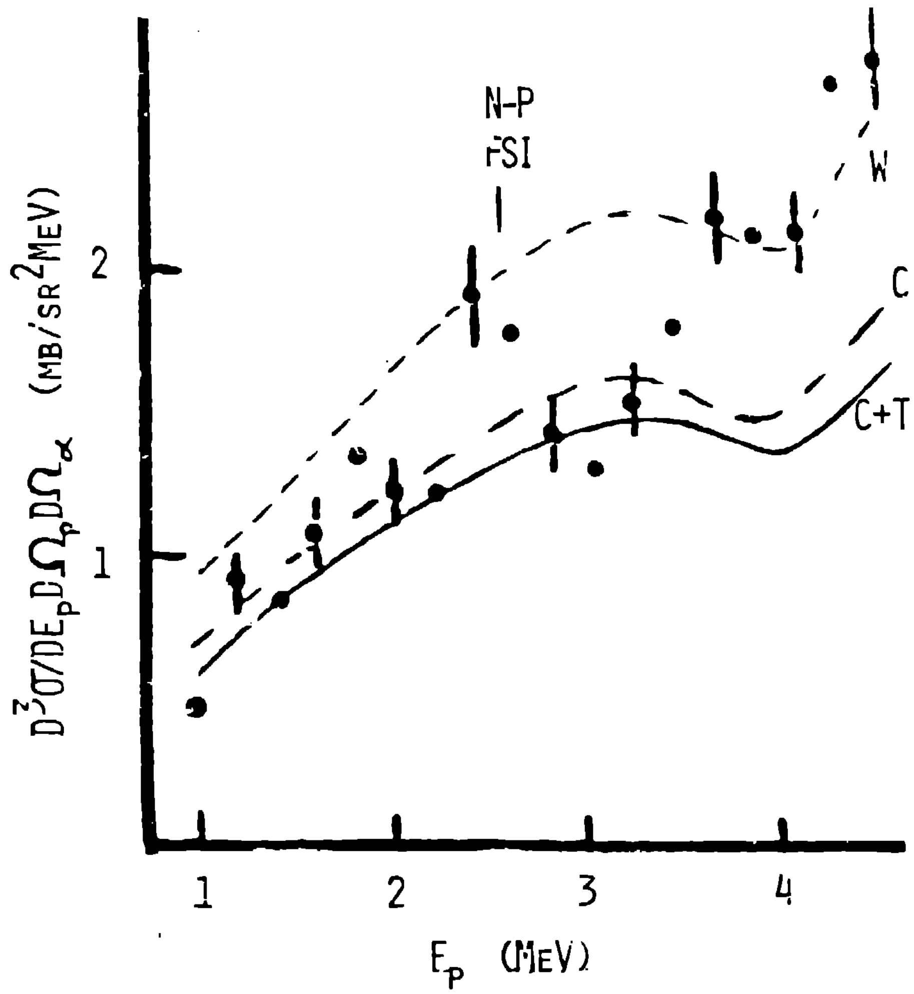


Figure 3b.

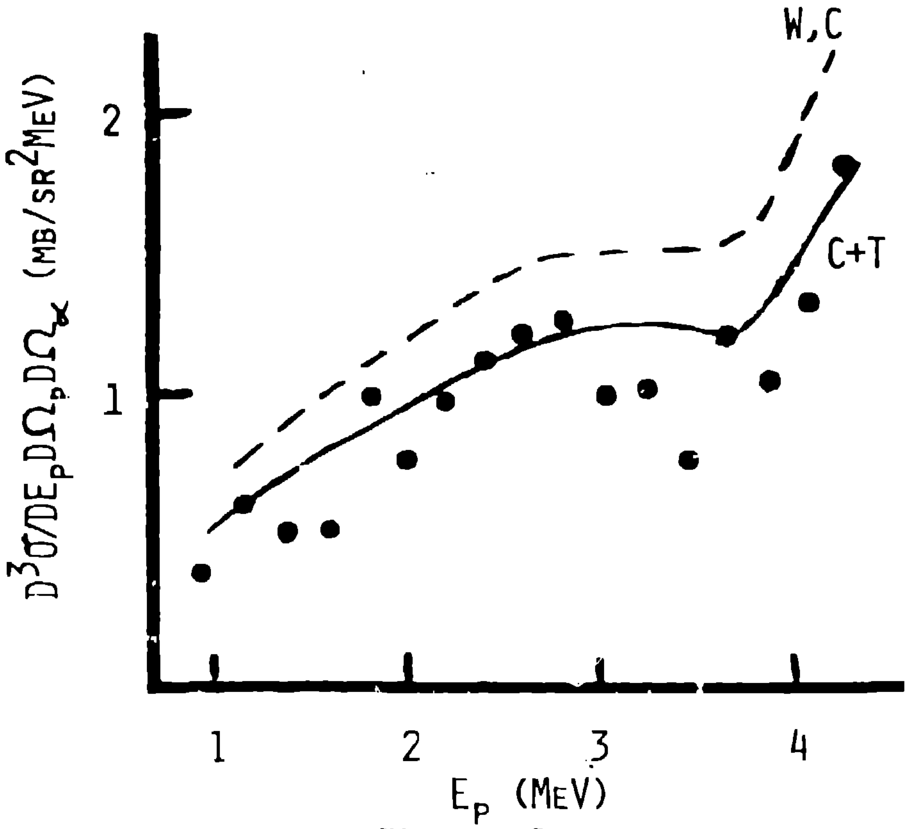


Figure 3a.