TENSOR ANALYZING POWERS IN DEUTERON-PROTON ELASTIC SCATTERING AND THE BREAKUP REACTION AT 45.4 MeV

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We have recently measured the tensor analyzing powers T_{20} and T_{22} in $\vec{d}$+p elastic scattering and in the breakup reaction at E_d = 45.4 MeV.[1,2] The elastic results now establish a rather complete set of polarization data in nucleon-deuteron scattering at E_N = 22.7 MeV, which consists of the proton analyzing power, the deuteron vector and tensor analyzing powers, and vec^tor polarization transfer measurements, as well. Certainly a primary goal of the three-body theory has been to reproduce the three-nucleon data from exact calculations that use the established two-nucleon interactions. During the past few years considerable success has been achieved in that direction.[3] The principal remaining discrepancy had been the failure to provide a quantitative fit to both the nucleon and deuteron vector analyzing powers, A_y and iT_{11}, at scattering angles forward of θ_{cm} = 120°. This is shown in Fig. 1 by the curves labeled T4M and T4D. These are Doleschall's[4] earlier calculations with two different separable nucleon-nucleon tensor interactions. The first (T4M) provided the proper $^3S_1$-$^3D_1$ mixing parameter ε_1, the second (T4D) fit the $^3D_1$ phase shifts, but neither did both. Thus, there was always the question of whether or not the discrepancies were due to the difficulty in providing a separable tensor interaction which would reproduce the

$^3S_1$, $^3D_1$ phase shifts <u>and</u> ε_1. That now seems not to have been the case, since Doleschall has recently noted that his two-nucleon interaction had an unreasonably long range. When this feature was corrected, a dramatic improvement was obtained in the calculated fits to the vector analyzing powers,[5] as is shown by the curves 2T4 in Fig. 1. I would call those perfect fits. However, it should be noted that the 2T4 tensor interaction does not reproduce the mixing parameter ε_1, as is shown in Fig. 2. This has a bearing on the fits to the tensor analyzing powers.

Since Doleschall's calculations[4,5] had shown a significant sensitivity of the tensor analyzing powers to changes in the nucleon-nucleon tensor interaction, we measured T_{20} and T_{22} in $\vec{d}$+p elastic scattering at E_d = 45.4 MeV for a direct comparison with the calculated results. Our data are shown in Fig. 3 along with Doleschall's calculated curves. Note that the 2T4 result, which agreed so well with the vector analyzing powers, does not provide the best fit to these tensor analyzing powers. This could very well be due to the poor representation of ε_1 provided by the 2T4 interaction. Support for this conclusion is given by a comparison of the T4D and 3$\tilde{T}$4 calculations for T_{22}, Fig. 3b. The T4D and 3$\tilde{T}$4 interactions differ only in that T4D does not provide the proper ε_1, whereas 3$\tilde{T}$4 does. They both, however, still have an improperly long range. Thus, the improved agreement with the T_{22} data at angles forward of θ_{cm} = 120° for the 3$\tilde{T}$4 calculation (as compared with the T4D) results from having the proper $^3S_1$ - $^3D_1$ mixing in 3$\tilde{T}$4. Clearly, the remaining discrepancy is likely to be associated with the too long range of the 3$\tilde{T}$4 interaction, and, hopefully, Doleschall is now in the process of correcting that deficiency already.

I turn now to the measurements of analyzing powers in the p+d breakup reaction. We had previously measured both proton and deuteron vector analyzing powers, at Ep = 22.7 (E_d = 45.4) MeV, in the production of final state np pairs with low relative energies E_{np}, the final-state interaction (FSI) region.[6] For np pairs with $E_{np} \leqslant 1$ MeV, we found both vector analyzing powers to be similar in their angular distributions (though of lesser magnitude) to the corresponding elastic analyzing powers. At first view, this was unexpected because of the known strong contribution to the FSI enhancement due to the $^1S_0$ np interaction, whereas the elastic np final state is the bound $^3S_1$ deuteron. This expectation was reinforced by the results of subsequent calculations by Bruinsma and van Wageningen[7] and by Stolk and Tjon[8] for the final state np energy of $E_{np} = 0$. However, Stolk and Tjon found that for E_{np} = 1 MeV, and the relative np momentum along the beam direction, their calculated vector analyzing powers were in much better agreement with the experimental results. Qualitatively, this is understandable from the fact that the np $^1S_0$ FSI enhancement peak has a width of about 0.1 MeV, while that of the $^3S_1$ enhancement is 2.2 MeV. Hence, at E_{np} = 1 MeV the contribution from the $^3S_1$ np final state is dominant, and the similarity to the elastic scattering results is expected. This suggests that in the range of $E_{np} \leqslant 1$ MeV of the experimental measurements, the np $^3S_1$ final-state contribution is the dominant one.

Our new measurements of the tensor analyzing powers in the FSI region of the $\vec{d}$+p breakup reaction at E_d = 45.4 MeV are shown in Fig. 4.

The two calculated curves are again from Stolk and Tjon,[8] for $E_{np} = 0$ and for $E_{np} = 1$ MeV. Again, the $E_{np} = 0$ calculation yields a poor representation of the data, whereas that with $E_{np} = 1$ MeV is certainly in qualitative agreement. I think it is now clear, as Stolk and Tjon remark, that for quantitative comparisons to these breakup analyzing power data an averaging over the experimental final-state E_{np} range must be made in the calculations. Alternatively, considerably better E_{np} resolution might be sought in the experiments. This may well be achieved most easily in a kinematically complete experiment, but, of course, there one always pays the price of limiting the angular range accessible during the course of a reasonable experiment.

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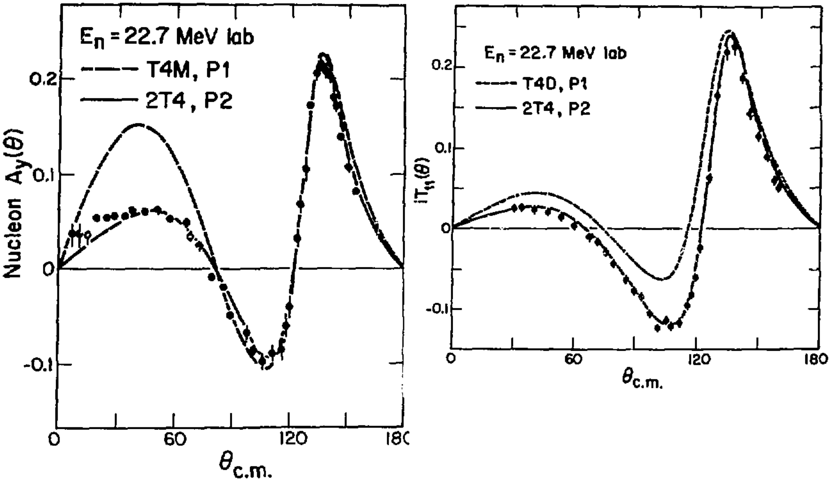

Fig. 1. (a) Proton analyzing power in $\vec{p}$+d scattering at 22.7 MeV and (b) deuteron vector analyzing power in $\vec{d}$+p scattering at 45.4 MeV. The curves are from Refs. 4 and 5.

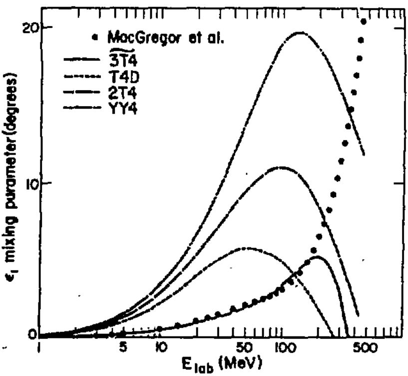

Fig. 2. The np $^3S_1$ - $^3D_1$ mixing parameter. The curves are from Ref. 5.

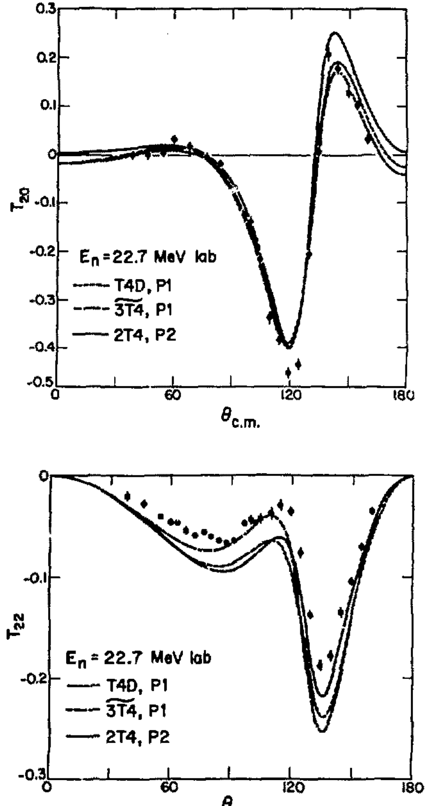

Fig. 3. Deuteron tensor analyzing powers (a) T_{20} and (b) T_{22} in $\vec{d}$+p scattering at 45.4 MeV. The curves are from Refs. 4 and 5.

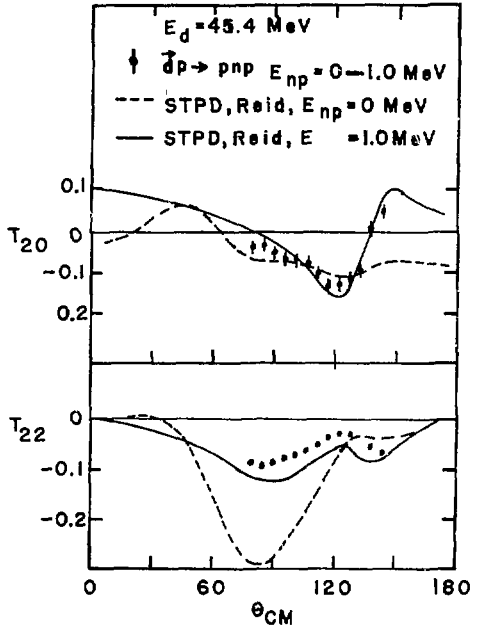

Fig. 4. Deuteron tensor analyzing powers T_{20} and T_{22} in the $\vec{d}$+p breakup reaction at 45.4 MeV. The curves are from Ref. 8.