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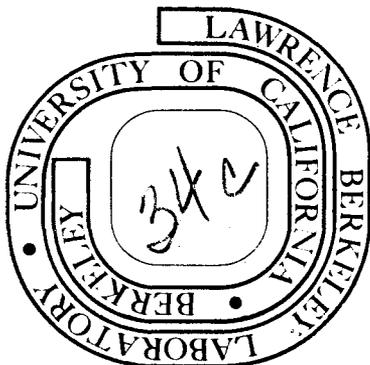
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THE VECTOR ANALYZING POWER IN d-p SCATTERING AT 45.4 MeV AND THE NUCLEON
NUCLEON INTERACTION*

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Abstract:

The deuteron vector analyzing power in deuteron-proton elastic scattering has been measured at $E_d = 45.4$ MeV. Our results, when compared with recent three-body calculations, suggest the possibility of deducing information on the n-p phase shift parameters which has not been available from n-p scattering itself.

- - -

During the past few years, three-body calculations¹⁻⁵ have achieved notable success in fitting measured polarization observables⁶⁻¹³ in elastic nucleon-deuteron scattering. These calculations, which use the Faddeev equations with separable nucleon-nucleon potentials, have been made with more and more complicated N-N interactions. The simple S-wave force had been sufficient to give agreement only with the differential cross-section data.^{14,15} The increasingly accurate and extensive polarization data, including nucleon and deuteron vector analyzing powers and deuteron tensor analyzing powers,¹⁶ have played a significant role in this theoretical refinement. It now seems possible to derive from such data, via the three-body calculations, information on the N-N interaction which, as yet, has not been available from N-N scattering experiments. The most recent calculations of Doleschall⁵ show

a surprisingly strong dependence of the nucleon and deuteron vector polarizations on variations of the input 3S_1 - 3D_1 N-N tensor interaction. We report here measurements¹⁷ of the deuteron vector analyzing power, iT_{11} , in d-p elastic scattering at $E_d = 45.4$ MeV, which can be compared directly with the calculated vector polarization at the equivalent nucleon energy $E_N = 22.7$ MeV.

Although it has been known^{1-3,12} that the vector polarizations in N-d scattering are essentially due to the N-N P-wave interactions, there have been conflicting conclusions concerning the contribution to these polarizations from the tensor force. Pieper⁴ reported only slight changes with the addition of the tensor force, and he suggested¹⁸ that changes in the 3S_1 - 3D_1 potential would have little effect on the nucleon polarizations. This conjecture was based on Sloan and Aarons¹ result, which demonstrated that none of the N-d polarizations were very sensitive to changes in the 3S_1 - 3D_1 potential. However, that calculation did not include the P-wave interactions, so the calculated vector polarizations were unrealistically small. Doleschall's first calculation³ showed a substantial change in the vector polarizations with the addition of the tensor force to the S and P-wave interactions, and his most recent calculation⁵ shows that the vector polarizations are quite sensitive to the details of the 3S_1 - 3D_1 potential. It is just this sensitivity that offers the promise of providing information on the 3S_1 - 3D_1 n-p mixing parameter ϵ_1 , and the 1P_1 phase shift, which are strongly correlated and poorly determined from phase shift analyses of n-p scattering data below 80 MeV.¹⁹ Although Doleschall does not address this question, it seems clear that correlated variations of ϵ_1 and the 1P_1 phase shift, in a search for improved fits to the vector polarization data, could

result in a better determination of these parameters than has been possible from n-p scattering data.

The polarized deuteron beam from the Berkeley 88-in. cyclotron, passed through a hydrogen gas target in a 36" diameter scattering chamber. The 7.5-cm-diameter gas cell with a 5- μ m Havar foil window was operated at pressures of 11.55 and 15.02 psi. The vector polarization of the beam was 83% of the maximum possible value $P_y = \frac{2}{\sqrt{3}}$ $t_{11} = 2/3$ with zero tensor components. Left-right asymmetry data were taken simultaneously at angles separated by 20° , using pairs of ΔE -E silicon detector telescopes. This allowed simultaneous detection of forward scattered deuterons and recoil protons from backward scattered deuterons. In order to eliminate instrumental asymmetries, alternate runs were taken with the spin vector of the beam oriented up and down with respect to the scattering plane. The angular resolution, defined by tantalum collimators, was 0.71° and 1.31° (FWHM) for the forward and backward telescopes, respectively. Two monitor counters were placed left and right of the beam axis at a scattering angle of $\theta \simeq 23^\circ$ and azimuthal angles $\phi \simeq 70^\circ$ and 110° . This enabled a relative cross section measurement to be made which was used in a finite geometry correction to the vector analyzing power. A helium gas cell along with a pair of ΔE -E counter telescopes at equal left and right scattering angles were positioned in a smaller scattering chamber downstream from the main scattering chamber and provided a continuous monitoring of the beam polarization. The analyzing power of the d - ^4He at this energy had been previously measured in detail.²⁰

Our experimental results are shown in Fig. 1, where the relative errors include the statistical error and a contribution of ± 0.004 which

was determined from measured asymmetries with the beam polarization set to zero. In addition, there is a $\pm 3\%$ normalization uncertainty from that of the d - ^4He analyzing power. Also shown in Fig. 1 are Doleschall's calculated results.⁵ In this calculation he used an improved set of P-wave potentials which provide much better agreement with the two-nucleon P-wave phase shifts¹⁹ for the lower energies which contribute in the three-nucleon calculation. Additionally, rank-2 tensor interactions were constructed in an attempt to simultaneously reproduce the 3S_1 , 3D_1 phase shifts, the mixing parameter ϵ_1 , and the deuteron properties. It was not possible to find a single rank-2 tensor force which satisfied all of these criteria, so two such sets were used. One, the T4D force, reproduced the low energy (≤ 100 MeV) 3D_1 phase shifts but gave larger values of ϵ_1 than have been deduced from n-p scattering.²¹ The other, the T4M force, reproduced the low energy ϵ behavior but not that of the 3D_1 phase shifts. As shown in Fig. 1, the T4M force calculation is in good agreement with our data backward of $\theta_c \simeq 80^\circ$, but the agreement deteriorates at the forward angles. Even though the calculations are for n-d scattering they can be compared with our data since charge symmetry of the nuclear interaction provides equality of the n-d and p-d polarizations in the absence of Coulomb effects. Such effects have been demonstrated to be small near $E_N = 22$ MeV, in that the nucleon analyzing power in n-d²² and p-d¹⁰ scattering are equal within the experimental error. In a further effort to improve the agreement between experiment and theory for the proton analyzing power data,¹⁰ Doleschall also included a 3D_2 interaction. Computational limitations precluded the addition of a complete set of D-wave interactions. The result of that calculation with the T4M interaction, the T4M + 3D_2

result, is also shown in Fig. 1. Some improvement toward agreement is seen at the forward angles at the expense of a slightly poorer fit in the region $\theta_c = 85^\circ$ to 115° . A very similar comparison between experiment and theory was found for the proton analyzing power data.⁵

The three-nucleon calculations represent major progress in predicting the polarization observables in N-d elastic scattering below 50 MeV. Small discrepancies remain with the vector polarizations in the forward angle region, which is just the region of greatest sensitivity to details of the 3S_1 - 3D_1 tensor interaction. Clearly, it would be most useful to do the calculation with a tensor force which simultaneously reproduces the N-N 3D_1 phase shift and the mixing parameter ϵ_1 , for example, the rank-4 potential recently constructed by Pieper.²³ It should then be possible to vary ϵ_1 and the 1P_1 phase shift, in the correlated manner required by the n-p scattering data,¹⁹ in a search for improved fits to the p-d proton and deuteron vector polarization data. It is quite possible that this procedure could provide a better determination of the low energy values of these two parameters than is possible via the suggested¹⁹ more difficult measurements of the $\bar{\sigma}(180^\circ)/\bar{\sigma}(90^\circ)$ ratio in n-p scattering to an accuracy of better than 2%.

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FOOTNOTES AND REFERENCES

* Work performed under the auspices of the U. S. Atomic Energy Commission.

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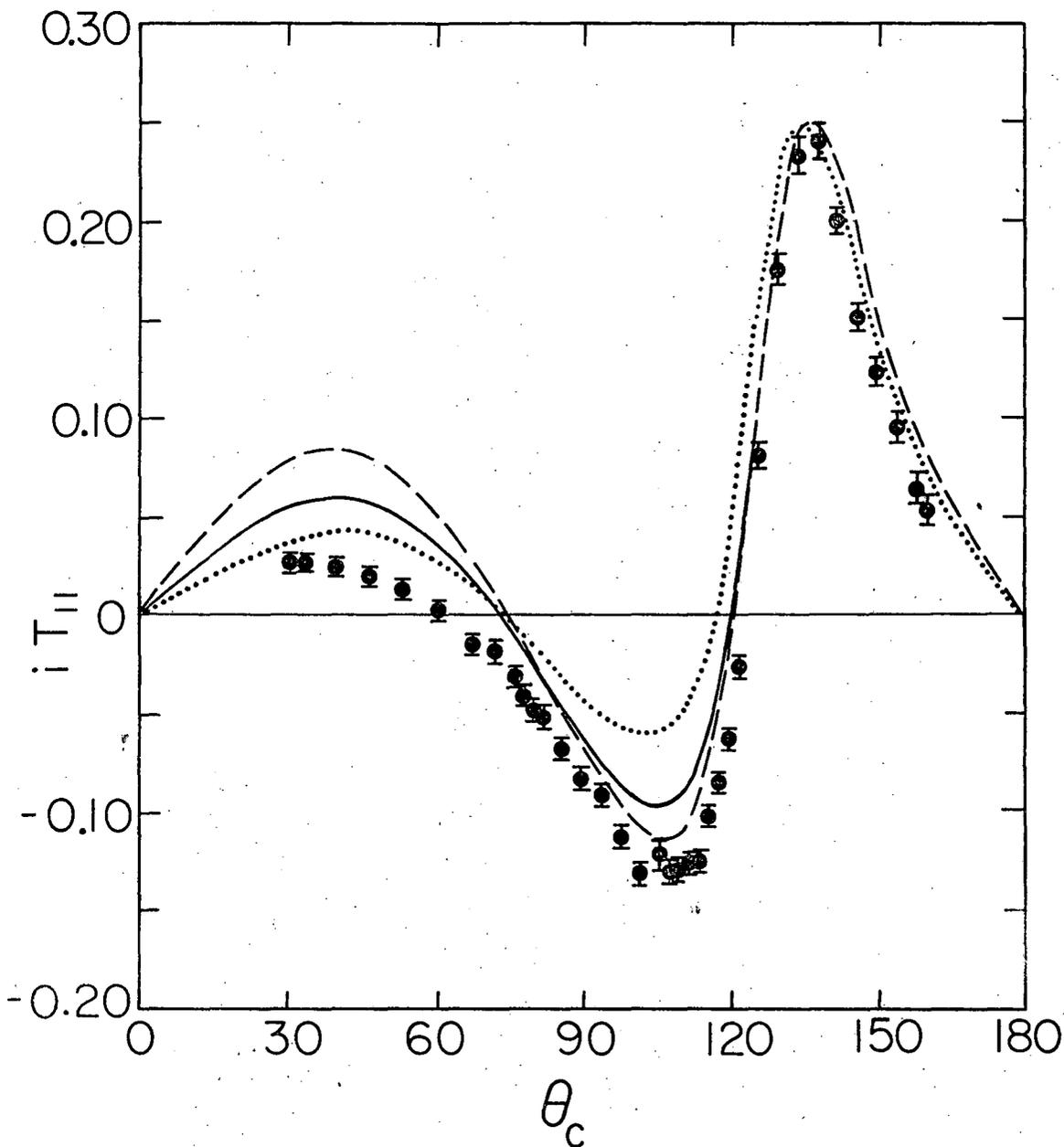
†† National Research Council of Canada, Post Doctoral Fellow.

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FIGURE CAPTION

Fig. 1. The deuteron vector and analyzing power, $iT_{11}(\theta)$, in d-p elastic scattering at $E_d = 45.4$ MeV. The curves are calculated results from Ref. 5 with different N-N interactions. Dotted line, set C (S and P-waves) + T4D tensor potential; dashed line, set C + T4M; solid line, set C + T4M + 3D_2 .



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Fig. 1

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