MEASUREMENT OF d+p ELASTIC SCATTERING ANALYZING POWERS AT 80 MeV

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This study is a continuation of an earlier investigation[1] of several light targets as possible polarization analyzers for t_{20}-polarized deuterons with energies near 100 MeV. If an analyzer were located with both large cross section and T_{20} tensor analyzing power, it would find immediate use in experiments to measure the recoil deuteron polarization from pion or electron scattering. Our previous study included the light targets ^{3}He, ^{6,7}Li, ^{9}Be, and ^{12}C. Medium and heavy targets have a small T_{20} tensor analyzing power of spin-orbit origin in most reaction channels, and were not included in our survey.

Up to this time, experiments with pion and electron scattering have used a polarimeter based on the ^{3}He(d,p)^{4}He reaction. This polarimeter accepts deuterons in the energy range from 20 to 27 MeV, and analyzes them with an efficiency (ratio of detected protons to incident deuterons) of $\varepsilon_o = 1.4 \times 10^{-4}$. A typical tensor analyzing power of the polarimeter is $T_{20} = 0.75$, giving a figure of merit of $Q = \sqrt{\varepsilon_o}|T_{20}| = 8.6 \times 10^{-3}$. The first polarimeter of this type has been described in detail elsewhere.[2] The scientific interest in electron-deuteron scattering at momentum transfers above 3 fm^{-1} now demands a polarimeter that has both greater efficiency and a higher operating range in energy. The light targets we investigated gave us no reaction with a figure of merit larger than that provided by the present ^{3}He(d,p)^{4}He polarimeter.

A hydrogen target was omitted from the original study. Later investigation of the analyzing powers[3] and cross sections[4] from the literature indicated that elastic d+p scattering near θ_{cm}=120° offered an excellent possibility as a t_{20} analyzer. We obtained running time adjacent to a d+p breakup experiment to examine the analyzing powers at 80 MeV.

The experiment used a large-diameter gas cell pressurized to 13 psia. Both elastic deuterons and recoil protons were detected by two Si-Ge telescopes on opposite sides of the beam. The last collimator before the detector telescope was active to reduce slit-edge scattering contributions in the continuum region of the spectrum. The detectors and gas cell were mounted on a rotating scattering table to examine either horizontal-plane or verticle-plane scattering. In these two configurations, the tensor polarized deuteron beams provided information on the A_{yy} and A_{xx} tensor analyzing powers from which T_{20} can be obtained as $T_{20} = -(A_{yy} + A_{xx})/\sqrt{2}$. Measurements were made between the angles of 15° and 45° in the lab, providing a sample of center-of-mass angles between 31° and 150°. Elastic deuterons were observed only at laboratory angles $\leqslant$ 27°. The final cross sections were renormalized to match the d(p,p)d results of Ref. 4.

The angular distributions of cross section and T_{20} for 80 MeV deuterons are shown in Fig. 1. The T_{20} analyzing power is large and negative near a center-of-mass angle of 120°. This feature arises from the interference of nucleon-nucleon scattering, which dominates the amplitude at small angles, and neutron exchange, which accounts for the cross section rise at large angles. This feature is advantageous for polarimetry because it is large over a wide range of energies and always appears at roughly the same scattering angle. Because this feature occurs for elastic scattering rather than a reaction, the cross section is favorably large.

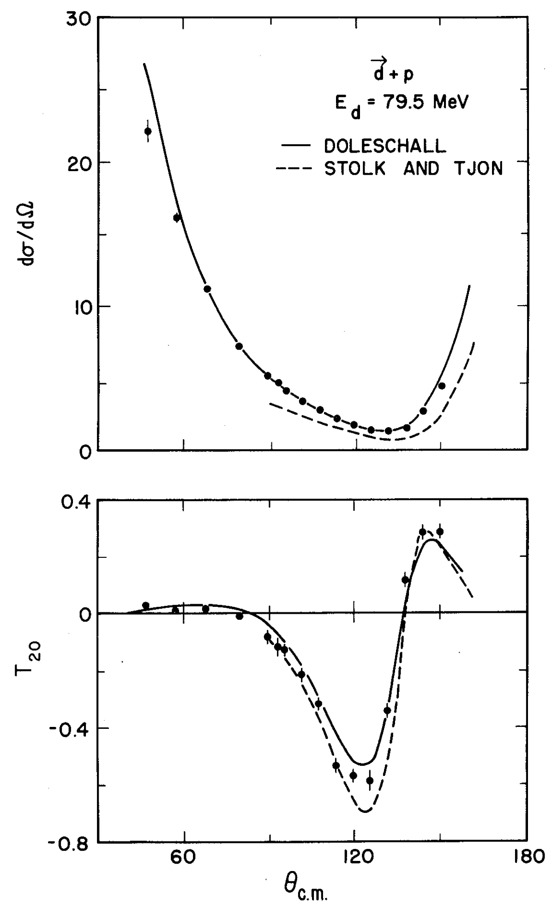

Figure 1. Measurements of the cross section and T_{20} tensor analyzing power for 80-MeV polarized deuterons elastically scattering from protons. The solid curve is a Fadeev calculation based on the work of P. Doleschall.[6] The dashed curve is a 92-MeV perturbative calculation by Stolk and Tjon.[7]

For comparison to the targets in the earlier study, an efficiency calculation was made for 100-MeV deuterons. Assuming that all recoil protons between 10° and 40° in the lab could be detected and their scattering angles measured, we find an efficiency for this polarimeter of $\varepsilon_0 = 60 \times 10^{-4}$, about 40 times larger than the present $^3He(d,p)^4He$ polarimeter. The target thickness was assumed to be 0.6 g/cm^2 thick, which would permit the recoil protons at all angles to be detected externally. By comparing both negative and positive lobes, an effective analyzing power of $T_{20} = 0.58$ should be obtained, giving a figure of merit of $Q = 32 \times 10^{-3}$. For the same deuteron flux, the statistical error in measuring t_{20} scales as the reciprocal of Q, which improves a factor of 4 in this case.

Deuteron-proton elastic scattering poses severe kinematic constraints for the design of a simple high-efficiency polarimeter. The recoil proton energy varies from 50% to 90% of the deuteron bombarding energy over the angular range desired, and this variation is greatly expanded when the energy loss in a thick target is taken into account. At the same time, the proton angle and energy must be measured with precision in order to separate elastic events from breakup protons. Fig. 2 shows that the breakup proton flux far exceeds the elastic flux in an inclusive measurement. The tensor analyzing power of the continuum, as shown in Fig. 3, is small. (The contribution of slit-edge or foil-foil scattering to the continuum cannot be neglected as a source of small spin dependence.) A polarimeter design following all these constraints is hard to achieve.

The measurements of deuteron-proton elastic scattering cross section and T_{20} tensor analyzing power compare favorably with calculations made using the

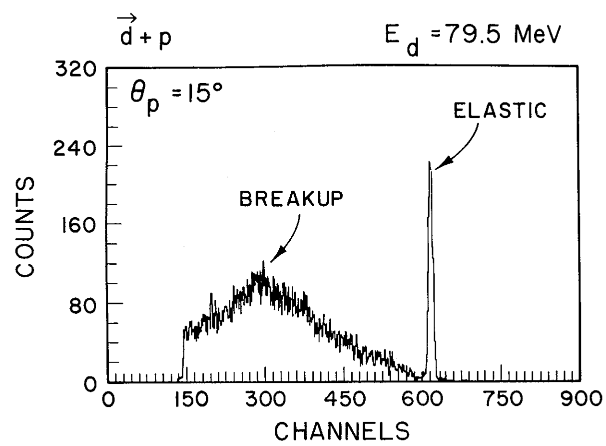

Figure 2. A sample inclusive proton spectrum for a laboratory proton angle of 15°. The continuum from breakup protons dominates the proton flux.

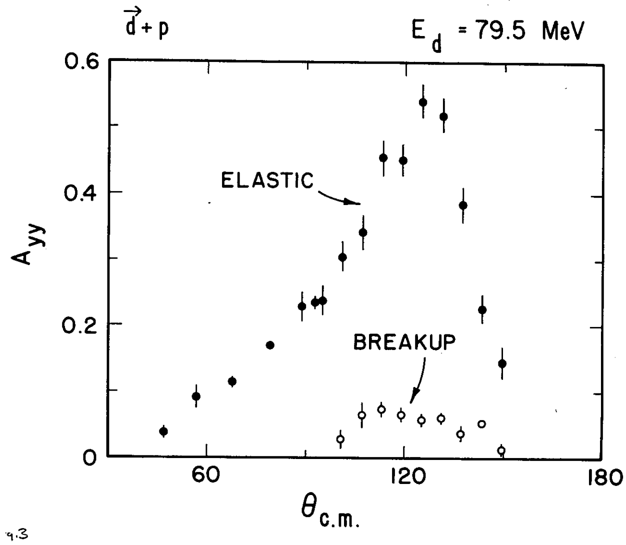

Figure 3. A comparison of the tensor (A_{yy}) analyzing power for recoil protons emerging from elastic scattering and deuteron breakup. The small values for the breakup spin dependence may contain the effects of slit-edge or foil-foil scattering.

Fadeev program written by P. Doleschall,[5] and also with perturbative calculations carried out by Stolk and Tjon.[6] The perturbative calculations are at a somewhat higher energy where the cross section is smaller.[4] Along with these measurements, we obtained values for the vector (iT_{11}) and tensor (T_{22}) analyzing power. These angular distributions are shown in Fig. 4. Here significant differences are seen between the Fadeev and perturbative calculations for T_{22}. The measurements clearly prefer the Fadeev result. All of these analyzing powers show large variations for large center-of-mass scattering angles. Any polarimeter capable of measuring t_{20} would be sensitive to these moments as well.

Values of the cross section and T_{22} tensor analyzing power can also be used to extract the asymptotic deuteron D-state coupling constant through analytic extrapolation. This has recently been shown to be a stable procedure if proper account is taken of the effects of neighboring singularities.[7] Following the prescription of Ref. 7 and references therein, a value of $\rho_D = 0.0242 \pm 0.0034$ is obtained for this set

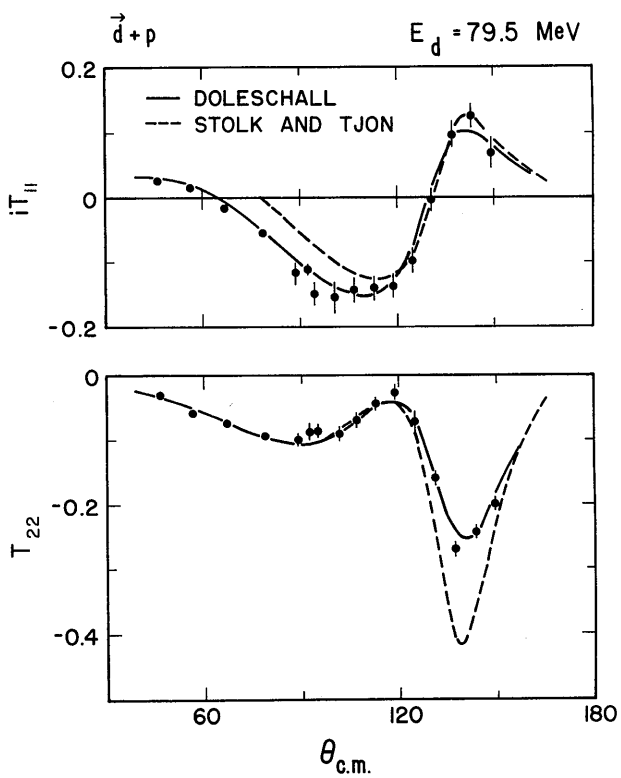

Figure 4. Measurements of the vector (iT_{11}) and tensor (T_{22}) analyzing powers for d+p elastic scattering. The curves are described in Fig. 1.

of data, in good agreement with the more extensive and precise results at lower energy. A polynomial extrapolation using the Coulomb-corrected extrapolation function is shown in Fig. 5.

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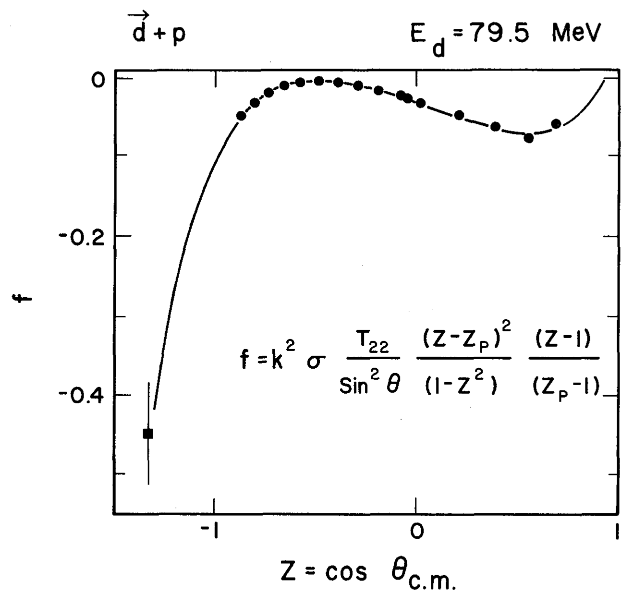

Figure 5. Measurements of the Coulomb-corrected extrapolation function f. The curve is a polynomial fit of order 5. The data point at $z_p = -1.313$ is the extrapolated measurement of $f(z_p)$. This corresponds to an asymptotic D- to S-state ratio of $\rho_D = 0.0242 \pm 0.0034$.

POLARIZATION IN THREE-NUCLEON $\vec{d}$+p BREAKUP AT E_d = 79 MeV

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During 1983 we have continued the series of kinematically complete three-nucleon breakup measurements d + p → p + p + (n) using a 79 MeV, polarized deuteron beam at IUCF. The initial measurements of the tensor analyzing power A_{yy} made in the so-called symmetric, constant-relative-energy (SCRE) geometry have been reported previously.[1] The new results include data on the tensor parameter A_{xx} for two noncoplanar SCRE configurations

The SCRE geometry attracted attention as a result of Faddeev calculations performed by Kloet and Tjon[2] and was first studied experimentally by van Oers.[3] It is characterized by equal polar angles of the two identical, detected particles (here, protons) and equal