LIGHT-ION SCATTERING

FEATURES OF THE ANALYZING POWERS
IN DEUTERON ELASTIC SCATTERING NEAR 80 MeV

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During the past year we extended measurements of the differential cross section and vector analyzing power for 80 MeV deuterons elastically scattered from ^{58}Ni back in angle to 112°. To this we also added new measurements of the tensor analyzing power A_{yy}. The results of these measurements are shown in Figure 1.

This experiment was motivated by earlier experiments$^{1)}$ where the more forward angles were measured. In those experiments it was apparent that as the angle increased, the diffraction pattern in the vector analyzing power became less pronounced and the analyzing power itself was rising toward unity. This effect was coupled with the observation of an enhancement in the cross section near 40° followed by a smooth exponential decline at larger angles. These latter effects have been recognized for some time as signatures of rainbow scattering, and have been observed predominantly with ^{3}He and ^{4}He projectiles.$^{2)}$

When the effects of the spin-orbit potential are considered within the context of the rainbow-scattering picture, it becomes apparent that large analyzing powers are expected.$^{3)}$ Each projection of the deuteron spin along an axis perpendicular to the scattering plane may be considered independently.$^{4)}$ Then, in the presence of a spin-orbit potential, the spin-up deuterons see the strongest attractive force in the surface region of the nucleus, and tend to follow trajectories where they bend towards the nucleus,

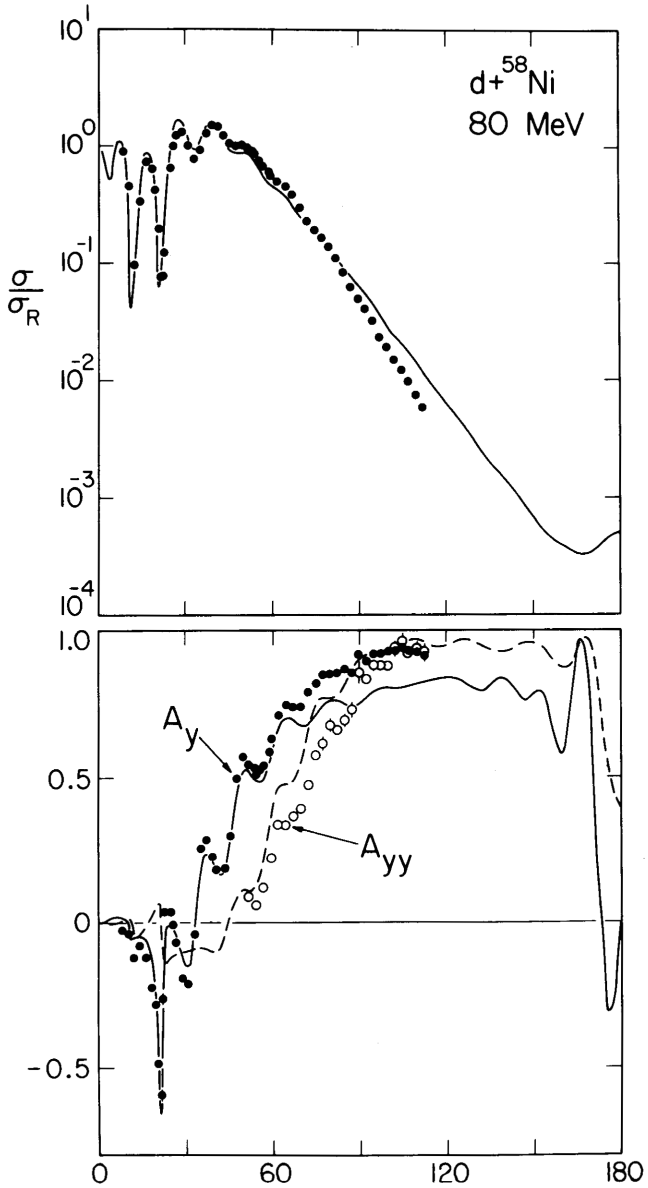

Figure 1. Measurements of the cross-section ratio to Rutherford, and the vector (A_y) and tensor (A_{yy}) analyzing powers for 80 MeV deuteron elastic scattering on ^{58}Ni. The calculations are from an optical-model program with potential shapes given by the global analysis of Daehnick.$^{5)}$

and tend to follow trajectories where they bend towards the nucleus and emerge at large angles on the opposite side. The dominance of back-angle scattering by spin-up deuterons gives values of A_y and A_{yy} near unity. The extension of the measurements on ^{58}Ni was undertaken to explore the signatures of rainbow scattering and to observe saturation of the vector and tensor analyzing powers. In the past, extensions of the measurements well beyond the rainbow peak have proven useful in determining the radial shapes of the phenomenological optical-potential components, even in to the nuclear half-density radius.2) The longer-term aims of the experiment are to provide a complete set of analyzing power measurements for deuteron elastic scattering at intermediate energies, and to use that set to investigate the spin-orbit and tensor components of the deuteron-nucleus interaction.

The extended measurements in Figure 1 show clearly the smooth exponential decline in the cross section associated with rainbow scattering. Both the A_y and A_{yy} analyzing powers become smooth and saturate near unity, the largest value of A_y being 0.97 ± 0.01 and of A_{yy}, 0.98 ± 0.02. This is the largest vector analyzing power ever observed for deuteron scattering.

The curves in Figure 1 are optical-model calculations using the global prescription of Daehnick.5) The potential shapes were determined from fits to forward-angle measurements of the cross section and vector analyzing power. They reproduce the measurements quite well in that region. At large angles, the calculated vector analyzing power is too small, and the tensor analyzing power too large. Attempts to correct this deficiency have met with only limited success so far, and investigation of the problem will continue.

It has been known for some time that the folding-model description for the deuteron optical potential in terms of nucleon-nucleus optical potentials is useful as a general guide, but does not produce detailed agreement with model prescription for the deuteron optical potential the measurements. Such a calculation is shown by the dashed curves in Figure 2. The nucleon-nucleus potentials were taken from the analysis of Becchetti and Greenlees.6) New A_{yy} measurements at forward angles have been added to this figure for completeness. Generally, the phenomenological optical potential requires more absorption, a less diffuse spin-orbit term, and substantially weaker tensor terms. As seen in Figure 2, such a potential overestimates the large-angle cross section by a factor of two and shows diffraction patterns in the analyzing powers that are much too small.

Starting from this point, Rawitscher and Mukherjee7) have included channel-coupling to deuteron breakup states. In this calculation, the neutron-proton continuum is divided into several energy bins, each of which is treated as a separate state. Relative neutron-proton angular momenta of 0 and 2 are included. Their calculation for deuteron elastic scattering is shown by the solid lines in Figure 2.

The effects of channel-coupling are large. The cross section is reduced a factor of two, and the analyzing powers become more diffractive and more positive. The agreement with the cross section is comparable at forward angles with the agreement provided by the optical model. In the region of the exponential decline, the reproduction by the channel-coupling calculation is better. The calculation also does well with A_{yy}, successfully reproducing the positive-going excursions between 10° and 40°, and the magnitude at angles less than 90°.

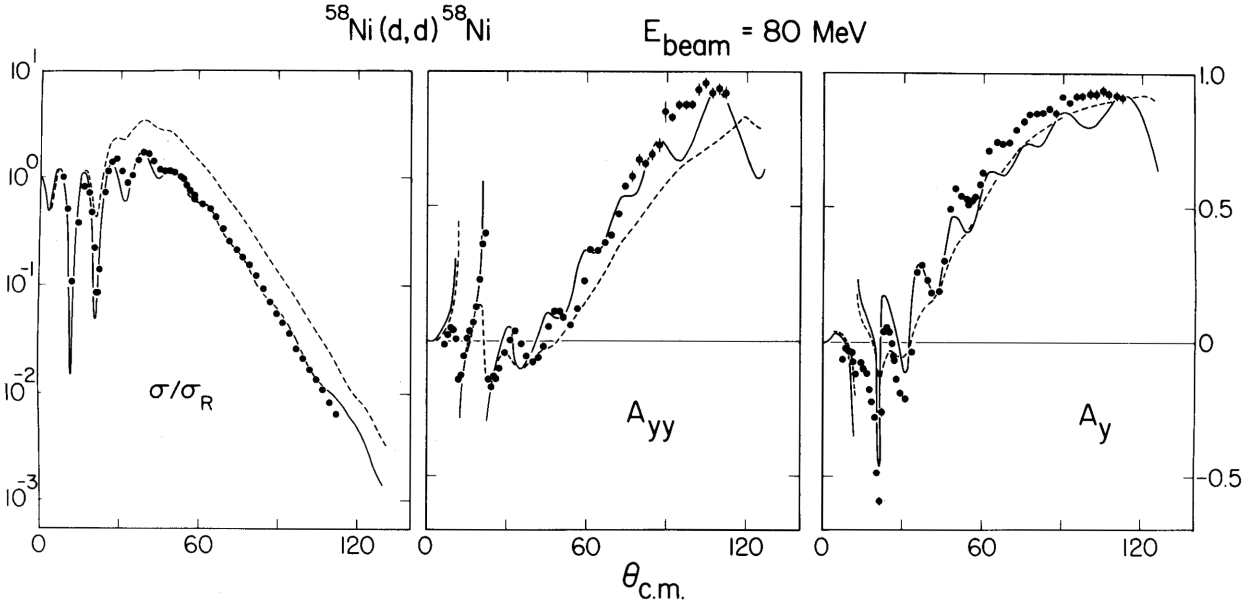

Figure 2. The measurements are the same as in Figure 1. The dashed curves are optical model calculations using a folding-model deuteron potential. The solid curves use the same potential but include coupling to deuteron breakup states.

The general shape of the vector analyzing power is given, but the differences between the calculation and the measurement are substantial at forward angles. This microscopic treatment of the deuteron-nucleus interaction is considerably more successful at this energy than at lower bombarding energies.7)

This also represents the first successful comparison between such a calculation and a tensor analyzing power. This result suggests that the derivation of a deuteron-nucleus potential through the folding model is sound, provided that the breakup channel (the new feature not already included in the nucleon-nucleus interaction) is coupled in explicitly. The high quality of the agreement also suggests that this is a nearly complete microscopic description.

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3) E.J. Stephenson, C.C. Foster, P. Schwandt, and D.A. Goldberg, to be published in Nucl. Phys.

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5) W.W. Daehnick, J.D. Childs, and Z. Vrcelj, Phys. Rev. C21, 2253 (1980).

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7) G.H. Rawitscher and S.N. Mukherjee, Nucl. Phys. A342, 90 (1980).

MEASUREMENTS OF THE TENSOR ANALYZING POWER, X_2, FOR ^{58}Ni($\vec{d}$,d)^{58}Ni AT 80 MeV.

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As part of a detailed study of elastic deuteron scattering from ^{58}Ni at E_d = 80 MeV, measurements of the tensor analyzing power $X_2 \propto 2A_{xx} + A_{yy}$ are in progress. Angular distributions of cross sections, $\sigma(\theta)$, vector analyzing powers, $A_y(\theta)$, and the tensor analyzing powers, $A_{yy}(\theta)$, have been measured in