^{58}Ni(d,d)^{58}Ni E_{beam} = 80 MeV

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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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

the angular range from about 6° to 112° and are
discussed in another contribution to this report.[1]
These measurements can be made at IUCF with the
vector-and tensor-polarized deuteron beams with
vertical spin quantization axis and the QDDM magnetic
spectrograph which defines a horizontal scattering
plane. Other Cartesian tensor moments which may be
measured in principle are A_{xx} and A_{xz}. The latter
requires the use of a spin-precession solenoid and
dipole magnets to produce a component of the deuteron
spin along the momentum direction, and cannot presently
be measured at IUCF. A_{xx} may be measured with a
detector in the vertical scattering plane.

A particular linear combination of A_{xx} and A_{yy} of
theoretical interest is the parameter $X_2 = (2A_{xx} + A_{yy})/\sqrt{3}$ which may be measured directly if the detection
plane is inclined at 54.7° to the horizontal. X_2 is,
to first order, independent of the spin-orbit component
of the optical potential as shown by Johnson[2].
Measurement of this quantity in the presence of large
spin-orbit effects such as those seen in the "rainbow"
scattering region[3] is of special interest. In
particular, we may hope to see effects of the
momentum-dependent tensor-potential term, T_P, which
arises from Pauli exclusion-principle effects on
deuteron propagation in nuclear matter[4], as well as
the now well-known radial tensor potential term, T_R,
arising from the deuteron D-state.

In order to make such studies, an out-of-
horizontal plane target chamber and detector system
were constructed. Figure 1 is a photograph of the
experimental facility. An angle plate was mounted
under an existing target chamber for the γ-cave with an
arm pivoting about the target location. A cryostat for
a silicon plus hyper-pure germanium detector
telescope[5] may be mounted at three radial locations

Figure 1. The X_2 target-chamber/detector-mount
apparatus installed in the γ-cave, looking in the beam
direction from above. A protective cover plate is in
place concealing the Kapton window. A 54.7 degree
angle from the horizontal is shown for the angle plate
and the detector is situated at a 90° scattering angle.

along the arm (20, 28 and 36 cm from the target).
Deuterons scattered from the target pass out of a 50 µm
thick Kapton window through 18 to 33 cm of air and a 8
µm thick nickel detector window. The target
chamber-detector mount may be rotated about the beam
direction and locked in position at any angle in the
range from 18° to 140°. An energy resolution of 180
keV and scattered deuterons with energies as low as

about 50 MeV have been observed with this device.

The first measurements of X_2 have been made with
this device over the angular range from 19° to 110°,
but analysis has not proceeded to the point where the
data can be presented in this report.

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REACTION MECHANISM IMPLICATIONS
OF DEUTERON RAINBOW SCATTERING

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In proton inelastic scattering and proton-induced
reactions, the vital information on nuclear structure
is carried in the details of the diffraction patterns
in the cross section and analyzing power. The same is
true for deuteron-induced reactions, except that the
diffractive oscillations are frequently much smaller in
magnitude, and precise information is therefore harder
to extract experimentally. The diffraction pattern is
further attenuated at large scattering angles because
of the appearance of rainbow scattering. There the
values of the vector (A_y) and tensor (A_{yy}) analyzing
powers approach unity in the deuteron elastic channel.

While information from the diffraction pattern is
disappearing at large angles, the rainbow scattering
picture suggests that the reaction mechanism itself has
undergone radical change. Since with
intermediate-energy deuterons, the spin effects in
rainbow scattering are being observed for the first
time, it is appropriate to consider the impact of
rainbow scattering on the analyzing powers for

deuteron-induced reactions. This region may be
sensitive to both structure and reaction mechanism in a
manner different from scattering at forward angles. It
is likely that detailed agreement between theory and
experiment will be hard to achieve, since these effects
will be superimposed on top of larger effects due to
the spin-orbit distortions in the entrance channel.

This contribution describes a series of
observations and measurements concerning the
implications of rainbow scattering for deuteron-induced
reactions.

1. Theoretical Framework. Rainbow scattering
takes place in the surface of the nucleus, and thus
emphasizes the importance of large angular momentum in
the scattering. By expanding the scattering matrix in
terms of irreducible spin tensor operators, it is
possible to specify in a simple fashion the character
of deuteron elastic scattering in the limit of very
large angular momentum. In that limit, it may be shown
that the scattering matrix commutes with the operator