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1.72 The Rainbow Scattering of 80-MeV Polarized Deuterons

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In Ref. 1, measurements of the cross section, vector (A_y) and tensor (A_{yy}) analyzing powers were reported for the elastic scattering of 80 MeV deuterons from ^{58}Ni. At large scattering angle, both analyzing powers lost most of their diffractive structure and took on large values near unity. This feature was attributed to "rainbow" scattering, a mechanism in which the flux at large angles originates from the far side of the nucleus. At 80 MeV, the surface partial waves have large ℓ-values, so the spin-orbit term changes the potential by a significant amount and greatly influences the refraction of waves around the nucleus. The extra attraction found for deuterons with spin parallel to their angular momentum makes these deuterons the dominant contributor to the large angle cross section, and gives rise to the analyzing powers near unity. This picture is supported by a more detailed analysis of deuteron scattering,[2] which demonstrates that the vertical projection of the deuteron spin is nearly conserved in the scattering process and that the three spin-orbit matrix elements affect the respective three spin projections as if they were nearly incoherent. To confirm this picture of deuteron scattering, we have made a separation of the scattering amplitude into near and far side contributions, following the method of Fuller.[3]

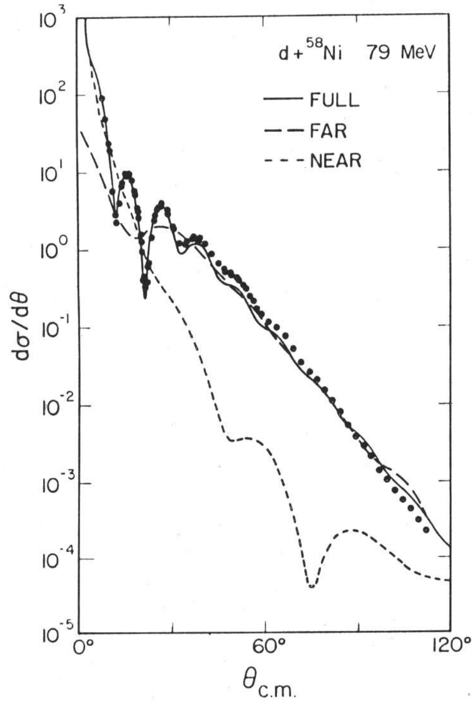

Fig. 1. Measurement of the cross section $d\sigma/d\Theta = \sin\Theta \, d\sigma/d\Omega$ for 79-MeV deuterons elastically scattered from ^{58}Ni. The full optical model calculation is shown by the solid curve. The long and short dashed curves decompose this calculation into far and near side contributions.

The cross section data of Ref. 4 is shown in Fig. 1 along with an optical model calculation. The solid curve, which comes from the full scattering amplitude, is separated into a near side (short dash) and a far side (long dash) contribution. The slope of the near side is much greater than that of the far side, a signal that most of the scattering amplitude originates with the real part of the optical potential.[5] Where the two contributions are of comparable size, the oscillating pattern of Fraunhofer interference appears in the full calculation and the data. The dominance of the far side contribution to the large angle cross section at 80 MeV persists for nuclei throughout the periodic table.

As it is the only significant contributor, the far side scattering generates the large analyzing powers shown in the right-hand panels of Fig. 2. The effects of the spin-orbit potential term are illustrated with the separation of the far side calculation into three pieces arising from the nearly incoherent scattering from each deuteron spin projection.[1]

If the absorptive potential is sufficiently weak, the far side scattering cross section will show an enhancement at the "rainbow" angle that is associated with a stationary (or turning) point in the classical deflection function. In the three spin projection cross sections of Fig. 2, these appear near 30°. The minimum which preceeds them near 20° can be interpreted

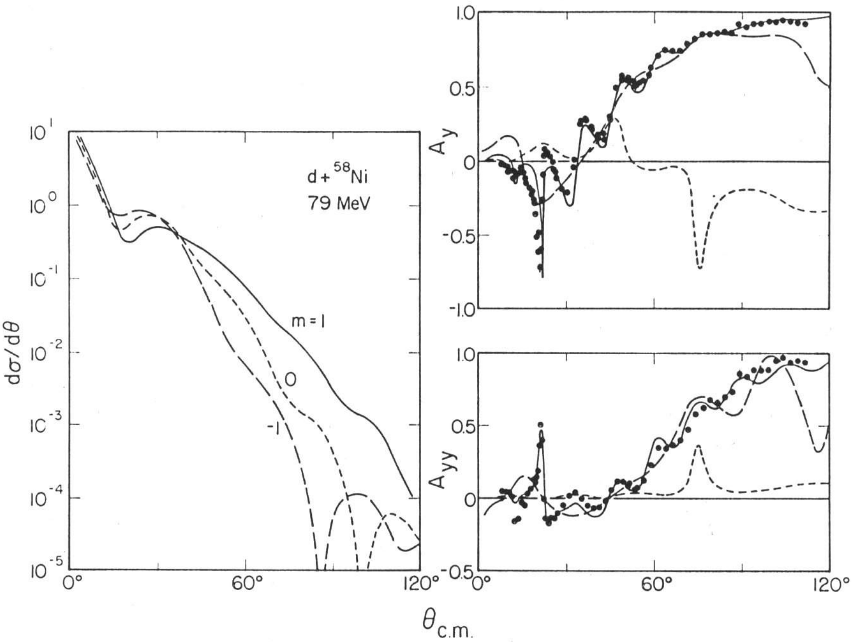

Fig. 2. The left panel shows the spin projection components of the far side cross section of Fig. 1. The right panels show vector (A_y) and tensor (A_{yy}) analyzing power measurements along with the calculations of Fig. 1.

either as a diffraction minimum from far side scattering, or as the destructive interference of amplitudes arising from the two lobes of the deflection function on either side of the stationary point. The inner amplitude (arising from small impact parameter) can only contribute if the absorption at that radius is small. The increased depth of the minimum for the m=1 projection indicates a reduced importance of the absorption for the m=1 inner amplitude.

Figure 3 shows the mass dependence of the minimum for the m=1 piece of the cross section. While the general features of the far side remain the same, the absorption has a smaller influence for heavier targets in this spin projection, and the depth of the minimum increases.

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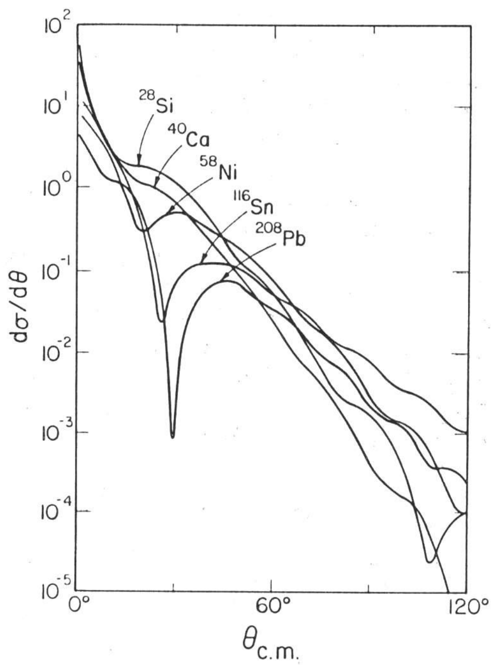

Figure 3: Calculations of the spin up, far side cross section for a series of isotopes bombarded with 79 MeV deuterons.

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