We measured the analyzing power for the $^{16}\text{O}(p,n)^{16}\text{F}$ ($4^-$, 6.37 MeV) reaction at 134.0 MeV and the differential cross section for the same reaction at 135.2 MeV. The shape of the cross section for the transition to this unnatural-parity, stretched state is described well by a distorted-wave-impulse-approximation (DWIA) calculation using a $(\pi d_5/2, -1, \nu p_3/2)\lambda^-$ configuration and the effective interaction derived by Love and Franey from nucleon-nucleon phase shifts. The analyzing power from this calculation reproduces all of the qualitative features of the data and supports the use of the impulse approximation as an excellent starting point for describing the reaction mechanism. Figure 1 is a plot of the angular distribution of the analyzing power for the $^{16}\text{O}(p,n)^{16}\text{F}$ ($4^-$, 6.37 MeV) reaction at 134.0 MeV. The points represent our data and the error bars denote statistical uncertainties. The curves represent DWIA calculations with the optical potential of Comfort and ICarpl and with the 140 MeV nucleon-nucleon t-matrix given by Love\(^2\) (dotted curve), Love and Franey\(^3\) (dashed curve), and Love (Sussex)\(^2\) (solid curve) wherein the tensor force is derived from the Sussex oscillator matrix elements. The agreement with experiment is best for the effective interaction of Love (Sussex), which has no imaginary tensor term.

DWIA calculations of both the analyzing power and the shape of the cross section with a modified Love and Franey interaction that uses the tensor term of Love (Sussex) is essentially the same as that obtained from use of the complete Love (Sussex) interaction; however, the use of the tensor term from Love (Sussex) results in a reduction of the normalization factor for the differential cross section from 0.37 to 0.27. The

\[ \text{Figure 1. The angular distribution of the analyzing power for the } ^{16}\text{O}(p,n)^{16}\text{F} \text{ reaction at } 134.0 \text{ MeV. The curves represent DWIA calculations with three different effective interactions as discussed in the text.} \]
Conclusions to be drawn from this analysis are that the present analyzing power data show a strong preference for a zero strength for the imaginary tensor term and a weaker preference for the real tensor term derived from the Sussex matrix elements. Both of these substitutions represent a departure from the requirements of the nucleon-nucleon phase shifts. We note also that the shape and magnitude of the DWIA calculation of the differential cross section is insensitive to the imaginary tensor term; however, the magnitude is sensitive to the real tensor term.

The analyzing power data are sensitive also to $t_I^L$, the imaginary part of the spin-orbit term in the effective interaction, as illustrated in Fig. 2. The $t_I^L$ dash-dot curve, which is calculated for $t_I^L = 0$ in the effective interaction of Love (Sussex), shows that the agreement with experiment worsens in the momentum transfer region from about 0.6 to 2.2 fm$^{-1}$. The other three curves in Fig. 2 show the effect of varying only the short-range ($R_1 = 0.25$ fm) triplet-odd (TO) strength of the imaginary part of the spin-orbit potential of Love from 0 MeV (dashed curve) to -831 MeV (solid curve) to -2000 MeV (dotted curve). The dotted curve fits the experimental data very well. This change has no effect on the normalization of the calculation of the cross section.

To explore the sensitivity of the DWIA calculations of the analyzing power to the choice of optical potentials, we carried out and compared calculations with five sets of optical potential parameters derived from elastic scattering data at 135 MeV. In four of these cases, the resulting changes in the analyzing power were similar and small. Typical results from two of these four cases are shown in Fig. 3 as the solid (Comfort and Karp) and the dotted (Kelly) curves. The "envelope of uncertainty" does not mask the difference in the analyzing powers calculated with the Love (Sussex) and the Love-Franey t-matrices. The other (dashed) curve in Fig. 3 is the exceptional fifth case coming from a global.

Figure 2. The angular distribution of the analyzing power for the $^{16}_0(p,n)^{16}_F (4', 6.37$ MeV) reaction at 134.0 MeV. The curves represent DWIA calculations to illustrate the sensitivity to the imaginary part of the short-range, triplet-odd, spin-orbit term of the effective interaction.

Figure 3. The angular distribution of the analyzing power for the $^{16}_0(p,n)^{16}_F (4', 6.37$ MeV) reaction at 134.0 MeV. The curves illustrate sensitivity to the choice of optical potential parameters.
parameterization, which might be expected to be inferior to the other potentials that are designed specifically for this energy region and for light (16O and 12C) targets. Also we note that this global potential forces the values of A(θ) in the angular region from 30° to 60° to decrease significantly. Our preference for the Love (Sussex) t-matrix is based on the need for the theoretical A(θ) values in this angular region to be increased.

As illustrated in Fig. 4, the optical model distortions (especially the spin-orbit effects) contribute significantly to the theoretical analyzing power. Yen et al7 showed that the interplay between the optical spin-orbit term and the tensor term of the effective interaction is important for transitions of this stretched type, and can introduce a quadratic dependence of the analyzing power on the tensor term.

In summary, this work suggests that the high-momentum transfer parts of the nucleon-nucleon effective interaction are not well-determined and may reflect either ambiguities in determining the effective interaction from the phase shifts or a hint of medium effects.

In addition to the 16O(p,n)16F reaction, we measured analyzing powers for the 17,18O(p,n)17,18F, 28Si(p,n)28F, and the 42,48Ca(p,n)42,48Sc reactions. For the 17O(p,n)17F (g.s.) reaction, analyzing powers were measured from 0° out to 63° where the cross section is only 6 μb/sr. The 28Si(p,n)28F reaction provides another "stretched-state" example, in this case to the 6° state at Ex = 4.75 MeV, and can be compared with available (p,p') analyzing powers to the analog state in 28Si. The 48Ca(p,n)48Sc reaction includes a transition to a "Oω"-type stretched state which will test the high-momentum components of the effective interaction in a somewhat different way than does a "1ω" stretched-state transition. Analyzing power data to several strongly excited 0+ and 1+ states (analog and "Gamow-Teller" states) were obtained also for the 18O, 28Si, 42Ca, and 48Ca(p,n) reactions. The analyses of these transitions are in progress.