PROTON ELASTIC AND INELASTIC SCATTERING AT INTERMEDIATE ENERGIES FROM ISOTOPES OF OXYGEN AND ^{9}Be AS PART OF A UNIFIED STUDY OF THESE NUCLEI

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This report will briefly describe the status of an experimental and theoretical program that combines electron scattering at the M.I.T.-Bates Linac and 135 MeV proton scattering at IUCF as part of a unified study of the oxygen isotopes. Since the time of the last report, 8 shifts of additional beam time at IUCF were used to clarify the systematics of the experiment and to complete cross-section measurements for the set of negative parity "octupole" states of ^{17}O and low lying states of ^{16}O. The experiment was described in the 1978 annual report.[1]

During the last year, the bulk of the effort has been directed towards performing calculations and interpreting this body of data.[2] Detailed electron scattering charge densities provide the proton transition density input to the proton scattering calculations. When reliable assumptions about the neutron densities can be made, we can study the effective interaction in the context of the impulse approximation. A second objective is to study isotopic differences, wherein the proton reaction uncertainties will hopefully be minimized by the comparison. A third objective is to use the understanding of the impulse approximation and the effective interaction that will have been obtained and the proton transition densities provided by electron scattering to disentangle the separate proton and neutron contributions to inelastic proton scattering and thereby obtain nuclear structure information not easily obtainable by either electron or proton scattering alone. In the following we will briefly illustrate each of these objectives with a sampling of the calculations that have been performed. For further information, see Ref. 2.

The study of the effective interaction is most readily performed with ^{16}O. Electron scattering provides precise proton distributions while the N=Z nature of ^{16}O allows us to reliably assume that the neutron densities equal the proton densities for the isoscalar transitions under study. Thus the nuclear structure uncertainties are minimized and we can isolate the effective interaction for study.

A striking example of the sensitivity to the effective interaction is shown in Fig. 1, which compares an impulse approximation[3] calculation for the lowest 1^- state with a calculation that employs a parametrization of the Brieva-Rook-Geramb density dependent interaction.[4] The transition density is taken from recent electron scattering data[5]. The impulse approximation ig-

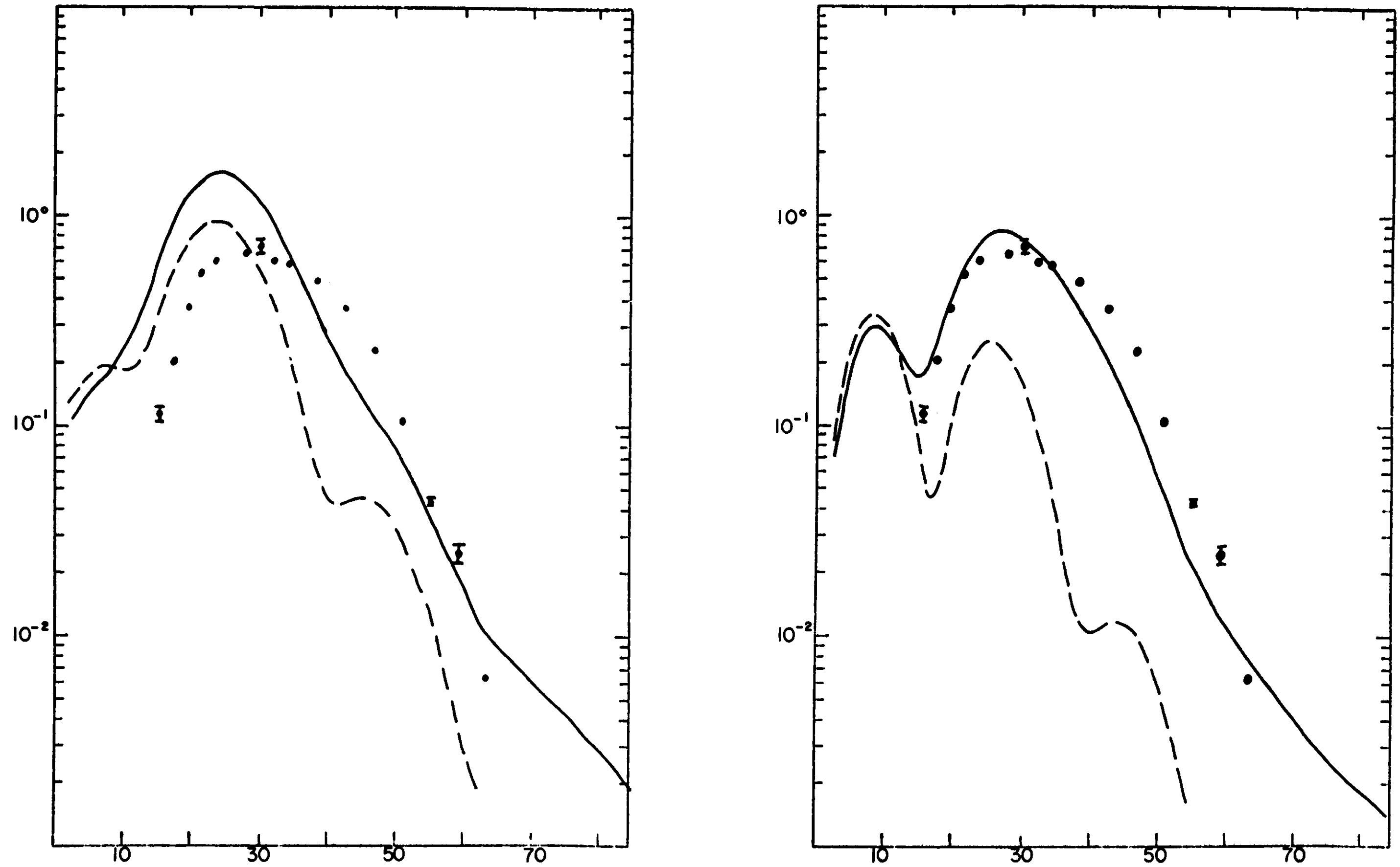

Figure 1. Comparison of a) impulse approximation and b) density dependent calculations for excitation of lowest 1^- state of ^{16}O. Dashed curves use only the central interaction; solid curves use central and spin-orbit.

nores the Pauli blocking effect of neighboring nucleons upon the interaction between the incident and struck nucleons. This state shows the effect dramatically because its transition density peaks in the high-density nuclear interior where the density dependence of the effective interaction is most noticeable. Other ^{16}O states also clearly display the effect of reduction of the effective central interaction.[2]

The example above illustrates our ability to study the effective interaction with minimal nuclear structure uncertainty. The next example is an isotopic comparison in which we expect the interaction uncertainty to be minimized. Namely, we expect the impulse approximation defects to be similar for ^{16}O and ^{18}O elastic scattering and to divide out of the ratio σ^{18}/σ^{16}. An example of this type of calculation is compared with the data in Fig. 2. The proton densities are both taken from electron scattering.[6] The ^{16}O neutron density $^{16}\rho_n$ is assumed equal to the proton density. The figure shows the results of two assumptions for the ^{18}O neutron density. The solid curve of Fig. 2 uses the assumption $^{18}\rho_n = \frac{10}{8}\, ^{18}\rho_p$, i.e., that the neutron density has the same geometry as the proton density, but is normalized to N instead of Z. The slightly larger radius for the proton density of ^{18}O than that for ^{16}O results in a downturn of the cross section ratio, but is not a large enough effect. The dashed curve shows the result of assuming that the ^{18}O neutron distribution consists of an eight neutron core that has the same distribution as the protons plus two valence neutrons in a $d_{5/2}$ harmonic oscillator orbital (b=1.8fm). This model appears to

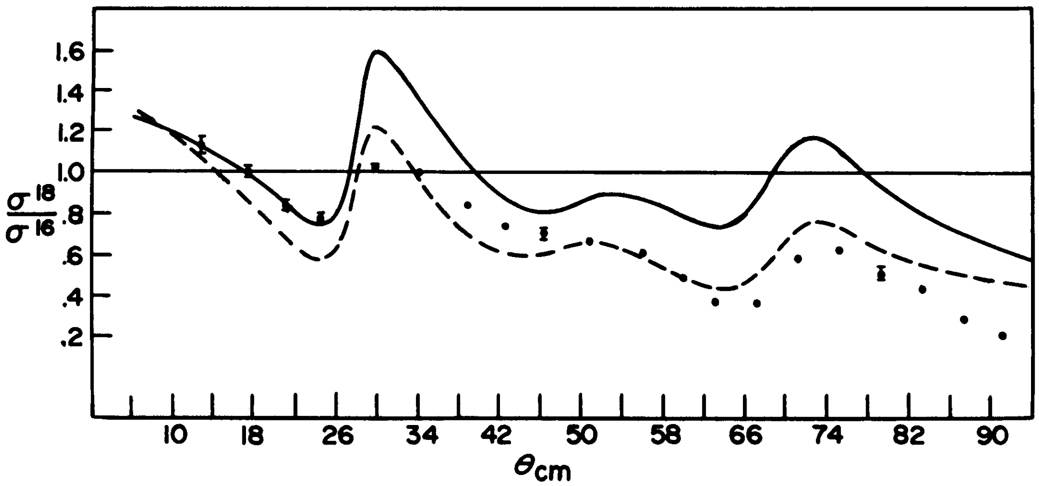

Figure 2. Solid curve $^{18}\rho_n = \frac{10}{8}\,^{18}\rho_p$. Dashed curve $^{18}\rho_p + 2\rho(d_{5/2})$.

have a sufficiently large matter radius.

Finally, we show an example sensitive to the separate proton-neutron contributions to an ^{18}O inelastic transition. Figure 3 shows an impulse approximation calculation for the third 2^+ state of ^{18}O in which the proton density is again taken directly from electron scattering.[7] The neutron transition density was assumed identically zero. If the neutron density had been taken equal to the proton density, the resulting cross-section would have been a factor of five above the data. Thus this state appears to be predominately a proton excitation.

In the future we plan to make asymmetry and (p,n) measurements[8] on the oxygen isotopes. The asymmetry measurements will provide us another means to study the nuclear structure relationships among the isotopes, the role of transverse form factors, and possible modifications of the impulse approximation spin-orbit interaction. The (p,n) measurements will provide another linear combination of interactions and densities further expanding the study of both.

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2) J. Kelly, W. Bertozzi, T. Buti, M. Deady, F.W. Hersman, C. Hyde, M.V. Hynes, S. Kowalski, J. Lichtenstadt, B. Norum, B. Pugh, F.N. Rad, R. Redwine, A. Bacher, G. Emery, C. Foster. W. Jones, D. Miller, B. Berman, F. Petrovich, W.G. Love, procedings of Los Alamos Workshop on Nuclear Structure with Intermediate Energy Probes, 1980.

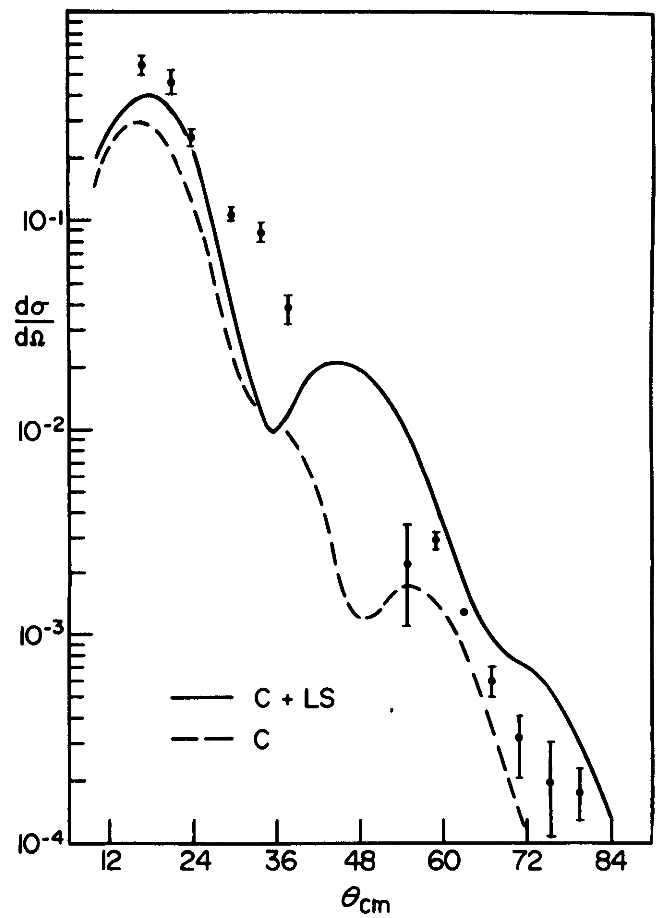

Figure 3. Impulse approximation prediction for third 2^+ state of ^{18}O. Proton density is from electron scattering while neutron density is taken identically zero.

3) F. Petrovich and W.G. Love, Los Alamos Workshop, 1980, and references therein.

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6) H. Miska, B. Norum, M.V. Hynes, W. Bertozzi, S. Kowalski, F.N. Rad, C.P. Sargent, T. Sasanuma, and B.L. Berman, Phys Lett. 83B, 165 (1979).

7) B. Norum, M.I.T. thesis (unpublished) 1979; B. Norum et al., to be published.

8) IUCF, Expt. No. 60.

ANALYZING POWER MEASUREMENTS FOR THE EXCITATION OF STATES IN ^{28}Si and ^{24}Mg BY INELASTIC SCATTERING OF POLARIZED PROTONS

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Analyzing powers $A_y(\theta)$ for the excitation of states in ^{28}Si and ^{24}Mg with excitation energies up to 16 MeV have been measured with a 135-MeV polarized proton beam. The scattered protons were detected with the QDDM magnetic spectrograph at angles between 25° and 65° with an overall resolution of about 70 keV. Results for the 6^-, T=1 (14.35 MeV), 6^-, T=0 (11.58 MeV), and 5^-, T=0 (9.70 MeV) states in ^{28}Si,[1] whose predominant configurations are all $(d_{5/2})^{-1}(f_{7/2})$, are shown in Fig. 1, where they are compared with the results of DWIA calculations using the t-matrix effective interaction derived by Love from the free nucleon-nucleon scattering data.[2] The cross section for the 6^-, T=1, state is due mainly to the tensor direct term in the interaction, while that for the 6^-, T=0, state is due mainly to tensor and spin-orbit exchange terms, and that for the 5^-, T=0, state is due mainly to spin-orbit and central interaction terms. The $A_y(\theta)$ results for the 6^- states are sensitive to interference both between the central and spin-orbit parts and between the spin-orbit and tensor parts of

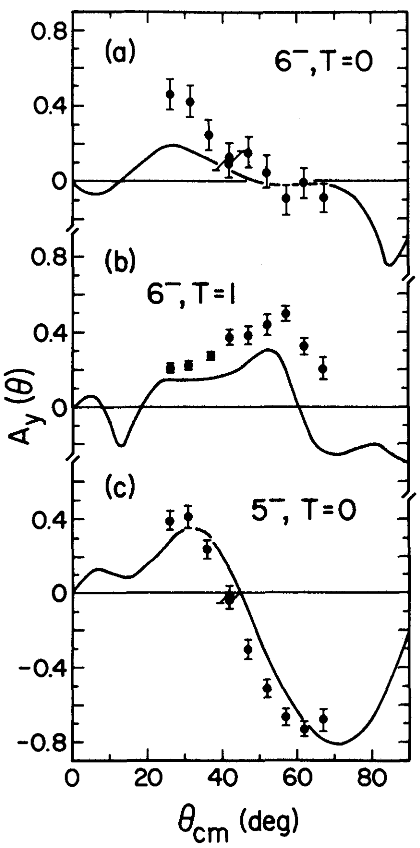

Figure 1. Analyzing powers, $A_y(\theta)$, for the 135-MeV $(\vec{p},p')$ excitation of (a) the 6^-, T=0, state at 11.58 MeV, (b) the 6^-, T=1, state at 14.35 MeV, and (c) the 5^-, T=0, state at 9.70 MeV. The experimental data are compared with results of DWIA calculations using the Love t-matrix.