STUDIES OF KNOCK-OUT REACTIONS

D.W. Devins, D.L. Friesel, W.P. Jones, A.C. Attard, B.M. Spicer,* V.C. Officer,*
G.G. Shute,* I.D. Svalbe,* and R.S. Henderson*

Of the many possible ways of studying the off-shell nucleon-nucleon interaction, the proton knock-out, or (p,2p), reaction provides one of the most sensitive tests of reaction formulations which are used at intermediate energies to study nuclear reaction data. In particular, the Distorted Wave Impulse Approximation (DWIA) has achieved a measure of success in understanding both knock-out and inelastic proton scattering.[1] Several features of the DWIA need to be understood before it can be used reliably to extract spectroscopic information from intermediate energy reactions or to test various phase-equivalent nucleon-nucleon potentials: a) neglect of higher order reactions, b) factorization of the proton-proton interaction, c) replacement of the nuclear boundstate overlap integral with a single-particle wavefunction generated from a Woods-Saxon well, and d) generation of the distorted waves by means of optical model potentials determined by elastic scattering.

Our first experiments with the temporary telescope-spectrograph arrangement[2] were done to examine the effects of neglecting higher order reactions. In the reaction $^{12}C(p,2p)^{11}B$, the second excited state ($5/2^-$ at 4.44 MeV) should not be seen, if the reaction proceeds purely by means of a single step knock-out. If multiple step processes occur, then this state could be reached via a variety of intermediate steps including inelastic excitation to low lying states by the incident or exiting protons or inelastic scattering to one or more giant resonances. At 50 MeV this state is quite strongly excited in the (p,2p) reaction.[3] Our results at 100 MeV indicate that multiple step processes, while they do occur, are much less important than at the lower energy and that the intermediate states involved very likely are not giant resonances.[4]

The next knock-out experiments were done to investigate the factorization approximation used in the DWIA. In this approximation it is assumed that the proton-proton interaction is not dependent on the momentum transfer of the reaction so that it may be factored out of the transition amplitude. This approximation has been tested for the knock-out of alpha clusters by alpha particles and found to be satisfactory.[5] But the (α,2α) reaction is believed to be highly surface localized; it was not clear the same satisfactory result would be obtained using the (p,2p) reaction. We used the $^{40}Ca(p,2p)^{39}K^*$ (1st excited state, $\frac{1}{2}^+$, 2.52 MeV) reaction for the test, and found that for a momentum transfer of zero, factorization was quite satisfactory.[6]

The summed energy spectra for four of the five momentum transfers used in the factorization tests are shown in Figure 1. In each spectrum a ten count bias has been added to each channel to enable background to be subtracted on-line. The events plotted are those which pass a proton window set on the telescope E vs. ΔE spectrum. The appropriate recoil energy has been calculated for each event and added on-line into the summed energy. The FWHM for these spectra vary from about 260 keV to 300 keV, most of this being the consequence of energy loss effects in the target (4 mg/cm^2). Several of the partially resolved peaks in the region of 5 MeV can be identified as parts of the fragmented $1d_{5/2}$ hole by comparison to $(d,^3He)$ transfer reaction results on the same target. Also visible in the 109 MeV/c spectrum are several partially resolved peaks at higher excitation, near 14 MeV. No states had been reported above 9 MeV in lower energy (d,^{3}He) transfer experiments.[7] A 76 MeV deuteron beam is available from IUCF; we speculated a higher incident energy could be more effective in producing higher excitations. We were able to use director's discretionary time to make a preliminary run[8] using ^{40}Ca(d,^{3}He)^{39}K, and later we received beam time through the normal Program Advisory Committee procedure for a more detailed study.[9]

The (d,^{3}He) data were taken with the spectrograph. A composite spectrum covering three spectrograph settings at a 6° scattering angle is shown in Figure 2. There are no strong states attributable to ^{39}K above about 9 MeV. We were able to confirm that the visible $1d_{5/2}$ states account for only about 70% of the $1d_{5/2}$ hold strength. Calculations[10] indicate this strength should extend above 9 MeV. We believe we are seeing it in the (p,2p) data. We think these states are not seen in the proton transfer reactions because individually they can have a very small spectroscopic factor, about .02. When this number is used with a DWBA calculation for states having 14 MeV excitation energy, a cross section is calculated which is not significantly higher than the measured background. The only background in the (p,2p) summed energy spectrum at 109 MeV/c has to come from the low energy tail of the presumably fragmented 1s and 1p hole states. But at this high value of momentum transfer the cross sections for $\ell=0$ and $\ell=1$ states should be very small compared to their values at small momentum transfer. On the other hand, the $\ell=2$ states (the suspected $1d_{5/2}$ states) would be near the peak of their cross sections and would thus stand out above the background.

*University of Melbourne, Australia

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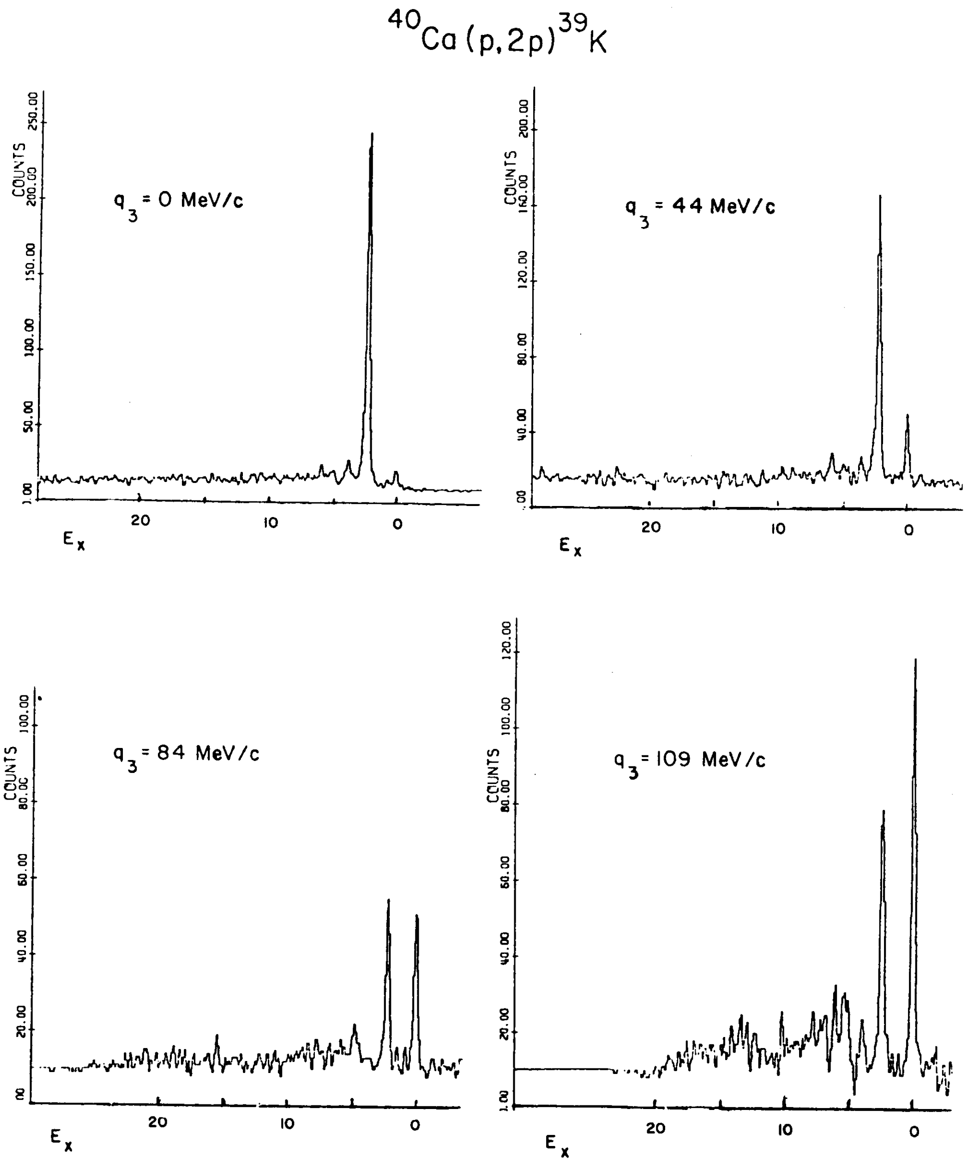

Figure 1.

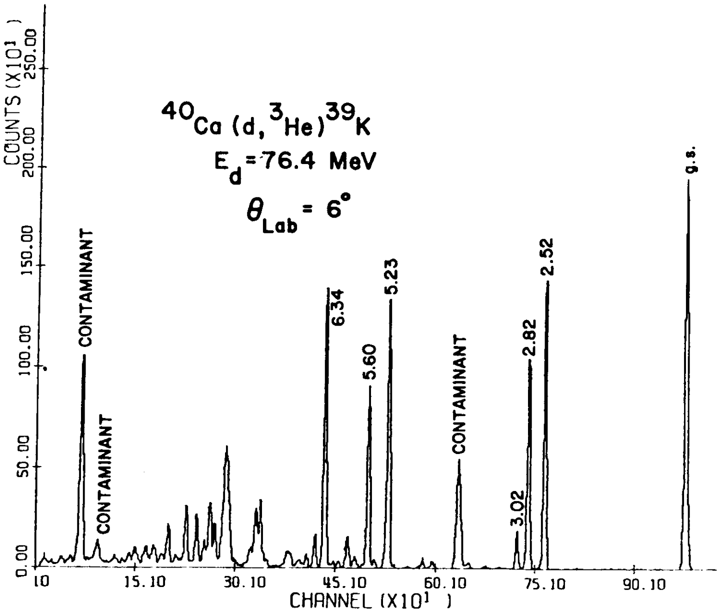

Figure 2.