ANALYZING POWER AND CROSS SECTION MEASUREMENTS OF THE CONTINUUM SPECTRA IN $\vec{p} + {}^2H$, ^3He and ^4He AT 100 AND 150 MeV

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The energy spectrum of protons produced by the interaction of medium- energy protons with light nuclei is often dominated by a broad quasifree peak representing a significant portion of the reaction cross section. An experimental study of the origin of the so-called "quasifree" peak provides insight into the reaction mechanisms which dominate the interaction and serves as a test of theoretical calculations of continuum yields. Previous work$^{1)}$ seems to indicate that the initial nucleon-nucleon scattering acts as a doorway to more complicated reaction processes. A predominance of evaporation-fast proton coincidences suggests rapid dissipation of the energy of the struck nucleon.

In an attempt to understand the quasifree process more fully we have embarked upon a program to study proton-nucleus interactions at intermediate energies on light ($A \leq 4$) targets. It is our hope that these few-body targets will allow us to more easily distinguish multiple-scattering processes from more complex multi-body mechanisms, as well as to examine changes in the quasifree process as the number of target nucleons and the binding energy increases.

Initial measurements of differential cross sections and analyzing powers of outgoing protons, deuterons and tritons for 100- and 150-MeV polarized proton beams incident on ^2H, ^3He and ^4He targets have been made. The beam had a typical current of 20 nA and polarization of 0.75. The latter was measured with a ^4He polarimeter between the injector and the final stage accelerators. Data were taken at 17.5°, 30°, 45°, and 60° for all targets at 100 MeV. At 150 MeV, measurements were made at 30° and 45° for ^2H, 17.5°, 30°, and 45° for ^3He, and 17.5° and 30° for ^4He.

Identical telescopes consisting of a 1 mm silicon surface barrier ΔE-detector followed by a 3" NaI(Tℓ) E-detector were used at symmetric angles on both sides of the beam to obtain the spectra for the higher energy particles. Such a symmetric geometry, combined with reversal of the sense of beam polarization (about once a minute) allows one to eliminate many systematic errors to first order. Spectra for low energy particles stopped in the ΔE detectors were obtained using time-of-flight between the detector and the RF signal. The target gases were contained in a 5"-diameter gas cell with Havar windows. Collimators with tantalum slits were used to prevent direct scattering from the gas cell windows into the detectors. In addition, a pair of active slits were used for each telescope to prevent particles double-scattered from the windows or target gas and the tantalum slits from entering the detectors. These active collimators reduced this source of background significantly.

Figure 1 shows unpolarized cross sections for all targets at 30° and 100 MeV bombarding energy. The sharp elastic peak on the right and the broad continuum peak on the left are common features of the data. As one goes to larger angles, the elastic and continuum peaks are observed to shift to lower energies and the yield of the continuum peak decreases much more slowly than that of the elastic peak. It is interesting to note that the unpolarized cross sections for ^{4}He are different from those for ^{3}He and ^{2}H. The ^{4}He spectra generally have much less structure, as shown in Fig. 1. The exception is ^{4}He at 17.5° at 150 MeV, which has a shape similar to those of ^{3}He and ^{2}H. The corresponding analyzing powers for the same runs are shown in Fig. 2.

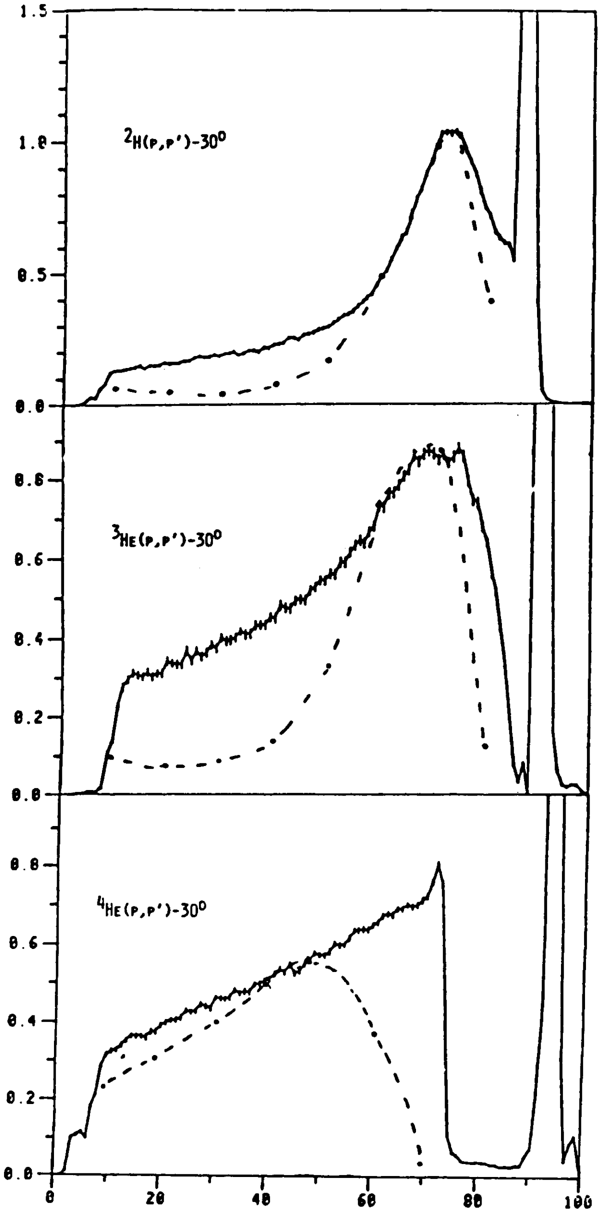

Figure 1. Unpolarized cross sections for (p,p') at 30° for ^{2}H, ^{3}He, and ^{4}He.

The dashed lines in Fig. 1 are results of a calculation (arbitrarily normalized to the data) in which the plane wave impulse approximation (PWIA) expression for the differential cross section for quasifree nucleon knockout is integrated over the direction of the undetected outgoing nucleon. This PWIA expression is proportional to a free nucleon-nucleon differential cross section multiplied by the absolute square of the momentum space wave function of the nucleon in the target nucleus. Nucleon-nucleon differential cross sections were obtained from the program NUSCAT.$^{2)}$ The momentum space wave functions were Gaussian with widths chosen to fit (p,2p) data.$^{3)}$

As seen in Fig. 1, the calculations underpredict the cross sections for low proton energies, presumably as a result of multiple scattering. The calculations are also too small at high proton energies, particularly in the case of ^{4}He. For ^{4}He this may be a result of inelastic scattering to unbound excited states in ^{4}He.

In the comparison of these calculations with the measured analyzing powers (Fig. 2), we see the shape is reasonably well predicted, but the magnitude is too large. This may be due to multiple scattering events which effectively lead to an unpolarized background, events which are not included in the simple PWIA calculation.

Further calculations are now being carried out, using better momentum wave functions for the target nuclei. In the near future, distorted-wave impulse approximation calculations of the quasifree mechanism will be performed. It is hoped that the inclusion of distortion effects will correct many of the deficiencies shown in the present calculations.

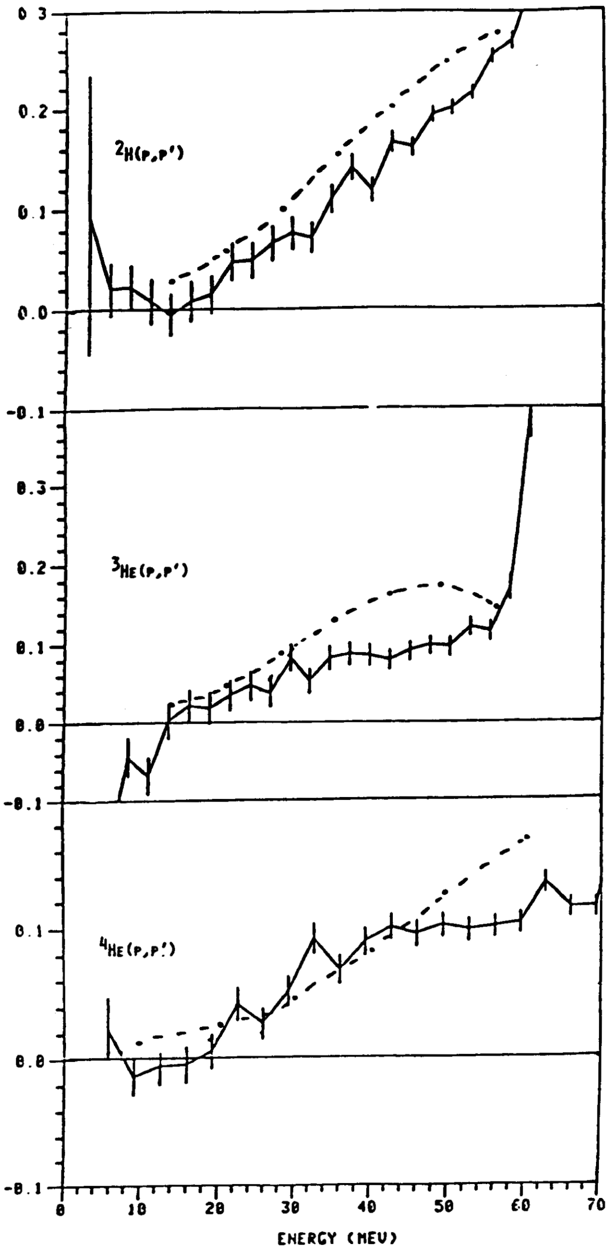

Figure 2. Analyzing powers for $(\vec{p},p')$ at 30° for ^{2}H, ^{3}He and ^{4}He.

1) A.A. Cowley et al., Phys. Rev. Lett. 45, 1930 (1980).

2) C.A. Miller, private communication.

3) A.A. Cowley et al., Nucl. Phys. A220, 429 (1974); H.G. Pugh et al., Phys. Lett. 46B, 192 (1973).