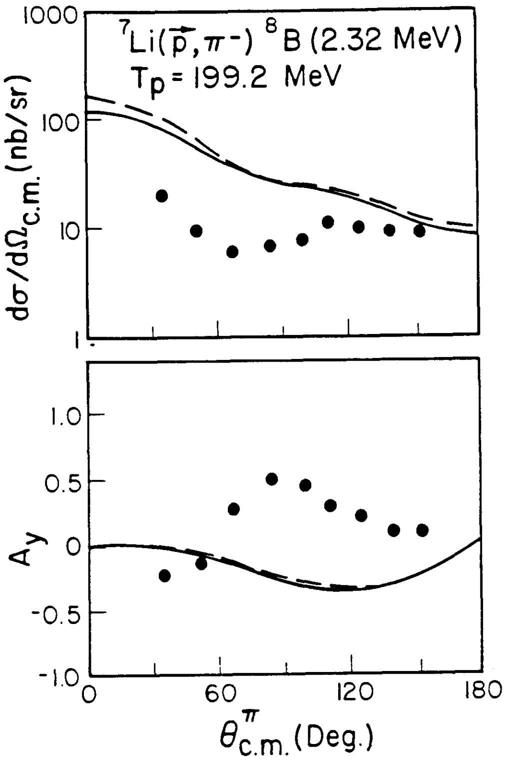

Figure 7. Calculated differential cross sections and analyzing powers assuming admixtures of two configurations (solid curves) and only the dominant configuration (dashed curves) for ^8B(2.32 MeV). The data were taken at IUCF in 1984.

the (p,π^-) reaction, but the results suggest that intermediate Δ formation may not play a dominant role in the $^7Li(p,\pi^-)^8B$ reaction at these energies, which are far below the isobar resonance.

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CONSTRAINTS ON THE PION-NUCLEUS OPTICAL POTENTIAL FROM THE (p,π) REACTION

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In their 1979 review article[1] on the (p,π) reaction, Measday and Miller stated that: "The use of the (p,π) reaction to provide constraints on the pion-nucleus optical potential may become its most outstanding contribution to knowledge of meson-nucleus dynamics". To explore this possible use of the (p,π) reaction, we have begun to investigate the sensitivity of our two-nucleon model[2] (p,π) calculations to details of the pion-nucleus optical potential.

A characteristic feature of the A(p,π)A+1 reaction is the large momentum transfer to the nucleus, which is more than twice the fermi momentum of nucleons. In a simple pionic stripping model, this momentum is carried into the nuleus by a single neutron, and the cross section provides a direct measure of the high momentum tail of the bound state wave function of the captured neutron. In the DWBA stripping model, momentum is also transferred to the nucleus via initial and final state interactions of the incident proton and outgoing pion, respectively. This reduces the sensitivity of the calculations to high momentum components of the bound state wave functions while introducing a sensitivity to details of the proton and pion nuclear optical potentials. It has been found that DWBA (p,π) calculations are extremely sensitive to pion distortions, which play a dominant role in the production process.

In the two-nucleon model of pion production the bulk of the momentum sharing is incorporated microscopically, but higher order rescattering effects still must be included and the calculations remain sensitive to details of the pion optical potential. The (p,π) calculations require knowledge of the pion wave function in the nuclear interior, and hence may be able to provide new information about meson-nucleus dynamics in a region not probed by pion elastic scattering. The problem is complicated by the fact that there is some overlap between the pion rescattering incorporated in the basic two-nucleon interaction operator and the rescattering included via distortions of the outgoing pion calculated in an optical potential. One should either correct for this or show that these double counted parts are small.

At energies near the pion production threshold, the (p,π) reaction mechanism can be complicated.[2] In contrast to energies in the 33-resonance region where the Δ-isobar dominates the nuclear dynamics, at low energies there is no clearly outstanding agency in the reaction mechanism; both s-wave and non-resonant p-wave rescattering can be important, and there is evidence[3] for very light nuclei that both the one-nucleon and two-nucleon mechanisms are important in the (p,π^+) reaction. In addition to the reaction mechnanism complexities, the (p,π) reaction is sensitive to the bound state nuclear wave functions.[4] So, in general, there are lots of unknowns.

Clearly, the reaction dynamics and nuclear structure must be pinned down if one is to learn anything about the pion-nucleus optical potential from the (p,π) reaction. We need a case for which the reaction mechanism is simple and the nuclear wave functions are relatively pure. The (p,π^-) reaction is simpler than (p,π^+) because this double-charge-exchange process must involve two nucleons and hence there is no one-nucleon (stripping) contribution to worry about. Experiments at IUCF[5] have shown that the $^{14}C(p,\pi^-)^{15}O$ reaction at 183 MeV bombarding energy populates strongly the $7/2^+$ state at 7.3 MeV excitation energy in ^{15}O. Shell model calculations made with the code OXBASH[6] give that the ^{14}C ground state and the ^{15}O $7/2^+$ state configurations are ~ 90% pure. Preliminary applications of our microscopic model to this reaction have shown that the strong $^{14}C(p,\pi^-)^{15}O$ (7.3 MeV, $7/2^+$) transition is reasonably well described by a simple two-nucleon reaction mechanism involving intermediate Δ formation and pure initial and final state configurations.[7] Thus, this appears to be a favorable case for exploring the sensitivity of the (p,π) reaction to details of the pion-nucleus optical potential.

To illustrate the degree to which our two-nucleon model calculations are sensitive to pion distortions, we show the results of three preliminary calculations in Fig. 1. Curve (a) was calculated with pion

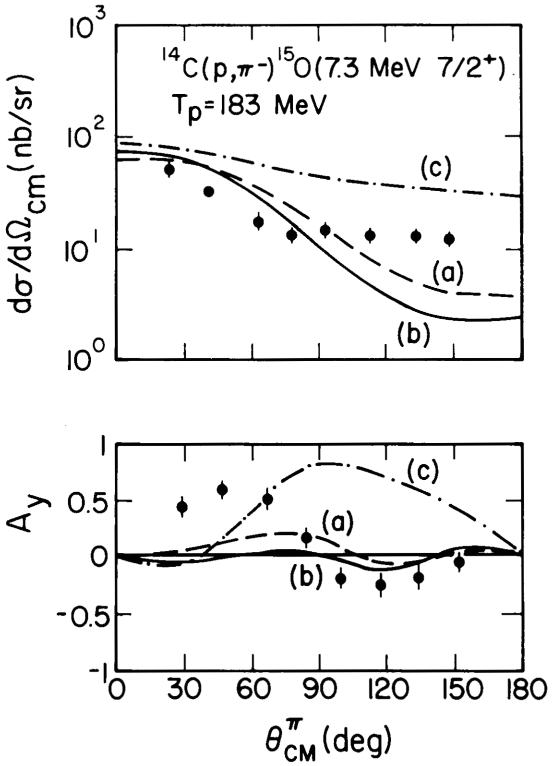

Fig. 1. Calculated differential cross sections and analyzing powers for the $^{14}C(p,\pi^-)^{15}O(7.3\ MeV,\ 7/2^+)$ transition at T_p = 183 MeV. The calculations were made with pion distorted waves derived from three different pion-nucleus optical potentials (see text) to illustrate the sensitivity of the (p,π) reaction to details of the potential. The data are from Ref. 5.

distorted waves derived from a realistic pion nucleus optical potential that includes Pauli blocking, Skyrme III densities and second order isoscalar and isovector parameters obtained from a complete, phenomenological, energy dependent analysis of pion nucleus elastic and single-charge exchange data.[8] The first-order parameters were calculated from the FP85 pion-nucleon phase shifts.[9] This potential, in which the parameters have a well established energy dependence, gives excellent fits to π^+ and π^- elastic data for energies between 0 and 80 MeV).[8] Curve (b) was calculated using the MSU pion optical potential[10] with parameter set C of Table IV in ref. 10. This potential has the same structure as that used for curve (a) but different first and second order parameters. This potential also produces a reasonable fit to pion elastic data. Curve (c) shows what happens when a badly behaved pion wave function is used. For this case, a Kisslinger potential was employed with parameters determined from a fit to π^+ and π^-elastic data at 40 MeV. In spite of the "effective" parameters used, this potential still suffers from the well known Kisslinger disease.[11]

As is seen from Fig. 2, the three potentials used for the (p,π) calculations shown in Fig. 1 give similar results for π^- elastic scattering. With regard to the differences seen in Fig. 2, potentials (a) and (c) are both best fit potentials at 40 MeV; but whereas the energy dependence of potential (a) has been well established,[8] for potential (c) it is unknown and the 40 MeV parameters were used at 37.48 MeV. Potentials (a) and (b) have the same mathematical structure but different first and second order parameters. The (p,π) calculations do not seem to be more sensitive to these differences than the pion elastic calculations. In contrast, the (p,π) calculations with potential (c) are noticeably different from the other two cases, whereas the elastic scattering calculations are not.

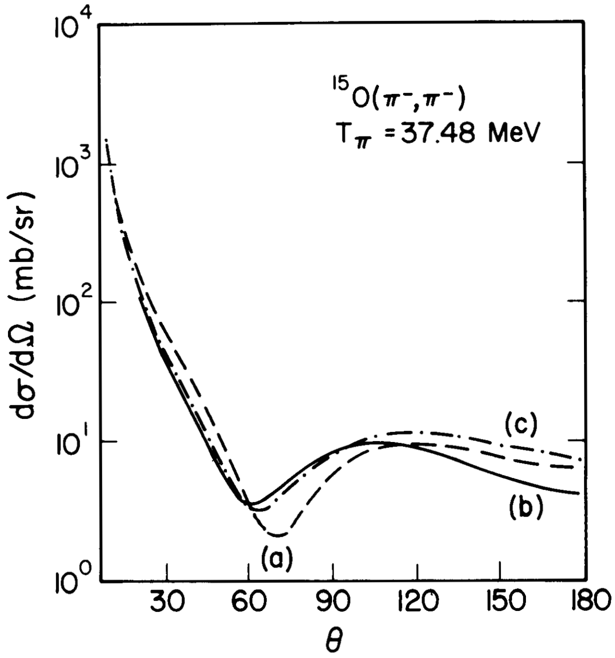

Fig. 2. Calculated pion elastic differential cross sections using the same pion nucleus optical potentials as in Figure 1.

This shows that the (p,π) reaction can distinguish between mathematically dissimilar optical potentials that give the same elastic scattering. Thus, the (p,π) reaction may provide useful constraints on the pion nucleus optical potential beyond those provided by pion elastic scattering.

We emphasize the preliminary nature of these results. More detailed studies, which will include an investigation of relativistic effects in the incident proton channel, are in progress.

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EXPLORATION OF (p,π°) AS A WAY OF STUDYING PIONIC ATOMS

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The 1s level of pionic atoms is not known for elements beyond aluminum. In conventional studies of pionic atoms the pion is captured into an outer atomic level and cascades down. But already for Z about ten absorption from the 2p level is appreciable, and it increases rapidly with Z. No results are available for Z greater than 12. One would like to know the strong-interaction shifts and widths in the 1s states for larger Z.

It is possible to make pionic atoms in a different way, as entrance-channel resonances in proton-nucleus collisions. At an appropriate energy below the threshold for making free negative pions in a (p,π^-) reaction, the pion can be created in an atomic level. The cross section can be estimated from the free cross section above threshold and the properties of pionic atoms.[1] This is an example of a threshold phenomenon with an attractive Coulomb field.[2] Some related possibilities have been discussed by Kilian.[3]

Detection of the pionic atom resonance is the primary difficulty. The dominant decay mode is presumably by emission of two fairly fast nucleons or clusters, followed by evaporation, and is difficult to pull out of the general background of proton-induced reactions at the necessary proton energies of about 140 MeV. Some initial attempts made in this lab have not been encouraging.[4] For light targets the resonance may be seen in proton elastic scattering at backward