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COMPARISON OF (d,p) AND (p,π^+) REACTIONS ON ^{28}Si AT SIMILAR MOMENTUM TRANSFER

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With a view to compare and contrast the (d,p) stripping reaction with the (p,π^+) reaction, angular distribution measurements of $^{28}Si(p,\pi^+)^{29}Si$ cross sections (E_p=191 MeV) to several low-lying excited states in ^{29}Si were made. In addition, existing (d,p) angular distribution measurements at E_d=76 MeV were extended to larger angles in order to overlap the momentum transfer (up to q∿600 MeV/c) inherent to the (p,π^+) reaction. Of particular interest is a comparison of the (d,p) and (p,π^+) results for the relative population of states of the same J^π, but different single-particle spectroscopic strengths, in ^{29}Si: two $3/2^+$ states (E_x=1.27 and 2.43 MeV) and two $5/2^+$ states (E_x=2.03 and 3.07 MeV). Such a comparison should be sensitive primarily to differences in residual-state wave function components sampled by the two reactions. Other differences between the two reactions, e.g., in angular momentum coupling and matching, and in distortions of the incident and outgoing waves, should effectively cancel in the population ratios.

Spectra for the two reactions are shown, for nominal momentum transfer q∿550 MeV/c, in Fig. 1. The low-yield (p,π^+) and large-angle (d,p) data were obtained with a detection/identification system in the QDDM spectrograph focal plane similar to that used previously at IUCF for other charged pion production measurements[1]. The (d,p) data ($5^\circ \le \theta_L \le 90^\circ$) were obtained with a natural Si target ∿6 mg/cm² thick. At angles larger than 65°, the 3.07 MeV $3/2^+$ state was contaminated by a contribution from the 5.28 MeV 3^- state of ^{30}Si (seen in Fig. 1a as a high-E_x shoulder). The 3.62 MeV $7/2^-$ state angular distribution, scaled to

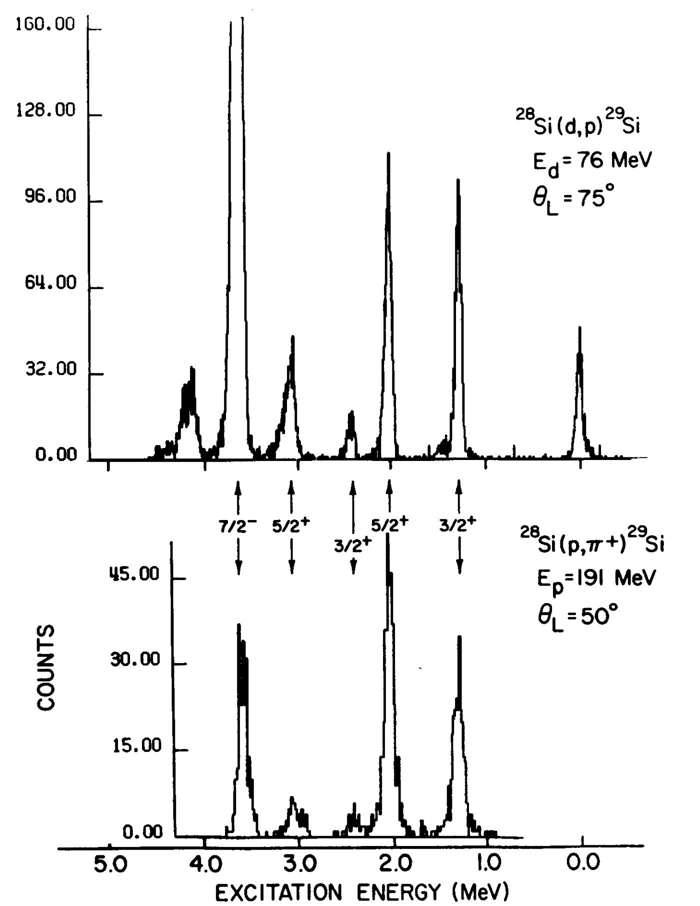

Figure 1. Comparison of (d,p) and (p,π^+) spectra from Si at a nominal momentum transfer q∿550 MeV/c. The location of the $3/2^+$ and $5/2^+$ states of interest in ^{29}Si are indicated by the arrows.

the forward-angle 5.28 MeV state yield, was used to make an accurate subtraction of the contaminating yield to the 3.07 MeV state of interest at the large angles. The (p,π^+) data $(30^o \leq \theta_L \leq 90^o)$ were taken with enriched ^{28}Si targets of 25-30 mg/cm^2 thickness. Contamination of the (p,π^+) spectra by products from light target nuclei (^{12}C or ^{16}O) were eliminated by Q-value considerations.

One can already notice differences in the relative population of states in a comparison of the spectra in Fig. 1. However, the difference in relative population of the $3/2^+$ versus $5/2^+$ states may not be related to a difference in nuclear structure sensitivity for the two reactions, but may rather arise simply from the fact that different angular momentum transfers, L, are allowed for the two final-state spins in (p,π^+), by virtue of the intrinsic negative parity of the pion. The 3.62 MeV $7/2^-$ state in the (p,π^+) spectrum was positioned partially off the region of 100% efficiency of the focal-plane detection system and thus couldn't be meaningfully included in the analysis.

Plots of the measured angular distributions are shown in Fig. 2. For the (d,p) results, the cross section for the 3.07 MeV $5/2^+$ state has been multiplied by a factor of 2 (the ratio of spectroscopic strengths for the two $5/2^+$ transitions observed[2] in (d,p) at E_d=18 MeV). The weak 2.43 MeV $3/2^+$ state has been multiplied by a factor of 30 (this state has a non-stripping character at lower energies[2]). The similarity over a wide range of q (up to ∿400 MeV/c for the $3/2^+$ states) of the distributions observed for states of the same spin and parity, but very different microscopic structure, suggests that here the (d,p) reaction is sampling primarily the single-particle components of the bound state wave functions. For the weak 2.43 MeV $3/2^+$ state the onset of another reaction mechanism may be the cause of the cross section enhancement (relative to the 1.27 MeV state) at the very large q. The solid lines in each case are DWBA calculations for the 1.27 and 2.03 MeV states with spectroscopic factors of 0.74 and 0.12, respectively, taken from lower energy (d,p) work[2]. The deuteron potential was constructed from the adiabatic model of Johnson and Soper[3], using global neutron and proton parameters of Becchetti et al.[4] For the proton potentials, a recent re-analysis of 135 MeV p + ^{28}Si data obtained at IUCF was scaled down to 80 MeV p + ^{28}Si using global proton parameter systematics for this energy region[5]. The DWBA calculations are in fairly good agreement with the magnitude of the observed (d,p) cross sections. In particular the agreement for the 3/2 states is very good (all the way out to large q for the 1.27 MeV state). The calculation fails in part for the $5/2^+$ states in not describing the experimentally observed J-dependence (increased cross section for J = L + 1/2 at larger angles).

From the (p,π^+) results also shown in Fig. 2, one can see that the two $5/2^+$ state distributions are qualitatively similar although not as close as in (d,p). However, the weak 2.43 MeV state distribution bears little resemblance to that of the 1.27 MeV state , suggesting population of these latter states by significantly different mechanisms. The ratios of (p,π^+) cross sections for the two $3/2^+$ and for the two $5/2^+$ states varies greatly over the angle range covered, from ∿1 to ∿6 for $5/2^+$ and from ∿5 to ∿40 for $3/2^+$. A simple average of these ratios over the whole angular range gives ∿3.5 for the $5/2^+$ states [compared to a nearly constant value of 2.0 for (d,p)] and ∿16 for $3/2^+$ (compared to the apparent ratio of ∿30 for the single particle strengths, as determined from the (d,p) results at $q \lesssim 400$ MeV/c). Over the momentum transfer range covered by the (p,π^+) data, the (d,p) results for

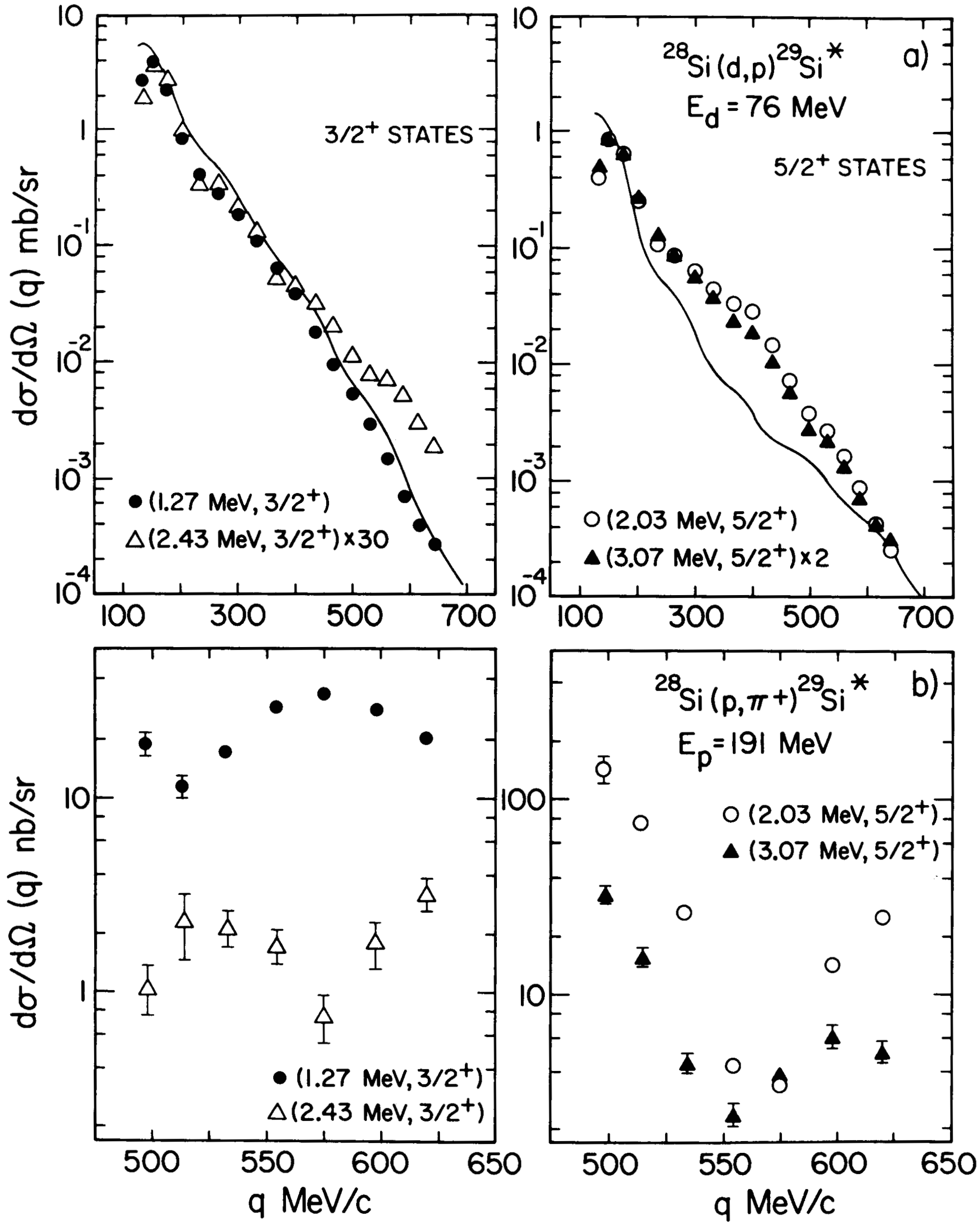

Figure 2. Angular distributions for $^{28}Si(d,p)^{29}Si^*$ and $^{29}Si(p,\pi+)^{29}Si^*$ to $J^\pi=3/2^+$ (E_x=1.27 and 2.43 MeV) and $5/2^+$ (E_x =2.03 and 3.07 MeV) states plotted against momentum transfer q (note scale difference for q in top and bottom panels). For the (d,p) distributions, the data for the 2.43 MeV $3/2^+$ and 3.07 MeV $5/2^+$ states are plotted with multiplying factors of 30 and 2, respectively. The error bars, where shown, reflect counting statistics and an estimation of background subtraction. The solid curves are DWBA calculations as described in the text.

the $3/2^+$ states yield an average strength ratio of ∿9.

For both pairs of states, then, we observe substantially greater differences between the (p,π^+) angular distributions than between those for the (d,p) reaction. The (p,π^+) differences cannot be attributed to Q-value effects: calculations using a code with distortions included in both entrance and exit channels[6] confirm the expectation that, within the pionic stripping model, no appreciable change in angular distribution shape can result from the small change in distortions (corresponding to the ∿2% change in outgoing pion kinetic energy) or a difference in neutron binding energy for the transitions to the two states of each pair. The present comparison thus suggests that (p,π^+) is more sensitive than (d,p) to other than single-neutron components in the bound-state wave functions (although there is reason to suspect that such other configurations do also contribute appreciably at high momentum transfer to the weakest of the four (d,p) transitions studied). In order to reach more specific conclusions concerning the nature of the mechanism differences between the (d,p) and (p,π^+) reactions, it would be necessary to compare the (p,π^+) experimental results (especially the state-to-state differences) with calculations based on various models.

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MEASUREMENT OF THE $^2H(\vec{p},\pi^0)^3He$ AND $^3H(\vec{p},\pi^0)^4He$ THRESHOLD CROSS SECTIONS AND ANALYZING POWERS

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In this experiment (#95) we plan to measure the differential cross sections and analyzing powers for the reactions $^2H(\vec{p},\pi^0)^3He$ and $^3H(\vec{p},\pi^0)^4He$ within 4.0 MeV of threshold. In few nucleon systems the high momentum components of the nuclear wave functions are well established ((e,e'), (p,p'), Fadeev calculations). With this in mind, the study of pion production from very light nuclei should enable us to separate the effect of particular reaction mechanisms from the influence of the wavefunctions of the participants.

The targets for this experiment are CD_2, and ^3H in a Ti foil. We filter out the ^3He or ^4He recoil nucleus by placing the QDDM spectrometer at 0°, requiring a coincidence with the two gamma-rays from a decaying π^0, detected by Pb glass detectors placed on opposite sides of the target. The distribution in energy of the recoils will give us, after certain corrections, the differential cross section. Because the flight time of the recoils of a given momentum is a function of the angle at which they enter the spectrometer, a measure of that distribution in time will yield the analyzing power for the reaction.

In order to stop the beam we must place a copper block within the QDDM itself. This block also functions as a Faraday cup. The background generated by this arrangement was measured in a short test run and was found to produce a count rate in the QDDM focal plane in excess of 1 MHz at the $\sim$30 nA polarized beam intensities which will be used in the experiment. However, with reduced intensity we were able to identify recoil ^3He, presumably from spallation in the CD_2 target. To handle the very high counting rates anticipated in the actual experiment, we are building a 12 element scintillator hodoscope for the focal plane. We hope to initiate the actual measurements in the spring of 1980.

STUDIES OF PROTON INDUCED NEUTRAL PION PRODUCTION NEAR THRESHOLD

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Experiment 18, the first in a series of experiments to investigate features of the (p,π^0) reaction near threshold, is now complete. In the course of this study it was necessary to develop Pb glass Čerenkov detectors whose response was reproducible over long periods of time, and which had close to