

The Munich group would like to thank W. Benenson, who suggested measuring heavy ion pion production using the recoil method.

1) J.R. Erskine et al., Nucl. Instr. and Methods 135, 57 (1976).

2) The self supporting Be targets were manufactured by H. Adair, ORNL, Be on Au was made by H. Maier, Sektion Physik der LMU, Munich, Li₂O and Melamine by P. Maier - Komor, Physik - Department der TUM.

3) F. Ajzenberg-Selove, Nucl. Phys. A248, 1 (1975).

THE DOMINANCE OF HIGH-SPIN TWO-PARTICLE ONE-HOLE TRANSITIONS IN (p, π^-) REACTIONS

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In the process of attempting to extend earlier measurements for (p, π^-) ground-state transitions¹ to different mass regions, we have recently discovered a striking and unexpected systematic feature of (p, π^-) spectra on many target nuclei: a dominant fraction of the total yield to discrete states is often concentrated in one or a few states in a narrow region of excitation energy (E_x). Initial systematics for these dominant transitions were established by measuring broad-range (p, π^-) spectra with the QQSP magnetic spectrograph for bombarding energies in the

range $E_p=183-206$ MeV, using Director's discretionary beam time during the period when the polarized ion source was being repaired. Representative forward-angle spectra for six targets are shown in Fig. 1. Qualitatively similar concentrations of strength have been observed for several other targets in each of these mass regions. E_x for the dominant states varies slowly with mass, from $\sim 6-7$ MeV for 1p-shell targets to ~ 3 MeV in the Zr region. The forward-angle cross sections vary rapidly, but not always monotonically, with neutron excess, and appear to be maximized when

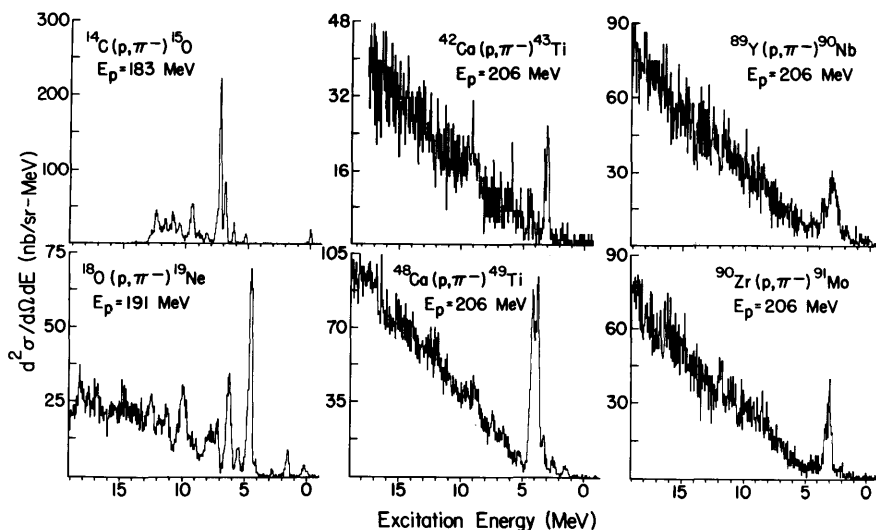


Figure 1. Spectra for the (p, π^-) reaction on several targets at $\theta_{lab}=30^\circ$ (28° for the ^{14}C target), showing strong selective excitation of one or a few low-lying states.

the target nucleus has a filled $j_{>} (= \lambda + 1/2)$ neutron shell and the corresponding proton shell is empty. Angular distributions measured for the strongest transitions in $^{13,14}\text{C}$, ^{48}Ca and $^{90}\text{Zr}(p, \pi^-)$ are strongly forward-peaked.

A consistent scenario for the structure of the states selectively excited by (p, π^-) has been developed in the context of a "two-nucleon" pion production model. In this picture, transitions to the residual bound states involve capture of the incident proton plus charge exchange of a target neutron, forming $2p(\text{protons})-1h(\text{neutron})$ states with respect to the target ground-state configuration. The strongest transitions are likely to involve optimal sharing of the very high momentum transfer characteristic of (p, π) reactions ($q=450-700$ MeV/c), and the maximum angular momentum transfer possible for simple excitations (including spin-flip in the $n \rightarrow p$ transition, as would be favored by the spin-dependent isovector part of the NN interaction). In $^{48}\text{Ca}(p, \pi^-)$ one would then expect preferential excitation of "stretched" $\{(\pi f_{7/2})^2_{6+}(\nu f_{7/2})^{-1}\}_{19/2^-}$ or $\{[(\pi f_{7/2})(\pi f_{5/2})]_{6+}(\nu f_{7/2})^{-1}\}_{19/2^-}$ states and nearly stretched states with similar configurations coupled to slightly lower J. The locations of such stretched $2p-1h$ states were not previously well established in ^{49}Ti or in the heavier residual nuclei we have studied in (p, π^-) . However, in $^{13,14}\text{C}$, ^{18}O , and $^{42}\text{Ca}(p, \pi^-)$, where the states at relatively low excitation are known, the strongest (p, π^-) peaks observed are consistent with this scenario, and furthermore suggest a very rapid falloff in strength as J decreases from the maximum value.

Stretched $2p-1h$ states may be excited in (p, π^+) reactions as well, but these transitions involving less optimal momentum sharing may be of comparable

strength due to the coherence of contributions for target nucleons from several orbitals. It is thus not surprising that no comparably pronounced selectivity for stretched states has been noted in (p, π^+) spectra. For medium-mass or heavy target nuclei, one should furthermore expect the absolute strength of stretched-state transitions to be smaller for (p, π^+) than for (p, π^-) , since the natural neutron excess of stable nuclei favors $n \rightarrow p$ over $p \rightarrow n$ transitions within a $j_{>}$ orbital. These features help to explain the striking difference observed in Fig. 2 between (p, π^+) and (p, π^-) spectra for reactions leading to the same final nucleus, ^{49}Ti .

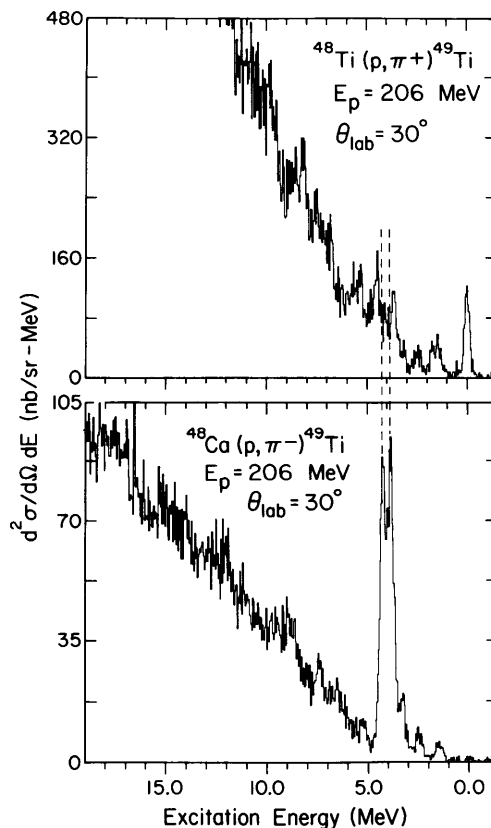


Figure 2. Comparison of (p, π^+) and (p, π^-) spectra for reactions leading to the same final nucleus ^{49}Ti , showing the striking difference in selectivity of the two reactions.

A brief report of this work has been recently published,² and a more detailed account (presented at the International Conference on Nuclear Structure, Amsterdam, August 30-September 3, 1982) is currently in press.³ Follow-up investigations with polarized beams have been initiated recently.^{4,5}

- 1) W.W. Jacobs et al., Phys. Rev. Lett. 49, 855 (1982).
- 2) S.E. Vigdor et al., Phys. Rev. Lett. 49, 1314 (1982).
- 3) S.E. Vigdor et al., Nucl. Phys., in press.
- 4) T.G. Throwe et al., this report, p. 93.
- 5) J.J. Kehayias et al., this report, p. 87.

THE MASS OF ^{59}Zn

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The nucleus ^{59}Zn is the heaviest $T_z = -1/2$ nucleus for which the mass and lifetime are known from β -decay measurements.¹ This makes it important for mass predictions and the calculation of Gamow-Teller matrix elements in nuclear beta decay. The mass measurement of ^{59}Zn also represents the first in a series of $Z > N$ nuclei in this mass region which are needed to extend the Garvey-Kelson symmetric mass predictions to $A > 56$. Further, since the mass of the $T_z = 1/2$ mirror nucleus is known, the Coulomb energy shift systematics can be extended to the $2p_{3/2}$ orbit.

The present measurement represents the first use of the (p, π^-) reaction to measure a nuclear mass. The (p, π^-) reaction allows a considerably more accurate (< 50 keV) mass measurement and ft-value calculation than the beta-endpoint technique commonly used to make mass measurements of proton rich nuclei.

The measurement was performed at the Indiana University Cyclotron Facility with a proton beam of 190 MeV. The QQSP spectrometer³ was set at 30° and used to determine the outgoing pion kinetic energy. At the focal plane of the spectrometer a vertical drift chamber detector measured both position and angle.⁴

The one difference from the standard setup described in Ref. 5 was the use of an aluminum absorbing wedge placed after the focal plane detector and between the first two scintillators which were used to measure time-of-flight and energy loss. The thickness of the wedge was chosen to cause the negative pions to stop in the second scintillator, where they deposited some part of their rest mass energy plus their kinetic energy. Thus, by gating on large ($E > 40$ MeV) energy signals in the back scintillator, we were able to reduce the background by two orders of magnitude while the efficiency remained virtually unchanged. The limitation of this technique is that it works for only a limited range of pion energy due to the geometry of the wedge and the pion orbits in the spectrometer.

The mass measurement itself was carried out by determining the Q-value of the reaction $^{58}\text{Ni}(p, \pi^-)^{59}\text{Zn}$ relative to the Q-values of the calibration reactions.⁴

$^{13}\text{C}(p, \pi^-)^{14}\text{O}$	$Q = -136.650$ MeV
$^{25}\text{Mg}(p, \pi^-)^{26}\text{Si}(E_x = 1.796$ MeV)	$Q = -140.595$ MeV
$^{25}\text{Mg}(p, \pi^-)^{26}\text{Si}(E_x = 2.783$ MeV)	$Q = -139.607$ MeV.

Since the QQSP detector system measured angle as well