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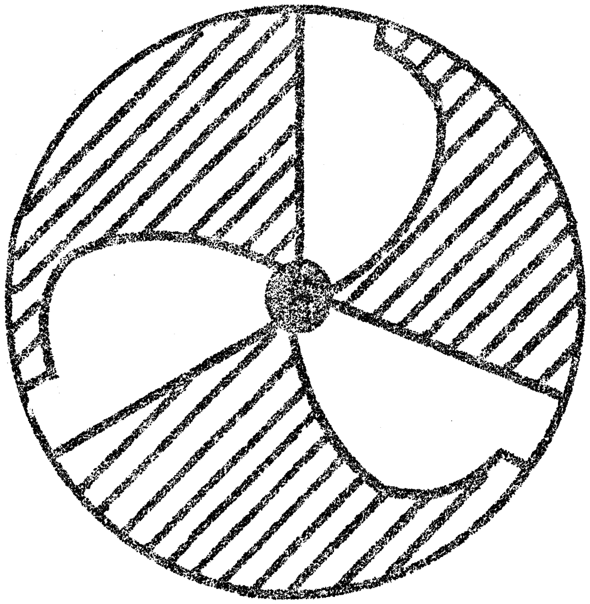

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Shapes of Angular Distributions in the $^{89}Y(^{3}He,t)^{89}Zr$ Reaction to Antianalog and Other $T_{<}$ States*

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ABSTRACT

The $^{89}Y(^{3}He,t)^{89}Zr$ reaction to $T_{<}$ states in ^{89}Zr shows the angular distributions to have shapes characteristic of non-allowed L transfers and not similar to microscopic predictions. The antianalog states appear not to be unique in possessing this feature.

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The (^{3}He,t) charge exchange reaction has served in recent years as a useful spectroscopic tool in determining the spins and parities of states in many odd-odd nuclei. As the angular distributions with transitions to states of the same J^π seemed to be nearly identical,[1] values of J^π could be assigned by comparing the shapes of the experimental angular distributions with transitions to known states. DWBA calculations, with the inclusion of a tensor term[2] to account for transitions to unnatural parity states, have also been quite successful in fitting the data. Recently, however, ambiguities have been noted[3] in (^{3}He,t) reactions with the observation that the angular distributions for 0^+ to 0^+ transitions to antianalog states in ^{40}K and ^{64,66}Ga were not fit by an L=0 angular momentum transfer shape as expected, but by L=1. This was not true for transitions to 0^+ isobaric analog states in these nuclei. Recent examinations of other charge-exchange results[4] for transitions to $T_<$ states (states with isospin one lower than the target) have also shown anomalies between the shapes of some experimental angular distributions and the shapes of the DWBA predictions. In these cases the angular distributions appeared to be shifted significantly in angle relative to the calculations. This letter reports upon a study of the ^{89}Y(^{3}He,t) reaction, with particular emphasis upon transitions to antianalog states. This situation is more complex than the 0^+ to 0^+ transitions as several angular momenta contribute and non-central terms need be included in the effective interaction.

The $^{89}Y(^3He,t)^{89}Zr$ reaction was studied at 33 MeV using the MSU sector-focused cyclotron. The data was taken with an Enge split-pole spectrograph, using both plates and a position sensitive counter. Although the energy spectrum showed many states quite strongly excited above 2.5 MeV in ^{89}Zr, only the well identified low-lying $T_<$ states will be discussed in this communication. The $1/2^-$ isobaric analog state of the ^{89}Y ground state lies at 8.0 MeV and, with the usual isospin splitting relationship, the antianalog state is the $1/2^-$ state at 0.59 MeV. The analog of the first excited state of ^{89}Y $(J^\pi=9/2^+)$ has its first excited antianalog state at 1.51 MeV.

Figure 1 shows the angular distributions for the $(^3He,t)$ transitions to the $1/2^-$ isobaric analog state (IAS) and antianalog state (AAS) for scattering angles between 3° and 45°. Also shown are several different sets of DWBA calculations made with the code DWUCK,[5] with both microscopic and macroscopic form factors. The angular distribution for the antianalog state is out of phase with both sets of the calculations. In fact the non-allowed L=1 macroscopic calculation fits much better. (This is similar to that for the 0^+ to 0^+ transitions to antianalog states reported in Ref. 3.) The isobaric analog state is fit quite well with a macroscopic calculation with a complex surface-peaked form factor, with the geometry for the imaginary well 20% larger than that used in the distorted wave channel. The smaller imaginary geometry did not fit the second maximum. The microscopic calculation for the analog state does not fit as well. The microscopic calculations included a tensor term in the effective interaction. The Woods-Saxon wave-functions used for the analog state were generated by the application of the isospin lowering operator to the ^{89}Y ground state, with the antianalog state being the orthogonal component. All fits shown used optical model parameters of Gibson _et al._[6] for both the ^{3}He and triton.

In attempting to fit the antianalog state distributions, several different sets of optical model parameters were tried and yielded little change in the overall phasing of the angular distribution, although there were some small differences in shape. A large increase in the imaginary potential strength and radius, particularly in the triton channel, had the effect of pulling in the maxima, although not enough to fit the data. Variations in the range of the Yukawa interaction between 0.7 and 1.4 F^{-1} changed the phase of the angular distributions only a little. Equal strengths for the tensor and central terms of the effective interaction were used; changing this ratio, in the case of the antianalog state, only increased the contribution from the L=0 or L=2 terms and did not change the overall phase. As 0^{+} antianalog states can only be excited when there is a difference in the radial integrals for two contributing orbitals,[7] different shapes of the Wood-Saxon well were tried in this case for both the $g_{9/2}$ and $p_{1/2}$ orbitals, but produced little change in the overall shape. Since the (^{3}He,t) reaction is surface-peaked, it is independent of the nuclear interior. Because of this and because the tails of the different form factors were quite similar, the final shapes are much more dictated by the angular momentum transfer than by the final state configuration.

Figure 2 shows ^{89}Y(^{3}He,t)^{89}Zr angular distribitions to the $9/2^+$ ground state of ^{89}Zr and the $9/2^+$ excited antianalog state at 1.51 MeV. The data for both transitions are quite similar. Microscopic calculations with a tensor term and L=3 and L=5 macroscopic calculations with a derivative surface interaction are also shown. The microscopic calculations for the ground state provide a very poor description of the data, especially at forward angles. Variations in the optical parameters and the form factors (as discussed above for the $1/2^-$ antianalog state) had small effects. Macroscopic calculations with a non-allowed L=2 term are also shown in Fig. 2. This fit is much better than with the allowed L=3 and L=5 calculations.

Transitions to other well identified $T_<$ states in ^{89}Zr are also shown in Fig. 2. The 1.74 and 1.87 MeV states, both identified as $3/2^-$ by recent (p,t) work,[8] have quite similar shapes. Microscopic calculations are out of phase with most of the data, while the L=1 macroscopic calculation fits the data rather well. The 1.45 MeV $5/2^-$ state can be fit by an L=2 macroscopic calculation but a microscopic calculation with equal contributions from the central and tensor terms places too much emphasis on the L=4 component.

A comparison of the similarities of the ground state and 1.51 MeV $9/2^+$ state transitions appears to show that the anomalies in the (^{3}He,t) angular distributions are not dependent upon the uniqueness of the antianalog state. A survey of recently published (^{3}He,t) experiments[9-12] yielded but a few unmentioned cases of discrepancies between data and theory. As yet there appears to be no trend in the anomalies except for their occurrence only for $T_<$ states and a preference for higher L transfer, although the data for the $3/2^-$ states in ^{89}Zr does show anomalies even for low L transfers. Since there are quite a few cases in which good fits to the data for $T_<$ states do exist, it appears that the anomalous effects may also be configuration dependent. Possible modifications to the conventional effective interaction that might be important in explaining the discrepancies noted here are the inclusion of exchange and a spin-orbit force. The two-body spin-orbit force is found to be important in exciting high spin states in (p,p')[13] and can allow values of L not permitted by the parity selection rule. Until such an understanding of these anomalies in (^{3}He,t) angular distributions is achieved, its role as a reliable spectroscopic tool is open to question.

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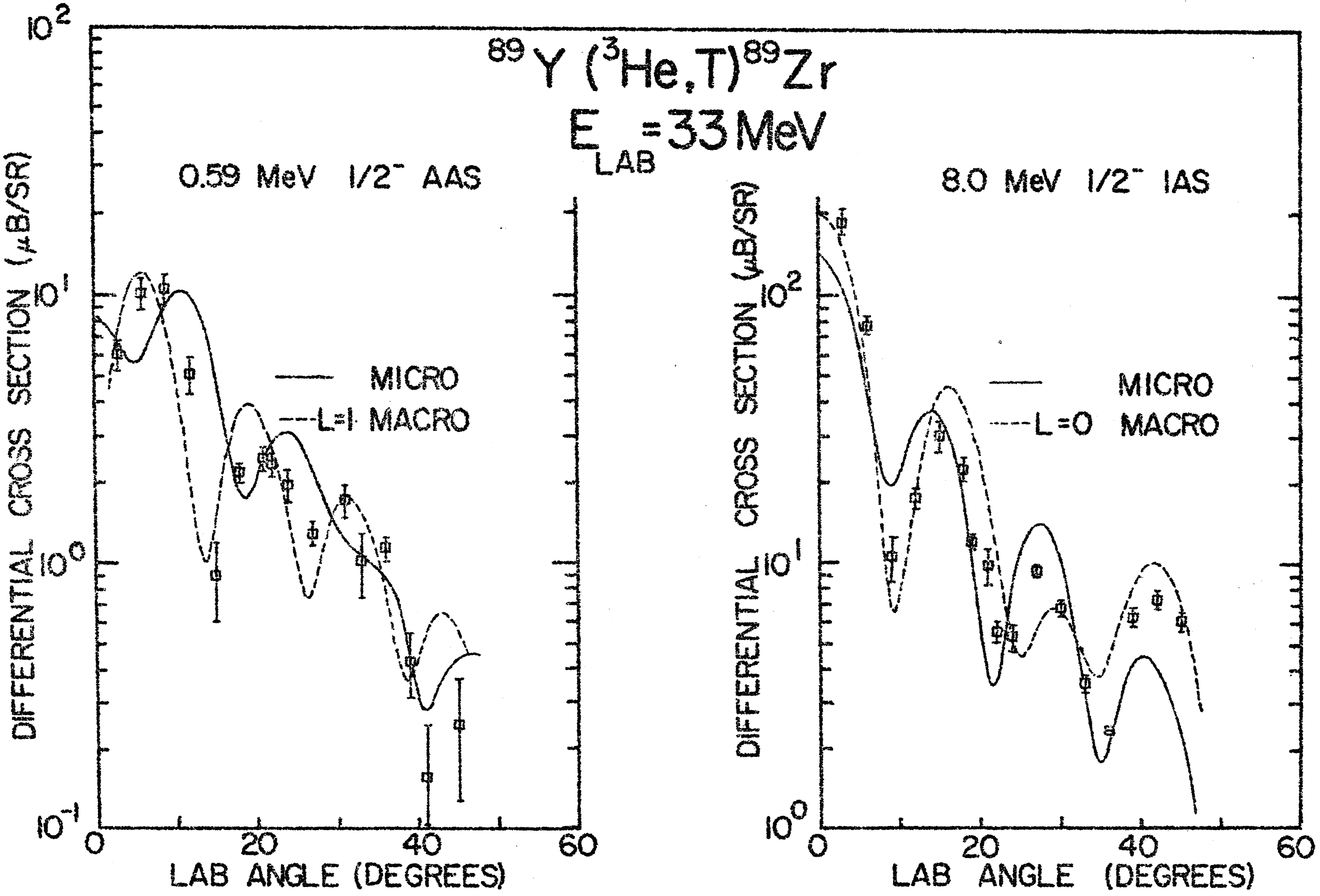
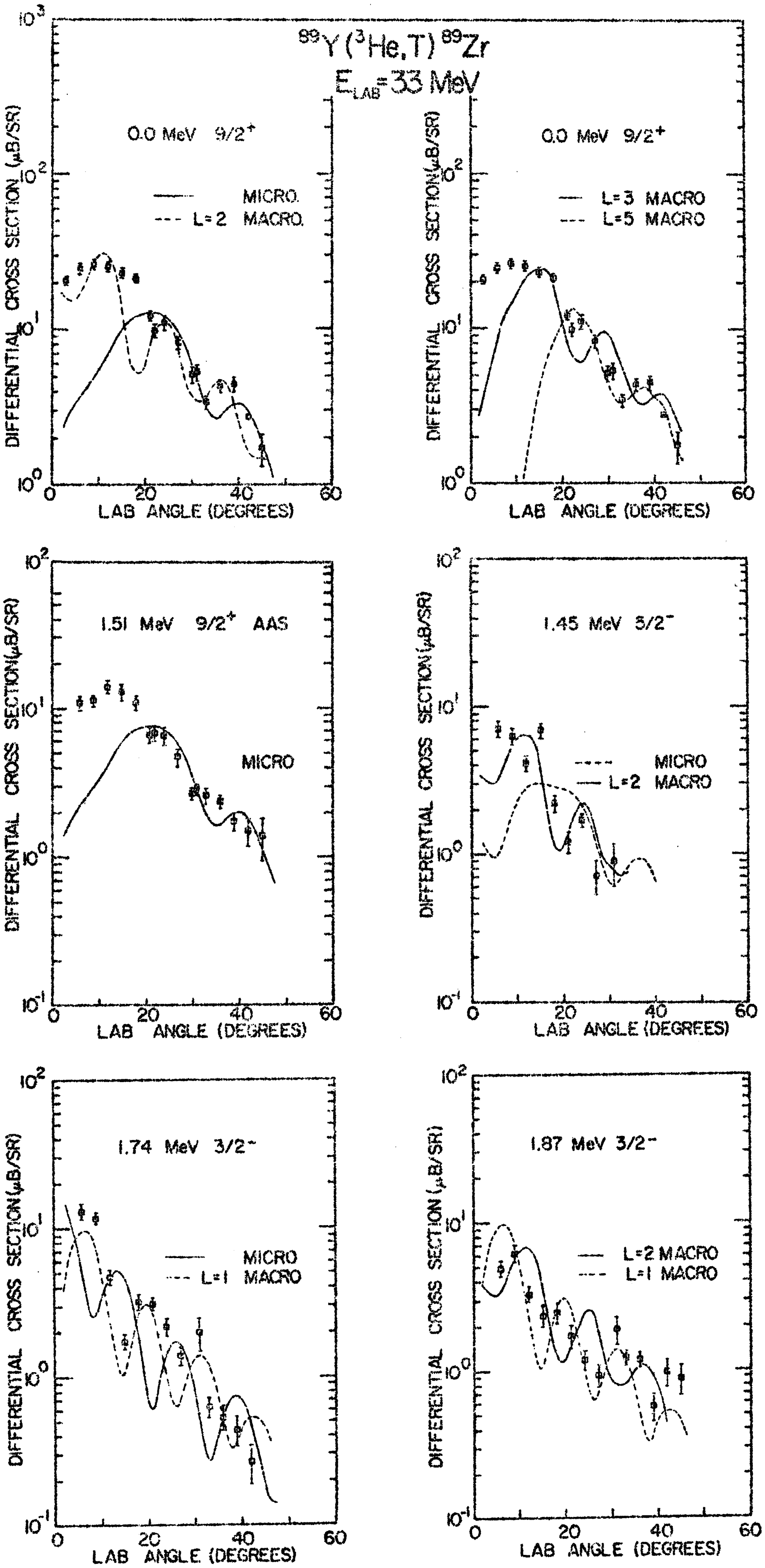
FIGURE CAPTIONS

Figure 1 ^{89}Y(^{3}He,t)^{89}Zr angular distributions for transitions to the 1/2^{-} antianalog (AAS) and isobaric analog (IAS) states. The lines shown are macroscopic DWBA calculations (with the indicated L transfer) or microscopic calculations (with a tensor term) with parameters as indicated in the text and are normalized to the data.

Figure 2 ^{89}Y(^{3}He,t)^{89}Zr angular distributions to $T_{<}$ states. The lines shown are macroscopic or microscopic DWBA calculations with parameters as indicated in the text and are normalized to the data.


^{89}Y (^{3}He,T)^{89}Zr
E_{LAB} = 33 MeV
0.59 MeV 1/2⁻ AAS
MICRO
L=1 MACRO
8.0 MeV 1/2⁻ IAS
MICRO
L=0 MACRO
DIFFERENTIAL CROSS SECTION (μB/SR)
LAB ANGLE (DEGREES)
10²
10¹
10⁰
10⁻¹
0
20
40
60



^{89}Y(^{3}He,T)^{89}Zr
E$_{LAB}$=33 MeV
0.0 MeV 9/2$^+$
MICRO.
L=2 MACRO.
0.0 MeV 9/2$^+$
L=3 MACRO
L=5 MACRO
1.51 MeV 9/2$^+$ AAS
MICRO
1.45 MeV 5/2$^-$
MICRO
L=2 MACRO
1.74 MeV 3/2$^-$
MICRO
L=1 MACRO
1.87 MeV 3/2$^-$
L=2 MACRO
L=1 MACRO
DIFFERENTIAL CROSS SECTION (μB/SR)
LAB ANGLE (DEGREES)
10^3
10^2
10^1
10^0
10^{-1}
0
20
40
60