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Comment on Recent Results for ^{40}Ca Giant Resonances obtained from the ^{40}Ca(^{3}He, ^{3}He$'$)^{40}Ca* $\rightarrow$ ^{36}Ar+α Reaction

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Abstract

Yamagata *et al.* (1978) have recently made measurements on ^{40}Ca giant resonance states using the ^{3}He inelastic scattering reaction. It is shown here that the ^{3}He spectrum obtained in coincidence with α particles leading to the ^{36}Ar ground state is similar in shape to the previously reported ^{36}Ar(α, γ_0)^{40}Ca giant dipole resonance excitation function. The assignments of $J^\pi = 0^+$ and 3^- (tentative) made to the 14·2 and 16·7 MeV states of ^{40}Ca respectively are reconsidered. It is concluded that the (^{3}He, ^{3}He$'$) data could be explained by assuming that the reaction proceeds through $J^\pi = 1^-$ giant dipole states.

A great deal of our understanding of giant resonances has come about in recent years from studies of high energy hadron inelastic scattering (e.g. Youngblood *et al.* 1976). These reactions not only excite the well-known giant dipole resonance (GDR) but also other collective modes of excitation such as the giant quadrupole resonance (GQR), thus enabling data on a wide range of collective phenomena to be obtained. Although coincidence methods are difficult to apply because of the pulsed nature of the accelerators used and the effects of large inelastic scattering backgrounds, a few measurements have been made. A notable example is that of Youngblood *et al.* (1977) in which ^{40}Ca was excited to the GQR region using 120 MeV α particles. Partial decay probabilities for subsequently emitted protons and α particles were determined from particle data taken in coincidence with the inelastically scattered α particles. An interesting feature of these results is that the inelastic α-particle spectrum obtained in coincidence with decay α particles leading to the ^{36}Ar ground state agrees reasonably well with the shape of the ^{36}Ar(α, γ_0)^{40}Ca E2 excitation function of Branford (1974). Also, the upper limit obtained for the absolute magnitude of the coincidence cross section is consistent with calculations made using the E2 radiative capture strength. These facts taken with other data were used by Youngblood *et al.* (1977) to support the assumption that inelastic α scattering preferentially excites the ^{40}Ca isoscalar GQR.

In a recent measurement, Yamagata *et al.* (1978) observed high energy ^{3}He particles inelastically scattered from ^{40}Ca at a mean angle of 1·2° with respect to the beam direction. The spectrum of ^{3}He particles observed in coincidence with α particles leading to the 0^+ ground state of ^{36}Ar is shown in Fig. 1. The ^{40}Ca states at E_x = 14·2 and 16·7 MeV were respectively assigned spins and parities of $J^\pi = 0^+$ and 3^- (tentative) from considerations of the coincidence α-particle angular distributions. Based on these assignments and distorted-wave Born approximation calculations of the ^{3}He cross sections, it was deduced that these 0^+ and 3^- states exhaust 6 ± 3 % and 6 ± 3 % of the energy weighted sum rules for monopole and octupole excitations respectively.

The purpose of this short comment is to point out that the (^{3}He, ^{3}He′) results are surprising in that the scattering of $T_z = \frac{1}{2}$ particles would, by analogy with proton scattering, be expected to excite the $T = 1$ GDR. In this respect, we note that there is a fairly strong correlation (not considered by Yamagata *et al.* 1978) between the ^{3}He data taken in coincidence with α particles leading to the ^{36}Ar ground state and the GDR radiative capture results of Watson *et al.* (1973) for the ^{36}Ar(α, γ_0)^{40}Ca reaction (see Fig. 1). Although the relative magnitudes are in poor agreement in the region $E_x \sim 18 \cdot 5$ MeV, this could be due to errors in the ^{3}He data background subtraction which becomes relatively worse as E_x increases. Taking this into account and bearing in mind the results of Youngblood *et al.* (1977) on the GQR, we see that the data of Fig. 1 suggest that the (^{3}He, ^{3}He′) reaction excites the ^{40}Ca GDR, as would be expected.

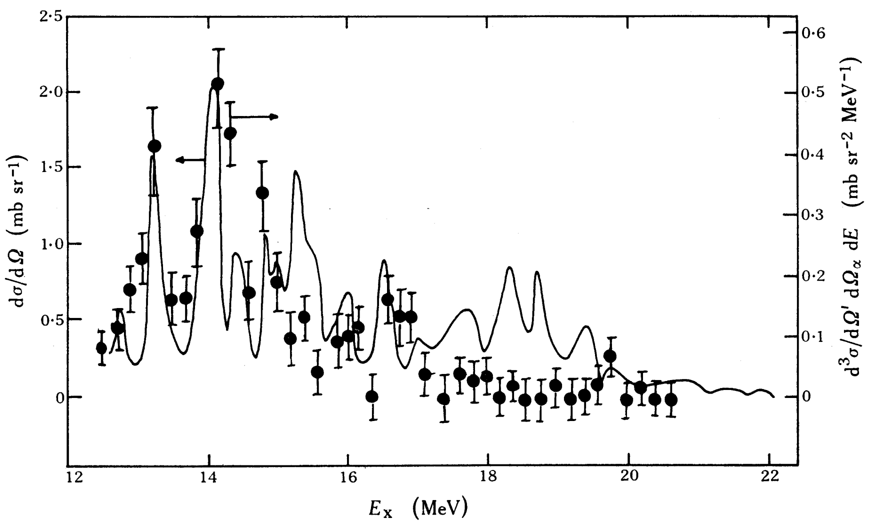

Fig. 1. Comparison of ^{40}Ca giant resonance data. The full circles show the results obtained by Yamagata *et al.* (1978) for the energy spectrum of ^{3}He particles inelastically scattered from ^{40}Ca nuclei in coincidence with α particles decaying to the ^{36}Ar ground state. The smooth curve is taken from the data of Watson *et al.* (1973) for the ^{36}Ar(α, γ_0)^{40}Ca excitation function at 90° to the beam direction. The two sets of data are normalized at $E_x = 14 \cdot 2$ MeV.

Clearly, the above explanation of the ^{3}He data requires spin assignments of $J^\pi = 1^-$ to both the $E_x = 14 \cdot 2$ and $16 \cdot 7$ MeV states, which disagree with the respective assignments of 0^+ and (3^-) made by Yamagata *et al.* (1978). However, these latter assignments are based on the questionable assumption that the (^{3}He, ^{3}He′) reaction at $\theta \sim 0°$ aligns the residual nucleus in the $M = 0$ magnetic substate with respect to the beam direction (that is, $P(0) = 1$). Since ^{3}He nuclei have $J = \frac{1}{2}$, the entrance and exit channel spins can combine in different ways such that either the $M = -1, 0$ or $+1$ magnetic substates of the residual nucleus are populated. Using this fact, it was found that theoretical angular distributions based on a $J^\pi = 1^-$ assignment to the $14 \cdot 2$ MeV state agreed with the data and gave minimum χ^2 values of ~ 3 for $P(0) \sim P(\pm 1)$, whereas a 0^{+} assignment gave a minimum χ^{2} of $3\cdot 6$. Also, in the case of the $16\cdot 7$ MeV data, which have large statistical uncertainties, an analysis in terms of a $J^{\pi} = 1^{-}$ assignment gave a minimum χ^{2} of ~ 6 for almost all values of the ratio $P(0)/P(\pm 1)$, which is comparable with the minimum χ^{2} of $6\cdot 6$ obtained for a $J^{\pi} = 3^{-}$ $(P(0) = 1)$ assignment.

It may be concluded therefore that assignments of $J^{\pi} = 1^{-}$ to the $E_{x} = 14\cdot 2$ and $16\cdot 7$ MeV states cannot be ruled out, and that an explanation of the $^{40}Ca(^{3}He, ^{3}He')^{40}Ca^{*}$ data in terms of excitation of the GDR is a possible alternative to the explanations put forward by Yamagata *et al.* (1978).

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