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No Two-proton Strength to 72Ge(02+)

H. T. Fortune, *University of Birmingham*
Craig Ogilvie, *University of Birmingham*
R. Gilman, *University of Pennsylvania*
J. D. Zumbro, *University of Pennsylvania*
D. L. Watson, *University of Bradford*, et al.

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No two-proton strength to $^{72}Ge(0_2^+)$

H. T. Fortune[*] and C. Ogilvie[†]
University of Birmingham, P. O. Box 363, Birmingham B15 2TT, United Kindgom

R. Gilman[‡] and J. D. Zumbro[§]
University of Pennsylvania, Philadelphia, Pennsylvania 19104

D. L. Watson,[**] M. J. Smithson,[††] M. D. Cohler,[**] A. Ghazarian,[**] R. Wadsworth,[**] and J. O'Donnell[‡‡]
University of Bradford, Bradford BD7 1DP, United Kingdom

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In $^{70}Zn(^{16}O,^{14}C)^{72}Ge$, at 110 MeV, the first-excited 0^+ state at 0.68 MeV (commonly thought to be a two-proton excitation) has vanishingly small transfer strength—the upper limit is less than one percent of the ground-state strength.

A structural transition appears to take place in the Ge isotopes.[1-14] For even Ge nuclei lighter than ^{72}Ge, the properties of their ground states are similar, as are their excited-state spectra. For $A > 72$, again the nuclei are similar to one another—but quite different from the lighter ones. The nucleus ^{72}Ge differs appreciably from both. It appears that the state that is the ground state (g.s.) of the lighter Ge isotopes becomes an excited 0^+ level in the heavier ones, and vice versa—an excited 0^+ level in the lighter Ge's becomes the ground state for $A > 72$.

The rather different nature of ^{72}Ge would then be understandable as arising from the simultaneous presence of both types of structure. Descriptions based on this coexistence idea have met with some success, but the exact character of the two types of states is still open to question.

The low-lying 0^+ state in ^{72}Ge, at $E_x = 0.69$ MeV, has been variously described as a two-neutron excitation,[1-3] a two-proton excitation,[4-8] or a shape isomer[9-12] having different deformation (positive, negative, or zero) from the g.s. (negative, zero, or positive). It is extremely weak in 2n stripping[13] (2×10^{-3} of g.s.), though not in pickup[2,14,15] (27% of g.s.). In α transfer, it has 32% of the g.s. strength in pickup[8] and 8.5% in stripping.[7] An analysis[16] of (p,t) and (t,p) data on several even-even Ge isotopes appears to demonstrate that the low-lying excited 0^+ state in these nuclei is *not* a neutron excitation. If it is assumed to be a two-proton excitation, it is possible to construct wave functions for ground states of neighboring Se and Zn nuclei that allow an approximate fit to α pickup[8] and stripping[7] data.

However, there has been no direct experimental test of the two-proton excitation character of these excited 0^+ levels. In most coexistence descriptions of the even Ge nuclei, it is ^{72}Ge that plays a pivotal role. It is in this nucleus that the 0_2^+ state lies lowest. In the present experiment, we have investigated its two-proton strength with the $(^{16}O,^{14}C)$ reaction.

A carbon-backed target of enriched ^{70}Zn of 100 $\mu g/cm^2$ areal density was bombarded with a ^{16}O beam at 110-MeV incident energy from the Daresbury Nuclear Structure Facility tandem accelerator. Energy width of the beam was the principal limiting factor to the resolution. Spectra were recorded in six-degree steps, from 6° to 24°. A 6° spectrum is displayed in Fig. 1. The excited 0^+ level at 0.691 MeV is barely resolvable from the stronger 2^+ level at 0.834 MeV, and the 0.69-MeV level is observed to be weak at all angles for which data exist—the ratio to the g.s. is less than 0.01. The results of this and other transfer experiments leading to ^{72}Ge are listed in Table I.

Thus, this excited 0^+ level of ^{72}Ge has very little two-proton stripping strength. In the wave functions of Vergnes *et al.*[9] it would have been expected to be much stronger, as discussed below. In fact, because of the assumptions made[7,8] in the analysis of α transfer data, the alpha amplitude ratio between basis states is the same as the amplitude ratio of two-proton transfer. Because Ref. 7 assumes the ground-state proton wave functions of ^{68}Zn

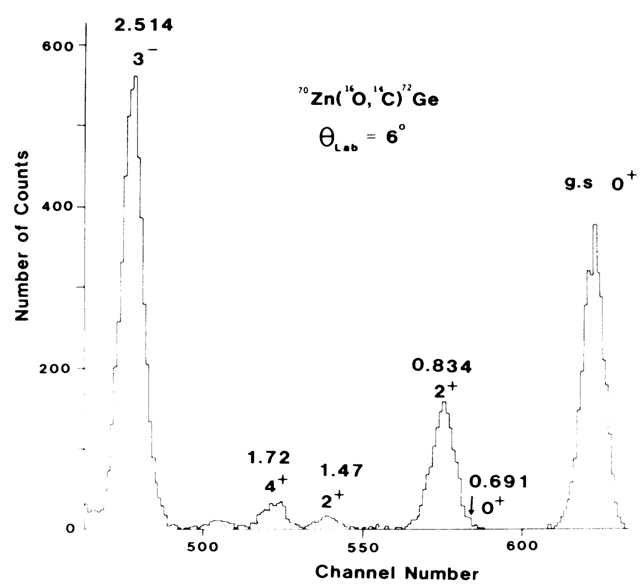

FIG. 1. Spectrum of outgoing ^{14}C ions from the reaction $^{70}Zn(^{16}O,^{14}C)^{72}Ge$. Beam energy is 110 MeV, laboratory angle is 6.0°. Upper limit on cross section for 0.691 MeV 0^+ state is 1% of g.s. cross section.

TABLE I. Cross-section ratios in transfer reactions leading to ^{72}Ge.

Reaction	Stripping $\sigma(0_2^+)/\sigma$(g.s.)	Ref.	Reaction	Pickup $\sigma(0_2^+)/\sigma$(g.s.)	Ref.
^{68}Zn(^{6}Li,d)	0.085	7	^{76}Se(d,^{6}Li)	0.32	8
^{70}Ge(t,p)	$(2.0\pm0.5)\times10^{-3}$	13	^{74}Ge(p,t)	0.27	2,14,15
^{70}Zn(^{16}O,^{14}C)	$\lesssim 0.01$	Present			

and ^{70}Zn to be identical, that model predicts identical ratios for ^{72}Ge(0_2^+)/^{72}Ge (g.s.) in 2p stripping and in α stripping. In Ref. 7, that predicted ratio is 0.29. The experimental α-stripping ratio is 0.085. If the calculation of Ref. 7 is redone, using the p^2/f^2 transfer ratio of 10 (as suggested by Ref. 8), rather than a p^2/f^2 ratio of 19 as used in Ref. 7, then the predicted ratio is 0.20. All these values are dramatically different from our current experimental ratio in 2p stripping of 0.01.

This extreme weakness in 2p transfer (in comparison with an order-of-magnitude larger ratio in α stripping) suggests that perhaps the excited 0^+ state in the Ge nuclei may not be a pure two-proton excitation, but rather may look more like an α-particle excitation.[17] Certainly, our result should present a strong challenge for future structure calculations of ^{72}Ge.

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*Permanent address: Physics Department, University of Pennsylvania, Philadelphia, PA 19104.

†Present address: Michigan State University, East Lansing, MI 48823.

‡Present address: Physics Division, Argonne National Laboratory, Argonne, IL 60439.

§Mailing address: Mail Stop H841, Los Alamos National Laboratory, Los Alamos, NM 87544.

**Present address: Physics Department, University of York, York Y01-5DD, U.K.

††Present address: University of Texas at Austin, Austin, TX 78712.

‡‡Present address: University of Pennsylvania, Philadelphia, PA 19104.

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