Decay of the first isobaric analog state in ^{69}Ge

A. E. Champagne, R. T. Kouzes, M. M. Lowry, and A. B. McDonald
Department of Physics, Princeton University, Princeton, New Jersey 08544

Z. Q. Mao
Department of Physics and Atmospheric Science, Drexel University, Philadelphia, Pennsylvania 19104

(Received 29 July 1988)

The alpha-decay branching ratio for the lowest isobaric analog state in ^{69}Ge has been measured to be less than 1.0×10^{-2}. Transitions to this level contribute significantly to the cross section for the capture of high-energy neutrinos by ^{69}Ga. Since the analog state decays almost exclusively by gamma-ray emission, induced ^{69}Ge radioactivity may be used for the detection of high-energy neutrinos in large-scale gallium neutrino detectors.

As a result of the persistent discrepancy[1,2] between the observed and expected flux of solar neutrinos, a number of new neutrino detectors are being developed. The gallium radiochemical detectors that are under construction[3,4] are sensitive to the *pp* solar neutrinos through capture by ^{71}Ga. However, the bulk of such a detector is composed of ^{69}Ga (60% natural abundance) with a neutrino-capture threshold ($E_{th}=2.226$ MeV) that is too high for it to be useful as a detector of *solar* neutrinos. In contrast, high-energy neutrinos will populate the isobaric analog state (IAS) of the ground state of ^{69}Ga [located at an excitation energy $E_x=7.00(5)$ MeV (Ref. 5) in ^{69}Ge] through a strong inverse Fermi transition. Because these detectors are designed to count germanium atoms, the decay of the IAS must ultimately populate the ground state of ^{69}Ge if ^{69}Ga is to be a viable neutrino detector. Possible uses for the ^{69}Ga fraction of a gallium detector include the detection of neutrinos eminating from supernova events as well as the monitoring of cosmic-ray-induced bankground during solar-neutrino measurements. In addition to gamma decay, the only other decay channel available to ^{69}Ge is an isospin-forbidden alpha decay ($E_\alpha=3.39$ MeV) and thus it may be expected that ^{69}Ge will predominantly gamma-ray decay. Nevertheless, the branching ratio for alpha decay is difficult to calculate accurately. Therefore, as part of our ongoing studies of the decays of the IAS relevant to neutrino detection,[6] we have measured the alpha-decay branching ratio for the IAS in ^{69}Ge using the ^{69}Ga (^{3}He,$t\alpha$)^{65}Zn reaction.

The ^{69}Ga(^{3}He,t)^{69}Ge reaction was measured using a 29.8-MeV ^{3}He beam provided by the Princeton AVF cyclotron and a natural Ga target of about 250 μg/cm^2 thickness. Outgoing tritons were detected in singles at $\theta_{lab}=0°$ in the focal plane of a QDDD magnetic spectrometer. A triton spectrum is shown in Fig. 1(a). Decay products were measured in coincidence with these tritons using a 300-mm^2 Si surface-barrier detector located close to the target. Because the IAS possesses spin $J=\frac{3}{2}$, the angular distribution of the ensuing alpha decay is of the form $a_0+a_2P_2(\cos\theta)$, where $P_2(\cos\theta)$ is the second-order Legendre polynomial. Hence, this detector was located at $\theta_{lab}=125°$ [near a zero of $P_2(\cos\theta)$] so that the observed counting rate would provide a direct measure of the branching ratio for the IAS. An energy calibration

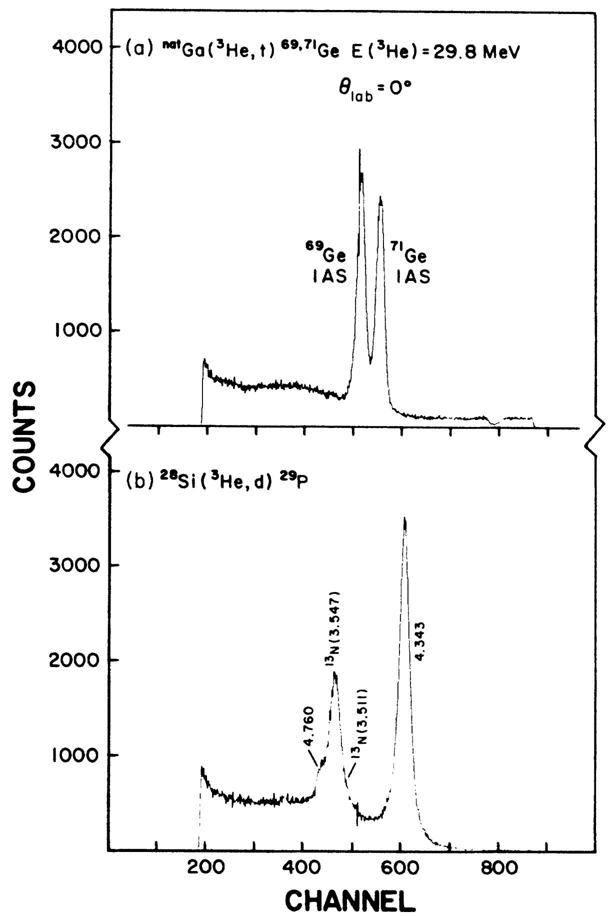

FIG. 1. Focal-plane spectra from (a) the ^{nat}Ga(^{3}He,t)^{69,71}Ge reactions showing the first IAS in ^{69,71}Ge, and (b) the ^{28}Si(^{3}He,d)^{29}P reaction. The excited states of ^{13}N appearing in the latter spectrum arise from carbon contamination of the target.

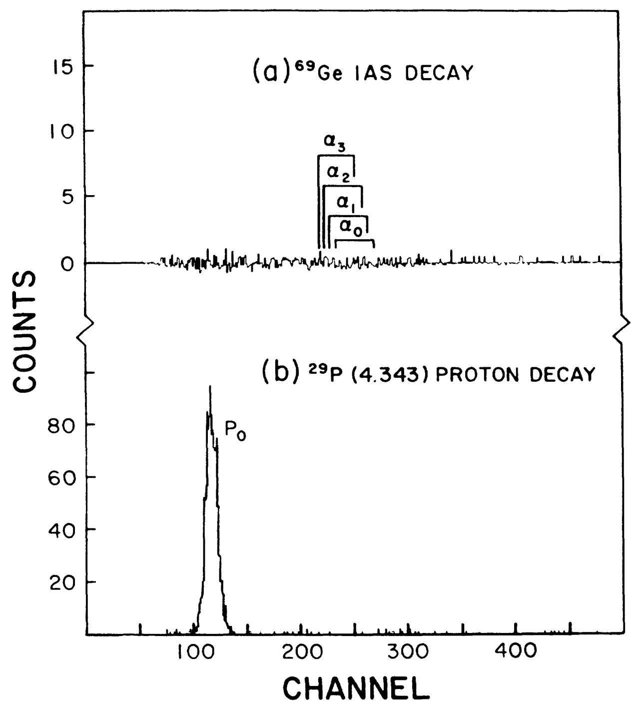

FIG. 2. Particle spectra from the decay of (a) the IAS in ^{69}Ge showing the expected locations of transitions to the ground state of ^{65}Zn (α_0) and to the first three excited states (α_1, α_2, and α_3, respectively), and (b) the 4.343-MeV state in ^{29}P.

was established using a source of ^{241}Am and a precision pulser. The absolute coincidence efficiency was determined to be 1.27(4)% from the proton decay of the 4.343-MeV state in ^{29}P (proton branching ratio $\Gamma_p/\Gamma=100\%$, $J=\frac{3}{2}$), populated via the ^{28}Si(^{3}He,d)^{29}P reaction [Fig. 1(b)]. This is in good agreement with the efficiency expected on the basis of geometrical considerations [1.20(15)%]. A proton spectrum from the decay of this state is shown in Fig. 2(b).

A particle spectrum from the decay of the IAS in ^{69}Ge is shown in Fig. 2(a). Alpha decay of the IAS would predominantly populate the ground state and first three excited states of ^{65}Zn. The relative penetrabilities to these states are 1.0:0.7:0.9:0.4, respectively. No evidence for any of these decays was observed. The number of excess counts in the region from channels 223 to 274 in Fig. 2(a) is less than 6 counts (95% confidence level). Taking into account the total number of detected tritons corresponding to population of the IAS and the measured coincidence efficiency, we obtain an upper limit on the alpha-particle branching ratio for the IAS of $\Gamma_\alpha/\Gamma \le 1.0\times10^{-2}$ (95% confidence level). These results are consistent with the expectation that this state primarily decays by gamma-ray emission and therefore ^{69}Ga can be used as a detector of high-energy neutrinos. For example, we estimate that a type-II supernova event in the center of our galaxy would produce a detectable amount (10 to 20 atoms) of ^{69}Ge in the Baksan[3] and GALLEX (Ref. 4) gallium detectors. The two-day half-life of ^{69}Ge is short enough to provide a strong correlation with such an event if rapid extraction and detection is accomplished.

We would like to thank D. R. Benton and K. P. Coulter for their assistance with these measurements. This work was supported in part by the National Science Foundation.

[1]R. Davis, Jr., D. S. Harmer, and K. C. Hoffman, Phys. Rev. Lett. **20**, 1205 (1968).

[2]J. N. Bahcall and R. Davis, Jr., Science **191**, 264 (1976).

[3]A. A. Pomansky, Nucl. Instrum. Methods **B17**, 406 (1986).

[4]W. Hampel, in *Solar Neutrinos and Neutrino Astronomy (Lead, South Dakota, 1984),* Proceedings of the Conference on Solar Neutrinos and Neutrino Astronomy, AIP Conf. Proc. No. 126, edited by M. L. Cherry, W. A. Fowler, and K. Lande (AIP, New York, 1985).

[5]R. T. Kouzes, M. M. Lowry, and C. L. Bennett, Phys. Rev. C **25**, 1076 (1982).

[6]A. E. Champagne, G. E. Dodge, R. T. Kouzes, M. M. Lowry, A. B. McDonald, and M. W. Roberson, Phys. Rev. C **38**, 900 (1988).