COMMENTS

Comments are short papers which criticize or correct papers of other authors previously published in the **Physical Review.** *Each Comment should state clearly to which paper it refers and must be accompanied by a brief abstract. The same publication schedule as for regular articles is followed, and page proofs are sent to authors.*

Comment on "Very weak γ transitions in the ϵ/β^+ decay of ^{68}Ga"

M. Skalsey
H. M. Randall Laboratory of Physics, University of Michigan, Ann Arbor, Michigan 48109
(Received 22 May 1995)

Gamma-ray coincidence spectra presented by Vo *et al.* [Phys. Rev. C **50**, 1713 (1994)] may indicate the existence of a positron (e^+) transition with a maximum decay energy of (15.9±1.2) keV. Possible sources of spurious coincidences, mimicking the e^+ signal, are discussed and, where possible, calculated or estimated. Considerable systematic uncertainty remains in estimating the noise coincidence rate; hence, the existence of this e^+ transition is not established. Another e^+ transition with a maximum decay energy of 243 keV has been identified for the first time. [S0556-2813(96)03107-X]

PACS number(s): 23.20.Lv, 27.50.+e, 29.25.−t

In a recent article [1], Vo *et al.* report on a detailed investigation of the gamma rays emitted in the decay of ^{68}Ga in secular equilibrium with the long-lived parent ^{68}Ge. Using coincidence techniques, several very weak gamma transitions were identified for the first time and placed in the existing decay scheme. This work arose from a search for resonances in low-energy electron-positron (e^-e^+) collisions leading to multiphoton final states [2,3]. The above-mentioned ^{68}Ge source was utilized in the latter studies.

The HERA array, 20 Compton-suppressed Ge detectors and 40 BGO crystals, was used to detect the γ rays. Roughly 2 MBq ^{68}Ge sources were encapsulated in Pb or Cu and then placed in the center of the HERA array. Running for 103 days over a 6-month period, they observed 5.5×10^8 double Ge-Ge coincidences, recording energy and timing data.

Chance coincidences were subtracted in the analysis performed later by setting a timing gate delayed from the prompt coincidences. A correction for the Compton continuum under the gating γ-ray line was included in the analysis by subtracting coincidence events from the continuum channels on both sides of the gate. Below, we established the importance of energy summing (pileup) in a single Ge detector from two γ rays arising from two different decays. It is not clear from Ref. [1], or from other publications, what is HERA's resolving time for a summing event, which typically is between 10^{-5} and 10^{-7} s.

The focus of this Comment is on Fig. 2 of Ref. [1], which will be called simply Fig. 2. Three coincidence spectra are presented in Fig. 2, differing in the gating line used to obtain the spectra. (Refer to Fig. 1 of Ref. [1] for the decay scheme of ^{68}Ga.) The lines used for coincidence gating are 579, 1261, and 1883 keV in Figs. 2(a), 2(b), and 2(c), respectively. The feature of interest in these spectra is the peak at 511 keV due to e^+e^- annihilation. The presence of the 511-keV peak in these figures is not discussed in Ref. [1].

In Fig. 2(a), the 579-keV gate, an easily discernible 511-keV peak is present and labeled in the diagram. This peak's intensity is about the same as the 683-keV peak in the same spectrum or the 483-keV peak in the following spectrum. One would roughly estimate that this 511-keV peak is at least five standard deviations ($>5\sigma$) above background based on the intensity and error quoted for the 683- and 483-keV peaks in Table II of Ref. [1]. A new, allowed Gamow-Teller e^+ feed to the 1656-keV level followed by e^+e^- annihilation is the explanation for this 511-keV peak, unless the Compton continuum correction was not done accurately, which seems unlikely.

There appears to be no indication of a peak at the 511-keV location in Fig. 2(b), the 1261-keV gate. Notice that there are relatively small fluctuations in the background channels to the left and right of the 511-keV location. Around 511 keV, the deviations of the fluctuations increase dramatically, but equally above and below the well-defined background level of the adjacent channels. The conclusion is that no 511-keV γ rays are in coincidence with the 1261-keV γ rays, implying that there is no e^+ feed to the 2338-keV level (see Fig. 1 in Ref. [1]). This conclusion agrees with energy conservation.

Finally, in the 1883-keV gate spectrum [Fig. 2(c)], an interesting feature appears at 511 keV. To the left and right of 511 keV, the background is well defined and very close to zero. At 511 keV, the values fluctuate grossly from channel to channel, but every channel is above the adjacent background levels. A rough estimate indicates that over 600 counts appear in the structure at 511 keV at a statistical significance of roughly 3σ. Taken at face value, Fig. 2(c) indicates that there is a e^+ feed (an allowed Gamow-Teller transition) to the 1883-keV level. This conclusion is consistent with energy conservation; the predicted maximum energy of this e^+ branch (using the measured energy of the major e^+

branch) is $(+15.9\pm1.2)$ keV [4]. Before accepting this conclusion, other false sources of 1883 keV/511 keV coincidences must be considered.

The possibility of accidental, chance coincidences between uncorrelated (i.e., arising from two different decays) 511- and 1883-keV γ rays is presumably eliminated by the subtraction scheme, mentioned earlier, used in Ref. [1]. Since the accidentals are uncorrelated in time, a subtraction is performed of events that are 60 ns out of time coincidence (the resolving time $\tau_{res} \leqslant 60$ ns) from events in prompt coincidence. The accuracy of this accidental subtraction is unknown, but it seems to work well in Fig. 2(b).

The final possibility for 511 keV/1883 keV noise coincidences involves a summing or pileup mechanism, as alluded to earlier. If the gating detector is triggered by a summing event from a 1077- and a 806-keV γ ray arising from two different decays, then a 511-keV γ ray could be recorded in coincidence with 1883 keV of γ-ray energy. Because of the known e^+ feed to the first excited state, the 1077-keV γ ray has a 37% probability to be in coincidence with a e^+ and the subsequent 511-keV γ rays. A calculation has been performed to estimate the effect of this summing mechanism on the 511-keV counts in Fig. 2(c). About half of the roughly 600 coincidence events can be accounted for with the calculation. A very conservative summing resolving time of 10^{-5} s was used in this calculation. The calculated summing background would scale linearly with changes in this resolving time [5].

The remaining ~300 events at 511 keV in Fig. 2(c) constitute quite a puzzle. A theoretical calculation of the electron capture to e^+ emission ratio [6] for the 1883-keV level predicts a ratio of about 10^8, far too few e^+ to be observed (i.e., $a \sim 10^{-11} e^+$ branch). The theoretical prediction disagrees with the apparent observations by 10^4. The reputed reliability of the theoretical calculation for allowed transitions is very high. The relevant parameter is $\alpha Z/\beta$ (α is the fine structure constant, Z is the daughter nucleus charge, and β is the e^+ velocity), which, for the calculation to work well, should not be a large number compared to 1. This parameter is 0.90 in Zn for a 15.9-keV e^+. Clearly, a suitable, reliable theoretical calculation is in complete disagreement with the implied experimental branching ratio.

In conclusion, the existence of the e^+ feed to the 1883-keV level ^{68}Ga decay cannot be considered to be established on the basis of Ref. [1]. The e^+ transition to the 1656-keV level seems clearly established, with 243 keV maximum energy and intensity roughly consistent with theory.

We wish to acknowledge very useful communication with R. S. Conti, G. W. Ford, D. W. Gidley, and R. R. Lewis. This research has been supported by NSF Grant No. PHY-9417854 and a grant from the University of Michigan.

[1] D. T. Vo, W. H. Kelly, F. K. Wohn, J. C. Hill, J. P. Vary, M. A. Delephanque, F. S. Stephens, R. M. Diamond, J. R. B. Oliveira, A. O. Macchiavelli, J. A. Becker, E. A. Henry, M. J. Brinkman, M. A. Stoyer, and J. E. Draper, Phys. Rev. C **50**, 1713 (1994).

[2] D. T. Vo *et al.*, Phys. Rev. C **49**, 1551 (1994).

[3] M. Skalsey and J. J. Kolata, Phys. Rev. Lett. **68**, 456 (1992).

[4] M. R. Bhat, Nucl. Data Sheets **55**, 1 (1988).

[5] There exists one further systematic effect in the background calculation beyond the uncertainty in pileup resolving time. Because of limitations in recording timing information for high multiplicities, only double coincidences were analyzed in Ref. [1]. The selection effect on the background calculation is not easily extracted, recalling that each 511-keV photon is a member of a back-to-back pair.

[6] *Table of Isotopes*, 7th ed., edited by C. M. Lederer and V. S. Shirley (Wiley, New York, 1978), pp. A21–A22.