Beta decay of ^{62}Ga

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We have completed our study of the beta decay of ^{62}Ga, whose dominant branch is a superallowed 0^+-to-0^+ transition to the ground state of ^{62}Zn. A manuscript has been submitted for publication [1].

We produced ^{62}Ga with the ^{1}H(^{64}Zn, 3n)^{62}Ga reaction, using 41 and 42*A* MeV ^{64}Zn beams from the K500 cyclotron on an LN_2-cooled hydrogen gas target. A 1.5-mg/cm^2 Al stripper foil was placed immediately after the gas cell so that most of the outgoing ^{62}Ga ions were in the 31+ charge state. Reaction products entered the MARS spectrometer at 0^o and exited as an 80-94% pure 37*A*-MeV ^{62}Ga beam in the focal plane with a typical intensity of 1000-1500 Hz. The remaining background nuclei consisted of other N=Z, fully stripped nuclei that had the same magnetic rigidity. When required for the lifetime measurement, the impurities in this beam were further reduced by another order of magnitude without any loss of ^{62}Ga intensity: the beam was degraded and collected on the thin tape of our tape-transport system. Since impurities have different ranges, the collected ^{62}Ga samples were ~ 99% pure.

For the half-life measurement, approximately 3 x 10^6 β-decay events were recorded. Collected activity was conveyed via tape transport to a 4π proportional gas counter. See reference [2] for a description of the methods we use for lifetime measurements. As always, data were taken under a broad range of experimental conditions: different combinations of counter high voltage, discriminator threshold, fixed event-by-event deadtime, and channel dwell time. In addition, a run was taken with a much longer decay time in order to expose longer-lived impurities. This latter run indicated that 1.1(1)% of the observed activity arose from 3.21-s ^{58}Cu. Based on detector measurements in the MARS focal plane, we also expected 1.46-min ^{54}Co^g to be a possible impurity at the 0.1% level.

We performed five-parameter maximum-likelihood fits on the data. The five parameters represented the yield and half-life of ^{62}Ga, the yields of the ^{58}Cu and ^{54}Co^g impurities, and an additional constant background. The half-lives of the ^{58}Cu and ^{54}Co^g impurities were fixed at their accepted values. The fitted result for the magnitude of the ^{58}Cu impurity was consistent with the yield observed during the run specially timed to expose it. The fits also indicated that ^{54}Co^g contributed a maximum of 0.05% of the measured decays. The maximum effect that these decays could have on the measured ^{62}Ga lifetime was 0.04%. We find that the ^{62}Ga half-life is 115.84(25) ms.

Two different procedures were used to determine the branching ratios of ^{62}Ga to excited states in ^{62}Zn. The primary goal of the first measurement was to observe any Gamow-Teller branches and either to observe or to set an upper limit on the forbidden Fermi transition to the first 0^+ excited state in ^{62}Zn at 2.33 MeV. The ^{62}Ga beam was stopped in a 0.66-mm thick Al target placed in air beyond the MARS focal plane. The Al target was surrounded on four sides by 2-mm-thick plastic-scintillator beta detectors, as shown in Fig. 1. Gamma rays were detected by 70% HPGe detectors placed behind three of the four plastic scintillators. A 5-cm-thick graphite cone was attached to the front of each Ge detector to shield it from decay positrons, while exposing it to a minimum of Bremsstrahlung radiation. Events were recorded if they contained a β-γ coincidence. Since we maximized the yield by implanting the ^{62}Ga in the

Al target and making the decay measurements simultaneously, the half-lives for the observed γ decays could not be determined.

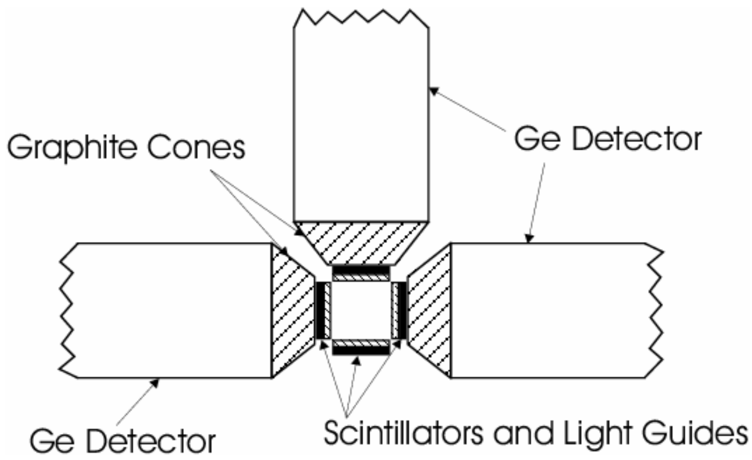

Figure 1. Detector configuration during the first branching-ratio measurement, as seen by looking into the ^{62}Ga beam. The aluminum stopping target was located in the center of the four-sided box formed by the scintillators and the light guides.

Most of the ^{62}Ga decays go to the ^{62}Zn ground state. Thus, to infer branching ratios from the observed β-γ coincidence yields, one must know both the strength of the ^{62}Ga source and the absolute efficiency of the β and γ detectors. The ^{62}Ga yield was calibrated relative to the integrated ^{64}Zn beam intensity in dedicated runs with a Si strip detector in the MARS focal plane. The Ge-detector efficiencies were measured *in situ* with a ^{152}Eu source that was calibrated to 5%. The β-detector efficiencies were calculated to 5% with a Monte Carlo simulation. They were nearly independent of endpoint energy.

Figure 2 shows one of the γ-ray spectra in the vicinity of the 0.954 MeV γ ray from the decay of the 2^+ first-excited state in ^{62}Zn. This decay was clearly visible in all three β-γ coincidence spectra and corresponds to an apparent β-decay branching ratio to the 0.954 MeV state of 0.120(21)%. If these γ rays were the result of β decays directly to the 2^+ state, they would represent a log *ft* of 6.2. This is far too small for a second-forbidden β decay, so these γ rays must be the result of cascade γ decays following Gamow-Teller transitions to higher lying 1^+ states in ^{62}Zn. A systematic search was performed of the measured γ–ray spectra for evidence of transitions that might populate the 2^+ state. None were found with γ–ray energies below 2.5 MeV. There was no evidence either for a 1.376 MeV γ ray, which would indicate population of the first 0^+ excited state in ^{62}Zn at 2.33

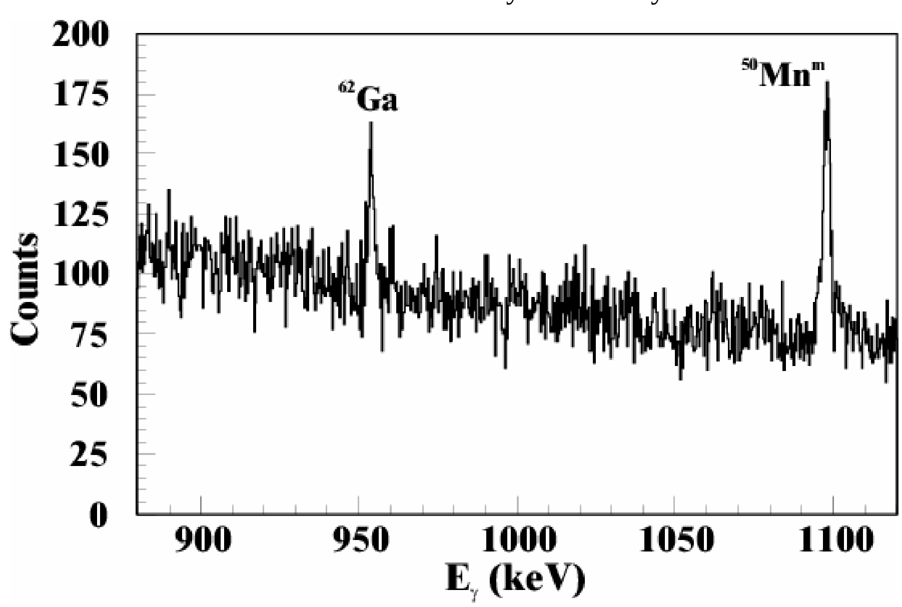

Figure 2. Gamma-ray spectrum from one of the Ge detectors in the vicinity of the ^{62}Zn first-excited state at 954 keV. The transitions are labeled according to the parent nucleus.

MeV. After accounting for statistical and systematic uncertainties, we conclude that the branching ratio for the forbidden Fermi decay from ^{62}Ga to ^{62}Zn(0+,2.33) is <0.043%, consistent with predictions [3].

A second branching-ratio measurement was performed with the tape transport system so that the decay of 0.954-MeV γ ray could be measured, albeit with lower statistics. We found its half-life to be 110(65) ms, thus confirming that it follows the β decay of the ^{62}Ga ground state.

Our measured γ-ray yields from the decay of ^{62}Ga would have been puzzling indeed without the recent calculations [4] of competing Gamow-Teller decays in superallowed emitters with A > 60. There, it is estimated that more than 100 such branches exist and, although their total strength is predicted to be significant (~0.3%), the individual branches themselves are considerably weaker and could well be unobservable. The calculations also predict the fraction of such branches that de-excite through the 0.954-MeV first-excited state and we can use that result, together with our measured intensity of the 0.954-MeV γ ray, to set limits on the total non-superallowed decay branches from ^{62}Ga. We thus find the superallowed branching ratio for ^{62}Ga decay to be 99.85(+5,-15)% and the corresponding corrected *Ft*-value to be 3050(47) s, in good agreement with 3072.2(8) s, the average *Ft*-value for the nine well-known cases studied to date. If the uncertainty on the Q_{EC}-value could be reduced to 1.7 keV – probably within the grasp of current technology – the uncertainty on the resulting *F*t-value would become 9 s. That would be sufficient to provide a demanding test of the structure-dependent corrections [3] used in obtaining the ^{62}Ga *Ft*-value.

References

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