

Beta decay of ^{62}Ga

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We report a study of the β decay of ^{62}Ga , whose dominant branch is a superallowed $0^+ \rightarrow 0^+$ transition to the ground state of ^{62}Zn . We find the total half-life to be 115.84 ± 0.25 ms. This is the first time that the ^{62}Ga half-life has been measured with a purified source. We find that $(0.120 \pm 0.021)\%$ of the β decays are followed by γ cascades that pass through the ^{62}Zn 2^+ first excited state at 0.954 MeV. The branching ratio to the first-excited 0^+ state in ^{62}Zn at 2.33 MeV is $< 0.043\%$. We conclude that the branching ratio for the superallowed transition is $99.85^{+0.05}_{-0.15}\%$.

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I. INTRODUCTION

Measurements of superallowed β decays between 0^+ , $T=1$ analog states provide the most precise determination of the Fermi coupling constant G_V in nuclear β decay. The result for G_V , currently obtained from nine well studied $0^+ \rightarrow 0^+$ decays of nuclei with $10 \leq A \leq 54$, may be combined with the muon decay constant G_μ to obtain V_{ud} , the weak coupling between up and down quarks in the Cabibbo-Kobayashi-Maskawa (CKM) matrix. In recent years, there has been a great interest in improving the precision of V_{ud} by extending our knowledge of ft values for $0^+ \rightarrow 0^+$ superallowed β decays to additional nuclear systems, inspired largely by the apparent nonunitarity of the CKM matrix at the two standard deviation level. (See Ref. [1] for a recent review.) Nonunitarity of the CKM matrix would unequivocally demand new physics, so considerable attention has been directed to sharpening the values of both V_{ud} and V_{us} , the dominant contributors to the unitarity sum. There are recent indications that the accepted value for the latter, which is derived from measurements of K_{e3} decay, may be flawed [2], and work will undoubtedly proceed in this area. We focus here, however, on reducing the uncertainty with which V_{ud} is obtained.

The coupling constant G_V can be obtained from the experimental ft value for a $0^+ \rightarrow 0^+$ β decay between analog states with the relation [3]

$$\mathcal{F}t \equiv ft(1 + \delta'_R)(1 + \delta_{NS} - \delta_C) = \frac{K}{2G_V^2(1 + \Delta_R^V)}, \quad (1)$$

where f is the β -decay phase-space factor, t is the partial half-life, K is a constant, δ'_R , δ_{NS} , and Δ_R^V are radiative corrections, and δ_C accounts for the deviation of the parent and daughter states from perfect isospin symmetry. Here, we have also defined $\mathcal{F}t$ as the ‘‘corrected’’ ft value. The greatest contributions to the uncertainty in G_V arise not from the experimental ft values but from the theoretical correction terms. Of these four terms, two, δ'_R and Δ_R^V , are dominated by well-understood QED processes, while the other two, δ_{NS} and δ_C , depend on the detailed structure of the specific nuclear states in question. Therefore, it is very important to

test the reliability of these nuclear structure-dependent calculations, which always act as a difference $\delta_C - \delta_{NS}$. Any reduction in their uncertainties will be reflected directly in the uncertainty obtained for V_{ud} .

Two approaches are being pursued. The $0^+ \rightarrow 0^+$ superallowed transitions in higher- Z nuclear systems are predicted to have substantially larger structure-dependent effects [3–5] than those present for the nine cases with $10 \leq A \leq 54$, which have been measured with high precision. If the calculations predict the structure-dependent effects for $A \geq 62$ nuclei successfully, this would provide strong evidence that the much smaller effects present in lighter nuclei are also being estimated correctly. The $A \geq 62$ nuclei with $N=Z$, 0^+ , and $T=1$ typically also have the opportunity to β decay to nonanalog 0^+ states in their daughter nuclei. The measured transition matrix elements for these forbidden Fermi β decays provide another test of the δ_C calculations [3,4,6]. However, a complication also arises in high- Z nuclei. The large energy range available for Gamow-Teller transitions may lead to a significant total Gamow-Teller decay yield, but spread over so many 1^+ daughter states that most individual transitions become unobservably weak [7]. Therefore, another approach is also being followed: measurements of β -decay ft values are now underway for the 0^+ , $T_z = -1$ nuclei ^{22}Mg , ^{30}S , and ^{34}Ar [8], where the structure-dependent corrections can also be large and, more importantly, where the nuclear model space is common with some of the nine currently well-known transitions.

The next heaviest nucleus (after ^{54}Co) in the sequence of $N=Z$, 0^+ , $T=1$ superallowed β emitters is ^{62}Ga . Before the ft value for the ^{62}Ga superallowed β transition can provide a stringent test of the structure-dependent corrections, its precision must reach $\sim 0.1\%$. This requires the corresponding Q_{EC} value to be measured to ± 1.7 keV or better, and the half-life and branching ratio must each be measured to $< 0.1\%$. To date, the only measured result for Q_{EC} is 9171 ± 26 keV [9]; however, techniques are now being developed that will soon make it possible to measure masses with the required precision [10]. Here, we address the ^{62}Ga half-life and branching ratios. The half-life has been measured several times [9,11,12], leading to the current weighted-average accepted value 116.12 ± 0.23 ms, but none

of the previous lifetime measurements used purified radioactive sources, an important consideration at this level of precision. Until very recently, there had been no measurement of branching ratios from ^{62}Ga to excited states in its daughter ^{62}Zn . However, as this work was being prepared for publication, an independent experiment was also reported [13], providing a valuable consistency check on these difficult measurements.

Although it may be a few years yet before the ft value for the ^{62}Ga superallowed transition is known precisely enough to test the nucleus-dependent correction terms, another test is already accessible. Since the first-excited 0^+ state in ^{62}Zn is known to be at an excitation energy of 2.33 MeV, the decay of ^{62}Ga provides an excellent opportunity to observe this nonanalog $0^+ \rightarrow 0^+$ transition. Two of the calculations that predict a large $(\delta_C - \delta_{NS})$ correction for the ^{62}Ga superallowed β decay also predict a value for the branching ratio of the forbidden Fermi transition to the 2.33 MeV state [3,4]. A measurement of—or even a limit on—the ^{62}Ga β -decay branching ratio to this state provides an immediate test of the calculations' effectiveness.

This paper reports a new study of the ^{62}Ga β decay. The ^{62}Ga half-life has been measured for the first time with a high-purity source. Two different techniques were used to measure the β -decay branching ratios to excited states in ^{62}Zn . Evidence is reported for population of the first excited 2^+ state in ^{62}Zn via γ cascades from β decays to higher excited states, and an upper limit is reported for the forbidden Fermi decay to the 2.33 MeV 0^+ excited state. Section II describes the ^{62}Ga production, Sec. III describes the lifetime determination, and Sec. IV describes the two different branching-ratio measurements. Finally, Sec. V discusses the results.

II. ^{62}Ga PRODUCTION

We produced ^{62}Ga with the $^1\text{H}(^{64}\text{Zn}, ^{62}\text{Ga})3n$ reaction, using 41A and 42A MeV ^{64}Zn beams from the Texas A&M University K500 Superconducting Cyclotron. The target material was contained in a LN₂-cooled cryogenic gas cell with Havar entrance and exit windows. The window thicknesses varied from run to run between 4 and 13 μm . A 1.5-mg/cm² Al stripper foil was placed immediately after the gas cell so that the majority of the outgoing ^{62}Ga ions were in the 31+ charge state. The gas target was located at the entrance to the Texas A&M Momentum Achromat Recoil Spectrometer, MARS. Reaction products, together with the remainder of the primary beam, entered MARS at 0° .

MARS consists of a quadrupole-quadrupole-dipole-quadrupole-dipole momentum achromat, followed by a velocity-filter-dipole-quadrupole-quadrupole mass spectrometer. It may be used to produce high-purity radioactive beams for decay studies or secondary nuclear-reaction measurements. A detailed description of the production of radioactive beams with MARS may be found in Ref. [14]. Here, we restrict our discussion to issues that play an important role in the ^{62}Ga β -decay measurements. A pair of slits at an intermediate focal plane within the achromat determine the overall momentum acceptance and, thus, the range straggle of the

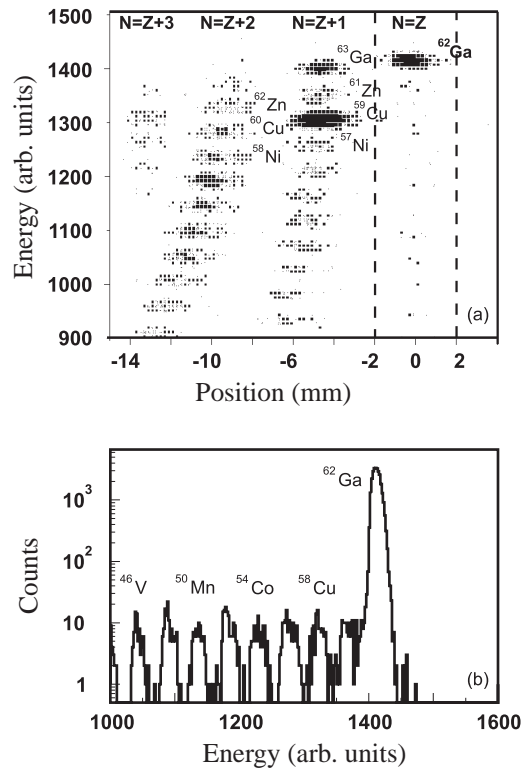


FIG. 1. (a) Spectrum of energy vs position as measured with the Si strip detector at the final MARS mass focus. The dashed vertical lines indicate the approximate settings chosen for the acceptance slits. (b) Energy spectrum from the strip detector taken after the slits had been set, showing the composition of the secondary beam during the first ^{62}Ga branching-ratio measurement. For clarity, only the odd-odd nuclei have been labeled.

final radioactive beam. These slits were set to provide a momentum acceptance of $\Delta p/p_0 = 1-1.5\%$ (full width). We monitored the intensity of the ^{64}Zn beam by stopping it in a Faraday cup within the achromat. As shown in Fig. 1(a), the size, composition, and intensity of the secondary beam were measured at the final MARS mass focus with a 5×5 cm², 1000- μm -thick, two-dimensional Si strip detector. MARS was tuned to focus fully stripped $N=Z$ nuclei to a 3×3 -mm spot. Slits near the focal plane were set to pass only the fully stripped $N=Z$ nuclei.

The radioactive beam itself consisted of 80–94% ^{62}Ga , depending on the ^{64}Zn beam energy and the thickness of the Havar windows on the cryogenic gas cell. The remaining background nuclei consisted of other $N=Z$, fully stripped nuclei that had the same magnetic rigidity, and hence also the same velocity as the ^{62}Ga nuclei of interest. MARS cannot distinguish between different nuclei that have both the same p/q and M/q values. However, different nuclei may be distinguished by measurements of their total energy. Figure 1(b) shows the beam composition during one of the ^{62}Ga branching-ratio studies. The typical ^{62}Ga intensity was 1000–1500 Hz.

When required for the lifetime measurement, the impurities in this beam could be reduced by another order of magnitude without any loss of ^{62}Ga intensity. As will be de-

scribed in the following section, the 37A MeV ^{62}Ga beam was degraded before being collected on a thin tape. Since impurities have different ranges, this resulted in collected ^{62}Ga samples that were $\sim 99\%$ pure.

III. LIFETIME

A high-speed tape-transport system was used to measure the half-life of ^{62}Ga . The radioactive beam exited the vacuum system through a thin Kapton window and then passed through a 300- μm -thick plastic scintillator that provided a continuous monitor of the intensity. The beam passed through thin Al and Mylar degrader foils, with thicknesses chosen to ensure that the ^{62}Ga stopping distribution was centered in a 10.5-mg/cm²-thick aluminized-Mylar tape. In addition to maximizing the fraction of the ^{62}Ga which stopped in the tape, this reduced our sensitivity to the lighter $N=Z$ background nuclei that can be seen in Fig. 1 because they have longer ranges. The ^{62}Ga was collected in the tape during a 0.25-s-long irradiation period. The primary ^{64}Zn beam from the K500 Superconducting Cyclotron was then disabled by a shift off-resonance in the phase of one of the rf dees. The tape transport required 135 ms to move the ^{62}Ga source into a shielded 4π gas proportional chamber. The discriminator for the proportional chamber readout was set well below the characteristic pulse height associated with minimum ionizing particles, providing nearly unit efficiency independent of positron energy. β -decay events observed by the proportional chamber were processed via circuitry that introduced a predetermined dominant dead time, and were then multiscaled during a 3-s-long counting period. The multiscaler was controlled by a precision frequency synthesizer. After the counting period, the ^{64}Zn primary beam was re-enabled and the next collection period began.

Approximately 3×10^6 β -decay events were recorded. Data were taken under a broad range of different experimental conditions to investigate possible systematic effects on the extracted half-life. Runs were taken with different combinations of high voltage, discriminator threshold, fixed event-by-event dead time, and channel dwell time. In addition, a run was taken with the synthesizer frequency reduced by a factor of 10 in order to expose longer-lived impurities. This latter run indicated that $(1.1 \pm 0.1)\%$ of the observed activity arose from 3.21-s ^{58}Cu in the radioactive beam stopped in the aluminized-Mylar tape. This intensity was consistent with measurements of the radioactive beam composition that were performed with the Si strip detector. Finally, background studies were performed with the tape motion disabled or with the ^{62}Ga beam blocked at an intermediate point within MARS; these showed only a low constant background of about 0.5 Hz.

An important potential contaminant was $^{54}\text{Co}^g$. It has a short half-life, $t_{1/2} = 193.3$ ms, which could affect our measured ^{62}Ga lifetime. Measurements of the radioactive beam composition with the Si strip detector indicated that it contained $< 0.5\%$ ^{54}Co , but even this small amount was further reduced in our collected samples since the ^{54}Co nuclei have longer ranges than the ^{62}Ga nuclei. Less than half of those produced could have stopped in the aluminized-Mylar tape.

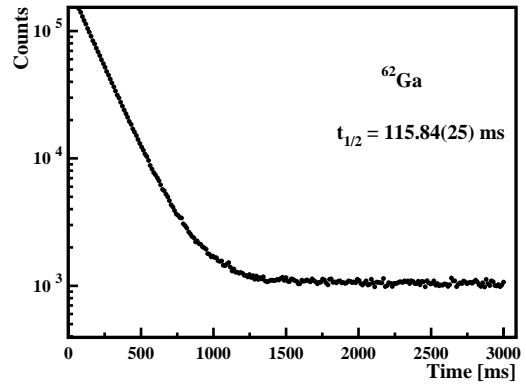


FIG. 2. The total ^{62}Ga decay spectrum for the subset of the data taken with the multiscaler set to 12 ms/channel.

Furthermore, β - γ coincidence measurements (see Sec. IV) indicate that the majority of the ^{54}Co was in the form of $^{54}\text{Co}^m$, a 1.5-m isomer. Overall, we expected $^{54}\text{Co}^g$ to represent less than 0.1% of the activity.

We first filtered the ^{62}Ga decay data to remove anomalous cycles. For each cycle, we extracted the ratio of events detected in the 4π counter relative to the number of ^{62}Ga nuclei detected in the plastic scintillator at the exit of MARS. We rejected cycles for which this ratio deviated by more than $\sim 20\%$ from its average value as showing evidence of electrical pickup associated with the tape-transport system (high ratios) or of some shortfall in the tape travel (low ratios). In order to maintain high signal-to-background ratio, we also rejected any cycles in which a sudden decrease in primary beam caused the absolute number of detected events to be less than $\sim 25\%$ of its average value. None of these filtering criteria introduces a time-dependent bias that could affect the extracted half-life.

Then, we performed five-parameter maximum-likelihood fits on the accepted data. The five parameters represented the yield and half-life of ^{62}Ga , the yields of the ^{58}Cu and $^{54}\text{Co}^g$ impurities, and an additional constant background. The half-lives of the ^{58}Cu and $^{54}\text{Co}^g$ impurities were fixed at their accepted values. Figure 2 shows the total decay spectrum for the subset of the data that were taken with the multiscaler operating at 12 ms/channel. 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 $^{54}\text{Co}^g$ contributed a maximum of 0.05% of the measured decays—consistent with our expectations based on the strip-detector observations. 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 ± 0.25 ms.

Half-life results were also extracted separately from the individual runs taken under different experimental conditions in order to search for possible systematic effects. As shown in Fig. 3, the results from the various individual analyses were consistent. We also performed four additional fits to the complete dataset, each with successively more channels removed from the beginning of the time-decay spectrum, to search for evidence of additional short-lived nuclei that were not included explicitly in the fitting function. The extracted

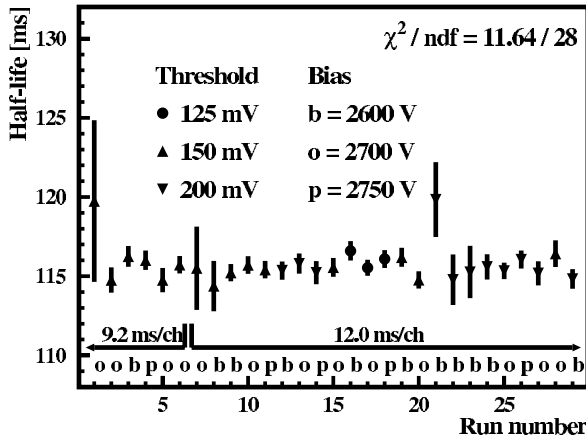


FIG. 3. A comparison of ^{62}Ga half-life results taken under a range of different experimental conditions. Runs were taken with different discriminator thresholds, high voltage, channel dwell time, and event-by-event dead time. The dead time was $10\ \mu\text{s}/\text{event}$ for runs 1–19 and $12\ \mu\text{s}/\text{event}$ for runs 20–29.

^{62}Ga half-life was found to be statistically stable against all these tests.

IV. BRANCHING RATIOS

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 branch, 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 final MARS focal plane. The Al target was surrounded on four sides by 2-mm-thick plastic-scintillator β detectors, as shown in Fig. 4. The scintillators were coupled to photomultiplier tubes by lucite light guides. Discriminator thresholds for the scintillators were set well below the minimum-ionizing pulses. Gamma rays were detected by 70% HPGe (high-purity Ge) detectors that were 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 brems-

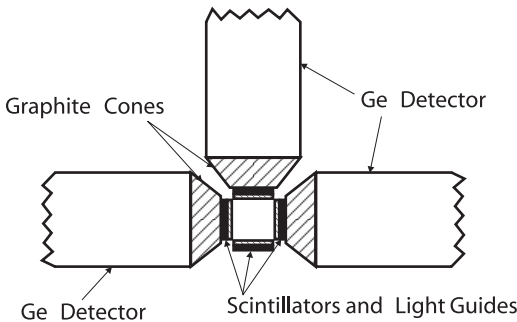


FIG. 4. Detector configuration during the first branching-ratio measurement, as seen by looking into the ^{62}Ga beam. The Al stopping target was located in the center of the four-sided box formed by the scintillators and light guides.

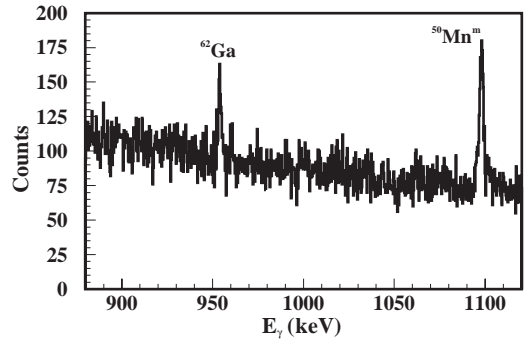


FIG. 5. Gamma-ray spectrum from one of the Ge detectors in the vicinity of the ^{62}Zn first-excited state. The transitions are labeled according to the parent nucleus.

strahlung radiation. Events were recorded if they contained a β - γ coincidence. Off-line, the signal-to-background ratio was optimized by rejecting events in which the β detector immediately in front of the γ detector fired. To maximize the yield, both the ^{62}Ga implantation in the Al target and the β - γ decay measurements ran continuously. This precluded any measurement of the half-lives for the observed γ decays. The Al stopping target was replaced every 12–24 h to minimize the buildup of ^{62}Cu activity following the decay of the $t_{1/2} = 9.186\ \text{h}$ nucleus ^{62}Zn .

Most of the ^{62}Ga decays go to the ^{62}Zn ground state. Therefore, one needs to know both the strength of the ^{62}Ga source and the absolute efficiency of the β and γ detectors to infer branching ratios from the observed β - γ coincidence yields. The ^{62}Ga yield was calibrated relative to the integrated ^{64}Zn beam intensity in dedicated runs with the Si strip detector. The Ge-detector efficiencies were measured *in situ* with a ^{152}Eu source that was calibrated to 5%. The β -detector efficiencies were calculated with an EGS4-based Monte Carlo simulation [15]. They were nearly independent of the end point energy. We estimated the systematic uncertainty in the calculated β detector efficiencies to be 5% by varying parameters in the simulation.

Figure 5 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. Combining the three measurements together, we find that the apparent β -decay branching ratio to the 0.954 MeV state is $(0.120 \pm 0.021)\%$. 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 on 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. In particular, there was no evidence for population of the ^{62}Zn second 2^+ state at 1.805 MeV.

The search for the 1.376 MeV γ ray that would provide evidence for population of the first-excited 0^+ state in ^{62}Zn at 2.33 MeV was complicated by the fact that this state has only been observed in charged-particle reactions, so the ex-

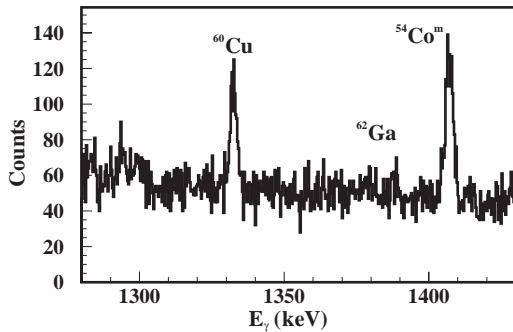


FIG. 6. γ -ray spectrum in the vicinity of 1.38 MeV. This is from the same Ge detector as was illustrated in Fig. 5. The transitions are labeled according to the parent nucleus. The ^{62}Ga label indicates the region where the γ -ray from the deexcitation of the 0^+ , 2.33 MeV state in ^{62}Zn should appear.

citation energy is only known to ± 10 keV. Figure 6 shows one of the three Ge-detector spectra in the vicinity of 1.38 MeV. Possible enhancements are seen near the expected decay energy. Similar enhancements were seen in all three Ge spectra, but the apparent decay energies were not consistent. Therefore, to be conservative, we choose to set an upper limit for the forbidden Fermi transition. We established the limit by fitting each of the Ge spectra to a Gaussian peak plus a linear background term. For each detector, the Gaussian width was fixed to match the nearby peaks seen in Fig. 6 at 1.332 and 1.407 MeV, and the centroid was fixed at finely spaced energies between 1.35 and 1.40 MeV. For each assumed γ -ray energy, the yield was extracted for each detector. The largest apparent branching ratio 0.032% was found for assumed transition energies of 1.377 or 1.388 MeV. After accounting for the additional statistical and systematic uncertainties, we conclude that the branching ratio for the forbidden Fermi decay, $^{62}\text{Ga} \rightarrow ^{62}\text{Zn}(0^+, 2.33 \text{ MeV})$, is $< 0.043\%$.

A second branching-ratio measurement was performed with the tape-transport system. The ^{62}Ga source was prepared with the same techniques as those described in Sec. III. After the collection period, the source was transported to a shielded counting station in 185 ms. There, β - γ coincidences were observed during a 0.5-s-long counting period by a 1-mm-thick plastic scintillator placed very close to one side of the tape and a 70% HPGe detector placed 0.5 cm away from the source on the opposite side of the tape.

There were far fewer background γ -ray lines present during this measurement, because of the additional isotopic selection obtained by requiring the radioactive nuclei to stop in the thin aluminized-Mylar tape. It also permitted the lifetimes of the observed γ rays to be measured. However, the event statistics were reduced substantially, compared to the previous measurement, since ^{62}Ga was only produced for a small fraction of the time, and over 80% of the nuclei decayed before they could be counted. The 0.954-MeV transition was the only γ ray observed following the ^{62}Ga β decay. We found that the half-life for the 0.954-MeV γ -ray transition was 110 ± 65 ms. This confirms that it follows the β decay of the ^{62}Ga ground state.

Blank [13] reported the observation of a possible 2.225-

MeV γ ray in coincidence with the 0.954-MeV γ ray. We do see a 2.228-MeV γ ray both in our first measurement at the stopping target and in the second measurement with the tape-transport system. However, it was considerably stronger relative to the 0.954-MeV peak in the former measurement than it was in the latter, where higher ^{62}Ga purity was assured. Thus, either the 2.228-MeV γ ray is entirely due to an impurity, or there are two γ rays with nearly the same energy, one from an impurity and the other from ^{62}Ga . Unfortunately, the meager statistics on the 2.228-MeV peak made further identification by half-life analysis impossible. Even if a portion of the 2.228-MeV peak is attributable to the ^{62}Ga decay, its intensity would be $< 0.15\%$ of the total decays of ^{62}Ga . Furthermore, if it were to feed the 0.954-keV state as suggested by Blank, then it would fully account for the direct feeding of that state and would not change the total nonanalog β feeding required to account for the observed intensity of the 0.954-keV γ ray.

V. DISCUSSION

Our result for the half-life of ^{62}Ga , 115.84 ± 0.25 ms, is lower than results from the two previous measurements with the best precision, 115.95 ± 0.30 ms [12] and 116.34 ± 0.35 ms [9], though it is statistically consistent with both. Since impurities tend to increase the observed half-life—they are usually from nuclei nearer stability—these differences could easily have been caused by undetected impurities in the earlier measurements. Our result for the ^{62}Ga half-life is the first to have been measured with a purified source.

Our measured γ -ray yields from the decay of ^{62}Ga would have been puzzling indeed without the recent calculations [7] of competing Gamow-Teller decays in superallowed emitters with $A \geq 62$. Observation of a γ -ray transition deexciting the first 2^+ state in ^{62}Zn with no evidence of another γ -ray transition populating that state would naively imply that the 2^+ state is fed directly by the β decay from ^{62}Ga . However, such $0^+ \rightarrow 2^+$ β -decay feeding would be second forbidden and could not possibly account for the observed intensity of the 0.954-MeV γ ray. The explanation of this paradox lies in the predicted existence of numerous weak Gamow-Teller branches in the decay of ^{62}Ga . In Ref. [7] it is estimated that there could be more than 100 such branches and, although their total strength is predicted to be significant ($\sim 0.3\%$), the individual branches themselves are considerably weaker and could well be unobservable. Our observations confirm the general validity of this prediction.

We can also make a more quantitative comparison with Ref. [7]. That work predicts that 80% of the summed Gamow-Teller strength ultimately feeds the first-excited 2^+ state in ^{62}Zn , thus producing a 0.954-MeV γ ray with a predicted intensity of 0.22%. This can be compared with our measured intensity for that γ ray of $(0.120 \pm 0.021)\%$, which is certainly within the expected accuracy of the earlier calculation. [The intensity measured by Blank [13], $(0.12 \pm 0.03)\%$, is the same as our result, but with a larger uncertainty.] The same calculation also predicts [16] that the 0.851-MeV γ ray deexciting the second-excited 2^+ state in

^{62}Zn should be $<20\%$ of the intensity of the 0.954-MeV γ ray. This is completely consistent with our not observing any γ ray at 0.851 MeV.

By combining the experimental intensity of the 0.954-MeV γ ray with the calculation of Gamow-Teller branching [7], we can arrive at a rather precise value for the superallowed $0^+ \rightarrow 0^+$ branching ratio. A lower limit for the total branching to nonsuperallowed β transitions is given by 0.10%, the minimum intensity actually observed for the 0.954-MeV γ ray. An upper limit can be obtained as follows: the shell-model calculation of the ^{62}Ga decay [7], which shows reasonable agreement with the observed γ -ray strength, also predicts that 0.06% of the decay strength bypasses the 0.954-MeV γ -ray transition; we conservatively place a factor-of-3 uncertainty on that result, which would encompass the possible existence of the 2.225-MeV γ ray as a direct decay to the ground state, and conclude that the upper limit for the total branching to nonsuperallowed β transitions is 0.30%. Thus, the superallowed $0^+ \rightarrow 0^+$ branching ratio for ^{62}Ga decay becomes $99.85_{-0.15}^{+0.05}\%$.

We can now calculate the corrected $\mathcal{F}t$ value for the ^{62}Ga decay using Eq. (1): we take the experimental Q_{EC} value [9] to calculate f ; our half-life and branching-ratio results to derive t ; and the tabulated values of Towner and Hardy [3] for the various correction terms. The result, $\mathcal{F}t = 3050 \pm 47$ s, agrees well with the average $\mathcal{F}t$ value, 3072.2 ± 0.8 s, obtained from the nine well-known superallowed decays of nuclei with $10 \leq A \leq 54$, but its precision is severely limited by the poorly known Q_{EC} value. However, if the uncertainty on that Q_{EC} value could be reduced to ± 1.7 keV, the uncertainty on the resulting $\mathcal{F}t$ value would become ± 9 s. This would be sufficient to provide a demanding test of the structure-dependent corrections.

It is also interesting to take the opposite approach and assume that the corrections are valid and that the $\mathcal{F}t$ value for the ^{62}Ga decay must have the same value as the average obtained from the nine lighter nuclei. Under these assumptions, we predict the Q_{EC} value for ^{62}Ga to be 9183 ± 6 keV.

Finally, we examine results for the forbidden $0^+ \rightarrow 0^+$ decay to the first-excited 0^+ state in ^{62}Zn . The two calculations that produce values of the structure-dependent corrections, δ_C and δ_{NS} , for the superallowed transition predict values of the transition matrix element for this decay channel as well. Converting these results into predicted branching ratios, we obtain a value of $(0.017 \pm 0.004)\%$ from Towner and Hardy [3] and values of 0.016% and 0.035% from Ormand and Brown depending on the effective interaction they use [4]. Our measured upper limit for this branching ratio of $<0.043\%$ is consistent with all three calculations; the limit obtained by Blank [13], $<0.017\%$, is also consistent with two of the calculations.

Insofar as it is possible, we have used the measured decay of ^{62}Ga to test the structure-dependent corrections required to determine the vector coupling constant from superallowed β decay. To current experimental precision, these calculations pass the test. However, a far more demanding test will be possible from these data once the masses of ^{62}Ga and its daughter ^{62}Zn have been measured with ~ 1 keV precision. This should be considered a high-priority goal.

ACKNOWLEDGMENTS

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