High-precision measurement of the half-life of ^{62}Ga

B. Blank[1,2], G. Savard[1], J. Döring[3], A. Blazhev[3,4], G. Canchel[2], M. Chartier[5], D. Henderson[1], Z. Janas[6], R. Kirchner[3], I. Mukha[3], E. Roeckl[3], K. Schmidt[7], and J. Żylicz[6]

[1]Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA; [2]Centre d'Etudes Nucléaires de Bordeaux-Gradignan, Le Haut-Vigneau, B.P. 120, F-33175 Gradignan, France; [3]GSI Darmstadt, Planckstrasse 1, D-64291 Darmstadt, Germany; [4]University of Sofia, BG-1164 Sofia, Bulgaria; [5]Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, UK; [6]Institute of Experimental Physics, University of Warsaw, PL-00-681 Warsaw, Poland; [7]Department of Physics & Astronomy, University of Edinburgh, Edinburgh EH9 3JZ, UK

The electroweak part of the standard model can be tested via the determination of corrected ft values, the so called Ft values. They are obtained by half-life, β^+-decay branching ratio and Q_β measurements with high accuracy. Hardy *et al.* [1] used the superallowed $0^+ \to 0^+$ Fermi transitions of nuclei from ^{10}C up to ^{54}Co to test the standard model via the Conserved Vector Current (CVC) hypothesis. This hypothesis seems to be fullfilled at a level of several 10^{-4} [1]. From these Ft values, the V_{ud} matrix element of the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix can be deduced. The standard model states that this matrix should be unitary. However, according to our present knowledge, the unitarity of the CKM matrix is not fullfilled at the 2.5 σ level.

For these studies, the extracted ft values must be corrected for radiative and Coulomb effects, calculated using various theoretical approaches [2, 3, 4]. While these corrections are generally in good agreement with each other for nuclei where experimental data are available, there are considerable differences between the predictions for heavier nuclei. To a large extent, precise measurements of ft values for Fermi superallowed β-decays in heavier nuclei (with T=1) coupled with the previous results will enable to test the different predictions.

In an experiment at the GSI on-line separator [5], we measured the half-life of ^{62}Ga with high precision. The activity was produced by means of the ^{28}Si(^{40}Ca,αpn)^{62}Ga reaction. A Febiad-E2 source was used to produce a low-energy ^{62}Ga beam which was then mass analysed by the GSI on-line mass separator and delivered to the measuring station. The activity was accumulated on a moving tape device for 350 ms and then moved into the detection setup (transport time about 100 ms). After a delay of 10 ms, the half-life measurement was started. Measurement times of 1600 ms and 1800 ms were used. During the measurement, the beam was deflected well ahead of the collection point. After about 2.2 s, a new cycle started with a new accumulation.

The detection setup consisted of a 4π gas detector used to detect β particles and a germanium detector for γ rays. The electronics chain allowed for two simultaneous measurements with fixed dead-times of 3 μs and 5 μs. In the off-line analysis this dead-time was then corrected for each measurement cycle. Each cycle was carefully check for counting rate, background conditions and other problems. Only cycles without any significant background increase and a minimum counting rate were accepted. For each accepted cycle, an equivalent cycle was generated by a simulation, subjected to the same dead-time and analysed in the same way as the real data sample in order to test the analysis procedure with the simulations.

In figure 1a, we show the experimental spectrum of one run corrected for dead-time. The fit of this particular run which lasted about 4h yielded a half-life of 116.22(16) ms. Part b of the figure shows the simulated spectrum. Here a half-life of 116.55(16) ms resulted.

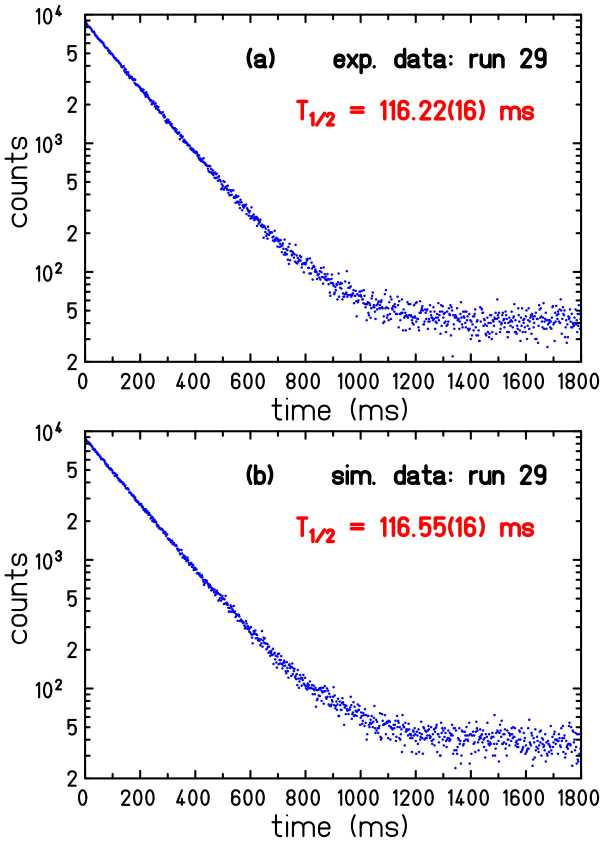

Figure 1: (a) Experimental decay spectrum for run 29. The spectrum has been corrected for dead-time. The half-life determined for this run is 116.22(16) ms. (b) Simulated spectrum generated with the same characteristics as the experimental spectrum, but an input half-life of 116.40 ms. After dead-time correction, the half-life determined is 116.55(16) ms.

Particular attention was paid to possible systematic errors originating from beam contaminants, from the electronics setting, or the analysis procedure and its parameters. Therefore, the germanium spectrum was analysed to detect a significant contribution from other isotopes, the electronics trigger threshold was varied, and the gas detector high voltage was changed during the run. No systematic bias could be found.

In figure 2, we show the half-life values for the individual runs as deduced from this data set. The average value is 116.18(3) ms. These results are in perfect agreement with the 5μs data set analysed in a similar way.

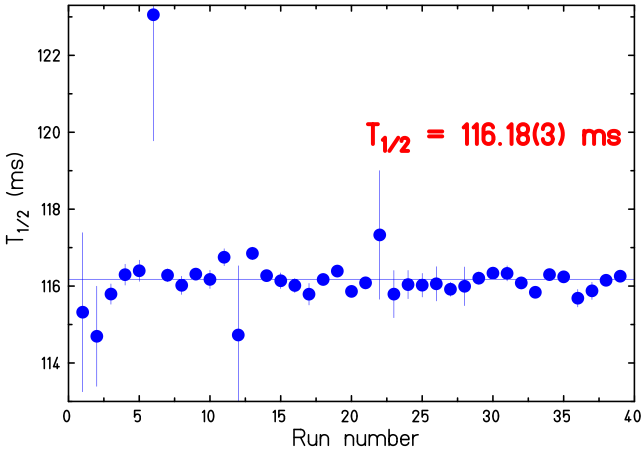

Figure 2: Experimental half-lives as determined from the data set registered with a fixed dead-time of 3 μs. The error weigthed average value is 116.18(3) ms with a reduced χ^2 of 1.65.

Our experimental result with its statistical error is 116.18(3) ms. However, when averaging the different runs we obtain a reduced χ^2 value of 1.6 which indicates that there might be some hidden inconsistencies between the different runs. A possible explanation could be that our cycle selection procedure does not remove all detector sparks or similar problems. We therefore multiply the error bars of the individual runs by the square-root of the reduced χ^2 value obtained from the averaging procedure. The subsequent averaging gives the final experimental value of 116.19(4) ms. The present result is in nice agreement with, but more than a factor of four more precise than any previous result. The average value of all these results is 116.18(4) ms.

This half-life value is now precise enough to contribute to a stringent test of CVC above Z=27 as soon as a more precise β-decay Q value and a refined value of the β-decay branching ratios are known. ^{62}Ga can then also be used to test the correction factors calculated to determine the nucleus independent Ft value.

References

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