The superallowed β-decay branching ratio in the decay of ^{34}Ar

V. E. Iacob, J. C. Hardy, H. I. Park, M. Bencomo, L. Chen, V. Horvat, N. Nica, and B. T. Roeder

Precise *ft* values for superallowed $0^+ \rightarrow 0^+$ β^+-decays contribute to the most demanding unitarity test of the Cabibbo-Kobayashi-Maskawa matrix. The decay from a $T_z = -1$ nucleus like ^{34}Ar is particularly valuable because it completes a mirror pair of superallowed decays and can thus constrain the isospin symmetry-breaking corrections that must be applied to the measured *ft*-values [1,2] before they can be used to extract V_{ud} for the unitarity test. The experimental *ft* values require three ingredients: the Q_{EC}-value of the decay, the half-life of the parent, and the branching ratio of the superallowed branch. If an *ft* value is to be relevant for the unitarity test or a mirror comparison, it needs to be determined to a precision of ~0.1% or better. For the case of ^{34}Ar, its only branching-ratio measurement was made four decades ago [3] and does not currently meet this criterion. Based on the significant improvement to the performance of our acquisition system for the measurement of branching ratios [4] we have repeated the measurement of the ^{34}Ar decay aiming at a precision exceeding 0.1%.

We produced a pure ^{34}Ar beam (>99%) at the exit of the MARS recoil separator using a 30*A* MeV ^{35}Cl beam from the K500 cyclotron to bombard a hydrogen gas target kept at a pressure of ~2 atm and at liquid-N_2 temperature. The ^{34}Ar beam was extracted into air, degraded and implanted in the center of the 75-µm-thick Mylar tape of our fast transport system. In repeated cycles, ^{34}Ar samples were collected for 2 s and then moved in 160 ms to the center of a well-shielded β-γ counting station, where β singles, γ singles (scaled only), and β-γ coincidences were recorded for 2 s. The β's were detected in a 1-mm-thick plastic scintillator, located 2.5 mm from one side of the tape. The γ's were detected in our precisely efficiency-calibrated HPGe detector located 151 mm away on the other side of the tape. The beam was checked daily for stability and purity to ensure maximum consistency in the acquired data.

More than 3 billion ^{34}Ar nuclei were implanted during a week-long experiment. A total of 22×10^6 β-γ coincidences (distributed over about 74×10^3 cycles) were recorded. Fig. 1 presents the spectrum of γ rays coincident with positrons from the decay of ^{34}Ar. Only γ rays associated to this decay are observed: full-energy γ-ray peaks at 461, 666, 2580 and 3129 keV; the annihilation peak at 511 keV and the single- and double-escape peaks for hard gammas.

As discussed in [4], we read the tape-to-HPGe distance with a laser sensor to a precision better than 0.1 mm. This distance is recorded for each cycle. The tape-to-HPGe is an important ingredient in the analysis of the experiment: A deviation of 0.1 mm from the nominal position translates in a change of 0.11% in the absolute detection efficiency of the HPGe detector. Fig. 2 presents the distribution of the distance as observed in this experiment. The histogram shows good consistency in the tape positioning, with a full-width-at-half-maximum of 0.4 mm (the central red region). Although the individual positions do not meet the accuracy requirement for the most precise superallowed beta decays, our knowledge of the exact value in each cycle overcomes this obstacle.

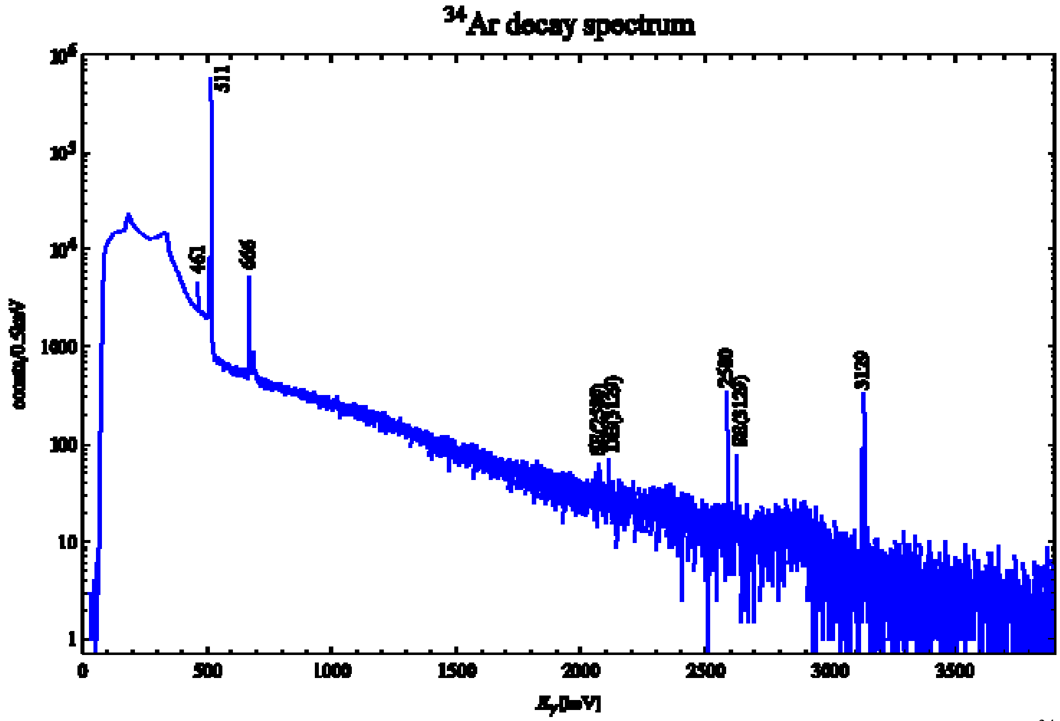

FIG. 1. Spectrum of γ rays observed in prompt coincidence with positrons from the decay of ^{34}Ar. The peaks are labeled with their energy and, in a few cases, their designation as single-escape (SE) or double-escape (DE) peaks. The structure just to the right of the 666-keV peak is the result of coincidence summing between one 511-keV γ ray from an annihilation pair with the back-scattered γ ray (171 keV) from the second 511-keV γ ray.

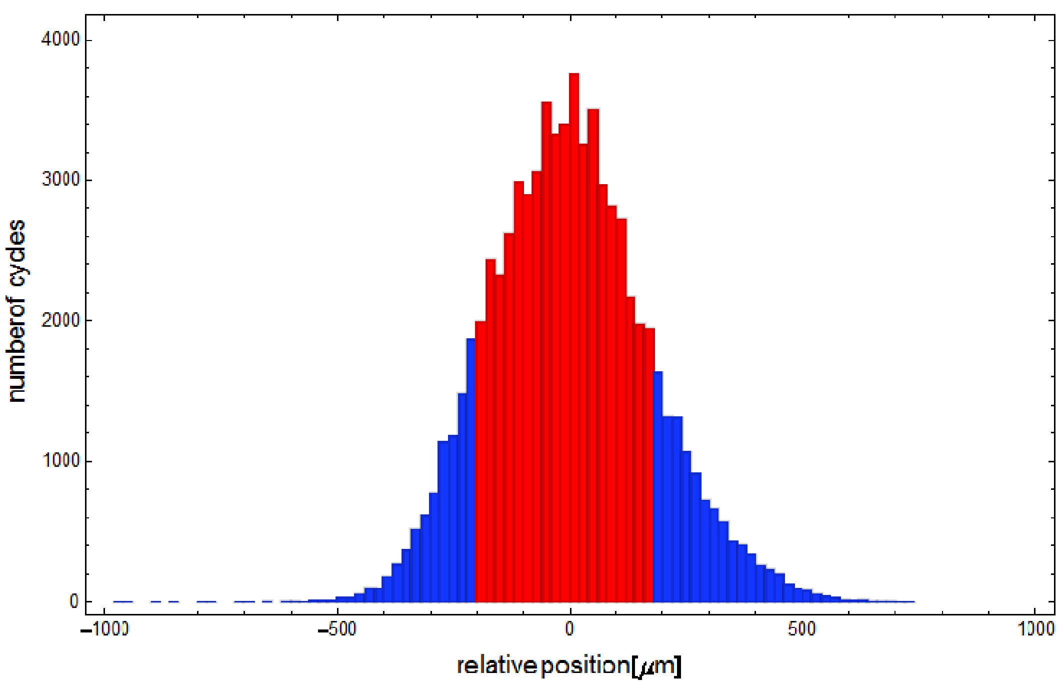

FIG. 2. Distribution of the tape-to-HPGe distance as recorded during the ^{34}Ar branching-ratio measurement. Zero on the position scale corresponds to the nominal distance of 151 mm. The FWHM of the distribution (in red) is less than 0.4 mm.

The experiment is still being analyzed but a very preliminary analysis yielded an *ft*-value consistent with the other superallowed emitters. The compete and detailed analysis is expected to produce a value with the accuracy and precision required to make a statistically-significant comparison with the mirror decay of ^{34}Cl, and from that to make a meaningful test of the isospin-symmetry-breaking corrections. The ultimate goal, of course, is to reduce the uncertainty on the CKM unitarity test.

[1] I.S. Towner and J.C. Hardy, *Progress in Research,* Cyclotron Institute, Texas A&M University (2013-2014), p. III-10.

[2] H.I. Park *et al.*, *Progress in Research,* Cyclotron Institute, Texas A&M University (2013-2014), p. I-16.

[3] J.C. Hardy, H. Schmeing, J.S. Geiger and R.L. Graham, Nucl. Phys **A223**, 157 (1974).

[4] V.E. Iacob, J.C. Hardy, and H.I. Park, *Progress in Research,* Cyclotron Institute, Texas A&M University (2011-2012), p. V-21; V.E. Iacob, H.I. Park, and J.C. Hardy, *Progress in Research,* Cyclotron Institute, Texas A&M University (2012-2013), p. IV-43.