Improvement in the precision of the ^{34}Ar half-life

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

Our recent ^{34}Ar branching-ratio measurement [1] along with a more precise half-life would yield an *ft* value for the ^{34}Ar decay whose accuracy would match that of the well-known cases [2] used in generating the corrected $\mathcal{F}t$ values that are instrumental in extracting V_{ud} and testing the unitarity of the CKM matrix [2].

The measurement was similar to the one reported in [3]. The radioactive beam was produced in the ^{1}H(^{35}Cl, 2n) reaction with a primary ^{35}Cl beam at 30A MeV from the K500 cyclotron. The hydrogen target was kept at liquid nitrogen temperature and at a pressure of ~2 atm. A pure (>99%) ^{34}Ar beam separated by the MARS spectrograph was extracted in air, degraded and eventually implanted in the center of the 76-μm-thick Mylar tape of our fast transport system. Then the beam was turned off and the implanted ^{34}Ar samples were moved into the center of a 4π proportional counter, from which the signals were multiscaled. In repeated collect-move-detect cycles we recorded more than 3×10^{8} combined β^{+}-events. The time-settings for the collect-move-detect intervals were 0.7 s-0.15 s-16 s.

We performed a variety of checks to test for possible systematic effects caused by the electronic setup: We changed the critical settings for:

- detector biases (2450, 2500, 2550, 2600, 2650, 2700, and 2750V),
- discriminator thresholds (150, 200, and 250mV), and
- dead-times: (3, 4, 6, 8, 10, and 12 μs).

The parent ^{34}Ar ($t_{1/2}$=0.84 s) decays to ^{34}Cl, which itself is β^{+}-unstable ($t_{1/2}$=1.53 s). As the 4π proportional counter is unable to distinguish between the β's generated by the parent and daughter nuclei, only a combined decay spectrum can be acquired. As discussed in Ref. [3], a precision half-life result cannot be obtained using a free fit: For cases like this one, with a parent-to-daughter half-life ratio close to 0.5, the composite decay curve shows very little deviation from a single exponential with the characteristic half-life of the daughter. Therefore a key ingredient in the fit must be the imposition of the independently determined parent-to daughter link based on the parent's implantation and decay history. Qualitatively, higher precision is achieved because use of the parent-to-daughter link reduces by one the number of parameters to be fit: A free fit would seek the amplitudes for the two components, the half-life of the parent and possibly the background. Using the parent-to daughter link, one of the two decay-amplitudes is fully expressed in terms of the other fit-parameters. Nevertheless, this gain results in an increase in the nonlinearity of the fit.

Quantitatively, to determine the parent-to-daughter link requires knowledge of the beam-profile (implantation history), the tape move-time and the ratio of the detection-efficiencies for the two components. At the time of the measurements reported in [3] the experimental setup was in its infancy. In the meantime, our experimental set-up has been subject to a series of upgrades and as such it is expected to allow an increased precision in the ^{34}Ar half-life. Most important from this perspective are more precise controls over the implantation profile and the timing of the cycle: We now monitor (and record) for each cycle the corresponding beam-profile [4] and move-time. Thus, the data analysis can exactly account for instantaneous changes in the beam current in each cycle; likewise it exactly accounts for "in-flight" adjustments in the move-times. These added features increase the accuracy of the ratio of the parent-to-daughter activities.

Moreover, to better control the dead-time corrections we have increased the number of multiscaler channels used to record the decay curve from 500 to 15,000, essentially removing the need to account for a variable rate during each channel's time-window.

The data analysis is in progress.

[1] V.E. Iacob *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2013-2014), p. I-20.

[2] J.C. Hardy and I.S. Towner, Phys. Rev. C **91**, 025501 (2015); J.C. Hardy and I.S. Towner, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. III-49.

[3] V.E. Iacob, J.C. Hardy, J.F. Brinkley, C.A. Gagliardi, V.E. Mayes, N. Nica, M. Sanchez-Vega, G. Tabacaru, L. Trache, and R.E. Tribble, Phys. Rev. C **74**, 055502 (2006).

[4] V.E. Iacob *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2008-2009), p. V-43.