Update on the superallowed branching ratio in the ^{34}Ar

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Last year we reported a measurement of the branching ratios in the decay of ^{34}Ar [1]. This experiment, along with a more precise half-life value [2] is expected to yield an *ft* value for the superallowed transition from ^{34}Ar whose accuracy matches that of the well-known superallowed decays used in generating the corrected $\mathcal{F}t$ values that are instrumental in extracting V_{ud} and testing the unitarity of the CKM matrix [3].

The experiment described in Ref. [1] measured β-γ coincidences and β singles from cyclotron-produced ^{34}Ar sources placed between a 1-mm-thick plastic scintillator (located 2.5 mm from the source) and our efficiency-calibrated HPGe detector [4] (151 mm from the source). Since then, we have analyzed the data to obtain the precise photopeak areas for all the γ rays observed (at 461, 666, 2580, and 3129 keV). The statistical uncertainties range from 0.8% to 2.5%, the higher ones being associated with the γ rays generated by the weaker β-decay branches (~1% or less).

These areas have to be corrected for losses. All observed γ rays de-excite an excited state directly to the ^{34}Cl ground state. Any γ-cascades, if they occur at all, are too weak to be detected. Thus, true γ-ray coincidences in the HPGe detector cannot occur. However, the γ rays and the decay positrons are coincident on the timescale of our electronics and there are two mechanisms by which those positrons can generate coincident photons: (a) bremsstrahlung and (b) annihilation, either in flight or at rest. If these photons appear in the HPGe detector in coincidence with a γ ray, then the total energy recorded in the detector is increased, thus resulting in some of the γ-ray photopeak events being lost. The combined correction associated with photon losses due to true coincidences with bremsstrahlung and positron annihilation is 2.4%.

The branching ratio for the β-decay branch *k*, which leads to emission of a γ_k photon, can be expressed as the ratio between the β_k-γ_k coincidences and the total number of decays (or β's). Highly simplified, this can be expressed as:

$$BR_k = \frac{N_{\beta_k-\gamma_k}}{\varepsilon_{\beta_k}\varepsilon_{\gamma_k}} \Big/ \frac{N_{\beta_{tot}}}{\langle \varepsilon_\beta \rangle} \qquad (1)$$

Here $N_{\beta_k-\gamma_k}$ is the number of observed β_k-γ_k coincidence events (the γ_k photopeak area), $N_{\beta_{tot}}$ is the total number of observed β's associated with the ^{34}Ar decay, ε_{γ_k} is the absolute photopeak efficiency for γ_k, ε_{β_k} is the absolute detection efficiency for a branch-*k* positron in the plastic scintillator, and $\langle \varepsilon_\beta \rangle$ is the average detection efficiency for all decay positrons in the plastic scintillator.

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). Obviously, it is only the β's associated with the ^{34}Ar decay alone that must be used in Eq. (1). Taking the known half-lives of the two nuclei, the measured time-profile of the ^{34}Ar beam implantation, and the collect-movedetect time-values, we determined that 47% of the total β singles recorded are associated with the parent decay. In addition, small corrections have to be applied to take account of beam impurities (~0.08%).

The plastic-scintillator efficiency for detecting β's has a small dependence on the β-spectrum energy and, as a result, small corrections related to the ratio $\langle \varepsilon_{\beta} \rangle / \varepsilon_{\beta_k}$ also must be applied. These corrections were derived from Monte Carlo calculations and range from -3% to +1%; the negative values correspond to weak β branches that populate high-energy excited states. Overall this leads to an average contribution of 0.4% to the final superallowed branching ratio since the whole decay is dominated by the ground-state branch.

Naturally, corrections are required to correct for all forms of dead time: in the singles channels and in the β-γ coincidences. Their combined contribution is 0.4%.

Last, small corrections must be applied to the results to incorporate the very small contribution from electron capture, which affects the decay branching but does not lead to β-coincident γ rays in our measured spectrum. For the branches in ^{34}Ar decay these corrections range from 0.07% to 1.2%

The data analysis continues.

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

[2] V.E. Iacob, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. I-46.

[3] J.C. Hardy and I.S.Towner, Phys. Rev. C **91**, 025501 (2015).

[4] J.C. Hardy *et al.*, Appl. Radiat. Isot. **56**, 65 (2002) ; R.G. Helmer *et al.*, Nucl. Instrum. Methods Phys. Res. **A511**, 360 (2003); R.G. Helmer *et al.*, Appl. Radiat. Isot. **60**, 173 (2004).