Impact of weak gammas in the superallowed β decay of ^{34}Ar

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We have reported previously on our precise measurements of the half-life and branching ratios for the decay of ^{34}Ar [1-3]. In order to achieve the desired accuracy (better than 0.1%) for the superallowed branching ratio, a thorough inspection is required of the γ-ray spectrum in coincidence with ^{34}Ar betas to identify weak peaks that could have been missed or are at the statistical limit of observation.

All γ-ray transitions in ^{34}Cl (E* < 5040 keV) that could possibly be fed in the beta-decay of ^{34}Ar have been considered and upper intensity-limits were assessed. Each limit was derived from statistical considerations for a 2×FWHM-wide region centered on the potential candidate; this region covers 98% of the events included in a Gaussian shaped peak. Each value was further reinforced by a visual inspection of the original spectrum, on which a virtual peak (with the correct FWHM and upper-limit area) was superimposed.

While the majority of the potential γ rays lie in regions where the background is easy to handle, some required special attention. This is the case with our most important finding in this analysis: the 519-keV γ ray, which is located in the vicinity of the annihilation-radiation peak. (See Fig. 1.) The intensity of the latter makes the analysis quite demanding: Only a finely tuned fit of the dominant 511-keV peak can give us access to a realistic area for the 519-keV peak. To get a reliable description of the 511-keV peak, a quite elaborate fit function was used. It is described as: 1) a Gaussian; plus 2) a short-range

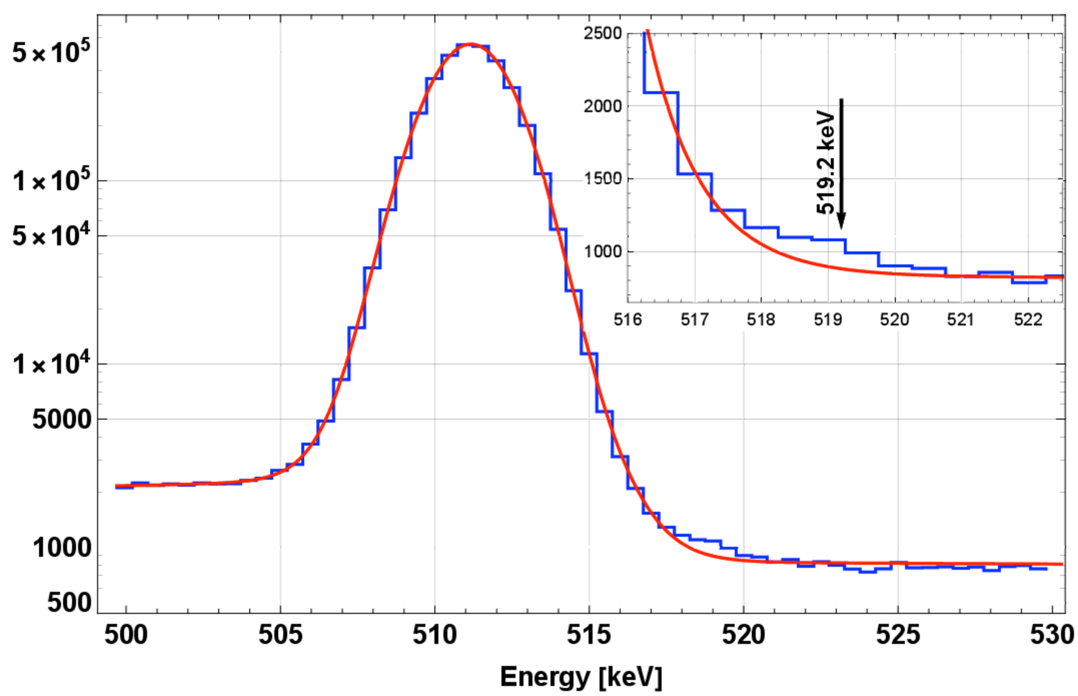

FIG. 1. Finely tuned fit of the annihilation peak observed in beta-gamma coincidences. The fit function contains 12 parameters. The inset zooms in on the right wing of the peak and clearly shows an excess of counts around 519.2 keV; the associated FWHM is consistent with the value expected for this energy.

skewed Gaussian on the left side; plus 3) a long-range skewed Gaussian on the left side; and 4) a short-range skewed Gaussian on the right side. The background under both peaks is described as: 1) a linear polynomial; plus 2) a step function.

With all these terms, the fit curve (the red-line in Fig. 1) passes through the centers of all channels describing the annihilation peak. The inset zooms in on the region centered at 519 keV and shows clearly a bump containing 700(200) events. The area of this peak is consistent with an intensity of 3% relative to the 666-keV γ-ray, the most intense one observed in the decay of ^{34}Ar. As seen in Fig. 2, the overall impact of the 519-keV gamma is small (the beta branch populating the 666-keV level is 2.6%); nevertheless, it needs to be accounted for in any precise analysis of the superallowed branching ratio or the half-life.

The main consequence of the presence of any of these weak branches is to increase of the total branching ratio for $0^+ \rightarrow 1^+$, Gamow-Teller branches; this in turn reduces the branching ratio deduced for the superallowed branch.

The effect that weak γ-ray branches potentially have on the ^{34}Ar half-life is less obvious. In the case of the 519-keV γ-ray, its presence induces a small change in the fitted ^{34}Ar half-life. Here is why: When we measure the half-life, we use our 4π proportional counter, which records the positrons from the 844-ms decay of ^{34}Ar and from the 1.53-s ground-state decay of its daughter, ^{34}Cl. Because their half-lives are related by nearly a factor of 2, the combined decay cannot be fitted as two independent decays. The only way to obtain a precise result is to incorporate the parent-to-daughter link as a constraint in the fitting procedure. If all the decay branches from ^{34}Ar ultimately populate the ^{34}Cl ground state, this linkage is one-to-one. However, the excited state at 666 keV, which is populated in the beta-decay of

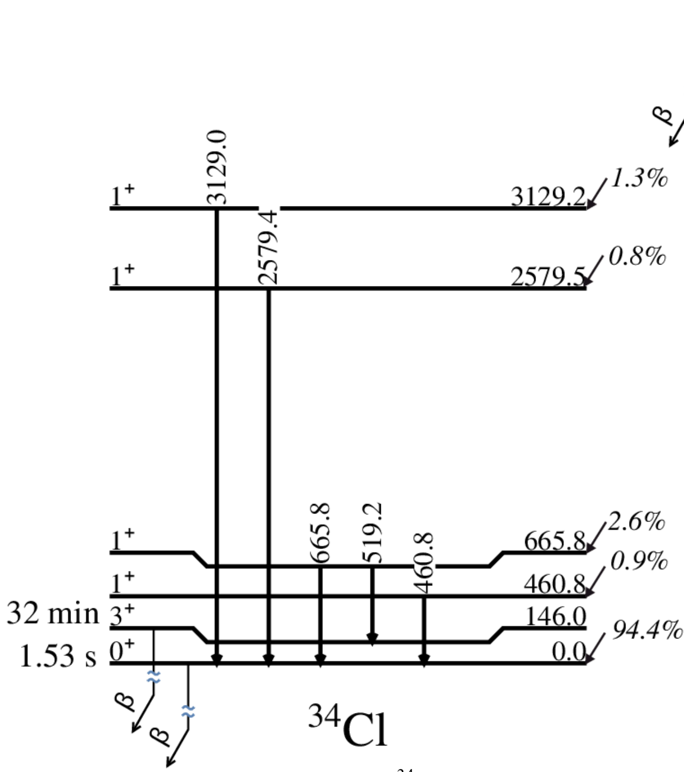

FIG. 2. Simplified decay scheme of ^{34}Ar as observed in beta-gamma coincidences**.**

^{34}Ar, can decay via a 669- or a 519-keV γ-ray. (See Fig. 2.) The latter populates the isomeric level at 146 keV, which has a half-life of 32min. Thus, this decay path for the 666-keV state does not lead to the subsequent emission of a beta from the decay of ^{34}Cl within our measurement time window. Thus, the parent-daughter linkage must be adjusted to account for the loss of betas from the daughter decay.

We plan a more definitive measurement of the γ-decay branching from the 666-keV level in ^{34}Cl by means of a collaborative (p, γ) experiment at Notre Dame University.

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

[2] V.E. Iacob, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. I-48.

[3] V.E. Iacob, *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2015-2016), p. I-14.