Superallowed $0^+ \rightarrow 0^+$ nuclear β decays: A new survey with precision tests of the conserved vector current hypothesis and the standard model

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Beta decay between nuclear analog states of spin-parity, $J^\pi = 0^+$, and isospin, T = 1, has been a subject of continuous and often intense study for five decades. The strengths, or *ft* values, of such transitions are nearly independent of nuclear-structure ambiguities and depend uniquely on the vector part of the weak interaction. Thus, their measurement has given nuclear physicists access to clean tests of some of the fundamental precepts of weak-interaction theory and, over the years, this strong motivation has led to very high precision being achieved in both the experiments and the theory required to interpret them.

As befits such an important issue, we have undertaken periodic surveys of the relevant world data (see, for example, refs [1-5]). Even though the last survey closed as recently as 2004, a large amount of significant new data has appeared in the four years since then, so that survey was already out of date. We have now published a thorough new overview [6] in which we critically survey all relevant measurements formally published before September 2008.

Compared with our last review, there are numerous improvements: First, we have added 27 recently published measurements and eliminated 9 references, either because they have been superseded by much more precise modern results or because there are now reasons to consider them fatally flawed; of particular importance, the new data include a number of high-precision Penning-trap measurements of decay energies. Second, we have used the recently improved isospin symmetry-breaking corrections [7], which were motivated by these new Penning-trap results. Third, our calculation of the statistical rate function *f* now accounts for possible excitation in the daughter atom, a small effect but one which merits inclusion at the present level of experimental precision. Finally, we have re-examined the systematic uncertainty associated with the isospin symmetry-breaking corrections by evaluating the radial-overlap correction using Hartree-Fock radial wave functions and comparing the results with our earlier calculations, which used Saxon-Woods wave functions; the provision for systematic uncertainty has been changed as a consequence.

The new corrected $\mathcal{Ft}$ values are impressively constant – see Fig. 1 – and their average, when combined with the muon lifetime, yields the up-down quark-mixing element of the Cabibbo-Kobayashi-Maskawa (CKM) matrix, $V_{ud} = 0.97425 \pm 0.00022$. The unitarity test on the top row of the matrix becomes $|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.99995 \pm 0.00061$. Both V_{ud} and the unitarity sum have significantly reduced uncertainties compared with our previous survey, although the new value of V_{ud} is statistically consistent with the old one. From these data we also set limits on the possible existence of scalar interactions, right-hand currents and extra *Z* bosons. Finally, we discuss the priorities for future theoretical and experimental work with the goal of making the CKM unitarity test even more definitive.

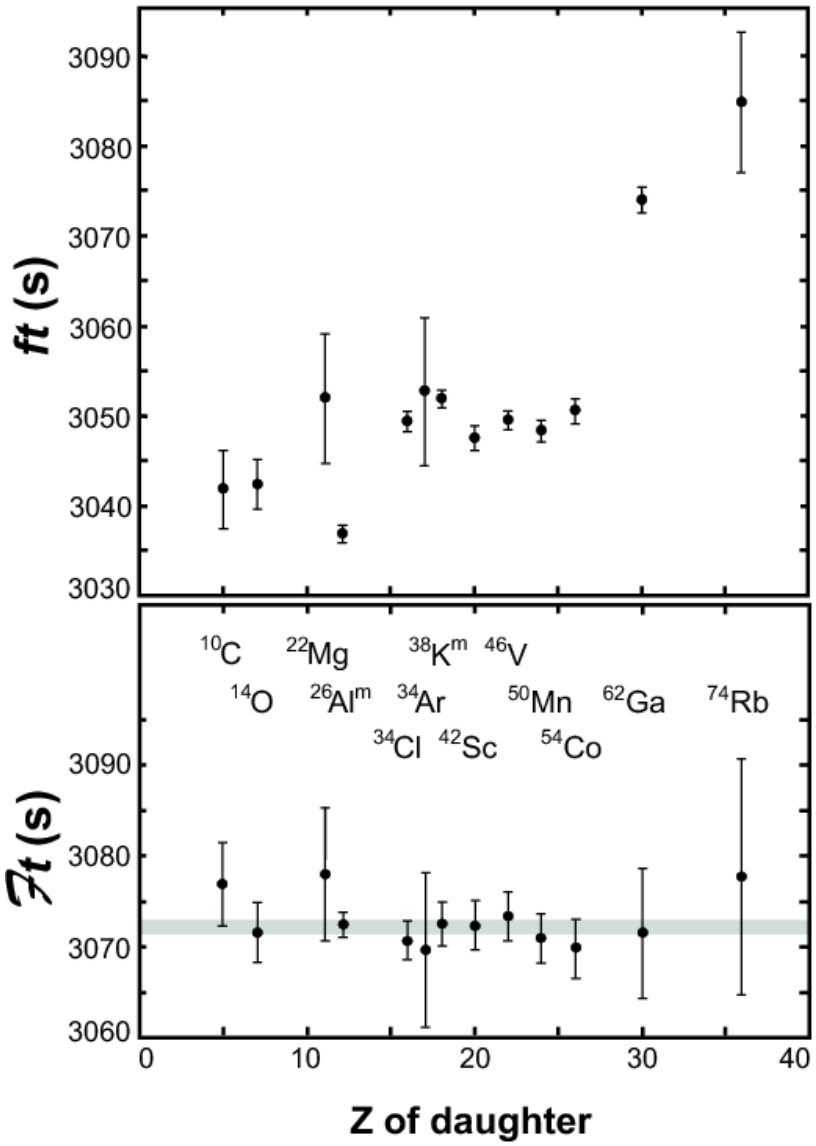

FIG. 1. In the top panel are plotted the experimental *ft* values. In the bottom panel, the corresponding $\mathcal{F}t$ values are given; they differ from the top panel principally by inclusion of the nuclear-structure-dependent corrections. The horizontal grey band in the bottom panel indicates the average $\mathcal{F}t$ value with its uncertainty.

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