# Precise Half Life Measurements: the Case of $^{10}$C

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The half-life of $^{10}$C was measured as part of our program to test the unitarity of the Cabibbo-Kobayashi-Maskawa (CKM) matrix via $0^+ \rightarrow 0^+$ superallowed β transitions; the case of $^{10}$C is of particular interest because of its higher sensitivity to the presence of scalar currents [1]. The $^{10}$C half-life has been measured twice before, with precisions of 0.10% [2] and 0.08% [3]. With our current techniques, we anticipate being able to improve that precision by more than a factor of two.

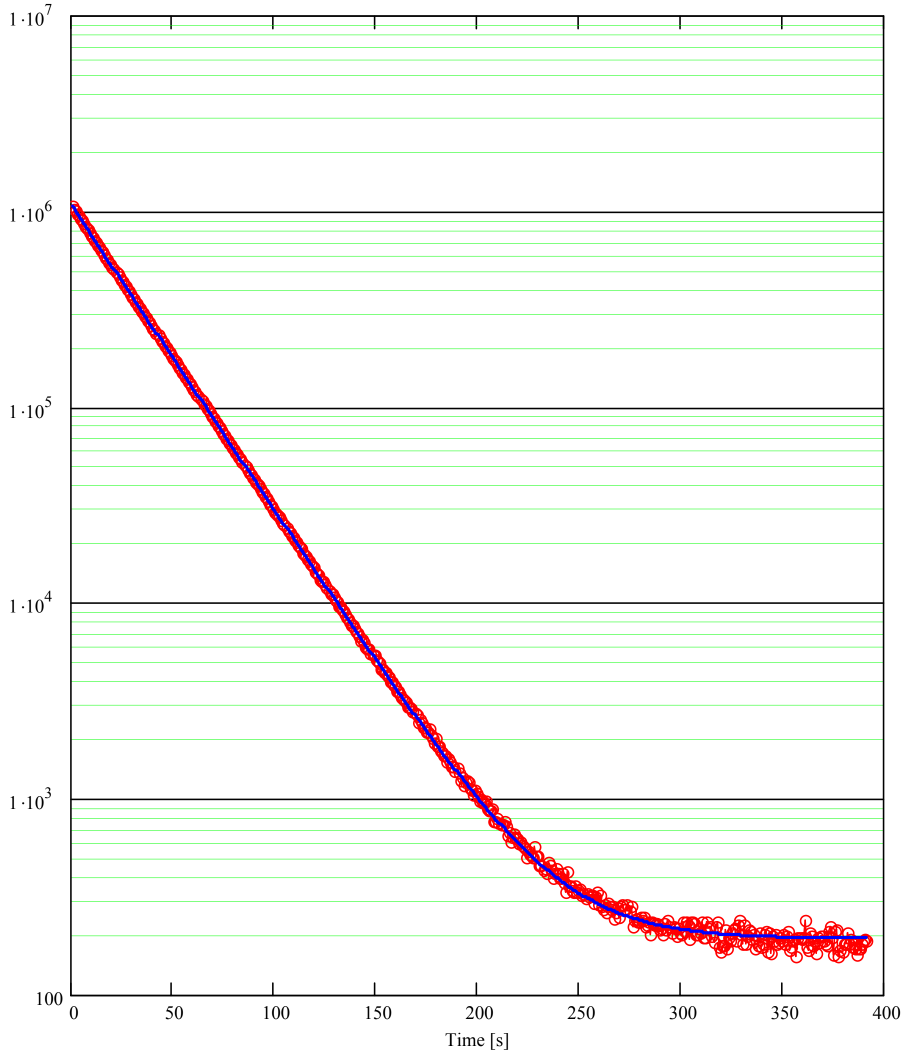

**Figure 1.** Total decay spectrum observed in the β-decay of $^{10}$C.

To obtain $^{10}$C, we used a $^{11}$B beam primary beam at 23*A* MeV from the cyclotron to bombard a cryogenic hydrogen target pressurized to 1.5 atm. From the reaction products, a high purity $^{10}$C radioactive beam at 18.5*A* MeV was separated by the MARS spectrograph. This beam was then extracted into air, passed through a 0.3-mm-thick BC-404 plastic scintillator and a set of Al degraders optimized to stop the $^{10}$C nuclei at the center of the 76-μm-thick aluminized mylar tape of our fast tape-transport system. We collected $^{10}$C nuclei for 10, 15 or 20s; then the beam was switched off and the activity was moved 90cm in 180ms to the center of a 4π proportional gas counter located in a well shielded region. The observed decay positrons were then multiscaled over a 400s time span. Such collect-move-detect cycles were repeated until we had collected more than $4\times10^7$ decays. The total decay spectrum obtained in this experiment is presented in Fig. 1.

To ensure an unbiased result, we split the experiment into 20 different runs, each differing from the others in their discriminator threshold (150, 200 and 250mV), detector bias (2450, 2550 and 2650V) or dominant dead-time (3, 4 and 6μs) setting. As long-lived impurities could alter the deduced result for

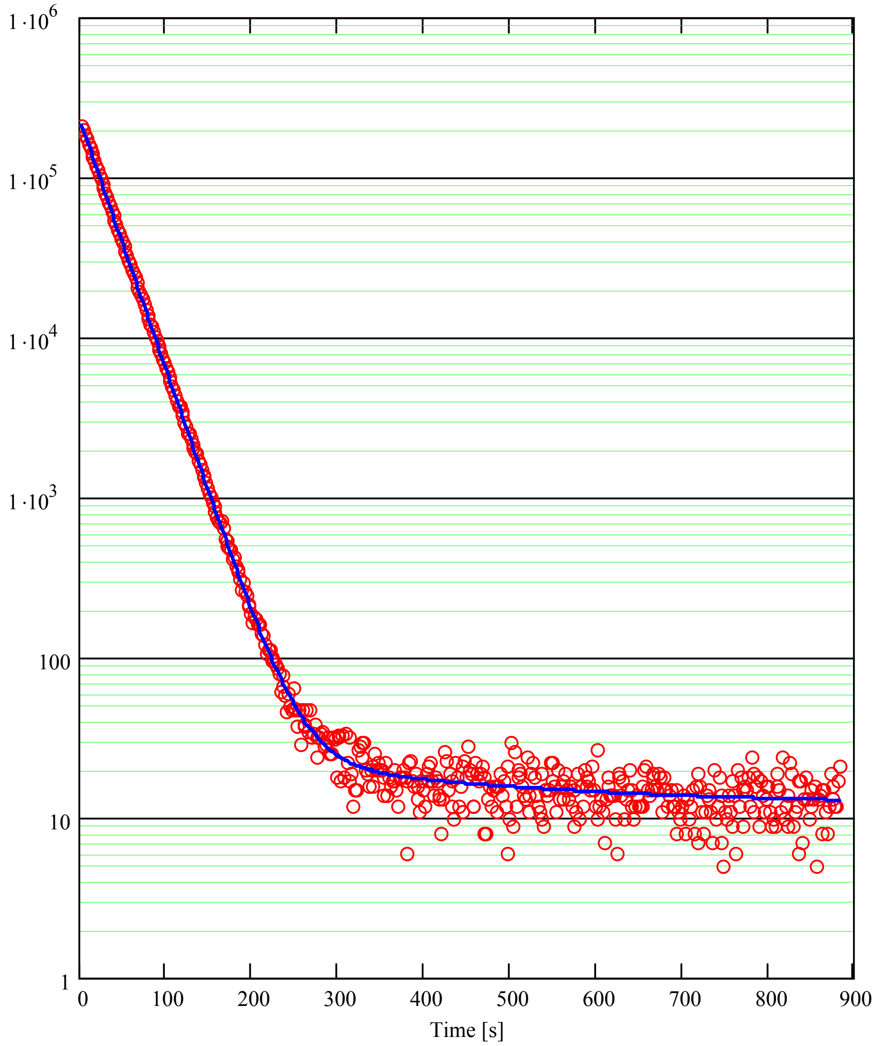

**Figure 2.** Evidence for the presence of $^{28}$Al (caused by neutron activation of $^{27}$Al) in the $^{10}$C experiment: $t_{1/2}(^{28}\mathrm{Al})$ =134.5s

$^{10}$C, we also performed a run with 60s-0.180s-900s collect-move-detect time settings. The total decay spectrum obtained in this run is presented in Fig. 2. It became obvious from the slight slope between 300 and 900s that we do have a second, long-lived component in the spectrum. Analysis revealed that this came from 134.5-s $^{28}$Al, which undoubtedly originated from neutron capture on $^{27}$Al, a material present both in our support structures and as a coating on our mylar tape. Adjusting for the different collect-move-detect times in this run, we determined that, for the first channel of our usual decay spectrum, the $^{28}$Al impurity was at the level of $2.5\times10^{-4}$ as compared to the main $^{10}$C component. We take account of this impurity in our analysis.

As a further test of the consistency of our results, we have re-done the fits over subsets of events: we removed the first few channels in the acquired spectra, thus eliminating (or at least diminishing) the contribution of any possible short-lived impurity and/or reducing possible rate-dependent counting losses. The results are presented in Fig. 3. As can be seen, the half-lives obtained for all different subsets are statistically consistent with one another, thus giving no indication of unidentified short-lived impurities or any rate-dependent counting losses. Our preliminary result for the half-life of $^{10}$C is 19.313(10)s. When the analysis is complete, we expect a further reduction in the uncertainty. As it stands, our result agrees with, but is already more precise than, the previously accepted (average) value, 19.290(12)s.

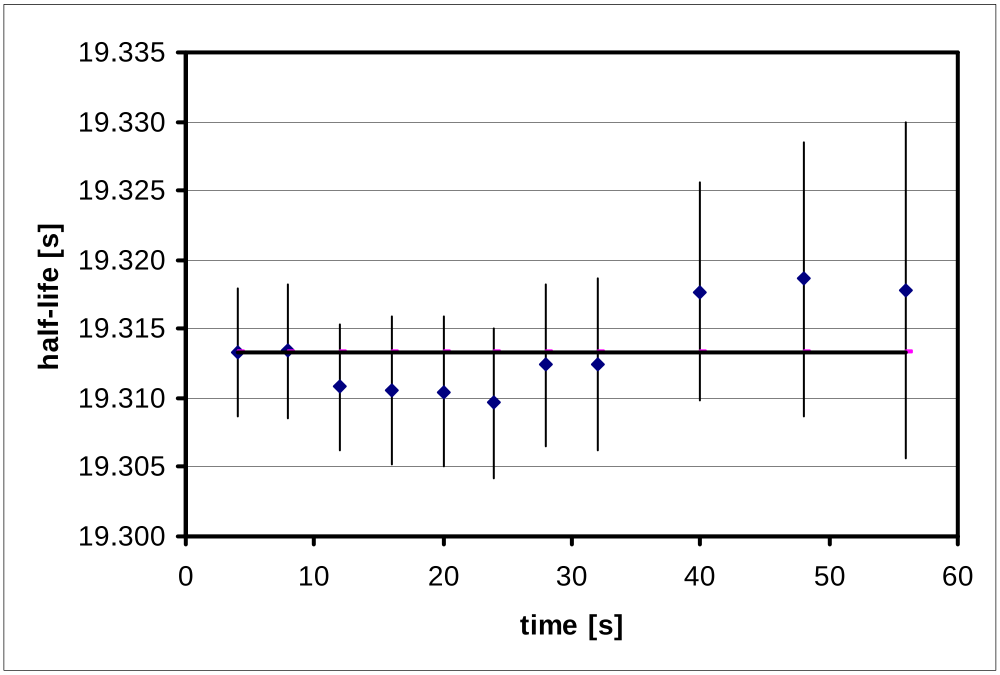

**Figure 3.** Test for possible systematic errors in the extracted half-life of $^{10}$C caused by unidentified short-lived impurities or by rate-dependent counting losses. The abscissa represents the time interval at the beginning of the detecting-time for which the data were eliminated from the fit.

[1] J.C. Hardy and I.S. Towner, Phys. Rev. C **71**, 055501 (2005).

[2] G. Azuelos, J.E. Crawford and J.E. Kitching, Phys. Rev. C **9**, 1213 (1974).

[3] P.H. Barker and G.D. Leonard, Phys. Rev. C **41**, 246 (1990).