Measurement of the Half-Life of $^{22}$Mg

V. E. Iacob, J. C. Hardy, M. Sanchez-Vega, A. Azhari, C. A. Gagliardi, E. V. Mayes, R. G. Neilson, L. Trache, R. E. Tribble, D. Willis and Y. Xiao

As part of our program [1] to test CKM unitarity via superallowed $\bar{\beta}$-decays, we have measured the half-life of $^{22}$Mg with a precision close to $\pm 0.05\%$. We performed the measurement at the end of the MARS recoil spectrometer, using our fast tape-transport system [2]. A high purity radioactive beam (containing more than 99.6% $^{22}$Mg) was produced via the MARS spectrometer with the $^1$H($^{23}$Na,2n)$^{22}$Mg reaction at 28A MeV. The 23A MeV $^{22}$Mg ions exited the beam-line through a 50-μm-thick Kapton window, passed through a 0.3-mm-thick BC-404 scintillator and a stack of aluminum degraders, and eventually implanted in a 76-μm-thick aluminized mylar tape. Since the few remaining impurities in the beam had different ranges from $^{22}$Mg, they were not collected on the tape: the purity of the collected sample was thus $>99.9\%$ [3].

In our experiment, the $^{22}$Mg activity was collected for 8 s, about two half-lives; then the beam was turned off and the sample moved within 180 ms to the center of a 4B proportional gas counter [4], located in a low background region. The detected counter signals were then multiscaled for a period of 80 s and an 8000-channel decay spectrum was recorded. This collect/move/detect cycle was clock-controlled and was repeated continuously. Within the counting period a pulse synthesizer accurate to 5 ppm provided the time-stamp. Special care was taken to avoid any systematic errors that could be generated by the acquisition system. The counter signals were amplified and sent to a fast discriminator, whose signals then went to a gate generator. The time duration of the gate signal was chosen to be much longer than any dead time introduced by the up-stream modules. This produced a well-defined non-extendable dead-time.

A total of about 10 million $^{22}$Mg decays were recorded in 14 separate runs (see Fig. 1). We pre-sorted the data by testing each cycle for the ratio of $\bar{\beta}$-particles recorded in the proportional counter versus the number of $^{22}$Mg nuclei deposited on the tape (as determined by the scintillator at the exit of MARS); thus, we discarded any anomalous cycles with low counts or high noise. Then we analyzed the results with two different fitting procedures to extract the half-life: (i) a maximum-likelihood fit to the sum of all dead-time corrected decay spectra; and (ii) a global fit of individual cycle spectra, with common half-life but with amplitudes and dead-times correctly matched to each cycle. The second procedure gives the best precision, as it contains no approximation. To further

![Figure 1: Total decay spectrum of $^{22}$Mg $\bar{\beta}$ particles](image)
consolidate the results, both fitting procedures and all tests were repeated on a parallel set of Monte-Carlo generated spectra, mimicking the trend of the real data, but with a known half-life and background. The accurate retrieval of the decay parameters used in the generation of the artificial data validated the fitting procedures and the final half-life result.

To test for possible systematic errors introduced by the electronics, we made measurements at various different settings of the discriminator threshold and the detector bias. No evidence of a systematic bias was found when these measurements were compared (see Fig. 2). We also tested for the possible presence of some short-lived impurities and/or counting-rate dependence. To do so, we removed the contribution of data from the first second of the counting period and repeated the fit; we then repeated the procedure removing the first two seconds, three seconds and so on. As seen in Fig. 3, the half-life is very stable against these changes. There is no evidence for either short lived contaminants or count-rate dependencies.

We still have not checked the stability of the result as a function of the value set for the dominant dead time. This test will be performed in late May. Since this check is not completed, our result is still preliminary: $t_{1/2} = 3.8777(20)$ s.

References