Upgrade of data-acquisition system for measuring β-decay half-lives

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We require a precision of better than 0.1% in half-life measurements for the superallowed emitters we use to test the Standard Model *via* the unitarity of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. This requires extreme care both in data acquisition and in the subsequent analysis. We have added a new feature to our data acquisition that allows us to record the time profile of the deposited activity for every cycle.

The β^+ emitters that we study are typically produced by a heavy-ion beam from the superconducting cyclotron impinging on a cryogenic hydrogen gas target kept at two atmospheres pressure. The ejectiles recoiling from the target pass through the MARS spectrometer, from which a pure beam of a single selected isotope is extracted into air, passed through a 0.3-mm-thick plastic scintillator as well as Al degraders, and eventually implanted in a 76-μm-thick mylar tape. We measure the half-life in a computer-controlled cyclic mode: First the radioactive sample is implanted in the tape (for up to about two half-lives); then the beam is turned off and the tape moved (in less than 0.2 s) so the activity is placed in the center of a proportional gas counter; finally the decay is multiscaled (for up to 20 parent half-lives). This cycle is repeated continuously until the desired statistics have been acquired.

One precision-limiting problem occurs in the decays of beta emitters which populate nuclei that are themselves radioactive with a similar half-life. This applies to the cases of ^{34}Ar [1] and ^{26}Si [2]. For such nuclei, the optimum precision for the parent half-life is achieved in a constrained fit of the combined parent and daughter decays, in which the total daughter activity is fixed relative to the activity of the parent. To determine this fixed ratio it is necessary to account for the decay of the parent – and consequent production of the daughter – which occurs during the sample-collection period, before the detection and multiscaling begins. The method used is described in more detail in [1]. A key requirement is that one must know the implantation history of the radioactive ions as well as the exact time it takes to transport the radioactive sample to the detector position.

While in a first approximation the intensity of the implantation beam can be considered constant in time, we have determined [1] that this is not exactly true. Because of local warming of the hydrogen-target gas on the beam path, and the associated lowering in gas density, we observe a drop in the radioactive beam intensity during approximately the first 0.1 s after the primary cyclotron beam is turned on and a partial recovery towards a quasi-constant value after another 0.1 s (see Fig. 8 in [1]). The magnitude of this fluctuation depends on the intensity of the cyclotron beam in the gas cell, which can change during an experiment from time to time.

Previously we have measured the beam time-profile in a separate experiment from the half-life measurement. However, to improve our control over this important parameter, we have added to our standard detection system (as described in [1]) the capability to measure the beam profile in each cycle. In the upgraded acquisition system we now record in each cycle three spectra: a beam profile and two time-decay spectra (associated to the two electronic chains processing the gas-counter signals). This is

done with a CMC206 universal logic module [3], programmed as a multiscaler module able to count three independent signals. Previously we only had two multiscaler channels available.

As with all precision measurements, consistency is a key factor. In our first test measurement, the new multichannel scaler CMC206 was included in our acquisition system in parallel with the "old" DDC-IS10A multiscalers (already verified in our previous measurements) and tested with standard ^{90}Sr sources (~1.0 and ~0.1 μCi). No discrepancies were identified. The same arrangement was then used in the study of ^{26}Si decay described elsewhere in this report [2]. Once again there were no discrepancies between the CMC and DDC multiscaler data. We now consider the new system to be fully commissioned and verified.

[1] V. E. Iacob, J. C. Hardy, J. F. Brinkley, C. A. Gagliardi, V. E. Mayes, N. Nica, M. Sanchez-Vega, G. Tabacaru, L. Trache, and R. E. Tribble, Phys. Rev. C **74**, 055502 (2006).
[2] V.E. Iacob *et al., Progress in Research,* Cyclotron Institute, Texas A&M University (2008-2009), p.I-XXXXXX "*^{26}Si half-life measurement*" in this progress report.XXXXX
[3] http://www.cmcamac.com/