Tests on digital system for precise half-life measurement of ^{42}Ti

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Last year, we reported a successful test measurement of the half-life of ^{42}Ti [1]. Our results showed that we would be able to produce approximately 2000 particles/s of ^{42}Ti with 300 nA of primary ^{40}Ca beam at 32*A*-MeV via the ^{4}He(^{40}Ca, 2n)^{42}Ti reaction. We also learned that quite pure ^{42}Ti samples could be obtained by setting tight extraction slits on the MARS recoil spectrometer and depositing ^{42}Ti samples near the back of the collection tape so that most produced impurities passed through the tape without stopping. For this test measurement, we used our digital data-acquisition system [2], which has prompted us to test this system more thoroughly and compare it with our standard analog system.

The first step was to verify the timing accuracy of our high-speed digitizer – a National Instruments PCI 5154 – in which the sample clock is set to 1 GS/s. We digitized sine and square waves generated from the Stanford Research Systems DS345 function generator [3] at 1 and 10 MHz respectively; and measured the frequency of these waveforms as a function of device temperature as read by the onboard sensor. The accuracy of the digitizer timebase was well within specs and sufficient for half-life measurements to 0.01% precision.

Our digital system was then connected to the gas proportional counter and used to measure the counts obtained from a 3.77-kBq ^{90}Sr/^{90}Y beta source as a function of the applied detector bias, from 2250 V to 2950 V in 50-V increments. Detector signals were processed through two cascaded fast amplification stages, the first a fast timing preamplifier, ORTEC VT-120A, and the second a SR445A amplifier from Stanford Research Systems. In the measurement we used the pre-triggered acquisition, with start and reference triggers. The start trigger, which the digitizer monitors for an acquisition arm-trigger, was specified as "immediate" and the recorded data consisted of a pre-defined number of pre-trigger and post-trigger samples relative to the reference trigger, which was an analog signal that passed the threshold level of 120 mV. The number of pre-trigger samples was set to 10% of the 200-ns recorded length. This configuration of our digitizer was identical to that used for the on-line test measurement of ^{42}Ti. The dead time of the system was 800 ns, dominated by the re-arming time of the digitizer.

Finally, for comparison, we repeated the ^{90}Sr/^{90}Y source measurement with our standard analog electronics. Signals from the detector were fed into a preamplifier followed by a fast timing amplifier (set to a gain of 500), a discriminator, a gate-and-delay generator (to impose a dominant dead-time) and a multichannel scalar. A 6-μs dominant dead time was imposed for measurements that we made with two different thresholds of 150 mV and 250 mV, respectively.

Fig. 1(a) displays the total number of counts recorded from the ^{90}Sr/^{90}Y β source as a function of detector bias between 2250 V and 2950 V, while the corresponding relative changes in slope per 100 V are plotted in Fig. 1b.. It is evident from the figure that fine discrimination between real beta events and spurious pulses for the digital system is critical to establishing a wide, flat plateau region, in which count rate is nearly independent of bias. A software filter that has already been developed for this purpose based on the pulse width and amplitude variability offers rather good separation [2], but there is still room for further improvements. An independent approach to design an alternative filter is described elsewhere in this report [4].

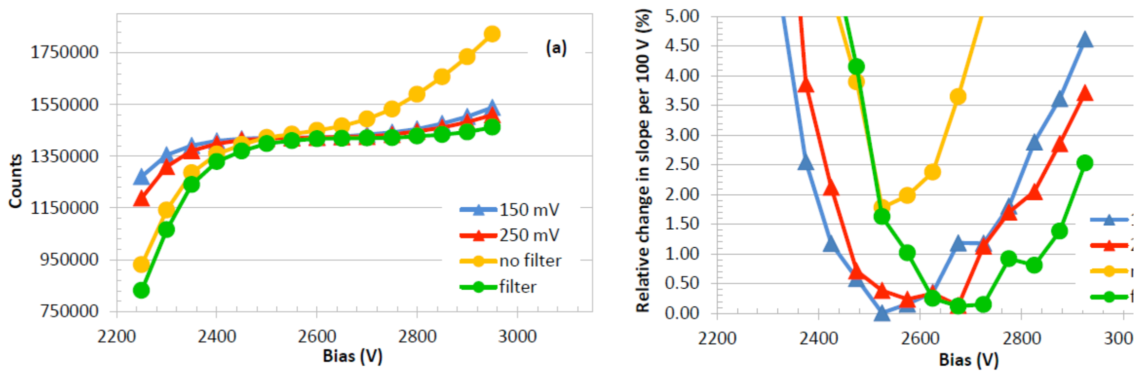

FIG. 1. (a) A total number of counts from the $^{90}Sr/^{90}Y$ β source were measured as a function of detector bias with digital and analog system. The points labeled with 150 mV and 250 mV correspond to the analog system; the other two sets of points refer to the filtered and unfiltered digital data. The count time for each data point was 300 seconds. (b) Relative change in slope per 100 V was calculated in % to define the plateau of our gas proportional counter.

Direct comparison of the flat plateau regions established by our two systems leads us to the conclusion that the gain of the digital system is likely insufficient for small but legitimate signals to be detected at lower bias voltages. Currently, we are evaluating the change in the plateau with different reference trigger thresholds in the digital system and applying those different threshold settings to the ^{42}Ti half-life analysis to see if the result shows any dependence on this threshold. The outcome from this test will guide us in improving the digital system.

[1] H.I. Park *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2013-2014), p. I-23.

[2] L. Chen *et al.*, Nucl, Instrum. Methods Phys. Res. **A728** , 81 (2013).

[3] SRS DS345 Function Generator: www.thinksrs.com/products/DS345.htm

[4] V. Horvat *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. IV-75.