Digital signal processing for improved half-life measurements

L. Chen and J. C. Hardy

We are exploring new methods for processing our 4π β-detector signals with a view to improving the precision with which we can make half-life measurements of superallowed β emitters. Elsewhere in this report [1] we describe a TDC-based data-acquisition system we have developed; here we describe another system based on digital signal processing.

Our present β-counting system takes signals from our gas proportional counter and passes them to a preamplifier followed by an amplifier, a discriminator, a gate-and-delay generator (to establish a single dominant dead-time) and a multichannel scaler. The main limitations of this kind of system are a relatively long dead time (> 3 μs) and the inability to completely exclude noise and spurious signals. Nowadays, digital signal-processing devices make it possible to perform a more subtle analysis of the detector signals than a traditional data-acquisition system allows. The essential idea of our new counting system is to use a high speed digitizer (NI PCI 5154; see Ref. [2]) to record pulses from the detector with a minimum dead time (~1μs) and then perform detailed analysis of the saved waveforms. After only one stage of amplification by a fast preamplifier (ORTEC VT120C) the detector signals are digitized at 1 GHz, and a 300-ns-long time window is saved, bracketing each signal.

Off-line we have done a detailed pulse analysis using a ^{90}Sr-^{90}Y β source. Based on an analysis of the pulse shapes (width, amplitude and integral) we were able to distinguish real β events from noise. Figure 1 shows the width distribution of pulses which we obtained at three different detector biases.
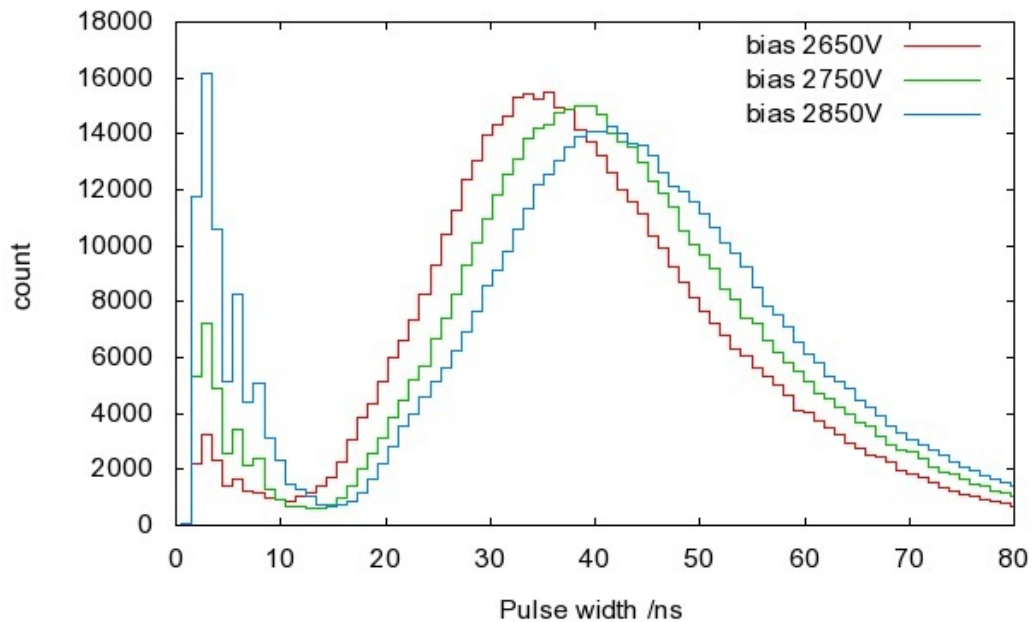

FIG. 1. The pulse-width distribution measured with three different different detector biases. The noise (pulses less than ~13 ns in width) and real β events are clearly separated by their width.

Because of their very different width distribution we can easily separate the real β events from the noise. Similar separation occurs for the amplitude and integral distributions but the width distribution shown in the figure is the most definitive. Once noise signals have been filtered out, the remaining signals – real β events – can be analyzed and compared with results obtained with our current experimental arrangement. Figure 2 shows a measurement of the total number of counts recorded from the ^{90}Sr-^{90}Y β source as a function of detector bias. Without noise discrimination, the plateau region, where count-rate is nearly independent of bias, is very limited. This is approximately what we encounter with our current system. With the implementation of noise filtering, a very flat plateau appears from 2600 V to 2950 V, showing that the digital system yields a big improvement.
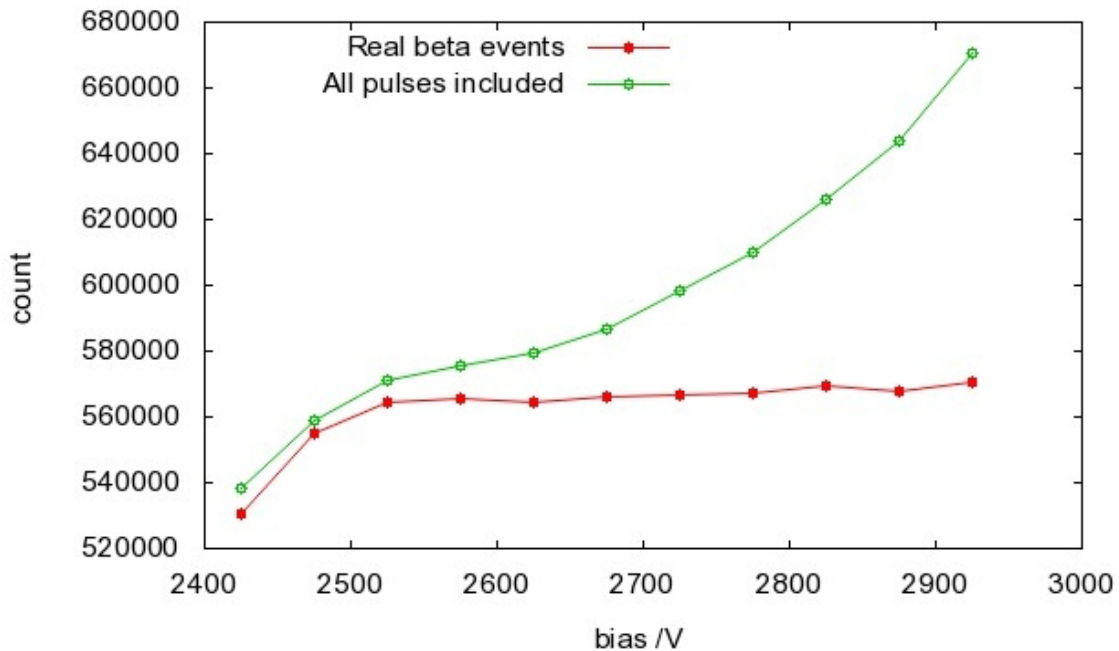

FIG. 2. Plateau measured using a high speed digitizer. Noise was removed by filtering the pulses according to their width, amplitude and integral.

With this arrangement, we expect to be able to reduce the system dead-time and increase the maximum count-rate that we can accept, thus improving the precision of our half-life results by at least a factor of two.

[1] V. Horvat and J.C. Hardy, *Progress in Research*, Cyclotron Institute, Texas A&M University (2009-2010) p. V-24.
[2] NI 5154 high speed digitizer: www.ni.com/digitizers