A new TDC-based data acquisition system for half-life measurements

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For accurate high-precision measurements of β-decay half-lives, two new data acquisition systems are being tested as possible alternatives to the one that is currently in use. One of these systems is described elsewhere in this report [1]. The other is described here, where its capabilities are compared with the system currently being used.

While both systems utilize Nuclear Instrumentation Module (NIM) electronics to convert analog signals from the beta detector to logic pulses, the current system processes those logic pulses using Computer Automated Measurement and Control (CAMAC) electronics interfaced with a personal computer (PC) running the Windows NT© operating system. In contrast, the new system processes the logic pulses using a single multi-channel time-to-digital converter (TDC) plugged directly into a Peripheral Component Interconnect (PCI) expansion bus slot of a personal computer (PC) running the Microsoft Windows XP© or Windows Vista© operating system. Consequently, it is a lot simpler, and far less expensive, than the old system. It eliminates the need for CAMAC electronics and a CAMAC-to-PC interface, as well as the dependency on the Microsoft Windows NT operating system, which is now considered obsolete and is no longer supported by the manufacturer.

Since a PC running the Windows NT operating system does not have adequate protection against cyber attacks, we are not allowed to connect it to the Institute's network. Furthermore, Windows NT does not support Universal Serial Bus (USB) ports, which precludes the use of convenient portable mass-storage devices. Therefore, the transfer of data files from an NT-based computer to another computer is inconvenient at best.

While the data-acquisition software for the new system (CoboldPC©) is written specifically for the TDC, it can be fully customized and used for data organization, visualization and analysis, since its data-acquisition and data-analysis modules (in the form of dynamic link libraries) can be reprogrammed using Microsoft Visual Studio C++ 2008© tools. For comparison, the current system is based on KmaxNT© software. It is more versatile, since it can also be used to program the graphics user interface, but it requires the use of a specific, not commonly known, programming language.

Apart from its technical advantages, the new system also has a better duty cycle. The data acquisition and buffering is done locally on-board the TDC, while transfer of the buffered data to the computer's mass-storage device runs concurrently. This means that there is no acquisition down time. The CAMAC-based system requires a brief pause in the data acquisition while the data are being transferred from the crate controller to the PC.

The main advantage of the new system is related to its mode of data acquisition. It stores each event (*i.e.* the arrival of a logic pulse) in a raw format, by recording the corresponding TDC channel and the time since acquisition start (within 16 ps). The latter is normally based on the on-board clock (having precision of 0.3 ppm), but the use of an external clock is also supported. This way a histogram of the time between consecutive events can be constructed and used to determine the system's dead time. If warranted, the dead time can also be artificially increased in the analysis until the optimum setting is found. This eliminates the need for repeated measurements with different pre-set dominant dead times, which has been a standard practice with the old system.

The current CAMAC-based system is set to pre-process the events by assigning them to pre-set time-spectrum channels. It then records the collected time spectra rather than individual events. While this reduces the amount of data transferred between the CAMAC controller and the PC, it also results in the loss of detailed information on the time sequence of events. Having the time sequence of events, which is provided by the new system, may prove to be useful in detecting and handling anomalies in the data stream such as sudden bursts of spurious pulses. Furthermore, with the new system, it is possible to select and adjust the number of channels in the decay time spectrum (*i.e.* the channel width) at the time of data analysis. This may be helpful in the case of two-component decays or if impurities contribute significantly to the time spectrum.

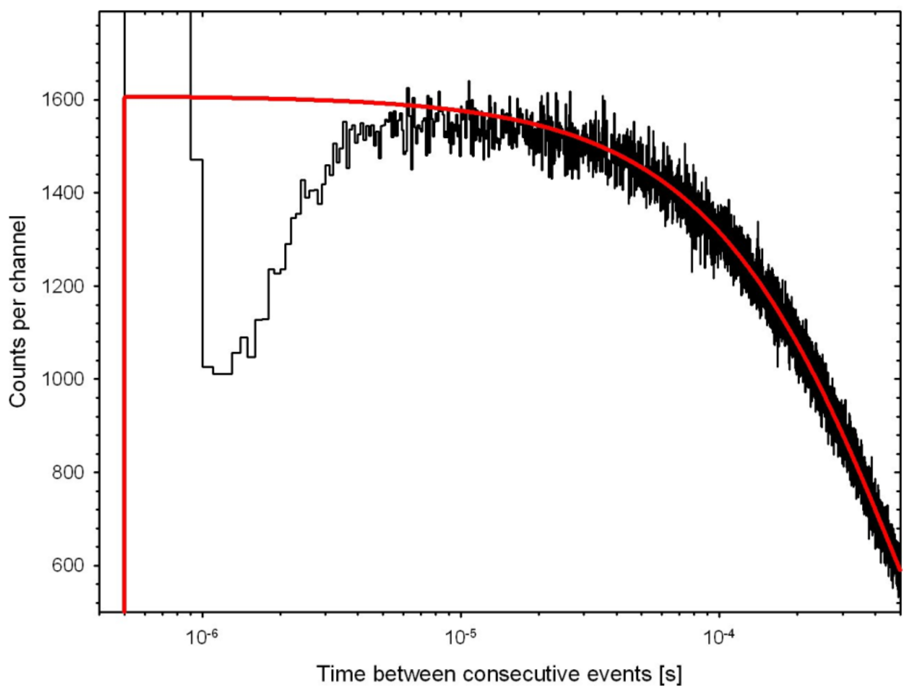

FIG. 1. Measured histogram of the time between consecutive pulses from a detector recording beta particles emitted from a ^{90}Sr-^{90}Y source (black line). The red line shows the expected trend. The cutoff at 0.5 µs is due to the imposed dominant dead time. Excessive counts between 0.5 µs and 0.9 µs are due to multiple pulsing. The dip between 0.9 µs and 10 µs is explained in the text. Note that the vertical scale is linear, while the horizontal scale is logarithmic.

A simplified version of the new data acquisition system was used to record the pulses due to beta particles emitted from a radioactive source (^{90}Sr-^{90}Y). Since the duration of the measurement was much shorter than the source half-life, the histogram of the time between consecutive events was expected to follow an exponential decay curve (with the decay constant equal to the event rate), featuring a sharp cutoff due to the dominant dead time imposed by the NIM gate-and-delay generator and the software. However, the measured histogram showed a smaller-than-expected number of events close to the dead-time cutoff, as illustrated by Fig. 1. This effect was found to be related to the shape of the analog pulses from the fast filter amplifier, which were subsequently converted to logic pulses by the discriminator: The negative pulses from the fast filter amplifier typically became slightly positive before returning to the base line. Consequently, a pulse that arrived between the crossover time of the previous pulse and its return to the base line was piled up and had a reduced chance of crossing the discriminator threshold, thus decreasing the chance of it being converted to a logical pulse and counted.

[1] L. Chen and J.C. Hardy, *Progress in Research*, Cyclotron Institute, Texas A&M University (2009-2010) p. V-29.