Precision measurement of $^{26}Al^{m}$ half-life with digital β^{+} counting method

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On-line experiments have been made in the past year to characterize our newly developed digital β counting system [1]. In particular, the half-life of the superallowed β^{+} emitter $^{26}Al^{m}$ was measured at Cyclotron Institute with the digital β^{+} counting method. The half-life of $^{26}Al^{m}$ is already rather well known ($t_{1/2}$ = 6.345 ± 0.002 s) [2] and is thus suitable for testing purposes. In our experiments the $^{26}Al^{m}$ beam was produced by impinging a 23-MeV/u ^{27}Al primary beam, delivered from the superconducting cyclotron at Texas A&M University, on a liquid-nitrogen cooled hydrogen gas target. The reaction products were analyzed by the MARS spectrometer and purified $^{26}Al^{m}$ ions were extracted out of vacuum at the MARS focal plane though a 51-μm-thick Kapton window. The extracted beam then passed though a 0.3-mm-thick plastic scintillator where the ions were counted and a set of degraders, which further purified the beam and reduced its energy so that it stopped in the center of a 76-μm-thick aluminized Mylar tape. The purity of $^{26}Al^{m}$ at the MARS focal plane was about 40%, with the main contamination being the ^{26}Al ground state, which has a half-life of 7.4×10^{5} years and consequently plays no role in our measurement. As seen from the particle identification spectrum at the MARS focal plane, shown in Fig.1, all other impurities are stable.

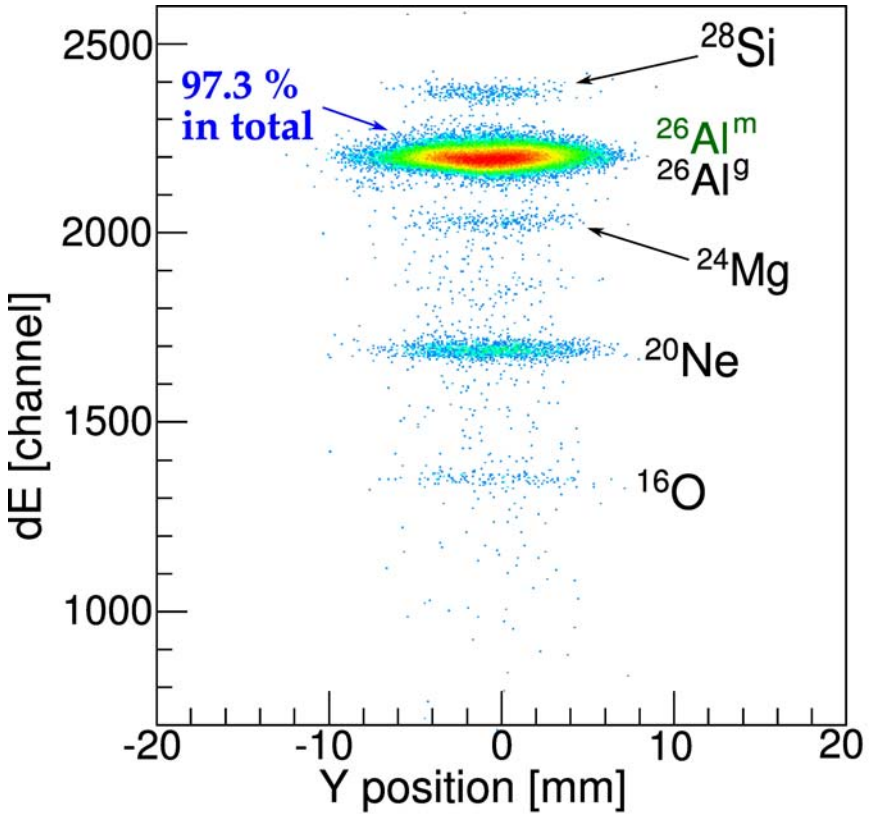

Figure 1. The particle identification spectrum taken at the MARS focal plane. All contaminants are stable isotopes and thus have no impact on the data

After implantation for 2-10 s (depending on the beam intensity and the desired count rate), the collected sample was moved in 185 ms to the center of the 4π gas proportional counter, where its decay was followed for 20 half-lives, after which the cycle was repeated. The signal from the gas proportional counter was amplified by two cascaded fast amplifiers with total gain of 1000, before being sent to a high-speed digitizer (NI-5154) for digitizing and pulse capture. The operation of the digitizer is illustrated in Fig.2. After being configured and initialized, the digitizer waits for an acquisition-start trigger from the tape-drive system indicating that the sample is ready to be counted. The digitizer then starts digitizing the pre-trigger samples continuously and, at the same time, monitors for the occurrence of reference (stop) triggers. A reference trigger is generated whenever the pulse-capture trigger condition is satisfied. As soon as a reference trigger is recognized the corresponding waveform is captured. This pulse-capture process is repeated until the counting period is over. The captured pulses are saved temporarily in the on-board 256-MB memory and then transferred to the host PC via a high-speed PCI bus in parallel to the pulse capture. In our experiment the reference trigger was configured to use a analog edge trigger method and the digitizer trigger level was set to -120 mV. The trigger level was chosen well above the background noise (~50mV) and is low enough to ensure a high efficiency for β particle detection.

The tape transport system and the digital devices were synchronized by TTL signals generated by

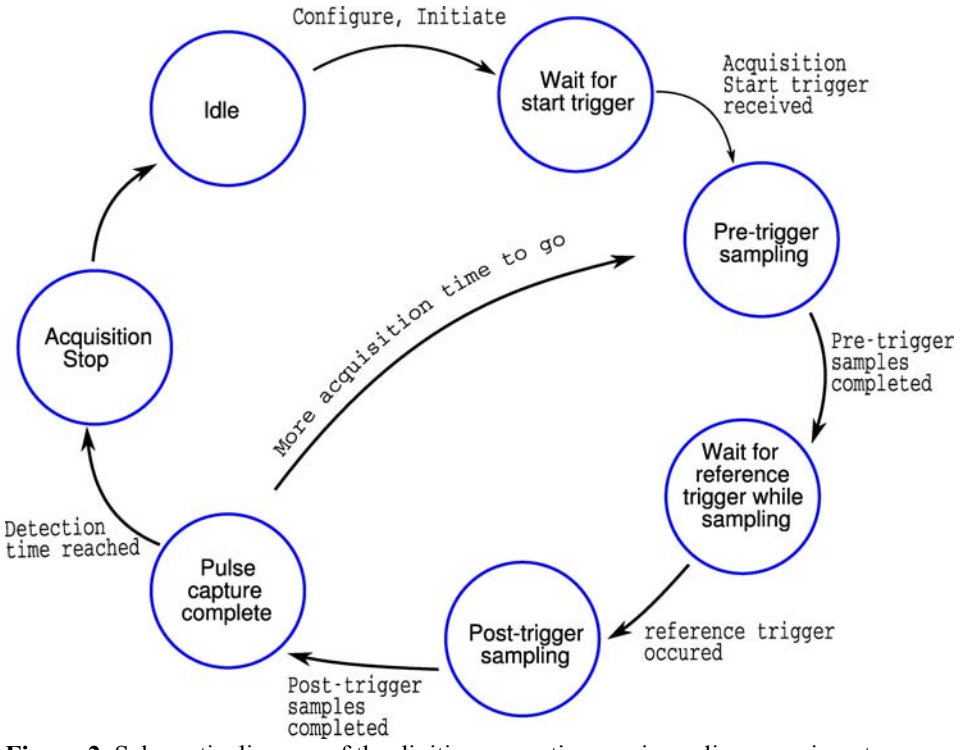

Figure 2. Schematic diagram of the digitizer operation our in on-line experiment.

the tape transport control system. In a cycle-by-cycle mode, two TTL signals were sent in each cycle from the tape system to control the data acquisition: the first triggered the DAQ to count the heavy ions (^{26}Al) using a digital counter (NI PCIe-6320); the second was the acquisition start trigger for the digitizer, which

indicated that the collected sample was positioned at the center of the proportional counter ready for counting.

In this experiment data were taken under different initial β-decay rates, from 4 kHz to about 10 kHz. In principle, higher rates up to ~40 kBq can be handled by the digitizer, which was actually only limited by the data transfer speed from the digitizer to the host PC. But, as our on-line tests have revealed, our gas proportional counter cannot handle counting rates above 10 kHz. At such high counting rates the change in gas-counter gain as the activity decays precludes high precision half-life measurements. Also, four different gas-counter biases, 2650V, 2700V, 2750V and 2800 V, were used to test for bias dependence. In total we collected about 100 million waveforms from 1700 cycles.

The on-line data processing procedure is quite different from that of our previous lifetime experiments [3]. Here, first we need to use software to distinguish true β pulses from "spurious" pulses. After pulse discrimination, we then impose an artificial dead time for all pulses. The intrinsic dead time of data acquisition is 870 ns. An imposed dead time can help us test for any systematic changes in extracted half-life as a function of the dead time correction. In this study, the imposed dead time was corrected using a "shadow window" technique, with which the loss of real β events in a dead-time window is compensated by the observed β events in a "shadow window" of identical length at a different (but nearby) time in the same decay spectrum. Our shadow window was located 10 ms away, at time that is negligible with respect to the half-life of $^{26}Al^{m}$. We tested imposed dead times from 2 to 10 μs and found that the corresponding half-lives are quite consistent within error bars. After the dead time correction, the decay spectra were built for each cycle. The fitting procedure was the same as used in our previous half-life measurements. In Fig.3 a summed decay spectrum is shown. In this experiment, we preliminarily obtained a half-life for $^{26}Al^{m}$ to be 6.3462(10) s.

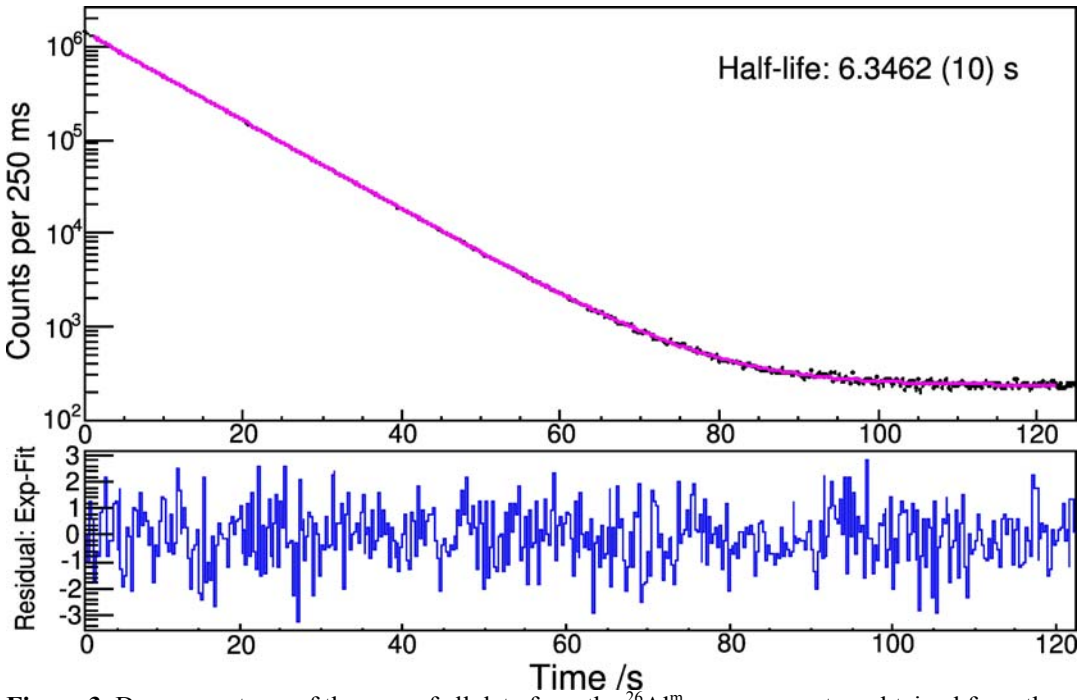

Figure 3. Decay spectrum of the sum of all data from the $^{26}Al^{m}$ measurement as obtained from the digital counting system. Residuals of the fit are shown at the bottom.

[1] L.

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