STUDYING SHORT-LIVED RADIOACTIVITIES BY CORRELATING BETA DECAYS WITH FRAGMENT IMPLANTS IN A SILICON MICROSTRIP DETECTOR

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Beta decay properties of nuclei with extreme neutron-to-proton ratios serve as sensitive tests for nuclear structure models in regions far from the valley of stability. Beta decay half-lives and endpoint energies are also important nuclear physics input parameters for astrophysical network calculations modeling rp- (neutron-deficient nuclei) and r- (neutron-rich nuclei) process nucleosynthesis. Previous fragment-correlated beta decay experiments performed at the NSCL [1] made use of a Si implantation telescope to identify fragment implants and a large, shielded plastic scintillator for beta detection. When a fragment of interest was implanted into the Si telescope, the primary cyclotron beam was stopped for a fixed time to reduce the beam-induced background in the scintillator during the beta detection period. To study the decay properties of short-lived, low intensity radioactive beams more efficiently, a new beta counting system has been developed. This system employs a silicon microstrip detector to correlate fragment implants with subsequent beta decays. Silicon microstrip detectors have received wide use in both proton decay studies [2] and superheavy element searches [3] due to their high efficiency for charged particle detection and high detector segmentation in a compact geometry. The goal was to take advantage of the high pixelization of the microstrip detector to continuously implant short-lived activities over the entire active area of the detector. Due to the relatively long half-lives associated with beta decay (tens of millisecond to seconds and longer) compared to proton and superheavy alpha decay (microseconds to milliseconds), it is important to maintain an implantation rate that allows sufficient time between implants to cleanly correlate a successive beta decay event.

The beta counting system consisted of a Micron Semiconductor Ltd. type BB1 double-sided silicon strip detector (DSSD). The DSSD, shown in figure 1 was a single silicon wafer segmented in 40 1-mm wide strips in both the x and y dimensions. A 985-μm thick DSSD was selected to ensure sufficient Si for detection of the high-energy beta particles expected from the decay of nuclei far removed from the line of

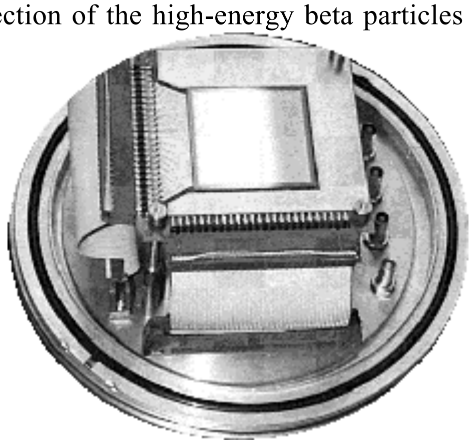

Figure 1. DSSD mounted on an ISO-400 flange.

stability. The DSSD was sandwiched between two 5 cm × 5 cm Si PIN detectors, placed at a distance of 1.9 cm and 2.2 cm, respectively from the center of the DSSD. The upstream PIN detector had a thickness of 309 μm, while the downstream detector was 503 μm thick. The PIN detectors and the DSSD were mounted on an ISO-160 flange for easy coupling to the beam-line vacuum. Two 50-pin feed-throughs on this flange were used to bring the DSSD signals to a grounding board placed immediately outside the vacuum chamber. The grounding board provided a common ground for each output channel and six 34-way ribbon cables to transmit the DSSD output to the shaping and fast amplifiers. During this experiment, NSCL fabricated preamplifiers with gains of 60 mV/MeV and rise and fall times of 50 ns and 100 μs, respectively, were used. These preamplifiers were chosen because of their relatively short rise time, which was necessary to trigger the constant fraction discriminators. The pre-amps were grounded to the same ground loop as the DSSD and the vacuum chamber. The pre-amp signals were teed in order to eventually produce both a slow (energy) and fast (time) signal for each DSSD channel. The energy signal was obtained by processing the pre-amp output through a variable gain Washington University CAMAC shaper, which was then digitalized using a Philips 7164H ADC in CAMAC. A timing signal was produced by first passing the pre-amp output through a fast amplifier. The amplified signal was sent through a constant fraction discriminator with 100 ns delay chips. This signal was delayed 100 ns and teed to provide inputs for a scaler, a coincidence register and a time-to-digital converter. The master gate, defined as any trigger from the DSSD, served as a common start signal for the TDC. A schematic of the electronics is depicted in figure 2.

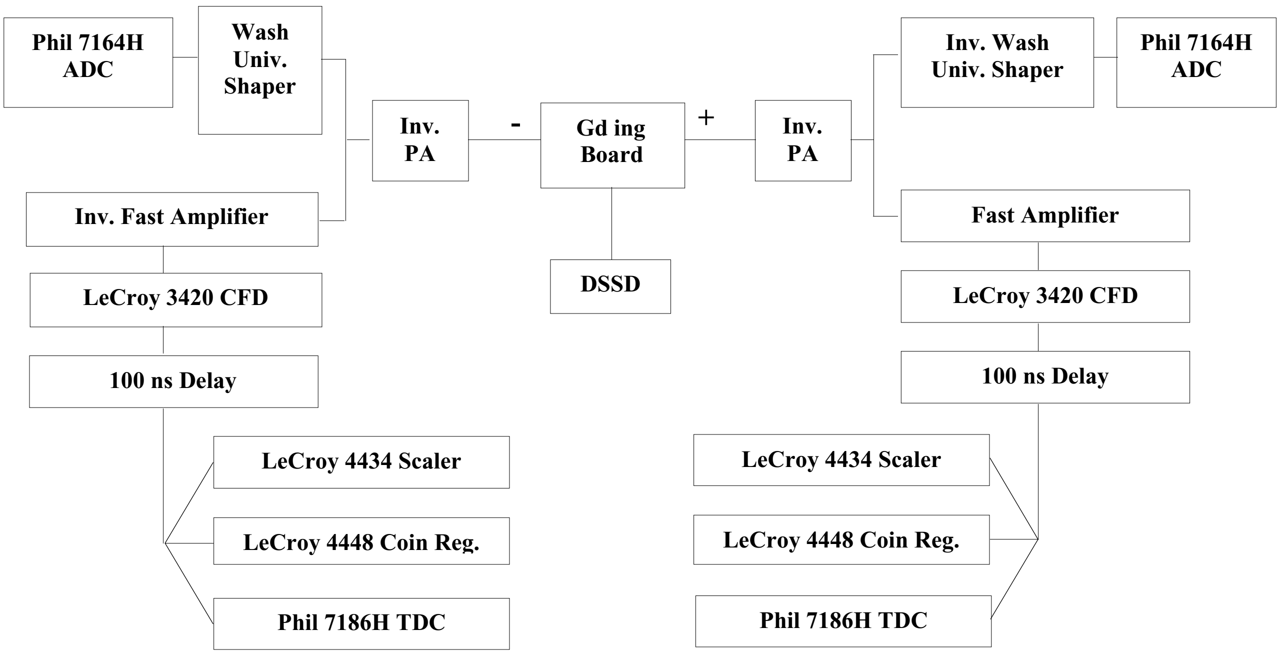

Figure 2. Electronic scheme for processing signals from the DSSD. Sequence to the right represents the electronics for the front of the detector and to the left, the electronics for the back of the detector.

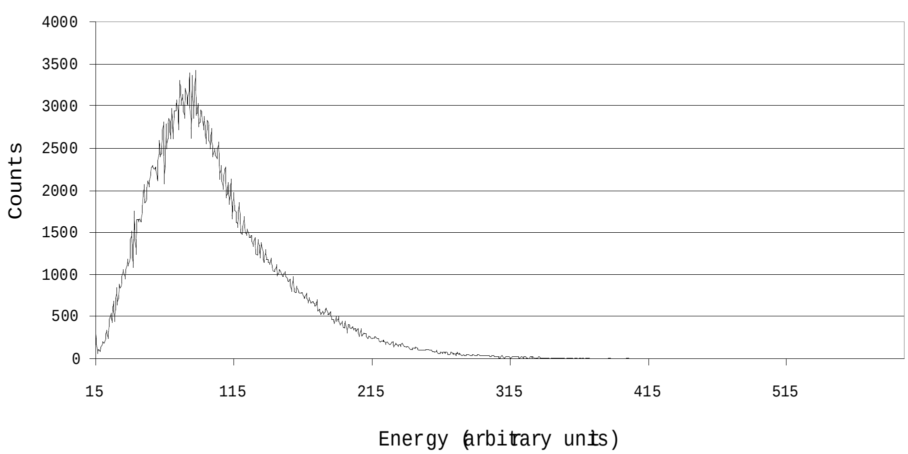

Figure 3. Beta decay spectrum for the DSSD with the condition that a single front and a single back strip fire simultaneously.

A typical beta decay spectrum is shown in figure 3. The resolution of the strip detector was 50 keV at 6.78 MeV using a ^{228}Th source.

To correlate the observed beta decays with a specific isotope, implant information is required. A 300 μm Si PIN detector was placed upstream from the PIN-DSSD-PIN detector telescope. The Si detector provided energy loss and, in conjunction with the cyclotron frequency, time of flight for particle identification. In addition, two PPAC detectors were also placed upstream from the silicon telescope to obtain the beam position. As a consequence of using single gain electronics to process the DSSD energy signals, the high-energy events, E > 17 MeV, fell outside the useful energy range and were recorded as overflow events. Moreover, the large pre-amp signal for a given strip induced signals in neighboring channels. This resulted in a multiplicity greater than one for any given implant in both front and back channels. A typical implant multiplicity spectrum is shown in figure 4. Unlike beta events, which could be isolated to the nearest strip, the exact strip that an implant occurred could not be determined. To obtain the pixel of each implant, the sum of each of the strip numbers hit during an implant was tallied and divided by the multiplicity for both the front and back of the DSSD. To improve the implant-decay correlation, an algorithm that considers all the DSSD channels that fire during an implant event is under development.

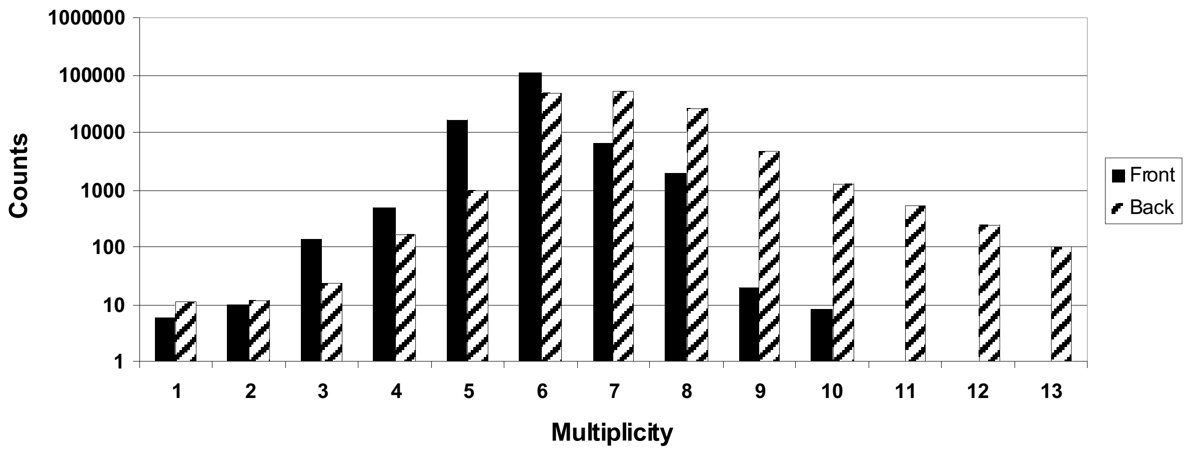

Figure 4. Implant multiplicity for the DSSD. Multiplicity refers to the number of strips that fire for a given event. On average, six strips fired on each side of the strip detector during implantation.

Figure 5 shows the correlated fragment-decay events. The beam was defocused in an attempt to cover the entire face of the DSSD. With the beam continually implanted into the strip detector, at an average rate of 100 s^{-1}, a two second time difference between successive implants in the central most portion of the DSSD was observed; allowing ample time for measuring the half-lives of short-lived radioactive species. All implant and decay events were tagged with absolute times. Half-lives were deduced by taking the difference between the absolute time of a fragment implant and its subsequent beta decay.

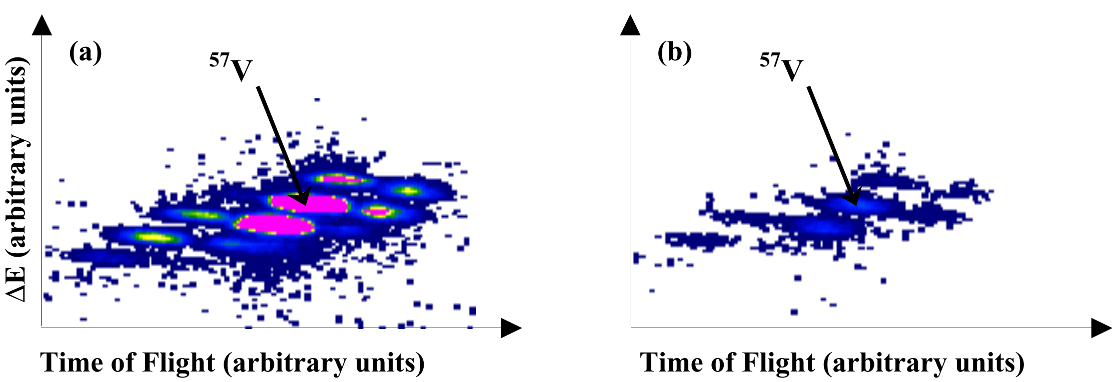

Figure 5. (a) Energy loss versus time of flight plot representing all nuclei implanted within the DSSD. (b) Implantation spectrum correlated with subsequent beta events.

One of the nine nuclides implanted within the strip detector during the experiment was ^{57}V. By gating on ^{57}V and correlating the implantation of ^{57}V with its subsequent beta, a preliminary half-life of 368(62) ms was extracted. The decay curve for this nucleus is depicted in figure 6. This value is consistent with the previous measurement of 323(30) ms by Sorlin *et al.* [4].

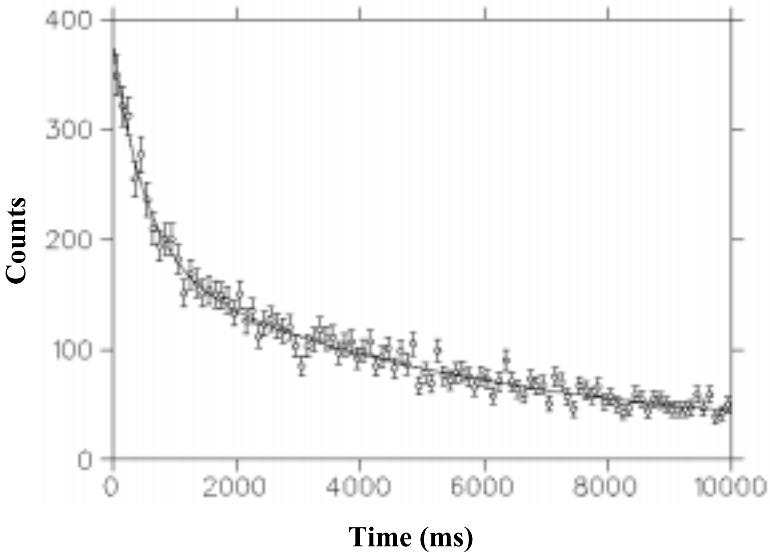

Figure 6. Beta decay curve following the decay of ^{57}V. The decay curve has been fit with a two-component exponential, one component attributed to ^{57}V decay ^{57}V nuclei and the other to random background.

Recently, integrated preamplifier electronics have been purchased to outfit one 40 x 40 DSSD with dual (low and high) gain capabilities. The new electronics should resolve the implant multiplicity issue that we have encountered, allowing us to narrow an implant to the nearest strip. In addition to using this beta detection system to measure the beta decay properties of radionuclides, incorporating the new MSU Ge detectors around the silicon array in compact geometry will allow us to monitor the emission of beta-delayed gamma rays with a high efficiency. These modifications should vastly improve the overall capabilities of this new beta detection system for future studies.

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References

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