Effect of Detector Coincidence Criteria on a High Precision Measurement of the Neutron Lifetime

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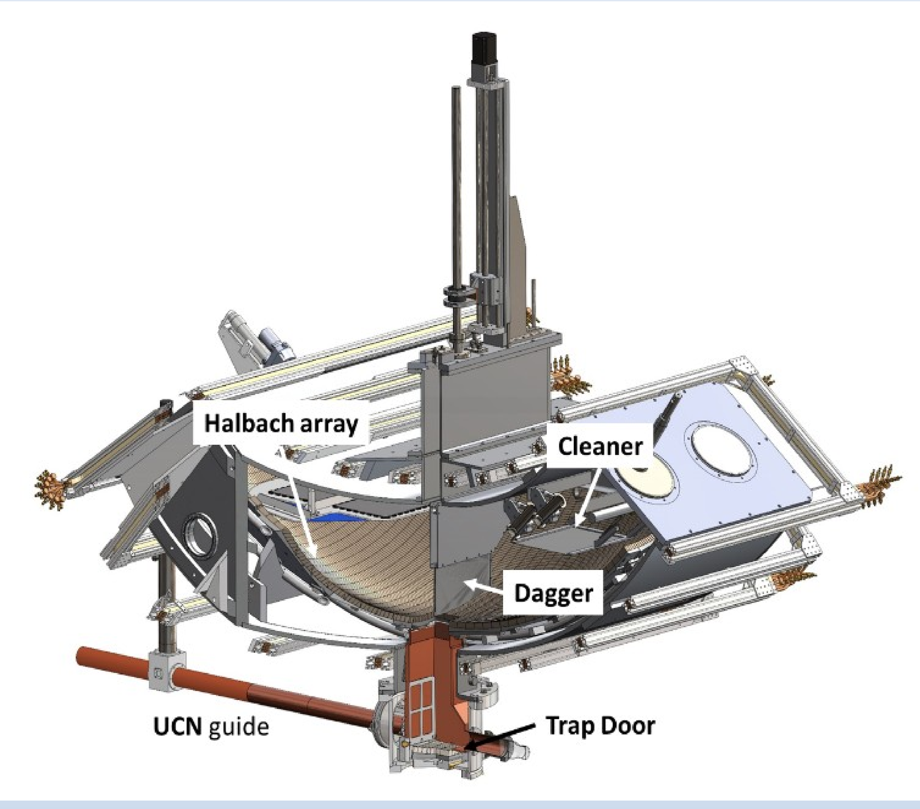
Experiment Overview

The UCNτ collaboration is working to measure the mean lifetime of a free neutron to 0.1s using very-low energy “ultracold” neutrons (UCN). A density of UCN is produced at Los Alamos in a solid-D_2 superthermal source and is then polarized and guided to a magneto-gravitational trap. The UCN that have high enough energy to escape the trapping potential are removed by a detector, known as “the cleaner”, which is lowered very slightly into the trap. The remaining neutrons are left to decay for either a short or a long holding time. The difference in the two holding times, along with the number of neutrons left in the trap normalized by the signal from a flux monitoring detector, at the end of the holding periods, are used to calculate the average lifetime of the neutrons in the trap.

Figure 1: The array is sealed inside a vacuum jacket.



The Trap

The geometry of the trap, shown in figure 1, is that of two half-tori, with major and minor radii interchanged, connected together to form an asymmetric array. This helps eliminate the possibility of neutrons getting trapped in orbits around the sides. The bottom of the array is lined with magnets that keep the polarized neutrons from interacting with the actual trap itself, and the neutrons are kept from escaping the top by the force of gravity.

Neutron Detection

The neutrons are detected using a newly-developed *in situ* active detector called the “dagger” that observes light from a ^{10}B-coated ZnS scintillation screen, shown in figure 3, via a pair of photomultiplier tubes (PMTs). Each time the detector absorbs a neutron it emits a certain number of photoelectrons which are detected by the PMTs in figure 2. The arrival time spectrum for these PMTs is then used with a specific coincidence criteria to determine a “fingerprint” of a single UCN event. An important consideration for this detector is optimizing the signal to background via adjustments of that coincidence criteria.

Coincidence Criteria

The coincidence parameters for the first extraction of the data is as follows:

- N=4, number of photoelectrons
- 50 nanosecond coincidence window
- 500 nanosecond integration window

Figure 2: Photomultiplier Tubes

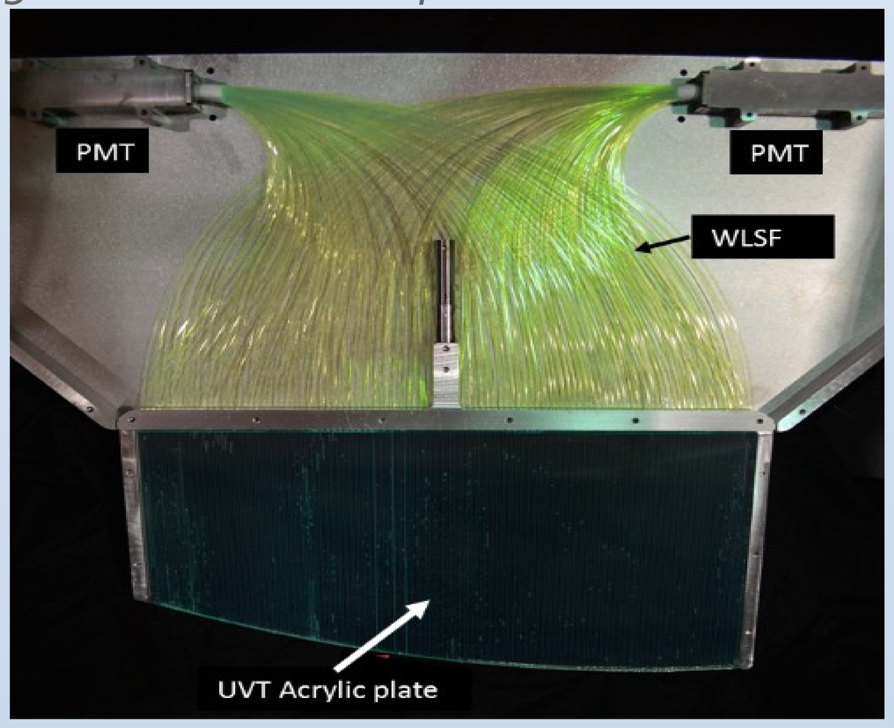
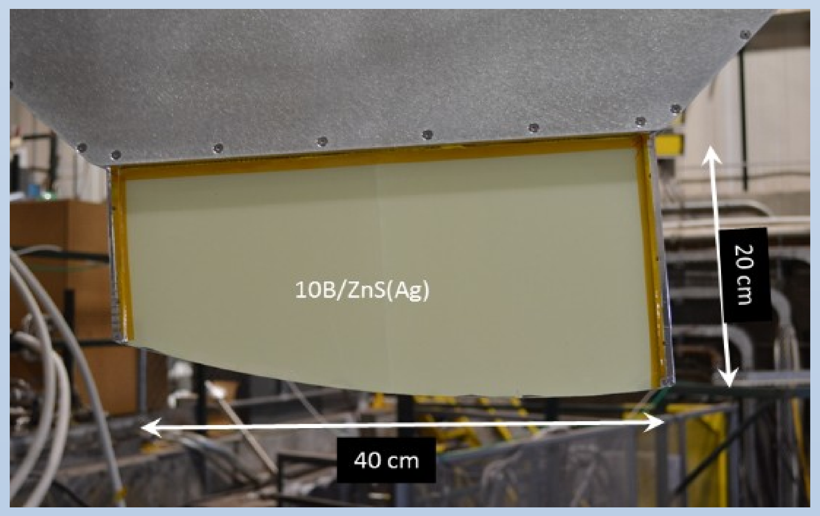


Figure 3: ^{10}B-coated ZnS scintillation screen.



Data Collection

A “trap door” is opened for 150s during the first part of a run to direct the flow of neutrons into the trap. Once it is closed the cleaning period begins, which is either done with the dagger itself or a horizontal “active cleaner”. The neutrons are then left to decay. After the holding time the dagger is lowered in either 4 steps, 2 steps, or just 1 step, to detect the remaining neutrons and we get an arrival time spectrum of the data shown in figures 4 and 5.

Figure 4: Short holding time with 4 dagger steps.

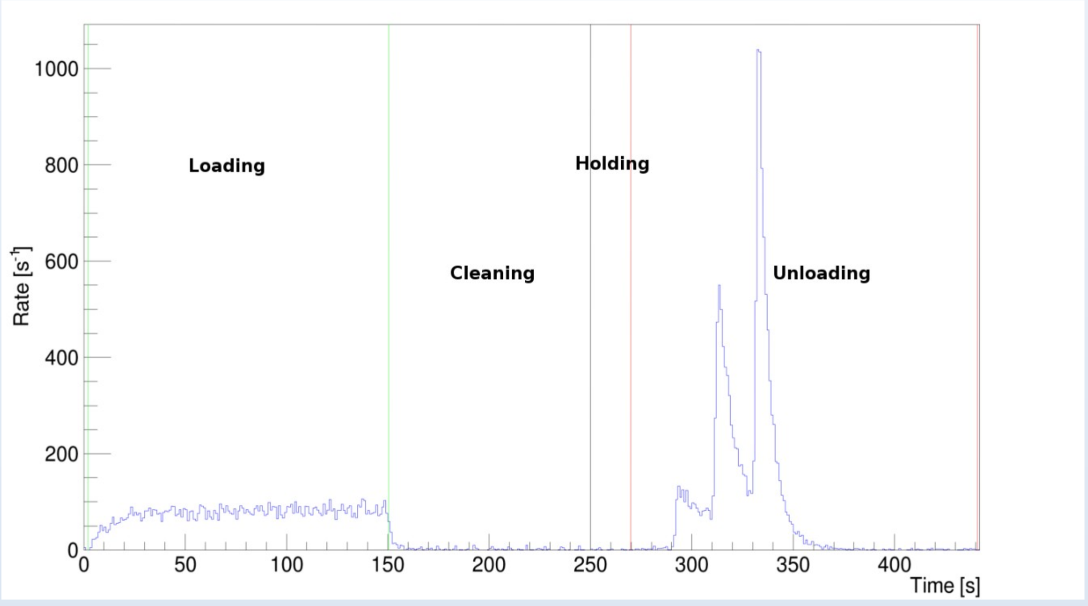
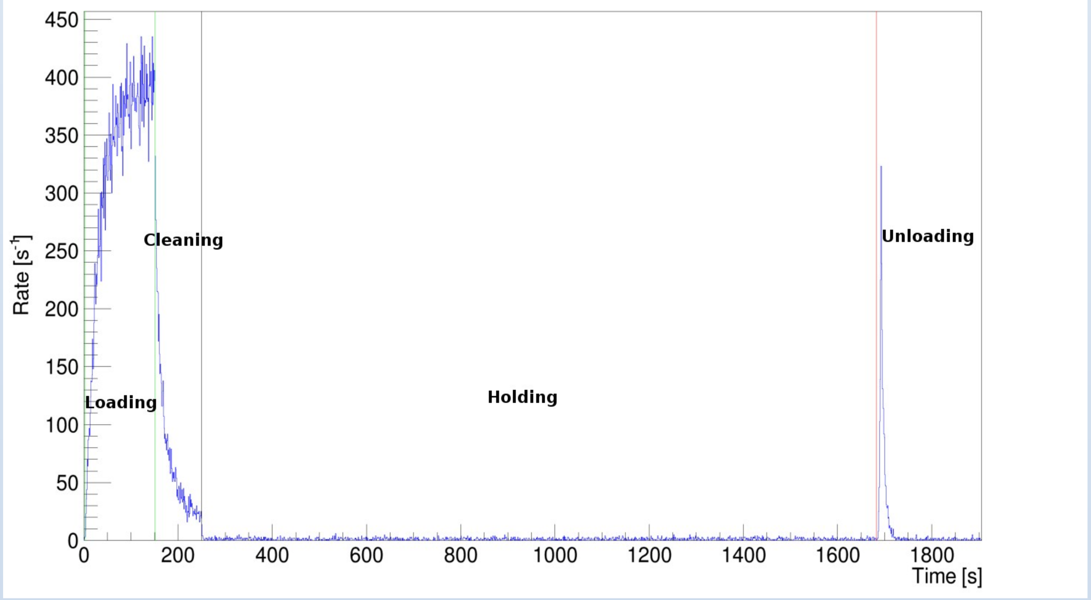


Figure 5: Long holding time with 1 dagger step.



Extracting Lifetimes

Each run of the experiment is categorized into a run unit which corresponds to identical conditions and are then further categorized into long(T_l) and short(T_s) holding times. After subtracting a background obtained during the long holding period from the total unloading counts and normalizing, long/short run pairs can be used in equation 1 to calculate the trapping lifetimes with only runs that have identical conditions.

Equation 1: N_i is the number of UCN events after unload, and n_i is a normalization factor.

$$\frac{1}{\tau}=\frac{1}{(T_l-T_s)}\ln\frac{(\sum_i N_i(s)/n_i)}{(\sum_i N_i(l)/n_i)}$$

Initial Results

Figure 6 shows a comparison of UCN events detected with N=4 and N=8. Doubling the number of photoelectrons required to trigger a UCN event decreased the amount of background by 97% while only decreasing the UCN events by 58%. As this analysis continues I will be examining many different variations of criteria.

Figure 6: The green represents UCN events with N=8, and the pink is N=4. This is a close up of the UCN events during the unload time.

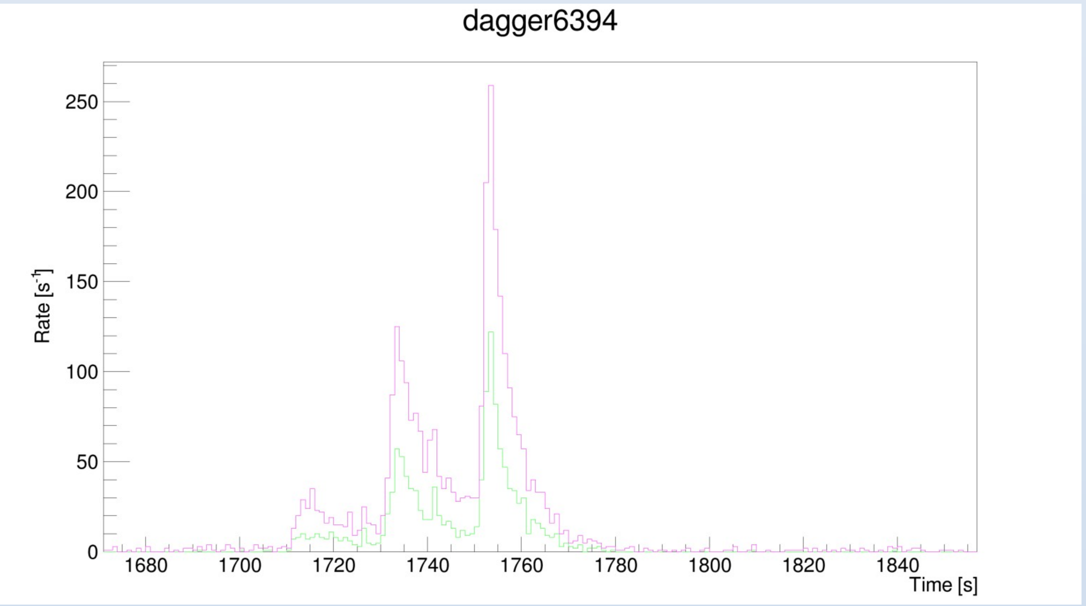


Table 1: Extracted lifetimes from identical run units, using unload segment 3+4, with coincidence window at 50ns and an integration window of 500ns. All lifetimes are blinded.

Lifetime Comparison		
Run Unit	N = 4	N = 8
4 Step Unload, 100s Cleaning, AC only	875 ± 3	879 ± 4
4 Step Unload, 100s Cleaning, AC + Dagger	862 ± 4	870 ± 6

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