A Phoswich Detector System to Measure Sub-Second Half-Lives using ICF Reactions

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I. Abstract

The ^{3}H(t,γ)^{6}He cross section has not been measured at any bombarding energy due to the difficulties of simultaneously producing both a tritium beam and target at accelerator labs. An alternative technique may be to use an ICF tt implosion at the OMEGA Laser Facility. The ^{3}H(t,γ)^{6}He cross section could be determined in situ by measuring the beta decay of ^{6}He beginning a few milliseconds after the shot along with other ICF diagnostics. A dE-E phoswich system capable of surviving in the OMEGA target chamber was tested using the SUNY Geneseo pelletron to create neutrons via ^{2}H(d,n)^{3}He and subsequently ^{6}He via ^{9}Be(n,α)^{6}He in a beryllium target. The phoswich dE-E detector system was used to select beta decay events and measure the 807 ms half-life of ^{6}He. It is composed of a thin, 2 ns decay time dE scintillator optically coupled to a thick, 285 ns E scintillator, with a linear gate to separate the short dE pulse from the longer E tail. Funded in part by a grant from the DOE through the Laboratory for Laser Energetics.

II. Introduction

The ^{3}H(t,γ)^{6}He radiative capture reaction occurs in almost every practical thermonuclear fusion scheme, and is therefore important for both fusion research and nucleosynthesis models. The first step toward measuring this cross section was to create and detect ^{6}He. In 2016, ^{6}He nuclei were created using the ^{9}Be(n,α)^{6}He reaction, and were detected by measuring the 807 ms half-life beta decay

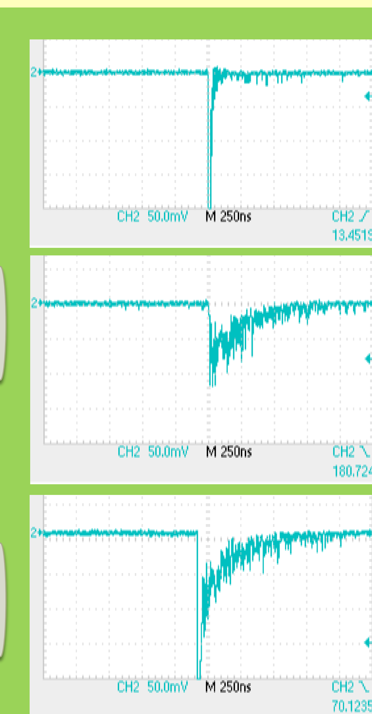
$$^6\text{He} \rightarrow {}^6\text{Li} + e^- + \bar{\nu}$$

with a silicon detector telescope. This success motivated the development of a new dE-E phoswich detector system capable of surviving in the ICF environment.

Thin, fast scintillator ONLY

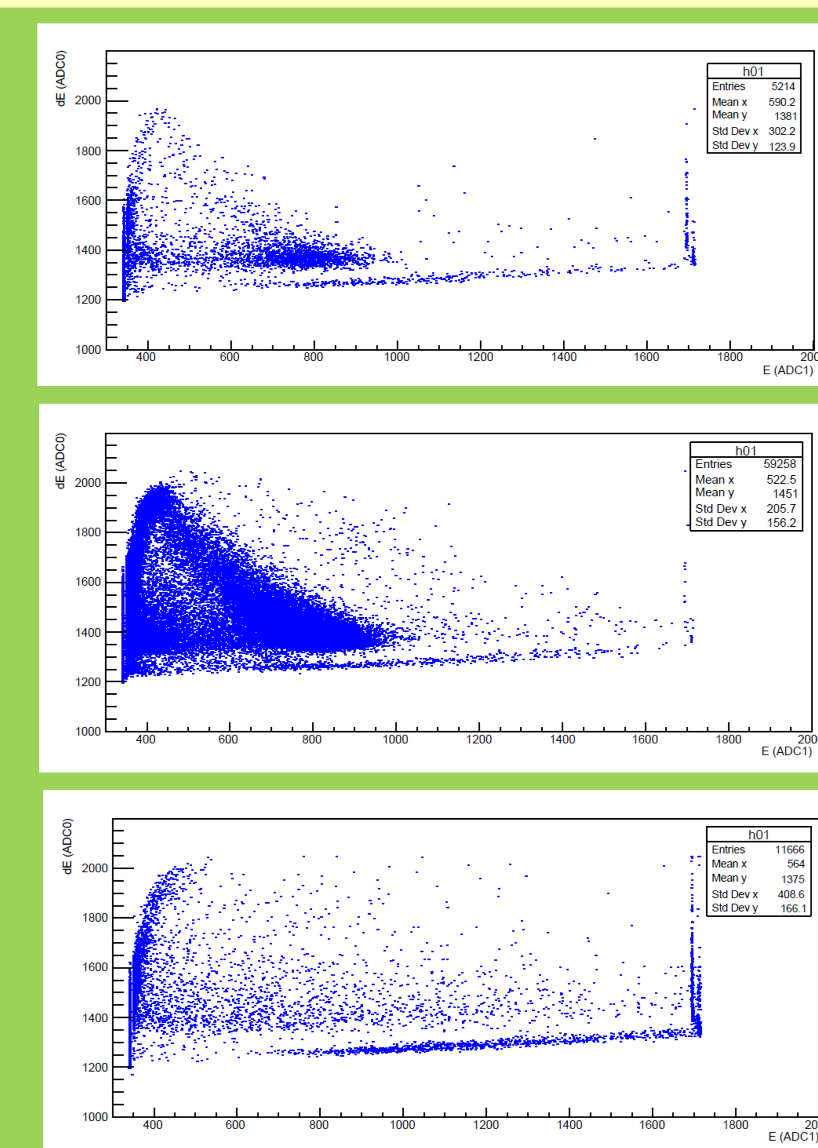
Thick, slow scintillator ONLY

Both thin and thick scintillators



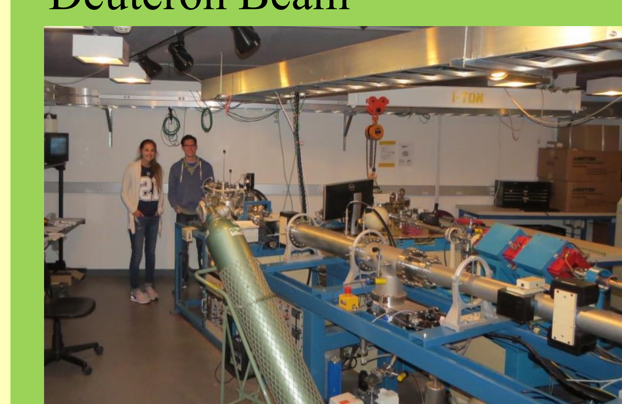
III. Phoswich Detector System

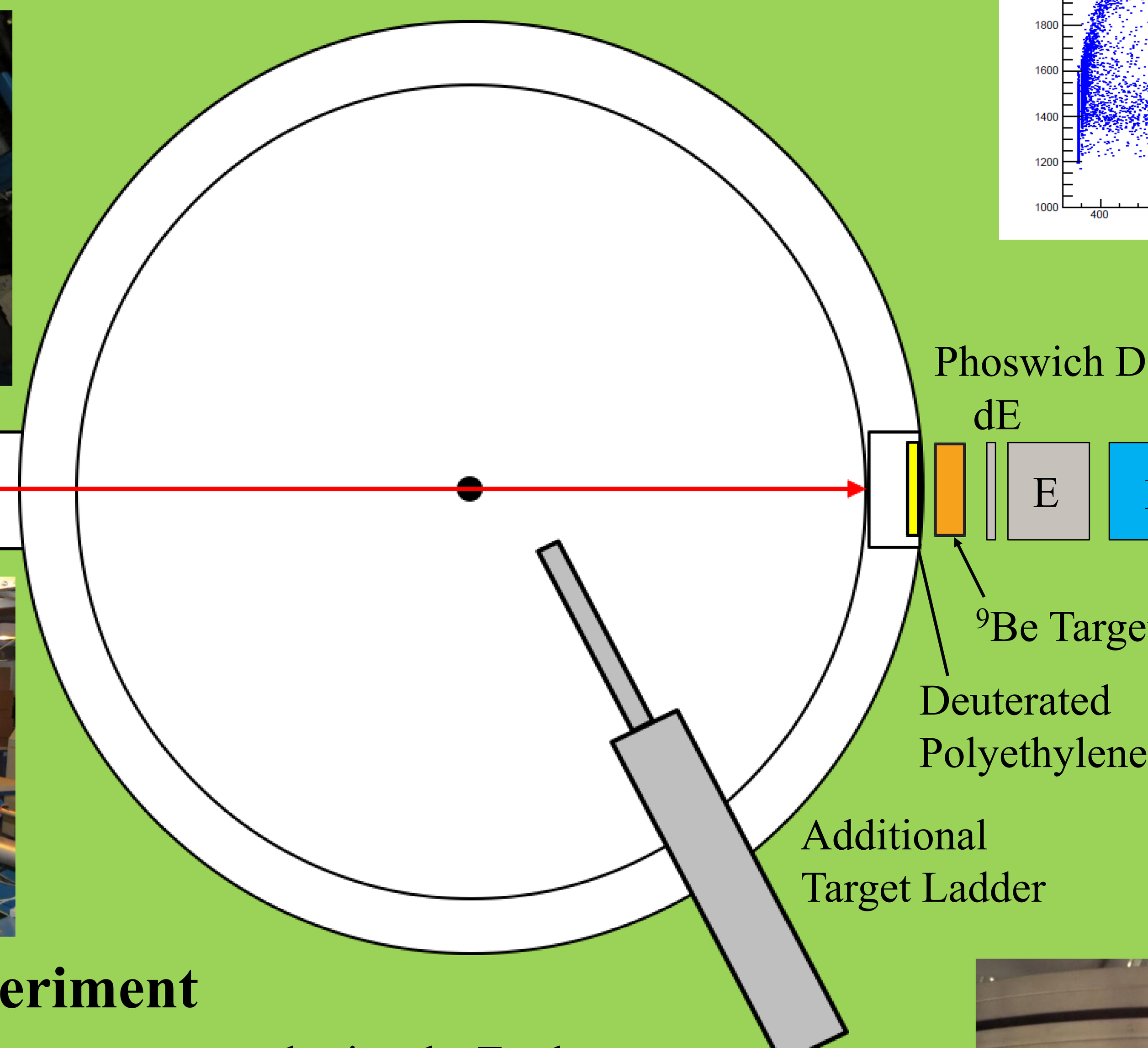
The phoswich detector system, composed of a thin, 2 ns decay time dE plastic scintillator optically coupled to a thick, 285 ns decay time E plastic scintillator, was used to identify beta particles emitted by the ^{6}He decay. The figure at left shows the PMT pulses created by an incident beta on each component (dE, E, both) of the phoswich detector system. 2D histograms of the dE and E pulse heights (right) show a signature band for collimated (top) and uncollimated (center) monoenergetic 947 keV betas from ^{207}Bi, and background (bottom).



Target Chamber

Deuteron Beam

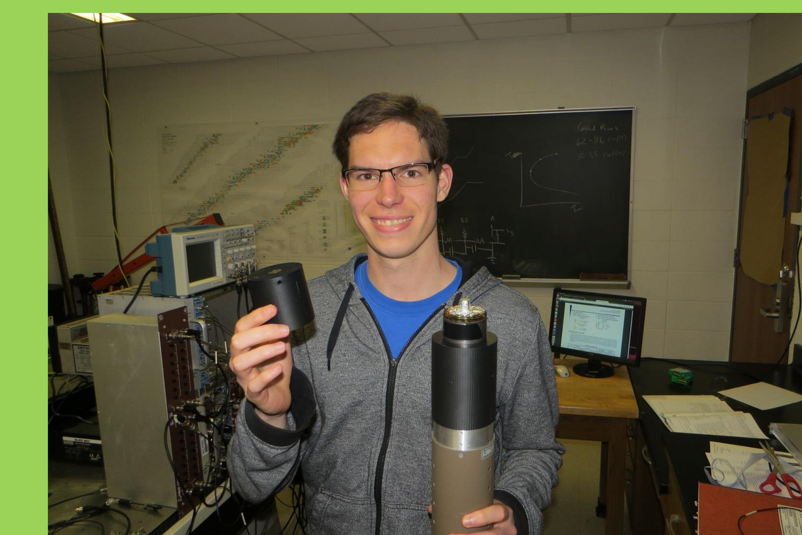




IV. ^{9}Be(n, α)^{6}He Experiment

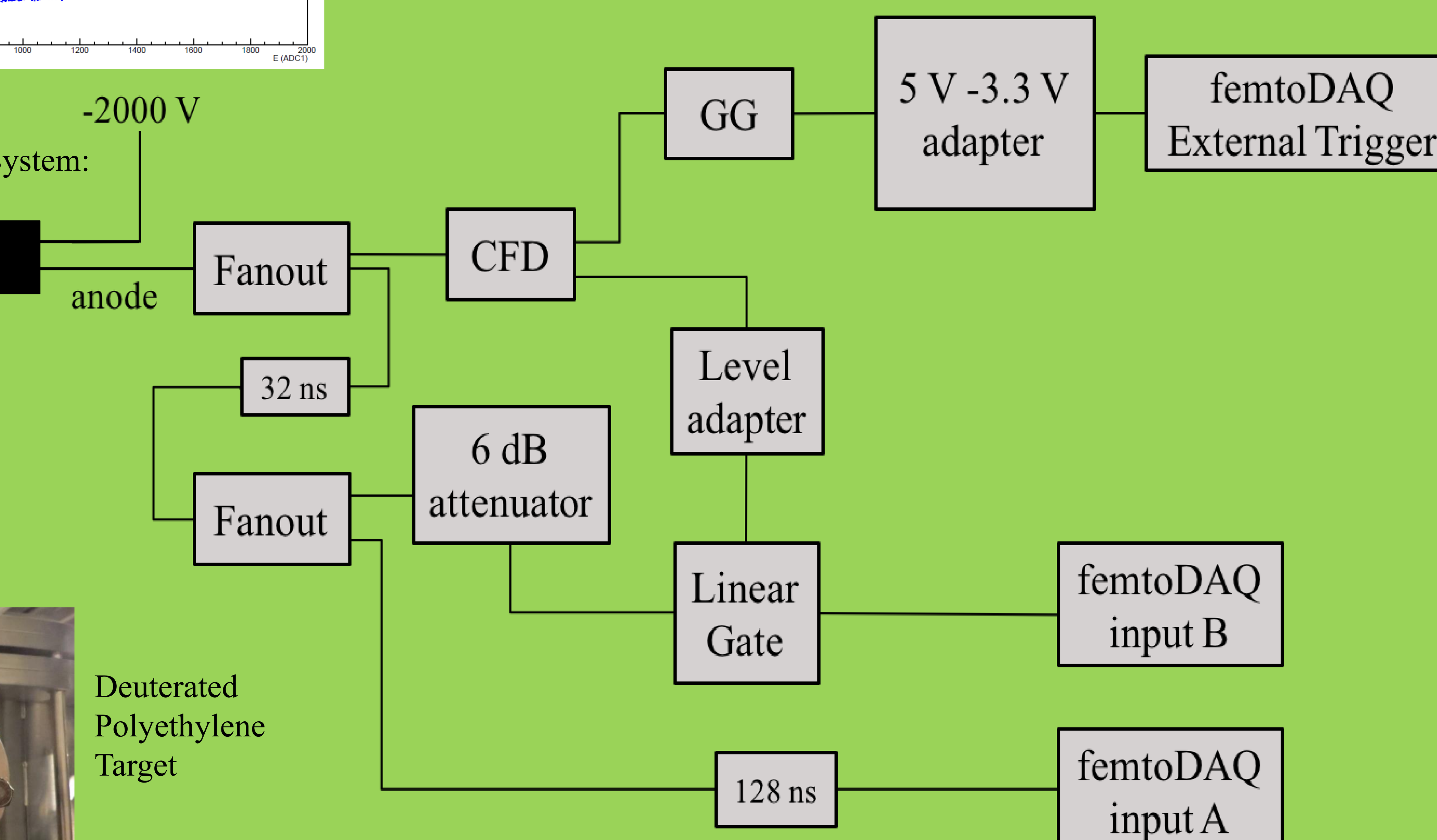
The phoswich dE-E detector system was tested using the Tandem Pelletron accelerator at SUNY Geneseo. A 2.19 MeV deuteron beam struck a deuterated polyethylene target which emitted neutrons via the ^{2}H(d,n)^{3}He reaction. These neutrons hit a thick ^{9}Be target to create ^{6}He nuclei via the ^{9}Be(n,α)^{6}He reaction. The beam was on for five seconds so the ^{6}He particles could build up in the ^{9}Be and then quickly blocked by a Faraday cup to measure the ^{6}He beta decay curve. A latch circuit (right) started the data collection when the count rate from a NaI detector located beside the phoswich detector fell below a fixed value. When the beam was shut off, the latch circuit signaled the femtoDAQ acquisition system to begin collecting data for ten seconds. This process was repeated 160 times for better statistics.

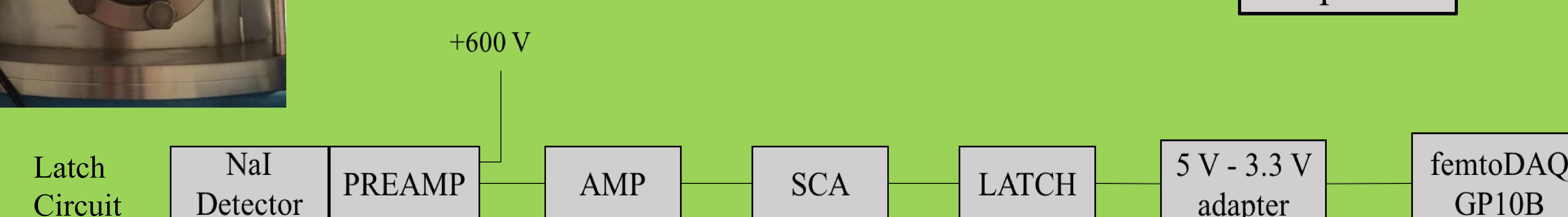
Deuterated Polyethylene Target



V. Electronics

Since the PMT signals consisted of a short dE pulse followed by a long E tail, a linear gate was used to separate the phoswich signals into the dE and E components to be digitized.





VI. Results

The dE-E spectrum in Figure 1 was used to identify ^{6}He beta decays. Figure 2 shows a histogram of these beta events as a function of time, giving a decay curve with a half-life of 789 ms ± 38 ms, in agreement with previous measurements of 807 ms. When the ^{9}Be target was replaced with graphite, the decay curve disappeared.

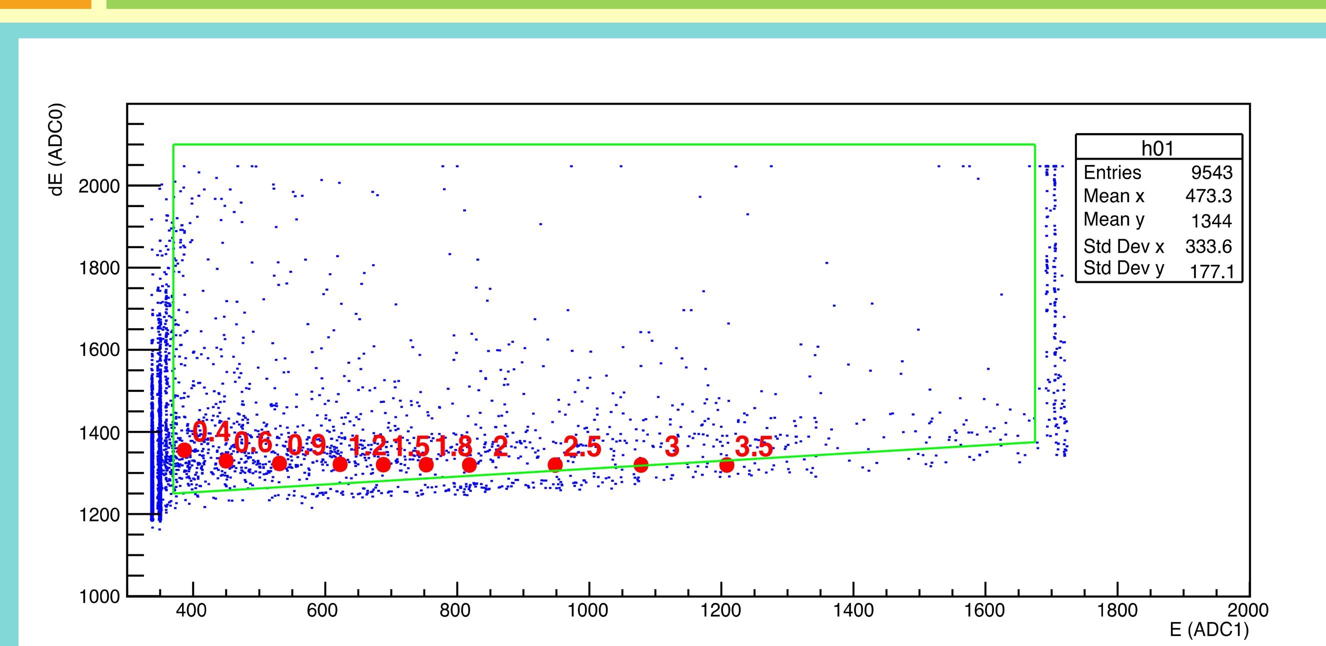


Figure 1. The dE-E histogram for the ^{9}Be target. Red circles are the expected dE and E as a function of beta energy. The green box selects betas from ^{6}He decays.

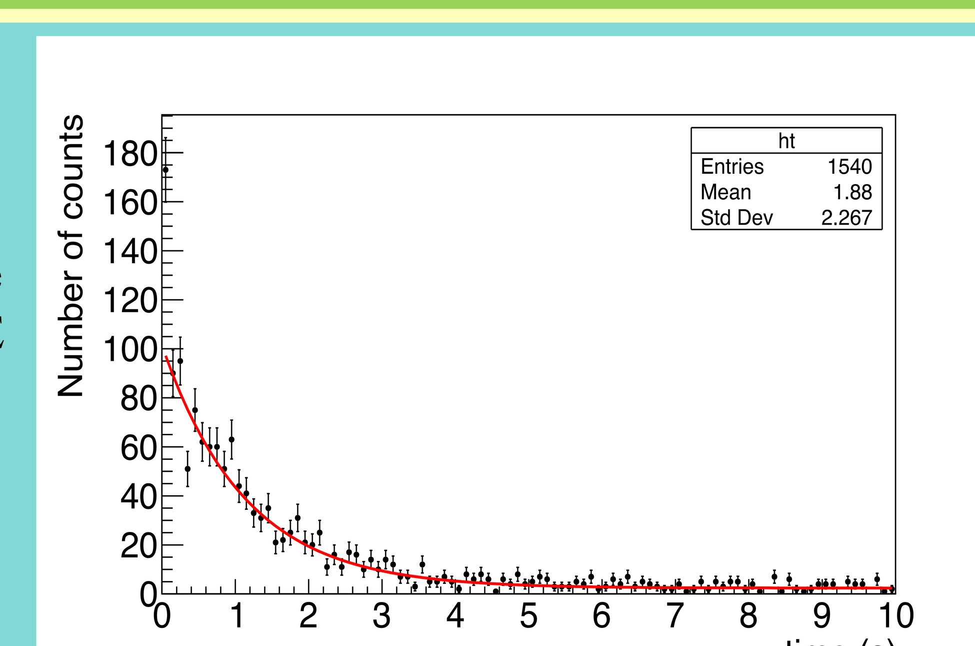


Figure 2. Beta count rate as a function of time for the ^{9}Be target. The best-fit decay curve (red) yields a half-life of 789.2 ± 37.8 ms.

VII. Future Plans

Now that we have shown that we can create and detect ^{6}He with a detector system capable of surviving the ICF conditions, our next step is some ride-along experiments at LLE. If that proves to be successful, we will propose our own TT shot at LLE.