Measurement of the ^{6}He Decay Produced by the ^{9}Be(n,α)^{6}He Reaction

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I. Abstract

The OMEGA laser at LLE is routinely used to implode gas-filled capsules to study light ion fusion reaction rates of interest to stellar nucleosynthesis. As a first step toward a possible measurement of the ^{3}H(t,γ)^{6}He radiative capture reaction, a detector system capable of measuring the 807 ms half-life of ^{6}He has been developed and is being tested using ^{6}He nuclei produced via the ^{9}Be(n,α)^{6}He reaction. Deuterons from the SUNY Geneseo tandem Pelletron produce neutrons in a thick deuterated polyethylene target via the ^{2}H(d,n)^{3}He reaction. These neutrons are allowed to strike a beryllium target placed in front of a silicon dE-E detector telescope, which is used to identify the β particles from ^{6}He decay. Following an approximately five second long activation period, the beryllium sample is immediately counted for about five seconds. The pulse heights for each detector and the timestamp are recorded using a specially configured femtoDAQ acquisition system and used to measure the decay curve. Funded in part by a grant from the DOE through the Laboratory for Laser Energetics.

II. Motivation

The ^{3}H(t,γ)^{6}He radiative capture reaction occurs in almost every practical thermonuclear fusion scheme, but the cross section has never been measured. This is because the predicted cross section is very small and few accelerator laboratories can produce tritium beams. Nonetheless, this cross section is important for DT and TT fusion research and nucleosynthesis models.

One way to measure the cross section may be to use inertial confinement fusion (ICF) at the Laboratory for Laser Energetics (LLE), as shown in Figure 1. Rather than detecting the gamma ray from the ^{3}H(t,γ)^{6}He reaction, we plan to detect the 807 ms half-life decay of the emitted ^{6}He nuclei. The ^{6}He decay

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

will occur much later than the radiation from the ICF implosion.

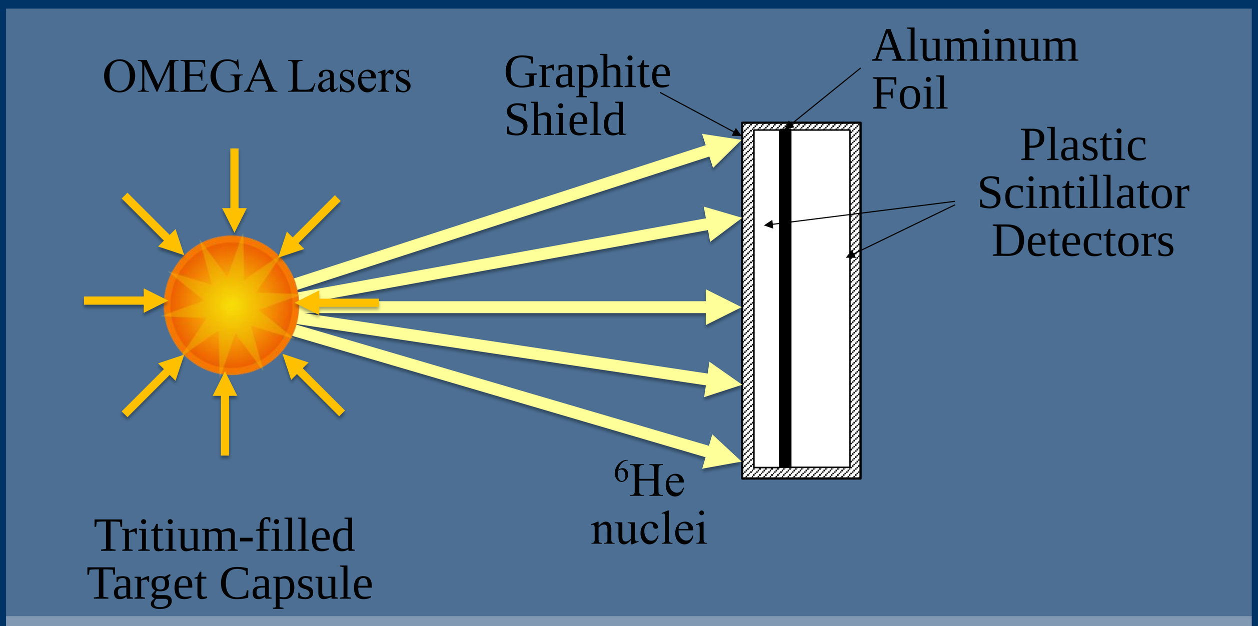

Figure 1. The ^{3}H(t,γ)^{6}He experiment at LLE. OMEGA lasers cause an ICF implosion in a tritium target, emitting a small number of ^{6}He nuclei. The ^{6}He embeds in a graphite shield in front of a plastic scintillator dE-E detector telescope, which identifies the ^{6}He beta decay events.

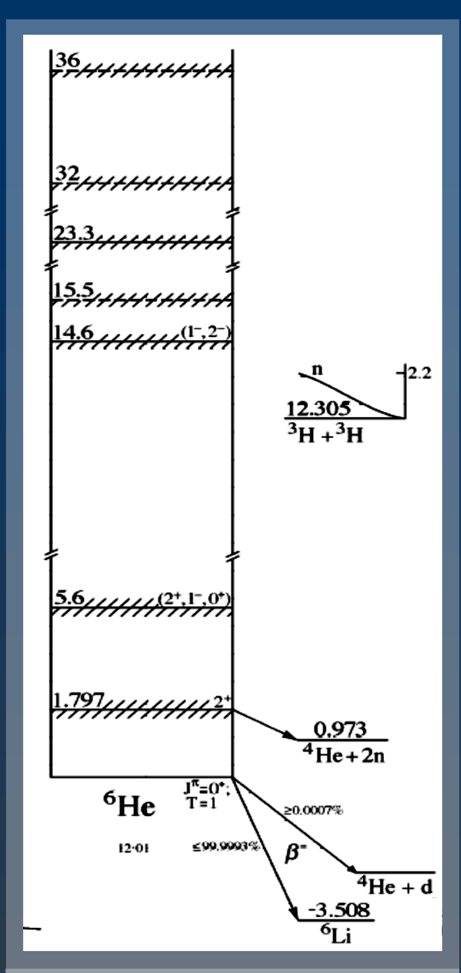

Figure 2. Energy level diagram for ^{6}He.
[D.R. Tilley et al., Nucl. Phys. **A**708, 3 (2002).]

The ^{3}H(t,γ)^{6}He cross section will be very small because a direct s-wave transition to the ground state of ^{6}He is forbidden. This leaves several other possibilities:

1. **Transition from initial state of higher orbital angular momentum ($\ell > 0$).** Reduces cross section at low energies.
2. **Transition to excited states of ^{6}He.** Most decay through the 2n+α channel.
3. **Resonance transition.** Energy level at 14.6 MeV could significantly increase cross section at low energy.
4. **Ground state admixture.** An admixture in the ^{6}He ground state could increase cross section, as was the case for ^{2}H(d,γ)^{4}He.

III. Experiment

The first step toward the ^{3}H(t,γ)^{6}He cross section measurement is to demonstrate that we can create and detect ^{6}He. This was done using the Tandem Pelletron accelerator at SUNY Geneseo. A deuteron beam struck a deuterated polyethylene target which then 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. Beta particles from the decay of ^{6}He were identified using a silicon dE-E detector telescope. The beam was on for five seconds so the ^{6}He particles could build up in the ^{9}Be, then, using a Faraday cup, the beam was quickly turned off so the ^{6}He beta decay curve could be measured.

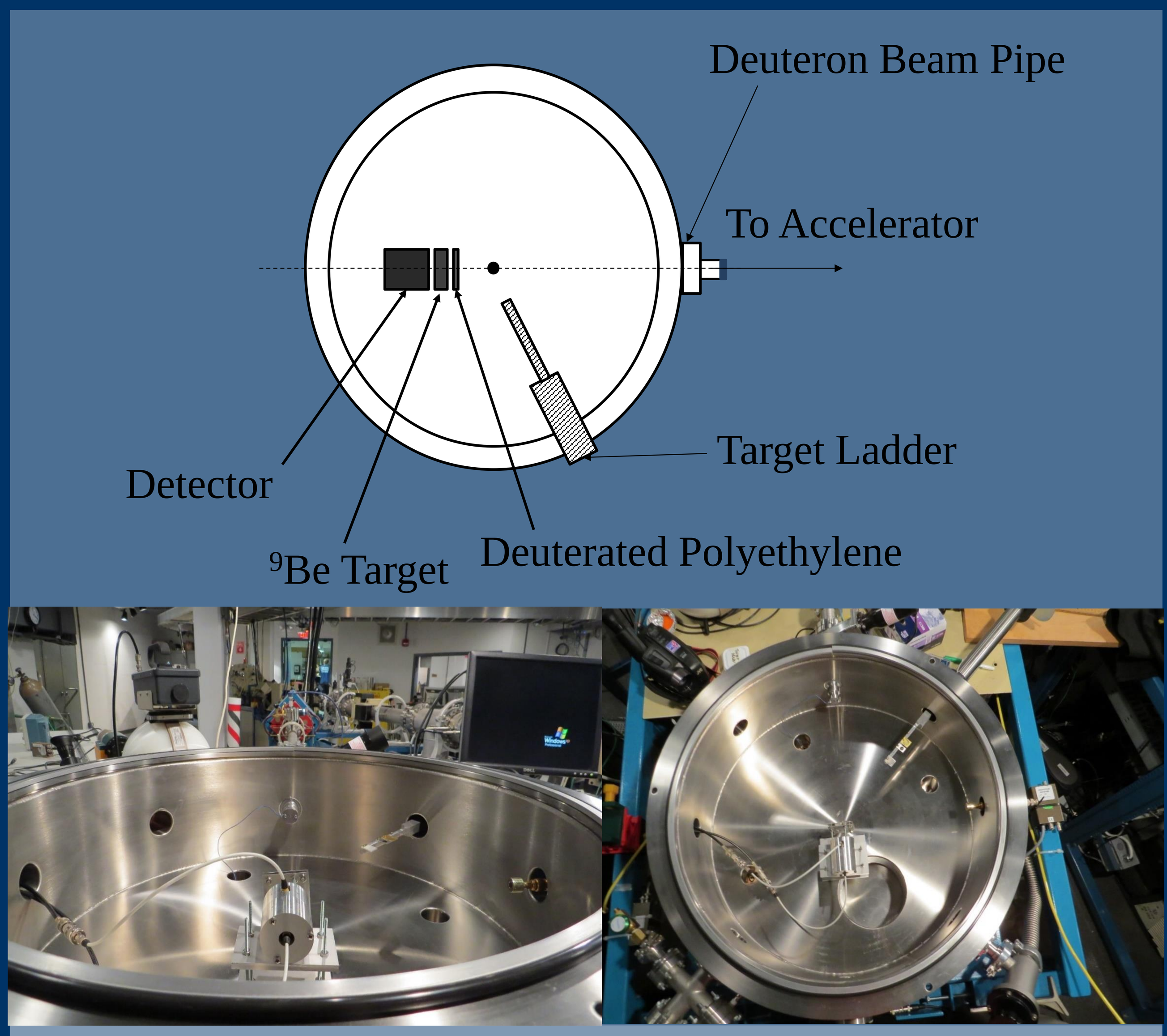

Figure 3. Target chamber set-up at SUNY Geneseo.

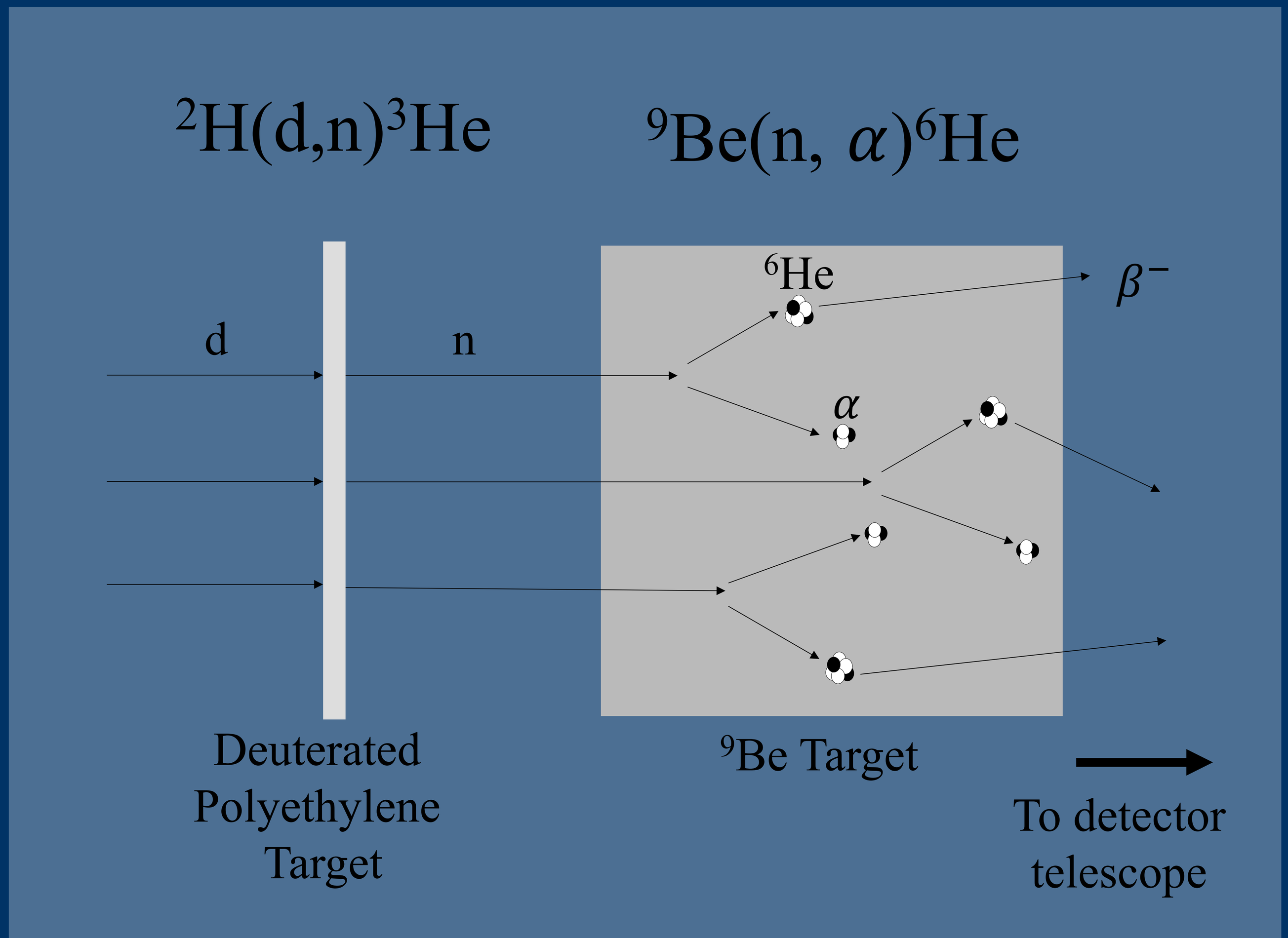

Figure 4. Test experiment at SUNY Geneseo. Deuterons incident on the deuterated polyethylene released neutrons which hit the ^{9}Be target, forming ^{6}He nuclei which beta decay.

Energy deposited in the dE-E detector system was converted into current pulses that were amplified and recorded by a femtoDAQ data acquisition system. Counts caused by beta particles were identified by their dE-E signature and binned by arrival time. Unfortunately, the current FPGA code requires events to be read out one at a time, which required about 4 ms per event, resulting in a large dead time.

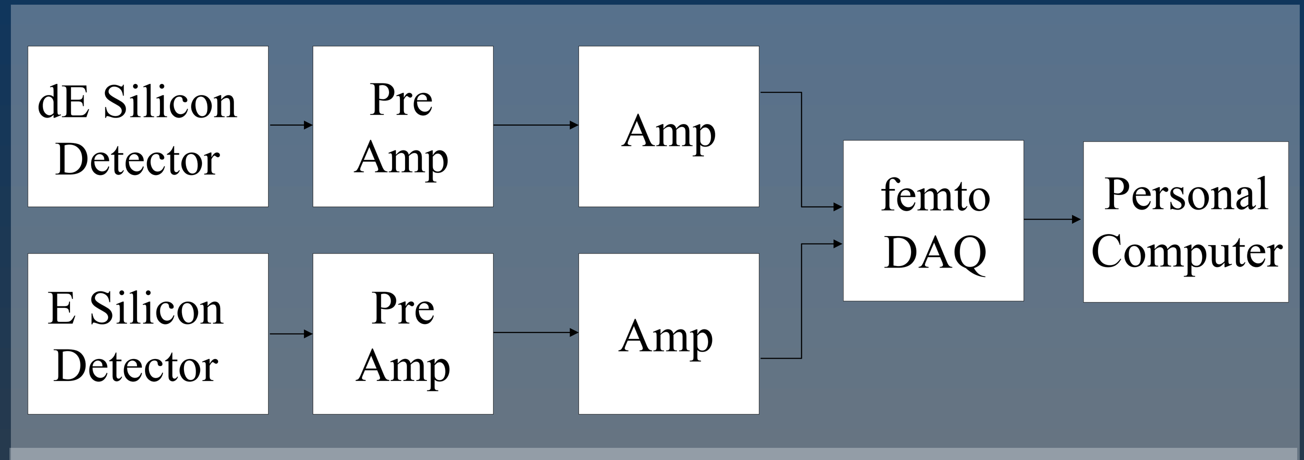

Figure 5. Electronics for the experiment. Signals from the silicon detectors in the dE-E detector telescope were amplified and recorded by a femtoDAQ acquisition unit, which recorded the pulse height and time for each event that triggered the E detector.

IV. Results

Figure 6 shows the dE-E spectrum for beta particles, which was used to select the beta events. The beta count rate was then plotted as a function of time in Figure 7. After the beam was cut, the count rate with the ^{9}Be target decreased approximately exponentially, with a half-life of about 610 ms rather than the expected ^{6}He half-life of 807 ms. The difference is probably due to poor dead-time correction. Modifications to the FPGA code in the femtoDAQ will allow 45 seconds of data collection before reading out, greatly reducing the dead time.

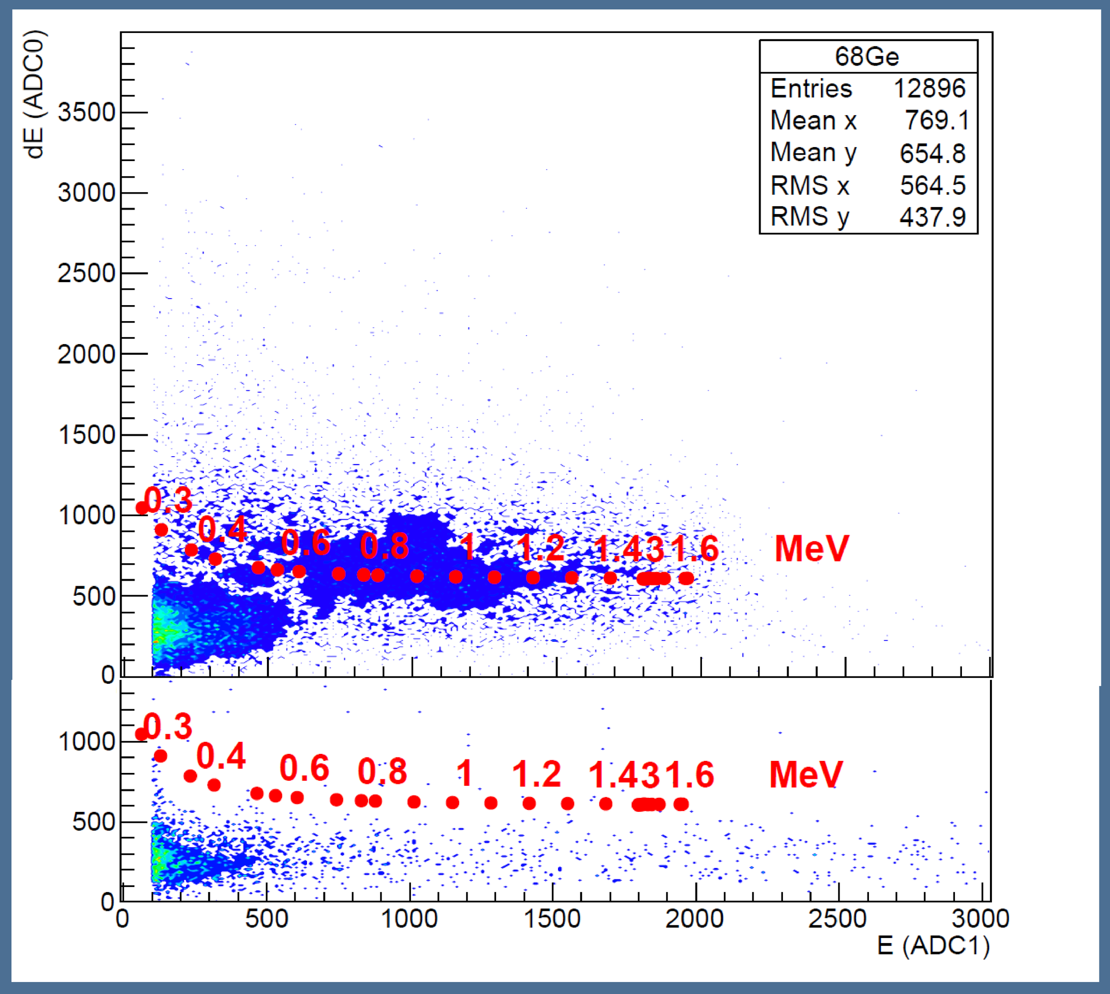

Figure 6. Histogram showing events from a collimated ^{68}Ge beta source with endpoint energy about 1900 keV (top) and background (bottom). Red circles show the projected electron range as a function of energy.

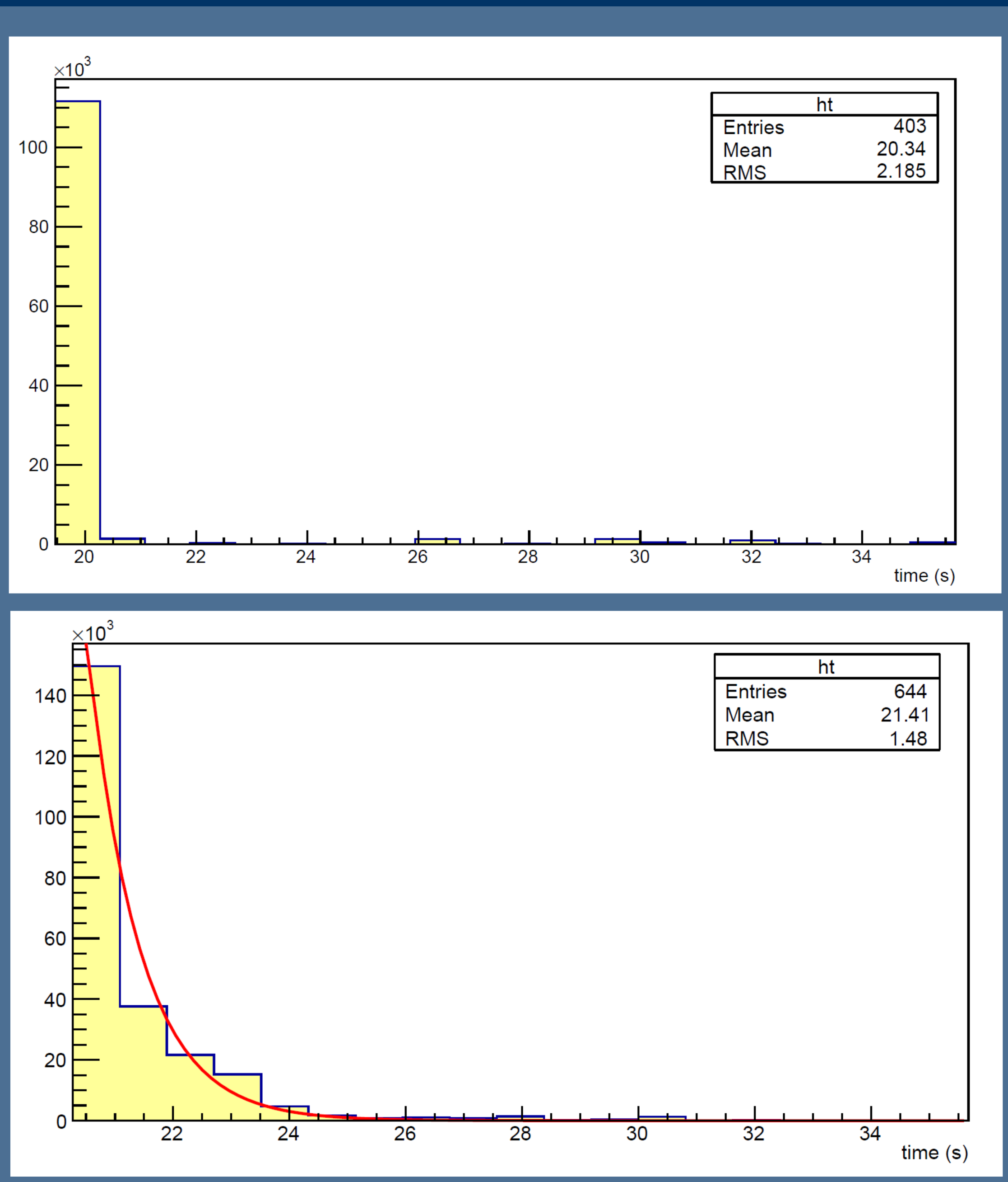

Figure 7. Beta count rate as a function of time for the graphite (top) and ^{9}Be target (bottom). The best-fit decay curve (red) yields a half-life of 610 ms.

V. Future Plans

- Create and Detect ^{6}He — Summer 2016
- New Detector — Summer 2017
- Ride-Along Experiment
- Tritium Shot at LLE