An Experiment to Simulate Trapping and Detection of Radioactive Isotopes Produced in ICF Implosions

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I. Abstract

It may be possible to measure the low energy nuclear cross sections of light ion reactions by trapping the reaction products from an Inertial Confinement Fusion (ICF) implosion and detecting their beta decays. To test this idea, an "exploding wire" experiment was designed to simulate the expanding gas released in an ICF event. A copper plated tungsten foil was inserted into a vacuum chamber and activated with a deuteron beam via ^{65}Cu(d, p)^{66}Cu. A current pulse through the tungsten then vaporized the copper to create an expanding radioactive gas, simulating the gas behavior in the ICF target chamber following the laser shot. Attempts were made to capture some gas and detect the ^{66}Cu beta decays using two trap designs, one using a getter and the other a turbopump. Both designs used the Short-Lived Isotope Counting System (SLICS), consisting of plastic scintillator phoswich detectors and fast electronics, to identify and count the beta particles.

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II. Motivation

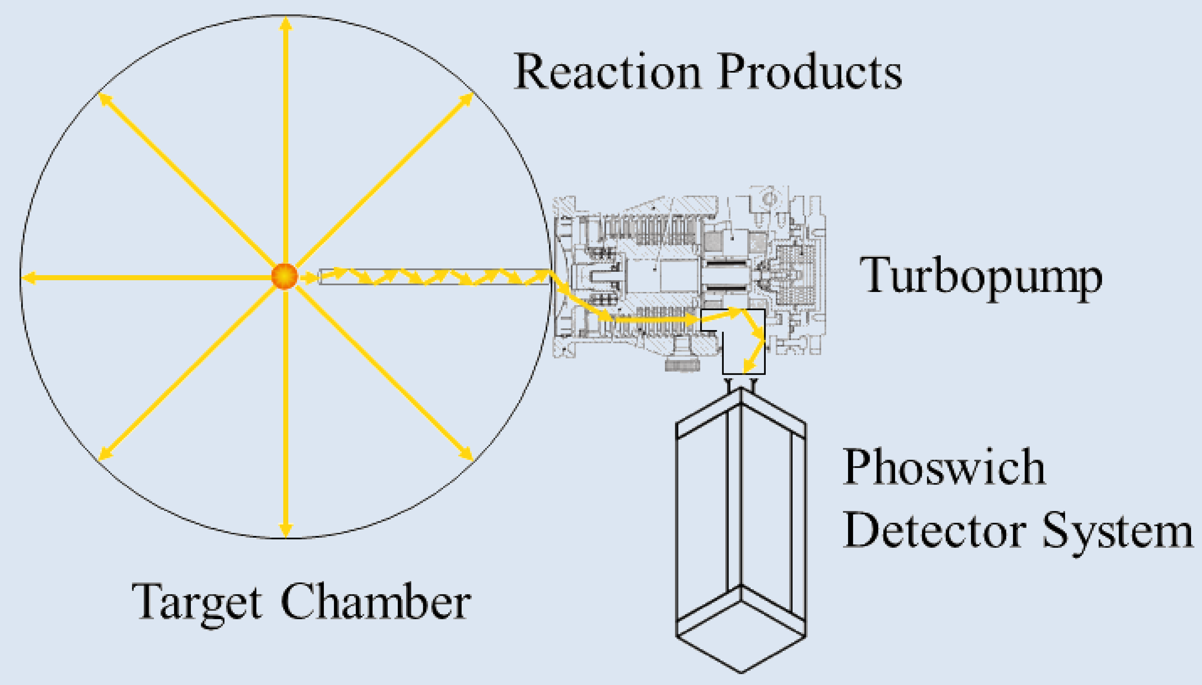
The nuclear cross sections of many light ion reactions have never been measured at relevant thermonuclear energies, even though they are required by nucleosynthesis models. ICF, which uses powerful lasers to heat macroscopic fuel targets to the point where thermonuclear reactions occur, is being considered as a technique to measure these low energy nuclear cross sections.

Reaction	Product Half-life	Predicted Yield
^{3}H(t,γ)^{6}He	807 ms	8×10^4
^{6}Li(t,p)^{8}Li	840 ms	$0.2\text{-}1\times10^7$
^{7}Li(t,α)^{6}He	807 ms	$0.7\text{-}2\times10^6$
^{9}Be(t,α)^{8}Li	840 ms	5×10^5

Table 1. Estimated yields for the most prolific light ion reactions that may be studied using ICF. The target capsule was assumed to be doped with 1% of the appropriate reactant isotope. Shot parameters for OMEGA shot 77951 were used, a tritium-filled SiO2 capsule "exploding pusher" that reached $T_i = 18.3$ keV. For ^{3}H(t,γ)^{6}He the predicted yield is based on assuming a branching ratio of 10^{-7}, which is simply an estimated "best case". For other reactions, reactivities were calculated using S-factor extrapolations and TALYS-1.9.

In a traditional accelerator experiment, for example, a 1 μA, 25 keV beam striking a 1.2 μm thick lithium target would take about 100 years to produce one million ^{7}Li(t,α)^{6}He reactions. In comparison, this number could be reached in less than 1 ns in an ICF experiment.

After an ICF shot, the reaction products expand outward in a gas. The first step in measuring the cross sections is trapping the gas and detecting the beta decays of the reaction products.



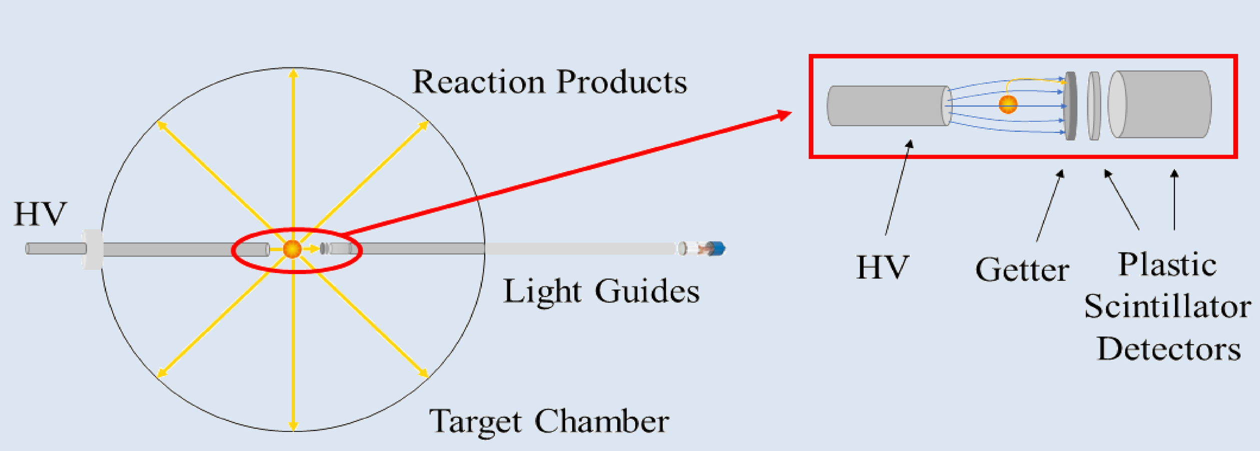
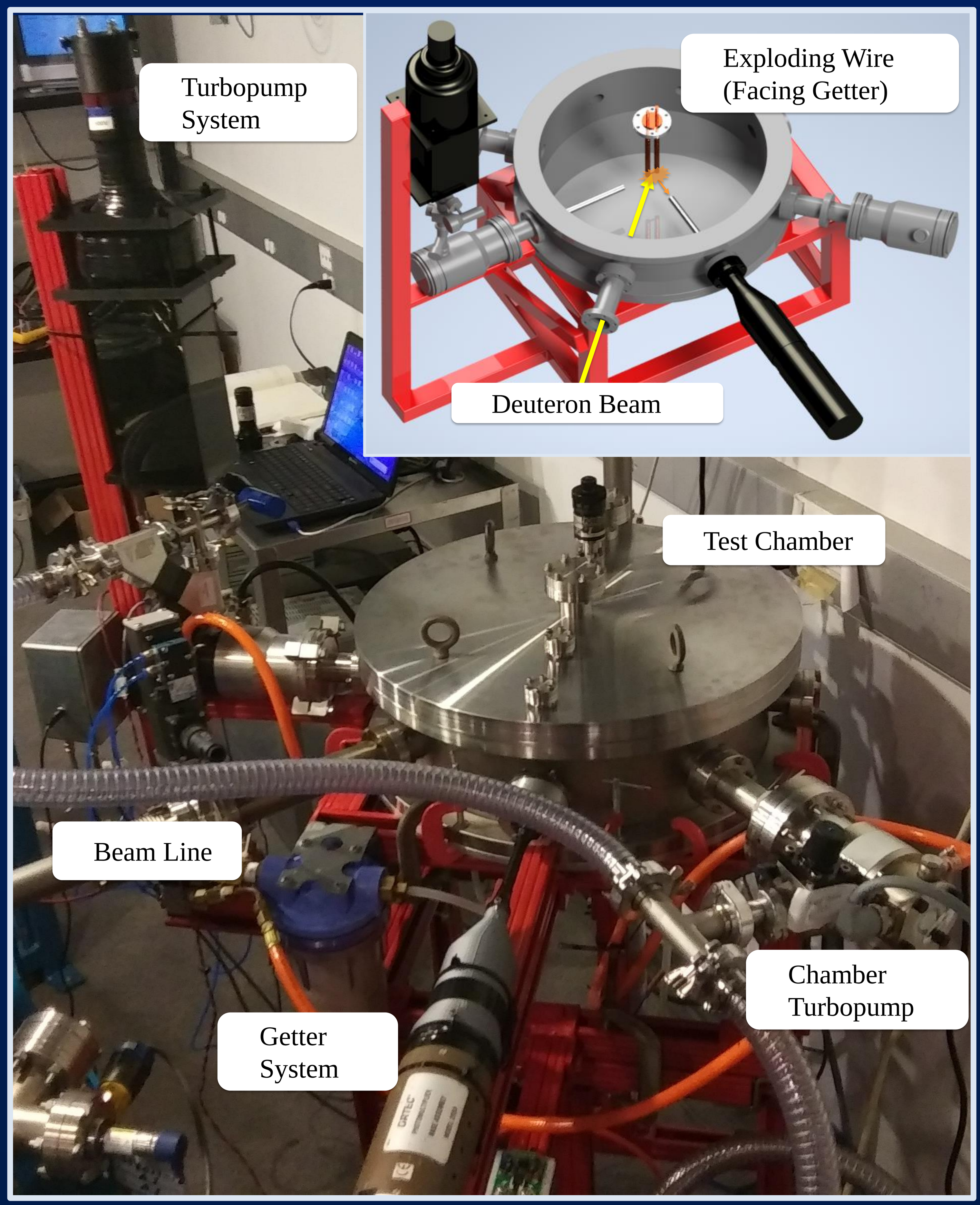


Figure 1. (Top) Turbopump trap. A collection tube placed close to the target guides the products into the turbopump, where they are pushed into a box-shaped phoswich detector system. (Bottom) Getter trap and detector system. A getter foil close to the target catches the expanding reaction products. A high voltage applied on the opposite side of the target may be used to propel more of the ionized products toward the getter before they recombine.

III. Experiment

To test the feasibility of the two trap and detector designs, an "exploding wire" experiment was designed to simulate the radioactive expanding gas produced in an ICF event.



Procedure:

1. Copper electroplated onto or Teflon wrapped around a tungsten foil is activated by ^{65}Cu(d,p)^{66}Cu or ^{19}F(d,p)^{20}F.
2. A rapid current pulse heats tungsten and vaporizes the ^{66}Cu or ^{20}F.
3. The ^{66}Cu or ^{20}F expands outward in a gas and sticks to the getter or is trapped in the turbopump.
4. ^{66}Cu or ^{20}F and beta decays are detected and identified using the dE-E phoswich system.

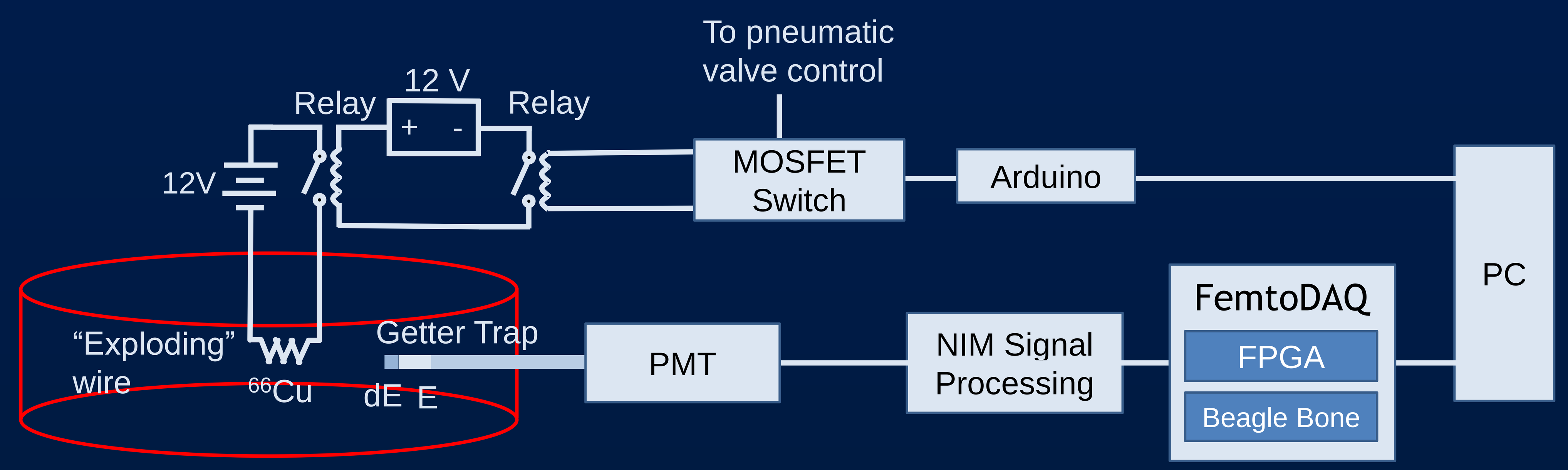


Figure 2. (Top Left) Photograph of experiment attached to the 30R beam line on the SUNY Geneseo Pelletron, showing both traps and detectors. (Inset) CAD drawing of experiment, showing the inside of the chamber and the "exploding wire." (Bottom) Block diagram of the main components in the experiment.

IV. Results

Both ^{65}Cu and ^{19}F were activated in the experiment, but only ^{66}Cu was evaporated. Beta decays from evaporated ^{66}Cu were detected in the getter trap but not the turbopump trap, most likely because the ^{66}Cu stuck to the collection tube. The getter detector counted beta particles from ^{20}F decay coming from the activated Teflon attached to the tungsten foil.

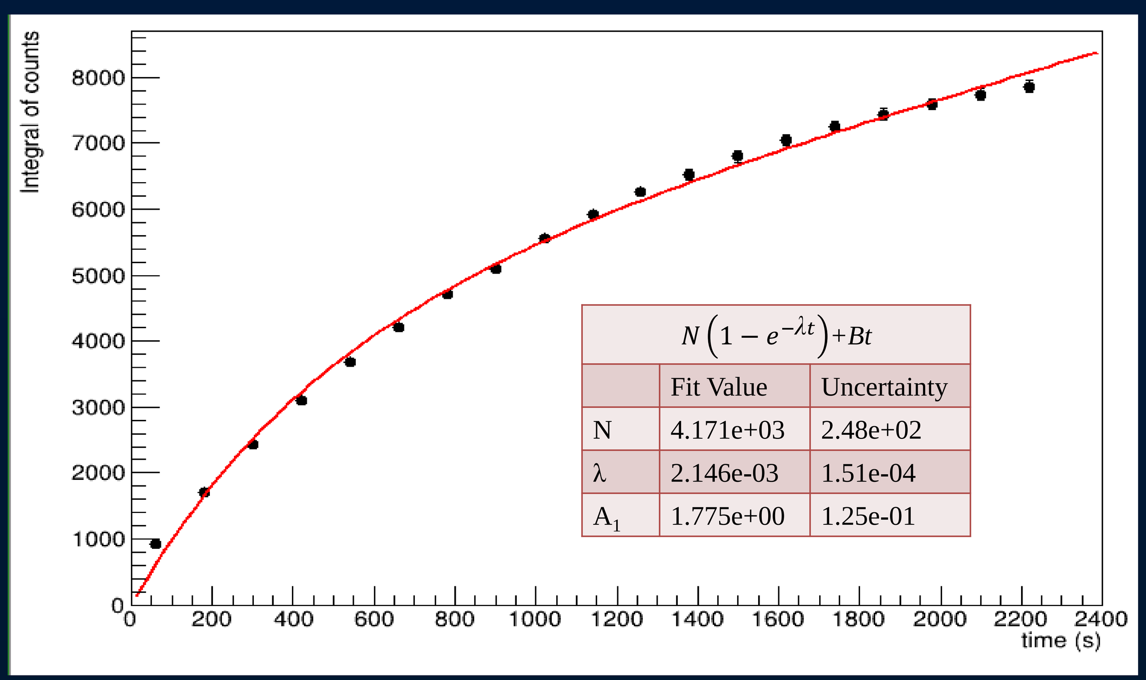


Figure 3. Growth curve of ^{66}Cu. A growth curve was yielding 4171 decays with a fit half-life of 5.38 ± 0.41 minutes compared to the previously measured value 5.12 min.

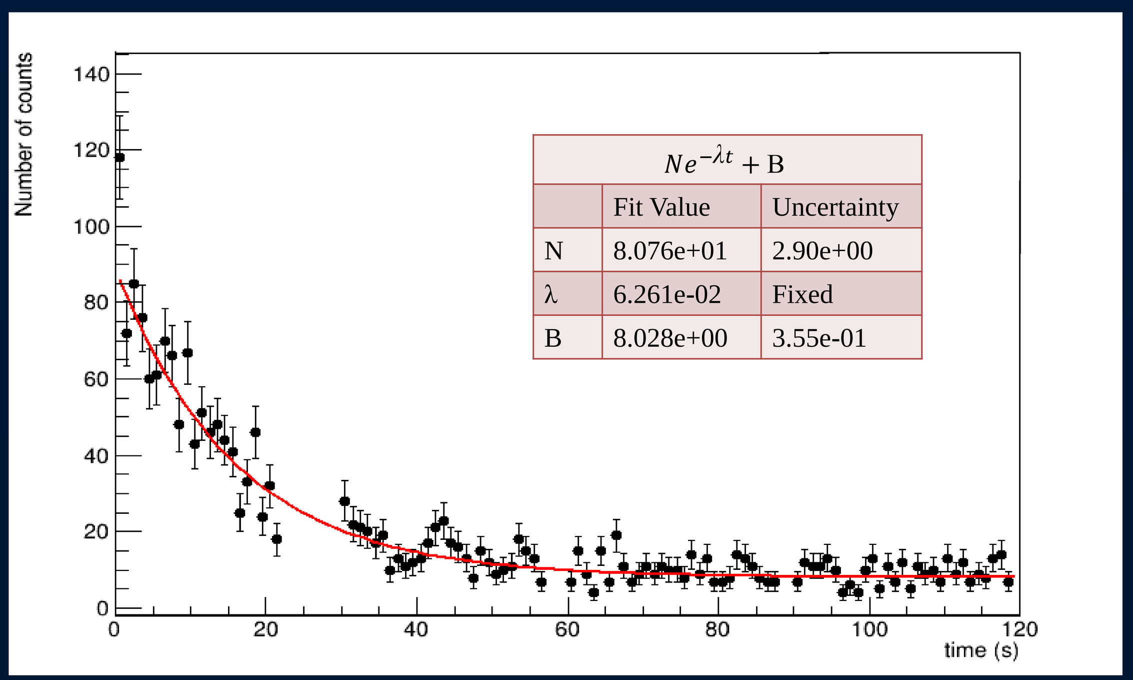


Figure 4. Decay curve of ^{20}F. The decay curve was fit yielding an initial rate of 87 decays per second with a fit half-life of 11.07 s compared to the previously measured value 11.02 s.

V. Conclusion and Future Plans

The ability to produce, release, trap and detect a short-lived radioactive gas has been demonstrated. The next step is to use isotopes that are less chemically reactive and have half-lives of hundreds of milliseconds. Ultimately, this system could be used to measure the efficiency of the detector and trap, a value needed to obtain cross sections in any ICF experiment.