Using a 64Cu source to test SLICS

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Acknowledgements
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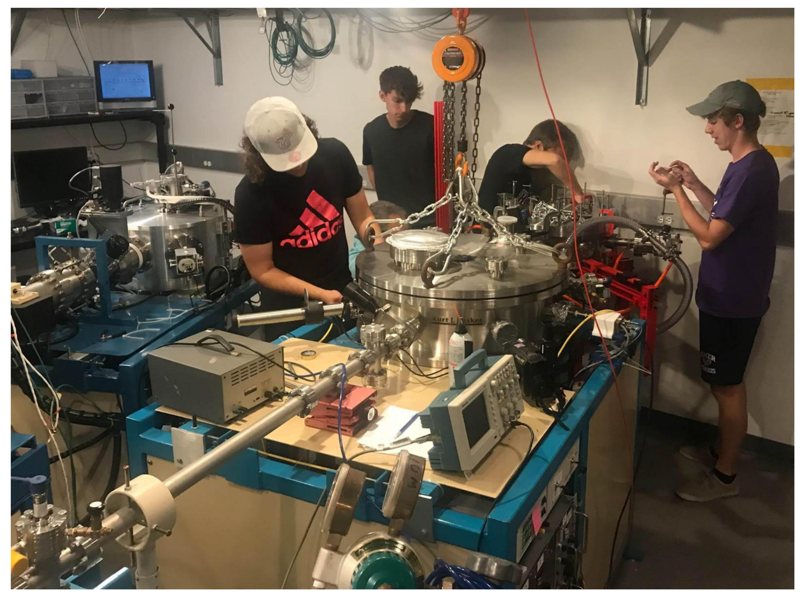
Abstract

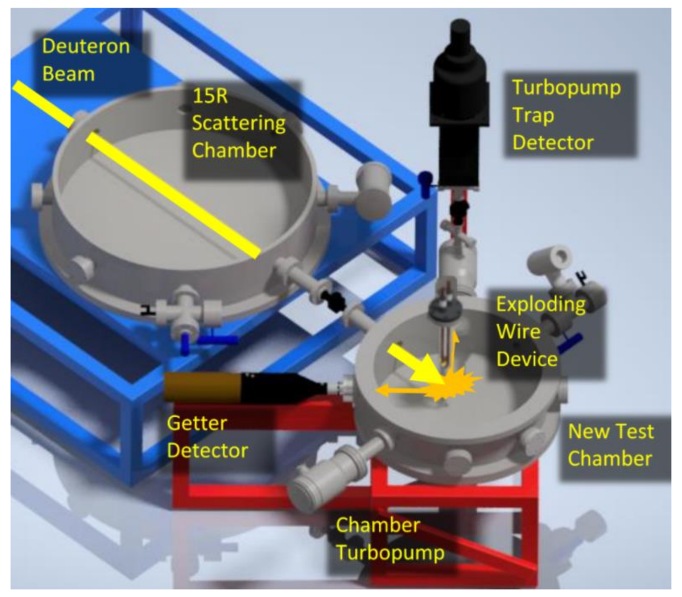
The short-lived isotope counting system (SLICS) being built for the OMEGA laser facility at LLE requires short-lived radioisotopes, such as 64Cu, for testing and calibration purposes. Using the SUNY Geneseo neutron howitzer, which contains a Plutonium-Beryllium (Pu-Be) source, 63Cu was bombarded with water moderated thermal neutrons to produce 64Cu via the 63Cu(n,γ) capture reaction. The 12.7 hour half-life of 64Cu allowed it to be transported to Houghton College where its signature was measured as a possible background to 66Cu used in future "exploding wire" experiments to simulate detection of radioisotopes produced in ICF implosion.

Motivation

The radioactive isotopes 66Cu and 64Cu can be successfully created using a PuBe neutron source. Copper can be used to test the short-lived isotope counting system (SLICS) being built for the OMEGA laser facility at LLE. The Gamma-X system could be used to detect lower magnitudes of gamma emissions from materials that primarily decay by beta emission. Tuning the Gamma-X system to this emission would assist with determining the proportion of potential beta decays seen with Dr. Mark Yuly's detection system SLICS at Houghton College. The neutron howitzer would be utilized to simulate, at a much smaller reaction yield, the 65Cu(d,p)66Cu reaction of the particle accelerator for applicable materials with thermal neutrons.



Labeled diagram inside(right) and outside(left) of the Houghton College Getter Detector vacuum chamber.



Radioisotope Team Timeline

Different radioactive sources have been produced and used to help test the SLICS detector system through the collaboration of SUNY Geneseo and Houghton College.

Summer 2018

- Accelerator based activation producing ^{6}He from the reaction of ^{9}Be(n, α)^{6}He

Summer 2019

- Dr. Mark Yuly brought the Turbopump Trap Detector portion of SLICS to SUNY Geneseo for testing. A dewar of liquid Argon-41, activated in the neutron howitzer was used to test the SLICS detector system once vaporized. 40Ar(n,γ)41Ar

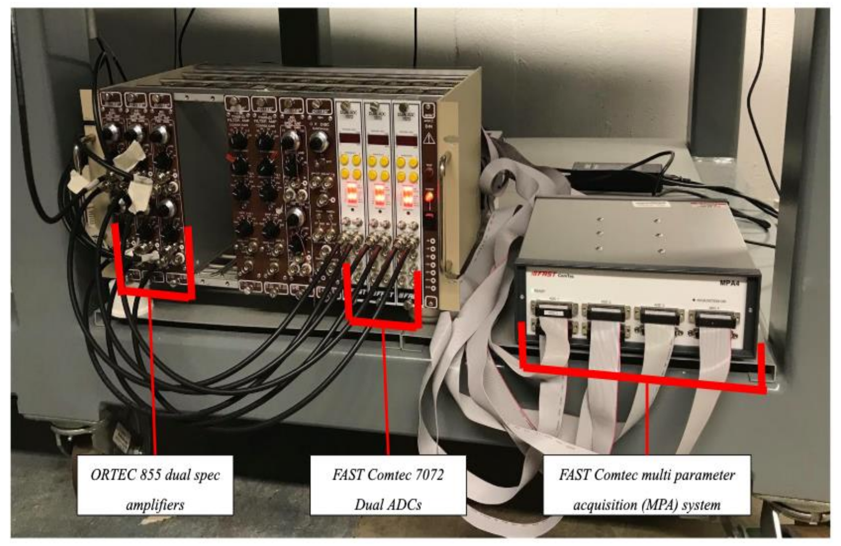
  → 41Ar→ e + 41K*

  → 41K* → γ+41K

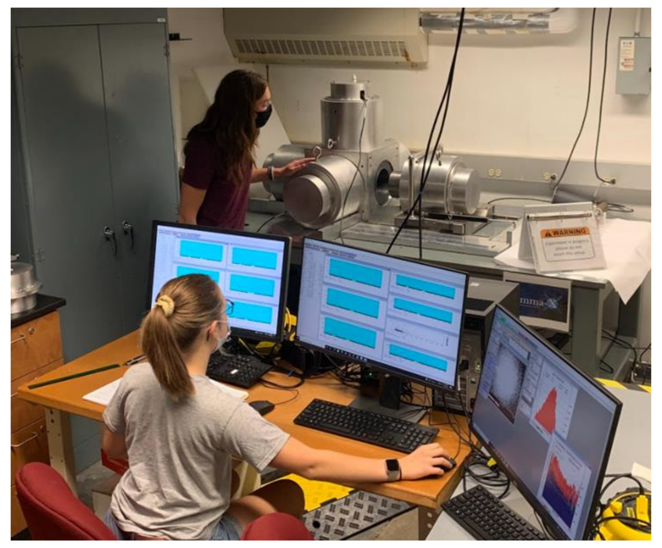
Summer 2021

- A Bismuth beta emitter was used in both the E and ΔE detectors of the phoswitch
- Thin foils of ^{64}Cu, radiated by the SUNY Geneseo neutron howitzer, were transported to Houghton via car and placed directly against the Getter detector
- The SUNY Geneseo neutron howitzer was used to produce ^{66}Cu and was placed in the Houghton College detector system as quickly as possible, due to the short half life of the isotope
- Cu targets were prepared through a method of electroplating copper on to tungsten ribbon; used in following particle accelerator activation
- Proton accelerator-based activation for ^{65}Cu(d,p)^{66}Cu reaction; activation was attempted to be recorded by thallium doped sodium iodide detectors from the Gamma-X setup

Experimental Setup

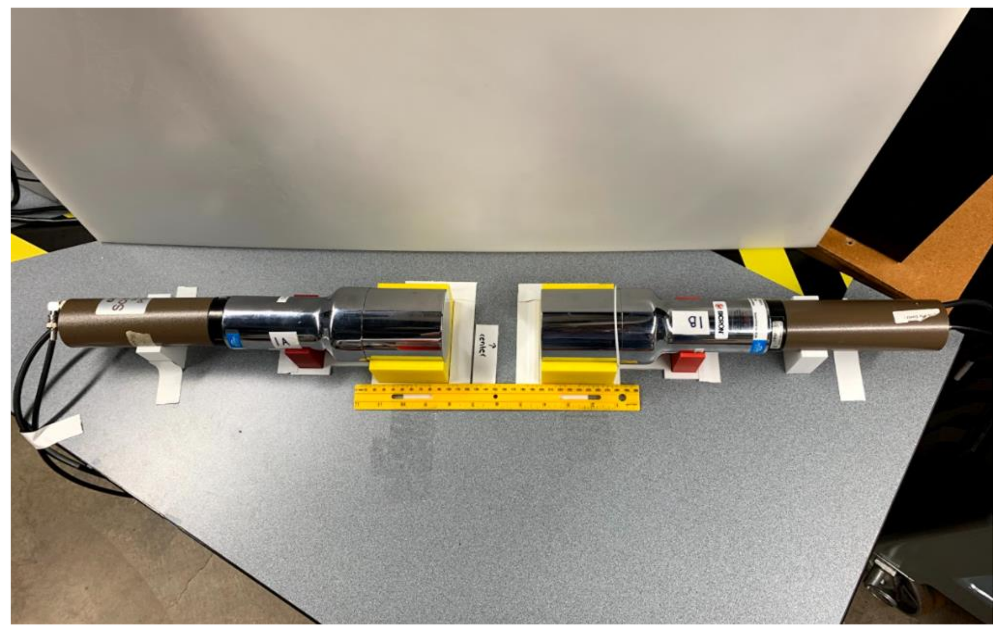


Electronics used for the Gamma-X setup in the detection of ^{64}Cu and ^{66}Cu.



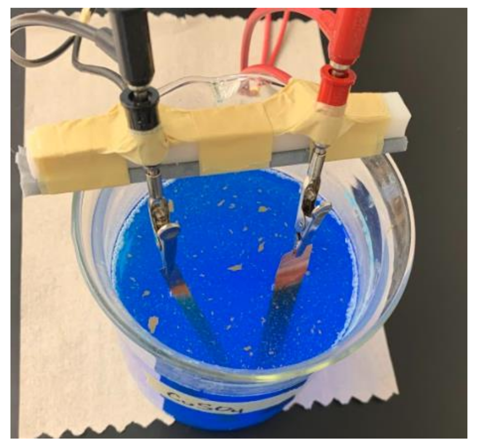
The Gamma-X setup at SUNY Geneseo, from which sodium iodide detectors were taken, with three computer monitors for data acquisition and analysis.

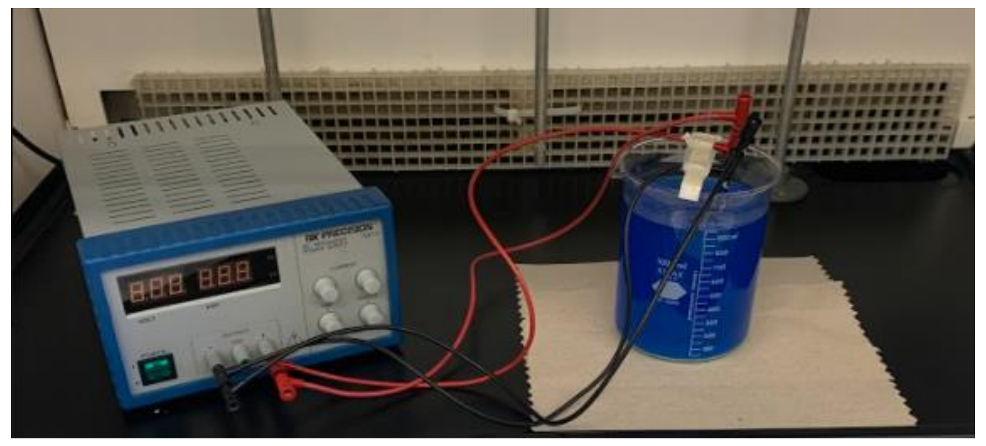
Two NaI(Tl) detectors were placed facing one another along a coaxial path with a separation distance of 10 cm between the detector faces. This method of detection was utilized to test the SLICS detection system and to confirm that ^{64}Cu and ^{66}Cu were made by the neutron howitzer and the SUNY Geneseo particle accelerator. The copper sources were placed inside the neutron howitzer at a water-moderated radial distance of approximately 165mm from the PuBe source. This detector setup was also used in determining the activation rate of the ^{65}Cu(d,p) ^{66}Cu reaction that occurred in the particle accelerator. In addition, the setup was utilized to observe gamma decay as a potential background for the beta decay spectra obtained by SLICS.



Left: Detection system setup outside of Gamma-X consisting of two NaI detectors.
Right: Nicole Gindling and the SUNY Geneseo Neutron Howitzer.

Target preparation for particle accelerator activation involved electroplating copper onto a tungsten ribbon. A 1.56M copper sulfate solution was used alongside a copper anode and tungsten cathode, shown below.





Left: An overhead view of the Cu and W held in place in the $CuSO_4$ solution by a polyoxymethylene rod. Right: The electroplating setup of $CuSO_4$ solution connected to a power supply by wires attached to the Cu and W set in the solution.

Procedure

The SUNY Geneseo neutron howitzer was used to irradiate ^{64}Cu and ^{66}Cu for use in the Gamma-X detection system as well as to test the SLICS detection system for Houghton College. For a ^{64}Cu source, the copper was irradiated for 5 half-lives of ^{64}Cu , or approximately 3 days. For a ^{66}Cu source, the copper was irradiated for 30 minutes, which is equivalent to approximately 5 half-lives. After the irradiation period, the copper sample was quickly transported to SLICS or the sodium-iodide detector setup for measurement.

$$^{63}_{29}Cu\ (n,\gamma)^{64}_{29}Cu$$

HL: 12.7 hrs
38.5%

$$\rightarrow\ ^{64}_{30}Zn^* + {}^{0}_{-1}\beta + \overline{\eta_e}$$

$$\rightarrow\ ^{64}_{30}Zn + \gamma$$

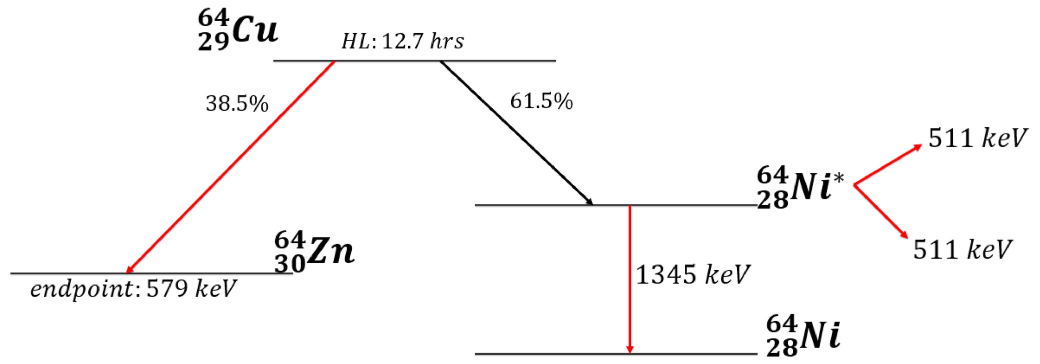
$$^{63}_{29}Cu\ (n,\gamma)^{64}_{29}Cu$$

HL: 12.7 hrs
61.5%

$$\rightarrow\ ^{64}_{28}Ni^* + {}^{0}_{+1}\beta + \eta_e$$

$$\rightarrow\ ^{64}_{28}Ni + \gamma$$

0.511 MeV
I_γ= 35.2%
0.511 MeV



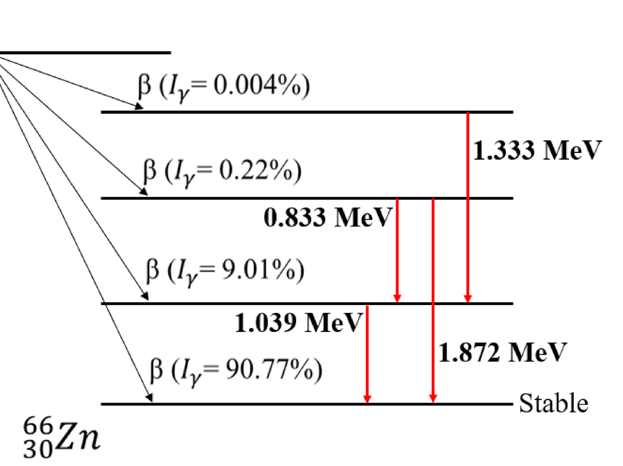
Left: The neutron transfer reaction that produces 64Zn and its released beta particle.
Right: The neutron transfer reaction that produces 64Ni and its subsequent gamma rays.

$$^{65}_{29}Cu\ (n,\gamma)^{66}_{29}Cu$$

HL: 5.2 min
100%

$$\rightarrow\ ^{64}_{30}Zn^* + {}^{0}_{-1}\beta + \overline{\eta_e}$$

$$\rightarrow\ ^{64}_{30}Zn + \gamma$$

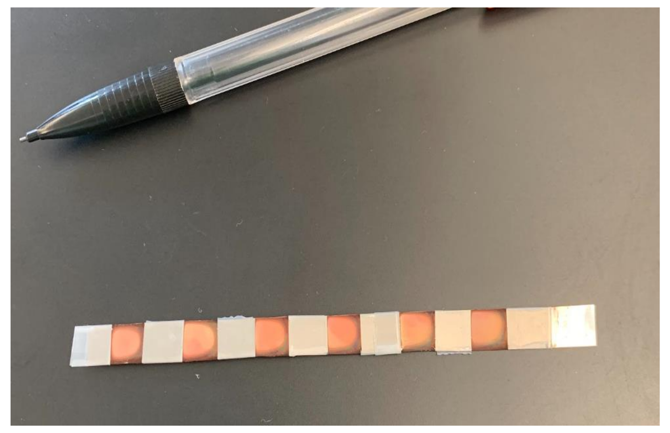


Above: The neutron transfer reaction that produces 66Zn and its subsequent beta and gamma emissions.

^{66}Cu from the SUNY Geneseo Particle Accelerator was also quickly transported to the sodium-iodide detector system to observe the gamma ray spectra from the accelerator-created copper source. In under 5 minutes, the source was transported from the vacuum chamber into the detection system across the lab.

Isotope	Natural abundance
^{63}Cu	69.2%
^{65}Cu	30.8%

^{63}Cu and ^{65}Cu are the most abundant copper isotopes and both undergo neutron capture when placed into the neutron howitzer. After confirming the creation of ^{64}Cu with the Gamma X system, the ^{64}Cu was used in the SLICS detection chamber as a test for proper operation. Results of this test conveyed how gamma rays from the irradiated ^{64}Cu impacted the SLICS system.

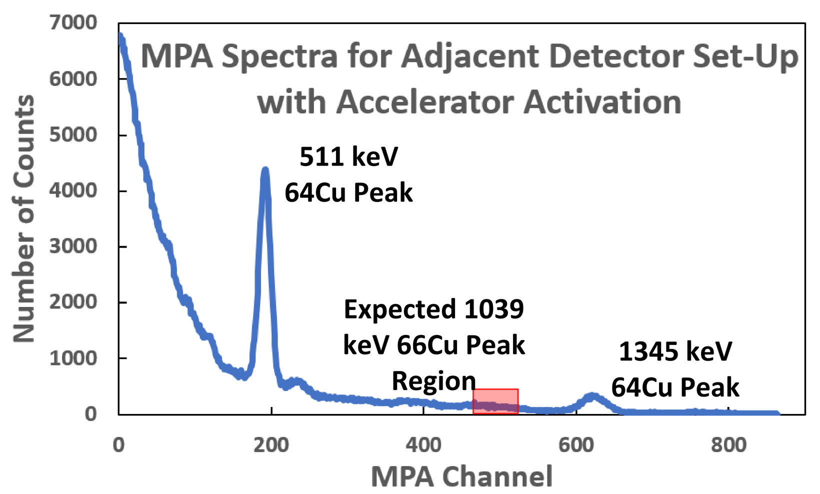


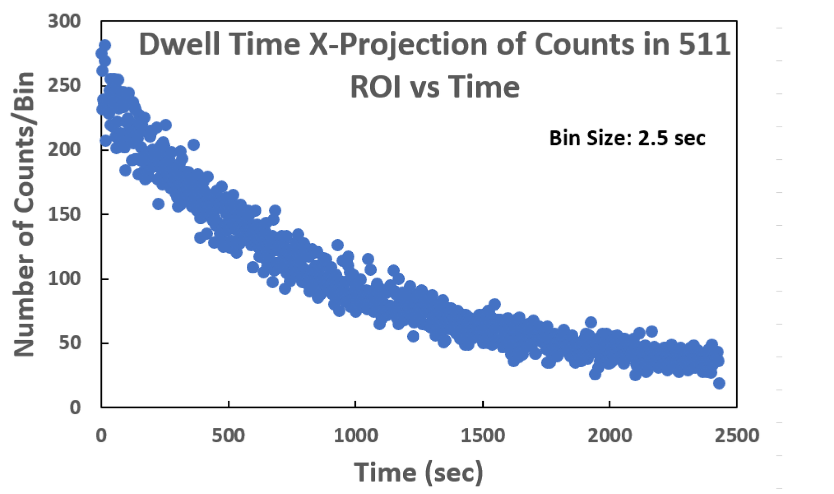
Left: Emma Parker and Kayla Andersen preparing a Cu coated W ribbon target in the SUNY Geneseo Chemistry laboratory. Right: A ribbon of tungsten with 11micron thick sections of copper coating produced via electroplating.

While preparing the copper-coated tungsten target via electroplating, the tungsten was cleaned using acetic acid, scored using emery cloth for greater plating strength, rinsed using a water bath, and dried prior to each plating. Based on efficiency of explosion from the tungsten ribbon at high current, the copper layer needed was 11 microns. The current was held constant and the deposition rate was determined by addition of copper mass over time.

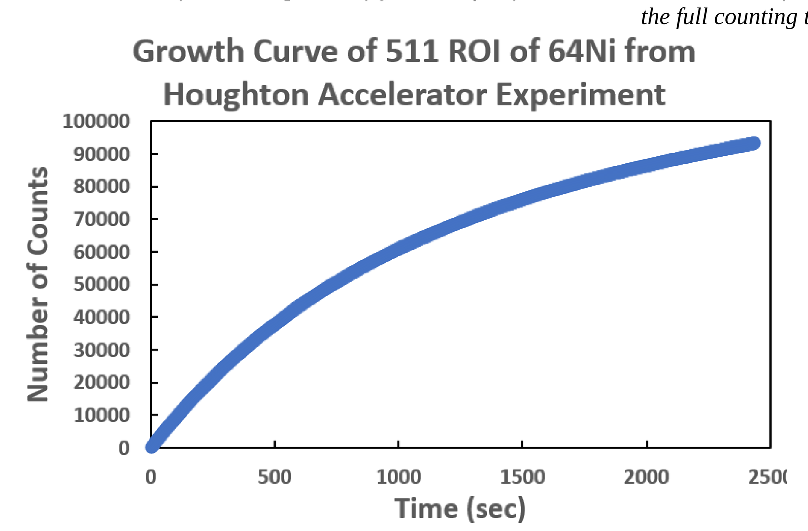
Results

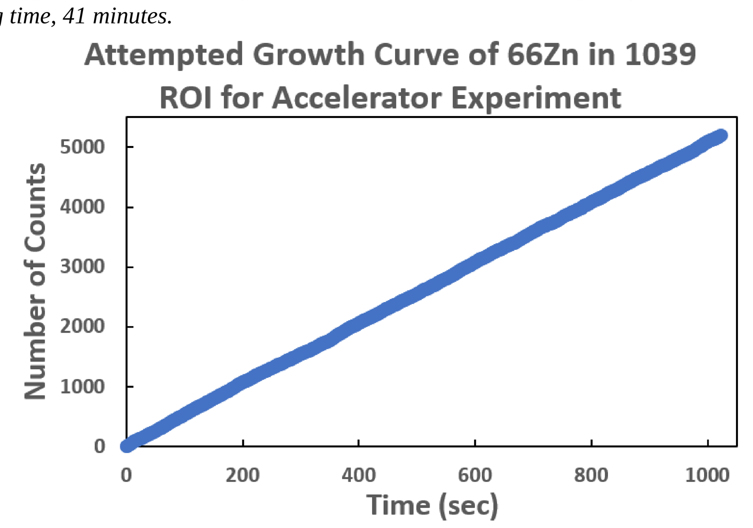
Both 64Cu and 66Cu were created using the SUNY Geneseo neutron howitzer and were confirmed to measure the 511 keV and 1345 keV, and 1039 keV gamma radiation, respectively. The gamma spectra from the 64Cu and 66Cu sources was used to test SLICS and to compare the SLICS spectra/counts to the Gamma-X spectra/counts.





Left: MPA4 Spectra of gamma rays after accelerator activation of copper. Right: Number of counts/bin in the 511 keV gamma peak for the full counting time, 41 minutes.





Left: Growth Curve of 64Ni from the 511 keV gamma ray peak after accelerator activation of copper. Right: Growth curve from where the 1039 keV gamma rays from the growth of 66Zn should have occurred.

It was expected that the spectra returned would show a gamma ray peak at the energy of 1039 keV, though due to the small amount of material activated and the sodium-iodide detector's inefficiency for this beta decay, no such spectra were seen. The gamma spectra obtained assisted with future SLICS experiments, as the creation of 64Cu will accompany 66Cu creation in the ^{65}Cu(d,p) ^{66}Cu reaction present in the most recent SUNY Geneseo particle accelerator experiment.

Future Work

To determine the amount of ^{64}Cu created by the SUNY Geneseo neutron howitzer and by the SUNY Geneseo particle accelerator, the efficiency of the Gamma-X NaI(Tl) detectors will be determined. This will assist Houghton College in determining the percentage of beta decays seen from the 64Cu, and eventually ^{66}Cu, which they should expect to detect in SLICS. Once the efficiency of the Gamma-X detectors has been determined, the full shielded Gamma-X counting system can then be utilized as a low background counting station to assist with SLICS instead of the unshielded detection setup.