Correlating reactor power with detector noise and Characterizing a D-T Neutron Generator

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Correlating Reactor Power with Detector Noise

Background

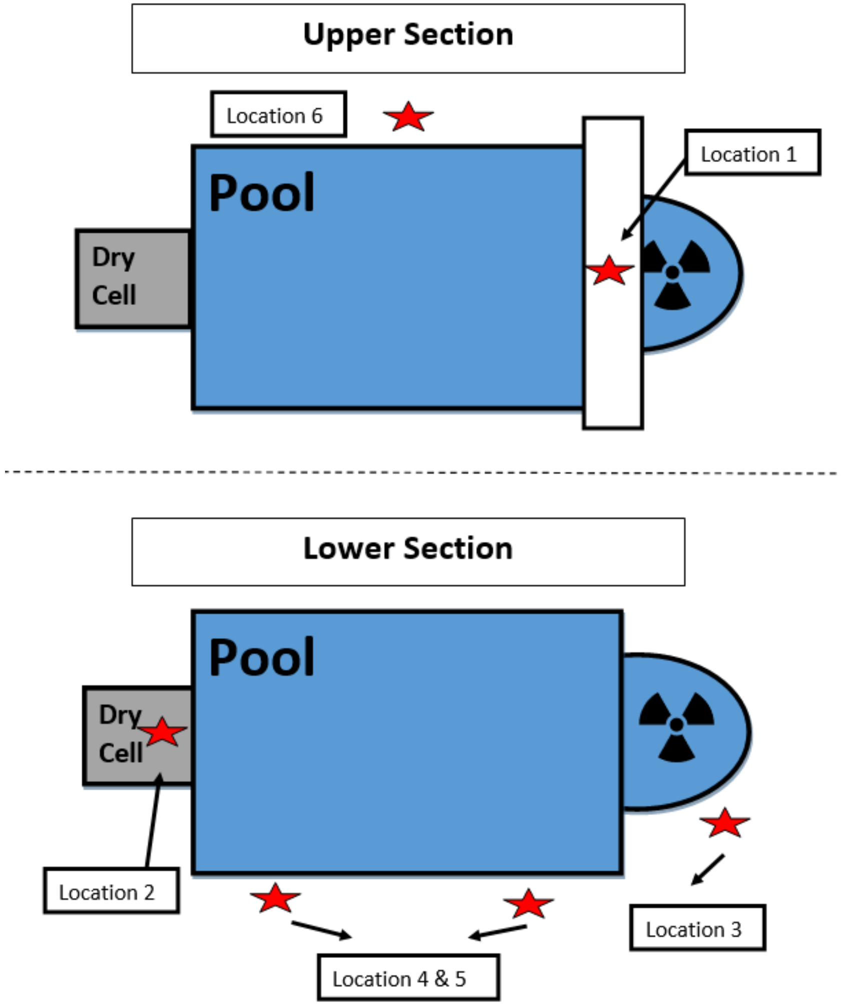
- Currently commercial and research reactors monitor the power of the reactor core using thermocouples and BF3 or Fission Chambers inside the core.
- With the push for smaller and more advanced reactor designs brings primary core systems operating at higher temperatures and therefore in-core instrumentation is more difficult to acquire due to the high temperatures
- Thermocouples can be used outside of the core but requires many instruments as well as higher grade quality due to the increased temperatures

Reactor Type	Operating Temperature (°C)
Pressurized Water Reactor/Boiling Water Reactor	200-300
Molten Salt Reactors	700-800
Very High Temperature Reactors	900-1000
Sodium Cooled Fast Reactor	500-600

https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/generation-iv-nuclear-reactors.aspx

Methodology

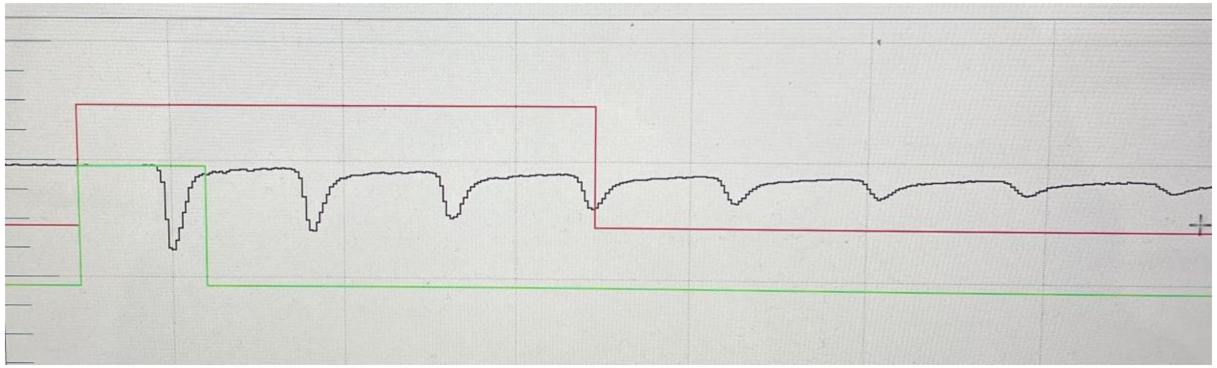
- Using the Texas A&M Mark II Triga Reactor, various detectors were placed around the outside of the primary core shielding and acquired data during normal operation of the reactor.
- Reactor operates from 1 W to 1 MW, capable of pulsing up to 1 GW for milliseconds
- Reactor is a pool type reactor capable of moving up and down the pool
- Detectors used:
  - 2x2 LaBr(Tl)
  - Polysiloxane Detectors
  - He-3 Proportional Counters
  - Boron Lined Proportional Counters
  - BF-3 Proportional Counters



Results

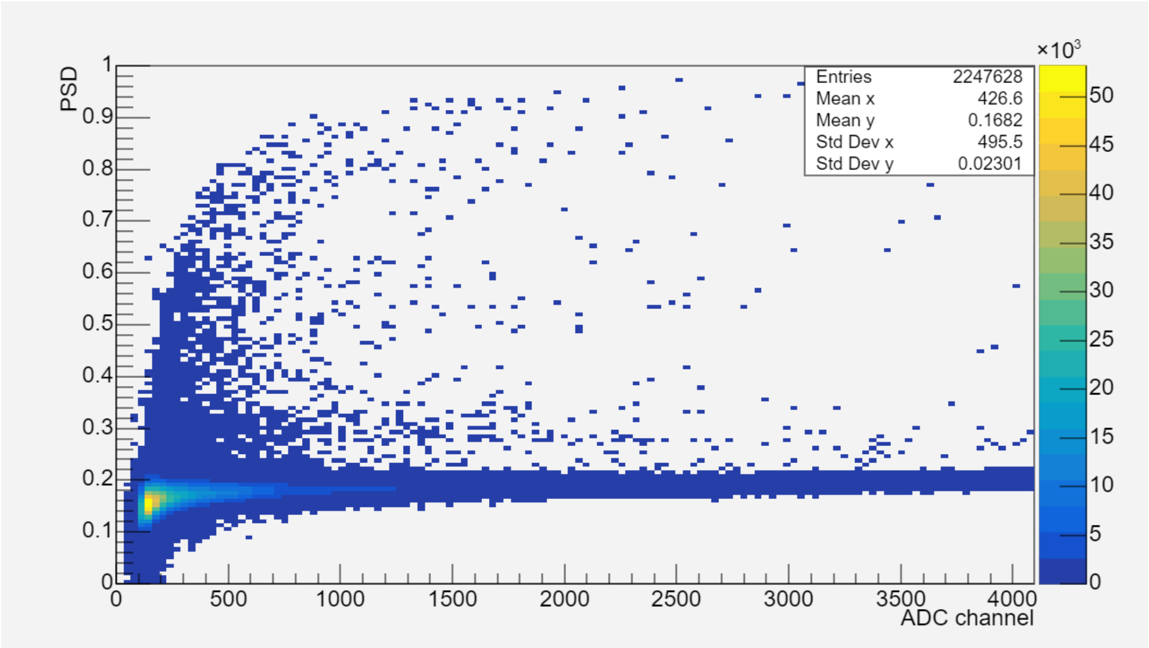
Waveform from detector

- Waveform consists of multiple waves rather one single wave
- Caused by noise from the power outlets



PSD vs ADC Channel Plot for EJ-309 above Reactor Core

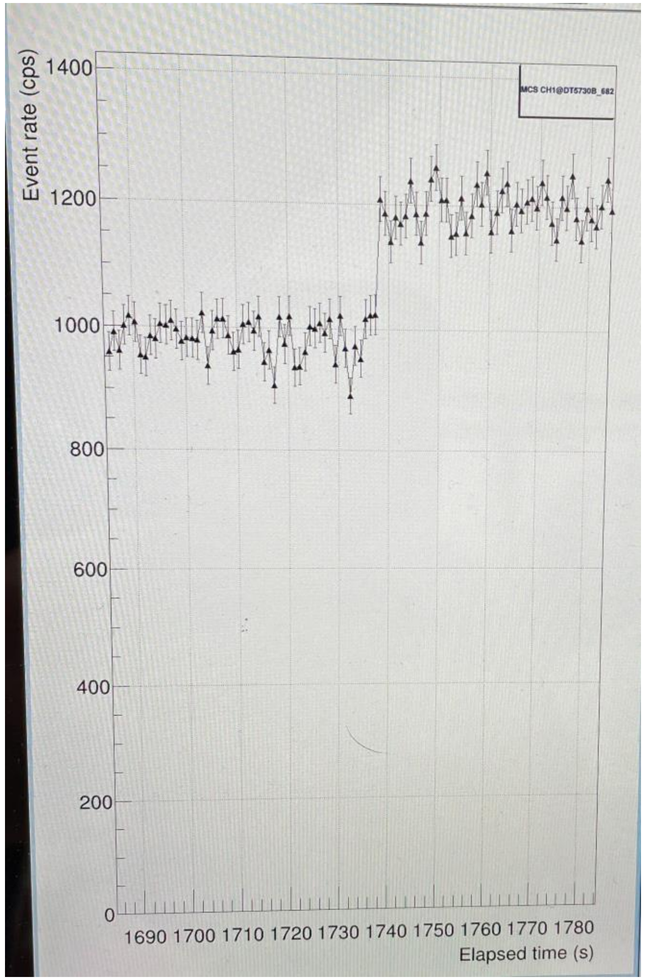
- Radiation field is primarily gamma



Results

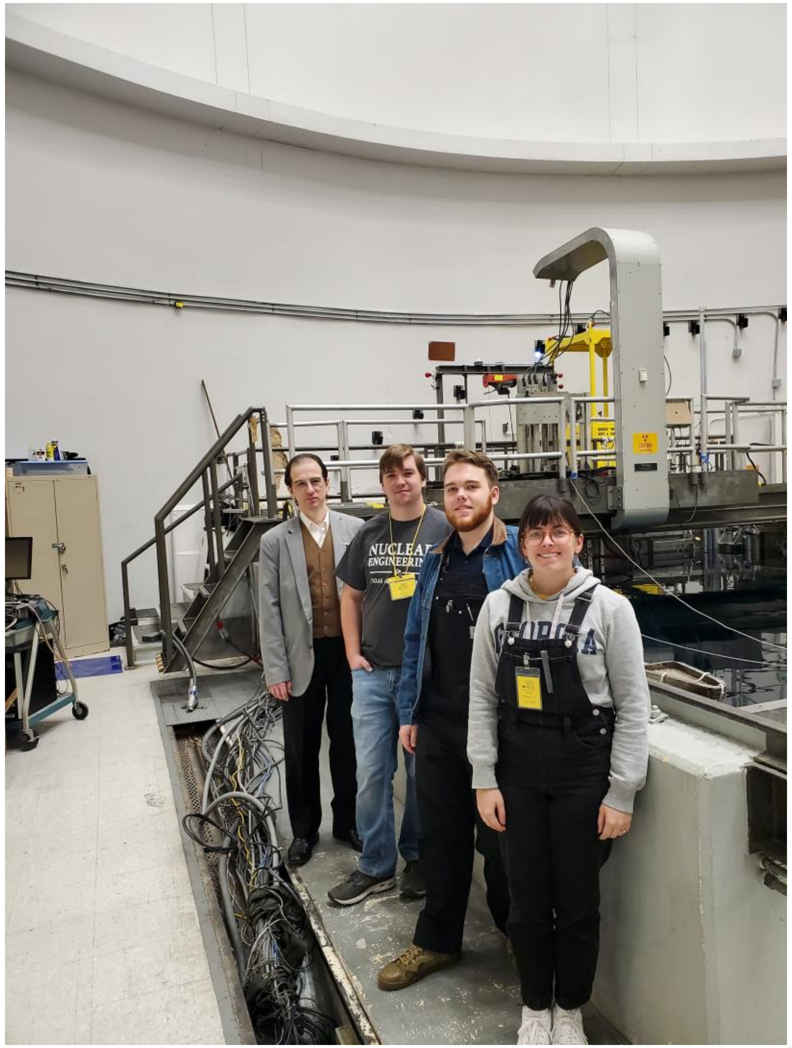
Count Rate vs Elapsed Time for LaBr Detector above reactor

- Power was increased from 1 W to 5 W
- Can visibly detect a change in power based on the count rate



Future Work

- Replicate reactor environment using sources located in basement or in lab by adding various shielding and changing power by changing detector distance to source
- Gather new results for analysis
- Perform simulations in MCNP or GEANT4



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Characterizing a D-T Neutron Generator

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Background

- Deuterium-Tritium Neutron generators are commonly used neutron sources for non-destructive assay, nuclear interrogation, and research
- Using neutron sources when conducting research, it is good practice to know the sources strength and spectrum to accurately interpret results.

https://www.x-raymachinefactory.com/news/saudi-arabia-jeddah-port-vehicle-hydraulic-sel-56341175.html

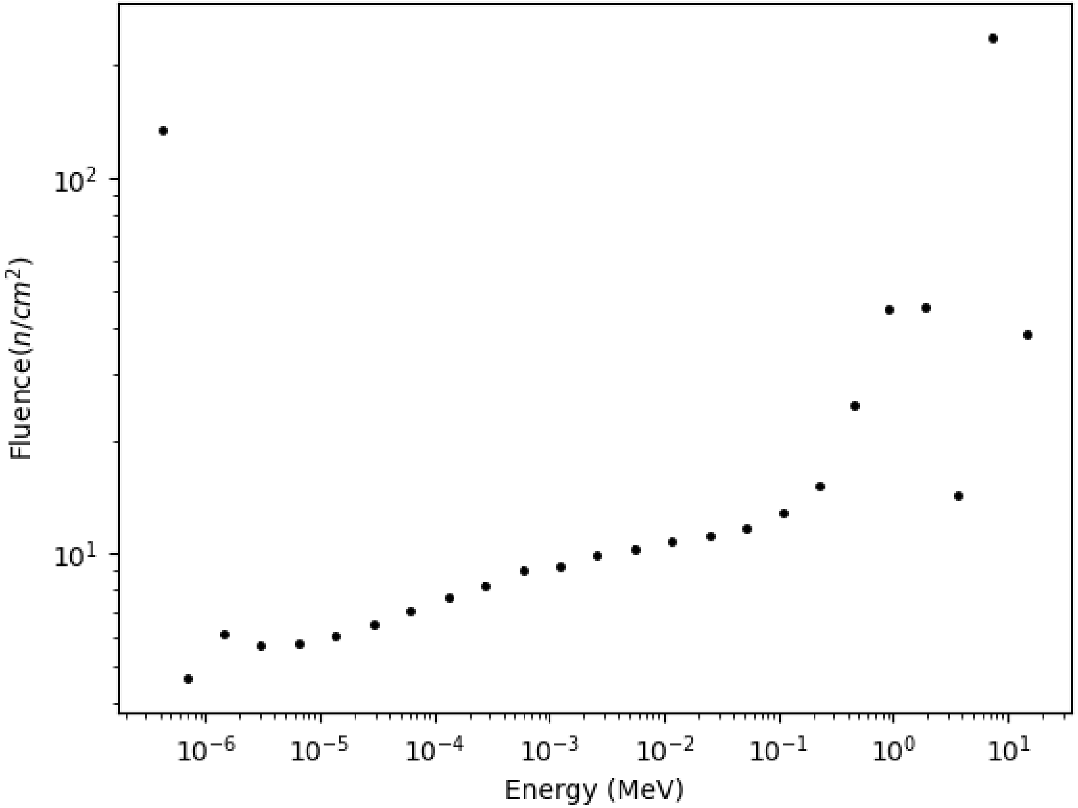
Methodology

- Thermo Scientific P 211 Pulsed D-T Neutron Generator was characterized for the neutron spectrum and neutron flux
- Bonner Sphere Spectroscopy system was used to determine the neutron spectra
- Shieldwerx Fast Neutron Foil Activation set was used in conjunction for the flux determination
- Modified Texas Convention Method for neutron flux determinations was used to calculate the neutron flux

Bonner Sphere Spectroscopy Results

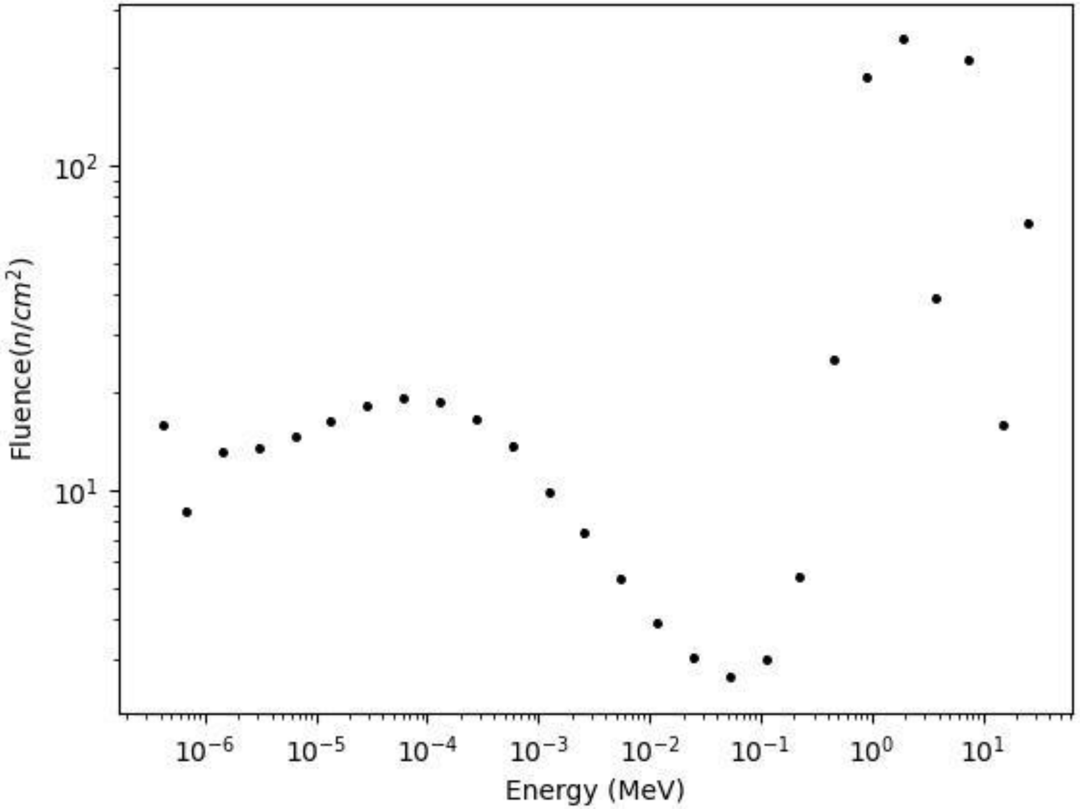
D-T Neutron Spectra

- Spectra shows peak at ~7 MeV when D-T reaction produces 14.1 MeV neutrons
- Large amounts of lower energy neutrons

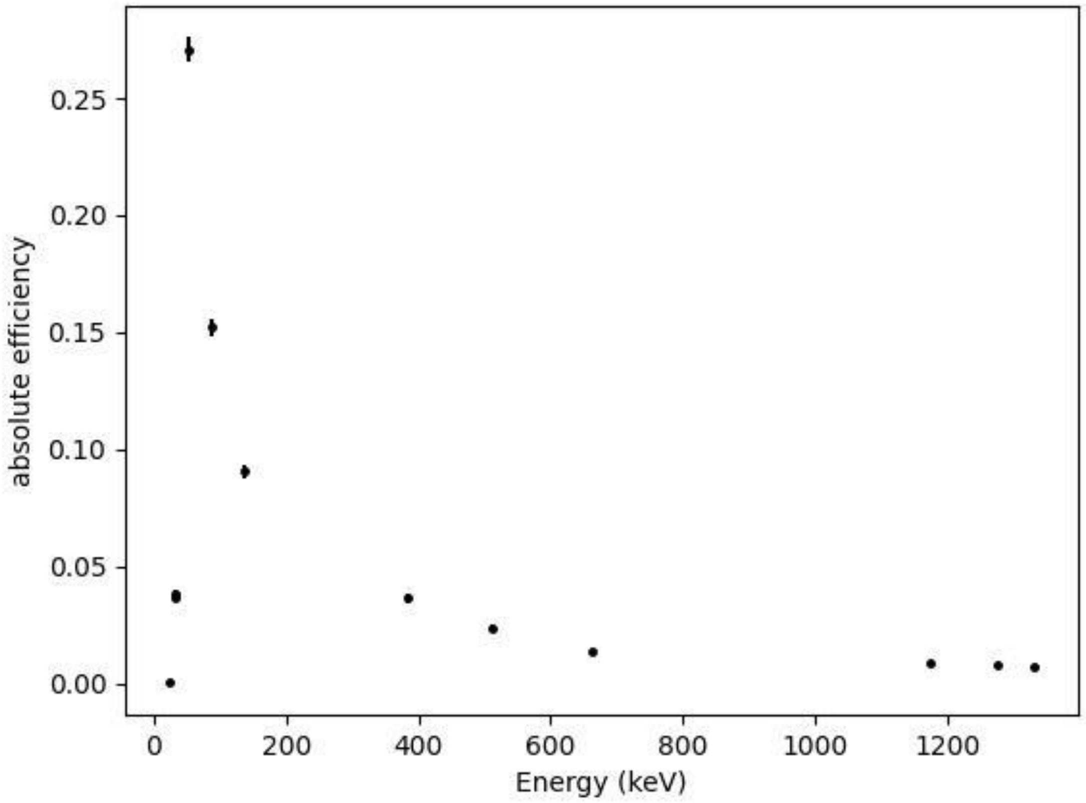


D-D Neutron Spectra

- Double peak (~2 MeV and 5 MeV)
- Large amount of lower energy neutrons



Efficiency Calculation for HPGe Detector



Absolute efficiency versus Energy for the HPGe Detector

- Calibration source kit from Berkely Neutronics was used
- Interspec by Sandia Labs was used for the spectroscopy software.
- Need to fit the curve

Neutron Flux Calculation

$$\phi = \frac{\frac{\sigma_t \lambda C}{\epsilon I \pi R_0^2 a \sigma} / \left[1 - \exp\left(-\frac{\sigma_t m N_A}{\pi R_0^2 M_M}\right)\right]}{[1 - \exp(-\lambda t_{irr})] \exp\left(-\lambda t_{decay}\right) [1 - \exp(-\lambda t_{meas})]}$$

Modified Texas Convention Method for Neutron Flux Calculations & Results from Foil Activation

- Texas Convention Method only uses the ${}^{65}Cu(n,2n){}^{64}Cu$ reaction, modified makes use of multiple reactions
- Manufacturer predicts 15×10^{6} $n/cm^2/s$ flux at foil irradiation location

Foil	Reaction	Gamma Ray (keV) (Intensity (%))	Half-Life	Neutron Flux ($n/cm^2/s$)
Aluminum	${}^{27}Al(n,p){}^{27}Mg$	843.76 (71.8)	9.458 mins.	$6.54 \times 10^{6} \pm 1 \times 10^{5}$
Aluminum	${}^{27}Al(n,p){}^{27}Mg$	1014.52 (28.2)	9.458 mins.	$8.8 \times 10^{6} \pm 7 \times 10^{4}$
Copper	${}^{63}Cu(n,2n){}^{62}Cu$	511.0 (195.66)	9.673 mins.	$4.0 \times 10^{4} \pm 343$
Iron	${}^{56}Fe(n,p){}^{56}Mn$	846.76 (98.85)	2.57 hrs.	$2.86 \times 10^{5} \pm 1 \times 10^{4}$
Iron	${}^{56}Fe(n,p){}^{56}Mn$	1810.73 (26.9)	2.57 hrs.	$2.51 \times 10^{5} \pm 4 \times 10^{3}$
Iron	${}^{56}Fe(n,p){}^{56}Mn$	2113.09 (14.2)	2.57 hrs.	$3.12 \times 10^{5} \pm 1 \times 10^{4}$
Zinc	${}^{64}Zn(n,2n){}^{63}Zn$	511.0 (185.5)	38.47 mins.	$8.06 \times 10^{5} \pm 1 \times 10^{4}$

Next Steps

- Determine the neutron spectrum with a finer resolution mesh using either a threshold reactions from activation foils or a different neutron spectrometer
    - STAYSL PNNL
- Redo the foil measurements and get a better flux determination
- Retrieve a Gamma-Ray spectrum from the generator
- Perform the measurements in a scatter free facility

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Laboratory Work

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Boggs 3-68 X-Ray Systems

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COMET SYSTEM

- August 2022, COMET system sitting idle inside Boggs 3-68
- February 2023, COMET system installed in Boggs 3-68
  - Electrical and Interlocks installed
  - Undergraduates currently working on building the stand for the x-ray tube
  - Project complete when Marietta NDT inspects room and systems, and initiates warranty

Hamamatsu Generator

- Have all the components for the interlocks and communications
- Need to install into the COMET interlocks and then inspected by Marietta NDT

3-19 SYSTEM

- Dr. Erickson has found money to fix it, need quote to order replacement parts

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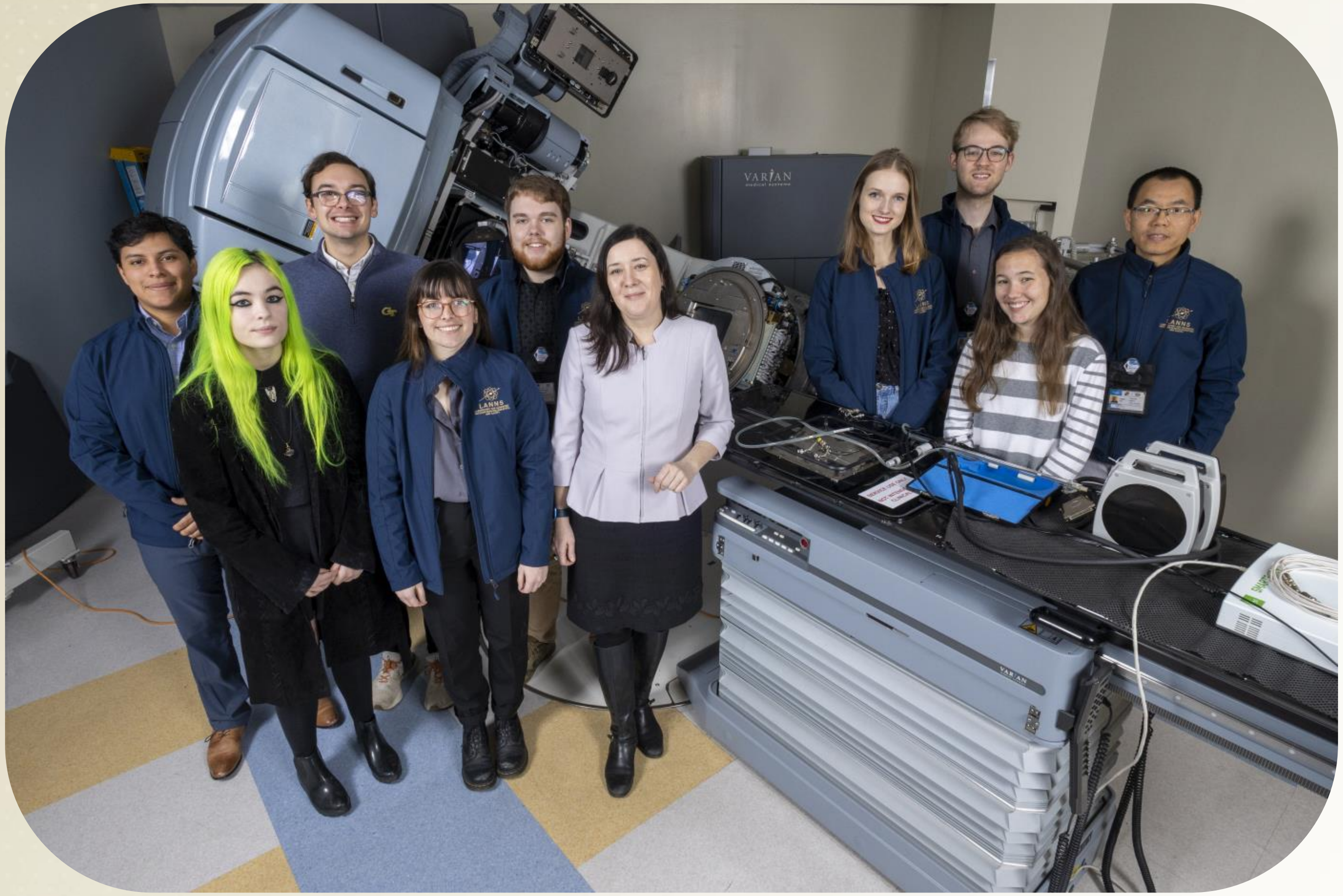
Thank you



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