Measurement of D-T Neutron Source Flux by Self-Neutron Activation Analysis with a $LaBr_3$ Detector

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Introduction and Motivation

- Active interrogation can be used to detect shielded SNM and other nuclear material. Neutron generator is often used as the interrogating source.
- Knowledge of absolute neutron output of a neutron generator is essential to predict reaction rates and validate simulations.
- Measurements can be subject to assumptions that are challenging to verify.
- Activating a $LaBr_3$ detector could simplify flux measurement because reactions of interest have high thresholds, the detector constrains its own β emissions, and activation products have relatively short half-lives.

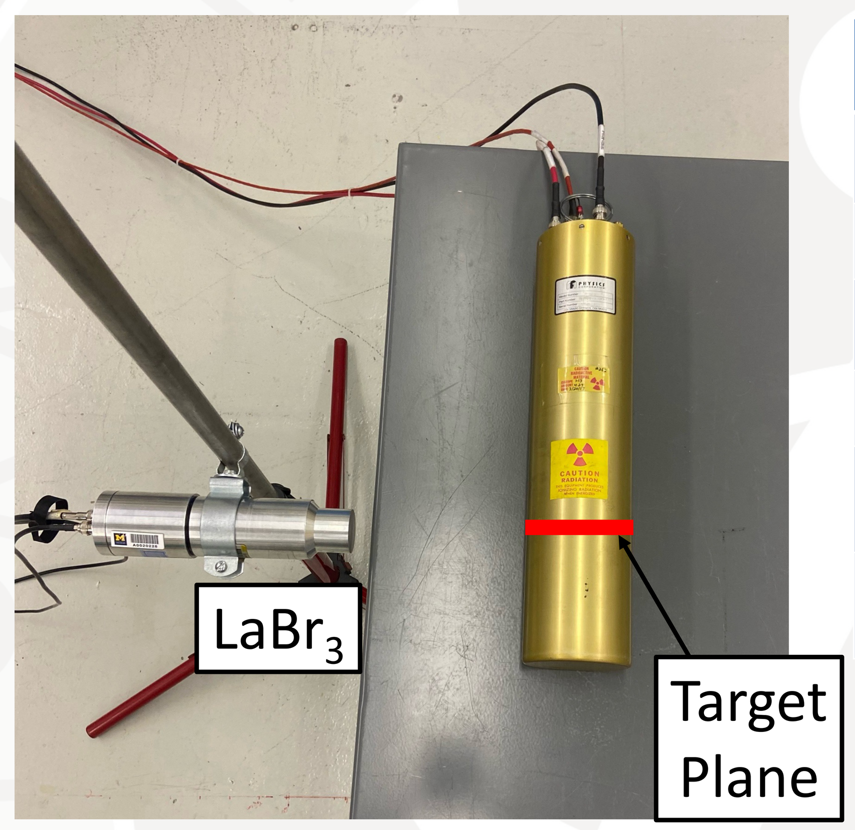
Mission Relevance

- Reduce uncertainties of nuclear analytical techniques that use neutron generators.
- Improve the capacity to detect and prevent illicit or unintended transfers of SNM.
- Support system development by better understanding of shielding and other regulatory requirements.

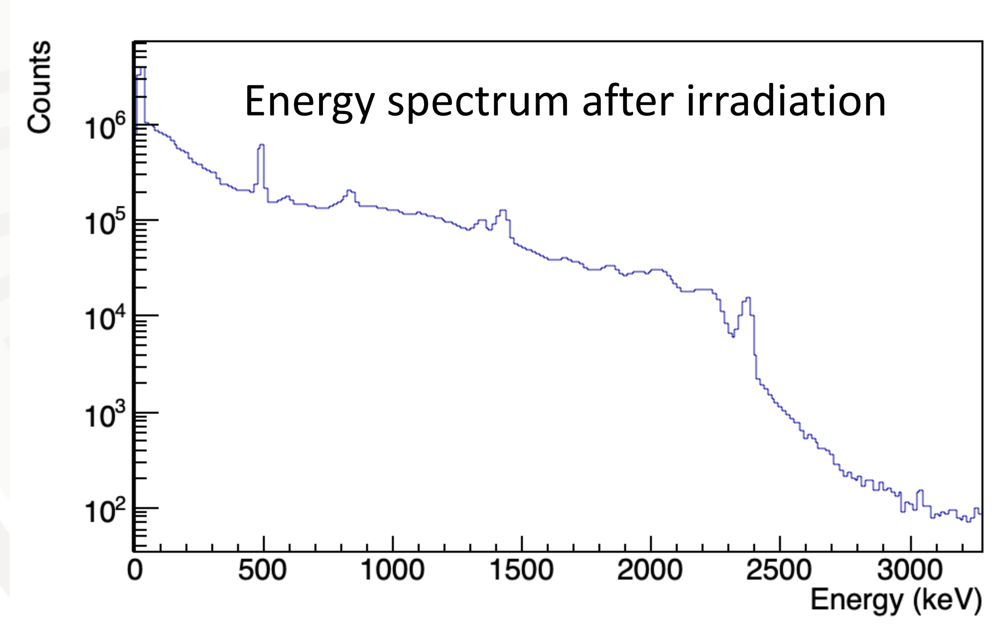
Technical Approach

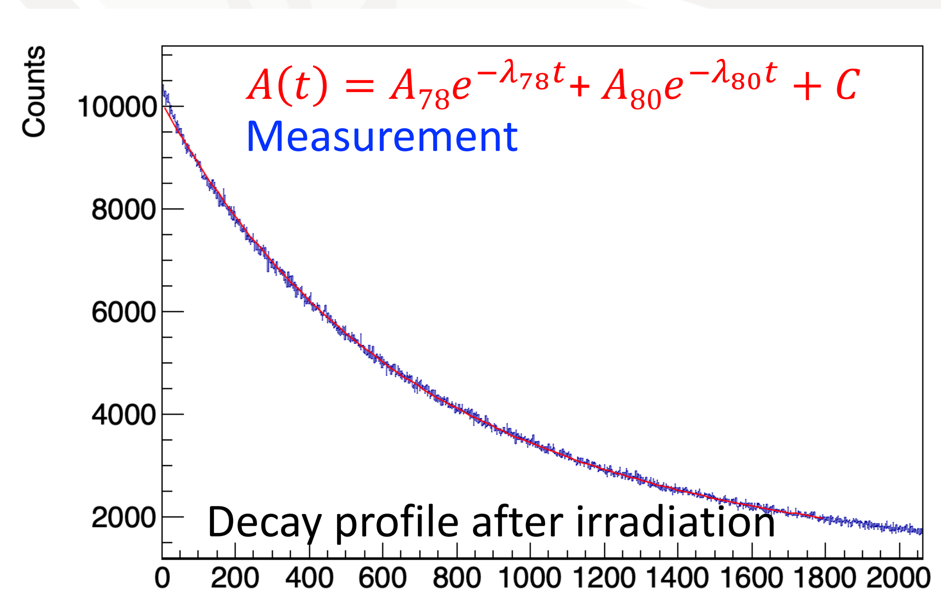
- Half-lives, cross sections, and thresholds for fast and thermal reactions of naturally occurring in a $LaBr_3$ detector were examined. The $^{79}Br(n,2n)^{78}Br$ was selected to determine the fast flux.
- The face of the detector was placed 20 cm from the target plane of the neutron generator and irradiated for 30 minutes to reach saturation activity.
- Decay of activation products was measured after the generator was shut off.

Thermal Reactions	Half-life
$^{79}Br(n,g)^{80}Br$	17.68 min
$^{81}Br(n,g)^{82}Br$	35.28 h
$^{139}La(n,g)^{140}La$	1.67 d



Fast Reactions	Q (MeV)	Cross Section (b)	Half-life
$^{79}Br(n,2n)^{78}Br$	-10.6	0.9	6.45 min
$^{79}Br(n,p)^{79}Se$	0.631	0.03	3.26 x10^5 y
$^{81}Br(n,2n)^{80}Br$	-10.1	1.02	17.68 min
$^{81}Br(n,p)^{81}Se$	-0.8	0.02	18.45 min
$^{139}La(n,2n)^{138}La$	-8.7	1.46	10^{11} y
$^{139}La(n,p)^{139}Ba$	-1.5	0.003	83 min





Results

Preliminary estimate:

- approximate the spectrum (100–2000 keV) to originate from ^{78}Br + ^{80}Br decay.
- fit initial activities and half-lives

	Forced Parameters	Unspecified Parameters	Percent Difference
A_{78} (Bq)	6075.60 ± 27.55	5918.11 ± 164.80	2.66 ± 2.90
$t_{1/2}(78)$	6.45 min	4.78 ± 0.08	34.94 ± 2.28
A_{80} (Bq)	3315.66 ± 32.45	3517.85 ± 211.47	5.75 ± 5.74
$t_{1/2}(80)$	17.68 min	12.84 ± 0.47	37.69 ± 5.04
χ^2/Ndf	1.09	1.03	

- Calculate flux and source strength from the fitted initial activity of ^{78}Br.

$$\phi = \frac{A_{78}(t=0)}{N_{79}\sigma(1-e^{-\lambda_{78}t_a})}$$

$$S = 4\pi\phi r^2$$

$$S = 6.44 \text{ x } 10^8 \pm 0.01 \text{ x } 10^8 \text{ n/s}$$

Expected Impact

- Generator characterization may become more routine if a simple and robust method is made available for applications.

MTV Impact

- MTV has allowed me to collaborate with Paul Hausladen and Jason Nattress at Oak Ridge National Laboratory to develop methods to verify results.

Conclusion

- Decay of ^{78}Br produced from the the $^{79}Br(n,2n)$ reaction is present in the spectrum plotted in the time domain.
- The neutron production rate reconstructed from preliminary estimate is ~6 x greater than the rated generator output
- Detailed analysis of activation needs to be carried out, and alternative method method of measurement should be used for comparison.

Next Steps

- Reduce scattering in measurement
- Monte Carlo simulation of activation is underway → properly account for various activation and decay reactions, and for flux attenuation in the detector.
- Measure neutron generator output using organic scintillators for comparison with the activation method.

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