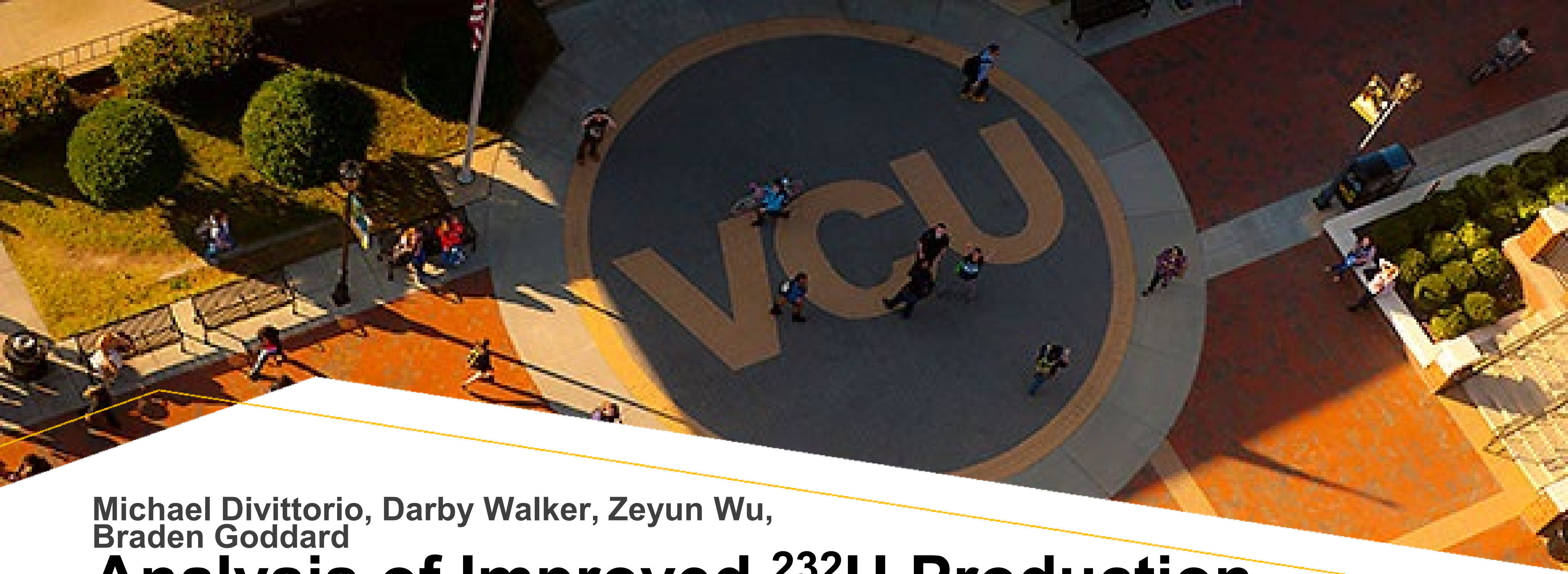

Michael Divittorio, Darby Walker, Zeyun Wu, Braden Goddard

Analysis of Improved ^{232}U Production Through Modification of Neutron Flux Spectra

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VCU College of Engineering
Mechanical and Nuclear Engineering

Motivation and Objectives

- ^{232}U has been identified by the scientific community as a potential tracer isotope and as a proliferation deterrent for use in uranium-based fuels [1].

- This research aims to improve the production of ^{232}U by analyzing the potential benefits of modifying neutron flux spectra on ^{230}Th targets.

- While this research was focused on the production of ^{232}U the process used for determining shielding materials can be applied to many isotope production applications.

Reaction Pathway Overview

- **Positive** interactions are those neutron interactions that lead from the starting target material to the desired nuclide.
- **Negative** interactions are those neutron interacts that lead away from the desired nuclide.

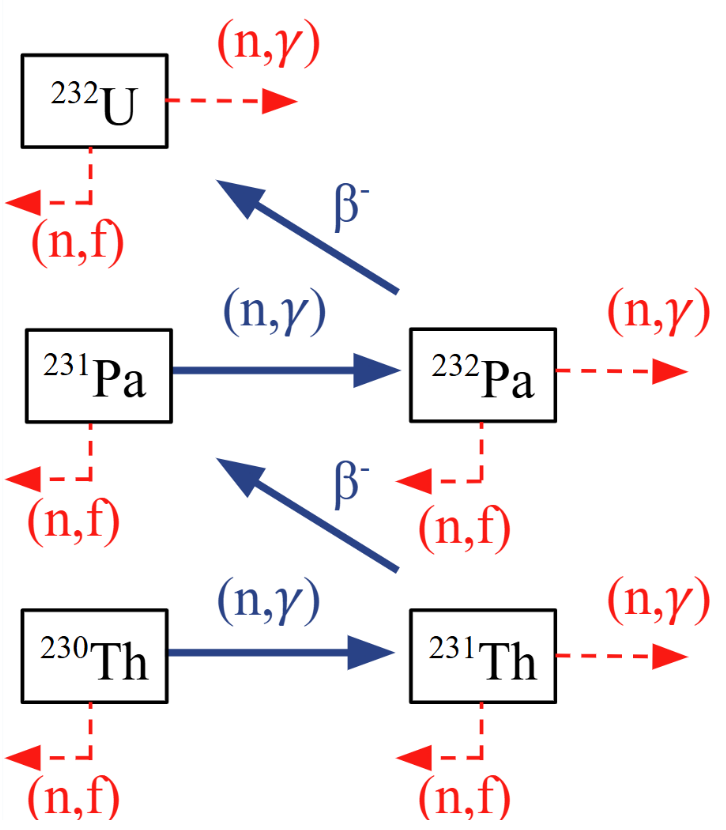


Figure 1: Production pathway for ^{232}U

Reaction Cross Sections

Taking a summation of the all **Positive** and all **Negative** interaction cross sections and plotting the two on a graph creates a visual tool that can aid in determining the optimal flux regions for production.

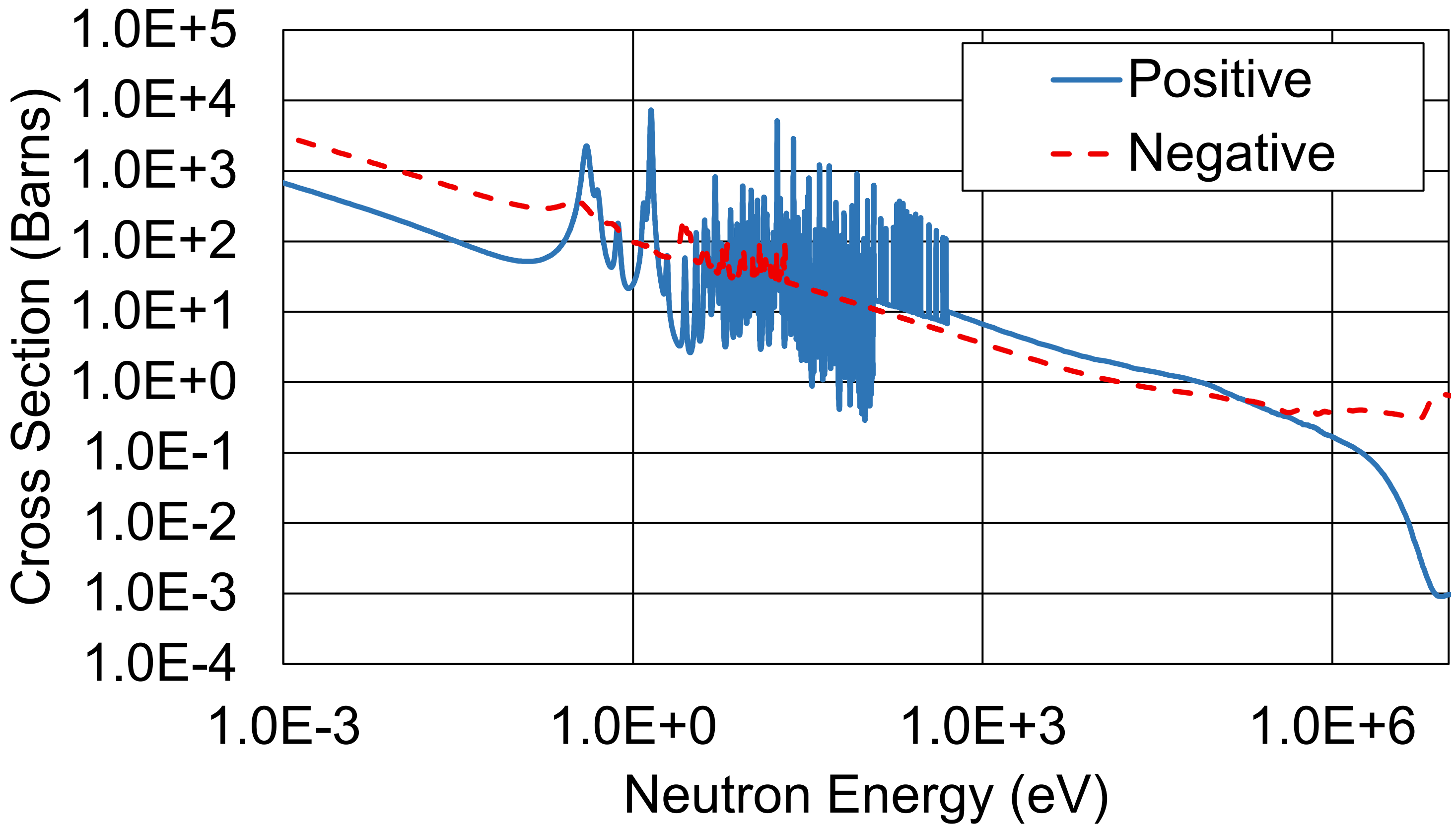
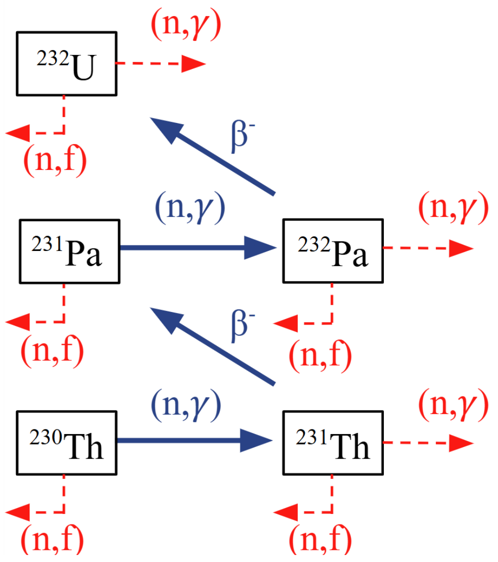


Figure 2: Positive vs negative cross sections



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HFIR Facility Overview

This research is focused on supporting experiments in Oakridge National Laboratory's High Flux Isotope Reactor (HFIR). For this reason, simulations were performed using the Monte Carlo N-Particle 6.3 (MCNP) Model [2]. The MCNP model of HFIR was provided by Oakridge National Laboratory [3].

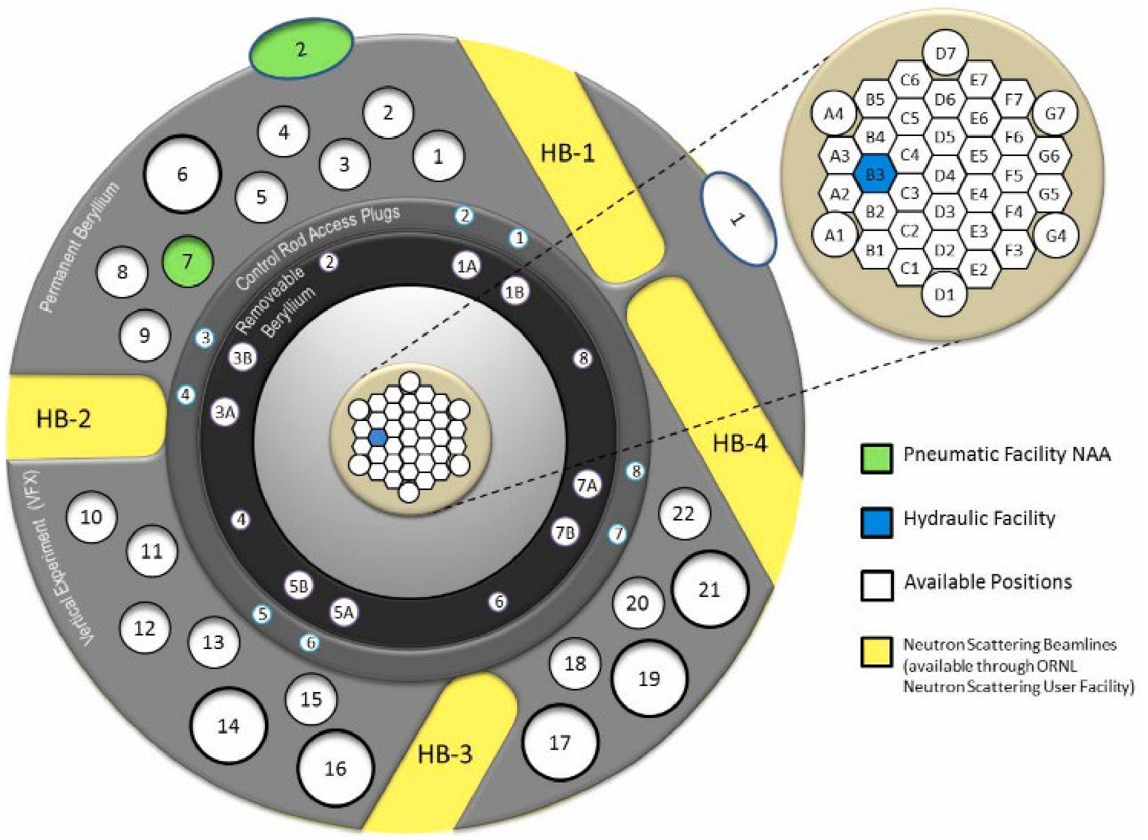


Figure 3: HFIR facility and D4 position [4]

Baseline Flux Spectrum

Plotting MCNP simulated neutron flux over top of the cross-section plots allowed us to determine flux regions that need to be modified.

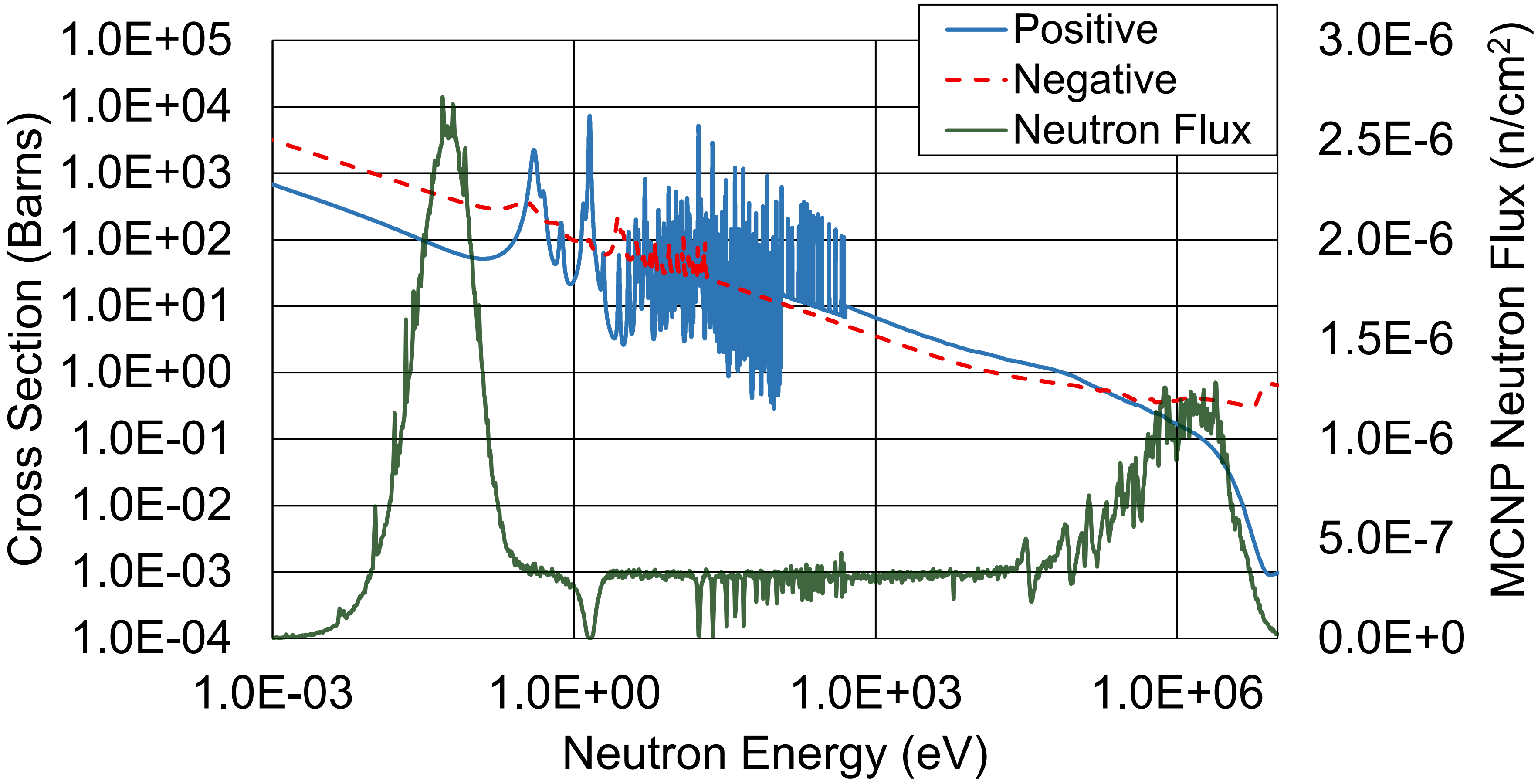
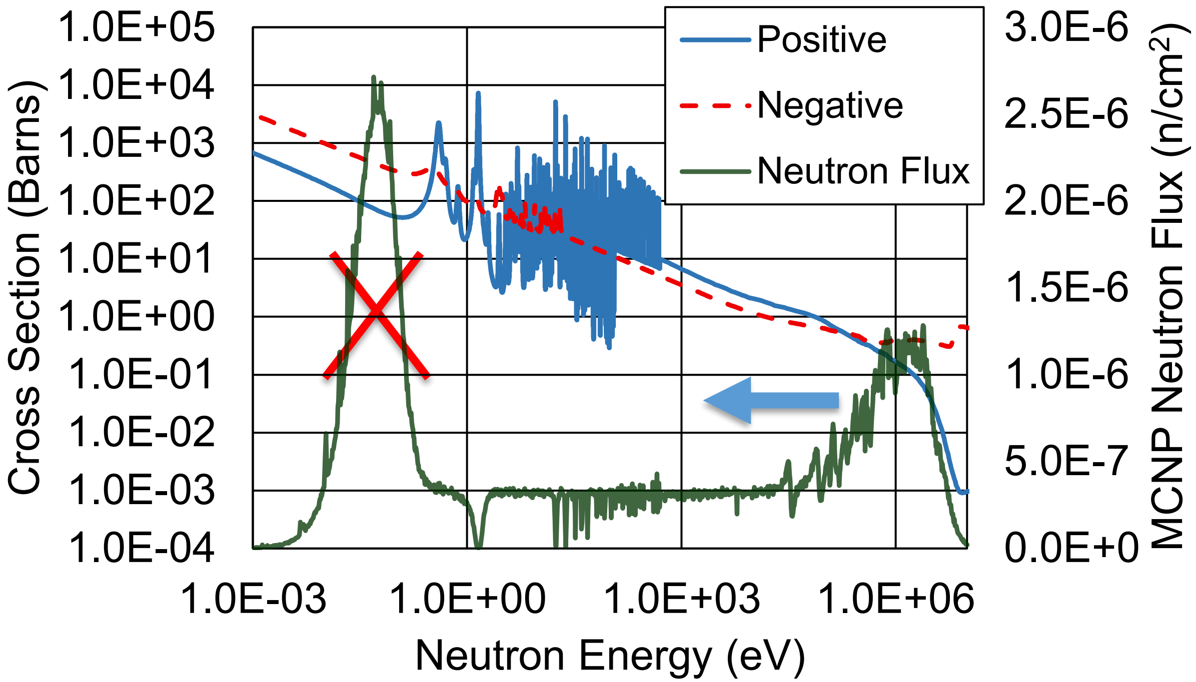


Figure 4: Unmodified flux spectrum

Shielding Material Selection

Based on the results of the neutron flux graph we determined we needed to eliminate the thermal region and moderate the fast. To accomplish this several shielding and moderating materials were examined.



Shielding Materials	Moderator Materials
Gadolinium	Graphite
Lithium	Light Water
Cadmium	Heavy Water
Boron	HDPE

MCNP Flux Gadolinium Filter

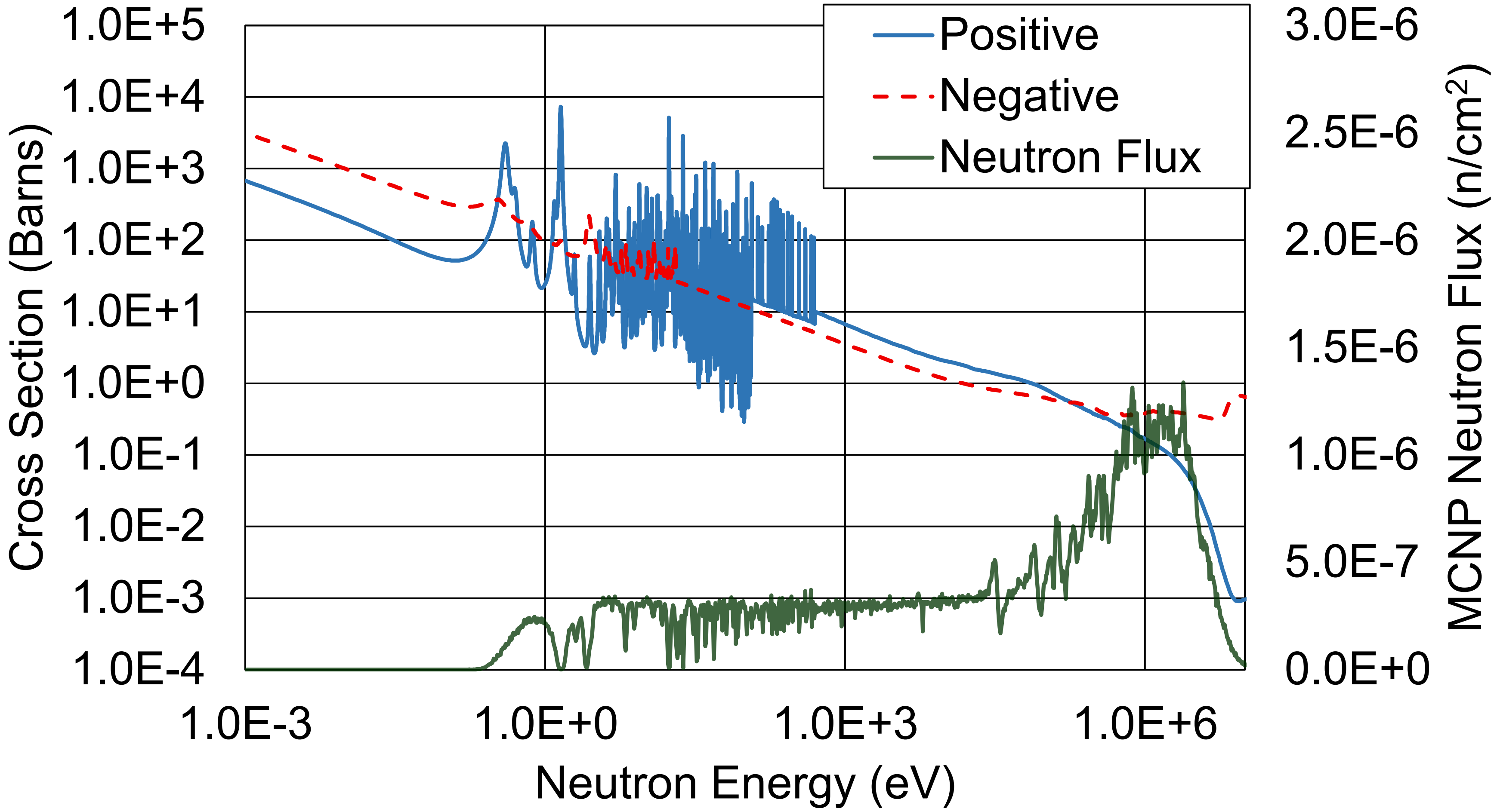


Figure 5: Gadolinium (1 mm) shielded flux spectrum

MCNP Flux Graphite + Gadolinium Composite Filter

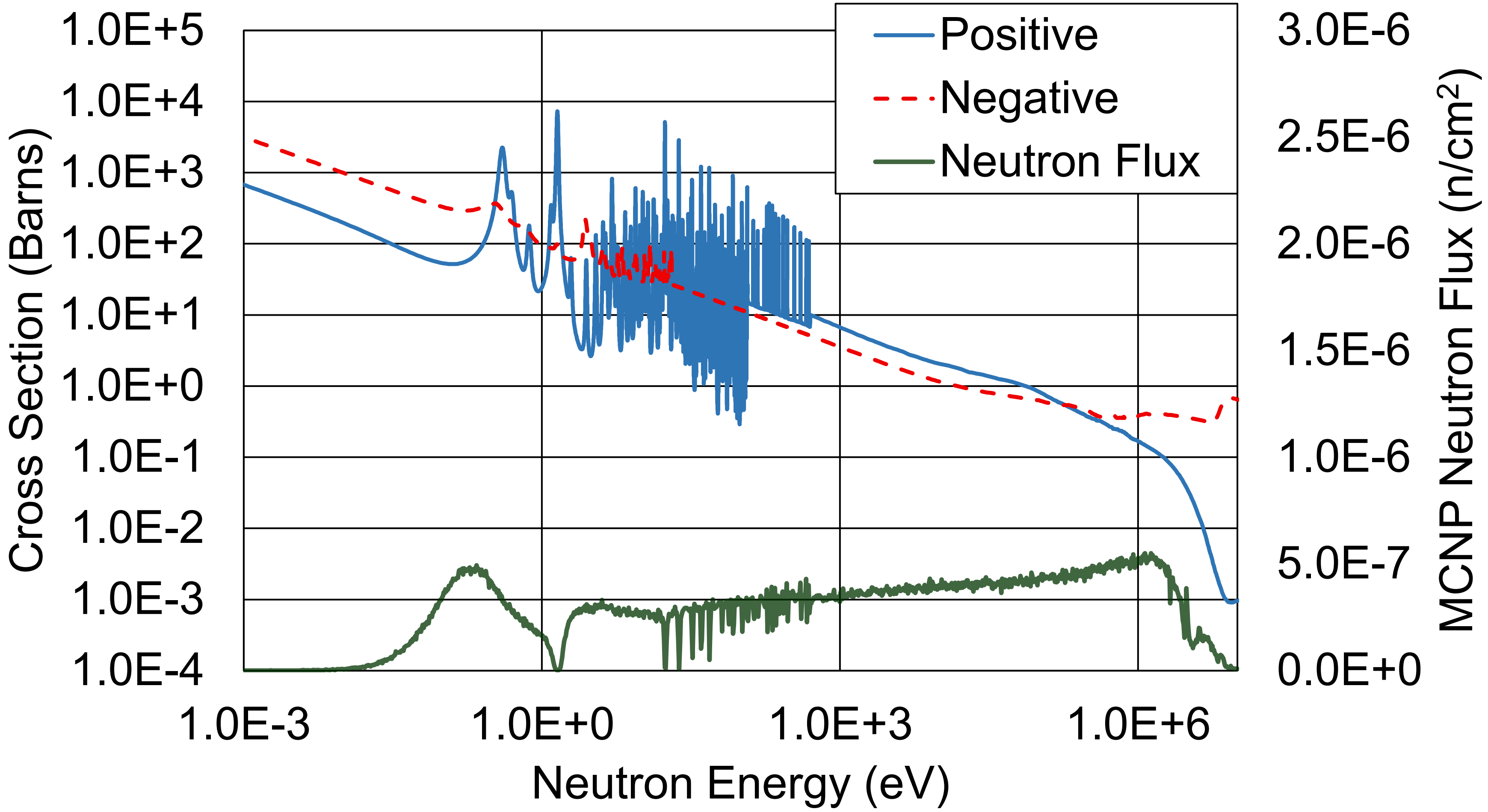


Figure 6: Gadolinium (1 mm) shielded; graphite moderated (10 cm) flux spectrum

MCNP Flux Graphite Filter

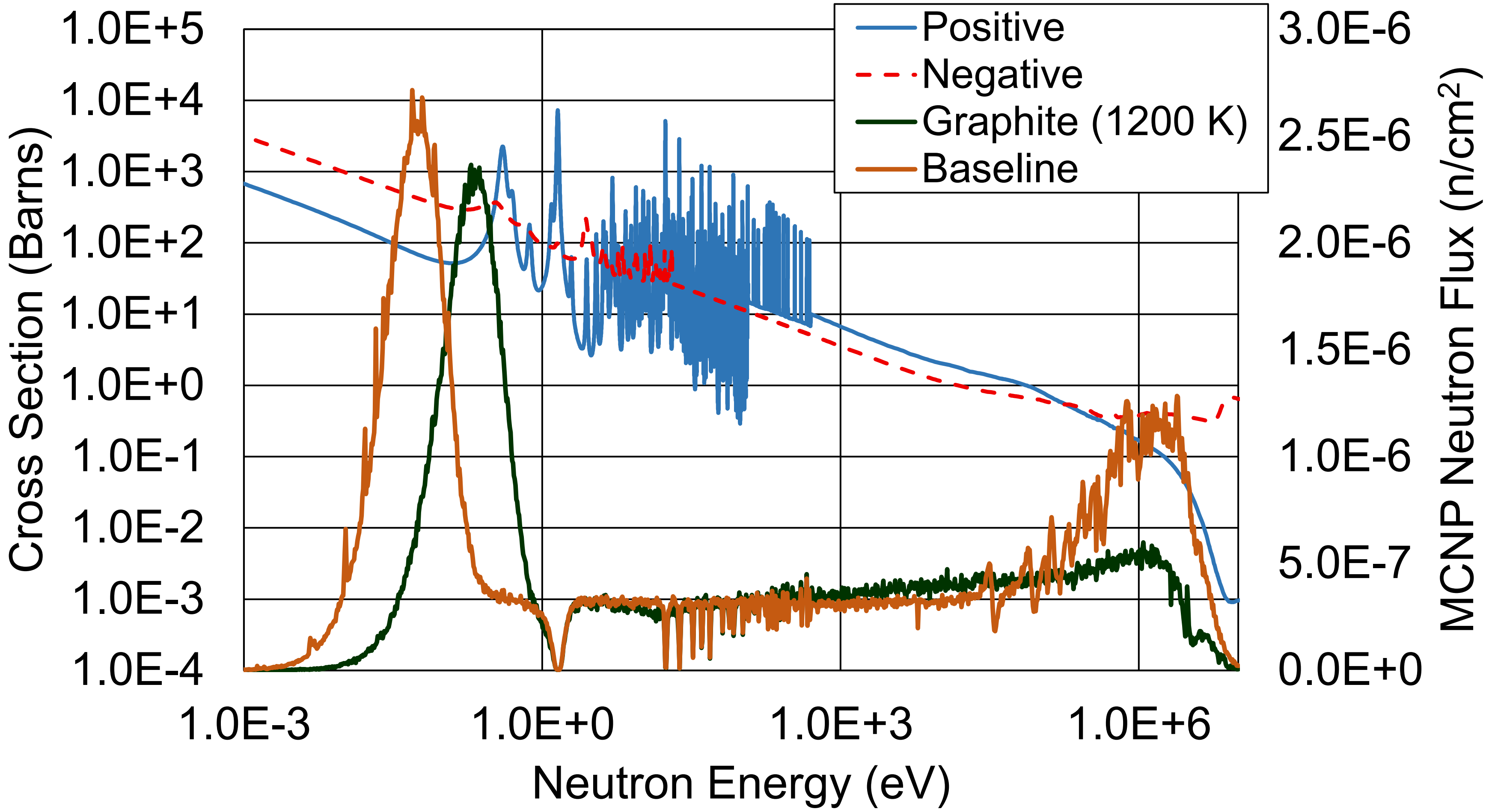


Figure 7: Graphite moderated (10 cm) flux spectrum

MCNP Flux Graphite Filter

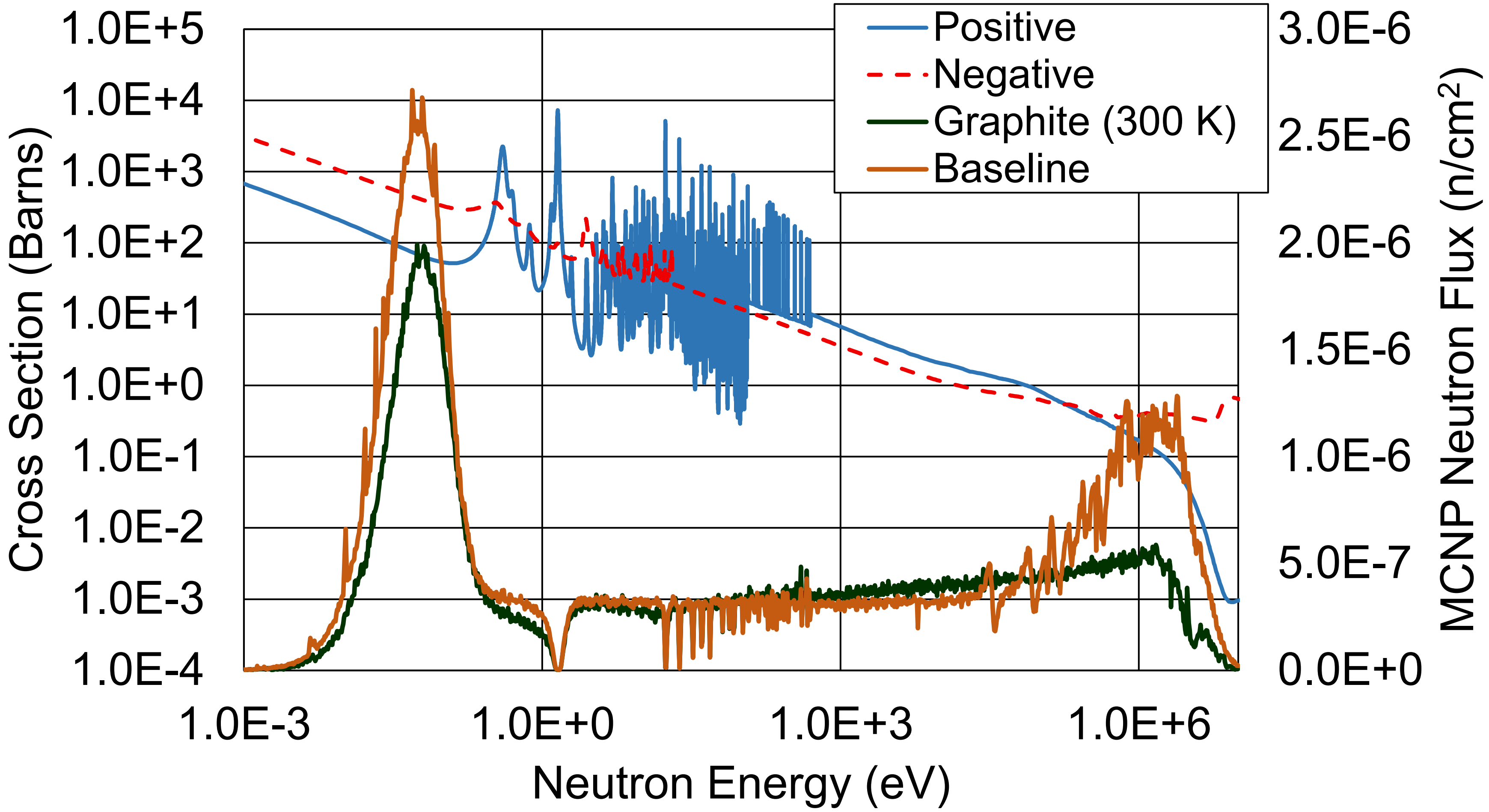


Figure 8: Graphite moderated (10 cm) flux spectrum

MCNP Flux Graphite Filter - Continued

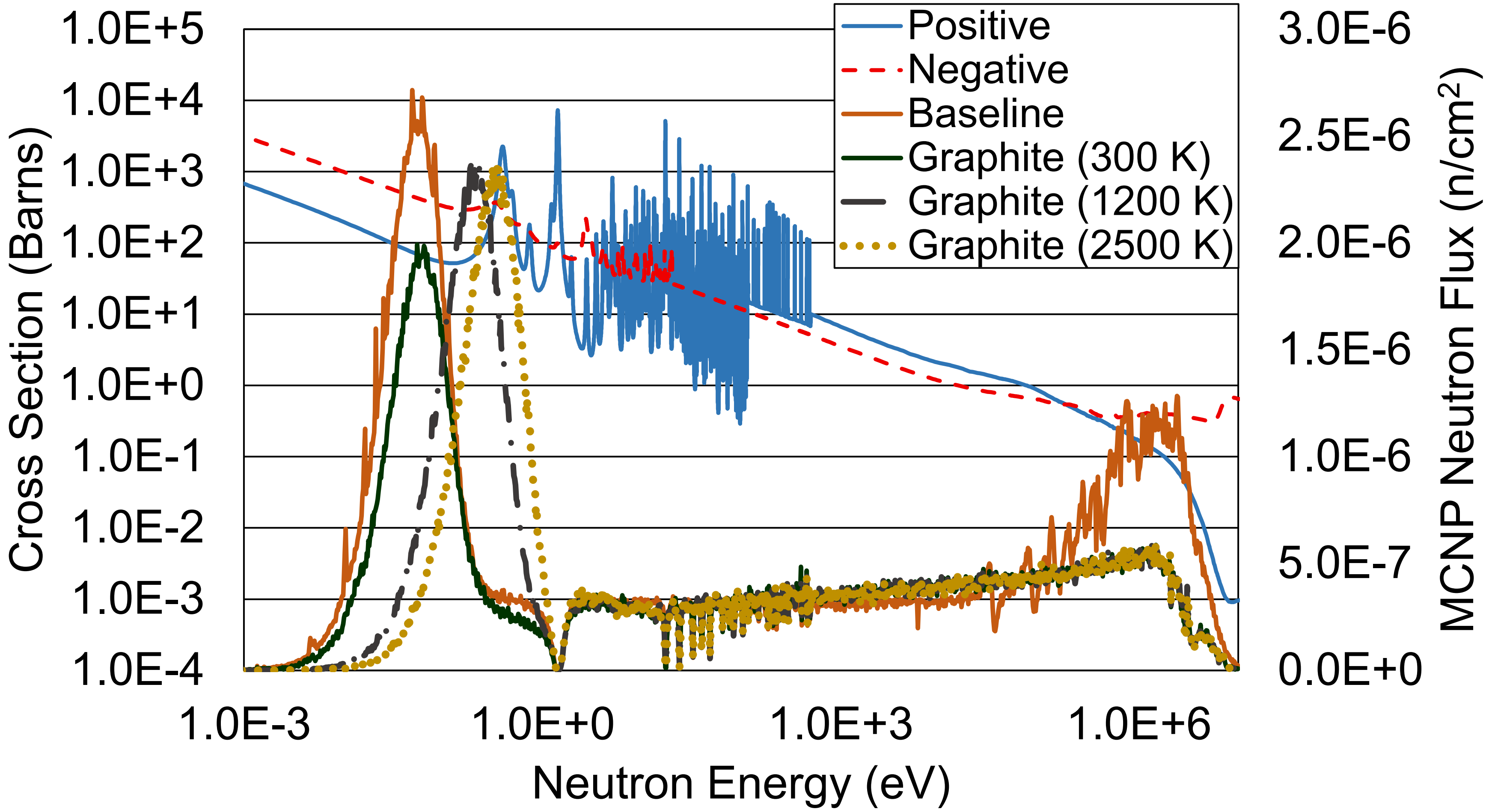


Figure 9: Graphite moderated (10 cm) flux spectrum at different temperatures

MCNP Burnup Analysis

With MCNP's Burnup tool we can simulate the irradiation of the ^{230}Th target in HFIR.

Several key metrics were used to gauge the improvement of modifying the flux spectrum.

- Mass of ^{232}U
- Production efficiency (η) - measures the percentage of consumed ^{230}Th that was converted into ^{232}U.
- ^{232}U Purity – measures what percentage of the produced uranium is ^{232}U.

Shielding material	Mass ^{232}U (g)	Production Eff. (η)	^{232}U Purity
No Shielding	1.3E-02 ± 3.2%	13% ± 0.5%	91.5% ± 0.3%
Gadolinium	1.0E-03 ± 10%	6% ± 0.6%	98.8% ± 0.3%
Graph. + Gd	1.1E-03 ± 11%	7% ± 0.9%	98.9% ± 0.5%
Graphite 300 K	7.2E-03 ± 12%	12% ± 0.2%	94.5% ± 0.1%
Graphite 1200 K	1.7E-02 ± 1.9%	24% ± 0.7%	95.0% ± 0.2%
Graphite 2500 K	2.0E-02 ± 1.5%	29% ± 0.1%	96.3% ± 0.1%

Acknowledgements

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References

[1] J. RHODES et al., “Exploration of producing uranium-232 for use as a tracer in uranium fuels,” *Applied Radiation and Isotopes*, 186, 110275 (2022).

[2] M. E. RISING et al., MCNP® Code Version 6.3.0 Release Notes. LANL Tech. Rep. LA-UR-22-33103, Rev. 1. Los Alamos, NM (2023).

[3] ILAS, GERMINA, CHANDLER, DAVID, ADE, BRIAN J., et al., "Modeling and Simulations for the High Flux Isotope Reactor Cycle 400," (2015),

[4] High Flux Isotope Reactor (HFIR) User Guide, Oak Ridge National Laboratory, Oak Ridge, TN (2015)