

Using Neural Networks to Model Multigroup Neutron Cross Sections

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Overview

- Deterministic particle transport tools (such as Griffin¹) require multigroup neutron cross-section data.
- Broad-group neutron cross sections must be tabulated not only on energy but also any parameters that can introduce self-shielding effects on the system such as temperature, burnup, control material position, etc.
- Traditional cross-section tabulation increase in size exponentially as the number of dimensions used for the tabulation increases.
- Reduced-order models can reduce the storage space and memory required for handling cross-section tabulations.

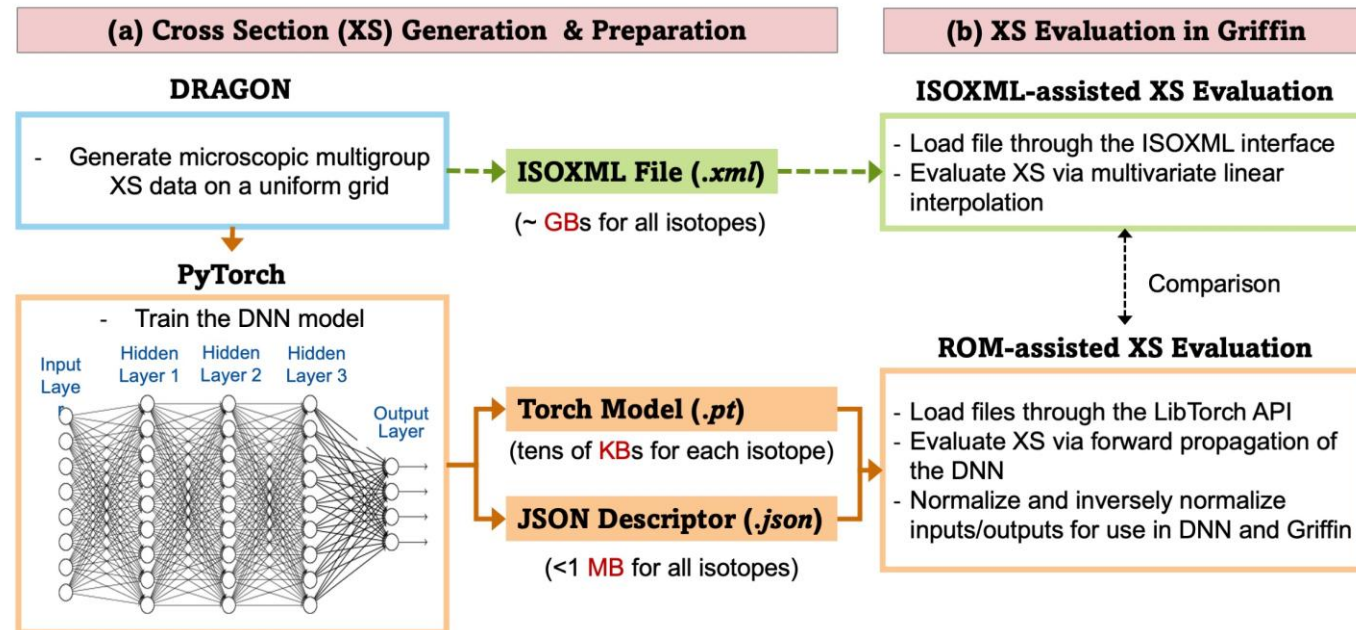
Number of Multiphysics Tabulation Variables	Memory Required for Tabulation
1	40.0 MB
2	800 MB
3	16.0 GB
4	320 GB
5	6.40 TB

Memory scaling with number of multiphysics variables used for tabulation assuming 500 nuclides, 25 energy groups, 20 reaction types, and 20 tabulation points per variable.

¹ Wang et al. “Griffin: A MOOSE-based reactor physics application for multiphysics simulation of advanced nuclear reactors.” Annals of Nuclear Energy (2025). DOI:10.1016/j.anucene.2024.110917

Deploying Neural Networks as Reduced-Order Models

- Deep neural networks (DNNs) are reduced-order models that can reduce the storage space and memory required for handling multigroup neutron cross-section tabulations.²



² Che et al. "Reduced-order modeling for efficient cross section library development in high-temperature gas reactor pebble-bed depletion analysis." Annals of Nuclear Energy (2026). DOI: 10.1016/j.anucene.2025.111956

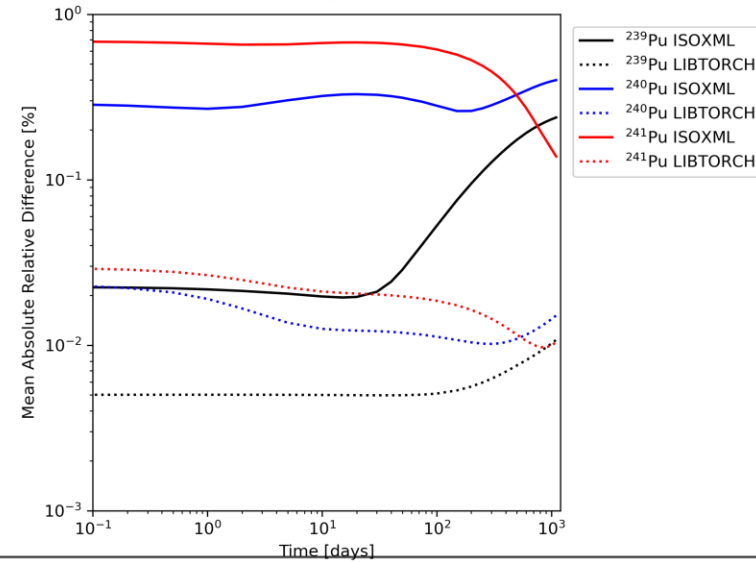
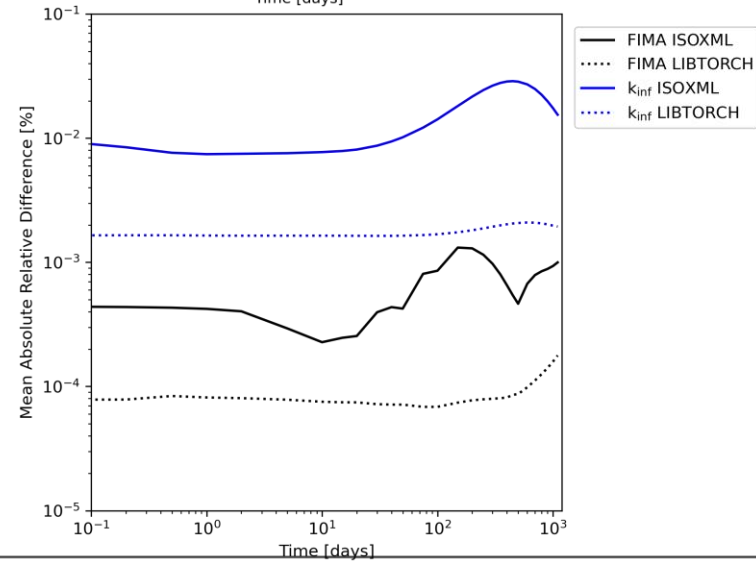
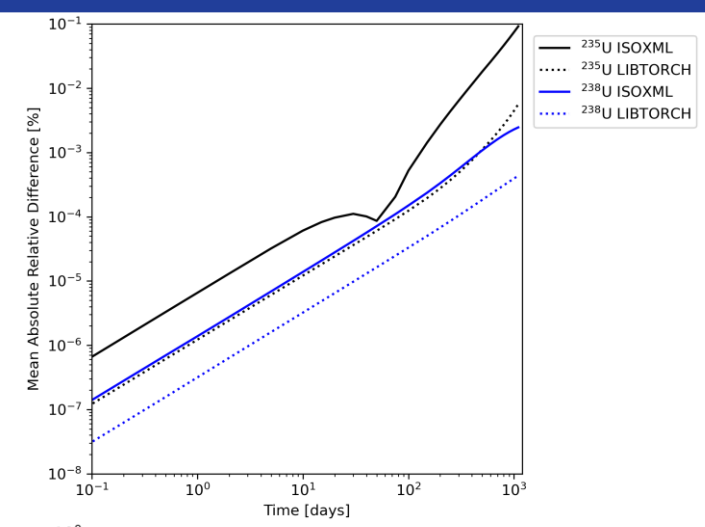
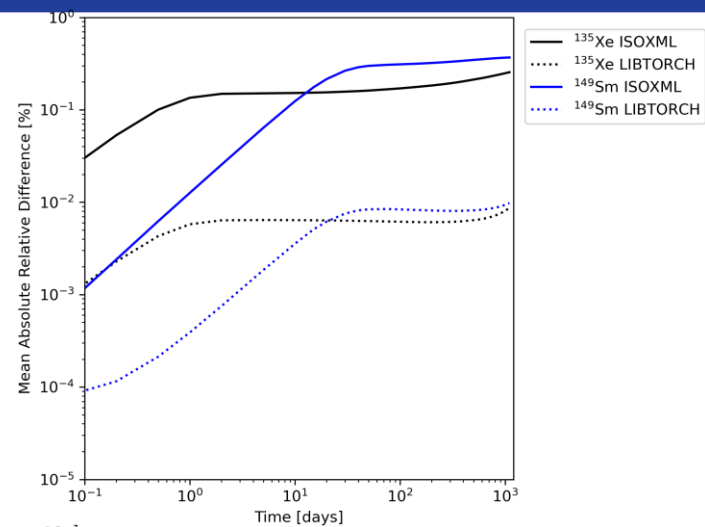
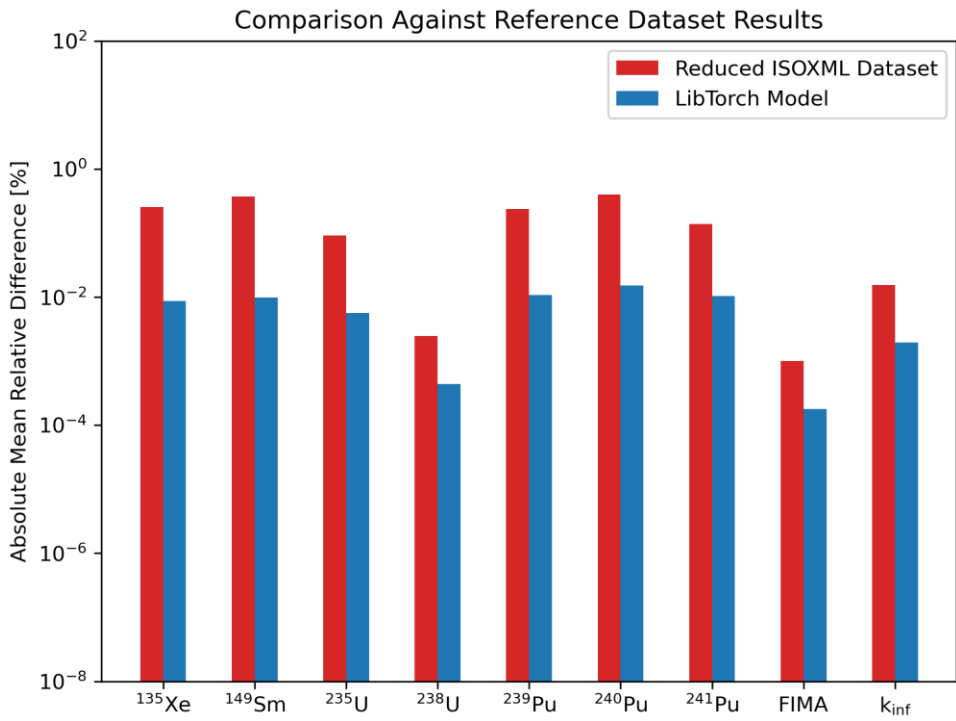
Implementation of Deep Neural Networks in Griffin

- The DNN models were generated using the open-source PyTorch application and trained on a four-group microscopic cross-section dataset generated by DRAGON5 for a pebble-bed reactor system.²
 - While DRAGON5 was used to generate the reference neutron cross-section tabulation, cross-sections can be generated from other tools, such as Shift or Griffin.
- MOOSE and MOOSE-based applications support LibTorch (PyTorch C++ API).
- The results generated by Griffin using the DNNs were compared against Griffin results using the reference dataset and a simplified dataset (1/64th of the tabulation points).

² Che et al. “Reduced-order modeling for efficient cross section library development in high-temperature gas reactor pebble-bed depletion analysis.” Annals of Nuclear Energy (2026). DOI: 10.1016/j.anucene.2025.111956



0D Fuel Pebble Depletion Comparison between DNNs (LibTorch) and the Simplified Tabulation (ISOXML)



Conclusions and Future Work

- DNNs can be trained on microscopic cross-section tabulations and outperform simplified cross-section tabulations in terms of accuracy, memory usage, and storage space.
- CPU Runtime is worse for DNNs because of the increased complexity of the DNN compared to a tabulation.³
- Investigate accuracy and performance effects from changing DNN complexity and training.
- Couple DNN generation and training to online cross-section generation capability in Griffin.

Quantity	Reference Tabulation	1/64 th Tabulation	DNN Model
Problem Setup Runtime [s]	1515	19.4	35.4
Problem Execution Runtime [s]	39.1	49.5	4336
Total Runtime [s]	1554	68.9	4372
RAM Usage [GB]	164.8	3.019	5.320
Storage Space [GB]	10.2	0.169	0.0112

³ Calvin et al. “Deployment of neural-network-based neutron microscopic cross sections in the Griffin reactor physics application.” Annals of Nuclear Energy (2025). DOI: 10.1016/j.anucene.2025.111509



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