Parameter interpolation for MSR core physics modules

2019 Technical Workshop on Fuel Cycle Simulation Physics & Technology Modeling

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Outline

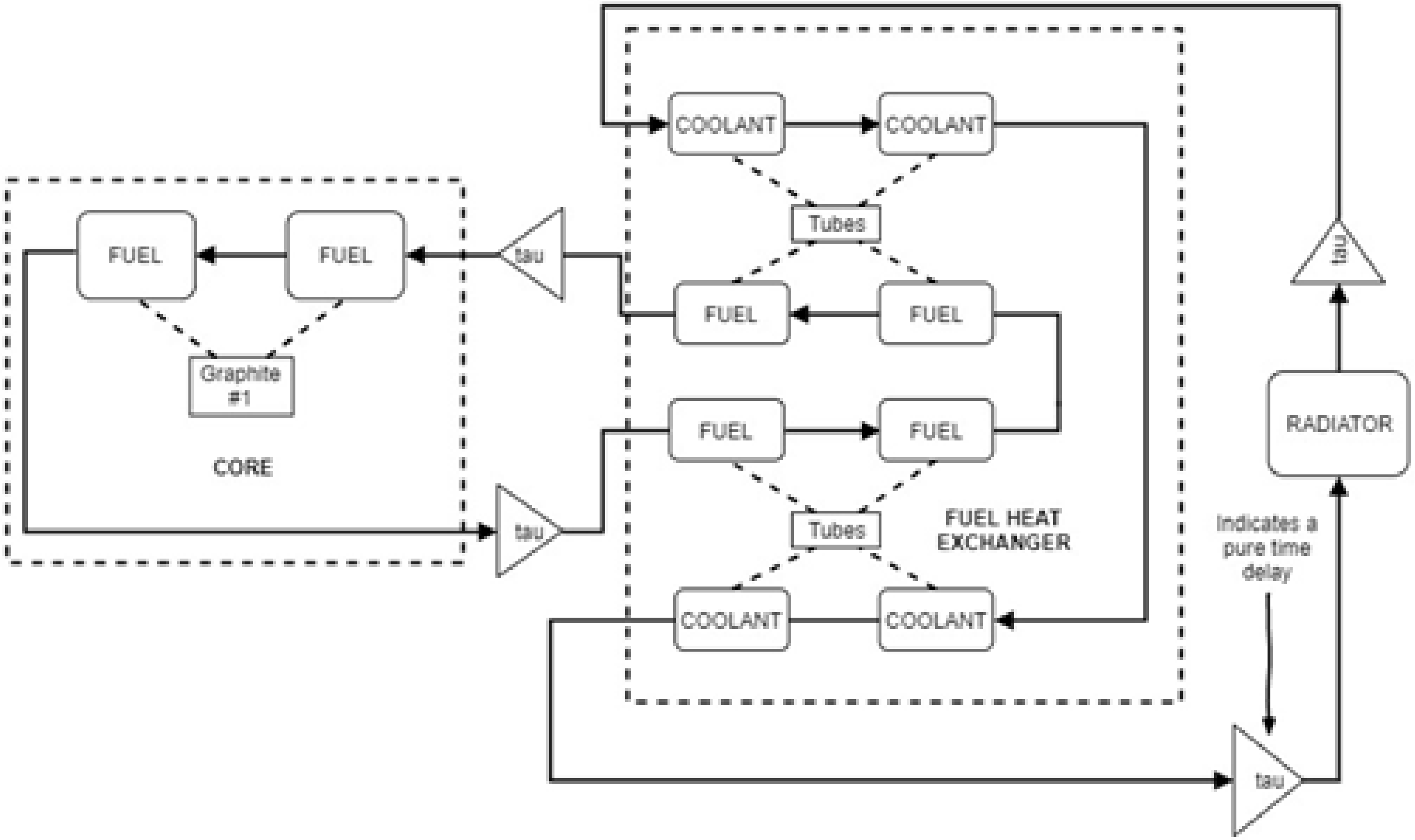
- Overall Research Project and Motivation
- Reactor Core Physics Module
- Reactor Data Libraries
- Interpolation and Spacing of Libraries

Project Goal and Motivation

- Project Goal is:
  - Develop a modular software framework to allow the testing of MC&A methods on a variety of MSR designs

- The Motivation is:
  - No reactors to test methods on
  - Large variety in the design space

Block Diagram of a Simple Model



Reactor Core Physics Module - Requirements

- Requirements:
  - Calculate depletion of fuel salt and PK data
  - Fast computational solution time
  - Ability to cover large design space

Reactor Core Physics Module - Methodology

- Requirements:
  - Calculate depletion of fuel salt and PK data
  - Fast computational solution time
  - Ability to cover large design space
- Methodology:
  - Utilize pre-generated collapse data libraries to run point depletion calculations

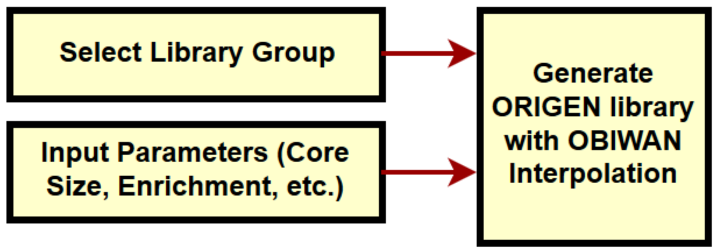
Reactor Core Physics Module - Methodology

- Requirements:
  - Calculate depletion of fuel salt and PK data
  - Fast computational solution time
  - Ability to cover large design space

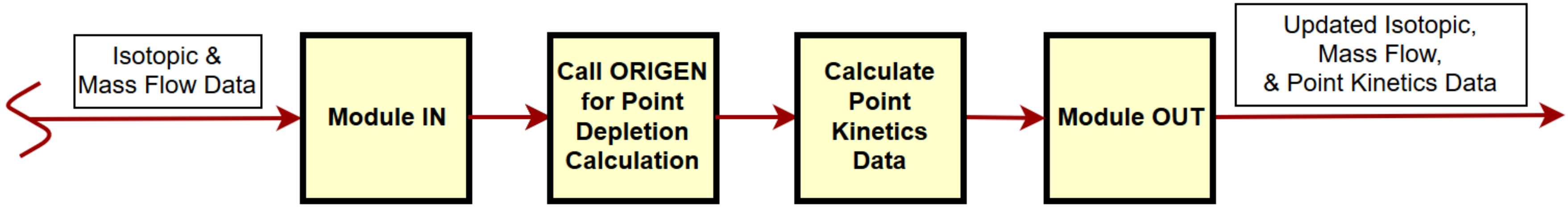
- Module Methodology:
  - Break up module by large scale design parameter (Fuel cycle, Spectrum type, etc.)
  - Interpolate over smaller design parameters

Reactor Core Physics Module Diagram

On Run Startup



During Run

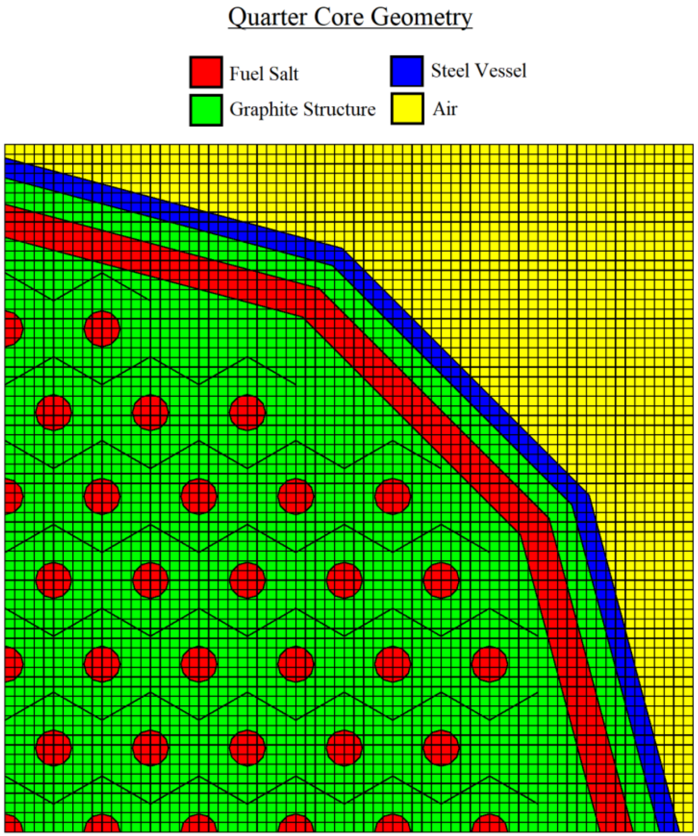


Interpolating between Data Libraries

- Reactor data libraries are interpolated over transition matrices

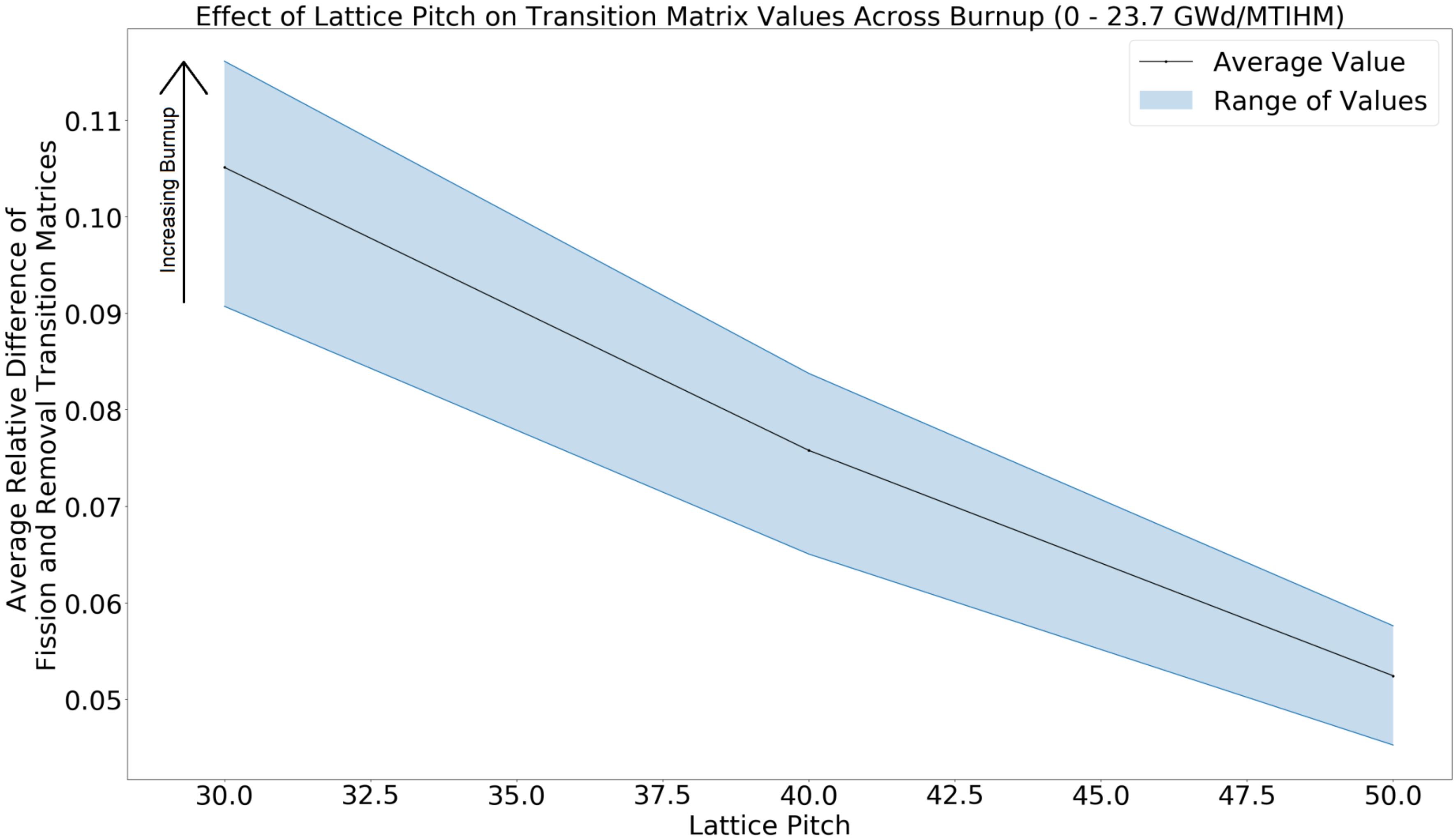
- The transition matrices can be studied to understand:
  - Importance of parameter
  - Predicted error in interpolation

Thermal FLIBE Group Library

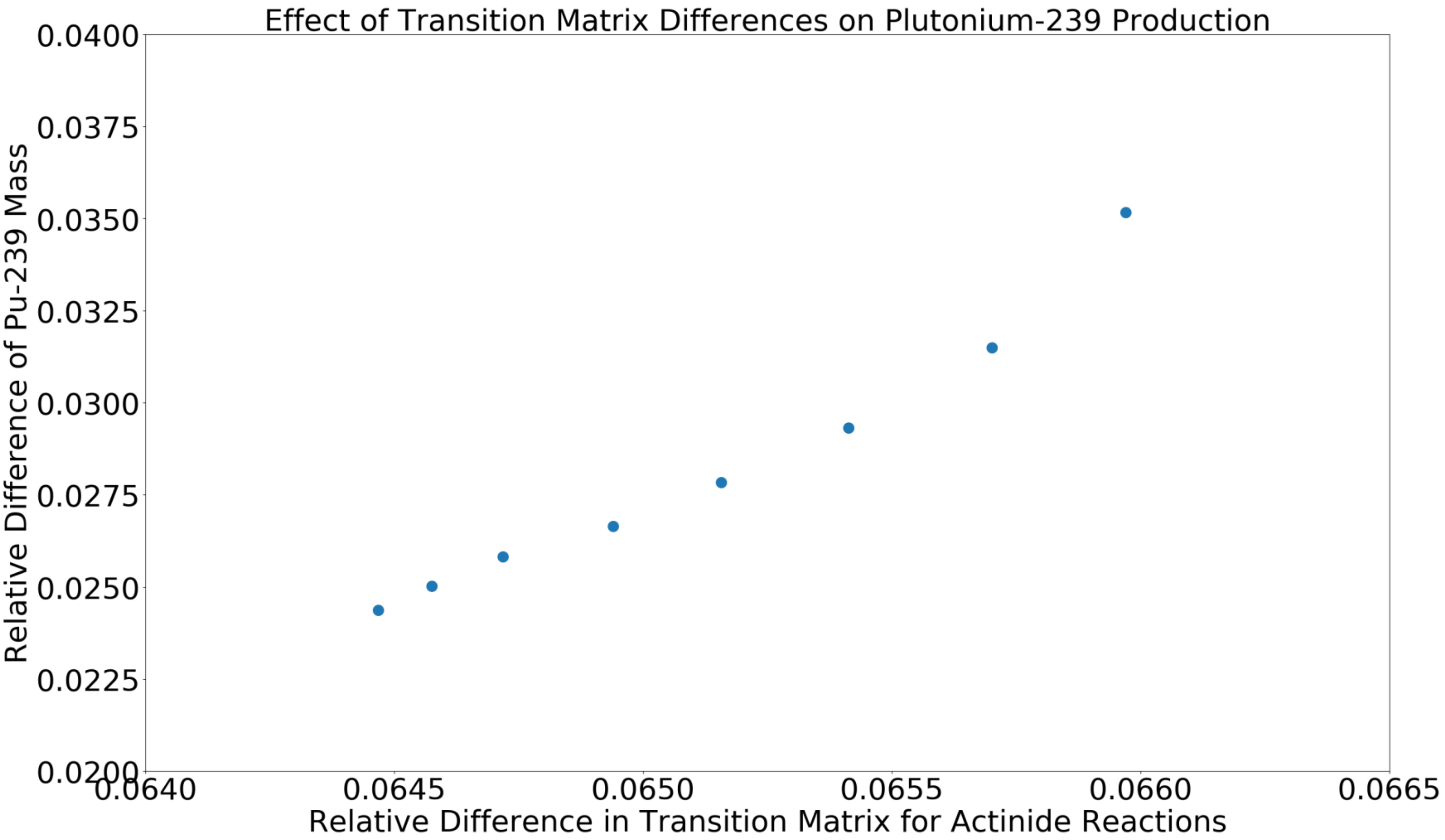


Parameter	Range	Spacing
Uranium Enrichment [wt. % U-235]	2 – 10	1
Lattice Pitch [cm]	10 – 50	10
Salt-Moderator Ratio	0.1 – 0.5	0.1
Number of Fuel Channels	7 – 169	Varies

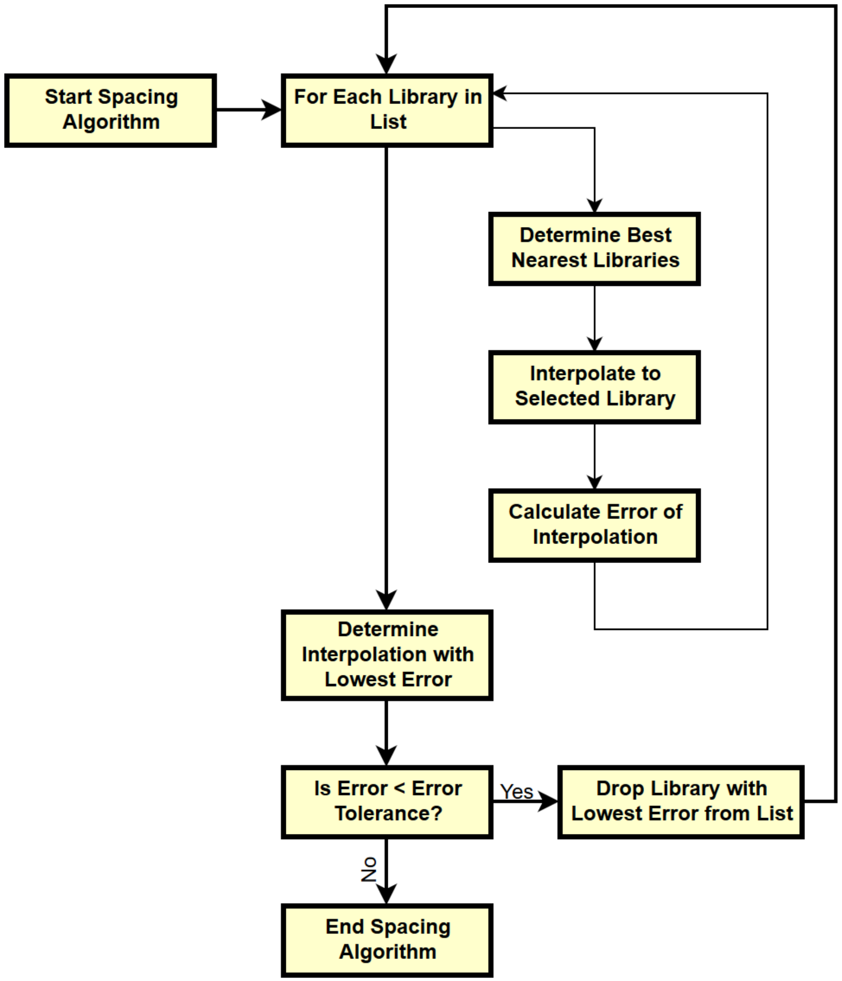
Averaged Effect of Lattice Pitch



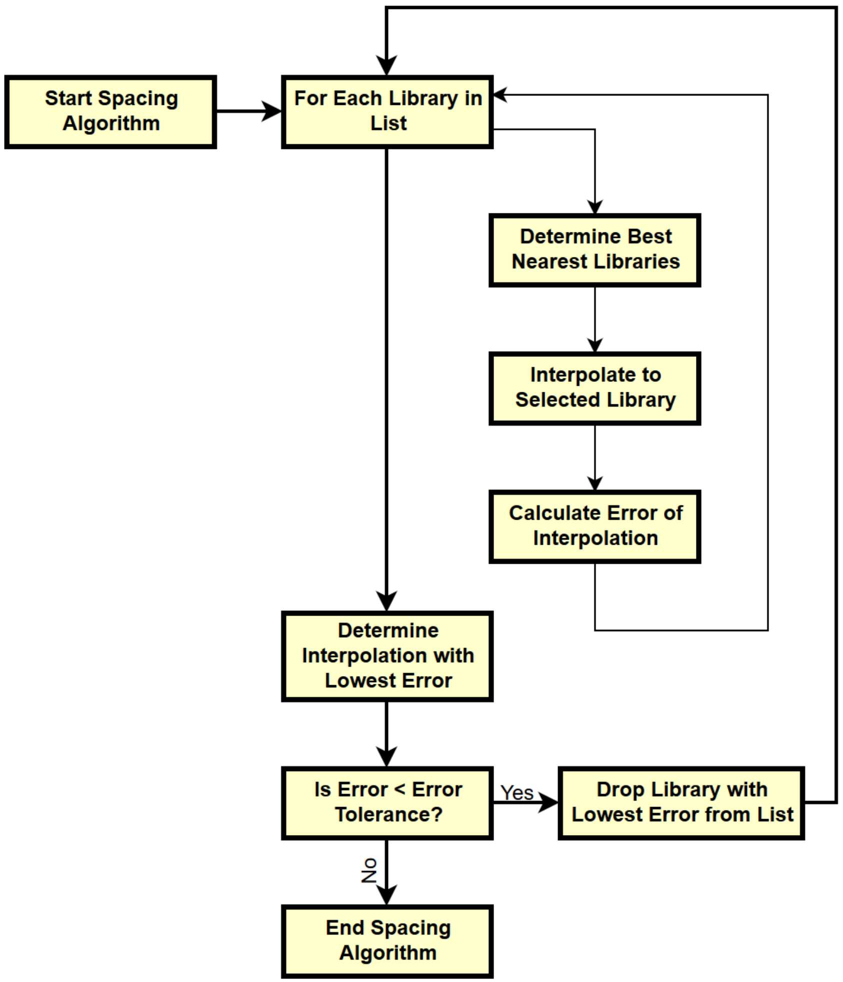
Pu-239 Mass Difference



Library Spacing Algorithm



Library Spacing Algorithm



Determining Next Libraries to Interpolate

- Potential to use difference in transition matrix value to determine next library

Acknowledgments

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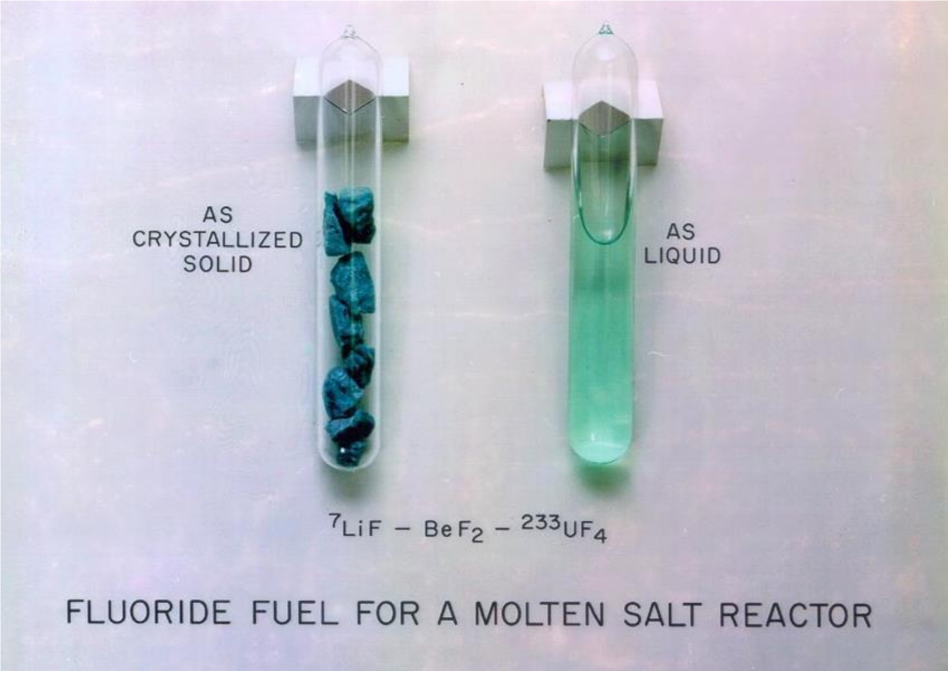
Summary

- A modular framework for testing MC&A methods on MSRs is being developed
- Core physics in the framework is being done using reactor data libraries
- The spacing and interpolation of the libraries is being studied through transition matrices

Questions or Clarifications?



<u>Additional Clarification Slides:</u>

Molten Salt Reactor Design Space
Definition of Transition Matrix
Averaged Effects of Enrichment and Salt-Moderator Ratio

Image Source: U.S. Dept. of Energy

MSR Design Space

- **Neutron Spectrum**
  - Thermal
  - Fast
  - Spatially or Temporally Varying
- **Fluid Number**
  - Single
  - One-and-half
  - Dual
- **Fuel Cycle**
  - Th/U
  - U/Pu

- **Additional Parameters**
  - Salt Choice
  - Fissile Content (Enrichment)
  - Salt-Moderator Ratio
  - Pitch

Transition Matrix

Nuclide Generation, Depletion, and Decay

$$\frac{dN_i}{dt} = \sum_{j \neq i} \left(l_{ij}\lambda_j + f_{ij}\sigma_j\phi \right) N_j(t) - (\lambda_i + \sigma_i\phi)\ N_i(t) + S_i(t)$$

Term Definitions

N_i = Amount of nuclide i
l_{ij} = Fractional yield of nuclide i from decay of nuclide j
λ_j = Decay constant of nuclide j
f_{ij}= Fraction yield of nuclide I from neutron-induced transmutation of nuclide j
ϕ = Neutron flux
S_i = Source term

Transition Matrix

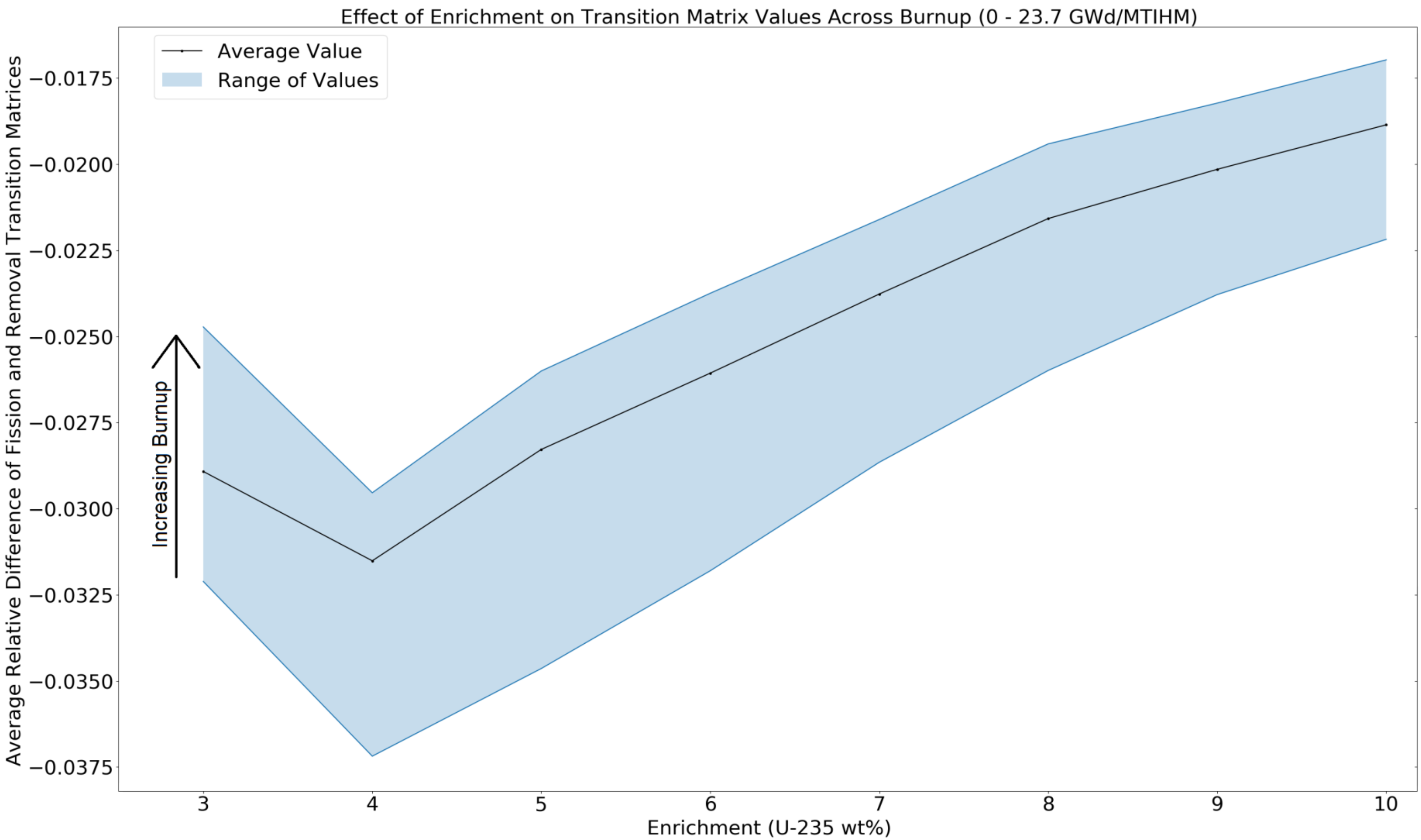
<u>**Nuclide Generation, Depletion, and Decay**</u>

$$\frac{dN_i}{dt} = \sum_{j\neq i}\Big(\underbrace{l_{ij}\lambda_j}_{\text{Decay in}} + \underbrace{f_{ij}\sigma_j\phi}_{\text{Transmute in}}\Big)N_j(t) - \big(\underbrace{\lambda_i}_{\text{Decay out}} + \underbrace{\sigma_i\phi}_{\text{Transmute out}}\big)\, N_i(t) + \underbrace{S_i(t)}_{\text{Source}}$$

Simply with **T** as "Transition Matrix"

$$\frac{dN}{dt} = \mathbf{T}N(t) + S(t)$$

Averaged Effect of Enrichment



Averaged Effect of Salt-Moderator Ratio