Experimental and Computational Validation of RAPID

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Introduction

RAPID (Real-time Analysis for Particle transport and In-situ Detection)

- Solves radiation transport problems using the MRT approach
- Solves the Fission Matrix equations to obtain k_{eff}, M, & 3D Fission Density

Benchmarking performed an the USNA Subcritical Reactor (USNA-SCR)

Fission Matrix Methodology

FM equations are obtained by recasting the Linear Boltzmann Equation.

Eigenvalue:

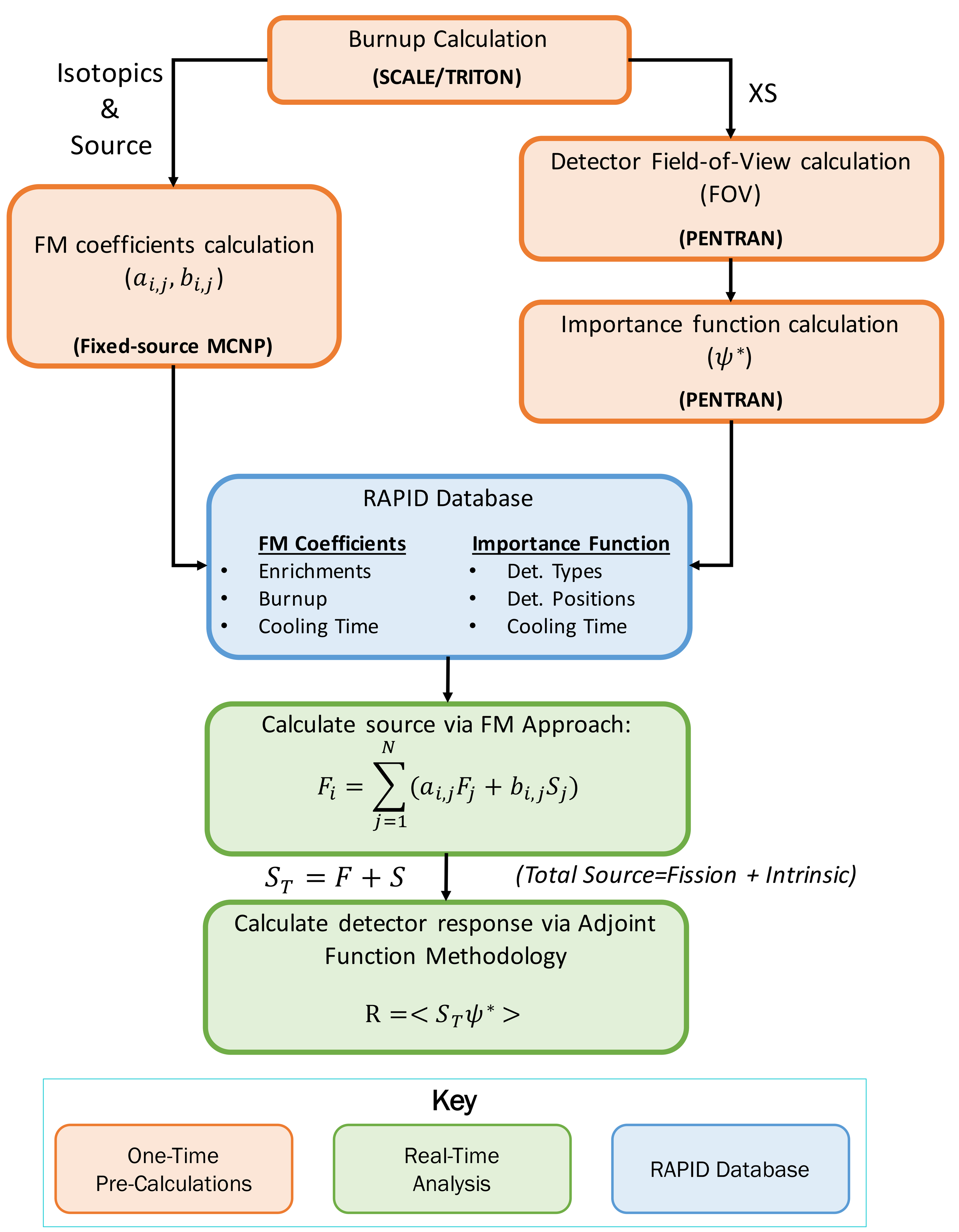
$$F_i = \frac{1}{k}\sum_{j=1}^{N} a_{ij} F_j$$

Subcritical Multiplication:

$$F_i = \sum_{j=1}^{N} a_{ij} F_j + b_{ij} S_j$$

F_j = fission neutron source
S_j = intrinsic neutron source
a_{ij} & b_{ij} = FM coefficients
N = number of cells

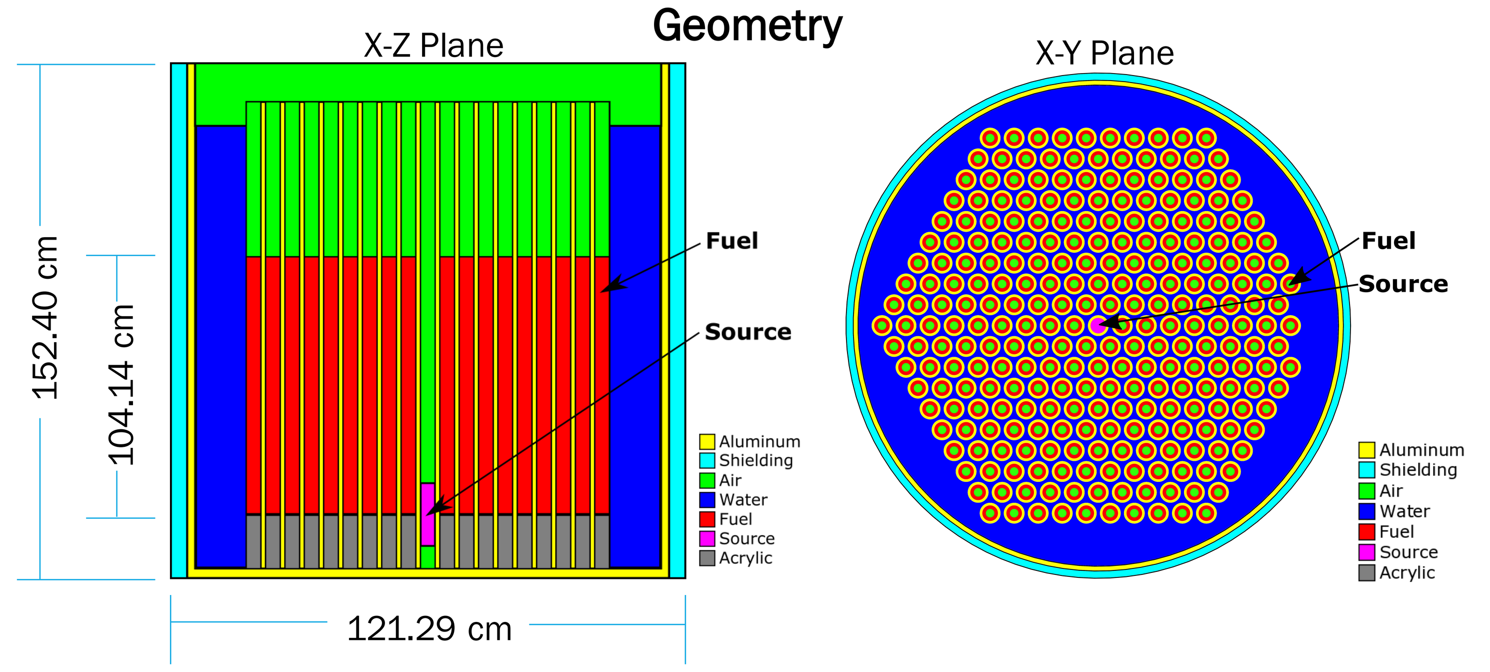
RAPID Code Flowchart using the MRT Methodology



USNA-SCR Geometry

- Light-water moderator
- PuBe neutron source
- Natural uranium fuel, coated with aluminum
- 268 annualar fuel rods

Geometry



RAPID vs. MCNP

Eigenvalue

Code	k	Rel. Diff. [pcm]	Time [min]
MCNP	0.87278[1]	-	876[2]
RAPID	0.87420	163	0.7[3]

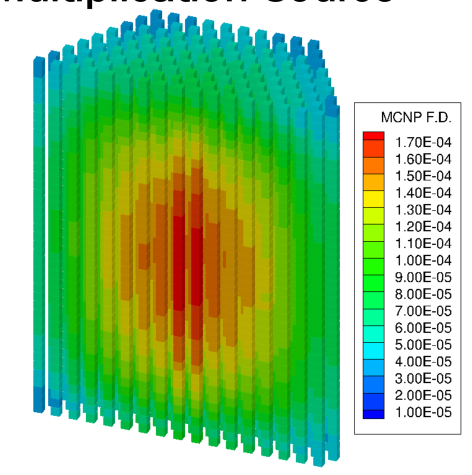
[1]1σ = 3 pcm; [2]On 16 processors;
[3]On 1 processor & Speedup = 1251

Subcritical Multiplication

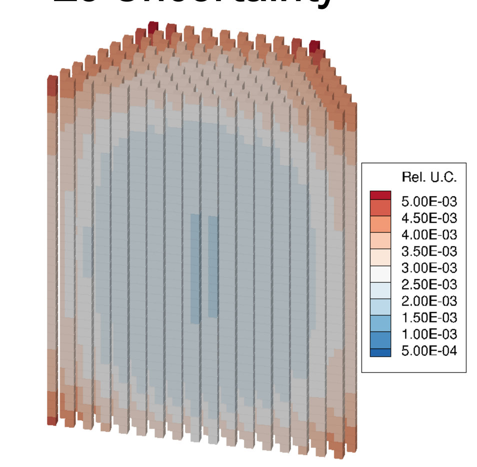
Code	M	Rel. Diff. [%]	Time [min]
MCNP	6.62042[1]	-	1134[2]
RAPID	6.54819	1.09	0.7[3]

[1]1σ = 0.002 %; [2]On 16 processors;
[3]On 1 processor & Speedup = 1623

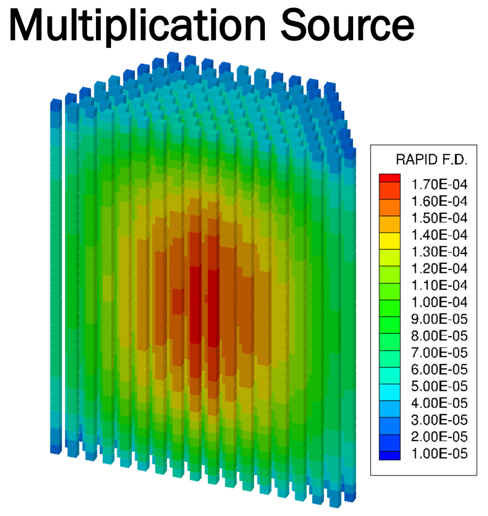
MCNP Subcritical Multiplication Source



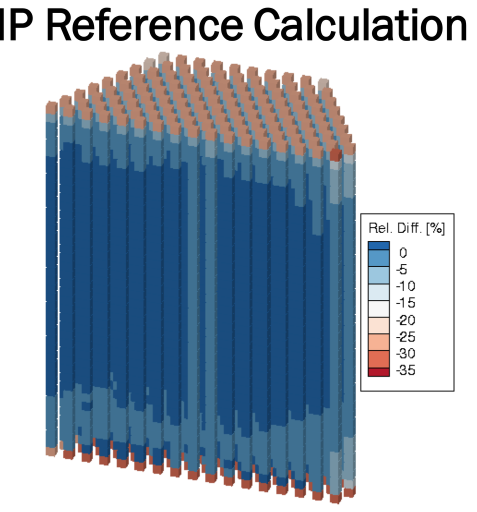
MCNP Tally 1σ Uncertainty



RAPID Subcritical Multiplication Source



Relative Differences vs. MCNP Reference Calculation



Detectors – Experimental Benchmarking

Fill Gas	Pressure	Dimension	Use
^{3}He	0.41 MPa	H=2.72 cm D=0.97 cm	In-Core
^{3}He	1.01 MPa	H=76.20 cm D=2.54 cm	Ex-Core

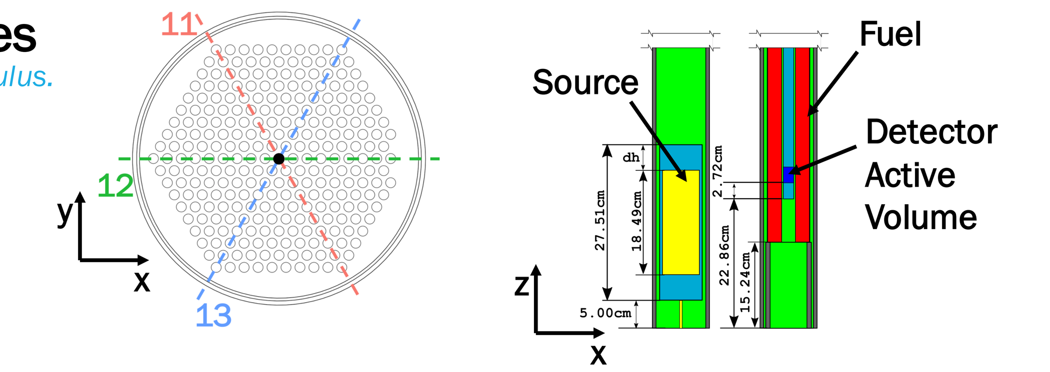
- Neutron Pulse Monitor with 128 Energy Discrimination Bins used for data collection
- Cutoff Bin at observed valley (between gamma noise and neutron counts)

Calculated vs. Experimental Detector Responses

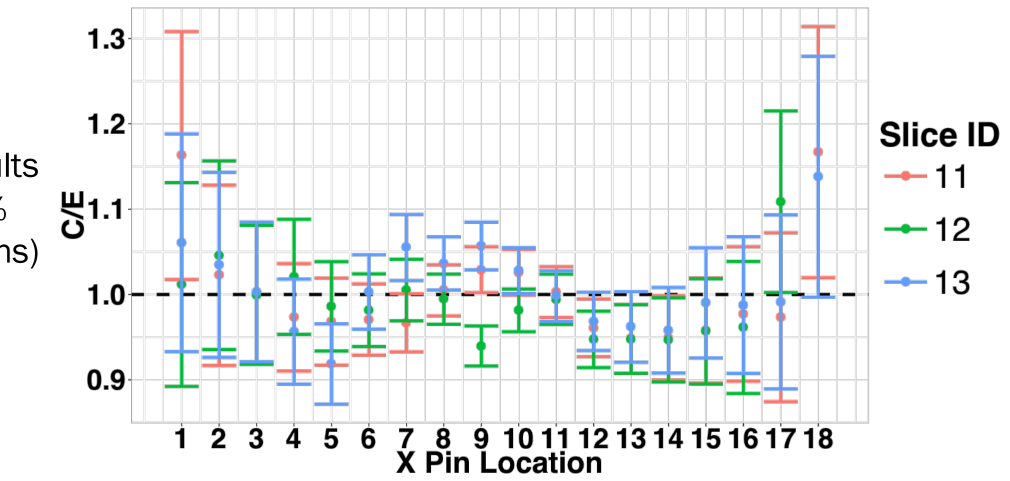
In-Core : Radial Profiles

Small ^{3}He detector within fuel annulus.

- 3 radial profiles measured along diagonals
- Detector at a fixed axial position



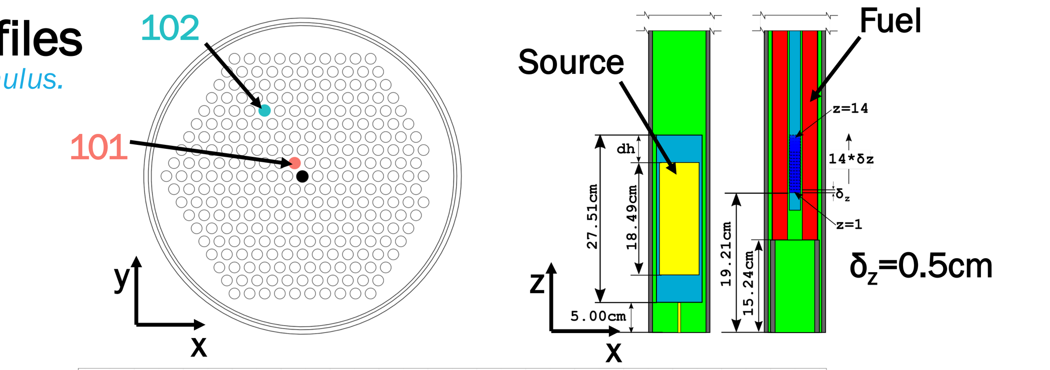
Calculated Results within +/- 10% (except edge pins)



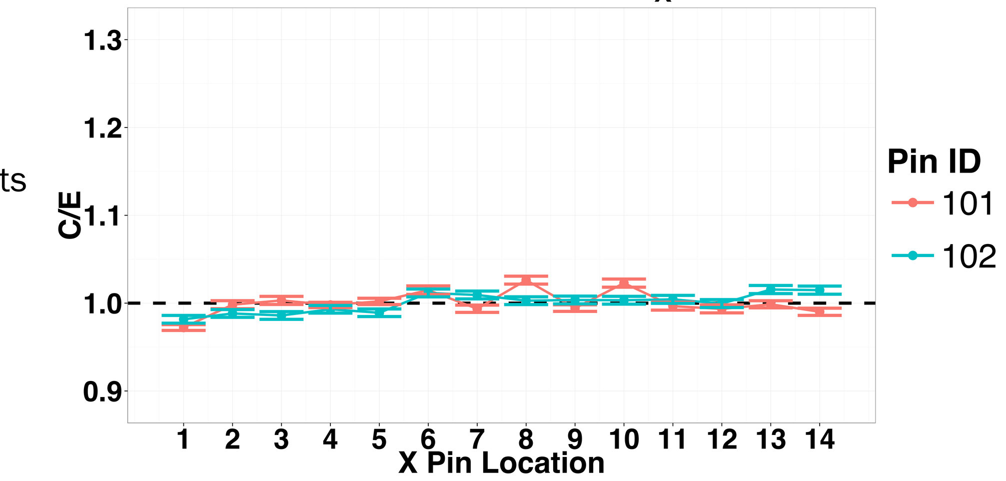
In-Core : Axial Pin Profiles

Small ^{3}He detector within fuel annulus.

- Axial profile of 2 pins
- 14 measurements at increments of 5mm



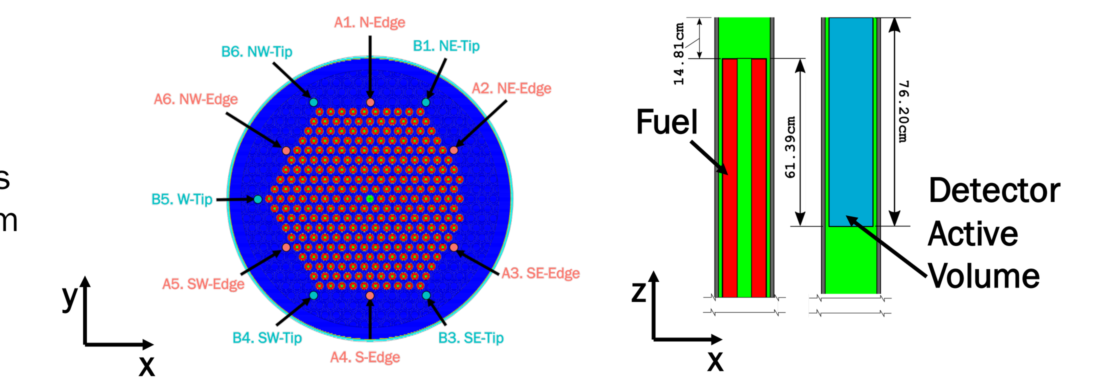
Calculated Results within +/- 3%



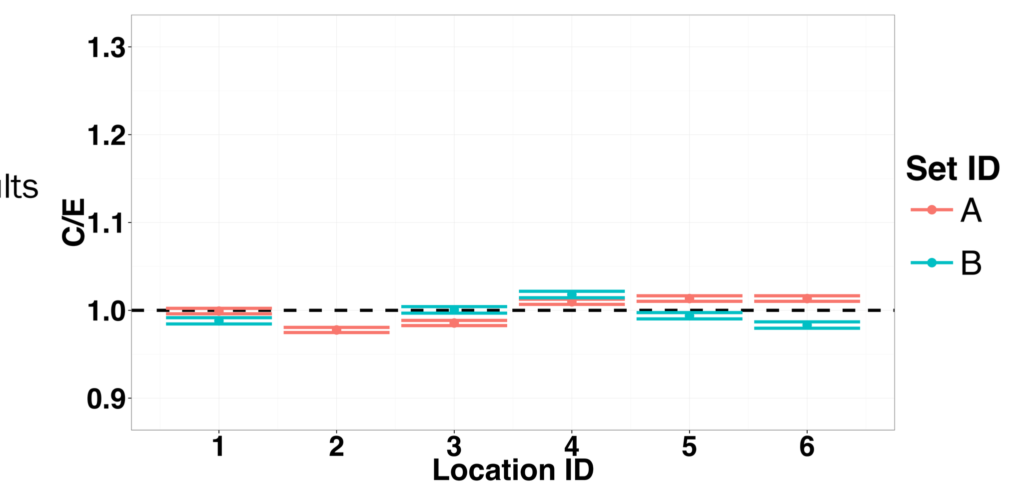
Ex-Core

Large ^{3}He detector

- 2 datasets measured at assembly tips and edges
- Detector suspended from the top of an empty fuel rod



Calculated Results within +/- 3%



Conclusions

This paper demonstrated through computational and experimental benchmarking that RAPID calculates accurate solutions in real-time.