CORTEX

Core monitoring techniques and experimental validation and demonstration

Modelling vibrating absorber in the time domain with diffusion theory

WP2 Validation Workshop

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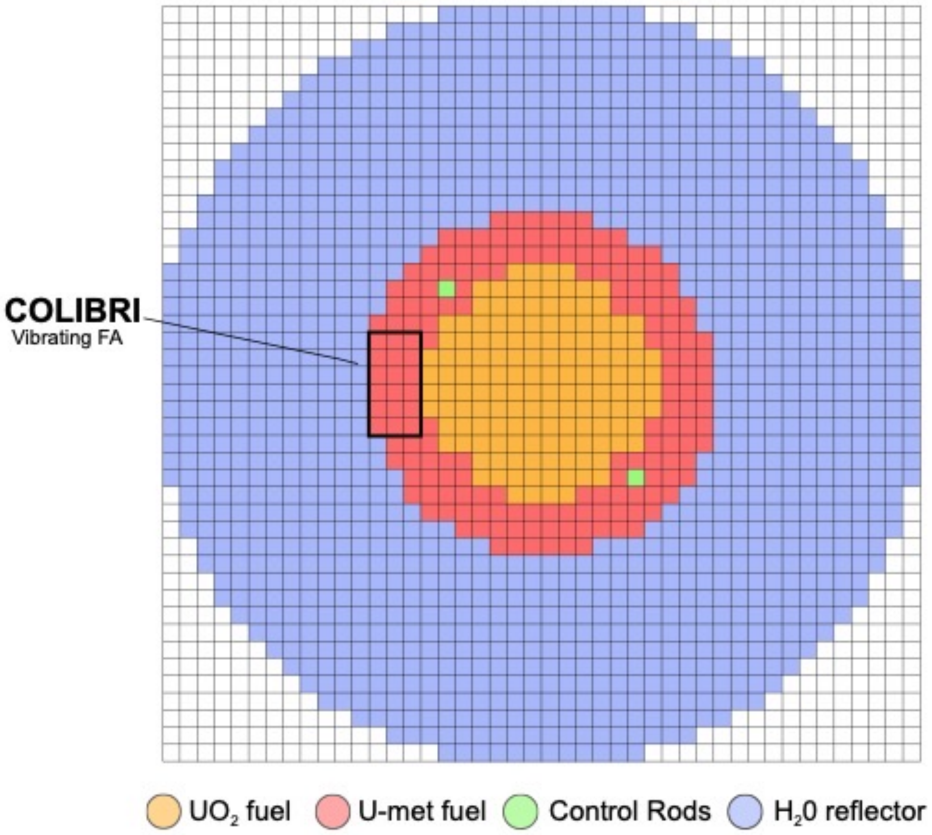
Introduction

- **Objective:** To solve the time dependent neutron distribution inside a nuclear reactor with **oscillating assemblies**.



Introduction

- **Objective:** To solve the time dependent neutron distribution inside a nuclear reactor with **oscillating assemblies**.

- Time-dependent computations.
- Diffusion approximation.
- Two group approximation.
- Direct representation of the mechanical oscillation.
- Fixed grid with volume-homogenized materials.
  - Locally refined meshes gives (essentially) the same results.
- Postprocess through APSD/CPSD.

Introduction

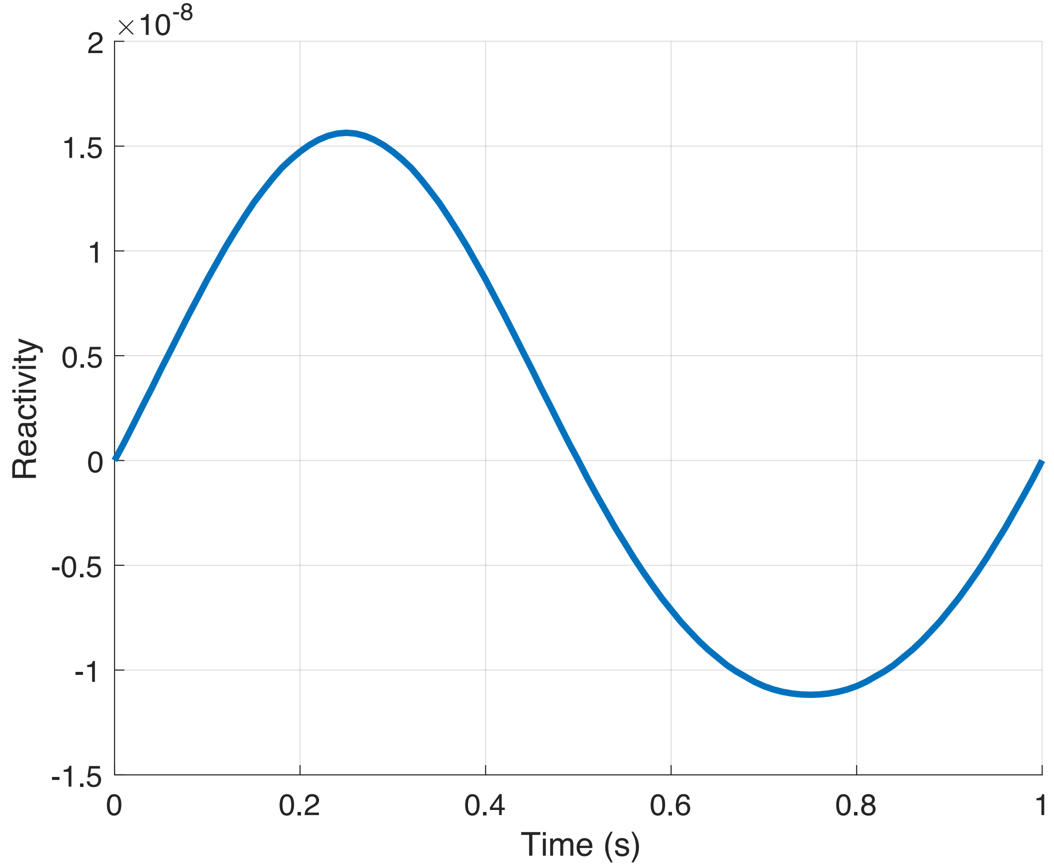
- Time dependent codes can show two different effects in the neutron field caused by a FA vibration.
  - An in-phase oscillation in the neutron flux with the assembly vibration called neutron noise. This neutron noise is spatially dependent.
  - A global slow variation of the power due to a change in the criticality of the system is observed. This effect is small and will be compensated by the thermal-hydraulic feedback.

- This paper also demonstrates that neglecting second order effects, as done in the frequency domain simulations, gives essentially the same results as not neglecting those.

A. Vidal-Ferràndiz, A. Carreño, D. Ginestar, C. Demazière and G. Verdú, "A time and frequency domain analysis of the effect of vibrating fuel assemblies on the neutron noise", Annals of Nuclear Energy, p. 107076, 2019.

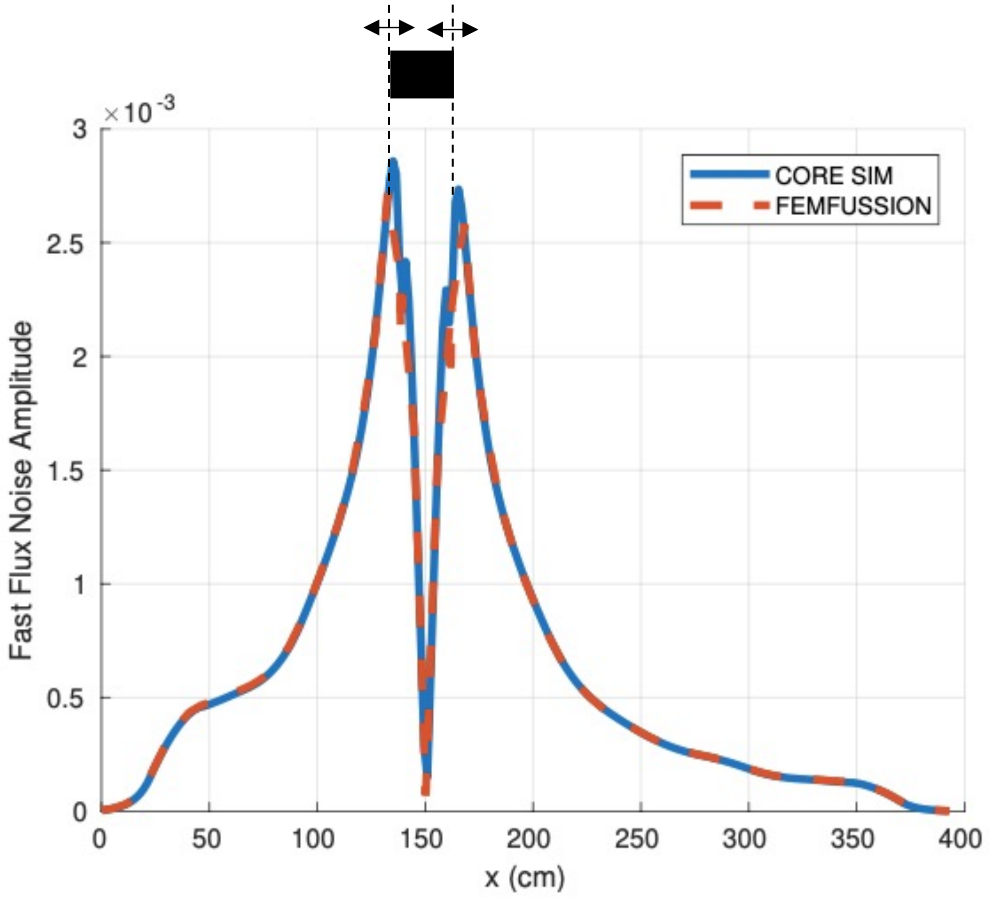
Neutron noise source

- The fuel assembly movement produces a small reactivity change that should be compensated by thermal-hydraulic feedback.

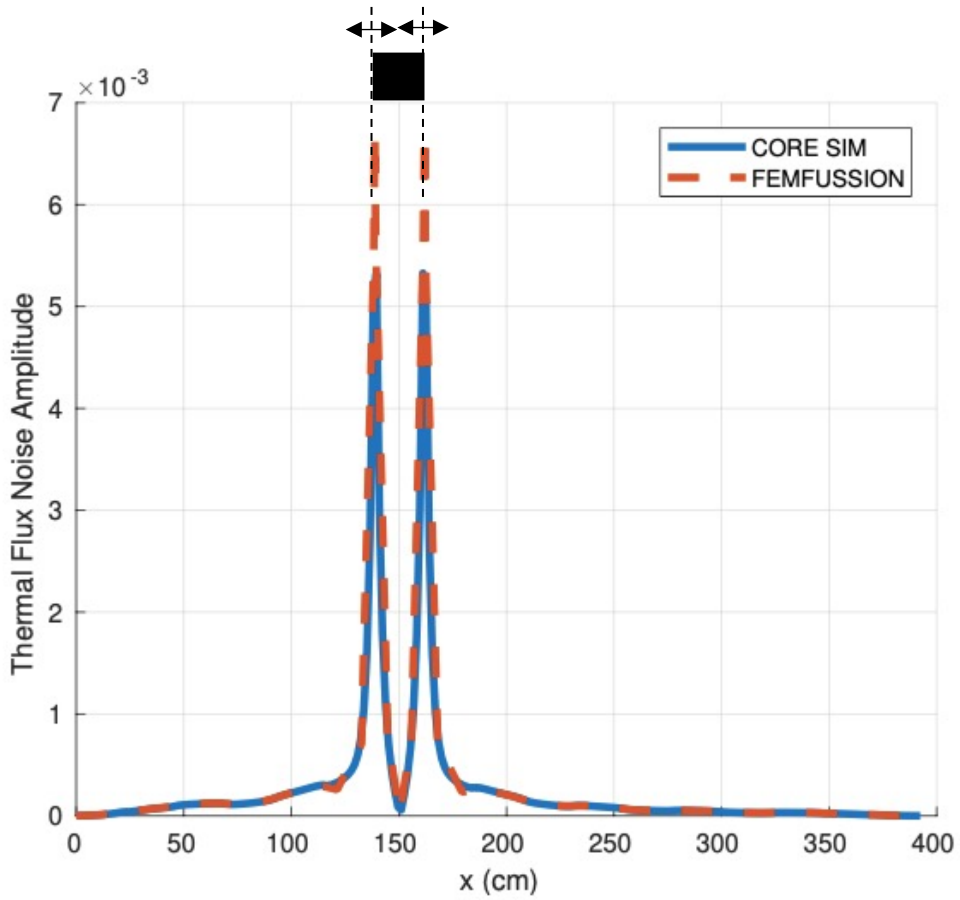


Introduction

- Comparison of noise magnitudes at FA vibration frequency.



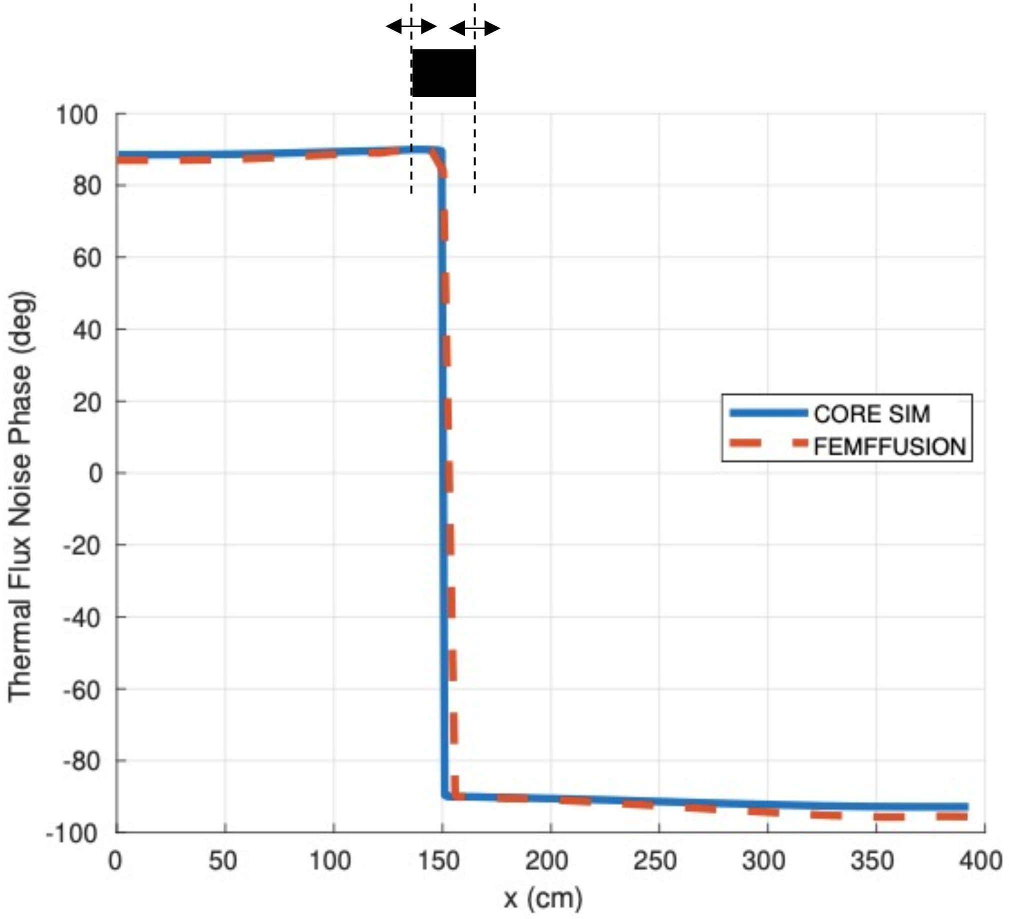
(a) Fast noise amplitude.



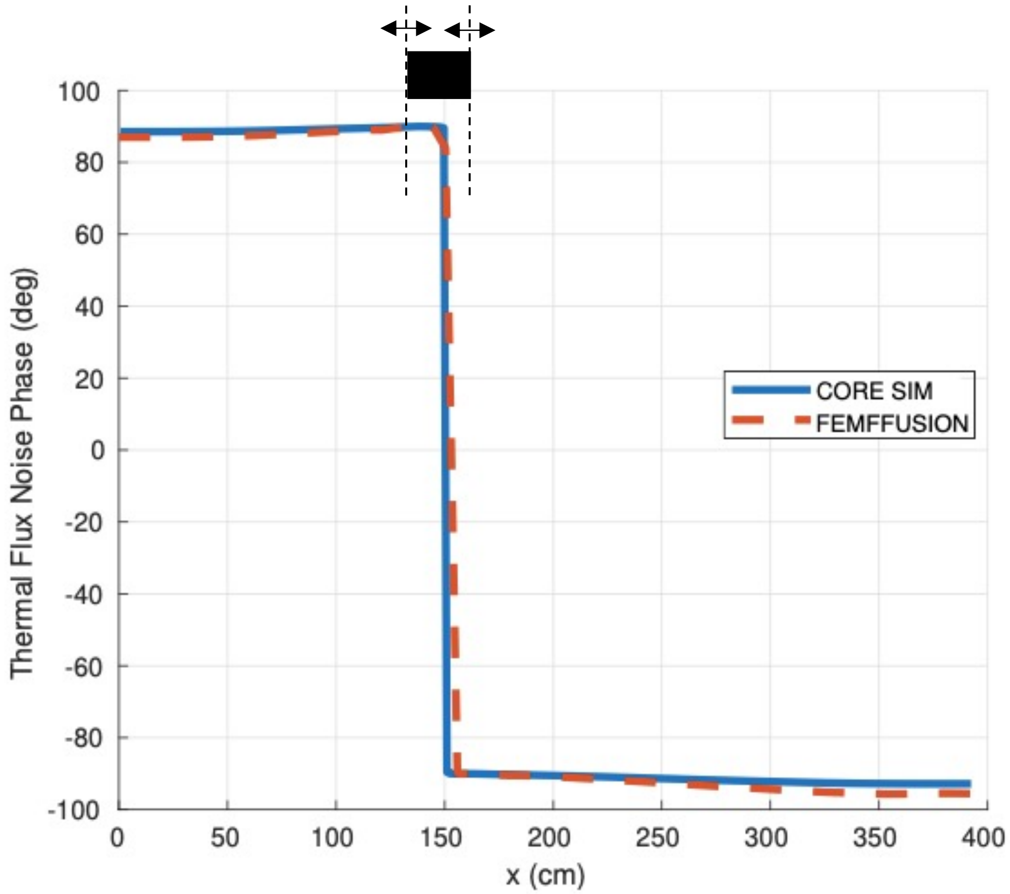
(b) Thermal noise amplitude.

Introduction

- Comparison of noise magnitudes at FA vibration frequency.



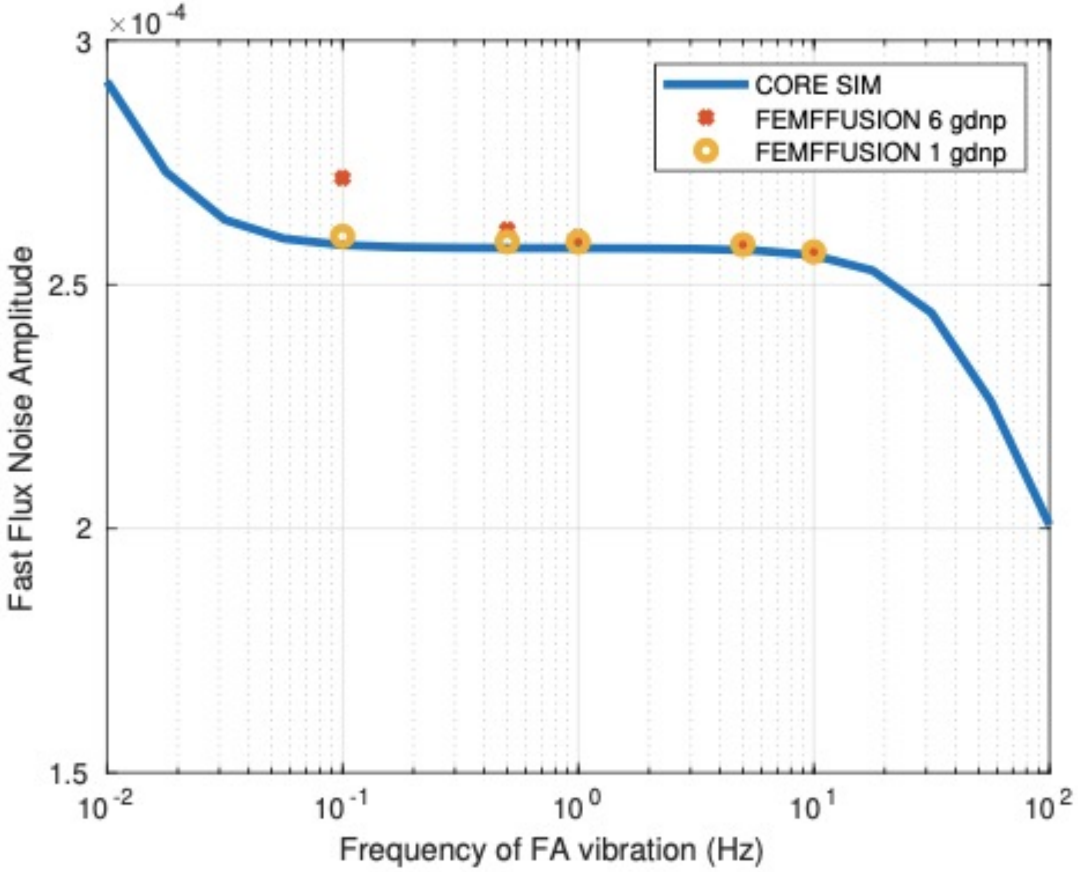
(a) Fast Noise.



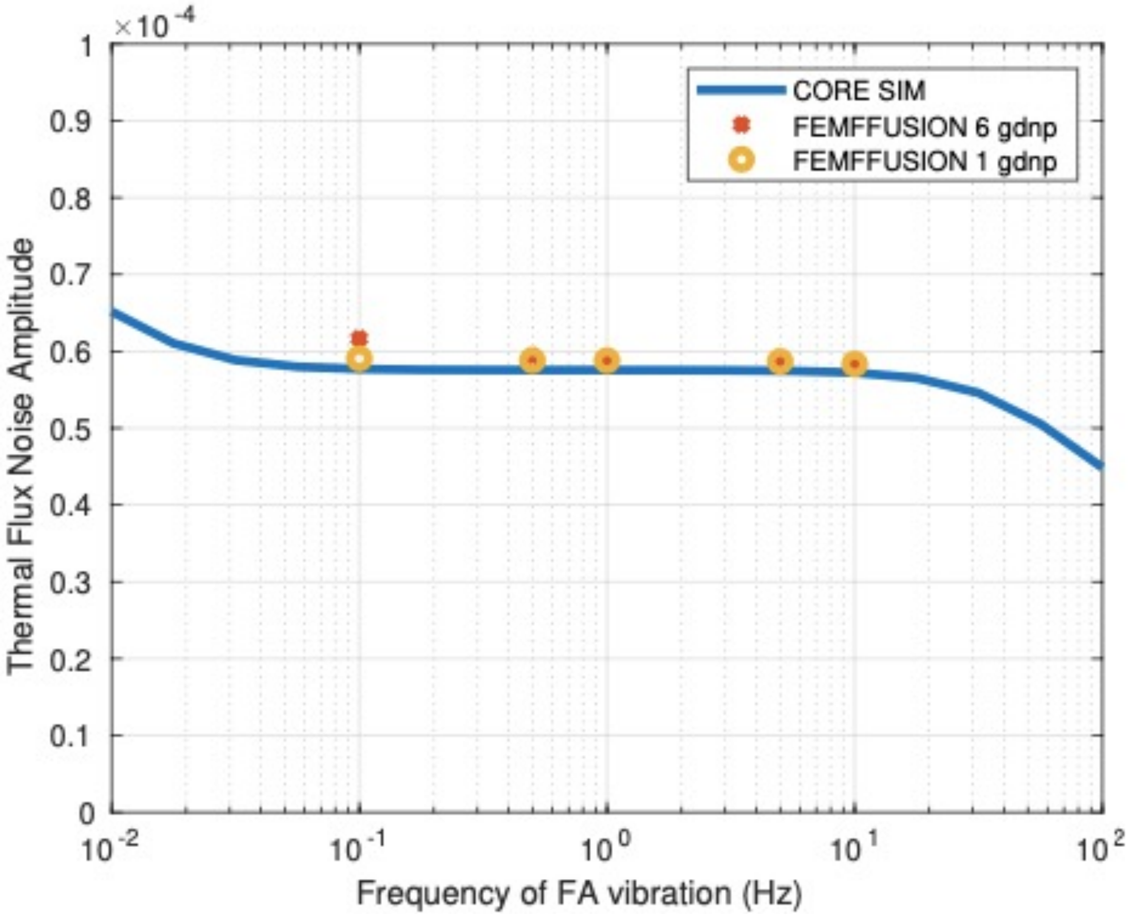
(b) Thermal Noise.

Introduction

- Comparison of noise magnitudes at FA vibration frequency.



(a) Fast Flux.



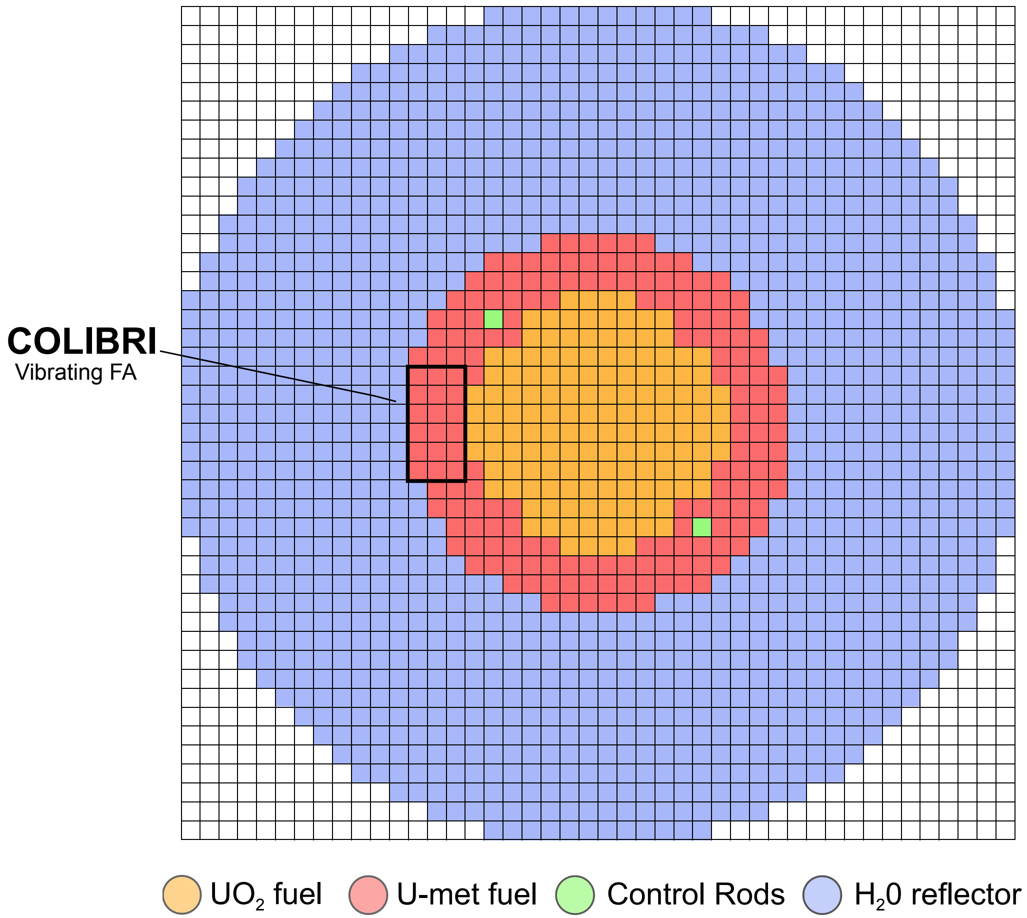
(b) Thermal Flux.

CROCUS model

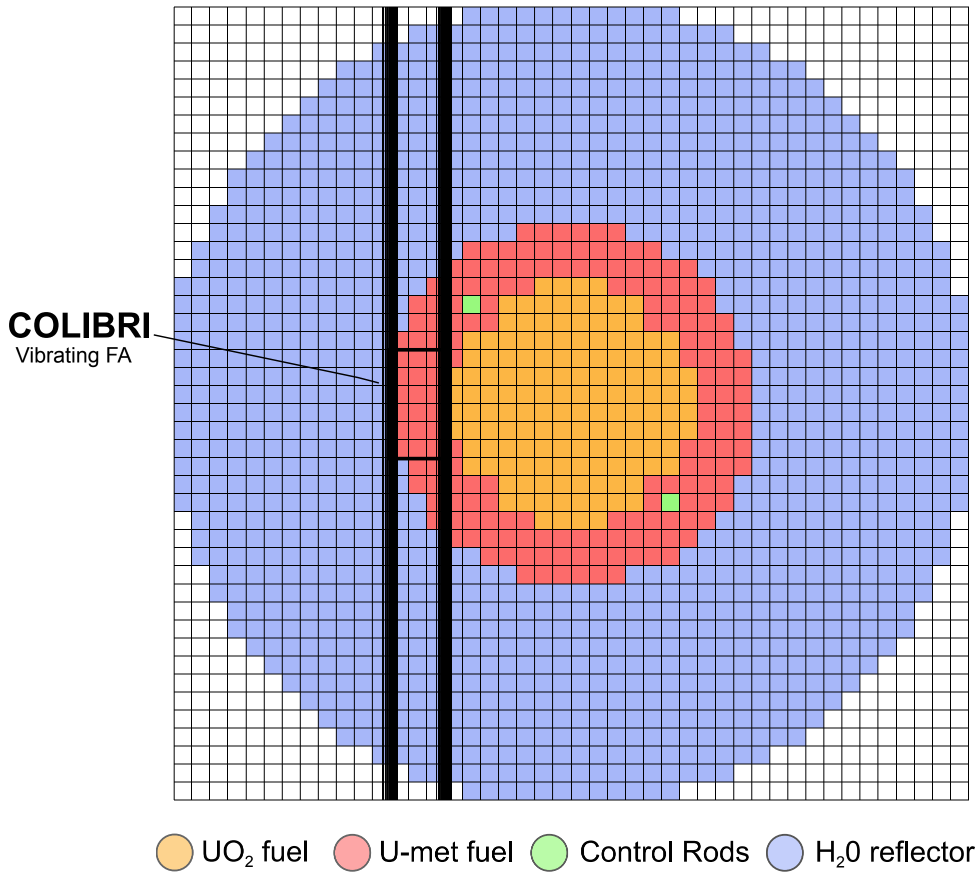
- A 2D model, based on EPFL model has been produced.
- Two time-dependent codes has been used.
  - **PARCS**: Using a finite difference method.
  - **FEMFFUSION**: Using a finite element method.
- Two meshes have been used:
  - A uniform mesh: 44x44 cells.
  - A local refined around the vibrating assembly: 96x44 cells.
- The computation have been done with high accuracy for the spatial and time discretization.
  - 5^{th} degree polynomials in the FEM.
  - 8x8 inner grid per cell in PARCS.
- Simulate 3 oscillation periods to have an accurate frequency analysis.

CROCUS model

- Meshes

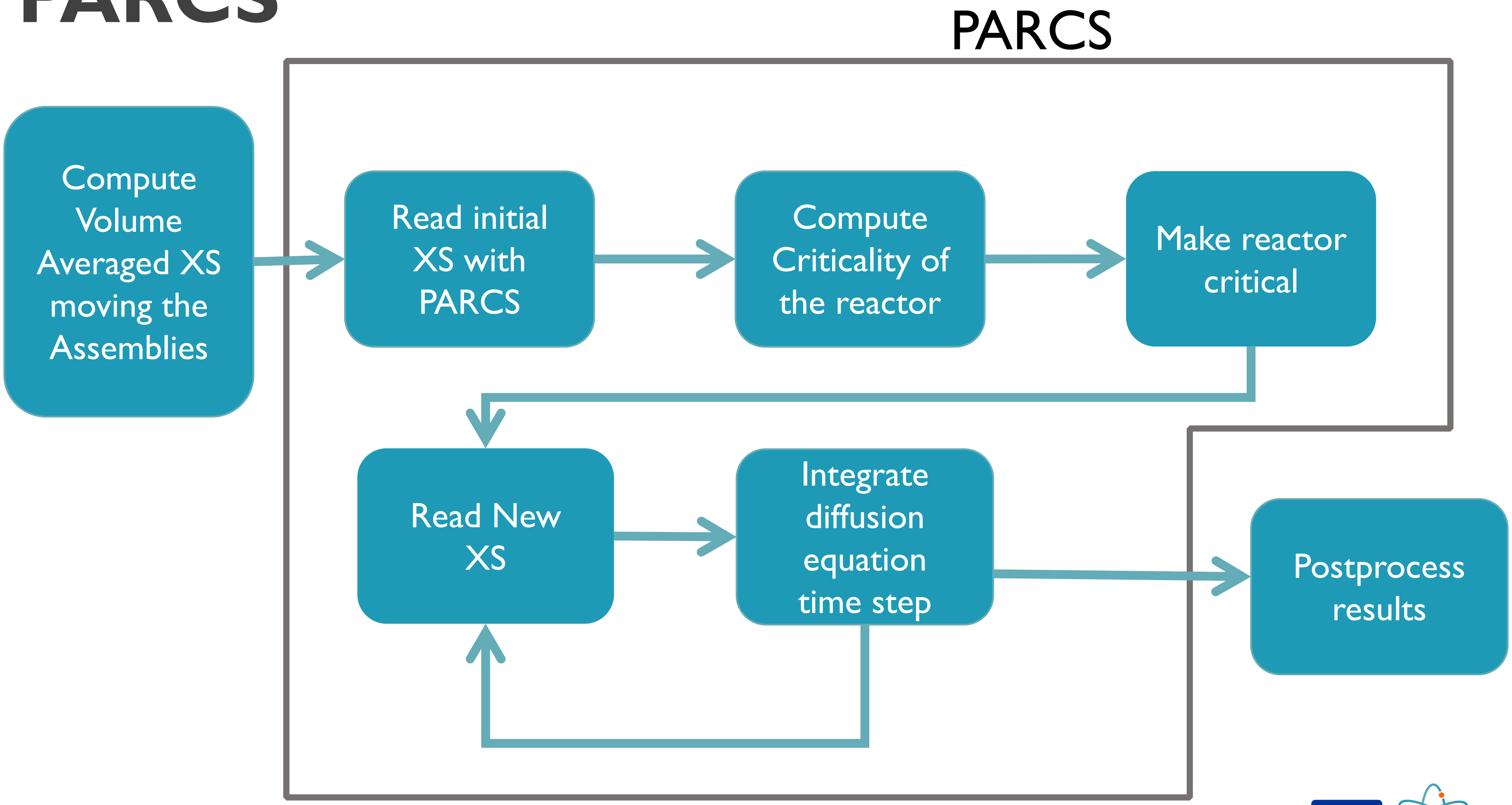


(a) Uniform Uniform



(b) Local Mesh

PARCS


PARCS
Compute Volume Averaged XS moving the Assemblies
Read initial XS with PARCS
Compute Criticality of the reactor
Make reactor critical
Read New XS
Integrate diffusion equation time step
Postprocess results

PARCS

make_parcs_input.py

- Frequency
- Amplitude
- Vibrating position
- Vibrating material
- Dynamic data
- Geometry

2D_CROCUS_uniform_12.inp
2D_CROCUS_uniform_12.xs
2D_CROCUS_uniform_12.gm

- Cross sections at each time step.
- Geometry data
- Precursor data

PARCS

2D_CROCUS_uniform.out

- Static flux
- Flux at each time step

Postprocess

detector_data.py

- Temporal data of each detector

APSD and CPSD

FEMFFUSION

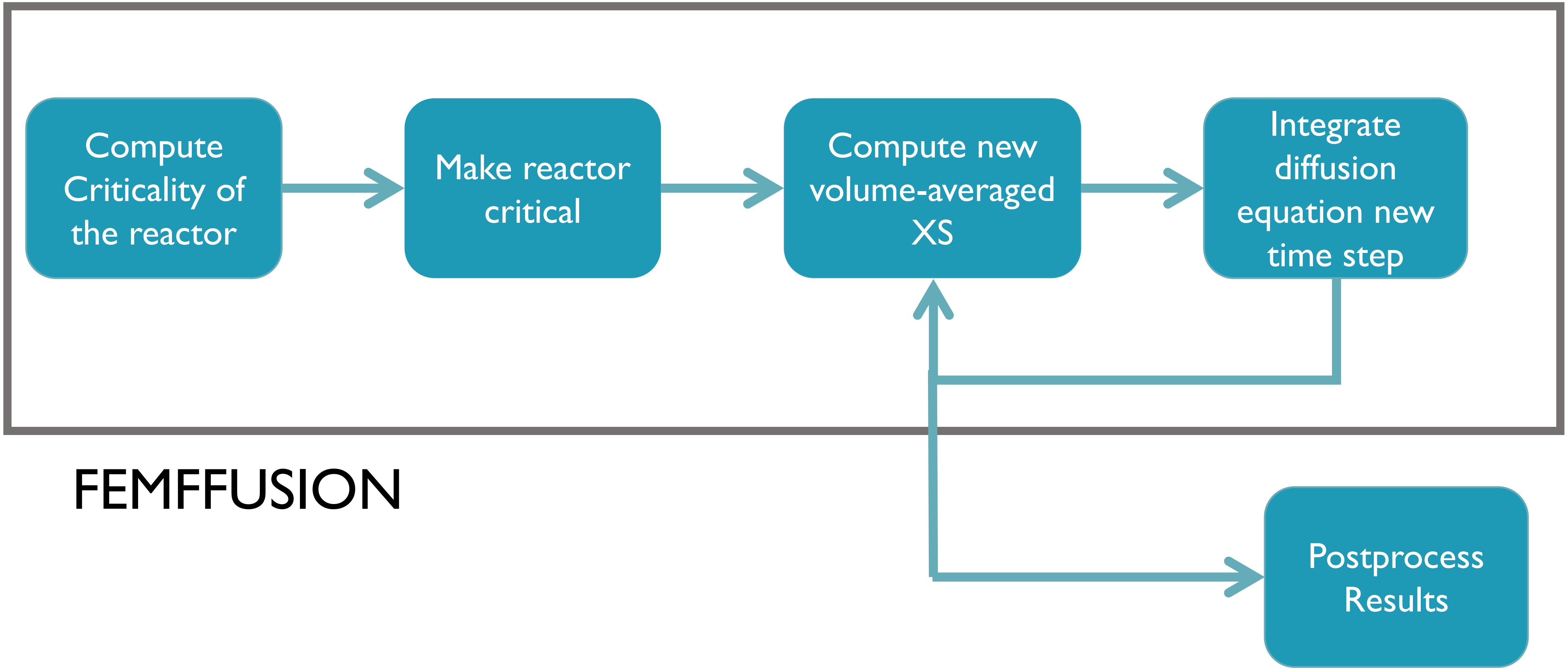
- Web page:

  https://www.femffusion.imm.upv.es/

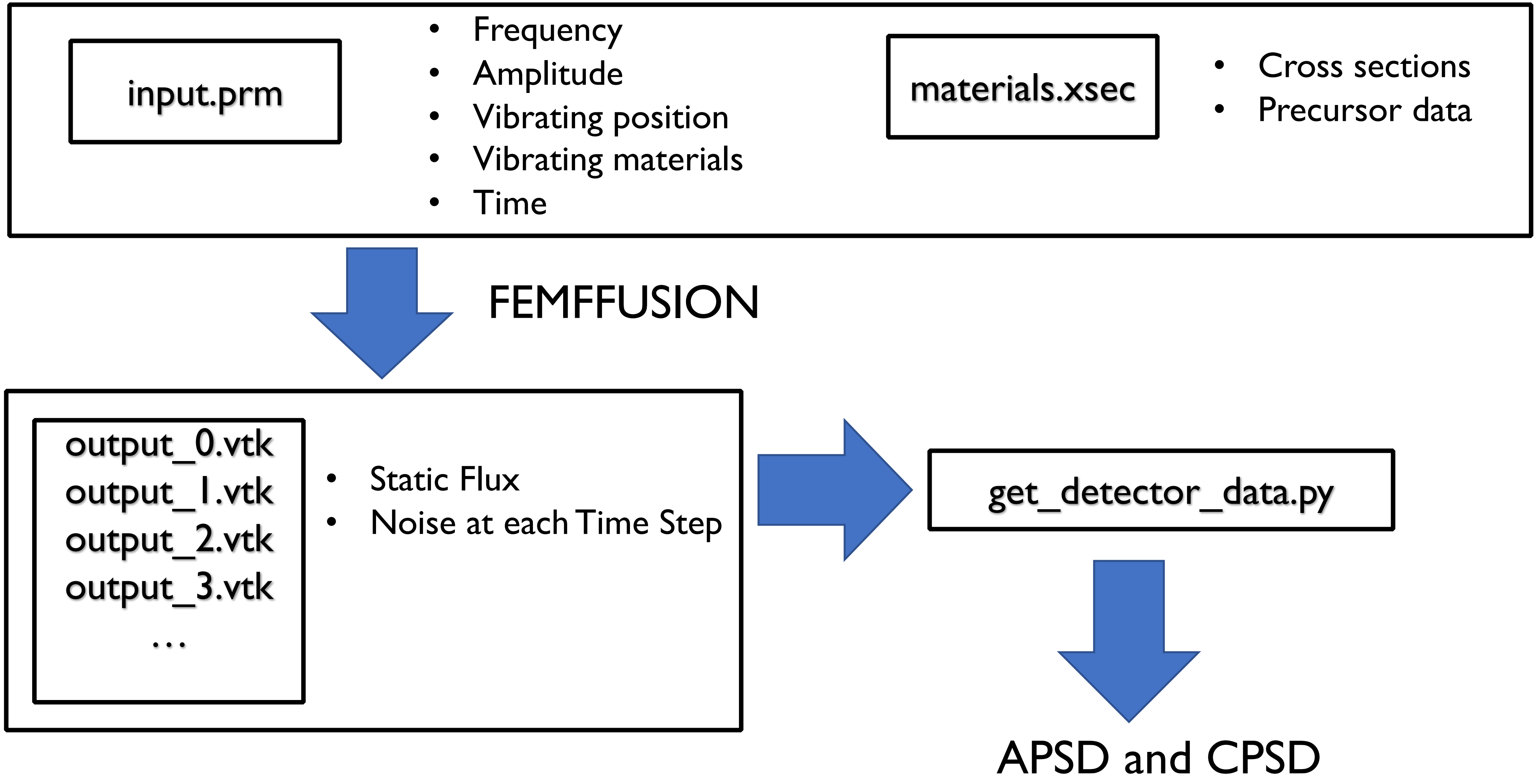
- Open repository at:

  https://bitbucket.org/Zonni/femffusion_vibration

FEMFFUSION

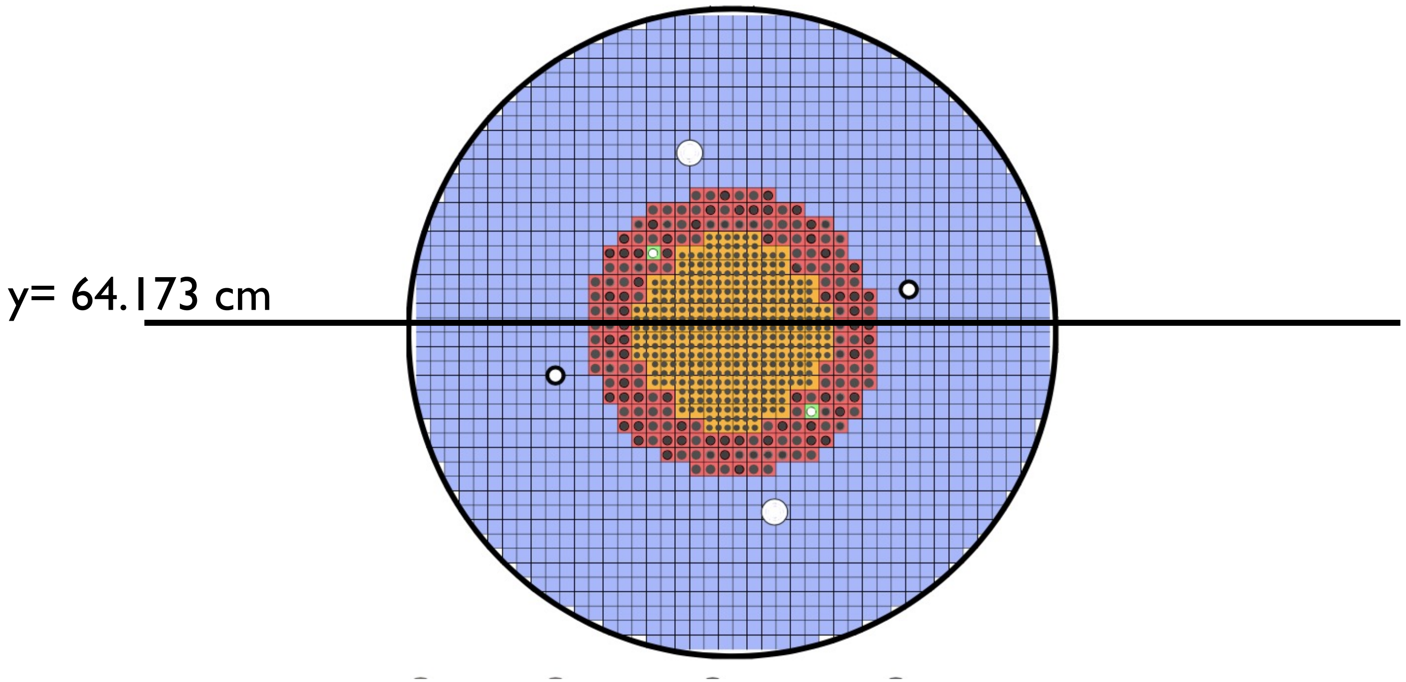

Compute Criticality of the reactor
Make reactor critical
Compute new volume-averaged XS
Integrate diffusion equation new time step
FEMFFUSION
Postprocess Results

FEMFFUSION


input.prm
Frequency
Amplitude
Vibrating position
Vibrating materials
Time
materials.xsec
Cross sections
Precursor data
FEMFFUSION
output_0.vtk
output_1.vtk
output_2.vtk
output_3.vtk
…
Static Flux
Noise at each Time Step
get_detector_data.py
APSD and CPSD

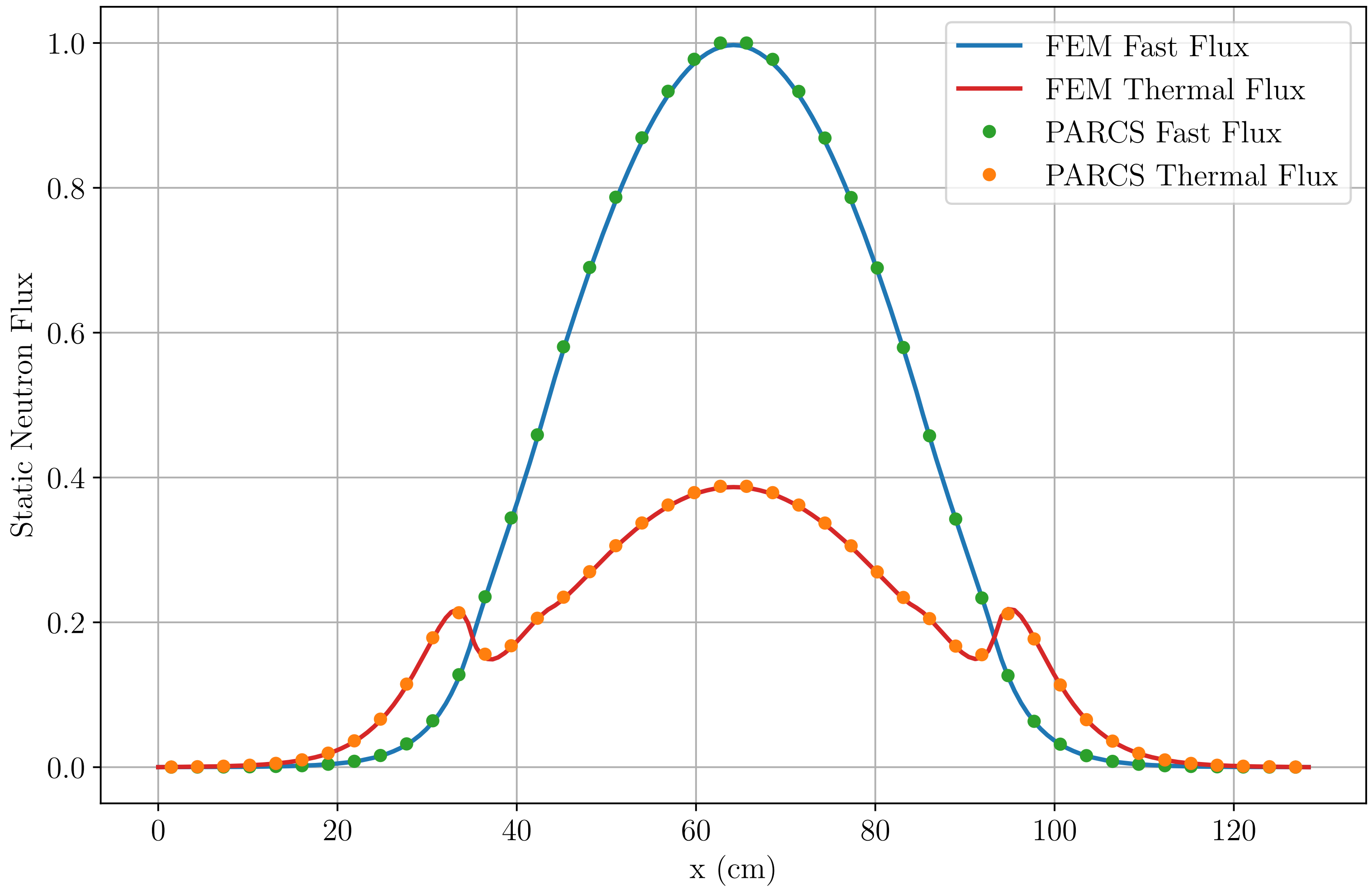
Numerical Examples

- Experiment 12 of the 1st campaign, ± 2 mm amplitude, 0.1Hz.
- Most of the results at centre line y= 64.173 cm



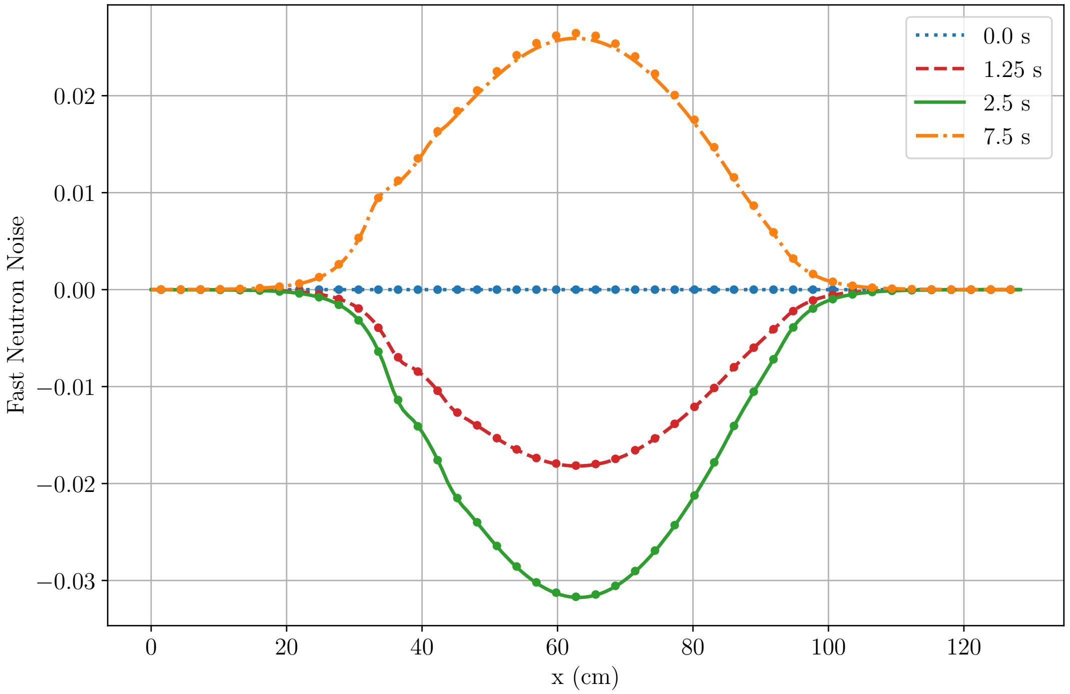
Static Flux Results

- Results at the center line.

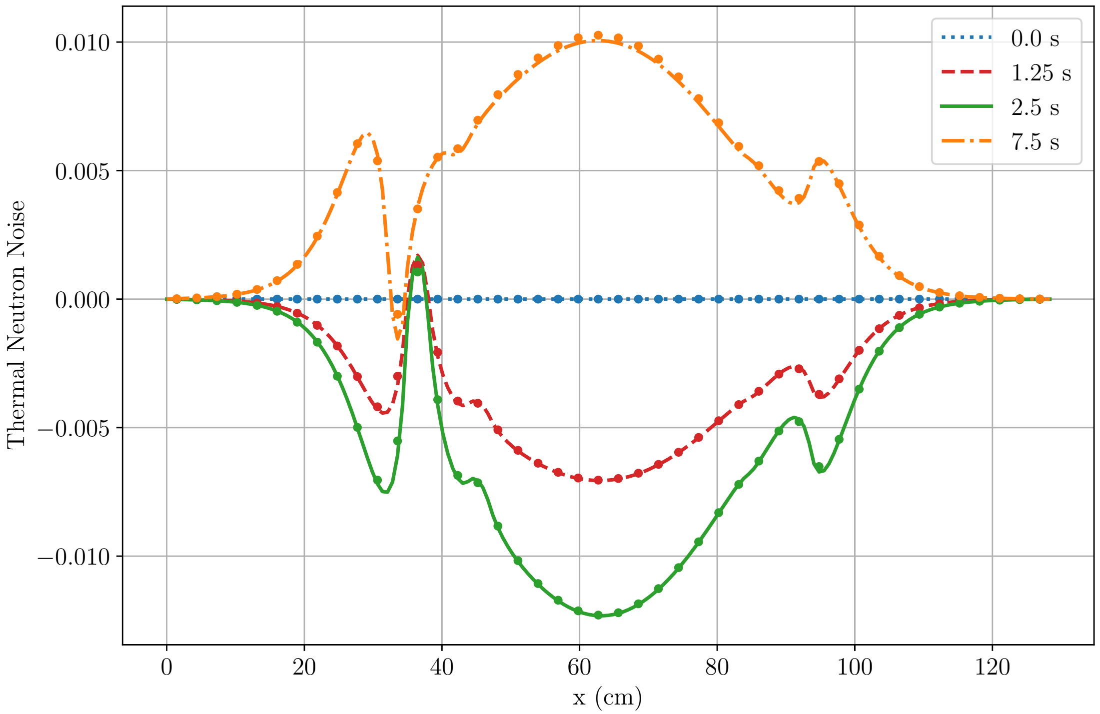


Static Flux Results

- Uniform refinement.



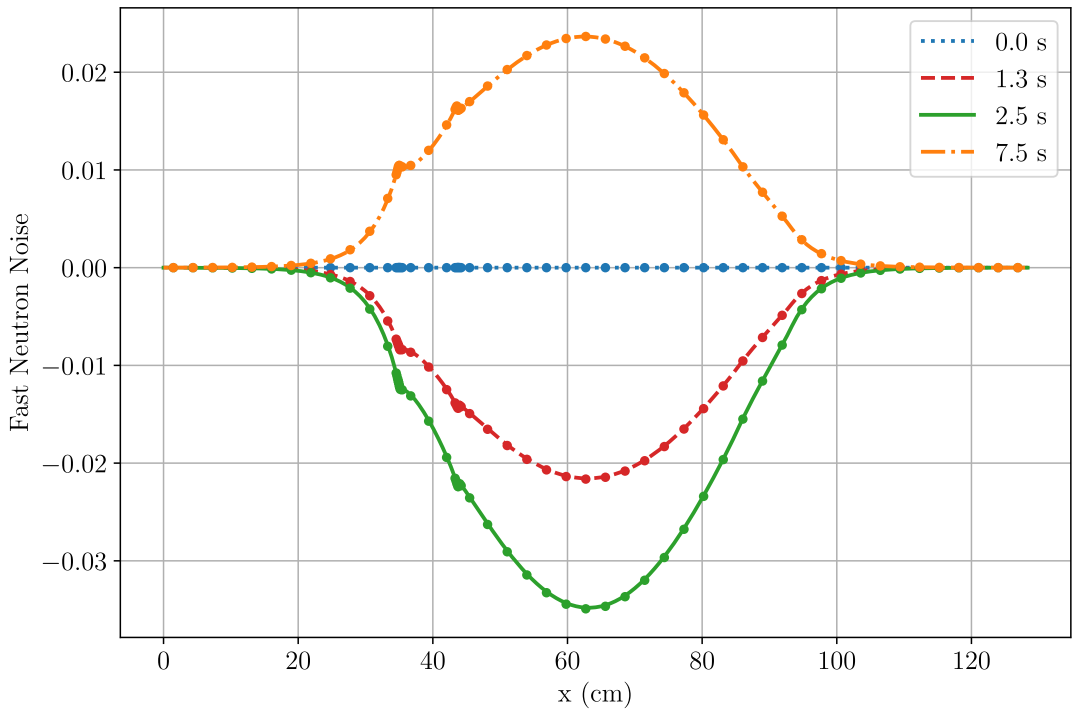
(a) Fast Flux Noise



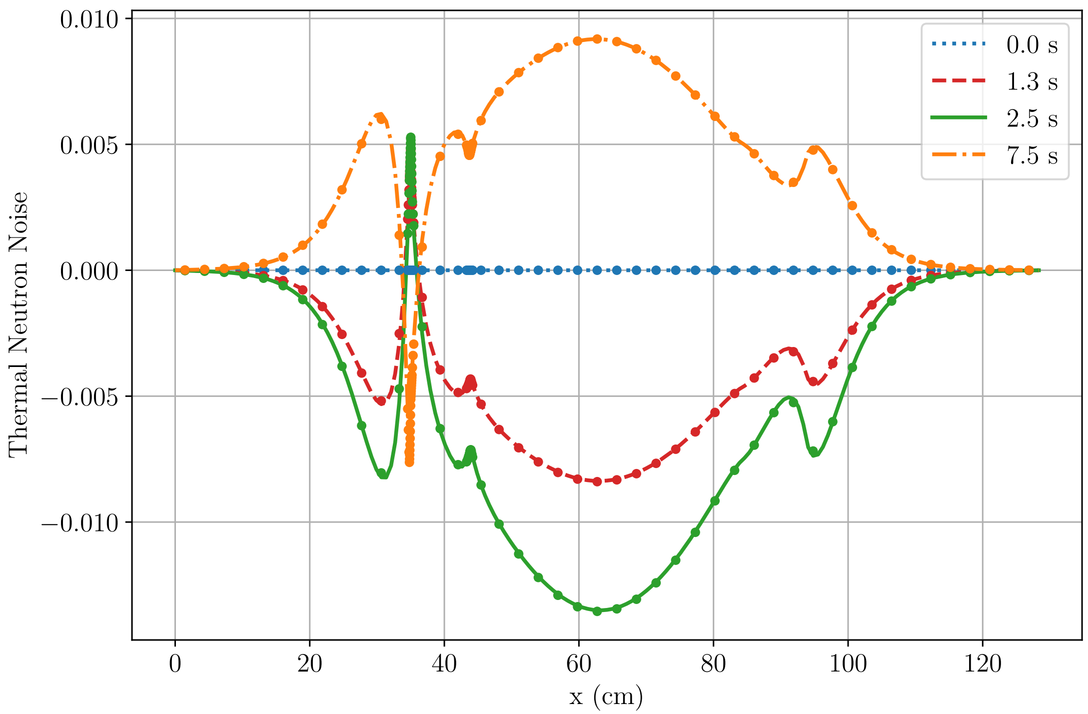
(b) Thermal Flux Noise

Time dependent noise

- **Local refinement.**



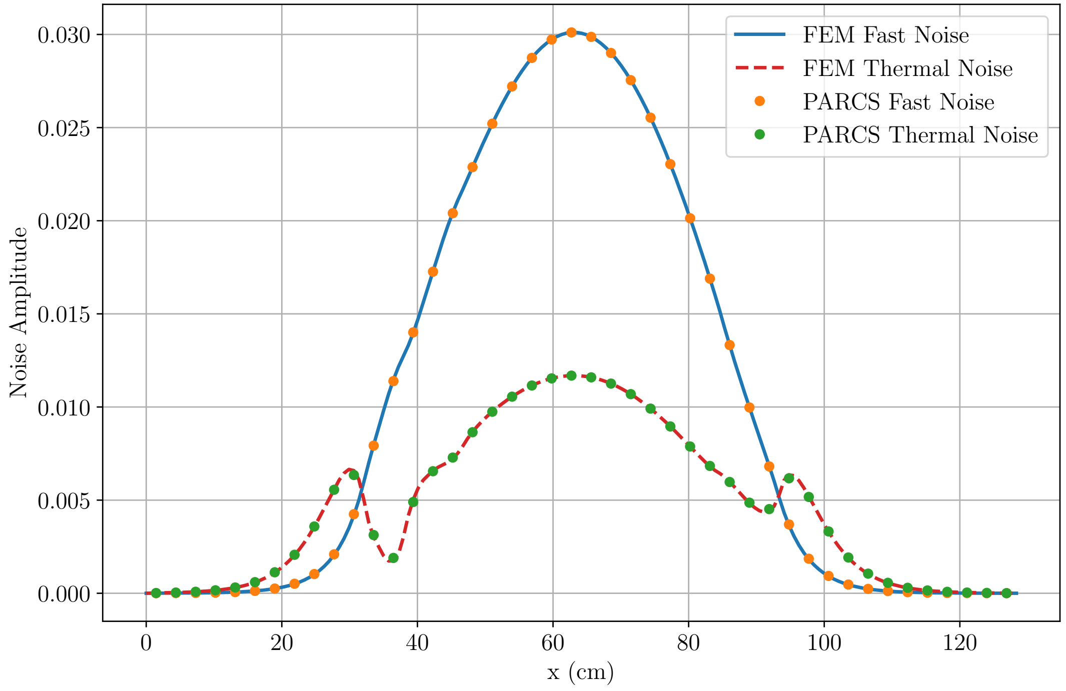
(a) Fast Flux Noise



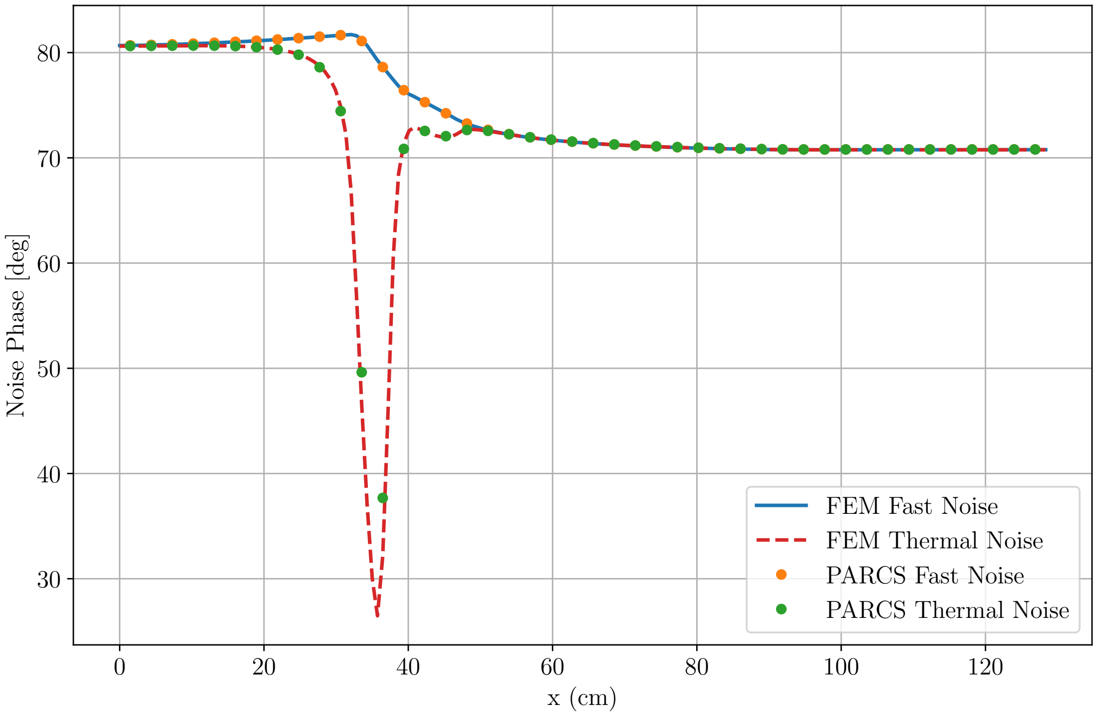
(b) Thermal Flux Noise

Fourier Transform at 0.1 Hz

- Uniform refinement.



(a) Noise magnitude

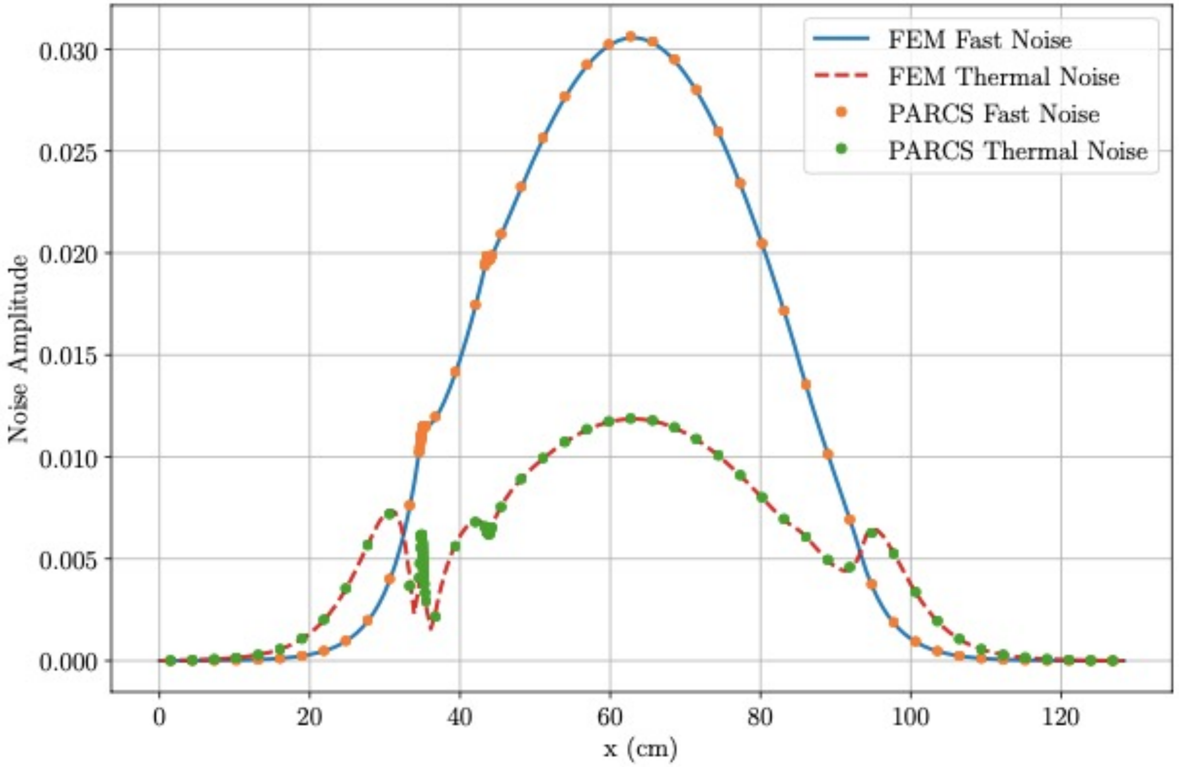


(b) Noise Phase

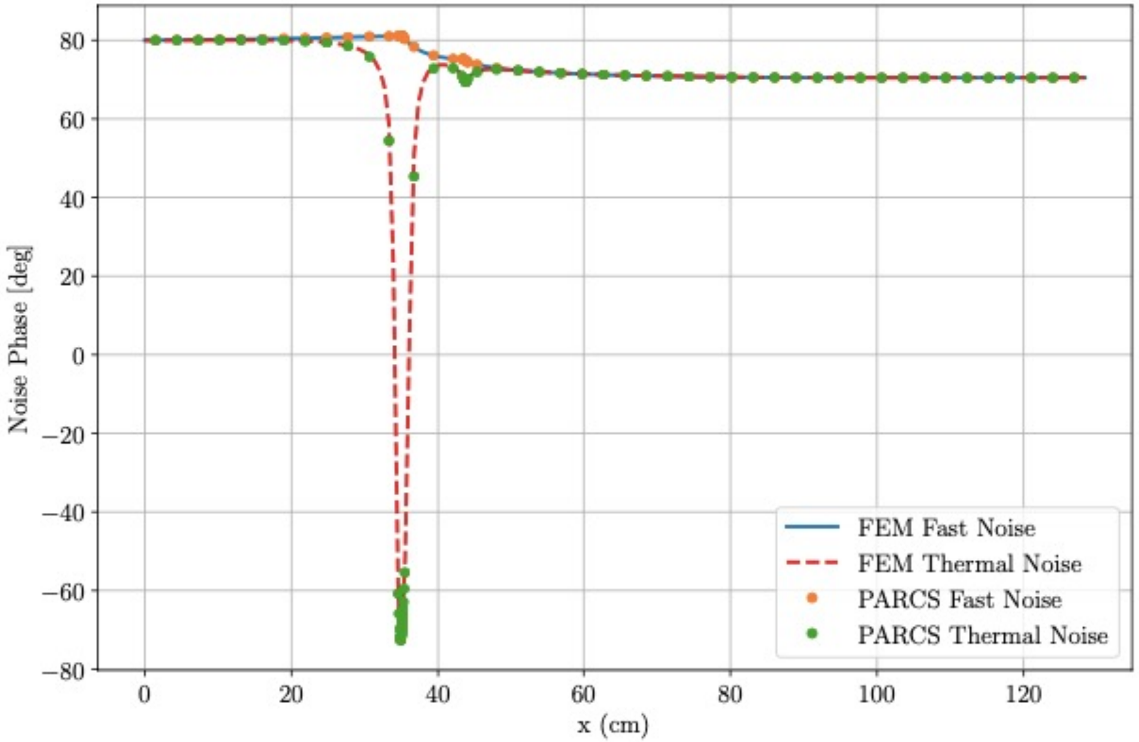
- Similar shape to the static results but some spatial

Fourier Transform at 0.1 Hz

- Local refinement.



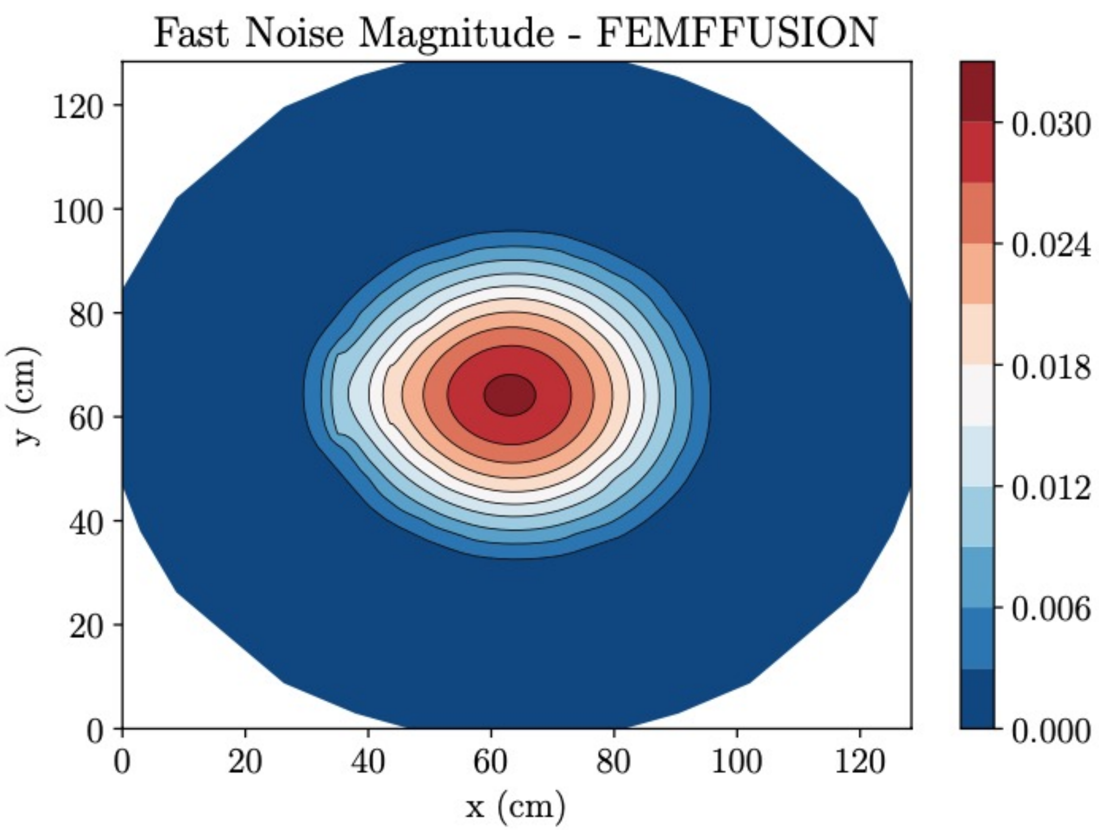
(a) Noise amplitude.



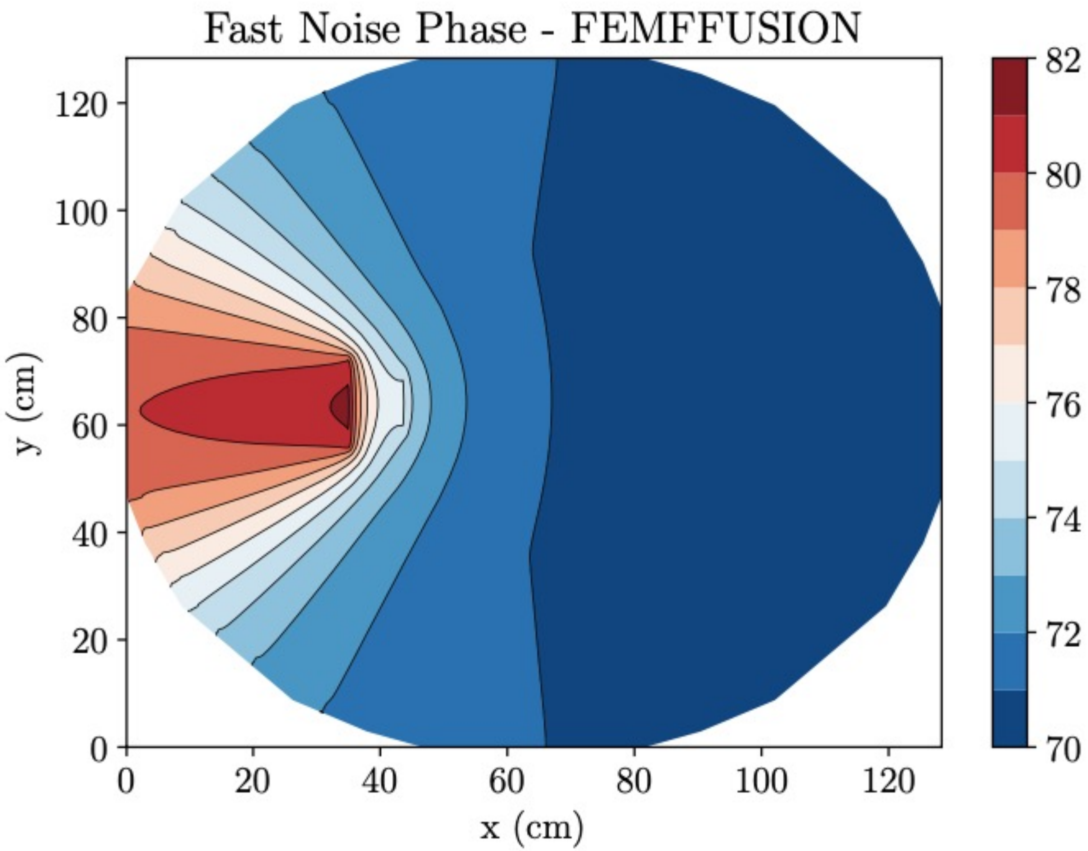
(b) Noise phase.

Frequency-domain comparison

- Uniform refinement at 0.1 Hz.



(a) Absolute noise amplitude.

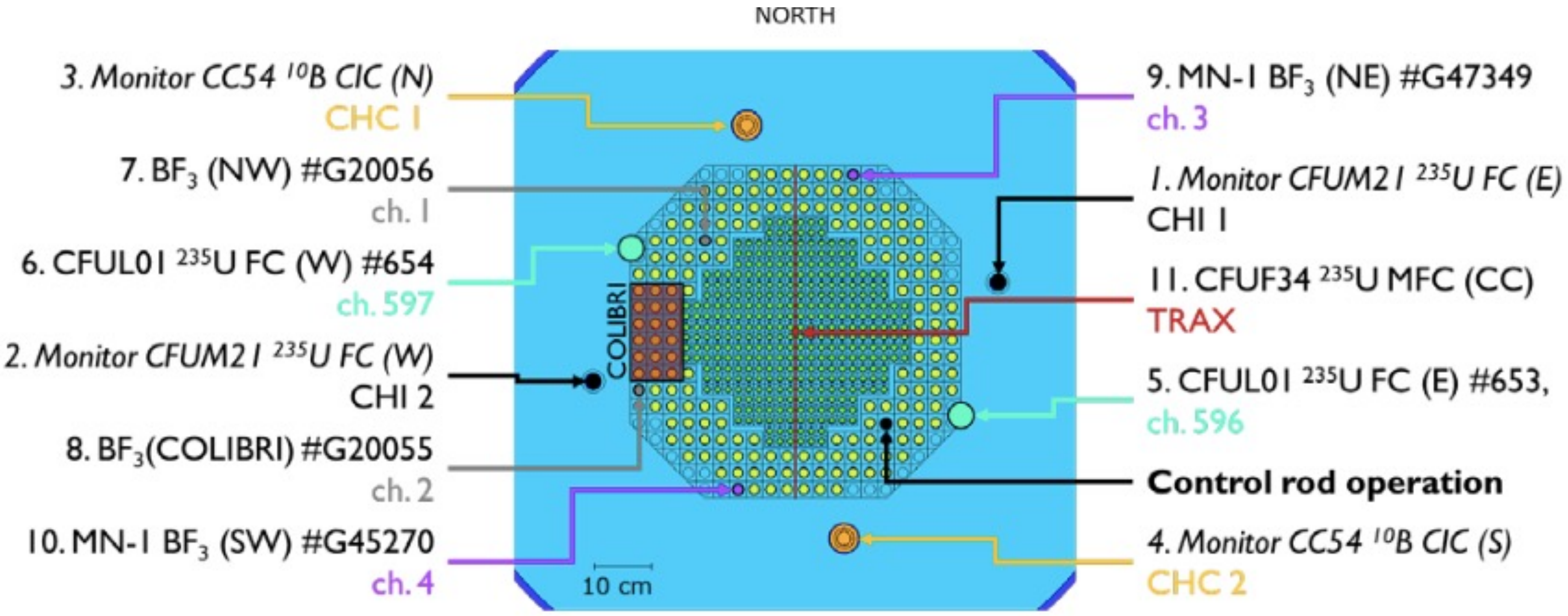


(b) Noise phase.

Detector Data

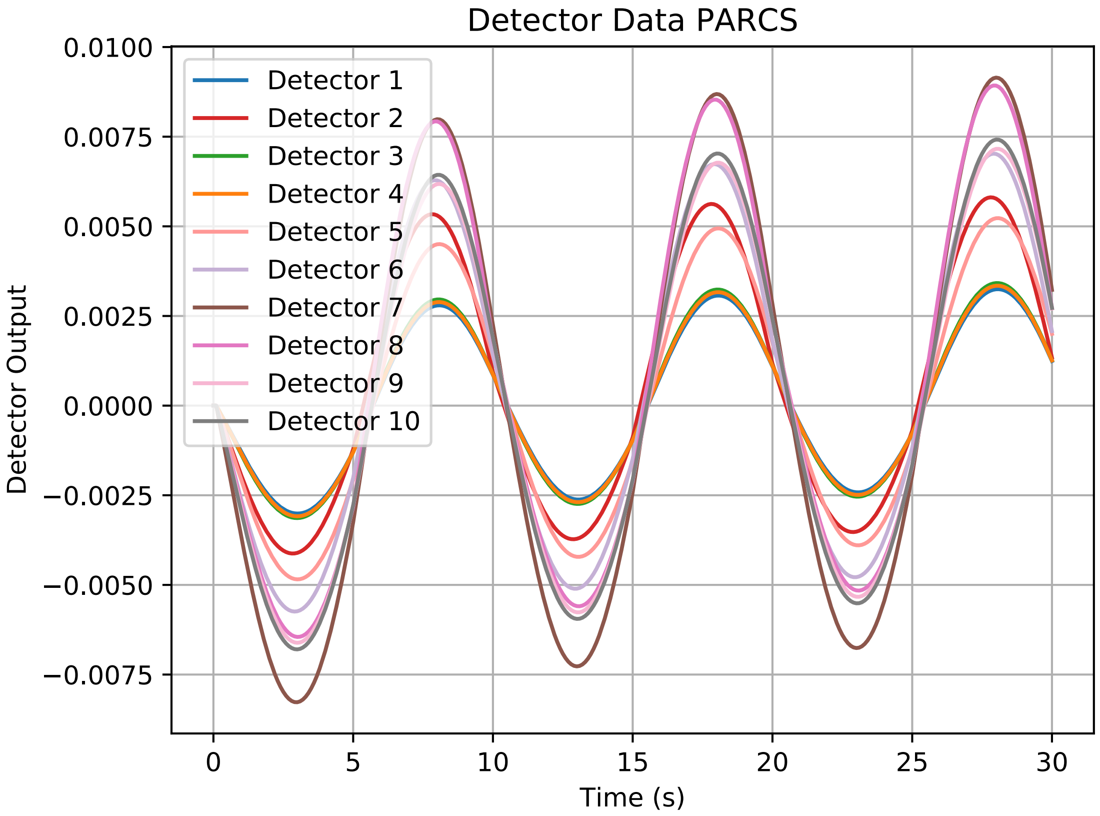
- Now, we can extract the detectors data from the models and compute the CPSD between detectors.

$$Detector\ Output = \phi_2(\vec{r}_{dtc})$$

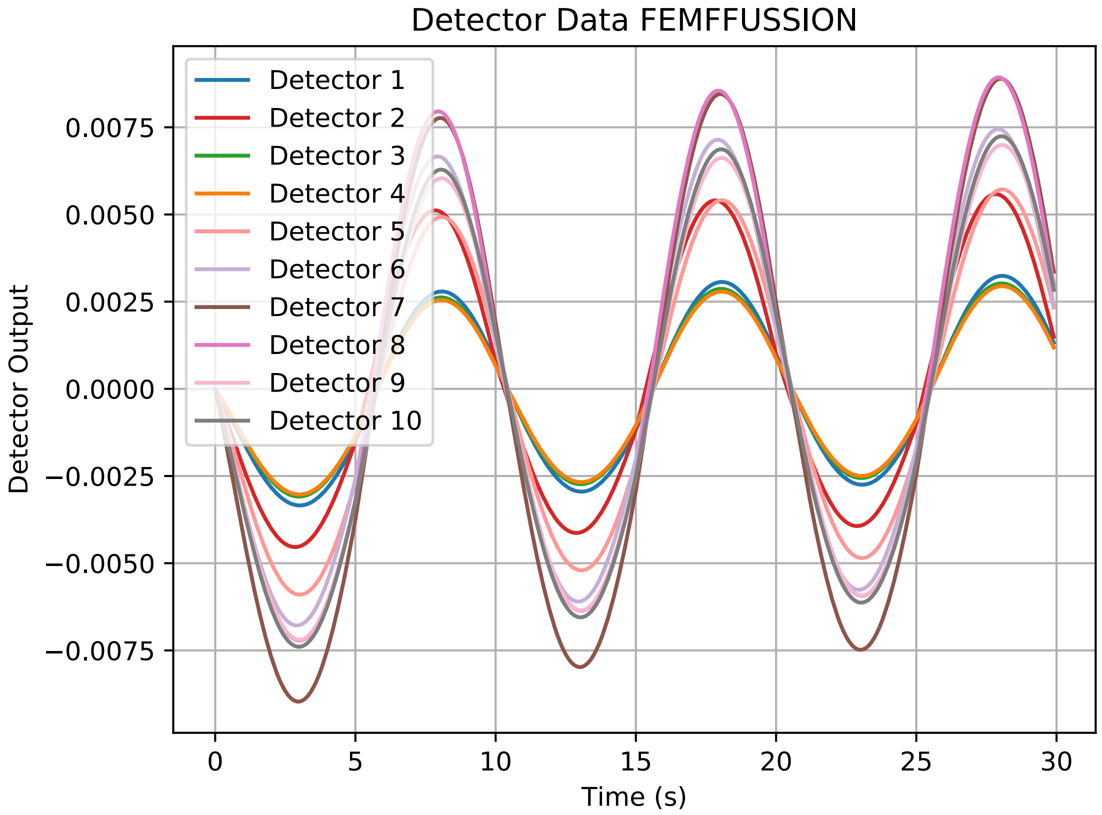


Detector Data

- Uniform refinement.



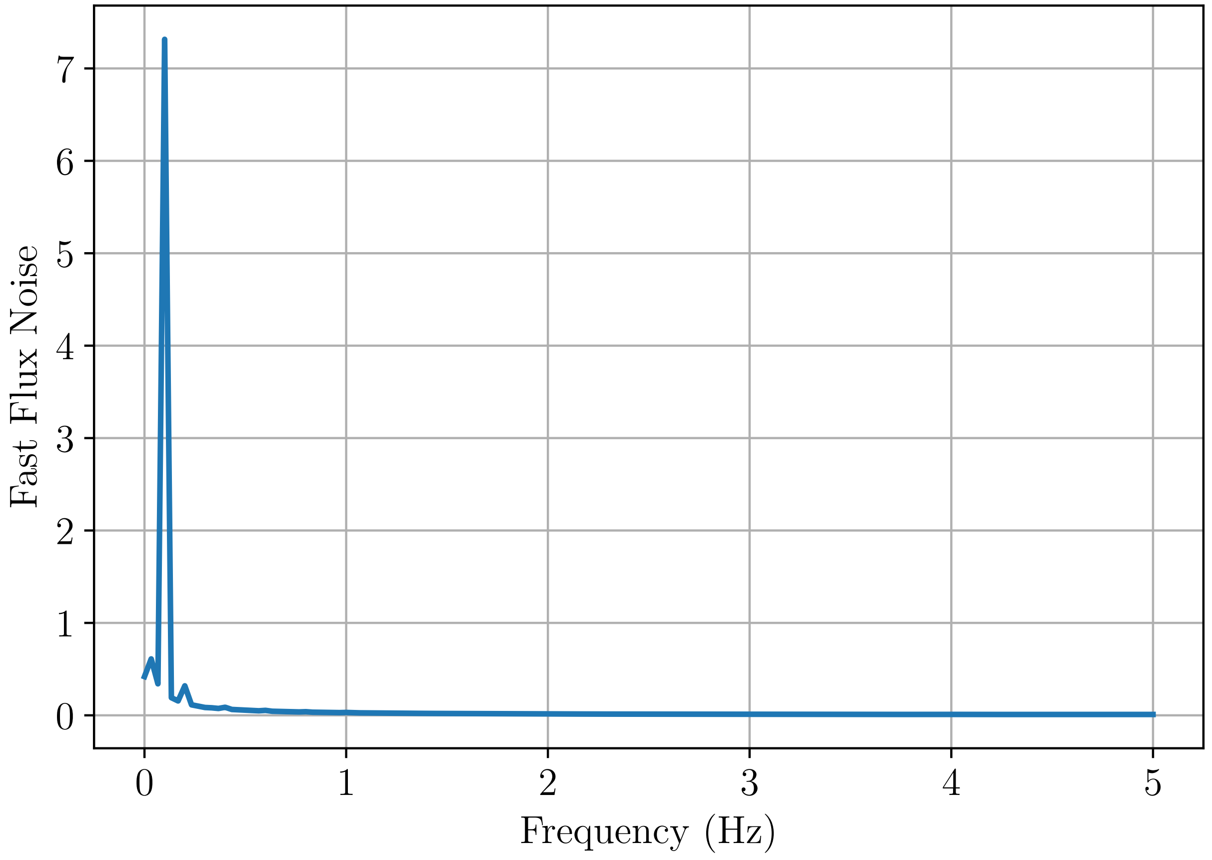
(a) PARCS



(b) FEMFFUSION

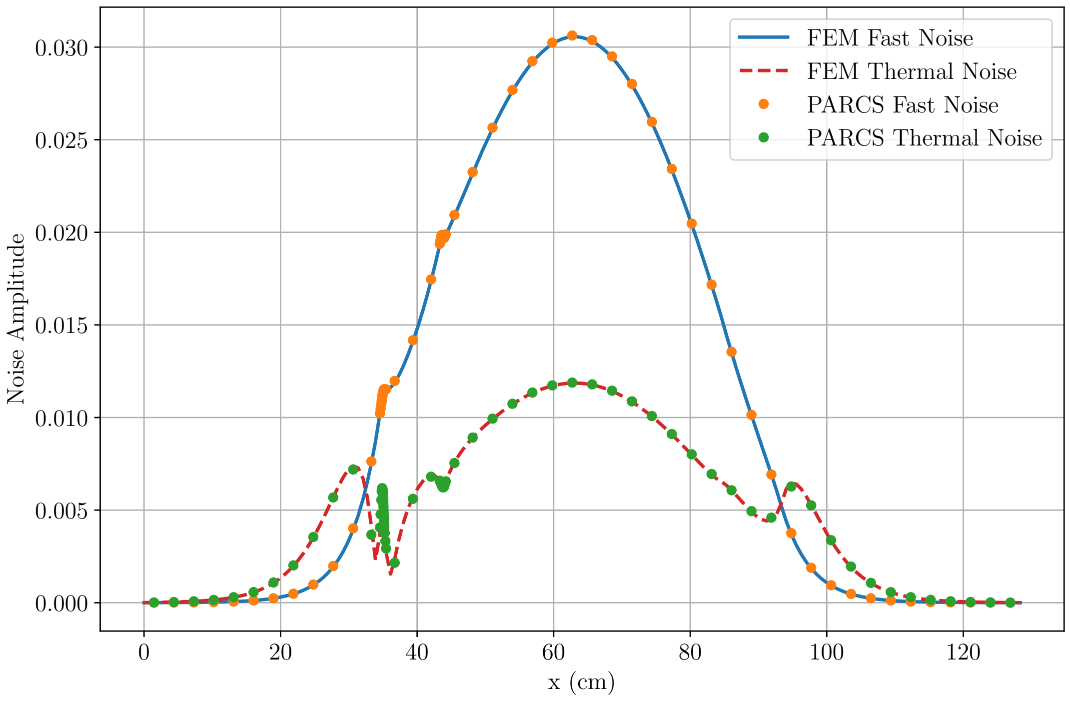
Fourier Transform

- If we make the Fourier, we can see that the induced noise is essentially **monochromatic**.

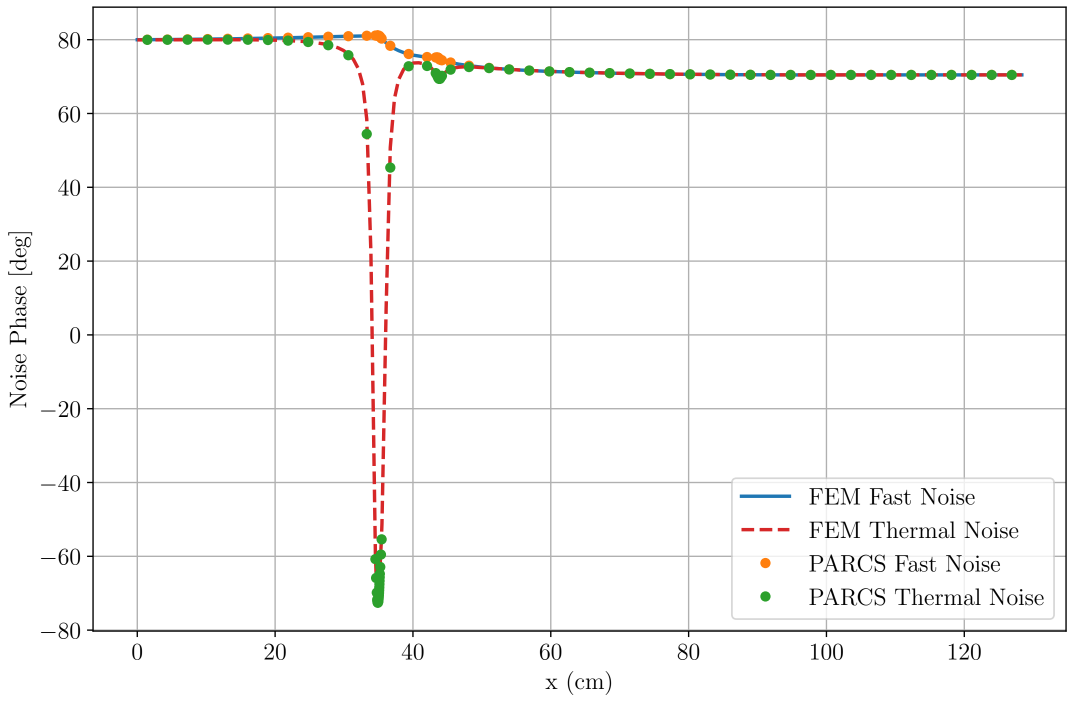


Fourier Transform at 0.1 Hz

- Local refinement.

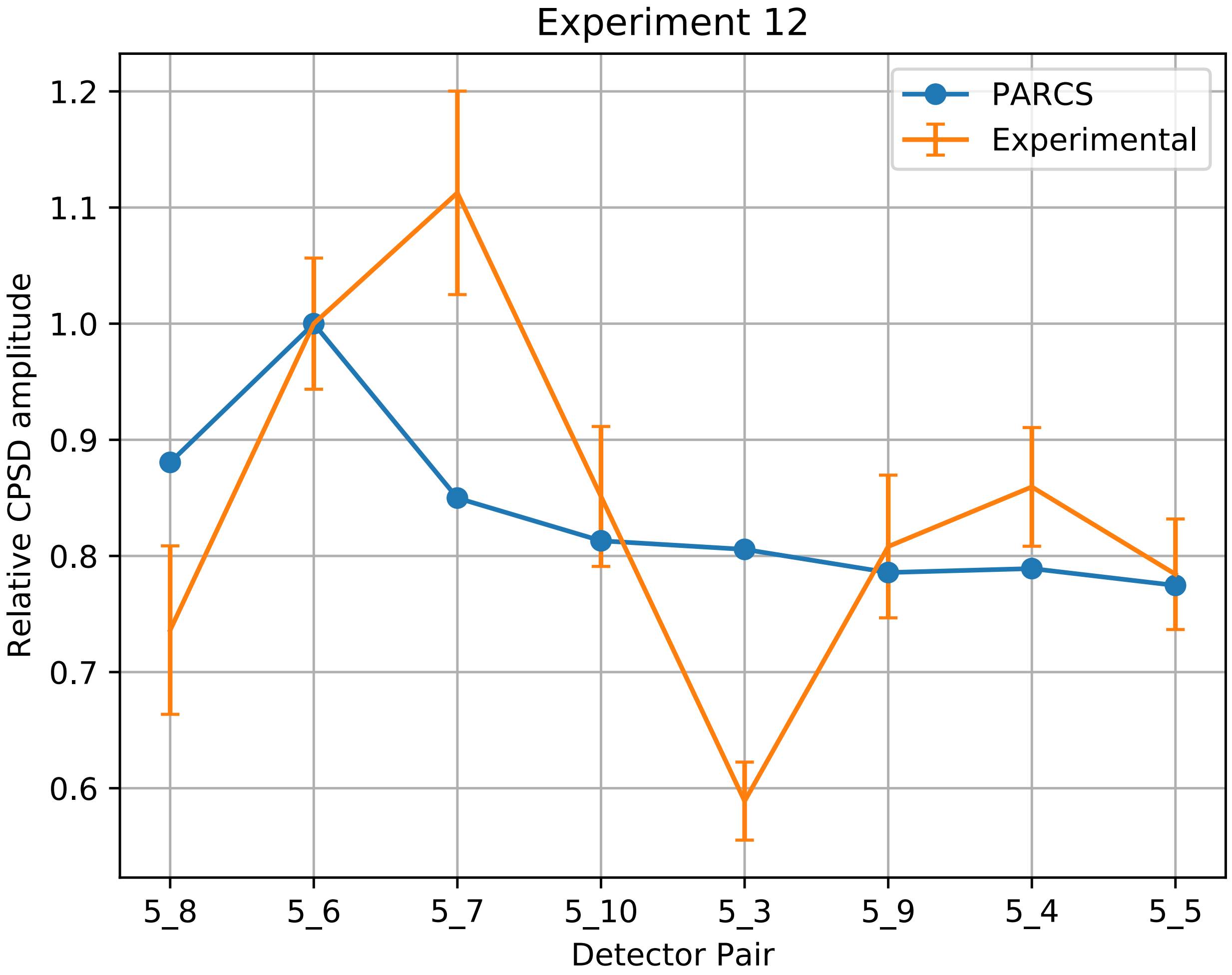


(a) Noise magnitude

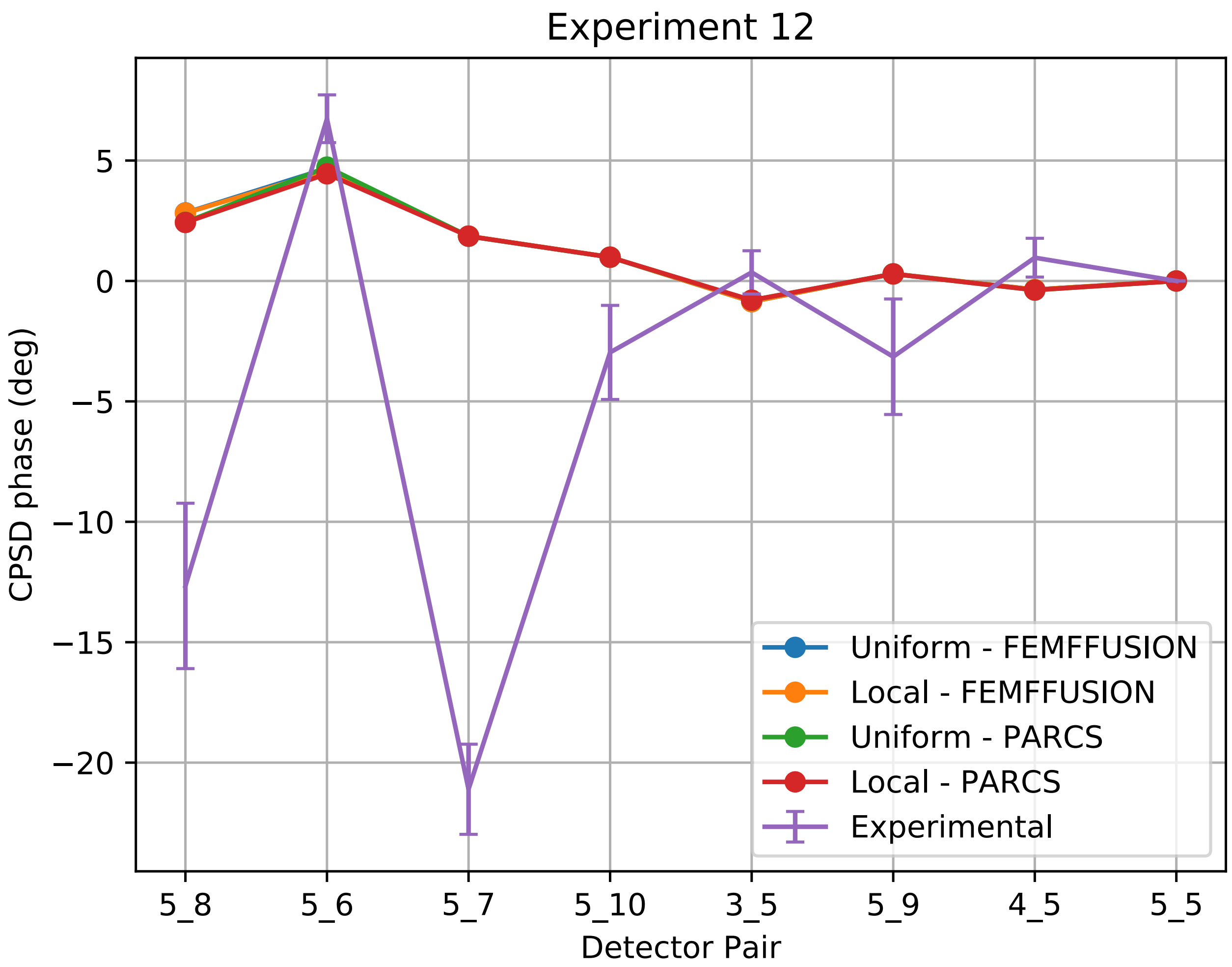


(b) Noise Phase

Experiment 12



Phase Comparison



Conclusions

- Different diffusion time-domain codes agree in the neutron noise shape.
  - Importance of the mesh refinement around the vibrating FA.
- Good agreement with frequency-domain codes as CORESIM.
  - It seems there is a discrepancy between diffusion codes and transport codes.
  - Probably, due to coarse-mesh versus fine-mesh homogenization.
- Time domain analysis is usually more demanding than frequency domain analysis.
- However, time-domain offers:
  - Exact representation of the assembly domain movement.
  - Analysis of all the frequencies. Verification of monochromatic hypothesis.
  - 6 groups of delayed neutron precursors. Visible effect at 0.1 Hz.

Thank you

CORTEX
Core monitoring techniques and
experimental validation and demonstration

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