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Establishing a Methodology for Performing a Multiphysics Run-In Analysis of the GPBR200

DOE ART Gas-Cooled Reactor (GCR) Review Meeting
Virtual Meeting
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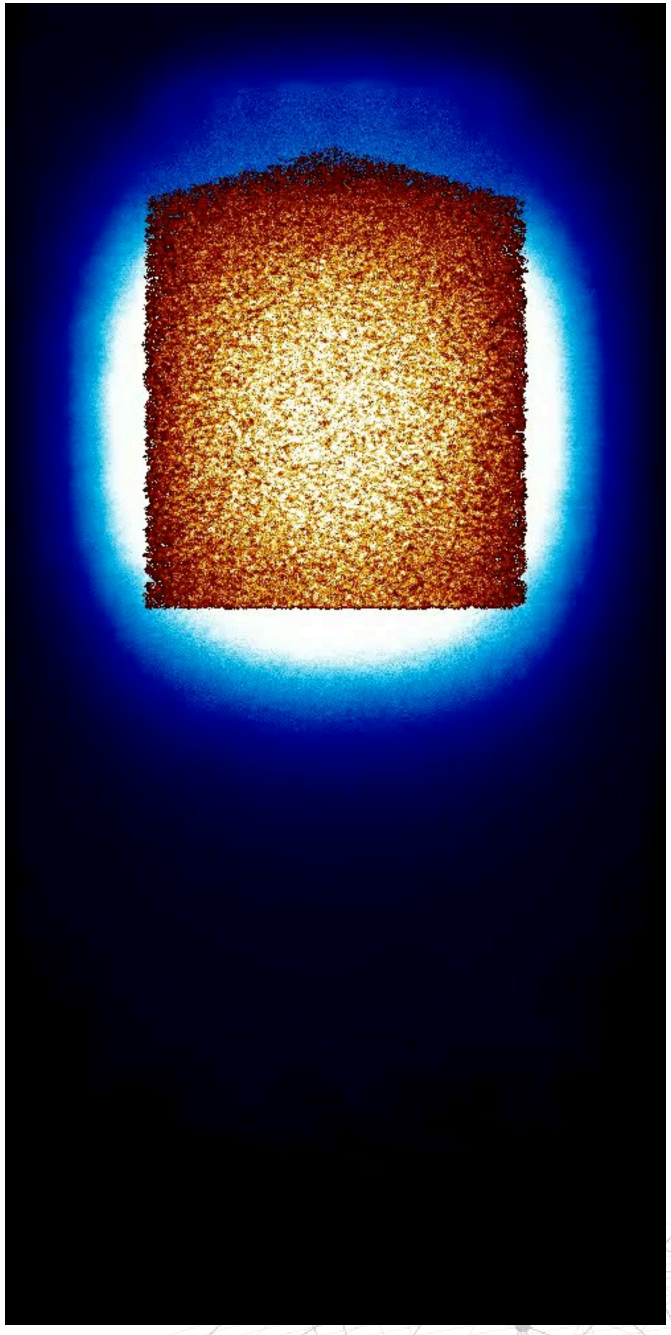
ART
Advanced Reactor Technologies

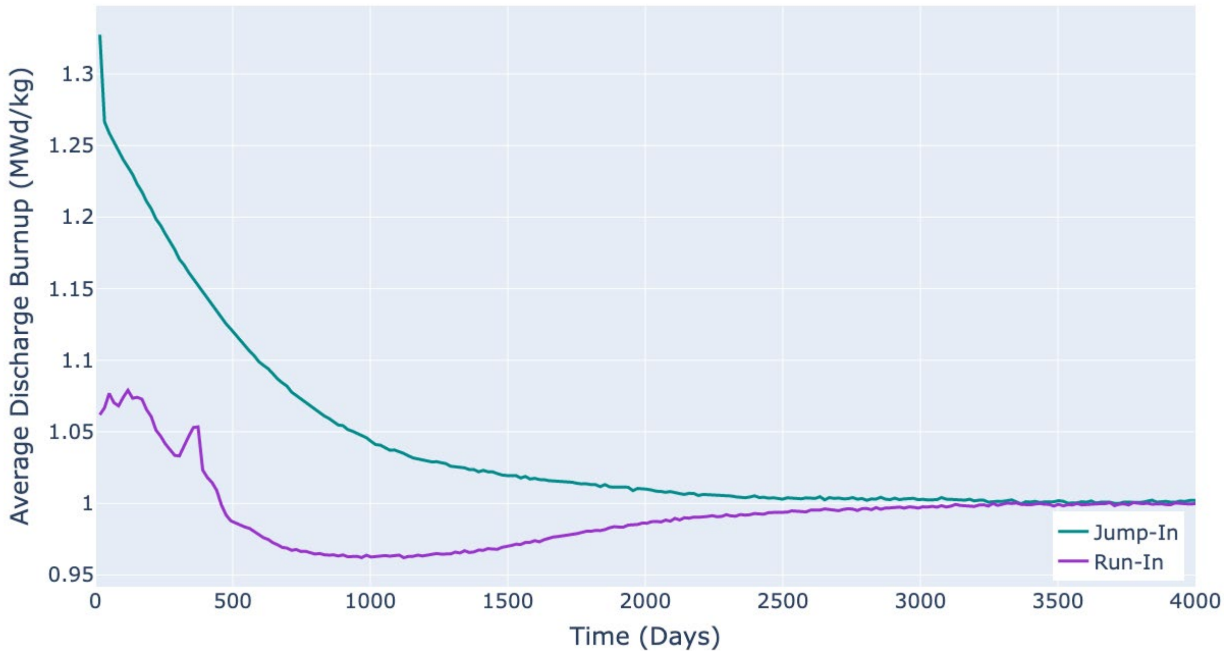
Introduction

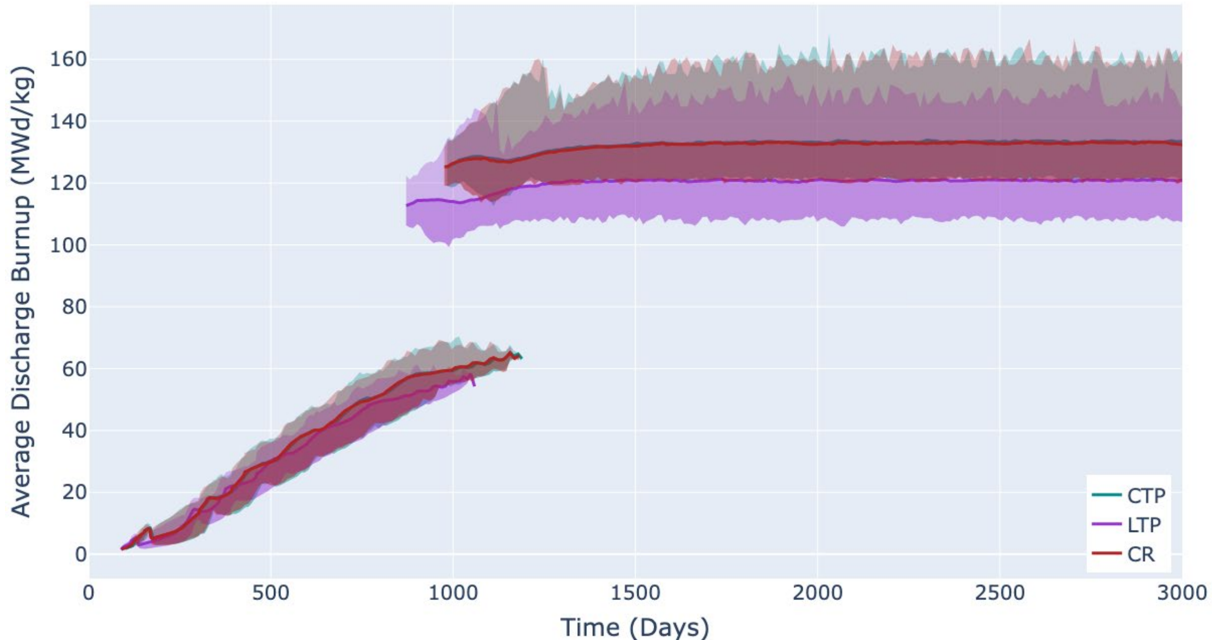
- The running-in phase of a pebble-bed reactor (PBR) is a complex time-dependent problem
  - Involves the use of multiple fuel types, graphite pebbles and a ramp-up of power
- Modeling this problem using high-fidelity simulation tools allows us to examine multiple physical phenomena that is important to PBR operations
  - quantities of interest: discharge burnup, time to full power, pebble power peaking, etc.
- Understanding the temperature distribution will provide insight into key physics missing in isothermal core analysis



Where have we come?

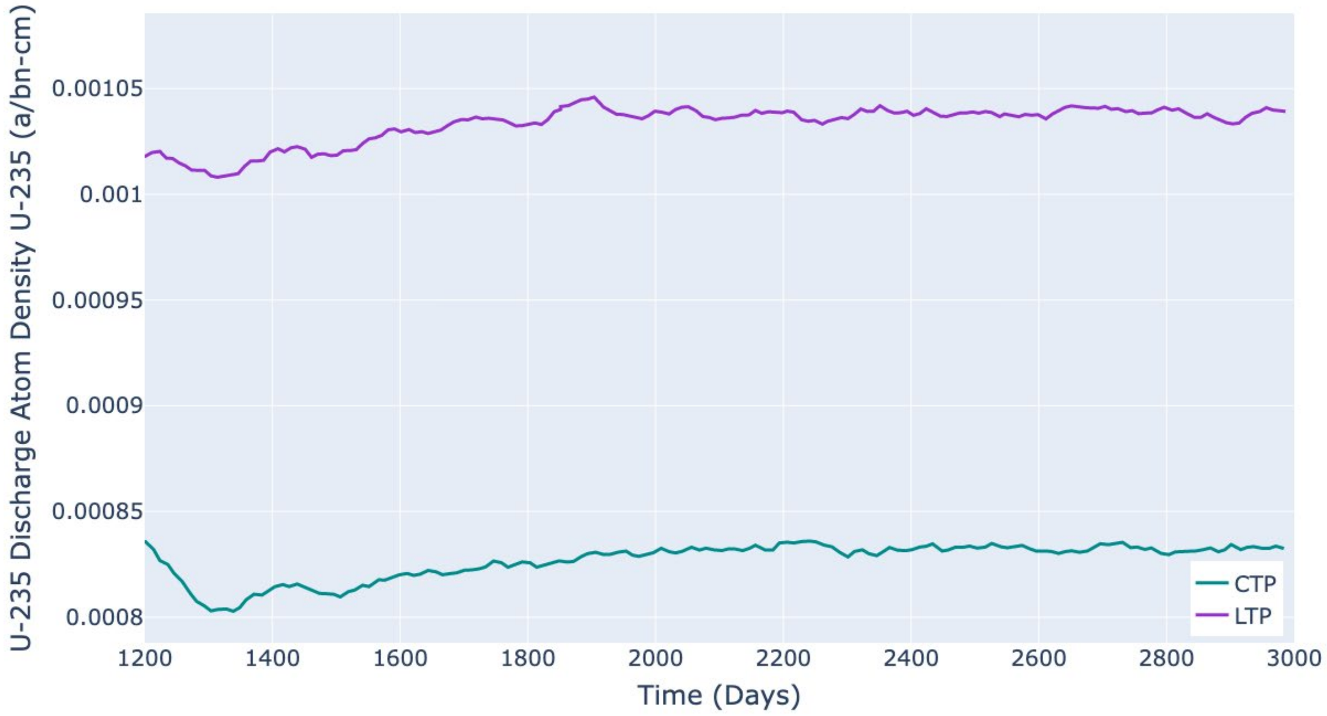
- Significant updates to the GPBR-200 model to ensure consistency between Serpent and Griffin/Pronghorn
- Incorporated the ability to adjust the time-step in our burnup calculation
  - Previous work had fixed time-steps
  - Allows for changes in pebble discharge rate
- Geometry refinement for core
  - Pebble placement using DEM
  - Control rod placement

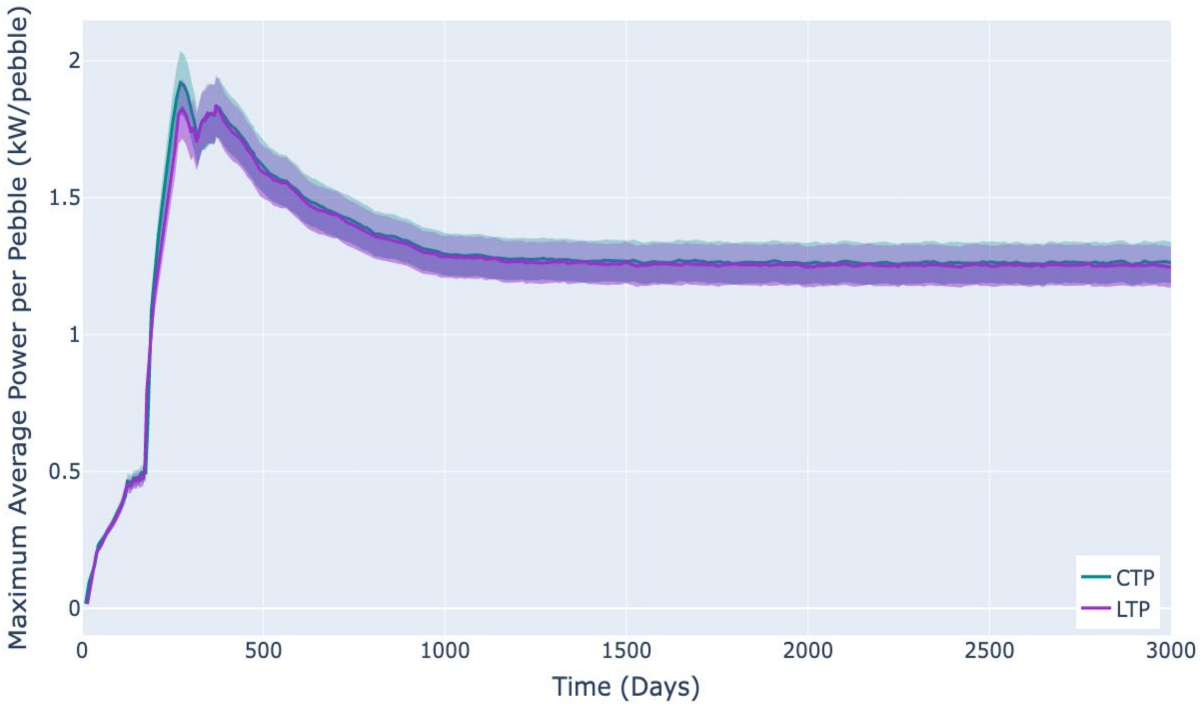




Justification of Research

- FY22 research provided proof of the importance of temperature during the run-in process
  - Constant temperature profile (CTP) vs linear temperature distribution (LTP)
- Provides changes in isotopics and power profiles in the core





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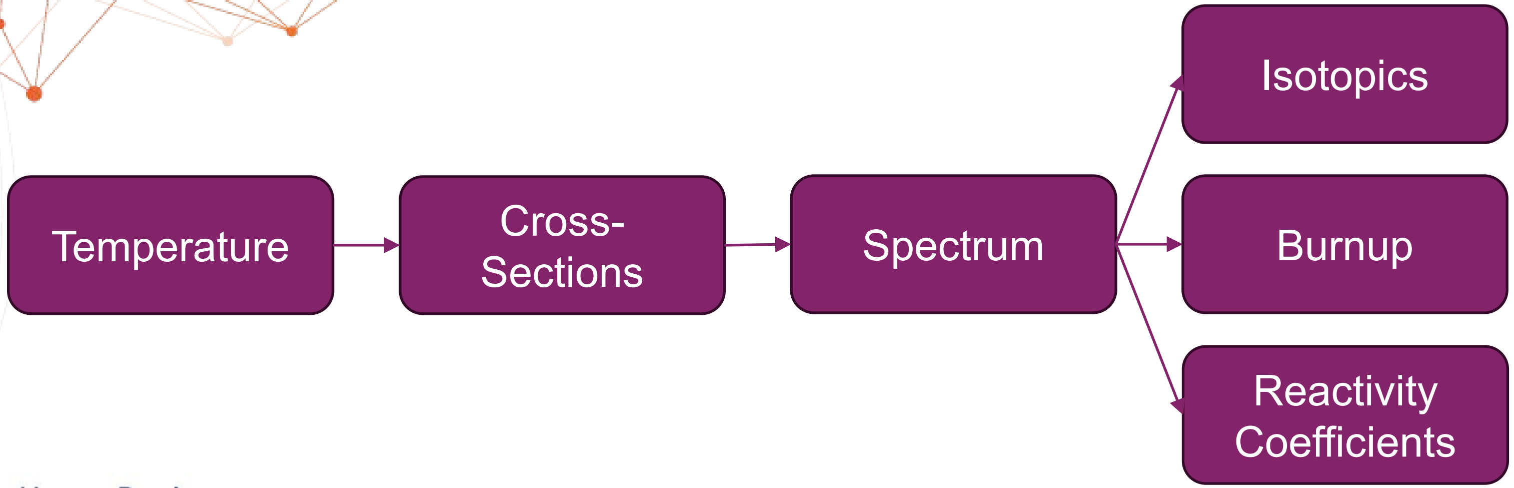
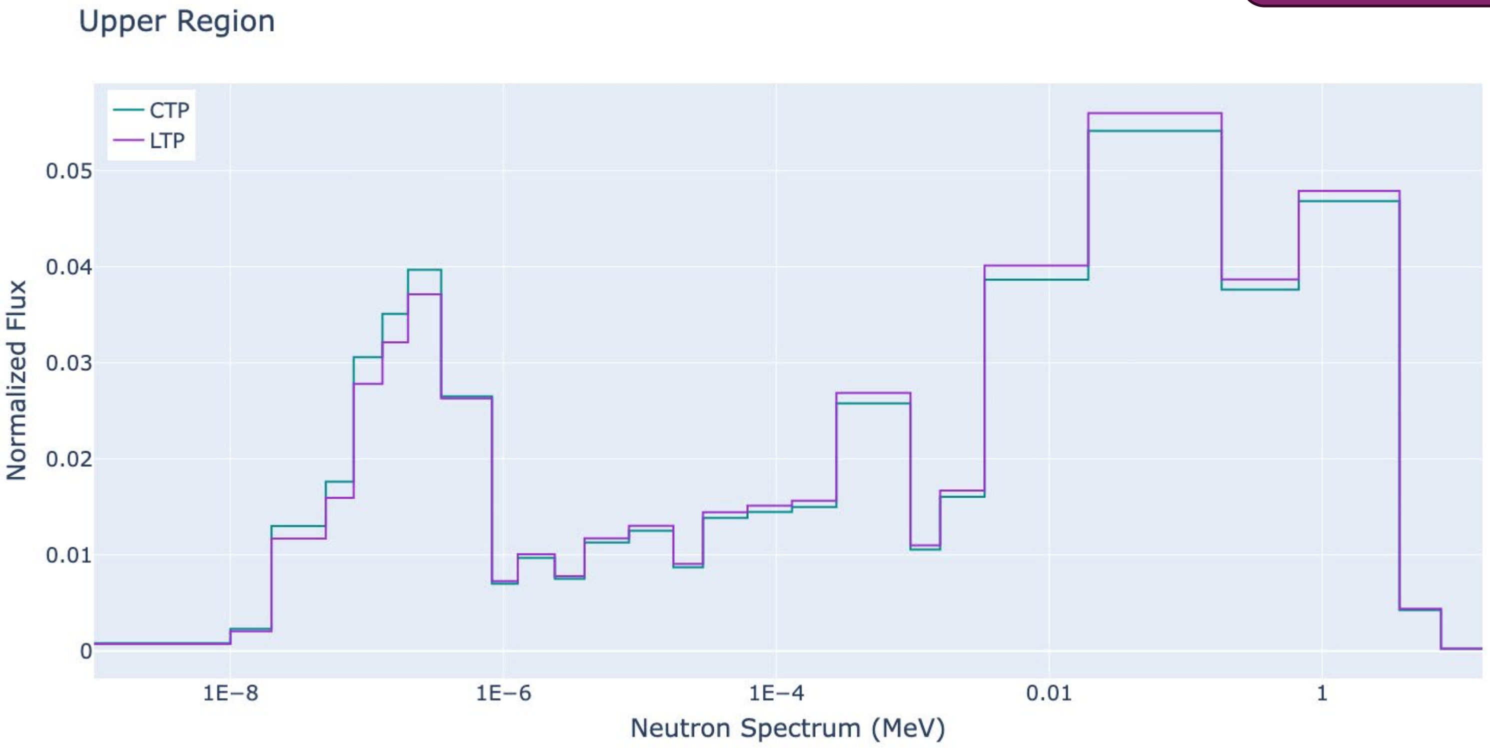
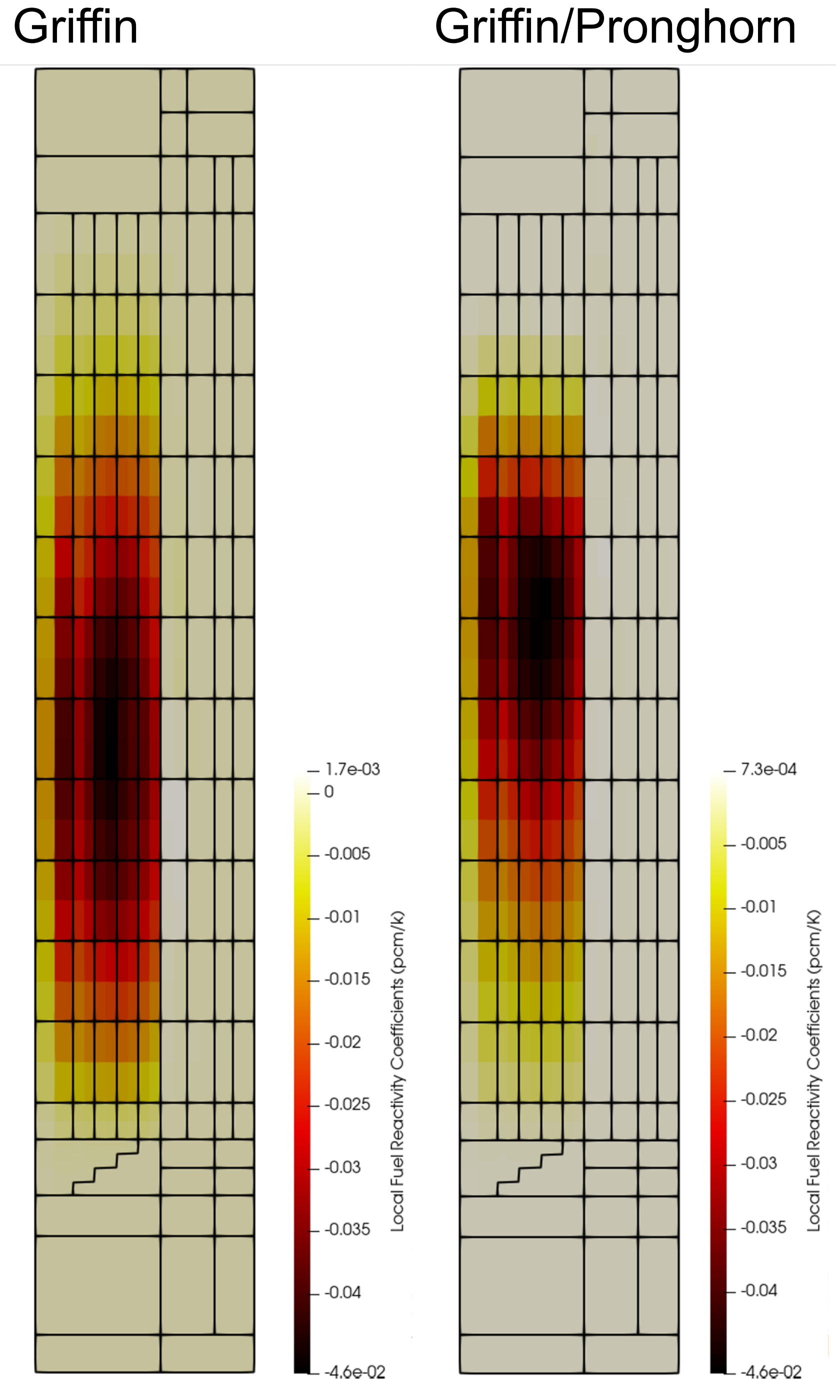


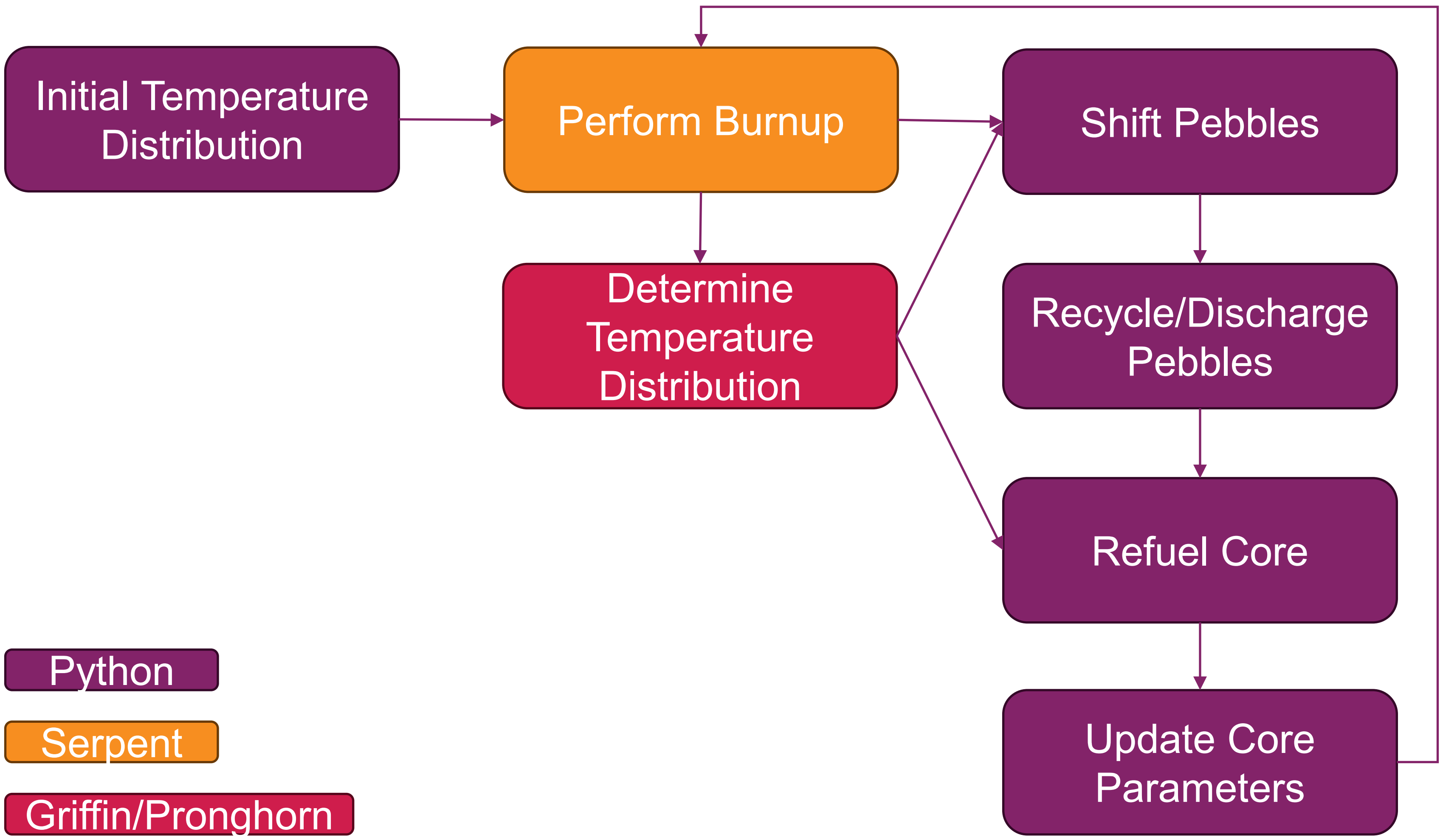


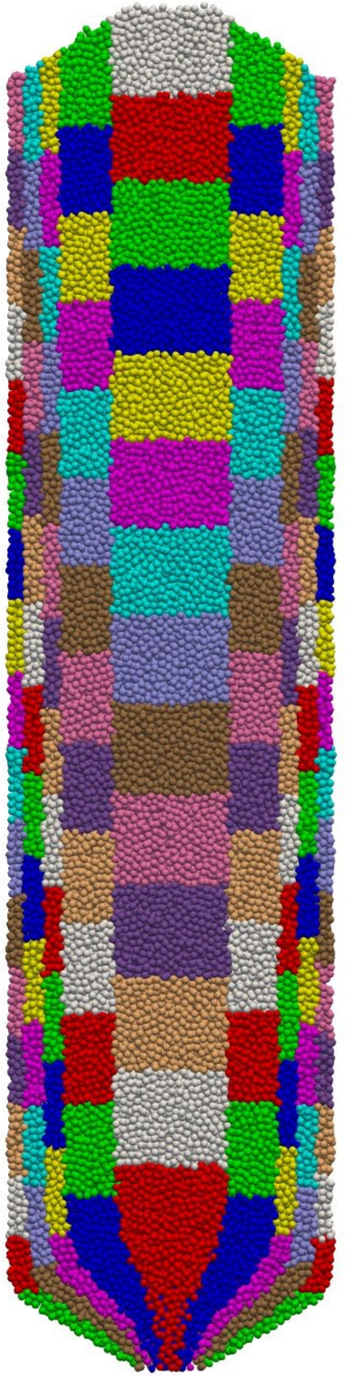


Project Goal

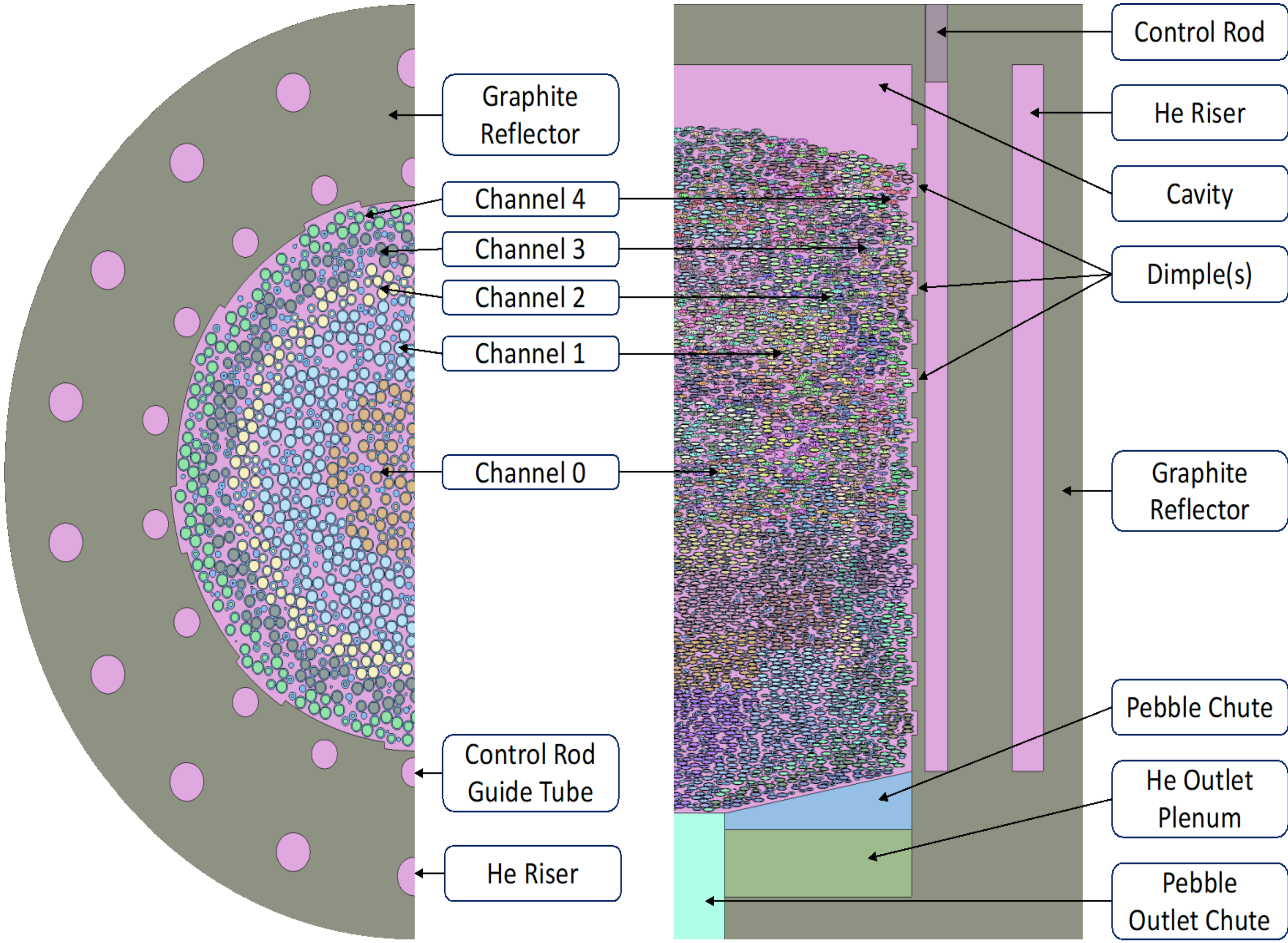
- **Goal**: Develop a methodology for incorporating multi-physics into our high-fidelity run-in simulation.
- **Approach**: Utilize Python to run a coupled Serpent-Griffin/Pronghorn simulation of the pebble movement in a PBR

Proposed Algorithm



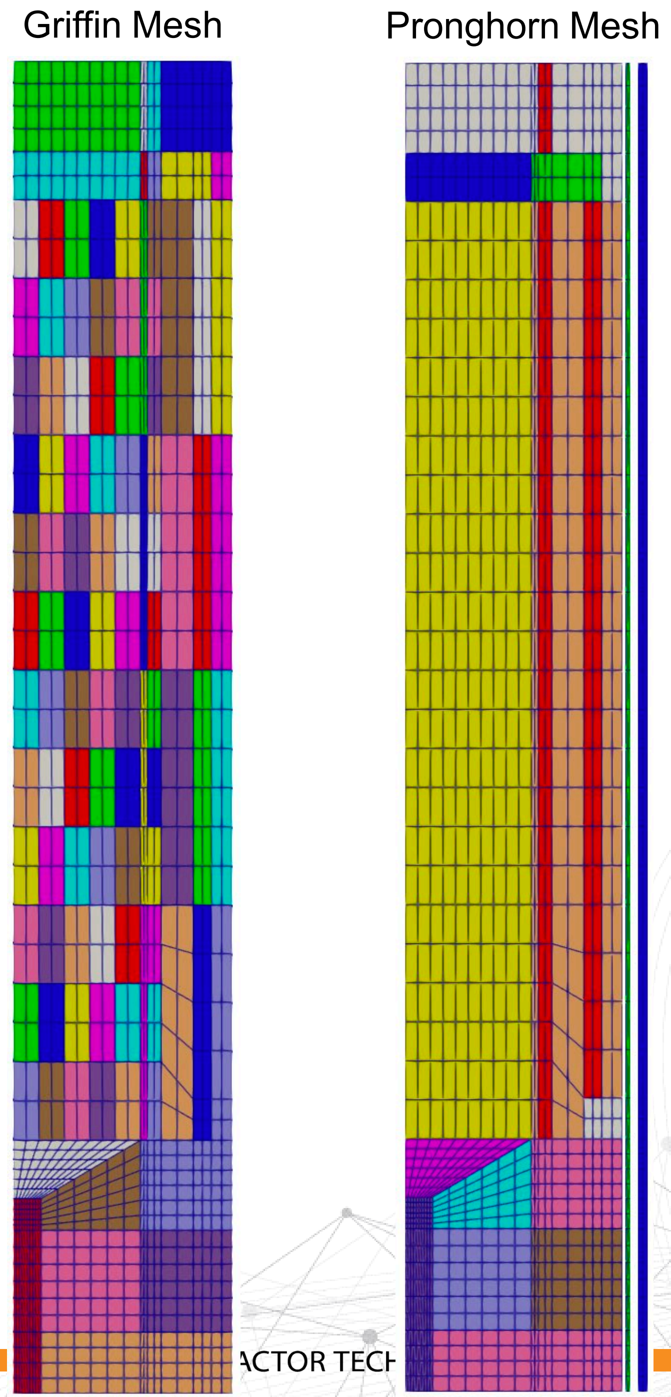


GPBR200 Model: Serpent



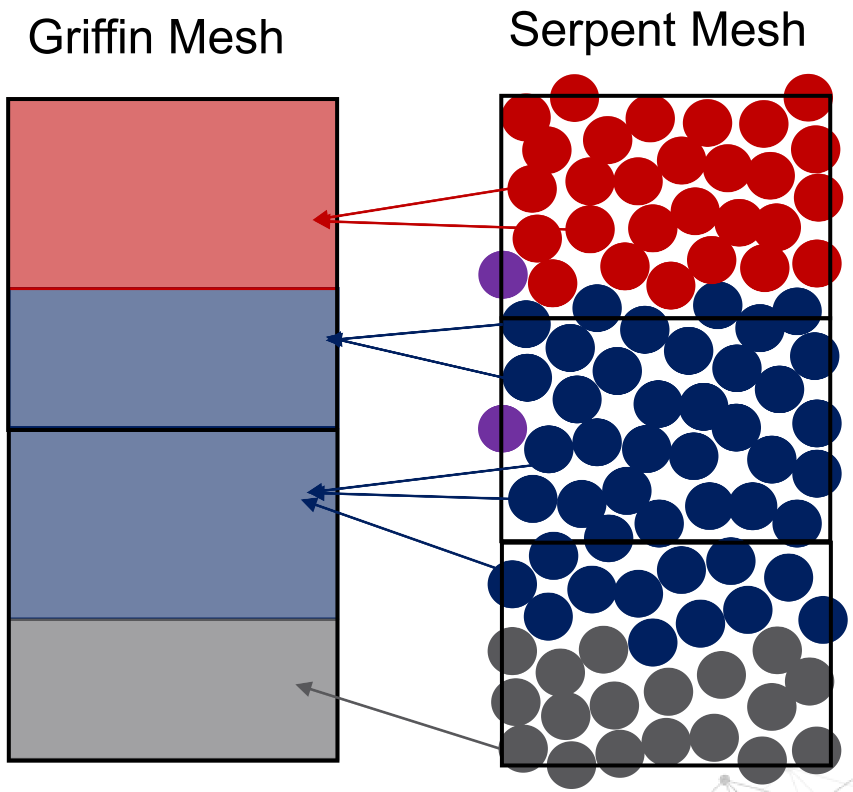
GPBR200 Model: Griffin/Pronghorn

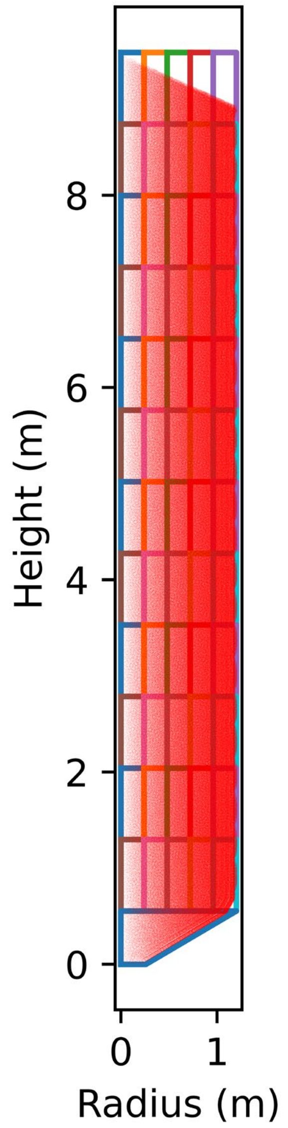
- Captured as much of the geometry into a 2D RZ mesh
  - Varying graphite density to capture lower plenum
  - Control rod and risers implemented
- Core region
  - No streamlines (60 blocks within the core)
  - Lower conus region is modeled explicitly
  - Upper conus is smeared into the top blocks



Data Transfer

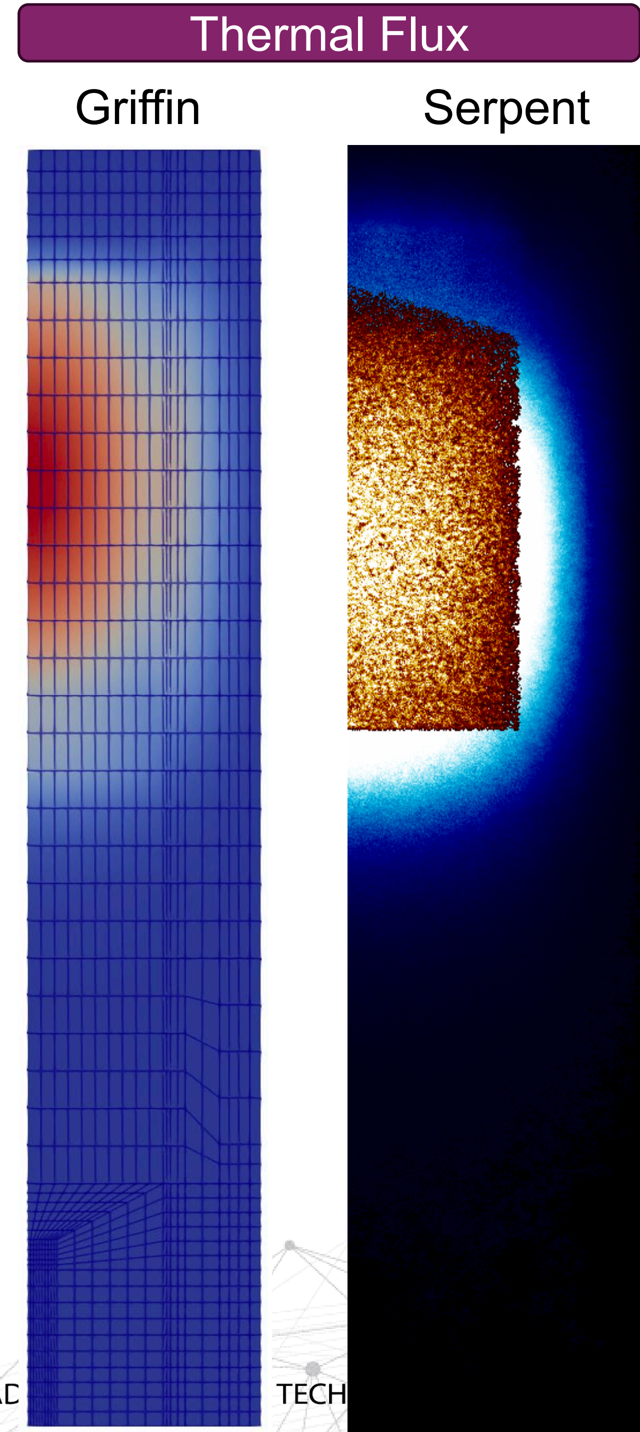
- Serpent provides explicit pebble positions; these can be easily mapped to a Griffin block and vice-versa
  - Material creation in Griffin is based on volume averaging based on the number of pebbles of each pass, fuel type, and each axial volume
- The reverse is performed to pass information in a block to a pebble





Results: Static Data Transfer

- Microscopic cross-sections have been generated from DRAGON
- Pebble isotopics can be passed from Serpent to Griffin
  - Mapping function performs the previous data transfer
- Coupled Griffin/Pronghorn calculations have been performed
  - Provides confidence in the methodology



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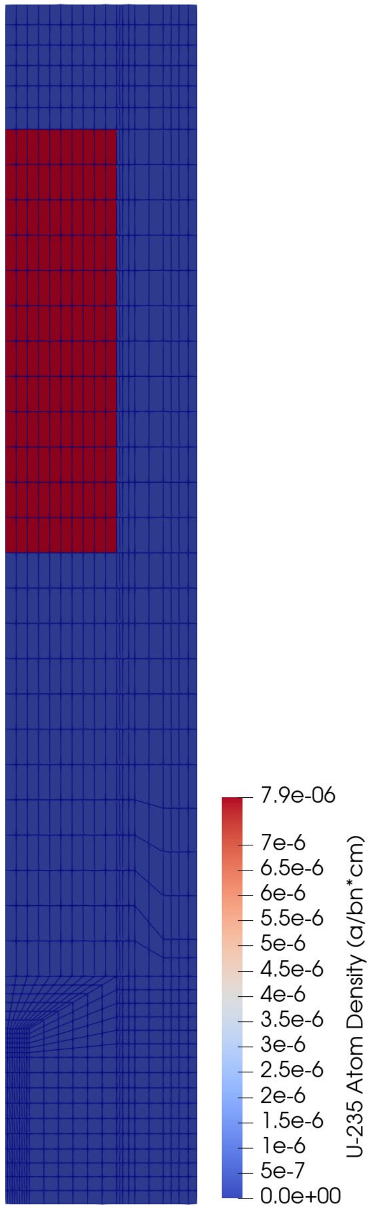
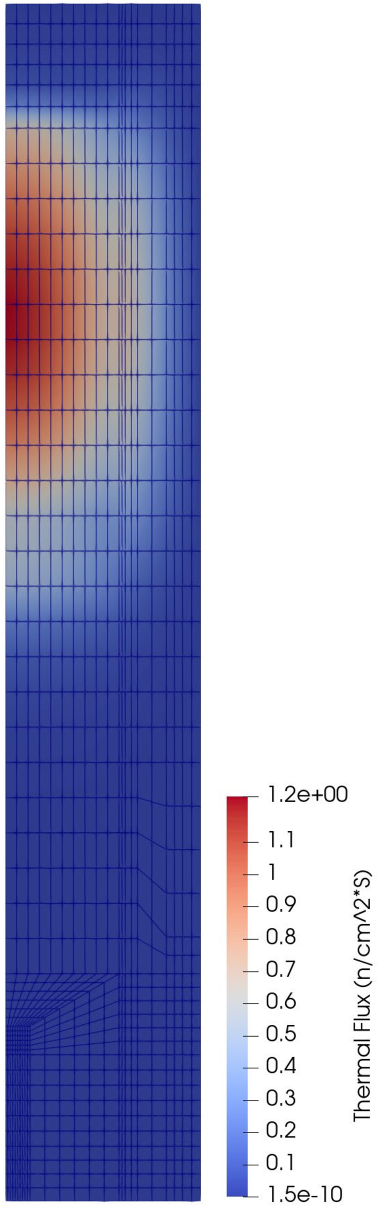
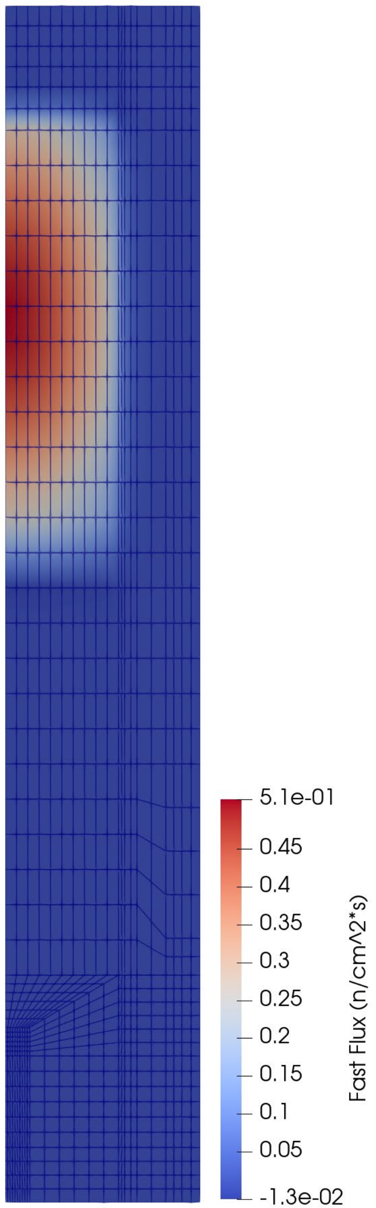
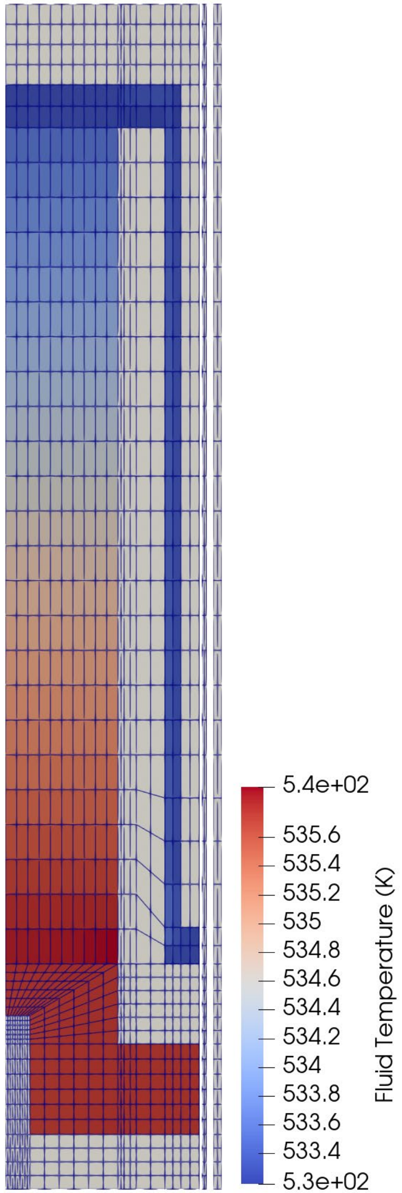
Results: Static Data Transfer



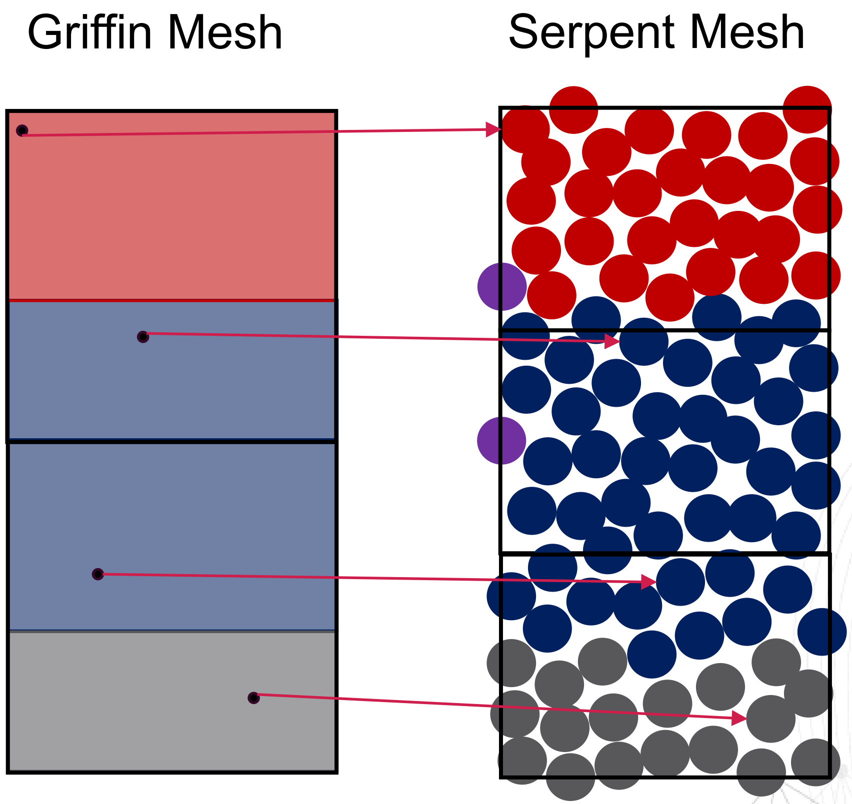






Results: Where are we going?

- Coupled Griffin/Pronghorn for each time step
  - Integration with Python to allow two-way coupling
- Regardless of approach, we generate a temperature field
  - Each element will have an associated temperature
  - Pass average temperature to Serpent (~50 K increments)
- Analysis of the temperature feedback effects



Collaboration

- University of Wisconsin NEUP (Ben Lindley)
  - Utilizing the GPBR model for telescopic control rod scoping studies
- Idaho State University (Leslie Kerby)
  - Utilizing Machine Learning to Model and Analyze the Run-In Scenario of a Pebble-Bed Reactor
- Oak Ridge National Laboratory (Rike Bostelmann)
  - Demonstrating Shift coupling as part of NEAMS reactor physics R&D (M2MS-23OR0301022)
- Idaho National Laboratory (Rodrigo de Oliveira)
  - Reference solution for Griffin run-in module (NEAMS)
- GPBR enabled an NNSA proposal for examining PBR safeguards during the run-in phase
- Journal articles
  - "High-Fidelity Simulations of the Run-In Process for a Pebble-Bed Reactor," *(submitted)*
  - "Parameter Study of the Run-In Process for a Pebble-Bed Reactor," *(in progress)*
  - "Multi-physics Analysis of the Run-In Process for a Pebble-Bed Reactor," *(in progress)*

Conclusions & Wrap Up

- We have provided a framework for coupling a high-fidelity Monte Carlo code with a deterministic solver
  - Provides an opportunity to incorporate thermal fluid feedback into our Monte Carlo simulation
- Initial Serpent to Griffin coupling has been performed
  - Working on developing coupled Griffin-Pronghorn
- Final stage will be to compare isothermal/linear temperature profile simulation with Multiphysics run-in simulation

Questions?