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SCALE/FAST Fuel Performance Update

2018 SCALE Users' Group

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ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Project Goals (end-date mid FY19)

- Enable SCALE neutronics-informed radial power profiles in the fuel performance code FAST
  - Currently, FAST has internal radial power profiles for UO2 <5% enr.
  - What about?
    - U-metal rods
    - Fast reactors
    - >5% enrichment
    - High-burnup
    - Lightbridge?
- Investigate inclusion/generation of additional T/H or fuel performance data at Polaris lattice physics (e.g. temperature, void distribution)

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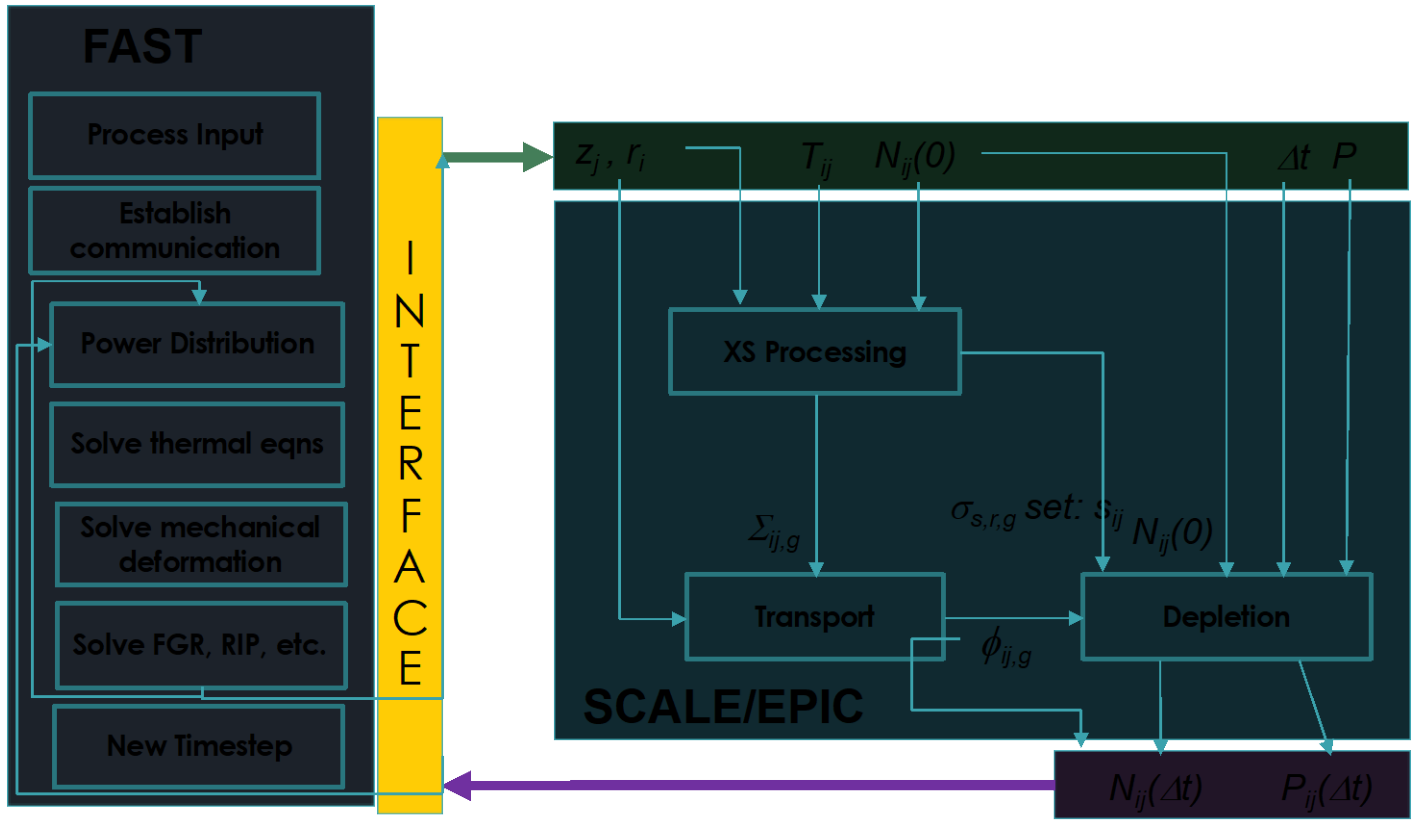
  - What about?
    - **U-metal rods**
    - **Fast reactors**

    } **So far, using EBR-II as application case**

    - >5% enrichment
    - High-burnup
    - Lightbridge?
- Investigate inclusion/generation of additional T/H or fuel performance data at Polaris lattice physics (e.g. temperature, void distribution)

Strategy #1: Single-rod calculation option

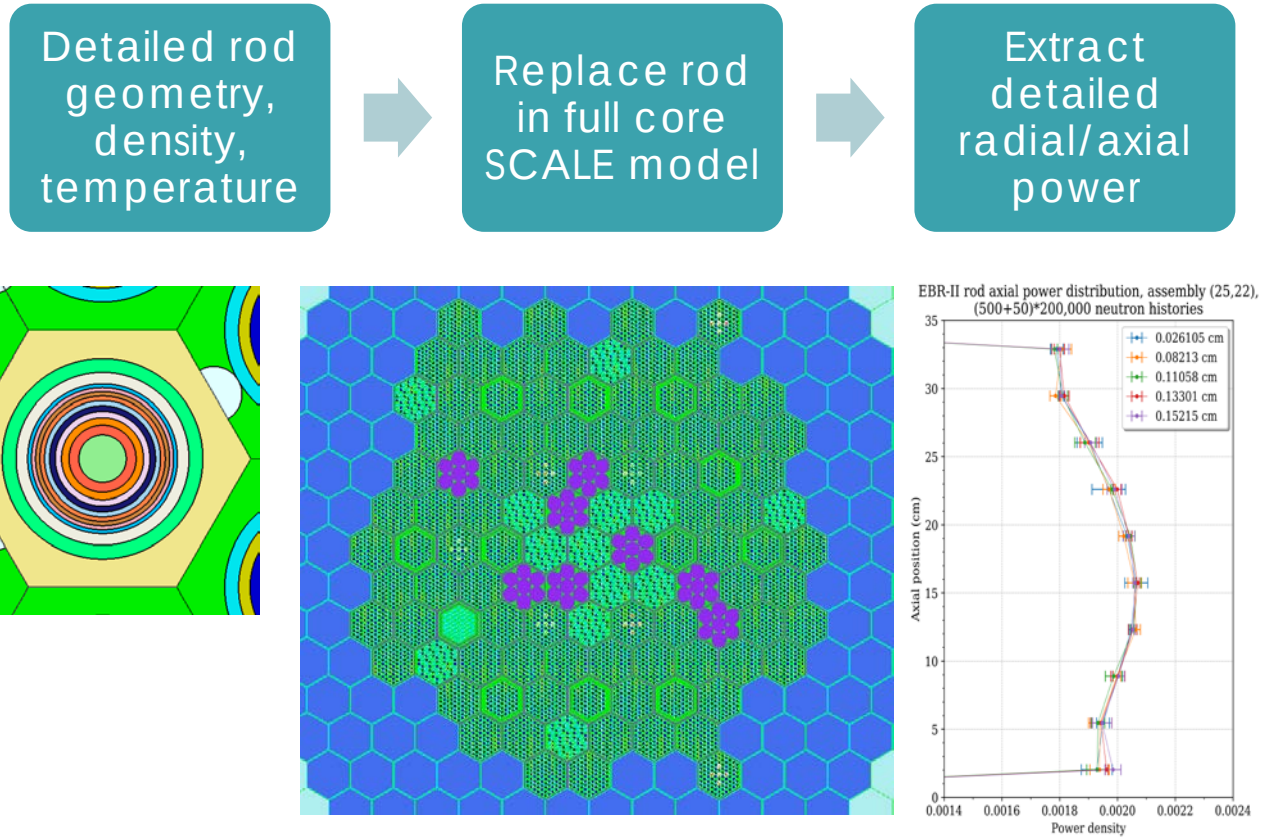
- **Overarching goal: neutronics as fast as FAST**
- Method
  - RZ SN transport model
  - ESSM self-shielding
  - Simplified depletion chains
- Generated by FAST
  - Mesh zones
  - Temperature distribution
  - Density distribution
  - Total or Axial power



- Generated by SCALE External Power Interface Coupler (EPIC)
  - Isotopic/Element distribution
  - Detailed power distribution

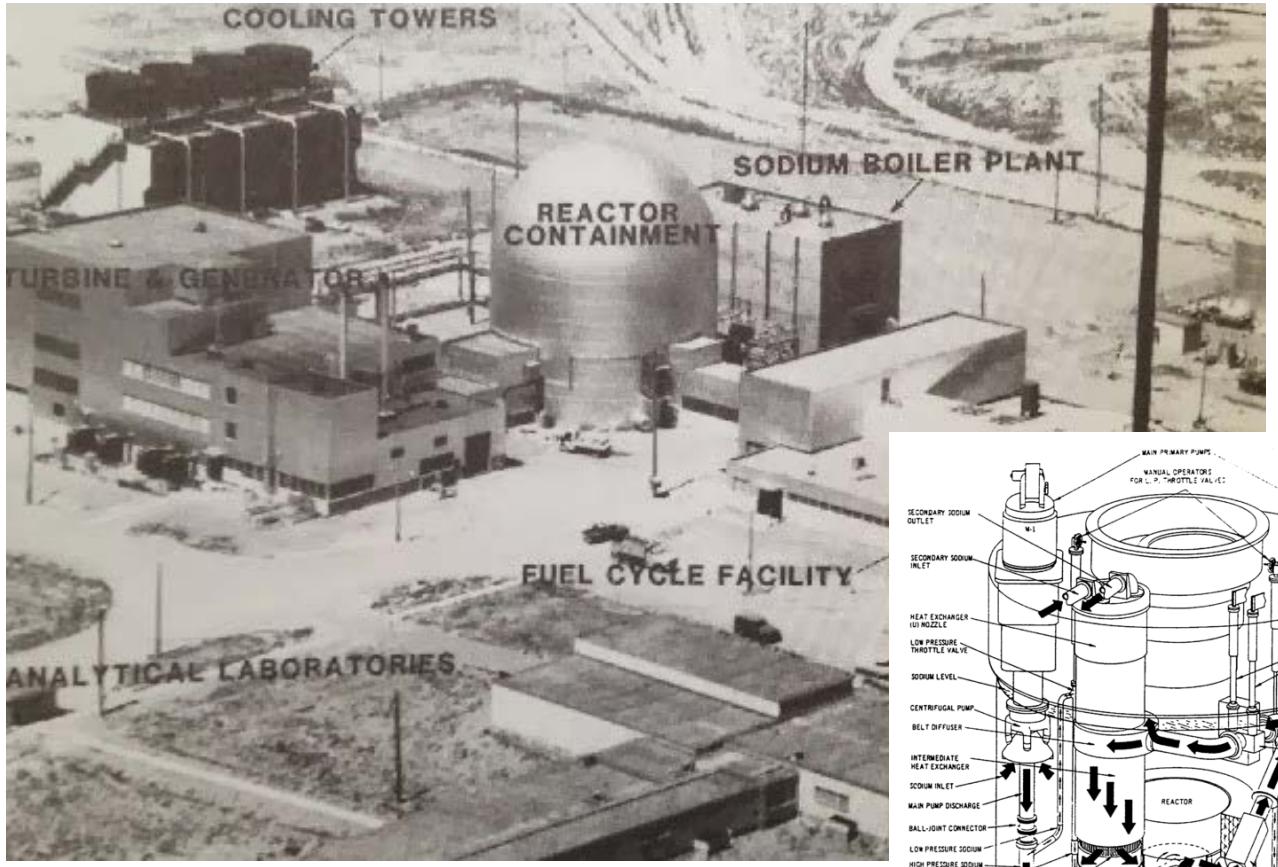
Strategy #2:
Full-core CE Monte Carlo with detailed rods

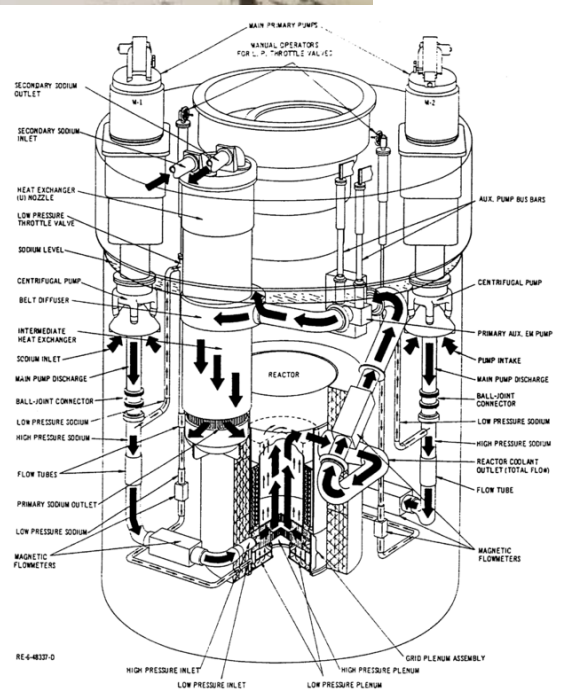
- **Overarching goal:**
  easy-to-use reference neutronics
- CE Monte Carlo TRITON/Shift
- Substitute detailed rod into existing core model
- Extract power and isotopic information
- Will lead to FAST internal radial power profile for different reactor types
- ***Currently one-way, one-time information flow***



Status as of FY18 Q4

- Created EPIC framework for Strategy #1 (single rod calculation)
- Shifted to prototype for Strategy #2 (substitute detailed rod in full-core calculation)
  - CE Monte Carlo with TRITON/SHIFT
  - Applied to EBR-II (SFR test)
- Working with Ian Porter (NRC) on Interface document
- Finalizing what we have so far for 6.3-beta1 (Fall 2018)





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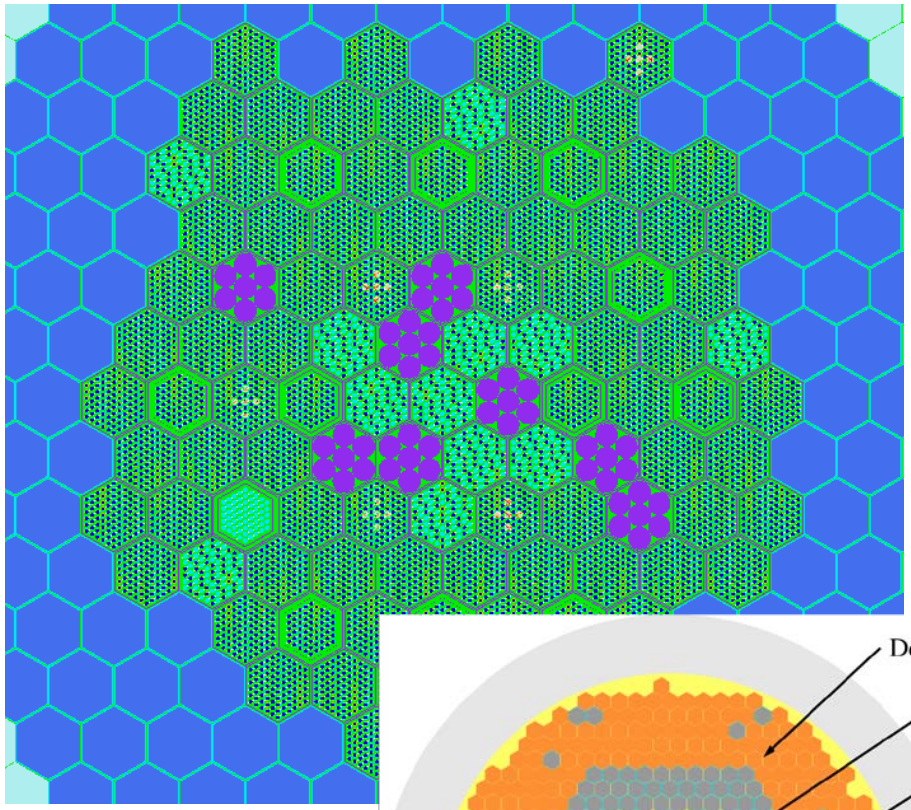
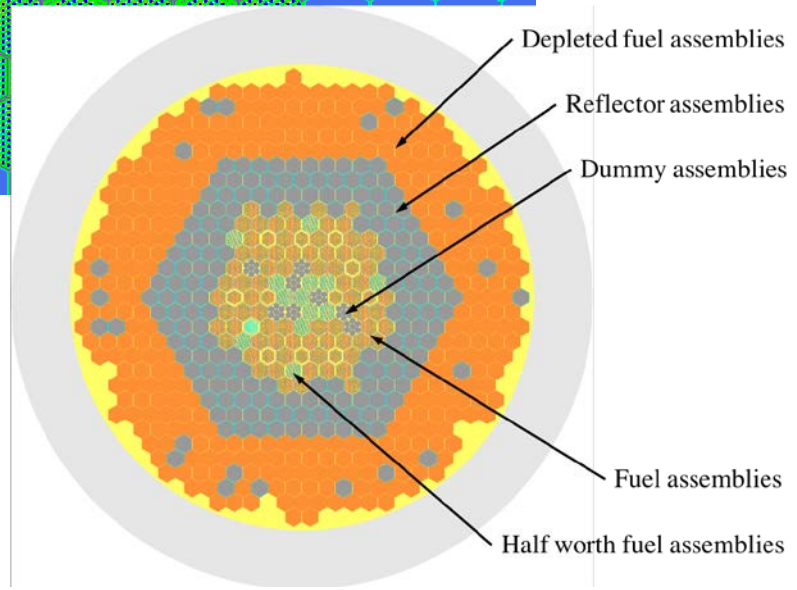
EBR-II Study

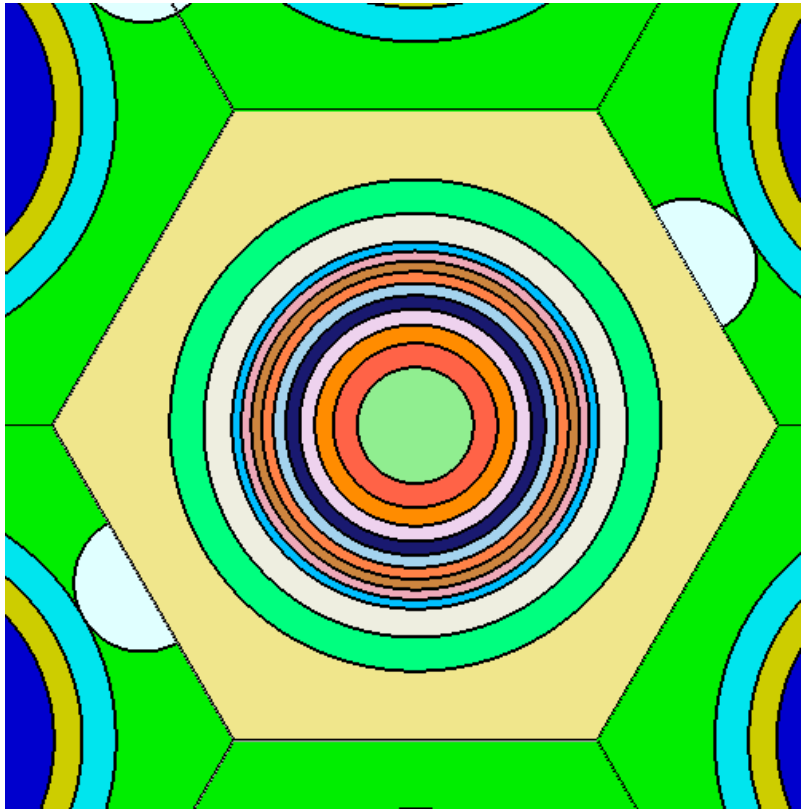
EBR-II power profile analysis

- **Goal: generate detailed power profiles**
- Existing SCALE model, tweaked for detailed rod insertion
- "Unit" should be entire axial height so that detailed rod unit can replace exising unit
- Currently cannot change state (density/temperature) during SCALE calc→**<u>one-way coupling</u>**



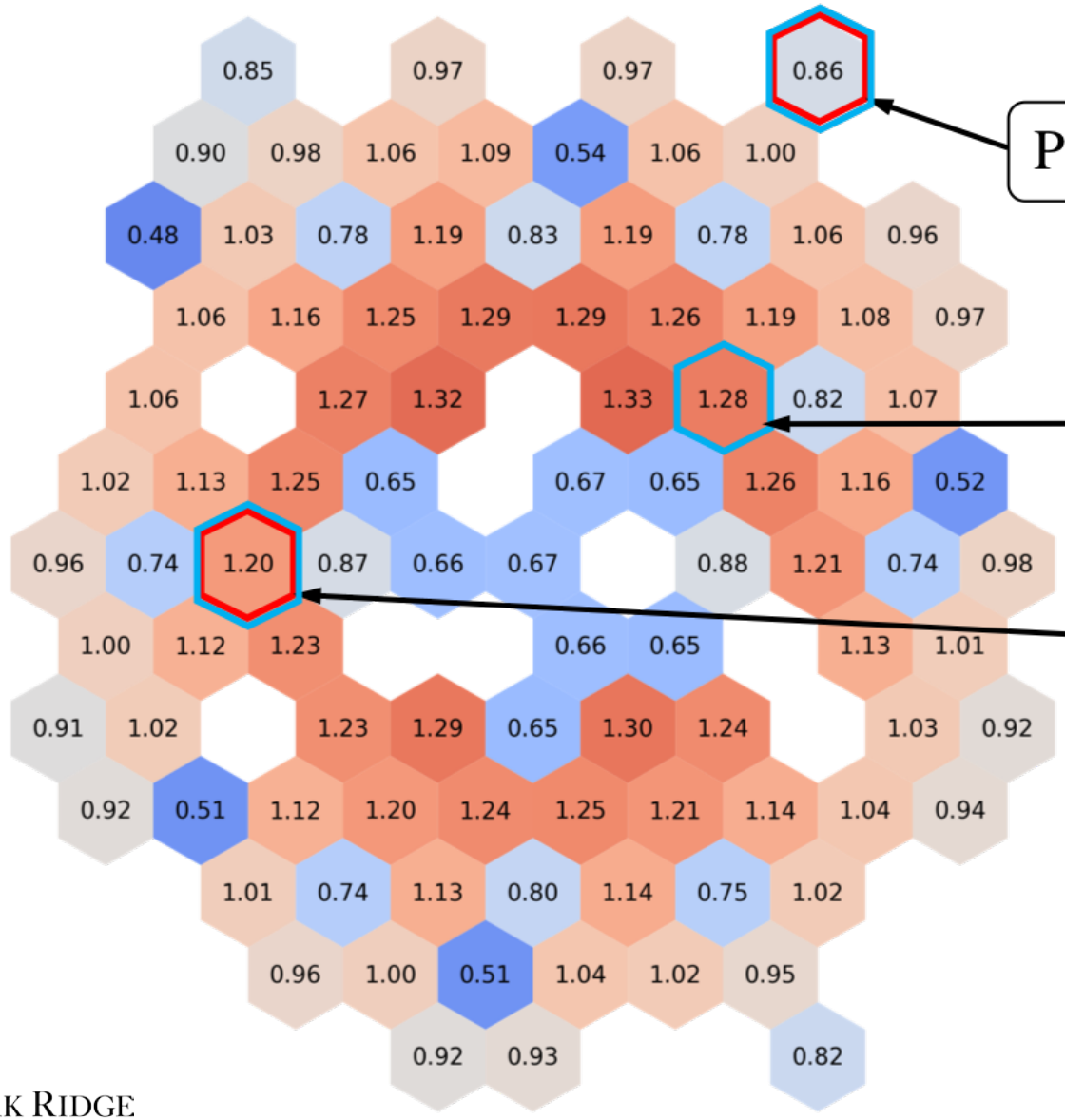


EBR-II Rod radial and axial segments



- FAST will eventually specify axial/radial mesh
- In these examples:
  - 10 axial zones
  - 10 equal-area radial zones

EBR-II assembly power map



Position 25-22

Position 21-21

Position 19-16

Detailed rods inserted in these assemblies

Studies with different number of neutron histories

Longer depletion calculations

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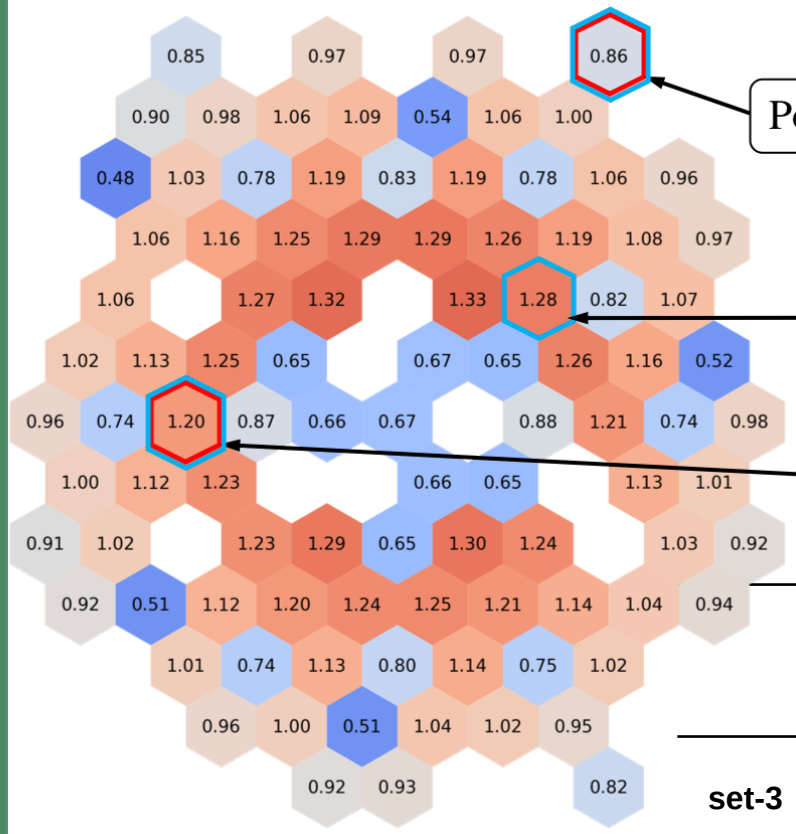
EBR-II Monte Carlo sensitivity study



Position 25-22

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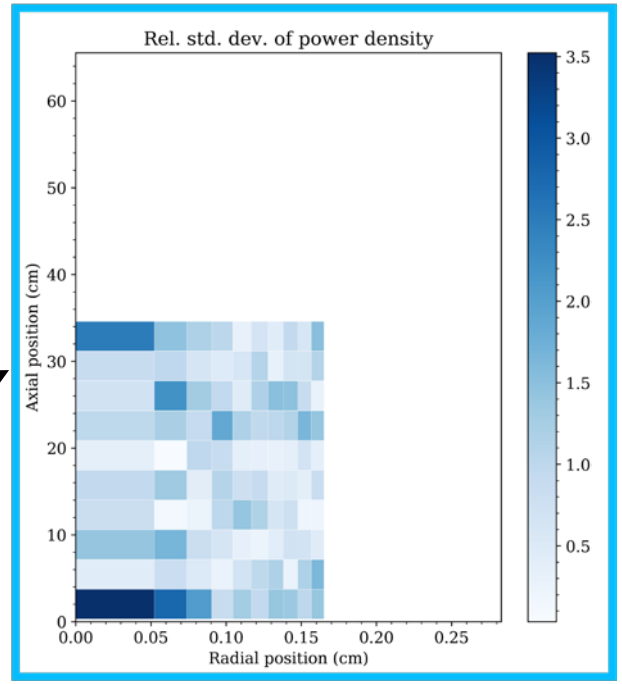
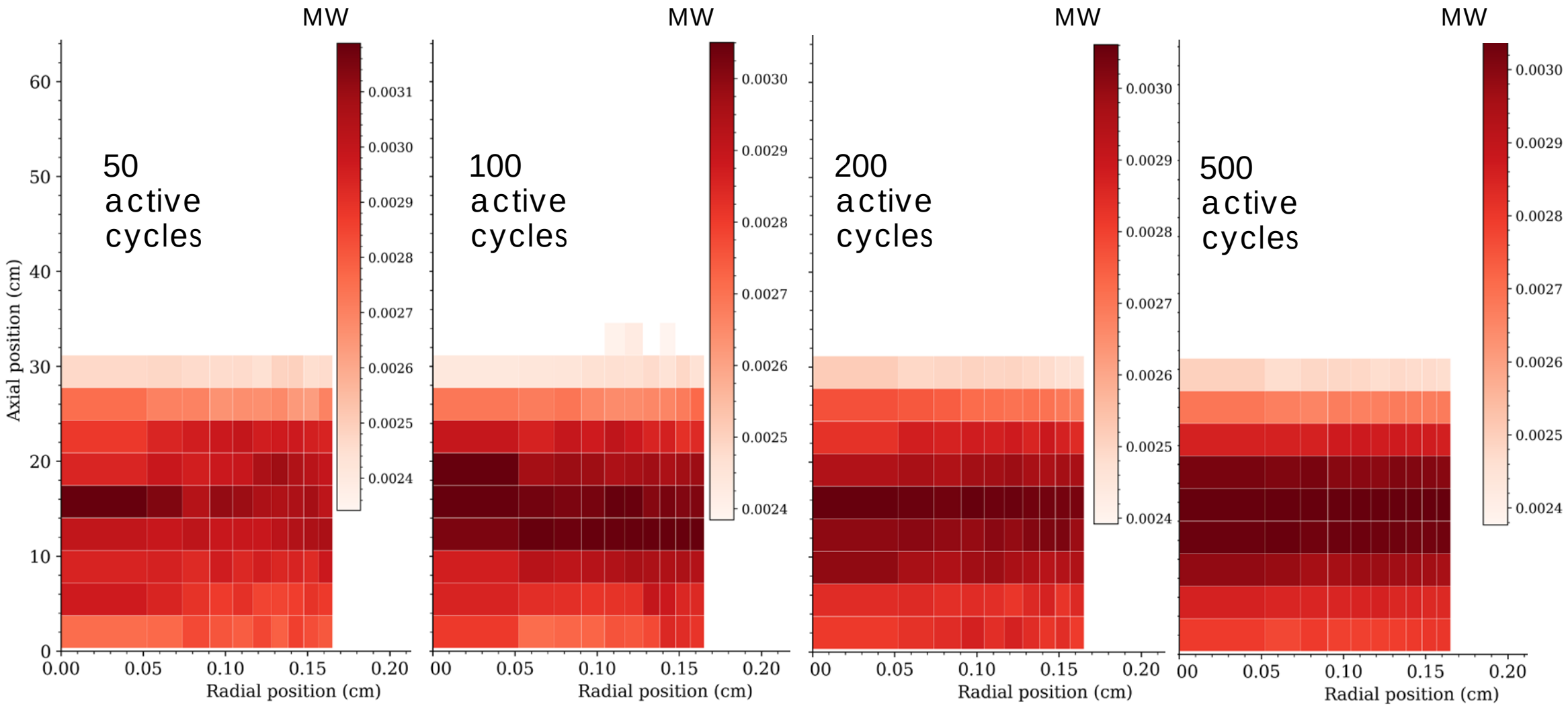
Position 19-16



100 active cycles

	neutrons per cycle	active cycles	skipped cycles	First cycle to cross over 1σ of the final entropy	Runtime per depletion step (32 MPI tasks)	Max. rel. err. of power in (25-22)	Max. rel. err. of power in (19-16)
set-3	100,000	50	50	8, 12, 6, 9, 7, 6	5 h	7.25%	2.7%
set-2	100,000	100	50	7, 7, 6, 10, 6, 7	8 h	3.4%	3.5%
set-1	100,000	200	50	8, 8, 10, 7, 9, 8	13 h	3.4%	1.5%
Ref.	200,000	500	50	6, 6, 8, 7, 9, 8	56 h	1.5%	1.2%

Detailed rod power in high-power assembly (19-16)



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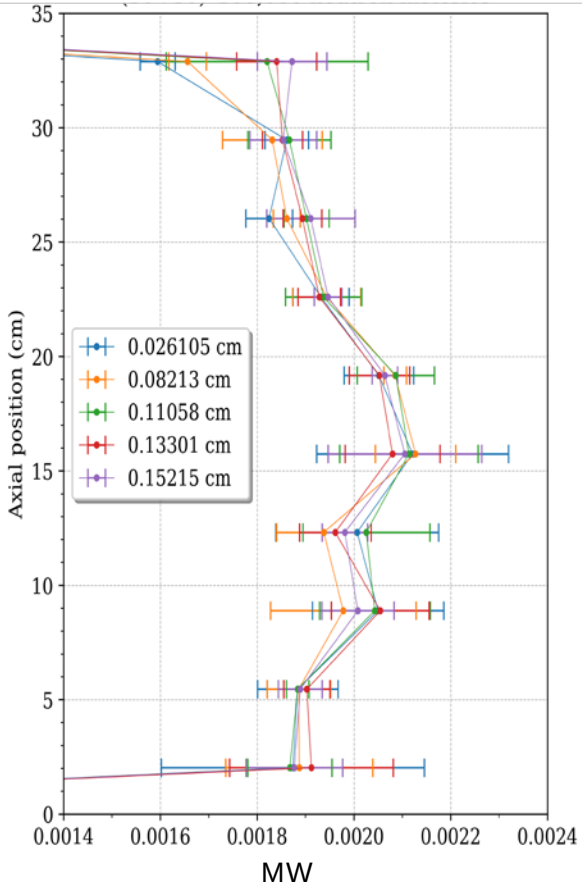
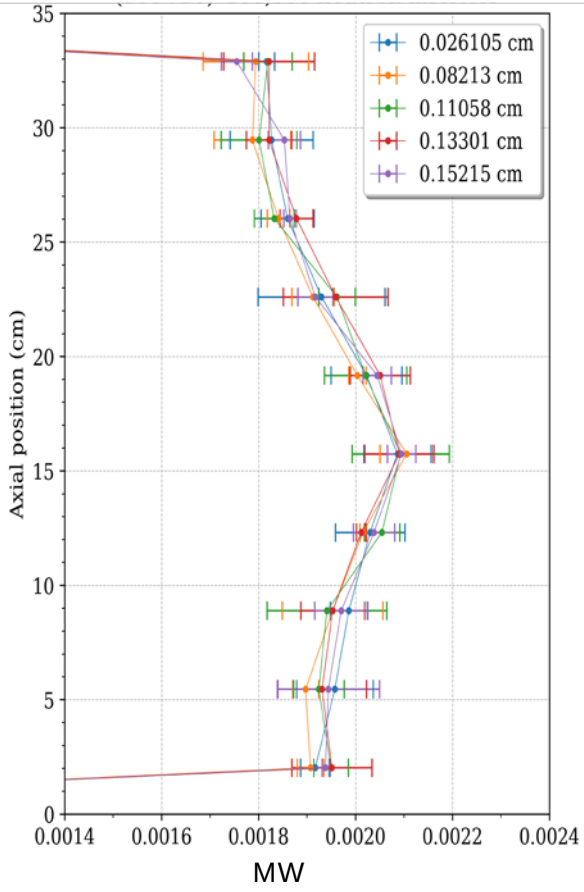
Detailed rod power in low-power assembly (25-22)

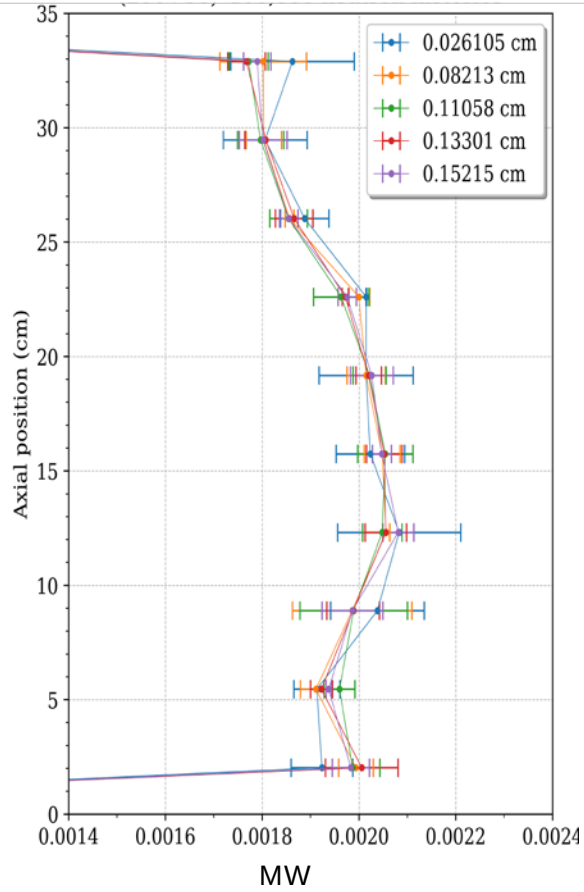
50 active cycles



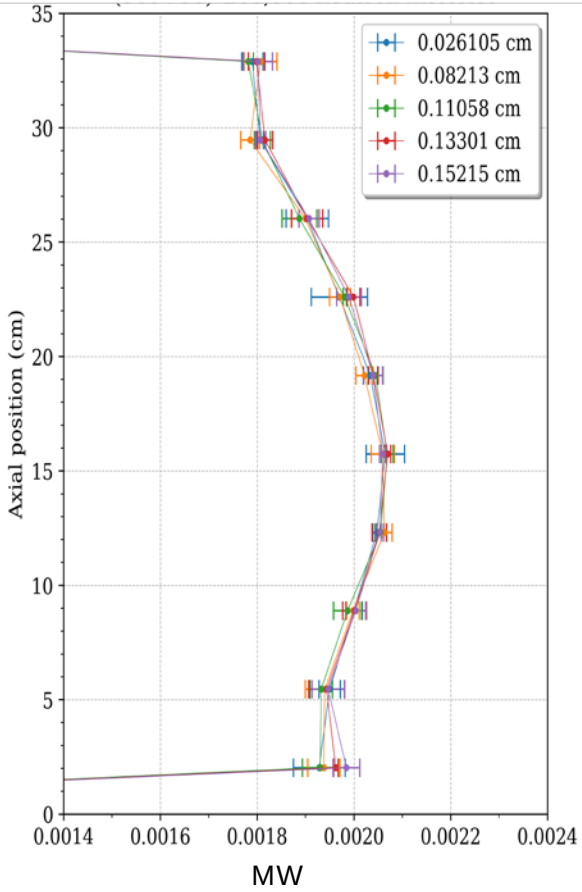
100 active cycles



200 active cycles



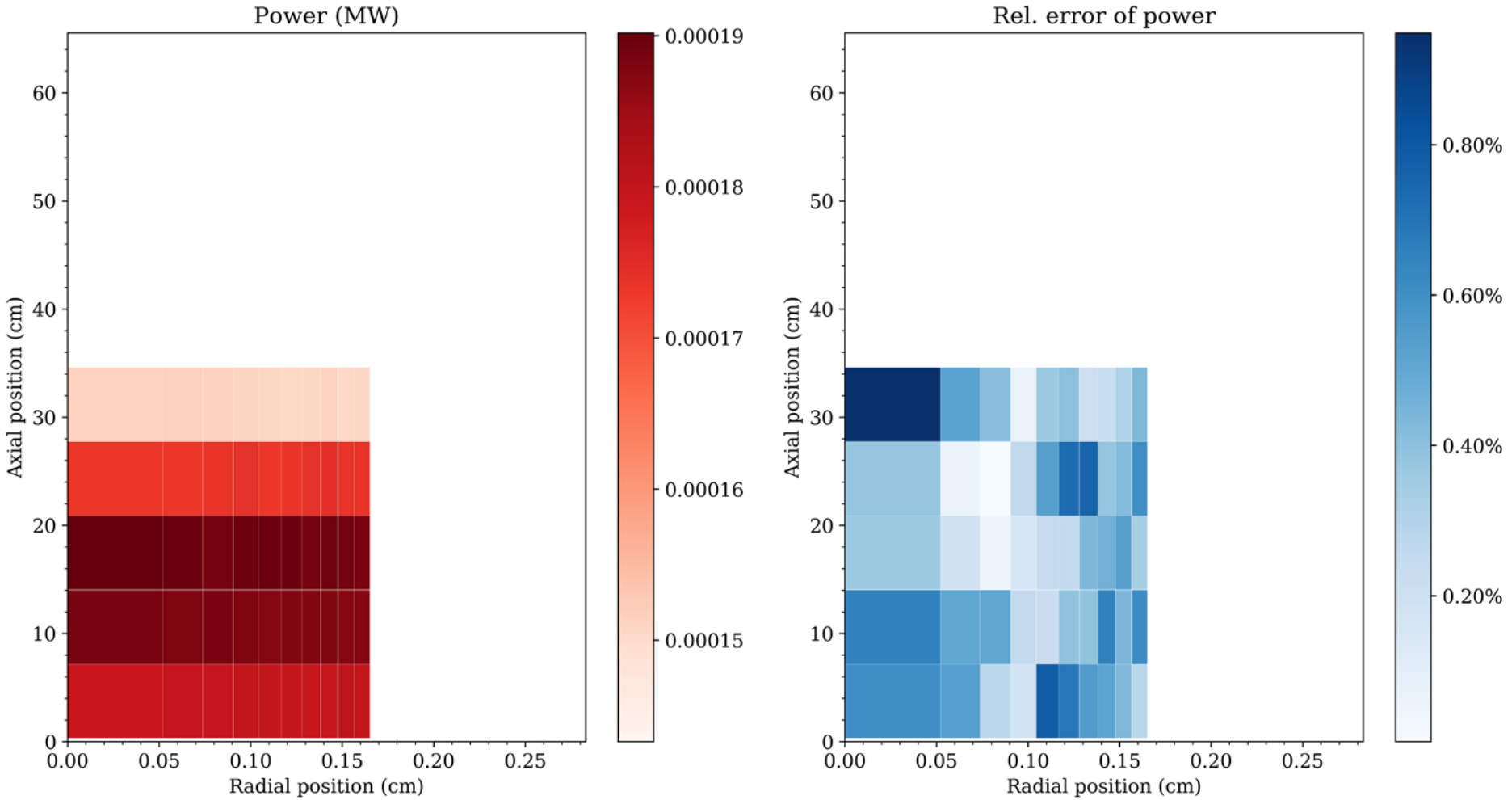
500 active cycles



Note: 2-sigma standard deviations are displayed.

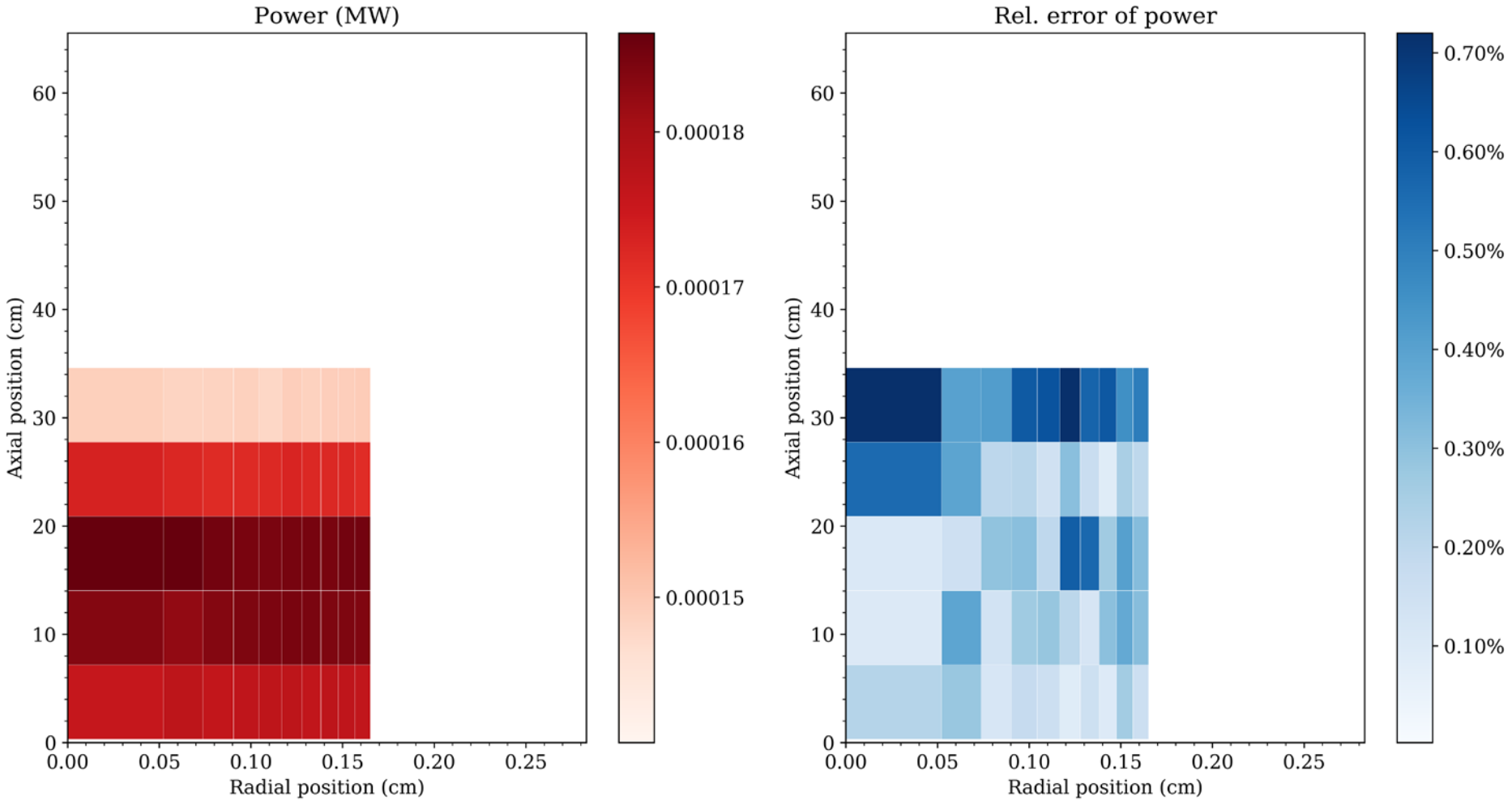
Depletion in high-power assembly (19-16)

10 days



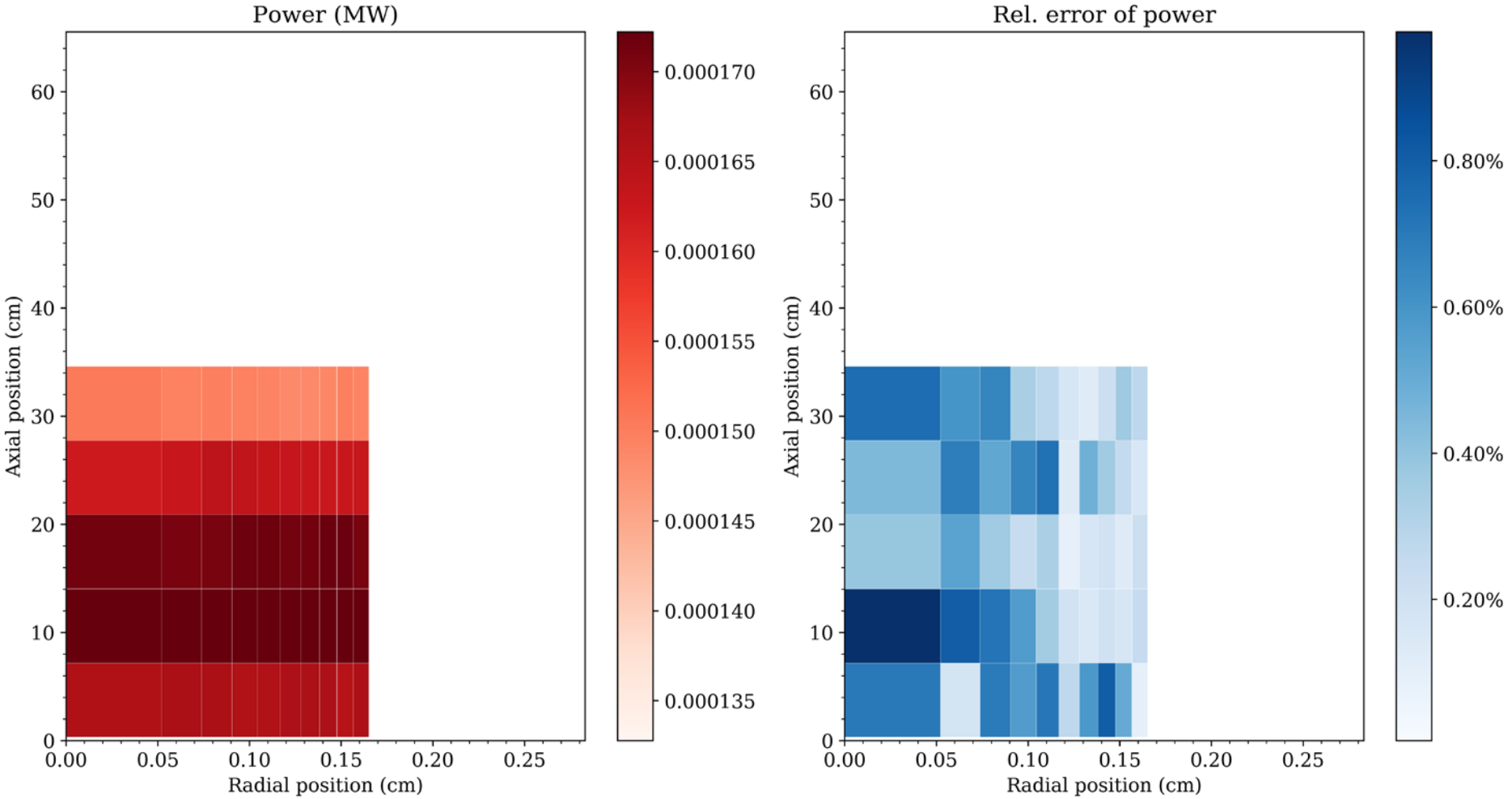
Depletion in high-power assembly (19-16)

110 days



Depletion in high-power assembly (19-16)

310 days



Summary

- EPIC is the new SCALE & NRC neutronics and fuel performance coupler
- Will eventually provide both "fast" (Strategy #1) and (Strategy #2) reference power and isotopics profiles to NRC fuel performance code FAST
- Current work applied Strategy #2 to EBR-II fast reactor model
  → *constant radial & +/-10% axial*
- Prototype Strategy #2 detailed rod reference calculation will be available in SCALE 6.3-beta1 Fall 2018
- Strategy #1 ("fast" single rod neutronics) in FY19