PWR PCI Screening Capability

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Oak Ridge National Laboratory

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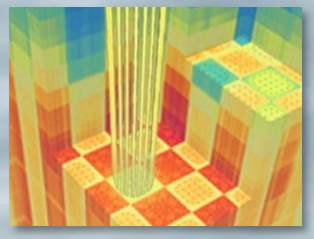
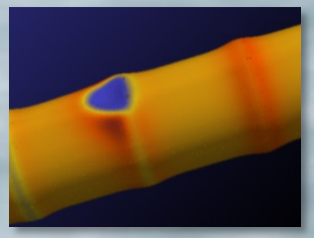
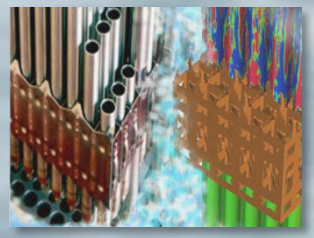






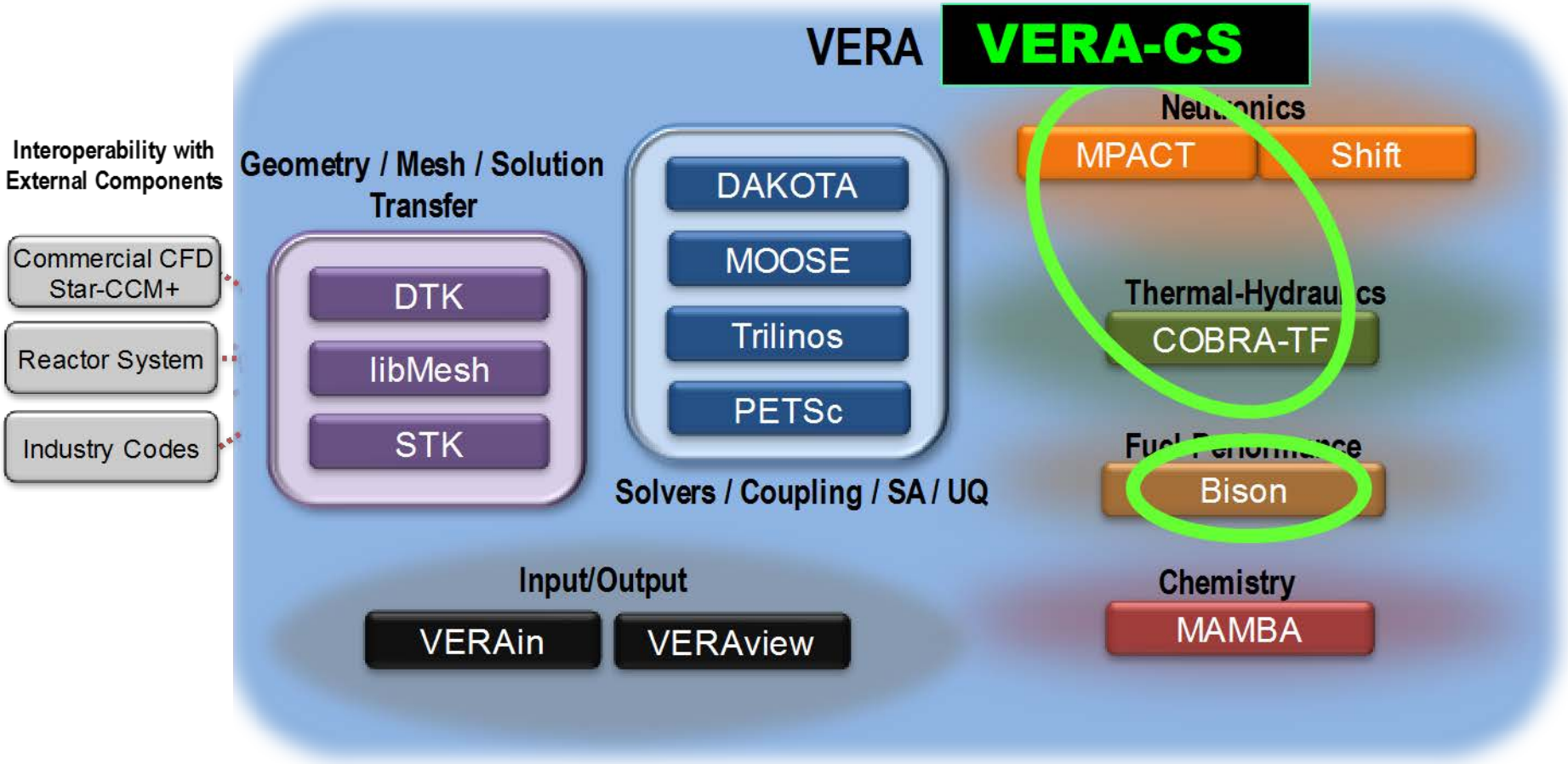
Objective

Application of the VERA capability to core-wide PCI screening and assessment of its performance

General Approach

- Identify VERA Modeling & Simulation Tools
- Select Target Reactor
- Perform Depletion Calculations, and
- Identify Potential Candidate Assemblies
- Perform Assembly/Rod Screening, and
- Select Candidate Rods
- Perform BISON PCI Analyses of Candidate Rods
- Describe Results
- Conclusions and Future Work

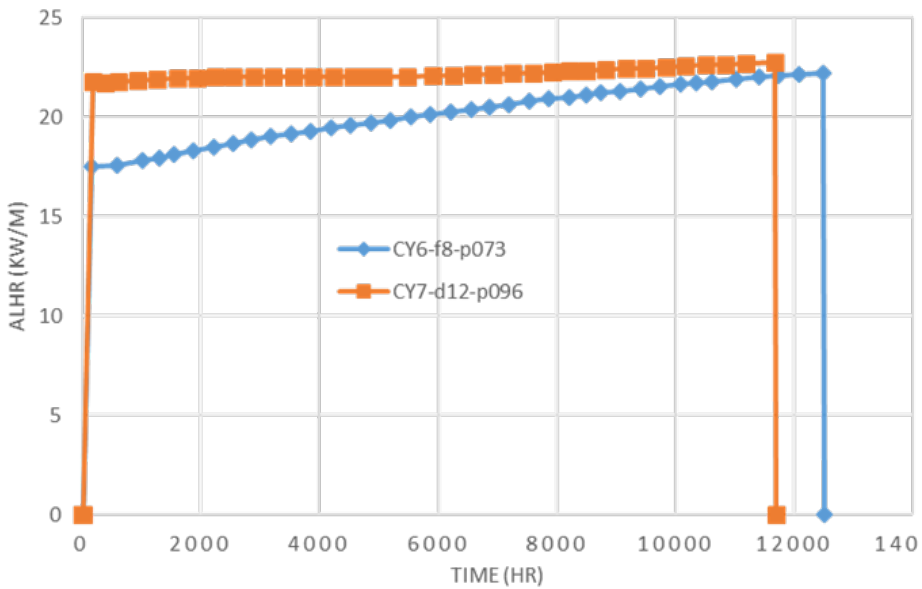
VERA Modeling and Simulation Tools

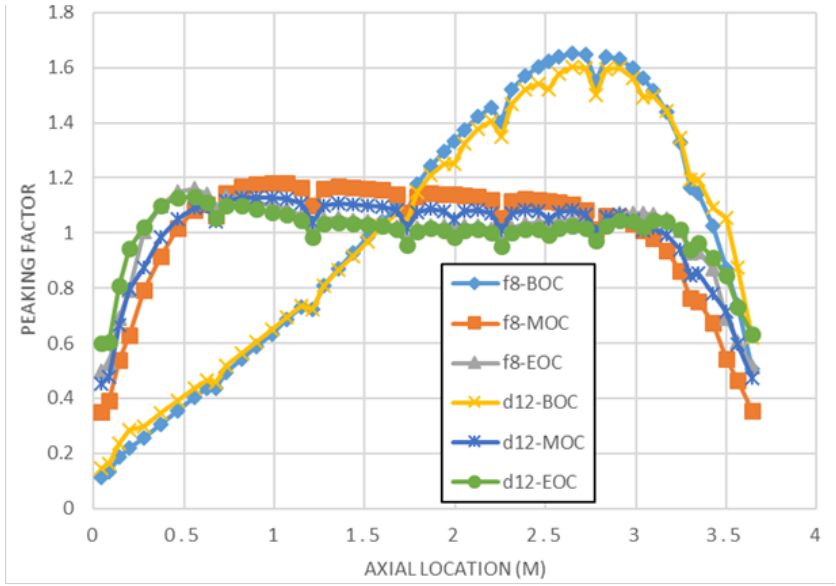


VERA-CS (MPACT + COBRA-TF)
BISON Fuel Performance

Select Target Reactor

- Watts Bar Unit 1, Cycles 6 and 7, Quarter Core
- Reasons ?:
- Offers interesting challenges
  - PCI failures occurred in both cycles despite moderate power levels
- Information readily available, C. Westinghouse

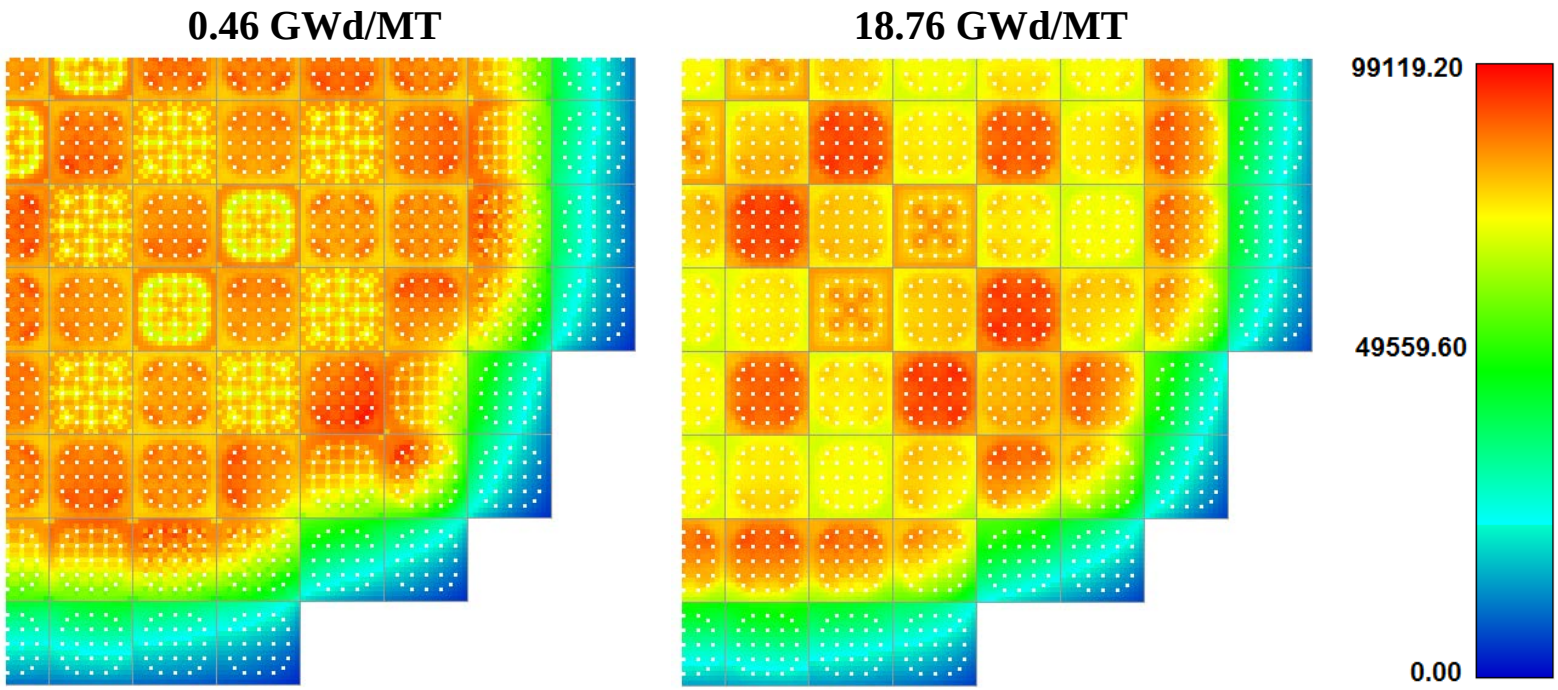




Cycles 6 and 7 Power Histories for Cycle-6 rod f8-p073 and cycle-7 rod d12-p096,

Perform Depletion Calculations

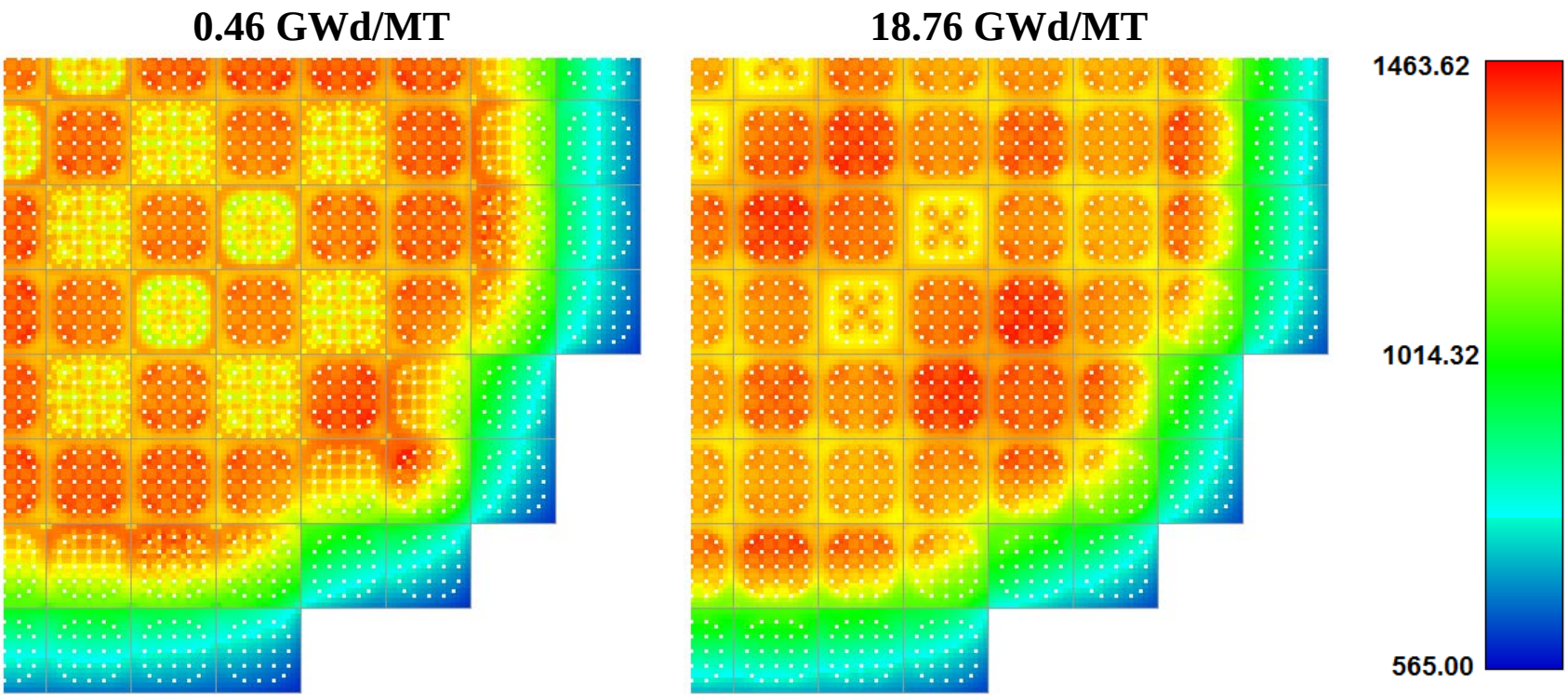
- Pre-VERA Simulation: Use BISON to construct look-up table for fuel temperatures input to Physics calculations
- VERA-CS + BISON calculations: **Power Distribution**



Rod Power (W) early (left) and late (right) in Cycle 6.

Perform Depletion Calculations cont.
Potential Candidate Assemblies

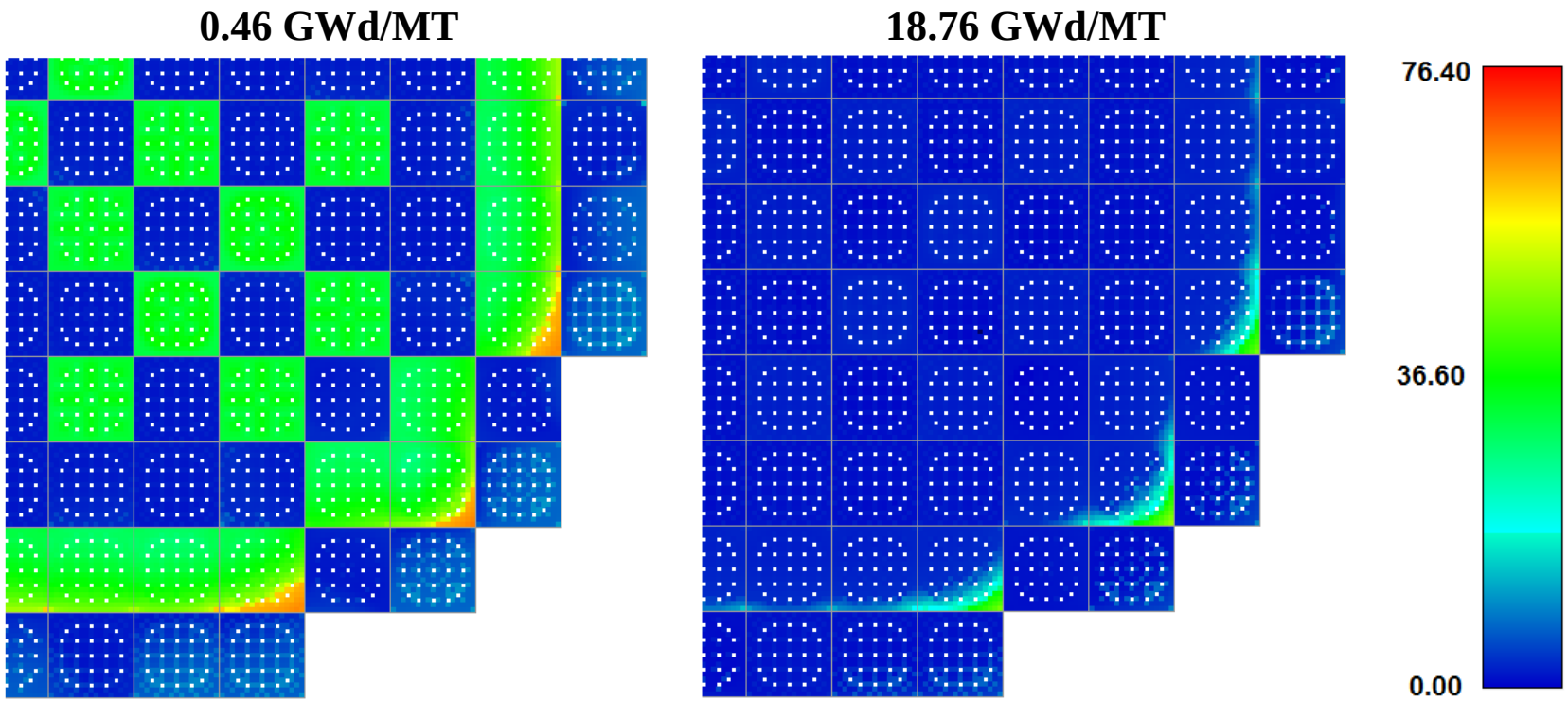
VERA-CS + BISON calculations: **Temperature Distribution**



Maximum Centerline Fuel Temperature (K) early (left) and late (right) in Cycle 6.

Perform Depletion Calculations cont.
Potential Candidate Assemblies

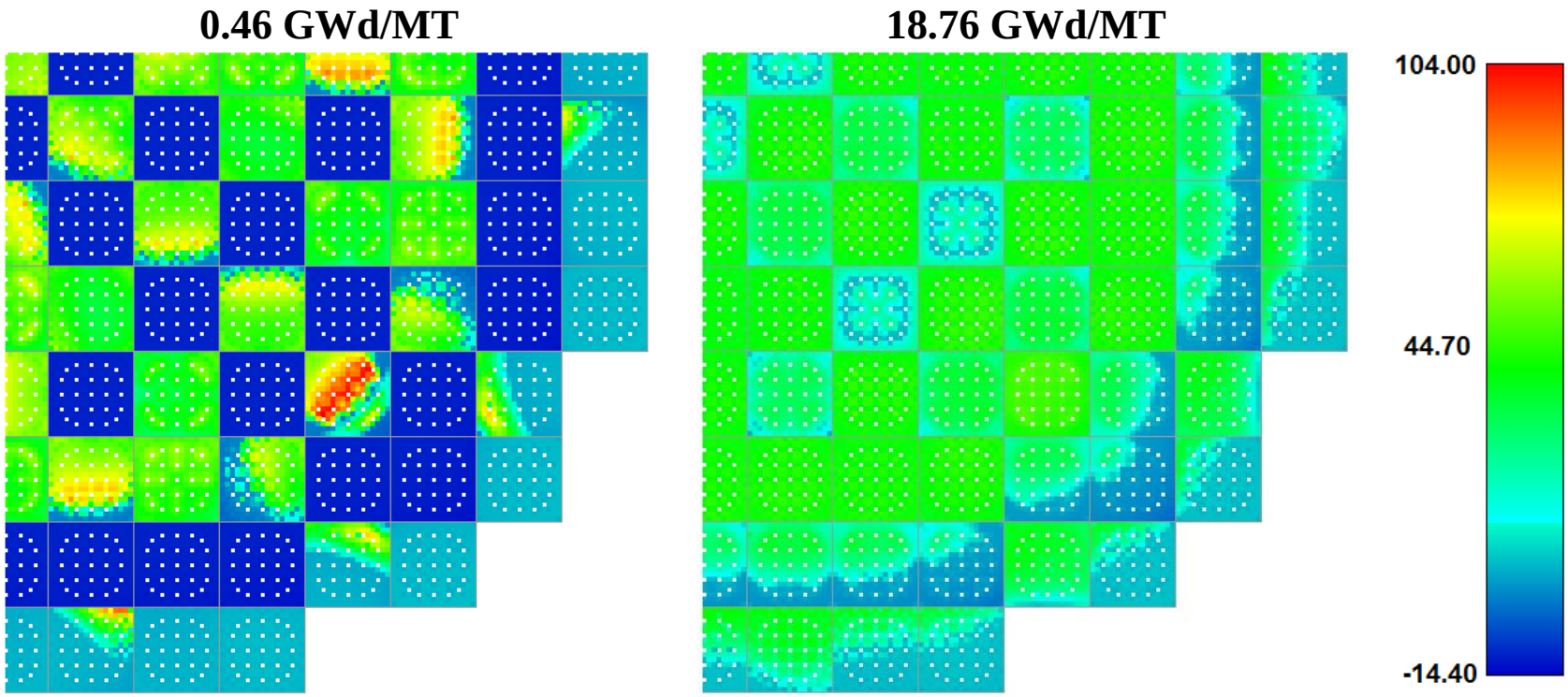
VERA-CS + BISON calculations: **Gap Thick. Distribution**



Gap Thickness [μm] early (left) and late (right) in Cycle 6.

Perform Depletion Calculations cont.
Potential Candidate Assemblies

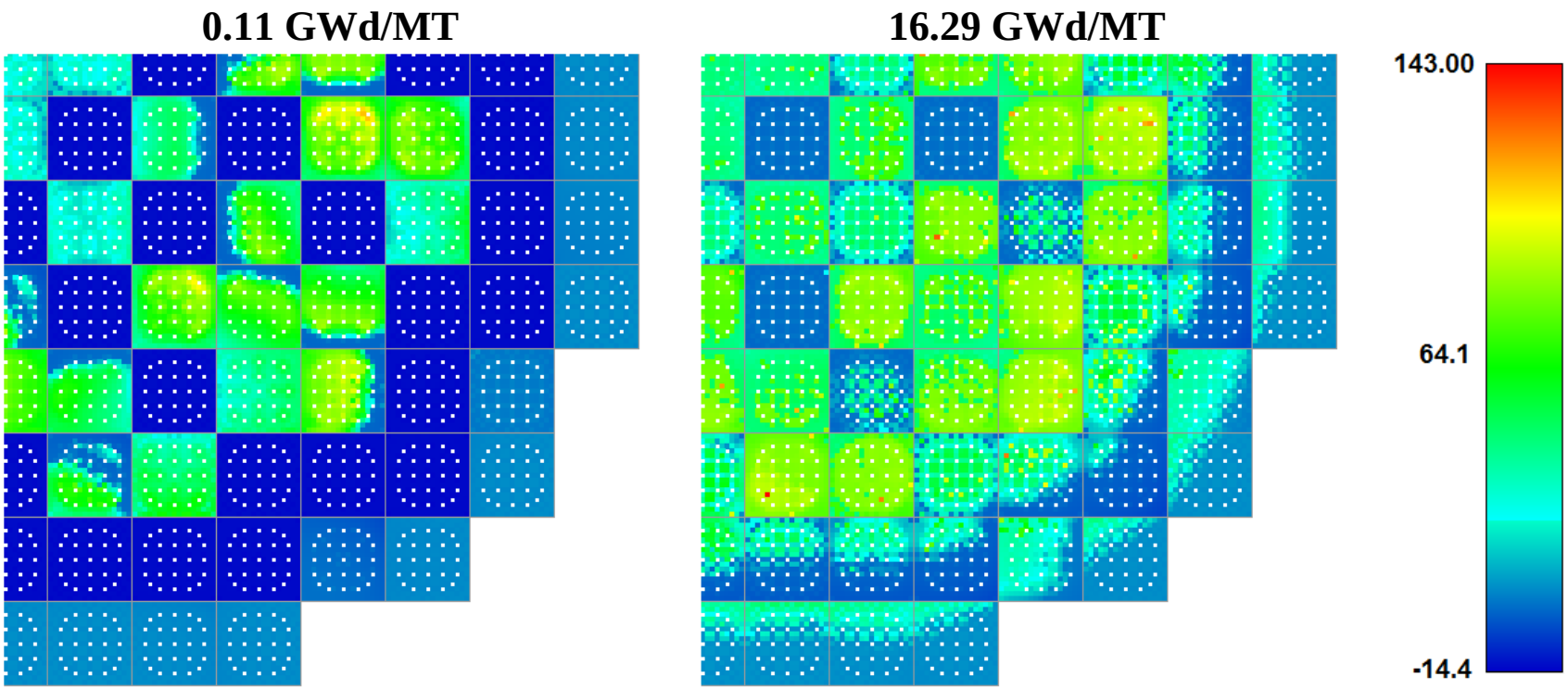
VERA-CS + BISON calculations: **Stress Distribution - Cycle 6**



Maximum Clad Hoop Stress (MPa) early (left) and late (right) in Cycle 6.

Perform Depletion Calculations cont.
Potential Candidate Assemblies

VERA-CS + BISON calculations: **Stress Distribution - Cycle 7**

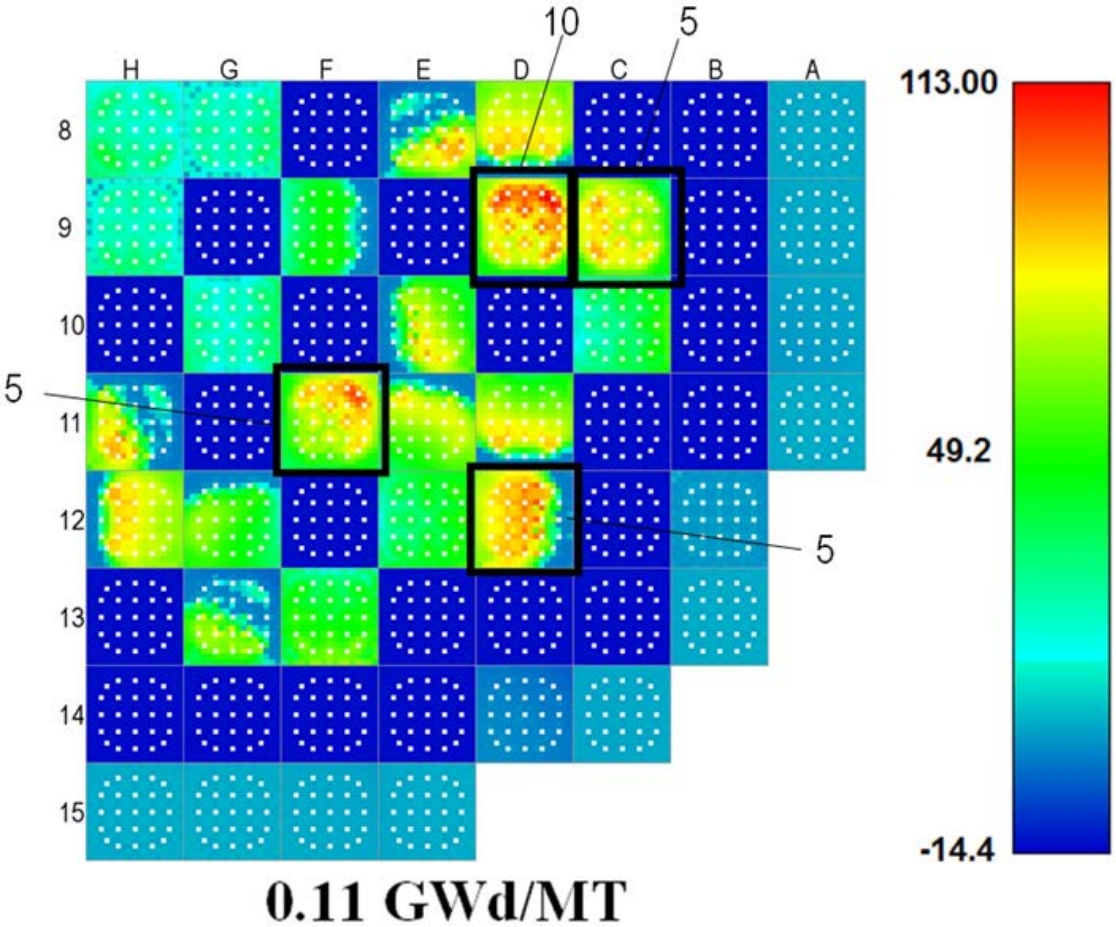


Maximum Clad Hoop Stress (MPa) early (left) and late (right) in Cycle 7.

Perform Assembly/Rod Screening
Select Candidate Rods

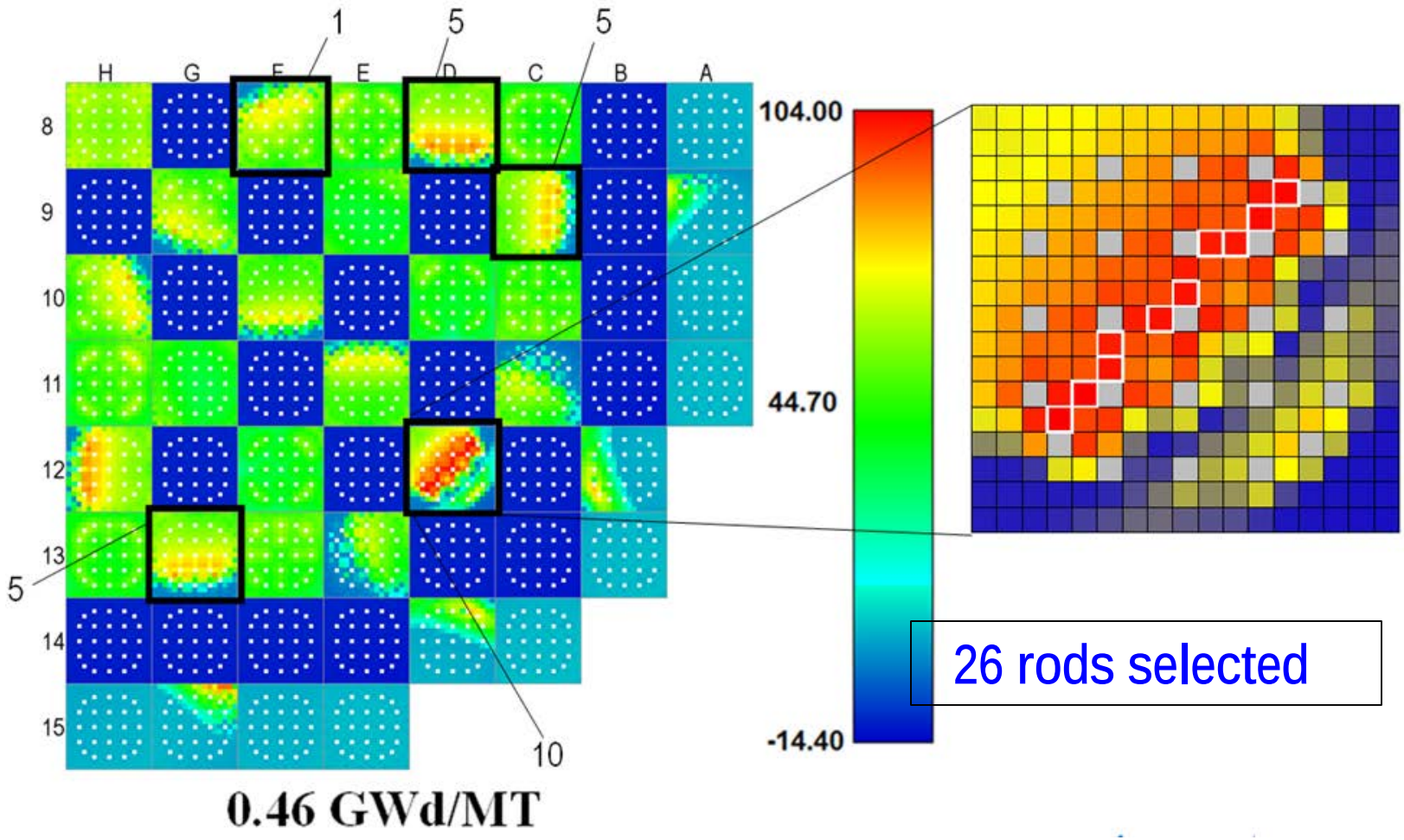
Selection Criteria
- High Power
- High Temperature
- Small gap
- High Stress

25 rods selected



Selected assemblies/rods from Cycle 7

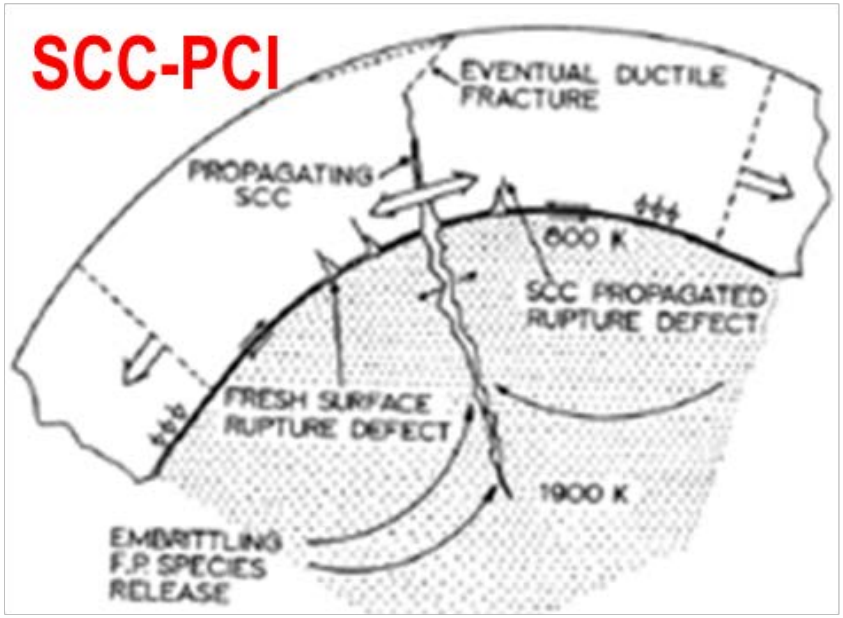
Perform Assembly/Rod Screening
Select Candidate Rods

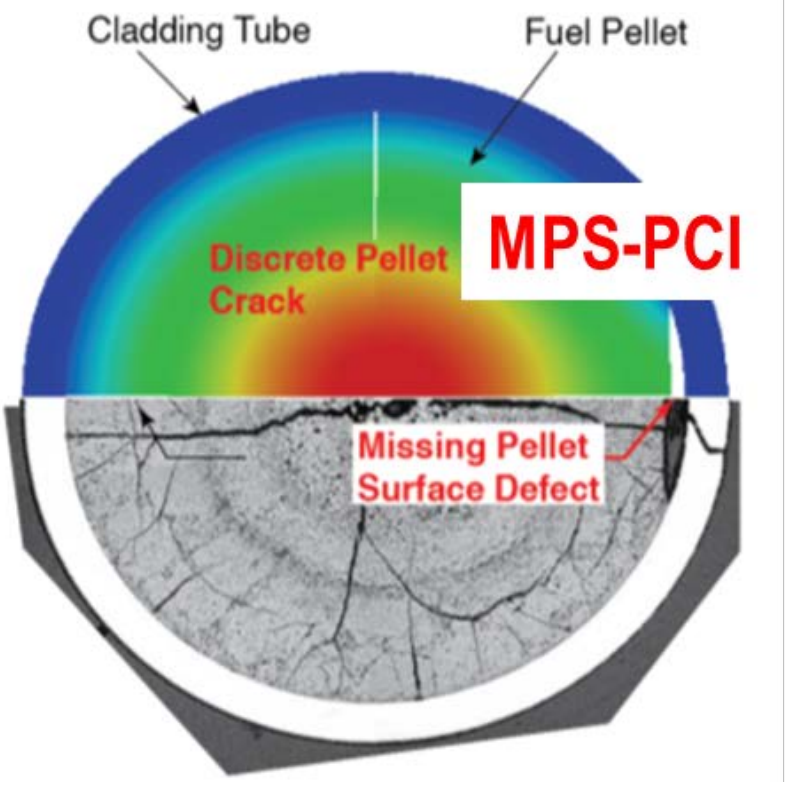


Selected assemblies/rods from Cycle 6

Perform BISON PCI Analyses of Candidate Rods

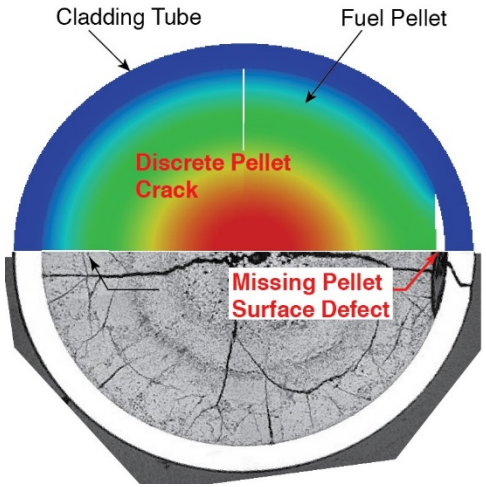
- Screen for two possible failure mechanisms:
  - Classical SCC-PCI
  - Missing Pellet Surface – MPS-PCI



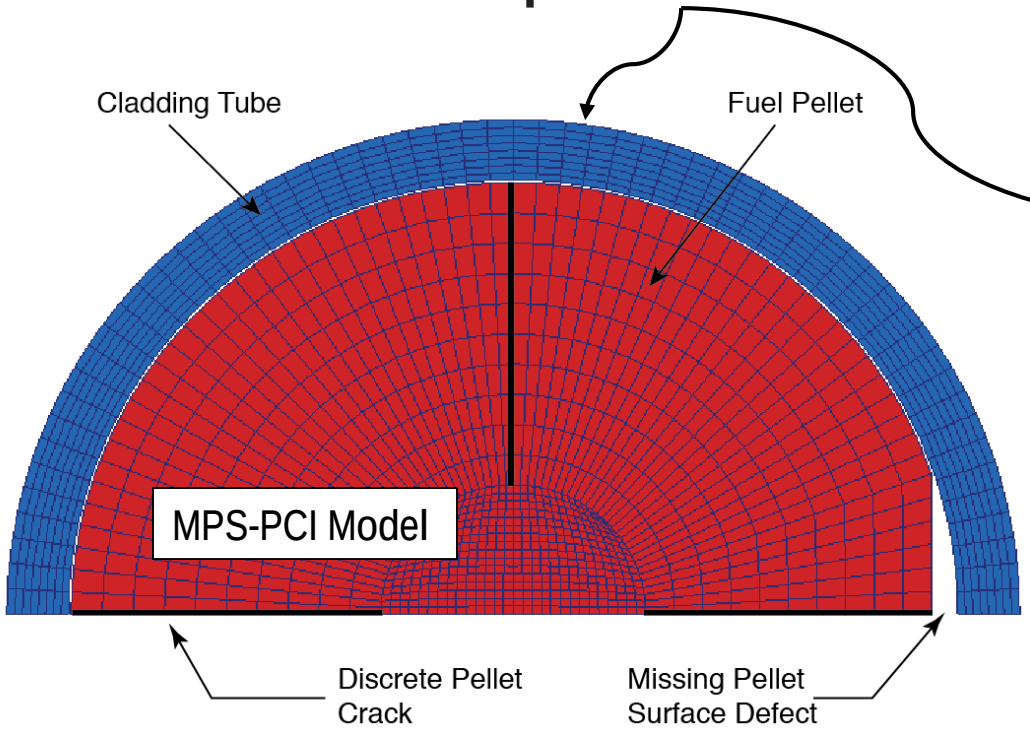


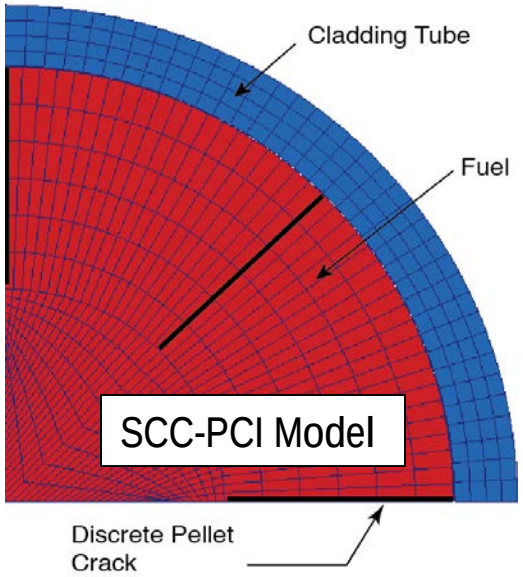
BISON's Modeling of PCI in Candidate Fuel Rods: SCC-PCI vs. MPS-PCI

- **Typical MPS cross-section**

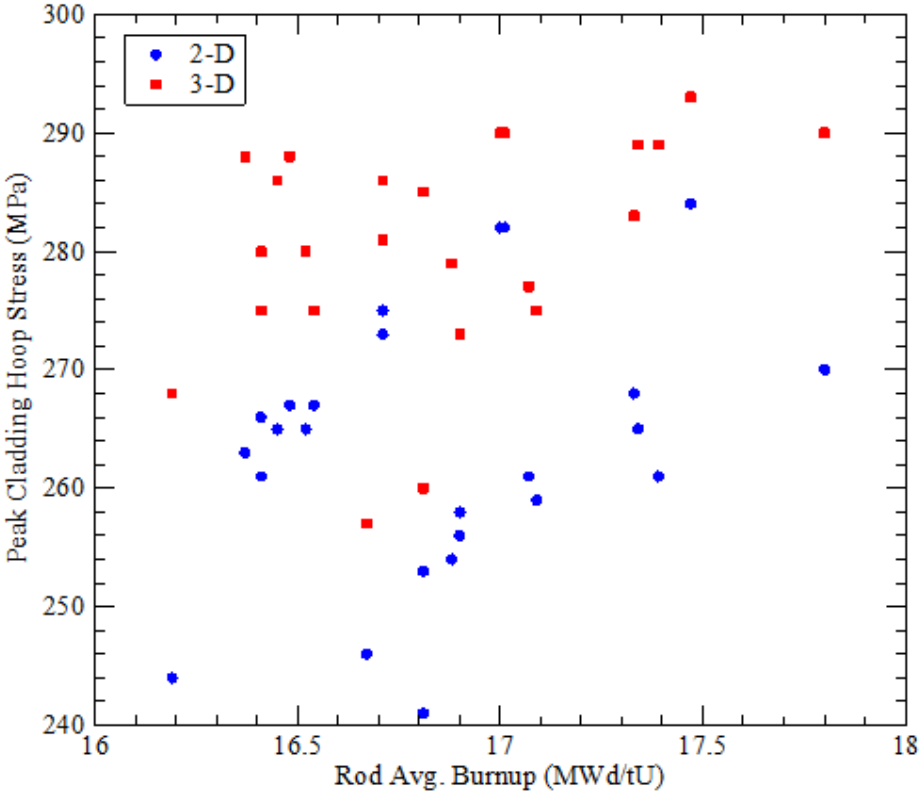


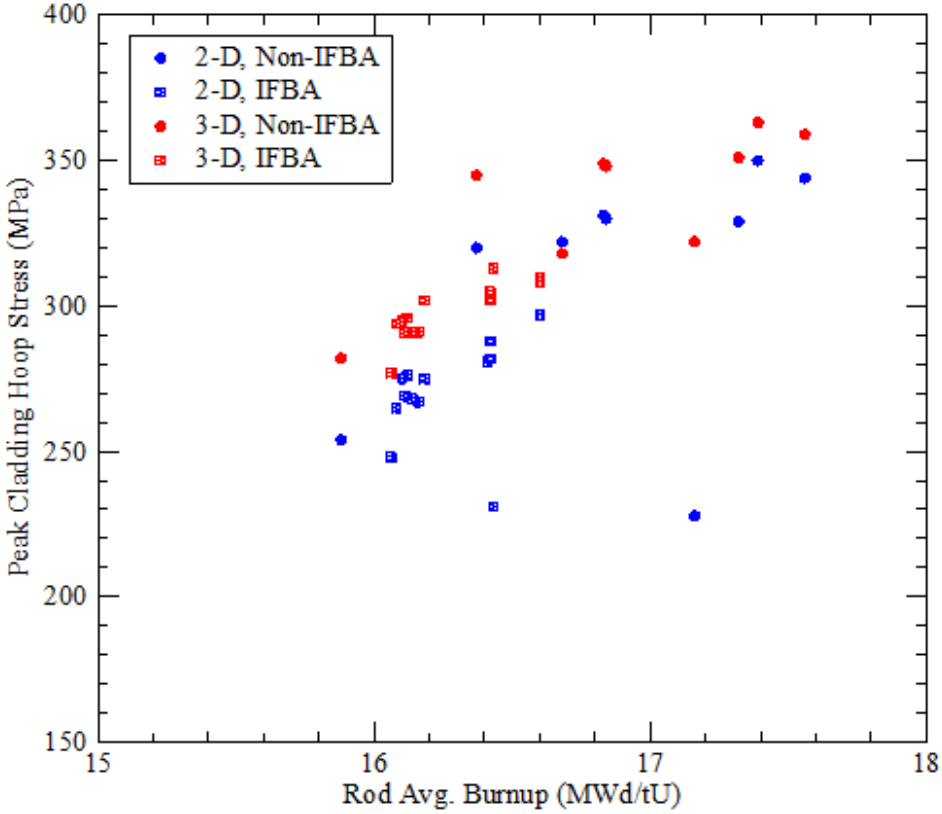
- **Finite Element 2D Representations**





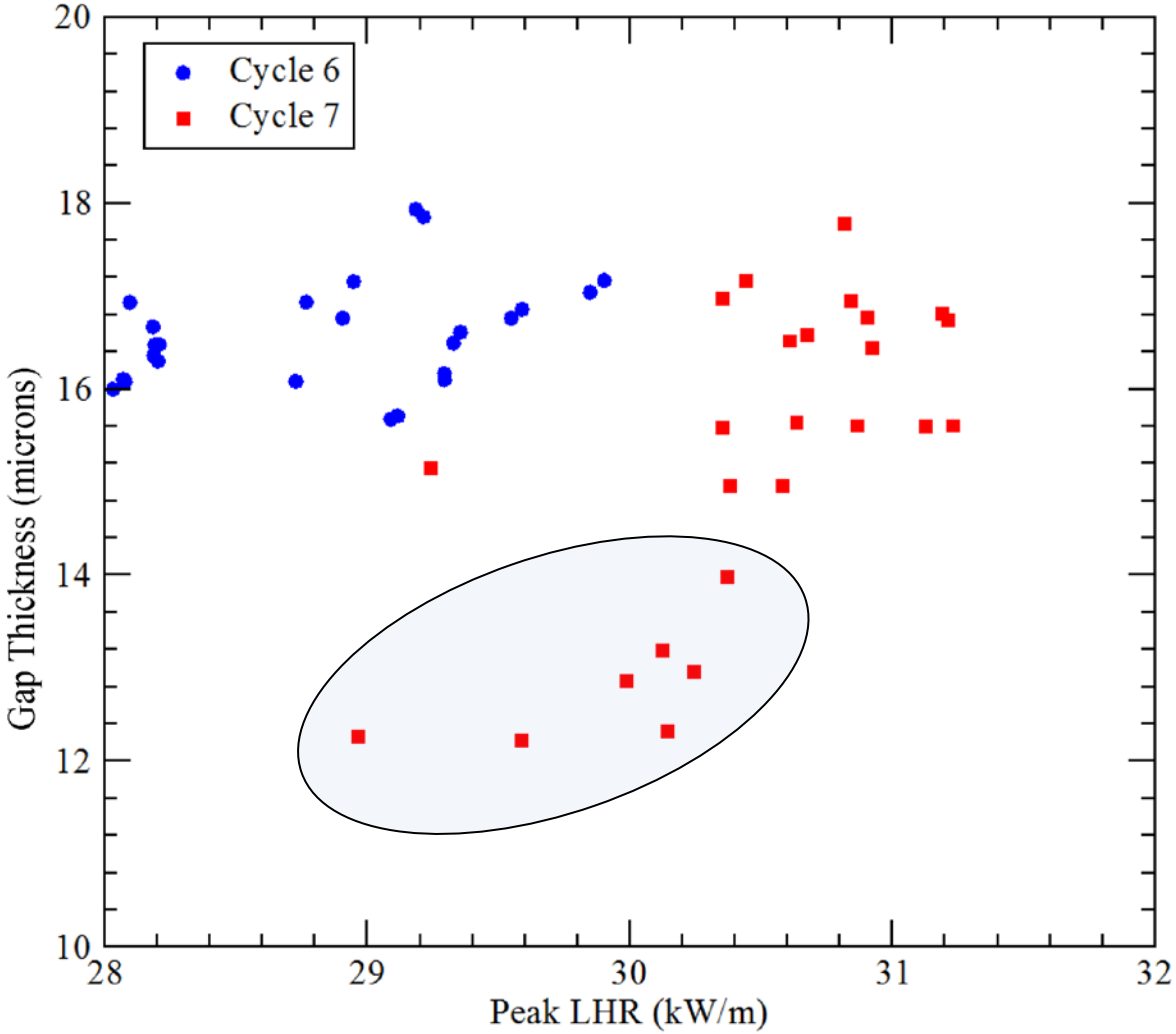
BISON PCI Analyses of Candidate Rods





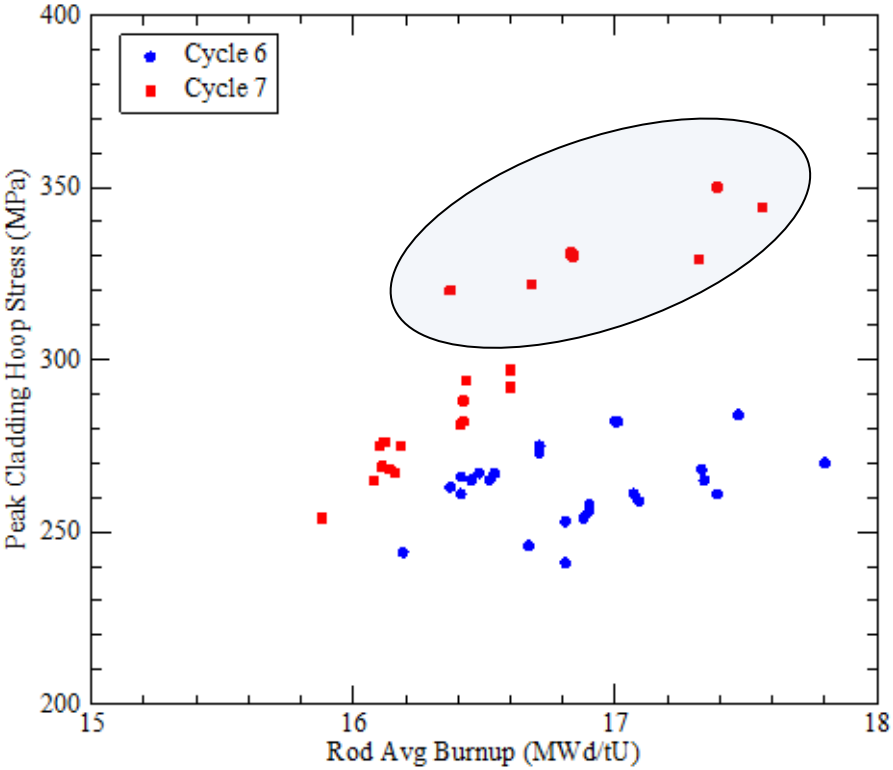
2-D and 3-D modeling of SCC-PCI for Cycle 6 (left) and for Cycle 7 (right): Cladding hoop stress – Can the differences be explained ?

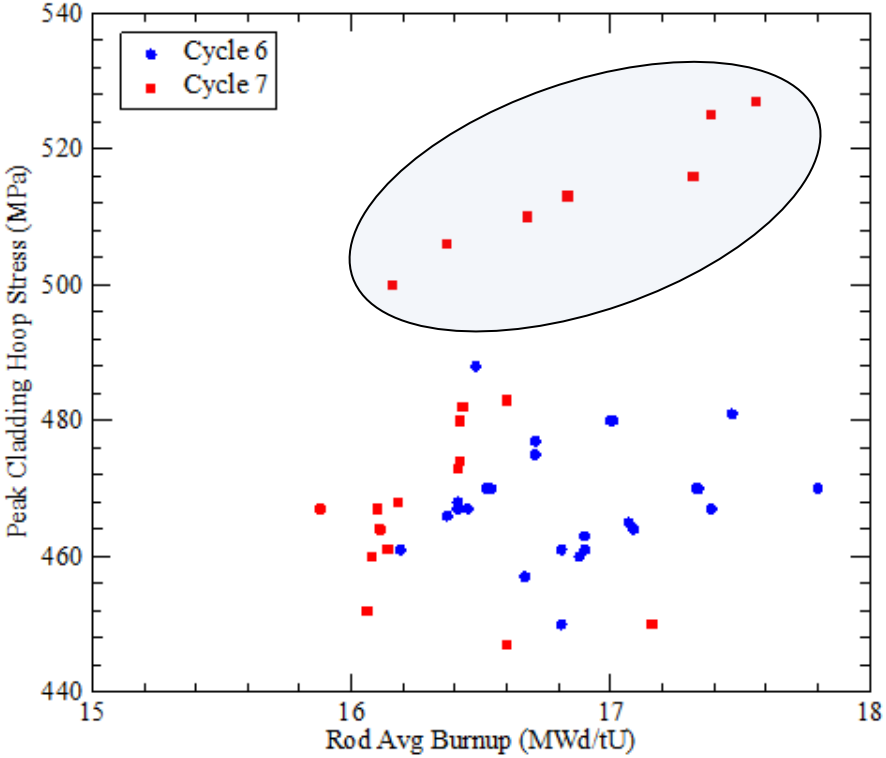
BISON PCI Analyses of Candidate Rods
Explaining the differences



BISON PCI Analyses of Candidate Rods

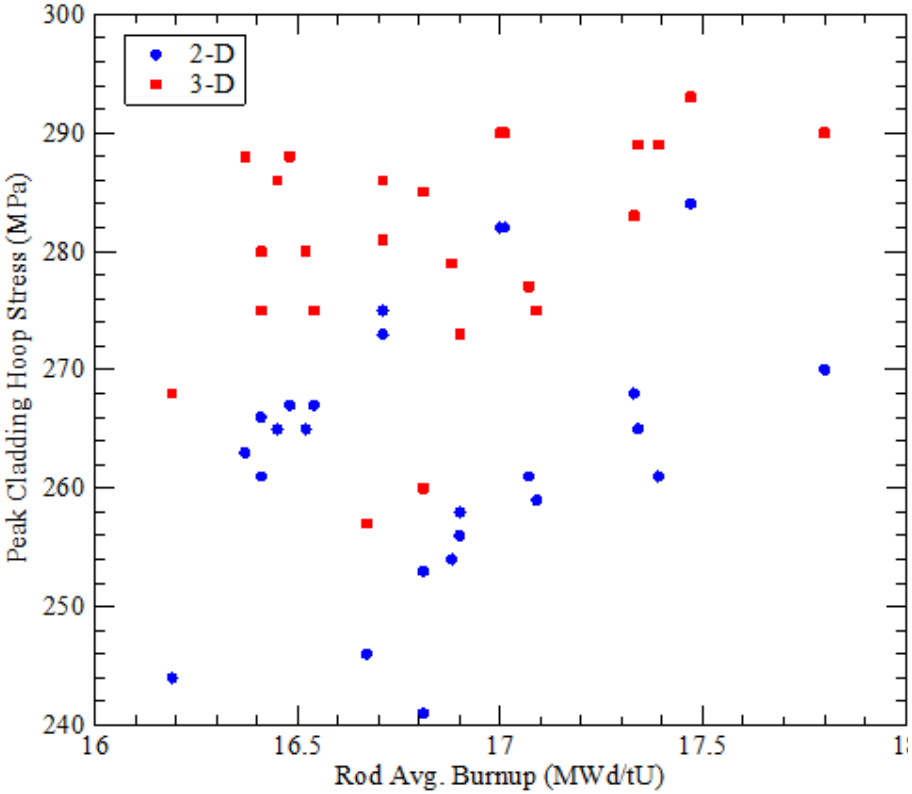
Explaining the differences

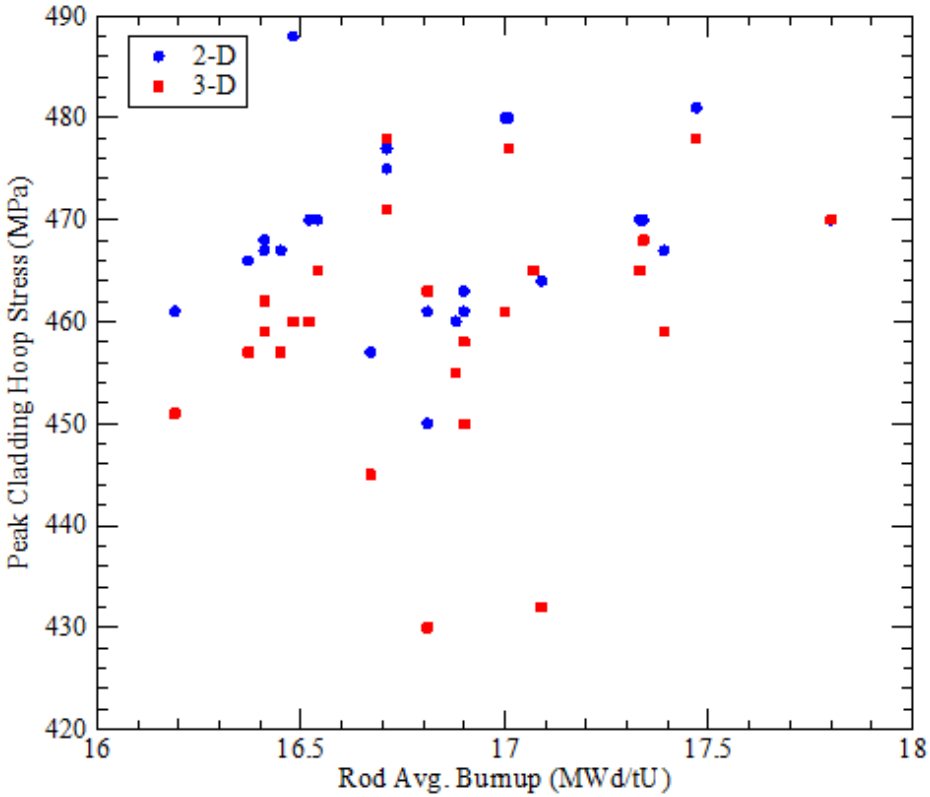




Rods with small fuel-cladding gap

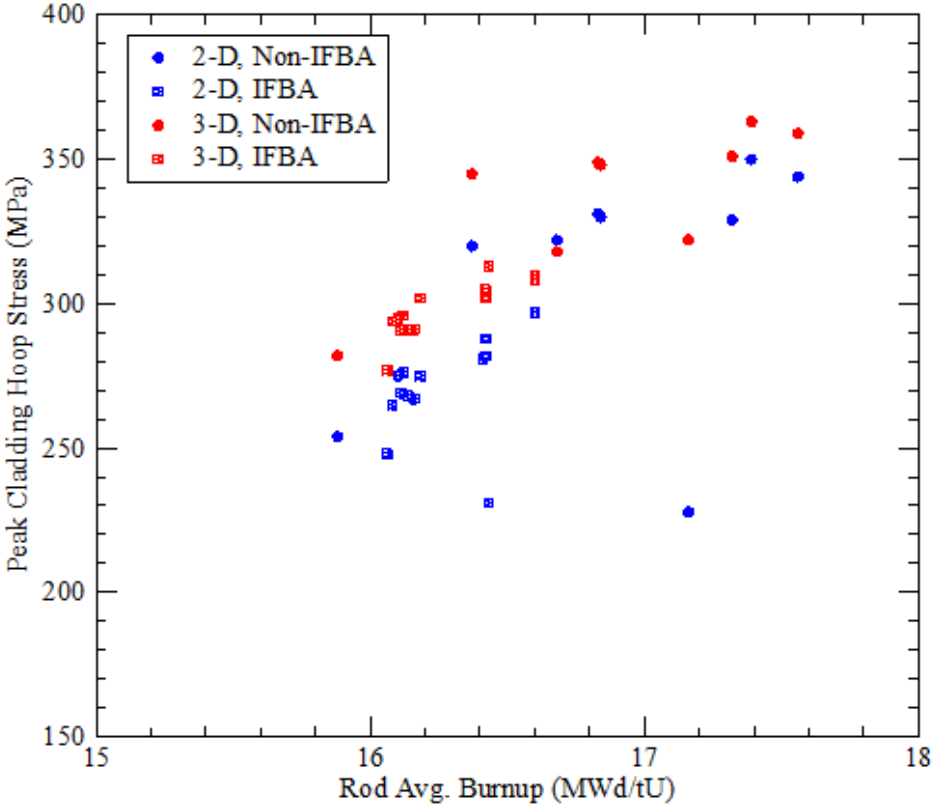
BISON PCI Analyses of Candidate Rods

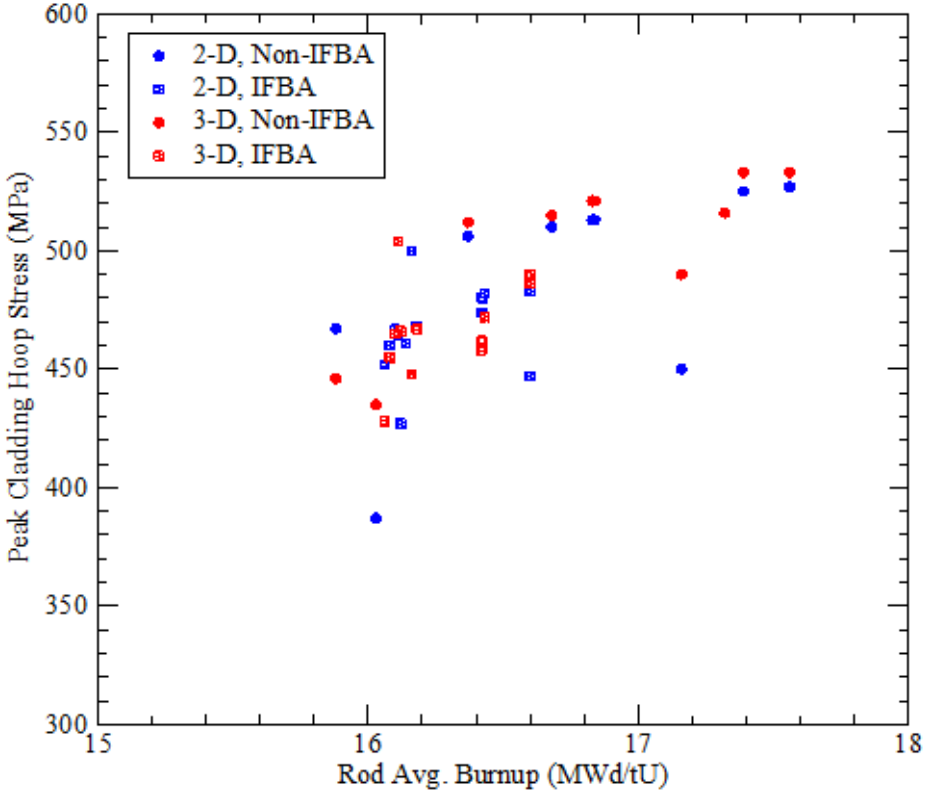




Cycle 6 – 2-D and 3-D modeling of SCC-PCI (left) and (MPS-PCI) (right): Cladding hoop stress

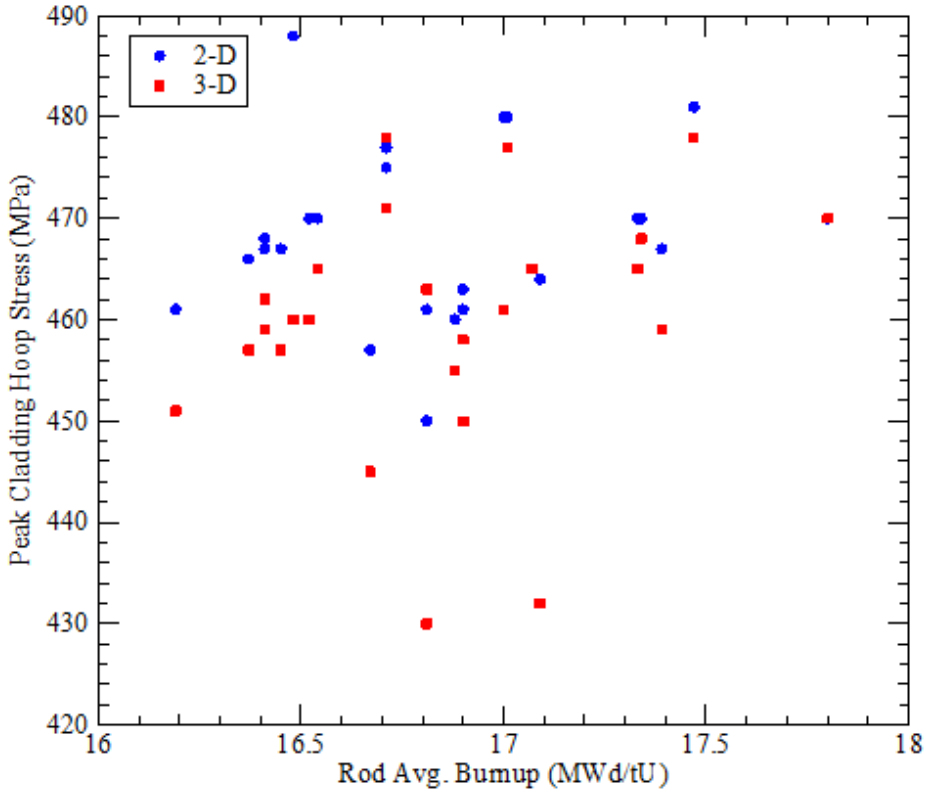
BISON PCI Analyses of Candidate Rods

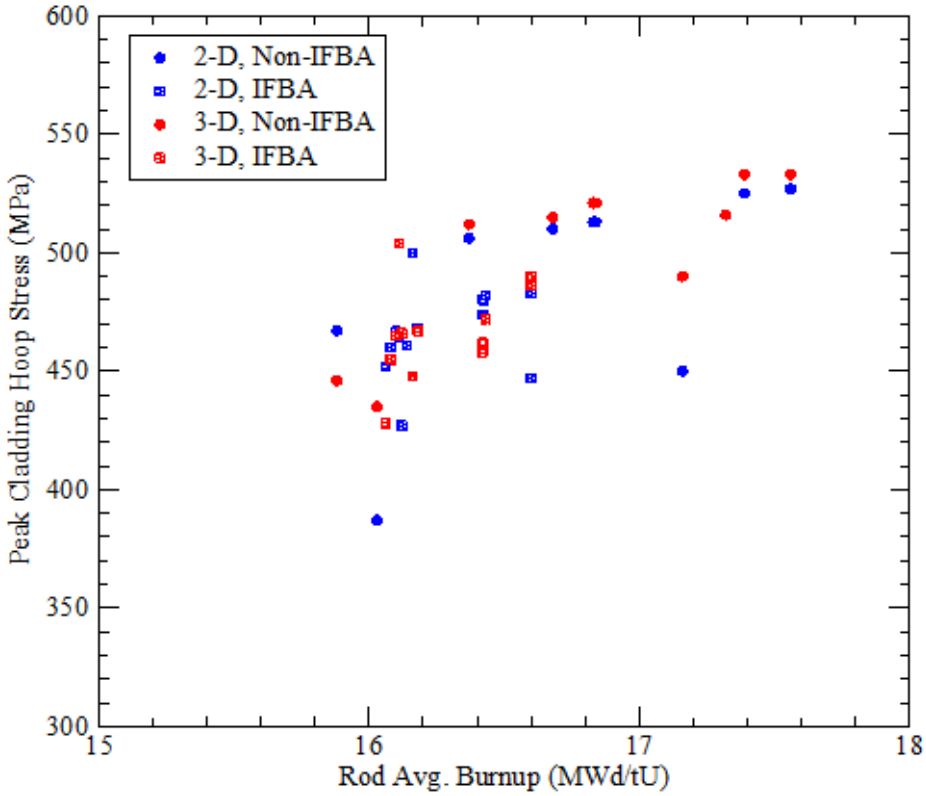




Cycle 7 – 2-D and 3-D modeling of SCC-PCI (left) and (MPS-PCI) (right): Cladding hoop stress

BISON PCI Analyses of Candidate Rods
Comparing Cycles 6 & 7 failure potentials





2-D and 3-D modeling of MPS-PCI for Cycle 6 (left) Compared to Cycle 7 (right): Cladding hoop stress

BISON PCI Analyses of Candidate Rods
Conclusions and Future Work

- The PCI screening capability of VIRA simulation has been fully demonstrated through
  - A quarter-core VERA-CS + BISON analysis of Cycles 6 and 7 of Watts Bar Unit 1.
  - Ability to identify differences in:
    - Power levels
    - Power History
    - PCI Failure modes (SCC-PCI vs. MPS-PCI)
- Future Work:
  - Improve temperature input to MPACT by creating fast running BISON Model to be coupled directle with MPACT to replace look-up table
  - Introduce a mechanistic failure model to replace stress based criteria.

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