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Coupled Serpent-thermal hydraulic analysis: BWR assembly test case

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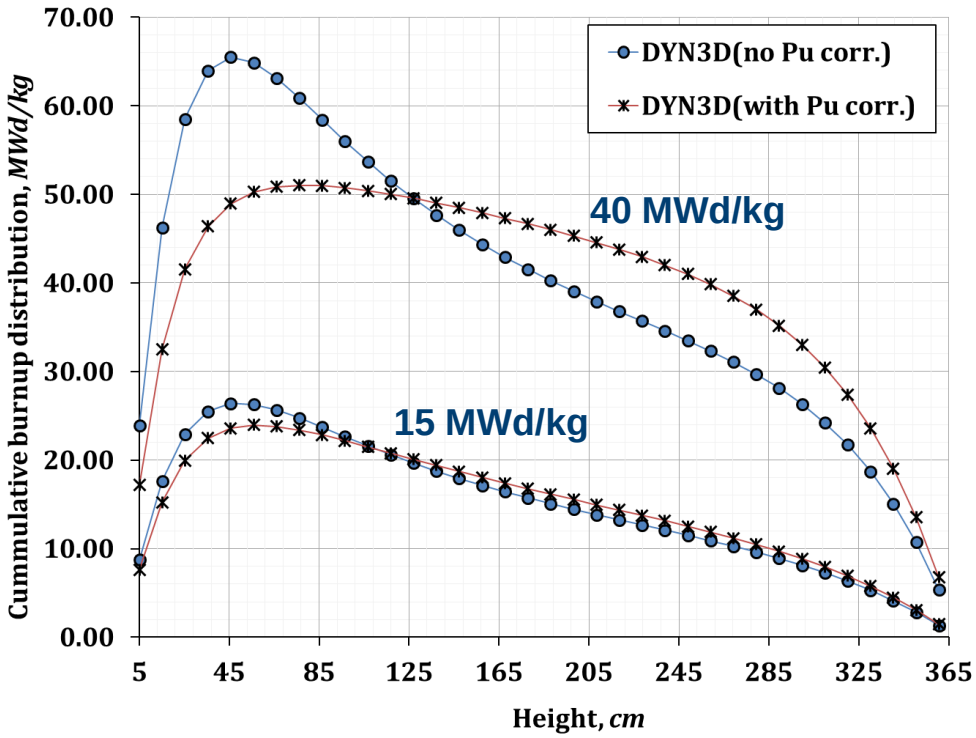
Outline

- **Objectives and motivations**
  - Benchmark DYN3D (void history spectral effect)
  - Obtain reference solution with Monte Carlo code/s
- **BWR assembly test case and results**
  - Serpent-TH vs. DYN3D and BGCore
- **Sensitivity studies**
  - Computational time vs. #nuclides
  - Cross section libraries
- **Conclusions**

Objectives and Motivations

- **Benchmark** DYN3D: new method to account for void history effect was developed and implemented
  - The main objective was:
    - Verify the accuracy

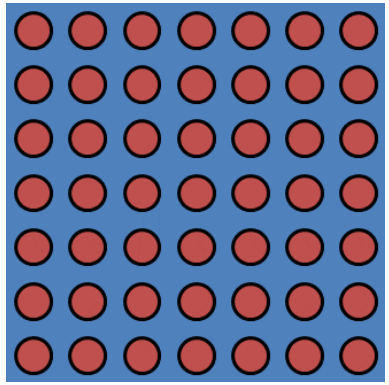


Original plan of actions

- **Stage 1:** Generate cross sections with Serpent (JEF3.1)
- **Stage 2:** Feed the homogenized parameters to DYN3D
- **Stage 3:** Perform full 3D calculation (BU+TH) with DYN3D
- **Stage 4:** Obtain reference solution with BGCore (JEF3.1)
- **Stage 5:** Compare results

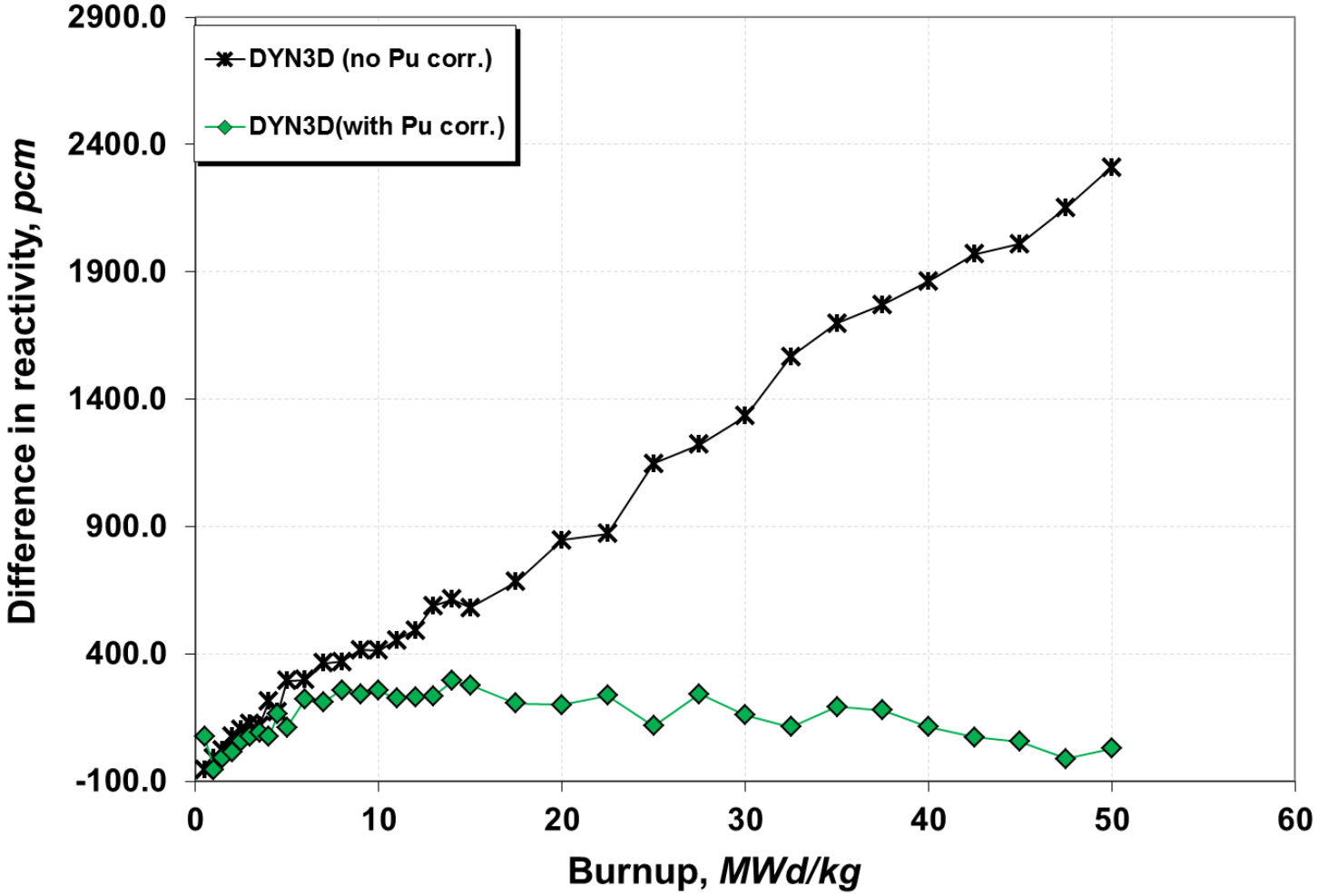
Test case description

- **BWR assembly (7x7)**
  - Divided to 36 axial layers
    - Burnup nodes *x36*
    - Thermal hydraulic nodes *x36*

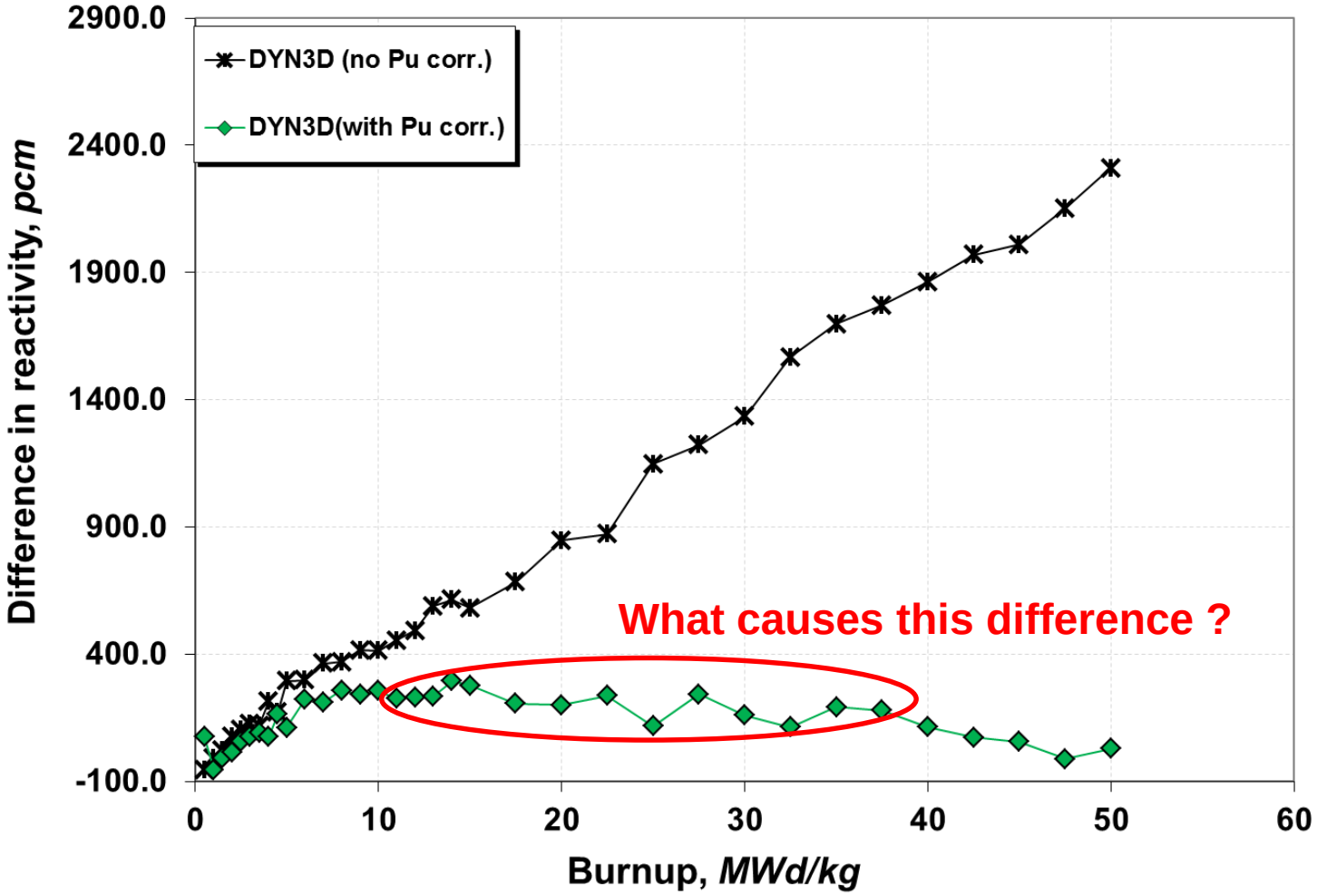


  - Inconsideration of the void history effect should lead to inaccuracies
    - These inaccuracies are more pronounced in boiling regime
      - Large coolant density decrement through the core
  - Coupled burnup-thermal hydraulic calculations were performed with BGCore to create the reference solution

Results: DYN3D vs. BGCore



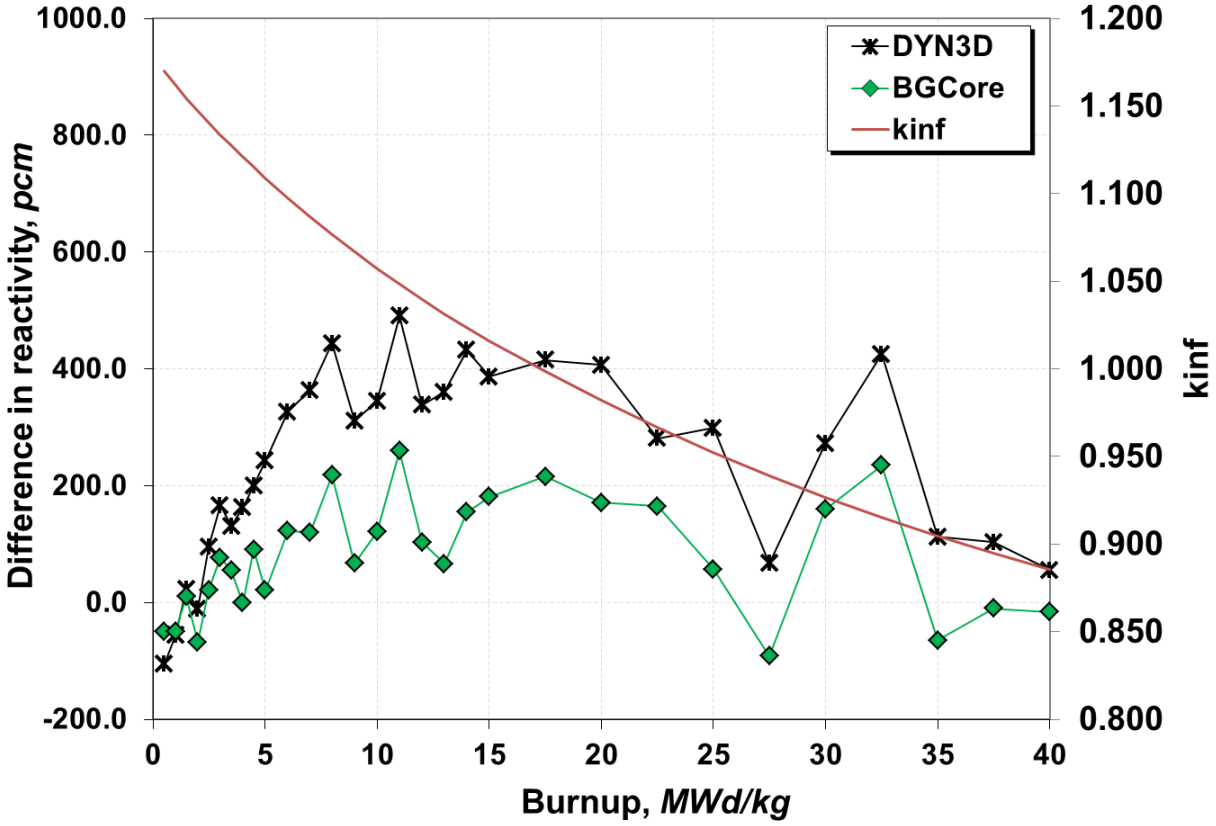
Results: DYN3D vs. BGCore



Modified plan of actions

- **Stage 1:** Generate cross sections with Serpent (JEF3.1)
- **Stage 2:** Feed the homogenized parameters to DYN3D
- **Stage 3:** Perform full 3D calculation (BU+TH) with DYN3D
- **Stage 4:** Obtain reference solution with BGCore (JEF3.1)
- **Stage 5:** Compare results
- **Stage 6:** Integrate Serpent with thermal hydraulics
- **Stage 7:** Create reference solution: Serpent (JEF3.1)

Results (1): reactivity



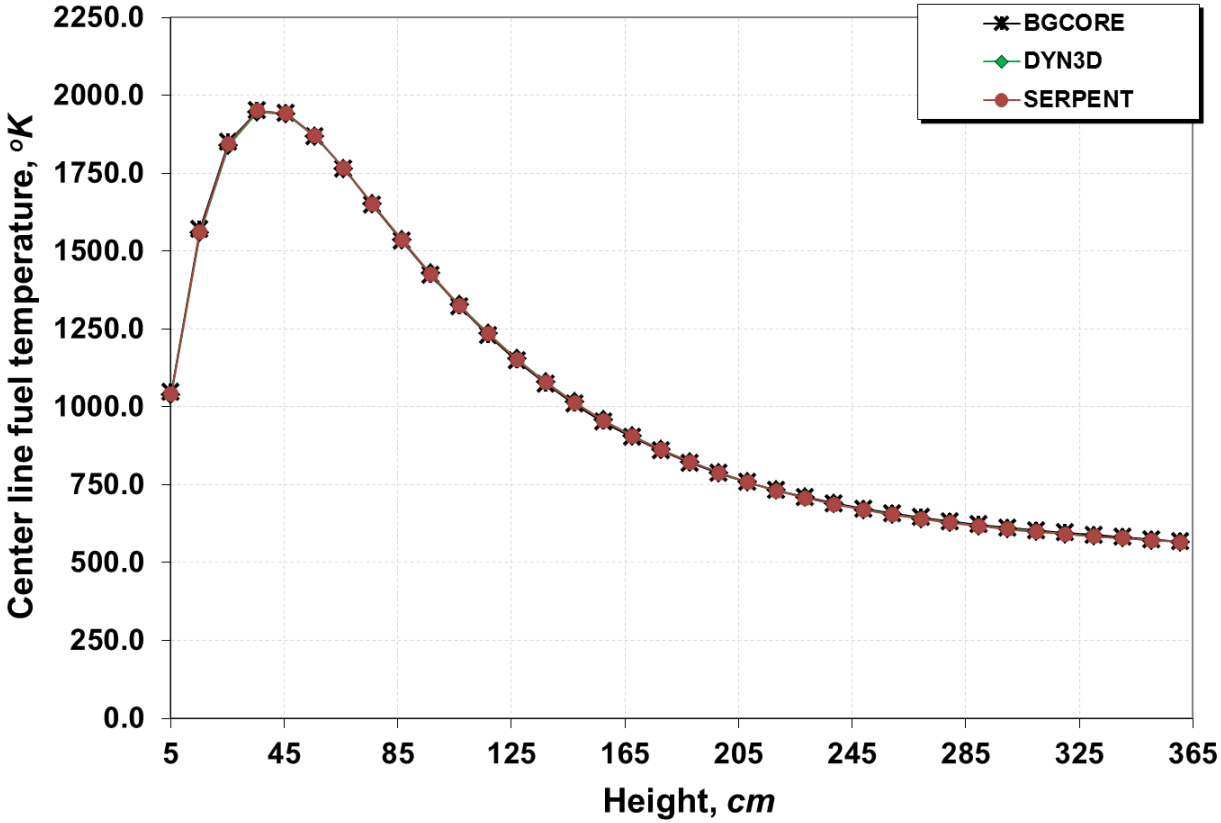
Reference solution:
Serpent (JEF3.1)

	$\Delta\rho_{max}$ *pcm*
BGCore	280
DYN3D	500

Results (2): CL fuel temperature (BOL)

1.21542	Δρ *pcm*
BGCore	-51
DYN3D	55

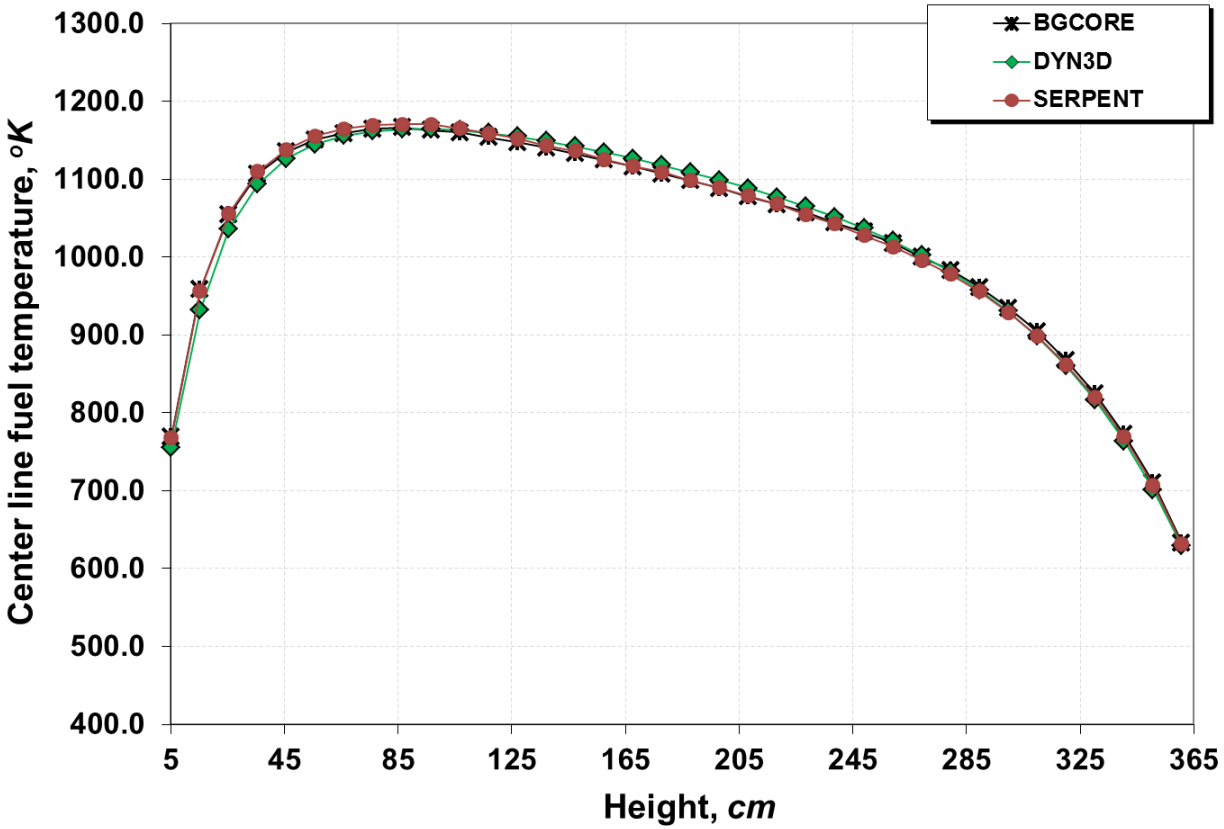
	ΔT_{max} *K*
BGCore	8
DYN3D	5



Results (2): CL fuel temperature (MOL)

1.02773	Δρ *pcm*
BGCore	66
DYN3D	360

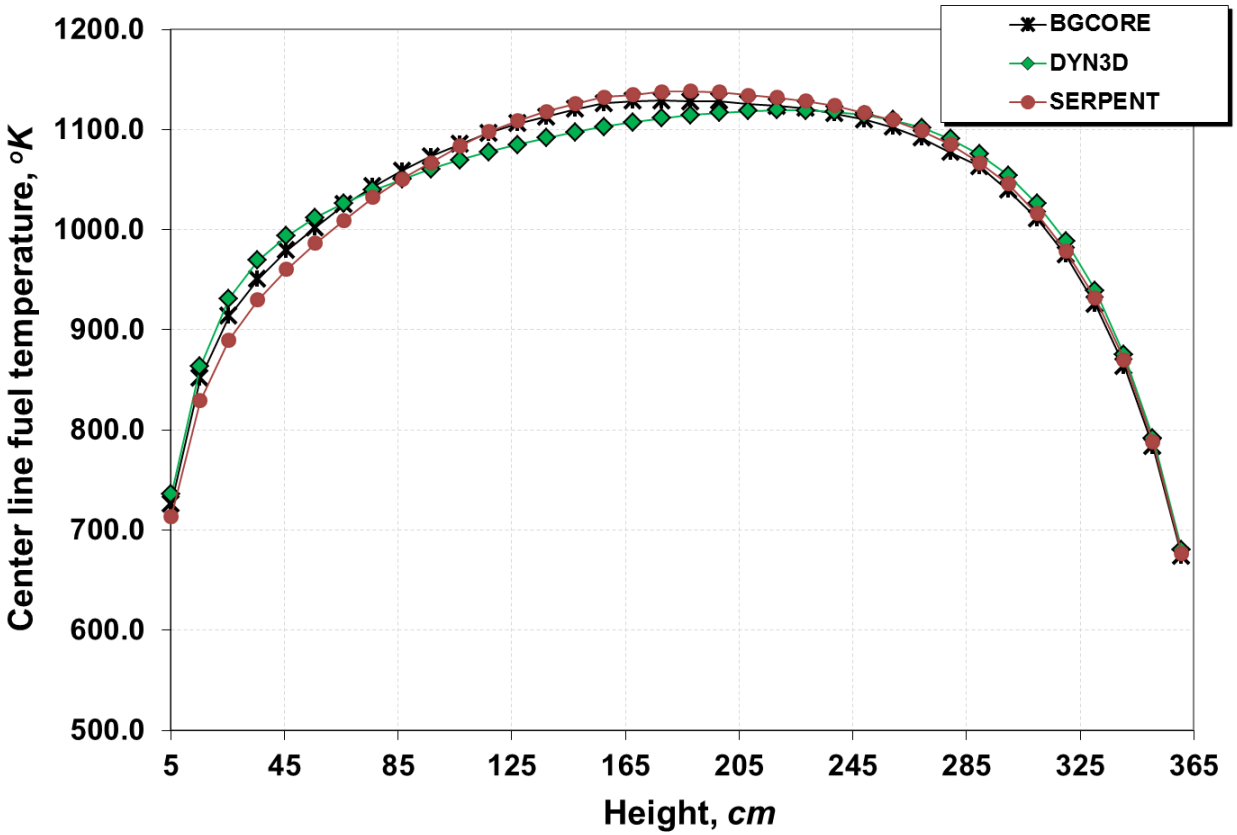
	ΔT_{max} *K*
BGCore	7
DYN3D	25



Results (2): CL fuel temperature (EOL)

0.885138	Δρ *pcm*
BGCore	-16
DYN3D	55

	ΔT_{max} *K*
BGCore	23
DYN3D	41

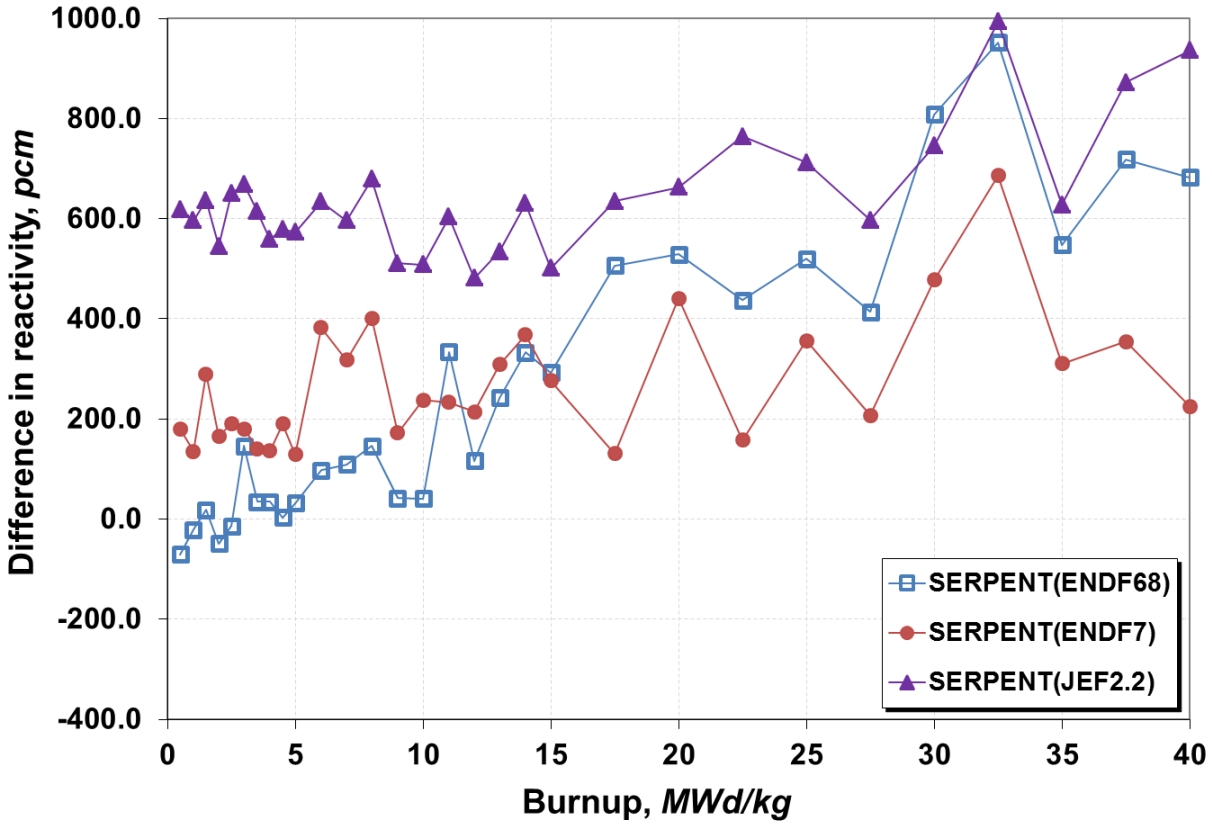


Intermediate conclusions and challenges

- **Good agreement between the codes**
  - Difference in power distribution and criticality values
    - In DYN3D (number of energy groups)
    - Thermal hydraulic solvers
      - Void correlations (2-phase)
- **Interesting question:**
  - Cross section libraries impact
- **Encountered challenges:**
  - Calculation time in Serpent (data generation)

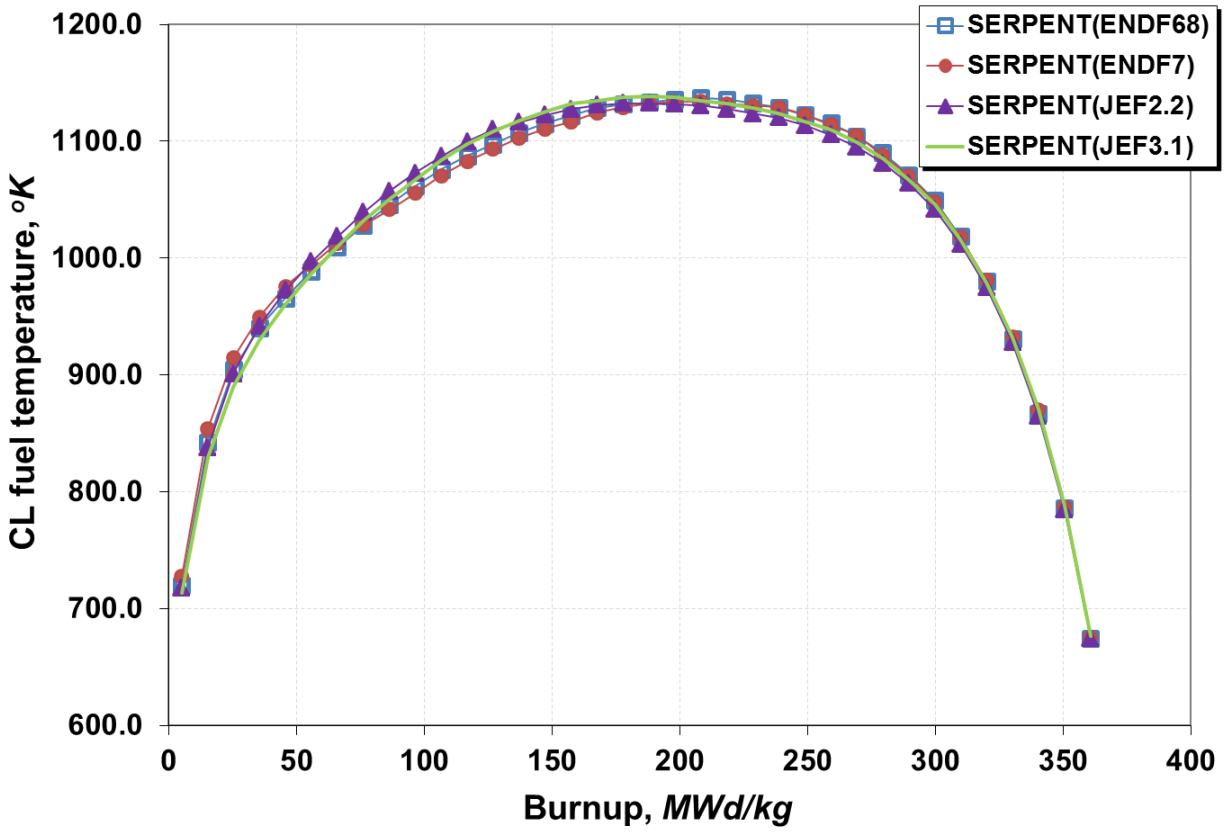
Sensitivity Studies (1): data libraries (1)

- **Reference:** JEF3.1
  - JEF2.2: $\Delta\rho_{max}$=1000
  - ENDF7: $\Delta\rho_{max}$=700
  - ENDF68: $\Delta\rho_{max}$=1000



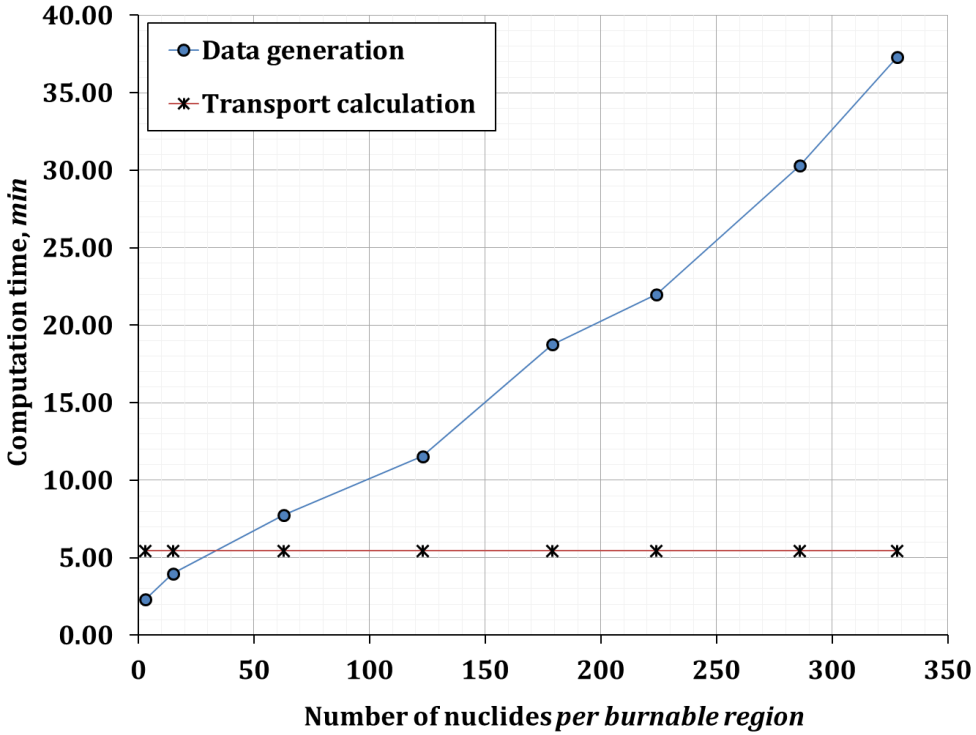
Sensitivity Studies (1): data libraries (2)

- **Reference:** JEF3.1
  - JEF2.2: ΔT_{max}=12
  - ENDF7: ΔT_{max}=25
  - ENDF68: ΔT_{max}=15



Sensitivity Studies (2): data generation time

- **Number of nuclides** was varied, i.e. from 3 till 328 nuclides (36 burnable regions)
  - Computation times:
    - 5.45 mins for transport
      - $50{,}000^{H}/150^{AC}/50^{IC}$
    - 8 msec per reaction type
  - Core calculations:
    - Hundreds of regions
      - Hours of data generation?



Conclusions

- **Benchmark**
  - Serpent-DYN3D sequence vs.
  - Serpent and BGCore coupled codes
    - Good agreement in all neutronic and TH parameters
- **Cross section data impact**
  - Maybe on the same order as methods
- **Calculation time**
  - Data preparation may be optimized (user defined)