Modeling of thermal expansion effects in SFRs with Serpent/DYN3D

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Outline

- Motivation
- Serpent-DYN3D codes sequence
- Modelling of axial fuel rod expansion
- Results
- Summary

Motivation

- Reactor dynamics code DYN3D
  - 3D multi-group nodal diffusion
  - Rectangular and hexagonal geometries
  - In-built thermal hydraulic model and coupling with other codes
  - Developed for LWR applications

- DYN3D is being extended for SFR application
  - Development of few-group XS generation methodology
  - Modeling of the thermal expansion feedbacks
    - Fuel rod thermal expansion
    - Diagrid thermal expansion
    - …

Axial thermal expansion of the fuel rods

- Main effects:
  - increase of leakage in radial direction
  - slight insertion of control rods
- Assumption:
  - Driven by the cladding temperature (closed gas gap)
- Modeling:
  - Increasing cladding temperature
  - Expanding pin dimensions
  - Decreasing both cladding and fuel densities
- Fuel-performance code for more detailed modelling
  - Swellings, pressure differences, cladding shape

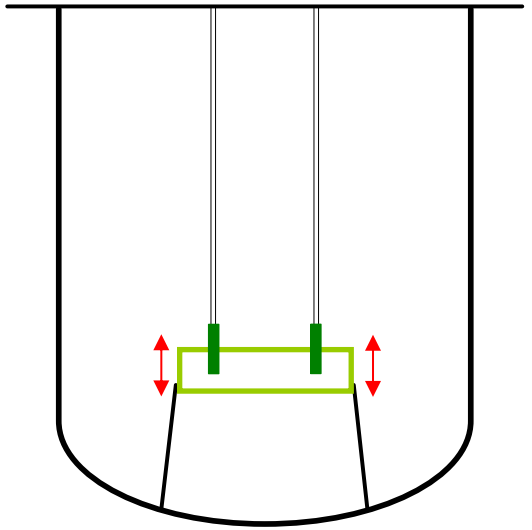
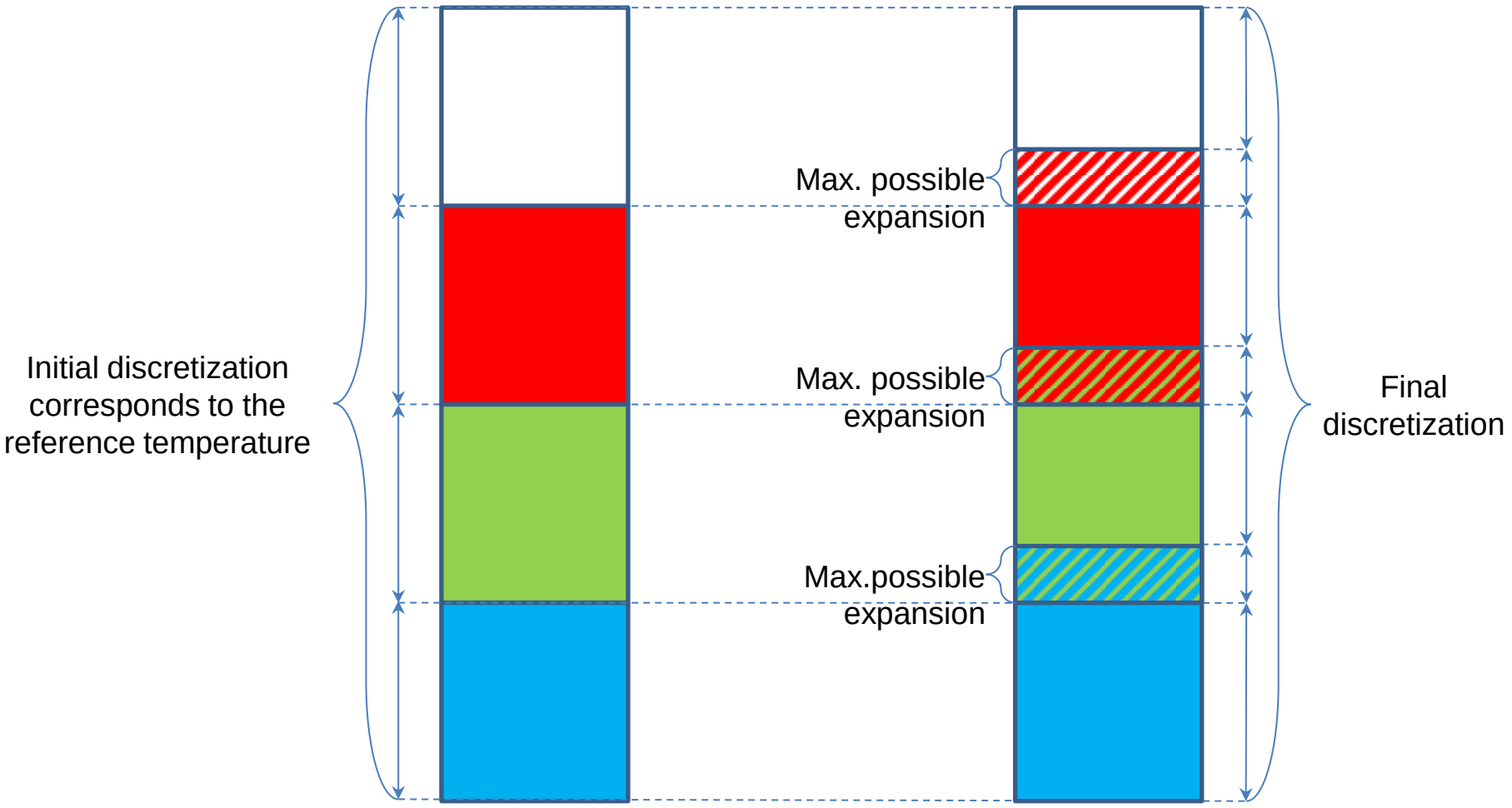


**Figure from Konstantin Mikityuk (PSI)*

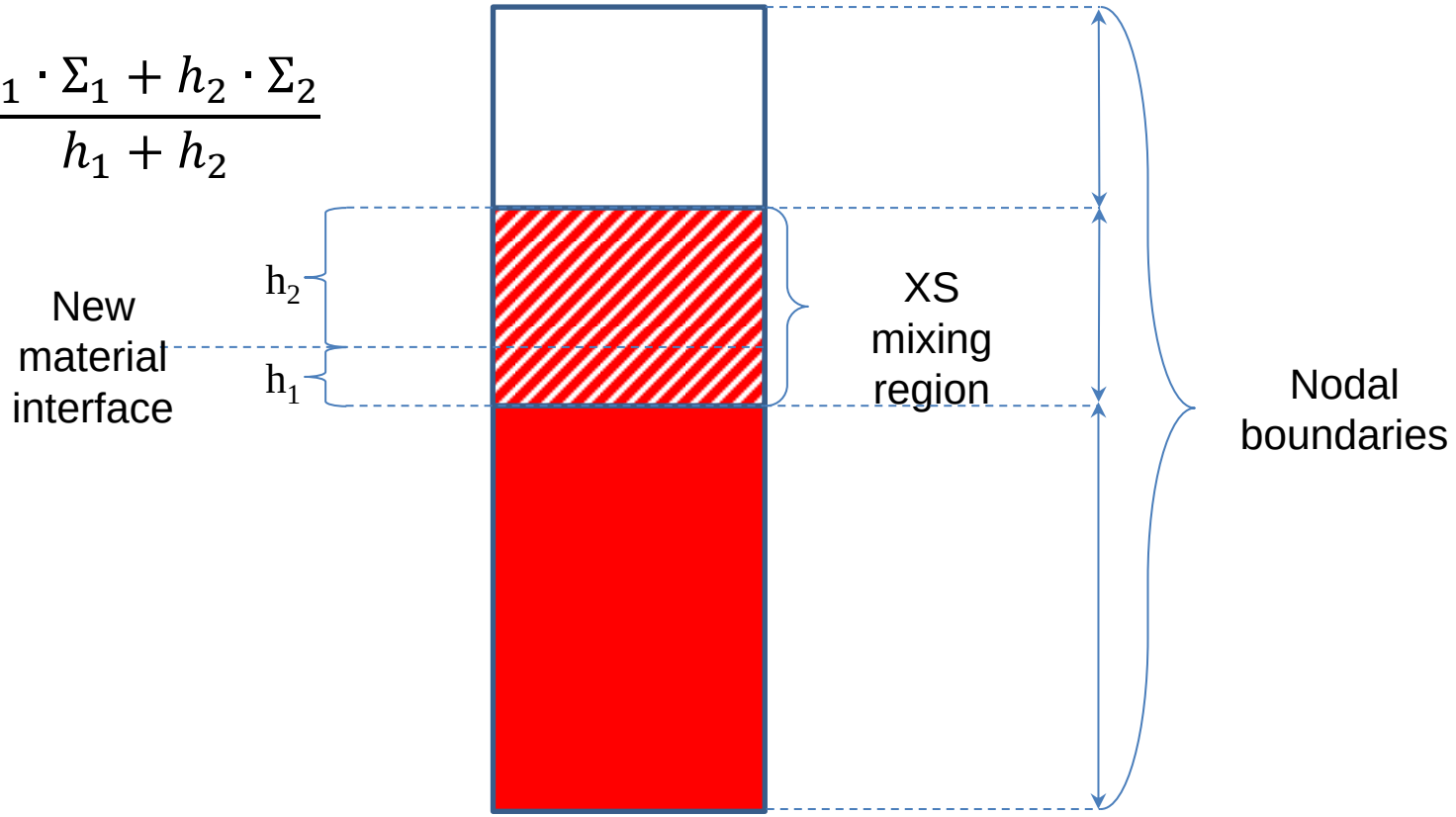
Axial fuel rod expansion model



Axial fuel rod expansion model

- Volume weighted averaged cross sections („mixing“)
- Similar to partially inserted control rod modeling

$$\Sigma = \frac{h_1 \cdot \Sigma_1 + h_2 \cdot \Sigma_2}{h_1 + h_2}$$

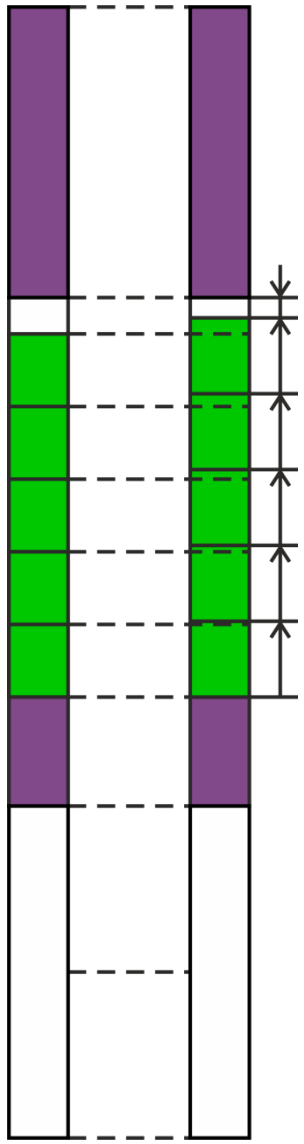


Verification in steady-state

- OECD-SFR full core calculation
  - Axial uniform expansion of the active core
  - XS and reference solution with Serpent
  - dL/L = 0.5; 1.0; 1.5; 2.0 %

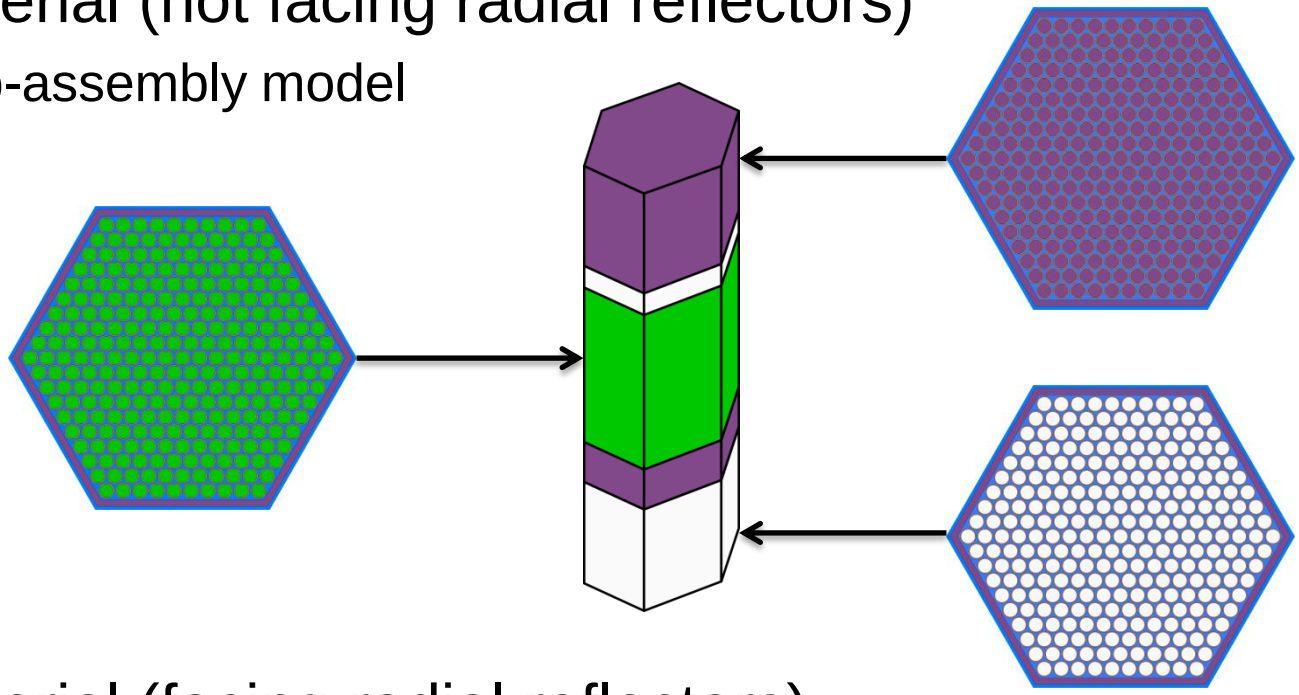
- Test cases
  1. Only fuel pellet expansion
  2. Fuel and cladding together

- Methods in DYN3D
  A. Changing geometry – equivalent to Serpent
  B. Fixed geometry, but using corresponding XS
  C. Fixed geometry and using the mixing model

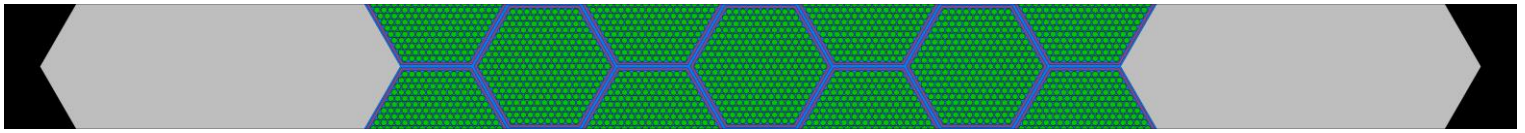


Few-group XS generation models

- Fuel material (not facing radial reflectors)
  - 3D sub-assembly model

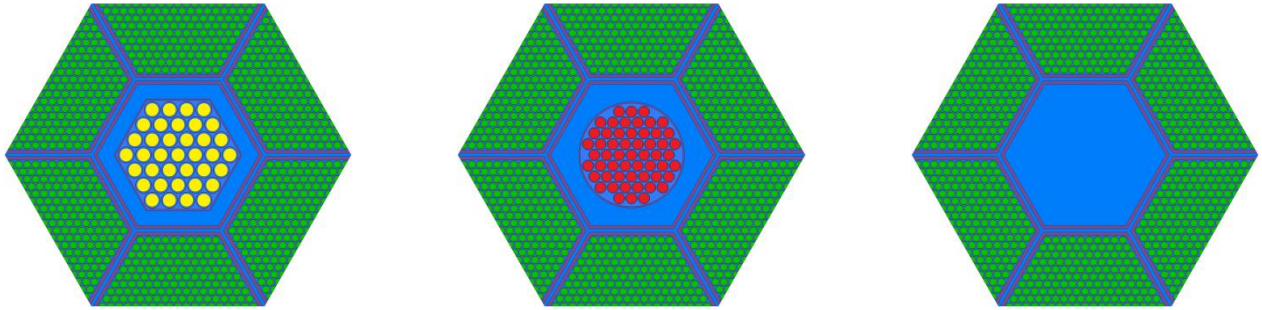


- Fuel material (facing radial reflectors)
  - 3D reflector model

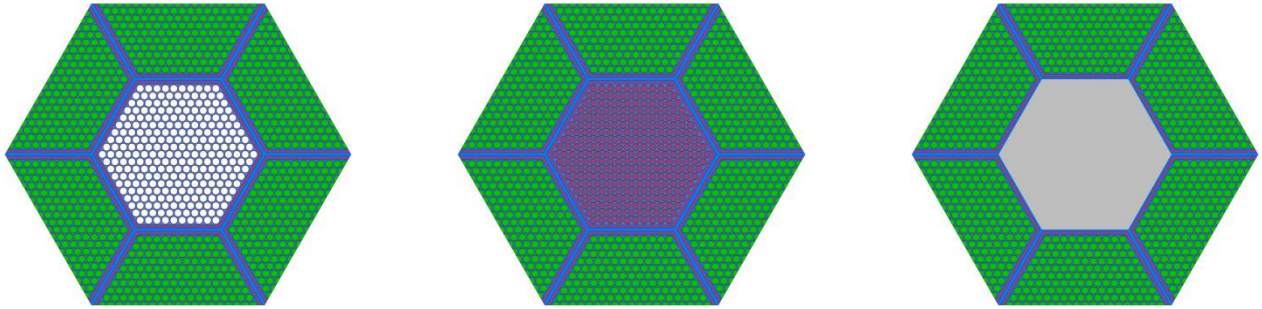


Few-group XS generation models

- Non-multiplying regions
  - 2D super-cell model
    - CSD, DSD and CR channel

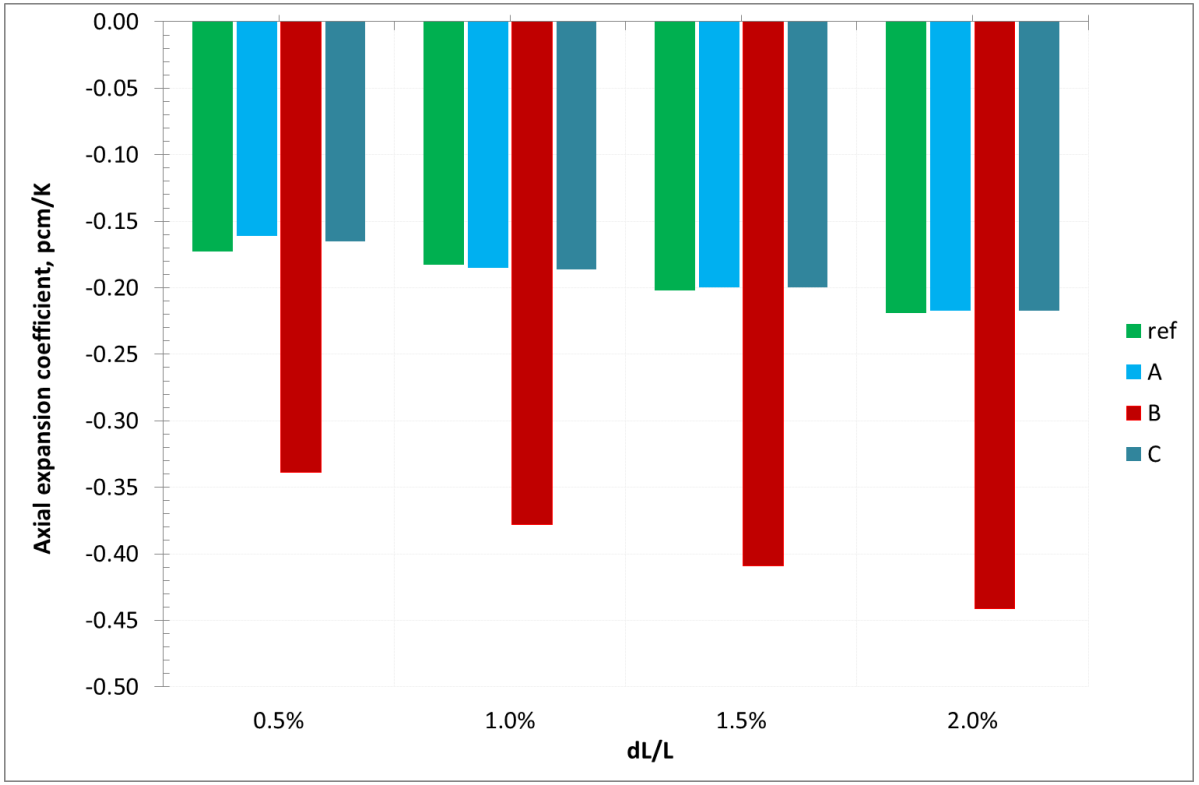


    - Gas/sodium plenum, axial and radial reflector



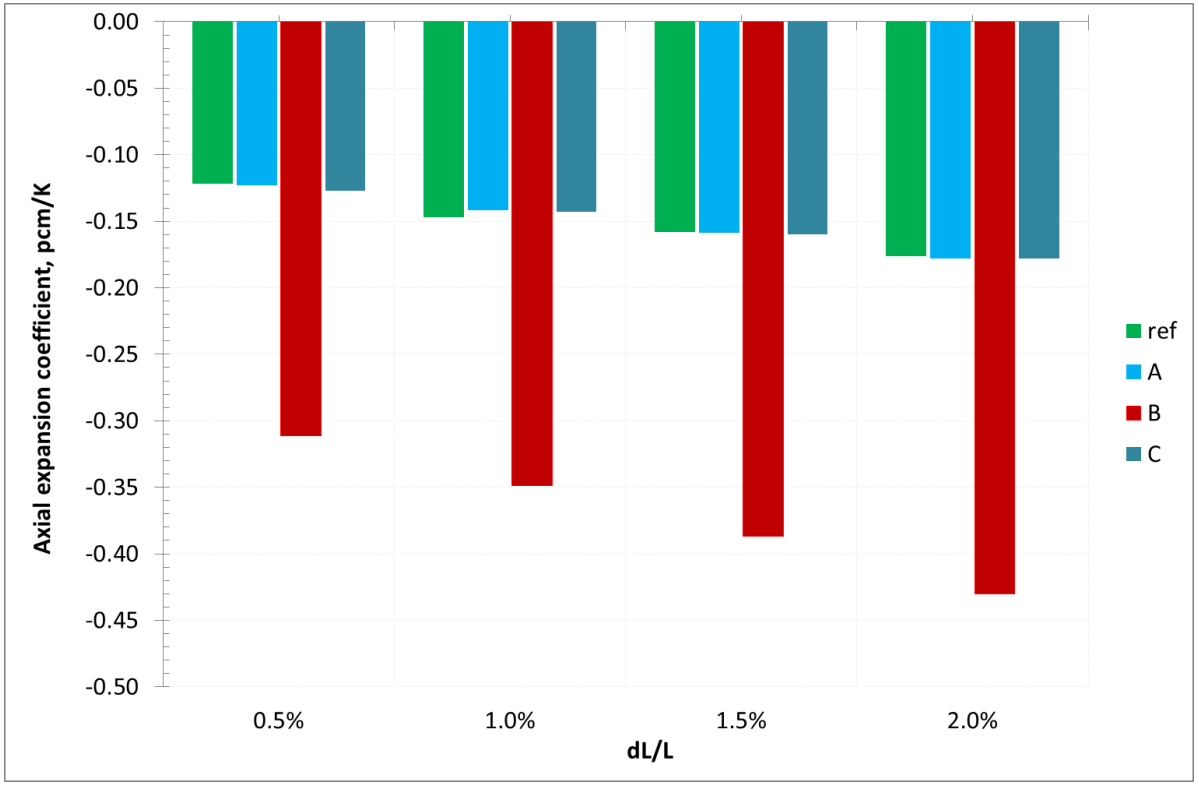
Axial expansion results – DYN3D vs. Serpent

- Fuel expansion only (linear expansion coeff. of MOX)
  A. Changing geometry
  B. Fixed geometry, but using corresponding XS
  C. Fixed geometry and using the mixing model



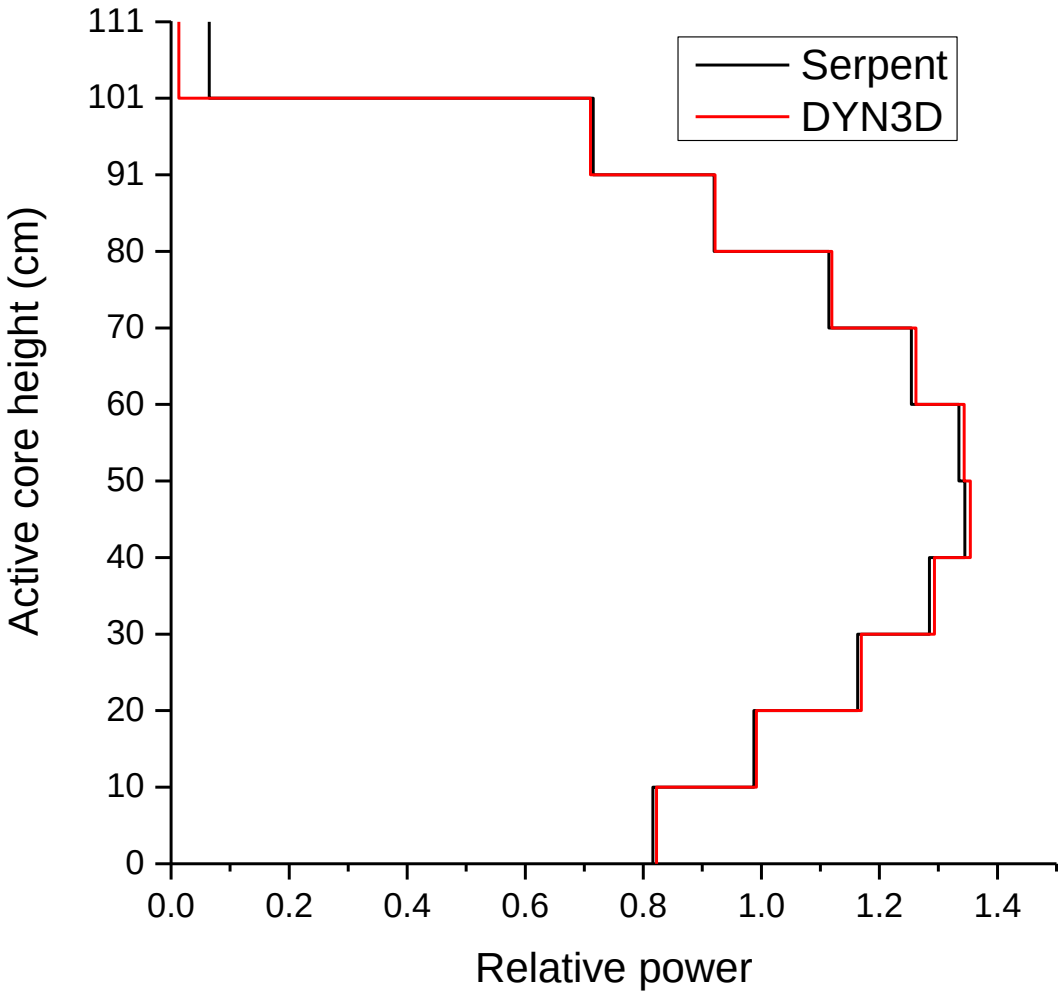
Axial expansion results – DYN3D vs. Serpent

- Fuel and cladding (linear expansion coeff. of ODS)
  A. Changing geometry
  B. Fixed geometry, but using corresponding XS
  C. Fixed geometry and using the mixing model



Axial expansion results – axial power profile (1.0%)

Level (cm)	Rel. Power	Rel. Diff. (%)
105.6	0.06	80.0
95.5	0.72	0.7
85.5	0.92	0.2
75.4	1.11	0.4
65.4	1.25	0.6
55.3	1.33	0.7
45.3	1.34	0.7
35.2	1.28	0.7
25.1	1.16	0.5
15.1	0.99	0.5
5.0	0.82	0.7



Summary

- The “mixing” model
  - A flexible way of handling the axial fuel rod expansion
  - Each sub-assembly and node can be treated independently
  - Can accurately account for axial expansion effects on full core level
- The model is implemented in DYN3D
- Ongoing work - application in coupled transient calculations

Thank you