Serpent solution of X2 benchmark fresh core HZP

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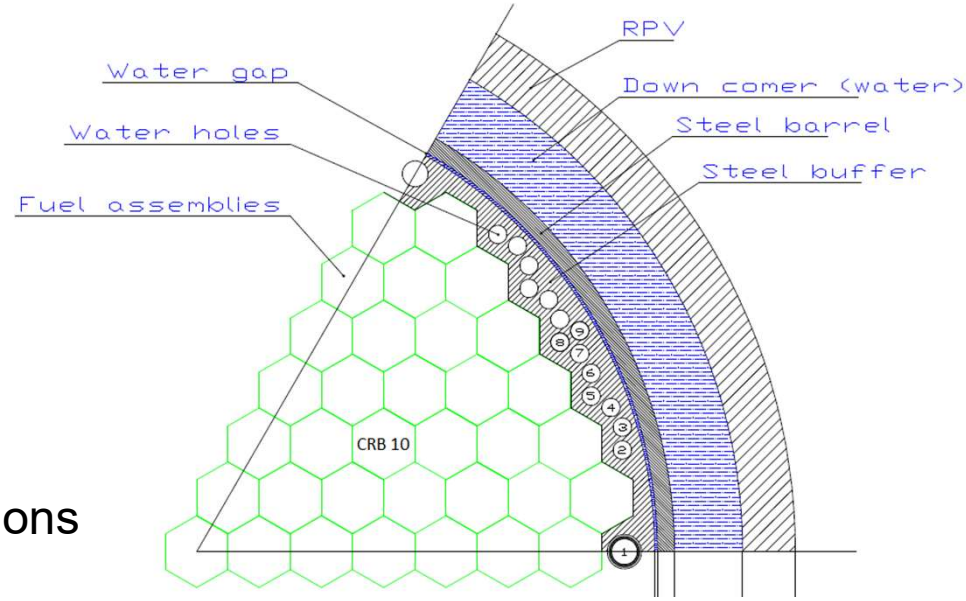
Outline

- X2 VVER-1000 benchmark
- Serpent model
- Serpent results
- XS models
- DYN3D results
- Summary

X2 VVER-1000 benchmark

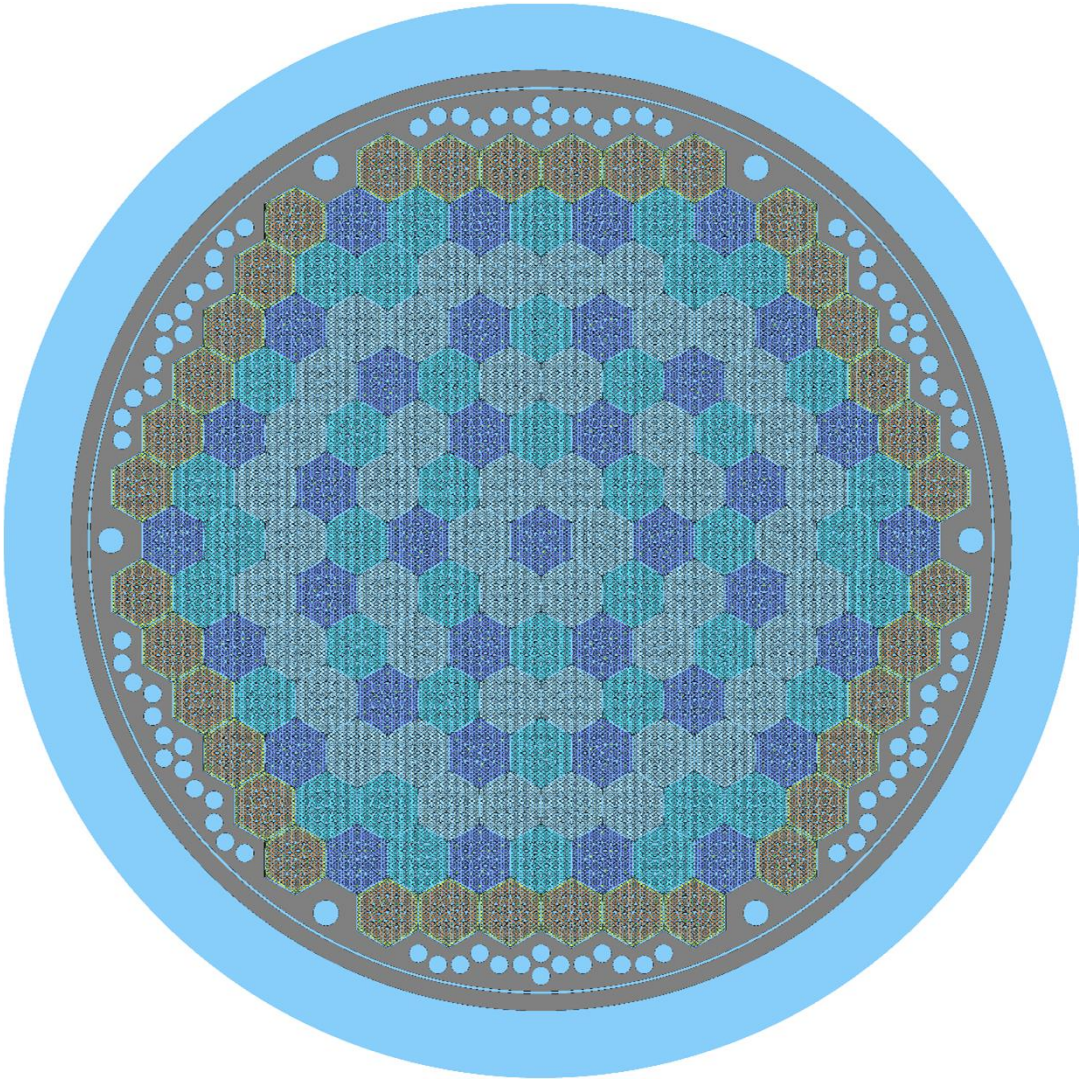
- defined by TUV, Munich and SSTC NRS, Kyiv
  - 19-20th AER Symposiums

- describes KhNPP-2 with VVER-1000 reactor
  - TVSA fuel types
  - reflector
  - 1-4 fuel cycles

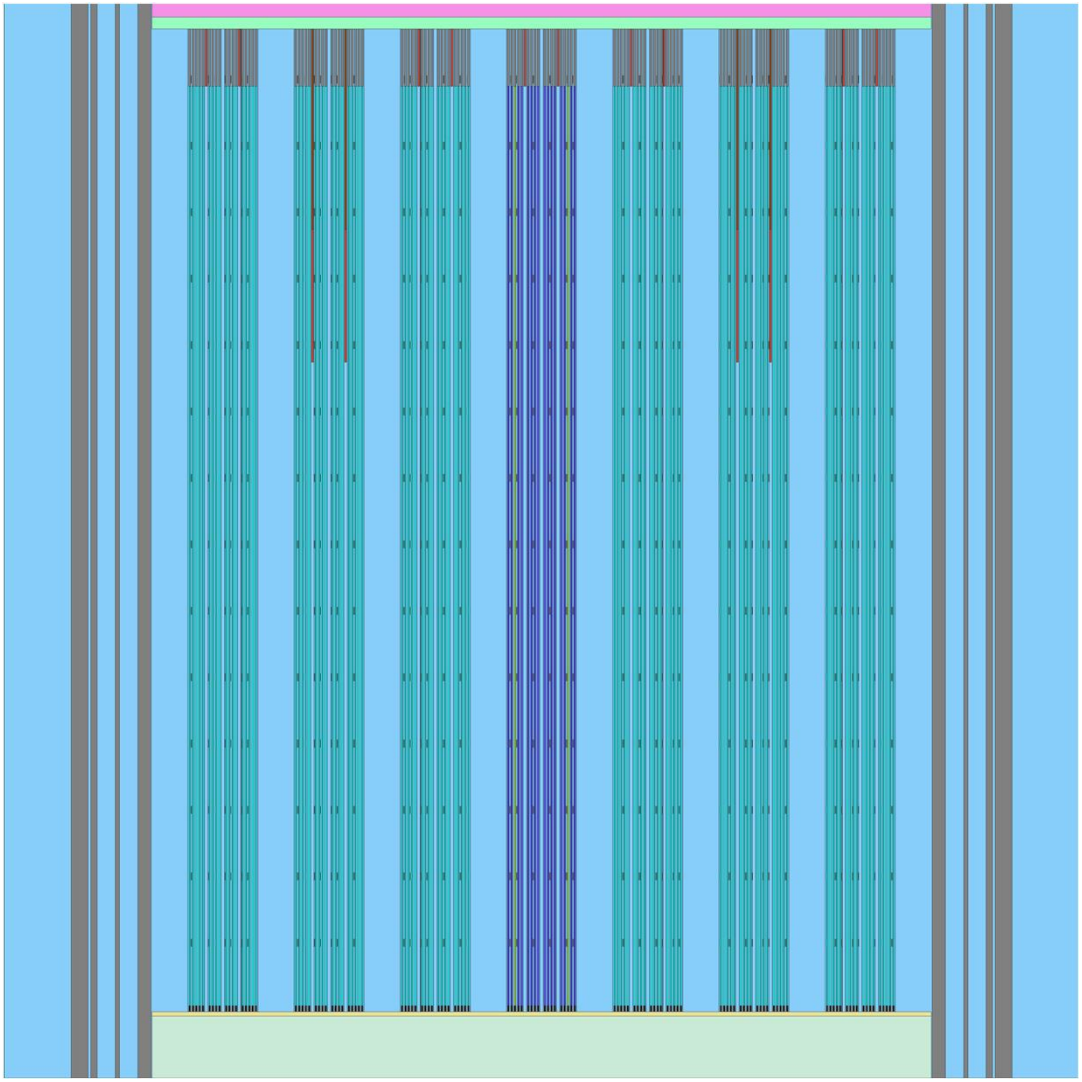


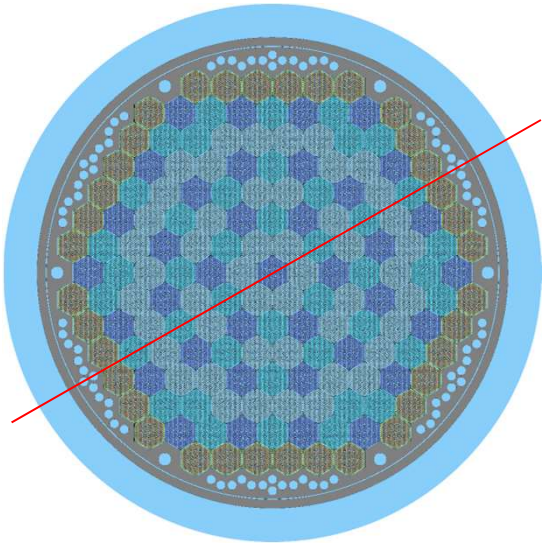
- plant measurements:
  - startup experiments
  - boron letdown
  - reconstructed power distributions

Serpent model – radial cut

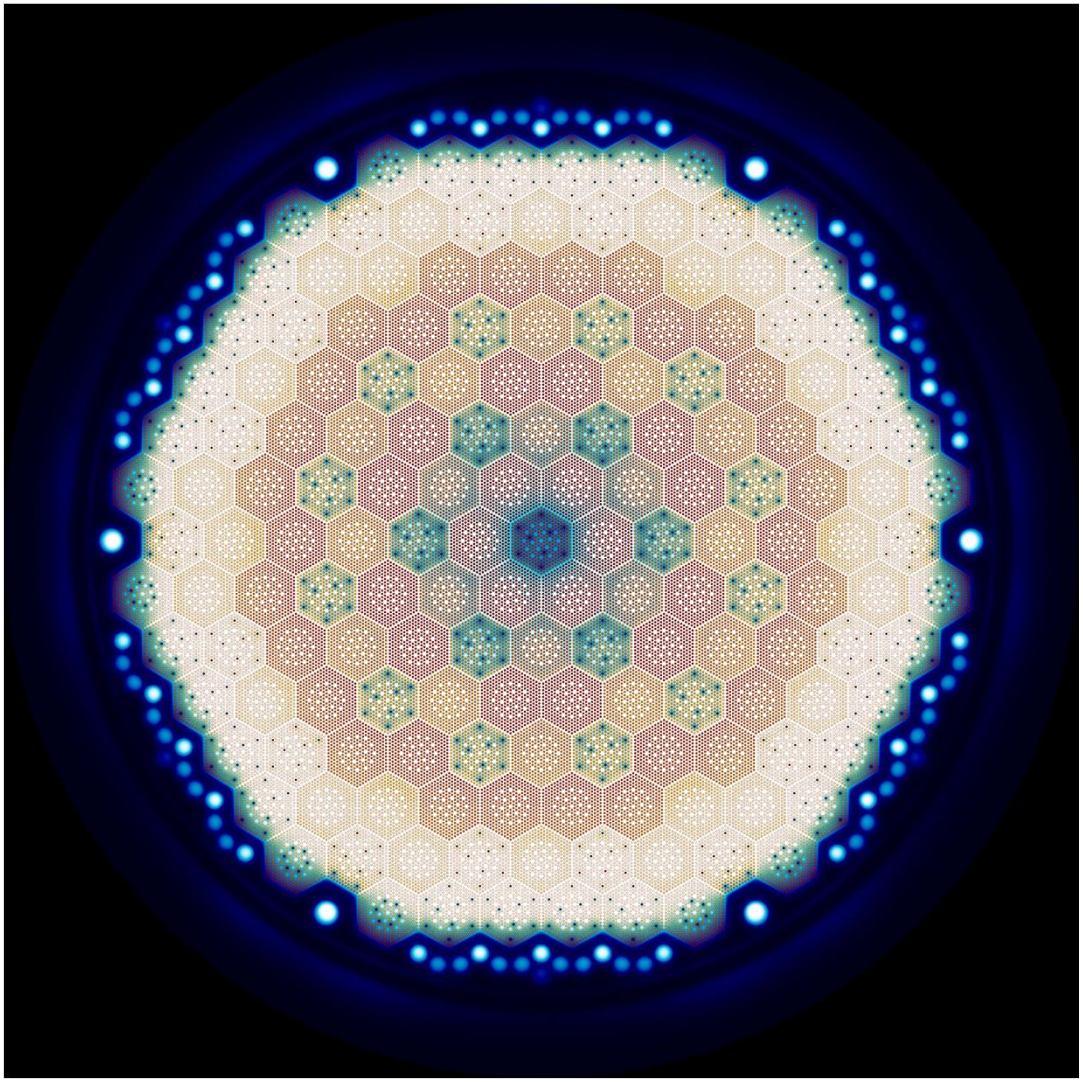


Serpent model – axial cut



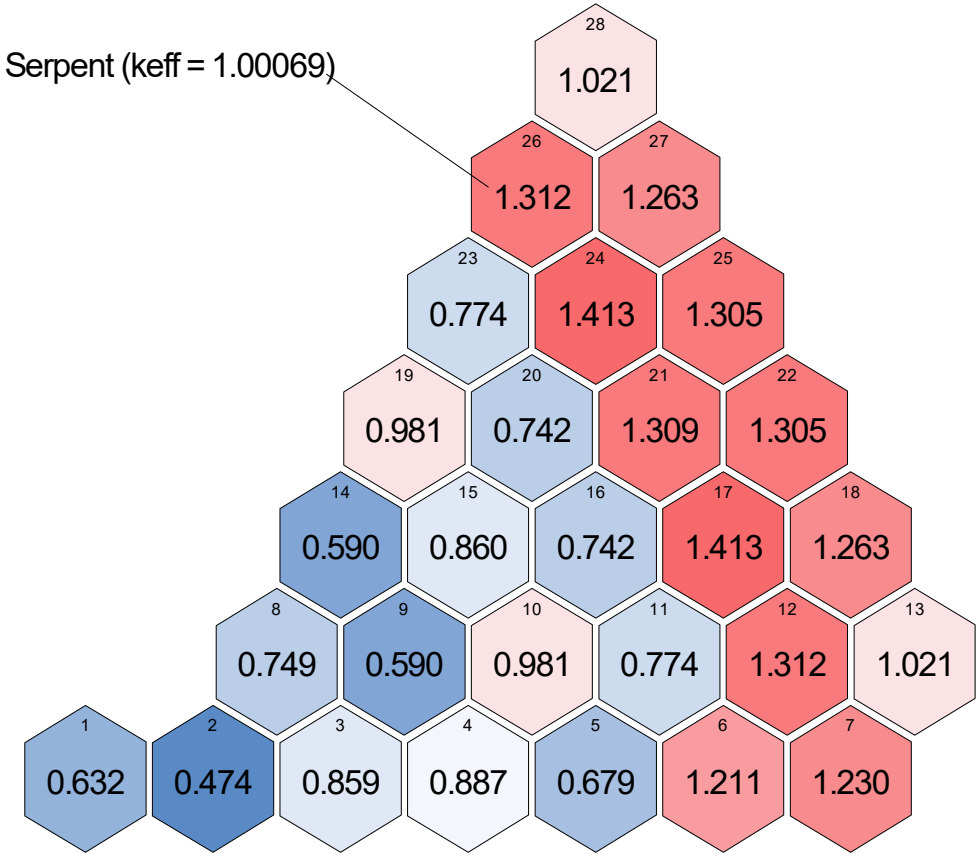


Serpent results



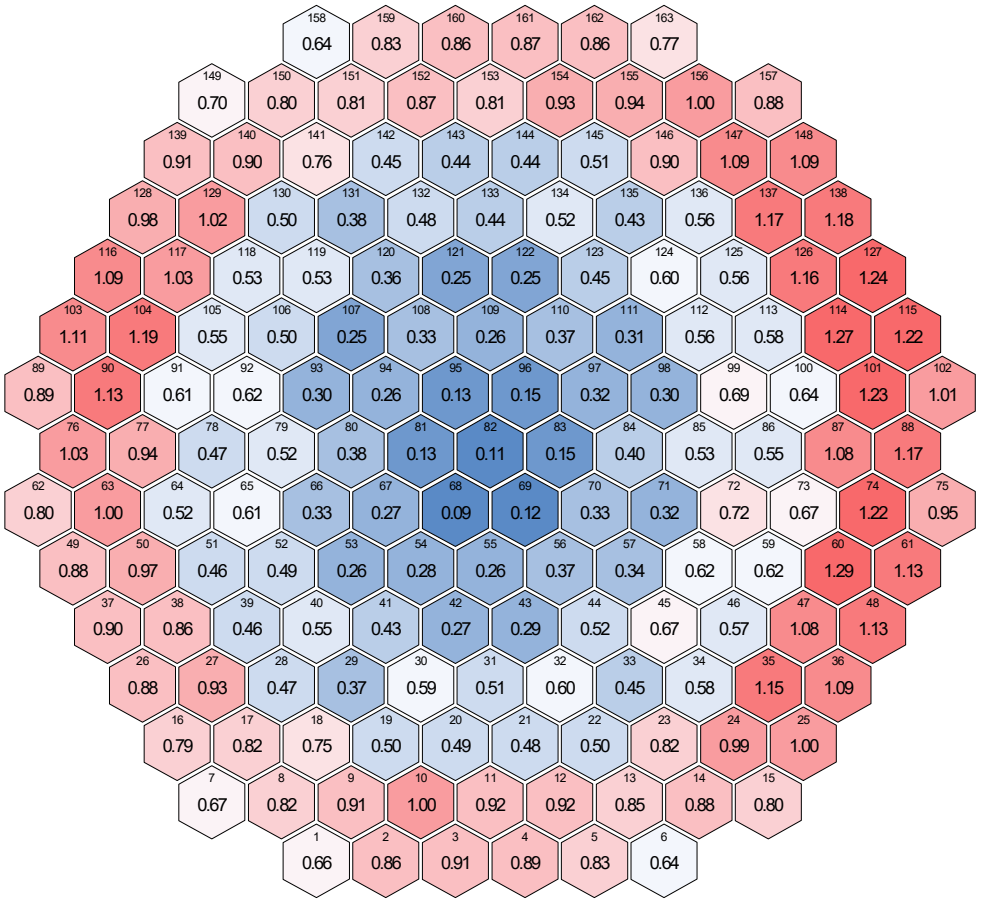
Serpent results

Normalized assembly power distribution



Average of 10 independent runs, each 2000 cycles (200 inactive) x $3*10^6 = 6*10^9$ neutron histories
1/6 core averaged, resulting σ=0.1%

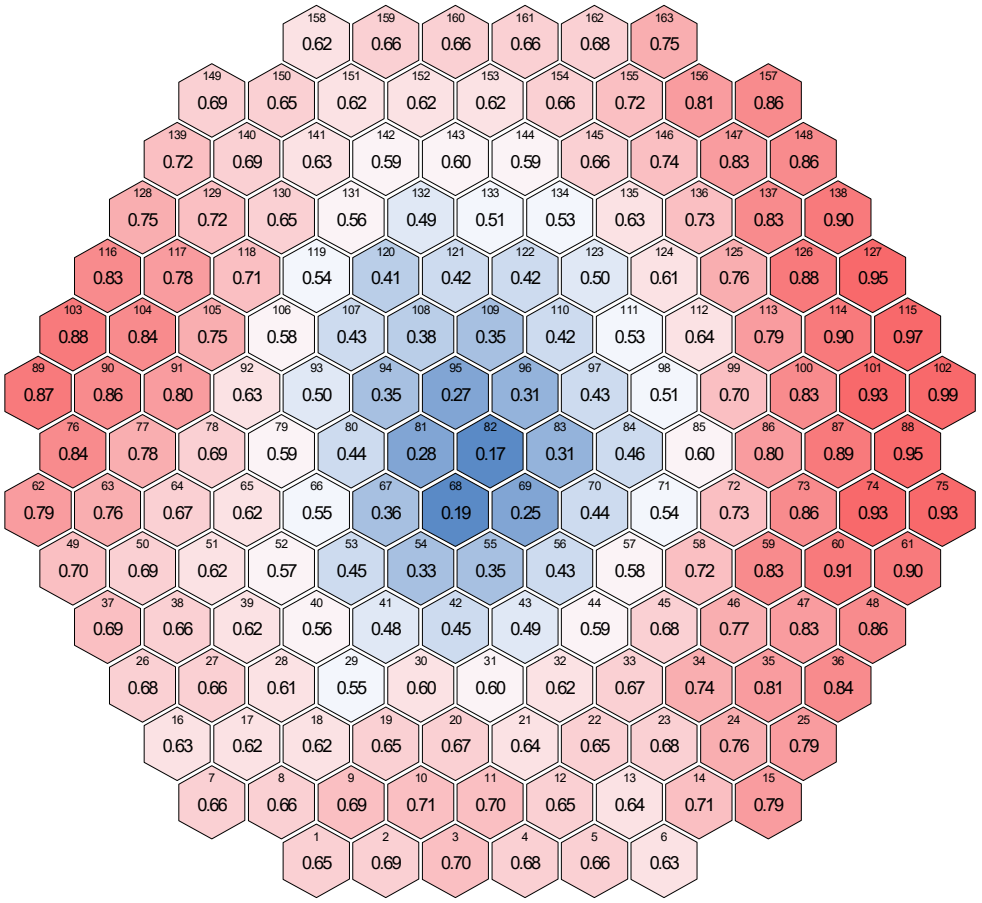
Serpent results uncertainty



std of each assembly power in 10 independent runs

$std(P_i^n)$ * 100

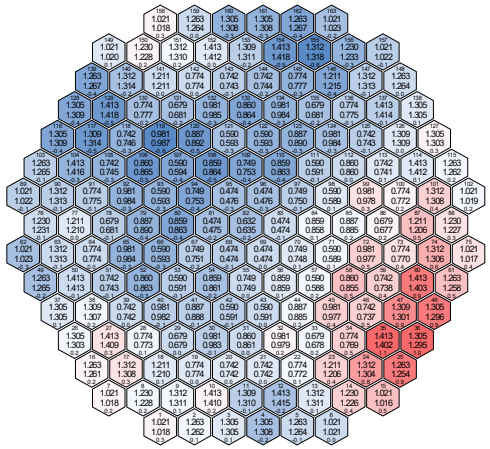
Serpent results uncertainty

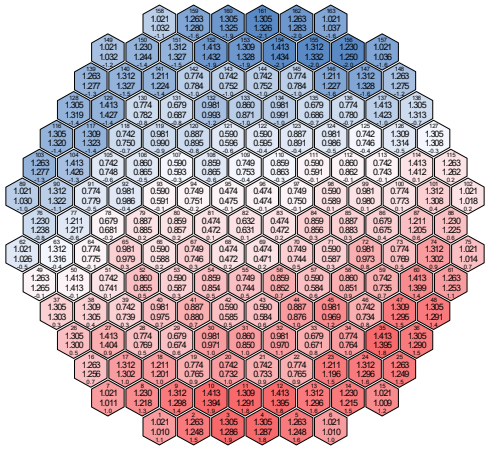


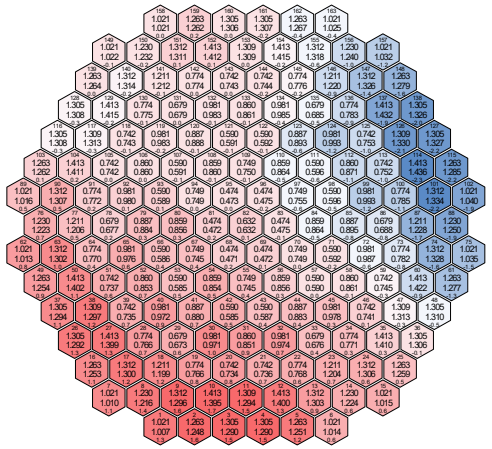
std of each assembly power in 10 independent runs / average value

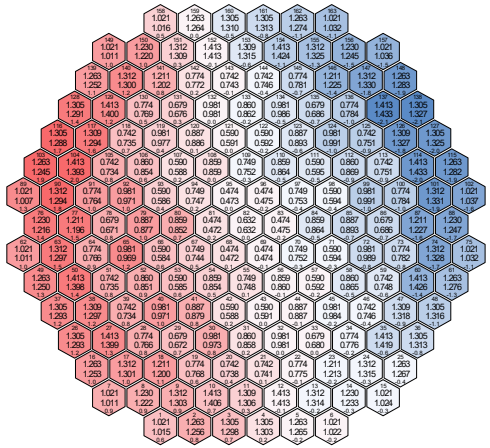
$std(P_i^n)/\overline{P_i}$

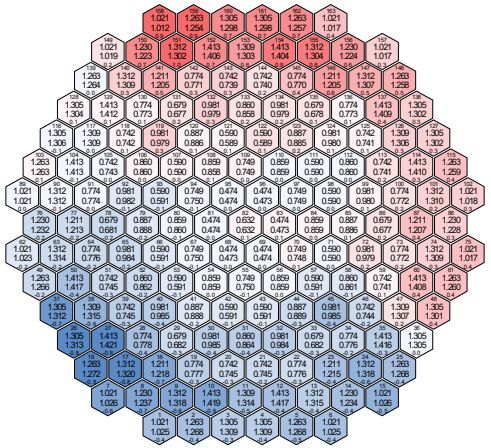
Serpent results uncertainty

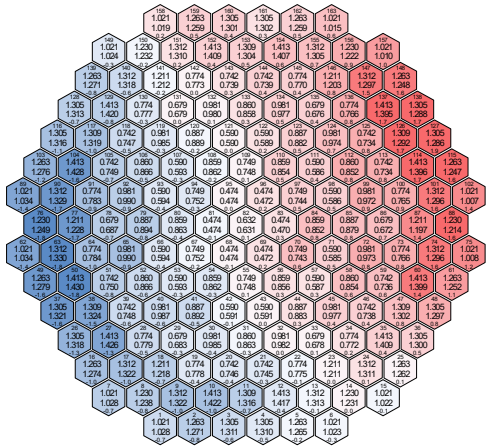






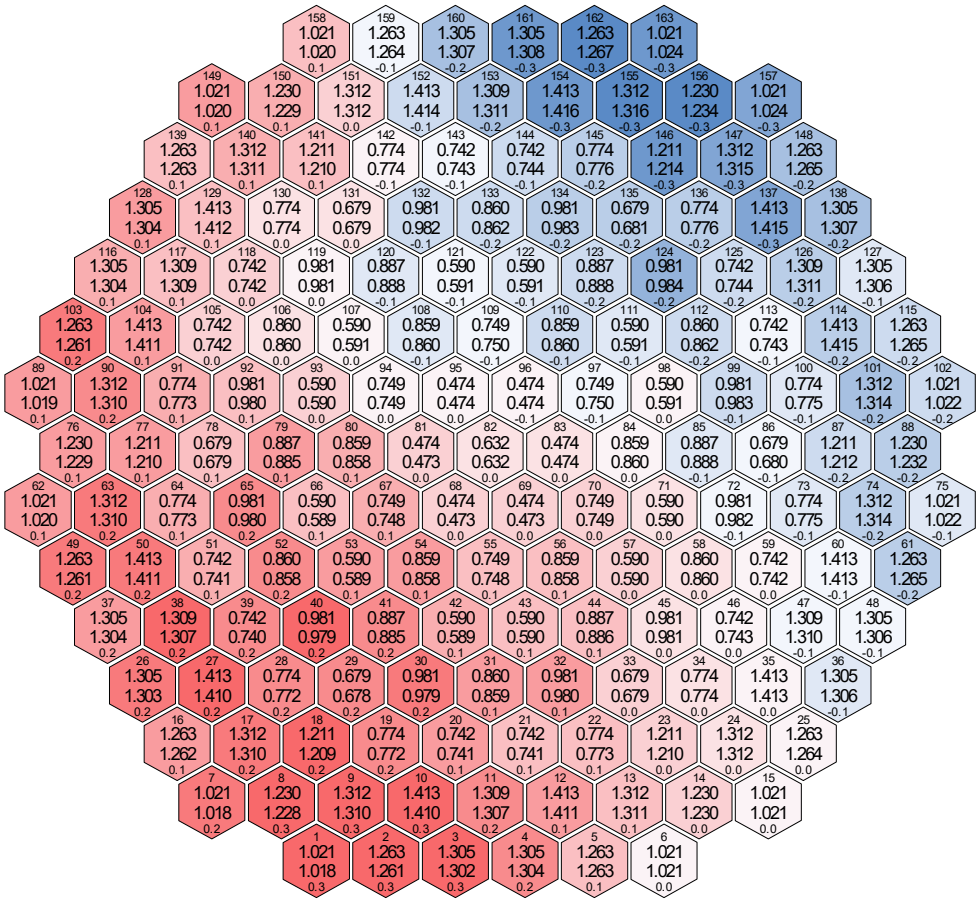






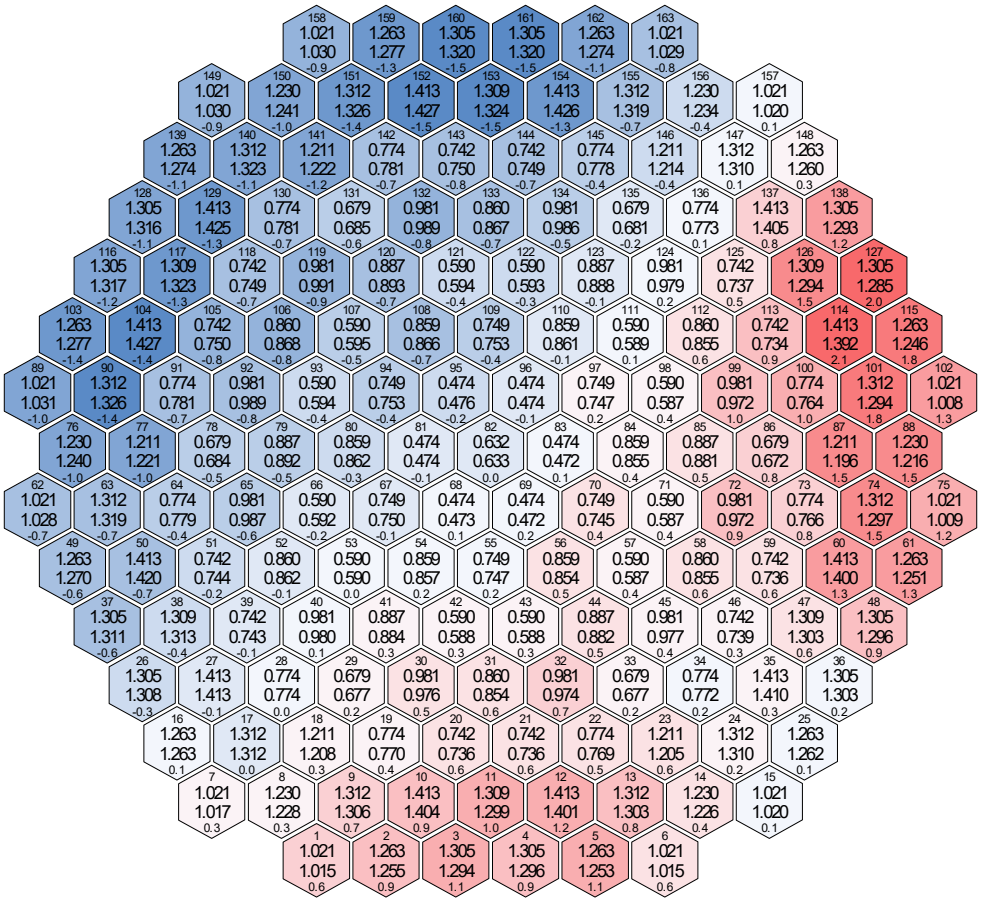
Deviation of individual calculations from the average

Serpent results uncertainty



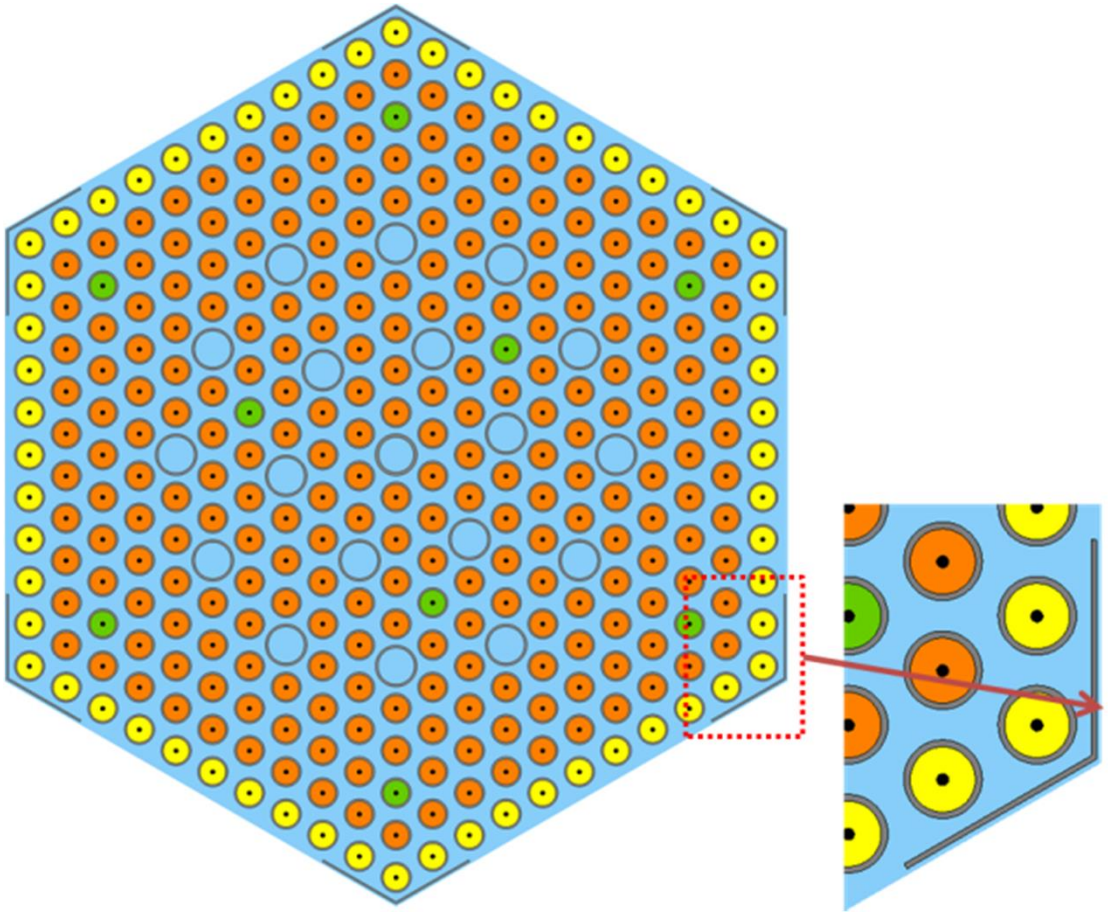
Deviation of 360° average from the 60° average

Serpent results with UFS



Deviation of single run UFS (double neutron histories to preserve running time) from the 60° average

XS for DYN3D



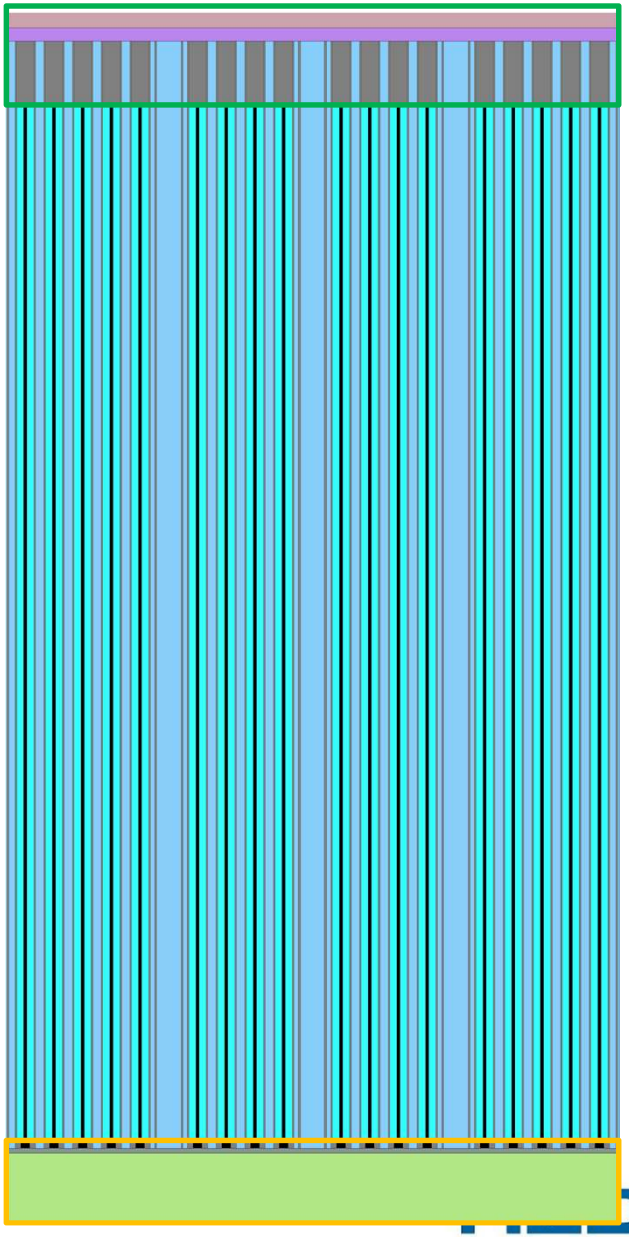
Fuel XS:

- single assembly in periodic BC
- transport-corrected (TRC) diffusion coefficient
- other XS from infinite spectrum INF_
- ADF from DF_SURF_DF

XS for DYN3D

Axial reflector XS:

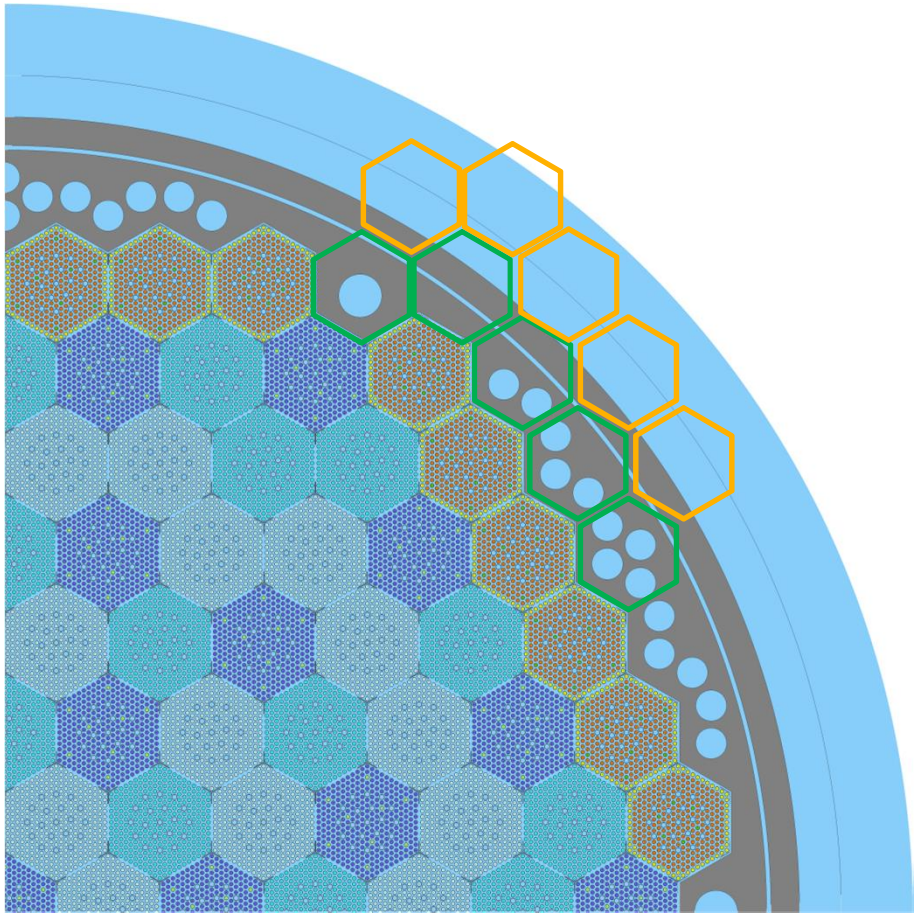
- single 3D fuel assembly in periodic boundaries
- transport-corrected (TRC) diffusion coefficient
- no axial ADF were used



XS for DYN3D

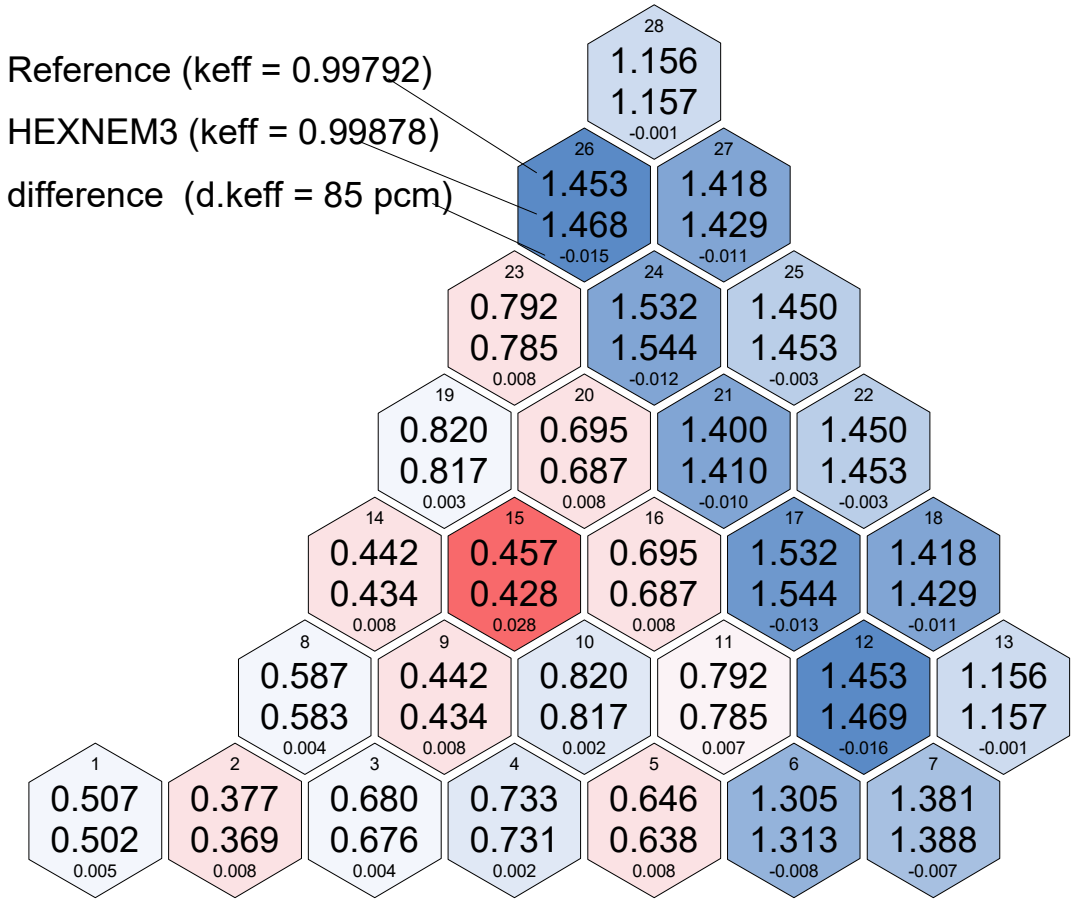
Radial reflector XS:

- reflector has 30° symmetry, 5 cells in first row and 5 cells in second row
- all reflector cells XS are calculated in single run ¼ of a core in reflective boundaries
- transport-corrected (TRC) diffusion coefficient
- ADF from DF_SURF_DF, side which faces fuel used for all 6 sides
- ADF for reflector are corrected by single-assembly fuel ADF $\widetilde{ADF}_R = ADF_R \frac{ADF_{SA}}{ADF_F}$



2D test model

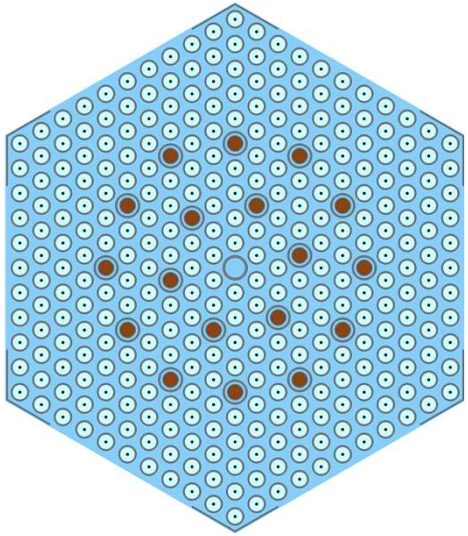
2D model with inserted CR

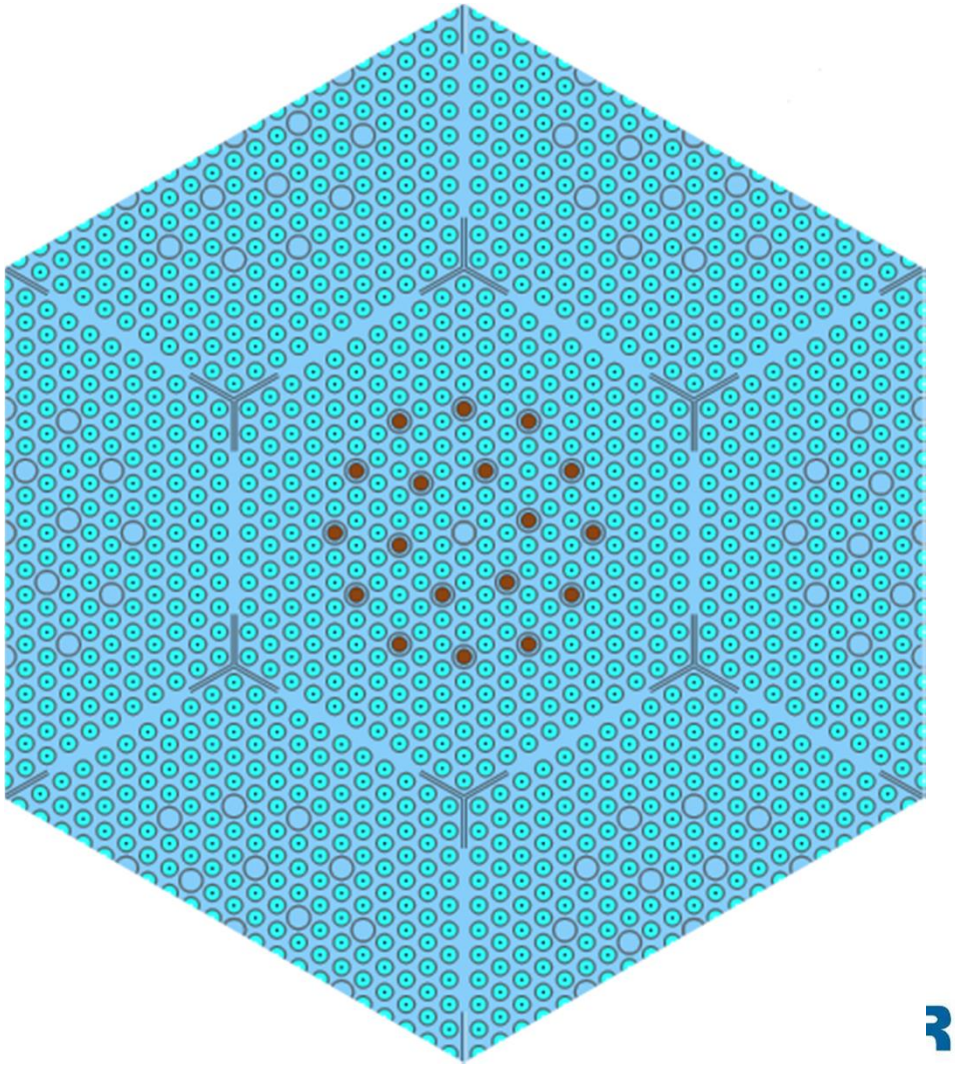


Deviation in the rodded assembly 2.8%

2D test model

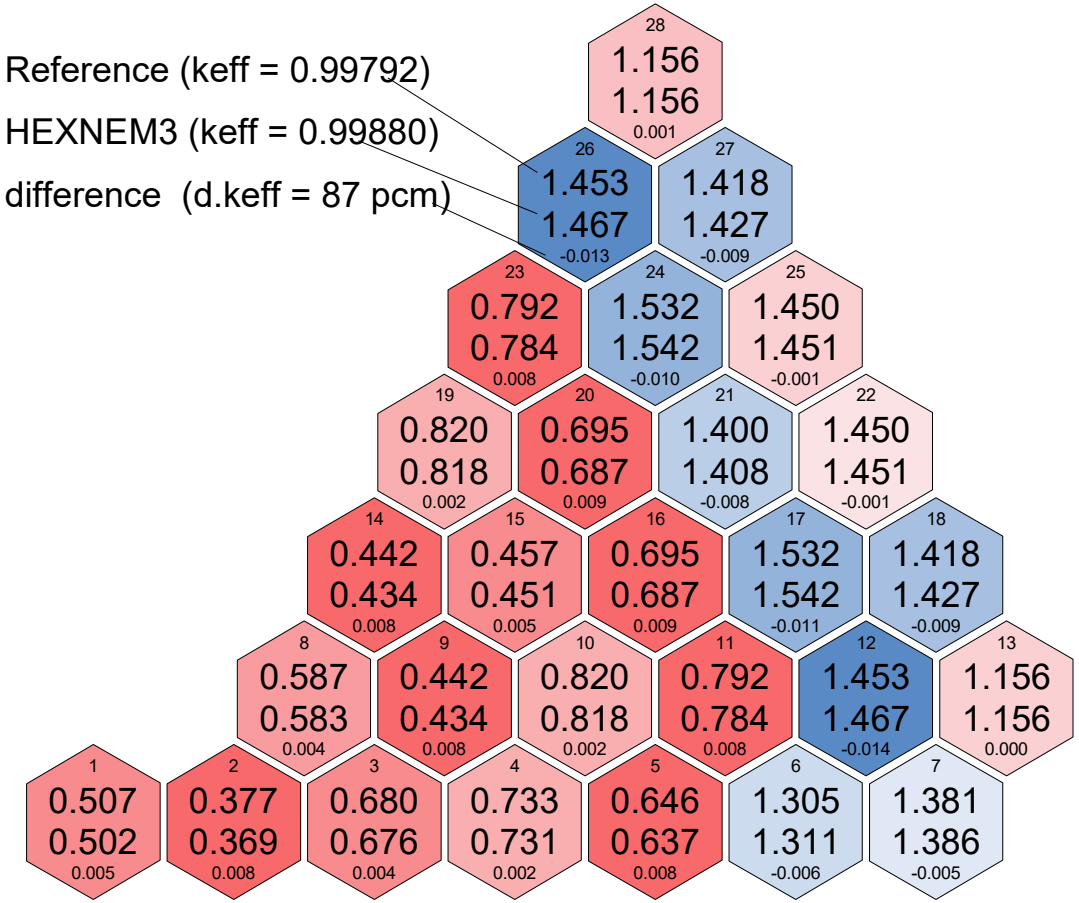
SA and colorset models of rodded assembly





2D test model

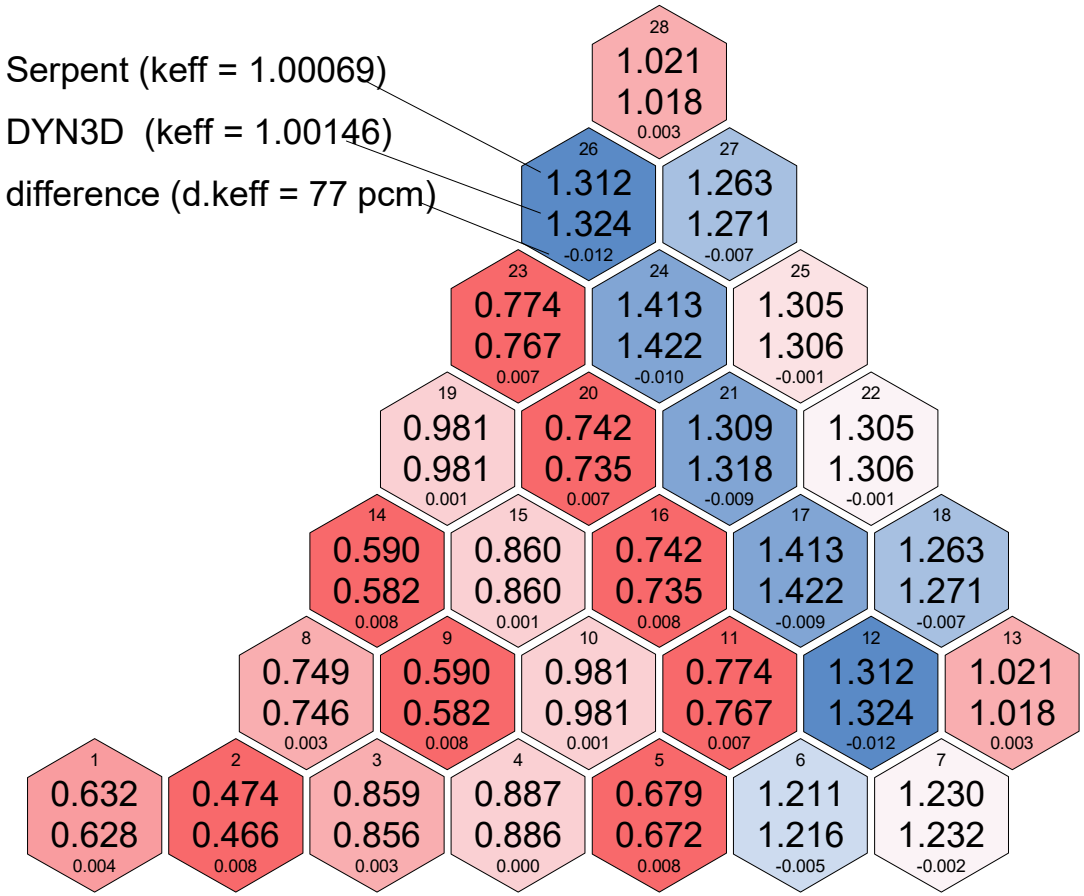
2D model with inserted CR



Deviation in the rodded assembly 0.5%

Serpent vs DYN3D 3D full core

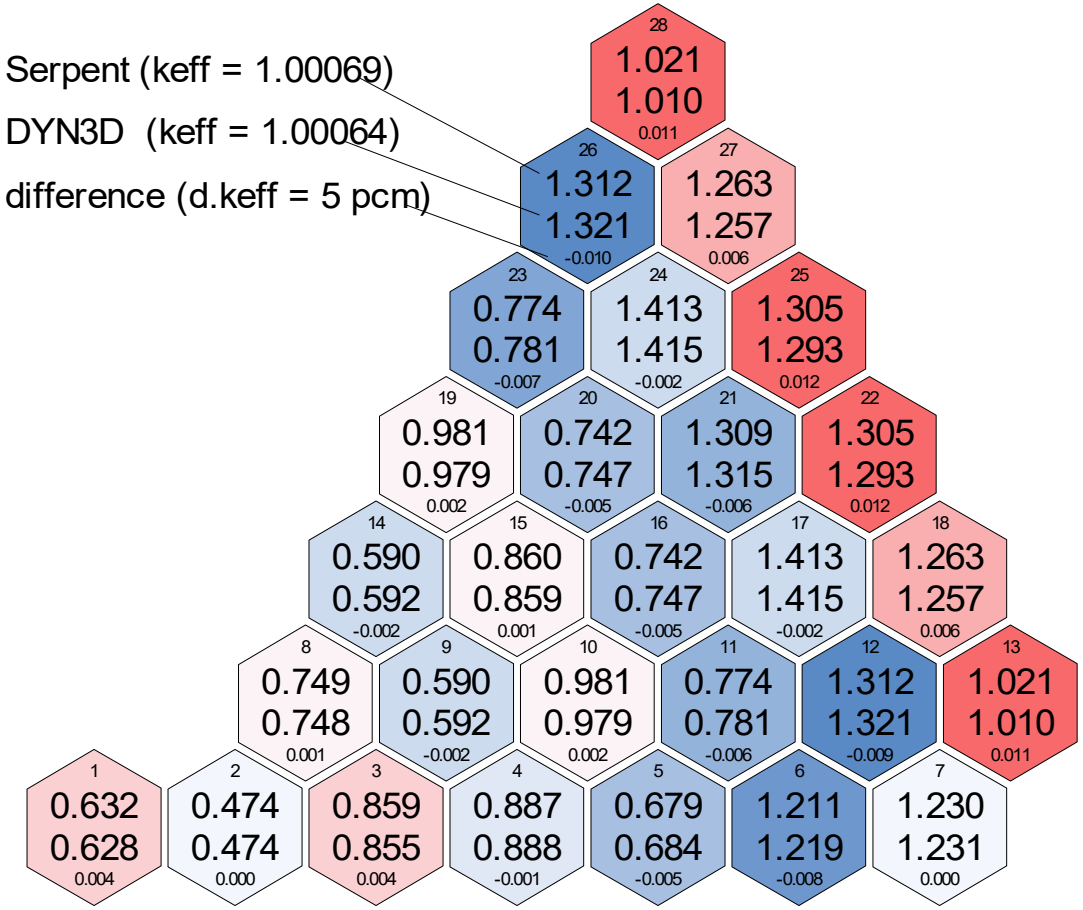
Preliminary results in 2G



Max deviation 1.2%, RMS = 0.7%

Serpent vs DYN3D

Preliminary results in 4G



Max deviation 1.2%, RMS = 0.6%

Summary

- Issues with Serpent full core modelling
  - Relatively high deviations on periphery, despite high flux
  - Slightly tilted power and fission source distribution
  - UFS does not help
  - Probably, problem is only relevant for cases without feedback
- Very satisfying agreement between Serpent and DYN3D
- Issues with XS
  - XS for rodded assembly in reflected single assembly fails
  - Serpent diffusion solver (for ADF) has problems in multi group
  - Proper critical spectrum correction might improve results
- Future work
  - refine baffle model and evaluate influence
  - Apply CMM for diffusion coefficients
  - compare DYN3D with Serpent (nodal and pin-wise)
  - solve full power and burnup exercises with coupled Serpent-TH

Thank you!