# Generation of pin level multi-dimensional XS tables with Serpent 2

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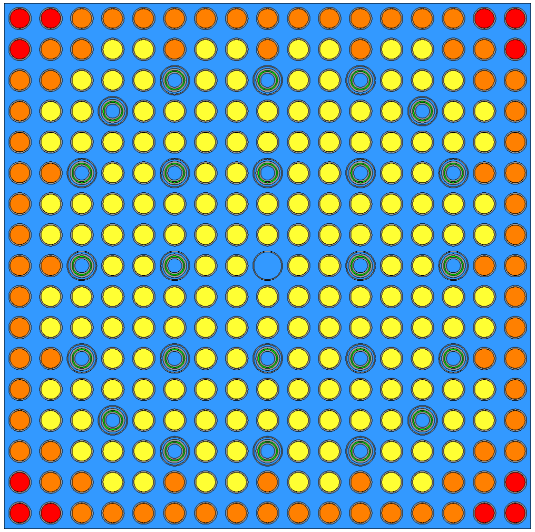
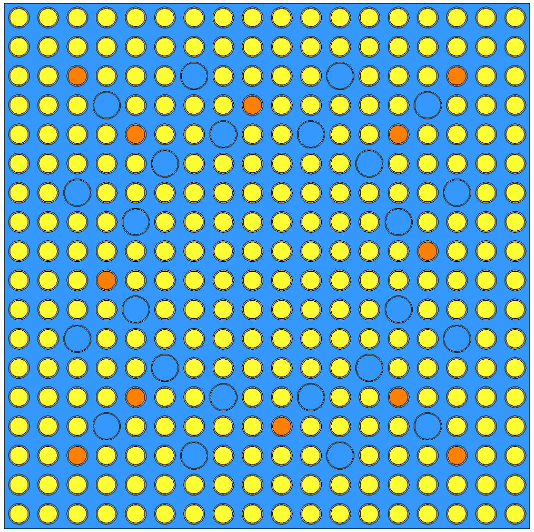
**Reactor Physics and Dynamic Group (RPD)**





# Agenda

- Pin power reconstruction
  - Using Serpent 2 for pin power reconstruction constant generation
  - Serpent 2 support in GenPMAXS
  - Selected verification cases
- Pin level cross section generation
  - General approach and pin level homogenization corrections
  - Serpent 2 support in createXSlib
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  - Impact on homogenization corrections on Serpent 2 performance
- Conclusions and outlook

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# Pin power reconstruction with Serpent 2

- Employing pin powers → cpd card

$$p_{pin,i} = \kappa \, \Sigma_f \, \overline{\Phi} \, f_i$$

- Employing group-wise form functions → new **ppw card**

$$p_{pin,i} = \sum_g \overline{\kappa} \, \overline{\Sigma_{fg}} \, \overline{\Phi_g} \, f_{g,i}$$

- PPW card syntax: set ppw <universe> <lattice>

# Serpent 2 support in GenPMAXS

- Verification cases to be done with U.S. NRC  reactor simulator PARCS v3.0
- GenPMAXS tool to generate PMAX-type multi-dimensional cross section tables for PARCS
- Extension of GenPMAXS to support Serpent 2 (based on partial Serpent 1 support)
- GenPMAXS Serpent 2 features:
  - general nodal few-group constants,
  - group-wise form functions,
  - reflector ADF and
  - 1D interface discontinuity factors
- Serpent 2 support should be available through U.S. NRC CAMP program starting with GenPMAXS v6.2 release

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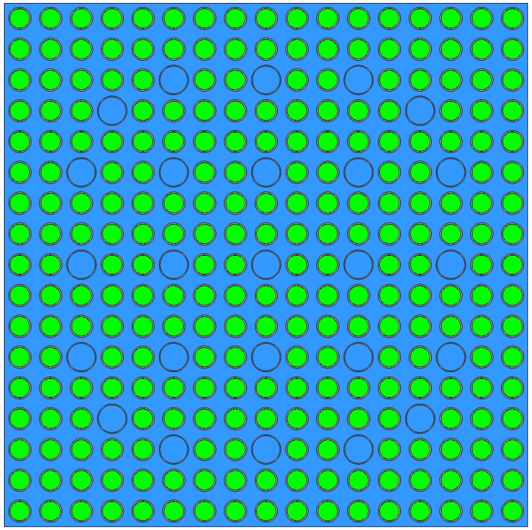
# Pin power reconstruction – HZP case 1 (1/3)

- Serpent 2: 100,000,000 histories in 500 active cycles
  2g cross sections (0.625 eV boundary)



UOX fuel assembly of PWR MOX/UOX benchmark

UOX 0.15 GWd/tU

| Code | $k_{inf}$ | Rel. Diff. [pcm] |
|---|---|---|
| Serpent 2 CE | 1.124230±0.00005 | - |
| PARCS 2g NEM | 1.1242304 | 0.04 |

# Pin power reconstruction – HZP case 1 (2/3)

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.0 | 2.2 | 0.4 | -0.5 | -0.7 | -0.9 | -1.0 | -1.0 | -0.9 | -1.0 | -1.0 | -0.7 | -0.8 | -0.5 | 0.3 | 2.2 | 9.9 |
| 2.3 | 0.9 | -0.2 | -0.5 | -1.2 | 1.0 | -1.5 | -1.3 | 0.9 | -1.3 | -1.3 | 1.1 | -1.2 | -0.5 | -0.1 | 0.8 | 2.1 |
| 0.3 | -0.1 | -0.8 | 1.2 | 0.6 | 0.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | 0.0 | 0.7 | 1.2 | -0.9 | -0.1 | 0.3 |
| -0.4 | -0.5 | 1.3 | 0.0 | 0.5 | 1.0 | -1.5 | -1.5 | 1.0 | -1.4 | -1.4 | 0.9 | 0.5 | 0.0 | 1.2 | -0.5 | -0.5 |
| -0.7 | -1.2 | 0.7 | 0.4 | -1.9 | 0.9 | -1.5 | -1.4 | 1.0 | -1.5 | -1.5 | 0.8 | -1.8 | 0.3 | 0.6 | -1.2 | -0.7 |
| -0.8 | 1.0 | 0.0 | 1.0 | 0.9 | 0.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | 0.0 | 0.8 | 0.9 | 0.0 | 0.9 | -0.8 |
| -0.9 | -1.3 | 0.9 | -1.5 | -1.5 | 1.0 | -1.5 | -1.4 | 1.1 | -1.3 | -1.5 | 1.0 | -1.6 | -1.5 | 1.0 | -1.4 | -0.9 |
| -1.0 | -1.3 | 1.1 | -1.4 | -1.5 | 1.0 | -1.3 | -1.4 | 1.1 | -1.3 | -1.4 | 1.0 | -1.5 | -1.5 | 1.0 | -1.4 | -0.9 |
| -0.8 | 0.9 | 0.0 | 1.0 | 1.0 | 0.0 | 1.1 | 1.1 | 0.0 | 1.0 | 1.1 | 0.0 | 1.0 | 0.9 | 0.0 | 1.1 | -0.8 |
| -1.0 | -1.3 | 1.0 | -1.4 | -1.4 | 0.9 | -1.3 | -1.4 | 1.1 | -1.3 | -1.4 | 1.0 | -1.5 | -1.5 | 1.0 | -1.3 | -1.0 |
| -1.0 | -1.3 | 0.9 | -1.4 | -1.4 | 0.9 | -1.5 | -1.4 | 1.0 | -1.4 | -1.4 | 0.9 | -1.5 | -1.5 | 1.0 | -1.3 | -1.1 |
| -0.8 | 0.9 | 0.0 | 1.0 | 0.9 | 0.0 | 0.8 | 1.1 | 0.0 | 1.0 | 0.9 | 0.0 | 0.9 | 1.0 | 0.0 | 1.0 | -0.8 |
| -0.7 | -1.2 | 0.7 | 0.4 | -1.8 | 0.9 | -1.5 | -1.4 | 1.0 | -1.4 | -1.5 | 0.9 | -1.8 | 0.5 | 0.5 | -1.1 | -0.7 |
| -0.4 | -0.4 | 1.2 | 0.0 | 0.5 | 1.0 | -1.4 | -1.5 | 1.0 | -1.4 | -1.6 | 0.9 | 0.4 | 0.0 | 1.2 | -0.6 | -0.4 |
| 0.3 | -0.1 | -0.8 | 1.2 | 0.7 | 0.0 | 1.0 | 1.0 | 0.0 | 1.1 | 1.1 | 0.0 | 0.6 | 1.2 | -0.8 | -0.1 | 0.4 |
| 2.3 | 0.9 | -0.1 | -0.5 | -1.1 | 1.0 | -1.3 | -1.2 | 1.0 | -1.3 | -1.3 | 1.0 | -1.1 | -0.5 | -0.1 | 0.9 | 2.2 |
| 10.0 | 2.3 | 0.3 | -0.5 | -0.8 | -0.7 | -1.0 | -1.0 | -0.8 | -0.9 | -0.9 | -0.8 | -0.6 | -0.5 | 0.3 | 2.3 | 10.0 |

Relative pin power errors PARCS vs. Serpent 2 in per cent

PARCS pin power reconstruction relationship for pin cell i:

$$p_{pin,i} = \sum_g \overline{\kappa}\, \overline{\Sigma_{fg}}\, \underbrace{\overline{\Phi_g}\, f_{g,i}}_{\Phi_{g,i}}$$

Serpent 2 pin power relationship for pin cell i:

$$p_{pin,i} = \sum_g \kappa_i\, \Sigma_{fg,i}\, \Phi_{g,i}$$
$$= \kappa_i\, \Sigma_{f,i}\, \Phi_i$$

# Pin power reconstruction – HZP case 1 (3/3)

Karlsruher Institut für Technologie

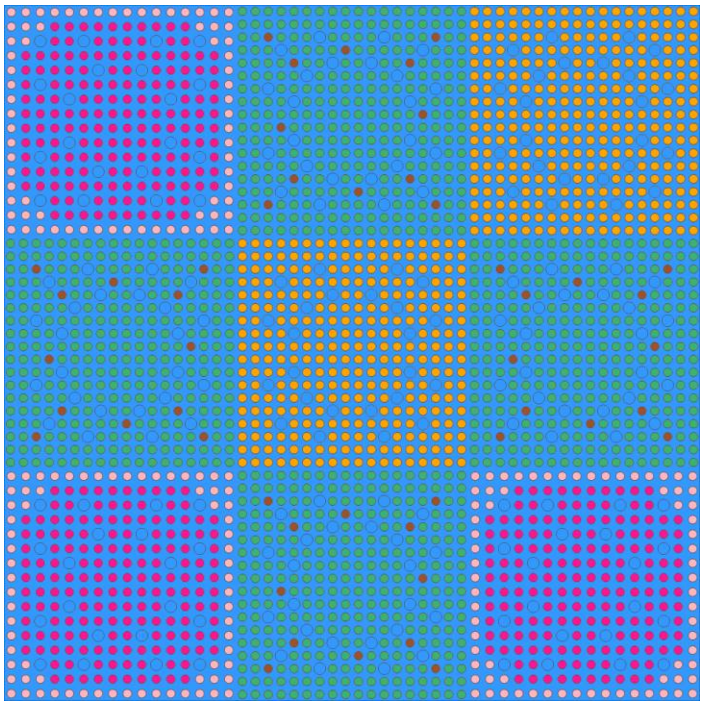
| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.53 | 1.52 | 0.52 | -0.07 | -0.25 | -0.38 | -0.51 | -0.48 | -0.54 | -0.49 | -0.53 | -0.20 | -0.30 | -0.03 | 0.43 | 1.37 | 5.39 |
| 1.49 | 0.78 | 0.12 | 0.00 | -0.55 | 0.54 | -0.90 | -0.65 | 0.52 | -0.66 | -0.73 | 0.74 | -0.43 | -0.18 | 0.12 | 0.73 | 1.35 |
| 0.42 | 0.25 | -0.21 | 0.83 | 0.36 | 0.00 | 0.60 | 0.40 | 0.00 | 0.52 | 0.54 | 0.00 | 0.48 | 0.74 | -0.25 | 0.24 | 0.49 |
| 0.06 | -0.10 | 0.84 | 0.00 | 0.31 | 0.52 | -0.89 | -0.95 | 0.38 | -0.95 | -0.87 | 0.41 | 0.25 | 0.00 | 0.80 | -0.10 | -0.04 |
| -0.21 | -0.43 | 0.47 | 0.12 | -1.07 | 0.33 | -1.00 | -0.86 | 0.27 | -1.05 | -1.09 | 0.40 | -1.02 | 0.07 | 0.34 | -0.55 | -0.15 |
| -0.26 | 0.68 | 0.00 | 0.45 | 0.34 | 0.00 | 0.31 | 0.20 | 0.00 | 0.25 | 0.29 | 0.00 | 0.26 | 0.39 | 0.00 | 0.55 | -0.30 |
| -0.40 | -0.48 | 0.33 | -0.93 | -1.05 | 0.24 | -1.07 | -1.15 | 0.20 | -1.03 | -1.18 | 0.31 | -1.09 | -0.88 | 0.46 | -0.82 | -0.41 |
| -0.41 | -0.68 | 0.59 | -0.88 | -1.03 | 0.23 | -0.92 | -1.12 | 0.22 | -1.03 | -1.05 | 0.14 | -1.01 | -0.95 | 0.47 | -0.87 | -0.38 |
| -0.31 | 0.52 | 0.00 | 0.36 | 0.38 | 0.00 | 0.20 | 0.13 | 0.00 | 0.19 | 0.30 | 0.00 | 0.19 | 0.26 | 0.00 | 0.58 | -0.51 |
| -0.46 | -0.69 | 0.47 | -0.83 | -0.88 | 0.21 | -1.10 | -1.11 | 0.26 | -1.07 | -1.09 | 0.25 | -1.08 | -0.93 | 0.44 | -0.70 | -0.53 |
| -0.43 | -0.57 | 0.47 | -0.83 | -0.83 | 0.23 | -0.99 | -1.01 | 0.17 | -1.07 | -1.08 | 0.24 | -1.00 | -0.82 | 0.53 | -0.72 | -0.65 |
| -0.33 | 0.39 | 0.00 | 0.58 | 0.45 | 0.00 | 0.18 | 0.38 | 0.00 | 0.27 | 0.26 | 0.00 | 0.35 | 0.56 | 0.00 | 0.62 | -0.31 |
| -0.18 | -0.49 | 0.48 | 0.20 | -1.04 | 0.42 | -0.91 | -0.99 | 0.42 | -0.93 | -0.97 | 0.36 | -1.08 | 0.31 | 0.38 | -0.49 | -0.22 |
| 0.06 | 0.03 | 0.87 | 0.00 | 0.44 | 0.51 | -0.82 | -0.82 | 0.51 | -0.86 | -0.99 | 0.37 | 0.27 | 0.00 | 0.84 | -0.14 | 0.03 |
| 0.51 | 0.23 | -0.17 | 0.85 | 0.53 | 0.00 | 0.54 | 0.52 | 0.00 | 0.54 | 0.57 | 0.00 | 0.43 | 0.73 | -0.18 | 0.19 | 0.51 |
| 1.54 | 0.78 | 0.18 | 0.02 | -0.39 | 0.67 | -0.65 | -0.56 | 0.51 | -0.66 | -0.58 | 0.64 | -0.45 | -0.06 | 0.22 | 0.80 | 1.46 |
| 5.62 | 1.58 | 0.45 | 0.03 | -0.31 | -0.26 | -0.48 | -0.49 | -0.30 | -0.43 | -0.31 | -0.35 | -0.14 | -0.06 | 0.40 | 1.51 | 5.52 |

Relative pin power errors Serpent 2 PPR
vs. Serpent 2 in per cent

# Pin power reconstruction – HZP case 2 (1/3)

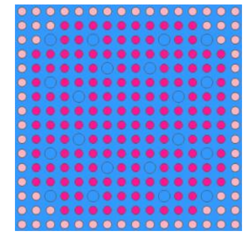
*reflective*

*reflective*

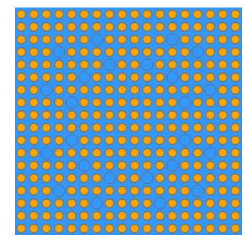


*reflective*

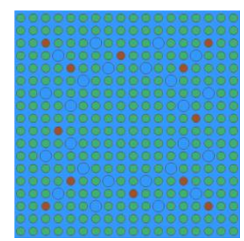
*reflective*



MOX, 0.0 GWd/tU
1.45 wt%
up to 2 wt% Pu



UOX, 0.0 GWd/tU
1.8 wt%



UOX, 0.0 GWd/tU
2.0 wt%
including Gd
poisoned rods

Fuel assemblies design based on AREVA fuel for KONVOI PWR

# Pin power reconstruction – HZP case 2 (2/3)

- Serpent 2: 2E+9 histories in 500 active cycles
  2g cross sections (0.625 eV boundary)

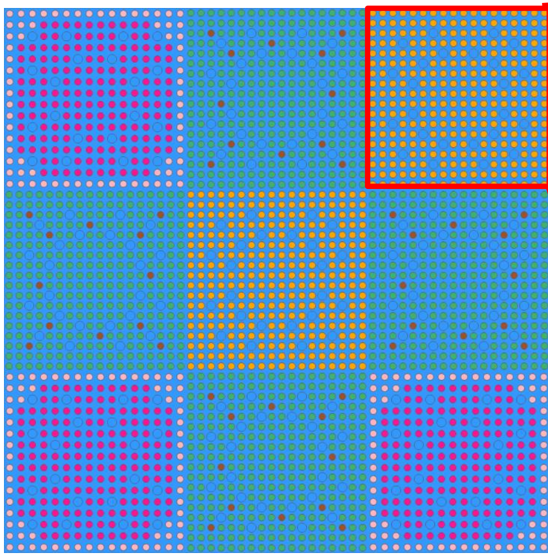
| Code | $k_{inf}$ | Rel. Diff. [pcm] |
|---|---|---|
| Serpent 2 CE | 0.961211±0.00003 | - |
| PARCS 2g NEM | 0.960741 | 47.0 |

Serpent 2 CE
*PARCS 2g*
**Rel. Diff. [%]**

| | | |
|---|---|---|
| 1.5441<br>*1.5386*<br>**-0.36** | 0.5843<br>*0.5904*<br>**1.04** | 0.4224<br>*0.4326*<br>**2.41** |
| 0.8849<br>*0.8845*<br>**-0.04** | 0.7056<br>*0.7123*<br>**0.96** | 0.5845<br>*0.5904*<br>**1.01** |
| 1.8449<br>*1.8281*<br>**-0.91** | 0.8848<br>*0.8845*<br>**-0.04** | 1.5445<br>*1.5386*<br>**-0.38** |

Normalized nodal powers as predicted by Serpent 2 and PARCS

# Pin power reconstruction – HZP case 2 (3/3)



| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23.27 | 6.91 | 6.89 | 5.59 | 4.62 | 3.60 | 2.70 | 3.06 | 3.66 | 3.66 | 3.36 | 2.90 | 3.39 | 4.93 | 5.62 | 6.53 | 6.60 | 6.15 |
| 6.92 | 6.95 | 5.74 | 4.64 | 4.22 | 2.31 | 0.37 | 2.08 | 3.63 | 3.43 | 2.12 | 0.63 | 2.23 | 4.00 | 5.04 | 6.10 | 6.71 | 6.87 |
| 7.62 | 6.48 | 4.07 | 1.43 | 2.10 | -0.40 | 0.00 | -0.63 | 1.91 | 2.29 | -0.42 | 0.00 | 0.44 | 1.86 | 1.55 | 4.36 | 6.12 | 6.64 |
| 6.83 | 5.25 | 1.63 | 0.00 | -0.73 | -0.80 | -2.42 | -1.95 | 0.91 | 0.68 | -1.74 | -2.29 | -0.04 | -0.59 | 0.00 | 1.72 | 5.09 | 6.42 |
| 5.71 | 4.63 | 2.12 | -0.67 | -0.51 | -2.41 | -2.86 | 0.00 | -0.76 | -1.01 | 0.00 | -2.75 | -2.19 | -0.33 | -0.37 | 2.64 | 4.72 | 5.83 |
| 4.32 | 2.70 | -0.05 | -0.58 | -2.07 | 0.00 | -2.04 | -0.77 | 1.51 | 1.20 | -0.75 | -1.80 | 0.00 | -2.12 | 0.09 | 0.56 | 3.51 | 5.02 |
| 3.41 | 1.02 | 0.00 | -2.39 | -2.74 | -2.33 | 0.98 | 2.97 | 3.83 | 3.78 | 2.71 | 1.35 | -2.04 | -2.29 | -1.80 | 0.00 | 1.91 | 4.84 |
| 3.92 | 2.56 | -0.43 | -2.00 | 0.00 | -1.17 | 2.42 | 4.04 | 5.22 | 5.13 | 4.47 | 2.76 | -0.85 | 0.00 | -1.40 | 0.52 | 3.60 | 5.15 |
| 4.14 | 3.48 | 1.82 | 0.54 | -1.16 | 1.41 | 3.47 | 5.04 | 5.72 | 6.21 | 5.18 | 3.80 | 1.87 | -0.59 | 1.22 | 3.32 | 4.93 | 5.95 |
| 3.80 | 3.44 | 2.07 | 0.28 | -1.13 | 1.21 | 3.70 | 5.15 | 5.88 | 5.58 | 5.02 | 3.76 | 1.66 | -0.32 | 1.80 | 3.83 | 5.16 | 6.30 |
| 3.16 | 2.07 | -0.57 | -2.22 | 0.00 | -1.23 | 2.26 | 4.29 | 4.69 | 5.01 | 4.44 | 3.04 | -0.59 | 0.00 | 0.05 | 2.81 | 4.52 | 5.71 |
| 2.84 | 0.25 | 0.00 | -2.68 | -3.10 | -2.32 | 0.42 | 2.45 | 3.45 | 3.83 | 2.83 | 1.32 | -1.87 | -2.45 | -0.10 | 0.00 | 3.32 | 5.25 |
| 3.44 | 2.45 | -0.68 | -0.83 | -2.65 | 0.00 | -2.67 | -0.98 | 1.18 | 1.37 | -1.13 | -2.04 | 0.00 | -2.11 | -1.99 | -0.05 | 1.34 | 4.62 |
| 5.00 | 3.79 | 1.12 | -1.24 | -0.88 | -2.45 | -3.24 | 0.00 | -1.16 | -1.17 | 0.00 | -3.16 | -2.42 | -1.40 | -2.21 | -0.71 | 2.80 | 5.11 |
| 6.25 | 4.60 | 1.08 | 0.00 | -1.15 | -0.85 | -2.56 | -1.78 | 0.65 | 0.53 | -2.13 | -2.78 | -0.66 | -1.36 | 0.00 | 0.80 | 4.06 | 5.55 |
| 7.06 | 5.88 | 3.98 | 1.17 | 1.65 | -0.25 | 0.00 | -0.55 | 2.18 | 2.38 | -0.54 | 0.00 | -0.29 | 1.16 | 1.13 | 3.62 | 5.51 | 6.79 |
| 6.62 | 6.68 | 5.51 | 4.81 | 4.02 | 2.59 | 0.91 | 2.73 | 3.77 | 3.81 | 2.77 | 0.75 | 3.02 | 4.06 | 4.63 | 5.76 | 6.73 | 7.31 |
| 23.87 | 6.75 | 6.33 | 5.78 | 5.18 | 4.63 | 3.62 | 4.18 | 4.64 | 4.69 | 4.32 | 3.96 | 4.15 | 5.02 | 6.06 | 6.38 | 7.16 | 7.45 |

Relative pin power errors PARCS vs. Serpent 2 in per cent

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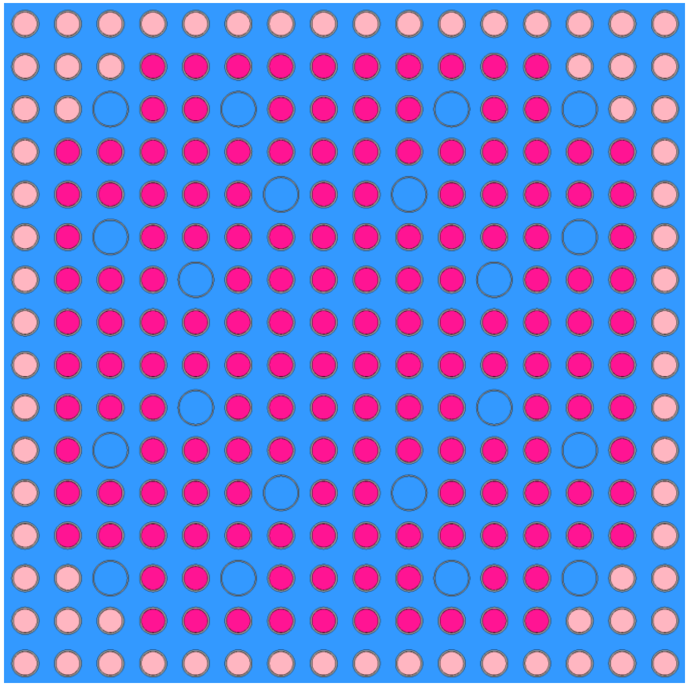
# General pin level cross section generation approach



16x16-20 MOX
0.0 GWd/tU

- Infinite lattice calculations per pin cell type
- Few-group constants per pin cell type generated based on finite lattice calculation for fuel assembly
  *(standard method)*
- Few-group constants per pin cell type and position generated based on finite lattice calculation for fuel assembly
- Few-group constants per pin cell type and position generated together with homogenization corrections based on finite lattice calculation for fuel assembly

Pin level XS in Serpent 2 have issue with kinetics parameters

Production XS libraries with critical spectrum correction

# Super-homogenization factors

- in case of zero currents across cell boundaries, SPH factors are the inverse of an ADF/CDF

- SPH factors are defined as for diffusion

$$\mu = \frac{\overline{\Phi}_{het}}{\overline{\Phi}_{hom}}$$

- They have to be obtained by an iterative procedure using the lower order formulation of the homogeneous system (DYN3D, COBAYA3k), based on the following expressions

$$\tilde{\Sigma} = \mu \, \Sigma$$
$$\tilde{\Sigma} \, \overline{\Phi}_{hom} = \Sigma \, \overline{\Phi}_{het}$$

# GET interface discontinuity factors

- GET discontinuity factors are defined as ratio of average heterogeneous and homogeneous neutron fluxes on each surface S of a node for diffusion

$$f_{GET}^{S} = \frac{\phi_S^{het}}{\phi_S^{hom}}$$

- Heterogeneous neutron surface fluxes can be obtained from lattice calculation

- The method of obtaining the homogeneous surface fluxes depends on and has to be consistent with spatial discretization of reactor simulator used

# BBH interface discontinuity factors

- BBH discontinuity factors are defined to preserve surface averaged partial currents

- Factors are applied to surface averaged partial currents, only for diffusion as the low order operator BBH factors can also be formulated in terms of surface fluxes

- BBH factors are of the generic form for diffusion:

$$f_{BBH}^{s} = 2\,\frac{J_{-s}^{het} + J_{+s}^{het}}{\phi_s^{hom}}$$

- The method of obtaining the partial currents depends on and has to be consistent with spatial discretization of reactor simulator used

# COBAYA3k: Interface discontinuity factors

- COBAYA3k employs FMFD method, an exact formula to compute GET IDF can be derived

$$f = \frac{\bar{\Phi}^s{}_{het}}{\bar{\Phi}^s{}_{hom}} = \frac{\bar{\Phi}^s{}_{het}}{\bar{\Phi}_{het} - \frac{J_{het}\, h}{2\, D}}$$

- The corresponding exact formula for flux discontinuity factor form of the BBH IDF

$$f = 2\, \frac{J^+{}_{het} + J^-{}_{het}}{\bar{\Phi}_{het} - \frac{J_{het}\, h}{2\, D}}$$

# DYN3D: Interface discontinuity factors

- Surface fluxes are **NOT** part of a **NEM solution**
- Expression for the transverse integrated, average neutron flux in direction u

$$\Phi_g{}^i(u) = \sum_{k=0}^{2} c_{g,k}{}^{i,u}\, h_k\left(\frac{u}{a_u}\right) + d_{g,+u}{}^i\, e^{B\,u} + d_{g,-u}{}^i\, e^{-B\,u}$$

with node index i, polynomial basis $h_k$ and node length in direction u $a_u$.

- Tranverse integrated diffusion equation:

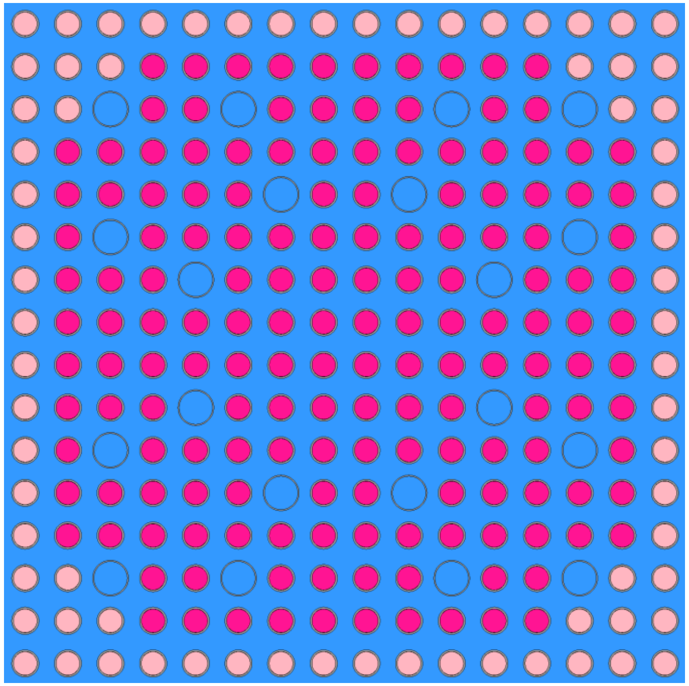
$$-D_g{}^i\ \frac{d^2}{du^2}\Phi_g{}^i(u) + \Sigma_R{}^i\Phi_g{}^i(u) = S_g(u) - L_g{}^{het}(u)$$

- Boundary conditions:

$$J_g{}^{het,s} = -D_g{}^i\frac{d}{du}\Phi_g{}^i(u)\,|\,u = u_s$$

$$\bar{\Phi}_{g,het} = c_{g,0}{}^{i,u} + \frac{2}{B\cdot a}\ \sinh\left(B\ \cdot\frac{a}{2}\right)\left(d_{g,+u}{}^i + d_{g,-u}{}^i\right)$$

# Pin level homogenization corrections with Serpent 2



16x16-20 MOX
0.0 GWd/tU

- SPH factors:
  pin cell average fluxes from group constant generation
- GET and BBH IDF:
  net pin cell surface currents, pin cell surface fluxes, pin cell average fluxes and pin cell surface partial currents
  → ADF card
- System of Python scripts to translate Serpent models for nodal XS into different classes of pin level XS models

**Adapted ADF card:**

set adf <universe> <bc_west> <bc_south> <bc_east> <bc_north>

# Serpent 2 support in createXSlib

- Verification cases to be done with reactor simulators DYN3D and COBAYA3k

- createXSlib is KIT INR inhouse tool to generate multi-dimensional NEMTAB cross sections tables for DYN3D and COBAYA3‘s solvers COBAYA3k and ANDES

- createXSlib Serpent 2 features:
  - General nodal and pin-by-pin few-group constants
  - Reflector ADF
  - GET and BBH IDF
  - SPH factors (DYN3D only)

# Agenda

- Pin power reconstruction
  - Using Serpent 2 for pin power reconstruction constant generation
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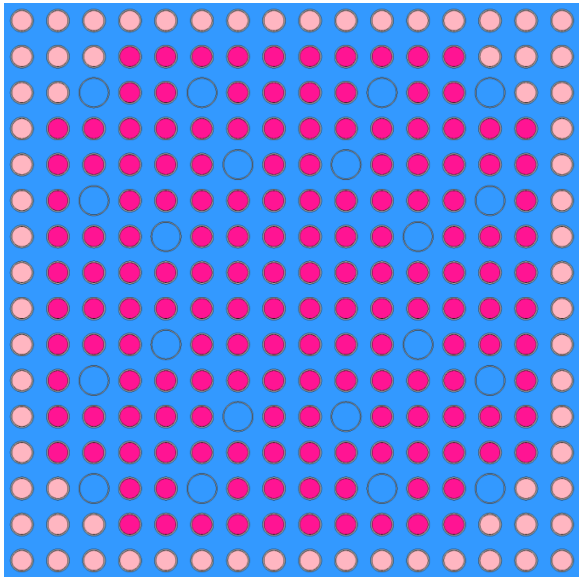
# Assessment of different pin level XS generation methods (1/3)

- Serpent 2: 2E+9 histories in 500 active cycles
  2g cross sections (0.625 eV boundary)

- Serpent 2 output translated with createXSlib, achievable accuracy tested with DYN3D and COBAYA3k

- XS tables generated per pin type (3M),
  per pin type and position (32M),
  per pin type and position with IDF (IDF) and
  per pin type and position with SPH (SPH)



16x16-20 MOX
0.0 GWd/tU

MOX fuel assembly for AREVA KONVOI PWR

# Assessment of different pin level XS generation methods (2/3)

| | MOX FA $k_{inf}$ | Rel. Diff. Eigenvalue [pcm] | Max. Rel. pin power error [%] |
|---|---|---|---|
| Serpent 2 CE | 1.08496±0.000030 | - | - |
| DYN3D diff (3M) | 1.087627 | 266.7 | 1.22 |
| DYN3D sp3 (3M) | 1.086733 | 177.3 | 1.50 |
| COBAYA3k diff (3M) | 1.084761 | 19.9 | 1.45 |
| DYN3D diff (32M) | 1.087578 | 261.8 | 0.49 |
| DYN3D sp3 (32M) | 1.086685 | 172.5 | 0.28 |
| COBAYA3k diff (32M) | 1.084710 | 25.0 | 0.60 |
| DYN3D diff (IDF) | 1.084950 | 1.0 | 0.05 |
| DYN3D diff (SPH) | 1.084951 | 0.9 | 0.01 |
| COBAYA3k diff (IDF) | 1.084950 | 1.0 | 0.02 |

Statistical uncertainty pin power below 0.04%

# Assessment of different pin level XS generation methods (3/3)

Karlsruher Institut für Technologie

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.098 | -0.143 | -0.264 | -0.091 | -0.031 | -0.127 | 0.126 | 0.426 | 0.291 | 0.225 | -0.079 | -0.042 | -0.170 | -0.333 | -0.260 | -0.093 |
| -0.245 | -0.422 | -0.888 | 0.083 | 0.210 | -0.182 | 0.532 | 0.830 | 0.813 | 0.426 | -0.213 | 0.278 | 0.070 | -0.931 | -0.484 | -0.193 |
| -0.339 | -0.941 | 0.000 | -0.481 | -0.478 | 0.000 | -0.223 | 0.520 | 0.486 | -0.307 | 0.000 | -0.418 | -0.553 | 0.000 | -0.904 | -0.398 |
| -0.133 | 0.104 | -0.486 | 0.032 | 0.025 | -0.630 | -0.516 | 0.276 | 0.229 | -0.512 | -0.522 | 0.003 | 0.090 | -0.532 | 0.168 | -0.126 |
| 0.004 | 0.243 | -0.436 | 0.098 | 0.036 | -0.502 | 0.000 | -0.280 | -0.425 | 0.000 | -0.576 | -0.018 | 0.052 | -0.431 | 0.171 | 0.017 |
| -0.115 | -0.196 | 0.000 | -0.550 | -0.457 | -0.053 | -0.144 | 0.508 | 0.568 | -0.205 | 0.000 | -0.565 | -0.560 | 0.000 | -0.216 | -0.027 |
| 0.167 | 0.438 | -0.282 | -0.424 | 0.000 | -0.076 | 0.678 | 1.036 | 1.127 | 0.590 | -0.110 | 0.000 | -0.393 | -0.295 | 0.478 | 0.124 |
| 0.438 | 0.875 | 0.569 | 0.238 | -0.283 | 0.531 | 1.113 | 1.448 | 1.500 | 1.075 | 0.490 | -0.296 | 0.296 | 0.571 | 0.739 | 0.322 |
| 0.311 | 0.921 | 0.537 | 0.226 | -0.349 | 0.472 | 1.128 | 1.342 | 1.381 | 1.062 | 0.527 | -0.364 | 0.276 | 0.598 | 0.926 | 0.281 |
| 0.160 | 0.446 | -0.289 | -0.447 | 0.000 | -0.052 | 0.624 | 1.093 | 1.056 | 0.657 | -0.115 | 0.000 | -0.509 | -0.382 | 0.598 | 0.151 |
| -0.076 | -0.084 | 0.000 | -0.566 | -0.533 | -0.097 | -0.180 | 0.430 | 0.577 | -0.166 | -0.090 | -0.536 | -0.512 | 0.000 | -0.181 | -0.102 |
| 0.012 | 0.169 | -0.484 | -0.011 | -0.114 | -0.479 | 0.000 | -0.364 | -0.329 | 0.000 | -0.566 | -0.003 | 0.022 | -0.459 | 0.238 | 0.076 |
| -0.165 | 0.145 | -0.475 | -0.003 | -0.021 | -0.565 | -0.479 | 0.201 | 0.226 | -0.356 | -0.503 | 0.003 | 0.034 | -0.517 | 0.195 | -0.172 |
| -0.369 | -0.869 | 0.000 | -0.419 | -0.566 | 0.000 | -0.220 | 0.520 | 0.520 | -0.319 | 0.000 | -0.527 | -0.477 | 0.000 | -0.935 | -0.419 |
| -0.152 | -0.453 | -0.938 | 0.099 | 0.233 | -0.130 | 0.382 | 0.799 | 0.822 | 0.505 | -0.143 | 0.204 | 0.107 | -0.848 | -0.427 | -0.149 |
| 0.017 | -0.143 | -0.315 | -0.079 | 0.049 | 0.015 | 0.111 | 0.315 | 0.399 | 0.146 | -0.167 | -0.093 | -0.111 | -0.282 | -0.203 | -0.073 |

Relative pin power errors DYN3D sp3 (3M) vs. Serpent 2 in per cent

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.129 | -0.156 | -0.221 | -0.087 | -0.127 | -0.229 | -0.192 | -0.211 | -0.166 | -0.172 | -0.228 | -0.172 | -0.107 | -0.179 | -0.081 | -0.123 |
| -0.127 | -0.113 | -0.282 | 0.155 | 0.153 | -0.016 | 0.078 | 0.064 | 0.143 | 0.092 | -0.002 | 0.164 | 0.182 | -0.184 | -0.039 | -0.092 |
| -0.206 | -0.244 | 0.000 | -0.081 | -0.042 | 0.000 | -0.079 | 0.054 | 0.051 | -0.023 | 0.000 | -0.008 | -0.003 | 0.000 | -0.225 | -0.173 |
| -0.125 | 0.208 | -0.059 | 0.122 | 0.129 | 0.059 | -0.033 | 0.129 | 0.128 | 0.023 | 0.056 | 0.158 | 0.165 | -0.005 | 0.209 | -0.050 |
| -0.133 | 0.126 | -0.012 | 0.158 | 0.025 | 0.005 | 0.000 | -0.046 | -0.036 | 0.000 | -0.024 | 0.025 | 0.161 | 0.010 | 0.154 | -0.122 |
| -0.259 | -0.024 | 0.000 | 0.065 | -0.003 | 0.150 | -0.020 | 0.102 | 0.091 | 0.051 | 0.136 | 0.008 | 0.064 | 0.000 | 0.021 | -0.257 |
| -0.233 | 0.040 | -0.041 | 0.054 | 0.000 | 0.001 | -0.033 | 0.063 | 0.112 | -0.079 | 0.057 | 0.000 | 0.028 | -0.079 | 0.129 | -0.160 |
| -0.220 | 0.080 | 0.060 | 0.134 | -0.049 | 0.095 | 0.090 | 0.095 | 0.015 | 0.061 | 0.157 | -0.033 | 0.145 | 0.038 | 0.141 | -0.129 |
| -0.168 | 0.111 | 0.041 | 0.133 | -0.004 | 0.105 | 0.067 | 0.058 | 0.009 | 0.068 | 0.113 | -0.005 | 0.149 | 0.048 | 0.138 | -0.158 |
| -0.147 | 0.134 | -0.041 | 0.045 | 0.000 | 0.022 | -0.002 | 0.079 | 0.066 | -0.018 | 0.003 | 0.000 | 0.056 | -0.062 | 0.165 | -0.198 |
| -0.218 | 0.000 | 0.000 | 0.061 | 0.040 | 0.169 | -0.022 | 0.095 | 0.134 | 0.000 | 0.123 | -0.017 | 0.067 | 0.000 | 0.019 | -0.216 |
| -0.140 | 0.130 | -0.050 | 0.188 | 0.085 | 0.028 | 0.000 | -0.007 | -0.002 | 0.000 | -0.009 | 0.023 | 0.121 | -0.004 | 0.132 | -0.187 |
| -0.111 | 0.186 | -0.064 | 0.136 | 0.171 | 0.080 | 0.104 | 0.160 | 0.165 | 0.023 | 0.044 | 0.207 | 0.157 | 0.004 | 0.199 | -0.118 |
| -0.202 | -0.205 | 0.000 | -0.020 | 0.014 | 0.000 | -0.033 | 0.050 | 0.092 | -0.042 | 0.000 | 0.017 | -0.013 | 0.000 | -0.238 | -0.168 |
| -0.106 | -0.093 | -0.211 | 0.236 | 0.173 | 0.042 | 0.140 | 0.105 | 0.139 | 0.142 | 0.033 | 0.142 | 0.213 | -0.223 | -0.070 | -0.053 |
| -0.138 | -0.112 | -0.176 | -0.075 | -0.098 | -0.153 | -0.156 | -0.119 | -0.117 | -0.122 | -0.222 | -0.149 | -0.121 | -0.220 | -0.105 | -0.071 |

Relative pin power errors DYN3D sp3 (32M) vs. Serpent 2 in per cent

# Agenda

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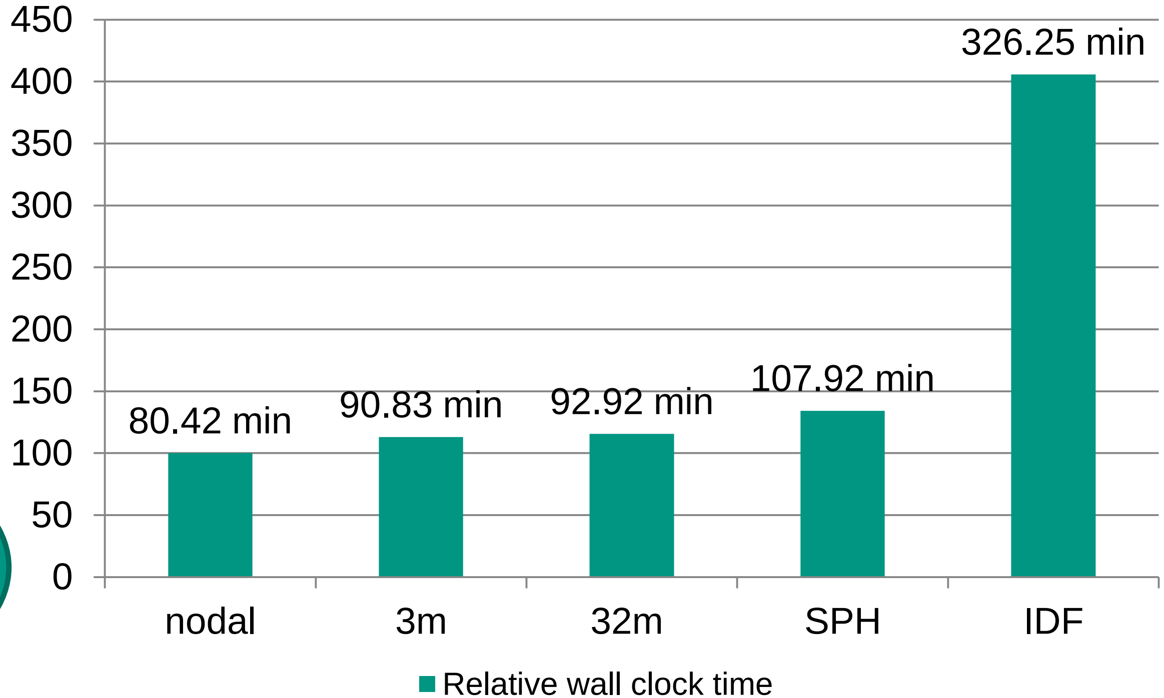
# Performance impact of homogenization corrections

Results for KIT HC3, dual socket Intel Xeon E5540 compute nodes with 24GB memory

- Measurements for 16x16-20 MOX FA using for 16 MPI processes with 8 OpenMP threads each
- Thread affinity and proper page placement assured by batch system
- 2E+9 histories in 500 active cycles, 2g cross sections (0.625 eV boundary)




Nodal and 3m cases would yield sufficient results with less histories

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# Conclusions and Outlook

- Group-wise form functions may now be obtained with Serpent 2
- Accuracy of PPR systematically limited
- All pin-level cross section generation approaches are supported by Serpent 2
- For high accuracy solutions, one should employ pin level homogenization corrections
- Homogenization corrections lead to a (large) penality in terms of computational resource, IDF: fourfold runtime increase compared to a nodal cross section generating model with same number of neutron histories
- Future work:
  - Kinetics parameters per pin cell
  - Performance optimization of IDF generation