Generation of SFR few-group constants by Serpent

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Outline

- Background
- OECD-SFR neutronic benchmark
- XS generation methodology
- SPH method
- Results
- Summary

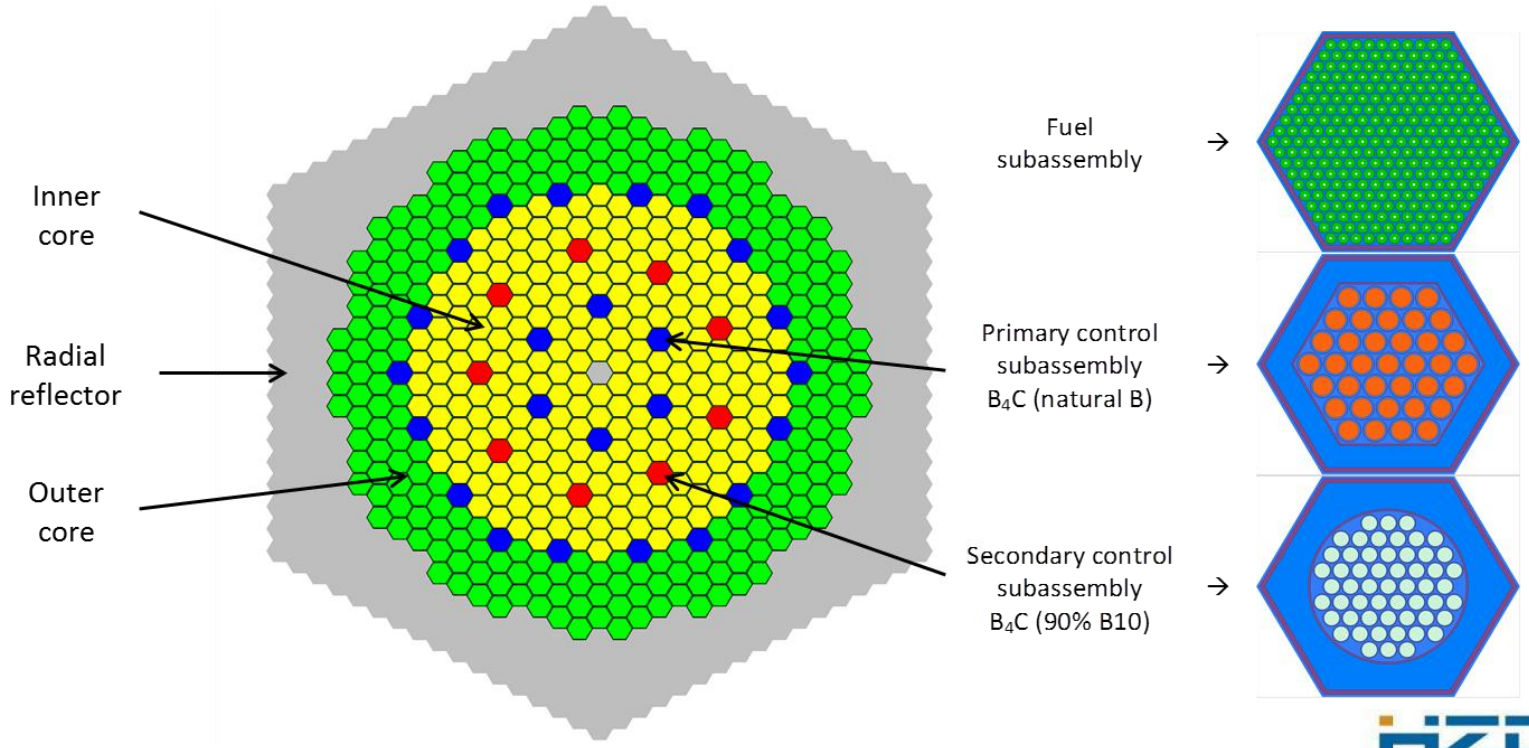
Generation of SFR few-group constants

- MC is too expensive for full-scale reactor calculations
  - Neutronics + TH + BU + kinetics
- Two-step procedure still dominates reactor analysis
  - Deterministic 2D lattice codes → homogenized constants
  - Deterministic 3D coarse mesh core simulators
- Increasing interest in using MC for homogenization
  - Improved computer performance
  - Flexibility - not limited to any particular technology
  - Especially useful for the modeling of innovative reactor concepts

OECD SFR Benchmark

https://www.oecd-nea.org/science/wprs/sfr-taskforce/

- Large oxide SFR core
- Detailed 3D core model
- Good for development and testing of XS generation methodology



Considered nodal codes

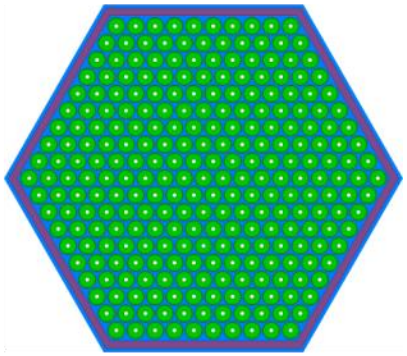
Code	DYN3D	PARCS
Developers	HZDR	Purdue/Michigan Univ.
Neutronics	• 3D multi-group diffusion and SP3 • Steady-state and transient	
Geometry	Square and hexagonal	
T-H	Built-in / ATHLET / RELAP	TRACE
Notes	• Developed for LWRs • Being extended to SFR analysis • Updated T-H module • Development of T-M module	• Developed for LWRs • Part of the FAST code system for fast reactor transient analysis

Modeling approach

- 3D full core calculations
  - At BOL
- DYN3D and PARCS
  - Multi-group diffusion solution
- Serpent:
  - Reference solution
  - Few-group XS for DYN3D and PARCS
- Compared parameters:
  - k-eff
  - Doppler constant
  - Coolant void reactivity
  - Control rod worth
  - Radial power distribution

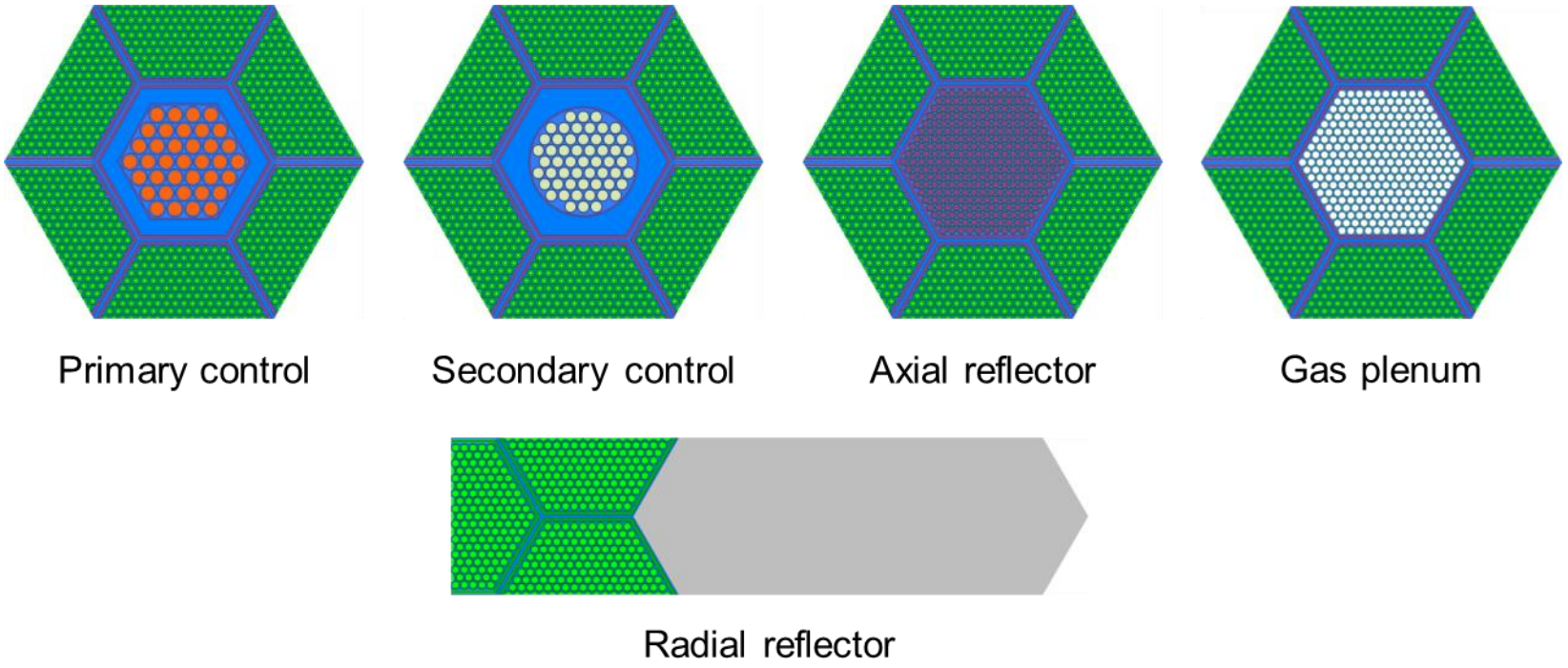
Single-assembly model for fuel assemblies

- 3D
  - Reflective radial and black axial boundary conditions



Super-cell models for non-multiplying regions

- 2D
  - Control rods, control rod channels, reflectors, etc



Results: integral core parameters

Parameter	Serpent, pcm	DYN3D vs. Serpent, pcm	DYN3D vs. PARCS, pcm
Reactivity - CR out	1059	-128	-84
Reactivity - CR in	-4988	-255	-264
Total CR worth	-6046	-127	-180
Doppler constant	-852	-15	-15
Na void reactivity	1864	87	81

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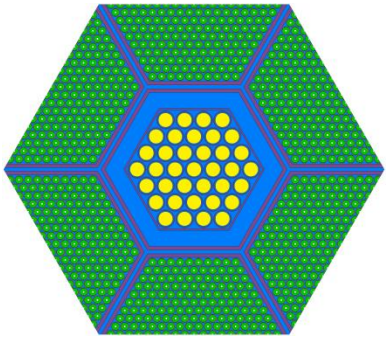
SPH factors for CRs and CR channels

- SPH = Super-homogenization
  - Typically used for pin-wise homogenization in LWRs
- Requires equivalent transport/diffusion model
  - $\mathbf{SPH = \mu = \frac{\phi^{Serpent}}{\phi^{DYN3D}}}$ and $\mathbf{\Sigma^* = \mu^* \cdot \Sigma}$
  - For every homogenized region and energy group
- Q: How to make equivalent model for hexagonal supercell?



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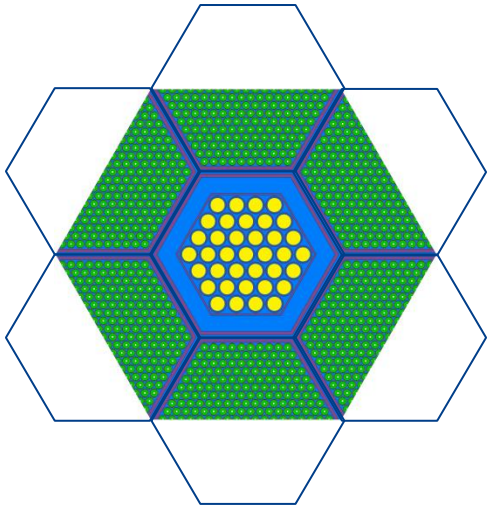
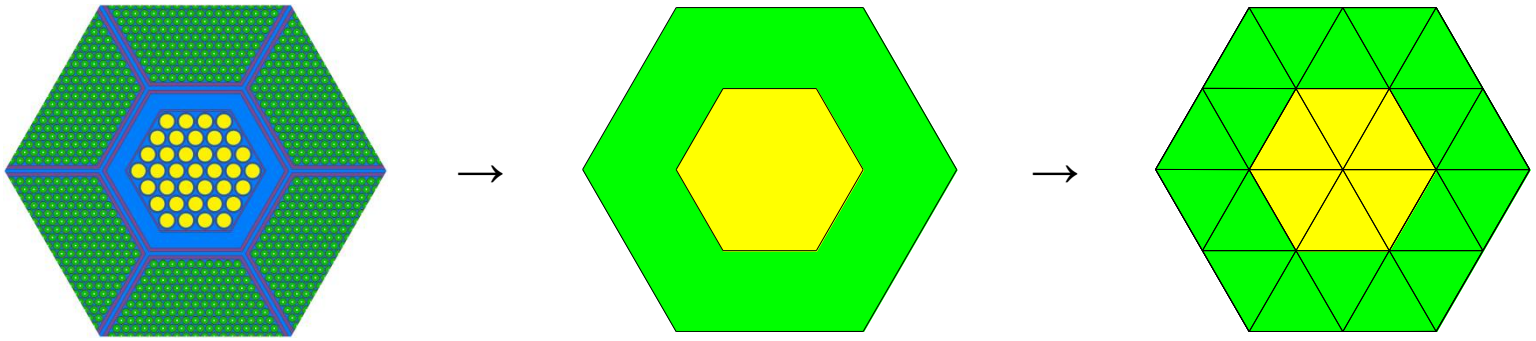


SPH factors for CRs and CR channels

- DYN3D has a trigonal diffusion solver
- SPH were generated as follows:



Serpent model → Homogenized regions Σ and $\phi^{Serpent}$ → DYN3D Δ diffusion ϕ^{DYN3D}

Results: integral core parameters

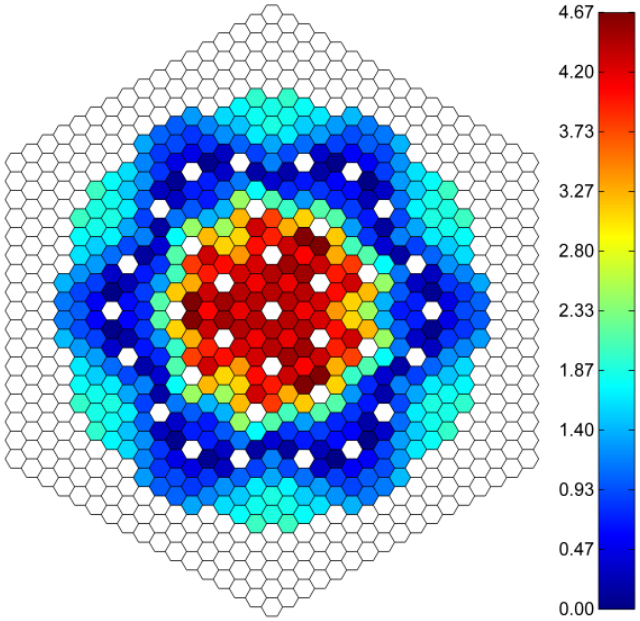
Parameter	DYN3D vs. Serpent, pcm
Reactivity - CR out	-128
Reactivity - CR in	-255
Total CR worth	-127
	PARCS vs. Serpent, pcm
Reactivity - CR out	-84
Reactivity - CR in	-264
Total CR worth	-180

Results: integral core parameters + SPH

Parameter	DYN3D vs. Serpent, pcm	DYN3D + SPH vs. Serpent, pcm
Reactivity - CR out	-128	-64
Reactivity - CR in	-255	-107
Total CR worth	-127	-43
	PARCS vs. Serpent, pcm	PARCS + SPH vs. Serpent, pcm
Reactivity - CR out	-84	-21
Reactivity - CR in	-264	-121
Total CR worth	-180	-100

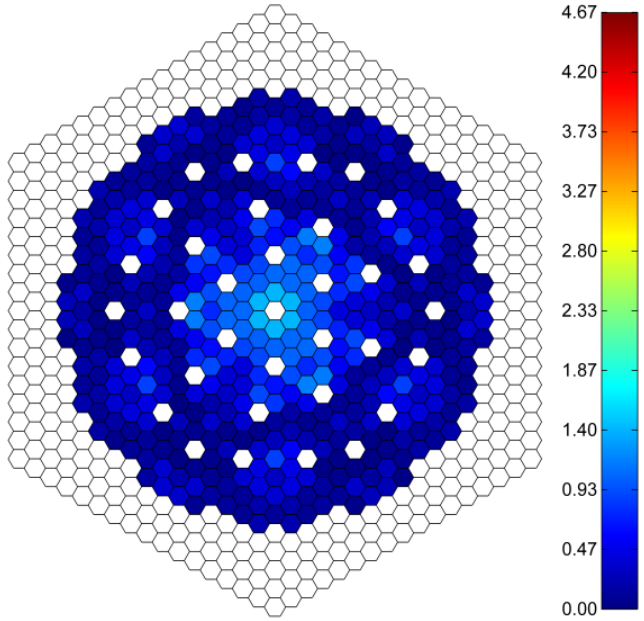
Difference in radial power distribution, CR in

DYN3D vs. Serpent, no SPH



ave. / max. diff. = **2.4 / 6.0 %**

DYN3D vs. Serpent, with SPH



ave. / max. diff. = **0.9 / 3.1%**

Summary and conclusions

- Serpent based few-group XS were used by nodal codes
  - DYN3D and PARCS
  - 3D nodal diffusion calculations of SFR core
- Verification of results
  - Diffusion vs. full core Serpent MC solution
  - Very good agreement between the codes
  - **SPH** method **noticeably improve** the accuracy of the nodal solutions
- Ongoing work
  - Modeling of thermal expansion effects
  - DYN3D + Serpent

Acknowledgments

- Evgeny Nikitin, HZDR
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Thank you!