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DEVELOPMENT OF A HIGH-FIDELITY MONTE CARLO THERMAL-HYDRAULICS COUPLED CODE SYSTEM SERPENT/SUBCHANFLOW – FIRST RESULTS

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Motivation

- Provide reference solution to improve deterministic reactor simulators
- Serpent designed as lattice code
- Universal multi-physics interface introduced in Serpent 2
- Development in framework of High Performance Monte Carlo Project (HPMC)

Implementation of external coupling

- Based on type 1 multi-physics interface
- On-the-fly treatment of temperature dependence with Target Motion Sampling (TMS)
- Sub-channel thermal-hydraulics
- Coupling affects fuel, clad and coolant temperatures as well as coolant density

$$T_{dopp} = (1-\alpha)\,T_{f,c} + \alpha\,T_{f,s}$$

- Coupled Convergence

$$\frac{\Delta X}{X} = \frac{X^n - X^{n-1}}{X^n} \le \varepsilon_X$$

with X being eigenvalue, local Doppler temperature and local moderator density
- Under-relaxation scheme

$$X_n = (1-\omega)\,X_{n-1} + \omega\,X_n$$

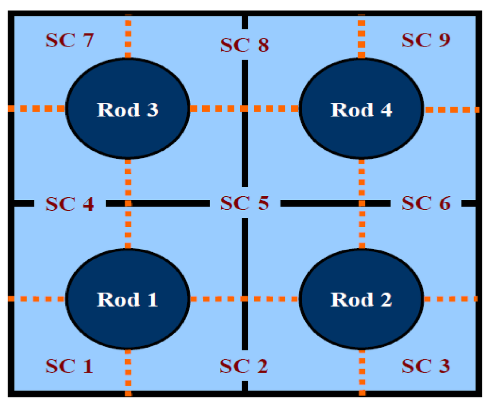

Fig. 1: Spatial Mapping

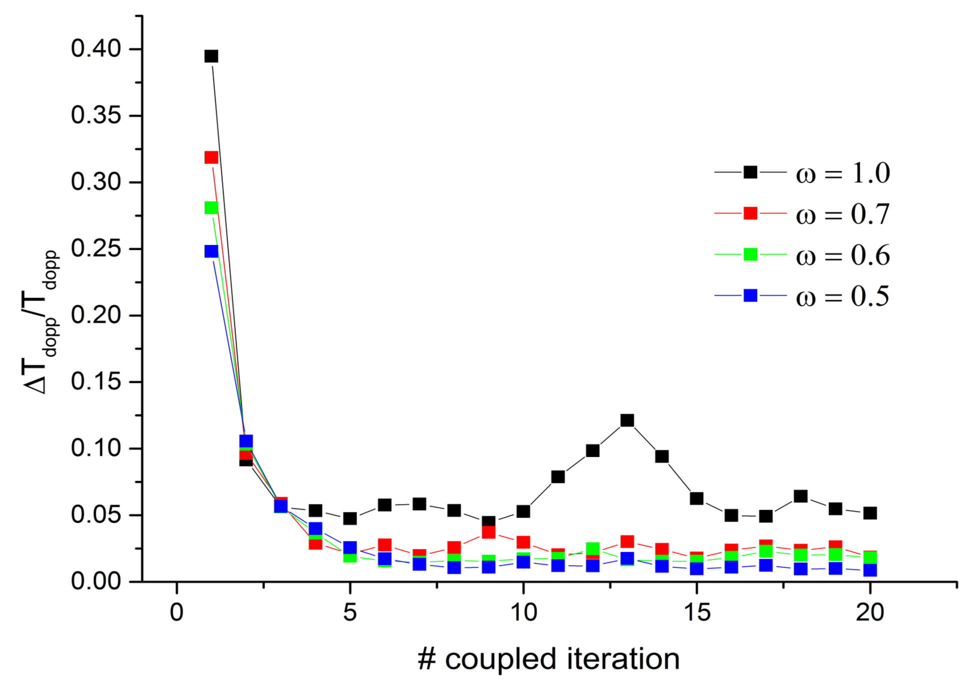

Fig. 2: Relaxation Effect

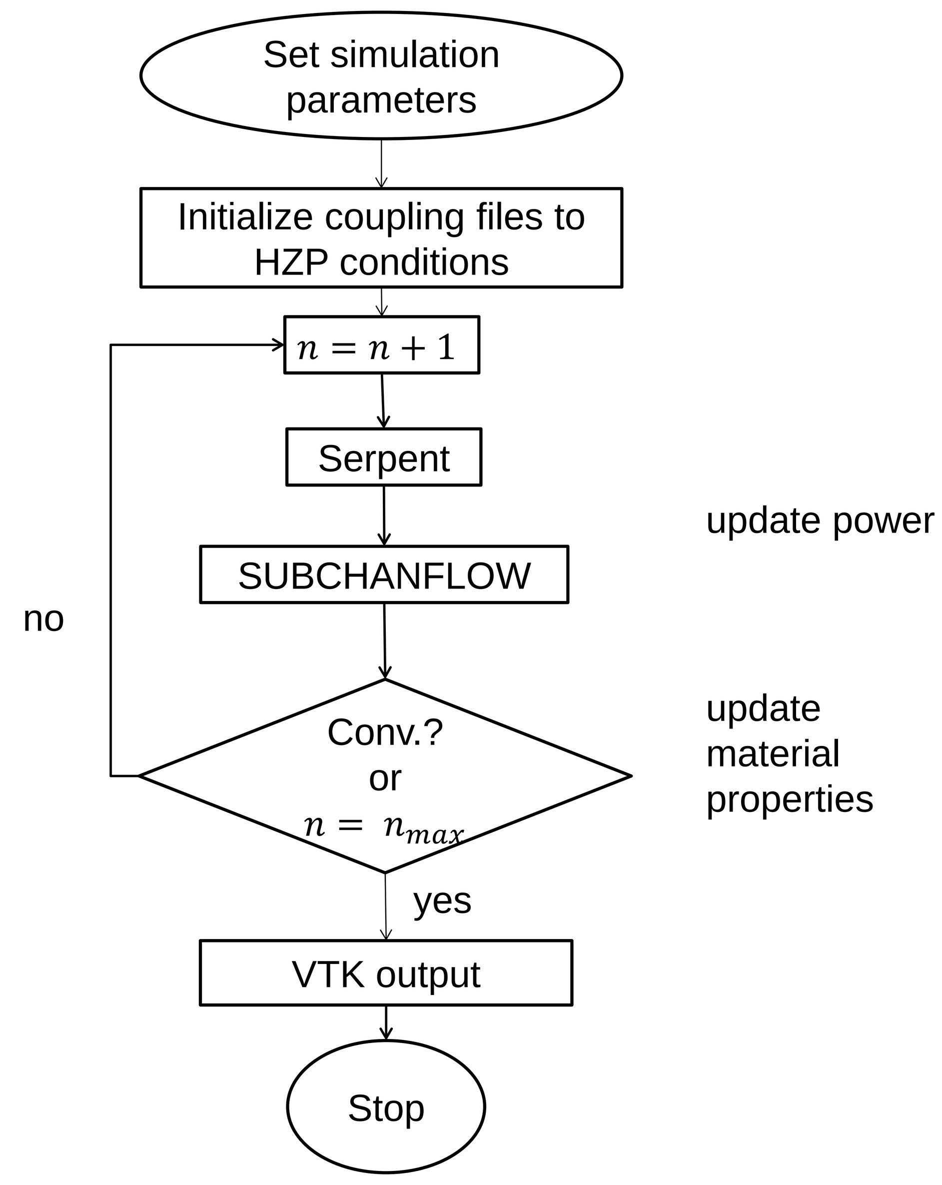

Fig. 3: Flow chart of external coupling

Code-to-code benchmark with DYNSUB

- Infinite lattice of 3.66m high fresh 17x17-24 UOX 4.2wt% FA
- 18.74 MW thermal power, 82.12 kg/s coolant flow outlet pressure of 15.5 MPa, 1000 ppm soluble poison
- 300 K basis CE ENDF/B-VII.0 cross section libraries
- 20 axial layers in feedback mesh

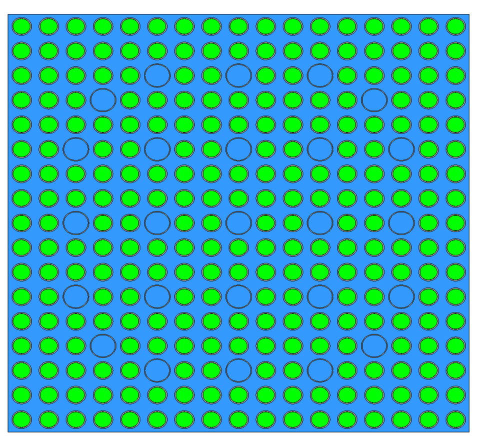

Fig. 4: UOX FA layout

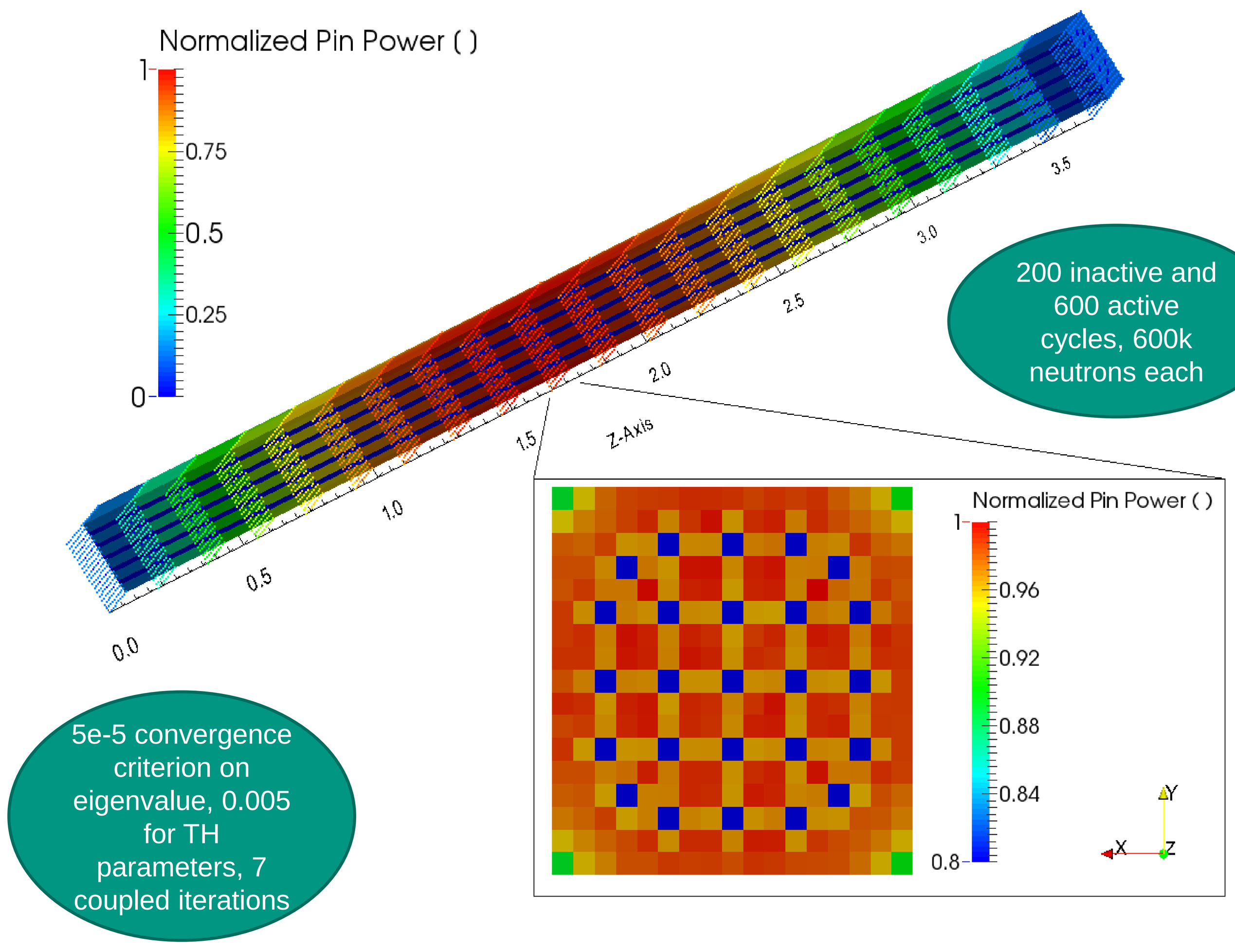

Fig. 5: Pin powers predicted by Serpent/SUBCHANFLOW

	HZP k_{eff}	HFP k_{eff}	Power defect in reactivity ρ [pcm]
DYNSUB pin-by-pin SP3	1.12189	1.11230	862.4
Serpent/ SUBCHANFLOW	1.12042±3·10^{-5}	1.11264±3·10^{-5}	624.1±0.043

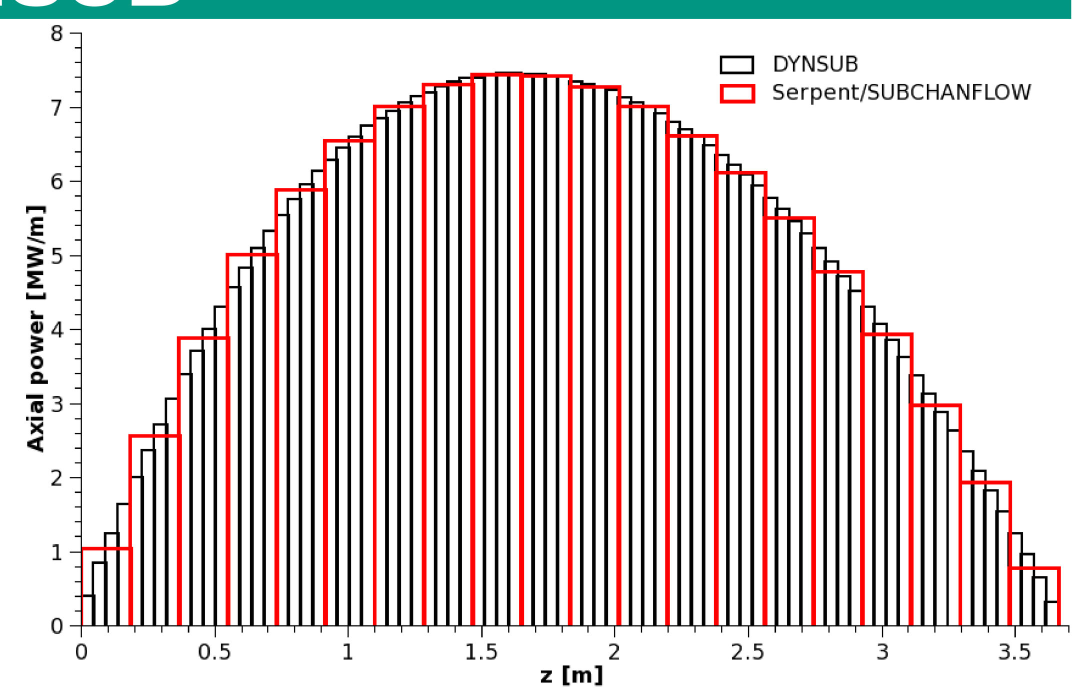

Fig. 6: Comparison of axial power profiles

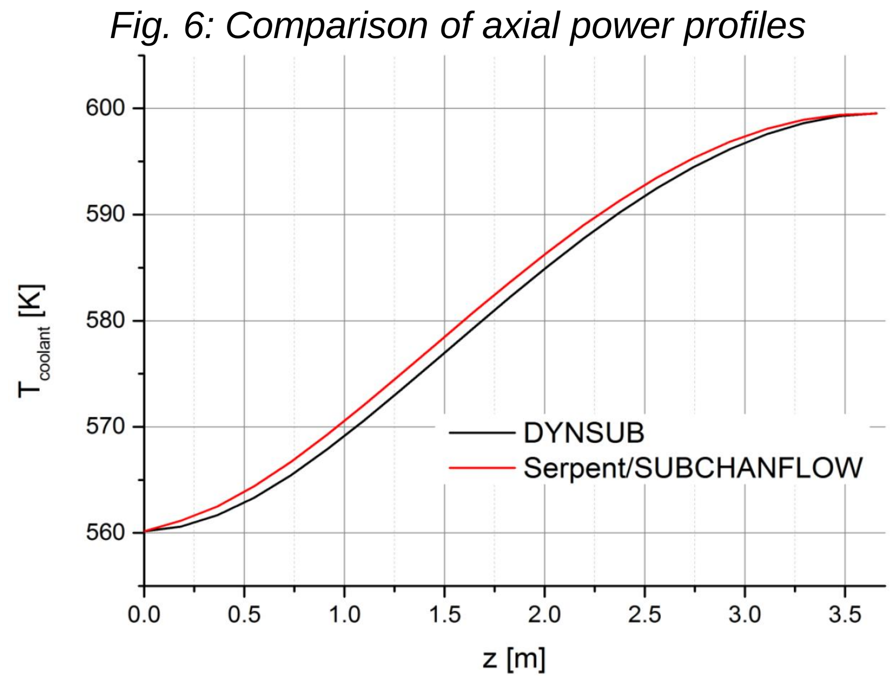

Fig. 7: Comparison of axial coolant temperatures

Numerical Performance

- SUBCHANFLOW contribution <0.01%
- Serpent:

	standard	HZP IFC	HFP IFC
Total Run Time	1.0	2.91	9.87
Initialization	1.0	1.47	2.16
Transport	1.0	2.97	10.21

Conclusion and Outlook

- Successfull verification (code-to-code benchmark with DYNSUB)
- Significant slow-down of Serpent from user point of view
- Deficiencies of TMS need to be resolved
- Internal coupling

Completed, presented at PHYSOR Serpent workshop