Karlsruhe Institute of Technology

Institute for Neutron Physics and Reactor Technology

Further Development of High-Fidelity Reactor Simulator DYNSUB

Reactor Physics and Dynamics Group (RPD)

M. Daeubler[1], **J. Jimenez**[1], **V. Sanchez**[1], **R. Stieglitz**[1], **R. Macian-Juan**[2]

[1] Karlsruhe Institute of Technology, Institute for Neutron Physics and Reactor Technology (KIT INR)

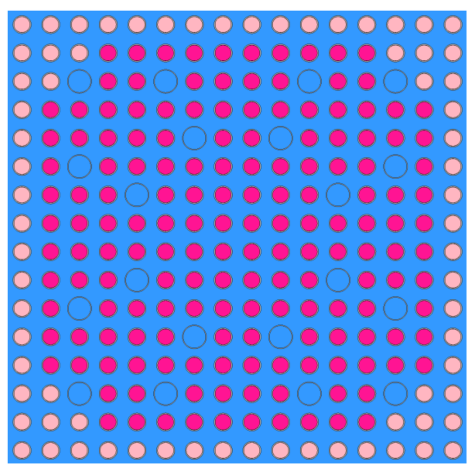
[2] Technical University of Munich (TUM)

High-fidelity coupled code system DYNSUB

- Homogeneous neutron kinetics code DYN3D:
  - Neutron diffusion and simplified transport at fuel pin level
  - Supported Interface Discontinuity Factors (IDF) and Super-Homogenization (SPH) factors
- Sub-channel code SUBCHANFLOW:
  - 3 mixture equations, two phase flow, 1 equation for cross flow
  - Coolants: water, lead, sodium and helium
  - Boron transport model
- Major features of DYNSUB:
  - Internal coupling, flexible spatial mapping, SMD parallelism
  - Resolution of active reactor core at fuel rods and sub-channel level
  - Direct evaluation of critical fuel rod level safety parameters (e.g. DNBR)
  - Current capabilities: static and transient simulation of square lattice PWR
  - Under development: support for square lattice BWR

Homogenization corrections

- Generation of such effective cross sections introduces homogenization errors into the simulation
- IDF and SPH factors evaluation developed for DYNSUB based on lattice codes SCALE 6.1/TRITON and SERPENT



Composition of a 18x18-24 MOX Fuel Assembly

Code	k-inf	Relative difference [pcm]
Serpent 2 CE	1.08496 ±0.000030	-
DYN3D 4g diff (3M)	1.087627	266.7
DYN3D 4g sp3 (3M)	1.086733	177.3
DYN3D 4g diff (32M)	1.087578	261.8
DYN3D 4g sp3 (32M)	1.086685	172.5
DYN3D 4g (324M) SPH	1.084951	0.9
DYN3D 4g (324M) GET IDF	1.084950	1.0
DYN3D 4g (324M) BBH IDF	1.084950	1.0

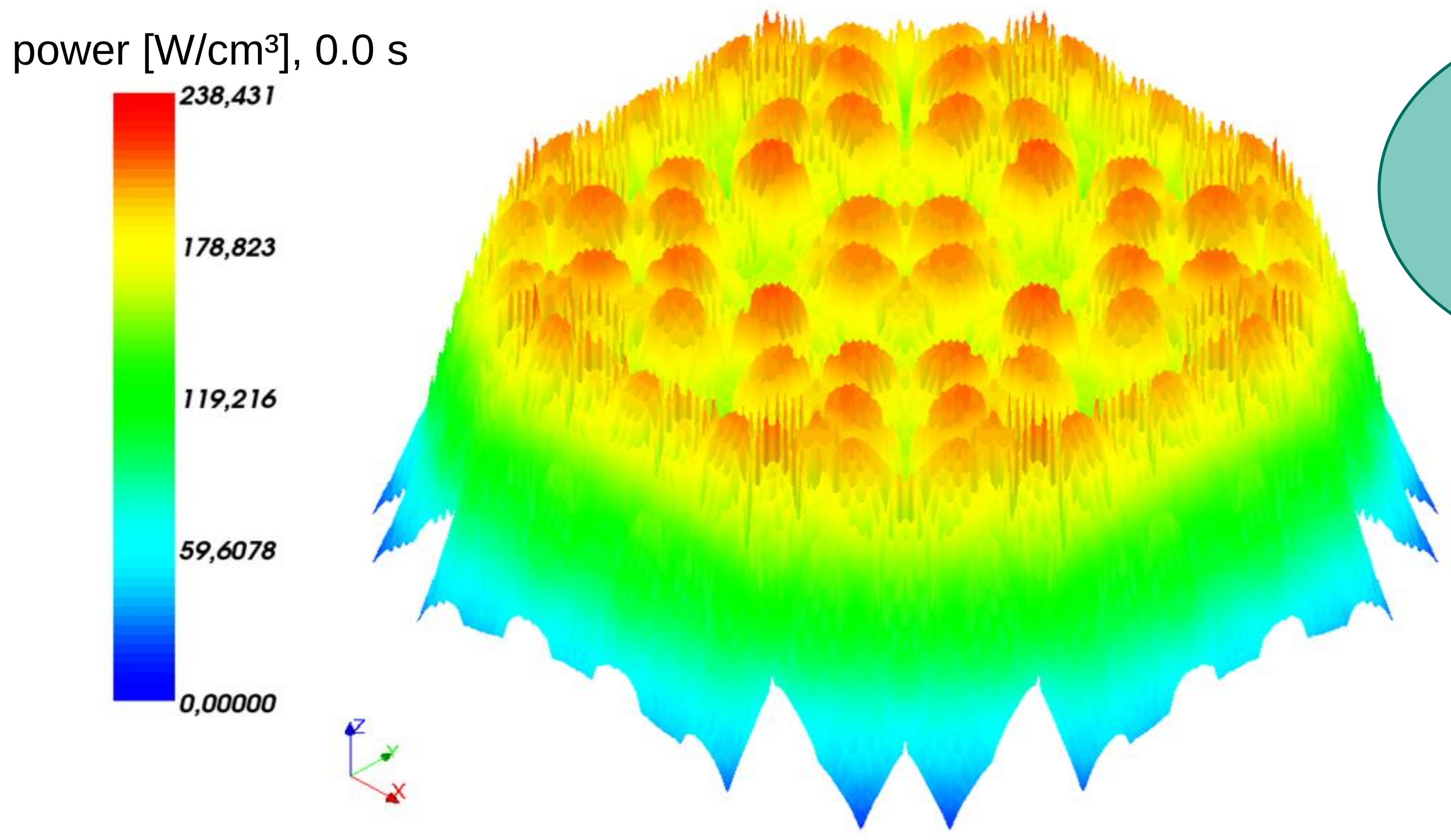
MOX Fuel Assembly Eigenvalue Comparison

Selected safety case: Reactivity-Initiated Accident in PWR

- OECD/NEA and U.S. NRC MOX/UO2 core transient benchmark
- Hot full power (HFP) steady-state and hot zero power (HZP) rod ejection

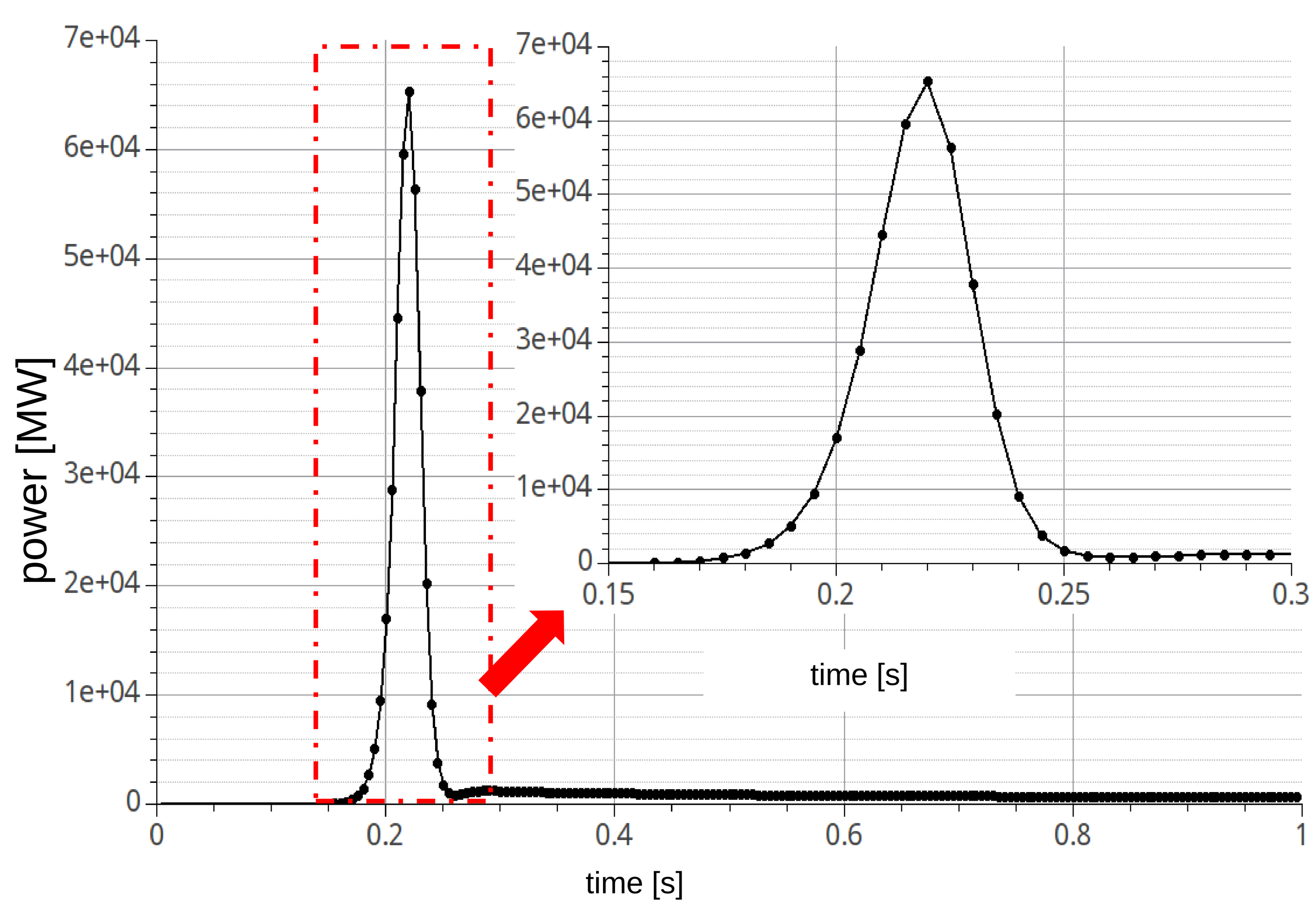
U 4.2% 32.5	U 4.5% 17.5	M 4.3% 35.0	U 4.5% 20.0				
U 4.5% (CR-C) 0.15	M 4.0% 0.15	U 4.5% (CR-B) 0.15	M 4.3% 0.15	U 4.2% (CR-SC) 17.5	U 4.5% 32.5		
M 4.3% 17.5	U 4.2% (CR-SB) 32.5	M 4.3% 17.5	U 4.5% (CR-SC) 20.0	U 4.5% 0.15	M 4.3% 0.15	U 4.5% 32.5	
U 4.% (CR-SB) 37.5	U 4.2% 0.15	U 4.2% 22.5	U 4.2% 0.15	U 4.2% (CR-D) 37.5	U 4.5% 0.15	U 4.2% (CR-SA) 17.5	
U 4.5% 0.15	M 4.0% 22.5	U 4.2% 0.15	M 4.0% 37.5	U 4.2% 0.15	U 4.5% (CR-SC) 20.0	M 4.3% 0.15	U 4.5% 20.0
U 4.2% (CR-A) 22.5	U 4.5% 32.5	U 4.2% (CR-C) 22.5	U 4.2% 0.15	U 4.2% 22.5	M 4.3% 17.5	U 4.5% (CR-B) 0.15	M 4.0% 35.0
U 4.2% 0.15	U 4.2% 17.5	U 4.5% 32.5	M 4.0% 22.5	U 4.2% 0.15	U 4.2% (CR-SB) 32.5	M 4.0% 0.15	U 4.5% 17.5
U 4.2% (CR-D) 35.0	U 4.2% 0.15	U 4.2% (CR-A) 22.5	U 4.5% 0.15	UOX 4.5% 37.5	M 4.3% 17.5	U 4.5% (CR-C) 0.15	U 4.2% 32.5

Fuel assembly loading pattern with enrichment of PWR benchmark core

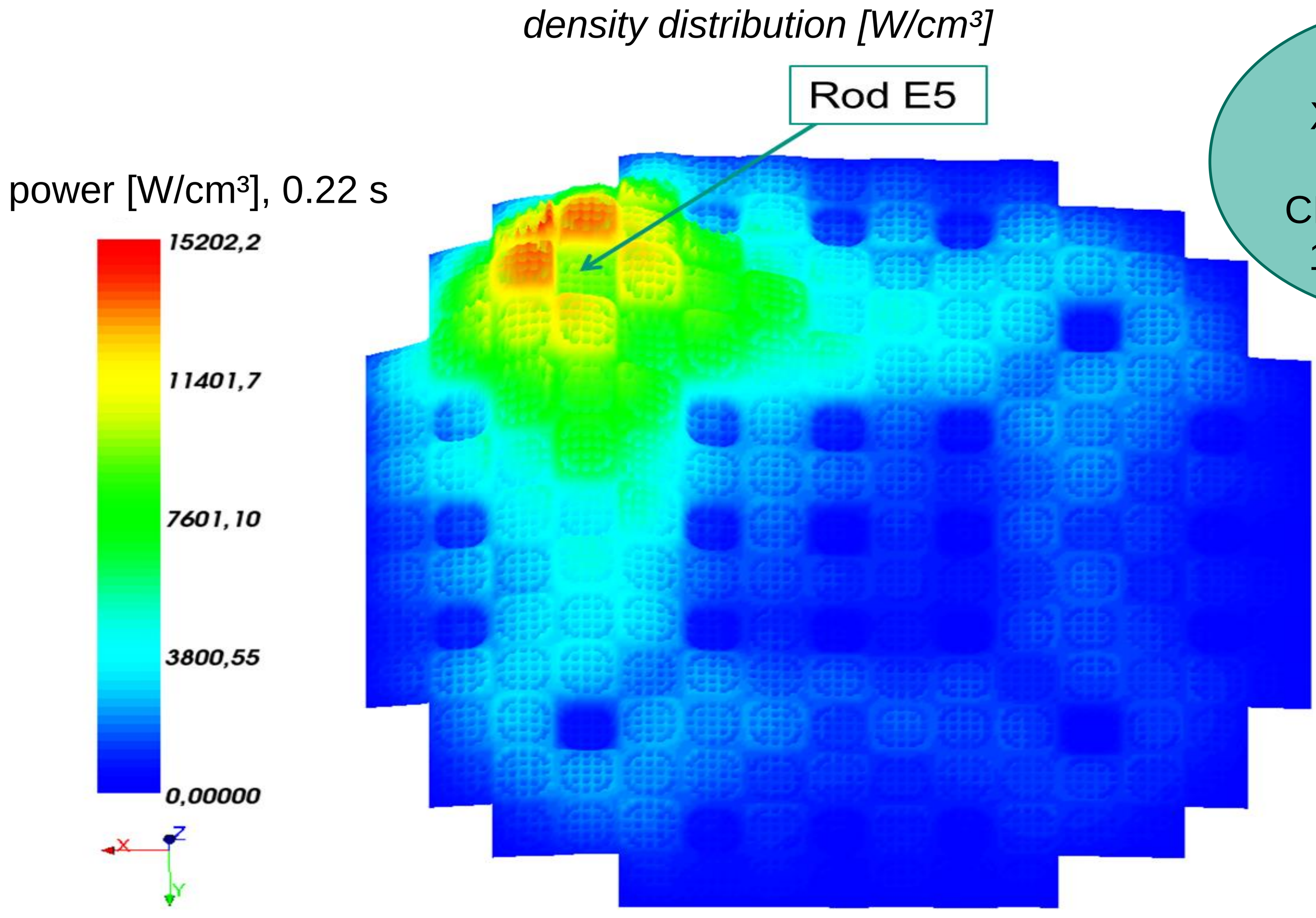


21.1GB, Intel Xeon E5620 platform, 8 CPUs, 1d and 10h run

Hot full power (HFP) all rods out (ARO) steady-state: axially cumulated power density distribution [W/cm³]



Evolution of thermal power during HZP rod ejection accident (REA)



25GB, Intel Xeon E5620 platform, 4 CPUs, 14d and 17h run time

HZP rod ejection accident (REA): axially cumulated power density distribution [W/cm³] at 0.22s

Conclusions

- First study of safety cases with DYNSUB proves general applicability for LWR safety analysis
- Run times too long for routine application, further improvements necessary to make DYNSUB cost-effective multi-physics tool