Preliminary results of the WPRS Sodium-Cooled Fast Reactor Benchmark problems

A. Keresztúri, I. Pataki, Á. Tóta, P. Vértes
Hungarian Academy of Sciences
Centre for Energy Research

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The codes applied

Two different sets of the solutions:

1. ERANOS ECCO for the cross section generation of the homogenized assemblies →
   KIKO3D multigroup nodal diffusion code for the core calculation

2. DANTSYS Sn code for the cross section generation of the homogenized assemblies →
   KENO Monte Carlo code

Only preliminary, not full solutions, supplements and improvements in the next months

Cross section generation by ECCO, four steps

- Calculation of the heterogeneous assembly by using a 33 energy group 2D transport method with buckling iteration → homogenization

- 33 group calculation of the homogenized medium, buckling iteration

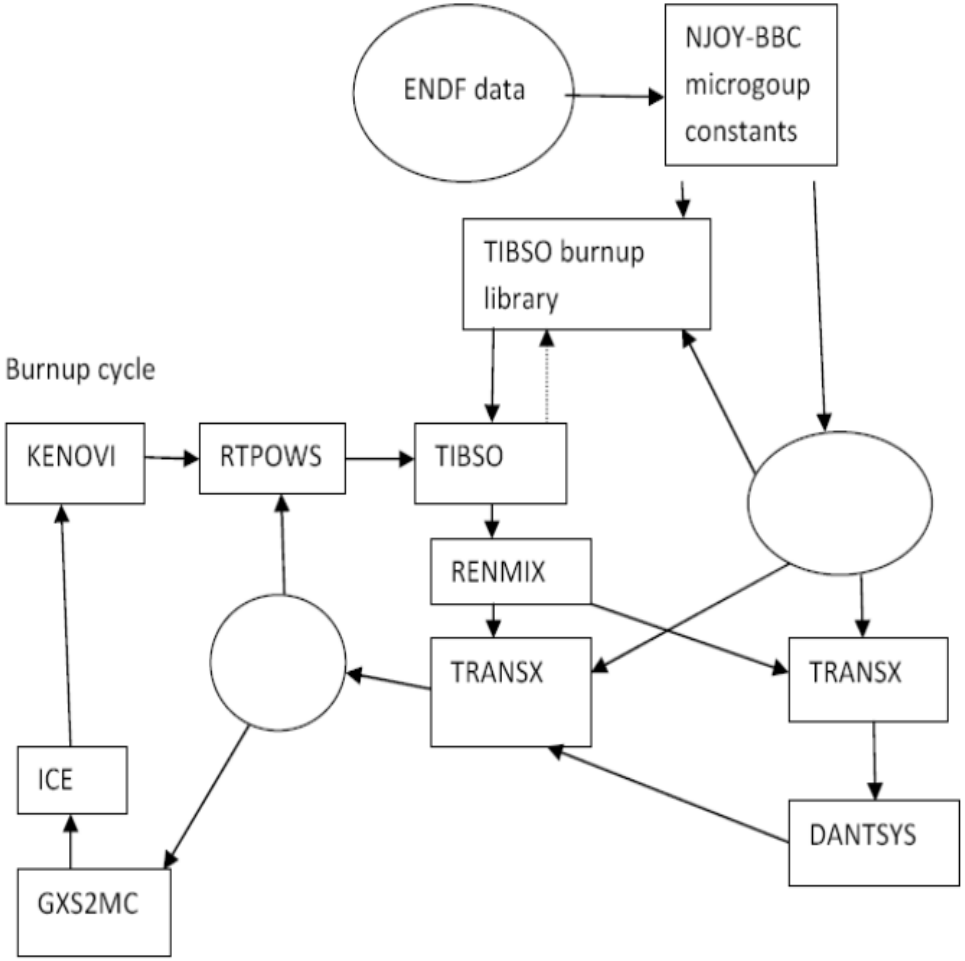
- 1968 group calculation of the homogenized medium, buckling iteration starting from the buckling in the previous step → condensation to 9 groups. Attempts to calculate the heterogeneous assembly instead of the homogenized.

- 9 group calculation of the homogenized medium, buckling iteration → KIKO3D. More energy groups can be foreseen if necessary.

KIKO3D 3D nodal code for static and dynamic calculations of the core

- Arbitrary number of energy groups
- The nodes are the fuel assemblies subdivided by axial layers.
- The unknowns are the scalar flux integrals on the reactor node interfaces.
- Linear anisotropy of the angle dependent flux on the node boundaries is assumed. The scalar flux and net current integrals are continuous on the node interfaces.
- Analytical solutions of the multigroup diffusion equation inside the nodes.
- Generalized response matrices of the time dependent problem and time dependent nodal equations are used.
- IQS (Improved Quasi Static) factorization; shape function equations and point kinetic equations.
- The absorbers and the reflector can be represented by pre-calculated albedo matrices. (Presently cross sections)
- Time dependent fuel heat up model by nodes
- Time dependent sodium heat up model for the assembly channels
- The stationary solution is also available.

The KENO-DANTSYS-TIBSO system



The KENO-DANTSYS-TIBSO system

- With the DANTSYS SN code in r-z geometry, the neutron flux in a single fuel pin immersed into moderator is calculated. The additional isotopes at the assembly periphery are mixed to the cladding and coolant to preserve the assembly ratios.

- 80 neutron group system is used in DANTSYS. The group constants are weighted with this flux and the macro-constants are given out to KENO.

- KENO gives the criticality factor and fluxes by media.

- Burnup is calculated by means of the TIBSO code. The new isotopic composition is used for the next criticality calculation and for the next burning, and so on.

KIKO3D results

	Large carbide core	Large oxide core
Effective multiplication factor	1.0085	1.0121
Void reactivity	1.26 %	0.13 %
Doppler coefficient	-1.1309 %	-0.9907 %
Control rod worth	5.6 %	7.6 %

KENO results

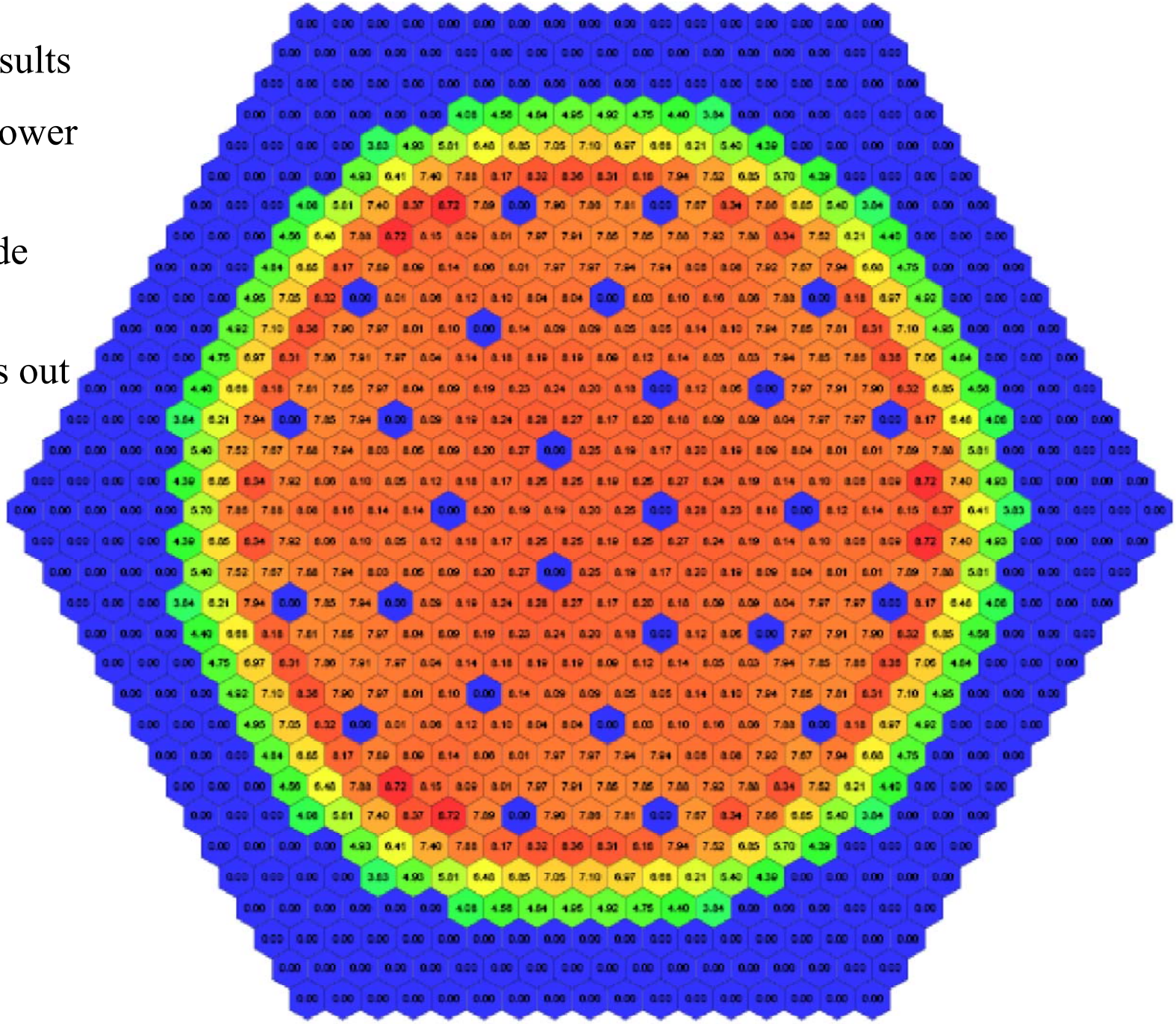
	Large carbide core	Large oxide core	Medium metallic core	Medium oxide core
Effective multiplication factor	0.9836	1.0042	0.9817	0.9656
Void reactivity	1.3 %	0.03 %	-11. 5%	-
Doppler coefficient	-0.514 %	-0.857 %	-0.910 %	-0.611 %
Control rod worth	7.1 %	5.0 %	17.6 %	12.5 %
Effective delayed neutron fraction	0.71 %	-	0.57 %	0.31 %

KIKO3D results

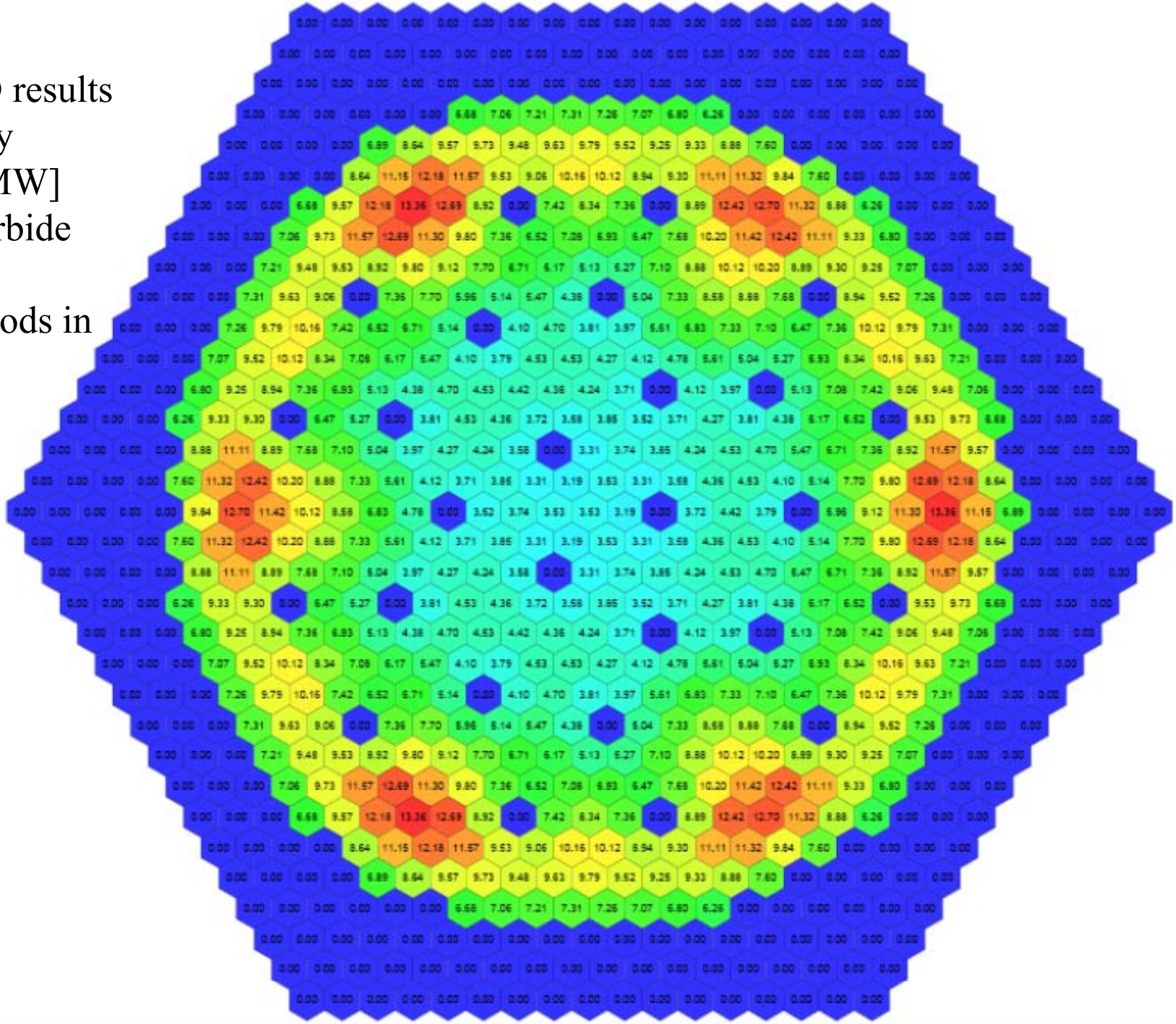
Assembly power [MW]

Large carbide core

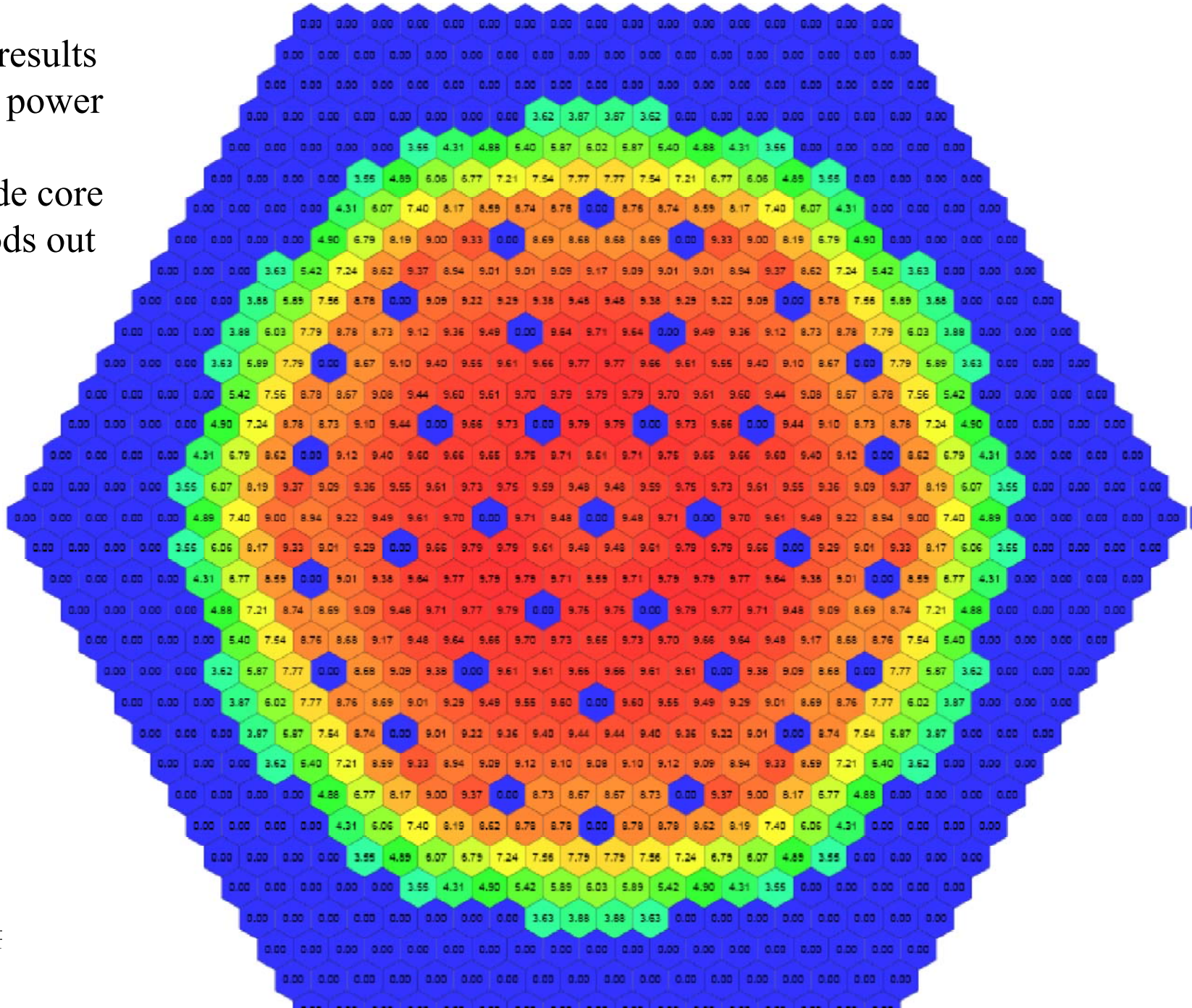
Control rods out



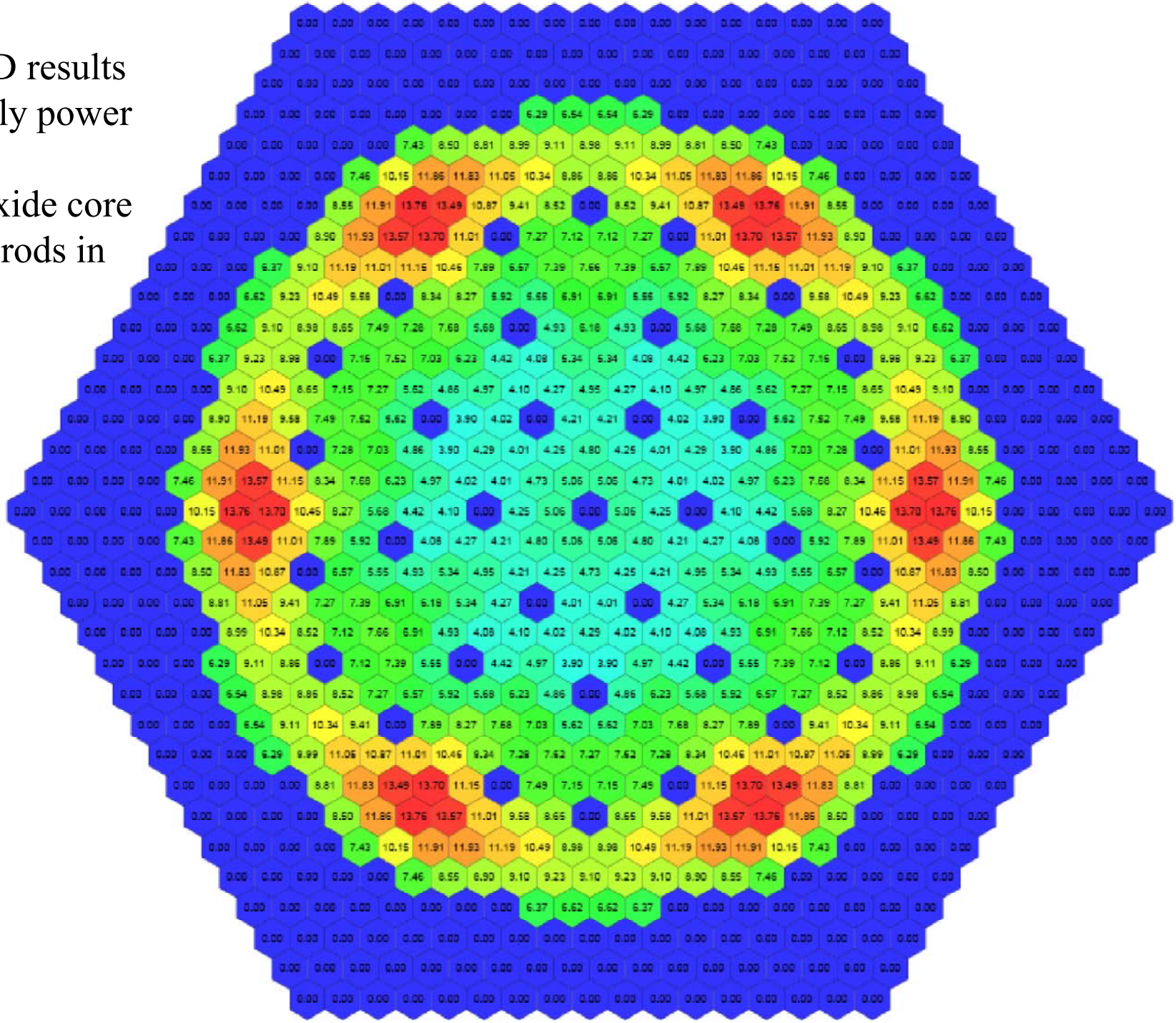
KIKO3D results
Assembly
power [MW]
Large carbide
core
Control rods in



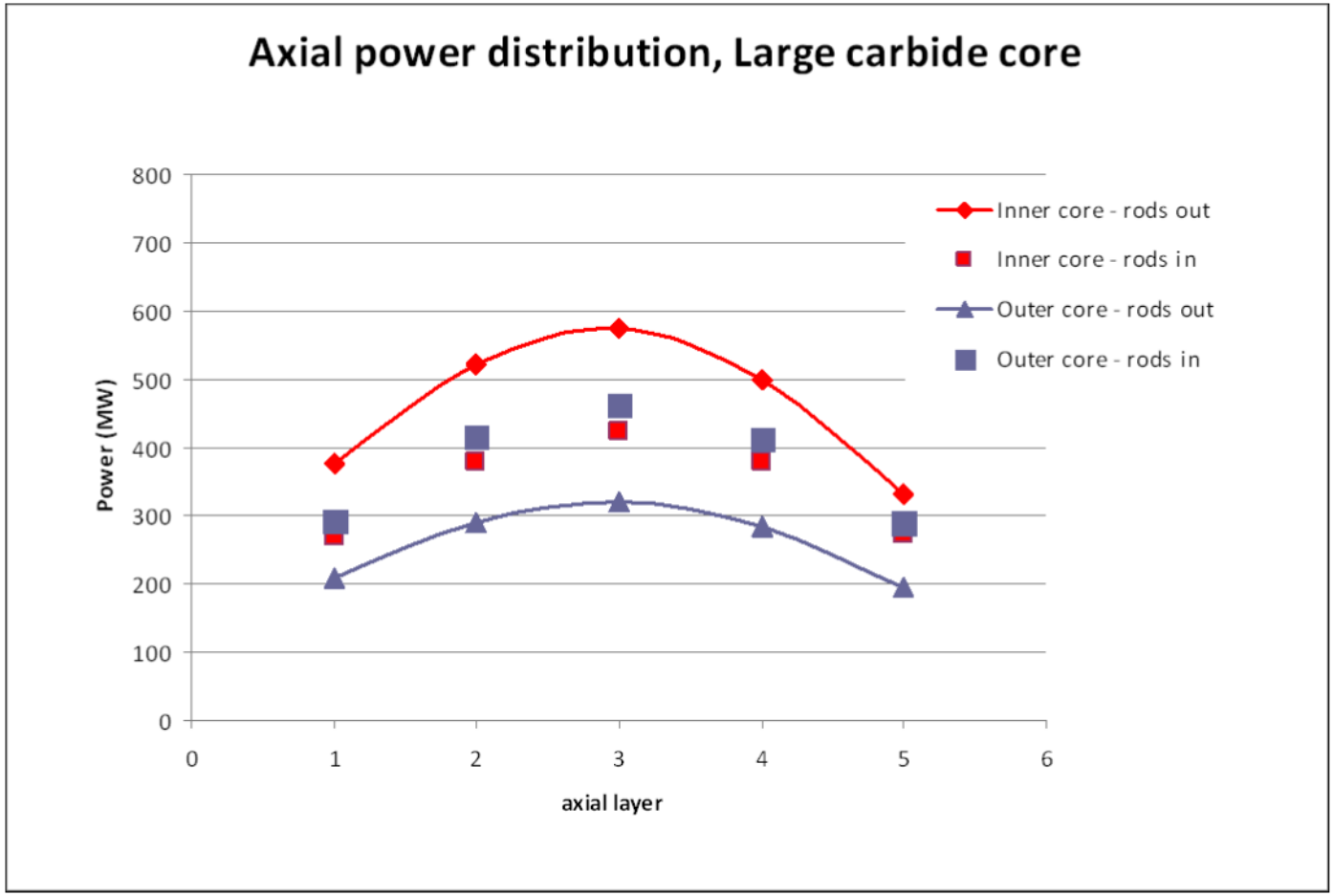
KIKO3D results
Assembly power
[MW]
Large oxide core
Control rods out



KIKO3D results
Assembly power
[MW]
Large oxide core
Control rods in



KIKO3D results, axial distributions of the inner and outer core power



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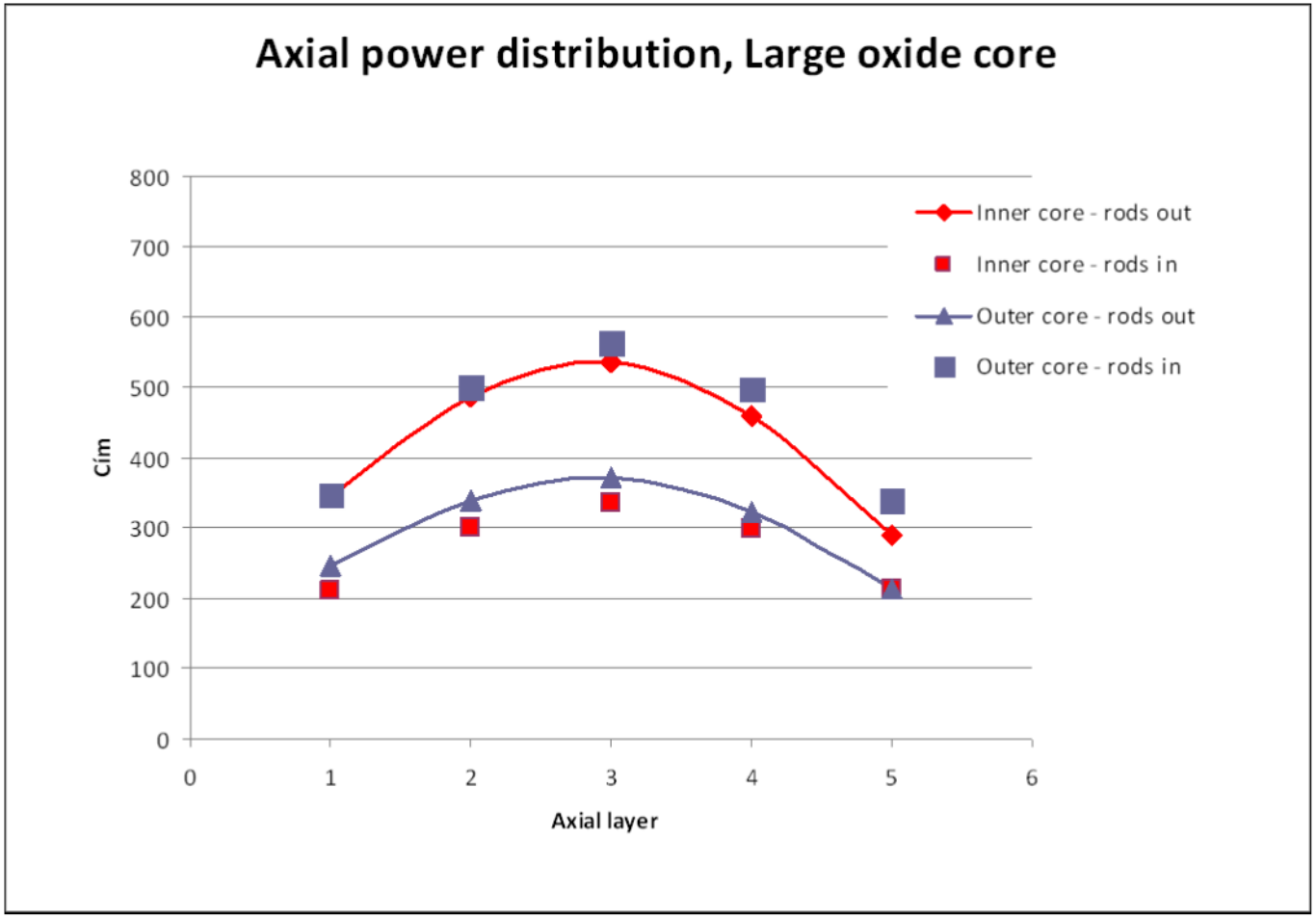
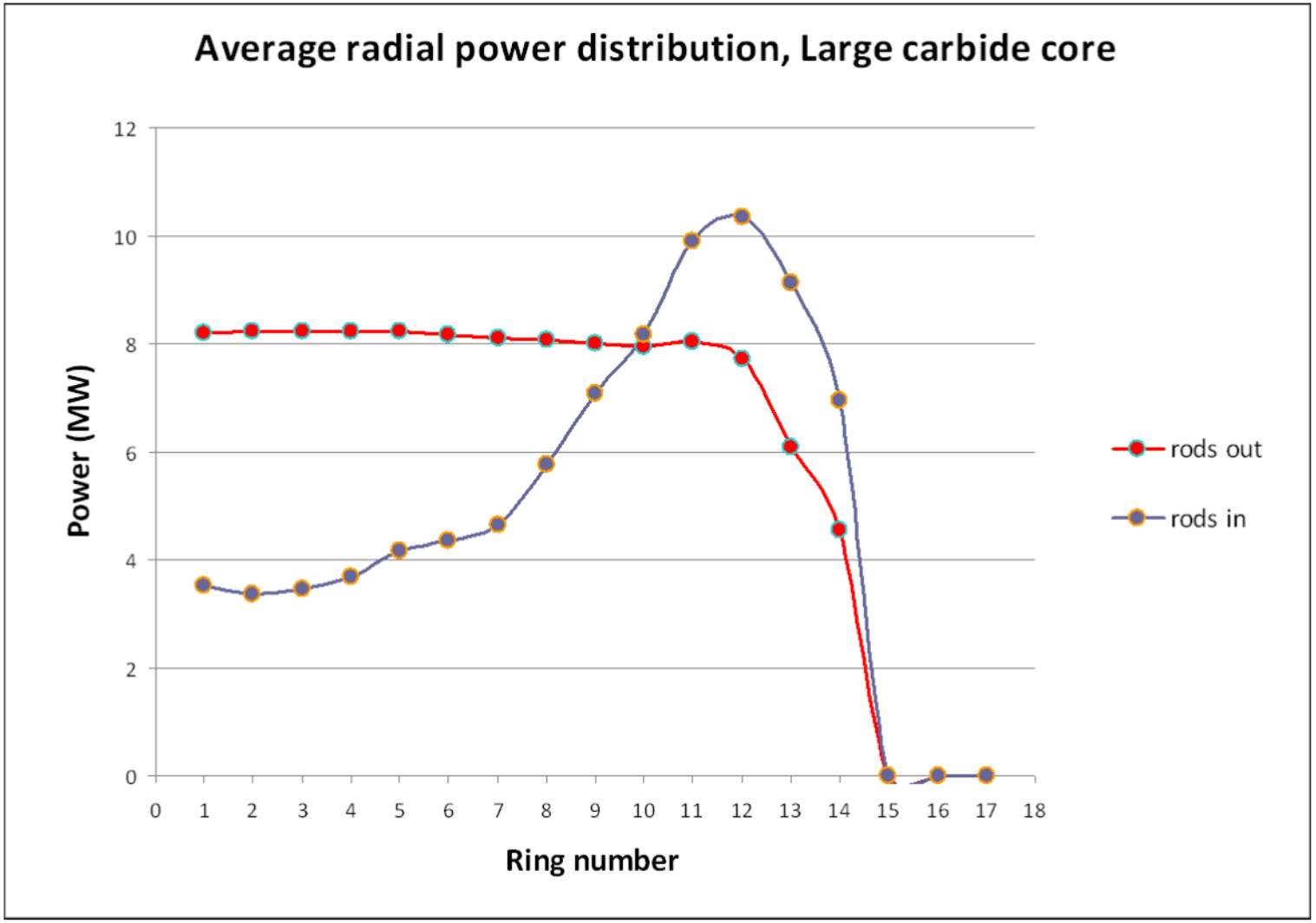


KIKO3D results, ring-wise averaged assembly power distributions



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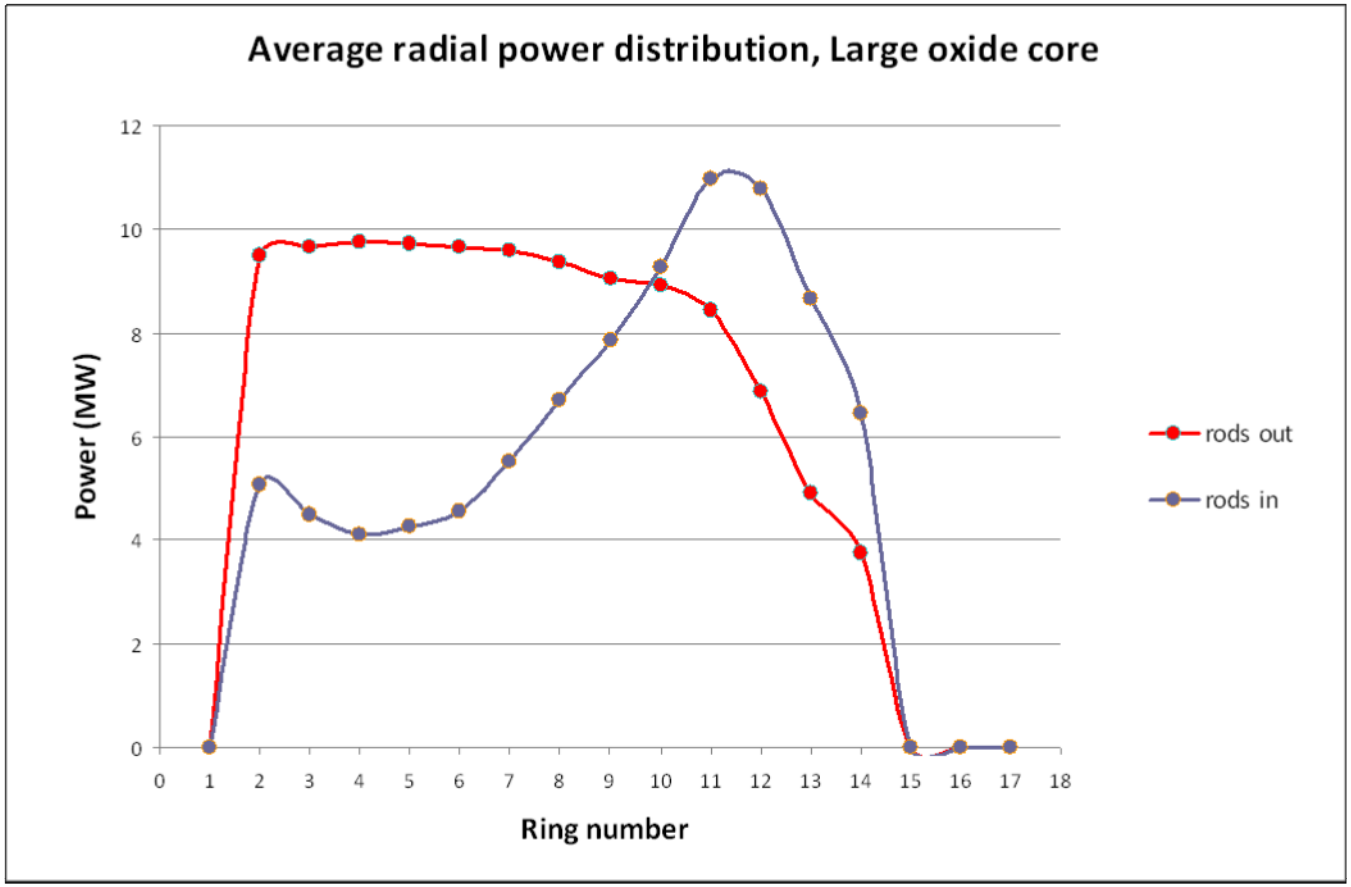
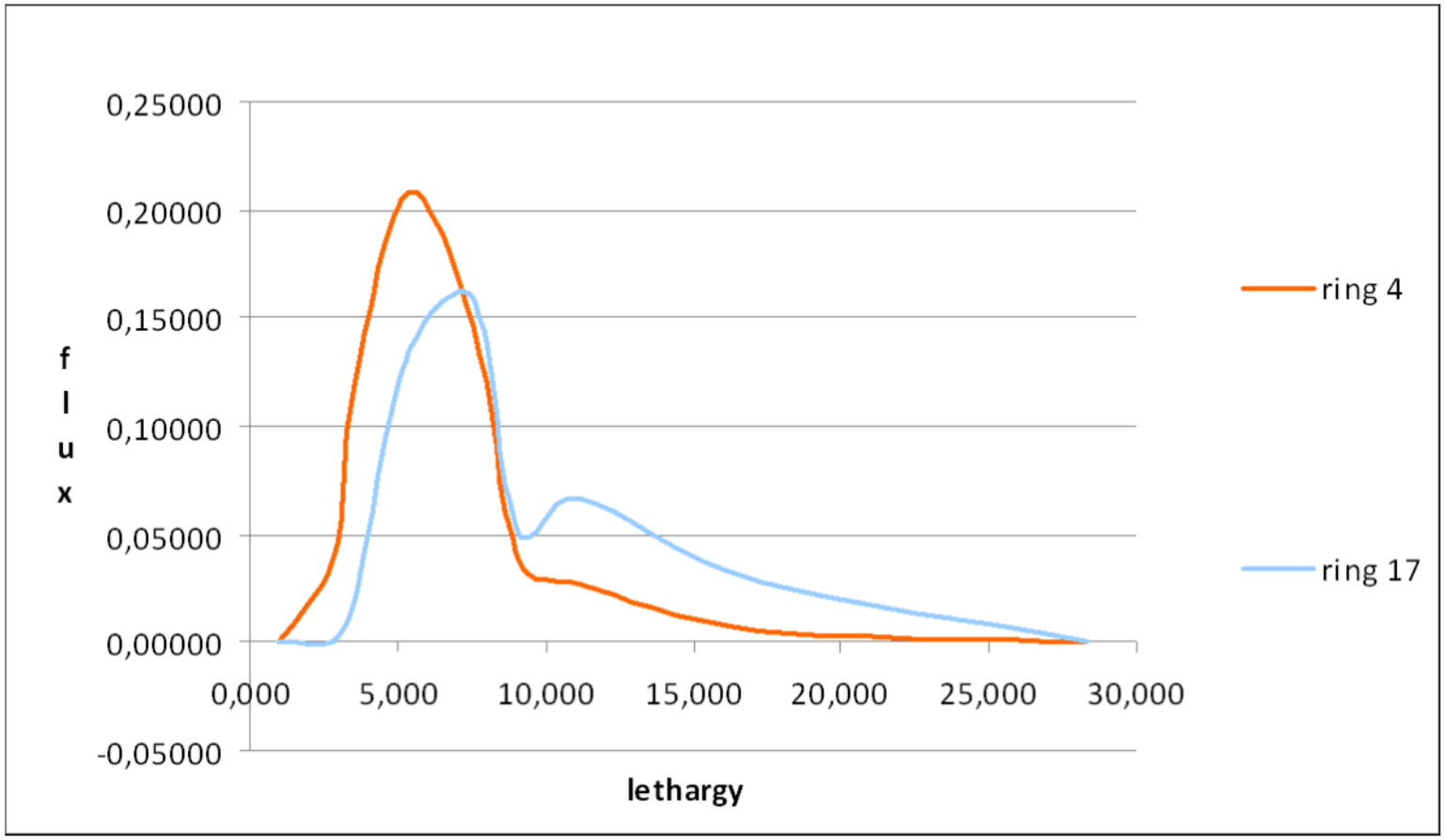


KIKO3D solution, ring averaged lethargy dependent spectra for the large carbide core



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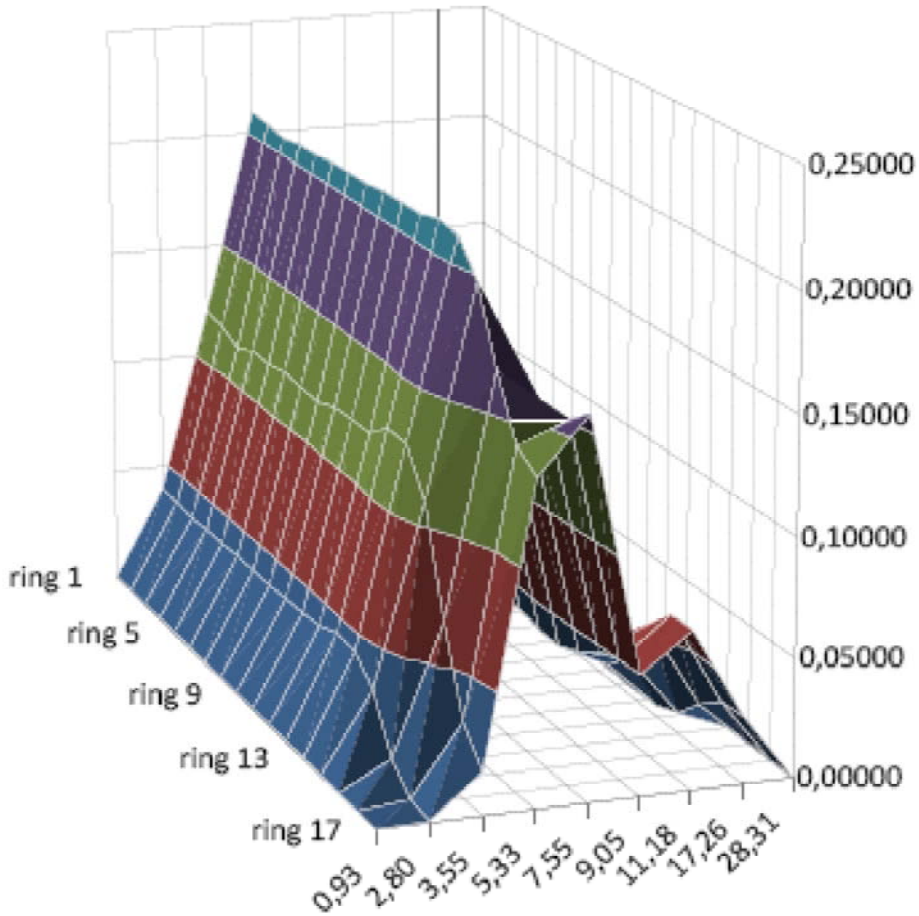

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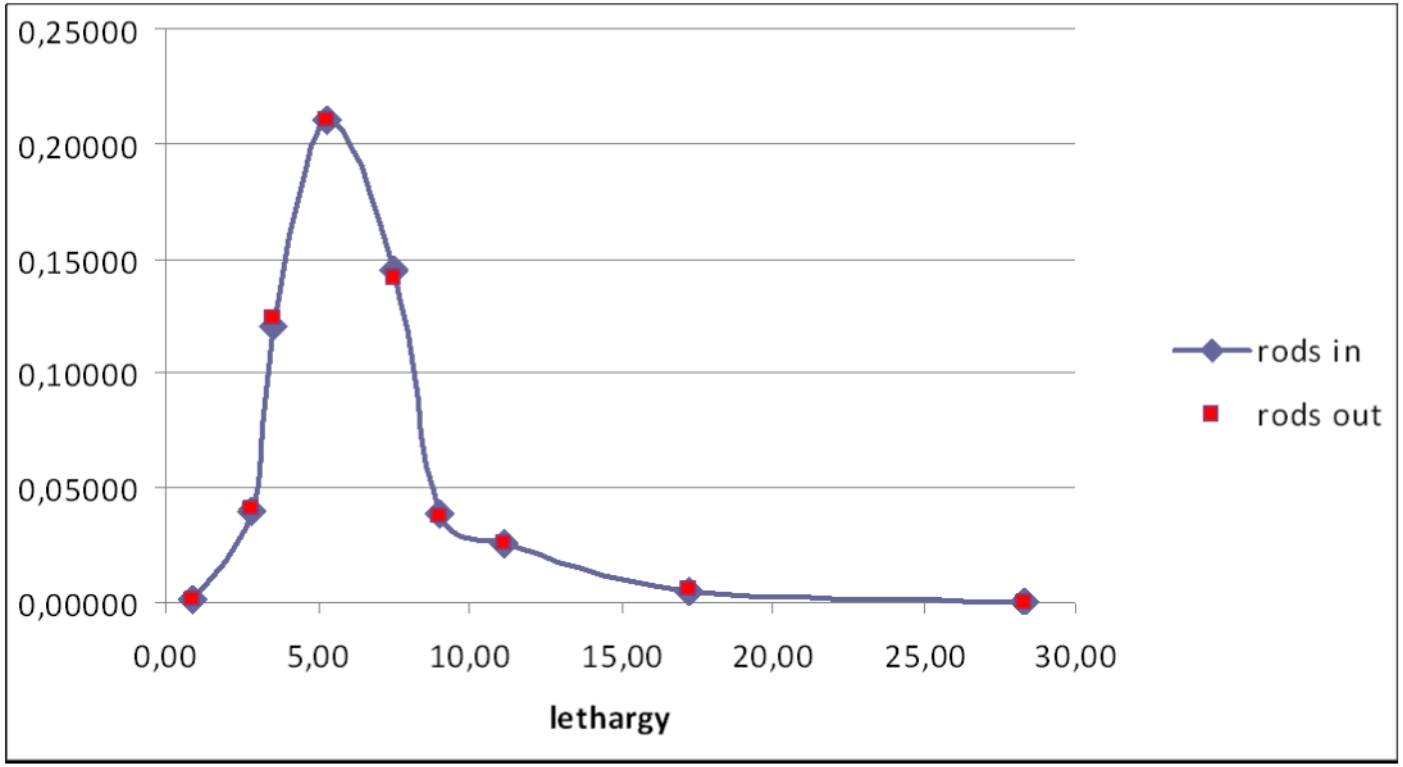
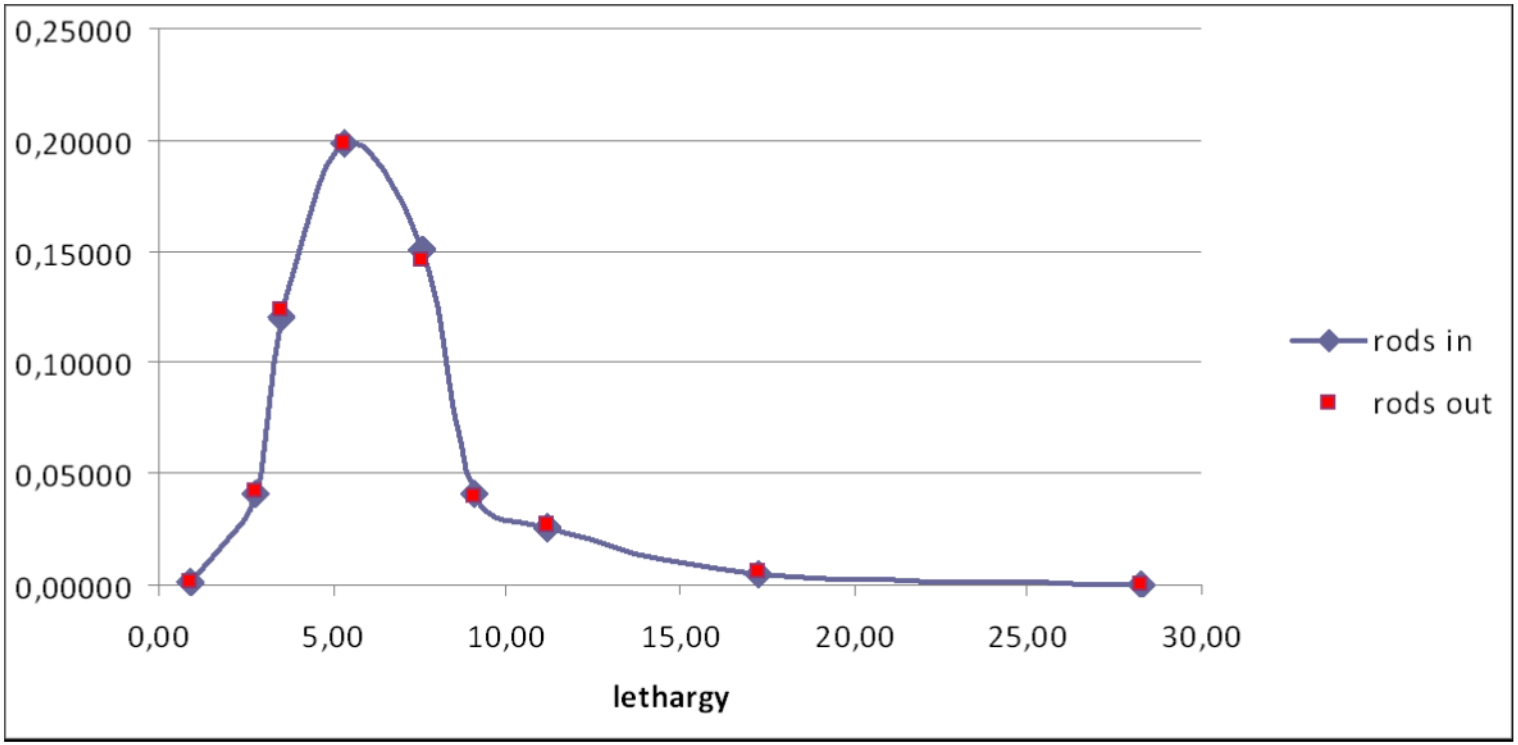


KIKO3D solution, core averaged lethargy dependent spectra for the large oxide core



Foreseen development

Supplementing the KIKO3D results, e.g. with the Doppler coefficient

1963 group transport calculation of the heterogeneous assembly

Burnup and isotopic composition calculation by KIKO3D

In case of necessity, revision of the KENO power estimation

UTPOP and ULOF transient calculations by KIKO3D