Cambridge University, UK

SERPENT users meeting

Sep, 2014

IAEA 10 MW_{th} MTR benchmark static calculation with SERPENT code

Presented: Marat Margulis

Yaniv Shaposhnik

Supervised by: Dr. Erez Gilad

Outline

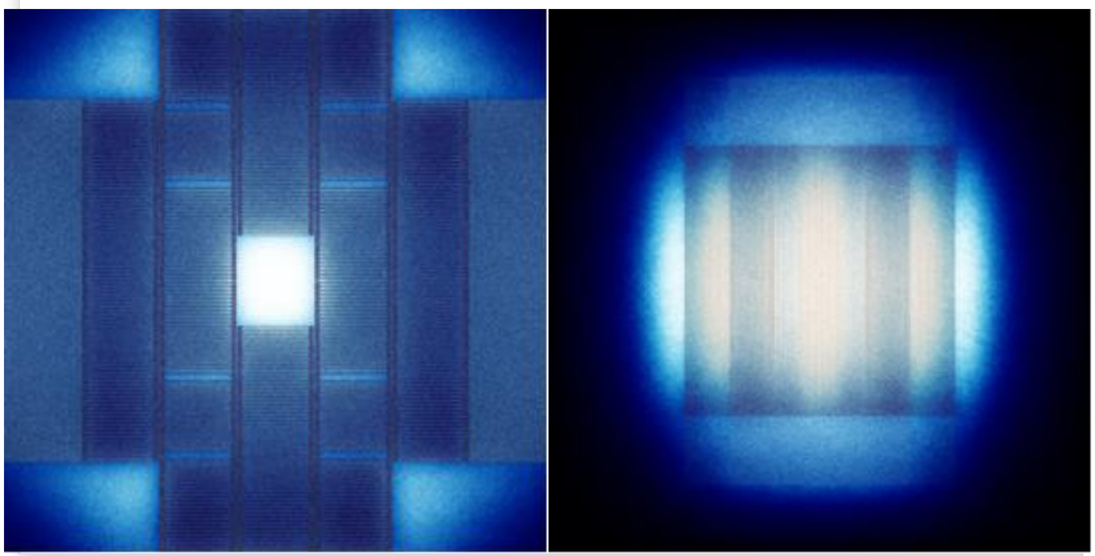
- Motivations and objectives
- IAEA Benchmark
- Steady-State results verification
- Summary

Motivations and objectives

- **Research Reactor core modeling lack of knowledge**
  - Predict the core performance in normal and accident states
    - e.g. fuel temperature (melting), criticality
  - Full core MC simulations are time and resource consuming
  - MC transient calculations – out of reach
- **The goal of this project is to**
  - Develop a general tool which will be accurate and also relatively fast for RR modeling
  - Therefore, the SERPENT-DYN3D sequence is developed
    - Validated against data taken from the IAEA benchmark

IAEA Benchmark

- 10 MW light water pool type MTR
  - Research Reactor core for conversion of HEU to LUE
- Provides a detailed MTR specifications
  - Steady-state neutronic kinetics and thermohydraulic
  - Several accident scenarios



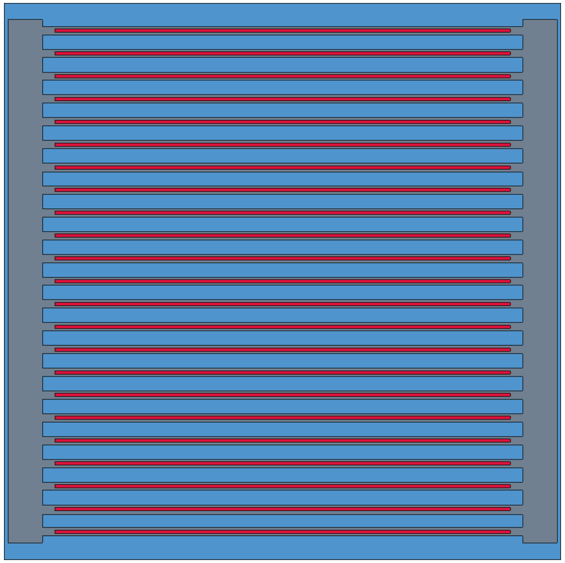
water	graphite	graphite	graphite	graphite	water
water	Fuel BOL 5% EOL 10%	Fuel BOL 25% EOL 30%	Fuel BOL 25% EOL 30%	Fuel BOL 5% EOL 10%	water
Fuel BOL 5% EOL 10%	Control BOL 25% EOL 30%	Fuel BOL 45% EOL 50%	Fuel BOL 45% EOL 50%	Control BOL 25% EOL 30%	Fuel BOL 5% EOL 10%
Fuel BOL 25% EOL 30%	Fuel BOL 45% EOL 50%	Fuel 45% 50% / H_2O + Al	Fuel 45% 50%	Fuel BOL 45% EOL 50%	Fuel BOL 25% EOL 30%
Fuel BOL 5% EOL 10%	Fuel BOL 25% EOL 30%	Fuel BOL 45% EOL 50%	Fuel BOL 45% EOL 50%	Fuel BOL 25% EOL 30%	Fuel BOL 5% EOL 10%
water	Fuel BOL 5% EOL 10%	Control BOL 25% EOL 30%	Fuel BOL 25% EOL 30%	Control BOL 5% EOL 10%	water
water	graphite	graphite	graphite	graphite	water

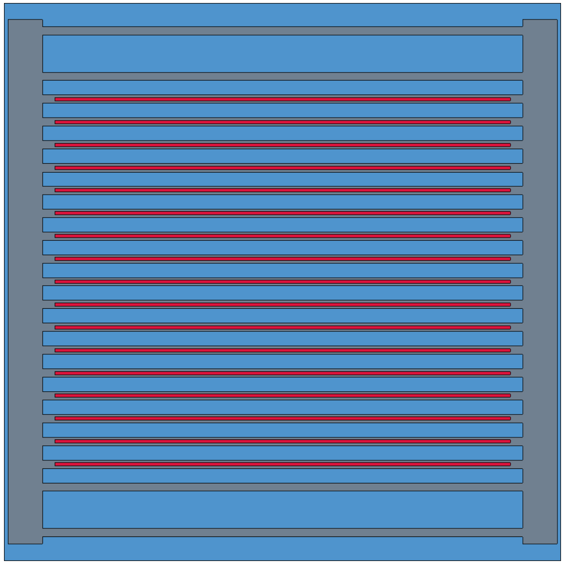
7.7 cm

8.1 cm

IAEA MTR core

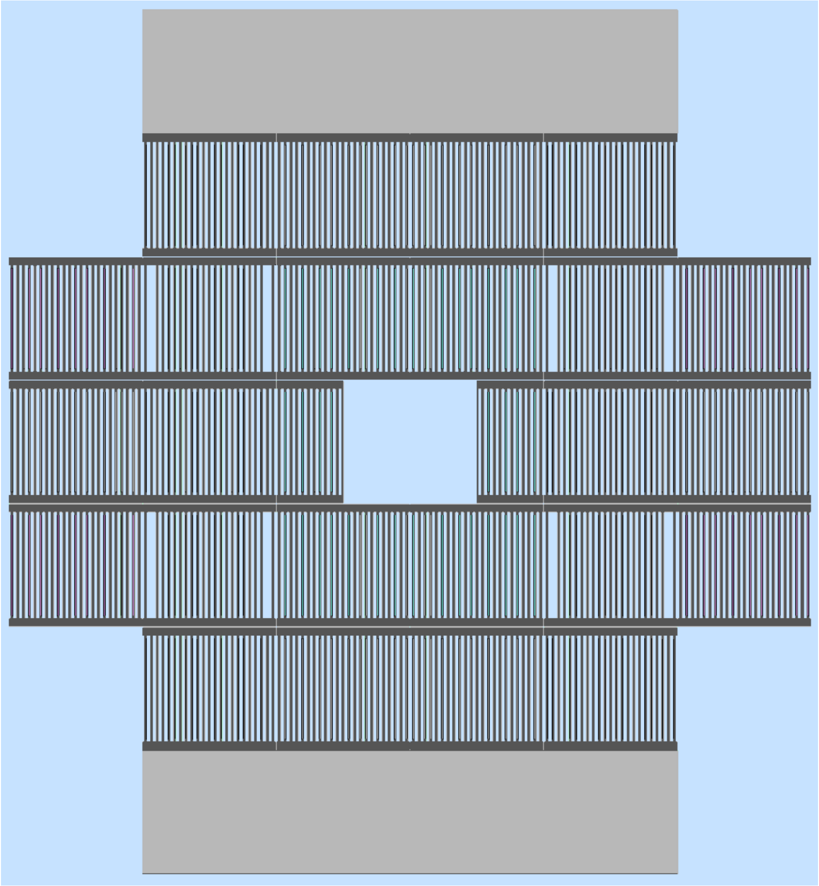
- Core grid – 6x5
  - 21 fuel assembly
    - 23 fuel plates
  - 4 control assembly
    - 17 fuel plates
- Core active length – 60 cm
- Axial reflector – 15 cm
  - 20% - Al
  - 80% - H_2O
- Radial reflector - Graphite



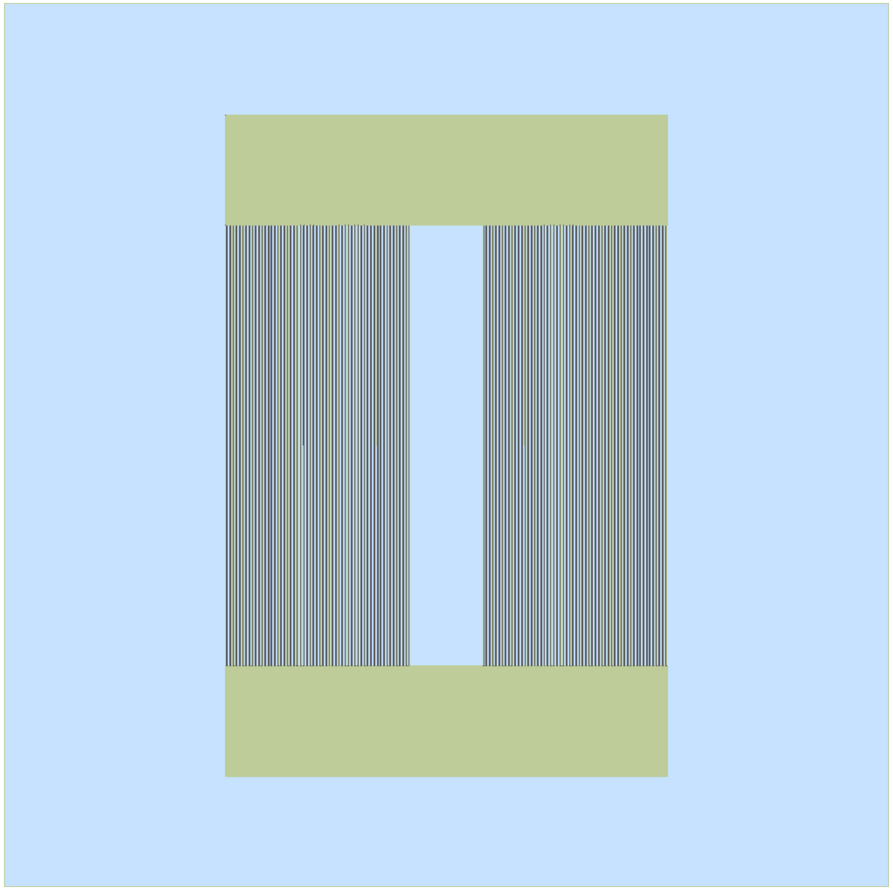


IAEA MTR core

Radial Geometry

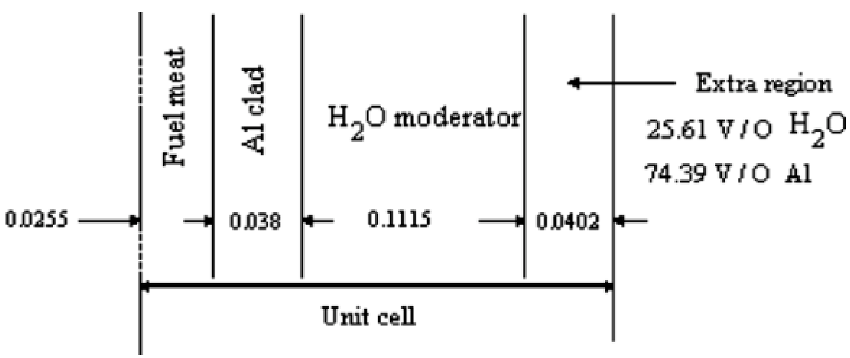


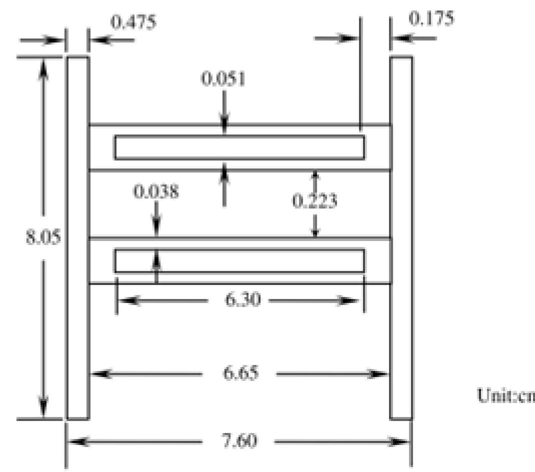
Axial Geometry



BU calculation

- The results obtained from SERPENT were compared to those obtained by WIMS-D4 and ANL Benchmark
  - Calculations performed on an unit cell configuration (IAEA-TECDOC, 1980)

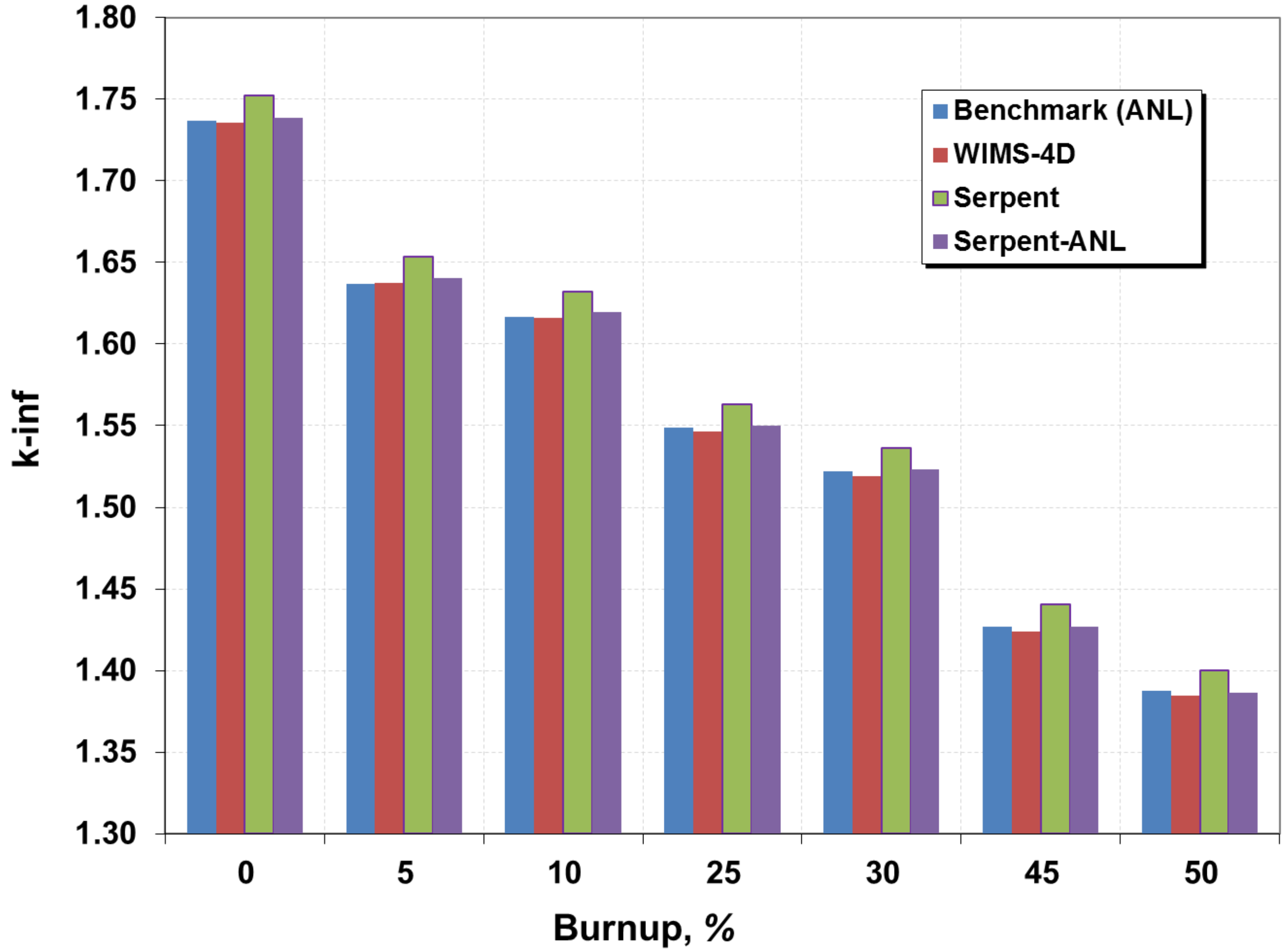




  - The simulation was performed both for HEU and LEU

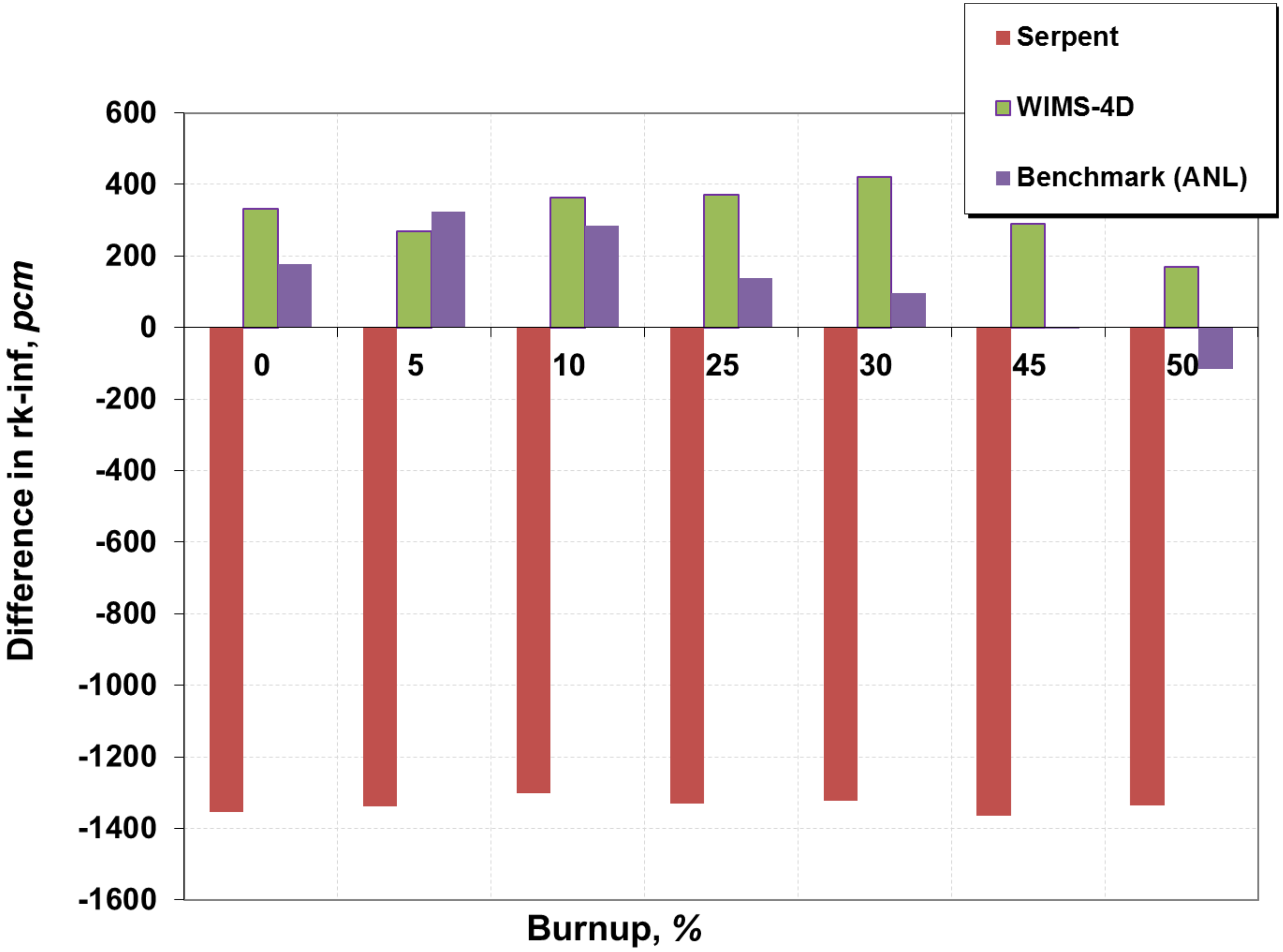
BU fuel element calculations - Results

HEU k-inf



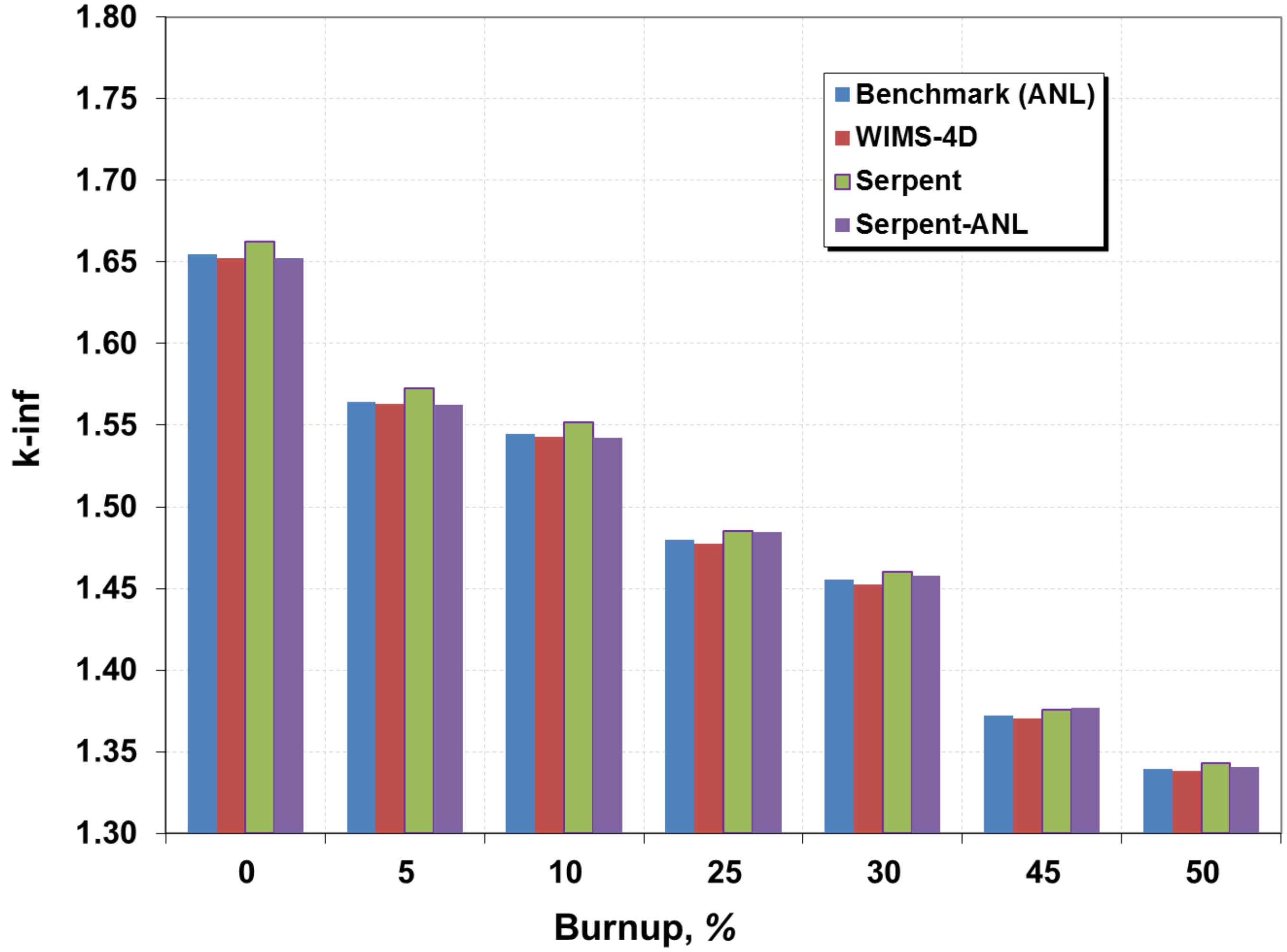
BU fuel element calculations - Results

HEU Difference in k-inf



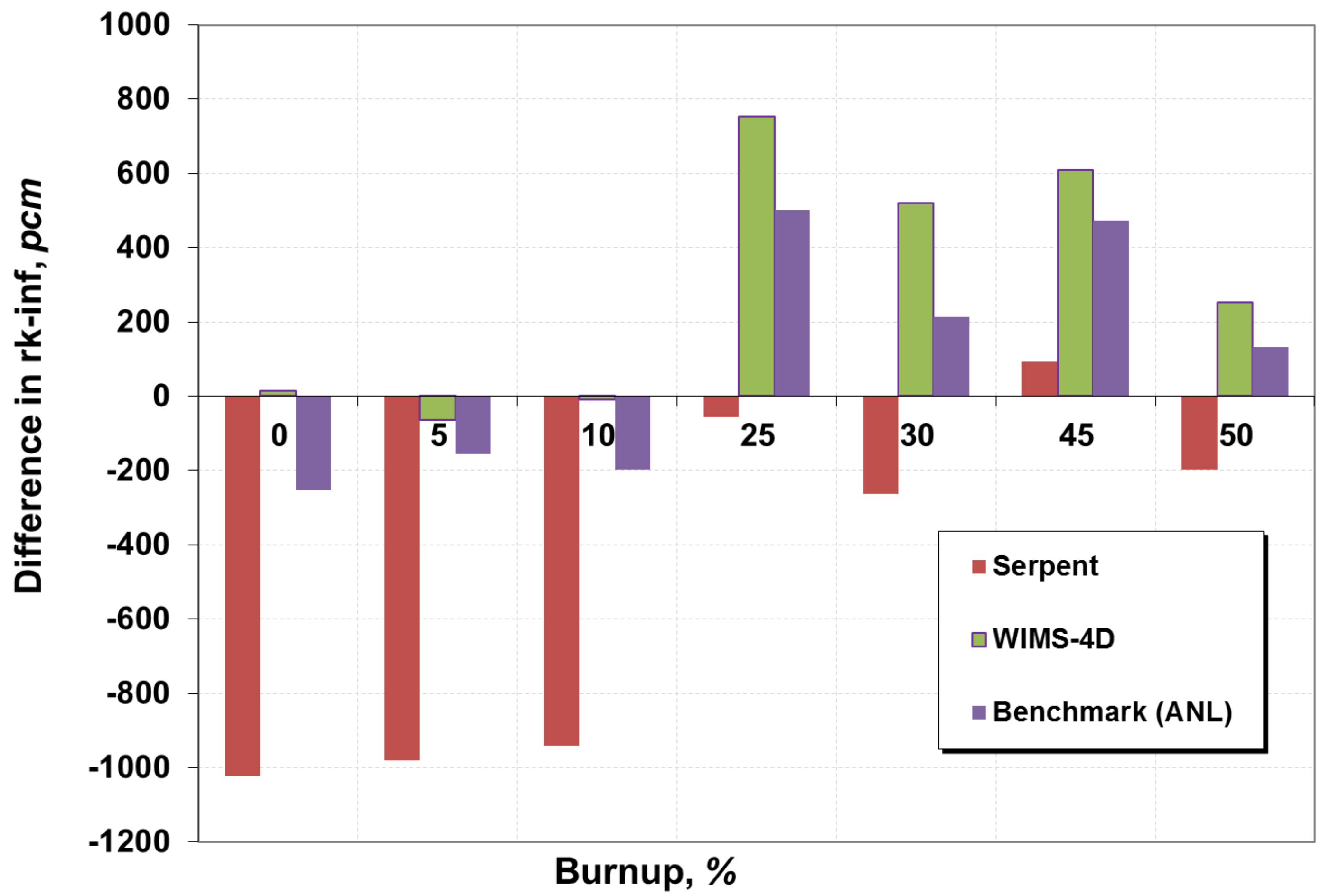
BU fuel element calculations - Results

LEU k-inf



BU fuel element calculations - Results

LEU Difference in k-inf



BU fuel element calculations - Results

- The next table present the atom densities in HUE fuel as a function of BU

Burnup (%)	U^{235}			U^{238}		
	Benchmark (ANL)	WIMS-4D	SERPENT	Benchmark (ANL)	WIMS-4D	SERPENT
0	1.61790E-03	1.61790E-03	1.6179E-03	1.20200E-04	1.20200E-04	1.2020E-04
5	1.53701E-03	1.53702E-03	1.5376E-03	1.19729E-04	1.19754E-04	1.1975E-04
10	1.45612E-03	1.45612E-03	1.4557E-03	1.19231E-04	1.19282E-04	1.1927E-04
25	1.21342E-03	1.21342E-03	1.2119E-03	1.17684E-04	1.17757E-04	1.1780E-04
30	1.13254E-03	1.13253E-03	1.1317E-03	1.17146E-04	1.17251E-04	1.1729E-04
45	8.89845E-04	8.89840E-04	8.8870E-04	1.15456E-04	1.15574E-04	1.1573E-04
50	8.08949E-04	8.08948E-04	8.0772E-04	1.14857E-04	1.15010E-04	1.1518E-04

  - The same behavior was spotted in all the benchmark cases

Core criticality result

- A fuel MTR calculation was carried out in SERPENT
  - The results were checked vs. previous calculation

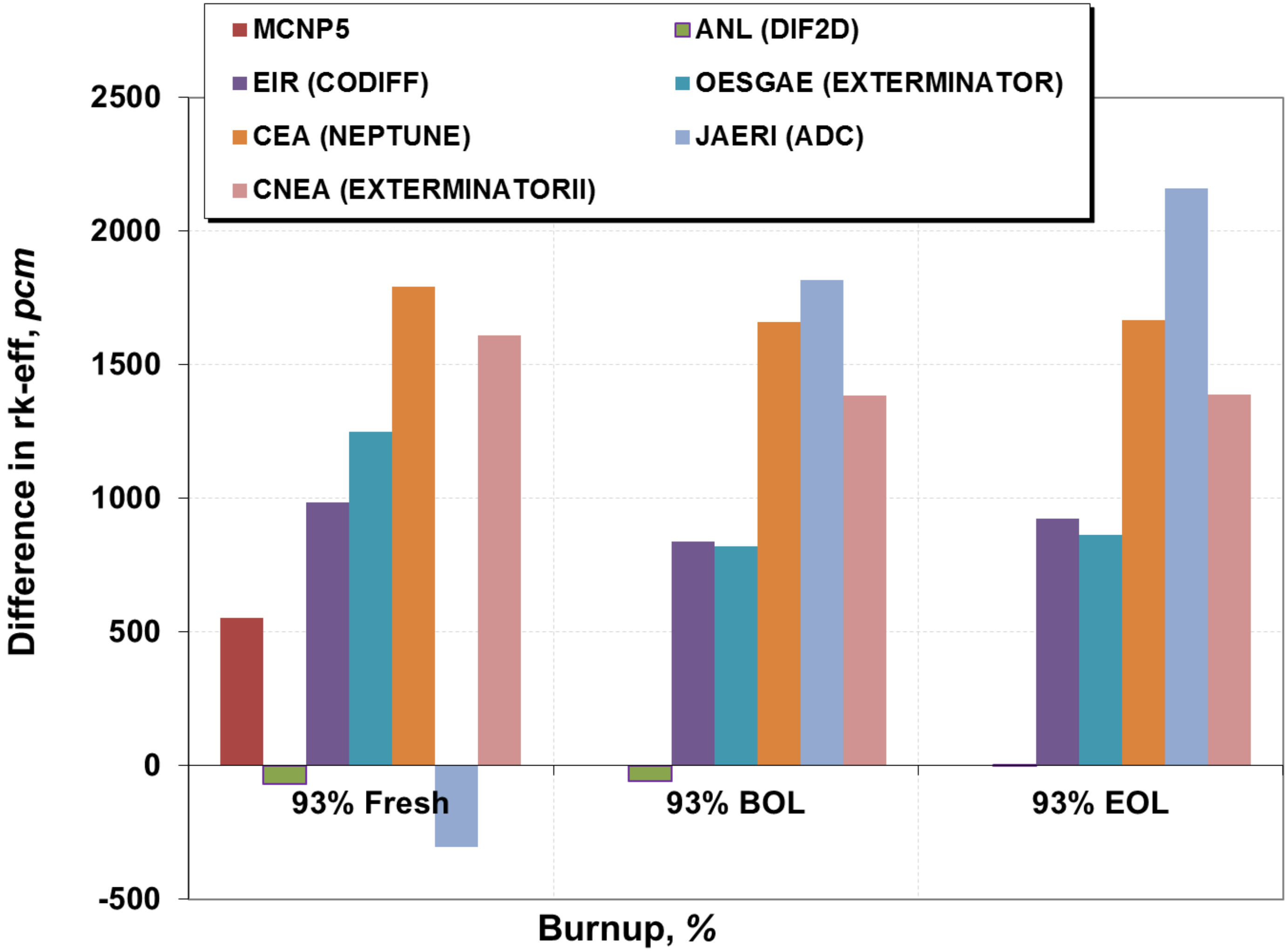
Organization (code)	93% Fresh	93% BOL	93% EOL	20% Fresh	20% BOL	20% EOL
SERPENT (ENDF-VII)	1.18410±0.00023	1.02381±0.00016	1.00037±0.00017	1.16636±0.00016	1.02003±0.00027	0.999156±0.00017
MCNP5	1.18962±0.00034	*	*	1.17238±0.00033	*	*
ANL (DIF2D)	1.18343	1.0232333	1.00038	1.1683	1.02127	1.00142
EIR (CODIFF)	1.1939413	1.032204	1.009607	1.15937	1.010724	0.992637
OESGAE (EXTERMINATOR)	1.1966	1.032	1.009	1.1813	1.032	1.012
CEA (NEPTUNE)	1.202	1.04041	1.01703	1.187	1.0394	1.01913
JAERI (ADC)	1.18104	1.04199	1.02195	1.18339	1.05782	1.04122
CNEA (EXTERMINATORII)	1.20018	1.03765	1.01425	1.1815	1.03316	1.013

* Data not available

  - The results obtained from SERPENT are in a good agreement with the result presented in the IAEA benchmark (ANL)

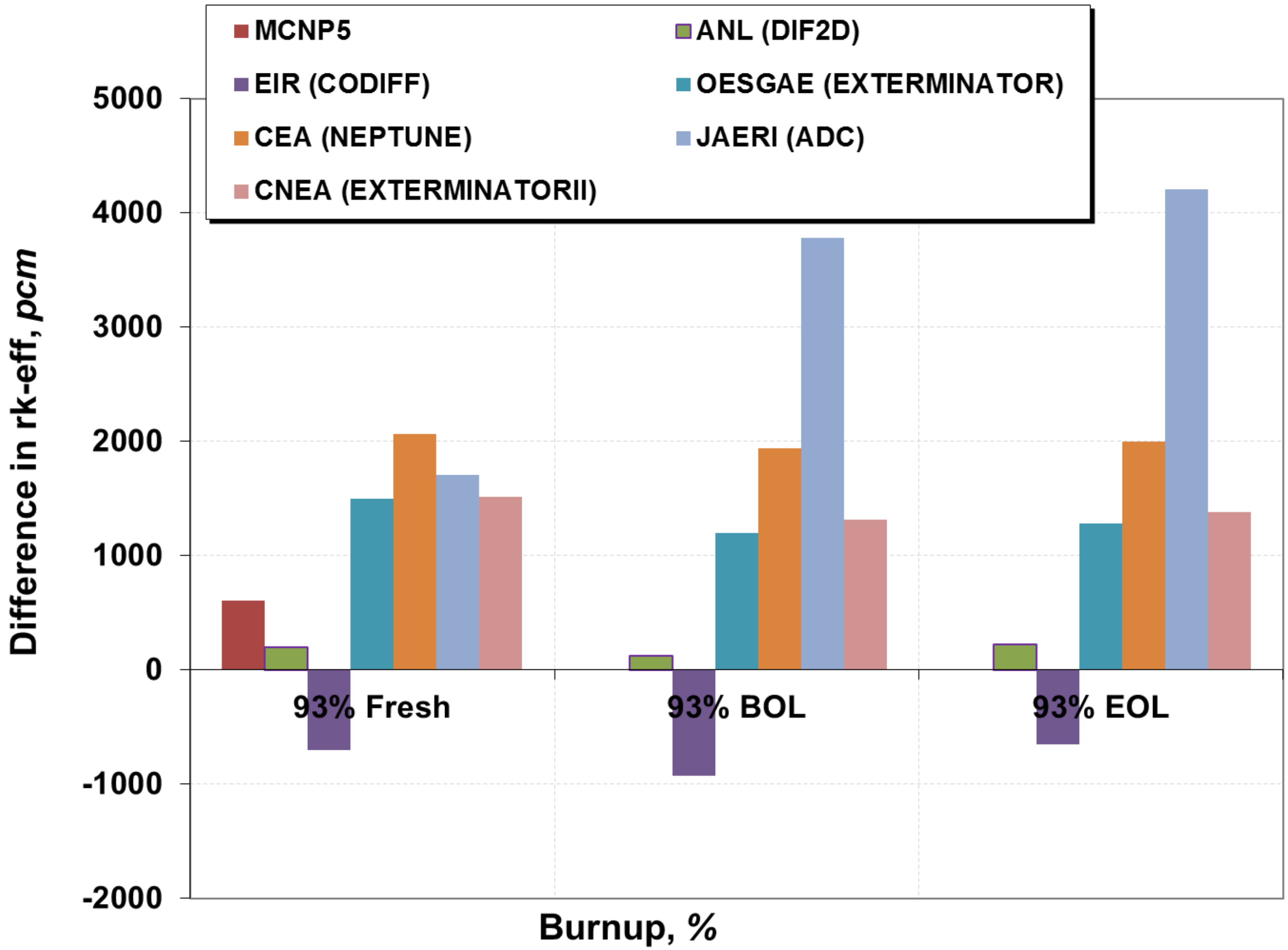
Core criticality result

HEU Difference in k-eff



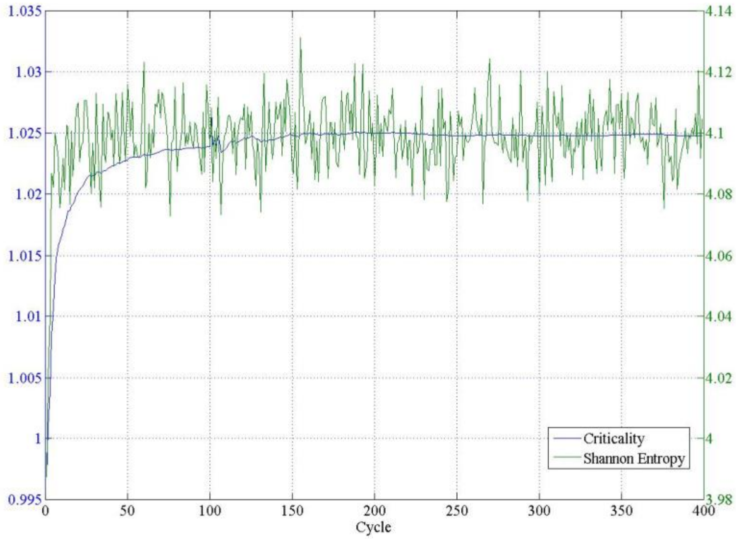
Core criticality result

LEU Difference in k-eff

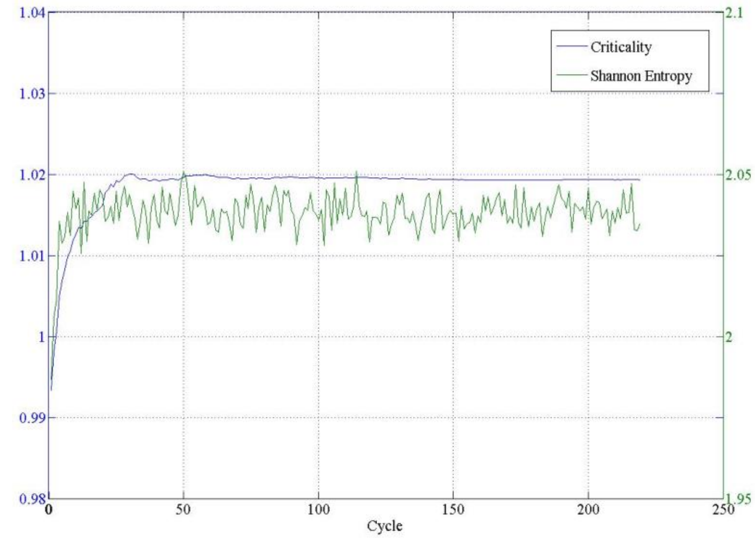


Core criticality result

- In order to verify that the results are not influenced by a statistical error
  - This was performed by the built in SERPENT option of Shannon Entropy verification



HUE

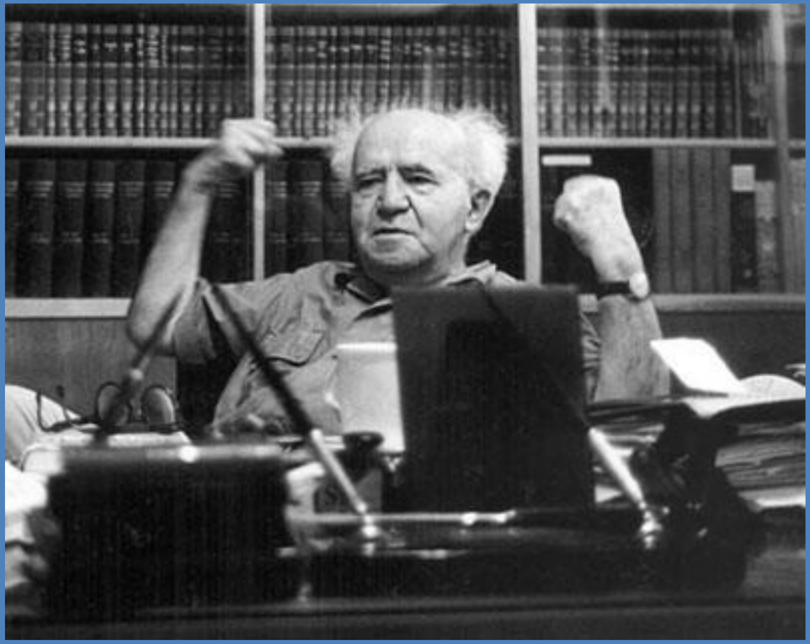


LUE

Summary

- Demonstrate the capabilities of SERPENT in MTR analysis
- IAEA 10 MW_{th} MTR core was examined
  - Good agreement on XS, ND & eigenvalues on assembly as well as core level (ANL)
- Future – Develop a general tool to accurately model MTR
  - Steady-state
  - Transients
- DYN3D - SERPENT simulation sequence

Thank you for your attention



Flux distribution

- The flux distribution obtained from SERPENT correspond to the one obtained in MCNP 5 calculation
  - Thermal flux in presented at the images below

    (left – SERPNET, right – MCNP5)