KHMELNITSKI VVER-1000 benchmark

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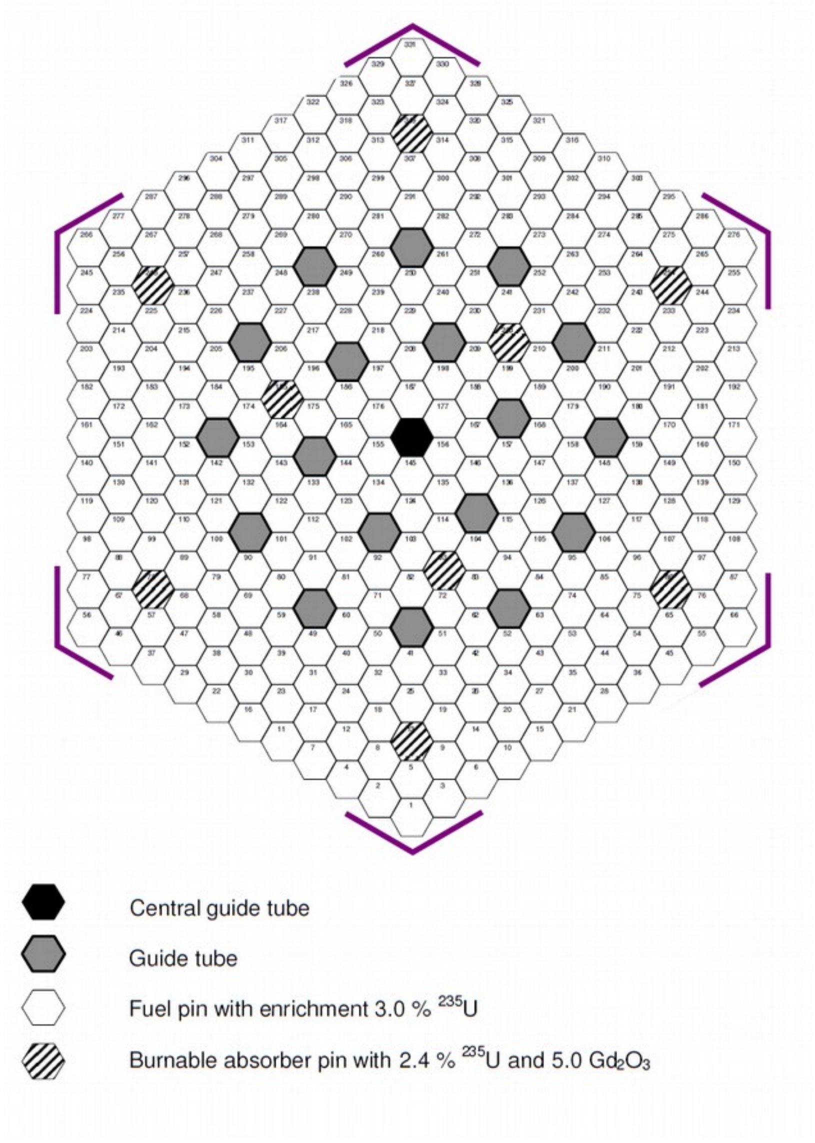
Fuel assembly

- VVER 1000 V-320

Table 1: The fuel assembly parameter summary

Fa design	FA type	Enrichment (w/o %)	No. of UO2 pins / enrichment	Number of Gd-pins (w/o Gd2O3/235U)
TVSA	13AU	1.3	312 / 1.30	–
TVSA	22AU	2.2	312 / 2.20	–
TVSA	30AV5	2.99	303 / 3.00	9 (5.0/2.4)
TVSA	39AWU	3.9	243 / 4.00; 60 / 3.60	9 (5.0/3.3)
TVSA	390GO	3.9	240 / 4.00; 66 / 3.60	6 (5.0/3.3)
TVSA	398GO	3.99	306 / 4.40	6 (5.0/3.3)
TVSA	430GO	4.3	240 / 4.40; 66 / 4.00	6 (5.0/3.6)
TVSA	439GT	4.39	306 / 4.40	6 (5.0/3.6)



Calculation setting

- 2D model, infinite lattice
- 1 000 000 neutrons per cycle, 125 active cycles and 25 inactive cycles

Table 2: Names and setting of all Serpent calculations

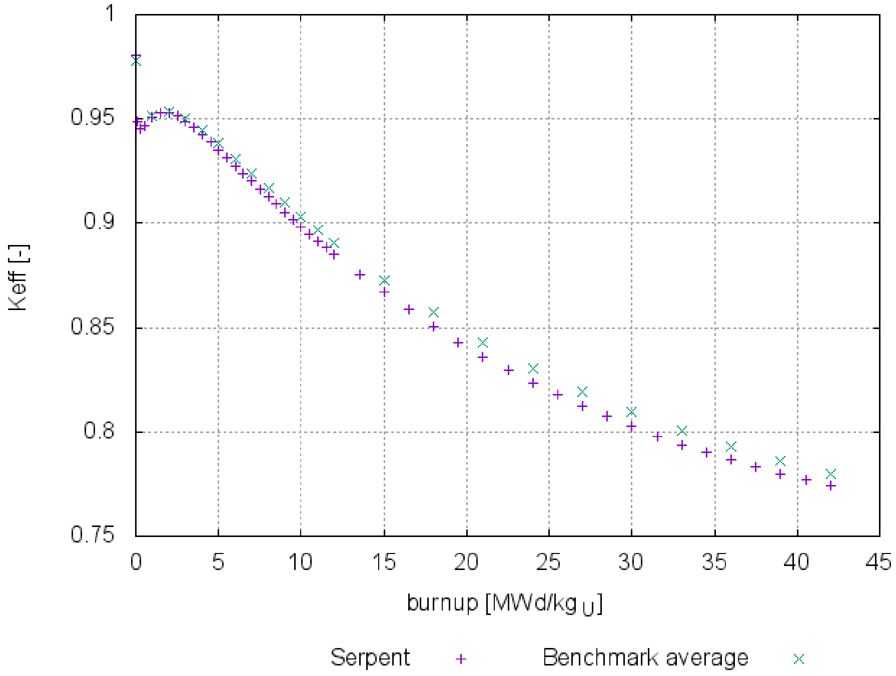
Setup name	pin by pin burnup seuence	libraries	# radila Gd regions
Nominal	no	ENDF/B-VII	6
PinBu	yes	ENDF/B-VII	6
JEFF	no	JEFF3.1.1	6
1reg	no	ENDF/B-VII	1

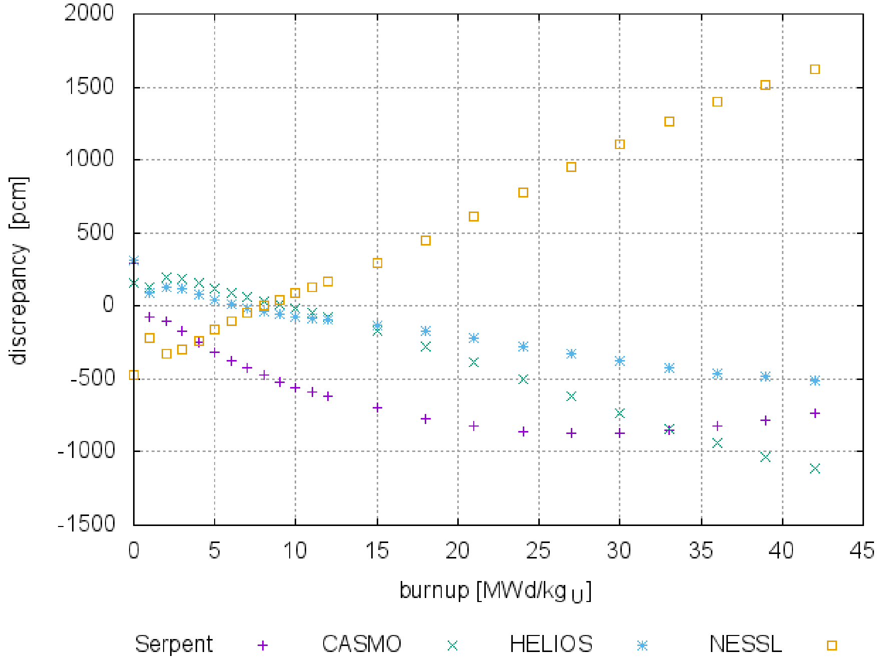
Results

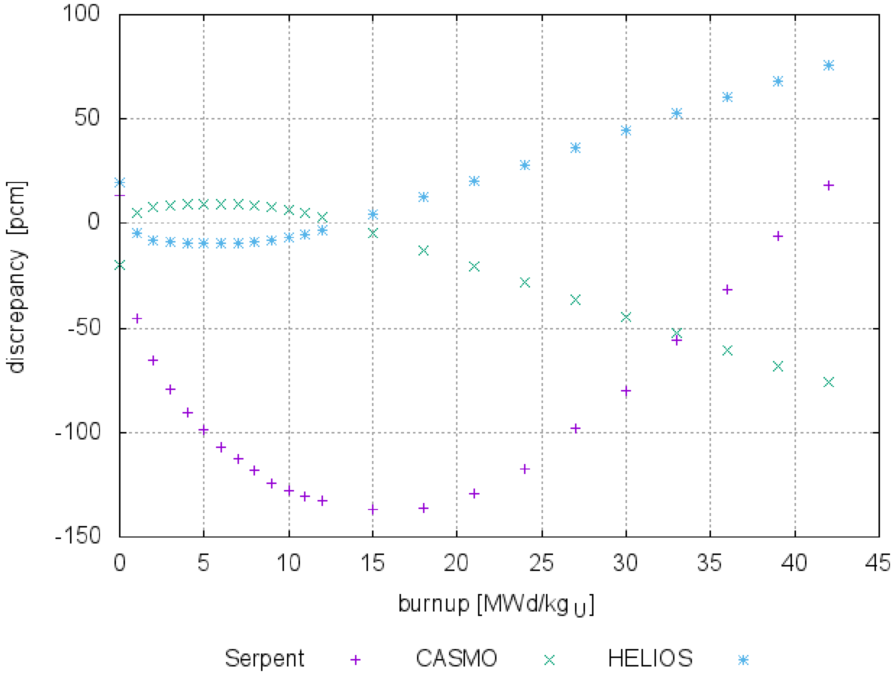
- Two main characteristic parameters were studied and compared with the published benchmark data
    1. Keff
    2. Isotopic concentration of selected isotopes

13av keff

- The Keff figure shows the keff behavior during burnup
- The discrepancy figures shows detail differences in keff for different codes
- The discrepancy figure without NESSEL shows the difference in results if compared with the average value based only on the CASMO and the HELIOS code
- NESSEL results differ from all other code results

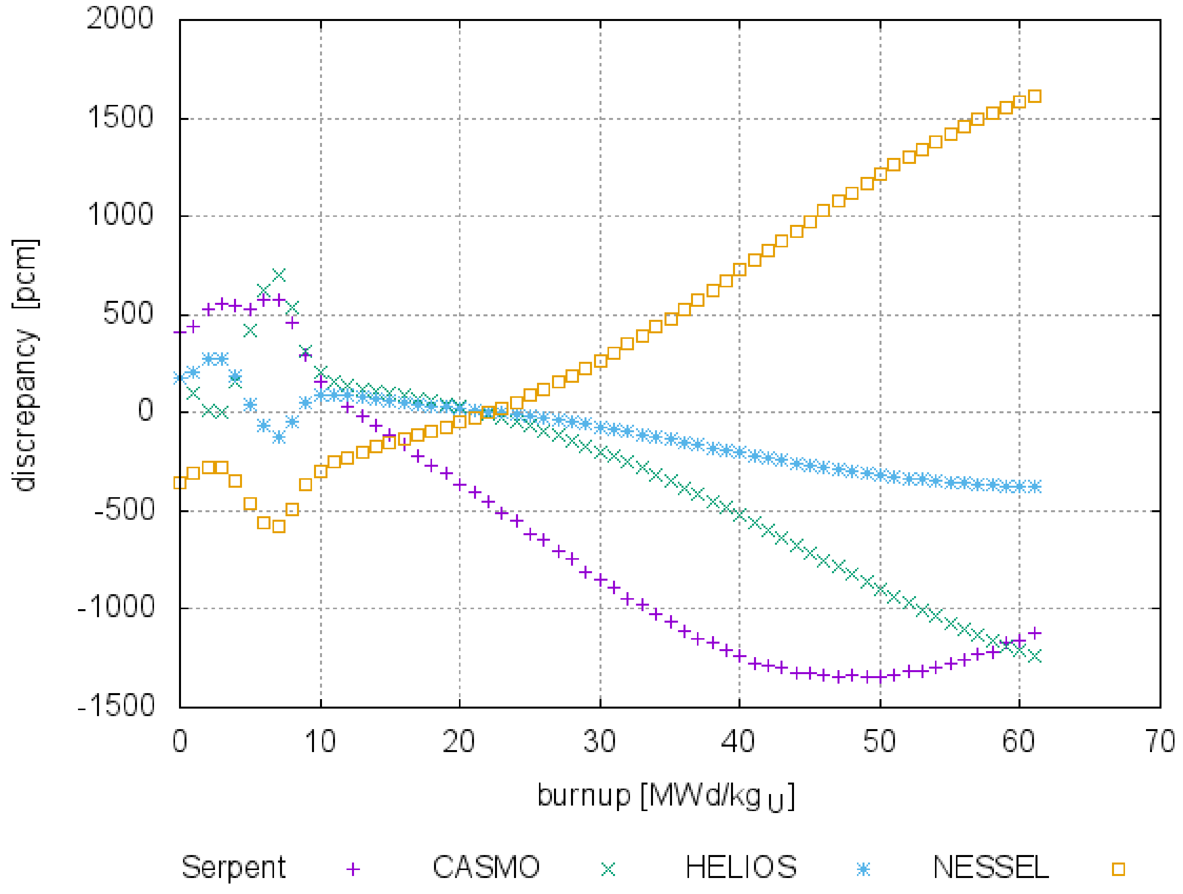


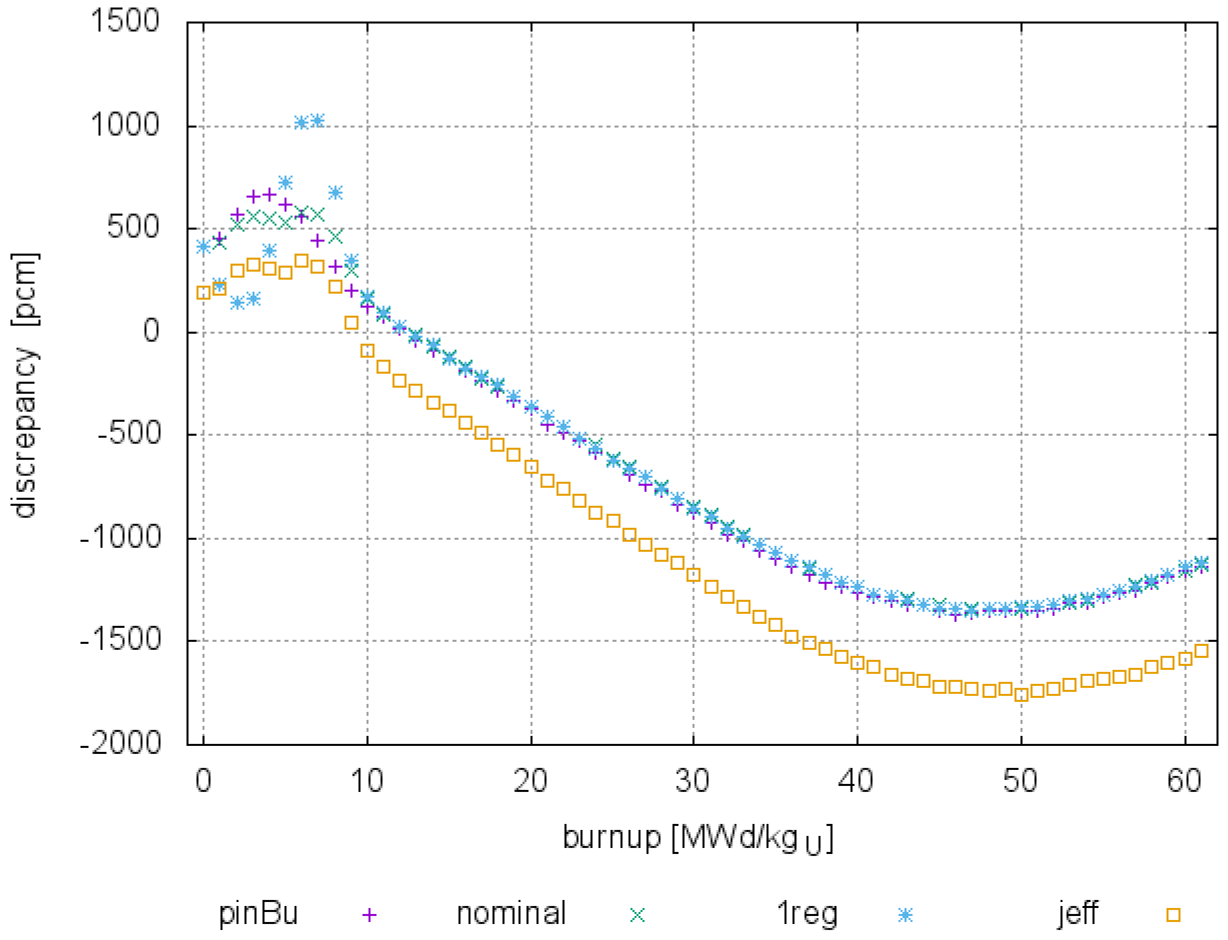




30av5 keff

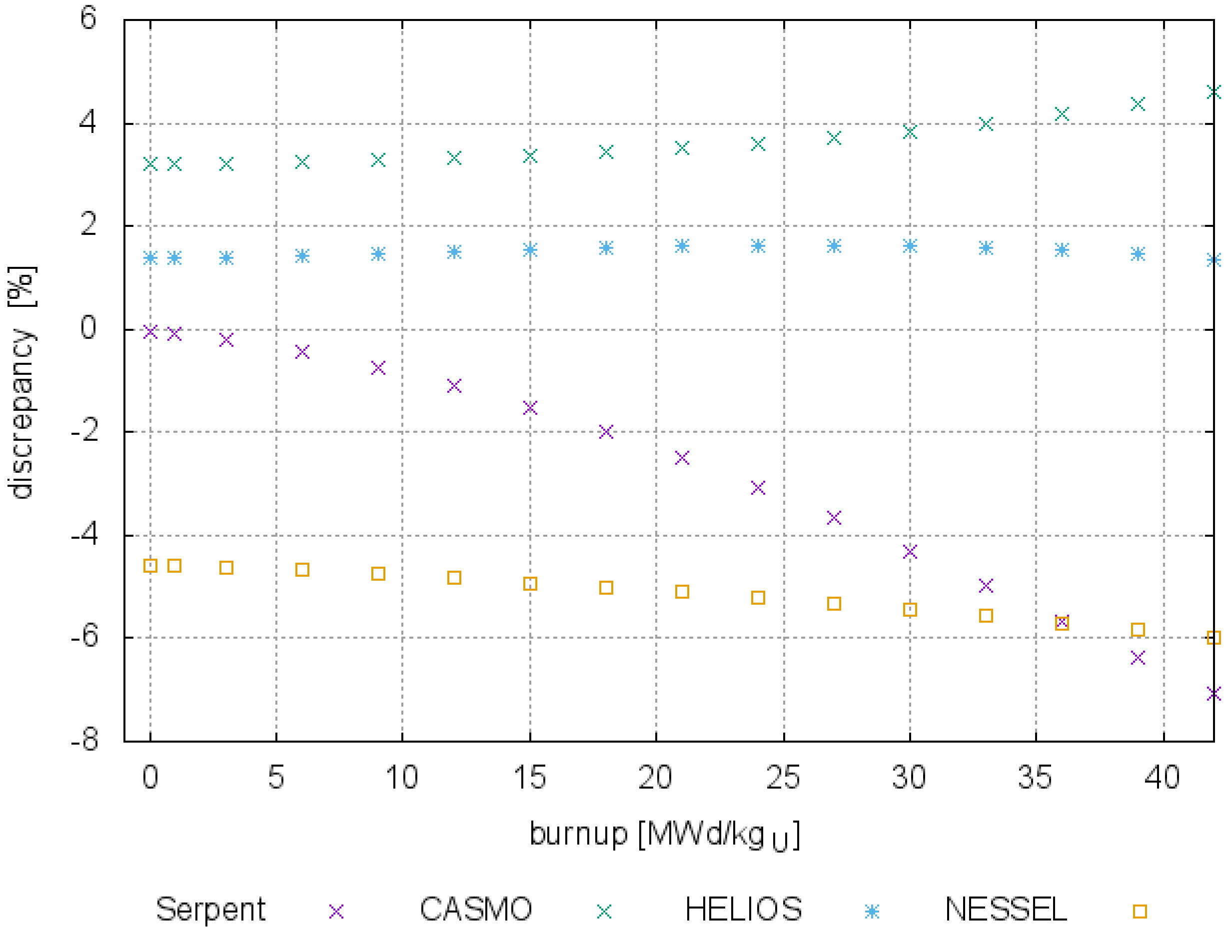
- The keff discrepancy figures for the fuel assembly containing gadolinium pins
- The discrepancy is based on the benchmark average (CASMO, HELIOS and NESSEL)

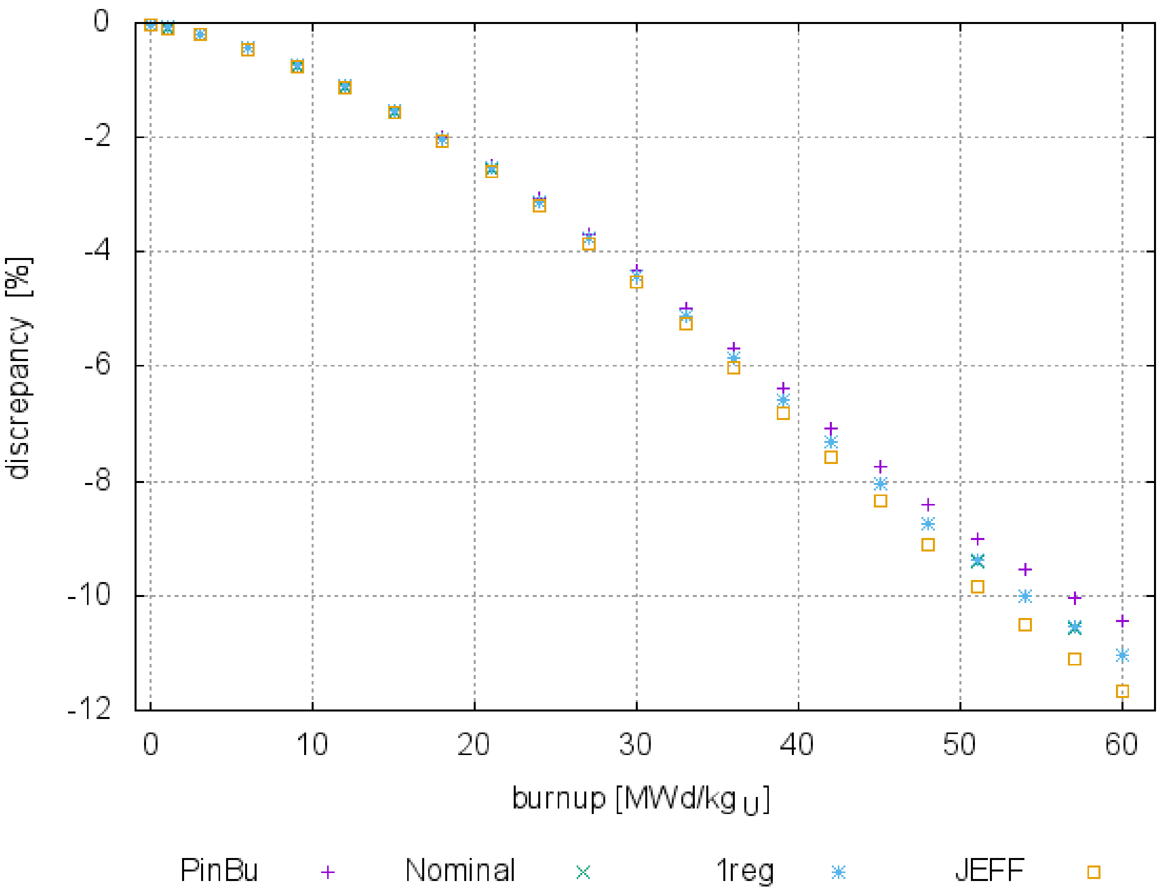




30av5 –U 235

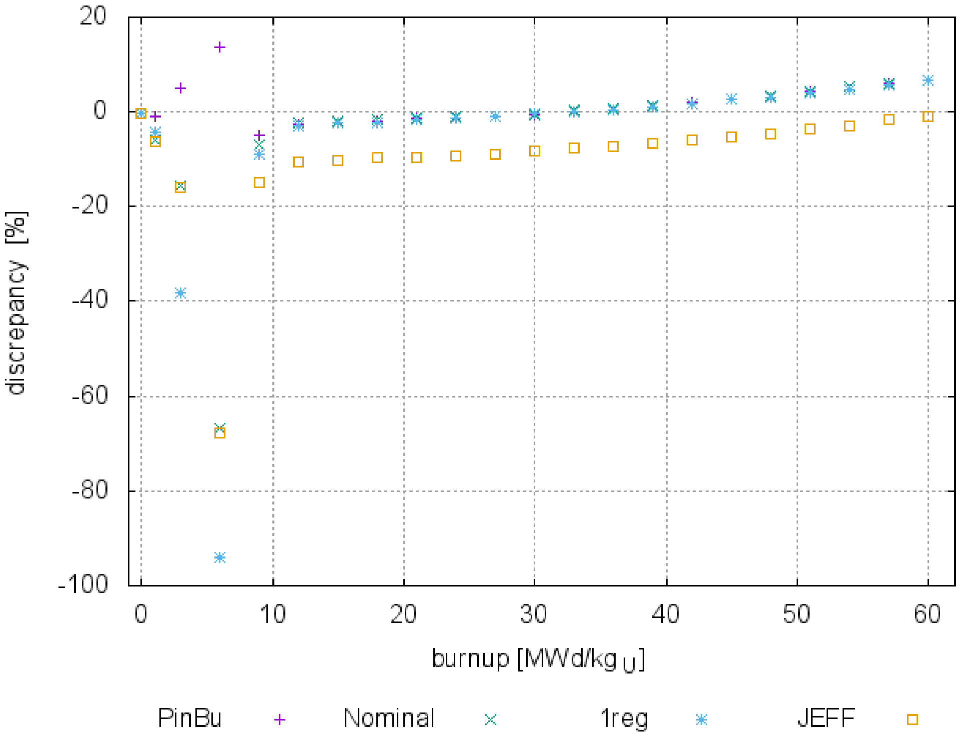
- The isotopic concentration discrepancy figures presents the behavior of the ^{235}U during burnup in the 30av5 fuel assembly
- The discrepancy is based on the benchmark average (CASMO, HELIOS and NESSEL)

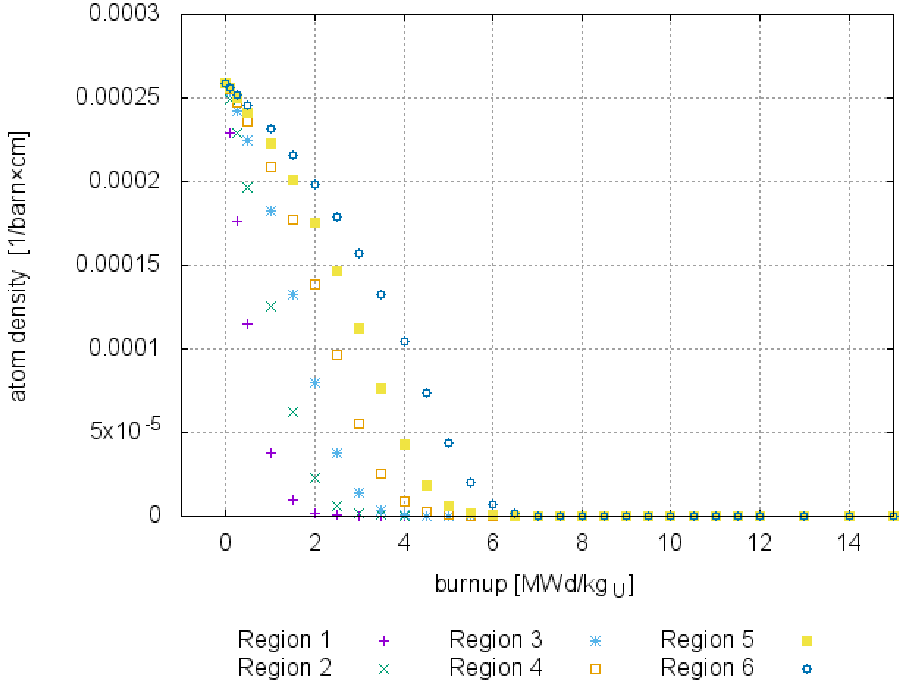


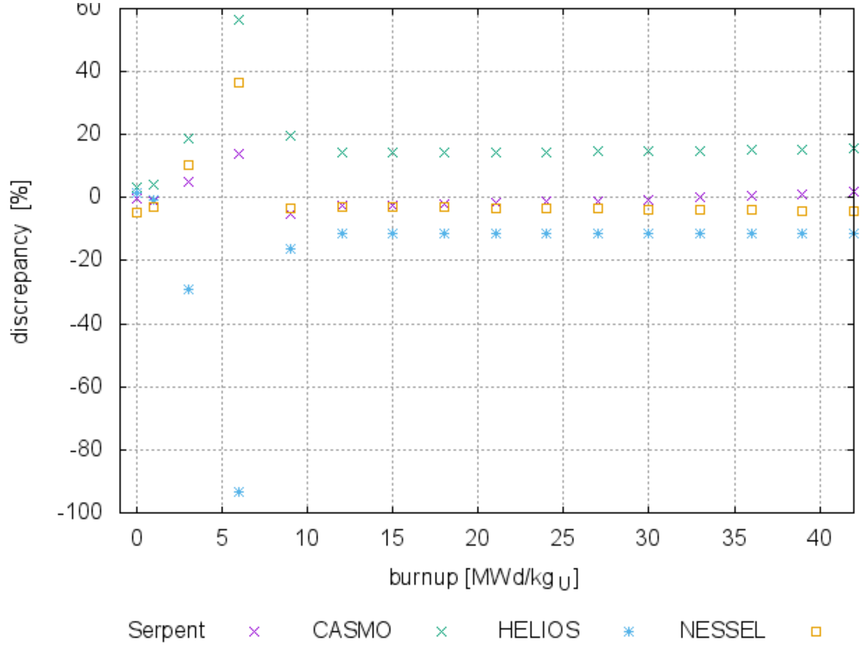


30av5 – Gd 157

- The isotopic concentration discrepancy figures presents the behavior of the ^{157}Gd during burnup in the 30av5 fuel assembly
- The figure below shows the importance of more radial regions in gadolinium pins
- The discrepancy is based on the benchmark average (CASMO, HELIOS and NESSEL)

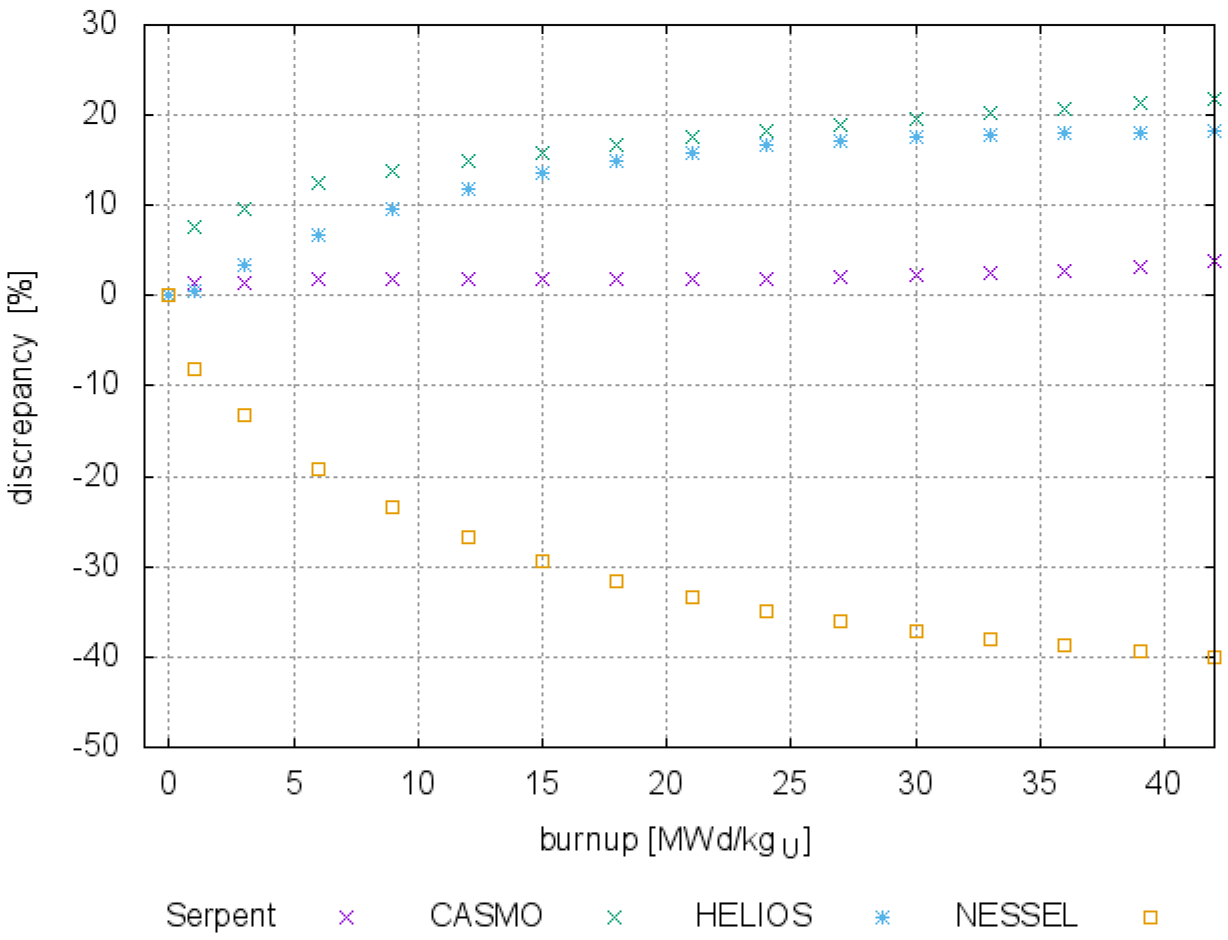


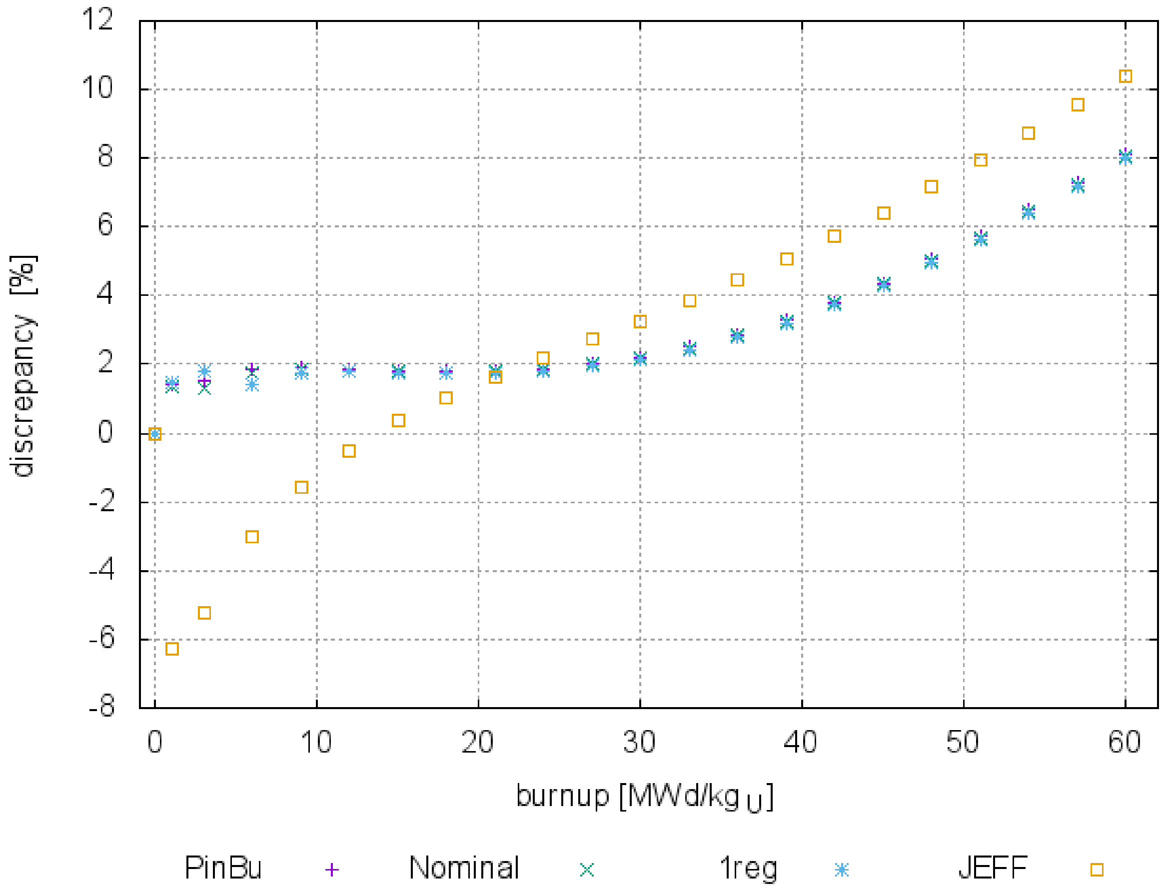




30av5 – Sm149

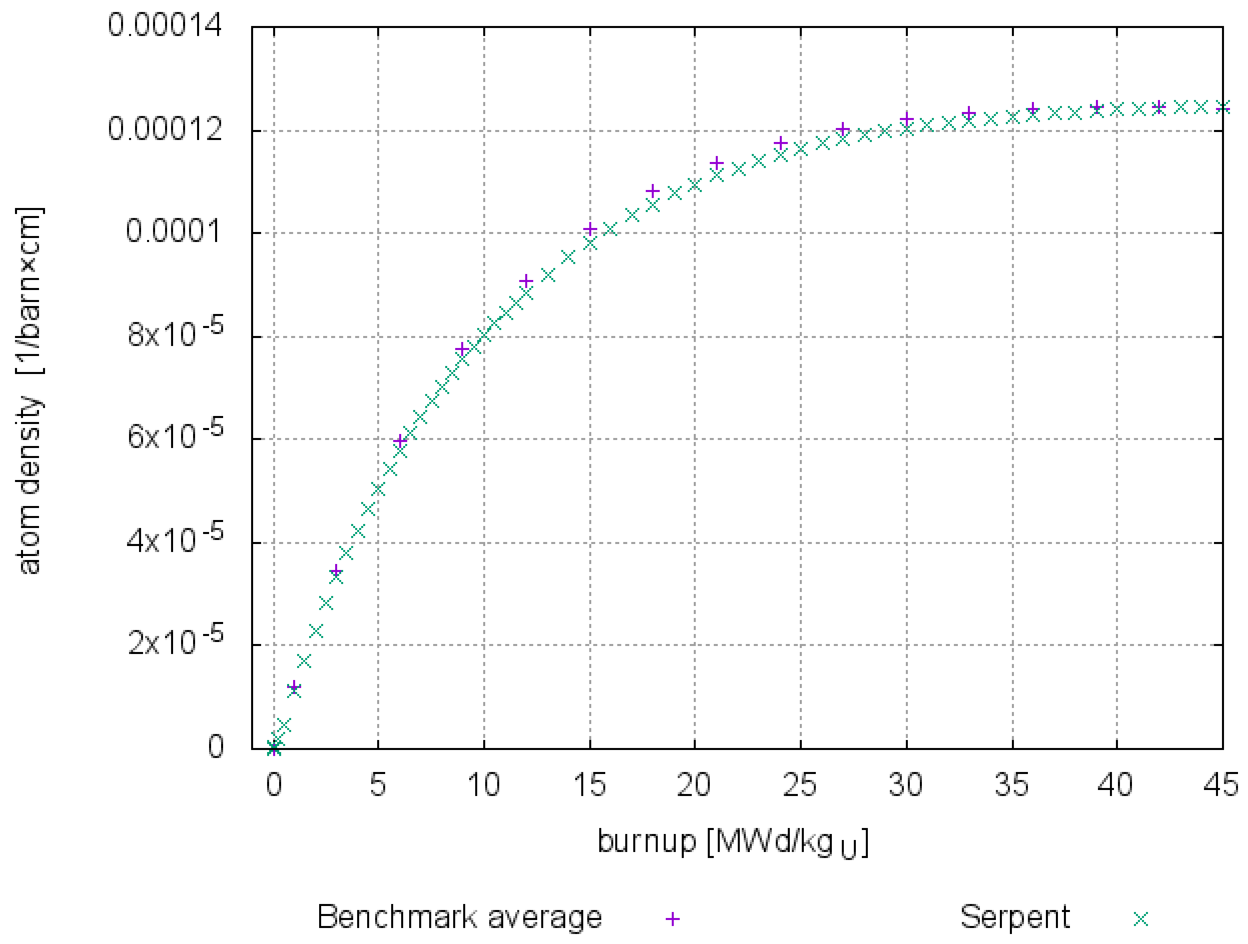
- The isotopic concentration discrepancy figures presents the behavior of the ^{149}Sm during burnup in the 30av5 fuel assembly
- The figures show that except NESSEL code, all code results are similar, and that the library selection impact significantly the results
- The discrepancy is based on the benchmark average (CASMO, HELIOS and NESSEL)

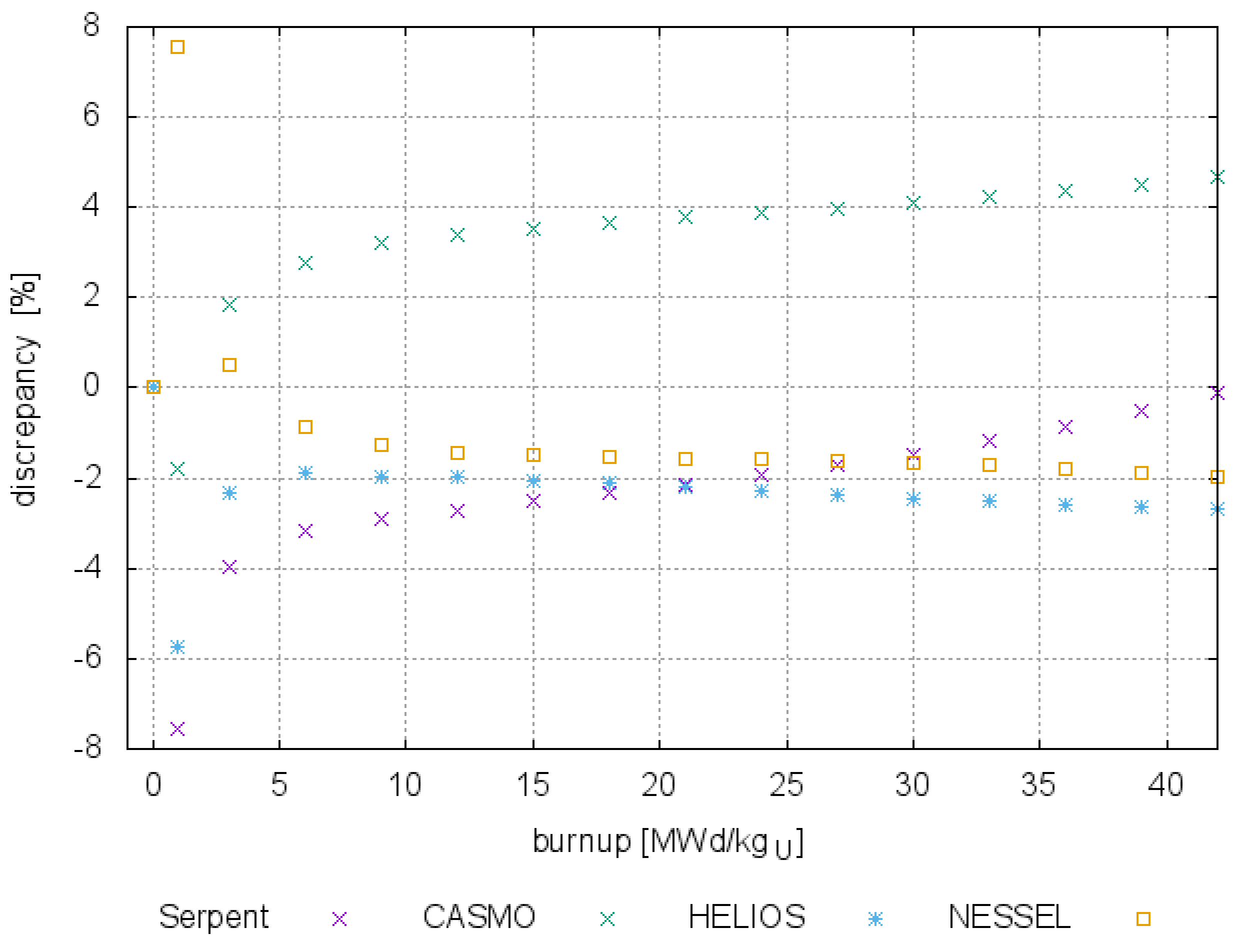




Pu 239

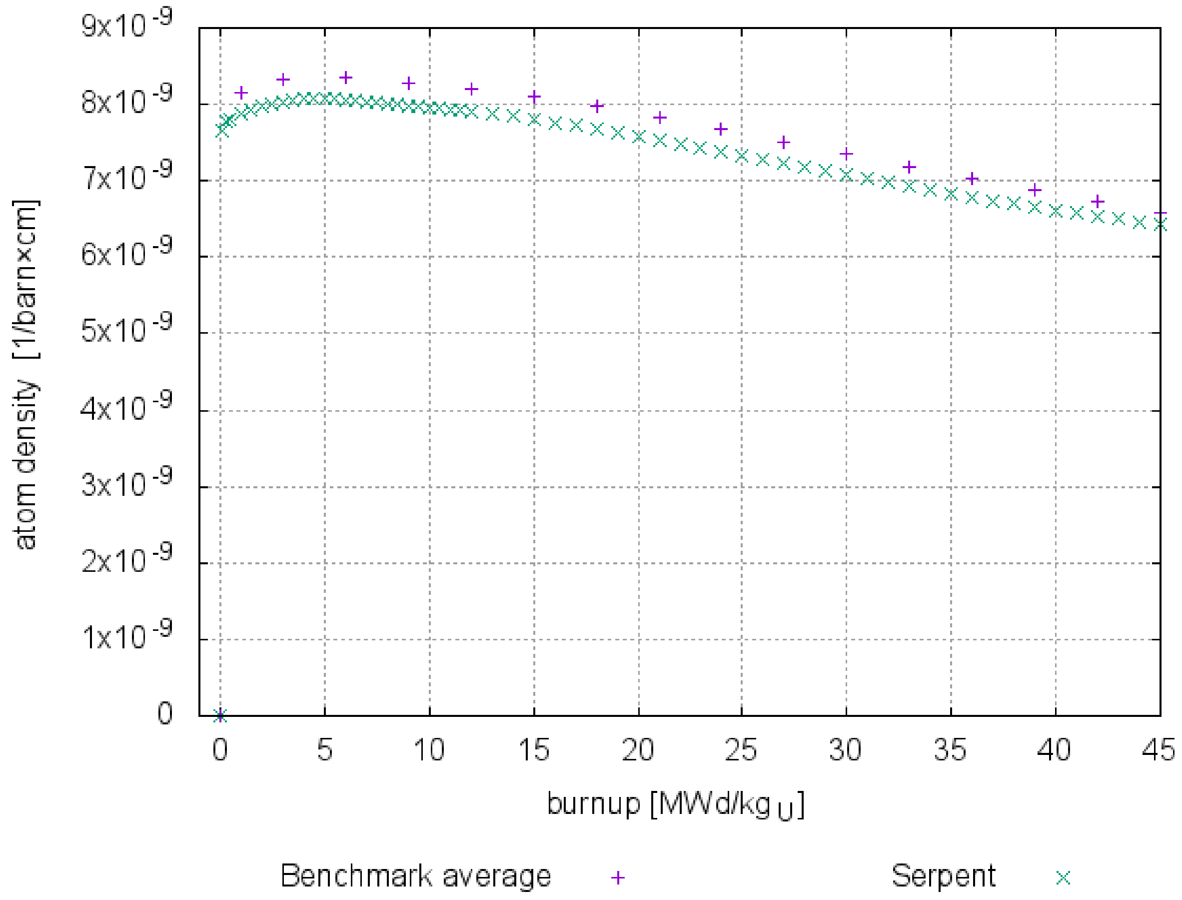
- The isotopic concentration discrepancy figures presents the behavior of the ^{239}Pu during burnup in the 30av5 fuel assembly
- The figures show that all code results are similar
- The discrepancy is based on the benchmark average (CASMO, HELIOS and NESSEL)

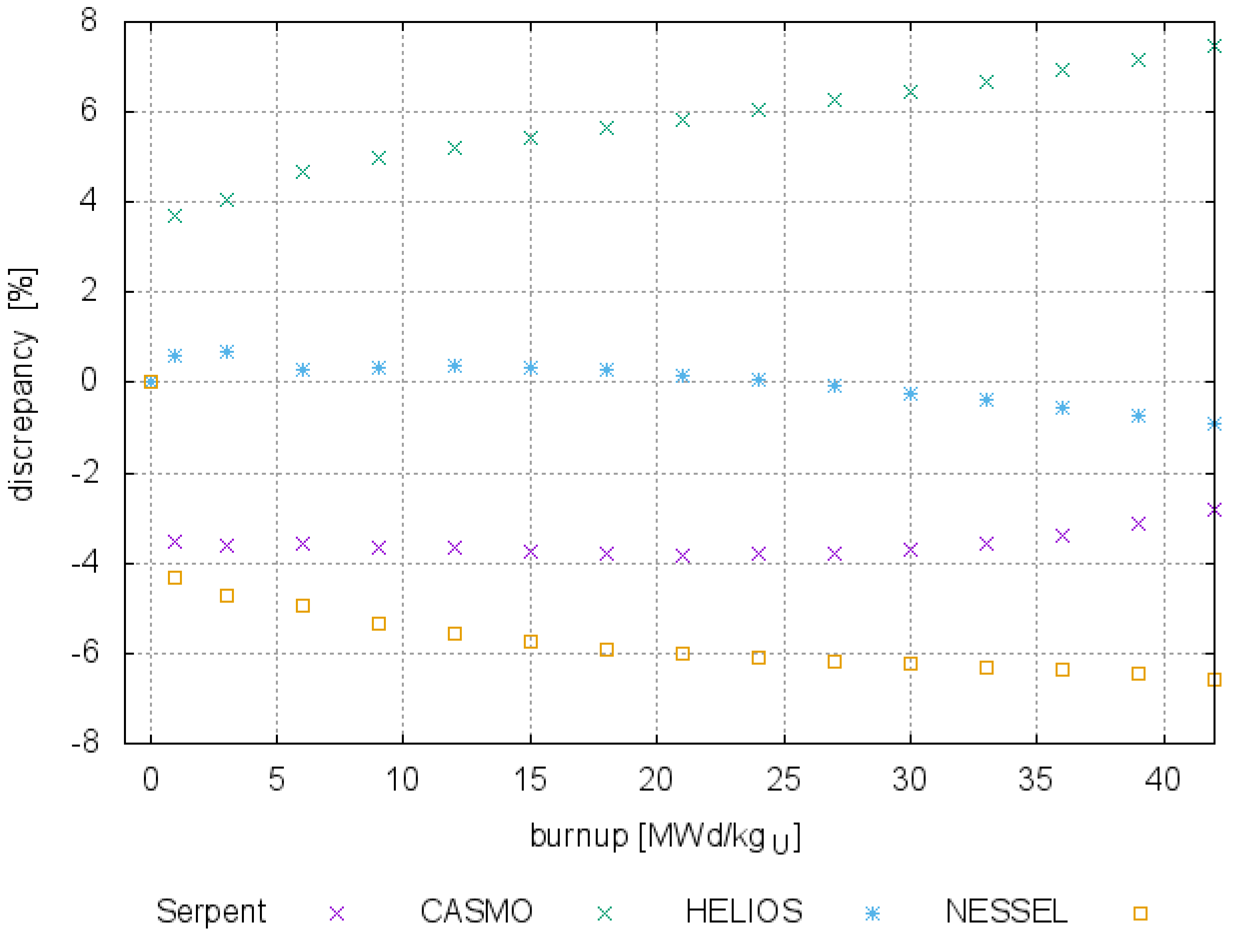




Xe 135

- The isotopic concentration discrepancy figures presents the behavior of the ^{135}Xe during burnup in the 30av5 fuel assembly
- The figures show that the Serpent values are slightly lower than the benchmark average but still closer than the NESSEL results
- The discrepancy is based on the benchmark average (CASMO, HELIOS and NESSEL)





Cross section preparation using Serpent 2

Serpent to NESTLE

NESTLE is a few-group neutron diffusion equation solver utilizing the nodal expansion method for eigenvalue, adjoint, fixed source steady-state and transient problems.

- Serpent → group collapsed and node homogenized cross-sections
- NESTLE → depletion calculation with thermal hydraulics feedback effects on fuel and moderator densities and temperatures

Motivation for NESTLE

- Fast full core calculations
- Thermal hydraulics feedback
- BWR or PWR
- Core follow of fuel cycle
- Detail simulation of real fuel cycle

Serpent code

- set gcu 0
- set fum 1
- ene 1 4 wms69
- surf 749 hexyc   0.0 0.0 11.8
- set adf 0 749 0 3

Isotopes

- Concentration of listed isotopes were followed and than used in NESTLE.
  - 235U, 238U, 239Pu, 240Pu, 241Pu, 155Gd, 157Gd, 135Xe, 149Sm, 135I, 149Pm
- Calculation of fission product poison cross section (production of I-135, Xe-135, Pm-149 and Sm-149 and absorption of Xe-135 and Sm-149) was switched on by: set poi 1.

Memory optimalization

- Memory optimization was used to reduce memory requirements. Option 2 was selected by this line in source code

```
set opti 2
```

- More about memory optimization and option number two is written in the Serpent forum.

Branches

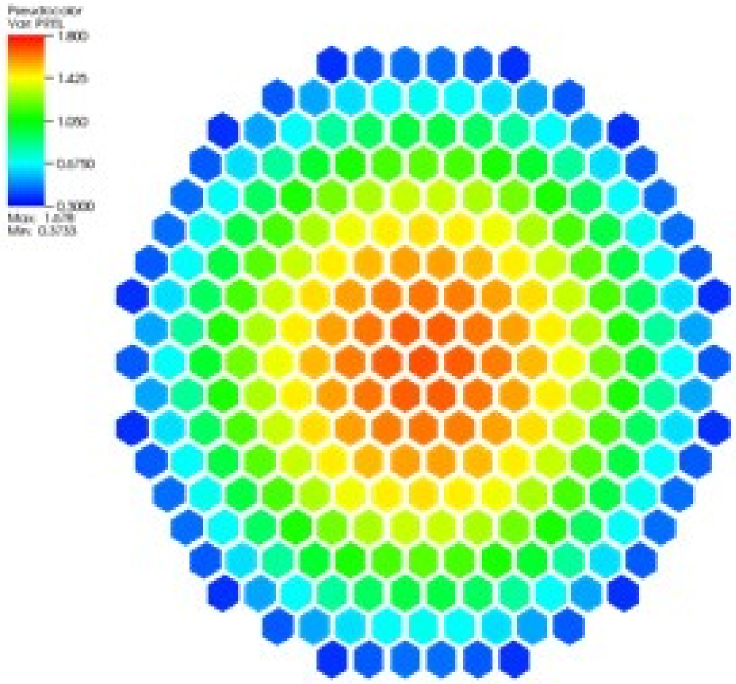
fuel temperature	300K	1005K	1800K
soluble boron concentration	0 ppm	525 ppm (3g/kg)	1575ppm
coolant density	-15%	0 %	+15 %
coolant temperature	300 K		900 K
control rod	No	upper part	Lower part

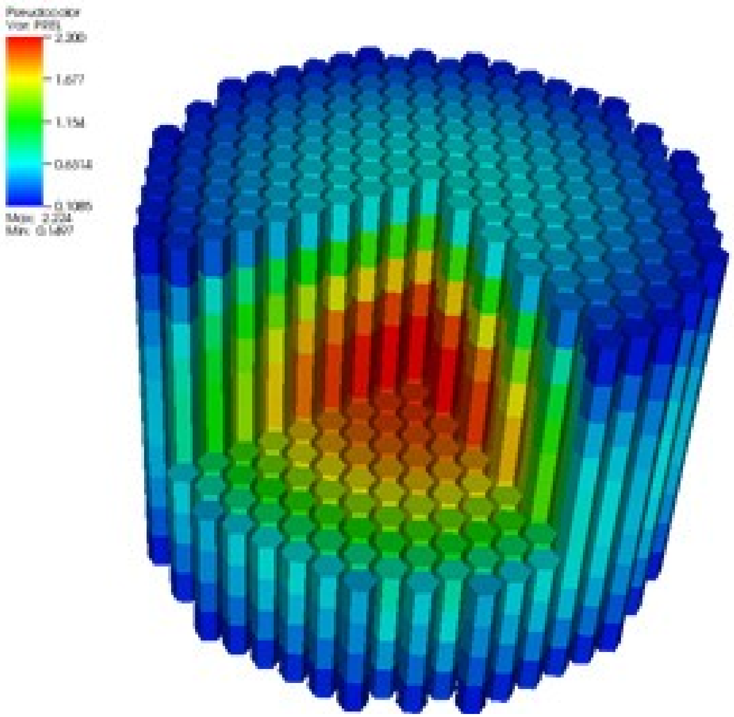
Serpent to NESTLE

- Calculated data needs to be transferred to different file format, which can be used
- L2X is a python script and X2N is a FORTRAN code
- L2X is meant to read the SERPENT output files ***res.m** and ***dep.m,** extract the requisite data from these files, and put it into the XML.
- The X2N script is meant to provide some last pieces of information that X2N needs, but does not know.

NESTLE results (work in progress)

- Keff and Isotopic concentration of FA
- Full core calculations
- Pin power and FA power calculation





Conclusions

- The Serpent results are close to the benchmark average
- Library selection has a significant impact on the produced results
- Radial sections are very important for the gadolinium pins
- Isotopic concentrations are slightly different leading to the higher discrepancy at the EOC

Conclusions 2

- Serpent is able to produce the cros-section data for NESTLE code
- The Serpent calculation requires significant computing power
- NESTLE could be used for full core reactor modeling, including pin power studies
- NESTLE is very fast compared to Serpent

- Thank you!
- Question?