RECENT EXPERIMENTS IN THE IPEN/MB-01 REACTOR

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The IPEN/MB-01 Research Reactor Facility

The IPEN/MB-01 thermal research reactor is a zero power critical facility specially designed for measurement of a wide variety of reactor physics parameters to be used as benchmark experimental data. Several IPEN/MB-01 critical configurations have been benchmarked by ICSBEP (see September 2014 edition) and many of its experiments are available at IRPhE DVD (see March 2015 edition)

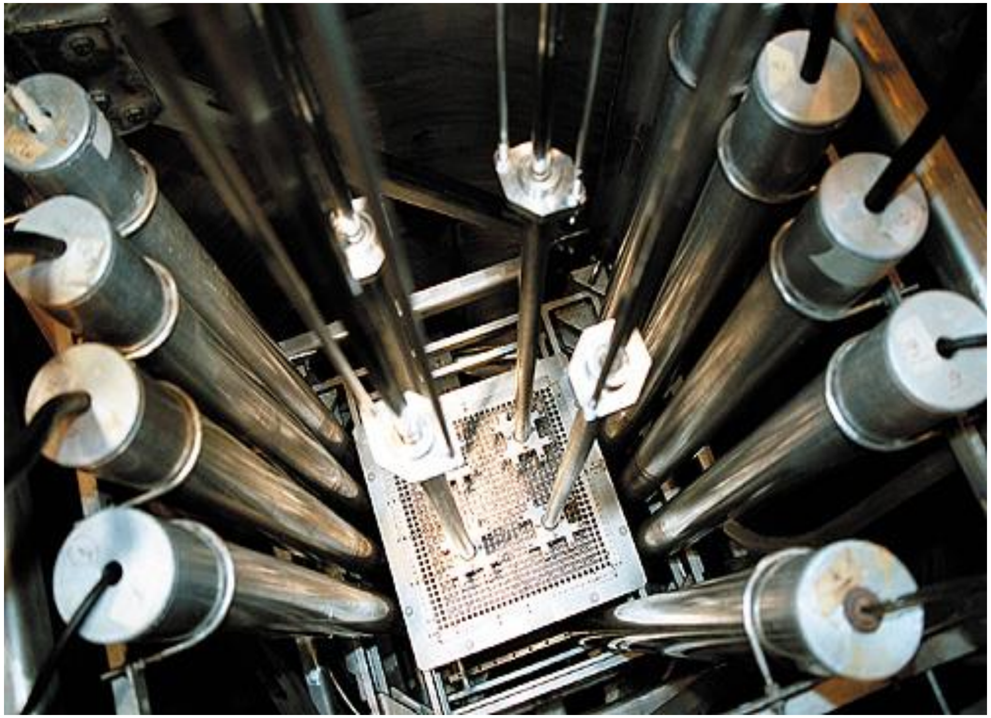
Location: São Paulo, Brazil

Core configuration: 28x26 rectangular array of UO_2 fuel rods inside a light water tank

^{235}U Enrichment: 4.3486 wt.%

Control banks: 12 Ag-In-Cd rods

Safety banks: 12 B_4C rods

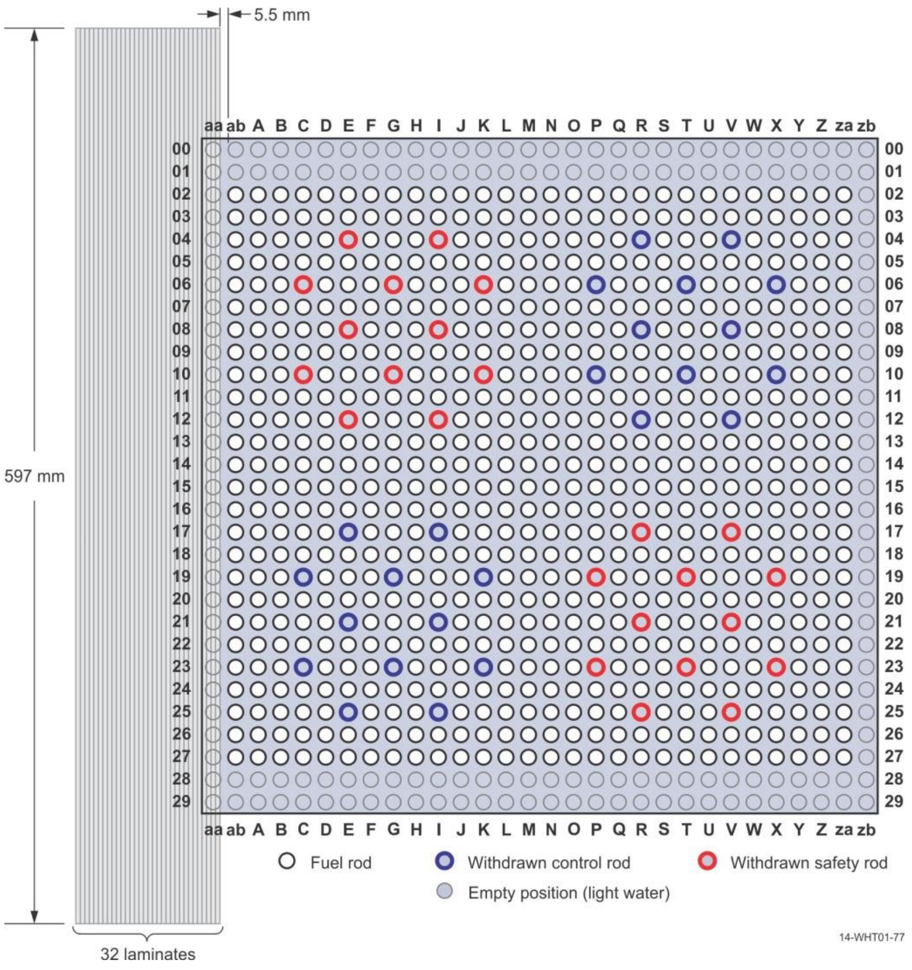


Two activities going on right now at the IPEN/MB-01 reactor are shown here.

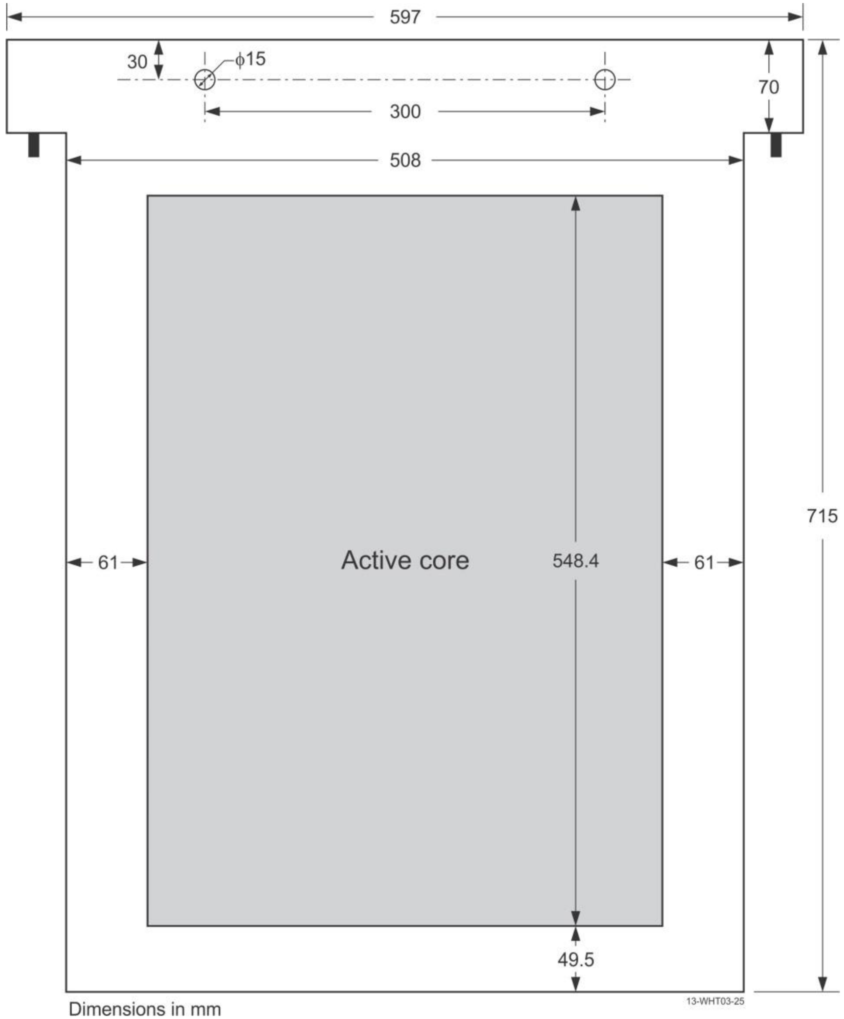
a) **Validation of the Delayed Neutron Data of the recent nuclear data libraries; namely: ENDF/B-VII.0, ENDF/B-VII.1, JENDL-4.0, JENDL-3.3, and JEFF 3.1.1. The Nickel heavy reflector experiment is employed for this purpose.**

b) **Experimental determination of the reaction rates ($^{238}U(n,\gamma)$ and $^{235}U(n,f)$) along the pellet radius.**

Delayed Neutron Data Validation
Nickel Heavy Reflector Experiment Configuration



Axial View of the Positioning of the Ni Plate relative to the IPEN/MB-01 core



Quantity Measured is the reactivity inserted per Ni plate. Inverse kinetic model is employed for this purpose.

$$\frac{dN(t)}{dt} = \frac{\rho(t)-\beta}{\Lambda} N(t) + \sum_{i=1}^{6} \lambda_i C_i(t)$$

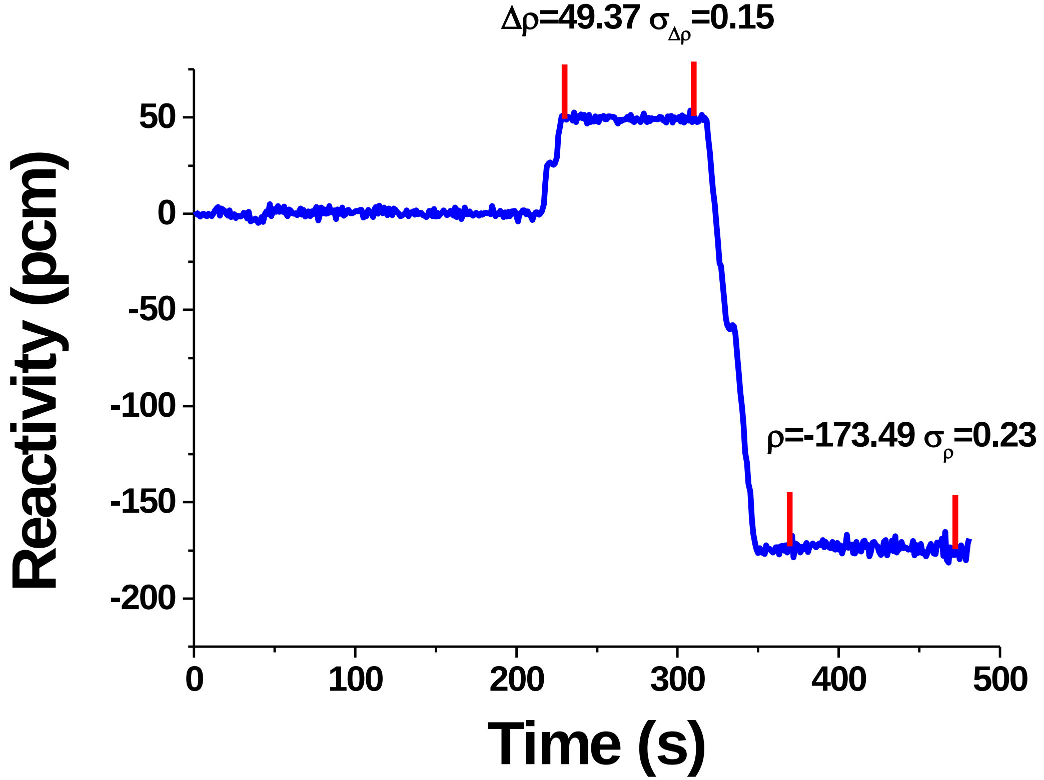
$$\frac{dC_i(t)}{dt} = \frac{\beta_i}{\Lambda} N(t) - \lambda_i C_i(t)$$

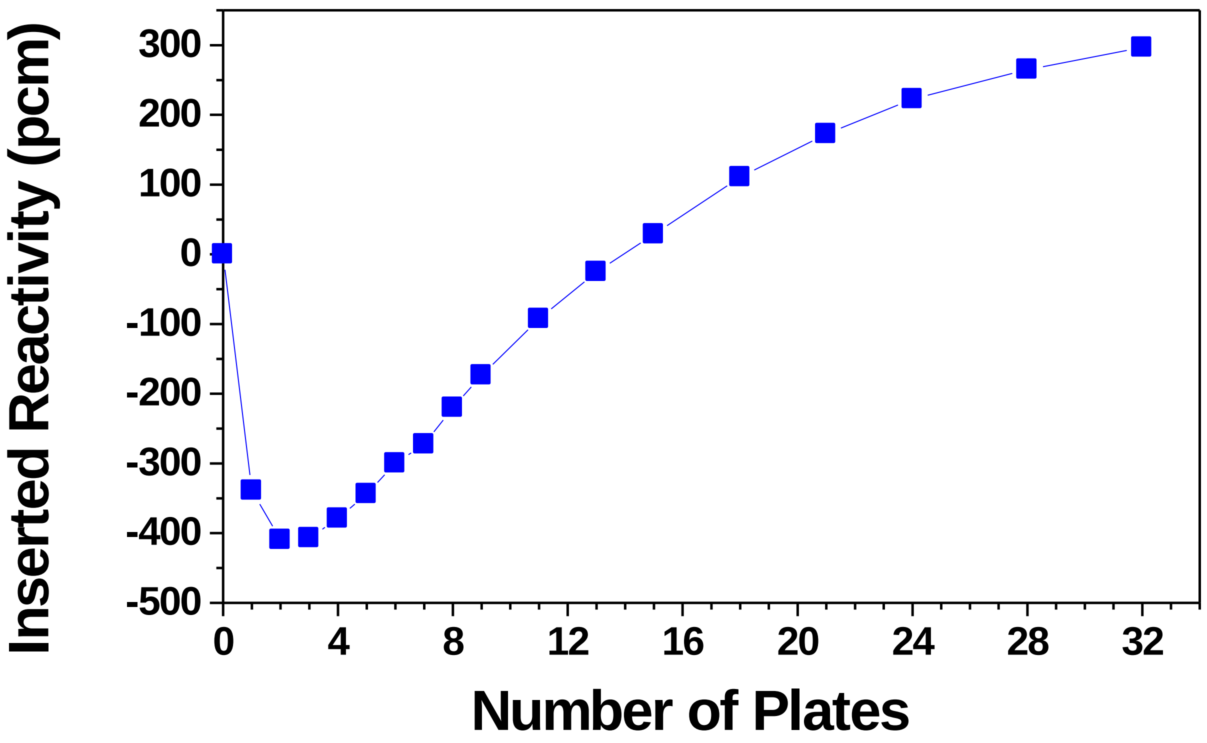
$$\rho(t) = \frac{\Lambda}{N(t)} \frac{dN(t)}{dt} + \beta_{eff} - \frac{\Lambda}{N(t)} \sum_{i=1}^{6} \lambda_i C_i(0) e^{-\lambda_i t}$$

$$- \frac{1}{N(t)} \sum_{i=1}^{6} \lambda_i \beta_i e^{-\lambda_i t} \int_0^t N(t') e^{\lambda_i t'} dt'$$

Measured effective kinetic parameters for the IPEN/MB-01 core

β_i	λ_i (s^{-1})
(2.679 ± 0.023)E-4	0.012456 ± 0.000031
(1.463 ± 0.069)E-3	0.0319 ± 0.0032
(1.34 ± 0.13)E-3	0.1085 ± 0.0054
(3.10 ± 0.10)E-3	0.3054 ± 0.0055
(8.31 ± 0.62)E-4	1.085 ± 0.044
(4.99 ± 0.27)E-4	3.14 ± 0.11
β_{eff} = (7.50 ± 0.19)E-3, Λ = 31.96±1.06 (μs)	


Δρ=49.37 σΔρ=0.15
ρ=-173.49 σρ=0.23
Reactivity (pcm)
50
0
-50
-100
-150
-200
0
100
200
300
400
500
Time (s)



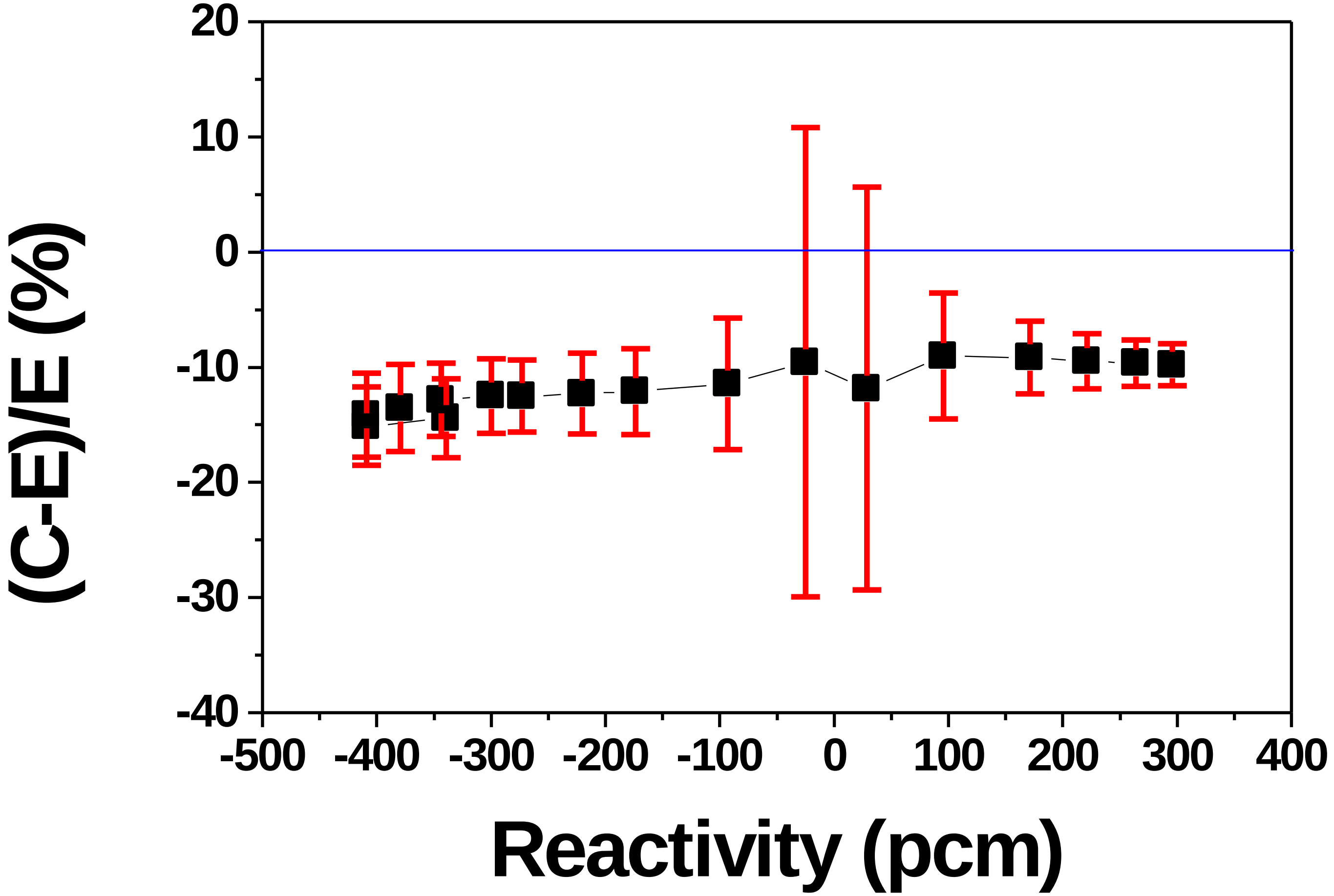
Inserted Reactivity (pcm)
300
200
100
0
-100
-200
-300
-400
-500
0
4
8
12
16
20
24
28
32
Number of Plates

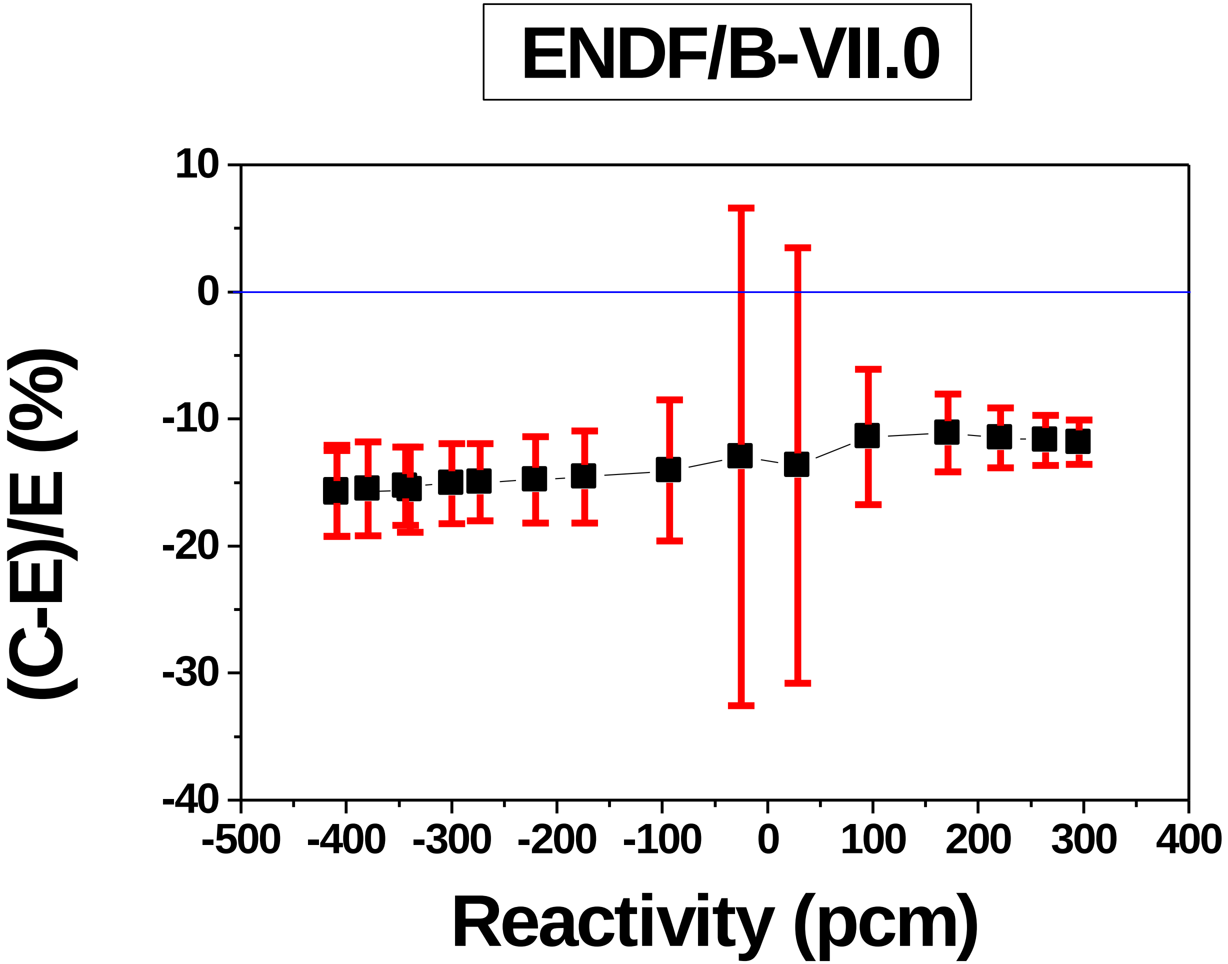
Theory/Experiment Comparison

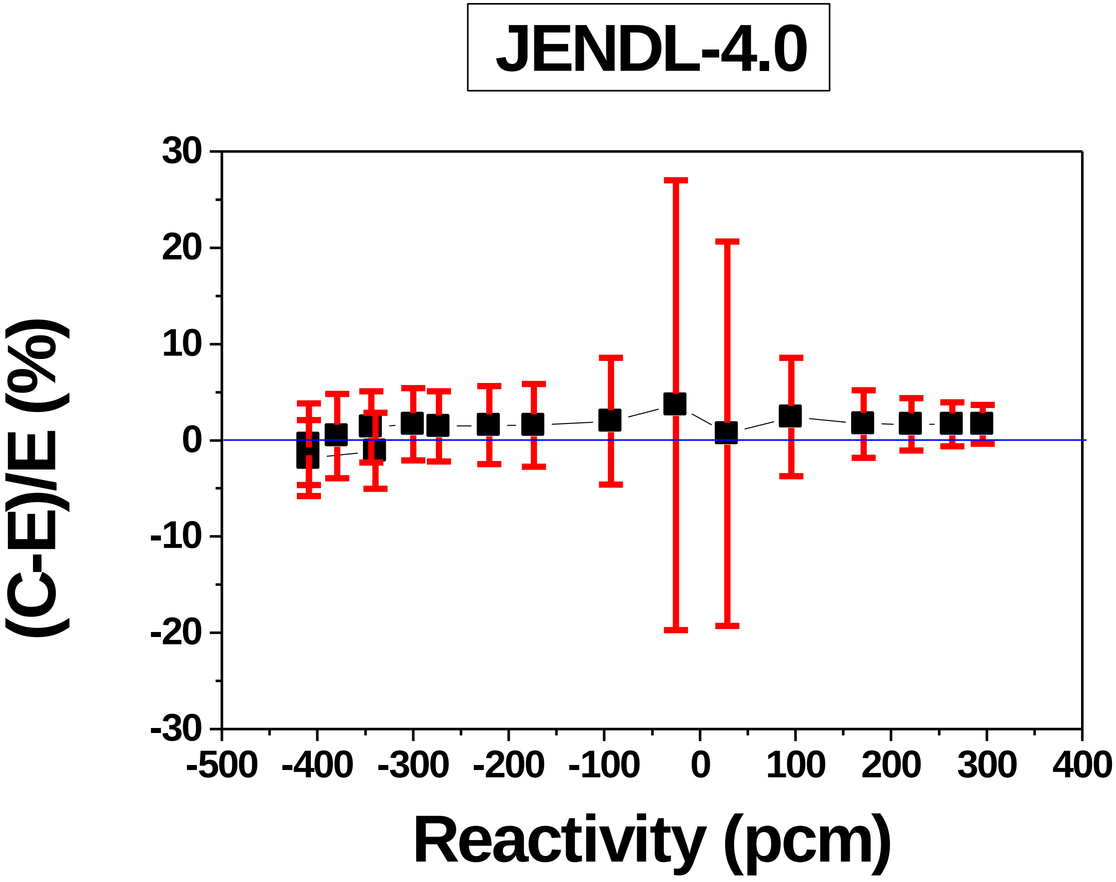
The Effective Delayed Neutron Parameter of the several nuclear data libraries of this work were calculated by Steven Van Der Mark, Netherlands employing MCNP5.

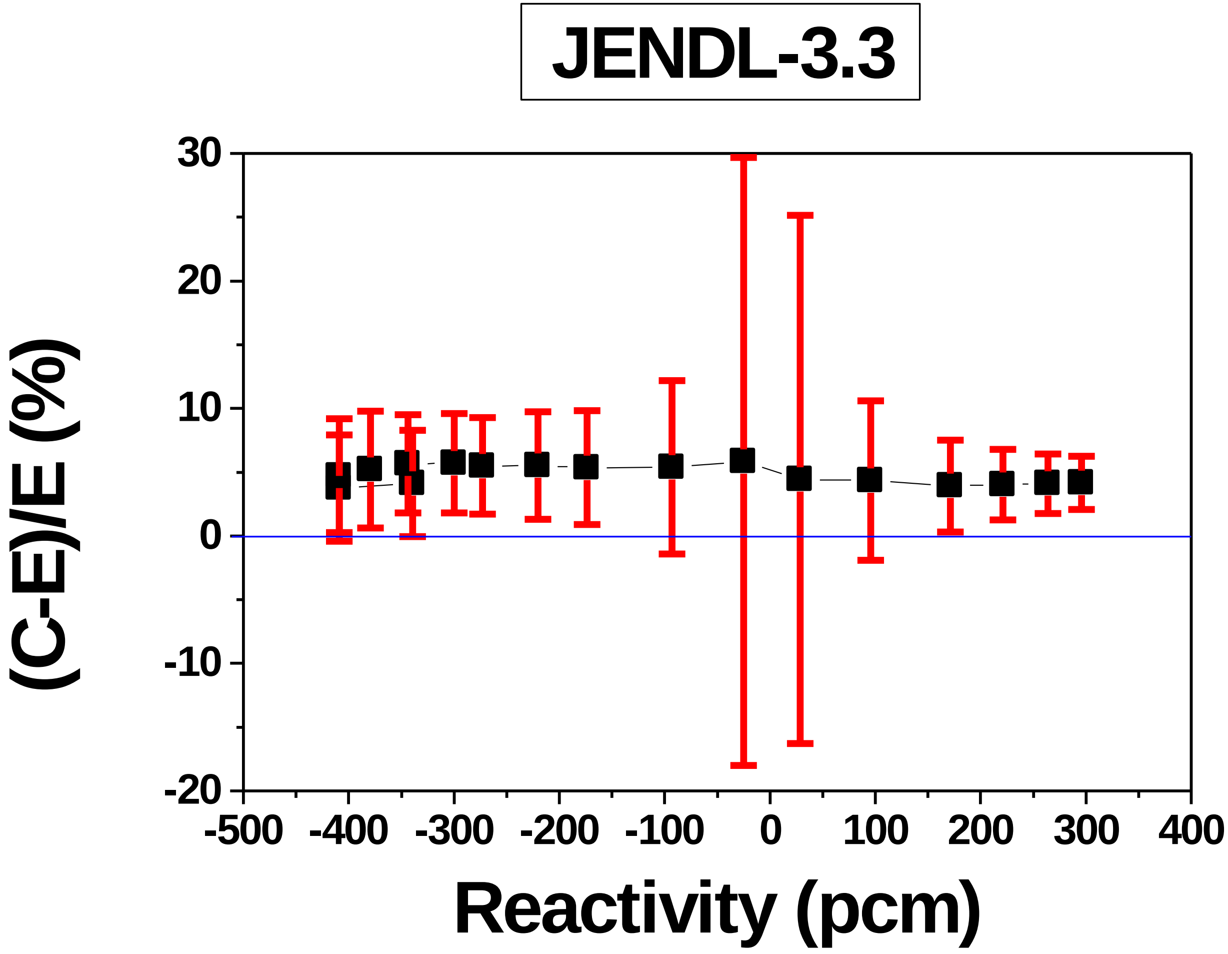
Comparison is shown as:
(C-E)/E ± 1σ in units of %.

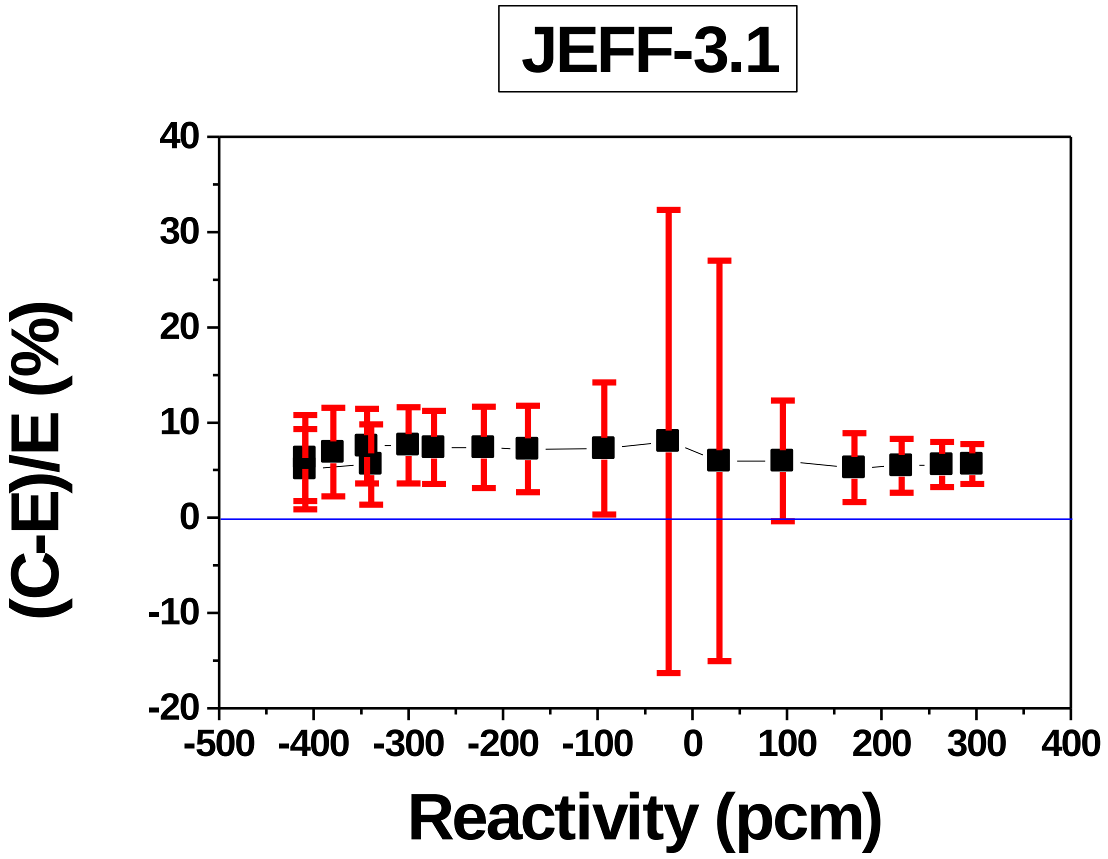
ENDF/B-VII.1


20
10
0
-10
-20
-30
-40
(C-E)/E (%)
-500
-400
-300
-200
-100
0
100
200
300
400
Reactivity (pcm)


ENDF/B-VII.0
10
0
-10
-20
-30
-40
(C-E)/E (%)
-500
-400
-300
-200
-100
0
100
200
300
400
Reactivity (pcm)


JENDL-4.0
30
20
10
0
-10
-20
-30
-500
-400
-300
-200
-100
0
100
200
300
400
(C-E)/E (%)
Reactivity (pcm)

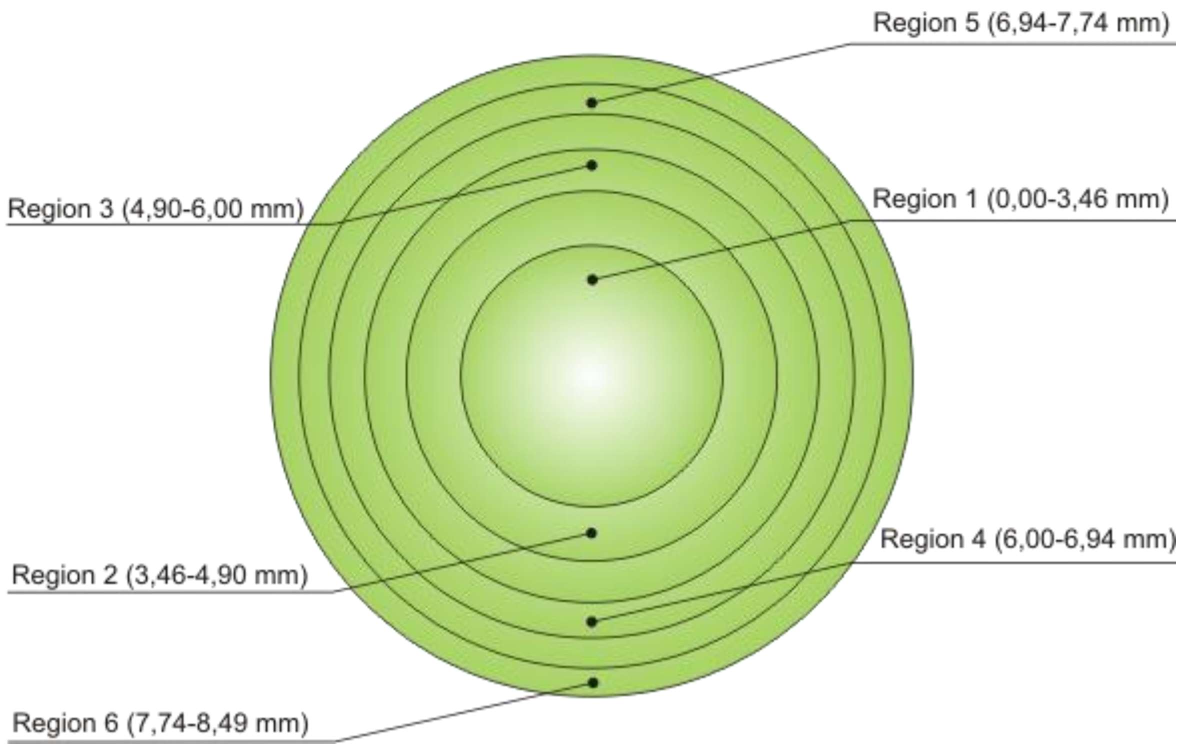

JENDL-3.3
30
20
10
0
-10
-20
-500
-400
-300
-200
-100
0
100
200
300
400
(C-E)/E (%)
Reactivity (pcm)


JEFF-3.1
40
30
20
10
0
-10
-20
(C-E)/E (%)
-500
-400
-300
-200
-100
0
100
200
300
400
Reactivity (pcm)

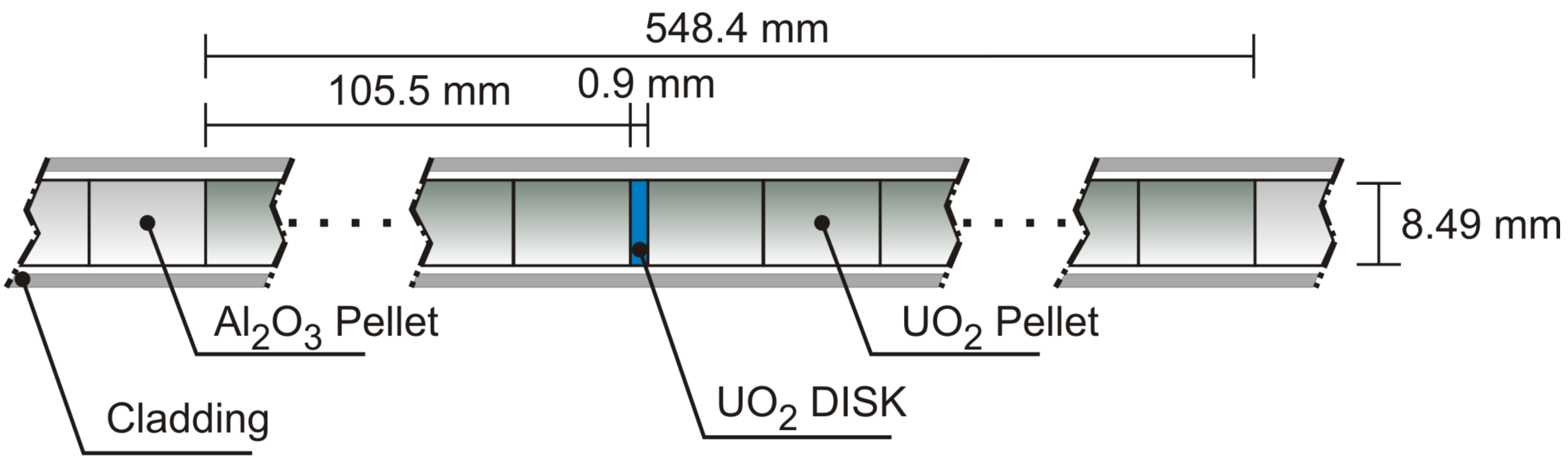
(C-E)/E (%)	β_{eff}	λ_1 (s^{-1})(a)
ENDF/B-VII.0	0.00 ± 0.82	0.01249
ENDF/B-VII.1	-0.53 ± 0.94	0.01335
JEFF-3.1.1	2.13 ± 0.95	0.01247
JENDL-3.3	-0.55 ± 0.94	0.01244
JENDL-4.0	-0.67 ± 0.94	0.01248

(a)The experimental value is 0.012456 ± 0.000031.

^{238}U capture and fission rates along the pellet radius.

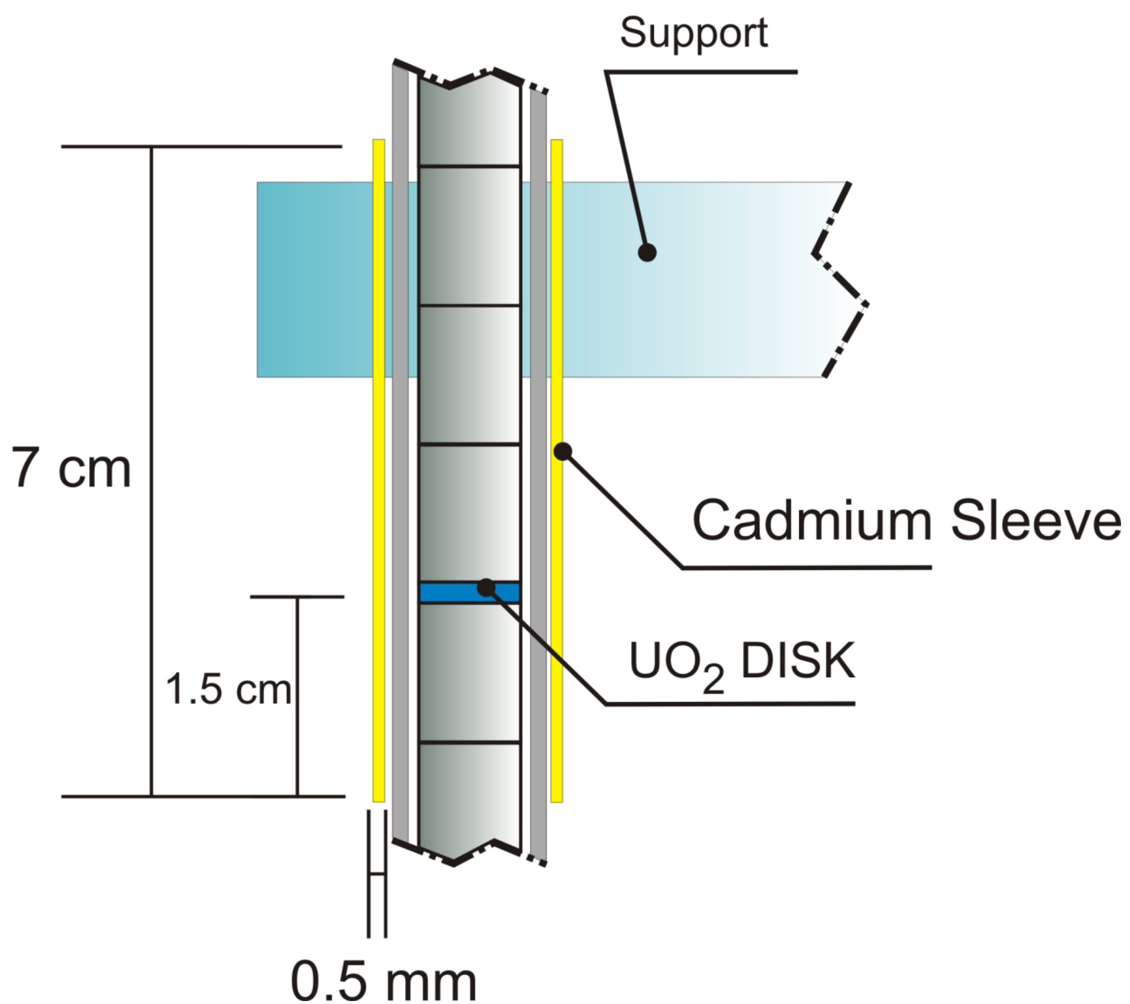


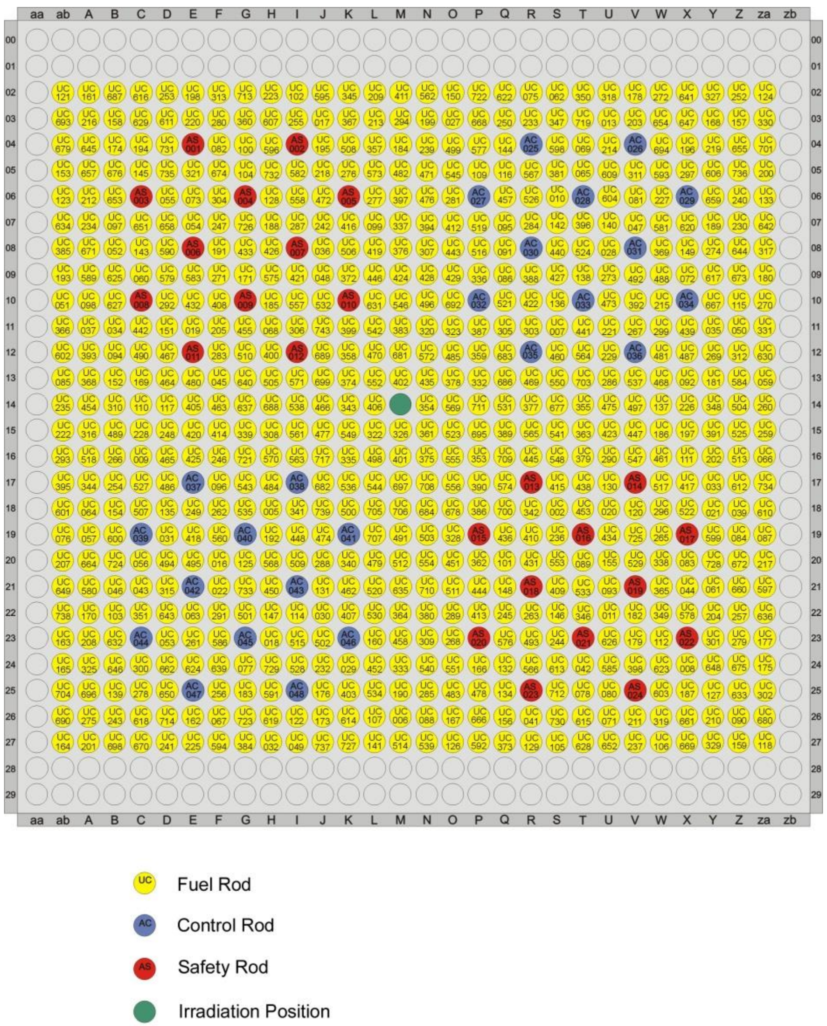
Dismountable Fuel Rod and Positioning of the UO_2 disk



The UO_2 disk was obtained cutting of the IPEN/MB-01 UO_2 pellets by a sharp tool. The Uncertainty in the UO2 disk thickness was less than 1%.

Cadmium Sleeve Arrangement and Positioning





Irradiation Conditions

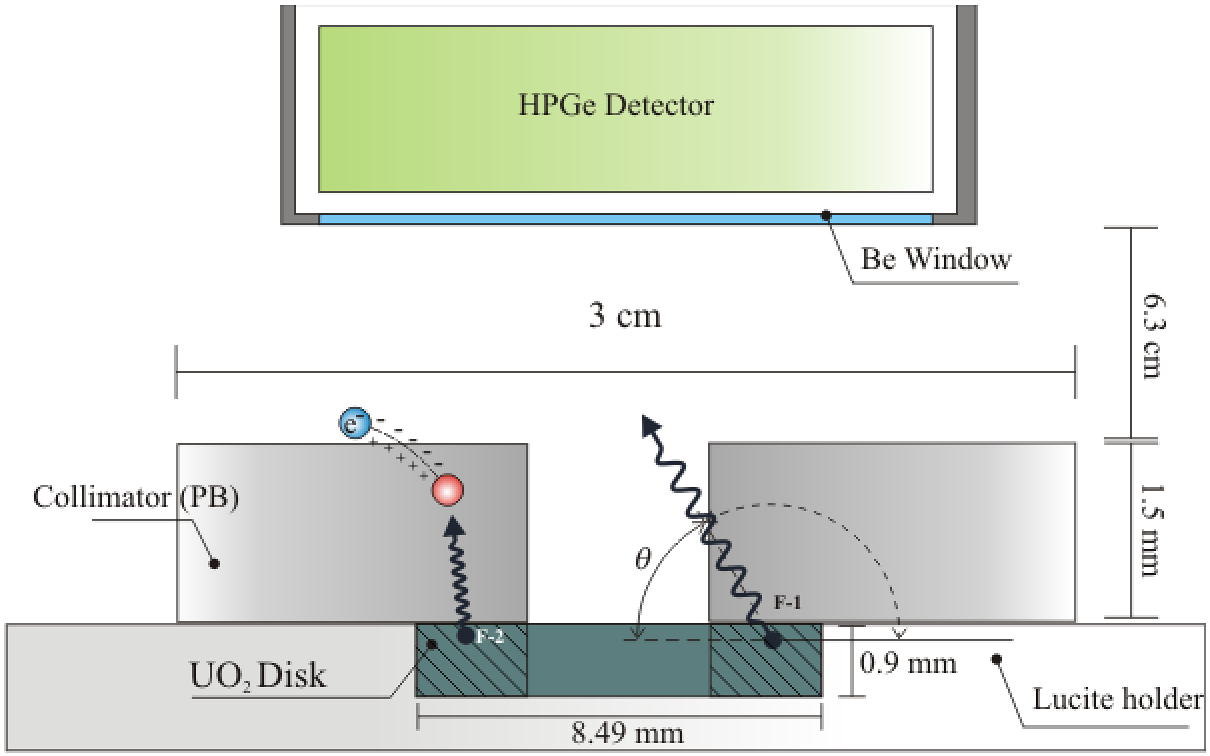
100W

One hour

20 ºC

Critical Control Bank Position: 58% Withdrawn

Gamma Detection System



LED HPGe Detector

-Small crystal with high efficiency for energies between 50 – 200 keV.

The selected gamma energies was chosen to improve the collimator effectiveness. The lower the better.

^{238}U Radiative Capture:

Inferred from the ^{239}Np gamma decay.
E_γ=106.12 keV with 27.2 emission probability

Total Uranium Fissions
Inferred from Gamma of FP ^{99}Mo.
$E\gamma$ = 140,51 keV

Lead Collimator Disk

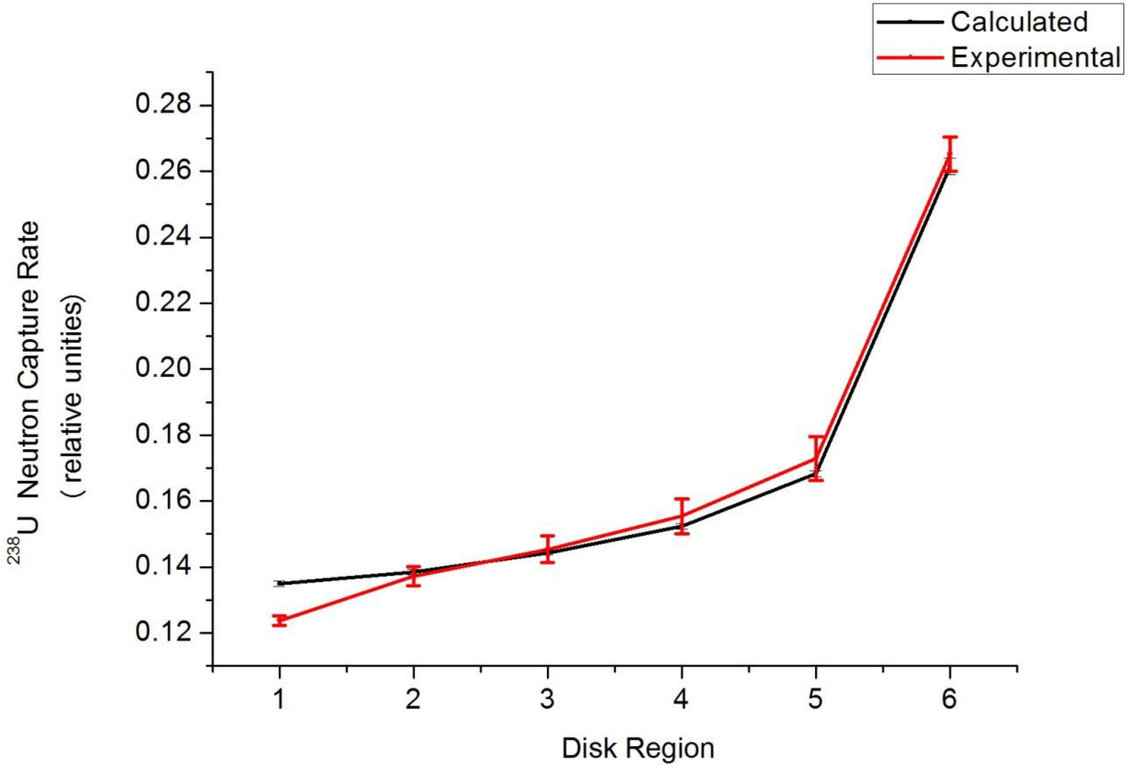
- Correction Factors Applied to the Experimental Data

a) Gamma Self-Absorption in the UO_2 Disk
b) Solid Angle Correction (Collimator)
c) Collimator Shielding Effectiveness.

- Reported Experimental Data are shown relative to the case without collimator (full disk).
- Quantities reported:

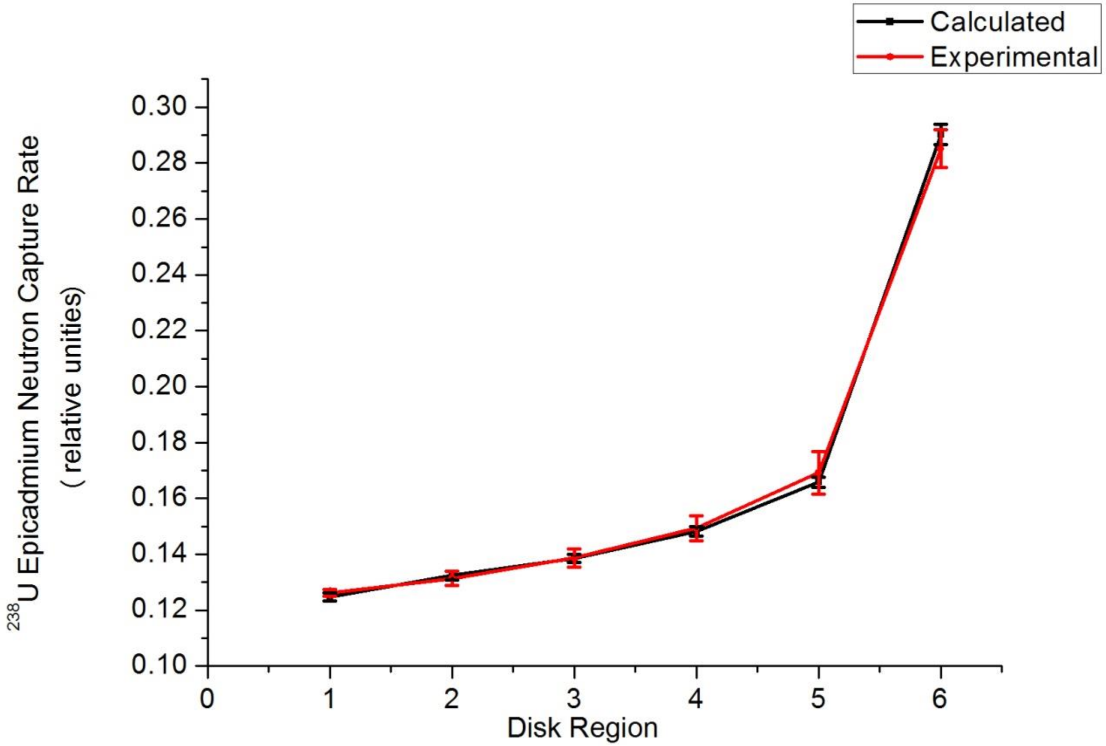
^{238}U neutron Capture
Uranium fission density

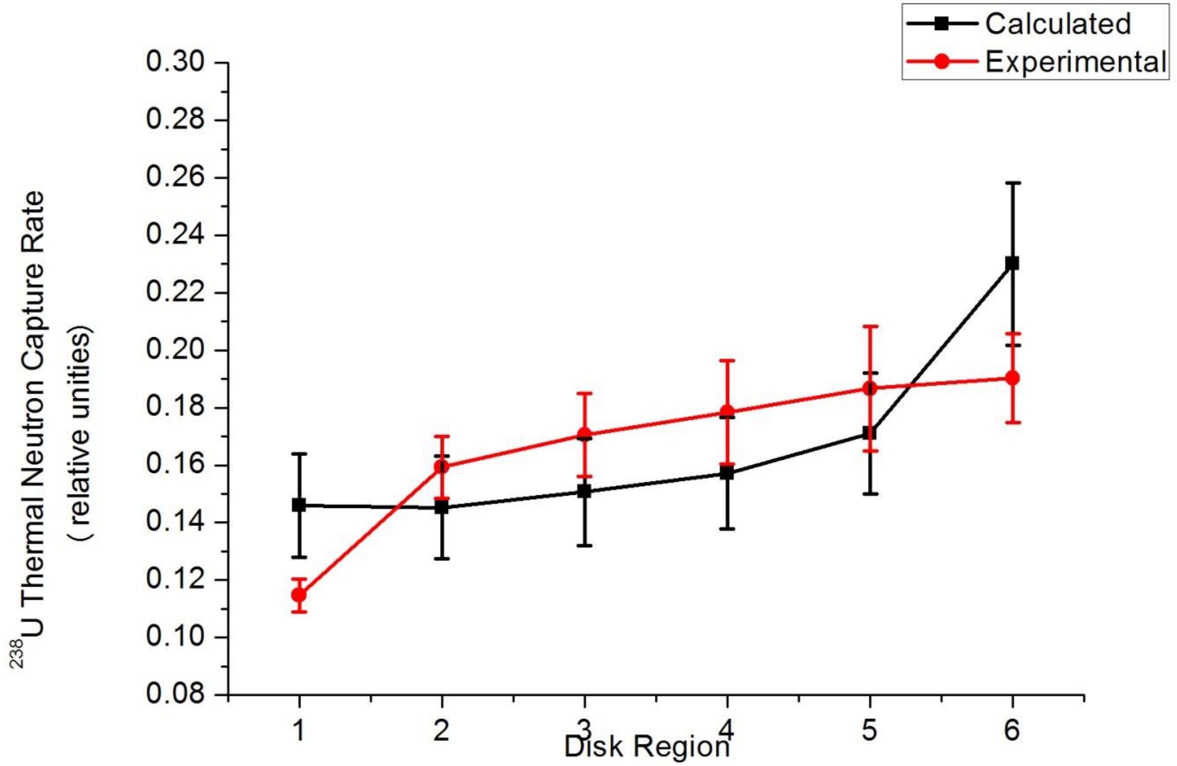
Theory/Experiment Comparisons. Calculated Values From MCNP5 (ENDF/B-VII.0) for all cases.



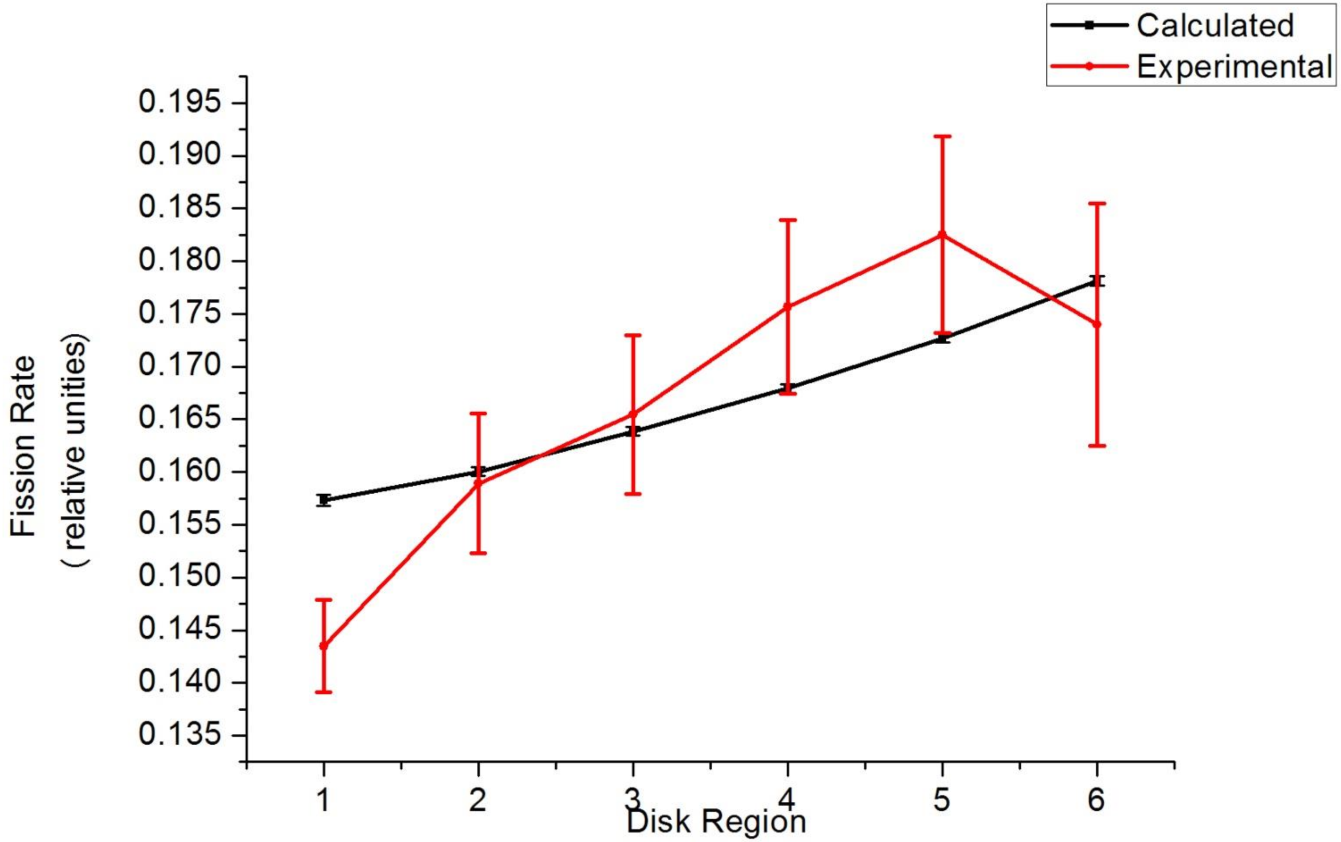
Total $^{238}U(n,\gamma)$

Epithermal $^{238}U(n,\gamma)$

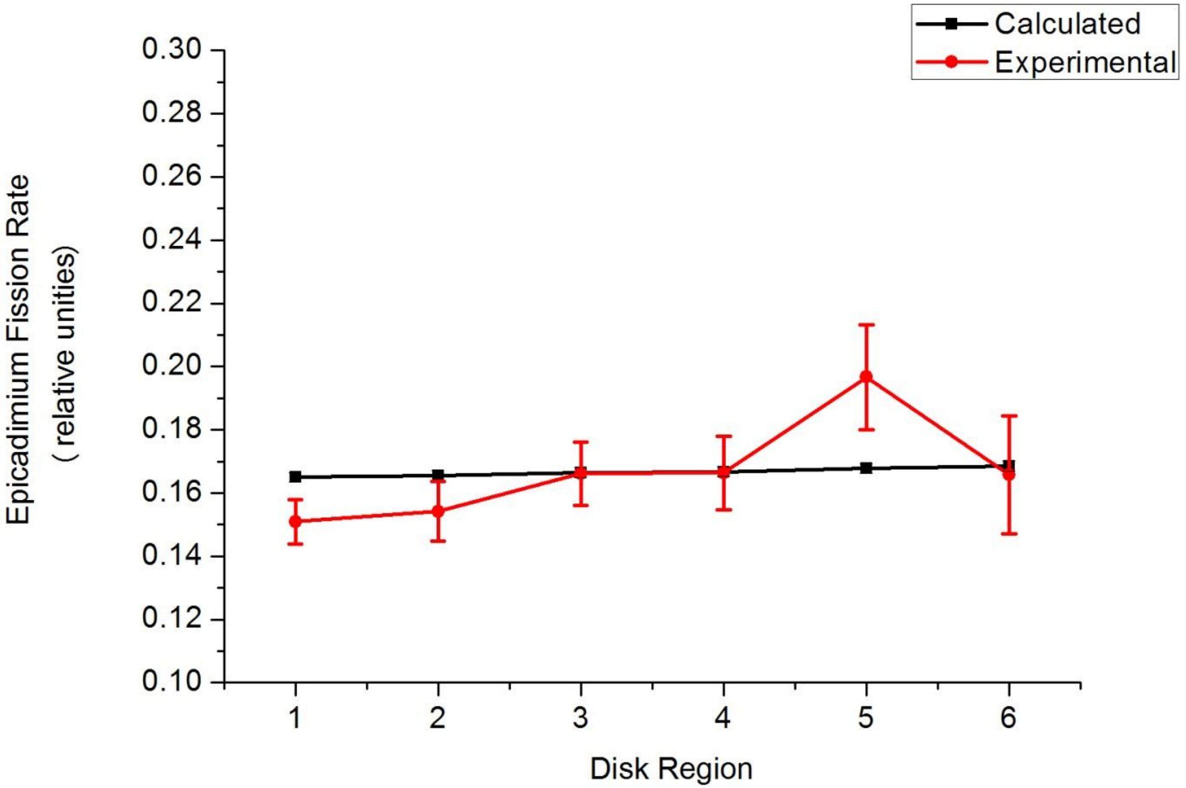




Thermal $^{238}U(n,\gamma)$


Calculated
Experimental
0.195
0.190
0.185
0.180
0.175
0.170
0.165
0.160
0.155
0.150
0.145
0.140
0.135
Fission Rate
(relative unities)
1
2
3
4
5
6
Disk Region

Total U(n,f)



Epithermal U(n,f)

Conclusions

-Effective Delayed Neutron Parameters

a) JENDL 4.0 shows excellent agreement. All calculated values are inside of 1σ of the experimental uncertainty.

b) JENDL3.3 and JEF 3.1.1 overestimated the reactivity by around 5%. A little bit over the 1σ value.

c) ENDF/B-VII.0 and –VII.1 underestimate the reactivity by around 11%.

Conclusions

-Reaction rates along the pellet radius

a) Experiments so far successfully performed

b) Epithermal $^{238}U(n,\gamma)$ shows very good agreement.

c) Thermal reaction rates show a lot of discrepancies.

d) The experiments suggest that the thermal cross section shape of $^{235}U(n,f)$ in ENDF/B-VII.0 is not well represented.

e) The same applies to the thermal $^{238}U(n,\gamma)$ cross sections.

Thanks for the Attention