Results of CIEMAT simulations of SAD

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CIEMAT

- Target studies
- System static simulations
- System kinetic simulations
- Reactivity insertion and Dynamic tests

SAD TARGET Simulations

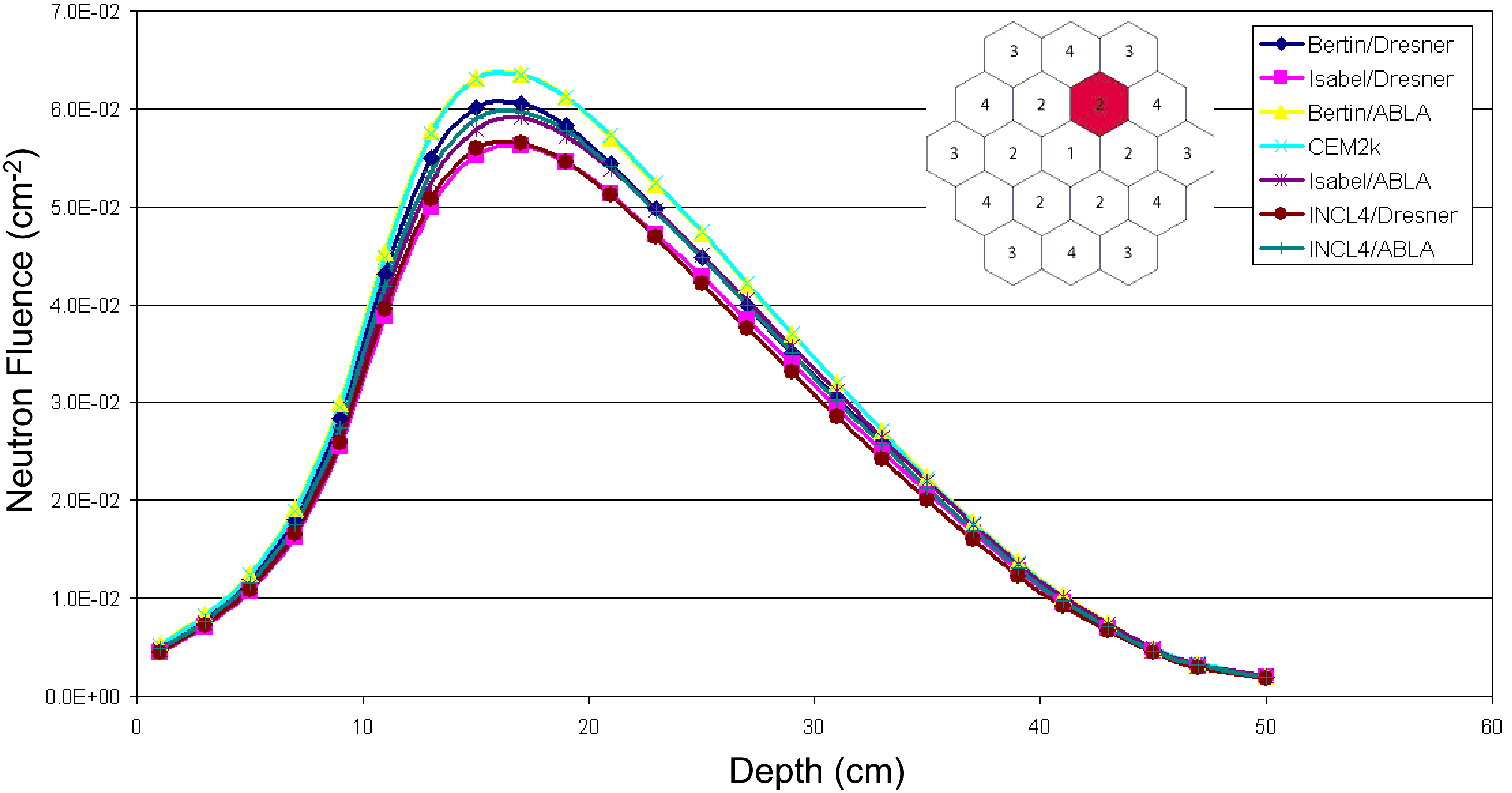
Up to 8 simulations had been performed with different high energy models using always the ENDFB6r6 data library and the MNCPx2.5e code

Computed: Neutron leakage, Neutron fluence, Energy deposition

Integrated number of neutrons per proton escaping from the lead target by the bottom, top and perimeter surfaces.

Surface	Bertin/Dresner	Isabel/Dresner	Bertin/ABLA	CEM2k
Bottom	5.3264E-01	4.8021E-01	5.7017E-01	5.5341E-01
Top	1.9548E-01	1.9345E-01	2.0721E-01	1.9581E-01
Perimeter	1.2595E+01	1.1851E+01	1.3372E+01	1.3212E+01
Surface	**Isabel/ABLA**	**INCL4/Dresner**	**INCL4/ABLA**	**INCL4/ABLA updated**
Bottom	5.1212E-01	5.1212E-01	4.8130E-01	5.18822E-01
Top	2.0438E-01	2.0438E-01	1.7675E-01	1.88195E-01
Perimeter	1.2552E+01	1.2552E+01	1.1761E+01	1.25800E+01

The deviations between different physics models in both tables range from 13% to 17%.



Neutron flux depth dependence for the cell #2 of the target

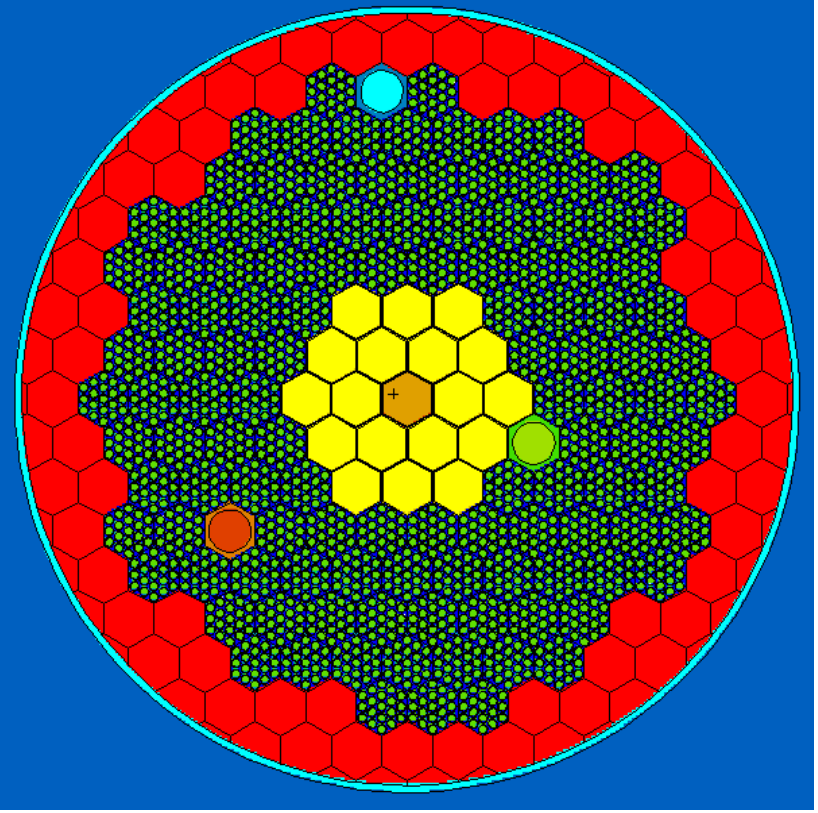
System static simulations

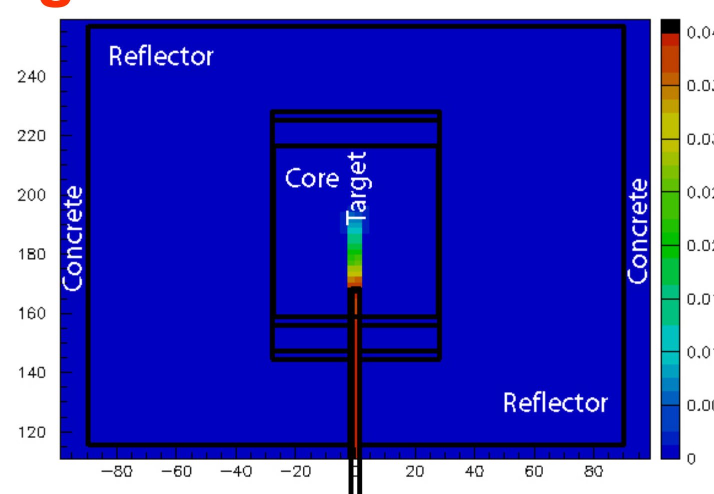
More than 20 simulations

K_{eff}, Spatial distributions of neutron and proton fluence and Energy deposition

Case number	New radius of the lead reflector	Number of fuel assemblies removed/Total	Modification	Keff ± Error
1	Without modification	none/145	none	0.94951 ± 0.00036
2	~60cm	none/145	none	1.00726 ± 0.00101
3	~70cm	none/145	none	1.01352 ± 0.00112
4	~80cm	none/145	none	1.01937 ± 0.00120
5	~60cm	4/141	none	1.00177 ± 0.00112
6	~60cm	8/137	none	0.99434 ± 0.00109
7	~60cm	12/133	none	0.98328 ± 0.00105
8	~60cm	16/129	none	0.97541 ± 0.00113
9	~60cm	20/125	none	0.96608 ± 0.00102
10	~60cm	24/121	none	0.95416 ± 0.00110
11	~60cm	28/117	none	0.94386 ± 0.00098
12	~60cm	26/119	none	0.94783 ± 0.00010
13	~70cm	26/119	none	0.95150 ± 0.00010
14	~80cm	26/119	none	0.95425 ± 0.00011
15	~60cm	26/119	10% of B-10 to the first 10 cm of of concrete close to lead reflector	0.94195 ± 0.00011
16	~60cm	24/121	Idem as case #15	0.95027 ± 0.00011
17	~60cm	25/120	Idem as case #15	0.94563 ± 0.00011
18	~60cm	22/123	0.5% of ^{10}B @ internal lead reflector 1.0% of ^{10}B @ bottom and top plates	0.95089 ± 0.000108
19			Latest SAD MCNP Input distributed	0.94627 ± 0.00101

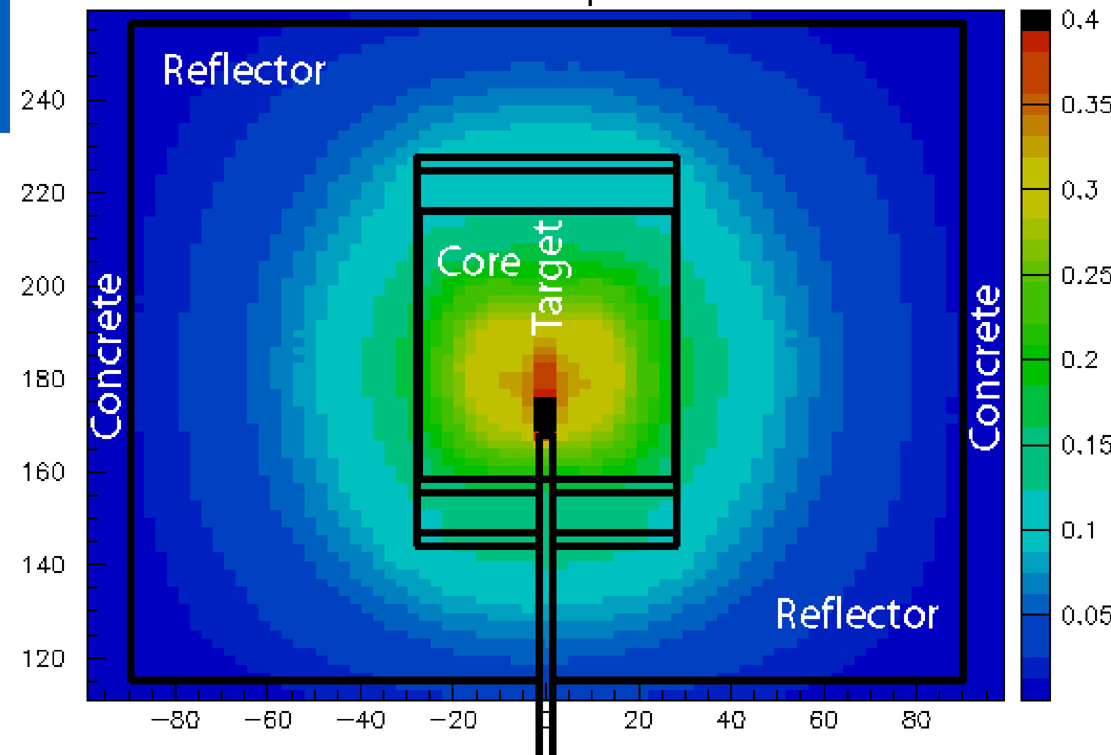
Configuration number #12

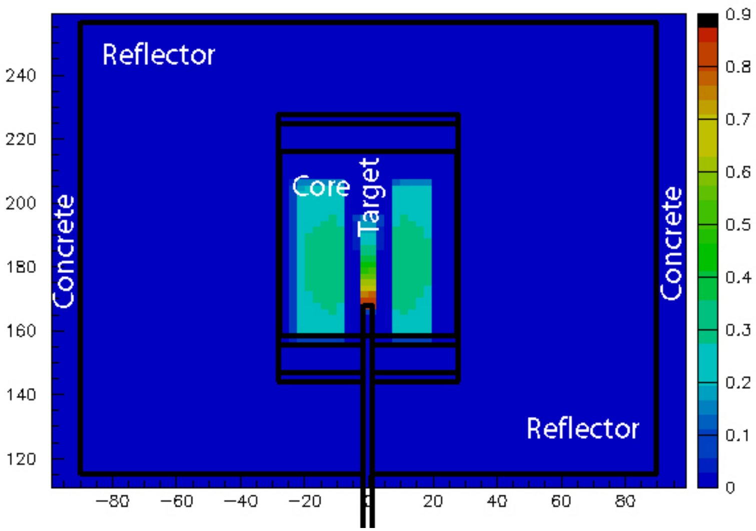




Proton Fluence/proton

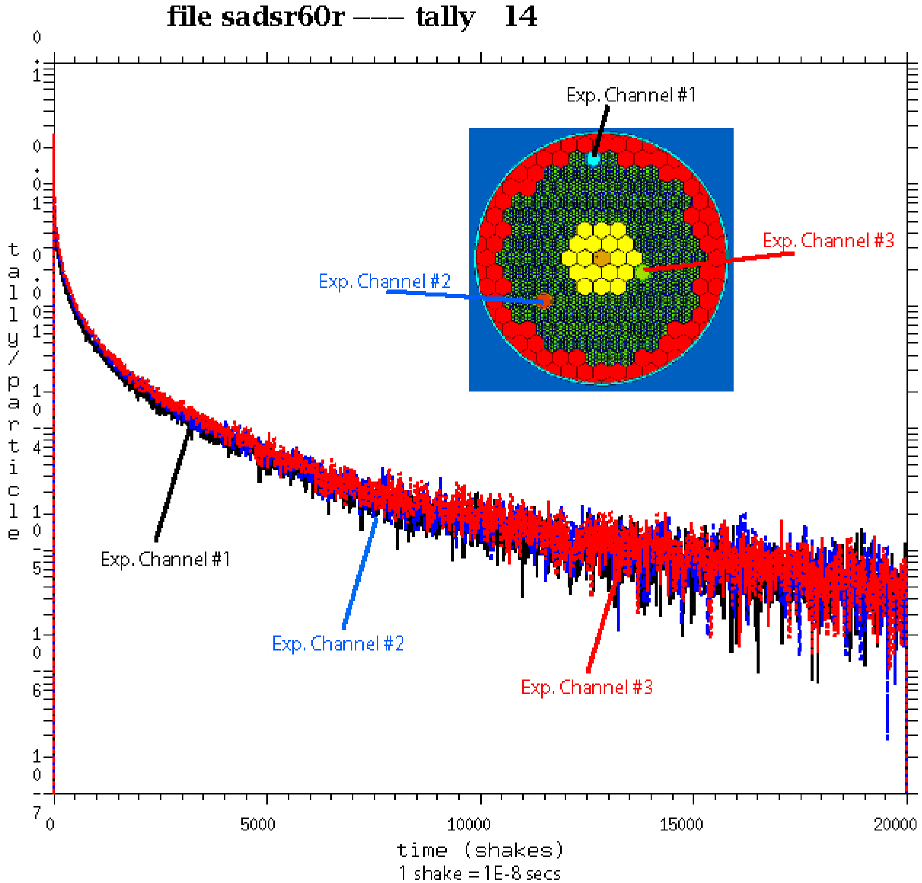
Neutron Fluence/proton





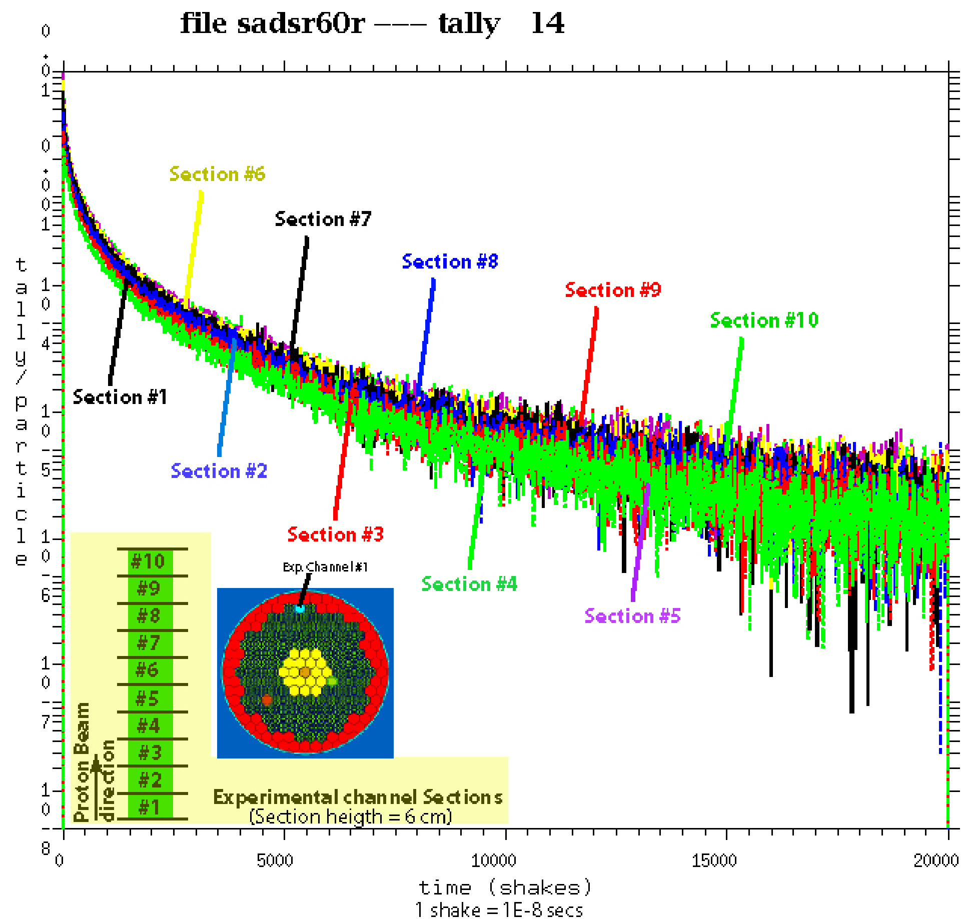
Deposited energy/proton (MeV/cm³/p)

System kinetic simulations

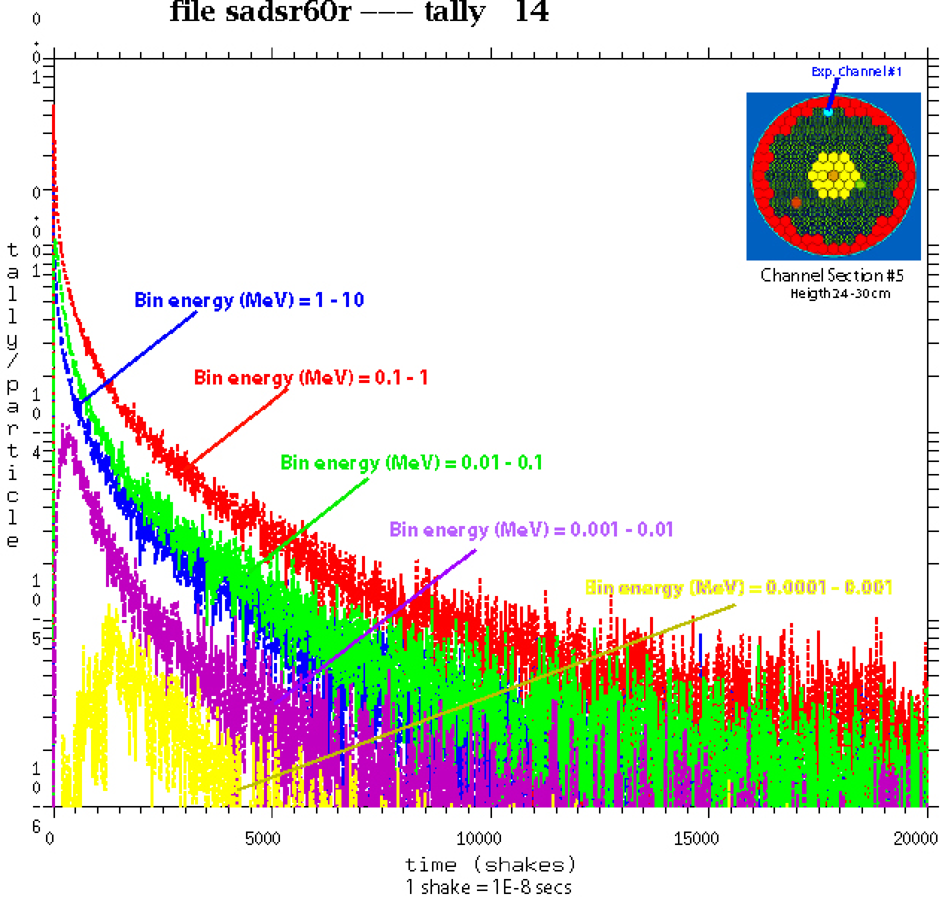


Case #12: Time evolution of ^{235}U fission counting rate. Central height.
Detectors in the 3 experimental channels at the core.

Case #12: Time evolution of ^{235}U fission counting rate. Exp. Channel 1 in the core.
Detectors at 10 different heights.



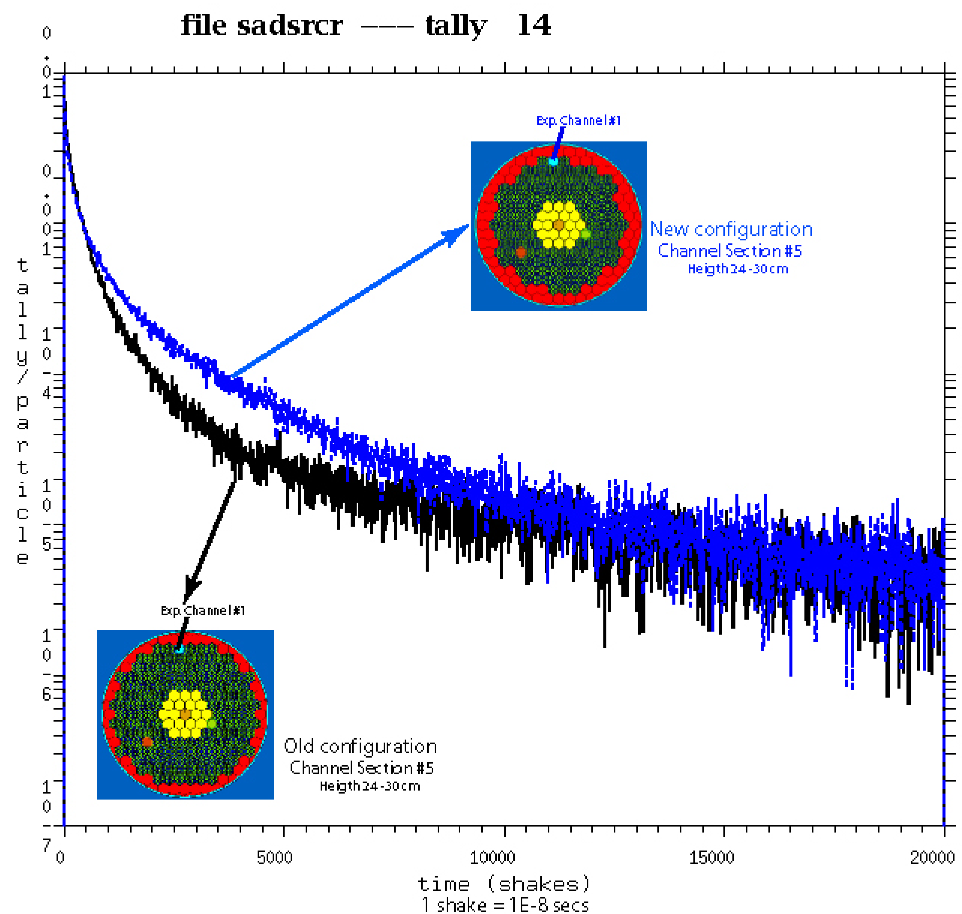
System kinetic simulations

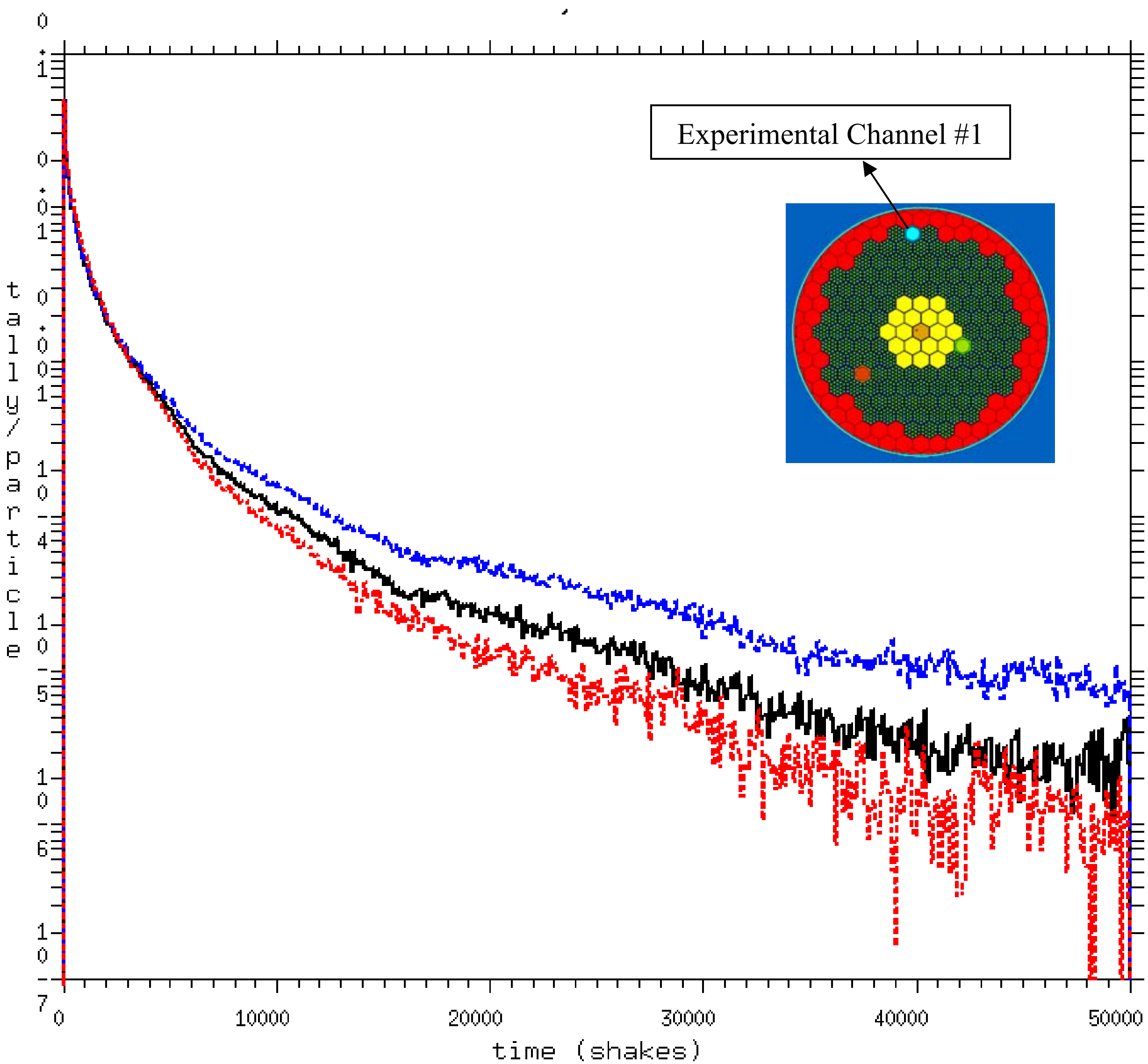


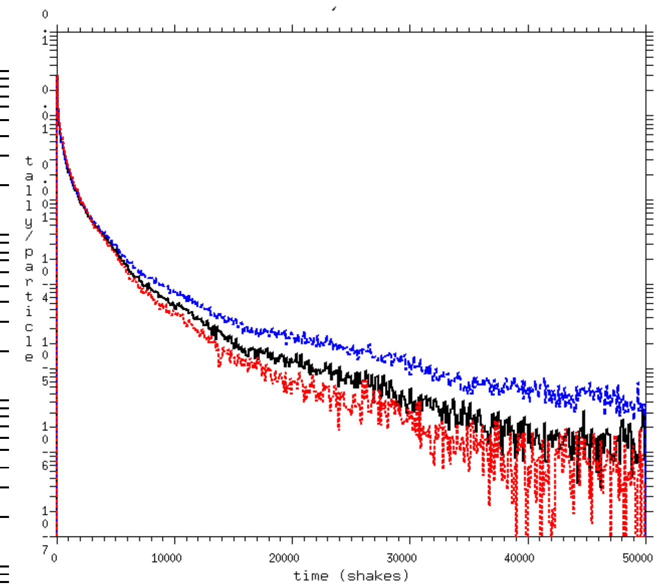
Case #12: Time evolution of ^{235}U fission counting rate. Exp. Channel 1 in the core. Central height.

Contributions from different energy intervals

Time evolution of ^{235}U fission counting rate. Exp. Channel 1 in the core. Central height. Case #1(0.94951) vs. Case #12 (0.94783).

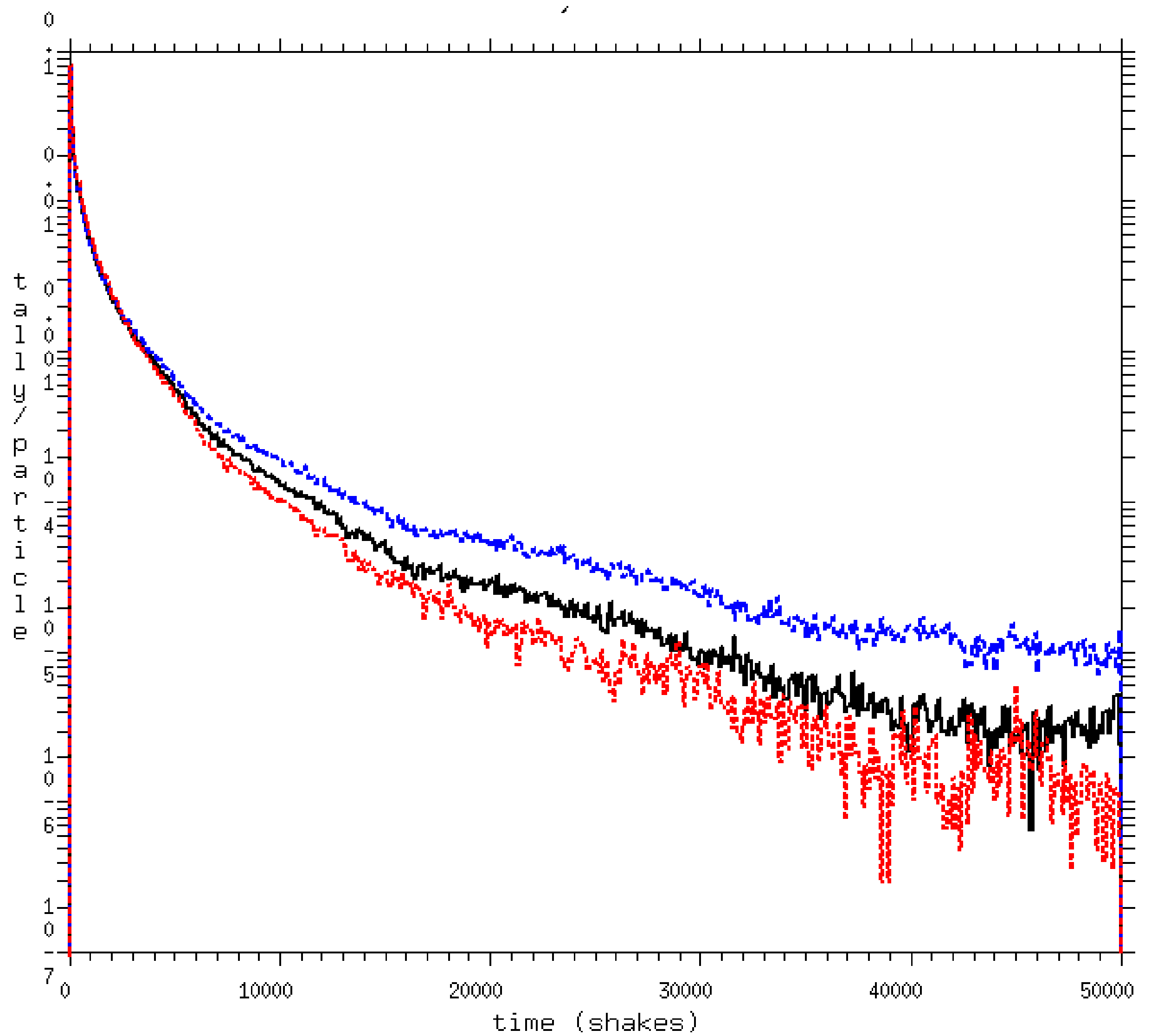






Energy interval between
0.1 MeV and 1 MeV

Neutron time response in the experimental channel #1 at central height.
Virtual ^{235}U fission detectors were placed in the center of the experimental channel.
Blue = Case #12; **Black** =Case #15 (Borated Concrete); **Red**=Case #18 (Borated Pb)



Neutron time response in the external experimental channel placed in the lead reflector (R=40.5cm) at central height.

Virtual ^{235}U fission detectors in the center of the experimental channel.

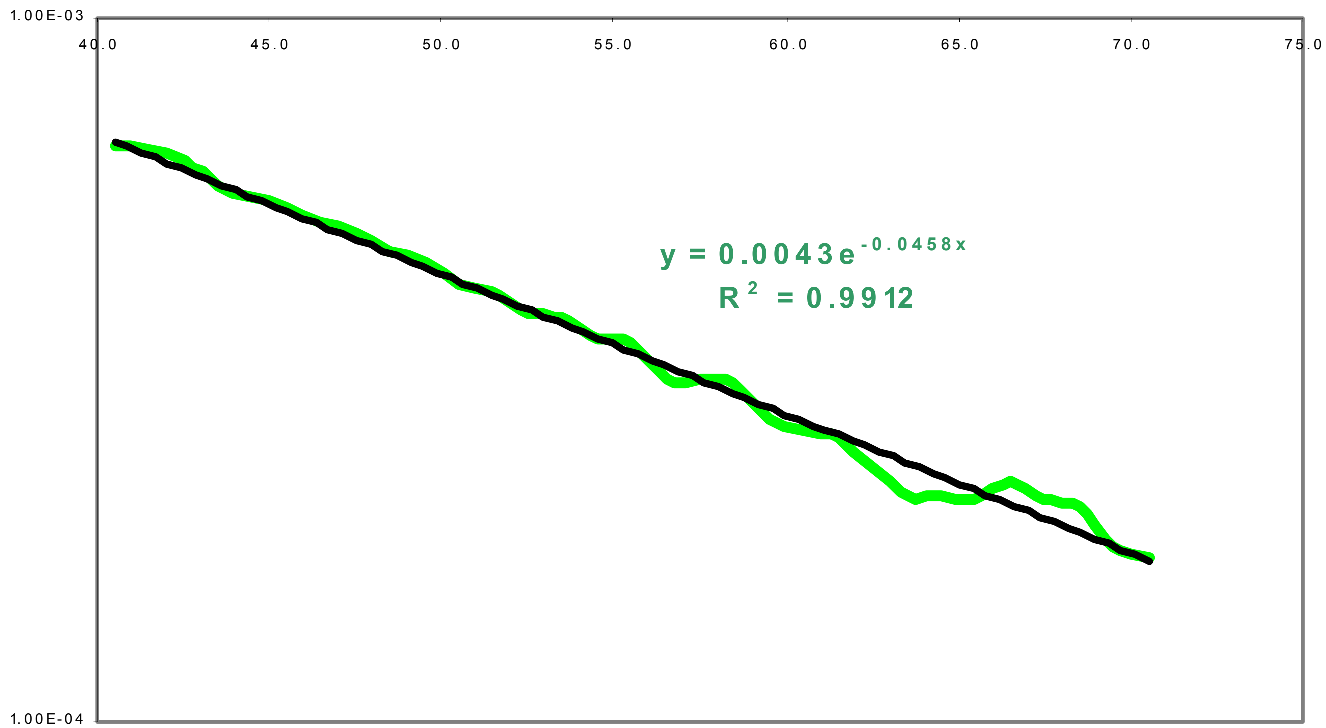
Blue = Case #12; **Black** =Case #15 (Borated Concrete); **Red**=Case #18 (Borated PB)

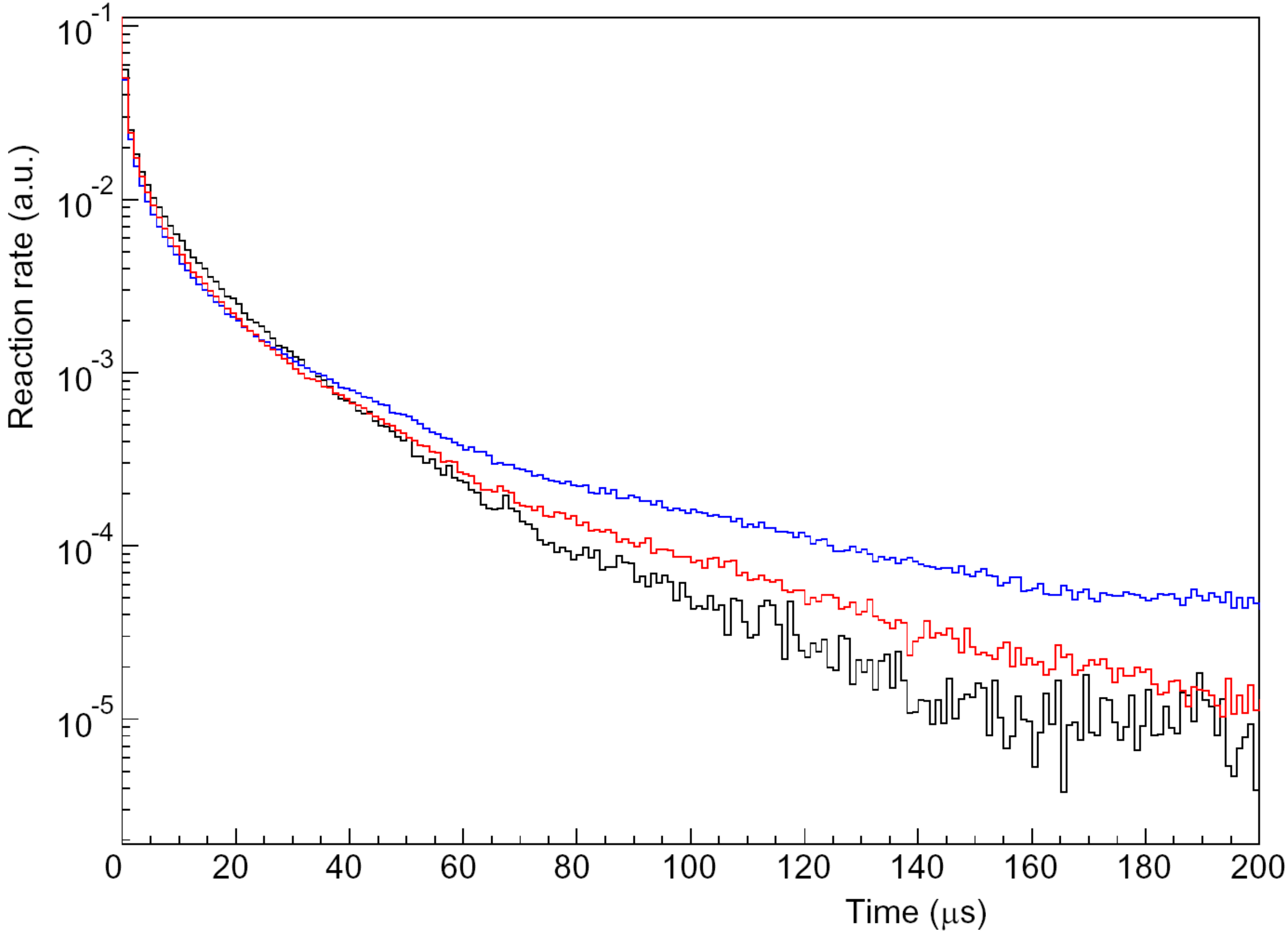
Application of simple point kinetics to case #18:

MCNP: Λ=9.543 10^{-7}s , β=345 pcm; FIT: α=45800 s^{-1}

then, $\rho(\$)$ = 11.6 so $K_{eff} = 0.9597$

Note: β_{eff}. Case #1 = 368 $\pm$ 10 (pcm)
β_{eff}. Case #12 = 350 $\pm$ 10 (pcm).



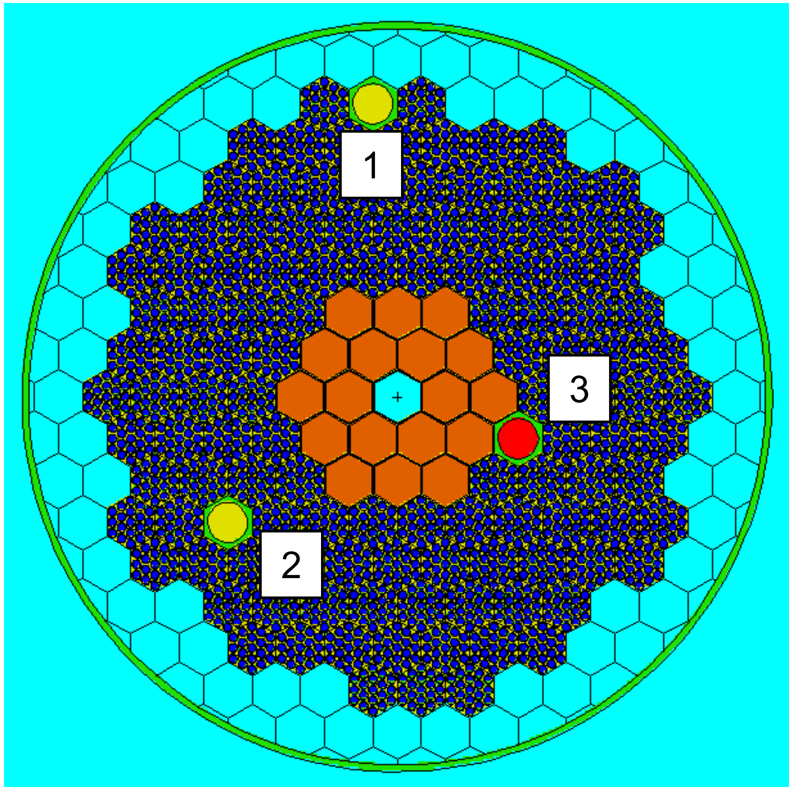


Neutron time response in the experimental channel #1 at central height.
Virtual ^{235}U fission detectors were placed in the center of the experimental channel.
Blue = Case #12; **Red**=Case #18 (Borated PB); **Black** =Case #19 (Latest SAD Distr. Input file)

Reactivity insertion simulations

Introduction of a B_4C cylinder (Ø3 cm × 51 cm long)

in the core experimental channels



K_{eff} reference =0.94783

Exp. Channel	K_{eff}	Δk_{eff}
3	0.92406	-0.02377
2	0.92720	-0.02063
1	0.93063	-0.01720

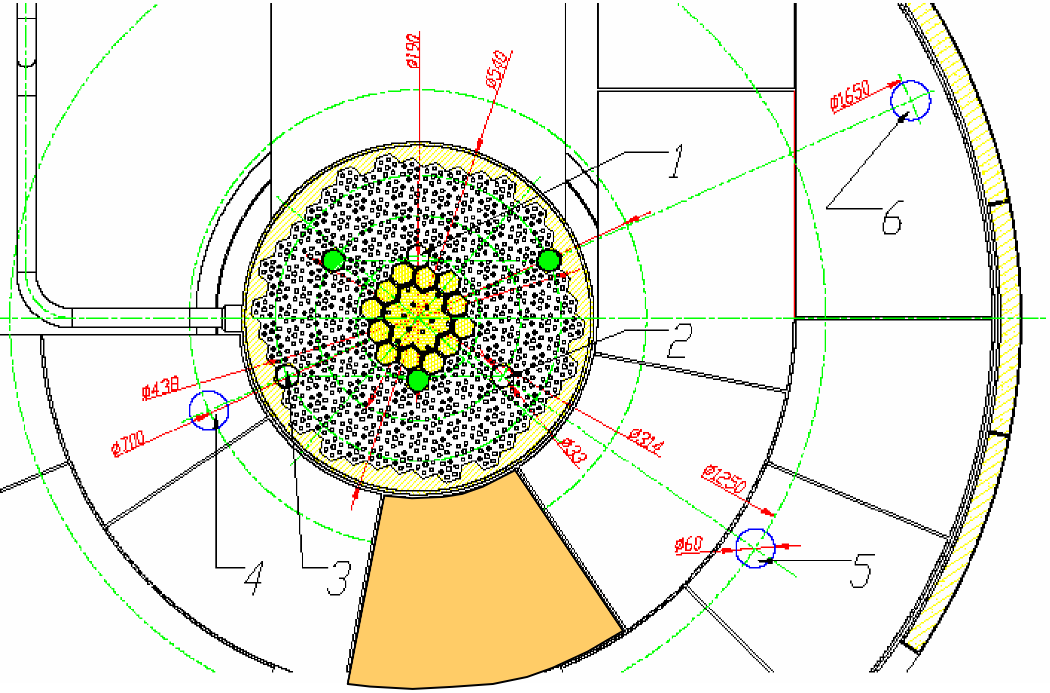
Reactivity insertion simulations

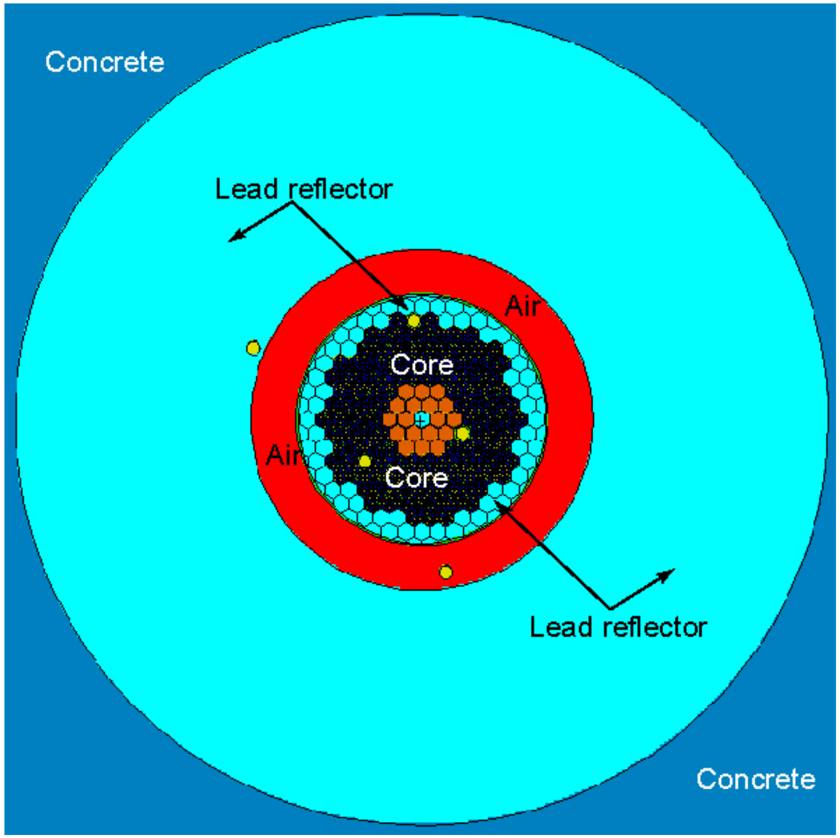
Reduction of the reflector effect:

- In reality extraction of one of the reflector elements.
- In the simulation reduction of the lead thickness.

K_{eff} reference =0.94783

Reduct. of Ø cm	K_{eff}	Δk_{eff}
20	0.84882	0.09901
6	0.91437	0.03346





Dynamic tests proposal

In the near future (<7 years) there will be no ADS system that

- Is similar to the proposed transmutation device: Fuel, Coolant, Neutron Spectrum
- and Has sufficient power / heaters as to introduce significant thermal feedbacks

Two complementary approaches:

1)Use a different system with significant feedbacks (TRADE-Plus)
2)Use a similar ADS system simulating the feedbacks ($\Rightarrow$ **SAD**)

The proposal is to study dynamic feed-backs of ADS systems by artificial introduction of reactivity variations following the pattern of the calculated thermal feedbacks in industrial ADS incidents.

The reactivity (positive/negative) insertions can be obtained by programmed reflector movements (more complicated options possible).

The follow up can be done by neutronic detectors, and actions can be applied by beam actuation or absorbers in the experimental channels.

It would be interesting to study insertions of as much as ±1000 pcm
(from 0.95 $\rightarrow$ 0.96 and from 0.95 $\rightarrow$ 0.94).

Conclusions

15% differences are observed on the neutron production/proton from different nuclear models in the target simulation

Large lead reflector:

- Reduce the number of fuel elements / fissile material (margin to increase K_{eff})
- Recover a kinetic behavior closer to point kinetics
- Low energy neutron absorber (^{10}B, ^{6}Li, Cd) around core improve kinetic response
- Attention to absorbing materials in the reflector

Kinetic techniques might be usable at SAD for reactivity determination

Large reactivity insertions can be obtained by:

- Reflector modification
- Absorber rods (B_4C) on the experimental channels
- Need of electromechanical fast actuators

These options might allow investigation of ADS dynamic behavior

SAD might allow to study: Source multiplication, source importance, Shielding aspects, and other static effects but probably also kinetic and dynamic ADS aspects