The use of the SERPENT code in safety studies of fast reactors

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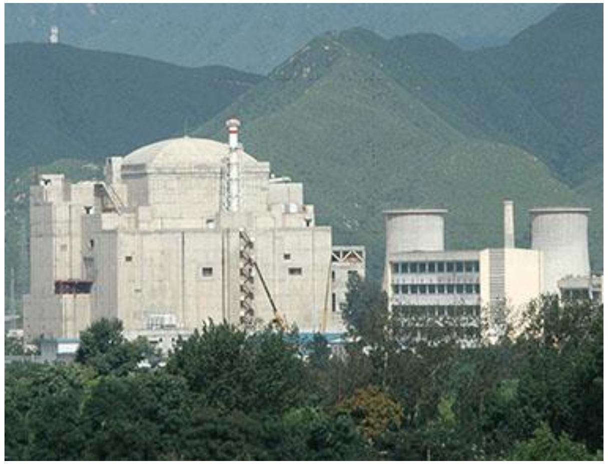

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Reactor Physics department

Outline

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- Why fast reactors
- Reference fast reactor designs
- Transient simulation tool and study scheme
- What we can obtain from SERPENT calculations
- Some expectations of SERPENT

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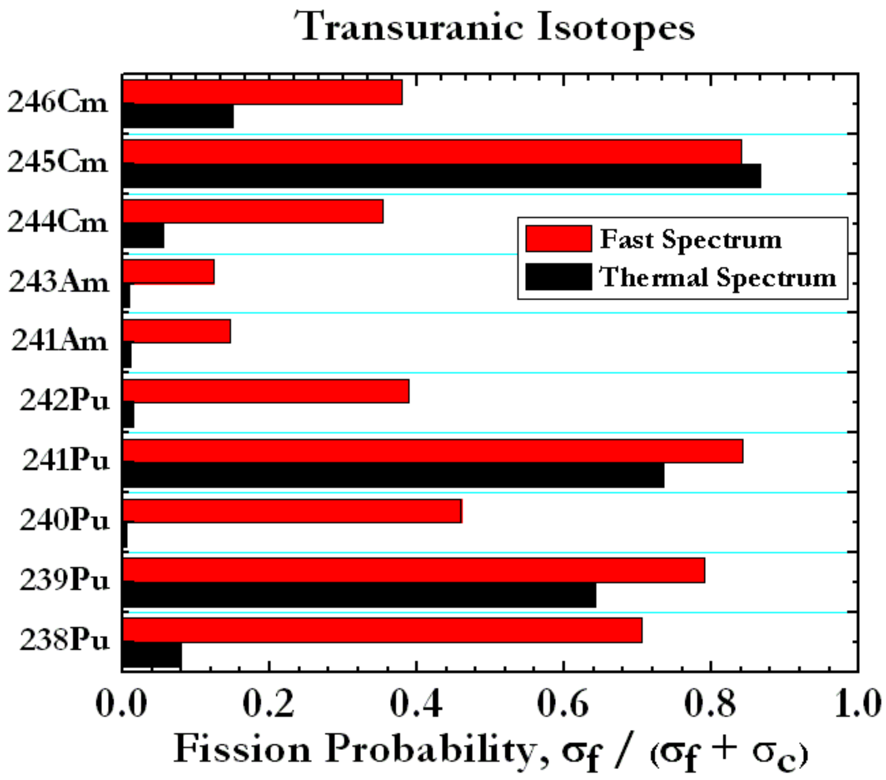
Why fast reactors ...

Recycling in LWR …



Transmutation in thermal spectrum

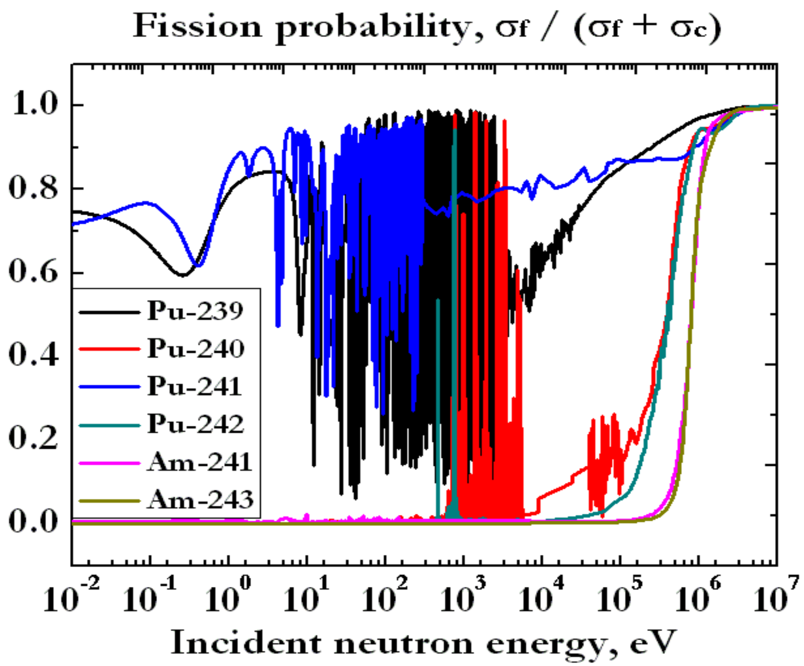
✓ Fission Pu-239 and Pu-241

⇒Reduction of Pu inventory

✓ Am-241 could be partly transmuted by neutron absorptions:

Am-241 + n -> Am-242 -> Cm-242 -> Pu-238

✓ Hard to fission nuclides with even neutron number, e.g., Pu-240, Pu-242, Am-241, Am-243, Cm-244, Cm-246



Neutron capturing

⇒ Accumulation of highly radioactive Cf-252

⇒ Difficulties of spent fuel handeling

Then ..fast spectrum

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Some fast reactor designs

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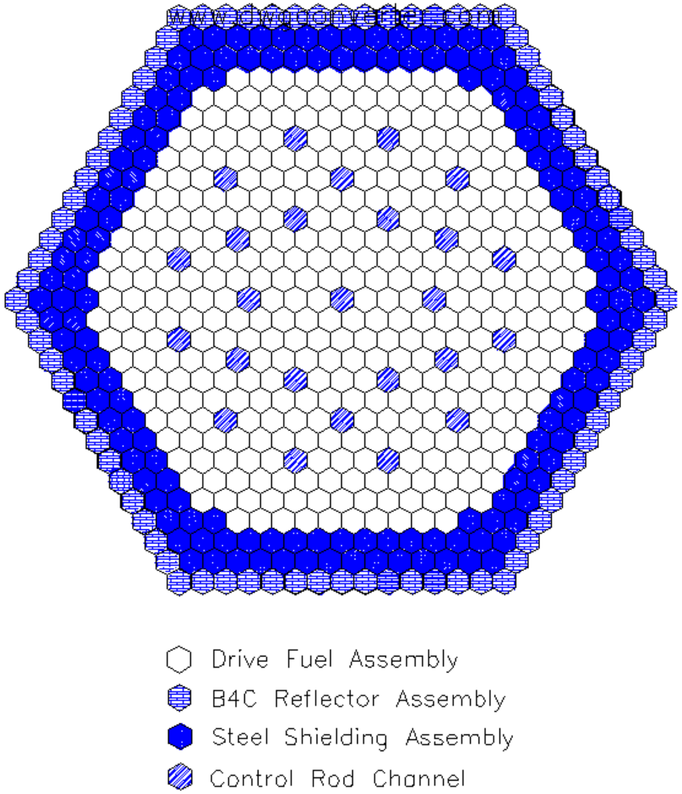
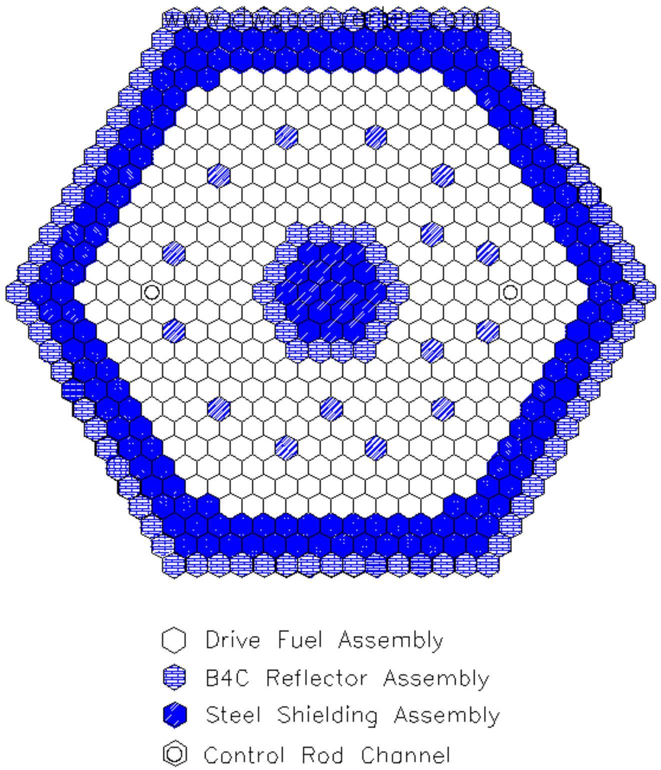


BN600

- Excellent operational performance since 1980
- Medium sized fast reactor (1470 MWth)
  - Good balance between safety and economics
- Fully loaded with MOX
- 127 pins per SA and 369 drive SA in core region
- Pin OD = 6.9 mm and P/D = 1.159
- Length of core active region = 1030 mm

IFR (Integral Fast Reactor)

- (U,Pu,Am)Zr loaded
- Rated power = 2500 MWth
- Reported good safety performance
- 271 fuel pins per SA and 456 SA in core region
- Pin OD = 7.2 mm and P/D = 1.667
- Length of core active zone: 970 mm



SERPENT models

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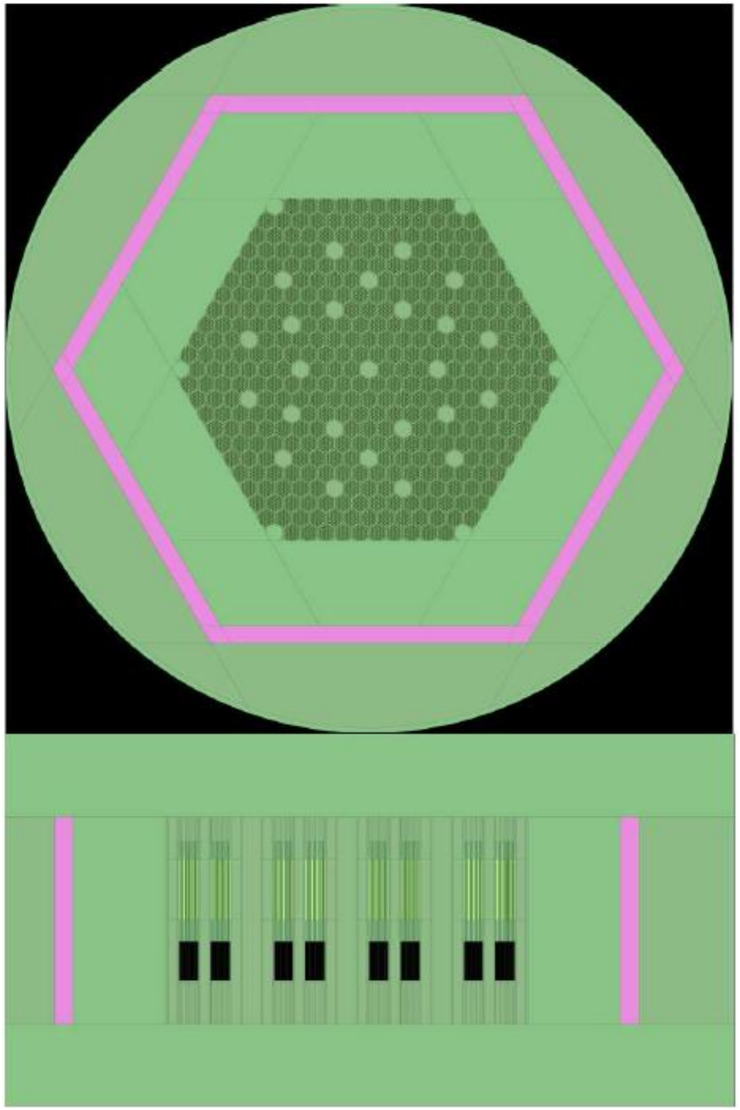
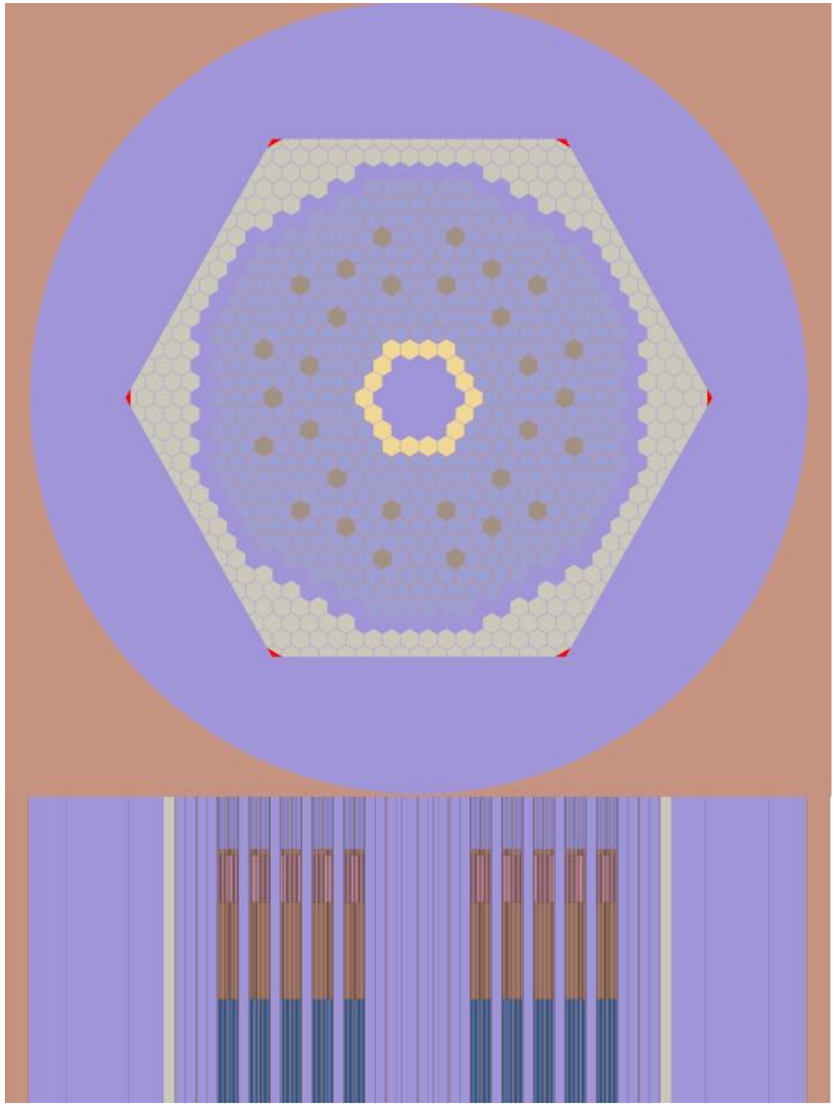


BN600



IFR

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Transient simulation tool and study scheme

SAS4A/SASSYS transient analysis code

- ***Point kinetic model – Evaluating neutronic behavior***
- ***Two-dimensional (r/z) heat conduction equation***
- ***One-dimensional, homogenous coolant flow model***

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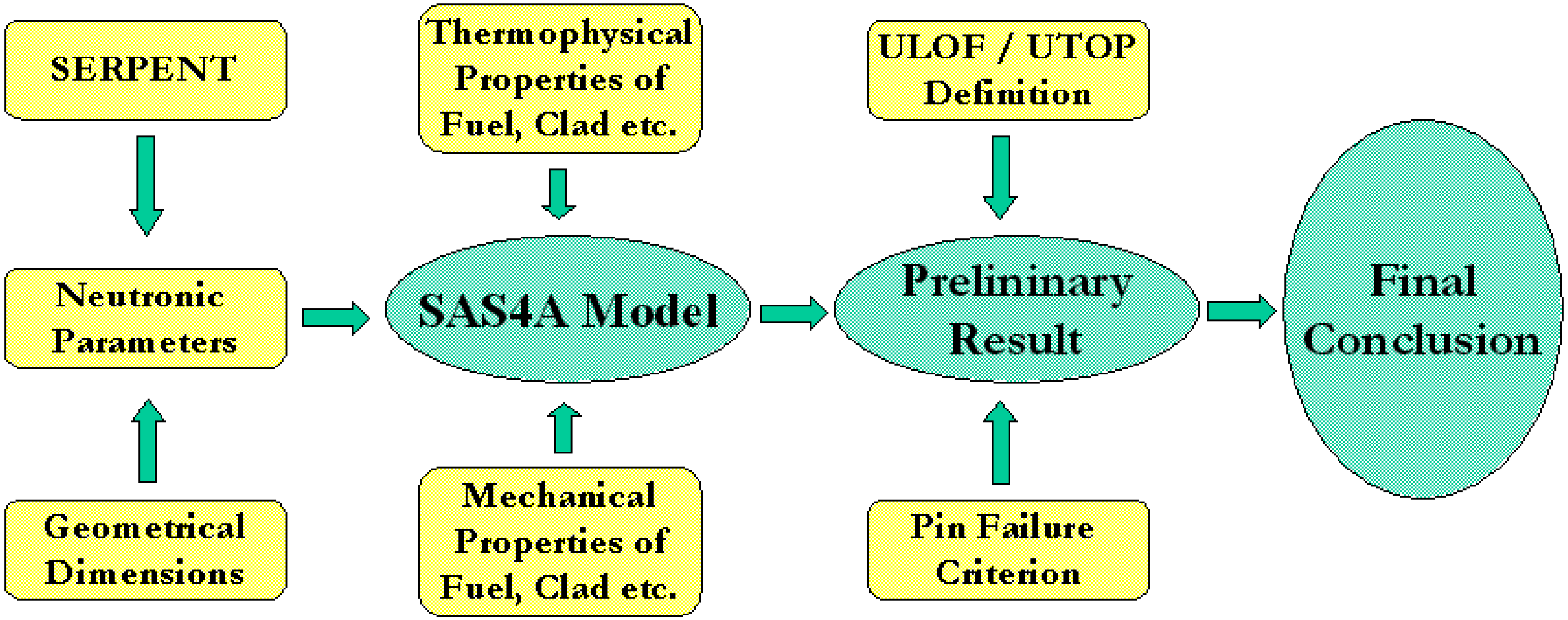

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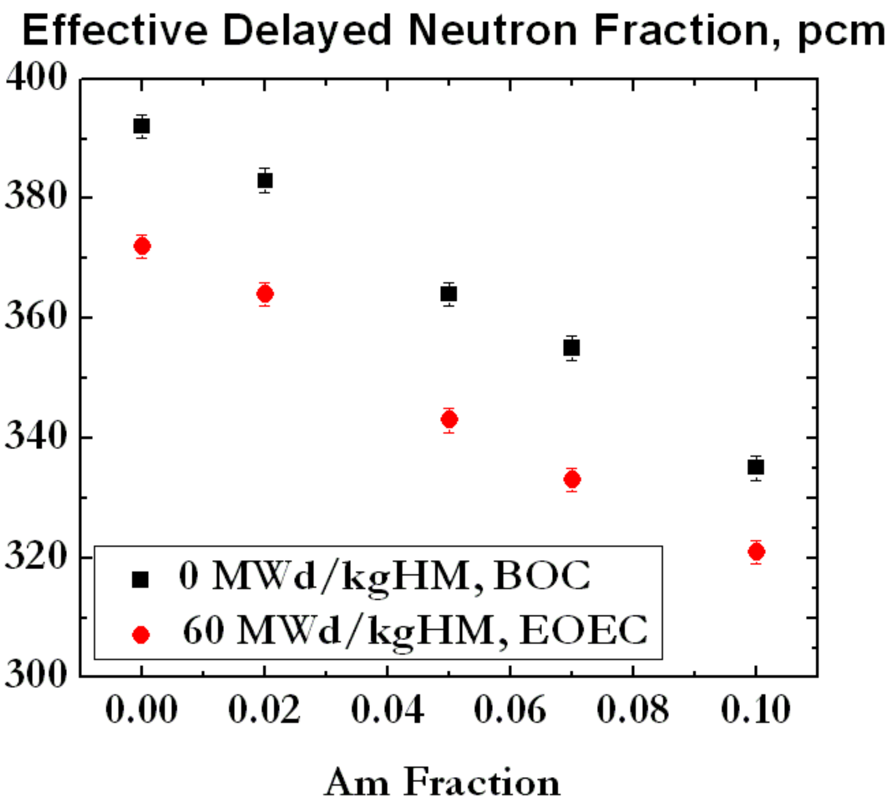
Neutronic calculation results of BN600 design

Effective delayed neutron fraction, β eff



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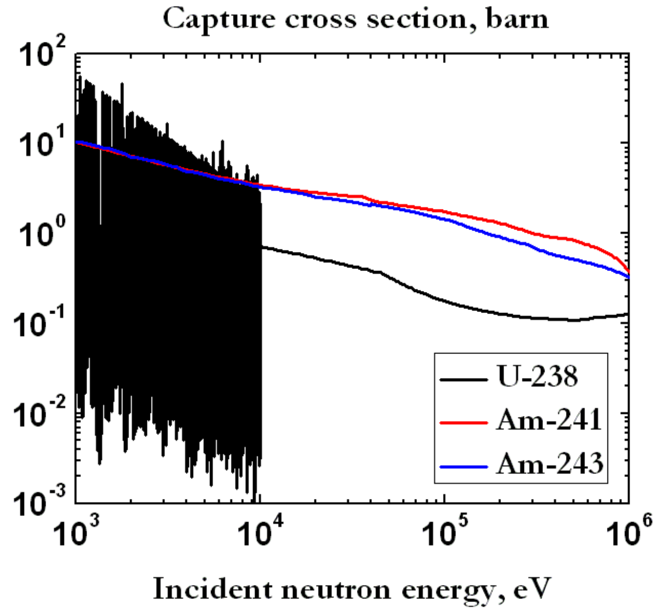
- U-238 to Pu and Am with lower *β*

⇨ Decrease with burnup

- Decrease with Am content's increase

Nuclide	ν (tot)	ν (delayed) / ν (tot)
U-238	2.53	1.89%
Pu-239	3.02	0.22%
Am-241	3.37	0.13%



- >80% delayed neutrons in 10 keV ~ 1 MeV
- 5 times higher capture cross section of Am nuclides in 10 keV ~ 1MeV

The Doppler effect

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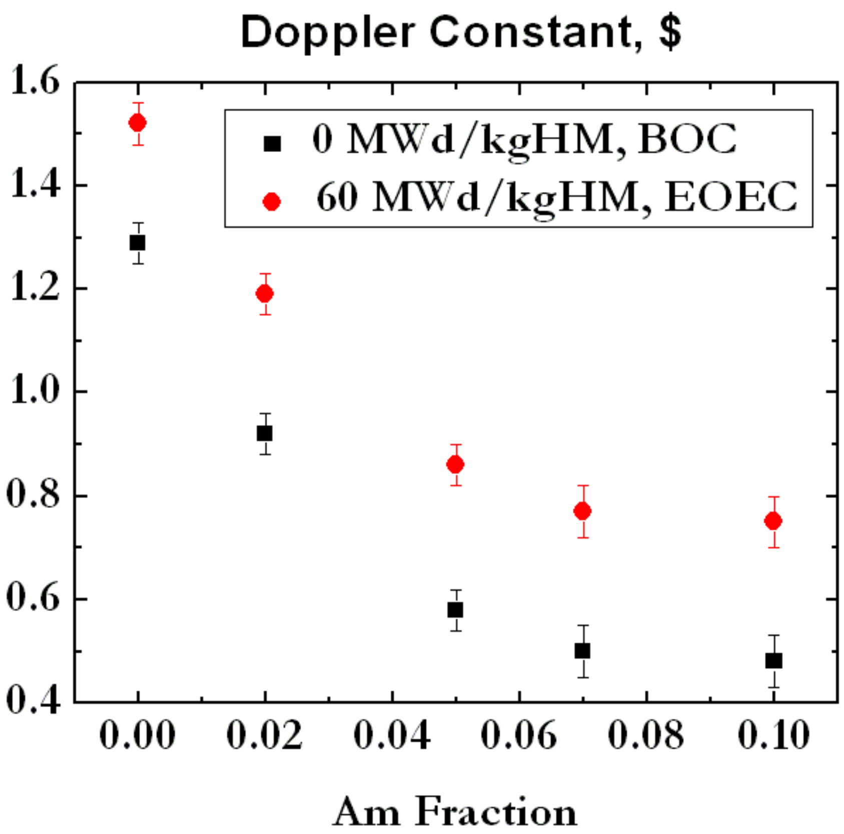
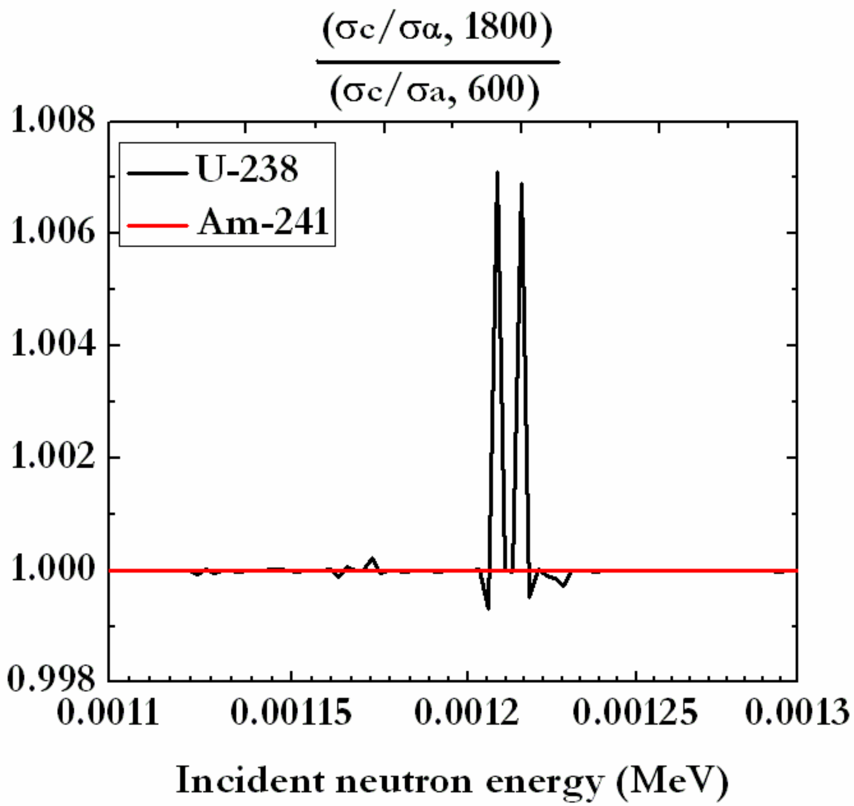


❖ **Decrease with Am content's increase**



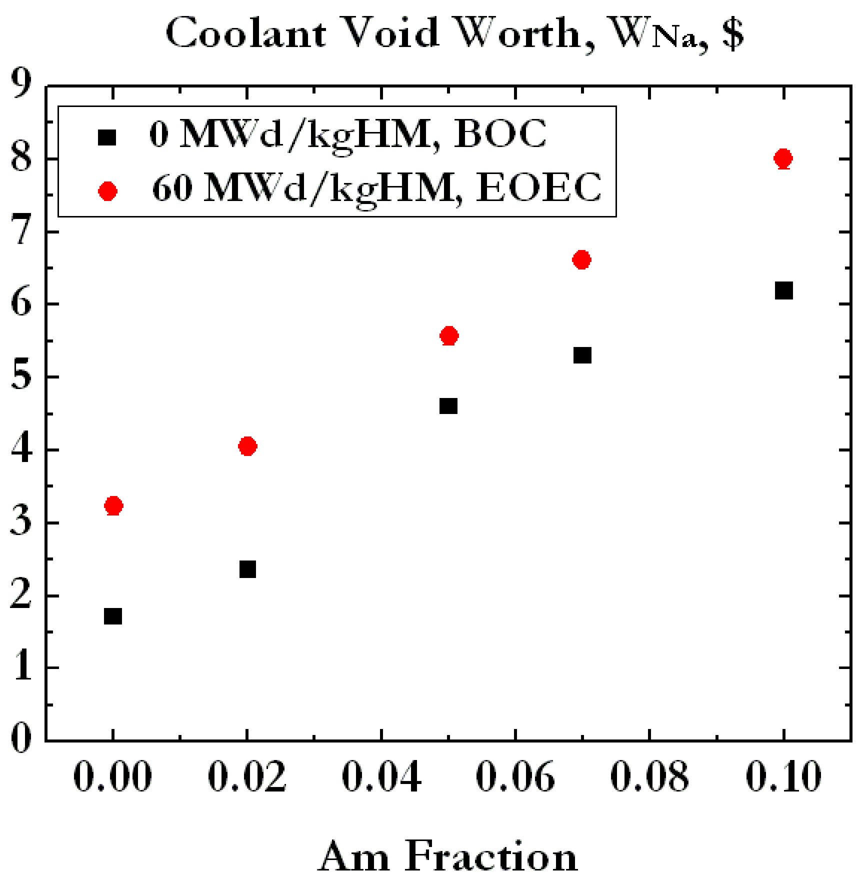
❖ **Accumulation of fission products**

➡ **Soften neutron spectrum**

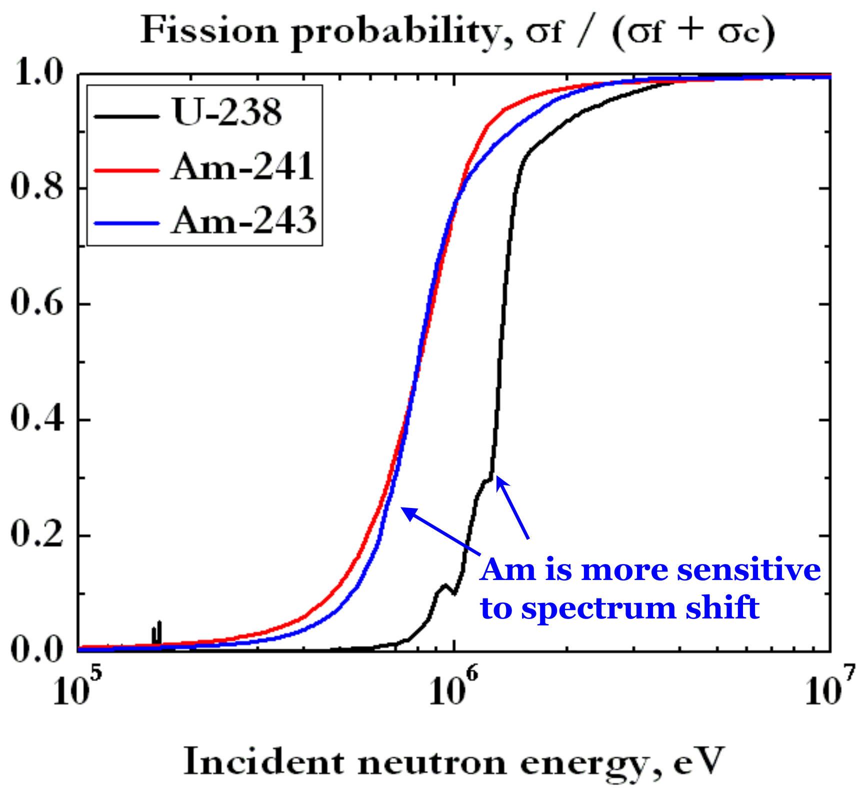
➡ **More fission neutrons into effective region**

➡ **Increase with burnup**

Coolant temperature coefficient



❖ **Increase with Am content's increase**



❖ **Increase of ratio between Am and fissile Pu nuclides**

❖ **Am contributes more positive void worth than fissile Pu**

⇨ **Increase with burnup**

Some other neutronic parameters ..

- ***Prompt neutron lifetime***
- ***Group-wised delayed neutron precursor decay constants***
- ***Group-wised decay heat precursor decay constants***

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Some other neutronic parameters ..

- ***Prompt neutron lifetime***
- ***Group-wised delayed neutron precursor decay constants***
- ***Group-wised decay heat precursor decay constants***
- ***Axial/radial power profile***

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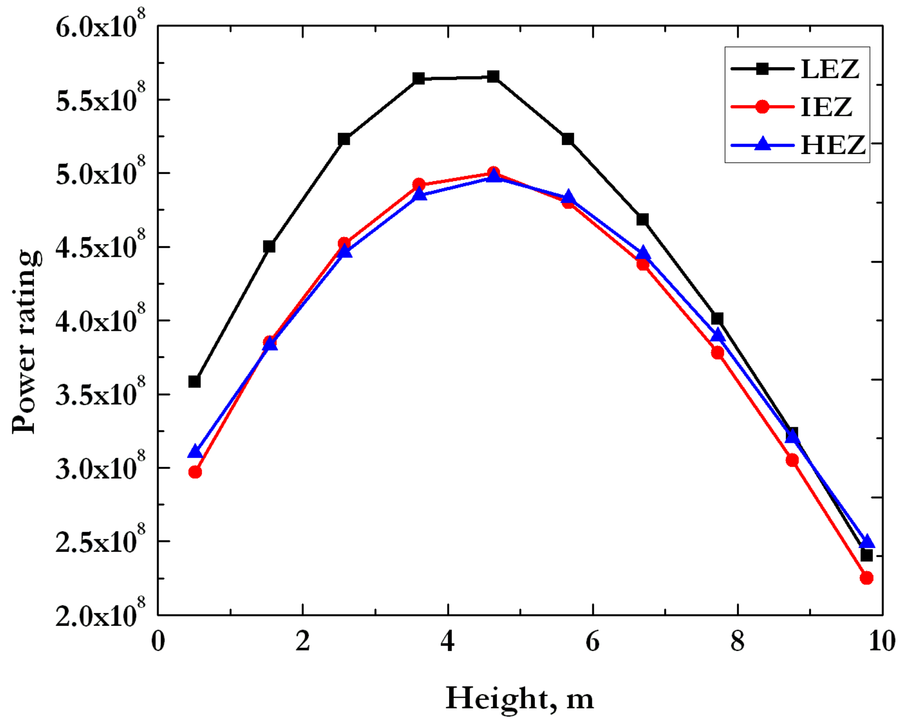

Some other neutronic parameters ..

- ***Prompt neutron lifetime***
- ***Group-wised delayed neutron precursor decay constants***
- ***Group-wised decay heat precursor decay constants***
- ***Axial/radial power profile***

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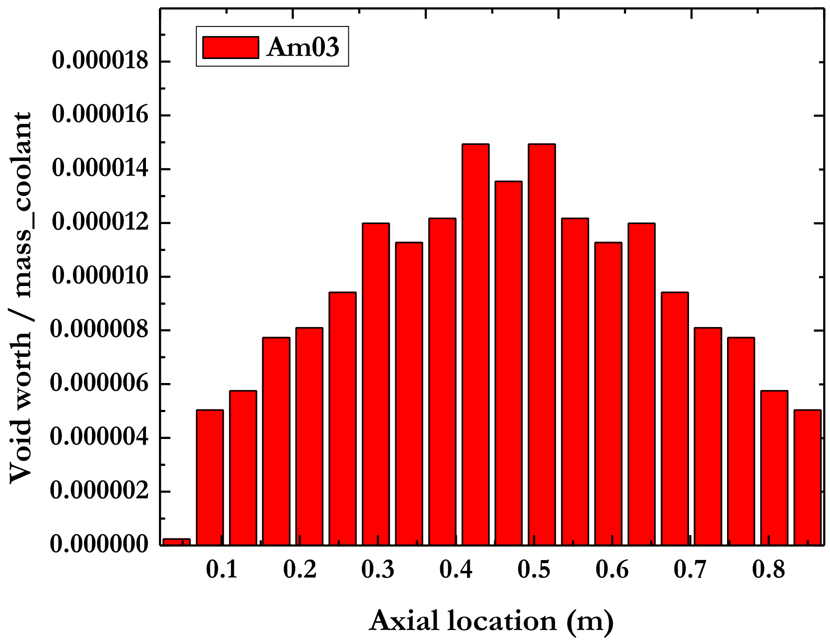
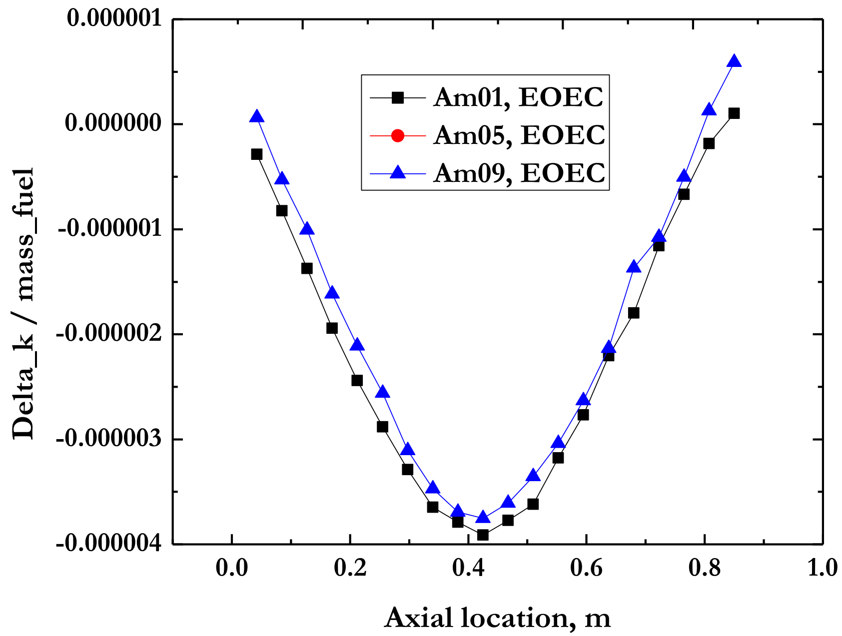
- ***Axial profile of coolant temperature coefficient***
  - ***Axial profile of fuel reactivity worth***





But .. some inconveniences

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- **Small energy grid size -> RAM occupation**
- **[set powdens] card has the unit of MWd/kgU**

  -> hard to be used for non-uranium fuels (like in ADS)
- **8 groups of delayed neutron precursors from SERPENT**

  -> But only 6 groups in SAS4A/SASSYS model

Thanks for listening

Questions are welcomed

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BN-600 Reactor Design