Modeling of ESFR core using Serpent and DYN3D codes

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Outline

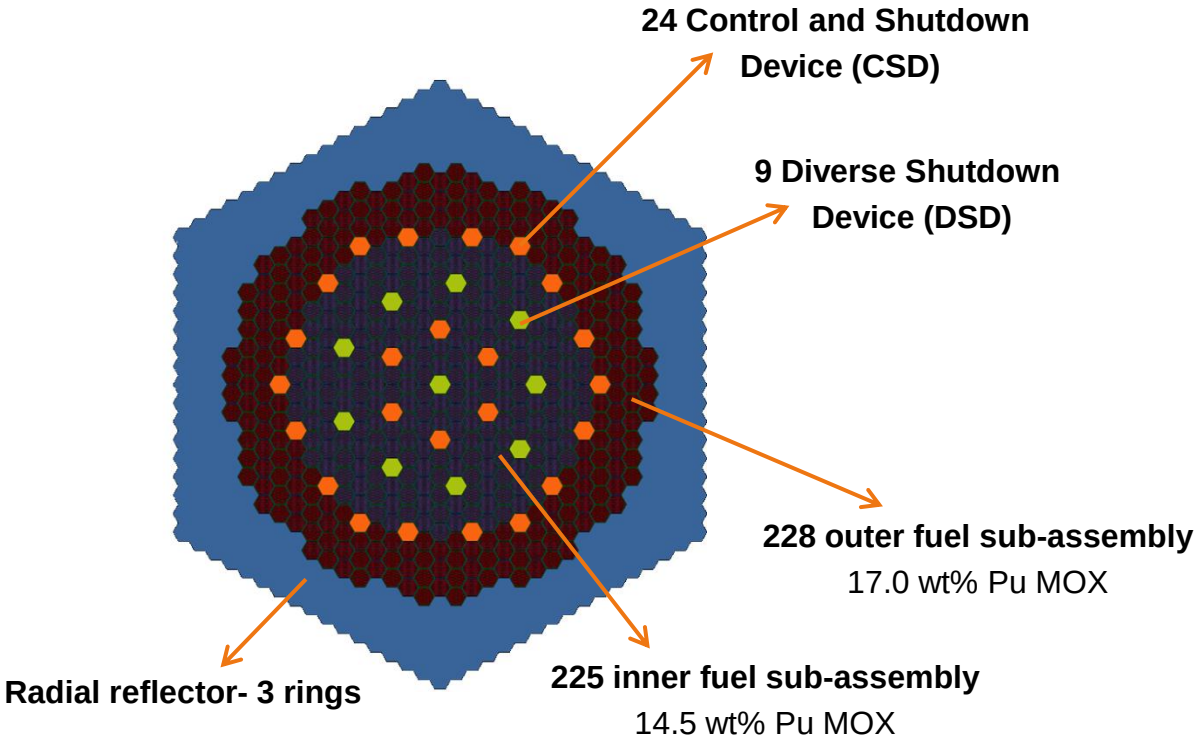
- Objectives
- Description of the reference SFR core
- Methodological approach for few-group XS generation
- Verification of few-group XS generation methodology
- Summary

Objectives

- Establishing of few-group XS generation procedure
  - For SFR cores analysis with DYN3D
  - Using Serpent
- Verification of few-group XS generation methodology
  - Via 2D full core modeling of SFR core

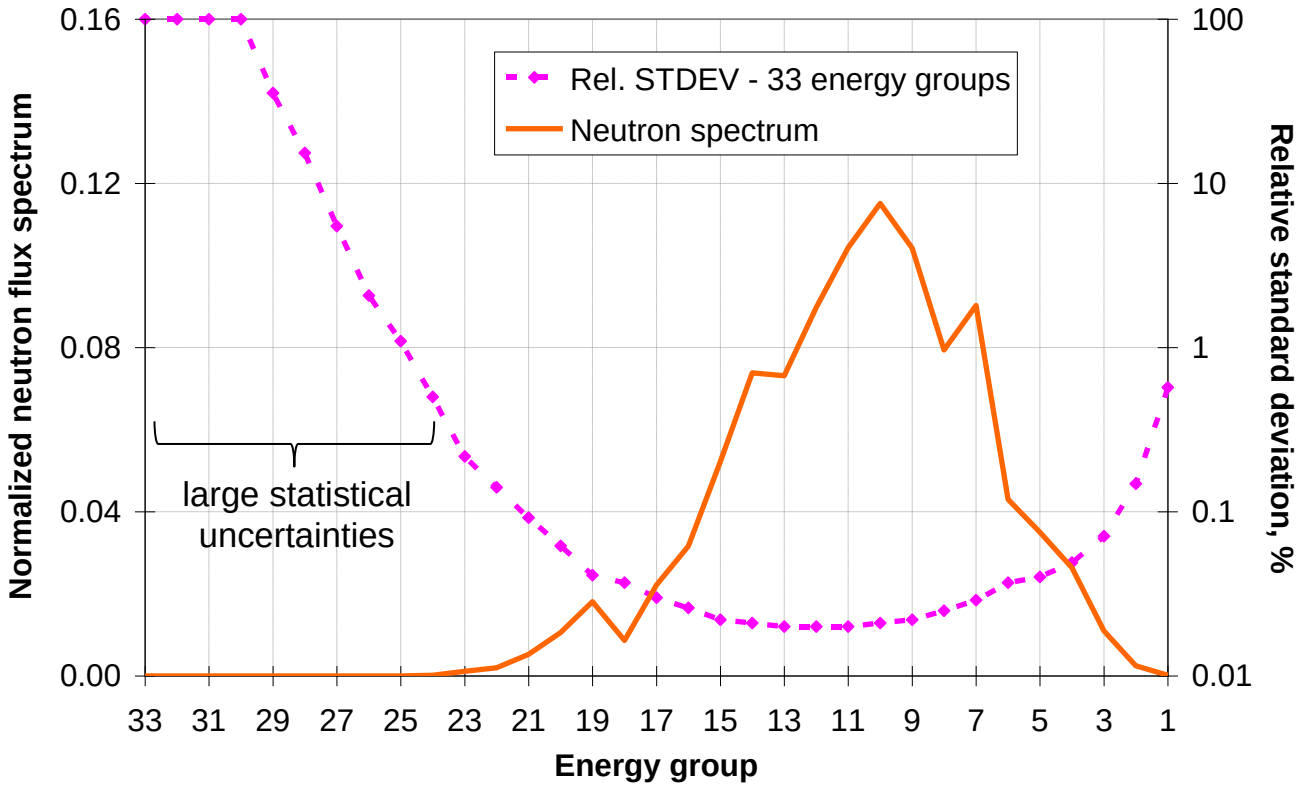
Reference SFR core

- "Working horse" MOX ESFR core design
  - Proposed in the frame of the Collaborative Project on European Sodium Fast Reactor (CP ESFR)



Methodological approach for few-group XS generation

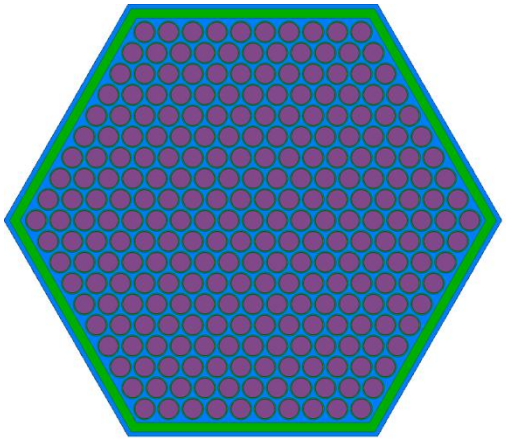
Selection of few-group energy structure



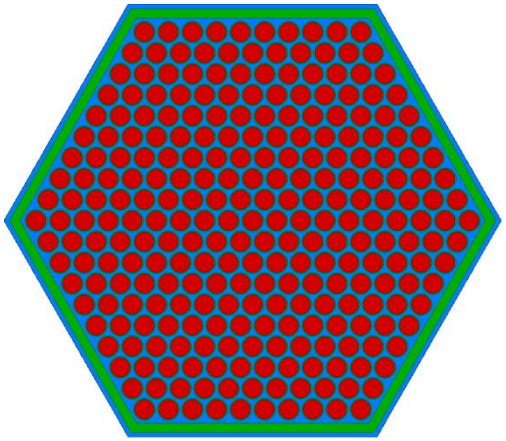
- 33 group structure is not appropriate
  - Very poor statistics in thermal energy groups
- 24 group structure is selected
  - Groups 24 to 33 collapsed into a single thermal group

Few-group XS for fuel sub-assemblies

- Generated in infinite assembly lattice calculations
  - For fuel sub-assemblies not facing non-multiplying regions



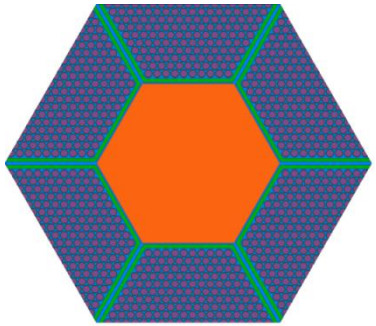
Inner fuel sub-assembly
14.5 wt% Pu MOX



Outer fuel sub-assembly
17.0 wt% Pu MOX

Few-group XS for reflector and CSD regions

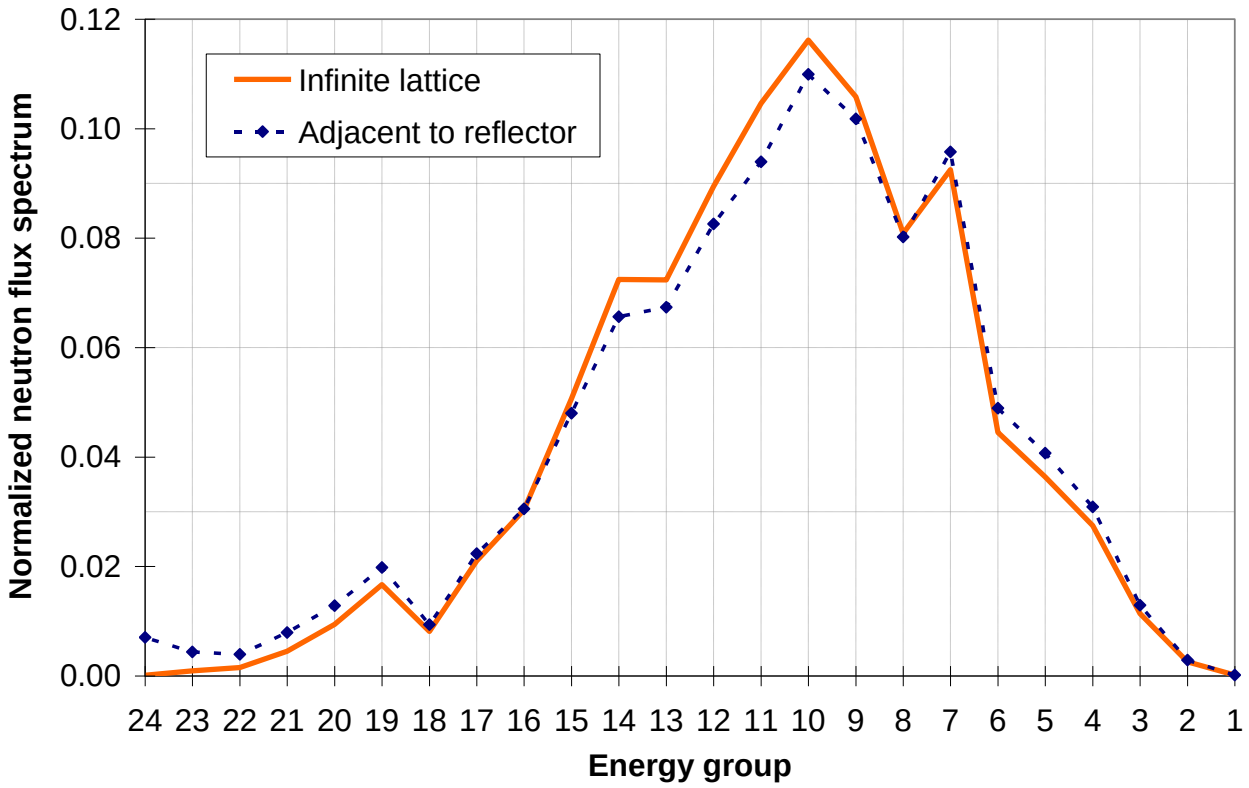
- Generated in realistic super-cell models
  - Fuel and non-multiplying regions are coupled in space and energy
- XS for adjacent fuel sub-assemblies are also extracted
  - Taking into account the spectral effects of non-multiplying regions



Fuel-CSD model

Fuel-Reflector model

Neutron flux spectra in sub-assemblies



- Reflector spectral effects
  - Noticeable flux softening in sub-assembly adjacent to reflector

Verification of few-group XS generation methodology

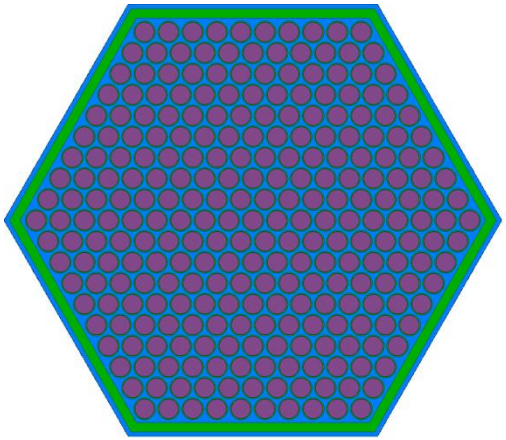
Verification of XS generation methodology

- 2D full core burnup calculation
  - DYN3D: diffusion calculations
  - Serpent: MC calculations
    - Generation of few-group XS for DYN3D
    - Reference solution

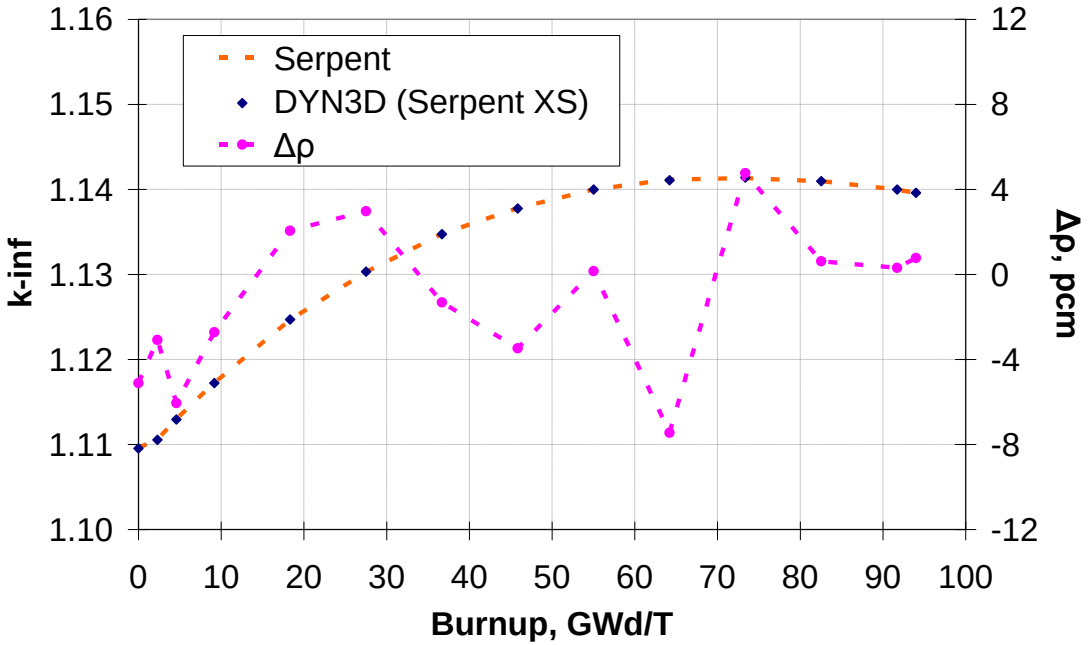
- Studied parameters:
  - k-inf, k-eff as a function of burnup
  - Reactivity coefficients
    - Doppler constant (k_D)
    - Coolant Void Reactivity (CVR)
    - Total CDS worth
  - Radial power distribution

k-inf vs. burnup

Inner fuel sub-assembly - 14.5 wt% Pu MOX



Homogenized XS

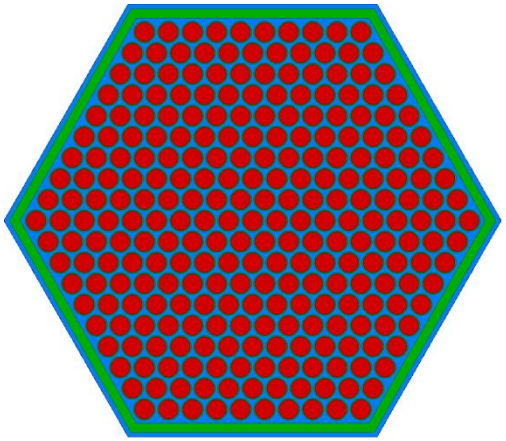


Max. rel. diff. = 7 pcm

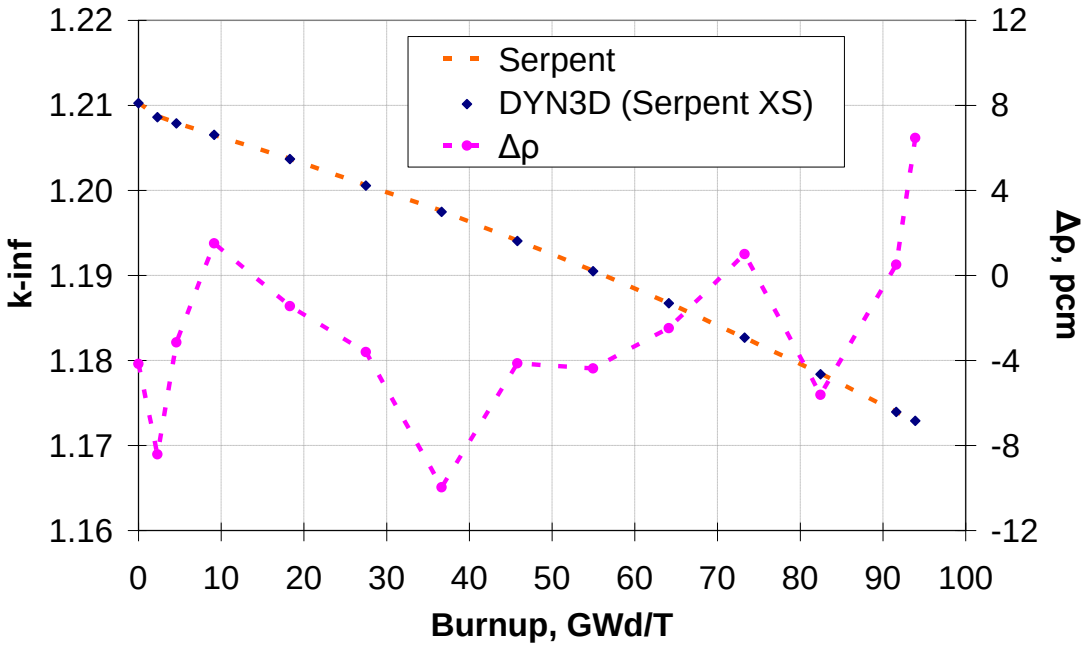
Ave. STDEV Serpent = 6 pcm

k-inf vs. burnup

Outer fuel sub-assembly - 17.0 wt% Pu MOX



Homogenized XS

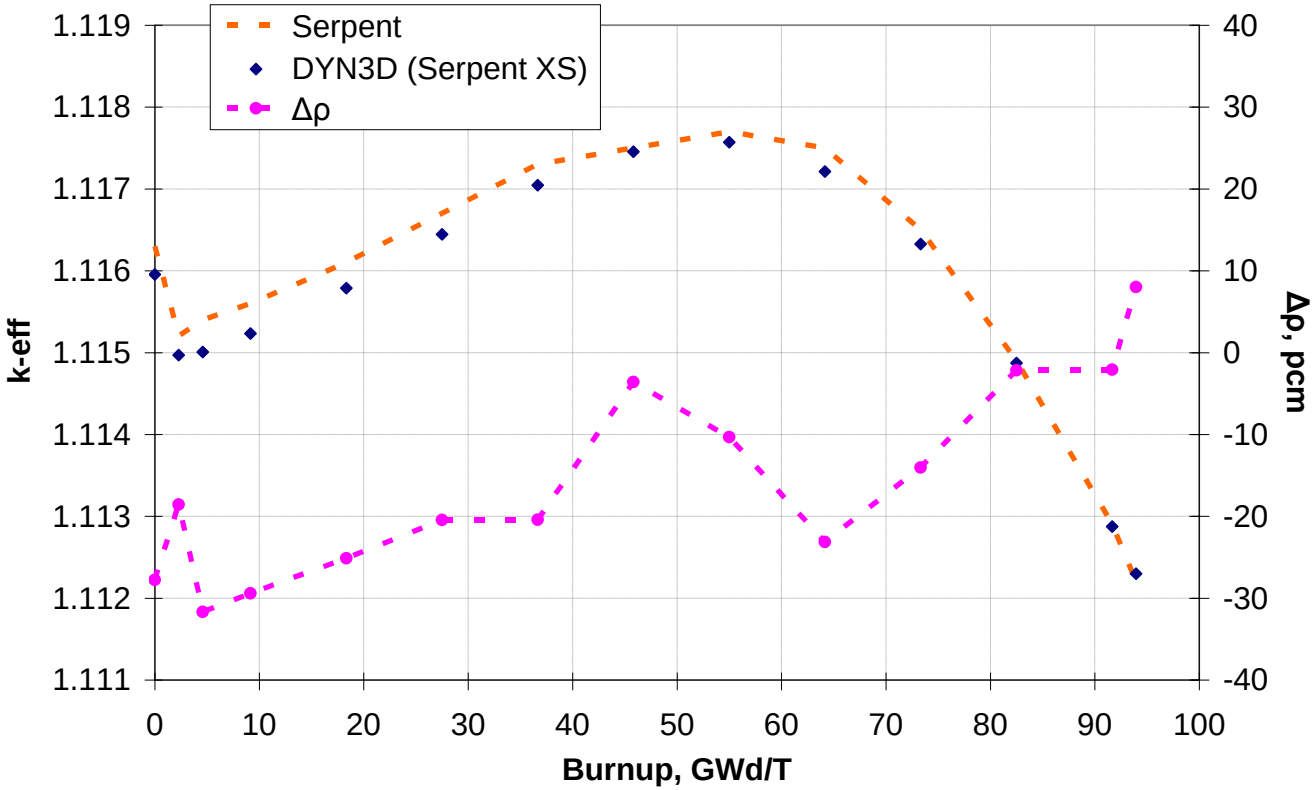


Max. rel. diff. = 10 pcm

Ave. STDEV Serpent = 6 pcm

k-eff vs. burnup

Full core



Max. rel. diff. = 32 pcm

Ave. STDEV Serpent = 6 pcm

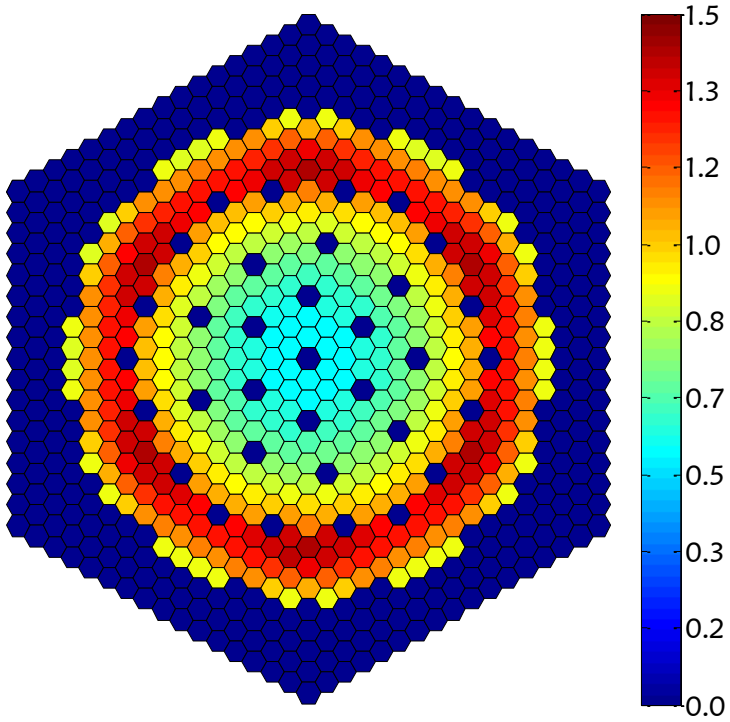
Reactivity coefficients

Parameter	Stage	Serpent	DYN3D	Diff., pcm Serpent vs. DYN3D
k_D, pcm	BOL	-1062	-1072	**-10**
	EOL	-723	-723	**0**
CVR, pcm	BOL	2821	2850	**29**
	EOL	3654	3702	**47**
Total CDS worth, pcm	BOL	-4678	-4629	**49**

Ave. STDEV k-eff (Serpent) = 6 pcm

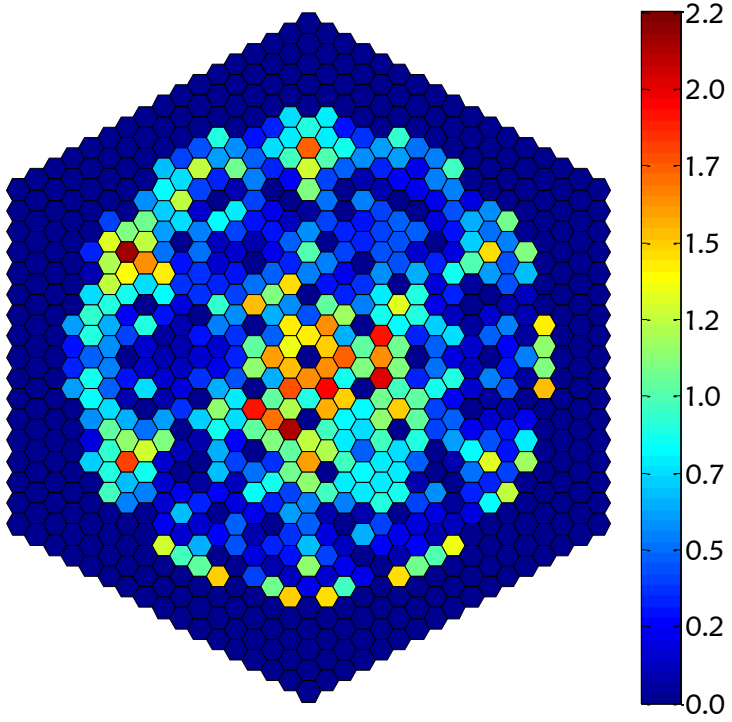
Power distribution at BOL

Control rods Out



Serpent

Ave. STDEV = 1.3 %

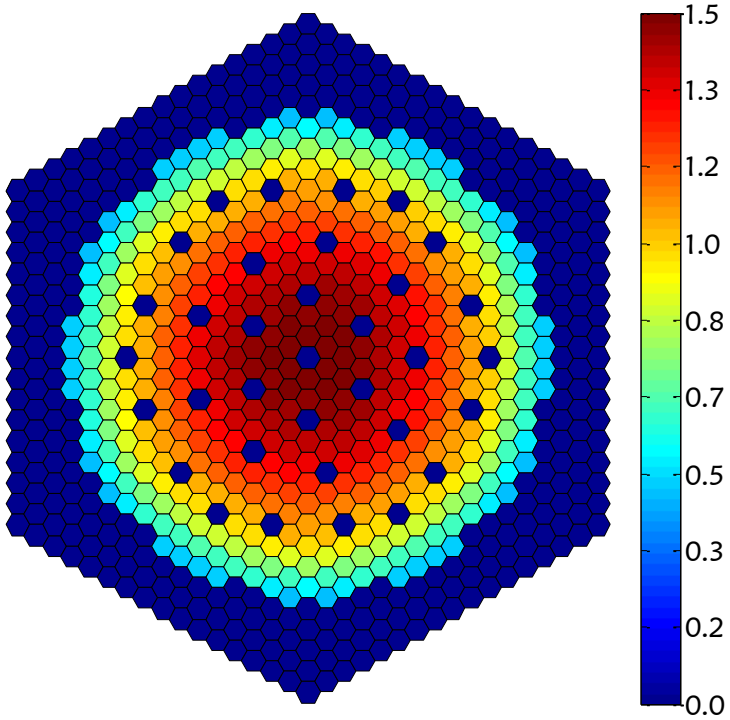


Rel. diff., %
Serpent vs. DYN3D

Max. rel. diff. = 2.1 %
Ave. rel. diff. = 0.6 %

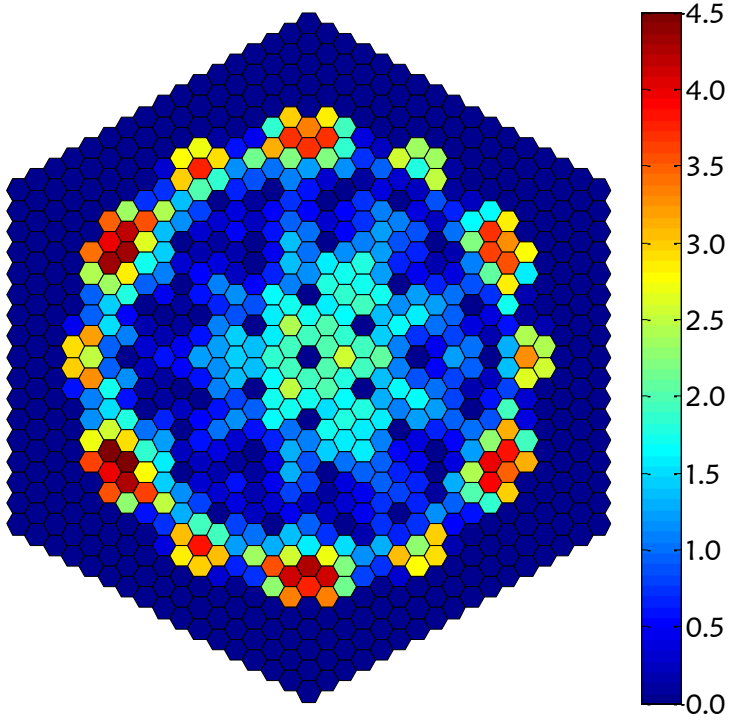
Power distribution at EOL

Control rods Out



Serpent

Ave. STDEV = 1.5 %

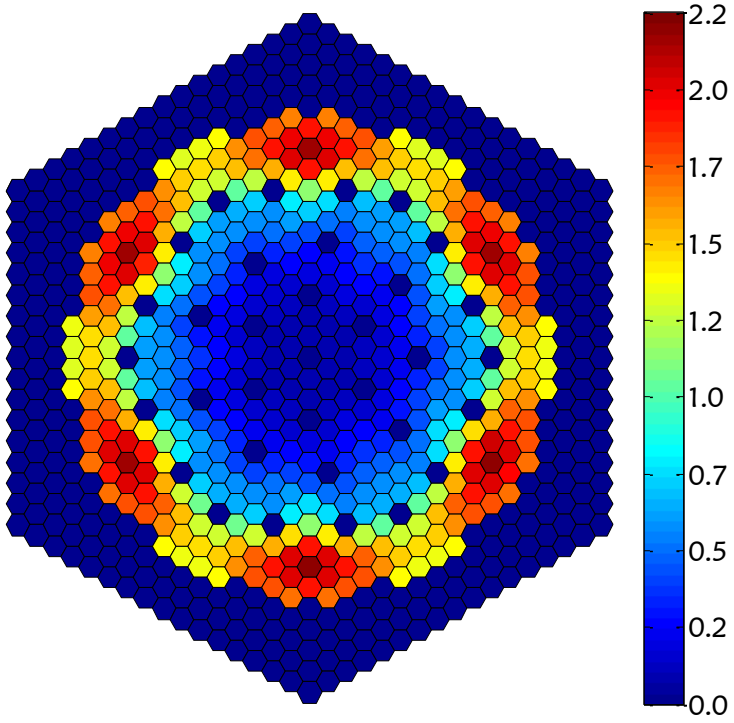


Rel. diff., %
Serpent vs. DYN3D

Max. rel. diff. = 4.5 %
Ave. rel. diff. = 1.4 %

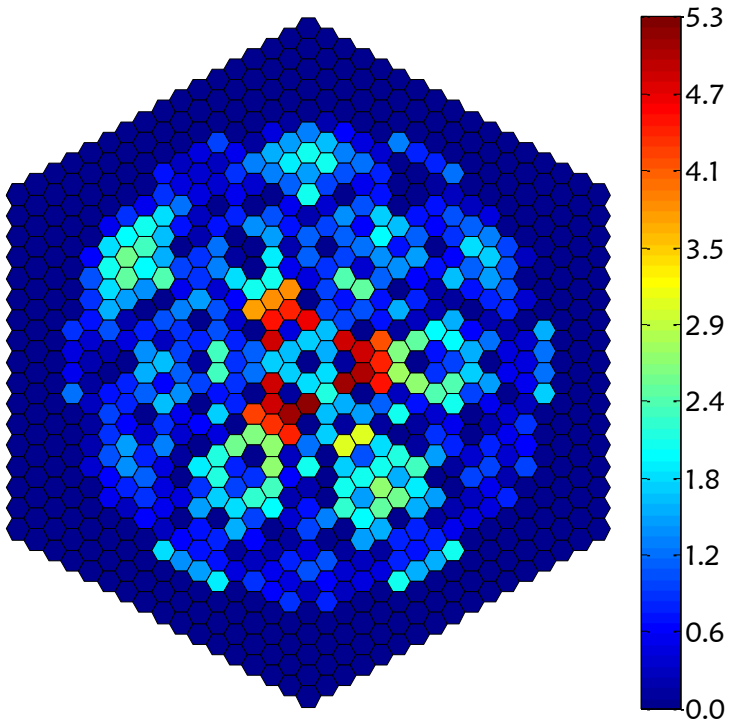
Power distribution at BOL

Control rods In



Serpent

Ave. STDEV = 2.1 %



Rel. diff., %
Serpent vs. DYN3D

Max. rel. diff. = 5.2 %
Ave. rel. diff. = 1.2 %

Summary

- Serpent based few-group XS were used by DYN3D
  - 2D full core nodal diffusion calculations of ESFR core
- DYN3D results were verified against full core Serpent MC solution
- Very good agreement between the codes was obtained
- Serpent can be used as a production code for XS generation

Thank you for your attention!