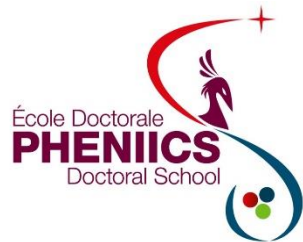


IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety



Mariya Brovchenko
Julien Taforeau

MEMBER OF

ETSON

EUROPEAN
TECHNICAL SAFETY
ORGANISATIONS
NETWORK



Impact of core power variations on the fast neutron flux incident on pressurized water reactor vessels

13/05/2019

Romain VUIART

ICAPP 2019

PSN-EXP/SNC/LN

Content

- 1. Introduction**
- 2. Impact of core power history on the assembly burnup**
- 3. Impact of core power history on the fast neutron flux at the vessel**
- 4. Conclusion**

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Study context

- **Extension of operation of 900 MWe PWRs ?**
- Vessel = 2nd barrier of confinement → **characterize its structural integrity**
- Neutron irradiation → **material embrittlement**

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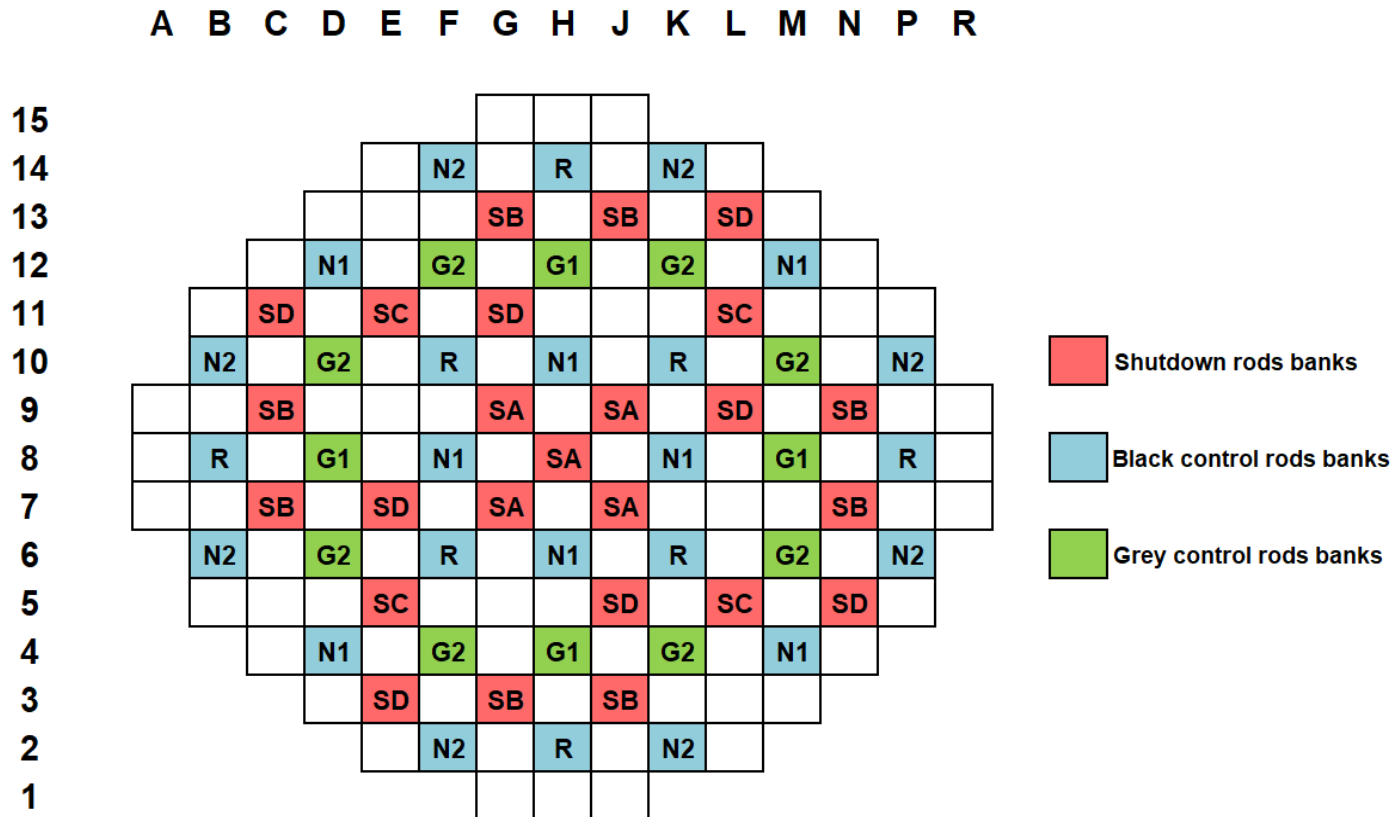
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Power history and variations of the operational parameters

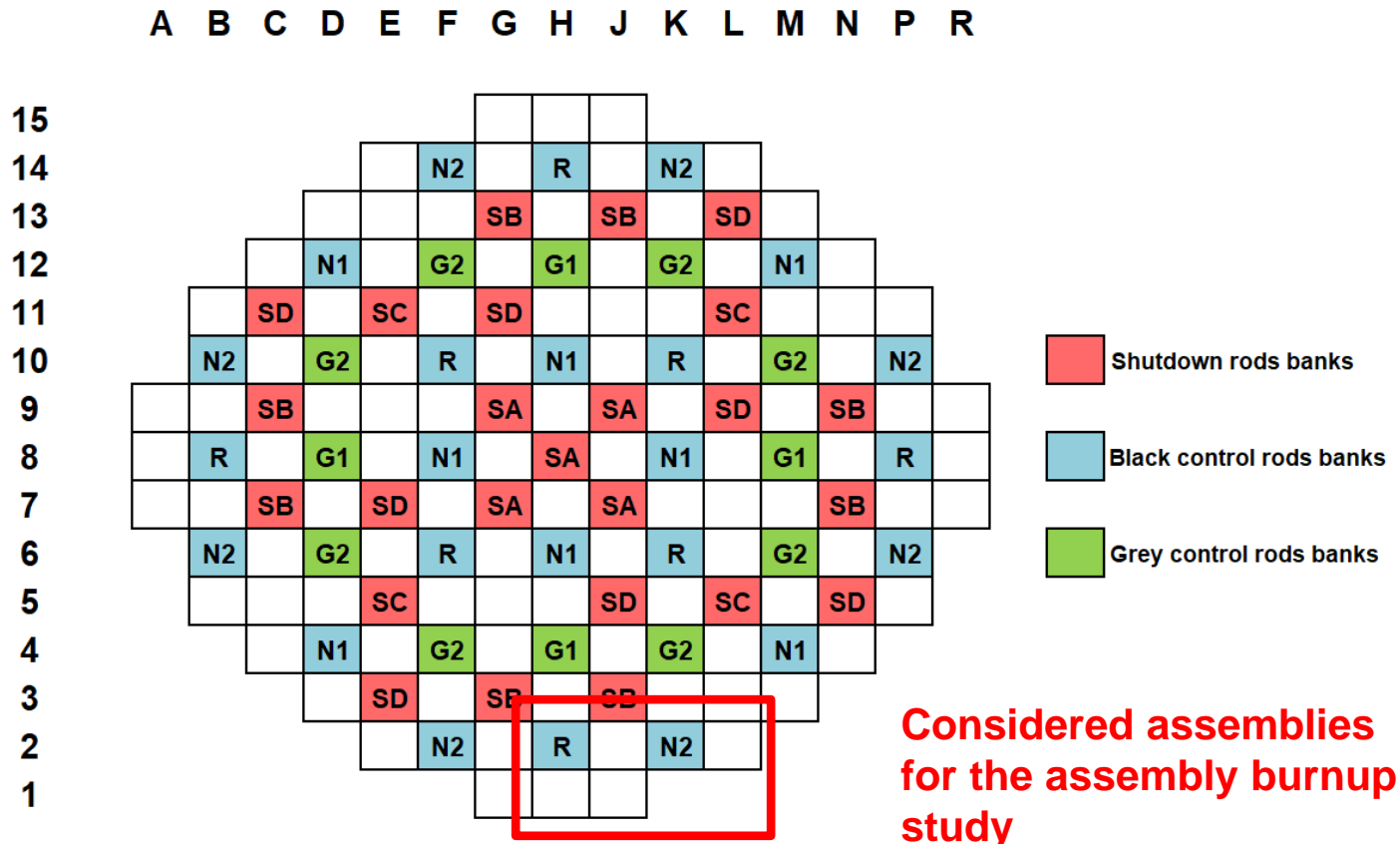
Core description

- Representative of a French 900 MWe PWR
- UOX/MOX fuel management
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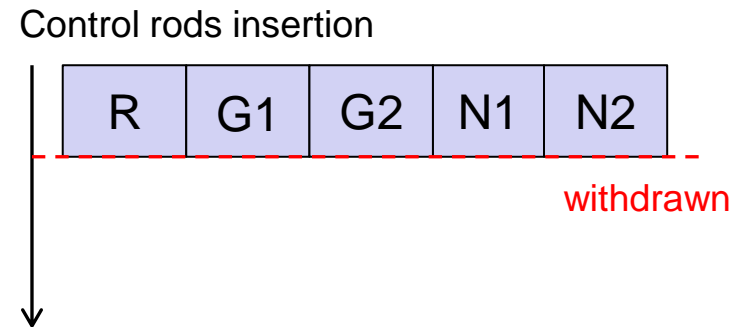
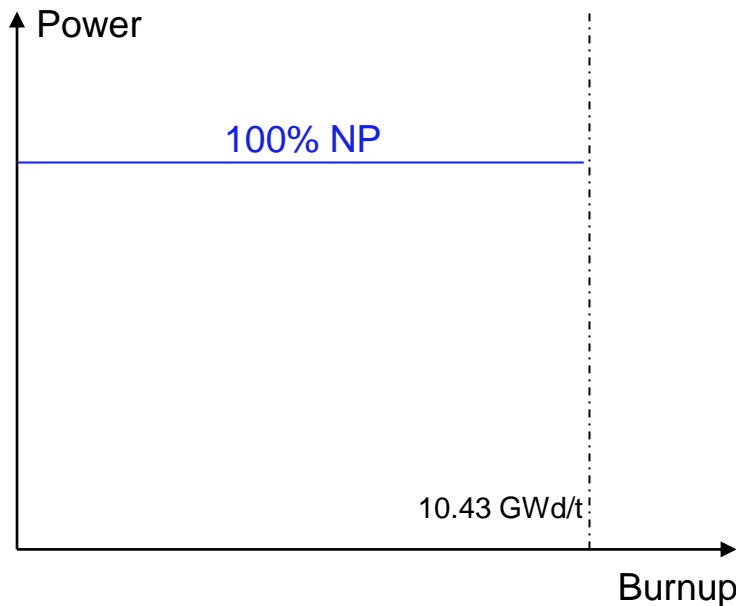
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COMPARISON OF 3 CASES

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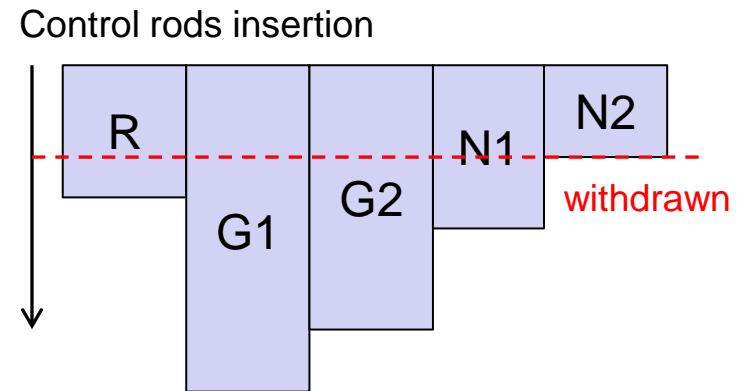
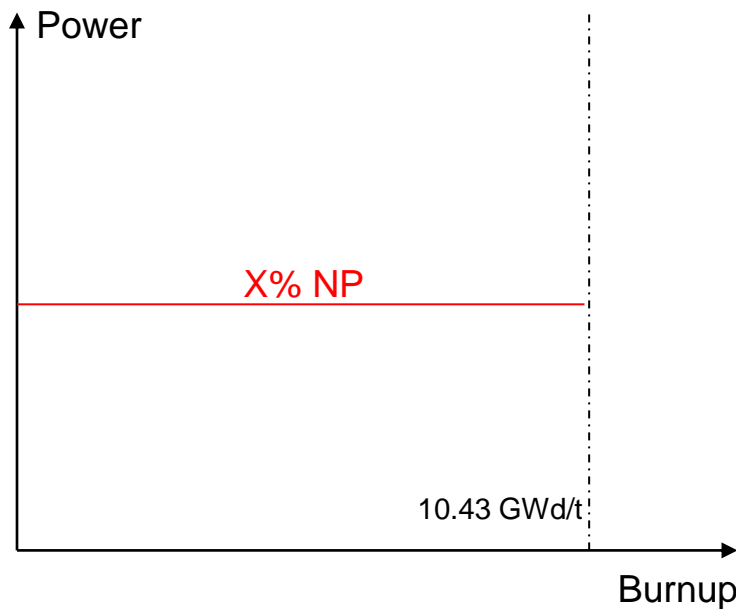
- **Nominal power (most simple)**



Impact of core power history ?

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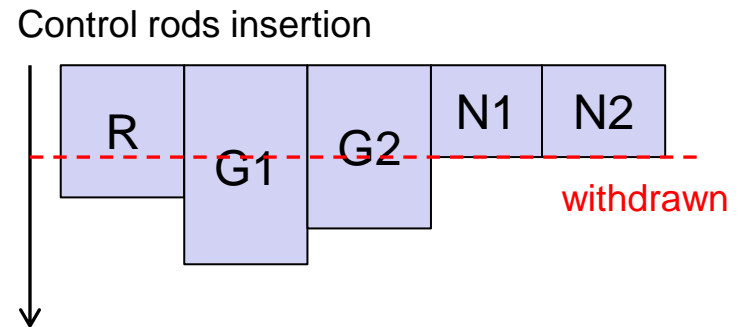
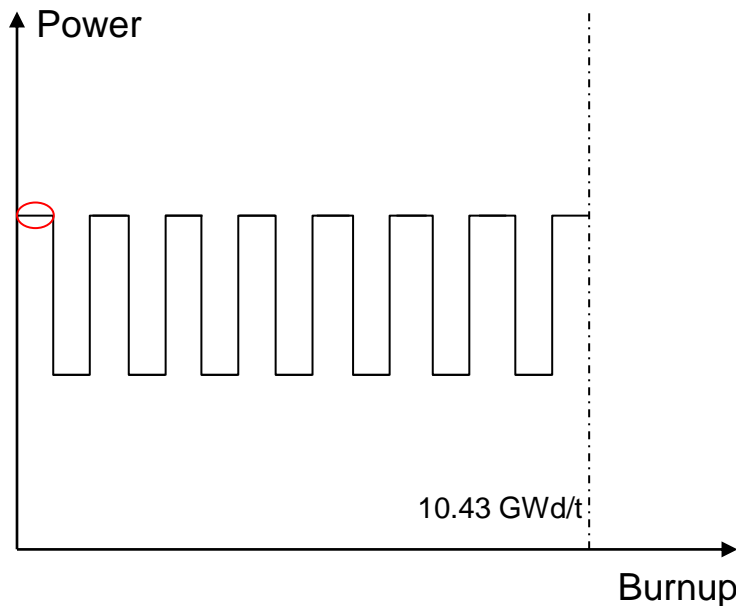
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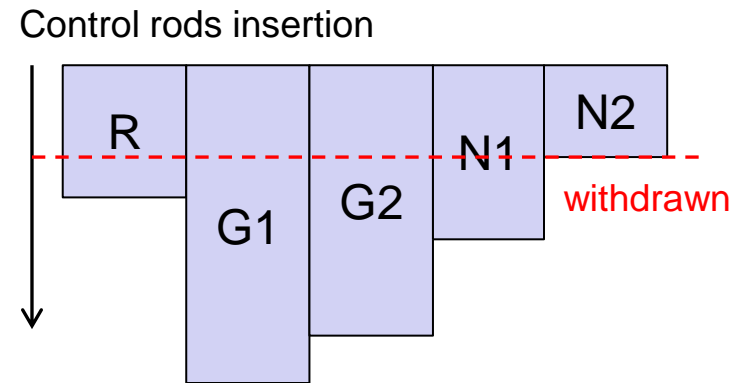
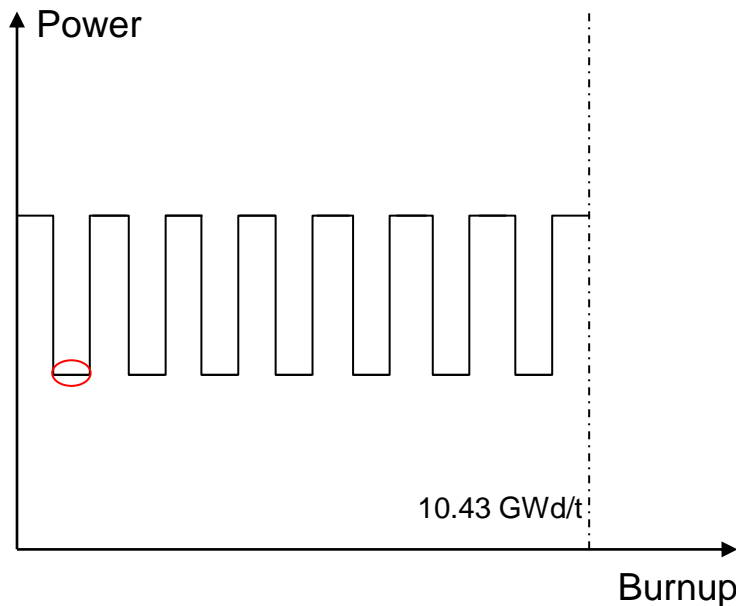
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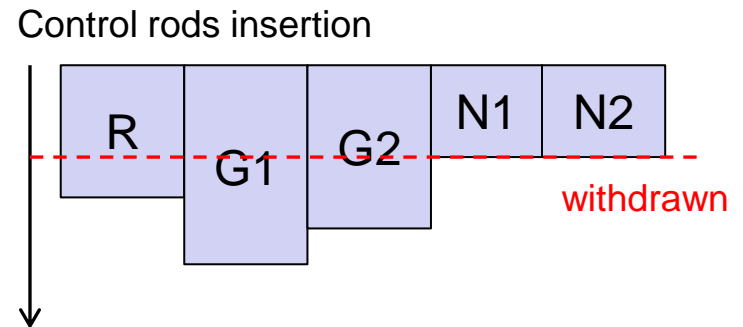
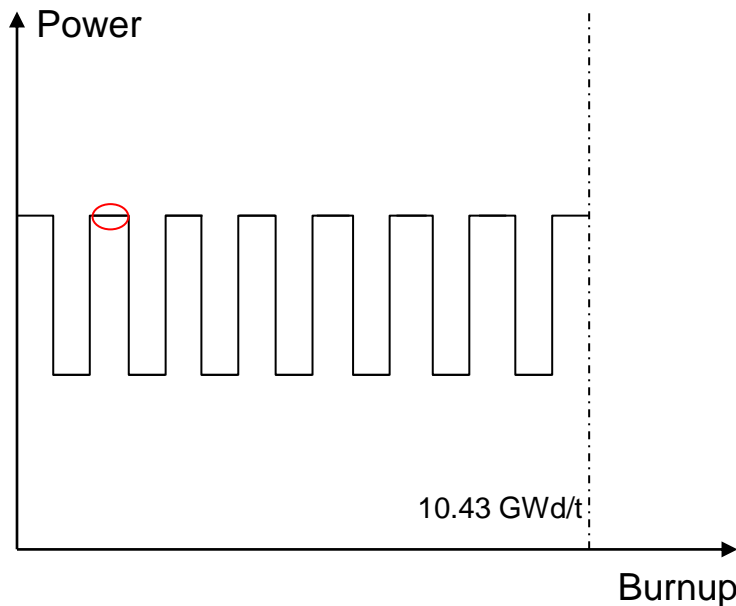
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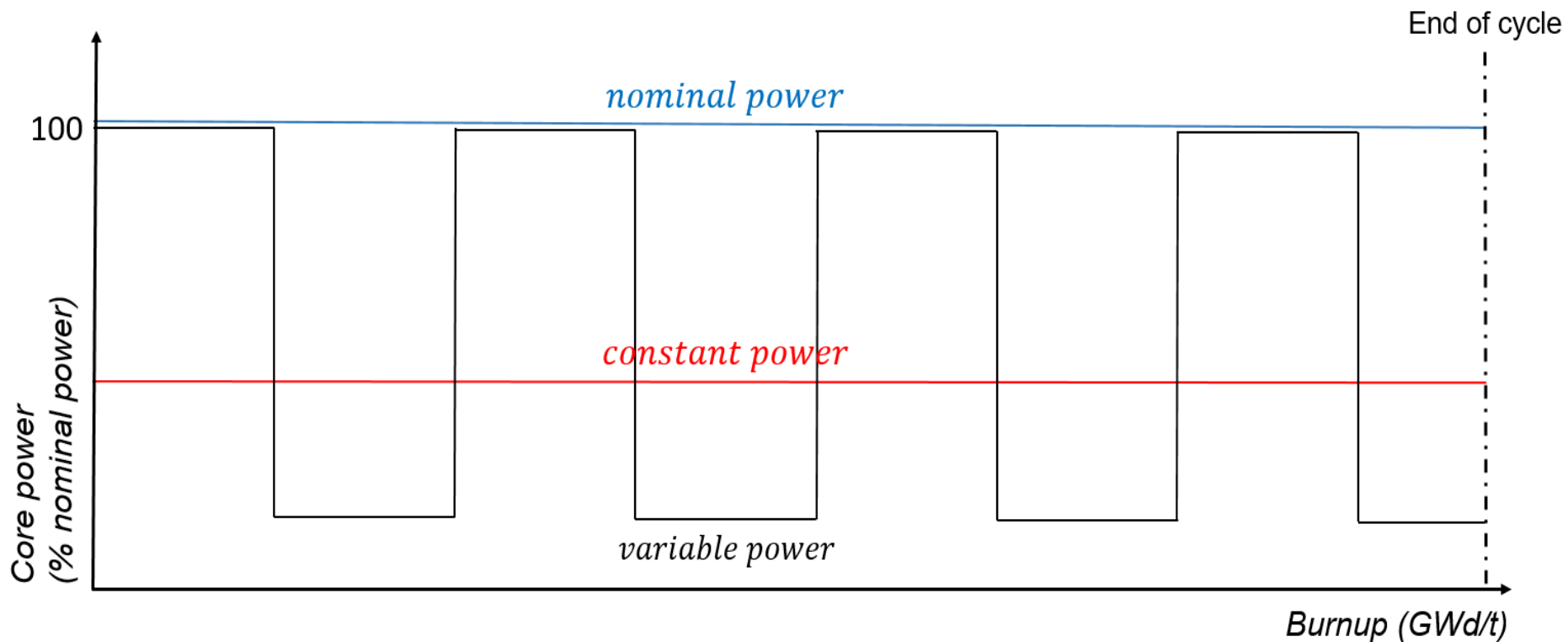
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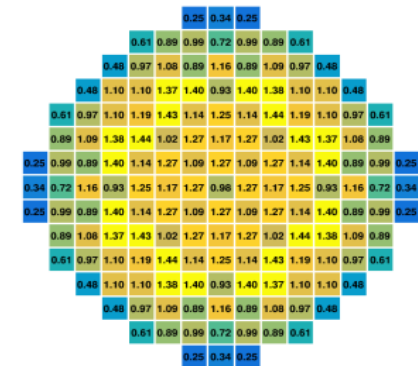
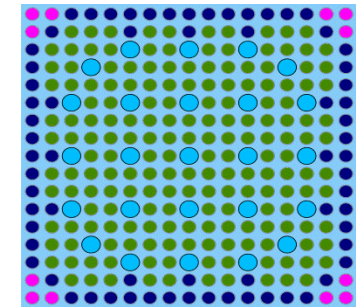
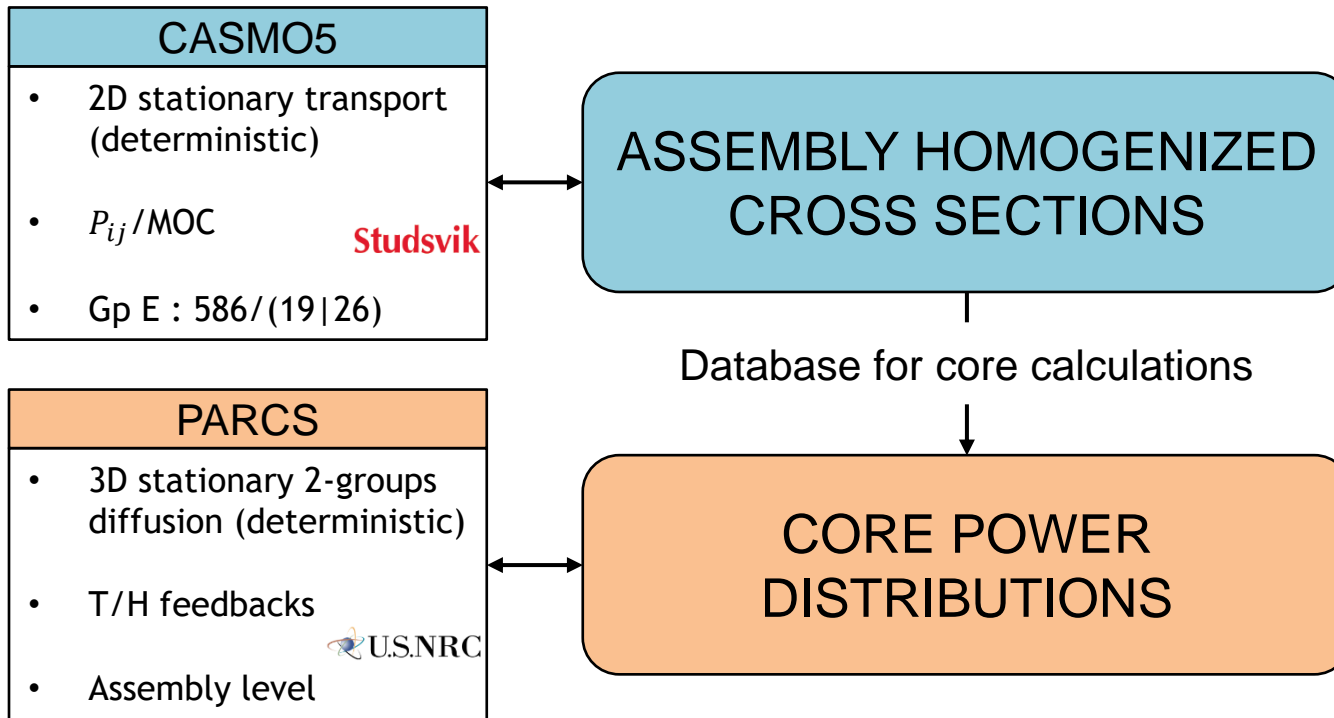
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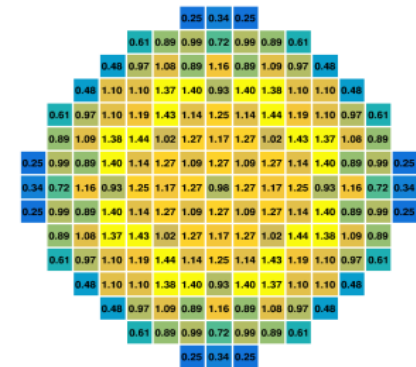
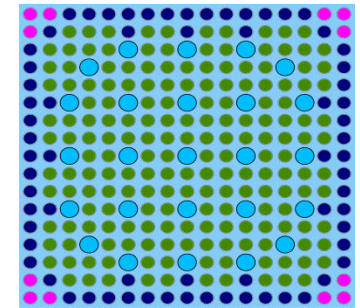
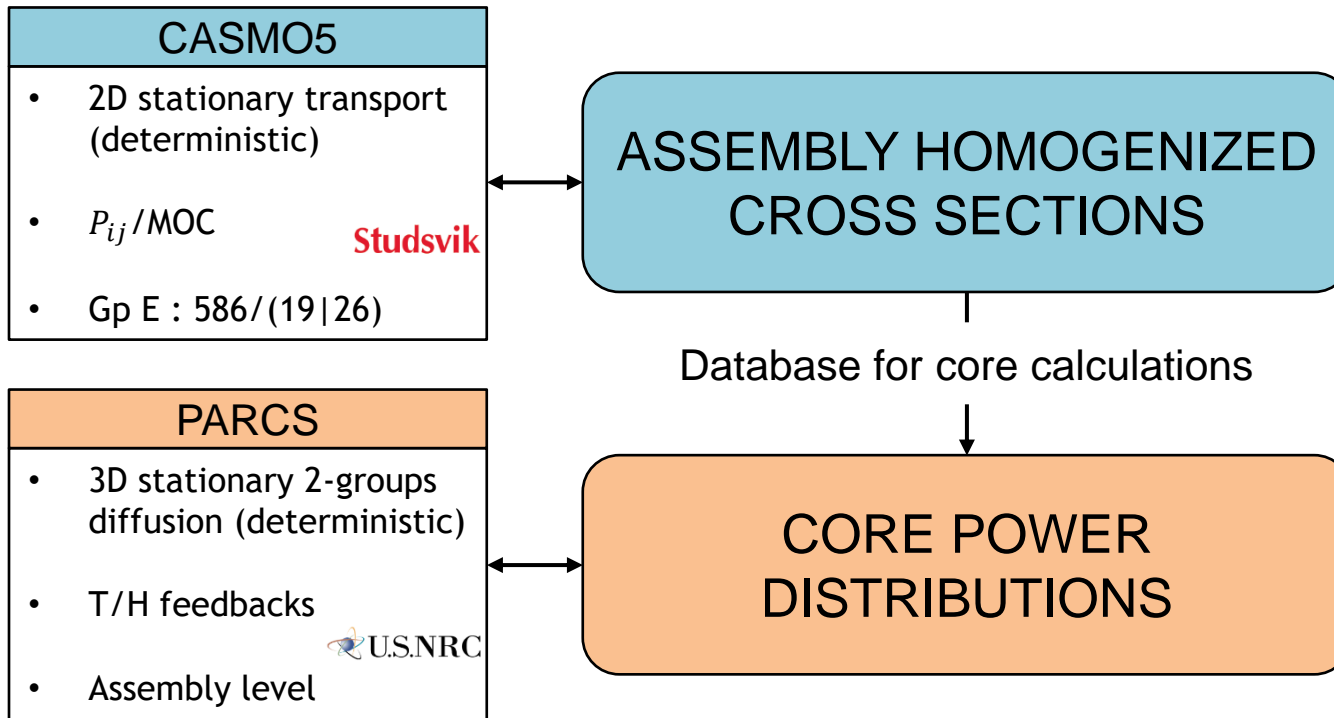
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Calculation scheme to model power histories

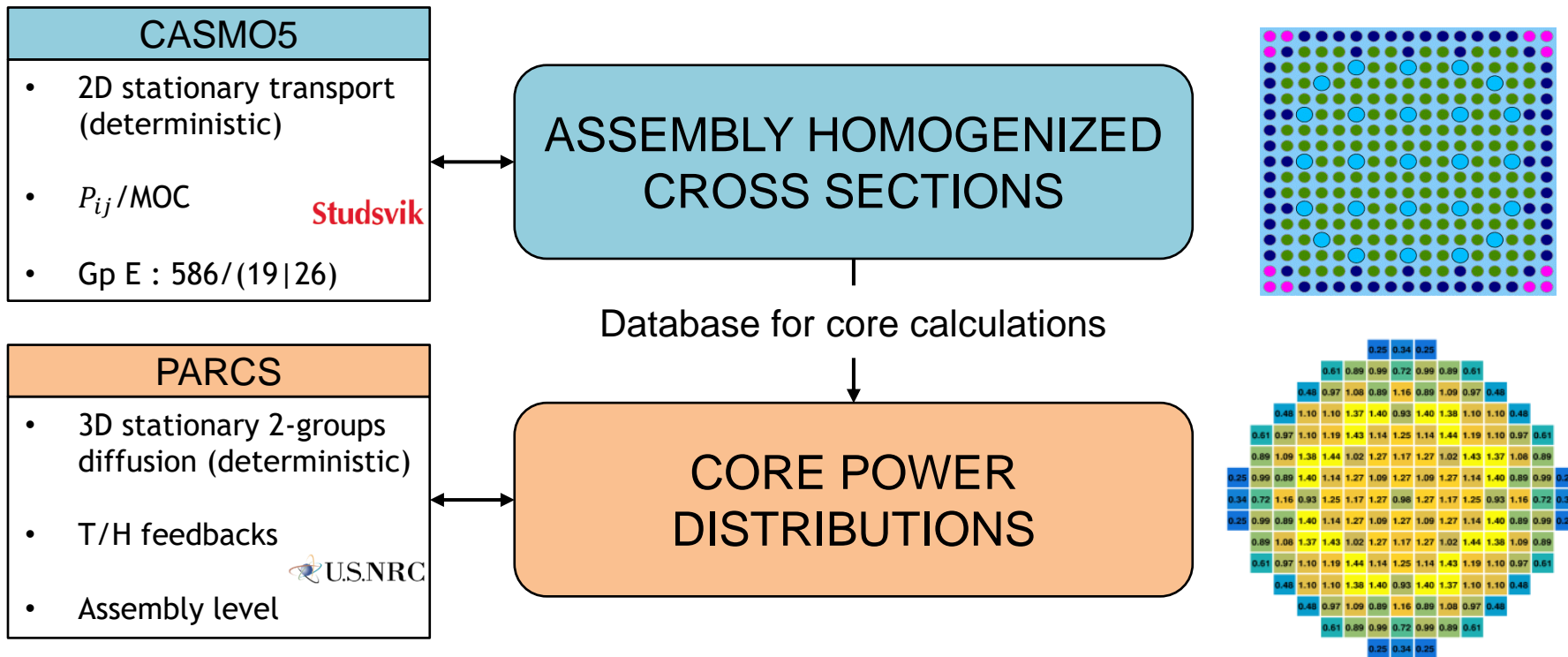


Calculation scheme to model power histories



- Cycle length (10.43 GWd/t) divided into 150 burnup steps

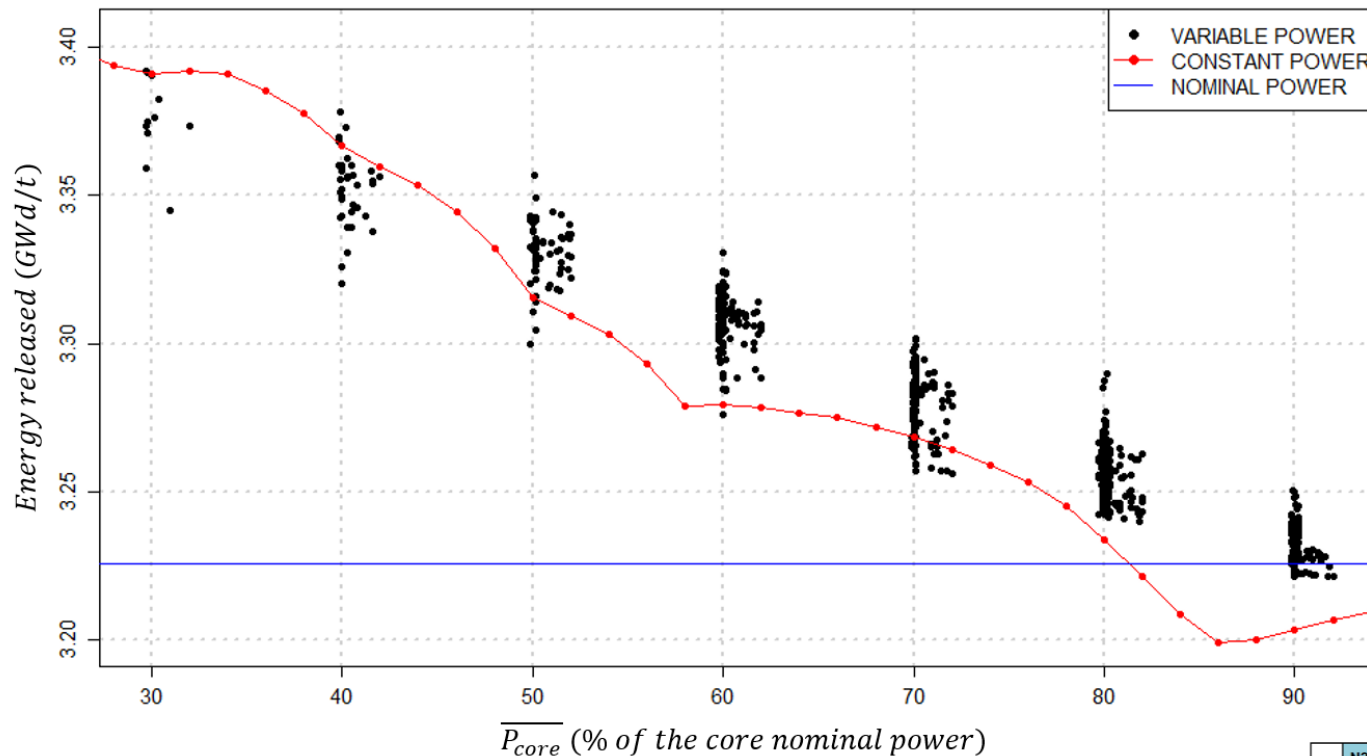
Calculation scheme to model power histories



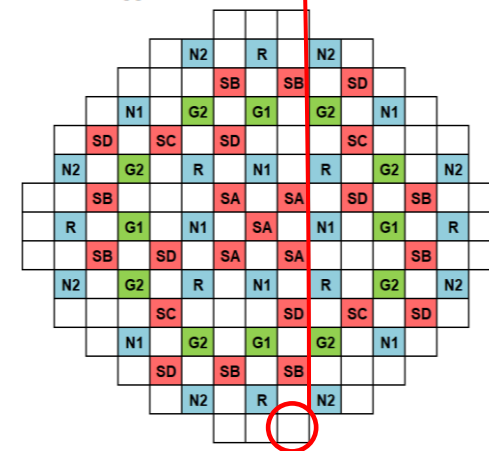
- Cycle length (10.43 GWd/t) divided into 150 burnup steps
- **Integration over time to compute the assembly burnup over the cycle :**

$$\rightarrow E_m = \sum_{i=1}^{N_{step}} P_{m,i} \cdot \Delta t_i$$

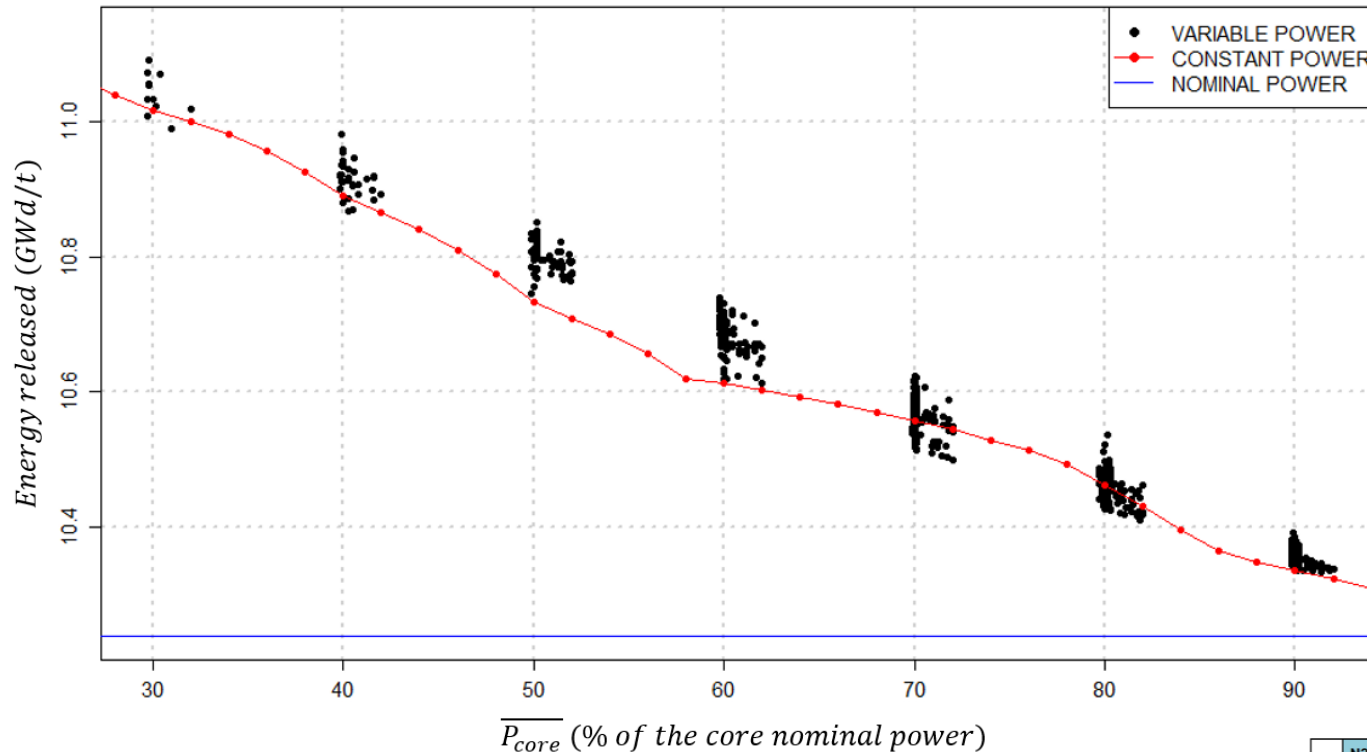
Results on the radial burnup



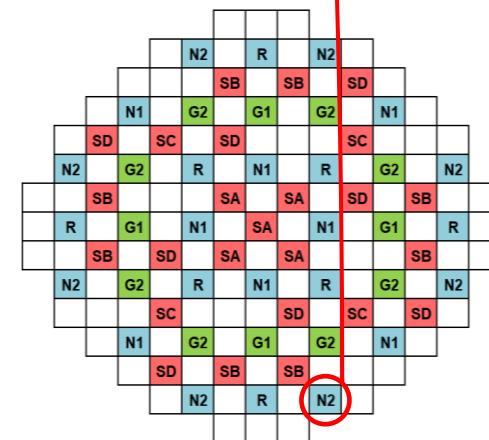
- Maximum bias of **nominal power** vs variable power ~ **8,5 %**
- Maximum bias of **constant power** vs variable power ~ **2,5 %**



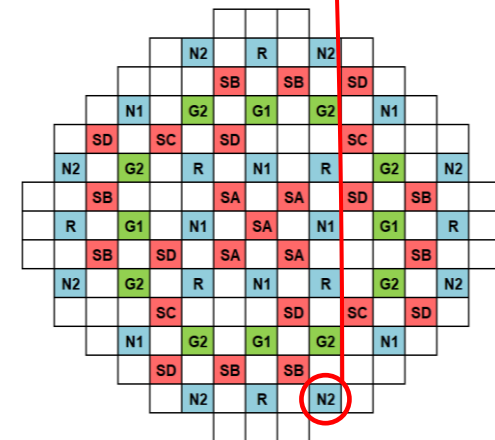
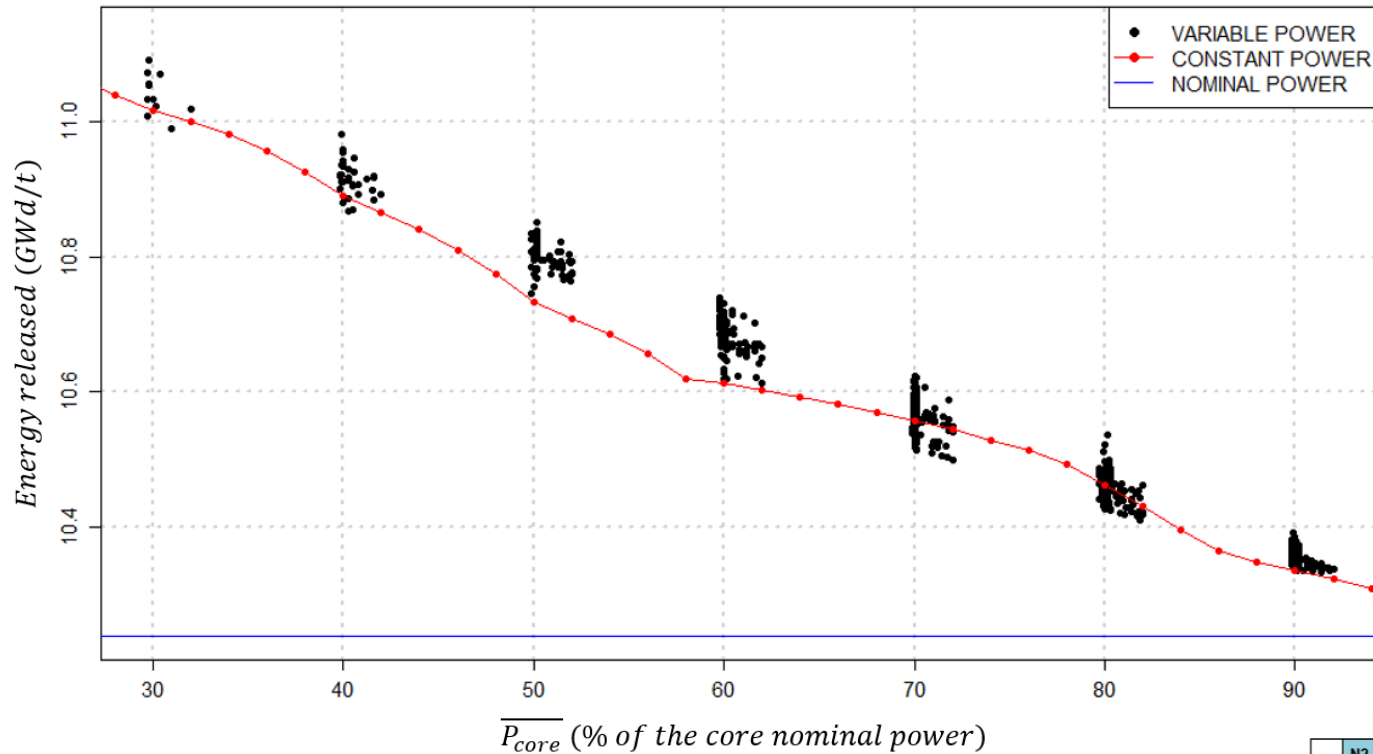
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Results on the radial burnup



USING AVERAGE OPERATING CONDITIONS IS SUFFICIENT TO MODEL POWER HISTORIES

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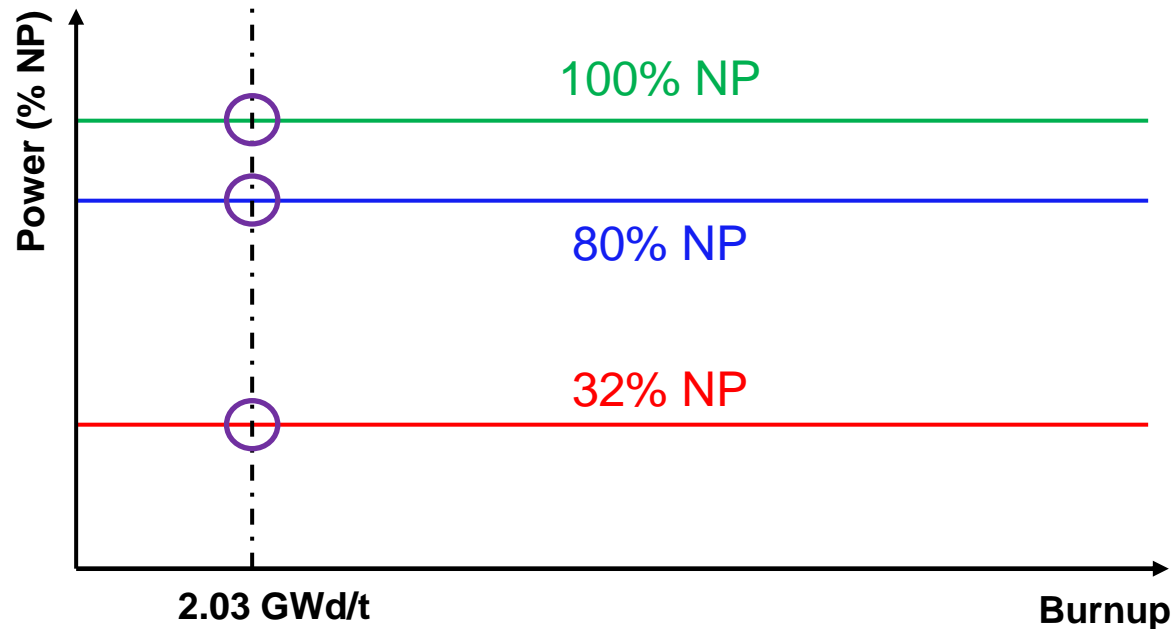
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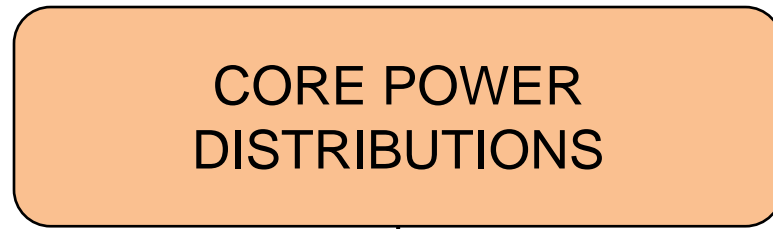
Impact of operating below the nominal power ?

➤ Comparison of 3 cases

- Constant power cases
- 100%, 80% and 32% of the nominal power
- 2.03 GWd/t (after Xe and Sm transient)



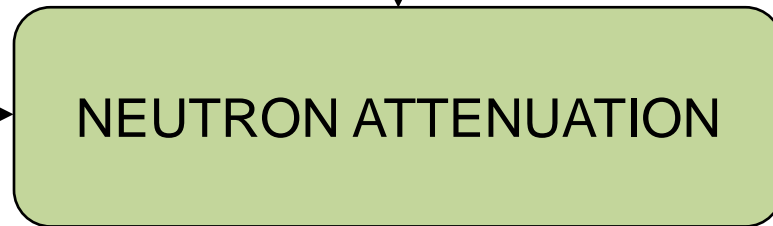
Modeling



From the **constant power case**

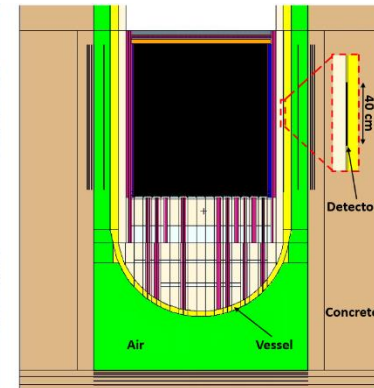
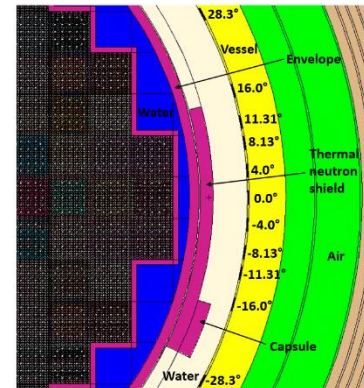
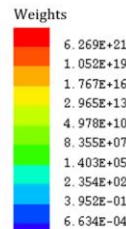
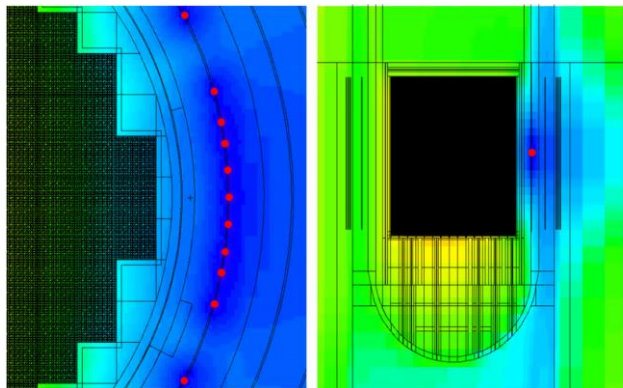
Conversion into a pin neutron source

$$S_p(E) = \frac{P_m}{N_{pin}} \cdot \chi(E)$$

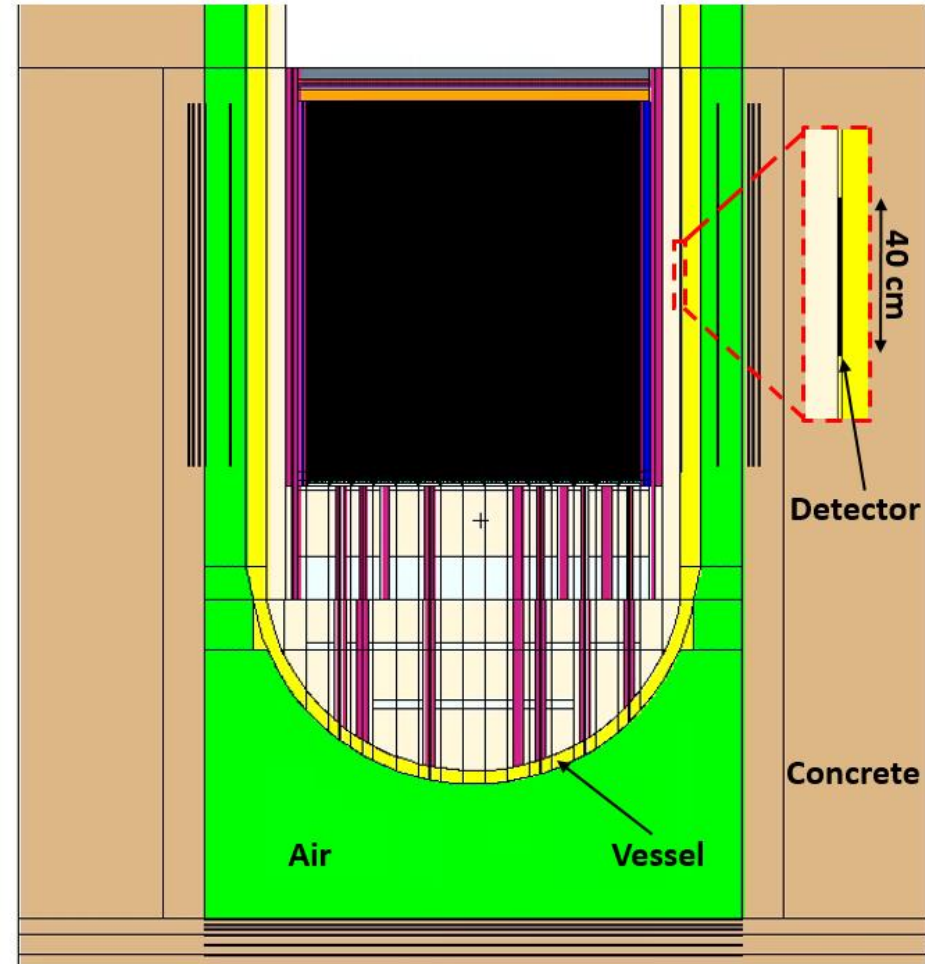
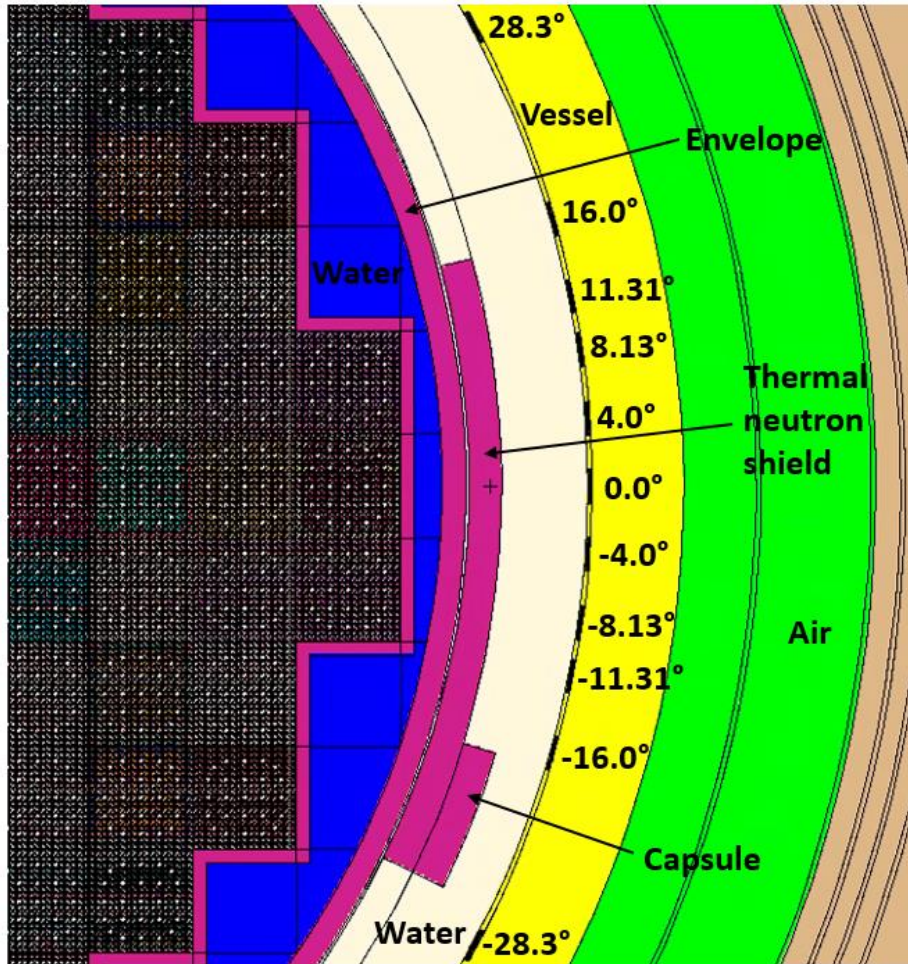


MCNP

- 3D stationary “transport” (monte-carlo)
- Fixed source calculation
- Use of weight-window variance reduction method

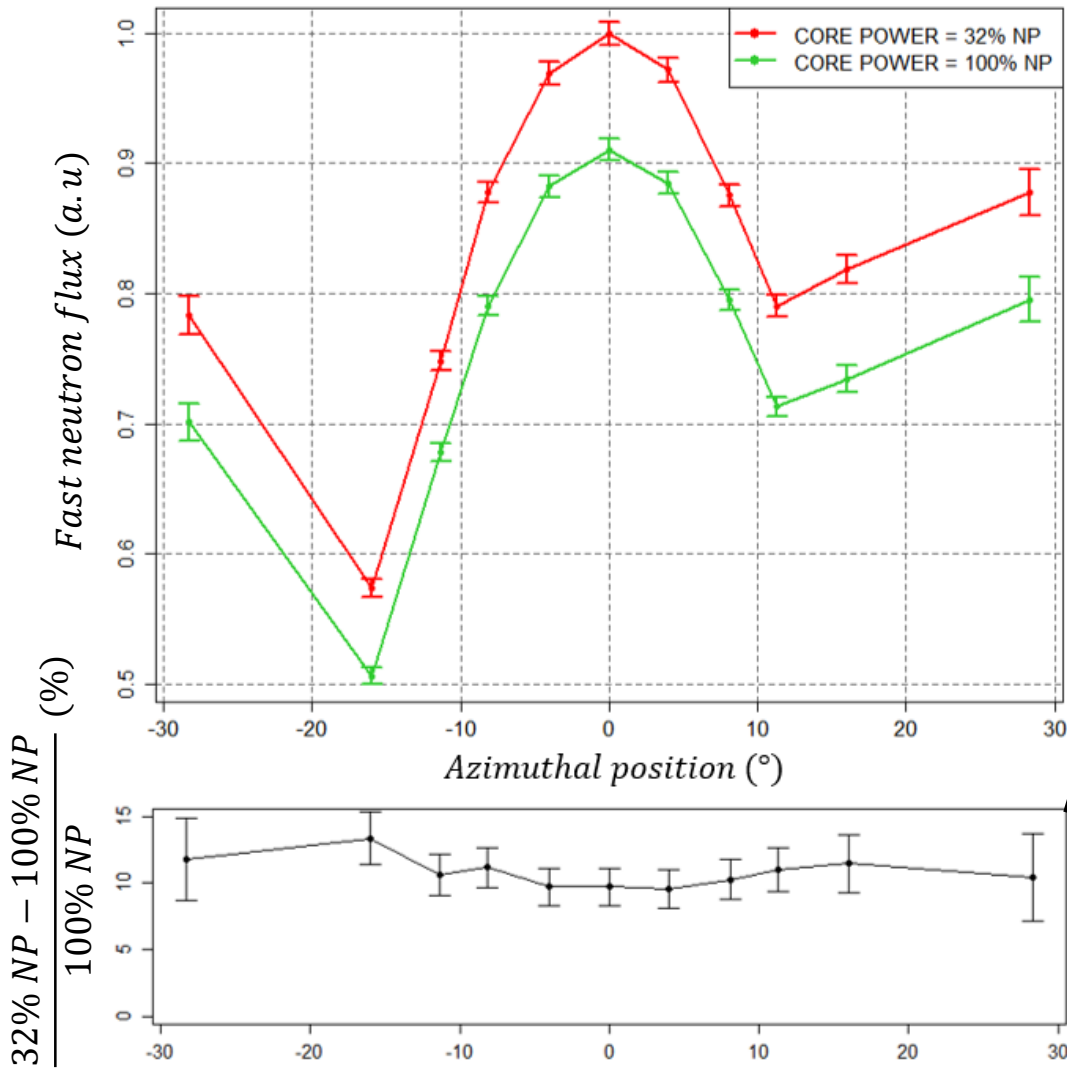


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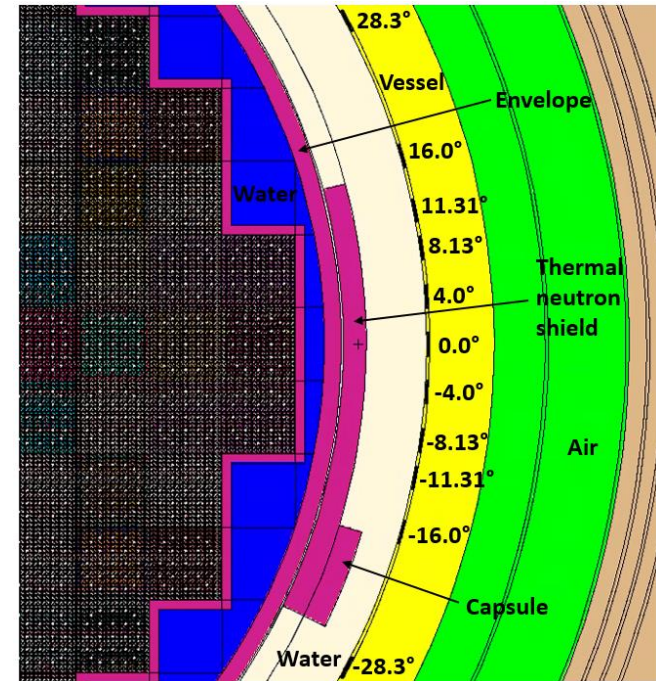


Obtained results

32% NP vs 100% NP

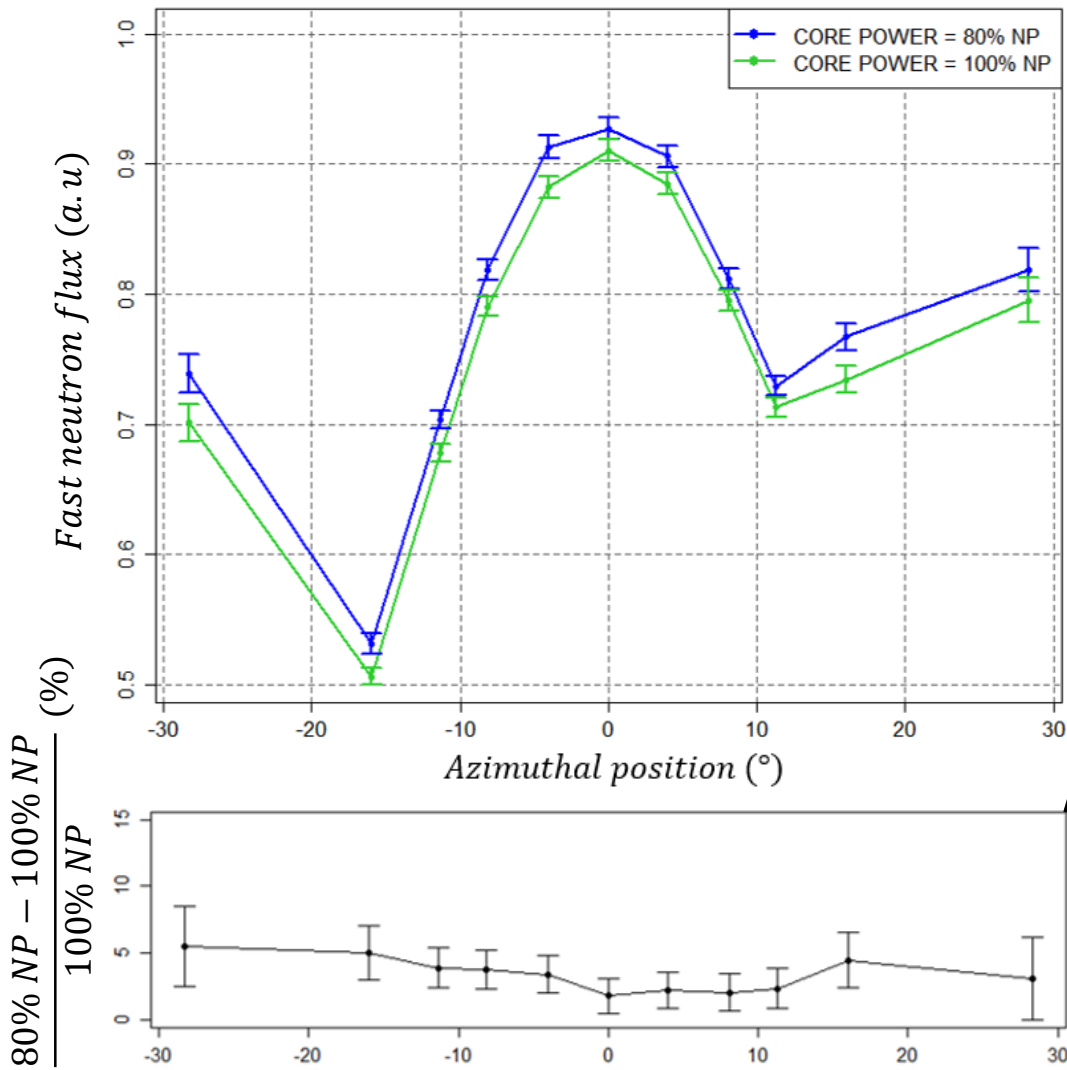


Impact on the fast flux at the vessel up to $\sim 13 \pm 2\%$

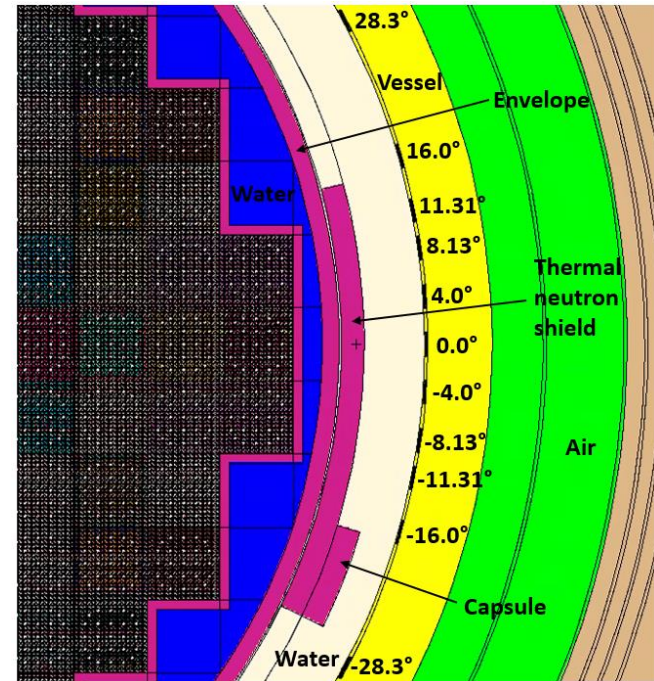


Obtained results

80% NP vs 100% NP

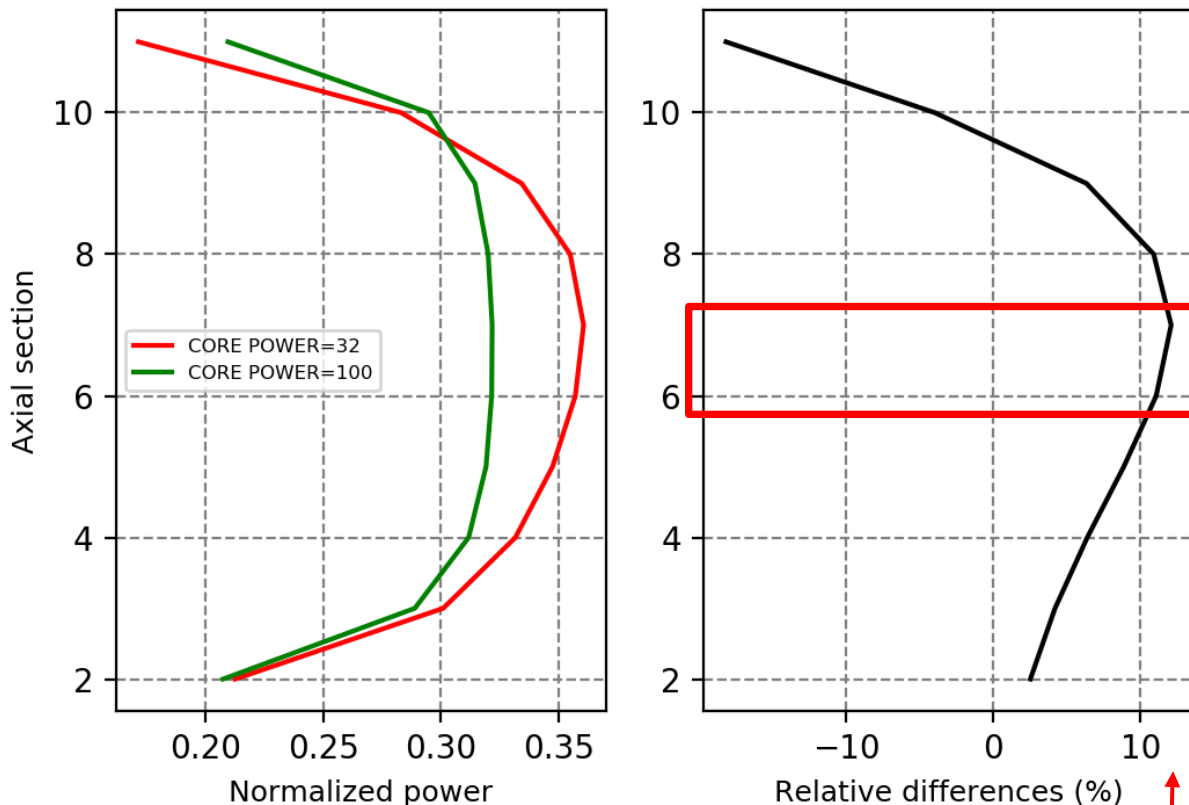


Impact on the fast flux at the vessel up to $\sim 5.5 \pm 2\%$

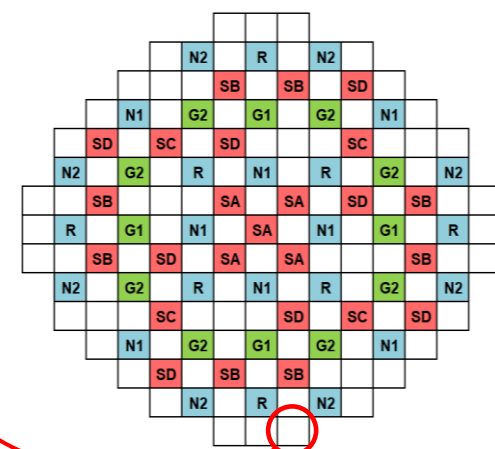


Comparison with the axial power profiles - azimuth 8°

32% NP vs 100% NP



Axial location of the detectors

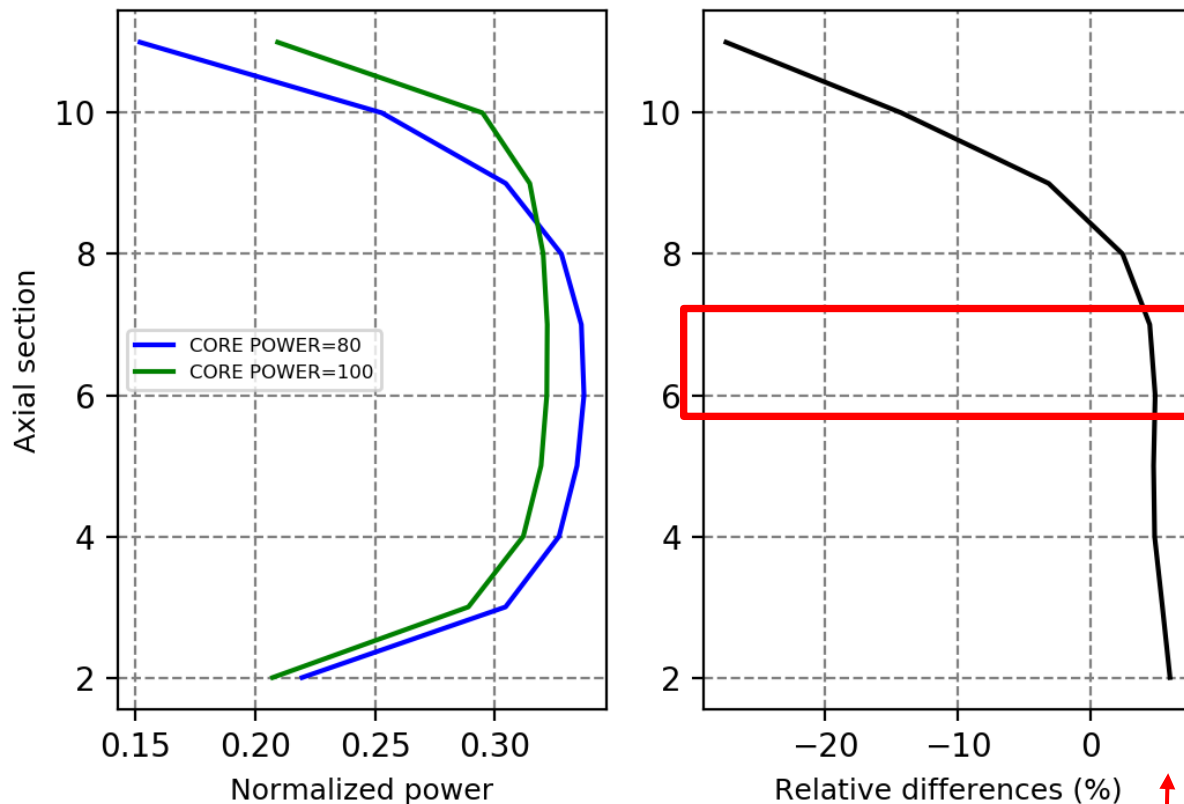


Impact ~ 11% at the detectors axial location

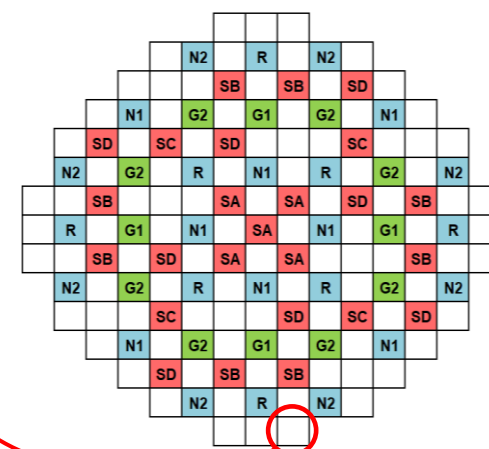
Flux azimuth 8 degrees ~ 11 ± 2%

Comparison with the axial power profiles - azimuth 8°

80% NP vs 100% NP



Axial location of the detectors

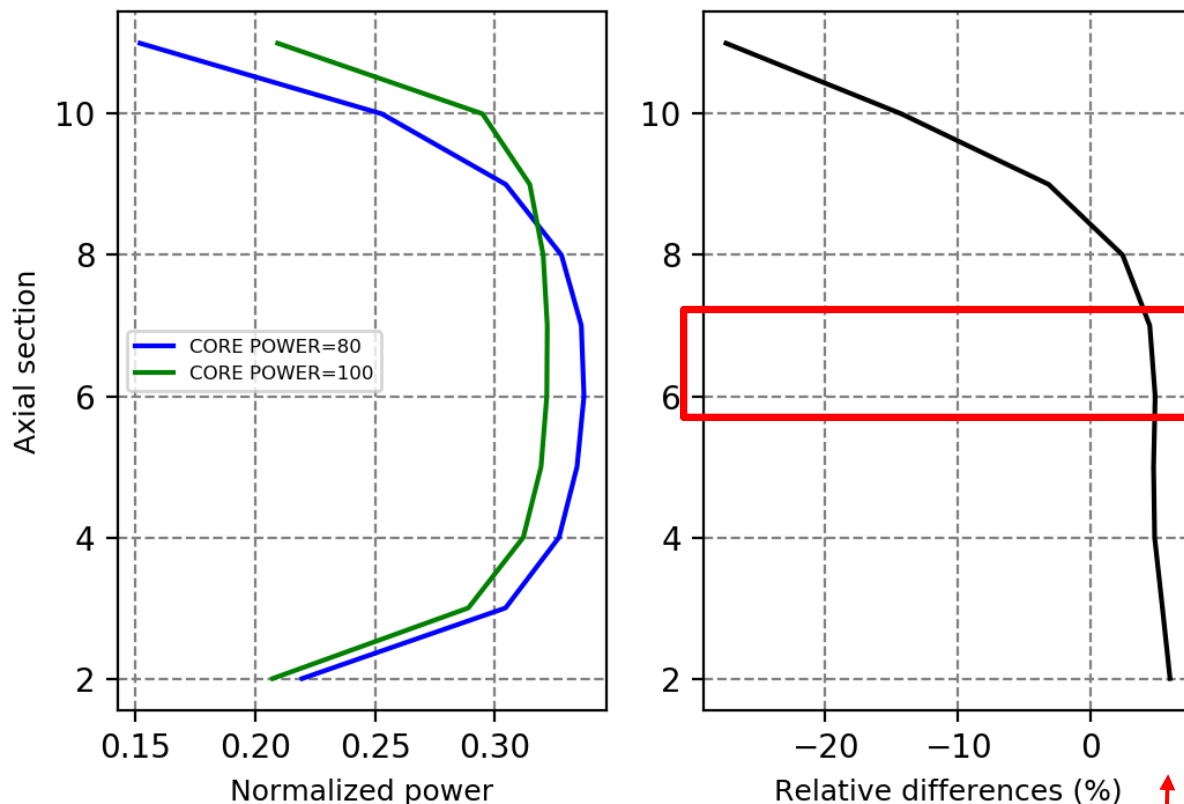


Impact ~ 4 % at the detectors axial location

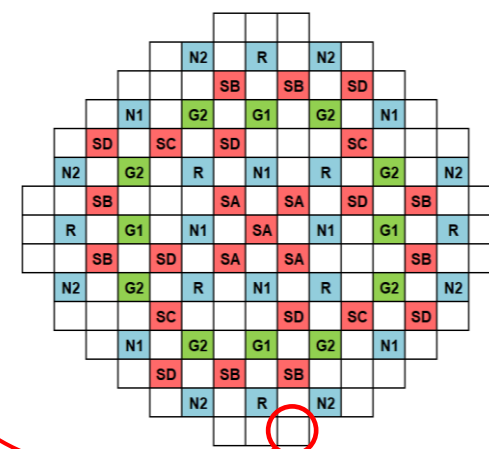
Flux azimuth 8 degrees ~ 4 ± 2%

Comparison with the axial power profiles - azimuth 8°

80% NP vs 100% NP



Axial location of the detectors



Same order of magnitude as flux differences !

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Phd objective

Propose a precise and accurate calculation scheme for vessel fluence

- Impact of power variations on the vessel flux ?

Core power decreases → flux at the vessel increases ! (due to control rods)
(Extreme ~ 13% | Realistic ~ 5.5%)

Load following reactors → may be necessary to consider the power history in vessel fluence evaluations

- How to take into account the power history ?

Use of average operating conditions is sufficient !

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- Prospects

- Time integration → $\Delta\text{Power} \approx \Delta\text{Flux}$ induces $\Delta\text{Burnup} \approx \Delta\text{Fluence}$?
- Verification of simulation assumptions
 - diffusion approximation
 - source definition
 - assembly power
 - ...

THANK YOU FOR YOUR ATTENTION

ICAPP 2019

Romain VUIART

