Nuclear reactor simulations: a bias quantification of neutron leakage impact

Alice Somaini

PhD director: Sylvain David

Supervisor : Xavier Doligez

Plan

I. **Reactor simulations:**

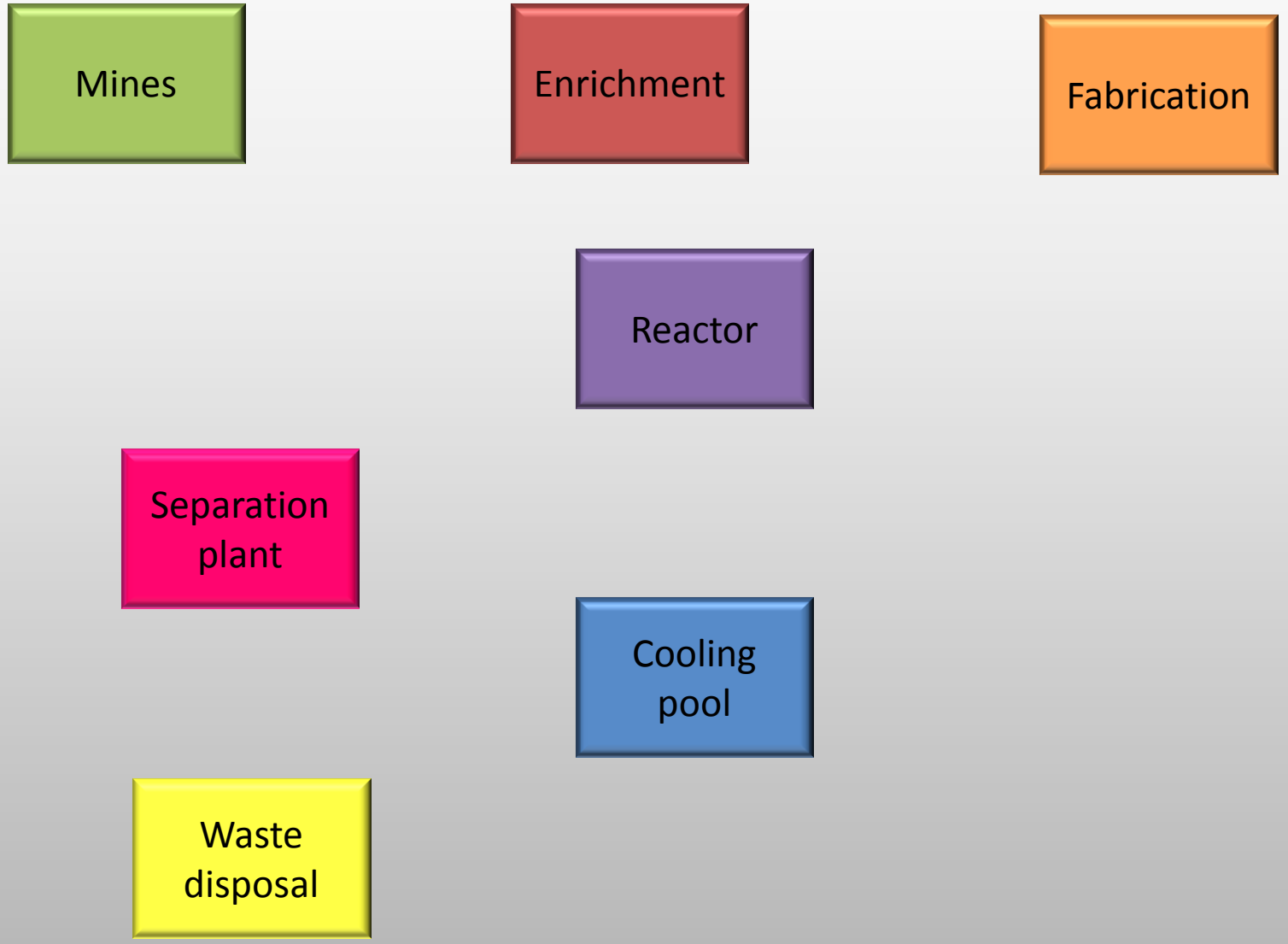
- *Tools and issues*
- *Simplified reactor model*

II. **Neutron axial leakage study:**

- *Methodology*
- *Results*

III. **Conclusions and perspectives**

Why and how simulate nuclear reactors



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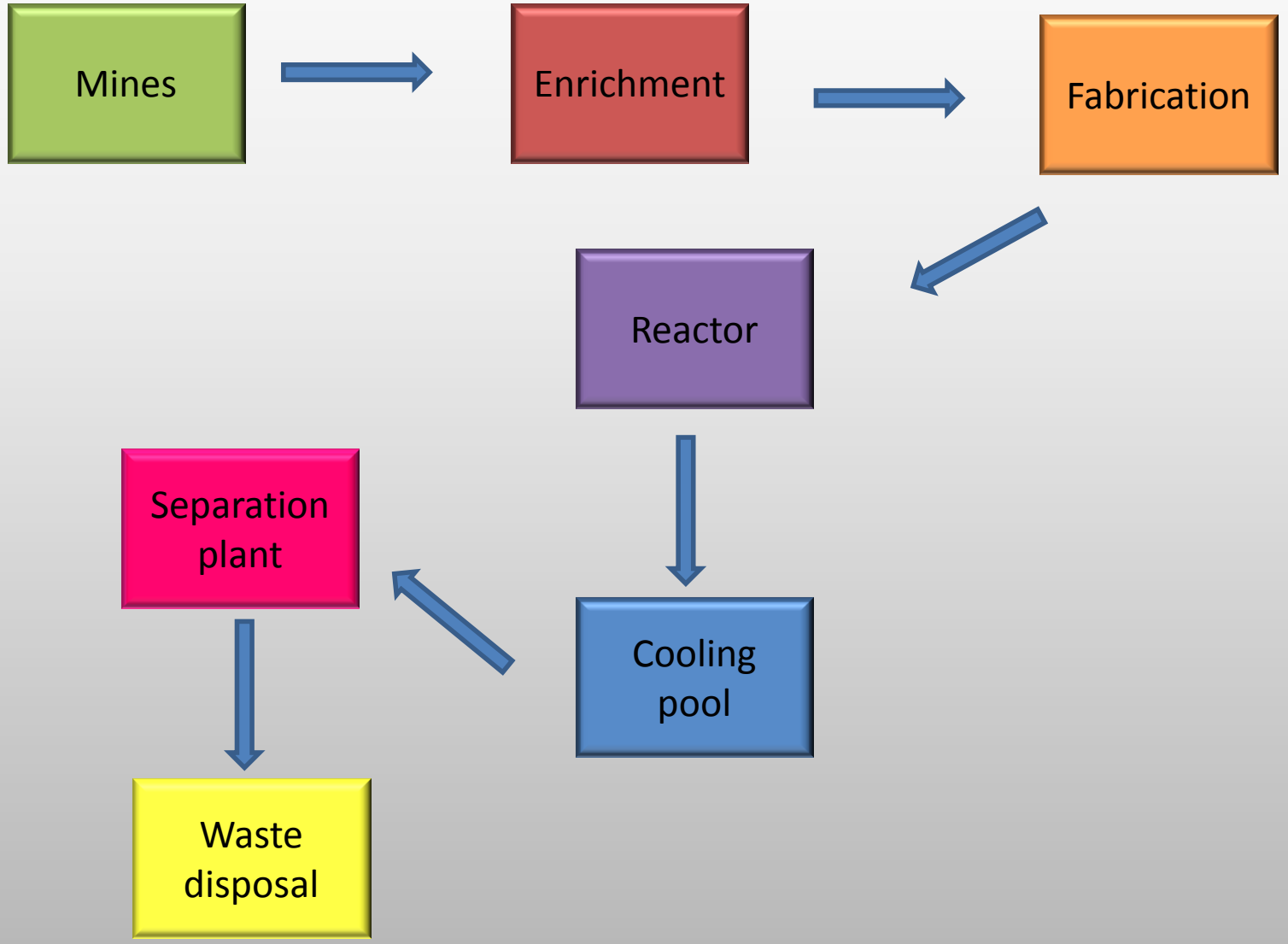

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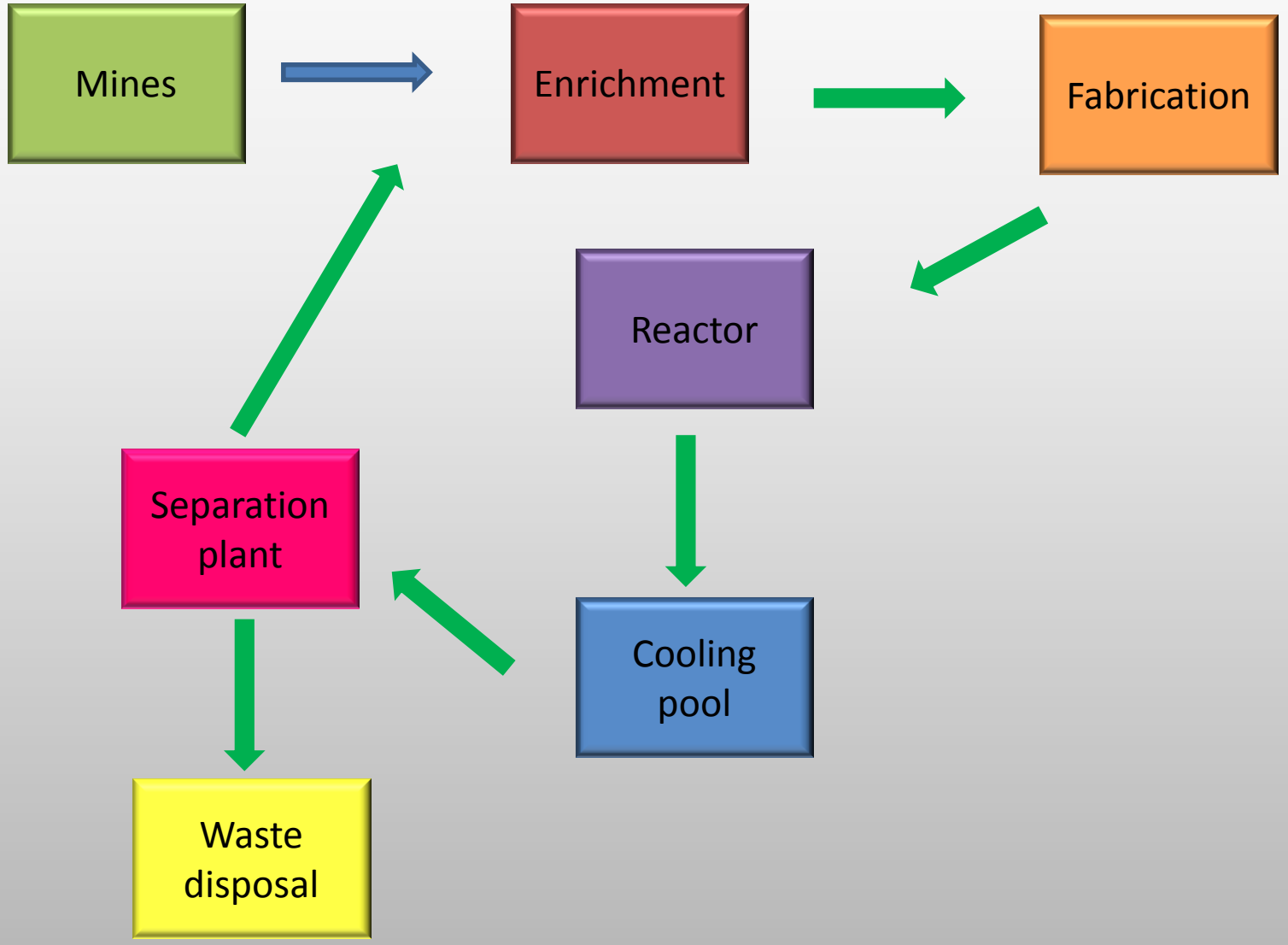

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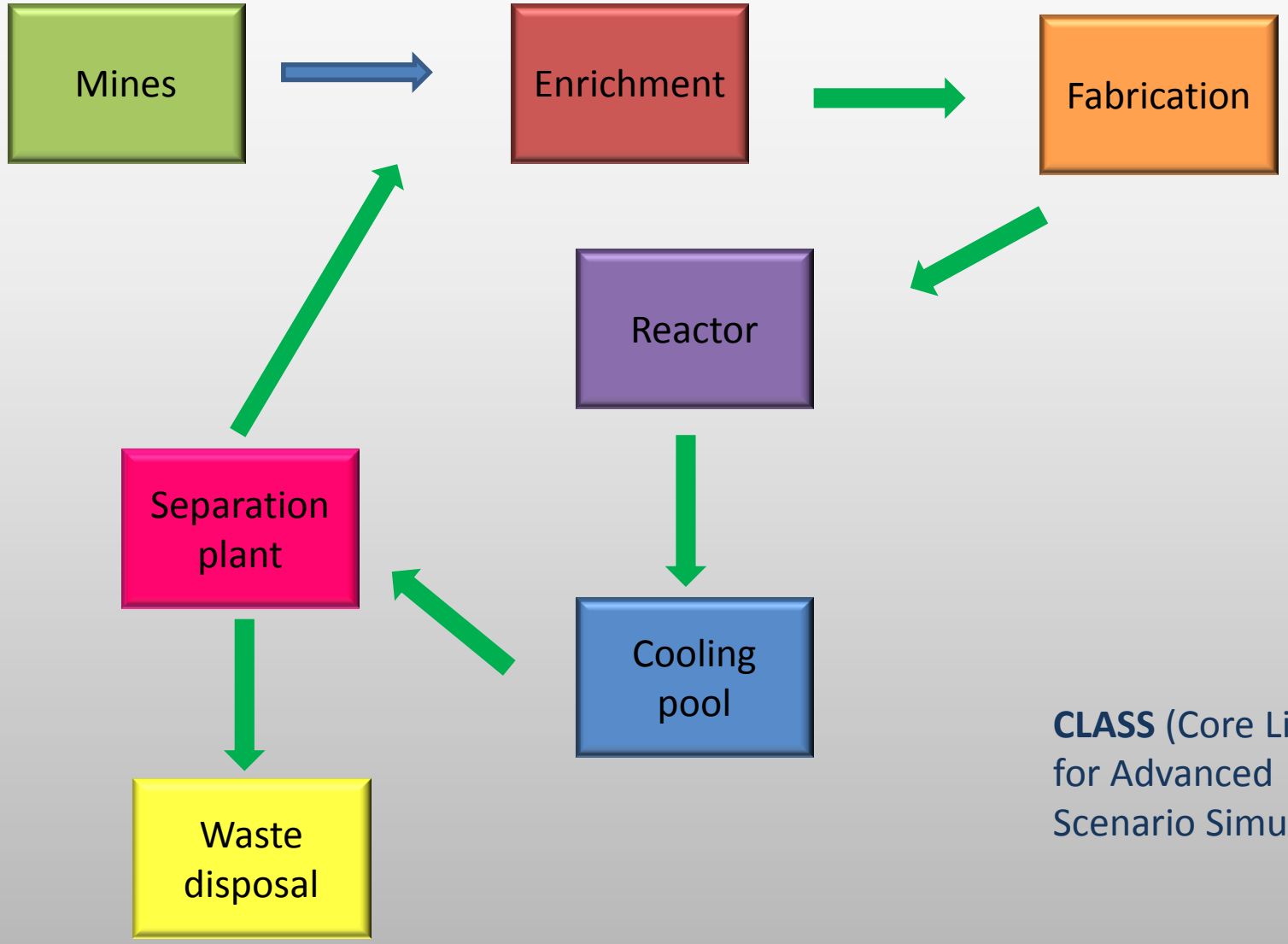

CLASS (Core Library for Advanced Scenario Simulation)

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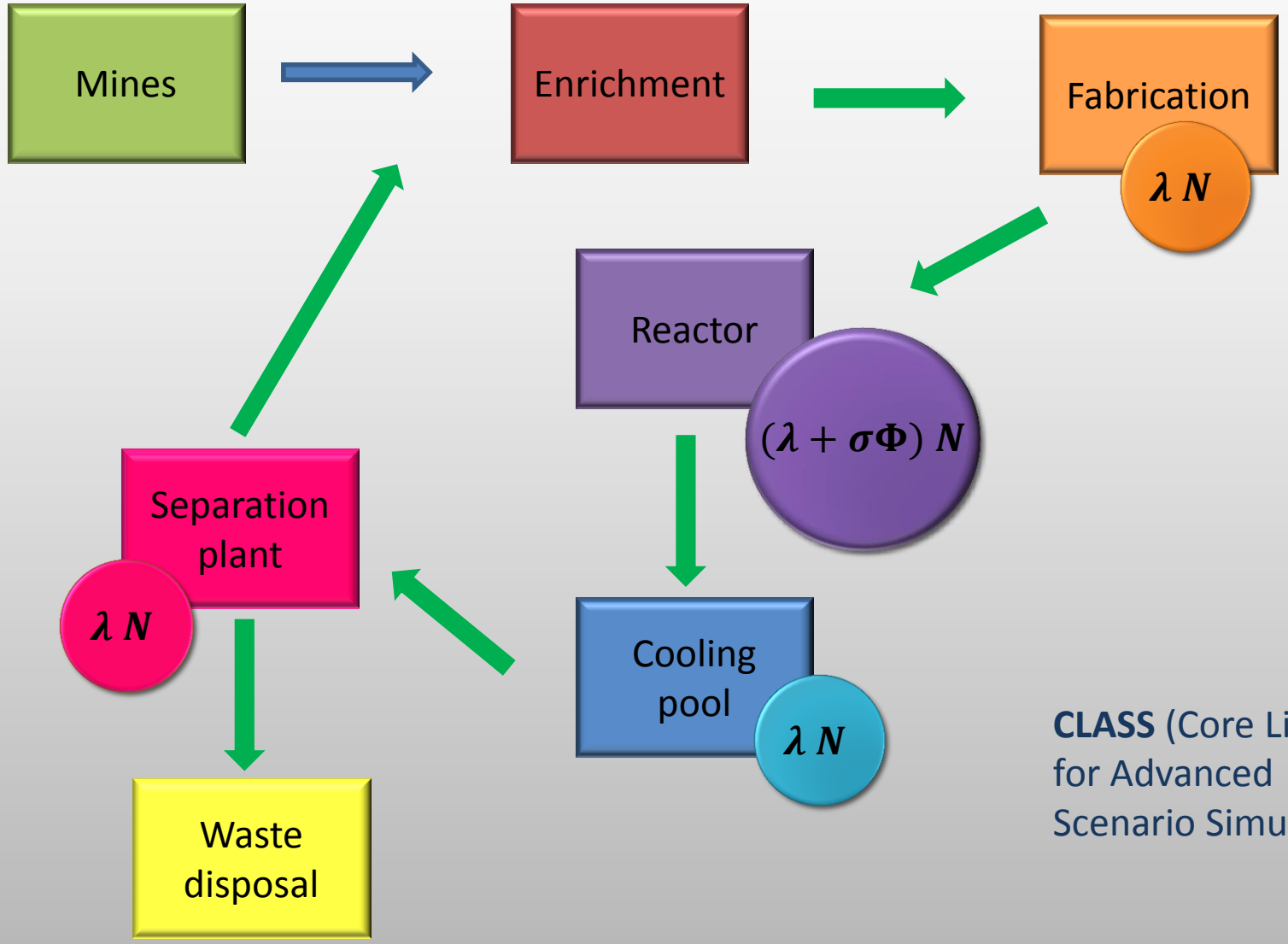

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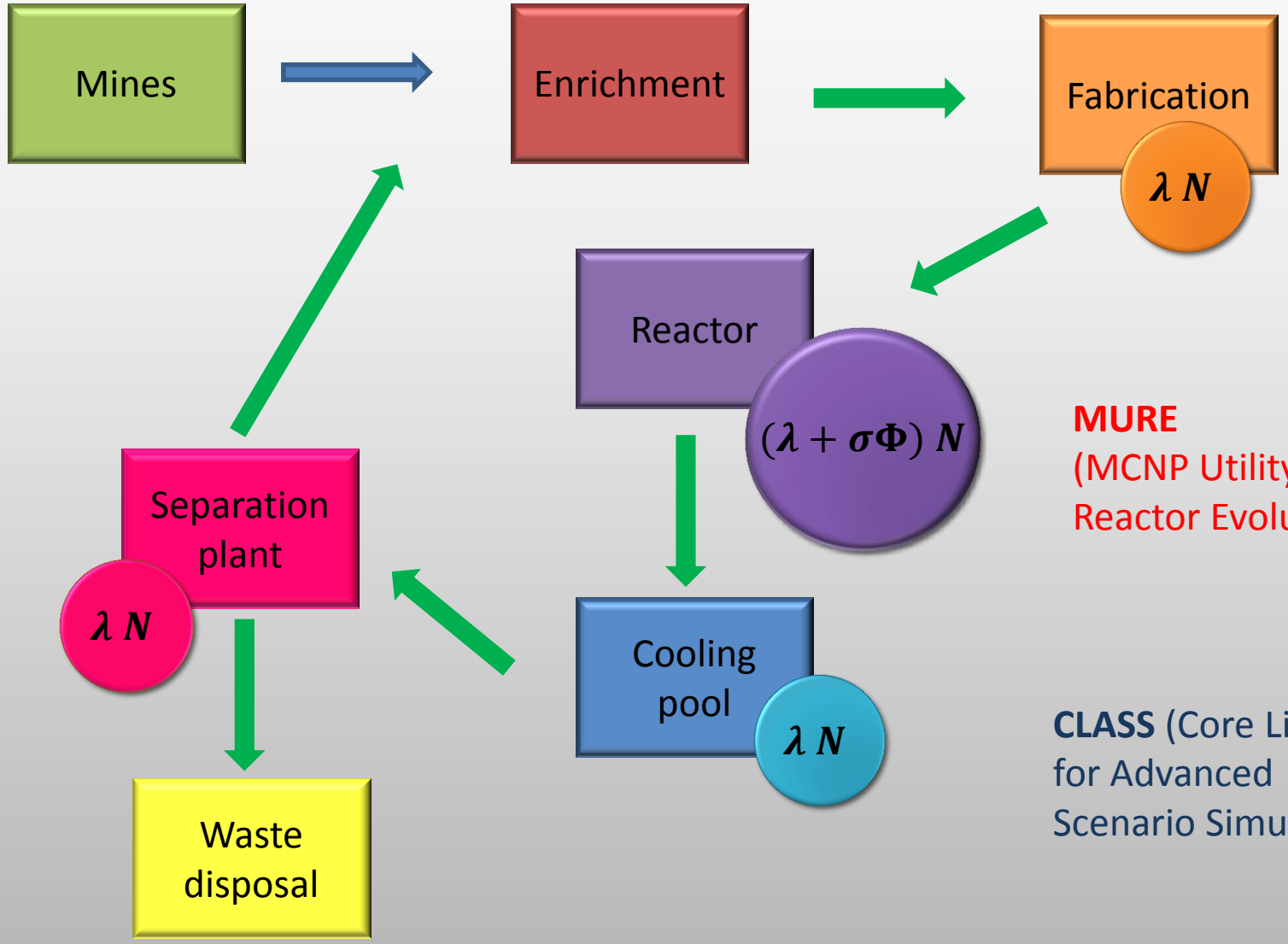
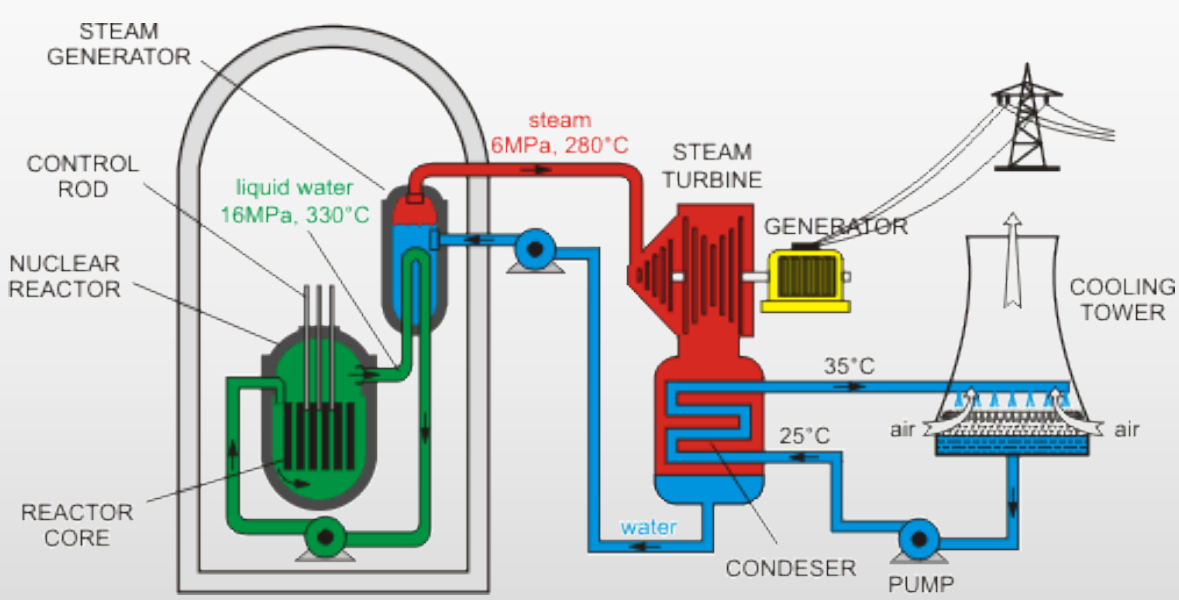


MURE
(MCNP Utility for Reactor Evolution)

CLASS (Core Library for Advanced Scenario Simulation)

The simplified reactor model

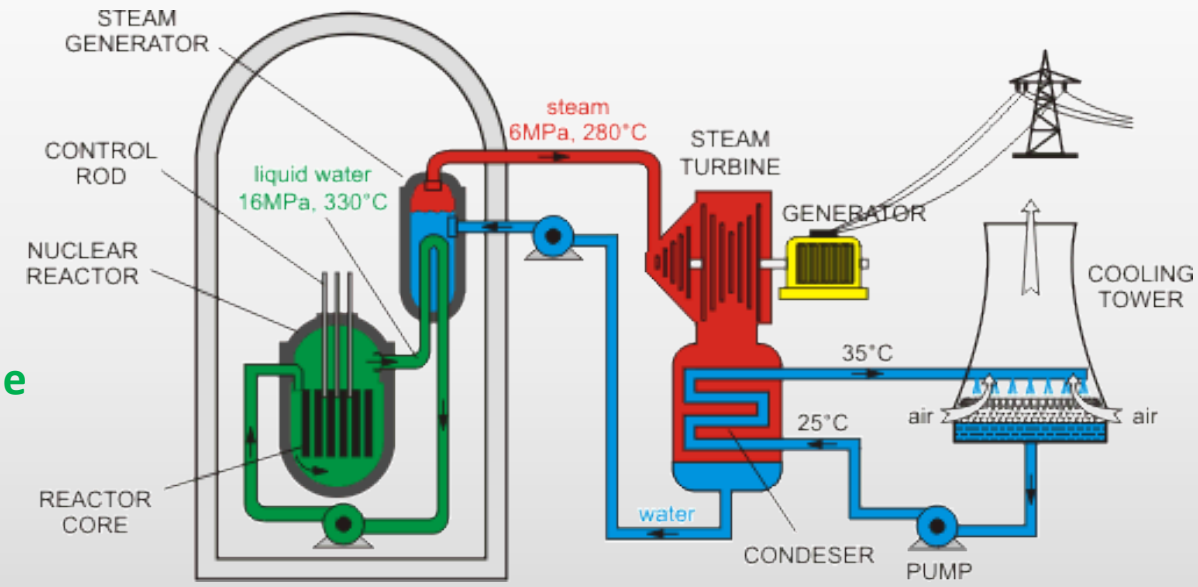
PWR



The simplified reactor model

Evolution of material composition

Determine the end of the cycle



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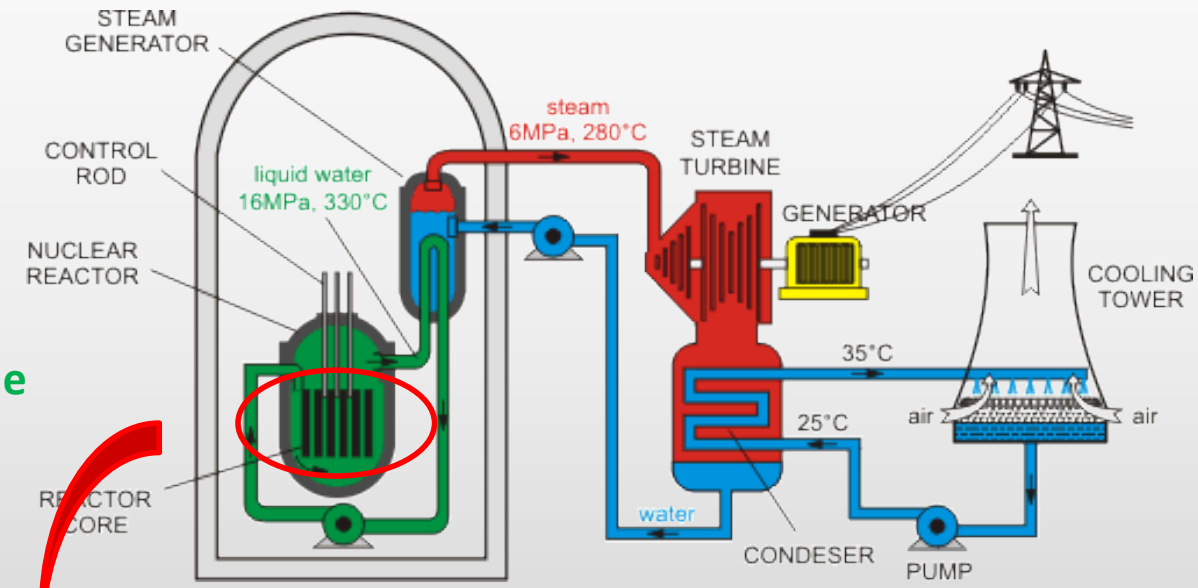

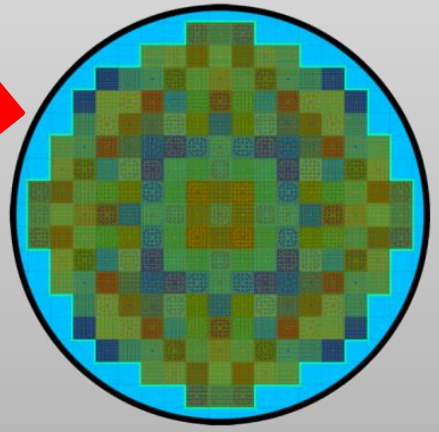

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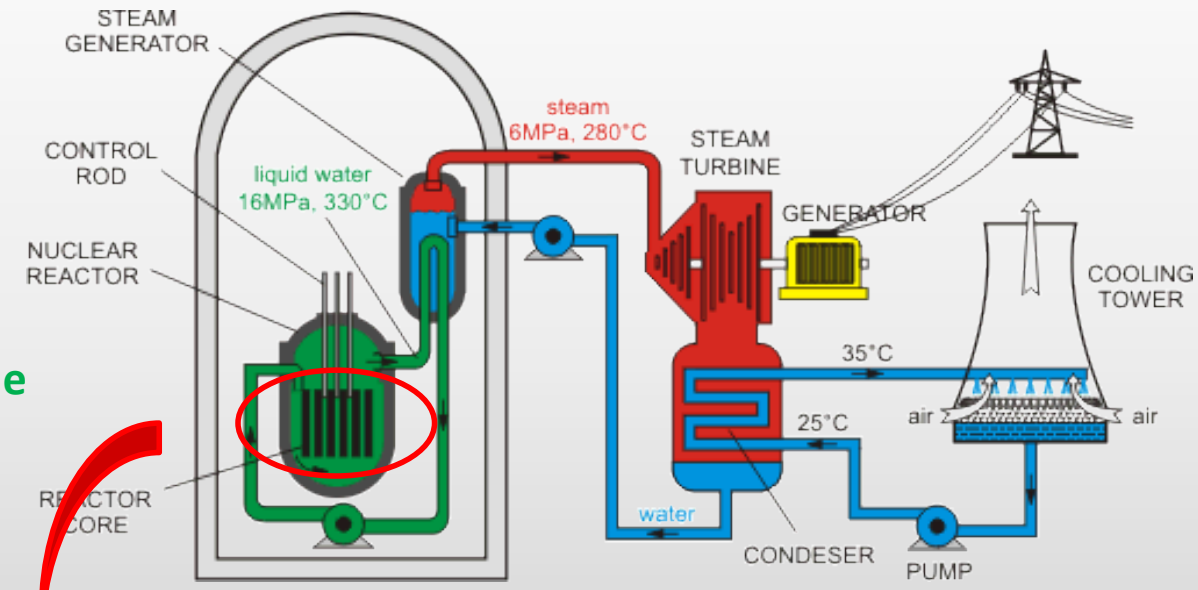
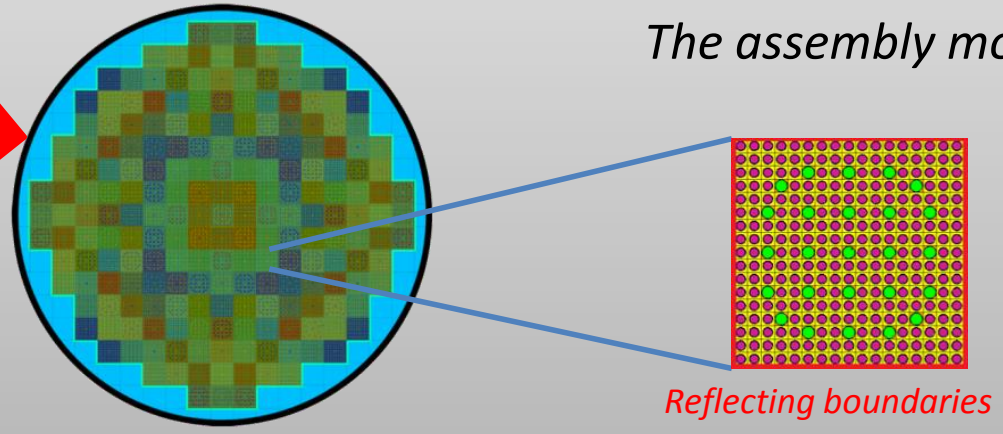


REP

Evaluation of strategies

The assembly model

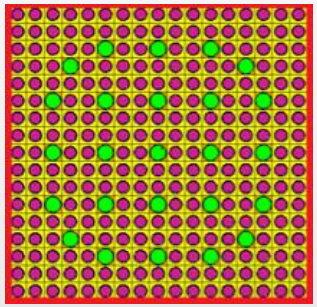


Reflecting boundaries

Homogeneous and infinite core

Assembly simulation

- **Simplified model approximations:**



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- Power control instrumentations approximately represented
- Neutron leakage neglected

Assembly simulation

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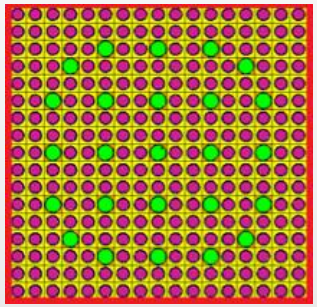

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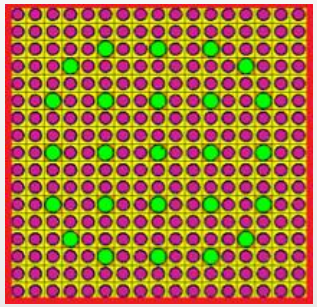

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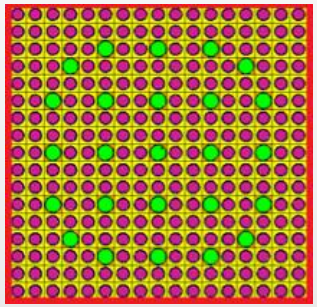

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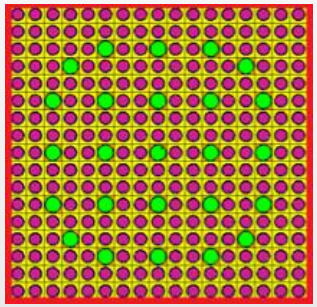

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Axial leakage

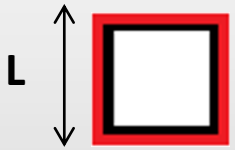
Axial leakage study: methodology

4 configurations of a PWR lattice:

- $\varepsilon_{U-235} = 3.5\%$
- *450 ppm* of boron

1. Cube

Assembly model



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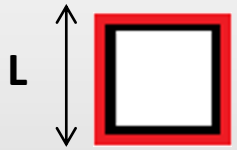

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Assembly model

Real assembly size
18 axial zones of height L

2. Reflected assembly

3. Open assembly

4. Moderated-reflected assembly

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- 80 independent MURE simulations
- Fresh fuel for 3 years
- Fixed power: 330 $\mathrm{W/cm^3}$

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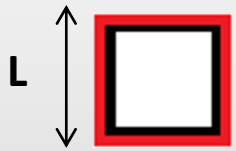

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Observables:

- Inventories of *U235, U238, Pu239, Pu240, Pu241, Cm244, Np237, Am241, Am243*
- Fission and capture cross sections of: *U235, U238, Pu239, Pu240*
- k_{eff}

Inventories: biases compared to the cube configuration

$$\Delta\% = \frac{\left(N_x^i - N_x^{cube}\right)}{N_x^{cube}} \%$$

Isotope	Refl	Open	Mod-Refl
U8	0.001	-0.03	-0.004
U5	0.02	8.76	3.87
Pu39	-0.01	-0.14	-0.74
Pu40	-0.07	-1.44	-0.82
Pu41	-0.02	-1.78	-1.33

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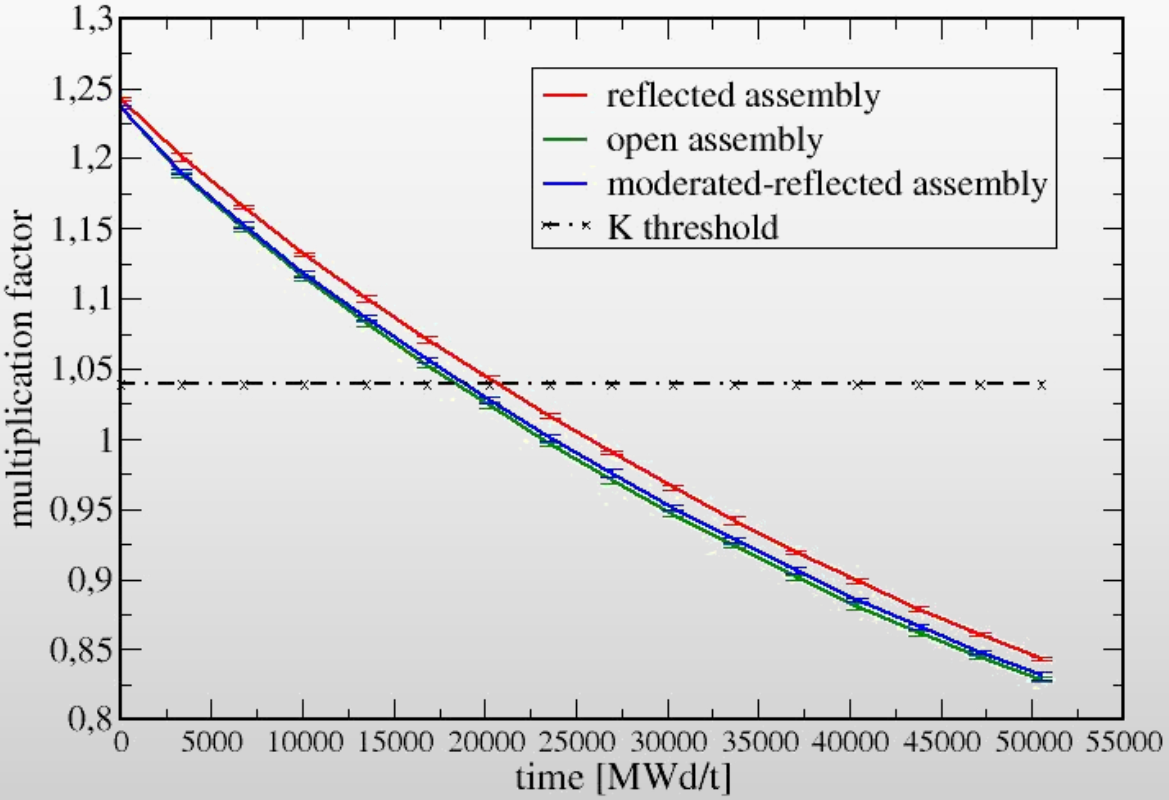

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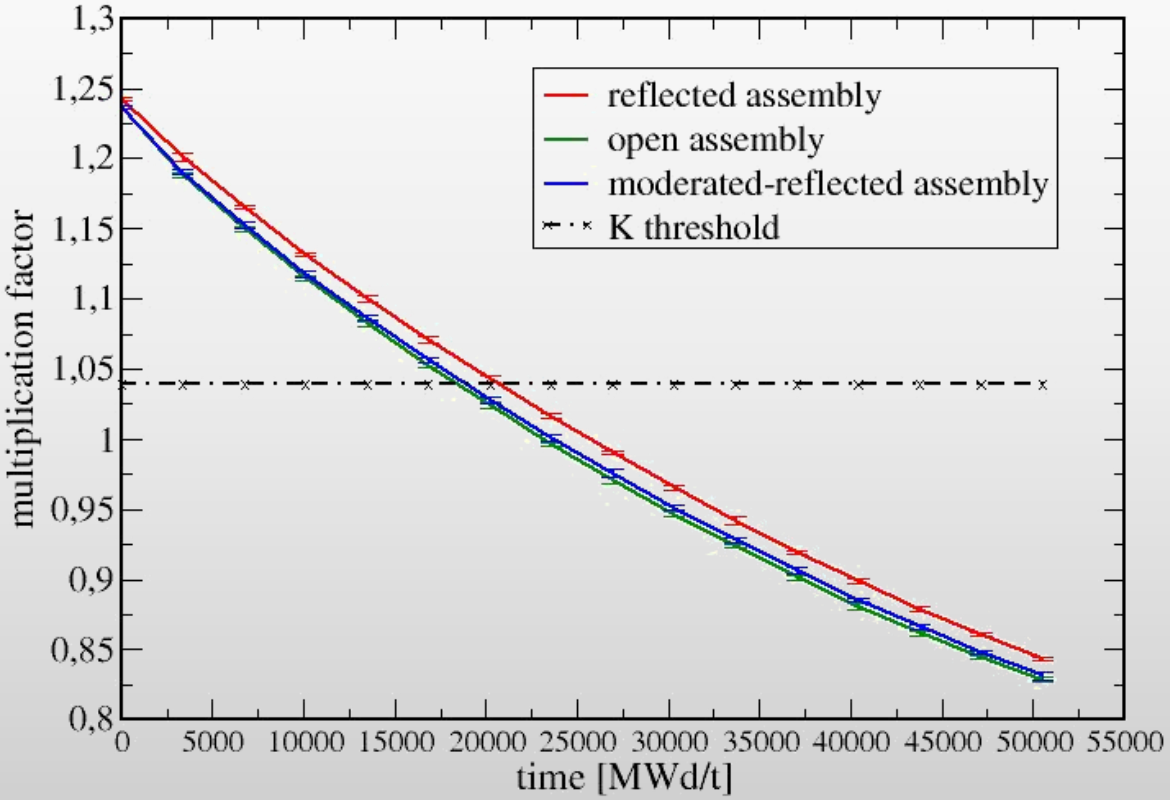
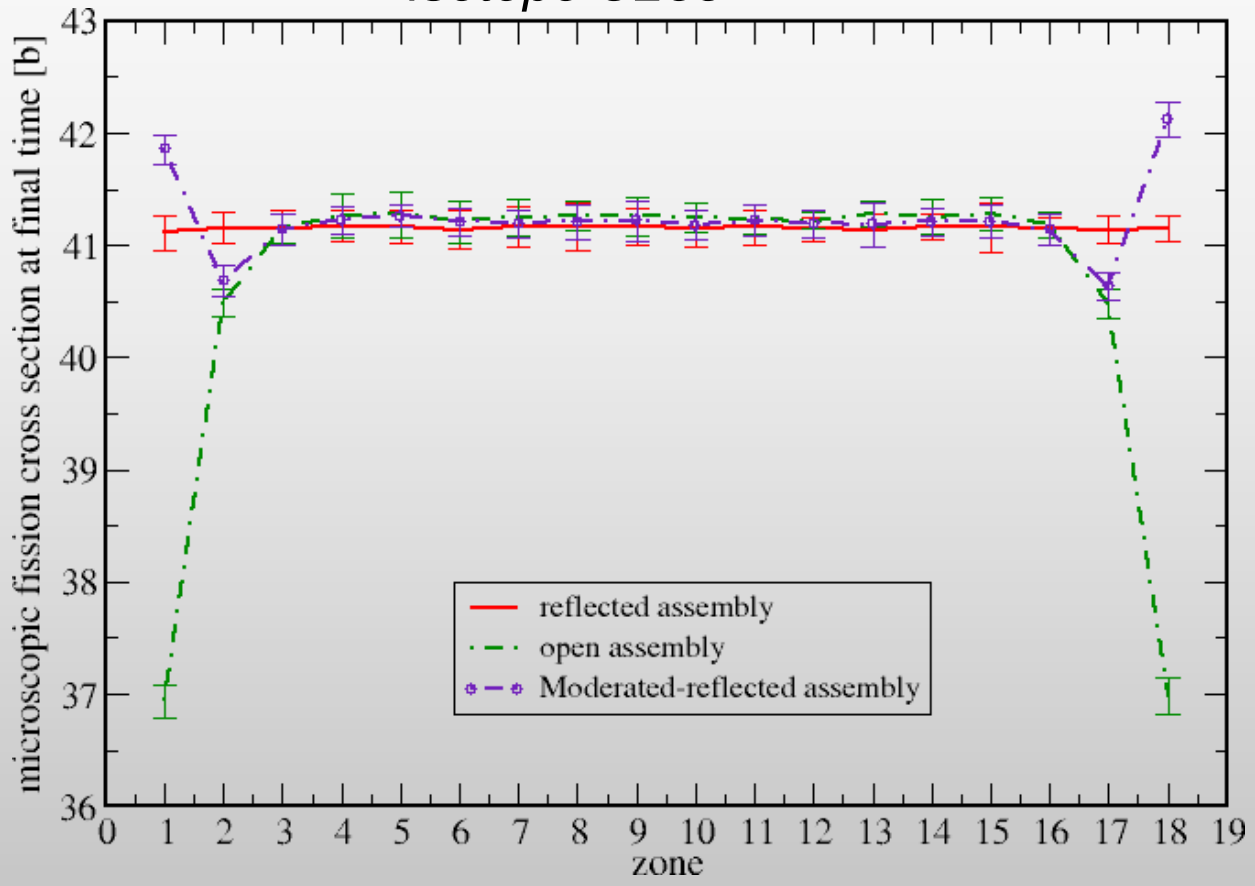


Case	$BU_{max}\left[\frac{GWd}{t}\right]$
Reflected	33,62
Open	30,54
MR	31,14

$\frac{BU_{max}^{open} - BU_{max}^{refl}}{BU_{max}^{refl}}\%$	$\frac{BU_{max}^{MR} - BU_{max}^{refl}}{BU_{max}^{refl}}\%$	$\frac{BU_{max}^{open} - BU_{max}^{MR}}{BU_{max}^{MR}}\%$
-9,15	-7,36	-1,94

Fission cross section @EOC

Isotope U235



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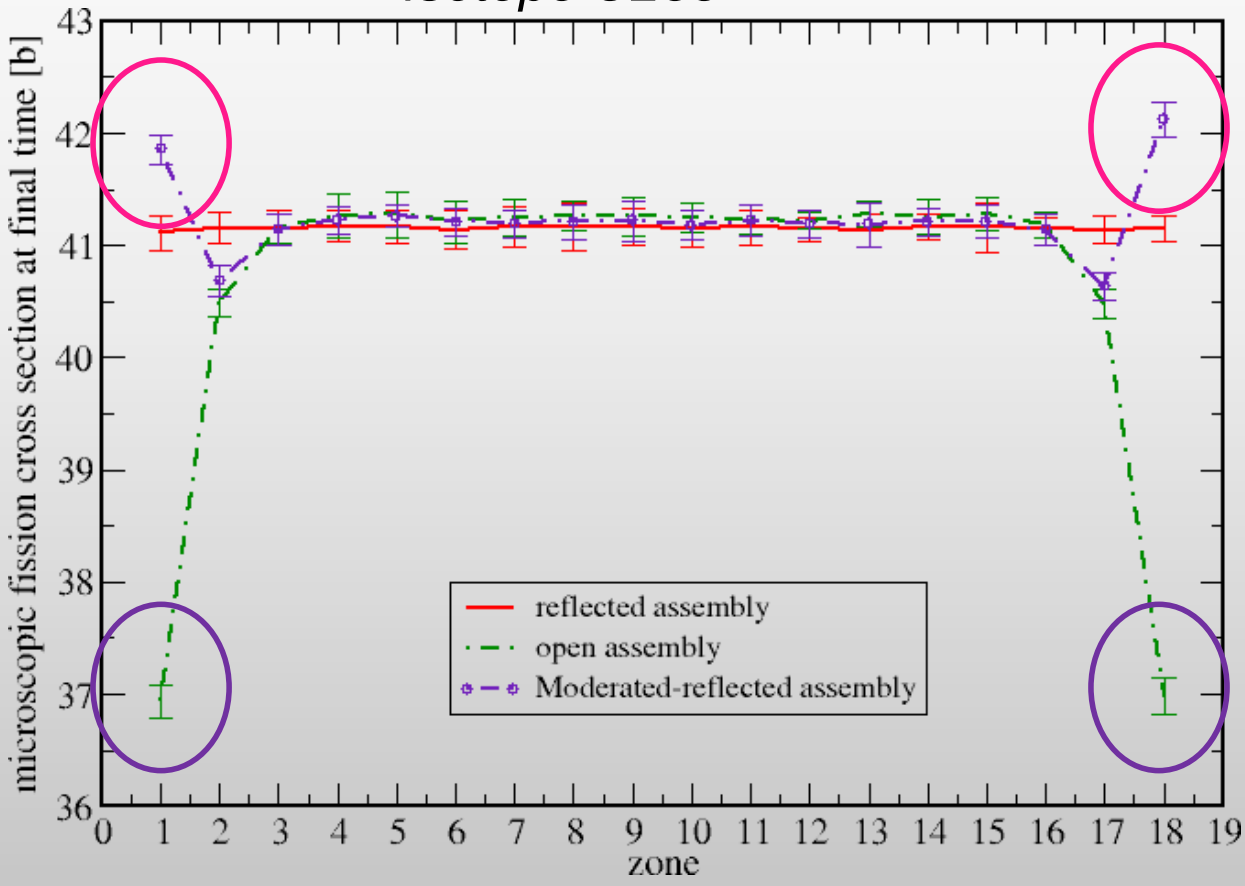
Modification of fission cross sections



Open assembly: neutron axial leakage
Moderated-reflected assembly: presence of moderator and reflector

Neutron axial leakage and more..

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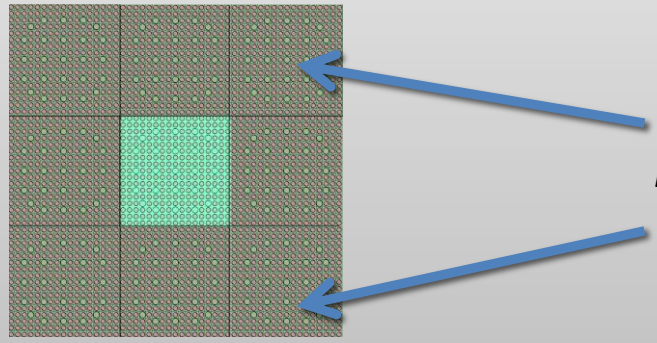

Impact of surrounding assemblies

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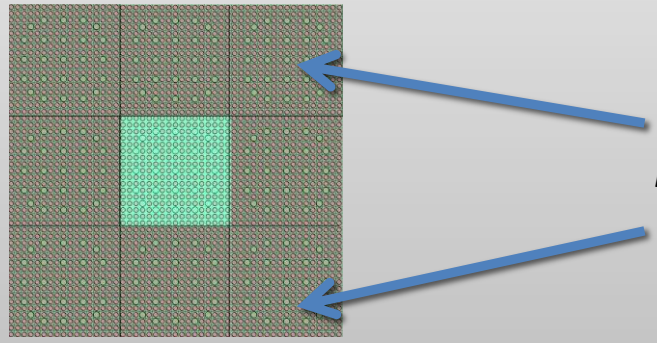

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Thank you for your attention