

COBAYA diffusion code Verification for SMR modelling NuScale

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Workshop on Neutronic Design of Small Modular Reactors
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- 1. UPM core simulation platform**
- 2. Verification activities**
- 3. NuScale core modelling**
- 4. Results**
- 5. Conclusions**

1. The UPM core simulation platform



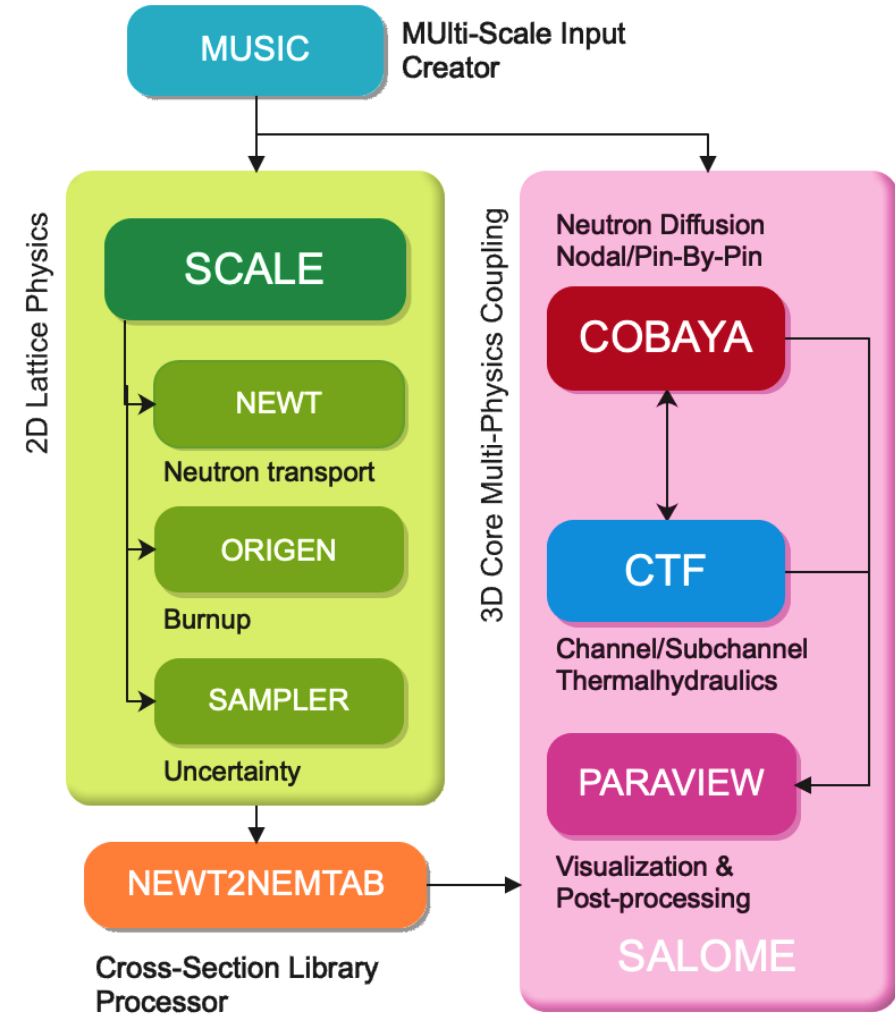
The UPM core simulation platform

- **Two-step standard approach to reactor simulation**
- **Multi-scale platform:** lattice and core simulation
- **Multi-physics platform:** neutron diffusion and subchannel thermal-hydraulics
- **Nodal and pin-by-pin resolution**

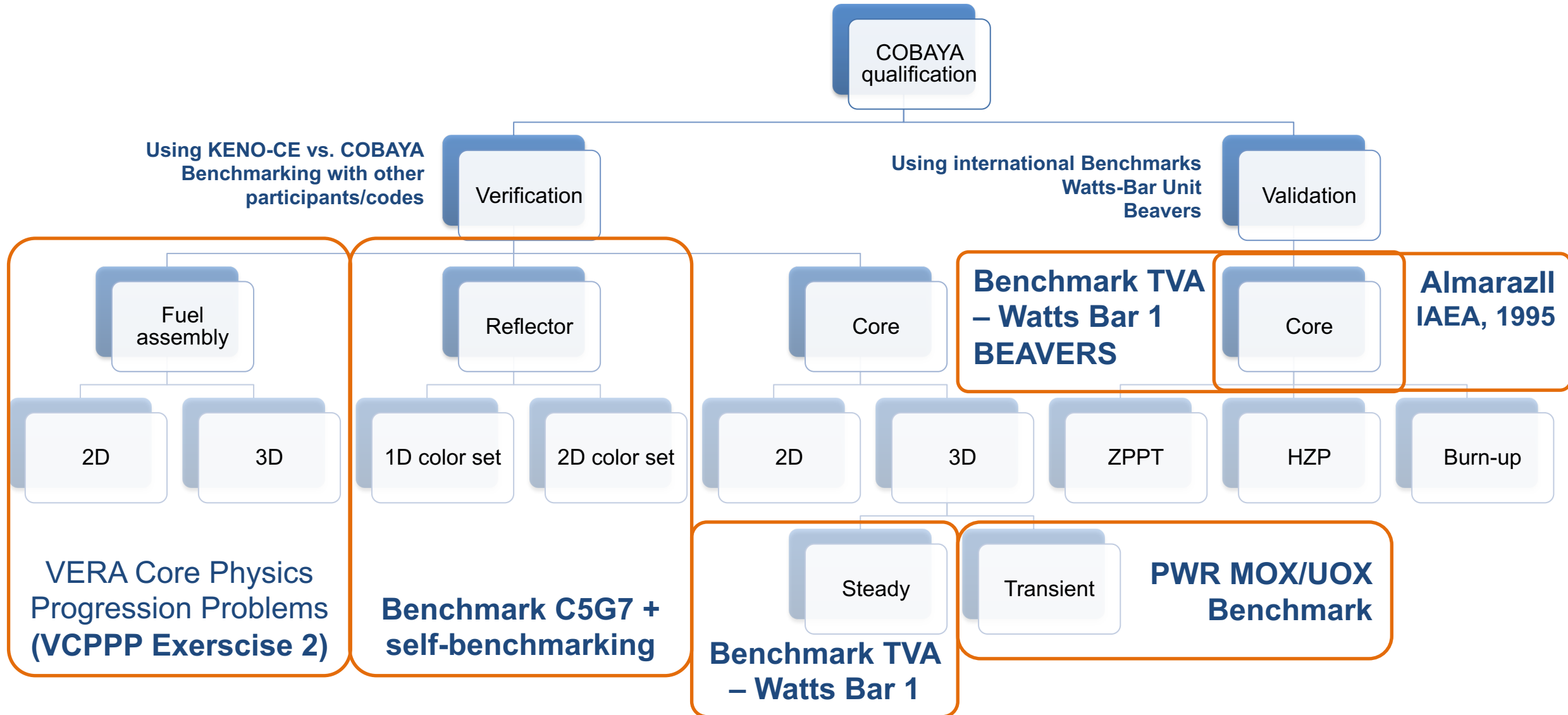
MUSIC: Multi-Scale Input Creator – User-friendly tool

A suitable python tool to tackle lattice modelling analysis, cross-sections generation that warrants the consistency between multi-scale, multi-physics simulation, and uncertainty propagation.

Whole platform V&V



2. Verification Activities



2. Verification Activities



Fuel Assembly simulation

- **VERA Core Physics Benchmark Progression Problems** (eigenvalue, pin power, and cross-section library generation)
 - 2D fuel assembly (Exercise 2):
 - HZP conditions FA
 - Other operation conditions
 - Pyrex, AIC, B₄C, Gad
 - Spacer grids
 - ADDITIONAL: WABA cases
 - 3D fuel assembly (Exercise 3):
 - HZP conditions active height
 - **Include SMR conditions and models (!)**

Reflector Color Set

- **Self benchmarking (eigenvalue and pin power)** (eigenvalue, pin power)
 - 1D water reflector color set
 - 2D water reflector color set
 - 1D heavy reflector color set
 - 2D heavy reflector color set

Reactor Core simulation

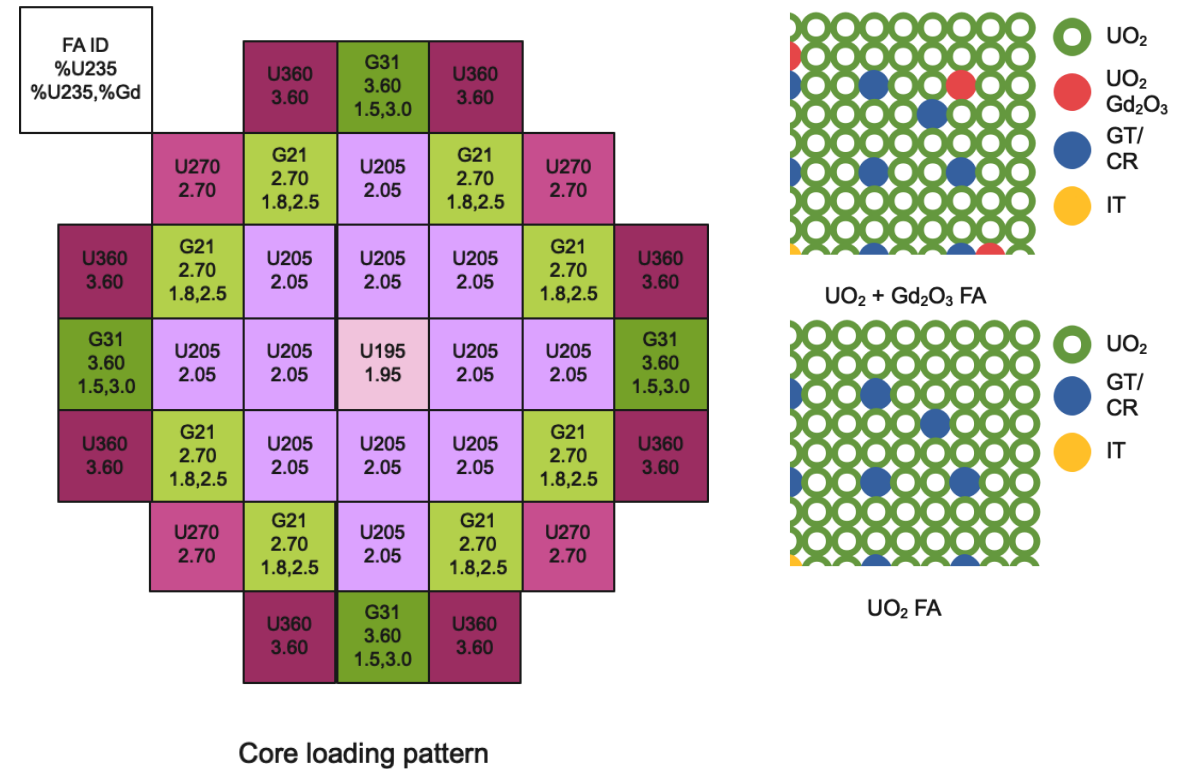
- **Self benchmarking**
 - **3D NuScale model: eigenvalue problems and rod worth (Today's presentation)**

3. NuScale Core Modelling



NuScale SMR core: loading pattern

- 160 MWth light-water cooled small modular reactor
- UO_2 fueled core
- 6 fuel assembly types (Suk et al., 2021)
 - 4 poison-free FA (UXXX)
 - 2 FA with 8 Gd pins (GXX)
- BOL HZP averaged conditions
 - $\rho = 0.851 \text{ g/cm}^3$
 - $T_{\text{mod}} = 491.75 \text{ K}$
 - $T_{\text{fuel}} = 491.75 \text{ K}$
 - $C_{\text{boro}} = 1413.8 \text{ ppm}$

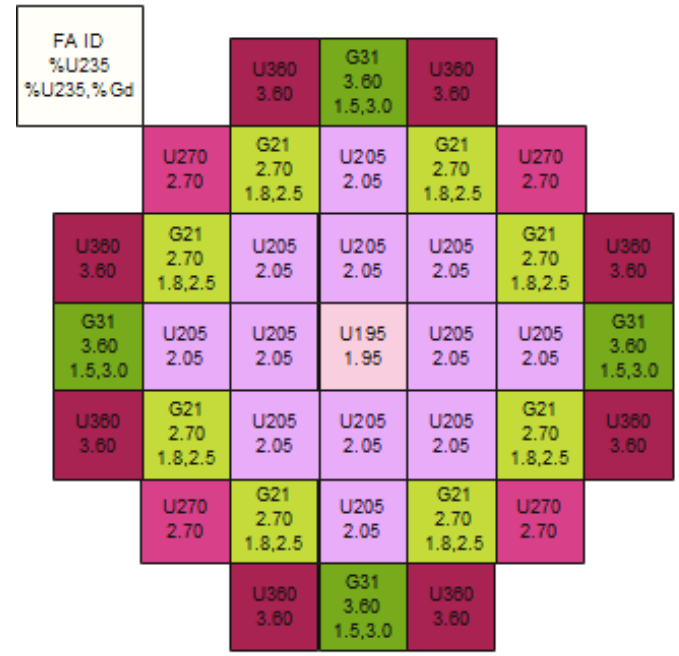


3. NuScale Core Modelling

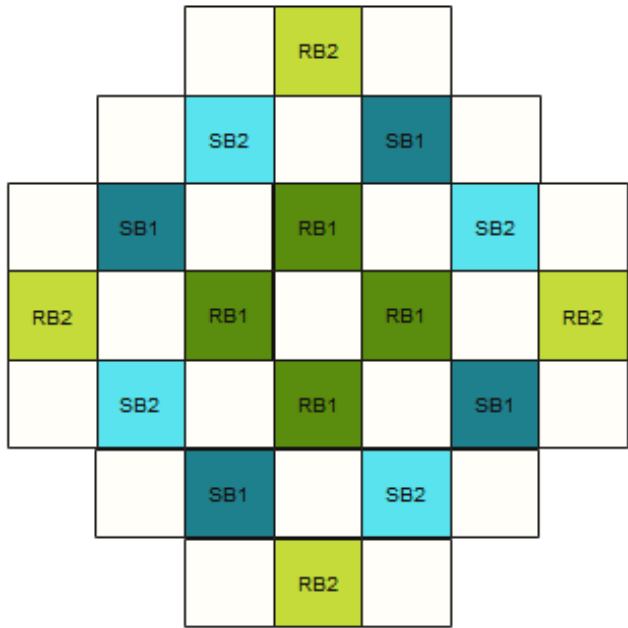


NuScale SMR core: control rods

- 4 control banks
 - 2 regulating groups (RG1, RG2)
 - 2 shutdown groups (SB1, SB2)
- Partial length
 - B₄C
 - AIC tips



Core loading pattern



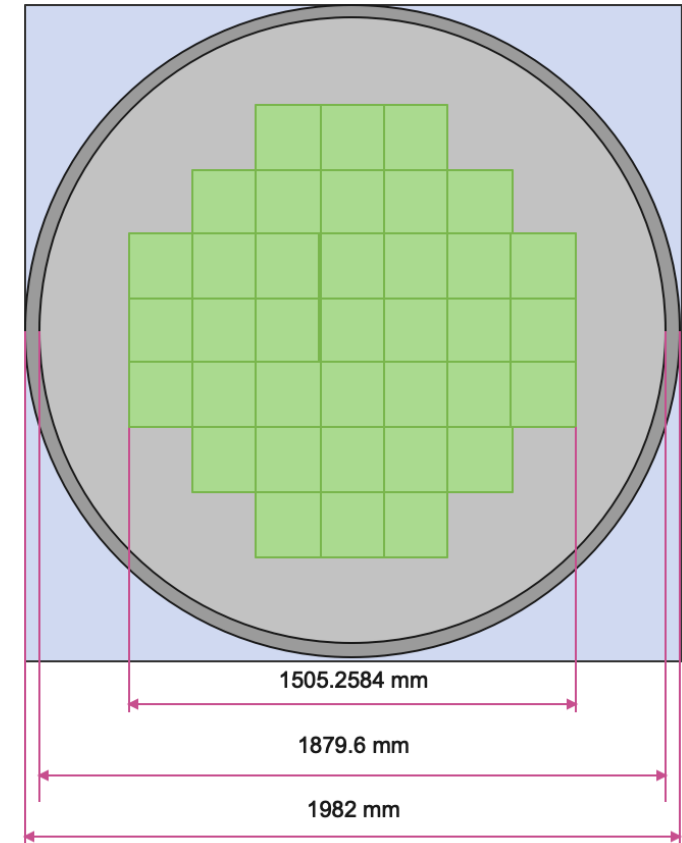
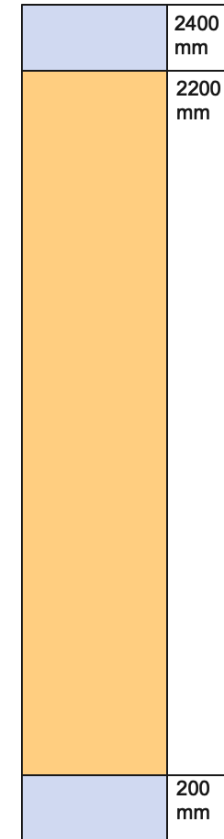
CRA banks

3. NuScale Core Modelling



NuScale SMR core: reflector modelling

- **Active height:** 2 m
- **Simplified upper and lower reflector**
 - 20 cm height
 - Water (no fuel rod plenum)
- **Radial reflector layers** (Burrell et al., 2019)
 - Baffle: 2.8 cm thick
 - Water-gap: 0.1 mm thick
 - Heavy reflector (SS304): 93.98 cm radii
 - Core barrel (SS304): 5.12 cm thick
 - Water pool: cuboid



3. NuScale Core Modelling



NuScale SMR core: modelling options

Nuclear data



- ENDF/B-VII.1
- 56 energy groups

Self-shielding



- Latticecell option
- 2D Method of Characteristics
- Resonance range PW calculation

Lattice



- 2D discrete ordinates
- Order for scattering (P_n 1)
- Moderator (P_n 3)

Discretization

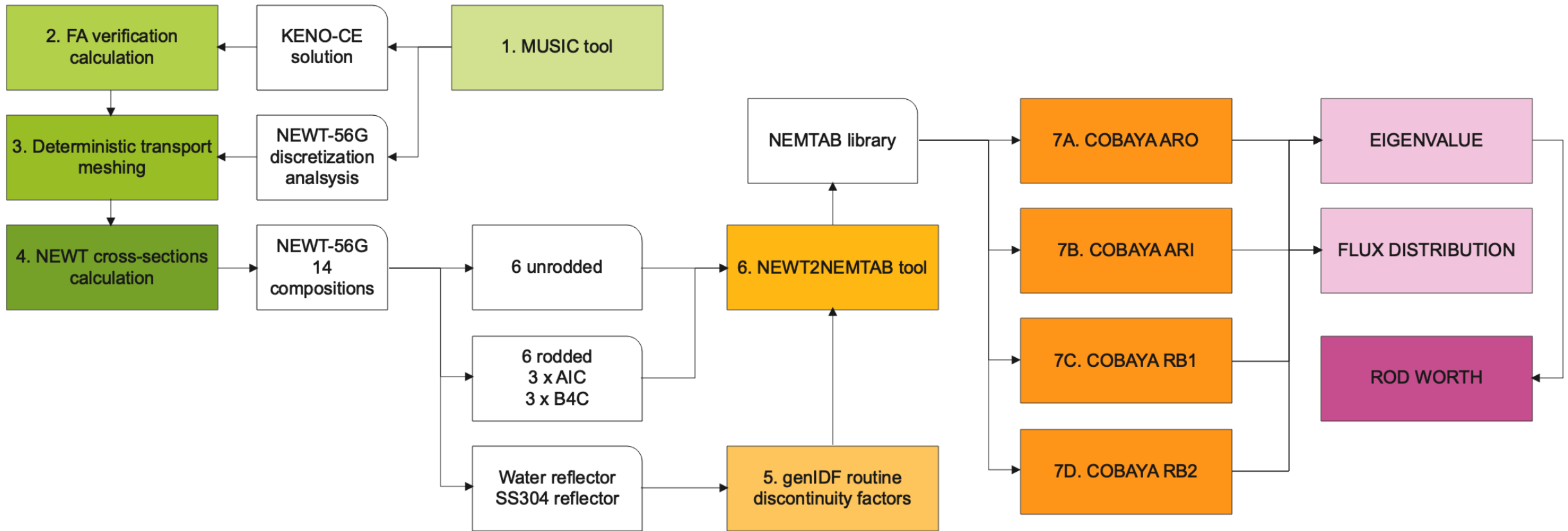


- 4x4 pincell mesh NEWT
- S_N 6 NEWT
- 2 energy groups
- Nodal calculation
- 66 axial nodes COBAYA

3. NuScale Core Modelling



NuScale SMR core: simulation flowchart



4. Results



Eigenvalues

Case	KENO	COBAYA	Δ (pcm)
ARO	1.00445(5)	0.99962	-483
ARI	0.85774(5)	0.85327	-447
RB1	0.98115(5)	0.97519	-596
RB2	0.98400(5)	0.98013	-387

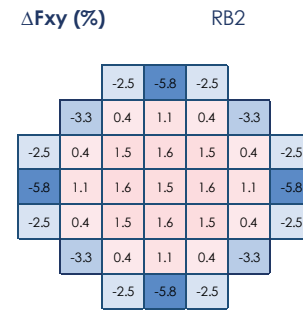
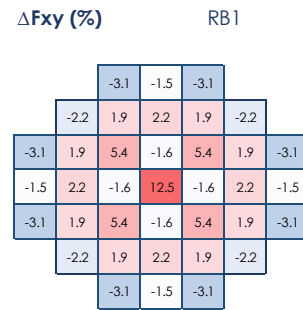
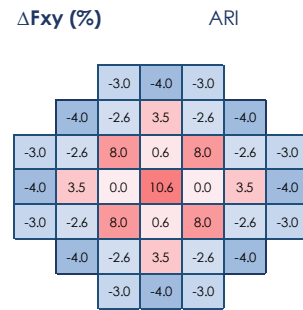
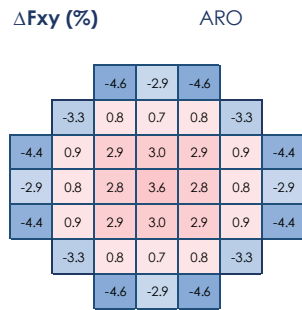
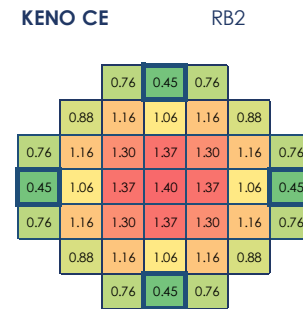
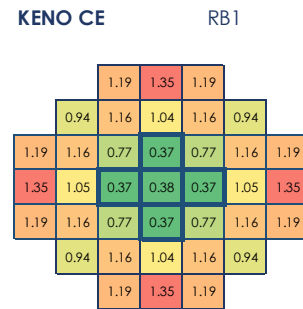
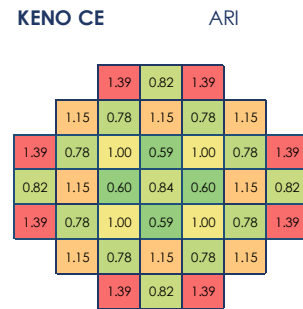
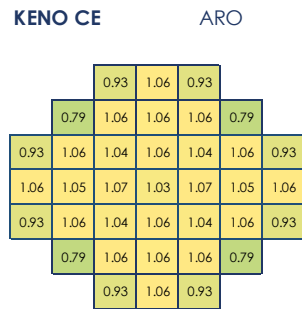
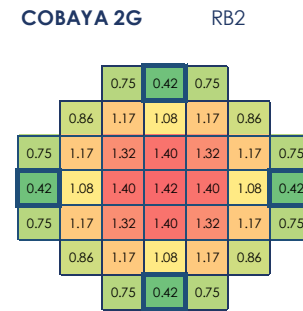
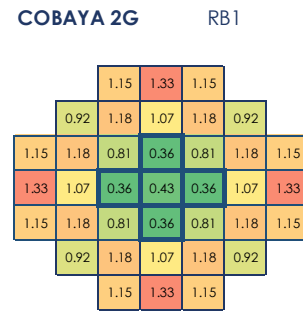
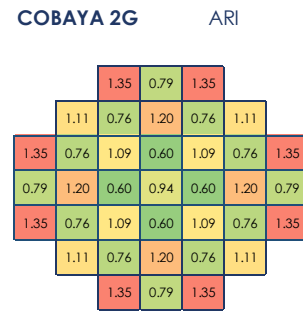
Bank worths

Case	KENO	COBAYA	Δ (pcm)
ARI	17028	17158	+130
RB1	2364	2506	+142
RB2	2069	1989	-80

4. Results



Power distributions



Case	ΔF_{xy} (%)	RMSE (%)
ARO	+3.6	2.97
ARI	+10.6	4.26
RB1	+12.5	3.44
RB2	-5.6	2.63

5. Conclusions



A baseline case has been created to be used as a reference for ongoing code and Modelling improvements

Identified biases contributors to the total core eigenvalues around -400 pcm are:

1. Each Fuel Assembly bias (-200 pcm unavoidable at Small Modular Reactor HZP Conditions)
2. AIC tips biases (-400 pcm, a fail in the control rod self-shielding)
3. Reflector Modelling (discontinuity factors treatment and peripheral fuel Assembly cross-sections processing)
4. In rodged cases, biases are also introduced by the infinite lattice calculations (not quantified)

Nonetheless, unrodged cases power distribution differences are not pessimistic and similar to other code comparisons*. Thank to this work, some improvement areas have been identified and the Issues Will be subsequently addressed.

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