HUN REN Centre for Energy Research

HUN-REN Hungarian Research Network

HUN-REN Centre for Energy Research

Reactor physics code development for SMR analysis

Csenge Komjáti, Zoltán István Böröczki, István Pataki, Vince Hegyi
Nuclear Safety Department

Research. Innovation. Impact.

Small Modular Reactor, SMR: wide range of technologies

Challenges

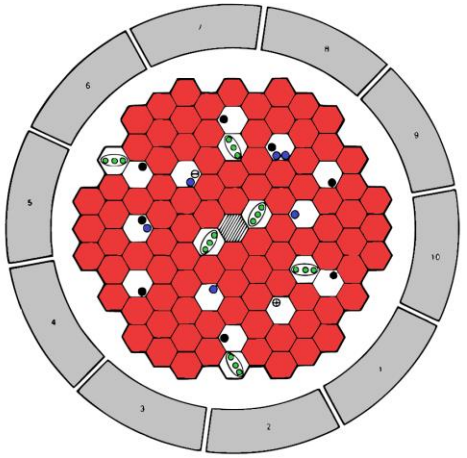
- Smaller core
- Innovative technological solutions

Goal of the CER NSL laboratory:

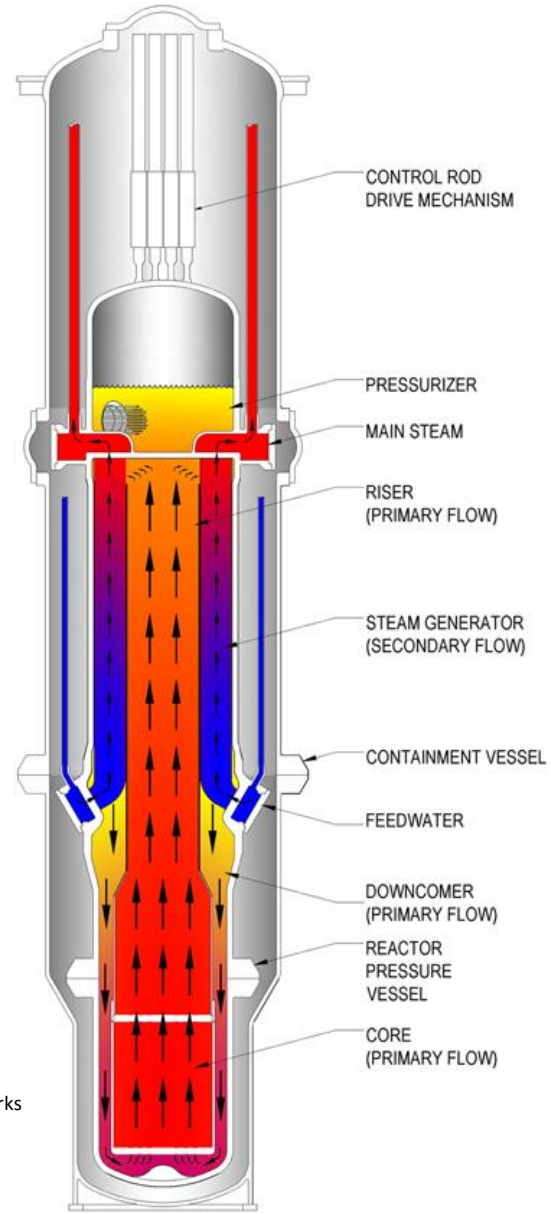
Flexible pipeline for development and testing SMR models of reactor physics codes

Ongoing benchmark calculations

- NuScale
  - Soluble boron free IPWR
  - Steady-state neutronics exercises
- PRATIC
  - Soluble boron free PWR
  - Multiphysics exercises in normal operating conditions
- SEFOR
  - Sodium-cooled fast reactor
  - Steady-state and transient multiphysics exercises

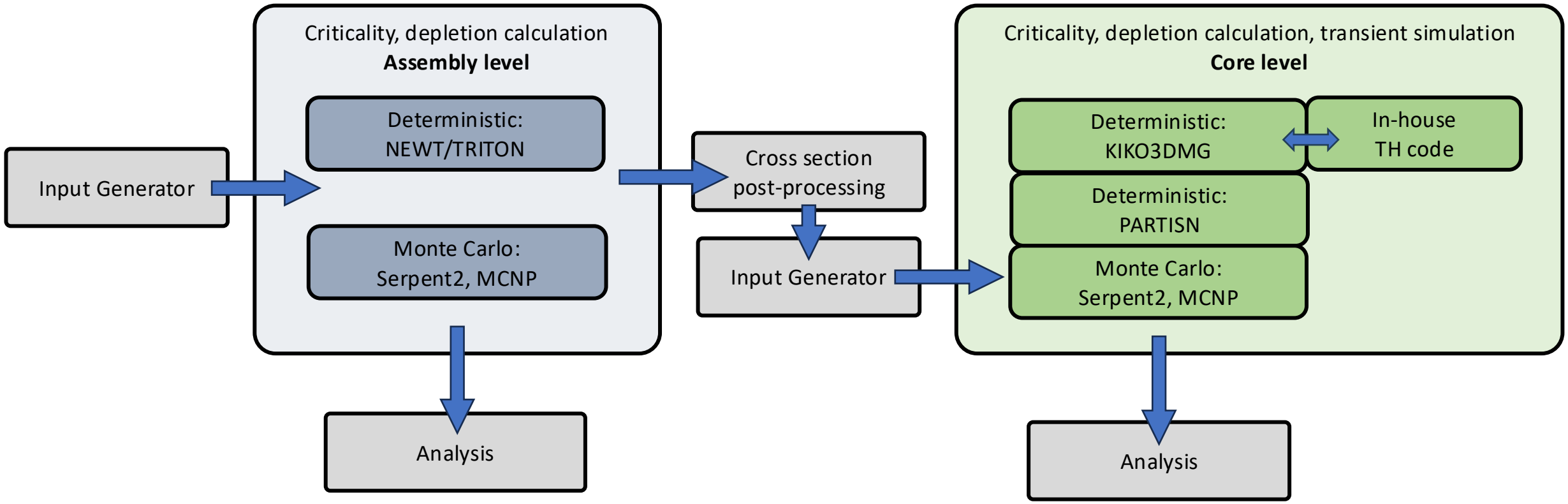


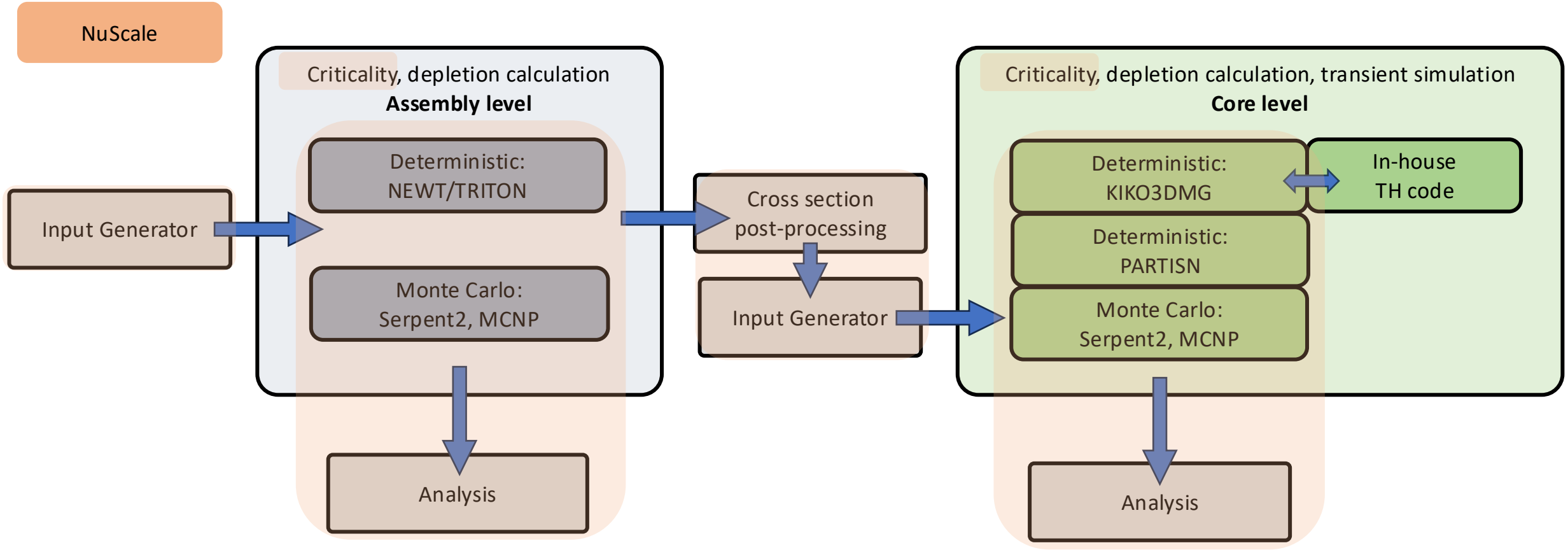
[1] Laurent Buiron, Elias Y. Garcia Cervantes „Proposal for SEFOR benchmarks related to Phase-I and Phase-III of the UAM-SFR" (2023)



[2] NuScale Power LLC. NuScale standard plant design certification application. *„Chapter 01: Introduction. and General Description of the Plant"* (2020).

Pipeline for analysis and development





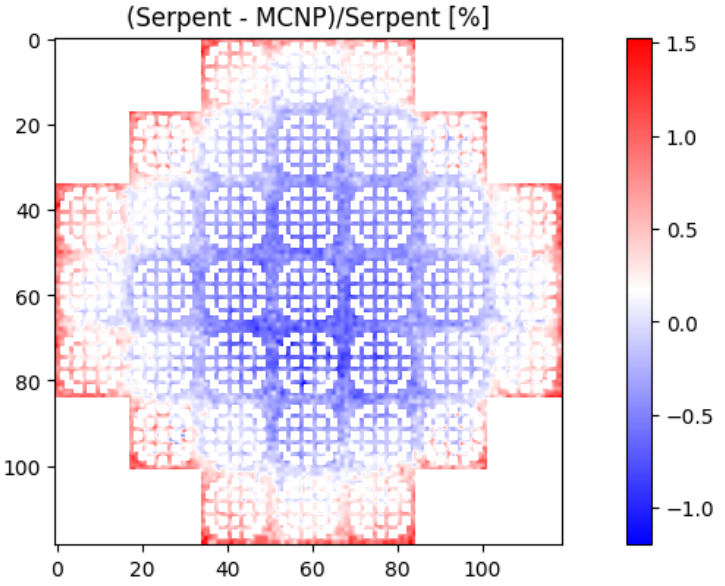
[1] E. Fridman, Y. Bilodid, V. Valtavirta. "Definition of the neutronics benchmark of the NuScale-like core." Nuclear Engineering and Technology (2023)

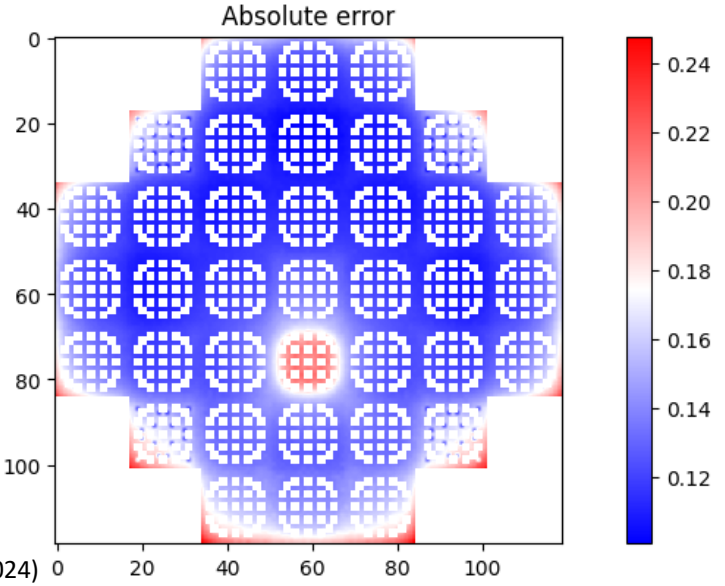
MCNP model validation with benchmark results

- Good agreement between power distributions, reactivity worth

Serpent2+KIKO3DMG model, number of energy groups: 14

- Mesh-dependence analysis, optimal: S1C1 SP3





Root mean square of relative difference of assembly level power distributions (RMS) [%]

	c\s	0	1	2
Ref	0	1.593	1.206	1.355
	1	1.058	1.314	1.413
RE1	0	1.833	1.645	1.621
	1	1.516	1.625	1.629

SP	1	3	5
Ref	1.314	1.103	1.126
RE1	1.625	1.650	1.671

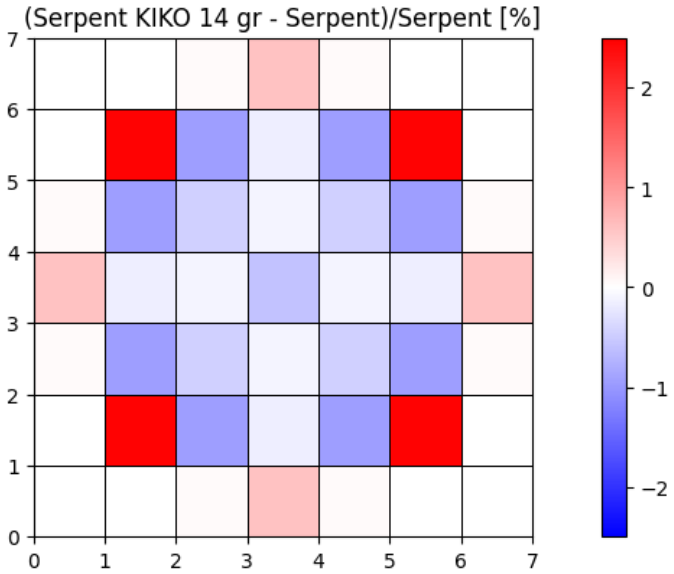
[3] Komjáti Cs., Böröczki Z., Pataki I., „Számítások NuScale-jellegű reaktorfizikai benchmarkhoz”, XXI. MNT Nukleáris Technikai Szimpózium (2024)

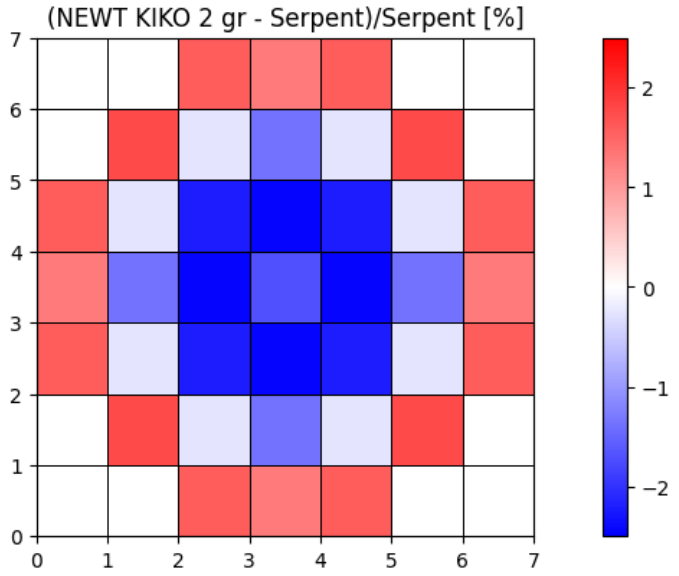
NEWT+KIKO3DMG model

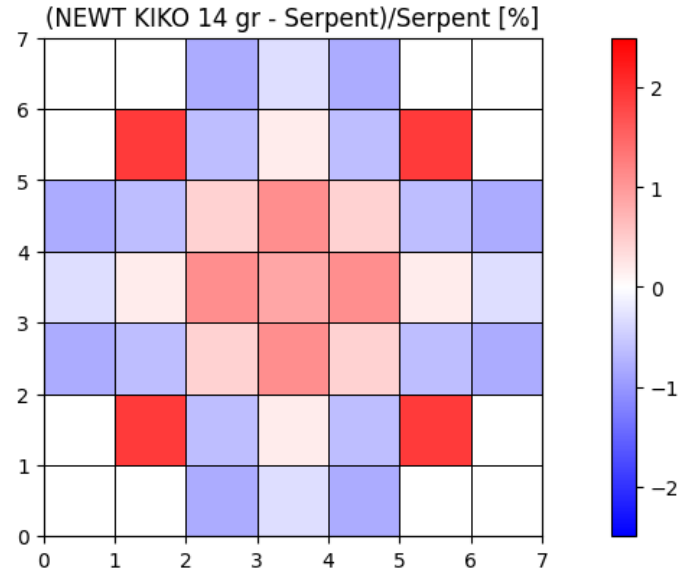
- S1C1 SP3, number of energy groups: 2, 14
- All control rods out
- RMS: 1.491%, 0.889%

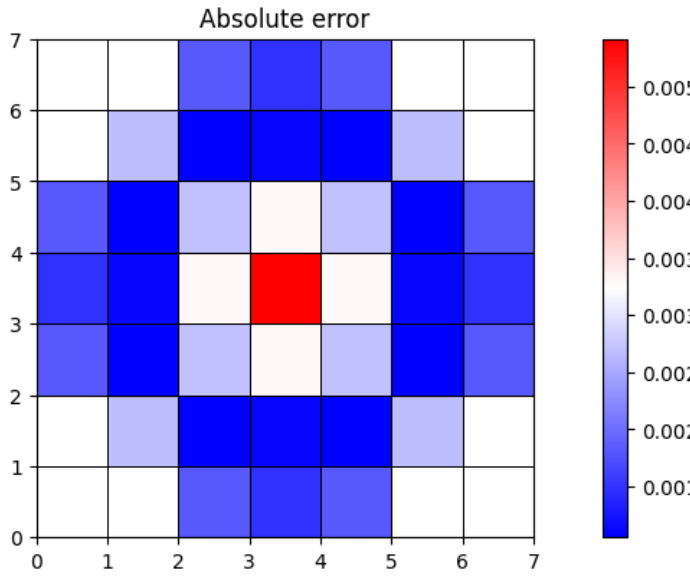
Comparison to Serpent2+KIKO3DMG model

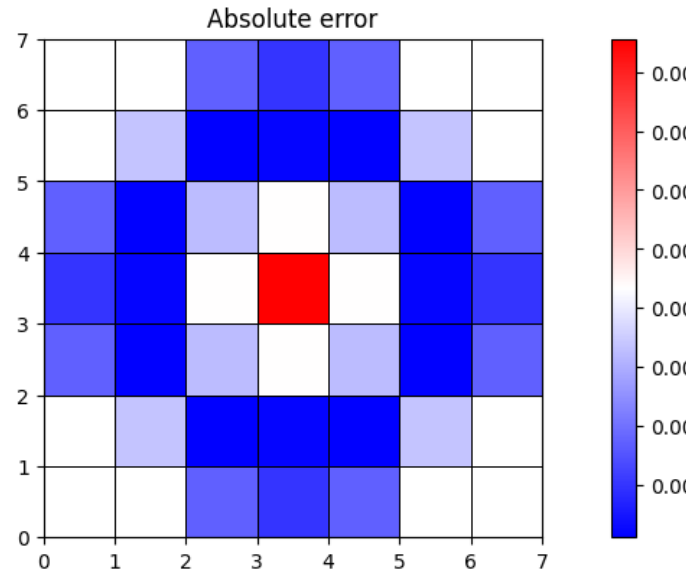
- Based on RMS, NEWT CS give slightly better results
  - Serpent2 CS: 0.966%
- Gd assemblies are less outstanding



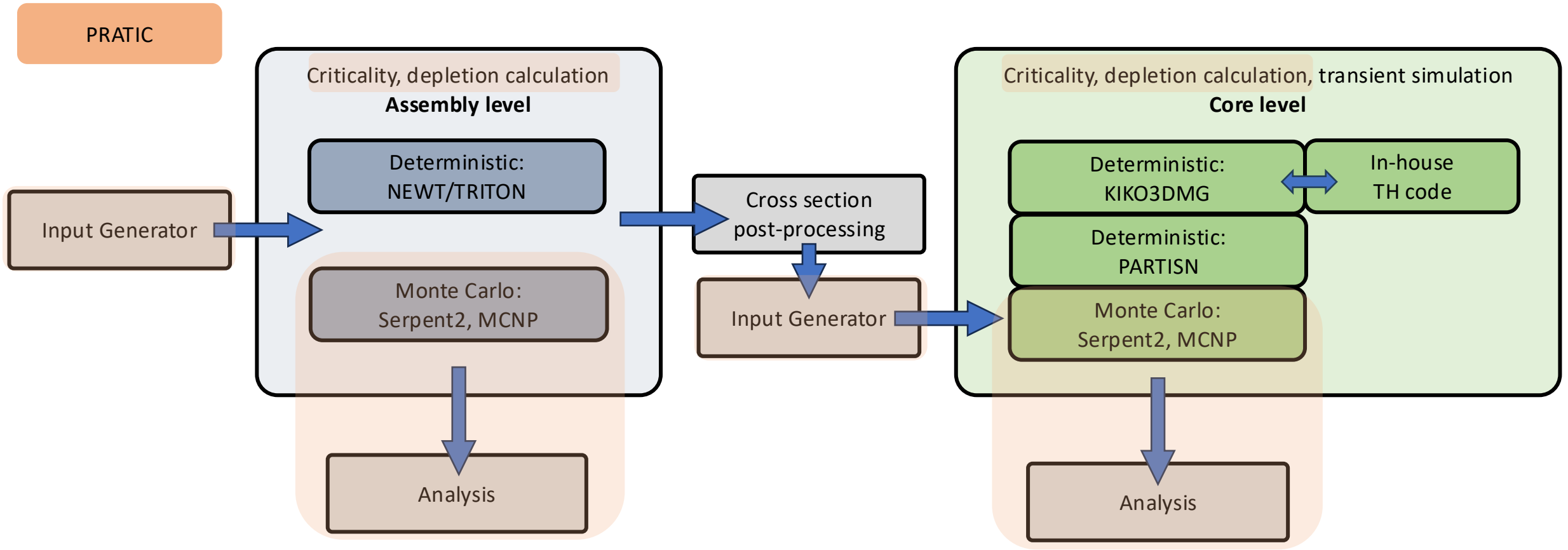








PRATIC benchmark



[4] R. Vuiart, A. Eustache , S. Eveillard, G. Prulhière „PRATIC: A soluble-boron-free, pressurized water cooled, SMR core benchmark" (2024)

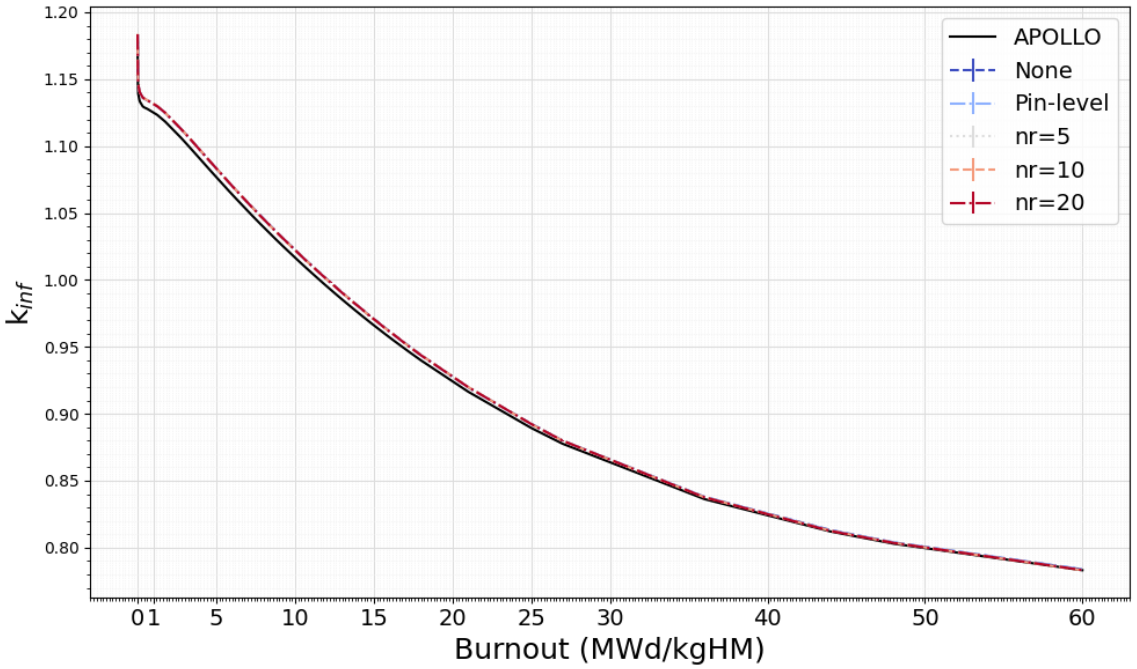
Ongoing: NEA WPRS, Light-water cooled small modular reactor benchmark for uncertainty quantification and propagation in multiphysics simulations

Serpent2 vs APOLLO2

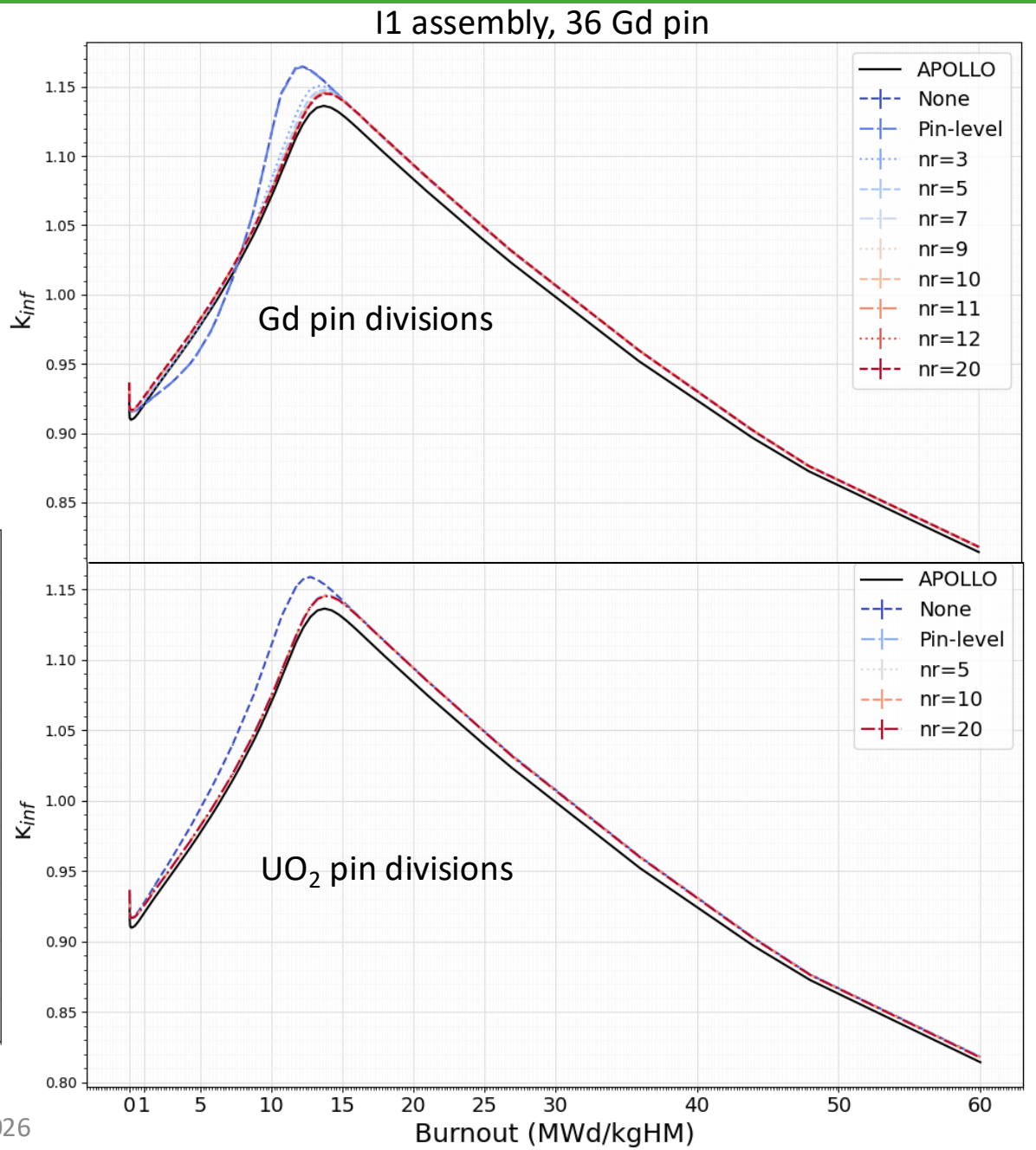
Assembly burnout

- MC steps: 42
- Deterministic steps: 111

I2 assembly, 0 Gd pin



I1 assembly, 36 Gd pin

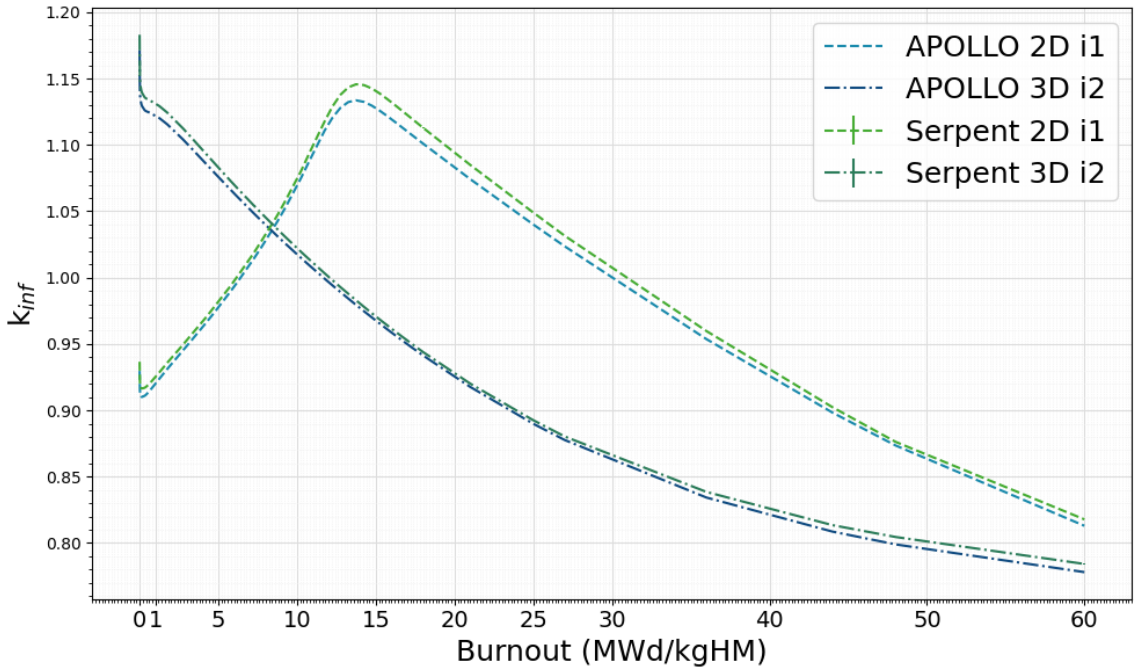


Serpent2 vs APOLLO2

- Serpent2 has higher multiplication factors
- Minimal change in difference through burnout

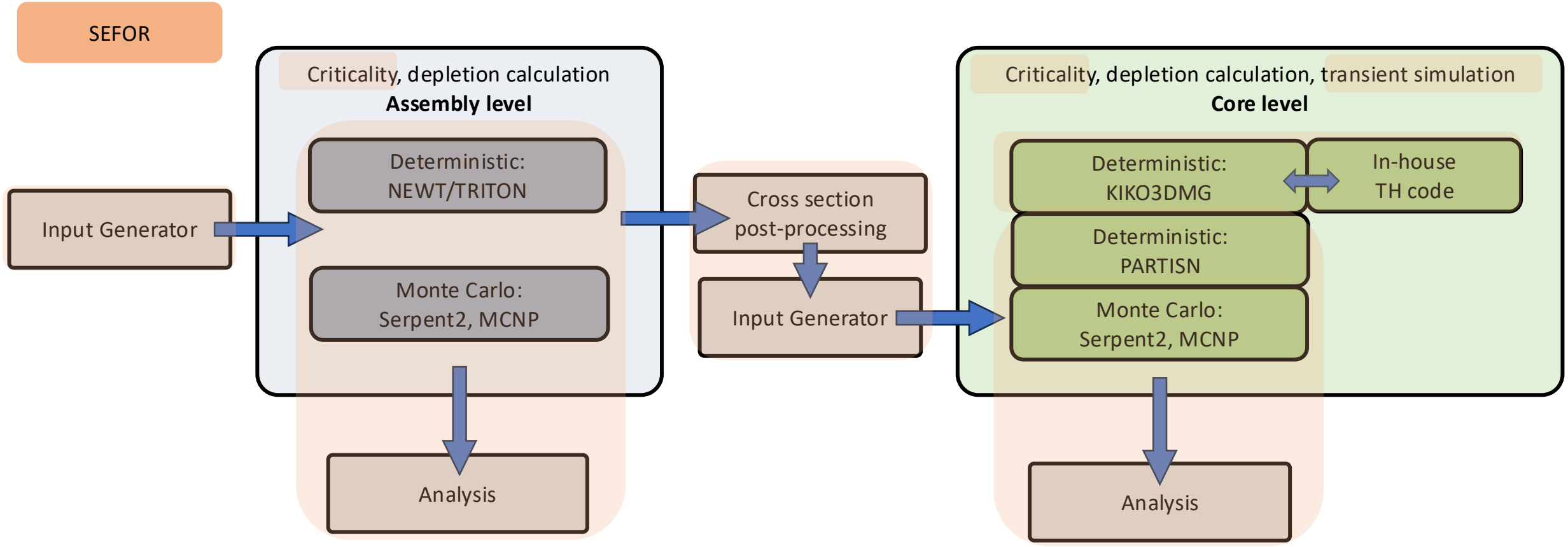
2D: Not modelling axial leakage

3D: Modelling axial leakage



Weighted RMSE [10^{-5}]

	c0 (2.5%, , 8 Gd)	i1 (5%, 28 Gd)	i2 (1.6%, 0 Gd)	e1 (3.5%, 36 Gd)	e2 (2.8%, 8 Gd)
2D	544	701	348	1003	649
3D	571	703	498	1014	677



[5] Laurent Buiron, Elias Y. Garcia Cervantes „Proposal for SEFOR benchmarks related to Phase-I and Phase-III of the UAM-SFR" (2023)

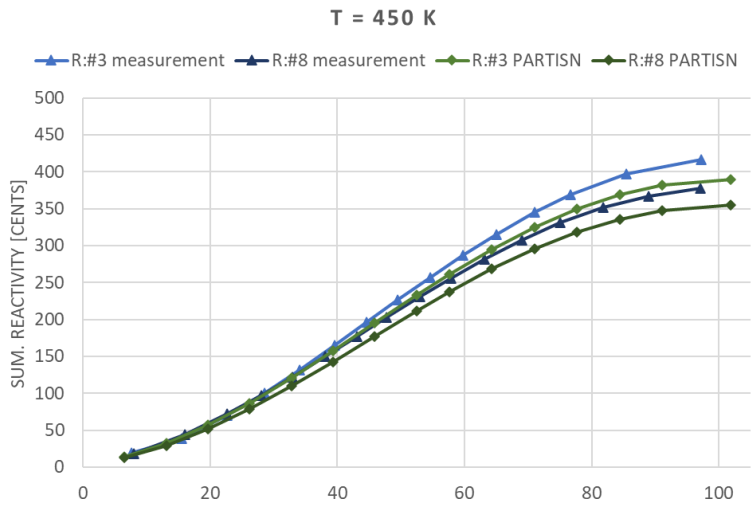
Ongoing: NEA WPRS, Uncertainty Analysis in Modelling for Design, Operation and Safety Analysis of Sodium-cooled Fast Reactors

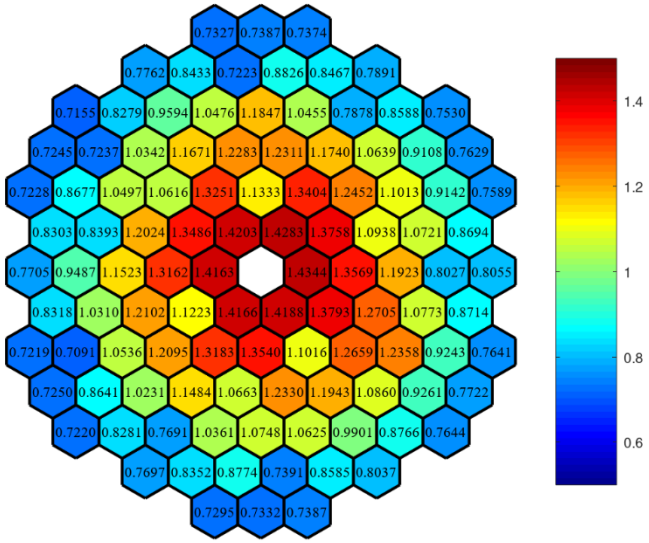
Cross-section generation

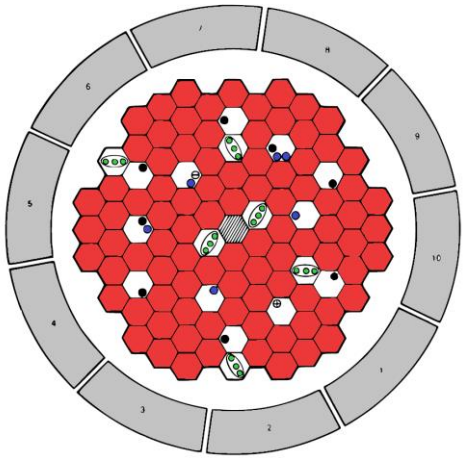
- **Serpent2** (24g)
- **SCALE NEWT** (33g, 13g)

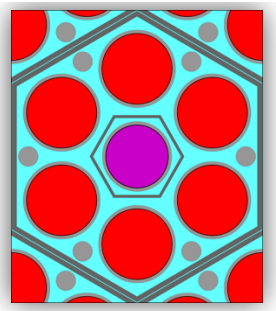
Deterministic full-core models

- **PARTISN (SN)** and **Serpent2**:
  - Reactivity worth calculations
  - Reactivity worth of reflectors 3 and 8
  - Assembly-wise power distributions
  - Rod reactivity worth measurements
- **KIKO3DMG (SP3)** :
  - Rod reactivity worth measurements







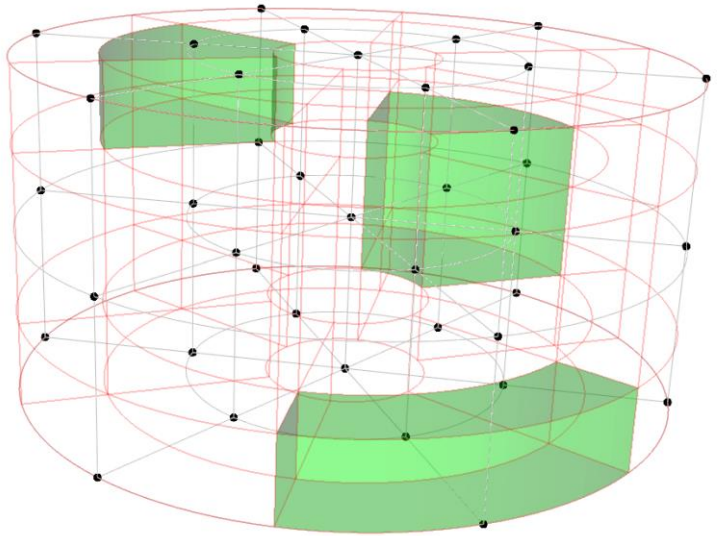


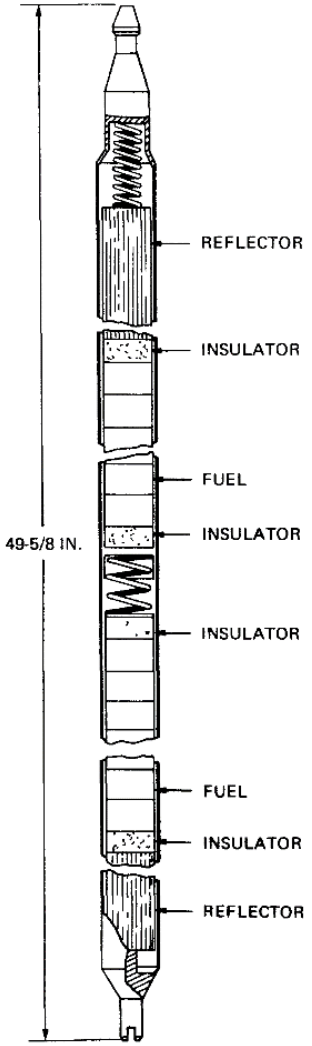
[6] Böröczki Z., Pataki I., „Részvétel a SEFOR benchmark feladatban”, XXI. MNT Nukleáris Technikai Szimpózium (2024)

In-house code development

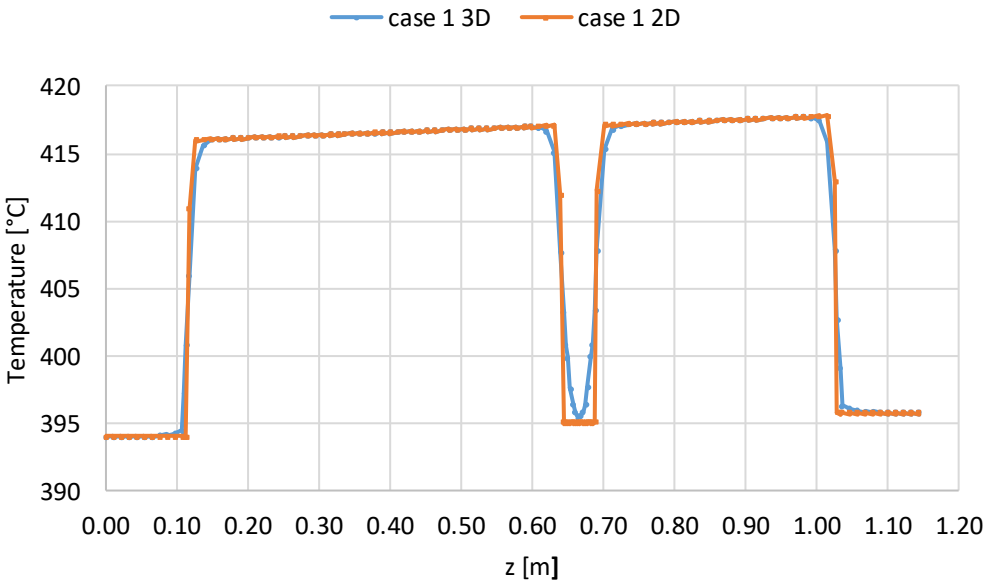
Achieved: 3D assembly-model

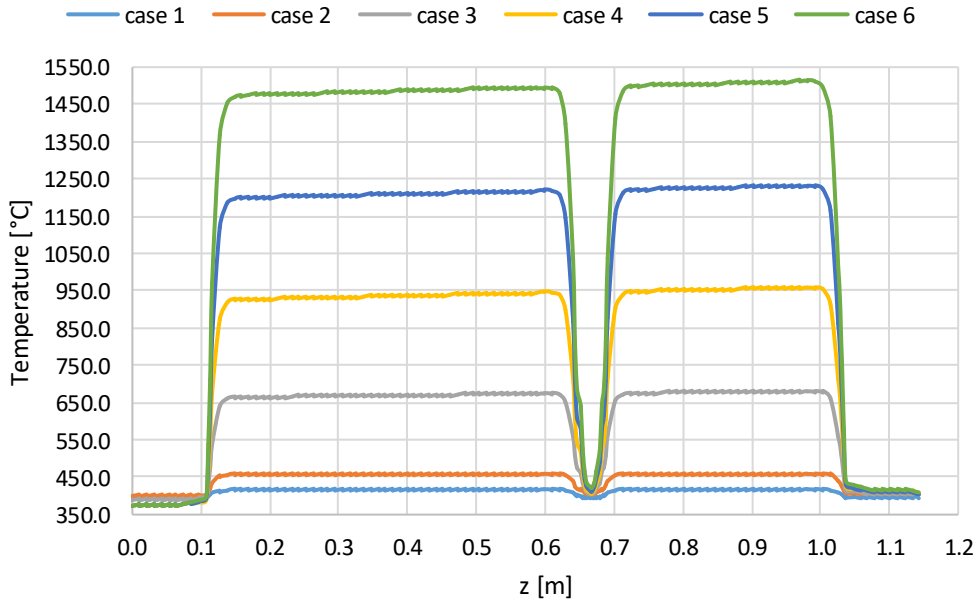
- 6 cases defined in benchmark





Fuel centerline temperature

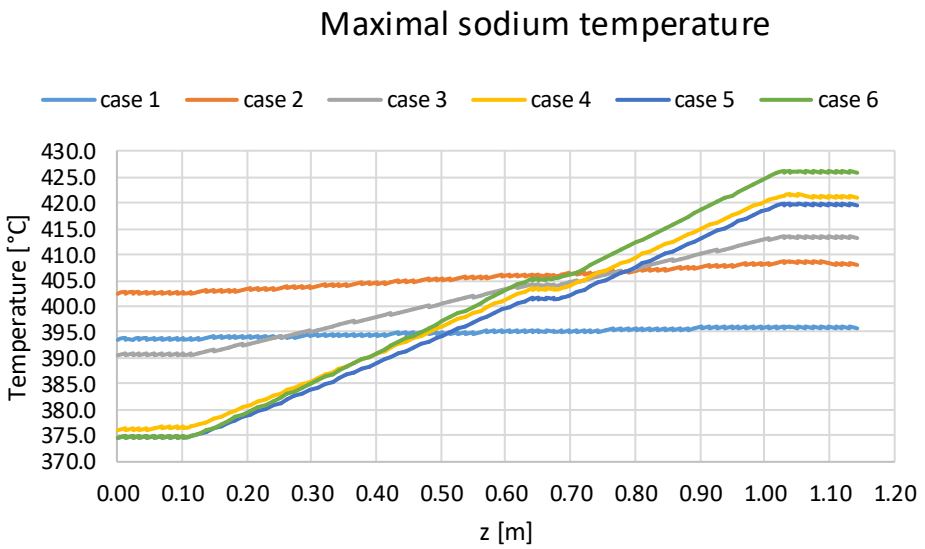


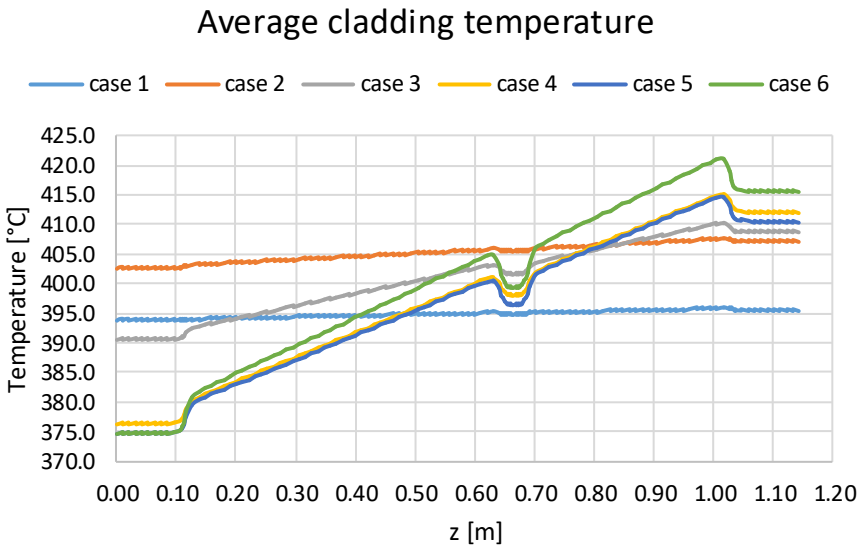


In-house code development

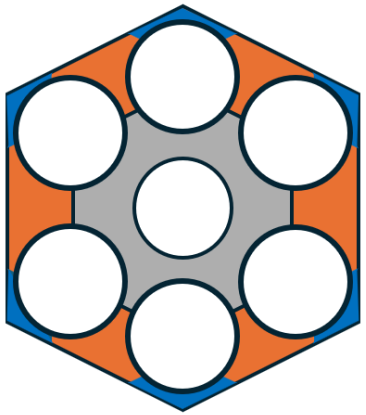
Achieved: 3D assembly-model

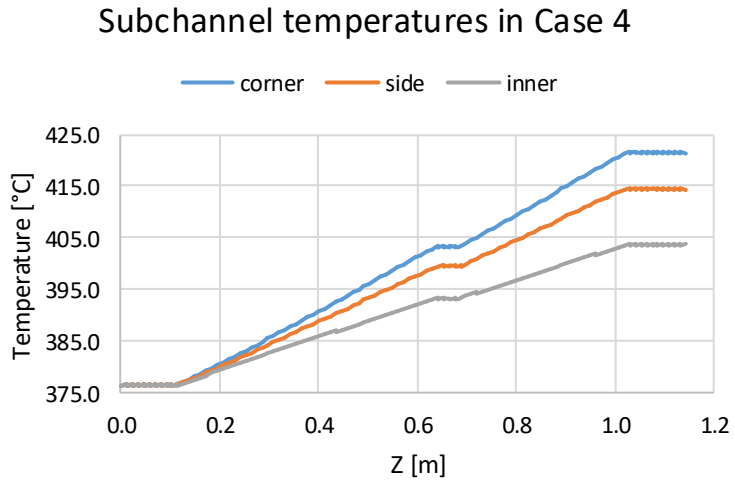
- 6 cases defined in benchmark





Subchannel model



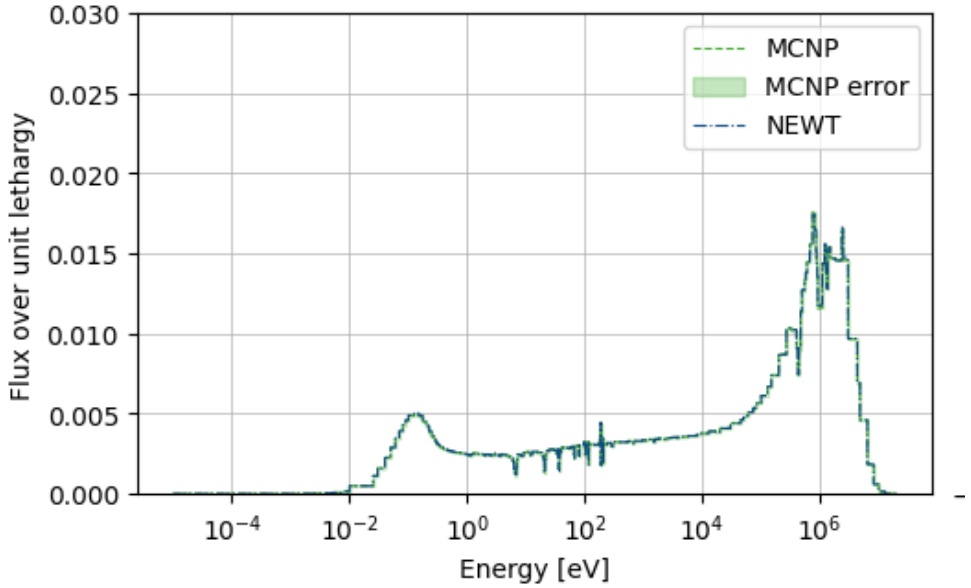


HUN-REN Centre for Energy Research

Thank you for your attention!

Validation of NEWT model

Spectra of the C02 assembly in NEWT and MCNP model



SEFOR case definitions

	Case #	Power (W)	Inlet Temperature (K)	Flowrate (m3/s)
Assembly	1	4,00E+03	667,2	0,002090242
	2	1,00E+04	676,0	0,002101814
	3	5,00E+04	663,9	0,002612014
	4	1,00E+05	649,7	0,002635157
	5	1,50E+05	647,9	0,003931171
	6	2,00E+05	647,9	0,004586541