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SAMOFAR Final Meeting
WP4: Accident Analysis

July 4, 2019

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Main contributors

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- PSI: R. de Oliveira, J. Krepel
- TUD: M. Tiberga, F. Alsayyari, Z. Perkó, D. Lathouwers

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Main work performed

- Definition of transients
- Code development
- Code verification
- Steady-state and transient analysis
- Uncertainty quantification

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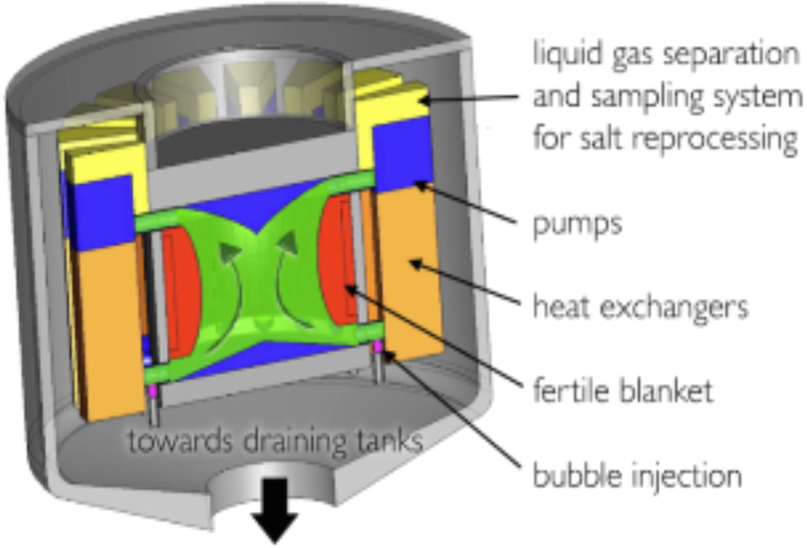
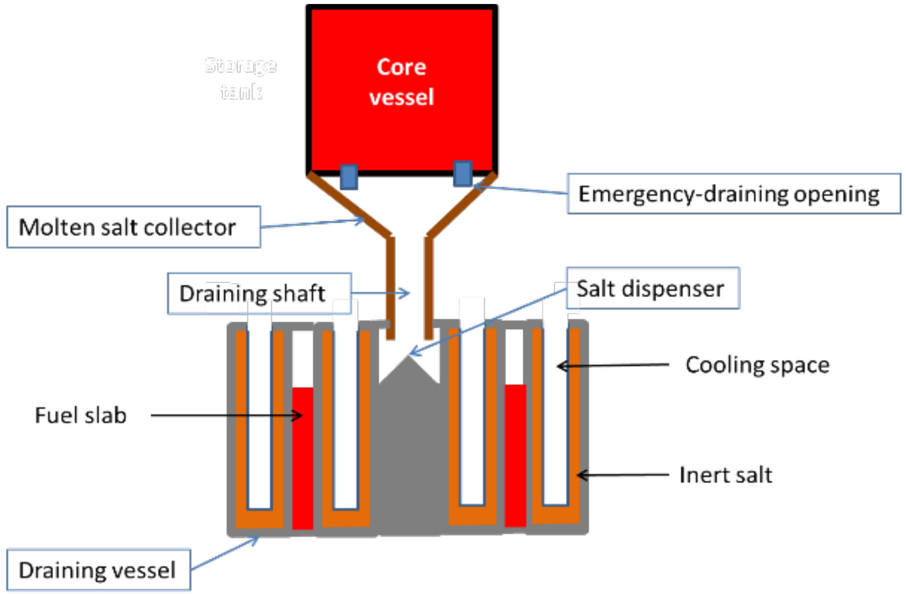
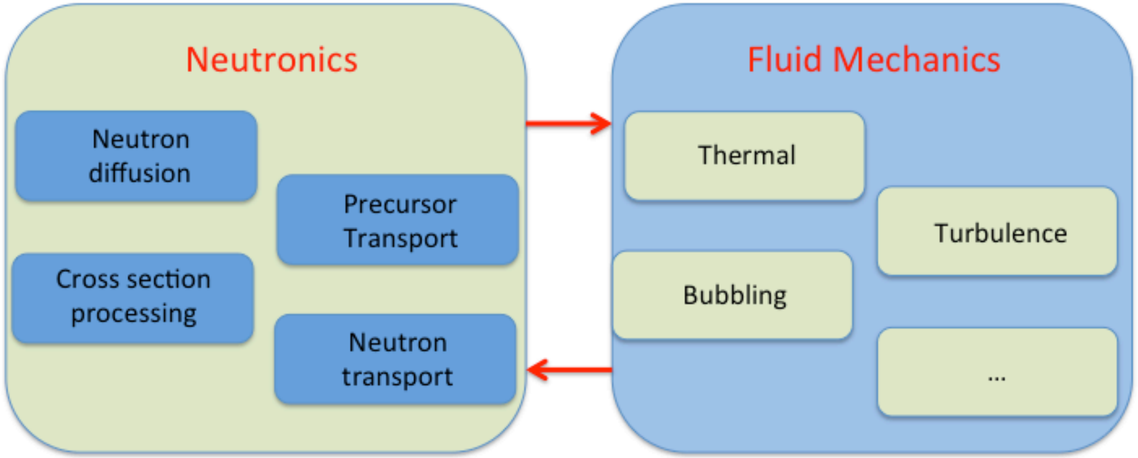
Relevant transients

- Two types of transients are considered
  - Fuel circuit transients
  - Transients involving the emergency draining tank





Code development



- Aim is to build new or extend existing code systems with special abilities for the multi-physics modeling of the MSFR
- The following capabilities are necessary
  - Moving fuel -> moving precursors
  - Three-dimensionality and geometric flexibility
  - Include feedback effects from temperature and of bubbling

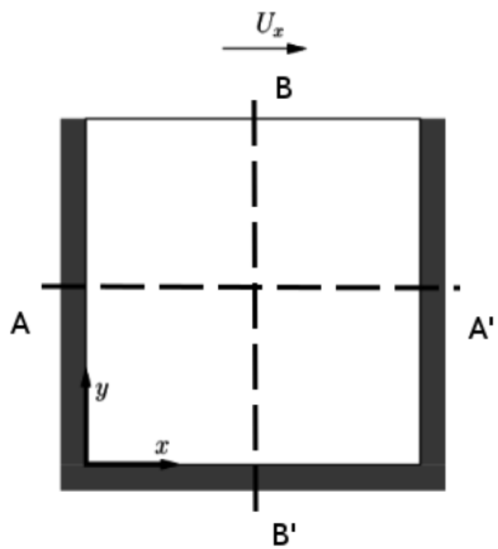
- Common features
  - Navier-Stokes-like
  - precursor transport
  - heat transfer
  - 3-dimensional
  - temperature feedback
- POLIMI and PSI: OpenFOAM based solvers for flow and neutronics
  - POLIMI: includes multiphase flow for bubbling analysis
  - PSI: includes freezing capabilities in the domain
- TUDelft: Finite element based in-house codes
- EdF/KIT: SIMMER system code

Inter-code benchmarking

The CNRS benchmark

dépasser les frontières

- **Simplified benchmark for multiphysics codes**, still representative of MSFR. Developed at **CNRS** by M. Aufiero, A. Laureau, P. Rubiolo.
- Goal: **easily test the capabilities of multi-physics codes** with respect to the characteristics of MSR systems (fuel motion and strong multiphysics coupling).
- **Step-by-step approach**, three phases: (0) single physics, (1) code coupling with increasing complexity and (2) transient analysis
- Main characteristics:
  - Prescribed nuclear data (condensed into 6 groups)
  - No Doppler feedback, only density
  - Laminar flow, Boussinesq approximation
  - Simple 2D geometry
  - Constant thermodynamic properties



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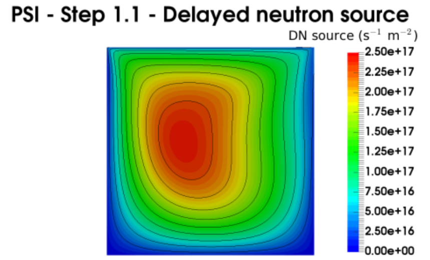
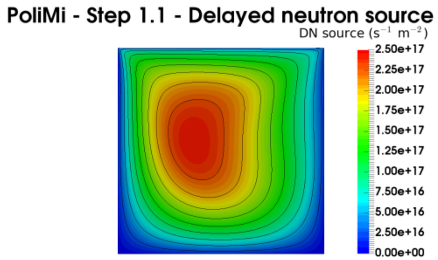
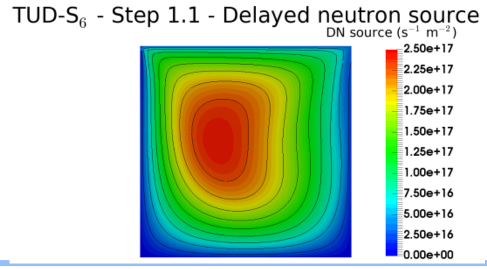
CNRS benchmark – Phase 1



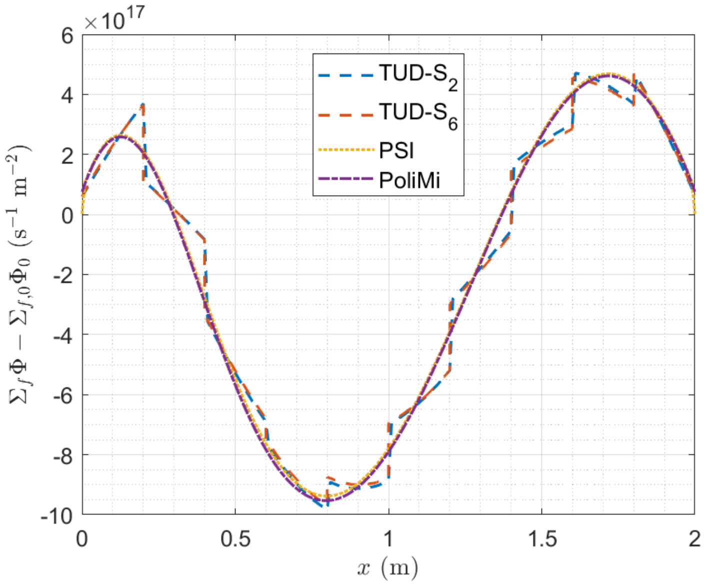
- Step 11 – Velocity coupling

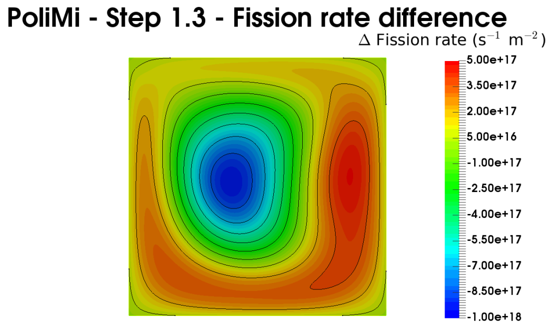
	(pcm)
PoliMi	– 62.0
PSI	– 63.0
TUD-S_2-P_1	– 62.0
TUD-S_6-P_3	– 60.7

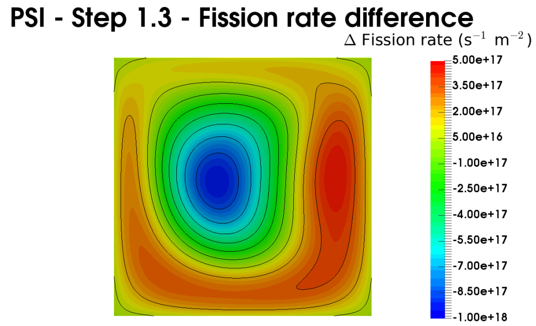


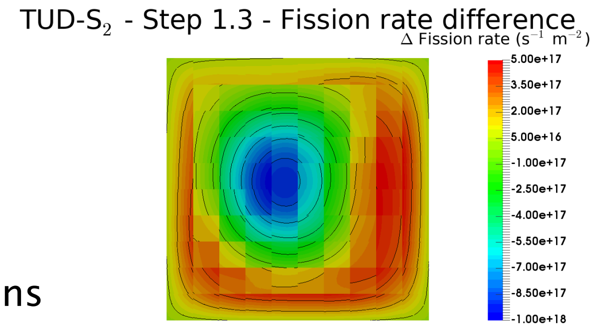


- Step 12 – Power coupling









Zoning used in TUD results explains observed differences

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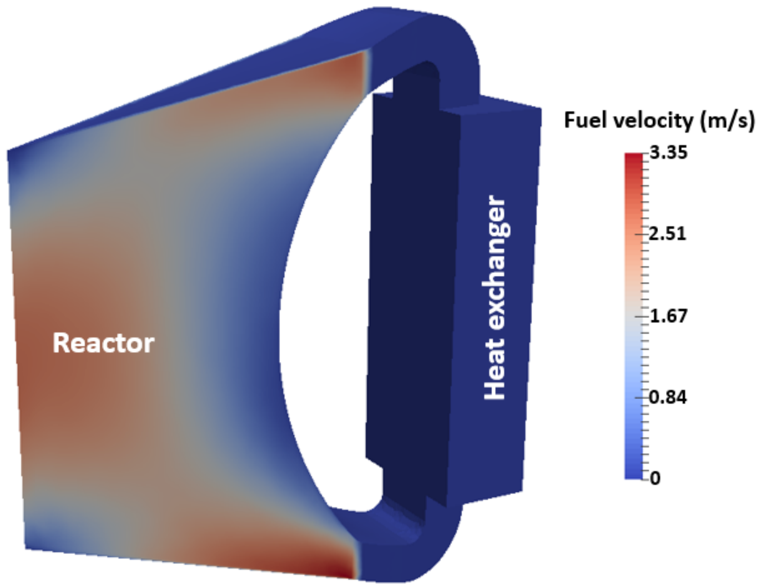
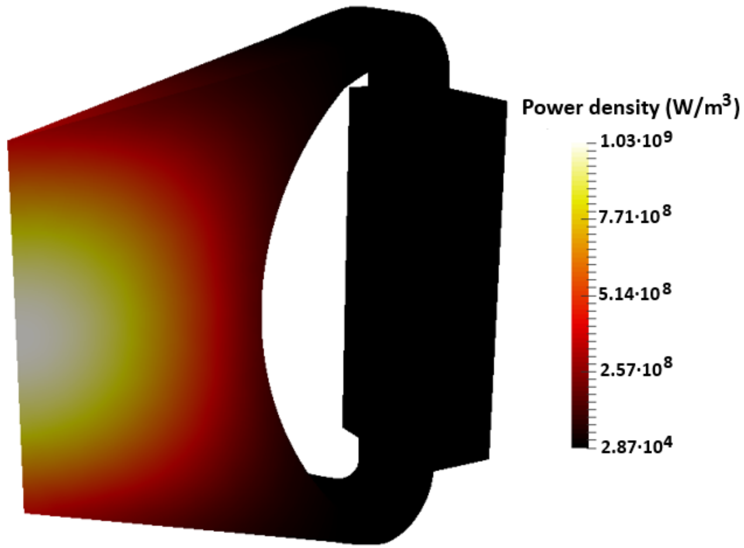
Steady-state

Nominal power	3000 MW
Nominal flow rate	4.5 m^3/s
Fuel cold leg temperature	923 K
Fuel hot leg temperature	1023 K
HX pressure drop	4.5 bar
Intermediate coolant temperature	908 K
Fuel composition (% mol.)	LiF (77.5) ThF (6.6) UF_4 (12.3) TRU-F_3 (3.6)





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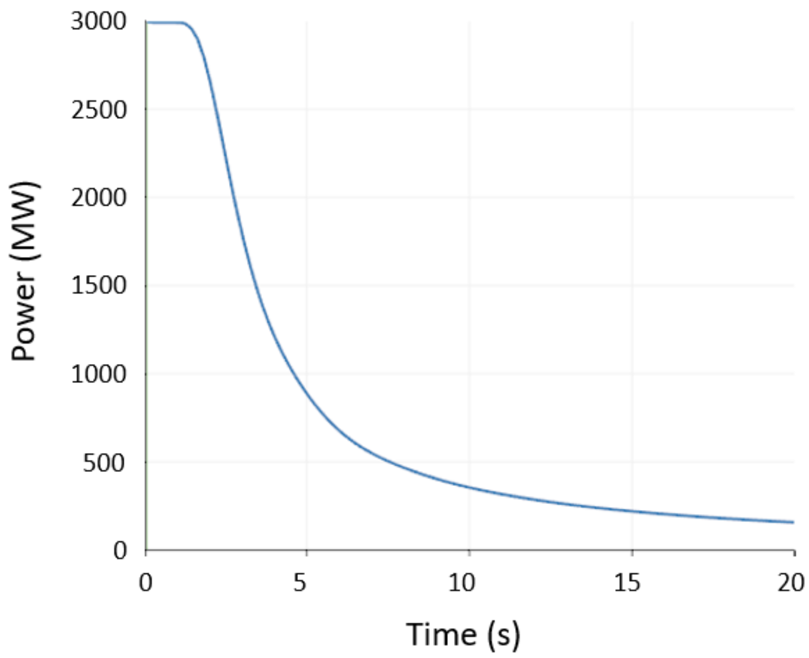
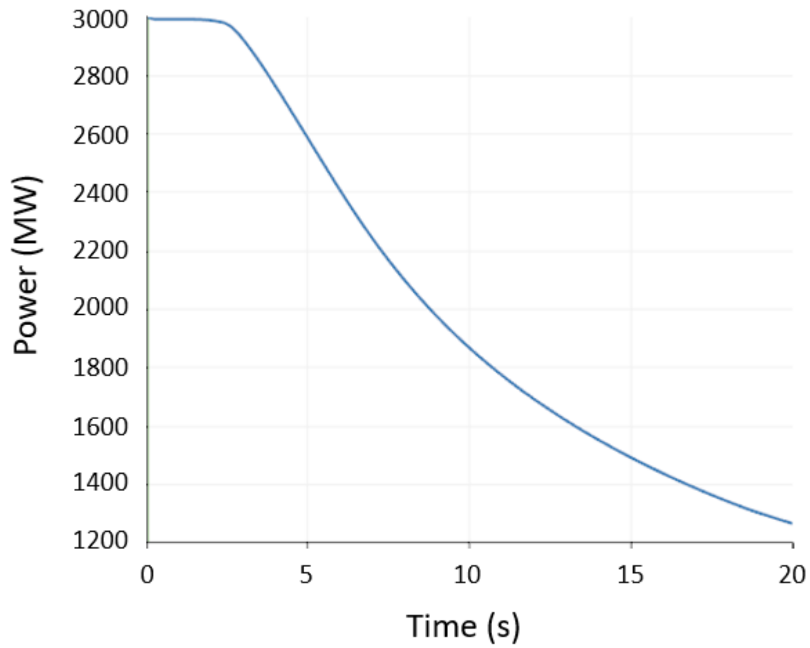
ULOHS transients

1) Stepwise reduction to zero of the HX heat transfer coefficient
2) Exponential reduction to 20% of intermediate and ECS mass flow rate, with time constant $\tau = 5s$

(1)



(2)



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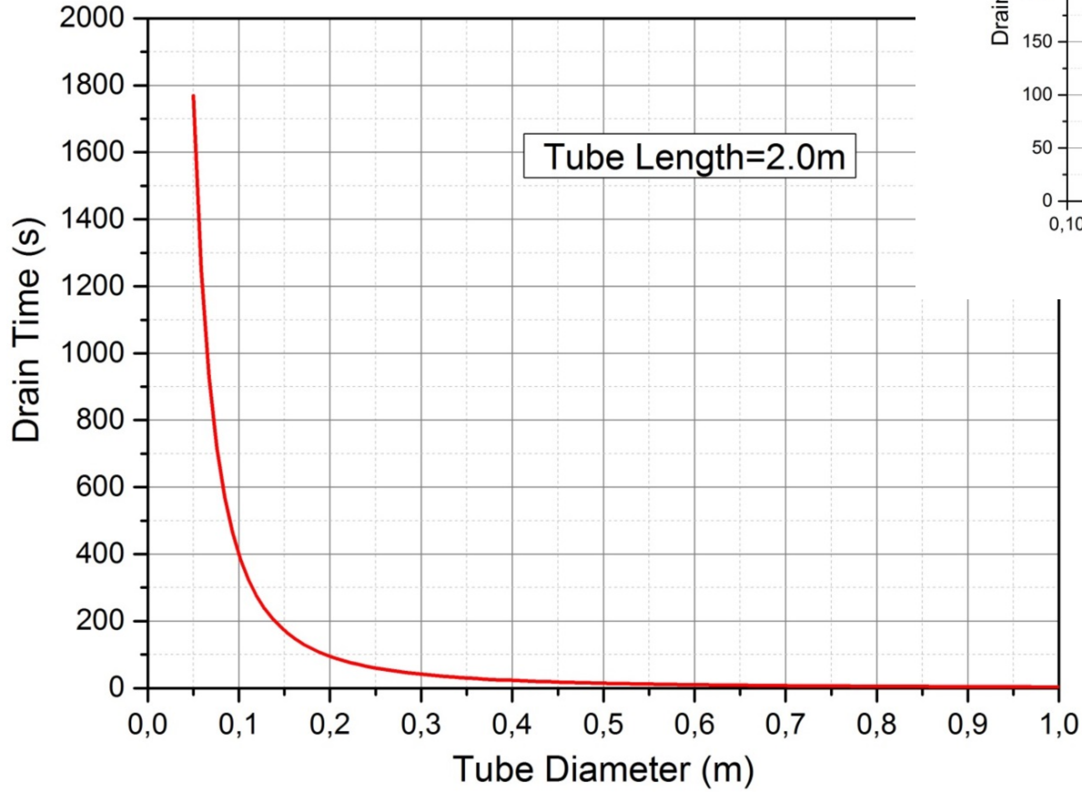
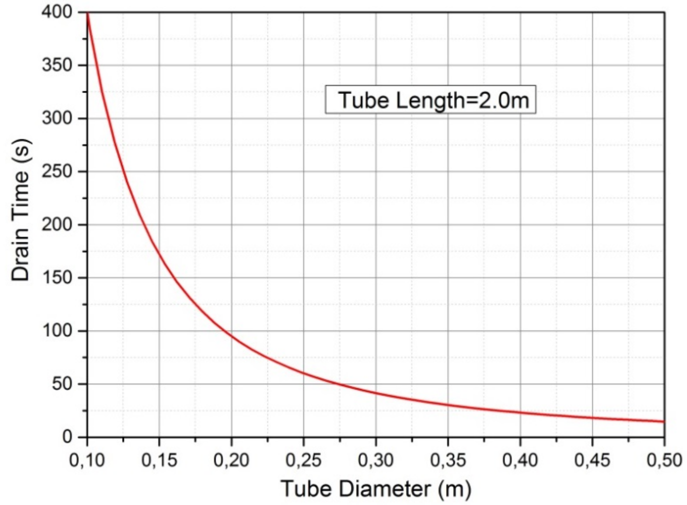
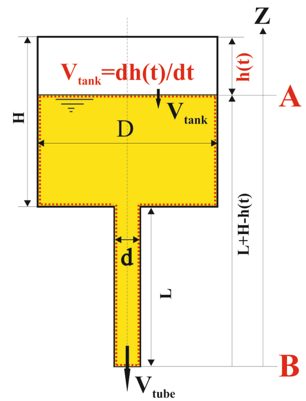
Core draining







Uncertainty Quantification

Neutronics ⟷ Thermo-hydraulics

Multi-group neutronic models (diffusion, S_N, …)

Monte Carlo code to homogenize and collapse nuclear data

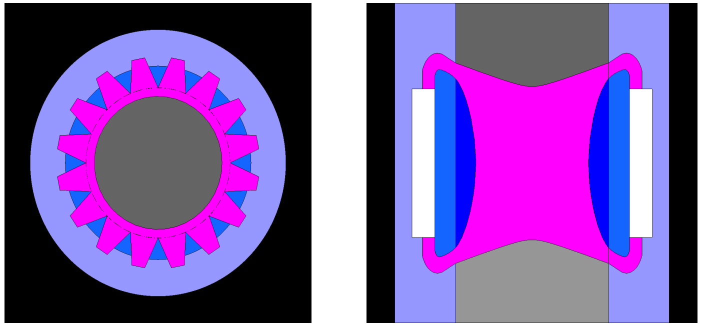
Library data (statistical uncertainty)

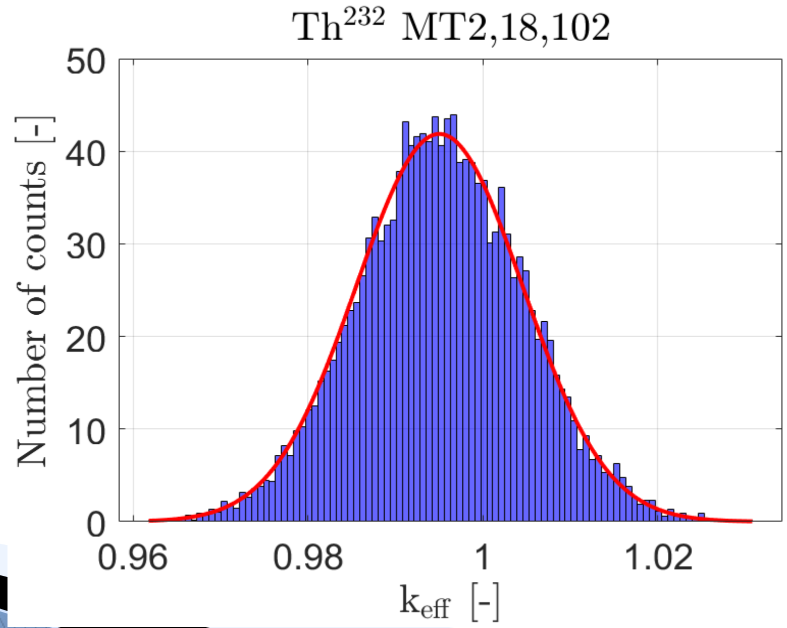
CFD models

Uncertainties in model data, geometry, pump, HX, etc.

Example of neutronics UQ by xGPT

- **MSFR model**: 3D, full-core simulation, uniform temperature of 900 K, equilibrium salt composition





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Scientific output

- 3 PhD thesis (directly funded from WP4)
- 8 Papers
- 7 Conference proceedings
- 20 MSc/BSc theses
- More to come …