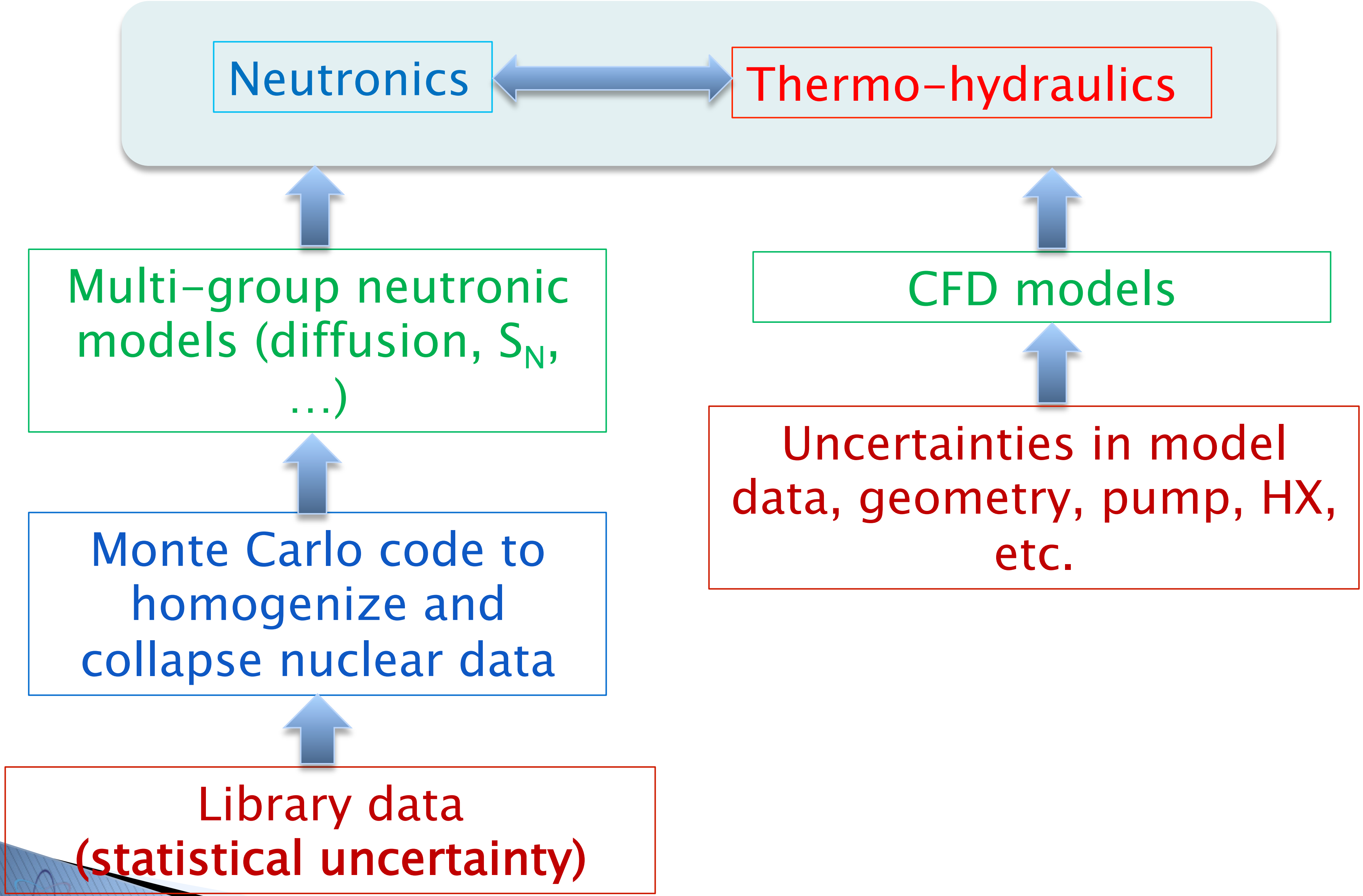
Uncertainty Quantification

SAMOFAR


Neutronics
Thermo-hydraulics
Multi-group neutronic models (diffusion, S_N, …)
CFD models
Monte Carlo code to homogenize and collapse nuclear data
Uncertainties in model data, geometry, pump, HX, etc.
Library data
(statistical uncertainty)

SAMOFAR

UQ on MSFR neutronics

PoliTo: N. Abrate, S. Dulla, A. Uggenti

UQ techniques

TMC

PROs	CONs
No curse of dimensionality, rich information	High computational burden
Non intrusive, no code modifications	Convergence

GPT → Available in Serpent-2

PROs	CONs
Low computational burden	Limited amount of information retrieved
Widely adopted, both in stochastic and deterministic codes	Difficulty to capture non-linearities
	Statistical convergence limited by the number of energy group

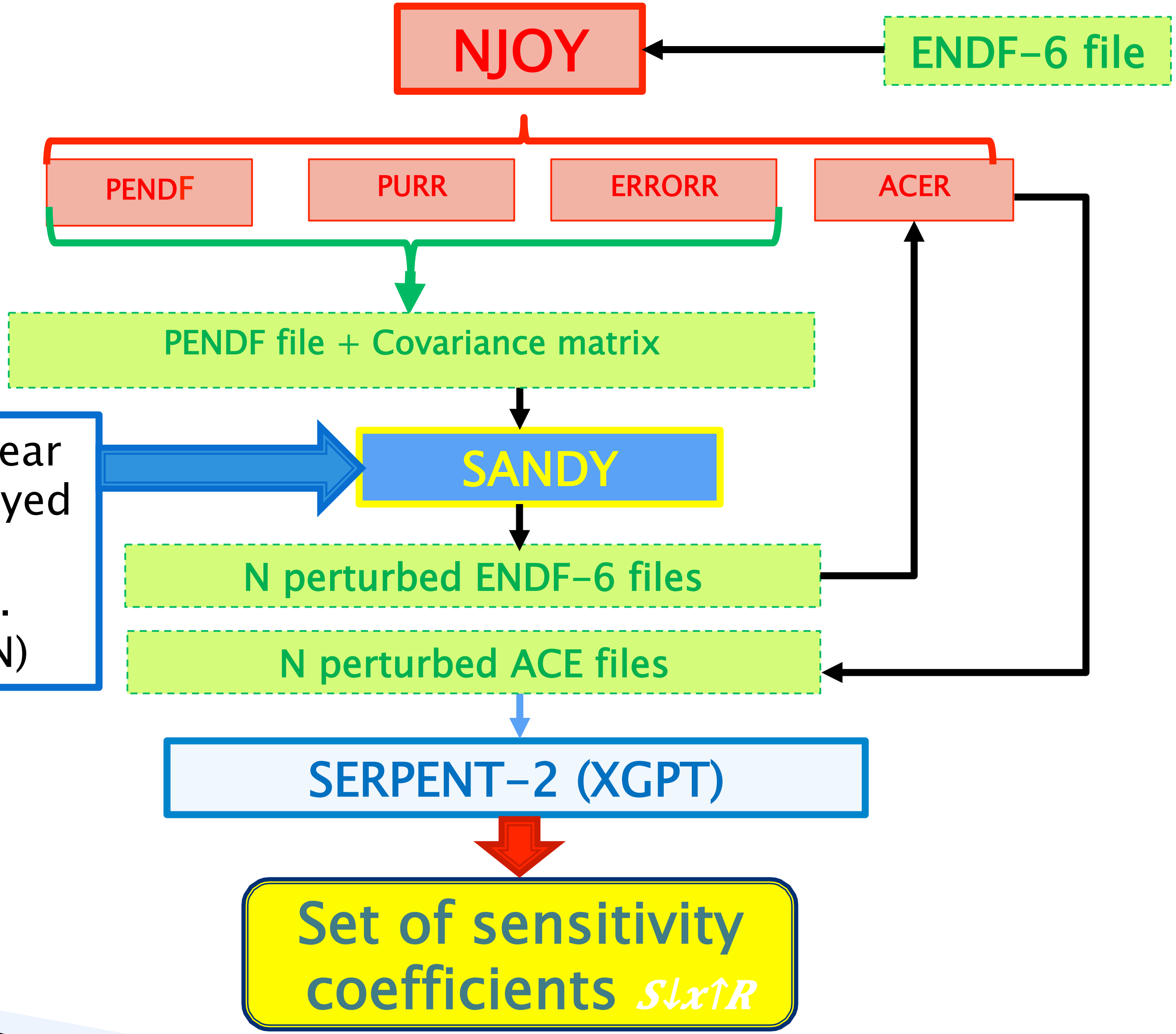
XGPT → Available in Serpent-2

PROs	CONs
Continuous-energy capabilities	Difficulty to capture non-linearities
Richer amount of information than GPT (it can produce response distributions)	Higher computational burden than GPT

SAMOFAR

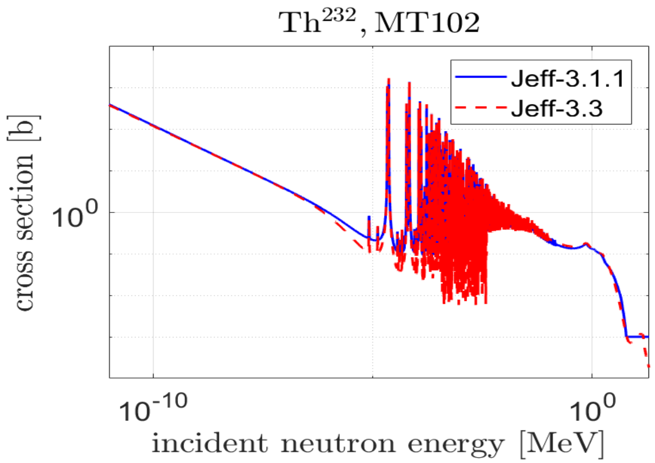
XGPT workflow

To perturb the nuclear data files, we employed the code SANDY (developed by L. Fiorito @ SCK-CEN)

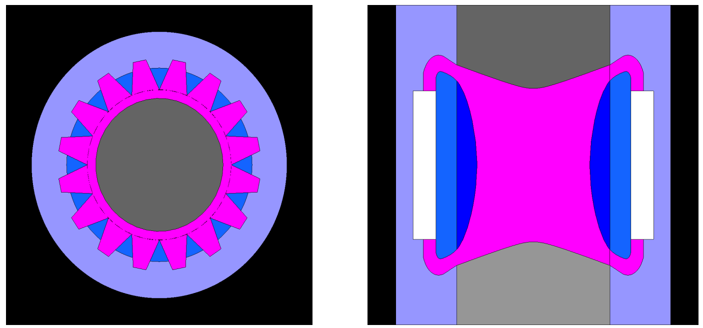


UQ setup

- **Library selection**: Jeff-3.3 (more recent, complete covariance information for the main nuclides of interest for MSFR, Th^{232} and U^{233})



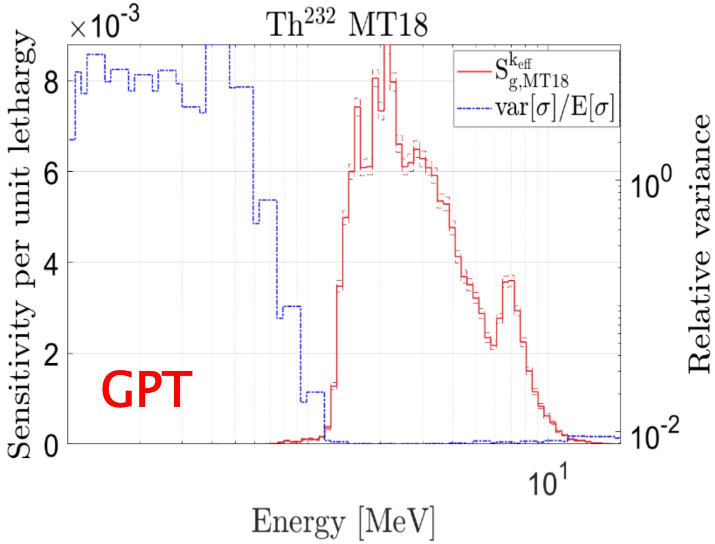
- **MSFR model**: 3D, full-core simulation, uniform temperature of 900 K, equilibrium salt composition

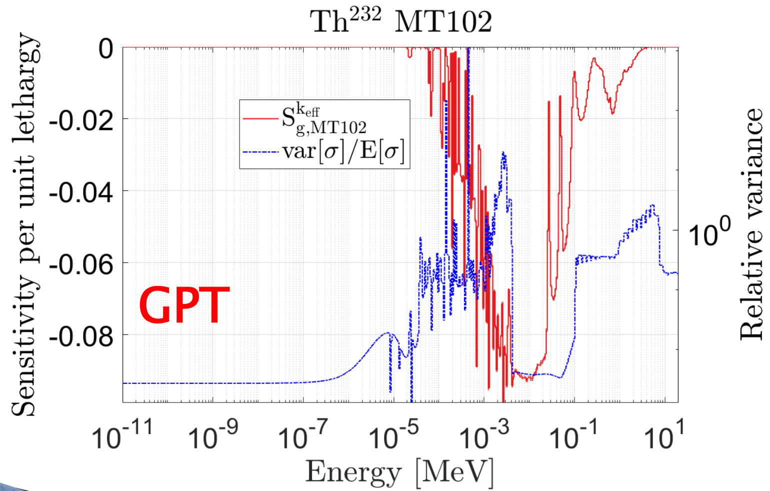


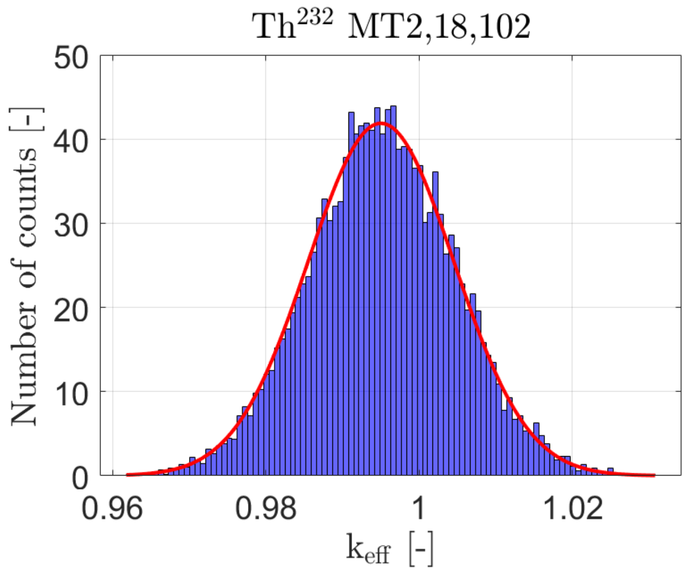
- Output: k_eff

SAMOFAR

Data uncertainties for Th^{232}







Distribution coming from XGPT calculation

SAMOFAR

Conclusions and perspectives

- Uncertainty on k_{eff} due to Th^{232} and U^{233} is significant (> 1000 pcm)
- Kinetic integral parameters and multi-group cross sections deserves more investigations
- Continuous-energy and finer multi-group covariances improve results quality
- Exploiting the latest Serpent-2 update, more complete calculations can be performed

SAMOFAR

Multi-physics UQ method development

TUDelft: F. Alsayyari, Z. Perkó, M. Santanoceto, M. Tiberga, D. Lathouwers
PoliTo: S. Dulla, M. Santanoceto

SAMOFAR

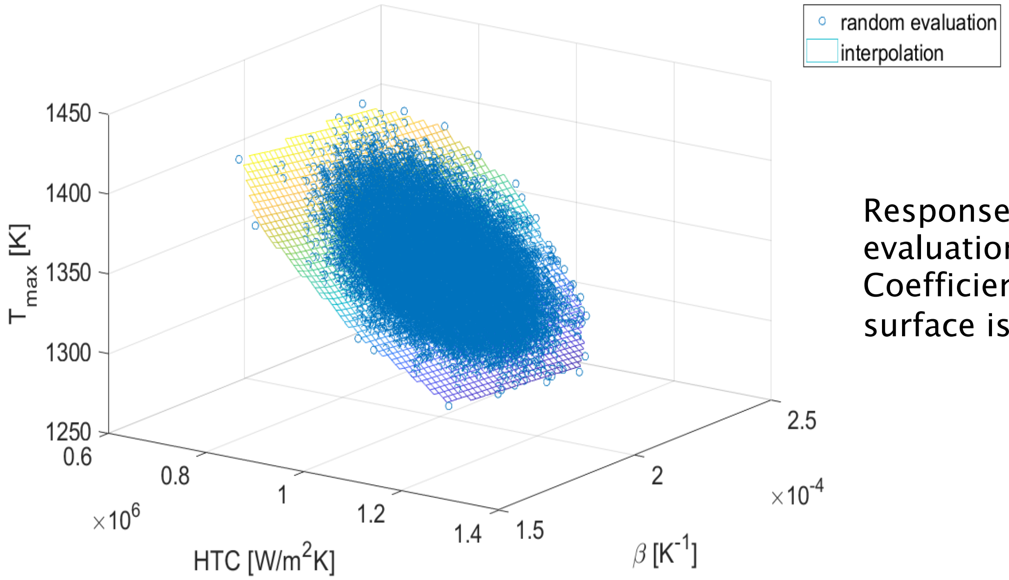
PCE-based approach

- PCE method is applied to the 2D CNRS benchmark case, which is representative of the MSFR physics

- Thermal-hydraulic and neutronics are analyzed separately and coupled

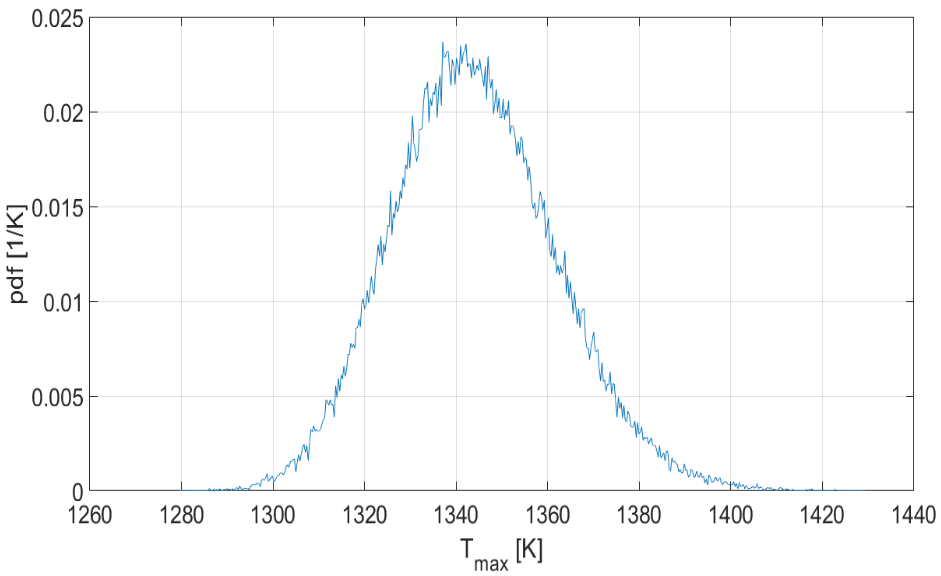
- Among stochastic inputs, the most relevant are:
  - Volumetric heat transfer coefficient (uniformly distributed)
  - Volumetric expansion coefficient (normally distributed)
  - Salt kinematic viscosity (normally distributed)
  - Total delayed neutron fraction (normally distributed)
  - Mean fission macroscopic cross section (normally distributed)

Thermal-hydraulic analysis example



Response dependence on inputs. Points represent random evaluations in the space of parameters (Heat Transfer Coefficient, Volumetric Expansion Coefficient), whereas the surface is the data interpolation using PCE

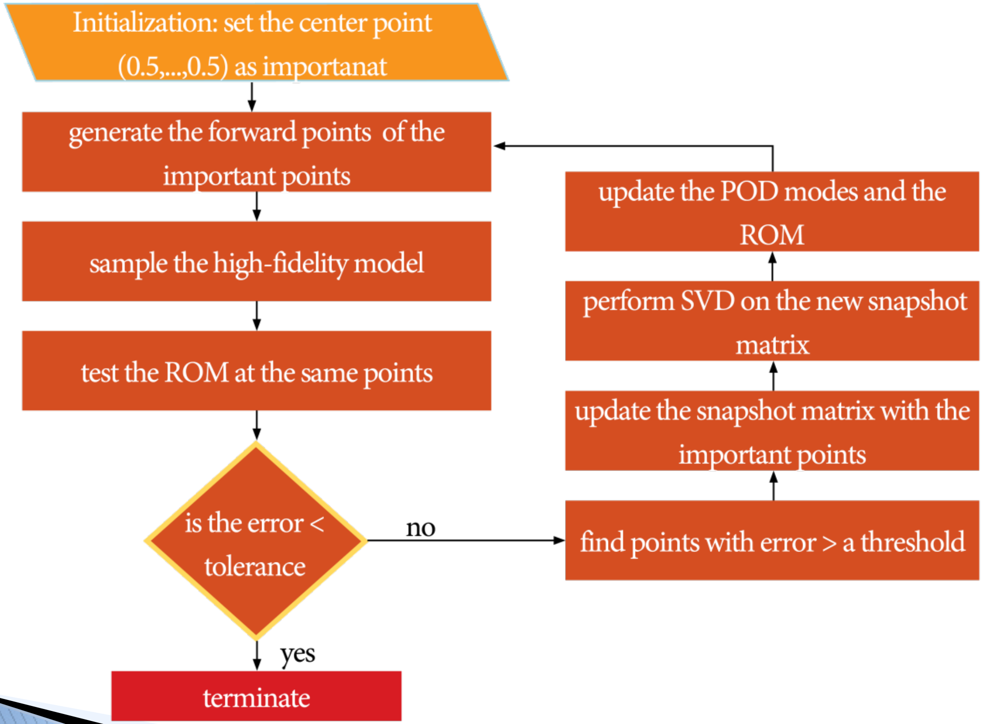
Probability density function referred to the same stochastic inputs (Heat Transfer Coefficient, Volumetric Expansion Coefficient).

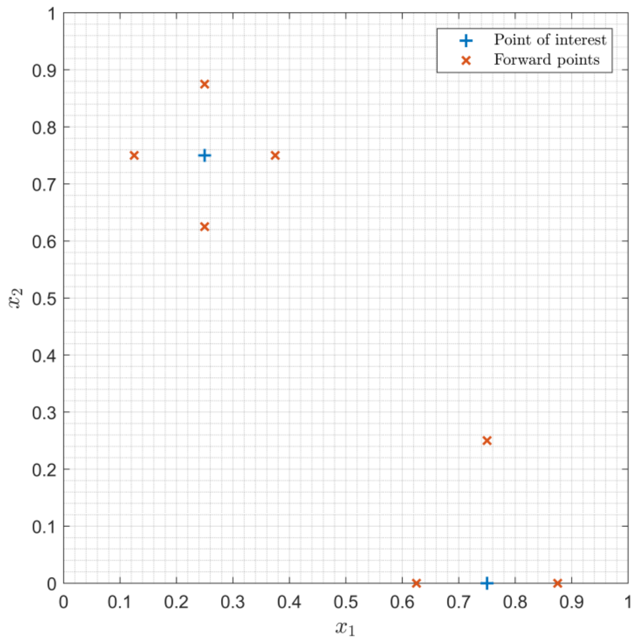


SAMOFAR

POD-Adaptive ROM methodology

- Algorithm Combines Proper Orthogonal Decomposition (POD) with the locally adaptive sparse grids
- The adaptive sparse grids selects the snapshots for the POD in an iterative manner



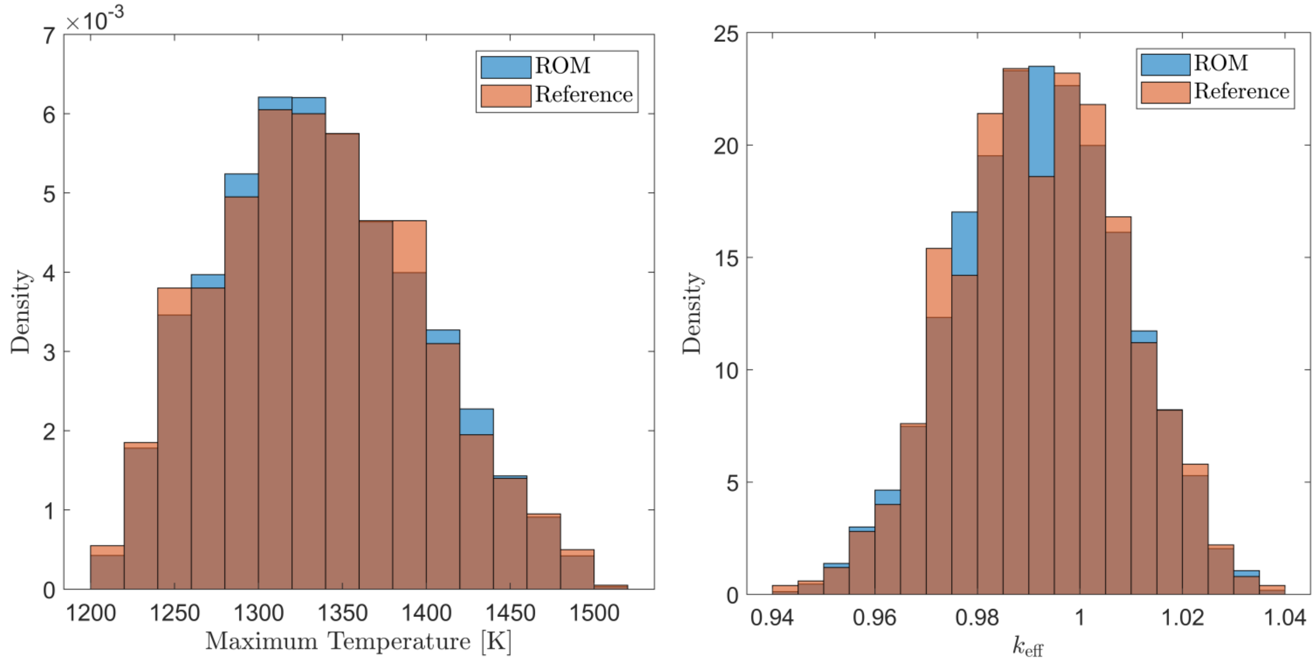


SAMOFAR

Application to MSFR benchmark

- 27 Parameters: Power, thermal expansion coefficient, lid velocity, heat transfer coefficient, viscosity, 6 groups fission cross sections, 8 groups β_i, 8 groups λ_i
- Output: neutron flux, temperature, k_{eff}
- POD-adaptive algorithm sampled the reference model 472 times to build the ROM

Time savings:
1.5 hour => 1ms



Estimated pdf for the maximum temperature and k_{eff} after testing the ROM on 10000 Latin hy[illegible]e sampled (LHS) points . The 1000 validation points from the full model are shown for reference.

Conclusions and perspectives

- New methodologies developed for building ROM of multi-physics systems with many parameters
- Methods are fully non-intrusive (models can be treated as black box)
- Extreme savings can be obtained during run-phase
- Analysis of full MSFR core ongoing

SAMOFAR