CORTEX Training Course

UP and SA under the Condition of Neutron Flux Oscillation

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UP and SA under Neutron Flux Oscillation

Uncertainty Propagation

Initial design/operating parameter #1 $\pm\sigma_1$

Initial design/operating parameter #2 $\pm\sigma_2$

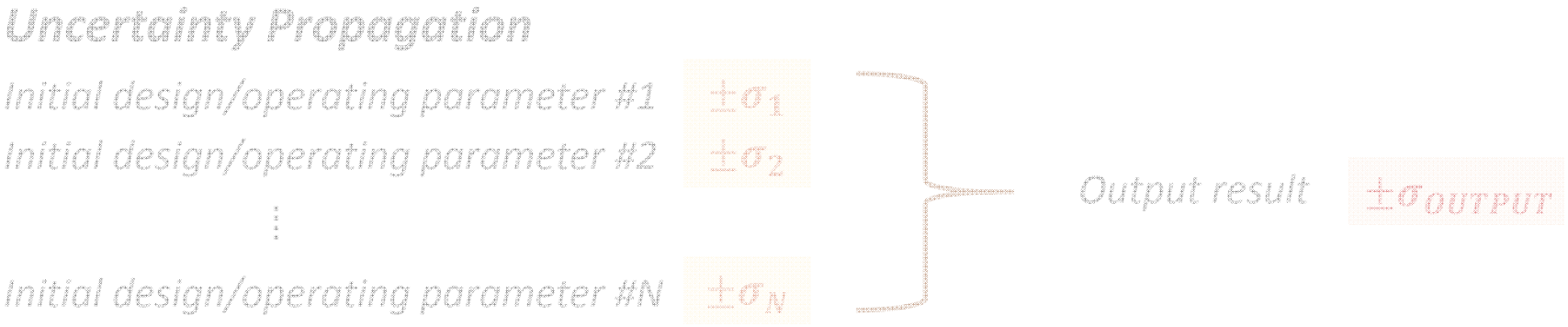
⋮

Initial design/operating parameter #N $\pm\sigma_N$

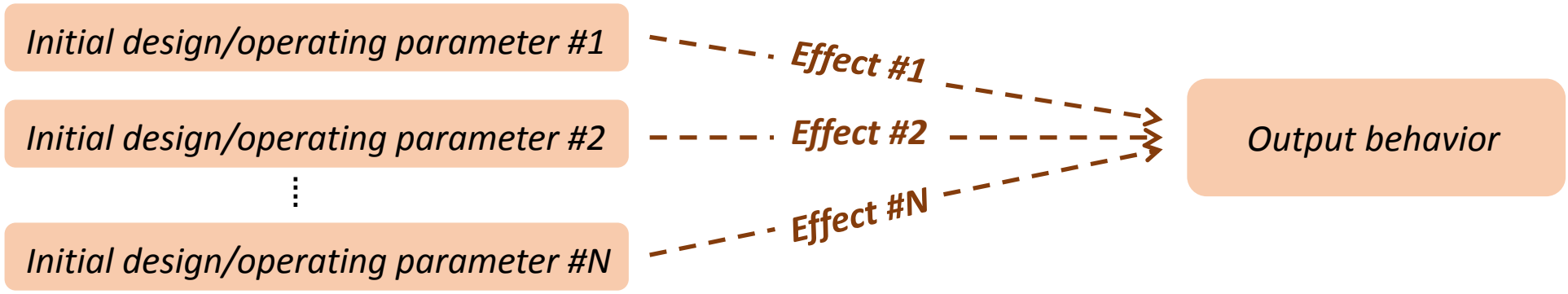
Output result $\pm\sigma_{OUTPUT}$

Sensitivity Analysis

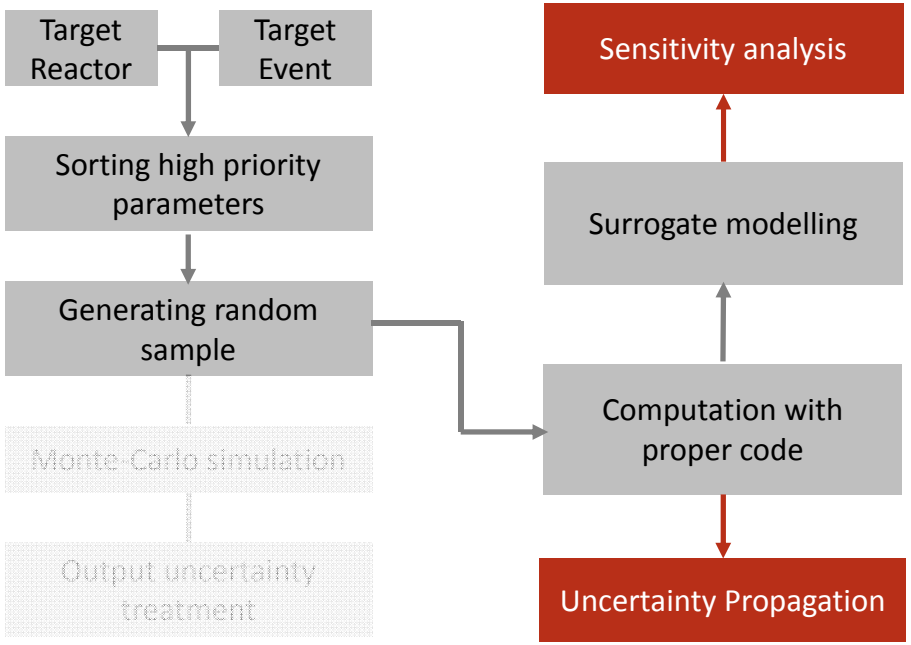
UP and SA under Neutron Flux Oscillation



Sensitivity Analysis



UP and SA under Neutron Flux Oscillation



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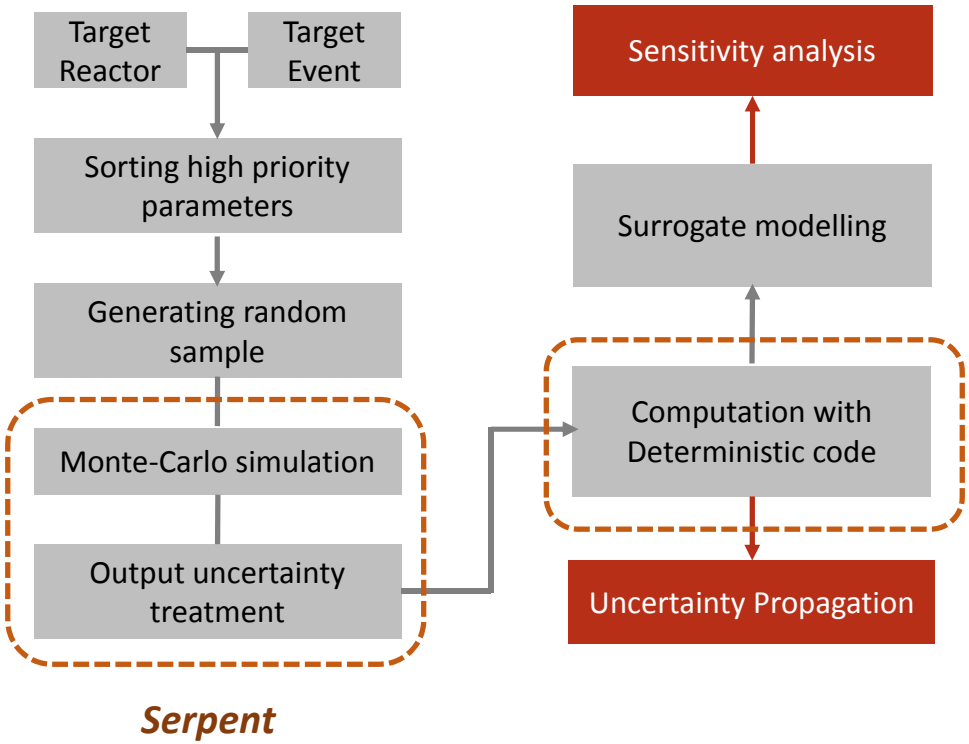
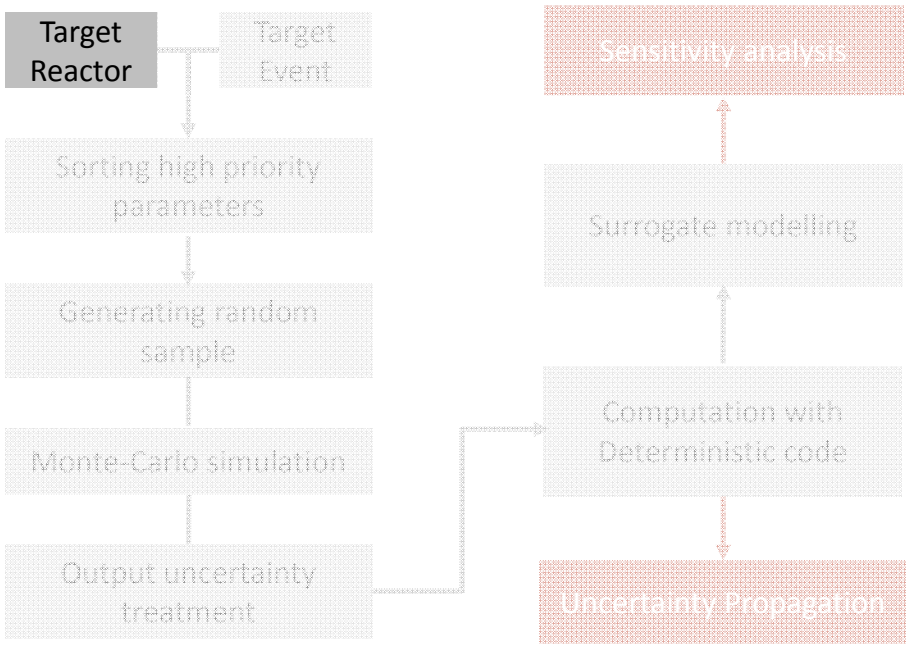
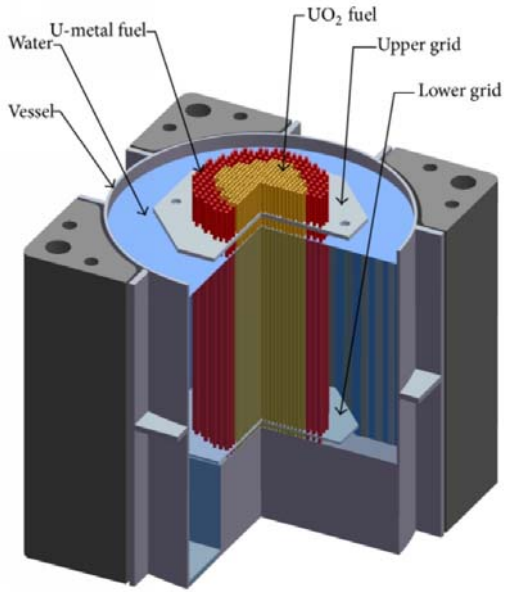


*Neutron noise simulator **CORE SIM***

UP and SA under Neutron Flux Oscillation

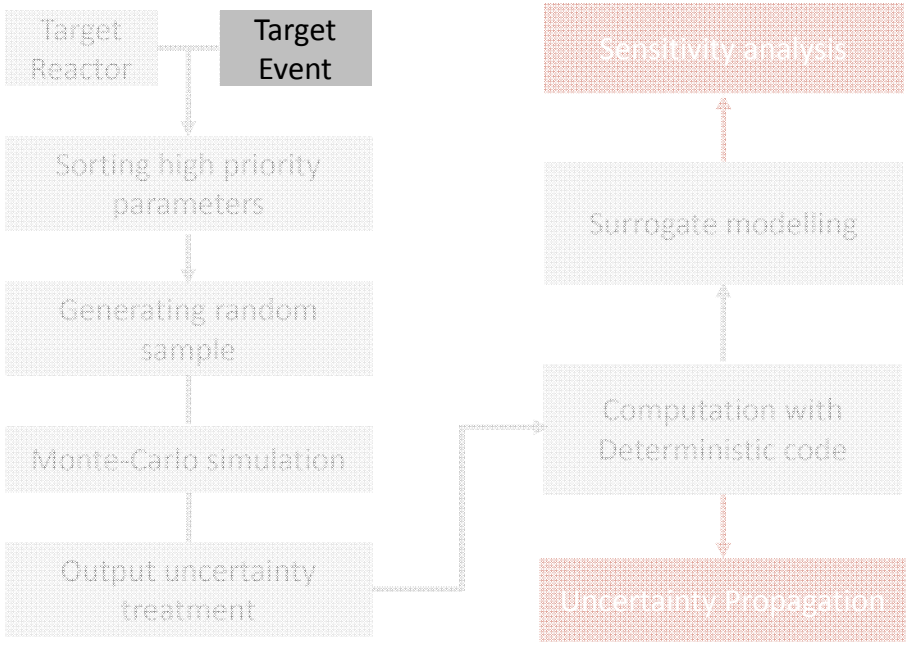


- *CROCUS at EPFL*
- *Zero power reactor (100W_{max})*
- *336 UO_2 cells, 176 U_{metal} cells*
- *Water reflector*



Adolfo Rais et al., „Methods and Models for the Coupled Neutronics and Thermal-Hydraulics Analysis of the CROCUS Reactor at EPFL", Science and Technology of Nuclear Installations, Vol 2015, 2015.

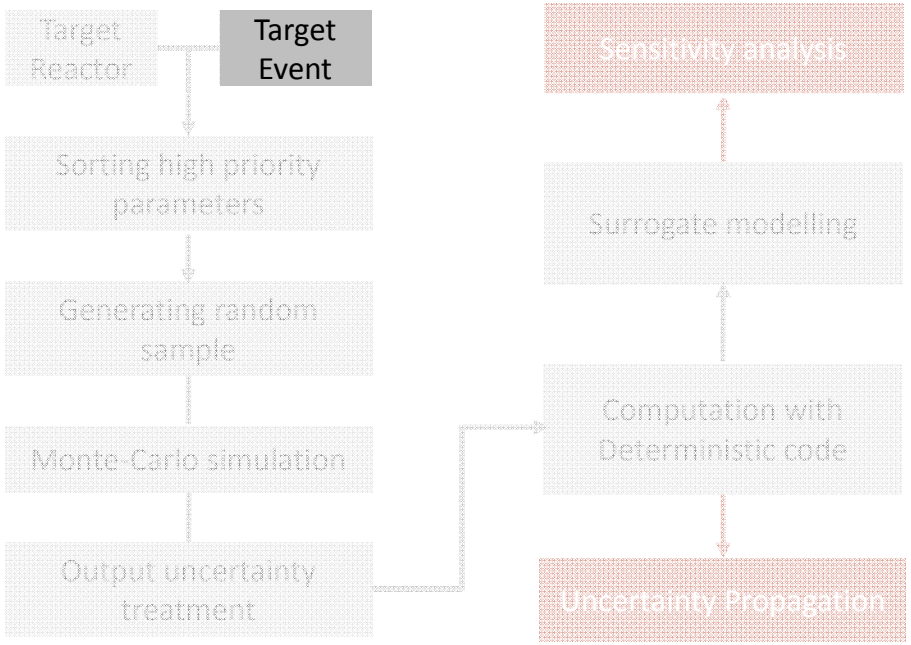
UP and SA under Neutron Flux Oscillation



1	Absorber of variable strength
2	Axially-travelling perturbations
3	Fuel assembly vibrations
4	Control rod vibrations
5	Core barrel vibrations

Different on how to model the input data for noise calculation

UP and SA under Neutron Flux Oscillation



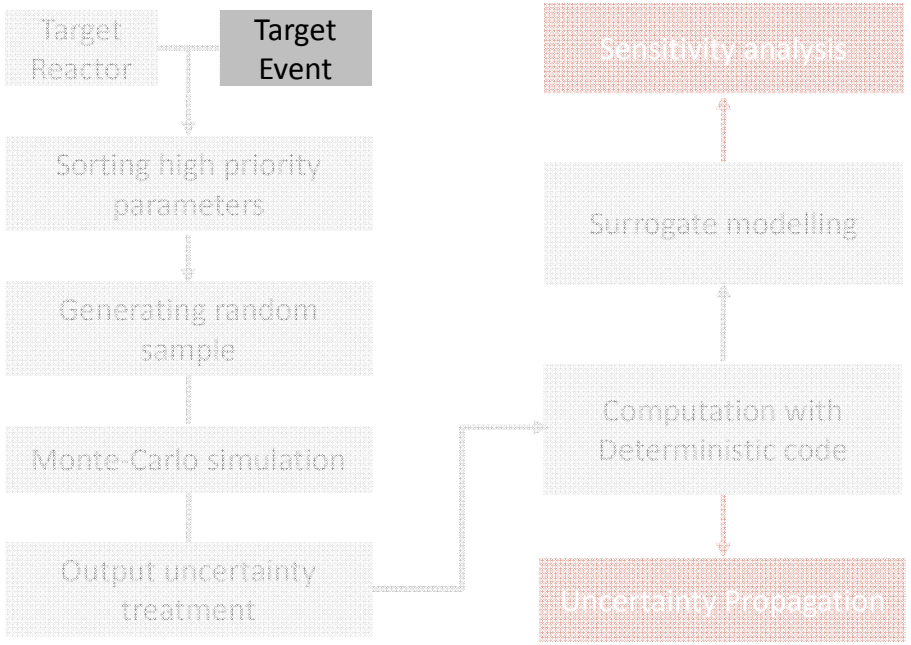
Absorber of variable strength

- *Perturbation of a macroscopic cross-section*
- *Artificial perturbation*
- *Constitutes Green's function*

Axial-travelling perturbation

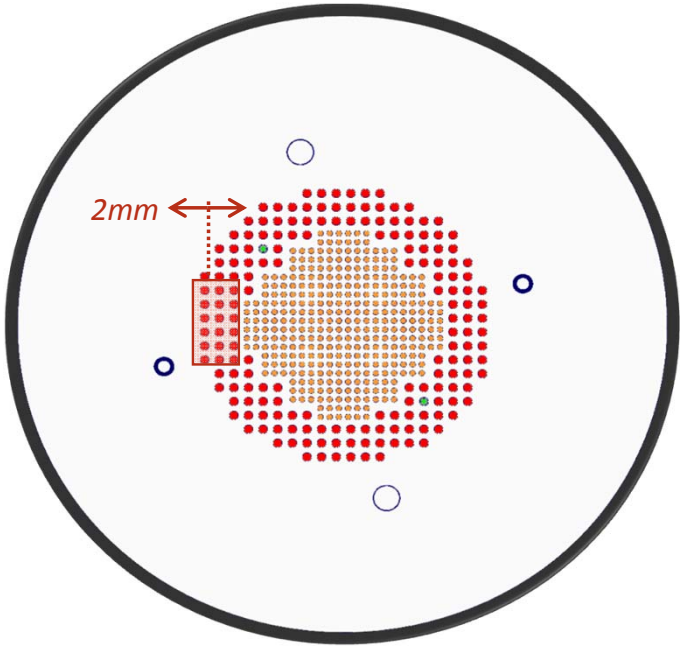
- *Perturbation of the coolant (inside of the core)*
- *Perturbation of the removal cross-section*

UP and SA under Neutron Flux Oscillation



Fuel assembly vibration

- *Non-harmonic oscillation of FA (independent from time)*
- *Test facility in CROCUS reactor (COLIBRI)*
  -up to 18 fuel rods vibration



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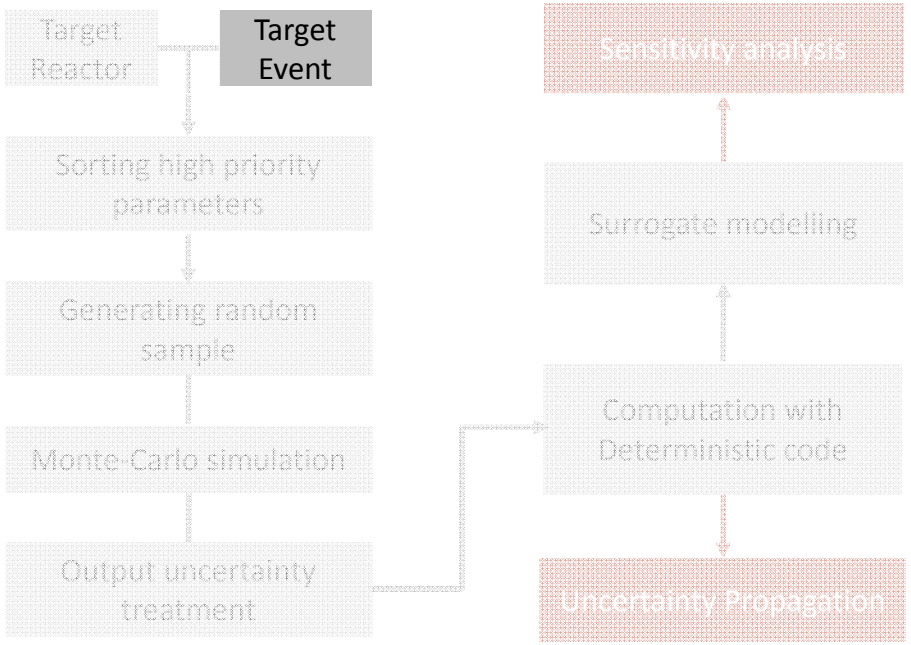


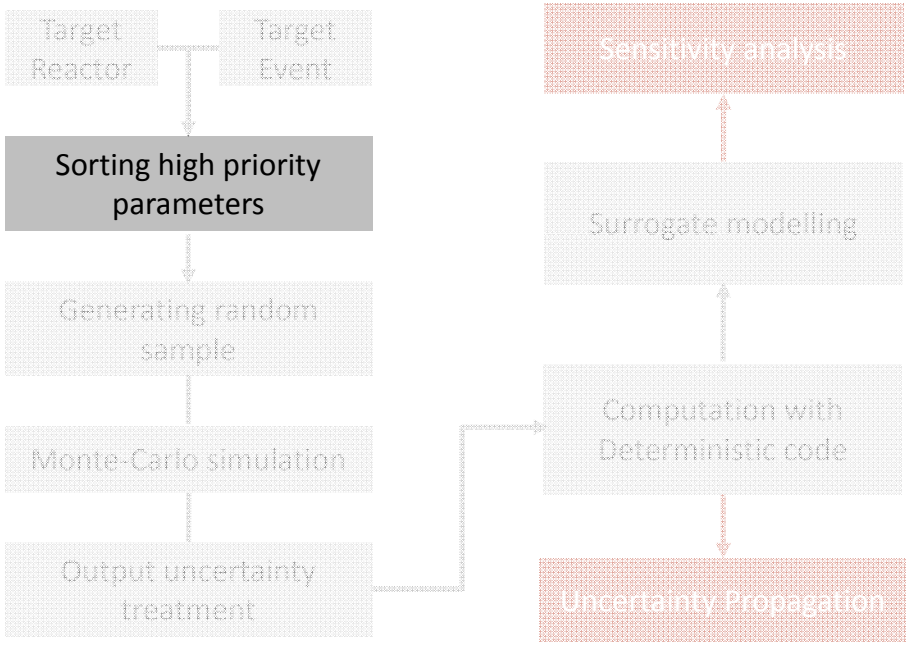
Control rods vibration

- *Vibration of control rod along the z-direction*
- *Perturbation of the thermal absorption cross-section*

Core barrel vibration

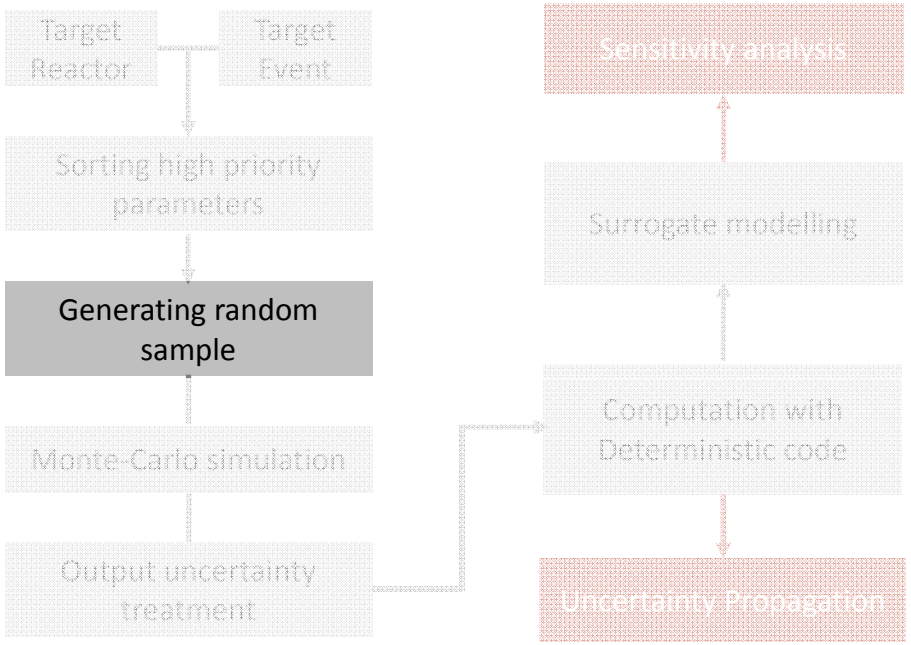
- *Vibration at higher frequency*
- *Results from the interplay between core barrel and RPV*
- *In-phase mode & out-of-phase mode*

UP and SA under Neutron Flux Oscillation



- *Depending on target reactor/ event*
- *Depending on governing theory for output behavior*
- *Expert judgements*

UP and SA under Neutron Flux Oscillation

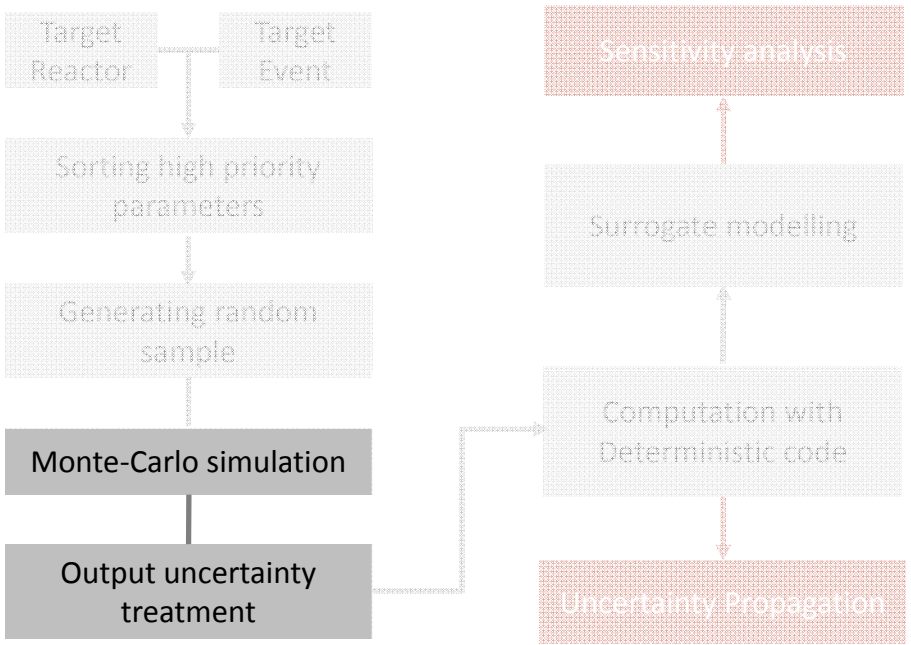


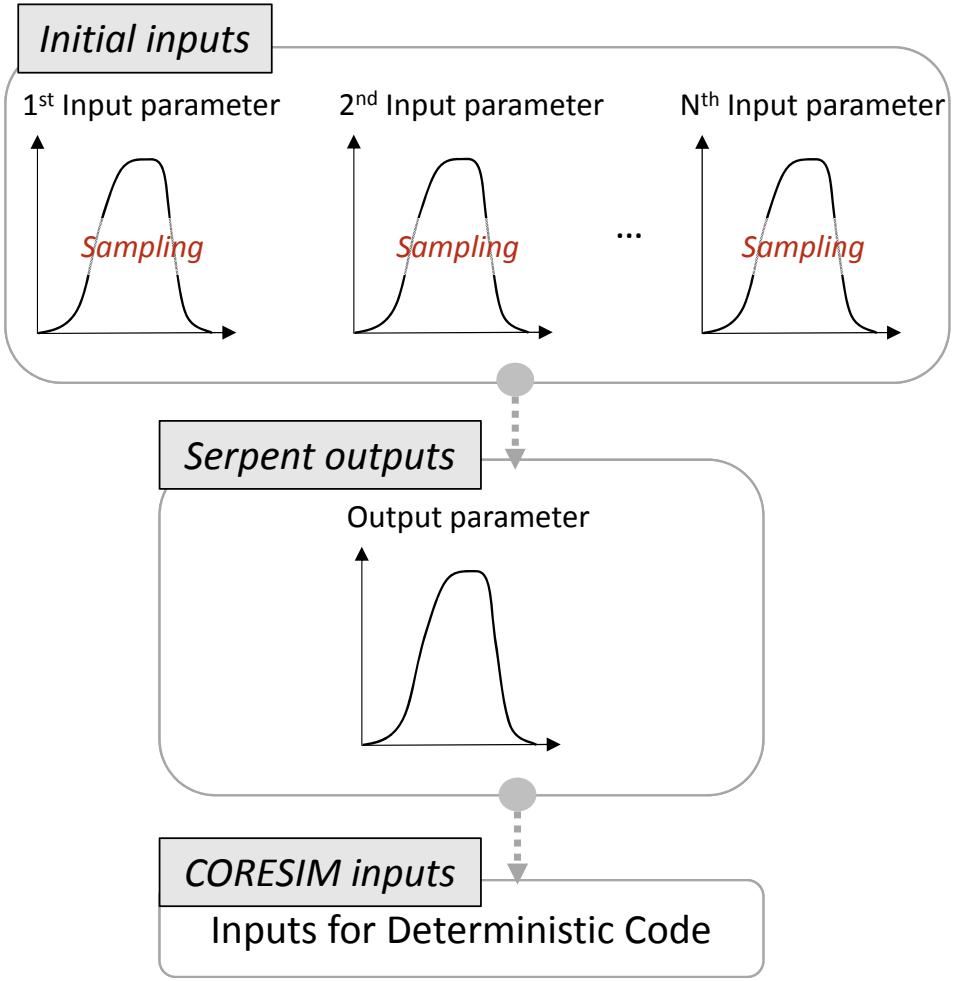
- *Depending on a distribution information*
- *SRS & LHS*

Number of samples?

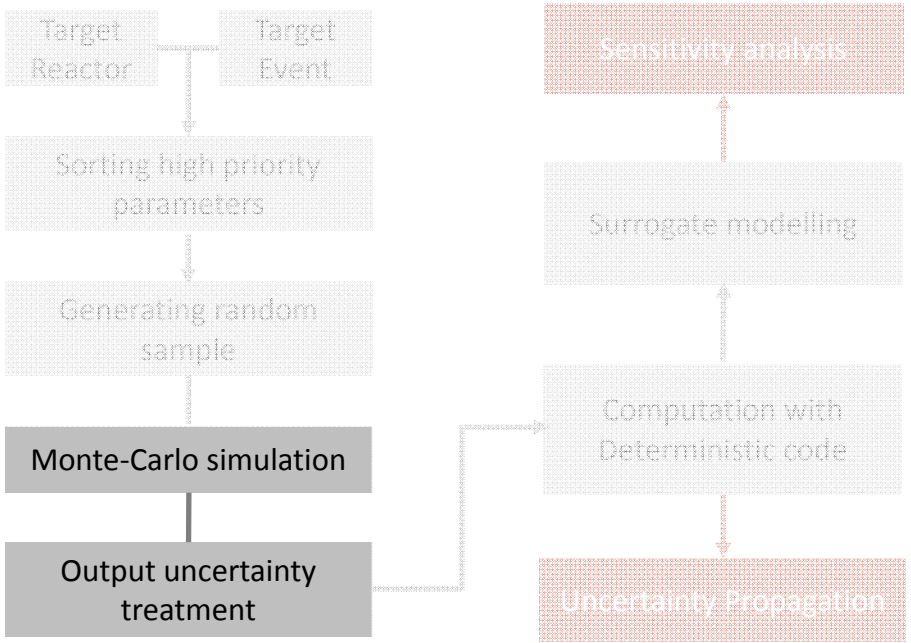
- *Depending on a purpose of the analysis*
  -Uncertainty propagation (Wilks' formula/ Monte-Carlo)
  -Sensitivity analysis (Regression based/Correlation based /variance based)

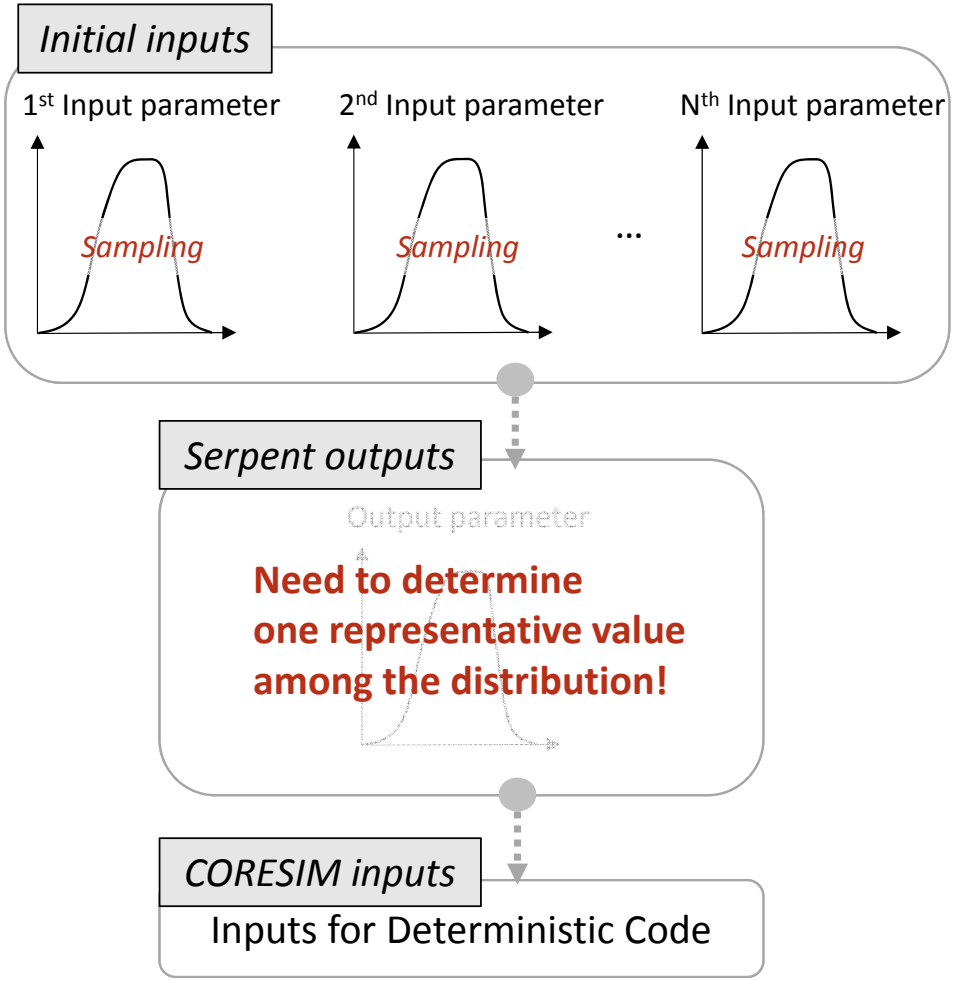
UP and SA under Neutron Flux Oscillation



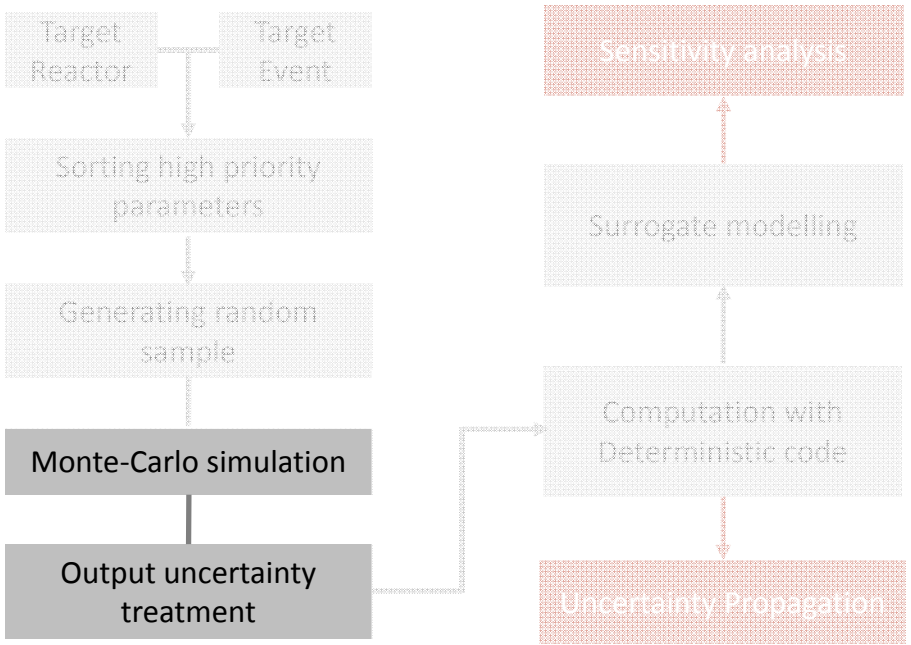


UP and SA under Neutron Flux Oscillation





UP and SA under Neutron Flux Oscillation



Resampling SERPENT output data

Target output data :

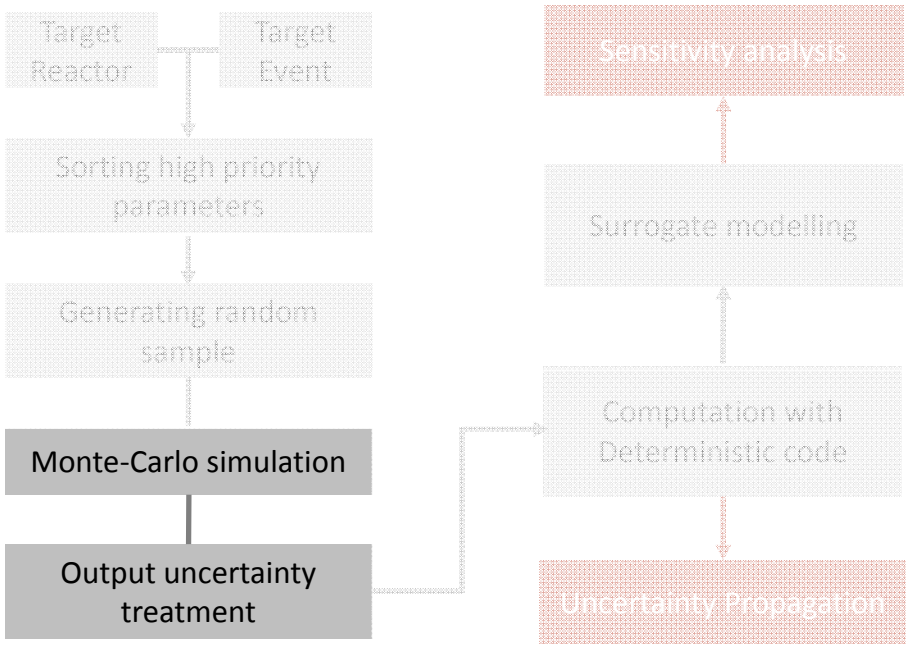
$$\Sigma_a, \Sigma_{rem}, \nu\Sigma_f, D, \beta, \lambda, \delta\Sigma_a, \delta\Sigma_{rem}, \delta\nu\Sigma_f$$

Output data from *N* input sets:

$$mean_k \pm error_k \ (1 \leq k \leq N)$$

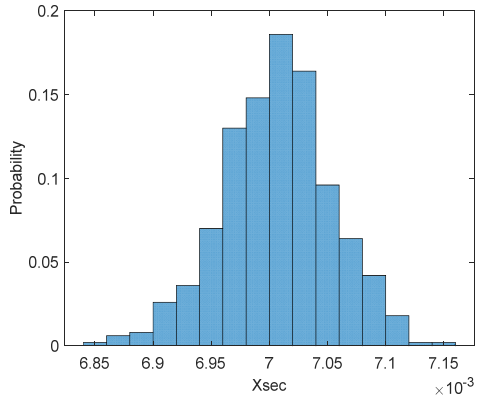
- Modelling normal distribution
- Sampling one value randomly from distribution
- Better to minimize '$error_k$'

UP and SA under Neutron Flux Oscillation



Additional consideration on nuclear data unc.

(1) Building a histogram, fitting into normal distribution



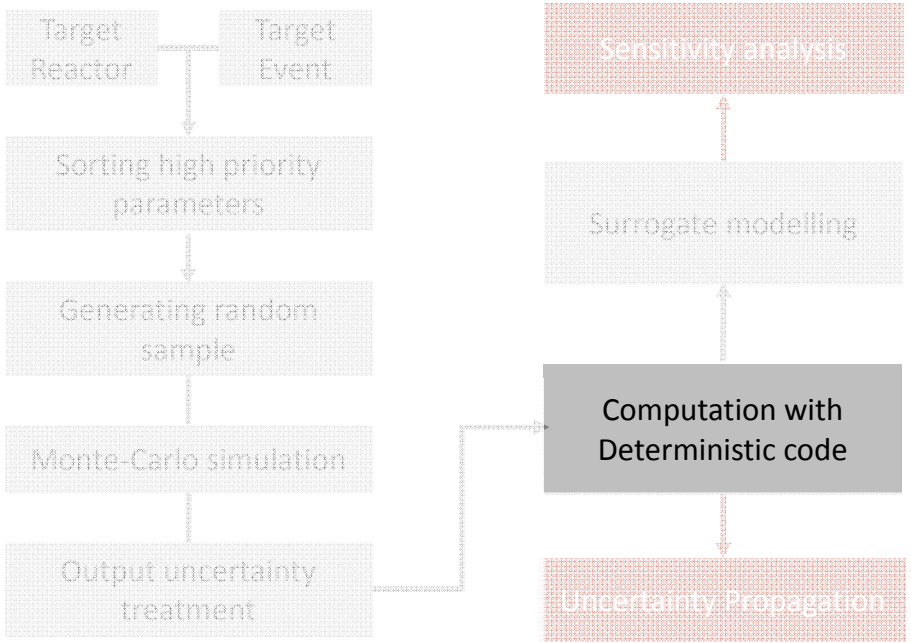
e.g. absorption cross section in UO2 region

(2) Obtaining standard deviation

(3) Combining with XS data (from Serpent) build normal distribution

(4) Extract one value by SRS

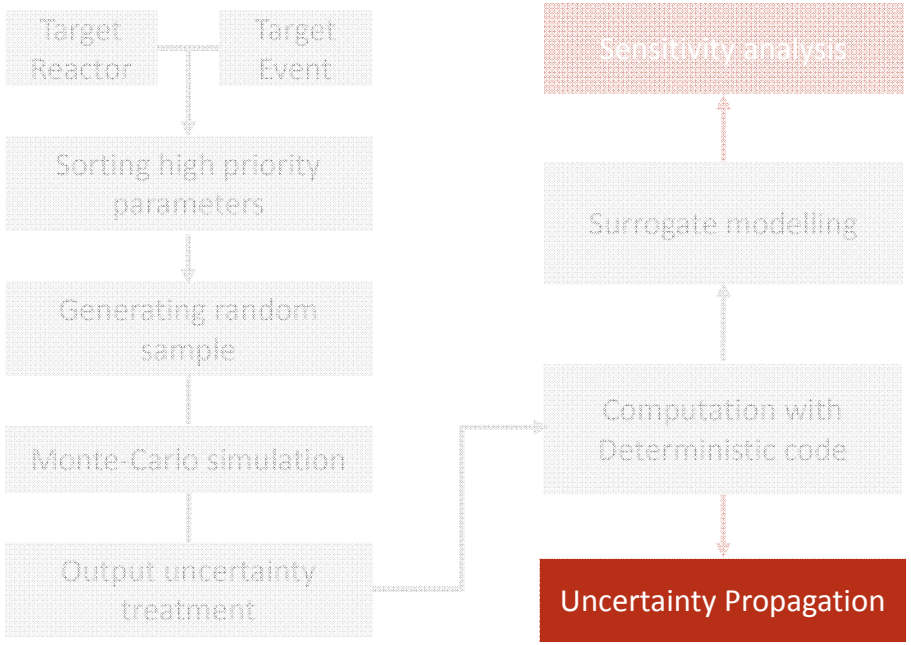
UP and SA under Neutron Flux Oscillation



Final output

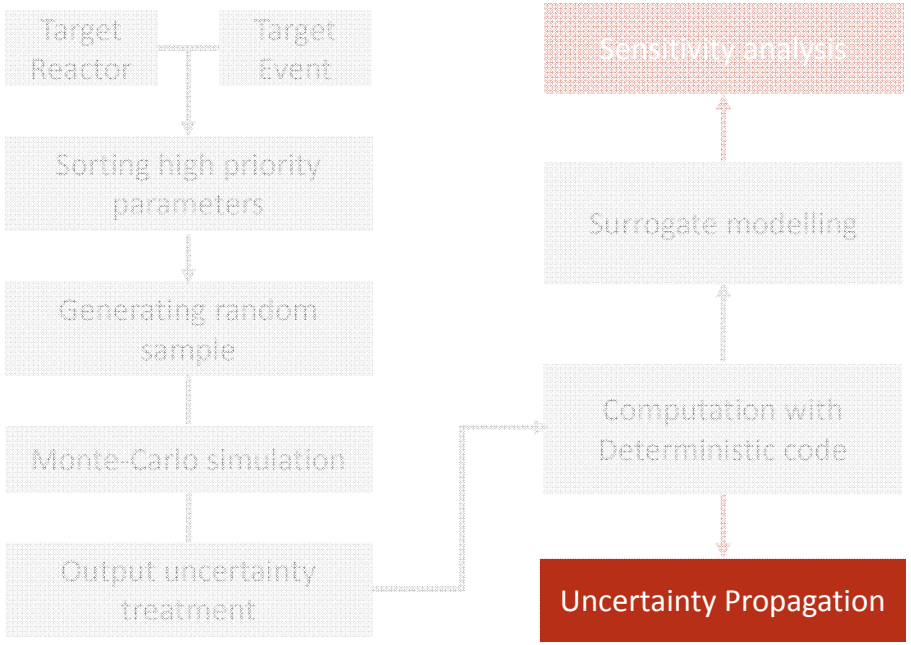
- *Neutron noise data*
  -Extract the value at the location of interest
  -Split the data into magnitude + phase
  -Save the data for further UP & SA

UP and SA under Neutron Flux Oscillation



- ***Wilks' formula***
- ***Monte-Carlo***

UP and SA under Neutron Flux Oscillation



- ***Wilks' formula***

  -Nonparametric method

  -Required number of sample sets are dependent on:

  1) Tolerance/confidence interval

  2) One sided limit/two sided limit

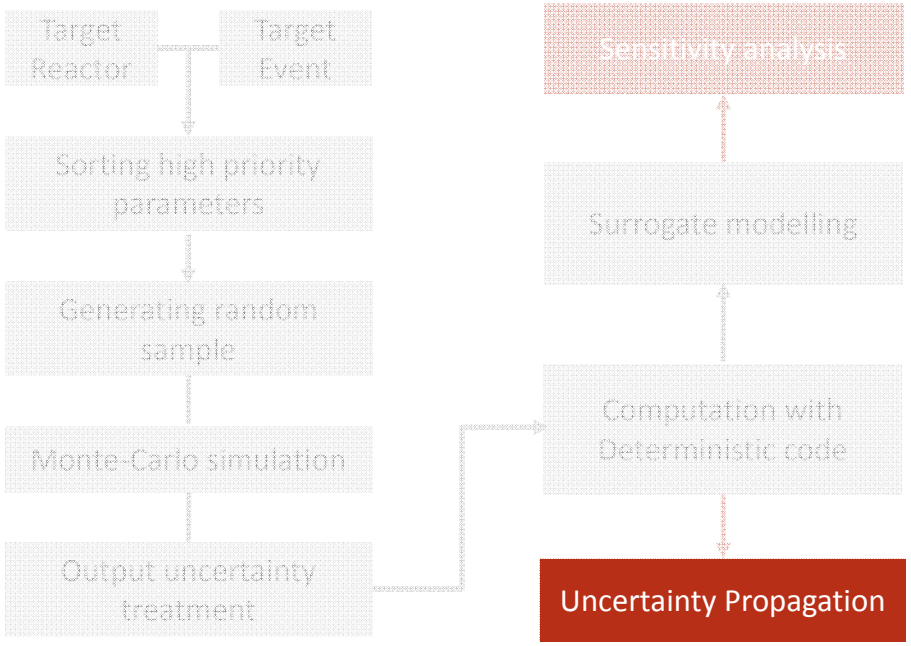
  3) Order of tolerance limit

  -Pros and cons

  Pros: easy to use, less number of sample sets

  Cons: certain level of conservatism

UP and SA under Neutron Flux Oscillation



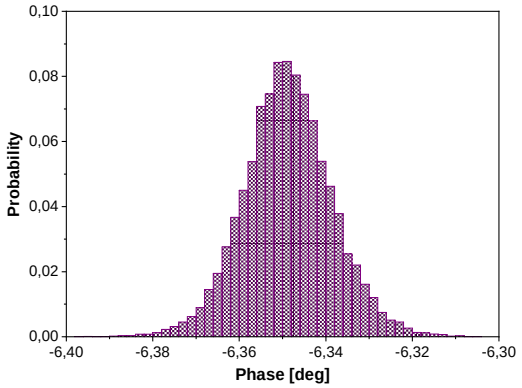
- ***Monte-Carlo***

-Pros and cons

Pros1- large number of sample sets→decrease consevatism

Pros2-able to yield a full PDF

Cons - require a large number of computation (rely on surrogate modelling)



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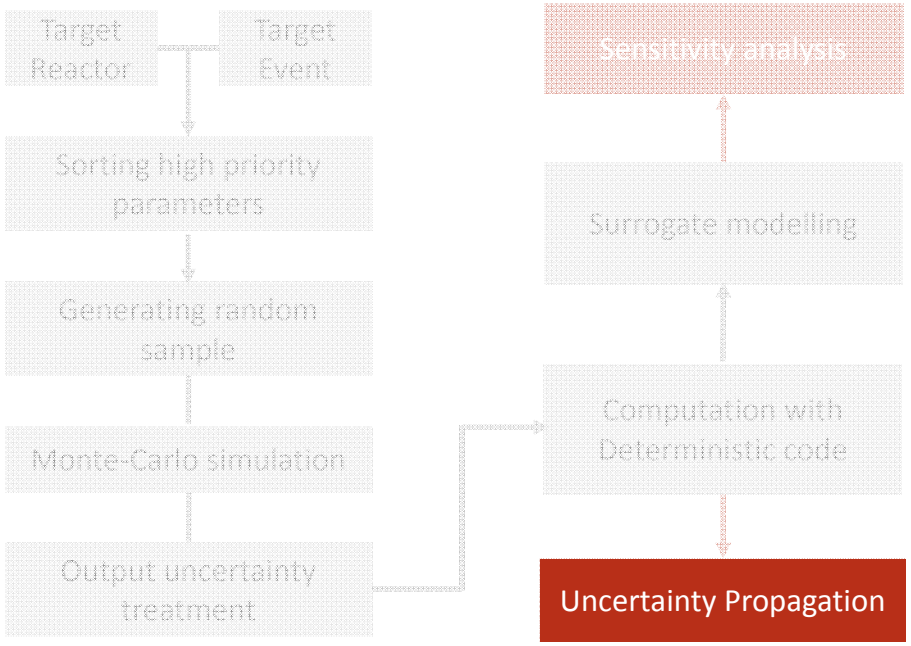
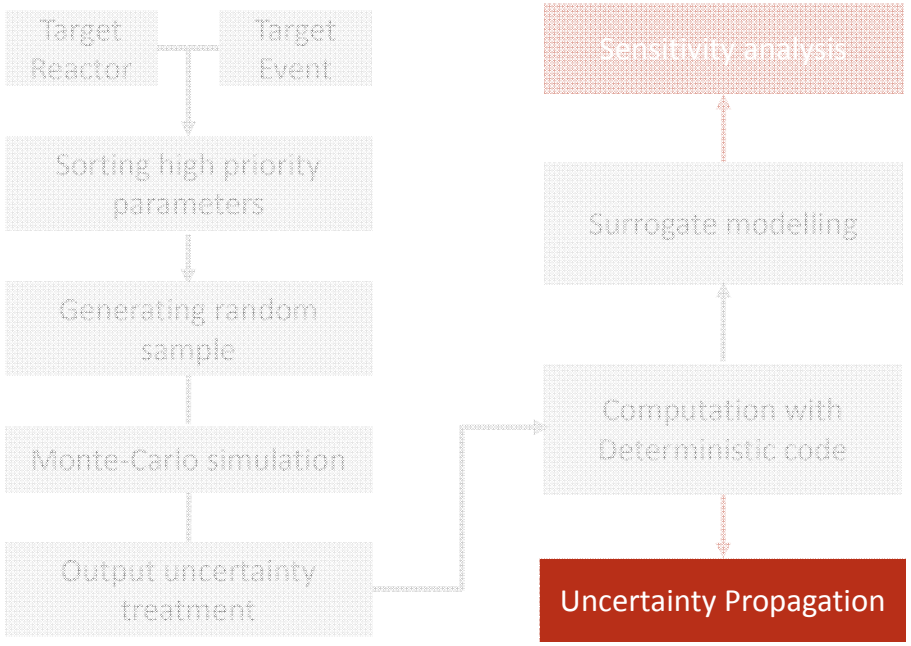


- ***Result comparison between Wilks' approach & Monte-Carlo approach***

  -Level of conservatism

UP and SA under Neutron Flux Oscillation

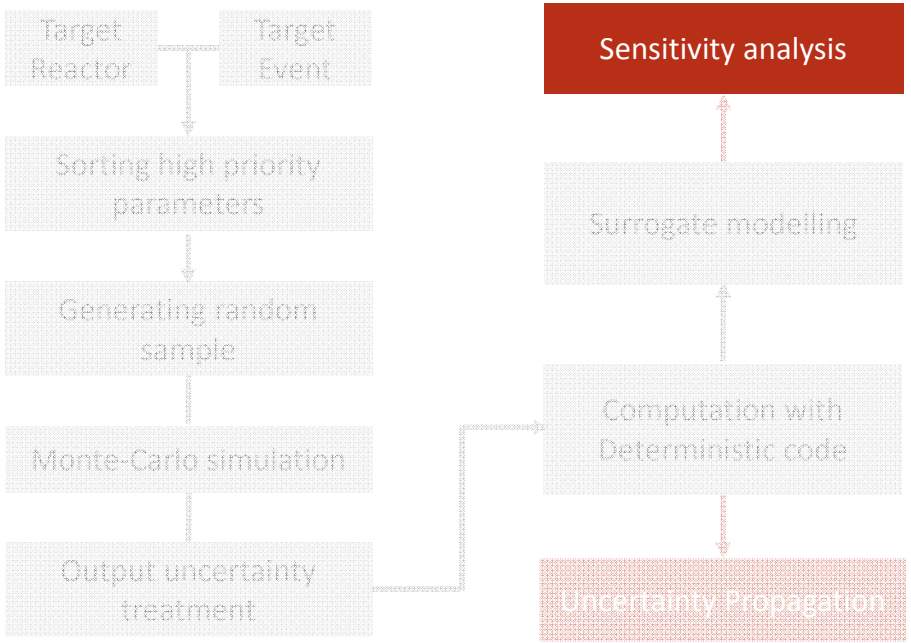


- ***The result from UP can be a preview of the result from SA!!***

  Larger output uncertainty range

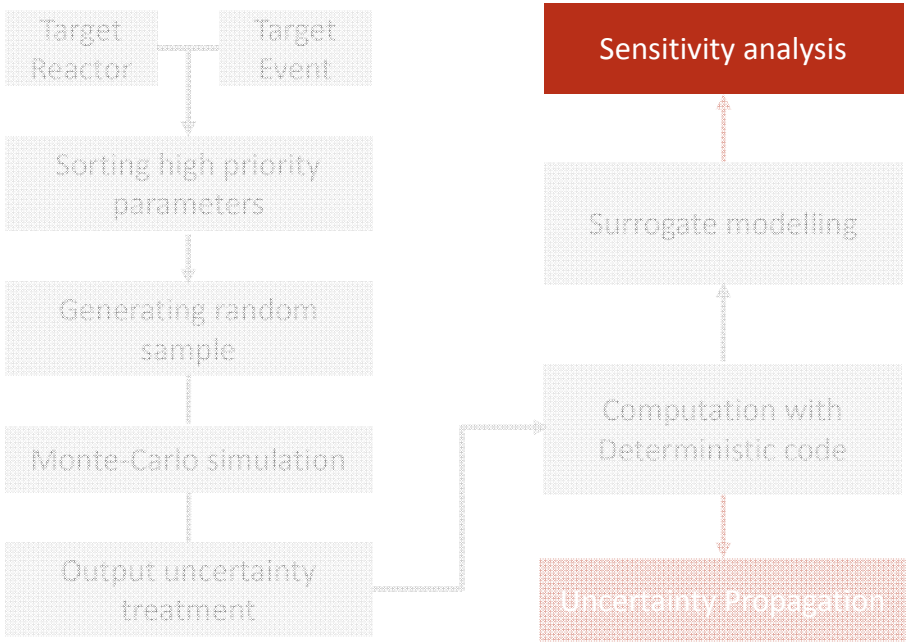
  → More sensitive to the input uncertainty

UP and SA under Neutron Flux Oscillation



- ***Regression-based coefficient***
- ***Correlation-based coefficient***
- ***Variance-based coefficient***

UP and SA under Neutron Flux Oscillation



- ***Variance-based coefficient***

  -Decomposition of output variance

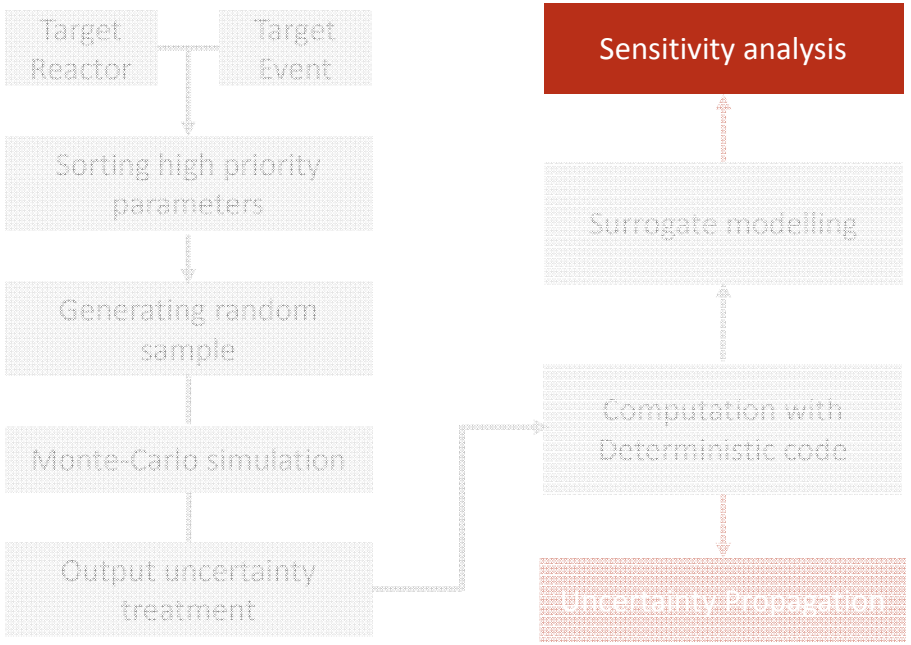
  -with main model nonlinear and non-monotonic

  -Pros and cons

  Pros: proper for complicated model

  Cons: costly in terms of the number of computation (> 10^4)

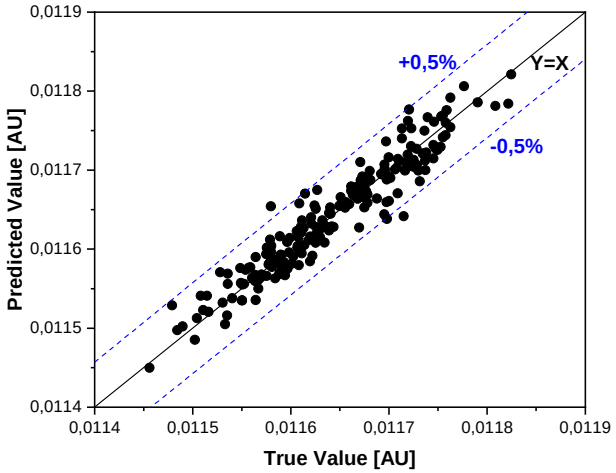
UP and SA under Neutron Flux Oscillation



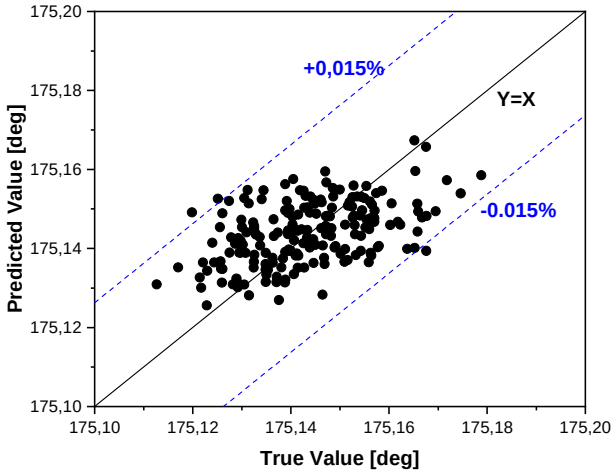
- ***Surrogate modelling***

  -The more training sample sets, the higher accuracy
  -Training can be failed when there is no/weak correlation between input and output
  (when the reactor is small and point-kinetic component is overwhelming, the phase shows less significant value.)

UP and SA under Neutron Flux Oscillation



Good!



Fail?!

- ***Surrogate modelling***

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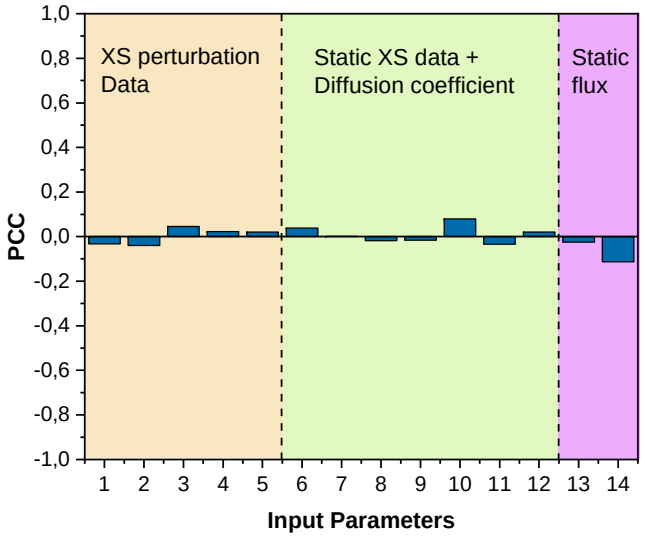

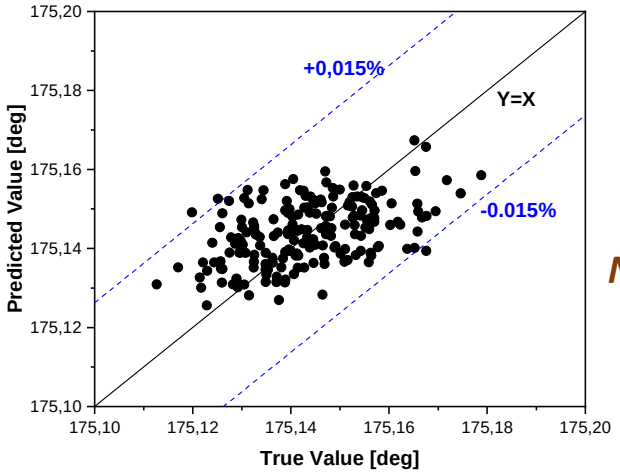

- ***Surrogate modelling***

  -The more training sample sets, the higher accuracy
  -Training can be failed when there is no/weak correlation between input and output
  (when the reactor is small and point-kinetic component is overwhelming, the phase shows less significant value.)

No strong correlation with input parameters!