2ⁿᵈ Validation Workshop – Uncertainty Analyses

2nd Validation Workshop

— Uncertainty Analyses

23 March 2021
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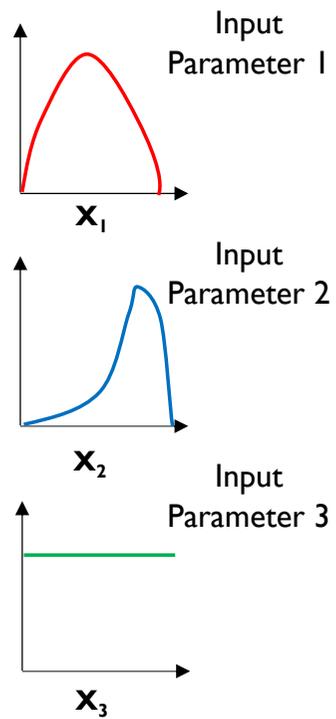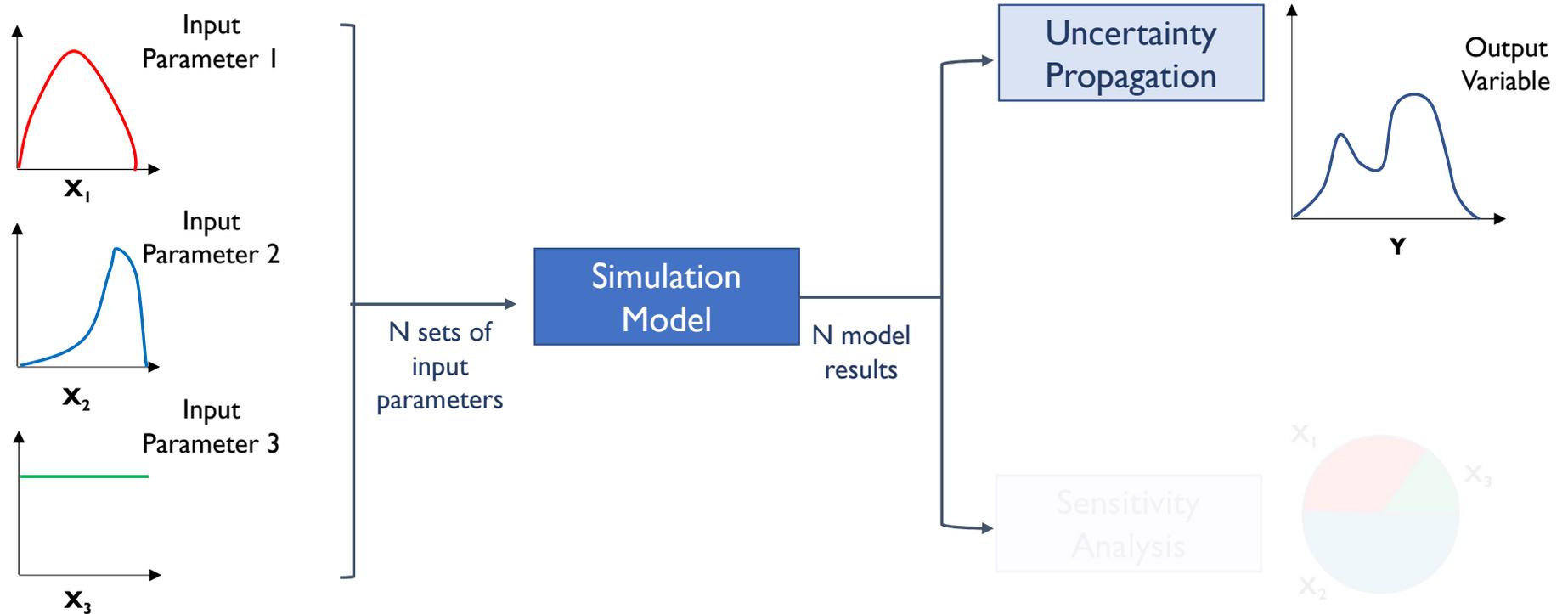# Main Objective

To build   **A General Methodology**   for   **Uncertainty Propagation + Sensitivity Analysis**

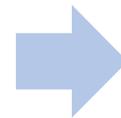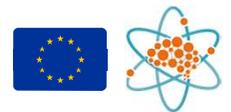under   **Neutron Flux Oscillating Condition** .
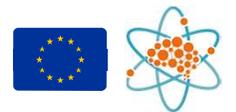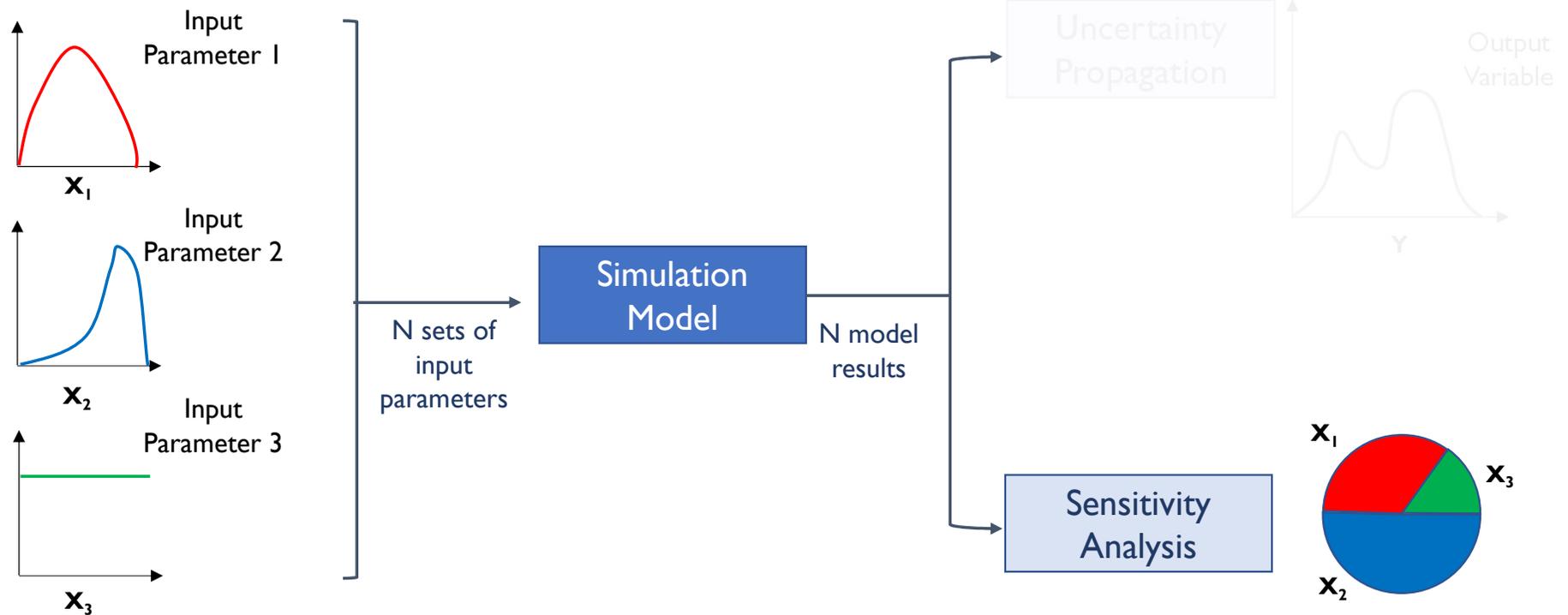
UP & SA
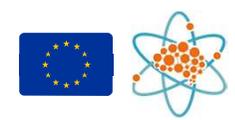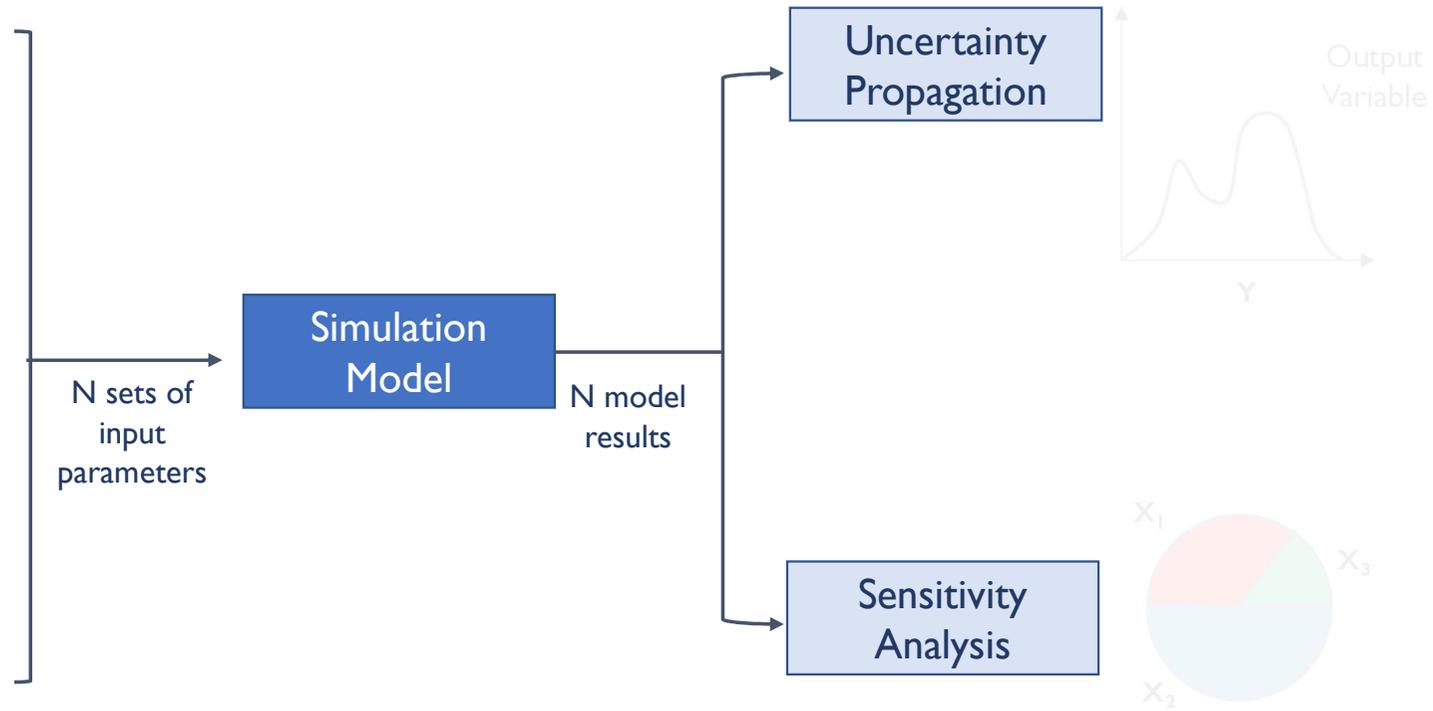
Uncertainty Propagation
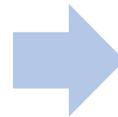

Determining the 'uncertainty range' of neutron noise

Contributing to the validation process of the noise simulator

Sensitivity Analysis
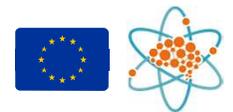

Identifying the '**relative level of contribution**' of uncertain parameters to neutron noise

Contributing to the reduction of output (neutron noise) uncertainties

Work Flowchart

Work Flowchart

Selection of target reactor and target event → reactor condition / noise condition → **Selection of the uncertain parameters**

N sets of nuclear data uncertainties

N noise source uncertainties

Uncertainty propagation

N noise solutions

$\delta\varphi_{fast}$, $\delta\varphi_{thermal}$

Neutron noise calculation with CORE SIM+

N static solutions

φ_{fast}, $\varphi_{thermal}$

Steady-state calculation with CORE SIM+

Sensitivity analysis

Nominal nuclear data

Work Flowchart

Work Flowchart

Work Flowchart

Selection of the uncertain parameters

N noise source uncertainties

N sets of nuclear data uncertainties
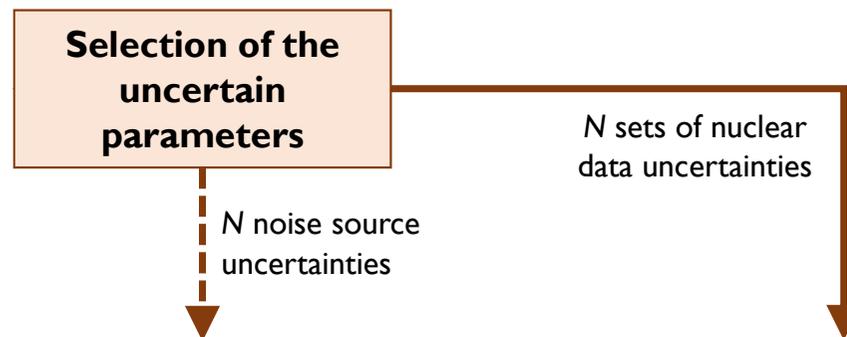
1. Design & operating parameters
2. Nuclear data uncertainty
3. Noise source uncertainty (depending on events)

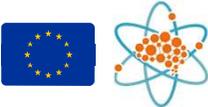   Frequency
   Amplitude of oscillation
   Location of noise source

4. …

Prepare *N* sets of samples
'Based on distribution information'

Work Flowchart

Selection of target reactor and target event → reactor condition, noise condition → Selection of the uncertain parameters → N sets of nuclear data uncertainties → Steady-state calculation with CORE SIM+

Selection of the uncertain parameters ⇢ N noise source uncertainties → Neutron noise calculation with CORE SIM+

Steady-state calculation with CORE SIM+ → N static solutions ϕ_{fast}, $\phi_{thermal}$ → Neutron noise calculation with CORE SIM+

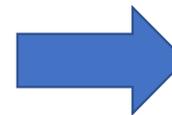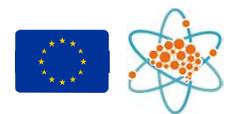Neutron noise calculation with CORE SIM+ → N noise solutions, $\delta\varphi_{fast}$, $\delta\varphi_{thermal}$ → Uncertainty propagation / Sensitivity analysis

Work Flowchart

$(\text{Input set})_1$
$(\text{Input set})_2$
...
$(\text{Input set})_N$
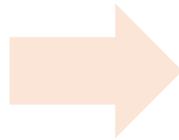
$(\phi_{fast}, \phi_{thermal})_1$
$(\phi_{fast}, \phi_{thermal})_2$
...
$(\phi_{fast}, \phi_{thermal})_N$

$(\delta\phi_{fast}, \delta\phi_{thermal})_1$
$(\delta\phi_{fast}, \delta\phi_{thermal})_2$
...
$(\delta\phi_{fast}, \delta\phi_{thermal})_N$

N times of batch computation

Neutron noise
calculation
with **CORE SIM+**

N static
solutions

$\phi_{fast}, \phi_{thermal}$

**Steady-state
calculation
with CORE SIM+**
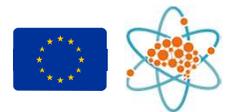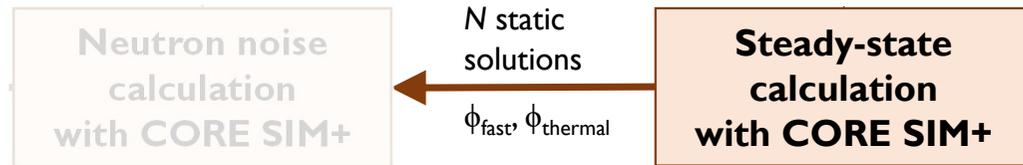
Work Flowchart

$(Nuclear\ Data)_1$
$(Nuclear\ Data)_2$
...
$(Nuclear\ Data)_N$

$(\phi_{fast}, \phi_{thermal})_1$
$(\phi_{fast}, \phi_{thermal})_2$
...
$(\phi_{fast}, \phi_{thermal})_N$

$(\delta\phi_{fast}, \delta\phi_{thermal})_1$
$(\delta\phi_{fast}, \delta\phi_{thermal})_2$
...
$(\delta\phi_{fast}, \delta\phi_{thermal})_N$

N times of batch computation

N noise
solutions

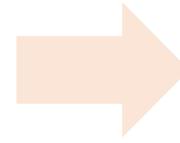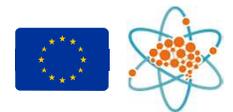$\delta\phi_{fast}, \delta\phi_{thermal}$

**Neutron noise
calculation
with CORE SIM+**

N static
solutions

$\phi_{fast}, \phi_{thermal}$

Steady-state
calculation
with CORE SIM+

N noise source
uncertainties

Work Flowchart

Selection of target reactor and target event → reactor condition / noise condition → Selection of the uncertain parameters

Selection of the uncertain parameters → N sets of nuclear data uncertainties

N noise source uncertainties

Uncertainty propagation

N noise solutions

$\delta\phi_{fast}, \delta\phi_{thermal}$

Sensitivity analysis

Neutron noise calculation with CORE SIM+

N static solutions

$\varphi_{fast}, \varphi_{thermal}$
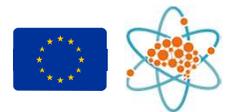
Steady-state calculation with CORE SIM+

Nominal nuclear data

Uncertainty Propagation

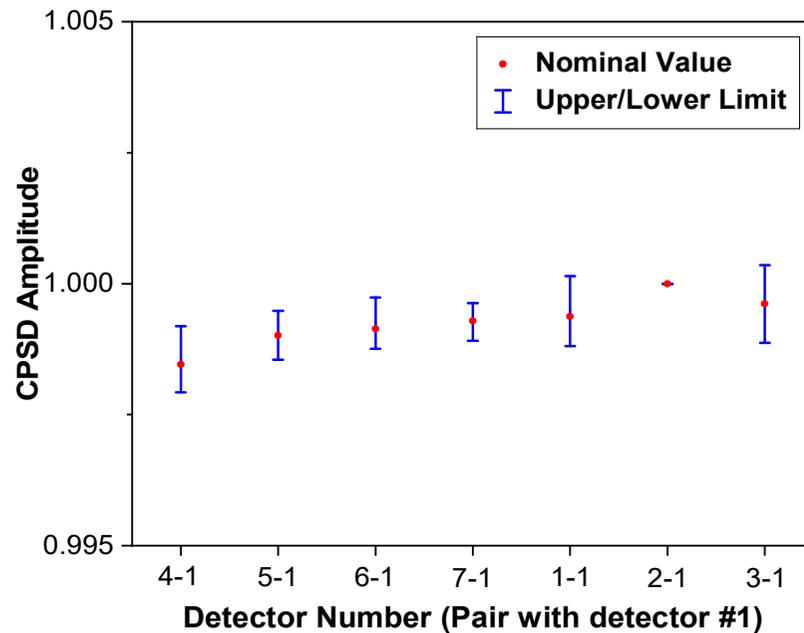*Determining the Upper/Lower bounds based on **Wilks' formula for two-sided limits***

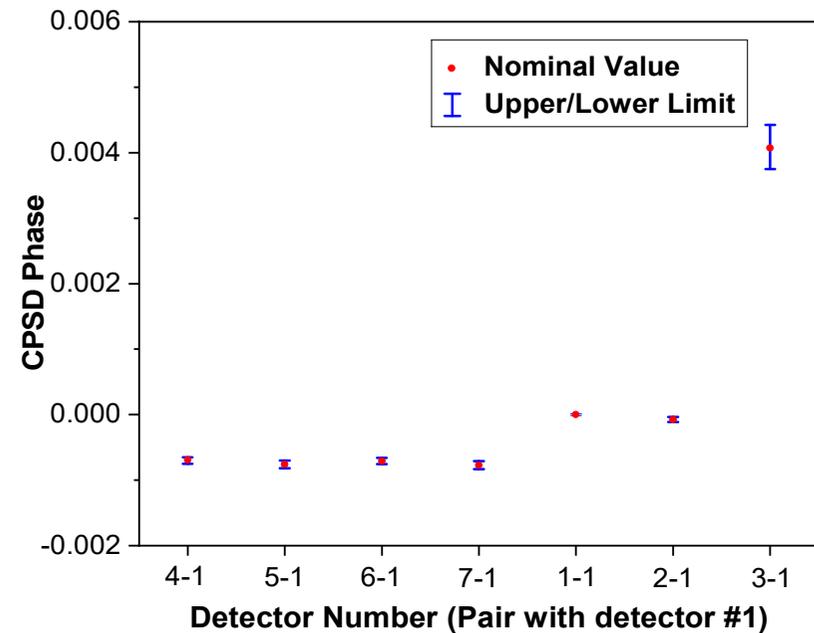*→**95%** probability content in the interval + **95%** confidence level*

Uncertainty Propagation

*Determining the Upper/Lower bounds based on **Wilks' formula for two-sided limits***
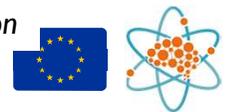
Figure 1. Examples of the outcome from the uncertainty propagation (AKR-2, Vibrating absorber, Exp#22)
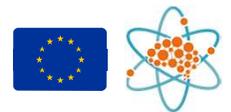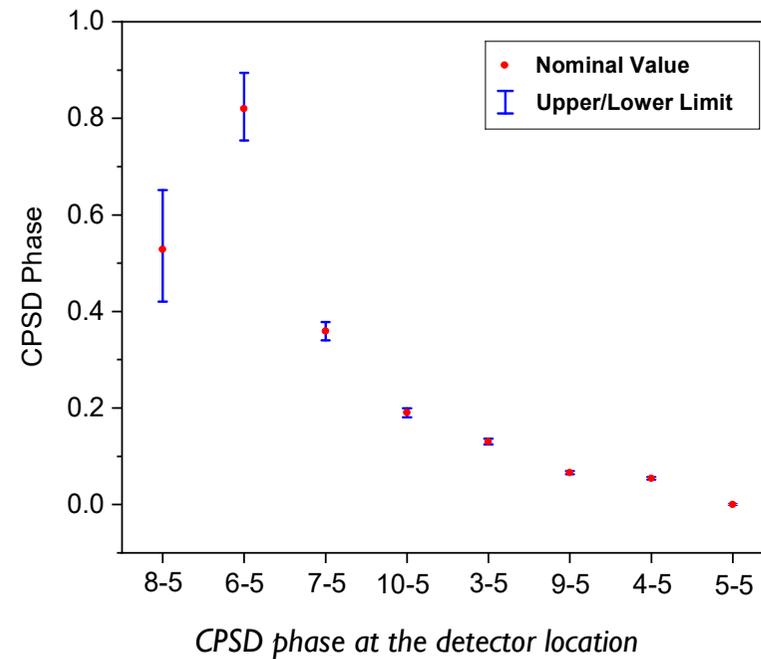

CPSD Amplitude at the detector location

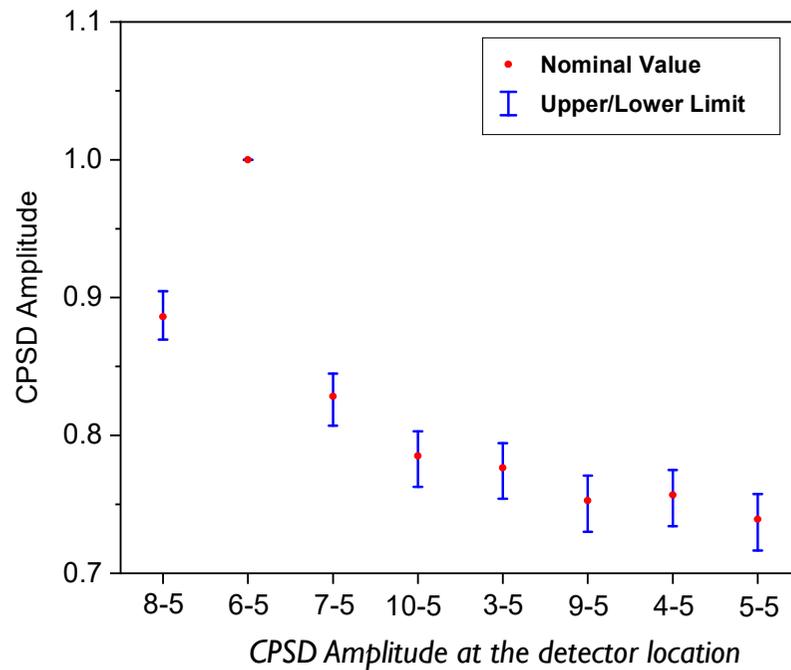*CPSD phase at the detector location*

Uncertainty Propagation

*Determining the Upper/Lower bounds based on **Wilks' formula for two-sided limits***
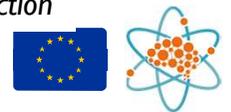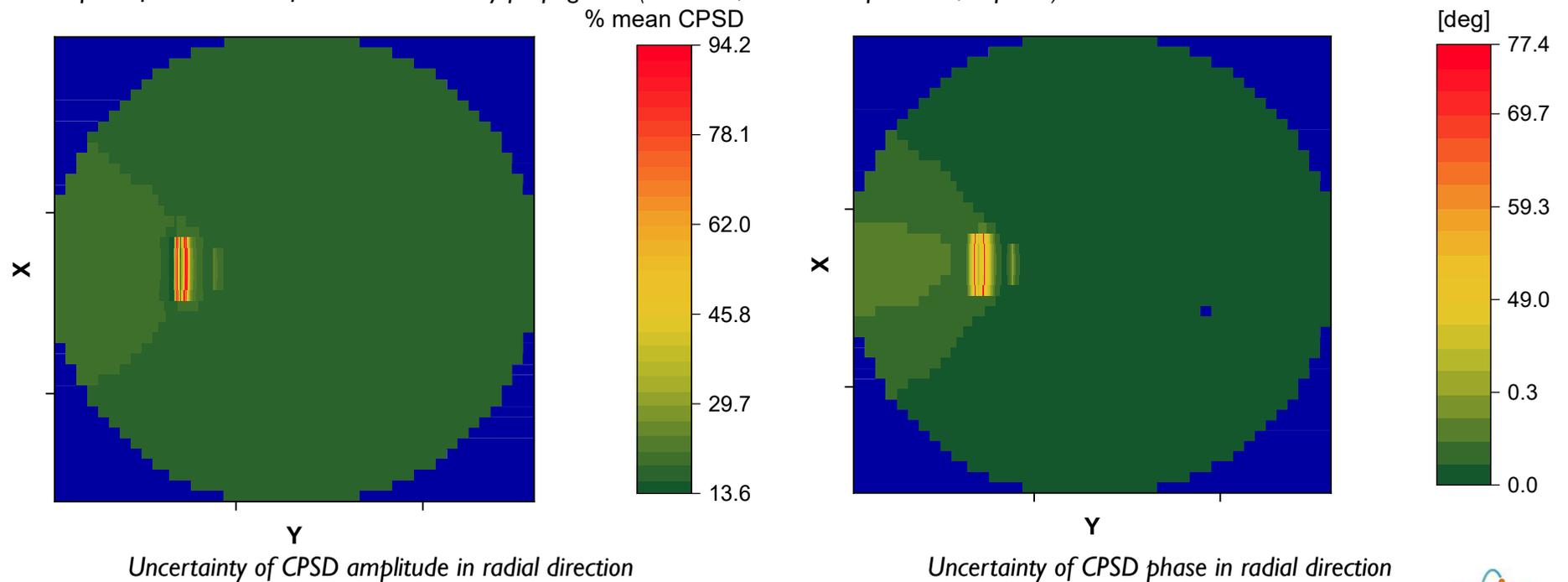
Figure 2. Examples of the outcome from the uncertainty propagation (CROCUS, COLIBRI experiment, Exp#13)

Uncertainty Propagation

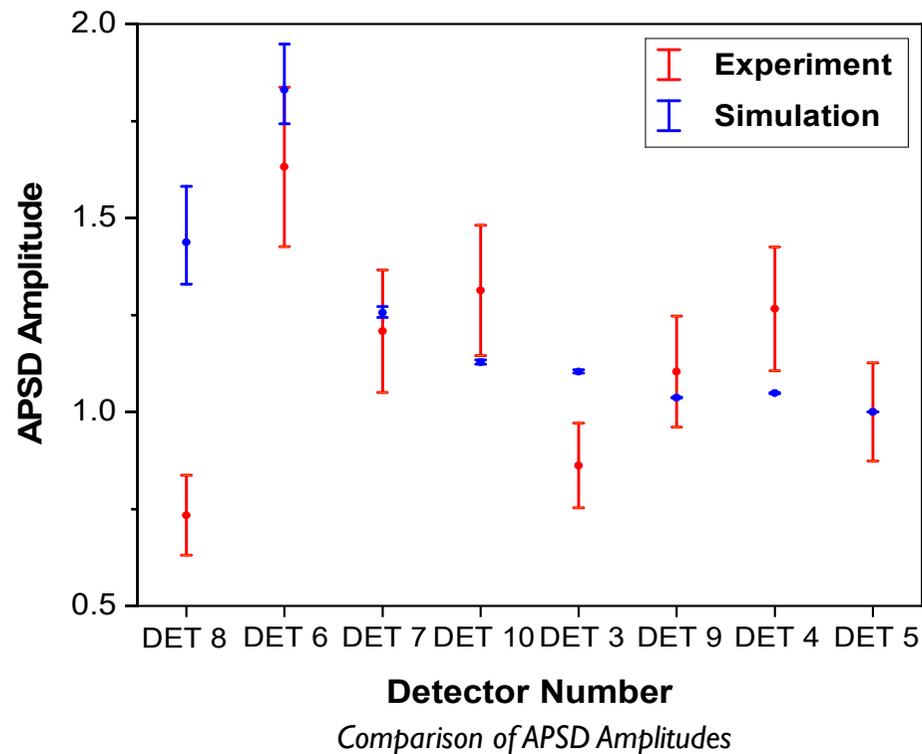*Determining the Upper/Lower bounds based on **Wilks' formula for two-sided limits***

Figure 3. Examples of the outcome from the uncertainty propagation (CROCUS, COLIBRI experiment, Exp#13)

Uncertainty of CPSD amplitude in radial direction

Uncertainty of CPSD phase in radial direction
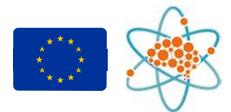
Uncertainty Propagation

*Determining the Upper/Lower bounds based on **Wilks' formula for two-sided limits***

Figure 4. Examples of the validation process with experimental and computation (CORE SIM+) results (CROCUS, COLIBRI experiment, Exp#13)

Comparison of APSD Amplitudes

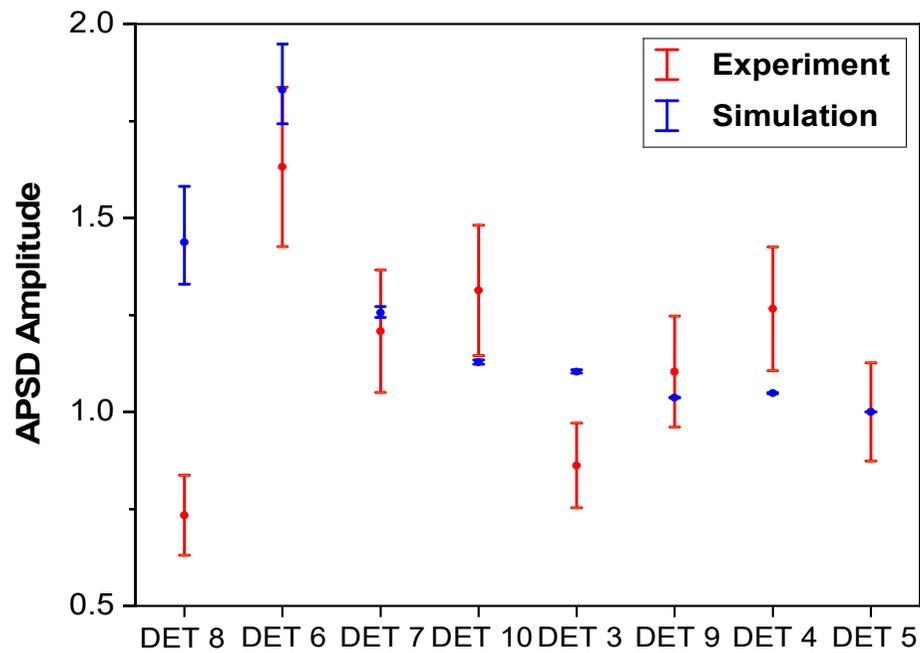*"Efficient way to reduce the uncertainties?"*

→Sensitivity analysis!

Uncertainty Propagation

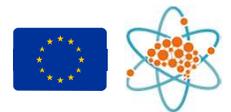*Determining the Upper/Lower bounds based on **Wilks' formula***

Figure 4. Examples of the validation process with experimental and computation (CORE SIM+) results (CROCUS, COLIBRI experiment, Exp#13)

Comparison of APSD Amplitudes
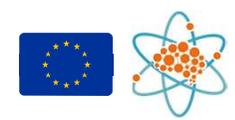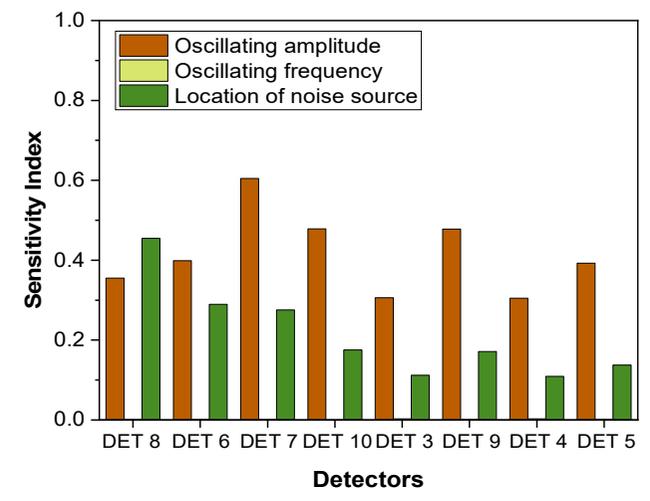
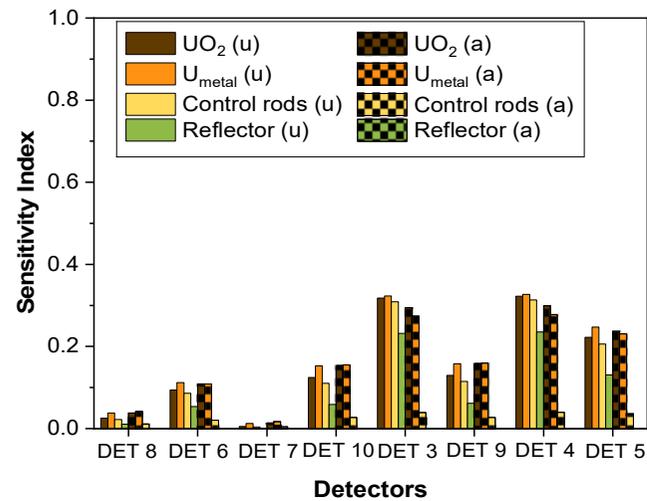*"Efficient way to reduce the uncertainties?"*

→Sensitivity analysis!

Sensitivity Analysis

*Sensitivity indices based on **Spearman Correlation Coefficients (SCC)***

Figure 5. Examples of sensitivity indices at detector locations (CROCUS, COLIBRI experiment, Exp#13)

Design and operating parameters

Fast diffusion coefficients

Noise source data

Sensitivity Analysis

Identifying the parameters with the largest importance at the detector location

X_1

X_3

X_2

e.g., The importance : $X_2 > X_1 > X_3$
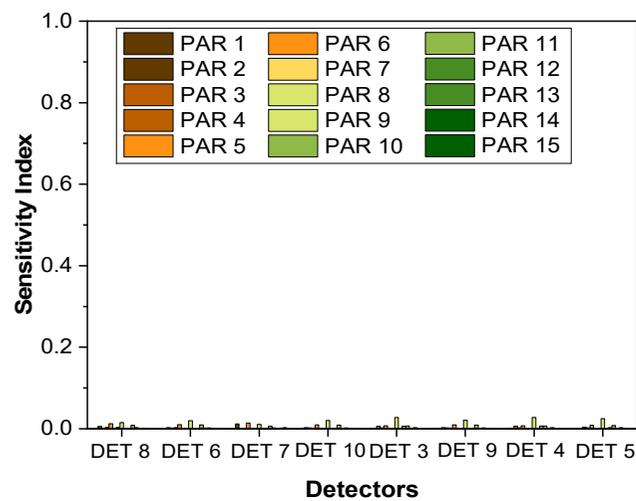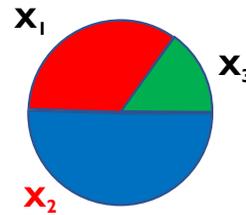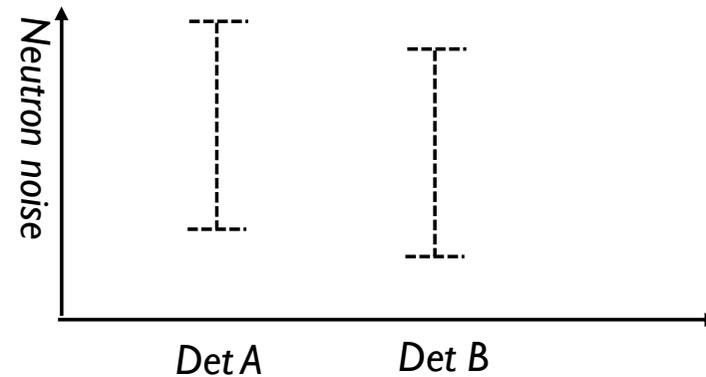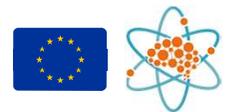
Modifying the perturbation of the parameters with high-priority to reduce the uncertainties of neutron noise

Neutron noise
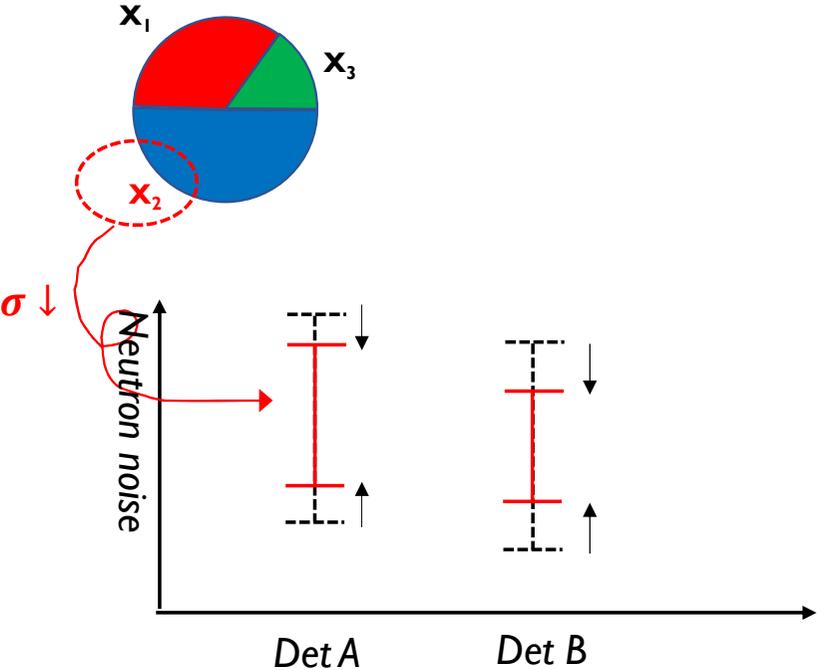
Det A   Det B

Original uncertainty

Sensitivity Analysis

Identifying the parameters with the largest importance at the detector location

Modifying the perturbation of the parameters with high-priority to reduce the uncertainties of neutron noise

$\sigma \downarrow$

Neutron noise

Det A   Det B

Original uncertainty

Decreased uncertainty after decreasing the perturbation of the parameter with high importance

Thank you