



# CORTEX

Core monitoring techniques and  
experimental validation and demonstration

## **Validation of neutron noise simulators**

**Validation workshop, 23-24 March 2021**

**On behalf of all partners involved in WP2**



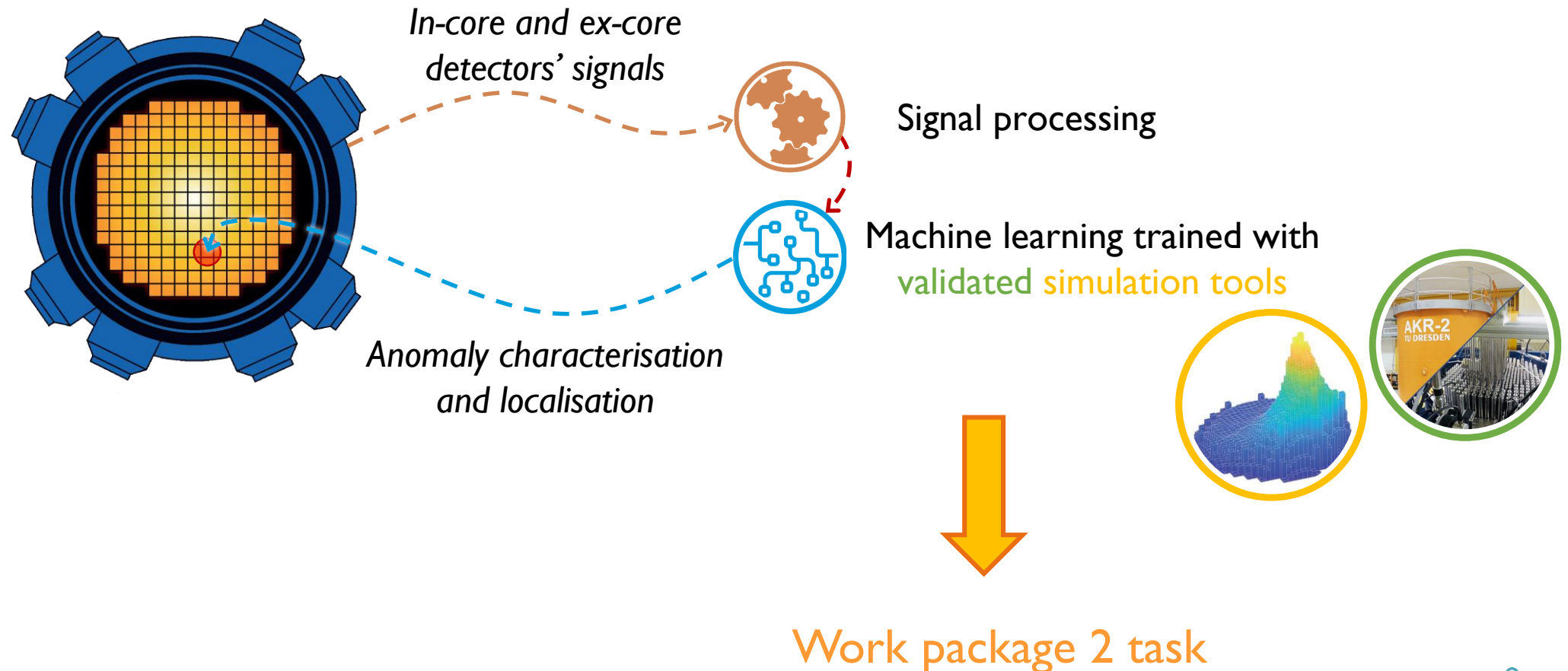
This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 754316.

# Outline

- Background information about CORTEX
- Interactions between Experimentalists and Modelers within CORTEX
- Validation of a code
- Quantities of Interest for the validation exercise
- Summary



# CORTEX in a picture

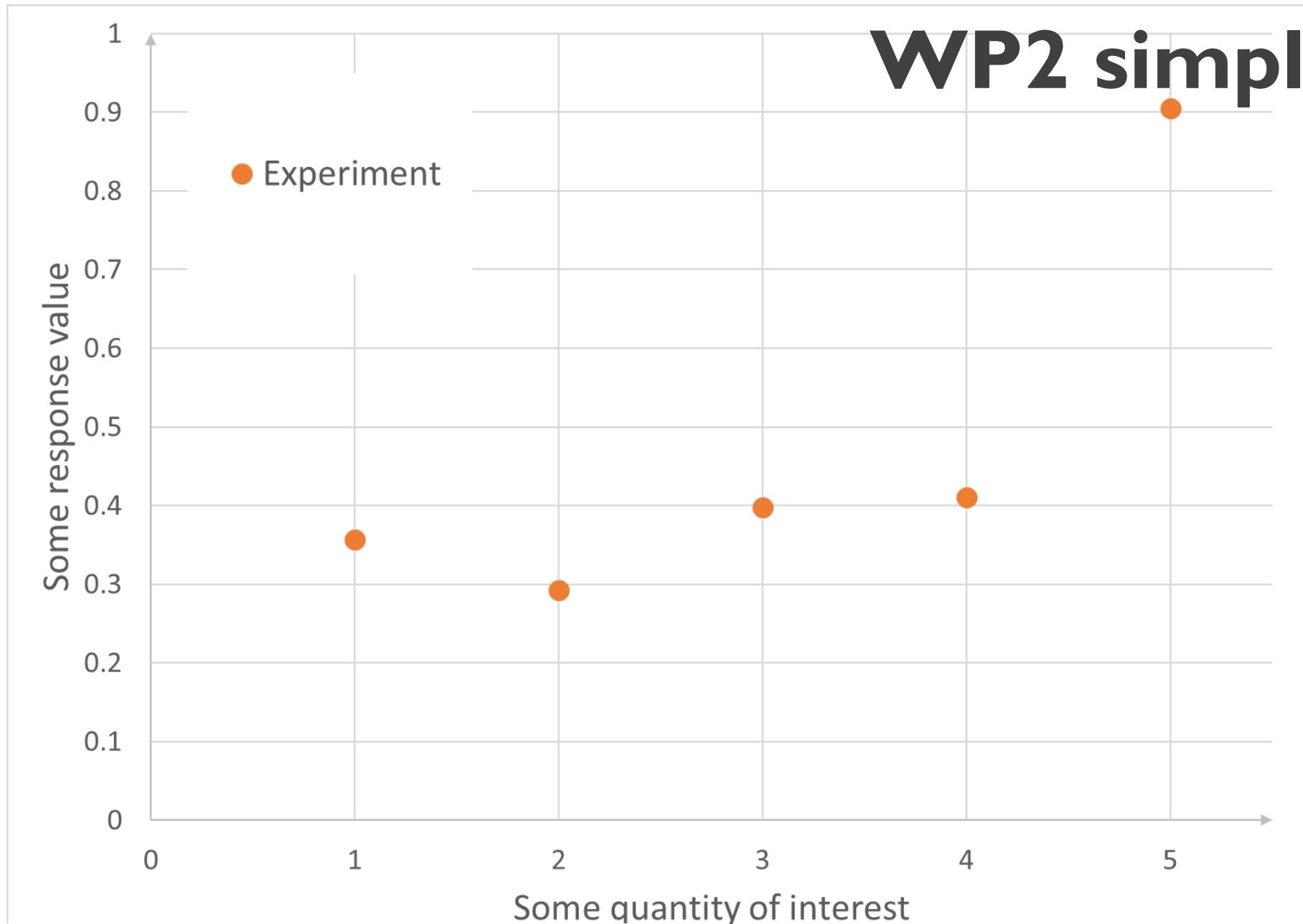


# WP2 simple life



The data shown in the next few slides is  
**NOT** the data produced by measurements  
and models within CORTEX

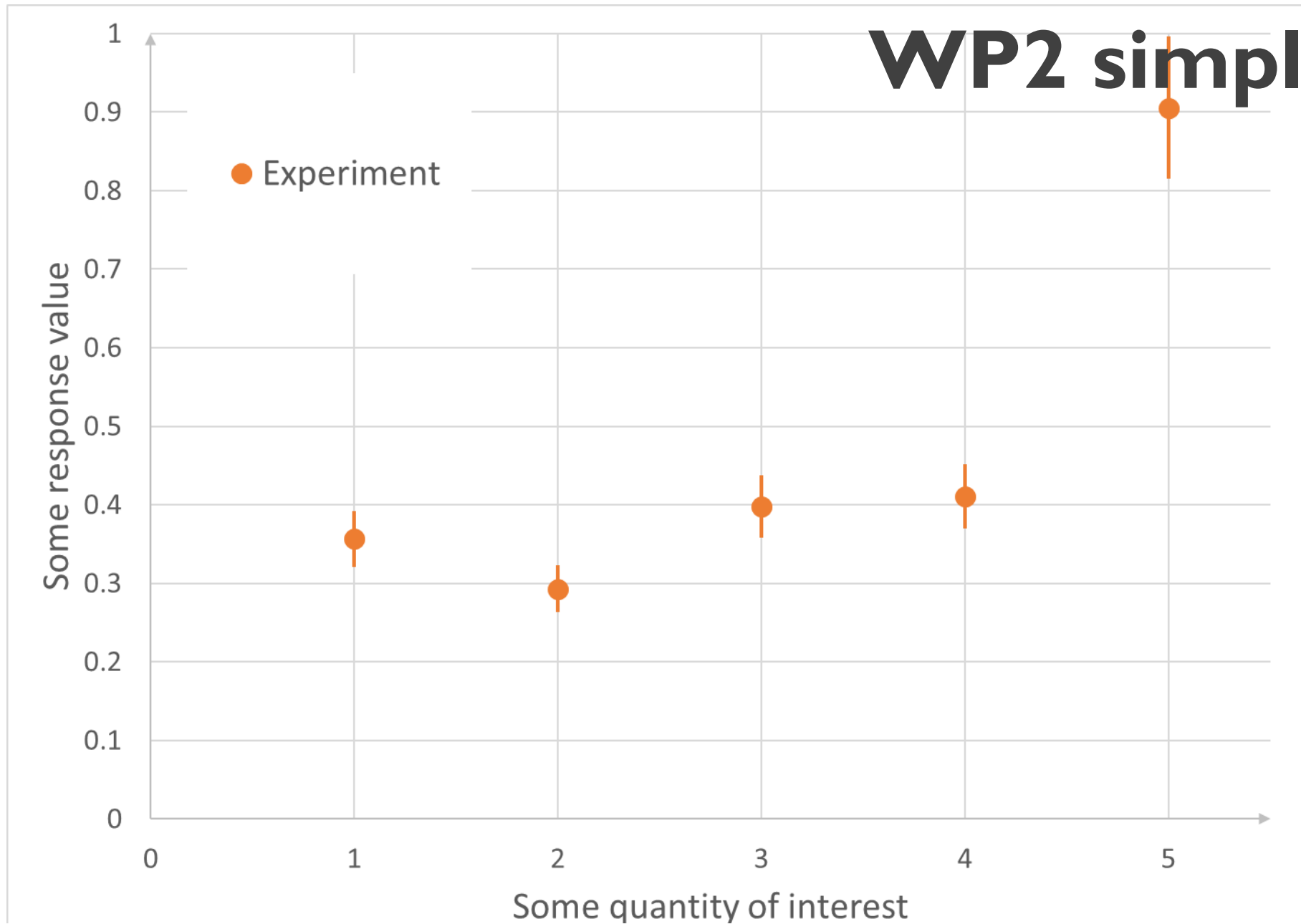
# WP2 simple life



Early in the project according to the Gantt Diagram



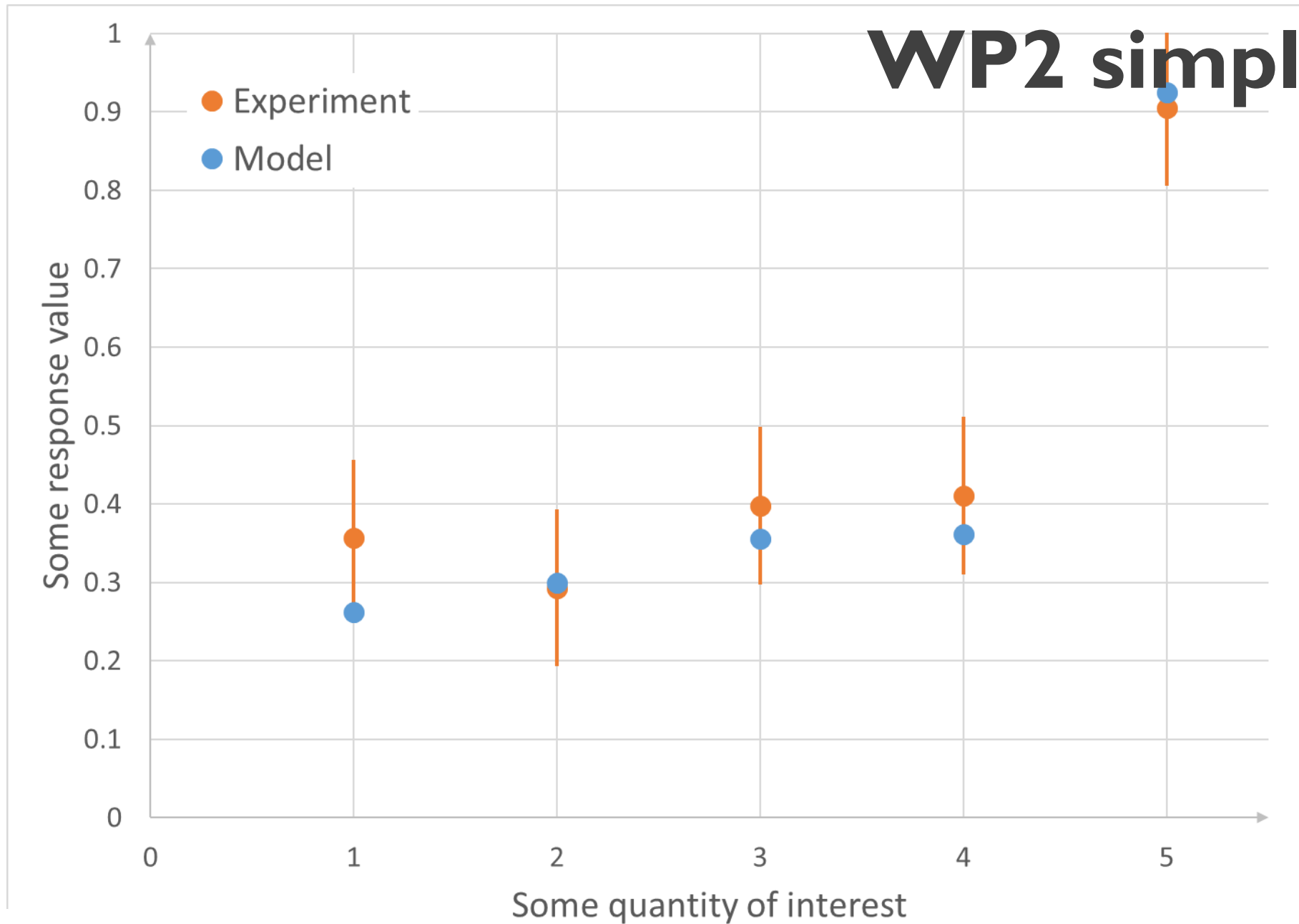
# WP2 simple life



Gantt Diagram, one month later



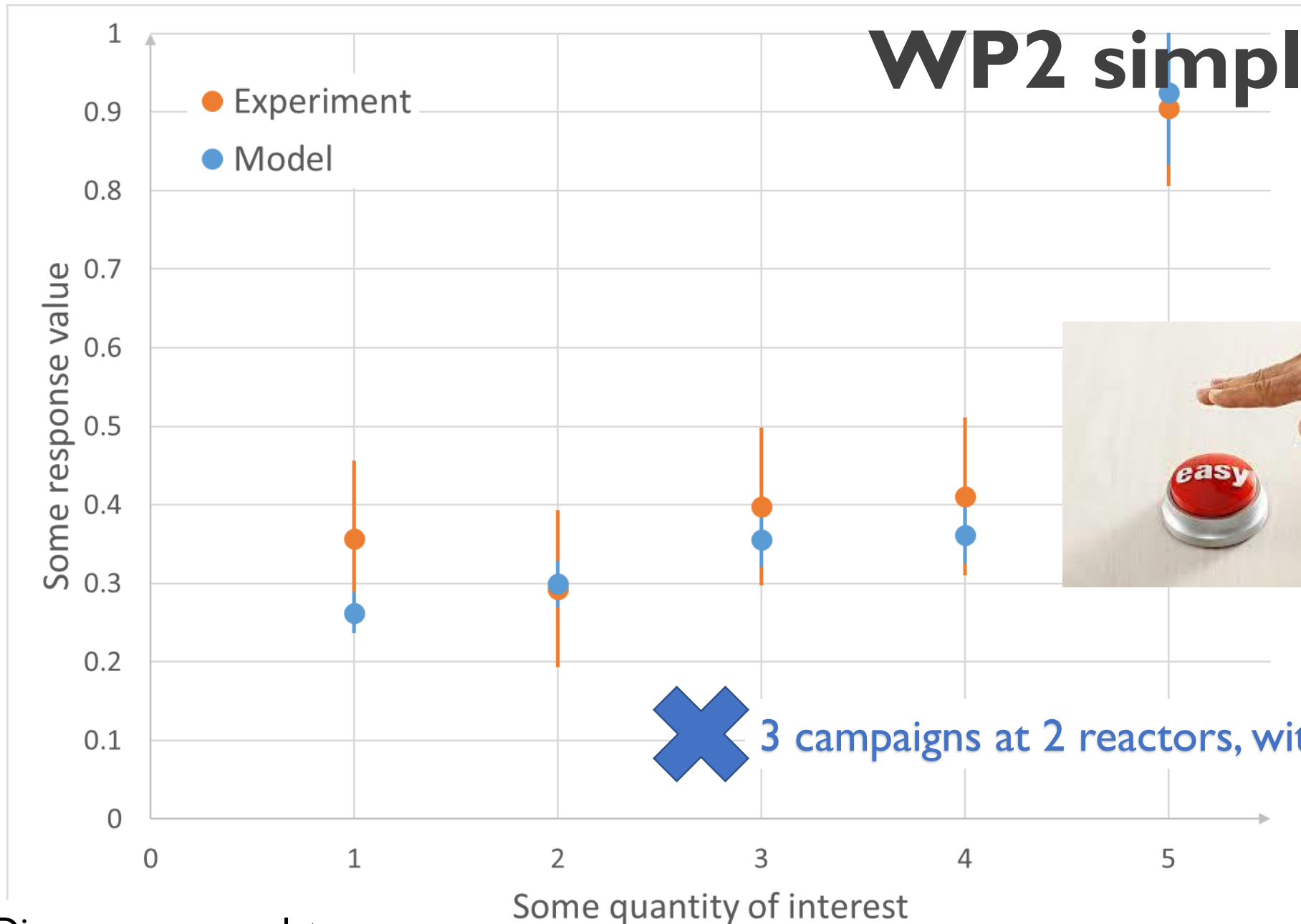
# WP2 simple life



Gantt Diagram, six months later



# WP2 simple life



**X** 3 campaigns at 2 reactors, with 7 models

Gantt Diagram, one year later



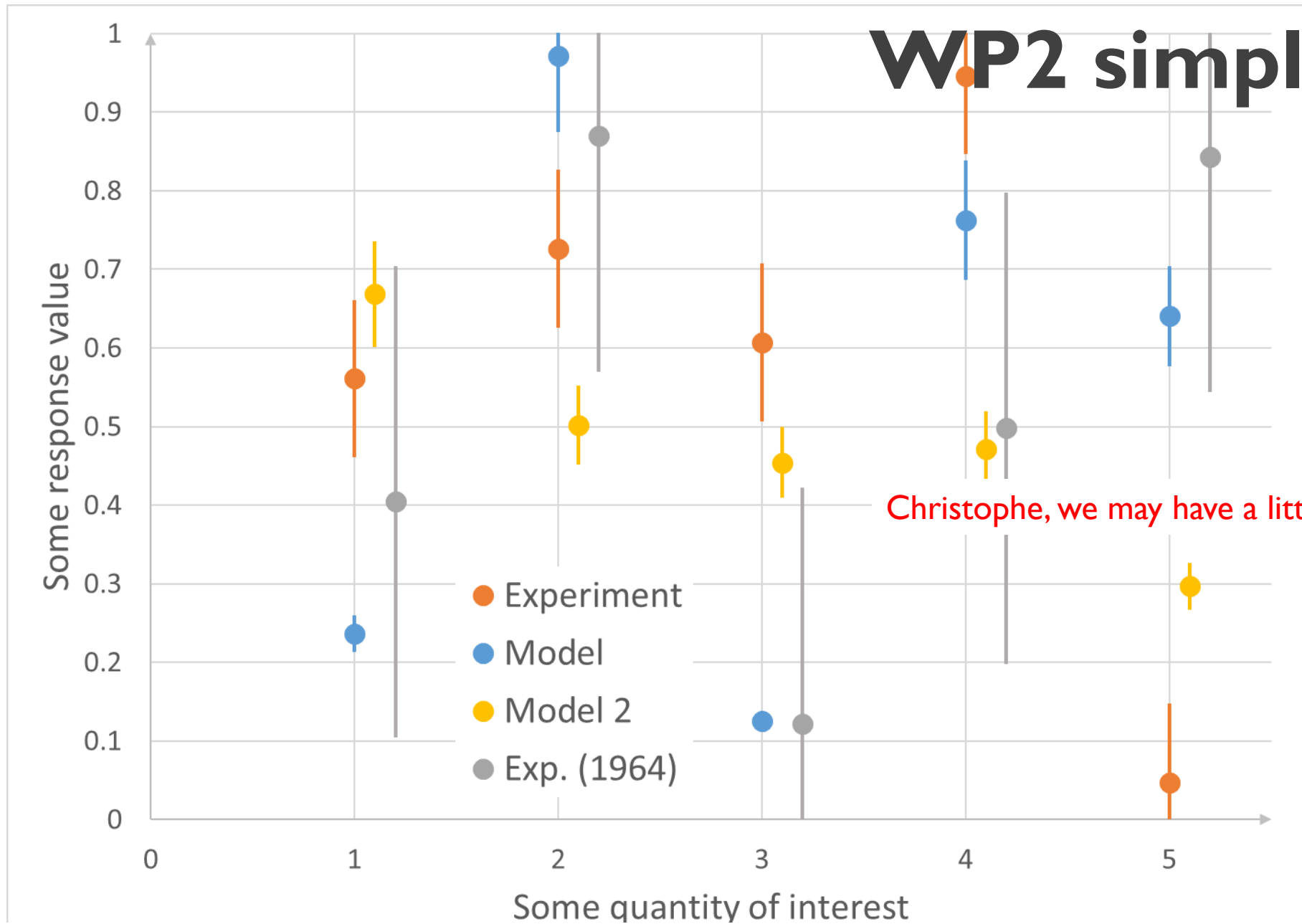
# WP2 simple life



What you see, one week before the workshop ...



# WP2 simple life



What you see, one week before the workshop ...

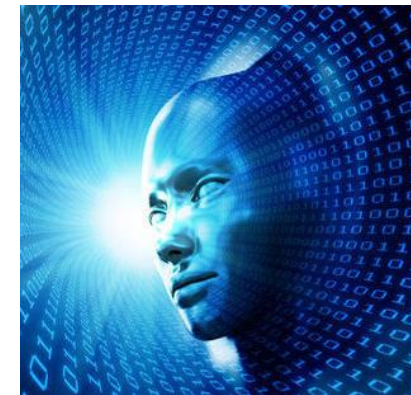


- Set up communication between experimentalists and simulation
  - What is reasonably ambitious about experiments?
  - What can reasonably be, or not be, the expectations for the validation of MP M&S tools?
  - **Initiate a virtuous progress loop between simulation and experiments**

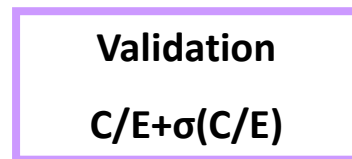
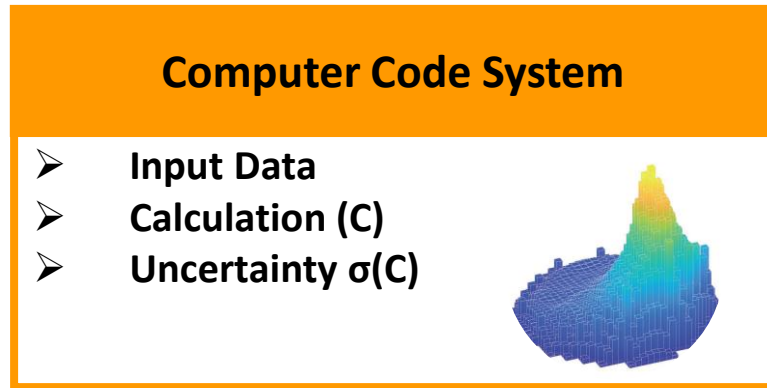


Experimentalists are so bad!  
I measure everything and  
perfectly

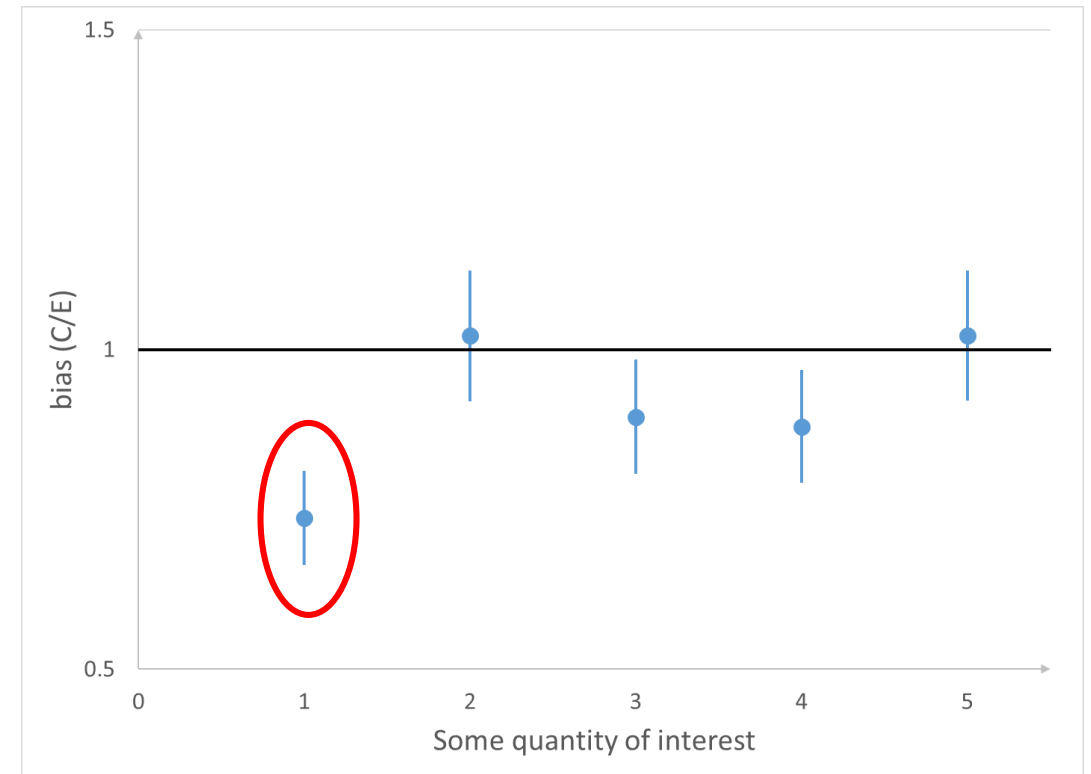
These simulation guys  
know I'll do what I can  
I can very well measured  
only few things



# Validation of Noise Simulators



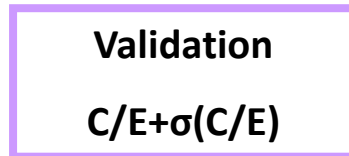
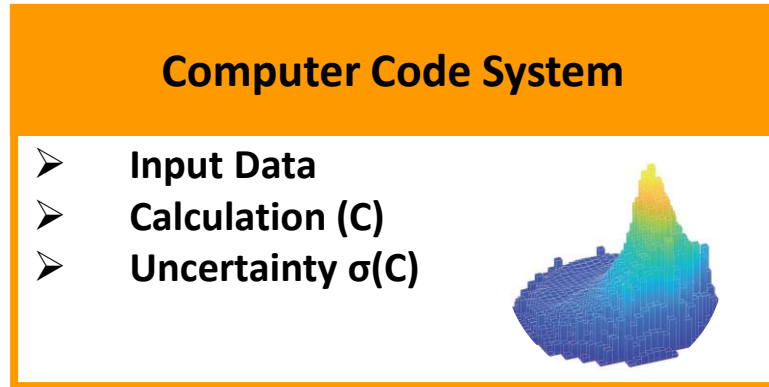
$$\sigma(C/E) = \sqrt{\sigma_E^2 + \sigma_C^2}$$



Alexander, Antonios, should I be worried?



# Validation of Noise Simulators



$$\sigma(C/E) = \sqrt{\sigma_E^2 + \sigma_C^2}$$



1) Reliable Predictive Tool?

2) Useful Experiment?



Bias Estimation

Q: How wrong can my code be for the envisioned application?

Representativity Analysis

Q: Is my experiment suitable to demonstrate the performance of my code?

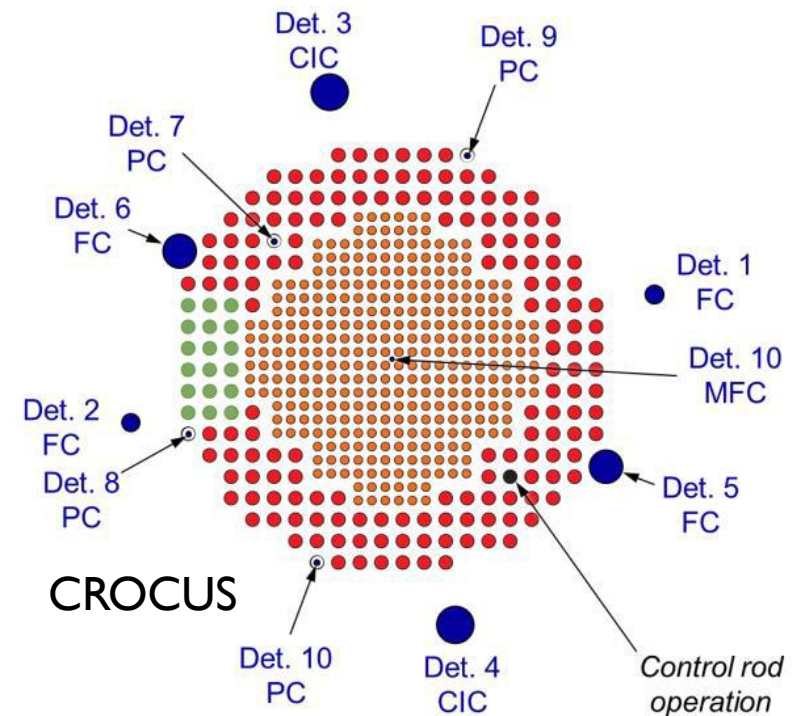
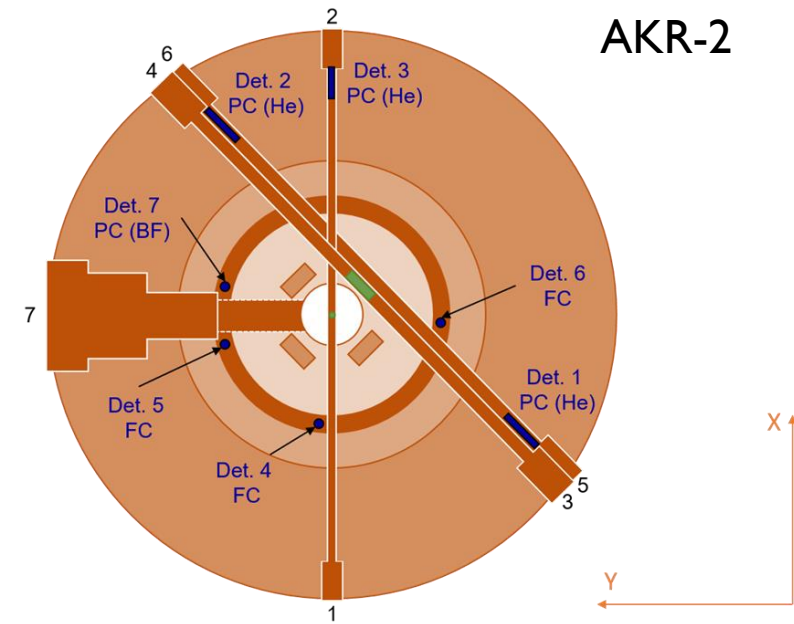


Not this project



# Experimental Facilities

- Absorber of variable strength (AVS)
  - localized perturbation with an amplitude varying in time at a fixed position
  - Channel 3-4 @ AKR-2
- Vibrating absorber (VA)
  - lateral movement of a weak absorber
  - COLIBRI @ CROCUS, Channel 1-2 @ AKR-2
- 3 experimental campaigns completed so far, data analysis not complete yet
- Number of detectors, locations have evolved throughout the project



# Neutron Noise Simulators

Code				
	Boltz. Eq.	Noise Eq.	Response	Det. Model
<b>TRIPOLI-4</b>	Monte Carlo	Freq.	Th. $\Phi$	yes
<b>MCNP</b>	Monte Carlo	Freq.	Reac. Rate	Yes
<b>CORESIM+</b>	Diffusion	Freq.	Th. $\Phi$	No
<b>APOLLO3</b>	Deterministic Transport	Time Dep.	Reac. Rate	No
<b>PARCS</b>	Diffusion	Time Dep.	Th. $\Phi$	No
<b>FEMFFUSION</b>	Diffusion	Time Dep.	Th. $\phi$	No
<b>NOISE-SN</b>	Deterministic Transport	Freq.	Th. $\Phi$	No

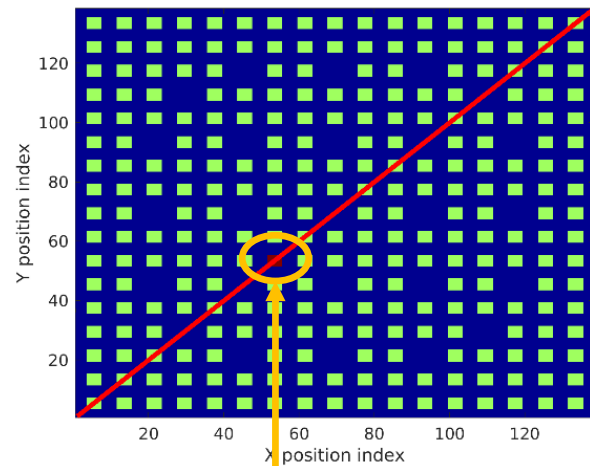


Uncertainty Quantification using CORESIM+

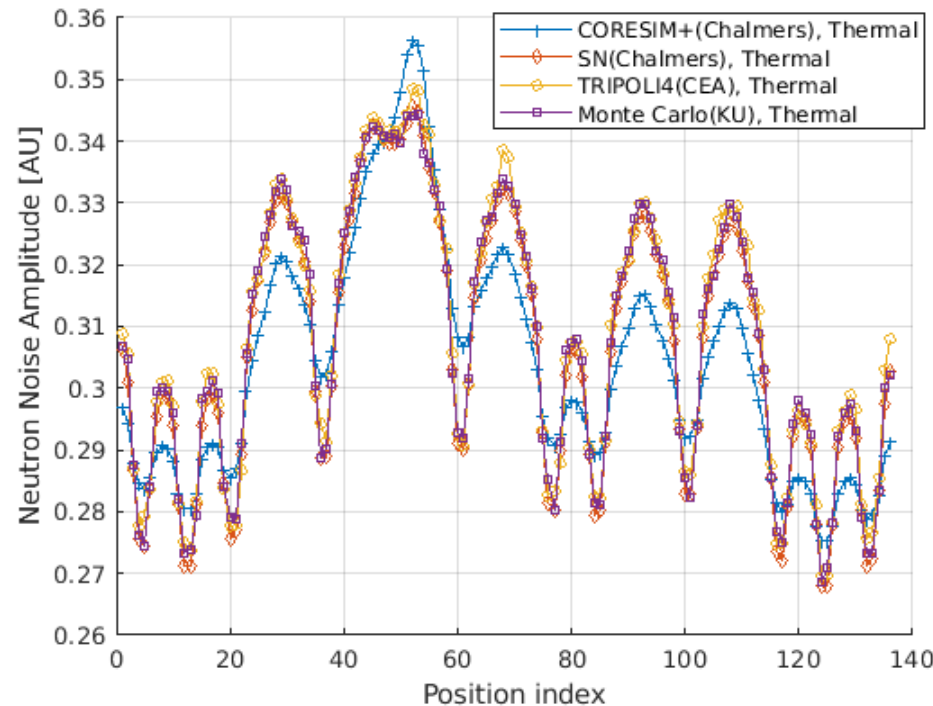


# Verification

- Done in another WP for simplified / sanitized cases
  - Neutron noise source: oscillation of nuclear properties in one fuel pin
- Example
  - TRIPOLI-4 (CEA), MC solver (KU), Sn solver and CORE SIM+ (Chalmers)



Perturbed pin



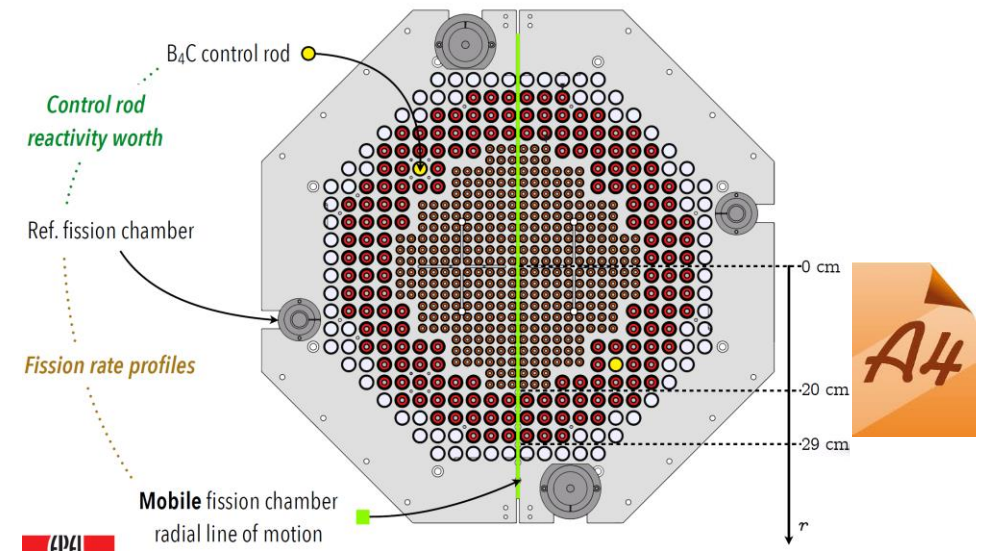
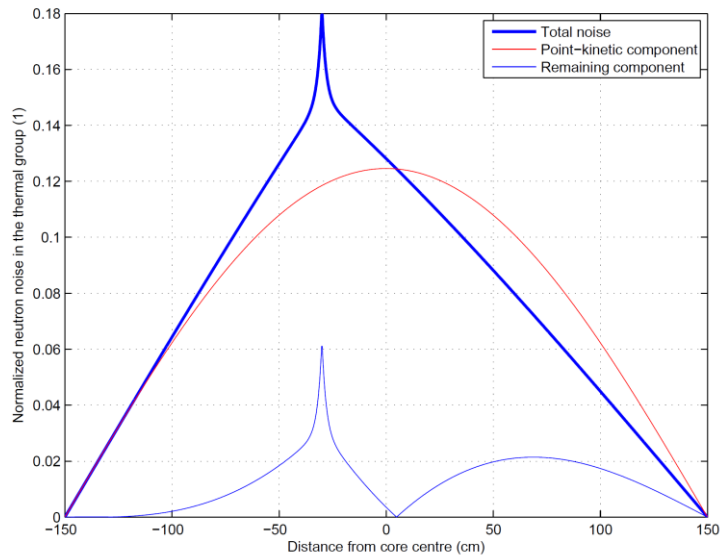
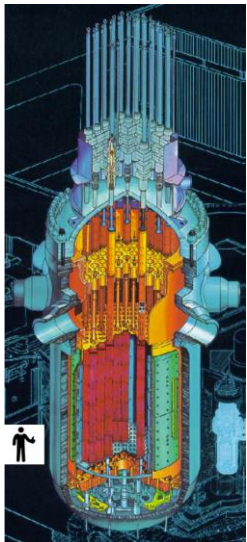
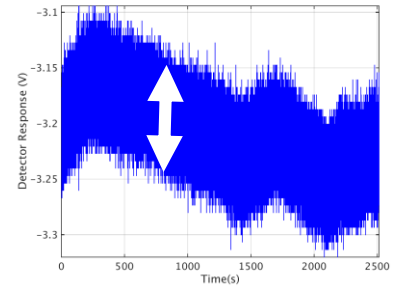
Thermal noise  
amplitude



# A useful experiment?

- We want to use small research reactors to demonstrate that our codes can determine a spatially dependent noise distribution
- Zero power reactors tend to behave like points (small deviations)

Absolute noise amplitude

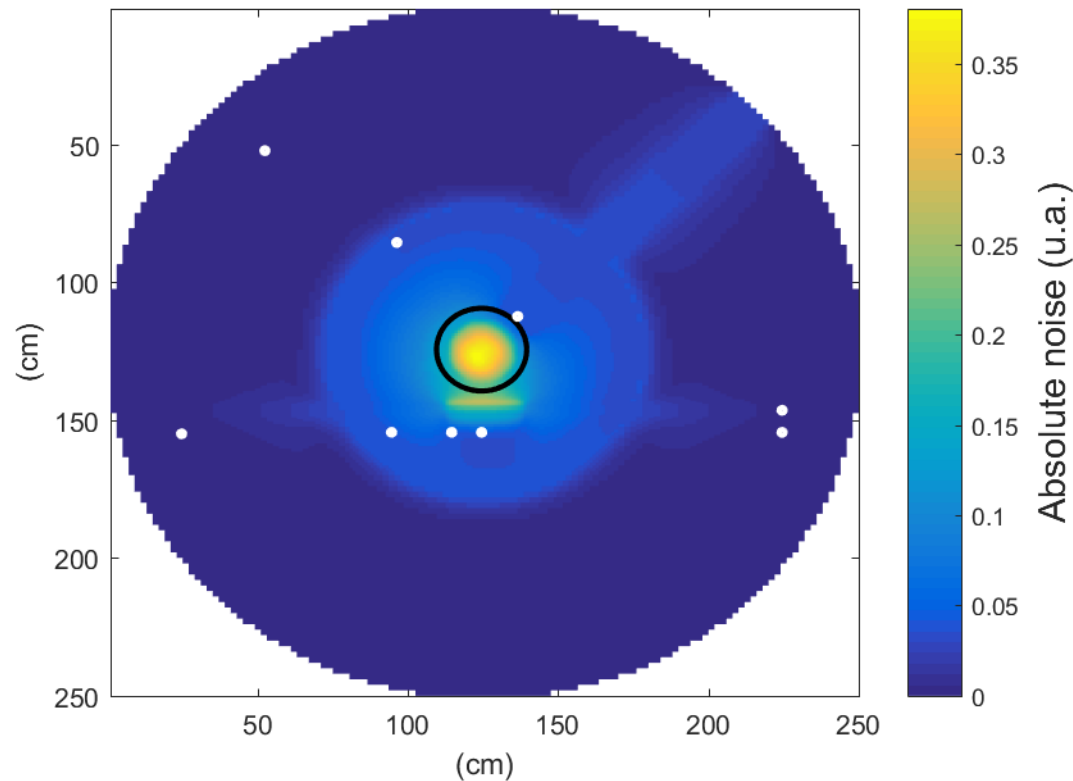
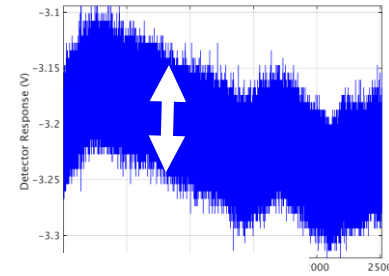


- Looking at the relative noise (relative to the fundamental flux distribution), allows to “filter out” the unwanted point kinetic component

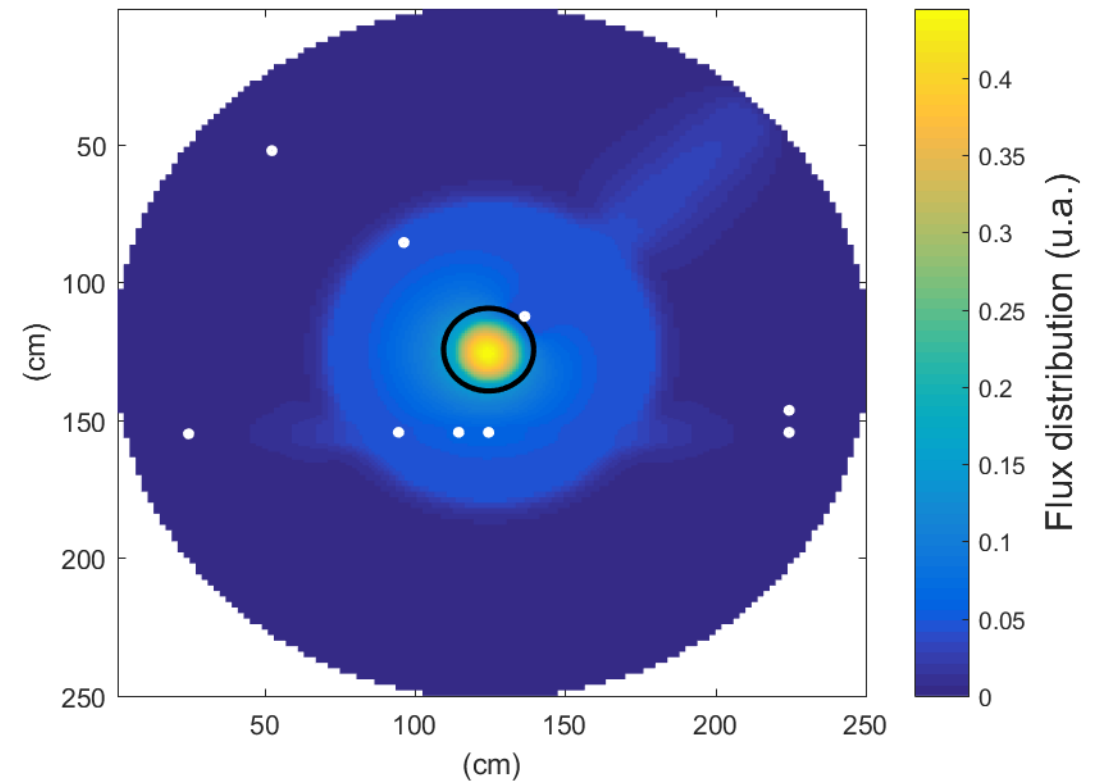


# Absolute vs Relative noise amplitude

Absolute noise amplitude



Absolute noise map at AKR-2

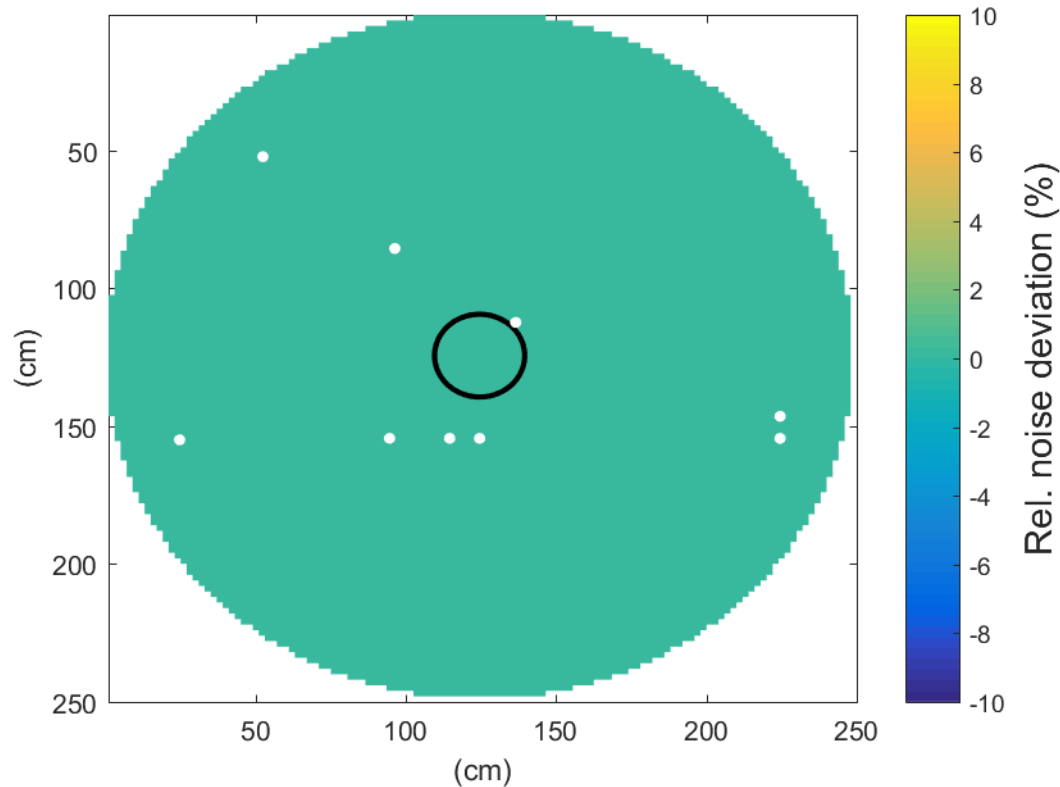


Fundamental flux map at AKR-2

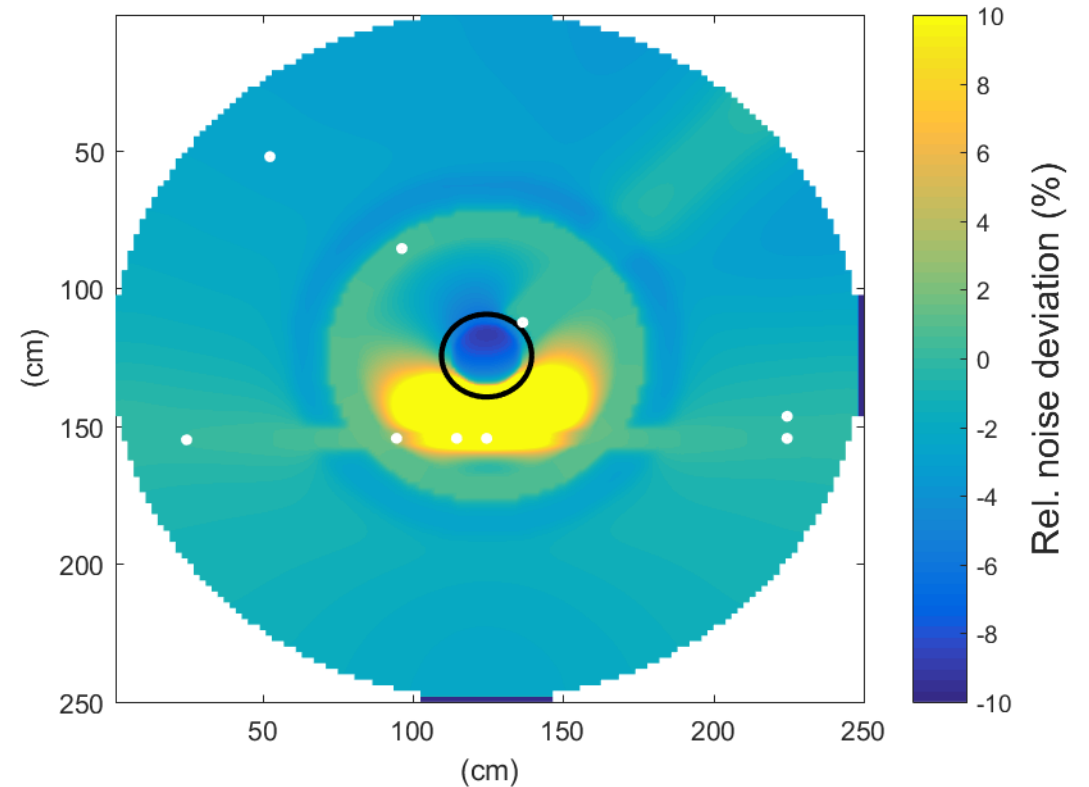


Absolute noise looks like fundamental flux distribution

# Absolute vs Relative noise amplitude



Relative noise map (perfect point reactor)



Relative noise map at AKR-2



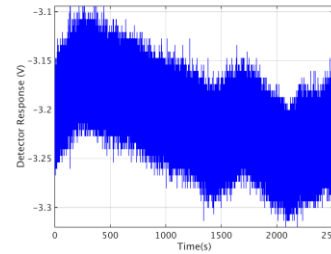
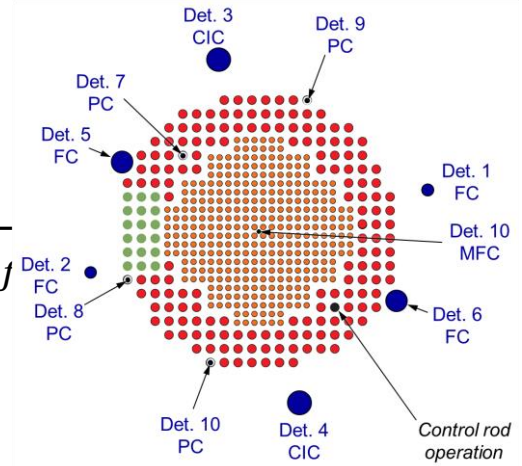
Relative noise magnifies the spatial component of the noise



# Quantities of Interest for validation

“Amplitude of the neutron population fluctuations relative to the fundamental mode distribution” at the detectors location

Power ratio:  $R_i = \frac{PSD_i}{PSD_{ref}}$

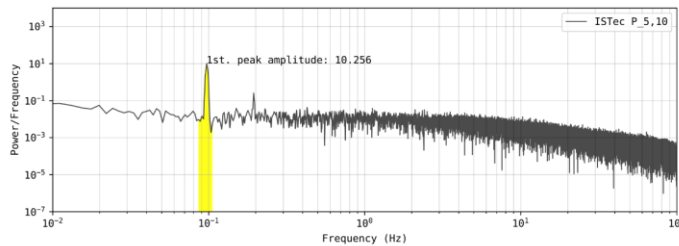


Make it relative

Time series + FFT

measurement and time-domain simulation

Cross/Auto Power Spectral Density



Frequency domain calculations

Amplitude

Relative peak power

Phase

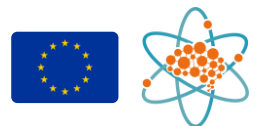
Phase at fundamental frequency

For a set of detectors



# Quantities of Interest for validation

- Power ratios are the main QoI in the validation exercises
  - One detector of reference
  - Filtering of the intrinsic detector noise is guaranteed nonetheless
  - Avoid issues related to FFT normalization
- Power ratios are based on the relative noise amplitude and phase at the detector location.
  - Consistent with experimental time series (t.s.) when the mean is subtracted and the resulting t.s. divided by the mean
- Focus on the frequency of perturbation (base, fundamental,  $\omega_0$ , etc...)



# Summary

- Goal #1 is to detect possible biases
- Goal #2 is to demonstrate that our experimental facilities are relevant for the project
- Workshop does not represent a final product, work is still on-going
- Experimental data analysis has started but has not completed yet
  - About 50% of the data has been considered so far
  - Tools are in place and should allow meaningful conclusions before the end of the project.
- Today we talk about AKR-2; tomorrow CROCUS



# Thank you

