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Making Virtual a Reality: Advancements in Reactor Physics
to Leap Forward Reactor Operation and Deployment

Simulation of neutron noise in the research reactor AKR-2: comparison between a discrete ordinates and a diffusion-based method

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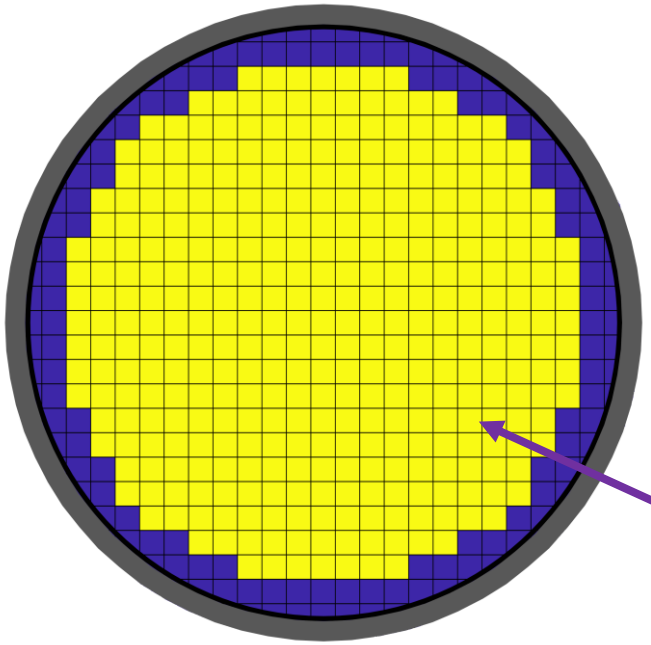
Outline

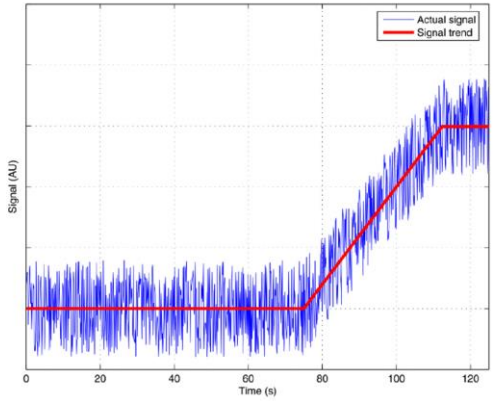
- Background
- Neutron noise solvers: CORE SIM+ and NOISE-SN
- AKR-2 and neutron noise experiments
- Comparison between CORE SIM+ and NOISE-SN
- Conclusions

Background (I)

- Neutron noise for core monitoring and diagnostics



in-core and ex-core neutron flux measurements



Identification and localization of perturbations

Analysis of neutron noise

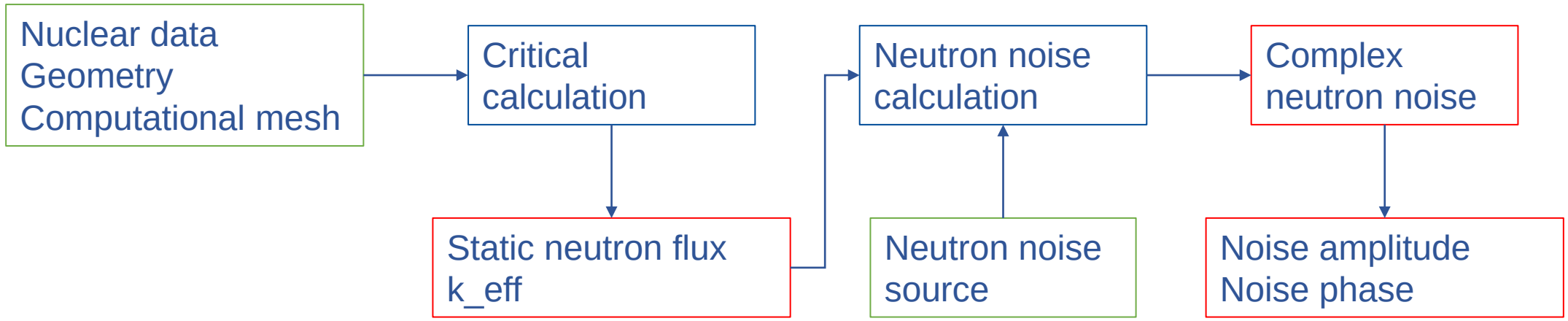
Modelling of the reactor transfer function

Background (II)

- Modelling of the reactor transfer function & simulations
  - Diffusion-based methods
    - Usual choice for reactor neutron noise applications
  - Higher-order neutron transport methods
    - Reference solutions
- Validation data from experiments in research reactors
  - Known perturbation, neutron noise measurements

Neutron noise solvers (I)

- CORE SIM+ and NOISE-SN developed at Chalmers
  - First-order perturbation theory
  - Neutron noise calculations in the frequency domain

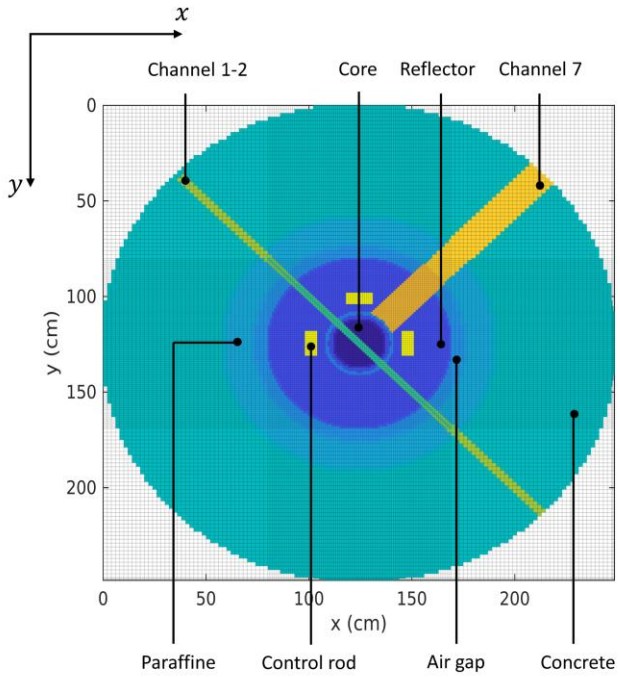


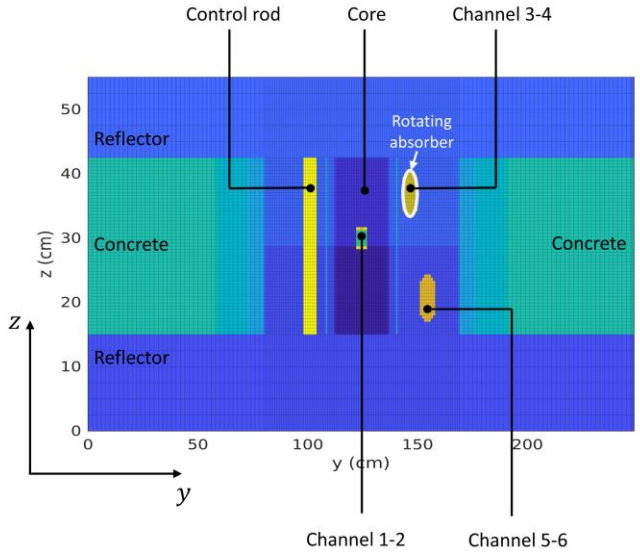
Neutron noise solvers (II)

- CORE SIM+
  - Diffusion theory
  - Finite differences
  - Two-energy group
  - Numerical methods for fine-mesh simulations
  - Green's function method for generation of neutron noise databases
- NOISE-SN
  - Discrete ordinates method
  - Diamond finite differences
  - Multi-energy group
  - Chebyschev-Legendre quadrature
  - CMFD acceleration

AKR-2 and neutron noise experiments (I)

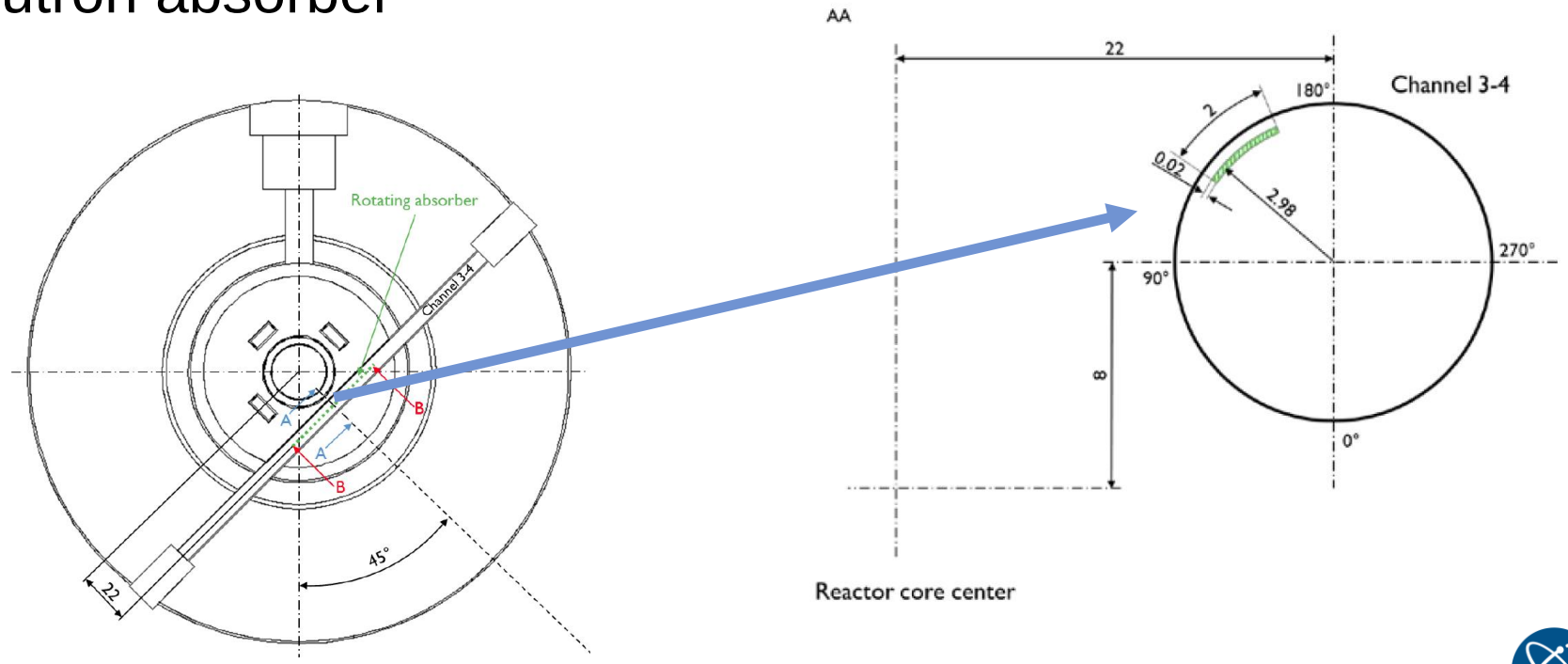
- AKR-2 at Technical University of Dresden
  - Zero-power reactor, small core, uranium oxide (U-235, 19.8%), strong heterogeneities





AKR-2 and neutron noise experiments (II)

- Neutron noise experiments to produce code validation data
  - Neutron absorber of variable strength (AVS)
  - Vibrating neutron absorber



Figures courtesy of TUD

Comparison between CORE SIM+ and NOISE-SN (I)

- Simulation of an experiment with AVS in AKR-2
  - Can CORE SIM+ reproduce properties of the induced noise in AKR-2?
  - How different are CORE SIM+ and NOISE-SN solutions?

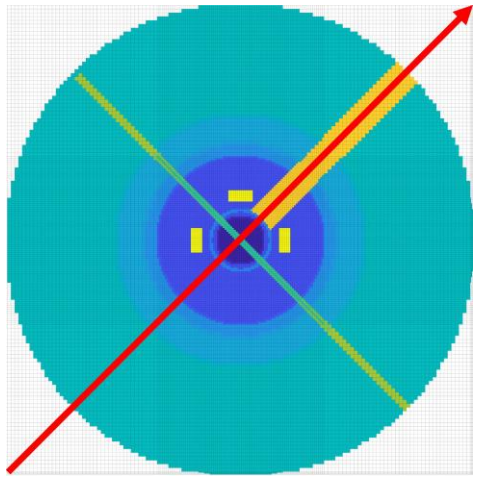
Comparison between CORE SIM+ and NOISE-SN (II)

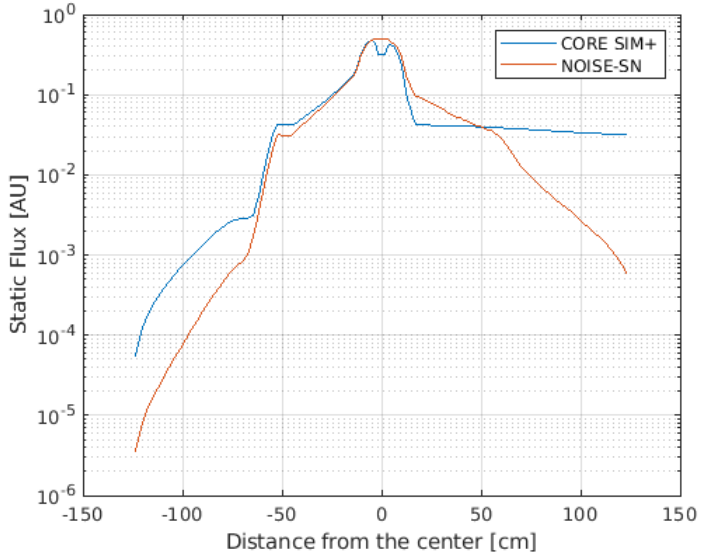
- Same spatial discretization
- Same macroscopic cross sections
  - Monte Carlo Serpent model (courtesy of TUD)
  - ENDF/B-VII nuclear data libraries

  - 2-energy group, homogenized set, with isotropic scattering
- Same neutron noise source
- k_eff = 0.96344 for CORE SIM+ and 1.02190 for NOISE-SN

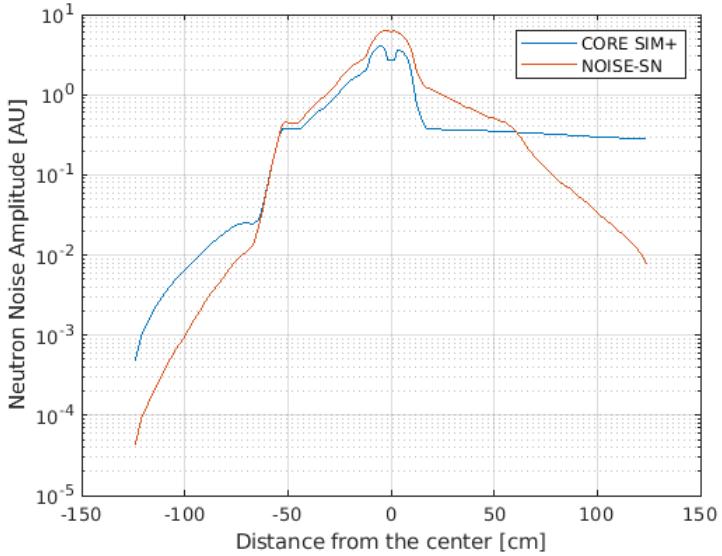
Comparison between CORE SIM+ and NOISE-SN (III)

- Thermal group, P-K behavior, effect of large heterogeneities





Static flux



Noise amplitude

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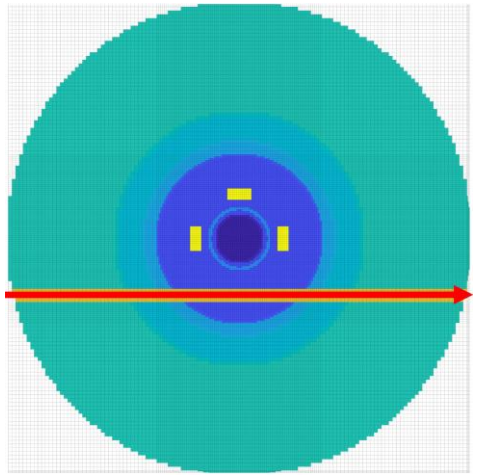
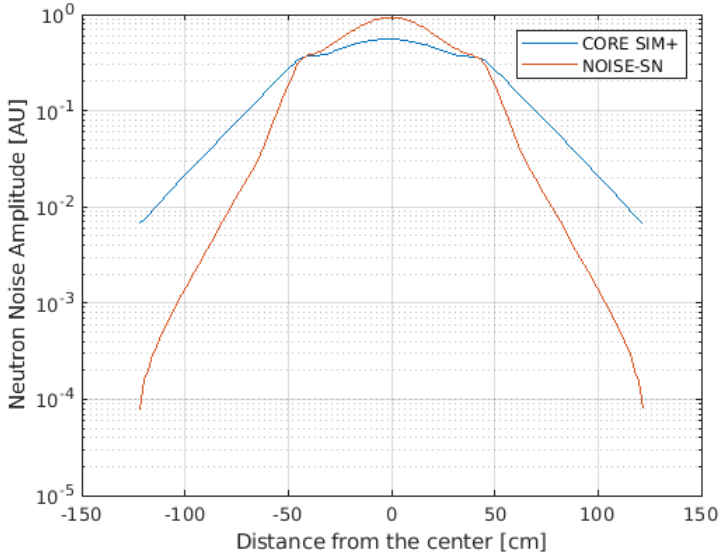
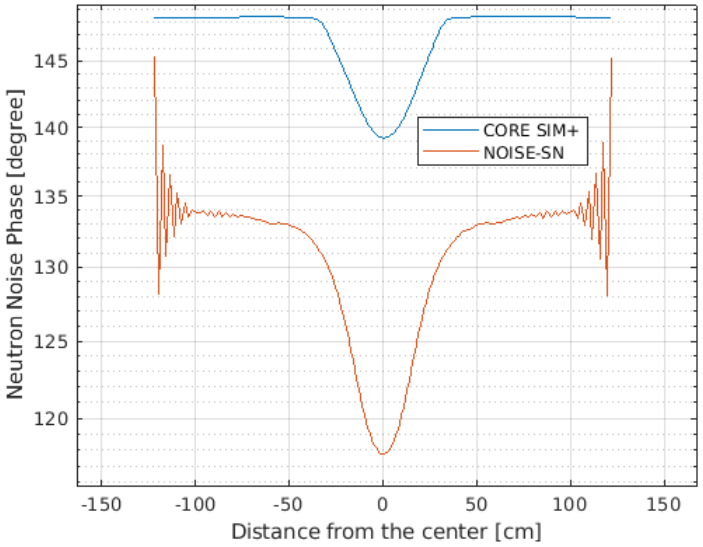
Comparison between CORE SIM+ and NOISE-SN (IV)

- Channel with detectors, thermal group





Noise amplitude



Noise phase

Conclusions

- Simulation of neutron noise in the zero-power reactor AKR-2
  - Neutron absorber of variable strength
- Comparisons between diffusion and discrete ordinates
  - Large discrepancies because of strong material variations and regions with low macroscopic cross sections
  - How much do these discrepancies count when comparing with measurements?
- Future work
  - Impact of order of discrete ordinates (ray effect)
  - Transport calculations with multi-energy group and anisotropic scattering
  - ‘Correction’ of the nuclear data for the diffusion solver
  - Comparison with measurements …

CORTEX

Core monitoring techniques and experimental validation and demonstration

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Thank you!

Questions?