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Comparison of neutron noise solvers based on numerical benchmarks in a 2-D simplified UOX fuel assembly

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- T. Yamamoto
  - Kyoto University

Outline

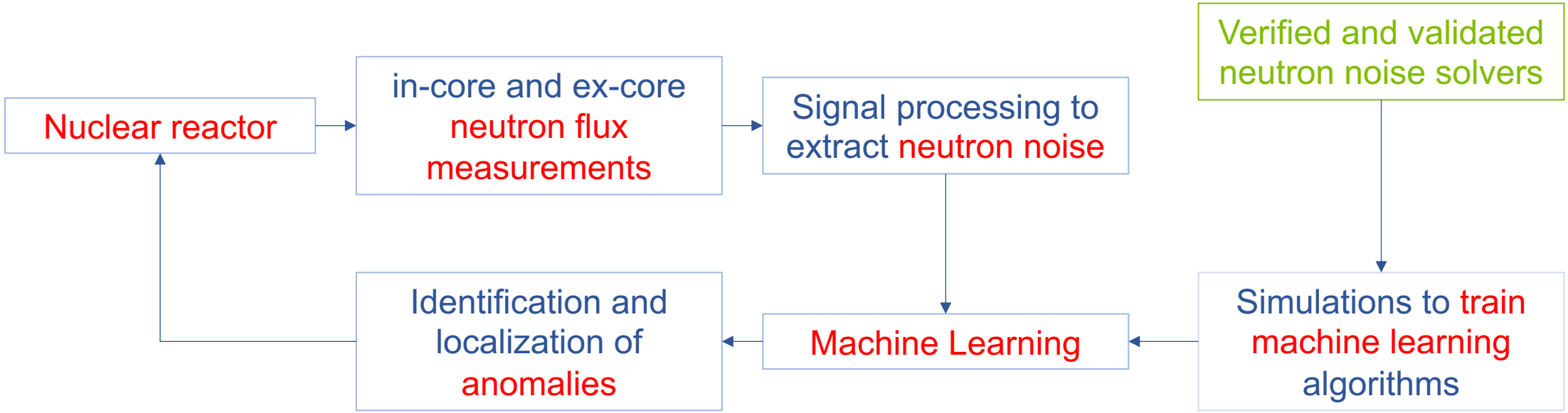
- Background
- Benchmarks
- Results
- Conclusions

Comparison of neutron noise solvers …

- Background

Background

- CORTEX neutron noise-based core monitoring methodology



Background

- Some of the neutron noise solvers developed and used in CORTEX

- Monte Carlo transport
  - TRIPOLI-4®
  - MC solver developed by KyotoU

- Deterministic transport
  - APOLLO3® (frequency-domain IDT solver)
  - NOISE-SN

- Diffusion
  - CORE SIM+
  - FEMFFUSION (time-dependent solver)

Background

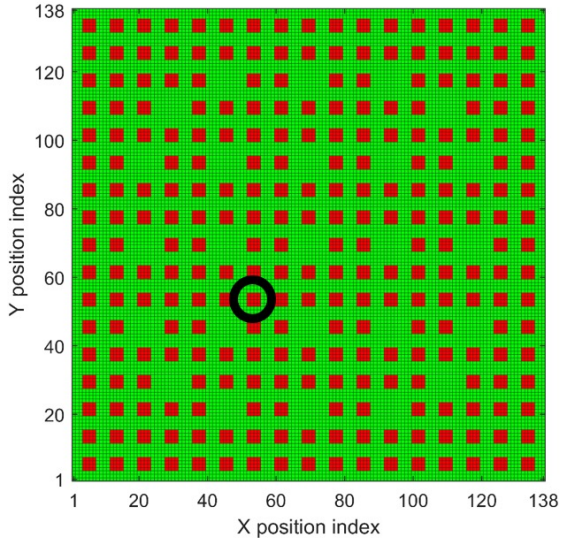
- Two numerical neutron noise benchmarks in a simplified fuel assembly to
  - Verify correct implementation of the solvers
  - Compare solvers based on different transport approximations
  - Generate reference solutions

Comparison of neutron noise solvers …

- Benchmarks

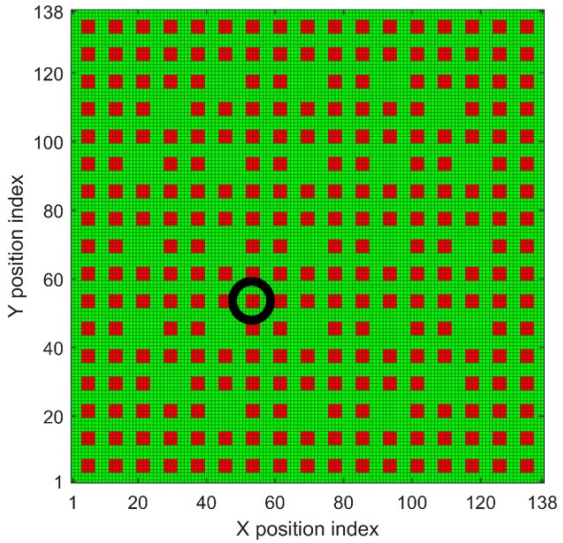
Benchmarks

- Simplified UOX fuel assembly
  - 2-D system, 21.58 cm x 21.58 cm
  - 264 homogeneous square pins
  - 25 water holes
  - Reflective boundary conditions
  - 2 energy-group macroscopic cross sections
    - Isotropic scattering



Benchmarks

- Exercise 1
  - Fast neutron noise source = 0
  - Thermal neutron noise source = $-1 + i$



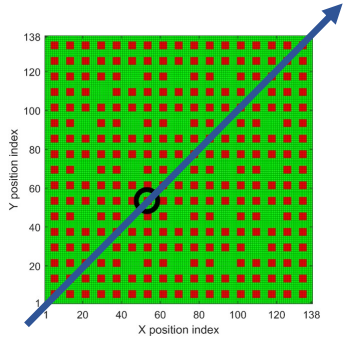
- Exercise 2
  - $\Sigma_{t,g} = \Sigma_{t,g,0} + \delta\Sigma_{t,g} = \Sigma_{t,g,0} + 0.041\Sigma_{t,g,0}\cos(\omega_0 t)$
  - $\Sigma_{s,g\to g\prime} = \Sigma_{s,g\to g\prime,0} + \delta\Sigma_{s,g\to g\prime} = \Sigma_{s,g\to g\prime,0} + 0.034\Sigma_{s,g\to g\prime,0}\cos(\omega_0 t)$
  - $\Sigma_{f,g} = \Sigma_{f,g,0} + \delta\Sigma_{f,g} = \Sigma_{f,g,0} + 0.021\Sigma_{f,g,0}\cos(\omega_0 t)$

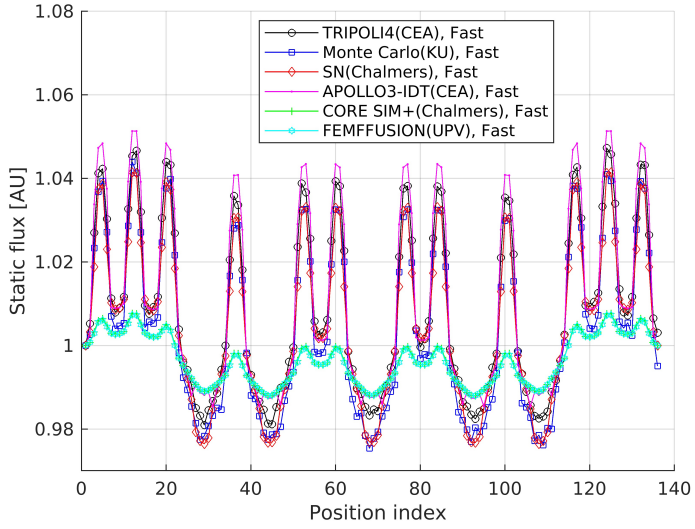
Comparison of neutron noise solvers …

- Results

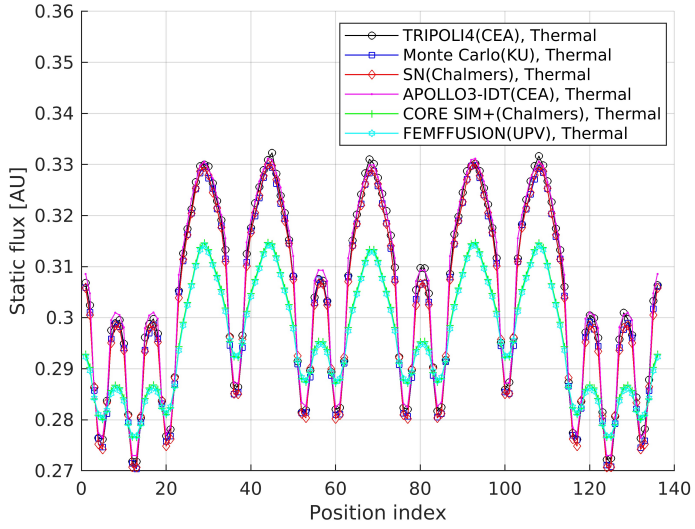
Results

- Static neutron flux and k_{eff}





Fast flux

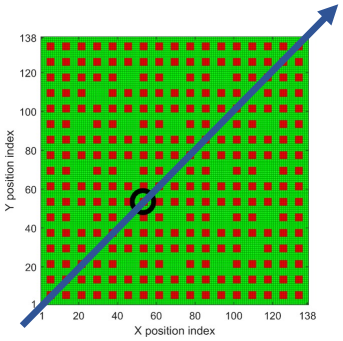


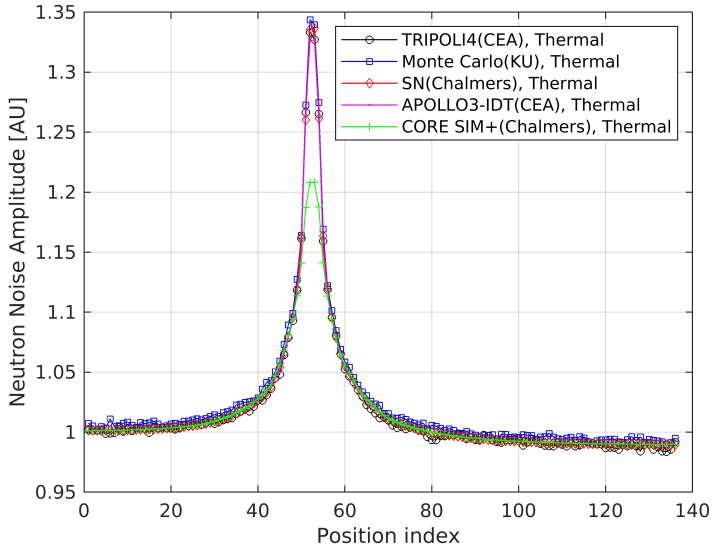
Thermal flux

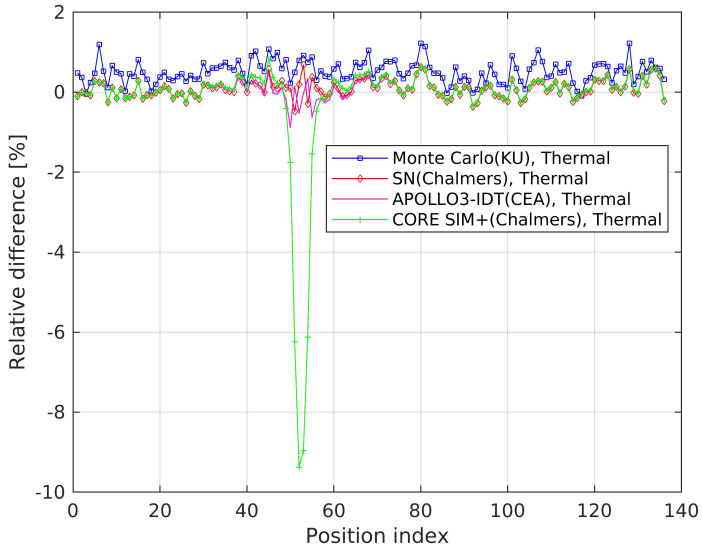
Solvers	k_{eff}	Difference [pcm]
TRIPOLI-4®	0.99912 ± 8 pcm	Reference
KU Monte Carlo solver	0.99919 ± 7 pcm	7
APOLLO3®	0.99784	-128
NOISE-SN	0.99996	84
CORE SIM+	1.01309	1397
FEMFFUSION	1.01367	1485

Results

- Exercise 1
  - Relative thermal neutron noise amplitude
  - Relative differences with respect to TRIPOLI-4







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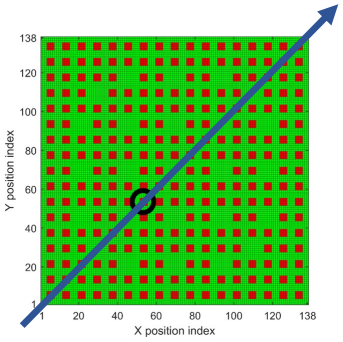
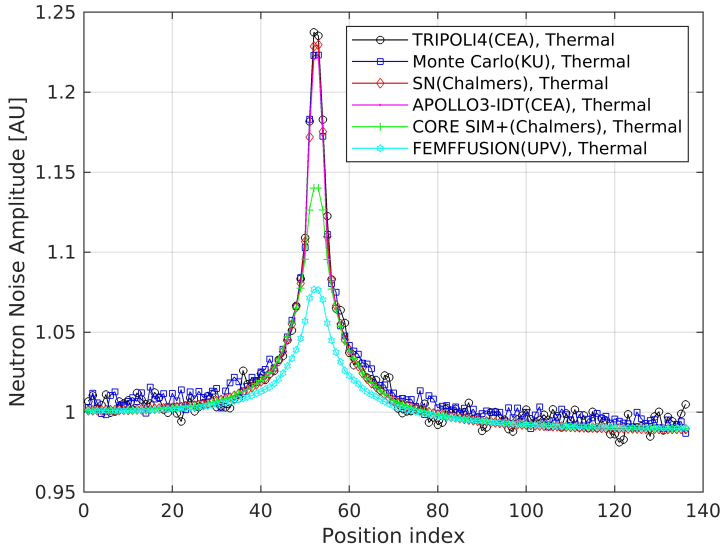
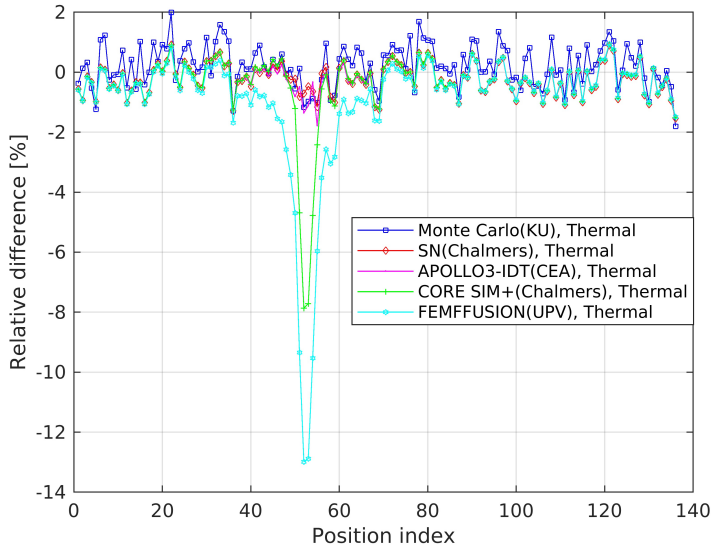
Results

- Exercise 2
  - Relative thermal neutron noise amplitude
  - Relative differences with respect to TRIPOLI-4







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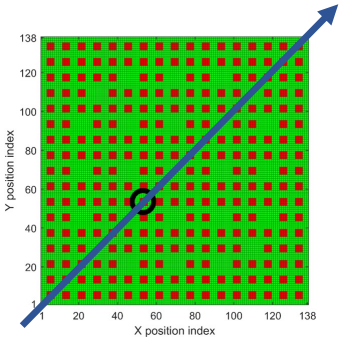
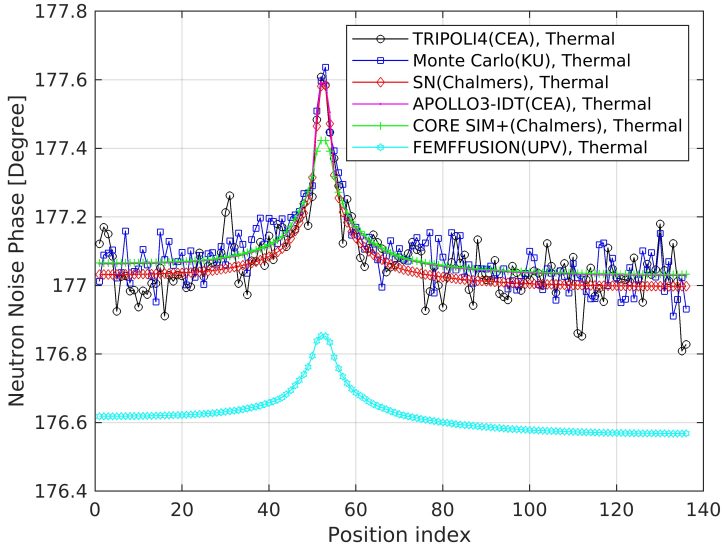
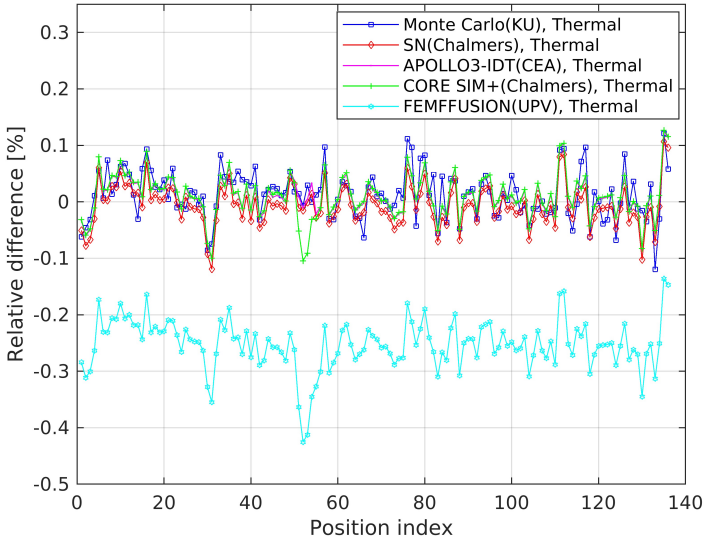
Results

- Exercise 2
  - Thermal neutron noise phase
  - Relative differences with respect to TRIPOLI-4







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Comparison of neutron noise solvers …

- Conclusions

Conclusions

- Different transport approximations for neutron noise simulations were compared
  - Similar results from the Monte Carlo and the deterministic higher-order transport solvers
  - Diffusion-based solvers show discrepancies close to the neutron noise source
- Next: benchmarks with more complex neutron noise sources, e.g.,
  - Vibrations of fuel pins

Acknowledgments

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- TRIPOLI-4® and APOLLO3® are registered trademarks of CEA. B. Gasse, A. Rouchon and A. Zoia gratefully acknowledge partial financial support from EDF and Framatome.

Comparison of neutron noise solvers …

- Thank you for the attention!
- Questions?