Assessing and Enhancing SCALE Capabilities to Model Fast Neutron Spectrum Systems

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Generation of AMPX MG libraries for fast reactor systems

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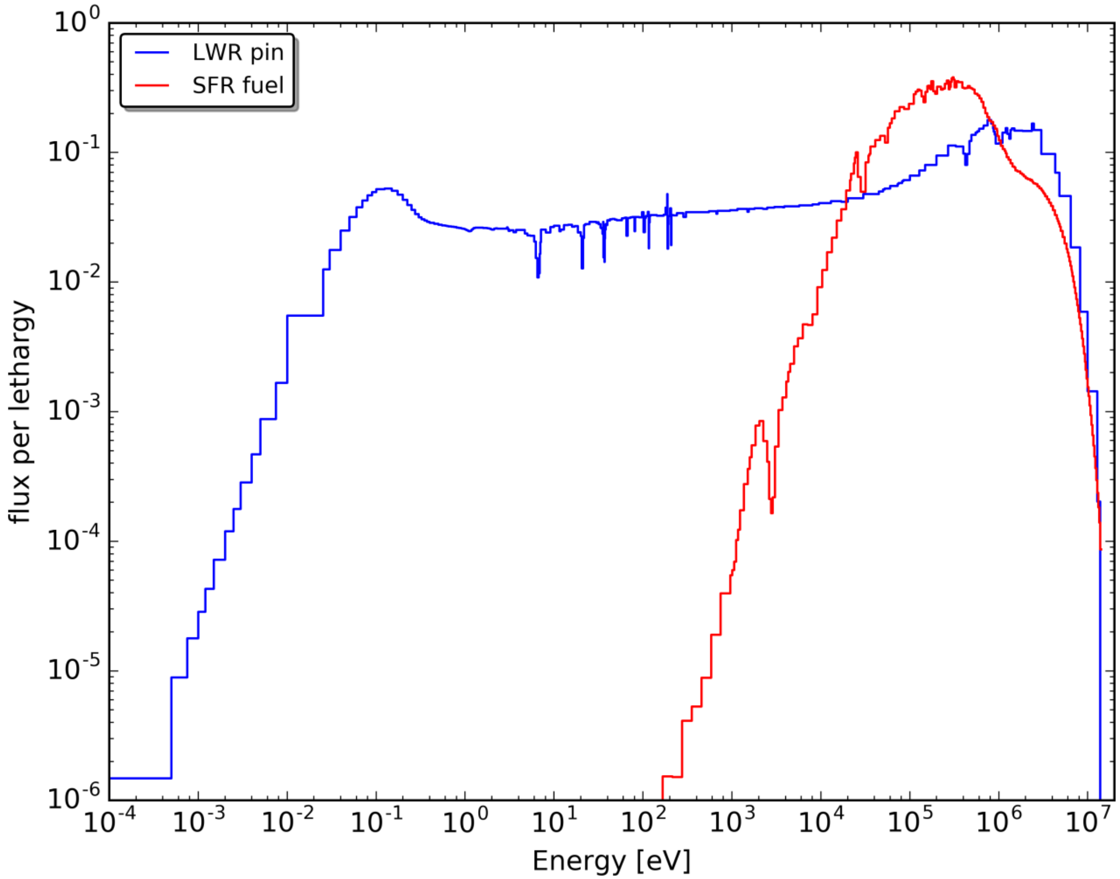
Outline

- Motivation and models of interest
- Generation of new AMPX MG libraries
- First results of criticality calculations
- First results of uncertainty calculations
- Summary and future work
- Acknowledgements

1. Motivation and models of interest

Why do we need another AMPX MG library for the analysis of fast reactor systems with SCALE?

Flux spectrum of typical LWR and SFR systems



Possible MG libraries in SCALE 6.2:

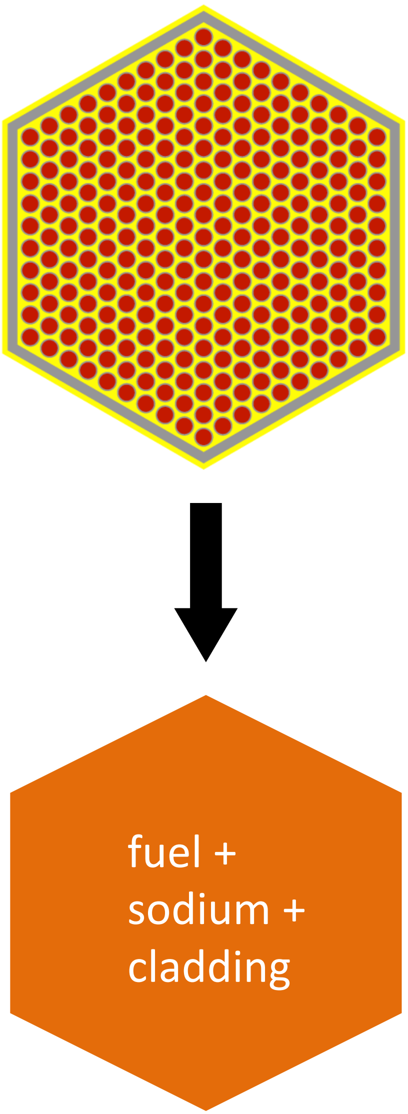
- 252g ENDF/B-VII.1
- 999g ENDF/B-VII.1

Investigated models: homogenized fuel assemblies

- Homogenization to avoid geometrical effects on results

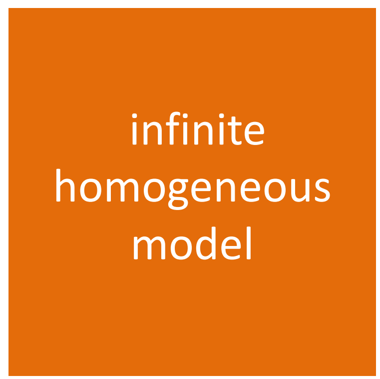
- Metallic fuel of MET1000:
  - 1000 MWth Advanced Burner Reactor
  - Proposed within the UAM SFR benchmark
  - Metallic driver fuel of the inner core zone
  - BOEC fuel: U/Pu/MA (U/TRU)

- Oxide fuel of MOX3600:
  - 3600MWth large oxide core
  - Proposed within the UAM SFR benchmark
  - Oxide driver fuel of the inner core zone
  - BOEC fuel: U/Pu/MA (U/TRU)

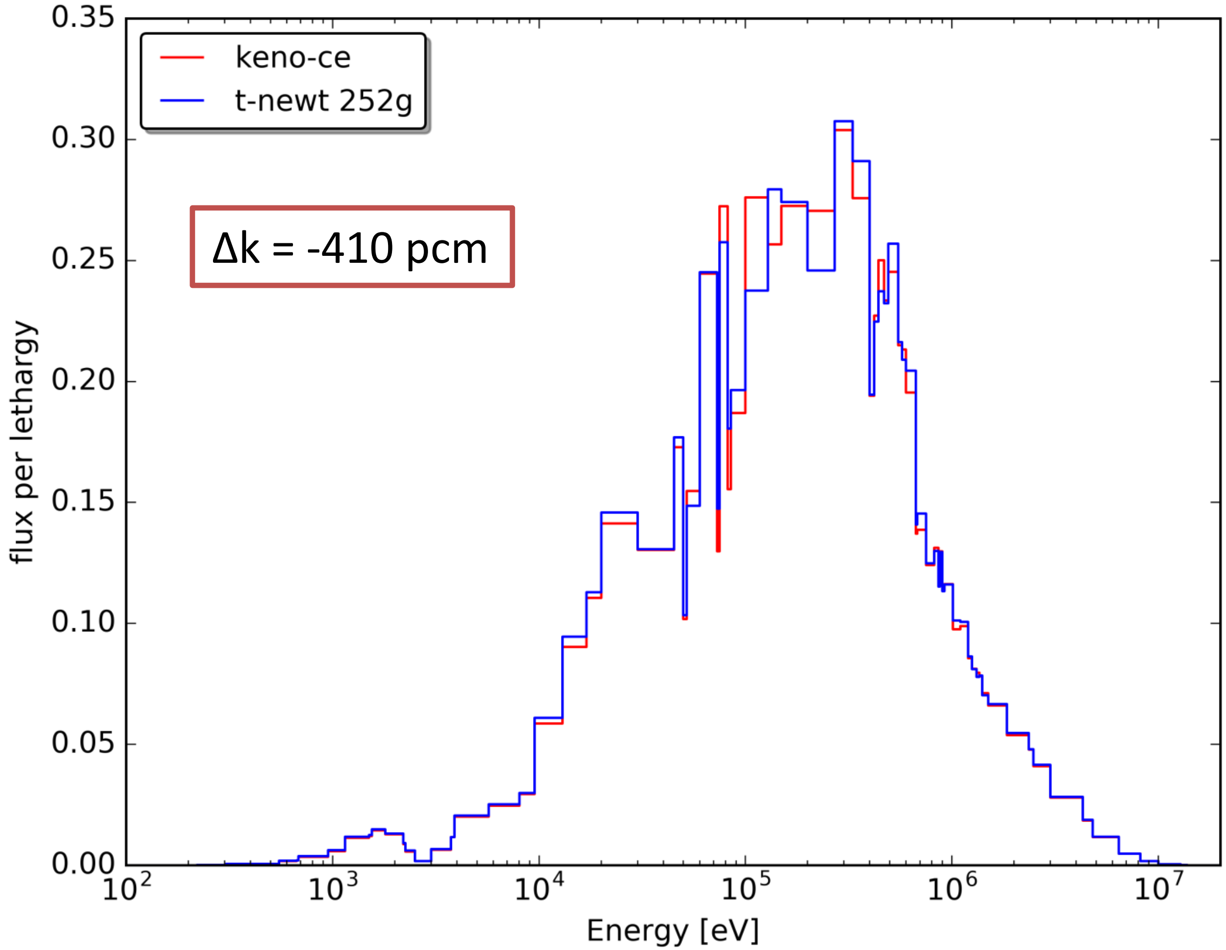


Utilized Codes

- Reference: KENO-CE (SCALE 6.2)
- Investigation of new MG libraries: T-NEWT (SCALE 6.2)



Comparison of KENO-CE and T-NEWT with the 252g library – MET1000



Comparison of the eigenvalues

	KENO-CE	T-NEWT 252g v7.1	T-NEWT 999g v7.1
MET1000	1.29389	1.28979 (-410 pcm)	1.29228 (-161 pcm)
MOX3600	1.19374	1.19699 (325 pcm)	1.19364 (-10 pcm)

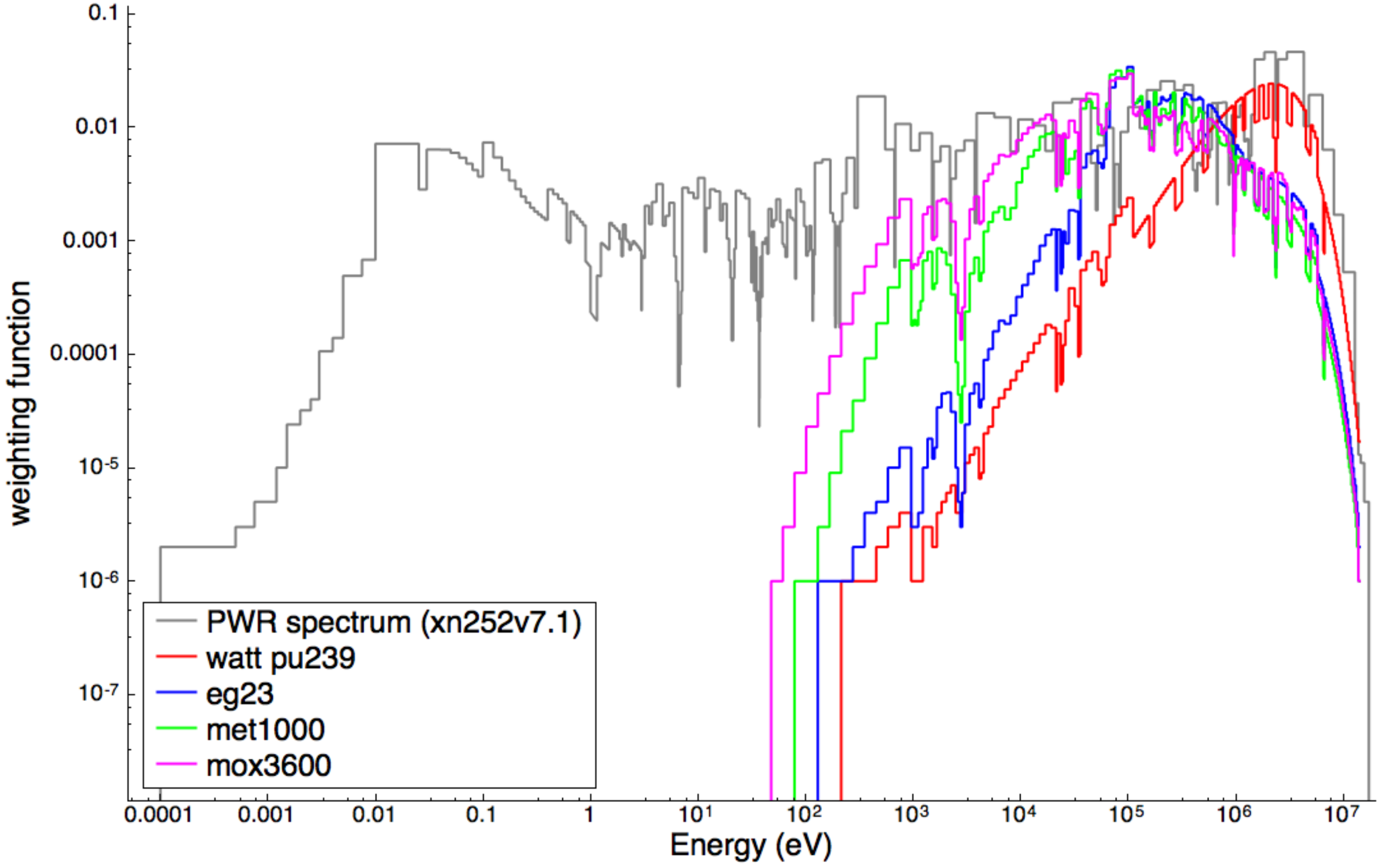
- The 252g library does not work well for the investigated fuel types
- The 999g library shows reasonable agreement; however, it is not an option for uncertainty calculations due to the long runtime
- We need another group structure for fast systems!

3. Generation of new AMPX MG libraries

MG structure and weighting spectrum

- Find suitable MG structure:
  - ANL group structures: 230g, 425g, 2082g
  - Based on 2082 equal lethargy bins between 0.414 eV and 14.191 MeV
  - Fine resolution for fast energies
  - E.g. only 13 groups up to 5 eV in 230g/425g structure compared to almost 100 in the 252g structure
- Find best weighting spectrum for the generation of MG cross sections:
  - Watt fission spectrum of Pu-239
  - Weighting spectra generated with CENTRM using the investigated homogenized fuel assemblies (MET1000, MOX3600)

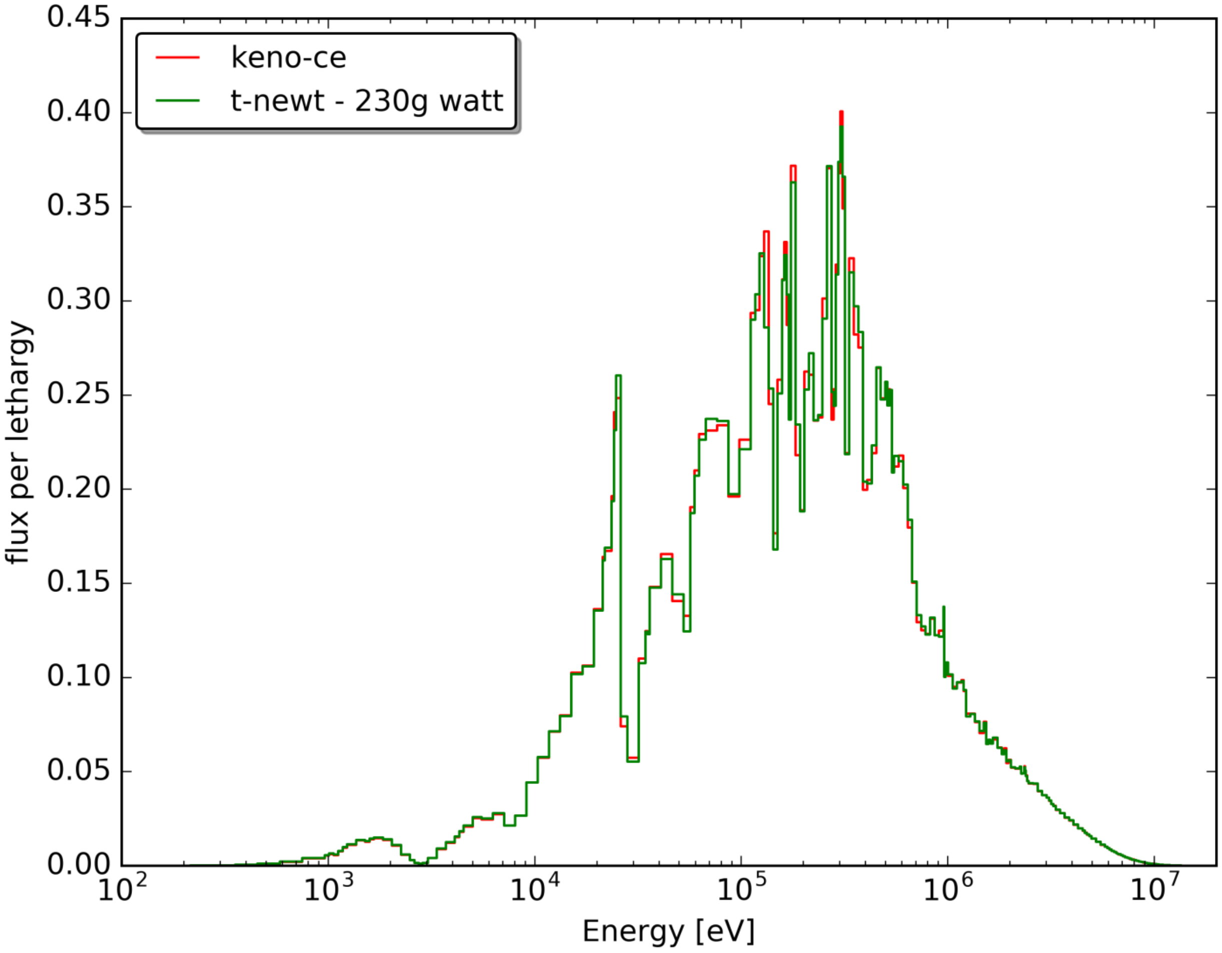
Considered weighting spectra



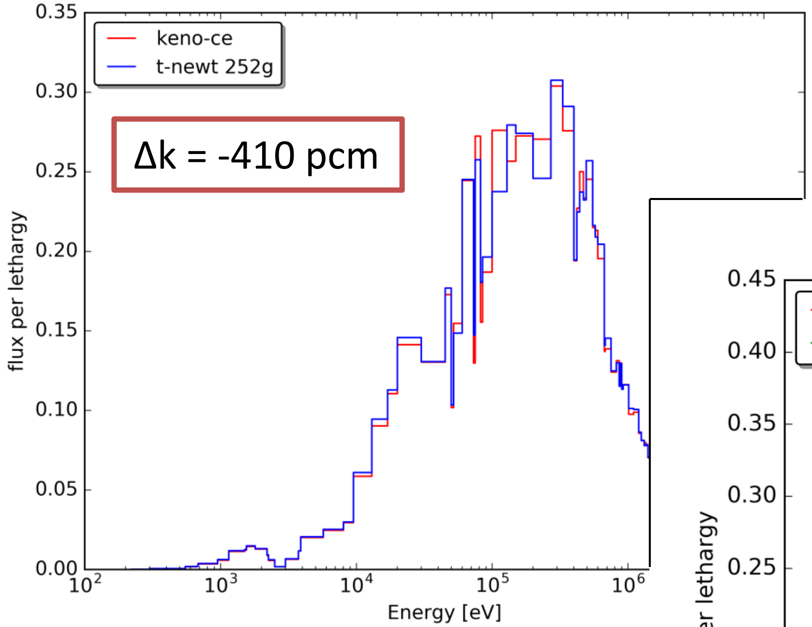
Oak Ridge National Laboratory GRS

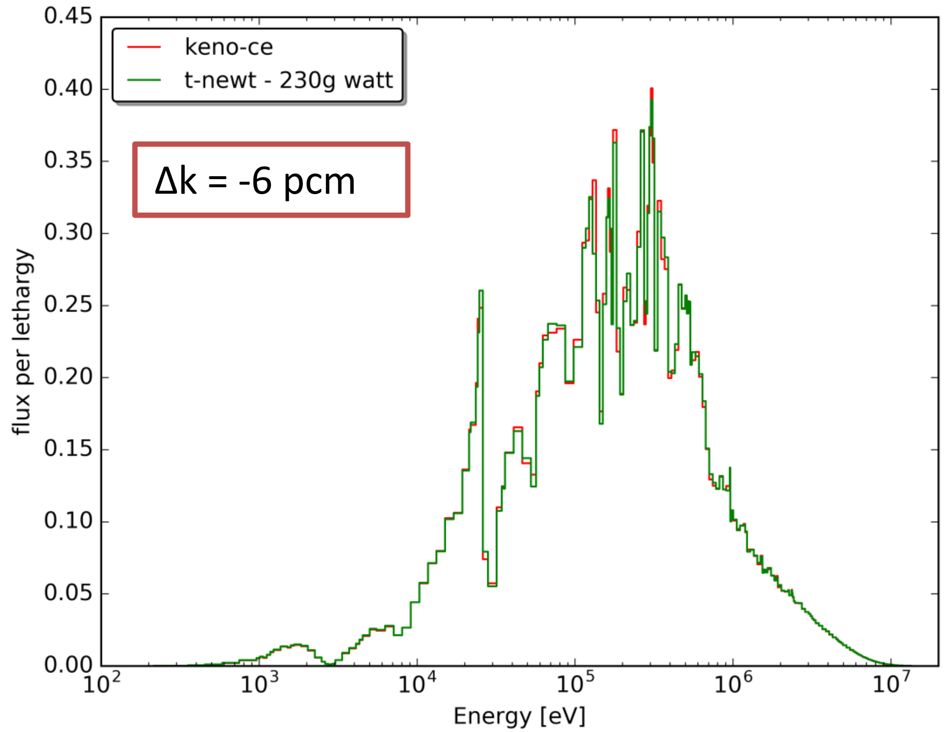
4. First results of criticality calculations

First comparison with 230g structure – MET1000

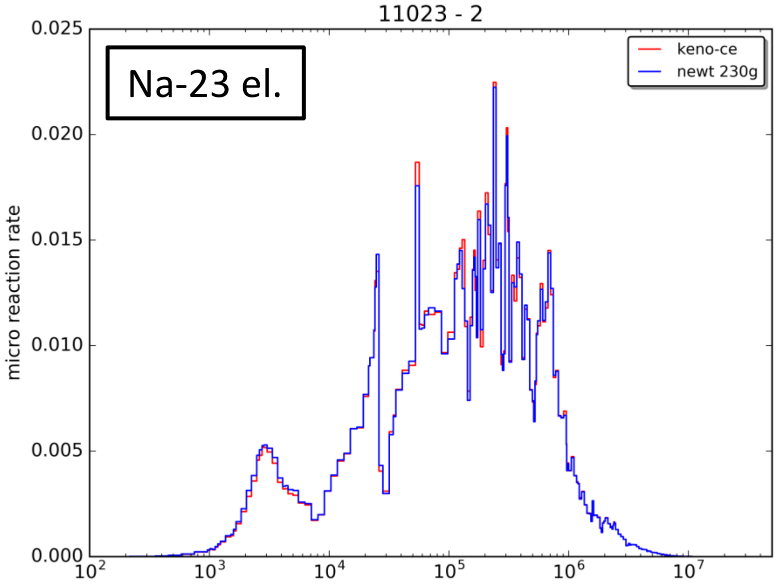


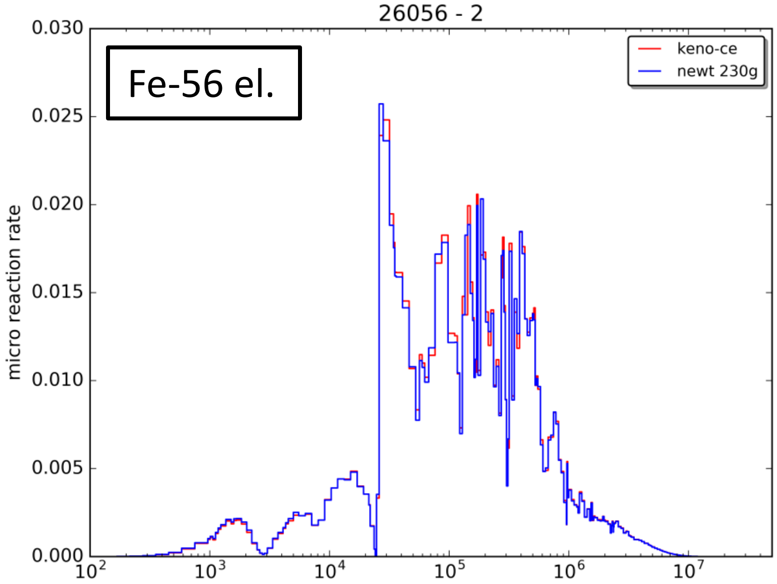
First comparison with 230g structure – MET1000

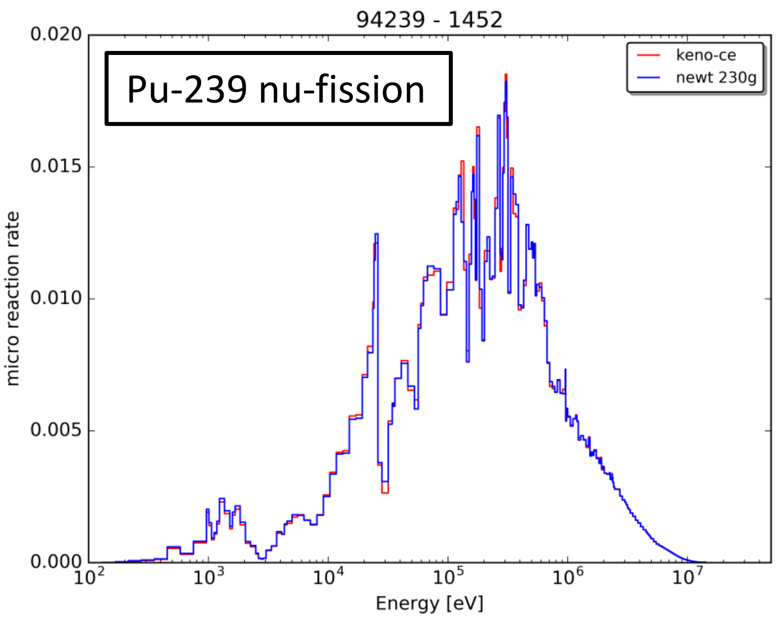


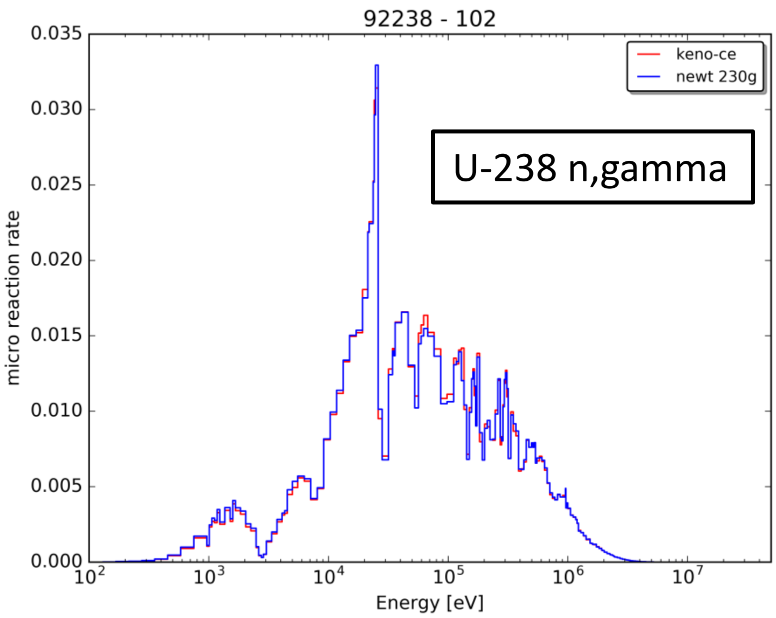


First comparison with 230g structure – MET1000

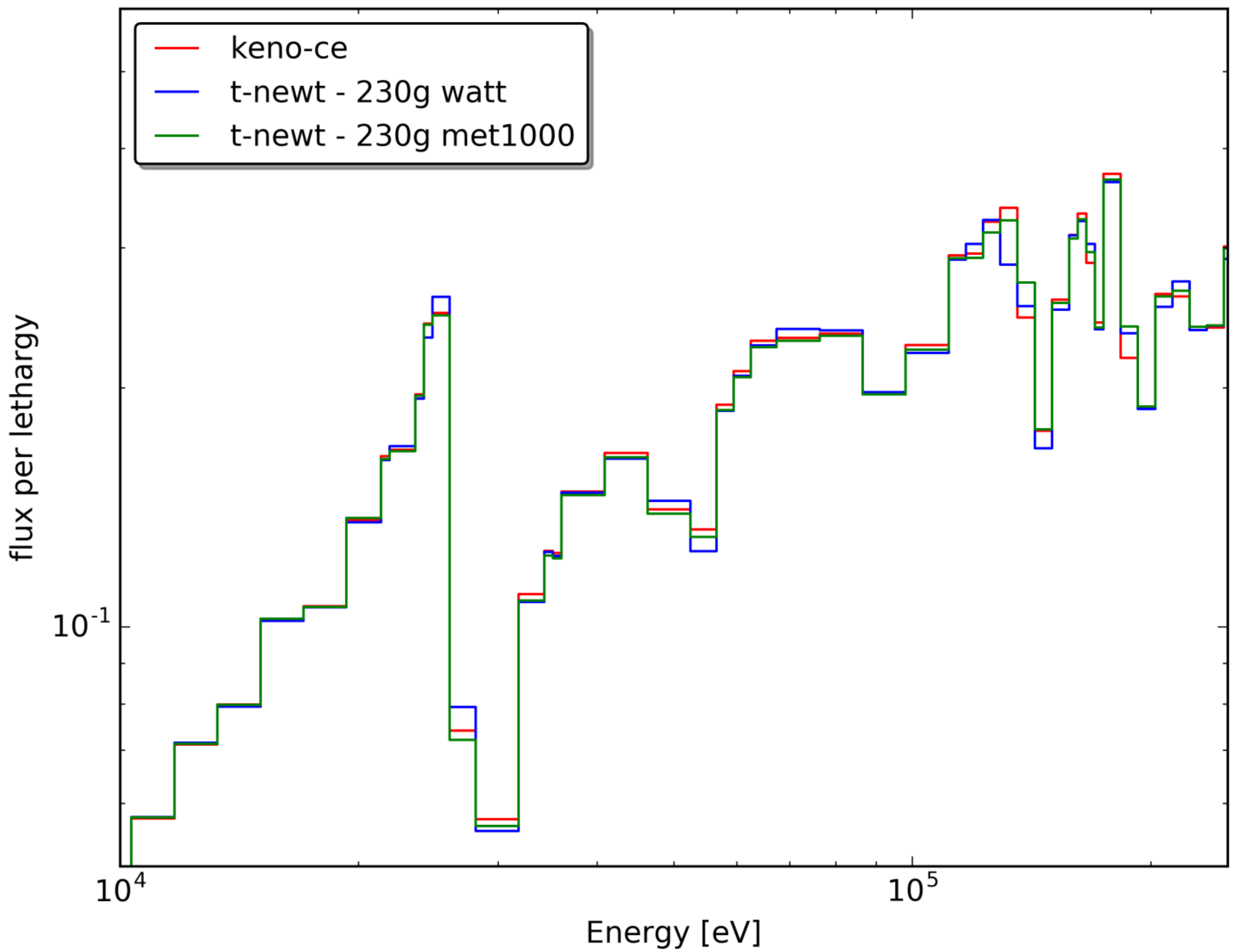








Influence of different weighting spectra – MET1000



watt	Δk=-6 pcm
met1000	Δk=-158 pcm

Overview of MET1000 (U/TRU) calculations

		k-inf	Δk [pcm]
KENO-CE	ENDF/B-VII.1	1.29389(10)	(ref)
T-NEWT	252g v7.1	1.28979	-410
T-NEWT	999g v7.1	1.29228	-161
T-NEWT	230g v7.1 – watt	1.29383	**-6**
T-NEWT	230g v7.1 – met1000	1.29547	**-158**
T-NEWT	425g v7.1 – watt	1.29248	-141
T-NEWT	2082g v7.1 – watt	1.29252	**-137**

Overview of MOX3600 (U/TRU) calculations

		k-inf	Δk [pcm]
KENO-CE	ENDF/B-VII.1	1.19374(11)	(ref)
T-NEWT	252g v7.1	1.19699	325
T-NEWT	999g v7.1	1.19364	-10
T-NEWT	230g v7.1 – watt	1.19576	**202**
T-NEWT	230g v7.1 – mox3600	1.19526	**152**
T-NEWT	245g v7.1 – watt	1.19486	113
T-NEWT	245g v7.1 – mox3600	1.19455	81
T-NEWT	253g v7.1 – mox3600	1.19423	49
T-NEWT	425g v7.1 – watt	1.19376	3
T-NEWT	2082g v7.1 – watt	1.19362	**-12**

5. First results of uncertainty calculations

Uncertainty analysis

- Requirements:
  - Generation of 230g covariance library
  - Weighting function: watt fission spectrum
  - Reference for uncertainty calculations: TSUNAMI-CE calculations

Uncertainty analysis of MET1000

	XS lib	Cov lib	% Δk/k	Δ(% Δk/k)
TSUNAMI-CE	ENDF/B-VII.1	56g	1.4352(12)	(ref)
TSUNAMI-CE	ENDF/B-VII.1	230g	1.4358(12)	0.0006
TSUNAMI-MG*	230g v7.1 - watt	230g	1.4308(6)	-0.0044
TSUNAMI-MG*	230g v7.1 – met1000	230g	1.4285(6)	-0.0067
TSUNAMI-MG*	425g v7.1 - watt	230g	1.4345(4)	-0.0007

*meaning TSUNAMI-3D-K6 with MG

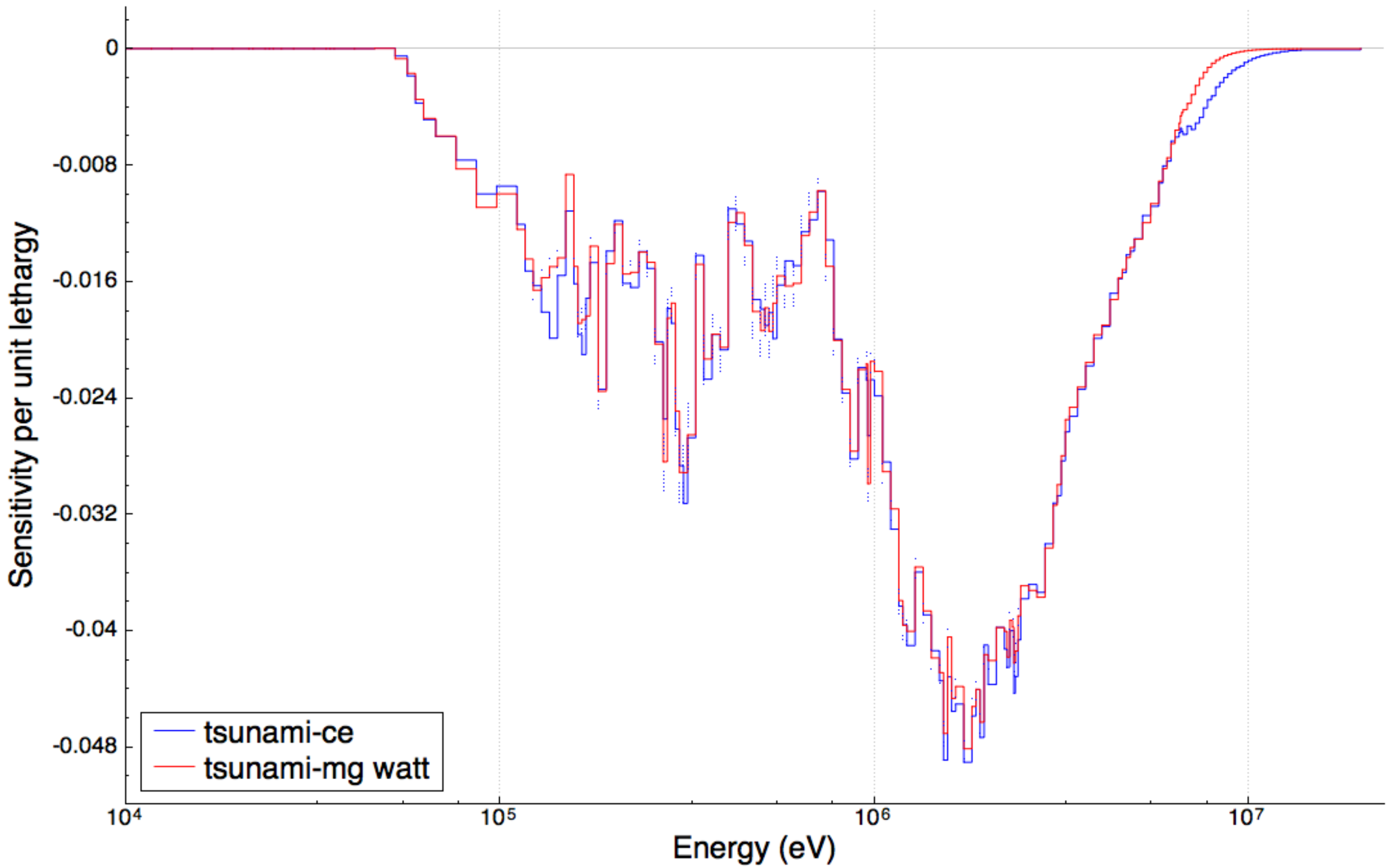
→ Simplified group structure for covariance data might be sufficient

Uncertainty analysis of MET1000

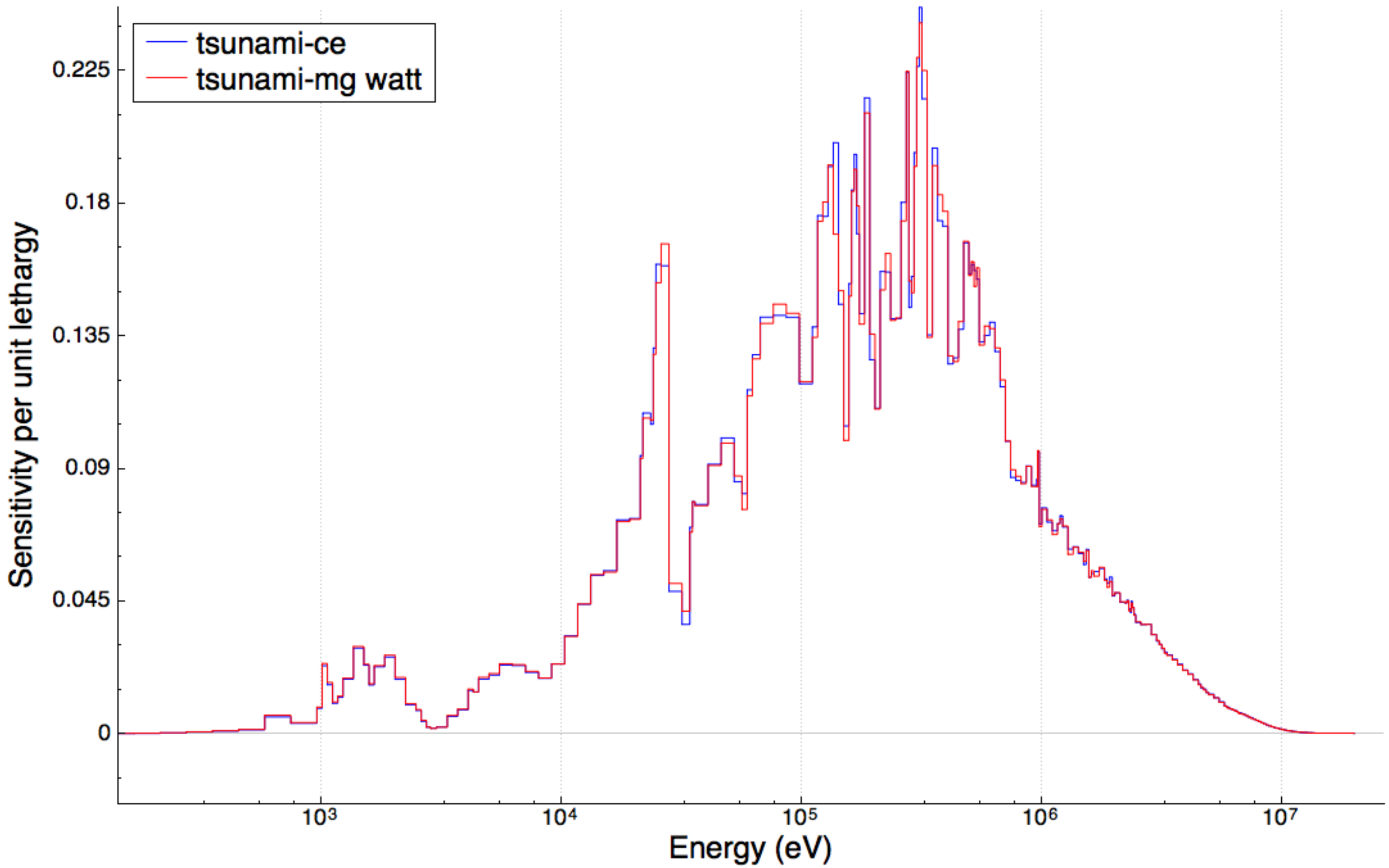
Top contributors to the uncertainty in k-inf:

nuclide-reaction		covariance matrix with	nuclide-reaction		% Δk/k due to this matrix
u-238	n,n'		u-238	n,n'	1.2053(9)
na-23	elastic		na-23	elastic	0.3242(2)
fe-56	elastic		fe-56	elastic	0.2590(3)
u-238	n,gamma		u-238	n,gamma	0.2435(1)
fe-56	n,n'		fe-56	n,n'	0.2388(1)

Sensitivities as a function of energy – U-238 n,n'



Sensitivities as a function of energy – Pu-239 nubar



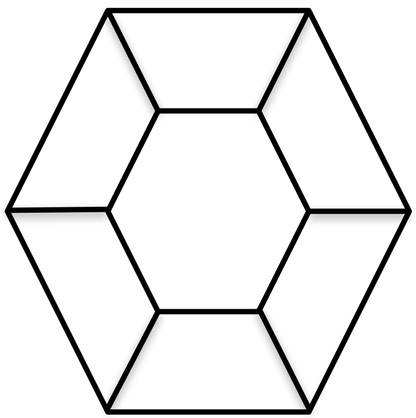
6. Summary and future work

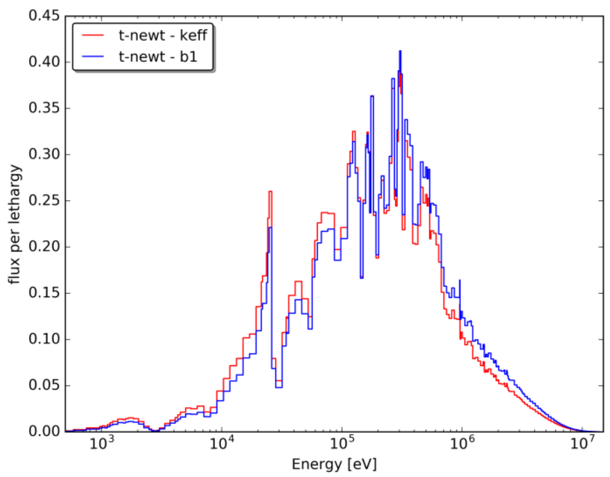
Summary

- The present fine-group cross section libraries are not optimal for fast systems
- A 230g structure with watt fission spectrum as weighting function generates reasonable agreement with reference in criticality and uncertainty calculations
- Results with 425g and 2082g are similar; a finer groups structure might therefore not be necessary
- Group structure of the covariance data has minor influence on uncertainty result

Future work

- 1) Generation of few-group xs with TRITON for use in nodal codes and 2) uncertainty calculations:
  - different fine-group libraries
  - homogeneous vs. heterogeneous fuel assemblies
  - different super-cells
  - leakage correction via B1 method
- Investigation of simplified group structure of covariance data on uncertainty quantification
- Systematic uncertainty analyses (fuel pin, assembly, full core)
- Calculation of full cores of the UAM SFR benchmark





Acknowledgements

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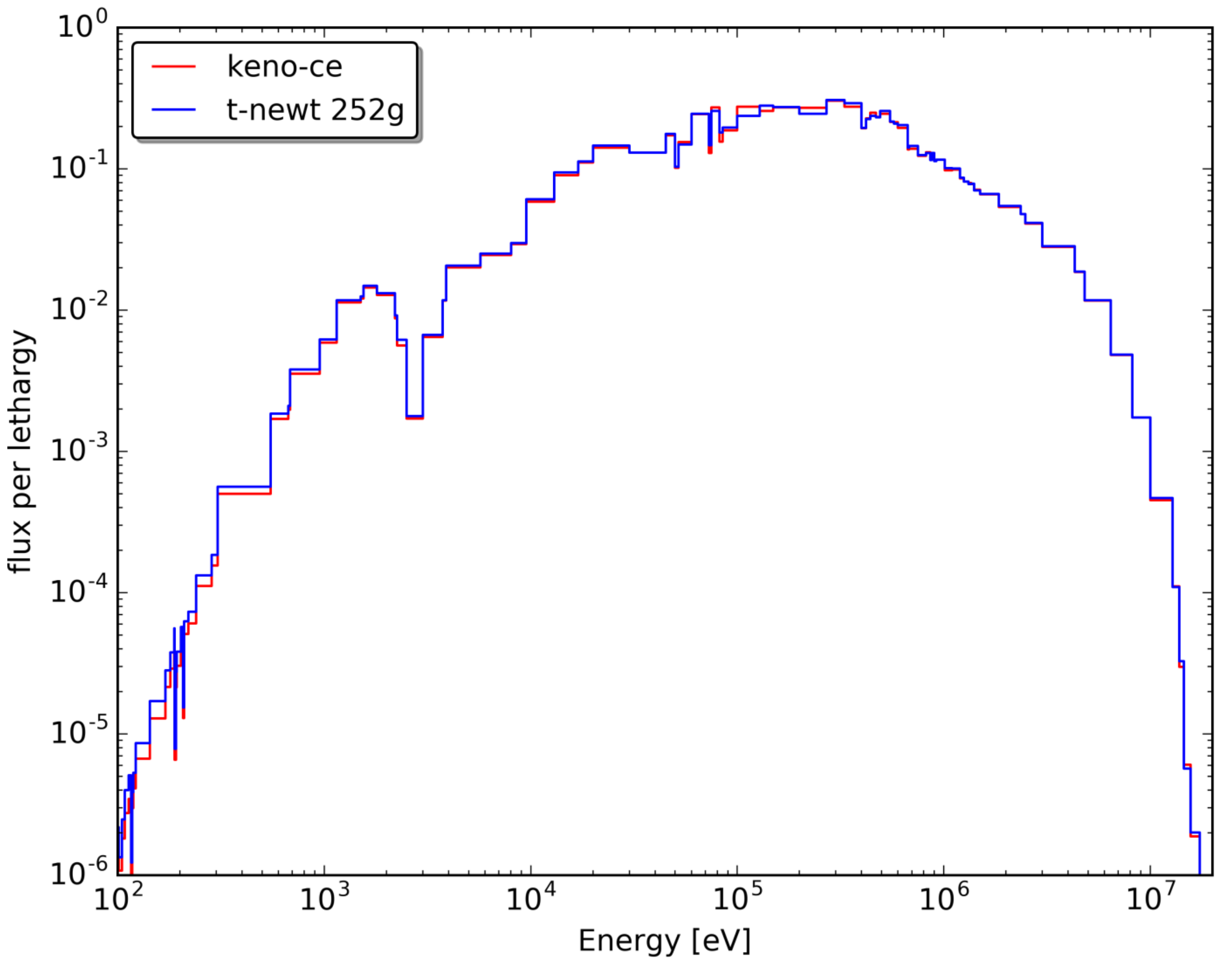
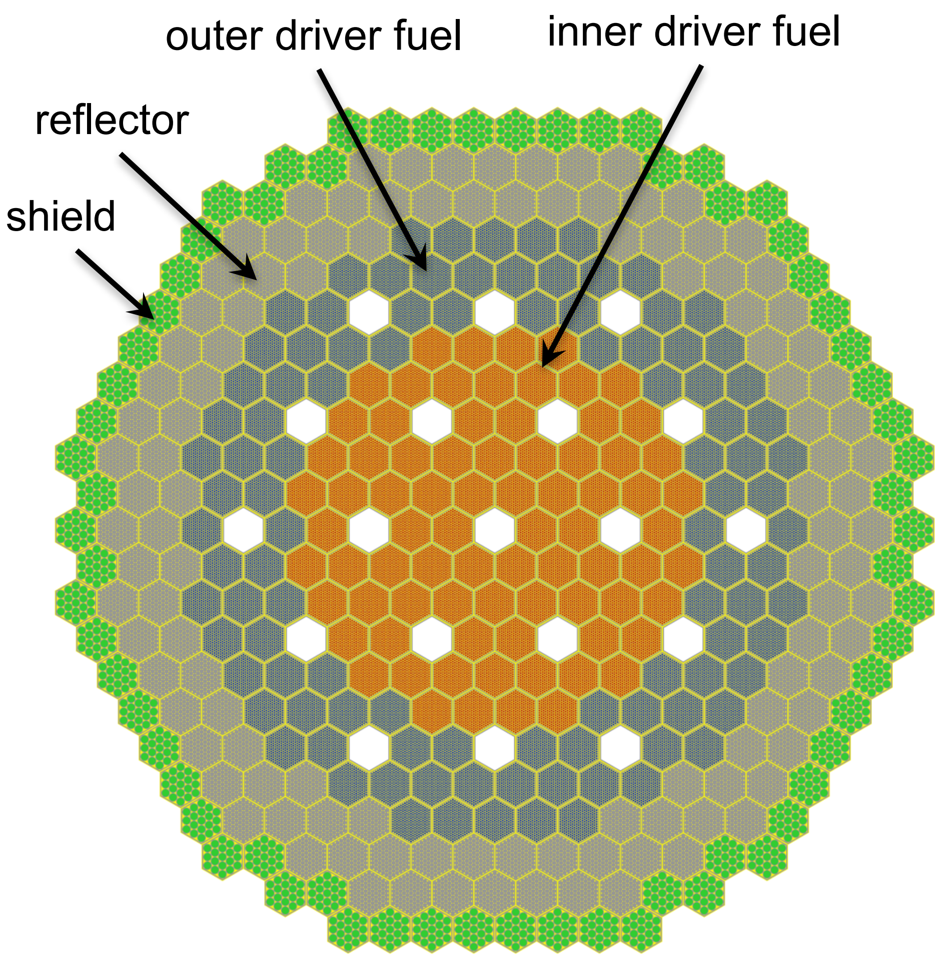
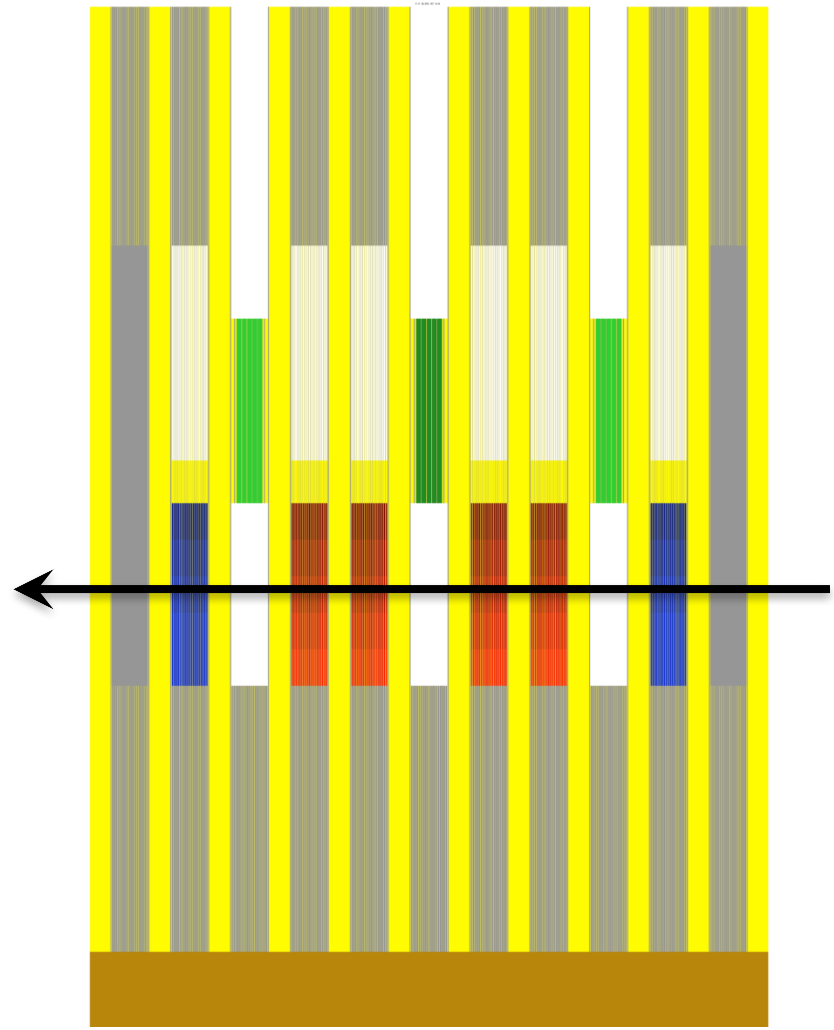
Comparison of KENO-CE and T-NEWT with the 252g library – MET1000



Investigated models – MET1000

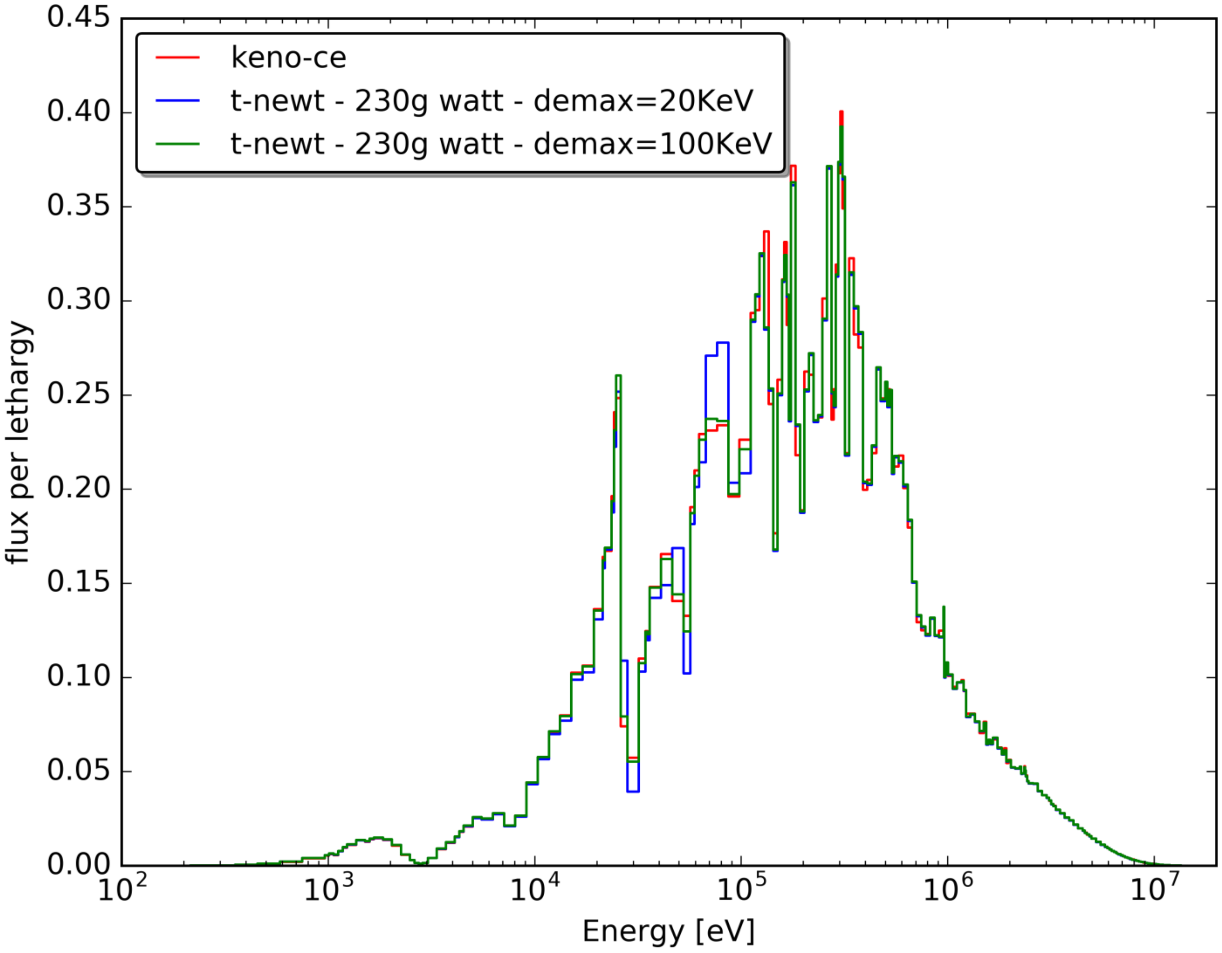


xy – plane

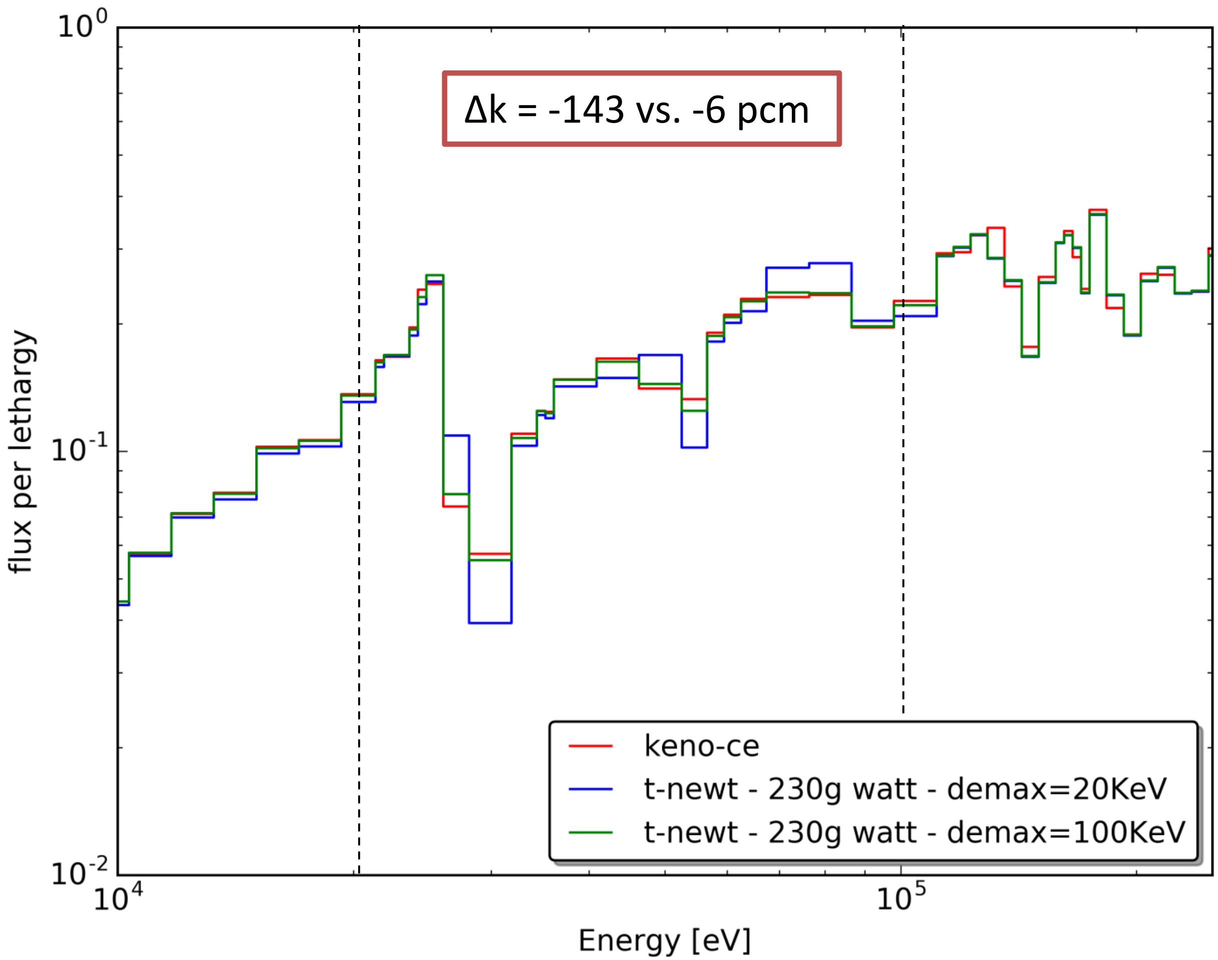


xz – plane

Influence of upper boundary of PW range in self-shielding calculation – MET1000



Influence of upper boundary of PW range in self-shielding calculation – MET1000



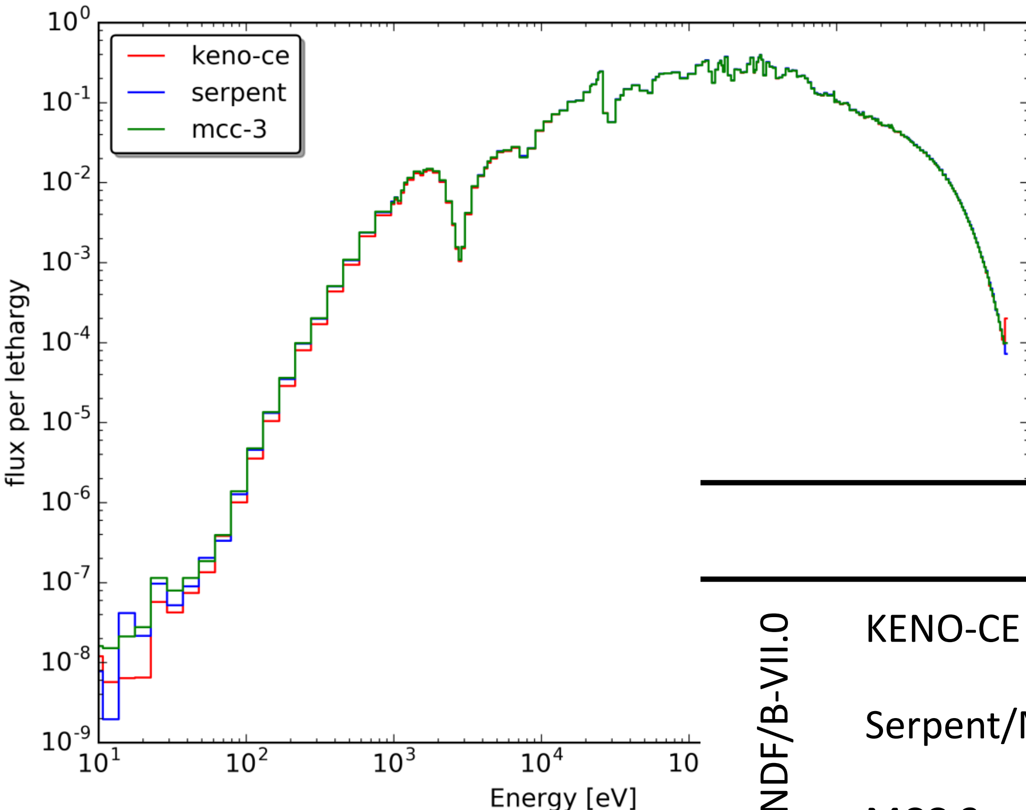
Influence of self-shielding factors in URR – MET1000

- Bondarenko shielding factors for the 238g library were computed using an analytical approximation for the flux spectrum

- In the unresolved resonance range, self-shielding factors were calculated using probability tables for the 252g library

230g, watt, with ptables	Δk=-6 pcm
230g, watt, w/o ptables	Δk=-258 pcm

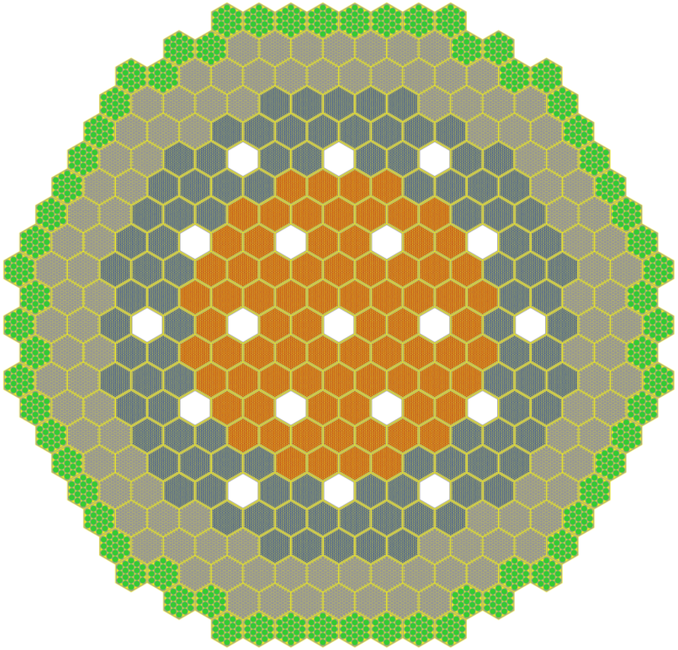
Difference between KENO-CE, Serpent and MCC-3 – MET1000



		k-inf	Δk [pcm]
ENDF/B-VII.0	KENO-CE	1.29350(11)	(ref)
	Serpent/MCNP	1.28750(9)	-600.0
	MCC-3	1.28894	-456.0
ENDF/B-VII.1	KENO-CE	1.29389(10)	(ref)
	Serpent/MCNP	1.28950(9)	-439.0

Difference between KENO-CE and Serpent – MET1000

Full core calculations:



		k-inf	Δk [pcm]
ENDF/B-VII.0	KENO-CE	1.04089(5)	(ref)
	Serpent	1.03771(5)	-318
ENDF/B-VII.1	KENO-CE	1.03928(5)	(ref)*
	Serpent	1.03638(5)	-290*

* Without ptables: agreement

Takeaways

- MET1000 (U/TRU):
  - The 230g library leads to good agreement with the reference
  - Influence of weighting spectrum is small regarding the flux spectrum; however, clearly noticeable regarding k-inf
  - Impact of different approach for Bondarenko factors in the URR region confirmed
  - Upper boundary of PW flux calculation should be raised up to 100KeV
  - Significant difference between KENO-CE and MCNP/Serpent due to differences in probability tables
  - More groups lead to larger disagreement regarding k-inf
- MOX3600 (U/TRU):
  - 425g library shows best agreement
  - Reasonable agreement can be obtained with 253g