Criticality Validation of SCALE 6.2

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Outline

- Introduction

- Critical Experiments Used

- Results

- Conclusions

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Introduction

- Validation effort demonstrates the general performance of the KENO V.a and KENO-VI codes across a wide range of systems
  - 15 experiment categories, > 600 individual cases

- Benchmarks are all from ICSBEP Handbook and included in the VALID library maintained at ORNL

- Models are executed using
  - 238-group and continuous energy libraries based on ENDF/B-VII.0
  - 56-group, 252-group, 200-group, and continuous energy libraries based on ENDF/B-VII.1

- Comparison of KENO V.a to KENO-VI using ENDF/B-VII.1 continuous energy library

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Valid procedure and library contents

- <u>V</u>erified, <u>A</u>rchived <u>L</u>ibrary of <u>I</u>nputs and <u>D</u>ata procedure is a SCALE project computational procedure at ORNL

- Quality behind VALID:
  - Independent preparation and review of models and documentation
  - Individuals must be certified as qualified for task assigned
  - Version control maintained on data
  - Data and documentation backed up and retrievable

- For more information on VALID, see NCSD 2013 presentation

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Critical experiments used

- Cases in blue are new since SCALE 6.1 validation report

- Cases in red are new since ICNC 2015 paper

- 561 cases with KENO V.a

- 57 cases with KENO-VI

Sequence	Experiment class	ICSBEP case numbers	Number of configurations
CSAS5/KENO V.a (also KENO-VI with ENDF/B-VII.1 CE library)	HEU-MET-FAST	15, 16, 17, 18, 19, 20, 21, 25, 30, 38, 40, 52, 65	19/23[a]
	HEU-SOL-THERM	1, 13, 14, 16, 28, 29, 30	52
	IEU-MET-FAST	2, 3, 4, 5, 6, 7, 8, 9	8/11[a]
	LEU-COMP-THERM	1, 2, 8, 10, 17, 42, 50, 78, 80	140
	LEU-SOL-THERM	2, 3, 4	19
	MIX-MET-FAST	5, 6	2
	MIX-COMP-THERM	1, 2, 4	21
	MIX-SOL-THERM	2, 7	10
	PU-MET-FAST	1, 2, 5, 6, 8, 10, 18, 22, 23, 24, 25, 26	12
	PU-SOL-THERM	1, 2, 3, 4, 5, 6, 7, 11, 20	81
	U233-COMP-THERM	1	3
	U233-MET-FAST	1, 2, 3, 4, 5, 6	10
	U233-SOL-INTER	1	29
	U233-SOL-MIXED	1, 2	8
	U233-SOL-THERM	1, 2, 3, 4, 5, 8, 9, 11, 12, 13, 15, 16, 17	140
CSAS6/KENO-VI	HEU-MET-FAST	5, 8, 9, 10, 11, 13, 24, 80, 86, 92, 93, 94	27
	IEU-MET-FAST	19	2
	MIX-COMP-THERM	8	28

[a]The larger number includes simplified cases that are duplicate cases for which detailed models are also available in the library.

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Results

- Average calculated-to-expected ratio (C/E) determined for each category of experiments
  - Uncertainty in C/E accounts for uncertainty in expected k_{eff} value and computational uncertainty
  - Experimental uncertainty >> computational uncertainty, dominates C/E uncertainty

- Results compared
  - Among ENDF/B-VII.1 libraries,
  - Between ENDF/B-VII.0 and respective ENDF/B-VII.1 libraries,
  - C/E with EALF, and
  - C/E with experimental and data uncertainty

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Average C/E difference from unity (bias) – KENO V.a
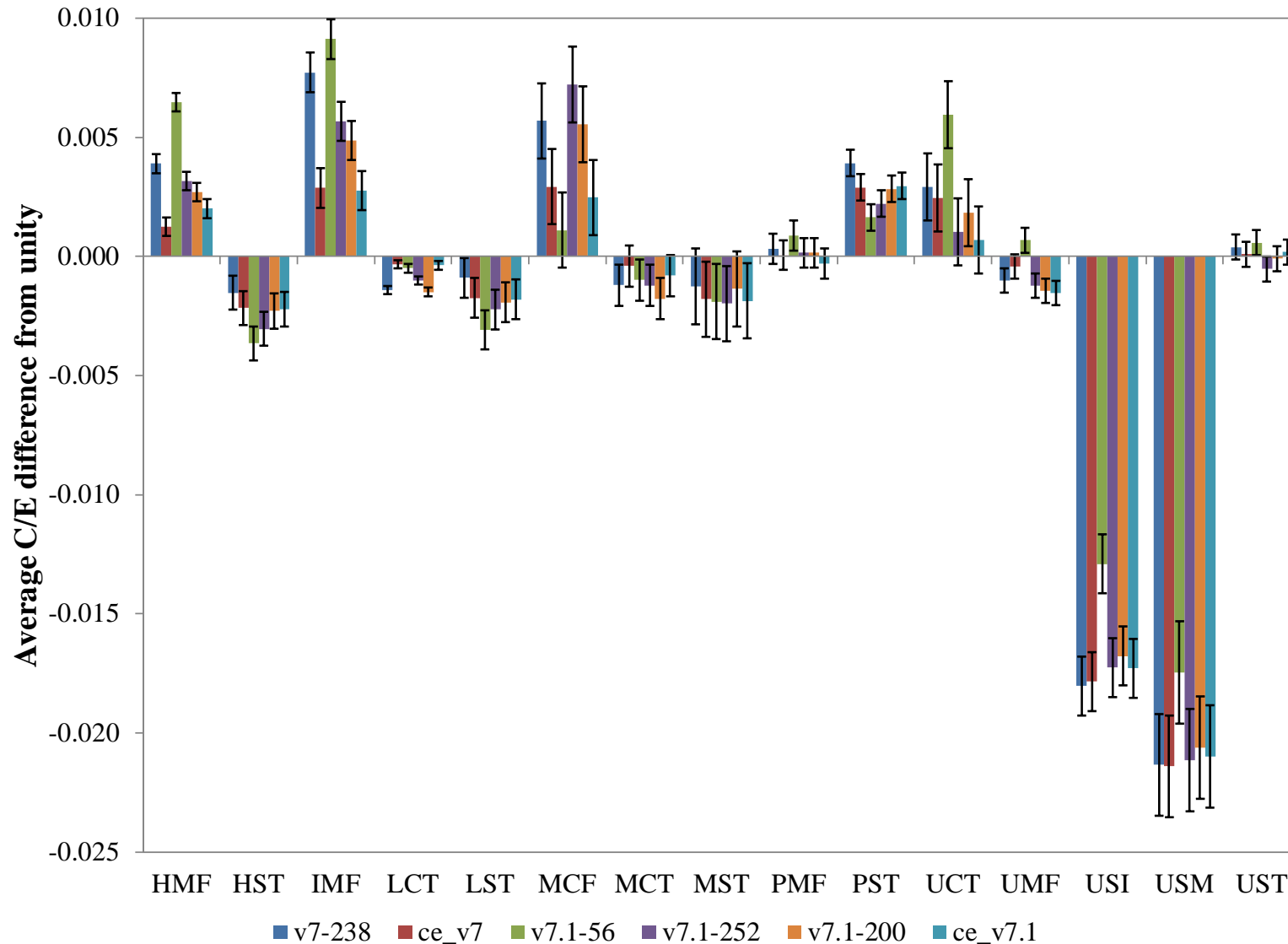
- USI and USM results are consistently poor for all libraries (intermediate and mixed energy)
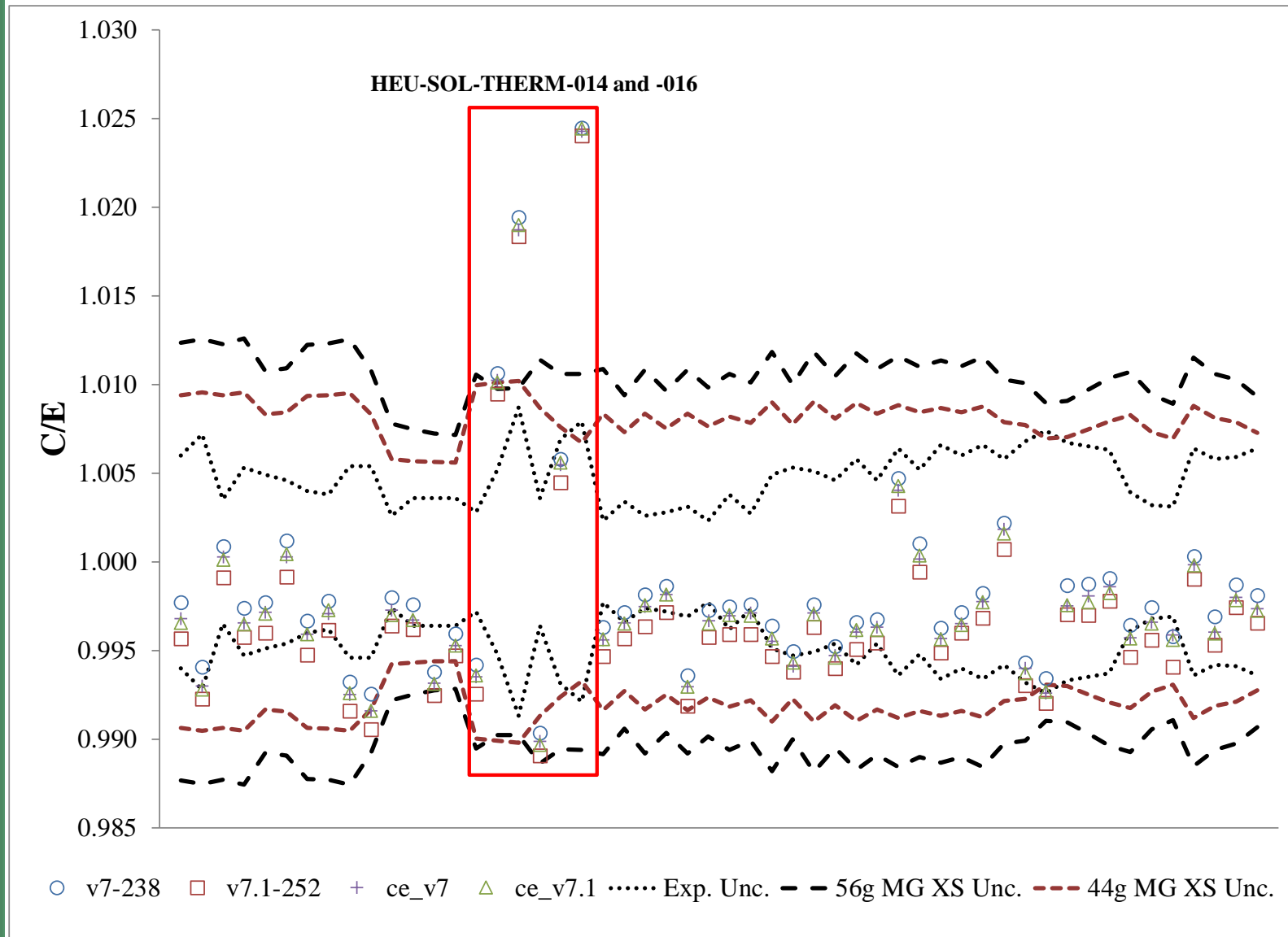
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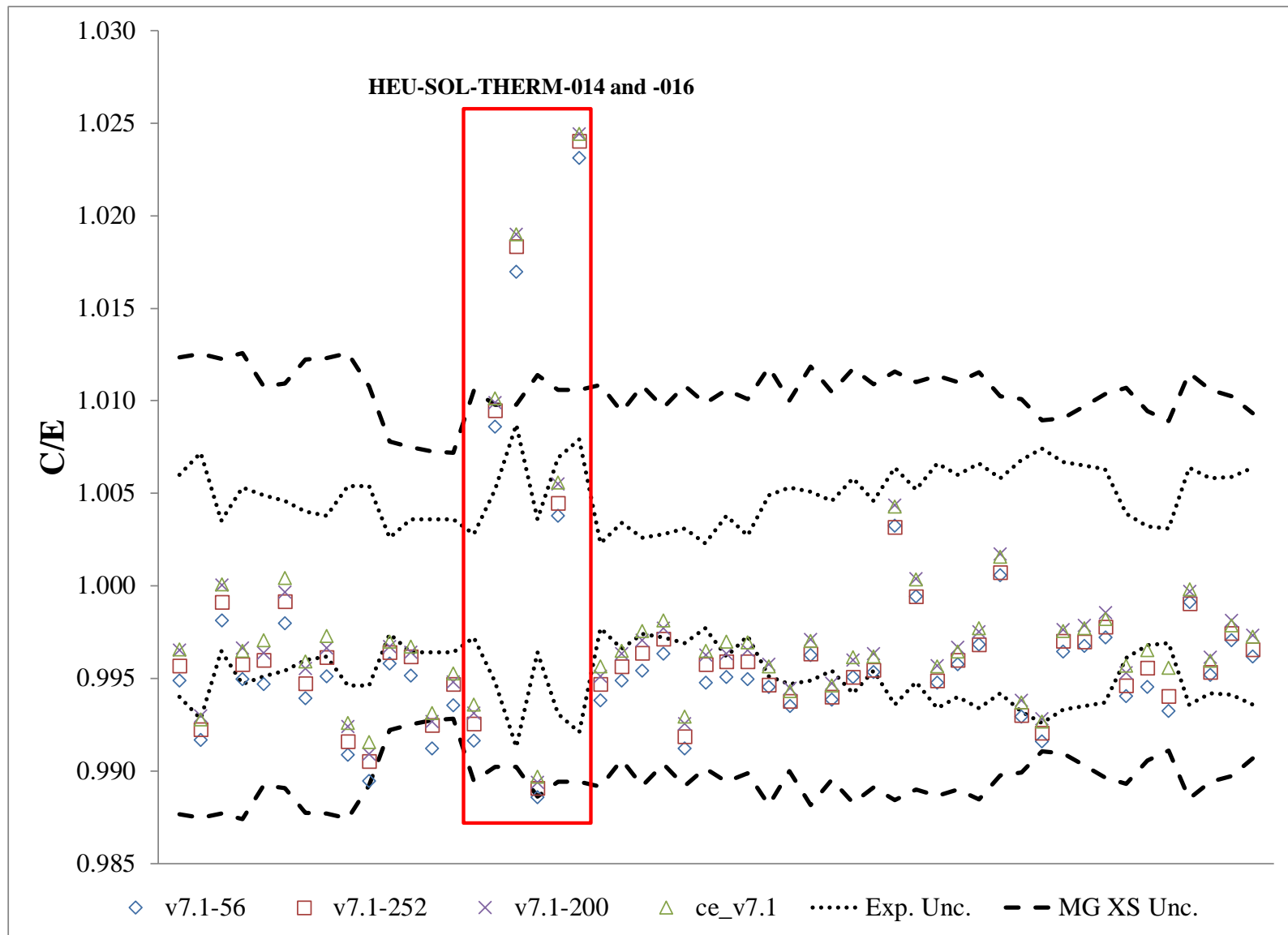
KENO V.a HST systems

- Comparing results for 56-group, 252-group, 200-group, and continuous energy libraries based on ENDF/B-VII.1

KENO V.a HST systems

HEU-SOL-THERM-014 and -016

Legend: ○ v7-238   □ v7.1-252   + ce_v7   △ ce_v7.1   ······ Exp. Unc.   – – 56g MG XS Unc.   – – 44g MG XS Unc.

- Comparing results for ENDF/B-VII.0 libraries and related ENDF/B-VII.1 libraries
  - For more information on HST-014 and -016 outliers, see Marshall's paper on Gadolinium bias from 2018 Summer ANS Meeting

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KENO V.a HST systems
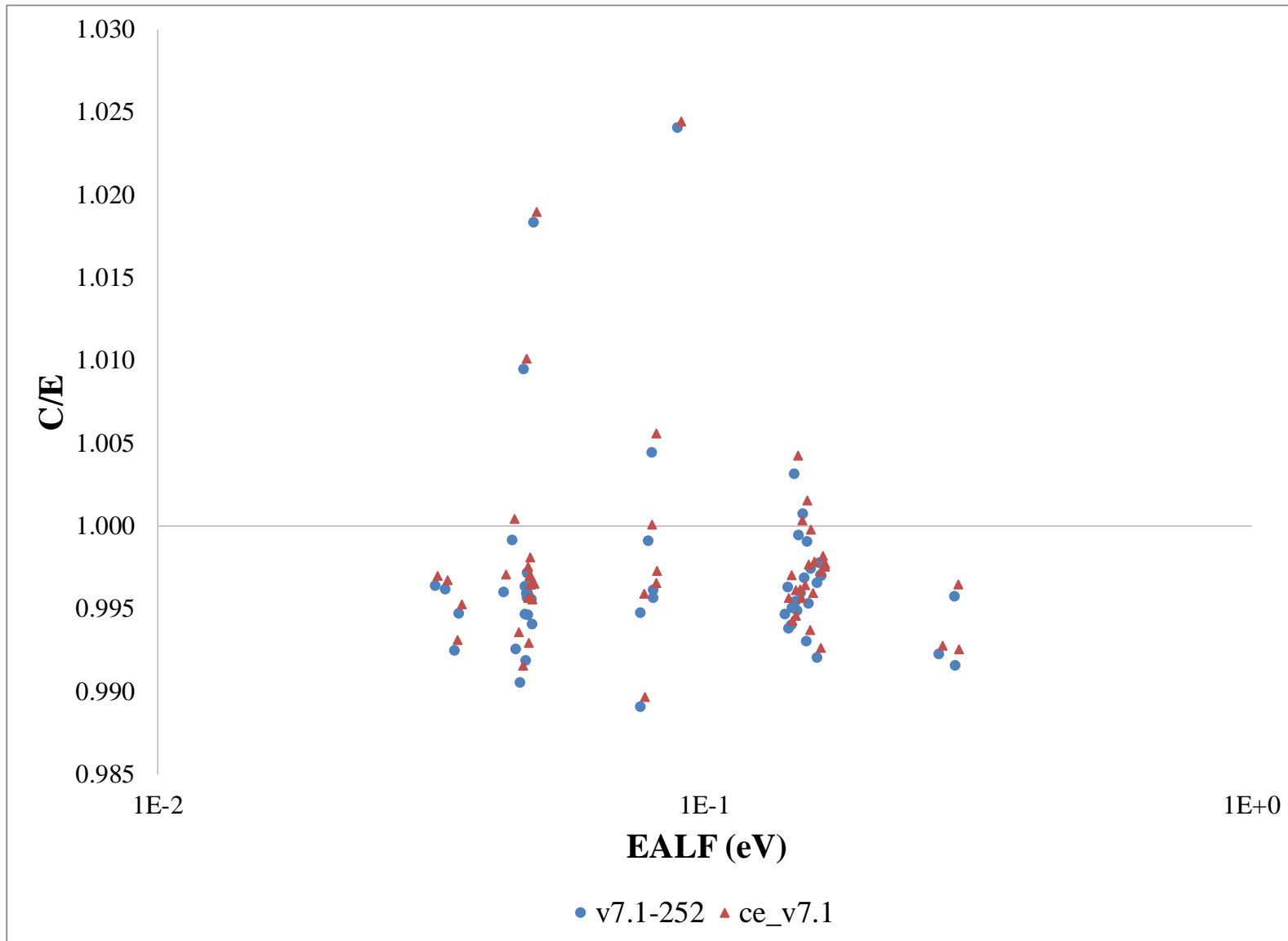
- C/E values as a function of EALF
  – Only for ENDF/B-VII.1 252-group and continuous energy libraries

- No clear evidence of trends seen on any individual category of experiments

# Average C/E difference from unity (bias) – KENO-VI
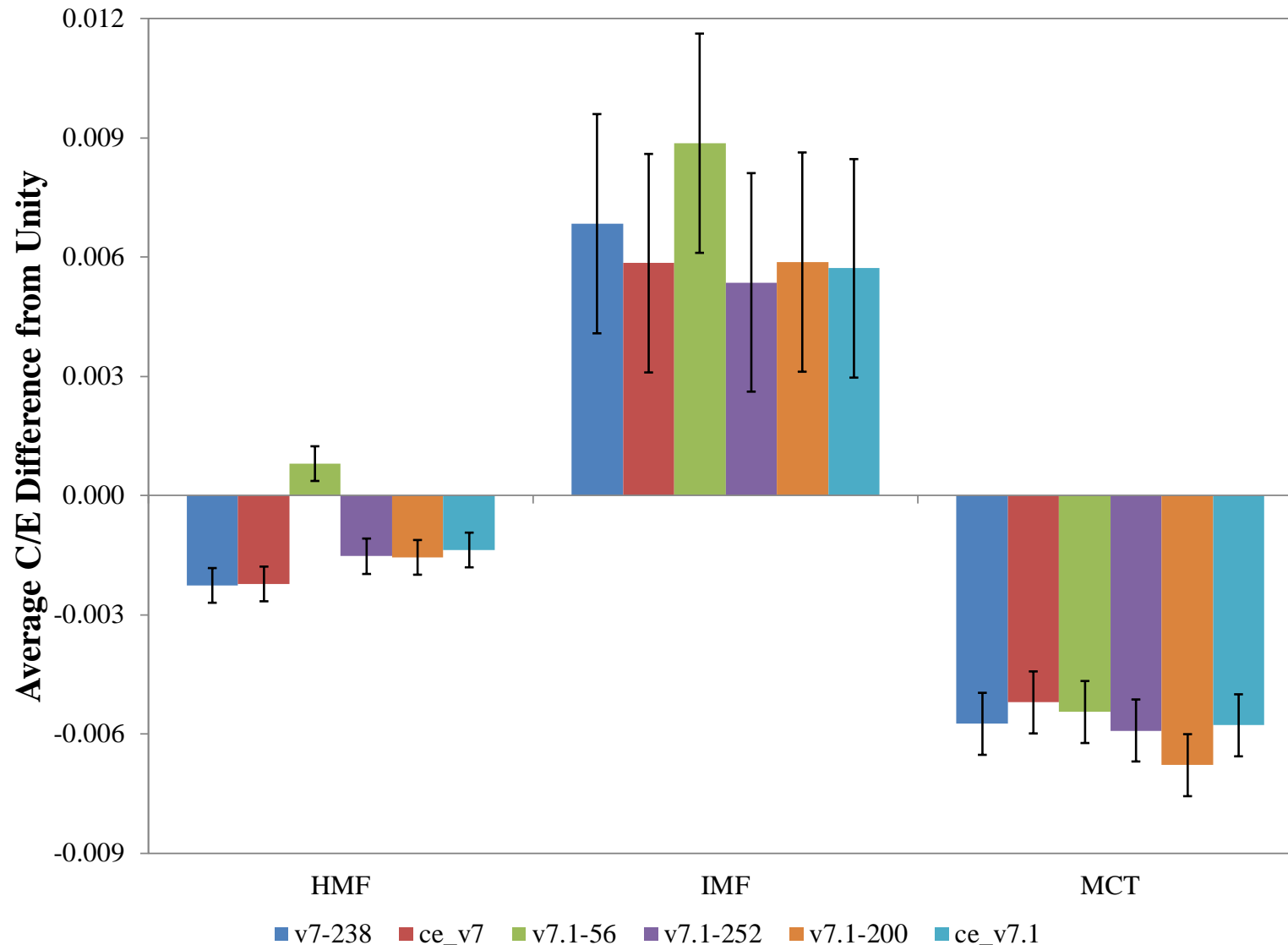
- Biases in KENO-VI appear to be generally slightly larger than in KENO V.a (not considering USI and USM systems)

- Result of more complex geometries?

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KENO V.a and KENO-VI comparison

- Different biases for KENO V.a and KENO-VI for same experiment categories, but with different experiments

- All KENO V.a experiments converted to KENO-VI models using c5toc6 utility

- Only run/compared with ENDF/B-VII.1 continuous energy library

- Same model-to-model comparison

- 94.6% of cases are within 2 sigma

- Monte Carlo uncertainty ranges between ~0.00006 - ~0.00049

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Differences (KENO-VI – KENO V.a)
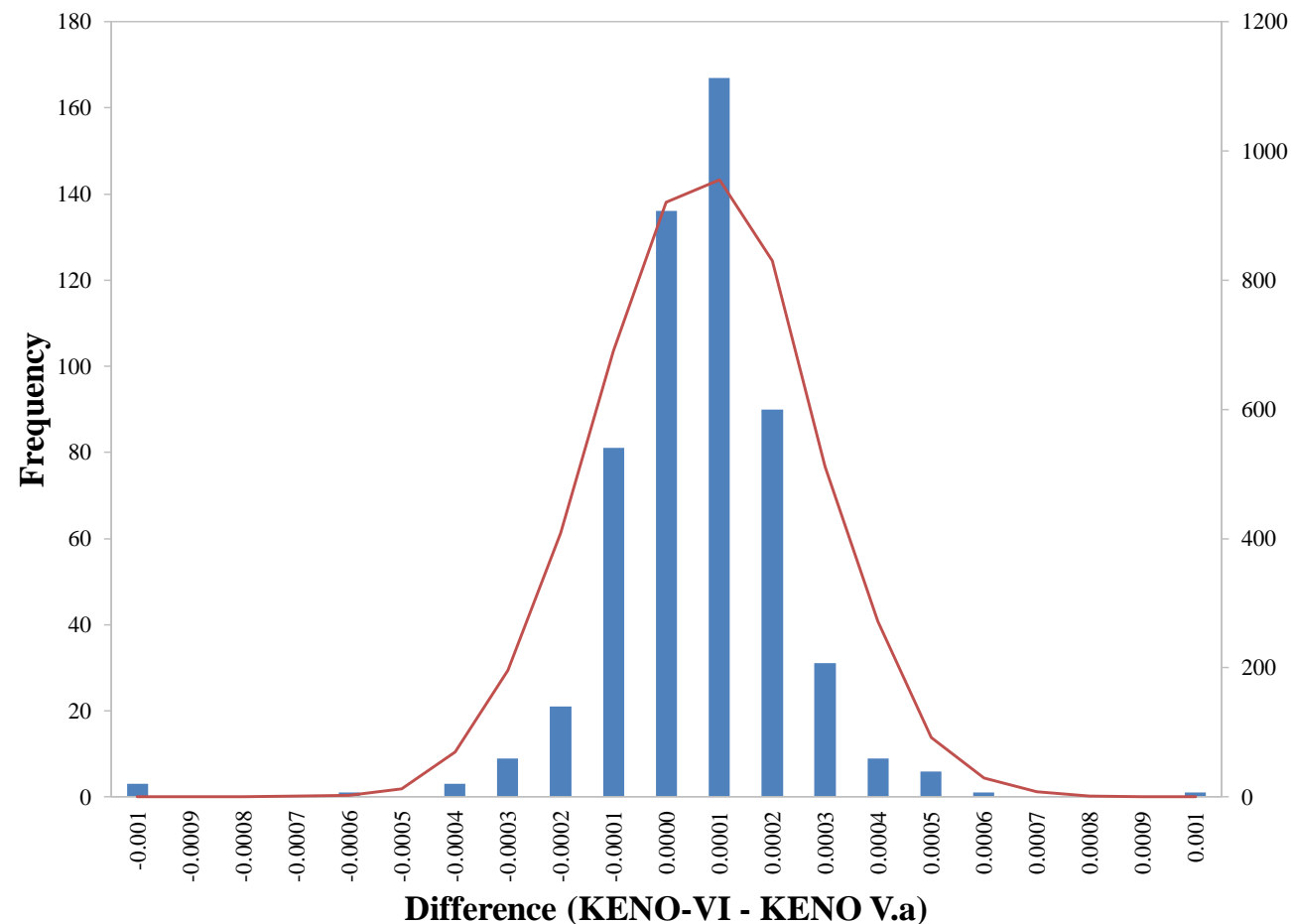
- Histogram of all individual case differences with overlay of an imposed normal distribution with the same mean and standard deviation

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Conclusions

- Code bias for a wide range of systems is fairly small
  - Less than 2.2% when considering all of the cases in all of the categories
  - For KENO V.a, bias is less than 0.92% when removing the USI and USM systems from consideration and less than 0.5% for almost all of the categories
  - For KENO-VI, bias is less than 0.9%

- Data can be used to identify potential discrepancies which may indicate poor experiment descriptions, disagreements between multigroup and continuous energy libraries/treatments, and/or possible errors in cross section libraries

- Evidence that KENO V.a and KENO-VI calculate equivalent k_{eff} values for identical systems

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