ENDF/B-VIII.0β4 Data Testing

Mini-CSEWG

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May 2017

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Abstract

We present the results of criticality and reaction rate data testing with ENDF/B-VIII.0β4 data files.

Outline

- NJOY Processing
- Criticality Data Testing
- Reaction Rate Data Testing
- Summary

NJOY Processing

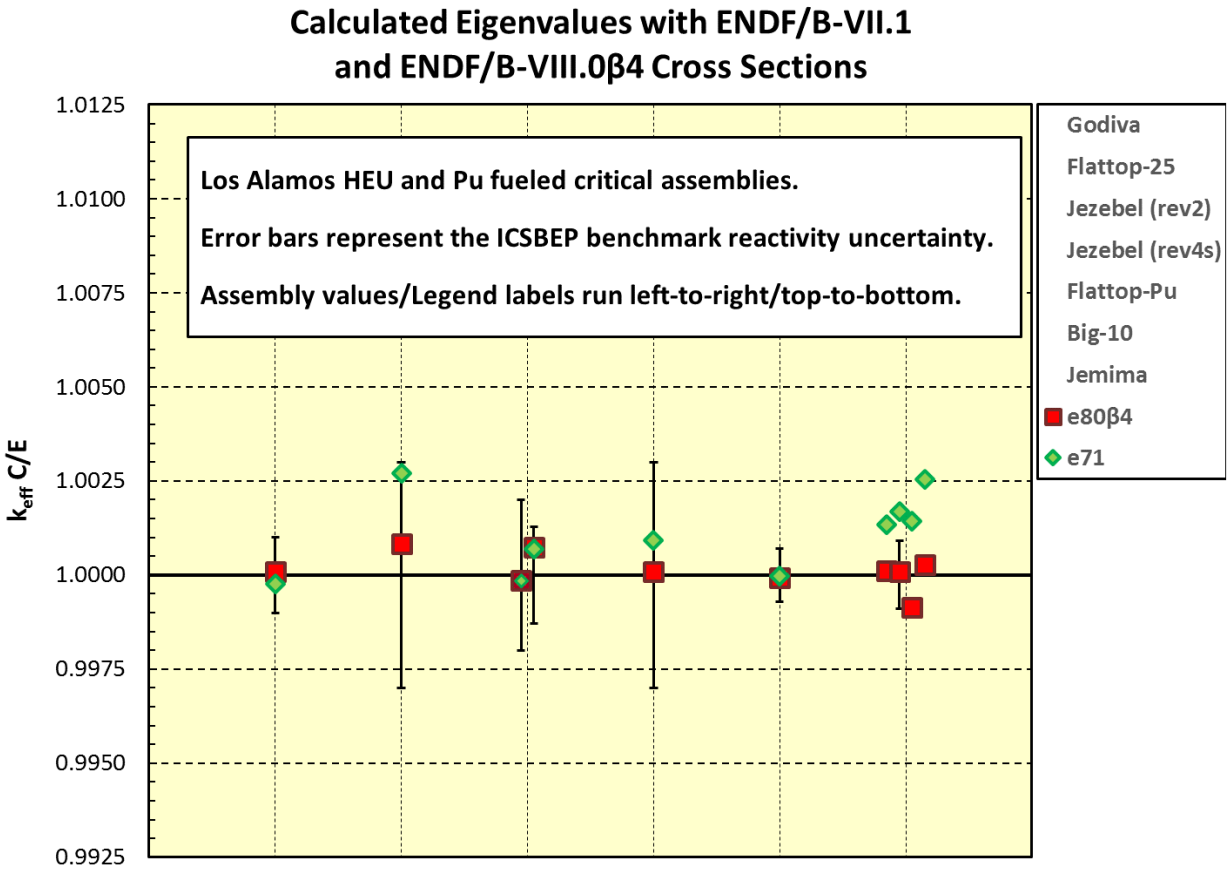
- **NJOY2016**
  - An open source release, available as of January 2017
  - Obtained from https://njoy.github.io/NJOY2016/ (or https://njoy.lanl.gov).
  - Users should periodically execute a GitHub "pull" to assure they have the latest version.
    - NJOY2016.8 was used to create the ACE files used in the data testing simulations reported here.
    - The latest release (as of 5/3/2017) is NJOY2016.9+, and includes modest revisions based upon feedback from the JEFF community as they processed their JEFF-3.3/3T test library.
- **NJOY2012**
  - Still available, with update files obtained from http://t2.lanl.gov/nis/codes/NJOY12/index.html
    - The current public release is NJOY2012.82 (equivalent to NJOY2016.3)
  - A ***final*** NJOY2012 update is planned for late June 2017.
    - This release will be consistent with the then latest NJOY2016 version.

Criticality Data Testing

- **Use models *derived* from the ICSBEP (International Criticality Safety Benchmark Evaluation Project) Handbook**
  - Over 4900 (2016 Handbook) configurations are defined.
    - HEU, IEU, LEU, Pu, mixed U-Pu, ^{233}U fuels.
    - Metal, Compound, Solution, Mixed fuel configurations.
    - Fast (>100 keV), Intermediate, Thermal (<0.625 eV), Mixed fluxes.
  - Focus on a small subset of the ICSBEP population.
    - Legacy LANL FAST critical assemblies – Godiva, Jezebel, Flattop's, Big-10, Jemima
    - HST suite, correlated against ATLF;
    - PST suite, correlated against ATLF;
    - LCT suite (varying rod pitch incorporates a wide range of H/U);
    - PMF suite, correlated against EALF;
    - Benchmarks with specific material of interest
      - Fe/steel, Ni/steel, polyethylene, Be, C, W, …

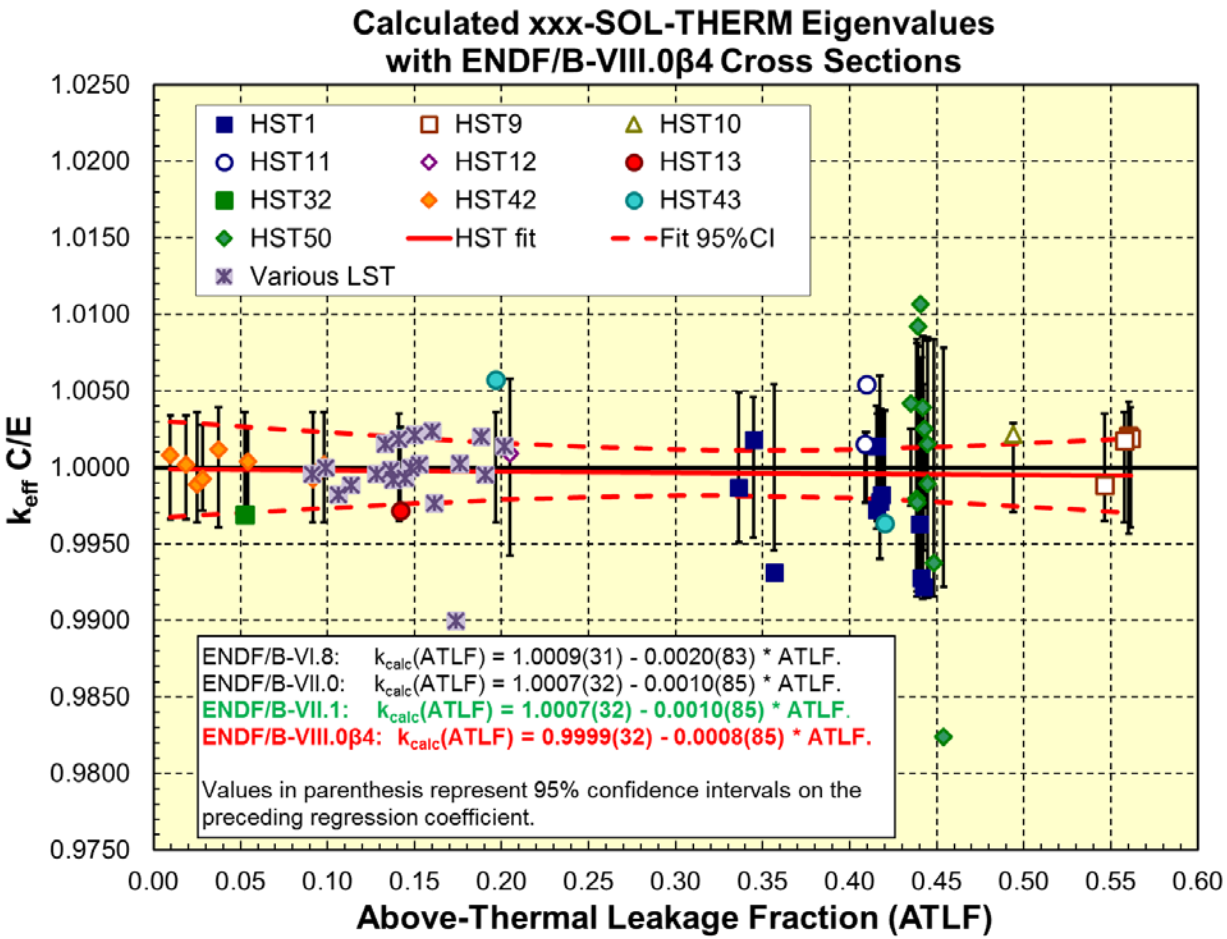
Criticality Data Testing – Legacy LANL Assemblies

- Previous (e71) good bare assembly results are retained with e80β4 cross sections.
- Reflected assembly results are significantly improved.



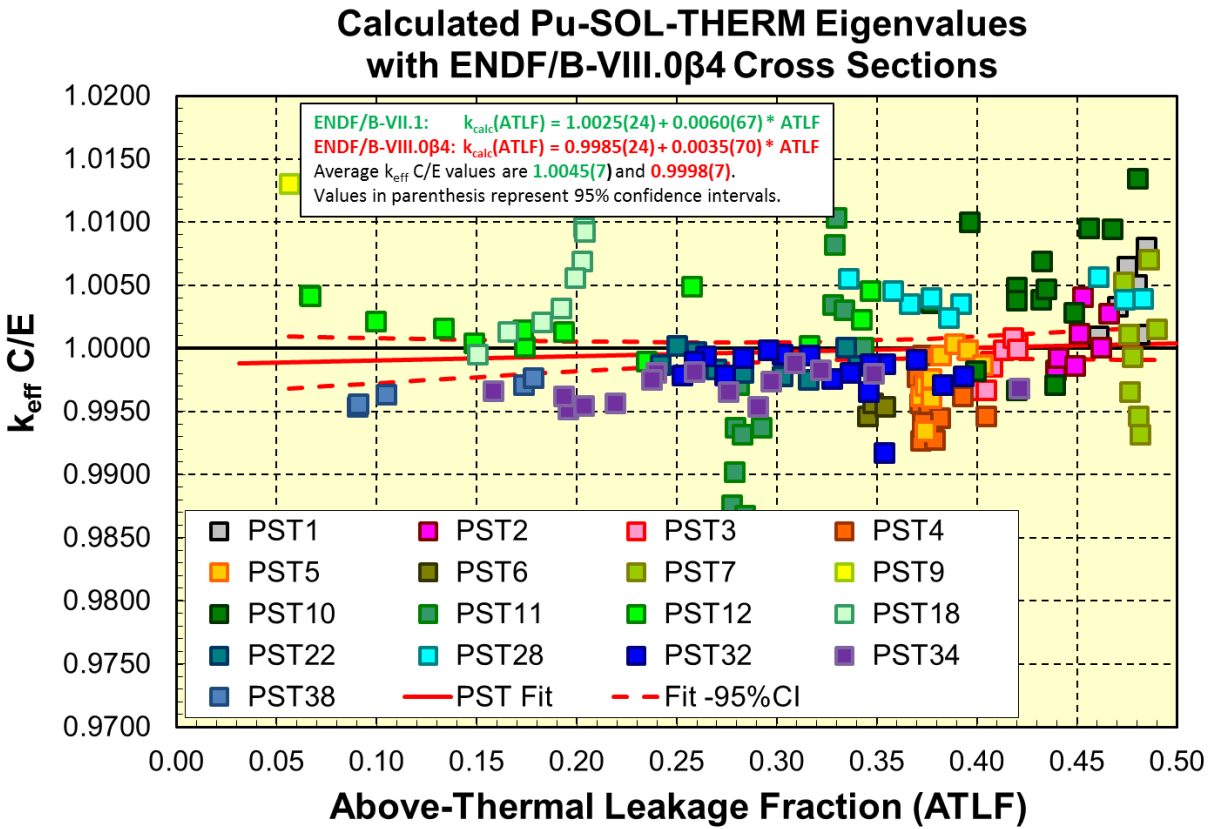
Criticality Data Testing – HST suite

- Previous (e71) result is retained with e80β4 cross sections.
- Correlations against other parameters such as ATFF, EALF, EAF, H/U all yield a "zero" slope and "unity" intercept.



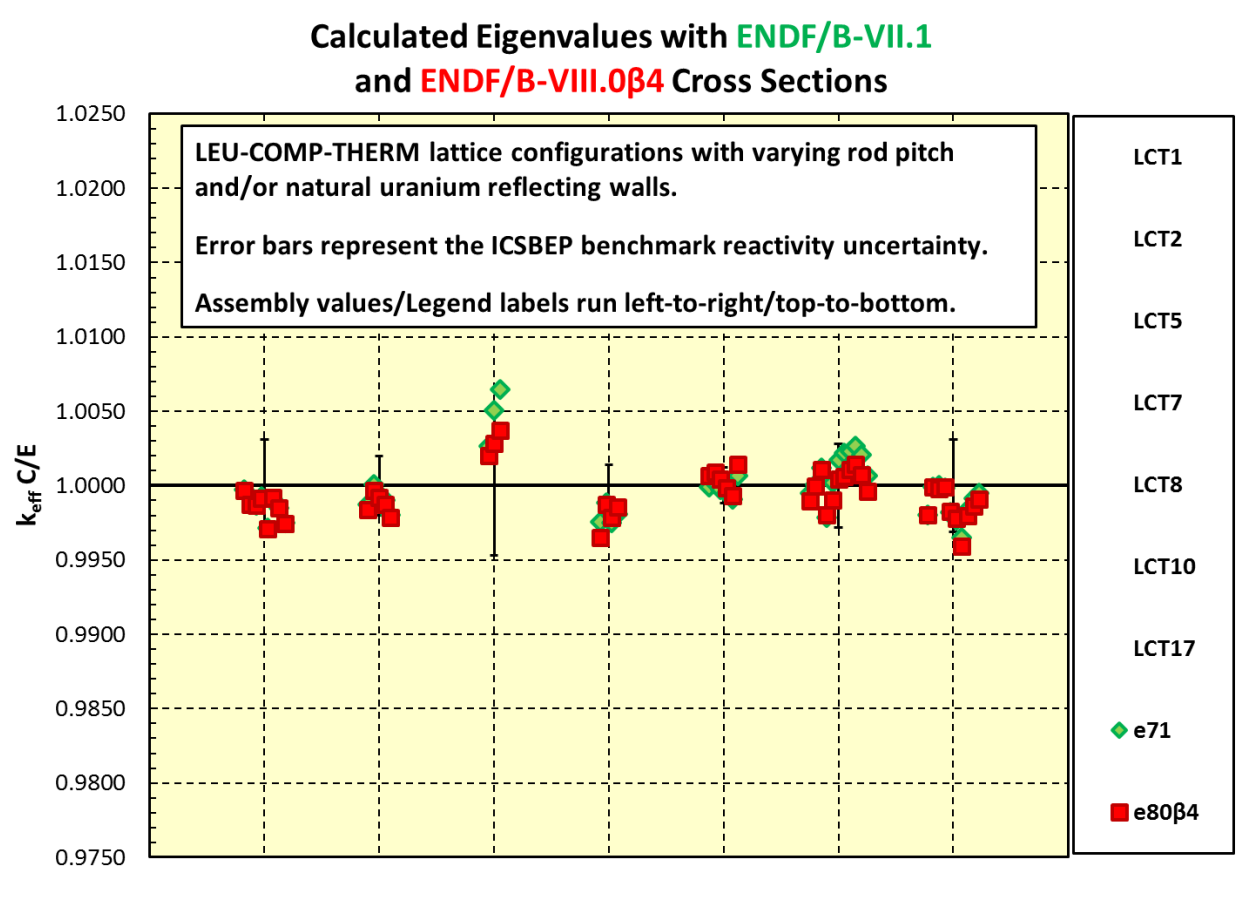
Criticality Data Testing – PST suite

- Previous (e71) result is retained with e80β4 cross sections.
- Correlations against other parameters such as ATFF, EALF, EAF yield a "zero" slope and "unity" intercept.
- Slight evidence for a trend and bias with ^{239}Pu abundance, but the database is small.



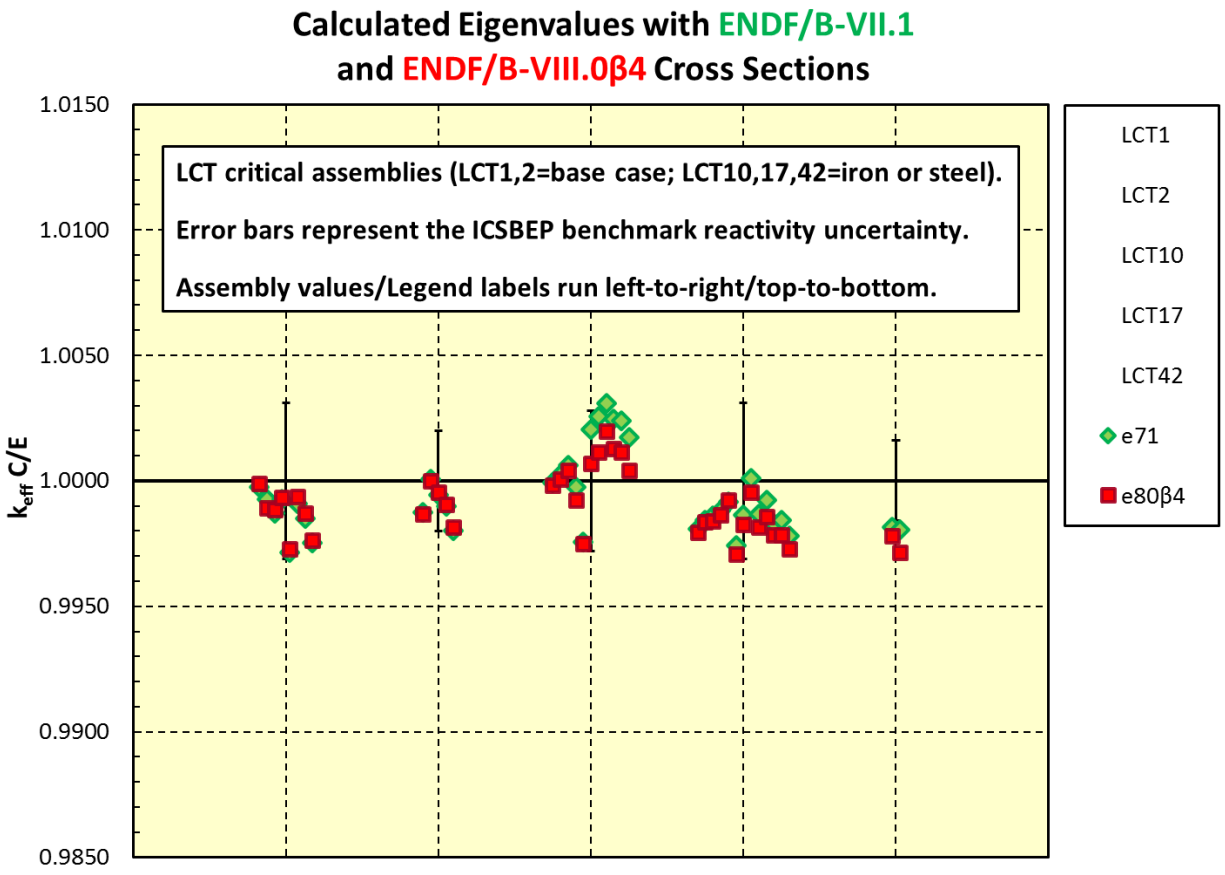
Criticality Data Testing – LCT suite

- Previous (e71) good results are retained with e80β4 cross sections.
- Average k_{eff} C/E change is -46 pcm, mainly due to the improved LCT5 and the ^{nat}U wall reflected LCT10 results.
  - LCT5: 1.00471 → 1.00287
  - LCT10: 1.00095 → 1.00009
- For a suite of 247 LCT assemblies the average k_{eff} C/E changed from 0.99951 to 0.99924, or -27 pcm.



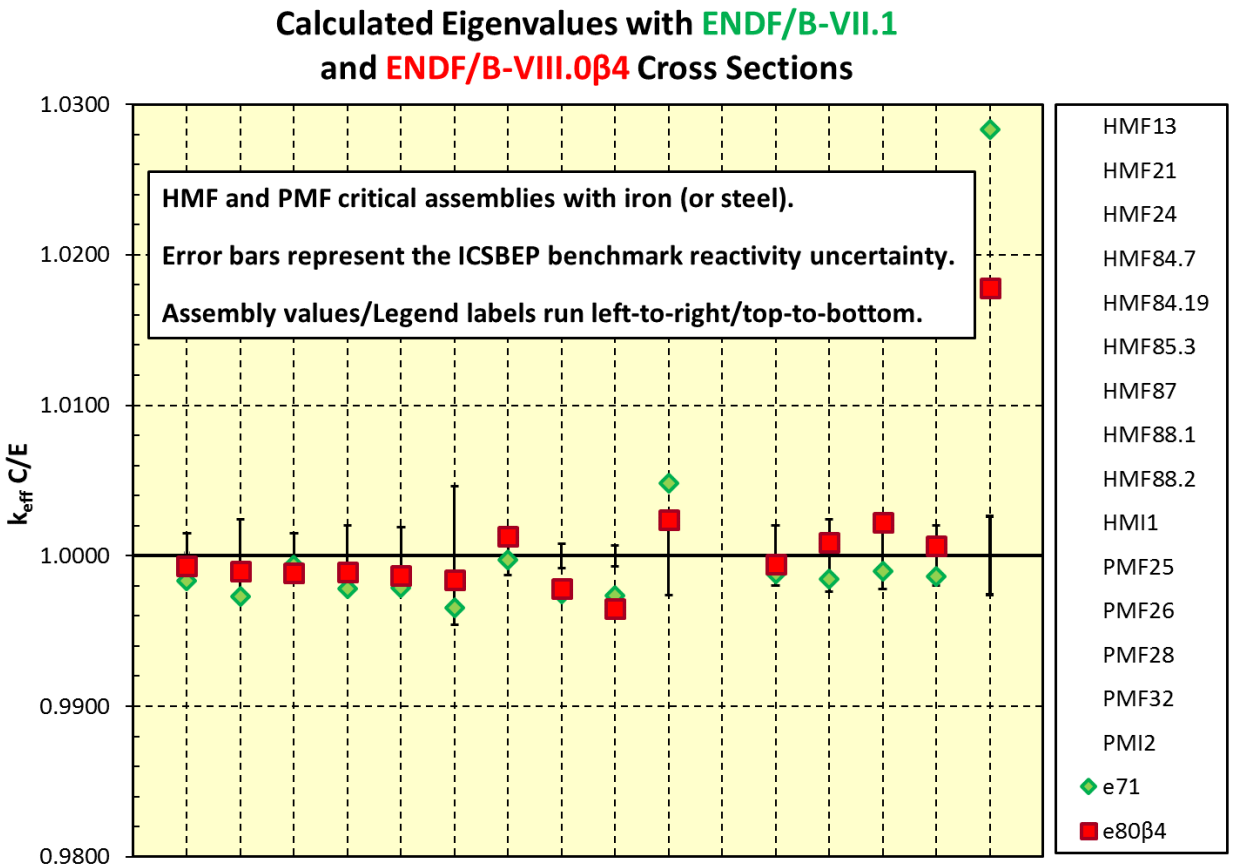
Criticality Data Testing – LCT suite with Fe

- Previous (e71) good results are retained with e80β4 cross sections.
- Slight decrease in LCT10 eigenvalues brings these results more in line with the LCT1 base case.



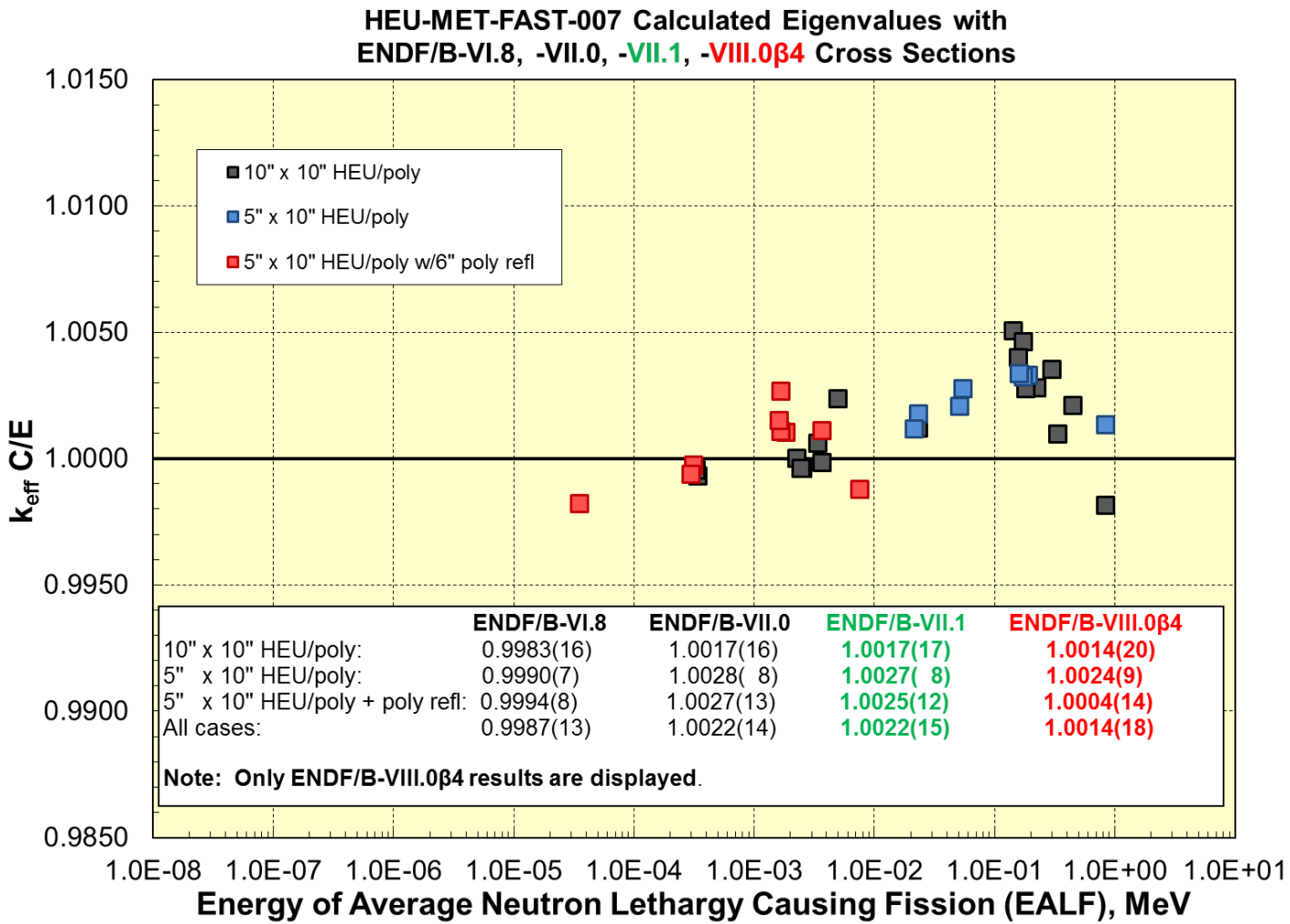
Criticality Data Testing – HMF & PMF suites with Fe

- **Previous (e71) results are mostly improved with e80β4 cross sections.**



HMF7 …

- Average calculated eigenvalues jumped from ENDF/B-VI to ENDF/B-VII.
- Higher values are retained with the latest cross section files.
- Shape versus energy is unchanged throughout.

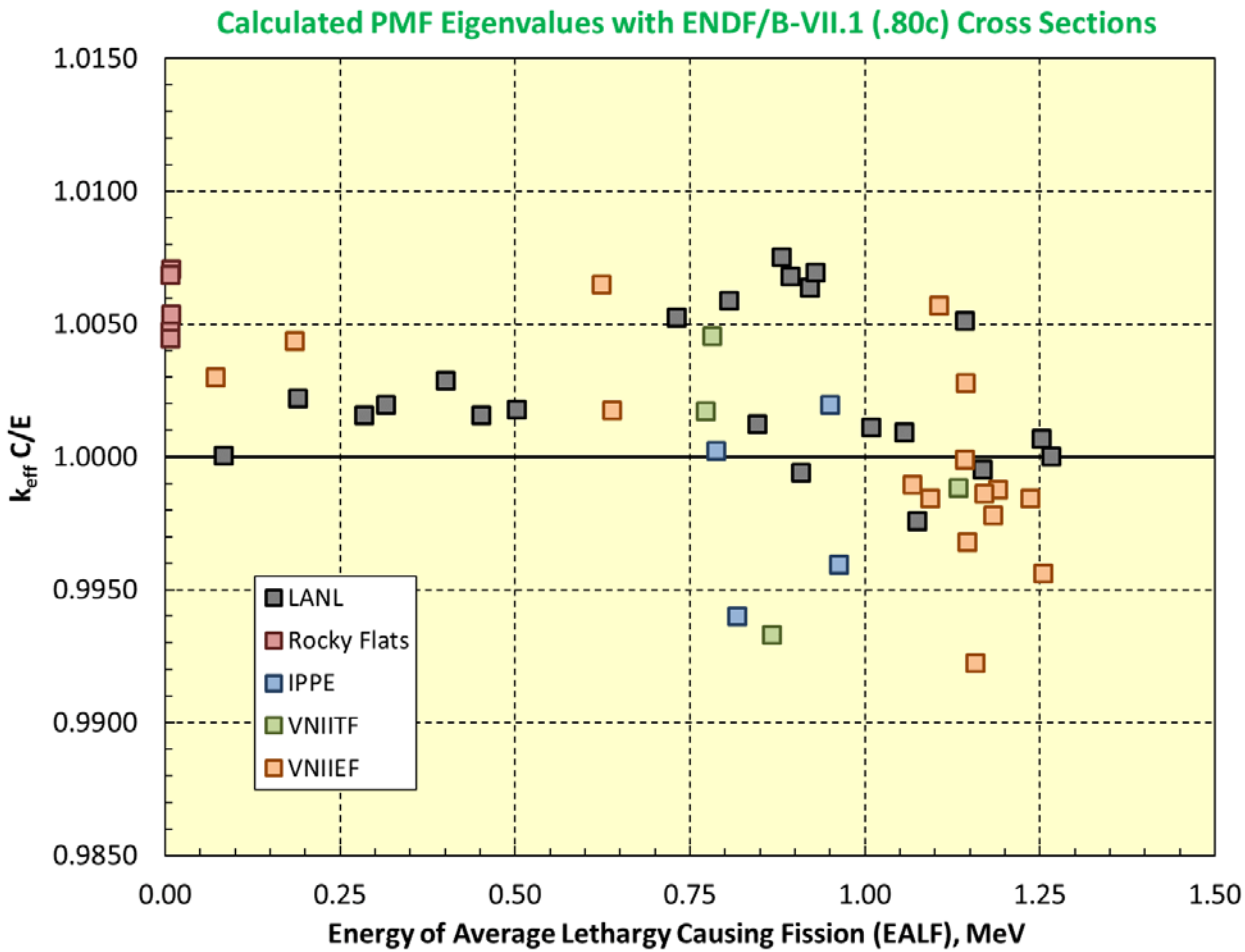


	ENDF/B-VI.8	ENDF/B-VII.0	ENDF/B-VII.1	ENDF/B-VIII.0β4
10" x 10" HEU/poly:	0.9983(16)	1.0017(16)	1.0017(17)	1.0014(20)
5" x 10" HEU/poly:	0.9990(7)	1.0028(8)	1.0027(8)	1.0024(9)
5" x 10" HEU/poly + poly refl:	0.9994(8)	1.0027(13)	1.0025(12)	1.0004(14)
All cases:	0.9987(13)	1.0022(14)	1.0022(15)	1.0014(18)

Note: Only ENDF/B-VIII.0β4 results are displayed.

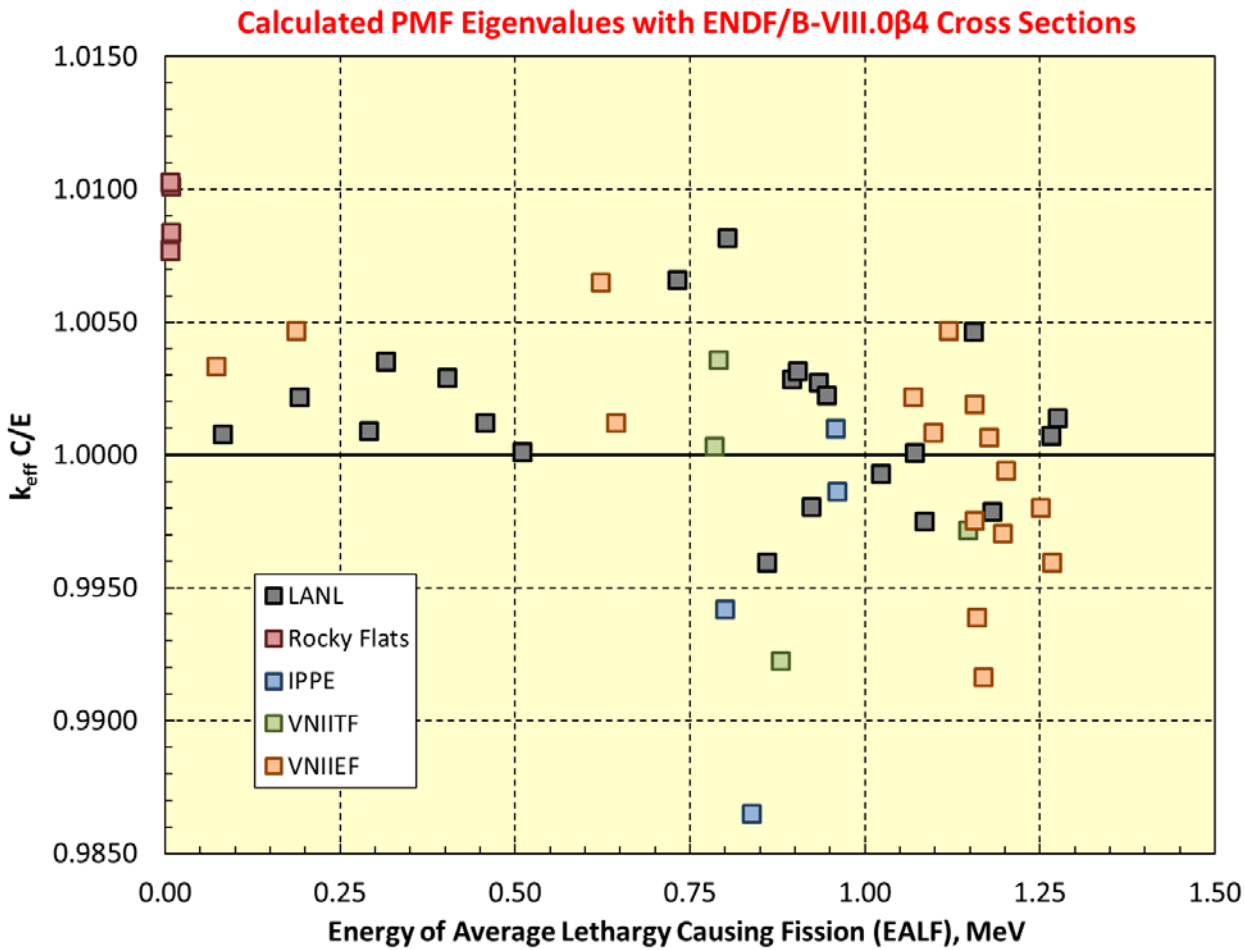
PMF suite … ENDF/B-VII.1

- Lots of scatter in these data, particularly in the 0.75 MeV to 1.25 MeV interval.
- Results are generally biased high for E < 0.75 MeV.



PMF suite … E80β4

- Lots of scatter in these data, particularly in the 0.75 MeV to 1.25 MeV interval – arguably worse than ENDF/B-VII.1
- Results are generally biased high for E < 0.75 MeV.



CSEWG Spectral Indices - I

- **e71 and e80b4 fission spectral indices …**

Exp-A = data as documented in the CSEWG Fast Reactor Benchmark compilation.
Exp-B = the same measurements, but re-analyzed by G.Hansen (private communication to R.E.MacFarlane, 1984).
We use "Exp-B" for C/E comparisons, when possible.

Assembly	Quantity	^{238}U(n,f)/^{235}(n,f)	^{237}Np(n,f)/^{235}(n,f)	^{233}U(n,f)/^{235}(n,f)	^{239}Pu(n,f)/^{235}(n,f)
Godiva (HMF001)	e71 calc	0.1579	0.8301	1.5687	1.3823
	e80b4 calc	0.1583	0.8318	1.5793	1.3846
	Exp-B	**0.1643 ± 0.0018**	**0.8516 ± 0.012**		**1.4552 ± 0.014**
	Exp-A	0.1642 ± 0.0018	0.837 ± 0.013	1.59 ± 0.03	1.402 ± 0.025
	e71 C/E	**0.9610**	**0.9747**	**0.9866**	**0.9768**
	e80b4 C/E	**0.9636**	**0.9767**	**0.9933**	**0.9784**
Jezebel (PMF001, Rev 4)	e71 calc	0.2085	0.9708	1.5561	1.4242
	e80b4 calc	0.2121	0.9770	1.5660	1.4273
	Exp-B	**0.2133 ± 0.0023**	**0.9835 ± 0.014**		**1.4609 ± 0.013**
	Exp-A	0.2137 ± 0.0023	0.962 ± 0.016	1.578 ± 0.027	1.448 ± 0.029
	e71 C/E	**0.9775**	**0.9871**	**0.9861**	**0.9749**
	e80b4 C/E	**0.9943**	**0.9934**	**0.9924**	**0.9770**
Jezebel-23 (UMF001)	e71 calc	0.2111	0.9970		
	e80b4 calc	0.2121	0.9851		
	Exp-B	**0.2131 ± 0.0026**	**0.9970 ± 0.015**		
	Exp-A	0.2131 ± 0.0023	0.977 ± 0.016		
	e71 C/E	**0.9906**	**1.000**		
	e80b4 C/E	**0.9951**	**0.988**		

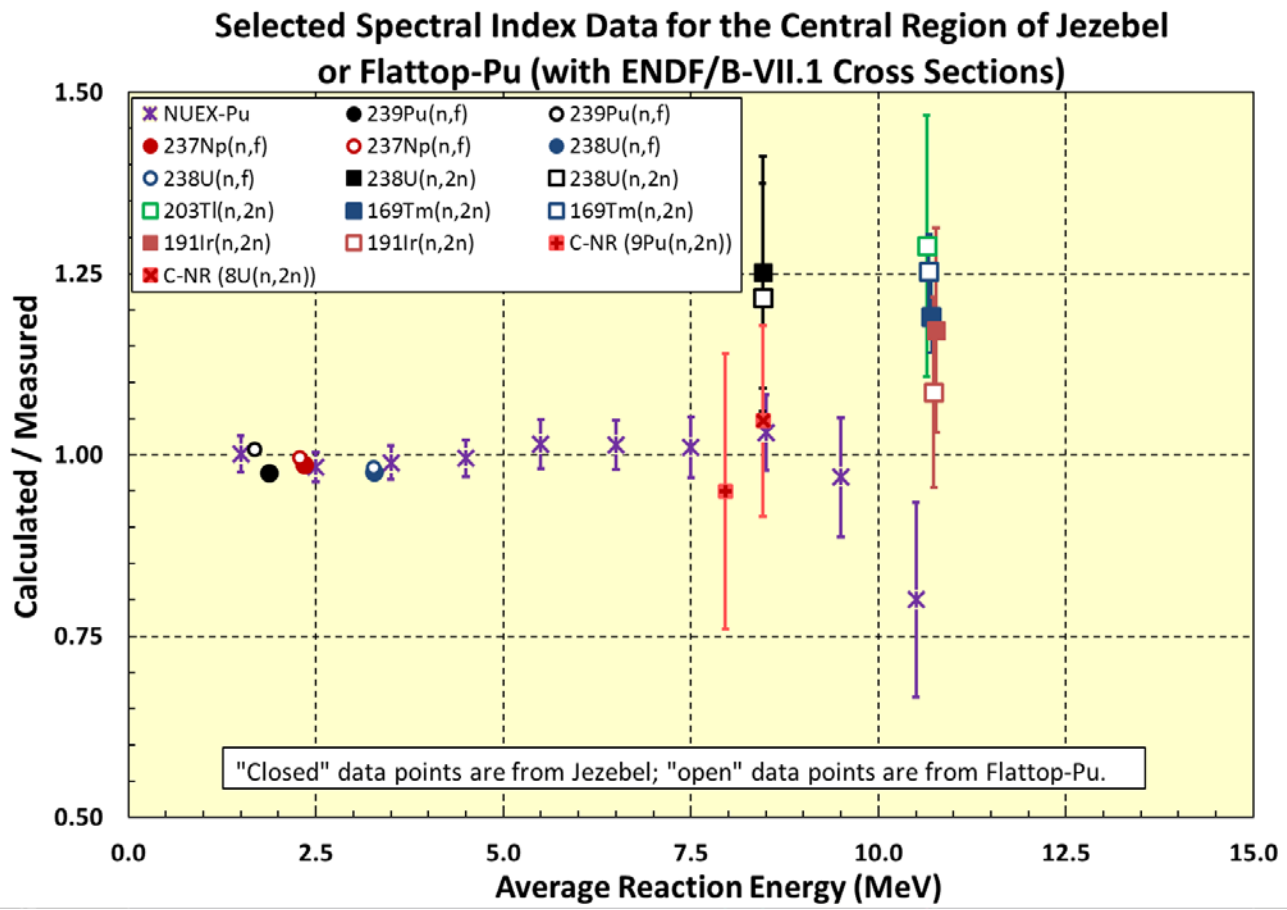
CSEWG Spectral Indices - II

- **e71 and e80b4 fission spectral indices …**

Flattop-25 (HMF028)	e71 calc	0.1438	0.7693	1.5674	1.3586
	e80b4 calc	0.1451	0.7735	1.5664	1.3622
	Exp-B	**0.1492 ± 0.0016**	**0.7804 ± 0.01**	**1.608 ± 0.003**	**1.3847 ± 0.0124**
	Exp-A	0.140 ± 0.002	0.76 ± 0.01	1.60 ± 0.003	1.37 ± 0.02
	e71 C/E	**0.9638**	**0.9858**	**0.9748**	**0.9812**
	e80b4 C/E	**0.9722**	**0.9911**	***0.9741***	**0.9837**
Flattop-Pu (PMF006)	e71 calc	0.1767	0.8521		
	e80b4 calc	0.1801	0.8593		
	Exp-B	**0.1799 ± 0.002**	**0.8561 ± 0.012**		
	Exp-A	0.180 ± 0.003	0.84 ± 0.01		
	e71 C/E	**0.9822**	**0.9953**		
	e80b4 C/E	**1.0011**	**1.0037**		
Flattop-23 (UMF006)	e71 calc	0.1882	0.9128		
	e80b4 calc	0.1892	0.9030		
	Exp-B	**0.1916 ± 0.0021**	**0.9103 ± 0.013**		
	Exp-A	0.191 ± 0.003	0.89 ± 0.01		
	e71 C/E	**0.9823**	**1.0027**		
	e80b4 C/E	**0.9876**	**0.9920**		

Central Region Spectral Indices – Jezebel & Flattop-Pu

ENDF/B-VII.1 results, presented at the ND2013 conference.



Central Region Spectral Indices – Jezebel & Flattop-Pu

	Reaction	Measured (original)	Measured (revised)	ENDF/B-VII.1 Calculated	ENDF/B-VII.1 C / E	ENDF/B-VII.1 C / E Unc	ENDF/B-VII.1 <E>		e80β4 Calculated	e80β4 C / E	e80β4 C / E Unc	e80β4 <E>
Jezebel												
23-Oct-73	^{239}Pu(n,f) / ^{235}U(n,f)	1.502	1.430	1.424	0.996		1.877		1.427	0.998		
	^{169}Tm(n,2n) / ^{235}U(n,f)	3.047E-03	3.125E-03	3.720E-03	1.190	0.049	10.703	A1	3.757E-03	1.202		
	^{191}Ir(n,2n) / ^{235}U(n,f)	3.048E-03	3.206E-03	3.757E-03	1.172	0.141	10.767	B1	3.793E-03	1.183		
	^{238}U(n,2n) / ^{235}U(n,f)	1.097E-02	1.058E-02	1.325E-02	1.252	0.160	8.461	D1	1.347E-02	1.273		
	^{238}U(n,f) / ^{235}U(n,f)	2.113E-01	2.121E-01	2.085E-01	0.983		3.279		2.121E-01	1.000		
Flattop-Pu												
5-Aug-63	^{238}U(n,2n) / ^{235}U(n,f)	8.562E-03	9.041E-03	1.097E-02	1.217	0.157	8.455		1.113E-02	1.232		
25-Mar-62	^{238}U(n,f) / ^{235}U(n,f)	0.1706	0.1712	1.769E-01	1.033		3.263		1.800E-01	1.051		
	^{238}U(n,2n) / ^{235}U(n,f)	8.513E-03	8.989E-03									
10-Aug-67	^{239}Pu(n,f) / ^{235}U(n,f)	1.487	1.415	1.379	0.975		1.680		1.383	0.978		
	^{169}Tm(n,2n) / ^{235}U(n,f)	2.372E-03	2.433E-03	3.047E-03	1.252	0.052	10.675	A2	3.075E-03	1.264		
	^{203}Tl(n,2n) / ^{235}U(n,f)	2.330E-03	2.270E-03	2.924E-03	1.288	0.180	10.642	C	2.952E-03	1.300		
	^{107}Ag(n,2n)^{106m}Ag / ^{235}U(n,f)	2.140E-04	1.973E-04									
5-Aug-70	^{238}U(n,f) / ^{235}U(n,f)	1.478E-01	1.484E-01	1.769E-01	1.192		3.263		1.800E-01	1.213		
	^{191}Ir(n,2n) / ^{235}U(n,f)	2.691E-03	2.831E-03	3.075E-03	1.086	0.131	10.737	B2	3.104E-03	1.097		

More Central Region reactions …

- **Some other reactions of local interest …**

Assembly	Quantity	^{239}Pu(n,2n) / ^{239}Pu(n,f)	^{239}Pu(n,γ) / ^{239}Pu(n,f)	^{241}Am(n,2n) / ^{239}Pu(n,f)	^{241}Am(n,γ)^{242m}Am →^{242}Cm / ^{239}Pu(n,f)
Jezebel	**e71 calc**	**0.0021**	**0.033**	**0.0007**	**0.1418**
(PMF001, rev4)	**e80b4 calc**	**0.0023**	**0.035**	**0.0008**	**0.1496**
	expt				**0.1486**
Flattop-Pu	**e71 calc**	**0.00184**	**0.044**	**0.0006**	**0.1849**
(PMF006)	**e80b4 calc**	**0.00197**	**0.046**	**0.0007**	**0.1937**
	expt				**0.1847**

Summary

- **With E80β4 we have retained the good ENDF/B-VII.1 eigenvalue performance.**
- **The long-standing PST eigenvalue bias has been eliminated.**
- **Benchmarks with significant quantities of iron are calculated more accurately.**
- ***Small trends in calculated eigenvalues over large energy intervals remain (HMF7, PMF suite).***
- ***Reaction rate C/E values at high energy (e.g., n,2n reactions) remain poor.***