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Latest development on Cu evaluation with benchmarking

INDEN Consultancy Meeting on the evaluated data of structural materials, IAEA, December 13-17, 2021

Summary

- Cu in existing libraries
  - Thermal, RI, MACS
  - k_{eff}
  - Shielding
- Cu benchmarks
- TENDL developments
- Conclusion

Cu in existing libraries (Cu-63, Cu-65)

- ENDF/B-VIII.0 from 2016 (RRR from ORNL)
- JENDL-4.0 from 2008 (JENDL fusion + updates)
- JEFF-3.3 from 2017 (KIT evaluation)
- JEFF-4.0T0 = JEFF-3.3

- In the following, libraries will be compared based a selection of
  - Differential data
  - Criticality benchmarks
  - Shielding benchmarks

- χ^2/n will be used for the comparison

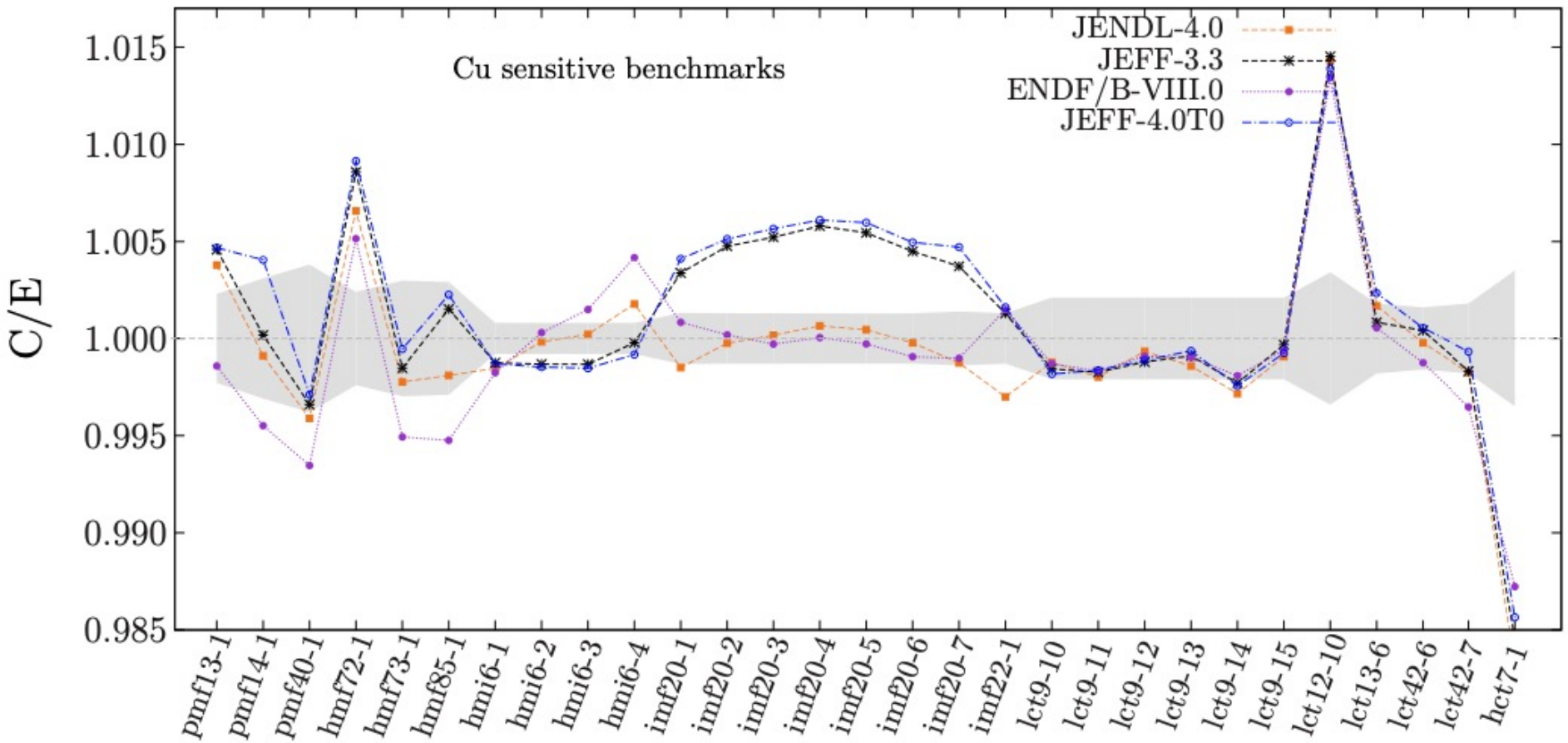
Selected differential data

Cu-63	ENDF/-B.VIII.0	JENDL-4.0	JEFF-4.0T0	Atlas	Sukhoruchkin	Kadonis
$(n,g)_{th}$ (b)	4.49	4.52	4.54	4.50 +/- 0.02	4.50 +/- 0.02	
RI (b)	4.89	4.91	5.31	4.97 +/- 0.08	4.99 +/- 0.09	
MACS (mb)	60	77	72	55 +/- 2	71 +/- 7	55 +/- 2
χ^2/n	2.5	35	27			

Cu-65	ENDF/-B.VIII.0	JENDL-4.0	JEFF-4.0T0	Atlas	Sukhoruchkin	Kadonis
$(n,g)_{th}$ (b)	2.16	2.18	2.13	2.17 +/- 0.03	2.17 +/- 0.03	
RI (b)	1.98	2.17	1.97	2.19 +/- 0.07	2.22 +/- 0.07	
MACS (mb)	34	37	39	29 +/- 2	39 +/- 3	30 +/- 1
χ^2/n	6.7	11	20			

Cu-0	ENDF/-B.VIII.0	JENDL-4.0	JEFF-4.0T0	Atlas		
$(n,g)_{th}$ (b)	3.77	3.80	3.80	3.78 +/- 0.02		
RI (b)	4.0	4.1	4.3	4.1 +/- 0.1		
χ^2/n	0.6	0.5	2.2			

Cu in criticality benchmarks

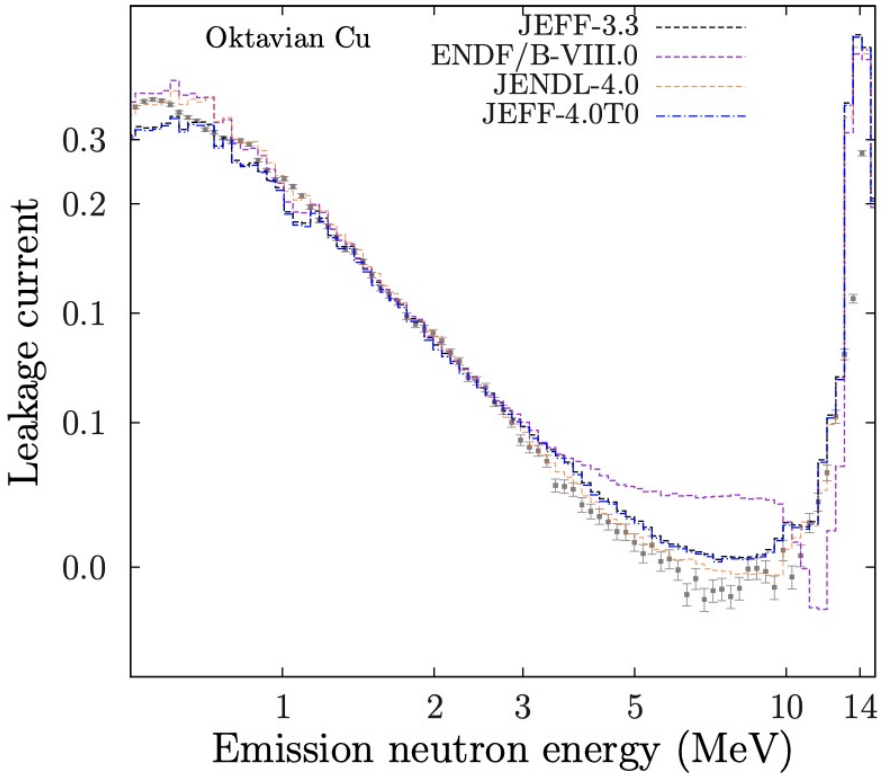


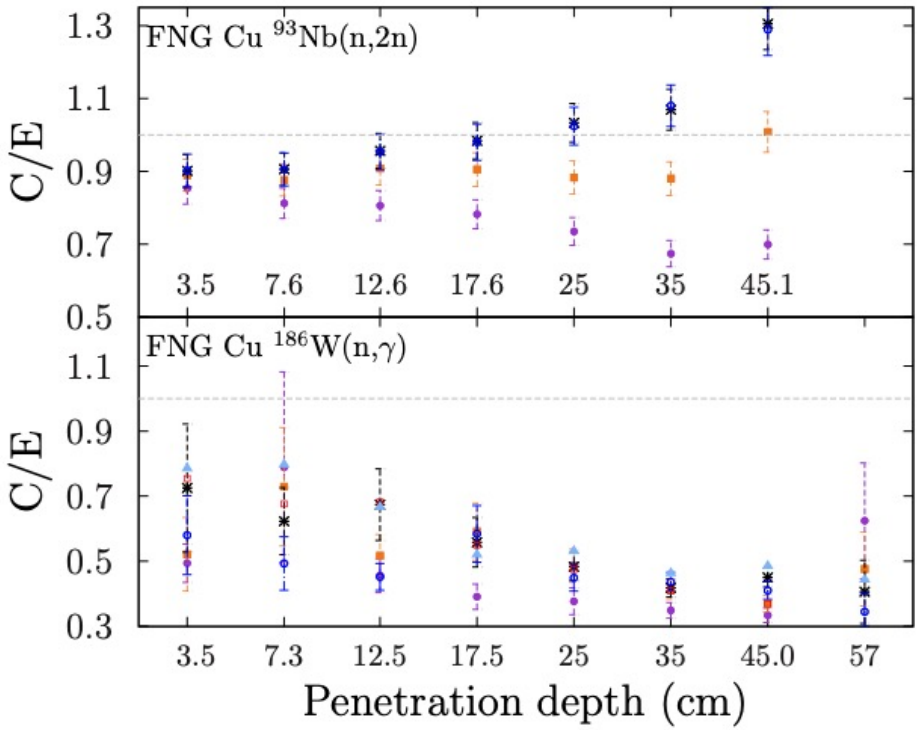
ENDF/B-VIII.0: $\chi^2/n = 3.6$

JENDL-4.0: $\chi^2/n = 1.8$

JEFF-4.0T0: $\chi^2/n = 6.0$

Cu in shielding benchmarks





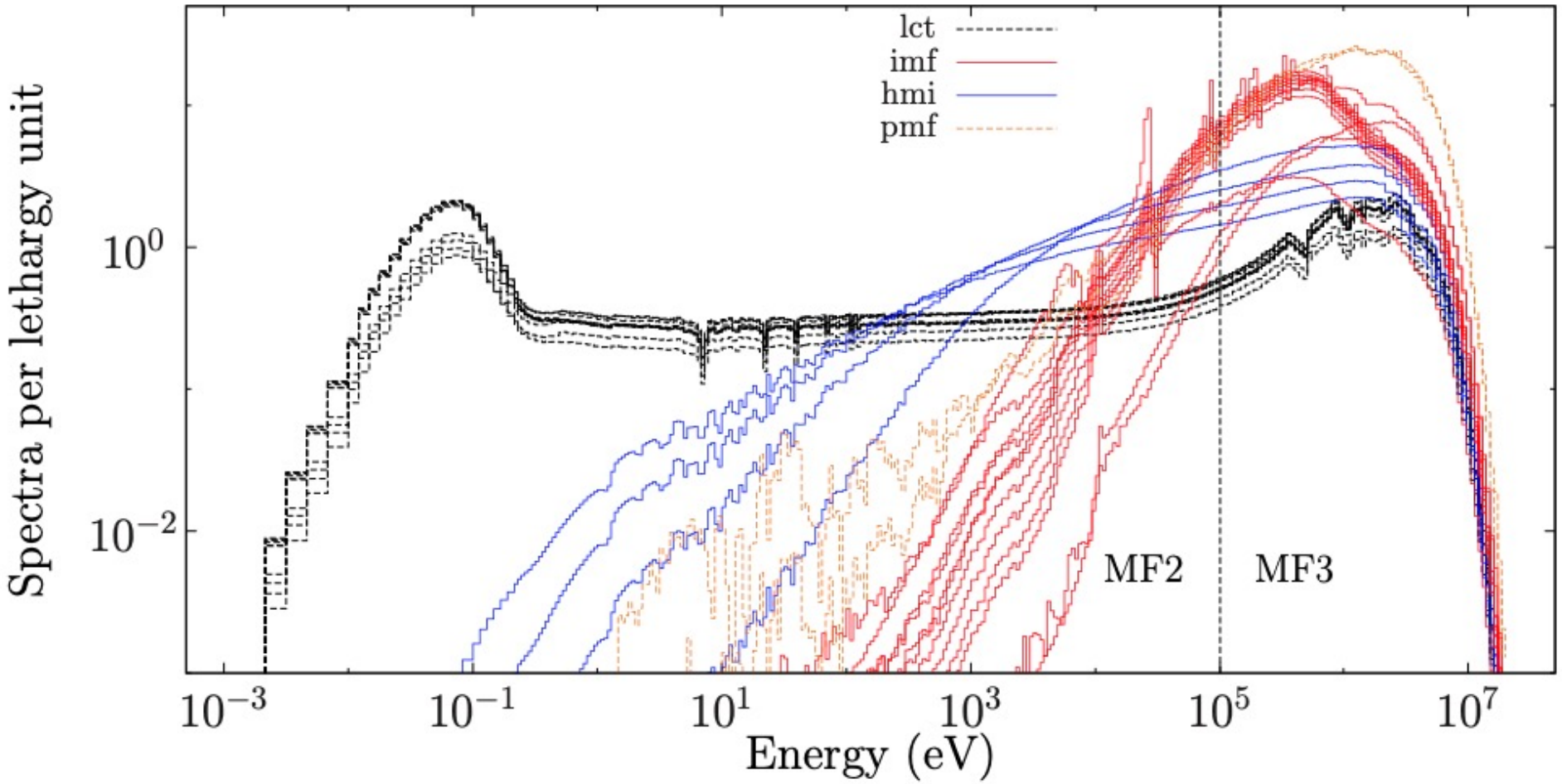
	Oktavian	FNG
ENDF/B-VIII.0:	χ^2/n = 78	χ^2/n = 51
JENDL-4.0:	χ^2/n = 4.9	χ^2/n = 28
JEFF-4.0T0:	χ^2/n = 39	χ^2/n = 36

Cu summary

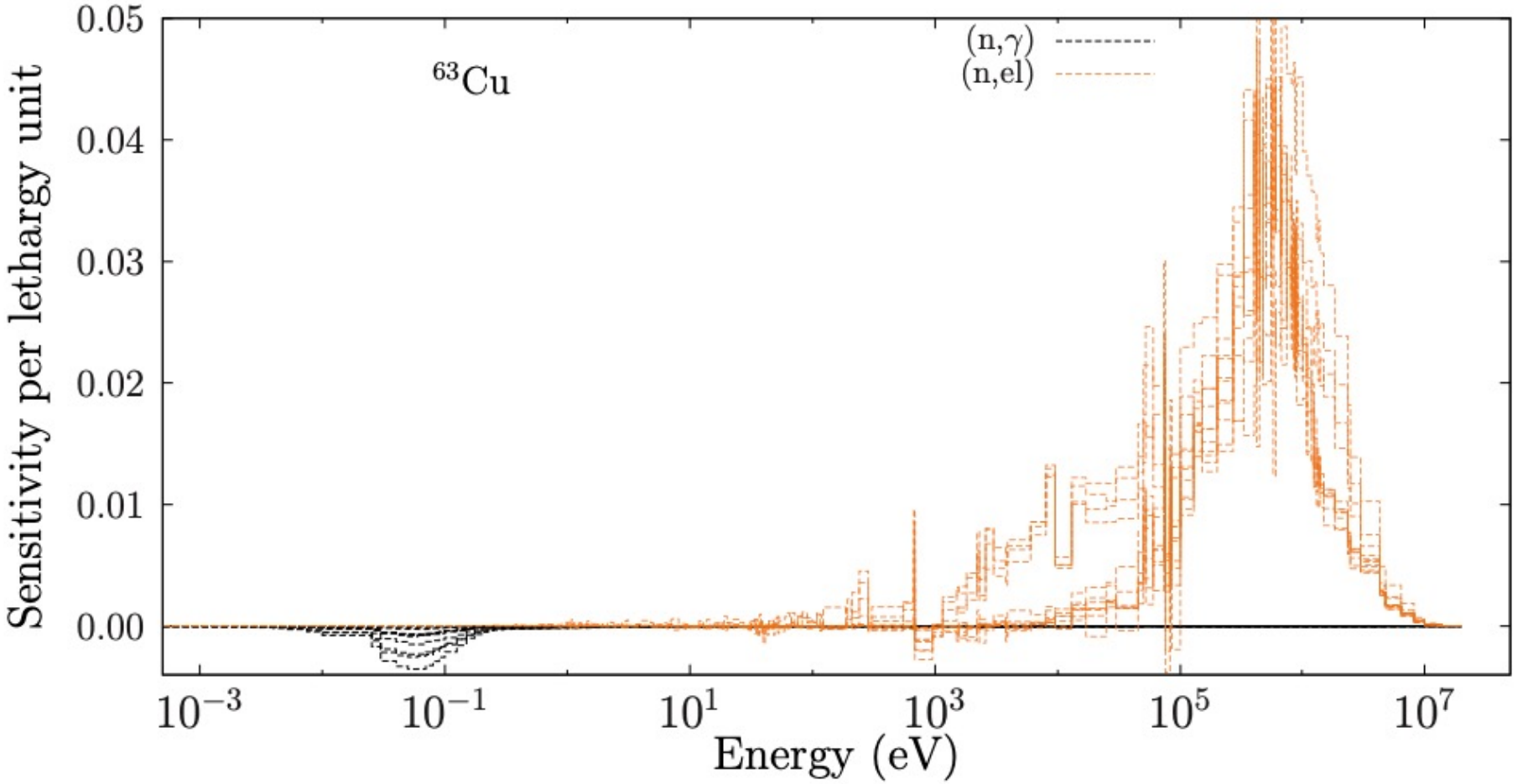
Sum of the previous χ^2/n

	ENDF/-B.VIII.0	JENDL-4.0	JEFF-4.0T0
Differential	4	16	16
k_{eff}	4	2	6
Oktavian	78	5	39
FNG	51	28	36
Sum	136	50	97

k_{eff} spectra



k_{eff} sensitivities



New Cu-63 and Cu-65 evaluations

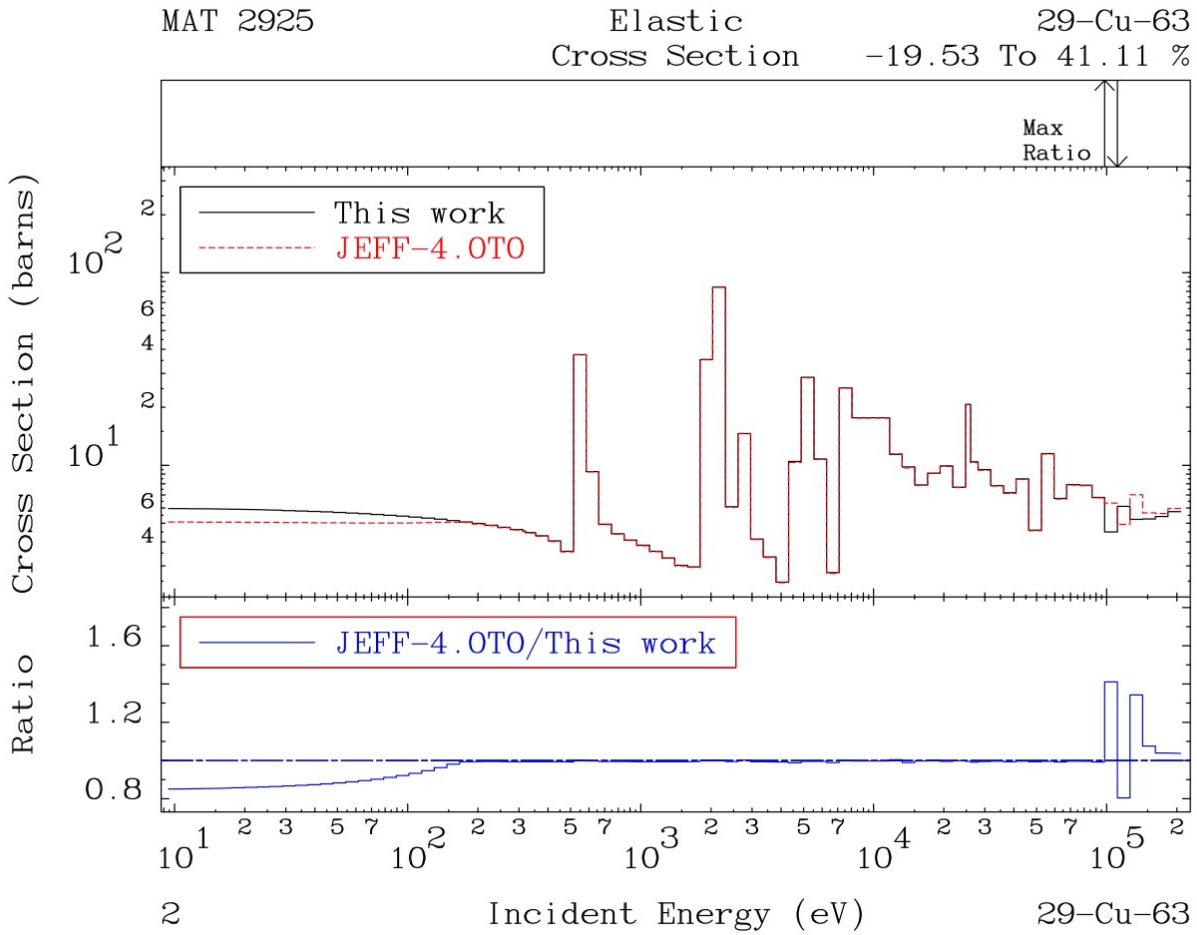
New evaluation:

- Using TALYS,
- Following the TENDL approach
- Import existing MF2 (JEFF-3.3) and adjust
- Import existing MF4 MT2 (ENDF/B-VIII.0), no change
- Adjust MF3 and MF4 to differential and integral data

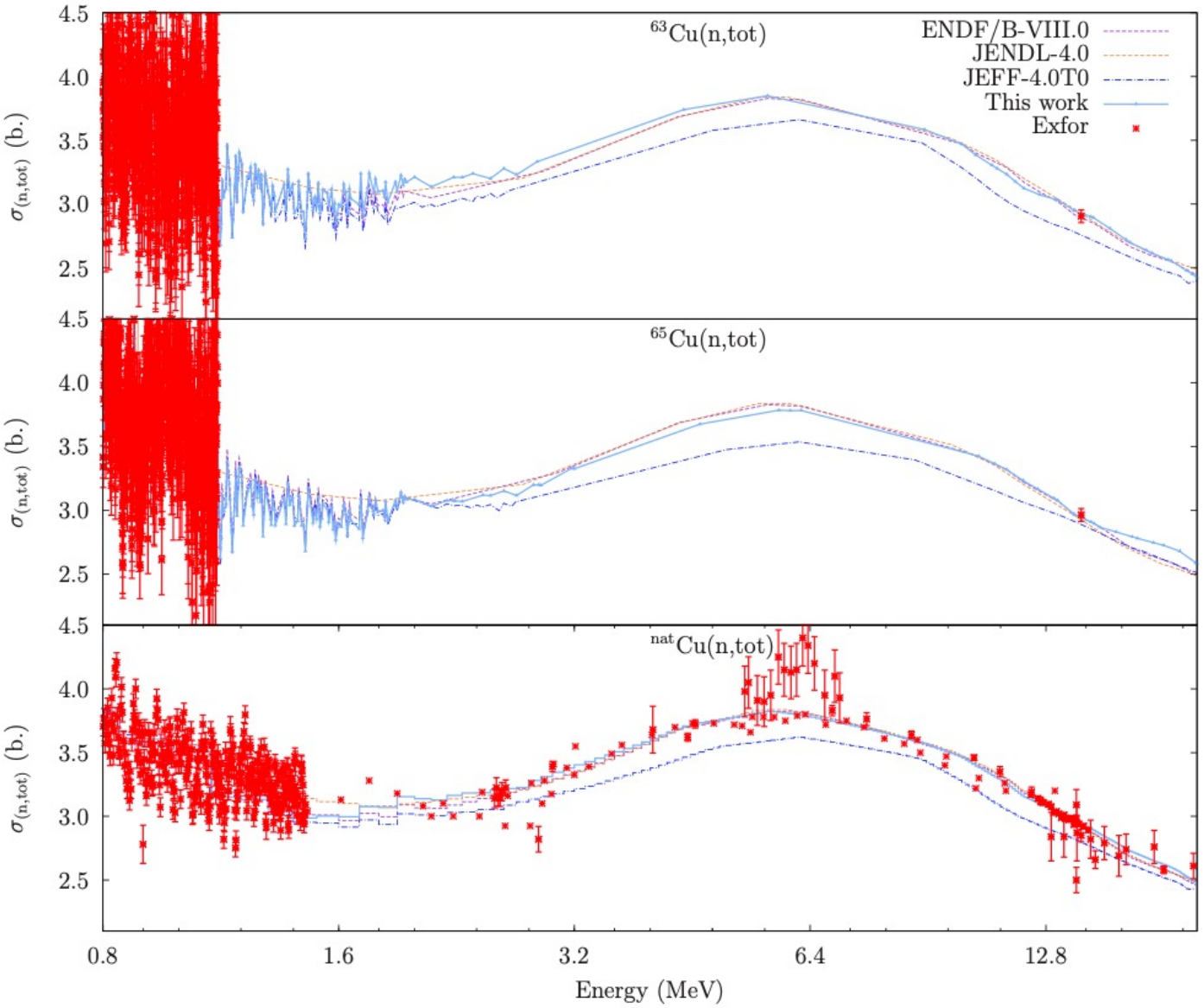
New Cu-63 and Cu-65 evaluations: MF2

Selection of RRR: JEFF-3.3

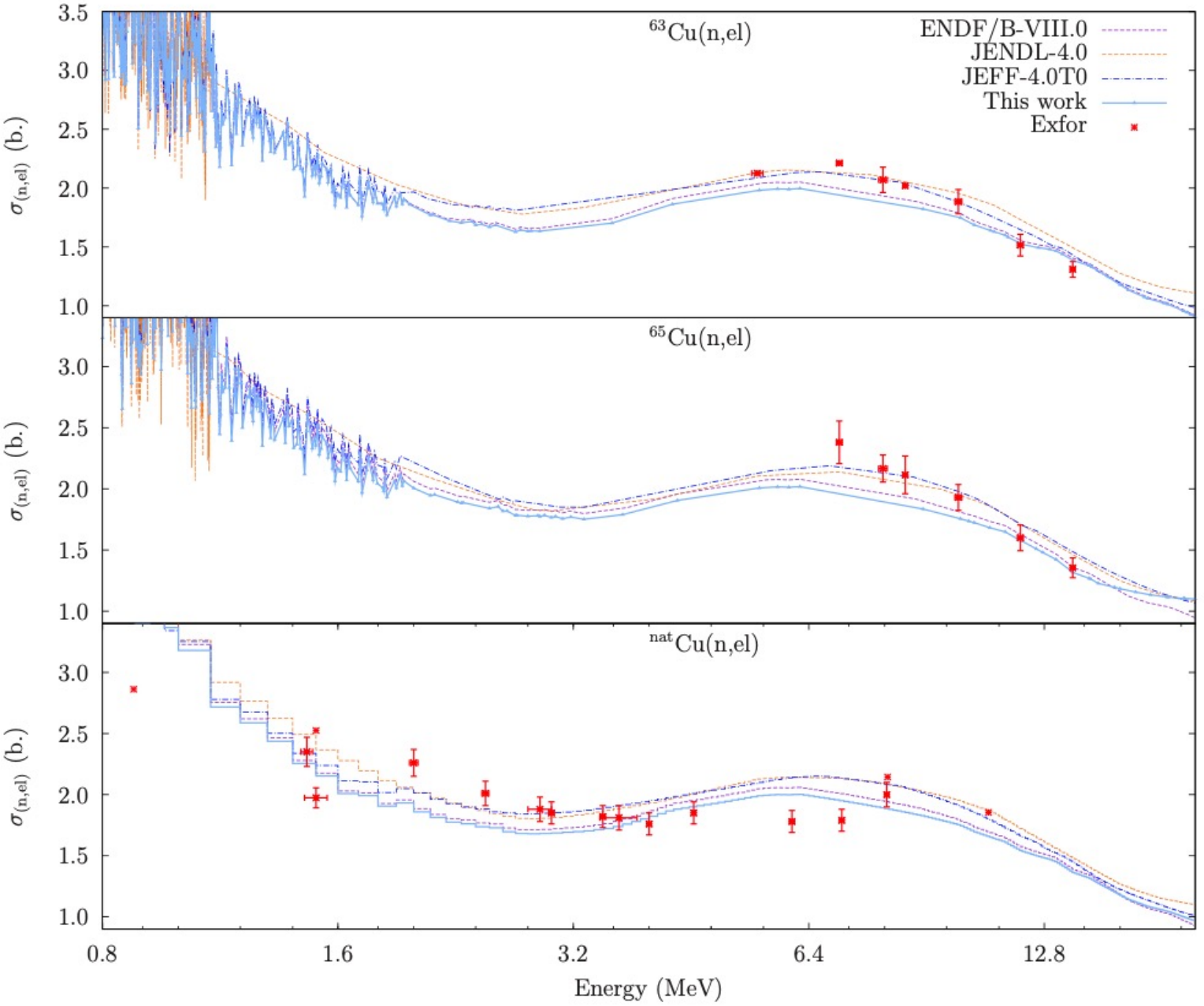
To be redone with B8 (LRF7), or JENDL



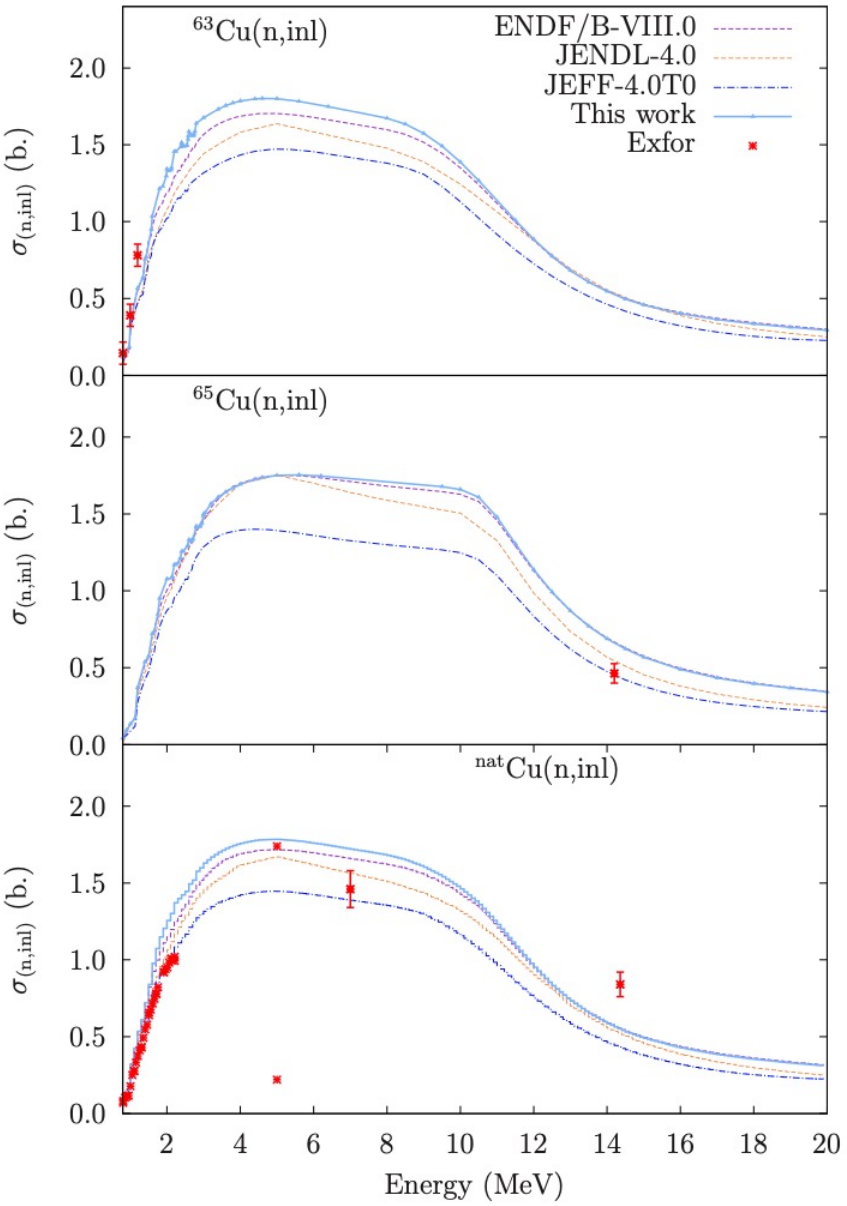
New Cu-63 and Cu-65 evaluations (n,tot)

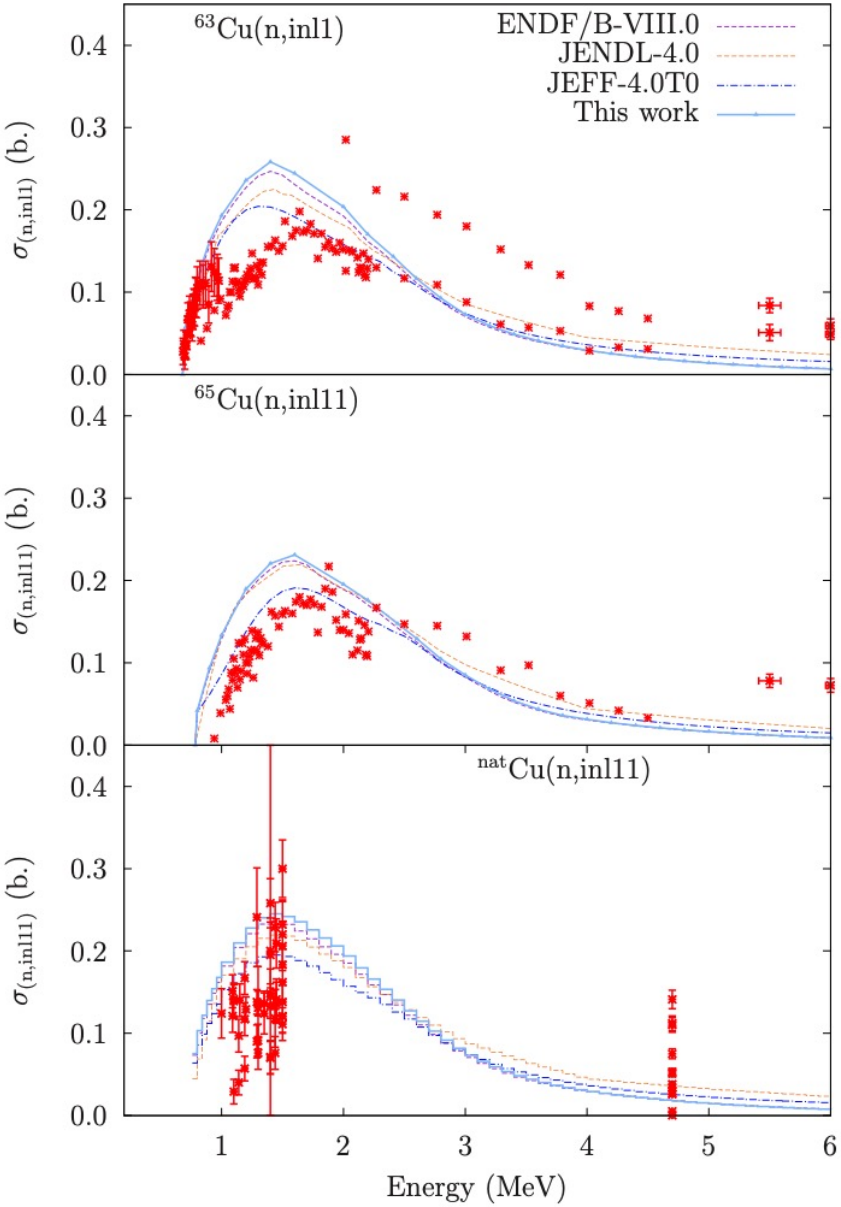


New Cu-63 and Cu-65 evaluations (n,el)

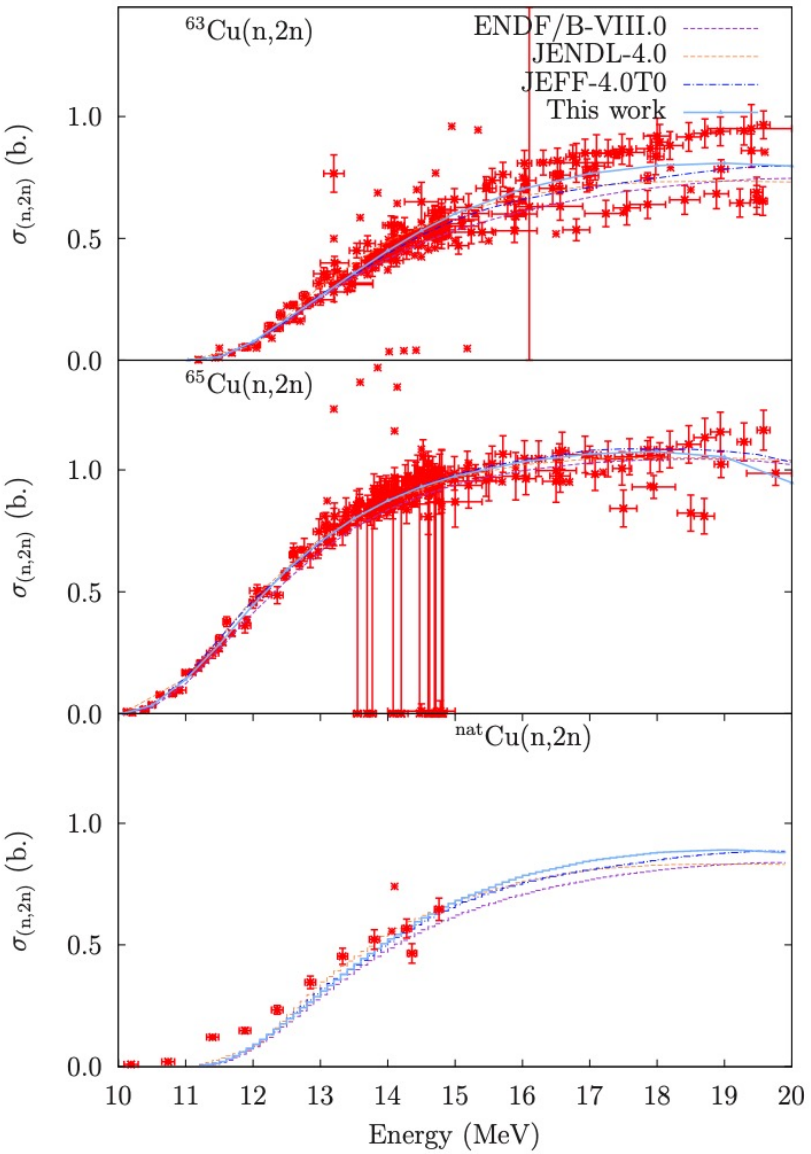


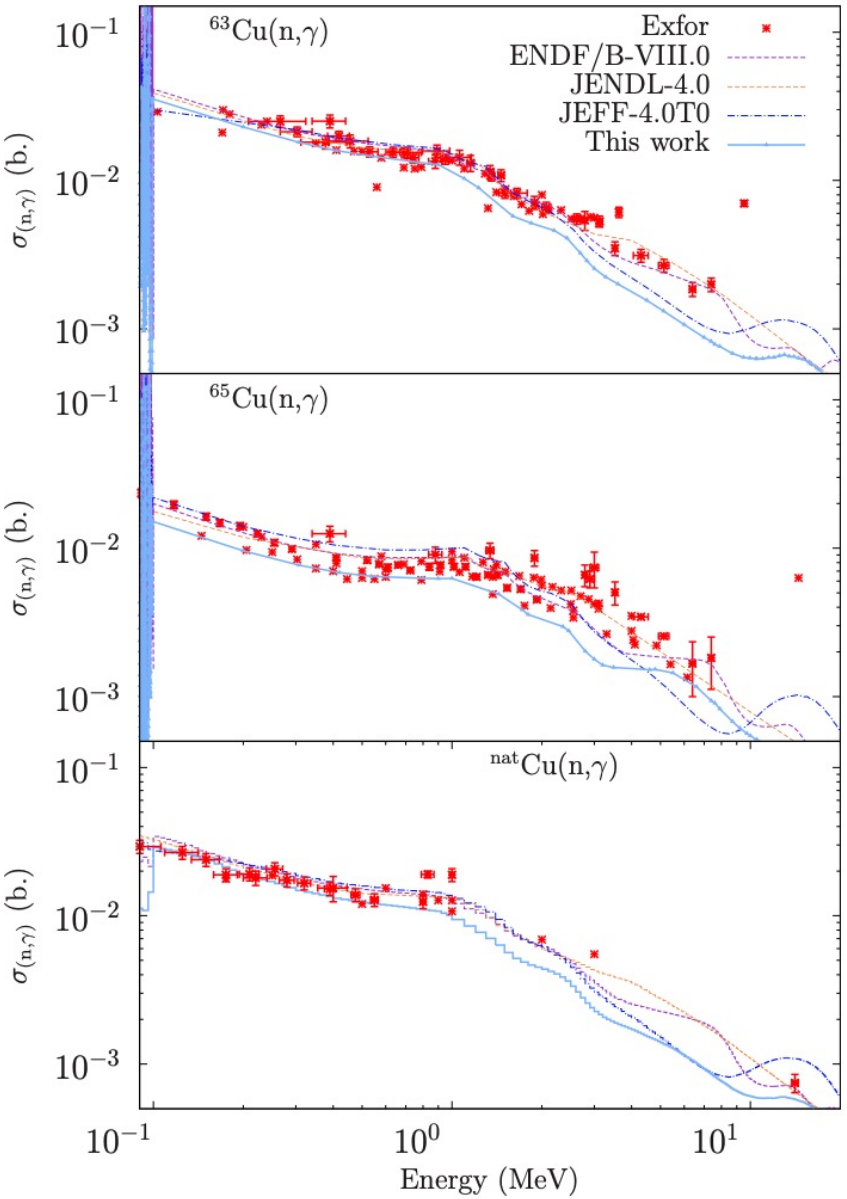
New Cu-63 and Cu-65 evaluations (n,inl)



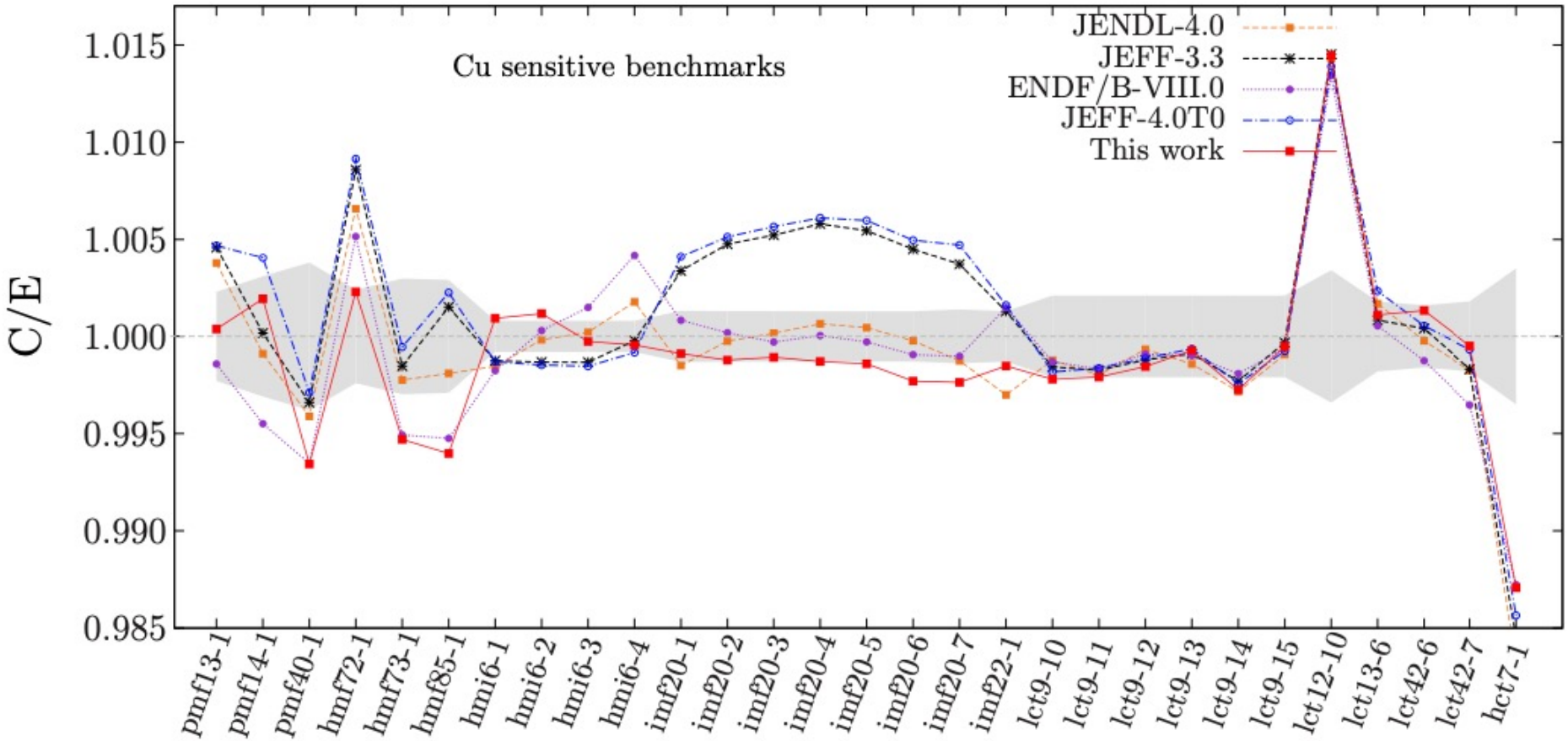


New Cu-63 and Cu-65 evaluations (n,2n) (n,g)





Cu in criticality benchmarks



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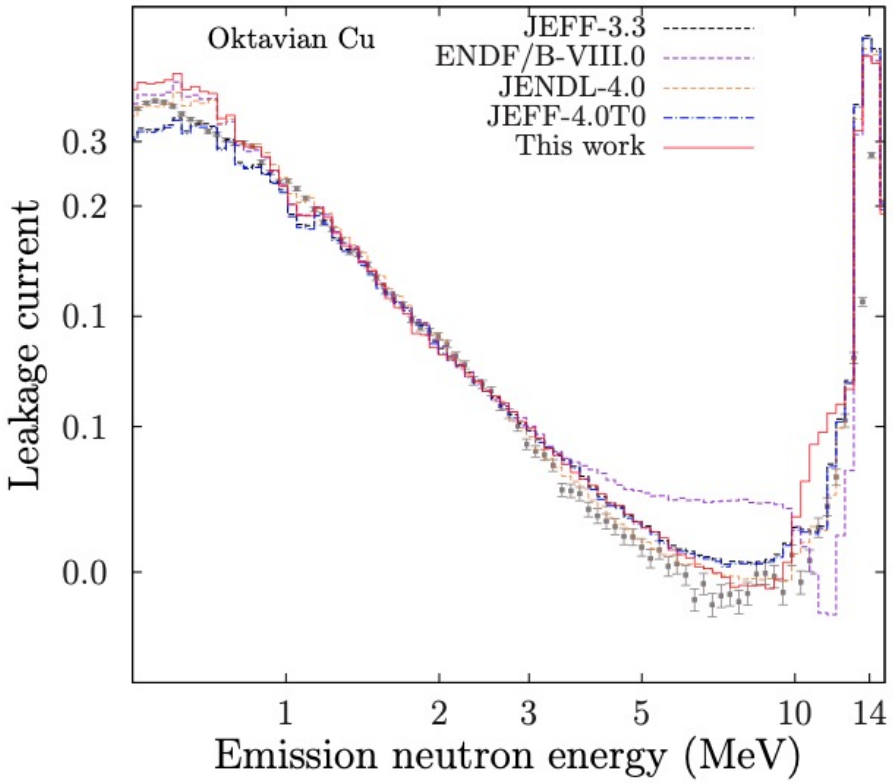
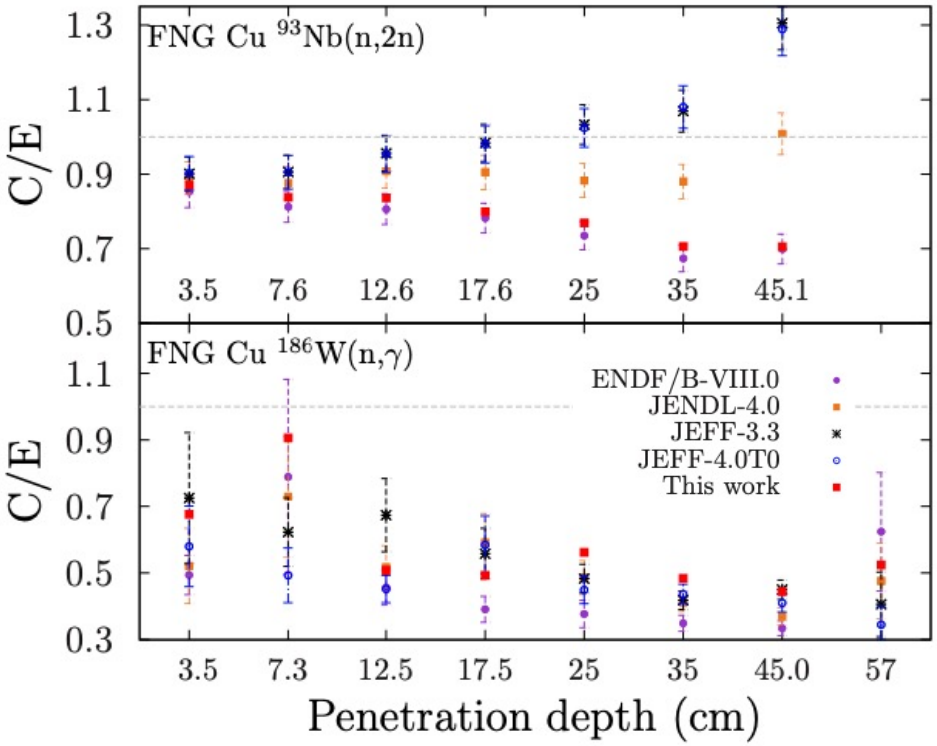
JENDL-4.0: $\chi^2/n = 1.8$

JEFF-4.0T0: $\chi^2/n = 6.0$

This work: $\chi^2/n = 1.5$

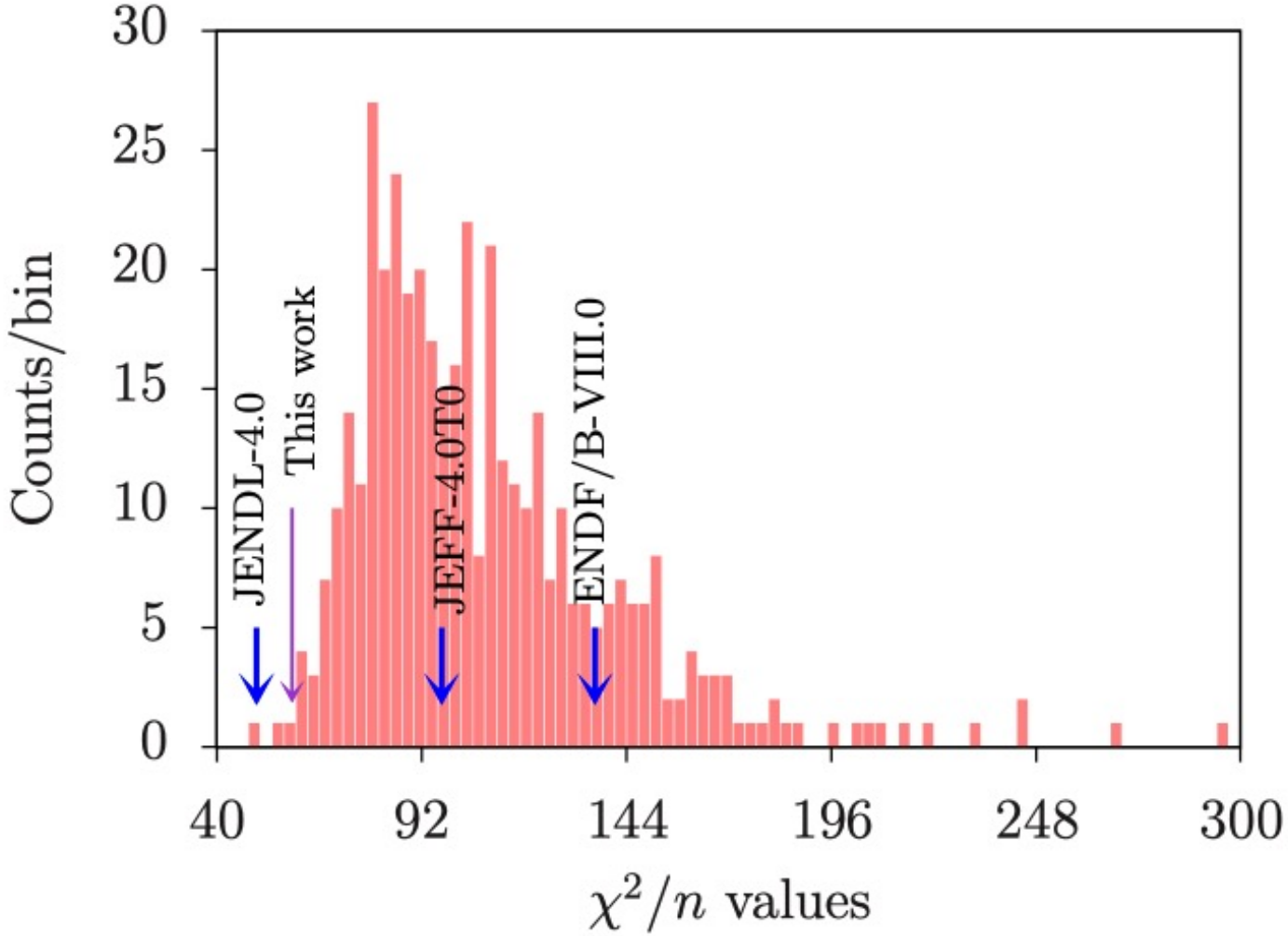
Cu in shielding benchmarks





ENDF/B-VIII.0:	$\chi^2/n = 78$	$\chi^2/n = 51$
JENDL-4.0:	$\chi^2/n = 5$	$\chi^2/n = 28$
JEFF-4.0T0:	$\chi^2/n = 39$	$\chi^2/n = 36$
This work:	$\chi^2/n = 18$	$\chi^2/n = 31$

New Cu-63 and Cu-65 evaluations



Cu summary

Sum of the previous χ^2/n

	ENDF/-B.VIII.0	JENDL-4.0	JEFF-4.0T0	This work
Differential	4	16	16	9
k_{eff}	4	2	6	1.5
Oktavian	78	5	39	18
FNG	51	28	36	31
Sum	136	50	97	59

Conclusion

- Good overall C/E values

- Use more shielding benchmarks
- Additional k_{eff} benchmarks ?

- Start from ENDF/B-VIII.0 MF2 (better between 40-100 keV, JEFF-3.3 using a background)
- Extract correlations benchmarks – MF/MT

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Wir schaffen Wissen – heute für morgen