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EUROfusion PPPT task: status and achievements

JEFF meeting, Fusion working group, 28-30 November 2018,
NEA, Paris, France

Summary

- PPPT Task specifications 2018
- Status and achievement

PPPT task specifications EPFL/PSI

- **PMI-3.3-T019: EPFL/PSI contribution to PPPT nuclear data development: Updating of evaluation methods and improvement of activation cross sections.**

Deliverable	Title	Deliverable owner	Due date
PMI-3.3-T00N-D001	Report or publication on the Fe56 evaluation methods and performances	D. Rochman	31.12.2018
PMI-3.3-T00N-D002	Report of publication on activation cross section improvement	D. Rochman	31.12.2018

PMI-3.3-T00N-D001

- Preliminary remarks:
  – Fe and Fe56 are still not well evaluated in the JEFF-3.3 and ENDF/B-VIII.0 libraries
  – Problems are still present for the shielding benchmarks
  – Modelling is not adequate in specific energy regions
  – Possible questions on the (n,inl) measurements
  – No theoretical solutions are foreseen in a short period

- Many international efforts are going on
  – In the resonance range (IRSN evaluation)
  – In the fast range (IAEA/INDEN network, JENDL…)
  – Support from the benchmark side (SINBAD)

- The present work aims at studying how far the current theoretical knowledge can be used to globally improve C/E, both for differential and integral data

PMI-3.3-T00N-D001

- Plan of study:
  - Generate random nuclear data files for Fe isotopes with TALYS
    - Random parameters
    - Random models
  - Generate random nuclear data files for Fe isotopes with EMPIRE
    - Random parameters
    - Random models
  - Benchmark the random files with criticality/shielding benchmarks and study the impact on possible future measurement programme (PETALE at CROCUS)
  - Provide a feedback for future improvements
- Some results will be presented in the Nuclear Data Sheets 2019 paper “TENDL: Complete Nuclear Data Library for innovative Nuclear Science and Technology”

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- Criticality benchmarks of interest

TABLE 7.1. LIST OF IRON AND STAINLESS STEEL REFLECTED BENCHMARKS

No.	ICSBEP Label	Short name	Common name
1	HEU-MET-FAST-013	hmf013	VNIITF-CTF-SS-13
2	HEU-MET-FAST-021	hmf021	VNIITF-CTF-SS-21
3	HEU-MET-FAST-024	hmf024	VNIITF-CTF-SS-24
4	HEU-MET-FAST-087	hmf087	VNIITF-CTF-Fe
5	HEU-MET-FAST-088	hmf088-001	hmf088-001
6	HEU-MET-FAST-088	hmf088-002	hmf088-002
7	HEU-MET-INTER-001	hmi001	ZPR-9/34
8	HEU-MET-THERM-013	hmt013-002	Planet_Fe-2
9	HEU-MET-THERM-015	hmt015	
10	IEU-MET-FAST-005	imf005	VNIIEF-CTF-5
11	IEU-MET-FAST-006	imf006	VNIIEF-CTF-6
12	LEU-COMP-THERM-042	lct042-001	lct042-001
13	LEU-COMP-THERM-042	lct042-002	lct042-002
14	LEU-COMP-THERM-043	lct043-002	IPEN/MB-01
15	LEU-MET-THERM-015	lmt015-001	RB-Vinca(01)
16	MIX-COMP-FAST-001	mcf001	ZPR-6/7
17	MIX-COMP-FAST-005	mcf005-s	ZPR-9/31
18	MIX-COMP-FAST-006	mcf006-s	ZPPR-2
19	PU-MET-FAST-015	pmf015	BR-1-3
20	PU-MET-FAST-025	pmf025	pmf025
21	PU-MET-FAST-026	pmf026	pmf026
22	PU-MET-FAST-028	pmf028	pmf028
23	PU-MET-FAST-032	pmf032	pmf032
24	PU-MET-INTER-002	pmi002	ZPR-6/10
25	PU-MET-INTER-003	pmi003-001s	ZPR-3/58(U)
26	PU-MET-INTER-004	pmi004-001s	ZPR-4/59(Pb)
27	IEU-COMP-INTER-005	ici005	ZPR-6/6A

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- Shielding benchmarks of interest

1. FNS 20, 40 and 60 cm
2. LLNL pulse spheres 0.9, 2.9, 4.8 mfp
3. TUD Fe
4. SG39 Fe SINBAD
   - Oktavian Fe
   - TUD Fe
   - FNG SS
   - IPPE Fe
   - Janus 1, Janus 8
   - Aspis Fe
   - Aspis88

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- One single model might not be enough to "fit" all experimental data,

- Usually only one set of model is used for a full evaluation, e.g. in TENDL:
  - OMP Local Koning-Delaroche
  - Gamma-strength function: Kopecky-Uhl generalized Lorentzian
  - Level density model: Constant temperature + Fermi gas model

- Other options are available in TALYS:
  - 8 gamma-strength functions (called *i*)
  - 6 level density models (called *j*)
  - Different OMP (local, general, microscopic) (called *k*)

  - In total: *i* x *j* x *k* possibilities (11n, 12n, 58n…)
  - For each of these possibilities, one can sample model parameters

- Other extreme solution: EMPIRE.
- In the following: -10 TALYS models (semi-empirical and microscopic)
  -8 EMPIRE models (semi-empirical and microscopic)
- In total: almost 18 000 random files

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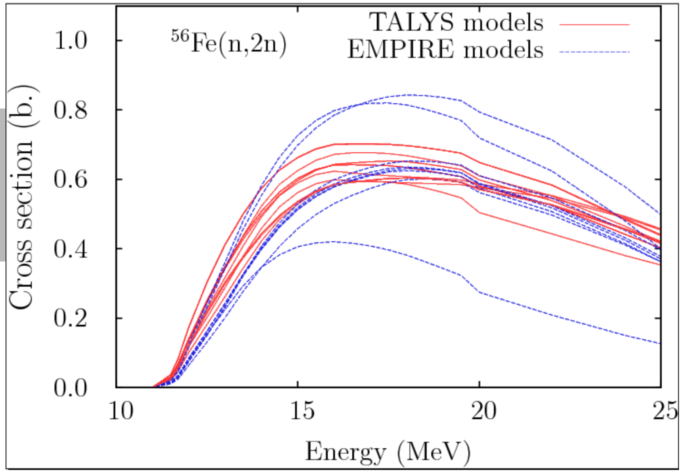
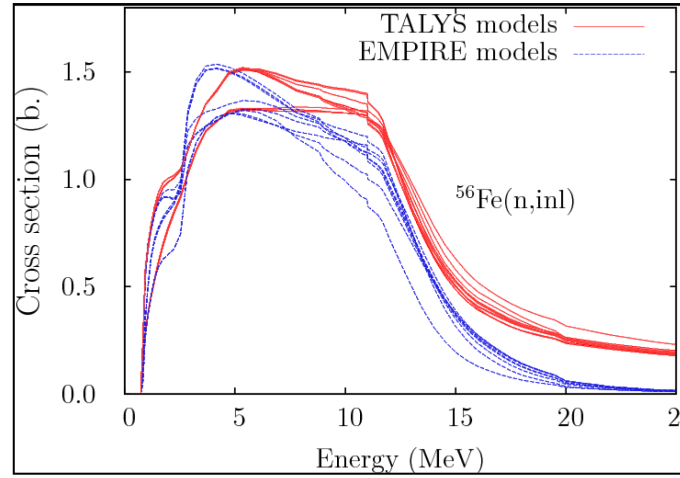
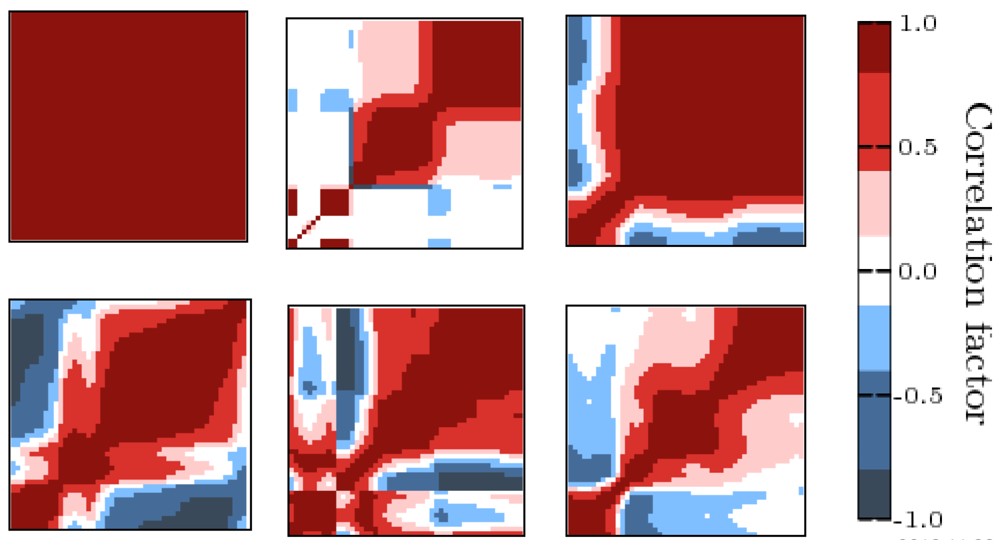
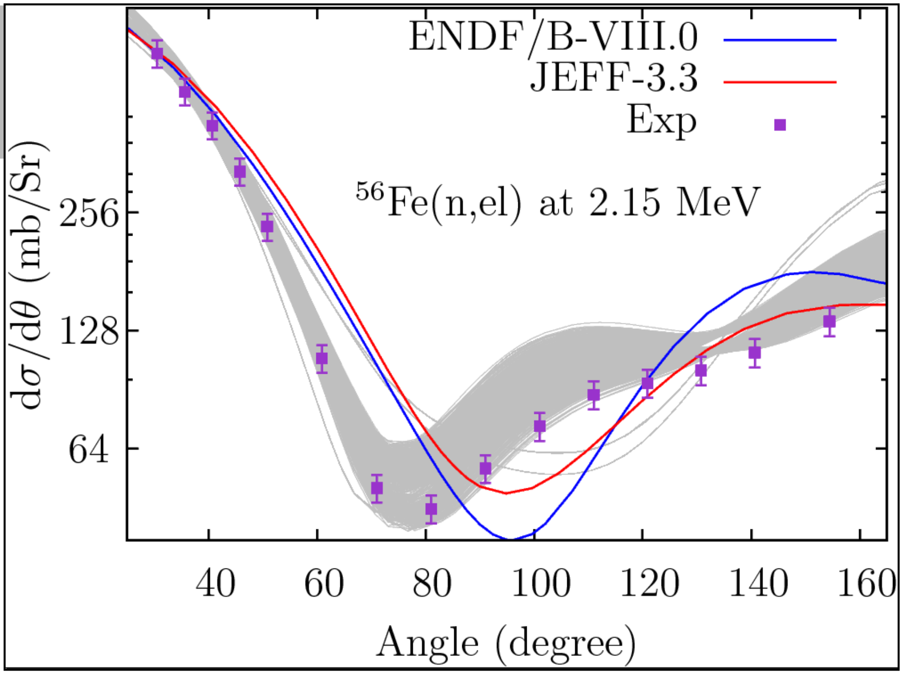


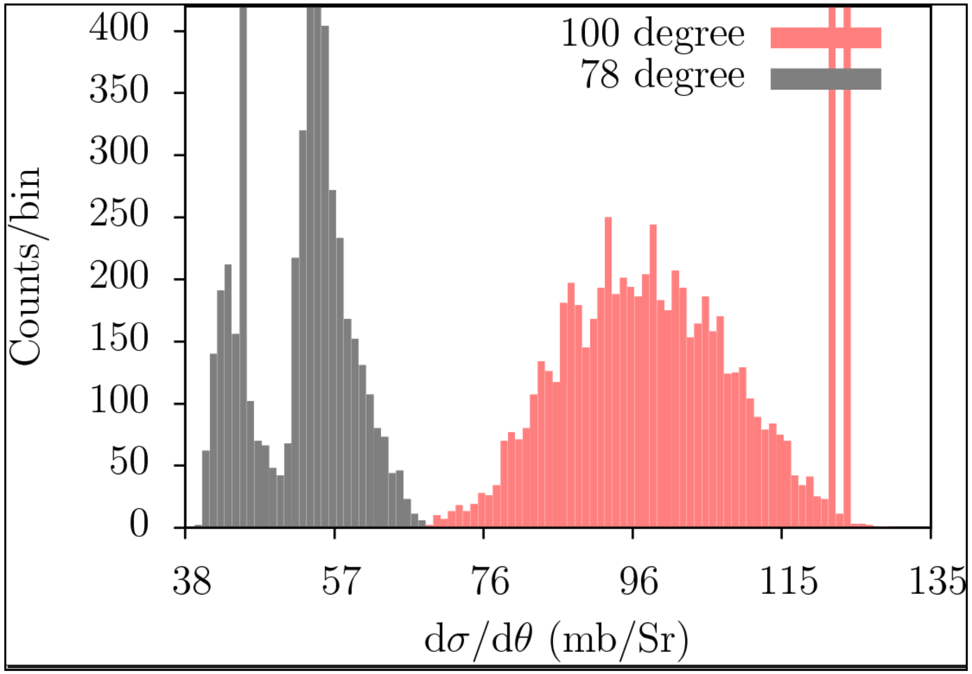


Many prior correlation matrices can be obtained depending on the models/combination, all for the same reaction. Examples for ^{56}Fe(n,inl):



- Example for ^{56}Fe angular distribution





- Angular distributions are not normally distributed.

- Variations of models and parameters might not be enough to cover experimental data.

- Model defects might help in this case

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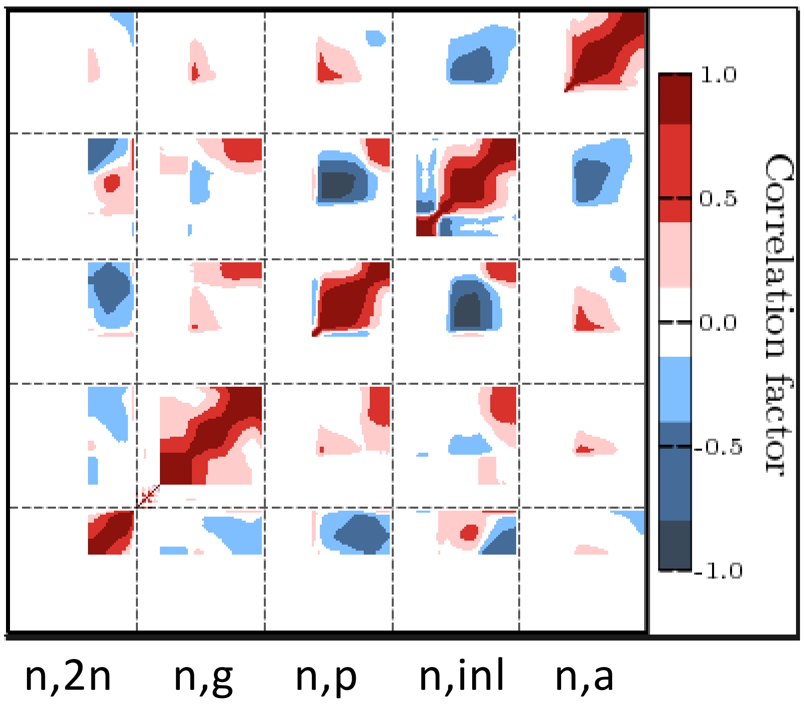
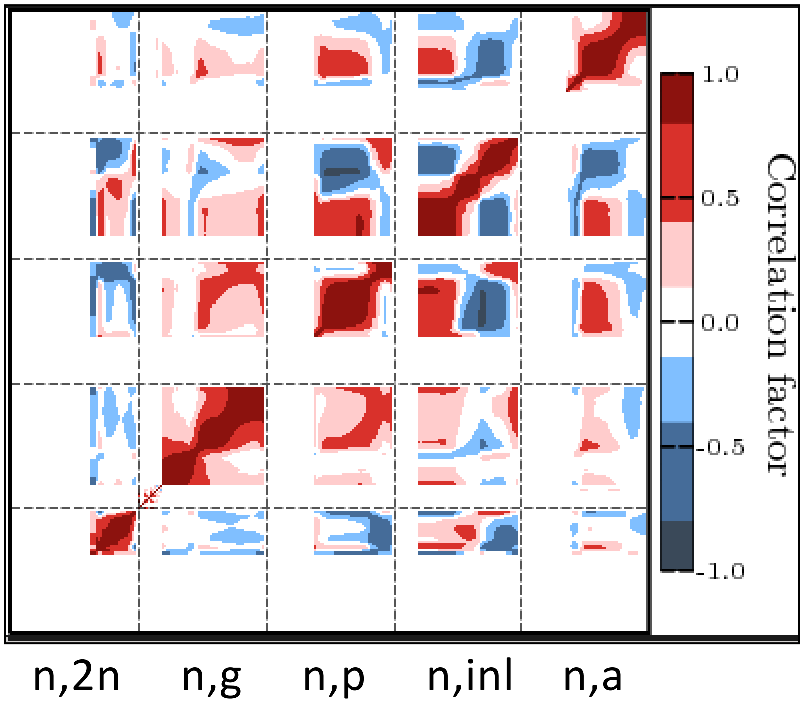
- ^{56}Fe: TALYS+EMPIRE+EXFOR+BFMC
- Generalization for many reactions (random models + random parameters)

1 model



2 models



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- Results on some criticality benchmarks
- Impact of varying Fe56 with different models/parameters
- Very skewed distributions can be obtained

	+/- (pcm)	skew		+/- (pcm)	skew
hmf72.1	702	0.30	hmf21.1	593	0.22
pmf15.1	1325	0.88	hmi1.1	1160	-0.06
hmf13.1	770	1.02	hmt13.2	410	-0.02
lct42.1	130	-0.14	mcf1.1	394	-0.30

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- Example for hmf13 and hmt13-002

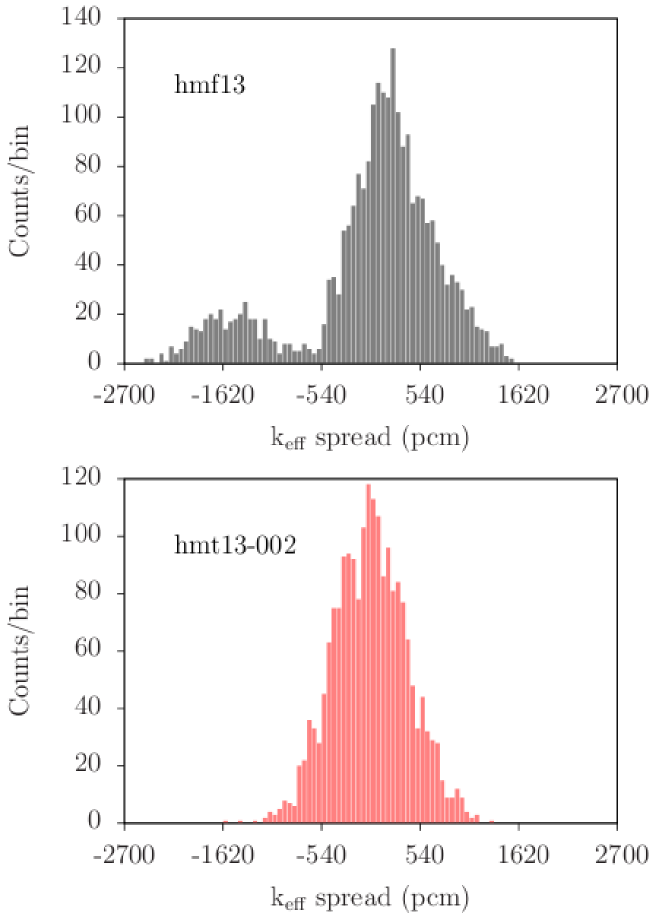

FIG. 36. Examples of the calculated k_{eff} spread for two benchmarks highly sensitive to iron. All nuclear data of ^{56}Fe are varied, using about 2400 random files, with different models and model parameters.

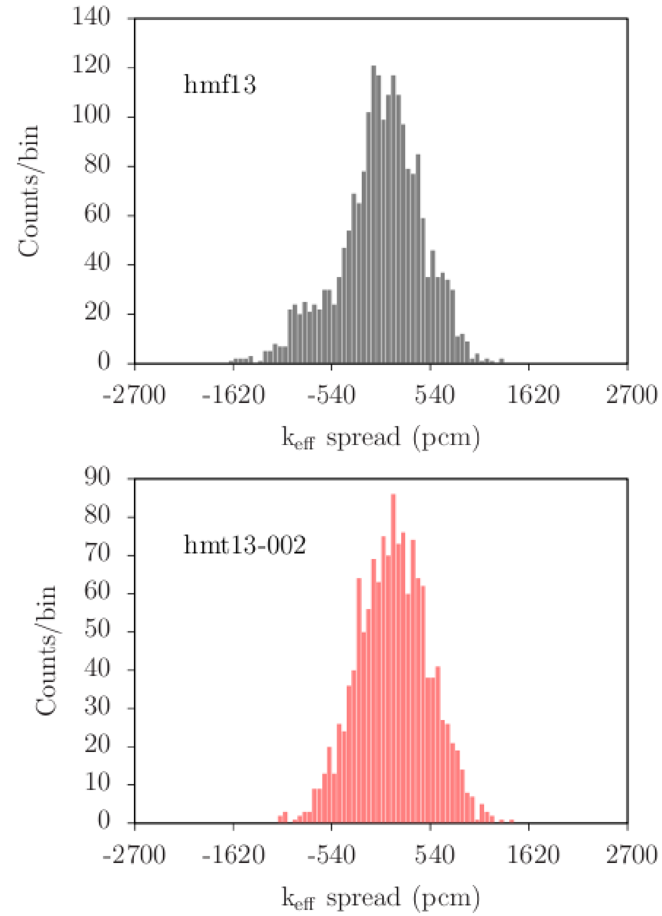

FIG. 37. Same as Fig. 36, but keeping MF4 fixed (no variation of the angular distributions).

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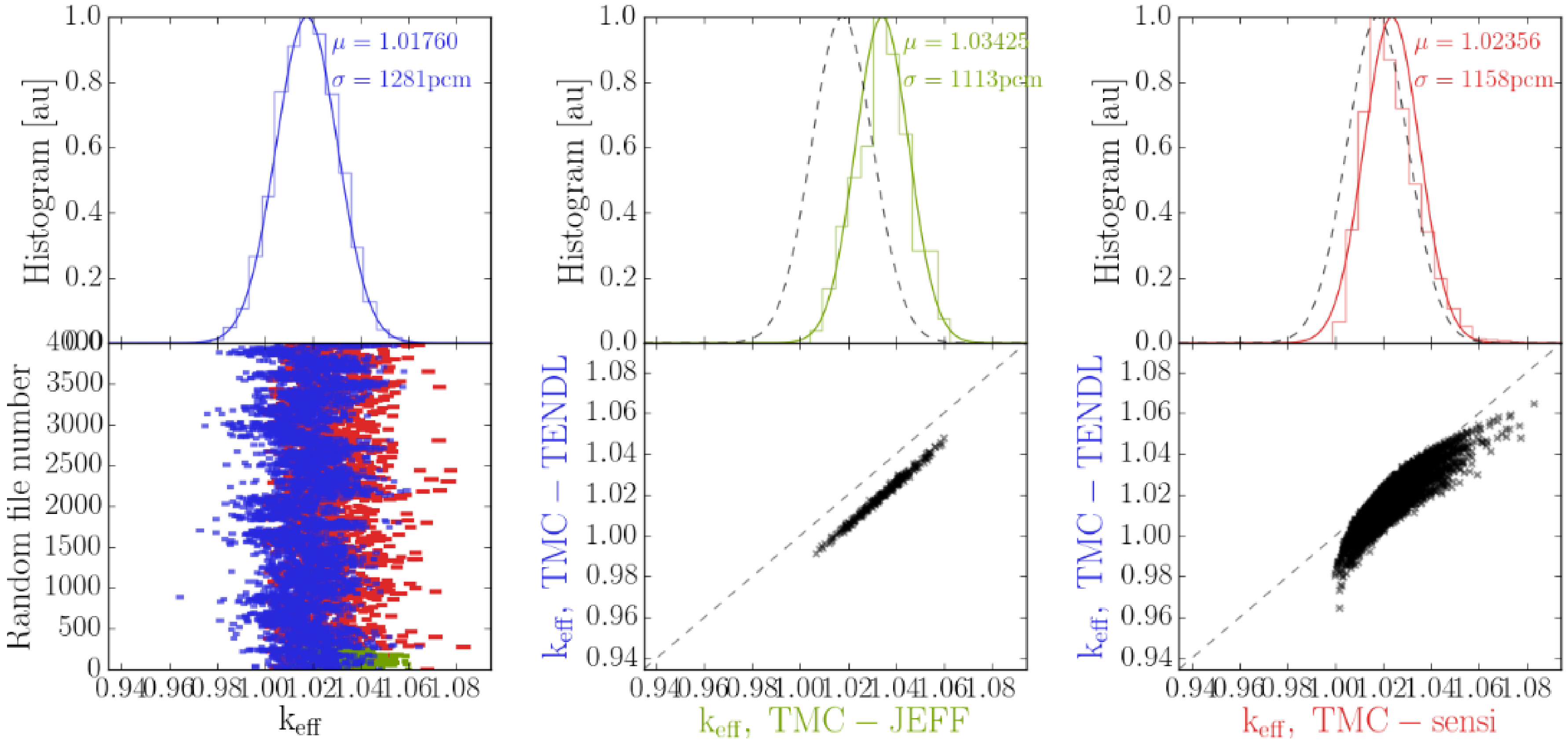
- Details of the hmi1 benchmark using TMC, TMC+JEFF for other Fe isotopes, and sensitivities
- Indicates the needs of studying all Fe isotopes together



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PMI-3.3-T00N-D001

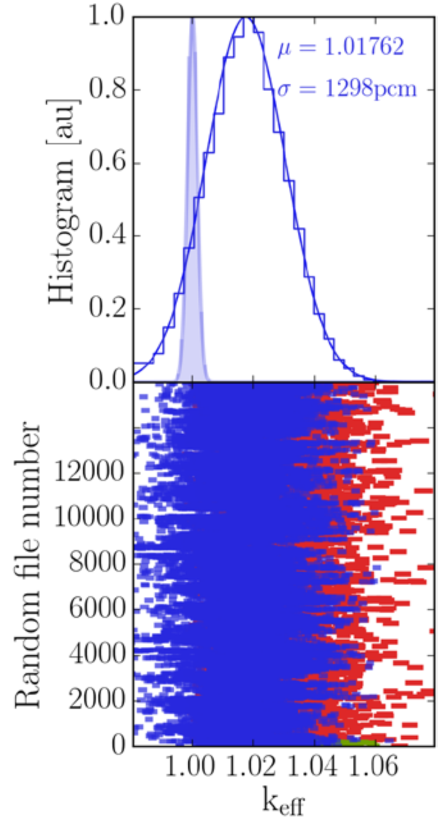
- HMI-001 - Impact of the BMC on the k_{eff} uncertainty propagation

HMI-001:

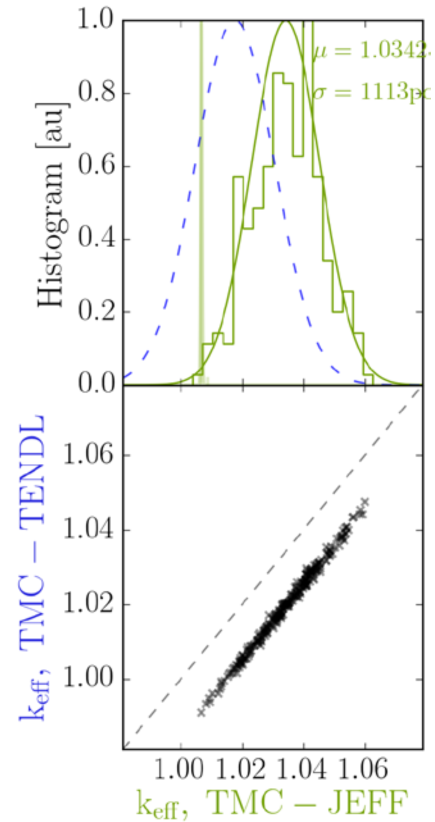
- System very sensitive to iron cross sections: metallic fuel + metallic reflector
- Nuclear data iron uncertainty larger than the experimental uncertainty
- \- $^{54\text{-}57\text{-}58}$Fe: TENDL
  \- ^{56}Fe: sampling on ND parameters & models
  \- other isotopes: JEFF3.3

BMC assimilation:

- Strong reduction of the posterior uncertainty
- Perspective: perform the BMC assimilation using all iron isotopes to avoid compensation effects



k_{eff} dispersion due to the nuclear data uncertainty



Using JEFF3.3 for $^{54\text{-}57\text{-}58}$Fe

Systematic shift larger than the assumed corresponding uncertainty

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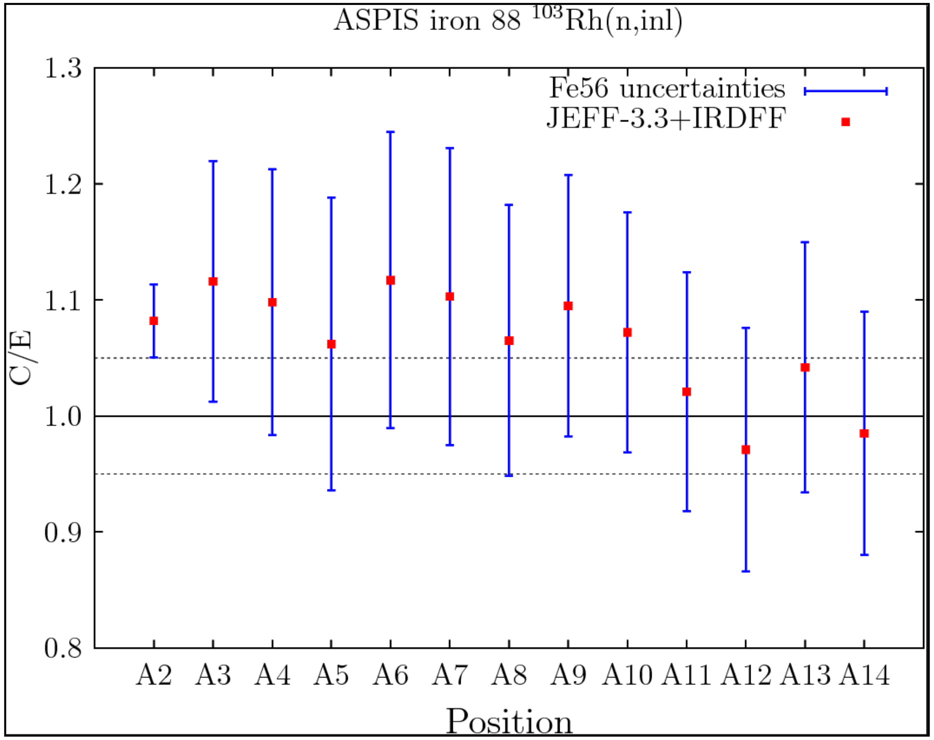
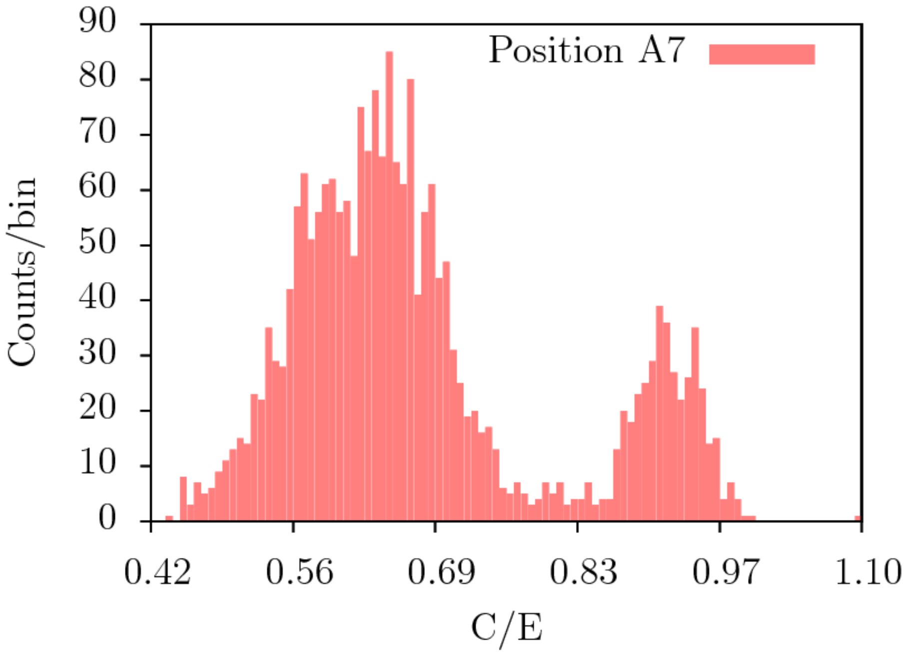
- Example for ASPIS (model received from I. Kodeli with very detailed reports and efficient MCNP model).
- ASPIS: Many activation measurements as a function of depth (In, Rh, S, Al,…)
- In the case of Rh: impact of Fe56

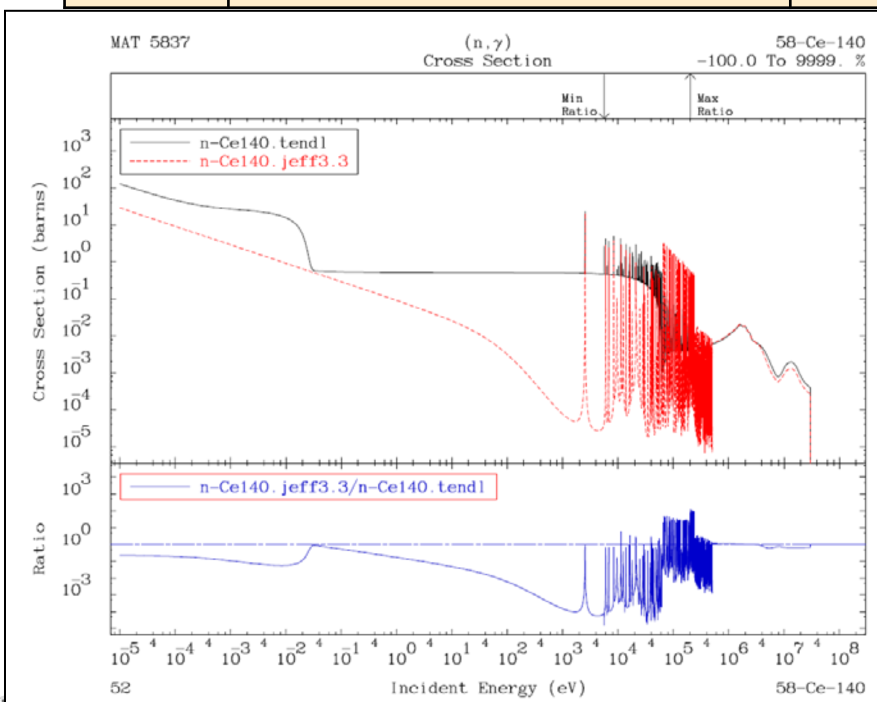


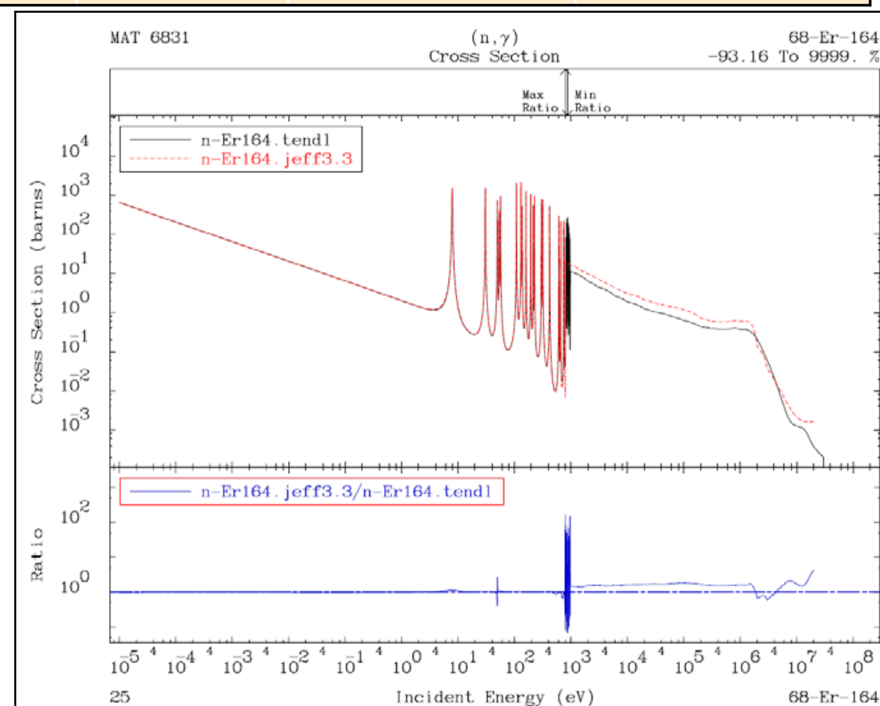


PMI-3.3-T00N-D002

- Improvement of activation cross sections
- Based on the previous work with NRG, some reactions still can be improved

				C/E			
	Reaction	RI (b)	ΔRI	EAF-2010	JEFF-3.3	ENDF/B-VIII	TENDL-2017
1	^{140}Ce(n,g)	0.54	0.05	0.49	0.55	0.55	0.55
2	^{164}Eu(n,g)	105	10	1.35	1.58	1.60	1.42





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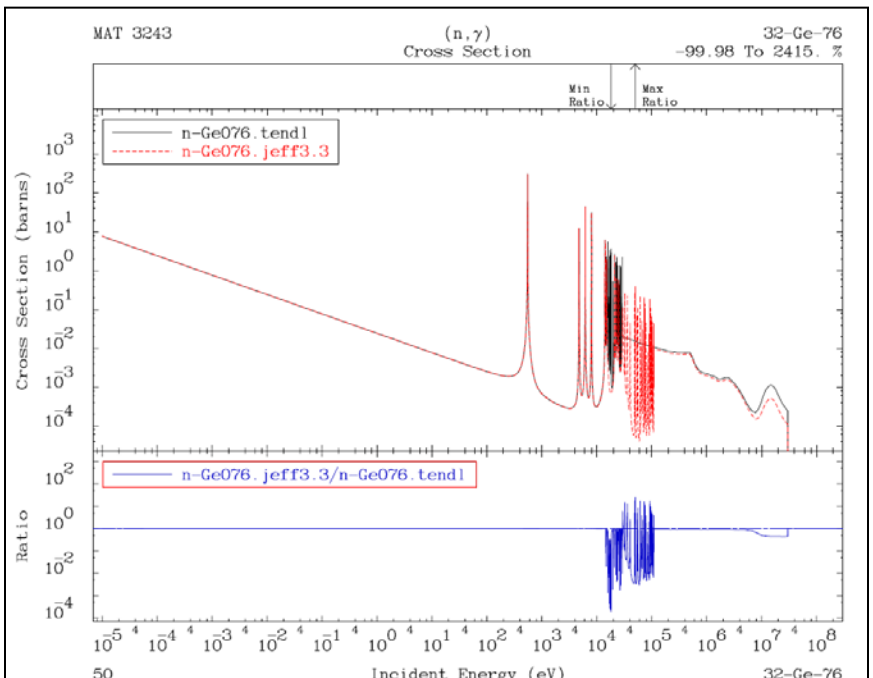
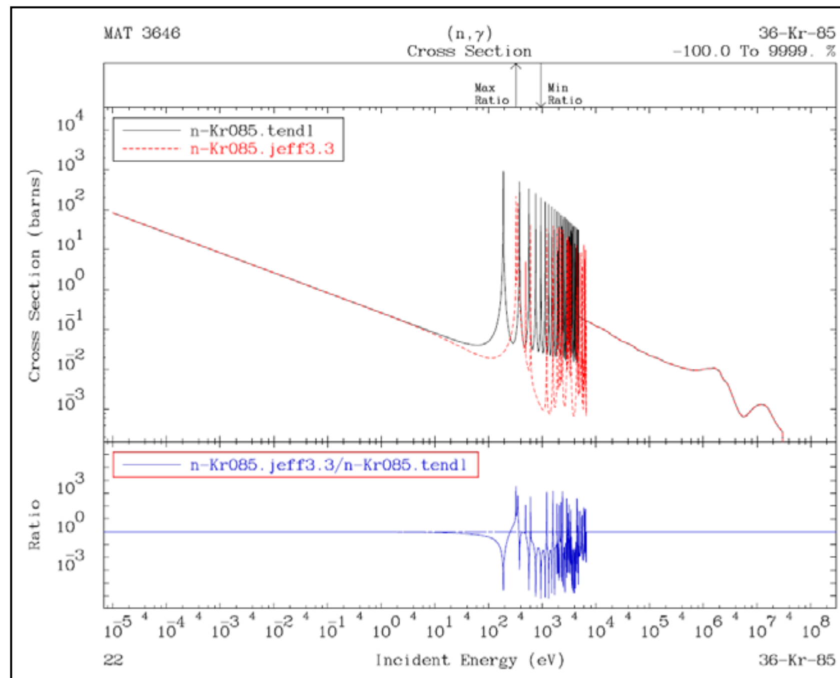
				C/E			
	Reaction	RI (b)	ΔRI	EAF-2010	JEFF-3.3	ENDF/B-VIII	TENDL-2017
3	^{76}Ge(n,g)	1.86	0.24	0.71	0.74	0.72	0.74
4	^{85}Kr(n,g)	1.8	1.0		2.7	1.6	2.3





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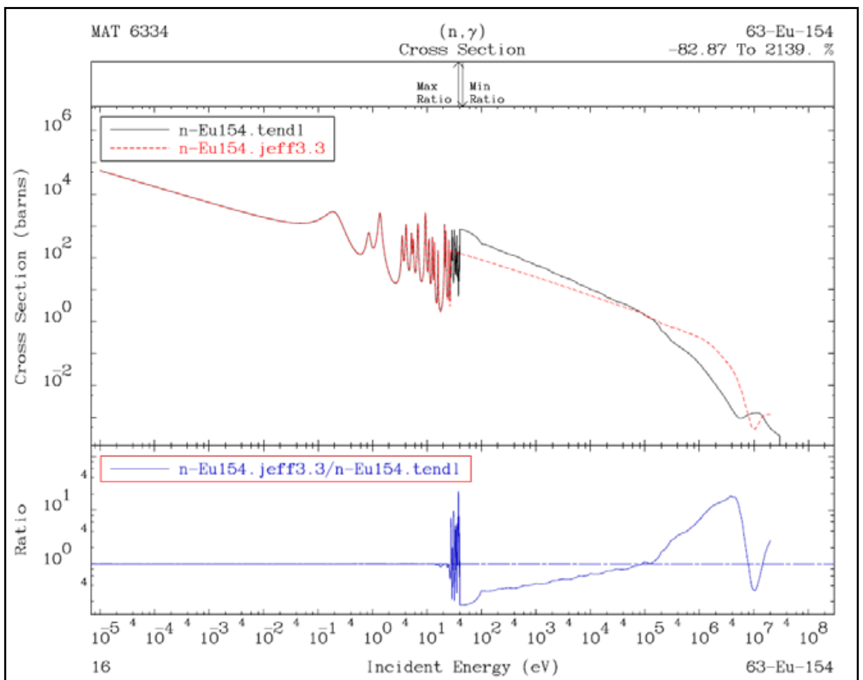
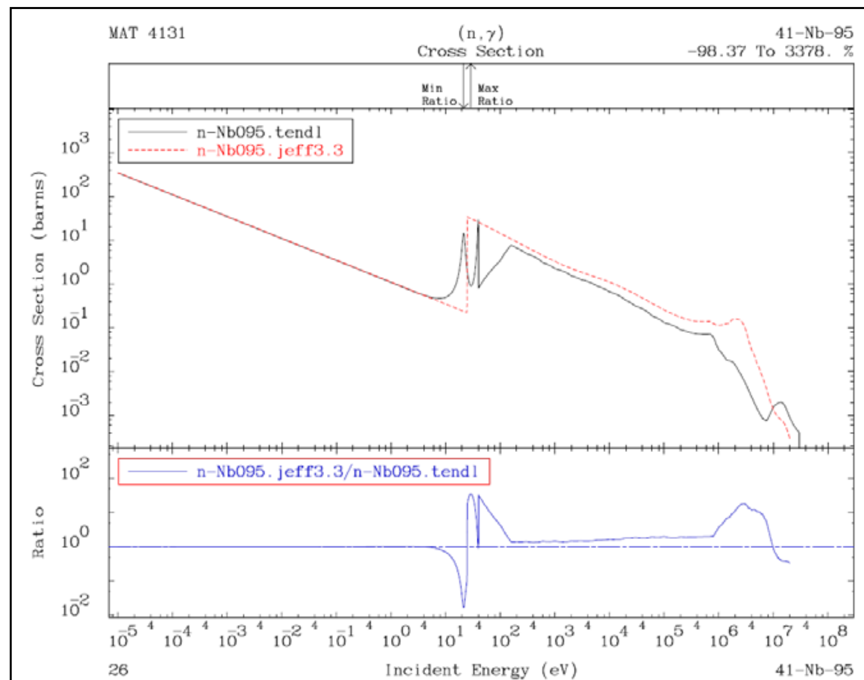
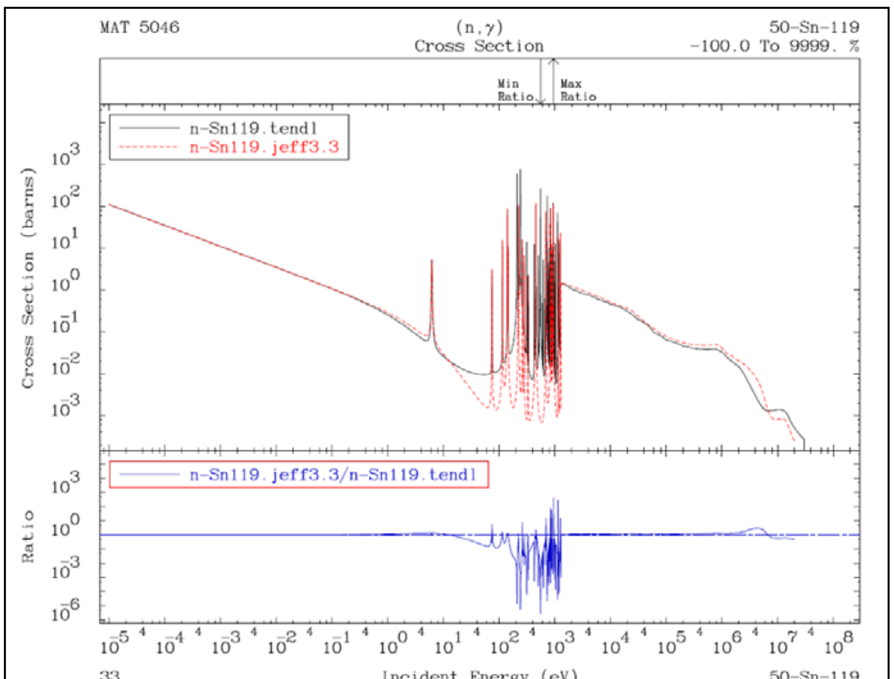
				C/E			
	Reaction	RI (b)	ΔRI	EAF-2010	JEFF-3.3	ENDF/B-VIII	TENDL-2017
5	^{154}Eu(n,g)	1320	130		1.6	1.6	2.3
6	^{95}Nb(n,g)				0.29	0.21	0.04





PMI-3.3-T00N-D002

				C/E			
	Reaction	RI (b)	ΔRI	EAF-2010	JEFF-3.3	ENDF/B-VIII	TENDL-2017
7	^{119}Sn(n,g)	4.56	0.49		1.92	1.94	1.55
8	^{88}Sr(n,g)	0.024			0.63	0.51	0.62
9	^{130}Te(n,g)	0.42	0.02		0.64	0.65	0.65



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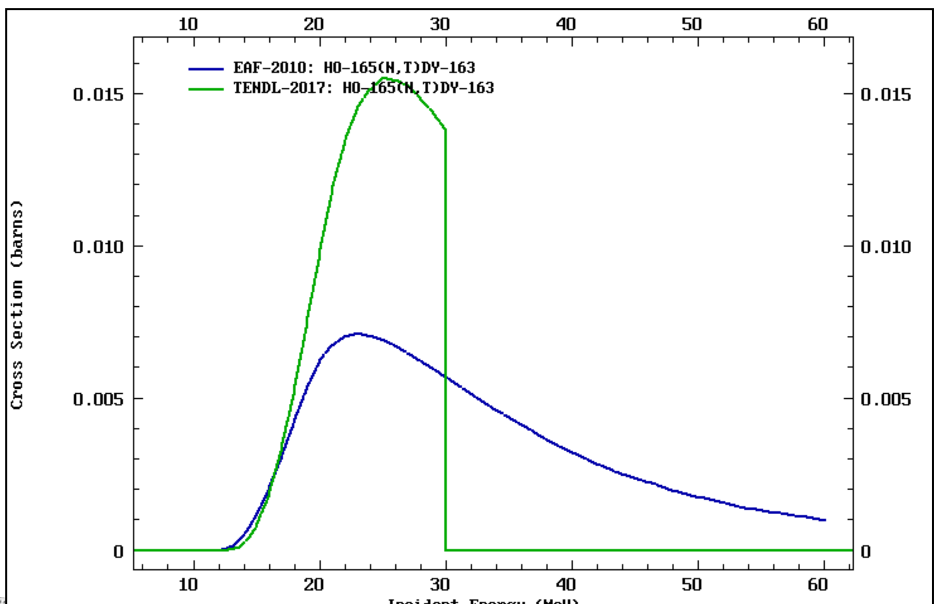
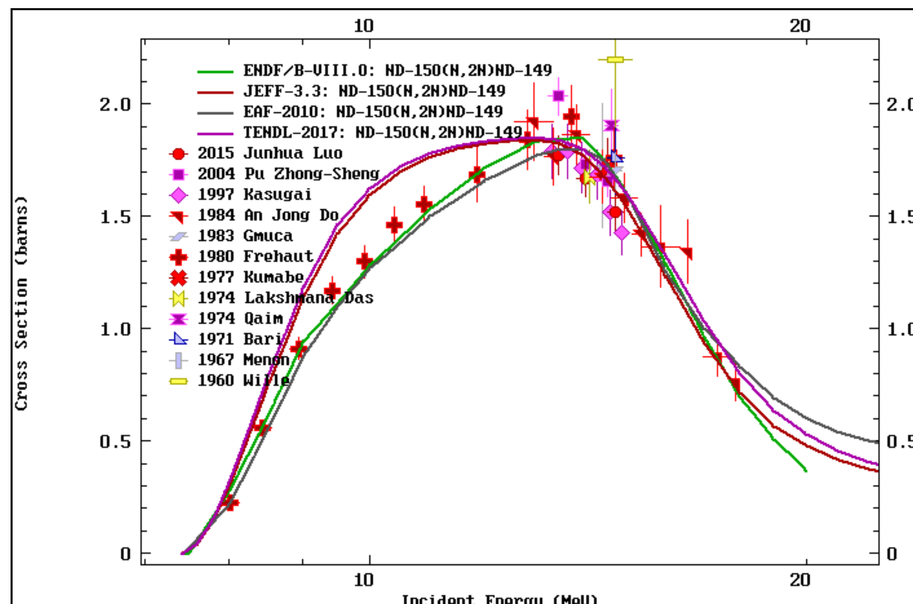
PMI-3.3-T00N-D002

			C/E			
	Reaction	reaction	EAF-2010	JEFF-3.3	ENDF/B-VIII	TENDL-2017
10	^{165}Ho(n,t)	d-Be	0.48			0.50
11	^{150}Nd(n,2n)	fng_5min	1.83			1.65
12	^{141}Pr(n,2n)	fng_5min	1.37			1.35
13	^{159}Tb(n,t)	d-Be	0.63			0.76





PMI-3.3-T00N-D002

- Comparison with IRDFF-1.05 and possible improvements

	Reaction	Remarks on TENDL-2017 compared to IRDFF-1.05
14	^{23}Na(n,2n)	XS probably too high between 19 and 30 MeV
15	^{24}Mg(n,p)	Energy grid not dense enough
16	^{27}Al(n,p)	Energy grid not dense enough
17	^{28}Si(n,p)	Autonorm needed on a dense energy grid
18	^{31}P(n,p)	Energy grid not dense enough
19	^{45}Sc(n,g)	XS too low between 100 and 200 keV Wrong shape above 14 MeV
20	^{52}Cr(n,2n)	XS too low above 18 MeV
21	^{54}Fe(n,2n)	XS too high above 18 MeV
22	^{54}Fe(n,a)	Resonances missing
23	^{56}Fe(n,p)	XS too high above 20 MeV

PMI-3.3-T00N-D002

- Comparison with IRDFF-1.05 and possible improvements

	Reaction	Remarks on TENDL-2017 compared to IRDFF-1.05
24	$^{58}Ni(n,2n)$	XS too low above 18 MeV
25	$^{67}Zn(n,p)$	Thermal 10^{18} too low
26	$^{90}Zr(n,2n)$	XS too low above 18 MeV

- A new database using the Atlas of Neutron Resonances 6th edition is being created

Conclusion

- PMI-3.3-T00N-D001:
  - Fe56 evaluation is not over
  - Model knowledge is not enough
  - Necessity to consider all isotopes together
  - For future work: make use of model defects

- PMI-3.3-T00N-D002:
  - Some specific reactions to be improved are identified
  - These 26 reactions need to be look at in details to ensure that integral (activation) results are not affected
  - Verification with the Atlas 6th edition is also necessary
  - For future work: go through these reactions and answer possible user feedback

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Wir schaffen Wissen – heute für morgen