Status of INDEN evaluations

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On behalf of the INDEN collaboration

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OAK RIDGE National Laboratory

JAEA

Universidad de Sevilla

CNDC China Nuclear Data Center

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The European Commission's science and knowledge service Joint Research Centre

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BERKELEY LAB Bringing Science Solutions to the World

Petersburg Nuclear Physics Institute Gatchina, Russia

Lawrence Livermore National Laboratory

INL Idaho National Laboratory

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NIST National Institute of Standards and Technology U.S. Department of Commerce

Uranium-238 - Status

New information from integral testing since ENDF/B-VIII.0 release & publications

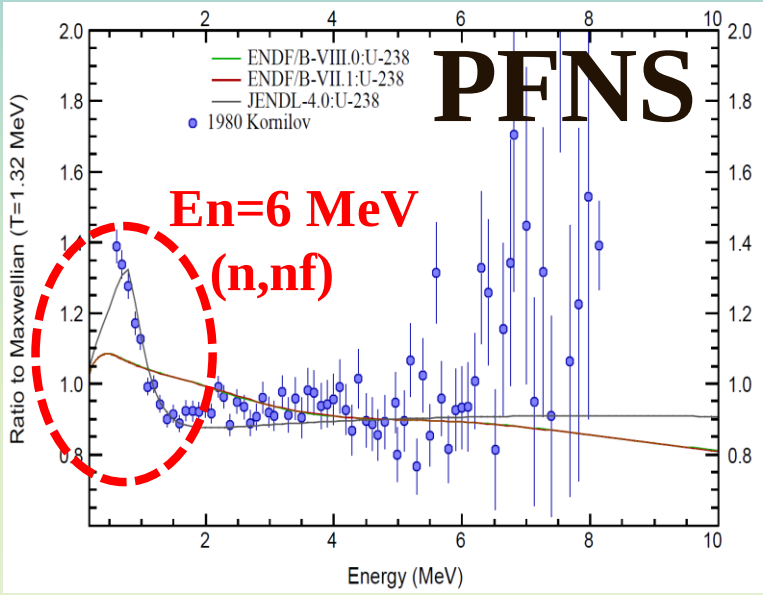
Criticality performance: any new/unexpected findings? ***No***

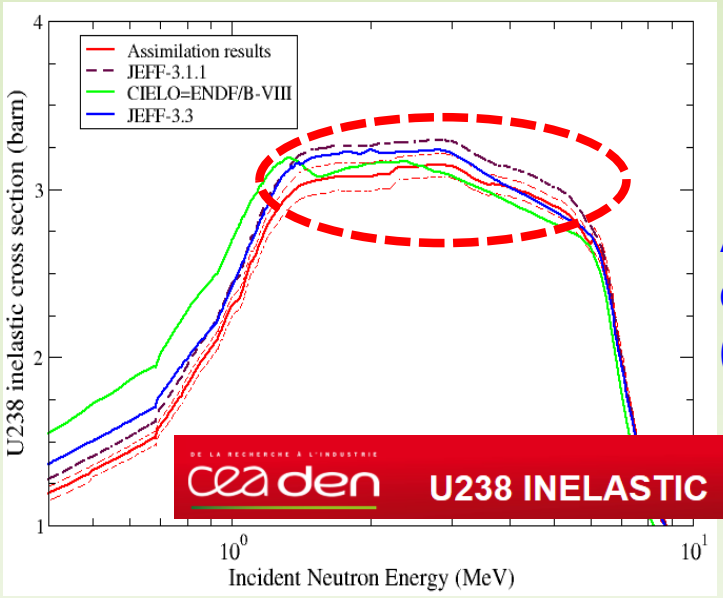
Neutron transmission: any new/unexpected findings? ***PFNS 5-8 MeV***

(n,xn) activations: any new/unexpected findings? ***No***

Known deficiencies/gaps:

- Ongoing ChiNu experiments to precisely measure PFNS. The current set of data will be completed within a year or two, and should impact next ENDF
- An updated ^{238}U resonance analysis (JRC EC Geel)
- (n,n'g) experiment & eval. – BNL/LLNL
- FPY, DN, Decay energy, PFGS, would benefit from various upgrades



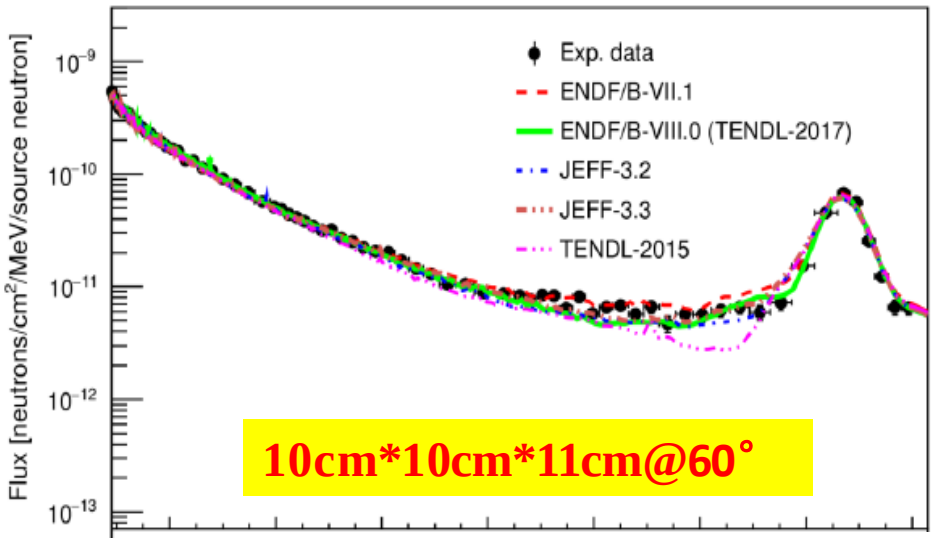


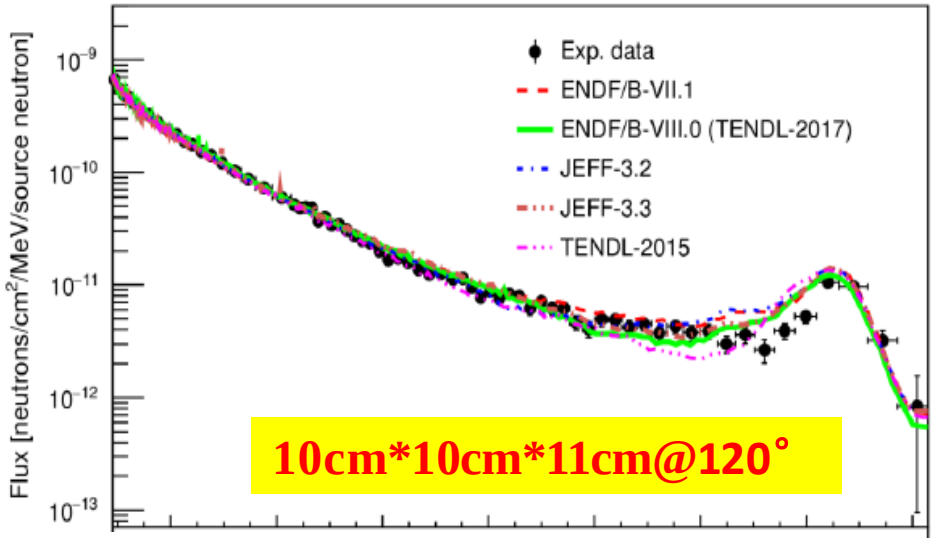
An important ENDF/B-VIII.0/CIELO trend in ^{238}U(n,inl) confirmed by CEA Cadarache adjustment studies (see G. Rimpault present., WONDER 2018)

Agreement in the plateau within quoted 7% uncertainties in ENDF/B-VIII.0 evaluation !!

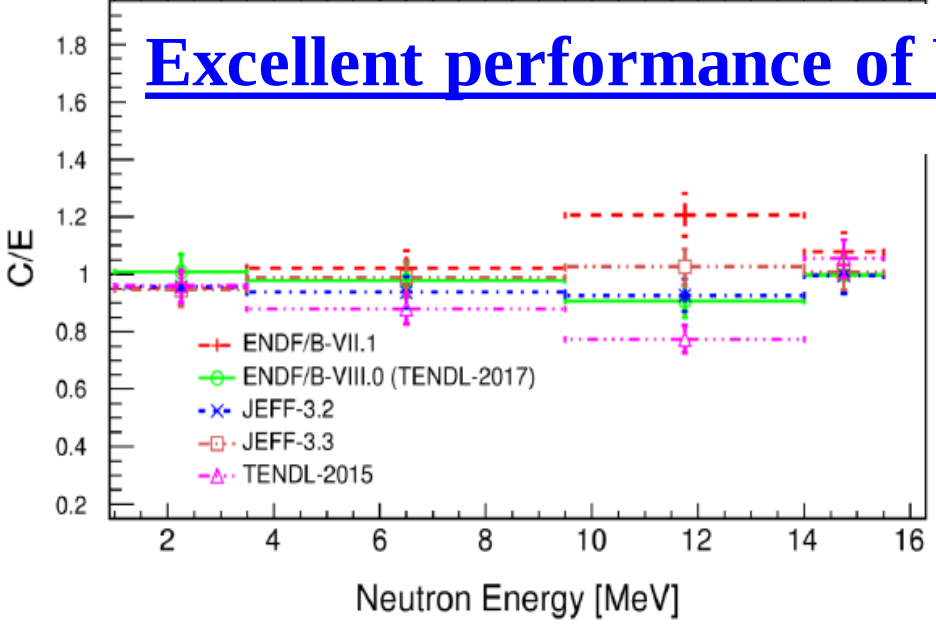
Uranium-238 - Validation

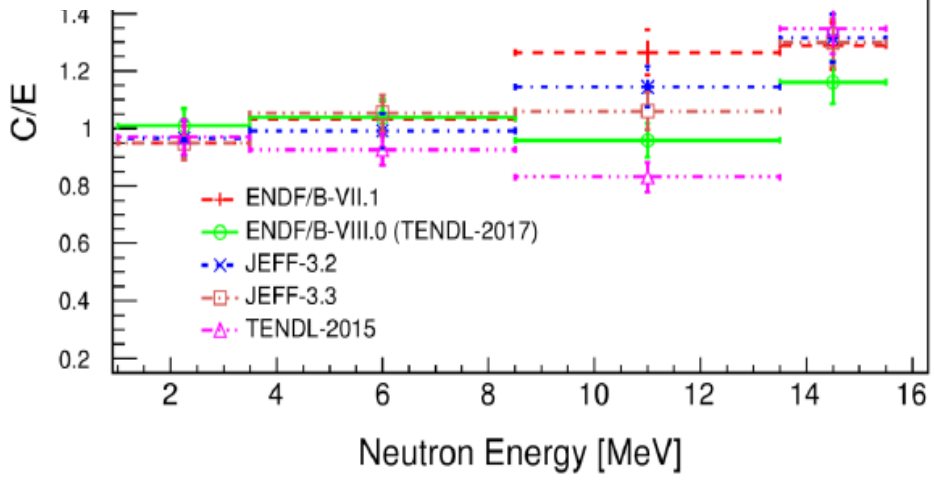
CIAE benchmarks, slabs, 14MeV n + ^{238}U





Excellent performance of U-238 evaluation confirmed !





Uranium-235 - Status

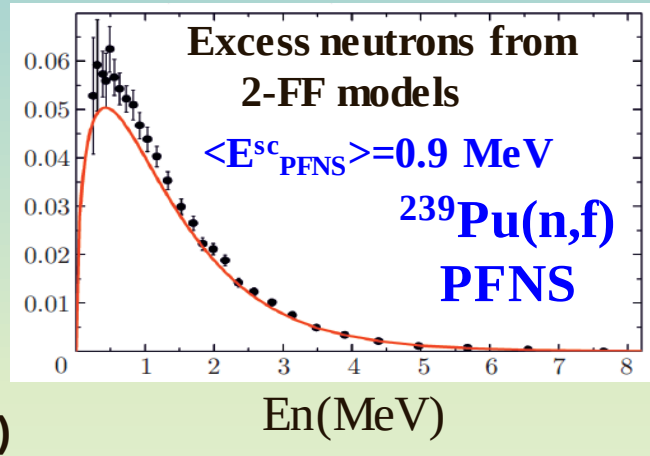
New information from integral testing since ENDF/B-VIII.0 release & publications

Criticality performance: any new/unexpected findings? No
Neutron transmission: any new/unexpected findings? No
(n,xn) activations: any new/unexpected findings? No

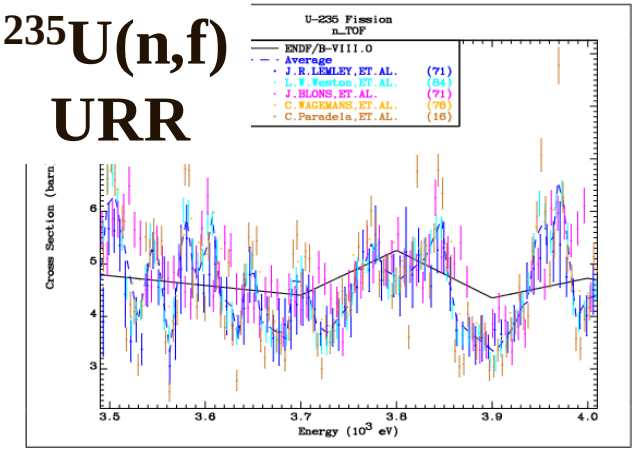
$$p_s(E) = p_0 \frac{E}{T_0^2} \exp\left(-\frac{E}{T_0}\right)$$

Known deficiencies/gaps:

- Ongoing evaluations of ChiNu experiments to be used
  (low energy "scission" neutrons ~ .05 n/fission ~ 2% to be added as model defect to MN model??)
- New thermal PFNS exp. in agreement with <E>
- Small 1% nubar fluctuations confirmed (Gook et al)
- Measured (n,2n) SACS validated $^{235}U(n_{th},f)$ PFNS (>8 MeV)
  (n,2n) on ^{169}Tm, ^{90}Zr, ^{89}Y, ^{127}I, ^{23}Na, ^{19}F, ^{59}Co, ^{55}Mn, ^{197}Au
  (Rez $^{252}Cf(sf)$+LR0 reactor, on-going @ ILL reactor Grenoble)
- An updated URR evaluation of fission cross section (no criticality change)



$^{235}U(n,f)$ URR



- RPI quasi-int/ exp. to verify fission, elastic/inelastic
- Inelastic and (n,2n) discrepancies with CEA/DAM evaluation being further studied
- FPY, DN, Decay energy, PFGS, would benefit from various upgrades

Fe evaluations - Status

New information from integral testing since ENDF/B-VIII.0 release & publications

Neutron transmission: any new/unexpected findings? ***Yes, 30% leakage underest. 1-7 MeV***

(n,xn) activations: any new/unexpected findings? ***No***

Known deficiencies/gaps:

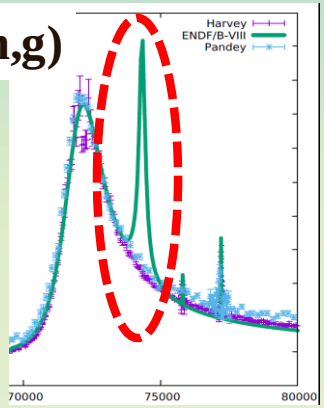
Fe-56: . **Elastic too low (vs Geel data), (n,inl) too high from 2-8 MeV,**

. (n,tot) minima poorly described (27 keV,~300keV, ...). Update of the ORNL ^{56}Fe planned

. (n_{th},γ) reduced by 10% (Firestone et al, 2017)

. (n,nonel) reduced above 40 MeV (TIARA)

^{54}Fe(n,g)



Fe-54 **(Pigni, Guber)**

. ORNL updated evaluation

(false resonances) & trials

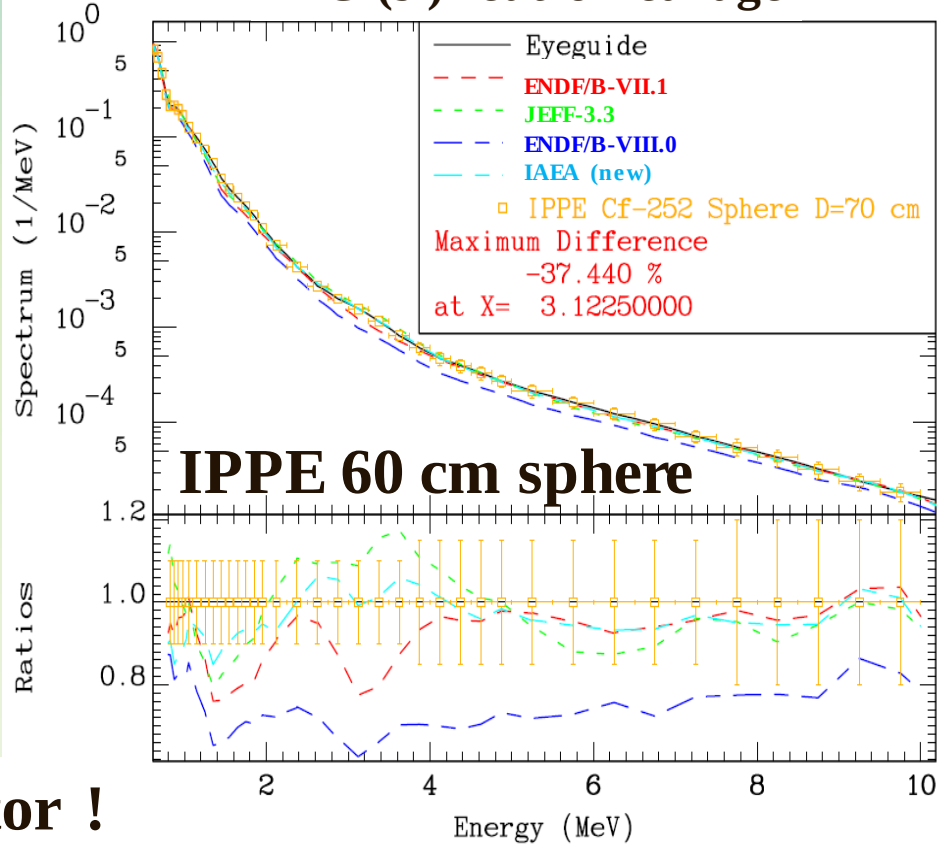
Fe-57

. RRR: inelastic, too low on average vs Negret (PRC 2017)

. New trial evaluation ^{56,57}Fe (IAEA INDEN); validation to be presented by Trkov

. Updated evaluations planned by ORNL/IAEA/BNL/LANL

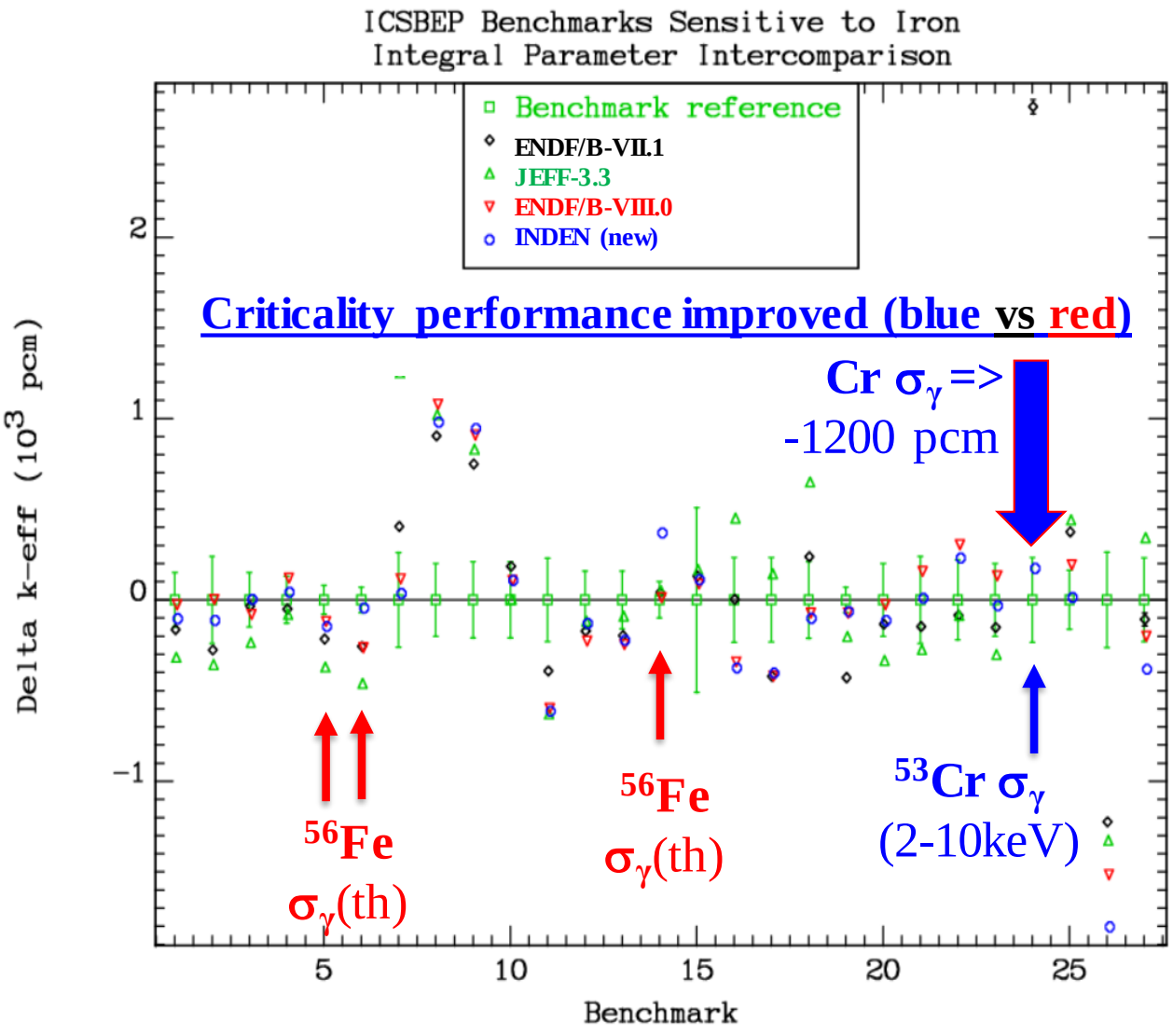
^{252}Cf(sf) neutron leakage



IPPE 60 cm sphere

^{252}Cf(sf) spectra ~ fast reactor !

Criticality impact of Fe/ ^{53}Cr – St.Steel



1	hmf013	VNIITF-CTF-SS-13
2	hmf021	VNIITF-CTF-SS-21
3	hmf024	VNIITF-CTF-SS-24
4	hmf087	VNIITF-CTF-Fe
5	hmf088-001	FKBN-2/SS-PE-1
6	hmf088-002	FKBN-2/SS-PE-2
7	hmi001	ZPR-9/34
8	hmt013-002	Planet_Fe-PE-2
9	hmt015	Planet_HEU/Fe/PE
10	imf005	VNIIEF-CTF-5
11	imf006	VNIIEF-CTF-6/Al
12	lct042-001	PNL_1.68p-1
13	lct042-002	PNL_1.68p-2
14	lct043-002	IPEN/MB-01
15	lmt015-001	RB-Vinca-01
16	mcf001	ZPR-6/7(s)
17	mcf005s	ZPR-9/31(s)
18	mcf006s	ZPPR-2
19	pmf015	BR-1-3
20	pmf025	VNIIEF Pu/SS 1.55
21	pmf026	VNIIEF Pu/SS-11.9
22	pmf028	VNIIEF Pu/SS 19.6
23	pmf032	VNIIEF Pu(88%)/SS
24	pmi002	ZPR-6/10
25	pmi003-001s	ZPR-3/58(U)
26	pmi004-001s	ZPR-3/59(Pb)
27	ici005	ZPR-6/6A

✓ 5), 6) hmf088 (1&2)

✓ 24) pmi002 (-1.2%)

X 14) lct043.002

Ni evaluations - Status

New information from integral testing since ENDF/B-VIII.0 release & publications

Criticality performance: any new/unexpected findings? Yes, problems found by SvdM

Neutron transmission: any new/unexpected findings? No

(n,xn) activations: any new/unexpected findings? ^{58}Ni(n,p), ^{58}Ni(n,2n), ^{60}Ni(n,p) IRDFF

Known deficiencies/gaps:

- Ni is among the candidate materials for the IAEA International Nuclear Data Evaluation Network – (INDEN meeting Oct 31-Nov 1 2018):

- Plans for new evaluation in JENDL-5 and at BNL (though lower priority than Cr)
  - In-depth evaluation using the TENDL approach
  - Produce the first reusable experimental nuclear data evaluation

- TENDL approach:

- A consistent, global, complete library with reasonable to good nuclear data.
- Next step: Zoom in on Ni for an in-depth evaluation, using the TALYS-based toolbox ('T6') that produces TENDL
- This will give rise to all kinds of detailed evaluation aspects not encountered so far, updates to software for automation of detailed input, etc.
- Produce evaluated libraries for Ni isotopes, as an option for ENDF/B and/or JEFF.
- This is expected to improve the global system to produce the next version of TENDL, in which in-depth evaluation aspects can be included efficiently. (TENDL will also benefit !)

Ni: Showcase for reusable experimental nuclear data evaluation

- A procedure/format exists to store quantitative operations on **EXFOR correction system** as a by-product of a data evaluation. For each EXFOR subentry, e.g.:
  - Rejection (outliers)
  - Acceptance
  - Normalization to e.g., new standards
  - Corrections
  - Operations on uncertainties, etc.
- Some of this information is subjective per evaluator, but at least the opinion is quantified which is better than reinventing the wheel every time. Information is no longer lost
- Create a new database between EXFOR and ENDF (**EXFOR correction system**)
- Different evaluation projects, using different model codes etc. can use this "derived" EXFOR database as a starting point.
- This is essential for automatic optimization, machine learning, uncertainty quantification, etc.
- 2019: Test case with nuclear data for the Ni isotopes