Status of the JENDL Project

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Japanese Nuclear Data Committee

chaired by N. Yamano, Univ. of Fukui

Subcommittee on Nuclear Data (H.Harada, JAEA)

- Activation Cross Section Evaluation WG (N.Iwamoto, JAEA)
- ENSDF Group (H.Iimura, JAEA)
- Japanese Nuclear Data Measurement Network (Y.Watanabe, Kyushu Univ.)

Subcommittee on Reactor Constants (K. Okumura, JAEA)

- Reactor Integral Test WG (G.Chiba, Hokkaido Univ.)
- Shielding Integral Test WG (C.Konno, JAEA)
- WG on Evaluation of Nuclide Generation and Decay Heat (K.Okumura, JAEA)
- Covariance Utilization WG (T.Iwasaki, Tohoku Univ.)
- Nuclear Data Processing Program WG (K.Suyama, JAEA)

A new subcommittee related to international strategy on nuclear data and neutronics calculation codes will be established in 2016.

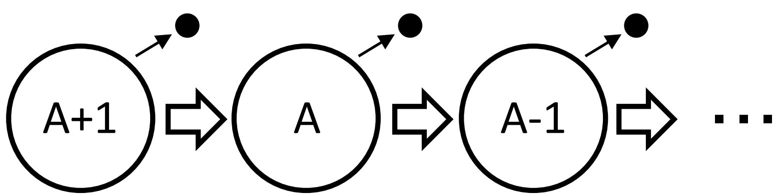
Newly released libraries in 2015

- JENDL Decay Data File 2015 (JENDL/DDF-2015)
  - 3,237 nuclei of A= 1 to 260
  - JENDL/FPD-2011 (1,284 nuclei) + ENSDF (1,953 nuclei)
- JENDL-4.0 High Energy File (JENDL-4.0/HE)
  - an extended version of JENDL-4.0 up to 200 MeV
  - Neutron 10^{-5} eV – 200 MeV （130 nuclei*）
  - Proton 1 MeV – 200 MeV （133nuclei*）
  - DDX, residual production

1. CCONE Calculation

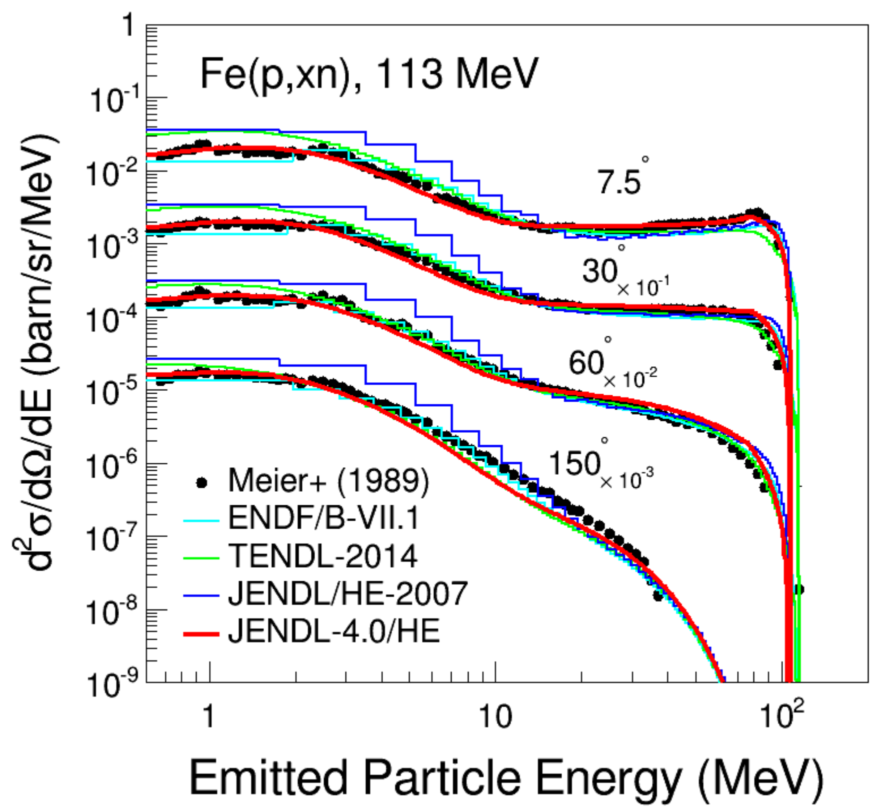
Extended CCONE（O.Iwamoto2013）

- Multi-particle emission (pre-equilibrium)
- Reasonable method for CMS->LAB (DDX)



Systematic model-parameters

- Optical potential（Kunieda-2007）
- Pre-equilibrium（Koning-Duijvestijn-2004）
- Level density（Mengoni-Nakajima-1994）

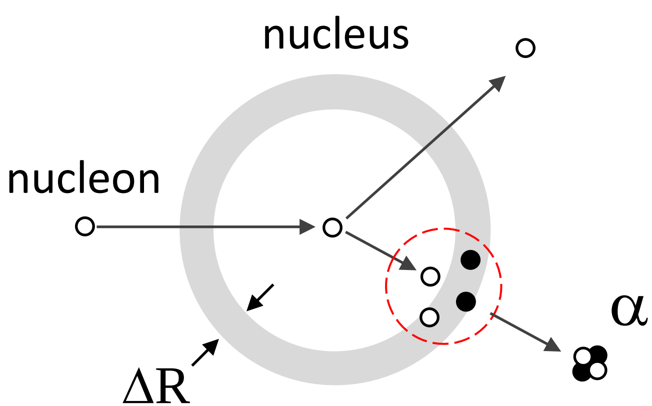


⇨ Very reasonable evaluation is achieved by the “systematic calculation”.

1. CCONE Calculation (cont.)

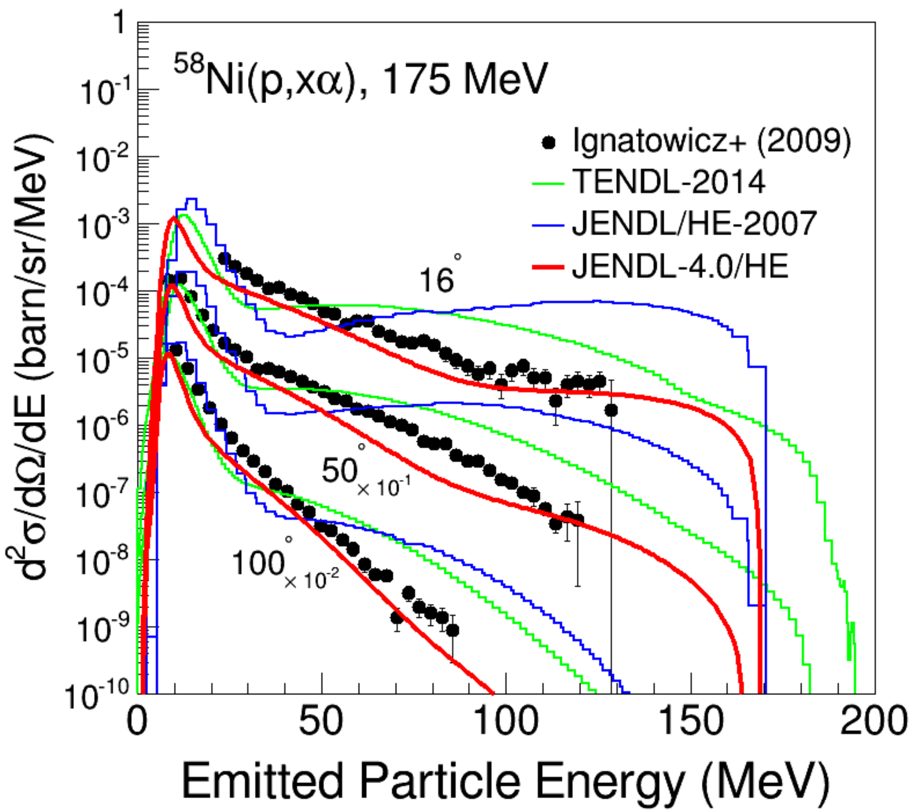
Advanced method for composite-particle emission

Clustering pre-equilibrium model
(Iwamoto-Harada-Sato model)



ΔR : Pick-up radius = 0.75 (fm)

see, Kunieda et al., PRC85,054602 (2012)

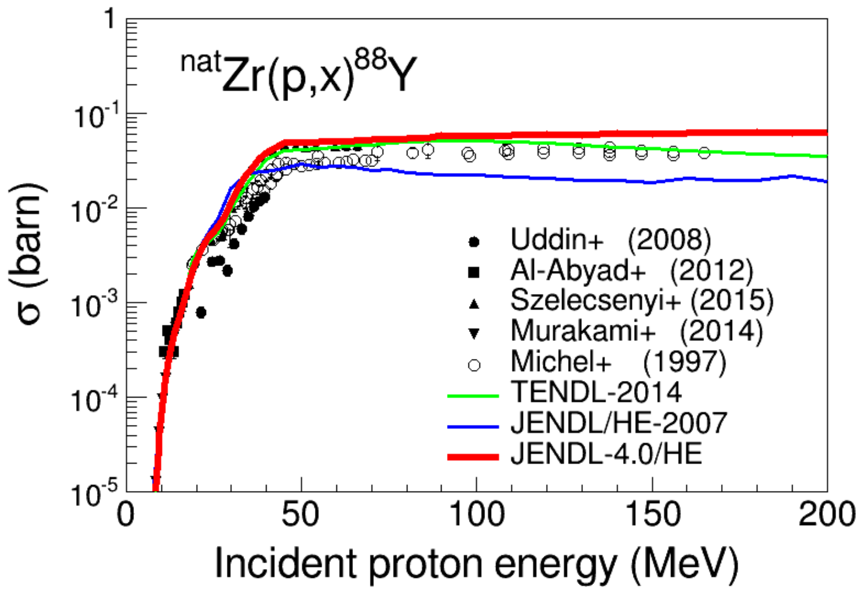


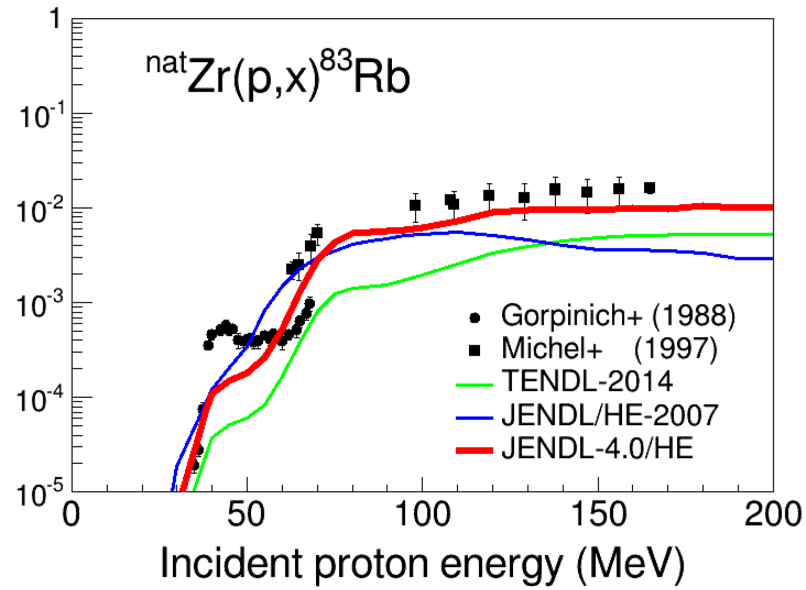
⇨ Consistent with experimental data, obviously better than the other evaluations.

1. CCONE Calculation (cont.)

Isotope-production XS calculated with CCONE

ex.) ^{nat}Zr { ^{90}Zr (51.5%), ^{91}Zr (11.2%), ^{92}Zr (17.2%), ^{94}Zr (17.4%), ^{96}Zr (2.8%),





⇨ Reasonable results are obtained by the systematic calculation

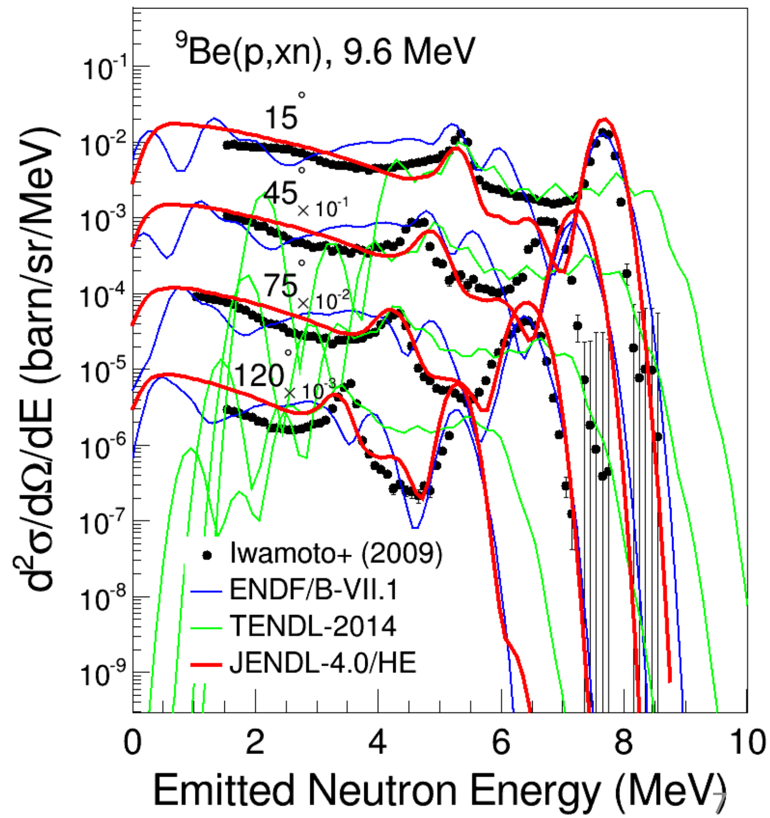
2. Challenges for Light-nuclei

^{1,2}H, ^{6,7}Li, ^{9}Be, ^{12,13}C, ^{14,15}N, ^{16,18}O, …

- Inherited from JENDL/HE-2007,
- New (p only) evaluation

We overcome the weakest point of JENDL/HE-2007

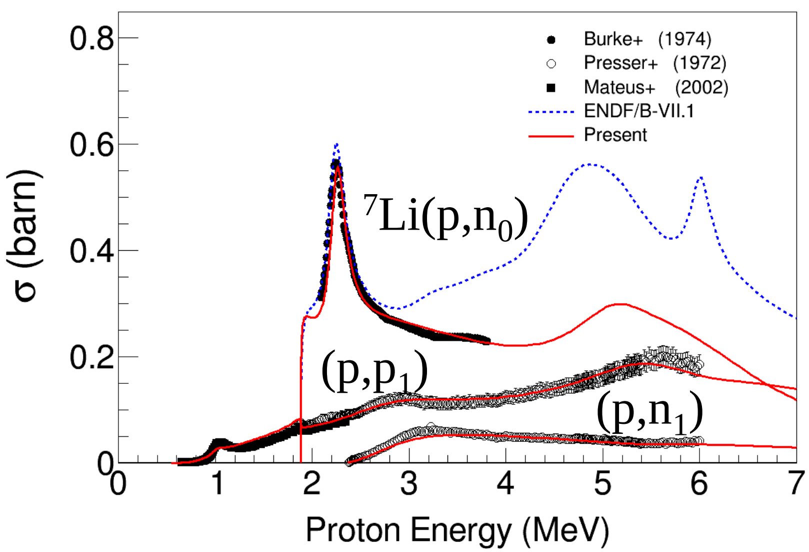
- ^{2}H : Faddeev theory with Paris-EST by S. Chiba (Tokyo tech.)
- ^{6,7}Li : R-matrix, DWBA+CCONE by S. Kunieda & Y.Watanabe (Kyushu)
- ^{9}Be : OPTMAN(ver.10) +CCONE （Soukhovitsuki + Kunieda）



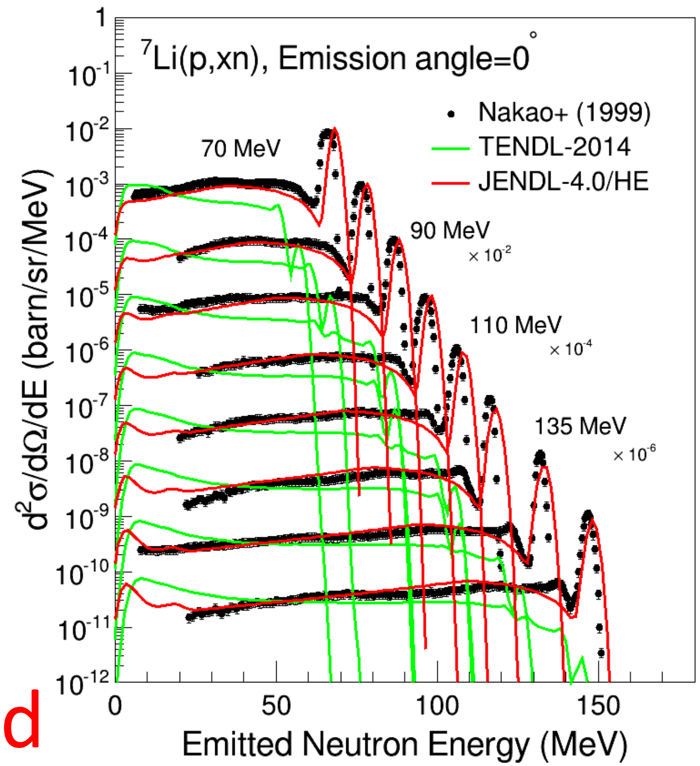
2. Challenges for Light-nuclei

Evaluated results for p+^{7}Li cross-sections

from R-matrix analysis



DWBA + CCONE



⇨ Unique data in the world
(covers low-to-200 MeV range)

Activation Cross-section File for Decommissioning of LWRs

To be released as JENDL/AD-2016

Compiled Results (T = 0 K, 293.6 K)

• JENDL-4.0	50 nuclides
• JENDL-4.0 + α	19 nuclides
• JENDL/A-96	1 nuclide
• JENDL/A-96 + α	5 nuclides
• Nuclear model calc.	158 nuclides
• Nuclear model calc. + α	69 nuclides
Total	302 nuclides

Figure $^{58}Ni(n,p)^{58}Co$

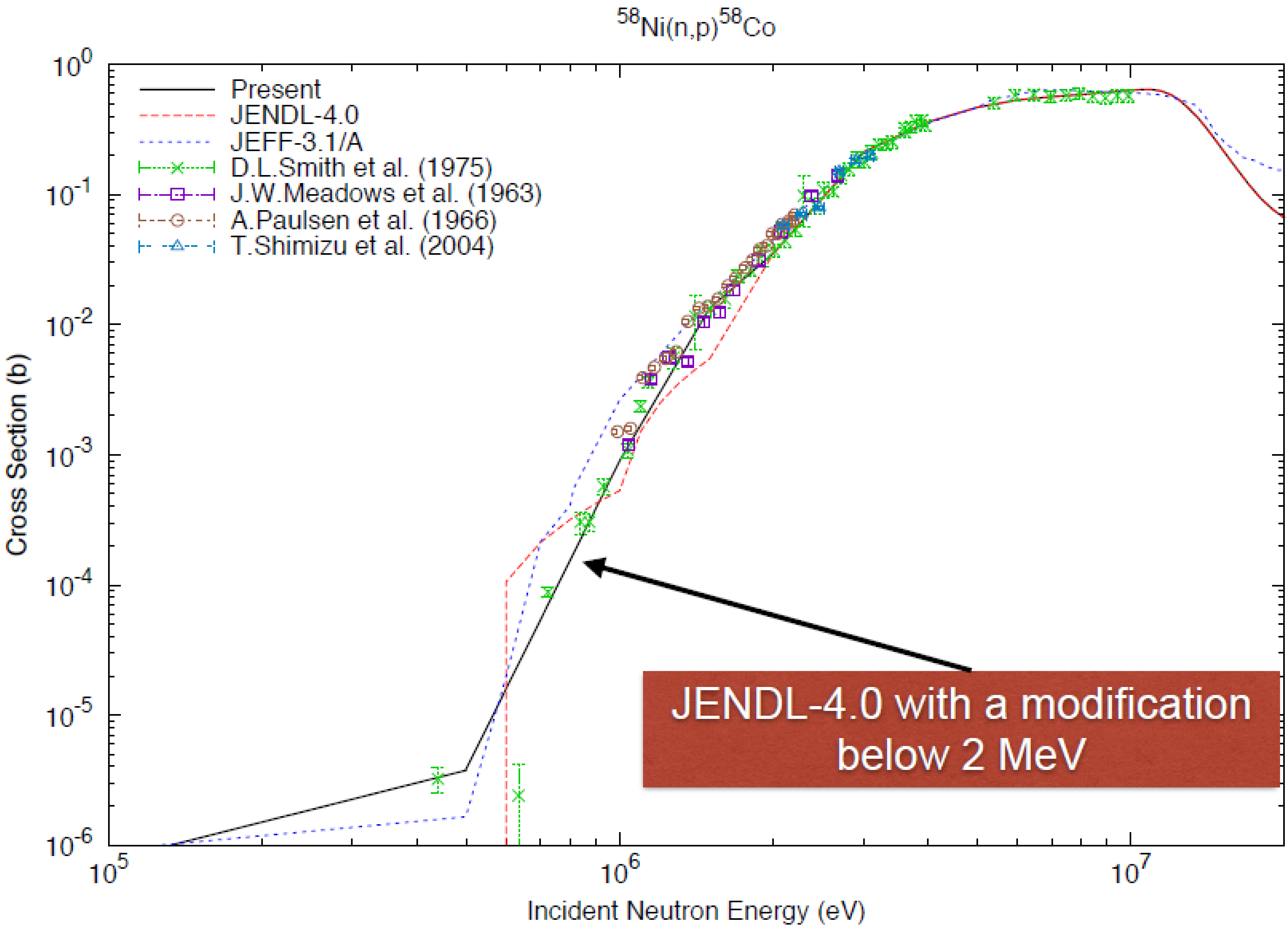
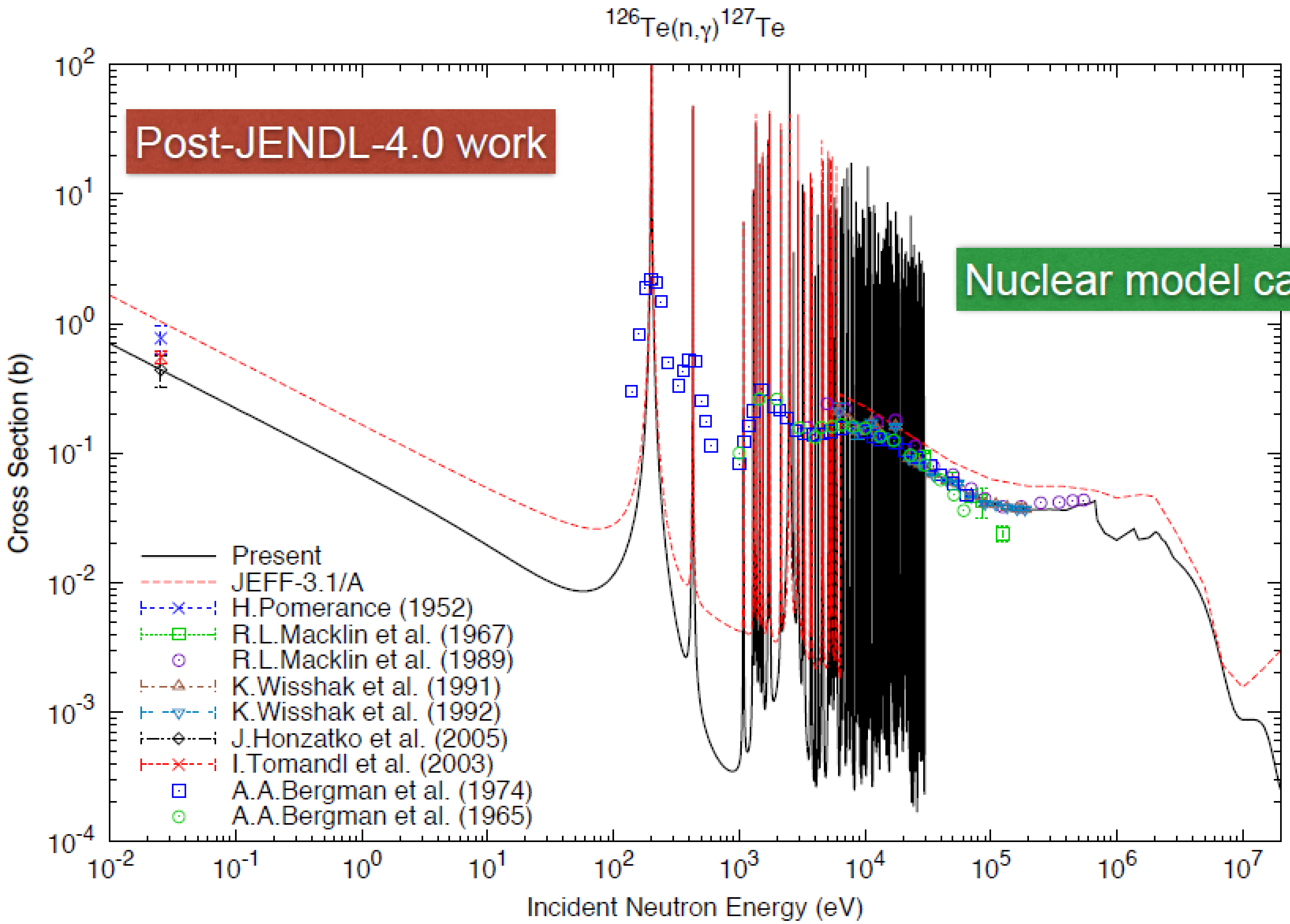


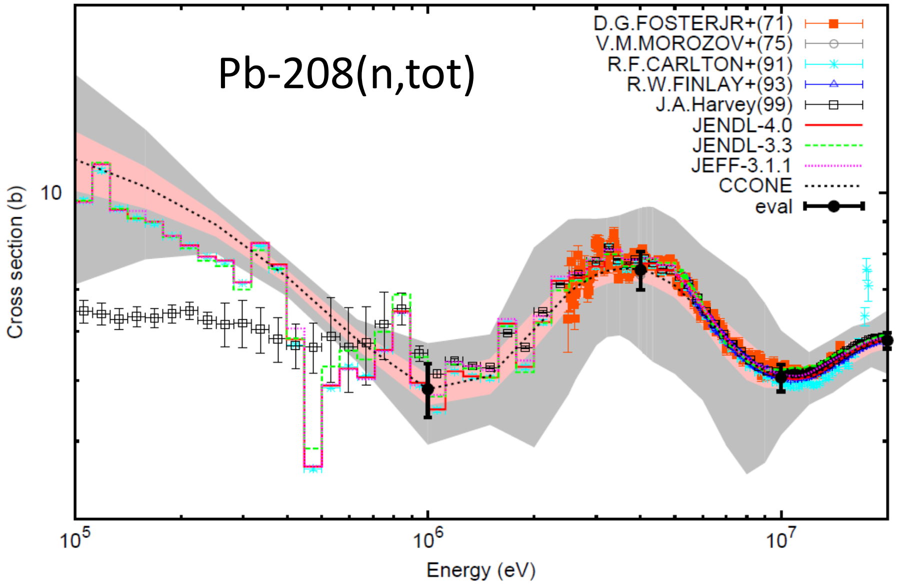
Figure $^{126}Te(n,\gamma)^{127}Te$

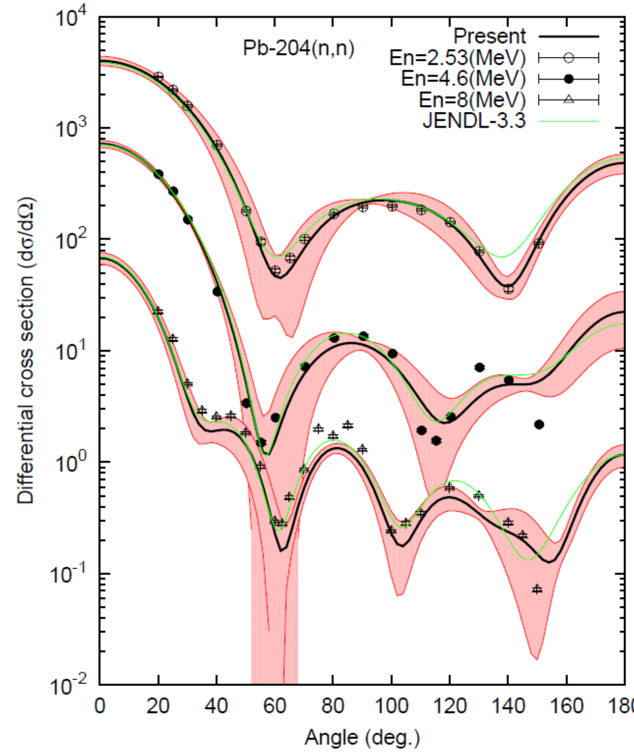


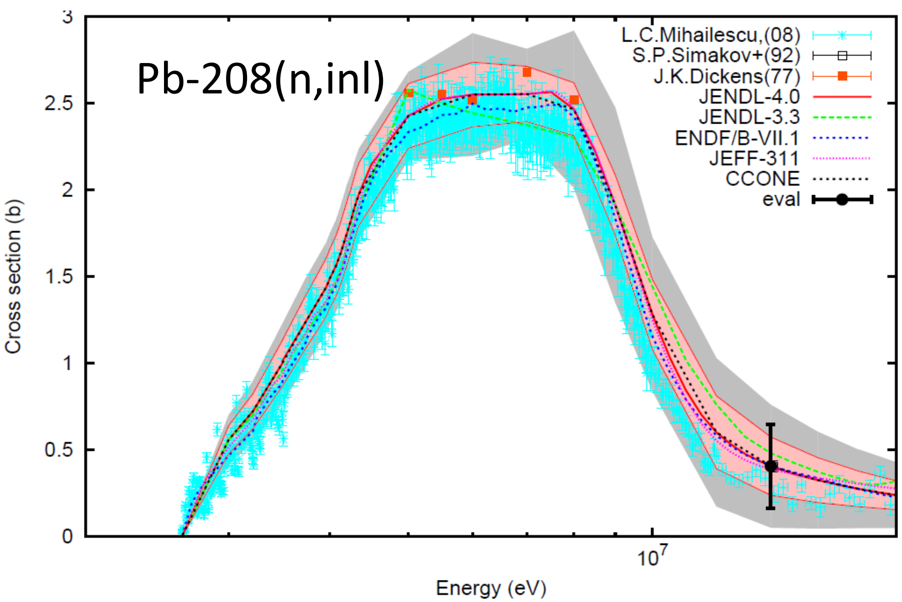
JENDL-4.0 update files

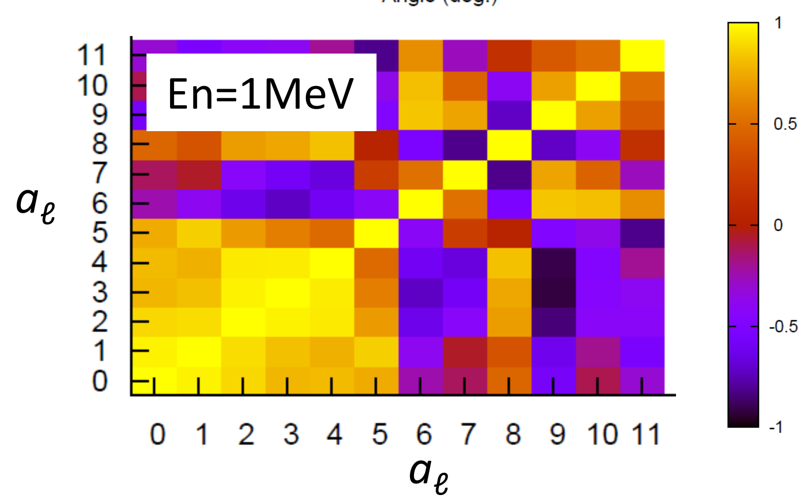
- Pb-204, 206, 207, 208
  - Covariance data were added.
  - cross sections (MF=33/MT=1, 2, 4, 16, 17, 51-91, 102)
  - angular distribution for elastic scattering (MF=34/MT=2)
- Rh-105
  - The target spin in RRR (MF/MT=2/151) was corrected.
  - The resonance parameters (pseudo resonance) were modified so as to reproduce the thermal capture cross section and resonance integral of Mughabghab et al.

Covariance data of Pb isotopes

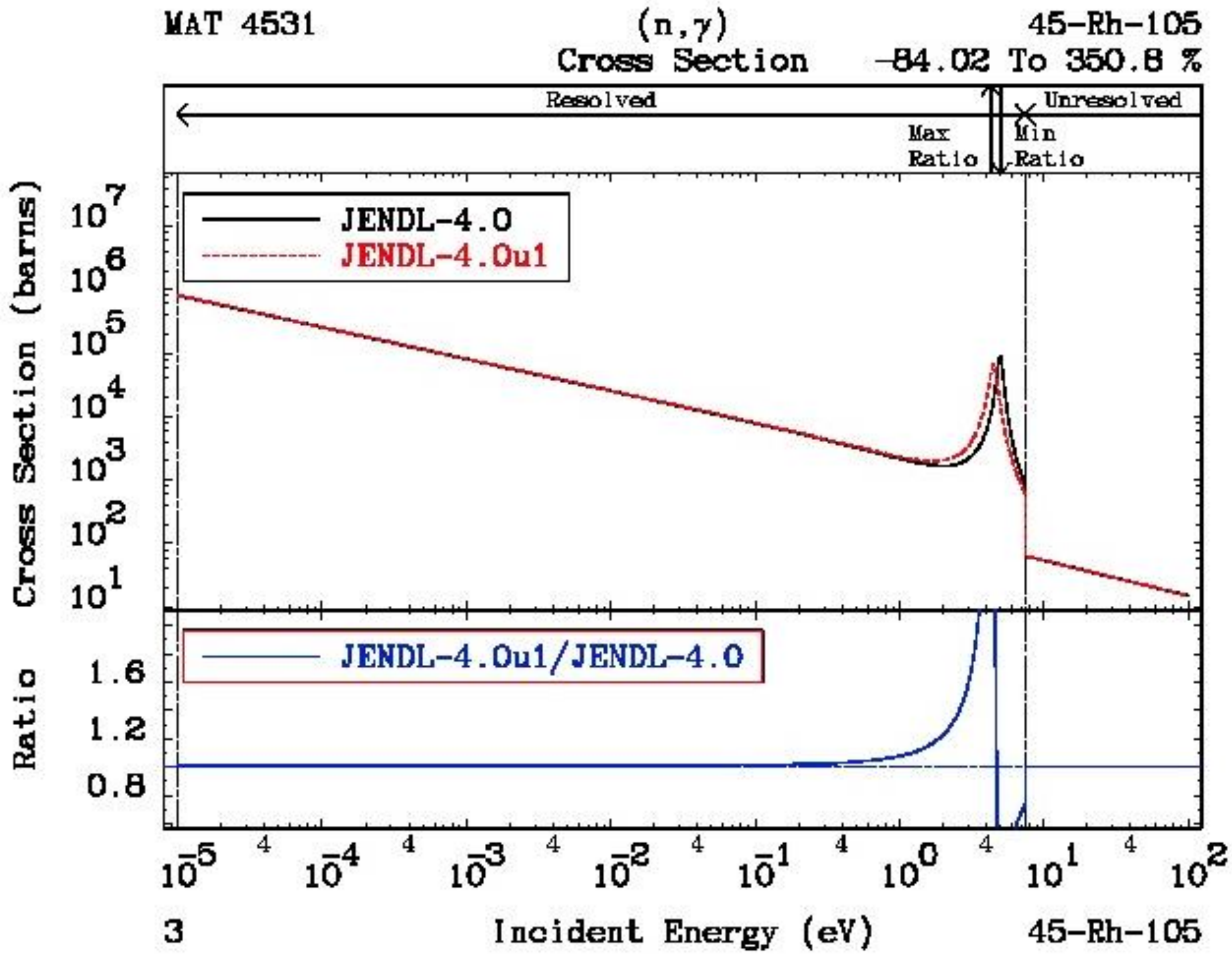








Rh-105 capture cross section



Benchmarking toward next JENDL

- On-going task of RIT-WG (Reactor Integral Test Working Group) in JENDL committee
  - Development of a comprehensive and ready-to-use standard benchmark set, based on Japanese Monte-Carlo code MVP, for LWR nuclear data by utilizing open and well-evaluated integral experiments, such as ICSBEP and IRPhEP (NEA-DBs)
- Present two main targets
  1. Light-water-moderated <u>low-enriched U</u> cores in NEA-DBs
  2. Light-water-moderated <u>MOX</u> cores in NEA-DBs
- Recent works
  - Extension of benchmark cases
  - Benchmark exercises with selected representative 10 cases from each target of 1. and 2.

1. Light-water-moderated Low-enriched U core benchmark (LCT)

Comparison with the existing benchmark reports (Light-water-moderated Low-enriched U)

JENDL-4.0 (This work)			JENDL-4.0(JNST, 2011)			ENDF/B-7.0(NDS*, 2006)			ENDF/B-7.1(NDS*, 2011)		
Name	# of data	U enrich.	Name	# of data	U enrich.	Name	# of data	U enrich.	Name	# of data	U enrich.
(Total	173	data)	(Total	18	data)	(Total	257	data)	(Total	134	data)
			TRX	2	1.3wt%	TRX	2	1.3wt%			
KRITZ-2	4	1.86wt%	KRITZ	4	1.86wt%						
						LCT-60(Kurchatov)	28	1.8wt% 2.0wt% 2.4wt%			
LCT-001(PNL)	8	2.35wt%	LCT-001(PNL)	1	2.35wt%	LCT-001(PNL)	8	2.35wt%	LCT-001(PNL)	8	2.35wt%
						LCT-003(PNL)	22	2.35wt%			
						LCT-016(PNL)	32	2.35wt%			
LCT-017(PNL)	29	2.35wt%				LCT-017(PNL)	19	2.35wt%	LCT-017(PNL)	14	2.35wt%
LCT-008(B&W)	17	2.46wt%	LCT-008(B&W)	1	2.46wt%				LCT-008(B&W)	12	2.46wt%
						LCT-051(B&W)	19	2.46wt%			
									LCT-011(B&W)	5	2.46wt%
LCT-006(TCA)	18	2.60wt%	LCT-006(TCA)	4	2.60wt%	LCT-006(TCA)	18	2.60wt%	LCT-006(TCA)	18	2.60wt%
									LCT-035(TCA)	3	2.60wt%
LCT-048(DIMPLE)	5	3.01wt%	LCT-048(DIMPLE)	1	3.01wt%	LCT-048(DIMPLE)	1	3.01wt%			
			MISTRAL	1	3.7wt%						
LCT-002(PNL)	5	4.31wt%				LCT-002(PNL)	5	4.31wt%	LCT-002(PNL)	5	4.31wt%
LCT-079(Sandia)	10	4.31wt%							LCT-079(Sandia)	10	4.31wt%
LCT-005(PNL)	16	2.35wt% 4.31wt%	LCT-005(PNL)	1	4.31wt%	LCT-005(PNL)	16	2.35wt% 4.31wt%	LCT-005(PNL)	11	2.35wt% 4.31wt%
						LCT-009(PNL)	27	4.31wt%			
LCT-010(PNL)	30	4.31wt%				LCT-010(PNL)	30	4.31wt%	LCT-010(PNL)	13	4.31wt%
LCT-007(Valduc)	10	4.74wt%				LCT-007(Valduc)	10	4.74wt%	LCT-007(Valduc)	10	4.74wt%
									LCT-027(Valduc)	4	4.74wt%
						LCT-039(Valduc)	17	4.74wt%	LCT-039(Valduc)	10	4.74wt%
LCT-026(IPPE)	4	4.92wt%	LCT-026(IPPE)	2	4.92wt%						
LCT-019(Kurchatov)	3	5wt%				LCT-019(Kurchatov)	3	5wt%			
LCT-018(DIMPLE)	1	7.0wt%	LCT-018(DIMPLE)	1	7.0wt%						
LCT-025(Kurchatov)	4	7.5wt%							LCT-025(Kurchatov)	4	7.5wt%
LCT-022(Kurchatov)	7	10.0wt%							LCT-022(Kurchatov)	7	10.0wt%
LCT-024(Kurchatov)	2	10.0wt%							LCT-024(Kurchatov)	2	10.0wt%

Green: added in the 2nd version, Yellow: added in the 1st version

* NDS: Nuclear Data Sheets

（Basic policy for selection of LCT representative cases）

① Independent of each other and open

② Well-documented uncertainty evaluation（rejection of abnormal C/E cases）

③ LWR-comparable U enrichment and H/U atomic number ratio

④ Cold condition and no disturbance (e.g. w/o Boron absorber)

Table 1-1 Representative 10 cases selected from LCT

Exp. Name	Case	pin pitch (cm)	Number of fuel pins	Boron conc. (wt.ppm)	Condition of water temp.	U enrich. (wt%)	H/U atomic number ratio
LCT001 (PNL)	1	2.032	361.6	0	cold	**2.35**	**9.5**
	8	2.032	912	0	cold	**2.35**	**9.5**
LCT018 (DIMPLE)	1	1.32	376	0	cold	**7**	**8.4**
LCT026 (IPPE)	1	1.29	621	0	cold	**4.92**	**6.7**
	3	1.09	1951	0	cold	**4.92**	**3.5**
LCT048 (DIMPLE)	1	1.32	1565	0	cold	**3**	**2.9**
LCT-079 (Sandia)	1	2.0	257	0	cold	**4.31**	**4.5**
	6	2.8	131	0	cold	**4.31**	**12.1**
LCT-007 (Valduc)	1	1.26	484	0	cold	**4.738**	**2.6**
	4	2.52	306	0	cold	**4.738**	**16.7**

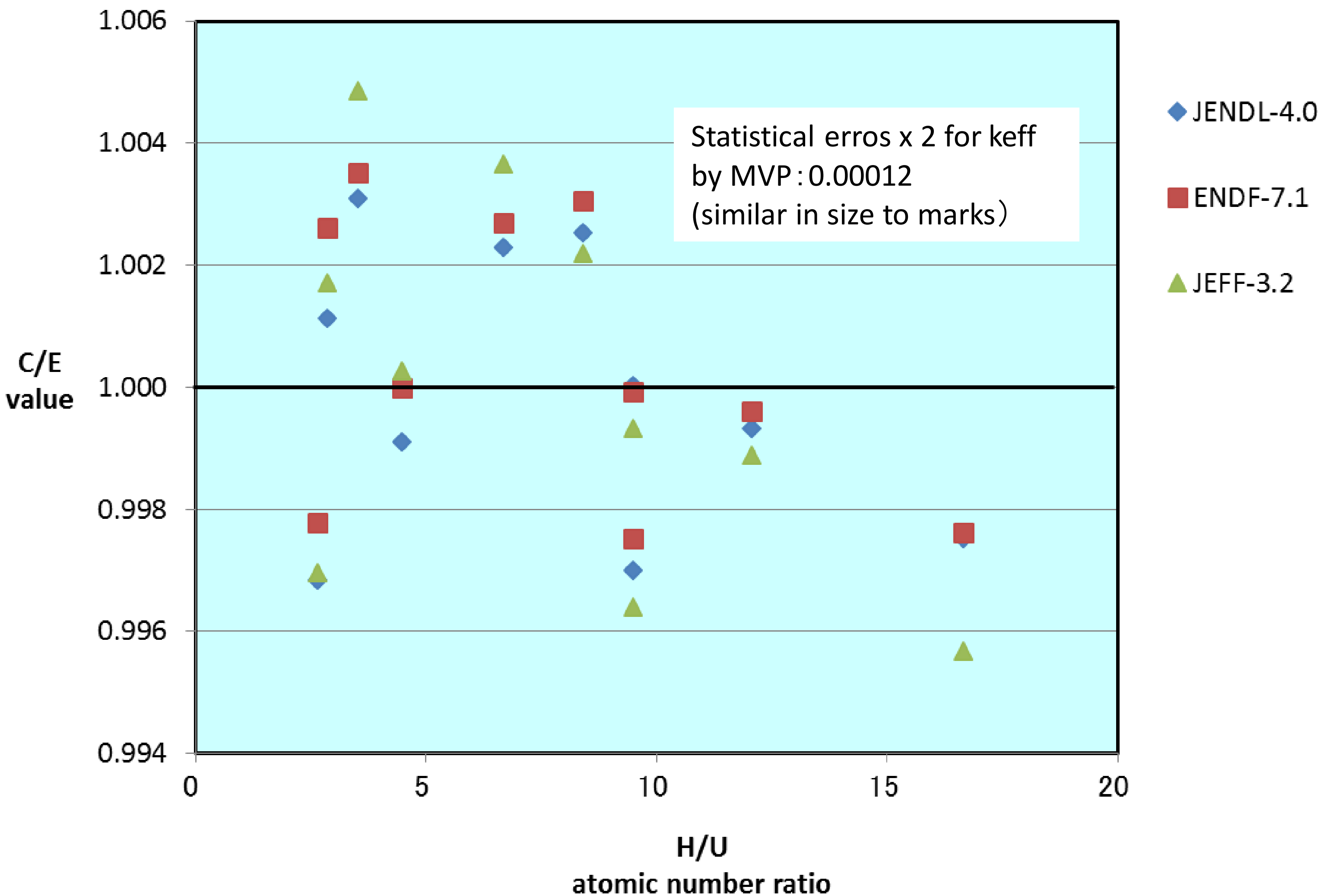


Fig. 1-1 C/E values for LCTs by JENDL-4.0, ENDF-VII.1, and JEFF-3.2

→ Although significant differences among three libraries are seen, it is difficult to discuss their good points and/or bad points only from C/E values

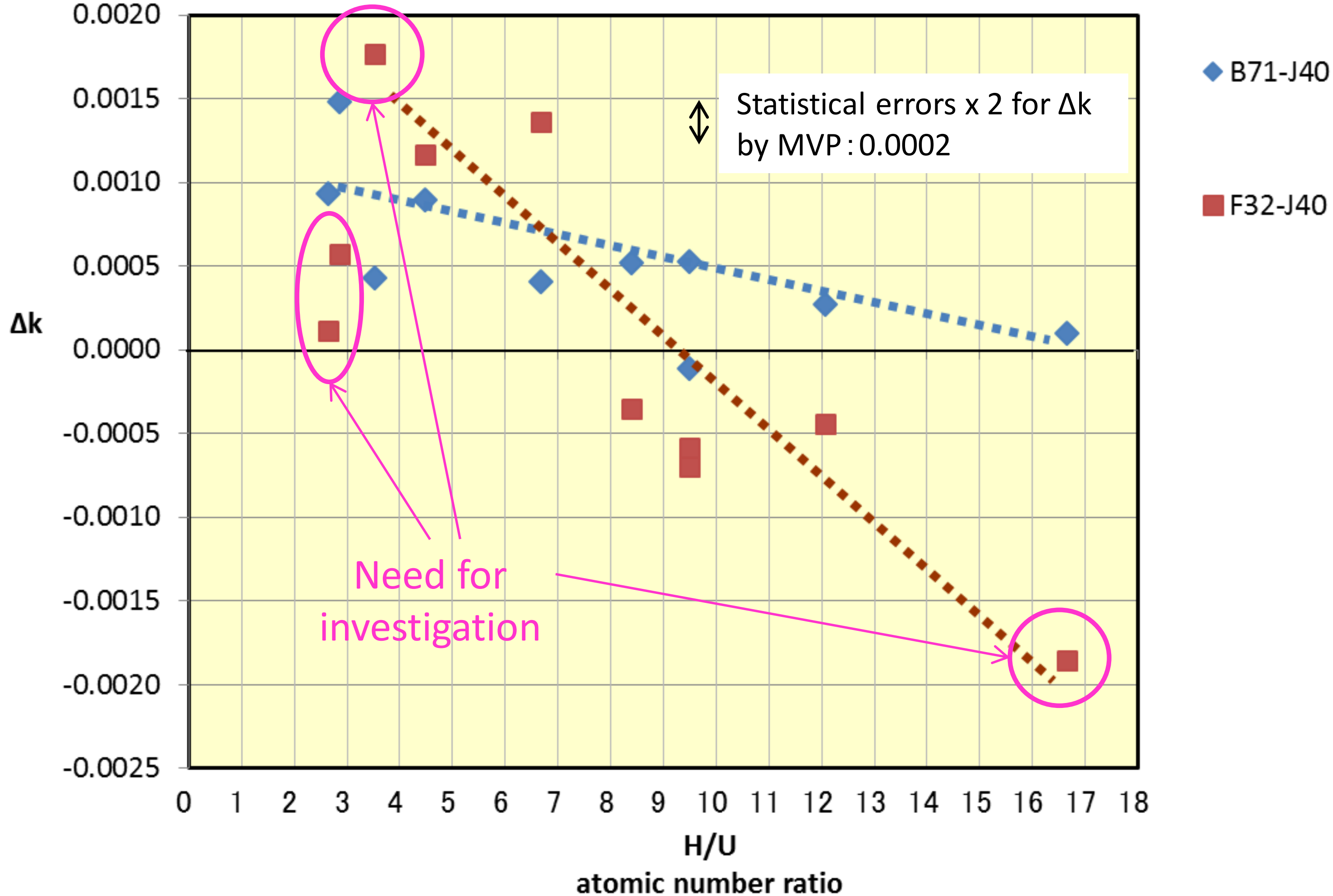


Fig. 1-2 Library-differences of keffs from JENDL-4.0 for the selected LCT benchmarks

→ Between JEFF-3.2 and JENDL-4.0, it is observed that the significant dependency of H/U atomic number ratio, which is clearly exceeding statistical errors

2. Light-water-moderated MOX core benchmark (MCT）

Comparison with the existing benchmark reports (Light-water-moderated MOX)

JENDL-4.0 (This work)			JENDL-4.0(JNST, 2011)			ENDF/B-7.0 (NDS*, 2006)			ENDF/B-7.1 (NDS* 2011)		
Name	# of data	Pu enrich.	Name	# of data	Pu enrich.	Name	# of data	Pu enrich.	Name	# of data	Pu enrich.
(Total 65 data)			(Total 67 data)			(Total 35 data)			(Total 6 data)		
KRITZ-2:19 (Studsvik, Sweden)	2	1.5 wt%	KRITZ-2:19 (Studsvik, Sweden)	1	1.5 wt%	KRITZ-2:19 (Studsvik, Sweden)	2	1.5 wt%			
MCT009 (CAF, Battelle-PNL)	6	1.5 wt%	MCT009 (CAF, Battelle-PNL)	6	1.5 wt%						
MCT002 (PRCF, PNL)	6	2.0 wt%	MCT002 (PRCF, PNL)	6	2.0 wt%				MCT002 (PRCF, PNL)	6	2.0 wt%
MCT006 (CAF, Hanford-PNL)	6	2.0 wt%	MCT006 (CAF, Hanford-PNL)	6	2.0 wt%						
MCT007 (CAF, Hanford-PNL)	5	2.0 wt%	MCT007 (CAF, Hanford-PNL)	5	2.0 wt%						
MCT008 (CAF, Battelle-PNL)	6	2.0 wt%	MCT008 (CAF, Battelle-PNL)	6	2.0 wt%						
MCT004 (TCA, JAERI)	11	3.0 wt% (低密度)	MCT004 (TCA, JAERI)	11	3.0 wt% (低密度)						
MCT005 (CAF, Hanford-PNL)	7	4.0 wt%	MCT005 (CAF, Hanford-PNL)	7	4.0 wt%						
MCT003 (CRX, WREC)	6	6.6 wt%	MCT003 (CRX, WREC)	6	6.6 wt%						
			MISTRAL	1	7.0、8.7 wt%						
			BASALA	1	3.0〜8.7 wt%						
			FUBILA	1	3.0〜11.5 wt%						
MCT001 (CML, Battelle-PNL)	4	22.3 wt%***	MCT001 (Battelle,PNL)	4	22.3 wt%						
MCT011 (Valduc, CEA)	6	25.8 wt%	MCT011 (Valduc, CEA)	6	25.8 wt%						
						MCT012 (HPCML, Battelle-PNL)	33	7.6〜30.0 wt%			

* NDS: Nuclear Data Sheets
** [yellow box] stands for the benchmarks that are commonly used for different libraries
*** converted into (Pu weight) / (Total metal weight) for comparison

(Basic policy for selection of MCT representative cased)

① Independent from each other and open

② Well-documented uncertainty evaluation (rejection of abnormal C/E cases)

③ LWR-compatible Pu enrichment, Pu-240 ratio and H/Pu atomic number ratio

④ Cold condition and no disturbance (e.g. w/o Boron absorber)

Table 2-1 Representative 10 cases selected from MCT

Name	Lattice	Case	Pu enrich. (wt%)	Pu240/Pu (at%)	Number of fuel pins	Pin pitch (cm)	Critical water level* (cm)	Water temp. (℃)	Boron conc. (ppm)	H/Pu atomic number ratio
MCT009 – Battelle	Hex.	2	1.50	7.8	829	1.524	—	25	0	330
	Hex.	6	1.50	7.8	488	2.3622	—	25	0	1176
MCT002 – PRCF	Rect.	1	2.04	7.7	459	1.778	—	22	1.7	185
	Rect.	5	2.04	7.7	161	2.51447	—	22	1.6	565
MCT006 – CAF	Hex.	1	2.04	7.7	320	2.032	—	22	0	235
	Hex.	6	2.04	7.7	181	3.52044	—	22	0	1093
MCT008 – CAF	Hex.	1	2.00	23.4	520	2.032	—	24	0	239
	Hex.	6	2.00	23.4	365	3.5204	—	24	0	1114
MCT003 – CRX	Rect.	1	6.59	8.5	506	1.3208	82.9	25.8	0	75
	Rect.	6	6.59	8.5	121	2.6416	79.5	19.9	0	482

*: distance from the bottom of MOX fuels

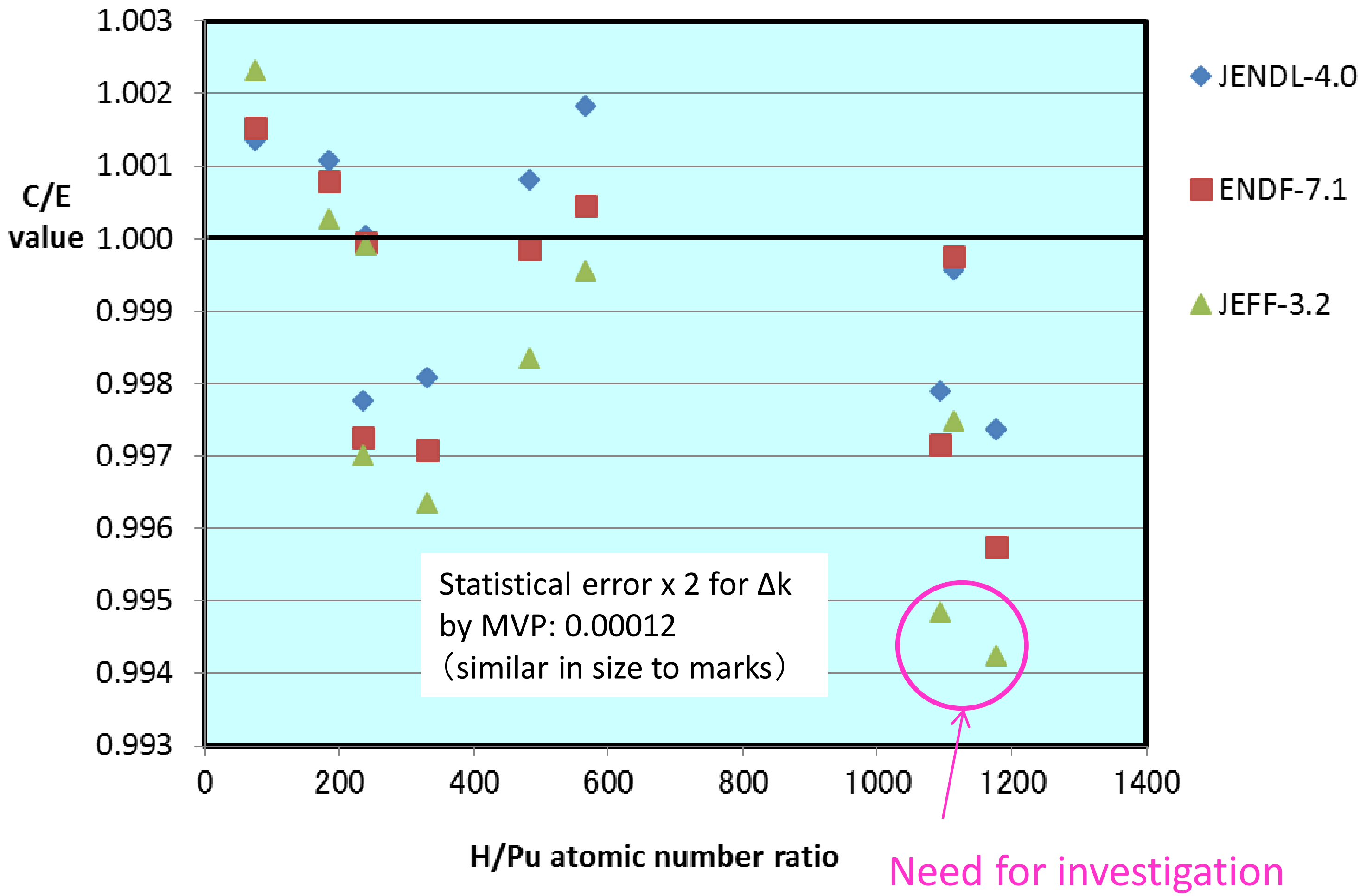


Fig. 2-1 C/E values for MCT by JENDL-4.0, ENDF-VII.1, and JEFF-3.2

→ **In the region of high H/Pu atomic number ratios**, C/E values of **JEFF-3.2** might be underestimated exceeding experimental errors

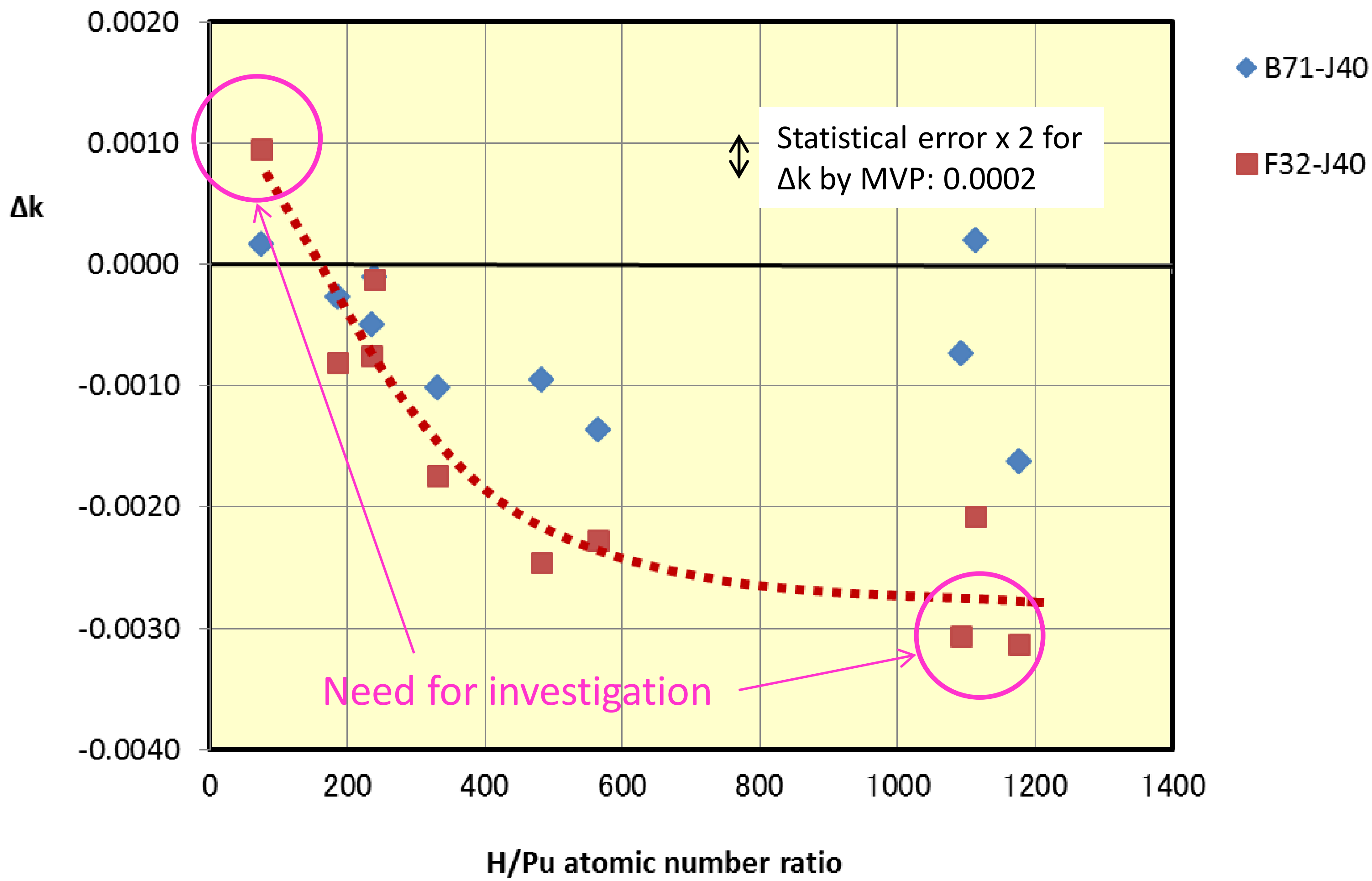


Fig. 2-2 Library-differences of keffs from JENDL-4.0 for the selected MCT benchmarks

→ It is observed that the significant dependency of H/Pu atomic number ratio among three libraries (especially between JEFF-3.2 and JENDL-4.0)

Concluding Remarks

1. LCT benchmarks
   ① Although significant differences among three libraries are seen, it is difficult to discuss their good points and/or bad points only from C/E values
   ② It is observed that the significant dependency of H/U atomic number ratio, which is clearly exceeding statistical errors, between JEFF-3.2 and JENDL-4.0
2. MCT benchmarks
   ① In the region of high H/Pu atomic number ratios, C/E values of JEFF-3.2 might be underestimated exceeding experimental errors
   ② It is observed that the significant dependency of H/Pu atomic number ratio among three libraries (especially between JEFF-3.2 and JENDL-4.0)

Future works

- Investigation of the findings by using sensitivity analysis
- Extension of the benchmark set (e.g. adding solution systems in ICSBEP)
- Development of an automated benchmark execution system