Status of the JENDL Project

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Recent and future release of JENDL

We are trying to develop nuclear data libraries to meet needs in the new era.

Special Purpose File

Recently released:

JENDL/AD-2017: activation CS file for decommissioning

JENDL/PD-2016: new photonuclear reaction data file

To be released:

JENDL/ImPACT-2018: LLFP transmutation CS

General Purpose File

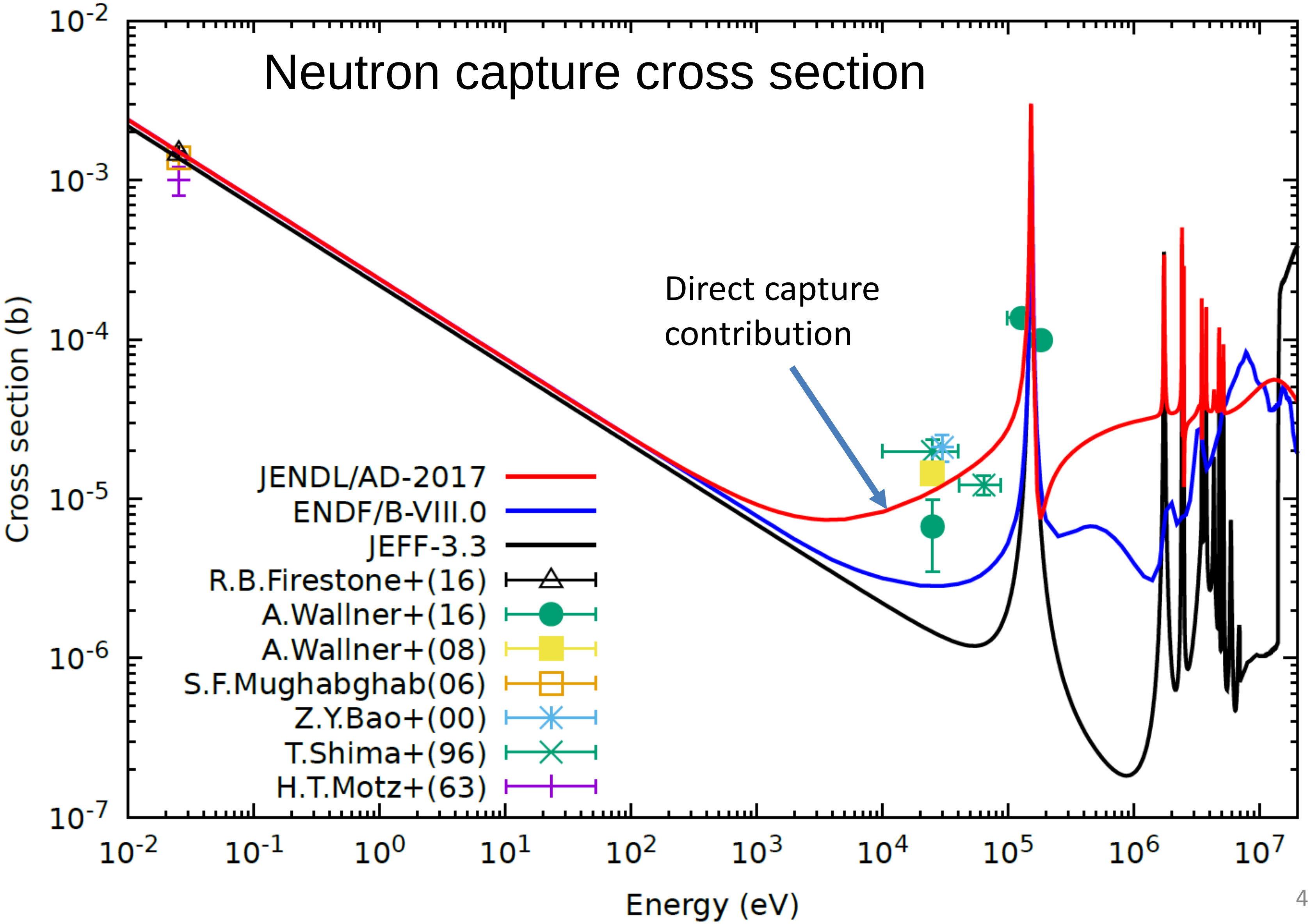
JENDL-5: developing next version of JENDL

JENDL/AD-2017

Activation Cross Section File for Nuclear Decommissioning

- For evaluation of radioactive inventory on decommissioning of nuclear facilities
- Neutron-induced nuclear reactions (except for Fe-56 for proton incident one)
- Includes 311 nuclides (which lead to production of 221 RI)
- Energy range: up to 20 MeV
- Pointwise CS data at 0 K and 293.6 K

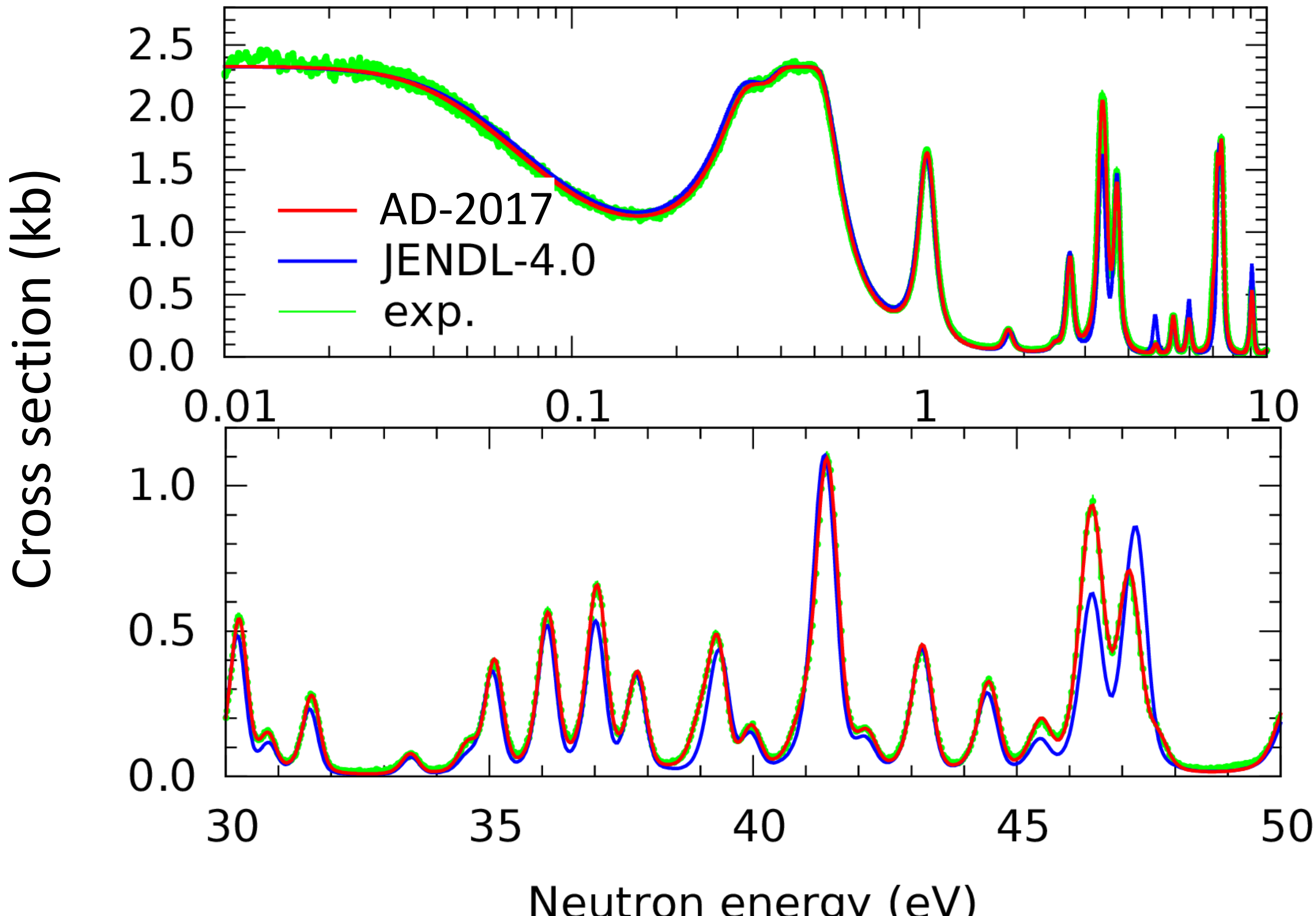
Result of C-13(n,γ)C-14



Eu evaluation with measured data by ANNRI at J-PARC

$^{151}Eu(n,\gamma)^{152}Eu$

Analyzed with REFIT code



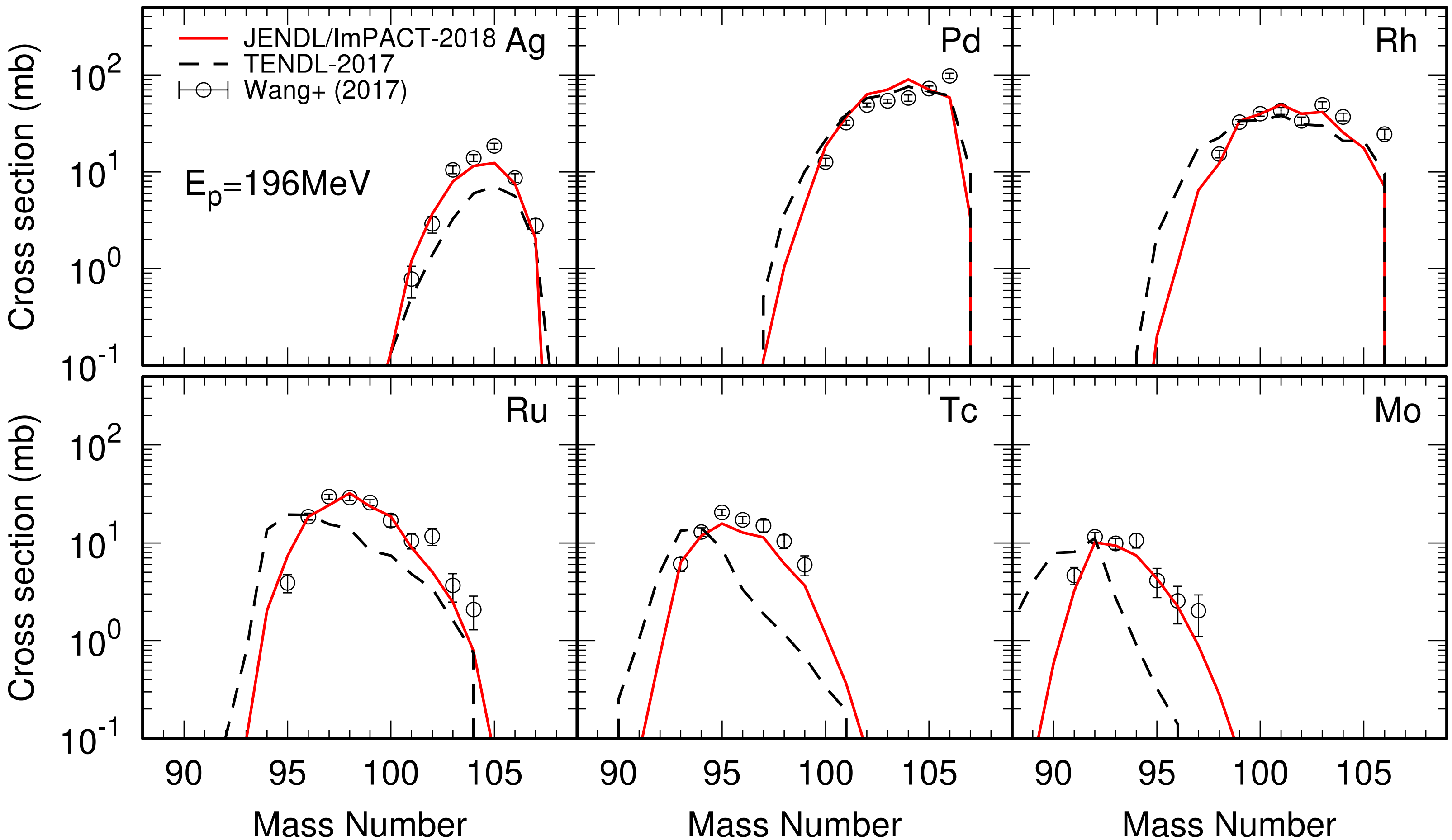
JENDL/ImPACT-2018

JENDL LLFP transmutation cross section File 2018

- R&D program for Reduction and Resource Recycling of High-level Radioactive Wastes through Nuclear Transmutation
- Aiming at establishing reasonable nuclear transmutation methods which will enable these wastes to be converted into stable nuclides or short-lived ones
- JENDL/ImPACT-2018 contains 163 nuclides which could produced in transmutation of LLFPs (Se-79, Zr-93, Pd-107, Cs-135).

This work was funded by the ImPACT Program of the Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

Isotope production from proton induced reaction on Pd-106



JENDL/ImPACT-2018

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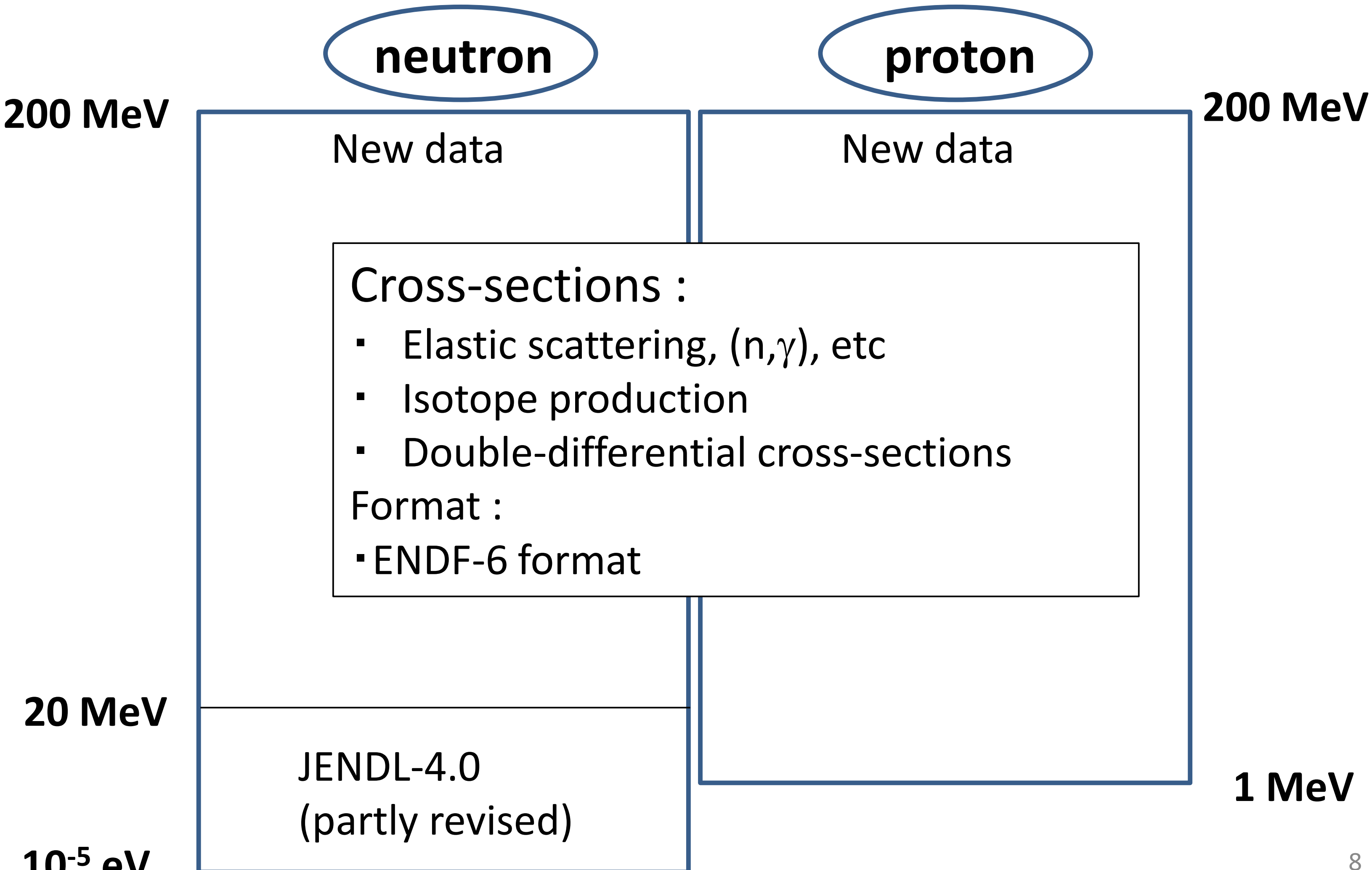


Plan of JENDL-5

For acceleration of nuclear innovation on backend
as well as various applications

- Neutron data
  - Include all stable isotopes
  - Add isomer production for activation
  - Resonance of light nuclei by a new R-matrix code AMUR
  - MA resonance with new J-PARC data
  - Fast neutron fission cross section for major actinide
  - covariance data of structure material and light nuclei
- Thermal scattering law for light water
- Charged particle induced reactions
- To be released in FY2021 (format GND?)

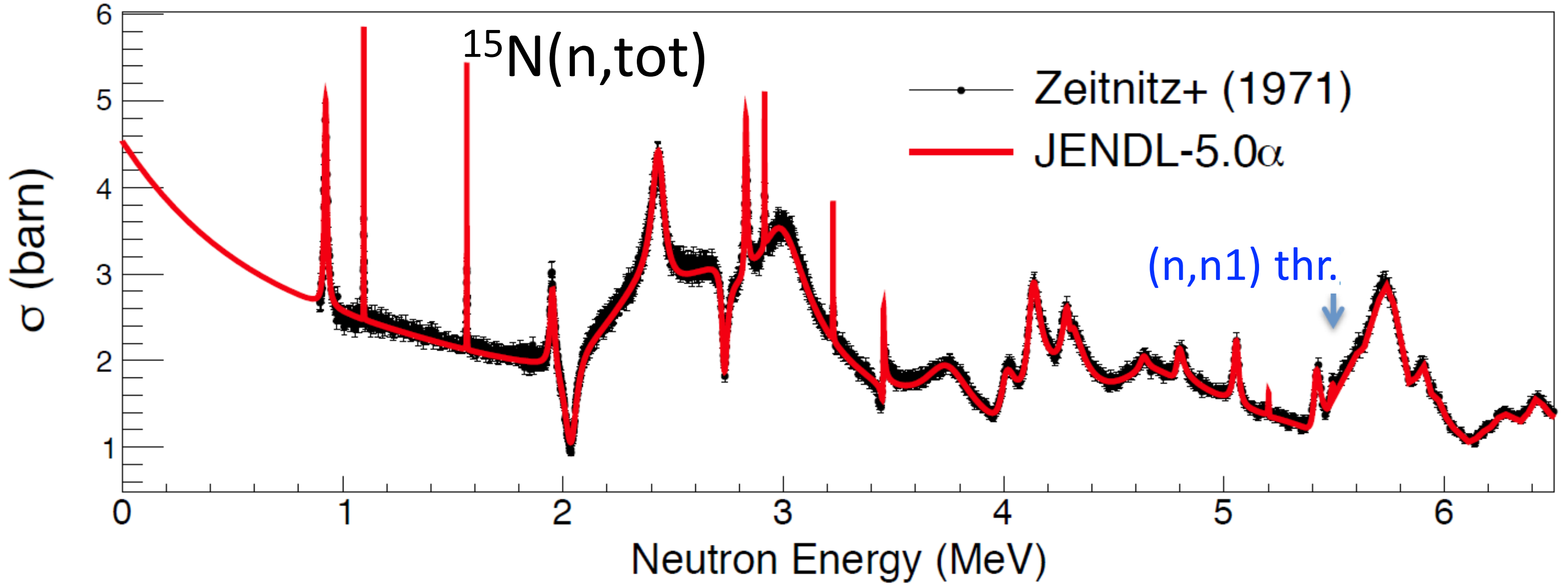
JENDL-5α1

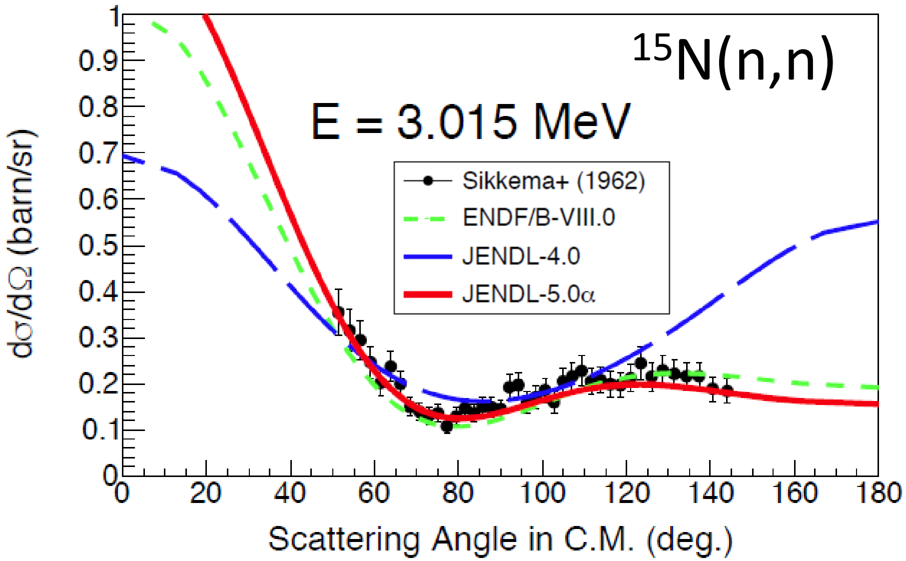
- The first test version was created in 2018
- Updated and newly evaluated elements in JENDL-5alpha1
  - Ga, Zr, Nb, Tc, Ru, Sb, Te, I, Pr, Gd, Er, Ta, Re, Pt, Hg, Tl, U, Pu, Am
- New evaluation of thermal scattering law for light water

Light nucleus evaluation

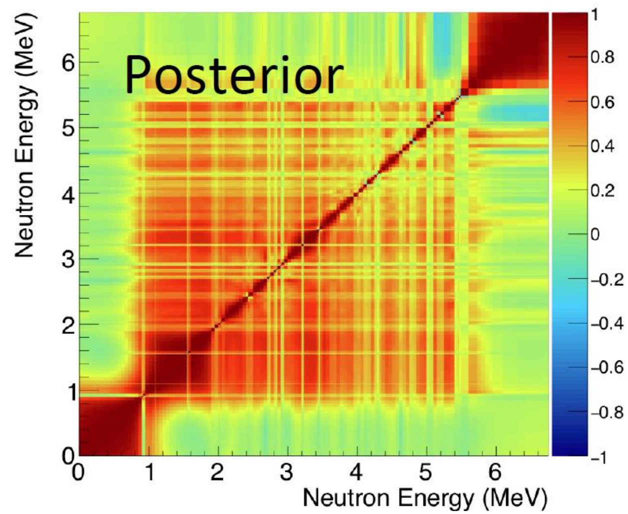
- New R-matrix code AMUR
  S. Kunieda, EPJ 146, 12029, (2017)
- Preliminary evaluation of N-15, O-16, F-19
- Covariance

Result of N-15 evaluation





Covariance of $^{15}N(n,tot)$

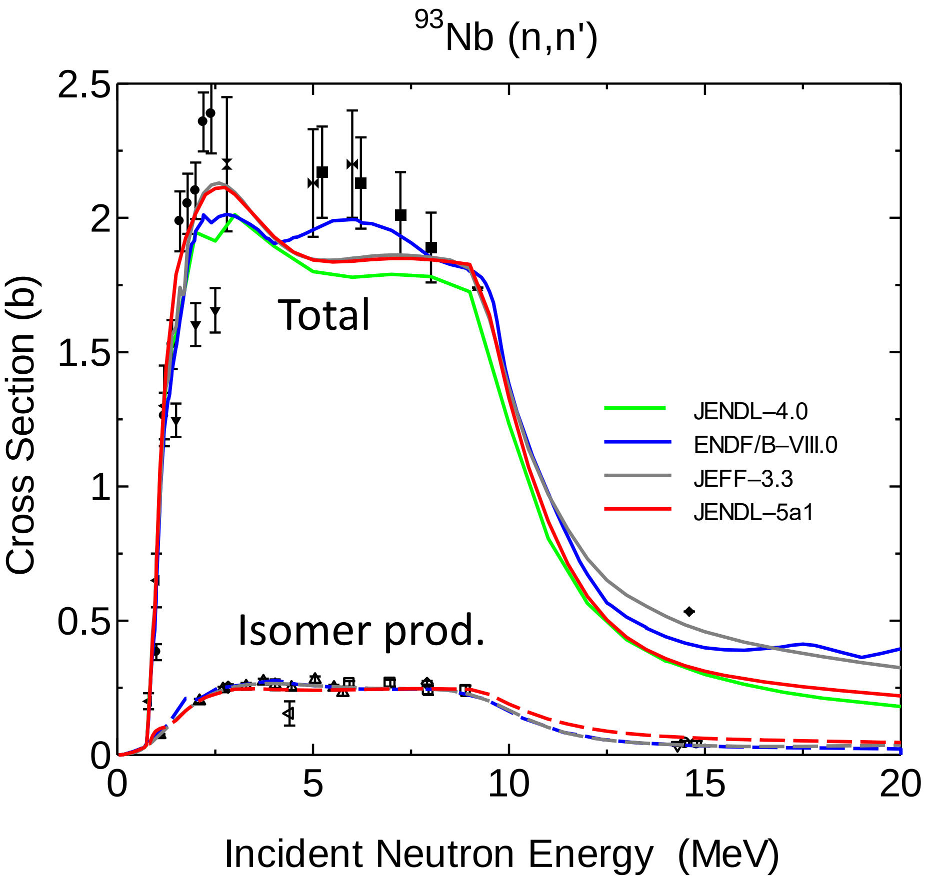


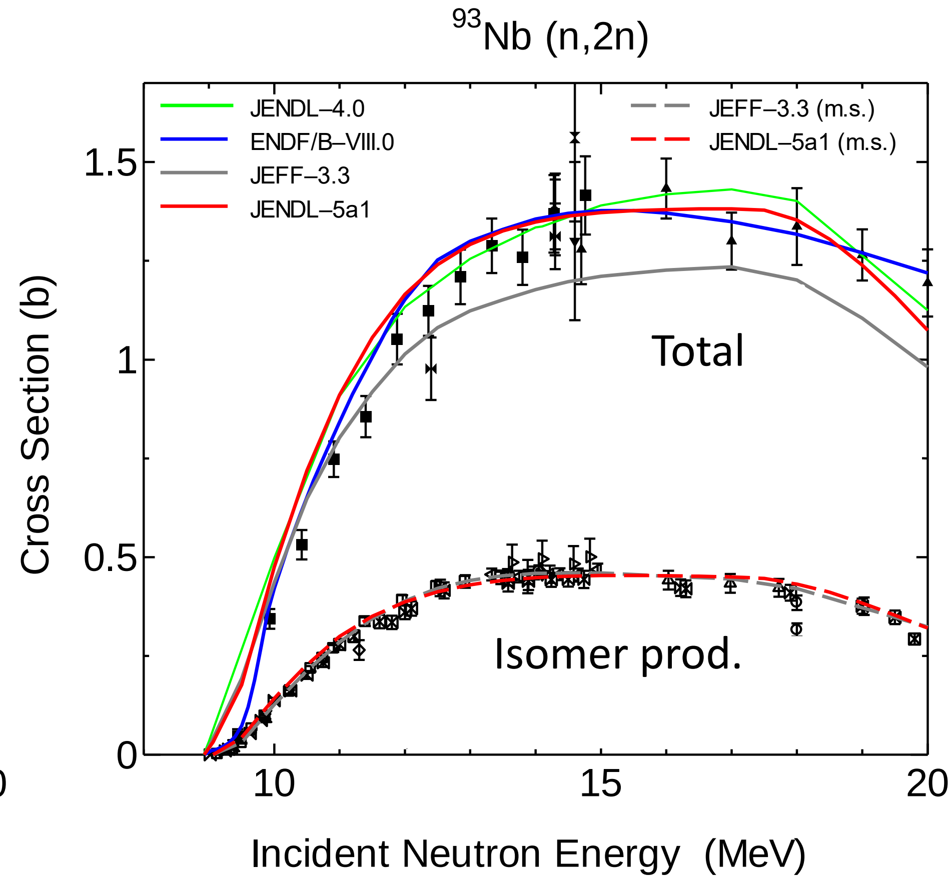
Structural material

- Add isomer production data
- Update resonance parameters
- Above the resonance region
  - model calculation with CCONE
  - Covariance data will be evaluated CCONE + KALMAN

Cross sections for Nb-93

Isomer productions are important as reactor dosimeter and neutron flux monitor.
CCONE calculations simultaneously reproduce isomer and total cross sections.



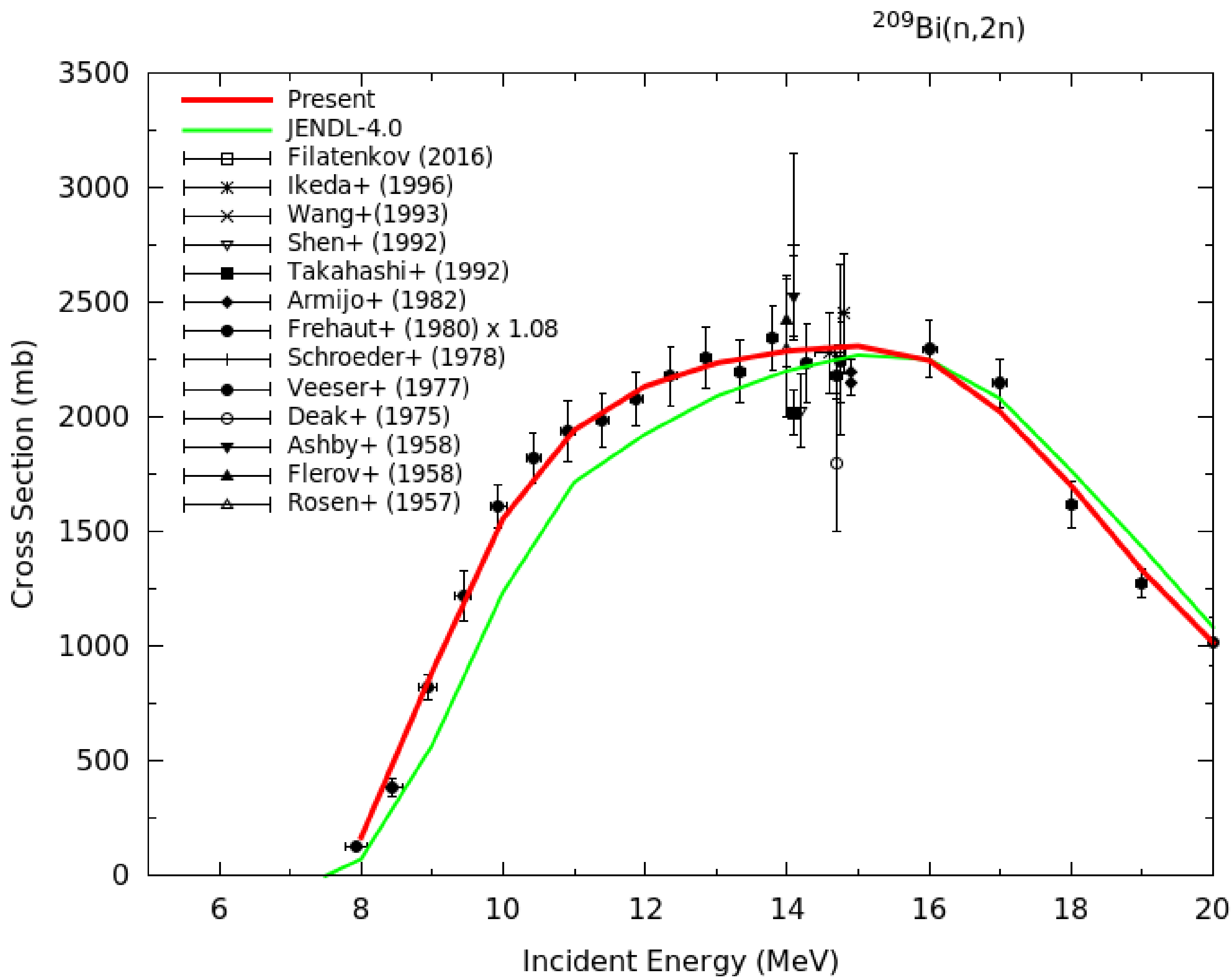


A. Ichihara, JNST 53,2049 (2016)

Fission products and medium heavy nuclides

- Objectives
  - Updating old FP evaluations
  - Providing activation cross sections for decommissioning of LWRs
- Evaluated nuclides
  - FP: Ga, Nb, Tc, Sb, Te, I, Er
  - MHN: Ta, Pt, Hg, Tl
  - Most of them has already been published in JNST

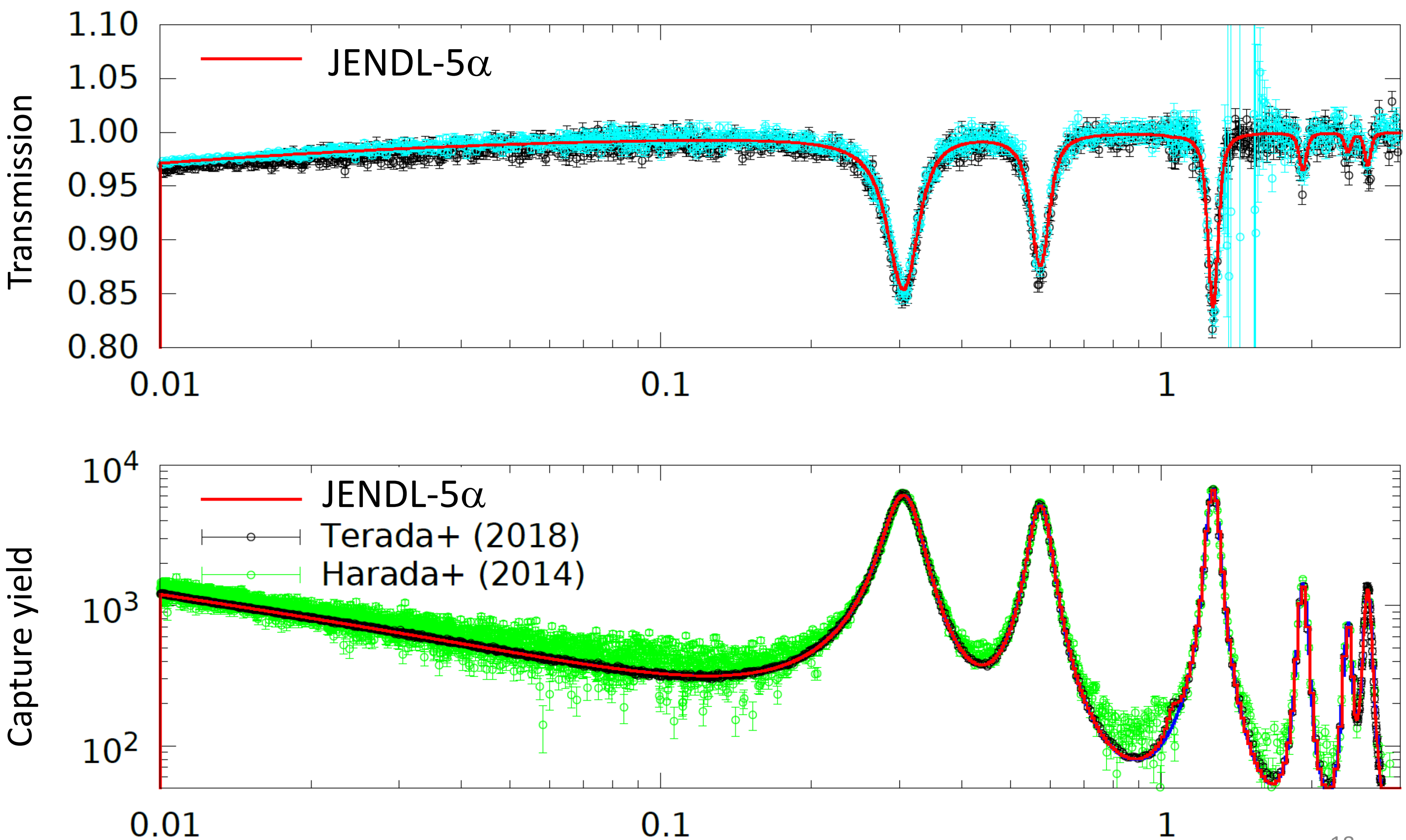
Evaluation of Bi-209



Actinide evaluation

- New resonance parameters deduced from new ANNRI measurements for MA.
- Create test files adopting CIELO evaluations of resolved resonance parameters of major actinides.
- Simultaneous evaluation of the fission cross sections in fast neutrons energy region for 6 isotopes of U and Pu.

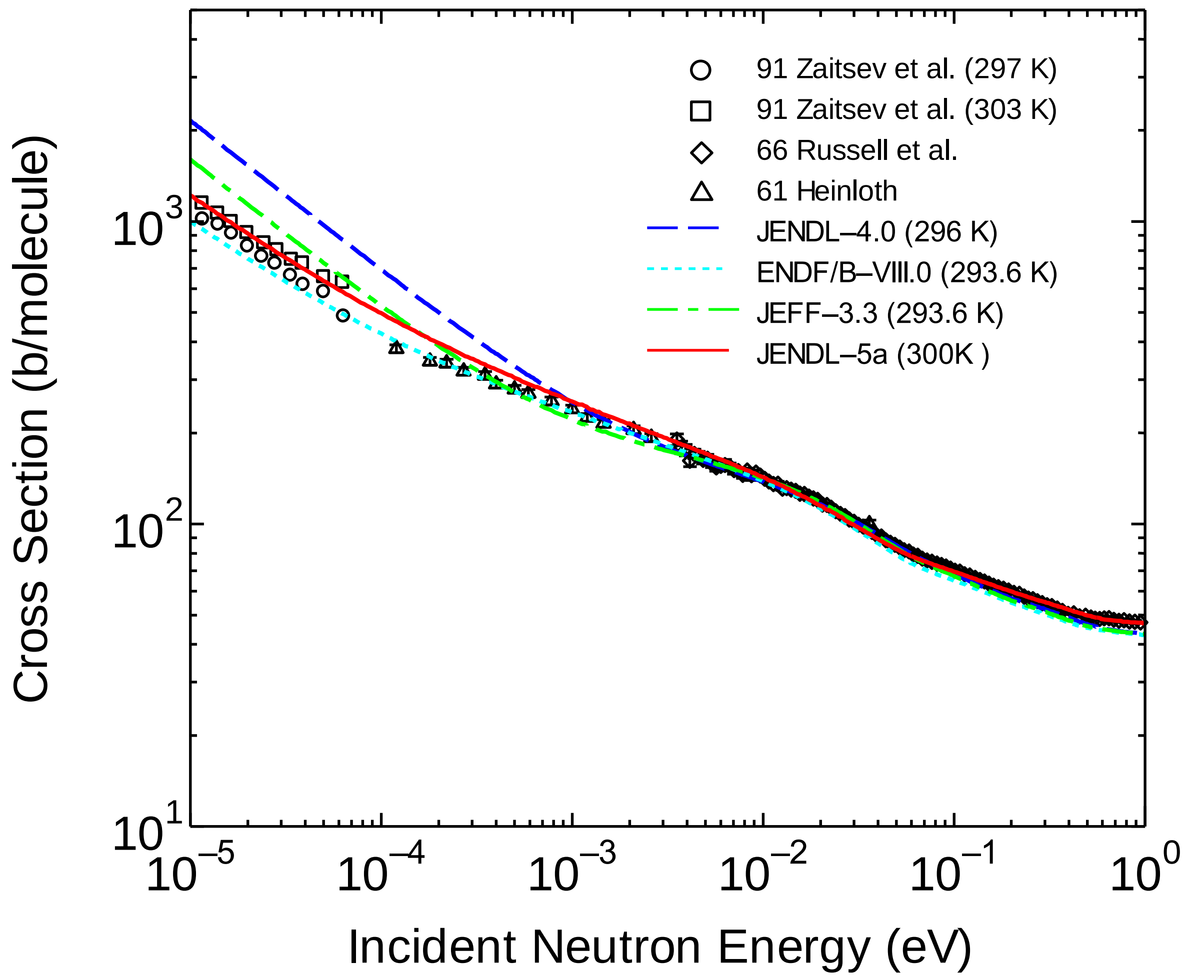
Am-241 resonance analysis with new data measured by ANNRI



Thermal scattering law data

Y.Abe et al., NIMA 735 (2014) 568-573 (MD based approach)

Total cross section for light water

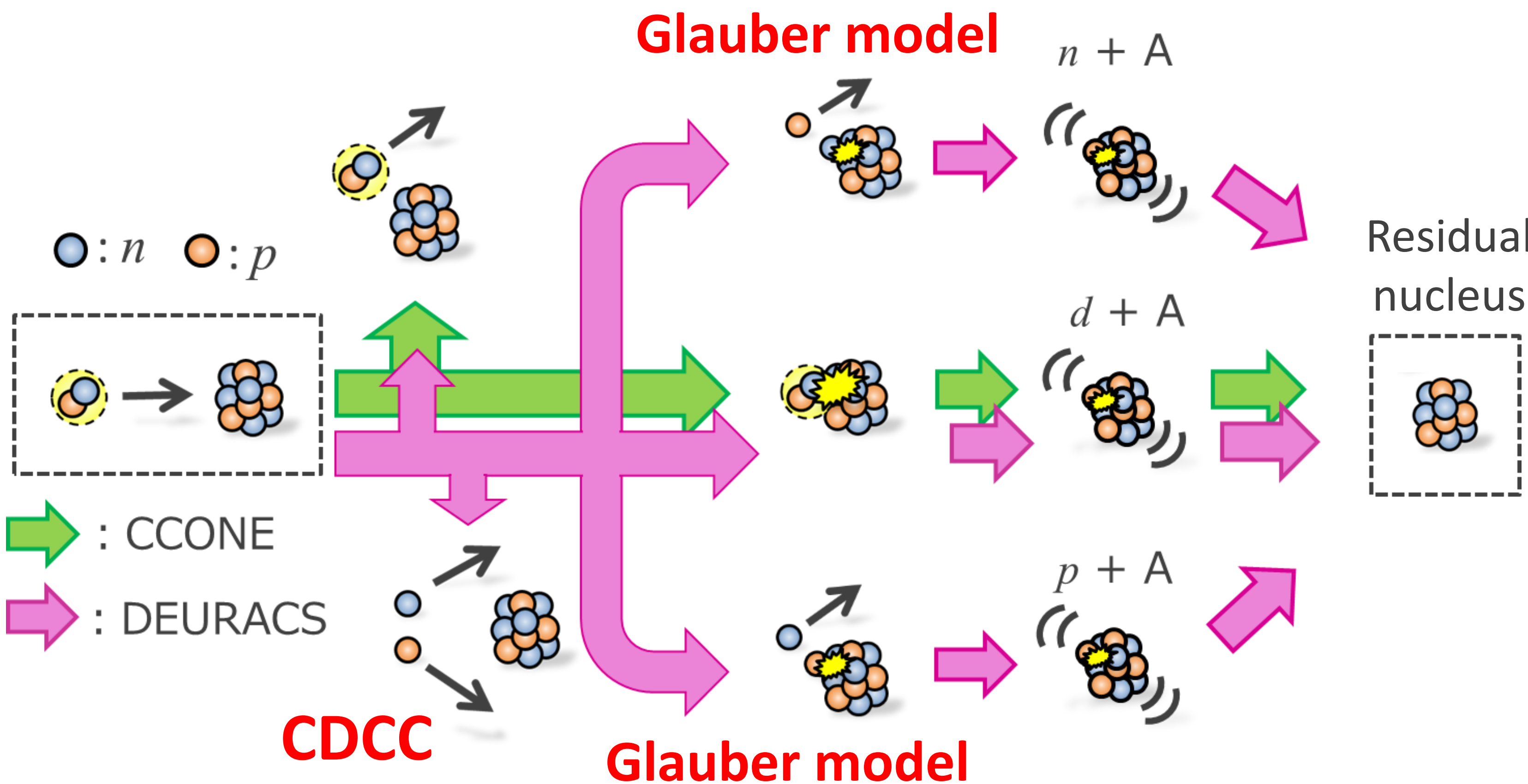


*JENDL-4.0, ENDF/B-VIII.0, JEFF-3.3 includes contribution only from H of H_2O.

Deuteron data

DEURACS was developed for deuteron data evaluation.

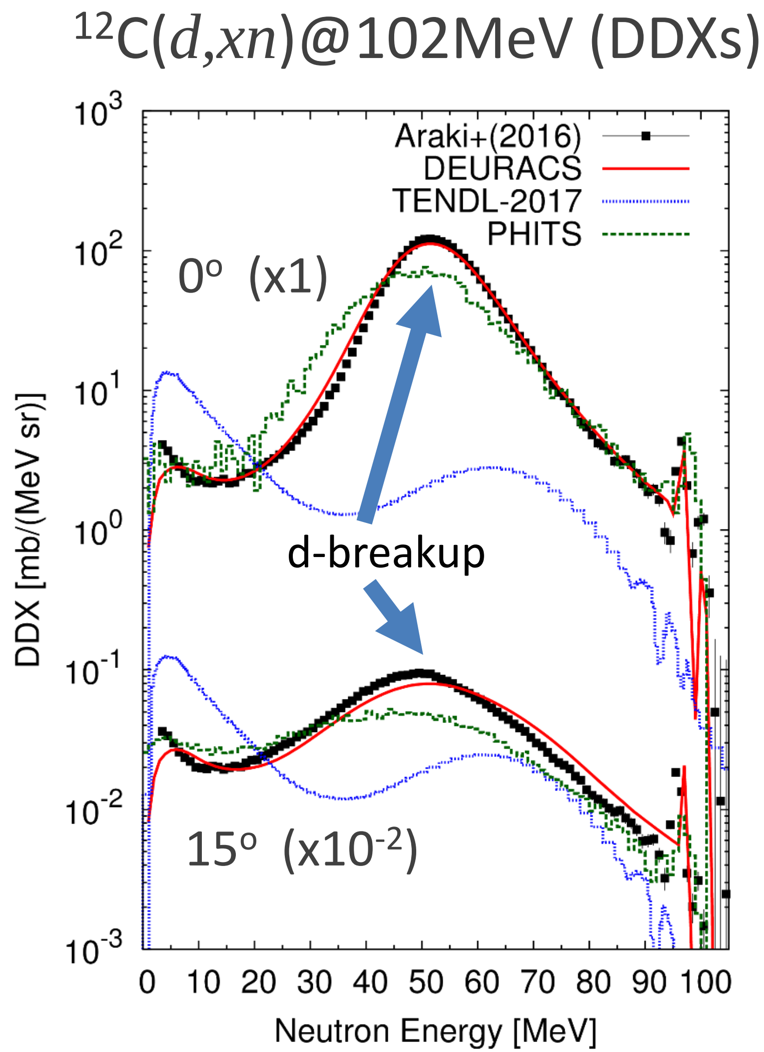
DEURACS: S. Nakayama, R0101@Room202, May 21

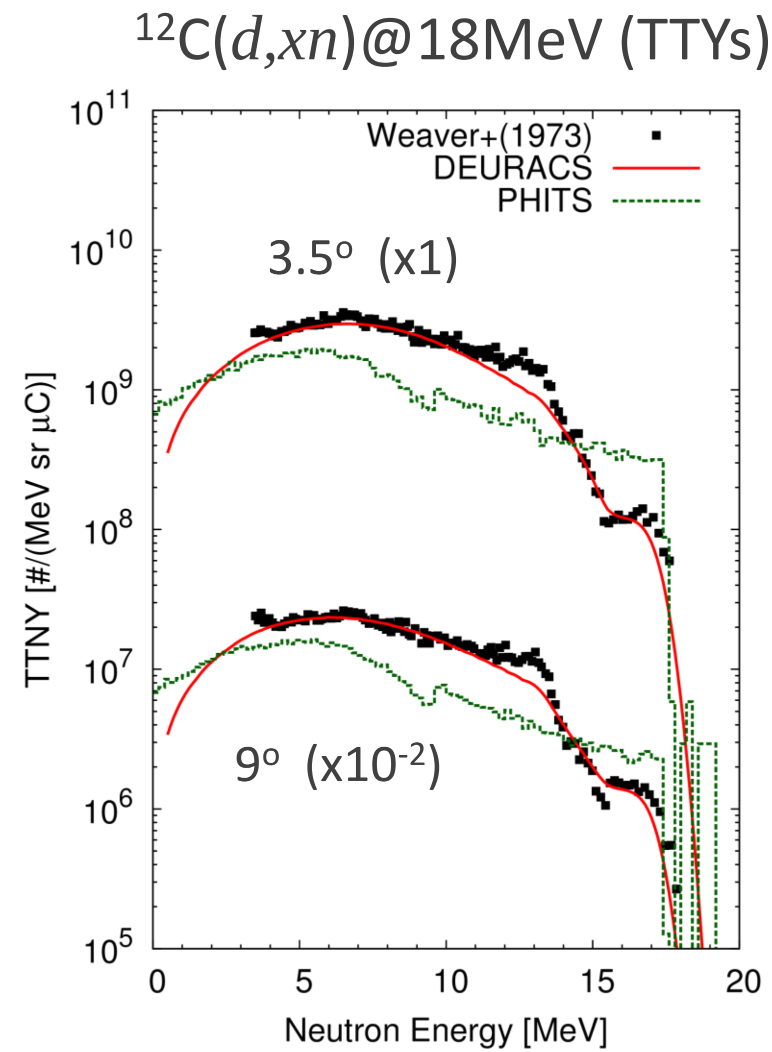


DEURACS explicitly considers the **"breakup"** processes.

⇨ Three production paths exist.

Neutron emission from d+C-12

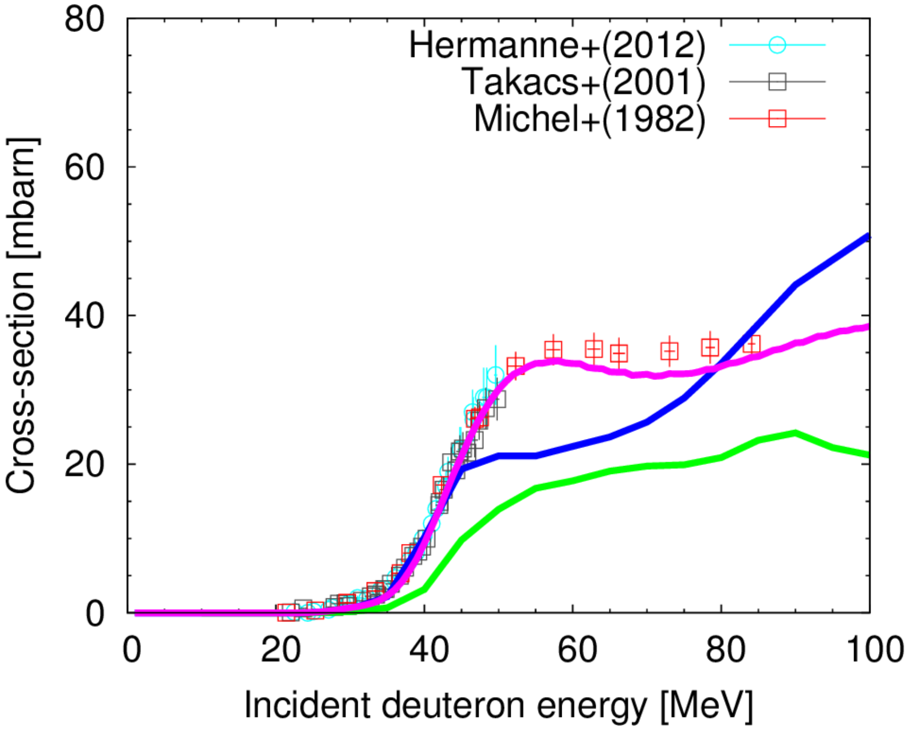




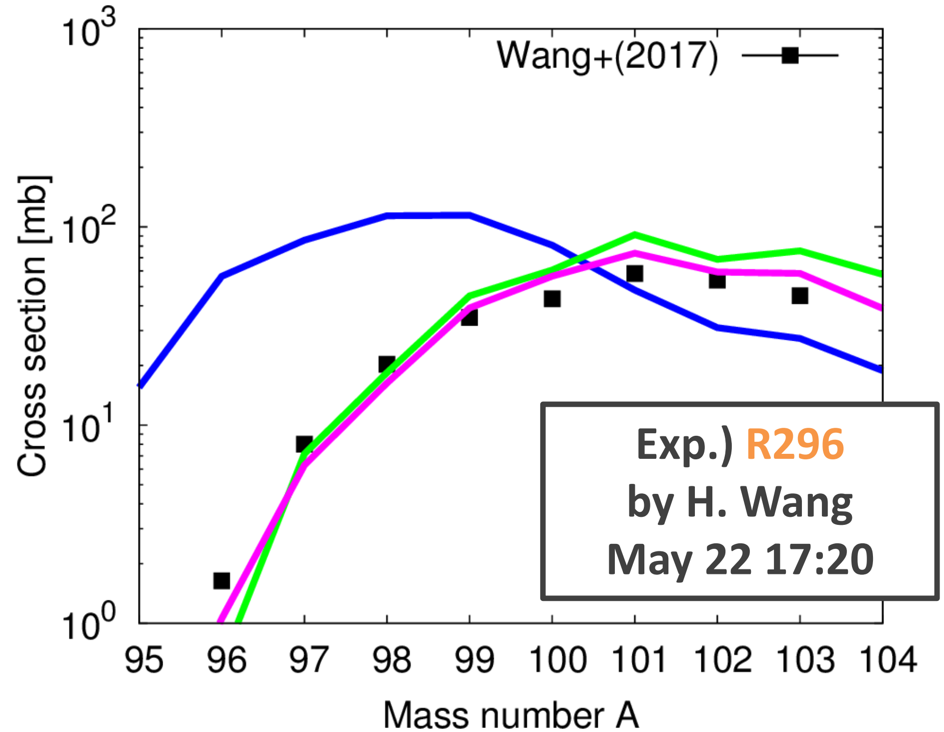
DEURACS reproduces the peaks arising from breakup.

Residual nucleus production

^{27}Al(d,x)^{22}Na@20-100MeV



^{107}Pd(d,x)^{A}Rh@200MeV [1]



DEURACS TENDL-2017 PHITS

✓ DEURACS reproduces experimental data in **wide energy range**.

[1] S. Nakayama et al., PRC **98**, 044606 (2018).

Future plan of JENDL-5

- Revision of data using feedback of benchmark results
- Covariance evaluation
- Fission product yields (Tokyo Tech.)
- Decay data
- Evaluation of thermal scattering law data
- Calculation of recoil nucleus spectrum for estimation of KERMA factor
- Data file of deuteron induced reactions
- Documentation

Benchmark for Next JENDL

- Benchmark tests for the first development (alpha) version of next JENDL, JENDL-5a1, was started last year
- The following benchmark sets for LWR prepared by RIT-WG* in JENDL committee and for FR by JAEA were applied
  - 10 keffs for UO2-LWR and 10 keffs for MOX-LWR
  - 6 keffs for Small-FR and 9 neutronic characteristics including SVR* and CWR* for Large-FR

* RIT-WG: Reactor Integral Test Working Group,

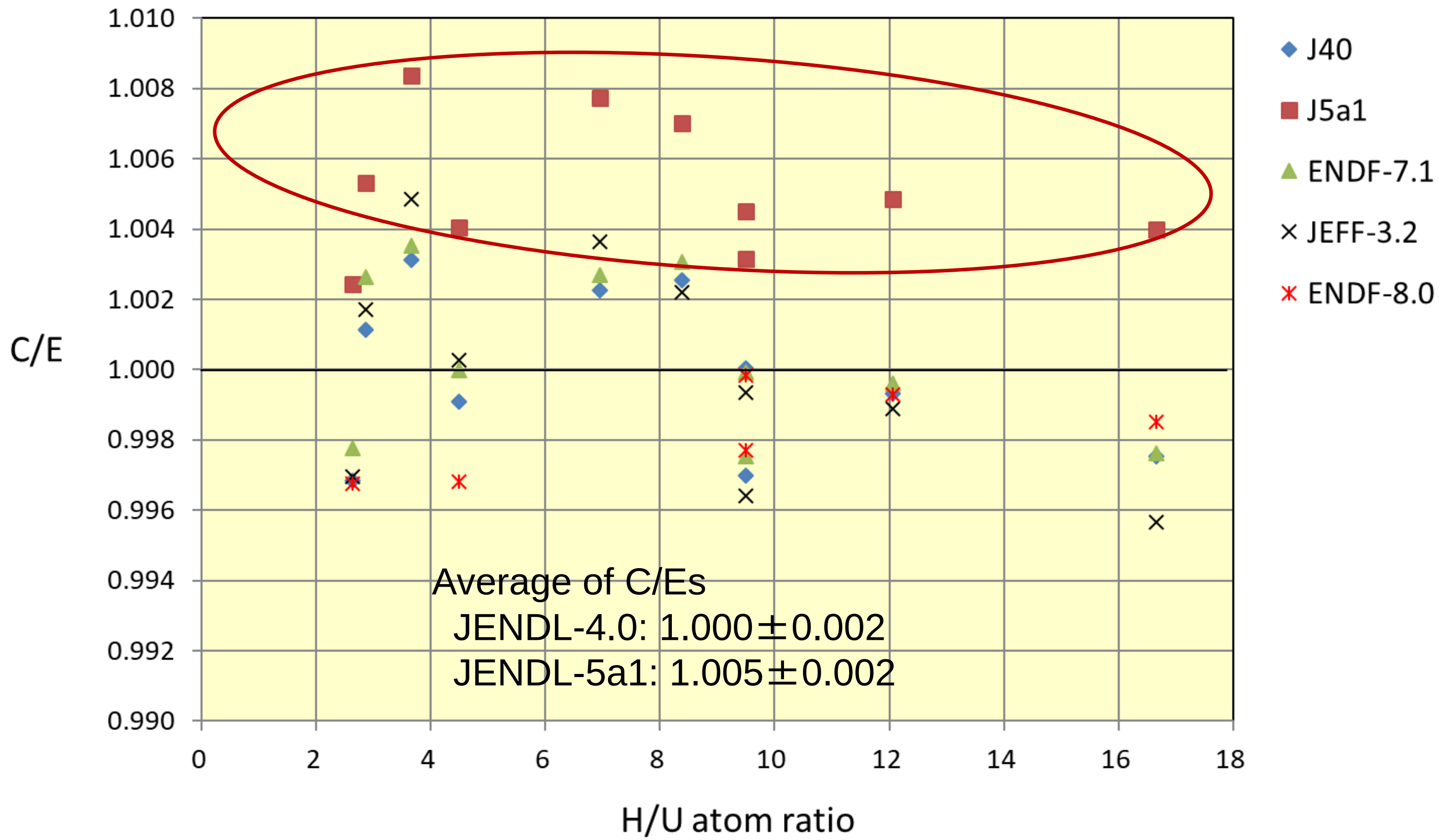
SVR: Sodium Void Reactivity, CWR: Control Rod Worth

Representative Benchmark Set for UO2-LWR

	Case	U enrichment (wt%)	Lattice type	Fuel pin pitch (cm)	Number of fuel pins	Diameter of fuel pellet (cm)	H/U atom ratio	Exp. Benchmark keff	Uncertainty of Exp. (Δk)
LCT-001 (PNL)	1	2.35	Rect.	2.032	361.6	1.118	9.5	0.9998	0.0030
	8				912 (3clusters)			0.9998	0.0030
LCT-048 (DIMPLE)	1	3.0	Rect.	1.32	1565	0.743	2.9	1.0000	0.0025
LCT-079 (Sandia)	1	4.31	Hex.	2.0	257	1.265	4.5	0.9999	0.0016
	6			2.8	131		12.1	0.9994	0.0008
LCT-007 (Valduc)	1	4.74	Rect.	1.26	484	0.789	2.6	1.0000	0.0014
	4			2.52	306		16.7	1.0000	0.0008
LCT-026 (IPPE)	1	4.92	Hex.	1.29	621	0.753	6.9	1.0000	0.0034
	3			1.09	1951		3.7	1.0018	0.0062
LCT-018 (DIMPLE)	1	7.0	Rect.	1.32	376	0.743	8.4	1.0000	0.0020

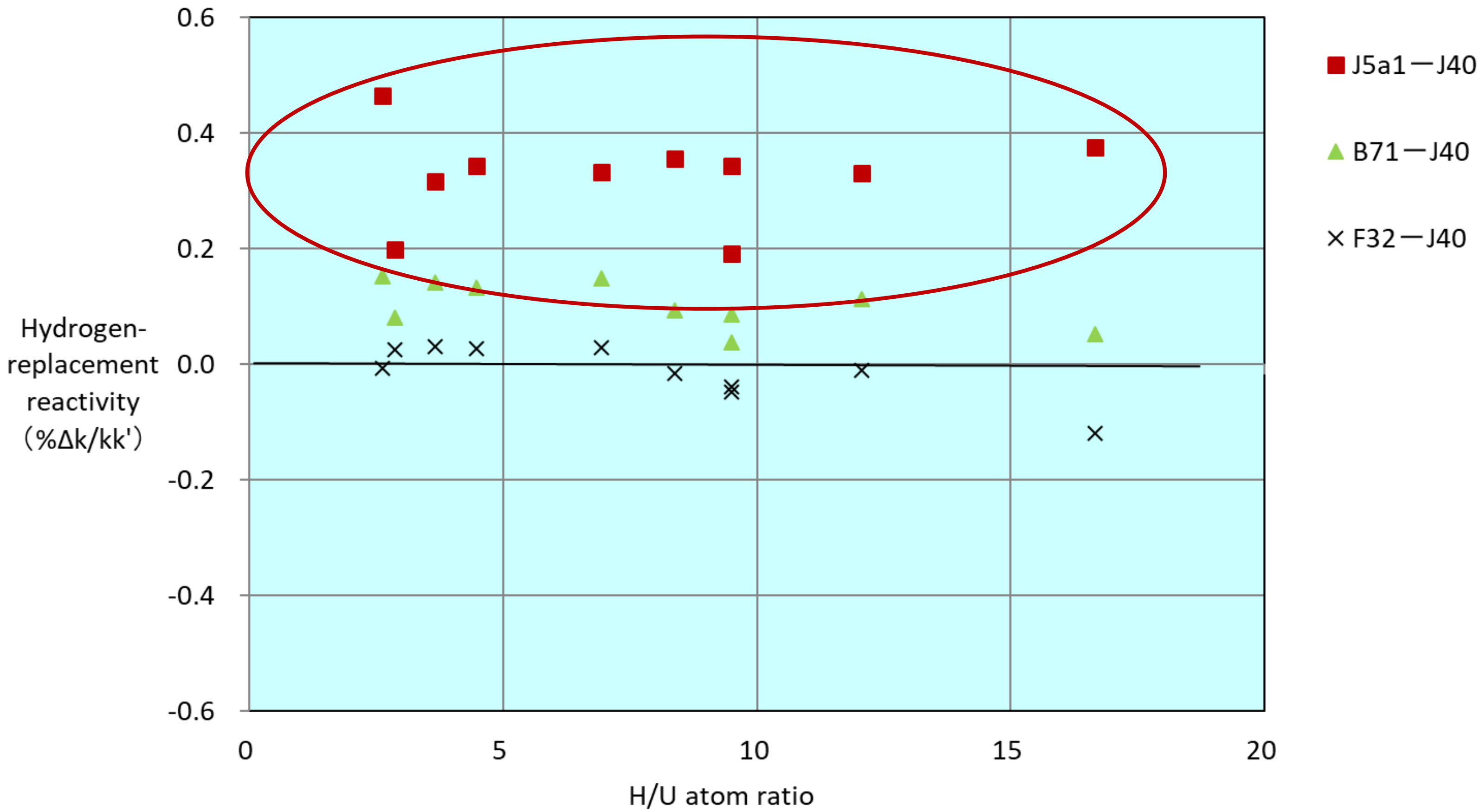
- Standard cases: no reflector and no neutron poison such as B and Gd
- Variations: U enrichment, fuel pin pitch, and H/U atom ratio

Preliminary Result of UO2-LWR Benchmark



- Systematic overestimation (0.52%Δk/kk' on average) by JENDL-5a1 is observed

Hydrogen-replacement Reactivity for UO2-LWR Benchmark



- H-1 in H2O of JENDL-5a1, which is evaluated with MD-based S(a,b)*, seems to have dominant contribution (0.33%Δk/kk’ on average) to the foregoing overestimation

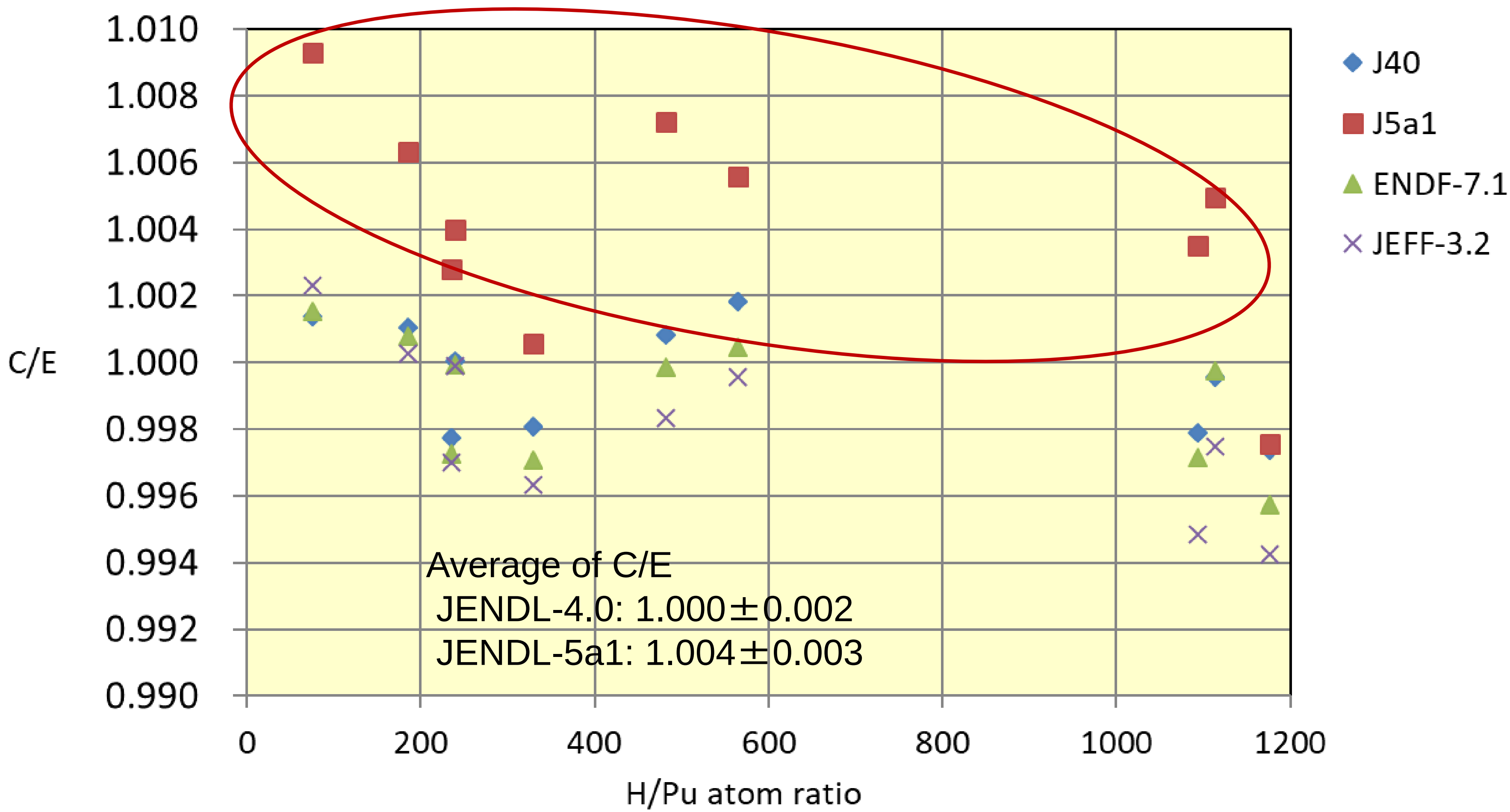
* Y. Abe et al., NIMA 735 (2014) 568-573

Representative Benchmark Set for MOX-LWR

	Case	Pu enrichmet (wt%)	Pu240/Pu (at%)	Lattice type	Fuel pin pitch (cm)	Number of fuel pins	Diameter of fuel pellet (cm)	H/Pu atom ratio	PuO_2 particle correction by MVP (25 μm) (%Δk/kk')	Benchmark keff	Uncertinty of Exp. (Δk)
MCT009 (CAF)	2	1.50	7.8	Hex.	1.52	829	0.945	330	0.21	1.0014	0.0049
	6				2.36	488		1176	0.51	1.0051	0.0080
MCT002 (PRCF)	1	2.04	7.7	Rect.	1.78	459	1.283	185	0.03	1.0005	0.0059
	5				2.51	161		565	0.20	1.0030	0.0022
MCT006 (CAF)	1			Hex.	2.03	320	1.283	235	0.07	1.0009	0.0051
	6				3.52	181		1093	0.29	1.0041	0.0051
MCT008 (CAF)	1	2.00	23.4	Hex.	2.03	520	1.283	239	0.01	0.9993	0.0032
	6				3.52	365		1114	0.29	1.0020	0.0065
MCT003 (CRX)	1	6.59	8.5	Rect.	1.32	506	0.857	75	0.04	1.0004	0.0017
	6				2.64	121		482	0.18	1.0018	0.0014

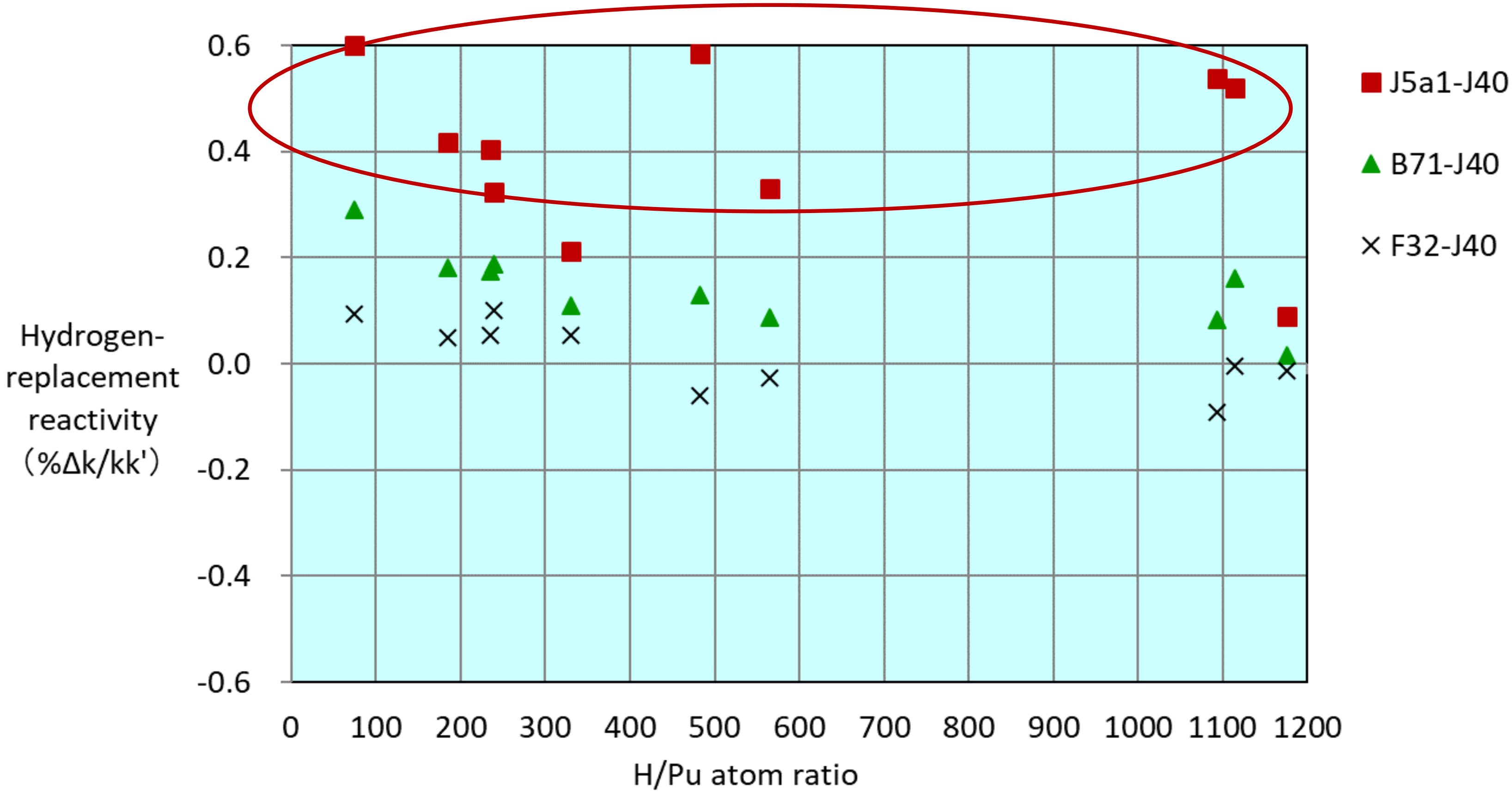
- Standard cases: no reflector and no neutron poison such as B and Gd
- Variations: Pu enrichment, Pu vector, and H/Pu atom ratio

Preliminary Result of MOX-LWR Benchmark



- Similarly to the UO2-LWR benchmark, systematic overestimation by JENDL-5a1 (0.46%Δk/kk' on average) is observed

Hydrogen-replacement Reactivity for MOX benchmark



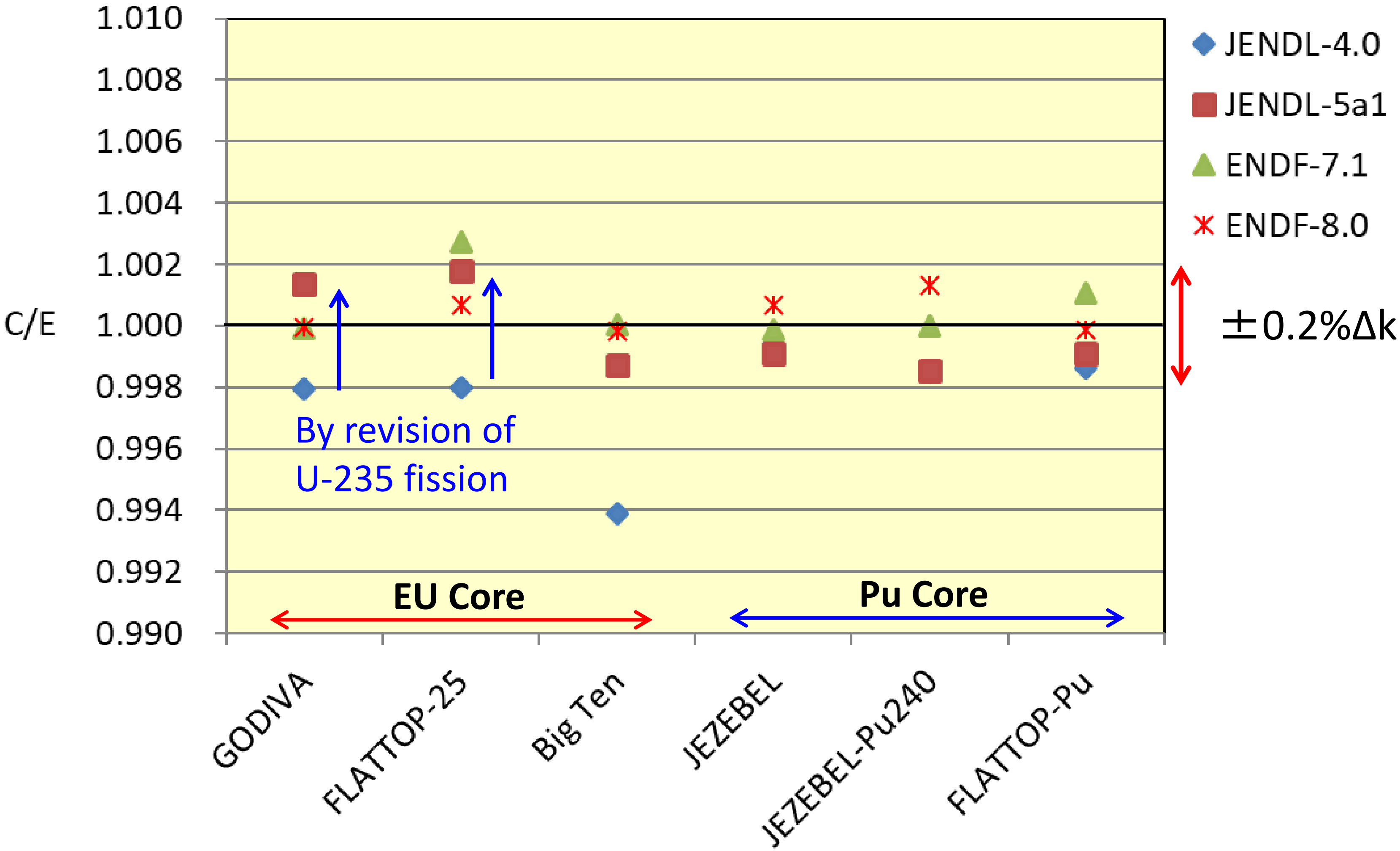
- As well as the UO2-LWR benchmark Hydrogen of JENDL-5a1 has dominant contribution (0.40%Δk/kk’ on average) to the overestimation

Representative Benchmark Set for Small-FR

	Core fuel (metallic)	Core shape	Reflector	Exp. Benchmark keff	Uncertainty of Exp. (Δk)
GODIVA (HMF001)	U-235 (^{235}U: 94wt%)	Sphere (diameter 17.5cm)	---	1.0000	0.0010
FLATTOP-25 (HMF028)	U-235 (^{235}U: 93wt%)	Sphere (diameter 12.2cm)	Natural U	1.0000	0.0030
Big Ten (IMF007)	U-235 + U-238 (^{235}U on ave.: 10wt%)	Cylinder (max. dia. 25.4cm, hight 26.7cm)	Natural U	1.0045	0.0007
JEZEBEL (PMF001)	Pu-239 (^{240}Pu/Pu: 4.5at%)	Sphere (diameter 12.8cm)	---	1.0000	0.0011
JEZEBEL-Pu240 (PMF002)	Pu-239 (^{240}Pu/Pu: 20at%)	Sphere (diameter 13.3cm)	---	1.0000	0.0020
FLATTOP-Pu (PMF006)	Pu-239 (^{240}Pu/Pu: 4.8at%)	Sphere (diameter 9.1cm)	Natural U	1.0000	0.0030

- Reference cases: widely-used benchmarks in nuclear data evaluations (This set is not necessarily important for FR design study)

Preliminary Result for Small-FR Benchmark



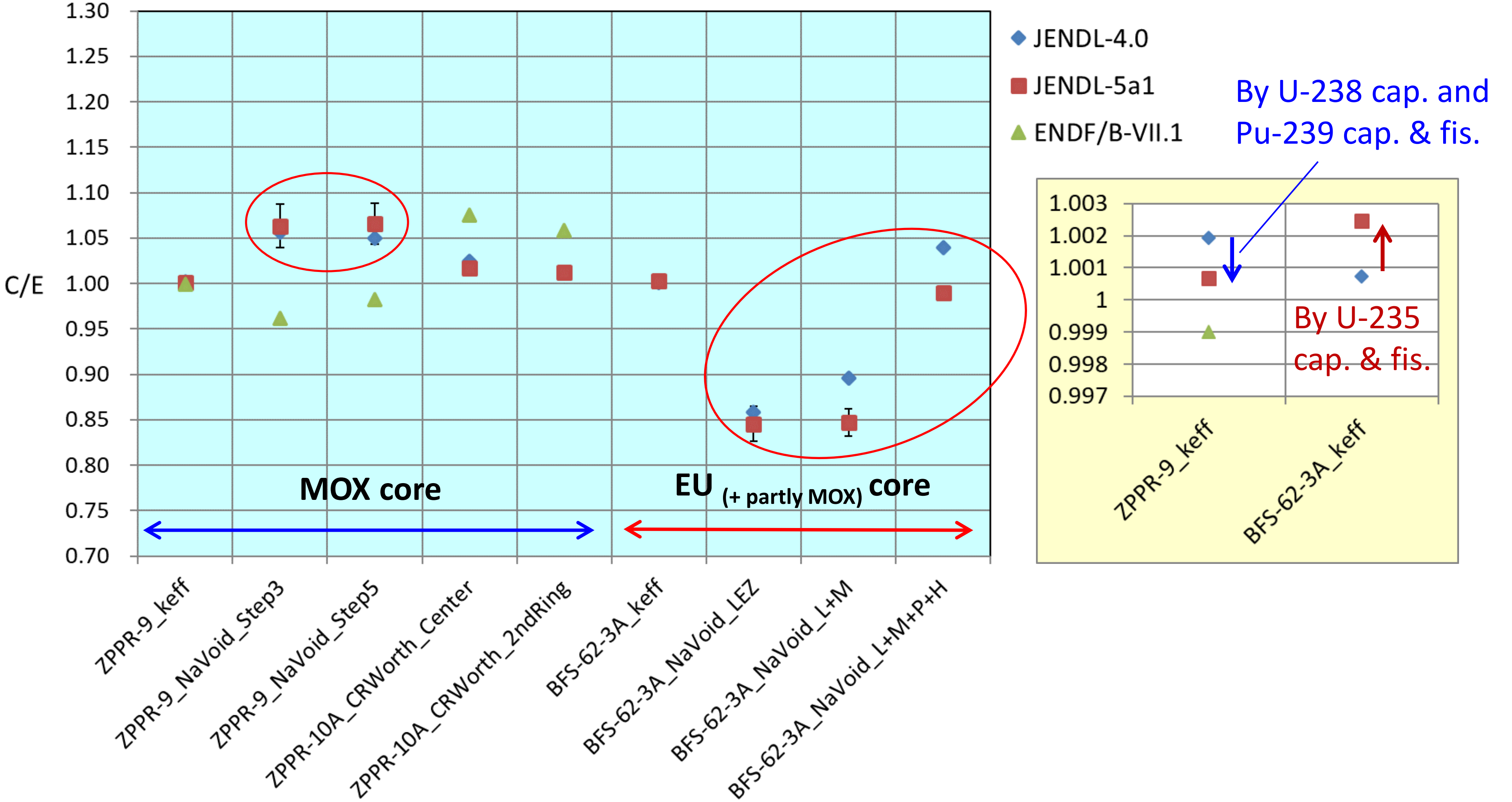
- All C/E values are equal to unity within ±0.2%Δk

Representative Benchmark Set for Large-FR

	Core fuel	Core characteristics	Exp. Benchmark keff	Uncertainty of Exp. (%)
ZPPR-9_keff (ZPPR-LMFR-EXP-002)	Pu-239 +U-238 (MOX)	Criticality (keff)	1.0008	0.12
ZPPR-9_NaVoid_Step3 (ZPPR-LMFR-EXP-002)		Na void reactivity (Low neutron leakage)	29.39 ¢	1.93
ZPPR-9_NaVoid_Step5 (ZPPR-LMFR-EXP-002)		Na void reactivity (High neutron leakage)	31.68 ¢	1.88
ZPPR-10A_CRWorth_Center (ZPPR-LMFR-EXP-001)		Control rod worth (Core center)	2.610 $	1.22
ZPPR-10A_CRWorth_2ndRing (ZPPR-LMFR-EXP-001)		Control rod worth (The 2nd ring)	21.090 $	1.19
BFS-62-3A_keff (BFS2-LMFR-EXP-001)	Enrich. U-235 +U-238 (+MOX ring region)	Criticality (keff)	1.0007	0.24
BFS-62-3A_NaVoid_LEZ (BFS2-LMFR-EXP-001)		Na void reactivity (Low-enriched U regions)	-9.2 ¢	5.43
BFS-62-3A_NaVoid_L+M (BFS2-LMFR-EXP-001)		Na void reactivity (Low&Middle-enriched U regions)	-11.7 ¢	4.98
BFS-62-3A_NaVoid_L+M+P+H (BFS2-LMFR-EXP-001)		Na void reactivity (Low&Middle-enriched U + MOX + High-enriched U regions)	-28.4 ¢	2.90

- Standard cases: important benchmarks for FR design study
- Variations: MOX and U-enriched fuel, CWR, and SVR

Preliminary Result for Large-FR Benchmark



- JENDL-5a1 shows good performance for keff and CRW
- There is room for improvement of C/E values for SVR

Sensitivity Analysis for Sodium Void Reactivity

ZPPR-9_Step3 (MOX core)

Nuclide	Reaction	Contribution (%Δk/kk')			Contribution ratio (%)
		Negative	Positive	Total	
U−235	capture	0.0	0.1	0.0	15.5
U−235	fission	−0.1	0.0	0.0	−14.5
U−235	elastic	0.0	0.0	0.0	0.1
U−238	**capture**	**−1.4**	0.3	−1.1	−370.8
U−238	fission	0.0	0.0	0.0	7.1
U−238	elastic	0.0	0.0	0.0	4.7
Pu−239	**capture**	−0.1	**1.5**	1.4	464.7
Pu−239	fission	−0.6	0.5	0.0	−11.4
Pu−239	ν	0.0	0.0	0.0	0.1
Pu−239	elastic	0.0	0.0	0.0	1.6
Pu−241	fission	0.0	0.0	0.0	−0.1
Others				0.01	3.0
Total				**0.3**	100.0

BFS-62-3A_L+M ($EU_{+partly\ MOX}$ core)

Nuclide	Reaction	Contribution (%Δk/kk')			Contribution ratio (%)
		Negative	Positive	Total	
U−235	**capture**	**−18.3**	**1.6**	−16.7	337.3
U−235	**fission**	**−5.1**	**12.1**	7.0	−141.9
U−235	elastic	−0.1	0.0	−0.1	1.0
U−238	**capture**	**−1.2**	**6.3**	5.1	−102.9
U−238	fission	−0.1	0.0	−0.1	1.3
U−238	elastic	−0.2	0.0	−0.2	3.4
Pu−239	capture	−0.3	0.1	−0.2	4.1
Pu−239	fission	−0.1	0.2	0.1	−1.5
Others				0.1	−0.8
Total				**−5.0**	100.0

- C/E of SVR in EU core has a large compensation effect between capture and fission of U-235
- This effect is occurred in the range of 100eV – 2keV and conflicts with C/E of keff in EU core (= suggests detailed investigation)

Summary of Preliminary Benchmark

- Considering application to LWR, preliminary benchmark for UO2-LWR and MOX-LWR has been done
  - Observed systematic overestimation will be fed back to nuclear data evaluators to improve the next alpha version
- In general, JENDL-5a1 provides good results for the small-FR and large-FR benchmarks
  - These benchmark sets will be continuously used to check and improve the performance through the evaluation of JENDL-5