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Recent Development of Fast Reactor Analysis System in Japan

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1. Topics

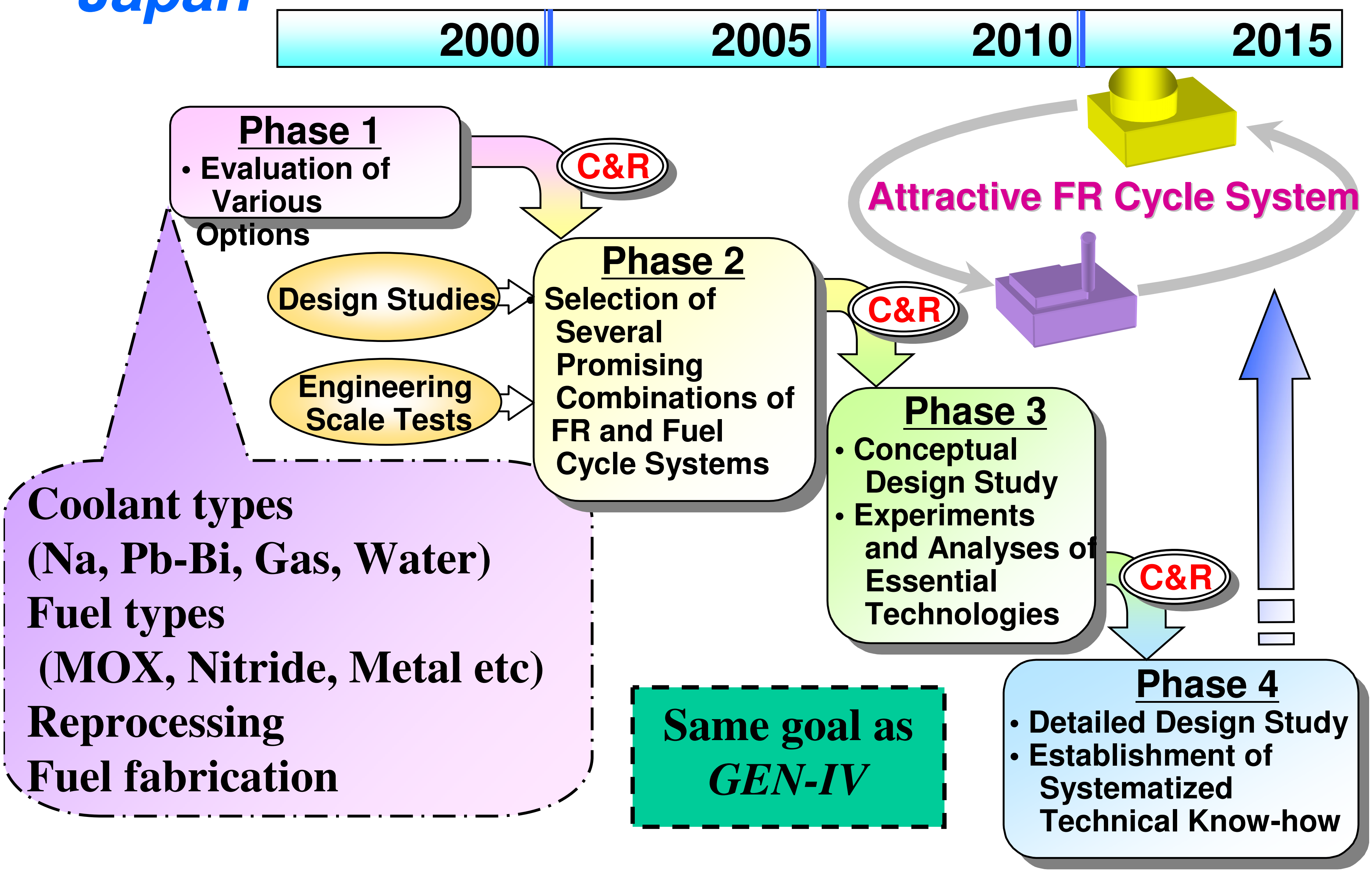
- Feasibility study on fast reactor cycle in Japan
- Reactor physics related issues

  (1) Adjusted cross-section

  (2) Cross-section uncertainty

  (3) Improvement in multi-group treatment

2. Feasibility study on fast reactor cycle in Japan



3. Role of Reactor Physics in F/S (reactor analysis system)

Provide reliable data on nuclear characteristics **with uncertainty**

- to make meaningful comparisons among various core types.
- to reduce unnecessary margins in core design.

Recent development of analysis system in JNC

Nuclear data

Adjusted cross section set “ADJ2000R”
Covariance processing code “ERRORJ”
Sensitivity analysis code “SAGEP-BURN”

Cell calculation

Fine and ultra-fine group calculation code “SLAROM-UF”

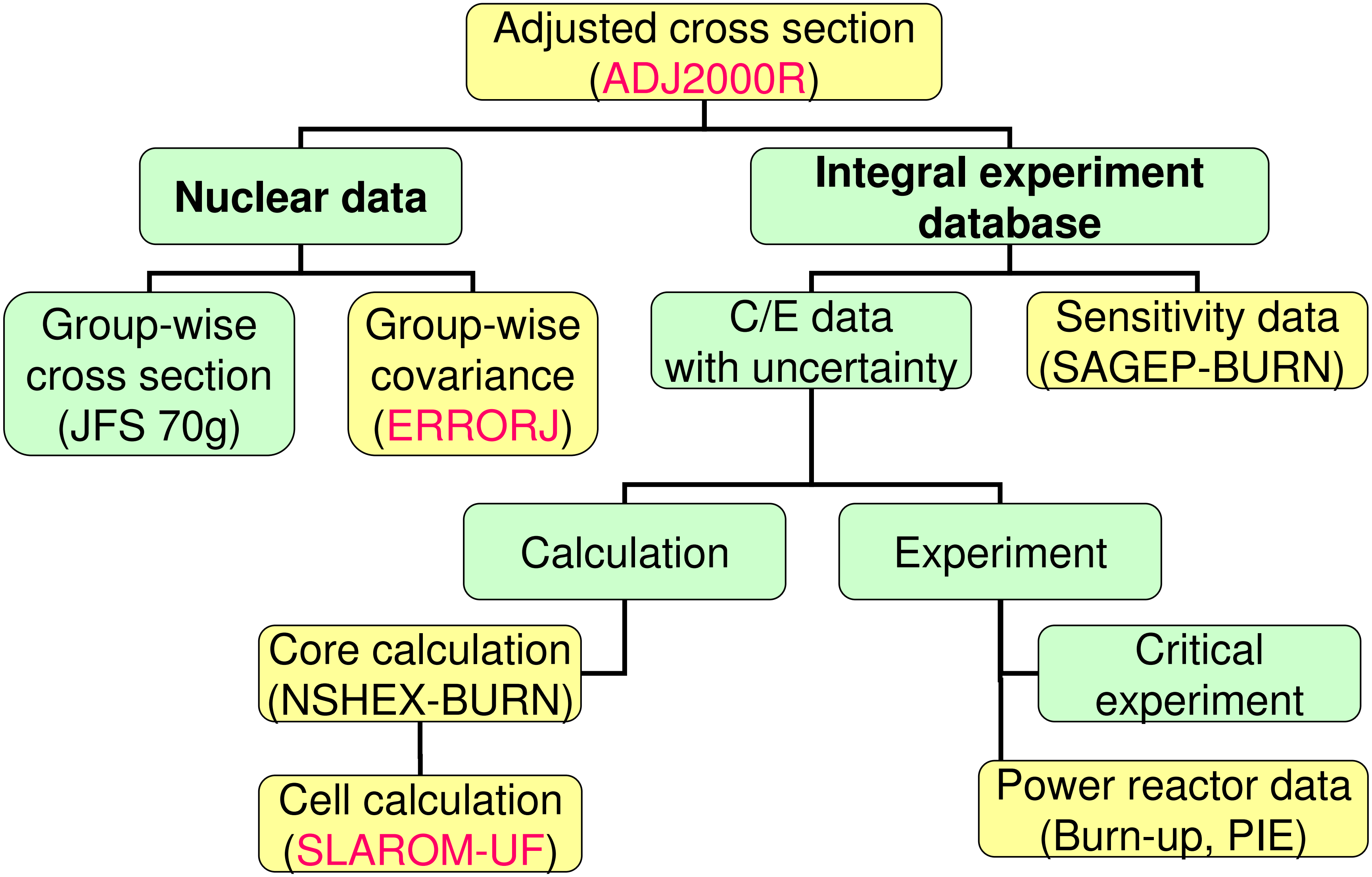
Core calculation

Nodal transport code with burn-up calculation code “NSHEX-BURN”

Integral data analysis

JOYO PIE analysis on fuel and MA sample, etc.

4. Relation in the analysis system



5.1. Adjusted cross section set: ADJ2000R

ADJ2000R has been developed by reflecting **integral experimental information** on the reactor constant set

- to improve reliability
- to minimize cross-section induced errors
  - Adjust JFS 70g constant based on **Bayesian theory**
  - Use various experimental data of small to large Na-MOX core including **burn-up** and **temperature** related reactivity
  - Use covariance data consistent with JENDL-3.2

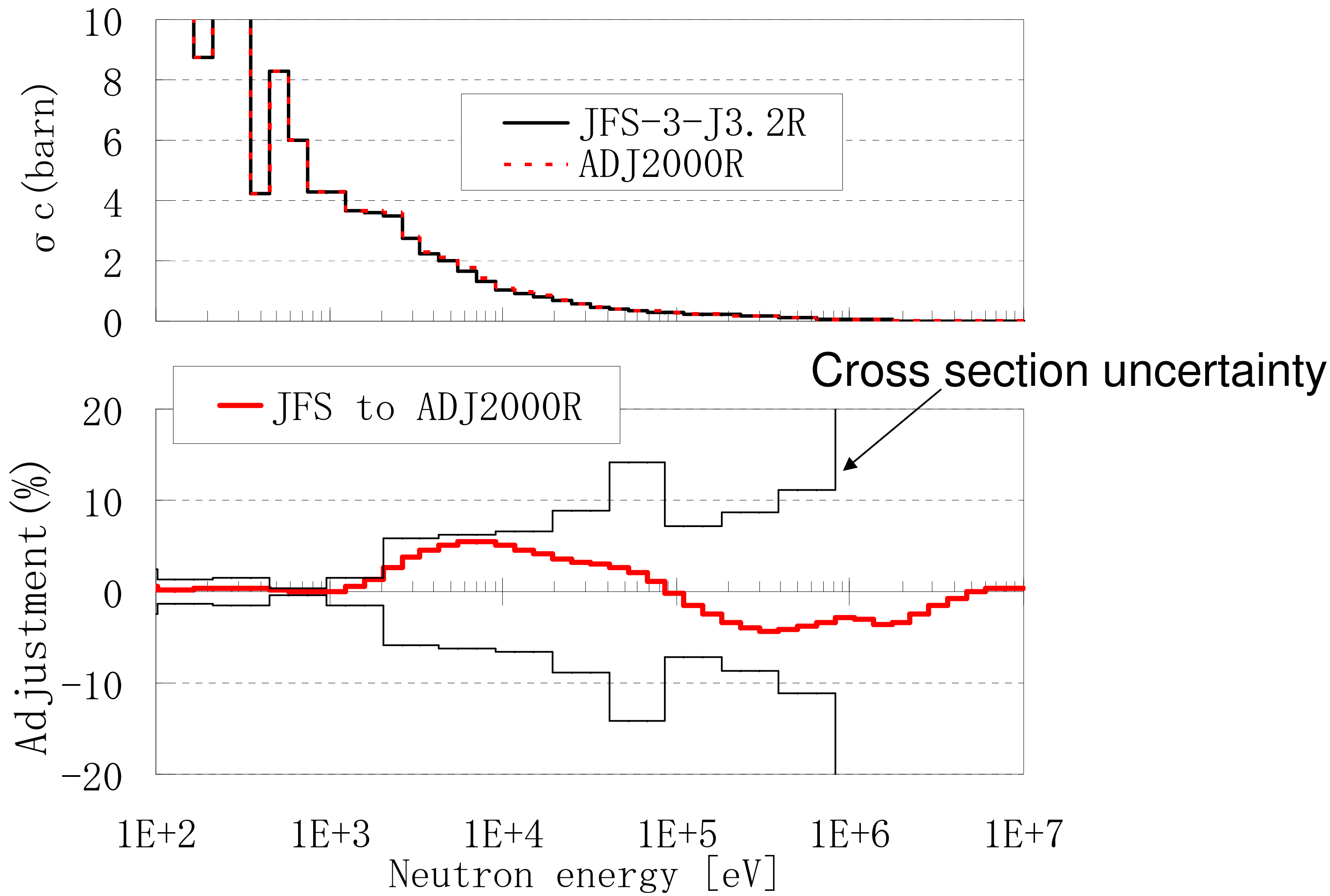
Uncertainty evaluated for 1500MW Na-MOX reactor [%]

Parameter	Source of uncertainty(1σ)		Total*
	Nuclear data	Analysis method	
Keff	0.97	0.14	0.98 (98)
Na void reactivity	4.3	4.2	6.0 (52)
Doppler reactivity	7.6	2.3	8.0 (92)

*The contribution of cross section induced error is in brackets [%]

5.2. Example of adjustment

Adjustment of Pu-239 capture cross section



5.3. Improvement in design accuracy

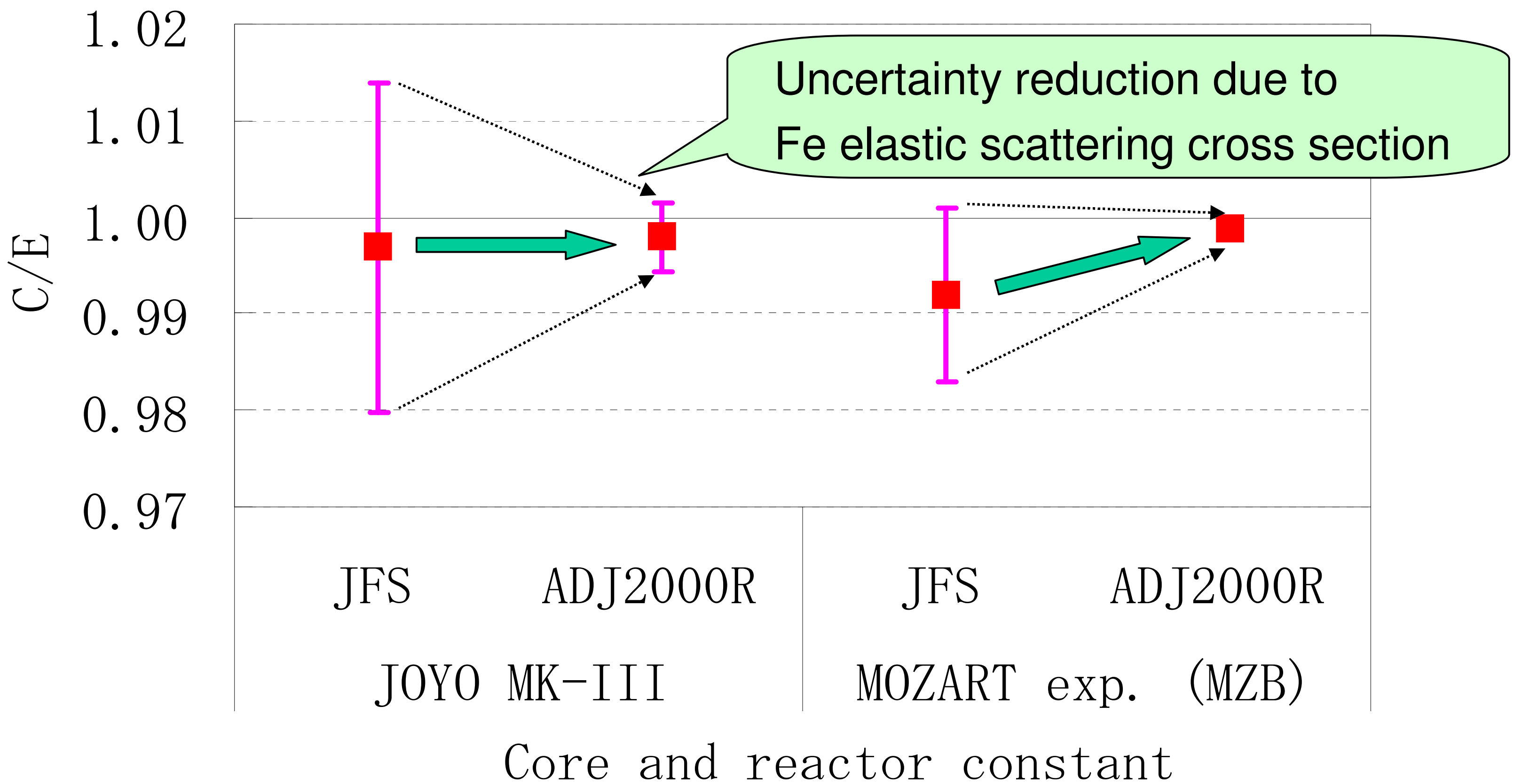
Comparison of uncertainty for the Na-MOX reactor

Parameter	JFS	ADJ2000R
Keff	0.98 (**0.97**)	0.26 (**0.17**)
Na void reactivity	6.0 (**4.3**)	4.4 (**2.1**)
Doppler reactivity	8.0 (**7.6**)	6.6 (**6.3**)

*Cross section induced errors are in brackets [Unit %]

Sufficient reduction in uncertainty has been achieved.

5.4. Application to real cores



JOYO MK-III : Recently modified ***JOYO*** core with enhanced irradiation capability

MOZART exp. (MZB) : ***MONJU*** mockup critical experiment performed in ZEBRA

5.5. Summary and Future work

- Adjusted cross section has advantages.
  - Reflecting knowledge on various integral experimental data
  - Effective for cores without a mockup experiment
  - Effective for burn-up reactivity as well

- **ADJ2000R** has been used in the feasibility study

- In the near future, the number of data will be doubled by including

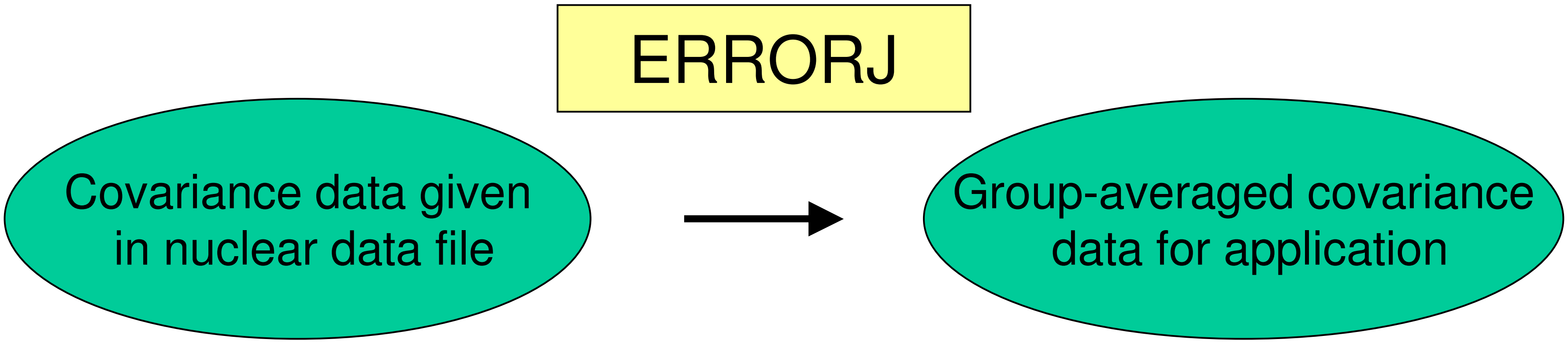
  MOZART experiment (MONJU mockup experiment in ZEBRA)

  SEFOR experiment (Whole core **Doppler** experiment)

  CIRANO experiment (Pu burning experiment in MASURCA)

  BFS experiment (BN-600 mockup experiment, Np loaded experiment)

6.1. Covariance Processing Code : ERRORJ



Developed from ERRORR module of NJOY94

Feature

○ Process covariance data on any **resonance parameters** by 1% Sensitivity method
○ Process μ and fission spectrum
○ Process covariance data in ENDF/B format

Available through OECE/NEA, RSICC etc.

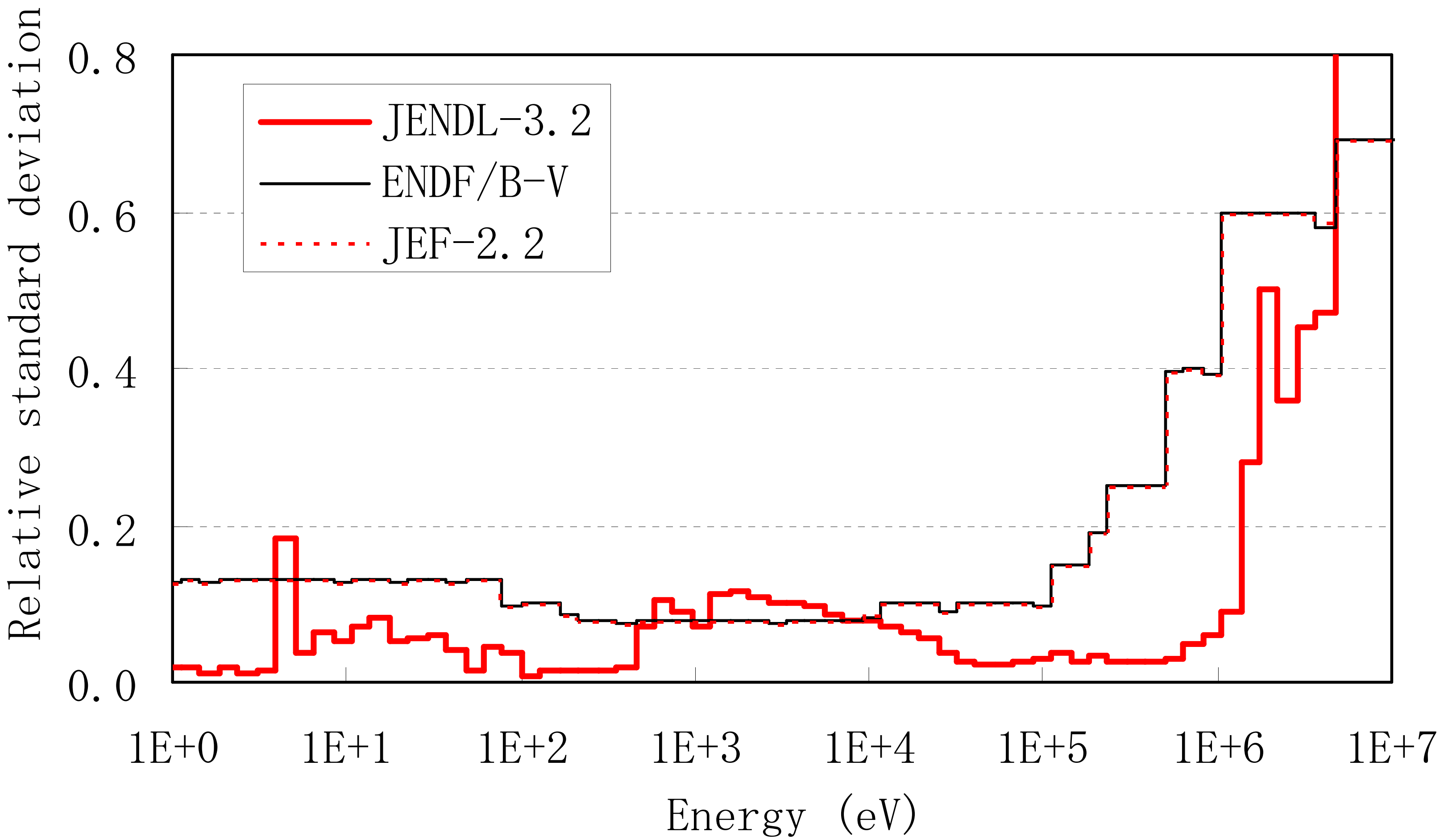
6.2. Comparison of covariance data

Covariance data available on major nuclides

	ENDF/B		JEF(F)		JENDL	
	V	VI	2.2	3	3.2	3.3
Na-23	32, 33	32, 33			33, 34	33, 34
Fe-Nat.	32, 33				32-34	
Fe-56		33		33, 34		33, 34
Ni-Nat.	33				33, 34	
Ni-58		33	33	33, 34		33, 34
U-235	31, 33	31	31, 33	31	31-35	31, 33-35
U-238	31, 33	31, 33	33	33	31-35	31-35
Pu-239					31-35	31-35

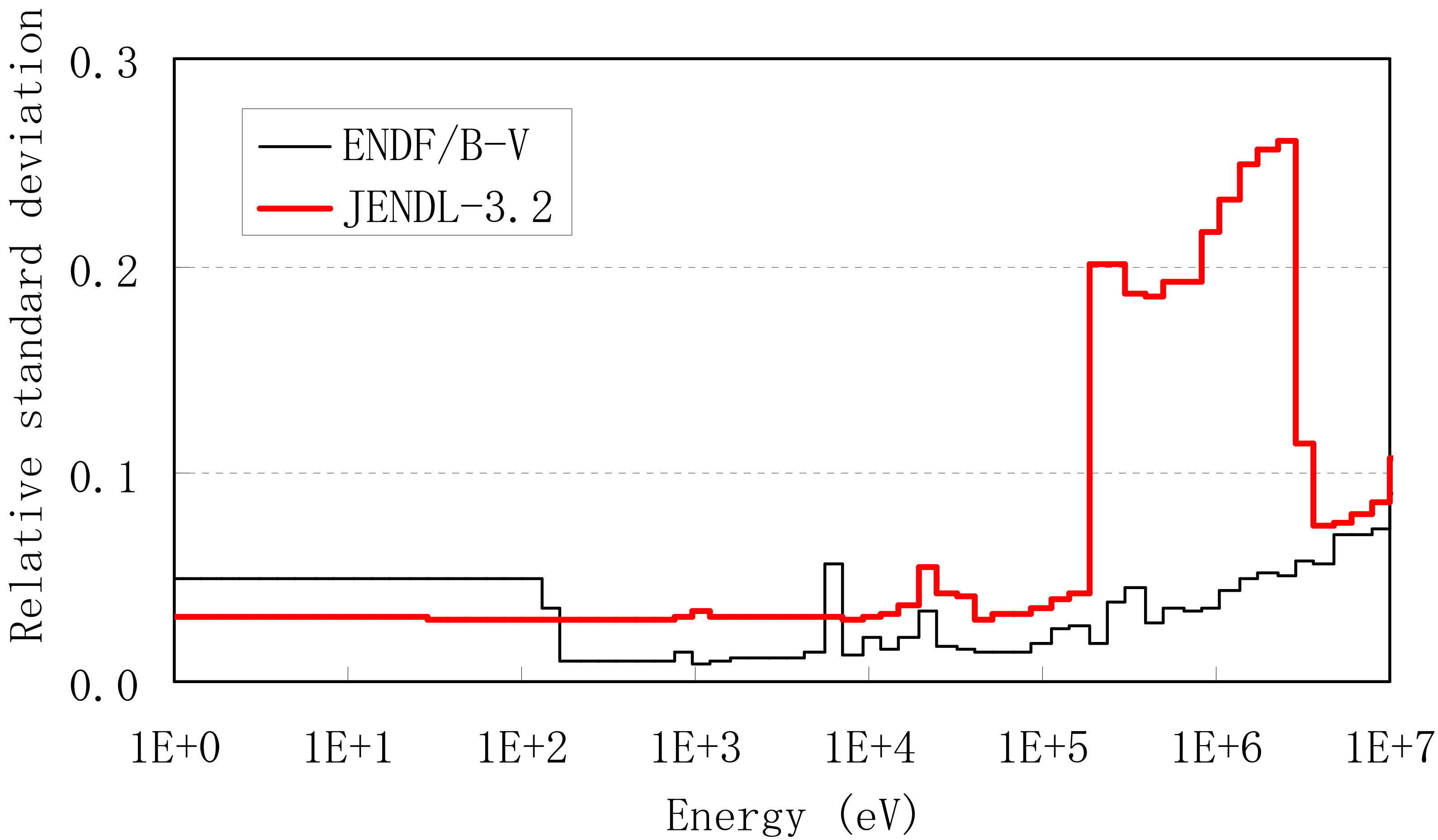
31 --- ν
32 --- resonance parameter
33 --- cross sections
34 --- μ
35 --- χ

6.3. Comparison of covariance : U-235 (n, γ)



Uncertainty of criticality in BFS-62-1 core (Uranium fueled core)
340 pcm (JENDL-3.2) **800 pcm** (ENDF/B-V)

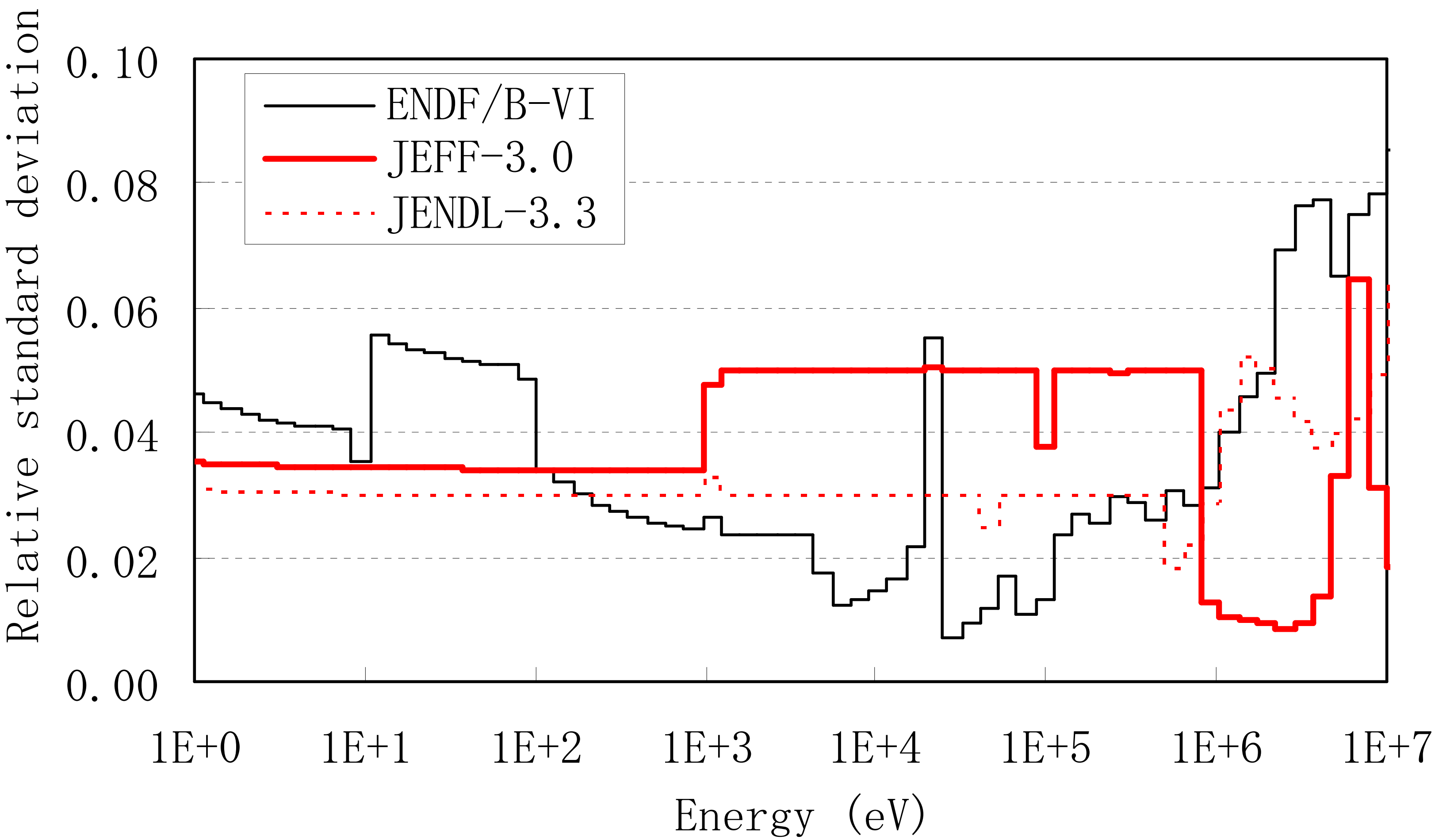
6.4. Comparison of covariance : Fe-*nat.(n, n)*



Uncertainty of criticality in "JOYO" MK-III

1500 pcm (JENDL-3.2) **180 pcm** (ENDF/B-V)

6.5. Comparison of covariance : Fe-56(*n*, *n*)



6.7. Summary and Future work

●Covariance data and ERRORJ are essential tools to evaluate uncertainty of nuclear characteristics

●Reason of the too large differences should be made clear

●Increase the number of covariance data

- Data have been prepared for Na-MOX fast reactor in JENDL.
- Recently evaluated

  Np-237, Am-241, Am-243 for **burn-up** or **transmutation**

  Priority on additional evaluation is now being discussed.

7.1. Fine and ultra-fine group calculation code : SLAROM-UF

70g constant with f-table (JFS) has been used in Japan

- Resonance self-shielding in a heterogeneous cell
- Resonance interaction between different **nuclides**, **regions**, and **temperatures**.
- Use for various fast reactor cores

  (Coolant/Fuel) Na/MOX, Pb-Bi/MN, Gas/MN reactor, etc.

↓

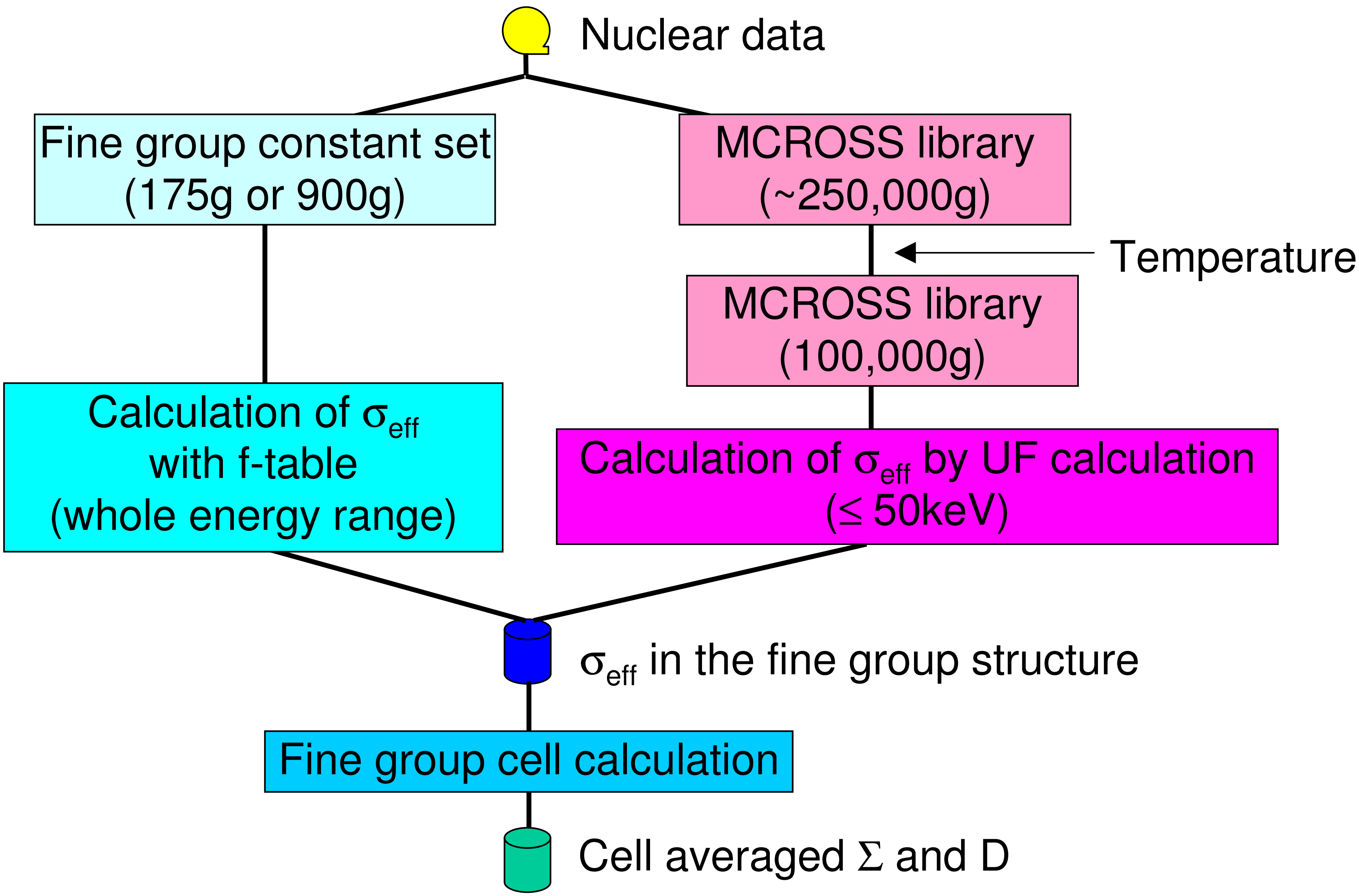
Developed new cell calculation code "**SLAROM-UF**"

Combination use of

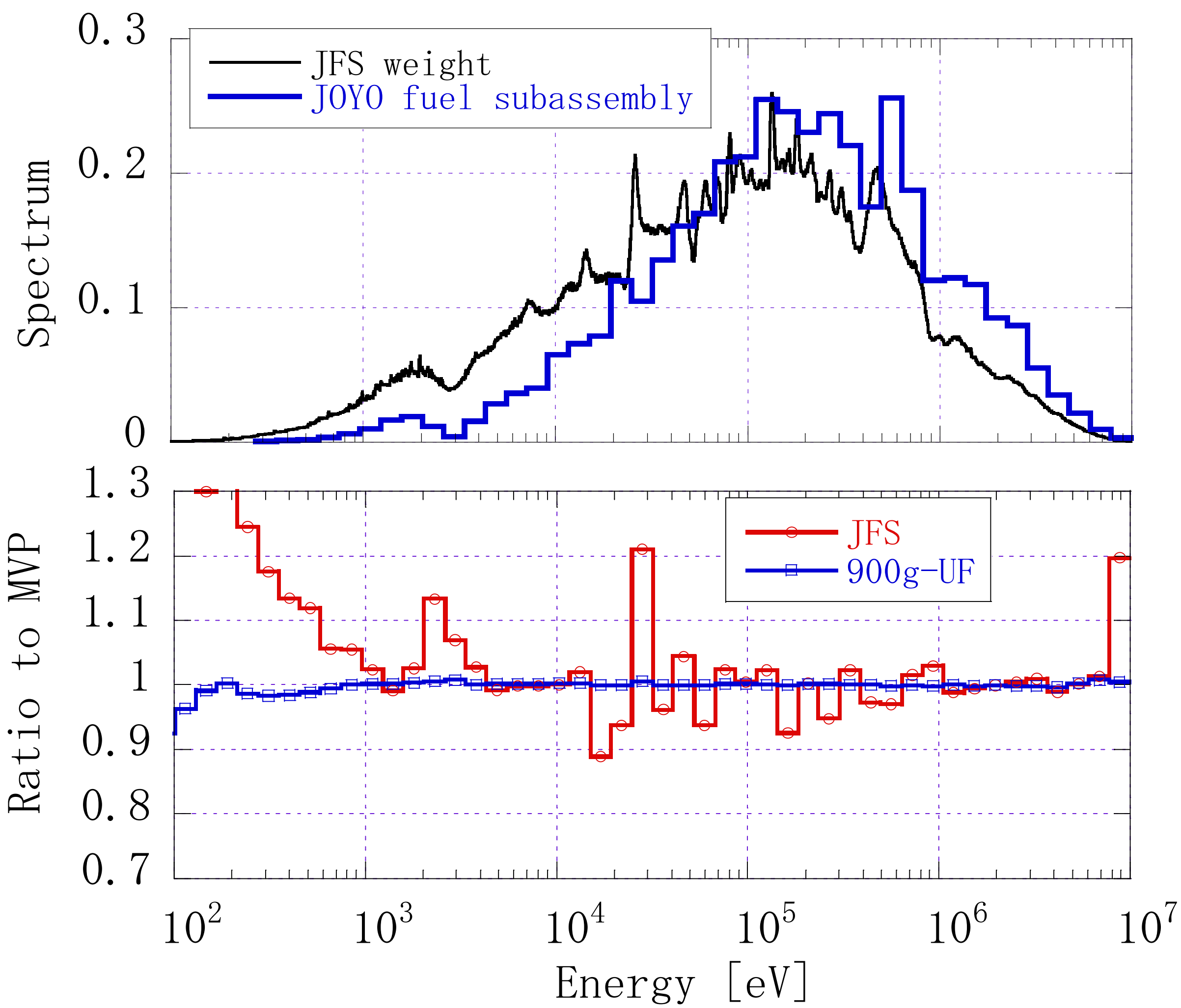
- Slowing down Pij calculation in ultra-fine **(100,000) group** structure **for ≦ 50keV**
- Pij calculation in fine (**900**) group structure

  Δu=0.008 for > 50keV (comparable to the ECCO 1,968-group library)

7.2. Outline of SLAROM-UF



7.3. Application of SLAROM-UF (I)



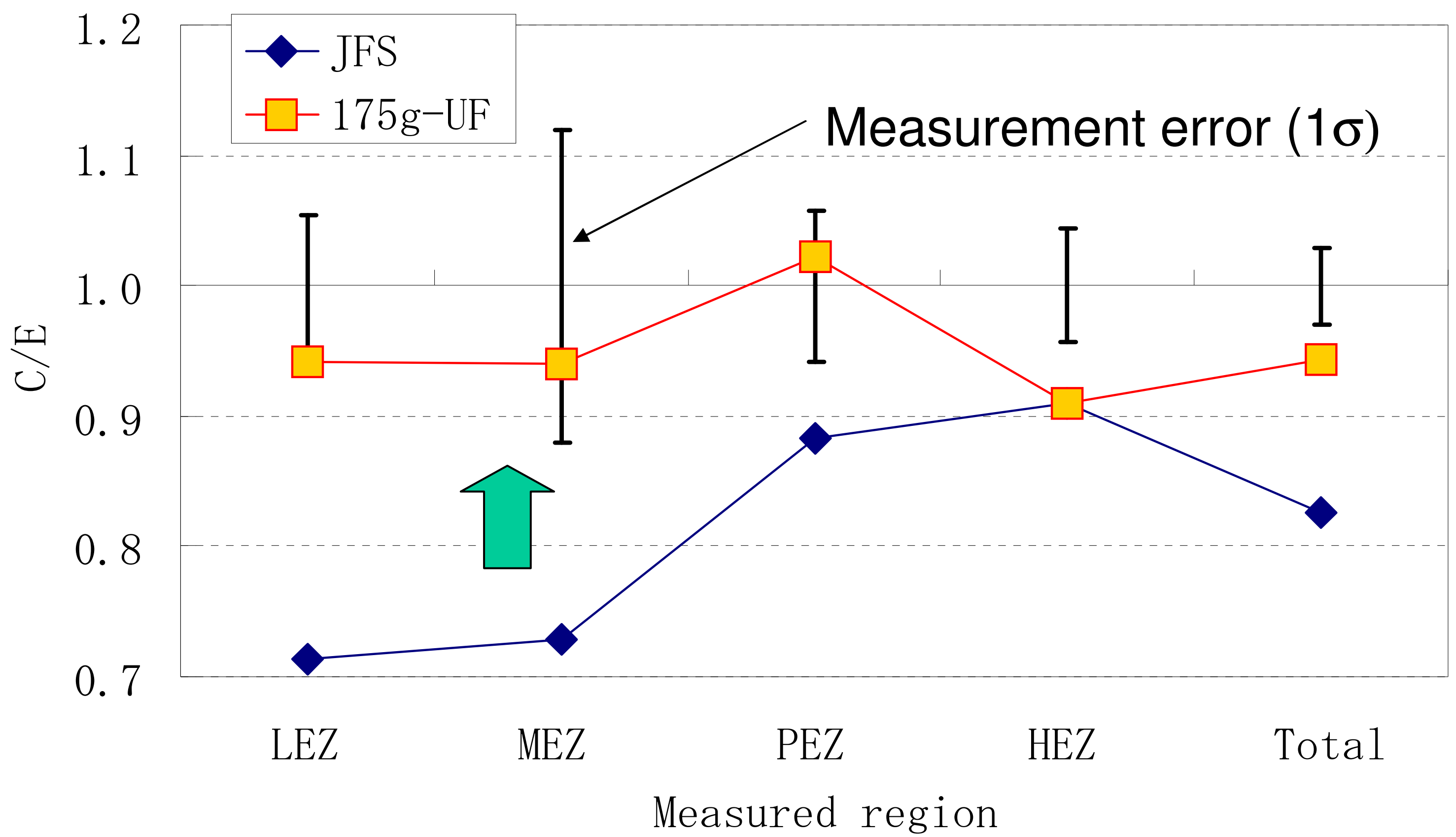
Neutron spectrum for
JFS weight
&
JOYO subassembly
Infinite cell spectrum

Ratio to MVP
on Infinite cell spectrum

900g-UF :
900g constant
with UF calculation

Neutron spectrum by SLAROM-UF shows perfect agreement with that by continuous energy Monte Carlo code.

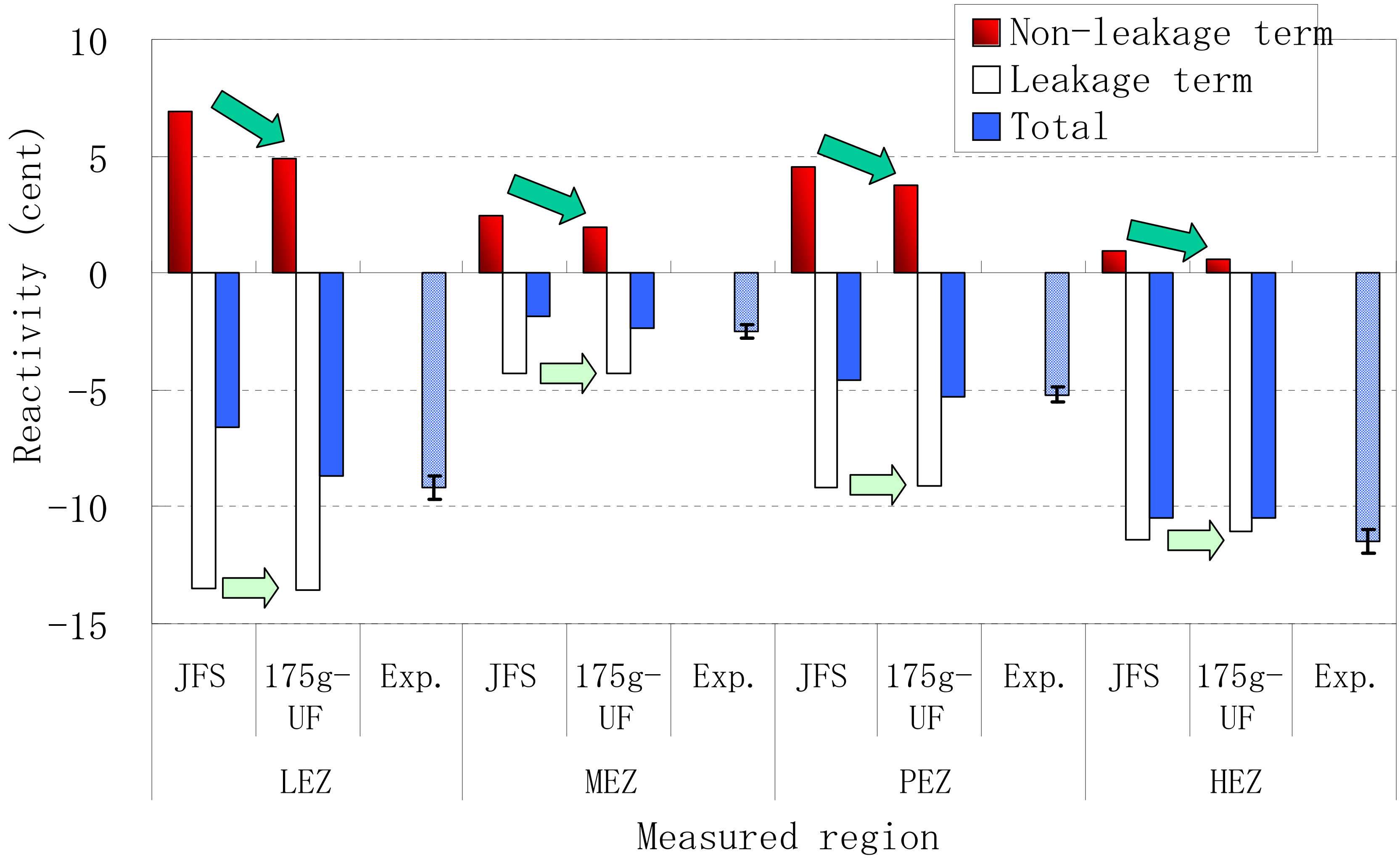
7.4. Application of SLAROM-UF (II)



Effect of SLAROM-UF on Na void reactivity measured in BFS-62-3A

Significant improvement was confirmed by adopting 175g-UF

7.5. Application of SLAROM-UF (III)



175g-UF caused evident reduction in the non-leakage term by improved resonance treatment.

8. Summary

JNC has established a core analysis system to utilize full capability of nuclear data and integral experimental data.

We will continue to improve the core design tools and methods for construction of promising commercial fast reactor core concepts.