Critical Experiments in Kyoto University Critical Assembly for Development of >5wt% Enrichment Erbia Bearing Super High Burnup Fuel

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- Outline of Kyoto University Critical Assembly experiment
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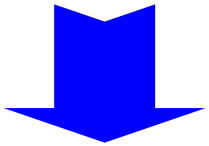
Background

- High burnup fuel is effective for reducing the amount of discharged fuel assemblies
- In order to achieve higher burnup, higher enrichment is needed as well
- Current enrichment of LWR fuels is already very close to the criticality safety limit (<5wt%)

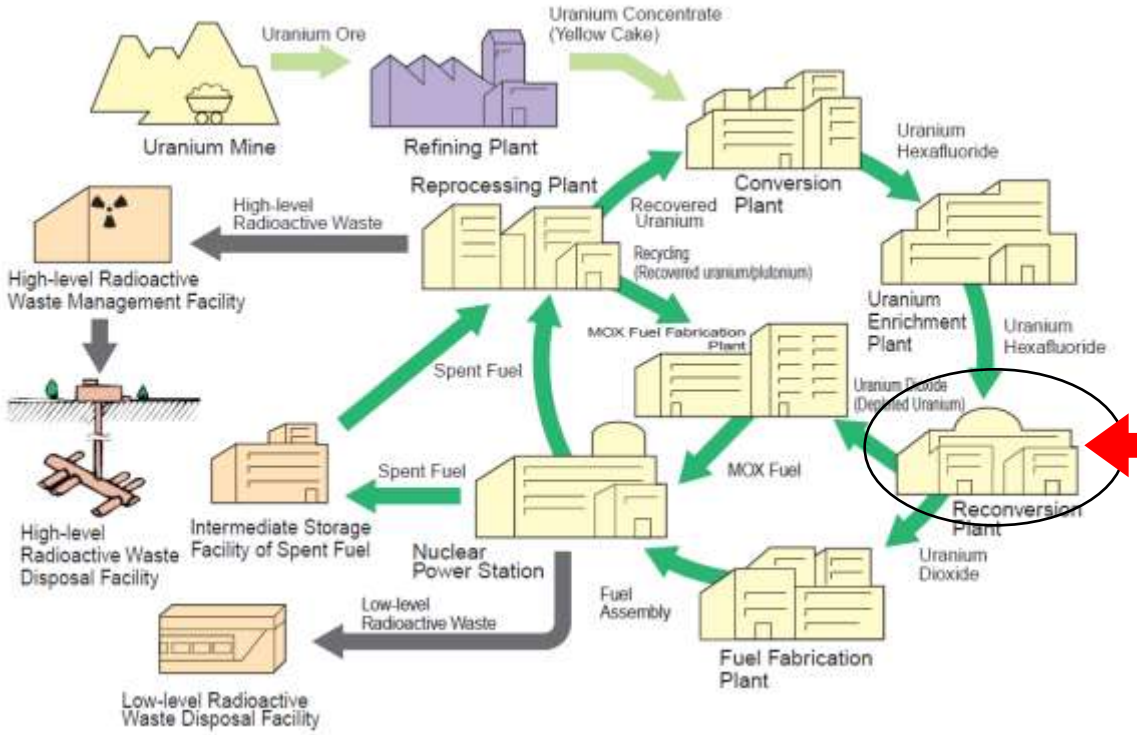


Er-Super High Burnup fuel :

- > 5wt% enrichment fuel with dilute burnable poison Erbia

What is Er-Super High Burnup fuel ?

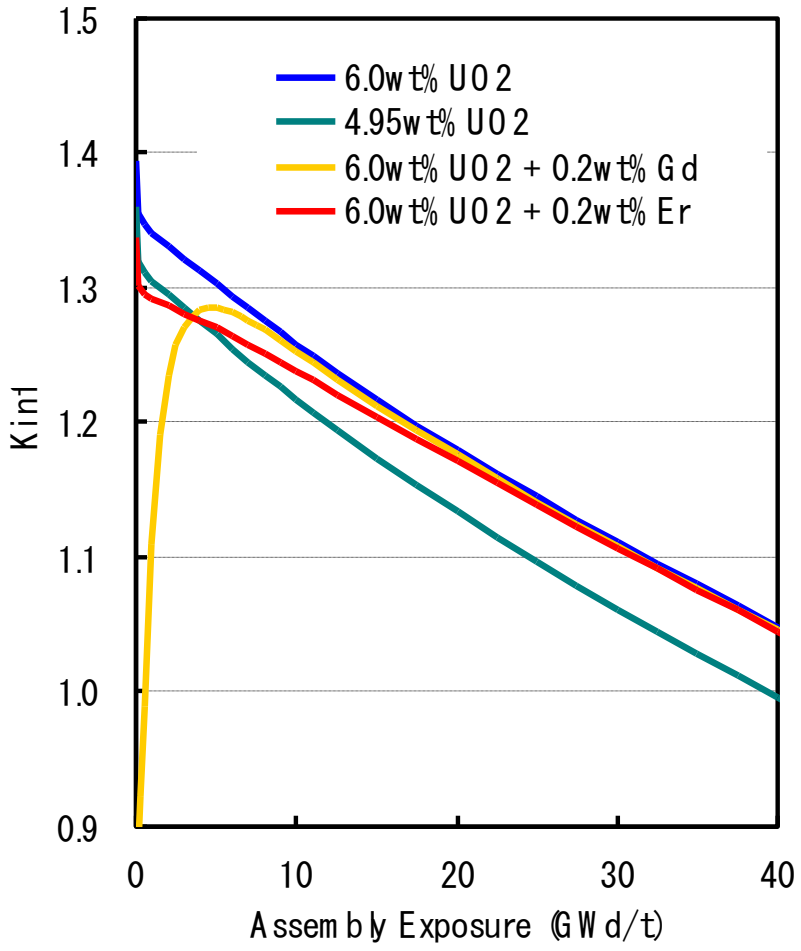
- Low content of Erbia (Er_2O_3) is added into all >5wt% UO2 powder just after the re-conversion process



Add Erbia

Why Erbia?

- Durable burnable absorber
  - Reactivity at BOL is slightly lower than that of current fuels(<5wt%)
  - Reactivity change is more smooth than that of Gd fuel
- More suitable feature for high burnup fuel



How effects?

- For >5wt% fuel, more stringent regulation will be applied in order to suppress its reactivity, which requires considerable cost
- Er-SHB has a possibility to bypass >5wt% enrichment barrier from the viewpoint of criticality safety
- Major modifications of fuel cycle infrastructure can be eliminated
  - Without reducing the amount of treated fuel, the efficiency of transport, storage and fabrication will be improved

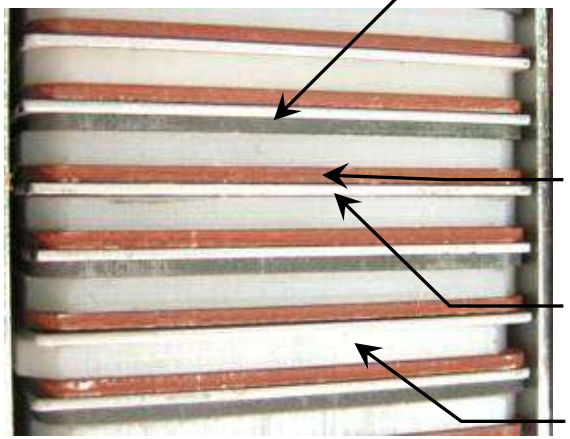
Purpose

- Achievement of critical experiments of > 5wt% enrichment cores with erbia

- Validation of nuclear analysis code and nuclear data library for Er loaded critical experiments

Kyoto University Critical Assembly

- Plate type fuel critical assembly
- By combination of material plates, various conditions of H/U ratio, average U235 enrichment and Er content can be simulated



Erbia coated graphite plate

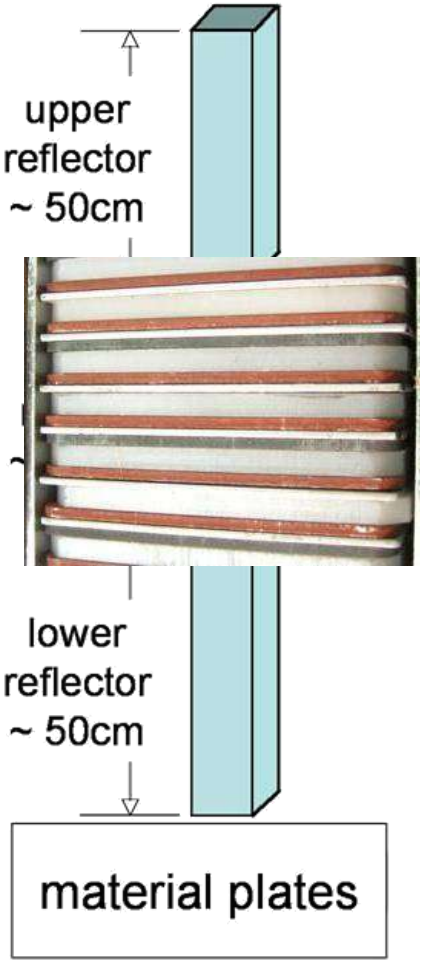
highly enriched U

natual U

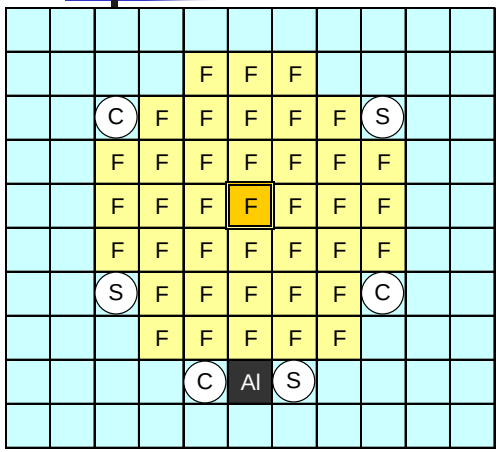
polyethylene

~0.3 g Er2O3 is coated on the engraved dish

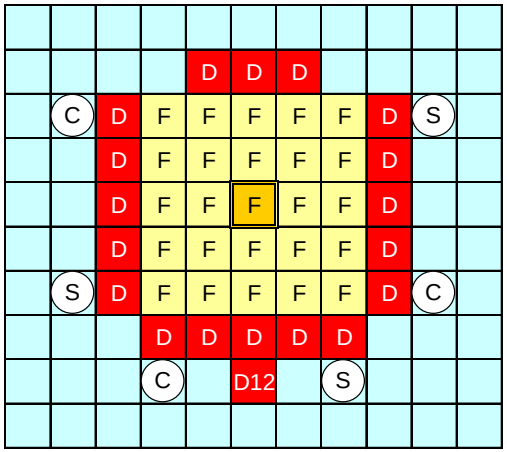
Outline of KUCA



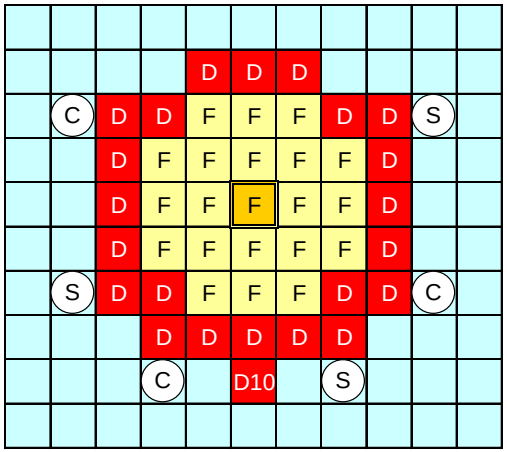
Core configuration



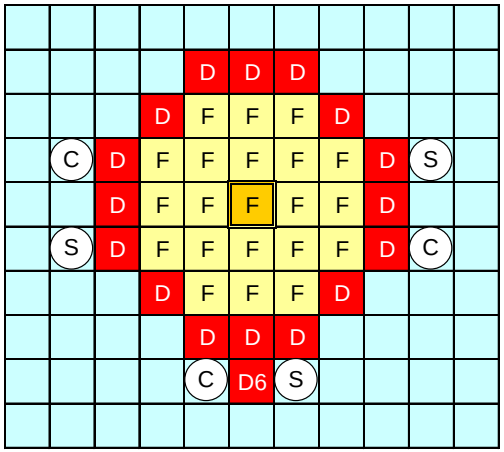
Core 1



Core 2



Core 3



Core-4

target of Er sample worth

F

F

Er loaded fuel

D

Dx

driver fuel

polyethylene

Al

Aluminum

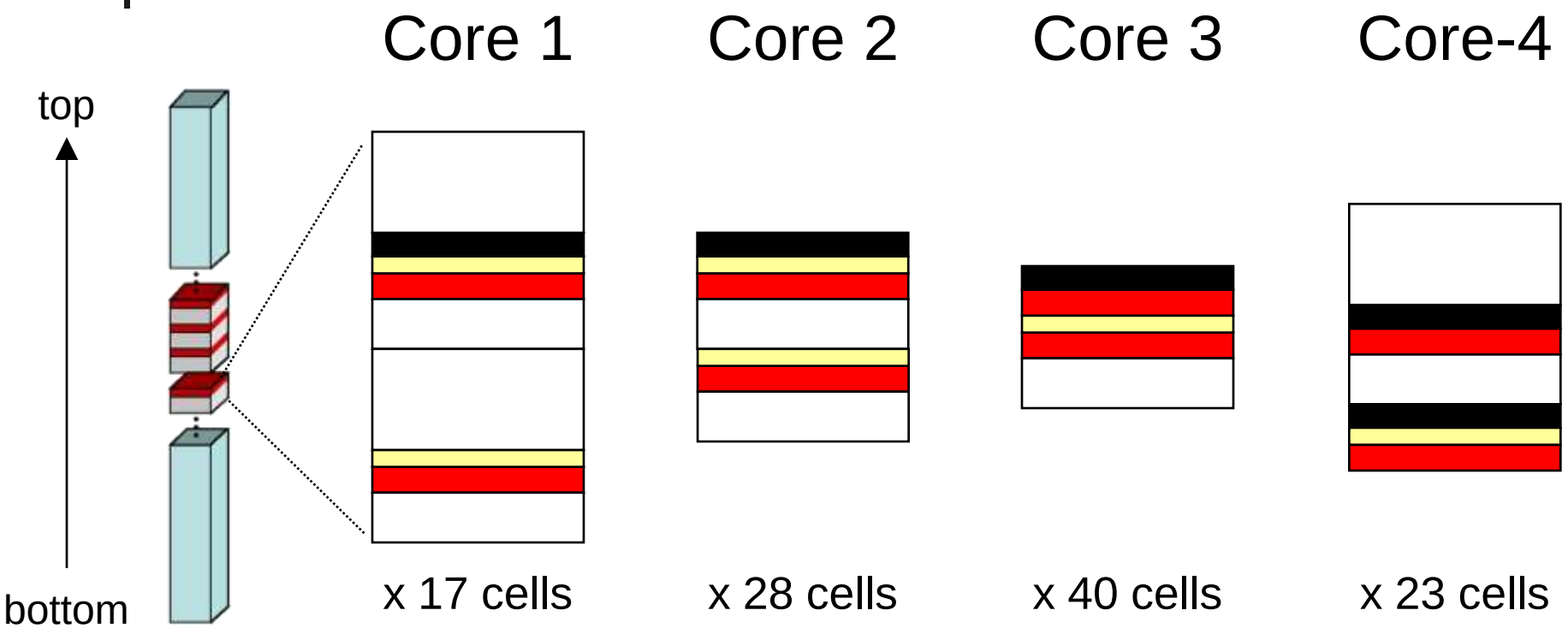
C

control rod

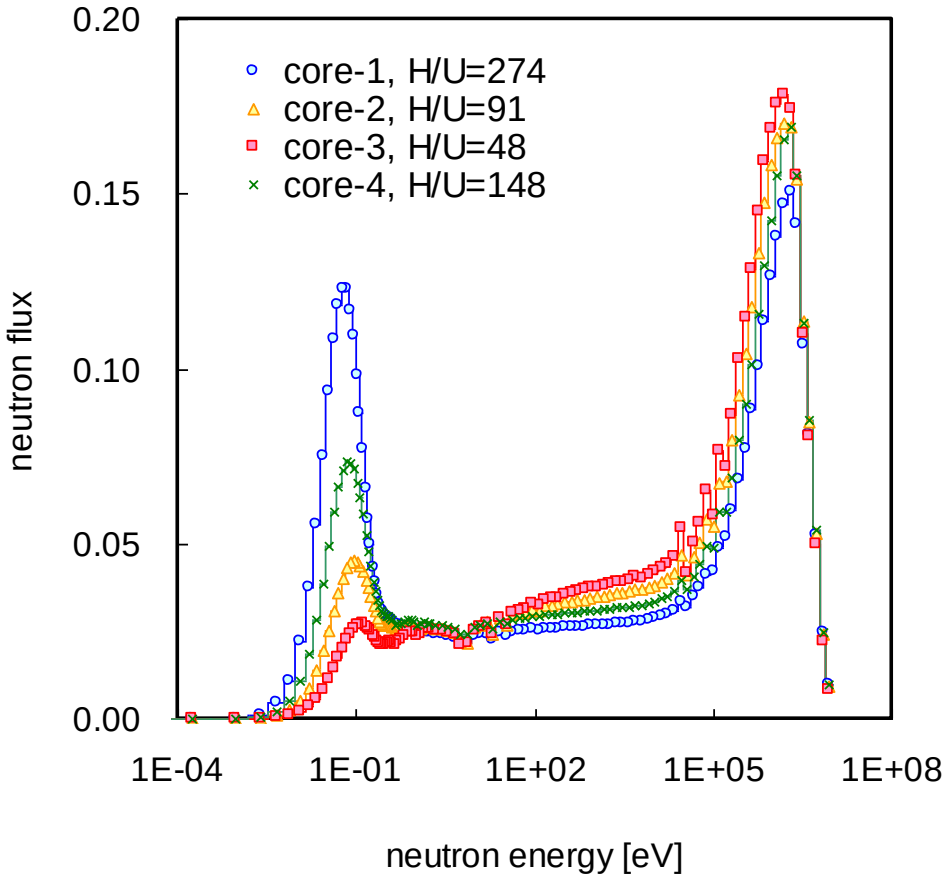
S

safety rod

Unit fuel cell



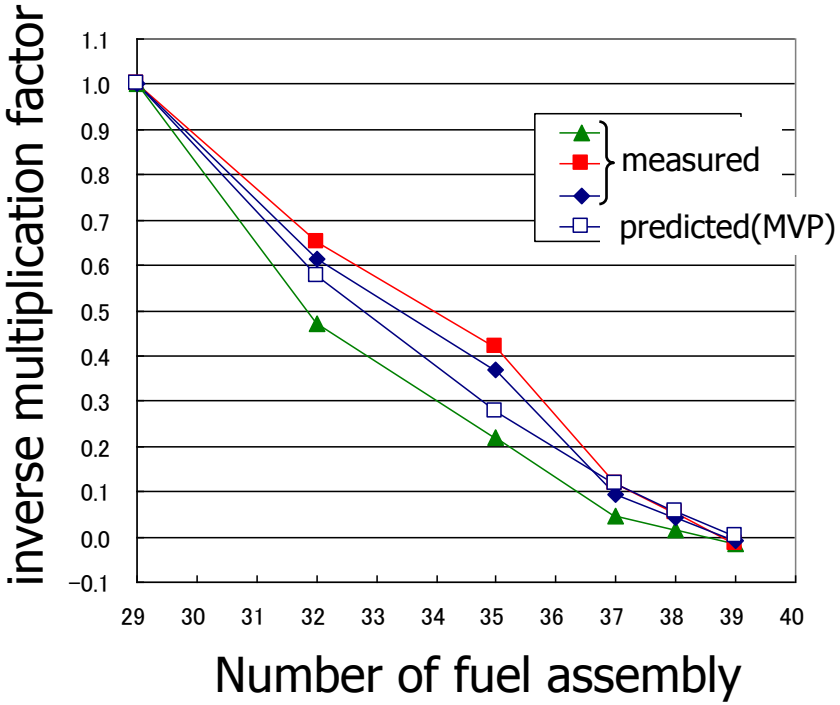
Summary of Er loaded cores



Core	average U-235 [wt%]	H/U-235	Er content [wt%]
1	5.4	274	0.3
2	5.4	91	0.3
3	9.6	48	0.6
4	9.6	148	1.12

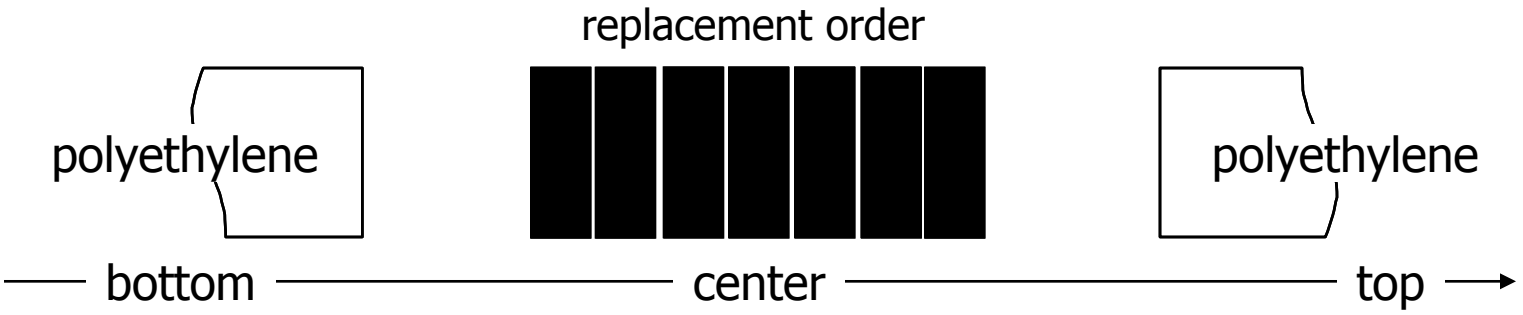
Criticality measurement

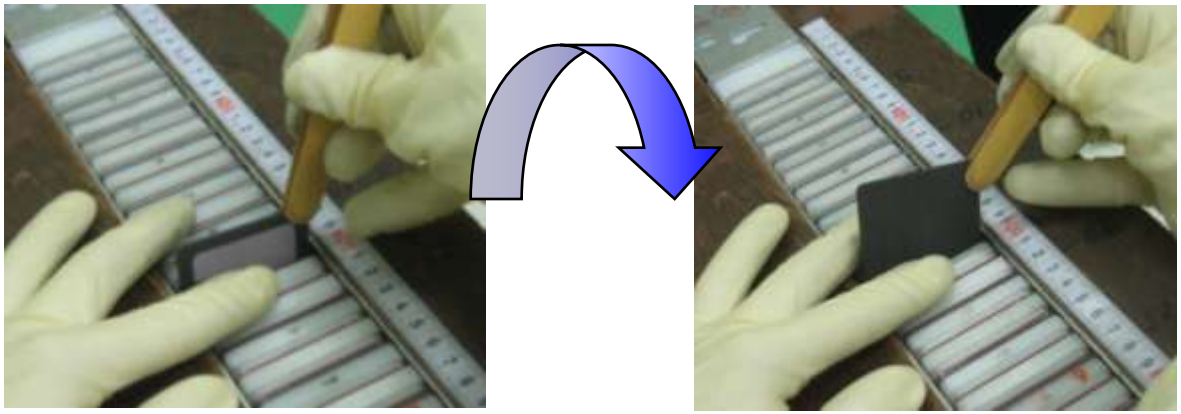
- Approach to criticality has been performed based on inverse multiplication method
- After achieving criticality, the excess reactivity of each core was measured by using period method



Erbia sample worth measurement

- Er coated graphite plates are replaced by just graphite plates without Er
  - central fuel element is target
  - from center to top/bottom, axially symmetrically





Erbia sample worth measurement

- The erbia sample worth was measured as reactivity difference caused by the replacement
  - The reactivity is measured by the period method

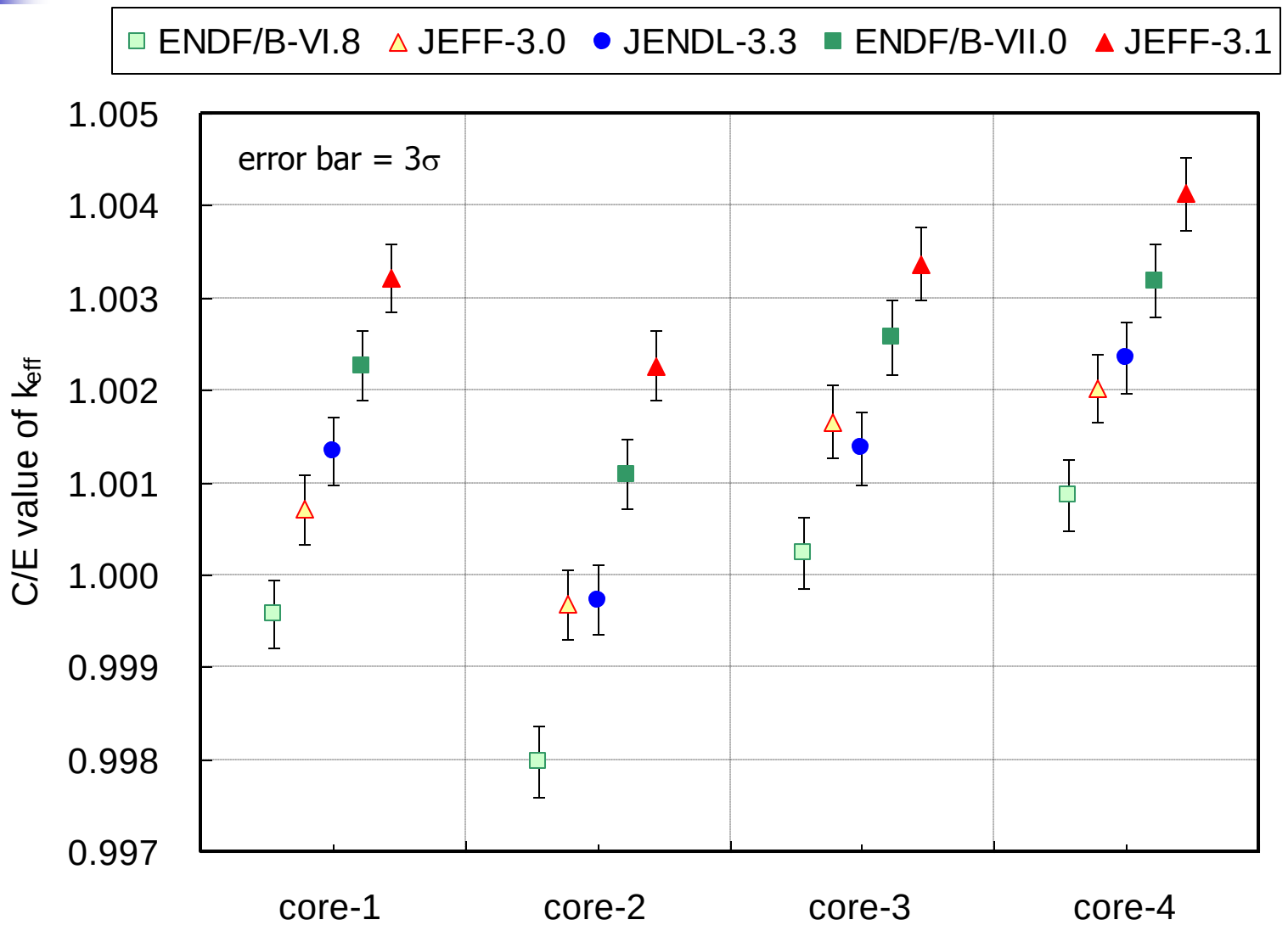
$$\Delta\rho = \rho - \rho_{Er}$$

- The accuracy (relative standard deviation) is estimated to be < 3% for most cases

Numerical Analysis

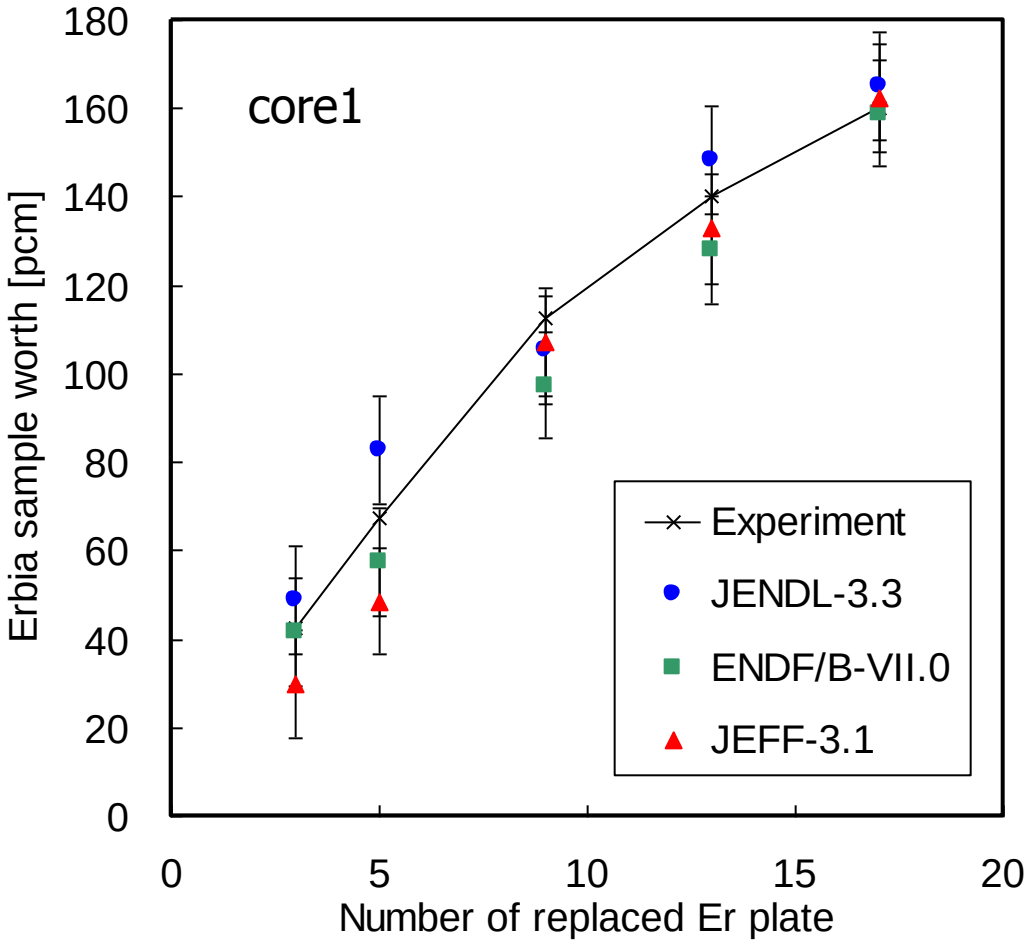
- Criticality
  - MVP
    - Continuous energy Monte Carlo method
    - 50,000,000 histories
    - JENDL-3.3, ENDF/B-VI.8 & VII.0, JEFF-3.0 & 3.1
- Erbia sample worth
  - MVP
  - SRAC2006/CITATON
    - Multigroup 3-D XYZ diffusion method
    - perturbation calculation
    - JENDL-3.3, ENDF/B-VI.8 & VII.0, JEFF-3.0 & 3.1
    - Macroscopic cross section of unit fuel cell is spatially homogenized, not heterogeneous

Criticality (Monte Carlo)

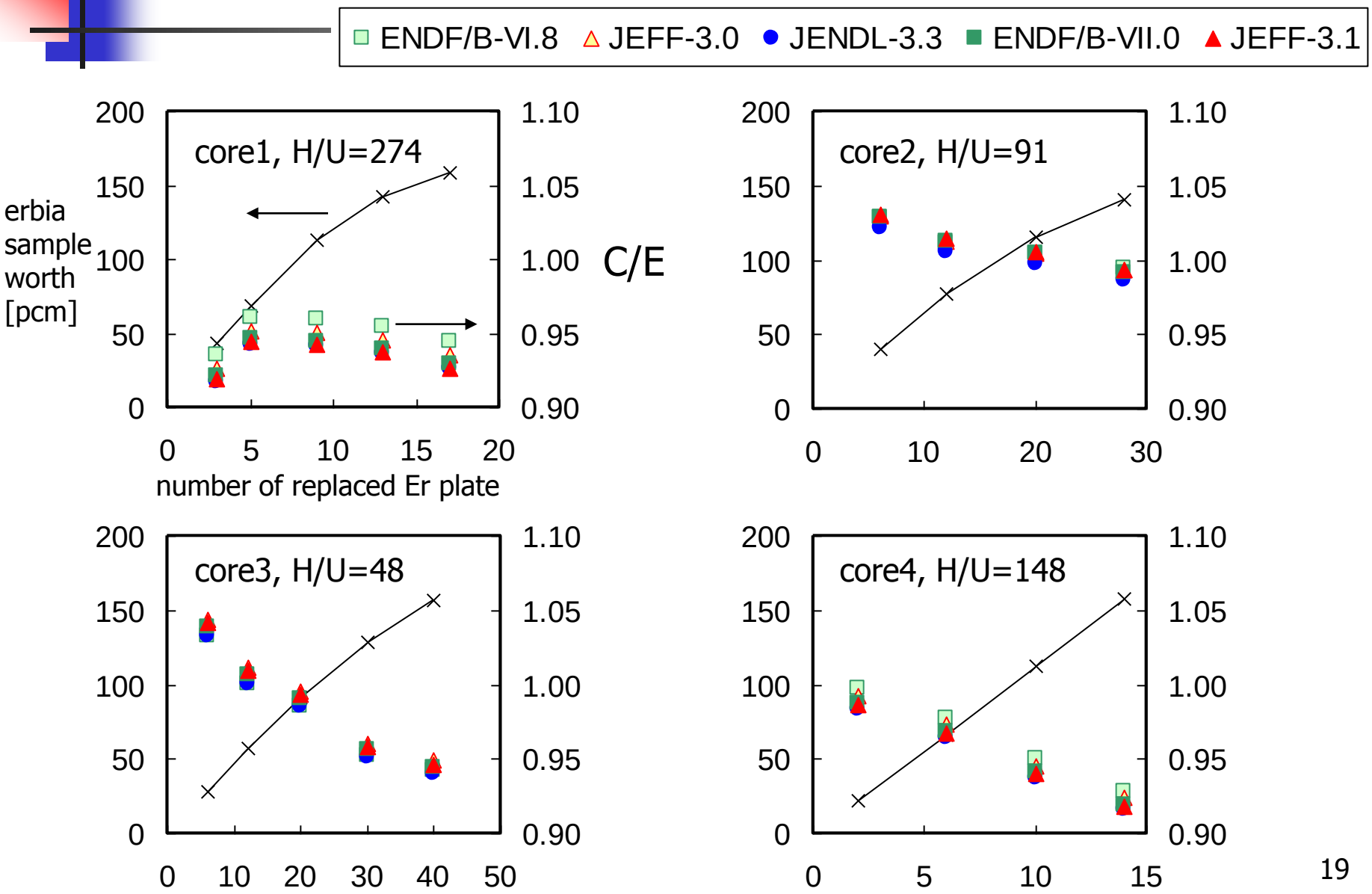


Er sample worth (Monte Carlo)

- Agreement within statistical errors
- Er sample worth is too small to quantitatively investigate the differences among nuclear data libraries



Er sample worth (Diffusion)



Conclusion (1/2)

- A series of critical experiments of erbia loaded cores have been successfully conducted at Kyoto University Critical Assembly (KUCA)
- Criticality, erbia sample worth, etc. were measured

- Numerical analysis of criticalty
  - Monte Carlo method is well agree
  - notable trends among the nuclear data libraries

Conclusion (2/2)

- Numerical analysis of erbia sample worth
  - Too small value, so that deterministic method is better suited for numerical analysis
  - It seems that high H/U ratio makes dispersion of C/E among the nuclear data libraries
  - Further study will be necessary to finalize C/E
    - such as the treatment of heterogeneous effects in the fuel elements
    - perturbation calculation by Monte Carlo method

Thank you for your attention