Analysis of Innovative Water Reactor for Flexible Fuel Cycle in FCA using JENDL-3.3

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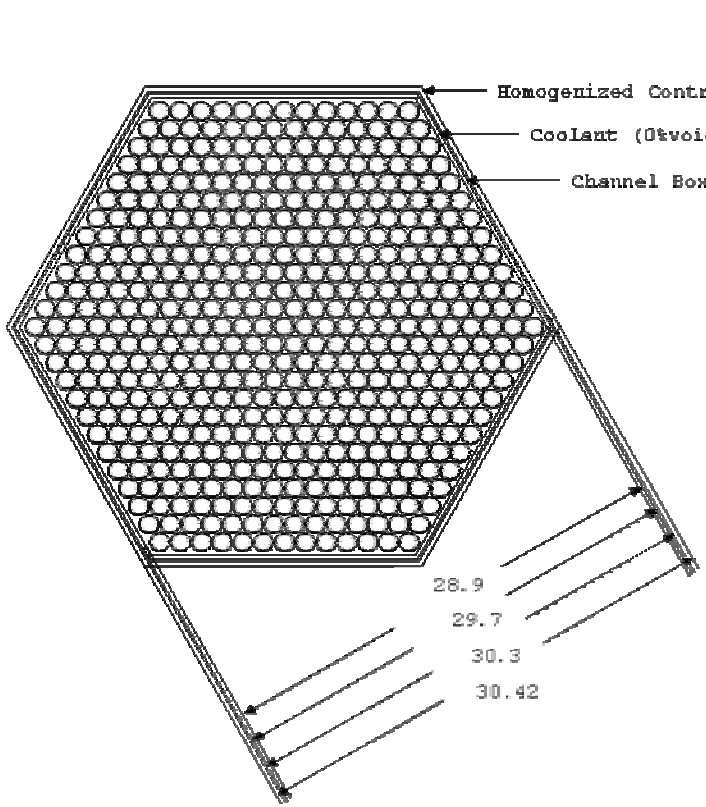
Background

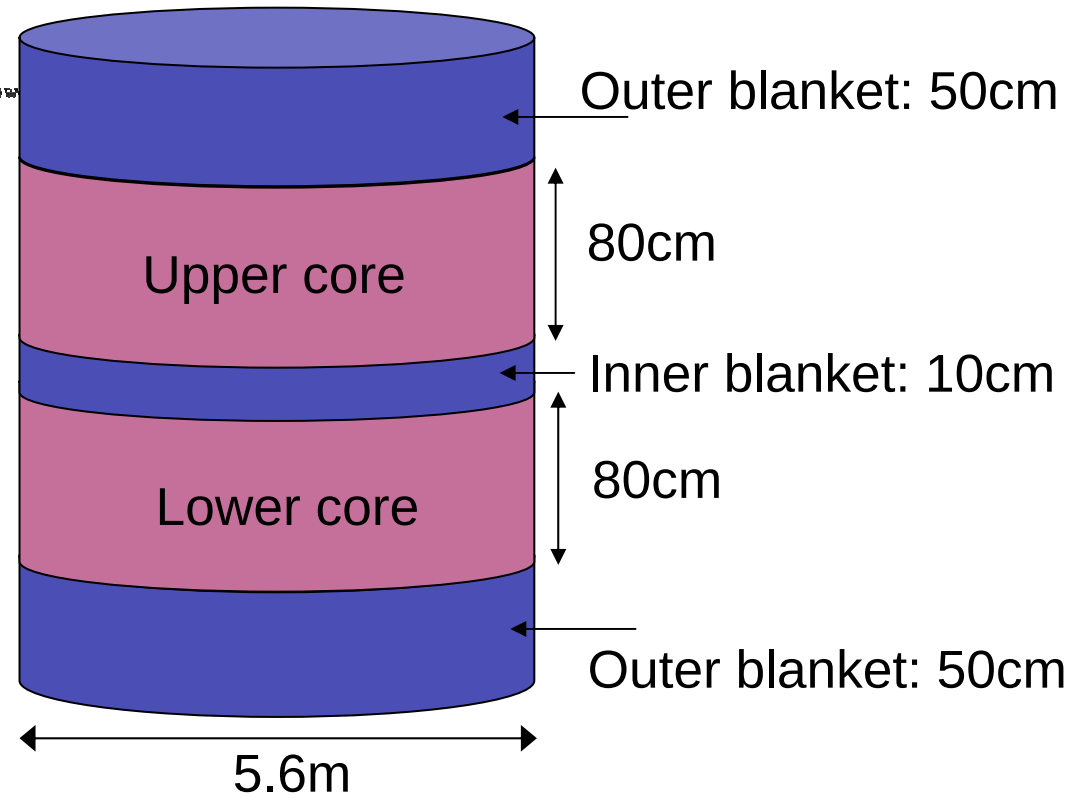
- **FLWR:** Innovative Water Reactor for Flexible fuel cycle
  - **A new reactor concept for the next generation**
  - **Pu recycling based on the LWR technology**
  - **High burn-up and high breeding ratio**

- **Principal characteristics of FLWR**
  - **Pu enrichment:10%~, Tight lattice pitch: 1.0mm**
  - **Neutronic reaction: intermediate (resonance) energy range**

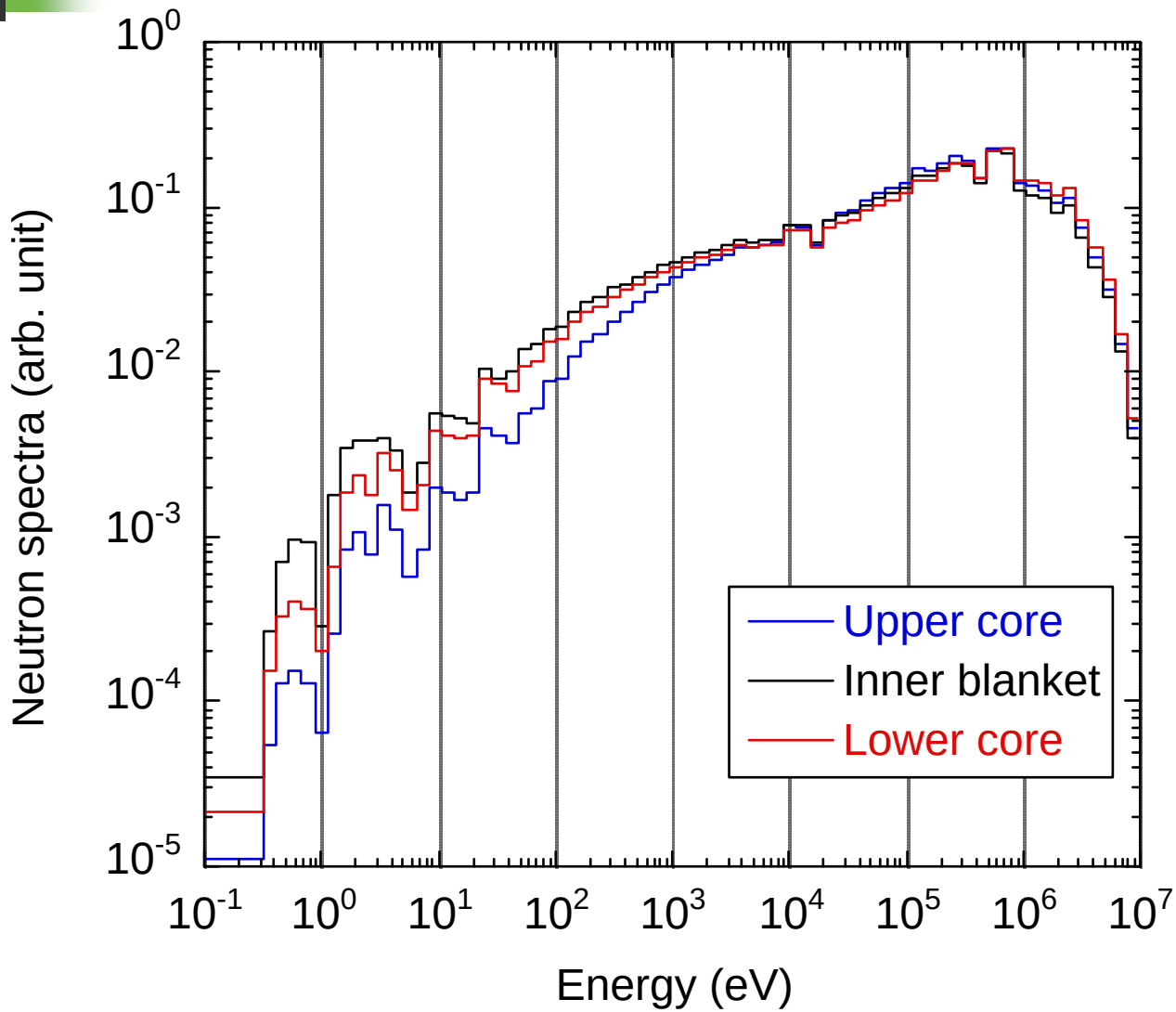
FLWR core concept

- **Core configuration of FLWR**





Neutron spectra in the FLWR core



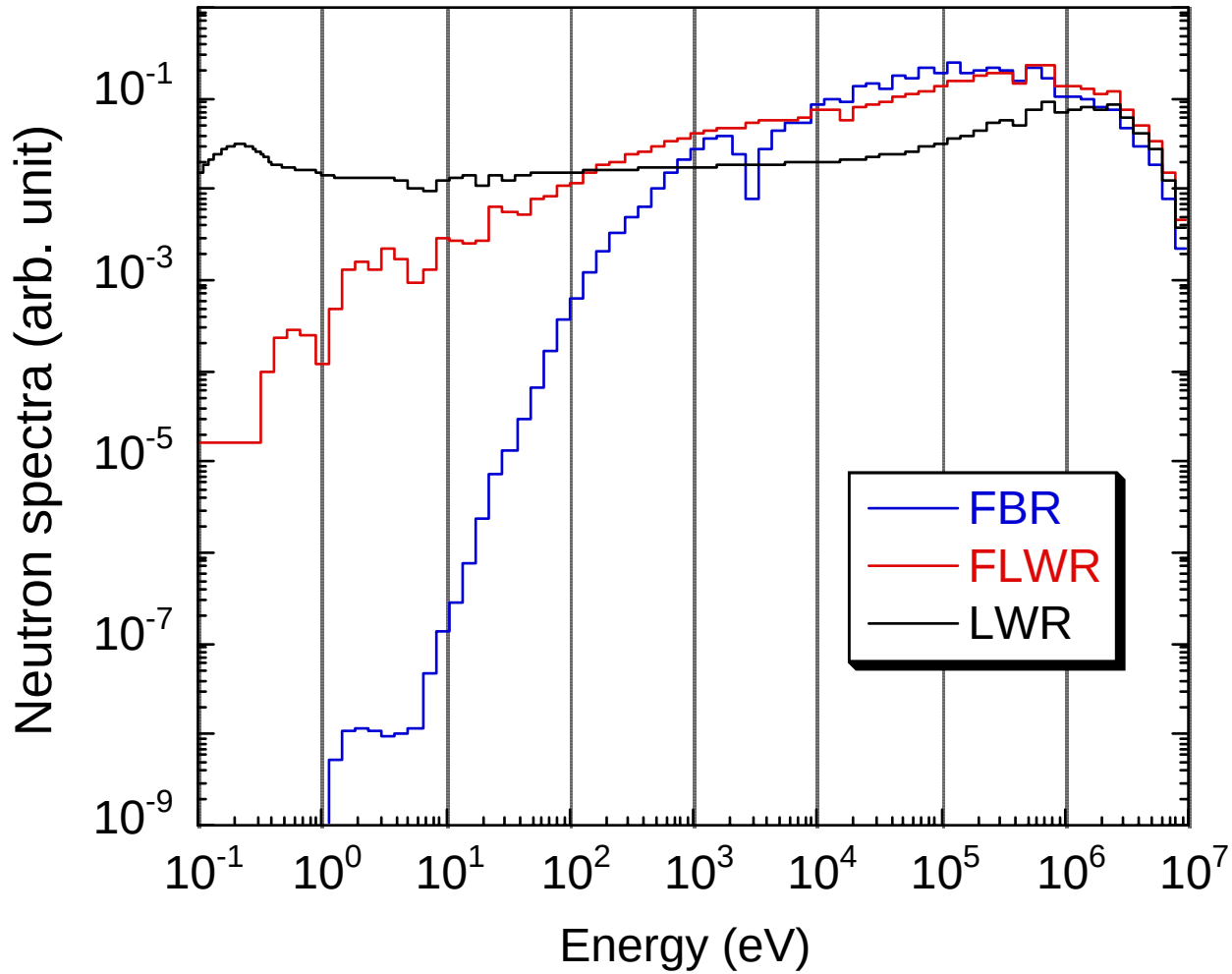
Moderator voidage

Upper core: 75%

Inner blanket: 65%

Lower core: 45%

Neutron spectra: FLWR and others



FLWR:
average of the upper and lower cores

Background of Experiment

- A few experimental data for design study

  ex.) Mockup experiment for HCLWR (1980's)

  PROTEUS(), EOLE(), FCA: Enrichment=8%

⇩

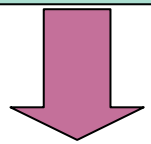
- Needs for experimental data in FLWR design study

  Mockup experiments with high enriched MOX fuel in tight lattice

  - To check the core performances
  - To estimate the accuracy of prediction

Purposes of FCA-FLWR experiments

- **To obtain nuclear characteistics data**
  - **tight lattice: reduced moderated spectrum**
  - **highly enriched MOX fuel**
- **Complementary to the experimental database for the design study**



- **Evaluate the accuracy of designing FLWR**

Program of FLWR mockup experiments

Experimental core: FCA-XXII-1 series

- Focus on the nuclear characteristics of the MOX fueled core
- Simulation of the neutron energy spectrum
- 3 different voide fraction of moderator (45%, 65%, 95%)

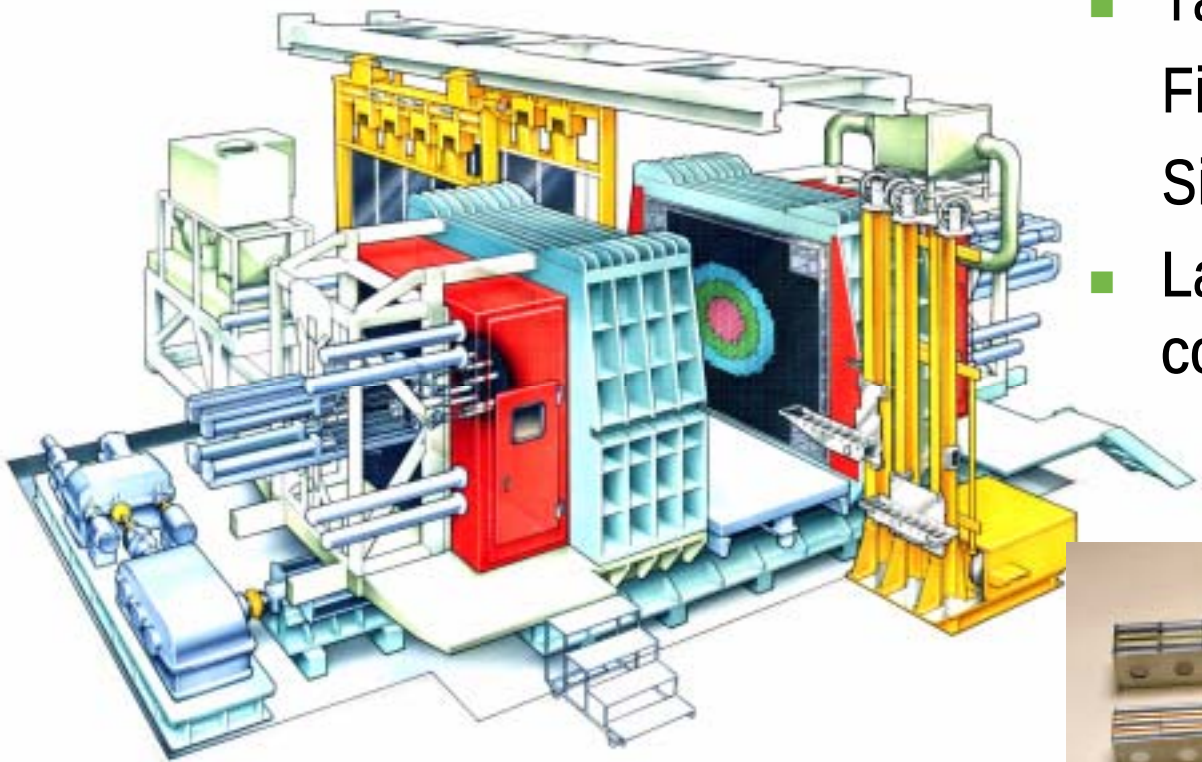
Outline of FCA-XXII-1 experiment

- MOX fueled core
  - Pu (92% fissile), Natural U, Depleted UO_2
- 3 different moderator voidage
  - Foamy polystyrene: 45%, 65%, 95% voided

	FCA-XXII-1			FCA-XV-1*
Enrichment (%)	16	16	16	8
V_m / V_f	0.6	0.6	0.6	0.6
Voidage (%)	45	65	95	0 ~ 95
H/HM**	0.8	0.5	0.09	1 ~ 0.06

*) HCLWR core, **) H: Hydrogen, HM: Heavy metal

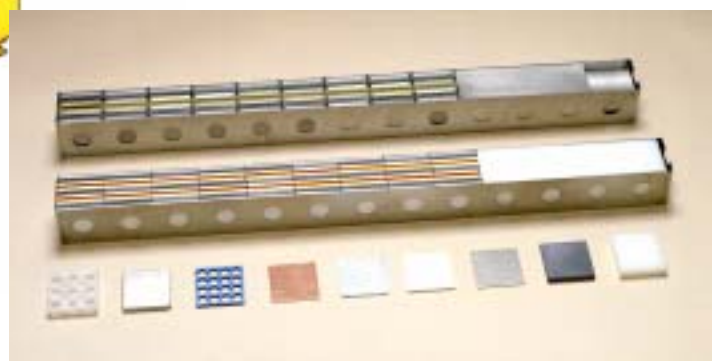
Fast Critical Assembly (FCA)



- Table-split type

  First critical in 1967

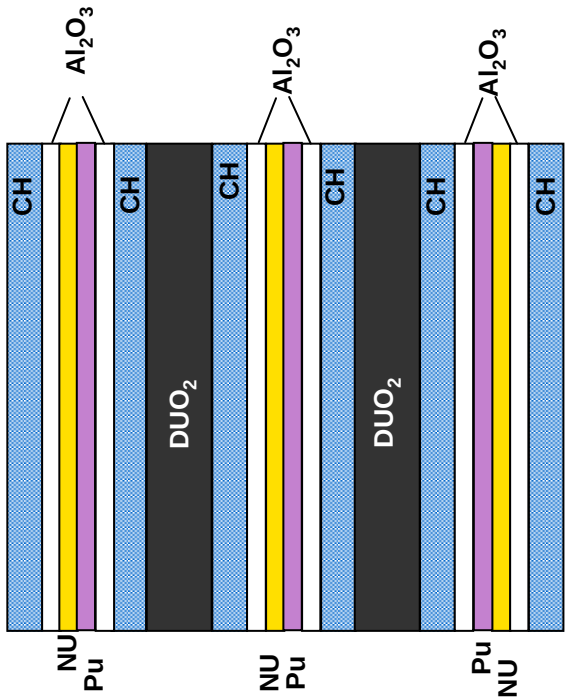
  Size: 2.7m x 2.7m x 1.3m
- Large flexibility in core compositions and geometries



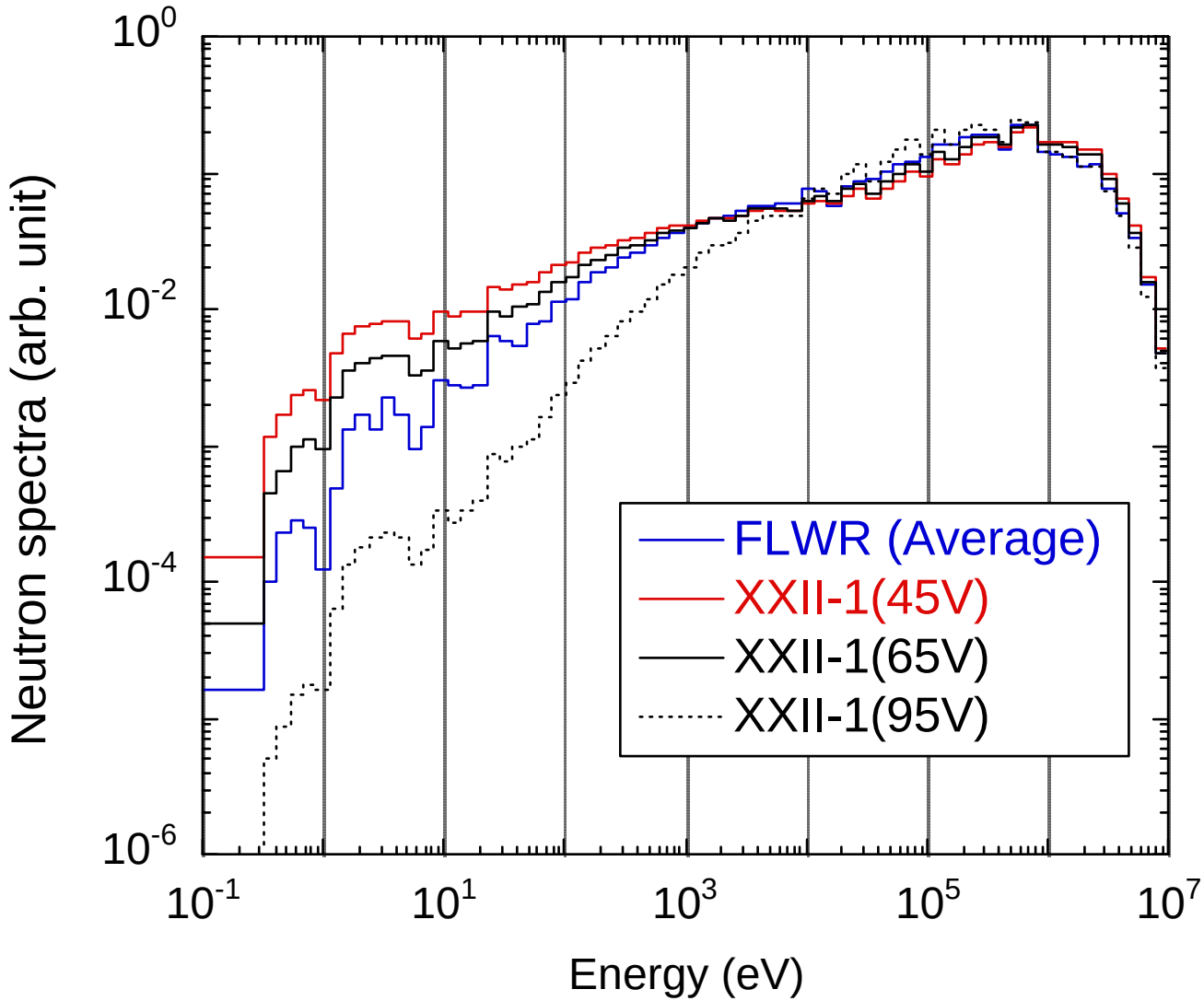
Fuel elements and fuel drawer

Neutron spectra of FCA-XXII-1 and FLWR

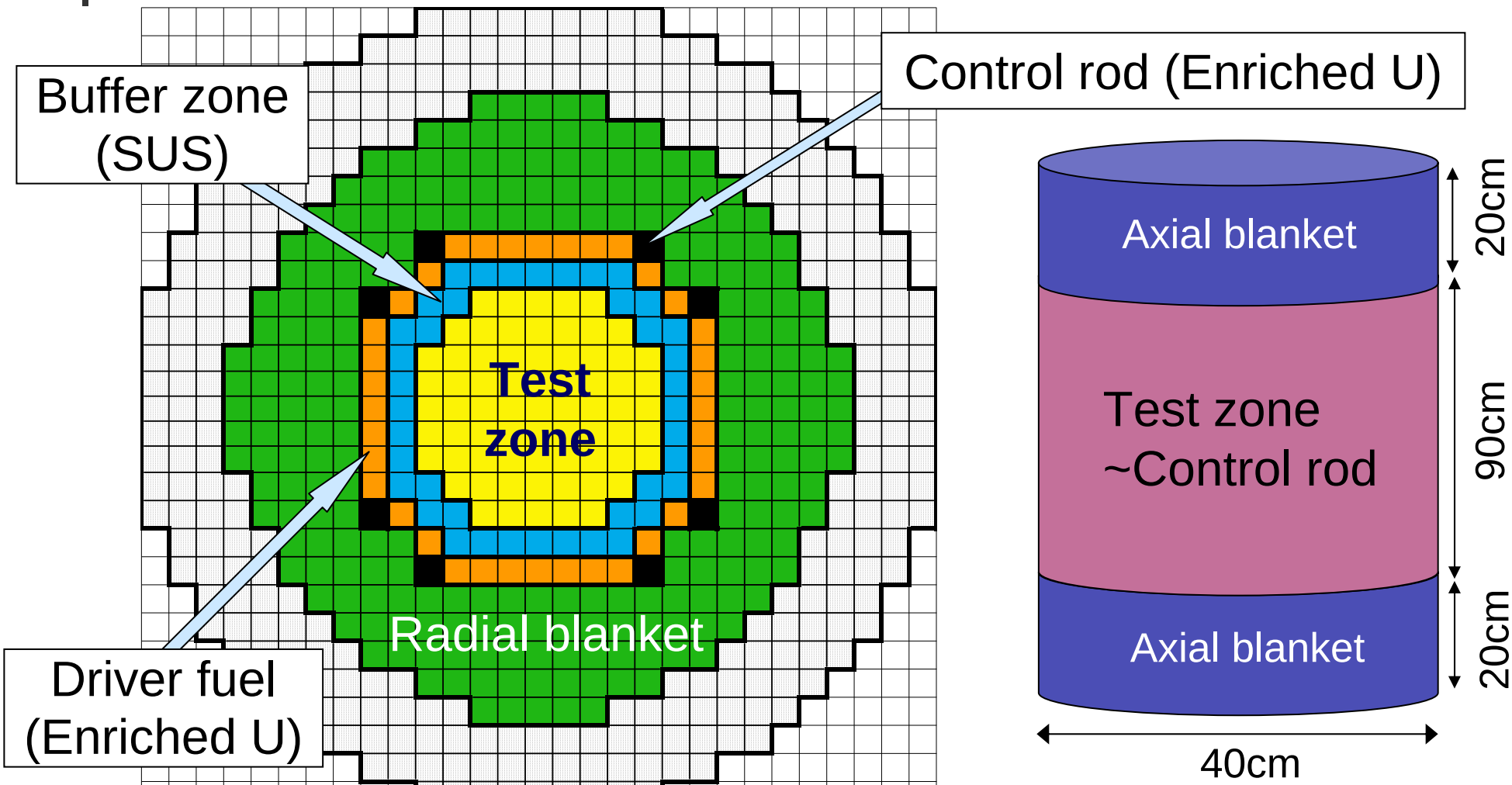
Cell patern



CH: Polystyrene



FCA-XXII-1 experimental core



Measurement items

	FCA-XXII-1 series		
	45V	65V	95V
Criticality	○	○	○
Reaction rate			
Central r. r. ratio	○	○	○
Axial & radial distribution	○	○	○
Void coefficient	○	○	-
Doppler effect			
U-238 （max.800℃）	○	○	○
Reactivity effect			
Pu (Pu92%, 81%, 75%)	○	○	○
B_4C(B-10: 20% - 90%)	○	○	○

Calculation method

- Deterministic method
  - Nuclear reactions in resonance energy region
    - ⇨ SRAC system, Calculation system for FR
  - Comparison of both results
    - Investigation of calculation methods for analysis
    - Estimation of accuracy of calculation
- Probabilistic method (MVP)
  - Criticality, void effect (perturbation method)
- Nuclear data : JENDL-3.3

Criticality: Comparison of k_{eff} (C/E)

XXII-1(65V)	SRAC	FR	MVP
J-3.2	1.0004±0.02%	0.9961±0.02%	1.0073±0.009%
J-3.3	1.0017±0.02%	0.9970±0.02%	1.0078±0.005%

Calculation condition

3D Transport (THREEDANT) : P0-S8

Inisotropic neutron leakage effect (along the plate direction) is considered

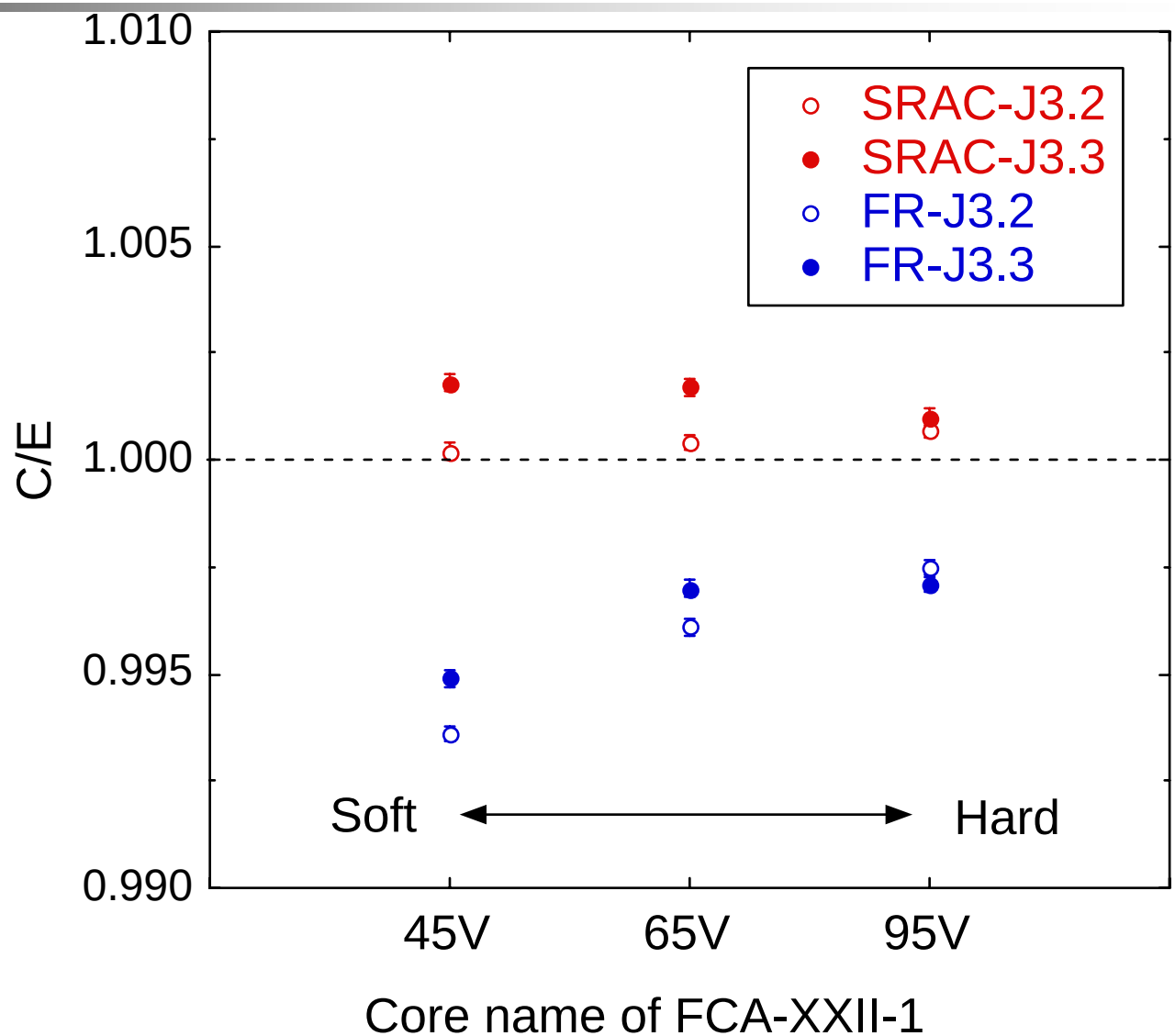
Energy group : 107 gr. (SRAC), 70gr. (FR)

Histories in MVP : 61M (J3.2), 200 M (J3.3)

- J-3.3 > J-3.2 (Δ=0.05% to 0.1%)

k_{eff} (C/E) in different voidage cores

error bar: expt. error



FR:
underestimate in softer spectrum

Central reaction rate ratio

- **Spectrum index**
  - F28/F25 = U-238 fission / U-235 fission
  - F49/F25 = Pu-239 fission / U-235 fission
- **Breeding performance index**
  - C28/F49 = U-238 capture / Pu-239 fission

Calculation condition

3D Diffusion (CITATION)

Inisotropic neutron leakage effect (along the plate direction) is considered

Energy group：107 gr. (SRAC), 70gr. (FR)

X-sec.: Ultra-fine energy collision probability

Central reaction rate ratio -1 (C/E)

F28/F25

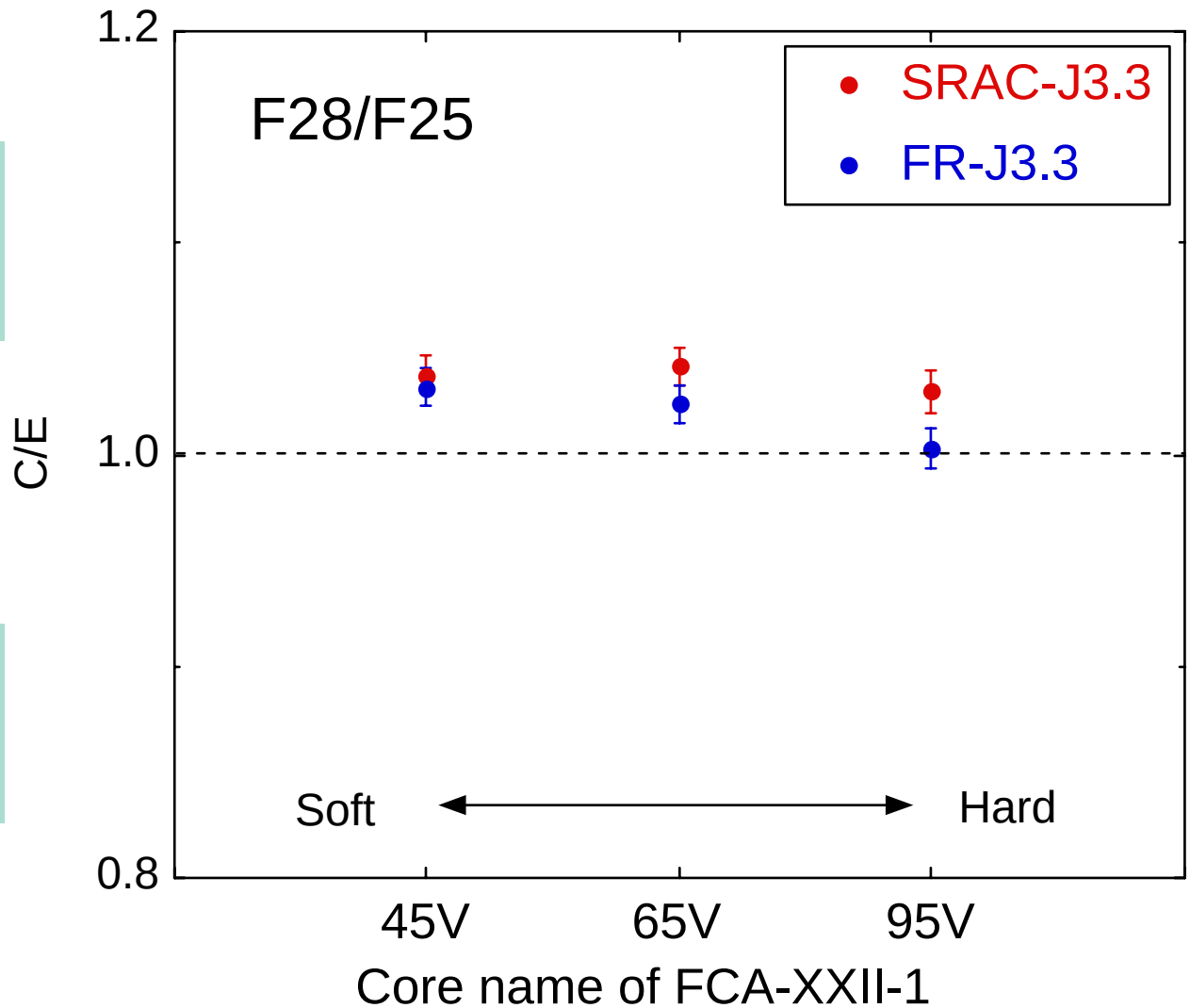
	SRAC	FR
J3.2	1.04-1.05	1.02-1.04
J3.3	1.03-1.05	1.00-1.03

■J3.3≦J3.2

F49/F25

	SRAC	FR
J3.2	0.97-1.01	0.99-1.02
J3.3	0.97-1.02	0.99-1.02

■J3.3~J3.2

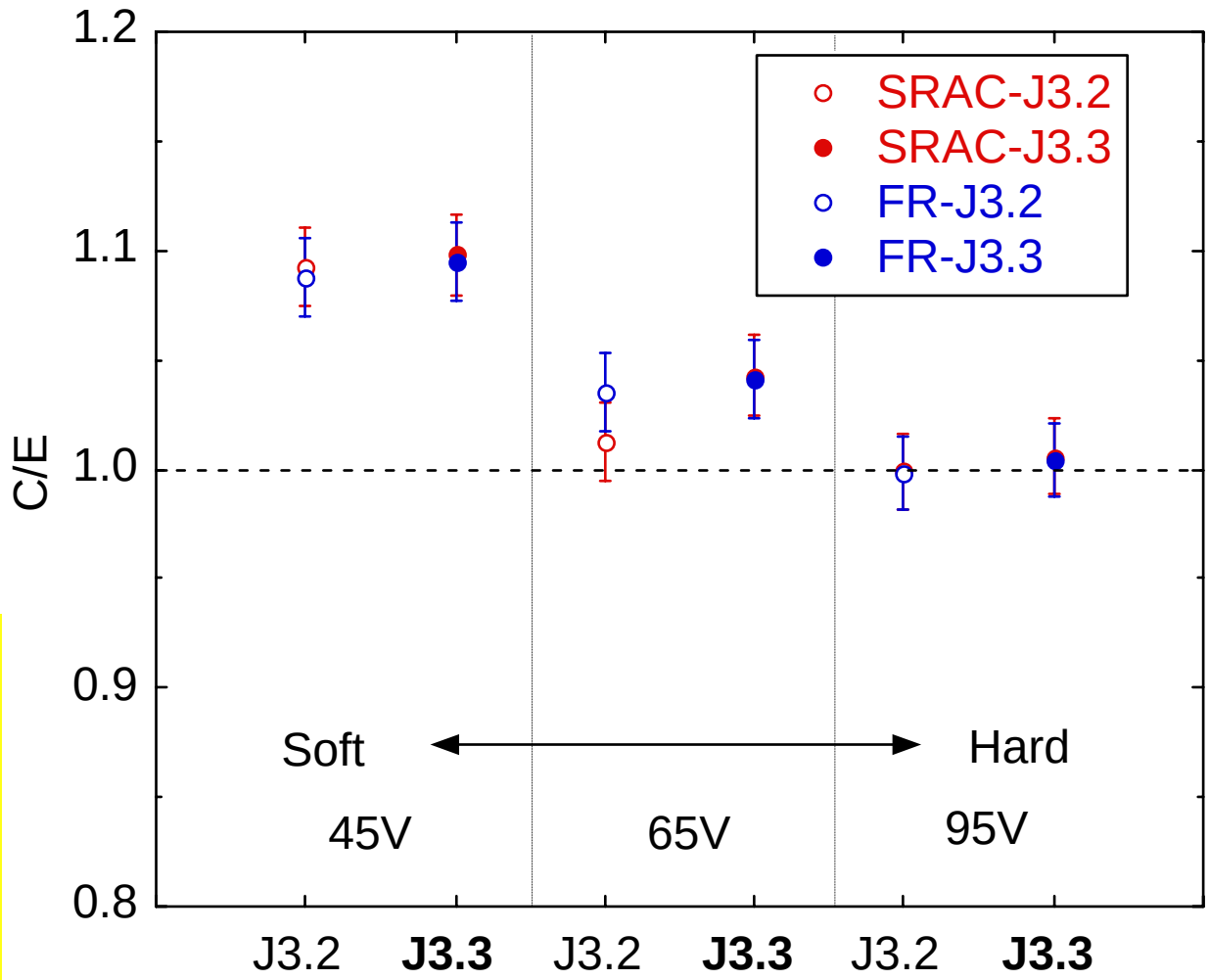


Central reaction rate ratio -2 (C/E)

C28/F49

	SRAC	FR
J3.2	1.00-1.09	1.00-1.09
J3.3	1.01-1.10	1.00-1.09

- J3.3 ~ J3.2
- SRAC ~ FR
- overestimate in softer spectrum

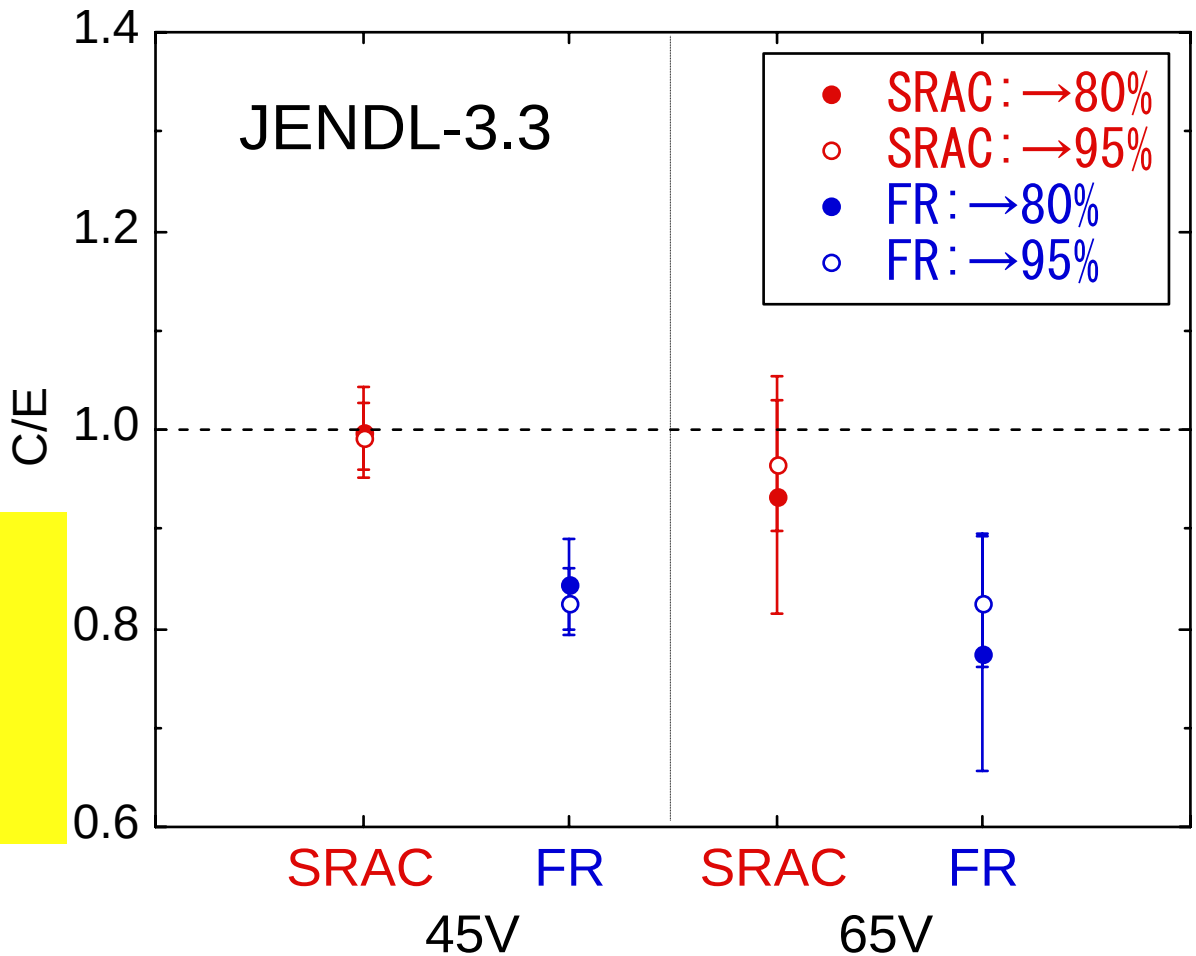


Moderator void effect -1 (C/E)

Void condition : moderator void fraction change to 80% and 95% at the core center (5.5cm cube)

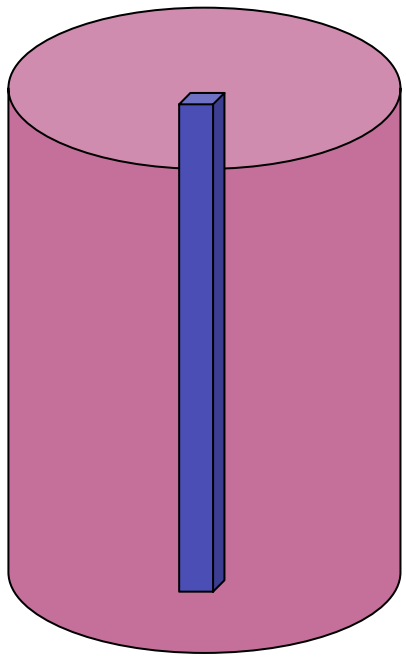
	SRAC	FR
J3.2	0.94-1.00	0.77-0.85
J3.3	0.93-1.00	0.78-0.84

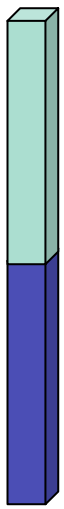
- J3.3~J3.2
- SRAC>FR
  - SRAC: good agreement
  - FR: ~20%underestimate



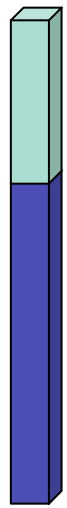
Moderator void effect - 2

Void condition : moderator void fraction change to 95% in different regions in central axis

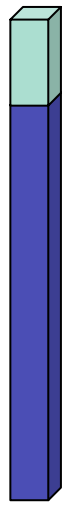




Upper 1/2
(9 cell)
95%



Upper 1/3
(6 cell)
95%



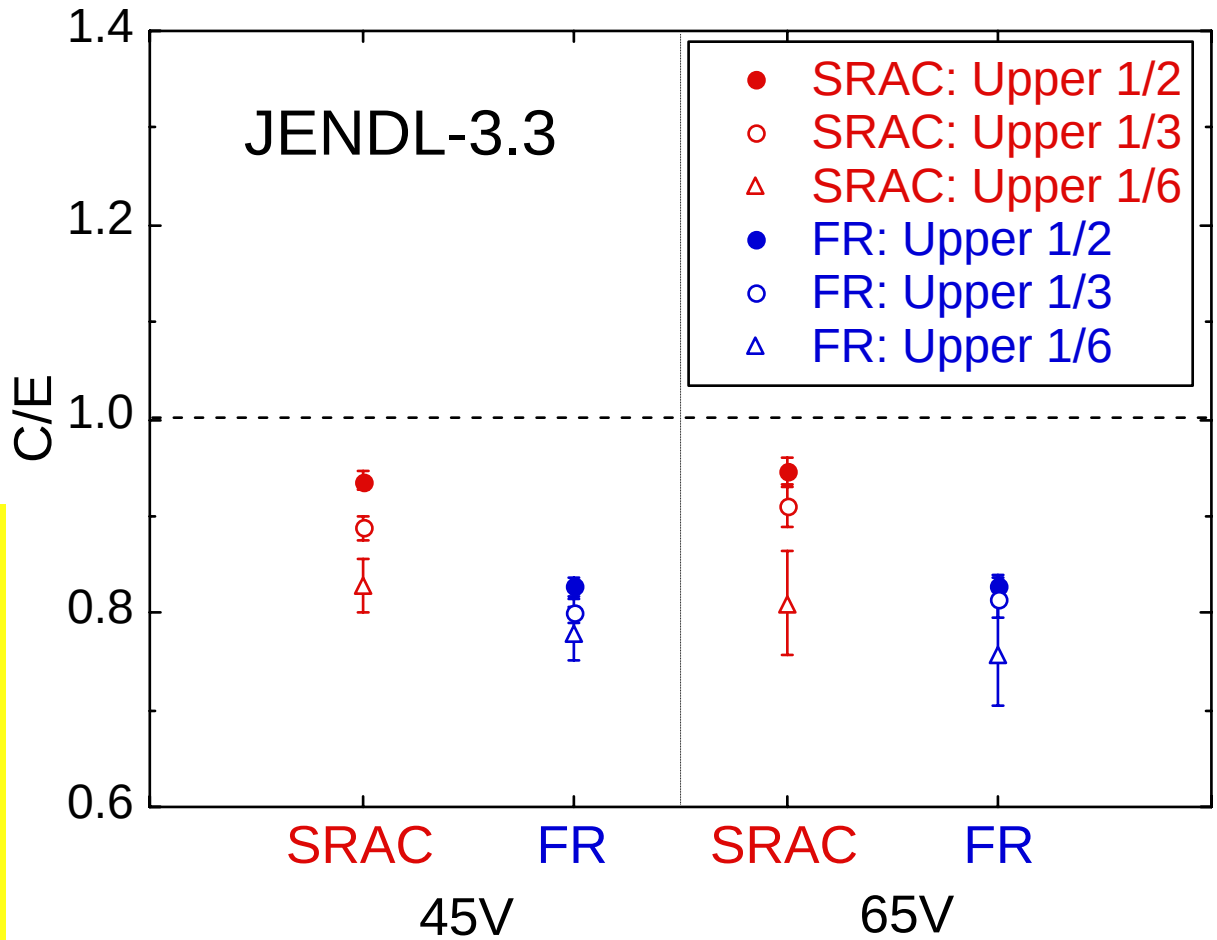
Upper 1/6
(3 cell)
95%

void fraction: 65%
(45%)

Moderator void effect - 2 (C/E)

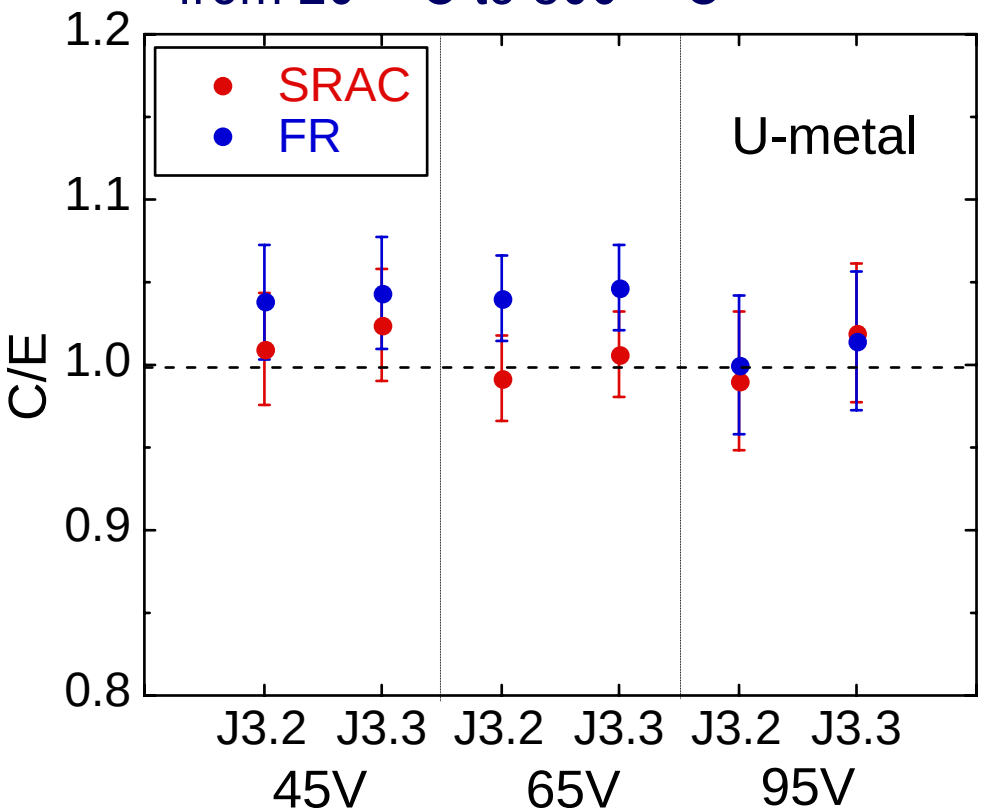
	SRAC	FR
J3.2	0.82-0.95	0.76-0.83
J3.3	0.81-0.95	0.76-0.83

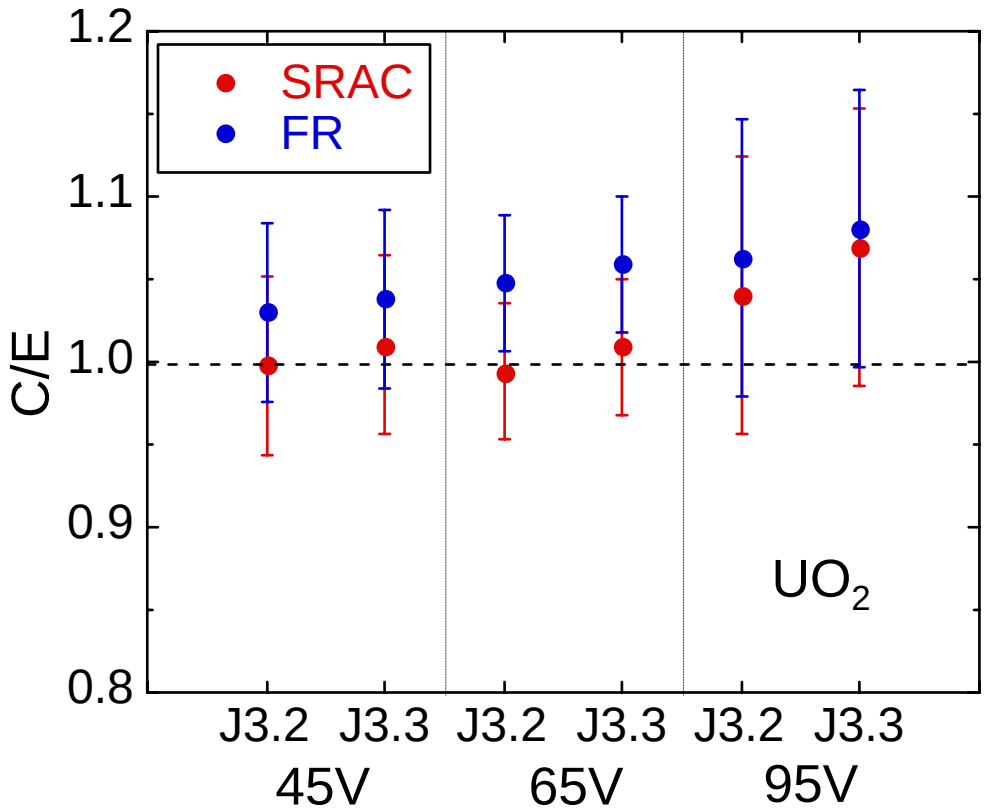
- J3.3~J3.2
- SRAC > FR
- Void region dependency: worse with increase of leakage



Doppler effect (C/E)

Measured values : Reactivity worth due to sample temp. change from 20° C to 800° C





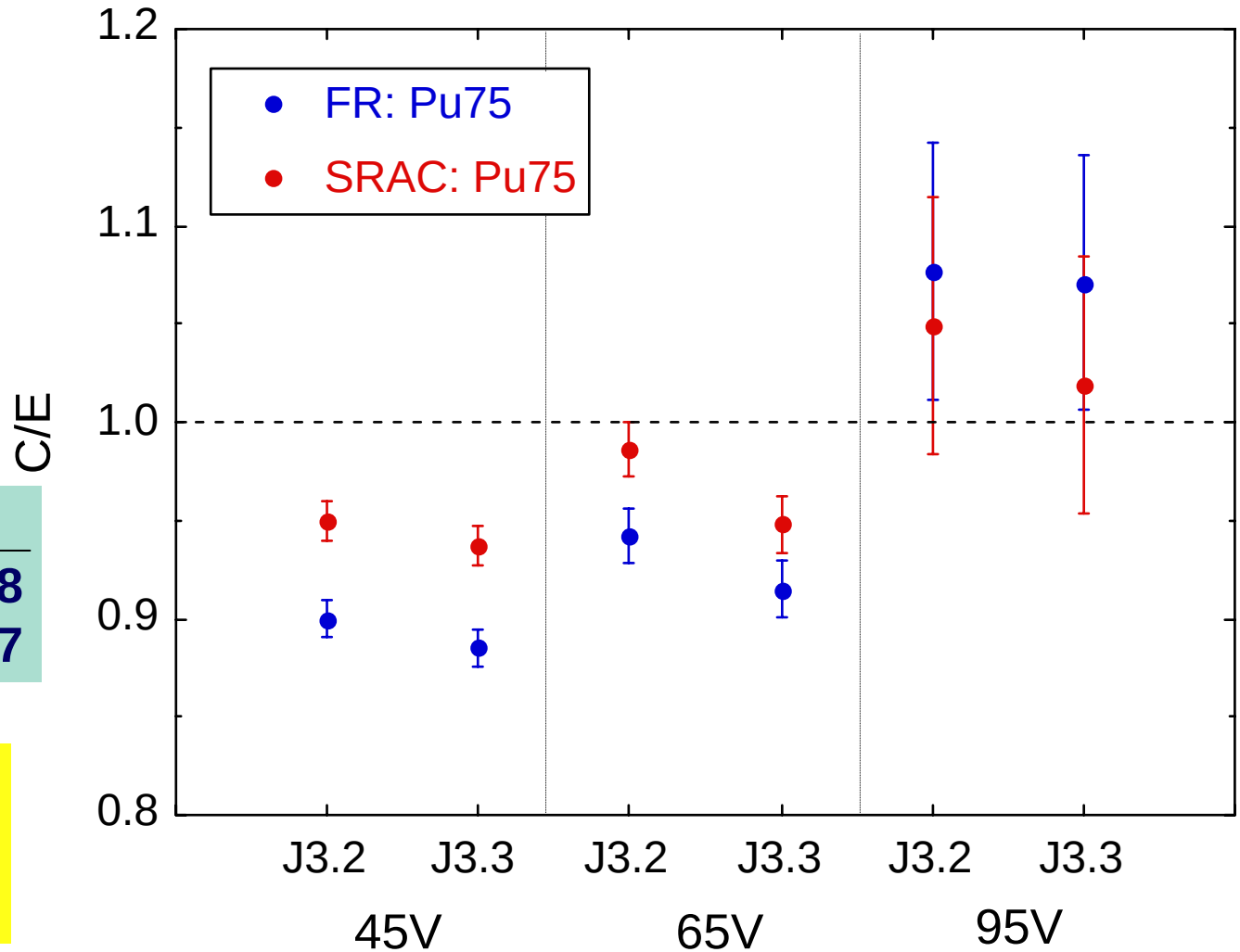
- **J3.3 ~ J3.2**
- Good agreement in most cases

Pu sample reactivity worth (C/E)

Pu75 : 92⟶75%
(Pu-239+241)

	SRAC	FR
J3.2	0.95-1.05	0.90-1.08
J3.3	0.94-1.02	0.89-1.07

- J3.3 ≦ J3.2
- SRAC: flat



Summary

- **FCA-FLWR mockup experiment**
  - **Neutron energy spectrum well simulated**
  - **Void fraction varied: 45%, 65%, 95%**
  - **Criticality, Reaction rate ratio, Moderator void effect, Doppler effect, Pu reactivity worth, etc.**
- **Analysis results**
  - **C/E values**

    C28/F25: 1.0 ~ 1.1, SRAC~FR, overestimate in softer spectrum

    Void effect: 0.76 ~ 0.99, region dependency**, better wih SRAC**

    Doppler effect: 0.99 ~ 1.08, SRAC~FR
  - **No large defference between JENDL-3.2 and JENDL-3.3**

Current status and future program

- FCA-FLWR mockup experiment
  - All the experiments have been finished
- Analysis results
  - Almost all the analyses have been finished
  - Detail analysis has just started
    - Evaluation of calculation accuracy
    - Sensitivity analysis
- Feedback to design study
  - Representativity