PIE Analysis for Minor Actinide

Kenya SUYAMA

Criticality Safety Laboratory,

Japan Atomic Energy Research Institute

2004 Symposium on Nuclear Data

11,12 November 2004

Purpose

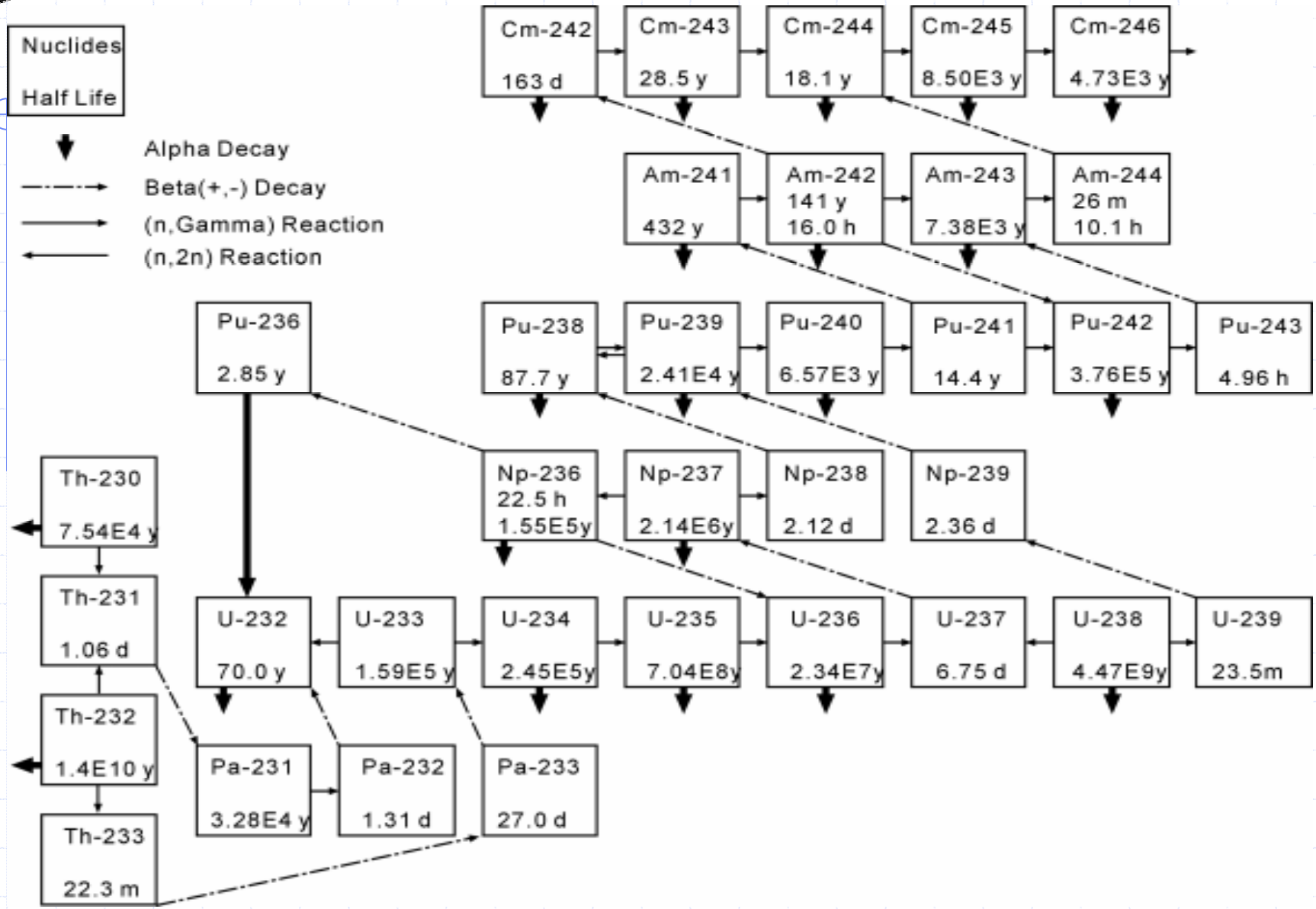
- To reconfirm “what is necessary” for improvement of nuclear data of MA from the view point of PIE analysis.

  - MA: ^{237}Np, ^{238}Pu, ^{241}Am, ^{243}Am, ^{244}Cm,^{254}Cm

Contents

- Quick Review of MA Generation.
- Status of PIE data of MA.
- Status of Analysis.
- Conclusion and Proposal.

MA Generation Chain



Quick Review of MA Generation(1)

	Half life [year]	Main Generation chain	σ_c [barn]*	σ_f [barn]*
^{237}Np	2.14×10^{6}	➢ ^{238}U(n,2n) ^{237}U $\Rightarrow$ β^- (6.75 day) ➢ ^{236}U(n, γ) ^{237}U $\Rightarrow$ β^- (6.75 day) ➢ ^{241}Am $\Rightarrow$ α (432 year)	33	0.54
^{238}Pu	87.7	➢ ^{237}Np(n,γ) ^{238}Np $\Rightarrow$ β^- (2.11 day) ➢ ^{242}Cm $\Rightarrow$ α (163 day) ➢ ^{239}Pu (n,2n)	29	2.4

* JENDL-3.3 ; PWR 17×17 Fuel Assembly Equiv.Pin Cell

Quick Review of MA Generation(2)

	Half life [year]	Main Generation chain	σ_c [barn]*	σ_f [barn]*
^{241}Am	432	➢ ^{241}Pu $\Rightarrow$ β^- (14.4 year)	118	1.2
^{243}Am	7,370	➢ ^{241}Pu(n,γ) ^{242}Pu (n,γ) ^{243}Pu $\Rightarrow$ β^-(5h)	49	0.44

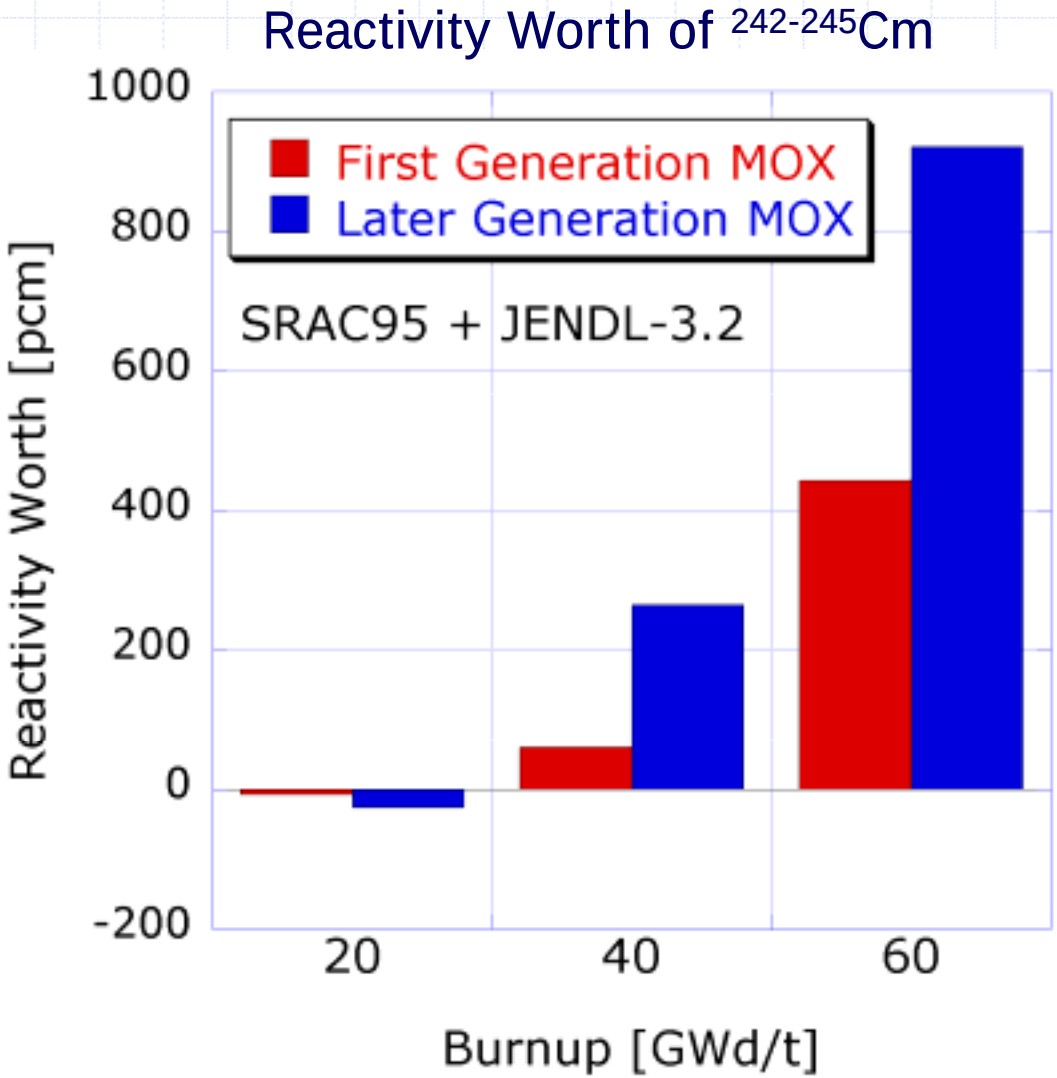
* JENDL-3.3 ; PWR 17×17 Fuel Assembly Equiv.Pin Cell

Quick Review of MA Generation(3)

	Half life [year]	Main Generation chain	σ_c [barn]*	σ_f [barn]*
^{244}Cm	18.1	➢ ^{243}Am(n,γ) $^{244/244m}$Am $\Rightarrow\beta^-$ (10.1h/26m) ➢ ^{243}Cm (n,γ)	18	0.82
^{245}Cm	8,500	➢ ^{244}Cm (n,γ)	18	118

* JENDL-3.3 ; PWR 17×17 Fuel Assembly Equiv.Pin Cell

Quick Review of MA Generation (4)



OECD/NEA/NSC
WPNCS/EGBUC

"Burnup Credit
Criticality Safety
Benchmark
Phase IV-A"

Reactivity Prediction
Calculation for Infinite
Arrays of PWR MOX
Fuel Pin Cells

Quick Review of MA Generation (5)

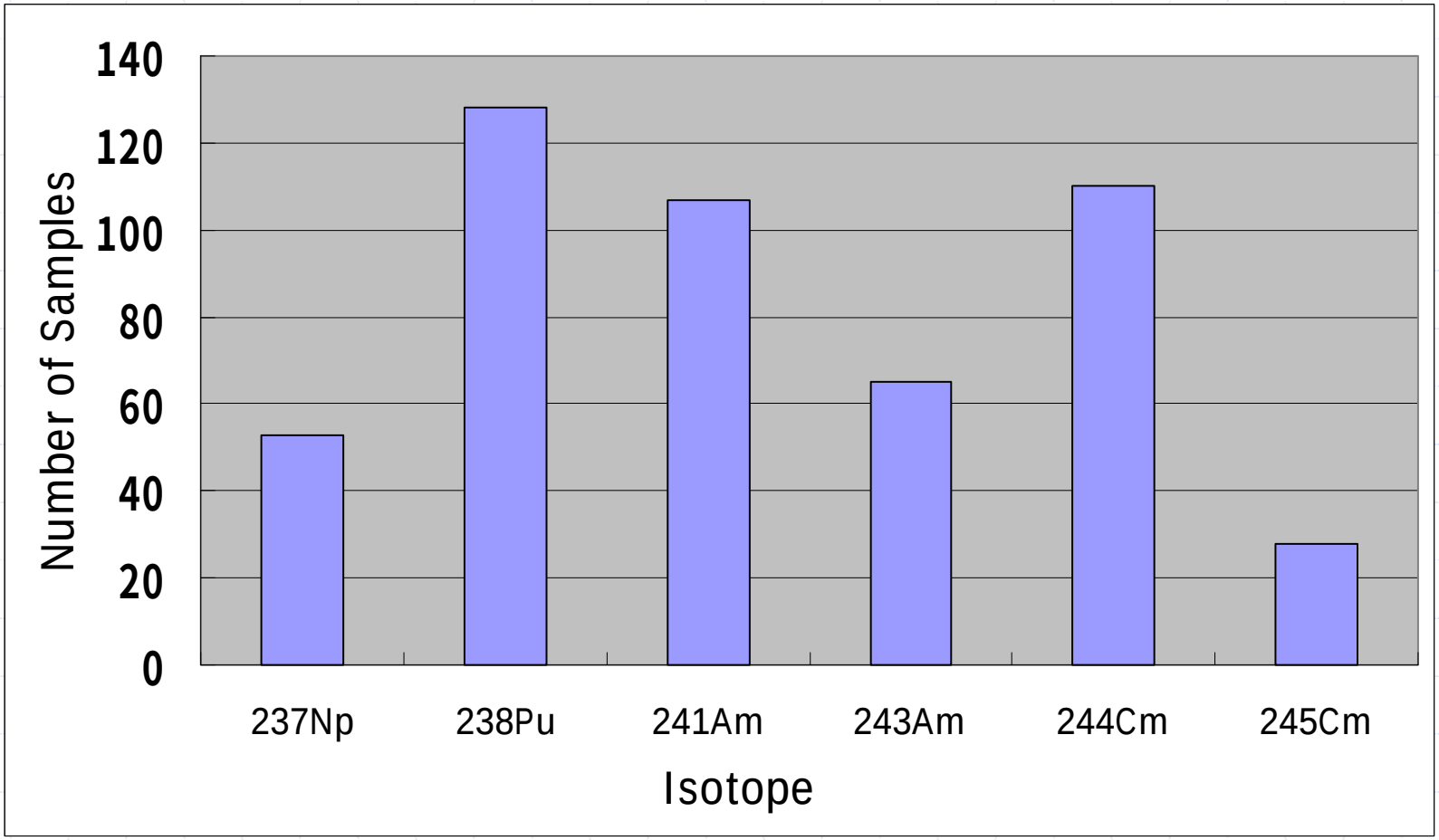
- MA accumulates through several generation paths. Accumulation during the cooling time (long).
  - example: ^{237}Np, ^{238}Pu
  - Chain Analysis is required.

- MA cross section's importance depends on the considering fuel cycle strategy and time scale.
  - Which isotope has the priority ?

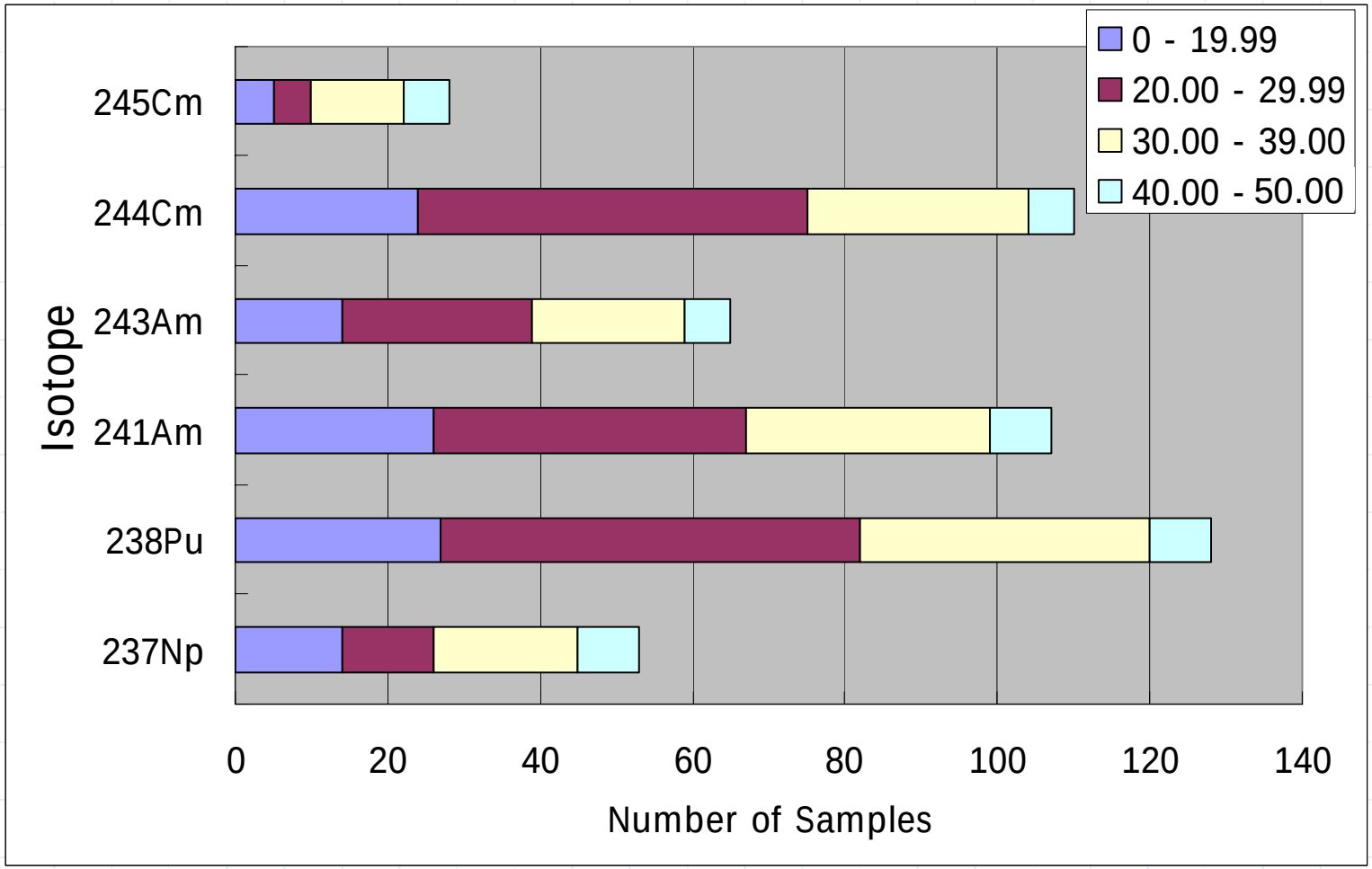
SFCOMPO – a Database of Isotopic Composition

- Isotopic Composition Database – SFCOMPO.
  - Developed in JAERI
  - Operated in OECD/NEA/DB
    - http://www.nea.fr/html/science/wpncs/sfcompo/

Number of PIE Samples - Total



Number of Samples (2) – Burnup



Current PIE Status (1)

- France
  - Active, but impossible to reach raw data
    - funded by Industries(EDF,COGEMA)
- Belgium
  - Belgonucleaire is active, but they are conducting commercial international programs (ARIANE)
- Switzerland
  - PSI joins BN's program

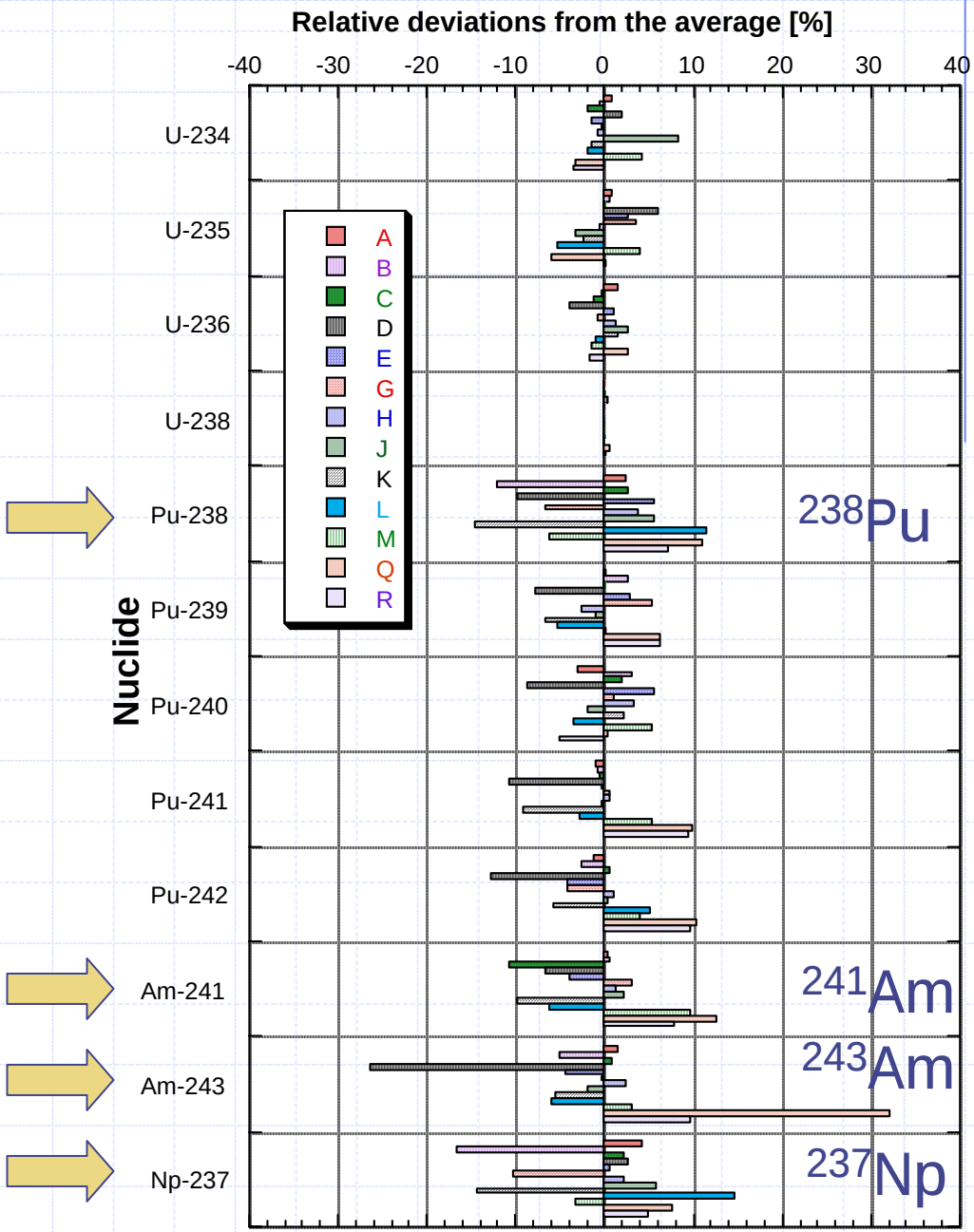
Current PIE Status (2)

- Japan
  - JAERI *had* the PIE activity. But, now, no program to obtain MA composition.

- See also, Special Session on PIE in ICNC2003.
  - http://typhoon.tokai.jaeri.go.jp/icnc2003/html/TopicSS.htm)

Calculational Benchmark

- OECD/NEA/NSC WPNCS/EGBUC
- Burnup Credit Criticality Benchmark Phase IIIB
  - MA calculation has larger deviation among participants.



Example of PIE Analyses – MVP-BURN

C/E Values : PIE data from Mihama-3 PWR

	JENDL-3.2			JEF-2.2	ENDF/B-6
	MVP	SWAT	SRAC	SRAC	SRAC
^{237}Np	0.90	0.95	0.91	0.92	0.93
^{238}Pu	0.81	0.83	0.81	0.85	0.85
^{241}Am	0.97	0.99	0.97	0.96	0.98
^{243}Am	1.00	0.99	0.98	0.95	1.07
^{244}Cm	0.78	0.76	0.74	0.72	0.82

K. Okumura et al., J. Nucl.Sci.Technol.37(2),pp.128-138 (2000).

Example of PIE Analyses - APOLLO2(1)

C/E-1 [%] Values : PIE data from Takahama-3 PWR

	JEF-2.2	JEFF-3.0	total σ
$^{237}Np/^{238}U$	-8.1	-3.7	0.7
$^{238}Pu/^{238}U$	-18.9	-14.1	3.8
$^{241}Am/^{238}U$	4.0	4.7	3.2
$^{243}Am/^{238}U$	-14.8	-7.7	4.7
$^{244}Cm/^{238}U$	-26.5	-19.3	6.4
$^{245}Cm/^{238}U$	-33.4	-22.9	7.7

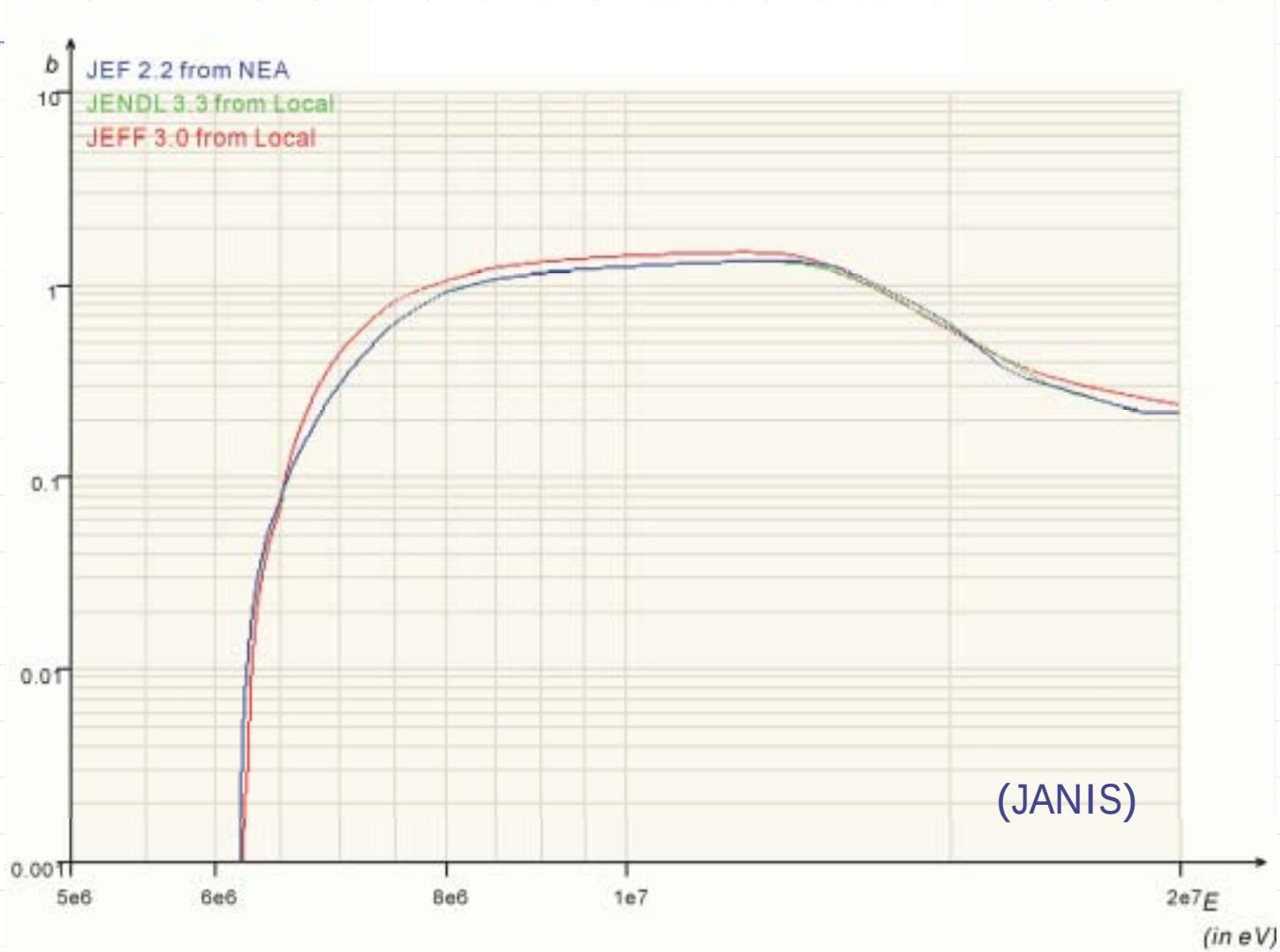
A. Courcelle et. al, " Proc. of PHYSOR-2004, Chicago, USA (2004).

Example of PIE Analyses - APOLLO2(2)

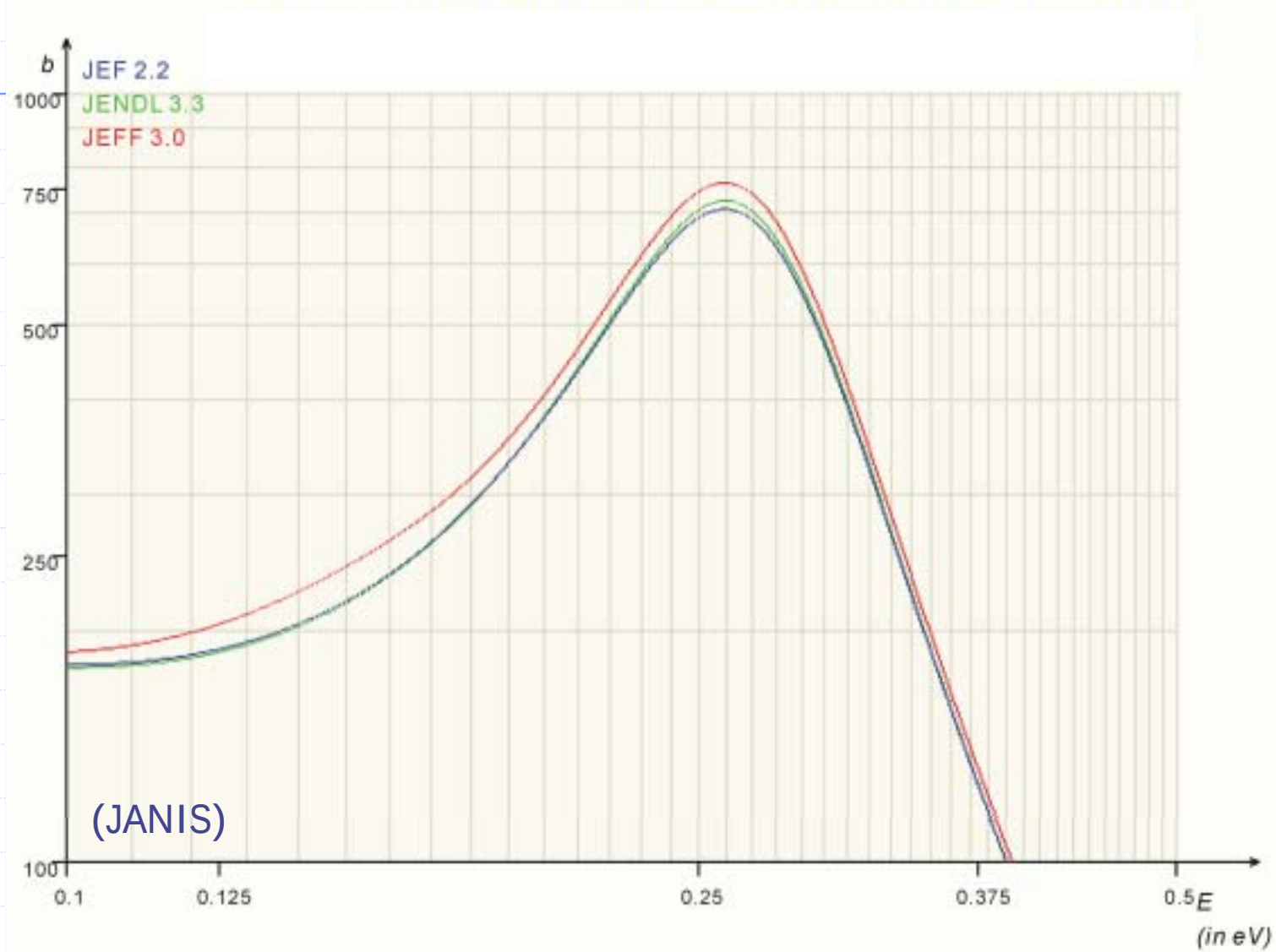
- Increase of Capture Resonance Integral of ^{235}U.
  - evaluation by Leal et.al
- Increase of (n,2n) Reaction Cross Section of ^{238}U.
  - 6.5E6 to 1.2E7 eV
- Larger ^{241}Pu Capture Cross Section at 0.26eV Resonance.
  - Integral Experiments (MISTRAL)

A. Courcelle et. al, " Proc. of PHYSOR-2004, Chicago, USA (2004).

(n,2n) Cross Section of ^{238}U



Capture Cross Section of ^{241}Pu



JENDL-3.2 and JENDL-3.3(1)

C/E Values : PIE data from Takahama-3 PWR

	JENDL-3.2	JENDL-3.3	J3.3/J3.2
$^{237}Np/^{238}U$	0.97	1.01	1.04
$^{238}Pu/^{238}U$	0.82	0.86	1.05
$^{241}Am/^{238}U$	1.14	1.10	0.96
$^{243}Am/^{238}U$	0.89	0.90	1.01
$^{244}Cm/^{238}U$	0.75	0.75	1.00
$^{245}Cm/^{238}U$	0.80	0.79	0.99

JENDL-3.2 and JENDL-3.3(2)

- Increase of Capture Resonance Integral of ^{235}U by adopting the evaluation by Leal et.al(JEFF-3.0).
- Harder Fission Spectrum of ^{235}U.
- Larger ^{241}Am Capture Cross Section shows better results of ^{241}Am.
- Cm isotopes are still underestimated.

Conclusion (1)

- Improved Prediction of MA amount in SNF is important issue in nuclear data evaluation.
- Difference among codes and libraries are large. Generally, MA is still underestimated (~10-20%).
- Current evaluation in JENDL-3.3 and JEFF-3.0 towards “improvement”. However, MA is still underestimated.

Conclusion (2)

- Accessing new PIE data in Japan seems to be difficult.
  - "International collaboration" is attractive, but is not omnipotence.

- *Mutual comparison* among codes and libraries is necessary.
  - Step-by-Step approach to collect *a piece of evidence*

Conclusion (3)

- Required Tools for *Mutual comparison*:
  - Automated system to generate reactor constants for several neutronics codes,
  - System to replace selected data in libraries (selection of isotope, reaction) to conduct sensitivity analysis, and
  - Development of open database to compare calculation results and PIE data.

Conclusion (4)

- Place for discussion among nuclear data users, evaluators and experimentalists

^{245}Cm in Irradiated in UO_2 Fuel