Sensitivity Analysis of Delayed Neutron with JENDL/FPD-2011 and JENDL/FPY-2011

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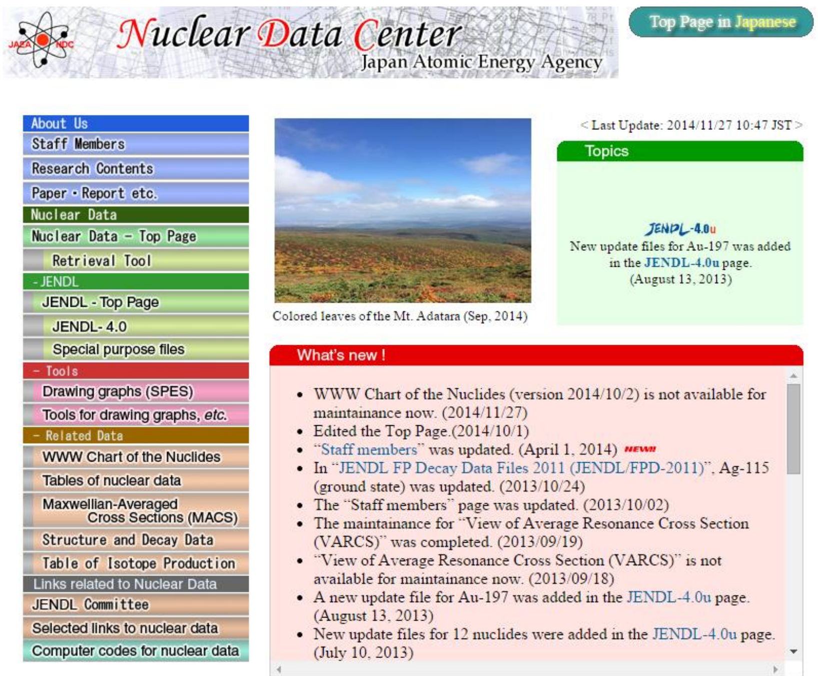
http://wwwndc.jaea.go.jp/index.html

Last update is **JENDL-4.0** in 2010

- JENDL-4.0u (updated file after 2010)

- neutron-nucleus data
- alpha-nucleus data
- gamma-nucleus data
- Activation Cross Section Data
- Decay Data of unstable nuclei
- Fission Yields of actinide & minor actinide nuclei
- Covariance Data, etc.



Delayed Neutron (DN)

- <u>Reactor Physics</u>

In a condition multiplication factor k=1.001

No DN → Reactor power becomes
20,000 times larger in 1 second

DN → 1.012 times larger in 1 second

- <u>Final r-process abundance after freeze-out</u>

This work is an “entrance” to improve DN Evaluated Data

JENDL/FPD-2011 & JENDL/FPY-2011 (updated in 2011)

J. Katakura, "JENDL FP Decay Data File 2011 and Fission Yields Data File 2011," JAEA-Data/Code 2011-025 (Mar 2012)

FPD-2011 (Decay Data)

	(2000)		(2011)
Total number of nuclei	1229	→	1284
Isomeric states	197	→	252
Second isomeric states	8	→	22

FPY-2011 (Fission Yields)

Based on ENDF/B-VII with modifications to be matched with FPD-2011.

Ternary Fission is also included.

Decay Heat (MeV/s)

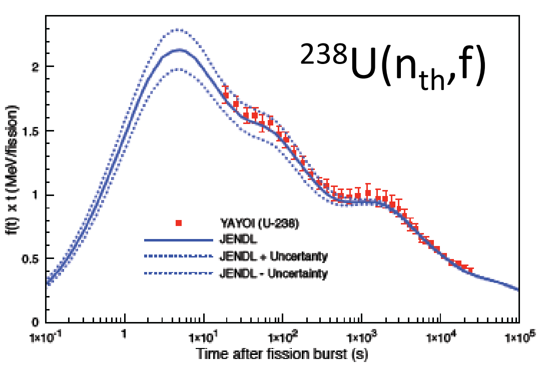
$$f(t) = \sum_i \underbrace{\lambda_{\beta+\gamma}(i)\bar{E}_{\beta+\gamma}(i)}_{\text{FPD}}\ \underbrace{N_i(t)}_{\text{FPD x FPY}}$$

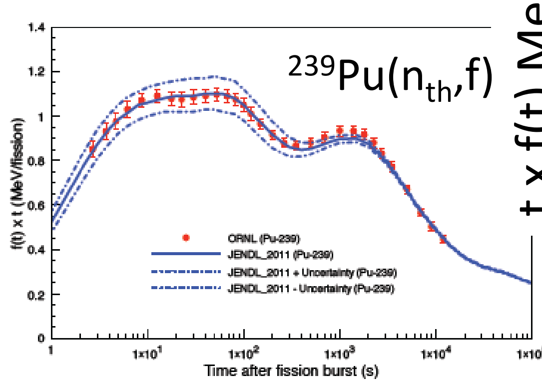
Decay Rate of β+γ

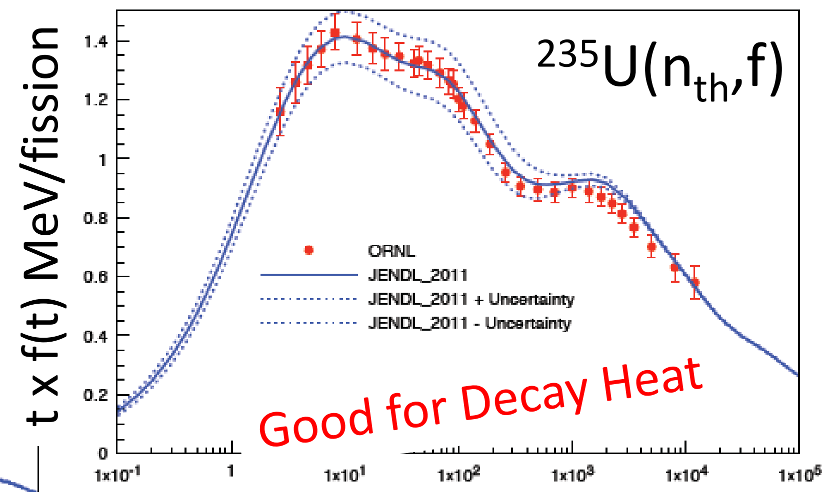
Average Energy

No. of Nuclide

Figure From Prof. J. Katakura (Nagaoka University of Technology)







PROBLEMS in JENDL/FPD & FPY-2011

Delayed Neutron (1/s)

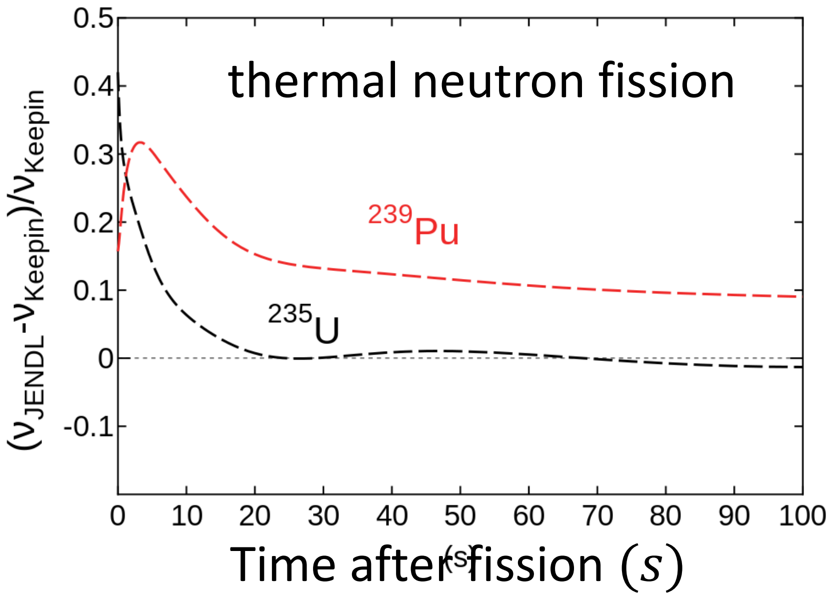
$$\nu_d(t) = \sum_i \underbrace{\lambda_{P_n}(i)}_{\text{FPD}} \; \underbrace{N_i(t)}_{\text{FPDxFPY}}$$

ν_d in JENDL-4.0 v.s. ν_d with JENDL/FPY & FPD-2011

	U-235 Thermal	**U-235 Fast**	**Pu-239 Thermal**
JENDL/FPY-2011 & JENDL/FPD-2011	0.0186	0.0204	0.00762
JENDL-4.0 [Based on exp.]	0.0158	0.0162	0.00622

Inconsistent with JENDL-4.0 !

Time distribution of ν_d (Deviation from **Keepin's data**)

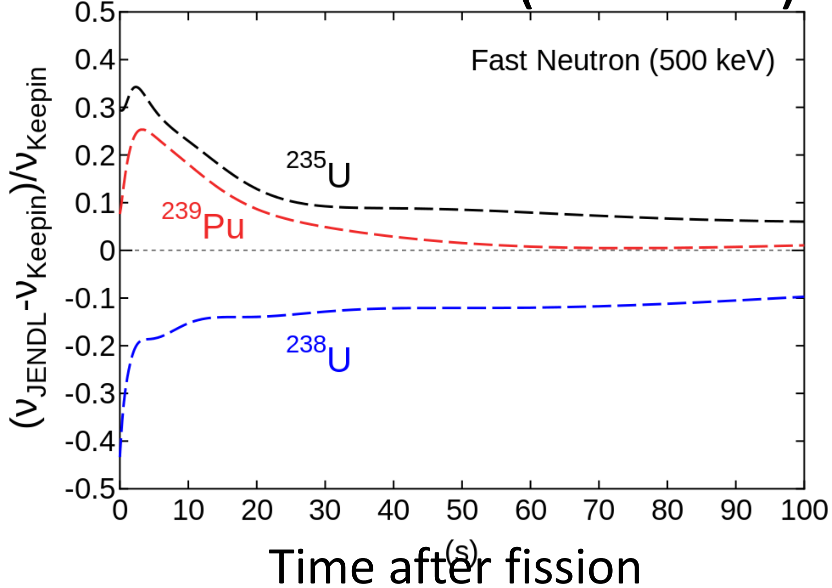


$$\frac{\nu_{FPY\times FPD}(t) - \nu_{Keepin}(t)}{\nu_{Keepin}(t)}$$

Large Difference from Keepin's data until 20 s.
After 20s, difference is small for U-235.

Pu-239 is still 10% larger at least until 100 s.

Fast Neutron (500 keV)



For next JENDL/FPD & FPY Library

Obviously, Differences Appear at First 20 s.

→ Nuclides with $T_{1/2}$ less than about 20 s are important.

Strategy = 1. Modify decay data & fission yields of nuclei with $T_{1/2} < 20$ s.

2. Then, carry out other improvements.

- Important delayed neutron emitters (precursor) are already known
- Evaluate them again with JENDL/FPD & FPY-2011 for next ones consistent with decay heat.

For this purpose, sensitivity analysis is useful

CALCULATION

K. Tasaka, JAERI-M 8727 (1980).
K. Oyamatsu, Proc. 1998 Symposium on Nuclear Data, Nov. 1998, JAERI, Tokai, Japan, JAERI-Conf 99-002, pp.234-239.

◆Bateman Equation (single decay chain)

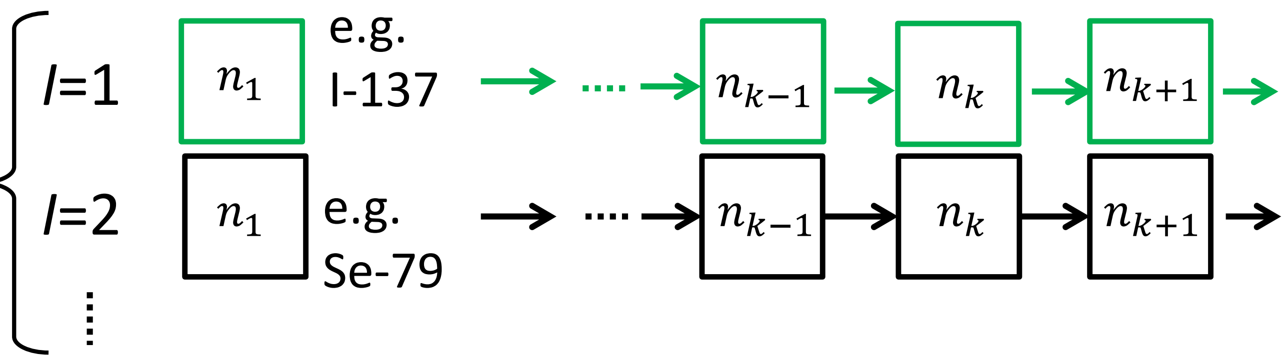
$$\begin{cases} \dfrac{dn_1(t)}{dt} = -\lambda_1 n_1(t) \\ \dfrac{dn_k(t)}{dt} = -\lambda_k n_k(t) + \lambda_{k-1} n_{k-1}(t) \ (2 \le k) \end{cases}$$

Solution: $n_i(t) = y_i \sum_{j=1}^{i} d_j e^{-\lambda_j t}$ $\quad n_1(0) = y_1$ =Fission Yield

$n_k(0) = 0 \ (2 \le k)$

$$d_j = \frac{\prod_{k=1}^{i-1} \lambda_k}{\prod_{k=1,k\neq j}^{j} (\lambda_k - \lambda_j)} (2 \le j \le i) \qquad d_j = 1 \ (i = j = 1)$$

Decay Chain Specified *I*



Superposing the Solution of Decay Chain *I*

$$N_i(t) = \sum_I n_i(t; I)$$

Delayed Neutron (1/s) $$\nu_d(t) = \sum_i \lambda_{P_n}(i) \quad N_i(t)$$

To check nuclei important for delayed neutron emitter …

Sensitivity

1. Fission Yields, Yi

$$S_{Y_i} = \frac{(\Delta\nu_d/\nu_d)}{(\Delta Y_i/Y_i)} \qquad \left(\frac{\Delta Y_i}{Y_i}\right) = 0.1 \rightarrow \frac{\Delta\nu_d}{\nu_d} = ?$$

2. Delayed Neutron Emission Probabilities, Pn

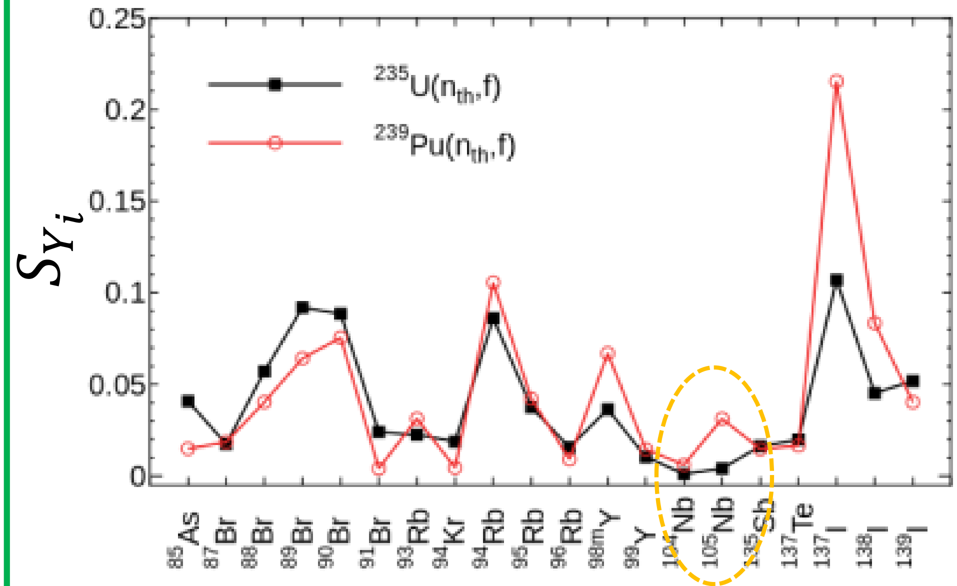
$$S_{P_{ni}} = \frac{(\Delta\nu_d/\nu_d)}{(\Delta P_{ni}/P_{ni})}$$

RESULTS

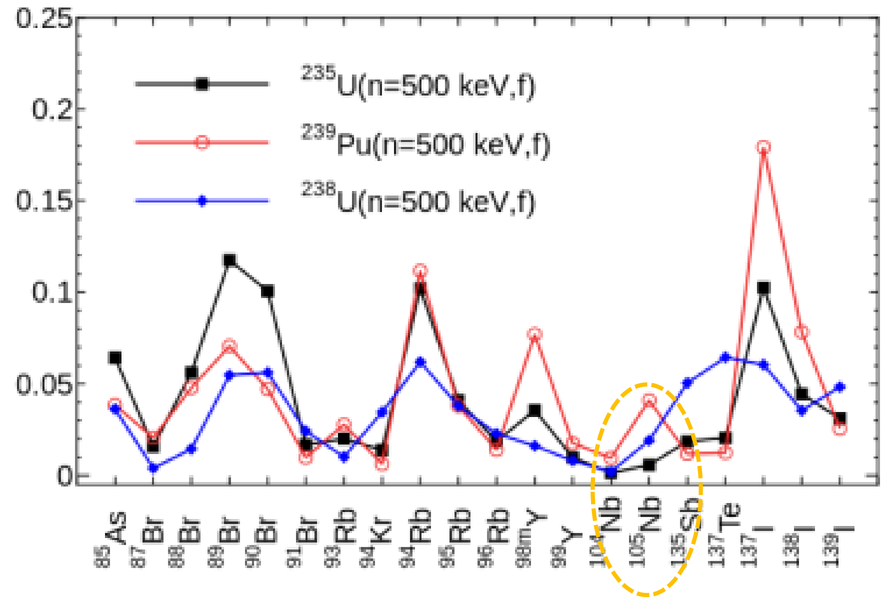
Lines are just guide for eye

Sensitivity to Fission Yields

Thermal Neutron



Fast Neutron (500 keV)



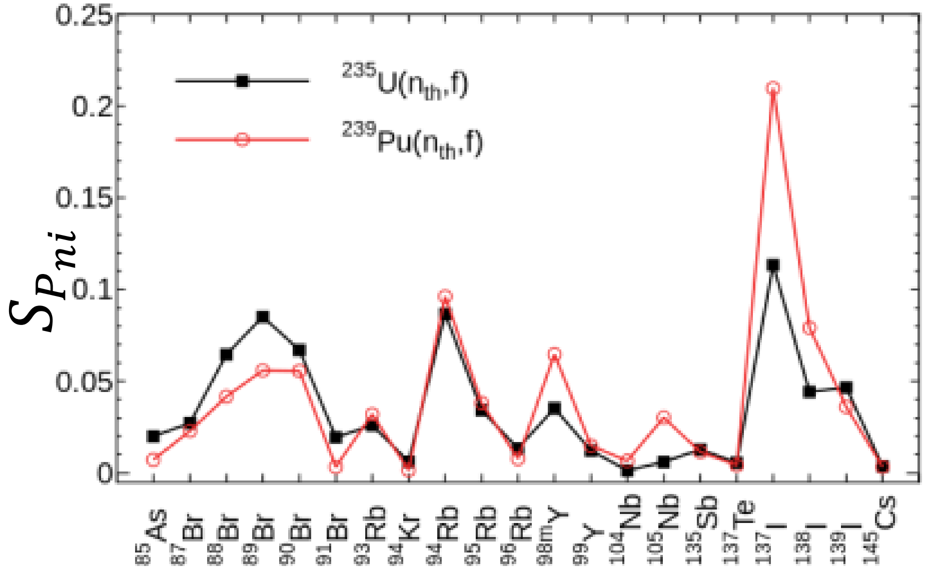
- Large Sensitivity:
  I-137 (24.5 s), Rb-94 (2.7 s),
  Br-88 (16.3 s), Br-89 (4.4 s), Br-90 (1.91 s), Y-98m (2.0 s)

- Nb-104 (4.9 s) Nb-105(3.0 s) are not in any of 6-group, but have a finite effect for Pu-239.
- U-235 & Pu-239 have similar sensitivity, but U-238 show different from them.

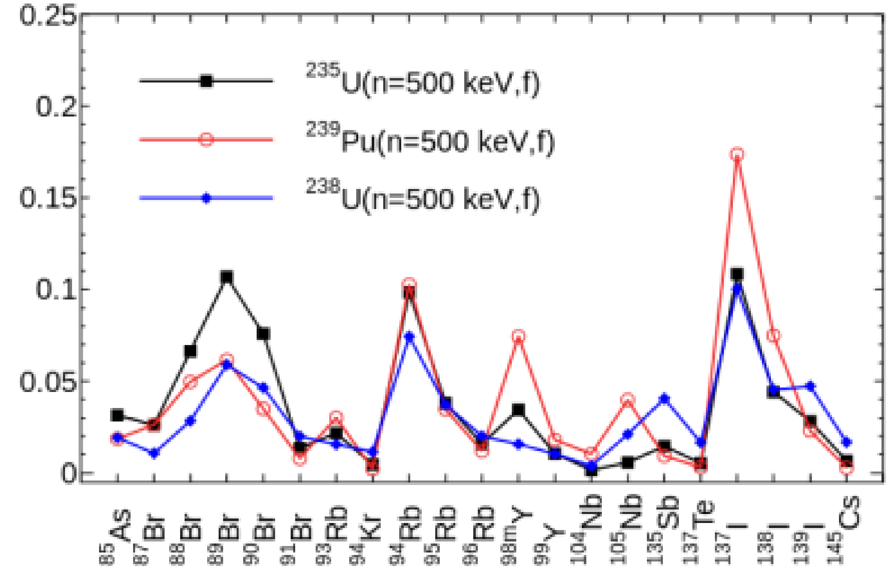
RESULTS

Sensitivity to P_n

Thermal Neutron



Fast Neutron (500 keV)

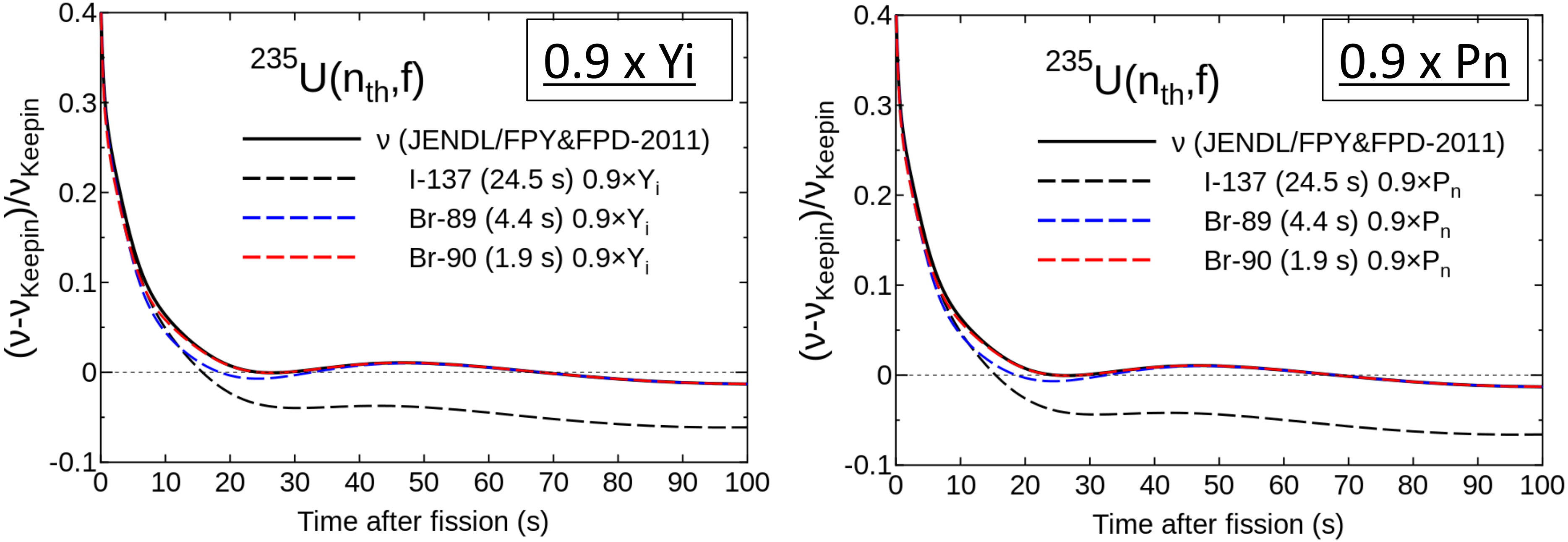


- S_{Y_i} & $S_{P_{ni}}$ lines are similar

TEST of ν_d by changing Y_i & P_n

$$\frac{\nu(t) - \nu_{Keepin}(t)}{\nu_{Keepin}(t)}$$

Change Y_i & P_n of I-137 ($T_{1/2}$=24.5 s), Br-89 (4.4 s), Br-90 (1.91 s) by a factor of 0.9 .



- Change of Y_i & P_n → Similar Curve
- I-137 gives large variation
- Br-89 reduces around 15 sec.
- Br-90 reduces difference around 8 sec.
- **Nuclei with shorter $T_{1/2}$** may have an important role in the deviation at first 10 s.

so-called group 6 nuclei

(not appeared in previous slides)

Summary

Large deviation of Aggregated Calculation with JENDL/FPD & FPY Libraries from observed data is found.

→ Sensitivity of v_d to Y_i & P_n are performed with JENDL/FPD & FPY-2011

- Nuclei with Large Sensitivity have $T_{1/2}$ less than 20 s.
- Nb isotopes are also important for Pu-239 and U-238.
- U-238 show different sensitivity from U-235 & Pu-239.
- S_{Y_i} & $S_{P_{ni}}$ lines are similar.
- For further improvement, accurate P_n & Y_i data of n-rich nuclei may be very important.

Perspectives

- Check Sensitivity as a function of time.
- Check Sensitivity of Decay Heat.

} This will lead improvement for next JENDL/FPD&FPY