

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.

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Colored leaves of the Mt. Adatara (Sep, 2014)

< Last Update: 2014/11/27 10:47 JST >

Topics

JENDL-4.0u
New update files for Au-197 was added in the JENDL-4.0u page. (August 13, 2013)

What's new !

- WWW Chart of the Nuclides (version 2014/10/2) is not available for maintenance now. (2014/11/27)
- Edited the Top Page. (2014/10/1)
- "Staff members" was updated. (April 1, 2014) **NEWS**
- In "JENDL FP Decay Data Files 2011 (JENDL/FPD-2011)", Ag-115 (ground state) was updated. (2013/10/24)
- The "Staff members" page was updated. (2013/10/02)
- The maintenance for "View of Average Resonance Cross Section (VARCS)" was completed. (2013/09/19)
- "View of Average Resonance Cross Section (VARCS)" is not available for maintenance now. (2013/09/18)
- A new update file for Au-197 was added in the JENDL-4.0u page. (August 13, 2013)
- New update files for 12 nuclides were added in the JENDL-4.0u page. (July 10, 2013)

Delayed Neutron (DN)

- Reactor Physics

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

- Final r-process abundance after freeze-out

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)

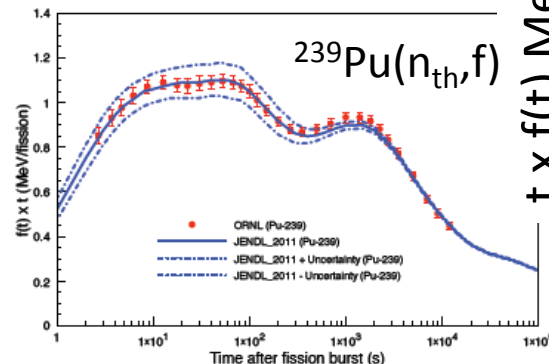
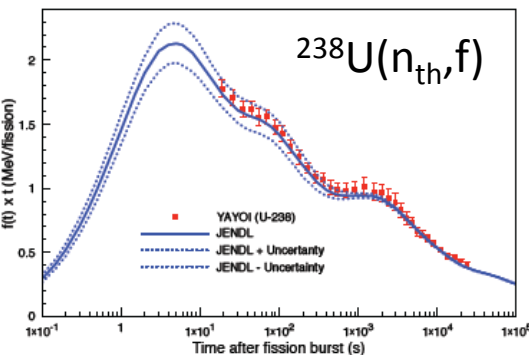
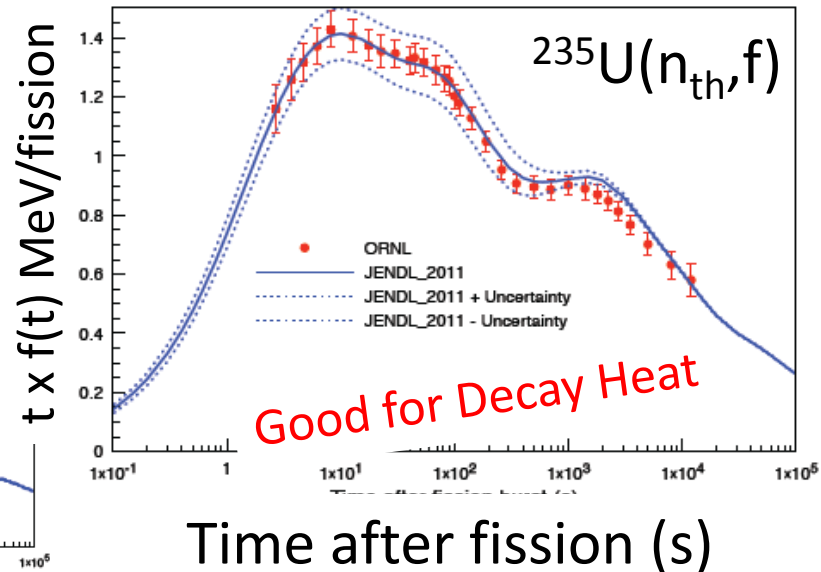
Based on ENDF/B-VII with modifications to be matched with FPD-2011.
 Ternary Fission is also included.

Decay Heat (MeV/s)

$$f(t) = \sum_i \underbrace{\lambda_{\beta+\gamma}(i)}_{\text{FPD}} \underbrace{\bar{E}_{\beta+\gamma}(i)}_{\text{FPD} \times \text{FPY}} \underbrace{N_i(t)}_{\text{No. of Nuclide}}$$

Decay Rate of $\beta+\gamma$
 Average Energy
 No. of Nuclide

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



PROBLEMS in JENDL/FPD & FPY-2011

Delayed Neutron (1/s)

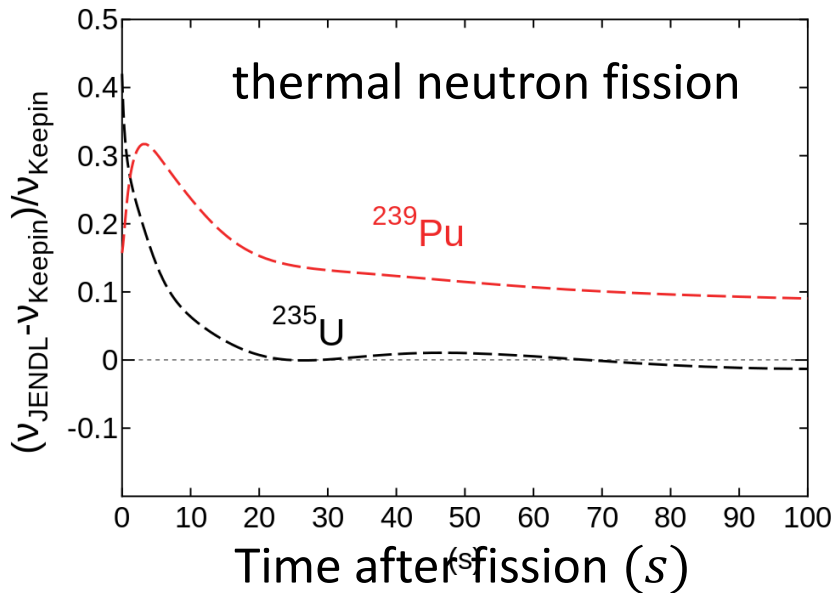
ν_d in JENDL-4.0 v.s. ν_d with JENDL/FPY & FPD-2011

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

	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 !

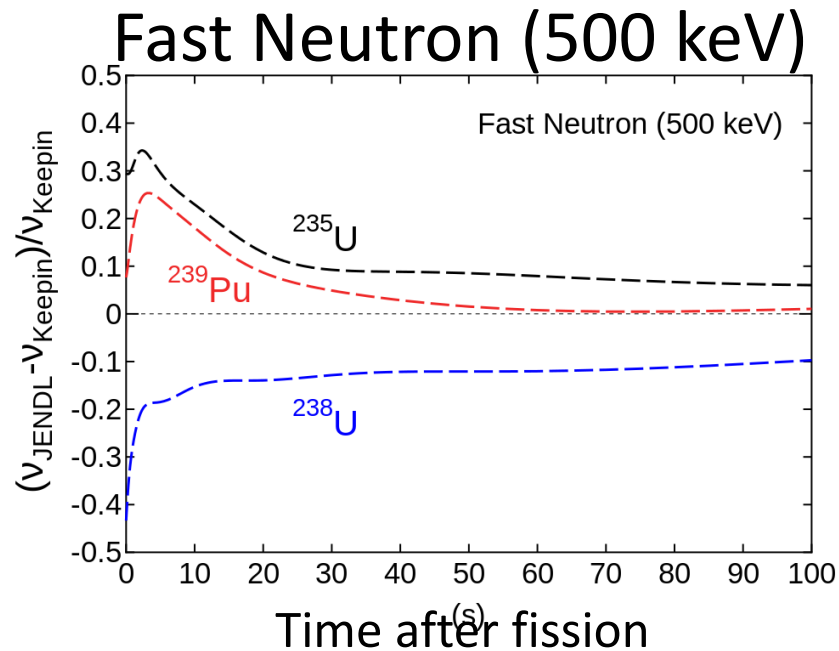
Time distribution of ν_d (Deviation from **Keepin's data**)



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

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.



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

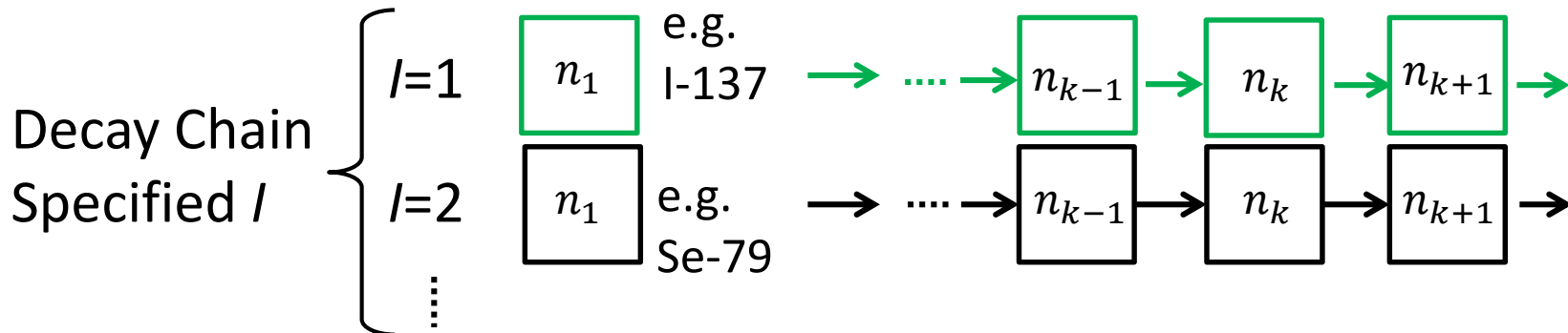
◆ Bateman Equation (single decay chain)

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

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.

Solution: $n_i(t) = y_i \sum_{j=1}^i d_j e^{-\lambda_j t}$ $n_1(0) = y_1 = \text{Fission Yield}$
 $n_k(0) = 0 \quad (2 \leq k)$

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



Superposing the Solution
of Decay Chain I

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

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

To check nuclei important for delayed neutron emitter ...

Sensitivity

1. Fission Yields, Y_i

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

2. Delayed Neutron Emission Probabilities, P_n

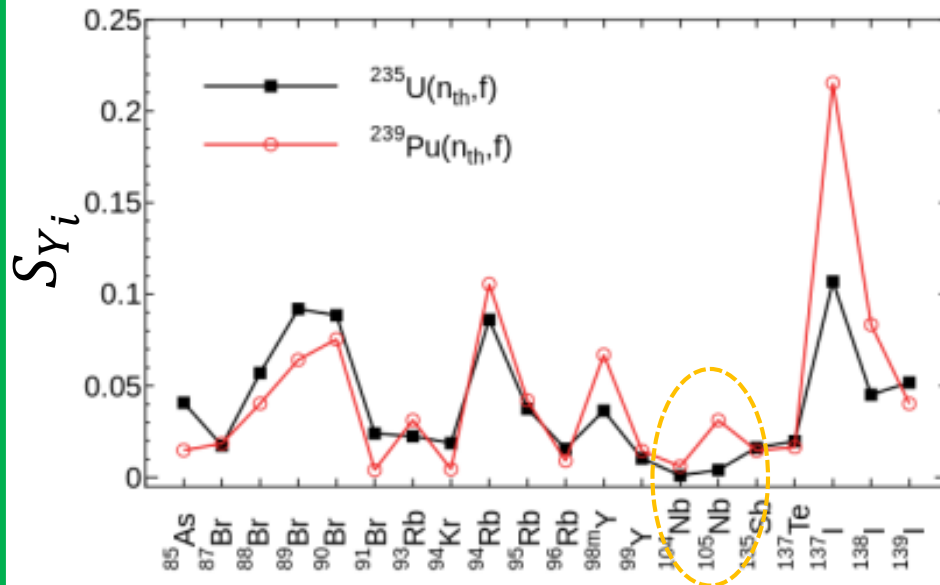
$$S_{P_{ni}} = \frac{(\Delta\nu_d/\nu_d)}{(\Delta P_{ni}/P_{ni})}$$

RESULTS

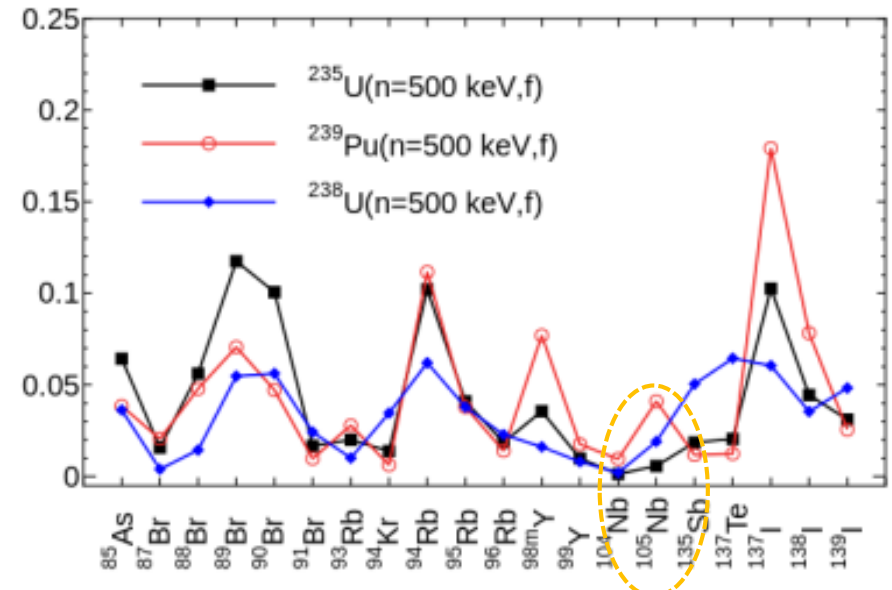
Lines are just guide for eye

Sensitivity to Fission Yields

Thermal Neutron



Fast Neutron (500 keV)

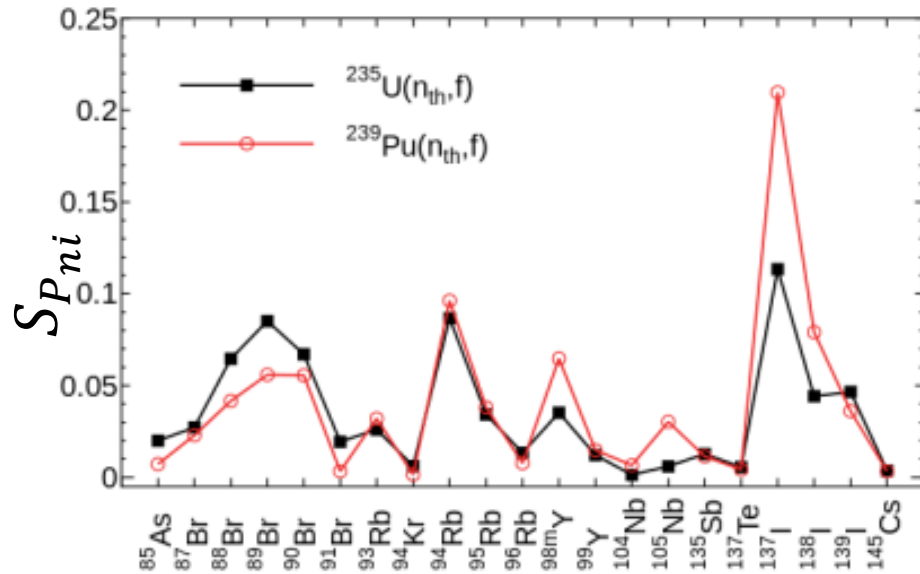


- Large Sensitivity:
I-137 (24.5 s), Rb-94 (2.7 s),
Br-88 (16.3 s), Br-89 (4.4 s), Br-90 (1.91 s), Y-98m (2.0 s)
- Nb-104 (4.9 s) Nb-105(3.0 s) are not in any of 6-group, but have a finite effect for Pu-239.
- U-235 & Pu-239 have similar sensitivity, but U-238 show different from them.

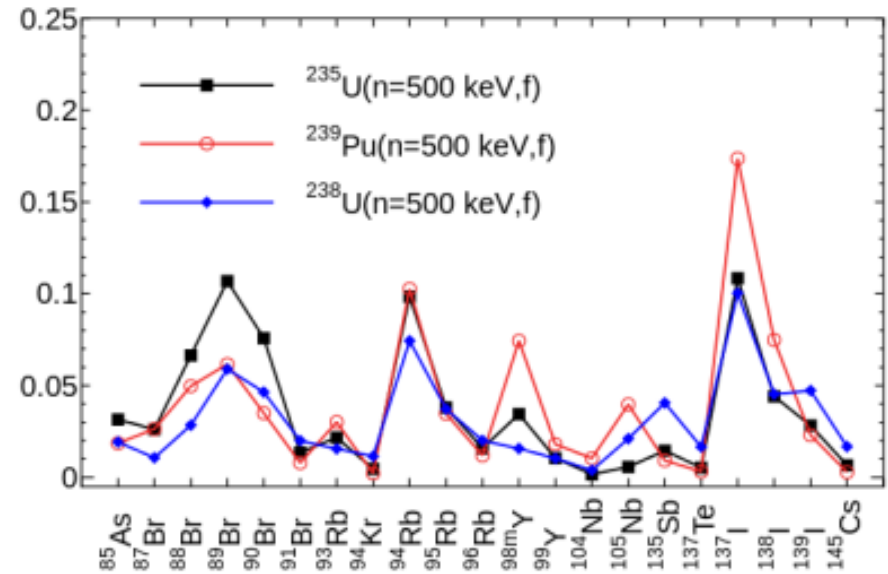
RESULTS

Sensitivity to P_n

Thermal Neutron



Fast Neutron (500 keV)

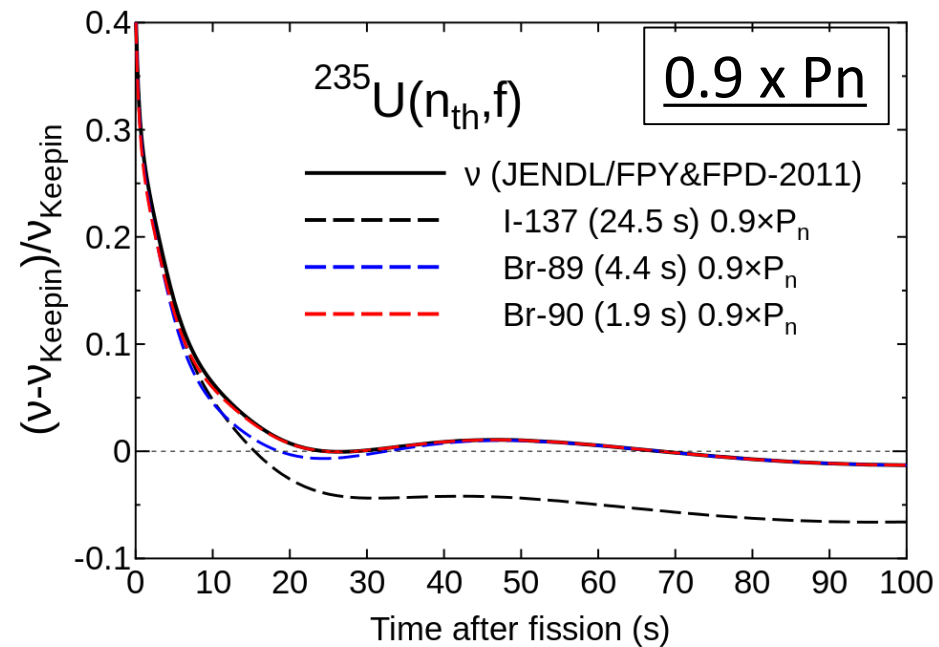
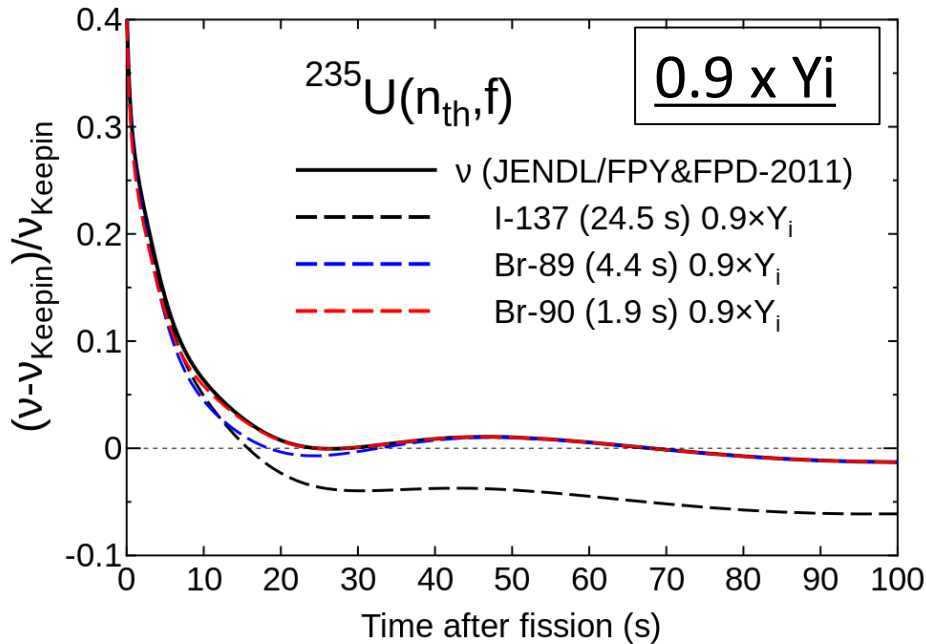


- S_{Y_i} & $S_{P_{ni}}$ lines are similar

TEST of v_d by changing Y_i & P_n

$$\frac{v(t) - v_{Keepin}(t)}{v_{Keepin}(t)}$$

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



- Change of Y_i & $P_n \rightarrow$ 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.

↑ (not appeared in previous slides)

so-called group 6 nuclei

Summary

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

→ Sensitivity of ν_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