Feedback on Delayed Neutron 6-Group Parameters

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June 22, 2010

Reminder

Delayed Neutron Production described as

$$R(t) = \sum_{i=1}^{N} \alpha_i \lambda_i e^{-\lambda_i t}$$

N: number of groups

6 (ENDF/JENDL)

8 (Subgroup 6 of WPEC/JEFF)

α_i: fractional abundance in group *i*

λ_i: decay constant in group *i*

ENDF/B-VI

delayed neutron production rates obtained by fitting calculations of CINDER-10 (England and Wilson 1993)

- Suffered from limited decay data, neutron emission probabilities, etc.
- **Some issues were well-known in community:**

Benchmark results for delayed neutron data

S.C. van der Marck, R. Klein Meulekamp, A. Hogenbirk, and A.J. Koning

Abstract. We have calculated the effective delayed neutron fraction β_{eff} for 32 benchmark configurations for which measurements have been reported. We use these results to test the delayed neutron data of JEFF-3.0, ENDF/B-VI.8, and JENDL-3.3.

- Almost all results are within 6% of the experimental value. Only in a limited number of cases, the results lie outside the combined experimental and statistical uncertainty margin.
- Judging by the results for TCA, IPEN/MB-01, Stacy, Winco, and Proteus, the JENDL-3.3 nuclear data library gives the best α and β_{eff} results for LWR and HTR type applications.
- JEFF-3.0, ENDF-B/VI.8 lead to ... tion of β_{eff} for LWR and HTR type applications.

- For fast systems the three libraries ... form roughly equally well, wh... sis of the results for Masu...

Jeff-3.0, ENDF/B-VI.8 lead to a ~4% over prediction of β_{eff} in LWR HTR type applications

ENDF/B-VI

Determination of Delayed Neutrons Source in the Frequency Domain
Based on in-pile Oscillation Measurements

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Figure 3: Absolute values of $g(\omega)$, as measured in IRR-II by KANDI II (blue) and KANDI III (black), as a function of angular frequency. Measured values are compared with calculated values based on Keepin (green), ENDF/B-VI (red), JEF-2.2 (magenta) and Brady & England (orange) group parameters. Calculated values account for photo-dissociation of deuterium [2] in heavy-water coolant and moderator of IRR-II.

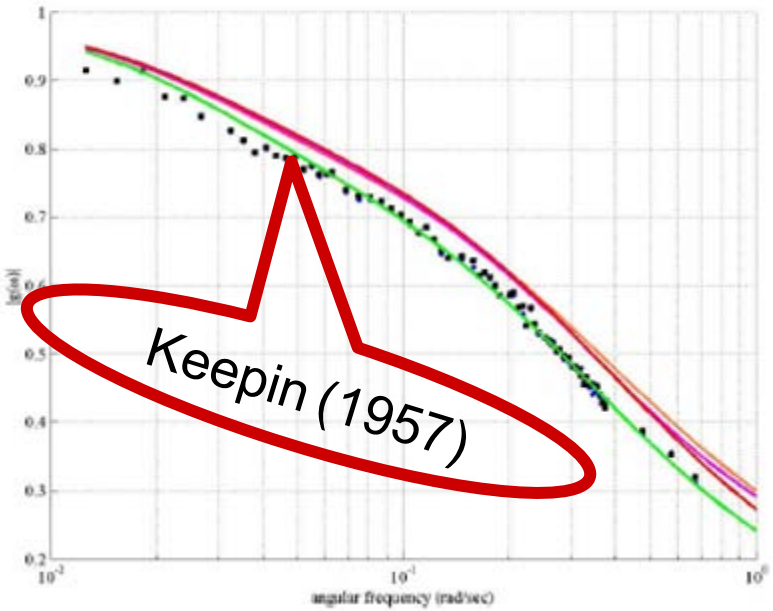
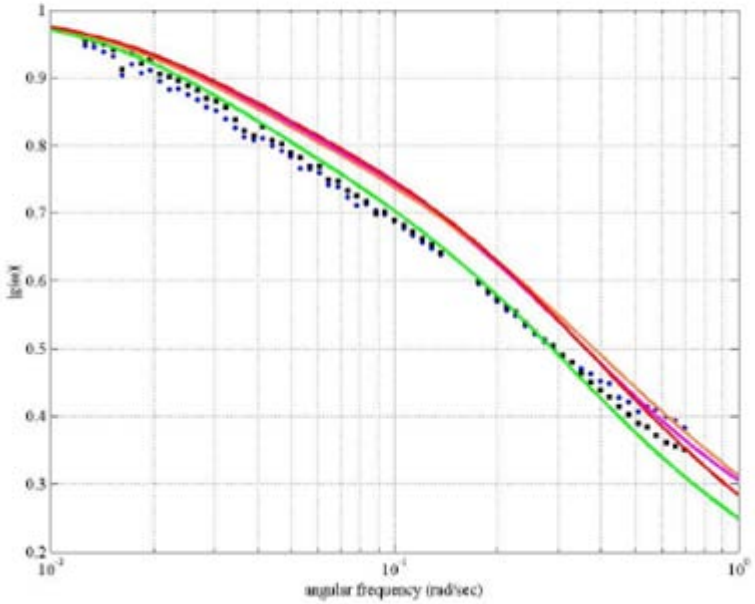


Figure 4: Absolute values of $g(\omega)$, as measured in IRR-I by the radial tunnel detector (blue) and tangential tunnel detector (black), as a function of angular frequency. Measured values are compared with calculated values based on Keepin (green), ENDF/B-VI (red), JEF-2.2 (magenta) and Brady & England (orange) group parameters.



WPEC-6 2002

- **Recommended a new 8 group representation**
- **Provided recommended parameters and spectra for 30+ systems**

- **Eight group structure adopted by JEFF**
- **Modified back to six-group by JENDL**

Table A3.3. Relative abundances and 16-group energy spectra (*cont.*)

```
89: U-235__fast: 0.624 MeV, 8-groups, Piksaikin et al. (1997)
Half-lives +/- 1 sigma  Rel. Abun. +/- 1 sigma
1 55.6  +/- .000    3.40E-02 +/- 7.00E-04
2 24.5  +/- .000    .150   +/- 3.00E-03
3 16.3  +/- .000    9.91E-02 +/- 3.00E-03
4  5.21  +/- .000    .200   +/- 4.00E-03
5  2.37  +/- .000    .312   +/- 7.00E-03
6  1.04  +/- .000    9.31E-02 +/- 4.00E-03
7  .424 +/- .000    8.71E-02 +/- 4.00E-03
8  .195 +/- .000    2.40E-02 +/- 1.00E-03
T-mean = Sum[a(i)*T(i)]    = 9.10 s
T-mean = 1.0/Sum[a(i)/T(i)] = 1.66 s

DELAYED NEUTRON SPECTRA:
DN Group Number-->
   1    2    3    4    5    6    7    8   Comb.
1  0.000 0.000 0.000 0.000 0.000 0.001 0.014 0.008 0.002
2  0.000 0.012 0.003 0.015 0.050 0.056 0.078 0.066 0.034
```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ENDF/B-VII.0

2002 - Wilson & England published an article
(Progress in Nuclear Energy 41 71 (2002))
Calculated new delayed neutron production rate parameters and <ν>
(no spectra) utilizing CINDER'90

with
Fission product set: England & Ryder (1994)
ENDF/B-VI fission produce decay data
P_n data
England and Brady
Pfeiffer, Kratz and Moller (QRPA)

Methods discussed appear to be those used to populate ENDF/B-VII.

More on this in a minute

ENDF/B-VII Benchmarking

Benchmarking ENDF/B-VII.0
Steve C. van der Marck
NDS 107 12 (2006)

TABLE LIII: The experimental and calculated β_{eff} (in pcm). The uncertainty for C/E includes only the statistical uncertainty of the calculation. This corresponds to the error bar in Fig. 144. The experimental uncertainty range is shown with dashed lines in Fig. 144.

	Experiment	Calculation		C/E
		ENDF/B-VI.8	ENDF/B-VII.0	ENDF/B-VII.0
TCA	771±17	812±9	769.2±1.3	0.998±0.002
IPEN	742±7	782±4	747.6±4.0	1.008±0.005
Masurca_R2	721±11	746±7	729.3±6.9	1.012±0.009
Masurca_Z2	349±6	343±5	339.5±4.5	0.973±0.013
FCA-XIX-1	742±24	746±8	732.4±7.5	0.987±0.010
FCA-XIX-2	364±9	365±5	367.6±4.8	1.010±0.013
FCA-XIX-3	251±4	255±4	246.2±4.1	0.981±0.017
Sneak-9C1	758±24	741±7	739.2±7.0	0.975±0.009
Sneak-7A	395±12	368±5	361.6±4.7	0.915±0.013
Sneak-7B	429±13	421±5	416.0±4.9	0.970±0.012
Sneak-9C2	426±19	388±5	376.4±4.8	0.884±0.013
Zpr-Heu	667±15	692±9	689.3±8.9	1.033±0.013
Zpr-U9	725±17	732±8	714.9±8.0	0.986±0.011
Zpr-Mox	381±9	363±6	367.0±5.1	0.963±0.014
Zpr-Pu	222±5	223±5	236.9±5.2	1.067±0.022
Godiva	659±10	670±8	668.7±4.0	1.015±0.006
Topsy	665±13	640±8	643.2±3.8	0.967±0.006
Jezebel	194±10	187±5	197.3±2.1	1.017±0.011
Popsy	276±7	278±5	266.4±2.4	0.965±0.009
Skidoo	290±10	313±6	312.1±2.7	1.076±0.009
Flattop-23	360±9	359±6	356.9±2.8	0.991±0.008

Feedback

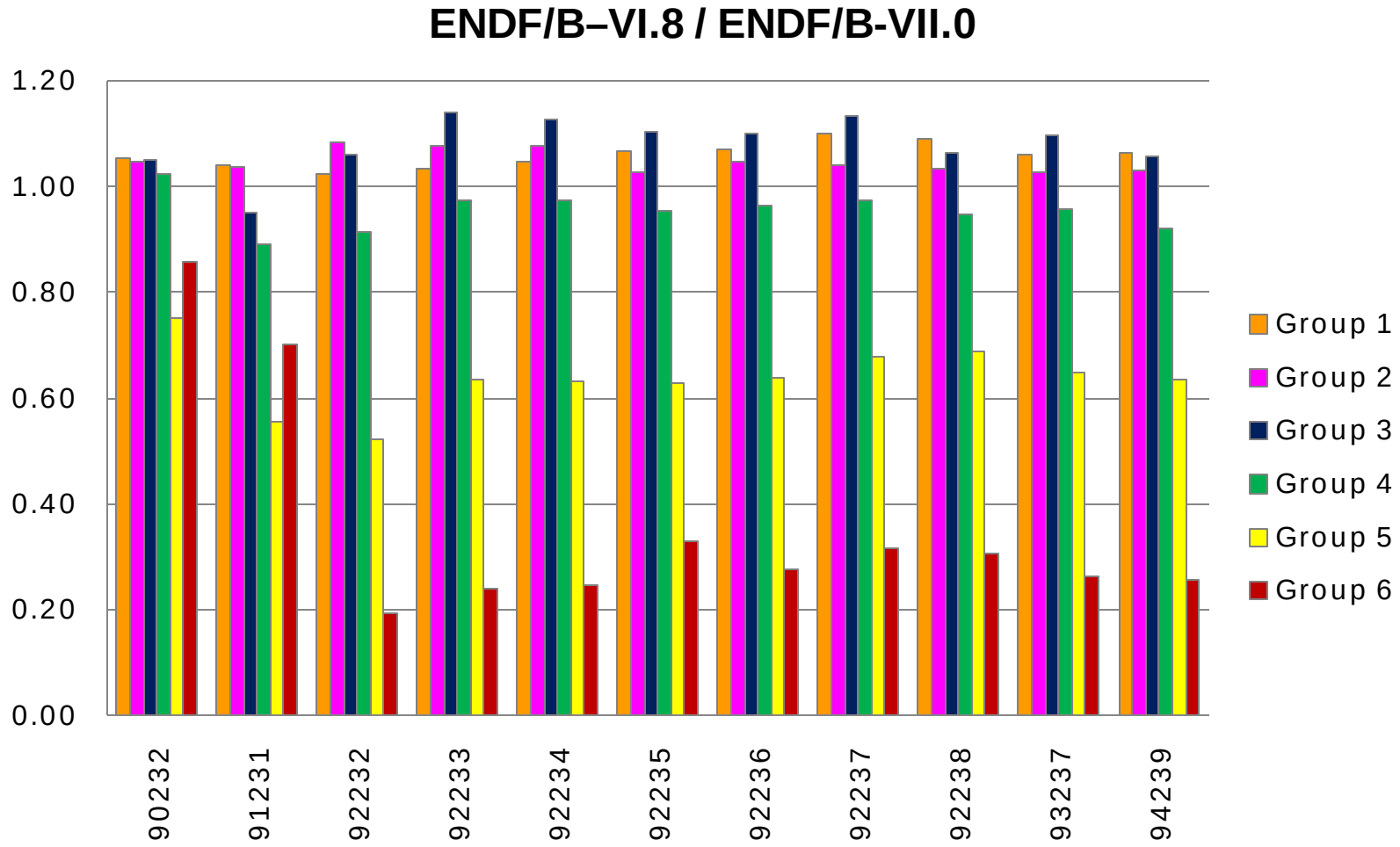
Something major happened in group 6

"…pure sample of ^{235}U … I get a lambda-6 of 8.63638 / sec with a corresponding half-life of 0.08026 s … GODIVA-4 I have lists a half-life of 0.181 +/- 0.0054 s

(Brian Kiedrowski MCNP development team)

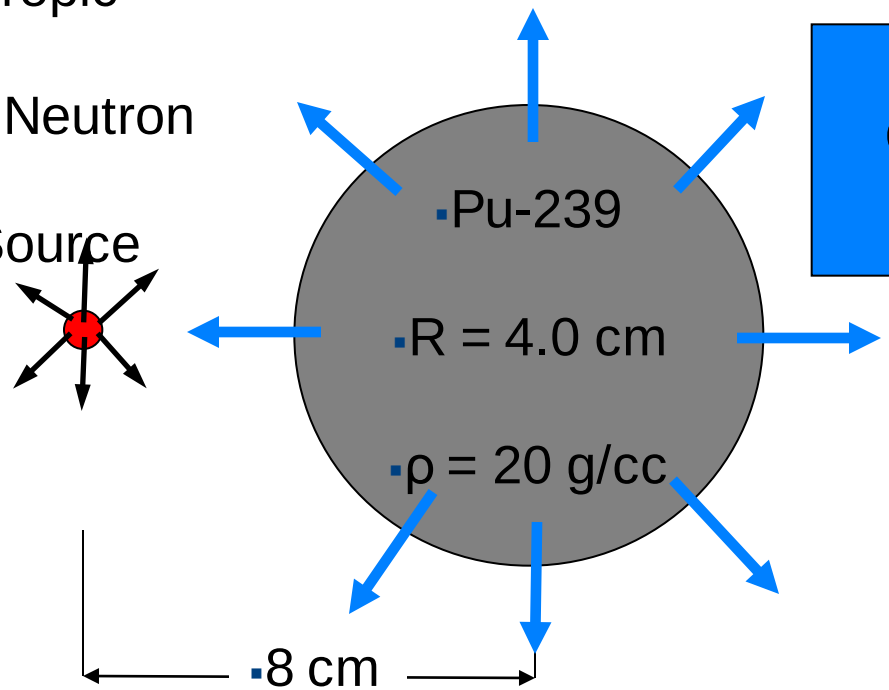
Group 6 does not contribute significantly to β_{eff}

Feedback


ENDF/B–VI.8 / ENDF/B-VII.0
1.20
1.00
0.80
0.60
0.40
0.20
0.00
90232
91231
92232
92233
92234
92235
92236
92237
92238
93237
94239
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6

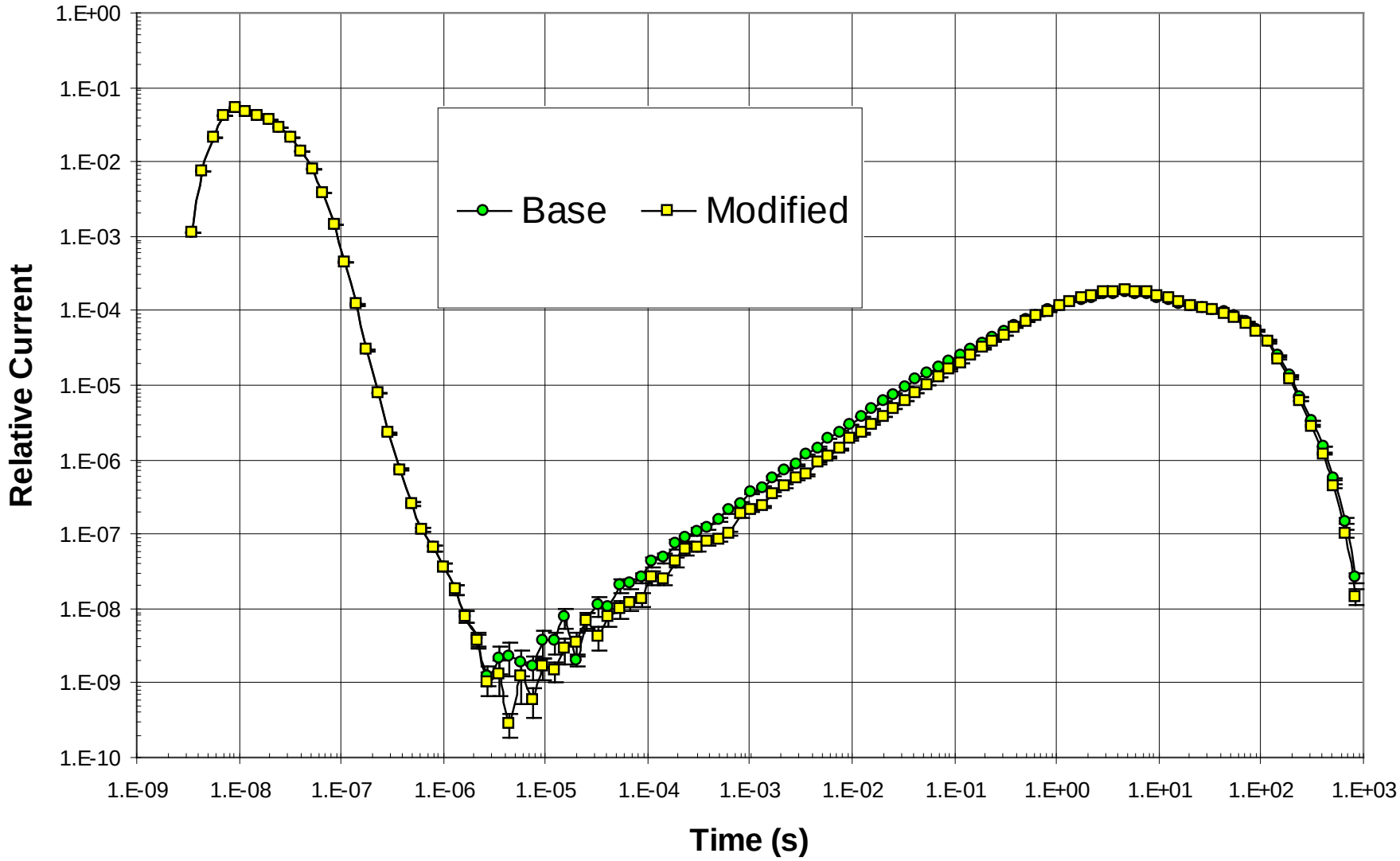
Test Problem

- Isotropic
- 1 MeV Neutron
- Pt. Source

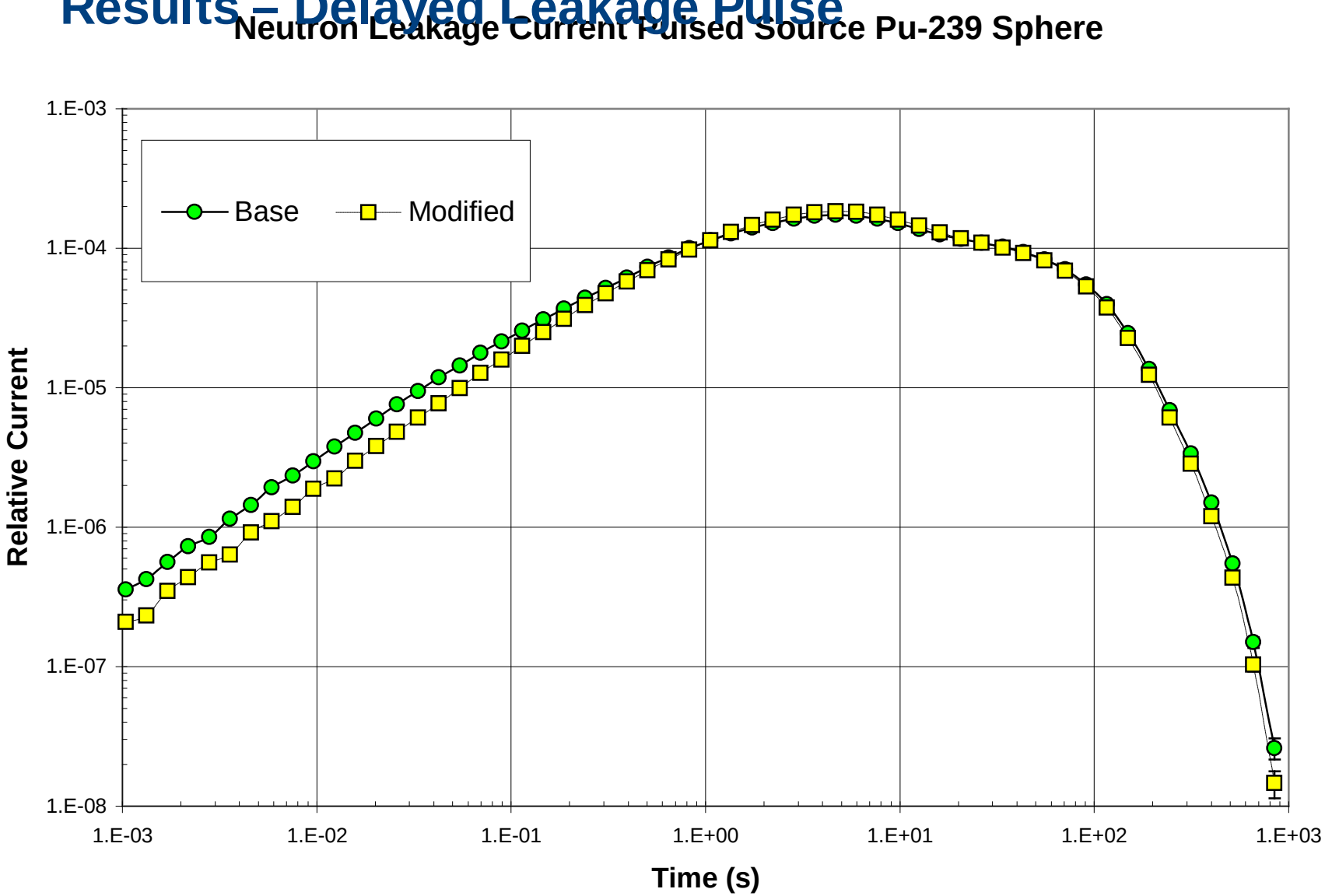


- Calculate time-dependent neutron leakage current

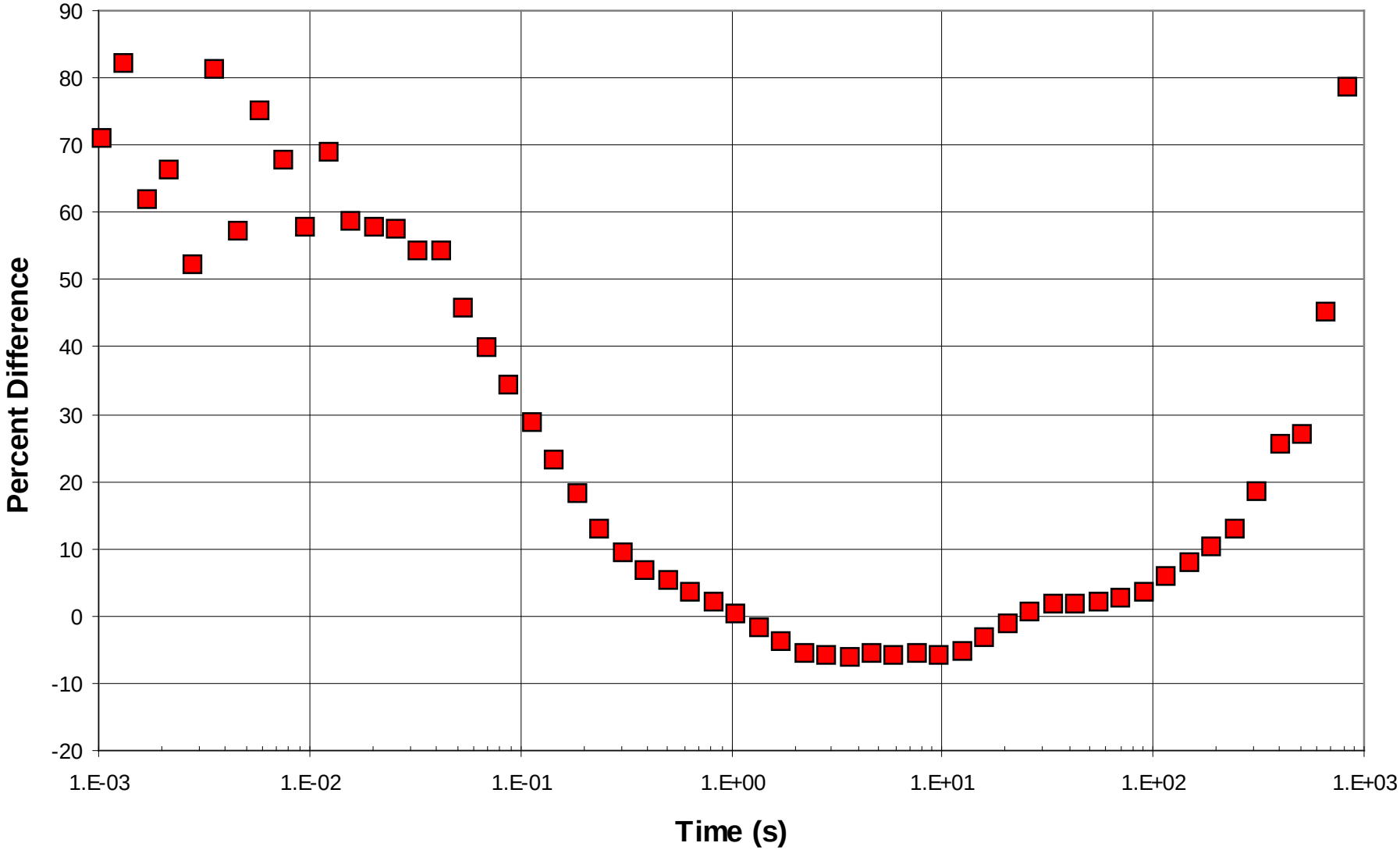
Results – Entire Leakage Pulse



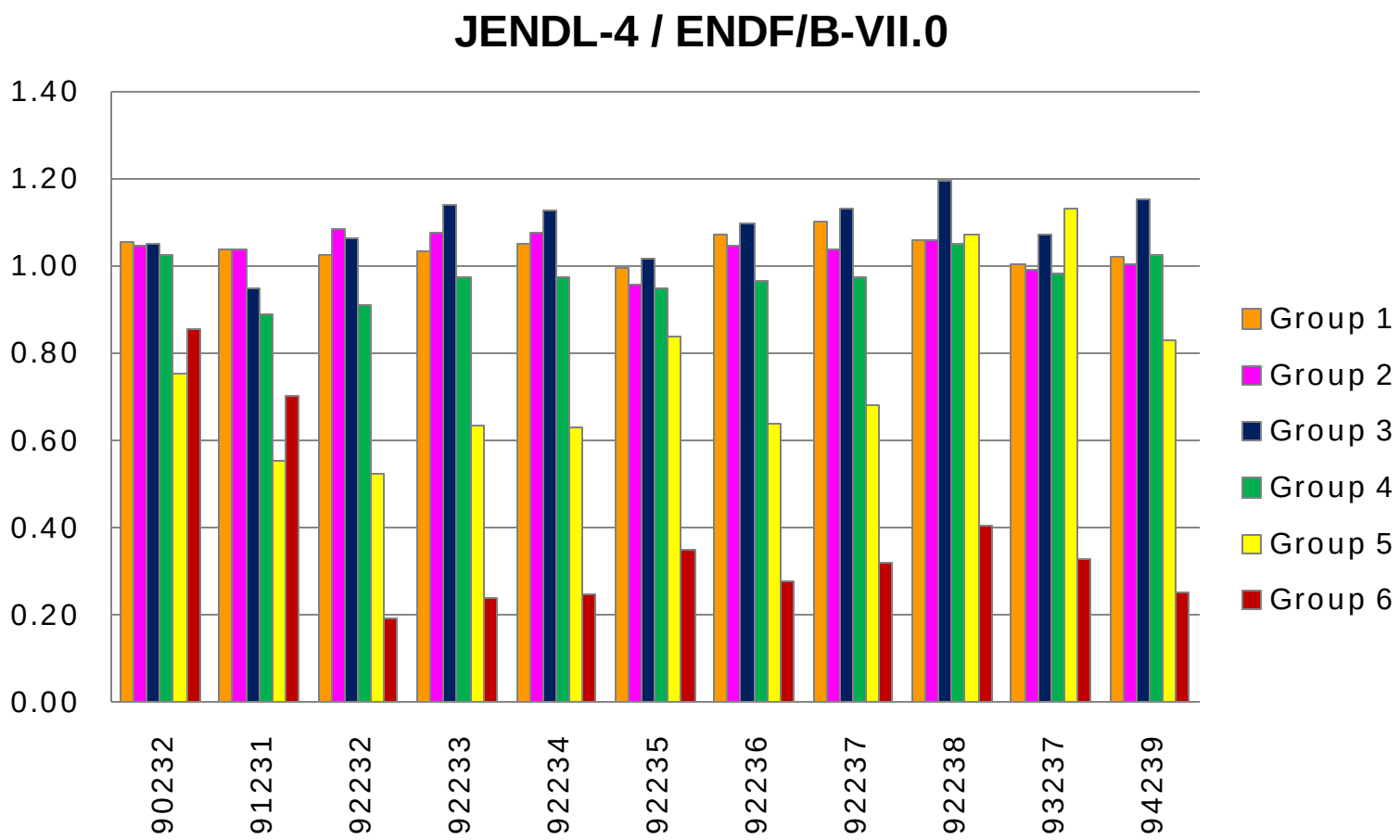
Results – Delayed Leakage Pulse



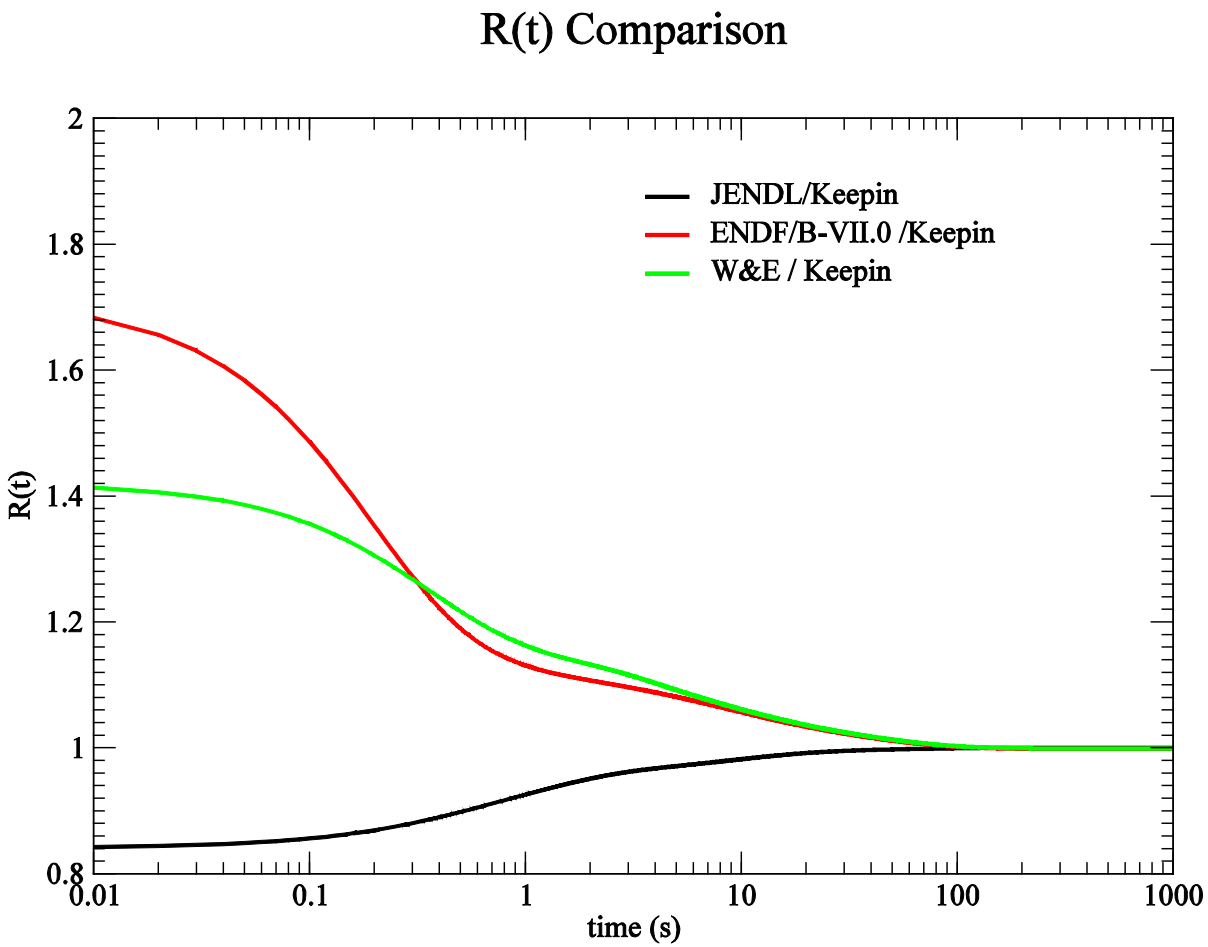
Results – Percent Difference



ENDF/VII vs. JENDL-4



ENDF/B-VII.0 vs. JENDL-4 (cont.)



What's Going On?

- **New Calculations Correct?**
- **Possible Processing Error?**

Table 12. 6-Group Parameters from Unconstrained STEPIT Fits to CINDER'90–P-K-M Results for a Range of Fission Histories and Decay Times Extending to 800 s

^{235}U(f)	0.377	1.073	a_i:	0.0309942	0.1623911	0.1432004	0.4412726	0.1594547	0.0626870
			λ_i:	0.0124983	0.0316523	0.1009416	0.2990340	1.0831110	4.7335680

λ	0.01249056	0.03182406	0.1093753	0.3169898	1.353983	8.636377
α	0.03197266	0.1663712	0.1613104	0.4596467	0.1334993	0.04719978

- **Problems in methodology?**

LANL Project
Delayed Particle Production

- Nuclear structure
  - Complete level schemes - **RIPL-3**
  - Beta decay Q-values
    - **Q_β from MM mass model (FRDM)**
  - Beta decay transition probabilities
    - **ENSDF (when available)**
      - **low-lying discrete states**
    - **FRDM + QRPA (Möller et al.)**
      - **Continuum**
      - **no ENSDF data**

- Nuclear De-excitation
  - **Statistical Hauser-Feshbach model**
  - **All possible transitions from (A,Z+1) to (A-1,Z+1) are included**

- **Nuclear inventory calculation, by the CINDER code system**
  - ENDF/B fission product yields (England & Ryder)
  - 3400 nuclei database (~3100 unstable)
  - Time dependent inventories and activities

We can obtain

- β and γ heating after fission burst
- Delayed neutron spectra
- Delayed γ energy spectra for fission

LANL Project
Delayed Particle Production

- Nuclear struct
  - Complete
  - Beta deca
    - Q_β fr
  - Beta deca
    - ENS
    - FRD
- Nuclear De-
  - Statistica
  - All possi
  - (A,Z+1) t

Find that QRPA tends to over populate high energy states

Over prediction of P_n?

ory
the CINDER

product
& Ryder)
abase
e)
t inventories

after

on spectra

- Delayed γ energy spectra for fission

Path Forward?

- **Keep what is there – more research**
  - might not be completed by VII.1 release
- **Go back to ENDF/VI.8**
  - know there were issues
- **Adopt WPEC-6 8 group structure**
  - Decision previously made to not to this?
- **Adopt JENDL's interpretation of WPEC recommendations**
- **…**

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Thank you!