Validation of FISPACT-II Decay Heat Predictions for LWR Spent Fuel

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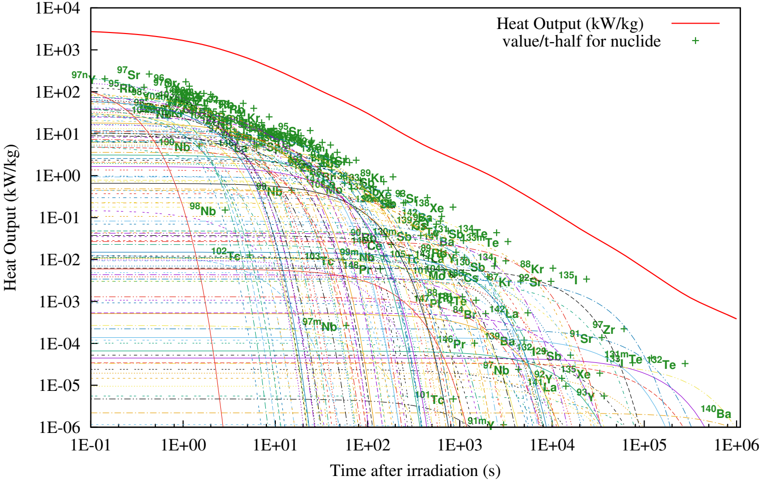
Contents

- Prediction of fission decay heat is essential in safety analysis of reactors and considerable effort has resulted in large (but narrow) experimental data-set for fissions (*cf* CCFE-R(15)25 for fusion decay heat)
- Decay heat simulation provides standard for validation of fission yield data, decay data and simulation codes
- No two libraries produce the same inventories – although DH can show uncanny similarity
- Complexity of inventory from fission makes deconvolution a challenge:



- $^{235}U_{th}$ pulse using JEFF-3.1.1 DD+nFY

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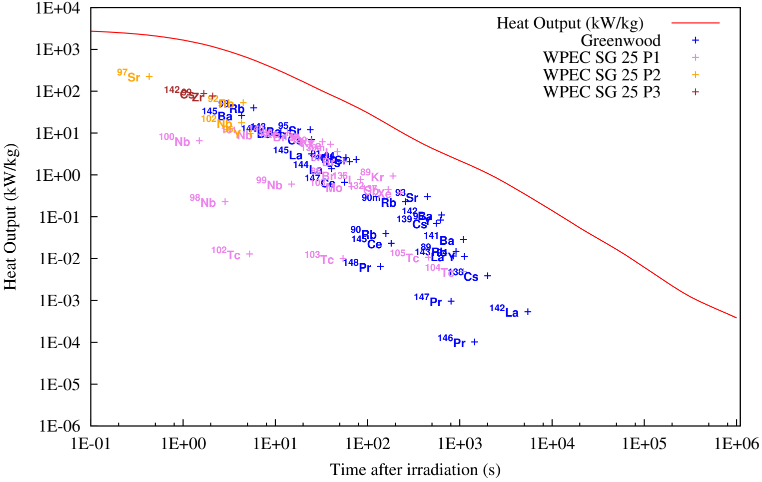


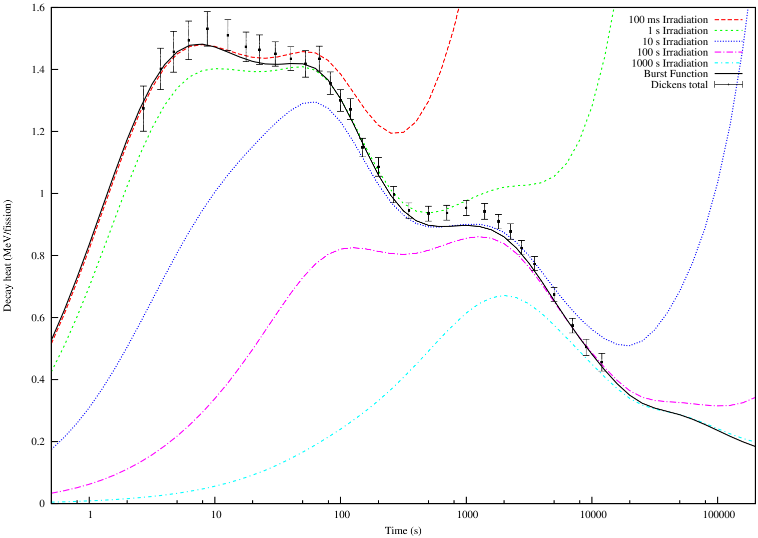
- Greenwood/WPEC25 priority nuclides shown

Fission decay heat has been the subject of several experiments over several decades. Even those experiments with the same fissile are all unique, notably differing in:

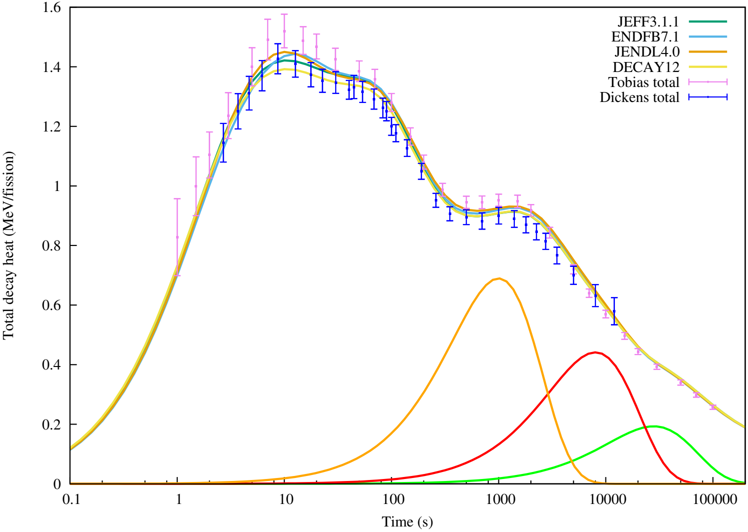
- Irradiation duration and flux spectrum
- Measurement techniques
- Fission rate determination
- Sample preparation/removal/post-irradiation processing
- Contamination corrections (capture/epithermal/impurity)
- **Correction methodology** (finite to pulse, noble loss, etc)

Author	Method	Nuclide(s)	Irr. (s)	Year
Yarnell, LANL	Calor.	^{233}U ^{235}U ^{239}Pu	2E4	1980
Dickens, ORNL	β,γ	^{235}U ^{239}Pu ^{241}Pu	1-100	1980
Baumung, KfK	Calor.	^{235}U	200	1981
Akiyama, YAYOI	β,γ	^{232}Th ^{233}U ^{235}U ^{238}U ^{239}Pu	10-300	1982
Johansson, Uppsala	β,γ	^{235}U ^{238}U ^{239}Pu	4-120	1987
Schier, Lowell	β,γ	^{235}U ^{238}U ^{239}Pu	<1	1997
Ohkawachi, YAYOI	β,γ	^{235}U ^{237}Np	10-300	2002
Tobias, CEGB	stat.	^{235}U ^{239}Pu	-	1989

- Tobias is a statistical meta-analysis over pre-1989 experiments not including Lowell
- Experimental data should not know borders



- ^{241}Pu thermal fission
- No individual experiment covers pulse



- Capture contamination depends upon precise knowledge of inventory and spectrum (^{235}U shown)

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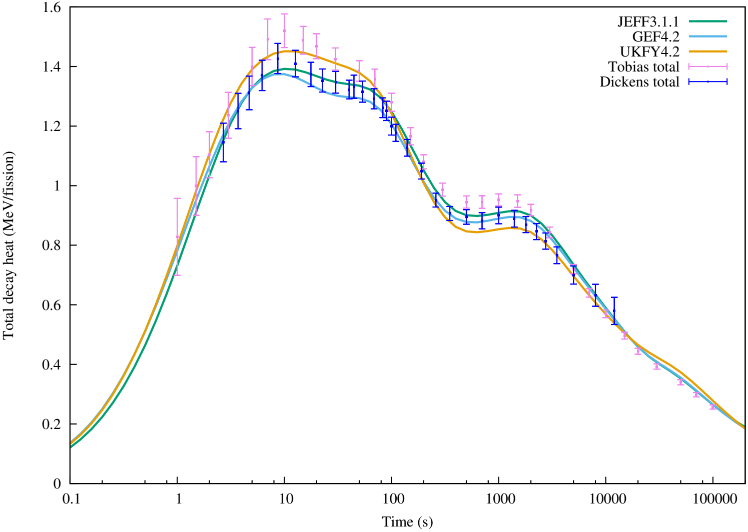
FISPACT-II is a general-purpose simulation code, completely rewritten from legacy FISPACT in modern Fortran

- Can use any ENDF-format nuclear data
- Calculates numerous observables: activity, heat, various doses, detailed inventory, sophisticated pathway trees
- RRR+URR self-shielding with PT from CALENDF
- Generate sources with multi-differential data
- Developed to accommodate a complete, technological library (*eg* TENDL) with all isomeric states, HFR, double-diff ...
- Provides robust simulation methodology that can be applied to reactor operation, activation/transmutation, fusion applications, high-energy, security, astrophysics ...



- ^{235}U thermal pulse total heat
- Varied nFY with JEFF-3.1.1 DD simulation

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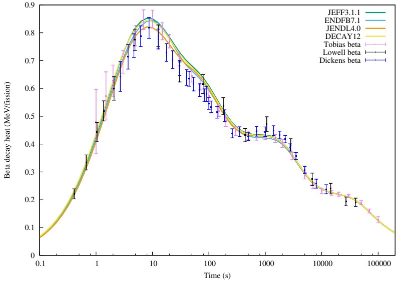
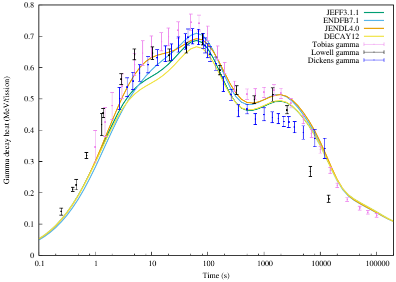
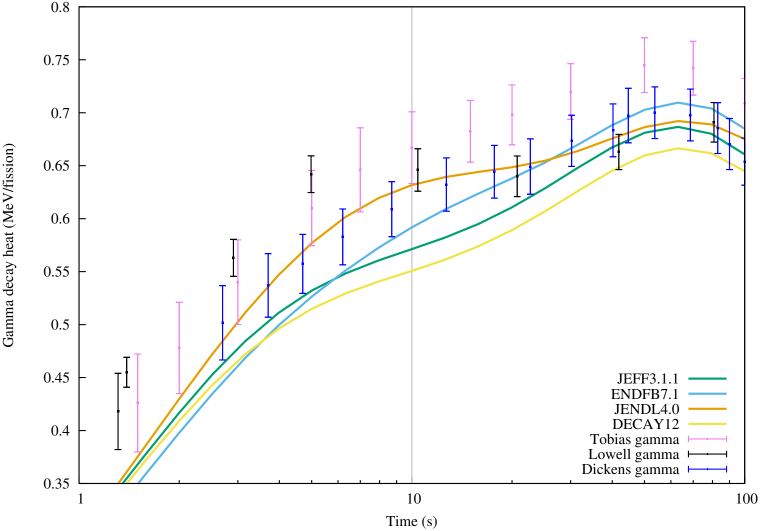




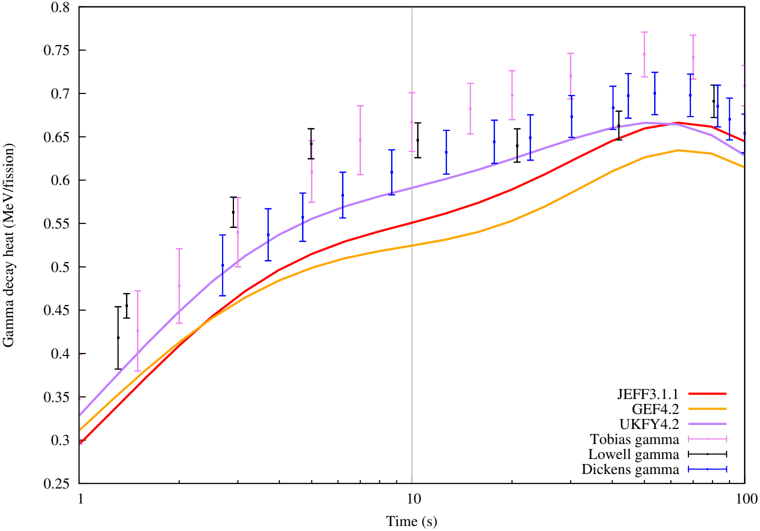
- JEFF-3.1.1 nFY simulation ^{235}U pulse beta (L) gamma (R)
- Well-known Pandemonium γ-deficiency can be probed through multi-library comparison



- Example: isolate γ-heat of ^{235}U pulse at 10s using same nFY to compare DD

Nuclide	JEFF3.1.1	ENDFB7.1	JENDL4.0	DECAY12
Rb92	3.12	3.85	3.85	3.13
Rb93	3.21	3.11	2.80	3.21
Nb102	1.56	2.50	0.64	1.56
Y96	0.15	0.15	2.23	0.15
Kr91	1.98	1.99	2.00	1.98
Y96m	1.93	1.85	1.85	1.93
Ba143	2.13	2.13	1.81	1.77
Nb102m	0.64	0.06	0.95	0.06

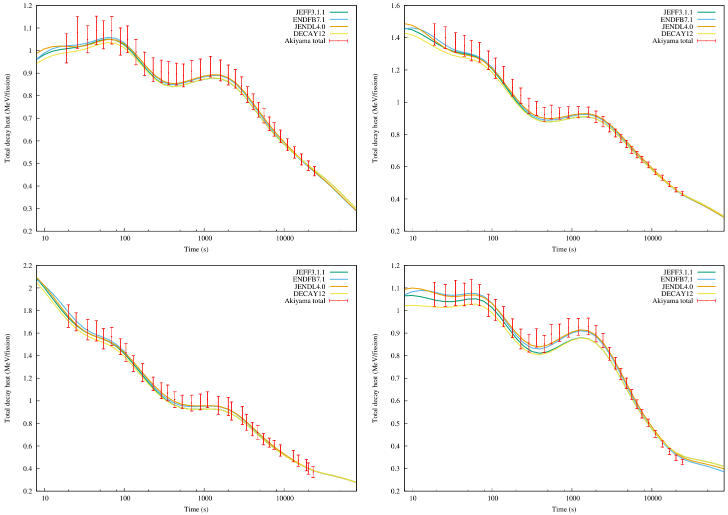
- Normalised heat output in W/fission for ^{235}U pulse at 10s
- Some appear corrected only in JENDL/ENDF, some may be re(mis?)-allocation to isomer, such as Nb102m.



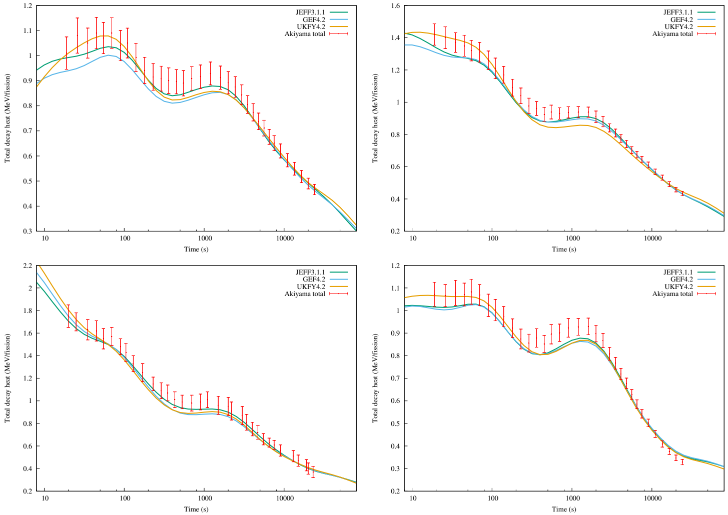
- Same story, but now variety of nFY for γ-heat of ^{235}U pulse at 10s

Nuclide	JEFF3.1.1	GEF4.2	UKFY4.2
Rb92	3.12	2.90	3.34
Rb93	3.21	3.14	3.95
Sr95	1.91	2.08	2.14
Y97	1.14	1.88	1.64
Nb102	1.56	1.23	0.58
Kr91	1.98	1.87	1.64
Y96m	1.93	0.38	**4.37**
Ba143	2.13	1.99	1.97

- Normalised heat output in W/fission for ^{235}U pulse at 10s
- Uncanny differences in dominant fission production yields, isomeric yields?



- Akiyama 3,5,8,9 vs 400keV (JEFF nFY)



- Akiyama 3,5,8,9 vs 400keV nFY (JEFF DD)

Some thoughts:

- Decay heat experiments are complex, old(er than me), and could benefit from review for specific fuels/times
- Meta-analysis of experiments with systematic challenges does not improve data quality
- Integration of new decay data needed for β/γ heat
- Difficult to assign superiority of files due to spread of experimental data
- FISPACT-II allows versatile simulation which can probe DH subtleties and expose unresolved issues with DD and/or nFY

http://www.ccfe.ac.uk/EASY.aspx

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Thank you for your attention