Decay heat calculations

An industrial perspective

Total, beta and g-ray with JEFF-3.1

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Work supported by the UK Nuclear Decommissioning Authority

nexiasolutions

Nuclear expertise intelligently applied

Date: 17/7/06

Summary of presentation

- Spent Nuclear Fuel Decay heat issues
- Validation for transport, storage and reprocessing
- Validation for short times
  - Thermal fission of U235: Total, ß and g-ray
  - Uncertainties on U235 g-ray summation calculations
  - Thermal fission of Pu239: Total, ß and g-ray
  - Effects of Greenway TAGS. Fission of Pu239 (C. Dean, Serco Assurance Ltd supported by the UK Nuclear Decommissioning Authority)
  - Thermal fission of Pu241: Total
  - Fast fission of U238: Total

Decay heat

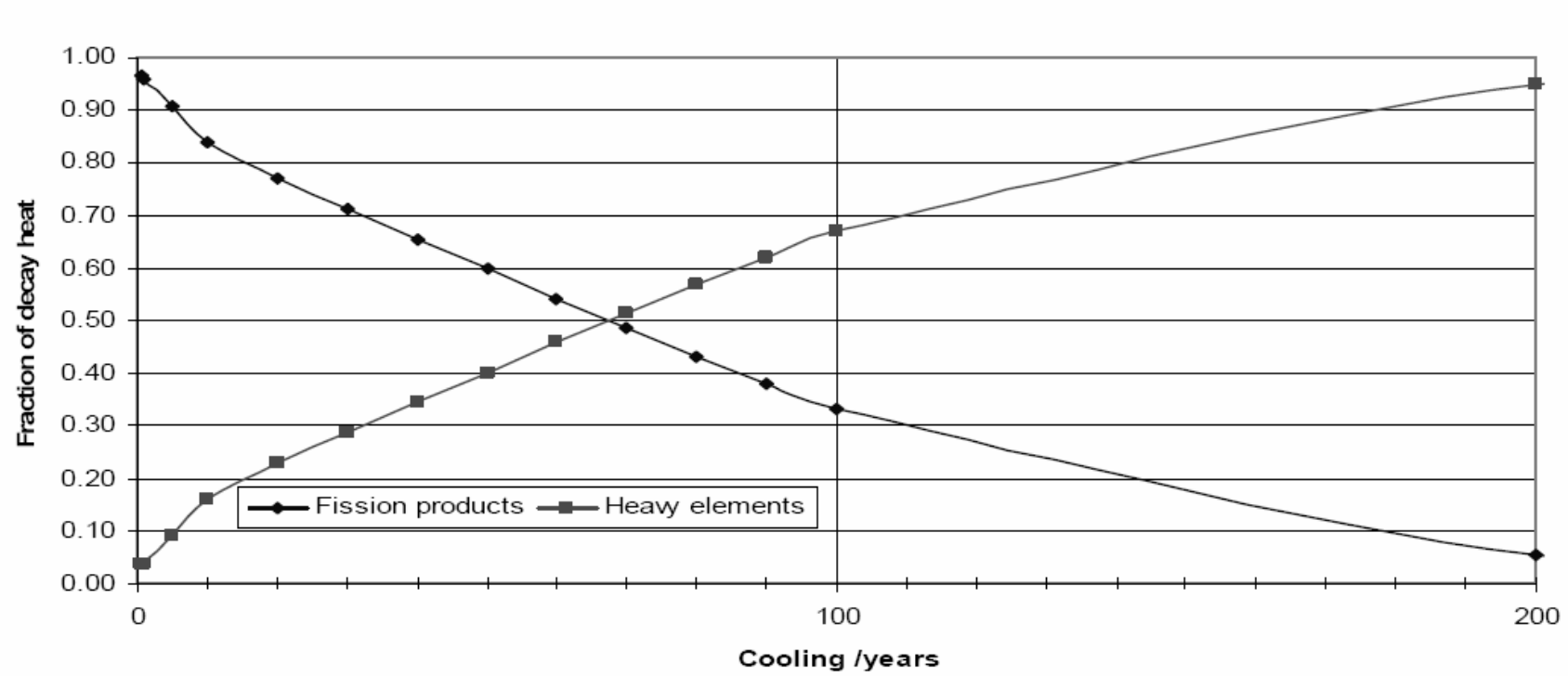
- This is the delayed heat released from components of nuclear systems after irradiation.
- In reactors this is dominated by the fuel assembly components (includes heavy elements, fission products, and activation products)
- Results from beta and alpha decay, internal transitions and spontaneous fission of nuclides present.
- Includes:
  - photons (x-rays and gamma),
  - leptons (electrons and positrons) and
  - baryons (alpha particles, neutrons, nucleus recoil)

Spent Fuel Decay Heat Issues

- Important for
  - Reactor transient analyses
  - Reactor shutdown analyses
  - Removal of fuel from reactors
  - Storage of spent fuel
  - Transport of spent fuel
  - Reprocessing of spent fuel
- Data used can be from two sources
  - Summation calculations
    (e.g. FISPIN, DARWIN, ORIGEN, etc.)
  - Standards (usually developed from calculations)

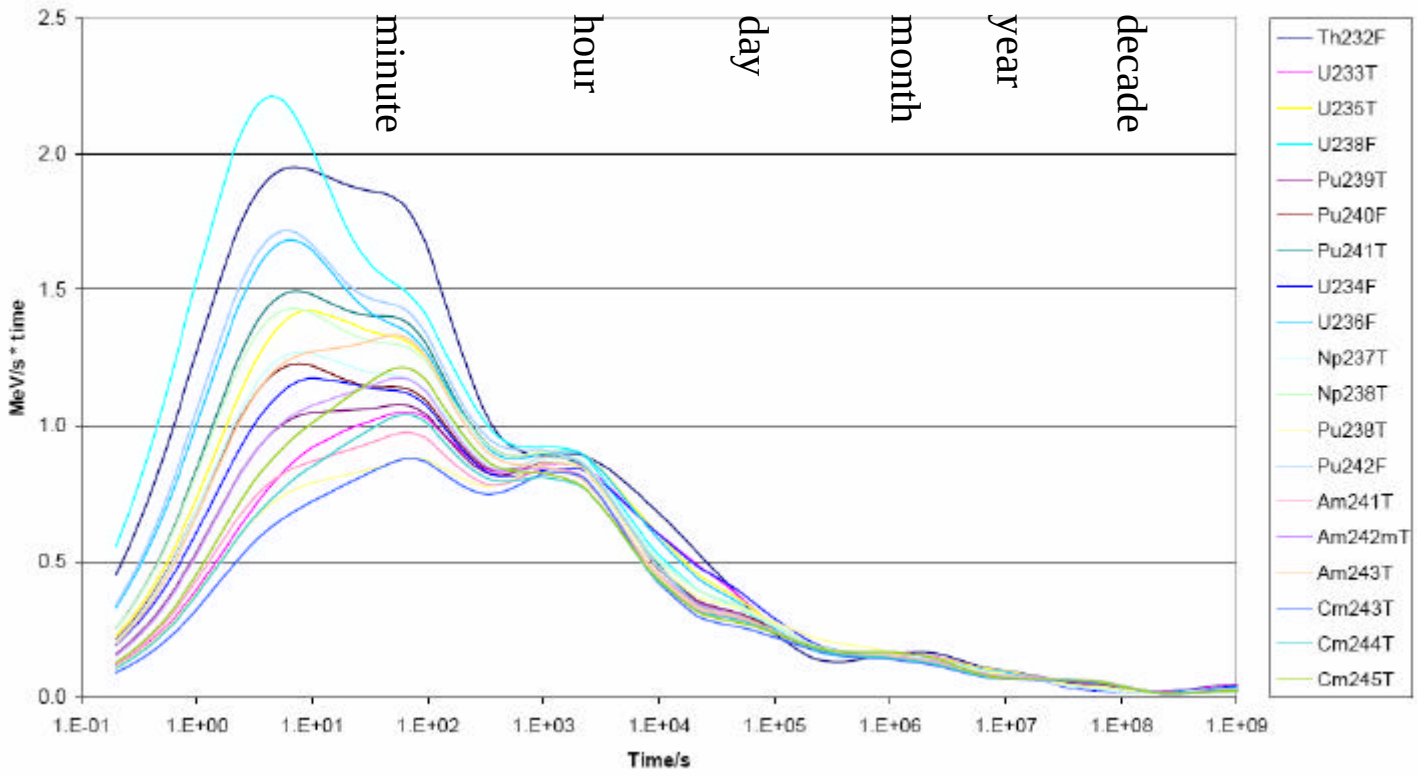
Spent Fuel Decay Heat Issues

- **Decay heat from fission products and heavy elements (Z>80)**



Spent Fuel Decay Heat Issues

- **delayed heat from fission products from a single fission in a thermal reactor neutron flux (JEFF-3.1 calculations)**



Validation for transport, storage and reprocessing

- **PWR fuel decay heat experimental data and calorimetric results (zircalloy clad fuel only: stainless steel clad fuel gave no cobalt content)**

Reactor	Assembly	Enrichment (%)	Irradiation (GWd/t)	Cooling (d)	Measured heat* (W)
WEPCO	C-52	3.397	31.914	1635	724
WEPCO	C-52	3.397	31.914	1635	723
WEPCO	C-56	3.397	38.917	1634	921
WEPCO	C-64	3.397	39.384	1633	931
WEPCO	C-66	3.397	35.433	1630	846
WEPCO	C-67	3.397	38.946	1629	934
WEPCO	C-68	3.397	37.057	1630	874
Turkey Point	D-15	2.556	28.430	962	1423
Turkey Point	D-15	2.556	28.430	2077	625
Turkey Point	D-22	2.556	26.485	963	1284
Turkey Point	D-34	2.556	27.863	864	1550
Turkey Point	B-43	2.559	25.595	1782	637

* The quoted experimental error is 2%.

F. Schmittroth, "ORIGEN2 Calculations of PWR spent fuel decay heat compare with calorimeter data." Report HEDL-TME 83-32 UC-85 (1984) and references therein.

Validation for transport, storage and reprocessing

- PWR validation: Comparisons with experiments

Measured heat* (W)	JEF-1 C/E	JEF-2.2 C/E	JEFF-3.1 C/E
724	1.04	0.98	0.97
723	1.04	0.98	0.97
921	1.04	1.01	1.00
931	1.04	1.01	1.00
846	1.03	0.97	0.96
934	1.03	1.00	0.99
874	1.04	1.00	0.99
1423	1.05	1.05	1.04
625	1.02	1.03	1.01
1284	1.06	1.06	1.05
1550	1.07	1.06	1.05
637	0.99	1.00	0.98

From JEF/DOC-1109, R.W. Mills
Preliminary validation of the JEFF-3.1 fission yields and decay data by decay heat and fission product inventories.

Mean ; Standard Deviation

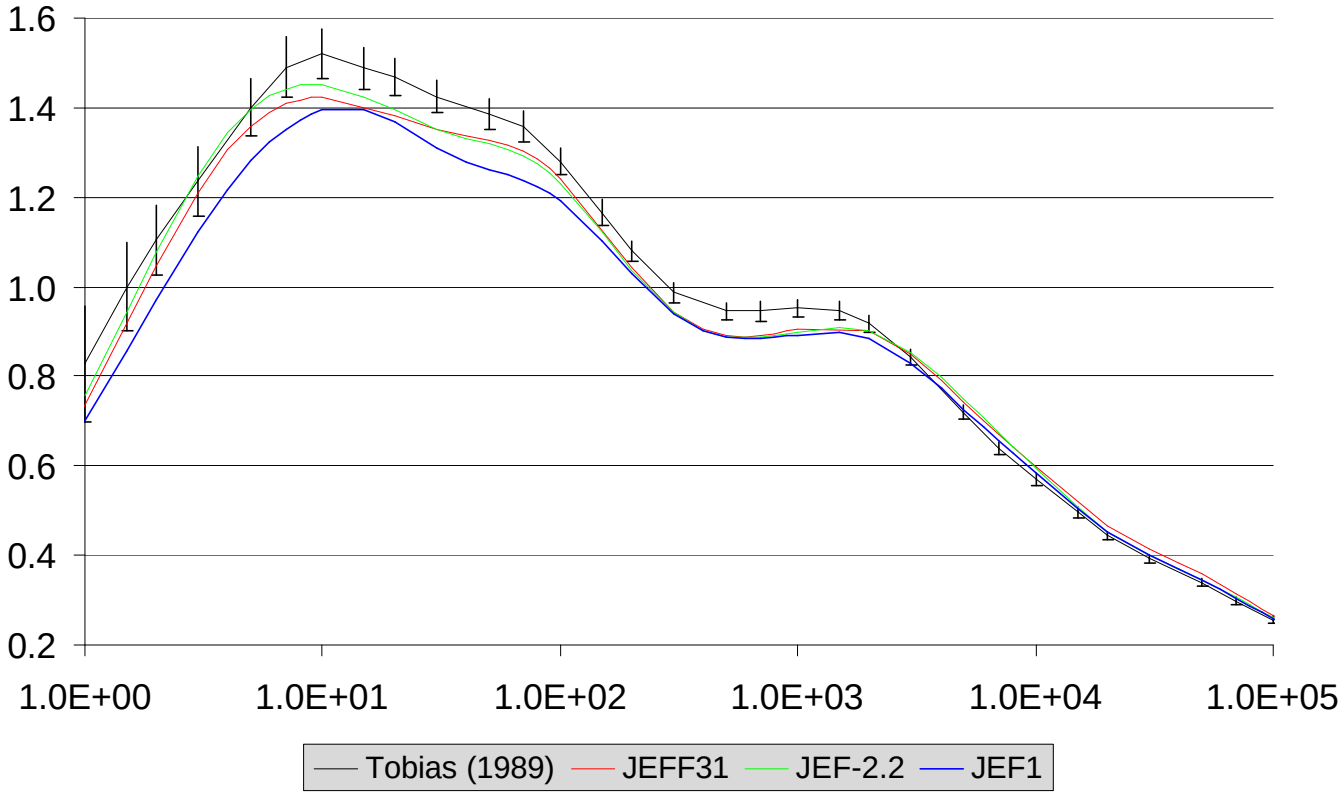
	JEF-1 C/E	JEF-2.2 C/E	JEFF-3.1 C/E
WEPCO	1.04 ± 0.01	0.99 ± 0.02	0.98 ± 0.02
Turkey Point	1.04 ± 0.03	1.04 ± 0.03	1.02 ± 0.03
All Zr-4	1.04 ± 0.02	1.01 ± 0.03	1.00 ± 0.03

Validation for short times (~1-10^5 seconds)

- Comparisons of inventory codes have shown there results are in agreement if using the same data:
  - B.F. Duchemin, C. Nordborg, "Decay Heat Calculation- An international nuclear code comparison" NEA report NEACRP- 319 "L" (1989).
- Evaluations of decay heat have been prepared:
  - A. Tobias, "Decay Heat", Progress in Nuclear Energy, Vol.5, No. 1, pp.1-193 (1980).
  - A. Tobias, "Derivation of Decay Heat Benchmarks for U235 and Pu239 by a Least Squares Fit to Measured Data", CEGB report RD/B/6210/R89 (1989).
  - These used 54 sets of U235 measurements and 28 sets for Pu239 in the analyses.
- Experimental data for other nuclides limited, but include
  - Pu241 thermal: J.K. Dickens, T.A. Love and J.W. McConnell, "Fission-Product Energy release for times following thermal-neutron Fission of plutonium-239 and plutonium-241 between 2 and 14000 seconds", Nuclear Science and Engineering, Vol. 78, pp. 126-146 (1981).
  - U238 fast: M. Akiyama et al, "Measurements of Fission-Product Decay heat for Fast Reactors" Proceedings of a Conference on Nuclear Data for Basic and Applied Physics", Sante Fe, USA (1985).

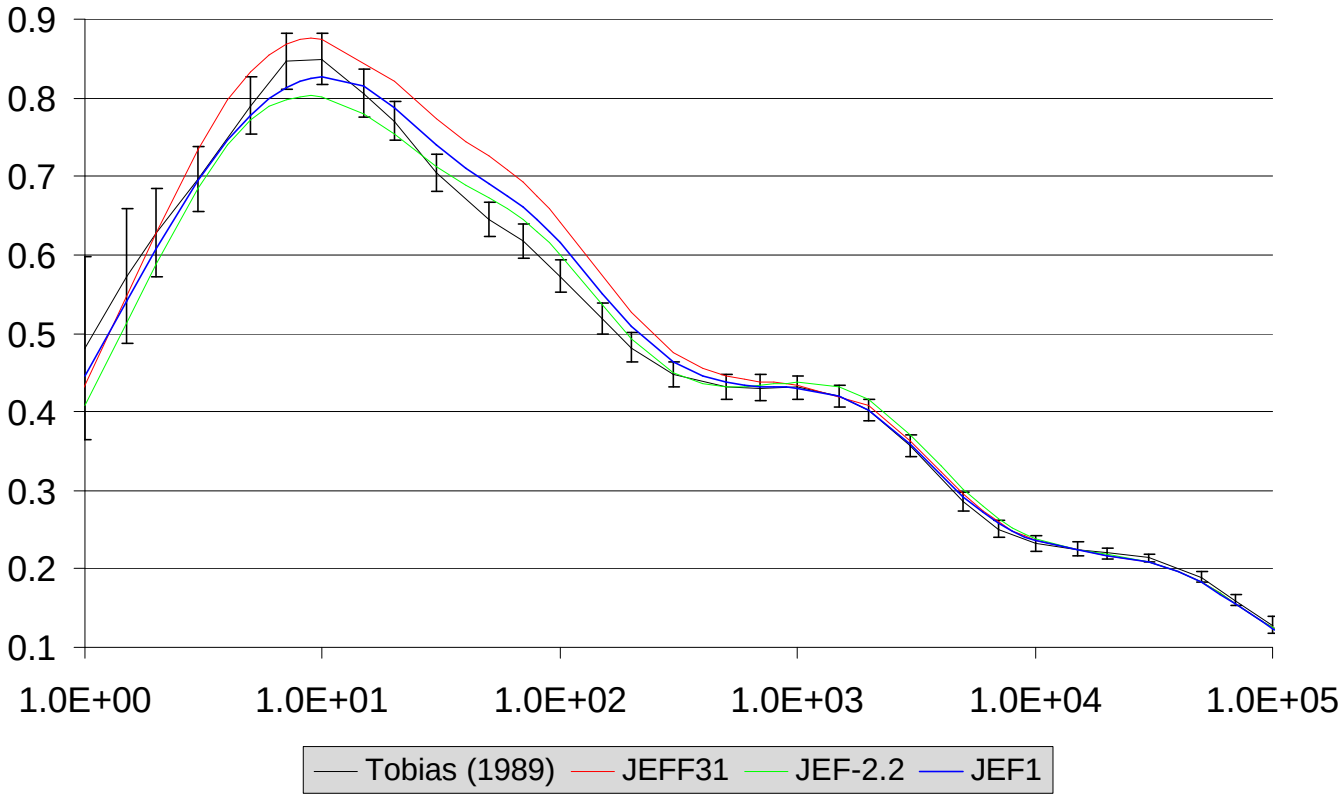
Validation for short times – U235

- **U235 thermal neutron induced Calculation (b+g)**



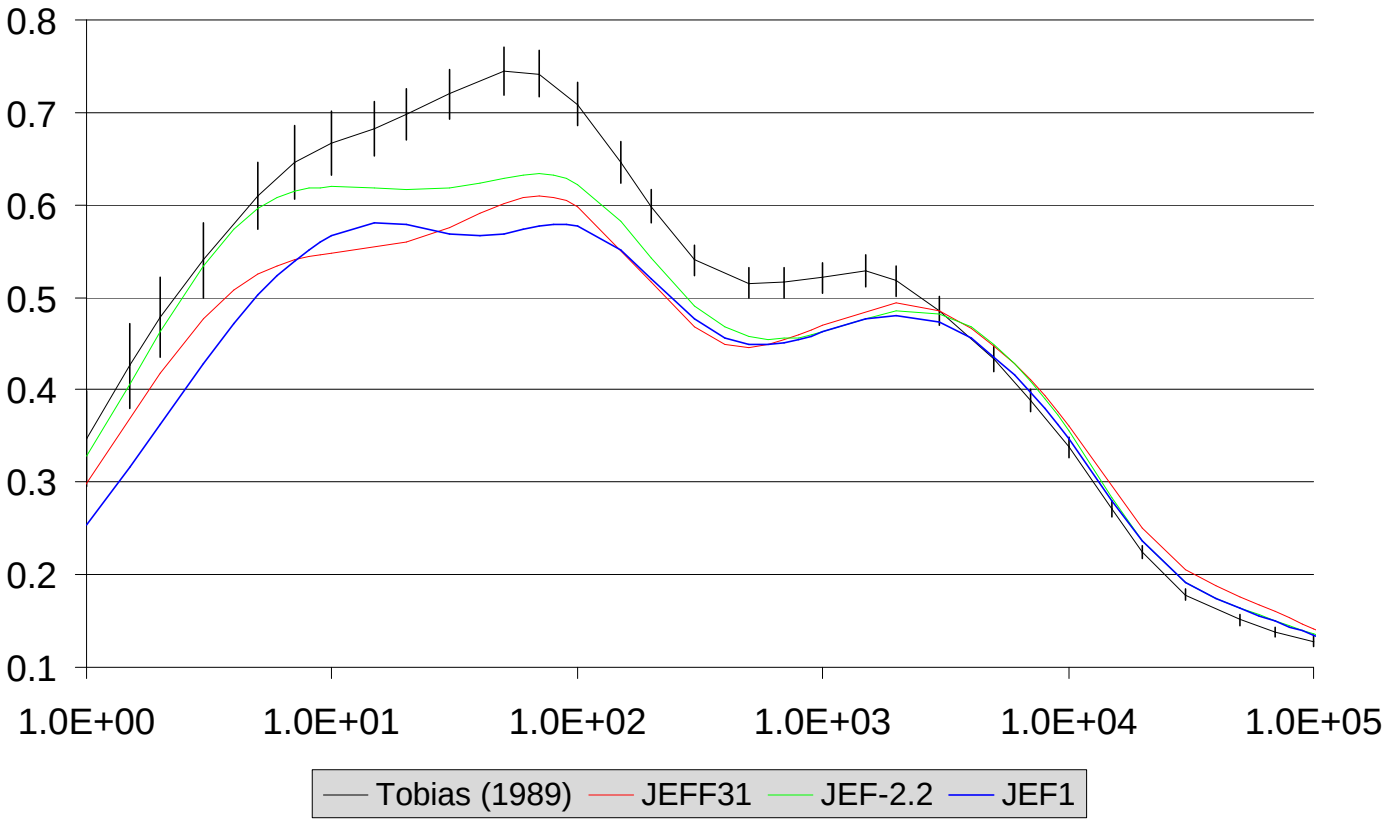
Validation for short times – U235

- **U235 thermal neutron induced Calculation (b)**



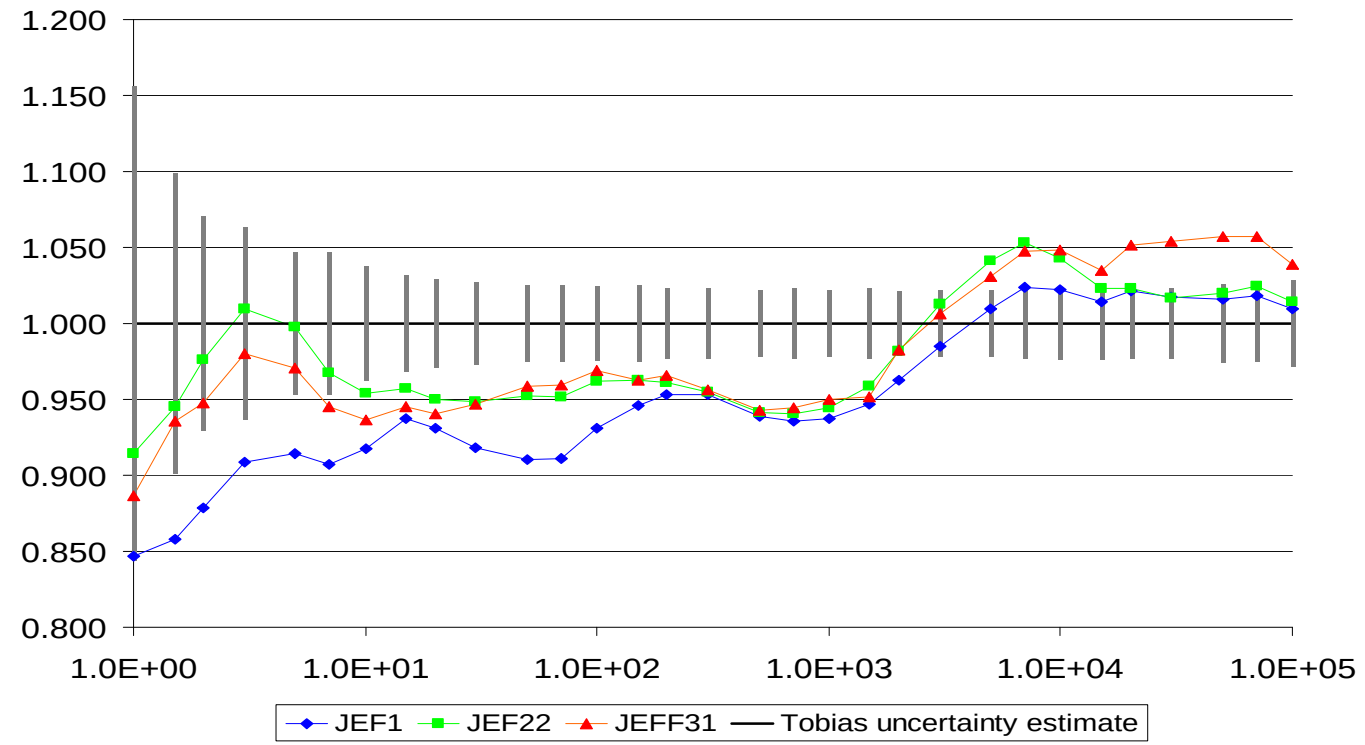
Validation for short times – U235

- **U235 thermal neutron induced Calculation (g)**



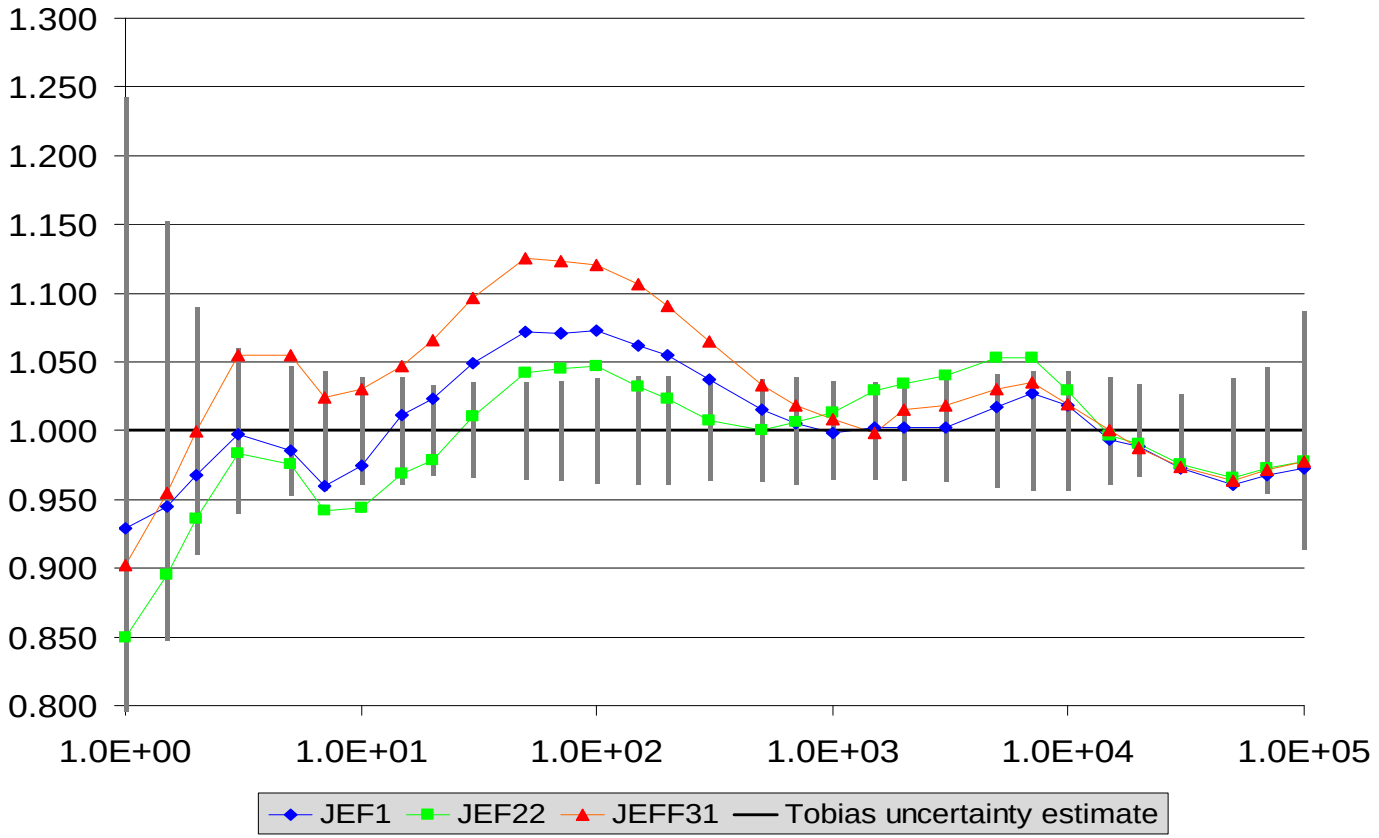
Validation for short times – U235

- **U235 thermal neutron induced Calculation/Evaluation (b.g)**



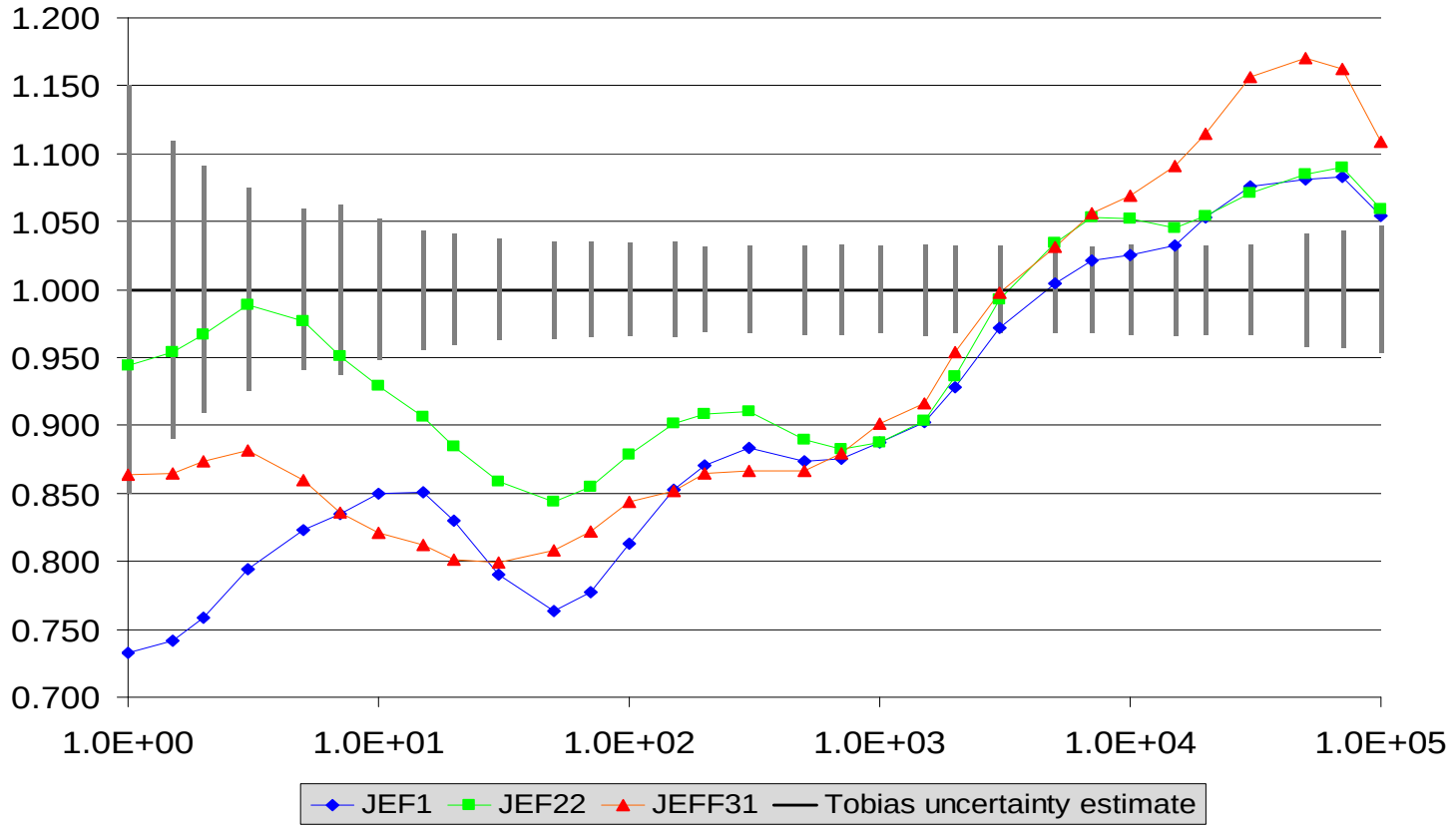
Validation for short times – U235

- **U235 thermal neutron induced Calculation/Evaluation (b)**



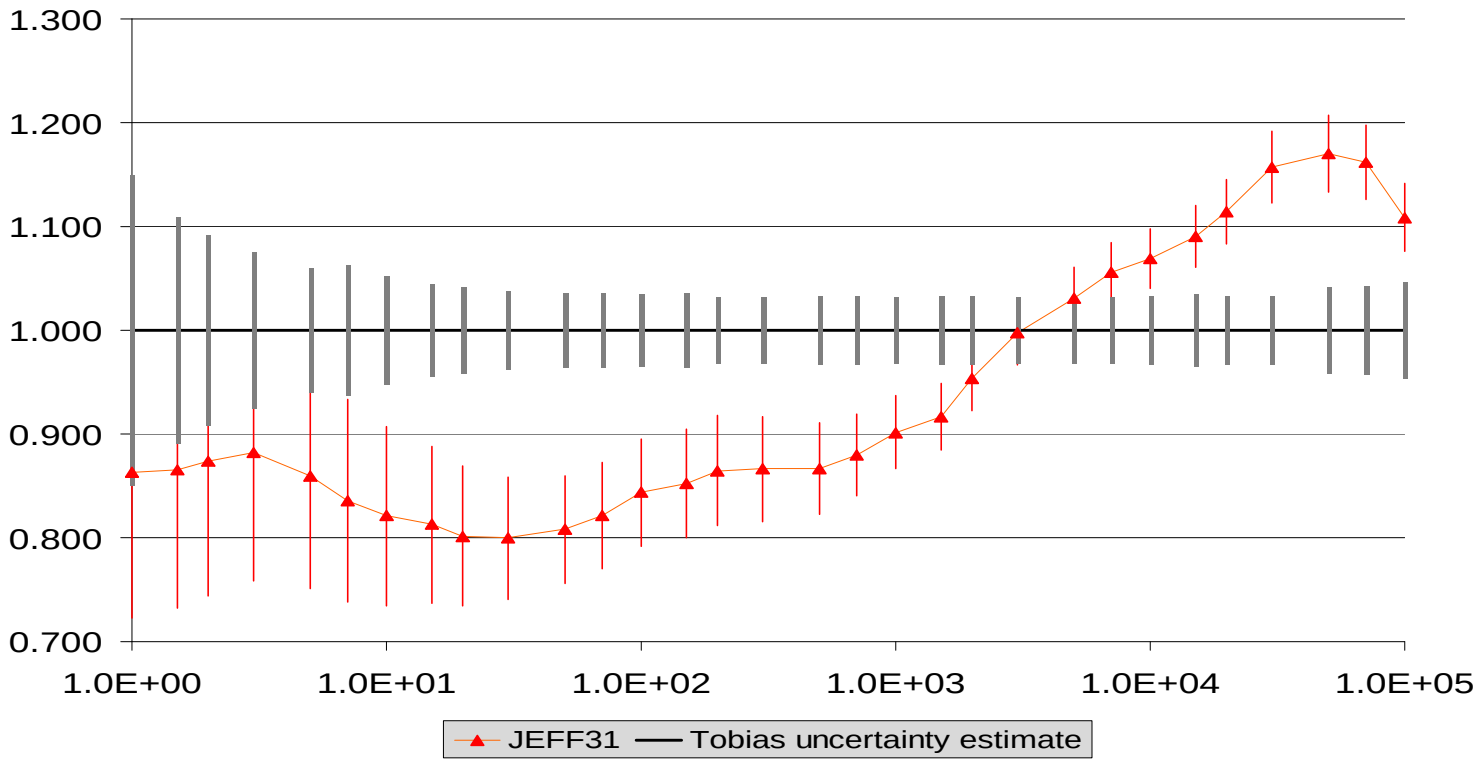
Validation for short times – U235

- **U235 thermal neutron induced Calculation/Evaluation (g)**



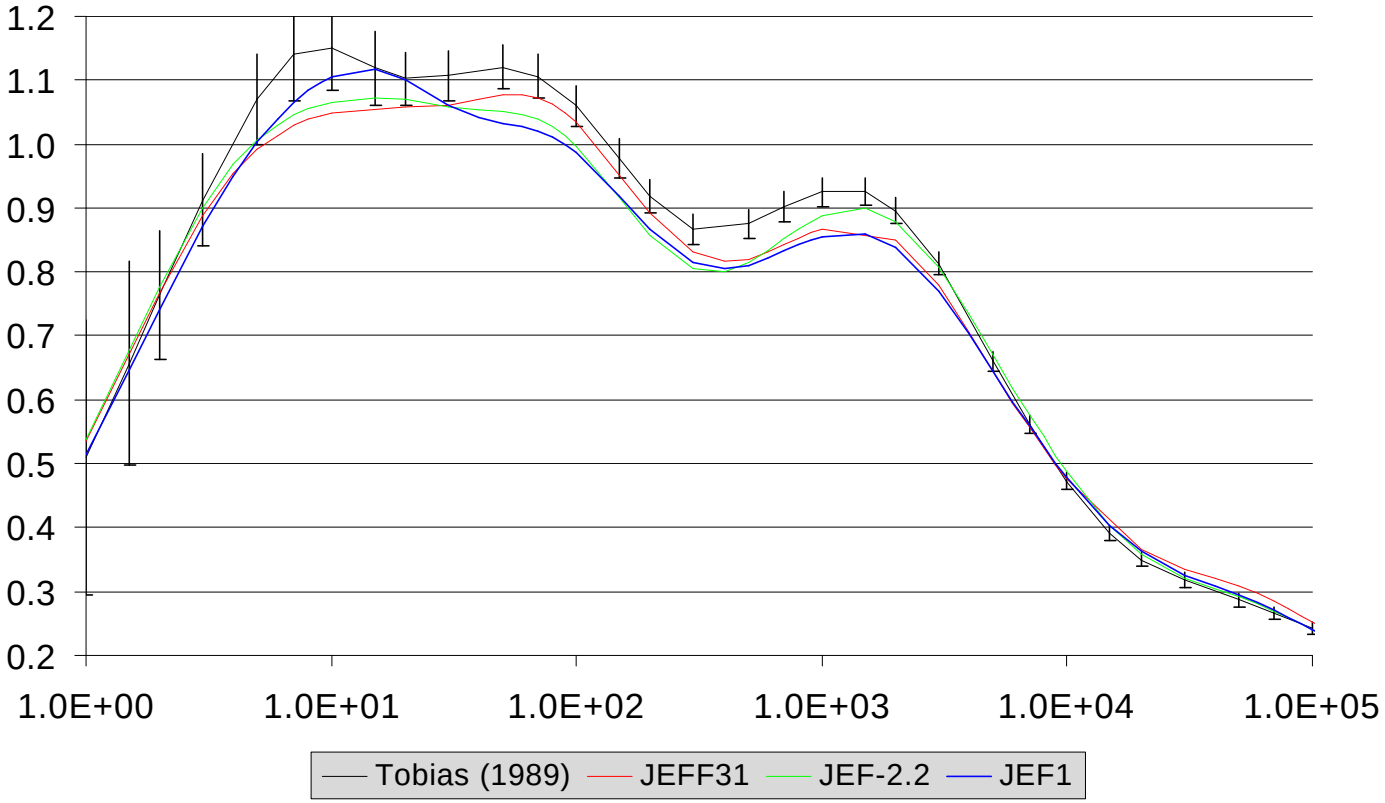
Validation for short times – U235

- **U235 thermal neutron induced Calculation/Evaluation (g) including estimate of uncertainty on calculation**



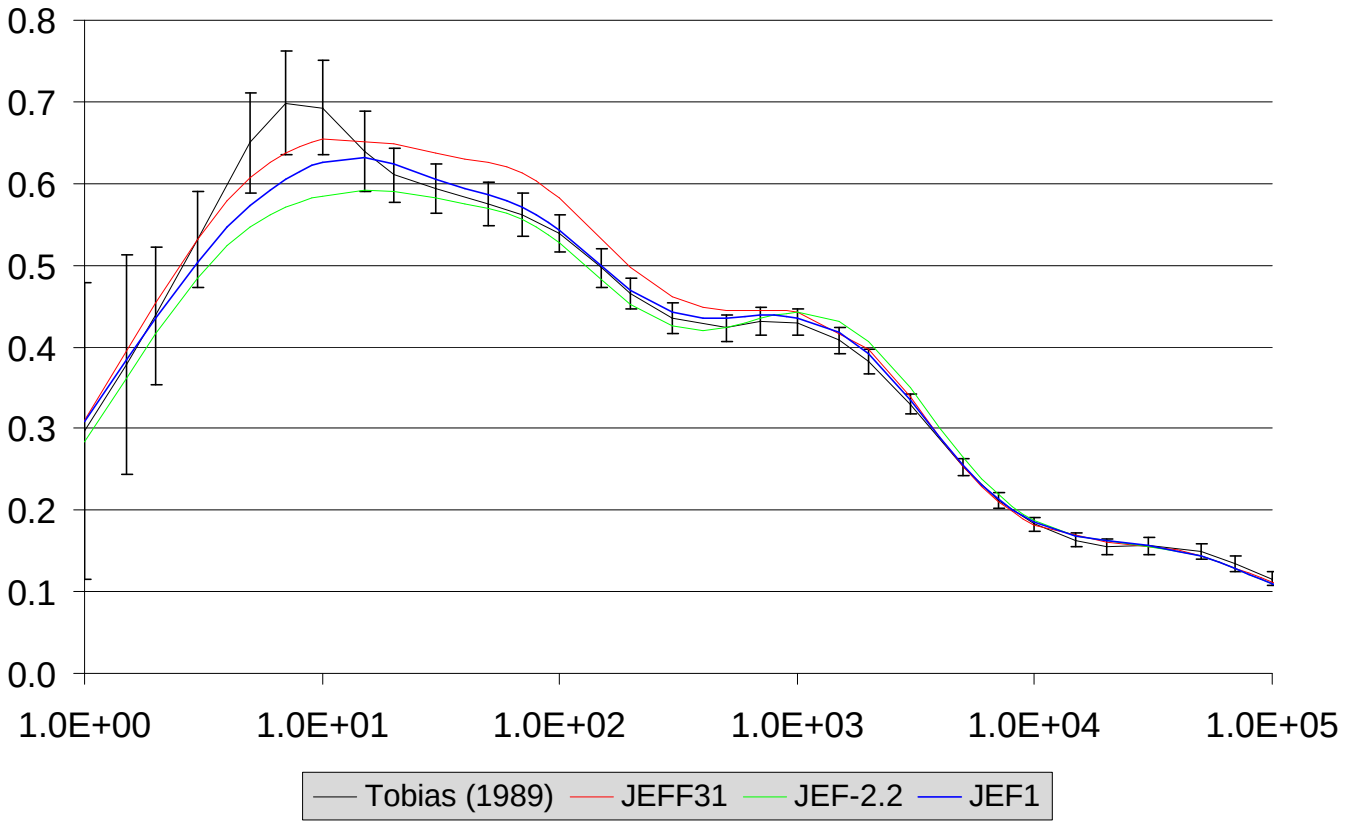
Validation for short times – Pu239

- **Pu239 thermal neutron induced Calculation (b+g)**



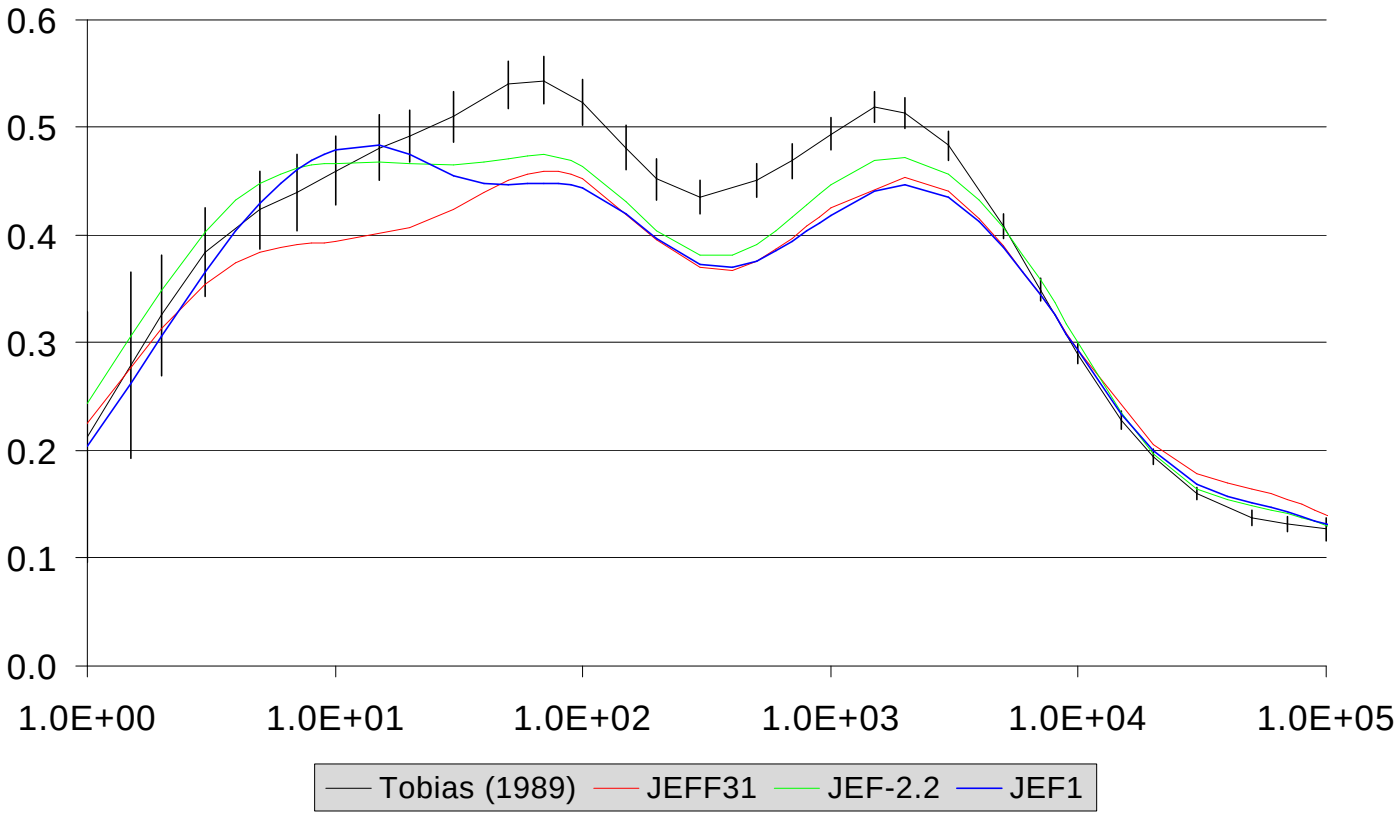
Validation for short times – Pu239

- **Pu239 thermal neutron induced Calculation (b)**



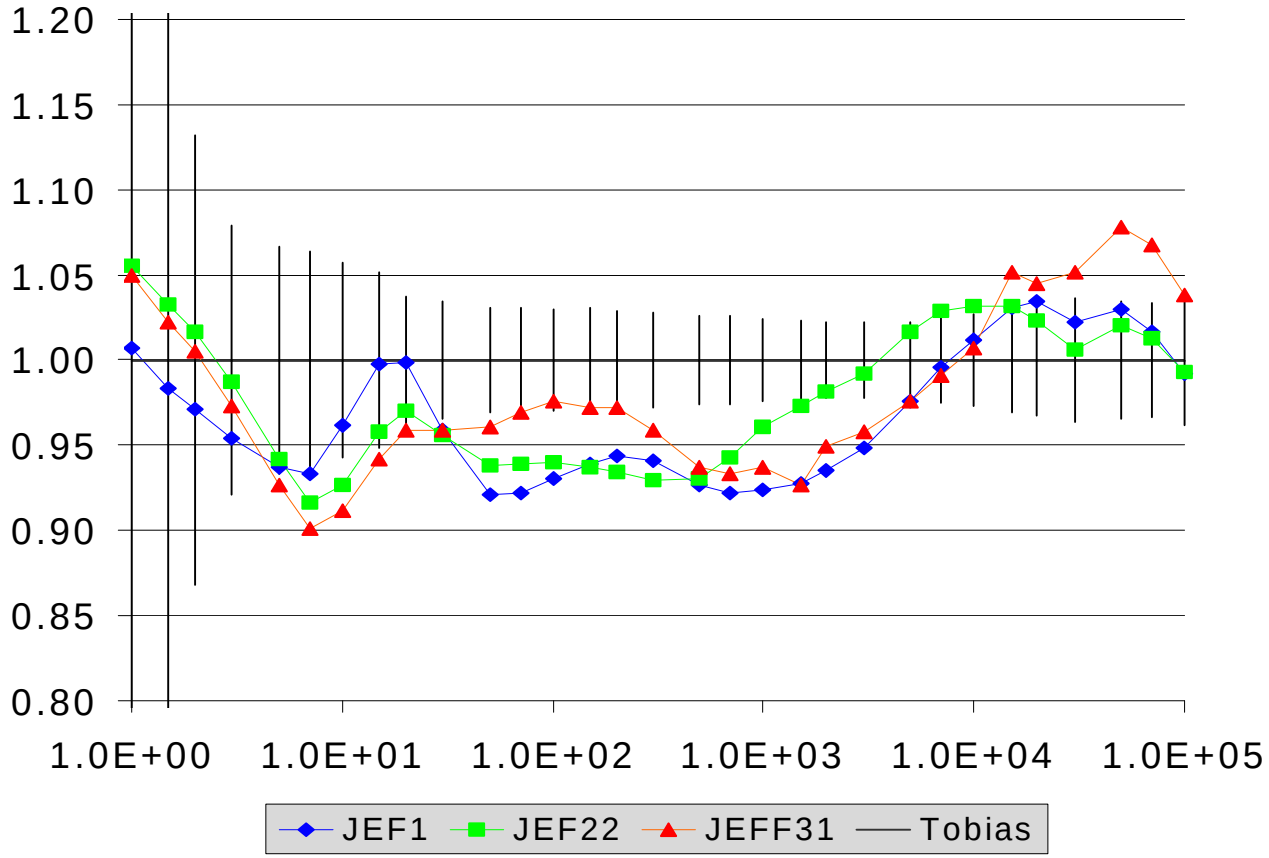
Validation for short times – Pu239

- **Pu239 thermal neutron induced Calculation (g)**



Validation for short times – Pu239

- **Pu239 thermal neutron induced Calculation / Evaluation**



Validation for short times – Pu239

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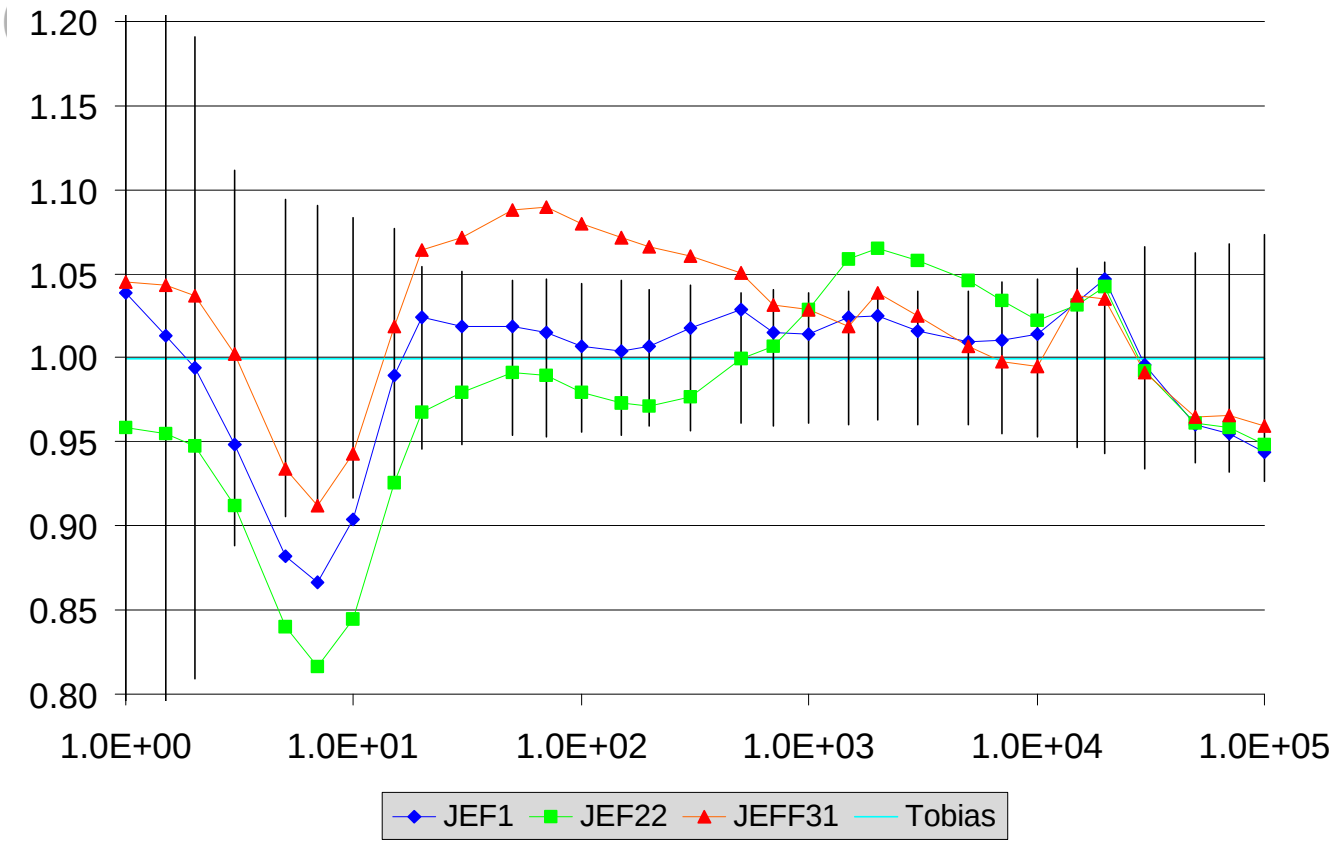
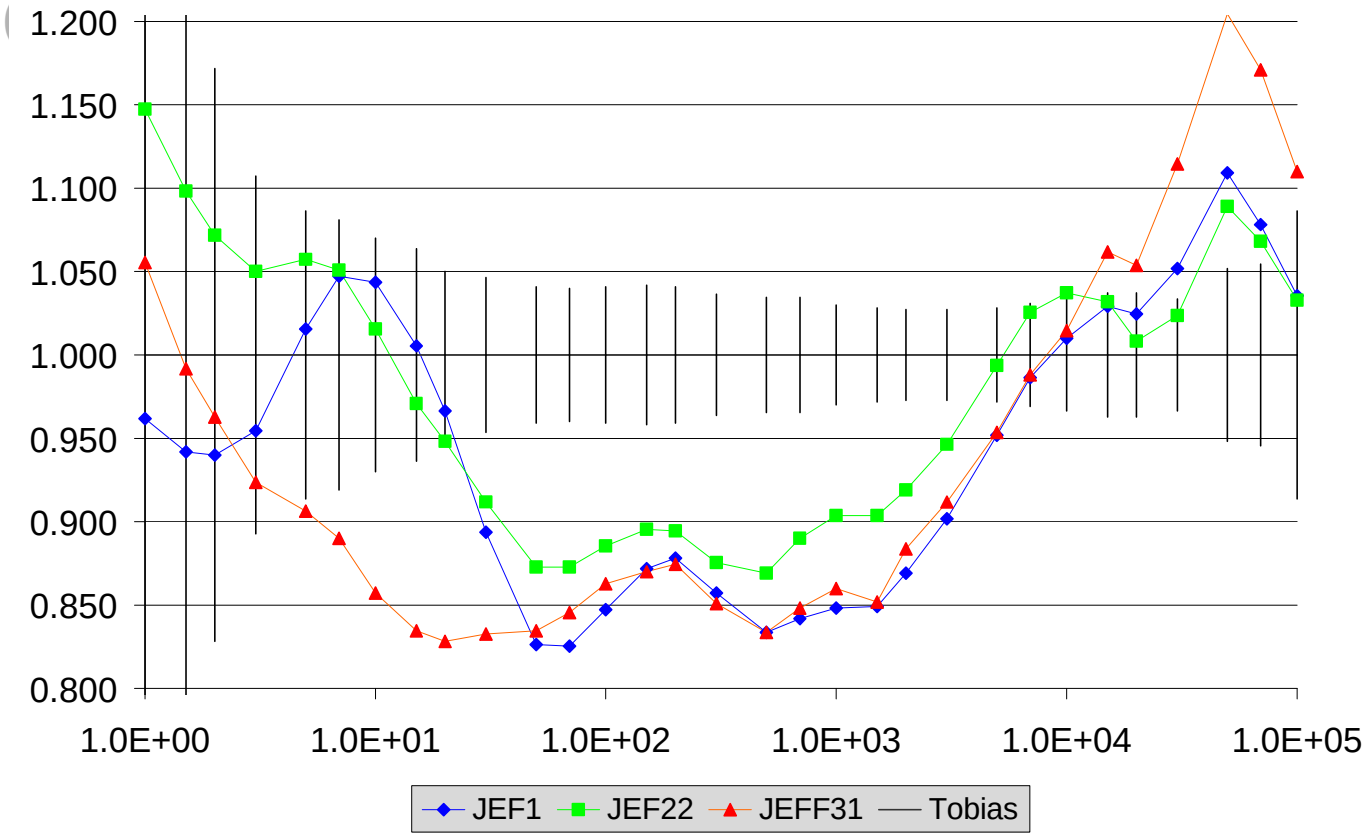


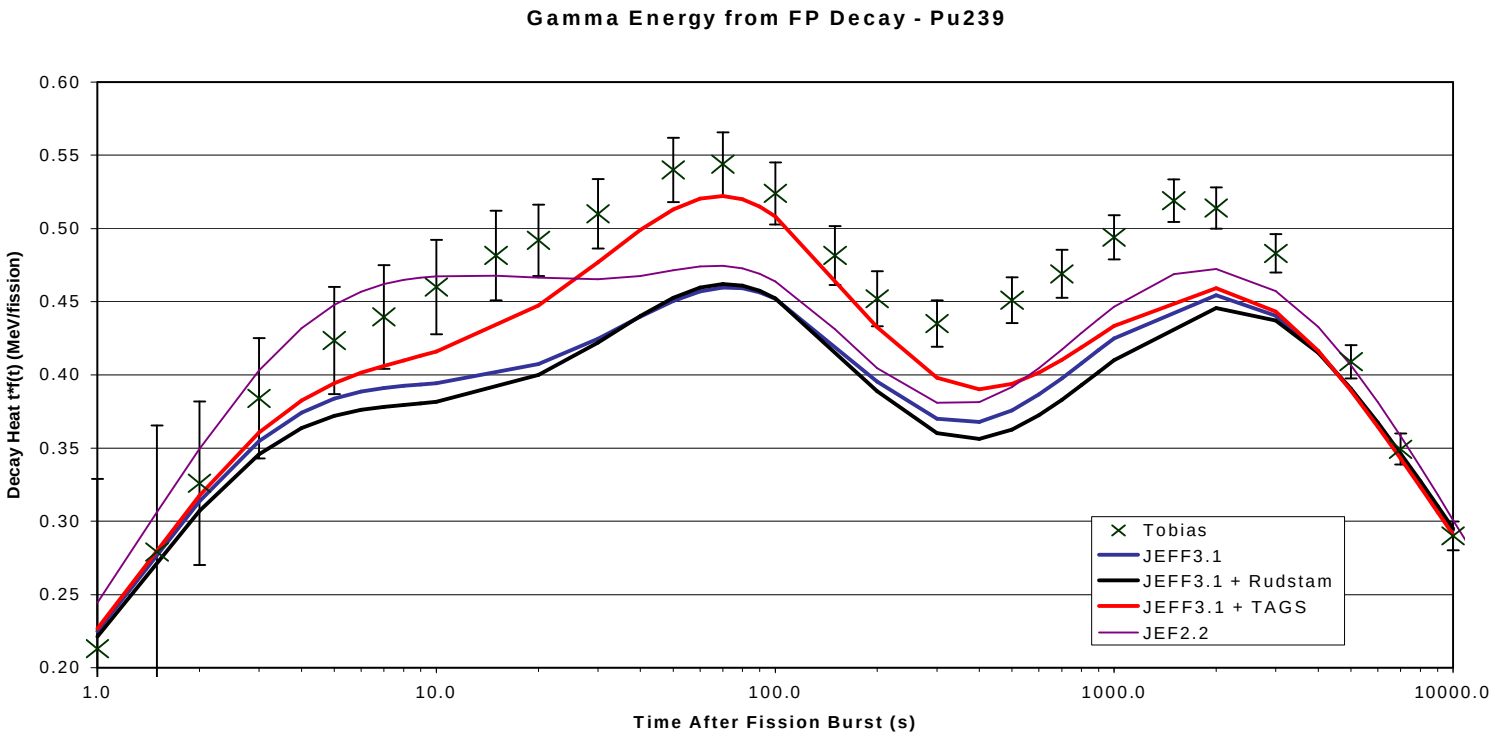
Validation for short times – Pu239

- **Pu239 thermal neutron induced Calculation / Evaluation**



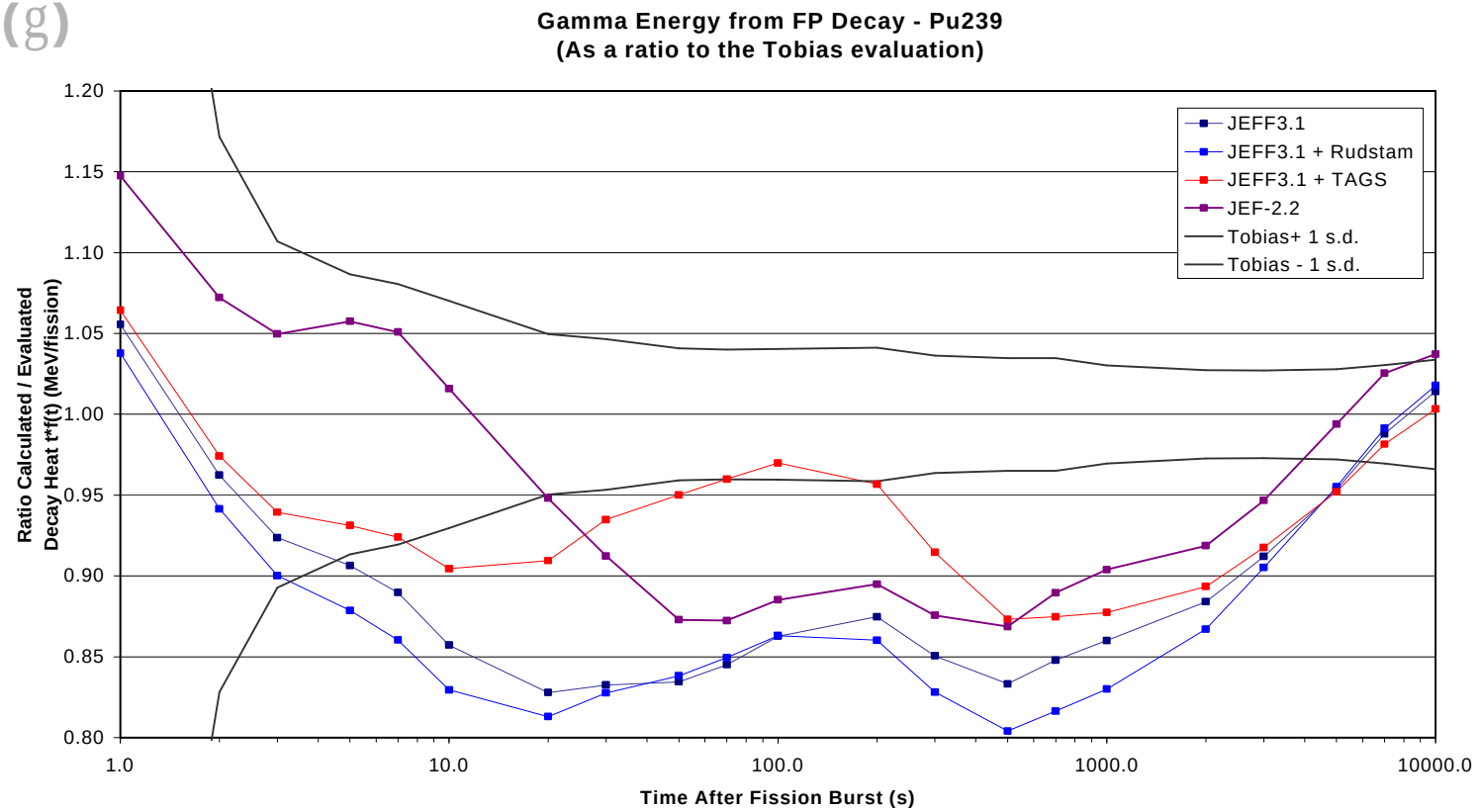
Greenway TAGS – Effect on Pu239 results

- **Pu239 thermal neutron induced Calculation (g)**
  Private communication from C. Dean, Serco Assurance Ltd
  (supported by the UK Nuclear Decommissioning Authority)



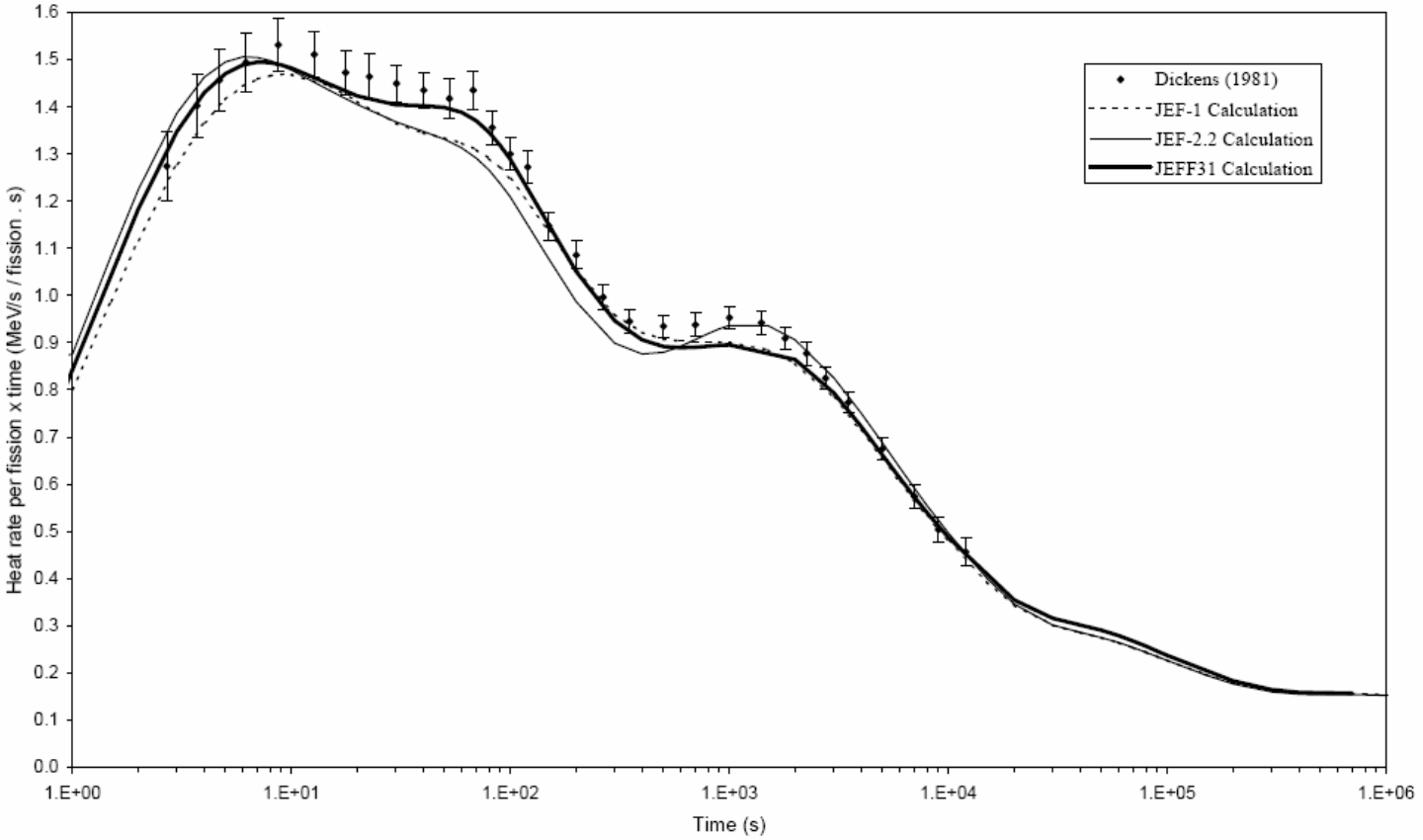
Greenway TAGS. Fission of Pu239

- **Pu239 thermal neutron induced Calculation / Evaluation (g)**



Validation for short times - Pu241

- **Pu241 thermal neutron induced fission pulse (b+g)**



Validation for short times – U238

- **U238 fast neutron induced fission pulse (b+g)**