Beta Delayed Neutrons & Electrons

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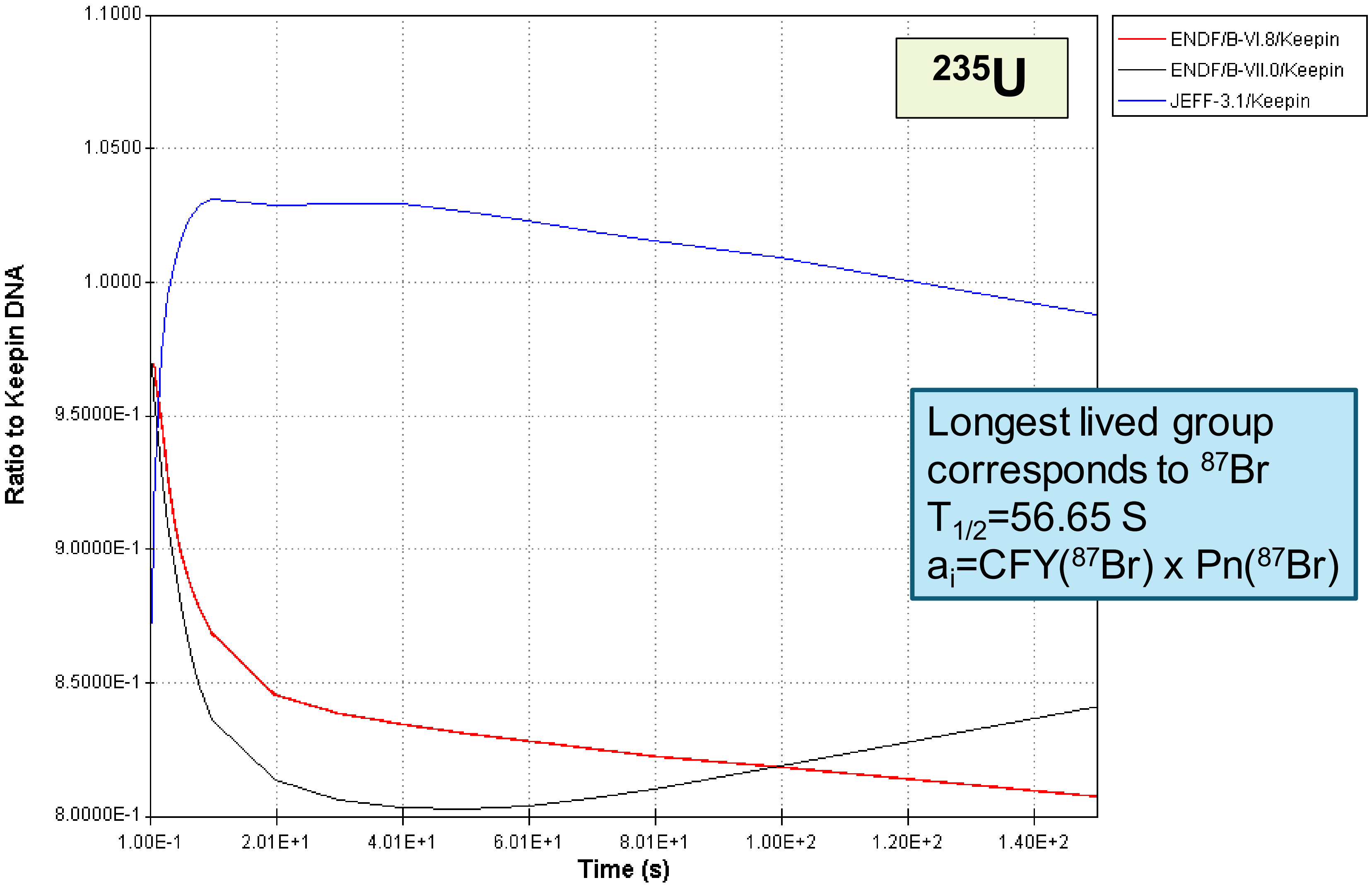
Beta-delayed neutrons activity

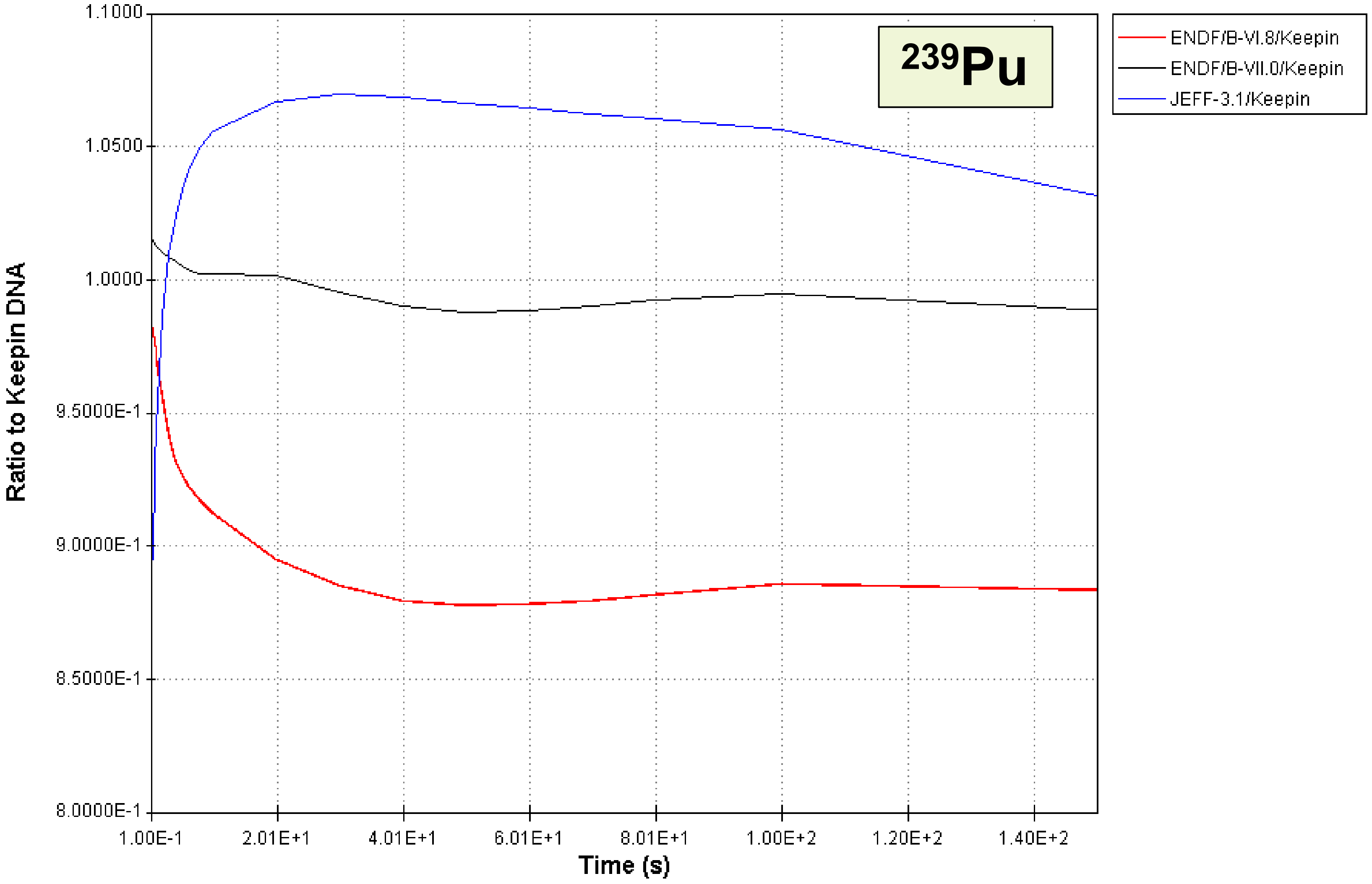
- Delayed neutron multiplicity (delayed nu-bar) and 6 decay constants (λ_i) values are found in MT=1 and MF=455.
- JEFF uses the same 8 λ_i values.
- $A=\sum a_i \times \exp(-\lambda_i \times t)$
- Divided by the Keepin 6-exponential fitting to precisely measured activities.
- Up to 20% differences with Keepin and JEFF.
- Issues raised recently by INL & ORNL



Longest lived group corresponds to ^{87}Br
$T_{1/2}$=56.65 S
a_i=CFY(^{87}Br) x Pn(^{87}Br)

Beta-delayed neutrons activity

- Comparison for ^{239}Pu
- $A=\Sigma\, a_i \times \exp(-\lambda_i \times t)$
- Divided by the Keepin 6-exponential fitting to precisely measured activities.
- The ENDF/B-VII.0 activity is a lot closer to Keepin.
- Note that the delayed nu-bar is not included here.
- $\nu_d(\mathrm{VI.8}) = \nu_d(\mathrm{VII.0}) = 6.45\mathrm{E}{-3}$



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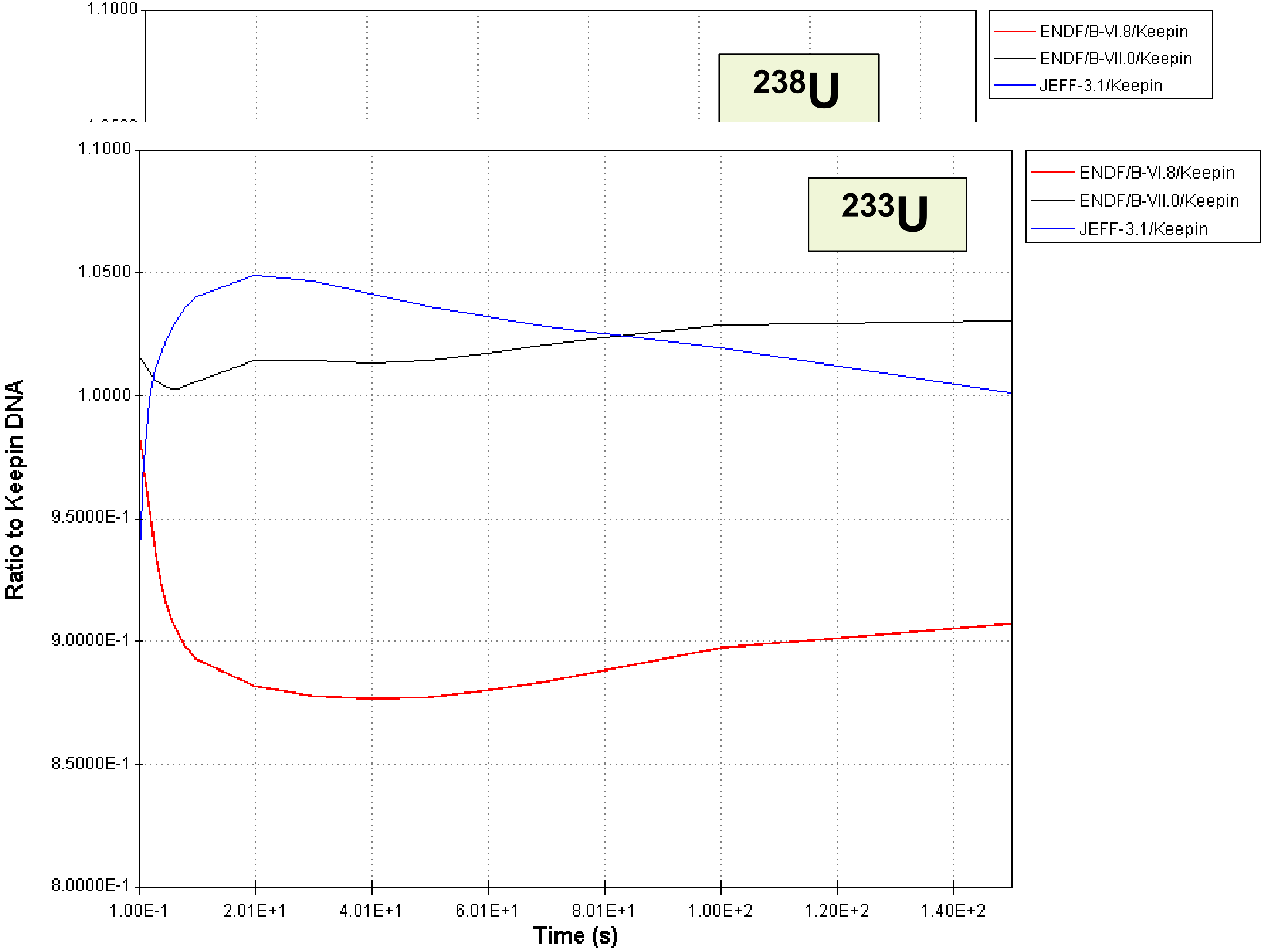
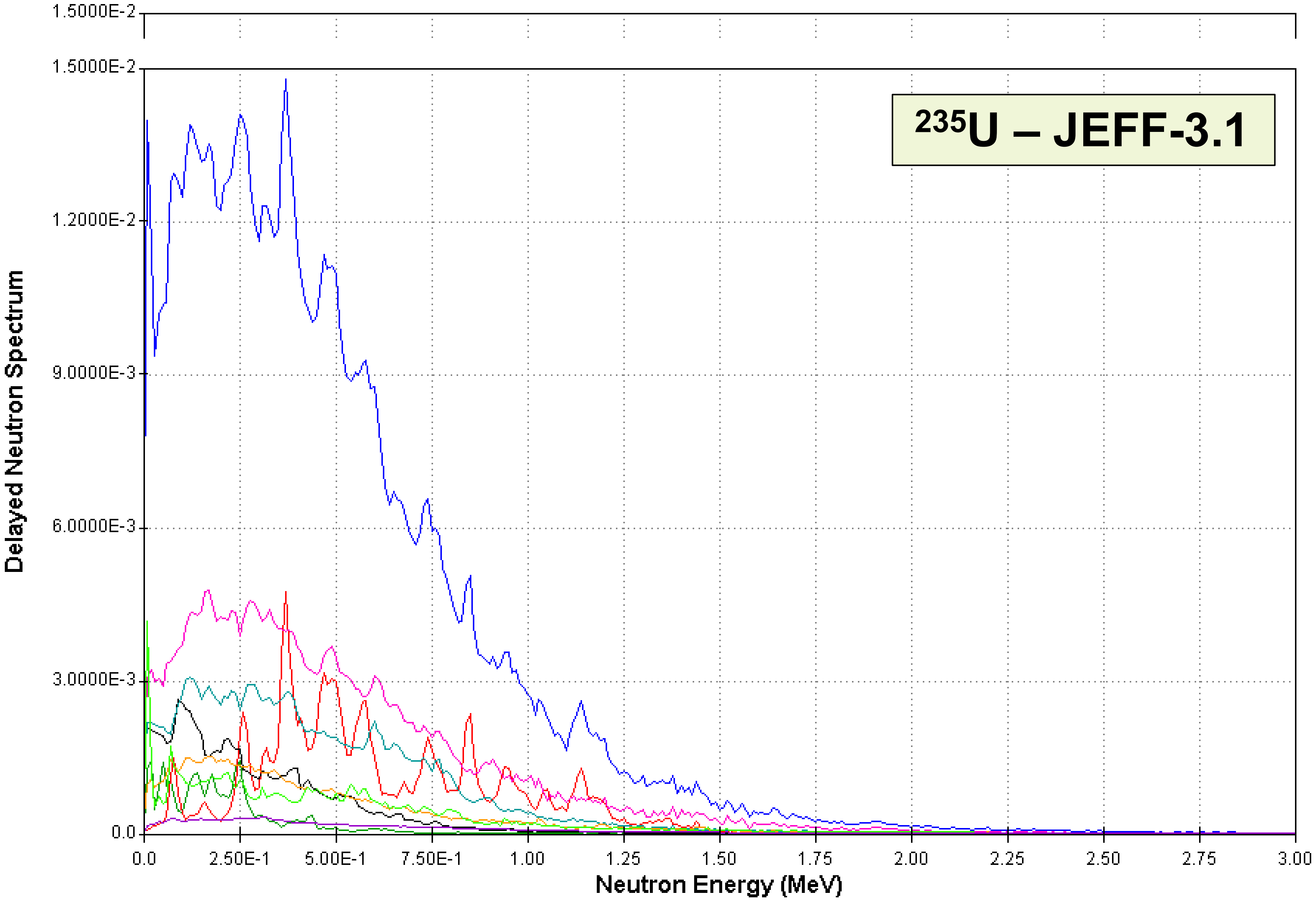
Beta-delayed neutrons

- Disagreement between ENDF/B-VIII.0 delayed neutron activity with Keepin and JEFF persists for other actinides, i.e. ^{233}U and ^{238}U.



Beta-delayed neutrons spectrum

- Probabilities (ai) and spectra for each of the groups are found in MT=5 MF=455.
- Group spectra plus the total one plotted for ^{235}U.



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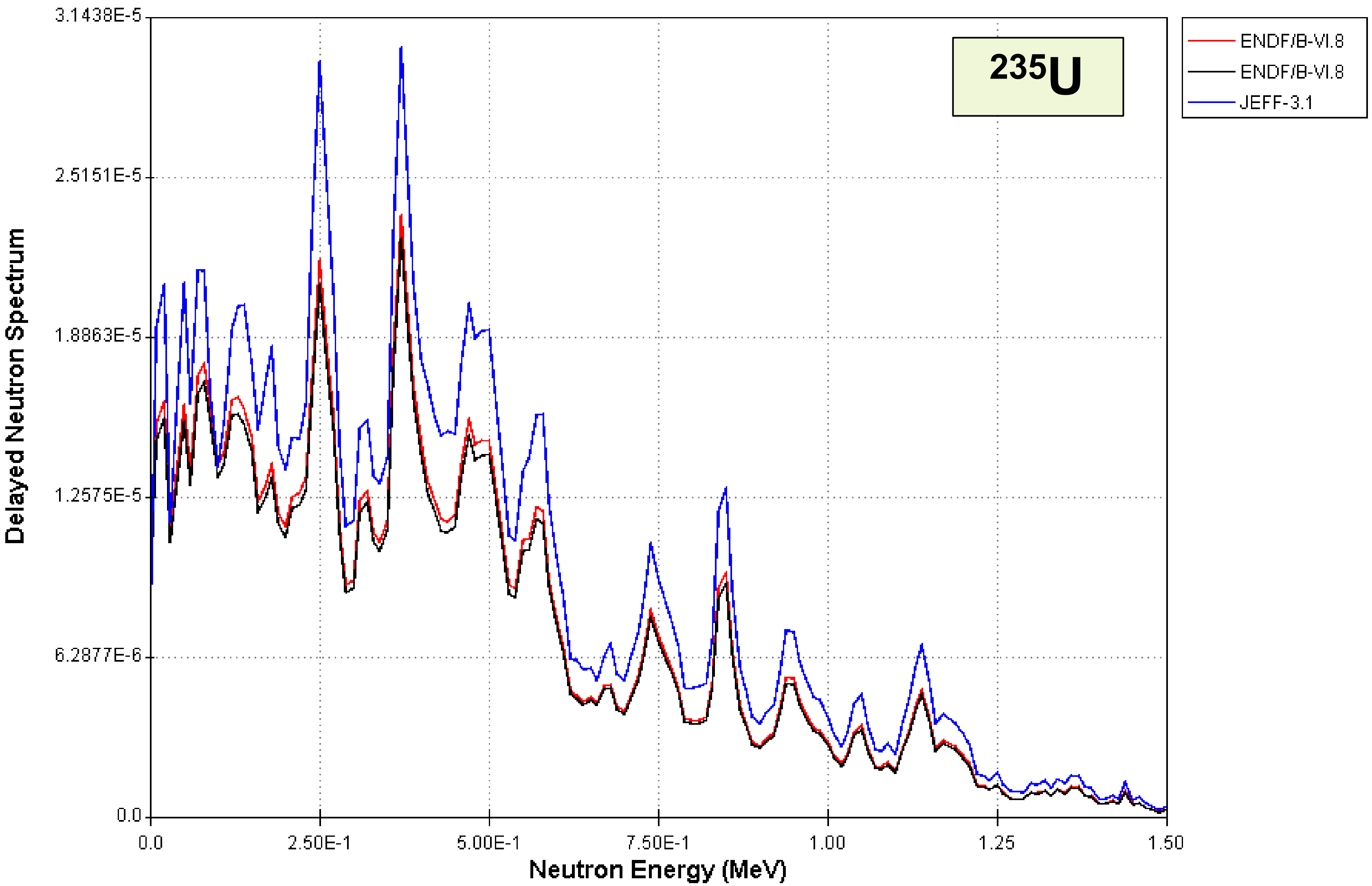
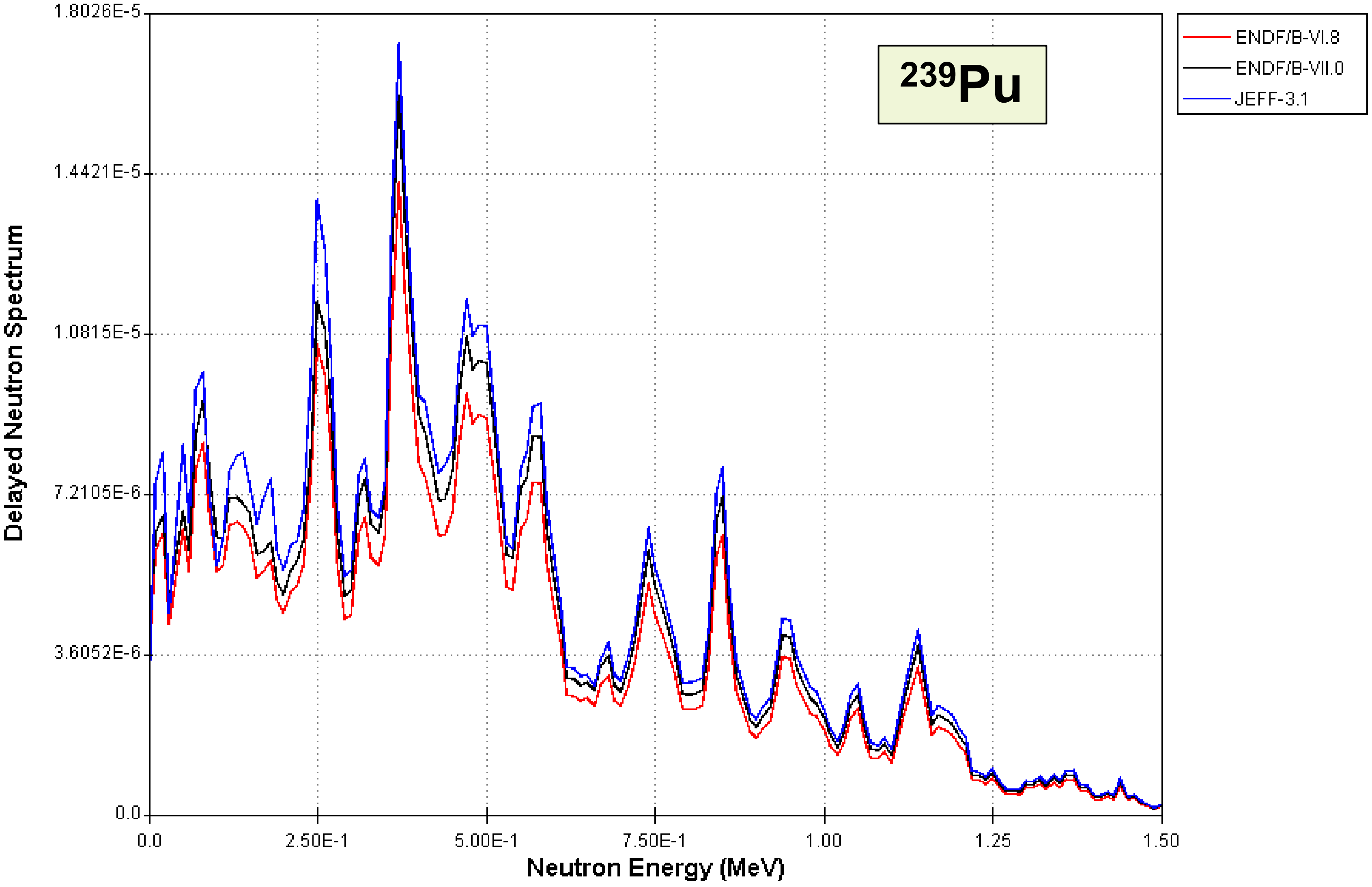
Beta-delayed neutrons spectrum

- Comparison for ^{235}U
- $S=\nu_d \times \Sigma\, a_i \times S_i \times \exp(-\lambda_i \times t)$
- t=40 seconds.
- About 30-40% differences between ENDF/B and JEFF.



Beta-delayed neutrons Spectrum

- Comparison for ^{239}Pu
- $S = \nu_d \times \Sigma\, a_i \times S_i \times \exp(-\lambda_i \times t)$
- t=40 seconds.
- About 30-40% differences between current ENDF/B and JEFF.



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Beta-delayed neutrons – path forward

- We propose to review and update the MT=1 MF=455 and MT=5 and MF=455 sections.

- Project will capitalize on the expertise developed in the recently completed IAEA Coordinated Research Project on Beta-delayed neutron emission, <u>Vivian Dimitriou *et al*.</u>

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Development of a Reference Database for Beta-Delayed Neutron Emission

P. Dimitriou,[1,*] I. Dillmann,[2,3] B. Singh,[4] V. Piksaikin,[5] K.P. Rykaczewski,[6] J.L. Tain,[7] A. Algora,[7] K. Banerjee,[8] I.N. Borzov,[9,10] D. Cano-Ott,[11] S. Chiba,[12] M. Fallot,[13] D. Foligno,[14] R. Grzywacz,[15,6] X. Huang,[16] T. Marketin,[17] F. Minato,[18] G. Mukherjee,[8] B.C. Rasco,[19,6,15,20] A. Sonzogni,[21] M. Verpelli,[1] A. Egorov,[5] M. Estienne,[13] L. Giot,[13] D. Gremyachkin,[5] M. Madurga,[15] E.A. McCutchan,[21] E. Mendoza,[11] K.V. Mitrofanov,[5] M. Narbonne,[13] P. Romojaro,[11] A. Sanchez-Caballero,[11] and N.D. Scielzo[22]

- For minor actinides, the microscopic data – fission yields and decay data – are of much higher fidelity now and can be used with higher confidence.

- Would interact with validation committee members to ensure improved benchmarks C/E values.

- Would require 2-3 years, in time for ENDF/B-VIII.1 release.

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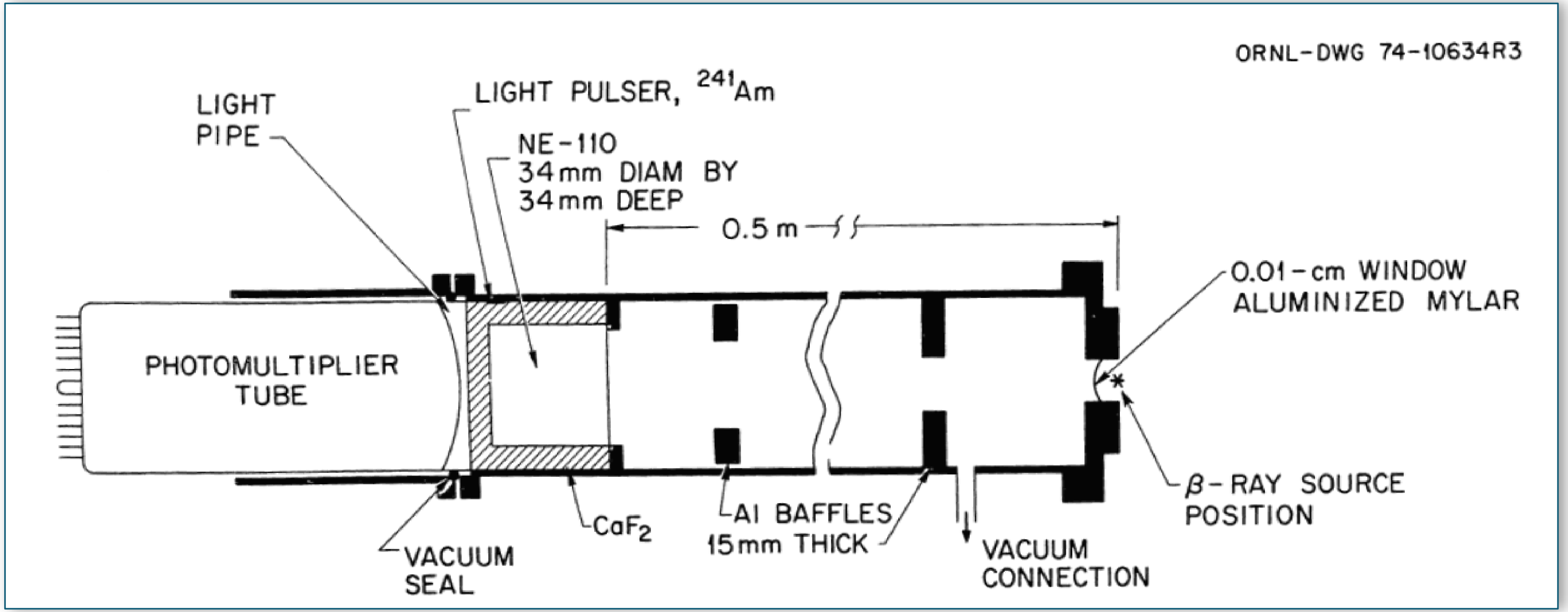
Beta-delayed electrons

- Measurements of gamma and beta spectra by **Kirk Dickens** and collaborators in the 1970s, to quantify decay heat in a Loss Of Coolant Accident scenario.
- Core irradiation with a rabbit system.
- Oak Ridge Research Reactor, 1-10 μg foils.
- Number of fissions determined from ^{97}Nb, ^{99}Mo, ^{132}Te Gammas, 1.5% uncertainty.



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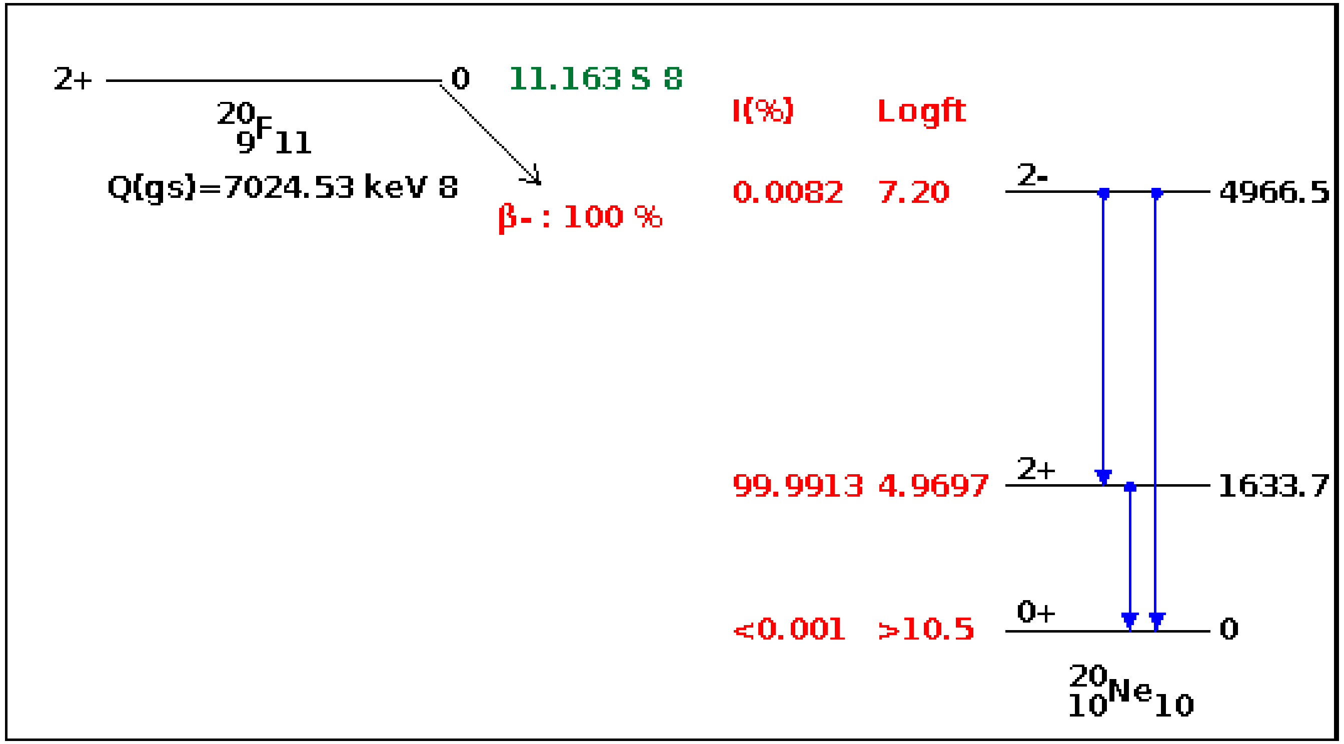
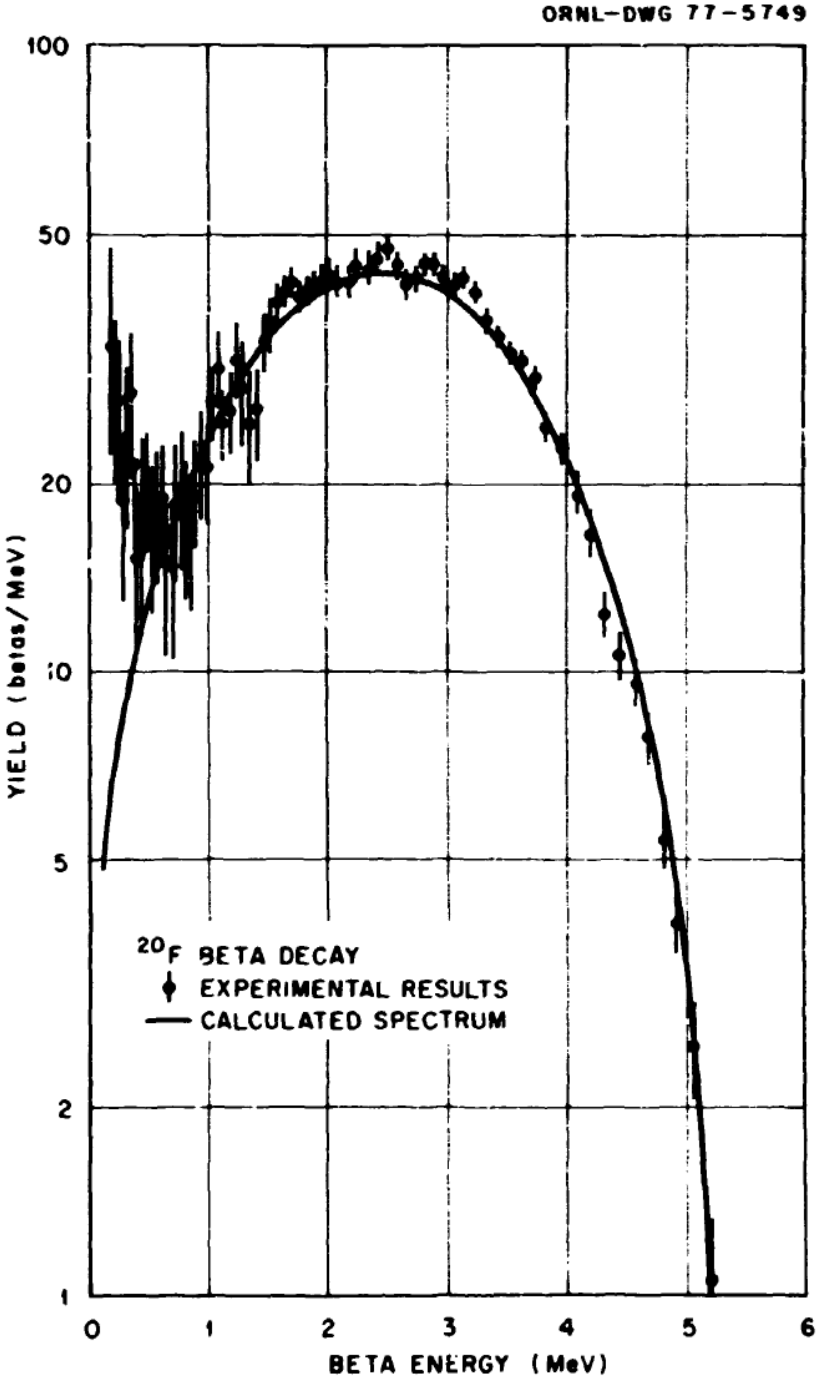
Beta-delayed electrons

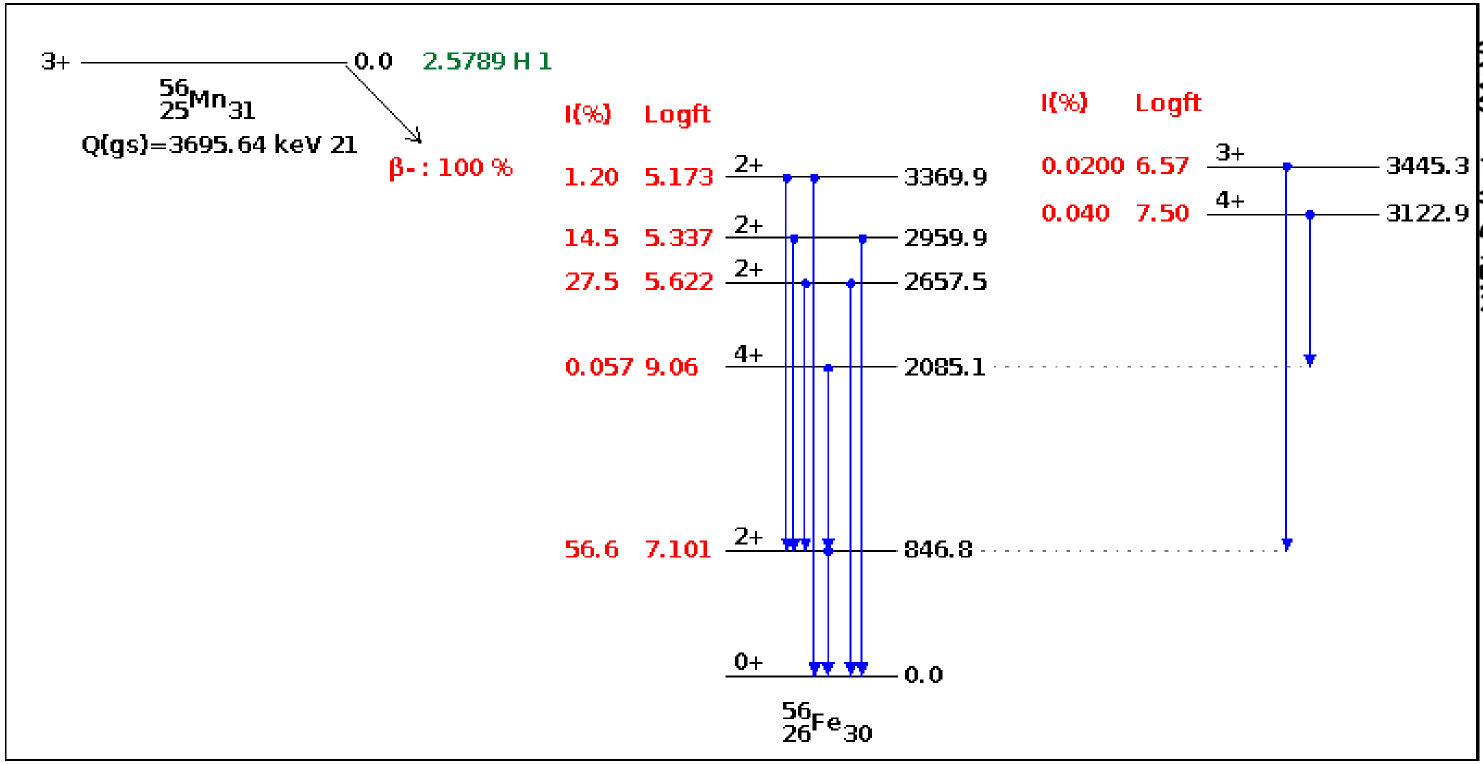
- Electron spectra measurements were benchmarked with the well known beta-minus decay of $^{19}F(n,\gamma)^{20}F$.

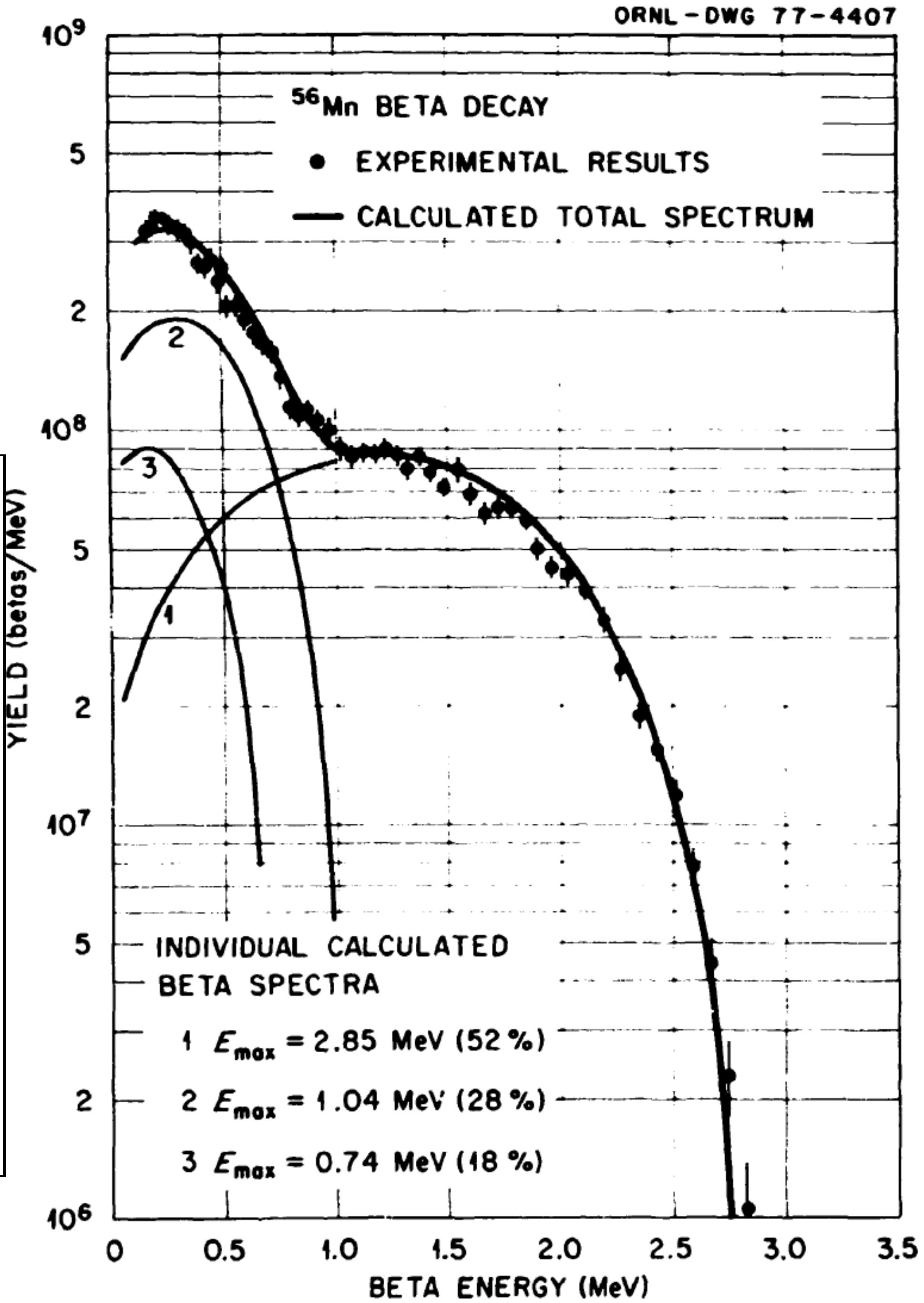




Beta-delayed electrons

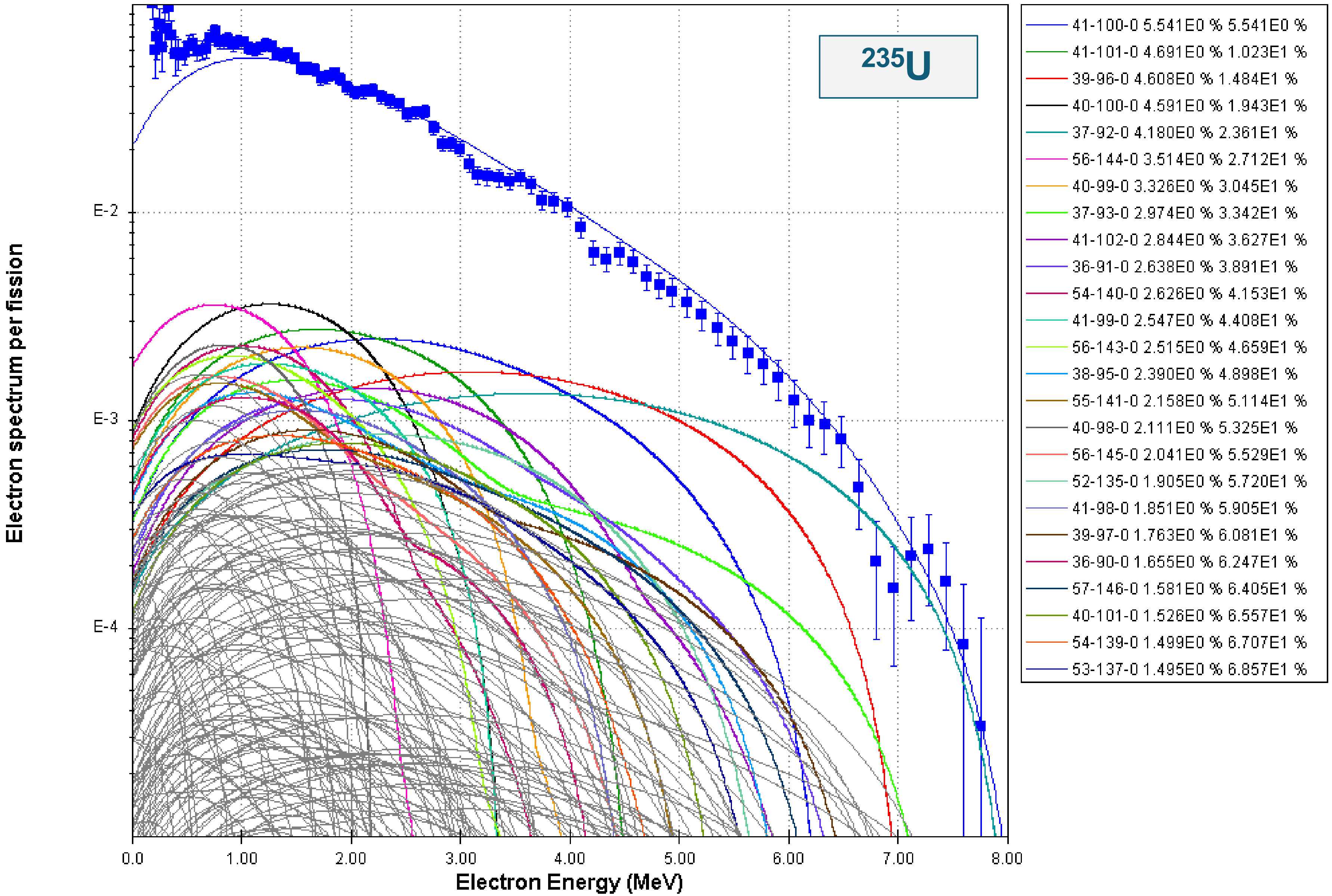
- Electron spectra measurements were benchmarked with the well known beta-minus decay of $^{55}Mn(n,\gamma)^{56}Mn$.





Beta-delayed electrons

- ❑ Measurements are compared with summation calculations, ENDF/B-VIII.1β decay and JEFF-3.3 yields, which highlights the 25 most important contributors.
- ❑ Good agreement is seen for ^{235}U, in this case 1 S irradiation, 6.7 S wait, and 3 S counting.



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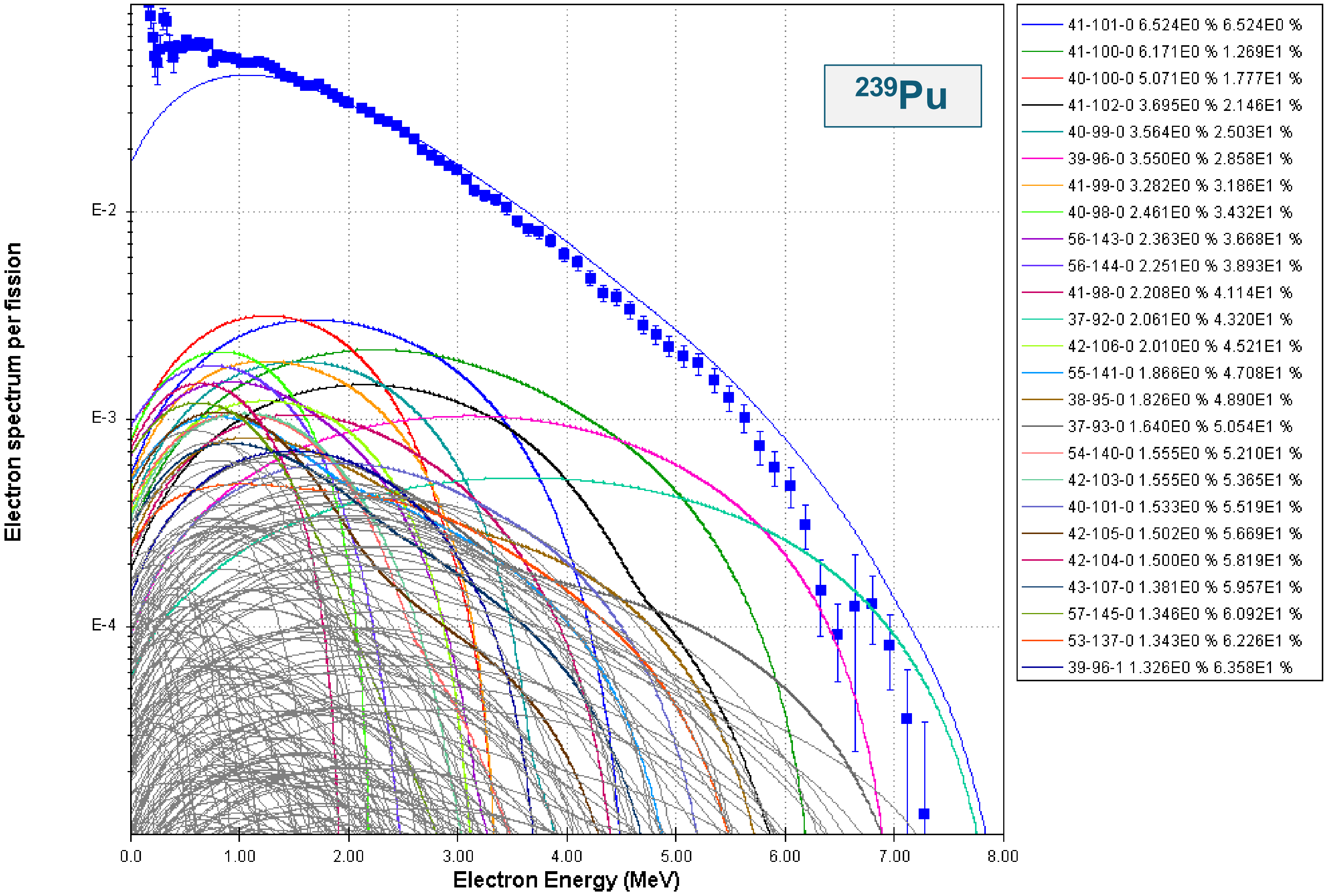
Beta-delayed electrons

- There is an overprediction for ^{239}Pu at energies higher than 3.5 MeV.
- Independent yields could be adjusted to match measured spectra.
- Independent yield correlations would be needed.



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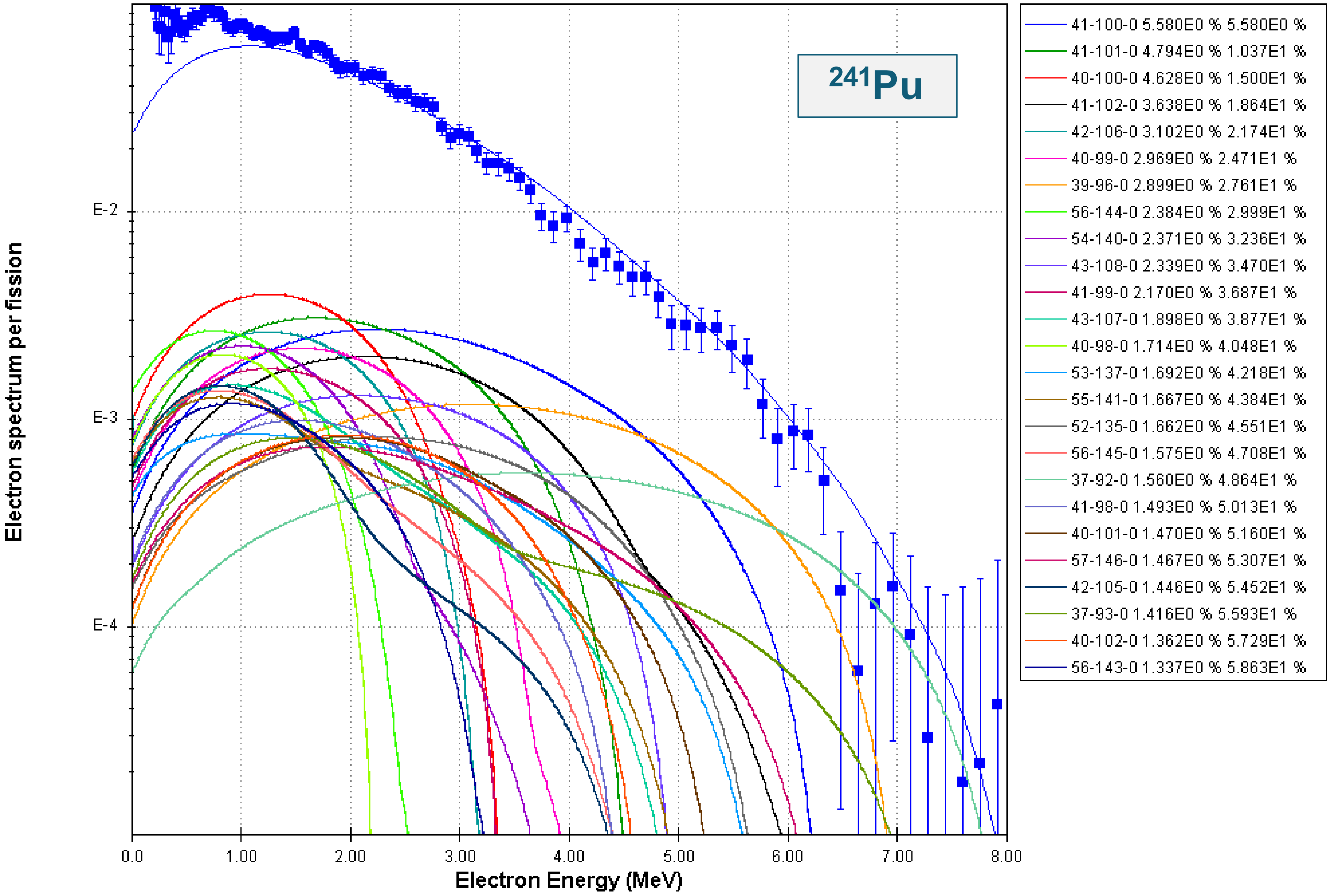
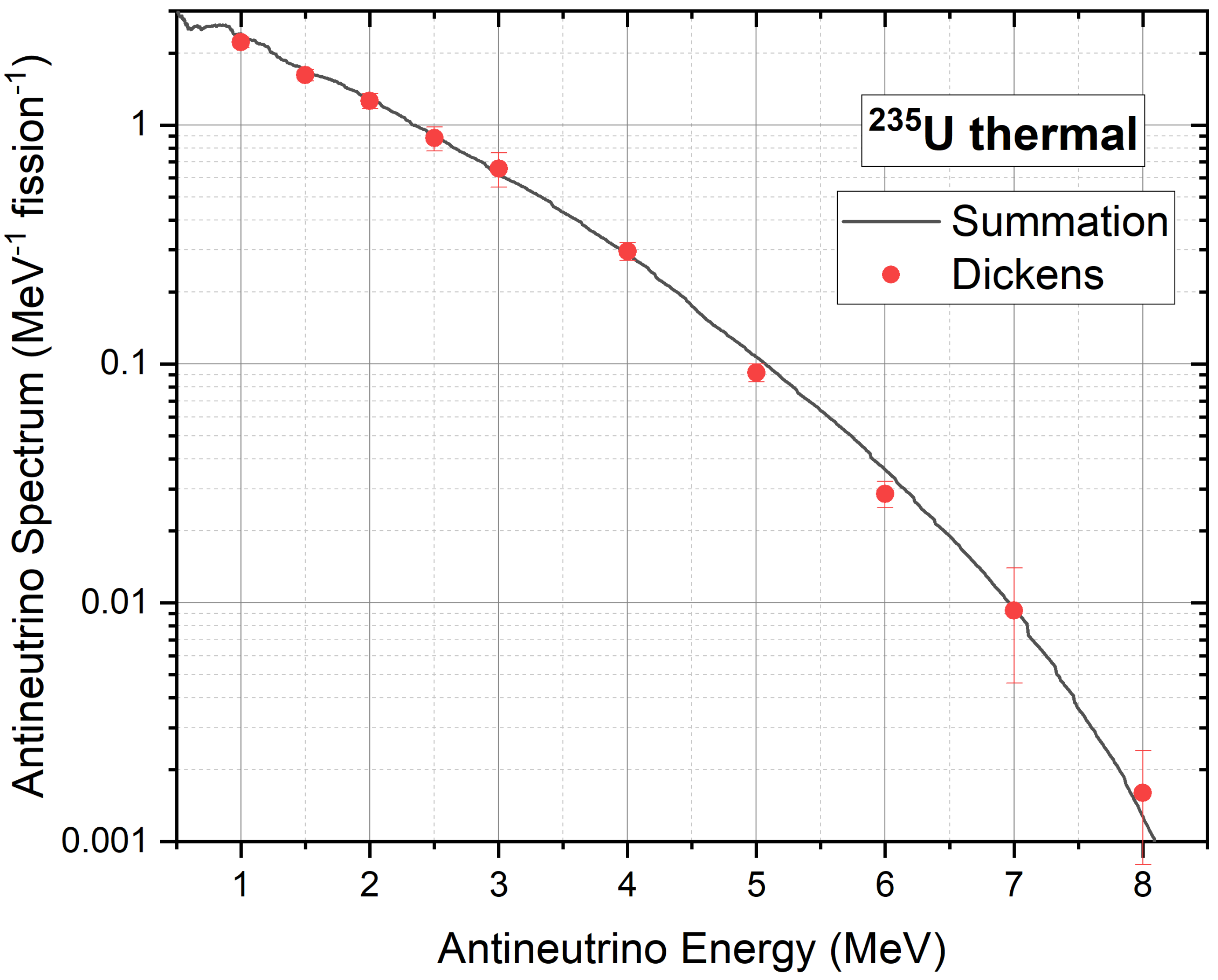
Beta-delayed electrons

- For ^{241}Pu, the agreement is quite good, but we see a slight overprediction at around 4 MeV.



Beta-delayed antineutrinos

This body of data was used to obtain the equilibrium antineutrino spectrum in 1981, with surprisingly good agreement with current summation results.



Beta delayed electrons (and gammas) future work.

- ❑ Complete digitizing the data and submit it to EXFOR.
- ❑ Obtain R59, R51 and R19 values as function of electron energy, including uncertainty estimates.
- ❑ Fit Independent Fission Yields to match measured electron and gamma spectra.