Antineutrino Spectra and Nuclear Databases

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ENDF/B-VII.1 Decay Data Sublibrary

- Based on the latest ENSDF file.
- EEM and ELP data for most of Greenwood nuclides and all of the Valencia results.
- CGM calculations by Kawano and Moller, with the latest Q-values, for nuclides with incomplete data in ENSDF (not available for antineutrinos due to a format issue).

ENDF/B-VII.1.1 (in progress)

Contains Iβ from Greenwood and Valencia TAGS.
Contains Iβ from a fit to Rudstam/Tengblad data for a few nuclides.
Iβ (gs) for 92Rb set to 95.1% (from Lhesornneau et al).

Recent work on Antineutrino Spectra Calculations

Antineutrino spectra are calculated as (Vogel 1981)

$$\text{Spectrum} = \Sigma\ \text{CFY}_i\ \text{Spectrum}_i$$

Cumulative Fission Yields from JEFF-3.1

No adjustable parameters

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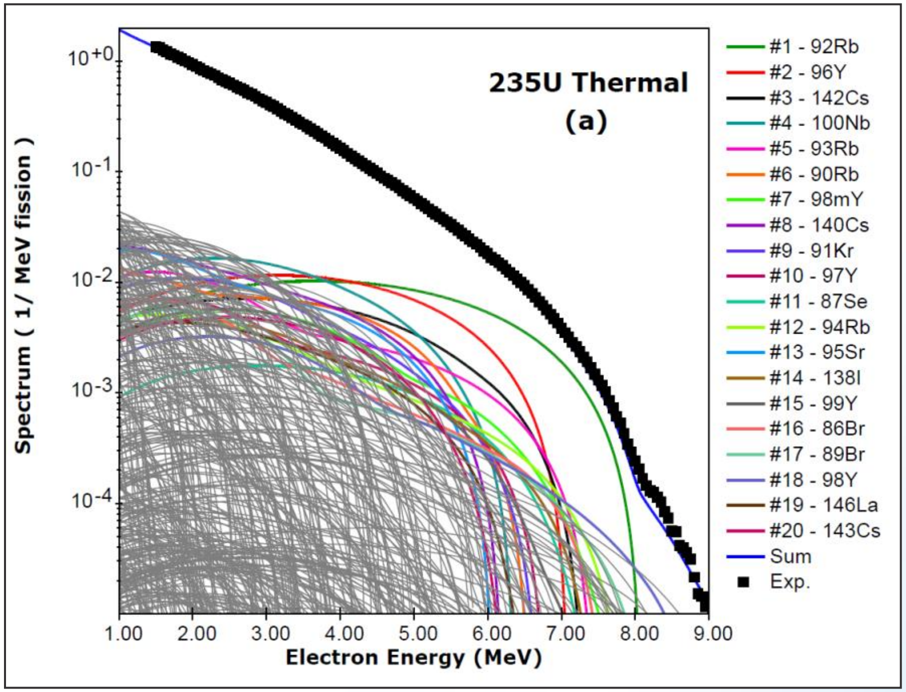
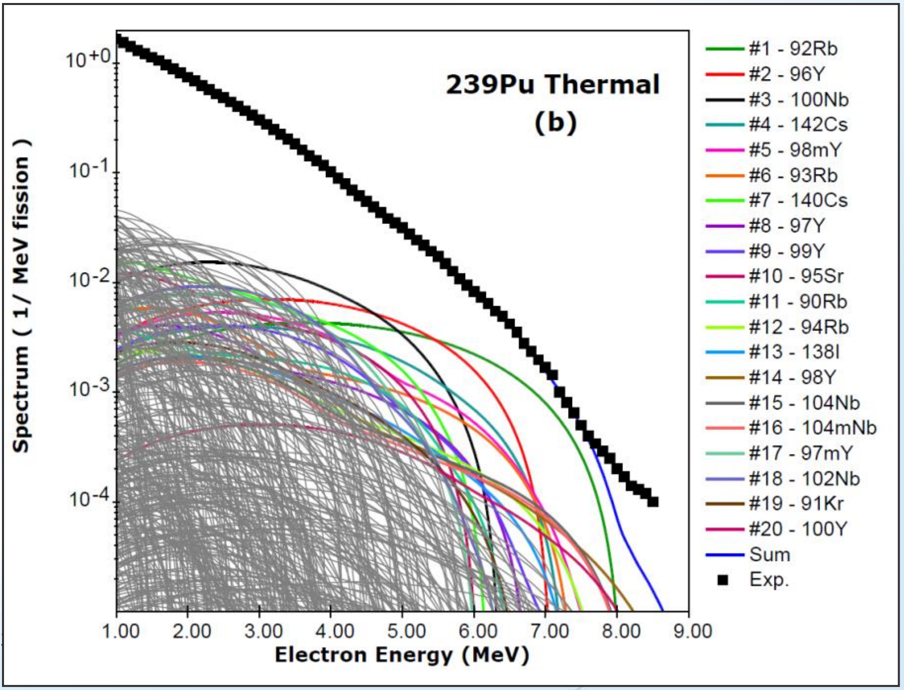
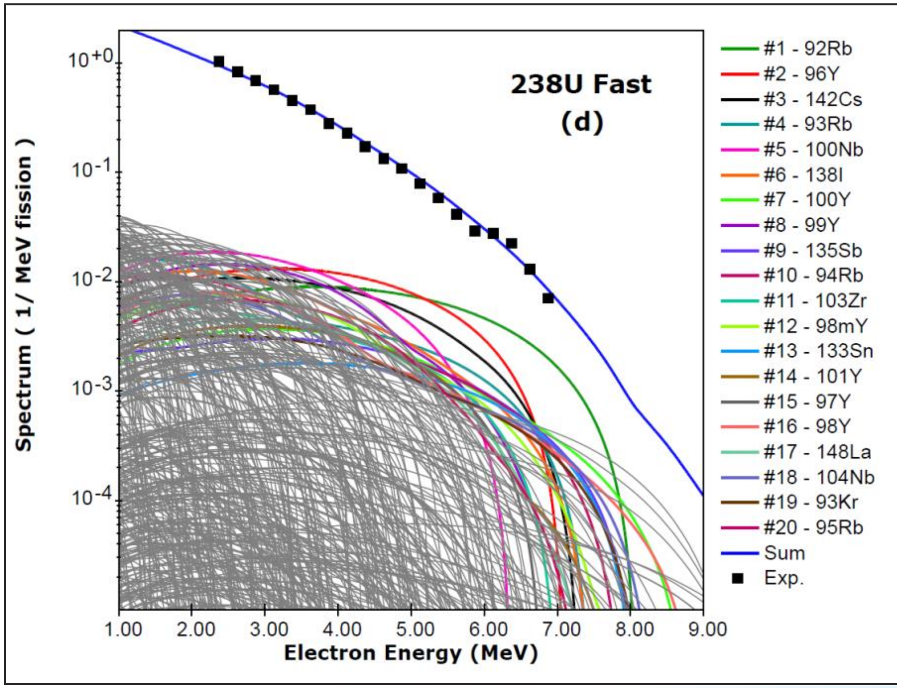
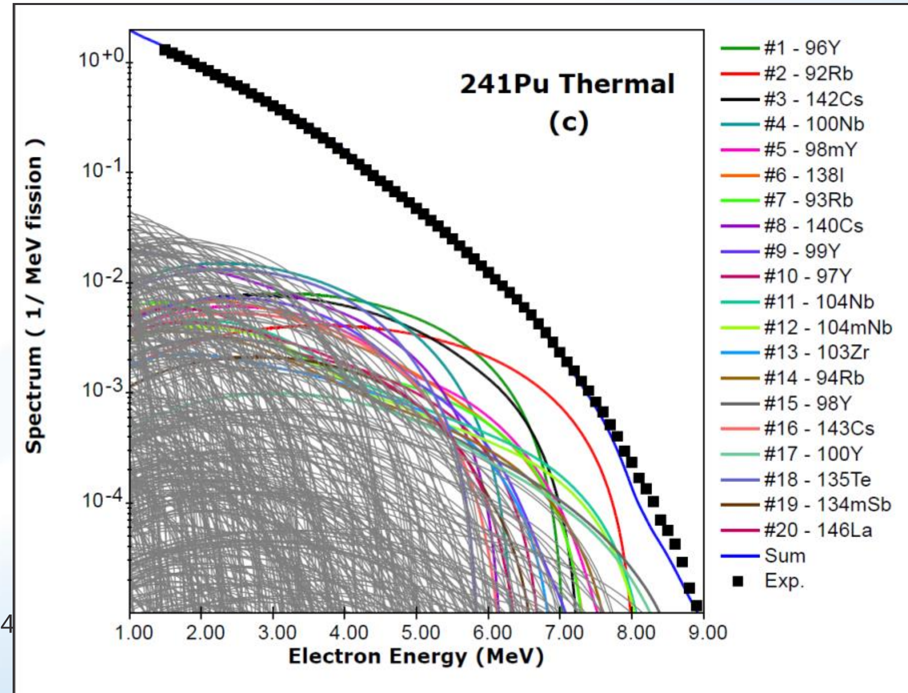




Recent work on Antineutrino Spectra Calculations



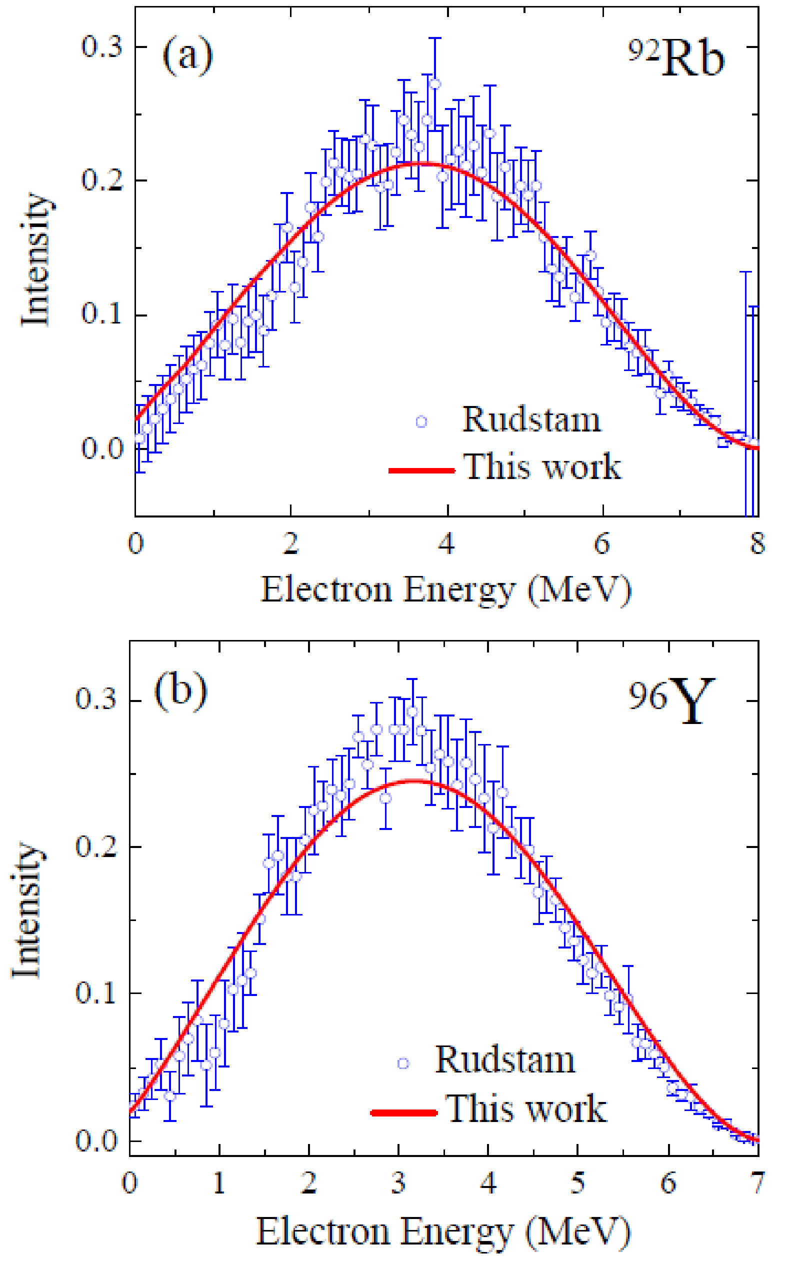
Nuclides with CGM calculations contribute about 4% for 235U, 14% for 238U, 7% for 239Pu and 12% for 241Pu, to the total <σI>.



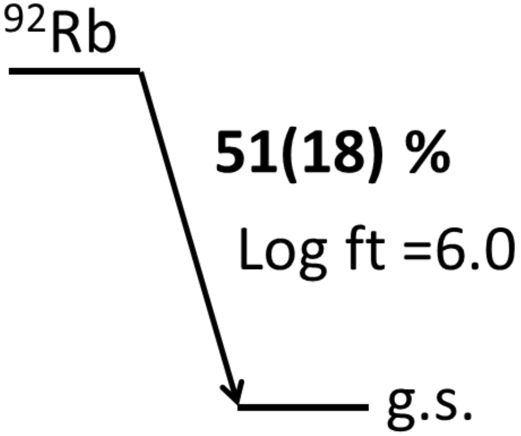
Recent work on Antineutrino Spectra Calculations

Comparison with Rudstam data for the two most important nuclides for energies higher than 5 MeV, assuming allowed shape.

New measurements are needed to test deviation from allowed shapes for first forbidden transitions.



Conflicting Results on ^{92}Rb decay

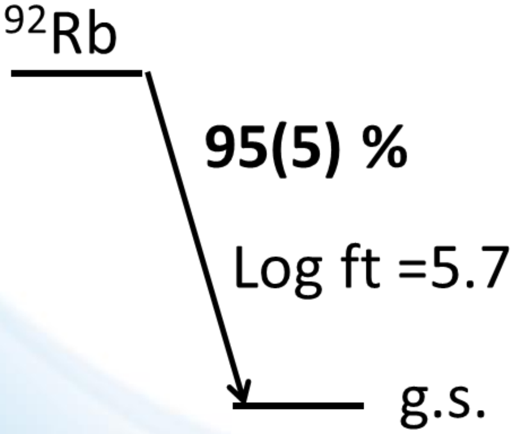


^{92}Rb

51(18) %

Log ft =6.0

g.s.

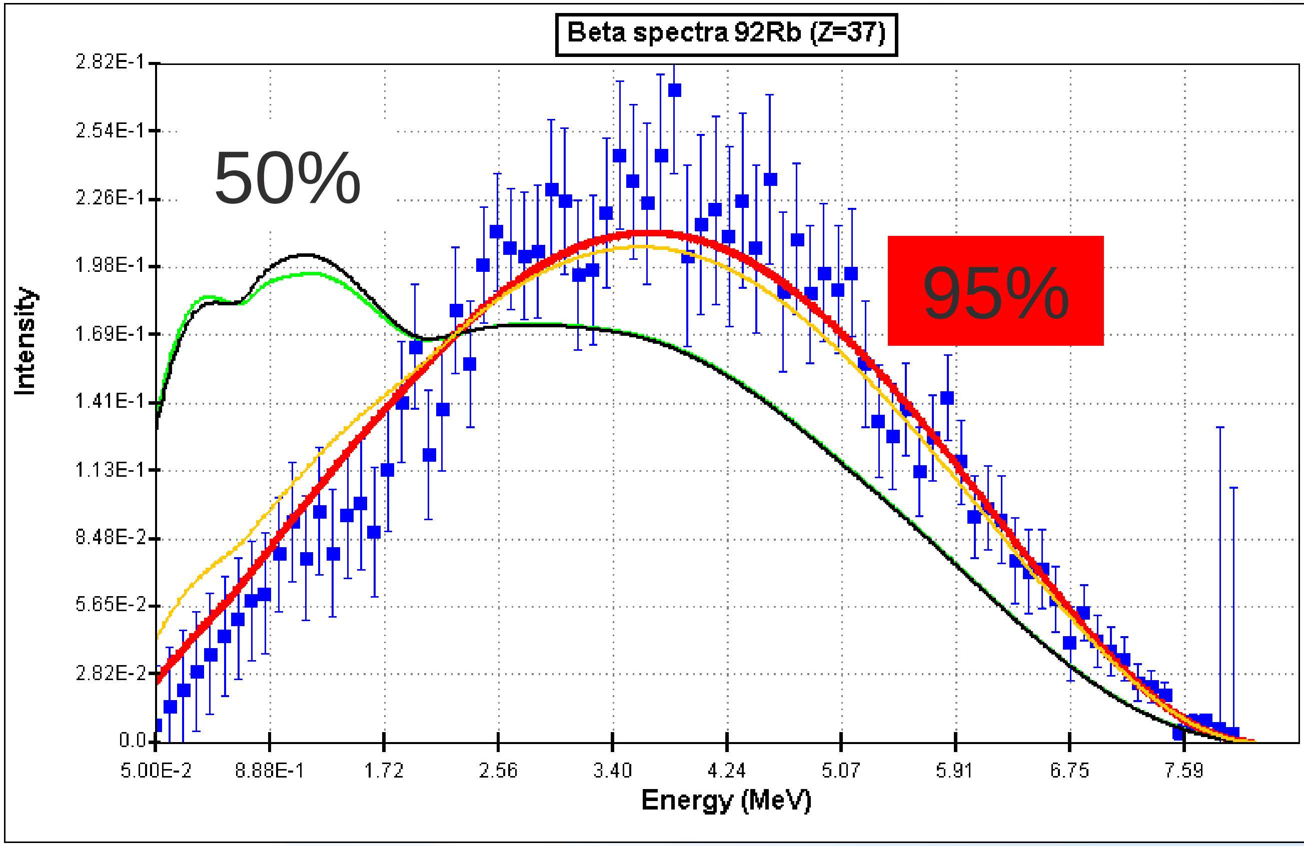


^{92}Rb

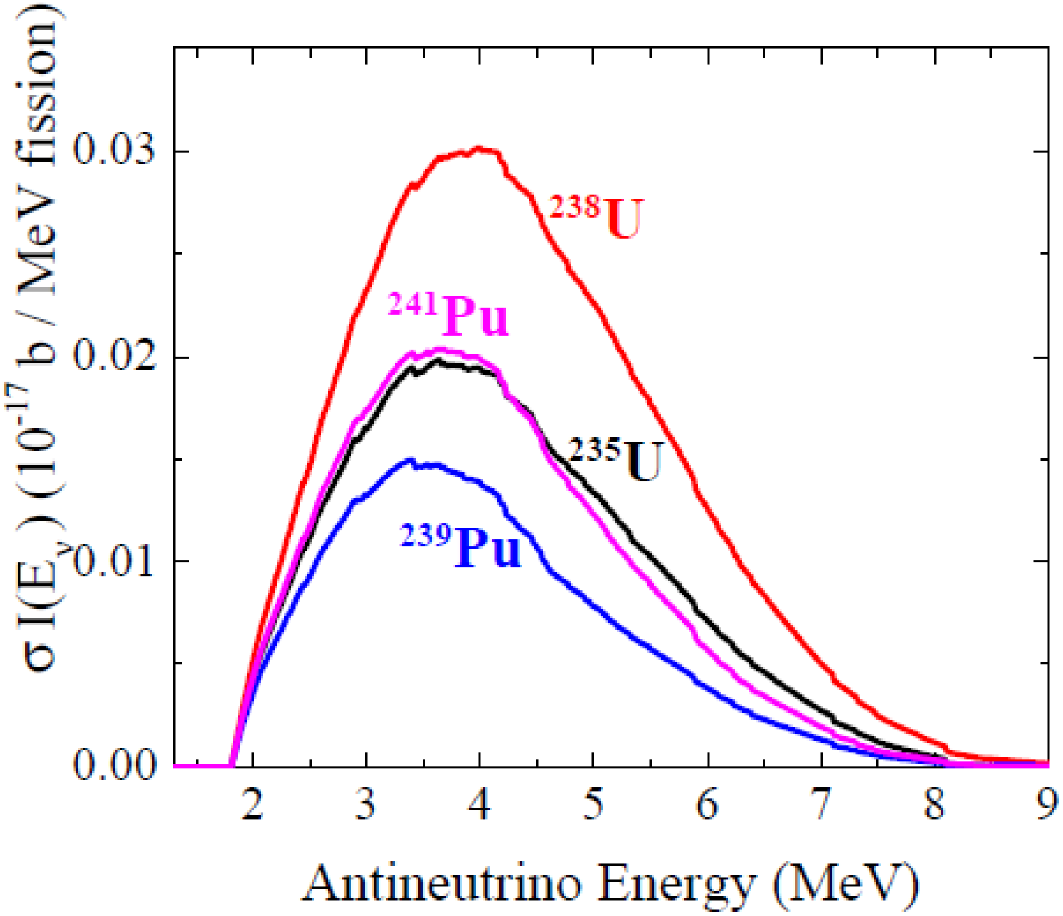
95(5) %

Log ft =5.7

g.s.

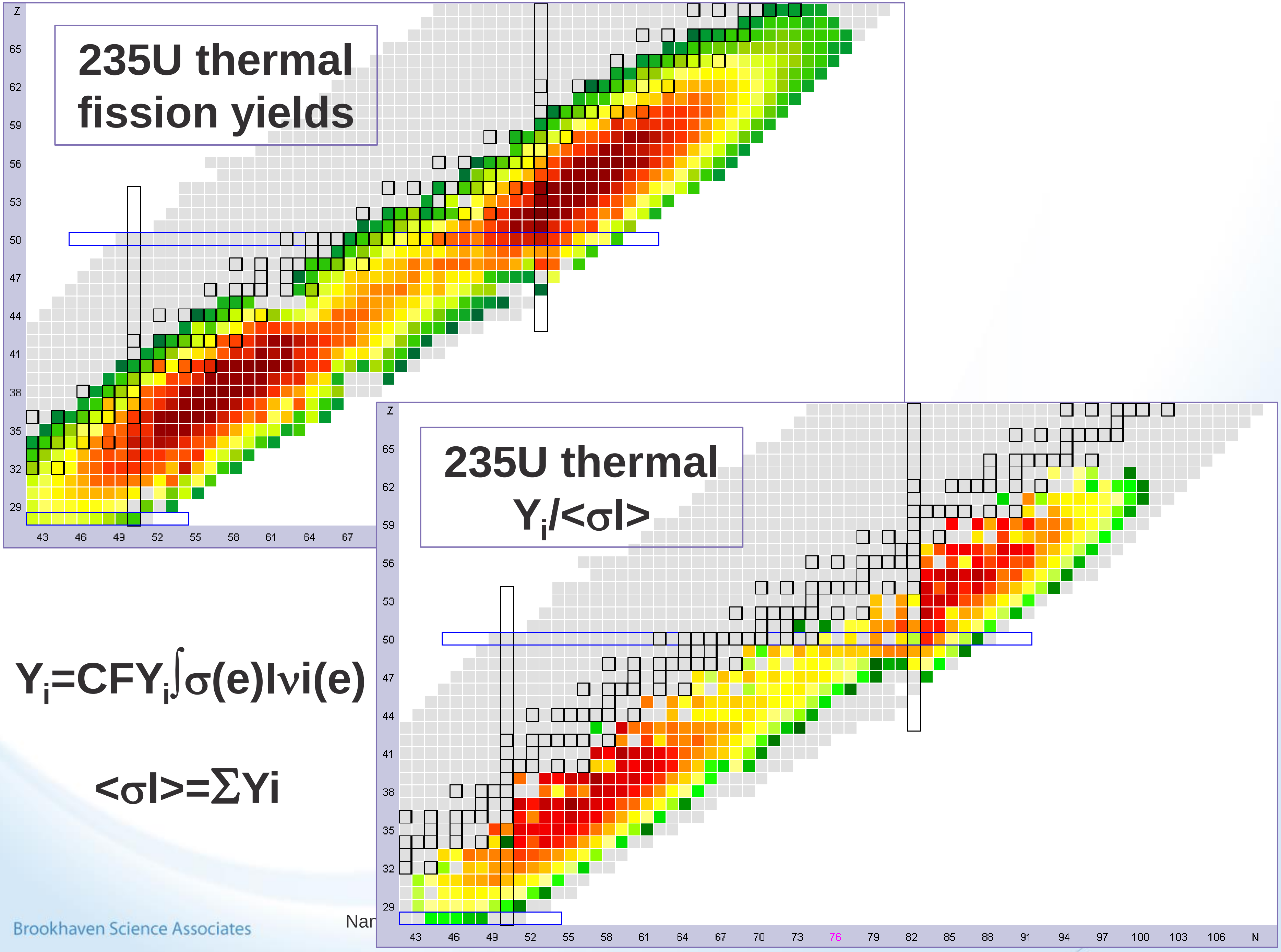


Antineutrino multiplicities



Target	Delayed neutron multiplicity/fission
238U	4.4E-2
235U	1.585E-2
241Pu	1.62E-2
239Pu	6.45E-3

The integral of antineutrino multiplicity has a similar behavior as the delayed neutron multiplicity.

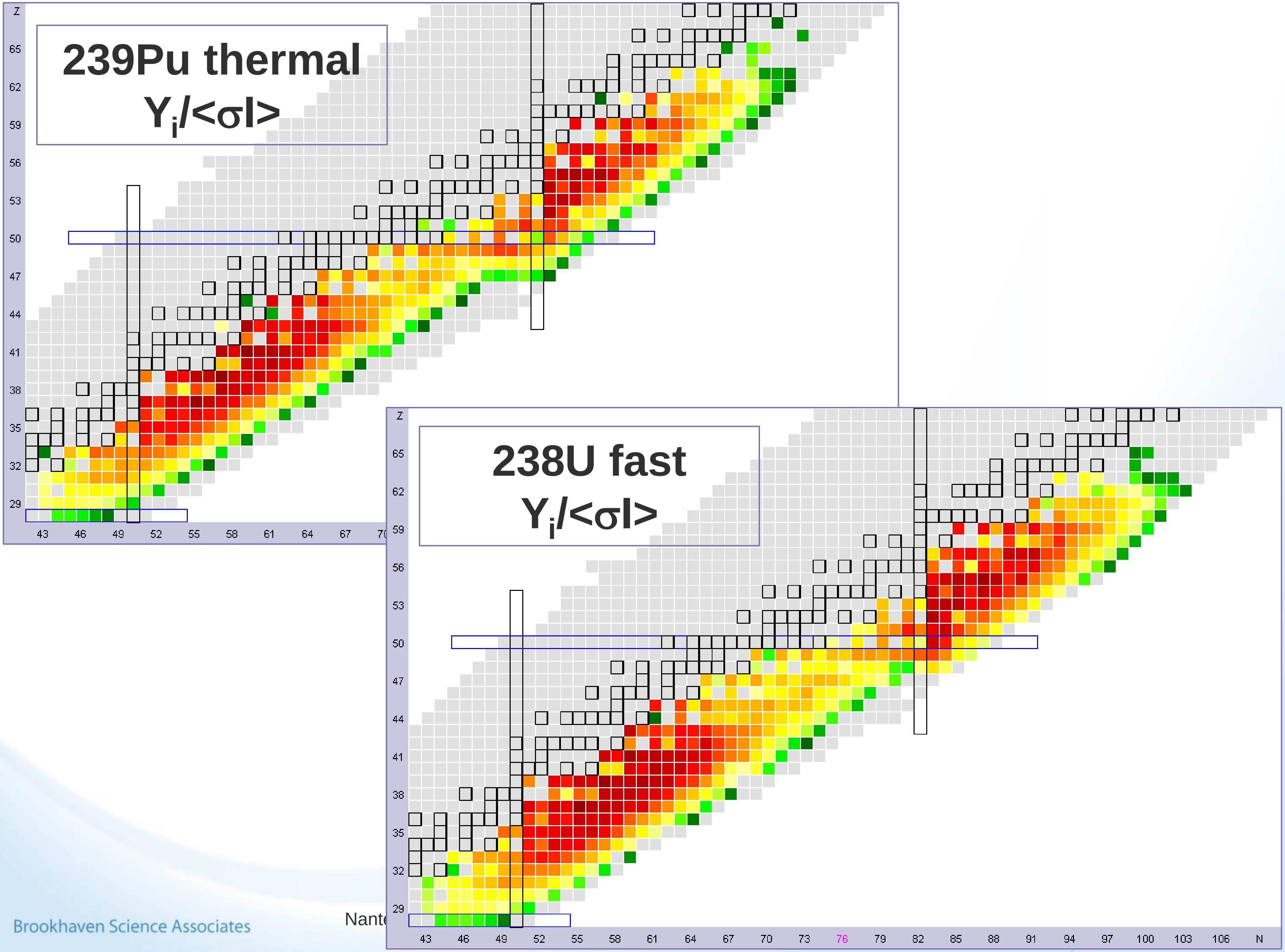


235U thermal fission yields

235U thermal $Y_i/\langle \sigma I \rangle$

$$Y_i = CFY_i \int \sigma(e) I \nu i(e)$$

$$\langle \sigma I \rangle = \Sigma Y i$$

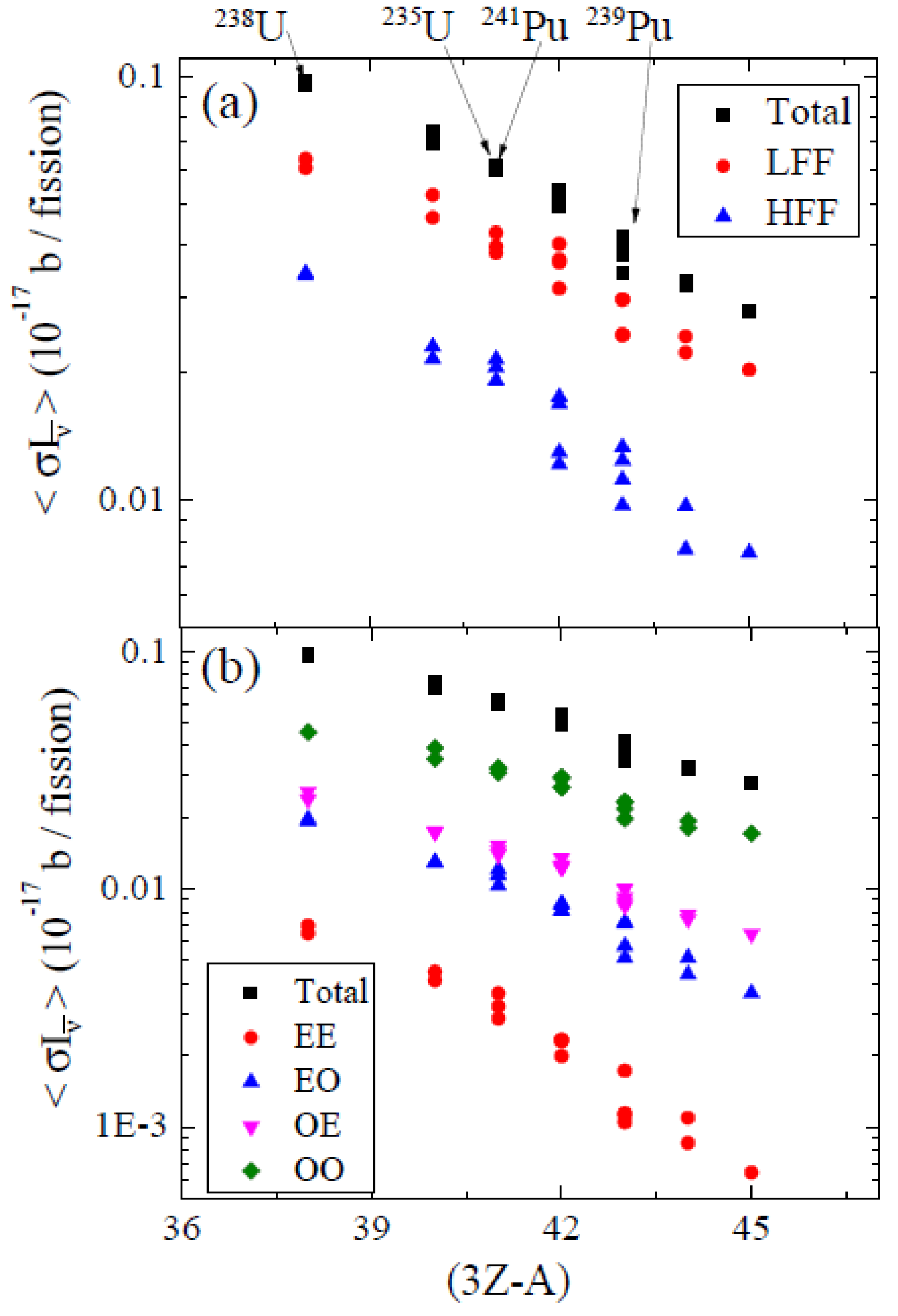


Systematics of <σl> with (3Z-A)

LFF: Light fission fragments (Z<47)

HFF: Heavy Fission Fragments (Z >= 47)

EE: Even-Z, Even-N
EO: Even-Z, Odd-N
OE: Odd-Z, Even-N
OO: Odd-Z, Odd-N



Qβ- using liquid drop model parameters

$Q\beta\text{-}(Z,A)=Mn-Mp-a_c(2Z+1)/A^{2/3}+a_{sym}(4N-2Z-4)/A+\Delta(Z+1,A)-\Delta(Z,A)$

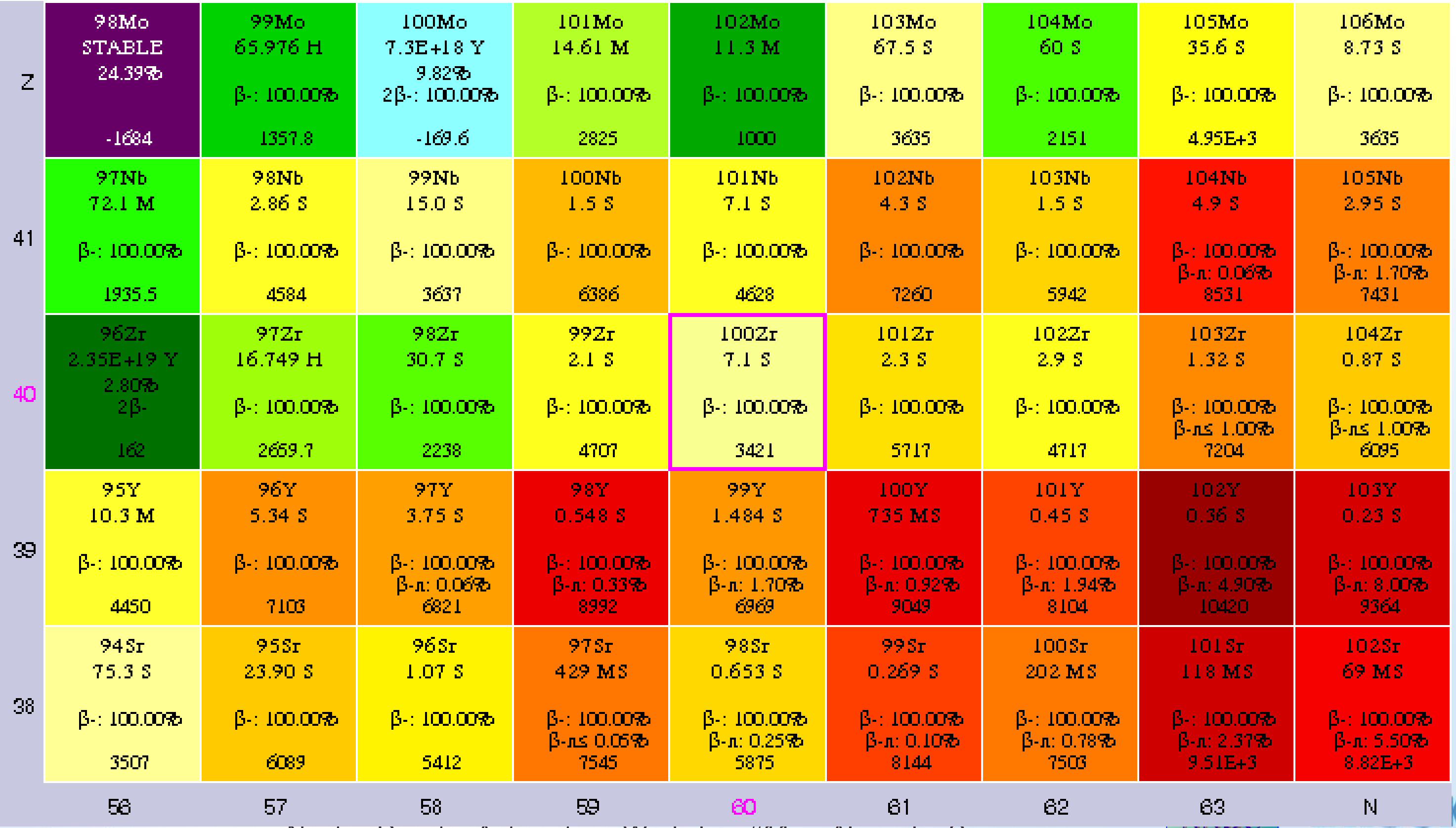
If Z,A= EE -> Z+1,A=OO -> $\Delta(Z+1,A)-\Delta(Z,A)=-2\delta/A^{1/2}$

If Z,A= EO -> Z+1,A=OE -> $\Delta(Z+1,A)-\Delta(Z,A)=0$

If Z,A= OE -> Z+1,A=EO -> $\Delta(Z+1,A)-\Delta(Z,A)=0$

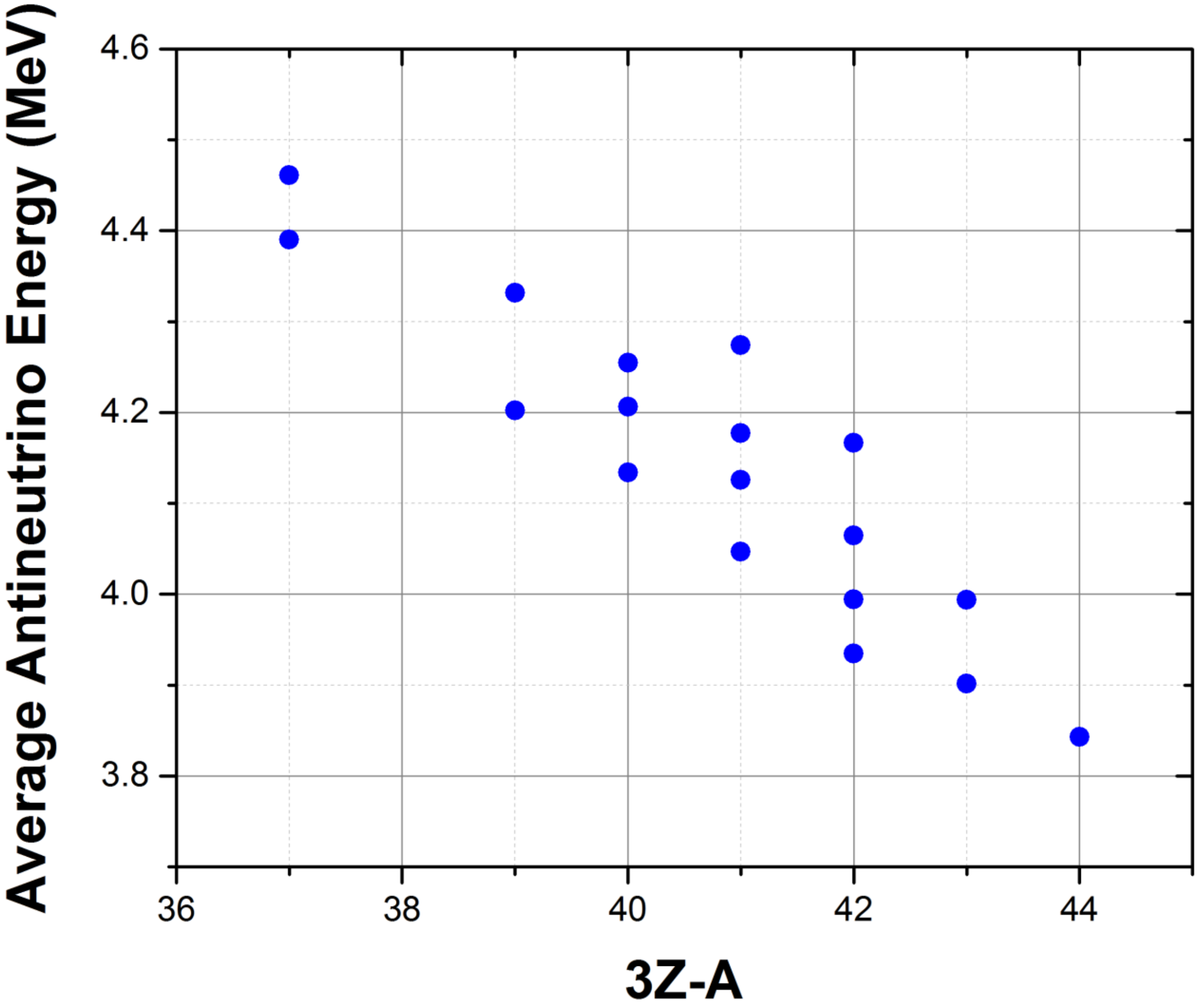
If Z,A= OO -> Z+1,A=EE -> $\Delta(Z+1,A)-\Delta(Z,A)=+2\delta/A^{1/2}$

$\delta\approx12$ MeV, $2\delta/A^{1/2}\approx2.4$ MeV for A=100

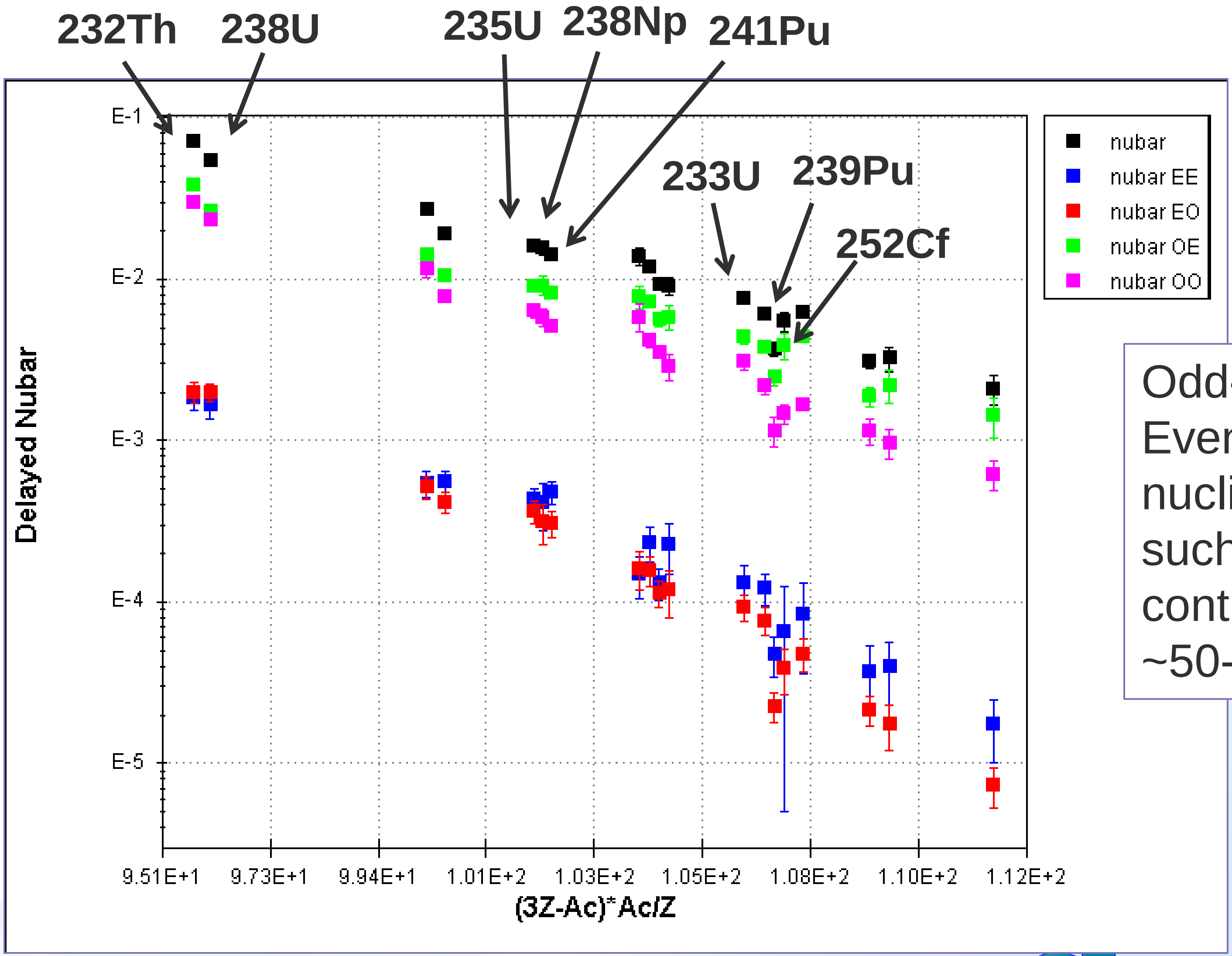


Z	98Mo STABLE 24.39% -1684	99Mo 65.976 H β-: 100.00% 1357.8	100Mo 7.3E+18 Y 9.82% 2β-: 100.00% -169.6	101Mo 14.61 M β-: 100.00% 2825	102Mo 11.3 M β-: 100.00% 1000	103Mo 67.5 S β-: 100.00% 3635	104Mo 60 S β-: 100.00% 2151	105Mo 35.6 S β-: 100.00% 4.95E+3	106Mo 8.73 S β-: 100.00% 3635
41	97Nb 72.1 M β-: 100.00% 1935.5	98Nb 2.86 S β-: 100.00% 4584	99Nb 15.0 S β-: 100.00% 3637	100Nb 1.5 S β-: 100.00% 6386	101Nb 7.1 S β-: 100.00% 4628	102Nb 4.3 S β-: 100.00% 7260	103Nb 1.5 S β-: 100.00% 5942	104Nb 4.9 S β-: 100.00% β-n: 0.06% 8531	105Nb 2.95 S β-: 100.00% β-n: 1.70% 7431
40	96Zr 2.35E+19 Y 2.80% 2β- 162	97Zr 16.749 H β-: 100.00% 2659.7	98Zr 30.7 S β-: 100.00% 2238	99Zr 2.1 S β-: 100.00% 4707	100Zr 7.1 S β-: 100.00% 3421	101Zr 2.3 S β-: 100.00% 5717	102Zr 2.9 S β-: 100.00% 4717	103Zr 1.32 S β-: 100.00% β-n≤ 1.00% 7204	104Zr 0.87 S β-: 100.00% β-n≤ 1.00% 6095
39	95Y 10.3 M β-: 100.00% 4450	96Y 5.34 S β-: 100.00% 7103	97Y 3.75 S β-: 100.00% β-n: 0.06% 6821	98Y 0.548 S β-: 100.00% β-n: 0.33% 8992	99Y 1.484 S β-: 100.00% β-n: 1.70% 6969	100Y 735 MS β-: 100.00% β-n: 0.92% 9049	101Y 0.45 S β-: 100.00% β-n: 1.94% 8104	102Y 0.36 S β-: 100.00% β-n: 4.90% 10420	103Y 0.23 S β-: 100.00% β-n: 8.00% 9364
38	94Sr 75.3 S β-: 100.00% 3507	95Sr 23.90 S β-: 100.00% 6089	96Sr 1.07 S β-: 100.00% 5412	97Sr 429 MS β-: 100.00% β-n≤ 0.05% 7545	98Sr 0.653 S β-: 100.00% β-n: 0.25% 5875	99Sr 0.269 S β-: 100.00% β-n: 0.10% 8144	100Sr 202 MS β-: 100.00% β-n: 0.78% 7503	101Sr 118 MS β-: 100.00% β-n: 2.37% 9.51E+3	102Sr 69 MS β-: 100.00% β-n: 5.50% 8.82E+3
	56	57	58	59	60	61	62	63	N

(3Z-A) Average antineutrino energy dependence



Delayed nu-bar=Σ CFY$_i$ Pn$_i$ using JEFF-3.1 yields and ENDF/B-VII.1 decay data



Odd-Z Even-N nuclides, such as 87Br contribute ~50-65%.

Relation to Decay Heat

Power released as a function of time following a single fission event.

$DH\gamma = \Sigma \langle E\gamma_i \rangle \lambda_i N_i(t)$,

aka EEM decay heat

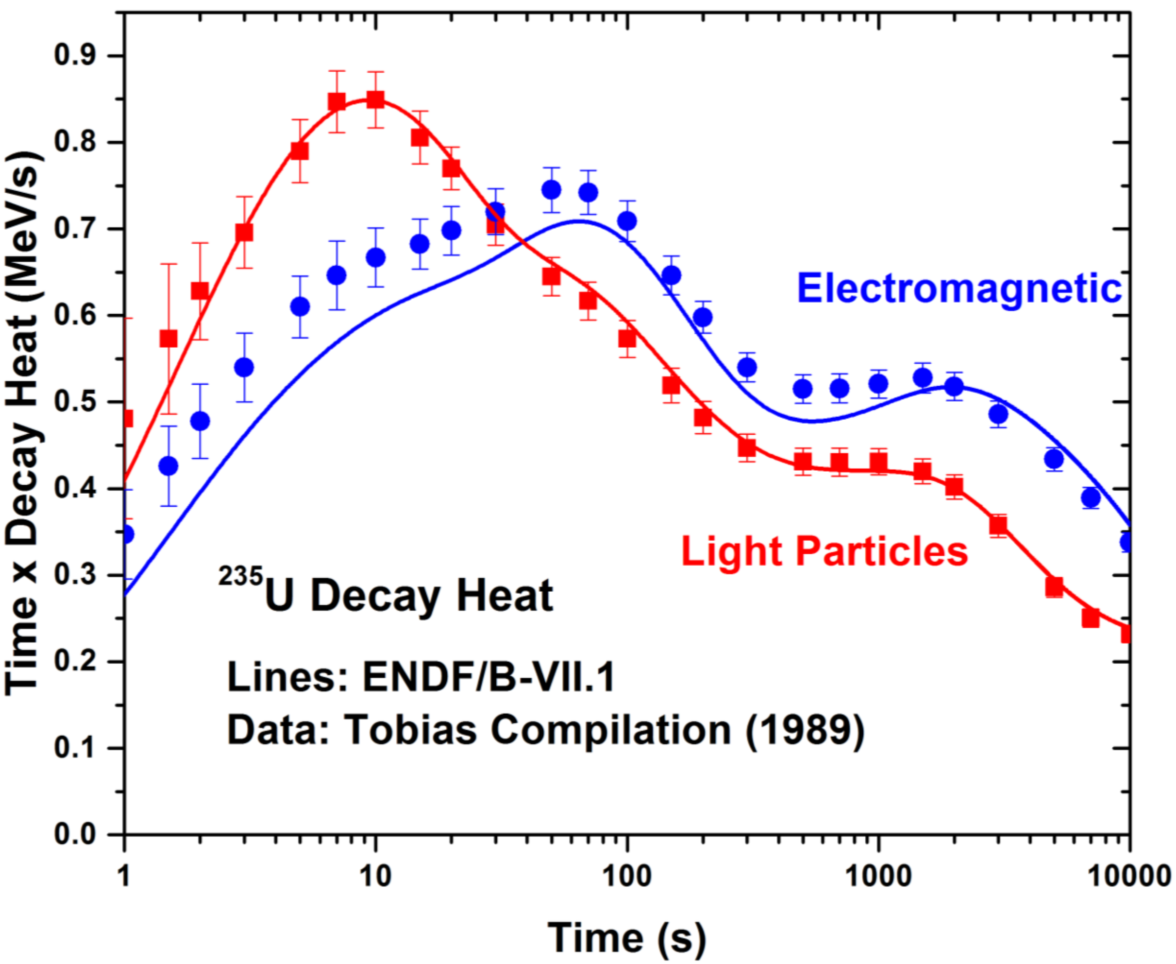
$DH\beta = \Sigma \langle E\beta_i \rangle \lambda_i N_i(t)$,

aka ELP decay heat

$dN_i/dt = -\lambda_i Ni + \Sigma \lambda_{ik} Nk$,

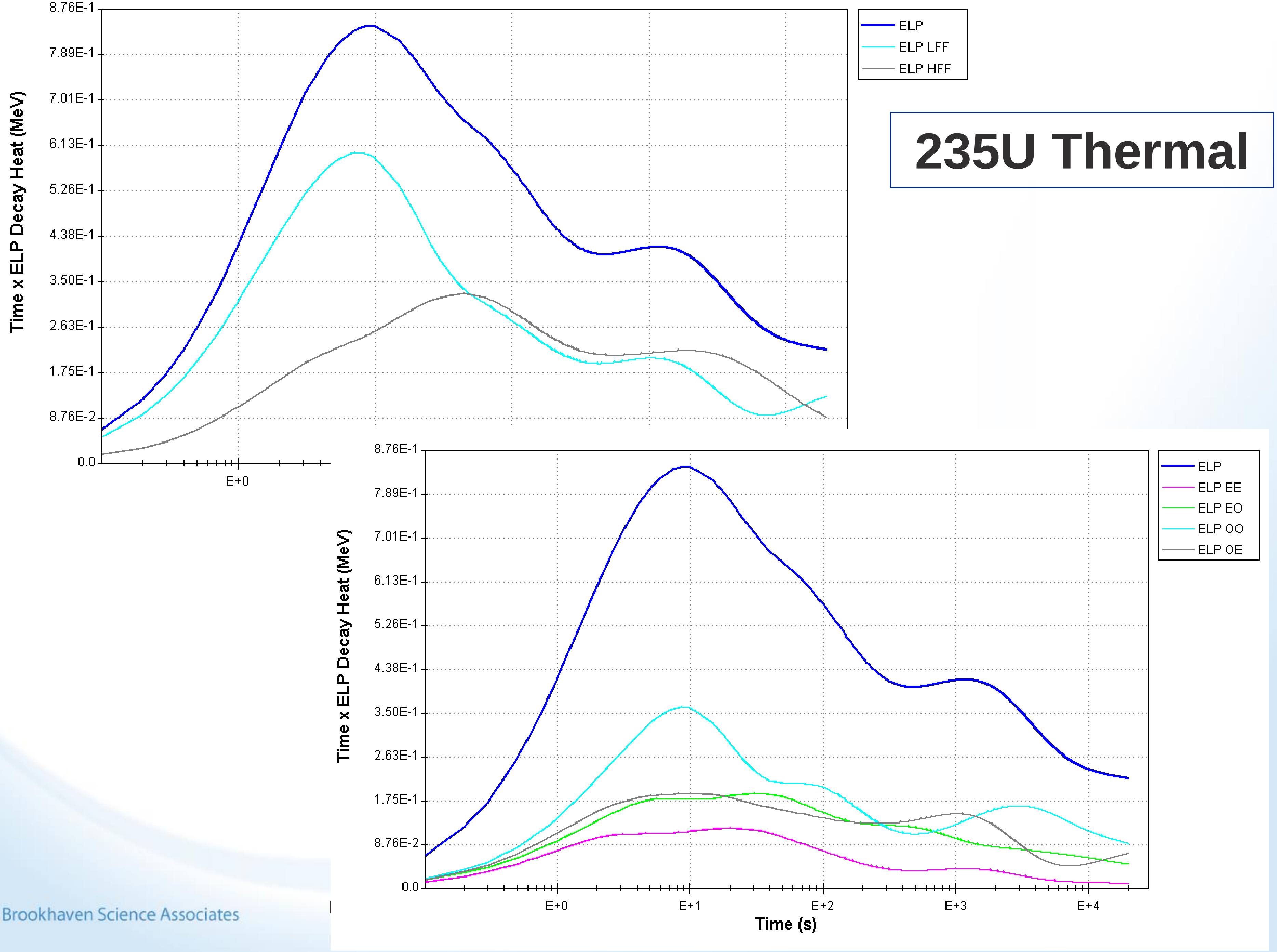
Solved with:

$N_i(0) = FY_i$



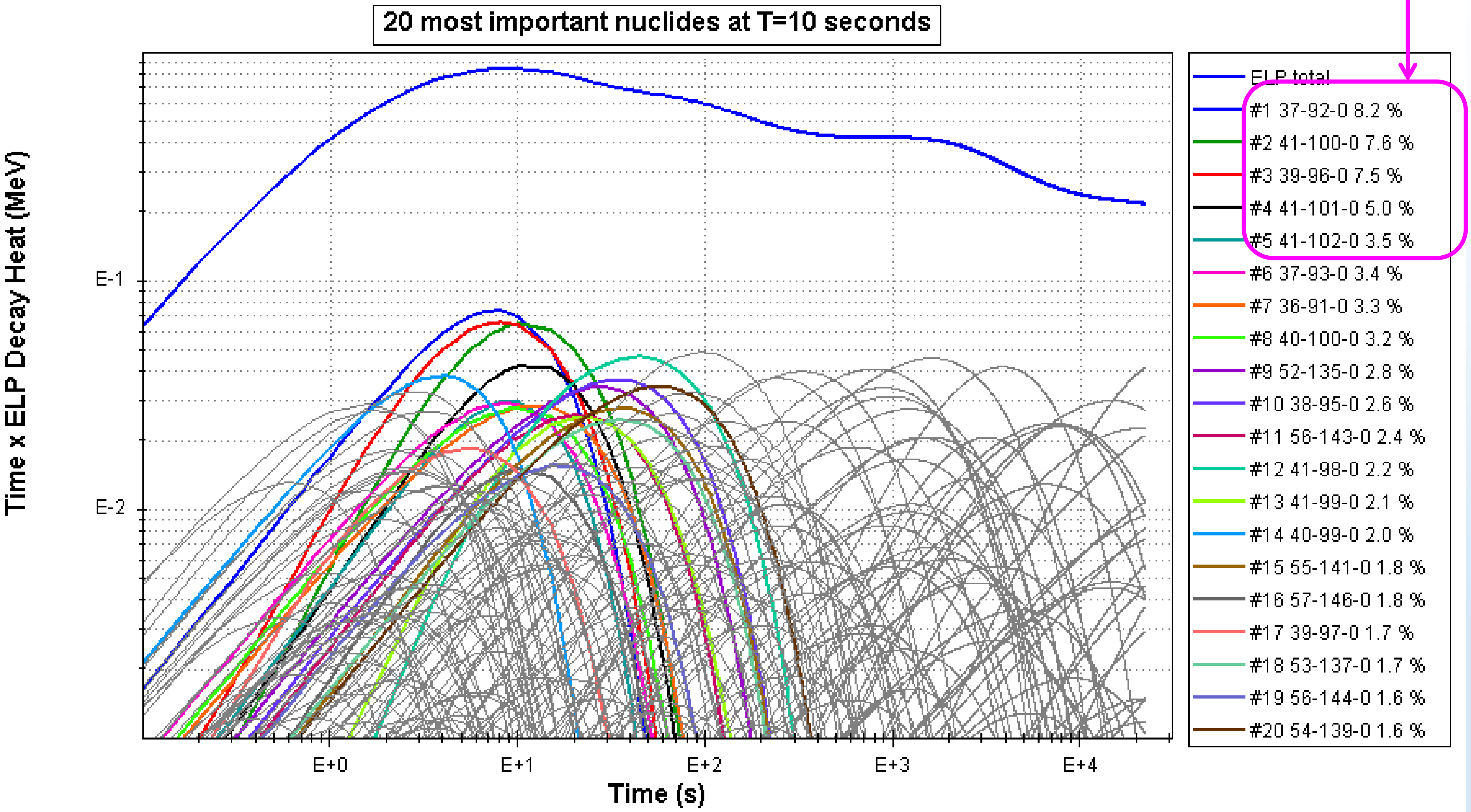
We will now do for decay heat an analysis similar to what we did for delayed neutrons

235U Thermal



235U Thermal

92Rb, 100Nb, 96Y,
101Nb,102Nb



Conclusions

Due to incomplete decay schemes and not very precise fission yields, the summation method can’t be used to calculate antineutrino spectra with high-precision.

However, one can learn a lot by exploiting from it, and relate it with the decay heat and delayed nu-bar phenomena.

Odd-Z, Odd-N nuclides are the main contributors to the antineutrino spectra, due to a) large Qβ and existence of low-spin ground state/isomer.

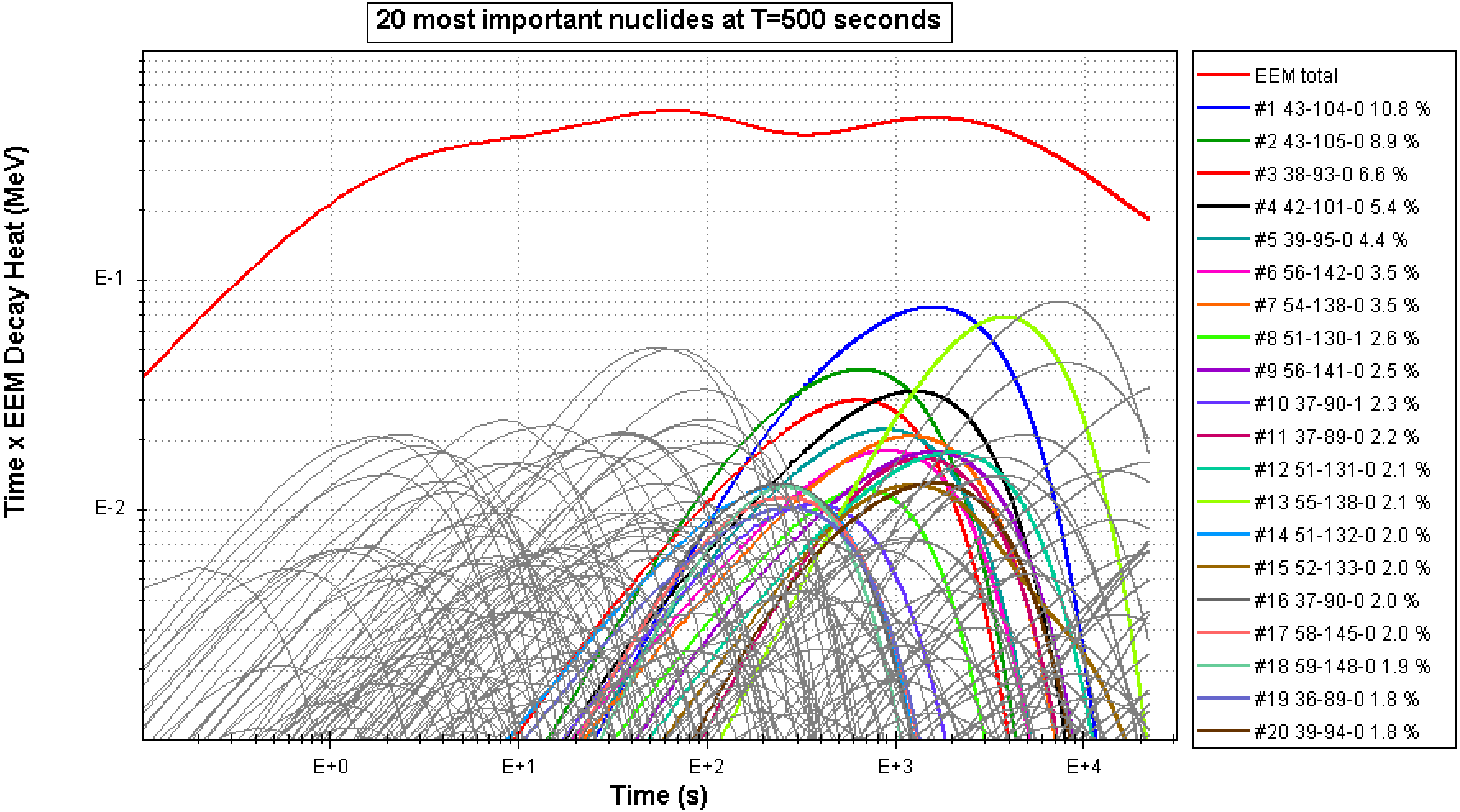
Similarly, the light fission fragment contributes more antineutrinos than the heavy group.

Fission yields are needed in summation and decay heat calculations. However, there are discrepancies between the different libraries.

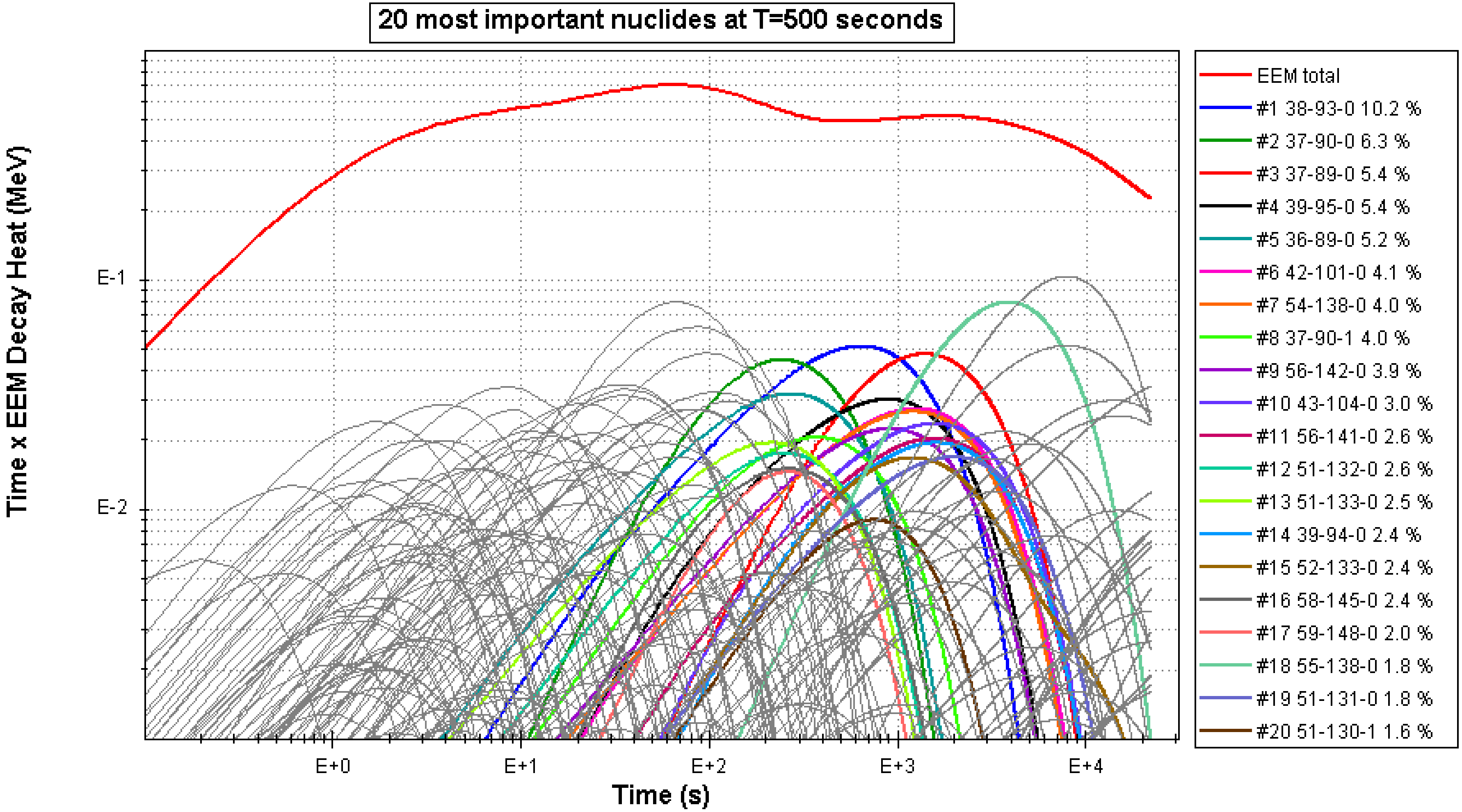
In particular, for 92Rb a measurement from Lowell puts the CFY at around 7%.

Back up slides

239Pu Thermal



235U Thermal


20 most important nuclides at T=500 seconds