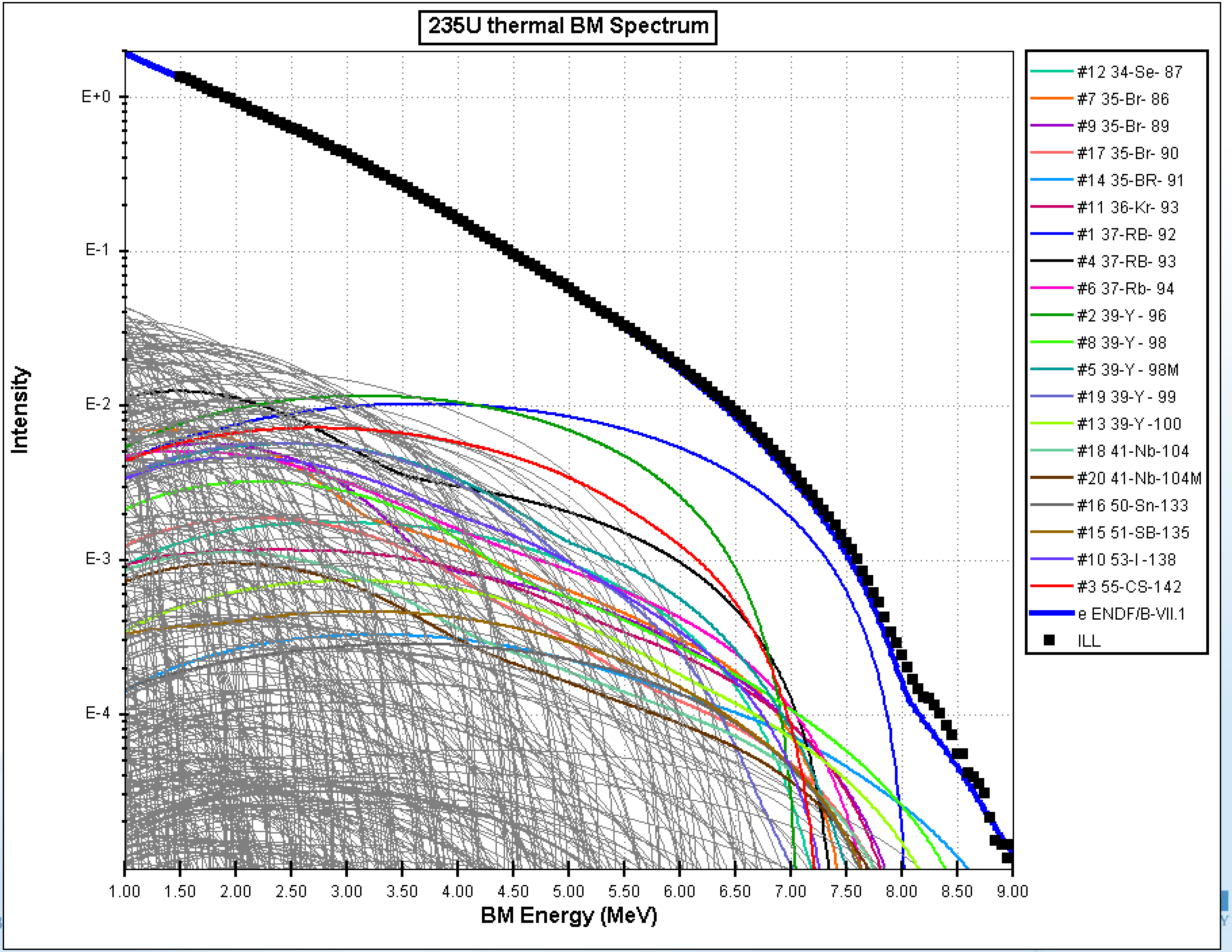
Experimental Opportunities for Improving Summation Calculations

E.A. McCutchan, A.A. Sonzogni, T.D. Johnson

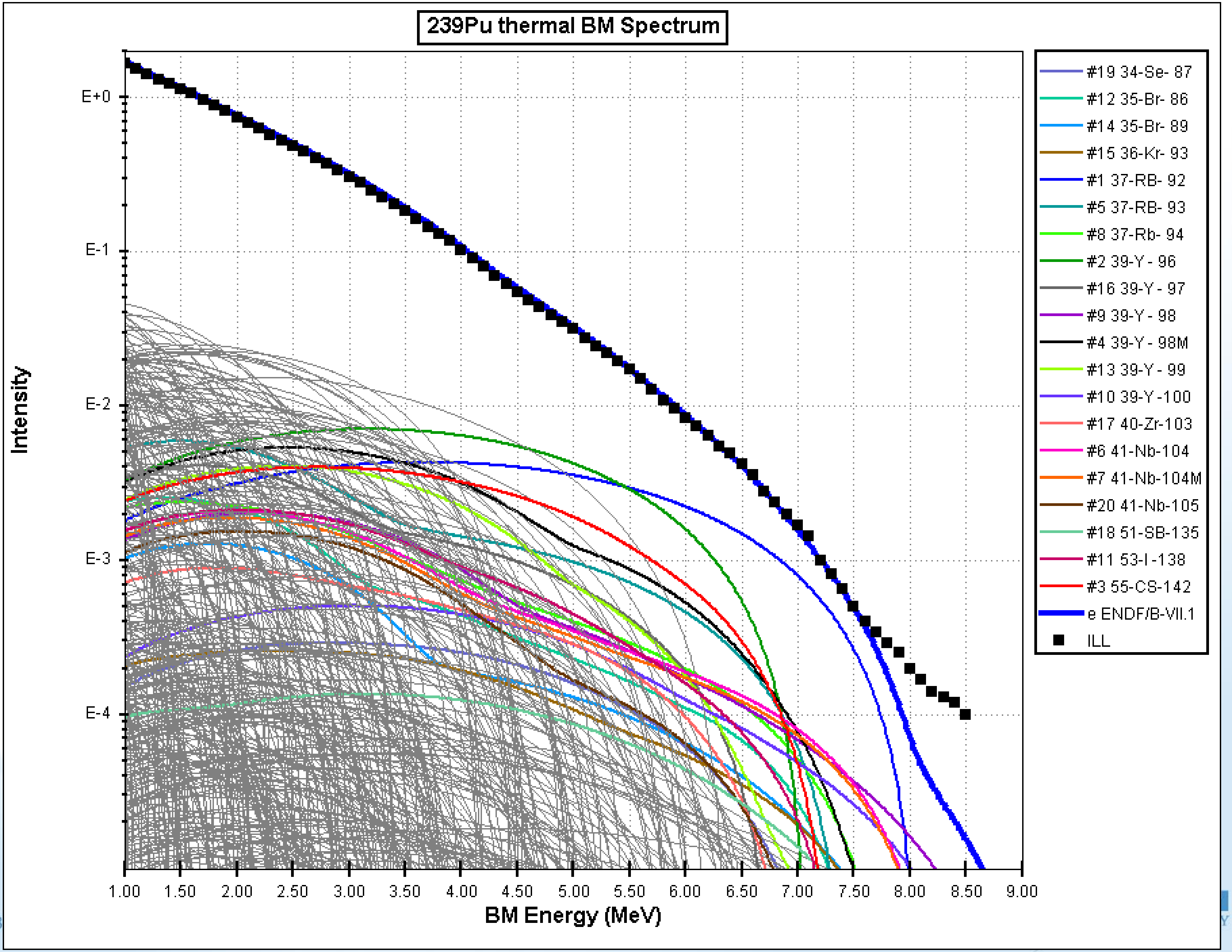
National Nuclear Data Center

Sensitivity Studies on Individual Contributors

- Summation calculations
- JEFF fission yields and ENDFVII.1 decay data
- Identify main contributors to different energy regions of the spectra

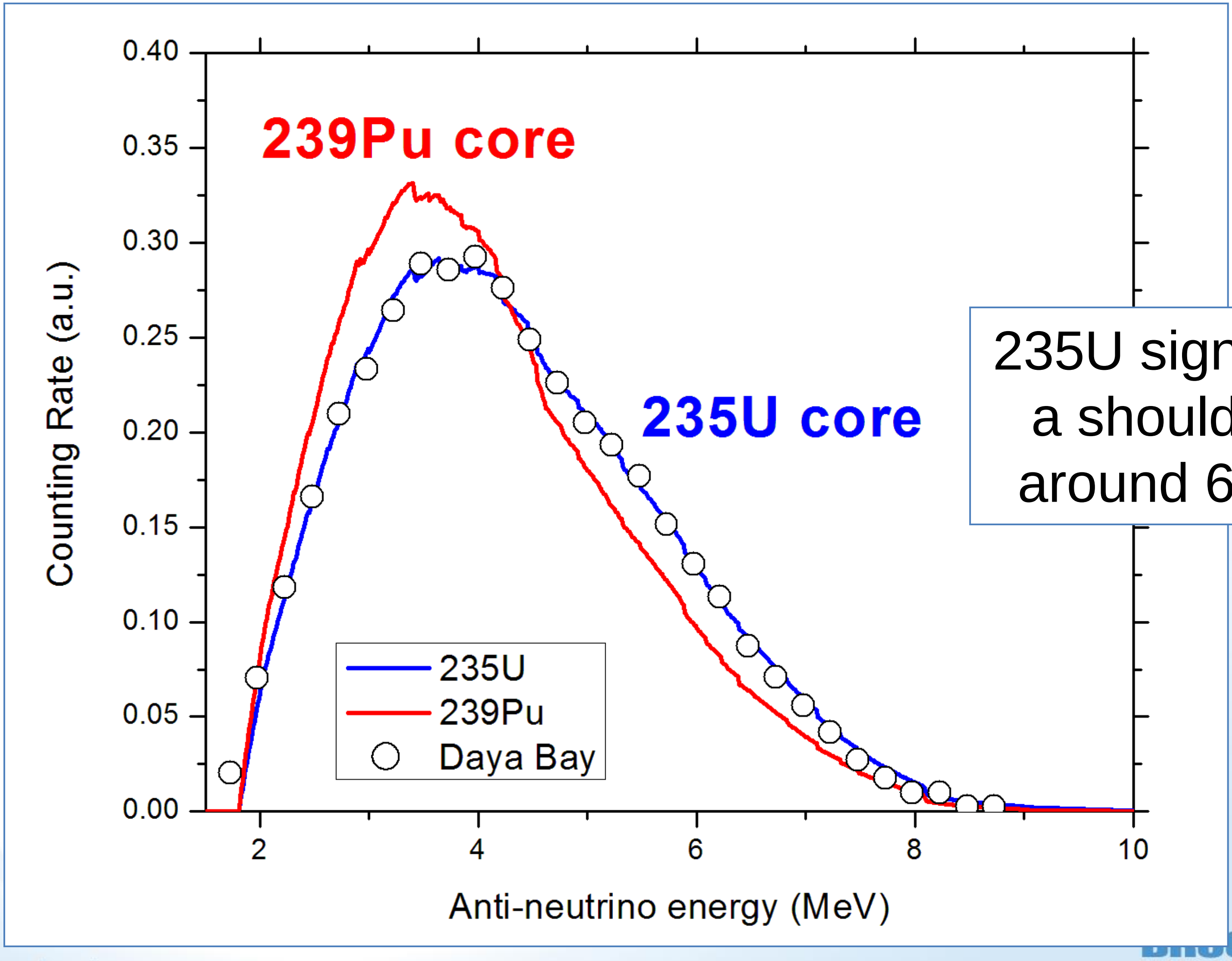


235U thermal BM Spectrum
Intensity
E+0
E-1
E-2
E-3
E-4
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
7.00
7.50
8.00
8.50
9.00
BM Energy (MeV)
#12 34-Se- 87
#7 35-Br- 86
#9 35-Br- 89
#17 35-Br- 90
#14 35-BR- 91
#11 36-Kr- 93
#1 37-RB- 92
#4 37-RB- 93
#6 37-Rb- 94
#2 39-Y - 96
#8 39-Y - 98
#5 39-Y - 98M
#19 39-Y - 99
#13 39-Y -100
#18 41-Nb-104
#20 41-Nb-104M
#16 50-Sn-133
#15 51-SB-135
#10 53-I -138
#3 55-CS-142
e ENDF/B-VII.1
ILL

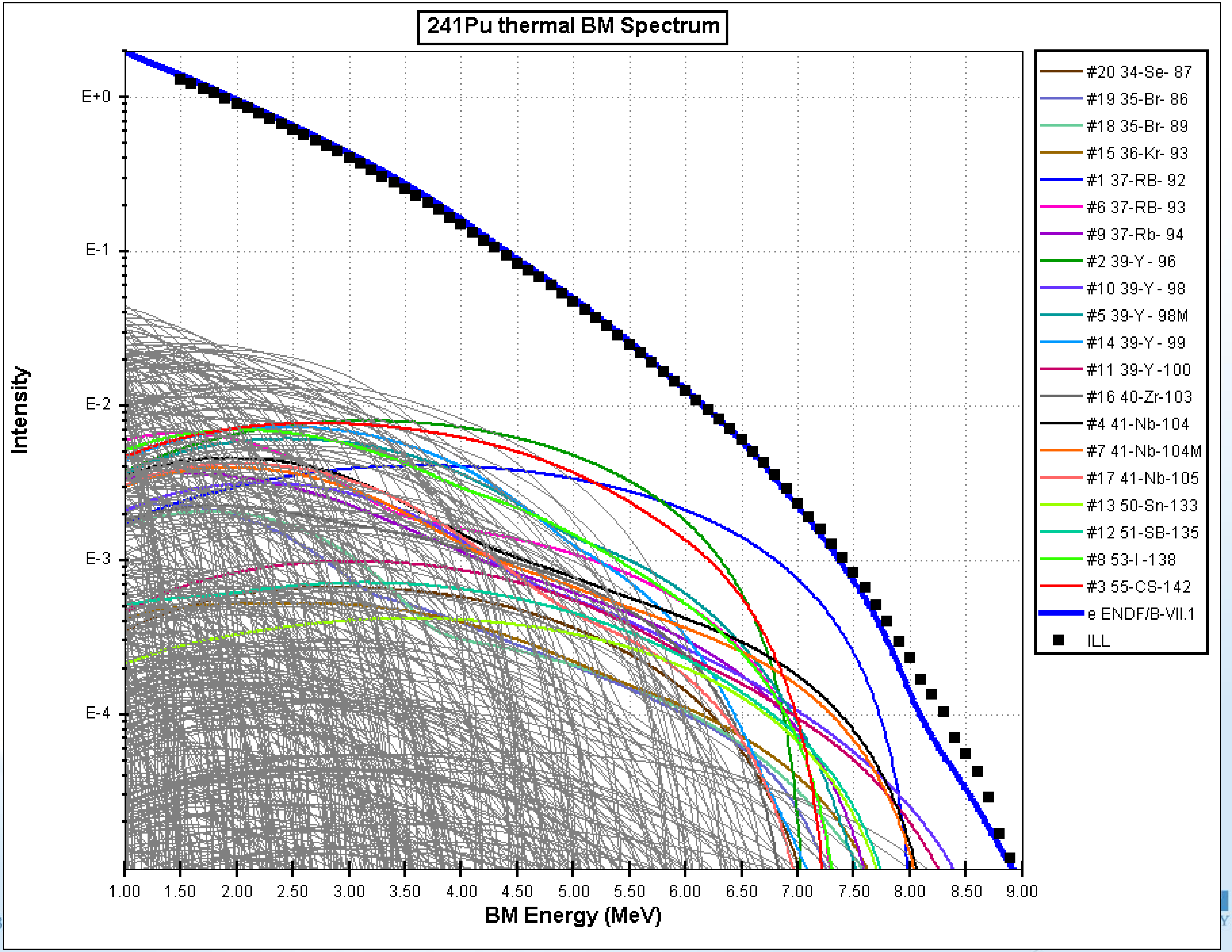


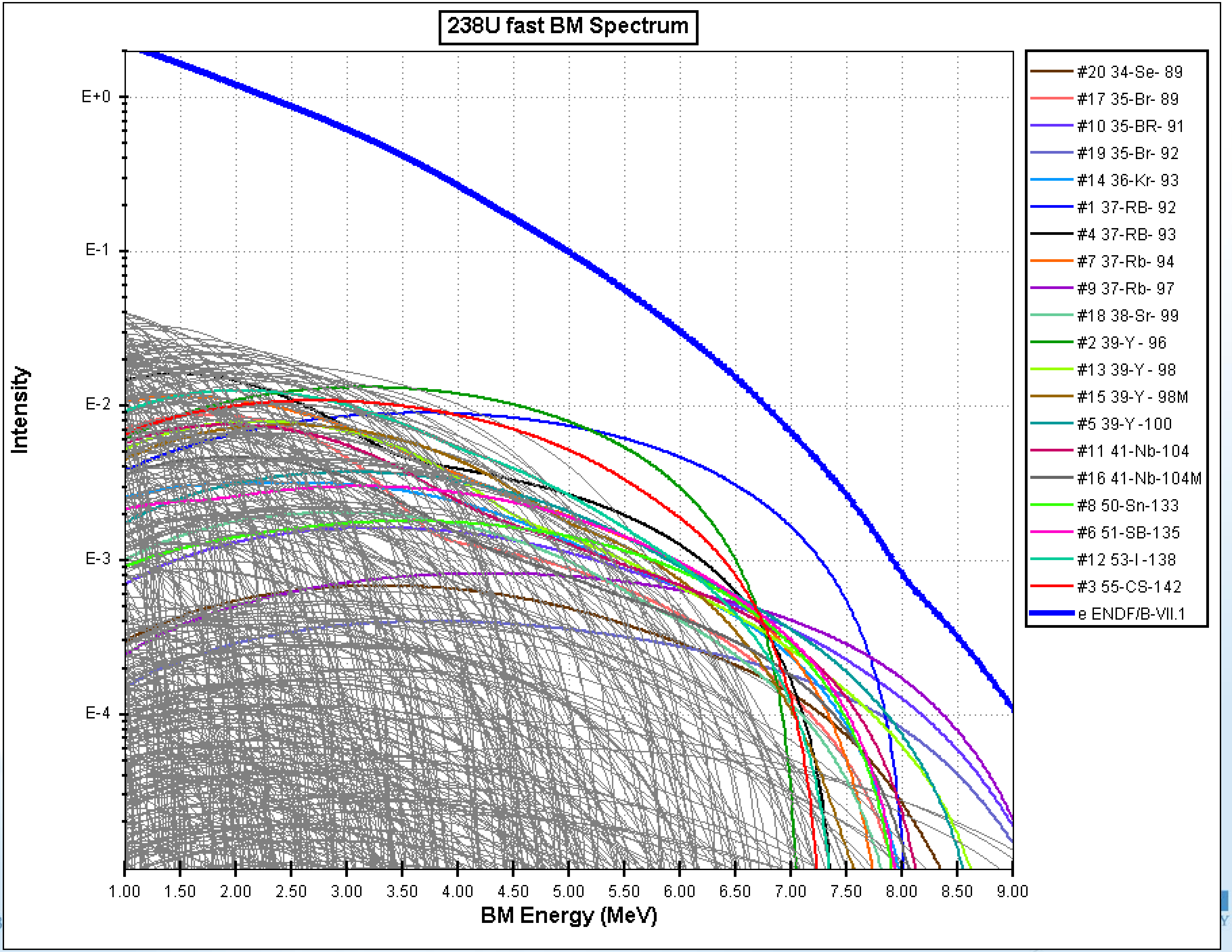
239Pu thermal BM Spectrum
Intensity
E+0
E-1
E-2
E-3
E-4
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
7.00
7.50
8.00
8.50
9.00
BM Energy (MeV)
#19 34-Se- 87
#12 35-Br- 86
#14 35-Br- 89
#15 36-Kr- 93
#1 37-RB- 92
#5 37-RB- 93
#8 37-Rb- 94
#2 39-Y - 96
#16 39-Y - 97
#9 39-Y - 98
#4 39-Y - 98M
#13 39-Y - 99
#10 39-Y -100
#17 40-Zr-103
#6 41-Nb-104
#7 41-Nb-104M
#20 41-Nb-105
#18 51-SB-135
#11 53-I -138
#3 55-CS-142
e ENDF/B-VII.1
ILL

NNDC calculations on the Daya-Bay signal



235U signal has a shoulder at around 6 MeV


241Pu thermal BM Spectrum
Intensity
E+0
E-1
E-2
E-3
E-4
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
7.00
7.50
8.00
8.50
9.00
BM Energy (MeV)
#20 34-Se- 87
#19 35-Br- 86
#18 35-Br- 89
#15 36-Kr- 93
#1 37-RB- 92
#6 37-RB- 93
#9 37-Rb- 94
#2 39-Y - 96
#10 39-Y - 98
#5 39-Y - 98M
#14 39-Y - 99
#11 39-Y -100
#16 40-Zr-103
#4 41-Nb-104
#7 41-Nb-104M
#17 41-Nb-105
#13 50-Sn-133
#12 51-SB-135
#8 53-I -138
#3 55-CS-142
e ENDF/B-VII.1
ILL


238U fast BM Spectrum
Intensity
E+0
E-1
E-2
E-3
E-4
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
7.00
7.50
8.00
8.50
9.00
BM Energy (MeV)
#20 34-Se- 89
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#4 37-RB- 93
#7 37-Rb- 94
#9 37-Rb- 97
#18 38-Sr- 99
#2 39-Y - 96
#13 39-Y - 98
#15 39-Y - 98M
#5 39-Y -100
#11 41-Nb-104
#16 41-Nb-104M
#8 50-Sn-133
#6 51-SB-135
#12 53-I -138
#3 55-CS-142
e ENDF/B-VII.1

Main Contributors at 6 MeV

235U	239Pu	241Pu	238U
37-Rb-92	37-Rb-92	37-Rb-92	37-Rb-92
39-Y-96	39-Y-96	39-Y-96	39-Y-96
55-Cs – 142	55-Cs – 142	55-Cs – 142	55-Cs – 142
37-Rb- 93	39-Y-98m	41-Nb- 104	37-Rb- 93
39-Y-98m	37-Rb- 93	39-Y-98m	39-Y-100
37-Rb- 94	41-Nb- 104m	37-Rb- 93	51-Sb- 135
35-Br – 86	41-Nb- 104	41-Nb- 104m	37-Rb- 94
39-Y-98	37-Rb- 94	53-I-138	50-Sn-133

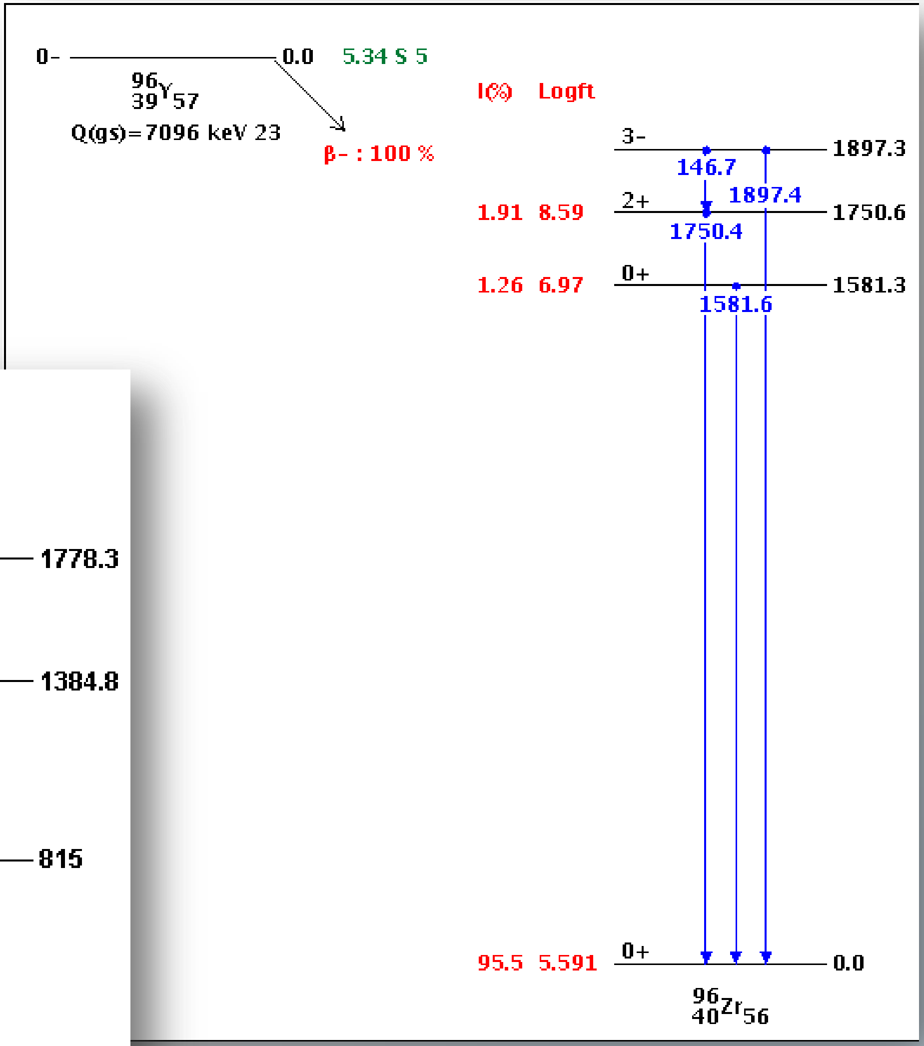
Why these?

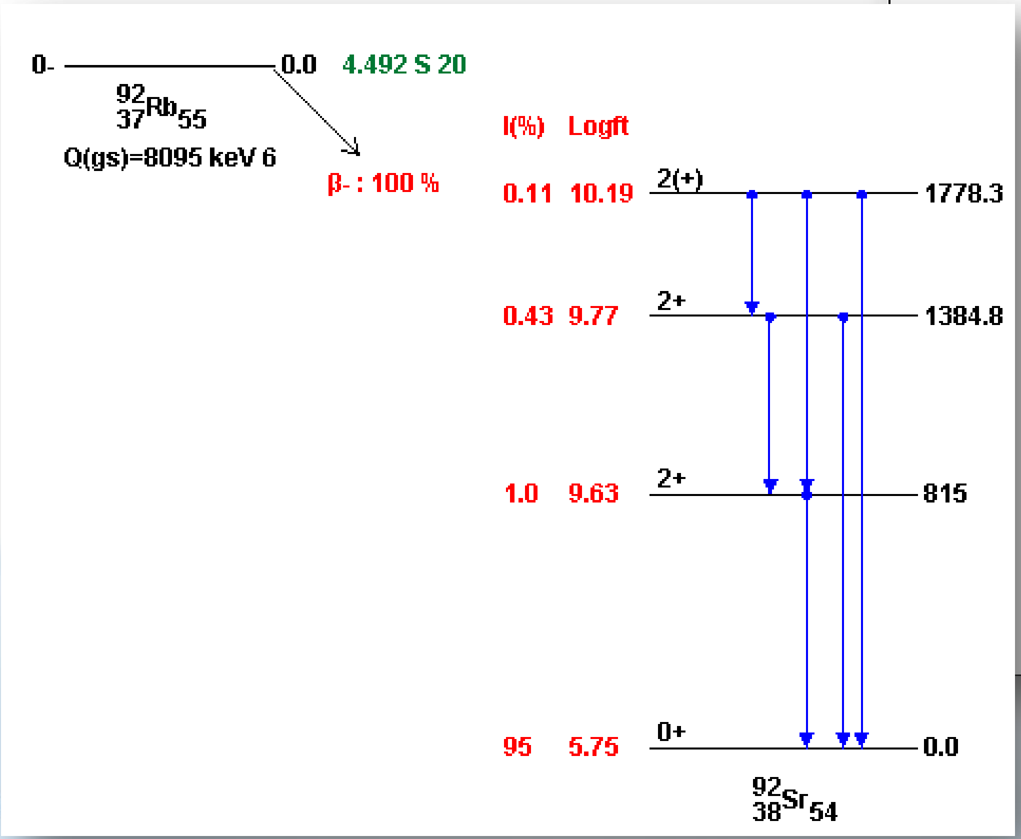
- Large Q value
- Large cumulative fission yield
- Large beta-feeding to low-lying states

235U	<beta> (MeV)	FY	FY * <beta>
37-Rb-92	3.887	0.048 (0.048)	0.19 (0.19)
39-Y-96	3.205	**0.047 (0.060)**	0.15 (0.19)
55-Cs – 142	2.924	0.029 (0.027)	0.085 (0.079)
37-Rb- 93	2.155	0.035 (0.036)	0.075 (0.078)
39-Y-98m	2.530	**0.019 (0.011)**	0.048 (0.028)
37-Rb- 94	2.020	0.015 (0.016)	0.030 (0.032)
35-Br – 86	1.944	0.019 (0.016)	0.037 (0.031)
39-Y-98	2.996	**0.011 (0.019)**	0.033 (0.057)

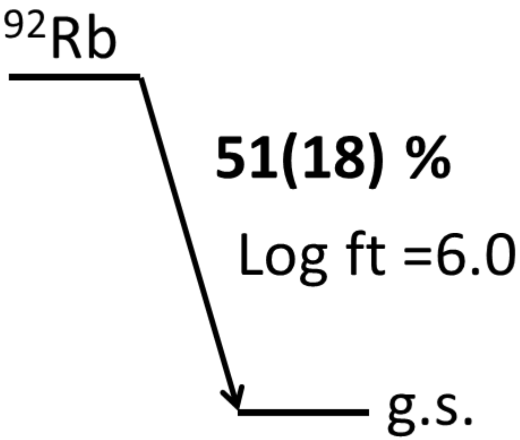
The top two…

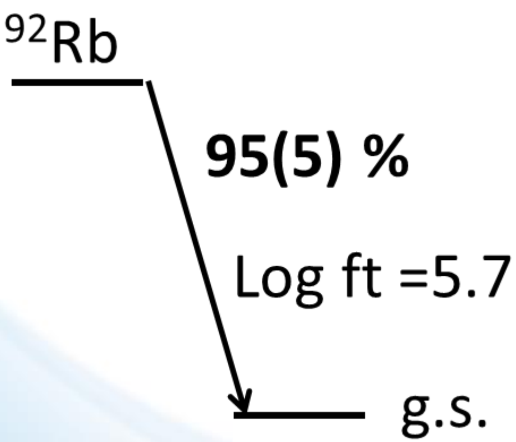
First forbidden non-unique, ground-state to ground-state transition accounting for 95% of beta intensity

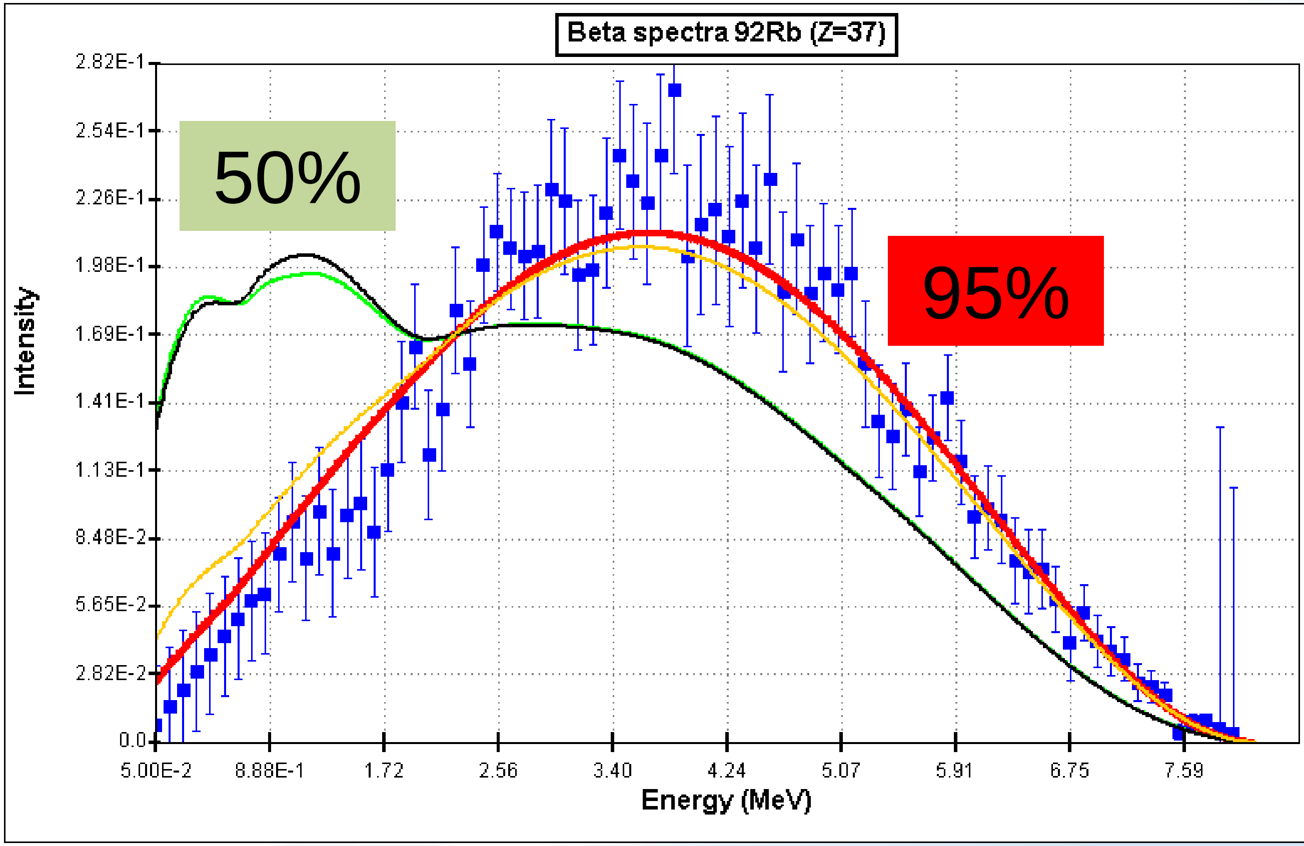




Conflicting Results on ^{92}Rb decay







One small nucleus, one big effect

^{92}Rb

a) 2000 ENSDF

51(18) %

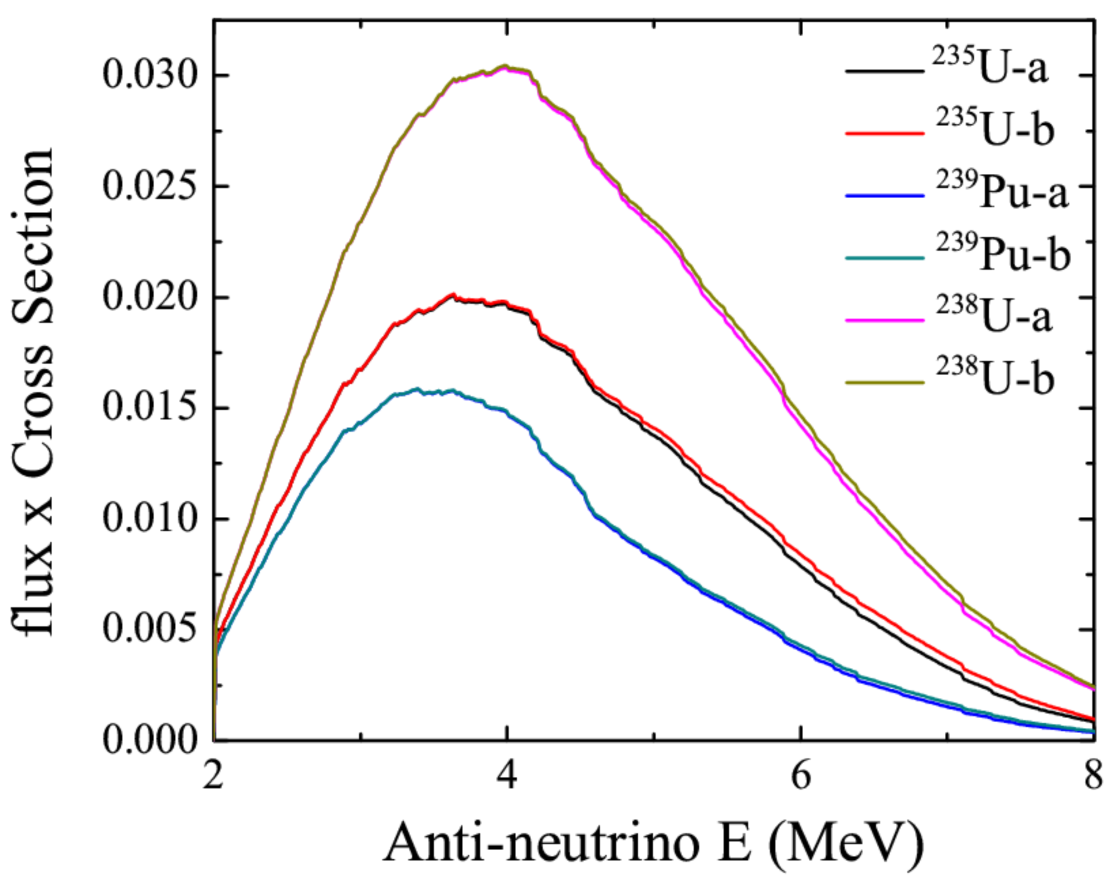
g.s.

^{92}Rb

b) Update with new data

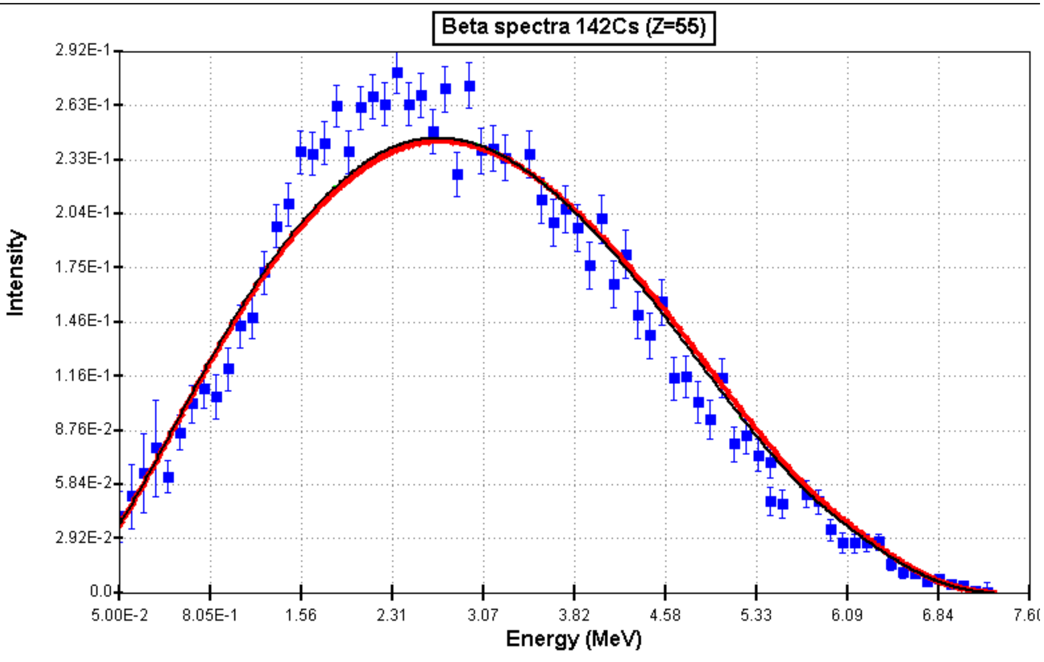
95(5) %

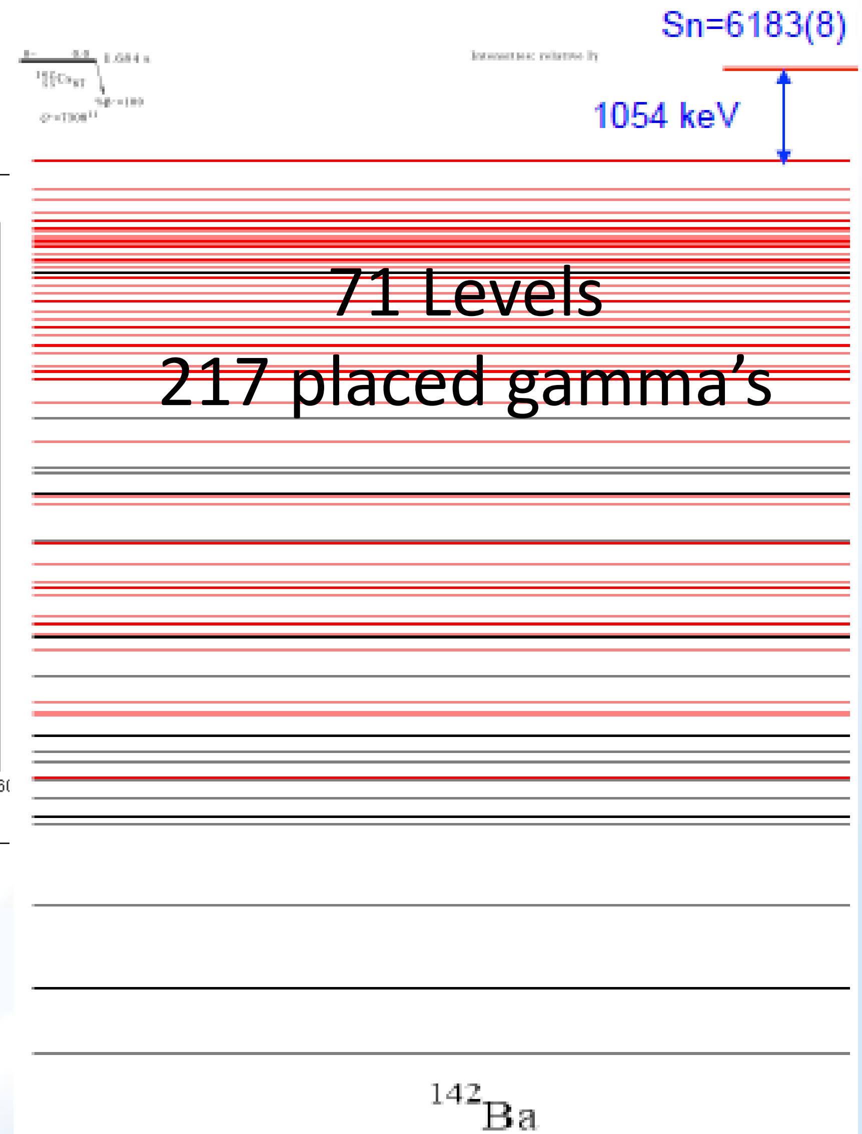
g.s.



^{142}Cs decay: Case closed

Reasonable agreement between discrete line data and Rudstam





20 Levels

~30 placed gamma's

~80 unplaced gamma's

Courtesy of S. Zhu -ANL

Main Contributors at 6 MeV

235U	239Pu	241Pu	238U
37-Rb-92	37-Rb-92	37-Rb-92	37-Rb-92
39-Y-96	39-Y-96	39-Y-96	39-Y-96
55-Cs – 142	55-Cs – 142	55-Cs – 142	55-Cs – 142
37-Rb- 93	39-Y-98m	41-Nb- 104	37-Rb- 93
39-Y-98m	37-Rb- 93	39-Y-98m	39-Y-100
37-Rb- 94	41-Nb- 104m	37-Rb- 93	51-Sb- 135
35-Br – 86	41-Nb- 104	41-Nb- 104m	37-Rb- 94
39-Y-98	37-Rb- 94	53-I-138	50-Sn-133

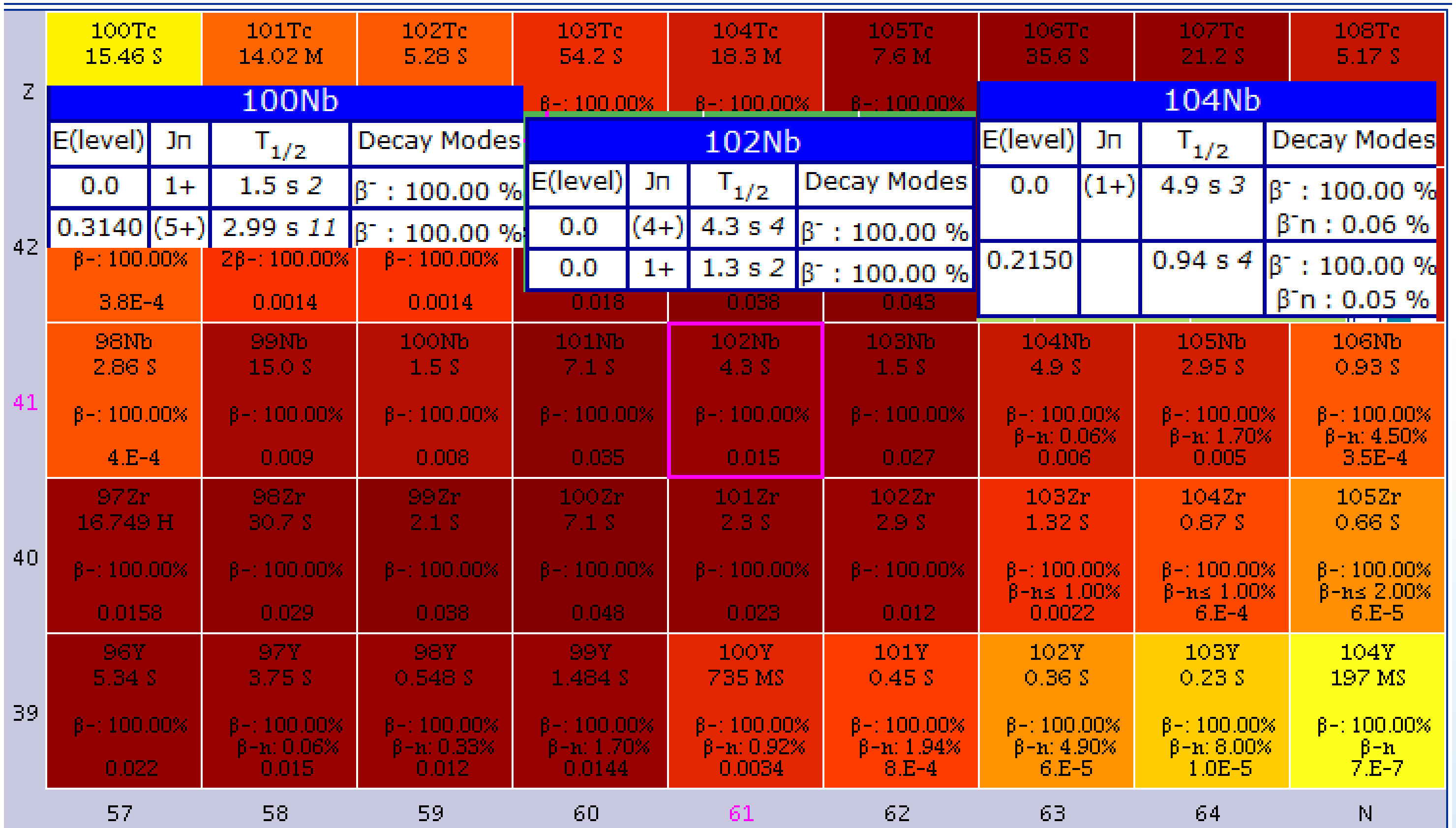
Closer look at $^{104,104m}Nb$

- No Rudstam data
- No TAGS data
- No discrete line data !!!

  (γ's from mixed source, no β feedings could be determined)

- Beta-spectra are from CGM calculation

Neutron-rich Nb’s

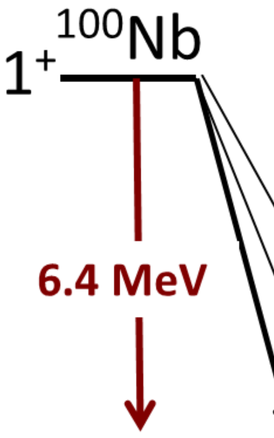


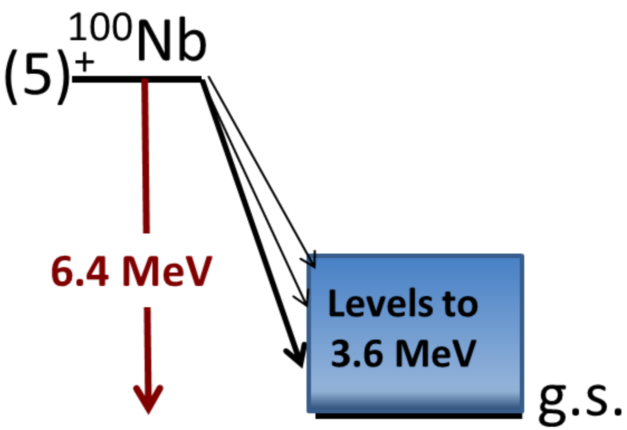
^{239}Pu:

Q=6384	Q=7210	Q=8100
CFY=0.057	CFY=0.028	CFY=0.0036

Very limited data

g.s. branch: 50 or 70%



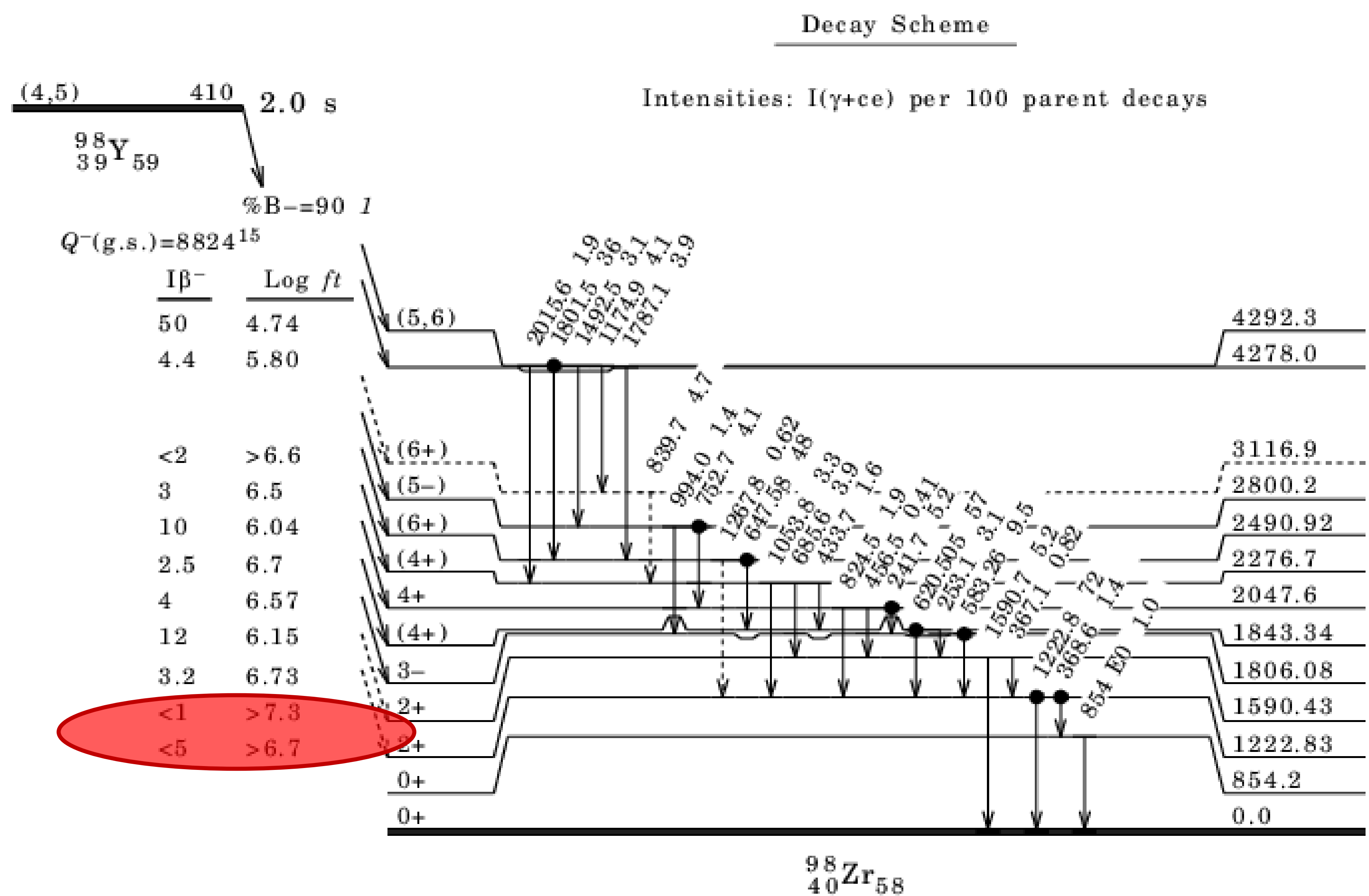


	EEM	ELP
1+	0.79	2.55
4+/5+	2.21	2.01

Main Contributors at 6 MeV

235U	239Pu	241Pu	238U
37-Rb-92	37-Rb-92	37-Rb-92	37-Rb-92
39-Y-96	39-Y-96	39-Y-96	39-Y-96
55-Cs – 142	55-Cs – 142	55-Cs – 142	55-Cs – 142
37-Rb- 93	39-Y-98m	41-Nb- 104	37-Rb- 93
39-Y-98m	37-Rb- 93	39-Y-98m	39-Y-100
37-Rb- 94	41-Nb- 104m	37-Rb- 93	51-Sb- 135
35-Br – 86	41-Nb- 104	41-Nb- 104m	37-Rb- 94
39-Y-98	37-Rb- 94	53-I-138	50-Sn-133

Beware of “false positives”



Other energy regions of the spectrum

^{235}U main contributors to anti-neutrino spectra

Nucleus	% at 3 MeV	Nucleus	% at 4 MeV	Nucleus	% at 5 MeV
54-Xe-137	3.519	41-Nb-100	4.872	37-Rb- 92	9.171
55-Cs-139	3.259	37-Rb- 92	3.694	39-Y - 96	7.475
39-Y - 94	3.120	39-Y - 96	3.545	41-Nb-100	6.592
40-Zr- 99	3.010	52-Te-135	2.994	55-Cs-142	4.585
41-Nb-100	2.916	39-Y - 94	2.897	55-Cs-140	4.153
41-Nb- 98	2.830	55-Cs-140	2.780	52-Te-135	3.636
39-Y – 92	2.812	39-Y - 95	2.646	39-Y - 99	3.460
41-Nb-101	2.654	54-Xe-139	2.606	38-Sr- 95	3.435

"Top three"

Rudstam β's and/or TAGS

Rudstam γ's

"High priority"

Reminder : There are others that don't even make the list !!

How to “fit in” with nuclear structure

Nucleus	% at 4 MeV
41-Nb-100	4.872
37-Rb- 92	3.694
39-Y - 96	3.545

Nucleus	% at 5 MeV
37-Rb- 92	9.171
39-Y - 96	7.475
41-Nb-100	6.592
55-Cs-142	4.585
55-Cs-140	4.153
52-Te-135	3.636
39-Y - 99	3.460
38-Sr- 95	3.435

Reliable calculations of antineutrino spectra through improved β-decay data: the decays of ^{100,102}Nb

E.A. McCutchan, A.A. Sonzogni, T.D. Johnson

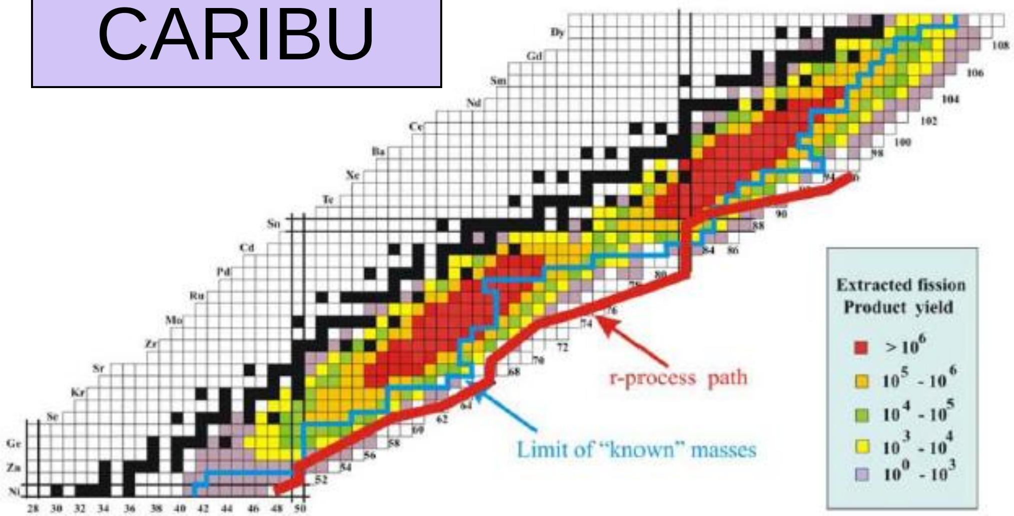
National Nuclear Data Center, Brookhaven National Laboratory

M.P. Carpenter, J. Clark, G. Savard, D. Sewernyiak, S. Zhu

It would undoubtedly be useful over time to measure the more important contributors among the "800 different fission fragments" produced in a reactor. Although improved results for the two Nb isotopes proposed for study here could have a small effect on the overall anti-neutrino spectrum, there is no indication that they would have a significant impact on neutrino physics via the Daya Bay experiment, for example. In fact, the

Possibilities at Argonne

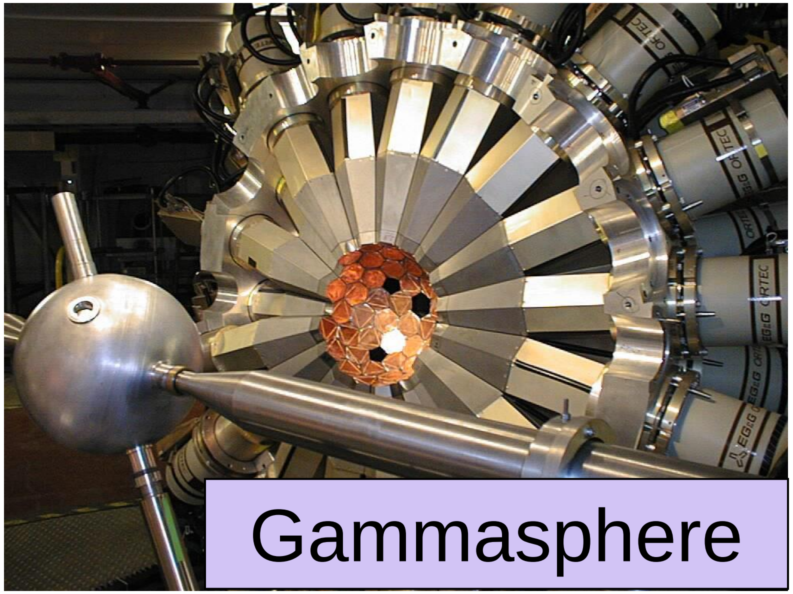
CARIBU



Nucleus	Low Energy Yield pps
102-Nb	5.5E4
104-Nb	5.8E4
98-Y	1.7E4
95-Sr	2.1E4
137-Xe	7.0E4
139-Cs	4.9E4

- ^{252}Cf fission source
- Gas catcher and mass separator
- Low-energy beams
- Re-accelerated (factor 10 loss in yield)

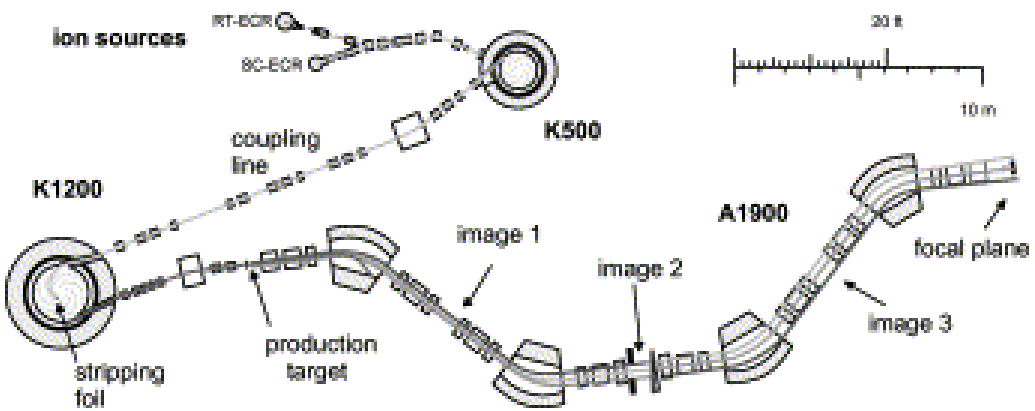
Possibilities at Argonne

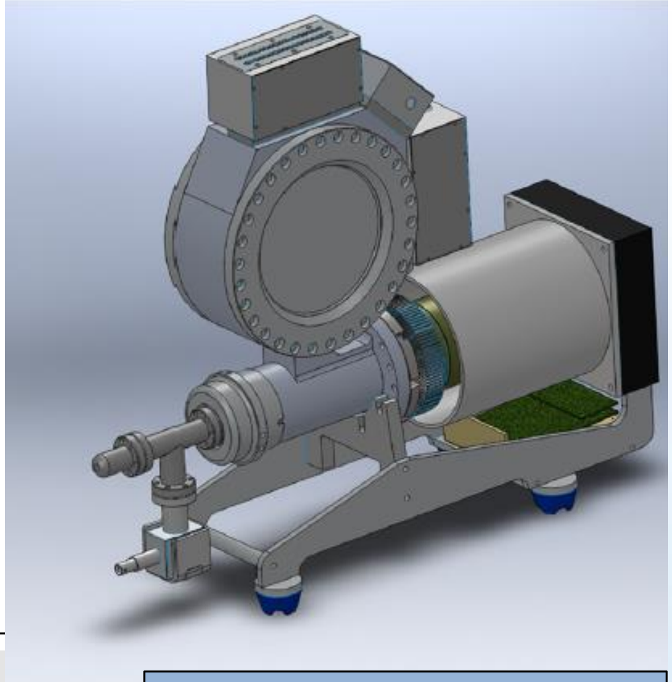


- 100 Compton-suppressed HPGe
- Loss of 10 in beam intensity
- But… high coincidence efficiency
- Possibility to use as calorimeter?

- 5 un-suppressed Clovers
- Closely packed, high efficiency
- Beta detectors
- Moving Tape Collector

Possibilities at MSU/NSCL





1cm x 9 cm
HPGe DSSD

Nuclear Instruments and Methods in Physics Research A 727 (2013) 59–64

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High efficiency beta-decay spectroscopy using a planar germanium double-sided strip detector

CrossMark

N. Larson[a,b,*], S.N. Liddick[a,b], M. Bennett[a,c], A. Bowe[a], A. Chemey[a,b], C. Prokop[a,b], A. Simon[a], A. Spyrou[a,c], S. Suchyta[a,b], S.J. Quinn[a,c], S.L. Tabor[d], P.L. Tai[d], Vandana Tripathi[d], J.M. VonMoss[d]

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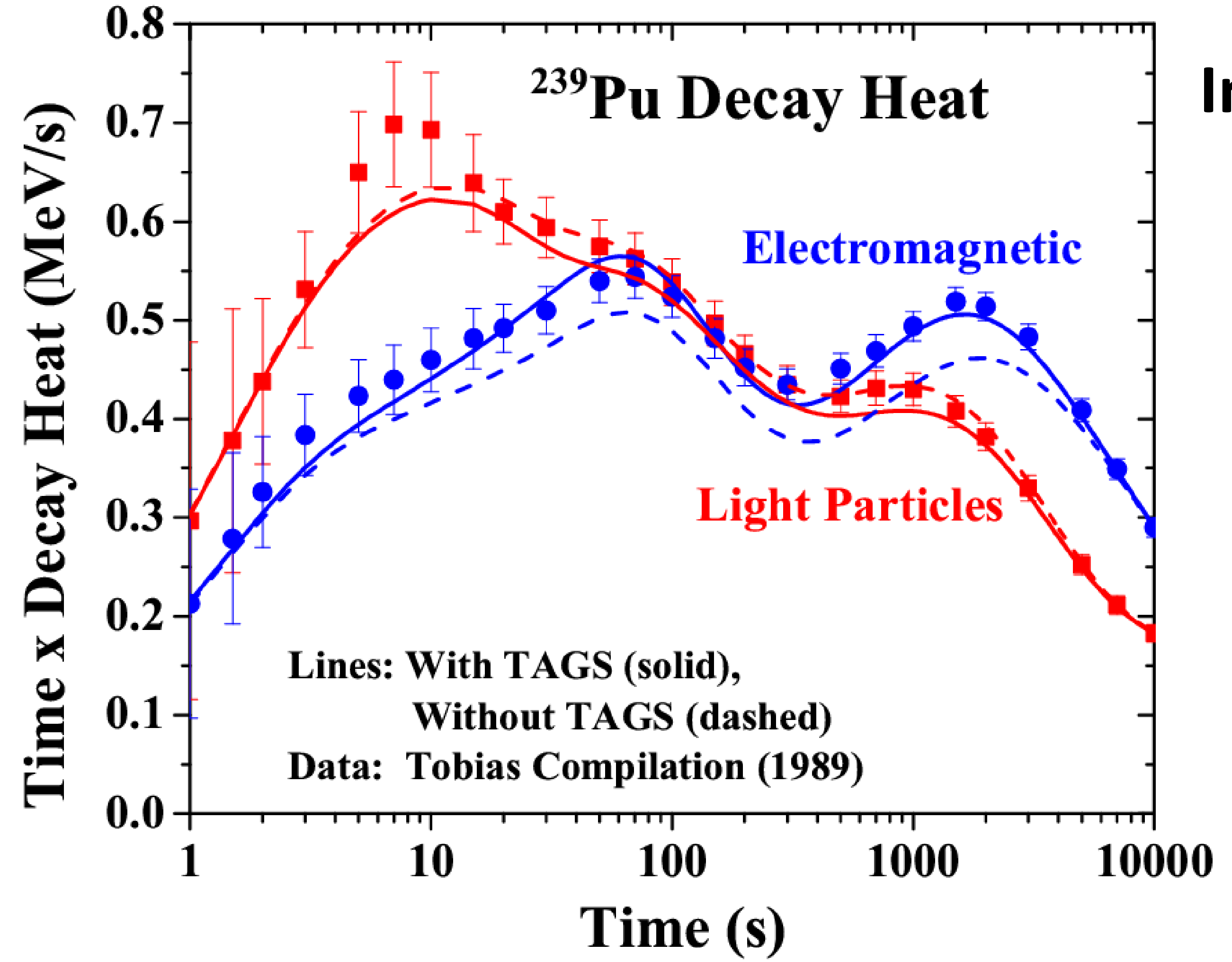
Connection to Decay Heat



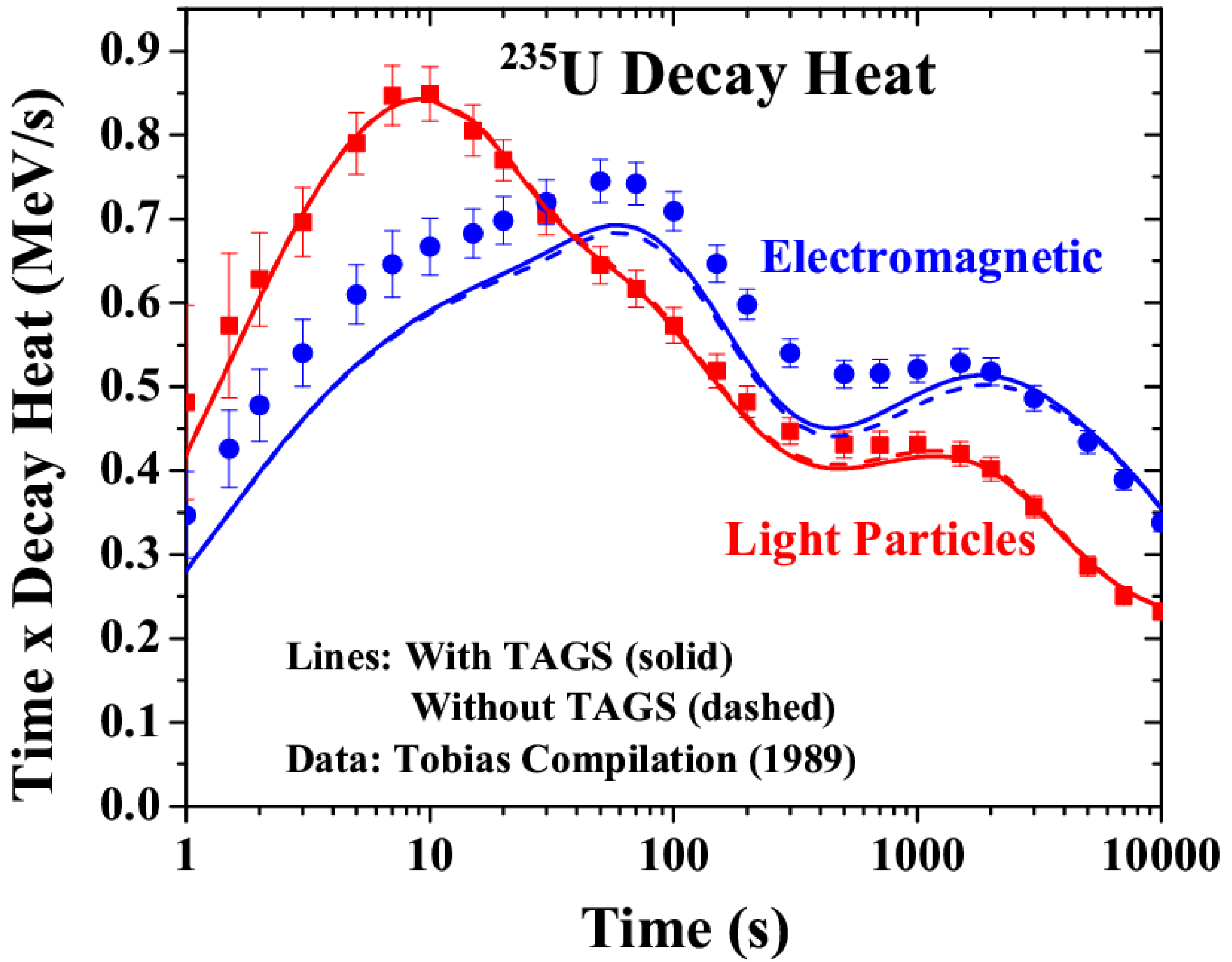
Inverse relationship

Increase in γ's

Decrease in β's

Decrease in ν's

Connection to Decay Heat



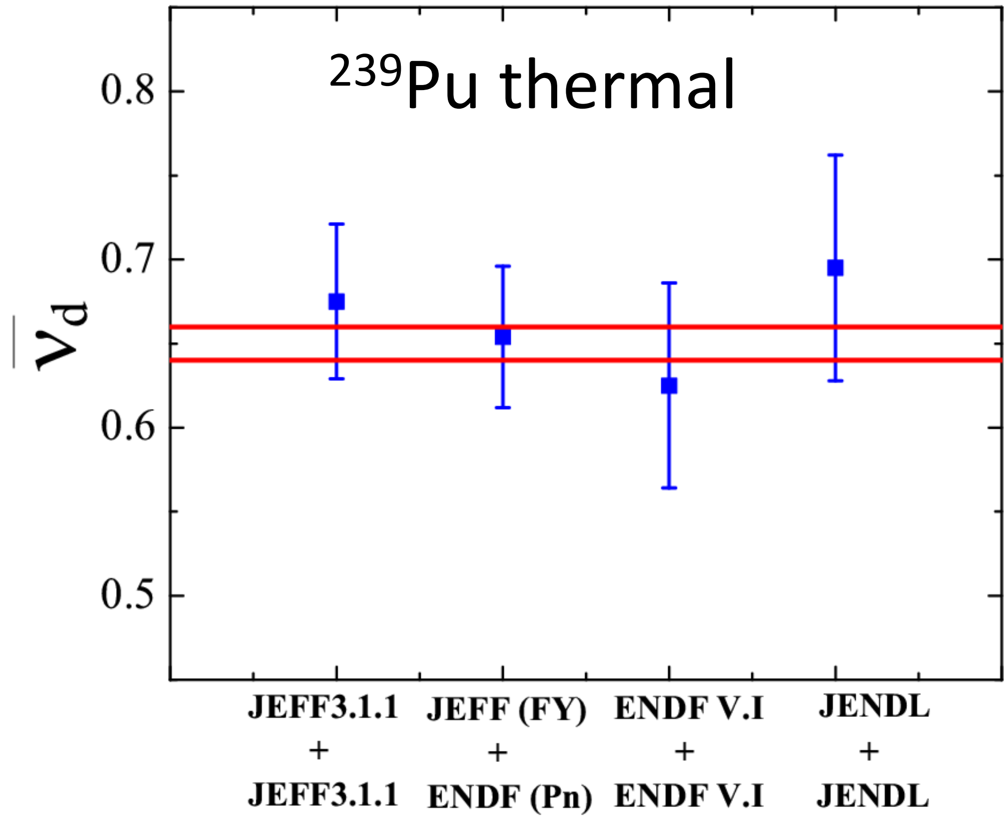
Other ways to test the libraries

Anti-neutrino rate per fission:

$$S(E) = \sum CFY_i S_i(E)$$

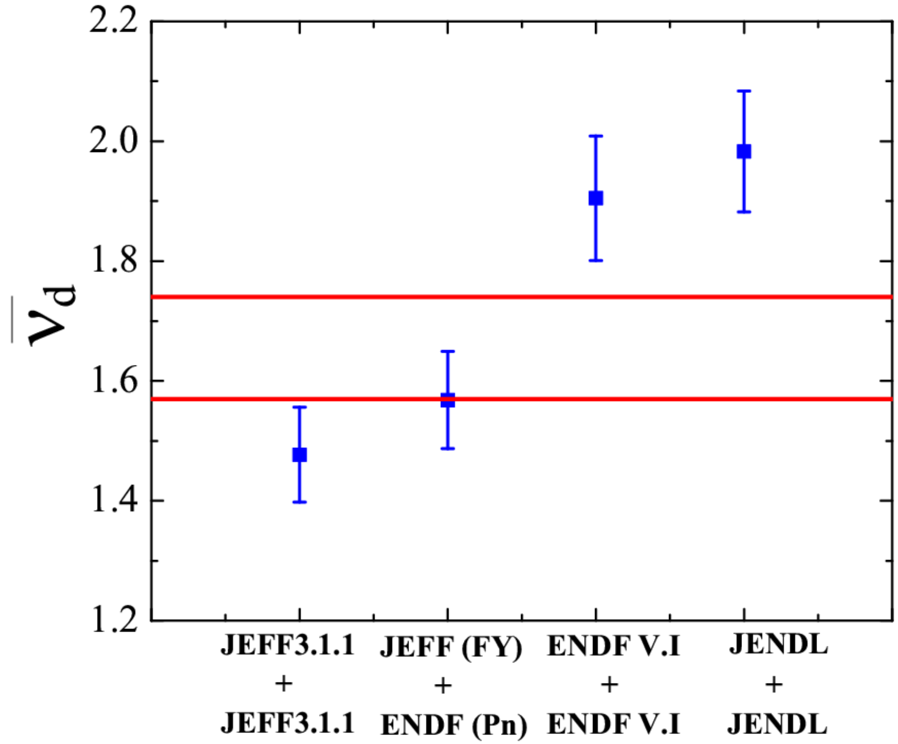
Delayed neutron rate per fission:

$$\overline{\nu_d} = \sum CFY_i P_{ni}$$



Other ways to test the libraries

^{235}U thermal



^{238}U fast