Data inconsistencies in summation calculations

Tim Johnson, E.A. McCutchan, Alejandro Sonzogni

National Nuclear Data Center

November, 2013

BROOKHAVEN NATIONAL LABORATORY

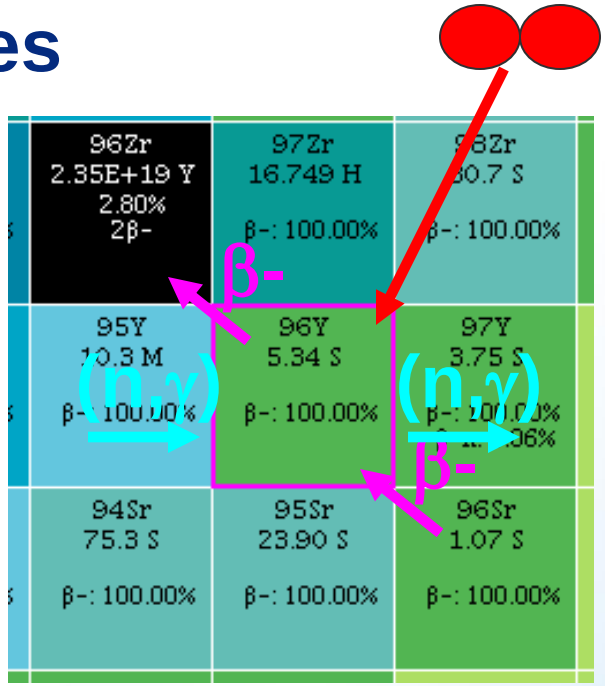
a passion for discovery

Office of Science U.S. DEPARTMENT OF ENERGY

How to calculate anti-neutrino rates

The nuclei in the core form a decay/processing network:

$$\frac{dN_i}{dt} = r(t)FY_i - \lambda_i N_i + \sum \lambda_{ik} N_k - \Phi_n(t)\sigma_i N_i + \Phi_n(t)\sum \sigma_{ik} N_k$$



Neglect processing as $\Phi_n\sigma << \lambda$ and consider an equilibrium situation:

$$\frac{dN_i}{dt} = 0 = rFY_i - \lambda_i N_i + \sum \lambda_{ik} N_k \longrightarrow N_i = rCFY_i / \lambda_i$$

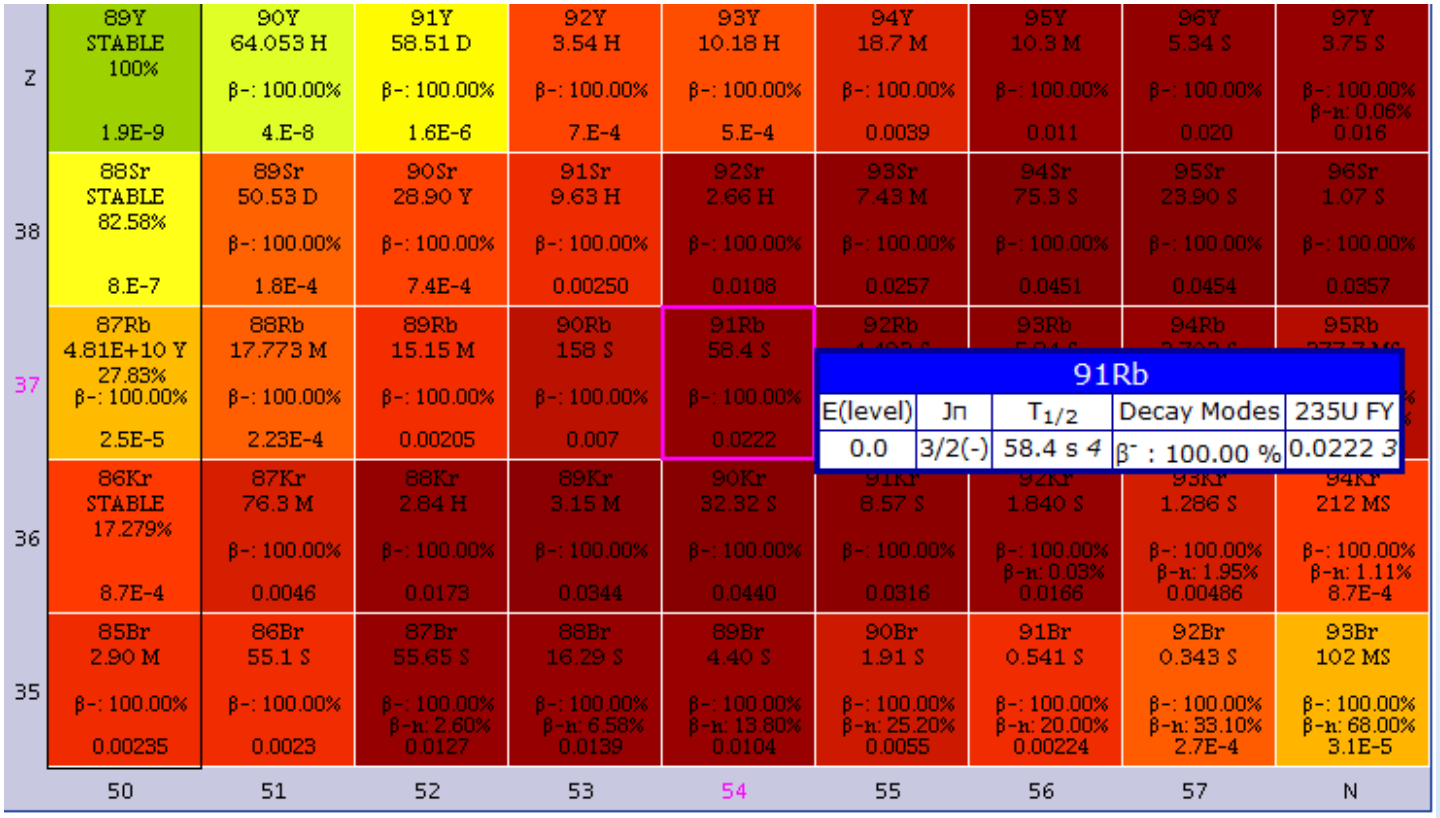
Then the anti-neutrino rate per fission is:

$$S(E) = \sum \lambda_i N_i S_i(E) / r = \sum CFY_i S_i(E)$$

Used by Vogel et al, 1981, ENDF/B-V

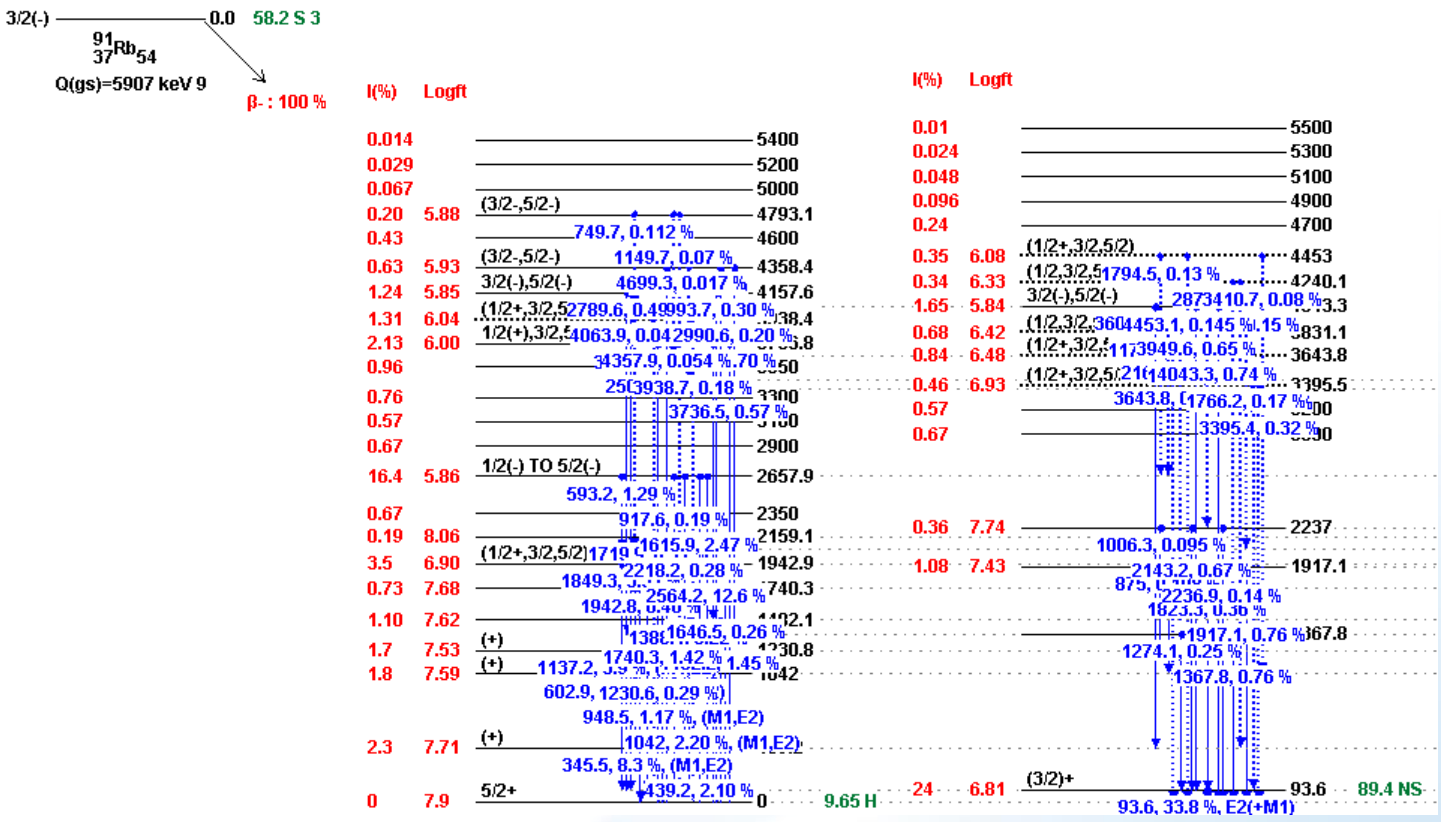
Needed: Decay data and fission yields

Example for ^{91}Rb

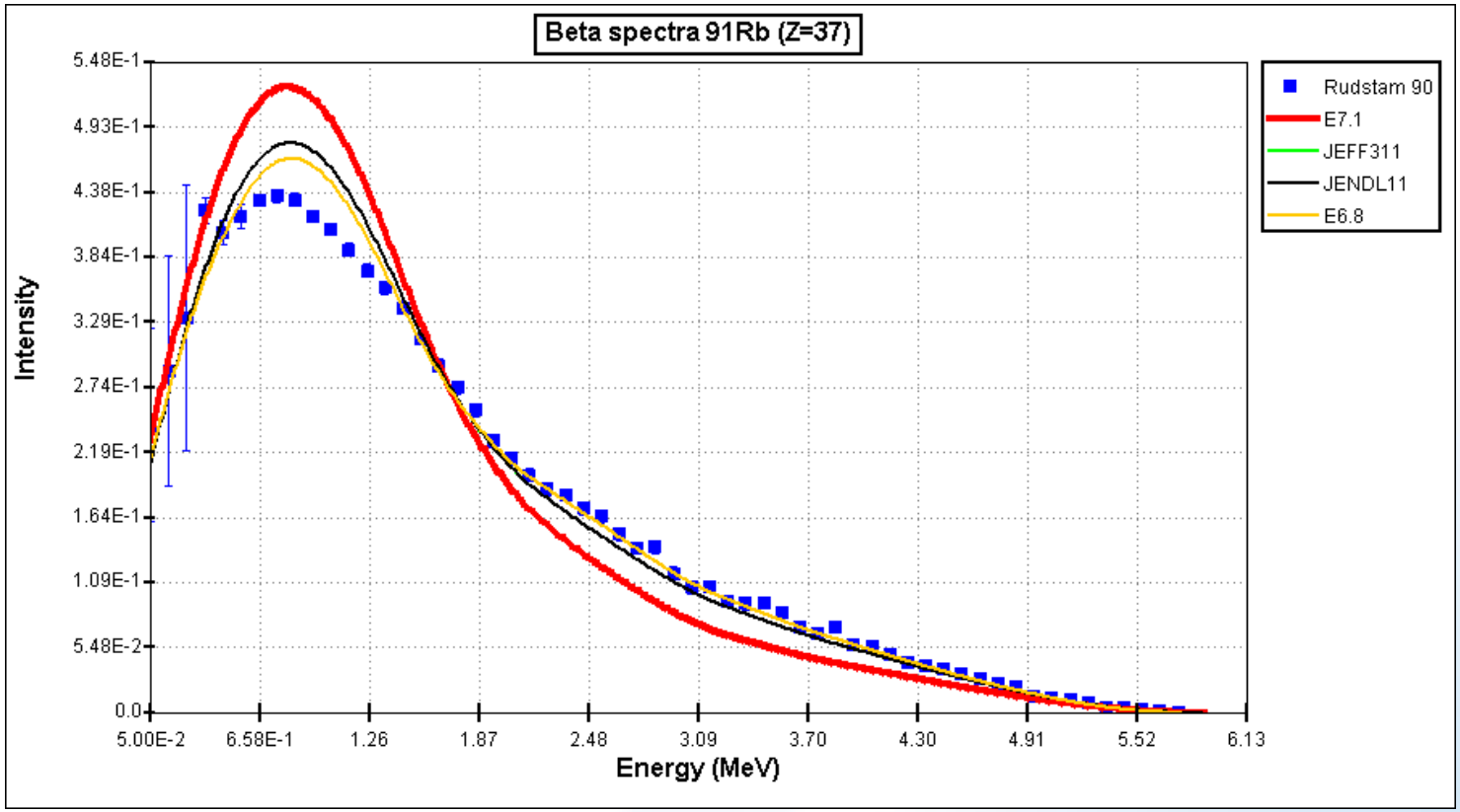


FY 0.0222

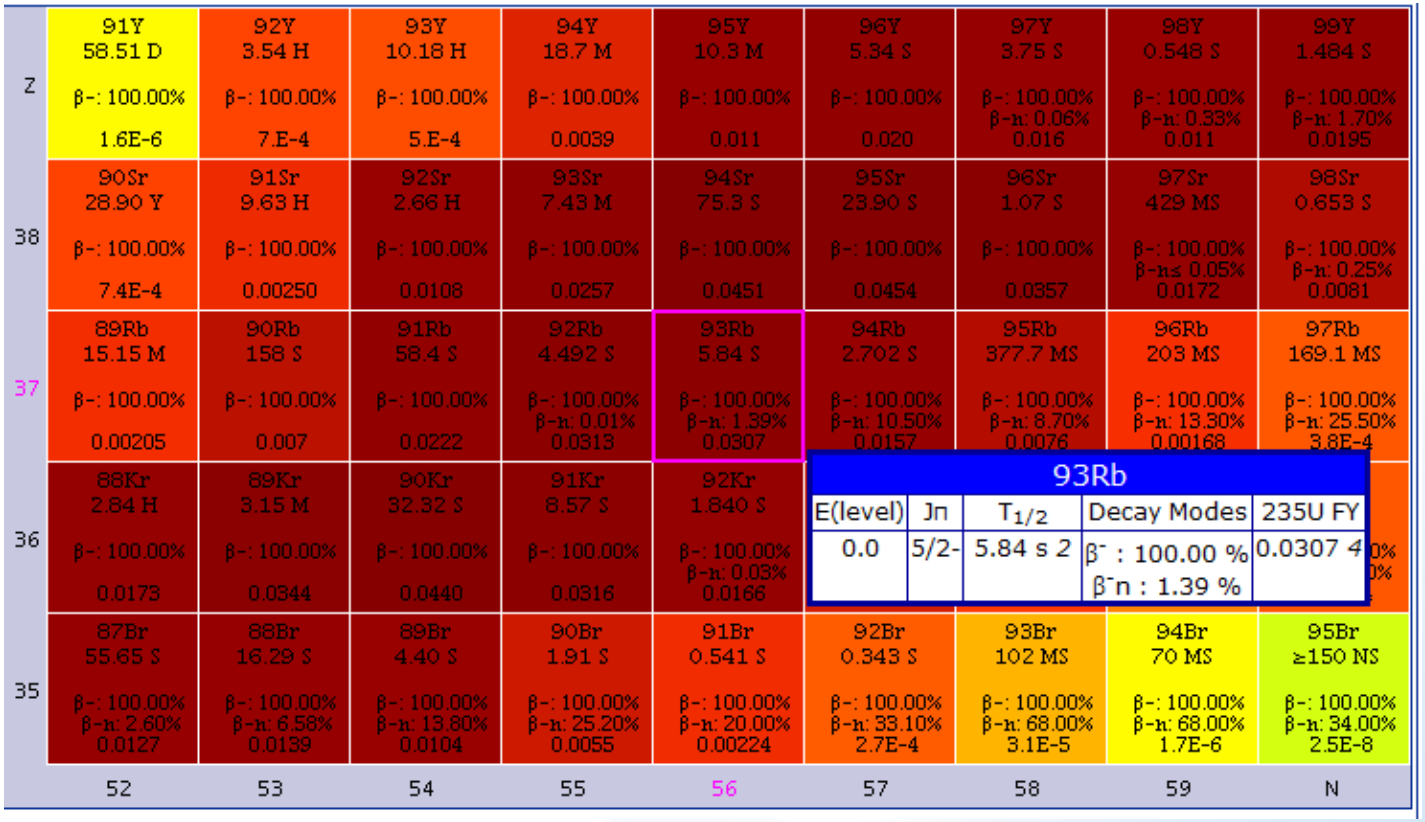
Partial decay for ^{91}Rb



TAS – Comparison of Rudstam with INL

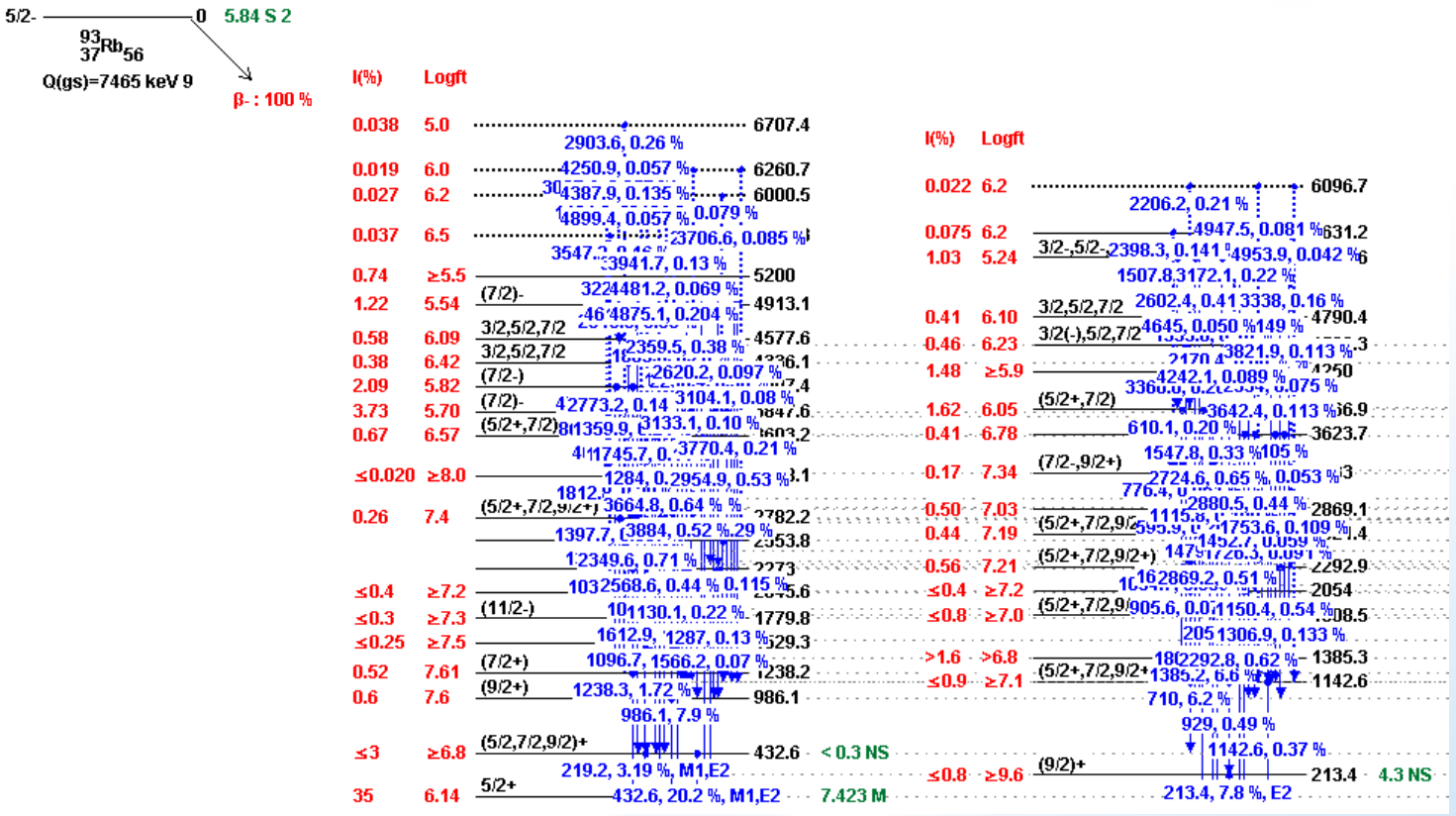


Example for ^{93}Rb

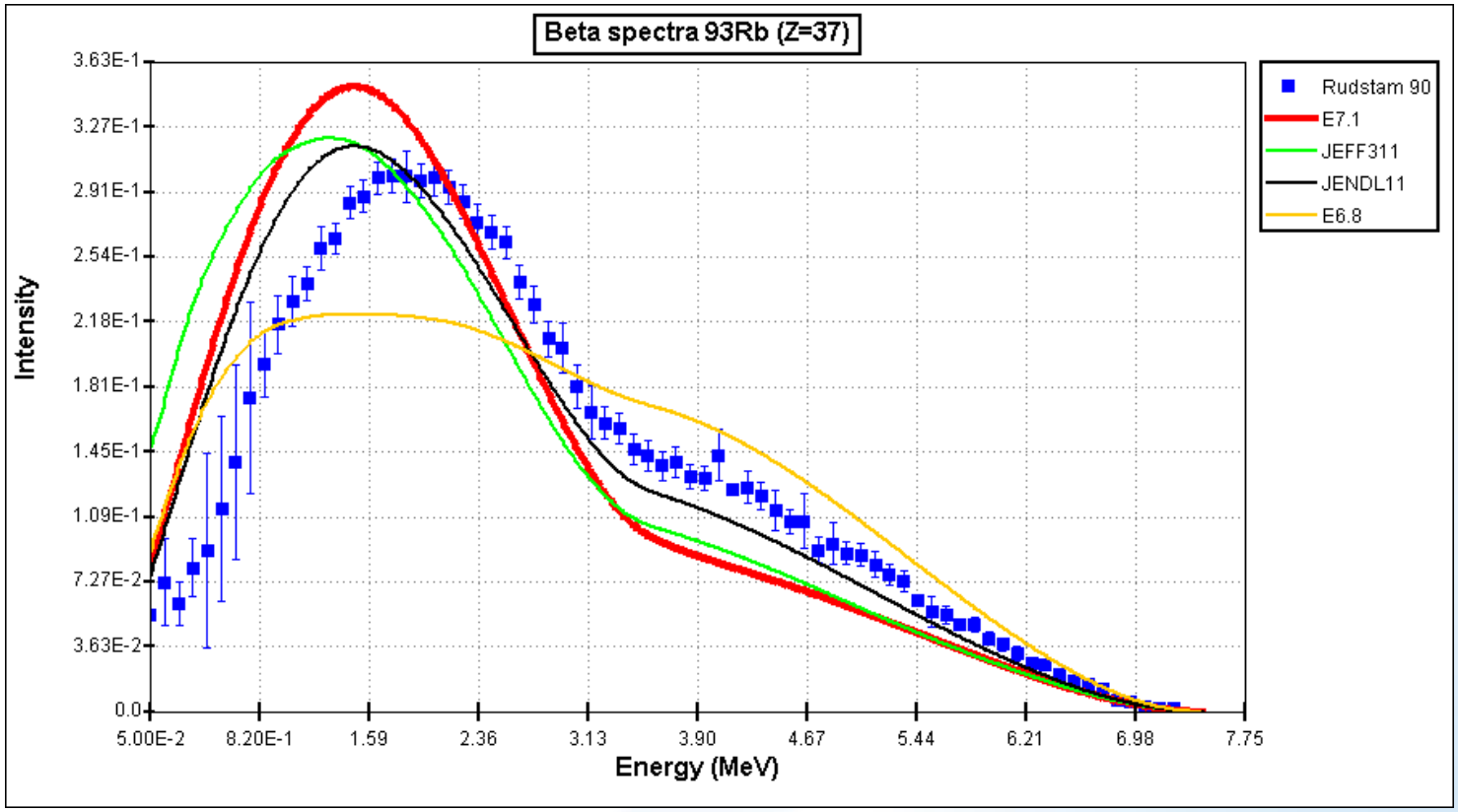


CFY 0.0355

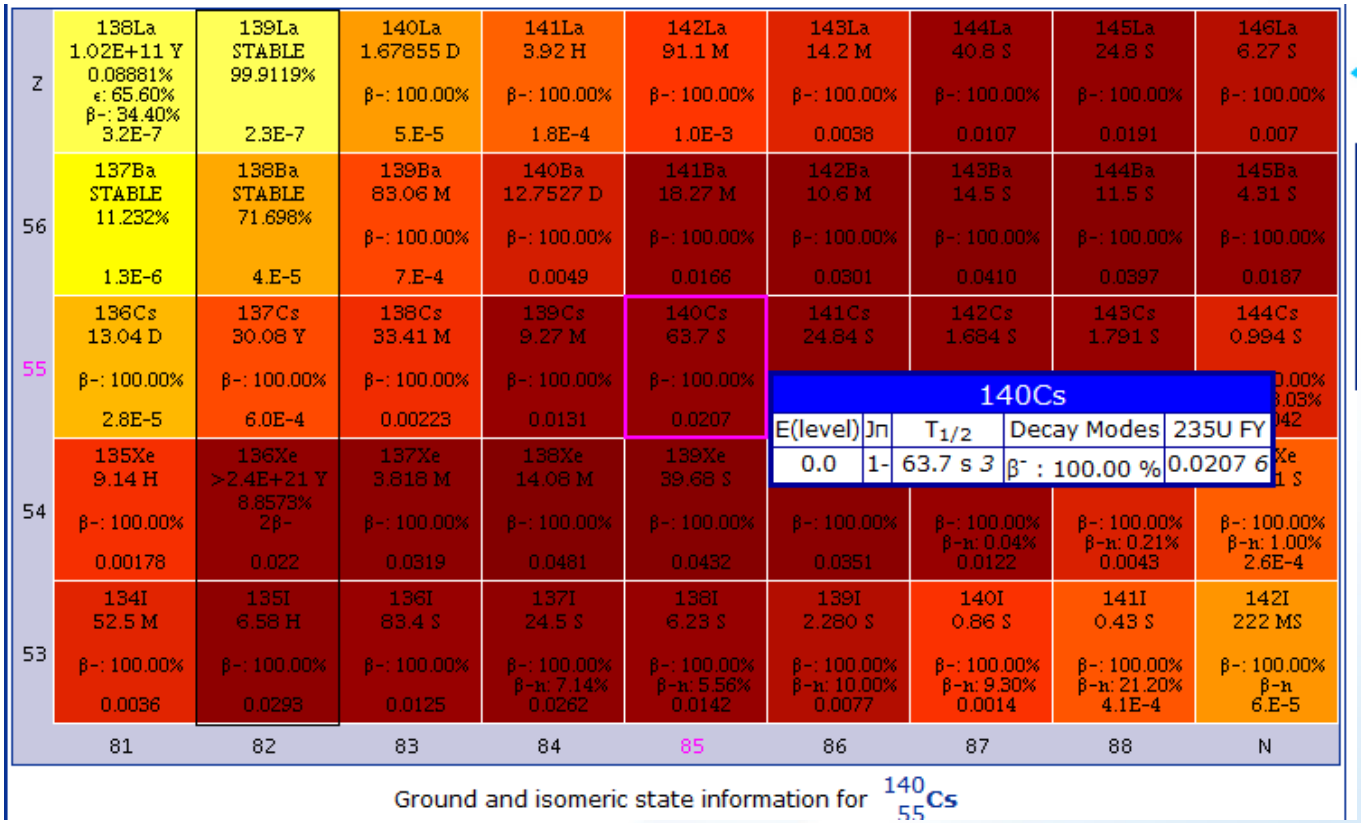
Decay scheme for ^{93}Rb



TAS – Comparison of Rudstam with INL (cont)



Example for ^{140}Cs



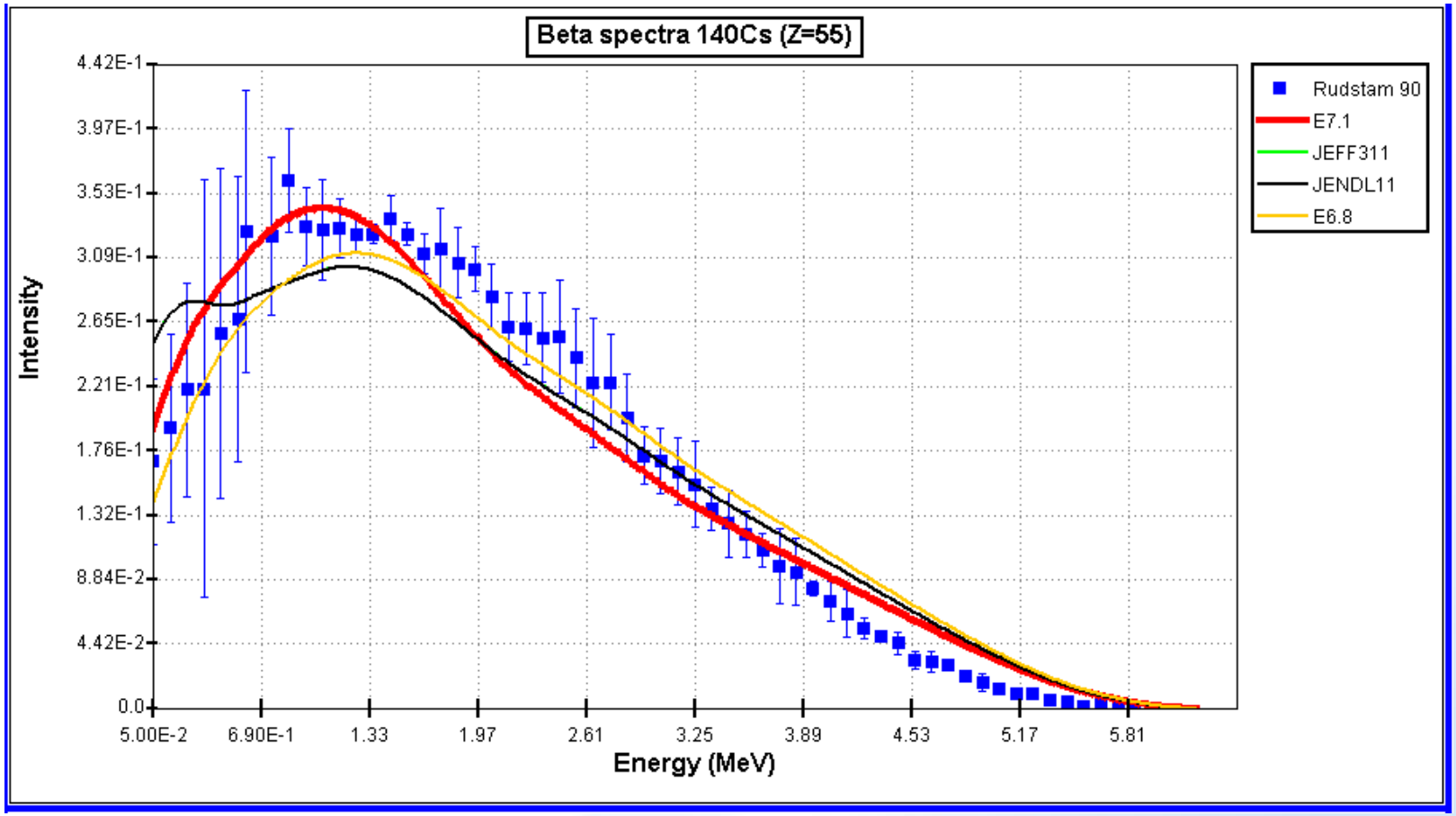
Z	138La	139La	140La	141La	142La	143La	144La	145La	146La
	1.02E+11 Y 0.08881% ε: 65.60% β-: 34.40% 3.2E-7	STABLE 99.9119% 2.3E-7	1.67855 D β-: 100.00% 5.E-5	3.92 H β-: 100.00% 1.8E-4	91.1 M β-: 100.00% 1.0E-3	14.2 M β-: 100.00% 0.0038	40.8 S β-: 100.00% 0.0107	24.8 S β-: 100.00% 0.0191	6.27 S β-: 100.00% 0.007
56	137Ba	138Ba	139Ba	140Ba	141Ba	142Ba	143Ba	144Ba	145Ba
	STABLE 11.232% 1.3E-6	STABLE 71.698% 4.E-5	83.06 M β-: 100.00% 7.E-4	12.7527 D β-: 100.00% 0.0049	18.27 M β-: 100.00% 0.0166	10.6 M β-: 100.00% 0.0301	14.5 S β-: 100.00% 0.0410	11.5 S β-: 100.00% 0.0397	4.31 S β-: 100.00% 0.0187
55	136Cs	137Cs	138Cs	139Cs	140Cs	141Cs	142Cs	143Cs	144Cs
	13.04 D β-: 100.00% 2.8E-5	30.08 Y β-: 100.00% 6.0E-4	33.41 M β-: 100.00% 0.00223	9.27 M β-: 100.00% 0.0131	63.7 S β-: 100.00% 0.0207	24.84 S	1.684 S	1.791 S	0.994 S
54	135Xe	136Xe	137Xe	138Xe	139Xe				Xe
	9.14 H β-: 100.00% 0.00178	>2.4E+21 Y 8.8573% 2β- 0.022	3.818 M β-: 100.00% 0.0319	14.08 M β-: 100.00% 0.0481	39.68 S β-: 100.00% 0.0432	β-: 100.00% 0.0351	β-: 100.00% β-n: 0.04% 0.0122	β-: 100.00% β-n: 0.21% 0.0043	1 S β-: 100.00% β-n: 1.00% 2.6E-4
53	134I	135I	136I	137I	138I	139I	140I	141I	142I
	52.5 M β-: 100.00% 0.0036	6.58 H β-: 100.00% 0.0293	83.4 S β-: 100.00% 0.0125	24.5 S β-: 100.00% β-n: 7.14% 0.0262	6.23 S β-: 100.00% β-n: 5.56% 0.0142	2.280 S β-: 100.00% β-n: 10.00% 0.0077	0.86 S β-: 100.00% β-n: 9.30% 0.0014	0.43 S β-: 100.00% β-n: 21.20% 4.1E-4	222 MS β-: 100.00% β-n 6.E-5
	81	82	83	84	85	86	87	88	N

140Cs				
E(level)	Jπ	$T_{1/2}$	Decay Modes	235U FY
0.0	1-	63.7 s *3*	β^- : 100.00 %	0.0207 *6*

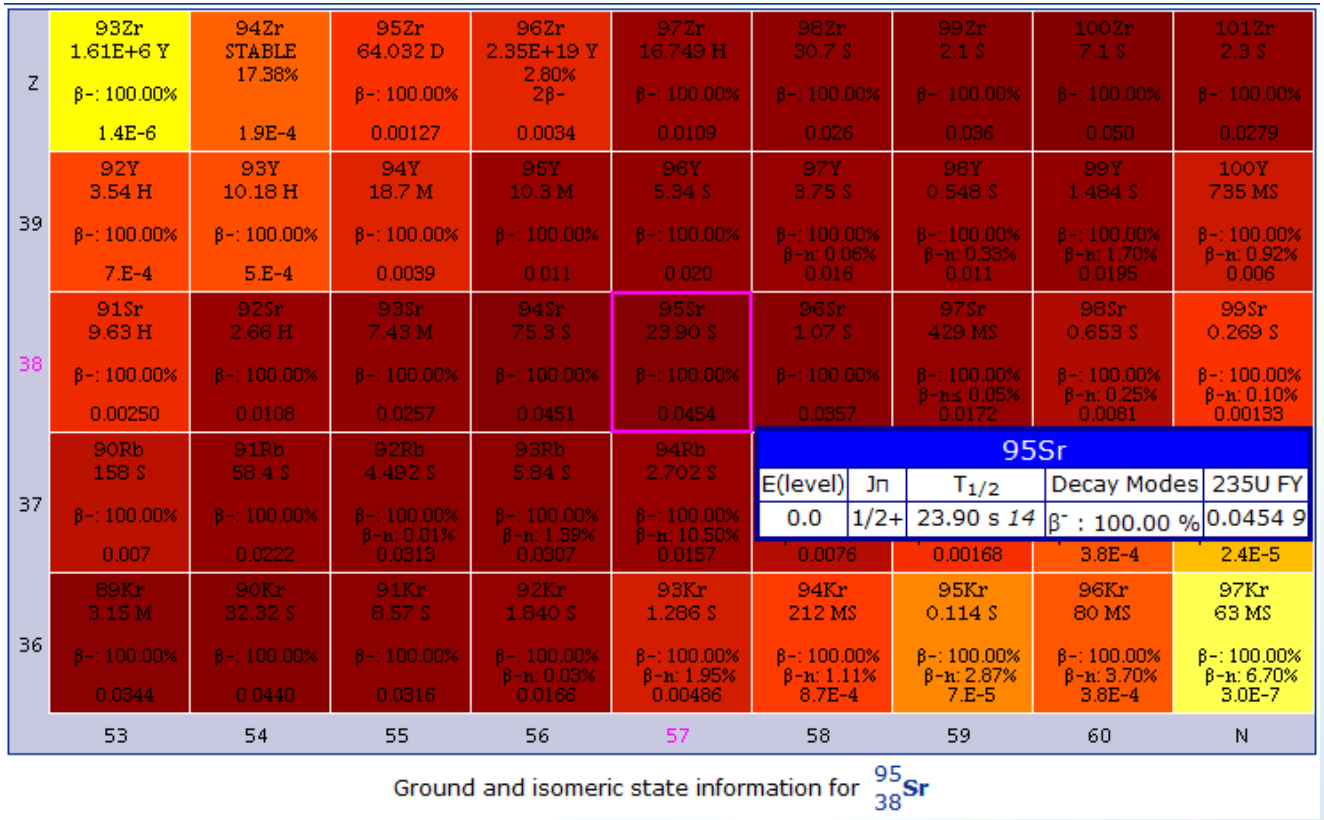
Ground and isomeric state information for $^{140}_{55}$Cs

FY 0.0207

TAS – Comparison of Rudstam with INL (cont)



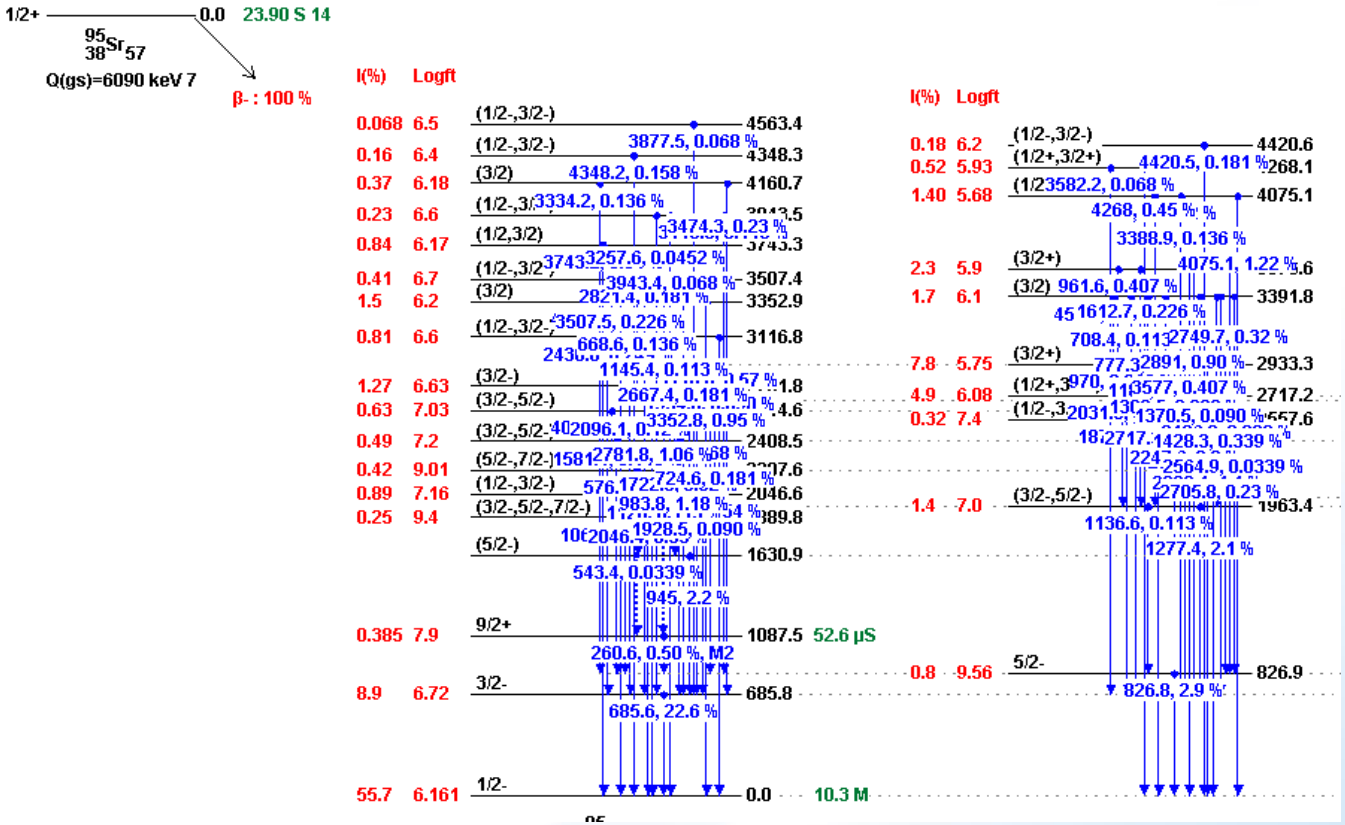
One more example: ^{95}Sr



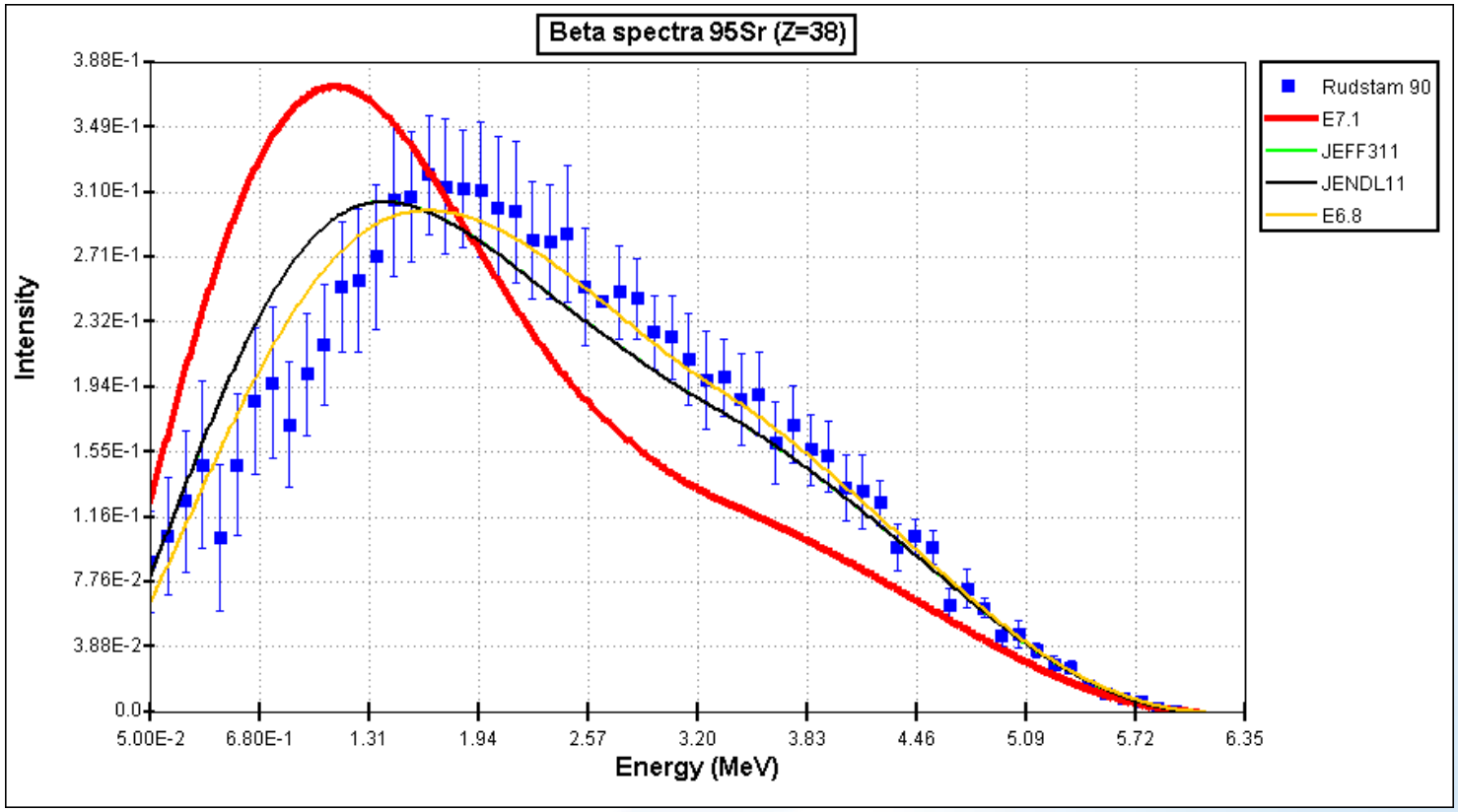
Z	53	54	55	56	57	58	59	60	N
	93Zr 1.61E+6 Y β-: 100.00% 1.4E-6	94Zr STABLE 17.38% 1.9E-4	95Zr 64.032 D β-: 100.00% 0.00127	96Zr 2.35E+19 Y 2.80% 2β- 0.0034	97Zr 16.749 H β-: 100.00% 0.0109	98Zr 30.7 S β-: 100.00% 0.026	99Zr 2.1 S β-: 100.00% 0.036	100Zr 7.1 S β-: 100.00% 0.050	101Zr 2.3 S β-: 100.00% 0.0279
39	92Y 3.54 H β-: 100.00% 7.E-4	93Y 10.18 H β-: 100.00% 5.E-4	94Y 18.7 M β-: 100.00% 0.0039	95Y 10.3 M β-: 100.00% 0.011	96Y 5.34 S β-: 100.00% 0.020	97Y 3.75 S β-: 100.00% β-n: 0.06% 0.016	98Y 0.548 S β-: 100.00% β-n: 0.33% 0.011	99Y 1.484 S β-: 100.00% β-n: 1.70% 0.0195	100Y 735 MS β-: 100.00% β-n: 0.92% 0.006
38	91Sr 9.63 H β-: 100.00% 0.00250	92Sr 2.66 H β-: 100.00% 0.0108	93Sr 7.43 M β-: 100.00% 0.0257	94Sr 75.3 S β-: 100.00% 0.0451	95Sr 23.90 S β-: 100.00% 0.0454	96Sr 1.07 S β-: 100.00% 0.0357	97Sr 429 MS β-: 100.00% β-n≤ 0.05% 0.0172	98Sr 0.653 S β-: 100.00% β-n: 0.25% 0.0081	99Sr 0.269 S β-: 100.00% β-n: 0.10% 0.00133
37	90Rb 158 S β-: 100.00% 0.007	91Rb 58.4 S β-: 100.00% 0.0222	92Rb 4.492 S β-: 100.00% β-n: 0.01% 0.0313	93Rb 5.84 S β-: 100.00% β-n: 1.39% 0.0307	94Rb 2.702 S β-: 100.00% β-n: 10.50% 0.0157	95Sr E(level) Jπ $T_{1/2}$ Decay Modes 235U FY 0.0 1/2+ 23.90 s *14* β⁻ : 100.00 % 0.0454 9 0.0076	0.00168	3.8E-4	2.4E-5
36	89Kr 3.15 M β-: 100.00% 0.0344	90Kr 32.32 S β-: 100.00% 0.0440	91Kr 8.57 S β-: 100.00% 0.0316	92Kr 1.840 S β-: 100.00% β-n: 0.03% 0.0166	93Kr 1.286 S β-: 100.00% β-n: 1.95% 0.00486	94Kr 212 MS β-: 100.00% β-n: 1.11% 8.7E-4	95Kr 0.114 S β-: 100.00% β-n: 2.87% 7.E-5	96Kr 80 MS β-: 100.00% β-n: 3.70% 3.8E-4	97Kr 63 MS β-: 100.00% β-n: 6.70% 3.0E-7

Ground and isomeric state information for $^{95}_{38}$Sr

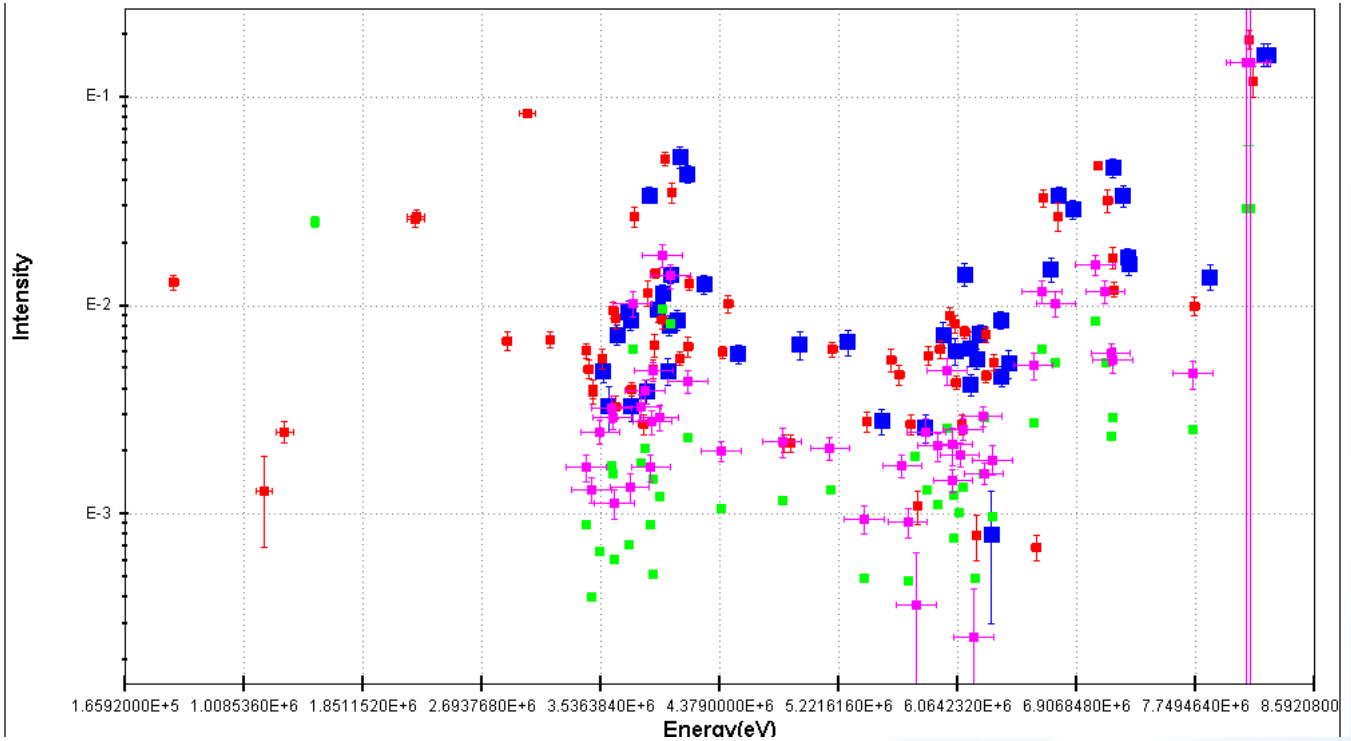
^{95}Sr decay


1/2+
0.0
23.90 S 14
95 38 Sr 57
Q(gs)=6090 keV 7
β- : 100 %
I(%) Logft
0.068 6.5
0.16 6.4
0.37 6.18
0.23 6.6
0.84 6.17
0.41 6.7
1.5 6.2
0.81 6.6
1.27 6.63
0.63 7.03
0.49 7.2
0.42 9.01
0.89 7.16
0.25 9.4
0.385 7.9
8.9 6.72
55.7 6.161
(1/2-,3/2-)
4563.4
3877.5, 0.068 %
4348.3
4348.2, 0.158 %
4160.7
3334.2, 0.136 %
3474.3, 0.23 %
3257.6, 0.0452 %
3943.4, 0.068 %
3507.4
3352.9
3507.5, 0.226 %
668.6, 0.136 %
3116.8
1145.4, 0.113 %
2667.4, 0.181 %
2096.1, 0
3352.8, 0.95 %
2408.5
2781.8, 1.06 %
724.6, 0.181 %
2046.6
983.8, 1.18 %
1928.5, 0.090 %
1630.9
543.4, 0.0339 %
945, 2.2 %
9/2+
1087.5
52.6 µS
260.6, 0.50 %, M2
3/2-
685.8
685.6, 22.6 %
1/2-
0.0
10.3 M
I(%) Logft
0.18 6.2
0.52 5.93
1.40 5.68
2.3 5.9
1.7 6.1
7.8 5.75
4.9 6.08
0.32 7.4
1.4 7.0
0.8 9.56
(1/2-,3/2-)
4420.6
(1/2+,3/2+)
4420.5, 0.181 %
268.1
(1/2
3582.2, 0.068 %
4075.1
4268, 0.45 %
3388.9, 0.136 %
(3/2+)
4075.1, 1.22 %
(3/2)
961.6, 0.407 %
3391.8
1612.7, 0.226 %
708.4, 0.11
2749.7, 0.32 %
(3/2+)
777.3
2891, 0.90 %
2933.3
(1/2+,3
970,
3577, 0.407 %
2717.2
(1/2-,3
2031,
1370.5, 0.090 %
2717.
1428.3, 0.339 %
2564.9, 0.0339 %
(3/2-,5/2-)
2705.8, 0.23 %
1963.4
1136.6, 0.113 %
1277.4, 2.1 %
5/2-
826.9
826.8, 2.9 %

TAS – Comparison of Rudstam with INL (cont)



Comparing Decay Sublibraries
^{89}Br



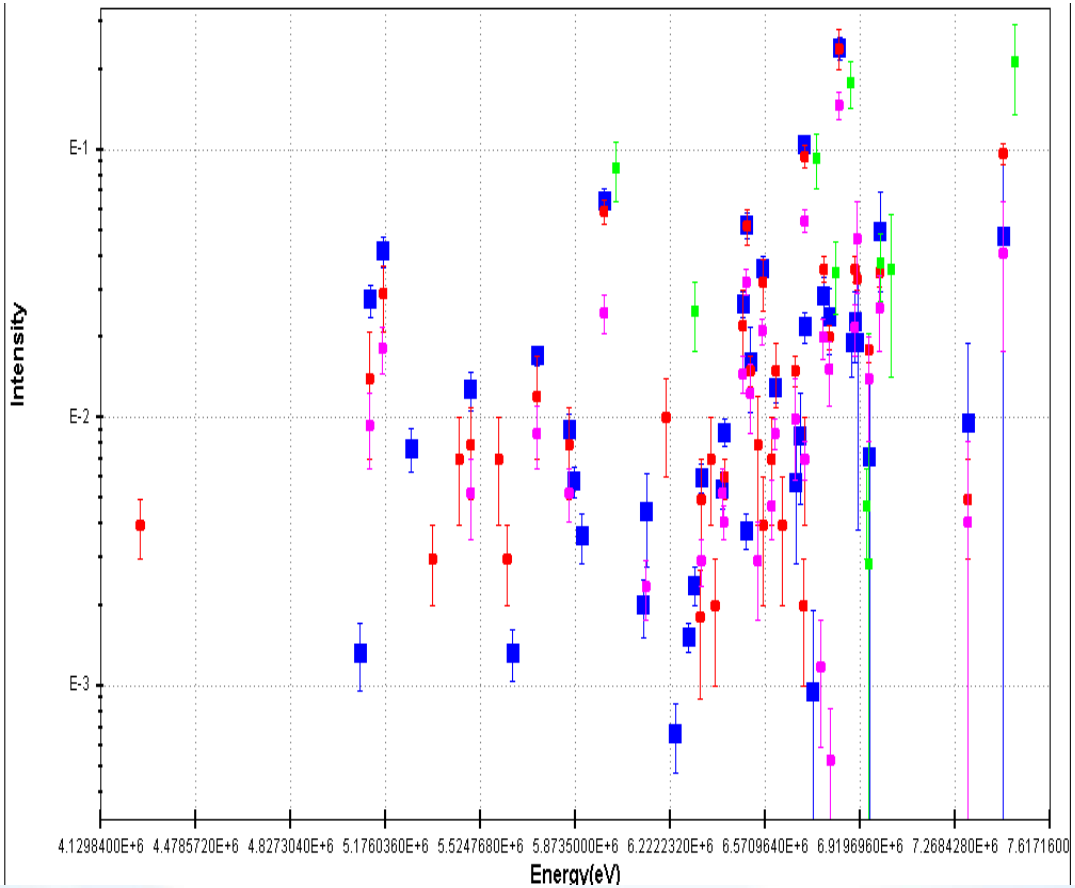
Blue: ENDF VII.1

Green: Jeff 3.1

Red: ENDF 6.8

Magenta: JENDL 4.0

Comparing Decay Sublibraries
^{99}Y



Blue: ENDF VII.1

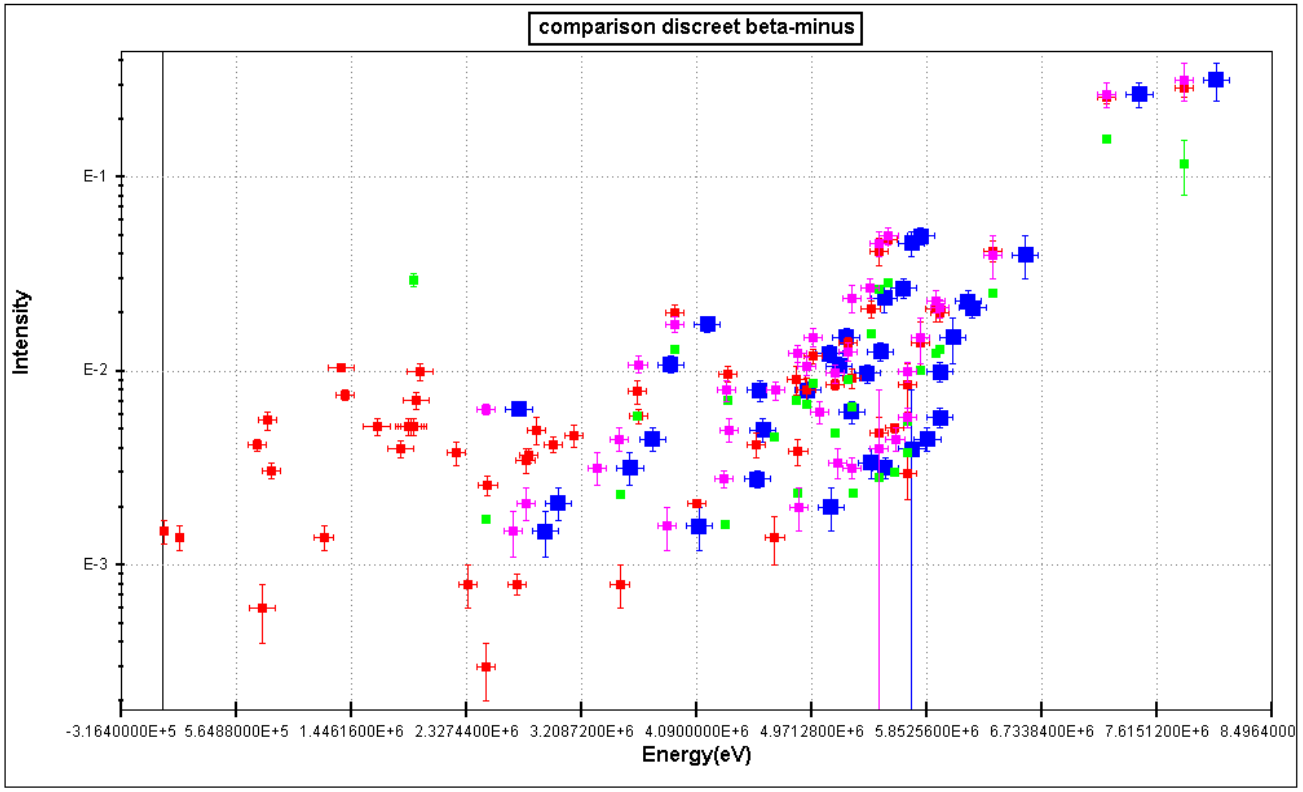
Green: Jeff 3.1

Red: ENDF 6.8

Magenta: JENDL 4.0

Comparing Decay Sublibraries

^{138}I



Blue: ENDF VII.1

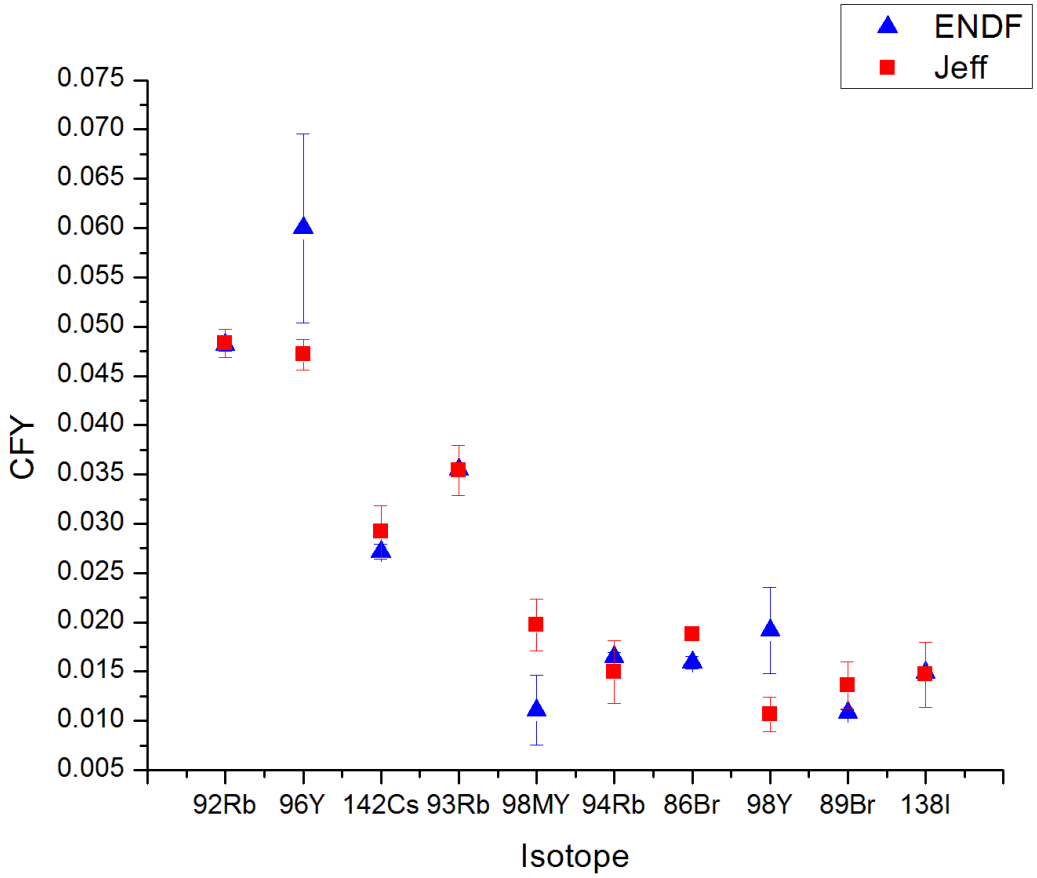
Green: Jeff 3.1

Red: ENDF 6.8

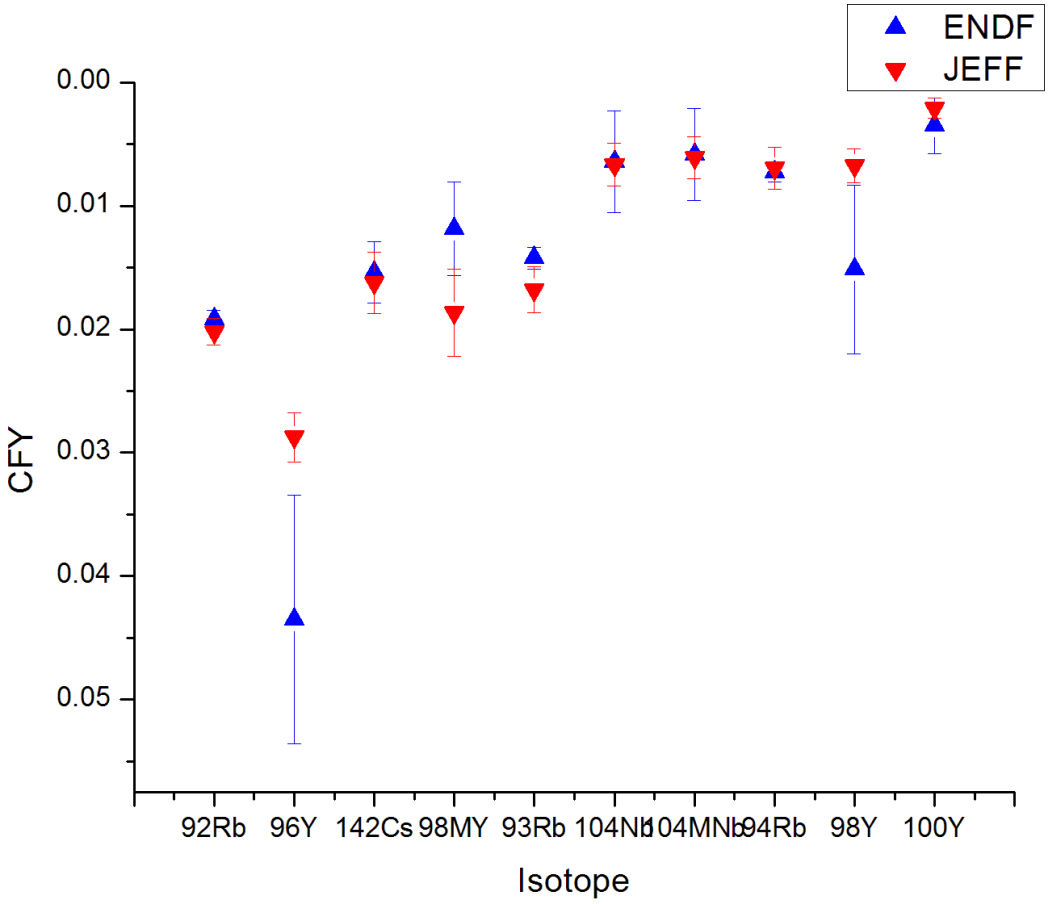
Magenta: JENDL 4.0

How do fission yields compare?

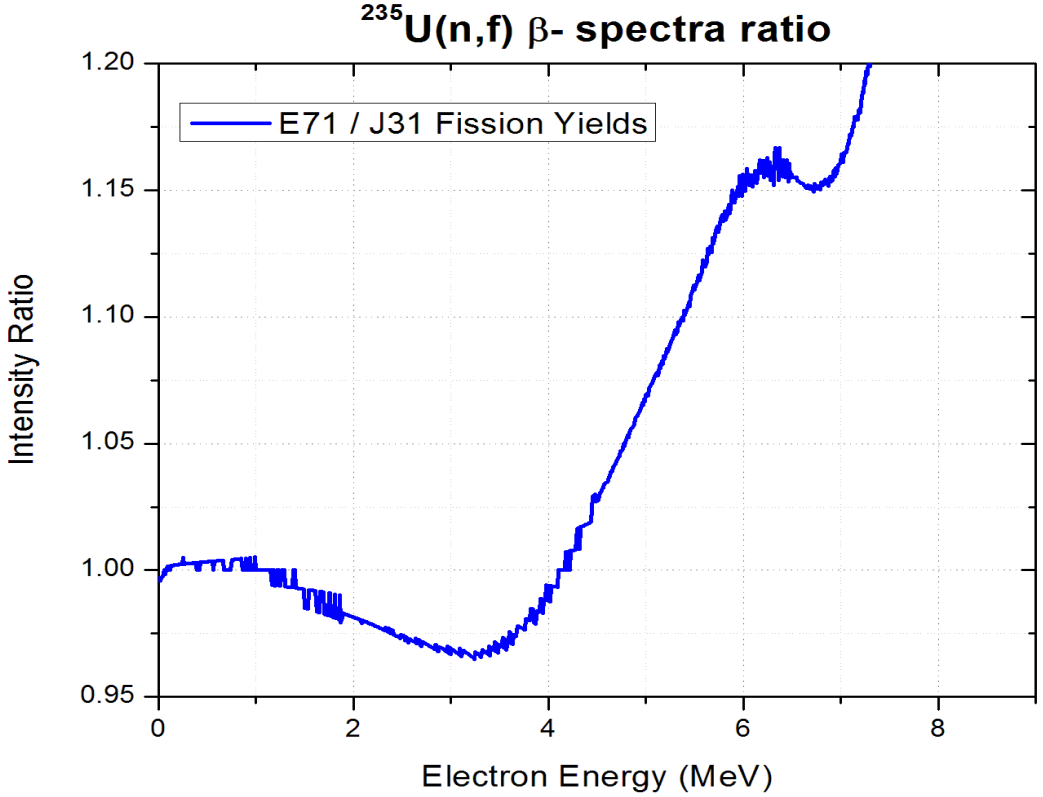
Comparison of ENDF VII.1 and Jeff 3.1 (top 10 contributors to beta spectra at 6 MeV for ^{235}U)



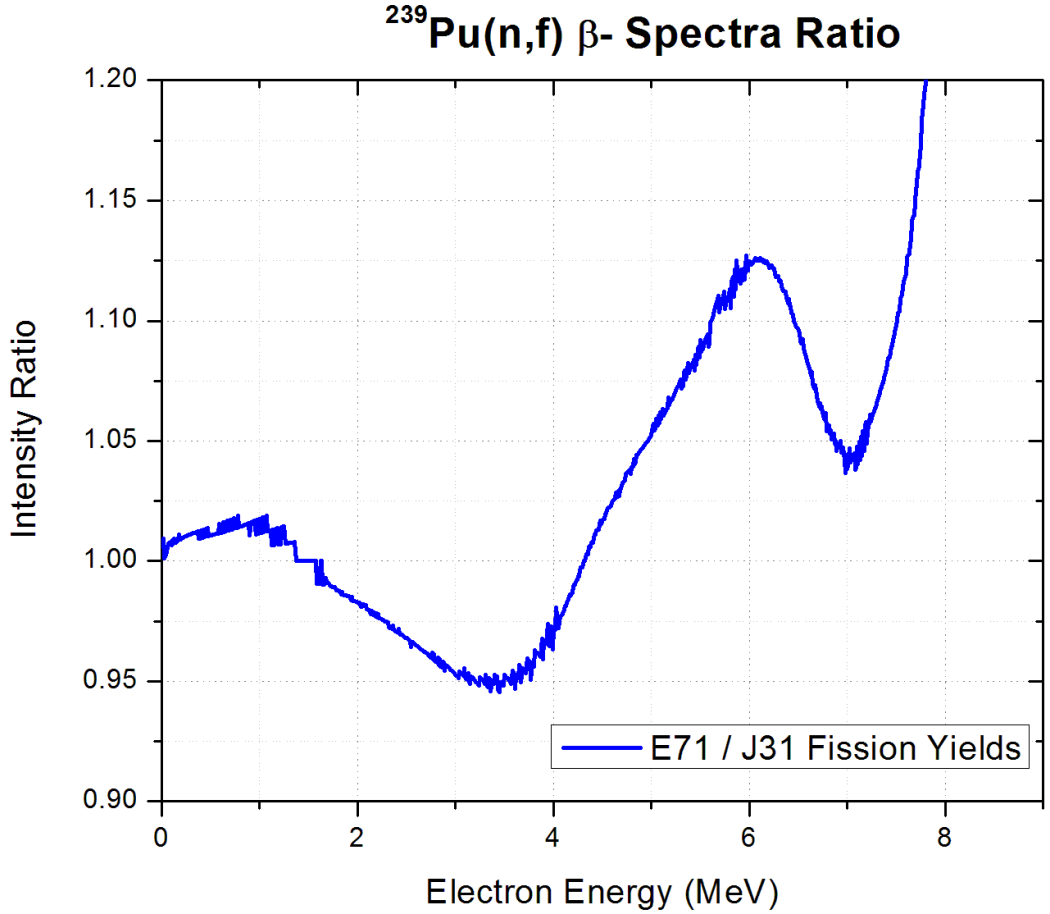
Comparison of ENDF VII.1 and Jeff 3.1 (top 10 contributors to beta spectra at 6 MeV, ^{239}Pu)



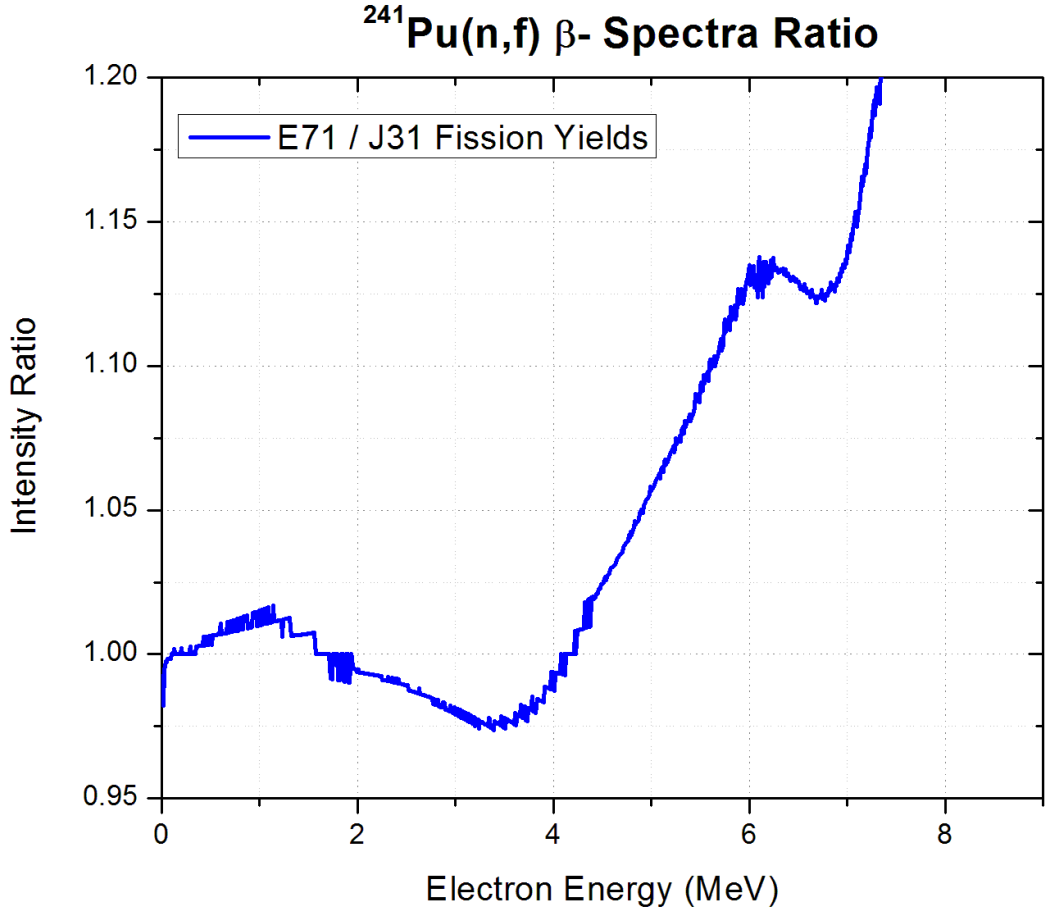
Effect of different yields on beta spectra



Effect of different yields on beta spectra (cont)



Effect of different yields on beta spectra (cont)



Wish List

- High resolution data corresponding to TAS when possible
- Common library of codes and data that all can use
  - Open source model?
- Centralized document with all equations, references, etc.

Next Meeting….?