BETA-DECAY and DECAY HEAT

Remarks on decay heat calculations

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TOOLS

CALCULATION

code: DECROI, self adaptative Bateman eqs. solver (home made)

evolution parameters: λ, decay modes, intensities... from JEFF-3.1

initial conditions: independent fission yields, from JEFF-3.1

POST PROCESSING

mean energies: from different libraries

for each decay time, individual heats sorted by decreasing value

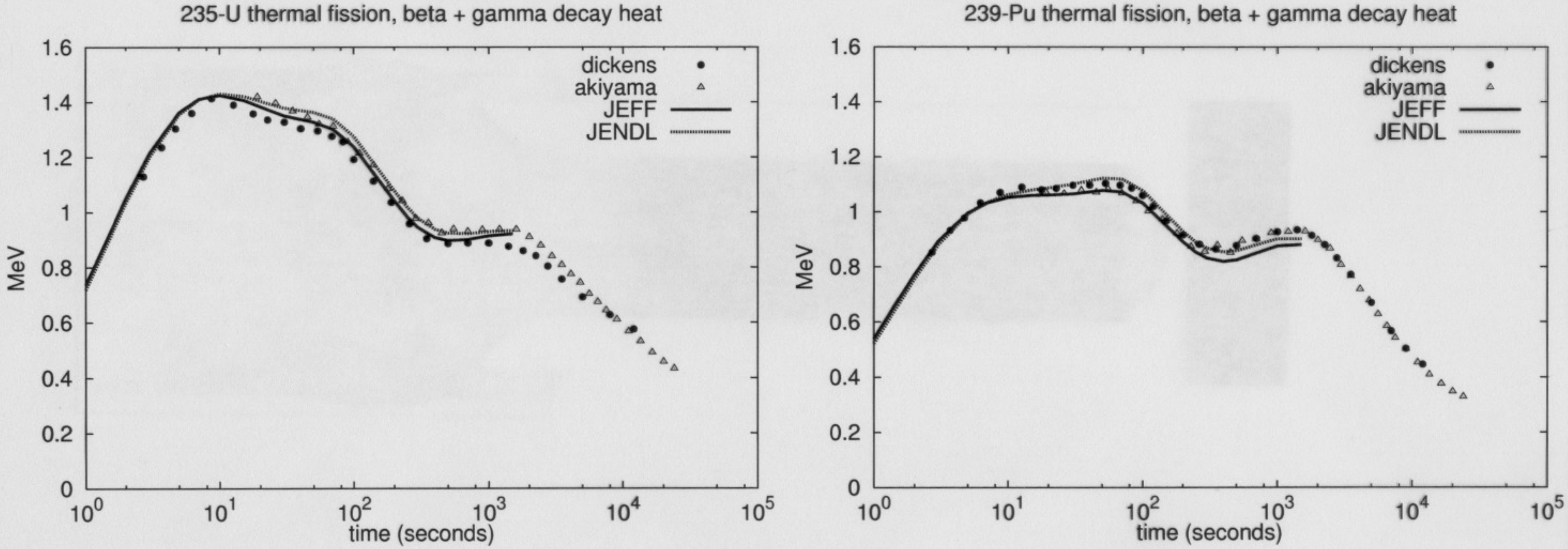
restriction to the major contributors cea

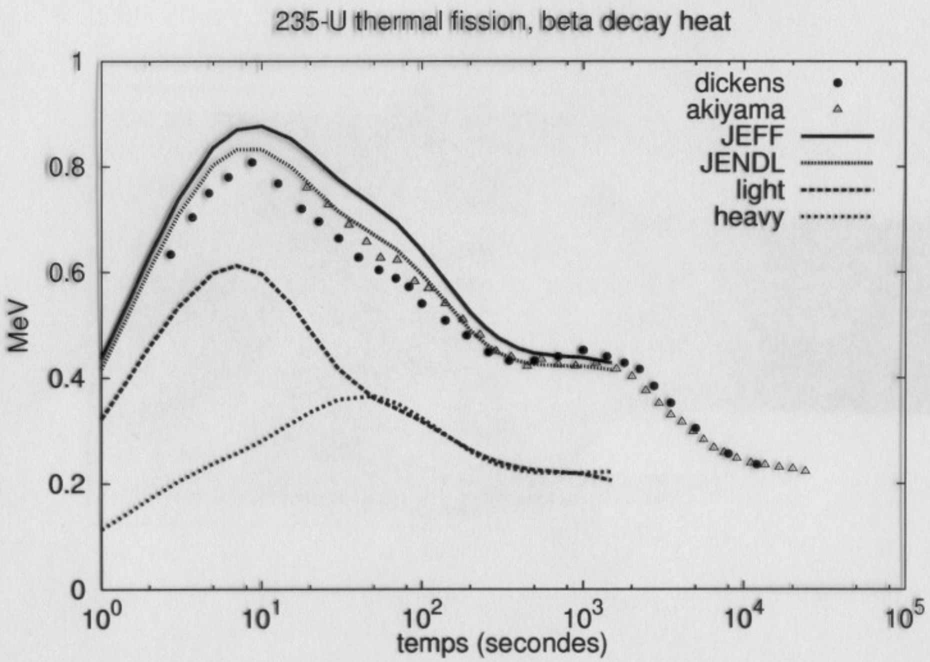
JEFF-3.1 Decay data library contents

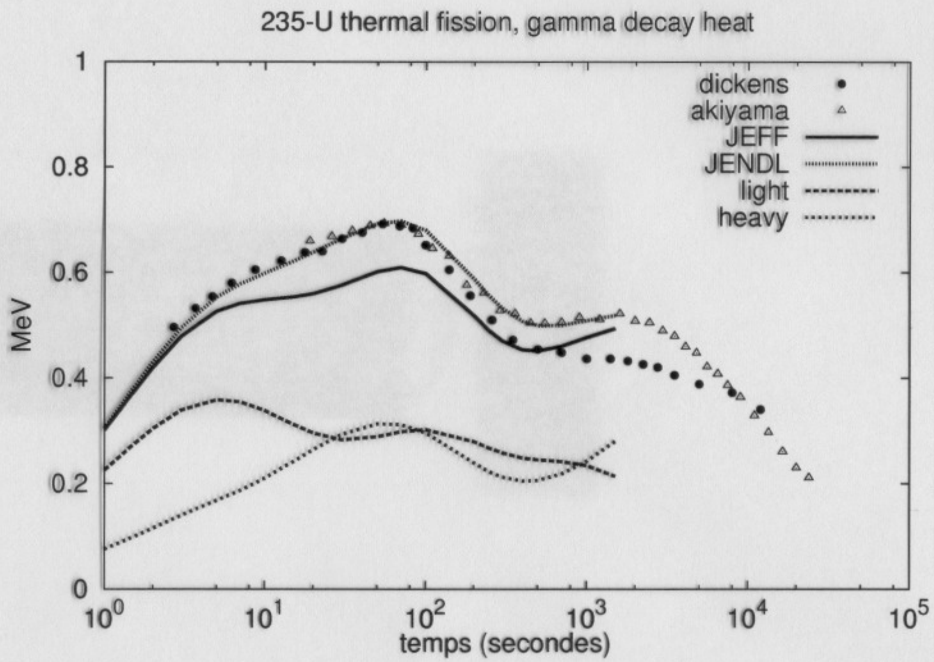
Library	contents	selected	all with mean energies	3852 nuclei
UKPADD	495	360		
UKHEDD	125	116		
LNHB	163	117	with spectral data	1493 (40 %)
ENSDF (*)	1491	900		
NUBASE	3852	2359	without spectral data	2359 (60 %)

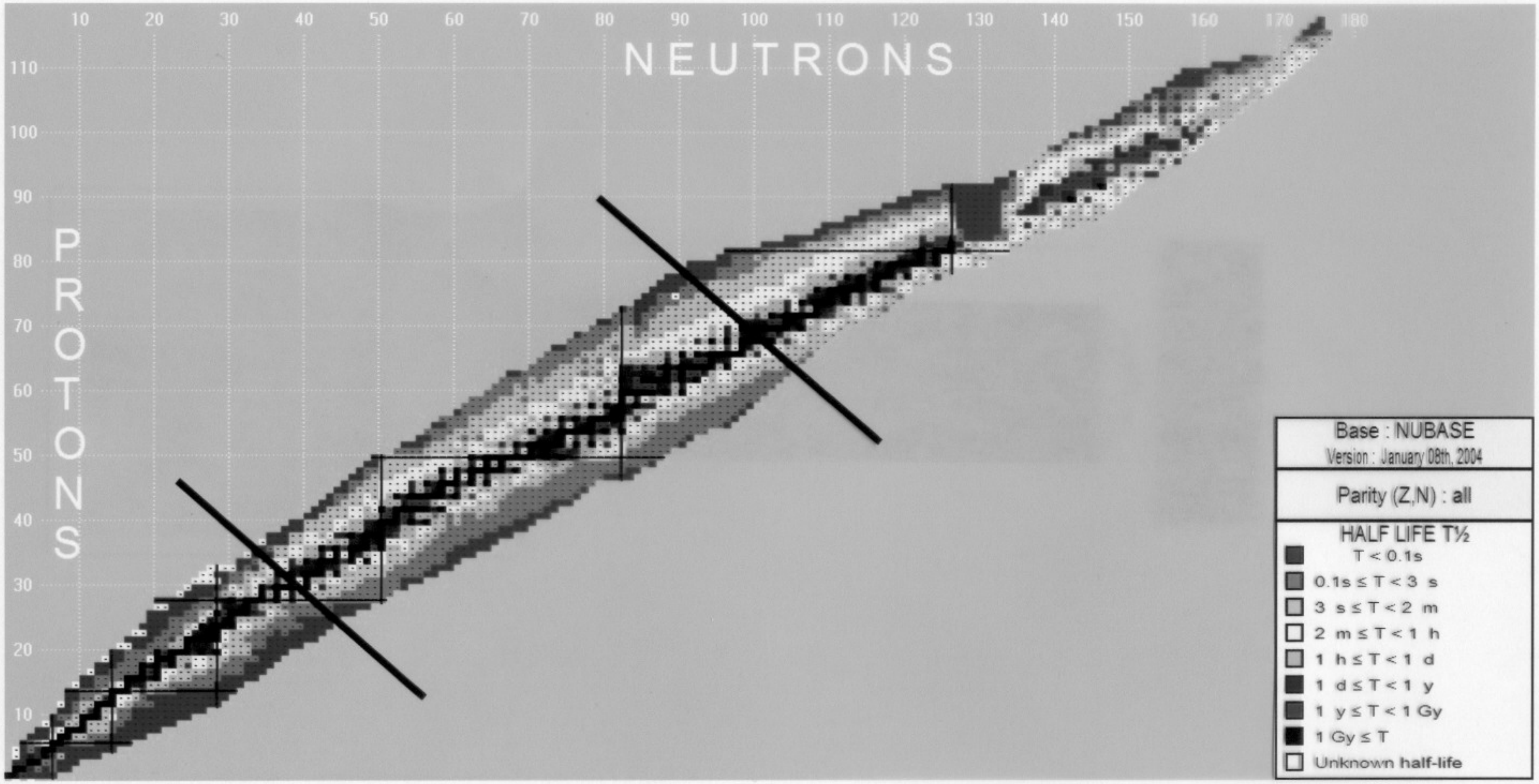
(*) Restricted to the nuclei having a "good" energy balance: $\delta Q < 2\ \%$

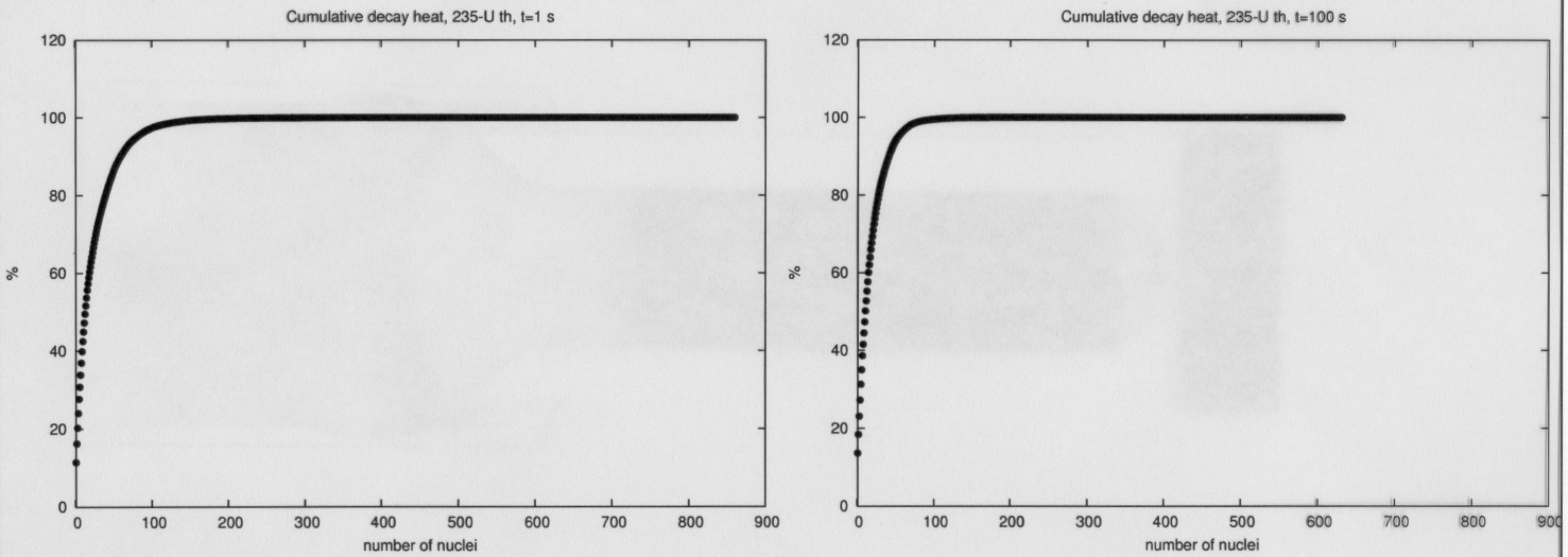
In a first step the goal was to assemble the best available evaluated data sets and afterwards only to compare with experimental data.

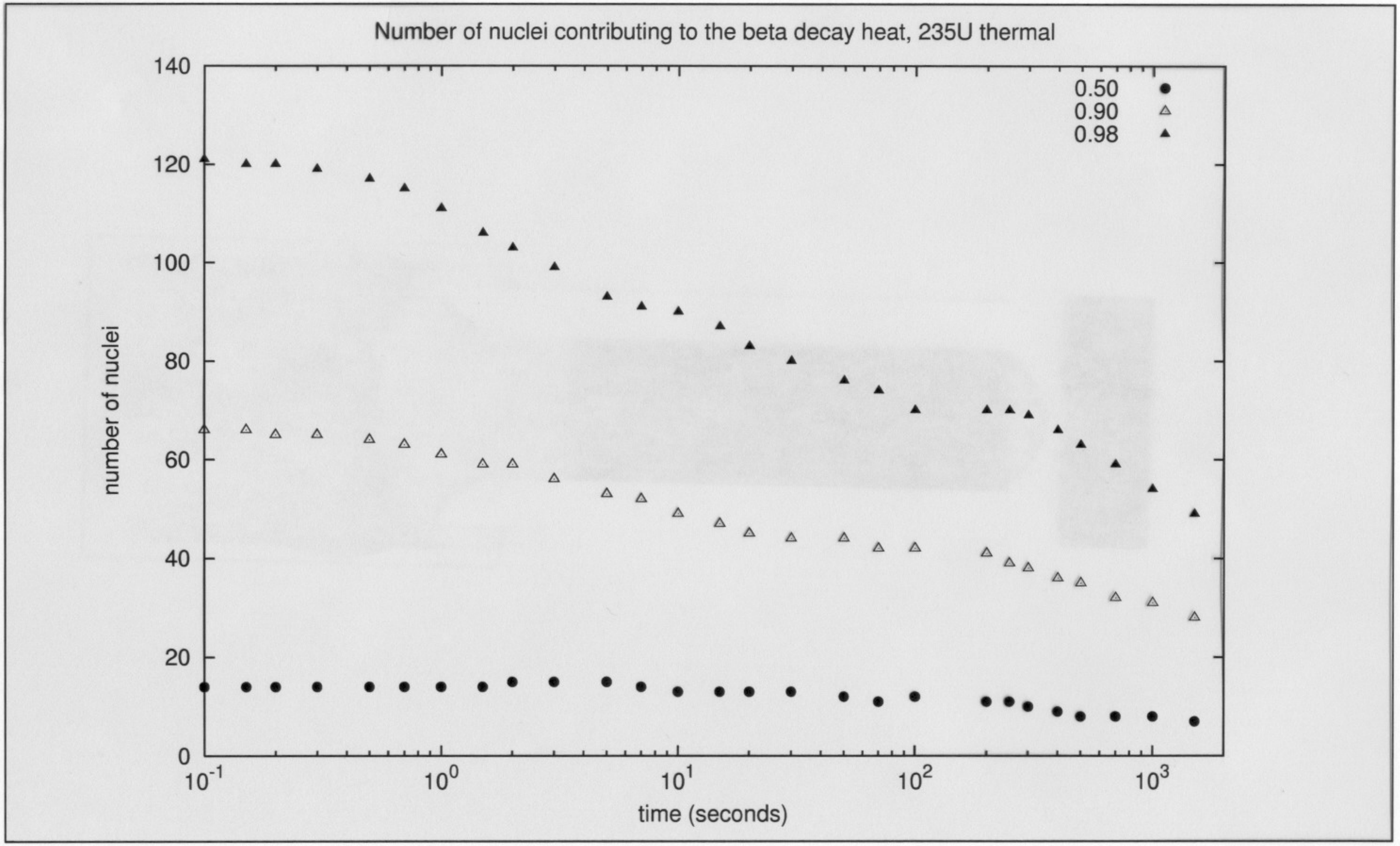

235-U thermal fission, beta + gamma decay heat
239-Pu thermal fission, beta + gamma decay heat
dickens
akiyama
JEFF
JENDL
MeV
time (seconds)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10^0
10^1
10^2
10^3
10^4
10^5


235-U thermal fission, beta decay heat
dickens
akiyama
JEFF
JENDL
light
heavy
MeV
temps (secondes)
0
0.2
0.4
0.6
0.8
1
10^0
10^1
10^2
10^3
10^4
10^5


235-U thermal fission, gamma decay heat
dickens
akiyama
JEFF
JENDL
light
heavy
MeV
temps (secondes)
0
0.2
0.4
0.6
0.8
1
10^0
10^1
10^2
10^3
10^4
10^5


NEUTRONS
PROTONS
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Base : NUBASE
Version : January 08th, 2004
Parity (Z,N) : all
HALF LIFE T½
T < 0.1s
0.1s ≤ T < 3 s
3 s ≤ T < 2 m
2 m ≤ T < 1 h
1 h ≤ T < 1 d
1 d ≤ T < 1 y
1 y ≤ T < 1 Gy
1 Gy ≤ T
Unknown half-life


Cumulative decay heat, 235-U th, t=1 s
%
number of nuclei
0
100
200
300
400
500
600
700
800
900
20
40
60
80
100
120
Cumulative decay heat, 235-U th, t=100 s
%
number of nuclei


Number of nuclei contributing to the beta decay heat, 235U thermal
number of nuclei
time (seconds)
0.50
0.90
0.98
0
20
40
60
80
100
120
140
10^-1
10^0
10^1
10^2
10^3

Major contributors to the beta decay heat, ^{235}U thermal

0.1 s		^{97}Sr	^{96}Sr	^{97m}Y	^{95}Rb	24 %
	⟨E⟩ Jeff	2456	1972	2433	2829	
	⟨E⟩ Jendl	2285	1970	2355	3102	
		- 7 %	=	- 3 %	+ 10 %	
0.3 s		^{96}Sr	^{97}Sr	^{97m}Y	^{142}Cs	23 %
	⟨E⟩ Jeff	1972	2456	2433	2899	
	⟨E⟩ Jendl	1970	2285	2355	2449	
		=	- 7 %	- 3 %	- 18 %	
1.0 s		^{96}Sr	^{97m}Y	^{142}Cs	^{99}Zr	20 %
	⟨E⟩ Jeff	1972	2433	2899	1539	
	⟨E⟩ Jendl	1970	2355	2449	1710	
		=	- 3 %	- 18 %	+ 11 %	
3.0 s		^{96}Y	^{92}Rb	^{99}Zr	^{142}Cs	20 %
	⟨E⟩ Jeff	3205	2875	1539	2899	
	⟨E⟩ Jendl	2657	3499	1710	2449	
		- 20 %	+ 22 %	+ 11 %	- 18 %	
10. s		^{96}Y	^{100}Nb	^{92}Rb	^{101}Nb	25 %
	⟨E⟩ Jeff	3205	2493	2875	1863	
	⟨E⟩ Jendl	2657	2480	3499	1686	
		- 20 %	=	+ 22 %	- 10 %	
30. s		^{98}Nb	^{95}Sr	^{141}Cs	^{135}Te	20 %
	⟨E⟩ Jeff	1965	2208	1935	2442	
	⟨E⟩ Jendl	1628	2210	1940	2084	
		- 21 %	=	=	- 17 %	
100. s		^{140}Cs	^{91}Rb	^{144}La	^{98}Nb	23 %
	⟨E⟩ Jeff	1964	1612	1382	1965	
	⟨E⟩ Jendl	1752	1500	1380	1628	
		- 12 %	- 7 %	=	- 21 %	
300. s		^{137}Xe	^{90}Rb	^{139}Cs	^{95}Y	27 %
	⟨E⟩ Jeff	1695	2049	1640	1437	
	⟨E⟩ Jendl	1700	1992	1640	1440	
		=	- 3 %	=	=	
1000. s		^{94}Y	^{139}Cs	^{95}Y	^{102}Tc	33 %
	⟨E⟩ Jeff	1814	1640	1437	1945	
	⟨E⟩ Jendl	1810	1640	1440	1420	
		=	=	=	- 37 %	

cea

Pandemonium ?

	E(last level)	Q_β	E / Q_β	$Q_{\beta-n}$	$I_{\beta-n}$
^{97}Sr	2558	7470	0.34	1488	< 0.05
^{96}Sr	1983	5416	0.37	197	0
^{97m}Y	2508	6680	0.38	1113	< 0.08
^{95}Rb	4661	9296	0.50	4915	8.73
^{142}Cs	5280	7307	0.72	1140	0.09
^{99}Zr	1976	4558	0.43		
^{96}Y	6231	7100	0.88		
^{92}Rb	7363	8100	0.91	802	0.01
^{100}Nb	3129	6245	0.50		
^{101}Nb	1099	4569	0.24		

Comparison between the JENDL and JEFF libraries

^{92}Rb		JEFF-3.1 (2003)	JENDL-3.2(1999)	δ
	Q_β	8105	8100	
	E_β	2875	3499	+ 22 %
	E_γ	1750	520	high
	δQ	0.27 %		

^{96}Y		JEFF-3.1 (1998)	JENDL-3.2(1999)	δ
	Q_β	7100	7100	
	E_β	3205	2657	- 20 %
	E_γ	80	1206	high
	δQ	0.0056%		
		Note: 96 % β^- to the g.s.!		

^{142}Cs		JEFF-3.1 (1991)	JENDL-3.2(1999)	δ
	Q_β	7317	7307	
	E_β	2899	2449	- 18 %
	E_γ	675	1787	high
	δQ	- 1.1 %		

Case of $^{97g,m,n}Y$

^{97g}Y		JEFF-3.1	JENDL-3.2	UKPADD-6.5
	Q_β	6680	6688	6689
	E_β	2228	2355	2135
	E_γ	2228	1468	1846

^{97m}Y		JEFF-3.1	JENDL-3.2	UKPADD-6.5
	Q_β	7356	7350	7357
	E_β	2433	2200	2318
	E_γ	2433	2680	2111

^{97n}Y		JEFF-3.1	JENDL-3.2	UKPADD-6.5
	Q_β	10212		10212
	E_β	681		121
	E_γ	2965		2803

CONCLUSIONS

ELEMENTARY FISSION CURVES

- we have seen many of them
- difficult to analyse
- we must move a step further: nucleus by nucleus basis

TAGS experiments

- contribution to the E_β and E_γ problem
- but 50 TAGS experiments (GH), 5 taken into account by ENSDF!
- tentative by Yoshida *et al.*

TO DO

- DDEP like structure (or WPEC25 itself)
- define important short lived FP (major contributors)

Decay-heat data

Which are the "correct" experimental data to compare with?

Dickens,

Akiyama,

Tobias,

...