Capture Cross Section Adjustments in the Thermal to Fast Energy Regions

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Basis for changes and improvements

- New differential data.
- New integral benchmarks

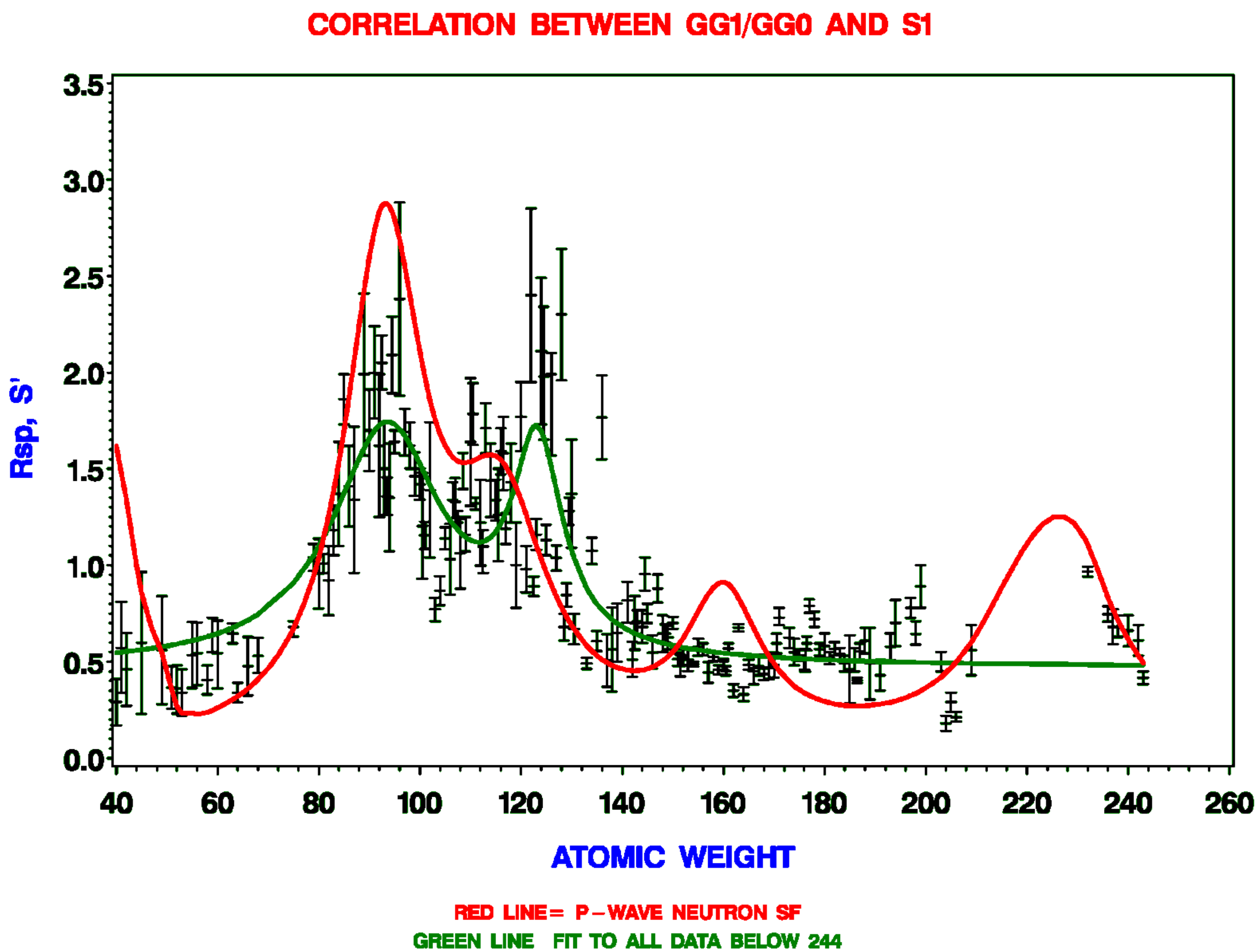
a. Reactivity worth measurements at Dimple reactor, thermal and fast neutron spectra, (Dean et al. 2007)

b. Irradiations at CEA fast reactor, PHENIX, (Palmiotti et al. MCNP analysis, 2011).

Methodology (continued)

- Physics considerations: a. recent results of variation of (average p-wave capture width) / (average s-wave capture width) with A, b. accurate derivations of R', S_0 , and S_1 from average (n, tot), c. comparisons of calculated resonance integrals with the Atlas values, d. comparisons of the calculated 30-keV Maxwellian capture cross sections with the Kadonis data base (Pritychenko Talk).

Comparison of $\Gamma_{\gamma 1}/\Gamma_{\gamma 0}$ with S1



Comparison: integral and differential data (Dean 2007)

FP ISOtOPE	JEF3.1 SOFT	WPEC23 SOFT	JF3.1 PWR	WPEC PWR	WPEC/JEF SOFT PWR
Mo-95 X	+9	+9	0	0	1.0 1.0
Tc-99 X	+9	+10	+8	+10	1.1 1.3
Rh-103 X	+10	+12	+6	+8	1.2 1.3
Ag-109	+5	+5	+2	+2	1.0 1.0
Cs-133 X	+11	+11	+10	+10	1.0 1.0
Nd-143	-1	-2	-3	-6	2.0 3.0
Nd-145 X	+1	+13	+1	+11	13 11 XXX
Sm-147	+7	+3	+4	0	0.4 0.0
Sm-149	+2	0	-4	-6	0.0 1.5
Sm-152	0	-1	0	0	
Eu-153 X	-11	-11	-6	-6	1.0 1.0
Gd155	+4	+4	+3	+3	1.0 1.0

^{58}Co

- ENDF/B-VII.0 adopted JEFF3.3

1. Thermal (n,γ) and I_γ discrepant with Atlas values.
2. Very large negative C/S in background.
3. Thermal (n,p) C/S seems quite high in this mass region, 1700 b.

The result is an original BNL evaluation for this nucleus.

^{58}Co

- Atlas methodology below the fast region and EMPIRE calculations above it.
- Aside from thermal (n,γ) and I_γ , no other measured neutron data are available.
- Since (n , p) threshold is open below neutron separation energy, two methods were applied to estimate the thermal (n , p) C/S.

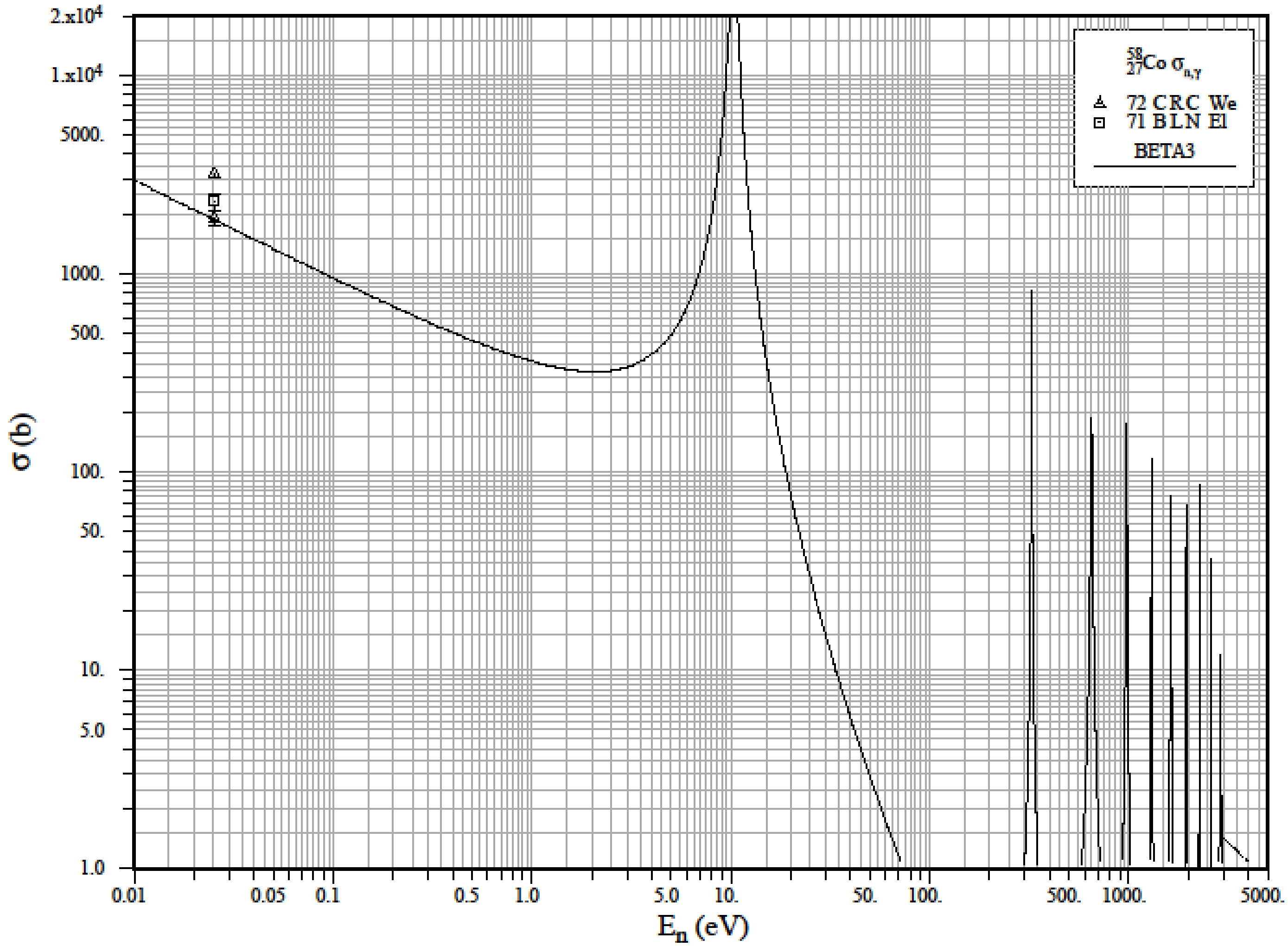
1. Reciprocity theorem applied to reaction ^{58}Fe(p , n)^{58}Co to obtain the (n , p) cross section

^{58}Co

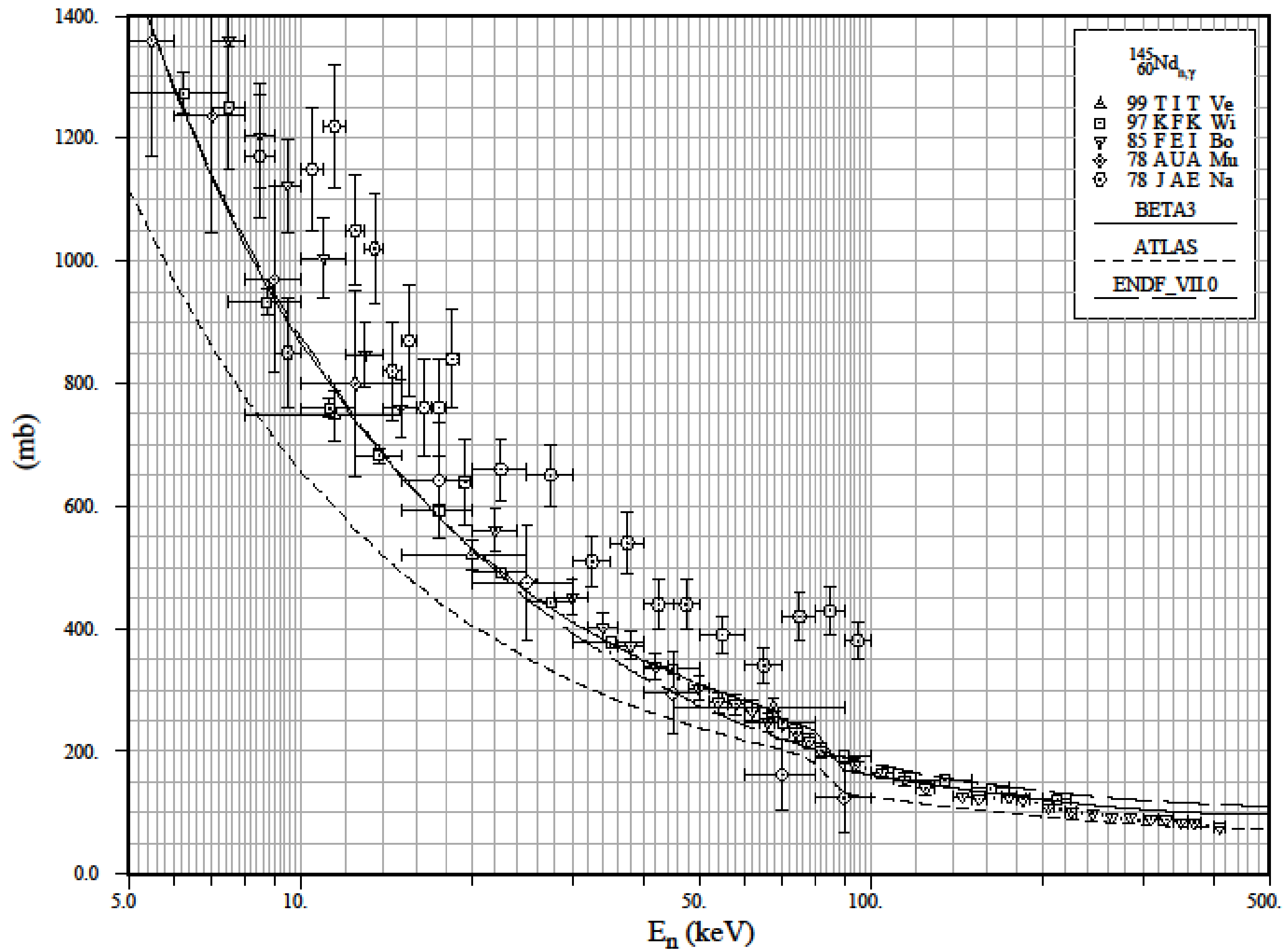
2. Ratio of (n , p) cross section of ^{58}Co to that of ^{59}Ni was computed by EMPIRE and normalized to the ^{59}Ni thermal value, 1.43 ± 0.13 b. The result from both methods is (n , p)= 101 b for ^{58}Co.

- The thermal (n,γ) and I_γ are attributed to a resonance located at 10.35 eV.
- Equidistant resonances with D=330 eV are invoked up to 3.0 keV
- URR region spans 3.0 keV- 24.9 keV.

^{58}Co Capture



^{145}Nd

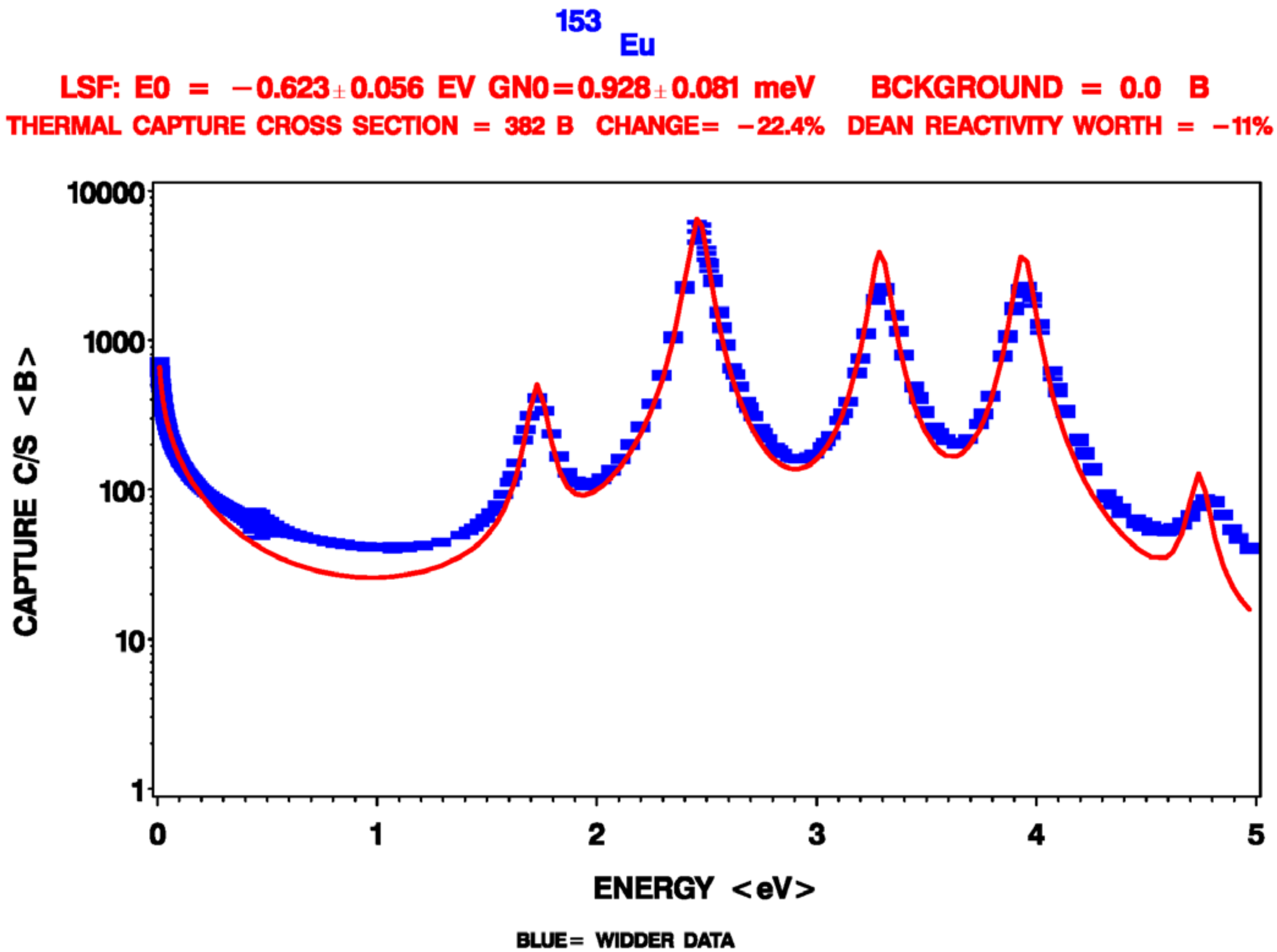


1400.
1200.
1000.
800.
600.
400.
200.
0.0
(mb)
5.0
10.
50.
100.
500.
En (keV)
145 60 Nd n,γ
99 T I T Ve
97 K F K Wi
85 F E I Bo
78 A U A Mu
78 J A E Na
BETA3
ATLAS
ENDF_VII.0

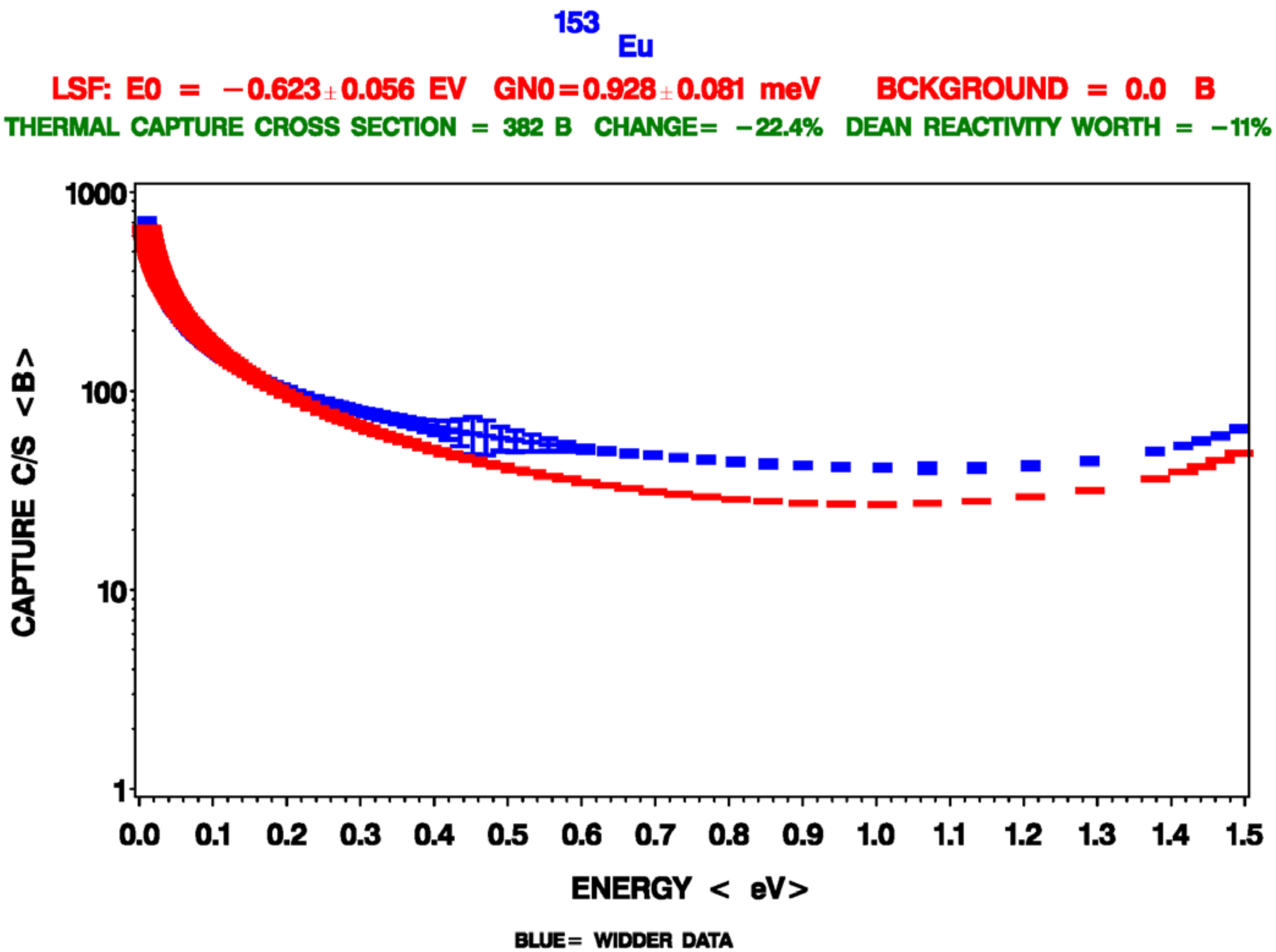
^{153}Eu

THERMAL CAPTURE C/S (b)	METHOD	AUTHOR
295 ± 5	ACTIVATION	HEFT-1978
603 ± 23	ACTIVATION	GRYNTAKIS-1975
405 ± 30	PILE OSCILATOR	LUCAS-1975
639 ± 7	ACTIVATION	SIMS-1967
317 ±5	PILE OSCILATOR	TATTERSALL-1960
448 ±16	TOTAL CROSS SECTION	PATTENDEN-1958
421 ± 30	MASS SEPARATION	HAYDEN-1949

Results

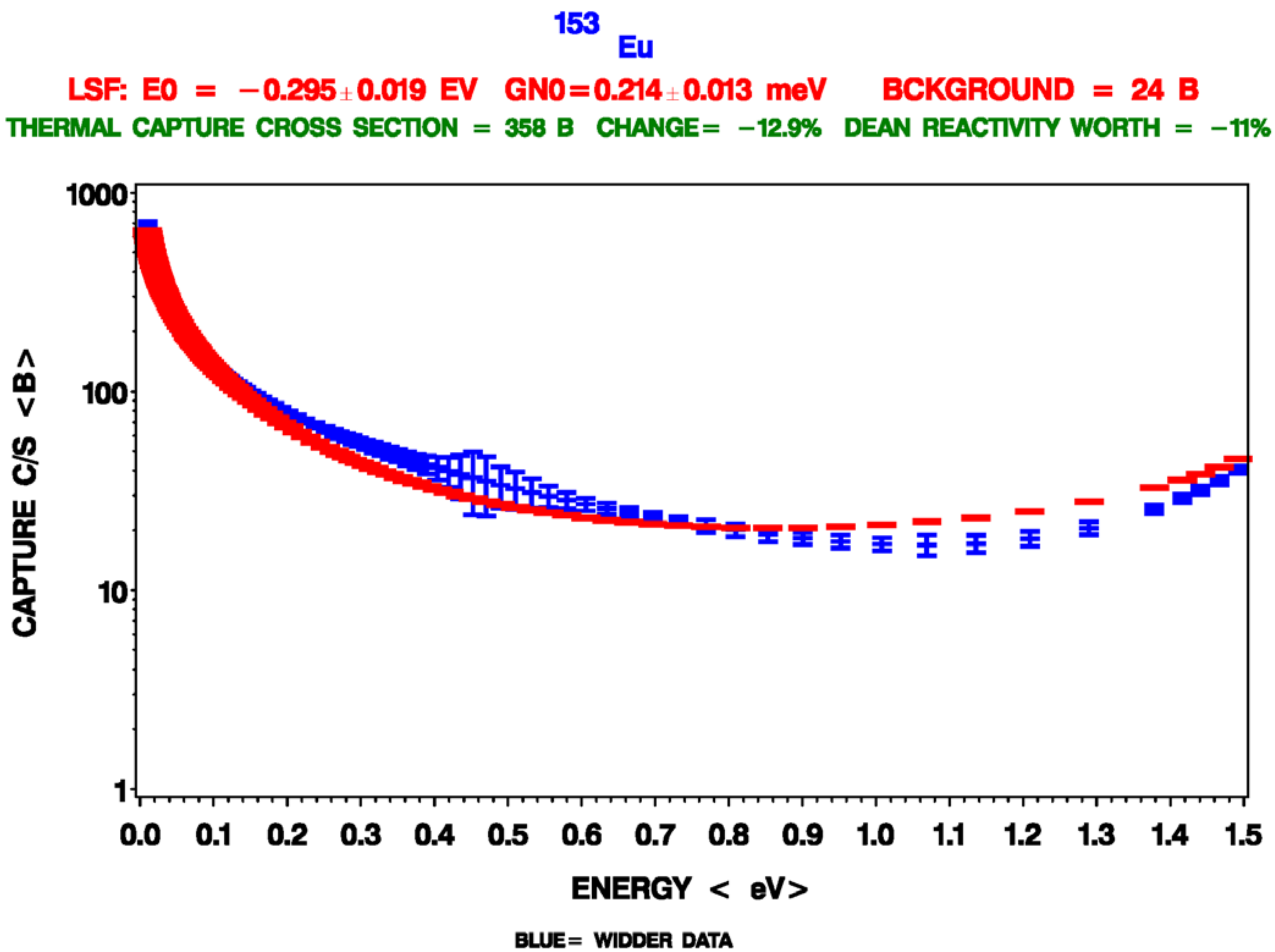

153 Eu
LSF: E0 = −0.623±0.056 EV GN0=0.928±0.081 meV BCKGROUND = 0.0 B
THERMAL CAPTURE CROSS SECTION = 382 B CHANGE= −22.4% DEAN REACTIVITY WORTH = −11%
CAPTURE C/S <B>
10000
1000
100
10
1
0
1
2
3
4
5
ENERGY <eV>
BLUE= WIDDER DATA

^{153}Eu



153 Eu
LSF: E0 = −0.623±0.056 EV GN0=0.928±0.081 meV BCKGROUND = 0.0 B
THERMAL CAPTURE CROSS SECTION = 382 B CHANGE= −22.4% DEAN REACTIVITY WORTH = −11%
CAPTURE C/S <B>
1000
100
10
1
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
ENERGY < eV>
BLUE= WIDDER DATA

^{153}Eu



153 Eu
LSF: E0 = −0.295±0.019 EV GN0=0.214±0.013 meV BCKGROUND = 24 B
THERMAL CAPTURE CROSS SECTION = 358 B CHANGE= −12.9% DEAN REACTIVITY WORTH = −11%
CAPTURE C/S <B>
1000
100
10
1
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
ENERGY < eV>
BLUE= WIDDER DATA

TESTING (Palmiotti et al.)

Capture c/s	ENDF/B-VII C/E	ENDF/BVII.1bet5 C/E	Exp. Uncertai. %
^{238} Pu	1.299	1.136	4.0%
^{239} Pu	0.906	0.906	3.0%
^{240}Pu	0.964	0.945	2.2%
^{242}Pu	1.061	1.020	3.5%
^{243}Am	0.834	0.939	5.0%
^{101}Ru	1.101	1.095	3.6%
^{105}Pd	0.852	0.845	4.0%
^{133}Cs	0.878	0.827	4.7%
^{145}Nd	0.955	0.936	3.8%
^{149}Sm	0.915	0.908	3.1%
^{95}Mo	1.032	1.063	3.8%

Comparison: integral and differential data (Dean 2007)

FP ISOtOPE	JEF3.1 SOFT	WPEC23 SOFT	JF3.1 PWR	WPEC PWR	WPEC/JEF SOFT PWR
Mo-95 X	+9	+9 X	0	0	1.0 1.0
Tc-99 X	+9	+10 X	+8	+10 Y	1.1 1.3
Rh-103 X	+10	+12 X	+6	+8 Y	1.2 1.3
Ag-109	+5	+5	+2	+2	1.0 1.0
Cs-133 X	+11	+11 X	+10	+10 Y	1.0 1.0
Nd-143	-1	-2	-3	-6	2.0 3.0
Nd-145 X	+1	+13 X	+1	+11 Y	13 11
Sm-147	+7	+3	+4	0	0.4 0.0
Sm-149	+2	0	-4	-6	0.0 1.5
Sm-152	0	-1	0	0	
Eu-153 X	-11	-11 X	-6	-6	1.0 1.0
Gd155	+4	+4	+3	+3	1.0 1.0

Comparisons VII.0 and VII.1 fission products

Nucleus	capture ENDF/BVII.1	capture ENDF/BVII.0	Iγ ENDF/BVII.1	Iγ ENDF/BVII.0
^{92}Mo	0.080	0.02075	0.0864	0.0968
^{95}Mo	13.1	13.57	104.4	110.28
^{99}Tc	20.0	22.80	322.4	361.7
^{103}Rh	142.0	144.9	967.5	1034.3
^{109}Ag	90.23	91.08	1467	1473
^{133}Cs	29.0	29.0	366.0 xk	420.5
^{145}Nd	42.0	49.8	222.8	245.0
^{153}Eu	358.0	312.7	1419	1410

Comparisons VII.0 and VII.1

Nucleus	capture ENDF/BVII.1	capture ENDF/BVII.0	Iγ ENDF/BVII.1	Iγ ENDF/BVII.0
^{58}co	1855	172	6519	221
^{62}Ni	14.9	14.4	7.26	6.01
^{90} Zr	0.010	0.078	0.13	0.19
^{91}Zr	1.22	0.832	5.99	5.88
^{113}Cd	19860	20610	383	392
^{157}Gd	236500	254200	732.8	753.3
^{243} Am	80.40	75.1	2051	1819
^{242}Pu	21.26	19.2	1123.4	1273

Actinides

^{242}Pu Thermal, resolved and URR changed
Fast region decreased by 20% based on a renormalized integral value of Druzhinin et. al.

^{243}Am Thermal, resolved and URR changed
Previously fast region of Weston +Todd based on thermal capture of 75.1 b. New value is 80.4 b. Fast region normalized to URR, +15.5%

^{157}Gd

Comparison with JENDL4.0

ENDF/BVII.1	JENDL4.1
BNL resonance	RPI resonance
Thermal capture=	Thermal capture =
253317 b	253250 b
236500 b (RPI)	
No background	Huge - background
Integral benchmarks	Integral benchmarks

^{169}Tm Puzzle

Low Energy <2 keV

Atlas

$S_0 = 1.60 \pm 0.12$

$\Gamma_\gamma = 0.086 \pm 0.007$ eV

Fast Energy > 3keV

Macklin et al.

$S_0 = 2.89 \pm 0.67$

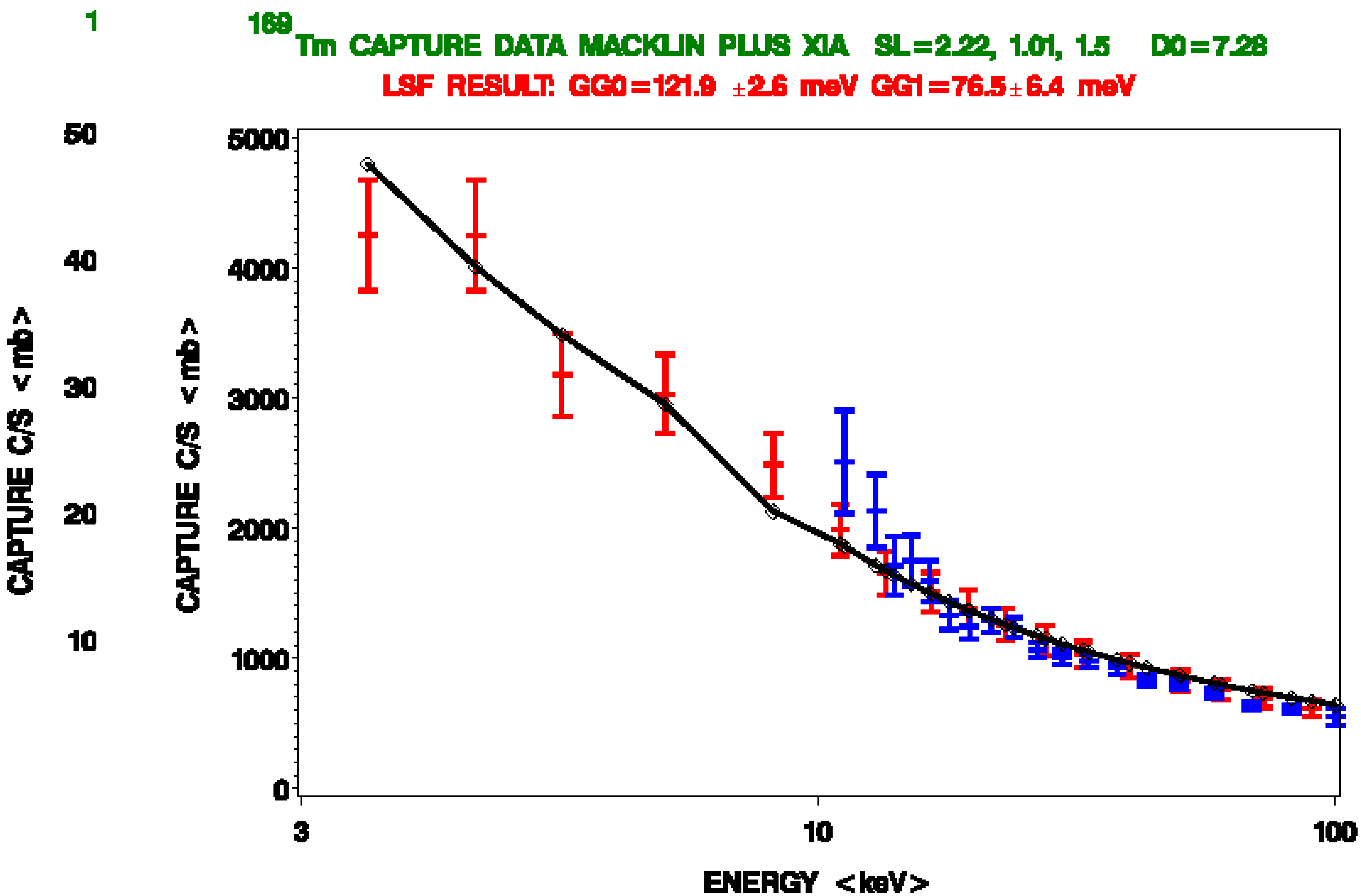
$\Gamma_\gamma = 0.120$ eV RR

Dilg 1971

at 2.7 keV

$S_0 = 2.1 \text{-+} 0.5$

LSF Fit of ^{169}Tm Capture



^{169}Tm Possible Solution

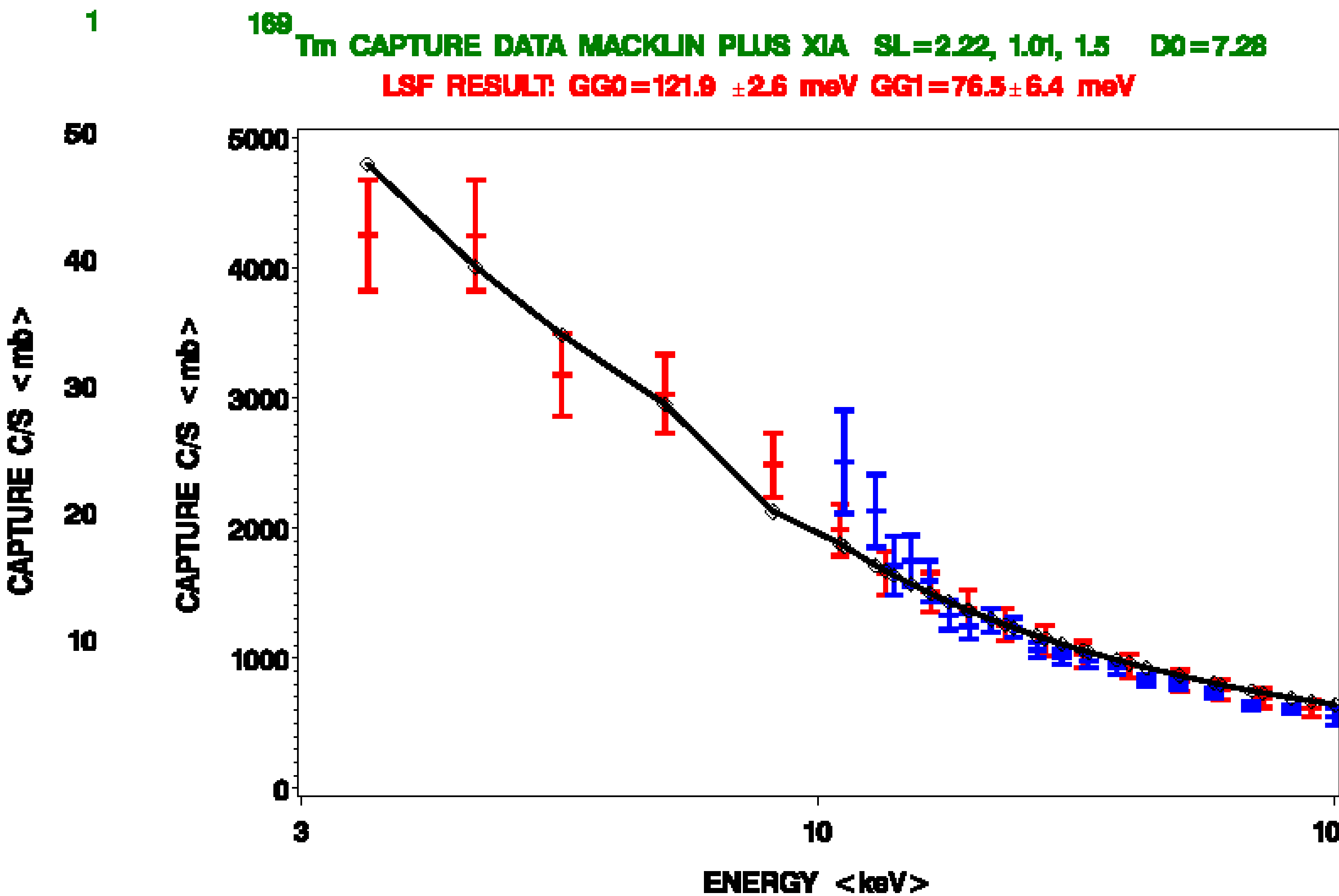
Experimental Measurement at 2.8 keV:

24.7-+2.0 keV

Dilg and Vonach 1971

E (keV)	S_0	Total (b)	Capture (b)
2.8	1.60	19.79	4.93
2.8	2.22	24.58	5.72
2.8	2.89	29.76	6.38

LSF Fit of ^{169}Tm Capture



^{169}Tm Solution

Low Energy <2 keV

Atlas

$S_0 = 1.60 \pm 0.12$

$\Gamma_\gamma = 0.086 \pm 0.007$ eV

.e

Fast Energy > 3keV

Mughabghab(URR)

$S_0 = 2.22 \pm 0.50$

$\Gamma_\gamma = 0.1219 \pm 0.0026$

$\Gamma_\gamma = 0.120$eV Macklin

Possible explanation:

Doorway state 3- 8keV Then

Γ_γ is strongly correlated with S_0

Total C/S in URR region strongly urged for RPI

Conclusion and Summary

- **6 important FP evaluations updated on basis of Dean et al. reactivity results.**
- **6 other evaluations updated, including Gd -157, Cd-113, and Co-58(new).**
- ***Pu-242 , Am243 updated on basis of Plalmioti and Hiruta analysis***
- **Palmiotti et al. ENDF/B-VII.1 testing shed light in the fast region on Pd105, Cs-133, Nd-145 Sm-149 . Results show that future attention in fast region is required.**