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Transmission Data Analysis of Natural Dy Using SAMMY Code from 0 eV to 100 eV

Kun Joong YOO, Young Ae Kim and Jonghwa Chang
Korea Atomic Energy Research Institute
150 Deokjin-dong, Yuseong-gu ,Daejeon, Korea

Abstract

Transmission data measured at the Time-Of-Flight facility in the Pohang Accelerator Laboratory in 2002 was analyzed over the energy range from 0 eV to 100 eV by SAMMY-M2a code. Resonance parameters within the above energy range are evaluated and external parameters below zero and above 100eV are also evaluated. Those values within the energy range from 0 eV to 100 eV are compared with ENDF data (Mughabghab's data). Significant discrepancies at 5.7 eV resonance of Dy-163, 9.7 eV resonance of Dy-161, 12.3 eV resonance of Dy-161 and 25.0 eV resonance of Dy-161 are found in this work.

1. Introduction

The interest of natural dysprosium material has recently increased because it can be used as an absorbing material in a reactor. And the Time-Of-Flight facility was installed at the Pohang Accelerator Laboratory (PAL) and transmission measurements were made using the facility in 2002. In this study the transmission data of natural Dy measured at PAL Time-Of-Flight facility[1] were fitted over the energy range from 0 eV to 100 eV by SAMMY-M2a[2] Code (Code System for Multilevel R-Matrix Fits to Neutron Data Using Bayes' Equations) and the result of SAMMY analysis was plotted using RSAP-Version 3[3].

2. Methodology Used in SAMMY Code

SAMMY code is used for analyses of neutron-induced cross section data in the resolved resonance region. In the resolved region, theoretical cross sections are generated using Reich-Moore approximation to R-matrix theory. In SAMMY code, Bayes' theorem (generalized least squares) is used to find the "best fit" values of parameters and the associated covariance matrix. In applying

Bayes' theorem, the following three basic assumptions are introduced:

(a) the prior joint pdf is a joint normal
(b) the likelihood function is a joint normal
(c) the true value is a linear function of the parameters

The expression of implicit data covariance matrix V used in this calculation is as follows:

$$V^{ij} = v^i \delta_{ij} + \sum_k X_k^i \omega_k X_k^j ,$$

where V is the data covariance, v represents the statistical uncertainties, X is the sensitivity matrix (partial derivative of data with respect to data-reduction parameters) and ω is the covariance matrix for the data-reduction parameters.

Resolution function used in this calculation is the convolution of Gaussian and exponential function and its mathematical expression is as follows:

The broadened cross section $f_{GE}(E)$ is given as

$$f_{GE}(E,E') = \frac{1}{\Delta_E \Delta_G \sqrt{\pi}} \int_{E-\Delta E_S}^{\infty} dE^0 \exp\left\{-\frac{\left(E^0-\left(E-\Delta E_S\right)\right)}{\Delta_E}\right\} \int_{-\infty}^{\infty} dE' \exp\left\{-\frac{\left(E'-E^0\right)^2}{\Delta_G^2}\right\} f(E')$$

$$= \frac{1}{2\Delta_E} \int_{-\infty}^{\infty} dE' f(E') \exp\left\{\left[\frac{\Delta_G}{2\Delta_E}\right]^2 - \left[\frac{E'-E+\Delta E_S}{\Delta_E}\right]\right\} erfc\left\{\frac{\Delta_G}{2\Delta_E} - \frac{E'-E+\Delta E_S}{\Delta_G}\right\}$$

where $f(E')$ represents the unbroadened cross section, the energy shift ΔE_S is introduced in order that the maximum of the broadening function be located at $E' = E$. Also Δ values are defined as follows:

$$\Delta_E = \frac{2E^{3/2}}{L\left(m/2\right)^{1/2}} \Delta t_E = \left(0.02766 \frac{\Delta t_E}{L}\right) E^{3/2}$$

$$\Delta_G^2 = \frac{2}{3} E^2 \left[\left(\frac{\Delta t_c}{t}\right)^2 + \left(\frac{\Delta L}{L}\right)^2\right] + \frac{E^3}{\frac{m}{2}\ln 2}\left(\frac{\Delta t_G}{L}\right)^2$$

$$= \frac{2}{m} E^3 \left[\frac{1}{\ln 2}\left(\frac{\Delta t_G}{L}\right)^2 + \frac{2}{3}\left(\frac{\Delta t_c}{L}\right)^2\right] + \frac{2}{3} E^2 \left(\frac{\Delta L}{L}\right)^2$$

$$\Delta_G = E\left[aE + b\right]^{1/2}$$

$$= E\left[\left\{\left(0.01661\frac{\Delta t_G}{L}\right)^2 + \left(0.011293\frac{\Delta t_c}{L}\right)^2\right\} E + \left(0.81650\frac{\Delta L}{L}\right)^2\right]^{1/2}$$

where m is the neutron mass, Δt_E is the exponential folding width in μsec, ΔL is the broadening in the flight path length L in meters, Δt_c is the finite channel width in μsec and Δt_G is the neutron burst width the full width at half max in μsec.

3. SAMMY Analysis

3.1. Experimental Conditions

Temperature: 298 ^oK

Flight path length: 10.81m ± 0.02 m [full width of square distribution]

Thermalization time constant: 0.25 μs [e-folding width of exponential resolution function]

Burst width: 0.68 μs [FWHM of Gaussian resolution function] which is corresponding to linac pulse duration of 1μs [full width of square distribution function]

Minimum channel width: 0.5 μs [full width of square distribution function]

Sample thickness: 0.001585 atoms/barn which is corresponding to the thickness of 0.5mm

3.2. SAMMY Input

Atomic weight of natural Dy: 162.50 amu

Channel radius: 7.935 Fermi

Spin group information

Dy-160	i = 0.5	I= 0.0	j= 0.5	l= 0	J= 0.5	ABN= 0.0234	Spin Group 1
Dy-161	i = 0.5	I= 2.5	j= 2.0	l= 0	J= 2.0	ABN= 0.1890	Spin Group 2
Dy-161	i = 0.5	I= 2.5	j= 3.0	l= 0	J= 3.0	ABN= 0.1890	Spin Group 3
Dy-162	i = 0.5	I= 0.0	j= 0.5	l= 0	J= 0.5	ABN= 0.2550	Spin Group 4
Dy-162	i = 0.5	I= 0.0	j= 0.5	l= 1	J= -0.5	ABN= 0.2550	Spin Group 5
Dy-162	i = 0.5	I= 0.0	j= 0.5	l= 1	J= -1.5	ABN= 0.2550	Spin Group 6
Dy-163	i = 0.5	I= 2.5	j= 2.0	l= 0	J= 2.0	ABN= 0.2490	Spin Group 7
Dy-163	i = 0.5	I= 2.5	j= 3.0	l= 0	J= 3.0	ABN= 0.2490	Spin Group 8
Dy-164	i = 0.5	I= 0.0	j= 0.5	l= 0	J= 0.5	ABN= 0.2820	Spin Group 9
Dy-164	i = 0.5	I= 0.0	j= 0.5	l= 1	J= -0.5	ABN= 0.2820	Spin Group 10
Dy-164	i = 0.5	I= 0.0	j= 0.5	l= 1	J= -1.5	ABN= 0.2820	Spin Group 11

Initial parameter file is generated based on the resonance data such as resonance energy, gamma widths and neutron widths given in ENDF file(URR/ENDFR.TXT). In this analysis, we used the transmission data measured at the Time-Of-Flight facility of The Pohang Accelerator Laboratory, at the Pohang University of Science and Technology and treated by Dr. V.R. Skoy, Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Moscow, Russia.

In SAMMY, there are two kinds of option for covariance matrix. One is explicit covariance matrix and the other is implicit covariance matrix. In this study, implicit covariance matrix option is used which is recommended in SAMMY.

3.3 Procedure of SAMMY analysis and plotting SAMMY output

SAMMY analysis is carried out according to the following five steps as shown in Fig.1 :

Step 1: Non-Bayes' analysis for adjusting resonance parameters manually

Step 2: Bayes' analysis

Step 3: Bayes' analysis for generating covariance matrix

Step 4: Repetition of Bayes' analysis with covariance matrix

Step 5: Confirmatory Non-Bayes' analysis with covariance matrix

In particular, in step 2, resonance parameters within the region to be analyzed are adjusted first, and then external resonance parameters outside the region to be analyzed are adjusted, and resonance parameters within the region to be analyzed are finally adjusted using external parameters newly obtained.

4. Results and Discussions

Fitting results are given in Figures 2 and 3. Figures 2 and 3 show fitting results of total cross section and transmission data obtained from final non-Bayes' analysis with a covariance matrix, which is performed to confirm fitting results. As shown in the above figures, the transmission data was well fitted and χ^2/N was 1.00.

Finally, the final parameter file obtained from Bayes' analysis with covariance matrix is provided in Table 1 and resonance parameters obtained in this study are compared with Mughabghab's data as shown in Table 2. There are differences about 1 to 5 eV between the energy levels of fitting data and Mughabghab's data above 20 eV. Significant discrepancies at 5.7 eV resonance of Dy-163, 9.7 eV resonance of Dy-161, 12.3 eV resonance of Dy-161 and 25.0 eV resonance of Dy-161, comparing Mughabghab's compilation are found in this work.

In future, the simultaneous analysis of capture cross section and transmission data of natural Dy will be performed in order to get better values of resonance parameters if good capture cross section data is available because SAMMY prediction in this study was made using transmission data only.

Acknowledgement

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References

1) G. N. Kim et al, “Measurement of neutron total cross-section of Dy at Pohang Neutron Facility”, Annals of Nuclear Energy 30 (2003) 1123-1134

2)RSICC Peripheral Shielding Routine Collection SAMMY-M2a: A Code System for Multilevel R-Matrix Fits to Neutron Data Using Bayes' Equations, PSR-158, SAMMY-M2a, ORNL, Sept. 1999

3) R.O. Sayer, RSAP - Royce's Sammy Plotter-Version 3, ORNL, June 3, 1999

4) V.R. Skoy, Neutron-Nucleus Interactions, Measurement of the Total Cross-Sections, Extraction of the Parameters of a Resonance, Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, 141900 Dubna, Moscow Region, Russia Currently at Pohang Accelerator Laboratory, Pohang University of Science and Technology

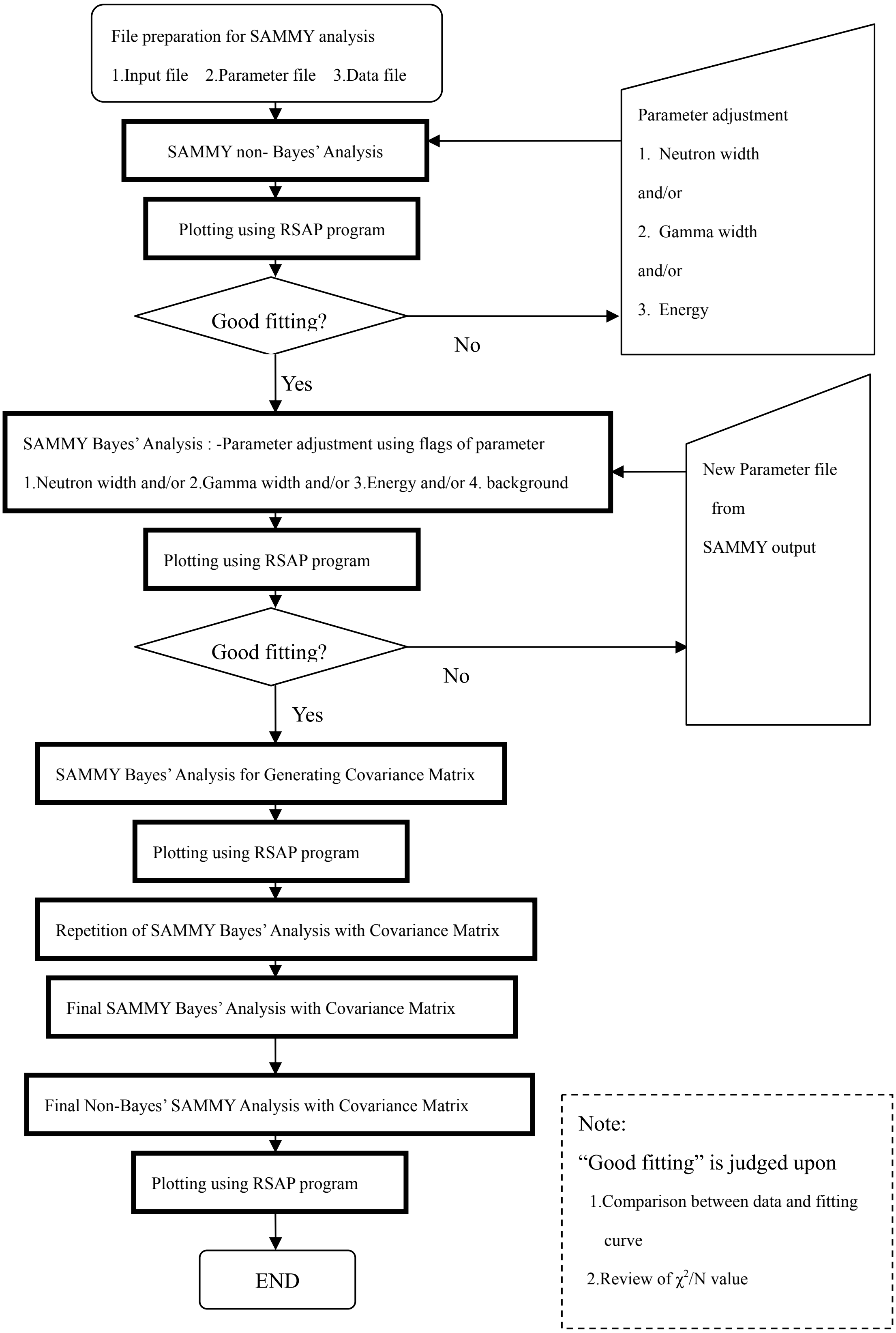

Fig.1 Procedure for the analysis of natural Sm transmission data using SAMMY and RSAP codes

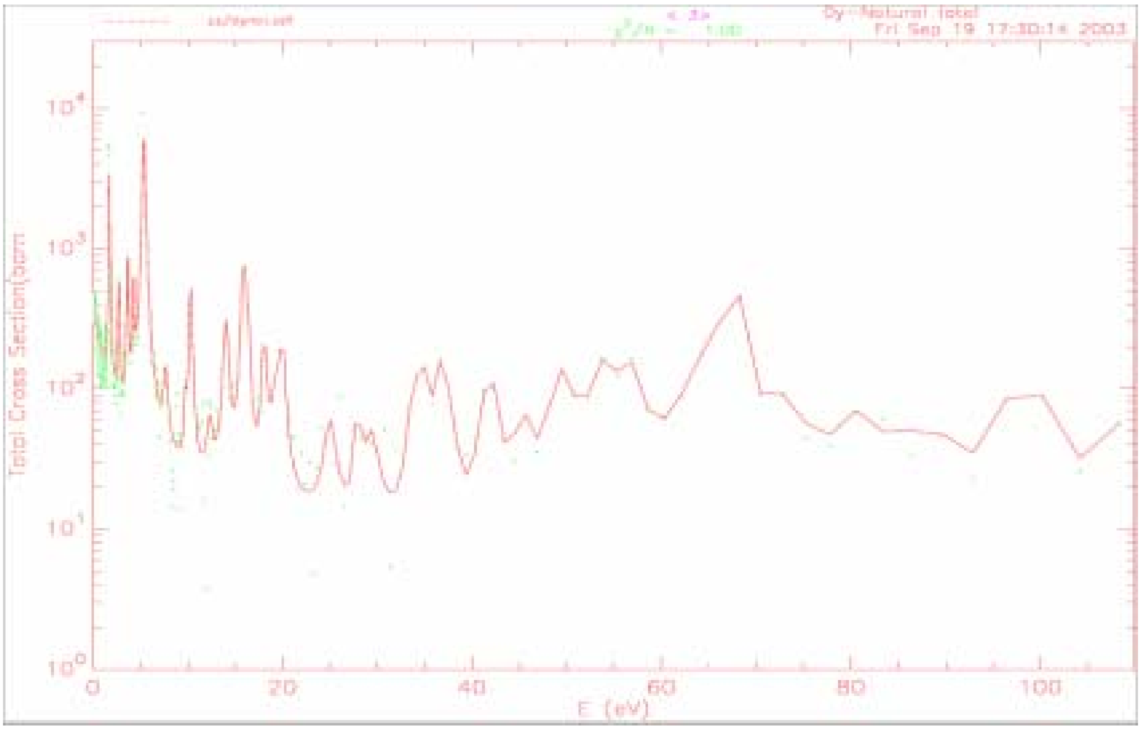

Fig. 2 . Measured data (green dot) and SAMMY prediction (red line) of total cross section of natural Dy obtained from non-Bayes' analysis with covariance matrix (Final)

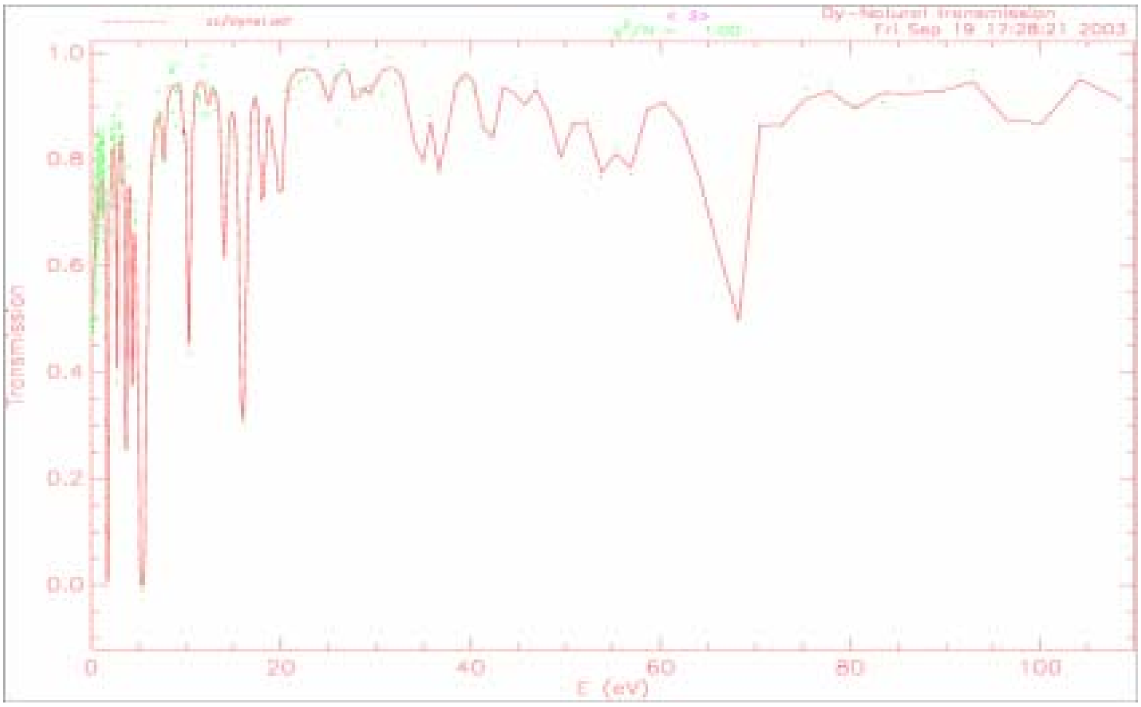

Fig. 3. Measured data (green dot) and SAMMY prediction (red line) of transmission of natural Dy obtained from non-Bayes' analysis with covariance matrix (Final)

Table 1. Parameter File Obtained from Bayes' Analysis with Covariance Matrix

```
-5.8184E+01 1.0632E+02 5.8876E+02          1 1 1    1
-1.8688E+00 1.0066E+02 6.3043E+00          1 1 1    3
-1.9973E+00 2.8065E+01 8.1790E+01          1 1 1    9
-1.6099E+00 1.0803E+02 2.4563E-01          1 1 1    8
1.708625518 8.7133E+01 2.1949E+00          1 1 1    7
1.856087630 1.3998E+02 2.5805E-01          1 1 1    1
2.697956589 1.2117E+02 6.3932E-01          1 1 1    3
3.662040941 1.3476E+02 2.2367E+00          1 1 1    2
4.281294417 1.2554E+02 1.5721E+00          1 1 1    2
5.367169847 2.5641E+02 1.4405E+01          1 1 1    4
5.718587375 9.1070E+01 5.4429E-02          1 1 1    7
7.643471818 4.2996E+02 1.1484E+00          1 1 1    3
9.714563584 1.4136E+02 5.3777E-01          1 1 1    2
10.28820844 2.0429E+02 2.4830E+01          1 1 1    1
10.64949506 8.9382E+01 2.5875E-01          1 1 1    3
12.31277544 5.2481E+02 9.0107E-01          1 1 1    3
14.02715136 4.4720E+02 1.0099E+01          1 1 1    2
15.93027684 3.5429E+02 1.6566E+01          1 1 1    8
16.41888877 7.0964E+01 2.1241E+00          1 1 1    3
18.05126512 2.6851E+02 8.0756E+00          1 1 1    2
19.31149779 7.5641E+02 4.1084E+00          1 1 1    8
19.97571983 1.0282E+02 1.3639E+00          1 1 1    2
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94.90669011 9.2936E+01 6.7104E+01          1 1 1    2
98.35907964 1.0477E+02 1.3304E+02          1 1 1    2
99.15675559 1.0679E+02 6.0112E-01          1 1 1    3
100.9855315 1.0609E+02 3.6832E+01          1 1 1    2
101.0040874 1.2824E+02 7.9272E+00          1 1 1    8
104.0247664 1.0866E+02 1.8919E+00          1 1 1    7
105.8514661 1.0710E+02 2.4857E+01          1 1 1    3
108.6107727 1.0683E+02 6.1331E+01          1 1 1    2
110.4044171 1.0680E+02 3.0078E+00          1 1 1    2
112.1504210 1.0586E+02 2.4935E+02          1 1 1    1
114.2007597 1.2006E+02 2.0849E+01          1 1 1    4
115.4161191 1.0681E+02 1.8875E+01          1 1 1    2
117.3275404 1.0865E+02 3.7779E+01          1 1 1    8
117.5049196 1.0683E+02 4.4625E+01          1 1 1    2
121.6500000 1.0700E+02 6.8400E+01          0 0 0    2
126.5800000 1.0860E+02 1.5257E+01          0 0 0    8
127.4600000 1.0860E+02 1.1229E+01          0 0 0    8
127.5400000 1.0680E+02 2.4857E+00          0 0 0    3
131.1600000 1.0680E+02 6.5143E+00          0 0 0    3
135.3100000 1.0860E+02 4.5429E+00          0 0 0    8


COVARIANCE MATRIX IS IN BINARY FORM
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Table 2. Comparison of Resonance Parameters

Nuclide	J	E(eV)	$g\Gamma_n$ (meV)	Γ_γ (meV)	$g\frac{\Gamma_r\Gamma_n}{(\Gamma_r+\Gamma_n)}$
Dy-160	1/2	-58.1839±0.3359 (-58.19*)	588.76±57.66 (555.3*)	106.32±10.62 (105.8*)	0.0111 0.0113
Dy-164	1/2	-1.9973±0.0320 (-1.88±0.04)	81.790±0.5957 (51.9*)	28.065±1.201 (61.4±3.0)	0.0479 0.0356
Dy-161	3	-1.8688±0.0520 (-1.89*)	3.6773±0.3524 (6.3230*)	100.66±9.776 (106.8*)	0.0983 0.0593
Dy-163	3	-1.6099±0.0539 (-1.613*)	0.1433±0.1429 (0.1487*)	108.03±10.79 (108.6*)	2.3797 2.2935
Dy-163	2	1.7086±0.0001 (1.713±0.004)	0.9146±0.0021 (0.85±0.05)	87.133±0.3289 (102.6±0.08)	0.1946 0.2083
Dy-160	1/2	1.8561±0.0045 (1.88±0.02)	0.2581±0.0164 (0.2±0.1)	139.98±8.602 (105.8*)	3.8816 5.0095
Dy-161	3	2.6980±0.0004 (2.71±0.02)	0.3729±0.0020 (0.3275±0.015)	121.17±1.122 (119.00±10)	0.9172 1.0438
Dy-161	2	3.6620±0.0003 (3.68±0.03)	0.9320±0.0038 (0.89±0.04)	134.76±0.9765 (124.00±15)	0.1894 0.1985
Dy-161	2	4.2813±0.0006 (4.33±0.02)	0.6551±0.0048 (0.575±0.065)	125.54±1.694 (80.00±3)	0.2684 0.3072
Dy-162	1/2	5.3672±0.0003 (5.44±0.02)	14.405±0.0706 (21.10±1.5)	256.41±2.007 (148±15)	0.0733 0.0542
Dy-163	2	5.7186±0.0268 (5.81±0.02)	0.0227±0.0018 (0.0135±0.0025)	91.070±9.739 (108.6*)	0.76539 12.8660
Dy-161	3	7.6435±0.0058 (7.74±0.03)	0.6699±0.0163 (0.30±0.01)	429.96±15.50 (107.00±4)	0.5093 1.1396
Dy-161	2	9.7146±0.0083 (10.26±0.20)	0.2241±0.0111 (0.12±0.02)	141.36±11.05 (106.8*)	0.7778 1.4509
Dy-160	1/2	10.2882±0.0013 (10.45±0.03)	24.8300±0.2294 (16.50±2.0)	204.29±3.715 (100.0±10)	0.0452 0.0706
Dy-161	3	10.6495±0.0215 (10.85±0.03)	0.1509±0.0118 (0.24±0.02)	89.382±9.184 (106.8*)	2.2613 1.4231
Dy-161	3	12.3128±0.0189 (12.65±0.04)	0.5256±0.0272 (0.028±0.007)	524.81±33.71 (106.8*)	0.6484 12.1569
Dy-161	2	14.0272±0.0031 (14.31±0.05)	4.2083±0.0512 (3.1±0.2)	447.20±9.037 (124.00±4)	0.0422 0.0594
Dy-163	3	15.9303±0.0016 (16.23±0.03)	9.6629±0.0678 (10.65±0.4)	354.29±4.489 (105.0±13)	0.0369 0.0375
Dy-161	3	16.4189±0.0047 (16.67±0.06)	1.2390±0.0505 (3.7±0.2)	70.964±7.849 (116.00±5)	0.2828 0.0970
Dy-161	2	18.0513±0.0039 (18.48±0.06)	3.3651±0.0685 (4.25±0.3)	268.51±10.95 (114.00±5)	0.0532 0.0445

Nuclide	J	E(eV)	$g\Gamma_n$ (meV)	Γ_γ (meV)	$g\frac{\Gamma_r\Gamma_n}{(\Gamma_r+\Gamma_n)}$
Dy-163	3	19.3115±0.0186 (19.65±0.03)	2.3964±0.1297 (0.50±0.015)	756.41±42.52 (108.6*)	0.1428 0.6858
Dy-161	2	19.9757±0.0396 (20.24±0.04)	0.5683±0.0538 (0.15±0.02)	102.82±10.37 (106.8*)	0.3096 1.1615
Dy-160	1/2	20.0105±0.0194 (20.47±0.05)	26.6570±1.3140 (31.00±3)	415.02±27.32 (108.0*)	0.0399 0.0415
Dy-161	2	25.0136±0.0304 (25.22±0.04)	2.6932±0.1175 (0.60±0.035)	1010.3±57.76 (102.00±7)	0.0649 0.2935
Dy-161	2	27.8991±0.0192 (29.04±0.04)	1.6866±0.0901 (1.35±0.1)	256.46±22.90 (126.00±8)	0.1046 0.1319
Dy-161	3	29.3479±0.0472 (29.92±0.04)	3.1366±0.1668 (0.46±0.04)	1219.2±80.53 (116.00±8)	0.1090 0.7447
Dy-160	1/2	33.8065±0.0286 (34.90±0.02)	39.211±2.093 (1.18±0.12)	663.18±46.74 (108.0*)	0.0270 0.8567
Dy-161	3	34.6790±0.0568 (35.74±0.04)	1.6065±0.1501 (1.4±0.1)	101.55±10.30 (106.8*)	0.2175 0.2485
Dy-163	2	34.8488±0.0324 (35.79±0.04)	4.9125±0.2605 (4.1±0.3)	625.98±52.01 (108.6*)	0.0360 0.0462
Dy-161	3	37.5908±0.0265 (38.51±0.05)	5.3867±0.2637 (7.15±1.0)	553.96±42.91 (110.00±6)	0.0642 0.0529
Dy-161	3	41.9259±0.0202 (43.27±0.05)	15.9334±0.4252 (6.5±0.5)	1164.4±54.72 (117.00±9)	0.0219 0.0573
Dy-161	2	44.4033±0.0512 (45.14±0.06)	2.4123±0.1651 (6.2±0.45)	145.53±15.00 (108.00±8)	0.0748 0.0319
Dy-161	2	46.0845±0.0250 (48.80±0.1)	5.2129±0.2274 (<0.35)	74.606±7.662 (106.8*)	0.0389 0.5000
Dy-163	3	47.6683±0.0678 (50.27±0.06)	1.6529±0.1539 (1.65±0.2)	109.97±10.94 (108.6*)	0.2111 0.2116
Dy-161	3	48.0339±0.0586 (50.86±0.06)	2.6163±0.2293 (2.425±0.20)	95.014±9.418 (93.00±13)	0.1362 0.1466
Dy-161	2	49.4686±0.0199 (51.80±0.4)	13.6386±0.4538 (10.5±0.5)	329.43±29.28 (113.00±10)	0.0140 0.0202
Dy-161	3	50.8405±0.0594 (52.24±0.08)	7.8238±0.4557 (0.8±0.1)	661.66±58.89 (106.8*)	0.0444 0.4308
Dy-161	2	52.0535±0.0375 (55.19±0.06)	6.3826±0.3590 (4.65±0.25)	110.51±11.03 (111.00±12)	0.0310 0.0411
Dy-163	3	53.6902±0.0135 (55.85±0.08)	14.5125±0.3590 (14±1)	143.69±13.05 (120.0±12)	0.0275 0.0292
Dy-163	2	55.9505±0.0234 (58.97±0.08)	20.2341±0.6509 (41±2)	796.62±47.24 (111.0±15)	0.0091 0.0080
Dy-161	2	56.9783±0.0433 (59.57±0.06)	9.3912±0.5850 (2.75±0.3)	102.53±10.38 (106.8*)	0.0226 0.0670

Nuclide	J	E(eV)	$g\Gamma_n$ (meV)	Γ_γ (meV)	$g\frac{\Gamma_r\Gamma_n}{(\Gamma_r+\Gamma_n)}$
Dy-161	2	59.0522±0.0551 (61.41±0.06)	10.7880±0.5567 (3.8±0.25)	700.44±62.94 (141.00±20)	0.0167 0.0486
Dy-161	3	60.6813±0.0745 (63.64±0.06)	4.5596±0.3436 (2.6±0.2)	104.47±10.46 (105.00±20)	0.0802 0.1364
Dy-163	3	62.6847±0.0314 (66.11±0.10)	10.7753±0.4491 (4.2±0.4)	104.23±10.62 (108.6*)	0.0372 0.0864
Dy-161	2	64.6320±0.0249 (67.55±0.07)	32.6693±1.1134 (0.05±0.05)	489.48±46.02 (106.8*)	0.0062 3.4767
Dy-162	1/2	66.7180±0.0339 (71.10±0.2)	44.7650±2.147 (400.00±15)	789.86±57.43 (125.00±15)	0.0236 0.0105
Dy-163	2	68.1048±0.0209 (72.00±0.11)	89.8822±3.0257 (1.75±0.15)	110.72±10.71 (108.6*)	0.0057 0.1031
Dy-160	1/2	69.6933±0.4432 (73.14±0.07)	12.7860±1.250 (6.50±0.599)	105.74±10.58 (108.0*)	0.0877 0.1631
Dy-161	2	69.8194±0.1492 (73.17±0.08)	6.2684±0.4925 (2.0±0.1)	106.37±10.66 (106.8*)	0.0316 0.0907
Dy-163	2	71.7475±0.0687 (75.48±0.10)	9.0999±0.4967 (1.15±0.05)	104.64±10.64 (108.6*)	0.0231 0.1548
Dy-161	3	73.6635±0.0554 (77.07±0.08)	15.6062±0.7367 (2.37±0.25)	100.05±10.35 (106.8*)	0.0276 0.1490
Dy-161	3	74.8847±0.5014 (78.09±0.09)	0.2484±0.0252 (0.29±0.045)	107.00±10.69 (106.8*)	1.3752 1.1787
Dy-163	2	76.3307±0.0753 (78.99±0.13)	8.4832±0.5330 (7.25±0.4)	104.37±10.64 (108.6*)	0.0245 0.0278
Dy-161	2	78.3026±0.3366 (82.27±0.09)	2.0704±.0.2092 (1.275±0.10)	107.72±10.77 (106.8*)	0.0877 0.1401
Dy-161	3	78.8868±0.1620 (85.07±0.09)	4.9446±0.4714 (3.0±0.2)	107.15±10.71 (106.8*)	0.0743 0.1189
Dy-160	1/2	81.7830±0.0437 (85.60±0.1)	243.23±8.4220 (91.00±7)	109.59±11.02 (112.0±15)	0.0132 0.0199
Dy-163	3	82.3079±0.5524 (86.30±0.14)	0.6046±0.0603 (0.6±0.15)	108.65±10.86 (108.6*)	0.5681 0.5724
Dy-161	3	83.9331±0.5582 (88.77±0.10)	0.6007±0.0590 (7±0.1)	106.44±10.66 (106±20)	0.5719 0.0541
Dy-161	2	87.7642±0.1256 (91.12±0.10)	19.5449±1.2914 (0.6±0.15)	105.44±10.59 (106.8*)	0.0128 0.2933
Dy-161	3	88.0807±0.5081 (93.29±0.11)	4.8376±0.4711 (11.5±1)	109.35±10.96 (110.00±15)	0.0757 0.0349
Dy-163	3	88.1123±0.4743 (94.08±0.08)	3.5402±0.3454 (10±1)	108.11±10.83 (108.6*)	0.1015 0.0394
Dy-161	3	90.7470±0.3306 (95.23±0.11)	4.2475±0.4090 (1.65±0.1)	106.55±10.67 (106.8*)	0.0856 0.2117

Nuclide	J	E(eV)	$g\Gamma_n$ (meV)	Γ_γ (meV)	$g\frac{\Gamma_r\Gamma_n}{(\Gamma_r+\Gamma_n)}$
Dy-161	2	94.9067±0.0738 (101.35±0.11)	27.9622±1.3122 (7.25±0.9)	92.936±9.425 (96.00±20)	0.0107 0.0283
Dy-161	2	98.3591±0.0490 (102.42±0.11)	55.4378±2.0160 (0.3±0.05)	104.77±10.56 (106.8*)	0.0071 0.5827
Dy-161	3	99.1568±0.7111 (104.12±0.11)	0.3506±0.0351 (0.35±0.15)	106.79±10.68 (106.8*)	0.9759 0.9776

Note that values within the parenthesis is Mughabghab's Data and * is ENDF Data.