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GAMUT

A Computer Code for γ-ray Energy and Intensity Analysis

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A. INTRODUCTION

GAMUT is a computer code to analyze γ-ray energies and intensities. It does a linear least-squares fit of measured γ-ray energies from one or more experiments to the level scheme. GAMUT also performs a non-linear least-squares analysis of branching intensities. For both energy and intensity data, a statistical Chi-square analysis is performed with an iterative uncertainty adjustment. The uncertainties of outlying measured values and sets of measurements with $\chi^2/f>1$ are increased, and the calculation is repeated until the uncertainties are consistent with the fitted values. GAMUT accepts input from standard or special-format ENSDF data sets. The special-format ENSDF data sets were designed to permit analysis of more than one set of measurements associated with a single ENSDF data set. GAMUT prepares a standard ENSDF format output data set containing the adjusted values. If more than one input ENSDF data set is provided, GAMUT creates an ADOPTED LEVELS, GAMMAS data set containing the adjusted level and γ-ray energies and branching intensities from each level normalized to 100 for the strongest γ ray. GAMUT also provides a summary of the results and an extensive log of the iterative analysis. GAMUT is interactive prompting the user for input and output file names and for default calculation options. This version of GAMUT has adjustable dimensions so that any maximum number of data sets, levels, and γ rays can be established at the time of implementation.

B. METHODS OF ANALYSIS

1. Energies

The least-squares fitting of γ-rays to the level scheme, a well known method for deriving *best* level energies, has been described by Helmer, *et al.*[1]. This method had been adopted by W.B. Ewbank for the computer code GTOL[2], which accepts ENSDF format data[3] as input. For GAMUT, the method has been extended to allow the simultaneous fit of several sets of data. In addition, an option has been added to allow the zero energy to vary.

The transition energies are related to the level energies by the equation

$$E_{ji}=\sum_{k=1}^{m} g_{ki}\xi_k-\Delta_j . \tag{1}$$

Here, E_{ji} refers to the i-th transition measured in the j-th experiment. The transition energies are in the center of mass reference frame and are related to laboratory energies by

$$E_{ji}(c.m.)=E_{ji}(lab)+E_R , \tag{2}$$

where the recoil energy (E_R) is

$$E_R=\frac{E_\gamma^2}{2M_R c^2} \tag{3}$$

and $M_R \approx A$ is the mass (in *amu*) of the recoiling daughter nucleus.

ξ_k in equation (1) is the energy of the k-th level, m is the number of levels, and g_{ki} indicates the placement of the γ ray in the level scheme where

$$g_{ki}=\begin{cases} 1 & \text{if the } i\text{–th transition deexcites the } k\text{–th level} \\ 0 & \text{if the } i\text{–th transition neither populates nor deexcites the } k\text{–th level} \\ -1 & \text{if the } i\text{–th transition populates the } k\text{–th level} \end{cases} \tag{4}$$

The term Δ_j in equation (1) allows the zero energy in each set of γ rays from the j-th experiment to vary independently. This *shift* is a systematic uncertainty in the energy calibration which is observed in some experiments. Equation (1) represents a linear regression in which maximum likelihood estimates of the level energies (ξ_k) and *shifts* (Δ_j) can be obtained in closed form, as follows.

Equation (1) can be written in matrix notation as

$$\vec{E}=G\xi. \tag{5}$$

The components of $\vec{E}$ and ξ are $E_1=E_{11}, E_2=E_{12},\ldots, E_r=E_{ji},\ldots, E_t=E_{pn}$, and $\xi_1, \xi_2, \ldots, \xi_m, \Delta_1, \Delta_2, \ldots, \Delta_p$, respectively, where t is the total number of γ rays measured in p experiments, and n is the number of γ rays from each individual experiment. Weighing the data by the inverse square of the experimental uncertainties, the solution to equation

(5) is

$$\xi=(G^T W G)^{-1} G^T W \vec{E}, \tag{6}$$

where G^T is the transpose of the placement matrix G, and W is the diagonal weight matrix

$$W_{rr}=\frac{1}{(\Delta E_{rr})^2 \sigma^2}. \tag{7}$$

In equation (7),

$$\sigma^2=\frac{1}{n-m}(\vec{E}^T W \vec{E} - \vec{E}^T W G \hat{\xi}) \tag{8}$$

for n transitions deexciting m levels.

The variances in the fitted level energies and *shifts* are

$$\Delta\xi_k=(U_{kk})^{1/2} \quad k=1,2,...m+p \ , \tag{9}$$

where the U_{kk}'s are the diagonal elements of the variance matrix

$$U=\sigma^2(G^T W G)^{-1}. \tag{10}$$

The adopted γ-ray energies are given by

$$\hat{E}_i=\sum_{k=1}^{m} g_{ki}\xi_k, \tag{11}$$

and their corresponding variances from the fit become

$$\Delta E_i=(V_{uu}+V_{ll}-2V_{ul})^{1/2}\sigma \ , \tag{12}$$

with the subscripts u and l referring to the upper and lower levels, respectively. V is the covariance matrix

$$V=(G^T W G)^{-1} . \tag{13}$$

GAMUT also provides a weighted-average analysis for the adopted γ-ray energies. In this analysis,

$$\hat{E}_i=\sum_{k=1}^{l} \frac{E_{ik}}{(\Delta E_{ik})^2} \tag{14}$$

and

$$\Delta\hat{E}_i=\frac{1}{\sum_{k=1}^{l}(\Delta E_{ik})^{-2}}, \tag{15}$$

where l is the number of measurements of the i-th γ ray. This method considers only the experimental uncertainties, and does not make use of the constraints from the decay scheme.

2. Intensities

The following statistical procedures provide a method for analyzing γ-ray intensities so that one consistent set of branching ratios is adopted for each nuclear level. γ-ray intensities depopulating a level are typically measured on unrelated scales, which are independent of the various parent isotopes or nuclear reactions populating the level. Following the procedures of Tepel[4] and Lederer[5], the scales are assumed to be linearly related by factors α_j, such that the expression

$$Q=\sum_i\sum_j\frac{(I_{ij}\alpha_j-\bar{I}_i)^2}{(\alpha_j\Delta I_{ij})^2} \tag{16}$$

is minimized. Here I_{ij} is the intensity of the i-th γ ray in the j-th measurement, ΔI_{ij} is the uncertainty in I_{ij}, $\bar{I}_i$ is the adopted branching ratio for the i-th γ ray, and the summations are over all γ rays. Equation (16) can be rewritten as

$$Q=\sum_i\sum_j\omega_{ij}(I_{ij}-\beta_j\bar{I}_i)^2, \tag{17}$$

where $\omega_{ij}=\Delta I_{ij}^{-2}$, $\beta_j=\alpha_j^{-1}$, and $\beta_1=1$. Equation (17) can be minimized, following the method of Tepel[4] by iteratively solving the following system of equations:

$$\bar{I}_i=\frac{\sum_j\omega_{ij}I_{ij}\beta_j}{\sum_j\omega_{ij}\beta_j^2} \tag{18}$$

$$\beta_j=\frac{1}{\alpha_j}=\frac{\sum_j\omega_{ij}I_{ij}\bar{I}_i}{\sum_j\omega_{ij}\bar{I}_i^2} \tag{19}$$

Initially $\beta_j=1$ is assumed for all values of j. $\bar{I}_i$'s are then calculated from equation (18) and substituted into equation (19) to recalculate β_j. This process is iterated until β_j converges to within 0.1%. The intensities are then converted to the original scale

$$\bar{I}_{ij}=\bar{I}_i\beta_j \tag{20}$$

where $\bar{I}_{ij}$ is the adopted intensity for the i-th γ ray in the j-th measurement. The uncertainty in $\bar{I}_i$ is calculated from the final parameters and the covariance matrix C, as shown in the equation

$$\overline{\Delta I}_i=(\beta_j^2C_{ii}+\bar{I}_i^2C_{jj}+2\beta_j\bar{I}_iC_{ij})^{1/2}. \tag{21}$$

This procedure is equally valid for the analysis of γ-ray intensities, whether for different measurements with the same parent isotope or nuclear reaction, or for the decay of a single level, which has been populated by various parent isotopes or nuclear reactions.

3. Chi-square analysis

The adopted energies and intensities are tested by a Chi-square analysis. The deviations of the input (experimental) values from the adopted (fitted) values are assumed to have a Chi-square distribution in which the χ_{ji}^2 for the i-th transition in the j-th experiment is

$$\chi_{ji}=\frac{(X_{ji}-X_i)^2}{\Delta X_{ji}^2}. \tag{22}$$

Here X_{ji} are the measured γ-ray energies or intensities, and X_i are the fitted values.

The analysis involves the removing of extreme outlying data (those with χ_{ji}^2 values with less than 0.5% likelihood). For these extreme outliers, the input uncertainty (ΔX_{ji}) is increased so that χ_{ji}^2=1, and the calculation is then repeated. Normally, a single iteration to correct extreme outliers is sufficient, but if ΔX_{ji} becomes greater than X_{ji}, the value is rejected. Once the unacceptable outliers have been removed, all of the γ rays from the parent isotope (data set) with χ_j^2/f >1.0 are adjusted. Here

$$\frac{\chi_j^2}{f}=\frac{1}{n-1}\sum_{i=1}^{n}\frac{(X_{ji}-X_i)^2}{\Delta X_{ji}^2}, \tag{23}$$

with n the number of measurements. The uncertainties of all input values for these data sets are increased so that χ_j^2=1, and then the calculation is reiterated. If χ_j^2 remains greater than 1, further increases in uncertainties and iterations are performed until either $\chi_j^2 \leq 1$ or ten iterations have been completed. Data with unacceptable outliers or slow convergence in the Chi-square analysis should be individually reviewed and adjusted.

C. USING GAMUT

1. General Usage

The program GAMUT can follow many paths depending on the needs of the user. A diagram outlining the program flow is given in figure 1. Initially, the user is requested to enter up to 10 input file names. Each file should contain a single ENSDF data set. If more than one file name is entered, GAMUT will create an ADOPTED LEVELS, GAMMAS data set. If only one ENSDF file (or a special-format ENSDF file) is provided, GAMUT will create a standard ENSDF data set with the same DSID and new level and/or γ-ray energies or intensities. GAMUT requests the output file name. The user may specify "none", in which case only the summary output files will be generated.

After the file names are entered, GAMUT asks if the user wants a constant energy shift (see theory discussion). If more than one input file was specified, the user is asked if the intermediate special-format ENSDF file should be saved. This file can be edited and resubmitted to GAMUT for the calculation of ADOPTED LEVELS, GAMMAS. The user can stop the calculation after creation of the intermediate file.

If a single ENSDF data set or special-format ENSDF data set is provided by the user, GAMUT asks if the default parameters should be modified. These parameters include default γ-ray energy and intensity uncertainties, minimum intensity uncertainty, and the default uncertainties for approximate or calculated values. The default parameters can also be specified within the special-format ENSDF data set. If the input file is a standard ENSDF format data set, GAMUT then begins the calculation. When the calculation is completed, the user is asked if the intensities should be renormalized. If the answer is "yes", the user is then asked to specify the normalizing transition and its intensity. GAMUT then renormalizes all other gamma intensities to the same relative scale. The user is next asked if, in addition to the fitted level energies, the γ-ray energies and/or intensities should be replaced in the output file.

Whenever the user has provided a special-format ENSDF data set, GAMUT asks if the γ-ray energy calculation should be constrained by the level scheme. If the answer is "no", GAMUT then calculates the weighted average and performs the Chi-square statistical analysis discussed in Section B.3. Level energies are derived from the least-squares fit of the γ-rays to the level scheme, as described above. The renormalization and output options are also available for the special-format data.

In addition to an output ENSDF data set, GAMUT provides two summary listings. The file GAM.OUT summarizes the final level energies and γ-ray energies and intensities. A longer output file, STAT.OUT, prints the result of each iteration of the Chi-square analysis and flags the outlying transitions. STAT.OUT may be very long and should only be printed with discretion.

2. Special-format ENSDF

The special-format ENSDF file allows the user to enter several data sets for a given experiment. Immediately following the DSID record, ID records containing the following information should be provided (default values in parentheses).

Column	Contents
1-5	NUCID (identical to DSID record)
6-8	blank
9	identifying character, e.g., A-Z
10-15	reference name
21-30	default intensity uncertainty for AP (50%)
31-40	default intensity uncertainty for blank (20%)
41-50	default energy uncertainty (1 keV)
51-60	minimum intensity uncertainty (0.01%)
61-70	default energy uncertainty for CA, SY (2.5 keV)

γ-rays corresponding to the various data sets are then entered on modified G records, where column 9 is used to indicate the identifying character (column 9 on the ID record) corresponding to that set. Modified G records should appear after the appropriate level record, and in groups of common transitions. If the intensity is left blank, it will not be considered in the calculation. If it is not appropriate to include an energy value in the calculation, it should be given with a large uncertainty.

3. Helpful hints

a. γ-ray final level matching

GAMUT determines the final level populated by a γ-ray from energy sums and differences. When level separations are small relative to the uncertainties of γ-rays feeding those levels, the final level may be incorrectly determined. This results in an incorrect analysis. In order to circumvent this problem, the final level can be specified on the GAMMA record. The sequence number of the desired final level can be determined by counting the levels from the ground state up the desired final level, and entering that level number in columns 78-79 of the GAMMA record. For example, if the final level is the first excited state (second level), enter 2 (right justified) in columns 78-79. This feature applies to both regular and special-format ENSDF data sets. If a final level (FL=) record follows the gamma record, it will over-ride the previous assignment.

b. Level matching for ADOPTED LEVELS, GAMMAS

When multiple data sets are combined to determine an ADOPTED LEVELS, GAMMAS data set, the levels are matched on the basis of energy. This match is unreliable when different level energies are consistent, within uncertainty, with a level observed in a particular data set. Commonly, this problem leads to either the adopting of extra levels, or the combining of several levels into a single state. The solution to this problem is to save the intermediate file, created by GAMUT, and edit that file to correct the level-matching errors. This intermediate file is a the special-format ENSDF file, and can be modified to assure the correct final levels, as described in Section C.3.a. If the intermediate file DSID is ADOPTED LEVELS, GAMMAS, then a data set of that type will be created.

c. Levels without interconnecting γ-rays

These levels are ignored by GAMUT and are not included in the output file.

d. Chi-square adjustment

It is necessary for the user to monitor the iterative Chi-square error adjustment. The results of each iteration are recorded on the file STAT.OUT. Fitted energies that lie more than one standard deviation outside their error bar are indicated by (N E_γ N) where N=1-9 indicates the number of standard deviations. For intensities, the number of standard deviations is noted by *N*. If N=9, then ≥9 standard deviations must be assumed. Large deviations may be indicative of incorrect final levels and misplaced transitions. The user should carefully check all values where N is large.

e. Intensity limits

GAMUT reinterprets intensities of the form I_γ as $\frac{I_\gamma}{2} \pm \frac{I_\gamma}{2}$ Lower limits are assumed to have an uncertainty of 300%. These values may then be averaged with other, better determined values. The user should modify the input files if these assumptions are inappropriate.

f. Creating an ADOPTED LEVELS, GAMMAS data set from a single data set

Normally, GAMUT analysis of a single data set produces an ENSDF data set with the γ-ray intensities on a relative scale. To obtain an ADOPTED LEVELS, GAMMAS data set, with γ-ray intensities normalized to 100 for the strongest transition from each level, the user can run GAMUT along with a second "dummy" data set, containing only a DSID record.

g. Using the shift

The energy shift Δ_j should be used when the energies are suspected of deviating by a constant value. This may happen, for example, in (n,γ) data sets, when the primary and secondary transitions are given separately.

h. Data set order

When more than one data set is entered, the most complex data sets should be entered first. Data sets without γ rays do not need to be entered.

i. Matrix inversion errors

A failure of the matrix inversion for the level energy calculation may indicate incorrect final-level matching or insufficient degrees of freedom for the fit. In the former case, correcting the level matching should solve the problem. For the latter case, if the shift had been invoked, GAMUT retries the calculation without the shift. If the problem is caused by more than one fixed energy, e.g., the ground state with unconnected isomer, the user should temporarily supply a transition connecting the isomer to the ground state, thus establishing its position in the level scheme.

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REFERENCES

[1]R.G. Helmer, R.C. Greenwood, and R.J. Gehrke, *Nucl. Instrum. & Methods* **155**, 189 (1978).

[2]*GTOL, a Computer Code for Least-squares Analysis of γ-ray and Level Energies*, W.B. Ewbank, unpublished; maintained by the National Nuclear Data Center, Brookhaven National Laboratory.

[3]*Evaluated Nuclear Structure Data File* (ENSDF), a computer file of evaluated nuclear structure and radioactivity decay data. The file is maintained by the National Nuclear Data Center (NNDC), Brookhaven National Laboratory, on behalf of The International Network for Nuclear Structure Data Evaluation.

[4]J.W. Tepel, *International Atomic Energy Agency, Vienna,* Report **INDC(NDS)-115/NE**, 121 (1980); private communication (1982).

[5]C.M. Lederer, private communication (1982).

[6]*Table of Radioactive Isotopes*, E. Browne and R.B. Firestone; V.S. Shirley, editor; John Wiley and Sons, Inc., New York (1986).

APPENDIX A. GAMUT with a special-format ENSDF data set

In this example, a special-format ENSDF data set was used to analyze the data from four experiments on ^{183}Re decay. The experiments are coded by A, B, D, and E in column 9 of special ID records immediately following the DSID record, and on special GAMMA records. Each experiment is identified by its NSR reference on the special ID record. This record can also include changes to the default parameters (default values were used here). This calculation was performed without a *shift*. Experiments B and C were used for energy and intensity analysis, while experiments A and D were used only for intensity analysis (approximate energies were entered as transition identifiers).

The output following the data shows a partial listing from STAT.OUT. This listing begins with the input file, annotated to indicate default assumptions. It is followed by the first and last iterations of the energy analysis, where the fitted level energies are given with their sequence numbers. In this example, the average energies were not constrained to the level scheme and are the simple weighted averages. When input values for a specific transition are identical, *CHECK* is written to alert the user that the transition might be averaged with itself. Several input transitions were flagged with *(N* indicating that they differ from the weighted average by *N* standard deviations. At the end of the iteration, there is a statistical summary indicating the χ^2/f for each experiment and for all transitions. Here the fit was excellent for each data set, however some flagged transitions disagreed with a probability of <0.5% (χ^2=1.411). These discrepancies were removed by increasing the uncertainties to make χ^2=1, and then performing additional iterations of the calculation. In the final iteration of the energy analysis, some of the input uncertainties are seen to have been increased.

Following the energy analysis, an intensity analysis was performed. A table of the input transition intensities, their fitted intensities on the scale of each experiment, and the best fitted intensities from all experiments (normalized to 100 for the most intense transition) is given. Discrepant transitions are flagged by **N**, where *N* again refers to the number of standard deviations. The statistical analysis is summarized at the end of the table. None of the data sets have acceptable χ^2/f values. GAMUT adjusts the uncertainties both for the outliers, as in the energy example, and for all input values belonging to discrepant data sets. The result from the last iteration, with the increased input uncertainties, is shown for comparison.

The output file, GAM.OUT, summarizing the results of this calculation, and a listing of the output ENSDF data set follow the STAT.OUT listing. Note that the key numbers from the input special-format data set are included on the DSID record.

DATA FOR A = 183 AND Z = 74(W) 183RE EC DECAY CONSTANT IS OFF

	DATASET	DAP	DBLANK	DGAMMA	DMIN	DSYS
183W	A74HEYN					
183W	B77BR22					
183W	D74TA02					
183W	E72BR55					
183W	L 0					
183W	L 46.5					
183W	GA46	34.24	24			
183W	GB46.484	12516	17			
183W	GD46.4837	261	18			
183W	GE46.5	192	13			
183W	L 99					
183W	GA53	9.71	69			
183W	GB52.596	1699	21			
183W	GD52.593	74	5			
183W	GE52.6	63	6			
183W	GA99	11.49	55			
183W	GB99.080	2850	17			
183W	GD99.079	88	5			
183W	GE99.079	89	5			
183W	L 207					
183W	GA108	9.5	12			
183W	GB107.933	2687	14			
183W	GD107.931	72	9			
183W	GE107.9	69	4			
183W	GA161	2.87	29			
183W	GB160.532	4186	4			
183W	GD160.53	222	3			
183W	L 208.8					
183W	GA110	12.1	11			
183W	GB109.731	2915	20			
183W	GD109.722	1092	9			
183W	GE109.7	91	5			
183W	GA162	100	6			
183W	GB162.330	57373	37			
183W	GD162.317	10763	53			
183W	GE162.3	755	40			
183W	GA209	12.64	57			
183W	GB208.812	2939	4			
183W	GD208.796	1096	4			
183W	GE208.8	93	7			
183W	L 291.7					
183W	GA83	1.36	6			
183W	GB82.919	280	1			
183W	GD82.918	10.4	4			
183W	GE82.9	9.3	6			
183W	GA85	4.27	23			
183W	GB84.712	2275	6			
183W	GD84.711	32.6	18			
183W	GE84.7	32	2			
183W	GA193	1.14	6			
183W	GB192.646	781	2			
183W	GD192.643	8.8	4			
183W	GE192.6	8.6	5			
183W	GA245	1.03	11			
183W	GB245.243	681	12			
183W	GD245.18	38	1			
183W	GA292	13.10	69			
183W	GD291.718	100				
183W	GE291.7	100				
183W	L 309					

```
183W   GA102          0.069    3
183W   GB101.933    375.5      5
183W   GD101.934      0.5      3
183W   GA210          1.00    10
183W   GB209.89     783        2
183W   GD209.88     38         1
183W   GE209.9       7        AP
                    ******************** INTENSITY =     7.00000+-   3.50000WAS ASSUMED
183W   L 309.4
183W   GB102.481    AP0.5     LT
                    ******************** INTENSITY =     0.25000+-   0.25000WAS ASSUMED
                    ******************** ENERGY ERROR =    2.50000 KEV WAS ASSUMED
183W   GD102.49       0.1     LT
                    ******************** INTENSITY =     0.05000+-   0.05000WAS ASSUMED
183W   GB210.3        2       LT
                    ******************** INTENSITY =     1.00000+-   1.00000WAS ASSUMED
183W   GD210.3        0.1     LT
                    ******************** INTENSITY =     0.05000+-   0.05000WAS ASSUMED
183W   L 412.1
183W   GA103          0.034   11
183W   GB103.1       11.2      5
183W   GD103.147      0.3      1
183W   GB120.372    900.98    17
183W   GD120.36       0.5     LT
                    ******************** INTENSITY =     0.25000+-   0.25000WAS ASSUMED
183W   GE120.4        0.5     AP
                    ******************** INTENSITY =     0.50000+-   0.25000WAS ASSUMED
183W   GA203          0.150   23
183W   GB203.269    1214.4     8
183W   GD203.32      21.1      2
183W   GA205          0.420   25
183W   GB205.081    935        1
183W   GD205.08      13.2      2
183W   GE205.1        5        1
183W   GA313          1.75    12
183W   GB313.021    5131       3
183W   GD313         13.3      9
183W   GE313         14        1
183W   GA366          0.340   25
183W   GB365.614    921.3      9
183W   GD365.64       2.6      2
183W   GE365.6        2.9      5
183W   L 453.1
183W   GB40.976      18        2
183W   GD40.9758
183W   GA144          0.59     3
183W   GB144.135    436.6      7
183W   GD144.125      4.5      3
183W   GE144.1        4        1
183W   GA161          2.9      3
183W   GB161.342    14114      5
183W   GD161.33     222        3
183W   GE161.4       10       AP
                    ******************** INTENSITY =    10.00000+-   5.00000WAS ASSUMED
183W   GA244          1.70     7
183W   GB244.266    3130       3
183W   GD244.28     113        2
183W   GE244.3       13.8     15
183W   GA246          5.50    45
183W   GB246.062    2417      12
183W   GD246.07     142        4
183W   GA354          2.30    14
183W   GB353.998    5169       3
183W   GD353.993     18        1
183W   GE354         17        1
183W   GA407          0.10     5
183W   GB406.593    157.9      5
183W   GD406.61       0.8      4
183W   GE406.6        1.5      2
```

LEAST-SQUARES LINEAR REGRESSION OF LEVEL AND GAMMA ENERGIES

LEVEL ENERGIES

1. 0.0
2. 46.4842 9
3. 99.0803 10
4. 207.0150 16
5. 208.8106 13
6. 291.7282 18
7. 308.943 4
8. 309.4 6
9. 412.101 2
10. 453.0772 18

GAMMA ENERGIES

NOT CONSTRAINED TO LEVELS

183RE EC DECAY 74HEYN		-183RE EC DECAY 77BR22		-183RE EC DECAY 74TA02		-183RE EC DECAY 72BR55	-	ENERGY	DE	L1	L2	
0.		40.976 1		41.0 10		0.	-	40.97600	0.00100	10	9	
46 1		46.484 1		46.5 10		46.5 10	-	46.48400	0.00100	2	1	
53 1		52.596 1		52.6 10		52.6 10	-	52.59600	0.00100	3	2	
83 1		82.919 2		82.9 10		82.9 10	-	82.91900	0.00200	6	5	
85 1		84.712 2		84.7 10		84.7 10	-	84.71200	0.00200	6	4	
99 1		99.080 2		99.1 10		99.1 10	-	99.08000	0.00200	3	1	CHECK
102 1		101.93 4		101.9 10		0.	-	101.93309	0.03695	7	4	
0.		102.5 25		102.5 10		0.	-	102.48876	0.92848	8	4	
103 1		103.1 1		103.1 10		0.	-	103.09948	0.09901	9	7	
108 1		107.933 2		107.9 10		107.9 10	-	107.93300	0.00200	4	3	
110 1		109.731 2		109.722 10		109.7 10	-	109.73065	0.00196	5	3	
0.		120.37 9		120.4 10		120.4 10	-	120.37213	0.08928	9	6	
144 1		144.135 4		144.1 10		144.1 10	-	144.13500	0.00400	10	7	
161 1		160.532 4		160.53 2		0.	-	160.53193	0.00392	4	2	
161 1		161.342 14		161.33 2		161.4 10	-	161.33802	0.01147	10	6	
162 1		162.330 5	(1	162.317 10	1)	162.3 10	-	162.32739	0.00447	5	2	
193 1		192.646 7		192.6 10		192.6 10	-	192.64601	0.00700	6	3	
203 1	(1	203.269 12	(1	203.32 2	1)	0.	-	203.28247	0.01029	9	5	
205 1		205.081 9		205.08 1		205.1 10	-	205.08055	0.00669	9	4	
209 1		208.812 2	(1	208.796 10	1)	208.8 10	-	208.81139	0.00196	5	1	
210 1		209.89 7		209.88 3		209.9 10	-	209.88166	0.02755	7	3	
0.		210.3 10		210.3 10		0.	-	210.30000	0.70711	8	3	CHECK
244 1		244.266 3	(1	244.28 1	1)	244.3 10	-	244.26715	0.00287	10	5	
245 1		245.243 6	(2	245.18 3	2)	0.	-	245.24057	0.00588	6	2	
246 1		246.062 2		246.07 1		0.	-	246.06231	0.00196	10	4	
292 1		0.		291.7 10		291.7 10	-	291.80600	0.57735	6	1	
313 1		313.021 5		313 1		313 1	-	313.02100	0.00500	9	3	CHECK
354 1		353.998 5		354.0 10		354 1	-	353.99800	0.00500	10	3	CHECK
366 1		365.614 9		365.6 10		365.6 10	-	365.61403	0.00900	9	2	
407 1		406.593 15		406.6 10		406.6 10	-	406.59310	0.01499	10	2	

DATA SET 1. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.1053 F= 17
DATA SET 2. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.1045 F= 20
DATA SET 3. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.7112 F= 20
DATA SET 4. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.1951E-02 F= 13
CHISQ/F = 0.1888 (FIT OF 106GAMMAS - 9LEVELS)

ITERATION - 3 CHISQ - 1.411
LEAST-SQUARES LINEAR REGRESSION OF LEVEL AND GAMMA ENERGIES

LEVEL ENERGIES

1.	0.0
2.	46.4842 9
3.	99.0804 10
4.	207.0150 16
5.	208.8109 13
6.	291.7285 18
7.	308.943 4
8.	309.4 6
9.	412.101 2
10.	453.0770 19

GAMMA ENERGIES
NOT CONSTRAINED TO LEVELS

183RE EC DECAY 74HEYN	-183RE EC DECAY 77BR22		-183RE EC DECAY 74TA02		-183RE EC DECAY 72BR55	- ENERGY	DE	L1	L2	
0.	40.976 1		41.0 10		0.	- 40.97600	0.00100	10	9	
46 1	46.484 1		46.5 10		46.5 10	- 46.48400	0.00100	2	1	
53 1	52.596 1		52.6 10		52.6 10	- 52.59600	0.00100	3	2	
83 1	82.919 2		82.9 10		82.9 10	- 82.91900	0.00200	6	5	
85 1	84.712 2		84.7 10		84.7 10	- 84.71200	0.00200	6	4	
99 1	99.080 2		99.1 10		99.1 10	- 99.08000	0.00200	3	1	CHECK
102 1	101.93 4		101.9 10		0.	- 101.93309	0.03695	7	4	
0.	102.5 25		102.5 10		0.	- 102.48876	0.92848	8	4	
103 1	103.1 1		103.1 10		0.	- 103.09948	0.09901	9	7	
108 1	107.933 2		107.9 10		107.9 10	- 107.93300	0.00200	4	3	
110 1	109.731 2		109.722 10		109.7 10	- 109.73065	0.00196	5	3	
0.	120.37 9		120.4 10		120.4 10	- 120.37213	0.08928	9	6	
144 1	144.135 4		144.1 10		144.1 10	- 144.13500	0.00400	10	7	
161 1	160.532 4		160.53 2		0.	- 160.53193	0.00392	4	2	
161 1	161.342 14		161.33 2		161.4 10	- 161.33802	0.01147	10	6	
162 1	162.330 5	(1	162.317 10	1)	162.3 10	- 162.32739	0.00447	5	2	
193 1	192.646 7		192.6 10		192.6 10	- 192.64601	0.00700	6	3	
203 1	203.269 12	(1	203.32 5	1)	0.	- 203.27217	0.01162	9	5	
205 1	205.081 9		205.08 1		205.1 10	- 205.08055	0.00669	9	4	
209 1	208.812 2	(1	208.796 15	1)	208.8 10	- 208.81173	0.00198	5	1	
210 1	209.89 7		209.88 3		209.9 10	- 209.88166	0.02755	7	3	
0.	210.3 10		210.3 10		0.	- 210.30000	0.70711	8	3	CHECK
244 1	244.266 3	(1	244.280 13	1)	244.3 10	- 244.26672	0.00292	10	5	
245 1	245.243 6	(1	245.18 6	1)	0.	- 245.24238	0.00597	6	2	
246 1	246.062 2		246.07 1		0.	- 246.06231	0.00196	10	4	
292 1	0.		291.7 10		291.7 10	- 291.80600	0.57735	6	1	
313 1	313.021 5		313 1		313 1	- 313.02100	0.00500	9	3	CHECK
354 1	353.998 5		354.0 10		354 1	- 353.99800	0.00500	10	3	CHECK
366 1	365.614 9		365.6 10		365.6 10	- 365.61403	0.00900	9	2	
407 1	406.593 15		406.6 10		406.6 10	- 406.59310	0.01499	10	2	

DATA SET 1. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.1050 F= 17
DATA SET 2. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.2897E-01 F= 20
DATA SET 3. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.3425 F= 20
DATA SET 4. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.1954E-02 F= 13
CHISQ/F = 0.9626E-01 (FIT OF 106GAMMAS - 9LEVELS)

GAMMA ENERGIES FITTED INTENSITIES

GAMMA ENERGIES	1.183RE EC DECAY 74HEYN / 4.183RE EC DECAY 72BR55			2.183RE EC DECAY 77BR22			3.183RE EC DECAY 74TA02			BEST INT.
40.9760	0.	0.11 3		8 2	8 2		0.	0.86 22		0.11 3
	0.	0.81 20								
46.4840	34.24 24	34.39 22		2516 17	2499 14		261 18	269 3		33.90 16
	192 13	253 3	*4*							
52.5960	9.7 7	9.54 24		699 21	693 17		74 5	74.7 20		9.40 23
	63 6	70.1 19	*1*							
82.9190	1.36 6	1.142 15	*3*	80 1	83.0 10	*3*	10.4 4	8.95 15	*3*	1.126 13
	9.3 6	8.40 14	*1*							
84.7120	4.27 23	3.93 7	*1*	275 6	285 5	*1*	32.6 18	30.8 7	*1*	3.87 7
	32 2	28.9 6	*1*							
99.0800	11.5 6	11.67 20		850 17	848 14		88 5	91.4 19		11.50 19
	89 5	85.8 18								
101.9331	0.069 3	0.070 3		5.5 5	5.1 2		0.5 3	0.550 23		0.069 3
	0.	0.52 3								
102.4888	0.	0.005 4		0.25 25	0.36 25		0.05 5	0.04 3		0.005 3
	0.	0.04 3								
103.0995	0.034 11	0.031 6		1.2 5	2.3 5	*2*	0.3 1	0.25 5		0.031 6
	0.	0.23 5								
107.9330	9.5 12	9.44 19		687 14	686 13		72 9	74.0 17		9.31 17
	69 4	69.4 16								
109.7307	12.1 11	12.51 25		915 20	909 18		92 9	98.0 23		12.33 24
	91 5	91.9 22								
120.3721	0.	0.020 5		0.98 17	1.43 23	*2*	0.25 25	0.154 25		0.019 3
	0.50 25	0.145 23	*1*							
144.1350	0.59 3	0.519 9	*2*	36.6 7	37.7 7	*1*	4.5 3	4.06 9	*1*	0.511 9
	4 1	3.81 8								
160.5319	2.9 3	2.58 6	*1*	186 4	187 4		22 3	20.2 5		2.54 5
	0.	19.0 6								
161.3380	2.9 3	1.85 7	*3*	114 5	135 5	*4*	22 3	14.5 6	*2*	1.83 7
	10 5	13.6 6								
162.3274	100 6	101.4 8		7373 37	7372 37		763 53	795 13		100.0 5
	755 40	746 12								
192.6460	1.14 6	1.125 22		81 2	81.8 16		8.8 4	8.81 19		1.109 21
	8.6 5	8.27 18								
203.2722	0.150 23	0.189 10	*1*	14.4 8	13.7 7		1.1 2	1.48 8	*1*	0.186 9
	0.	1.39 24								
205.0805	0.420 25	0.464 11	*1*	35 1	33.7 8	*1*	3.2 2	3.64 10	*2*	0.458 11
	5 1	3.41 9	*1*							
208.8117	12.6 6	12.91 10		939 4	938 4		96 4	101.1 16	*1*	12.73 5
	93 7	94.9 15								
209.8817	1.0 1	1.13 3	*1*	83 2	82.1 19		8 1	8.85 24		1.11 3
	7 4	8.31 23								
210.3000	0.	0.010 7		1 1	0.7 5		0.05 5	0.08 6		0.010 7
	0.	0.07 5								
244.2667	1.70 7	1.77 4		130 3	128.6 25		13 2	13.9 3		1.74 3
	13.8 15	13.0 3								
245.2424	1.03 11	1.05 8		81 12	76 5		8 1	8.2 6		1.03 7
	0.	7.7 6								
246.0623	5.5 5	5.69 15		417 12	413 11		42 4	44.5 13		5.61 15
	0.	41.8 15								
291.8060	13.1 7	13.1 7		0.	953 83		100 20	103 5		12.9 6
	100 20	96 5								
313.0210	1.75 12	1.80 4		131 3	131 3		13.3 9	14.1 3		1.77 4
	14 1	13.2 3								
353.9980	2.30 14	2.32 4		169 3	169 3		18 1	18.2 4		2.29 4
	17 1	17.1 4								
365.6140	0.340 25	0.313 10	*1*	21.3 9	22.7 7	*1*	2.6 2	2.45 8		0.308 10
	2.9 5	2.30 8	*1*							
406.5931	0.10 5	0.126 7		7.9 5	9.1 5	*2*	0.8 4	0.98 6		0.124 7
	1.5 2	0.92 5	*2*							

	1	2	3
CHI/F	1.8373442	2.0450773	1.3641614
SKEW	1.5287061	-1.8299451	1.0369040
NDEGREES	26	29	29

CHI/F 2.2463586

SKEW -0.9404691

NDEGREES 21

ITERATION - 7

GAMMA ENERGIES — FITTED INTENSITIES

1.183RE EC DECAY 74HEYN; 2.183RE EC DECAY 77BR22; 3.183RE EC DECAY 74TA02; 4.183RE EC DECAY 72BR55; BEST INT.

GAMMA ENERGIES	1./4. Input	1./4. Fitted		2. Input	2. Fitted		3. Input	3. Fitted		BEST INT.
40.9760	0.	0.11 3		8.0 21	8.0 21		0.	0.83 23		0.11 3
	0.	0.82 22								
46.4840	34.24 24	34.20 22		2516 18	2519 15		261 18	262 4		34.16 17
	192 61	258 4	*1*							
52.5960	9.7 7	9.5 3		699 22	700 19		74 5	73.0 21		9.49 25
	63 9	71.7 21								
82.9190	1.36 22	1.24 6		80 10	91 5	*1*	10.4 15	9.5 5		1.24 6
	9.3 6	9.3 5								
84.7120	4.3 3	4.20 15		275 32	310 11	*1*	32.6 18	32.3 12		4.20 15
	32 2	31.7 12								
99.0800	11.5 6	11.55 21		850 18	851 15		88 5	88.7 19		11.54 20
	89 5	87.1 19								
101.9331	0.069 3	0.070 3		5.5 5	5.15 21		0.5 3	0.537 23		0.070 3
	0.	0.53 4								
102.4888	0.	0.005 4		0.3 3	0.4 3		0.05 5	0.04 3		0.005 4
	0.	0.04 3								
103.0995	0.034 11	0.036 8		1.2 13	2.6 6	*1*	0.3 1	0.27 6		0.036 8
	0.	0.27 6								
107.9330	9.5 12	9.31 19		687 15	686 14		72 9	71.5 17		9.30 18
	69 4	70.2 18								
109.7307	12.1 11	12.3 3		915 21	909 19		92 9	94.7 23		12.33 25
	91 5	93.0 23								
120.3721	0.	0.06 3		1 3	4.3 19	*1*	0.25 25	0.45 20		0.06 3
	0.50 25	0.44 20								
144.1350	0.59 9	0.501 10	*1*	36.6 7	36.9 7		4.5 6	3.85 10	*1*	0.500 10
	4 1	3.78 10								
160.5319	2.9 3	2.55 6	*1*	186 4	188 4		22 3	19.6 5		2.55 6
	0.	19.2 6								
161.3380	2.9 10	2.6 6		114 73	194 44	*1*	22 8	20 5		2.6 6
	10 10	20 5	*1*							
162.3274	100 6	100.1 9		7373 40	7373 39		763 53	768 12		100.0 5
	755 40	755 13								
192.6460	1.14 6	1.119 23		81.0 21	82.4 16		8.8 4	8.59 19		1.118 22
	8.6 5	8.43 19								
203.2722	0.15 4	0.192 11	*1*	14.4 9	14.1 8		1.1 3	1.47 9	*1*	0.192 11
	0.	1.4 7								
205.0805	0.42 5	0.471 14	*1*	35.0 11	34.7 10		3.2 4	3.62 12		0.471 14
	5.0 14	3.55 12	*1*							
208.8117	12.6 6	12.74 10		939 4	939 4		96 4	97.8 16		12.73 6
	93 7	96.1 16								
209.8817	1.00 12	1.12 3		83.0 21	82.3 20		8 1	8.58 25		1.12 3
	7 4	8.43 25								
210.3000	0.	0.010 7		1.0 11	0.7 5		0.05 5	0.08 6		0.010 7
	0.	0.07 5								
244.2667	1.70 7	1.75 4		130 3	129 3		13 2	13.4 3		1.75 4
	13.8 15	13.2 3								
245.2424	1.03 11	1.05 8		81 13	77 6		8 1	8.0 6		1.05 8
	0.	7.9 6								
246.0623	5.5 5	5.63 16		417 13	414 11		42 4	43.2 13		5.62 15
	0.	42.4 16								
291.8060	13.1 7	13.1 7		0.	965 85		100 20	101 5		13.1 7
	100 20	99 5								
313.0210	1.75 12	1.78 4		131 3	131 3		13.3 9	13.6 3		1.78 4
	14 1	13.4 3								
353.9980	2.30 14	2.30 4		169 3	169 3		18 1	17.6 4		2.29 4
	17 1	17.3 4								
365.6140	0.340 25	0.338 17		21 3	24.9 12	*1*	2.6 2	2.60 13		0.338 16
	2.9 5	2.55 13								
406.5931	0.10 5	0.119 17		7.9 13	8.7 12		0.8 4	0.91 13		0.118 17
	1.5 6	0.89 13	*1*							

	1.	2.	3.
CHI/F	0.2816075	0.3434863	0.2534655
SKEW	-0.2252278	-1.4142174	-0.2532596
NDEGREES	26	29	29

183W		183RE EC DECAY	
183W	L	0.0	
183W	L	46.4842 9	
183W	G	46.484 1	34.16 17
183W	L	99.0804 10	
183W	G	52.596 1	9.49 25
183W	G	99.080 2	11.54 20
183W	L	207.0150 16	
183W	G	107.933 2	9.30 18
183W	G	160.532 4	2.55 6
183W	L	208.8109 13	
183W	G	109.7307 20	12.33 25
183W	G	162.327 5	100.0 5
183W	G	208.8117 20	12.73 6
183W	L	291.7285 18	
183W	G	82.919 2	1.24 6
183W	G	84.712 2	4.20 15
183W	G	192.646 7	1.118 22
183W	G	245.242 6	1.05 8
183W	G	291.8 6	13.1 7
183W	L	308.943 4	
183W	G	101.93 4	0.070 3
183W	G	209.88 3	1.12 3
183W	L	309.4 6	
183W	G	102.5 9	0.005 4
183W	G	210.3 7	0.010 7
183W	L	412.101 2	
183W	G	103.10 10	0.036 8
183W	G	120.37 9	0.06 3
183W	G	203.272 12	0.192 11
183W	G	205.081 7	0.471 14
183W	G	313.021 5	1.78 4
183W	G	365.614 9	0.338 16
183W	L	453.0770 19	
183W	G	40.976 1	0.11 3
183W	G	144.135 4	0.500 10
183W	G	161.338 11	2.6 6
183W	G	244.267 3	1.75 4
183W	G	246.0623 20	5.62 15
183W	G	353.998 5	2.29 4
183W	G	406.593 15	0.118 17

FINAL ADOPTED LEVEL AND GAMMA ENERGIES

LEVEL ENERGY	GAMMAS DEEXCITING THE LEVEL
46.4842 9	46
99.0804 10	53, 99
207.0150 16	108, 161
208.8109 13	110, 162
291.7285 18	83, 85, 193, 245
308.943 4	102, 210
309.4 6	102, 210
412.101 2	103, 120, 203, 205, 313, 366
453.0770 19	41, 144, 161, 244, 246, 354, 407

FINAL ADOPTED GAMMA ENERGIES AND INTENSITIES

GAMMA ENERGY -183RE EC DECAY

40.976 1	0.11 3
46.484 1	34.16 17
52.596 1	9.49 25
82.919 2	1.24 6
84.712 2	4.20 15
99.080 2	11.54 20
101.93 4	0.070 3
102.5 9	0.005 4
103.10 10	0.036 8
107.933 2	9.30 18
109.7307 20	12.33 25
120.37 9	0.06 3
144.135 4	0.500 10
160.532 4	2.55 6
161.338 11	2.6 6
162.327 5	100.0 5
192.646 7	1.118 22
203.272 12	0.192 11
205.081 7	0.471 14
208.8117 20	12.73 6
209.88 3	1.12 3
210.3 7	0.010 7
244.267 3	1.75 4
245.242 6	1.05 8
246.0623 20	5.62 15
291.8 6	13.1 7
313.021 5	1.78 4
353.998 5	2.29 4
365.614 9	0.338 16
406.593 15	0.118 17

SYSTEMATIC ENERGY ERROR = 0.00000 KEV

S=SYSTEMATIC VALUE   T=TOTAL INTENSITY

>=LOWER LIMIT $=SYSTEMATIC TOTAL INTENSITY LOWER LIMIT

APPENDIX B. ADOPTED LEVELS, GAMMAS with GAMUT

In this example, the ^{183}Re decay data set created in Appendix A is combined with a ^{183}Ta decay data set to create an ADOPTED LEVELS, GAMMAS data set. A partial listing from the STAT.OUT file follows. The input ENSDF data sets, listed at the beginning of STAT.OUT, are followed by the intermediate, special-format ENSDF data set, which was created by GAMUT. The intermediate data set could have been saved for editing or to correct mistakes in the level ordering or final level assignments. The first iteration of the energy analysis is shown. This output is similar to that described in Appendix A. Here the γ rays have been constrained to the level scheme, and several discrepancies between the input and fitted values can be seen. The first iteration of the intensity analysis is shown next. This output is ordered by level rather than γ-ray energy, and the best fitted intensities are normalized to 100 for each level. The output ADOPTED LEVELS, GAMMAS data set, created by GAMUT, is listed at the end of this Appendix.

DATA FOR A = 183 AND Z = 74(W) 183RE EC DECAY CONSTANT IS OFF

		DATASET	DAP	DBLANK	DGAMMA	DMIN	DSYS
183W	L	0.0					
183W	L	46.4842 9					
183W	G	46.484 1	34.16 17				
183W	L	99.0804 10					
183W	G	52.596 1	9.49 25				
183W	G	99.080 2	11.54 20				
183W	L	207.0150 16					
183W	G	107.933 2	9.30 18				
183W	G	160.532 4	2.55 6				
183W	L	208.8109 13					
183W	G	109.7307 20	12.33 25				
183W	G	162.327 5	100.0 5				
183W	G	208.8117 20	12.73 6				
183W	L	291.7285 18					
183W	G	82.919 2	1.24 6				
183W	G	84.712 2	4.20 15				
183W	G	192.646 7	1.118 22				
183W	G	245.242 6	1.05 8				
183W	G	291.8 6	13.1 7				
183W	L	308.943 4					
183W	G	101.93 4	0.070 3				
183W	G	209.88 3	1.12 3				
183W	L	309.4 6					
183W	G	102.5 9	0.005 4				
183W	G	210.3 7	0.010 7				
183W	L	412.101 2					
183W	G	103.10 10	0.036 8				
183W	G	120.37 9	0.06 3				
183W	G	203.272 12	0.192 11				
183W	G	205.081 7	0.471 14				
183W	G	313.021 5	1.78 4				
183W	G	365.614 9	0.338 16				
183W	L	453.0770 19					
183W	G	40.976 1	0.11 3				
183W	G	144.135 4	0.500 10				
183W	G	161.338 11	2.6 6				
183W	G	244.267 3	1.75 4				
183W	G	246.0623 20	5.62 15				
183W	G	353.998 5	2.29 4				
183W	G	406.593 15	0.118 17				

```
DATA FOR A = 183   AND Z =  74( W)    183TA B- DECAY (5.1 D)          CONSTANT IS OFF

          DATASET     DAP     DBLANK    DGAMMA     DMIN      DSYS

183W  CG E$WEIGHTED AVERAGE OF 65GR16,70GR13 AND 75BO05 LEAST-SQUARES FIT
183W 2CG TO THE LEVEL SCHEME.
183W  CG RI$WEIGHTED AVERAGE OF 62SCZZ AND 65ED01.
183W  CG MR$FROM SUBSHELL BRANCHING RATIOS AND ICC MEASUREMENTS OF
183W 2CG 55MU19, 62HA24, 65ED01, 70AG06, 72BB21, AND 80AR22
183W 3CG EXCEPT WHERE NOTED.
183W  CG MR(B)$FROM ANGULAR DISTRIBUTION MEASUREMENTS (73KR01).
183W  CG RI(A)$TOTAL INTENSITY OF 313.0+313.3 KEV G IS 26.7 7 RELATIVE
183W 2CG TO 100 FOR THE 246-KEV G.  THE ADOPTED INTENSITY IS OBTAINED
183W 3CG FROM A WEIGHTED AVERAGE OF VALUES DERIVED BY ASSUMING THAT
183W 4CG I(313.3)*(1+ALPHA)=I(102.5)(1+ALPHA) (I=17.2 11) AND
183W 5CG I(313.3)=14.3 9 DERIVED FROM I(313.0)/I(205.1)=3.78 14 FROM
183W 6CG 183RE DECAY.
183W  CG M(A)$FROM 65ED01 L1/L2/L3=58/5/0.6 FOR THE COMBINED TRANSITIONS.
183W 2CG IF BOTH TRANSITIONS ARE M1(+E2) THIS YIELDS MR=0.08.  THE
183W 3CG SMALL ADMIXTURE CANNOT BE APPORTIONED TO THE INDIVIDUAL
183W 4CG TRANSITIONS AND IS NEGLECTED HERE.
183W  CN NR$ASSUMING 100% OF BETA FEEDING TO LEVELS AT 412-,
183W 2CN 453-, 595-, AND 623-KEV.  THIS IS CONSISTENT WITH
183W 3CN A LIMIT OF LE 5% FEEDING TO LOWER LEVELS (55MU19)
183W 4CN AND THE INTENSITY BALANCES THROUGH THE LOWER LEVELS.
183W  CG RI(B)$FROM 62SCZZ.  FOR THE LOW ENERGY GAMMAS, THE INTENSITIES
183W 2CG OF 65ED01 APPEAR TO BE SYSTEMATICALLY TOO LOW.
183TA  N   0.268  14             1.00
183TA CG RI        FOR ABSOLUTE INTENSITY PER 100 DECAYS MULTIPLY BY 0.268.
183TA2CG FOR UNCERTAINTY COMBINE  5.3 % IN QUADRATURE WITH RELATIVE INTENSITY,
183TA3CG EXCEPT AS NOTED.
183TA  P 0.0          7/2+              5.1 D     1              1070.5   19
183W   G    101.0   1   15    1
183W   G    201.0   1   3     1
183W   L       0.0   1/2-
183W   L    46.4838 6 3/2-
183W   G    46.4838 6   21.5 15 M1+E2     0.081  2        8.51 17             B
183W 2 G              LC=   6.61 14$MC=    1.52 3$NC+=   0.384 7
183W   L    99.0792 7 5/2-
183W   G    52.5953 5   21.5 12 M1+E2     0.124   5       6.37 13             B
183W 2 G              LC=   4.90 14$MC=    1.13 3$NC+=   0.340 7
183W   G    99.0791 7   24.9 10 E2                        4.12 8
183W 2 G KC=  0.909 18$LC=   2.42 5$MC=  0.609 12$NC+=   0.178 4
183W   L  207.0110 9
183W   G  107.9318 7   40.9 16 M1+E2     0.31    5       3.85 11
183W 2 G KC=    3.04 9$LC=   0.62 5$MC=  0.143 13$NC+= 0.0434 24
183W   G  160.5271 8    10.9 3 E2                       0.667 13
183W 2 G KC=   0.305 6$LC=   0.274 6$MC= 0.0683 14$NC+=  0.0200 4
183W   L 208.8049 12
183W   G 109.7257 11    2.23 9 M1+E2     0.15    2       3.73 8
183W 2 G KC=    3.06 6$LC=  0.517 18$MC=   0.118 4$NC+=  0.0360 8
183W   G 162.3210 11    18.2 6 M1+E2     0.41    1      1.148 23
183W 2 G KC=  0.919 18$LC=   0.176 4$MC= 0.0409 10$NC+=0.01229 20
183W   G 208.8047 12    2.22 9 M1+E2     0.5     1       0.54 3
183W 2 G KC=  0.435 24$LC=   0.082 8$MC= 0.0189 19$NC+=0.00563 11
183W   L 291.7233 11
183W   G  82.9184 8    1.44 8 M1+E2     0.63    3      8.44 24
183W 2 G KC=   5.30 15$LC=   2.38 13$MC=    0.58 3$NC+=   0.171 7
183W   G   84.7123 10   5.00 23 M1+E2     0.18    4      7.90 18
183W 2 G KC=   6.38 14$LC=    1.17 9$MC=  0.270 23$NC+=   0.081 5
183W   G 192.6440 10   1.31 4 M1+E2     0.91    14      0.58 5
183W 2 G KC=    0.43 4$LC=  0.112 13$MC=   0.027 3$NC+=0.00784 20
183W   G 245.2393 11   1.53 7 M1                        0.390 8
183W 2 G KC=   0.324 7$LC= 0.0510 10$MC=0.01159 23$NC+= 0.00344 7
183W   G 291.7231 11   13.9 4 E2                      0.0932 19
183W 2 G KC= 0.0617 12$LC=  0.0240 5$MC=0.00584 12$NC+= 0.00169 3
183W   L 308.9451 15
183W   G 101.9341 13   1.24 6 M1                        4.63 9
183W 2 G KC=    3.84 8$LC=  0.611 12$MC=   0.139 3$NC+=  0.0424 9
183W   G 209.8658 14   16.7 4 E2                        0.266 5
183W 2 G KC=   0.150 3$LC= 0.0878 18$MC=  0.0217 4$NC+=0.00631 13
```

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183W   L    309.493 3
183W   G    102.481 3    0.50 3 M2                          40.3 8
183W 2 G KC=    28.1 6$LC=   9.22 18$MC=    2.27 5$NC+=  0.708 14
183W   L  412.0943 15
183W   B                 2.4 10             8.5524
183W 2 B EAV=   205.1 7$
183W   G  103.1492 14     1.0 5 IF M1                      4.48 18
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.13 PER 100 DECAYS.
183W 2 G KC=   3.71 15$LC=  0.591 24$MC=   0.134 5$NC+= 0.0410 16
183W   G  120.3710 14  0.253 16 E2+M1     1      GT      2.2 9
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.006 PER 100 DECAYS.
183W 2 G KC=     1.1 4$LC=   0.83 17$MC=   0.21 4$NC+=   0.061 5
183W   G  203.2893 15    1.43 4 E2                         0.295 6
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.023 PER 100 DECAYS.
183W 2 G KC=  0.163 3$LC= 0.1002 20$MC=  0.0248 5$NC+=0.00722 14
183W   G  205.0832 14    3.28 9 M1+E2     0.18    6     0.629 16
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.05 PER 100 DECAYS.
183W 2 G KC=  0.519 12$LC=   0.084 3$MC=  0.0192 8$NC+=0.00575 11
183W   G  313.0149 14 12.4     6 M1+E2      0.225    8     0.195 5            A
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.24 PER 100 DECAYS.
183W 2 G KC=   0.167 3$LC=  0.0262 5$MC=0.00592 12$NC+= 0.00175 4
183W   G  365.6101 15    1.84 7 E2                       0.0483 10
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.03 PER 100 DECAYS.
183W 2 G KC=  0.0344 7$LC=0.01060 21$MC= 0.00255 5$NC+=.000738 15
183W   L  453.0699 14                     18.8 NS   5
183W  CL T$WEIGHTED AVERAGE OF 18.4 NS 4 (67MA28), 18.0 NS 4 (67ME01), AND
183W 2CL 19.5 NS 3 (71HO14).
183W   B 615       10       92 5            6.88 3
183W 2 B EAV=   190.4 7$
183W  CB E$FROM 66MO17
183W   G     40.9756 9   1.76 18 M1                        11.16 22             B
183W 2 G               LC=   8.79 18$MC=    2.00 4$NC+=   0.367 7
183W   G  144.1247 12     9.3 3 M1+E2      0.07     AP      1.72 7
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.15 PER 100 DECAYS.
183W 2 G KC=    1.42 6$LC=   0.227 9$MC= 0.0518 21$NC+=  0.0158 6
183W   G  161.3465 12   33.3 10 M1+E2      0.2      AP      1.23 5
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.5 PER 100 DECAYS.
183W 2 G KC=    1.01 4$LC=   0.169 7$MC= 0.0386 15$NC+=  0.0117 4
183W   G  244.2649 13    31.7 9 E2                          0.162 3
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.5 PER 100 DECAYS.
183W 2 G KC= 0.0996 20$LC= 0.0476 10$MC=0.01169 23$NC+= 0.00338 7
183W   G  246.0587 12    100 14 M1+E2      0.07     3      0.385 8
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 2.4 PER 100 DECAYS.
183W 2 G KC=   0.321 6$LC= 0.0505 10$MC=0.01148 23$NC+= 0.00341 7
183W   G  353.9904 13   41.9 11 M1+E2      0.22     3      0.140 3
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.7 PER 100 DECAYS.
183W 2 G KC= 0.1165 25$LC=  0.0185 4$MC=0.00418 10$NC+=.001232 25
183W   G  406.5856 13    1.91 8 (E2)                      0.0361 14
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.03 PER 100 DECAYS.
183W 2 G KC= 0.0264 11$LC=  0.0074 3$MC= 0.00177 7$NC+=.000513 21
183W   L    595.339 6
183W   B                0.99 5             8.46 3
183W 2 B EAV=   141.2 6$
183W   G    142.269 6    1.35 6 M1+E2     0.3      1        1.72 8
183W 2 G KC=    1.39 6$LC=    0.25 3$MC=    0.059 8$NC+= 0.0178 10
183W   G    286.394 6    0.04 2
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.005 PER 100 DECAYS.
183W   L     622.76 3
183W   B 470       30       5.0 5            7.67 5
183W 2 B EAV=   132.0 6$
183W  CB E$FROM 66MO17
183W   G     313.27 3   15.5 14 M1                        0.200 4             A
183W  CG           UNCERTAINTY IN ABSOLUTE INTENSITY IS 0.4 PER 100 DECAYS.
183W 2 G KC=   0.167 3$LC=  0.0261 5$MC=0.00591 12$NC+= 0.00174 4
```

SUMMARY OF TRANSITION DATA FOR ADOPTED LEVELS, GAMMAS   CALCULATION

		E(DE)	I(DI)
183W	L1	0.0	
183W	L1	46.4842 9	
183W	G1	46.484 1	34.16 17
183W	G2	46.4838 6	21.5 15
183W	L1	99.0804 10	
183W	G1	52.596 1	9.49 25
183W	G2	52.5953 5	21.5 12
183W	G1	99.080 2	11.54 20
183W	G2	99.0791 7	24.9 10
183W	L1	207.0150 16	
183W	G1	107.933 2	9.30 18
183W	G2	107.9318 7	40.9 16
183W	G1	160.532 4	2.55 6
183W	G2	160.5271 8	10.9 3
183W	L1	208.8109 13	
183W	G1	109.7307 20	12.33 25
183W	G2	109.7257 11	2.23 9
183W	G1	162.327 5	100.0 5
183W	G2	162.3210 11	18.2 6
183W	G2	208.8047 12	2.22 9
183W	G1	208.8117 20	12.73 6
183W	L1	291.7285 18	
183W	G1	82.919 2	1.24 6
183W	G2	82.9184 8	1.44 8
183W	G1	84.712 2	4.20 15
183W	G2	84.7123 10	5.00 23
183W	G1	192.646 7	1.118 22
183W	G2	192.644 1	1.31 4
183W	G1	245.242 6	1.05 8
183W	G2	245.2393 11	1.53 7
183W	G1	291.8 6	13.1 7
183W	G2	291.7231 11	13.9 4
183W	L1	308.943 4	
183W	G1	101.93 4	0.070 3
183W	G2	101.9341 13	1.24 6
183W	G1	209.88 3	1.12 3
183W	G2	209.8658 14	16.7 4
183W	L1	309.4 6	
183W	G1	102.5 9	0.005 4
183W	G2	102.481 3	0.50 3
183W	G1	210.3 7	0.010 7
183W	L1	412.101 2	
183W	G1	103.1 1	0.036 8
183W	G2	103.1492 14	1.0 5
183W	G1	120.37 9	0.06 3
183W	G2	120.3710 14	0.253 16
183W	G1	203.272 12	0.192 11
183W	G2	203.2893 15	1.43 4
183W	G1	205.081 7	0.471 14
183W	G2	205.0832 14	3.28 9
183W	G1	313.021 5	1.78 4
183W	G2	313.0149 14	12.4 6
183W	G1	365.614 9	0.338 16
183W	G2	365.6101 15	1.84 7
183W	L1	453.0770 19	
183W	G1	40.976 1	0.11 3
183W	G2	40.9756 9	1.76 18
183W	G1	144.135 4	0.50 1
183W	G2	144.1247 12	9.3 3
183W	G1	161.338 11	2.6 6
183W	G2	161.3465 12	33.3 10
183W	G1	244.267 3	1.75 4
183W	G2	244.2649 13	31.7 9
183W	G1	246.0623 20	5.62 15
183W	G2	246.0587 12	100 14
183W	G1	353.998 5	2.29 4
183W	G2	353.9904 13	41.9 11
183W	G1	406.593 15	0.118 17
183W	G2	406.5856 13	1.91 8
183W	L2	595.339 6	
183W	G2	142.269 6	1.35 6
183W	G2	286.394 6	0.04 2
183W	L2	622.76 3	
183W	G2	313.27 3	15.5 14

LEAST-SQUARES LINEAR REGRESSION OF LEVEL AND GAMMA ENERGIES

LEVEL ENERGIES

1.	0.0
2.	46.4840 4
3.	99.0793 4
4.	207.0113 5
5.	208.8057 5
6.	291.7238 5
7.	308.9453 8
8.	309.492 3
9.	412.0948 6
10.	453.0707 6
11.	595.340 4
12.	622.76 3

GAMMA ENERGIES

	183RE EC DECAY		- 183TA B- DECAY (5- 74HEYN.1 D)		ENERGY	DE	L1	L2
	40.976 1		40.9756 9	-	40.97588	0.00050	10	9
	46.484 1		46.4838 6	-	46.48396	0.00039	2	1
	52.596 1		52.5953 5	-	52.59534	0.00033	3	2
	82.919 2		82.9184 8	-	82.91804	0.00050	6	5
	84.712 2		84.7123 10	-	84.71246	0.00050	6	4
	99.080 2		99.0791 7	-	99.07929	0.00042	3	1
	101.93 4		101.9341 13	-	101.93399	0.00072	7	4
	102.5 9		102.481 3	-	102.48100	0.00300	8	4
	103.1 1		103.1492 14	-	103.14945	0.00074	9	7
	107.933 2		107.9318 7	-	107.93193	0.00043	4	3
(2	109.7307 20	2)	109.7257 11	-	109.72635	0.00048	5	3
	120.37 9		120.3710 14	-	120.37098	0.00058	9	6
	0.		142.269 6	-	142.26891	0.00426	11	1
(2	144.135 4	2)	144.1247 12	-	144.12530	0.00071	10	7
(1	160.532 4	1)	160.5271 8	-	160.52724	0.00045	4	2
	161.338 11		161.3465 12	-	161.34683	0.00054	10	6
(1	162.327 5	1)	162.3210 11	-	162.32166	0.00049	5	2
	192.646 7		192.644 1	-	192.64433	0.00046	6	3
(1	203.272 12	1)	203.2893 15	-	203.28896	0.00061	9	5
	205.081 7		205.0832 14	-	205.08337	0.00057	9	4
(3	208.8117 20	3)	208.8047 12	-	208.80557	0.00053	5	1
	209.88 3		209.8658 14	-	209.86585	0.00072	7	3
	210.3 7		0.	-	210.41286	0.00303	8	3
	244.267 3		244.2649 13	-	244.26479	0.00057	10	5
	245.242 6		245.2393 11	-	245.23962	0.00046	6	2
(1	246.0623 20	1)	246.0587 12	-	246.05920	0.00052	10	4
	0.		286.394 6	-	286.39409	0.00426	11	7
	291.8 6		291.7231 11	-	291.72351	0.00051	6	1
(1	313.021 5	1)	313.0149 14	-	313.01517	0.00054	9	3
	0.		313.27 3	-	313.27000	0.03000	12	8
(1	353.998 5	1)	353.9904 13	-	353.99098	0.00050	10	3
	365.614 9		365.6101 15	-	365.61042	0.00055	9	2
	406.593 15		406.5856 13	-	406.58621	0.00051	10	2

DATA SET 1. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 1.692 F= 20
DATA SET 2. ENERGIES CORRECTED BY 0.0000000+- 0.0000000 KEV CHISQ/F = 0.1532 F= 21
CHISQ/F = 0.7410 (FIT OF 62GAMMAS - 11LEVELS)

GAMMA ENERGIES FITTED INTENSITIES

1.183RE EC DECAY 74HEYN — 2. 183TA B- DECAY (5.1 D) — BEST INT.

LEVEL-46.4838 4							
46.4838	34.16 17	34.16 17		21.5 15	21.5 15		100
LEVEL-99.0792 4							
52.5954	9.49 25	9.55 23		21.5 12	20.9 8		82.9 20
99.0792	11.54 20	11.51 19		24.9 10	25.2 9		100.0 16
LEVEL-207.0112 5							
107.9319	9.30 18	9.33 17		40.9 16	40.3 11		100.0 17
160.5273	2.55 6	2.54 5		10.9 3	11.0 3		27.2 5
LEVEL-208.8051 6							
109.7258	12.33 25	12.35 23		2.23 9	2.21 6		12.35 22
162.3212	100.0 5	100.0 5		18.2 6	17.9 4		100.0 5
208.8049	12.73 6	12.73 6		2.22 9	2.28 5		12.72 6
LEVEL-291.7235 5							
82.9184	1.24 6	1.23 5		1.44 8	1.45 6		10.2 4
84.7123	4.20 15	4.22 12		5.00 23	4.97 16		34.9 10
192.6441	1.118 22	1.116 20		1.31 4	1.31 3		9.23 15
245.2395	1.05 8	1.23 5	*2*	1.53 7	1.45 6	*1*	10.2 4
291.7232	13.1 7	12.1 4	*1*	13.9 4	14.2 4		100.0 25
LEVEL-308.9453 8							
101.9341	0.070 3	0.074 3	*1*	1.24 6	1.15 4	*1*	6.79 22
209.8659	1.12 3	1.10 3		16.7 4	17.0 4		100.0 18
LEVEL-309.492 3							
102.4810	0.005 4	0.005 4		0.50 3	0.50 3		50 40
210.4128	0.010 7	0.010 7		0.	1	*S*	100 70
LEVEL-412.0945 6							
103.1492	0.036 8	0.054 11	*2*	1.0 5	0.37 8	*1*	3.0 6
120.3710	0.06 3	0.0377 25		0.253 16	0.255 16		2.11 13
203.2893	0.192 11	0.208 6	*1*	1.43 4	1.40 4		11.6 3
205.0832	0.471 14	0.478 11		3.28 9	3.24 7		26.7 5
313.0150	1.78 4	1.79 4		12.4 6	12.1 3		100 2
365.6103	0.338 16	0.298 10	*2*	1.84 7	2.02 6	*2*	16.6 5
LEVEL-453.0703 6							
40.9757	0.11 3	0.098 10		1.76 18	1.79 17		1.75 17
144.1249	0.50 1	0.503 9		9.3 3	9.17 19		8.95 15
161.3467	2.6 6	1.84 6	*1*	33.3 10	33.5 10		32.7 10
244.2650	1.75 4	1.75 3		31.7 9	31.8 7		31.1 6
246.0589	5.62 15	5.62 15		100 14	102 3		100 3
353.9907	2.29 4	2.29 4		41.9 11	41.8 8		40.8 6
406.5859	0.118 17	0.106 5		1.91 8	1.93 8		1.88 8
LEVEL-595.339 4							
142.2691	0.	0.		1.35 6	1.35 6		100 4
286.3939	0.	0.		0.04 2	0.04 2		3.0 15
LEVEL-622.76 3							
313.2700	0.	0.		15.5 14	15.5 14		100

CHI/F	0.9692464	0.5182614
SKEW	-0.3010883	-0.9390661
NDEGREES	29	30

183W ADOPTED LEVELS, GAMMAS

183W	L	0.0			
183W	L	46.4838	5		
183W	G	46.4838	5	100	
183W	L	99.0794	6		
183W	G	52.5955	4	82.2	19
183W	G	99.0793	6	100.0	16
183W	L	207.0117	8		
183W	G	107.9323	6	100.0	17
183W	G	160.5278	7	27.2	5
183W	L	208.8065	11		
183W	G	109.7271	10	12.35	22
183W	G	162.3226	10	100.0	5
183W	G	208.8064	11	12.72	6
183W	L	291.7247	10		
183W	G	82.9182	7	10.3	4
183W	G	84.7130	9	35.1	10
183W	G	192.6452	9	9.28	15
183W	G	245.2407	10	10.8	5
183W	G	291.7245	10	100	3
183W	L	308.9467	14		
183W	G	101.9349	12	6.8	3
183W	G	209.8672	13	100.0	18
183W	L	309.493	3		
183W	G	102.481	3	50	40
183W	G	210.413	3	100	70
183W	L	412.0967	12		
183W	G	103.1500	13	8	4
183W	G	120.3719	12	2.06	13
183W	G	203.2901	12	11.5	3
183W	G	205.0849	11	26.5	5
183W	G	313.0170	11	100.0	22
183W	G	365.6124	12	16.5	12
183W	L	453.0725	11		
183W	G	40.9759	7	1.69	14
183W	G	144.1258	11	8.95	15
183W	G	161.3478	11	32.8	10
183W	G	244.2659	11	31.1	6
183W	G	246.0607	10	100	3
183W	G	353.993	1	40.8	6
183W	G	406.5882	10	1.88	8
183W	L	595.342	6		
183W	G	142.269	6	100	
183W	L	622.76	3		
183W	G	313.27	3	100	

APPENDIX C. GAMUT PROGRAM NOTES

GAMUT was originally written (1982) in FORTRAN for a CDC-7600 computer, and was later converted to run on VAX computer systems. It has evolved into a progressively more complex computer code. GAMUT generally complies with the 1977 FORTRAN standard although some input/output statements may be peculiar to VAX systems. Documentation is sparse, and the author recommends that all modifications should be performed with extreme care.

GAMUT is a computer program with several subroutines. It also calls upon the LBLLIB utility library. The main program reads the data, handles default parameters, and calls the required subroutines. Subroutines GI, NORMAL, AVERAGE, LINREG, and RENORM perform the intensity analysis. Subroutine GEETOL does the energy analysis, using the subroutine MATINV2 (adapted from the program GTOL*), to perform the matrix inversion. Subroutine ENSDFIO controls the output options and writes the output ENSDF file. The subroutines GADOPT and ADOPTER combine data sets into the intermediate special-format ENSDF file for the creation of ADOPTED LEVELS, GAMMAS. Subroutine SORTER is a utility for sorting information, and subroutine MDCHI calculates the probability associated with a given Chi-square value.

This version of GAMUT has variable dimensions that can be reset before compilation, by modifying the PARAMETER statements found in the main program and all subroutines. The variable dimensions are M1 (maximum number of data sets), M2 (maximum number of gammas per data set), M3 (maximum number of levels), and M4 (maximum number of gammas for all data sets). The compiled version should be linked with the LBL library. For the VAX-6410 computer at LBL, GAMUT is normally dimensioned to accept up to 10 data sets, 500 gammas per data set, 150 levels, and 1000 gammas total. The running time for GAMUT will vary with the computer and the size of the matrix inversion. On the VAX-6410 computer GAMUT takes a few seconds for a small data set and can take over five minutes for a very large data set.

**GTOL, a Computer Code for Least-squares Analysis of* γ*-ray and Level Energies*, W.B. Ewbank, unpublished; maintained by the National Nuclear Data Center, Brookhaven National Laboratory.

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