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CODE CUGEL

A CODE TO UNFOLD Ge(Li) SPECTROMETER POLYENERGETIC GAMMA PHOTON EXPERIMENTAL DISTRIBUTIONS

July 1970

Prepared by

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and
U. Born

For

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TABLE OF CONTENTS

Page

1. INTRODUCTION 1

2. CODE DESCRIPTION 3

2.1 Introduction 3

2.2 Code Logic 4

2.2.1 Main Program 4

2.2.2 Response Function Matrix 9

2.2.2.1 Response Matrix Generation 9

2.2.2.2 *Spectrum Normalization* 12

2.2.2.3 Photopeak Fitting 13

2.2.2.4 Compton Continuum Interpolation 16

2.2.3 Analysis of Monoenergetic Spectral Contributions 18

2.2.4 Spectral Unfolding 21

2.2.5 Analysis of Unfolded Spectra 25

2.3 Code Constants 28

3. CODE OPERATING INFORMATION 31

3.1 General 31

3.2 Card Input Details 34

3.3 Code Output 47

4. SUMMARY AND CONCLUSIONS 50

REFERENCES 52

FIGURES 54

APPENDIX I Glossary of Subprograms 67

II FORTRAN Card Deck Listing 71

III Sample Input Card Deck Listing 95

IV Sample Output Listing 102

V Photopeak and Backscatter Peak Distributions 123

VI Reproduction of Appendix II of Reference (2): Photopeak Function Fitting 137

FIGURES

Figure No.	Description	Page
1	Code CUGEL Subprogram Connectivity	55
2	Code CUGEL Main Program Simplified Flow Diagram	56
3	Comparison of Standard Source and Code Generated Compton Continua, Pulse-Height Normalized to Unit Area Photopeak	57
4	Comparison of Standard Source and Code Generated Photofractions	58
5	Photopeak Standard Deviation for Fitted Gaussian as a Function of Energy	59
6	Variation of Compton Edge and Backscatter Peak Pulse Heights (Vc and Vb) as a Function of Photon Energy	60
7	Flow Diagram Showing the Logic of Subprogram RESMAT	61
8	Example Unknown Spectrum	62
9	Geometry for Equation (12)	63
10	Photopeak Efficiency (P * E) as a Function of Photon Energy	64
11	General Arrangement for Input Card Data Deck	65
12	Subprogram SOLN Simplified Flow Diagram	66

SUMMARY

A FORTRAN code has been developed for the UNIVAC-1108 digital computer to unfold lithium-drifted germanium semiconductor spectrometer polyenergetic gamma photon experimental distributions. It was specifically designed to analyze the combination continuous and monoenergetic gamma radiation field of radioisotope volumetric sources. The code generates the detector system response matrix function and applies it to the monoenergetic spectral components discretely and to the continuum iteratively. It corrects for system drift, source decay, background, and detection efficiency. Results are presented in digital form for differential and integrated photon number and energy distributions, and exposure dose.

1. INTRODUCTION

This report presents a description of and the user requirements for, code CUGEL - - - a digital computer code to unfold semiconductor spectrometer polyenergetic gamma photon experimental distributions developed for the JET PROPULSION LABORATORY under Contract No. 952706. Code CUGEL, written in the FORTRAN V language for the JPL UNIVAC-1108 digital computer, is a very much modified and redesigned version of code CUPED which was developed under contracts NAS5-10133 and NAS5-10337 for NASA- Goddard Space Flight Center(1-4). The experimental distributions which the code has been specifically developed to analyze, are those recorded by the germanium (lithium-drifted) - - - Ge(Li) - - - semiconductor detector coupled to a multichannel pulse-height analyzer and exposed to the continuous and line energy photons emitted by radioisotope volumetric sources.

The code can either read or generate the detector system response function matrix and apply it to unfold the pulse-height analyzer distributions to determine differential and integrated photon number and energy distributions, and exposure dose. The response matrix generation procedure relies on the spectra of standard radioisotopes such as Cd^{109}, Ce^{139}, Hg^{203}, Sr^{85}, Cs^{137}, Nb^{95}, Mn^{54}, Zn^{65} and Co^{60}. The standard spectra are normalized with respect to photopeak pulse-height and area, and their photopeaks subtracted to obtain normalized Compton continua. The response matrix vectors are determined at each energy by interpolating the normalized continua and computing the associated Gaussian photopeaks. The thus interpolated vectors are redistributed in pulse-height to correspond to the detector system energy response and to satisfy the requirements of the spectra to be unfolded. Quadratic interpolation of the normalized continua is carried out by a specifically developed 'Method of Parts', described in this report.

Code CUGEL applies the response function either iteratively or discretely depending on whether the unknown is either a continuous spectrum, a complex spectrum consisting of a limited number of photopeaks or a spectrum consisting of a continuum-plus-photopeaks. The code determines the detector incident photon lines in the unknown spectra by photopeak analysis. The corresponding photopeak associated Compton continua are determined by an interpolation of the standard Compton continua. The thus determined photopeak-plus-continuum spectra are then subtracted to leave, ideally, either a continuous or zero residual spectrum. Continuous and residual spectra are iteratively unfolded according to the matrix inversion technique of Scofield(5-8), to determine detector-incident continuous photon spectra. The total incident gamma photon spectrum is determined as the sum of the line and continuous components.

The code corrects for partial photon energy deposition in the Ge(Li) detector through the application of the response function matrix. It corrects for the number of photon interactions in the detector crystal and for absorptions by the crystal cladding materials, interposed absorbers such as aluminum and the air medium between the source and the detector active region. In addition, it corrects for primary source decay, pulse-height drift and natural background.

2. CODE DESCRIPTION

2.1 INTRODUCTION

Code CUGEL is written in the FORTRAN V compiler language for the JPL UNIVAC-1108 digital computer. It was designed to run under the Executive 8 monitor system at the Jet Propulsion Laboratory. Input data are read from card-to-tape - - - TAPE 5, digital output is written on tape for print out - - - TAPE 6. The code calls only standard library subroutines, such as transcendental functions. Although CUGEL is designed for the UNIVAC-1108 it may be readily adapted to CDC and IBM machines. It has a total word size requirement of less ~ than 65000.

The code consists of a main control program and thirty subprograms. A subprogram glossary is given in Appendix I, in alphabetic name order, and a code FORTRAN punch card deck listing in Appendix II. Appendix III consists of a sample input card deck listing and Appendix IV of a program output listing corresponding to the input given in Appendix III: the execution time for the sample data was approximately 70 seconds with compile and loading time being approximately 45 seconds.

The logic and function of the main program, referred to as MAIN, and its subprograms are discussed in Section 2.2, in some detail. Those subprograms not discussed are considered as being adequately described in either Appendix I or references (1) through (4). The user is also referred to these same references for the theoretical bases of the precursor code, CUPED. The constants required by the code are explained in Section 2.3. Reference to this Section will allow the user to make changes as necessary, in for example, the relationship of such as the detector system photopeak resolution function. The general logic of code CUGEL is discussed in Section 3.1. The code input is detailed in Section 3.2, and the output is defined in Section 3.3. FORTRAN names and variables are shown capitalized in what follows, with 'zero' and 'oh' thus: 0, Ø.

2.2 CODE LOGIC

2.2.1 MAIN PROGRAM

The main program was designed to execute data input and output operations, many of them under initially input option signals, and provide the control connectivity for the hierarchy of thirty subprograms presented in Figure 1. Figure 2 shows a simplified flow diagram of the main program; the called subprograms are:

RESFUN	GANE	DEC	DISCRT
SØLN	DECAY	GEØMTR	DETECT

Subprogram RESFUN is called by MAIN to generate and return the detector system response matrix and the associated vectors relating pulse-height to photon energy; photopeak-area-to-total-spectrum-area ratios (experimental photofractions, for code check purposes); and standard spectra photopeak mean pulse-height and resolution. Under control of an input option signal, the response matrix and its associated vectors may be read as a card deck, instead of generated. For the analysis of many sets of unknown spectra one response matrix may be applicable, and thus the main program includes an option to bypass either the calling of RESFUN or the input of a matrix card deck. For similar reasons an option is provided to call RESFUN to generate a response matrix based on previously input standard spectra.

Input options allow either the execution of MAIN to continue, return to start or call EXIT, after the calling of RESFUN. Thus, for example, the code may be run only for the purpose of generating a response matrix.

Unknown spectra may be input to the code in uninterrupted blocks of up to 20 spectra through the calling of subprogram DEC by MAIN. If pulse-height analyzer background subtracted counts are recorded in a complement mode, i.e. as positive numbers, the code converts them to true negative numbers in subprogram DEC. A count greater than 9×10^5 is assumed to be in the complement mode.

MAIN is coded to subtract background spectra from source-plus-background spectra under an input option control signal. This allows the subtraction or addition, of a fraction or multiple of a background spectrum. It further allows the continued reuse, as desired, of a previously stored background spectrum, and of course the addition of similar spectra if this is the requirement of the user.

The energy correspondence of an unknown spectrum to the response function matrix is matched through MAIN calling subprogram GANE(1,2,9,10). Subprogram GANE returns the unknown spectrum to the main program after normalization to pulse-height analyzer true zero pulse-height and gain changing such that channel width corresponds to that of the response matrix.

Additional automated modification of an unknown spectrum may be optionally carried out by the code, namely:

(a) the counts in the first n 'dead' channels of the spectrum may be replaced with either the count stored in channel n + 1 or determined by a straight line function of specified slope; and/or

(b) the counts between specified limiting channels may be replaced by counts determined by a straight line function of specified slope.

Item (a) allows the user to make judgments with respect to the first few percent of the spectrum which is often either suspect or electronically distorted. Item (b) allows the removal of a known spurious peak, etc. in order to allow more meaningful subsequent analysis to be carried out.

At this point in the main program on both the first and subsequent loops, the response matrix is stored, and an unknown pulse-height analyzer spectrum is ready for analysis and conversion to a photon number spectrum. According to an input option signal the code is instructed that the unknown spectrum is either a pure continuum or a specified number of monoenergetic spectra "super-imposed" on a continuous spectrum. If the input option indicates the presence of superimposed monoenergetic spectra and if either their line energies and/or photopeak tail channel limits are input, MAIN calls subprogram DISCRT prior to calling subprogram SØLN to carry out iterative unfolding of the continuum. In the event that neither the energies or channel limits of the unknown spectrum peaks are input they may optionally be 'searched-for' from channel MS to MX in subprogram FIND, which is called by DISCRT.

Subprogram DISCRT is called by MAIN to analyze the photopeaks indicated by the input options for the monoenergetic components of the unknown spectrum. Gaussian distributions may be fitted to each photopeak and the associated Compton continua determined by DISCRT calling subprogram RESFUN and the corresponding line photon numbers calculated. In this manner the monoenergetic spectral components may be calculated in turn and subtracted, i.e. stripped, from the unknown spectrum to leave a residual continuum spectrum. The residual spectrum is returned to MAIN for subsequent analysis and unfolding. The monoenergetic photon numbers thus obtained are added to the residual photon number spectrum determined later by unfolding, to give the total photon number corresponding to the input pulse-height analyzer spectrum. If the photopeak is distributed over less than 6 channels a Gaussian function will not be fitted. In this last event the peak pulse-height and area will be obtained by moments and channel summation analysis, respectively.

Before calling subprogram SØLN the code tests certain input options, M(I), to determine specific requirements, e.g.

(a) is unknown spectrum to be corrected for detection efficiency by calling subprogram DETECT prior to gain changing, (eg. from 200 to 30 channels) and before unfolding or after?; or

(b) is unknown spectrum to be actually unfolded?

Item (a) allows the user to make decisions with respect to efficiency correction effects and accuracies. Item (b) allows the user to make decisions with respect to such as the significance of actually carrying out the unfolding procedure on a low energy spectrum such as that of Pm^{147}. The above options and all others, are defined in more detail in Section 3.2. The called subprograms RESFUN, DISCRT, DETECT, SØLN and GEØMTR are discussed further in Subsections 2.2.2 through 2.2.7.

At this point in the main program on both the first and subsequent loops, unknown spectra are considered as prepared for unfolding, and thus, they and the response matrix are communicated to subprogram SØLN. This subprogram is called by MAIN to control the iterative unfolding process according to the Scofield method(2,5,6) and to apply efficiency corrections. It returns the corrected photon number spectrum to the main program.

The main program calls subprogram DECAY to determine the primary source decay factor. Subprogram DECAY returns a correction factor by which the number spectrum is later multiplied. The calling of subprogram DECAY may be optionally bypassed, in which case a multiplying factor of unity is assumed.

Subprogram GE0MTR is called by the main program to apply the decay correction factor, carry out geometrical corrections, compute differential and integral photon number and energy distributions, and exposure dose.

Subprogram GE0MTR returns the final results to the main program for output, after which the code loops back along either paths 1,2, or 3, as shown in Figure 2. The code loops back along path 1 primarily to read new data pertaining either to the response matrix or to the control options or both. The code loops back along path 2 to read new data pertaining either to the unknown source or if the maximum number (20) of allowable passes along path 3 have been equaled; the second reason is dictated by either code DIMENSION or computer finite capacity. The code loops back along path 3 to read a new unknown spectrum

2.2.2 RESPONSE FUNCTION MATRIX

2.2.2.1 Response Matrix Generation

The detector system response function matrix is generated under the control of subprogram RESFUN. The subprograms called by RESFUN are namely:

SPNØRM POGELI BS XPLØT
ADPEAK GANE TE TA VECTMX

The main program supplies RESFUN with control parameters, and variables. RESFUN begins execution by input of a card deck of spectra of standard radioisotopes. The number of such spectra is equal to NSTAND, where NSTAND ≤ 9. This card deck is preceded by one parameter card containing information regarding the number of spectra in the deck (NSTAND) and the number of channels in the input standards (NXLIM). The single parameter card is followed by a card set of NSTAND spectra. Each spectrum is preceded by one parameter card and is input in order of energy ascendance. The parameter card for each spectrum contains the source identity, data regarding peak approximate locations and the deviation of the spectrum from true zero pulse-height, i.e. the ± normalizing spectrum shift required; further details are referred to Section 3.

The standard source spectra allowed by the code must be monoenergetic e.g.

Cd^{109} Ce^{139} Hg^{203} Cr^{51}
Mn^{54} Nb^{95} Sr^{85} Cs^{137}

Zn^{65} and Na^{22} are allowed if Sr^{85} has been input; Zn^{65} is preferred to Na^{22} because of the 0.51 MeV photopeak intensity relative to the high energy photopeak.

The code as presently designed also allows the inclusion of Co^{60} and 'hand' prepared monoenergetic spectra of higher energies, e.g. the sample data in this report includes a hand modified spectrum of Th^{228}.

According to an input option and after the first call, calling of RESFUN by MAIN allows the by-passing of input of standard spectra. This allows the code to generate a response matrix based on already stored and normalized standard spectra. Similarly subprogram DISCRT calls RESFUN to determine Compton continua based on already stored current standard spectra.

After spectral data is input to RESFUN, counts in the complement mode are converted to their true negative value. The spectra are shifted to true-zero pulse-height by the calling of subprogram GANE. Their order of input is established prior to the calling of subprogram SPNØRM for spectral normalization.

Subprogram SPNØRM is called by subprogram RESFUN to normalize the single-photopeak and Zn^{65} standard spectra with respect to photopeak area and pulse-height; photopeaks and source-characteristic X-ray peaks are subtracted. The multipeak spectrum of Co^{60} is normalized in RESFUN after the return from SPNØRM. The residual spectra determined by SPNØRM (and RESFUN in the case of Co^{60}) consist of Compton continua characteristic of the primary photon energy. X-ray peaks are optionally subtracted where they are not representative of the primary photon energy but rather of the radioisotope source. The 0.51 MeV component photopeaks and their Compton continua are subtracted for the same reason. Figure 3 shows a typical set of spectral continua in the energy domain 0.166 MeV to 2.615 MeV, normalized by subprogram SPNØRM as described in Section 2.2.2.2.

Subprogram SPNØRM returns the normalized differential standard Compton distributions to subprogram RESFUN. The energy ordered normalized continua are interpolated quadratically with respect to the energy axis of the desired response function matrix through subprogram RESFUN calling subprogram POGELI. The result of this interpolation consists of N(corresponding to the required matrix size) Compton continuum vectors normalized to unit photopeak area and pulse-height. Subprogram DISCRT similarly calls RESFUN to obtain interpolated normalized Compton continua over a required number of channels and at the specific energies corresponding to photopeak analysis.

Unit area and mean pulse-height Gaussian photopeaks are added to the interpolated differential Compton continua to give N (matrix size) complete spectra (matrix vectors). The peaks are computed through RESFUN calling subprogram ADPEAK. The Gaussian photon energy dependent standard deviation σ (E), is determined by interpolation of those values obtained by the earlier photopeak fitting. Subprogram ADPEAK computes a Gaussian photopeak histogram in accord with the methods described for Equation (4) in Section 2.2.2.3 of this report. The N determined unit size differential spectra are redistributed linearly in pulse-height as a function of photon energy. The redistribution is obtained through RESFUN calling subprogram GANE.

At this point in the subprogram RESFUN execution, a response function matrix has been determined. This matrix and its corresponding vectors for pulse-height photon energy and photofraction are returned to the main program. Figure 4 compares the photofractions of the response matrix vectors as determined by RESFUN with actual values separately determined for the standard source experimental spectra.

2.2.2.2 Spectrum Normalization

Subprogram SPN0RM normalizes the standard spectra input to RESFUN. It begins execution by carrying out necessary initializations. SPN0RM calls subprogram PKFUN to carry out a Gaussian fit to the spectral photopeaks. Subprogram PKFUN estimates the necessary initial values of the peak function parameters: straight-line-base slope and intercept, Gaussian photopeak standard deviation, area and mean pulse-height. Subprogram PKFUN returns the parameters of the fitted and subtracted photopeaks and the residual spectra to subprogram SPN0RM. Subprogram PKFUN calls subprogram STDFT3 to carry out the non-linear regression of the peak function. The peak function is obtained by STDFT3 calling subprogram FUNZ.

Subprogram SPN0RM uses the determined photopeak pulse-height and area parameters to normalize the continua of the standard spectra. A subtraction of the characteristic X-ray peaks is carried out in the case of those spectra where they occur. The 0.51 MeV photopeak and continuum of Sr^{85}, if it has been input, is employed to subtract the 0.51 MeV spectrum contribution of Zn^{65}. This operation requires both count and pulse-height gain normalization, the gain normalization being carried out through the calling of subprogram GANE.

The residual Compton continua are gain normalized to a photopeak pulse-height of N0RM (e.g. = 200) channels by the calling of subprogram GANE and count normalized to unit photopeak area by a division operation.

The resulting residual normalized continua are checked for negative count values, which are replaced by zero, and returned to the calling subprogram RESFUN. The fitted photopeak parameters are also returned to subprogram RESFUN.

The two-component spectrum of Co^{60} is normalized in RESFUN, although the photopeaks are subtracted under the control of SPN0RM. The normalization is actually carried out on the 1.33 MeV contribution only, the 1.17 MeV contribution being discarded. The 1.33 MeV continuum is obtained as the residual remaining in the input Co^{60} continuum after subtraction of the 1.17 MeV continuum. The 1.17 MeV continuum is obtained by an extrapolation in subprogram POGELI based on the three highest energy standard normalized continua (e.g. Cs^{137}, Mn^{54} and Zn^{65}). The 1.33 MeV residual continua so found is then normalized and included as a member of the previously determined set of standards. Figure 3 shows an example 1.33 MeV continuum and Figure 4 the photofraction determined by the code.

2.2.2.3 Photopeak Fitting

Subprogram SPN0RM calls PKFUN, which in turn calls STDFT3, to fit the photopeaks of the standard source spectra with a 'Gaussian-plus-straight-line-base' function. Under options discussed in Section 2.2.4., subprogram DISCRT calls STDFT3 to fit the photopeaks in the unknown spectrum with the same function. As presently coded PKFUN requires that only the standard source energy and the approximate peak location be specified by SPN0RM.

Initial estimates of the photopeak function parameters, which are regression fitted in STDFT3, are determined in PKFUN. The mean pulse-height parameter B (1) is estimated from the channel of maximum count in the vicinity of the specified approximate channel location of the peak. The standard deviation parameter B(2) , of the Gaussian, is obtained from the expression

$$B(2) = \sigma\,(B(1)/E)\ ,\ \text{channels}, \tag{1}$$

where

$$\sigma = 0.001536 \exp(0.395 * E),\ \text{MeV}, \tag{2}$$

and

E = photon energy corresponding to specific photopeak, MeV.

Figure 5 compares the above expression for σ with the regression fitted values obtained for the JPL standard spectra. The area parameter of the Gaussian B (3), is initially estimated from the expression

$$B(3) = H * B(2) * 2.35,\ \text{counts}, \tag{3}$$

where

H = count above straight-line-base in channel of maximum count i.e. in channel B (1),

2.35 = a Gaussian constant relating standard deviation to width at half of maximum peak height.

The photopeak base is taken as the straight line between the counts in the channels defined by $\left[B(1) \pm 6.0 * B(2), \text{rounded up or down to integer}\right]$.

Subprogram STDFT3 is called twice by PKFUN to fit the photopeaks of the standard source spectra. On the first call the Gaussian is fitted over the channel range defined by B (1) ± 6.0 * B (2), but since Ge(Li) photopeaks are quite assymetrical in comparison to those measured in NaI(Tℓ) spectrometry, the parameters determined on the first call are used as initial estimates for a second call. On the second call the photopeak is fitted with the Gaussian function from channel N1 to channel B (1) + 6.0 * B (2). N1 is taken as the lowest count channel satisfying, $N(0.8H) \geq N1 < B(1)$, where

N(0.8H) defines the channel < B (1) containing ≥ 80% of the count in channel B (1). In this manner the photopeak is systematically fitted with a Gaussian over the relatively symmetrically upper two-thirds of its extent. Appendix V shows sample residual counts for a number of the standard spectra after subtraction of the fitted Gaussian. The value of the count H, in the integer-B (1) channel is indicated. The residual can be seen to relatively consistent, especially in view of the limited number of photopeak channels over which the measurements were made.

Subprogram STDFT3 carries out the non-linear regression of the photopeak function. The logic of this subprogram is very similar to that of subprogram STDFIT, described in reference (4). The theoretical logic of STDFIT is given in Appendix VI; it is directly reproduced from reference (2) and is generally applicable to STDFT3. There are two major differences between the STDFIT and STDFT3 codes, the former is designed for a single Gaussian whereas STDFT3 is designed for n-Gaussians, although it is presently only 'DIMENSIONED' for two. The second major difference is that whereas STDFIT calls FUNUS to compute the photopeak function $f(x_i)$ to be fitted to the photopeak counts $y(x_i)$, STDFT3 calls FUNZ to determine $F(x_i)$, a histogram, where x_i is the mid-channel pulse-height and

$$F(x_i) = \int_{x_i - 0.5}^{x_i + 0.5} f(v)\, dv, \tag{4}$$

$$\simeq \sum_{j=1}^{m} f(v_j)\, \Delta v, \tag{5}$$

where

v = pulse-height variable of integration for channel x_i;

m = number of subdivisions of channel x_i

The above approach is necessary for Ge(Li) photopeaks because of the superior resolution as compared to NaI(Tℓ). A comparison of experimental and fitted photopeak distributions are given in Appendix VI.

2.2.2.4 Compton Continuum Interpolation

Subprogram POGELI quadratically interpolates or extrapolates normalized Compton continua. It is called by RESFUN for response matrix vector generation purposes and multipeak standard spectrum analysis. Actual quadratic interpolation is performed by function subprogram TE. For energies between zero and that of the lowest energy input standard, the interpolation is necessarily linear. The linear interpolation assumes, reasonably, that at zero energy the channel counts are also zero.

Although the interpolation is quadratic, the redistribution of the standards before and after interpolation is such that the method developed here is referred to as one of 'parts'. While code CUPED uses the 'method-of-three-parts' (11), CUGEL uses the 'method-of-two-parts'. This method divides the continuum into two characteristic regions: A) zero energy to Compton edge, and B) Compton edge to photopeak mean pulse-height. The mutual boundary of each region is overlapped for continuity reasons. The dashed curves in Figure 3 indicates the regional boundaries.

The major difference between the CUGEL and CUPED methods is in the handling of the backscatter peak, which is smaller but sharper in Ge(Li) than its counterpart in NaI(Tℓ). In code CUGEL, the backscatter peaks are subtracted from the main continuum, normalized and interpolated separately. The subtraction is done in subprogram FITLIN which is called by subprogram BS. The normalization is carried out in BS with respect to the standard of lowest energy; the interpolation is carried out in BBS. Where backscatter peaks are merged with the Compton edge, as in the case of Hg^{203}, a backscatter peak is interpolated and subtracted in subprogram BS to leave an unmasked Compton edge. Figure 6 shows the backscatter and Compton edge peak pulse-height as a function of photon energy. The merged-region is clearly seen in this figure to be defined as $0.24 < E < 0.34$, MeV.

Prior to interpolation (or extrapolation) the continuum regions A and B are aligned such that the regional boundaries on which the Compton edges lie are at the same pulse-height. Alignment is carried out with respect to the continuum of highest energy for the set of three standards in the quadratic, by the calling of subprogram GANE. The two interpolated components, A and B, are unaligned by gain changing to obtain the desired continuum. The pulse-height axis direction of region B is reversed for convenience during the whole operation, i.e. zero pulse-height is taken at the photopeak mean pulse-height. An empirically modified form of the Compton angular-energy relationship is used to aid in automatically locating the Compton edges and backscatter peaks.

POGELI returns the interpolated Compton continuum to the calling program, RESFUN. Figure 3 shows example Compton continua as determined by CUGEL; they can be seen to compare well with the normalized continua from which they were determined. The photofractions of Figure 4 also substantiate the interpolated continua.

2.2.3 Analysis of Monoenergetic Spectral Contributions

Subprogram DISCRT is called by MAIN according to an input option to analyze photopeaks and their associated Compton continua, in complex spectral distributions. Subprogram DISCRT will fit a 'single or double Gaussian-plus-straight-line' function to the photopeaks of a multipeak spectrum. It will subtract the fitted photopeaks and their associated continua to leave a residual continuous spectrum. In the case of no continuous component in the complex spectrum, the residual will, ideally, have zero intensity.

The code CUGEL user may optionally input either the energy of the photopeaks to be fitted in DISCRT, the photopeak fitting limits (channel numbers), request the code to search for peaks or alternately combine these three options. In the event that the energies of only certain peaks are known they may be input, while the remainder may be defined by fitting limits. The choice of energy order of monoenergetic peak analysis and spectral stripping is left to the user; the code permits a mixed order to be chosen.

In addition to fitting and subtracting the monoenergetic components of an unknown spectrum, DISCRT determines their corresponding efficiency-corrected detector-incident photon number. The thus determined photon number may be, optionally, either added to the continuous photon number determined by later unfolding or diverted for separate output. In this way the separated radiations can be studied, e.g. bremsstrahlung analyses may be carried out even though the subject source also emits monoenergetic photons.

Subprogram DISCRT begins execution by determining whether the photopeak fitting limits have been input to MAIN by the user or whether they are to be calculated. In the event that they are to be calculated, DISCRT begins execution by estimating their channel locations based on the peak input energies. It first establishes the approximate channel region of the photopeak. It then ascertains it more accurately for the approximated channel region by calling subprogram VECTMX to establish the channel of maximum count. The fitting limits are determined as a function of the photon energy dependent standard deviation. In the event that neither peak limits nor energies are input, DISCRT calls subprogram FIND to search for photopeaks. A check is made to ensure that all the limits determined are within the spectrum and that their domains do not overlap each other.

Subroutine FIND searches for peaks from channel MS to MX, excepting those channel regions where limits have been input. It will not examine spectral regions where the count is $<$ G. The logic of FIND consists of testing the count y_i in channel i against the count in channels i - 1 and i + 1, between channels N1 and N2, where N2 = N1 + II; II = 4 was found to work satisfactorily for all spectra tested. A peak is assumed if

$$Y_{N1} + T * Y_{N1}^{1/2} < Y_i > Y_{N2} + T * Y_{N2}^{1/2} \; ; \; N1 < i < N2, \qquad (6)$$

where

T = 6 to 10 and G = 100.0, were found to work satisfactorily for all spectra tested.

With the fitting limits established a single or double Gaussian distribution is regression fitted to each photopeak in turn providing the number of channels in the peak is greater than six. Actual photopeak function fitting is carried out by the calling of subprogram PKFUN. In the case of double or merged peaks, subprogram GUESS3 is called to estimate initial values of the Gaussian parameters. GUESS3 estimating is carried out using the general logic described in Section 2.2.2.3 for PKFUN.

In the event that the photopeak is distributed over six or less channels, the area and mean pulse-height are determined from the counts in excess of a straight line joining the counts in the limit channels and from the first moment of rotation, respectively.

The Compton continuum associated with each photopeak is determined by DISCRT calling subprogram RESFUN, which returns an interpolated continuum normalized with respect to a photopeak of unit area and pulse-height (NØRM channels). The continuum is then scaled and gain changed according to the determined peak area and pulse-height.

Gain changing is carried out through DISCRT calling subprogram GÀNE. The photopeak and Compton continuum are then subtracted from the unknown spectrum for each monoenergetic spectral component in turn to finally leave a continuous residual spectrum. If no continuous contribution was present in the unknown, then ideally a zero spectrum will result.

Prior to returning the residual continua to MAIN for iterative unfolding, DISCRT determines the photon number corresponding to each monoenergetic spectral component. This is done by computing the photofraction, P(E), the detector interaction efficiency, $\epsilon(E)$, and the attenuation term for air and other material interposed between the source and detector, k(E). The photon number is then determined from the relationship:

$$N(E) = \frac{\text{Photopeak Area (or Counts)}}{P(E) \cdot \eta(E)} \tag{7}$$

where

$$\eta(E) = \epsilon(E) \cdot k(E).$$

The corrections noted are carried out by subprogram DISCRT calling subprogram DETECT. N(E) is returned to MAIN to be optionally either added to the iteratively unfolded continuum number spectrum or to be output separately.

2.2.4 Spectral Unfolding

The reduction of pulse-height analyzer continuous spectra to photon number spectra and the application of efficiency corrections are carried out under the control of subprogram SØLN called by the main program. Subprogram SØLN begins execution by carrying out certain initializations after which it calls subprogram RESMAT to unfold the pulse-height analyzer spectra according to the Scofield method(2,5,6). The number spectra returned by subprogram RESMAT are corrected for efficiency by SØLN calling DETECT. The thus corrected number spectra are returned to MAIN. The remainder of this section describes the logic of the unfolding subprogram RESMAT and of the efficiency vector subprogram DETECT, AIRABS and ALUM.

Subprogram RESMAT unfolds the pulse-height analyzer spectra by solving the matrix equation (in matrix notation)

$$\vec{P} = \bar{\bar{R}}\,\vec{N}' \tag{8}$$

where $\vec{P}$ and $\vec{N}'$ are the m-dimensional vectors of the PHA spectrum and the efficiency uncorrected photon number spectrum, respectively, and $\bar{\bar{R}}$ is the m x m square response function matrix. Equation (8) is formally solved as

$$\vec{N}' = \bar{\bar{R}}^{-1}\vec{N} \tag{9}$$

where $\bar{\bar{R}}$ is non-singular and $\bar{\bar{R}}^{-1}$ is its inverse. Subprogram RESMAT executes equation (9) iteratively according to the Scofield method$^{(5,6)}$. Figure 7 shows a flow diagram of the iterative algorithm coded in subprogram RESMAT. Further details are referred to references (1-8).

The efficiency corrected photon number spectrum N, is determined from equation (9), as$^{(2)}$

$$\vec{N} = \bar{\bar{\eta}}^{-1}\vec{N}' \tag{10}$$

where $\bar{\bar{\eta}}$ is a diagonal efficiency matrix accounting for interaction efficiency and photon attenuation by detector cladding, air and aluminum interposed between the source and the detector active region. Subprogram SØLN calls subprogram DETECT which in turn calls function subprograms EFFIC2, AIRABS and ALUM, to determine $\bar{\bar{\eta}}$. SØLN then executes equation (10) and returns the determined photon number spectrum to MAIN. Figure 8 shows an example spectrum before ($\vec{P}$) and after ($\vec{N}$) unfolding.

Subprogram EFFIC2 determines the interaction efficiency for the right-cylindrical Ge(Li) detector exposed to an axially located source of photons of energy E, as$^{(2,12)}$

$$\epsilon\,(E,r) = \frac{1}{\Omega} \int_{\text{detector}} (1 - e^{-\mu(E)x})\, d\,\Omega \tag{11}$$

where

$\mu(E)$ = total linear attenuation coefficient of Ge(Li) for photons of energy E (excluding coherent scattering)$^{(13-17)}$, x = photon vector path length in the detector prior to interaction,

r = source-to-detector distance,

Ω = the solid angle subtended at the source by the detector.

Equation (11) may be rewritten in a form more suitable for solution, as (2,18)

$$\epsilon(E,r) = \frac{\int_0^{\alpha_1}\left[1-e^{-\mu(E)\, H \sec\alpha}\right]\sin\alpha\, d\alpha + \int_{\alpha_1}^{\alpha_2}\left[1-e^{-\mu(E)\,(R_x \operatorname{cosec}\alpha - r\sec\alpha)}\right]\sin\alpha\, d\alpha}{\int_0^{\alpha_1}\sin\alpha\, d\alpha + \int_{\alpha_1}^{\alpha_2}\sin\alpha\, d\alpha} \qquad (12)$$

where

$$\alpha_1 = \tan^{-1}\left(\frac{R_x}{r+H}\right)$$

$$\alpha_2 = \tan^{-1}\left(\frac{R_x}{r}\right)$$

H = cylindrical length of Ge(Li) detector active region

R_x = cylindrical radius of Ge(Li) detector active region

The geometry for equation (12) is given in Figure 9.

In practice the source will have finite dimensions, but as long as they are relatively small, equation (12) is valid. The interaction efficiency for small line and disc sources relative to a point source may be estimated from reference (17). Equation (12) is evaluated by a numerical integration, which is carried out by subprogram SIMPSN, which calls function FC to determine the integrand. The photon flux incident on the crystal is corrected for air and aluminum absorption. This correction, multiplied by Equation (12), yields the diagonal efficiency-matrix η, as

$$\eta_{ij} = \epsilon\,(E_i, r)\,\exp\,(-r\,\mu_{air}\,(E_i)\,)\cdot\;\exp\,(-\ell\cdot\mu_{alum}\,(E_i)\,);$$

$$i = j = 1,\,2,\,\cdots,\,m, \qquad (13)$$

where

μ (E) = total linear attenuation coefficient of the material (air and aluminum per subscripts) interposed between source and detector for photons of energy E_i,$^{(13-17)}$

ℓ = thickness of the aluminum absorber material interposed between source and Ge(Li) detector, active region

m = matrix size.

In accord with input option signal m(19) $\neq 0$, the interactions efficiency given by Equations (12) and (13) may be bypassed and instead obtained from an empirical relationship as$^{(19)}$

$$\epsilon\,(E) = 0.441\,E^{-1.32}/P(E), \qquad (14)$$

The agreement between this equation and equation is seen in Figure 10.

2.2.5 Analysis of Unfolded Spectra

Subprogram GE0MTR is called by MAIN to carry out a final analysis on the unfolded photon number spectra. The spectra are corrected for primary source decay and converted by GE0MTR to differential photon number flux at the detector per unit time, $N_x(E)$, (coded as PHI), as

$$N_x\,(E) = \frac{N\,(E)}{\pi R_x^2} \quad , \gamma/\text{cm}^2 \text{ sec} \tag{15}$$

where

R_x = Ge(Li) crystal radius, cm.

The differential energy flux incident on the crystal per unit time, $I_x(E)$, (codes as ENXTAL), is determined as

$$I_x\,(E) = N_x\,(E) \cdot E,\ \text{MeV/cm}^2 \text{ sec} \tag{16}$$

The energy integrated exposure dose rate at the crystal, D, (coded as DOSDET), is determined as

$$D = \int_{\text{energy}} N_x(E)\ E\mu_{air}\ (E)\ K\, dE,\ \text{roentgens/hours} \tag{17}$$

where

$\mu_{air}(E)$ = energy mass absorption coefficient of air, cm^2/gm

K = conversion constant

= $3600/5.24 \times 10^7$, (roentgens-second-gm air)/
MeV-hour

The integration in equation (17) is carried out numerically by GE0MTR, as

$$D = \sum_{i=1}^{m} N(E_i)\, E_i\, \mu_{air}\, (E_i)\, K\, \Delta E_i \quad , \qquad (18)$$

The energy integrated photon number and photon energy flux at the crystal is determined by integrating N_x (E) and I_x (E) over E, (coded as SUMNUM and SUMENY); the units are γ/cm^2-sec and MeV/cm^2-sec. The following tabulated data are also determined by subprogram GE0MTR for output by the calling main program:

FORTRAN NAME	EQUAL TO	DEFINITION & UNITS
(AT THE CRYSTAL)		
AVENGY	$\frac{\Sigma N(E) \cdot E \Delta E}{\Sigma N(E) \cdot \Delta E}$	average energy, MeV
PHNUBE	$\frac{\Sigma N(E) \cdot \Delta E}{N_\beta}$	integrated photon number flux per beta source strength, (γ/cm^2-sec)/β/sec)/MeV; (N_β defined below)*
ENBENY	$\frac{\Sigma N(E) \cdot E \cdot \Delta E}{E_{\beta max}}$	integrated energy flux per beta maximum energy, (MeV/cm^2-sec)/MeV; ($E_{\beta max}$ defined below)*
PHENBE	$\frac{\Sigma N(E) \cdot \Delta E}{N_\beta}$	integrated energy flux per beta source strength, (MeV/cm^2 -sec)/(β/sec)*
DOXBEX	D/N_β	dose rate per beta source strength, (r/hr)/(β/sec); (D defined in equation)13)).*
(AT THE SOURCE)		
DOSCYL	$\frac{DOSBEX}{G}$	dose rate per beta source strength, (r/hr)/(β/sec); (G defined below)*

---

*Beta, N_{β_A} and $E_{\beta_{max}}$ are used in this section because of earlier bremsstrahling analyses; gamma (γ) may be the substituted meaning where it applies.

DCYVOL	DOSCYL Source Volume	dose rate per beta source strength per cm^3 of source volume, = DOSCYL/cm^3

where

$E_{\beta_{max}}$ = maximum beta (or chosen γ) energy in MeV

= EBMAX of card ⑥ of report section 3.2*

N_β = number of source emitted betas or γ's per unit time

= (SBETA of card ⑥ of report section 3.2) $\div$ 3.7×10^{10}.**

and

$$G = \Omega_x/\Omega = 1/2(1 - r/(r^2 + R_x^2)^{1/2}) \tag{19}$$

where

Ω_x = solid-angle subtended by the crystal at the source geometric center,

Ω = total solid-angle at the source = 4 π steradian

r = source to crystal distance.

Subprogram GE0MTR returns all of the above data to the main program for output.

* if not meaningful to code user, then input as, EBMAX = 1.0

** if not meaningful to code user, then input as, SBETA = $1.0/(3.7 \times 10^{10})$.

2.3 Code Constants

In this section the origin and meaning of certain constants coded into CUGEL, are discussed. The discussion is carried through in alphabetic order of subprograms, except for General Discussion and MAIN which are presented first. Certain subprograms require no discussion.

General Discussions: Certain constant values appear periodically throughout CUGEL. The values 2.35482, 2354.82, 0.3989423 and 1.065 are Gaussian or normal distribution constants$^{(20)}$. The values 60 (minutes/hr and seconds/min) and 1440 (minutes/day) are clock time conversion constants. Other values are either obvious (e.g. $\pi = 3.14159265$) or constants unique to the code logic except as explained below.

MAIN: Certain constants required by CUGEL subprograms are coded in MAIN and communicated by COMMON/CNSTNT/. The constant TKLUM is the thickness of aluminum absorber in front of the Ge(Li) detector; it is presently coded as 0.9 cm for subprogram ALUM. The constants T 20 = 20.0, T 50 = 50.0 and T 01 = .0001 are used by the code if input (ON, HITMAX, EPS) left blank; this is discussed in Section 3.2. The constant T 1293 = 0.001293 is the density of air coded for subprogram AIRABS. The constants T 90 = 900000. and T100 = 1000000. are used by subprograms DEC and RESFUN for checking for spectral counts in the complement mode. The constants associated with UT at statement numbers 40 to 47 are explained in Section 3.2. The constant 3.7 E + 10 at statement number 128 + 1 is the conversion factor for Curies to disintegrations/second. IFIFTY = 50, is the maximum number of photopeaks allowed in the unknown spectrum. TEN and IFOUR = 10. and 4 are T and G of equation (6). T06 $= 10^{-6}$, is the integration criterion for function SIMPSN. NORM = 200, is continuum pulse-height normalizing constant for RESFUN. NLI = 800 and NLIMIT = 400 are related to allowed vector dimensions.

EFFIC2: The total (less coherent scattering) linear attenuation coefficients for Ge(Li) in cm^{-1} are stored in the R DATA Statement;(16) the corresponding energies are stored in the X DATA Statement. Ge(Li) density was taken as 5.32 gm/cc.

ALUM: The total linear attenuation coefficients of aluminum in cm^{-1}, are stored in the R DATA Statement;(18) the corresponding energies are stored in the X DATA Statement.

FITLIN: The constants 5, .5, and 12.0 are associated with the fitting of a straight line base under the backscatter peak based on the six channels on either side of the defined peak region.

AIRABS: The mass absorption coefficients of air are given in the A DATA statement in cm^2/gm.(13) The coefficients include coherent scattering; the corresponding energies are stored in the X DATA statement. They are multiplied by the density of air (T 1293) in gm/cc to give output units in cm^{-1}.

DOSE: The energy mass absorption coefficients for air are given as R in the DATA statement in cm^2/gm.(13) They are based at 20°C and a fractional weight composition of

Nitrogen	0.755
Oxygen	0.232
Argon	0.013

The energies corresponding to R are given the X DATA statement.

GEOMRT: The constant defined as CONST has been already discussed for Equation (17).

STDFT3: The constant EPS = .00001 (at statement 100 - 3), is the fitting criterion for the photopeak non-linear regression. The constant NI = 10 is a stopping criterion for non-linear regression in the event of a non-convergence.

DISCRT: The product of the constants 1.2 and 0.00128 has been defined as 0.001536 in Equation (2); the constant 0.395 has also been defined in Equation (2).

DECAY: The constant 1440 = the number of minutes in 24 hours.

SIMPSN: TMAX = 2048 is the maximum allowable number of integration increments.

RESFUN: The constants 0.75, 0.85, 0.80, 0.85, 178./200. and 105./200 are general empirical values associated with analyzing of the JPL Co^{60} standard spectrum supplied; they may be interpreted as fraction of photopeak pulse-height.

BS: The equation expressed by Statement 61, is for smoothening the standard spectrum in the region below the backscatter peak, when $E > 0.34$ Mev; the constants were derived from the JPL standard spectra. The equation expressed by Statement 62 + 1 allows the backscatter peak to be normalized with respect to the lowest input standard even though the backscatter peak may be merged with the Compton edge; the constants were derived from the JPL standard spectra. The constants 0.875 and 1.16 at Statement 70 + 4 and 70 + 5 were derived from the JPL standard spectra to define the backscatter peak region for analysis in the Compton edge merging region, 0.24 to 0.34 Mev.

3. CODE OPERATING INFORMATION

3.1 GENERAL

Code CUGEL is written in a generalized FORTRAN-V for the UNIVAC-1108. It may be readily run on other computers with sufficient core size; i.e., the present version requires ~ 50K words. There are no Sense Switch or special tape requirements. Input formats are standard FORTRAN-IV or V, as given in any UNIVAC, IBM, or CDC FORTRAN manual; the code has been designed with a view to ease of translation for use on other computers. Input/output tapes are presently coded as LI and LØ equal to 5 and 6, respectively, at the beginning of MAIN (statement 2602 + 5 and + 6). A code listing is given in Appendix II.

Figure 11 shows a general arrangement for the data input cards. Input card details, order, formats, restrictions and location are given in Section 3.2. Card numbers are encircled and defined in the order in which they are read by the code. A sample input listing is presented in Appendix III.

The code CUGEL input data card deck consists of twelve (12) types of cards, referred to as Card ① , Card ② , etc. If the type requires more than a single card, the reference is made to Card Set ○. Card ① is a single card, input only once. Cards ② ③ and ④ are single cards input at least once. Card set ⑤ ((5A) or (5B)) is input at least once in order to define the response matrix. If the user only wishes to generate a response matrix but not to apply it to any data, then no further input is required. If the matrix is to be applied to analyze unknown spectra, further input is required to define the spectral data and the required analysis.

Card set ⑥ consists of two cards which must be input to define parameters which are common to all PHA spectra in the PHA spectral data set (card set ⑫), e.g., source size, counting time, source strength, etc. Card set ⑦ must be input to define parameters unique to each PHA spectrum in the PHA spectral data set, e.g., zero shift required, subtract background or not, source-to-detector distance, energy calibration data, etc. Card ⑧ and card sets ⑨ through ⑪ are optional. Card set ⑫ consists of the unknown PHA-spectra to be analyzed and their PHA-background-spectra. The code will analyze spectra of up to 400 channels, although up to 1000 channels may be input and code gain-changed to 400 for analysis.

The optional cards are as follows: Card ⑧ is a single card to allow the user to study the iterative unfolding convergence, i.e., intermediate unfolding data is output. Card set ⑨ allows the user to replace undesirable peaks, prominences or spurious spectral counts with a straight-line shape. Card set ⑨ also allows the user to load initial spectral channels with a straight-line shape. Card set ⑩ allows the user to input the energy of photopeaks to be analyzed. Card set ⑪ allows the user to input the channel region of photopeaks to be analyzed. The input of both card set ⑩ and ⑪ allows the user to give the energy of certain peaks and the channel region of others. Card set ⑪ allows the user to input energy as well as channel domain for peaks, in which case the code will use the input energy as opposed to the code determined energy for such as efficiency calculations. This last is useful in applications where a prior knowledge indicates that the energy which the code would determine might not be precise.

The input of channel number values must be as recorded by the pulse-height analyzer. The code will change the input values in accord with requested shifts or gain changes. In Section 3.2, 'rounded-up' refers to the 'next highest integer value', i.e., 3.7 rounded-up is 4. The input order of card sets ⑦ , ⑨ , ⑩ , ⑪ , and ⑫ must correspond to the spectra of card set ⑫ .

The code output is reviewed in Section 3.3. Appendix IV is a sample output listing. It corresponds to sample input of Appendix III. Debug type output may be optained by input of M(8) = 8 on card ③ . The user is cautioned with respect to profusion of output under this option - - - a trial using sample data is recommended first.

3.2 Card Input Details

Card ① (one card; once only)

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
SET	1-10	F10.5	Total number of spectra to be unfolded by a code run (see index KK in Figure 2)
Card ② (single card)			
CASE	2-72 (column 1 for printer control)	A	User's problem description (alphanumeric)
Card ③ (single card) (See Figures 2 and 12 for additional M(I) details)			
M (1)	1-3	I3	Signal for routing after response matrix generation > 0 CALL EXIT = 0 Continue < 0 Return to READ card ②
M (2)	4-6	I3	= 0, use existing response matrix ≠ 0, generate new response matrix using existing standard spectra
M (3)	7-9	I3	If ≠ 0, read card ⑧ (iterative unfolding output signal)
M (4)	10-12	I3	If ≠ 0, read card set ⑨ (replace peak with straight line and/or "fill-in" initial NFILL channels)
M (5)	13-15	I3	If ≠ 0, by-pass RESMAT (unfolding) in subprogram SØLN (See Figure 12)
M (6)	16-18	I3	If ≠ 0, add photopeak contributions to iteratively unfolded continuous photon number spectrum
M (7)	19-21	I3	If ≠ 0, DISCRT called for mono-energetic contribution analysis.
M (8)	22-24	I3	Intermediate output (for de-bugging) if ≠ 0
M (9)	25-27	I3	If ≠ 0, the monoenergetic contributions determined by DISCRT are converted to photon flux, and output but they are not added to the unfolded flu

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
M (10)	28-30	I3	If ≠ 0, subprograms DETECT and SØLN are bypassed in MAIN. (See Figure 2)
M (11)	31-33	I3	If ≠ 0, the unknown spectrum is corrected for interaction efficiency before pulse-height gain change reduction (See Figure 2)
M (12)	34-36	I3	If = 0, call GANE before iterative unfolding (See Figure 2)
M (13)	37-39	I3	If 0, by-pass SØLN (See Figure 2)
M (14)	40-42	I3	If ≠ 0, by-pass DETECT (efficiency) in subprogram SØLN (See Figure 12)
M (15)	43-45	I3	If ≠ 0, assume efficiency vector elements = unity in subprogram SØLN (See Figure 12)
M (16)	46-48	I3	If ≠ 0, do <u>not</u> correct for source decay, i.e., assume decay factor = 1.0
M (17)	49-51	I3	If ≠ 0, output the PHA spectrum
M (18)	52-54	I3	If ≠ 0, bypass final result computations, i.e., bypass GEØMTR
M (19)	55-57	I3	If ≠0. Equation (14) used instead of equation (13).

NOTE: The choice of non-zero values required for M (I) is arbitrary, however, actual subscript index values will aid in identity, e.g., if M (7) ≠ 0 then input as = 7. Options M(19) to M(24) are spare.

Card ④ (single card; last 5 variables may be blank)

ELIMIT	1-10	F10.5	The energy of the upper edge of the response matrix highest channel (MeV); should correspond to unknown spectra to be analyzed. e.g. if unknown 400 channel spectrum has 2.615 MeV calibrating peak in channel 380, then ELIMIT = (400/380)*2.615 = 2.753 MeV

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
0JS0	11-20	F10.5	Loop limit; number of sets of source data (card sets ⑦ through , except ⑧ , before loopback to READ card ② .
0MM	21-30	F10.5	If < 0 READ a response matrix, (card set 5B), = 0 use already computed matrix. > 0 generate new matrix; call RESFUN. Choice of values are arbitrary, e.g. -1. and +1.
0N	31-40	F10.5	The size of the response matrix, i.e. number of channels; also the size of final flux spectra, ≤ 40.0.
HITMAX	41-50	F10.5	The maximum number of unfolding iterations; an even number such as 50.0 unless iterating output per M (3) required. ≤ 100.0.
EPS	51-60	F10.5	Convergence tolerance at which iteration will cease. e.g. .0001.
RX	61-66	F6.4	Radius of Ge(Li) active region (cm).
H	67-72	F6.4	Cylindrical length of Ge(Li) active region (cm).

NOTE: RX and H set equal to 1.63 and 3.1, respectively in two statements following read statement (in MAIN); if other values to be input, remove these statements.

Also,

Card ⑤

Card 5 refers to a deck of cards of which two kinds are allowable, namely: (5A) or (5B) .

Card set (5A) to be input, if 0MM > 0 (read by subprogram RESFUN to generate a response matrix).

Card Set (5B) to be input if $0MM < 0$ (response matrix input to program MAIN).

Neither set to be input if $0MM = 0$, i.e. a correct response matrix is assumed as existing in storage.

Card Set (5A) (Standard source spectra and associated parameters)

Card (5A) - 1 (single card) (See Figure 4)

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
NSTAND	1-5	I5	The number of standard source spectra.
NXLIM	6-10	I5	Number of channels in each standard spectrum.
NADD	11-15	I5	The number of standard spectra with energy, STDEN (J, 1) 1.33 MeV

Card Set (5A) - 2.1 (Single card preceding each spectrum) (See Appendix III)

ALABEL (I), BLABEL (I)	2-6	2A3	Standard source identity; user choice e.g. CS137.
STDEN (J, 1)	11-20	F10.5	Energy corresponding to standard source spectrum photopeak (MeV) (highest energy if two peaks, e.g. 1.33 for Co^{60} and 1.114 for Zn^{65}).
STDEN (J, 2)	21-30	F10.5	Energy corresponding to standard source spectrum photopeak (MeV) (lowest energy if two peaks, e.g. 1.17 for Co^{60} and 0.511 for Zn^{65}).
SHIFT (I)	31-40	F10.5	The channel location (±) of the standard spectrum true zero pulse-height. The code carries out a shift correction.
MENSJ	41-45	I5	Approximate mean pulse-height of standard source spectrum photopeak corresponding to STDEN (J, 1) (channel)
MS0	46-50	I5	Atomic number corresponding to standard source spectrum (e.g. 60 for Co^{60} and 203 for Hg^{203}).

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
MSXJ	51-55	I5	Replace region from channel MSXJ to MFXJ with straight line, e.g. use for removal of 0.073 MeV Hg^{203} X-ray (channel).
MFXJ	56-60	I5	Replace region from channel MSXJ to MFXJ with straight line, e.g. use for removal of 0.073 MeV Hg^{203} X-ray (channel).
MENCS	61-65	I5	Replace initial ENCS + 1 (channel).

Card Set (5A) - 2.2 (NXLIM/10 (rounded-up) cards); (See Appendix III)

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
R (1, 1)	1-7	F7.1	The count in the first channel of the first input standard spectrum.
R (2, 1)	8-14	F7.1	The count in the second channel of the first input standard spectrum.
⋮			
R (10, 1)	63-70	F7.1	The count in the tenth channel of the first input standard spectrum.
R (11, 1)	1-7	F7.1	The count in the eleventh channel of the first input standard spectrum.
⋮			
R (NXLIM, 1)	-	F7.1	The count in the MXLIMth channel of the first input standard spectrum.

NOTE: Repeat Card (5A) - 2.1 and Card Set (5A) - 2.2 for each standard source spectrum i.e. NSTAND times; the lowest energy standard must be input first and the remainder must be in energy ascending order (with respect to STDEN (J, 1)).

Card Set (5B) (Response matrix)

Card Set (5B) - 1 ((0N x 0N/5) Cards); ((R(J, I), I = 1, 0N), J = 1, 0N)

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
R (1, 1)	1-11	E11.4	Response Matrix Element 1, 1
R (1, 2)	12-22	E11.4	" " " " 1, 2

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
R (1, 3)	23-33	E11.4	Response Matrix Element 1, 3
R (1, 4)	34-44	E11.4	" " " " 1, 4
R (1, 5)	45-55	E11.4	" " " " 1, 5
R (1, 6)	1-11 (second card)	E11.4	" " " " 1, 6
⋮			
R (ØN, ØN)	45-55	E11.4	" " " " ØN, ØN

NOTE: The first ØN elements input represent the lowest energy matrix vector spectrum (analogous to a PHA spectrum); similarly, the second ØN elements, etc. The sum over each vector must = unity.

Card (5B) -2 (single card)

NSTAND	1-10	I10	Number of cards in 5B -3.
K	11-20	I10	Index of first non-zero increment in response matrix.

Card Set (5B) -3 (NSTAND cards)

(Photopeak calibration energies, pulse-heights and standard deviations e.g. from a previous RESFUN output.)

STDEN (1,1)	1-10	F10.5	First calibration energy (MeV).
PARAV (1,1)	11-20	F10.5	First calibration photopeak pulse-height (channels).
PARAS (1,1)	21-30	F10.5	First calibration photopeak Gaussian standard deviation (channels).
⋮			
STDEN (NSTAND,1)	1-10	F10.5	NSTAND calibration energy (MeV).
PARAV (NSTAND, 1)	11-20	F10.5	NSTAND calibration photopeak pulse-height (channels).
PARAS (NSTAND, 1)	21-30	F10.5	NSTAND calibration photopeak Gaussian standard deviation (channels).

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
Card ⑥ (two cards)			
First Card:			
BTAG, BTAGA	2-6	A4, A2	Unknown source identity (alphanumeric)
SBETA	11-20	F10.5	Unknown source strength (Curies); see page 27 footnote.
EBMAX	21-30	F10.5	Unknown source maximum or reference energy (MeV) (see page 27 footnote).
CYLDIA	31-40	F10.5	Unknown source cylindrical diameter (cm).
TH	41-50	F10.5	Unknown source half-life (optional units; see UT this card).
RUNS	51-60	F10.5	Number of spectra per unknown source data set, ≤ 20.0.
CHANLS	61-66	F6.0	Number of channels in unknown spectrum ≤ 400. If > 400, use CHANLS = 400 and refer to MNX (See next card)
UT	67-72	F6.0	Multiplier for TH: UT = 0.0; TH in years = 1.0; TH in seconds = 60.0; TH in minutes = 24.0; TH in hours = 365.0; TH in days (Values other than these will cause output of error flag followed by CALL EXIT)
Second Card:			
M222	1-5	I5	The number of peaks to be fitted with a Gaussian for which channel limits must be input (per card set ⑪) ≥ 20-M66; See card set ⑩ note.
M66	6-10	I5	The number of peaks to be fitted with a Gaussian for which only the energy is to be input (per card set ⑩); ≥ 20-M22.

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
MZ	11-15	I5	The number of channels, in each unknown spectrum, which are to be loaded with zero counts (beginning at channel 1).
MNX	16-20	I5	Unknown spectra of MNX channels may be input to code
MBX	21-25	I5	Same as MNX, except that it refers to background spectra.
MSM	26-30	I5	If ≠ 0, smooth spectra before analysis; use 1.0 or 2.0 for single or double smoothing pass by subprogram GANE.
MS	31-35	I5	Subroutine FIND will "search" for peaks from channel MS to MX.
MX	35-40	I5	Subroutine FIND will "search" for peaks from channel MS to MX.

NOTE: BTAG/BTAGA, SBETA and EBMAX may be 'blank', 1.0 and 1.0 respectively, if not known prior to analysis. Actual values are used only for normalizing in subprogram GE0MTR prior to output of analysis results; see page 27 footnote.

Card Set ⑦

"Number of cards in set ⑦" = RUNS. Input of card I = 1 detailed below, cards 2 to RUNS similar. Card order must correspond to related pulse-height analyzer unknown spectra, I ≥ 20.0.

If number of channels in the unknown spectrum is > 400 then specify the value as MNX and input CHANLS = 400 (see last card).

DOST (I)	1-10	F10.5	Distance from unknown source to front face of Ge(Li) active region (cm).
DELT (I)	11-20	F10.5	Live time counting duration for unknown spectrum (minutes).

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
TM1 (I)	21-30	F10.5	Time duration from reference time to start of counting (days).
TTZ (I)	31-40	F10.5	Pulse-height analyzer channel location of true zero pulse-height (channels).
BK (I)	41-50	F10.5	BK (I) times a background spectrum may be subtracted from the unknown spectrum (if BK (I) negative, then is added).
BNBK (I)	51-60	F10.5	Background spectrum signal: < 0 subtract previously stored background = 0 no background > 0 read and subtract backgroud Background spectra are read following unknown spectra with which they are associated.

<u>Card ⑧</u> (one card input if M (3) ± 0)

This card may contain up to 18 integer numbers to define the interating or unfolding loop at which intermediate output is desired. ≥ eighteen indices may be input. The card format is 18I4.

Example:

MN (1)	1-4	I4	Iterating loop index e.g. 3
MN (2)	5-8	I4	" " " e.g. 5
MN (3)	9-12	I4	" " " e.g. 9

will cause subprogram RESMAT to output on iterating loops 3, 5 and 9.

<u>Card Set ⑨</u> (RUNS cards (rounded-up) to be input if M (4) ‡ 0)

NIX (1)	1-5	I5	Replace a peak (or other prominence in spectrum 1 of card set ⑫ with a straight line from channel N1X (1) to N2X (1); the count rate in M1X (1) and N2X (1) are used to determine the slope and intercept of a straight line replacement.

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
N2X (1)	6-10	I5	See above.
NFILL (1)	11-15	I5	Replace in unknown spectrum 1 of card set ⑫ , channels 1 to (NFILL (1) -1) with a straight line of slope VAL (1) based on the count in channel NFILL (1).
VAL (1)	16-25	F10.5	Same as above.
N1X (2)	26-30	I5	Same as N1X (1) only for second spectrum.
N2X (2)	31-35	I5	Same as N2X (1) only for second spectrum.
NFILL (2)	36-40	I5	Same as NFILL (1) only for second spectrum.
VAL (2)	41-50	F10.5	Same as VAL (1) only for second spectrum.
• • • •			
N1X (RUNS)	-	I5	Same as N1X (1); for spectrum RUNS.
N2X (RUNS)	-	I5	Same as N2X (1); for spectrum RUNS.
NFILL (RUNS)	-	I5	Same as NFILL (1); for spectrum RUNS.
VAL (RUNS)	-	F10.5	Same as VAL (1); for spectrum RUNS.

NOTE: VAL (9) would be the fourth and last field of fifth card for RUNS = 9; the number of cards (≥ 10) depends on RUNS.

Card Set ⑩ (1 to 4 cards input if M6 ≠ 0)

This card set is input only when M6 ≠ 0. It must consist of M6/5 (rounded-up) cards corresponding to the number of unknown energy-specified peaks in the card set ⑫ spectra. Each card contains ≥ 5 photopeak photon energies corresponding to the unknown complex-plus-continuous spectrum to be analyzed. From one to 20(= M222) photopeaks may be energy specified per spectrum i.e. a maximum of 4 cards per spectrum.

EU (1)	1-10	F10.5	Energy of the first energy specified photopeak in card set 12 spectra (MeV).

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
EU (2)	11-20	F10.5	Energy of the second energy-specified photopeak in card set 12 spectra (MeV).
EU (3)	21-30	F10.5	Similar to above.
⋮			
EU (M6)	-	F10.5	Similar to above.

NOTE: The first photopeak in each spectrum is that of lowest energy with the remainder being in energy ascending order. The user is cautioned that peak channels may also be input instead or in addition, per card set ⑪ if M22 ≠ 0; M22 + M6 ≥ 20.

Card Set ⑪ (1*RUNS to 7* RUNS cards input if M22 ≠ 0) (See Figure 12).

This card set is input only when M22 ≠ 0. It must consist of (M22/3 (rounded-up) cards corresponding to the number of unknown channel-limit specified spectral photopeaks in card set 12 . Each card contains information for ≥ 3 photopeaks. The information advises the code of whether peak is a single peak or is instead one of a pair, of the upper and lower fitting limits (channels) and of the energy if it is not known.

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
NJ (1)	1-4	I4	Signal for first channel-limit-specified peak of set ⑫ spectra: = 1, if a single peak = 2, if one of two peaks in a pair.
NSS (1)	5-8	I4	Channel number defining fitting limit on low energy side of first channel-limit-specified peak, i.e. fit peak from channel NSS (1) to NFNN (1).
NFNN (1)	9-12	I4	Channel number defining fitting limit on high energy side of first channel-limit-specified peak, i.e. fit peak from channel NSS (1) to NFNN (1).
EU (1)	13-20	F8.4	Energy of first specified peak (MeV).

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
NJ (2)	21-24	I4	Similar to NJ (1).
•			
•			
•			
EU (3)	53-60	F8.4	Similar to EU (1).
NJ (4)	1-4	I4	Similar to NJ (1).
•			
•			
•			
EU (M22)	-	F8.4	Similar to EU (1).

NOTE: The user is cautioned that peak energy data may also be input instead or in addition, per card set ⑩ if M66 ‡ 0; M222 + M66 ≥ 20. If M66 = 0 and M222 ‡ 0 then photopeaks data may be input in any evergy order; if M66 ‡ 0 and M222 ‡ 0 then input is expected in energy ascending order. Where data is input for double peaks NJ (I) and NJ (I + 1) = 2 and 0, respectively, then energy ascending order is expected if (I and I + 1) = 2 and 3, is given:

NJ (2)	NSS (2)	NFNN (2)	EU (2)	NJ (3)	NSS (3)	NFNN (3)	EU (3)
2	46	-	0.501	0	7	66	0.575

This specifies that the code shall carry out a double peak analysis between channels 46 and 66, that peak energies are 0.501 and 0.575 MeV and that the peaks are approximately 7 channels apart. The code analysis will determine the actual separation distance and thus 7 is given only as an estimate.

Card Set ⑫

The number of cards in this set = (CHANLS * RUNS/10.0 + the number of background cards if any)*. The cards will contain the unknown source spectra to be unfolded. The number of spectra which may be input is limited by the DIMENSION (20) = RUNS. The spectra, corresponding to card sets 6 and 7 , may be stacked together. A background spectrum, if input, must directly follow the unknown spectrum from which it is to be subtracted. Twenty unknown spectra, each followed by a background spectrum, are regarded as twenty spectra from the standpoint of 20 being the maximum number. Each spectrum contains CHANLS (or MNX) channels and background spectra must correspond*. Each card contains 10 channels of information. Thus, the following is typical of card set ⑫ as read by subprogram DEC:

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
S (1)	1-7	F7.1	Pulse-height analyzer count in channel 1.
S (2)	8-13	F7.1	Pulse-height analyzer count in channel 2.
S (3)	15-20	F7.1	Pulse-height analyzer count in channel 3.
⋮			
S (10)	64-70	F7.1	Pulse-height analyzer count in channel 10.
S (11)	1-7	F7.1	Pulse-height analyzer count in channel 11.
⋮			
S (CHANLS)*	-	F7.1	Pulse-height analyzer count in channel CHANLS.*

(last card in spectrum)

*For input purposes, if MNX > CHANLS then replace CHANLS above with MNX for unknown and MBX for backgrounds, i.e. CUGEL will read spectra up to 1024 channels in size (per MNX and MBX) but will immediately reduce them to CHANLS = 400, by DEC calling GANE.

3.3 CODE OUTPUT

Throughout the discussion in this section, reference to Appendix IV, Sample Code Output Listing, is necessary and understood. Those outputs which are clearly defined by format headings are either not discussed or are mentioned only briefly. Output pages are referred to through the encircled letters A, B, C, etc.

A. The values on this page are output by MAIN, and are as input on card sets ① to ④, with the exception of EM(=EN/ELIMIT).

B. The values on this page are output by RESFUN, and correspond to those standard source spectral parameters input on card sets (5A) -1 and -2. Indicated channel numbers are those values after shifting with respect to true zero channel has been carried out.

C. The values on this and following similar pages are the standard source spectral counts corrected for input in the complement mode and true zero channel. This output by RESFUN corresponds to card set (5A) -3 input.

D. The results of the Gaussian function regression analysis by STDFT3 for the standard spectra photopeaks are output on these two pages by SPN0RM. The output is for the two photopeak energies STDEN (I,1) and STDEN (I,2) and is otherwise self-explanatory.

E. The output on this and the following similar pages, by RESFUN, consists of the Compton continua of the standard source spectra normalized with respect to unit photopeak area and pulse-height. The integral normalized count for the continuum and photofraction are also output.

F. This page presents the response matrix generated by RESFUN and output by MAIN. It corresponds to that input which would be required for card set (5B) -1.

G. This page presents the energies (MeV), pulse-heights (channels) and photofractions corresponding to the generated response matrix, at increment midpoints, as determined by RESFUN and output by MAIN. The photofractions correspond to the folid curve in Figure 4. Standard spectra photopeak standard deviations in channels for unit pulse-height are also output.

H. The output on this page, by MAIN, corresponds to the input specified for card sets ⑥ and ⑦, excepting that the units in some cases are modified before output and are as indicated.

I. Optional output by MAIN giving the indices for which unfolding iteration output has been requested by input of card ⑧.

K. The output on this page by MAIN corresponds to the (first) spectrum to be analyzed and as input on card set ⑫. Background spectrum subtraction and complement mode correction is carried out before output.

L. Output of spectrum before entry to DISCRT.

M. The output on this page by DISCRT is self-explanatory and refers to the fitting of an monoenergetic spectral component of the unknown spectrum.

N. The output gives the PHA spectrum after stripping of photopeaks and associated continua by SINGLE; gain parameters for subsequent unfolding are also output. The optionally subtracted discrete peak photon number flux at the detector is also given.

O. The output on this page by MAIN corresponds to the unknown spectrum after gain changing and before unfolding analysis.

P. The output on this page by RESMAT is that requested by input of card ⑧. It consists of the gain changed unknown spectrum normalized to unit integral count; output at loop IT, corresponding to that requested (per MN), of the determined photon number spectrum (PHI) and the iterated input spectrum (PP); the iterated spectrum and the iteration convergence loop (IT), the normalizing integral count (SU); the final value of the iteration arresting criterion term (TERM = χ^2, Pearson's Chi Square); and the rate of convergence or fitting differences, during unfolding ($\Delta\chi^2$).

Q. The output on this page by DETECT is self-explanatory and consists of the components of the diagonal efficiency matrix, η, defined by Equation (13) of Section 2.2.4.

R. The optional output on this page by MAIN, consists of the efficiency corrected and unfolded spectrum after post-normalization.

S. The optional output on this page, by MAIN, is self-explanatory and consists of $N_x(E)$ and $I_x(E)$, as already discussed in Section 2.2.5.

T. The output on this page, by MAIN, is self-explanatory and consists of SUMNUM, SUMENY, D (Equation 14), AVENGY, etc., in order of, and as already discussed in, Section 2.2.5.

4. SUMMARY AND CONCLUSIONS

A FORTRAN-V, UNIVAC 1108 package code --- CUGEL, has been developed for the rapid analysis of complex gamma photon spectra. The code is readily applicable to the analysis of Ge(Li) semiconductor detector complex-continuous spectra. The response matrix generating portion of the code is suitable for use as a separate entity for problems in spectral analysis such as are frequently encountered in the various fields of gamma spectrometry.

The code employs an iterative unfolding method which has been used successfully by its authors: N. E. Scofield (5,6) and R. Gold, (7) by the present author (1-4, 18) and others. (8) While this method is necessarily approximate because of the iterative technique used, it is most suitable where continuous spectra are involved. It is suggested that degree of accuracy be the subject of future work, wherein the iterative method results would be compared with results obtained by other methods. The best value of the matrix size consistent with non-oscillatory good results and computer efficiency would be of interest here. The present contract did not allow for detail studies during the development of code CUGEL.

It is proposed that the response matrix generating portion of the code be made more versatile by studying the use of additional standard sources. A detailed debugging of the code in energy range 1.4 to 3.0 MeV was not possible because of the lack of standard spectra in this range.

It is proposed that standard spectra generated by the Monte Carlo technique be considered for energies in the range 3.0 to 10.0 MeV. NUS has developed such an NaI(Tℓ) scintillation detector code --- NUGAM-3 --- for NASA/GSFC under contract NAS5-11781. NUGAM-3 considers the crystal cladding and associated photomultiplier. A Ge(Li) code version may be efficiently adapted from NUGAM-3.

It is concluded that the developed code CUGEL is an operable and useful addition to the field or gamma photon spectrometry. It allows the semi-automatic generation of Ge(Li) detector system response function matrices, spectral unfolding process and final analysis of unknown complex-continuous spectra to be carried out in a single computer run; i.e., without human interfacing. It is very suited for modification to on-line applications.

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FIGURES

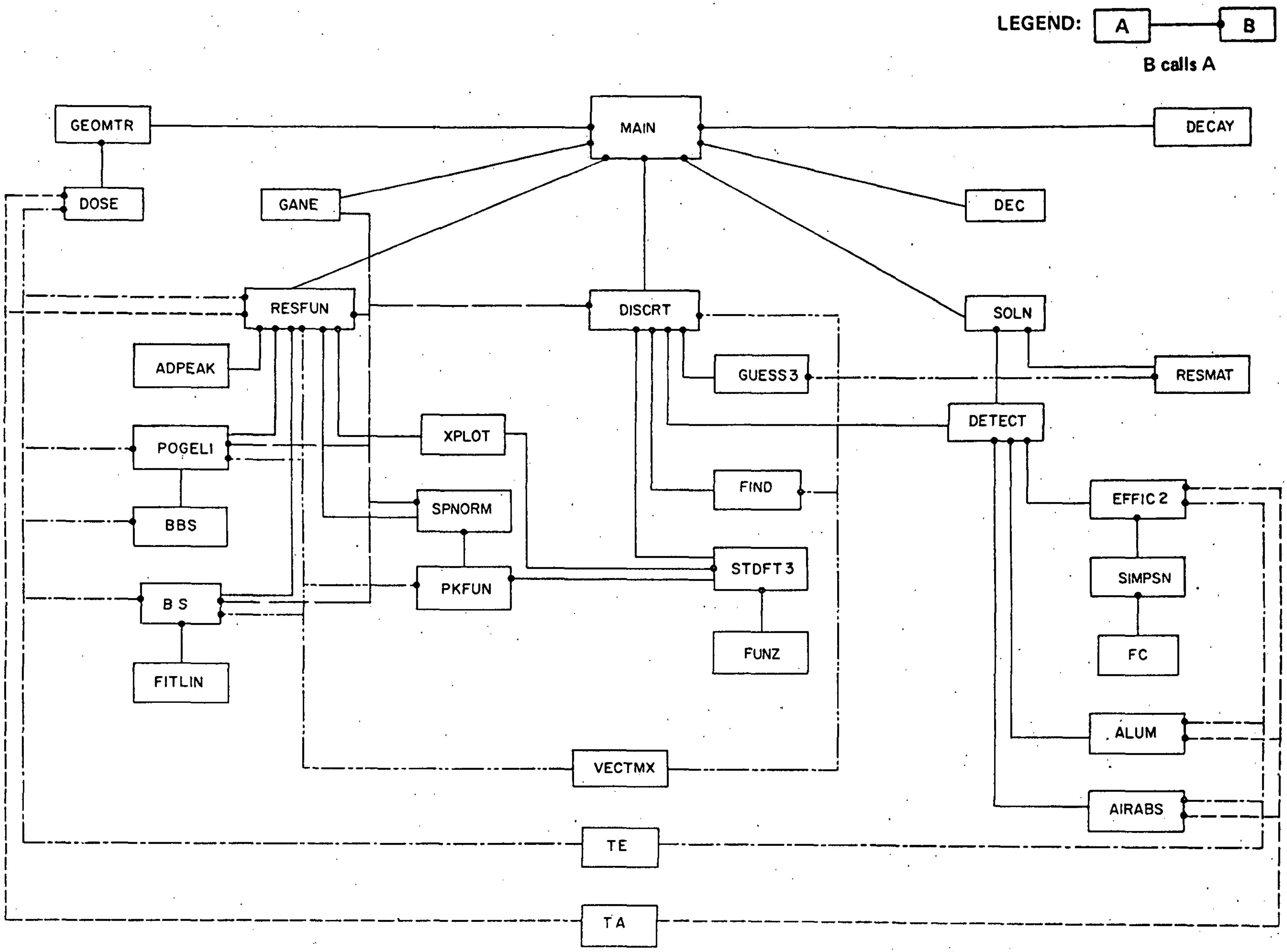


Figure 1
CODE CUGEL SUBPROGRAM CONNECTIVITY

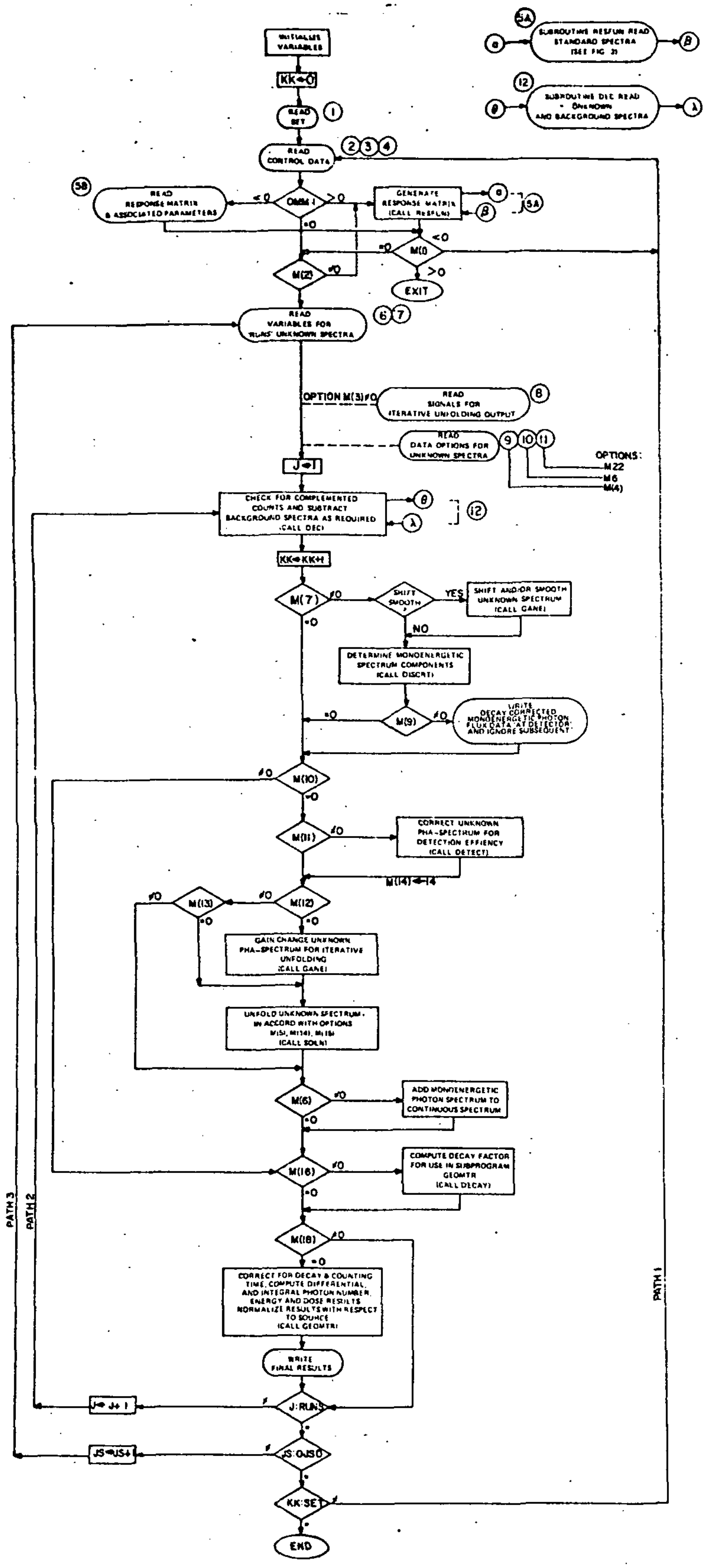


Figure 2

CODE CUGEL MAIN PROGRAM SIMPLIFIED FLOW DIAGRAM

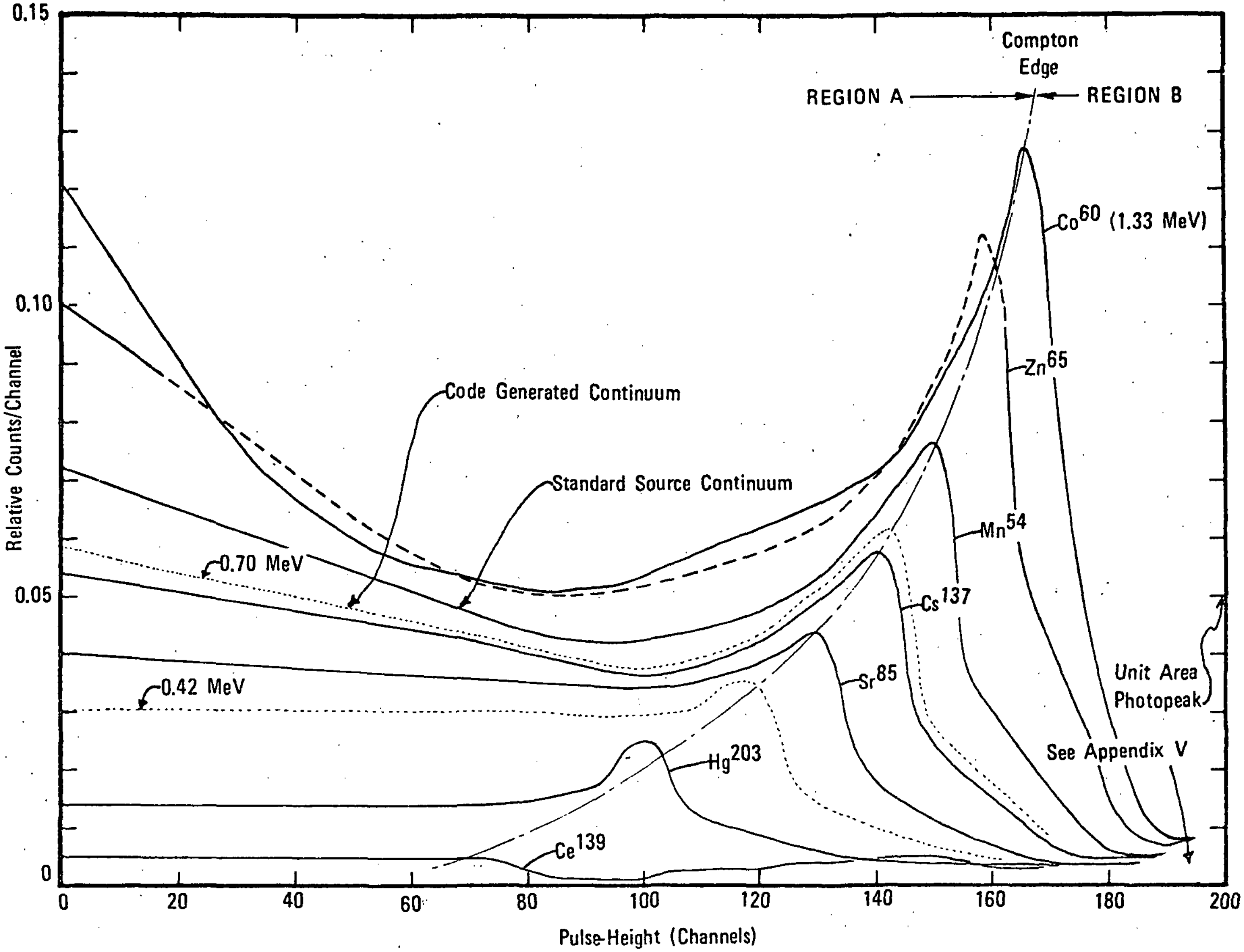


Figure 3

COMPARISON OF STANDARD SOURCE AND CODE GENERATED COMPTON CONTINUA, PULSE–HEIGHT NORMALIZED TO UNIT AREA PHOTOPEAK

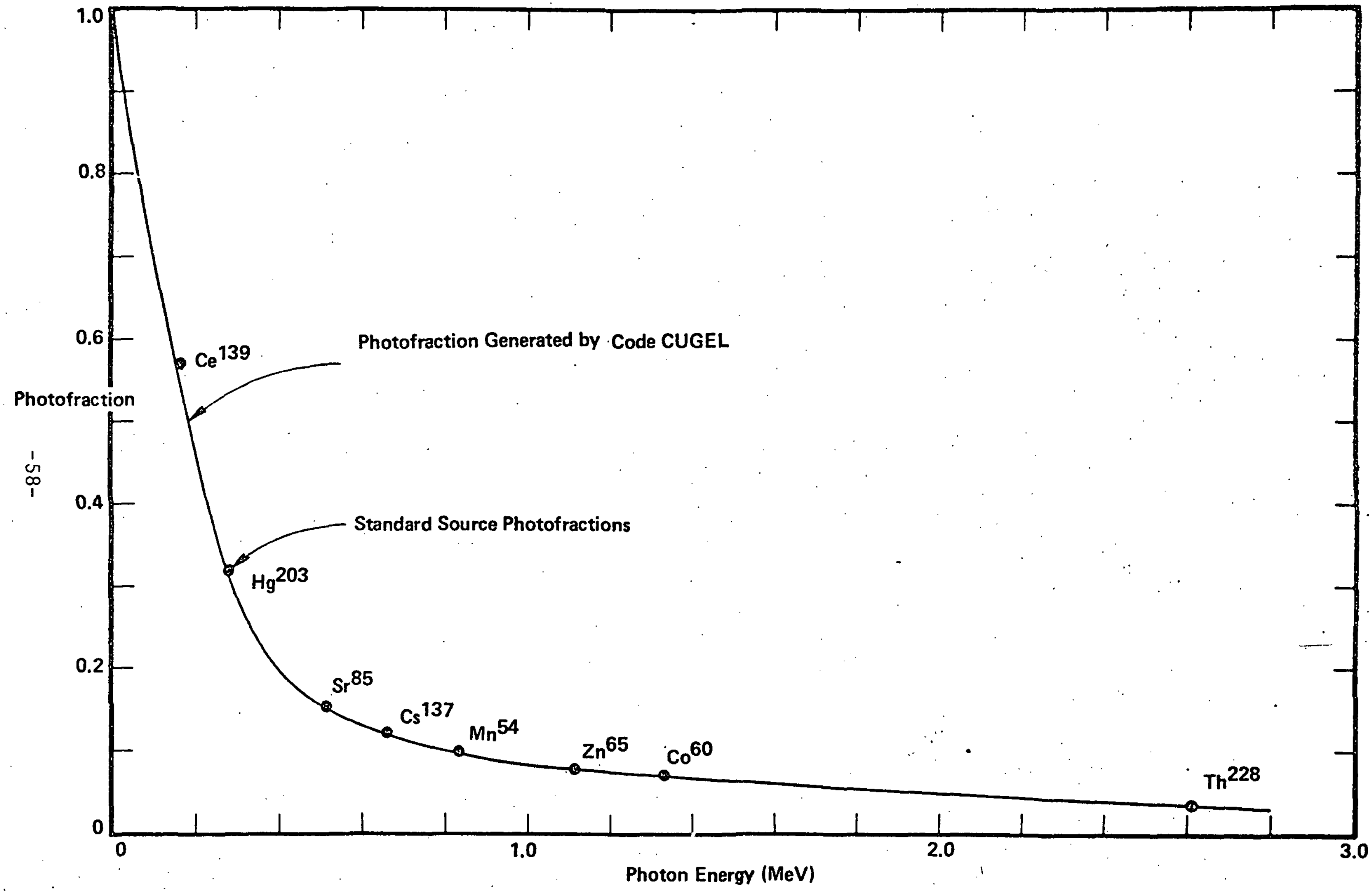


Figure 4

COMPARISON OF STANDARD SOURCE AND CODE GENERATED PHOTOFRACTIONS

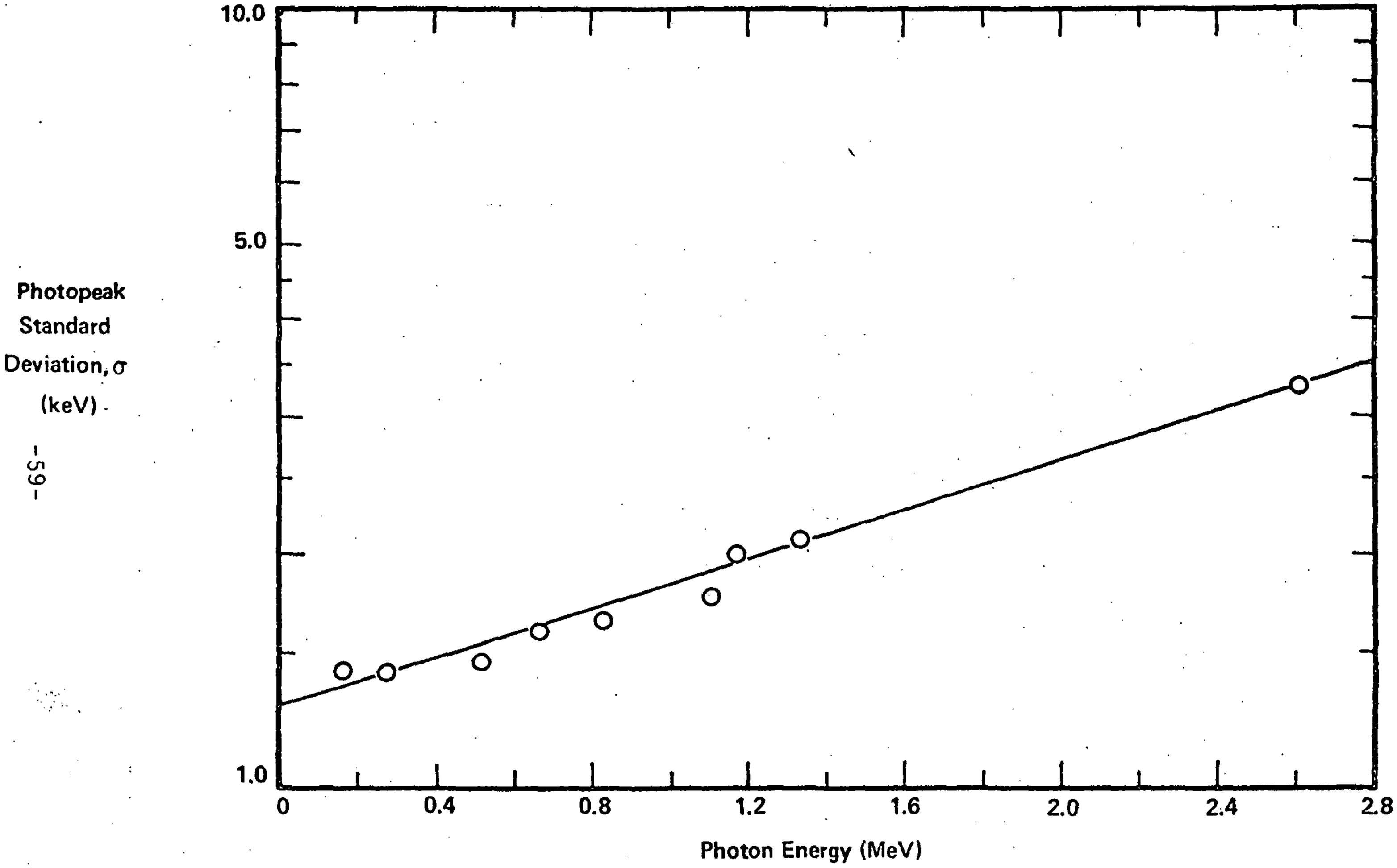


Figure 5
PHOTOPEAK STANDARD DEVIATION
FOR FITTED GAUSSIAN AS A FUNCTION OF ENERGY

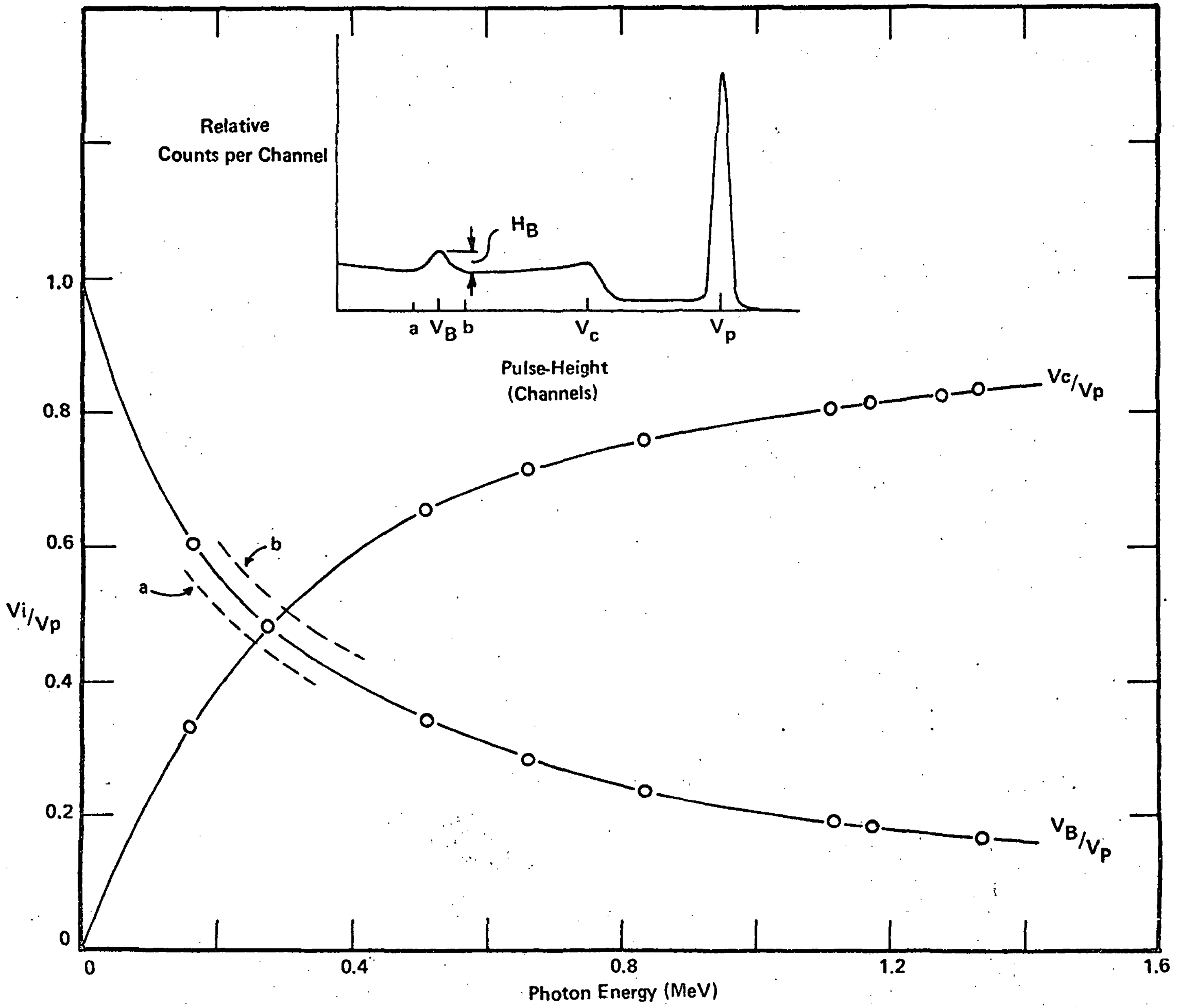
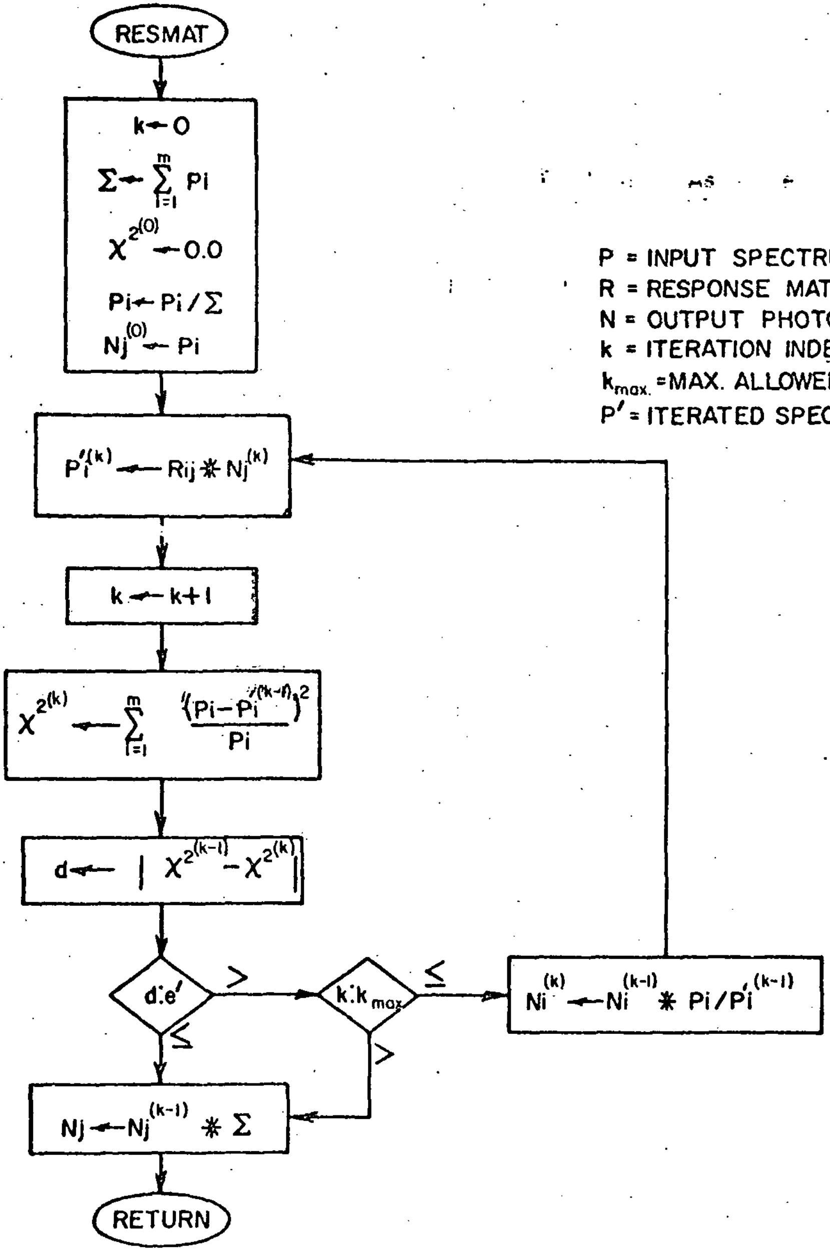


Figure 6
VARIATION OF COMPTON EDGE AND BACKSCATTER PEAK PULSE HEIGHTS (Vc and Vb) AS A FUNCTION OF PHOTON ENERGY



P = INPUT SPECTRUM
R = RESPONSE MATRIX
N = OUTPUT PHOTON SPECTRUM
k = ITERATION INDEX
$k_{max.}$ = MAX. ALLOWED ITERATIONS
P′ = ITERATED SPECTRUM ⇒ P

FIGURE 7

FLOW DIAGRAM SHOWING THE GENERAL LOGIC OF SUBPROGRAM RESMAT

FIGURE 8

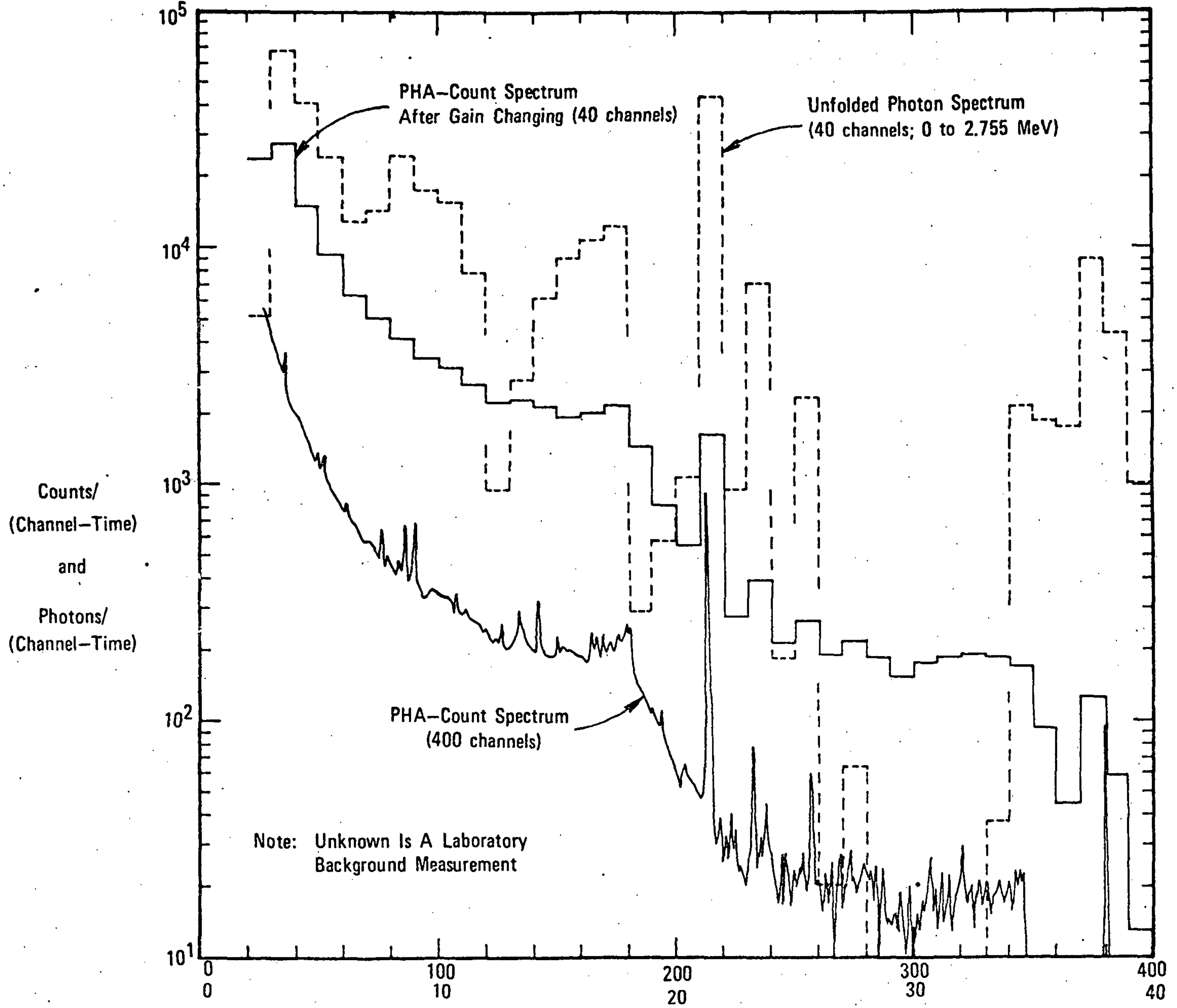


Figure 8

EXAMPLE UNKNOWN SPECTRUM

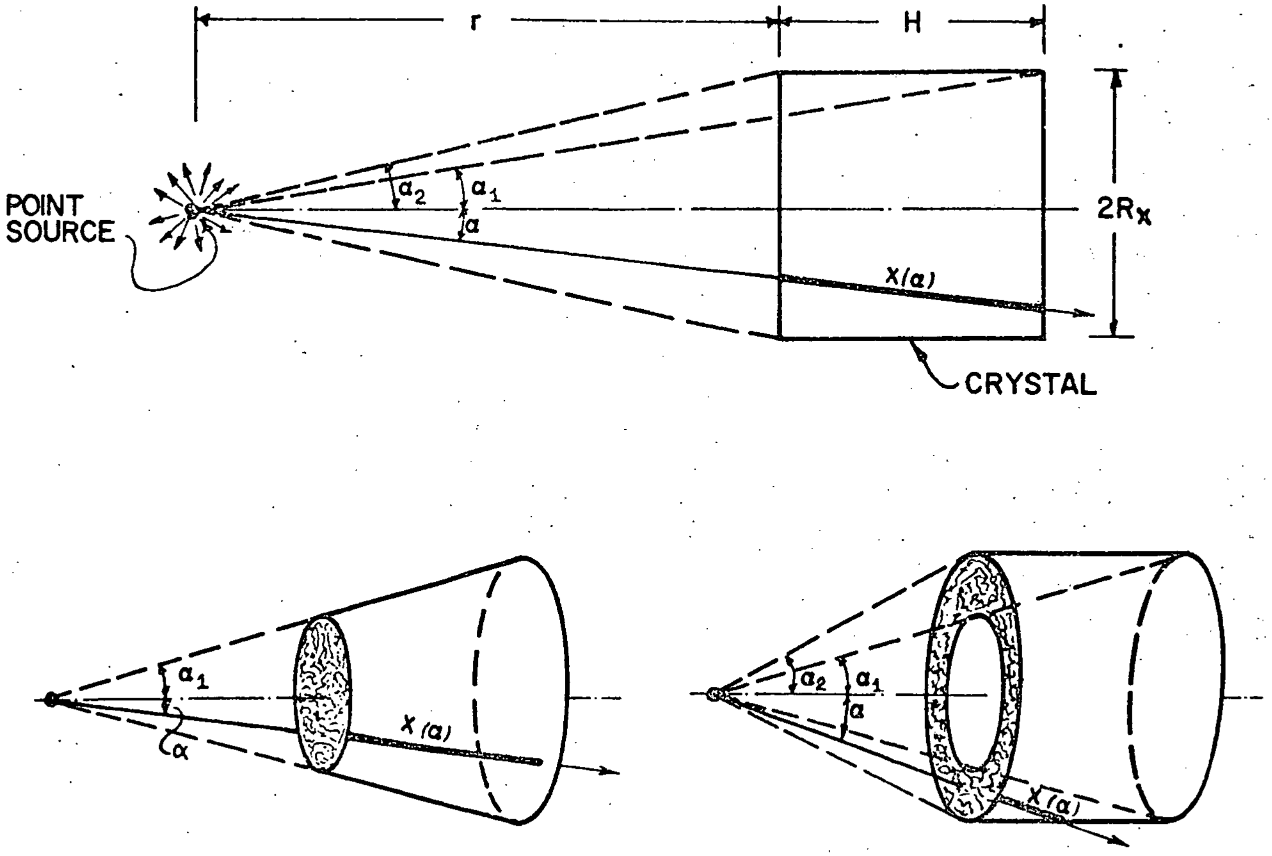


FIG. 9
GEOMETRY FOR EQUATION (12)

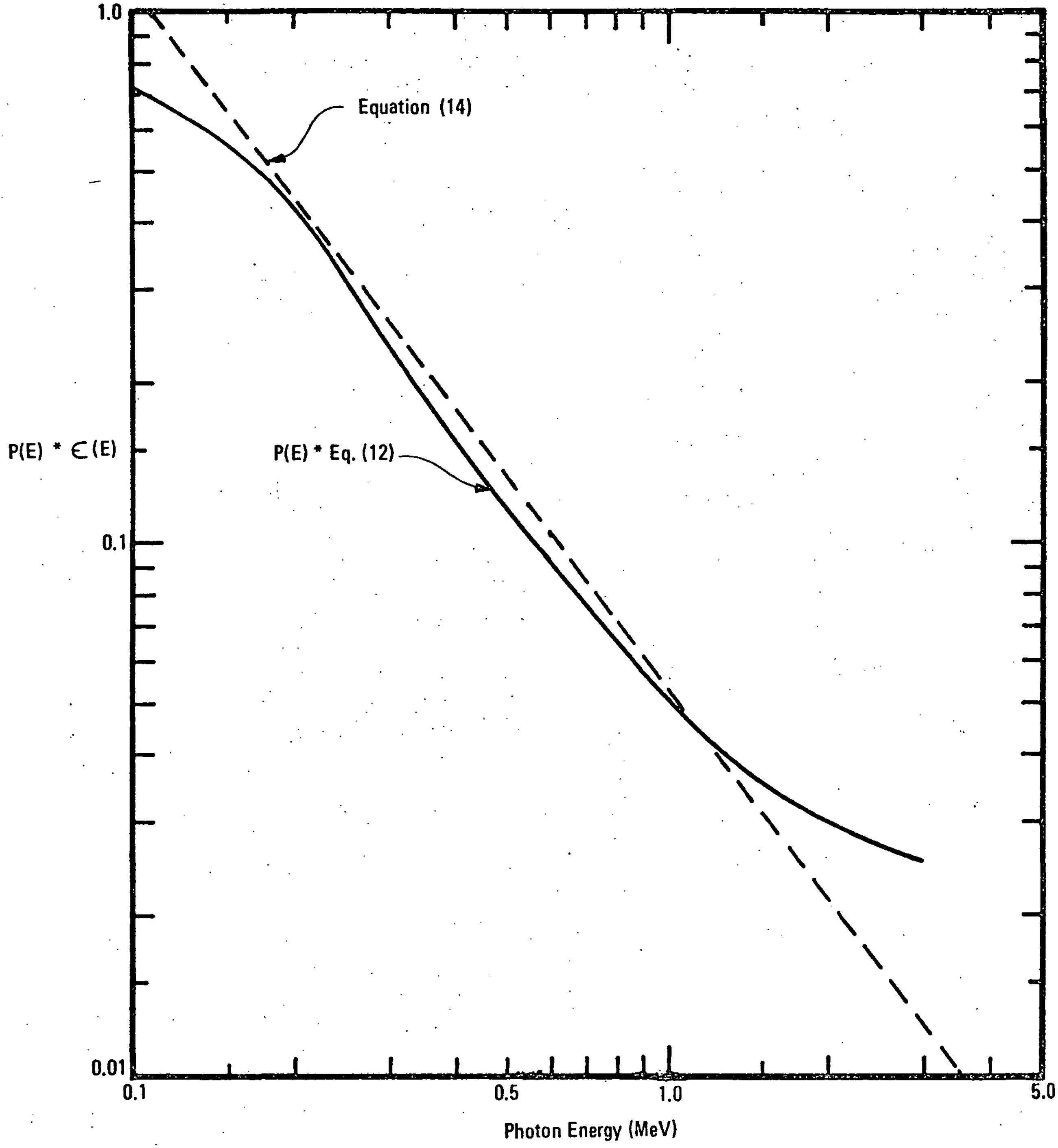


Figure 10

PHOTOPEAK EFFICIENCY (P * ∈) AS A FUNCTION OF PHOTON ENERGY

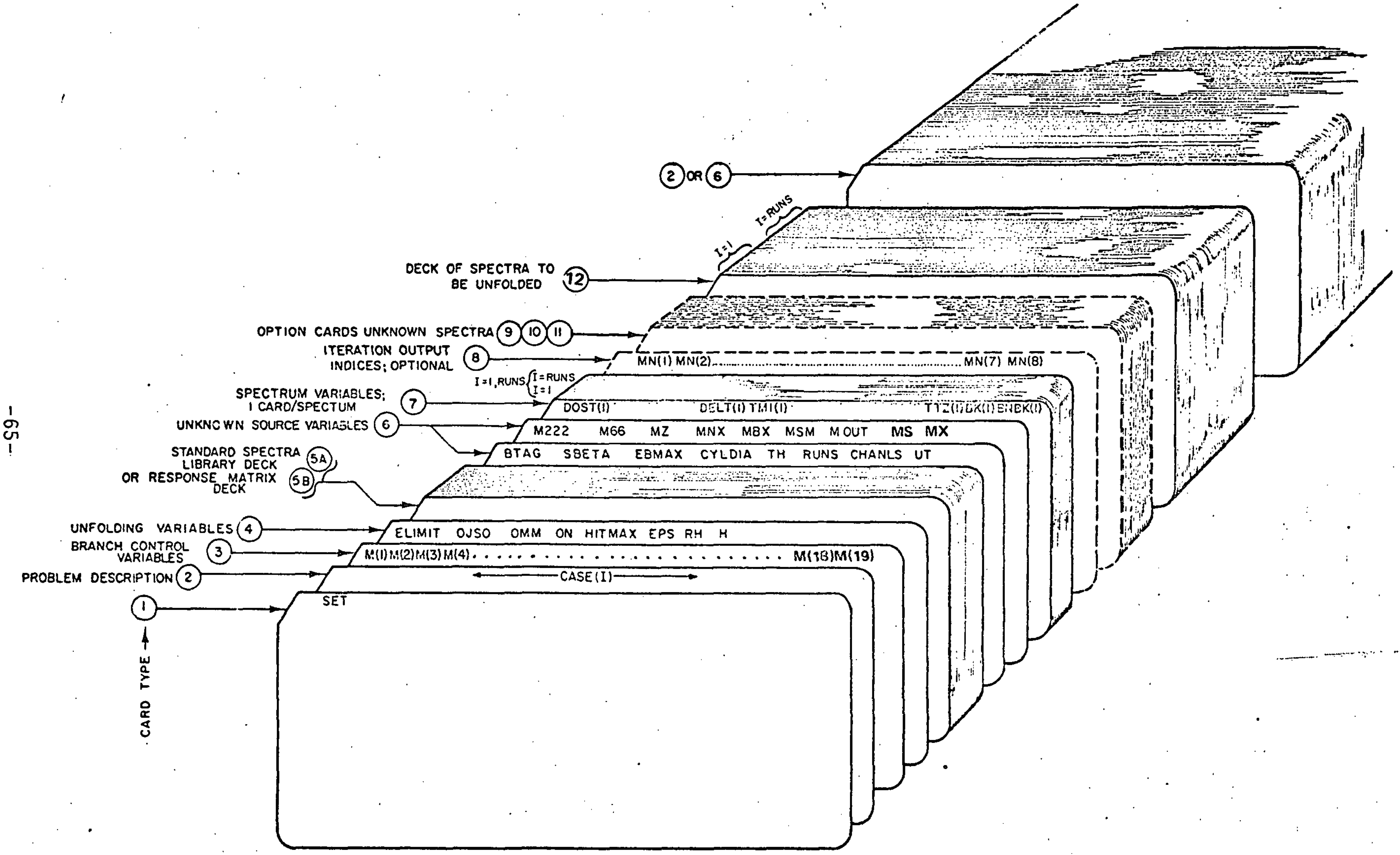


Figure 11

GENERAL ARRANGEMENT FOR INPUT CARD DATA DECK

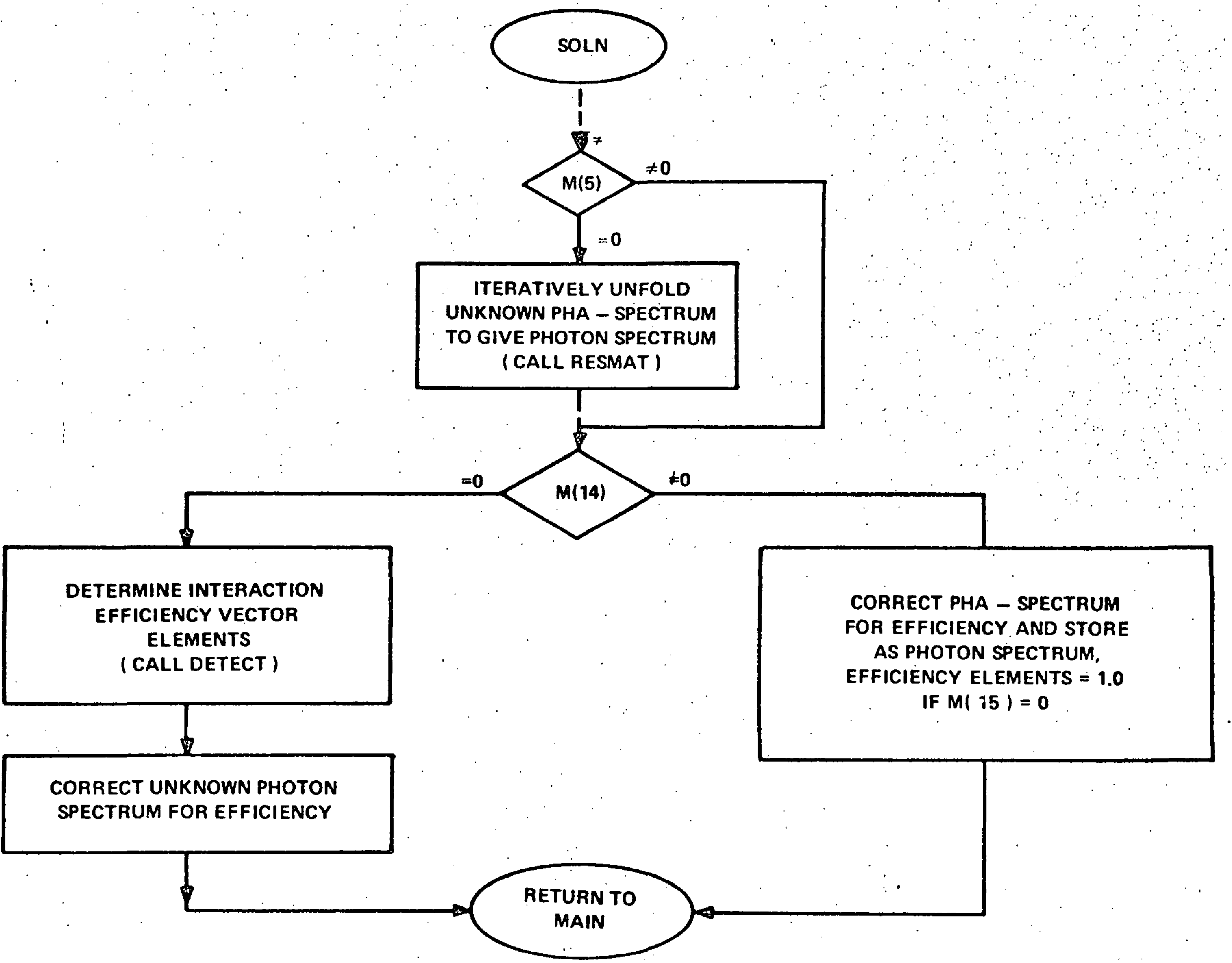


Figure 12
SUBPROGRAM SOLN SIMPLIFIED FLOW DIAGRAM

APPENDIX I

GLOSSARY OF SUBPROGRAMS

APPENDIX I

GLOSSARY OF PROGRAMS FOR CODE CUGEL

(In alphabetical order, except for MAIN)

NUMBER	NAME	FUNCTION or USE	
1	MAIN	Input, output and linking of subprograms.	
2	ADPEAK	Adds photopeaks to interpolated Compton continua.	
3	AIRABS	Computes air attenuation factor.	(F)
4	ALUM	Computes Ge(Li) detector aluminum absorber attenuation factors.	(F)
5	BBS	Interpolates normalized backscatter peaks.	
6	BS	Normalizes and subtracts backscatter peaks.	
7	DEC	Reads pulse-height analyzer spectra; checks for PHA-complemented counts.	
8	DECAY	Computes source decay correction factor.	(F)
9	DETECT	Controls computation of Detector total efficiency.	
10	DISCRT	Determines monoenergetic spectral contribution in unknown spectra.	
11	DØSE	Converts gamma photon flux to exposure dose.	(F)

NUMBER	NAME	FUNCTION or USE	
12	EFFIC2	Computes elements of detector interaction efficiency vector.	(F)
13	FC	Ge(Li) interaction efficiency function.	(F)
14	FIND	Determines location of photopeaks in unknown spectra.	
15	FITLIN	Determines continuum base for backscatter and photopeaks.	
16	FUNZ	Photopeak fitting function, partial derivatives and Chi-square term for STDFT3.	
17	GANE	Gain changing program; also spectral shifting and smoothing.	
18	GEØMTR	Computes geometry factors, integrates number and energy spectra and calculates normalized dose data for final code results.	
19	GUESS3	Provides initial estimates of the photopeak function parameter for non-linear regression analysis in subprogram STDFT3, for double peaks.	
20	PKFUN	Control program for photopeak fitting and subtraction.	
21	POGELI	Interpolates normalized Compton continua by the method of parts.	
22	RESFUN	Control program for response matrix generation.	

NUMBER	NAME	FUNCTION or USE	
23	RESMAT	Pulse-height analyzer spectrum unfolding according to the Scofield algorithm.	
24	SIMPSN	Simpson's rule integrating program for function FC.	(F)
25	SØLN	Control program for unfolding and detector efficiency correction.	
26	SPNØRM	Orders and normalizes standard spectra for response matrix interpolation.	
27	STDFT3	Non-linear regression analysis of standard spectra photopeaks.	
28	TA	Binary table searching program.	
29	TE	n-degree Lagrangian interpolation program.	(F)
30	VECTMX	Determines the index and value of the maximum valued element in a vector of elements.	
31	XPLØT	Plots spectral distributions.	

APPENDIX II

FORTRAN CARD DECK LISTING

```
[RUN,A ISWDC, IS040T,841E2I00102,10, 300'
[FOR,IS CUGEL
C  NUS CORPORATION (J.J.STEYN,U.BORN)              (1970) REF NUS
C                   *****MAIN PROGRAM*****
C**********  PROGRAM NUMBER -  1   CUGEL      ************
C                   *********************
C
C  CODE *CUGEL*....CODE TO UNFOLD POLYENERGETIC EXPERIMENTAL DISTRIBUTIONS
C
C  MAIN PROGRAM CONTROLS, INPUTS,OUTPUTS AND CONNECTS SUBPROGRAMS.
C
      DIMENSION CASE(18),M(24),R(40,40),FM(800),PFRACT(40),PV(40),Q(400)
     1,DIF(100),PHI(400),DOST(20),EU(50), DELT(20), EXX(12),      TM1(20)
     2,TTZ(20),MN(18)     ,ETA(400),ENXTAL(400),BNBK(20),B(400)
     3,QT(400),EUG(50),PHOT(50),BK(20),N1X(20),N2X(20),NFILL(20),VAL(20)
      COMMON/A/DI,H,MF
      COMMON/SOLRES/EPS,II,ITMAX,MN,DUM3(2),DIF,SIGMA(12)
      COMMON/SING/NJ(50),NSS(50),NFNN(50),GG,NSIN,IN,DIST,MS,MX,PHOT,
     1  M22,M6,BTAG,BTAGA,EUG,EU,M77,M267,IFIFTY,TEN,IFOUR,SLOP
      COMMON/SPCT/PP(1000)
      COMMON/GAN/NLI
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/FUN/DUMFUN(883),NUMFUN(4)
      COMMON/SPN/RDUM(4800),STDEN(12,2),BB(8),PARAV(12,2),PARAS(12,2),
     1SDUM(48),NSDUM(48),NSTAND
      COMMON/RES/R,N,EM,ELIMIT,NDEGRE,Q,PV,PFRACT,K,MRPEAT,ESING,MEM
      COMMON/CNSTNT/T01,T20,T50,T1293,T90,T100,T06
      COMMON/BS1/RVDUM(756)
      COMMON/OOORM/ORM,OORM
      COMMON/XLIM/NXLIM,IIDUM(17)
      COMMON/ B /BBDUM(5)
      COMMON/C/ SUMNUM,SUMENY,DOSDET,AVENGY,PHNUBE,ENBENY,PHENBE,
     1 DOSBEX,DOSCYL,DBXVOL,DCYVOL ,SBETA ,EBMAX ,CYLDIA
      NRU=20
      IFIFTY=50
      KS=0
      TEN=10.0
      IFOUR=4
      NLI=800
      DO 2602 I=1,756
 2602 RVDUM(I)=0.0
      NORM=200
      ORM=NORM
      OORM=ORM-0.5
      NLIMIT=400
      LI=5
      LO=6
      LP=7
      TKLUM=0.9
      T01=0.0001
      T20=20.0
      T50=50.0
      T1293=0.001293
      T90=900000.
      T100=1000000.
      T06=1.0E-06
      MRPEAT=0
      MF=0
      MM=1
      NS=1
      KK=0
      K=0
      NDEGRE=2
      NGD=1
      NGE=1
      NGC=1
      NGX=1
      NGA=1
      NGL=1
      DIF(1)=0.0
      READ(LI,27000)  SET
27000 FORMAT (F10.5)
      NSET=SET
    1 READ   (LI,1001)   (CASE(I),I=1,18),(M(I),I=1,24),
     1ELIMIT,OJSO,OMM,ON,HITMAX,EPS,RX,H
      RX=1.63
      H=3.1
 1001 FORMAT (18A4/24I3    /6F10.5,2F6.4)
      MOUT=0
      IF(M(8).EQ.MOUT)MOUT=1
C  INPUT CHECKING AND FILLING BLANK OPTIONS
      JSO=OJSO
      MM=OMM
      IF(ON)7709,7708,7709
 7708 ON=T20
 7709 N=ON
      IF(HITMAX)8809,8808,8809
 8808 HITMAX=T50
 8809 IF(EPS)9909,9908,9909
 9908 EPS=T01
 9909 ITMAX=HITMAX
      EN=N
      EM=EN/ELIMIT
      DXX=2.0*RX
      HXX=H
      WRITE  (LO,4001) (CASE(I),I=1,18),(I,M(I),I=1,24)
 4001 FORMAT (1H1,30H BRIEF DESCRIPTION OF PHA RUNS   /1X,18A4//
     116H CONTROL NUMBERS    /(6(3H M(,I2,4H) = I3,1X)))
      WRITE  (LO,4002) EM,ELIMIT,EPS,JSO,MM,ITMAX,N,DXX,HXX
 4002 FORMAT (    6H0EM =    ,F10.5,14H CHANNELS/MEV ,/9H0ELIMIT =,F10.5,
     1/33H0ITERATIVE ERROR TOLERANCE,EPS = ,F10.5,/36H0NUMBER OF BETA SO
     2URCE SETS,OJSO =    ,I3,5X,5HMM =  ,I3,/33H0MAX NUMBER OF ITERATION
     3S,ITMAX= ,I3,5X,/30H0NUMBER OF CHANNELS INPUT, N=  ,I3, /
     4  25H0NAI(TL) CRYSTAL SIZE =    ,F4.2,3H X ,F4.2,9H  (CM)     /1H1)
      JS=1
      IF(MM)120,21234,12
21234 IF(M(2)) 21244,2,21244
21244  MRPEAT=M(2)
      GO TO 12
  120 READ(LI,1966) ((R(I,J),I=NS,N),J=NS,N)
 1966 FORMAT (10F7.0)
      READ(LI,208)NSTAND,K,(STDEN(I,1),I=1,NSTAND),(PARAV(I,1),I=1,NSTAN
     1D),(PARAS(I,1),I=1,NSTAND)
  208 FORMAT(2I10/(3F10.5))
      DELQ=ELIMIT/EN
      DO 6619 I=1,N
      PV(I)=I-0.5
 6619 Q(I)=PV(I)*DELQ
      NSTAN=NSTAN-1
      KS=1
      GO TO 6691
   12 ESING=0.0
C
      CALL RESFUN
C
 6691 EXX(1)=0.0
      SIGMA(1)=0.0
      NSTAN=NSTAND+1
      DO 207 I=1,NSTAND
```

```
      II=I•1
      SIGMA(II)=PARAS(I,1)*OORM/PARAV(I,1)
  207 EXX(II)=STUEN(I,1)
      DO 212 I=NS,N
  212 QT(I)=Q(I)
      NP=N
  121 META=8
      MSKIP=1
      WRITE  (LO,2001)((R(I,J),I=NS,N),J=NS,N)
 2001 FORMAT (//34H1SYSTEM RESPONSE FUNCTION MATRIX  //(10E11.4))
      WRITE  (LO,2009)
 2009 FORMAT (1H1)
      WRITE  (LO,2000) (Q(I),I=NS,N)
 2000 FORMAT(49H REPONSE MATRIX ENERGY INTERVAL MIDPOINTS IN MEV
     1  //(10F7.4))
      WRITE  (LO,9876)  (PV(I),I=NS,N)
 9876 FORMAT (/////37H PULSE-HEIGHT IN CHANNELS (MIDPOINTS) //(10F7.2))
      WRITE(LO,30770) (PFRACT(I),I=NS,N)
30770 FORMAT (///32H RESPUNSE MATRIX PHOTOFRACTIONS   //(1X,10F7.4))
      WRITE(LO,2208)(I,EXX(I),SIGMA(I),I=1,NSTAN)
 2208 FORMAT(///
     1         37H   INDEX       ENERGY        STO. DEV  /(1X,I5,4X,2E14.7))
      WRITE  (LO,2009)
      IF(M(1)) 1,16,15
   15 CALL EXIT
   16 MM=0
    2 READ (LI,20000)BTAG,BTAGA,SBETA,EBMAX,CYLDIA,TH,RUNS,CHANLS,UT
     1,M22 ,M6 ,MZ,MNX,MBX,MSM ,MS,MX
20000 FORMAT (2A3  ,4X,5F10.5,2F6.0/8I5)
      NX=CHANLS
      NRUN=RUNS
C  HALF-LIFE CHECK
      IF(UT)41,40,41
   40 UT=365.25*1440.
      TH=TH*UT
      GO TO 50
   41 IF(UT-1.)43,42,43
   42 TH=TH/60.
      GO TO 50
   43 IF(UT-60.)44,50,44
   44 IF(UT-24.)46,45,46
   45 TH=TH*60.
      GO TO 50
   46 IF(UT-365.)48,47,48
   47 TH=TH*1440.
      GO TO 50
   48 WRITE  (LO,49) UT
   49 FORMAT (35H HALF-LIFE FACTOR ...ERROR... UT =  F10.5, 6H EXIT  )
      GO TO 15
   50 CONTINUE
      WRITE (LO,128) BTAG,BTAGA,SBETA,EBMAX,CYLDIA,TH,NRUN,NX,UT ,M22 ,
     2 M6 ,MZ,MNX,MBX,MSM,MS,MX
  128 FORMAT (1H1, 90H   GAMMA   SOURCE   REFERENCE  SOURCE   SOURCE
     1NUMBER OF    NUMBER      HALF-LIFE              /90H    SOURCE STRENG
     2TH   ENERGY   DIAMETER HALF-LIFE  PHA RUNS   OF CHANNELS  MULTIPLI
     3ER            /80H             (CURIES)     (MEV)      (CM.)  (MINUTES)
     4  THIS SET   PER SPECTRUM           //3X,2A3  ,3F10:4,E11.4,I6,8X,I4,
     55X,E11.4///////8X,75H M22          M6           MZ          MNX        MBX
     6          MSM          MS           MX               //2X,8I10, /////)
      SBETA=SBETA*3.7E•10
      DO 5007 I=1,NRUN
      DOST(I)   =0.0
      DELT(I)   =0.0
      TM1(I)    =0.0
      BK(I)     =0.0
      TTZ(I)    =0.0
```

```
 5007 BNBK(I)   =0.0
      READ   (LI,12000)(DOST(I)                       ,DELT(I),TM1(I),
     1                TTZ(I),BK(I),BNBK(I),I=1,NRUN)
12000 FORMAT ( 6F10.5)
      WRITE  (LO,127) (DOST(I)                        ,DELT(I),TM1(I),
     1                TTZ(I),BK(I),BNBK(I),I=1,NRUN)
  127 FORMAT (1H0,2X,71H  SOURCE       COUNTING     REFERENCE     SPECTRA
     1BACKGROUND  BACKGROUND  / 3X:71H CRYSTAL       DURATION          TIME
     2       ZERO          SIGNAL     MULTIPLIER  /
     33X,50H DISTANCE   (MINUTES)         (DAYS)         SHIFT             /
     42X,50H    (CM)                                   (CHANNELS)          /
     51X,(F10.5,5F12.5))
      WRITE  (LO,2009)
      ROGAIN=EN
      IF(M(3)) 333,444,333
  333 READ    (LI,555)   (MN(I),I=1,18)
  555 FORMAT (18I4)
      WRITE   (LO,556)   (MN(I),I=1,18)
  556 FORMAT (53H1ITERATING OUTPUT ON ITERATION LOOPS NUMBERED BELOW
     1///(1X,5I10))
      WRITE   (LO,2009)
  444 CONTINUE
 9111 DO 3200 J=1,NRU
      N1X(J)=0
      N2X(J)=0
      NFILL(J)=0
 3200 VAL(J)=0.0
      DO 32000 I=1,IFIFTY
      EUG(I)=0.0
      EU(I)=0.
      NJ(I)=0
      NSS(I)=0
32000 NFNN(I)=0
      IN=M6 •M22
 1119 IF(M(4)) 3205,3208,3205
 3205 READ (LI,3242)  (N1X(J),N2X(J),NFILL(J),VAL(J),J=1,NRUN)
 3242 FORMAT(2(3I5,F10.5))
      WRITE(LO,3243)  (N1X(J),N2X(J),NFILL(J),VAL(J),J=1,NRUN)
 3243 FORMAT(//44H CHANNEL AND SLOPE FOR DEAD CHANNEL FILL-IN
     1 /(2(2X,3I5,F10.5)))
 3208 CONTINUE
      IF(M6   ) 770,771,770
  770 CONTINUE
      READ(LI,700)  (EU (I)    ,I=1,M6 )
  700 FORMAT(5F10.5)
      WRITE(LO,701)(EU  (I)    ,I=1,M6 )
  701 FORMAT(35H0 ENERGIES IN MEV OF UNKNOWN PEAKS    ///(1X,4F10.5))
  771 IF(M22 ) 1494,1495,1494
 1494 M77=M6•1
      READ  (LI,1496)  (NJ(I),NSS(I),NFNN(I),EU(I), I=M77,IN)
 1496 FORMAT(3(3I4,F8.4))
      WRITE(LO,1490)  (NJ(I),NSS(I),NFNN(I),EU(I), I=M77,IN)
 1490 FORMAT(//14H  CARD SET 12  //(2X,3(3I4,F10.4)))
 1495 CONTINUE
C
C MAIN EXECUTION LOOP FROM HERE
C
      DO 500 J=1,NRUN
      KK=KK•1
      DIST=DOST(J)
      DT=DELT(J)
      TM=TM1(J)
      BKGD=BK(J)
      NBK=BNBK(J)
      N=NX
      JJ=J
```

```
      CLAMDA=ALOG(2.0)/TH
C
C
      CALL DEC (NX,FM,MNX)
C
      IF(NBK)6,22222,11
C
   11 CALL DEC (NX,B,MBX)
C
    6 DO 3 I=1,NX
    3 FM(I)=FM(I)-BKGD*B(I)
22222 CONTINUE
      WRITE(LO,25123) JJ,BTAG,BTAGA,(FM(I),I=1,NX)
25123 FORMAT(1H1,17H SPECTRUM NUMBER    ,I3,5H FOR ,A4,A2,8H SOURCE     //
     133H  (AFTER BACKGROUND SUBTRACTION)     //(1X,10F8.0))
      TZ=TTZ(J)
      NTZ=TZ
      GAIN=NX-TZ
      SLOP=ELIMIT/GAIN
      SM=0.0
      IF(N1X(J)) 3230,3234,3230
 3230 NX1=N1X(J)
      NX2=N2X(J)
      XNX1=NX1
      XNX2 = NX2
      SLP= (FM(NX2)-FM(NX1))/(XNX2-XNX1)
      NX11=NX1+1
      NX22=NX2-1
      DO 3231 I=NX11,NX22
      X=I-NX1
 3231 FM(I)=FM(NX1)+SLP*X
      WRITE(LO,3239)NX1,NX2
 3239 FORMAT(40H XRAY PEAK SUBTRACTED BETWEEN CHANNELS  I5,5H AND I5)
 3234 IF(NFILL(J))3232,3233,3232
 3232 IF(VAL(J))3235,3236,3235
 3235 NX2=NFILL(J)
      NX1=1
      FILL = NX2
      SLP = (FM(NX2)-VAL(J))/FILL
      NX11=NX1+1
      NX22 = NX2-1
      DO 3237 I= NX11,NX22
      X =I-NX1
 3237 FM(I) = VAL(J)+SLP*X
      WRITE(LO,7242)NX22,SLP,VAL(J)
 7242 FORMAT (6H FIRST,I4,2X,48H DEAD CHANNELS FILLED PER FM(I)=M*X+C WH
     1ERE M = ,E14.7,9H AND C =     ,E14.7)
      GO TO 3233
 3236 NX2 = NFILL(J)-1
      NX1 = NFILL(J)
      DO 3238 I=1,NX2
 3238 FM(I) = FM(NX1)
      SLP=0.0
      WRITE(LO,7242)NX2,SLP,FM(NX1)
 3233 CONTINUE
      IF(MZ)8881,25,8881
 8881 DO 8882 I=1,MZ
 8882 FM(I)=0.0
   25 CONTINUE
C
C IF *DISCRT* REQD, M(7)=7
      IF(M(7)) 773,306,773
  773 AM=MSM
      IF(TZ+AM)1492,32,1492
C
 1492 CALL GANE (TZ,N,1.0,1.0,AM,FM)
C
   32 CONTINUE
      WRITE(LO,22333) (FM(II),II=1,N)
22333 FORMAT(40H1 UNKNOWN SPECTRUM BEFORE PEAK FITTING  //(4X,10F10.0))
      NSIN=N
      GG=GAIN
      M19=M(19)
C
      CALL DISCRT (FM,ETA,NP,RX,TKLUM,M19)
C
      WRITE(LO,22332)TZ,N,GAIN,RQGAIN,SM,(FM(I),I=1,N)
22332 FORMAT(1H1,43H GAIN PARAMETERS AFTER CALL SINGLE IN MAIN
     1/1X,F8.3,I5,3F10.4/(1X,10F7.0 ))
      WRITE(LP,22330)TZ,N,GAIN,RQGAIN,SM,(FM(I),I=1,N)
22330 FORMAT(1X,F8.3,I5,3F10.4/(1X,10F7.0))
 1493 IF(M(9)) 300,306,300
  300 WRITE(LO,302)
  302 FORMAT(1H0,38X,43HSUBTRACTED DISCRETE PEAK PHOTON NUMBER FLUX //
     133X,5HINDEX,15X,6HENERGY,17X,11HNUMBER FLUX /
     253X,5H(MEV),14X,19H(PHOTONS/CM**2-SEC) //)
      DE=DECAY(DT,TH,TM,CLAMDA)
      DO 301 I=1,IN
      PHOT(I)=(DE*PHOT(I))/(DT*60.*3.14159265*RX*RX)
      WRITE(LO,303)I,EU(I),PHOT(I)
  303 FORMAT(1H ,34X,I2,2E25.7)
  301 CONTINUE
C     WRITE(LO,13303)IN,DE,DT,TH,TM,CLAMDA
C3303 FORMAT(1X,I5,5E14.7)
      DO 305 I=1,IN
  305 PHOT(I)=0.0
  306 CONTINUE
      IF(M(10))21,124,21
  124 IF(M(11))110,113,110
  110 ENN=N
      ELN=ELIMIT/GAIN
      DLN=ELN/2
      DO 116 I=1,N
  116 Q(I)=I*ELN-DLN
      MSKIP=1
C
      CALL DETECT (NS,N,Q,H,ETA,DIST,RX,TKLUM,PFRACT,0)
C
      IF(M(17))113,202,113
  202 DO 502 I=NS,N
  502 FM(I)=FM(I)/ETA(I)
      M(14)=14
      MF=1
  113 IF(M(12))209,778,209
  209 IF(M(13))206,112,206
C
C  MAKE SPECTRUM COMPATIBLE IN GAIN WITH RESP MATRIX
C
  778 CALL GANE (TZ,N,GAIN,RQGAIN,SM,FM)
      WRITE  (LO,8852) N,       GAIN,RQGAIN,(FM(I),I=1,N)
 8852 FORMAT (1H1,32H INPUT SPECTRUM GAIN CHANGED TO      ,I5,9H CHANNELS
     1/22H  GAIN CHANGE RATIO =   ,F10.5,1H/ ,F10.5      ///(1X,5E14.7))
C
  112 DO 213 I=NS,N
  213 Q(I)=QT(I)
      NPPP=N+1
      DO 205 I=NPPP,NLIMIT
  205 Q(I)=0.0
C
  114 CALL SOLN (NS,PHI,FM,ETA,DIST,M,RX,TKLUM,PFRACT,M19)
C
      WRITE(LO,2009)
```

```
      MSKIP=0
  206 IF(MF)122,79,122
  122 WRITE  (LO,126)   (PHI(I),I=1,N)
  126 FORMAT (1H1,40H PHA SPECTRUM CORRECTED FOR EFFICIENCY  /(5(2X,E12.
     15)))
      MF=0
      GO TO 21
   79 IF(M(6)) 179,125,179
  179 DO 70 JN=1,IN
      OY=EU(JN)*EM
      I=OY
      OIY=I
      IF((OY-OIY)-.5)71,71,72
   72 IF(I-N)76,77,75
   77 NJK=N
      GO TO 78
   76 I=I+1
      OIY=I
      GO TO 74
   71 IF(I)73,73,74
   73 NJK=1
   78 PHI(NJK)=PHI(NJK)+PHOT(JN)
      GO TO 75
   74 OIY=OIY-OY+0.5
      TWO=1.0-OIY
      PHI(I)=PHI(I)+PHOT(JN)*OIY
      PHI(I+1)=PHI(I+1)+PHOT(JN)*TWO
   75 CONTINUE
   70 CONTINUE
  125 CONTINUE
   20 WRITE(LO,2020) IT,
     1  (PHI(I),I=NS,N)
 2020 FORMAT ( 41H0DIFFERENTIAL FLUX AT ITERATION NUMBER =   ,I5/
     1    (5(2X,E12.5)))
   21 IF(M(16))800,801,800
  800 DE=1.0
      GO TO 802
  801 DE=DECAY(   DT,TH,TM,CLAMDA)
  802 CONTINUE
      WRITE  (LO,2025) N,(FM(I),I=NS,N)
 2025 FORMAT (1H1,17H SINGLE SPECTRUM ,I5,10HCHANNELS  /(1X,10F9.0))
   99 IF(M(18))500,24,500
C
   24 CALL GEOMTR (ENXTAL,Q,PHI,NS,N,DE,DT,VOL,RX,DIST)
C
      WRITE(LO,8890)(I,Q(I),PHI(I),ENXTAL(I),I=NS,N)
 8890 FORMAT (44H1NUMBER AND ENERGY SPECTRUM AT THE CRYSTAL       ///
    1 19H INCREMENT   ENERGY,13X,11HNUMBER FLUX,13X,11HENERGY FLUX/
    2 13X,5H(MEV),10X,19H(PHOTONS/CM**2-SEC),7X,15H(MEV/CM**2-SEC)//
    3 (1X,I6,3X,F10.5,10X,E14.7,10X,E14.7))
      WRITE(LO,8892)
 8892 FORMAT (42H1INTEGRATED RESULTS AT SOURCE AND CRYSTAL  ///
    1 58H ENERGY INTEGRATED PHOTON (BREMSS.) VALUES AT THE CRYSTAL // )
      WRITE(LO,8895)  SUMNUM,SUMENY,DOSDET,AVENGY,PHNUBE,ENBENY,PHENBE,
    1 DOSBEX,DBXVOL
 8895 FORMAT (37H0PHOTON NUMBER (PHOTONS/CM**2-SEC) = ,E14.7/37H PHOTON
    1ENERGY (MEV/CM**2-SEC)      = ,E14.7/37H PHOTON DOSE   (ROENTGENS/H
    2OUR)    = ,E14.7//24H AVERAGE ENERGY (MEV) = ,E14.7//77H PHOTON NU
    3MBER / SOURCE EMITTED BETA NUMBER (PHOTONS/CM**2-SEC)/(BETA/SEC) =
    4 ,E14.7/77H PHOTON ENERGY / SOURCE EMITTED BETA ENERGY ((MEV/CM**2
    5-SEC)/MEV)             = ,E14.7/77H PHOTON ENERGY / SOURCE EMITTED BE
    6TA NUMBER (MEV/CM**2-SEC)/(BETA/SEC)      = ,E14.7/77H PHOTON DOSE
    7  / SOURCE EMITTED BETA NUMBER (R/HR)/(BETA/SEC)               = ,
    8 E14.7/92H PHOTON DOSE   / SOURCE EMITTED BETA NUMBER PER SOURCE V
    9OLUME (((R/HR)/(BETA/SEC))/CM**3) = ,E14.7////)
      WRITE  (LO,8891) DOSCYL,DCYVOL
 8891 FORMAT (25H AT THE SOURCE CYLINDER     //
    1 77H PHOTON DOSE   / SOURCE EMITTED BETA NUMBER (R/HR)/(BETA/SEC)
    2                = ,E14.7//92H PHOTON DOSE   / SOURCE EMITTED BETA NUM
    3BER PER SOURCE VOLUME (((R/HR)/(BETA/SEC))/CM**3) = ,E14.7)
  500 CONTINUE
      IF(JS-JSO)61,1111,61
   61 JS=JS+1
      GO TO 2
 1111 IF(KK.LT.NSET) GO TO 1
      STOP
      END
[FOR,IS ADPEAK
      SUBROUTINE ADPEAK(FM,NXLIM,B1,B2,B3,PH,NF)
C**********  PROGRAM NUMBER -  2   CUGEL      ************
C
C     ADDS PHOTOPEAKS TO INTERPOLATED COMPTON CONTINUA
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      DIMENSION FM(800)
      SUM=0.0
      NS=B1-7.*B2 -1.
      NF=B1+7.*B2 +1.
      IF(NS.LE.0)NS=1
      IF(NF.GT.NXLIM)NF= 30
      ND=1
      NSFDIF=NF-NS+1
   52 IF(NSFDIF-50)51,50,50
   51 ND=2*ND
      NSFDIF=NSFDIF+NSFDIF
      GO TO 52
   50 DNN=ND
      DN=1.0/(2.0*DNN)
      DE=DN+DN
      CONS=0.3989423*B3/B2
C     WRITE(LO,99)B1,B2,B3,DNN,DN,DE,CONS,NS,NF,ND,NSFDIF
C  99 FORMAT(15H BS,DS, NS      /1X,7E15.4/15X,4I5)
      DO 800 I=NS,NF
      X=I-1
      X=X-DN
C     WRITE(LO,98)I,X,DN
C  98 FORMAT(3H I=,I4,5X,3H X=,E14.4,5X,4HDN= ,E14.4)
      SAM=0.0
      DO 900 II=1,ND
      X=X+DE
      PON=(X-B1)/B2
      PON2=PON*PON
      AR=0.5*PON2
      IF(AR-20.0)2,3,3
    2 P=CONS*EXP(-AR)*DE
      FM(I)=FM(I)+P
      SAM=SAM+P
C     WRITE(LO,97)II,X,PON,PON2,AR,P,FM(I)
C  97 FORMAT(6H INDEX,I5,6E16.5)
    3 CONTINUE
  900 CONTINUE
      SUM=SUM+SAM
  800 CONTINUE
      SUMP=0.0
      DO 555 I=1,NF
  555 SUMP=SUMP+FM(I)
      DO 5555 I=1,NF
 5555 FM(I)=FM(I)/SUMP
      PH=1.0/SUMP
C     WRITE(LO,96)NS,NF,NXLIM,SUM,PH,B1,B2,B3,SUMP,(I,FM(I),I=NS,NF)
C  96 FORMAT(7H NS,NF= ,3I5,6E14.7/(I10,E16.4))
      RETURN
```

```
      END
[FOR,IS AIRABS
      FUNCTION AIRABS (E,DIST)
C**********  PROGRAM NUMBER -  3   CUGEL      ************
C
C      COMPUTES AIR INTERACTION FACTOR.
C
      DIMENSION X(22),Z(3),Y(3),A(22)
    . COMMON/CNSTNT/T01,T20,T50,T1293,T90,T100,T06
      DATA     X          /.01,.02,.03,.04,.05,.06,.07,.08,.09,.10,.2,.3,
     1.4,.5,.6,.7,.8,.9,1.0,1.5,2.0,3.0/
      DATA     A          /4.97,.749,.347,.243,.203,.185,.174,.166,.160,
     1.155,.123,.106,.0953,.0868,.0804,.0750,.0706,.0668,.0635,.0517,
     2.0445,.0357/,NGO/1/
      GO TO (1,2),NGO
    1 NGO=2
      DO 3 I=1,22
    3 A(I)=A(I)*T1293
C
    2 CALL TA (E,X,22,1,MOX,MUN,Z,Y,A,2,L,0)
C
      AERMEW=TE (3,Z,Y,E)
      ARG=AERMEW*DIST
      IF(ARG-100.0)5,4,4
    5 AIRABS=EXP(-ARG)
      RETURN
    4 AIRABS=EXP(-100.0)
      RETURN
      END
[FOR,IS ALUM
      FUNCTION ALUM (E,TKLUM)
C**********  PROGRAM NUMBER -  4   CUGEL      ************
C
C      COMPUTES ALUMINUM ABSORPTION FACTOR.  (F)
C
      DIMENSION X(24),R(24),Z(3),Y(3)
      DATA     X          /.01,.015,.02,.03,.04,.05,.06,.07,.08,.09,.10,
     1.2,.3,.4,.5,.6,.7,.8,.9,1.0,1.5,2.0,3.0,4.0/
      DATA     R          /71.025,21.17,8.9807,2.819,1.369,.880,.6685,.562,
     1.5022,.462,.4330,.3232,.27806,.2486,.2268,.2097,.1958,.1842,.1735,
     2.1655,.1349,.1165,.09534,.08365/
C
      CALL TA (E,X,24,1,MOX,MUN,Z,Y,R,2,L,0)
C
      P=TE (3,Z,Y,E)
      ARG=P*TKLUM
      IF(ARG-100.0)1,2,2
    1 ALUM=EXP(-ARG)
      RETURN
    2 ALUM=EXP(-100.0)
      RETURN
      END
[FOR,IS BBS
      SUBROUTINE BBS (E,FOUT,JMIN)
C**********  PROGRAM NUMBER -  5   CUGEL      ************
C
C      INTERPOLATES NORMALIZED BACKSCATTER PEAKS
C
      COMMON /LIO/ LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/SPN/RDUM(4800),STDEN,BDUM(104),NSDUM(49)
      COMMON/BSI/RV,EBS,VBS,BY
      DIMENSION Z(3),Y(3),RV(60,12),VBS(12),FOUT(400),EBS(12),BY(12),STD
     1EN(12,2)
C
C      INTERPOLATE NEW BS-PEAK
C
      EXB=E/(1.0+(E/0.511)*2.0)
      Z(1)=EBS(JMIN)
      Z(2)=EBS(JMIN+1)
      Z(3)=EBS(JMIN+2)
      Y(1)=VBS(JMIN)
      Y(2)=VBS(JMIN+1)
      Y(3)=VBS(JMIN+2)
      BSA=TE(3,Z,Y,EXB)
C     WRITE(LO,152) EXB,Y(1),Y(2),Y(3),BSA,E
C     WRITE(LO,152)EXB,Z(1),Z(2),Z(3),BSA,E
      NBSA=BSA+0.5
      Z(1)=STDEN(JMIN,1)
      Z(2)=STDEN(JMIN+1,1)
      Z(3)=STDEN(JMIN+2,1)
      Y(1)=BY(JMIN)
      Y(2)=BY(JMIN+1)
      Y(3)=BY(JMIN+2)
      AB=TE(3,Z,Y,E)
      FF=AB/BY(1)
C     WRITE(LO,151) JMIN,Z(1),Z(2),Z(3),Y(1),Y(2),Y(3),AB,FF,BY(1)
      M9=60
      DO 41 I=1,M9
      K=NBSA-30+I
      IF(K.LT.1)GO TO 41
      Y(1)=RV(I,JMIN)
      Y(2)=RV(I,JMIN+1)
      Y(3)=RV(I,JMIN+2)
      FN=TE(3,Z,Y,E)*FF
      FOUT(K)=FOUT(K)+FN
   41 CONTINUE
C 151 FORMAT(1H1,10H BBS 1     //I5,9F10.6)
C 152 FORMAT(1X,10H BBS 2-    //6F10.6)
      RETURN
      END
[FOR,IS BS
      SUBROUTINE BS (NY,NSIG, M3)
C**********  PROGRAM NUMBER -  6   CUGEL      ************
C
C      NORMALIZES AND SUBTRACTS BACKSCATTER PEAKS
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/SPN/R,STDEN,BDUM(8),PARAV,PARAS,PAREA,DUM(24),NDUM(48),
     1NSTAND
      COMMON/BSI/RV,EBS,VBS,BY
      COMMON/XLIM/NXLIM,I5,INZ,INA,ICO,I24,IDUM(12)
      DIMENSION R(400,12),Y(3),FM(800),EBS(12),VBS(12),RV(60,12),STDEN(1
     12,2),Z(3),BY(12),M1(12),M2(12),NBS(12),M3(12),PARAV(12,2),
     2PARAS(12,2),PAREA(12,2),NINT(12)
      NDEGRE=2
      JE=1
      TAZ=0.0
      ELOW=0.24
      EHIGH=0.34
      IF(NSIG-3)81,82,81
   82 J=ICO
      NY=J
      GO TO 26
   81 J=1
      NSI=0
      DO 881 I=1,12
      BY(I)=0.0
  881 NINT(I)=0
   25 IF(STDEN(J,JE).GT.ELOW.AND.STDEN(J,JE).LT.EHIGH)GO TO 5
   26 EBS(J)=STDEN(J,JE)/(1.0+(STDEN(J,JE)/0.511)*2.0)
      VBS(J)=EBS(J)*NORM/STDEN(J,JE)
      DO 6 I=1,NORM
```

```
    6 FM(I)=R(I,J)
C     WRITE(LO,12)NY,J,ICO,NSIG,NSI,VBS(J),EBS(J),STDEN(J,JE)
C  12 FORMAT(9H BS TEST ,5I5,3E14.7)
      NW=NORM
      SM1=1.0
      CALL GANE(TAZ,NW,1.0,1.0,SM1,FM)
      N1=VBS(J)-.07*VBS(J)
      N2=VBS(J)+.07*VBS(J)
C     WRITE(LO,155) NW,N1,N2,J,NSI,NINT(1),NINT(2)
      CALL VECTMX(FM,N1,N2,JMAX,A)
      NBS(J)=JMAX
      M1(J)=NBS(J)*0.875
      M2(J)=NBS(J)*1.16
      NU1=M1(J)
      NU2=M2(J)
C     WRITE(LO,150)NBS(J),M1(J),M2(J),J,N1,N2
      MX=J
C     WRITE(LO,7510)(FM(I),I=1,150)
C7510 FORMAT(1X,10E11.4)
      CALL FITLIN(FM,NU1,NU2,       MX,JMAX,SLNYX,SLNU1)
      BY(J)=A-SLNYX
C     WRITE(LO,157)JMAX,NU1,NU2,MX,M3(J),M9,A,SLNYX,BY(J)
      DO 14 I=NU1,NU2
   14 R(I,J)=FM(I)
      IF(STDEN(J,JE)-0.34)65,65,61
   61 A1=0.1024*STDEN(J,JE)-0.0137
      A2=SLNU1
      B1=1.0
      B2=NU1
      ES=(A1-A2)/(B1-B2)
      BBB=A1
      DO 710 I=1,NU1
  710 R(I,J)=ES*I+A1
   65 CONTINUE
C     WRITE(LO,100)(R(I,J),I=1,NU2)
C     WRITE(LO,100)(RV(I,J),I=1,60)
      IF(MX-1)503,503,504
  504 FF=BY(J)/BY(1)
      DO 505 I=1,60
  505 RV(I,J)=RV(I,J)/FF
  503 CONTINUE
C     WRITE(LO,100)(RV(I,J),I=1,60)
      IF(NSIG-3)64,84,64
   84 RETURN
C
C     STANDARD CONTINUA WITH BS-PEAK SUBTR.
C
    5 NSI=1
      IF(J-1)63,63,64
   63 IF(STDEN(J,JE).GT.ELOW.AND.STDEN(J,JE).LT.EHIGH)GO TO 62
      GO TO 64
   62 EW=STDEN(J,JE)
      BY(1)=0.04112*EW-0.001846
   64 IF(J-NY)4,24,24
    4 J=J+1
C     WRITE(LO,156)
      GO TO 25
C
C     INTERPOLATE AND SUBTRACT BS-PEAKS OF CONTINUA IN THE ENERGY RANGE
C     OF 0.24 TO 0.34 MEV
C
   24 IF(NSI)10,11,10
   10 K=0
      J=1
   41 IF(BY(J))21,8,21
    8 K=K+1
```

```
      NINT(K)=J
   21 IF(J-NY)30,31,31
   30 J=J+1
      GO TO 41
   31 DO 32 JJ=1,K
      J1=NINT(JJ)-1
      J2=NINT(JJ)+1
      J3=NINT(JJ)+2
      J=NINT(JJ)
C     WRITE(LO,155)J1,J2,J3,K,J,NINT(1),NINT(2)
      E=STDEN(J,JE)
      Z(1)=STDEN(J1,JE)
      Z(2)=STDEN(J2,JE)
      Z(3)=STDEN(J3,JE)
      Y(1)=BY(J1)
      Y(2)=BY(J2)
      Y(3)=BY(J3)
      BY(J)=TE(3,Z,Y,E)
      FF=BY(J)/BY(1)
C     WRITE(LO,5000)JJ,J,NINT(JJ),E,BY(J),FF,Z(1),Z(2),Z(3),Y(1),Y(2),
C    1Y(3)
C5000 FORMAT (10H BY-CHECK ,3I5,4E14.7/1X,5E14.7)
      DO 70 L=1,60
      Y(1)=RV(L,J1)
      Y(2)=RV(L,J2)
      Y(3)=RV(L,J3)
      RV(L,J)=TE(3,Z,Y,E)
      IF(RV(L,J))71,72,72
   71 RV(L,J)=0.0
   72 CONTINUE
   70 CONTINUE
C     WRITE(LO,103)(RV(I,J),I=1,60)
      EBS(J)=STDEN(J,JE)/(1.0+(STDEN(J,JE)/0.511)*2.0)
      VBS(J)=EBS(J)*NORM/STDEN(J,JE)
      NBS(J)=VBS(J)
      KK=NBS(J)*0.875
      L=NBS(J)*1.16
      LA=30-(NBS(J)-KK)
      DO 19 I=KK,L
      KA=LA+I-KK
   19 R (I,J)=R(I,J)-RV(KA,J)
C     WRITE(LO,2000)JJ,J,KK,L,KA,LA,NBS(J),E,VBS(J),EBS(J),BY(J),FF,Z(1)
C    1,Z(2),Z(3)
C2000 FORMAT(1H0,6H BS 6  /1X,7I5/1X,8E12.5)
   32 CONTINUE
C 100 FORMAT(1H0,6H BS 4  /(1X,10F10.8))
C 103 FORMAT(1H1,24H INTERPOLATED BS-PEAK   ///(1X,10F10.8))
C 150 FORMAT(1H0,6H BS 2 ,6I5)
C 153 FORMAT(1H1,12H POGELI  2  /(1X,6F10.6)/(1X,6F10.6))
C 154 FORMAT(1H1,12H POGELI  3  /(1X,10F10.8))
C 155 FORMAT(1H0,11H BS 1        ,7I5//)
C 156 FORMAT(1H1,35H ENERGY BETWEEN 0.24 AND 0.34 MEV  //)
C 157 FORMAT(1H0,10H BS 3      /1X,6I5,4F10.4)
C1001 FORMAT(1X,4I6//)
C1002 FORMAT(1X,7H POGE  //I5,3F6.4//)
C1003 FORMAT(1X,3F10.6,3I5)
   11 RETURN
      END
@FOR,IS DEC
      SUBROUTINE DEC (NX,S,MX)
C**********  PROGRAM NUMBER -  7   CUGEL     ************
C
C     READS PULSE-HEIGHT ANALYZER SPECTRA.  CHECKS FOR PHA-COMPLEMENTED COUNTS.
C
      DIMENSION S(400),FM(1000)
      COMMON /LIO/ LI,LO,LP,NLIMIT ,NORM,MOUT
```

```
      COMMON/CNSTNT/    T01,T20,T50,     T1293,T90,T100,             T06
      COMMON/GAN/NLI
      IF(MX-NX) 1,1,2
    2 READ(LI,3000)(FM(I),I=1,MX)
      MCX=MX
      GO TO 7
    1 READ           (LI,3000)(FM(I),I=1,NX)
      MCX=NX
 3000 FORMAT (10F7.1)
    7 DO 4 I=1,MCX
      IF(FM(I)-T90) 5,5,6
    6 FM(I)=FM(I)-T100
    5 CONTINUE
    4 CONTINUE
      IF(MX-NX)11,11,20
   20 IF(MX-NLIMIT)11,11,21
   21 RQGAIN=NX
      GAIN=MX
      MXX=MX
      NLI=1000
      CALL GANE(0.0,MXX,GAIN,RQGAIN,0.0,FM)
      NLI=800
   11 DO 3 I=1,NX
    3 S(I)=FM(I)
      RETURN
      END
(FOR,IS DECAY
      FUNCTION DECAY (  DT,TH,T1,   CLAMDA )
C**********  PROGRAM NUMBER -  8   CUGEL      ************
C
C     COMPUTES DECAY CORRECTION FACTOR.
C
      T1=T1*1440.0
      IF( (DT/TH    )  - 0.001)2,2,1
    1 T2=T1 + DT
      TE=(-1.0/CLAMDA    )*ALOG ((EXP(-CLAMDA    *T1)-EXP(-CLAMDA    *T2))/
     1  (CLAMDA    *DT))
      GO TO 3
    2 TE=T1 + DT/2.0
    3 DECAY=EXP (CLAMDA    *TE)
      RETURN
      END
IFOR,IS DETECT
      SUBROUTINE DETECT(NS,NF,E,H,ETA,DIST,RX,TKLUM,PHOT,M19)
C**********  PROGRAM NUMBER -  9   CUGEL      ************
C
C     COMPUTES DETECTOR TOTAL EFFICENCY
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/CNSTNT/T01,T20,T50,T1293,T90,T100,T06
      DIMENSION E(400),ETA(400)   ,PHOT(40)
C
      WRITE(LO,3000).
 3000 FORMAT (1H1,50X,18HEFFICIENCY FACTORS  /// 8X,5HINDEX,10X,
     1 6HENERGY,12X,3HAIR,10X,8HABSORBER,                   9X,7HCRYSTAL,
     211X,5HTOTAL/
     3 22X,5H(MEV), 9X,11HATTENUATION,6X,11HATTENUATION,
     4                  6X,10HEFFICIENCY,7X,10HEFFICIENCY///)
      DO 2 I=NS,NF
      IF(E(I)-0.01)5,6,6
    5 G=0.0
      ABSORB=0.0
      ETA(I)=1.0E+20
      GO TO 66
    6 Q=E(I)
      IF(M19)20,20,21
   21 ETA(I)=(0.441*Q**(-1.32))/PHOT(I)
      GO TO 23
   20 ETA(I)=EFFIC2(Q,     DIST,RX,H)
   23 G=AIRABS (Q,DIST)
      ABSORB=ALUM(Q,TKLUM)
   66 A=ETA(I)*G*      ABSORB
      WRITE(LO,1000) I,Q,G,     ABSORB,ETA(I),A
 1000 FORMAT (1H ,8X,I3,    6E17.5)
    2 ETA(I)=A
      RETURN
      END
(FOR,IS DISCRT
      SUBROUTINE DISCRT (FM,ETA,NP,RX,TKLUM,M19)
C**********  PROGRAM NUMBER -  10  CUGEL      ************
C
C     DETERMINES MONOENERGETIC SPECTRAL CONTRIBUTION.
C
      DIMENSION FM(800),SLINE(400),EUG(50),EU(50),           RM(40,40),PV
     1(40),PFRACT(40),Q(400),PHOT(50),       NSS(50),NFNN(50),ETA(400)
     2  ,EUGN(50),EUU(50),NAS(50),NAF(50),NAJ(50),BB(8),NSM(50)
     3  ,TITLE(2),NPARA(8)  ,FA(80),PH(1)
C
C  FM-IN IS  A BREMSS+LINE SPECTRUM.  FM-OUT IS A BREMSS ONLY, AND PHOT
C  CONTAINS THE LINE DATA TO BE ADDED TO PHI IN *MAIN*.
C
      COMMON/A/DI,H,MF
      COMMON/RES/RM,N,EM,ELIMIT,          NDEGRE,Q,PV,PFRACT,K,MRPEAT,ENY,
     1  MEM
      COMMON/LIO/LI,LO,LP,NLIMIT ,NORM,MOUT
      COMMON/SING/NJ(50),NSS,NFNN,GG,NSIN,IN,DIST,MS,MX,PHOT,M22,M6,
     1 BTAG,BTAGA,EUG,EU,M77,M267 ,IFIFTY,TEN,IFOUR,SLOP
      COMMON/SPCT/PP(1000)
      COMMON/CNSTNT/     T01,T20,T50,     T1293,T90,T100,             T06
      COMMON/FUN/DUMFUN(883),NUMFUN(4)
      COMMON/SPN/RDUM(4800),STDEN(12,2),B(8),PARAV(12,2),PARAS(12,2),
     1SDUM(48),NSDUM(48),NSTAND
      COMMON/XLIM/NXLIM,IIDUM(17)
      COMMON/OOORM/ORM,OORM
      COMMON/GAN/NLI
C     WRITE (LO,1111) (FM(I),I=1,400)
C1111 FORMAT(10H SINGLE 00 /(1X10E12.6))
C     WRITE(LO,1113)M22,M6, IN,M77,  (J,NSS(J),NFNN(J),NJ(J),EU(J),
C    1 EUG(J),J=1,20)
C1113 FORMAT(10H M22, M6= ,4I10/(1X,4I10,2E14.7))
      NLI=800
      NONE=1
      NX=1
      NOX=NX
      HH=H
      M8=.8*NORM
      KM=0
      IF(M6)8001,8000,8001
 8001 DO 1501 J=1,M6
      EUG(J)=EU(J)/SLOP
      SIG=(1.2*0.00128*EXP(0.395*EU(J)))*EUG(J)/EU(J)
      NS=EUG(J)-6.0*SIG-0.5
      NFN=EUG(J)+6.0*SIG+0.5
      CALL VECTMX(FM,NS,NFN,IBIG,BIG)
      EUG(J)=IBIG
      NSS(J)=EUG(J)/6.0*SIG-0.5
      NFNN(J)=EUG(J)+6.0*SIG+0.5
C     WRITE(LO,9555)NSS(J),NFNN(J),SIG,EUG(J),EU(J)
C9555 FORMAT(10H SINGLE 1   /1X,2I10,3E14.7)
      NJ(J)=1
 1501 CONTINUE
      KM=1
```

```
 8000 IF(M22)8005,8007,8005
C  CHECK-OUT ESTIMATED FITTING LIMITS.
 8005 J=M77
      KM=KM+1
  502 NS=NSS(J)
      NOJ=0
      IF(NJ(J)-2)504,503,504
  503 NFN=NFNN(J+1)
      NOJ=2
      GO TO 506
  504 NFN=NFNN(J)
  506 CONTINUE
C     WRITE(LO,1112)NS,NFN
C1112 FORMAT(9H NS, NFN  /(2I8))
      CALL VECTMX(FM,NS,NFN,IBIG,BIG)
      EUG(J)=IBIG
  507 IF(EU(J))5000,5000,5002
 5000 EU(J)=EUG(J)*SLOP
 5002 CONTINUE
      IF(NOJ)509,8006,509
  509 NOJ=0
      JP1=J+1
  562 EUG(JP1)=IBIG+NSS(J+1)
      NEUG=EUG(JP1)
      IF(FM(NEUG)-FM(NS)) 560,560,561
  560 NSS(JP1)=-NSS(JP1)
      GO TO 562
  561 J=JP1
      GO TO 507
 8006 IF(J-IN)501,500,500
  501 J=J+1
      GO TO 502
  500 CONTINUE
 8007 IF(MS+MX)7008,7008,8070
 8070 CALL FIND(FM,MS,MX,IN,IFOUR,TEN,IFIFTY,M678,M267,EUG,NSS,NFNN,
     1 SLOP,EU,NJ         )
      KM=KM+1
 7008 IF(KM-1)56,56,4441
 4441 DO 5049 J=1,IN
      EUU(J)=EU(J)
      NAS(J)=NSS(J)
      NAF(J)=NFNN(J)
      NAJ(J)=NJ(J)
 5049 EUGN(J)=EUG(J)
      DO 5053 JK=1,IN
      SMALL=10000.
      DO 5050 J=1,IN
      IF(EUG(J)-SMALL)5051,5052,5052
 5051 NSMALL=J
      SMALL=EUG(J)
 5052 CONTINUE
 5050 CONTINUE
      NSM(JK)=NSMALL
      EUG(NSMALL)=10000.
 5053 CONTINUE
      DO 5057 J=1,IN
      NORDER=NSM(J)
      EUG(J)=EUGN(NORDER)
      EU(J)=EUU(NORDER)
      NSS(J)=NAS(NORDER)
      NFNN(J)=NAF(NORDER)
 5057 NJ(J)=NAJ(NORDER)
      IIN=IN-1
      DO 769 J=1,IIN
      JNS=J+1
      IF(NFNN(J)-NSS(JNS))762,762,763
```

```
  763 MEAN=(NFNN(J)-NSS(JNS))/2
      NFNN(J)=NFNN(J)-MEAN
      NSS(JNS)=NFNN(J)+1
  762 CONTINUE
      IF(NSS(J)-1)64,64,65
   64 NSS(J)=2
   65 IF(NFNN(J)-NSIN)66,67,67
   67 NSS(J)=NSIN-1
   66 CONTINUE
  769 CONTINUE
      IF(NFNN(IN)-NSIN)56,57,57
   57 NSS(J)=NSIN
   56 CONTINUE
      NSN=NSIN+1
      DO 766 I=NSN,NLI
  766 FM(I)=0.
C     WRITE (LO,1115)   (FM(J),J=1,400)
C     WRITE(LO,1113)M22,M6, IN,M77,   (J,NSS(J),NFNN(J),NJ(J),EU(J),
C    1 EUG(J),J=1,IN)
C
      TITLE(1)=BTAG
      TITLE(2)=BTAGA
      J=1
 8015 NBS=0
      IF(NJ(J)-2)8011,8010,8011
 8010 NS=NSS(J)
      NFN=NFNN(J+1)
  577 V1=EUG(J)
      V2=EUG(J+1)
      IF(V1-V2) 575,575,576
  576 EUG(J)=V2
      EUG(J+1)=V1
      GO TO 577
  575 GO TO 8016
 8011 NS=NSS(J)
      NFN=NFNN(J)
      ENY=EU(J)
      VENY=EUG(J)
      IF((NFN-NS)-6)515,515,8016
  515 BB(3)=0.0
      EE=(FM(NFN)-FM(NS))/(NFN-NS)
      BBB=0.0
      DO 517 I=NS,NFN
      SLINE(I)=FM(I)-(FM(NS )+EE*(I-NS))
      BBB=BBB+SLINE(I)*(I-NS-0.5)
      FM(I)=FM(I)-SLINE(I)
  517 BB(3)=BB(3)+SLINE(I)
      BBB=BBB/BB(3)
      BB(1)=NS+BBB
      B(1)=BB(1)
      EU(J)=B(1)*SLOP
      ENY=EU(J)
      B(3)=BB(3)
      B(2)=0.
      GO TO 8020
 8016 DO 760 I=1,NLIMIT
  760 SLINE(I)=0.0
      DO 761 I=NS,NFN
  761 SLINE(I)=FM(I)
C     WRITE(LO,1115) (SLINE(I),I=1,400)
C1115 FORMAT (7H SLINE  /(1X,10E11.4))
      IF(NJ(J)-2)8013,8012,8013
C     FIT DOUBLE PEAK AND SUBTRACT.
 8012 BB(1)=V1
      BB(3)=V2
      BB(2)=(1.2*0.00128*EXP(0.395*EU(J)))*V1/EU(J)
```

```
      BB(4)=BB(2)
      CALL GUESS3(NS,NFN,SLINE,BB,V1,V2)
      NPARA(1)=1
      NPARA(2)=3
      NPARA(3)=4
      NPARA(4)=6
      CALL STDFT3(SLINE,BB,NFN,NS,4,2,NPARA,N1S,FA,TITLE,1)
      CALL STDFT3(SLINE,BB,NFN,NS,4,2,NPARA,N1S,FA,TITLE,0)
      N1S=NS
      DO 1351 I=NS,NFN
      II=I-NS+1
 1351 FM(I)=FA(II)
      IF(BB(1)-BB(4))516,518,518
  516 IF(EU(J)-EU(J+1)) 519,519,518
  518 AT=EU(J)
      EU(J)=EU(J+1)
      JP1=J+1
      EU(JP1)=AT
  519 CONTINUE
      B(1)=BB(1)
      B(2)=BB(2)
      B(3)=BB(3)
      B(4)=BB(7)
      B(5)=BB(8)
      EU(J)=BB(1)*ELIMIT/GG
      VENY=BB(1)
      ENY=EU(J)
      NBS=1
      GO TO 8020
 8013 BB(1)=EUG(J)
      BB(2)=(1.2*0.00128*EXP(0.395*EU(J)))*EUG(J)/EU(J)
      NS=NSS(J)
      NFN=NFNN(J)
C
      CALL VECTMX(SLINE,NS,NFN,JMAX,YMAX)
C
      BB(3)=BB(2)*2.35*(YMAX-((SLINE(NFN)+SLINE(NS))/2.0))
      XNF=NFN-NS+1
      BB(4)=(SLINE(NS)-SLINE(NFN))/(-XNF)
      BB(5)=SLINE(NS)
      NPARA(1)=1
      NPARA(2)=2
      NPARA(3)=3
      N1S=NS
      ENY=BB(1)*SLOP
C
      CALL STDFT3(SLINE,BB,NFN,NS,3,1,NPARA,N1S,FA,TITLE,1)
      CALL STDFT3(SLINE,BB,NFN,NS,3,1,NPARA,N1S,FA,TITLE,0)
C
      DO 1350 I=NS,NFN
      II=I-NS+1
 1350 FM(I)=FA(II)
 8020 DO 99 I=1,NLIMIT
   99 PP(I)=0.0
      MRPE=MRPEAT
      MEMY=MEM
      NNP=N
      N=NP
C
      CALL RESFUN
C
      N=NNP
      MRPEAT=MRPE
      MEM=MEMY
      DO 850 I=M8,NLIMIT
      IF(PP(I))851,851,852
  851 INDEX=I
      GO TO 853
  852 CONTINUE
  850 CONTINUE
  853 DO 854 I=INDEX,NLIMIT
  854 PP(I)=0.0
      SUM=0.0
      DO 999 I=1,NORM
  999 SUM=SUM+PP(I)
      PHOT(J)=1.0/(1.0+SUM)
      NX=NORM
      GAINB1=B(1)
      PHO=PHOT(J)
C     WRITE (LO,19888) K,N,NS,NFN,MRPEAT,MEM,MEMY,NORM,MOUT,NSIN,NSN,
C    1  NLI,EM,ELIMIT,ENY,GAINB1,PHO,VENY,EE,B(2)
C9888 FORMAT (6H TEST    ,12I5/1X,8E13.6)
C     WRITE (LO,19777)NP,EM,BB(1),BB(3),PHOT(J),(FM(I),I=NS,NFN)
C9777 FORMAT (10H SINGLE 3    /1X,I10,4E14.7/(1X,5E14.7))
      CALL GANE(0.0,NX,OORM, GAINB1,0.0,PP)
C
      IF(NX-NLIMIT)1800,1801,1801
 1801 NX=NLIMIT-1
 1800 DO 1100 I=1,NX
      FM(I)=FM(I)-PP(I)*B(3)
      IF(FM(I))1873,1874,1874
 1873 FM(I)=0.0
 1874 CONTINUE
 1100 CONTINUE
C     WRITE(LO,800)NX,GAINB1,(FM(I),I=1,NLIMIT),(PP(I),I=1,NLIMIT)
C 800 FORMAT (10H SINGLE 3A     ,I10,E14.7/(1X,5E14.7))
      PHOT(J)=B(3)/PHOT(J)
      ETAT=ETA(J)
      J1=J
      SLINE(J)=ENY
      PH(1)=PHO
C
      CALL DETECT(J1,J1,SLINE,HH,ETA,DIST,RX,TKLUM,PH,M19)
C
      PHOT(J)=PHOT(J)/ETA(J)
      ETA(J)=ETAT
      WRITE(LO,555)PHOT(J),PHO
  555 FORMAT(1H0//69X,25HPHOTON NUMBER                =,E20.7/
     1 69X,           25HPHOTOFRACTION                =,E20.7////)
      WRITE(LO,1500)
 1500 FORMAT (1H0/43X,31HDISCRETE PHOTOPEAK FITTING DATA  ///
     1 6X,8HLOCATION,15X,6HENERGY,16X,12HPULSE-HEIGHT,10X,    18HSTANDARC
     2 DEVIATION,14X,4HAREA/ 19H CHANNEL TO CHANNEL,10X,5H(MEV),18X,
     3 10H(CHANNELS),15X,10H(CHANNELS),14X,13H(COUNTS/TIME)//)
      WRITE(LO,1600) NS,NFN,ENY,B(1),B(2),B(3)
 1600 FORMAT (1H ,2X,I3,8X,I3,E22.7,3E25.7)
  100 IF(J-IN) 9020,8030,9020
 9020 J=J+1
      IF(NBS)8040,8015,8040
 8040 NBS=0
      DO 8041 I=1,NLIMIT
 8041 SLINE(I)=0.0
      DO 8042 I=NS,NFN
 8042 SLINE(I)=FM(I)
      EUG(J)=BB(4)
      VENY=EUG(J)
      B(3)=BB(6)
      B(2)=BB(5)
      B(1)=BB(4)
      IF(EU (J))532,532,534
  534 ENY=EU(J)
      GO TO 533
```

```
  532 ENY=BB(4)*SLOP
  533 GO TO 8020
 8030 NGE=1
      NX=NOX
  840 RETURN
      END
(FOR,IS DOSE
      FUNCTION DOSE (E)
C**********  PROGRAM NUMBER -  11  CUGEL     ************
C
C     COMPUTES GAMMA PHOTON DOSE.
C
      DIMENSION X(20),R(20),Z(3),Y(3)
C
      DATA     X        /.01,.015,.02,.03,.04,.05,.06,.08,.1,.15,.2,.3
     1   ,.4,.5,.6,.8,1.,1.5,2.,3./
      DATA     R        /4.5723,1.2532,.50292,.14456,.06216,.03767,.02864
     1,.02364,.02321,.02511,.02681,.02874,.02954,.02966,.02959,.02884,
     2.02794,.02556,.02355,.02071/
C
      CALL TA(E,X,20,1 ,MOX,MUN,Z,Y,R,2,L,0)
C
      DOSE=TE ( 3,Z,Y,E)*E
      RETURN
      END
(FOR,IS EFFIC2
      FUNCTION EFFIC2(E,DAST,ROX,HH)
C**********  PROGRAM NUMBER -  12  CUGEL     ************
C
C     COMPUTES ELEMENTS OF DETECTION EFFICIENCY VECTOR.
C
      COMMON/CNSTNT/T01,T20,T50,T1293,T90,T100,T06
      COMMON /LIO/ LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON /B/ KL,UEGAM,RX,DIST,H
      DIMENSION X(29),R(29),Z(3),Y(3)
      DIST=DAST
C
      H=HH
      RX=ROX
      ARG=RX/(DIST+H)
      EPS=T06
C     WRITE(LO,100)DIST,H,RX,ARG
C 100 FORMAT(1X,4E14.7)
      DATA     X        /.011103,.015,.020,.03,.04,.05,.06,.07,.08,.09,.1
     1,.125,.150,.2,.3,.4,.5,.6,.7,.8,.9,1.0,1.25,1.5,2.0,2.5,3.0,3.5,
     24.0/
      DATA     R        /1126.4,504.03,226.85,72.34,31.40,16.59,10.127,
     17.00,4.725,3.52,2.7615,1.800,1.2444,0.8301,0.5742,.4804,.42694,
     2.3893,.3600,.3363,.3185,.30183,.2685,.24634,.21642,.1992,.18726,
     3.1795,.17394/
C     WRITE(LO,110)(I,X(I),R(I),I=7,29)
C 110 FORMAT(1X,I5,2E14.7)
C
      CALL TA    (E,X,29,1,MOX,MUN,Z,Y,R,2,L,0)
C
      UEGAM=TE (3,Z,Y,E)
C     WRITE(LO,120) MOX,MUN,L,UEGAM,E
C 120 FORMAT (1X,3I5,2E14.7)
      IF(ARG-0.0124)6,6,5
    5 A=0.0
      B=ATAN(ARG)
      KL=0
      CASE=SIMPSN(A,B,EPS)
      A=B
      B=ATAN(RX/DIST)
      KL=1
```

```
      UNUM=CASE + SIMPSN(A,B,EPS)
      DEN=        1.0-DIST/SQRT(DIST*DIST+RX*RX)
C     WRITE(LO,130) A,B,CASE,UNUM,DEN
C 130 FORMAT (1X,5E14.7)
      EFFIC2=UNUM/DEN
      RETURN
    6 EFFIC2=1.0 - EXP(-UEGAM*H)
      RETURN
      END
(FOR,IS FC
      FUNCTION FC(X)
C**********  PROGRAM NUMBER -  13  CUGEL     ************
C
C     CRYSTAL INTERACTION EFFICIENCY FUNCTION.
C
      COMMON /B/ KL,UEGAM,R ,DIST,H
      IF(KL)1,2,1
    1 IF(X)3,4,3
    3 A=UEGAM*(R/SIN(X)-DIST/COS(X))
      IF(A.GT.100.)GO TO 5
      FC=(1.0-EXP(-A))*SIN(X)
      RETURN
    4 FC=0.0
      RETURN
    2 AA=UEGAM*H/COS(X)
      IF(AA.GT.100.)GO TO 5
      FC=(1.0-EXP(-AA))*SIN(X)
      RETURN
    5 FC=SIN(X)
      RETURN
      END
(FOR,IS FIND
      SUBROUTINE FIND (Y,MS,MX,IN,IFOUR,TEN,IFIFTY,M678,M267,P,NS,NF,
     1  SLOP,EU,NJ  )
C**********  PROGRAM NUMBER -  14  CUGEL     ************
C
C     SEARCHES SPECTRUM FOR PEAKS
C
      DIMENSION Y(400),P(50),NS(50),NF(50),NJ(50),EU(50)
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      K=1
      NOP=0
      J=IN
      M678=IN+1
      I=MS
  501 IF(IN)105,106,105
  105 DO 107 K=1,IN
      IF(I.EQ.NS(K).AND.I.LT.NF(K)) GO TO 108
      GO TO 109
  108 I=NF(K)
      GO TO 106
  109 CONTINUE
  107 CONTINUE
  106 IF(Y(I)-100.)12,12,21
   21 N1=I
      N2=I+IFOUR
      IF(N2-MX)2,2,18
    2 CALL VECTMX (Y,N1,N2,IBIG,YMAX)
      IF(IBIG.GT.N1.AND.IBIG.LT.N2) GO TO 4
      GO TO 5
    4 IF((Y(N1)+TEN*SQRT(Y(N1)))-Y(N1+1))7,8,8
    7 IF((Y(N2)+TEN*SQRT(Y(N2)))-Y(N2-1))9,10,10
   10 N2=N2-1
      GO TO 11
    8 N1=N1+1
   11 IF(N1-N2)4,12,4
```

```
    9 IF(IBIG-NOP)35,36,35
   35 NOP=IBIG
      J=J+1
      IF(J-IFIFTY)37,37,18
   37 P(J)=IBIG
      EU(J)=P(J)*SLOP
      NS(J)=N1
      NF(J)=N2
      NJ(J)=3
      GO TO 5
   36 NF(J)=N2
    5 CONTINUE
   12 CONTINUE
      IF(I-MX)17,18,18
   17 I=I+1
      GO TO 501
   18 M267=J
      IF(M267-IN)118,118,119
  119 IN=M267
  118 CONTINUE
C     WRITE (LO,200) M267,IN,MS,MX,M678,IFOUR,IFIFTY,TEN,SLOP,
C    1  (J,P(J),EU(J),NS(J),NF(J),NJ(J),J=1,IN)
C 200 FORMAT ( 6H FIND  ,7I5,2E14.7/(1X,I5,5X,2E14.7,3I10))
      RETURN
      END
[FOR,IS FITLIN
      SUBROUTINE FITLIN(FM,M1,M2,    MX,NYX,SLNYX,SLNU1)
C**********  PROGRAM NUMBER -  15  CUGEL      ************
C
C     STRAIGHT-LINE BASE FITTING
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/BS1/RBS,VOUM(36)
      DIMENSION FM(800),RBS(60,12)
      M3=M2-M1
      N1=M1-5
      N2=M2+5
      SUMX=0.0
      SUMX2=0.0
      SUMY=0.0
      SUMXY=0.0
      DO 1 I=N1,M1
      SUMX=SUMX+I
      SUMY=SUMY+FM(I)
      SUMX2=SUMX2+I*I
    1 SUMXY=SUMXY+I*FM(I)
      DO 2 I=M2,N2
      SUMX=SUMX+I
      SUMX2=SUMX2+I*I
      SUMY=SUMY+FM(I)
    2 SUMXY=SUMXY+I*FM(I)
      A=SUMXY*SUMX-SUMY*SUMX2
      B=SUMX**2-12.0*SUMX2
      BE=A/B
      EM=(SUMY-BE*12.0)/SUMX
      SLNYX=EM*NYX+BE
      SLNU1=EM*M1+BE
C     WRITE(LO,101)A,B,BE,EM,SLNYX,SLNU1
C 101 FORMAT(1H0,13H FITLIN 2    /1X,6E14.7)
      IF(M3-1)10,11,10
C     LOAD ALIGNED(IN CH.30) BS PEAK IN RBS
   10 ND=NYX-30
      DO 7 I=M1,M2
      J=I-ND
      RBS(J,MX)=FM(I)-(EM*I+BE)
      FM(I)=EM*I+BE
```

```
      IF(RBS(J,MX))5,6,6
    5 RBS(J,MX)=0.0
    6 CONTINUE
    7 CONTINUE
   11 RETURN
      END
[FOR,IS FUNZ
      SUBROUTINE FUNZ(NPK,B,FA)
C**********  PROGRAM NUMBER -  16  CUGEL      ************
C
C     COMPUTES NP GAUSSIANS
C
      COMMON/FUN/A(80,8),Y(80),FC(80),FU(80),FIT,DN,DNN,NS,NF,ND,MP
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      DIMENSION B(8),FA(80)
      FIT=0.0
      DO 50 I=1,80
      FU(I)=0.0
      FC(I)=0.0
      DO 50 J=1,8
   50 A(I,J)=0.0
C     PHOTOPEAK BASE
      DE=DN+DN
      NPS=NPK*3+1
      NPI=NPS+1
C     WRITE(LO,99)NPK,NS,NF,ND,MP,DN,DNN,(B(I),I=1,5)
C  99 FORMAT(6H FUN 1,5I5,7E12.5)
      DO 403 I=NS,NF
      X=I
      X=X-0.5
      FU(I)=B(NPS)*X + B(NPI)
      FA(I)=FU(I)
      A(I,NPS)=X
  403 A(I,NPI)=1.0
C     NP PHOTOPEAKS (GAUSSIANS)
      DO 700 K=1,NPK
      NMULT=3*(K-1)
      NP1=NMULT+1
      NP2=NMULT+2
      NP3=NMULT+3
      CONS=0.3989423*B(NP3)/B(NP2)
      DO 800 I=NS,NF
      X=I-1
      X=X-DN
      DO 900 II=1,ND
      X=X+DE
      PON=(X-B(NP1))/B(NP2)
      PON2=PON * PON
      AR=0.5*PON2
      IF(AR -20.0) 2,3,3
    2 P=CONS*EXP(-AR)*DE
      A(I,NP1)=P*PON/B(NP2) + A(I,NP1)
      A(I,NP2)=P*(PON2-1.0)/B(NP2) + A(I,NP2)
      A(I,NP3)=P/B(NP3) + A(I,NP3)
      FU(I)=FU(I)+P
    3 CONTINUE
  900 CONTINUE
  800 CONTINUE
  700 CONTINUE
      DO 600 I=NS,NF
      FC(I)=Y(I)-FU(I)
      FA(I)=FC(I)+FA(I)
  600 FIT=FIT+(FC(I)**2)/Y(I)
C     WRITE(LO,999)NP1,NP2,NP3,NMULT,AR,Y(NS),FU(NS),FC(NS),CONS,P,FIT,
C    1PON2,X
C 999 FORMAT(6H FUN 2,4I5,5E12.5/1X,4E12.5)
```

```
      RETURN
      END
*FOR,IS GANE
      SUBROUTINE GANE (TZ,NX,GAIN,RQGAIN,SMOOTH,C)
C*********  PROGRAM NUMBER -  17  CUGEL      ************
C
C     REF. JR. NUC. SCI. AND ENG. VOL 35, MAR. 1969 STEYN AND ANDREWS
C     MARCH 1968 VERSION, I.E. DIMENSION CAPACITY CHECK
C     GAIN CHANGING PROGRAM,  ALSO SPECTRAL SHIFTING.
C
      COMMON/GAN/NLI
      DIMENSION C(800),FM(800)
      NLIMIT=NLI
      WONX=NX
      ONX=(RQGAIN/GAIN)*WONX
      NONX=ONX
      IF(NONX-NLIMIT)620,620,621
  621 NX=NX-(NLIMIT-NONX)-1
  620 IF(TZ)600,601,601
  600 JTZ=ABS(TZ)
      NX=NX-JTZ
      IF(NX-NLIMIT)601,601,603
  603 NX=NLIMIT
  601 IF(TZ)1000,275,1000
 1000 NZC=TZ
      NXO=NX-NZC
C
C INTEGER SHIFT IF *NZC* NOT EQUAL TO ZERO.
C
      IF(TZ )913,910,911
  913 NZC=NZC-1
      NS=NZC*(-1) + 1
      NSX=NS-1
      NSXO=1
      NXO=NSX+NX
  955 DO 956 I=NS,NXO
      K=I+NZC
  956 FM(I)=C(K)
      DO 957 I=NS,NXO
  957 C(I)=FM(I)
      GO TO 93
  911 NS=1
      NSXO=NXO+1
      NSX=NX
  945 DO 91 I=NS,NXO
      K=I+NZC
   91 C(I)=C(K)
   93 DO 92 I=NSXO,NSX
   92 C(I)=0.0
  910 NX=NXO
C
C  DECIMAL SHIFT.
C
  274 TNZC=NZC
      DIF=TZ-TNZC
      IF(DIF)271,272,271
  271 NXON=NX-2
      DDIF=1.0-DIF
      DO 270 I=2,NXON
      C(1)=C(1) - C(2)*DIF
  270 C(I)=C(I)*DDIF + C(I+1)*DIF
      C(NXON +1)=C(NXON +1)*DDIF + C(NX)
      GO TO 273
  272 IF(NZC)273,275,275
  273 NX=NX-1
  275 TZ=0.
```

```
      L=1
      G=GAIN
      DO 50 I=1,NLIMIT
   50 FM(I)=0.0
      FMULT=GAIN/RQGAIN
C
C DEL=0.5 WHEN GAIN/RQGAIN=0.5, I.E. DOUBLING REQUIRED.
C DEL=2.0 WHEN GAIN/RQGAIN=2.0. I.E. HALVING REQUIRED.
C
    1 DEL=GAIN/RQGAIN
      IF(DEL-2.0)402, 204, 402
  402 IF(DEL-0.5)3, 3, 4
    3 L=L+1
      GAIN=GAIN*2.0
      GO TO 1
C
C  INITIALIZE FOR REDUCING ALGORITHM.
C
    4 I=1
      K=1
      X=0.
      XN=1.0
      DELT=0.
   60 DE=DEL
      IF(DEL-1.0)5,499 ,105
  499 IF(L-1)497,500,497
  497 DELT=RQGAIN/2.0
      L=L-1
  496 DO 498 I=1,NX
  498 FM(I)=C(I)
      GO TO 201
C
C  INCREASE.  ......  LOAD EVEN CHANNELS WITH QUADRATICALLY
C  INTERPOLATED COUNT.   SHIFT ENTIRE SPECTRUM UPWARD ONE-HALF CHAN.
C
    5 DELT=RQGAIN/2.0
      DEL=GAIN/DELT
      GO TO 60
  303 NOX=J-4
      DO 305 J=1,NOX,2
      I=J+1
  305 C(I)= (3.0*C(J) + 6.0*C(J+2) - C(J+4))*.125
      C(I+2)= (3.0*C(I+3) + 6.0*C(I+1) - C(I-1))*.125
      NX=I+3
      DO 936 I=2,NX
  936 FM(I)=(C(I)+C(I-1))*0.5
      FM(1)=C(1)*0.5
      DO 935 I=1,NX
  935 C(I)=FM(I)
      GO TO 304
C
C  REDUCTION ALGORITHM.
C
  105 XK=DEL
      DEL=XN-X
      XKX=XK
  106 FM(K)=FM(K)+DEL*C(I)
      IF(I-NX)112,202,202
  112 X=X+DEL
      IF(X-XK+1.0E-9)108,107,107
  107 K=K+1
      XN=I
      DEL=XN-X
      XK=XK+XKX
      GO TO 106
  108 XN=XK
```

```
      DEL=XN-X
  109 IF(DEL-1.0)111,111,110
  110 DIF=DEL-1.0
      DEL=DEL-DIF
      GO TO 109
  111 I=I+1
      GO TO 106
  202 DO 1999 INX=1,NLIMIT
 1999 C(INX)=0.0
      XNX=NX
      XNX=XNX/DE
      NX=XNX
C
C  LOAD ODD CHANNELS IF *DELT* EQUAL TO ZERO.
C
  201 IF(DELT) 300,301,300
  300 NC=2
      ND=1
      GO TO 302
  301 NC=1
      ND=0
  302 DO 200 I=1,NX
      J=NC*I - ND
  200 C(J)=FM(I)
      IF(DELT) 303,304,303
  304 IF(L-1)404, 500 ,404
  404 L=L-1
      GO TO 496
C
C  HALVING.
C
  204 I=1
      NCHECK=NX
      NX=NX/2
      NCK=NCHECK -(NX+NX)
      IF(NCK)555, 504, 555
  555 NX=NX+1
  504 K=2*I-1
      C(I)=C(K)+C(K+1)
      IF(I-NX)502,503,503
  502 I=I+1
      GO TO 504
  503 IF(L-1)525,525,205
C
C  SMOOTHING IF *SMOOTH* NOT EQUAL TO ZERO.
C
  525 IF(SMOOTH)526,500,526
  526 DELT=DEL
      SMOOTH=SMOOTH - 1.0
      FMULT=0.5
      GO TO 496
  205 L=L-1
      GO TO 204
C
C  COUNTS SCALED IN ACCORD WITH *FMULT* FOR INCREASED SPECTRA.
C
  500 KK=0
  915 CONTINUE
      IF(KK)1499,1500,1499
 1500 FAC=1.0
      GO TO 1501
 1499 FAC=1.0/2.0**KK
 1501 IF(FMULT-FAC)916,917,917
  916 KK=KK+1
      GO TO 915
  917 DO 920 I=1,NX
  920 C(I)=C(I)*FAC
      IF(SMOOTH)204,527,204
  527 GAIN=G
      RETURN
      END
(FOR,IS GEOMTR
      SUBROUTINE GEOMTR (ENXTAL,E,PHI,NS,NX,DE,DT,VOL,RX,RO)
C**********  PROGRAM NUMBER -  18  CUGEL      ************
C
C     COMPUTES GEOMETRY FACTORS.  INTEGRATES NUMBER AND ENERGY SPECTRA.
C     CALCULATES NORMALIZED DOSE DATA FOR FINAL CODE RESULTS.
C
      COMMON /C/ SUMNUM,SUMENY,DOSDET,AVENGY,PHNUBE,ENBENY,PHENBE,
     1 DOSBEX,DOSCYL,DBXVOL,DCYVOL ,BETNUM,BETENY,CYLDIA
      DIMENSION PHI(400),E(400),ENXTAL(400)
      PIE=3.14159265
      VOL=(PIE*CYLDIA**3)/4.0
      TIME=DT*60.0
      AREAXT=PIE*RX*RX
      CONST=3600./5.24E+07
      SUMNUM=0.0
      SUMENY=0.0
      SOGEOM=0.5*(1.0-RO/SQRT(RO*RO+RX*RX))
      DOSDET=0.0
C INTEGRATE.
      DO 2 I=NS,NX
      PHI(I)=DE*PHI(I)/(AREAXT*TIME)
      ENXTAL(I)=PHI(I)*E(I)
      EC=E(I)
      DOSXTL   =   PHI(I)*CONST*DOSE (EC)
      SUMNUM=SUMNUM+PHI(I)
      SUMENY=SUMENY+ENXTAL(I)
    2 DOSDET=DOSDET+DOSXTL
C
      AVENGY=SUMENY/SUMNUM
      PHNUBE=SUMNUM/BETNUM
      ENBENY=SUMENY/BETENY
      PHENBE=SUMENY/BETNUM
      DOSBEX=DOSDET/BETNUM
      DOSCYL=DOSBEX/SOGEOM
      DBXVOL=DOSBEX/VOL
      DCYVOL=DOSCYL/VOL
C
      RETURN
      END
(FOR,IS GUESS3
      SUBROUTINE GUESS3(NS,NFN,Y,B,V1,V2)
C**********  PROGRAM NUMBER -  19  CUGEL      ************
C
C     DOUBLE PHOTOPEAK INITIAL PARAMETER ESTIMATES
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      DIMENSION B(8),Y(400),VT(50)
      AREAT=0.0
      II=0
      XNS=NS
      XNF=NFN
      B(7)=(Y(NFN)-Y(NS))/(XNF-XNS)
      NT=NS
      IF(V2)25,26,25
   25 N1=1
      NV1=V1
      NV2=V2
      DO 100 I=NV1,NV2
      J=I-NV1+1
  100 VT(J)=1.0/Y(I)
```

```
      N2=J
      CALL VECTMX(VT,N1,N2,JMAX,BIG)
      II=JMAX+NV1-1
      IF(II-NV1)105,105,106
  106 IF(II-NV2)26,105,105
  105 II=(V1-V2)/2.0+1.0
   26 DO 3000 I=NS,NFN
      X=I-NS
      AREAT=AREAT+Y(I)-(Y(NT)+X*B(7))
      IF(I-II)50,50,3000
   50 A1=AREAT
 3000 CONTINUE
      B(3)=A1
      B(6)=AREAT-A1
      B(8)=Y(NS)
      IF(MOUT)2,1,2
    1 WRITE(LO,10)(B(I),I=1,8)
   10 FORMAT(8H GUESS3 /(1X,8E14.7))
    2 RETURN
      END
(FOR,IS PKFUN
      SUBROUTINE PKFUN (NX,NPK,NFREE,J,NSS,NS,NFNN,NPARA,E,FM,B,TITLE)
C**********  PROGRAM NUMBER -  20  CUGEL      ************
C
C      PHOTOPEAK FITTING CONTROL
C
      DIMENSION TITLE(2),FM(800),NPARA(8),B(8),FA(80),A(5)
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      NPS=3*NPK+1
      NPI=NPK*3+2
C     WRITE(LO,2)NS,(NPARA(I),I=1,5),E
      B2=0.00128*EXP(0.395*E)
      B2=B2*1.2
      ANS=NS
      BX=B2*ANS/E
      N1=ANS-6.*BX-0.5
      N2=ANS+6.*BX+0.5
      CALL VECTMX (FM,N1,N2,JMAX,YMAX)
      YMAX=YMAX-((FM(N2)+FM(N1))/2.0)
      B(1)=JMAX
      B(2)=B2*B(1)/E
      B(3)=YMAX*B(2)*2.35
C     WRITE (LO,7) NSS,NFNN,B(1),B(2),B2,YMAX
C     WRITE(LO,7)N1,N2,BX,ANS,B(2),B(3)
      SS=B(1)- 6.0*B(2)-0.5
      FNN=B(1)+6.0*B(2)+0.5
      NSS=SS
      NFNN=FNN
C     WRITE(LO,7)NSS,NFNN,SS,FNN,B2,B(3)
C   7 FORMAT(8H PKFUN 2,2I5,4E14.7)
C     WRITE(LO,5)(B(I),I=1,NPI)
      XNF=NFNN-NSS+1
      B(NPI)=FM(NSS)
      B(NPS)=(FM(NSS)-FM(NFNN))/(-XNF)
      NAS=NSS
      DO 31 K=1,2
      IF(K-1)30,30,22
   22 IF(FM(NSS)-0.8*FM(JMAX))20,21,21
   20 NSS=NSS+1
      GO TO 22
   21 CONTINUE
      A(1)=B(1)
      A(2)=B(2)
      A(3)=B(3)
      A(4)=B(4)
      A(5)=B(5)
```

```
      B(NPI)=FM(NFNN)
      B(NPS)=-.0005
   30 CONTINUE
      B(1)=B(1)-NSS
C     WRITE(LO,7)NSS,NFNN,SS,FNN,B2,[illegible]
C     WRITE(LO,5)(B(I),I=1,NPI)
      CALL STDFT3 (FM,B,NFNN,NSS,NFREE,NPK,NPARA,NAS,FA,TITLE,0)
   31 CONTINUE
      DO 36 I=1,3
      AA=A(I)/B(I)
      IF(AA.GT.0.93.AND.AA.LT.1.08)GO TO 38
      B(1)=A(1)
      B(2)=A(2)
      B(3)=A(3)
      B(4)=A(4)
      B(5)=A(5)
      GO TO 37
   38 CONTINUE
   36 CONTINUE
   37 CALL STDFT3 (FM,B,NFNN,NSS,NFREE,NPK,NPARA,NAS,FA,TITLE,1)
      DO 60 I= NSS,NFNN
      II=I-NSS+1
   60 FM(I)=FA(II)
      B22=B(2)*B(1)/E
      B23=B(1)/E
      B32=E/B(1)
C     WRITE(LO,100) NSS,NFNN,(FM(I),I=NSS,NFNN)
C 100 FORMAT(9H PEAK SUB ,2I10/(1X,10E11.4))
C     WRITE(LO,4)B22,B23,YMAX,B32,E
C   4 FORMAT (8H PKFUN 4,5E14.7)
C   2 FORMAT(8H PKFUN 1,6I5,F10.5)
C   5 FORMAT(8H PKFUN 3,5F10.2)
      RETURN
      END
(FOR,IS POGELI
      SUBROUTINE POGELI (FOUT,NSIG,MSIG,JMIN,E,CEA,DEA)
C**********  PROGRAM NUMBER -  21  CUGEL      ************
C
C      2-PART CONTINUUM INTERPOLATION
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/SPN/R,STDEN,BDUM(8),PARAV,PARAS,PAREA,DUM(24),NDUM(48),NSTA
     1ND
      COMMON/BSI/RV,EBS,VBS,BY
      COMMON/XLIM/NXLIM,I5,INZ,INA,ICO,I24,IDUM(12)
      COMMON/GAN/NLI
      DIMENSION R(400,12),FOUT(400),Y(3),FM(800),EBS(12),VBS(12),ECE(3),
     1VCE(3),NCE(3),BY(12),VNCE(12),NVX(12),RC(400,3),Z(3)
     2,STDEN(12,2),PARAV(12,2),PARAS(12,2),PAREA(12,2),RV(60,12)
C     WRITE(LO,507) NSIG,NSTAND,((STDEN(I,II),I=1,12),II=1,2)
C     WRITE(LO,507)MSIG,JMIN,(EBS(I),I=1,12),(VBS(I),I=1,12)
      NLI=800
      DEA=0.0
      NDEGRE=2
      SM=0.0
      TAZ=0.0
      NY=NSTAND
      GO TO (3,2,3,4),NSIG
C  GO TO 2 FOR COBALT 1.17 CONTINUUM
    2 NY=ICO
      MIN1=NY-3
      MIN2=NY-2
      MIN3=NY-1
      EX=STDEN(ICO,2)
      EXB=EX/(1.0+(EX/0.511)*2.0)
      EXC=EX-EXB
```

```
      JMIN=MIN1
      N=2
      GO TO 7
C  GO TO 4 FOR GENERAL INTERPOLATION
    4 MIN1=JMIN
      MIN2=JMIN+1
      MIN3=JMIN+2
      N=3
      EX=E
      EXB=E/(1.0+(E/0.511)*2.0)
      EXC=E-EXB
    7 DO 44 I=1,NORM
   44 FM(I)=R(I,MIN3)
C     WRITE(LO,502) MIN1,MIN2,MIN3,JMIN,NSIG,MSIG,NY,NSTAND,EXB,EX,EXC,E
      DO 40 J=1,3
      JJ=J+MIN1-1
      ECE(J)=STDEN(JJ,1)-EBS(JJ)
C     WRITE(LO,2500) JJ,STDEN(JJ,1)
   40 VCE(J)=ECE(J)*NORM/STDEN(JJ,1)
C     WRITE(LO,104) (EBS(I),I=MIN1,MIN3)
C     WRITE(LO,104)(ECE(I),I=1,3)
C     WRITE(LO,104)(VCE(I),I=1,3)
      N1=VCE(3)-0.05*VCE(3)
      N2=VCE(3)+0.05*VCE(3)
      CALL VECTMX(FM,N1,N2,JMAX,YMAX)
      NCE(3)=JMAX
      FNCE=NCE(3)
      FNCE=FNCE/VCE(3)
      DO 45 J=1,2
   45 VNCE(J)=VCE(J)*FNCE
      VNCE(3)=NCE(3)
      NCE(1)=VNCE(1)+0.5
      NCE(2)=VNCE(2)+0.5
      DO 81 I=1,NORM
   81 FM(I)=0.0
C     WRITE(LO,503) (NCE(I),I=1,3),N1,N2,JMAX,EXC
C
C     CHANGE FIRST HALF OF STANDARD CONTINUA
C
      DO 46 J=1,3
      DO 46 I=1,NORM
   46 RC(I,J)=0.0
      NVX(3)=NCE(3)+20
      DO 48 J=1,2
      GAIN=VNCE(J)
      RQGAIN=VNCE(3)
      NX=NVX(3)
      JJ=J+MIN1-1
      DO 49 I=1,NX
   49 FM(I)=R(I,JJ)
      MX=NX
C     WRITE(LO,1000) NVX(3),NX,GAIN,RQGAIN
      CALL GANE(TAZ,MX,GAIN,RQGAIN,SM,FM)
      NVX(J)=NX
      DO 50 I=1,NX
   50 [illegible](I,J)=FM(I)
      [illegible] 51 I=1,NORM
   51 [illegible]=0.0
      [illegible]101) NVX(1),NVX(2),NX,NVX(3),MX,J
   59 [illegible]
      Z[illegible]N(MIN1,1)
      Z(2)=STDEN(MIN2,1)
      Z(3)=STDEN(MIN3,1)
      WRITE(LO,10[illegible]) Z(1),Z(2),Z(3)
      RC(1,[illegible])=RC(2,[illegible])
      RC(1,2)=RC(2,2)
```

```
      IF(N-2)5252,5253,5252
 5253 Z(1)=Z(2)
      Z(2)=Z(3)
      DO 5254 I=1,NX
      Y(1)=RC(I,2)
      Y(2)=R(I,MIN3)
 5254 FOUT(I)=TE(2,Z,Y,EX)
      GO TO 5255
 5252 DO 52 I=1,NX
      Y(1)=RC(I,1)
      Y(2)=RC(I,2)
      Y(3)=R(I,MIN3)
   52 FOUT(I)=TE(3,Z,Y,EX)
 5255 Z(1)=ECE(1)
      Z(2)=ECE(2)
      Z(3)=ECE(3)
      CEA=TE(3,Z,VNCE,EXC)
C     WRITE(LO,8000)NX,EX,CEA,EXC,ECE(1),ECE(2),ECE(3),(FOUT(I),I=1,
C    1NORM)
C8000 FORMAT(10H FIRST 1/2 ,I5,6E14.7/(1X,10E11.4))
      IF(NSIG-2)950,951,950
  951 DO 952 I=1,NLIMIT
  952 FM(I)=R(I,NY)
      GAIN=PARAV(NY,2)
      RQGAIN=NORM
      KM=NLIMIT
      CALL GANE(TAZ,KM,GAIN,RQGAIN,SM,FM)
      SM1=1.0
      NW=NORM
      CALL GANE(TAZ,NW,1.0,1.0,SM1,FM)
      NS=CEA-5.0
      NF=CEA+10.0
      CALL VECTMX(FM,NS,NF,JMAX,YMAX)
      DEA=JMAX-CEA
C     WRITE(LO,1003) NY,NS,NF,JMAX,NSIG,DEA,GAIN
  950 CONTINUE
C     WRITE(LO,1002) CEA,Z(1),Z(2),Z(3),VNCE(1),VNCE(2),VNCE(3)
      GAIN=VNCE(3)
      RQGAIN=CEA
      NX=NVX(3)
      MX=NX
C     WRITE(LO,1000)NX,NVX(3),GAIN,RQGAIN
      DO 9000 I=1,NORM
 9000 FM(I)=FOUT(I)
      CALL GANE(TAZ,MX,GAIN,RQGAIN,SM,FM  )
      DO 9050 I=1,NORM
 9050 FOUT(I)=FM(I)
      NOX=NX+1
      DO 53 I=NOX,NORM
   53 FOUT(I)=0.0
C     WRITE(LO,105)(FOUT(I),I=1,NX)
C
C     RELOCATE 2ND HALF OF STANDARD CONTINUA
C
      DO 71 I=1,NORM
   71 FM(I)=0.0
      NX=NORM-VNCE(1)+20
      RQGAIN=NORM-VNCE(3)+1.0
      GG=RQGAIN
      DO 56 J=1,2
      NCE(J)=VNCE(J)+0.5
      GAIN=NORM-NCE(J)+1
      J2=J+MIN1-1
      DO 57 I=1,NX
      I1=NORM+1-I
   57 FM(I)=R (I1,J2)
```

```
      MX=NX
C     WRITE(LO,1000)                           NX,J2,GAIN,RQGAIN
      CALL GANE (TAZ,MX,GAIN,RQGAIN,SM,FM)
      DO 58 I=1,NX
   58 RC(I,J)=FM(I)
      DO 59 I=1,NORM
   59 FM(I)=0.0
   56 CONTINUE
      DO 60 I=1,NORM
      K=NORM+1-I
   60 RC(I,3)=R(K,MIN3)
      M4=NORM-NX
      Z(1)=STDEN(MIN1,1)
      Z(2)=STDEN(MIN2,1)
      Z(3)=STDEN(MIN3,1)
C     WRITE(LO,1004) M4,NORM,NX,Z(1),Z(2),Z(3),(RC(I,3),I=1,NORM)
      DO 5000 JK=1,3
C     WRITE(LO,100)(RC(I,JK),I=1,NORM)
 5000 CONTINUE
      IF(N-2)6252,6253,6252
 6253 Z(1)=Z(2)
      Z(2)=Z(3)
      DO 6254 I=1,NX
      Y(1)=RC(I,2)
      Y(2)=RC(I,3)
 6254 FM(I)=TE(2,Z,Y,EX)
      GO TO 6255
 6252 DO 61 I=1,NX
      Y(1)=RC(I,1)
      Y(2)=RC(I,2)
      Y(3)=RC(I,3)
   61 FM(I)=TE(3,Z,Y,EX)
 6255 CONTINUE
C     WRITE(LO,100)(FM(I),I=1,NX)
      GAIN=GG
      RQGAIN=NORM-CEA+1.0
      MX=NX+20
C     WRITE(LO,1000) NX,MX,GAIN,RQGAIN
      CALL GANE(TAZ,MX,GAIN,RQGAIN,SM,FM)
      M6=CEA+1.0
      M7=NORM-M6+1
      DO 62 I=M6,NORM
      II=M7-I+M6
   62 FOUT(I)=FM(II)
      FOUT(1)=FOUT(2)
C 240 WRITE (LO,110)(FOUT(I),I=1,NORM)
      SUM=0.0
      DO 7483 I=1,NORM
 7483 SUM=SUM+FOUT(I)
C     WRITE(LO,7484) SUM
C     WRITE(LO,110) (FOUT(I),I=1,NORM)
C 100 FORMAT(1H1,(1X,10F10.8))
C 101 FORMAT(1X,3I5)
C 102 FORMAT(1H1,12F10.8)
C 104 FORMAT(1H0,27H LOCATION OF COMPTON EDGE  ///(1X,3F10.4))
C 105 FORMAT(1H1,56H FIRST HALF OF INTERPOLATED CONTINUUM WITHOUT BS-PEA
C    1K   ///(1X,10F10.8))
C 106 FORMAT(1X,21H LOCATION OF PEAKS   (2F6.2))
C 107 FORMAT(1H1,53H FIRST HALF OF INTERPOLATED CONTINUUM WITH BS-PEAK
C    1 ///(1X,10F10.8))
C 108 FORMAT(1H1,20H MODIFIED SPECTRUM   ///1X,4I5,2F10.5/(1X,10F10.8))
C 109 FORMAT(1H1,40H SECOND HALF OF INTERPOLATED CONTINUUM   ///(1X,10F1
C    10.8))
C 110 FORMAT(1H1,16H FINAL RESULT   ///(1X,10F10.8))
      CALL BBS(EX,FOUT,MIN1)
C 118 FORMAT(1X,I5,2F10.5/(1X,10F10.8))
```

```
C 150 FORMAT(1X,6I5)
C 152 FORMAT(1H1,12H POGELI  1  ,2I4,4F6.3/))
C 155 FORMAT(1H1,12H POGELI  4  ,3I5//)
C 500 FORMAT(1H1,26H CO-60, 1.33 MEV BS-PEAK  //(1X,10F10.8))
C 501 FORMAT(1H1,28H CO-60, 1.33 MEV CONTINUUM  //(1X,10F10.8))
C 502 FORMAT(1X,17H CHECK POGELI    ,8I5,4E12.5///)
C 503 FORMAT(1H1,26H COMPTON EDGE AND ENERGY  //(1X,6I5,E14.7))
C 504 FORMAT(1H1,21H NORMALIZED BS-PEAK  ///(1X,10F10.8))
C 505 FORMAT(1H1,23H NORMALIZED CONTINUUM  ///(1X,10F10.8))
C 506 FORMAT(1X,F10.8)
C 507 FORMAT(1H0,10H Q-CHECK  /1X,2I5/(1X,12F9.4))
C1000 FORMAT(1X,2I5,2F10.5/)
C1001 FORMAT(1X,3F10.5/)
C1002 FORMAT(1X,7F10.5//)
C1003 FORMAT(1X,5I5,2F10.5/)
C1004 FORMAT(1X,3I5,3F10.5//(1X,10F10.8/))
C2500 FORMAT(1X,16H ENERGY CHECK   ,I5,F10.6/)
C7484 FORMAT(14H POLATE SUM =  ,E14.7//)
    3 RETURN
      END
[FOR,IS RESFUN
      SUBROUTINE RESFUN
C**********  PROGRAM NUMBER -  22  CUGEL     ************
C
C     CONTROL PROGRAM FOR RESPONSE MATRIX GENERATION.
C
      DIMENSION RM(40,40),R(400,12),M3(12), X(12),PV(40),PFRACT(40),ALAB
     1EL(12),   Q(400),STDEN(12,2),Z(3),Y(3),RR(12),NSJ(12,2),NFNJ(12,2)
     2,NSXJ(12),NFXJ(12),SHIFT(12),B(8),PARAV(12,2),PARAS(12,2),ISO(12)
     3  ,PAREA(12,2),           BLABEL(12),NCS(12),FOUT(400),TITLE(2)
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/SPN/R,STDEN,B,PARAV,PARAS,PAREA,ALABEL,BLABEL,NSJ,NFNJ,NSTA
     1ND
      COMMON/RES/RM,N,EM,ELIMIT,NDEGRE,Q,PV,PFRACT,K,MRPEAT,ESING,MEM
      COMMON/CNSTNT/T01,T20,T50,T1293,T90,T100,T06
      COMMON/XLIM/NXLIM,IS,INZ,INA,ICO,I24,ISO
      COMMON/OOORM/ORM,OORM
      COMMON/GAN/NLI
      COMMON/SPCT/FM(1000)
C
C READ STANDARD LIBRARY SPECTRA.
C
      NLI=800
      NMAT=40
      KKK=K
      SM=0.0
      NL=0
      TAZ=0.0
      IF(ESING)815,816,815
  816 IF(MRPEAT)31234,21234,31234
21234 DO 9052 J=1,12
      NFXJ(J)=0.0
 9052 NSXJ(J)=0.0
      DO 380 J=1,12
      DO 8081II=1,NLIMIT
 8081 R(II,J)=0.0
      DO 380 I=1,2
      NSJ(J,I)=0
      NFNJ(J,I)=0
      PARAV(J,I)=0.0
      PARAS(J,I)=0.0
      PAREA(J,I)=0.0
  380 STDEN(J,I)=0.0
      READ(LI,6) NSTAND,NXLIM,NADD
    6 FORMAT(3I5)
      DO 8080 J=1,NSTAND
```

```
      READ(LI,88)ALABEL(J),BLABEL(J),STDEN(J,1),STDEN(J,2),ENSJ,SO,SXJ,F
     1XJ,ENCS,SHIFT(J),(R(I,J),I=1,NXLIM)
   88 FORMAT(2A3,8F6.0/(10F7.0))
      R(NXLIM,J)=1.0
      NSJ(J,1)=ENSJ
      NSXJ(J)=SXJ
      NFXJ(J)=FXJ
      ISO(J)=SO
      NCS(J)=ENCS
 8080 CONTINUE
C
C  COMPLEMENT OVERSUBTRACTED COUNTS.
      DO 8000 J=1,NSTAND
      DO 8000 I=1,NXLIM
      IF(R(I,J)-T90) 8001,8001,8002
 8002 R(I,J)=R(I,J)-T100
 8001 CONTINUE
 8000 CONTINUE
C     WRITE(LO,3456)N,MRPEAT,EM,ELIMIT,ESING
C3456 FORMAT(10H SHAPE-1  ,2I5,5X,3E14.7)
C
C  SHIFT SPECTRA AN AMOUNT TZ IF TZ NOT =0
      NTZ=0
      DO 9000 J=1,NSTAND
      IF( SHIFT(J))9001,9002,9001
 9001 TZ= SHIFT(J)
      NTZ=TZ
      IF(NSXJ(J))9018,9019,9018
 9018 NSXJ(J)=NSXJ(J)-NTZ
      NFXJ(J)=NFXJ(J)-NTZ
 9019 NSJ(J,1)=NSJ(J,1)-NTZ
      NCS(J)=NCS(J)-NTZ
      NX=NXLIM
      GAIN=1.0
      RQGAIN=1.0
      DO 9003 I=1,NXLIM
      FM(I)=R(I,J)
 9003 R(I,J)=0.0
      CALL GANE (TZ,NX,GAIN,RQGAIN,SM,FM)
      DO 9004 I=1,NX
 9004 R(I,J)=FM(I)
 9002 CONTINUE
 9000 CONTINUE
      DO 7002 J=1,NSTAND
      NPHA=NCS(J)
      DO 7002 I=1,NPHA
 7002 R(I,J)=R(NPHA  ,J)
C
C SUBTRACT X-RAY PEAKS,ETC.
C
      DO 5001 J=1,NSTAND
      IF (NSXJ(J)+NFXJ(J))5029,5001,5029
 5029 DEL=NFXJ(J)-NSXJ(J)
      NXX=NSXJ(J)
      NSX=NSXJ(J)+1
      NFXX=NFXJ(J)
      NFX=NFXJ(J)-1
      DO 5021 I=NSX,NFX
      W=I-NXX
 5021 R(I,J)=R(NXX,J)+W*(R(NFXX,J)-R(NXX,J))/DEL
 5001 CONTINUE
      UNGAIN=0.0
      WRITE(LO,7) NSTAND,NPHA,UNGAIN,  (ALABEL(J),
     1BLABEL(J),NSJ(J,1),NSJ(J,2),NSXJ(J),NFXJ(J),SHIFT(J),STDEN(J,1),
     2STDEN(J,2),J=1,NSTAND)
    7  FORMAT(1H1,15X ,37H STANDARD SOURCE SPECTRAL PARAMETERS  ,///
```

```
     1  14X,I5,33H SPECTRA IN STANDARD SOURCE DECK   ,//
     2  13X,16H CHANNELS ONE TO ,I4,22H ASSUMED AS REDUNDANT   ,//
     3  17X,25H REFERENCE COARSE GAIN =     ,F10.5,////
     41X,72HSTANDARD          PHOTOPEAK      X-RAY OR .5 PEAK      SHIFT
     5 PHOTOPEAK    ,/73H  SOURCE         FROM        TO       FROM       TO
     6      SPECTRUM  ENERGIES   //10X,70H   CHANNEL  CHANNEL   CHANNEL
     7 CHANNEL   CHANNELS        MEV         MEV               ,/
     8 (2X,2A3,6X,I4,5X,I4,7X,I3,6X,I3,4X,F9.4,1X,2F10.5))
      DO 27123 J=1,NSTAND
      WRITE (LO,8999) ALABEL(J),BLABEL(J),(R(I,J),I=1,NXLIM)
 8999 FORMAT (1H1,32X,25H STANDARD SOURCE SPECTRA    ////////  3X,2A3,
     1 8H SOURCE ////(1X,10F9.0))
27123 CONTINUE
      WRITE  (LO,3)
    3 FORMAT (1H1)
C
C CALL SPNORM TO CALC GAUSSIAN PARAMETERS AND UNIT CONTINUA FOR STANDS.
C
C
      CALL SPNORM
C
      IF(ICO)607,607,608
  607 ICY=NSTAND-NADD
      GO TO 609
  608 ICY=ICO-1
  609 CONTINUE
C     WRITE(LO,930)ICY,ICO,(NCS(I),I=1,12)
C 930 FORMAT(11H NCS CHECK ,14I4)
      CALL BS(ICY,1,M3)
      IF(ICO)24,20,24
   24 NSIG=2
      E=STDEN(ICO,2)
      JMIN=ICO-3
C     WRITE(LO,100)ICO,NSTAND,STDEN(ICO,2)
C
      CALL POGELI (FOUT,NSIG,MSIG,JMIN,E,CEA,DEA)
C
      XNL=NXLIM
      DD=DEA*XNL/ORM
      PARAV(ICO,2)=PARAV(ICO,2)-DD
      PARAV(ICO,1)=PARAV(ICO,1)-DD
      TITLE(1)=ALABEL(ICO)
      TITLE(2)=BLABEL(ICO)
C     CALL XPLOT(TITLE,FOUT,FOUT,1,NORM)
C     WRITE(LO,200)(FOUT(I),I=1,NORM)
      A3=NORM*PARAV(ICO,2)/PARAV(ICO,1)
      MX=NORM  +1
      GAIN=NORM
      RQGAIN=A3
      N3=A3+1.
      DO 9090 I=1,NORM
 9090 FM(I)=FOUT(I)
      CALL GANE(TAZ,MX,GAIN,RQGAIN,SM,FM)
      DO 9091 I=1,NORM
 9091 FOUT(I)=FM(I)
C     WRITE(LO,200)(FOUT(I),I=1,200)
      DO 910 I=1,N3
  910 FOUT(I)=FOUT(I)*PAREA(ICO,2)
C     WRITE(LO,100)MX,N3,RQGAIN
C     WRITE(LO,412)(FOUT(I),I=1,NORM)
C     WRITE (LO,100)ICO,NXLIM,DD
      DO 911 I=1,NXLIM
      FM(I)=R(I,ICO)
  911 R(I,ICO) =0.0
C     WRITE (LO,412) (FM(I),I=1,NXLIM)
      MX=NXLIM
```

```
      GA=1.0
      RQ=1.0
      CALL GANE(DD ,MX ,GA,RQ,SM,FM)
C     WRITE (LO,412) (FM(I),I=1,MX)
      MX=NXLIM
      GAIN=PARAV(ICO,1)
      ROGAIN=NORM
      FM(1)=FM(2)
      CALL GANE(TAZ,MX,GAIN,ROGAIN,SM,FM)
C     WRITE(LO,412)(FM(I),I=1,NORM)
      DO 9130 I=1,NORM
 9130 R(I,ICO)=FM(I)-FOUT(I)
C     WRITE (LO,412) (R(I,ICO),I=1,NORM)
      DO 913 I=1,NORM
  913 R(I,ICO)=R(I,ICO)/PAREA(ICO,1)
      N1=.75*NORM
      N2=.85*NORM
      DO 912 I=N1,N2
  912 FM(I)=R(I,ICO-1)
      CALL VECTMX(FM,N1,N2,NC1,FC1)
      N1=.80*NORM
      N2=.85*NORM
      DO 916 I=N1,N2
  916 FM(I)=R(I,ICO)
      CALL VECTMX(FM,N1,N2,NC2,FC2)
      FP=FC2/FC1
      DELT=NC2-NC1
      NUP=(178.0/200.)*NORM
      NAP=(105./200.)*NORM
C     WRITE (LO,19765) NAP,NUP,NC1,NC2,FC1,FC2,FP
C9765 FORMAT (9H NAP ETC    ,4I5,3E14.7)
      DO 917 I=NAP,NUP
      II=I-DELT
  917 R(I,ICO)=R(II,ICO-1)*FP
C     WRITE(LO,200)(R(I,ICO),I=1,NORM)
      DO 1976 I=1,NORM
      IF(R(I,ICO))1977,1978,1978
 1977 R(I,ICO) =0.0
 1978 CONTINUE
 1976 CONTINUE
C
      CALL BS(ICO,3,M3)
C
   20 CONTINUE
      DO 19123 J=1,NSTAND
      WRITE(LO,3)
      WRITE(LO,81) ALABEL(J),BLABEL(J),STDEN(J,1),(R(I,J),I=1,210)
   81 FORMAT (10X,42H NORMALIZED CONTINUUM OF STANDARD SPECTRA //////
     13X,2A3,8H SOURCE ///5X,8HENERGY= ,F10.4,5H MEV ////(1X,5E14.7))
      TITLE(1)=ALABEL(J)
      TITLE(2)=BLABEL(J)
      SUM=0.
      DO 9060 I=1,NORM
      SUM =SUM+R(I,J)
 9060 FM(I)=R(I,J)
      PHOTO=1.0/(SUM+1.0)
      WRITE(LO,6791) SUM,PHOTO
 6791 FORMAT(/17H INTEGRAL        =  ,E14.7/17H PHOTOFRACTION = ,E14.7)
C     CALL XPLOT ( TITLE,FM,FM,1,NORM )
19123 CONTINUE
31234 K=0
      NO=NLIMIT
      NMAX=NO
      P=0.0
      NS=1
      DO 10 I=NS,NO
   10 FM(I)=0.0
      DO 11 I=NS,NMAT
      PFRACT(I)=0.0
      PV(I)=0.0
      DO 11 J=NS,NMAT
   11 RM(I,J)=0.0
      EN=N
      DE=ELIMIT/EN
      DEL=DE/2.0
      MM=N
      WRITE(LO,3)
C
      KJ=NS
  920 GAIN=OORM
      E=KJ
      E=E*DE-DEL
      GO TO 718
C  INTERPOLATE FROM ENERGY X(1) TO ENERGY X(NTOP)
  815 E=ESING
      V=E*EM
C     WRITE(LO,818)    MRPEAT,E,V,EM
C 818 FORMAT (10H SHAPE 01 /1X,I10,5X,3E14.7)
      KJ=1
      GAIN=OORM
  718 NTOP=NSTAND
      LOW=1
      DO 754 INDEX=1,NSTAND
      X(INDEX)=STDEN (INDEX,1)
  754 RR(INDEX)=PARAS(INDEX,1)
      CALL TA (E,X,NTOP,LOW,MOX,MUN,Z,Y,RR,NDEGRE,L,NL)
      IF(MUN-(NSTAND-1))8171,8172,8172
 8172 MUN=NSTAND-2
 8171 JMIN=MUN
      DO 7181 IS=1,3
      JM=JMIN+IS-1
 7181 Y(IS)=Y(IS)*OORM/PARAV(JM,1)
      SIG=TE(3,Z,Y,E)
      IF(E-STDEN(1,1))9070,9080,9080
 9070 DO 9081 I=1,NORM
 9081 FM(I)=R(I,1)*E/STDEN(1,1)
      GO TO 9085
 9080 NSIG=4
C
      CALL POGELI(FOUT,NSIG,MSIG,JMIN,E,CEA,DEA)
C
      DO 9069 I=1,NORM
 9069 FM(I)=FOUT(I)
 9085 NX=NORM
C 950 FORMAT(10H SHAPE-1    /1X,7I5,E14.7/(1X,5E14.7))
C
C     WRITE(LO,951) KJ,NO,NMAX,N,NSTAND,MOX,MUN,E,(FM(I),I=1,210)
C 951 FORMAT(10H SHAPE-2    /1X,7I5,E14.7/(1X,5E14.7))
      IF(ESING)821,822,821
  821 KJ=1
      GO TO 824
C
C SET ENERGY AND PULSE-HEIGHT SCALES
  822 Q(KJ)=E
      V=E*EM
      PV(KJ)=V
      IF(E-0.010)60,60,59
   60 K=K+1
      NMAX=N
      DO 30880 I=1,NLIMIT
30880 FM(I)=0.0
      P=0.0
```

```
      GO TO 61
   59 SCA  =GAIN/V
      AREA=1.0
    8 NMA=GAIN+1.0+6.0*SIG
C     WRITE(LO,952) NMA,NO,SCA  ,GAIN,V,SIG
C 952 FORMAT(10H SHAPE-1A   ,2I5,4E14.7)
      IF(NMA-NO)123,123,124
  124 GN=GAIN
      GAIN=GAIN/2.0
      SIG=SIG/2.0
      SCA  =GAIN/V
C REDUCE VECTOR LENGTH TO ALLOW COMPLETE PEAK TO BE FORMED (I.E.LOW E)
      CALL GANE (TAZ,NMAX,GN,GAIN,SM,FM)
      GO TO 8
C
  123 CALL ADPEAK(FM,NXLIM,GAIN,SIG,AREA,P,NF)
      DO 1955 I=NF,NLIMIT
 1955 FM(I)=0.0
      NMXX=NLIMIT
C
      CALL GANE (TAZ,NMXX,GAIN,V,SM,FM)
      IF(MOUT.NE.0) GO TO 61
      WRITE(LO,12321) NMA,NF,K,NMXX,E,V,SIG,SCA  ,GAIN,GN,ESING
12321 FORMAT (10H PHOFRA 2   ,4I5/1X,7E14.7)
      SUM=0.0
      DO 700 I=1,NMXX
  700 SUM=SUM+FM(I)
      WRITE(LO,500) SUM,NMXX
  500 FORMAT(/10H SUM,NMXX E15.8,I10)
      WRITE(LO,86) KJ,N,E,(FM(I),I=1,NMAT)
   86 FORMAT(1X,//////////
     1       36H INTERPOLATED RESPONSE MATRIX VECTOR,I3,4H OF ,I3,
     214H FOR ENERGY = ,F10.5,5H MEV      /(1X,5E14.7))
   61 M=NMXX+2
      IF(M-NMAT)90,90,91
   91 M=NMAT
   90 PFRACT(KJ)=P
      DO 2 I=NS,M
    2 RM(I,KJ)=FM(I)
      IF(KJ-MM)918,919,919
  918 KJ=KJ+1
      GO TO 920
  919 CONTINUE
  100 FORMAT(2I6,E14.7)
  101 FORMAT(3F10.6)
  102 FORMAT(6F10.2)
  103 FORMAT(6F10.4)
  104 FORMAT(6I5)
  110 FORMAT(2H2,8H CO-60 /1X,F10.0/(1X,10F12.5))
  111 FORMAT(3I10)
  200 FORMAT(1H1,15H FINAL RESULT  //(1X,10F7.5))
  201 FORMAT(1H0,23H NORMALIZED CONTINUA  /(1X,10F7.5))
  202 FORMAT(1X,6E14.7)
  203 FORMAT(1H1,17H INPUT SPECTRUM   ,2A4//(1X,10F10.0))
  400 FORMAT(1X,6I5,2E14.7)
  410 FORMAT(1X,10H COBOL-1  //1X,2I10,2E14.7)
  411 FORMAT(1X,10H COBOL-2  //1X,2I10,4E14.7)
  412 FORMAT(1H1,10H COBOL-3  //(1X,10E12.5))
  824 RETURN
      END
(FOR,IS RESMAT
      SUBROUTINE RESMAT (PHI,P)
C**********  PROGRAM NUMBER -  23   CUGEL      ************
C
C  PULSE-HEIGHT ANALYZER SPECTRUM UNFOLDING ACCORDING TO THE SCOFIELD ALGORITHM.
C
      COMMON/RES/R,N,EMDUM(2),NDEG,DUM1(480),K,MRP,DUM2(2)
      COMMON/SOLRES/EPS,IT,ITMAX,MN,DUM3(2),DIF,SIGMA(12)
      COMMON/LIO/LI,LO,LP,NLIMIT ,NORM,MOUT
      DIMENSION PP( 50),P(800),R( 40, 40),PHI(400) ,FIT(100),DIF(100)
     1 ,MN(18)
C
C  INITIALIZE
C
      NCHECK=ITMAX/2
      NCHECK=ITMAX-2*NCHECK
      SU=0.0
      DO 1999 I=K,N
 1999 SU=SU + P(I)
      DO 1800 I=K,N
 1800 P(I)=P(I)/SU
      YMAX=0.0
C
      CALL VECTMX (P,K,N,JMAX,YMAX)
C
      YLOW=YMAX*(1.0E-15)
      DO 1 I=1,N
      PP(I)=0.0
    1 PHI(I)=P(I)
C  WRITE IF ITMAX IS AN ODD-NUMBER.
      IF(NCHECK)8999,8000,8999
 8999 WRITE  (LO,8989) (P(I),I=1,N)
 8989 FORMAT (30H1 NORMALIZED INPUT SPECTRUM              /(1X,10E11.4))
      INDEX=1
 8000 CONTINUE
      IT=1
      FIT(1)=0.
C
C  MATRIX MULTIPLICATION P=R.PHI
C
   10 DO 2 I=K,N
      PP(I)=0.0
      DO 2 J=K,N
      IF(R(I,J))2001,2000,2001
 2001 PP(I)=PP(I) + R(I,J)*PHI(J)
 2000 CONTINUE
    2 CONTINUE
      TERM = 0.0
C
C  ARRESTING CHECK WHEN  DIF(SUM(P-PP)**2/P) FOR LOOP(IT) AND LOOP(IT-1)
C  ARE LESS THAN EPS.... OR IT=ITMAX.
C
      DO 5 I=K,N
      IF(P(I))4,6,4
    4 TERM = ((P(I) - PP(I))**2)/P(I) + TERM
    6 CONTINUE
    5 CONTINUE
      IF(NCHECK)16000,15000,16000
16000 IF(MN(INDEX) - IT)15000,17000,15000
17000 WRITE(LO,19000) IT,MN(INDEX),(PHI(I),I=K,N)
      WRITE(LO,19005) IT,MN(INDEX),(PP(I) ,I=K,N)
      INDEX=INDEX+1
15000 CONTINUE
19000 FORMAT (51H INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I)) 2I5
     1/     (1X,10E11.4))
19005 FORMAT (51H INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))  2I5
     1/     (1X,10E11.4))
      IT=IT+1
      FIT(IT)=TERM
      DIF(IT)=ABS (FIT(IT-1) - FIT(IT) )
      IF(  DIF(IT)                                     -EPS)7,7,29
   29 IF(IT-ITMAX)229,7,7
```

```
C
C  SCOFIELD CORRECTION FACTOR METHOD.
C
  229 DO 25 I=K,N
      IF(PP(I))125,52,125
  125 PHI(I)=PHI(I)*P(I)/PP(I)
   52 CONTINUE
   25 CONTINUE
      DO 1000 I=K,N
      IF(ABS(PHI(I)) -    YLOW   )1001,1002,1002
 1001 PHI(I)=0.0
 1002 CONTINUE
 1000 CONTINUE
      GO TO 10
C
C  RESULTS.
C
    7 DO 600 I=K,N
      P(I)=P(I)*SU
  600 PHI(I)=PHI(I)*SU
C  WRITE IF ITMAX IS AN ODD-NUMBER.
      IF(NCHECK)9999,10000,9999
 9999 WRITE  (LO,9998) (PP(I),I=1,N)
 9998 FORMAT (20H ITERATED SPECTRUM                    /(1X,10E11.4))
10000 CONTINUE
   60 FORMAT (20H0 IT,SU,TERM                    /I10,2E14.7)
      WRITE  (LO,60)  IT,SU,TERM
      RETURN
      END
[FOR,IS SIMPSN
      FUNCTION SIMPSN (A,B,EPS)
C**********  PROGRAM NUMBER -  24  CUGEL     ************
C
C      SIMPSONS RULE INTEGRATING PROGRAM FOR FUNCTION -FC-.
C
      COMMON /B/ KL,UEGAM,RX,DIST,H
      TMAX=2048.
      AN=2.0
      FA=FC(A)
      FB=FC(B)
      FP=0.0
      SI=0.0
      DELT=B-A
  405 FOUR=0.0
      AK=1.0
      AKN=AN/2.0
  399 FFX=FC(A+(((2.0*AK-1.0)*DELT)/AN))
      FOUR=FOUR+FFX
      IF(AKN-AK)400,401,400
  400 AK=AK+1.0
      GO TO 399
  401 SIM=(DELT/(AN*3.0))*(FA+FB+4.0*FOUR+2.0*FP)
      IF(TMAX-AN)503,503,499
  499 DIFX=ABS(SIM-SI)
      IF(EPS-DIFX/SIM)402,403,403
  402 AN=AN+AN
      FP=FP+FOUR
      SI=SIM
      GO TO 405
  503 CONTINUE
  403 SIMPSN=SIM
      RETURN
      END
[FOR,IS SOLN
      SUBROUTINE SOLN  (NS,PHI,P,ETA,DIST,M,RX,TKLUM,PFRACT,M19)
C**********  PROGRAM NUMBER -  25  CUGEL     ************
C
C      DETERMINES AND APPLIES DETECTOR EFFICIENCY VECTOR.
C
      COMMON /A/ DI,H,MF
      COMMON/RES/R,N,DUM(2),NDUMN,E,DUM2(80),K,MRDUM,DUM3(2)
      COMMON/SOLRES/EPS,IT,ITMAX,   MN,MSKIP,M14,DIF ,SIGMA(12)
      COMMON/LIO/LI,LO,LP,NLIMIT ,NORM,MOUT
      DIMENSION P(800),R(40,40),PHI(400),ETA(400),E(400),DIF(100),M(24),
     1   MN(18) ,PFRACT(40)
      MF=0
      IF(K)50,30,50
   30 K=1
   50 KK=K-1
      IF(KK-1)601,602,602
  602 DO 600 I=1,KK
  600 P(I)=0.0
  601 CONTINUE
      IF(M(5))12,11,12
C
   11 CALL RESMAT (PHI,P)
      WRITE  (LO,1424) (DIF(I),I=1,IT)
 1424 FORMAT (30H FITTING DIFFERENCES                    /(1X,5E14.7))
C
   12 IF(DIST-DI)3,40,3
   40 IF(MSKIP)3,4,3
    3 IF(M(14))2,13,2
C
   13 CALL DETECT (NS,N,E,H,ETA,DIST,RX,TKLUM,PFRACT,M19)
C
    2 DI=DIST
    4 IF(M(14))54,44,54
   44 DO 22 I=NS,N
   22 PHI(I)=PHI(I)/ETA(I)
      MF=0
C  WRITE DIF(I) IF (IT=ITMAX)
      IF(IT-ITMAX)89,100,100
  100 WRITE(LO,105) (DIF(I),I=1,IT)
  105 FORMAT (1H1,36H FLUX FITTING DIFFERENCES (IT=ITMAX)/(1X,5E14.7))
   89 RETURN
   54 IF(M(15))98,99,98
   98 DO 96 I=NS,N
   96 ETA(I)=1.0
   99 DO 9999 I=NS,N
 9999 PHI(I)=P(I)/ETA(I)
      MF=1
      RETURN
      END
[FOR,IS SPNORM
      SUBROUTINE SPNORM
C**********  PROGRAM NUMBER -  26  CUGEL     ************
C
C      CALLED BY *RESFUN* TO NORMALIZE STANDARD SPECTRA
C      FITS GE(LI) PHOTOPEAKS. NORMALIZES COMPTON CONTINUA
C
      DIMENSION R(400,12),ALABEL (12),BLABEL(12),STDEN(12,2),
     1PARAV(12,2),PARAS(12,2),PAREA(12,2),ISO(12),NCODE(12),
     2NPARA(8),B(8),TITLE(2),NSJ(12,2),NFNJ(12,2),FM(800)
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/SPN/R,STDEN,B,PARAV,PARAS,PAREA,ALABEL,BLABEL,
     1NSJ,NFNJ,NSTAND
      COMMON/XLIM/NXLIM,IS,INZ,INA,ICO,I24,ISO
      COMMON/GAN/NLI
      NLI=800
      NFNO=NLIMIT
      NFNORM=NFNO-1
      IS=0
```

```
      INZ=0
      INA=0
      ICO=0
      I24=0
      DO 1 J=1,12
    1 NCODE(J)=0
      DO 2 J=1,NSTAND
      IF(ISO(J)-85)4,3,4
    3 IS=J
      NCODE(J)=1
      GO TO 14
    4 IF(ISO(J)-65)7,5,7
    5 IF(IS)6,7,6
    6 INZ=J
      NCODE(J)=2
      GO TO 14
    7 IF(ISO(J)-22)10,8,10
    8 IF(IS)9,10,9
    9 INA=J
      NCODE(J)=3
      GO TO 14
   10 IF(ISO(J)-60)12,11,12
   11 ICO=J
      NCODE(J)=4
      GO TO 14
   12 IF(ISO(J)-24)14,13,14
   13 I24=J
      NCODE(J)=5
   14 CONTINUE
    2 CONTINUE
C     WRITE(LO,300)IS,INZ,INA,ICO,I24,(ISO(J),J=1,12),(NCODE(J),J=1,12)
C 300 FORMAT(1X,30I3)
C
      NFREE=3
      NPK=1
      NPARA(1)=1
      NPARA(2)=2
      NPARA(3)=3
      NPARA(4)=0
      NPARA(5)=0
      DO 16 I=1,2
      DO 15 J=1,NSTAND
      JJ=J
      E=STDEN(J,I)
      IF(I-2)18,17,18
   17 IF(E)200,200,217
  200 NSS=0
      NFNN=0
      B(1)=0.
      B(2)=0.
      B(3)=0.
      GO TO 219
  217 NSJ(J,I)=PARAV(J,1)*E/STDEN(J,1)
   18 CONTINUE
      DO 19 K=1,NXLIM
   19 FM(K)=R(K,J)
      NS=NSJ(J,I)
      TITLE(1)=ALAHEL (J)
      TITLE(2)=BLAHEL (J)
      CALL PKFUN(NXLIM,1,3,JJ,NSS,NS,NFNN,NPARA,E,FM,B,TITLE)
      DO 199 K=1,NXLIM
  199 R(K,J)=FM(K)
  219 NSJ(J,I)=NSS
      NFNJ(J,I)=NFNN
      PARAV(J,I)=B(1)
      PARAS(J,I)=B(2)
      PAREA(J,I)=B(3)
   15 CONTINUE
   16 CONTINUE
C
C     SUBTRACT SI COMPONENTS FROM ZN65 AND NA22
C
      IF(IS)20,21,20
   20 IF(INZ)27,23,27
   27 IQ=INZ
   22 NF=NXLIM
      DO 24 I=1,NF
   24 FM(I)=R(I,IS)
      GAIN=PARAV(IS,1)
      ROGAIN=PARAV(IQ,2)
      SM=0.0
      TAZ=0.0
      CALL GANE(TAZ,NF,GAIN,ROGAIN,SM,FM)
      NOF=NFNJ(IQ,2)+1
      NSF=NSJ(IQ,2)-1
      DF=NOF-NSF
      NAF=NOF-1
      SLO=(R(NOF,IQ)-R(NSF,IQ))/DF
      DO 25 I=1,NAF
   25 R(I,IQ)=R(I,IQ)-FM(I)*PAREA(IQ,2)/PAREA(IS,1)
      NOSF=NSF+1
      DO 26 I=NOSF,NOF
      X=I-NSF
   26 R(I,IQ)=R(NSF,IQ)+SLO*X
   23 IF(INA)37,21,37
   37 IQ=INA
      GO TO 22
   21 CONTINUE
C
C     NORMALIZE CONTINUA (CEPT CO60 AND NA24) FOR GAIN AND COUNT
C
      DO 7010 J=1,NSTAND
      SUM=0.0
      SAM=0.0
      IF(NCODE(J)-3)30,30,31
   30 DO 7003 I=1,NLIMIT
      SAM=SAM+R(I,J)
      FM(I)=R(I,J)/PAREA(J,1)
      SUM=SUM+FM(I)
 7003 R(I,J)=0.0
      GAIN=PARAV(J,1)
      NX=NLIMIT
      SUMP=PAREA(J,1)/(SAM*PAREA(J,1))
      IF(GAIN-100.0)9991,9992,9992
 9991 NX=(200.0*GAIN/100.0)-1.0
 9992 NF=GAIN+1.0
C     WRITE(LO,818)J,NX,NF,NOF,NAF,SUMP,SUM,SAM,DF,R(20,J),(FM(II
C    1I),III=1,NLIMIT)
C 818 FORMAT (10H RESGEN 1    /1X,5I5,5X,5E14.7/(1X,5E14.7))
      TAZ=0.0
      SM=0.0
      ROG=NORM
C
      CALL GANE (TAZ,NX,GAIN,ROG,SM,FM)
C
      SUM=0.0
      DO 30000 I=1,NLIMIT
      IF(FM(I))30001,30002,30002
30001 NFNORM=I-1
      NFNO=I
      GO TO 1100
30002 CONTINUE
```

```
30000 CONTINUE
C  ZERO FROM THE FIRST NEGATIVE CHANNEL TO 260
11004 DO 30509I=NFNO,NLIMIT
30509 FM(I)=0.0
      DO 7004 I=1,NLIMIT
      SUM=SUM+FM(I)
 7004 R(I,J)=FM(I)
C     WRITE(LO,225)SUM
C 225 FORMAT(7H SUM = ,E14.7)
   31 CONTINUE
 7010 CONTINUE
      DO 32 I=1,2
      WRITE(LO,820)(J,ALABEL(J),BLABEL(J),PARAV(J,I),PARAS(J,I),PAREA(J,
     1I),J=1,NSTAND)
  820 FORMAT (1H1,45X,28HRESULTS OF PHOTOPEAK FITTING  ///
     1  8X,5HINDEX,12X,15HSTANDARD SOURCE,11X,12HPULSE-HEIGHT,10X,
     2 18HSTANDARD DEVIATION,14X,4HAREA/ 52X,10H(CHANNELS),15X,
     3 10H(CHANNELS),14X,13H(COUNTS/TIME)//(9X,I3,18X,2A3,3X,3E25.7))
   32 CONTINUE
      RETURN
      END
(FOR,IS STDFT3
      SUBROUTINE STDFT3(YY,B,NFNN,NSS,NFREE,NPK,NPARA,NAS,FA,TITLE,JUMP)
C**********  PROGRAM NUMBER -  27  CUGEL      ************
C
C      NON-LINEAR REGRESSION PROGRAM FOR PHOTOPEAKS
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      COMMON/FUN/A(80,8),Y(80),FC(80),FU(80),FIT,DN,DNN,NS,NFN,ND,MP
      DIMENSION YY(800),     NPARA(8),B(8),    G(9,9),FA(80),TITLE(2)
      MP=0
      ICT=0
      IF(JUMP)5058,5058,5059
 5059 B1=NAS
      BH=B(1)
      B(1)=B(1)-B1
      NSS=NAS
 5058 CONTINUE
      A2=B(2)
      A3=B(3)
  458 NS=1
      NFN=NFNN-NSS+1
      XXNS=NSS
      DO 500 I=NS,NFN
  500 Y(I)=YY(I+NSS-1)
      DO 502 I=NS,NFN
      IF(Y(I))503,503,502
  503 Y(I)=1.0
  502 CONTINUE
      NPS=3*NPK+1
      NPI=NPS+1
      IF(JUMP)6050,6050,6051
 6050 ND=1
      NSFDIF=NFN-NS+1
      XNF=-NSFDIF
   52 IF(NSFDIF-50)51,5050,5050
   51 ND=2*ND
      NSFDIF=NSFDIF+NSFDIF
      GO TO 52
 5050 DNN=ND
      DN=1.0/(2.0*DNN)
 6051 IF(JUMP)5055,5055,5056
 5056 CALL FUNZ(NPK,B,FA)
      GO TO 42
 5055 EPS=0.00001
      NI=15
```

```
      L=0
C     WRITE(LO,5000)NS,NFN,NPS,NPI,ND,NSFDIF,DNN,DN,XNF,B(NPI),B(NPS)
C5000 FORMAT(9H STDFT3 1,6I5,5E14.7)
    5 CALL FUNZ(NPK,B,FA)
 1011 DO 58 J=1,NFREE
      NARP=NPARA(J)
      B(J)=B(NARP)
      DO 58 K=1,NFN
   58 A(K,J)=A(K,NARP)
C     CONSTRUCT THE NORMAL EQUATIONS
      M=NFREE+1
      DO 21 I=1,NFREE
      G(I,M)=0.0
      DO 21 J=NS,NFN
   21 G(I,M)=G(I,M)+A(J,I)*FC(J)/Y(J)
      DO 22 I=1,NFREE
      DO 22 K=1,NFREE
      G(I,K)=0.0
      DO 22 J=NS,NFN
   22 G(I,K)=G(I,K)+A(J,I)*A(J,K)/Y(J)
C     SOLVE NORMAL EQUATIONS FROM HERE TO STATEMENT 11
      K=1
  100 IF(K-NFREE)2,2,18
    2 J=K+1
  101 IF(J-M)3,3,4
    3 IF(G(K,K))4055,4056,4055
 4056 G(K,K)=1.0E-10
 4055 G(K,J)=G(K,J)/G(K,K)
      J=J+1
      GO TO 101
    4 I=K+1
  102 IF(I-NFREE)7,7,6
    6 K=K+1
      GO TO 100
    7 J=K+1
  103 IF(J-M)17,17,16
   16 I=I+1
      GO TO 102
   17 G(I,J)=G(I,J)-G(I,K)*G(K,J)
      J=J+1
      GO TO 103
   18 K=NFREE
   15 IF(K-1)11,10,10
   10 I=1
   14 IF(I-K)12,13,12
   12 G(I,M)=G(I,M)-G(I,K)*G(K,M)
      I=I+1
      GO TO 14
   13 K=K-1
      GO TO 15
   11 CONTINUE
C     FIT ARRESTING CHECK
      L=L+1
      IF(L-1)29,29,28
   28 IF(ABS(FITLM1-FIT)/FIT-EPS)42,42,29
   29 IF(L-NI)8,42,42
    8 DO 24 I=1,NFREE
   24 B(I)=B(I)+G(I,M)
      IF(B(2))60,60,61
   60 B(2)=A2
   61 IF(B(3))62,62,63
   62 B(3)=A3
   63 CONTINUE
C     WRITE(LO,5432)L,ICT,(G(I,M),I=1,5)
C5432 FORMAT(8H B-CHECK ,2I10,5E14.7)
      IF(B(1))456,456,457
```

```
  456 IF(ICT-4)654,654,42
  654 B(1)=1.0
      B(2)=A2
      B(3)=A3
      NSS=NSS-1
      ICT=ICT+1
      GO TO 458
  457 CONTINUE
      FITLMI=FIT
   89 DO 90 J=1,NFREE
      NARP=NPARA(J)
   90 B(NARP)=B(J)
      GO TO 5
   42 CONTINUE
      DO 6000 I=1,NPK
      K=3*I-2
 6000 B(K)=B(K)+XXNS
C     WRITE(LO,7222) (B(I),I=1,5)
C7222 FORMAT(11H0  STDFT3 B ,5E14.7)
C     CALL XPLOT(TITLE,Y,FU,NS,NFN)
C     WRITE(LO,27)(FC(I),I=NS,NFN)
C     WRITE(LO,27)(FA(I),I=NS,NFN)
C  27 FORMAT (9H STDFT3 2,/(1X,10E11.4))
C     WRITE (LO,8888)L,FITLMI,FIT,XXNS,B1
C8888 FORMAT (9H STDFT3 3,I5,4E14.7)
C     WRITE(LO,3999)(B(I),I=1,5)
C3999 FORMAT(1H1,45HPARAMETERS FOR GAUSSIAN AND STRAIGHT LINE FIT ///
C    11X,10HPEAK NO. 1  //1X,12HPULSE HEIGHT,7X,1H=,F15.4 /
C    21X,20HSTANDARD DEVIATION =,F15.4 /1X,4HAREA,15X,1H=,F15.4 ///
C    31X,13HSTRAIGHT LINE  //1X,5HSLOPE,14X,1H=,F15.4 /
C    41X,9HINTERCEPT,10X,1H=,F15.4 )
      RETURN
      END
[FOR,IS TA
      SUBROUTINE TA (E,X,M,MM,MOX,MUN,Z,Y,R,NDEGRE,L,LL)
C**********  PROGRAM NUMBER -  28  CUGEL      ************
C
C     BINARY TABLE SEARCHING PROGRAM.
C
      DIMENSION X(45),Z(3),Y(3),R(45)
      MOX=M
      MUN=MM
    7 KDEL=(MOX-MUN)/2
    8 IF(KDEL)18,14,18
   18 KP=MUN+KDEL
      IF(X(KP)-E)12,12,11
   11 MOX=KP
      GO TO 7
   12 IF(E-X(KP))24,24,13
   13 MUN=KP
      GO TO 7
   24 MUN=KP
      MOX=KP+1
C
   14 IF(MOX-M)4,5,4
    5 L=MUN-2
      GO TO 6
    4 L=MUN-1
    6 NN=NDEGRE+1
      IF(LL)15,2,15
    2 DO 3 I=1,NN
      J=I+L
      Z(I)=X(J)
    3 Y(I)=R(J)
   15 RETURN
      END
```

```
[FOR,IS TE
      FUNCTION TE (N,X,Y,E)
C**********  PROGRAM NUMBER -  29  CUGEL      ************
C
C     N-DEGREE LAGRANGIAN INTERPOLATION PROGRAM.
C
      DIMENSION X(3),Y(3)
      S=0.
      I=1
   28 IF(I-N)21,21,22
   21 P=Y(I)
      J=1
   27 IF(J-N)23,23,24
   23 IF(I-J)25,26,25
   25 P=P*(E-X(J))/(X(I)-X(J))
   26 J=J+1
      GO TO 27
   24 S=S+P
      I=I+1
      GO TO 28
   22 TE =S
      RETURN
      END
[FOR,IS VECTMX
      SUBROUTINE VECTMX (Y,N1,N2,JMAX,YMAX)
C**********  PROGRAM NUMBER -  30  CUGEL      ************
C
C     DETERMINES THE INDEX AND VALUE OF THE MAX ELEMENT IN A VECTOR OF ELEMENT
C
      DIMENSION Y(400)
      YMAX=0.0
      DO 1 I=N1,N2
      IF(Y(I)-YMAX)3,3,4
    4 YMAX=Y(I)
      JMAX=I
    3 CONTINUE
    1 CONTINUE
      RETURN
      END
[FOR,IS XPLOT
      SUBROUTINE XPLOT(TITLE,FM,FU,NS,NX)
C**********  PROGRAM NUMBER -  31  CUGEL      ************
C
C     PRINTER PLOTTING
C
      COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
      DIMENSION           TITLE(2),X(140),FM(800),FU(400)
      DATA BB,ASTER,XMINS,XA,XB/1H ,1HX,1H+,1HO,1H*/
      CALL VECTMX (FM,NS,NX,IBIG,YMAX)
      CALL VECTMX(FU,NS,NX,IBI ,YM)
      IF(YM-YMAX)5,5,6
    6 YMAX=YM
    5 SCAL=YMAX/119.
      WRITE (LO,2) (TITLE(I),I=1,2),SCAL,YMAX,YM,IBIG,IBI,NS,NX
    2 FORMAT (1H1,1X,2A3,3E20.7,5X,4I5)
      DO 7 J=NS,NX
```

APPENDIX III

SAMPLE INPUT CARD DECK LISTING

```
  1.0
 TEST RUN WITH RESFUN GROUP
 0  0  3  0  0  0  7  0  9  0  0  0  0  0  0 16 17  0  0  0  0  0  0  0
 2.755    1.0       1.0       40.0        51.        .00001     1.63  3.1
   8  400    1
CE139 .166  0.0  358.  139.                      89.   0.0
  -133.  -447.  -791.  -687.  -233.   466.  1104.  1508.  1955.  2251.
  2385.  2646.  2970.  3081.  3382.  3577.  3692.  3670.  3931.  4043.
  4344.  4467.  4465.  4718.  4815.  4891.  4898.  5042.  5087.  5236.
  5218.  5348.  5470.  5480.  5618.  5436.  5583.  5634.  5775.  5696.
  5857.  6113.  5865.  6019.  6003.  6175.  6346.  6467.  6526.  6888.
  6988.  7238.  7709.  8165.  8442.  8896.  9596. 10588. 11662. 12650.
 14341. 15744. 16374. 16384. 15429. 13640. 11493.  9071.  7215.  5814.
  5353.  5088.  5173.  5022.  5090.  4430.  3718.  3066.  2373.  1814.
  1350.  1097.   850.   790.   802.   750.   746.   772.   785.   790.
   753.   833.   780.   785.   803.   779.   795.   785.   793.   725.
   779.   765.   830.   895.   822.   829.   805.   816.   817.   843.
   863.   865.   850.   838.   877.   866.   881.   840.   894.   811.
   889.   866.   856.   862.   753.   845.   863.   845.   823.   769.
   704.   745.   731.   675.   687.   799.   595.   546.   487.   490.
   452.   479.   435.   411.   389.   413.   370.   387.   402.   361.
   409.   392.   363.   361.   416.   395.   424.   404.   374.   316.
   330.   394.   337.   364.   414.   415.   341.   388.   323.   338.
   350.   353.   400.   391.   316.   362.   359.   341.   406.   366.
   421.   365.   392.   401.   432.   449.   408.   458.   387.   375.
   365.   399.   396.   438.   426.   489.   453.   548.   494.   486.
   549.   568.   595.   582.   599.   686.   709.   817.   889.  1007.
  1014.  1138.  1255.  1365.  1462.  1430.  1490.  1480.  1466.  1452.
  1330.  1373.  1282.  1227.  1125.  1125.  1110.   961.  1023.   961.
   859.   877.   856.   868.   866.   833.   795.   776.   739.   747.
   798.   793.   834.   823.   807.   858.   828.   770.   807.   838.
   833.   812.   906.   852.   872.   829.   827.   743.   819.   805.
   782.   799.   787.   727.   822.   740.   730.   765.   752.   713.
   767.   677.   666.   651.   645.   613.   665.   637.   593.   630.
   557.   615.   614.   548.   599.   541.   556.   513.   542.   538.
   589.   574.   531.   557.   570.   602.   491.   530.   600.   563.
   603.   572.   534.   567.   568.   566.   572.   542.   573.   571.
   592.   567.   598.   535.   584.   606.   556.   611.   625.   614.
   612.   574.   630.   637.   578.   656.   610.   683.   596.   633.
   631.   616.   745.   627.   665.   632.   721.   718.   694.   725.
   706.   734.   778.   738.   769.   807.   870.  1082.  1375.  2217.
  3749.  6936. 11275. 17899. 25589. 33364. 37937. 40357. 37755. 32225.
 24148. 16654. 10329.  5766.  2847.  1238.   516.   158.    72.     8.
     8.   -17.     7.    -4.     8.     0.    -2.   -12.    -6.     1.
    -2.    -1.     2.    -7.    14.    14.    14.   -10.     9.    11.

HG203 .279  0.0  381.  203.                     132.  0.0
     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
     0.     0.     9.    83.   151.   269.   372.   392.   390.   448.
   349.   414.   392.   435.   468.   385.   428.   381.   380.   363.
   357.   402.   397.   353.   416.   337.   353.   408.   344.   364.
   406.   401.   400.   388.   345.   325.   332.   345.   315.   328.
   401.   374.   350.   326.   407.   338.   397.   338.   347.   308.
   354.   329.   378.   346.   381.   338.   324.   339.   314.   367.
   363.   327.   386.   384.   366.   356.   368.   356.   432.   406.
   435.   441.   493.   410.   458.   490.   446.   493.   460.   456.
   437.   499.   590.   629.   835.  1077.  1337.  1764.  2072.  1976.
  1796.  1326.   910.   596.   402.   338.   375.   333.   303.   471.
   517.   648.   721.   815.   651.   584.   511.   455.   386.   347.
   287.   283.   291.   196.   335.   237.   299.   255.   331.   371.
   307.   274.   338.   217.   227.   271.   269.   251.   319.   314.
   224.   268.   287.   256.   388.   238.   258.   269.   235.   269.
   308.   331.   311.   346.   292.   284.   276.   316.   372.   341.
```

```
  328.   281.   322.   328.   419.   292.   380.   343.   370.   333.
  330.   339.   420.   419.   409.   363.   417.   463.   441.   470.
  504.   555.   595.   540.   559.   587.   527.   562.   489.   464.
  504.   536.   494.   490.   433.   428.   445.   467.   353.   287.
  286.   316.   302.   263.   263.   256.   217.   207.   223.   212.
  228.   224.   192.   257.   156.   216.   215.   239.   197.   183.
  165.   185.   193.   200.   188.   146.   167.   176.   183.   187.
  186.    96.   148.   139.   121.   131.   145.   147.   161.   147.
  137.   114.   157.   103.   146.   142.   115.   109.   126.    80.
  148.    94.   111.   111.    92.    93.    85.    81.    72.    78.
   93.    70.    95.    81.    59.   113.    69.    57.    96.    82.
   49.   101.    74.    46.    86.    54.    94.   104.    68.    56.
   93.    51.    41.   106.    63.    66.    84.    63.    75.    52.
   66.    69.    72.    48.    67.    64.    99.    85.    93.    55.
   32.    74.    96.    70.    95.    82.    57.    84.    71.    80.
   71.    56.    66.    67.    82.    83.    47.    53.   100.    75.
   73.   100.    66.    53.    62.    97.    64.    53.    93.    59.
   49.    58.    60.    77.    82.    90.    61.    95.    83.    92.
   49.    62.    95.    99.    84.   105.    42.    73.    64.    62.
   72.    54.    83.    86.    65.    42.    61.    78.    84.    86.
   58.    53.    91.    74.    81.    74.    90.    80.    88.    70.
   94.   122.   129.   154.   315.   906.  1950.  3958.  6245.  7493.
 7127.  4908.  2644.  1090.   358.    97.    39.     6.     4.    21.
  -19.   -28.     0.     0.    14.     9.     1.    17.    14.    -3.
 SR85 .514  0.0  389.    65.    90.   108.  26.   0.0
    0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
    0.     0.    18.   228.   708.  1161.  1445.  1673.  1701.  1877.
 1869.  1968.  1977.  1968.  2005.  1913.  1924.  2034.  1888.  1961.
 1956.  1883.  1845.  1816.  1920.  1911.  1814.  1840.  1841.  1867.
 1882.  1813.  1782.  1706.  1745.  1794.  1885.  1860.  1741.  1853.
 1855.  1783.  1717.  1794.  1776.  1671.  1713.  1779.  1817.  1729.
 1826.  1819.  1681.  1699.  1656.  1787.  1769.  1679.  1680.  1810.
 1699.  1754.  1647.  1727.  1796.  1691.  1729.  1684.  1679.  1759.
 1787.  1820.  1782.  1700.  1704.  1598.  1790.  1690.  1819.  1822.
 1700.  1967.  1890.  1857.  1652.  1750.  1621.  1762.  1668.  1637.
 1610.  1877.  2192.  2338.  2003.  1871.  1683.  1688.  1650.  1636.
 1650.  1647.  1635.  1727.  1727.  1612.  1816.  1698.  1773.  1771.
 1743.  1750.  1769.  1874.  1866.  1909.  1983.  2135.  2246.  2417.
 2750.  2645.  2679.  2572.  2479.  2410.  2268.  2306.  2153.  2072.
 2053.  1922.  1891.  1859.  1799.  1856.  1804.  1670.  1655.  1534.
 1600.  1614.  1706.  1582.  1680.  1601.  1617.  1674.  1651.  1567.
 1652.  1548.  1596.  1515.  1525.  1577.  1582.  1574.  1642.  1646.
 1643.  1648.  1540.  1697.  1554.  1683.  1555.  1519.  1631.  1598.
 1531.  1604.  1558.  1493.  1556.  1563.  1605.  1632.  1520.  1543.
 1534.  1511.  1533.  1570.  1481.  1463.  1567.  1522.  1494.  1753.
 1847.  1759.  1656.  1561.  1553.  1536.  1519.  1537.  1563.  1600.
 1648.  1744.  1609.  1567.  1555.  1554.  1643.  1636.  1615.  1633.
 1654.  1710.  1581.  1619.  1643.  1687.  1722.  1735.  1710.  1647.
 1745.  1757.  1738.  1812.  1829.  1789.  1868.  1810.  1810.  1850.
 1845.  1958.  1998.  1893.  1922.  1943.  1990.  1982.  1936.  1961.
 1957.  1972.  1928.  1996.  1956.  1890.  1810.  1812.  1678.  1556.
 1369.  1302.  1137.  1068.  1014.   998.   933.   893.   824.   830.
  789.   782.   819.   799.   812.   734.   746.   680.   720.   694.
  606.   639.   603.   632.   602.   605.   613.   605.   589.   537.
  515.   468.   454.   523.   507.   518.   503.   460.   474.   454.
  419.   397.   427.   470.   374.   383.   327.   282.   320.   294.
  313.   257.   243.   263.   239.   242.   255.   233.   263.   225.
  216.   208.   207.   190.   224.   243.   218.   194.   214.   208.
  195.   197.   208.   175.   198.   183.   216.   216.   172.   195.
  154.   205.   203.   179.   162.   221.   184.   170.   193.   211.
  187.   172.   181.   174.   176.   195.   172.   166.   199.   192.
  164.   200.   198.   166.   184.   207.   193.   169.   170.   168.
  203.   216.   178.   227.   196.   200.   224.   217.   214.   239.
  266.   296.   327.   341.   524.  1737.  7557. 21759. 31361. 22583.
 7597.  1195.   102.    -2.    13.    -5.     1.     8.    -5.     4.
CS137.6616  0.0  375.   137.   344.   368.  29.   0.0
```

```
     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
     0.     1.    42.  1972.  7029. 10472. 13955. 19355. 23462. 19501.
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001215 001315 001283 000982 000880 000897 000849 000818 000771 000765
000801 000717 000701 000673 000698 000638 000609 000563 000589 000578
000533 000561 000511 000485 000548 000625 000459 000499 000467 000457
000422 000460 000460 000428 000427 000640 000384 000411 000431 000670
000363 000358 000361 000325 000343 000349 000355 000356 000330 000335
000339 000324 000309 000331 000326 000280 000351 000287 000302 000278
000317 000299 000274 000268 000271 000255 000270 000237 000264 000243
000246 000213 000226 000224 000213 000254 000205 000199 000239 000202
000225 000210 000290 000283 000195 000221 000218 000205 000219 000199
000238 000326 000219 000195 000193 000187 000177 000189 000189 000227
000191 000191 000206 000199 000199 000191 000198 000188 000190 000190
000186 000179 000179 000231 000197 000223 000182 000201 000232 000193
000191 000210 000219 000193 000222 000232 000218 000218 000258 000234
000246 000178 000150 000140 000137 000134 000134 000113 000107 000112
000092 000098 000095 000110 000083 000075 000076 000068 000054 000060
000050 000058 000063 000064 000057 000055 000064 000051 000042 000046
000052 000082 000885 000392 000038 000033 000030 000036 000038 000025
000033 000025 000040 000028 000034 000023 000024 000023 000019 000024
000029 000079 000068 000023 000031 000026 000040 000043 000030 000026
000022 000018 000017 000027 000016 000028 000025 000016 000023 000020
000022 000023 000026 000019 000018 000023 000059 000031 000020 000025
000017 000016 000022 000023 000016 000025 000010 000023 000027 000020
000016 000021 000023 000028 000022 000021 000019 000020 000023 000025
000021 000023 000022 000017 000024 000010 000024 000016 000014 000014
000014 000015 000013 000019 000015 000013 000009 000020 000010 000025
000015 000013 000018 000016 000016 000026 000026 000014 000019 000013
000015 000023 000014 000019 000022 000018 000013 000017 000020 000025
000029 000017 000019 000020 000020 000013 000021 000017 000020 000015
000021 000017 000015 000018 000019 000021 000018 000017 000019 000021
000016 000023 000021 000023 000020 000022 000019 000009 000007 000010
000007 000012 000010 000006 000010 000017 000006 000006 000015 000004
000005 000008 000007 000004 000006 000001 000005 000003 000003 000003
000006 000001 000001 000000 000004 000001 000006 000006 000008 000096
000053 000000 000002 000001 000000 000000 000000 000000 000001 000002
000001 000002 000001 000002 000003 000003 000000 000001 000000 000000
(FIN
```

APPENDIX IV

SAMPLE OUTPUT LISTING

```
 BRIEF DESCRIPTION OF PHA RUNS
  TEST RUN WITH RESFUN GROUP

CONTROL NUMBERS
M( 1) =    0  M( 2) =    0  M( 3) =    3  M( 4) =    0  M( 5) =    0  M( 6) =    0
M( 7) =    7  M( 8) =    0  M( 9) =    9  M(10) =    0  M(11) =    0  M(12) =    0
M(13) =    0  M(14) =    0  M(15) =    0  M(16) =   16  M(17) =   17  M(18) =    0
M(19) =    0  M(20) =    0  M(21) =    0  M(22) =    0  M(23) =    0  M(24) =    0

EM =   14.51906 CHANNELS/MEV

ELIMIT =   2.75500

ITERATIVE ERROR TOLERANCE.EPS =    0.00001

NUMBER OF BETA SOURCE SETS.OJSO =    1     MM =   1

MAX NUMBER OF ITERATIONS.ITMAX=  51

NUMBER OF CHANNELS INPUT. N = 40

 GE(LI) CRYSTAL SIZE =  3.26 X 3.10  (CM)
```

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                  STANDARD SOURCE SPECTRAL PARAMETERS

                   8 SPECTRA IN STANDARD SOURCE DECK

                CHANNELS ONE TO   2 ASSUMED AS REDUNDANT

                   REFERENCE COARSE GAIN =    0.0


STANDARD      PHOTOPEAK       X-RAY OR .5 PEAK     SHIFT     PHOTOPEAK
 SOURCE     FROM      TO       FROM      TO       SPECTRUM   ENERGIES

           CHANNEL  CHANNEL  CHANNEL  CHANNEL    CHANNELS     MEV       MEV
  CE139      358       0        0        0         0.0      0.16600   0.0
  HG203      391       0        0        0         0.0      0.27900   0.0
   SR85      389       0       90      108         0.0      0.51400   0.0
  CS137      375       0      344      368         0.0      0.66160   0.0
   MN54      376       0        0        0         0.0      0.83500   0.0
   ZN65      385       0        0        0         0.0      1.11400   0.51000
   CO60      386       0       88       94         0.0      1.33000   1.17000
  TH228      380       0      230      310         0.0      2.61530   0.0
```

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STANDARD SOURCE SPECTRA

CE139 SOURCE

```
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     785.
     785.     785.     785.     785.     785.     785.     785.     785.     785.     790.
     753.     833.     780.     785.     803.     779.     795.     785.     793.     725.
     779.     765.     839.     895.     822.     829.     805.     816.     817.     843.
     863.     865.     850.     838.     877.     866.     881.     840.     894.     811.
     889.     866.     856.     862.     753.     845.     863.     845.     823.     769.
     704.     745.     731.     675.     687.     799.     595.     546.     487.     490.
     452.     479.     435.     411.     389.     413.     370.     387.     402.     361.
     409.     392.     363.     361.     416.     395.     424.     404.     374.     316.
     330.     394.     337.     364.     414.     415.     341.     388.     323.     338.
     350.     353.     400.     391.     316.     362.     359.     341.     406.     366.
     421.     365.     392.     401.     432.     449.     408.     458.     387.     375.
     365.     399.     356.     438.     426.     489.     453.     548.     494.     486.
     549.     568.     595.     582.     599.     686.     709.     817.     889.    1007.
    1314.    1138.    1255.    1365.    1462.    1430.    1490.    1480.    1466.    1452.
    1330.    1373.    1282.    1227.    1125.    1125.    1119.     961.    1023.     961.
     859.     877.     856.     868.     866.     833.     795.     776.     739.     747.
     798.     793.     834.     823.     807.     858.     828.     770.     807.     838.
     833.     812.     906.     852.     872.     829.     827.     743.     819.     805.
     782.     799.     787.     727.     822.     740.     730.     765.     752.     713.
     767.     677.     666.     651.     645.     613.     665.     637.     593.     630.
     557.     615.     614.     548.     599.     541.     555.     513.     542.     538.
     589.     574.     531.     557.     570.     602.     491.     530.     600.     563.
     603.     572.     534.     567.     568.     566.     572.     542.     573.     571.
     592.     567.     559.     535.     584.     606.     556.     611.     625.     614.
     612.     574.     630.     637.     578.     656.     610.     683.     596.     633.
     631.     616.     745.     627.     665.     632.     721.     718.     694.     725.
     706.     734.     778.     739.     769.     807.     870.    1082.    1375.    2217.
    3749.    6936.   11275.   17899.   25589.   33364.   37937.   40357.   37755.   32225.
   24148.   16654.   10329.    5766.    2847.    1238.     516.     158.      72.       8.
       8.     -17.       7.      -4.       8.       0.      -2.     -12.      -6.       1.
      -2.      -1.       2.      -7.      14.      14.      14.     -10.       9.      11.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       1.
```

STANDARD SOURCE SPECTRA

HG203 SOURCE

```
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     274.     274.     274.     274.     274.     274.     274.     274.
     274.     274.     338.     217.     227.     271.     269.     251.     319.     314.
     224.     268.     287.     256.     388.     238.     259.     269.     235.     269.
     308.     331.     311.     346.     292.     284.     276.     316.     372.     341.
     328.     281.     322.     329.     419.     292.     380.     343.     370.     333.
     330.     339.     420.     419.     439.     363.     417.     463.     441.     470.
     504.     555.     555.     540.     559.     587.     527.     562.     489.     464.
     504.     536.     494.     490.     433.     428.     445.     467.     353.     287.
     286.     316.     302.     263.     263.     256.     217.     207.     223.     212.
     228.     224.     152.     257.     156.     216.     215.     239.     197.     183.
     165.     185.     193.     200.     188.     145.     167.     176.     183.     187.
     186.      96.     148.     139.     121.     131.     145.     147.     161.     147.
     137.     114.     157.     103.     146.     142.     115.     109.     126.      86.
     148.      94.     111.     111.      92.      93.      85.      81.      72.      78.
      93.      70.      55.      81.      59.     113.      69.      57.      96.      82.
      49.     101.      74.      46.      86.      54.      94.     104.      68.      56.
      93.      51.      41.     106.      63.      66.      84.      63.      75.      52.
      66.      69.      72.      48.      67.      64.      99.      85.      93.      55.
      32.      74.      96.      70.      95.      82.      57.      84.      71.      80.
      71.      56.      66.      67.      82.      83.      47.      53.     100.      75.
      73.     100.      66.      53.      62.      97.      64.      53.      93.      59.
      49.      59.      60.      77.      82.      90.      61.      95.      83.      92.
      49.      62.      55.      99.      94.     105.      42.      73.      64.      62.
      72.      56.      83.      86.      65.      42.      61.      78.      84.      86.
      58.      53.      91.      74.      81.      74.      90.      80.      88.      79.
      94.     122.     129.     154.     315.     906.    1950.    3958.    6245.    7493.
    7127.    4908.    2644.    1090.     359.      97.      39.       6.       4.      21.
     -19.     -28.       0.       0.      14.       9.       1.      17.      14.       1.
```

STANDARD SOURCE SPECTRA

SR85 SOURCE

1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.
1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.
1913.	1913.	1913.	1913.	1913.	1913.	1924.	2034.	1888.	1961.
1956.	1883.	1845.	1816.	1920.	1911.	1814.	1840.	1841.	1867.
1882.	1813.	1782.	1706.	1745.	1794.	1885.	1860.	1741.	1853.
1855.	1783.	1717.	1794.	1776.	1671.	1713.	1779.	1817.	1729.
1826.	1819.	1681.	1699.	1656.	1787.	1769.	1679.	1680.	1810.
1699.	1754.	1647.	1727.	1796.	1691.	1729.	1684.	1679.	1759.
1787.	1820.	1782.	1700.	1704.	1598.	1790.	1690.	1819.	1822.
1815.	1807.	1800.	1792.	1785.	1777.	1770.	1762.	1755.	1748.
1740.	1733.	1725.	1718.	1710.	1703.	1695.	1688.	1650.	1636.
1650.	1647.	1635.	1727.	1727.	1612.	1816.	1698.	1773.	1771.
1743.	1750.	1769.	1874.	1866.	1909.	1993.	2135.	2246.	2417.
2750.	2645.	2679.	2572.	2479.	2410.	2268.	2306.	2153.	2072.
2053.	1922.	1891.	1859.	1799.	1856.	1804.	1670.	1655.	1534.
1600.	1614.	1706.	1592.	1680.	1601.	1617.	1674.	1651.	1567.
1652.	1548.	1556.	1515.	1525.	1577.	1582.	1574.	1642.	1646.
1643.	1648.	1540.	1657.	1554.	1683.	1555.	1519.	1631.	1598.
1531.	1604.	1558.	1493.	1556.	1563.	1605.	1632.	1520.	1543.
1534.	1511.	1533.	1570.	1481.	1463.	1567.	1522.	1494.	1753.
1847.	1759.	1656.	1561.	1553.	1536.	1519.	1537.	1563.	1600.
1648.	1744.	1609.	1567.	1555.	1554.	1643.	1636.	1615.	1633.
1654.	1710.	1581.	1619.	1643.	1687.	1722.	1735.	1710.	1647.
1745.	1757.	1738.	1812.	1829.	1759.	1868.	1810.	1810.	1850.
1845.	1958.	1998.	1893.	1922.	1943.	1990.	1982.	1936.	1961.
1957.	1972.	1928.	1996.	1956.	1890.	1810.	1812.	1678.	1556.
1369.	1302.	1137.	1068.	1014.	998.	933.	893.	824.	830.
789.	782.	819.	799.	812.	734.	746.	680.	720.	694.
606.	639.	603.	632.	602.	605.	613.	605.	589.	537.
515.	468.	454.	523.	507.	518.	503.	460.	474.	454.
419.	397.	427.	470.	374.	383.	327.	282.	320.	294.
313.	257.	243.	263.	239.	242.	255.	233.	263.	225.
216.	208.	207.	190.	224.	243.	218.	194.	214.	208.
195.	197.	208.	175.	198.	183.	216.	216.	172.	195.
154.	205.	203.	179.	162.	221.	184.	170.	193.	211.
187.	172.	181.	174.	176.	195.	172.	166.	199.	192.
164.	200.	198.	186.	184.	207.	193.	169.	170.	168.
203.	218.	178.	227.	196.	200.	224.	217.	214.	239.
266.	296.	327.	341.	524.	1737.	7557.	21759.	31361.	22583.
7597.	1195.	102.	-2.	13.	-5.	1.	8.	-5.	1.

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STANDARD SOURCE SPECTRA

CS137 SOURCE

6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.
6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.
6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6271.
6020.	6035.	6113.	5882.	5965.	5911.	5901.	5919.	5886.	5946.
5893.	5902.	5904.	5969.	5734.	5688.	5890.	5706.	5787.	5862.
5689.	5479.	5400.	5496.	5529.	5635.	5512.	5506.	5434.	5498.
5122.	5575.	5776.	5606.	5631.	5635.	5524.	5476.	5466.	5532.
5553.	5396.	5463.	5478.	5369.	5364.	5431.	5411.	5328.	5342.
4482.	5479.	5336.	5247.	5275.	5192.	5141.	5203.	5181.	5148.
5312.	5208.	5175.	5143.	5208.	5269.	5262.	5456.	5509.	5514.
4792.	5901.	6096.	6746.	7453.	7946.	8292.	7892.	7665.	7434.
6950.	6598.	6364.	5996.	5997.	5561.	5412.	5329.	5232.	5042.
5092.	4982.	4898.	4830.	4764.	4762.	4601.	4652.	4749.	4682.
4693.	4603.	4774.	4719.	4680.	4725.	4761.	4748.	4653.	4643.
3946.	4679.	4714.	4779.	4598.	4666.	4573.	4654.	4438.	4493.
4517.	4538.	4427.	4458.	4429.	4416.	4266.	4421.	4469.	4383.
3938.	4280.	4265.	4292.	4249.	4092.	4299.	4089.	4108.	4126.
4164.	4108.	4091.	4177.	4032.	4055.	4159.	4044.	4129.	4210.
4059.	4088.	4075.	4139.	4035.	3968.	4010.	4188.	4039.	4133.
4154.	4165.	4106.	4115.	4150.	4121.	4150.	4169.	4189.	4254.
4102.	4297.	4371.	4265.	4203.	4252.	4094.	4293.	4189.	4414.
4332.	4326.	4450.	4426.	4402.	4508.	4529.	4526.	4573.	4623.
4642.	4413.	4592.	4694.	4781.	4818.	4884.	4860.	4877.	4994.
4998.	4977.	5057.	5097.	5081.	5255.	5226.	5201.	5369.	5341.
5436.	5496.	5401.	5571.	5650.	5695.	5585.	5728.	5744.	5751.
5992.	5972.	5939.	6053.	6189.	6336.	6021.	6182.	6355.	6347.
6467.	6411.	6457.	6428.	6285.	6209.	6163.	5989.	5618.	5337.
4514.	4138.	3618.	3438.	3225.	3042.	3046.	2890.	2770.	2788.
2280.	2566.	2614.	2462.	2305.	2323.	2284.	2256.	2233.	2198.
2037.	1990.	2002.	1957.	1853.	1908.	1811.	1761.	1628.	1696.
1574.	1584.	1515.	1367.	1385.	1354.	1309.	1315.	1148.	1123.
1025.	977.	936.	905.	876.	841.	847.	787.	746.	772.
706.	589.	738.	658.	655.	665.	567.	573.	598.	516.
551.	593.	542.	524.	523.	533.	552.	523.	484.	520.
483.	503.	504.	548.	545.	543.	543.	537.	534.	532.
529.	526.	524.	521.	519.	516.	513.	510.	507.	505.
502.	499.	497.	454.	491.	488.	486.	483.	486.	508.
1224.	3940.	23224.	72927.	79962.	28766.	3302.	167.	19.	30.
43.	16.	20.	19.	10.	18.	14.	20.	20.	15.
10.	18.	12.	18.	10.	5.	13.	27.	20.	1.

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STANDARD SOURCE SPECTRA

MN54 SOURCE

```
 3438.   3438.   3438.   3438.   3438.   3438.   3438.   3438.   3438.   3438.
 3438.   3438.   3438.   3438.   3438.   3438.   3438.   3438.   3438.   3438.
 3438.   3438.   3438.   3432.   3500.   3484.   3256.   3500.   3425.   3434.
 3405.   3424.   3370.   3388.   3390.   3530.   3592.   3634.   3433.   3391.
 3319.   3328.   3338.   3434.   3277.   3230.   3145.   3221.   3295.   3254.
 3278.   3268.   3322.   3093.   3317.   3254.   3095.   3221.   3140.   3073.
 3179.   3212.   3194.   3074.   3086.   3000.   2953.   3083.   3066.   2947.
 2917.   3068.   2933.   2873.   2951.   2967.   2903.   2981.   2951.   2857.
 2903.   2990.   3130.   3006.   3109.   3253.   3351.   3783.   4315.   4658.
 4533.   4231.   4162.   3861.   3662.   3578.   3475.   3158.   3193.   2974.
 2769.   2892.   2611.   2665.   2612.   2557.   2618.   2441.   2442.   2510.
 2541.   2494.   2432.   2507.   2516.   2629.   2533.   2401.   2486.   2501.
 2515.   2591.   2525.   2519.   2565.   2510.   2457.   2506.   2487.   2362.
 2317.   2356.   2331.   2401.   2416.   2348.   2370.   2228.   2305.   2305.
 2169.   2283.   2274.   2342.   2278.   2272.   2194.   2125.   2232.   2211.
 2161.   2234.   2116.   2208.   2043.   2204.   2173.   2114.   2007.   2129.
 2249.   2237.   2152.   2192.   2085.   2078.   2043.   2076.   2111.   2131.
 2250.   2215.   2021.   2162.   2164.   2110.   2194.   2073.   2116.   2221.
 2152.   2060.   2155.   2203.   2122.   2151.   2190.   2149.   2154.   2171.
 2202.   2209.   2146.   2111.   2185.   1953.   2129.   2105.   2117.   2142.
 2133.   2235.   2240.   2254.   2195.   2190.   2219.   2224.   2261.   2320.
 2241.   2257.   2299.   2313.   2203.   2322.   2224.   2307.   2298.   2264.
 2258.   2357.   2379.   2396.   2320.   2310.   2311.   2341.   2428.   2453.
 2374.   2475.   2474.   2403.   2553.   2534.   2497.   2625.   2493.   2550.
 2537.   2639.   2665.   2660.   2654.   2639.   2774.   2722.   2741.   2828.
 2755.   2960.   2893.   2925.   2994.   3012.   3091.   2971.   3055.   3155.
 3124.   3201.   3255.   3294.   3303.   3302.   3203.   3452.   3432.   3502.
 3559.   3469.   3511.   3619.   3546.   3775.   3674.   3710.   3869.   3821.
 3774.   3877.   3876.   3719.   3719.   3573.   3397.   3071.   2546.   2296.
 2330.   1894.   1875.   1780.   1737.   1638.   1611.   1594.   1516.   1522.
 1409.   1503.   1385.   1382.   1302.   1291.   1216.   1231.   1185.   1166.
 1154.   1060.   1035.   1030.   1014.    963.    901.    903.    784.    805.
  736.    699.    640.    626.    529.    534.    554.    547.    463.    463.
  394.    367.    366.    373.    310.    340.    394.    295.    292.    252.
  276.    319.    253.    297.    288.    249.    282.    240.    264.    250.
  286.    256.    278.    248.    271.    255.    235.    268.    230.    255.
  236.    304.    272.    294.    296.    301.    300.    368.    353.    392.
  414.    524.    855.   4929.  28054.  46336.  15927.   1052.     20.      9.
   -1.     -2.      9.     -2.      9.      8.      1.      8.      4.      7.
   11.      1.     -2.      9.      6.      8.      6.     -1.      0.      1.
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STANDARD SOURCE SPECTRA

ZN65 SOURCE

```
 1751.   1751.   1751.   1751.   1751.   1751.   1751.   1751.   1751.   1751.
 1751.   1751.   1751.   1751.   1751.   1751.   1751.   1751.   1751.   1751.
 1751.   1751.   1751.   1751.   1751.   1751.   1779.   1913.   1867.   1994.
 1730.   1850.   1917.   1787.   1721.   1788.   1751.   1730.   1785.   1880.
 1840.   1682.   1749.   1742.   1721.   1645.   1600.   1735.   1583.   1729.
 1628.   1664.   1674.   1657.   1641.   1499.   1576.   1467.   1636.   1527.
 1750.   1660.   1652.   1565.   1534.   1554.   1580.   1551.   1642.   1490.
 1751.   1861.   2093.   2243.   2030.   1989.   1943.   1781.   1705.   1613.
 1535.   1479.   1505.   1536.   1344.   1377.   1286.   1217.   1312.   1272.
 1267.   1244.   1243.   1237.   1245.   1224.   1315.   1282.   1273.   1314.
 1276.   1265.   1259.   1288.   1253.   1260.   1279.   1209.   1242.   1182.
 1265.   1192.   1165.   1170.   1120.   1192.   1256.   1160.   1108.   1031.
 1159.   1106.   1025.    967.   1054.   1038.   1013.    912.    972.    988.
  973.    978.    928.    920.    949.    911.    931.    848.    963.    942.
  921.    956.    852.    953.    931.    969.    831.    881.    892.    906.
  875.    922.    882.    884.    888.    923.    858.    900.    850.    868.
  903.    903.    915.    836.    873.    917.    900.    852.    857.    851.
  917.    859.    866.    863.    928.   1423.   3368.   2704.   1065.    896.
  857.    935.    888.    899.    894.    838.    880.    998.    854.    871.
  858.    868.    950.    857.    914.    899.    858.    836.    883.    980.
  853.    871.    915.    877.    917.    944.    942.    895.    922.    953.
  918.    936.    855.    934.    915.    925.    884.    974.    946.    991.
  915.    953.    934.    975.    904.    927.    937.    948.    969.    984.
  933.    945.    956.    964.    972.   1050.    959.   1010.    992.   1049.
  996.   1021.   1015.   1051.    965.   1045.   1030.   1031.   1039.   1050.
 1050.    997.   1019.   1044.   1077.   1057.   1039.   1135.   1091.   1129.
 1106.   1146.   1134.   1150.   1152.   1113.   1180.   1168.   1193.   1227.
 1178.   1200.   1237.   1236.   1276.   1295.   1373.   1298.   1293.   1341.
 1339.   1406.   1352.   1437.   1352.   1404.   1399.   1533.   1469.   1472.
 1550.   1511.   1534.   1578.   1533.   1667.   1596.   1679.   1718.   1694.
 1753.   1776.   1924.   1857.   1909.   1863.   1929.   1858.   1800.   1837.
 1795.   1794.   1562.   1409.   1122.   1018.    949.    809.    879.    848.
  864.    817.    783.    772.    743.    714.    693.    702.    638.    643.
  689.    622.    534.    555.    567.    539.    518.    497.    432.    436.
  396.    377.    353.    333.    312.    288.    228.    250.    224.    197.
  195.    180.    165.    162.    137.    129.    133.    136.    105.    125.
  110.    135.    110.    126.    127.    135.     99.    107.    119.    106.
  137.    125.    122.    128.    168.    129.    147.    122.    154.    166.
  166.    234.    474.   3539.  16691.  12643.   1014.     20.      2.      3.
    1.      4.      2.      3.      0.     -6.     -4.      1.      7.      1.
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STANDARD SOURCE SPECTRA

CO60 SOURCE

12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.
12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.
12673.	12673.	12673.	12673.	12673.	12863.	13206.	13056.	12836.	12577.
12483.	12466.	12228.	12179.	12069.	11990.	12069.	12172.	11710.	11621.
11395.	11515.	11329.	11048.	11007.	10894.	10603.	106[illegible].	10430.	10491.
10195.	10259.	10048.	9999.	10227.	10329.	10202.	10615.	10811.	10862.
11741.	13724.	15301.	15307.	14343.	13292.	12225.	11399.	10696.	10068.
9775.	9494.	9056.	8770.	8726.	8554.	8375.	8066.	8469.	8236.
8213.	8375.	8259.	8215.	8026.	8058.	8022.	8146.	8099.	8052.
9035.	7957.	7910.	7863.	7761.	7607.	7458.	7449.	7411.	7351.
7318.	7353.	7270.	7253.	7126.	7019.	6982.	6936.	6991.	6979.
6838.	6976.	6814.	6699.	6664.	6826.	6627.	6546.	6641.	6644.
6857.	6683.	6613.	6652.	6549.	6567.	6583.	6585.	6546.	6412.
6562.	6592.	6456.	6496.	6560.	6416.	6343.	6528.	6463.	6452.
6466.	6464.	6551.	6478.	6472.	6508.	6301.	6516.	6564.	6498.
6467.	6339.	6355.	6546.	6422.	6462.	6378.	6556.	6487.	6493.
6279.	6575.	6500.	6499.	6412.	6374.	6488.	6590.	6595.	6543.
6473.	6513.	6473.	6380.	6500.	6536.	6621.	6675.	6658.	6524.
6586.	6962.	6610.	6758.	6638.	6644.	6608.	6742.	6718.	6639.
6660.	6713.	6724.	6835.	6844.	6648.	6872.	6858.	6949.	7065.
7137.	7045.	6959.	7002.	6971.	7056.	7107.	7159.	7141.	7038.
7293.	7142.	7141.	7146.	7283.	7252.	7187.	7400.	7444.	7578.
7464.	7601.	7644.	7611.	7552.	7807.	7620.	7687.	7833.	7857.
7768.	7955.	7815.	8006.	8078.	8169.	8293.	6503.	8565.	8349.
8384.	9589.	8621.	8492.	8774.	8790.	8877.	8873.	9000.	9233.
9174.	9240.	9240.	9406.	9721.	9672.	9914.	9893.	9882.	10117.
10174.	10560.	10286.	10645.	10680.	10807.	10967.	11012.	11224.	11460.
11343.	11607.	11730.	11965.	11914.	12010.	11767.	11512.	10809.	9828.
8821.	8439.	8308.	8068.	7935.	7858.	7708.	7868.	7875.	7736.
7813.	7708.	7447.	7812.	7571.	7615.	7504.	7484.	7280.	7422.
7394.	7508.	7303.	7275.	7074.	7039.	6966.	7057.	7107.	6900.
6979.	7129.	7287.	7173.	7235.	7242.	7178.	7399.	7232.	7353.
7181.	7324.	6857.	5982.	4954.	4378.	4067.	3926.	3778.	3634.
3618.	3536.	3430.	3393.	3462.	3391.	3507.	4720.	26371.	74800.
22532.	3078.	2168.	2001.	1951.	1820.	1698.	1517.	1482.	1363.
1278.	1045.	1043.	913.	890.	815.	743.	633.	611.	584.
506.	529.	503.	469.	462.	414.	446.	460.	435.	443.
466.	453.	508.	441.	441.	462.	479.	538.	506.	488.
607.	679.	954.	3429.	30675.	57738.	11347.	501.	83.	34.
39.	15.	30.	31.	14.	25.	30.	28.	26.	1.

STANDARD SOURCE SPECTRA

TH228 SOURCE

3160.	3160.	3140.	3120.	3100.	3080.	3060.	3040.	3020.	3000.
2990.	2975.	2955.	2949.	2920.	2900.	2885.	2865.	2850.	2835.
2820.	2795.	2780.	2760.	2750.	2735.	2720.	2700.	2690.	2675.
2660.	2640.	2625.	2615.	2600.	2590.	2575.	2560.	2545.	2530.
2520.	2500.	2490.	2480.	2460.	2445.	2440.	2425.	2410.	2400.
2390.	2380.	2360.	2350.	2340.	2320.	2315.	2300.	2285.	2280.
2265.	2255.	2240.	2235.	2220.	2205.	2195.	2180.	2175.	2160.
2150.	2140.	2135.	2120.	2115.	2100.	2095.	2085.	2080.	2075.
2060.	2055.	2045.	2040.	2035.	2025.	2020.	2015.	2005.	2000.
1995.	1985.	1980.	1975.	1965.	1960.	1955.	1950.	1945.	1940.
1935.	1930.	1925.	1920.	1915.	1905.	1900.	1895.	1890.	1885.
1880.	1875.	1875.	1870.	1865.	1860.	1855.	1850.	1845.	1840.
1840.	1835.	1830.	1825.	1920.	1820.	1815.	1810.	1805.	1800.
1759.	1659.	1758.	1757.	1805.	1841.	1780.	1715.	1971.	1950.
1741.	1829.	1856.	1917.	1766.	1744.	1588.	1720.	1827.	1794.
1759.	1740.	1735.	1798.	1851.	1768.	1800.	1805.	1810.	1815.
1786.	1850.	1789.	1789.	1778.	1859.	1781.	1827.	1852.	1776.
1859.	1843.	1851.	1827.	1916.	1748.	1881.	1853.	1932.	1916.
1857.	1876.	1878.	1831.	1793.	1854.	1890.	1910.	1844.	1751.
1775.	1809.	1788.	1897.	1836.	1933.	1803.	1829.	1858.	1887.
1917.	1885.	1883.	1922.	1760.	1818.	1793.	1719.	1698.	1668.
1729.	1725.	2113.	1948.	1752.	1729.	1730.	1703.	1717.	1834.
2056.	1823.	1681.	1721.	1685.	1650.	1662.	1705.	1772.	1705.
1714.	1723.	1732.	1741.	1750.	1759.	1768.	1777.	1786.	1795.
1804.	1813.	1922.	1831.	1840.	1849.	1858.	1867.	1876.	1885.
1893.	1902.	1911.	1920.	1929.	1938.	1947.	1956.	1965.	1974.
1983.	1992.	2001.	2010.	2019.	2028.	2037.	2046.	2055.	2064.
2073.	2082.	2091.	2100.	2109.	2118.	2127.	2136.	2145.	2154.
2163.	2172.	2181.	2190.	2199.	2208.	2217.	2226.	2235.	2244.
2252.	2261.	2270.	2279.	2288.	2297.	2106.	2315.	2324.	2333.
2342.	2351.	2360.	2369.	2378.	2387.	2396.	2405.	2414.	2423.
2549.	2596.	2430.	2602.	2610.	2576.	2546.	2655.	2698.	2737.
2757.	2925.	2857.	2827.	2952.	2898.	2979.	2939.	3056.	3086.
3225.	3123.	3309.	3233.	3431.	3423.	3572.	3676.	3750.	3704.
3322.	3865.	4006.	3929.	2921.	3735.	2885.	2311.	2037.	1971.
1961.	1851.	1746.	1631.	1664.	1561.	1457.	1405.	1216.	1159.
983.	827.	690.	592.	515.	392.	361.	339.	297.	289.
324.	237.	278.	291.	284.	291.	331.	541.	2345.	18725.
8173.	85.	57.	31.	38.	33.	34.	27.	45.	19.
31.	19.	22.	19.	17.	16.	15.	9.	8.	1.

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                                        RESULTS OF PHOTOPEAK FITTING

INDEX        STANDARD SOURCE       PULSE-HEIGHT        STANDARD DEVIATION          AREA
                                    (CHANNELS)             (CHANNELS)          (COUNTS/TIME)

  1               CE139           0.3584167E 03          0.3066857E 01        0.3102433E 06
  2               HG203           0.3806990E 03          0.1923298E 01        0.3694376E 05
  3                SR85           0.3895884E 03          0.1094684E 01        0.8907631E 05
  4               CS137           0.3750823E 03          0.9007936E 00        0.2089790E 06
  5                MN54           0.3753264E 03          0.7370086E 00        0.9434950E 05
  6                ZN65           0.3858713E 03          0.6066732E 00        0.3282250E 05
  7                CO60           0.3862827E 03          0.6031659E 00        0.1016444E 06
  8               TH228           0.3807041E 03          0.4792651E 00        0.2873323E 05
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                                        RESULTS OF PHOTOPEAK FITTING

INDEX        STANDARD SOURCE       PULSE-HEIGHT        STANDARD DEVIATION          AREA
                                    (CHANNELS)             (CHANNELS)          (COUNTS/TIME)

  1               CE139           0.0                    0.0                  0.0
  2               HG203           0.0                    0.0                  0.0
  3                SR85           0.0                    0.0                  0.0
  4               CS137           0.0                    0.0                  0.0
  5                MN54           0.0                    0.0                  0.0
  6                ZN65           0.1778325E 03          0.6738757E 00        0.5125484E 04
  7                CO60           0.3404636E 03          0.5818627E 00        0.1171379E 06
  8               TH228           0.0                    0.0                  0.0
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            NORMALIZED CONTINUUM OF STANDARD SPECTRA

 CE139 SOURCE            ENERGY=      0.1660 MEV

0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534453E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534453E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02
0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4534457E-02 0.4544195E-02
0.4499003E-02 0.4611749E-02 0.4591342E-02 0.4541155E-02 0.4556350E-02
0.4345391E-02 0.4479129E-02 0.4991516E-02 0.4778638E-02 0.4689261E-02
0.4744347E-02 0.4941694E-02 0.4952993E-02 0.4931588E-02 0.5036689E-02
0.4968464E-02 0.4895430E-02 0.5071320E-02 0.4961684E-02 0.4603472E-02
0.4939057E-02 0.4802771E-02 0.4269794E-02 0.4252177E-02 0.3984410E-02
0.4270557E-02 0.3280515E-02 0.2822481E-02 0.2687569E-02 0.2544689E-02
0.2304204E-02 0.2253854E-02 0.2268688E-02 0.2202023E-02 0.2259242E-02
0.2110744E-02 0.2341291E-02 0.2395550E-02 0.2096425E-02 0.1942754E-02
0.2084468E-02 0.2243090E-02 0.2238457E-02 0.2094791E-02 0.1935700E-02
0.2037856E-02 0.2286413E-02 0.1956472E-02 0.2053202E-02 0.2196050E-02
0.2291434E-02 0.2177353E-02 0.2368727E-02 0.2521051E-02 0.2506502E-02
0.2497525E-02 0.2557063E-02 0.2616600E-02 0.2676134E-02 0.2735672E-02
0.2795209E-02 0.2854747E-02 0.2914284E-02 0.2973822E-02 0.3033360E-02
0.3092897E-02 0.3152431E-02 0.3211969E-02 0.3271506E-02 0.3331044E-02
0.3390581E-02 0.3450119E-02 0.3509657E-02 0.3569194E-02 0.3628728E-02
0.3688266E-02 0.3747803E-02 0.3807341E-02 0.3866878E-02 0.3926415E-02
0.3985953E-02 0.4045486E-02 0.4105024E-02 0.4164562E-02 0.4224099E-02
0.4283637E-02 0.4343174E-02 0.4402712E-02 0.4462250E-02 0.4521783E-02
0.4581321E-02 0.5007189E-02 0.4859123E-02 0.4504524E-02 0.4692174E-02
0.4563164E-02 0.4475277E-02 0.4514966E-02 0.4243661E-02 0.4394689E-02
0.4247099E-02 0.4011326E-02 0.3785817E-02 0.3624521E-02 0.3768052E-02
0.3524824E-02 0.3386437E-02 0.3517172E-02 0.3319770E-02 0.3171513E-02
0.3049272E-02 0.3165569E-02 0.3333638E-02 0.3142498E-02 0.3359505E-02
0.3307179E-02 0.3316274E-02 0.3382830E-02 0.3198631E-02 0.3262210E-02
0.3280090E-02 0.3207583E-02 0.3304941E-02 0.3353400E-02 0.3311882E-02
0.3340504E-02 0.3342296E-02 0.3573753E-02 0.3541933E-02 0.3445640E-02
0.3600567E-02 0.3606034E-02 0.3746361E-02 0.3545461E-02 0.3620693E-02
0.3965342E-02 0.3745952E-02 0.3910813E-02 0.4094012E-02 0.4127506E-02
0.4233431E-02 0.4355691E-02 0.4467014E-02 0.4719015E-02 0.4492670E-02
0.3457265E-02 0.1561723E-02 0.0           0.0           0.0
0.0           0.0           0.0           0.0           0.0
0.0           0.0           0.0           0.0           0.0

INTEGRAL       =  0.7511505E 00
PHOTOFRACTION  =  0.5710532E 00


            NORMALIZED CONTINUUM OF STANDARD SPECTRA

 HG203 SOURCE            ENERGY=      0.2790 MEV

0.1411760E-01 0.1411760E-01 0.1411760E-01 0.1411760E-01 0.1411760E-01
0.1411760E-01 0.1411760E-01 0.1411760E-01 0.1411750E-01 0.1411755E-01
0.1411755E-01 0.1411755E-01 0.1411755E-01 0.1411755E-01 0.1411755E-01
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0.1411755E-01 0.1411755E-01 0.1411755E-01 0.1411755E-01 0.1547312E-01
0.1160727E-01 0.1388113E-01 0.1468972E-01 0.1409402E-01 0.1403121E-01
0.1576668E-01 0.1393011E-01 0.1329699E-01 0.1377064E-01 0.1651460E-01
0.1687742E-01 0.1479116E-01 0.1529202E-01 0.1835092E-01 0.1582207E-01
0.1618724E-01 0.1831056E-01 0.1744843E-01 0.1723162E-01 0.1557201E-01
0.1783491E-01 0.1910402E-01 0.1613504E-01 0.1832011E-01 0.1997327E-01
0.2450301E-01 0.2435723E-01 0.2558737E-01 0.2477425E-01 0.2239806E-01
0.2499292E-01 0.2374966E-01 0.2134326E-01 0.2305344E-01 0.1640563E-01
0.1517489E-01 0.1477139E-01 0.1323059E-01 0.1127175E-01 0.1093554E-01
0.1144945E-01 0.1084553E-01 0.1040321E-01 0.1112216E-01 0.1128820E-01
0.9074263E-02 0.9579528E-02 0.1005081E-01 0.8256812E-02 0.9029407E-02
0.9503334E-02 0.6915264E-02 0.7297581E-02 0.5526235E-02 0.7521644E-02
0.7952966E-02 0.6639611E-02 0.6845150E-02 0.7051524E-02 0.6180461E-02
0.5796034E-02 0.6061260E-02 0.5378857E-02 0.5171992E-02 0.4591470E-02
0.3963232E-02 0.4313838E-02 0.4205556E-02 0.3946081E-02 0.4633293E-02
0.3515683E-02 0.4192635E-02 0.4065648E-02 0.3087278E-02 0.3565385E-02
0.5088456E-02 0.3330125E-02 0.3799959E-02 0.3276098E-02 0.3733292E-02
0.3953070E-02 0.3473058E-02 0.3164127E-02 0.3559454E-02 0.3003403E-02
0.4198422E-02 0.4594391E-02 0.2528779E-02 0.3912617E-02 0.4227094E-02
0.4072104E-02 0.3904095E-02 0.3931490E-02 0.3229220E-02 0.3457905E-02
0.4250947E-02 0.2589331E-02 0.4467528E-02 0.4272573E-02 0.3484636E-02
0.3558301E-02 0.3635117E-02 0.3861509E-02 0.2763537E-02 0.3095624E-02
0.4104819E-02 0.3922101E-02 0.4547570E-02 0.3852818E-02 0.3648770E-02
0.4646638E-02 0.4410617E-02 0.3199634E-02 0.3293699E-02 0.3262950E-02
0.4337683E-02 0.2761303E-02 0.3503398E-02 0.4343383E-02 0.3088963E-02
0.4075669E-02 0.4201908E-02 0.4304562E-02 0.4263793E-02 0.4487824E-02
0.6207559E-02 0.5418032E-02 0.4523482E-02 0.0           0.0
0.0           0.0           0.0           0.0           0.0
0.0           0.0           0.0           0.0           0.0

INTEGRAL       =  0.2128635E 01
PHOTOFRACTION  =  0.3196281E 00
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              NORMALIZED CONTINUUM OF STANDARD SPECTRA

   SR85 SOURCE              ENERGY=     0.5140 MEV

0.3889347E-01 0.3885337E-01 0.3881327E-01 0.3877317E-01 0.3873307E-01
0.3869297E-01 0.3865287E-01 0.3861278E-01 0.3857268E-01 0.3853257E-01
0.3849247E-01 0.3845238E-01 0.3841228E-01 0.3837218E-01 0.3833208E-01
0.3829198E-01 0.3825188E-01 0.3821178E-01 0.3817168E-01 0.3813158E-01
0.3809148E-01 0.3805138E-01 0.3801128E-01 0.3797118E-01 0.3793108E-01
0.3789099E-01 0.3785088E-01 0.3781078E-01 0.3777068E-01 0.3773059E-01
0.3769049E-01 0.3765039E-01 0.3761029E-01 0.3757019E-01 0.3753009E-01
0.3748999E-01 0.3744989E-01 0.3740979E-01 0.3736969E-01 0.3732959E-01
0.3728949E-01 0.3724939E-01 0.3720929E-01 0.3716919E-01 0.3712909E-01
0.3708899E-01 0.3704889E-01 0.3700880E-01 0.3696870E-01 0.3692860E-01
0.3688850E-01 0.3684840E-01 0.3680830E-01 0.3676820E-01 0.3672810E-01
0.3668800E-01 0.3664790E-01 0.3660780E-01 0.3656770E-01 0.3655555E-01
0.3650330E-01 0.3645105E-01 0.3639881E-01 0.3634656E-01 0.3629431E-01
0.3624206E-01 0.3618981E-01 0.3613756E-01 0.3608532E-01 0.3603307E-01
0.3598082E-01 0.3592857E-01 0.3587632E-01 0.3582407E-01 0.3577183E-01
0.3571958E-01 0.3566733E-01 0.3561508E-01 0.3600939E-01 0.3587374E-01
0.3583220E-01 0.3547119E-01 0.3507688E-01 0.3415861E-01 0.3364255E-01
0.3452465E-01 0.3556425E-01 0.3597074E-01 0.3592788E-01 0.3545552E-01
0.3488425E-01 0.3466156E-01 0.3420384E-01 0.3442792E-01 0.3339892E-01
0.3465300E-01 0.3449449E-01 0.3363895E-01 0.3327809E-01 0.3347594E-01
0.3290075E-01 0.3319710E-01 0.3810519E-01 0.3814721E-01 0.3453041E-01
0.3358670E-01 0.3351189E-01 0.3495530E-01 0.3697412E-01 0.3454883E-01
0.3421216E-01 0.3579772E-01 0.3557036E-01 0.3674550E-01 0.3500909E-01
0.3640398E-01 0.3777418E-01 0.3681438E-01 0.3811058E-01 0.3867370E-01
0.3963514E-01 0.4016190E-01 0.3984917E-01 0.4105983E-01 0.4290782E-01
0.4196906E-01 0.4318740E-01 0.4274711E-01 0.4287365E-01 0.4269255E-01
0.4298590E-01 0.4032030E-01 0.3790028E-01 0.3185822E-01 0.2667116E-01
0.2281858E-01 0.2120473E-01 0.1895571E-01 0.1778565E-01 0.1741281E-01
0.1763216E-01 0.1643120E-01 0.1540978E-01 0.1481088E-01 0.1360623E-01
0.1350638E-01 0.1323956E-01 0.1323551E-01 0.1209641E-01 0.1060517E-01
0.1078216E-01 0.1127590E-01 0.1050599E-01 0.1014489E-01 0.8941729E-02
0.9733718E-02 0.8396957E-02 0.6873786E-02 0.6689440E-02 0.6365802E-02
0.5503684E-02 0.5349264E-02 0.5386207E-02 0.5390659E-02 0.4741821E-02
0.4465934E-02 0.4714202E-02 0.4897032E-02 0.4497133E-02 0.4384633E-02
0.4408862E-02 0.4098171E-02 0.4366633E-02 0.4262045E-02 0.3941131E-02
0.4395869E-02 0.3811933E-02 0.4383568E-02 0.3934104E-02 0.4380479E-02
0.3882336E-02 0.3850255E-02 0.4040938E-02 0.3818160E-02 0.4131854E-02
0.4107140E-02 0.4154831E-02 0.4331969E-02 0.3912088E-02 0.3730877E-02
0.4594538E-02 0.4438763E-02 0.4330464E-02 0.4912211E-02 0.4917786E-02
0.6030746E-02 0.7179942E-02 0.1389029E-01 0.0           0.0
0.0           0.0           0.0           0.0           0.0
0.0           0.0           0.0           0.0           0.0

INTEGRAL      =  0.5497600E 01
PHOTOFRACTION =  0.1539029E 00


              NORMALIZED CONTINUUM OF STANDARD SPECTRA

   CS137 SOURCE             ENERGY=     0.6616 MEV

0.5388384E-01 0.5371992E-01 0.5355599E-01 0.5339206E-01 0.5322813E-01
0.5306420E-01 0.5290027E-01 0.5273635E-01 0.5257242E-01 0.5240849E-01
0.5224456E-01 0.5208063E-01 0.5191670E-01 0.5175277E-01 0.5158884E-01
0.5142492E-01 0.5126099E-01 0.5109706E-01 0.5093313E-01 0.5076920E-01
0.5060527E-01 0.5044135E-01 0.5027742E-01 0.5011349E-01 0.4994956E-01
0.4978564E-01 0.4962170E-01 0.4945778E-01 0.4929385E-01 0.4912992E-01
0.4896599E-01 0.4880206E-01 0.4863814E-01 0.4847421E-01 0.4831028E-01
0.4814635E-01 0.4798242E-01 0.4781849E-01 0.4765457E-01 0.4749063E-01
0.4732671E-01 0.4716278E-01 0.4699885E-01 0.4683492E-01 0.4667099E-01
0.4650706E-01 0.4634314E-01 0.4617921E-01 0.4601528E-01 0.4599142E-01
0.4580364E-01 0.4561586E-01 0.4542807E-01 0.4524029E-01 0.4505251E-01
0.4486472E-01 0.4467694E-01 0.4448916E-01 0.4430137E-01 0.4411359E-01
0.4392581E-01 0.4373803E-01 0.4355024E-01 0.4336246E-01 0.4317468E-01
0.4298689E-01 0.4281698E-01 0.4168675E-01 0.4226941E-01 0.4191643E-01
0.4221109E-01 0.4216294E-01 0.4255833E-01 0.4226060E-01 0.3949307E-01
0.4086805E-01 0.4238972E-01 0.4155463E-01 0.4132504E-01 0.4010224E-01
0.4062714E-01 0.3989366E-01 0.3973069E-01 0.3892457E-01 0.3932979E-01
0.3736394E-01 0.3834650E-01 0.3827750E-01 0.3762379E-01 0.3685551E-01
0.3712888E-01 0.3691269E-01 0.3700821E-01 0.3646825E-01 0.3674958E-01
0.3742881E-01 0.3655261E-01 0.3681642E-01 0.3610245E-01 0.3637843E-01
0.3676122E-01 0.3723492E-01 0.3705564E-01 0.3709705E-01 0.3710945E-01
0.3748123E-01 0.3762558E-01 0.3844374E-01 0.3838219E-01 0.3779935E-01
0.3776907E-01 0.3869962E-01 0.3884735E-01 0.3979586E-01 0.3986767E-01
0.4040273E-01 0.4103730E-01 0.4127975E-01 0.4069393E-01 0.4256931E-01
0.4352871E-01 0.4368786E-01 0.4471671E-01 0.4501225E-01 0.4566057E-01
0.4663821E-01 0.4699907E-01 0.4806423E-01 0.4904911E-01 0.4915473E-01
0.5077445E-01 0.5066832E-01 0.5152725E-01 0.5308395E-01 0.5350462E-01
0.5504936E-01 0.5554846E-01 0.5628511E-01 0.5741690E-01 0.5776682E-01
0.5744796E-01 0.5585545E-01 0.5399840E-01 0.4879793E-01 0.3928160E-01
0.3194154E-01 0.2953005E-01 0.2691087E-01 0.2514775E-01 0.2226007E-01
0.2316432E-01 0.2130249E-01 0.2067303E-01 0.2016383E-01 0.1922866E-01
0.1796019E-01 0.1743966E-01 0.1682960E-01 0.158496[illegible]E-01 0.1491850E-01
0.1418672E-01 0.1394323E-01 0.1231[illegible]E-01 0.1182985E-01 0.1060[illegible]E-01
0.9390488E-02 0.8504256E-02 0.7963125E-02 0.7573504E-02 0.6920643E-02
0.5693479E-02 0.6343037E-02 0.62655[illegible]E-02 0.5793395E-02 0.51446[illegible]E-02
0.4959296E-02 0.5143081E-02 0.480824[illegible]E-02 0.4726954E-02 0.4946685E-02
0.4519083E-02 0.4437544E-02 0.4559[illegible]E-02 0.4902728E-02 0.4856598E-02
0.4810371E-02 0.4764996E-02 0.4719[illegible]E-02 0.4674252E-02 0.4628882E-02
0.4583508E-02 0.4538137E-02 0.4457[illegible]E-02 0.4445776E-02 0.4430406E-02
0.4355932E-02 0.4409132E-02 0.9715[illegible]E-02 0.0           0.0
0.0           0.0           0.0           0.0           0.0
0.0           0.0           0.0           0.0           0.0

INTEGRAL      =  0.7144479E 01
PHOTOFRACTION =  0.1227825E 00
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                NORMALIZED CONTINUUM OF STANDARD SPECTRA

    MN54 SOURCE            ENERGY=      0.8350 MEV

0.7146639E-01 0.7112885E-01 0.7079136E-01 0.7045382E-01 0.7011634E-01
0.6977880E-01 0.6944132E-01 0.6910378E-01 0.6876630E-01 0.6842875E-01
0.6809127E-01 0.6775373E-01 0.6741625E-01 0.6707871E-01 0.6674117E-01
0.6640369E-01 0.6606615E-01 0.6572866E-01 0.6539112E-01 0.6505364E-01
0.6471610E-01 0.6437862E-01 0.6404108E-01 0.6370360E-01 0.6336606E-01
0.6302851E-01 0.6269103E-01 0.6235354E-01 0.6201603E-01 0.6167851E-01
0.6134100E-01 0.6100348E-01 0.6066597E-01 0.6032846E-01 0.5999094E-01
0.5965343E-01 0.5931592E-01 0.5897840E-01 0.5864089E-01 0.5830337E-01
0.5796586E-01 0.5762835E-01 0.5752129E-01 0.5707674E-01 0.5663218E-01
0.5618762E-01 0.5574306E-01 0.5529850E-01 0.5485394E-01 0.5440938E-01
0.5396482E-01 0.5352027E-01 0.5307571E-01 0.5263115E-01 0.5218659E-01
0.5216205E-01 0.5133055E-01 0.4878984E-01 0.5038309E-01 0.4914839E-01
0.4999013E-01 0.5149357E-01 0.4884670E-01 0.4986783E-01 0.5099481E-01
0.5037209E-01 0.5049241E-01 0.4949379E-01 0.4850619E-01 0.4658328E-01
0.4700489E-01 0.4777449E-01 0.4660361E-01 0.4544532E-01 0.4449902E-01
0.4543683E-01 0.4610644E-01 0.4468428E-01 0.4328493E-01 0.4389170E-01
0.4367451E-01 0.4294793E-01 0.4269093E-01 0.4261189E-01 0.4123867E-01
0.4466891E-01 0.4337737E-01 0.4127698E-01 0.4106096E-01 0.4197459E-01
0.4396275E-01 0.4205638E-01 0.4313800E-01 0.4286199E-01 0.4184920E-01
0.4355510E-01 0.4195892E-01 0.4334656E-01 0.4282893E-01 0.4317892E-01
0.4315999E-01 0.4398338E-01 0.4254818E-01 0.4173074E-01 0.4173325E-01
0.4228470E-01 0.4295163E-01 0.4466919E-01 0.4426068E-01 0.4397617E-01
0.4468964E-01 0.4555946E-01 0.4524531E-01 0.4348373E-01 0.4528198E-01
0.4544358E-01 0.4549535E-01 0.4612123E-01 0.4760918E-01 0.4625374E-01
0.4630141E-01 0.4827130E-01 0.4818564E-01 0.4910344E-01 0.4979479E-01
0.5022516E-01 0.5099015E-01 0.5071764E-01 0.5266623E-01 0.5302415E-01
0.5339655E-01 0.5464014E-01 0.5562412E-01 0.5731710E-01 0.5805501E-01
0.5988150E-01 0.6056262E-01 0.6143489E-01 0.6285079E-01 0.6483006E-01
0.6581306E-01 0.6510413E-01 0.6866848E-01 0.7041556E-01 0.6959766E-01
0.7142955E-01 0.7395571E-01 0.7459706E-01 0.7623643E-01 0.7561831E-01
0.7533157E-01 0.7259887E-01 0.6467843E-01 0.4936084E-01 0.4019609E-01
0.3692688E-01 0.3441921E-01 0.3224223E-01 0.3082692E-01 0.2914339E-01
0.2879783E-01 0.2686582E-01 0.2520756E-01 0.2421713E-01 0.2327744E-01
0.2157826E-01 0.2053659E-01 0.1954781E-01 0.1798949E-01 0.1583846E-01
0.1440072E-01 0.1279784E-01 0.1094949E-01 0.1091069E-01 0.9766687E-02
0.8334998E-02 0.7311318E-02 0.6819341E-02 0.6449776E-02 0.5879369E-02
0.5302289E-02 0.5849320E-02 0.5636312E-02 0.5316362E-02 0.5159892E-02
0.5119443E-02 0.5422059E-02 0.5275492E-02 0.5235951E-02 0.4953831E-02
0.4888419E-02 0.5024135E-02 0.5727394E-02 0.5886819E-02 0.5993083E-02
0.7150784E-02 0.7785335E-02 0.1159447E-01 0.2287994E-01 0.2511517E-02
0.0           0.0           0.0           0.0           0.0
0.0           0.0           0.0           0.0           0.0

INTEGRAL       =  0.9086666E 01
PHOTOFRACTION  =  0.9914076E-01
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               NORMALIZED CONTINUUM OF STANDARD SPECTRA

    ZN65 SOURCE            ENERGY=      1.1140 MEV

0.9963143E-01 0.9888941E-01 0.9814733E-01 0.9740531E-01 0.9666330E-01
0.9592128E-01 0.9517926E-01 0.9443724E-01 0.9369522E-01 0.9295321E-01
0.9221119E-01 0.9146917E-01 0.9072715E-01 0.8998513E-01 0.8924311E-01
0.8850110E-01 0.8775908E-01 0.8701706E-01 0.8627504E-01 0.8553302E-01
0.8479100E-01 0.8404899E-01 0.8330697E-01 0.8256495E-01 0.8182293E-01
0.8108091E-01 0.8033890E-01 0.7959688E-01 0.7885486E-01 0.7811284E-01
0.7737082E-01 0.7662880E-01 0.7588679E-01 0.7514477E-01 0.7496065E-01
0.7403451E-01 0.7310843E-01 0.7218230E-01 0.7125616E-01 0.7033002E-01
0.6940389E-01 0.6847775E-01 0.6755161E-01 0.6662554E-01 0.6559940E-01
0.6278080E-01 0.6364954E-01 0.6067590E-01 0.6134073E-01 0.6169034E-01
0.6387889E-01 0.6416742E-01 0.6237485E-01 0.6233137E-01 0.6117812E-01
0.5958702E-01 0.5705733E-01 0.5787399E-01 0.5414572E-01 0.5322128E-01
0.5750898E-01 0.5418062E-01 0.5849556E-01 0.5414154E-01 0.5447212E-01
0.5356950E-01 0.5138336E-01 0.5329853E-01 0.5170661E-01 0.5127364E-01
0.5064119E-01 0.4996062E-01 0.5236709E-01 0.5243137E-01 0.5329344E-01
0.5222915E-01 0.4983984E-01 0.5103994E-01 0.5147974E-01 0.5051699E-01
0.5163782E-01 0.5025382E-01 0.4932692E-01 0.5179144E-01 0.5003105E-01
0.5115931E-01 0.5029679E-01 0.4982828E-01 0.5197997E-01 0.5259052E-01
0.5277585E-01 0.5295118E-01 0.5314652E-01 0.5333184E-01 0.5270667E-01
0.5228733E-01 0.5030740E-01 0.5138219E-01 0.5080197E-01 0.5335866E-01
0.5206062E-01 0.5191464E-01 0.5031504E-01 0.5121605E-01 0.5178823E-01
0.5265837E-01 0.5506377E-01 0.5371463E-01 0.5510441E-01 0.5403583E-01
0.5283644E-01 0.5400704E-01 0.5473646E-01 0.5431001E-01 0.5477557E-01
0.5597924E-01 0.5437500E-01 0.5521953E-01 0.5701484E-01 0.5566651E-01
0.5736363E-01 0.5790713E-01 0.5956579E-01 0.5910554E-01 0.5990274E-01
0.5992288E-01 0.5915400E-01 0.6098915E-01 0.6081833E-01 0.6168237E-01
0.5945195E-01 0.6135174E-01 0.6197880E-01 0.6482607E-01 0.6549430E-01
0.6655955E-01 0.6731606E-01 0.6673563E-01 0.6906176E-01 0.7116703E-01
0.6997633E-01 0.7267731E-01 0.7547683E-01 0.7856762E-01 0.7712781E-01
0.7983766E-01 0.8157137E-01 0.9132774E-01 0.8422107E-01 0.8741111E-01
0.8928764E-01 0.9034003E-01 0.9188771E-01 0.9586036E-01 0.9989536E-01
0.1013210E 00 0.1078976E 00 0.1118246E 00 0.1112631E 00 0.1084968E 00
0.1068307E 00 0.1015655E 00 0.8044249E-01 0.6062352E-01 0.5079260E-01
0.5059810E-01 0.4885613E-01 0.4553381E-01 0.4270388E-01 0.4100212E-01
0.3766962E-01 0.3865585E-01 0.3270271E-01 0.3200435E-01 0.2996117E-01
0.2608993E-01 0.2344927E-01 0.2048583E-01 0.1792520E-01 0.1478000E-01
0.1357049E-01 0.1144840E-01 0.1069719E-01 0.8765545E-02 0.7696290E-02
0.7182468E-02 0.6899793E-02 0.7237109E-02 0.7293625E-02 0.7223729E-02
0.6365661E-02 0.6832257E-02 0.7524241E-02 0.7752654E-02 0.8549284E-02
0.7999063E-02 0.9487905E-02 0.1240705E-01 0.4430006E-01 0.2661803E-02
0.1449165E-03 0.2077379E-03 0.1351299E-03 0.1565966E-03 0.0
0.0           0.0           0.0           0.0           0.0

INTEGRAL       =  0.1196219E 02
PHOTOFRACTION  =  0.7714742E-01
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              NORMALIZED CONTINUUM OF STANDARD SPECTRA

     CO60 SOURCE            ENERGY=      1.3300 MEV

 0.1208785E 00 0.1192651E 00 0.1176518E 00 0.1160384E 00 0.1144251E 00
 0.1128117E 00 0.1111984E 00 0.1095850E 00 0.1079717E 00 0.1063583E 00
 0.1047449E 00 0.1031316E 00 0.1015182E 00 0.9990484E-01 0.9829152E-01
 0.9667814E-01 0.9506476E-01 0.9345144E-01 0.9183806E-01 0.9022474E-01
 0.8861136E-01 0.8699799E-01 0.8538467E-01 0.8377129E-01 0.8215791E-01
 0.8054459E-01 0.7893121E-01 0.7929705E-01 0.7802957E-01 0.7677203E-01
 0.7551455E-01 0.7425702E-01 0.7299954E-01 0.7174200E-01 0.7048452E-01
 0.6611609E-01 0.6804879E-01 0.6377661E-01 0.6544524E-01 0.6752932E-01
 0.6931436E-01 0.6758505E-01 0.6876218E-01 0.6835353E-01 0.6479001E-01
 0.6290764E-01 0.6104275E-01 0.5767201E-01 0.5744189E-01 0.5839419E-01
 0.6083419E-01 0.6159427E-01 0.5819190E-01 0.5587415E-01 0.5480928E-01
 0.5428543E-01 0.5274102E-01 0.5430265E-01 0.5363135E-01 0.5500024E-01
 0.5772097E-01 0.5665006E-01 0.5584640E-01 0.5514678E-01 0.5264921E-01
 0.5163722E-01 0.5227648E-01 0.5359657E-01 0.5172658E-01 0.5260152E-01
 0.5224746E-01 0.5342090E-01 0.5388422E-01 0.5270498E-01 0.5300335E-01
 0.5367247E-01 0.5141248E-01 0.5203121E-01 0.5987027E-01 0.5002353E-01
 0.4943162E-01 0.4780973E-01 0.4941321E-01 0.4810173E-01 0.5070805E-01
 0.5325719E-01 0.5219654E-01 0.5076420E-01 0.4976301E-01 0.5280786E-01
 0.5509555E-01 0.5347962E-01 0.5532225E-01 0.5278426E-01 0.5030049E-01
 0.5106822E-01 0.5105477E-01 0.5193771E-01 0.5320492E-01 0.5220062E-01
 0.5362312E-01 0.5623136E-01 0.5795478E-01 0.5767615E-01 0.5832865E-01
 0.5766998E-01 0.6057231E-01 0.5929879E-01 0.5893307E-01 0.5711722E-01
 0.5814005E-01 0.5878957E-01 0.5977735E-01 0.6250453E-01 0.6097642E-01
 0.6255406E-01 0.6134104E-01 0.5997950E-01 0.6130835E-01 0.6213639E-01
 0.6165228E-01 0.6218078E-01 0.6354713E-01 0.6138550E-01 0.6268471E-01
 0.6472278E-01 0.6319213E-01 0.6511867E-01 0.6573570E-01 0.6648791E-01
 0.6709611E-01 0.6870109E-01 0.6802392E-01 0.6715113E-01 0.6923437E-01
 0.6904948E-01 0.7002133E-01 0.6743258E-01 0.7021356E-01 0.7035780E-01
 0.7358998E-01 0.7434857E-01 0.7555783E-01 0.7641661E-01 0.7575774E-01
 0.7839835E-01 0.8072007E-01 0.7943654E-01 0.8250266E-01 0.8568066E-01
 0.8918929E-01 0.8755481E-01 0.9063107E-01 0.9260142E-01 0.9232259E-01
 0.9560704E-01 0.9922832E-01 0.1013579E 00 0.1022127E 00 0.1043102E 00
 0.1048199E 00 0.1134004E 00 0.1150187E 00 0.1224845E 00 0.1269423E 00
 0.1263106E 00 0.1211647E 00 0.1212733E 00 0.1152964E 00 0.9131765E-01
 0.6831928E-01 0.5765935E-01 0.5743855E-01 0.5547243E-01 0.5166961E-01
 0.4947710E-01 0.4654527E-01 0.3826453E-01 0.3435582E-01 0.2963057E-01
 0.2609871E-01 0.2136434E-01 0.1831211E-01 0.1604638E-01 0.1329298E-01
 0.1132160E-01 0.9893380E-02 0.9349763E-02 0.8502536E-02 0.8242134E-02
 0.8334405E-02 0.8486565E-02 0.8909322E-02 0.8414768E-02 0.8737460E-02
 0.9702235E-02 0.9909626E-02 0.1396297E-01 0.2007571E-01 0.3631772E-02
 0.0           0.0           0.0           0.0           0.0
 0.0           0.0           0.0           0.0           0.0

INTEGRAL       =  0.1305908E 02
PHOTOFRACTION  =  0.7112837E-01
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              NORMALIZED CONTINUUM OF STANDARD SPECTRA

     TH228 SOURCE           ENERGY=      2.6150 MEV

 0.2093437E 00 0.2075241E 00 0.2050085E 00 0.2024928E 00 0.1999772E 00
 0.1980295E 00 0.1959980E 00 0.1939669E 00 0.1914359E 00 0.1892416E 00
 0.1873229E 00 0.1847767E 00 0.1826946E 00 0.1809819E 00 0.1789212E 00
 0.1772085E 00 0.1750852E 00 0.1733237E 00 0.1717514E 00 0.1699929E 00
 0.1680926E 00 0.1653431E 00 0.1647282E 00 0.1627651E 00 0.1613929E 00
 0.1597016E 00 0.1583721E 00 0.1565623E 00 0.1551237E 00 0.1534477E 00
 0.1518419E 00 0.1505689E 00 0.1489934E 00 0.1477205E 00 0.1460062E 00
 0.1445256E 00 0.1431929E 00 0.1419109E 00 0.1407521E 00 0.1394944E 00
 0.1364182E 00 0.1376308E 00 0.1363499E 00 0.1353974E 00 0.1346281E 00
 0.1337825E 00 0.1328986E 00 0.1321293E 00 0.1312333E 00 0.1303998E 00
 0.1296443E 00 0.1290124E 00 0.1283697E 00 0.1277408E 00 0.1271119E 00
 0.1262050E 00 0.1255229E 00 0.1248939E 00 0.1243185E 00 0.1239673E 00
 0.1233385E 00 0.1227096E 00 0.1220670E 00 0.1217526E 00 0.1211373E 00
 0.1206185E 00 0.1202108E 00 0.1155919E 00 0.1161372E 00 0.1155829E 00
 0.1185062E 00 0.1196055E 00 0.1221404E 00 0.1229568E 00 0.1214576E 00
 0.1229886E 00 0.1146783E 00 0.1152354E 00 0.1199920E 00 0.1156338E 00
 0.1175317E 00 0.1195791E 00 0.1194189E 00 0.1200632E 00 0.1202041E 00
 0.1189441E 00 0.1196114E 00 0.1195130E 00 0.1209304E 00 0.1212834E 00
 0.1222507E 00 0.1203120E 00 0.1205298E 00 0.1253164E 00 0.1252565E 00
 0.1242229E 00 0.1208807E 00 0.1227448E 00 0.1251869E 00 0.1180796E 00
 0.1188889E 00 0.1225103E 00 0.1249353E 00 0.1203191E 00 0.1239318E 00
 0.1260001E 00 0.1256789E 00 0.1195911E 00 0.1179027E 00 0.1124624E 00
 0.1132010E 00 0.1286121E 00 0.1186909E 00 0.1145765E 00 0.1132610E 00
 0.1273546E 00 0.1188084E 00 0.1129406E 00 0.1096334E 00 0.1128821E 00
 0.1144017E 00 0.1140029E 00 0.1151318E 00 0.1162607E 00 0.1174084E 00
 0.1185486E 00 0.1196774E 00 0.1208063E 00 0.1219351E 00 0.1230640E 00
 0.1241929E 00 0.1253217E 00 0.1264527E 00 0.1275796E 00 0.1287048E 00
 0.1298537E 00 0.1309824E 00 0.1321110E 00 0.1332397E 00 0.1343682E 00
 0.1354969E 00 0.1366256E 00 0.1377542E 00 0.1388828E 00 0.1400114E 00
 0.1411677E 00 0.1422989E 00 0.1434276E 00 0.1445562E 00 0.1456848E 00
 0.1468135E 00 0.1479420E 00 0.1490707E 00 0.1501993E 00 0.1513279E 00
 0.1524739E 00 0.1536154E 00 0.1547440E 00 0.1558727E 00 0.1570013E 00
 0.1581299E 00 0.1592585E 00 0.1614780E 00 0.1697753E 00 0.1674184E 00
 0.1717321E 00 0.1755263E 00 0.1796092E 00 0.1864977E 00 0.1991986E 00
 0.1929354E 00 0.1953530E 00 0.2002944E 00 0.2095206E 00 0.2137215E 00
 0.2211210E 00 0.2314844E 00 0.2452977E 00 0.2496095E 00 0.2586675E 00
 0.2427595E 00 0.2212797E 00 0.1612645E 00 0.1320076E 00 0.1250163E 00
 0.1115284E 00 0.1058286E 00 0.9516340E-01 0.8003426E-01 0.6305128E-01
 0.4507381E-01 0.3310441E-01 0.2420986E-01 0.2052285E-01 0.2004674E-01
 0.1727159E-01 0.1903723E-01 0.2350212E-01 0.2867120E-01 0.6607447E-02
 0.6765541E-02 0.2541683E-02 0.2287373E-02 0.2124940E-02 0.0
 0.0           0.0           0.0           0.0           0.0

INTEGRAL       =  0.2755370E 02
PHOTOFRACTION  =  0.3502173E-01
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SYSTEM RESPONSE FUNCTION MATRIX

```
0.1000E 01 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.2152E 00 0.7848E 00 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.2212E 00 0.1758E 00 0.6030E 00 0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.2289E 00 0.2795E 00 0.8869E-01 0.4030E 00 0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.2147E 00 0.2333E 00 0.2118E 00 0.4851E-01 0.2916E 00 0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1943E 00 0.1998E 00 0.2286E 00 0.1211E 00 0.3076E-01 0.2255E 00 0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1720E 00 0.1714E 00 0.1936E 00 0.1761E 00 0.7856E-01 0.2226E-01 0.1861E 00 0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1541E 00 0.1496E 00 0.1669E 00 0.1386E 00 0.1547E 00 0.5864E-01 0.1785E-01 0.1596E 00 0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1420E 00 0.1349E 00 0.1478E 00 0.1169E 00 0.1148E 00 0.1395E 00 0.4775E-01 0.1542E-01 0.1409E 00 0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1315E 00 0.1231E 00 0.1332E 00 0.1057E 00 0.9426E-01 0.1041E 00 0.1262E 00 0.4172E-01 0.1345E-01 0.1269E 00
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1229E 00 0.1142E 00 0.1218E 00 0.9607E-01 0.8506E-01 0.8375E-01 0.9888E-01 0.1125E 00 0.3639E-01 0.1143E-01
0.1171E 00 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1151E 00 0.1062E 00 0.1116E 00 0.9004E-01 0.7716E-01 0.7338E-01 0.7766E-01 0.9497E-01 0.1020E 00 0.3314E-01
0.1003E-01 0.1088E 00 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1082E 00 0.9998E-01 0.1024E 00 0.8443E-01 0.7214E-01 0.6638E-01 0.6690E-01 0.7337E-01 0.9210E-01 0.9321E-01
0.3050E-01 0.9072E-02 0.1013E 00 0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.1019E 00 0.9459E-01 0.9574E-01 0.7941E-01 0.6605E-01 0.6138E-01 0.6041E-01 0.6252E-01 0.7018E-01 0.8995E-01
0.8634E-01 0.2862E-01 0.6477E-02 0.9447E-01 0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.9651E-01 0.8920E-01 0.8871E-01 0.7695E-01 0.6053E-01 0.5661E-01 0.5579E-01 0.5557E-01 0.5966E-01 0.6758E-01
0.8778E-01 0.8967E-01 0.2736E-01 0.8033E-02 0.8904E-01 0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.9204E-01 0.9414E-01 0.8253E-01 0.7302E-01 0.5780E-01 0.5194E-01 0.5070E-01 0.5137E-01 0.5291E-01 0.5729E-01
0.6365E-01 0.8536E-01 0.7641E-01 0.2649E-01 0.7685E-02 0.8466E-01 0.0        0.0        0.0        0.0
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0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.8908E-01 0.7975E-01 0.7687E-01 0.6936E-01 0.5430E-01 0.4868E-01 0.4672E-01 0.4744E-01 0.4836E-01 0.5989E-01
0.5547E-01 0.6438E-01 0.8304E-01 0.7160E-01 0.2568E-01 0.7674E-02 0.8070E-01 0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.8677E-01 0.7551E-01 0.7159E-01 0.6491E-01 0.5008E-01 0.4571E-01 0.4325E-01 0.4276E-01 0.4431E-01 0.4697E-01
0.4944E-01 0.5398E-01 0.6273E-01 0.8048E-01 0.6995E-01 0.2517E-01 0.7590E-02 0.7832E-01 0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.8443E-01 0.7264E-01 0.6865E-01 0.5956E-01 0.4714E-01 0.4280E-01 0.4070E-01 0.3906E-01 0.4034E-01 0.4295E-01
0.4557E-01 0.4818E-01 0.5241E-01 0.6122E-01 0.7777E-01 0.6886E-01 0.2443E-01 0.7422E-02 0.7586E-01 0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.8208E-01 0.7003E-01 0.6379E-01 0.5665E-01 0.4524E-01 0.3996E-01 0.3842E-01 0.3720E-01 0.3709E-01 0.3809E-01
0.4230E-01 0.4453E-01 0.4710E-01 0.5112E-01 0.5989E-01 0.7488E-01 0.6769E-01 0.2334E-01 0.7198E-02 0.7341E-01
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.7964E-01 0.6773E-01 0.5997E-01 0.5429E-01 0.4338E-01 0.3744E-01 0.3655E-01 0.3588E-01 0.3394E-01 0.3558E-01
0.3777E-01 0.4145E-01 0.4309E-01 0.4612E-01 0.4997E-01 0.5862E-01 0.7178E-01 0.6613E-01 0.2281E-01 0.6928E-02
0.7094E-01 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.7712E-01 0.6563E-01 0.5973E-01 0.5016E-01 0.4119E-01 0.3623E-01 0.3428E-01 0.3351E-01 0.3295E-01 0.3308E-01
0.3351E-01 0.3845E-01 0.4027E-01 0.4194E-01 0.4528E-01 0.4832E-01 0.5727E-01 0.6820E-01 0.6488E-01 0.2234E-01
0.6636E-02 0.6846E-01 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.7459E-01 0.6366E-01 0.5739E-01 0.4869E-01 0.3800E-01 0.3594E-01 0.3150E-01 0.3247E-01 0.3255E-01 0.3051E-01
0.3256E-01 0.3284E-01 0.3760E-01 0.3974E-01 0.4100E-01 0.4428E-01 0.4818E-01 0.5586E-01 0.6485E-01 0.6316E-01
0.2159E-01 0.6397E-02 0.6603E-01 0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.7198E-01 0.6175E-01 0.5556E-01 0.4702E-01 0.3631E-01 0.3540E-01 0.3068E-01 0.3124E-01 0.3084E-01 0.3004E-01
0.3011E-01 0.3971E-01 0.3398E-01 0.3682E-01 0.3869E-01 0.4025E-01 0.4311E-01 0.4760E-01 0.5440E-01 0.6196E-01
0.6129E-01 0.2044E-01 0.6216E-02 0.6361E-01 0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.6939E-01 0.5984E-01 0.5404E-01 0.4530E-01 0.3516E-01 0.3507E-01 0.3046E-01 0.2998E-01 0.2910E-01 0.3020E-01
0.2812E-01 0.3040E-01 0.2915E-01 0.3473E-01 0.3597E-01 0.3757E-01 0.3964E-01 0.4206E-01 0.4707E-01 0.5292E-01
0.5767E-01 0.5978E-01 0.1997E-01 0.6071E-02 0.6124E-01 0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.6677E-01 0.5796E-01 0.5270E-01 0.4365E-01 0.3506E-01 0.3343E-01 0.3059E-01 0.2679E-01 0.2899E-01 0.2902E-01
0.2810E-01 0.2786E-01 0.2900E-01 0.2981E-01 0.3393E-01 0.3554E-01 0.3678E-01 0.3895E-01 0.4125E-01 0.4652E-01
0.5149E-01 0.5318E-01 0.5827E-01 0.1961E-01 0.5874E-02 0.5891E-01 0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.6417E-01 0.5612E-01 0.5146E-01 0.4209E-01 0.3516E-01 0.3146E-01 0.3046E-01 0.2716E-01 0.2808E-01 0.2699E-01
0.2843E-01 0.2653E-01 0.2860E-01 0.2727E-01 0.3065E-01 0.3292E-01 0.3505E-01 0.3597E-01 0.3835E-01 0.4058E-01
0.4595E-01 0.5018E-01 0.5914E-01 0.5490E-01 0.1916E-01 0.5662E-02 0.5567E-01 0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.6157E-01 0.5421E-01 0.5024E-01 0.4064E-01 0.3499E-01 0.3315E-01 0.3086E-01 0.2748E-01 0.2554E-01 0.2696E-01
0.2758E-01 0.2691E-01 0.2637E-01 0.2791E-01 0.2655E-01 0.3124E-01 0.3216E-01 0.3413E-01 0.3516E-01 0.3773E-01
0.3987E-01 0.4536E-01 0.4897E-01 0.4642E-01 0.5281E-01 0.1831E-01 0.5507E-02 0.5445E-01 0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.5904E-01 0.5236E-01 0.4898E-01 0.3949E-01 0.3464E-01 0.2972E-01 0.3048E-01 0.2757E-01 0.2453E-01 0.2693E-01
0.2580E-01 0.2704E-01 0.2540E-01 0.2707E-01 0.2621E-01 0.2722E-01 0.3069E-01 0.3184E-01 0.3329E-01 0.3452E-01
0.3704E-01 0.3924E-01 0.4474E-01 0.4808E-01 0.4171E-01 0.5086E-01 0.1813E-01 0.5171E-02 0.5233E-01 0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.5656E-01 0.5954E-01 0.4764E-01 0.3836E-01 0.3425E-01 0.3004E-01 0.2915E-01 0.2747E-01 0.2543E-01 0.2538E-01
0.2529E-01 0.2638E-01 0.2591E-01 0.2523E-01 0.2665E-01 0.2524E-01 0.2755E-01 0.2975E-01 0.3158E-01 0.3260E-01
0.3397E-01 0.3628E-01 0.3867E-01 0.4423E-01 0.4734E-01 0.3813E-01 0.4697E-01 0.1797E-01 0.5117E-02 0.5030E-01
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.5411E-01 0.4872E-01 0.4614E-01 0.3733E-01 0.3335E-01 0.3037E-01 0.2788E-01 0.2797E-01 0.2580E-01 0.2361E-01
0.2568E-01 0.2499E-01 0.2592E-01 0.2482E-01 0.2558E-01 0.2587E-01 0.2473E-01 0.2791E-01 0.2899E-01 0.3096E-01
0.3198E-01 0.3340E-01 0.3549E-01 0.3808E-01 0.4359E-01 0.4692E-01 0.3562E-01 0.4253E-01 0.1794E-01 0.4979E-02
0.4831E-01 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.5178E-01 0.4694E-01 0.4385E-01 0.3733E-01 0.3347E-01 0.3049E-01 0.2731E-01 0.2803E-01 0.2579E-01 0.2370E-01
0.2555E-01 0.2414E-01 0.2533E-01 0.2513E-01 0.2442E-01 0.2572E-01 0.2451E-01 0.2496E-01 0.2767E-01 0.2839E-01
0.3023E-01 0.3136E-01 0.3285E-01 0.3472E-01 0.3756E-01 0.4289E-01 0.4686E-01 0.3234E-01 0.3809E-01 0.1793E-01
0.4726E-02 0.4644E-01 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.4945E-01 0.4513E-01 0.4236E-01 0.3633E-01 0.3310E-01 0.3035E-01 0.2728E-01 0.2742E-01 0.2566E-01 0.2448E-01
0.2339E-01 0.2455E-01 0.2421E-01 0.2495E-01 0.2435E-01 0.2456E-01 0.2506E-01 0.2396E-01 0.2483E-01 0.2702E-01
0.2807E-01 0.2953E-01 0.3068E-01 0.3223E-01 0.3398E-01 0.3690E-01 0.4216E-01 0.4690E-01 0.2977E-01 0.3644E-01
0.1551E-01 0.4595E-02 0.4480E-01 0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.4725E-01 0.4347E-01 0.4083E-01 0.3548E-01 0.3273E-01 0.3318E-01 0.2756E-01 0.2658E-01 0.2599E-01 0.2467E-01
0.2292E-01 0.2446E-01 0.2331E-01 0.2436E-01 0.2439E-01 0.2384E-01 0.2478E-01 0.2416E-01 0.2333E-01 0.2487E-01
0.2629E-01 0.2775E-01 0.2891E-01 0.3007E-01 0.3163E-01 0.3327E-01 0.3626E-01 0.4141E-01 0.4696E-01 0.2879E-01
0.3104E-01 0.1495E-01 0.4496E-02 0.4307E-01 0.0        0.0        0.0        0.0        0.0        0.0
0.4512E-01 0.4172E-01 0.3899E-01 0.3592E-01 0.3233E-01 0.2992E-01 0.2775E-01 0.2607E-01 0.2695E-01 0.2455E-01
0.2338E-01 0.2322E-01 0.2358E-01 0.2350E-01 0.2407E-01 0.2394E-01 0.2382E-01 0.2435E-01 0.2323E-01 0.2321E-01
0.2464E-01 0.2564E-01 0.2727E-01 0.2834E-01 0.2949E-01 0.3105E-01 0.3256E-01 0.3561E-01 0.4060E-01 0.4693E-01
0.2854E-01 0.2637E-01 0.1387E-01 0.4229E-02 0.4141E-01 0.0        0.0        0.0        0.0        0.0
0.4308E-01 0.4038E-01 0.3750E-01 0.3421E-01 0.3189E-01 0.2964E-01 0.2775E-01 0.2598E-01 0.2574E-01 0.2450E-01
0.2377E-01 0.2260E-01 0.2380E-01 0.2265E-01 0.2350E-01 0.2366E-01 0.2361E-01 0.2374E-01 0.2358E-01 0.2309E-01
0.2265E-01 0.2426E-01 0.2516E-01 0.2669E-01 0.2779E-01 0.2893E-01 0.3036E-01 0.3186E-01 0.3495E-01 0.3974E-01
0.4679E-01 0.2890E-01 0.2100E-01 0.1283E-01 0.3920E-02 0.3984E-01 0.0        0.0        0.0        0.0
0.4113E-01 0.3850E-01 0.3598E-01 0.3350E-01 0.3135E-01 0.2937E-01 0.2764E-01 0.2607E-01 0.2537E-01 0.2458E-01
0.2378E-01 0.2284E-01 0.2284E-01 0.2280E-01 0.2284E-01 0.2323E-01 0.2352E-01 0.2316E-01 0.2378E-01 0.2284E-01
0.2234E-01 0.2242E-01 0.2376E-01 0.2479E-01 0.2611E-01 0.2725E-01 0.2840E-01 0.2971E-01 0.3118E-01 0.3426E-01
0.3889E-01 0.4626E-01 0.2995E-01 0.1754E-01 0.1009E-01 0.3604E-02 0.3834E-01 0.0        0.0        0.0
0.3924E-01 0.3694E-01 0.3456E-01 0.3261E-01 0.3076E-01 0.2904E-01 0.2747E-01 0.2612E-01 0.2516E-01 0.2445E-01
0.2367E-01 0.2306E-01 0.2232E-01 0.2293E-01 0.2216E-01 0.2269E-01 0.2293E-01 0.2334E-01 0.2320E-01 0.2313E-01
0.2222E-01 0.2201E-01 0.2210E-01 0.2324E-01 0.2437E-01 0.2556E-01 0.2670E-01 0.2784E-01 0.2905E-01 0.3047E-01
0.3354E-01 0.3706E-01 0.4526E-01 0.3180E-01 0.1563E-01 0.6625E-02 0.3009E-02 0.3690E-01 0.0        0.0
0.3746E-01 0.3545E-01 0.3347E-01 0.3170E-01 0.3013E-01 0.2869E-01 0.2726E-01 0.2607E-01 0.2517E-01 0.2422E-01
0.2363E-01 0.2333E-01 0.2256E-01 0.2230E-01 0.2218E-01 0.2220E-01 0.2238E-01 0.2295E-01 0.2287E-01 0.2295E-01
0.2210E-01 0.2247E-01 0.2114E-01 0.2166E-01 0.2281E-01 0.2391E-01 0.2504E-01 0.2618E-01 0.2732E-01 0.2840E-01
0.2978E-01 0.3282E-01 0.3702E-01 0.4413E-01 0.3407E-01 0.1499E-01 0.1789E-02 0.2160E-02 0.3555E-01 0.0
0.3577E-01 0.3401E-01 0.3246E-01 0.3068E-01 0.2946E-01 0.2829E-01 0.2704E-01 0.2592E-01 0.2525E-01 0.2409E-01
0.2346E-01 0.2297E-01 0.2271E-01 0.2194E-01 0.2224E-01 0.2169E-01 0.2198E-01 0.2222E-01 0.2288E-01 0.2254E-01
0.2280E-01 0.2167E-01 0.2180E-01 0.2053E-01 0.2121E-01 0.2247E-01 0.2340E-01 0.2456E-01 0.2567E-01 0.2679E-01
0.2777E-01 0.2908E-01 0.3211E-01 0.3610E-01 0.4282E-01 0.3667E-01 0.1582E-01-0.3921E-02 0.8081E-03 0.3427E-01
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REPONSE MATRIX ENERGY INTERVAL MIDPOINTS IN MEV

0.0344 0.1033 0.1722 0.2411 0.3099 0.3788 0.4477 0.5166 0.5854 0.6543
0.7232 0.7921 0.8609 0.9298 0.9987 1.0676 1.1364 1.2053 1.2742 1.3431
1.4119 1.4808 1.5497 1.6186 1.6874 1.7563 1.8252 1.8941 1.9629 2.0318
2.1007 2.1696 2.2384 2.3073 2.3762 2.4451 2.5139 2.5828 2.6517 2.7206



PULSE-HEIGHT IN CHANNELS (MIDPOINTS)

  0.50    1.50    2.50    3.50    4.50    5.50    6.50    7.50    8.50    9.50
 10.50   11.50   12.50   13.50   14.50   15.50   16.50   17.50   18.50   19.50
 20.50   21.50   22.50   23.50   24.50   25.50   26.50   27.50   28.50   29.50
 30.50   31.50   32.50   33.50   34.50   35.50   36.50   37.50   38.50   39.50


RESPONSE MATRIX PHOTOFRACTIONS

 0.8652 0.6814 0.5321 0.3651 0.2678 0.2089 0.1735 0.1500 0.1341 0.1214
 0.1111 0.1024 0.0946 0.0877 0.0824 0.0783 0.0758 0.0741 0.0722 0.0702
 0.0682 0.0661 0.0640 0.0618 0.0597 0.0575 0.0554 0.0533 0.0513 0.0494
 0.0474 0.0456 0.0437 0.0420 0.0403 0.0387 0.0372 0.0357 0.0343 0.0329
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  INDEX        ENERGY          STD. DEV
    1      0.0              0.0
    2      0.1659999E 00 0.1707057E 01
    3      0.2790000E 00 0.1007876E 01
    4      0.5140000E 00 0.5605643E 00
    5      0.6616000E 00 0.4791170E 00
    6      0.8350000E 00 0.3917066E 00
    7      0.1113999E 01 0.3136572E 00
    8      0.1330000E 01 0.3161970E 00
    9      0.2615000E 01 0.2511438E 00



GAMMA   SOURCE   REFERENCE  SOURCE    SOURCE    NUMBER OF    NUMBER     HALF-LIFE
SOURCE STRENGTH   ENERGY   DIAMETER HALF-LIFE  PHA RUNS   OF CHANNELS  MULTIPLIER
       (CURIES)   (MEV)     (CM.)   (MINUTES)  THIS SET   PER SPECTRUM

TH228    1.0000    2.6150    1.0000 0.5260E 07    1          400      0.5260E 06



      M22         M6         MZ         MNX        MBX        MSM        MS         MX

       0          0          25          0          0          0         27        395
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 SOURCE     COUNTING    REFERENCE    SPECTRA   BACKGROUND  BACKGROUND
 CRYSTAL    DURATION      TIME        ZERO       SIGNAL    MULTIPLIER
 DISTANCE   (MINUTES)    (DAYS)       SHIFT
  (CM)                              (CHANNELS)
32.30000    10.00000    1.00000      0.0         0.0         0.0




ITERATING OUTPUT ON ITERATION LOOPS NUMBERED BELOW

          1          3          5          7          9
         10         15         20         25         30
          0          0          0          0          0
          0          0          0
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SPECTRUM NUMBER   1 FOR  TH228 SOURCE

(AFTER BACKGROUND SUBTRACTION)

     0.      0.      0.      0.      0.      0.      0.      0.      0.    110.
  5057.   9609.  12019.  12709.  12785.  12294.  11802.  11155.  10284.   9699.
  9156.   8323.   7568.   6905.   6991.   5632.   5269.   4923.   4416.   4165.
  3848.   3631.   3287.   3075.   2942.   3708.   2572.   2170.   2051.   1968.
  1998.   1885.   1678.   1649.   1550.   1428.   1308.   1252.   1330.   1167.
  1215.   1315.   1283.    982.    880.    897.    849.    818.    771.    765.
   891.    717.    701.    673.    698.    638.    609.    553.    589.    578.
   533.    561.    511.    485.    548.    625.    459.    499.    467.    457.
   422.    460.    460.    428.    427.    640.    384.    411.    431.    670.
   363.    358.    361.    325.    343.    349.    355.    356.    330.    335.
   339.    324.    309.    331.    326.    280.    351.    287.    302.    278.
   317.    299.    274.    268.    271.    255.    270.    237.    264.    243.
   246.    213.    226.    224.    213.    254.    205.    199.    239.    202.
   225.    210.    293.    283.    195.    221.    218.    205.    219.    199.
   238.    326.    219.    195.    193.    187.    177.    189.    189.    227.
   191.    191.    206.    199.    199.    191.    198.    188.    190.    190.
   186.    179.    179.    231.    197.    223.    182.    201.    232.    193.
   191.    210.    219.    193.    222.    232.    218.    218.    258.    234.
   246.    178.    150.    140.    137.    134.    134.    113.    107.    112.
    92.     98.     95.    110.     83.     75.     76.     68.     54.     60.
    50.     58.     63.     64.     57.     55.     64.     51.     42.     46.
    52.     82.    885.    392.     38.     33.     30.     36.     38.     25.
    33.     25.     40.     28.     34.     23.     24.     23.     19.     24.
    29.     79.     68.     23.     31.     26.     40.     43.     30.     26.
    22.     18.     17.     27.     16.     29.     25.     16.     23.     20.
    22.     23.     26.     19.     18.     23.     59.     31.     20.     25.
    17.     16.     22.     23.     16.     25.     10.     23.     27.     20.
    16.     21.     23.     28.     22.     21.     19.     20.     23.     25.
    21.     23.     22.     17.     24.     10.     24.     16.     14.     14.
    14.     15.     13.     19.     15.     13.      9.     20.     10.     25.
    15.     13.     18.     16.     16.     26.     26.     14.     19.     13.
    15.     23.     14.     19.     22.     18.     13.     17.     20.     25.
    29.     17.     19.     20.     20.     13.     21.     17.     20.     15.
    21.     17.     15.     18.     19.     21.     18.     17.     19.     21.
    16.     23.     21.     23.     20.     22.     19.      9.      7.     10.
     7.     12.     10.      6.     10.     17.      6.      6.     15.      4.
     5.      8.      7.      4.      6.      1.      5.      3.      3.      3.
     6.      1.      1.      0.      4.      1.      6.      6.      8.     96.
    53.      0.      2.      1.      0.      0.      0.      0.      1.      2.
     1.      2.      1.      2.      3.      3.      0.      1.      0.      0.
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UNKNOWN SPECTRUM BEFORE PEAK FITTING

         0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
         0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
         0.         0.         0.         0.         0.      5632.      5269.      4923.      4416.      4165.
      3848.      3631.      3287.      3075.      2942.      3708.      2572.      2170.      2051.      1968.
      1998.      1885.      1678.      1649.      1550.      1428.      1308.      1252.      1330.      1167.
      1215.      1315.      1283.       982.       880.       897.       849.       818.       771.       765.
       891.       717.       701.       673.       698.       638.       609.       563.       589.       578.
       533.       561.       511.       485.       548.       625.       459.       499.       467.       457.
       422.       460.       460.       428.       427.       640.       384.       411.       431.       670.
       363.       358.       361.       325.       343.       349.       355.       356.       330.       335.
       339.       324.       309.       331.       326.       280.       351.       287.       302.       278.
       317.       299.       274.       268.       271.       255.       270.       237.       264.       243.
       246.       213.       226.       224.       213.       254.       205.       199.       239.       202.
       225.       210.       293.       283.       195.       221.       218.       205.       219.       199.
       238.       326.       219.       195.       193.       187.       177.       189.       189.       227.
       191.       191.       206.       199.       199.       191.       198.       188.       190.       190.
       186.       179.       179.       231.       197.       223.       182.       201.       232.       193.
       191.       210.       219.       193.       222.       232.       218.       218.       258.       234.
       246.       178.       150.       140.       137.       134.       134.       113.       107.       112.
        92.        98.        95.       110.        83.        75.        76.        68.        54.        60.
        50.        58.        63.        64.        57.        55.        64.        51.        42.        46.
        52.        82.       885.       392.        38.        33.        30.        36.        38.        25.
        33.        25.        40.        28.        34.        23.        24.        23.        19.        24.
        29.        79.        68.        23.        31.        26.        40.        43.        30.        26.
        22.        18.        17.        27.        16.        29.        25.        16.        23.        20.
        22.        23.        26.        19.        18.        23.        59.        31.        20.        25.
        17.        16.        22.        23.        16.        25.        10.        23.        27.        20.
        16.        21.        23.        28.        22.        21.        19.        20.        23.        25.
        21.        23.        22.        17.        24.        10.        24.        16.        14.        14.
        14.        15.        13.        19.        15.        13.         9.        20.        10.        25.
        15.        13.        18.        16.        16.        26.        26.        14.        19.        13.
        15.        23.        14.        19.        22.        18.        13.        17.        20.        25.
        29.        17.        19.        20.        20.        13.        21.        17.        20.        15.
        21.        17.        15.        18.        19.        21.        18.        17.        19.        21.
        16.        23.        21.        23.        20.        22.        19.         9.         7.        10.
         7.        12.        10.         6.        10.        17.         6.         6.        15.         4.
         5.         8.         7.         4.         6.         1.         5.         3.         3.         3.
         6.         1.         1.         0.         4.         1.         6.         6.         8.        96.
        53.         0.         2.         1.         0.         0.         0.         0.         1.         2.
         1.         2.         1.         2.         3.         3.         0.         1.         0.         0.
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                                  EFFICIENCY FACTORS

   INDEX       ENERGY          AIR           ABSORBER       CRYSTAL        TOTAL
               (MEV)       ATTENUATION     ATTENUATION    EFFICIENCY     EFFICIENCY


     1      0.24451E 00    0.99527E 00     0.76257E 00    0.83176E 00    0.63127E 00

                                                  PHOTON NUMBER        =      0.4192742E 04
                                                  PHOTOFRACTION        =      0.3593062E 00


                              DISCRETE PHOTOPEAK FITTING DATA

     LOCATION               ENERGY              PULSE-HEIGHT      STANDARD DEVIATION          AREA
 CHANNEL TO CHANNEL         (MEV)                (CHANNELS)           (CHANNELS)          (COUNTS/TIME)

   35          37        0.2445061E 00          0.3550000E 02          0.0                0.9510000E 03
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                                  EFFICIENCY FACTORS

   INDEX       ENERGY          AIR           ABSORBER       CRYSTAL        TOTAL
               (MEV)       ATTENUATION     ATTENUATION    EFFICIENCY     EFFICIENCY


     2      0.58888E 00    0.99665E 00     0.82671E 00    0.65423E 00    0.53905E 00

                                                  PHOTON NUMBER        =      0.3260663E 04
                                                  PHOTOFRACTION        =      0.1334171E 00


                              DISCRETE PHOTOPEAK FITTING DATA

     LOCATION               ENERGY              PULSE-HEIGHT      STANDARD DEVIATION          AREA
 CHANNEL TO CHANNEL         (MEV)                (CHANNELS)           (CHANNELS)          (COUNTS/TIME)

   85          87        0.5888808E 00          0.8550000E 02          0.0                0.2345000E 03
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                                      EFFICIENCY FACTORS

        INDEX        ENERGY          AIR          ABSORBER        CRYSTAL          TOTAL
                     (MEV)       ATTENUATION    ATTENUATION     EFFICIENCY      EFFICIENCY


          3       0.61643E 00    0.99672E 00    0.82983E 00     0.64623E 00     0.53450E 00

                                                                PHOTON NUMBER          =        0.3988115E 04
                                                                PHOTOFRACTION          =        0.1280698E 00



                                  DISCRETE PHOTOPEAK FITTING DATA

       LOCATION                ENERGY                 PULSE-HEIGHT          STANDARD DEVIATION            AREA
   CHANNEL TO CHANNEL           (MEV)                  (CHANNELS)               (CHANNELS)            (COUNTS/TIME)

      89          91        0.6164308E 00             0.8950003E 02             0.0                   0.2730000E 03
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                                      EFFICIENCY FACTORS

        INDEX        ENERGY          AIR          ABSORBER        CRYSTAL          TOTAL
                     (MEV)       ATTENUATION    ATTENUATION     EFFICIENCY      EFFICIENCY


          4       0.14656E 01    0.99784E 00    0.88431E 00     0.49655E 00     0.43815E 00

                                                                PHOTON NUMBER          =        0.3968964E 05
                                                                PHOTOFRACTION          =        0.6653214E-01



                                  DISCRETE PHOTOPEAK FITTING DATA

       LOCATION                ENERGY                 PULSE-HEIGHT          STANDARD DEVIATION            AREA
   CHANNEL TO CHANNEL           (MEV)                  (CHANNELS)               (CHANNELS)            (COUNTS/TIME)

     212         215        0.1465612E 01             0.2127933E 03             0.0                   0.1157000E 04
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GAIN PARAMETERS AFTER CALL DISCRT IN MAIN
  0.0     400  400.0000   40.0000    0.0
    0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
    0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
    0.      0.      0.      0.      0.   5453.   5083.   4739.   4231.   3973.
 3652.   3439.   3111.   2915.   2792.   2638.   2455.   2055.   1937.   1856.
 1887.   1773.   1565.   1534.   1434.   1311.   1190.   1136.   1215.   1054.
 1104.   1204.   1171.    868.    763.    779.    731.    700.    655.    654.
  696.    615.    602.    580.    610.    553.    525.    482.    512.    505.
  463.    492.    443.    418.    492.    559.    393.    433.    401.    391.
  356.    395.    396.    364.    364.    346.    325.    353.    374.    343.
  307.    301.    302.    267.    285.    291.    295.    295.    268.    273.
  278.    265.    252.    274.    269.    222.    292.    227.    241.    215.
  252.    233.    207.    200.    201.    185.    200.    168.    196.    176.
  178.    144.    155.    152.    140.    182.    133.    127.    167.    130.
  152.    137.    217.    210.    121.    147.    144.    130.    143.    122.
  160.    247.    149.    115.    113.    106.     96.    108.    108.    146.
  109.    108.    121.    112.    111.    102.    108.     97.     98.     96.
   91.     81.     77.    127.     93.    118.     77.     95.    125.     84.
   79.     96.    102.     73.     97.    102.     83.     79.    118.     94.
  109.     47.     27.     28.     38.     46.     57.     44.     45.     56.
   41.     53.     56.     76.     54.     50.     55.     53.     38.     46.
   37.     47.     52.     54.     47.     45.     54.     41.     32.     36.
   43.     82.     67.     53.     38.     33.     30.     36.     38.     25.
   33.     25.     40.     28.     34.     23.     24.     23.     19.     24.
   29.     79.     68.     23.     31.     26.     40.     43.     30.     26.
   22.     18.     17.     27.     16.     28.     25.     16.     23.     20.
   22.     23.     26.     19.     18.     23.     59.     31.     20.     25.
   17.     16.     22.     23.     16.     25.     10.     23.     27.     20.
   16.     21.     23.     28.     22.     21.     19.     20.     23.     25.
   21.     23.     22.     17.     24.     10.     24.     16.     14.     14.
   14.     15.     13.     19.     15.     13.      9.     20.     10.     25.
   15.     13.     18.     16.     16.     26.     26.     14.     19.     13.
   15.     23.     14.     19.     22.     18.     13.     17.     20.     25.
   29.     17.     19.     20.     20.     13.     21.     17.     20.     15.
   21.     17.     15.     18.     19.     21.     18.     17.     19.     21.
   16.     23.     21.     23.     20.     22.     19.      9.      7.     10.
    7.     12.     10.      6.     10.     17.      6.      6.     15.      4.
    5.      8.      7.      4.      6.      1.      5.      3.      3.      3.
    6.      1.      1.      0.      4.      1.      6.      6.      8.     96.
   53.      0.      2.      1.      0.      0.      0.      0.      1.      2.
    1.      2.      1.      2.      3.      3.      0.      1.      0.      0.

                         SUBTRACTED DISCRETE PEAK PHOTON NUMBER FLUX

                  INDEX              ENERGY                  NUMBER FLUX
                                     (MEV)              (PHOTONS/CM**2-SEC)


                    1             0.2445061E 00            0.8373457E 00
                    2             0.5988808E 00            0.6511977E 00
                    3             0.6164398E 00            0.7964801E 00
                    4             0.1465612E 01            0.7926548E 01
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2174

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INPUT SPECTRUM GAIN CHANGED TO    40 CHANNELS
GAIN CHANGE RATIO =  400.00000/  40.00000


0.0            0.0            0.2347911E 05 0.2684916E 05 0.1409902E 05
0.8629164E 04 0.5690238E 04 0.4475867E 04 0.3616177E 04 0.2684473E 04
0.2535301E 04 0.2018468E 04 0.1506749E 04 0.1522471E 04 0.1339065E 04
0.1062190E 04 0.9684143E 03 0.9234124E 03 0.4983555E 03 0.5176294E 03
0.4436489E 03 0.4452463E 03 0.2730000E 03 0.3950000E 03 0.2120000E 03
0.2660000E 03 0.1990000E 03 0.2180000E 03 0.1850000E 03 0.1530000E 03
0.1760000E 03 0.1860000E 03 0.1910000E 03 0.1860000E 03 0.1700000E 03
0.9300000E 02 0.4500000E 02 0.1290000E 03 0.5900000E 02 0.1300000E 02
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NORMALIZED INPUT SPECTRUM
 0.0        0.0        0.2202E 00 0.2518E 00 0.1322E 00 0.8092E-01 0.5326E-01 0.4197E-01 0.3391E-01 0.2705E-01
 0.2377E-01 0.1893E-01 0.1413E-01 0.1428E-01 0.1256E-01 0.9960E-02 0.9081E-02 0.8659E-02 0.4673E-02 0.4854E-02
 0.4160E-02 0.4175E-02 0.2560E-02 0.3704E-02 0.1988E-02 0.2494E-02 0.1866E-02 0.2044E-02 0.1735E-02 0.1435E-02
 0.1650E-02 0.1744E-02 0.1791E-02 0.1744E-02 0.1594E-02 0.8721E-03 0.4220E-03 0.1210E-02 0.5532E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))    1    1
 0.0        0.0        0.2202E 00 0.2518E 00 0.1322E 00 0.8092E-01 0.5326E-01 0.4197E-01 0.3391E-01 0.2705E-01
 0.2377E-01 0.1893E-01 0.1413E-01 0.1428E-01 0.1256E-01 0.9960E-02 0.9081E-02 0.8659E-02 0.4673E-02 0.4854E-02
 0.4160E-02 0.4175E-02 0.2560E-02 0.3704E-02 0.1988E-02 0.2494E-02 0.1866E-02 0.2044E-02 0.1735E-02 0.1435E-02
 0.1650E-02 0.1744E-02 0.1791E-02 0.1744E-02 0.1594E-02 0.8721E-03 0.4220E-03 0.1210E-02 0.5532E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))    1    1
 0.1894E 00 0.1930E 00 0.2411E 00 0.1511E 00 0.6768E-01 0.3834E-01 0.2487E-01 0.1825E-01 0.1380E-01 0.1069E-01
 0.8832E-02 0.7982E-02 0.5598E-02 0.4816E-02 0.3965E-02 0.3183E-02 0.2739E-02 0.2408E-02 0.1858E-02 0.1653E-02
 0.1440E-02 0.1260E-02 0.1042E-02 0.9957E-03 0.8008E-03 0.7472E-03 0.6345E-03 0.5771E-03 0.4911E-03 0.4069E-03
 0.3330E-03 0.2692E-03 0.2203E-03 0.1677E-03 0.1167E-03 0.5704E-04 0.2274E-04 0.4535E-04 0.1977E-04 0.4177E-05
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))    3    3
 0.0        0.0        0.1245E 00 0.3647E 00 0.2252E 00 0.1462E 00 0.9344E-01 0.7974E-01 0.6976E-01 0.5640E-01
 0.5310E-01 0.4015E-01 0.2595E-01 0.3421E-01 0.3314E-01 0.2505E-01 0.2441E-01 0.2583E-01 0.6662E-02 0.8866E-02
 0.6923E-02 0.8508E-02 0.2662E-02 0.8141E-02 0.1747E-02 0.3633E-02 0.1876E-02 0.2697E-02 0.2023E-02 0.1484E-02
 0.3047E-02 0.4909E-02 0.7052E-02 0.1048E-01 0.1566E-01 0.1024E-01 0.6866E-02 0.3225E-01 0.1548E-01 0.3557E-02
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))    3    3
 0.2696E 00 0.2829E 00 0.2707E 00 0.2451E 00 0.1267E 00 0.7733E-01 0.5172E-01 0.4010E-01 0.3164E-01 0.2525E-01
 0.2207E-01 0.1795E-01 0.1408E-01 0.1287E-01 0.1072E-01 0.8340E-02 0.7423E-02 0.6936E-02 0.4997E-02 0.4742E-02
 0.4341E-02 0.4107E-02 0.3601E-02 0.3865E-02 0.3490E-02 0.3639E-02 0.3591E-02 0.3715E-02 0.3716E-02 0.3631E-02
 0.3439E-02 0.3275E-02 0.3148E-02 0.2606E-02 0.1942E-02 0.1059E-02 0.4443E-03 0.1210E-02 0.5533E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))    5    5
 0.0        0.0        0.8397E-01 0.3713E 00 0.2340E 00 0.1520E 00 0.9438E-01 0.8276E-01 0.7547E-01 0.6080E-01
 0.5724E-01 0.4153E-01 0.2466E-01 0.3954E-01 0.4334E-01 0.3578E-01 0.3722E-01 0.4109E-01 0.6765E-02 0.1085E-01
 0.7629E-02 0.1062E-01 0.1709E-02 0.9170E-02 0.7143E-03 0.2128E-02 0.6248E-03 0.9959E-03 0.5264E-03 0.2690E-03
 0.7941E-03 0.1534E-02 0.2463E-02 0.5050E-02 0.1128E-01 0.8105E-02 0.6384E-02 0.3225E-01 0.1548E-01 0.3557E-02
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))    5    5
 0.2715E 00 0.2866E 00 0.2560E 00 0.2540E 00 0.1337E 00 0.8249E-01 0.5521E-01 0.4340E-01 0.3489E-01 0.2833E-01
 0.2547E-01 0.2107E-01 0.1656E-01 0.1533E-01 0.1258E-01 0.9218E-02 0.8052E-02 0.7520E-02 0.4297E-02 0.4026E-02
 0.3476E-02 0.3240E-02 0.2503E-02 0.2914E-02 0.2430E-02 0.2579E-02 0.2577E-02 0.2710E-02 0.2803E-02 0.2868E-02
 0.2831E-02 0.2818E-02 0.2798E-02 0.2318E-02 0.1747E-02 0.9221E-03 0.4258E-03 0.1210E-02 0.5532E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))    7    7
 0.0        0.0        0.6476E-01 0.3697E 00 0.2327E 00 0.1493E 00 0.9014E-01 0.7925E-01 0.7249E-01 0.5585E-01
 0.4957E-01 0.3265E-01 0.1704E-01 0.3226E-01 0.4023E-01 0.3827E-01 0.4284E-01 0.4907E-01 0.7502E-02 0.1486E-01
 0.1057E-01 0.1717E-01 0.1907E-02 0.1492E-01 0.5181E-03 0.2145E-02 0.3537E-03 0.6104E-03 0.2155E-03 0.7113E-04
 0.2820E-03 0.6072E-03 0.1035E-02 0.2940E-02 0.9629E-02 0.7392E-02 0.6302E-02 0.3225E-01 0.1548E-01 0.3557E-02
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))    7    7
 0.2624E 00 0.2783E 00 0.2392E 00 0.2496E 00 0.1303E 00 0.7946E-01 0.5220E-01 0.4089E-01 0.3303E-01 0.2701E-01
 0.2473E-01 0.2113E-01 0.1740E-01 0.1635E-01 0.1379E-01 0.1053E-01 0.9473E-02 0.8942E-02 0.4968E-02 0.4614E-02
 0.3830E-02 0.3537E-02 0.2277E-02 0.2994E-02 0.2128E-02 0.2287E-02 0.2268E-02 0.2394E-02 0.2506E-02 0.2618E-02
 0.2631E-02 0.2669E-02 0.2684E-02 0.2210E-02 0.1675E-02 0.8734E-03 0.4227E-03 0.1210E-02 0.5532E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))    9    9
 0.0        0.0        0.5536E-01 0.3742E 00 0.2384E 00 0.1549E 00 0.9508E-01 0.8540E-01 0.7878E-01 0.5839E-01
 0.4801E-01 0.2742E-01 0.1164E-01 0.2517E-01 0.3390E-01 0.3386E-01 0.3838E-01 0.4454E-01 0.6198E-02 0.1540E-01
 0.1169E-01 0.2246E-01 0.2433E-02 0.2170E-01 0.4686E-03 0.2623E-02 0.2479E-03 0.4608E-03 0.1066E-03 0.2191E-04
 0.1132E-03 0.2631E-03 0.4658E-03 0.1857E-02 0.8826E-02 0.7099E-02 0.6288E-02 0.3225E-01 0.1548E-01 0.3557E-02
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))    9    9
 0.2636E 00 0.2804E 00 0.2367E 00 0.2526E 00 0.1324E 00 0.8039E-01 0.5185E-01 0.3990E-01 0.3166E-01 0.2520E-01
 0.2272E-01 0.1925E-01 0.1602E-01 0.1528E-01 0.1318E-01 0.1051E-01 0.9707E-02 0.9300E-02 0.5569E-02 0.5154E-02
 0.4290E-02 0.3955E-02 0.2265E-02 0.3314E-02 0.2004E-02 0.2191E-02 0.2136E-02 0.2256E-02 0.2372E-02 0.2506E-02
 0.2542E-02 0.2604E-02 0.2636E-02 0.2156E-02 0.1641E-02 0.8817E-03 0.4221E-03 0.1210E-02 0.5532E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))   10   10
 0.0        0.0        0.5149E-01 0.3730E 00 0.2382E 00 0.1559E 00 0.9768E-01 0.8983E-01 0.8437E-01 0.6266E-01
 0.5023E-01 0.2696E-01 0.1026E-01 0.2351E-01 0.3230E-01 0.3210E-01 0.3590E-01 0.4147E-01 0.5202E-02 0.1450E-01
 0.1134E-01 0.2372E-01 0.2749E-02 0.2426E-01 0.4647E-03 0.2987E-02 0.2165E-03 0.4175E-03 0.7797E-04 0.1254E-04
 0.7351E-04 0.1762E-03 0.3165E-03 0.1502E-02 0.8576E-02 0.7022E-02 0.6286E-02 0.3225E-01 0.1548E-01 0.3557E-02
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))   10   10
 0.2643E 00 0.2812E 00 0.2364E 00 0.2537E 00 0.1337E 00 0.8171E-01 0.5281E-01 0.4048E-01 0.3188E-01 0.2502E-01
 0.2227E-01 0.1855E-01 0.1532E-01 0.1466E-01 0.1275E-01 0.1027E-01 0.9557E-02 0.9219E-02 0.5707E-02 0.5280E-02
 0.4425E-02 0.4082E-02 0.2290E-02 0.3449E-02 0.1971E-02 0.2177E-02 0.2098E-02 0.2216E-02 0.2333E-02 0.2474E-02
 0.2515E-02 0.2585E-02 0.2623E-02 0.2139E-02 0.1630E-02 0.8786E-03 0.4220E-03 0.1210E-02 0.5532E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))   15   15
 0.0        0.0        0.3932E-01 0.3653E 00 0.2236E 00 0.1391E 00 0.8795E-01 0.9012E-01 0.9579E-01 0.7933E-01
 0.6426E-01 0.3212E-01 0.9607E-02 0.2552E-01 0.3608E-01 0.3325E-01 0.3339E-01 0.3514E-01 0.1853E-02 0.9192E-02
 0.7613E-02 0.2358E-01 0.4086E-02 0.2851E-01 0.5281E-03 0.5666E-02 0.1337E-03 0.3100E-03 0.1958E-04 0.8885E-06
 0.9506E-05 0.2566E-04 0.4831E-04 0.5706E-03 0.7380E-02 0.6883E-02 0.6284E-02 0.3225E-01 0.1548E-01 0.3557E-02
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))   15   15
 0.2572E 00 0.2736E 00 0.2251E 00 0.2506E 00 0.1322E 00 0.8220E-01 0.5503E-01 0.4306E-01 0.3435E-01 0.2710E-01
 0.2371E-01 0.1869E-01 0.1438E-01 0.1380E-01 0.1207E-01 0.9624E-02 0.8877E-02 0.8642E-02 0.5691E-02 0.5274E-02
 0.4524E-02 0.4243E-02 0.2487E-02 0.3694E-02 0.1912E-02 0.2256E-02 0.2013E-02 0.2125E-02 0.2242E-02 0.2400E-02
 0.2455E-02 0.2544E-02 0.2595E-02 0.2094E-02 0.1605E-02 0.8730E-03 0.4220E-03 0.1210E-02 0.5532E-03 0.1219E-03
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I))   20   20
 0.0        0.0        0.3692E-01 0.3740E 00 0.2291E 00 0.1372E 00 0.8105E-01 0.8364E-01 0.9059E-01 0.7531E-01
 0.6012E-01 0.3032E-01 0.7202E-02 0.2780E-01 0.4127E-01 0.3907E-01 0.3811E-01 0.3704E-01 0.7393E-03 0.6442E-02
 0.5158E-02 0.2170E-01 0.4152E-02 0.2838E-01 0.6447E-03 0.8289E-02 0.9418E-04 0.2633E-03 0.5590E-05 0.6930E-07
 0.1329E-05 0.3932E-05 0.7608E-05 0.2327E-03 0.7807E-02 0.6862E-02 0.6284E-02 0.3225E-01 0.1548E-01 0.3557E-02
INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I))   20   20
 0.2565E 00 0.2736E 00 0.2219E 00 0.2514E 00 0.1315E 00 0.8032E-01 0.5302E-01 0.4184E-01 0.3396E-01 0.2733E-01
 0.2429E-01 0.1958E-01 0.1504E-01 0.1437E-01 0.1245E-01 0.9741E-02 0.8856E-02 0.8514E-02 0.5502E-02 0.5119E-02
 0.4453E-02 0.4238E-02 0.2624E-02 0.3715E-02 0.1912E-02 0.2388E-02 0.1989E-02 0.2099E-02 0.2216E-02 0.2379E-02
 0.2437E-02 0.2512E-02 0.2589E-02 0.2079E-02 0.1597E-02 0.8722E-03 0.4220E-03 0.1210E-02 0.5532E-03 0.1219E-03
ITERATED SPECTRUM
 0.2571E 00 0.2744E 00 0.2223E 00 0.2519E 00 0.1329E 00 0.8047E-01 0.5277E-01 0.4155E-01 0.3374E-01 0.2716E-01
 0.2417E-01 0.1963E-01 0.1524E-01 0.1451E-01 0.1254E-01 0.9805E-02 0.8895E-02 0.8519E-02 0.5432E-02 0.5062E-02
 0.4423E-02 0.4226E-02 0.2645E-02 0.3714E-02 0.1914E-02 0.2424E-02 0.1984E-02 0.2094E-02 0.2211E-02 0.2376E-02
 0.2434E-02 0.2530E-02 0.2588E-02 0.2075E-02 0.1596E-02 0.8721E-03 0.4220E-03 0.1210E-02 0.5532E-03 0.1219E-03

 IT.SU.TERM
       23 0.1066426E 06 0.2222112E-02
FITTING DIFFERENCES
 0.0             0.2194778E 00 0.4664737E-01 0.1432350E 00 0.1088815E-01
 0.5794268E-02 0.3970269E-02 0.2143484E-02 0.1138382E-02 0.6513856E-03
 0.4534882E-03 0.4319251E-03 0.4616261E-03 0.4408215E-03 0.3583436E-03
 0.2538057E-03 0.1630683E-03 0.9875442E-04 0.5777739E-04 0.3293669E-04
 0.1854403E-04 0.1107040E-04 0.8236815E-05
```

```
                                                EFFICIENCY FACTORS

   INDEX         ENERGY          AIR           ABSORBER        CRYSTAL          TOTAL
                 (MEV)       ATTENUATION     ATTENUATION     EFFICIENCY       EFFICIENCY


      1      0.34437E-01     0.98795E 00     0.15704E 00     0.99872E 00     0.15495E 00
      2      0.10331E 00     0.99366E 00     0.68011E 00     0.97665E 00     0.66002E 00
      3      0.17219E 00     0.99462E 00     0.73160E 00     0.91306E 00     0.66440E 00
      4      0.24106E 00     0.99524E 00     0.76148E 00     0.83510E 00     0.63289E 00
      5      0.30994E 00     0.99567E 00     0.78090E 00     0.77223E 00     0.60042E 00
      6      0.37881E 00     0.99598E 00     0.79550E 00     0.73306E 00     0.58080E 00
      7      0.44769E 00     0.99624E 00     0.80746E 00     0.70255E 00     0.56515E 00
      8      0.51656E 00     0.99646E 00     0.81761E 00     0.67711E 00     0.55165E 00
      9      0.58544E 00     0.99664E 00     0.82630E 00     0.65528E 00     0.53964E 00
     10      0.65431E 00     0.99680E 00     0.83387E 00     0.63575E 00     0.52844E 00
     11      0.72319E 00     0.99695E 00     0.84053E 00     0.61779E 00     0.51768E 00
     12      0.79206E 00     0.99707E 00     0.84656E 00     0.60161E 00     0.50780E 00
     13      0.86094E 00     0.99718E 00     0.85247E 00     0.58828E 00     0.50008E 00
     14      0.92981E 00     0.99728E 00     0.85732E 00     0.57518E 00     0.49178E 00
     15      0.99869E 00     0.99737E 00     0.86153E 00     0.56241E 00     0.48327E 00
     16      0.10676E 01     0.99745E 00     0.86538E 00     0.55037E 00     0.47597E 00
     17      0.11364E 01     0.99753E 00     0.86906E 00     0.53900E 00     0.46727E 00
     18      0.12053E 01     0.99760E 00     0.87257E 00     0.52836E 00     0.45993E 00
     19      0.12742E 01     0.99767E 00     0.87591E 00     0.51889E 00     0.45344E 00
     20      0.13431E 01     0.99773E 00     0.87909E 00     0.51056E 00     0.44781E 00
     21      0.14119E 01     0.99779E 00     0.88209E 00     0.50255E 00     0.44232E 00
     22      0.14808E 01     0.99785E 00     0.88491E 00     0.49489E 00     0.43699E 00
     23      0.15497E 01     0.99790E 00     0.88732E 00     0.48799E 00     0.43209E 00
     24      0.16186E 01     0.99794E 00     0.88953E 00     0.48151E 00     0.42744E 00
     25      0.16874E 01     0.99798E 00     0.89168E 00     0.47527E 00     0.42293E 00
     26      0.17563E 01     0.99803E 00     0.89375E 00     0.46930E 00     0.41860E 00
     27      0.18252E 01     0.99807E 00     0.89574E 00     0.46359E 00     0.41445E 00
     28      0.18941E 01     0.99810E 00     0.89766E 00     0.45817E 00     0.41050E 00
     29      0.19629E 01     0.99814E 00     0.89950E 00     0.45305E 00     0.40676E 00
     30      0.20318E 01     0.99818E 00     0.90112E 00     0.44855E 00     0.40347E 00
     31      0.21007E 01     0.99821E 00     0.90254E 00     0.44461E 00     0.40056E 00
     32      0.21696E 01     0.99824E 00     0.90391E 00     0.44080E 00     0.39774E 00
     33      0.22384E 01     0.99828E 00     0.90526E 00     0.43710E 00     0.39501E 00
     34      0.23073E 01     0.99830E 00     0.90657E 00     0.43353E 00     0.39236E 00
     35      0.23762E 01     0.99833E 00     0.90784E 00     0.43009E 00     0.38980E 00
     36      0.24451E 01     0.99836E 00     0.90908E 00     0.42678E 00     0.38735E 00
     37      0.25139E 01     0.99839E 00     0.91028E 00     0.42364E 00     0.38501E 00
     38      0.25828E 01     0.99841E 00     0.91145E 00     0.42070E 00     0.38284E 00
     39      0.26517E 01     0.99843E 00     0.91259E 00     0.41787E 00     0.38074E 00
     40      0.27206E 01     0.99845E 00     0.91369E 00     0.41515E 00     0.37873E 00
```

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```
DIFFERENTIAL FLUX AT ITERATION NUMBER =     23
   0.0          0.0           0.58288E 04   0.63146E 05   0.41037E 05
   0.25555E 05  0.15487E 05   0.16341E 05   0.17914E 05   0.14937E 05
   0.11691E 05  0.59386E 04   0.13457E 04   0.59201E 04   0.92311E 04
   0.91382E 04  0.91256E 04   0.98815E 04   0.12625E 03   0.13874E 04
   0.10891E 04  0.51470E 04   0.97073E 03   0.70399E 04   0.17568E 03
   0.22847E 04  0.21358E 02   0.64994E 02   0.89960E 00   0.66656E-02
   0.16235E 00  0.50036E 00   0.98336E 00   0.44577E 02   0.21279E 04
   0.18887E 04  0.17407E 04   0.89841E 04   0.43361E 04   0.10017E 04

 SINGLE SPECTRUM    40CHANNELS
       0.        0.    23479.    26849.    14399.     8629.     5680.     4476.     3616.     2884.
    2535.     2018.     1557.     1522.     1339.     1062.      968.      923.      498.      518.
     444.      445.      273.      395.      212.      266.      199.      218.      155.      153.
     176.      186.      191.      186.      170.       93.       45.      129.       59.       13.
```

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NUMBER AND ENERGY SPECTRUM AT THE CRYSTAL

INCREMENT    ENERGY            NUMBER FLUX                ENERGY FLUX
             (MEV)         (PHOTONS/CM**2-SEC)         (MEV/CM**2-SEC)

    1        0.03444          0.0                        0.0
    2        0.10331          0.0                        0.0
    3        0.17219          0.1163864E 01              0.2004027E 00
    4        0.24106          0.1260876E 02              0.3039497E 01
    5        0.33994          0.8194021E 01              0.2539633E 01
    6        0.37881          0.5102632E 01              0.1932958E 01
    7        0.44769          0.3092307E 01              0.1384386E 01
    8        0.51656          0.3262915E 01              0.1685498E 01
    9        0.58544          0.3577054E 01              0.2094140E 01
   10        0.65431          0.2982470E 01              0.1951466E 01
   11        0.72319          0.2374355E 01              0.1717102E 01
   12        0.79206          0.1185794E 01              0.9392222E 00
   13        0.86094          0.2686964E 00              0.2313306E 00
   14        0.92981          0.1182099E 01              0.1099130E 01
   15        0.99869          0.1843223E 01              0.1840801E 01
   16        1.06756          0.1824664E 01              0.1947940E 01
   17        1.13644          0.1822163E 01              0.2070770E 01
   18        1.20531          0.1773426E 01              0.2137529E 01
   19        1.27419          0.2523994E-01              0.3212213E-01
   20        1.34306          0.2770238E 00              0.3720597E 00
   21        1.41194          0.2174669E 00              0.3070493E 00
   22        1.48081          0.1027729E 01              0.1521872E 01
   23        1.54969          0.1938300E 00              0.3003755E 00
   24        1.61856          0.1405691E 01              0.2275196E 01
   25        1.68744          0.3507823E-01              0.5919223E-01
   26        1.75631          0.4561951E 00              0.8012202E 00
   27        1.82518          0.4264582E-02              0.7783648E-02
   28        1.89406          0.1297769E-01              0.2458052E-01
   29        1.96294          0.1796286E-03              0.3525992E-03
   30        2.03181          0.1330953E-05              0.2704242E-05
   31        2.10069          0.3241778E-04              0.6809954E-04
   32        2.16956          0.9990876E-04              0.2167581E-03
   33        2.23843          0.1962939E-03              0.4393889E-03
   34        2.30731          0.8901004E-02              0.2053737E-01
   35        2.37618          0.4248816E 00              0.1009597E 01
   36        2.44506          0.3771341E 00              0.9221153E 00
   37        2.51394          0.3475731E 00              0.8737762E 00
   38        2.58281          0.1793910E 01              0.4633327E 01
   39        2.65168          0.8658088E 00              0.2295852E 01
   40        2.72056          0.2000070E 00              0.5441334E 00
```

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INTEGRATED RESULTS AT SOURCE AND CRYSTAL


ENERGY INTEGRATED PHOTON (BREMSS.) VALUES AT THE CRYSTAL


PHOTON NUMBER (PHOTONS/CM**2-SEC) =  0.5993245E 02
PHOTON ENERGY (MEV/CM**2-SEC)     =  0.4281345E 02
PHOTON DOSE   (ROENTGENS/HOUR)    =  0.7778591E-04

AVERAGE ENERGY (MEV) =  0.7143617E 00

PHOTON NUMBER / SOURCE EMITTED BETA NUMBER (PHOTONS/CM**2-SEC)/(BETA/SEC) =  0.1619796E-08
PHOTON ENERGY / SOURCE EMITTED BETA ENERGY ((MEV/CM**2-SEC)/MEV)          =  0.1637225E 02
PHOTON ENERGY / SOURCE EMITTED BETA NUMBER (MEV/CM**2-SEC)/(BETA/SEC)     =  0.1157120E-08
PHOTON DOSE   / SOURCE EMITTED BETA NUMBER (R/HR)/(BETA/SEC)              =  0.2102322E-14
PHOTON DOSE   / SOURCE EMITTED BETA NUMBER PER SOURCE VOLUME (((R/HR)/(BETA/SEC))/CM**3) =  0.2676760E-14



AT THE SOURCE CYLINDER

PHOTON DOSE   / SOURCE EMITTED BETA NUMBER (R/HR)/(BETA/SEC)              =  0.3247201E-11

PHOTON DOSE   / SOURCE EMITTED BETA NUMBER PER SOURCE VOLUME (((R/HR)/(BETA/SEC))/CM**3) =  0.4134465E-11
```

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APPENDIX V

PHOTOPEAK AND BACKSCATTER PEAK DISTRIBUTIONS

APPENDIX V

Photopeak and Backscatter Peak Distributions

Figures V-1 through V-8 give the residual spectral count distributions in the photopeak region after systematic fitting and subtraction of the Gaussian function. The residuals are approximately zero at channels greater than the Gaussian mean pulse height. For Ce^{139} and Hg^{203} the residuals below mean pulse height are as expected, i.e., the Compton tail appears regular in shape. The Compton tail of the other standards exhibits peak assymetry, perhaps associated with Ge(Li) electron-hole trapping. A more detailed analysis was not possible within the economic constraints of the present work.

Figures V-9 through V-17 (generated by subroutine XPLOT) give the generally very good agreement between the fitted Gaussian function (zeros' i.e., 0) and the experimental photopeaks (ex's i.e., x); the asterisks indicate x and o superimposed. In these figures the true photopeak channel is obtained by adding the figure specified-number to plot channels (at bottom of figure).

Figure V-18 shows the normalized backscatter peak distributions, with respect to unit pulse height (200 channels) and photopeak area. These peaks were obtained after fitting a straight line base through counts on both sides of the peak region (see FITLIN description in Section 2.2.2.4). All peaks exhibit a regular shape pattern with the exception of Ce^{139}; Ce^{139} continuum counts were statiscally poor and thus this may account in part for spurious region between channels 10 and 20 in Figure V-18. Figure V-19 presents the backscatter peak height as a function of energy. The behaviour is seen to be satisfactorily regular.

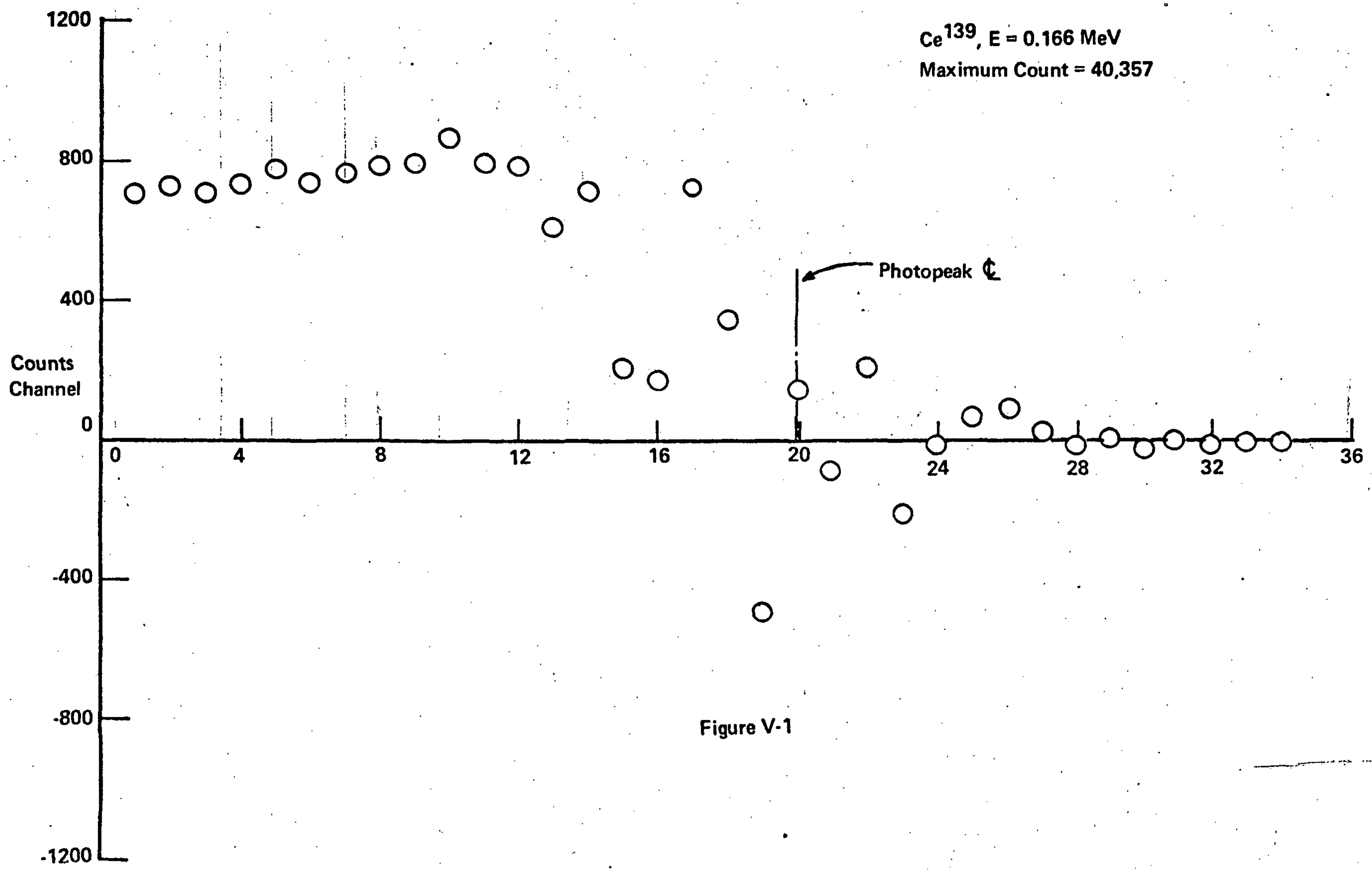

Ce^{139}, E = 0.166 MeV
Maximum Count = 40,357
Photopeak ℄
Counts
Channel
1200
800
400
0
-400
-800
-1200
0
4
8
12
16
20
24
28
32
36

Figure V-1

Hg^{203}, E = 0.279 MeV
Maximum Count = 7,493

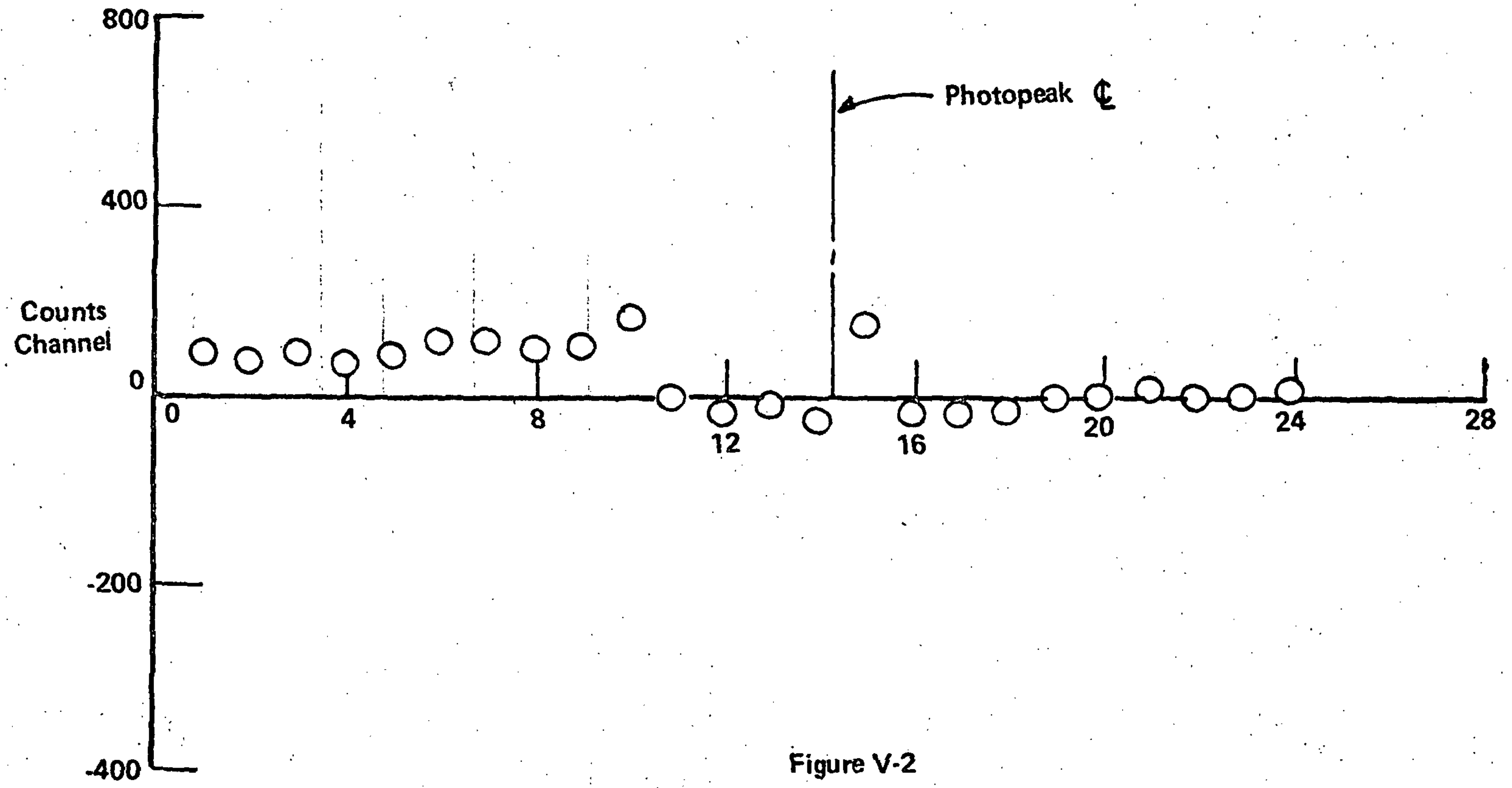


Figure V-2

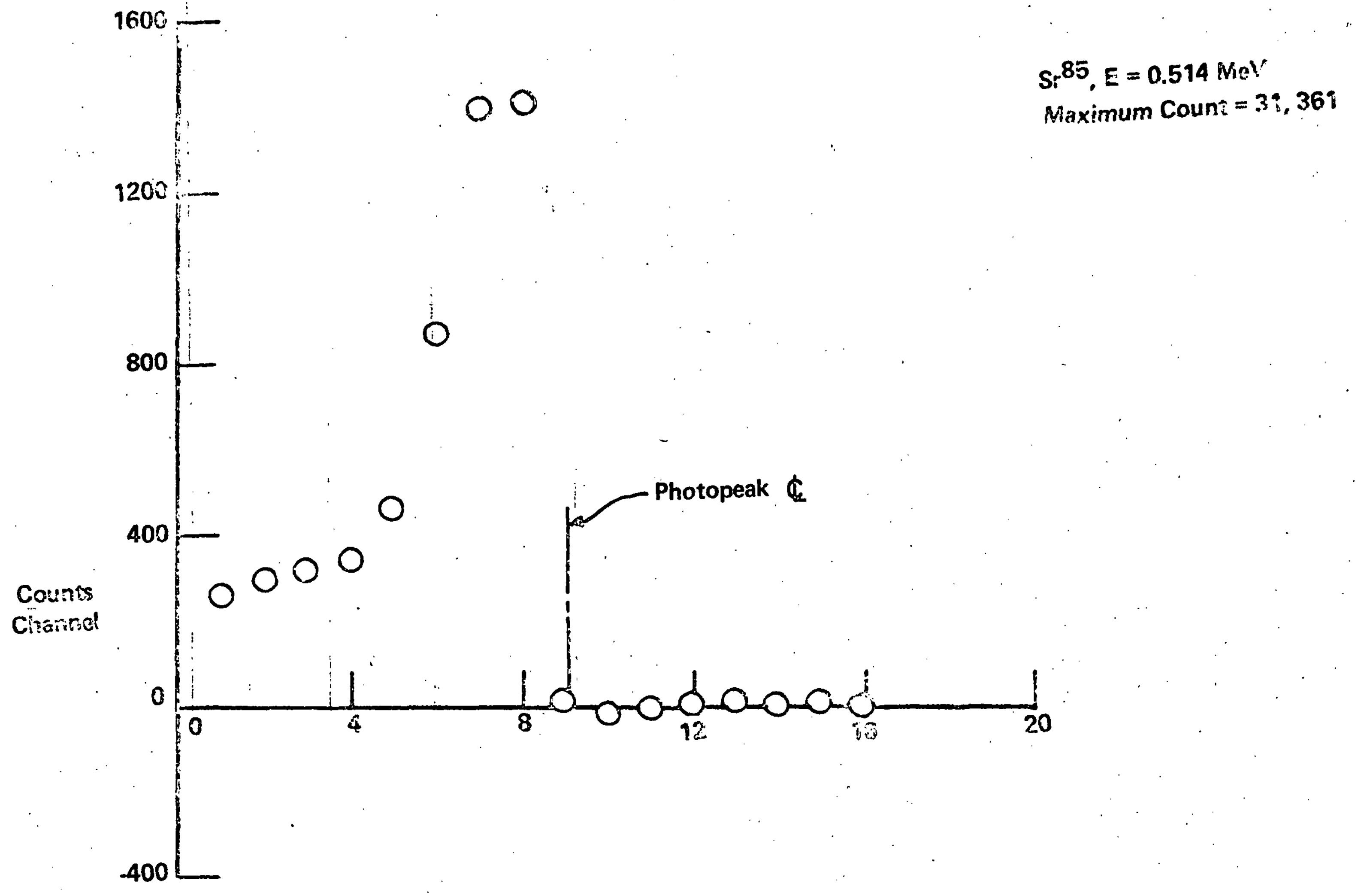
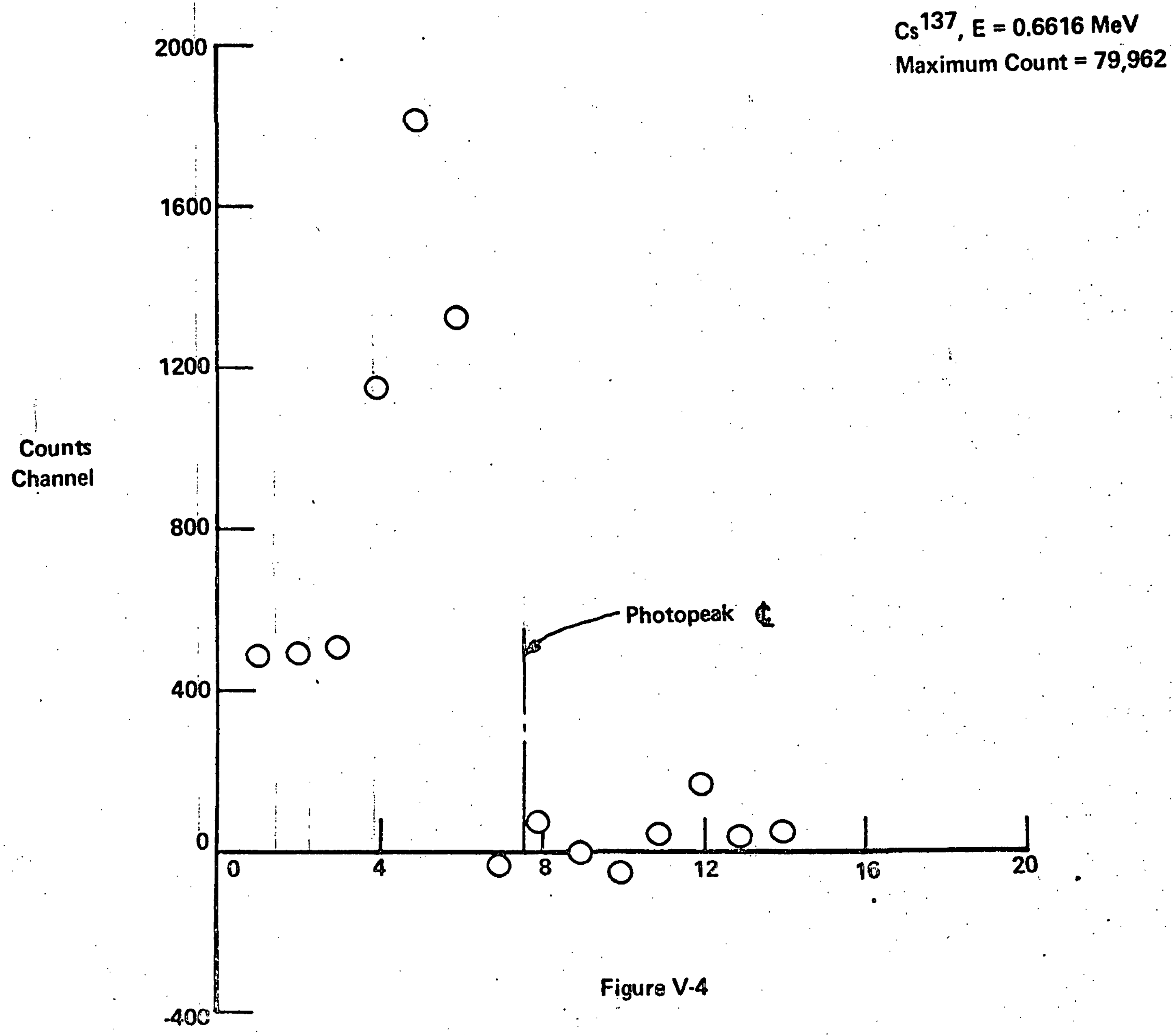

Sr85, E = 0.514 MeV
Maximum Count = 31, 361
1600
1200
800
400
0
-400
Counts
Channel
0
4
8
12
16
20
Photopeak ℄

Figure V-3



Cs^{137}, E = 0.6616 MeV
Maximum Count = 79,962

Figure V-4

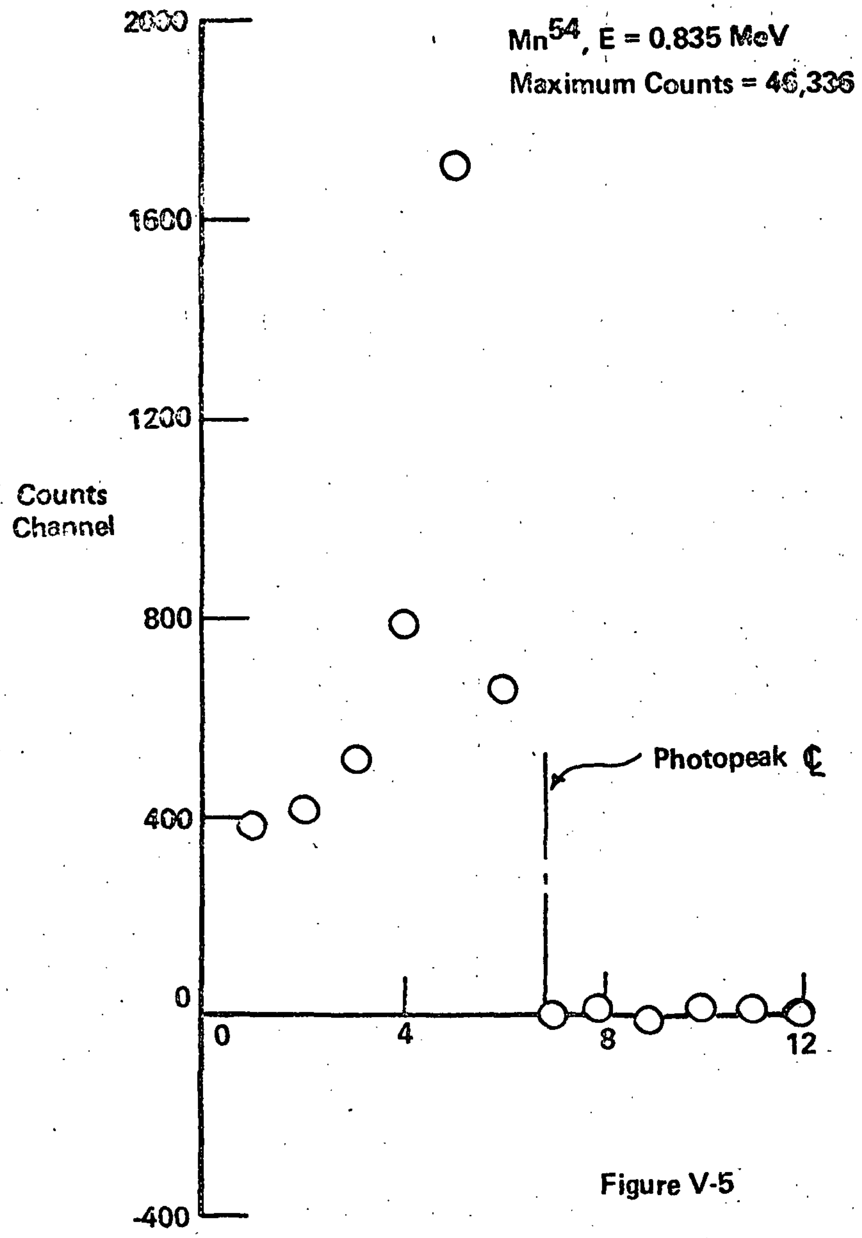


Figure V-5

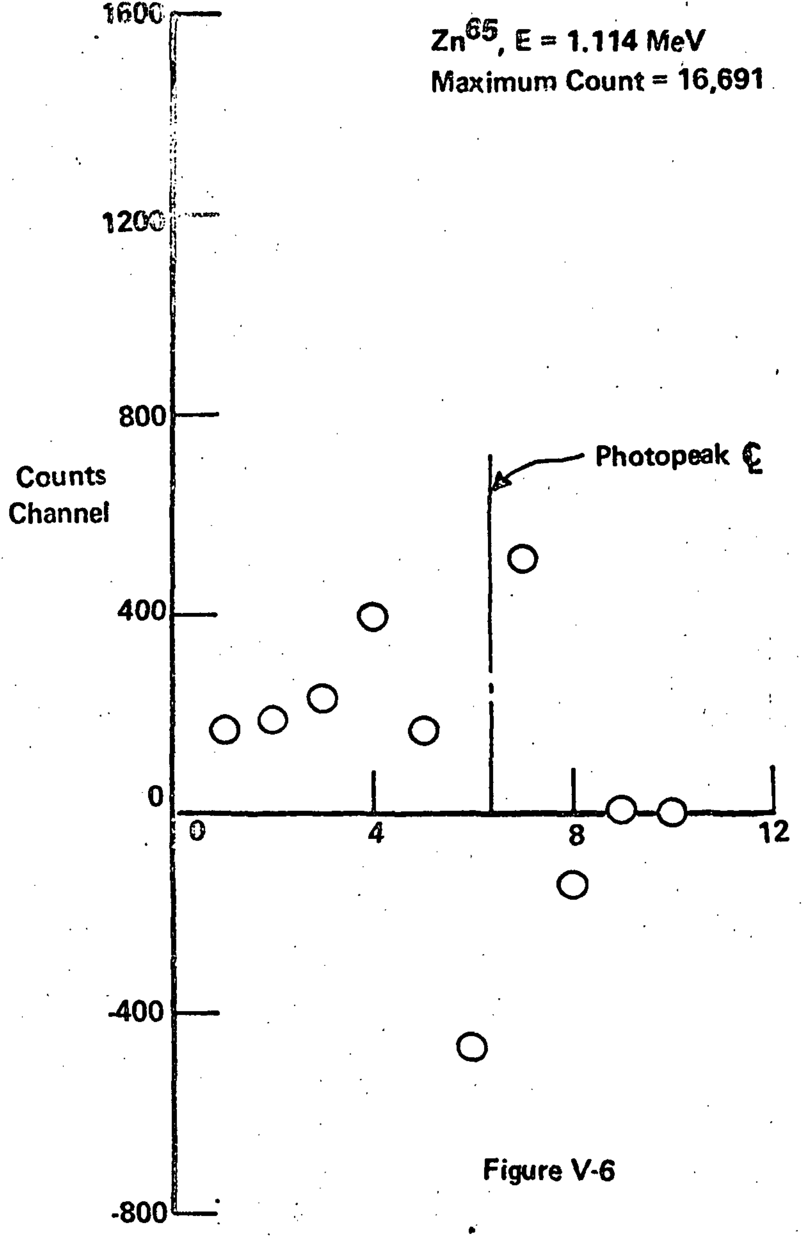


Figure V-6

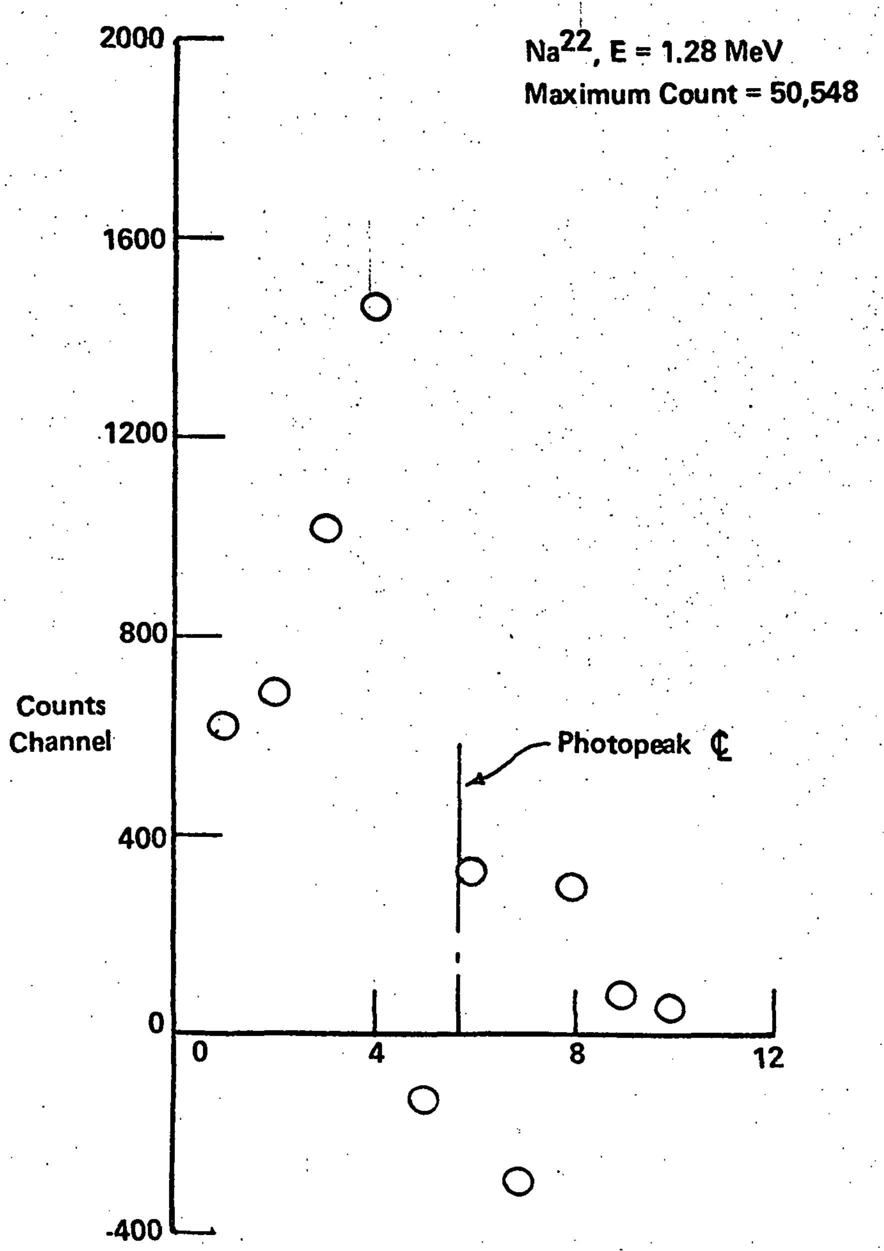


Figure V-7

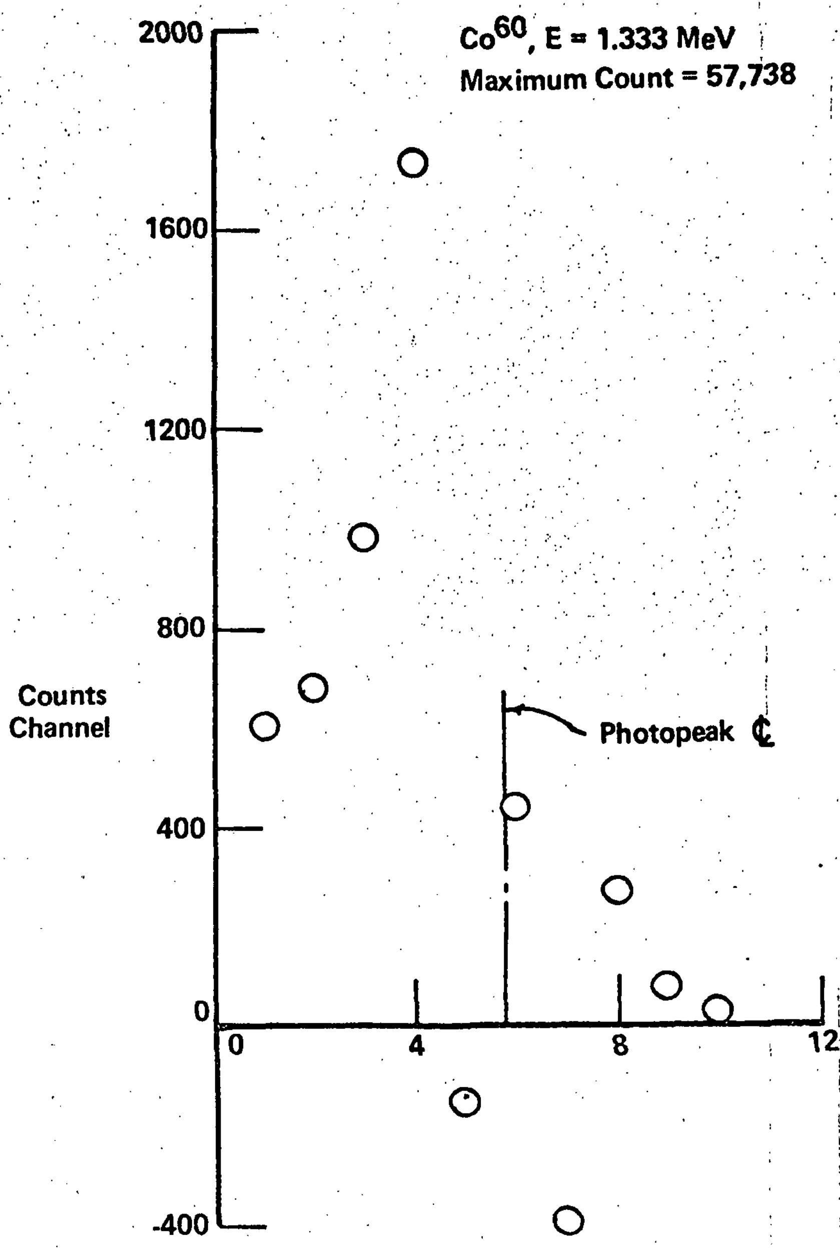
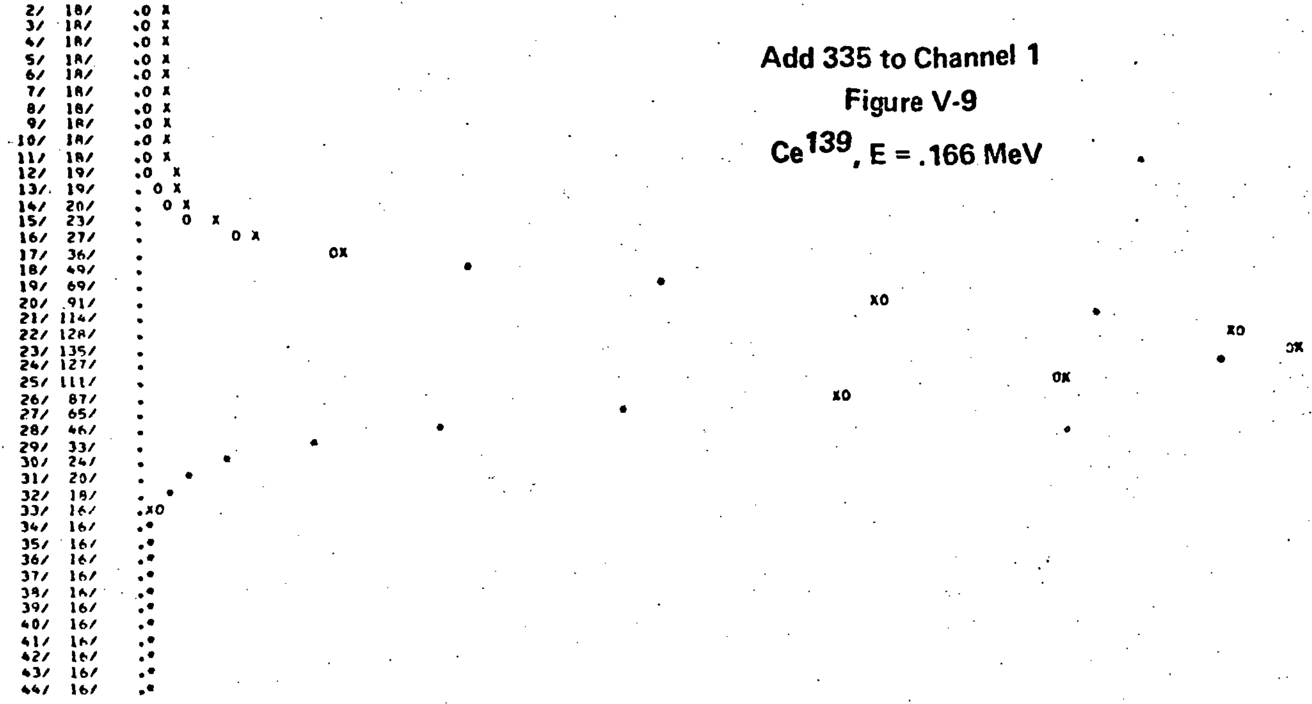


Figure V-8

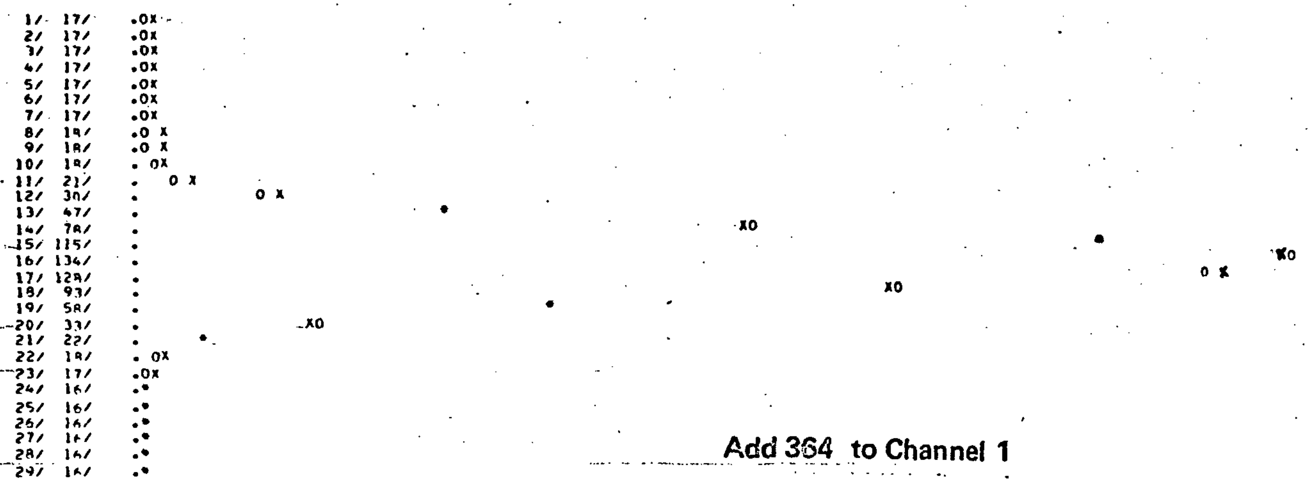


```
 1/  18/
 2/  18/
 3/  18/
 4/  18/
 5/  18/
 6/  18/
 7/  18/
 8/  18/
 9/  18/
10/  18/
11/  18/
12/  19/
13/  19/
14/  20/
15/  23/
16/  27/
17/  36/
18/  49/
19/  69/
20/  91/
21/ 114/
22/ 128/
23/ 135/
24/ 127/
25/ 111/
26/  87/
27/  65/
28/  46/
29/  33/
30/  24/
31/  20/
32/  18/
33/  16/
34/  16/
35/  16/
36/  16/
37/  16/
38/  16/
39/  16/
40/  16/
41/  16/
42/  16/
43/  16/
44/  16/
```

Add 335 to Channel 1

Figure V-9

Ce^{139}, E = .166 MeV

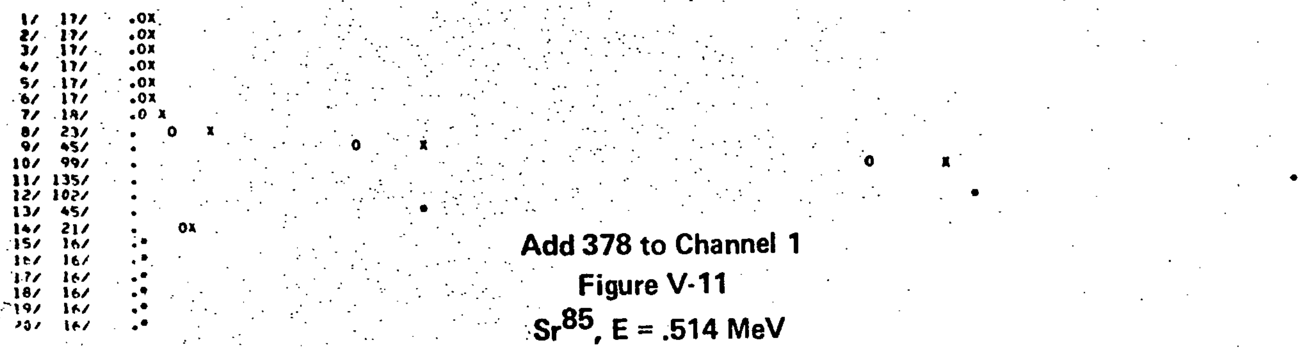


```
 1/  17/
 2/  17/
 3/  17/
 4/  17/
 5/  17/
 6/  17/
 7/  17/
 8/  18/
 9/  18/
10/  18/
11/  21/
12/  30/
13/  47/
14/  78/
15/ 115/
16/ 134/
17/ 128/
18/  93/
19/  58/
20/  33/
21/  22/
22/  18/
23/  17/
24/  16/
25/  16/
26/  16/
27/  16/
28/  16/
29/  16/
30/  16/
```

Add 364 to Channel 1

Figure V-10

Hg^{203}, E = .279 MeV

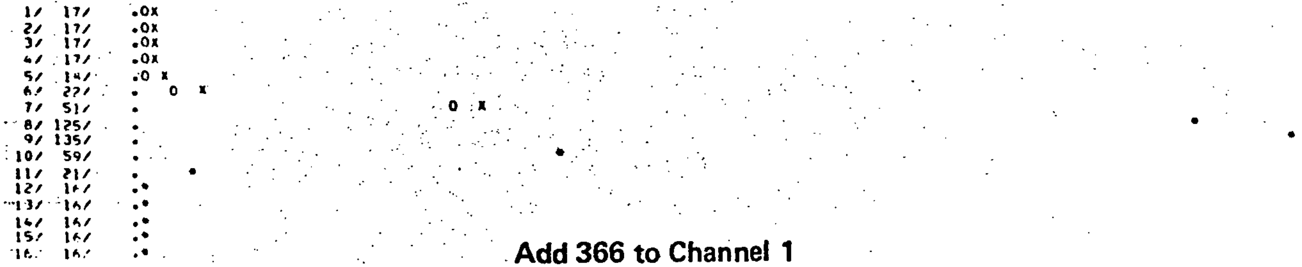


```
 1/  17/    .OX
 2/  17/    .OX
 3/  17/    .OX
 4/  17/    .OX
 5/  17/    .OX
 6/  17/    .OX
 7/  18/    .O X
 8/  23/    .    O    X
 9/  45/    .
10/  99/    .
11/ 135/    .
12/ 102/    .
13/  45/    .
14/  21/    .      OX
15/  16/    .*
16/  16/    .*
17/  16/    .*
18/  16/    .*
19/  16/    .*
20/  16/    .*
```

Add 378 to Channel 1

Figure V-11

Sr^{85}, E = .514 MeV



```
 1/  17/    .OX
 2/  17/    .OX
 3/  17/    .OX
 4/  17/    .OX
 5/  14/    .O X
 6/  22/    .    O   X
 7/  51/    .
 8/ 125/    .
 9/ 135/    .
10/  59/    .
11/  21/    .       *
12/  16/    .*
13/  16/    .*
14/  16/    .*
15/  16/    .*
16/  16/    .*
```

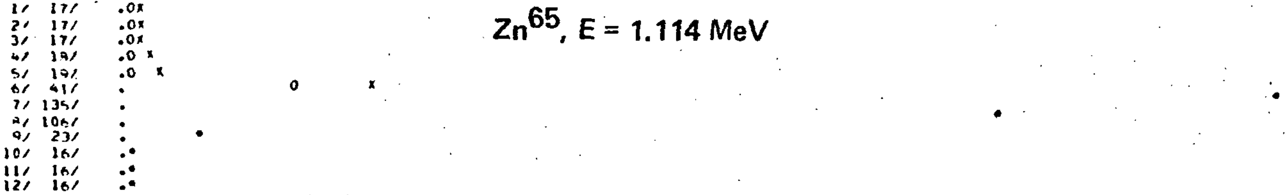
Add 366 to Channel 1

Figure V-12

C_s^{137}, E = .6616 MeV

Add 368 to Channel 1
Figure V-13
Mn^{54}, E = .835 MeV

Add 378 to Channel 1
Figure V-14
Zn^{65}, E = 1.114 MeV

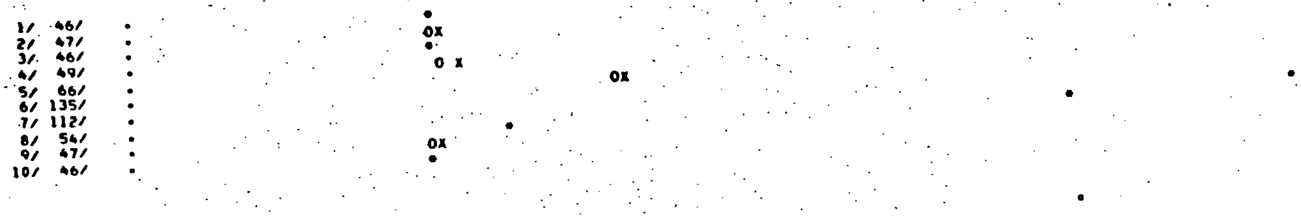


Add 379 to Channel 1
Figure V-15
Co^{60}, E = 1.333 MeV

Add 171 to Channel 1

Figure V-16

Zn^{65}, E = 0.51 MeV



Add 334 to Channel 1

Figure V-17

Co^{60}, E = 1.173 MeV

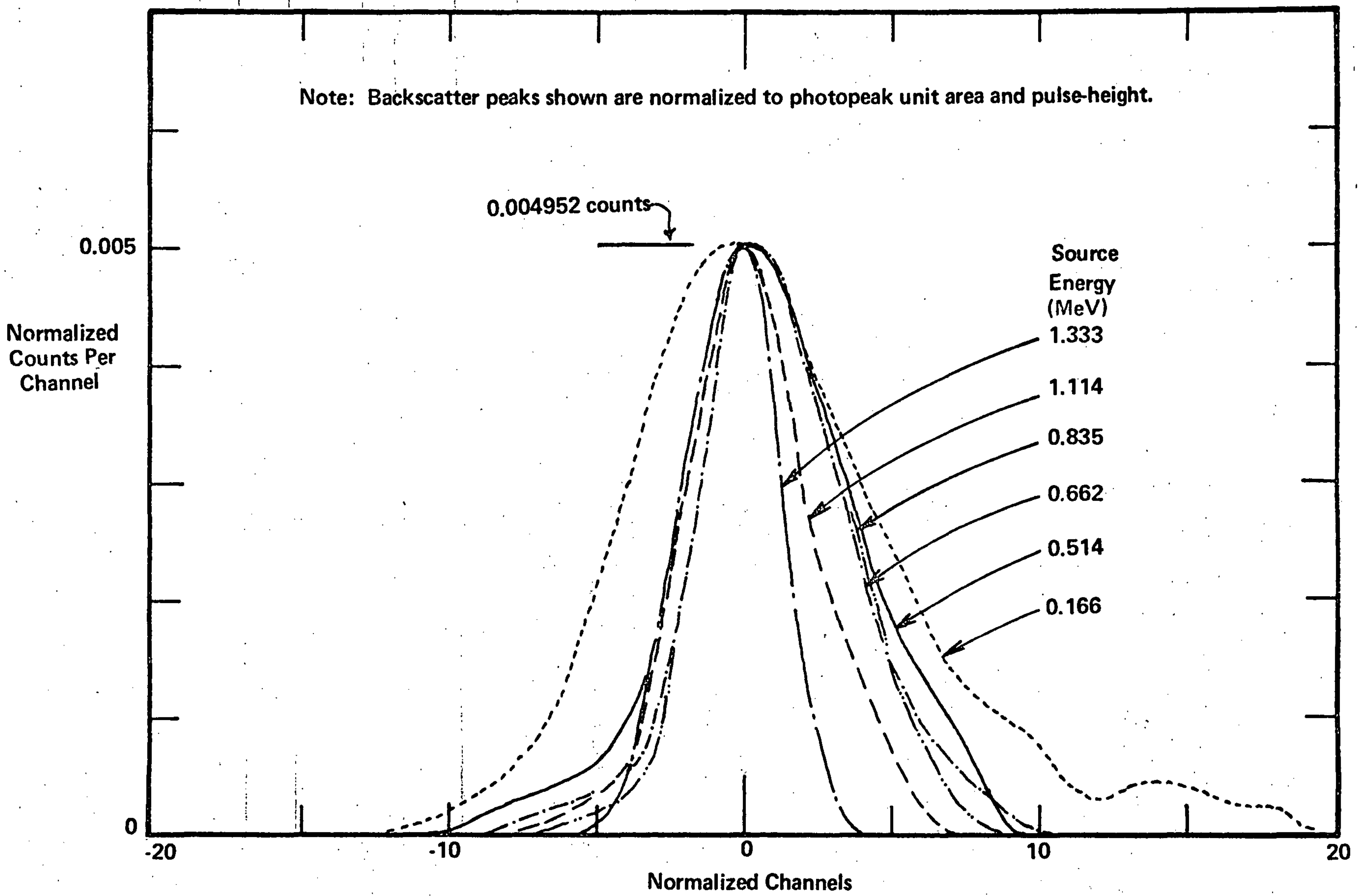


Figure V-18
Normalized Backscatter Peaks

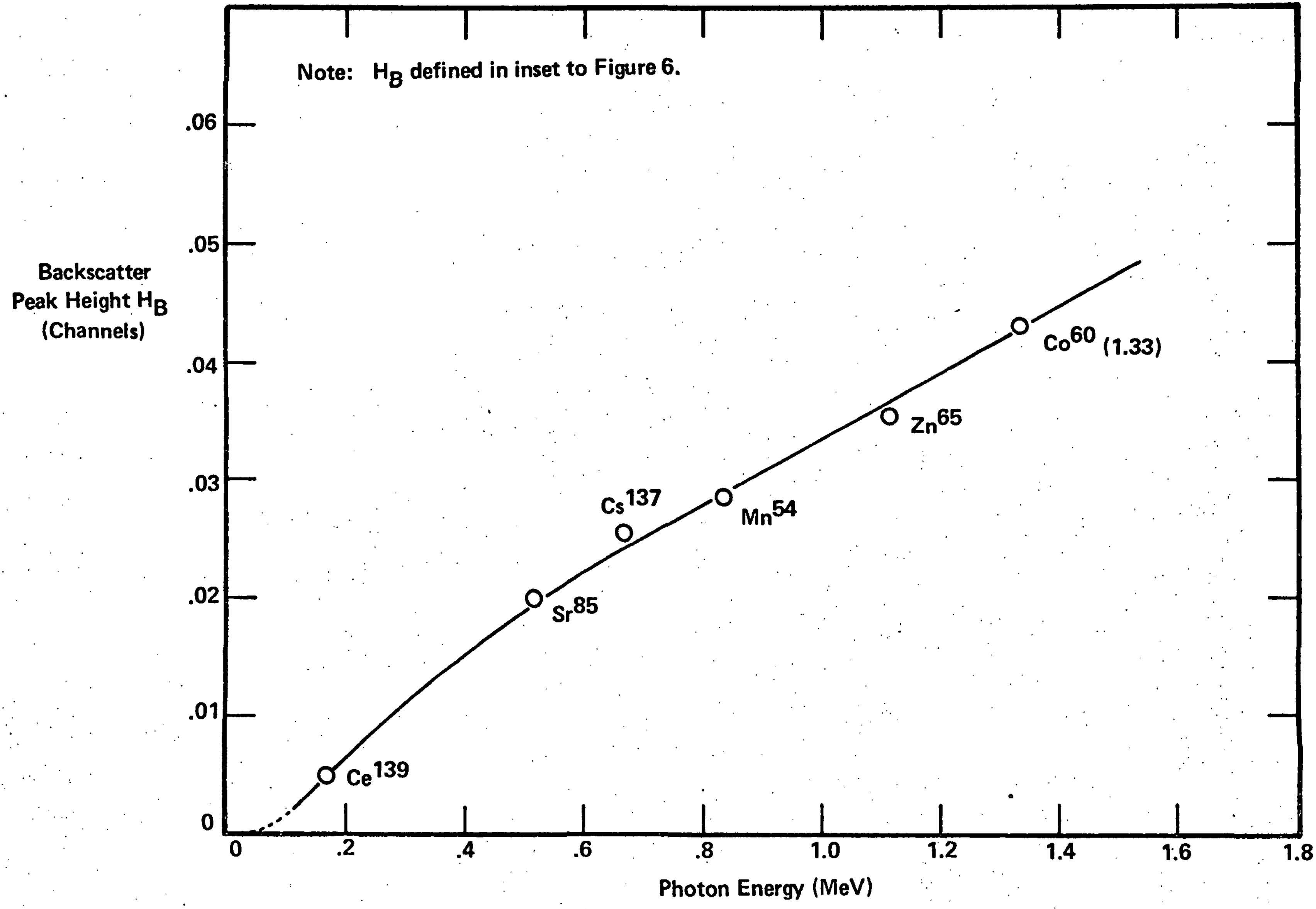


Figure V-19

Backscatter Peak Height as a Function of Photon Energy

APPENDIX VI

REPRODUCTION OF APPENDIX II OF REFERENCE (2): PHOTOPEAK FUNCTION FITTING

Note: The Following Are Approximately Equivalent in This Appendix:

CUBED,	read as	CUGEL
STDFIT,	read as	STDFT3
GUESS,	read as	PKFUN
PHOFRA,	read as	RESFUN

APPENDIX II

PHOTOPEAK FUNCTION FITTING

The pulse-height analyzer spectral photopeak counts, $y(x_i)$, are fitted to the Gaussian-plus-straight-line non-linear function

$$f(x_i) = f(x_i\,;\,p_j) = \frac{G\,p_3\,e^{-\frac{(x_i-p_1)^2}{2p_2^{\,2}}}}{p_2} + p_4\,x_i + p_5 \qquad (1)$$

where

p_1 = photopeak mean pulse-height.
p_2 = photopeak standard deviation.
p_3 = photopeak area.
p_4 = slope of photopeak assumed straight-line base.
p_5 = intercept of photpeak assumed straight-line base.
G = 0.3989423, a Gaussian constant.
i = ℓ, $\ell+1$, ..., n; ℓ and n are input to code CUBED.
j = 1, 2, ..., m; m=5 in equation (1) and in code CUBED.

The partial derivatives of equation (1), with respect to the parameters, p_j, are determined as

$$\left.\begin{aligned} f_{p_1} &= \left(\frac{\partial f}{\partial p_1}\right)_i = f(x_i)^{*}\left(\frac{x_i - p_1}{p_2^{\,2}}\right) \\ f_{p_2} &= \left(\frac{\partial f}{\partial p_2}\right)_i = \frac{f(x)_i^{*}}{p_2}\left(\left(\frac{x_i - p_1}{p_2}\right)^2 - 1\right) \end{aligned}\right\} \qquad (2)$$

$$\left.\begin{aligned} f_{p_3} &= \left(\frac{\partial f}{\partial p_3}\right)_i = f\,(x_i)^*/p_3 \\ f_{p_4} &= \left(\frac{\partial f}{\partial p_4}\right)_i = x_i \\ f_{p_5} &= \left(\frac{\partial f}{\partial p_5}\right)_i = 1 \end{aligned}\right\} \qquad (2)$$

where

$$f\,(x_i)^* = f\,(x_i) - p_4 x_i - p_5$$

Equations (1) and (2) are coded in subprogram FUNUS. Equation (1) is fitted to the experimental data, (x_i, y_i), according to the iterative least-squares method of differential correction[(34)]; it is coded in subprogram STDFIT. This method, as it is applied in code CUBED, is outlined as follows:

A set of non-linear residual equations are defined and after some manipulation expressed as first linear approximations. An initial estimate of values of the fitting function parameters is employed for the first approximation (iteration). The linearized approximation residual equations are minimized by the method of least-squares such as to generate a set of normal equations which are in turn solved to determine the coefficients. These differential correction coefficients are applied additively to the current (initial on first iteration) parameter values to obtain the values for the next (second, third, etc.) iteration. This is repeated until the sum of the squares of the residuals (between function and experimental values) differ by less then some preassigned value, as determined for consecutive iterations.

The set of non-linear residual equations are defined as;

The set of non-linear residual equations are defined as:

$$R_i = f\ (x_i\ ;\ p_j{}^{(k)}) - y\ (x_i) \tag{3}$$

which may be rewritten as

$$R_i = f\ (x_i\ ;\ p_j{}^{(k)} + q_j^{(k)}) - y\ (x_i) \tag{4}$$

where

$p_j{}^{(o)}$ = initially estimated value of j^{th} parameter.

$p_j{}^{(k)}$ = value of j^{th} parameter for iteration k.

k = iteration index

$q_j^{(k)} = p_j{}^{(k)} - p_j$, differential correction coefficient (ideally equal to zero).

Expanding equation (4) by means of Taylor's theorem for a function of several variables, it may be seen that

$$R_i = f\ (x_i\ ;\ p_j{}^{(k)}) - y\ (x_i) + \sum_{j=1}^{m} q_j{}^{(k)} \left(\frac{\partial f}{\partial p_j{}^{(k)}} \right)_i + \delta \tag{5}$$

where

δ = neglected higher order terms in p_j.

Thus equation (5) can be expressed as:

$$R_i = r_i + \sum_{j=1}^{m} q_j{}^{(k)} \left(\frac{\partial f}{\partial p_j{}^{(k)}} \right)_i \tag{6}$$

a set of residual equations, linear in p_j.

Minimizing as

$$\sum_{i=\ell}^{n} R_i{}^2 = u\ (p_j{}^{(k)}) \tag{7}$$

The normal equations may be written as:

$$\left.\begin{array}{l}
\left(\sum f_{p_1} f_{p_1}\right)_i q_1 + \left(\sum f_{p_1} f_{p_2}\right)_i q_2 + \ldots + \left(\sum f_{p_1} f_{p_m}\right)_i q_m + \sum f_{p_1} r_i = 0 \\
\left(\sum f_{p_2} f_{p_1}\right)_i q_1 + \left(\sum f_{p_2} f_{p_2}\right)_i q_2 + \ldots + \left(\sum f_{p_2} f_{p_m}\right)_i q_m + \sum f_{p_2} r_i = 0 \\
\qquad \vdots \\
\left(\sum f_{p_m} f_{p_1}\right)_i q_1 + \left(\sum f_{p_m} f_{p_2}\right)_i q_2 + \ldots + \left(\sum f_{p_m} f_{p_m}\right)_i q_m + \sum f_{p_m} r_i = 0
\end{array}\right\} \quad (8)$$

and solved for the differential correction coefficients $q_j^{(k)}$. Iterating is continued with the iteration parameter values determined as

$$p_j^{(k+1)} = p_j^{(k)} + q_j^{(k)} \qquad (9)$$

until the arresting criterion employed is satisfied. Iterating is arrested when

$$\left| \frac{S^{(k-1)} - S^{(k)}}{S^{(k)}} \right| \leq e'$$

where

e' = an assigned tolerance value; $e' = 10^{-5}$ in code CUBED subprogram STDFIT.

$$S^{(k)} = \sum_{i=\ell}^{n} (y(x_i) - f(x_i ; p_j^{(k)}))^2 \cdot W(x_i)$$

$W(x_i)$ = set of statistical weights; $= \left((y(x_i))^{\frac{1}{2}}\right)^{-2}$ in code CUBED subprogram STDFIT.

In general, subprogram STDFIT ceased fitting equation (1) at $k=5$. Subprogram GUESS communicates the $p_j^{(o)}$ to subprogram STDFIT semi-automatically, i.e., it requires ℓ and n, the lower and upper fitting indices to be input to subprogram PHOFRA (encoded as NSJ and NFNJ). Equation (8) is solved according to the conventional Gauss-Jordan pivoting method(35).