FPDCYS and FPSPEC: Computer Programs for Calculating Fission-Product Beta and Gamma Multigroup Spectra from ENDF/B-IV Data

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FPDCYS AND FPSPEC: COMPUTER PROGRAMS
FOR CALCULATING FISSION-PRODUCT
BETA AND GAMMA MULTIGROUP SPECTRA
FROM ENDF/B-IV DATA

by

M. G. Stamatelatos and T. R. England

ABSTRACT

FPDCYS and FPSPEC are two FORTRAN computer programs used at the Los Alamos Scientific Laboratory (LASL), in conjunction with the CINDER-10 program, for calculating cumulative fission-product beta and/or gamma multigroup spectra in arbitrary energy structures, and for arbitrary neutron irradiation periods and cooling times. FPDCYS processes ENDF/B-IV fission-product decay energy data to generate multigroup beta and gamma spectra from individual ENDF/B-IV fission-product nuclides. FPSPEC further uses these spectra and the corresponding nuclide activities calculated by the CINDER-10 code to produce cumulative beta and gamma spectra in the same energy grids in which FPDCYS generates individual isotope decay spectra. The code system consisting of CINDER-10, FPDCYS, and FPSPEC has been used for comparisons with experimental spectra and continues to be used at LASL for generating spectra in special user-oriented group structures.

I. INTRODUCTION

A computer code system has been developed at the Los Alamos Scientific Laboratory (LASL) to calculate fission-product beta and gamma decay energies and spectra from thermal, fast, and 14-MeV neutron-induced fission of a number of important fissionable nuclides (including $^{232}$Th, $^{233}$U, $^{235}$U, $^{238}$U, $^{239}$Pu, and $^{241}$Pu). This system has been used for a wide range of neutron irradiation periods ($10^{-4}$ to $10^{13}$ s) and for cooling times from fractions of one second to many years. There are many reactor safety and safeguards areas and other applications where this type of information is of interest. In recent years, great emphasis has been placed on obtaining experimental and computational
information of this kind at short cooling times for nuclear reactor safety studies of the hypothetical loss-of-coolant accident. In this connection, comparisons have been made between computational and experimental results, in the form of total decay heating and/or radiation (beta and/or gamma) spectra, measured at a number of research establishments (e.g., Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, Intelcom Rad Tech, and the University of Illinois). Such benchmark comparisons have demonstrated the accuracy of both the general computational methods and the specific input data. Subsequently, the code system and data have proved to be of use in nonreactor applications.

The most complete and up-to-date sources of fission-product data are the Evaluated Nuclear Data Files (ENDF/B) Version IV whose contents are summarized in Ref. 4. These files contain cross sections, fission-yield sets, and decay parameters for 824 important fission products. Spectral data (i.e., beta endpoint energies and intensities, gamma line energies and intensities) exist for the most important decay-heat contributors among the 824 nuclides. Thus, beta spectral data exist for 163 fission products and gamma spectral data exist for 172 nuclides (nuclides emitting both beta and gamma radiation are included separately in both types of radiation counts).

The computer codes discussed in this report, FPDCYS and FPSPEC, are essentially designed to use ENDF/B-IV data. Use of alternate data sets, depending upon their formats, would require some program input modifications. Beyond the input format, however, the programs are general and would need no further changes if used with fission-product files other than ENDF/B-IV.

FPDCYS and FPSPEC are part of a LASL computer system shown schematically in Fig. 1. The CINDER-10 code is the latest and most versatile version of a well-known fission-product and depletion code. The most recent documentation on the CINDER code is Ref. 5. The additional features of version 10 are discussed in Ref. 6. This code calculates fission-product and actinide concentrations, activities, gaseous contents, energy releases, effective group absorption cross sections, etc., for any fissionable nuclide mixture irradiated in arbitrary neutron fluxes for arbitrary intervals of time and for arbitrary cooling times. The spectral codes discussed in this report utilize a small portion of the

* A single fission-product file in ENDF/B-IV format with corrections as in Ref. 4 was used.
CINDER-10 output, namely fission-product activities and total decay energies at the instant of time when corresponding spectra are sought.

CINDER-10 also incorporates a spectral subroutine capable of utilizing the multigroup data produced by the FPDCYS code. This feature has been used for few-group (~20) spectral calculations and also for multigroup calculations involving a limited number of nuclides. However, decay energies are the only major nuclide parameters that are usually not needed in calculations of the behavior of coupled nuclides. Therefore, to conserve computer storage, most spectral calculations have been made subsequent to the calculation of activities using the FPSPEC code. This also permits calculation of any number of spectral groupings for a single run of the CINDER-10 code.

![Diagram](image)

**Fig. 1.**
LASL Code System for generating multigroup $\beta^-$ and $\gamma$ fission-product spectra.

3
FPDCYS reads the same ENDF/B-IV fission-product file used for preparing the CINDER library to generate multigroup beta and gamma spectra for individual nuclides for which spectral data exist on the ENDF/B-IV file.

FPSPEC combines the individual spectra from FPDCYS and the nuclide activities from CINDER-10 to generate cumulative fission-product spectra for any irradiation and shutdown condition desired. Both the beta and the gamma spectra are generated in multigroup form of arbitrary size grid.

II. THE FPDCYS PROGRAM

The FPDCYS code incorporates a number of options for computing multigroup spectra of individual fission-product nuclides. There are four options for calculating beta spectra and two options for calculating gamma spectra. The beta-spectrum options are selected by a flag which controls the calling of one of the four beta-spectrum calculating routines, BETAl, BETA2, BETA3 or BETA4. Similarly, the gamma-spectrum option is selected by another flag which calls one of the two available gamma-spectrum calculating routines, GAMMA1 or GAMMA2. These options are discussed below and a flow diagram is shown in Fig. 2.

The probability of beta disintegration with total relativistic energy $W$, in electron rest energy units, in group $i$ is

$$N_i(Z) = \int_{W_i}^{W_{i+1}} N(Z,W) \, dW,$$

where $W_i$ and $W_{i+1}$ are the $i$-th group energy boundaries, $Z$ is the atomic number, and $N(W) \, dW$ is the probability of beta disintegration with energy in the $W$ to $W + dW$ interval:7-8

$$N(Z,W) \, dW = CM^2 F(Z,W) K(W) W(W^2-1) \frac{1}{2} (W_0-W)^2 \, dW,$$

where

$$F(Z,W) = \text{electron density ratio or Fermi function},$$

$$C = \text{a constant},$$
\[ |M|^2 \] = the square modulus of the transition matrix element, 
\[ W_0 \] = maximum value of \( W \), 
\[ K(W) \] = shape factor dependent upon the type of transition (allowed, forbidden unique, etc.).

The electron density ratio, \( F(Z,W) \), has a relativistic form,\(^7,8\)

\[
F_{R}(Z,W) = \frac{4(1+2S)}{|\Gamma(3+2S)|^{2/\lambda C}} \left( \frac{2R}{\lambda C} \right)^{2S} e^{\pi y \left( \frac{W^2-1}{2} \right)^S} |\Gamma(1+S+iy)|^2 ,
\]

where

\[
S = (1-\alpha^2 Z^2)^{1/2} - 1 ,
\]

\[
\lambda C = \frac{\hbar}{m e} = 386 \times 10^{-13} \text{ cm} ,
\]

the rationalized wavelength of the electron,

\[
\alpha = \frac{e^2}{\hbar c} \simeq \frac{1}{137} ,
\]

the fine structure constant, and a nonrelativistic form,\(^7\)

\[
F_{N} = \frac{2\pi y}{1-\exp(-2\pi y)} ,
\]

where

\[
y = \alpha Z W (W^2-1)^{-1/2} .
\]

A well-known expression for \( R \), the nuclear radius, is\(^9\)

\[
R = \left( \frac{1}{3} - \frac{1}{3} \right) x 10^{-13} \text{ cm} .
\]
The difference among the four beta-spectrum subroutines given as options depends mainly on the way in which the Fermi function, \( F(Z,W) \), is represented and calculated.

Since the relativistic form of \( F(Z,W) \), Eq. (3), makes Eq. (1) nonintegrable analytically, one may resort to numerically integrating Eq. (1). Subroutine BETA2 provides a variable-grid Simpson integration method designed to iterate until the user-requested accuracy is achieved. This method is accurate but quite time-consuming especially when high accuracy (e.g., 0.01\%) is requested.

Alternately, one may accelerate the integration of Eq. (1) by calculating \( F(Z,W) \) at a number of points per group and applying a histogram integration procedure. Subroutine BETA4 uses such a method with three equidistant points per group.

The remaining two options provided by subroutines BETA1 and BETA3 use approximations to \( F(Z,W) \) which make Eq. (1) analytically integrable.

Subroutine BETA1 uses a very simple approximation to \( F(Z,W) \) that proved to be of good accuracy and wide use in calculating average beta energies. This method, however, has produced considerably less accurate spectra. It uses a simplified version of the nonrelativistic form of \( F(Z,W) \), Eq. (7), namely,

\[
F(Z,W) \approx 2\pi y .
\] (10)

A new and better approximation to \( F(Z,W) \) is used in subroutine BETA3. It consists of replacing the relativistic form of \( F(Z,W) \), Eq. (3), by a polynomial expression in \( W \):

\[
F(Z,W) \approx \left( \frac{2R}{\lambda_c} \right)^{2S} \left( W^2 - 1 \right)^{-\frac{1}{2}} \left[ A_0(Z) + A_1(Z) W + A_2(Z) W^2 \right] ,
\] (11)

where the \( A \)'s are functions of the atomic number \( Z \). For a more detailed discussion of this method, the reader should consult Ref. 11.

There are two options for calculating the gamma spectra. One, used in the GAMMA1 subroutine, consists of incorporating the unbroadened gamma lines weighted by their intensities into an arbitrary number of constant-width energy groups over the interval of interest.

When comparing calculated spectra with experimental ones, the latter have an inherent energy broadening which must be accounted for in calculations.
The energy dependence of the line broadening depends on the particular gamma spectrometer used. Line broadening of calculated gamma spectra is of little importance if the chosen energy grid is such that the detector resolution (Full Width at Half Maximum, FWHM) is small by comparison with the group width. If the reverse is true, the broadening can be applied to the multigrouped line data without great loss of accuracy. For intermediate cases, however, the gamma lines must be properly broadened before multigrouping. Such a procedure is offered in subroutine GAMMA2.

It is customary to assume that the energy resolution of a spectrometer is essentially Gaussian, i.e., that the gamma line at $E_0$ is represented by a Gaussian curve about $E_0$, the area under which equals the line intensity, $I$:

$$ G = \frac{I}{\sqrt{2\pi} \sigma} \exp \left[ -\frac{(E-E_0)^2}{2\sigma^2} \right] . \quad (12) $$

The FWHM of the Gaussian is related to $\sigma$ by

$$ \text{FWHM} = \sigma \sqrt{8 \ln 2} = 2.35482 \sigma \quad . \quad (13) $$

Subroutine GAMMA2 broadens each line according to a prescribed energy dependence of $\sigma$ (variable SIGMA in the program) and then proceeds with the multigrouping into the required fixed energy grid. Subroutine GAMMA2 contains a specific relationship between $\sigma$ and energy but it must be replaced with the appropriate one specified for the gamma spectrometer under consideration.

III. THE FPSPEC PROGRAM

The FPSPEC program calculates aggregate beta and gamma fission-product spectra. The temporal activities of the 824 fission products on the ENDF/B-IV file are calculated by the CINDER-10 code at the desired irradiation and cooling times. The beta and gamma multigroup spectra of the individual fission products for which spectral data are available are provided by the FPDCYS code as discussed above. CINDER-10 calculates concentrations, activities, and decay energies for the 824 fission products on the ENDF/B-IV file. The most important of these from the decay energy point of view (a total of 181) have either beta or gamma spectral data or both. These are the ones for which FPDCYS constructs
cumulative multigroup beta and/or gamma spectra.\textsuperscript{12}

The FPSPEC program reads the output spectral file of FPDCYS and it then searches in the CINDER-10 output for activities of corresponding nuclides and for total beta and gamma decay energies of the decaying fission products among the 824 (some of them are stable). Cumulative beta and gamma spectra for the 181 fission products with spectral data on ENDF/B-IV are first obtained. These spectra are then normalized to the total beta or gamma energy release of all 824 fission products as calculated by CINDER-10 so that the spectra be representative of all 824 fission products. In other words, it is assumed that the fission products for which there are no spectral data in ENDF/B-IV yield the same cumulative spectral shape as those 181 for which there are spectral data in ENDF/B-IV. This assumption was seen to be an excellent approximation when calculated and experimental spectra were compared.\textsuperscript{2}
The cumulative spectra calculated by FPSPEC are given both in terms of disintegrations (betas or gammas) per fission per energy bin and energy release (MeV) per fission per energy bin. The latter representation tends to emphasize the high-energy portion of the spectrum when plotted.

The output of FPSPEC also contains a summary of data either calculated in the code or extracted from the CINDER-10 output. All quantities qualified by the word "CINDER" are from the CINDER-10 code. All quantities qualified by the word "TOTAL" refer to all 824 fission products; the rest refer to the 181 fission products with spectral data in ENDF/B-IV.

The programming language in FPSPEC is standard ANSI FORTRAN. The plotting subroutines for paper output and for film called by FPSPEC are LASL library routines and can be replaced by comparable plotting routines. The two subroutines EXL and EXH, also called by the program, are used only to determine the line intensity for plotting on film.

A general flowchart of the FPSPEC program is shown in Fig. 3. Card input descriptions for both programs, FPDCYS and FPSPEC, are given in the following sections. Listings of the two codes as used at LASL are given in Appendices A and B. Sample outputs for the two programs are given in Appendices C and D.
### IV. CARD INPUT TO FPDCYS

<table>
<thead>
<tr>
<th>Card No.</th>
<th>Format</th>
<th>Variable</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1X,14,6I5</td>
<td>MTOT</td>
<td>Total number of MATS to be read; MTOT = 1 gets special printout, normally 0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NXC</td>
<td>Number of cross-section cards (this option is not used, leave blank or 0).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MTR1</td>
<td>First mass number on File 5, the fission-product file.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MTR2</td>
<td>Last mass number on File 5.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NPNCH</td>
<td>Index to get punch output of decay branching; normally 0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JOP1</td>
<td>Index not used in this version; use 0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JOP2</td>
<td>Index to get spectral data; use 1.</td>
</tr>
<tr>
<td>2</td>
<td>7I10</td>
<td>NTAPE</td>
<td>Index; NTAPE = 1 causes output spectral File 11 to be written.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NBETS</td>
<td>Index; NBETS = 1 causes beta spectra to be calculated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NGAMS</td>
<td>Index; NGAMS = 1 causes gamma spectra to be calculated.</td>
</tr>
<tr>
<td>3</td>
<td>2I5</td>
<td>NBDB</td>
<td>Number of beta-group boundaries.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IBET</td>
<td>Index; if equal to 1, 2, 3, 4, subroutine BETA1, BETA2, BETA3 or BETA4, respectively, is called.</td>
</tr>
<tr>
<td>4</td>
<td>6E12.4</td>
<td>EBDB(I), I=1,NBDB</td>
<td>Energies of beta-group boundaries (eV).</td>
</tr>
<tr>
<td>5</td>
<td>2I5</td>
<td>NBDG</td>
<td>Number of gamma-group boundaries.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IGAM</td>
<td>Index; if equal to 1, 2, subroutine GAMMA1 or GAMMA2, respectively, is called.</td>
</tr>
<tr>
<td>6</td>
<td>6E12.4</td>
<td>EBDG(I), I=1,NBDG</td>
<td>Energies of gamma-group boundaries (eV).</td>
</tr>
</tbody>
</table>

### V. CARD INPUT TO FPSPEC

<table>
<thead>
<tr>
<th>Card No.</th>
<th>Format</th>
<th>Variable</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2I10</td>
<td>NPUN</td>
<td>Index controlling punch card output; if NPUN = 1, punch spectral output is produced.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NGAS</td>
<td>Index; if NGAS = 1, beta and gamma spectra from gaseous fission products only are generated (noble gases and halogens).</td>
</tr>
<tr>
<td>2</td>
<td>2I10</td>
<td>NPL0T</td>
<td>Index; if NPL0T = 1, plots of spectra will be generated,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IOPT</td>
<td>Index; set equal to 0.</td>
</tr>
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</table>
### FPSPEC (continued)

<table>
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<tr>
<th>Card No.</th>
<th>Format</th>
<th>Variable</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2I10</td>
<td>ICOMPB</td>
<td>Index; if ICOMPB = 1, calculated and experimental beta spectra are compared.*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ICOMPG</td>
<td>Index; if ICOMPG = 1, calculated and experimental gamma spectra are compared.*</td>
</tr>
<tr>
<td>4</td>
<td>2I10</td>
<td>NBPLT</td>
<td>Number of calculated beta spectral points to be plotted,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NGPLT</td>
<td>Number of calculated gamma spectral points to be plotted. Omit this card if NPLOT ≠ 1.</td>
</tr>
<tr>
<td>5</td>
<td>I10</td>
<td>NBEXP</td>
<td>Number of experimental beta-group boundaries for comparison. Omit this card if ICOMPB ≠ 1.</td>
</tr>
<tr>
<td>6</td>
<td>I10</td>
<td>NGEXP</td>
<td>Number of experimental gamma-group boundaries for comparison. Omit this card if ICOMPG ≠ 1.</td>
</tr>
<tr>
<td>7</td>
<td>I10</td>
<td>NBXPLT</td>
<td>Number of experimental beta spectral points to be plotted. Omit this card if ICOMPB ≠ 1 and NPLOT ≠ 1.</td>
</tr>
<tr>
<td>8</td>
<td>I10</td>
<td>NGXPLT</td>
<td>Number of experimental gamma spectral points to be plotted. Omit this card if ICOMPG ≠ 1 and NPLOT ≠ 1.</td>
</tr>
<tr>
<td>9</td>
<td>E12.4</td>
<td>QLMPLT</td>
<td>Lower limit value for the ordinate when plotting spectra. Omit this card if NPLOT ≠ 1.</td>
</tr>
<tr>
<td>10</td>
<td>6E12.4</td>
<td>EGX(I),</td>
<td>Experimental group-energy gamma boundaries (MeV).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I=1,NGEXP</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>6E12.4</td>
<td>GAMEXP(I),</td>
<td>Experimental gamma spectral points (MeV/fission/MeV of scale).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I=1,NGEXP-1</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>6E12.4</td>
<td>GAMERR(I),</td>
<td>Experimental gamma errors corresponding to GAMEXP(I). Omit cards 10-12 if ICOMPG ≠ 1.</td>
</tr>
<tr>
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<td></td>
<td>I=1,NGEXP-1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>6E12.4</td>
<td>EBX(I),</td>
<td>Experimental group-energy beta boundaries (MeV).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I=1,NBEXP</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>6E12.4</td>
<td>BETEXP(I),</td>
<td>Experimental beta spectral points (MeV/fission/MeV of scale).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I=1,NBEXP-1</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>6E12.4</td>
<td>BETERR(I),</td>
<td>Experimental beta errors corresponding to BETEXP(I). Omit cards 13-15 if ICOMPB ≠ 1.</td>
</tr>
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<td></td>
<td></td>
<td>I=1,NBEXP-1</td>
<td></td>
</tr>
</tbody>
</table>

*Use nonunity index if experimental data are not input.
REFERENCES


LISTING OF THE FPDYS PROGRAM

PROGRAM FPDYS(INP,OUT,PUN,FSET5,FSETA,FSET1)

DIMENSION H1(20),H2(510),ATYP(109),RF5(109),Q(100),OQ(100),
19R(190),DBR(190),KMI(900),KZ(900),KHZ(900),KS(900),
2KZC(200),KMC(200),KJC(200),AK4(200),RIK(200),BK1(200),
3KZC(200),BK3(200),R5(900),PI(900),FIC(900),
4KZCS(900),MC5(900),IC(900),A4(900),RI(900),
5R1(909),B2(900),B3(900),PER(900),PEQ(900),
6CQ(900),E0(900),LM(900),CV(900),CY(200),DE(900),
DIMENSION ERDB(200),SPEBET(200),SORSB(200),RATEN(200),BETAS(200),
1BERTAES(200)
DIMENSION ERDG(200),SPEGAM(200),SORSG(200),GAMASP(200),GAMASTE(200),
DIMENSION WOT(200)
DIMENSION E1D1(200),W1ID(200),EP02(200)

APPENDIX A LASL Identification No. LP-476.

DCYS IS EXTRACTED FROM DCY8 CODE TO PROCESS FP DATA ONE
NUCLIDE AT A TIME. USE DCY8 FOR MORE EXTENDED CAPABILITIES

C-------N WILL BE USED AS A COUNT OF MASSES
C-------MOTOT=MAXIMUM MATERIAL USED FOR PRINT OF SAVED DATA ***
C-------KN WILL BE USED TO COUNT MATERIAL IN SAVE STATEMENTS (FOLLOWING
C-------STATEMENT 125 UP TO 3 DECAY MODES ASSUMED
C-------Z,A, AND STATE READ FROM FILE 8
C-------X-SFC AND (N,GAMMA) BRANCHINGS READ FROM INPUT CARDS
C/////////// MODIFIED 7/30/75 (TO CAL EICC,ETC.) /////////////

C CONTROLS PARAMETERS READ FROM INPUT CARD
C MTOT=TOTAL NUMBER OF MASSES TO BE READ
C NXC=NUMBER OF CROSS SECTION CARDS
C MTR1-FIRST MASS NUMBER ON FILE 5
C MTR2-LAST MASS NUMBER ON FILE 5
C NPNCH=INDEX TO GET PUNCH OF DECAY BRANCHING NORMALLY 0
C JOP1=INDEX NOT USED IN DCYS, INSERT 0 FOR JOP1
C JDP2=INDEX TO GET SPECTRAL DATA, 0, ICC, ETC (SEE INSERT AT STMT 48)
C NOTE MTOT=0 GETS SPECIAL PRINT
C///////////

MTR=0
N=0
KN=0
ERF=5.11106E+05
DO 509 I=1,900
PCB(I)=0.0
PEQ(I)=0.0
PDO(I)=0.0
CQ(I)=0.0
ENQ(I)=0.0
CV(I)=XXXX
CYM2(I)=XXXX
DEO(I)=0.0
509 CONTINUE
2022 FORMAT(2E12.4)

APPENDIX A LASL Identification No. LP-476.

READ CHARGE, MASS AND STATE R24 NUCLIDES
READ (8,1000) (KZ(I),KMI(I),KS(I),I=1,824)
1000 FORMAT(1X,12,13,11,56X)

APPENDIX A LASL Identification No. LP-476.

READ SIGMA2200,PI,(N,GAMMA), BRANCHING (BOTH GROUPS), AND CORRELS

PONDING CHARGE MASS AND STATE, NXC NUCLIDES

APPENDIX A LASL Identification No. LP-476.

READ CONTROL CARD ****

READ 1001,MTOT,NXC,MTR1,MTR2,NPNCH,JOP1,JDP2
1001 FORMAT(1X,I4,6E15)
READ 2101,NTAPE,NBETS,NGAMS
2101 FORMAT(7I10)
PROGRAM FPDCYS(INP,OUT,PUN,FSET5,FSETA,FSET11)
DIMENSION HI(20),H2(500),RTYP(100),PFSC(100),N(100),DO(100),
BR(100),DBR(100),KNI(900),KZ(900),KMI(900),KS(900),
2KZC(200),KMC(200),KIC(200),AK4(200),AK1(200),
3KZC(200),K3(200),ES(900),PI(900),PFC(900),
4KZCS(900),MC(900),ICM(900),EM(900),RI(900),
5K1(900),RZ(900),RA(900),REM(900),PS(900),PS(900),
6K2(900),EN(900),LMAT(900),CM1(900),CM2(900),DELO(900),
DIMENSION ERBG(200),SPEBET(200),SORSG(200),GAMASP(200),GAMAES(200),
DIMENSION MTOT(200)
DIMENSION FR1(200),WMID(200),ERD2(200)

C-----DCYS IS EXTRACTED FROM DCY8 CODE TO PROCESS Fp DATA ONE
C-----NUCLIDE AT A TIME. USE DCY8 FOR MORE EXTENDED CAPABILITIES
C-----
C-----N WILL BE USED AS A COUNT OF HATS
C-----SET MTOT=MAXIMUM MATERIAL USED FOR PRINT OF SAVED DATA ***
C-----KN WILL BE USED TO COUNT MATERIAL IN SAVE STATEMENTS (FOLLOWING
C-----STATEMENT 125 UP TO 3 DECAY MODES ASSUMED
C-----Za, AND STATE READ FROM FILE 8
C-----X-SEC AND (N,GAMMA) BRANCHINGS READ FROM INPUT CARDS
C/////////// MODIFIED 7/30/75 (TO CAL EICC,Etc.) /////////////
C
C CONTROL PARAMETERS READ FROM INPUT CARD
C MTOT=TOTAL NUMBER OF MATS TO BE READ
C NXC=NUMBER OF CROSS SECTION CARDS
C MTR1=FIRST MASS NUMBER ON FILE 5
C MTR2=LAST MASS NUMBER ON FILE 5
C NPNC=INDEX TO GET PUNCH OF DECAY BRANCHING NORMALLY 0
C JOP1=INDEX NOT USED IN DCYS. INSERT 0 FOR JOP1
C JOP2=INDEX TO GET SPECTRAL DATA, Q, ICC,Etc (SEE INSERT AT STMT 48)
C NOTE MTOT=0 GETS SPECIAL PRINT
C/////////// MODIFIED 7/30/75 (TO CAL EICC,Etc.) /////////////

MTOT=0
N=0
KN=0
EREST=5.11906E+05
DO 500 I=1,900
PFBC(I)=0.0
PFGB(I)=0.0
PFO(I)=0.0
CQ(I)=0.0
ENQ(I)=0.0
CM1(I)=XXXX
CM2(I)=XXXX
DELO(I)=0.0
500 CONTINUE

202 FORMAT(3E12.4)
C-----READ CHARGE, MASS AND STATE A24 NUCLIDES
C-----READ (8,1000) (KZ(I),KMI(I),KS(I),I=1,824)
1000 FORMAT(1AX,13,11,56X)
C-----READ SIGMA2200, (N,GAMMA), BRANCHING (Both GROUPS), AND CORRESPONDING CHARGE MASS AND STATE, NXC NUCLIDES
C-----READ CONTROL CARD *****
C-----READ 1001,MTOT,NXC,MTR1,MTR2,NPNC,JOP1,JOP2
1001 FORMAT(1X,14,615)
C-----READ 2101, NTAPE, NBETS, NGAMS
2101 FORMAT(71I9)
IF(NNTAPE.NE.1) GO TO 6773
WRITE(11,6774)NBET3,NGAMS
6774 FORMAT(21I0)
6773 CONTINUE
READ 201,NRD8,IRET
NRD1=NRD8-1
NINT=150/(NRD8-1)
JRD8=1+(1*NINT)*(NRD8-1)
JRD8=1+IRET
2001 FORMAT(21S)

C IF NTAPF = 1, TAPE11 IS WRITTEN.
C IF NBET = 1, BETA SPECTRA ARE CALCULATED.
C IF NGAMS = 1, GAMMA SPECTRA ARE CALCULATED.
C IF IBER = 1, BETA1 ROUTINE IS USED.
C IF IBER = 2, BETA2 ROUTINE IS USED.
C IF IBER = 3, BETA3 ROUTINE IS USED.
C IF IBER = 4, BETA4 ROUTINE IS USED.
C IF IGAM = 1, GAMMA1 ROUTINE IS USED.
C IF IGAM = 2, GAMMA2 ROUTINE IS USED.
READ 2002,(ERDR(I),I=1,NBD8)
2002 FORMAT(6E12.4)
QINT=NINT+1
DO 2023 I=1,NBD8
DLT=(EBD1(I+1)-ERDR(I))/QINT
JN1=(I-1)*(NINT+1)+1
JN2=JN1+NINT
IL=0
DO 2023 II=JN1,JN2
IL=IL+1
QIL=IL+1
2023 EBD1(II)=EBD1(I)+QIL*DLT
EBD1(NBD8)=EBD1(NBD8)
DO 2024 I=1,NBD8
2024 EBD2(I)=EBD1(I)/EREST+1.
DO 2025 I=1,NBD8
2025 WRTD(I)=0.5*(FRD2(I)+FRD2(I+1))
READ 2001,NBDG,IGAM
READ 2002,(FRDG(I),I=1,NBDG)
NBDGM1=NBDG+1
IF(NNTAPE.NE.1) GO TO 6200
WRITE(11,6210)NBD8,IBET
6210 FORMAT(21S)
WRITE(11,6220)(EBD1(I),I=1,NBD8)
6220 FORMAT(6E12.4)
WRITE(11,6210)NBD8,IBET
6210 CONTINUE
PRINT 6201,IRET
6201 FORMAT(1H1,IAX,METHOD *,1* FOR BETA SPECTRA*/)
PRINT 6237,IGAM
6237 FORMAT(1H1,IAX,METHOD *,1* FOR GAMMA SPECTRA*/)
PRINT 8101
8101 FORMAT(1H0,2PX,BETA ENERGY BOUNDARIES (EV)*)
PRINT 8110
8110 FORMAT(1H0,2PX,GAMMA ENERGY BOUNDARIES (EV)*)
PRINT 8120
8120 FORMAT(1H0,2PX,BETA ENERGY BOUNDARIES (EV)*)
PRINT 8130
8130 FORMAT(1H0,2PX,GAMMA ENERGY BOUNDARIES (EV)*)
FORMAT(1H,20X,*----------------------------------------)
PRINT 8120, (FBG(I), I=1, NRDG)
PRINT 8150

FORMAT(1H0,////)
DO 2003 I=1, NRDG1
BETAS(I)=0.
2003 BETAS(I)=0.
DO 2004 I=1, NRDG1
GAMAS(I)=0.
2004 GAMAS(I)=0.
C READ I0R3, (KKZCCI, KKC(I), KKC(I), AK4(I), RIK(I), BK1(I), BK2(I),
C 19K3(I), I=1, NXC)
1003 FORMAT(15X, I2, I3, I1, I2, I3, I1, I2, I3, I1)
1006 CONTINUE
PRINT 100
100 FORMAT(1H1)
107 CONTINUE
C------CONTROL IS RETURNED TO THIS POINT AFTER EACH PROCESSED MAT
NEPB=0
NEPG=0
NEPBG=0
NS=0
PRINT 100
1 CONTINUE
N=N+1
DO 2 I=1, 20
M1(I)=1
2 CONTINUE
DO 3 I=1, 5000
M2(I)=1
3 CONTINUE
DO 4 I=1, 100
RTPS(I)=1, 0
RFS(I)=1, 0
Q(I)=1, 0
DO(I)=1, 0
BR(I)=1, 0
DBR(I)=1, 0
4 CONTINUE
MAT=0
FQ=0, 0
MAT1=0
MAT2=0
MAT3=0
MAT4=0
MAT5=0
MAT6=0
MF=0
MF1=0
MF2=0
MF3=0
MF4=0
MF5=0
MF6=0
LRP=0
LFI=0
NXC=0
MF6=0
MT=0
MT1=0
C-----READ TO FIRST MEND RECORD (ASSUMED TO BE FIRST CARD)

5 CONTINUE
READ(5,6) MAT1, MF1, MT1, NSE01
IF(EOF,5)201, 1213
1213 CONTINUE
6 FORMAT(66X, I4,12,I3,15)
1111 CONTINUE
MFT=MAT1+MF1+MT1
ISEQ=ISEQ+1
IF(MFT.GT.0) GO TO 111
IF(MFT.NE.0) PRINT 110, ISEQ, MAT1, MF1, MT1, NSE01
111 CONTINUE
110 FORMAT(1X,AH** CARD, 16,15H NOT HEND RECORD, 16H MAT, MF, MT, NSEQ=, I4, 11?, I3, I5).
   IF(MF, NE, 0) GO TO 5
   CONTINUE
   C------READ FIRST RECORD AFTER HEND TO MT=451
   READ(5, R) C1, C2, L1, L2, N1, N2, MAT2, MF2, MT2, NSEQ2
   IF (EOF, 5) 201, 1300
   1300 CONTINUE
   ISEQ=ISEQ+1.
  8 FORMAT(2E11.4,4I11, I4, I2, I3, I5)
   IF(MT2, NE, 451) GO TO 7
   IF(MF2, NE, 1) PRINT 40, ISEQ
   C------SET ZA, AWR, MAT, MF, MT
   ZA=C1
   AWR=C2
   LRP=L1
   LFI=L2
   NXC=N2
   MAT=MAT2
   MF=MF2
   MT=MT2
   ID=10, 0*ZA
   C------READ FIRST HOLLFRITH CARD
   READ(5, R) C1, C2, L1, L2, N1, N2, MAT3, MF3, MT3, NSEQ3
   IF(EOF, 5) 201, 1301
   1301 CONTINUE
   ISEQ=ISEQ+1.
   LDD=L1
   LFP=L2
   NWD=N1
   C------NWD=N(). HOLLERITH CARDS, 17 WORDS PER CARD
   C------USE FIRST CARD TO DEFINE SYMBOL(SYM1, SYM2)
   C------AND REMAINING TITLE H1(I), AND USE H2(I) FOR
   C------REMAINING HOLLERITH INFO.
   NW=17**(NWD-1)
   C------READ REMAINING HOLLERITH
   READ(5, 11) SYM1, SYM2, (H1(I), I=1, 14)
   DECODE(5, 22?2, SYM1) IZEE
   2222 FORMAT(1I2, 3Y)
   DECODE(5, 2223, SYM2) IAAA
   2223 FORMAT(1I2, 3Y)
   DECODE(5, 2224, SYM2) ATRAN
   2224 FORMAT(4X, A1)
   IF(EOF, 5) 201, 1302
   1302 CONTINUE
   ISEQ=ISEQ+1.
   11 FORMAT(1X, 2A5, (13A4, A2))
   C *** IF IH, GT, A SKIP READ TO MT=0
   IH=1
   IF(IH, GT, 0) GO TO 36
   READ(5, 12) (H2(I), I=1, NW)
   IF(EOF, 5) 201, 1303
   1303 CONTINUE
   ISEQ=ISEQ+1.
   12 FORMAT(16A4, A?)
   14 CONTINUE
   GO TO 39
   37 CONTINUE
   36 READ(5, 38) MT
   IF(EOF, 5) 201, 1304
1304 CONTINUE
ISEQ=ISEQ+1
38 FORMAT(72X,13)
   IF(MT,NE.0) GO TO 37
39 CONTINUE
C------ READ TO MT=457
READ(5,8) C1,C2,L1,L2,N1,N2,MAT5,MT5,NSEQ
   IF(EOF,5) 201,1305
1305 CONTINUE
ISEQ=ISEQ+1
IF(MT5,NE.457) GO TO 36
MTF5=MFS5+MT5
IF(MT5,NE.457) GO TO 116
   IF(MTF5,NE.0) GO TO 16
   IF(MTF5,NE.457) GO TO 39
   LIS=L1
   ID=(10,P*ZA+L1)
   NISP=NIS
   IF(ZA,NE.C1) PRINT 40,ISEQ
40 FORMAT(1H0,5HCARD,15,5H5IN ERROR)
   IF(ZA,NE.C1) GO TO 900
C------ READ HALFLIFE, NO. OF AVE. DECAY ENERGIES
READ(5,45) T,OT,NAV2,NAV1
   IF(EOF,5) 201,1306
1306 CONTINUE
ISEQ=ISEQ+1
45 FORMAT(2E11.4,22X,2I11)
C------ READ AVERAGE DECAY ENERGIES
READ(5,46) EB,DEB,EG,DEG,EA,DEA
   IF(EOF,5) 201,1307
1307 CONTINUE
ISEQ=ISEQ+1
46 FORMAT(6E11.4)
C------ READ NO. OF DECAY MODES
READ(5,47) NDK
   IF(EOF,5) 201,1308
1308 CONTINUE
ISEQ=ISEQ+1
47 FORMAT(55X,111)
C------ READ TYPE OF DECAY, ISOSTATES OF DAUGHTERS, Q AND BRANCHINGS
READ(5,46) (RTYP(I),RFS(I),(J(I),DQ (I), BR(I), DQ(R(I),DBR(I)),I=1,NDK)
   IF(EOF,5) 201,1309
1309 CONTINUE
ISEQ=ISEQ+1
C//////// INSERT 7/75 TO GET SPECTRAL DATA, ICC, ETC, WHEN JOP2=1 //----------
C VARIABLES
C ESC(I)= GAMMA OR BETA END POINT ENERGIES
C PI(I)= INTENSITIES
C FICC(I)= ICC
C F=NORMALIZATION
C STYP= TYPE SPECTRA
C NEP= NO ENERGY POINTS (CARDS) FOR SPECTRA
C NSP= NO OF SPECTRA
C NDK= NO OF DECAY MODES
C QENDK= Q VALUE WEIGHTED BY BRANCHING FRACTION
C ----CAL QUANTITIES PER MODE (NO BRANCHING FRACT INCLUDED)----
C ETG= TOTAL GAMMA E
C EICC= INT,CONVERSION E
C ETR= TOT TRANSITION E
FCE = ICC FRACTION OFTOT TRANSITION E
W = BETA E IN MC**2 UNITS.
WAVE = BETA WEIGHTING FACTOR
EBN= BETA+ NEUTRINO E
ERA= AVE BETA E
QQ= Q VALUE
NEPR=RUNNING COUNT OF RFTA END POINTS
NFPG=RUNNING COUNT OF GAMMA LINES
NOTE FND/F values of tot E-GAMMA INCLUDES ICC ENERGY, THEREFORE
COMPARE WITH ETR, NOT ETG

IF(JOP2.LE.0) GO TO 390
IF(NSP.LE.0) GO TO 390
NS=NS+1
PRINT 292,NS
292 FORMAT(1X,4I0)
PRINT 325,SYM1,SYM2,MAT5,NDK,NSP
325 FORMAT(15X,2A5/16X,F4.2/16X,F4.2/16X,F4.2/16X,F4.2/16X,F4.2/16X)
PRINT 2325,IDE
2325 FORMAT(1H,15X,*IDE=*,11$?)
IF(NTAPE,NE,1) GO TO 6100
WRITE(11,6110)SYM1,SYM2,IDE,MAT5,NDK,NSP
6110 FORMAT(2A5,11I0)
6100 CONTINUE
PRINT 297,ER,EG,FA,T
297 FORMAT(1H,15X,*ER=,E11.4/15X,*EG=,E11.4/15X,*FA=,E11.4/15X)
PRINT 298,(BR(I),I=1,NDK)
QENDF=0.0
PRINT 296,(Q(I),I=1,NDK)
296 FORMAT(1X,11H0=VALUE(S)=,3E11.4)
DO 295 I=1,NDK
QENDF=BR(I)*DQ(I)+QENDF
DELQ(NS)=BR(I)*DQ(I)+DELQ(NS)
295 CONTINUE
PRINT 294,QENDF,DELQ(NS)
294 FORMAT(1X,11HBRANCHINGS=,3E11.4)
298 FORMAT(1X,11HBRANCHINGS=,3E11.4)
QD=0.0
KSP=0
NSP=NS
NEP=0.0
ETG=0.0
ETR=0.0
EICC=0.0
FICC=0.0
EBA=0.0
EBN=0.0
ETN=0.0
FCE=0.0
F=0.0
299 CONTINUE
KSP=KSP+1
DO 300 I=1,700
ES(I)=0.0
PT(I)=0.0
FICC(I)=0.0
300 CONTINUE
300 CONTINUE
  IF(NSP.EQ.0) GO TO 48
  READ(5,301) STYP,NEP,MAT8,MFR,MTR,NSEQ8
301  FORMAT(E11.4,5X,I11,I4,I2,I3,I5)
  IF(NTAPE.NE.1) GO TO 677
  WRITE(11,6772)STYP
6772  FORMAT(F6.2)
6771  CONTINUE
  READ(5,302) F
302  FORMAT(E11.4,69X)
  DO 310 I=1,NEP
  READ(5,315) ES(I),PI(I),FICC(I)
310  CONTINUE
315  FORMAT(E11.4,11X,E11.4,11X,E11.4,25X)
  ISEQ= ISEQ+NEP+2
  IF(STYP.EQ.0,0,0) PRINT 326
326  FORMAT(1H9,14HGAMMA SPECTRUM/$X,7(2H--))
  IF(STYP.EQ.1,0,0) PRINT 327
327  FORMAT(1H9,13RETA SPECTRUM/$X,7(2H--))
  IF(STYP.EQ.2,0,0) PRINT 328, STYP
328  FORMAT(1H9,10HSPECTRUM TYPE=,E11.4/IX,13(2H--))
  PRINT 329, F,NEP
329  FORMAT(1H9,21HNORMALIZATION FACTOR=,E11.4/IX,14HNO. OF POINTS=,I4)
  CONTINUE
  TNEP= TNEP+ NEP
  IF(NEP.GT.700) PRINT 331
331  FORMAT(1X,16HNEP GT 700**(*)
  IF(NEP.GT.799) GO TO 48
C-------CALCULATE GAMMA TRANSITION ENERGIES AND TABULATE
  IF(STYP.EQ.0,0,0) GO TO 342
  DO 335 I=1,NEP
  ETG= ETG + F*ES(I)*PI(I)/100.0
  EICC= EICC+ F*FS(I)*PI(I)*FICC(I)/100.0
335  CONTINUE
  ETG= ETG + EICC
  FCE= FICC/ETG
  NEPG=NEP*F/NEP
  IF(FCE.GT.1.0E-10) NICC=NICC+1
  PRINT 337
337  FORMAT(1X,5@X,*THF SUM OF THE GAMMA ENERGY SPECTRUM IS
338  FORMAT(1H9,9X,E11.4,1X,E11.4/IX,13(2H--))
  PRINT 340 (I,ES(I),PI(I),FICC(I),I=1,NEP)
340  FORMAT(1X,14X,E11.4,1X,E11.4,1X,E11.4,4X,E11.4)
  IF(NGAMSM.NE.1) GO TO 7101
  DO 338 I=1,NBDGM1
  SPEGA(I)=0.
338  FORMAT(1H9,5@X,*THF THE GAMMA SPECTRUM IS
339  SPEGA(I)=0.
  SUMENG=0.
  IF(IGAM,EQ.1) CALL GAMMA1(ES,PI,NBDG,EBDG,SPEGA,SORSG,NEP)
  IF(IGAM,EQ.2) CALL GAMMA2(ES,PI,NBDG,EBDG,SPEGA,SORSG,NEP)
  DO 419 I=1,NBDGM1
419  SUMENG=SUMENG+SORSG(I)
  PRINT 421, SUMENG
421  FORMAT(1H9,5@X,*THF THE SUM OF THE GAMMA ENERGY SPECTRUM IS
422  FORMAT(1H9,5@X,*THF THE SUM OF THE GAMMA ENERGY SPECTRUM IS
423  SUMENG=SUMENG*F/100.
  PRINT 9101
9101  FORMAT(1H9,5@X,*THF THE SUM OF THE GAMMA ENERGY SPECTRUM IS
9110  FORMAT(1H9,5@X,*THF THE SUM OF THE GAMMA ENERGY SPECTRUM IS
         21
SPEGAN(I)=SPFGAM(I)*F/100.
SORSG(I)=SORSG(I)*F/100.
PRINT 9104,(SPFGAM(K),K=1,NBDGM1)
FORMAT(1H5X,6E12.4)
PRINT 9160
FORMAT(1H90,5PX,*NORMALIZED GAMMA ENERGY SPECTRUM*)
PRINT 9170
FORMAT(1H90,5PX,*---------------------*)
PRINT 9100,(SORSG(K),K=1,NBDGM1)
IF(NTAPE,NE,1) GO TO 6300
WRITE(11,6310)(SPFGAM(I),I=1,NBDGM1)
FORMAT(6E12.4)
WRITE(11,6310)(SORSG(I),I=1,NBDGM1)
6300 CONTINUE
PRINT 3421,SUMENG
FORMAT(1H90,5PX,*TOTAL GAMMA ENERGY EQUALS *,E12.4)
7101 CONTINUE
QQ=QQ+ETR
PRINT 341,ETG,EICC,ETR,QQ
FORMAT(1X,4HE-TG=,EI12,D11,4/1X,4HEETR=,EI12,D11,4/1X,
13HEQ=,EI12,D11,4)
IF(NGAMS,NE,1) GO TO 7102
IF(NTAPE,NE,1) GO TO 6400
WRITE(11,6310)ETG,SUMENG
6400 CONTINUE
GAMPDF=100.*(1.-ETG/SUMENG)
AGMPDF=ARS(GAMPDF)
IF(AGMPDF,GE,1.,RE=.3) PRINT 3419,GAMPDF
3419 FORMAT(1H90,10X,*1 = ETG / ENERGY-SPECTRUM=SUM ) X 100 = *,E12,4/)
7102 CONTINUE
LNSP=LNSP-1
IF(LNSP,LE,1) GO TO 399
GO TO 299
C------CAL BETA AND PRINT SPECTRUM
342 CONTINUE
IF(STYP,GT,1.,0) GO TO 355
PRINT 345
345 FORMAT(1H90,1PX,6HE-BETA,2X,13HRFL INTENSITY)
IF(NBETS,NE,1) GO TO 7103
DO 343 I=1,NBDGM1
BETAS(I)=1.
SUMX=0.
SUMY=0.
343 CONTINUE
DO 349 I=1,NFP
PRINT 346,I,(BETAS(I),PI(I))
IF(PI(I),LE,1.,OE=20) PI(I)=1.,OE=20
IF(PI(I),LE,1.,OE=20) PRINT 3346
3346 FORMAT(1H90,35X,*THE INTENSITY IS ZERO BUT IT IS SET TO 1.,OE=20*)
IF(NBETS,NE,1) GO TO 7104
EZ=ES(I)
PKE=PI(I)
7104 CONTINUE
346 FORMAT(1X,I4,1X,E11.4,1X,E11.4)
IF(NBETS,NE,1) GO TO 7105
WHAX=ES(I)/EPEST+1.
DO 348 J=1,KBD
WTOT(J)=ERDB(J)/EPEST+1.
22
RATEN(J) = (ERDB(J) + EREST) / (ES(I) + EREST)

IF(IRFT.EQ.1) CALL BTA1(EZ, PK, NBDB, EBD, SPEBET, PLAMDA, CRAT, SORSB, RATEN, C2Z)
ZEE=1EZE
AAA=1AAA
IF(IRFT.EQ.2) CALL BTA2(EZ, PK, NRDB, EBD, SPEBET, SDSRB, RATEN, C2Z, WDT, WMAX, ZEE, AAA)
IF(IRFT.EQ.3) CALL BTA3(EZ, PK, NBDB, EBD, SPEBET, SORSB, RATEN, C2Z, WDT, ZEE, AAA, WMAX, A0, A1, A2)

IF(IRFT.EQ.4) CALL BTA4(EZ, PK, NBDB, EBD, SPEBET, SORSB, RATEN, C2Z, WDT, WMAX, ZEE, AAA)

PUICH 3355, SYM1, SYM2, C2Z, EZ, PK

CONTINUE
3355 FORMAT(2A5, 3E12.4)
3344 FORMAT(2A5, E12.4)

IF(NBETS.NE.1) GO TO 7106
SUMX = SUMX + C2Z*PI(I)
SUMY = SUMY + PI(I)
DO 347 K = 1, NBDM1
BETAS(K) = BETAS(K) + SPEBET(K)
BETAES(K) = BETAES(K) + SORSB(K)

CONTINUE

IF(NBETS.NE.1) GO TO 7107
PRINT 334
334 FORMAT(1H, 35X, *TOTAL BETA SPECTRUM*)
PRINT 334, (BETAS(K), K = 1, NBDM1)
PRINT 333
333 FORMAT(1H, 35X, 6E12.4)

DO 303 K = 1, KROM1
BETAS(K) = BETAS(K) * F / 100.
BETAES(K) = BETAES(K) * F / 100.
PRINT 9340, (BETAs(K), K = 1, NBDM1)

FORMAT(1H, 35X, *THE SUM OF THE BETA ENERGY SPECTRUM IS *, E12.4)
SUMENB = SUMENB + RETAES(I)
PRINT 9310, (BETAs(K), K = 1, NBDM1)

FORMAT(1H, 35X, *NORMALIZED TOTAL BETA SPECTRUM*)
PRINT 9310
9310 FORMAT(1H, 35X, *----------------------------------------*)
DO 9320 I = 1, NBDM1
BETAS(I) = BETAS(I) * F / 100.
9320 BETAS(I) = BETAES(I) * F / 100.
PRINT 9340, (BETAs(K), K = 1, NBDM1)

FORMAT(1H, 35X, 6E12.4)
PRINT 9370
9370 FORMAT(1H, 35X, *NORMALIZED TOTAL BETA ENERGY SPECTRUM*)
PRINT 9380
9380 FORMAT(1H, 35X, *----------------------------------------*)
PRINT 9340, (BETAs(K), K = 1, NBDM1)

IF(NTAPE.NE.1) GO TO 6500
WRITE(11, 6310) (BETAS(I), I = 1, NBDM1)
WRITE(11, 6310) (BETA(K), I = 1, NBDM1)

CONTINUE
PRINT 334, SUMFNRA
3344 FORMAT(1H, 35X, *TOTAL BETA ENERGY EQUALS *, E12.4)
C2ZAV = SUMX/SUMY
C PUNCH 3344, SYM1, SYM2, C2ZAV

CONTINUE
DO 350 I = 1, NEP
$W = \frac{ES(I)}{(1.511E+6)}$

$WAVz(ia: O+8,0*W+?,0*W**2) /(U,R*(10,0+5,0*w+W**2) )$

$ERN= ES(I)*pI(l)*F/laO,O +EBN$

$ERA= ERA + ES(I)*pI(I)*F*WAV/100.$

350 CONTINUE
ETN=ERN=EBA
QQ=EQ*ERN.
NPB=NFPR+NEP
PRINT 351,ERN,FBA,ETN,QQ

351 FORMAT(IX,12HE-BETA/NU=FM=,E11.4/I1X,7HE-BETA=,E11.4/I1X,
11HE-NU=0=,E11.4/I1X,3HE-Q=,E11.4/I1X)

IF(NBETS.NE.1) GO TO 7108
IF(NTAPE.NE.1) GO TO 6600
WRITE(11,6310) ERA,SUMEB

6600 CONTINUE
BETPDF=100.*(1.-ERA/SUMEB)
ARTPDF=ABS(BETPDF)
IF(ABTPDF.GE.3.E0) PRINT 3334,RETPOF

3334 FORMAT(1HE,100X,*((1.-E-BETA/ENERGY=SPECTRUM-SUM)*100 = *,
1E12.4/)

7108 CONTINUE
LNSP=LNSP+1
IF(LNSP.EQ.0) GO TO 390
GO TO 299

355 IF(STYP,GT,1.0) PRINT 356
356 FORMAT(IX,38H ANOTHER SPEC IS INCLUDED *****)

390 IF(NSP,LE,0) GO TO 48
FQ=EQ*QNDT)/QNDF
IF(EB,GT,0.0) PEB(NS)=100.0*(ERA-EB)/ER
IF(EG,GT,0.0) PEG(NS)=100.0*(ETR-EG)/EG
PEQ(NS)=100.0*FQ
CO(NS)=QQ
ENQ(NS)=QNDF
LMAT(NS)=MAT5
SYM1(NS)=SYM1
SYM2(NS)=SYM2
PDQ=DELQ(NS)*100.0/QNDF

C

IF(JDP2,LE,0) GO TO 48

C

PRINT 357

357 FORMAT(1HE,20HCALCULATED ENERGIFS (ENDF/B))
PRINT 358,ERA,EB,ETR,ETG,ETN,EICC,FCE,QQ,QNDF,PDQ

358 FORMAT(IX,9HAVE BETA=,E11.4/I1X,1H(E11.4,1H)/
11X,17HAVE TRANSITION E=,E11.4/I1X,1H(E11.4,1H)/
61X,24HFRACTOT E=,E11.4/I1X,
22HQN=,1H(E11.4,3H=,F8.4,5H PCT))
PRINT 5001,FQ

5001 FORMAT(IX,3HFQA=,E11.4)
IF(EICC,GT,1.0) PRINT 5002,EICC,FCE

5002 FORMAT(0X,13HFICC AND FCE=,E11.4)
IF(ABS((ERA-EB)/EB),0.001) PRINT 5010

5010 FORMAT(0X,26HRETA ENERGIES DO NOT AGREE)
IF(ABS((ETR-EG)/(EG-0.001)),-1.0,0.001) PRINT 5011

5011 FORMAT(0X,27H GAMMA ENERGIES DO NOT AGREE)
TO=ABS(QO-QNDF)/QNDF+0.0001
IF(TO,GT,0.03) PRINT 5012
5012 FORMAT(50X,32H**Q DIFFERENCE EXCEEDS 3 PCT***)
      IF(Delo(NS),EQ,0.0) GO TO 5015
      DTO=DTO*(DENDF+0.0001)
      IF(DTO,GT,DELQ(NS)) PRINT 5014
      IF(DTO,LE,DELQ(NS)) PRINT 5016
5016 FORMAT(50X,34H0 DIFFERENCE IS WITHIN UNCERTAINTY)
5014 FORMAT(50X,32H0 DIFFERENCE EXCEEDS UNCERTAINTY)
5015 CONTINUE
PRINT 5000
5000 FORMAT(11H39(PH=))
C---------------------------------------------------------------------------------------
48 CONTINUE
C---------- SKIP REMAINDER OF 457 THRU MEND CARD
READ(5,6) MAT6,MF6,MT6,NSEC6
      IF(EOF,5) 201,1310
1310 CONTINUE
      ISE0=ISE0+1
      IF(MAT6,NE,MAT) PRINT 120,ISE0,MAT6,MF6,MT6
120 FORMAT(1X,36HNO MEND CARD OR CARD ERROR, CARD ,15,3X,14,12,13)
      KFEND=MF6+MT6
      IF(KFEND,NE,0) GO TO 48
C--------- PRINT DATA FOR THIS MAT IF MTOT .NE.0
C--------- NEXT CARD SHOULD BE MEND
C--------- PRINT DATA FOR THIS MAT
C ***** CONTROL XFERRED BACK TO HERE FROM 16
125 CONTINUE
C--------- AT THIS POINT ALL NUCLIDE DATA HAS BEEN READ FOR THIS MAT,
C--------- FOLLOWING VARIABLES ARE SAVED PER MAT.** NOTE THAT SAVE ASSUMES
C---------- NK,LE,4, ADD CHECK FOR THIS
      MTR=MTR+1
      KDI(MTR)=ID
      KR=KDI(MTR)-(If**2*KZC(MTR)+10*KMI(MTR)+KS(MTR))
      IF(KR,GT,0) GO TO 1010
      IF(MTOT,GT,0) GO TO 1010
1011 FORMAT(1X,27HINPUT AND TAPE ID NOT EQUAL1217)
1010 CONTINUE
      IF(JOP2,LE,0) GO TO 360
      IF(N,NE,MTOT,AND,JOP2,GT,1) GO TO 221
359 FORMAT(1H1,26HNO OF SPECTRAL POINTS==, I6)
      IF(N,GT,MTOT) GO TO 900
360 CONTINUE
      IF(NSp,LE,0) NSp=0
      IF(NK,LE,0) NK=0
C--------- INSERT CROSS SECTIONS AND (N,GAMMA) BRANCHING RATIOS
DO 1033 I=1,181
      NID=10000*KKCZC(I)+10*KMC(I)+KIC(I)
      IF(NID,NE,0) GO TO 1034
      KZC5(MTR)=KKCZC(I)
      MC5(MTR)=KMC(I)
      KIC(MTR)=KIC(I)
      A6(MTR)=AK6(I)
      RC(MTR)=RK6(I)
      B1(MTR)=BK1(I)
      B2(MTR)=BK2(I)
      B3(MTR)=BK3(I)
1034 CONTINUE
1033 CONTINUE
151 CONTINUE
C---------------------------------------------------------------------------------------
C--------- FOLLOWING QUANTITIES ARE STORED IN THE ORDER FOUND ON

THE BNL TAPE - INDEX MTR RUNS FROM 1 - 825 AND NUCLIDES ARE IN ORDER Z,A,I. DO LOOP AT STATEMENT 263 ORDERS THE PRINT A,Z,I. CROSS SECTIONS ARE APPROXIMATE. NOTE IN FOLLOWING LIST, THE SUBSCRIPT IS OMITTED IF THERE IS A SINGLE SUBSCRIPT.

SYMBOL MEANING
KDI NUMERICAL ID=10000*Z+10*A+I
SM1,SM2 TOGETHER THESE GIVE THE ALPHANUMERIC
SBR(I,MTR) BRANCHING FRACTION, MODE I

CALCULATE PERCENT DEVIATIONS FROM ENDF/B VALUES.
PB(I)= PERCENT OF AVERAGE BETA
PG(I)= PERCENT OF AVERAGE GAMMA
PEQ(I)= PERCENT OF Q VALUE
CQ(I)= CALCULATED Q
ENQ(I)= ENDF/B Q
LMAT(I)= MAT No.
CSM(I)= HALF OF ID
CSM2(I)= HALF OF ID
DEL(I)= UNCERTAINTY IN Q

FOLLOWING VALUES ARE INSERTED -------
WHEN THE NUCLIDE HAS A CROSS SECTION.
OTHERWISE ALL VALUES ARE SET TO -9
KZCS Z OF CS NUCLIDE
MC5 A VALUE OF CS NUCLIDE
ICS ISOMERIC STATE OF CS NUCLIDE
A4 220A H/S CROSS SECTION
RI RES, INT.
B1,2,3 (N/GAMMA) BRANCHING TO GND, FIRST
AND SECON ISOISOMIC STAT OF
DAUGHTER.

IF(HTOT.GT.9) GO TO 260
PRINT 10,SYM1,SYM2,ID,MAT

FOLLOWING PRINT OF REFS TEMPORARILY REMOVED
PRINT 29,SYM1,SYM2,(HI(I),I=1,14)
PRINT 30,(H2(I),I=1,NW)
PRINT 31,ZA,AWR,NDK,NSP
TM=$T/60.0
TH=$T/3600.0
TD=$T/86400.0
Y=3.15569*(1**7)
Y=3.15569E+7
IF(T.LE.60.0) GO TO 146
IF(T.LE.3600.0) GO TO 147
IF(T.LE.86400.0) GO TO 148.
IF(T.GE.Y) GO TO 149
IF(T.GT.Y) GO TO 153
146 PRINT 141,T
GO TO 144
147 PRINT 144,TH
GO TO 144
148 PRINT 142,TH
GO TO 144
149 PRINT 143,T0
GO TO 144
153 PRINT 152,TY
144 CONTINUE
140 FORMAT(1X,1AHHALFLIFE,=,E12.5,1HS)
141 FORMAT(1X,1AHHALFLIFE,=,E12.5,1HM)
142 FORMAT(1X,1OHHALFLIFE,=,E12.5,1HH)
143 FORMAT(1X,1OHHALFLIFE,=,E12.5,1HD)
152 FORMAT(1X,1OHHALFLIFE,=,E12.5,1HY)
31 FORMAT(1H0,4ZHAE,=,E11.4/
11X,5HAWR=,E11.4/
21X,18HNO, OF OXY MOSES=,I3/
31X,16HNO, OF SPEF CTRA=,I5)
PRINT 60,1,1X,1RHFC,1X,1RTD,1X,1RDB,1X,1RD,1X,1REA
60 FORMAT(1H0,34X,1RAHDFCEAY ENERGIES(EV) /
14X,13HHHALFLIFE(SEC),AX,4HMBETA,7X,5HGAMMA,7X,5HALPHA/4X,4E12.4/
21X,3H+=,4E12.4/
C====PRINT DECAY MODE DATA
PRINT 80
80 FORMAT(1H0,34X,1RAHDFCEAY MODE DATA /
18X,4HMODE,2X,9HSTATE DTR,4X,7HQ VALUE,7X,4H+/=Q,3X,8HRR RATIO,6X,5
2H+=/RR)
PRINT 90, (RTYP(I),RFS(I),Q(I),QD(I),BR(I),DBR(I),I=1,NDK)
90 FORMAT(1X,6E11.4)
PRINT 50
GO TO 1
C====CONTROL GOES TO THIS POINT (16) IF NEXT CARD HAS MF5 AND MT5=0
16 CONTINUE
IF(MTOT.GT.0) GO TO 125
C====CHECK FOR END CARD
PRINT 10,SYM1,SYM2,IND,MAT
10 FORMAT(1H0,10(2H- ),2A5,1X,10(2H- )/20X,4HID=,1A/20X,5HMAT=,18//
1)
PRINT 20,SYM1,SYM2,(H1(I),I=1,14)
20 FORMAT(1X,2A5,(13A4,A2))
30 FORMAT(1X,16A4,A2)
PRINT 53
53 FORMAT(1H0,1SHND MF=457 FOUND)
PRINT 50
50 FORMAT(1X,79(1H-)/1X,79(1H-))
C====NEXT CARD SHOULD BE SEND, RETURNS TO 1
GO TO 1
200 CONTINUE
IF(MTOT.EQ.0) GO TO 1
IF(N.NE.MTOT) GO TO 1
201 CONTINUE
C====FOLLOWING STATEMENTS PRINT STORED DATA,
PRINT 210
210 FORMAT(1H0,15HRTYP=DECAY MODE/
11X,3HRRFS=ISOMERIC STATE OF DAUGHTER/
25X,4HRTYP=14H MODE OF DECAY/
36X,29H0,0 GAMMA (NOT USED FOR RTYP)/
46X,6H1,0 BETA/
56X,22H2,0 POSITRON AND/OR EC/
66X,6H3,0 IT/
76X,9H4,0 ALPHA/
86X,29H5,0 DELAYED NEUTRONS AND BETA/
96X,23H6,0 SPONTANEOUS FISSION)
220 CONTINUE
NPAGE=3
221 CONTINUE
IF(JOPZ.EQ.0) GO TO 901
PRINT 232
232 FORMAT(1H1,17X,38HPFRCENT DIFFERENCE OF CAL AND ENDF/B-4/8X,
17NUCLIDE, 7X, 4HET, 6X, 5H GAMMA, 10X, 1HQ, 2X, 3HMAT
PRINT 233, (I, CYMI(I), CYM2(I), PEB(I), PFG(I), PEQ(I),
1LMAT(I), I=I, NS)
233 FORMAT (1X, I4, 2X, 2A5, 3E11.4, I5)
PUNCH 234, (I, CYMI(I), CYM2(I), CG(I), ENQ(I), PEQ(I),
1I=I, NS)
234 FORMAT (1X, I4, I5, 1X, 2A5, 3E11.4)
PUNCH 232
PRINT 233, (I, CYMI(I), CYM2(I), PEB(I), PEQ(I), PEQ(I),
1LMAT(I), I=I, NS)
NEPB=NEPB+NPFG
PRINT 231, NEPB, NPFG, NEPB, NS, NICC
231 FORMAT (14H1, 17HNO DF SPEC LINES=1, I6, 5H BETA, I6, 6H TOTAL, I6, /1X,
121HNO DF NUCS WITH SPEC=I5/I1X,
217HNO DF NUCS WITH ICC=I7)
900 CONTINUE
901 CONTINUE
END

SURROUTINE BETA3(EX, PJ, NRO8, ERDB, SBERET, SDRSB, RATEN, C2Z, WZ, A, WMAX
1, AR, A1, A2)
DIMENSION ERDB(200), SPEBET(200), SDRSB(200), RATEN(200), W(200)
ERET=5.11*ER*85
AZRO=3.132e-10+4.8126E-02*ZEE+9.3870E-05*ZEE**2+4.8527E-06*ZEE**3
1+2.6034E-08*ZEE**4
AONE=3.124E-01+1.5766E-02*ZEE+4.3264E-04*ZEE**2+1.1359E-07*ZEE**3
1+3.8354E-08*ZEE**4+2.8702E-10*ZEE**5
ATWO=1.2837-6.026AF-03*ZEE+3.8474E-04*ZEE**2+
16.962E-07*EXP(-2.8566E-04*(1+0.01-ZEE)**2)
A1=3.1AZRO+4.*AONE+ATWO
A2=AZRO+2.*AONE+ATWO
ZALPHA=Z/117.04
Z2=ZALPHA*ZALPHA
S=(1-Z2)**0.5=1.
WZSQ=WMAX*WMAX
CK1=AW
CK2=A1=2.*A2*WMAX
CK3=A2=2.*A1*WMAX+A2*WZSQ
CK4=A1*WZSQ=2.*A0*WMAX
CK5=A0*WZSQ
WM3=WMAX*WZSQ
WM4=WM3*WMAX
WM5=WM4*WMAX
WM6=WM5*WMAX
WM7=W6*WMAX
FIN1=CK1*(W6=1.)/6.*CK2*(W5=1.)/5.*CK3*(W4=1.)/4.
1+CK4*(W3=1.)/3.+CK5*(WZSQ=1.)/2.
FINT1=CK1*(W7=1.)/7.+CK2*(W6=1.)/6.*CK3*(W5=1.)/5.+
1CK4*(W4=1.)/4.+CK5*(W3=1.)/3.
EAV=FREST*(FIN1/FINT2=1.)
PI=3.141592654
SUM5=0.
SUMES=0.
TEM5=2.
APWR=A1*0.3333333333333333
R=1.123+APWR/0.401/APWR
COMPTW=3.861444F+R2
TEMP2 = (?*R/COMPTW)**TWOS
C1ZA = TEMP2
NGPS = NDATA + 1

DO 10 I = 1, NGPS
IF(W(I).GT.WMAX) GO TO 5
IF(W(I+1).GT.WMAX) W(I+1) = WMAX
W7 = W(I+1)**7 - W(I)**7,
W6 = W(I+1)**6 - W(I)**6,
W5 = W(I+1)**5 - W(I)**5,
W4 = W(I+1)**4 - W(I)**4,
W3 = W(I+1)**3 - W(I)**3,
W2 = W(I+1)**2 - W(I)**2,
SPEBET(I) = (C1*K1*W7/6 + C2*K2*W6/5 + C3*K3*W5/4 +
1*C4*K4*W4/3 + C5*K5*W3/2 + C6*K6*W2)*C1ZA
SORSB(I) = (C1*K1*W7/7 + C2*K2*W6/6 + C3*K3*W5/5 + C4*K4*W4/4 +
1*C5*K5*W3/3)*C1ZA*SPEBET(I) * FREST
5 SPEBET(I) = 0,
SORSB(I) = 0,
6 CONTINUE
SUMS = SUMS + SPEBET(I)
SUMES = SUMES + SORSB(I)
10 CONTINUE
C2Z = PJ/SUMS
DO 15 I = 1, NGPS
SPEBET(I) = C2Z * SPEBET(I)
SORSB(I) = C2Z * SORSB(I)
SUMS = SUMS * C2Z
SUMES = SUMES * C2Z
TMPR1 = ABS((I - SUMS/EAV/PJ)
IF(TMPR1 = 1.0F-06) 30, 30, 40
40 PRINT 45, TMPR1
45 FORMAT(1H, * SPE. NORM. WRONG, TMPR1 = *, E12, 4)
30 CONTINUE
TMPR2 = ABS((I - SUMES/EAV/PJ)
IF(TMPR2 = 1.0F-06) 35, 35, 55
55 PRINT 56, TMPR2
56 FORMAT(1H, * EN. SPE. NORM. WRONG, TMPR2 = *, E12, 4)
35 CONTINUE
PRINT 50
50 FORMAT(1H, 35X, * BETA SPECTRUM*)
PRINT 65, (SPEBET(K), K = 1, NGPS)
65 FORMAT(1H, 35X, E12, 4)
PRINT 80
80 FORMAT(1H, 35X, * BETA ENERGY SPECTRUM*)
PRINT 90, (SORSB(K), K = 1, NGPS)
90 FORMAT(1H, 35X, E12, 4)
101 FORMAT(1H, 35X, AVERAGE BETA ENERGY = *, E12, 4)
RETURN
END
SUBROUTINE BETA4(EK, PJ, NBDR, EBDR, SPEBET, SORSB, RATEN, 
NC27, W, WMAX, Z, A, AO, AI, A2)
DIMENSION EBDR(200), SPEBET(200), SORSB(200), RATEN(200), W(200)

SAME AS BETA2 BUT USES THE MIDPOINTS, NOT NUMERICAL INTEGRATION

NGPS=NBDR-1
EREST=5.11086E+05
OVR3=1./3.
AA=A
APWR=A**OVR3

DO 10 I=1,NGPS
IF(W(I);GE.WMAX) GO TO 5
IF(W(I+1).GT.WMAX) W(I+1)=WMAX
W4=5*(W(I)+W(I+1))
W2=5*(W(I)+W4)
W6=5*(W4+W(I+1))
W1=5*(W(I)+W2)
W3=5*(W2+W4)
W5=5*(W4+W6)
W7=5*(W6+W(I+1))
DELW=W1-W(I)
CALL FERM1(W1, ZALPHA, S, SP1, SPH, WMAX, CONST, PN1, PEN1, F7W1)
CALL FERM1(W3, ZALPHA, S, SP1, SPH, WMAX, CONST, PN3, PEN3, FZW3)
CALL FERM1(W7, ZALPHA, S, SP1, SPH, WMAX, CONST, PN7, PEN7, FZW7)
SPEBET(I)=DELW*(PN1+PN3+PN5+PN7)
SORSB(I)=SPEBET(I)*C2Z
GO TO 6
5 SPEBET(I)=0.
SORSB(I)=0.
6 SUMN=SUMN+SPBRET(I)
10 SUMEN=SUMN+SORSB(I)
EAV=SUMEN/SUMN
ENPD=(1.-AVN/EAV)*100.
ENPDS=(1.-EAVS/EAV)*100.
C2Z=PJ/SUMN
DO 20 I=1,NGPS
SPEBET(I)=SPEBET(I)*C2Z
20 SORSB(I)=SORSB(I)*C2Z
PRINT 5A
5A FORMAT (1H0, 35X, *BETA SPECTRUM*)
PRINT 65, (SPEBFT(K), K=1, NGPS)
SUBROUTINE RETA1(EX, NPDB, EBDB, SPEBET, PLAMDA, CRAT, SORPB, RATEN, IC22)
DIMENSION ERDB(200), SPEBET(200), SORPB(200), RATEN(200)

THIS SUBROUTINE CALCULATES BETA SPECTRA, BETA ENERGY SPECTRA,
THEORETICAL INTENSITIES AND NORMALIZATION FACTORS.
IT USES THE LOW BETA ENERGY APPROXIMATION FOR F(z,w)
NPDB = NUMBER OF GROUP BOUNDARIES,
EBDB = ENERGIES OF GROUP BOUNDARIES,
SPEBET = BETA SPECTRUM,
SORPB = BETA ENERGY SPECTRUM,
NGPS = NUMBER OF ENERGY GROUPS.

EREST=5.11006E+05
EY=EX/EREST+1.
SUM1=0.
SUM2=0.
SUM3=0.
SUM4=0.
EY2=EY*EY
EY3=EY2*EY
EY5=EY2*EY3
EY6=EY3*EY3
EY2=EY2*EY5
EY3=EY2*EY6
EY5=EY2*EY3
EY6=EY3*EY3
EAV=(EY6-2.*EY5+5.*EY2-6.*EY+2.)/(EY5-10.*EY2+15.*EY-6.)/2.,
FAV=EAV*FAV
TEMPQ=(1.-1./EY3)/3.*0.2*(1.-1./EY5)-0.5*(1.-1./EY4)
NGPS=NPDB-1
XP=NGPS
DO 10 I=1,NGPS
IF(RATEN(I).GT.1.) GO TO 5
IF(RATEN(I+1).GT.1.) RATEN(I+1)=1.
RI2=RATEN(I)*RATEN(I)
RI3=RI2*RATEN(I)
RI4=RI2*RI2
RI5=RI2*RI3
RI6=RI3*RI3
RI7=RI3*RI4
SPEBET(I)=((RI7-R16)/6.+0.4+0.2/EY)*R16*RI15*R16
SORPB(I)=((RI6-R15)/6.+0.4+0.2/EY)*R15*RI15
I1 R15
SAGE TO 6
SUBROUTINE BFTA2(Et, PJ, NBDR, EBDR, SPERET, SORSR, RATEN, 
1 C2Z, W, WMAX, Z, A)
DIMENSION EBDB(200), SPEGET(200), SORSB(200), RATEN(200), W(200)

SAME AS BETA1 BUT USES THE RELATIVISTIC F(Z,W) EXPRESSION

NGPS=NBDB-1
EREST=5.11006E+05
OVR3=1.7/3.
AA=A
APWR=A**OVR3
R=1.123*APWR=0.941/APWR
ALPHA=7.2972E-03
ZALPHA=Z*ALPHA
COMPTW=3.861U+02
S=(1.0-ZALPHA*ZALPHA)**0.5-1.
TWOS=S*2,AK2=(2.0/R/COMPTW)**TWOS
GMARG=3.4+TWOS
GH=GM1(GMARG)
GM2=GM*GM
AK1=4.0*(1.0+S/2.)/GM2
CONST=AK1*AK2
SPL=S+1,
SPH=S+0.5
SUMN=9.,
SUME=9.
CONV=.1
DO 10 I=1,NGPS
IF(W(I),GE,WMAX) GO TO 5
A=W(I)
IF(W(I+1),GT,WMAX) W(I+1)=WMAX
B=W(I+1)
CALL SIMPSN(A,B,1,CONV,QNTGRL,ZALPHA,S,SP1,SPH,WMAX,CDNST)
SPEBET(1)=QNTGRL
CALL SIMPSN(A,B,2,CONV,QNTGRL,ZALPHA,S,SP1,SPH,WMAX,CDNST)
SPRSR(I)=QNTGRL*EREST
GO TO 6
5 SPEBET(I)=0.
SORSB(I)=0.
6 SUMN = SUMN+SPEBET(I)
10 SUMEN = SUMEN+SORSB(I)
EAV=SUMFN/SUMN
CZ=PJ/SUMN
DO 20 I=1,NGPS
SPEBET(I)=SPEBET(I)*C2Z
20 SORSB(I)=SPRSR(I)*C2Z
PRINT 50.
50 FORMAT (1H0,35X,*BETA SPECTRUM*)
PRINT 65, (SPEBET(K),K=1,NGPS)
65 FORMAT (1H0,35X,6E12.4)
PRINT A0.
80 FORMAT (1H0,35X,*BETA ENERGY SPECTRUM*)
PRINT 65, (SORSB(K),K=1,NGPS)
PRINT 101,EAV
101 FORMAT (1H0,35X,*AVERAGE BETA ENERGY = *,E12.4)
RETURN
END

SUBROUTINE SIMPSN(A,B,IFLG,CDNV,QNTGRL,ZALPHA,S,SP1,SPH,WMAX,CDNST)
      DX=(B-A)/?,
      CALL FERMI(B,ZALPHA,S,SP1,SPH,WMAX,CDNST,PNB,PNB,FZWB)
      CALL FERMI(A,ZALPHA,S,SP1,SPH,WMAX,CDNST,PNB,PNB,FZWA)
      IF(IFLG.EQ.1) FI1=PNB+PHA
      IF(IFLG.EQ.2) FI1=PNB+PHA
      APDX=A+DX
      CALL FERMI(APDX,ZALPHA,S,SP1,SPH,WMAX,CDNST,PNQ,QEN,PHA,FZWA)
      IF(IFLG.EQ.1) FI2=PNQ
      IF(IFLG.EQ.2) FI2=PNQ
      F13=0.
      FI=DX*(FI1+4.*FI2)/3.
      2 FI3=FI+FI3
      FI2=0.
      TDX=DX
      DX=0.5*DX
      X=A+DX
      3 CALL FERMI(X,ZALPHA,S,SP1,SPH,WMAX,CDNST,PNQ,QEN,FZWA)
      IF(IFLG.EQ.1) FI2=FI2+PNQ
      IF(IFLG.EQ.2) FI2=FI2+PNQ
      X=X+TDX
      IF(X-B)3,4,6
      4 FIP=DX*(FI1+4.*FI2+2.*FI3)/3.
           QDIF=1./FIP
           IF(ABS(QDIF)=CDNV)6,6,5
      5 FIP=FIP
      GO TO 2
6 QNTGRL=FIP
RETURN
END
SUBROUTINE FERMI(WI, ZALPHA, SP1, SPH, WMAX, CONST, PNI, PENI, FWI)
COMPLEX QARG, QCE, QGX, LNGAM
IF(WI.LT.1.000) GO TO 10
W2M1=WI*WI-1.
Y=ZALPHA*WI*W2M1**0.5
PIY=3.141592654*Y
EPIY=EXP(PIY)
QYH=W2M1**S
QXS=W2M1**SPH
QQ1=WMAX-WI
QXZ=QQ1*QQ1
QPPRD=CONST*QXS*EPIY*QXZ*WI
QARG=COMPLEX(SP1, Y)
QGX=LNGAM(QARG)
QCE=CEXP(QGX)
QGAM=CARQ(QCE)
QGAM2=QGAM*QGAM
PNI=QPPRD*QGAM2
FWI=CONST*QYH*EPIY*QGAM2
GO TO 20
10 TPZA=8.83185286*ZALPHA
PNI=TPZA*CONST*WI*(WMAX-WI)*(WMAX-WI)*((ZALPHA*ZALPHA+0.25)*WI*1WI-0.25)**S
FWI=1.0E+20
20 PNI=PNI*(WI-1.)
RETURN
END

SUBROUTINE GAMMA2(FS, PI, NBDG, FBDG, SPEGAM, SORSG, NEP)
DIMENSION EBDG(200), SPEGAM(200), SORSG(200), ES(900), PI(900),
SPVPM1(90), SPTH2(90)

Same as GAMMA1 but gives Gaussian energy spread to line spectra.

NGPS=NBDG-1
NSTDEV=2
STDEVN=NSTDEV
DO 3 I=1, NGPS
SPEGAM(I)=0.
DO 10 J=1, NEP
IF(PI(J)=1,0E-35)31,4,4
3 SIGMA=5742684E02*(ES(J)/1000.)*679988668*(ES(J)/1000.)*0.5
PIES=PI(J)*FS(J)
IF(SIGMA)23,23,5
4 FWHP=P.3542*SIGMA
ESPRED=STDEVN*FWHP*1000.
EPSPRD=FS(J)*ESPRED
EMSPRD=FS(J)*ESPRED
SIGSQ=SIGMA*SIGMA*2,
DO 12 I=1, NBDG
K=I+1
IF(EBDG(I)=ES(J)) 12, 13, 13
12 CONTINUE
13 K=K
14 CONTINUE
IF(EBDG(K)+1)=EPSPRD 15, 16, 16
15 KJ = K1 + 1
   GO TO 14
16 KUL = K1
   IF (KUL = NGPS) 17, 17, 18
18 KUL = NGPS
17 CONTINUE
   IF (EBDG(K2) = ESMPRD) 9, 9, 8
8 K2 = K2 + 1
   GO TO 17
9 KLL = K2
   IF (KLL = 1) 19, 20, 20
19 KLL = 1
20 SMNRME = 0.
   SPTMP1 = 0.
   SMNRM = 0.
   JK1 = 0
   KMAX = KUL - KLL + 1
   DO 120 I = 1, KMAX
       SPTMP1(I) = 0.
120 SPTMP1(I) = 0.
   DO 21 JK = KLL, KUL
       DELTE = EROG(JK + 1) - EROG(JK)
       EMID = EBDG(JK) + 0.5*DELTE
       JK1 = JK + 1
       EDIFSO = (EMID - ES(J))**2 / 1.0e+06
       EARG = EDIFSO / SIGSQ2
       IF (EARG < 0.05) 201, 203, 204
       SPTMP1(JK1) = PI(J) * DELTE * (1. - EARG)
   GO TO 210
201 SPTMP1(JK1) = PI(J) * DELTE * (1. - EARG)
   GO TO 210
202 IF (EARG > 0.5) 201, 203, 204
204 SPTMP1(JK1) = 0.
   GO TO 210
203 SPTMP1(JK1) = PI(J) * DELTE * EXP(-EARG)
210 CONTINUE
   SMNRME = SMNRME + SPTMP1(JK1)
   SPTMP2(JK1) = SPTMP1(JK1) * EMID
21 SMNRME = SMNRME + SPTMP2(JK1)
   JK1 = 0
   QNORM1 = PI(J) / SMNRM
   QNORM2 = PIES / SMNRME
   DO 22 JK = KLL, KUL
       SPTMP1(JK1) = SPTMP1(JK1) * QNORM1
       SPTMP2(JK1) = SPTMP2(JK1) * QNORM2
       SPEGAM(JK) = SPEGAM(JK) + SPTMP1(JK1)
       SORSG(JK) = SORSG(JK) + SPTMP2(JK1)
22 SORSG(JK) = SORSG(JK) + SPTMP2(JK1)
   GO TO 31
23 CONTINUE
   DO 24 I = 1, NBOG
       KK = I - 1
       IF (EBDG(I) = ES(J)) 24, 25, 25
24 CONTINUE
25 SPEGAM(KK) = SPEGAM(KK) + PI(J)
   SORSG(KK) = SORSG(KK) + PIES
31 CONTINUE
10 CONTINUE
   PRINT 40
40 FORMAT(1H , 5PX, *GAMMA SPECTRUM*/)
   PRINT 45, (SPEGAM(K), K = 1, NGPS)
45 FORMAT(1H, 50X, 6E12.4)
   PRINT 50
50 FORMAT(1H, 50X, *GAMMA ENERGY SPECTRUM*/)
   PRINT 45, (SORSG(K), K = 1, NGPS)
   RETURN
END
SUBROUTINE GAMMA1(ES, PI, NRG, EBDG, SPEGAM, SORSG, NEP)

DIMENSION ENDG(200), SPEGAM(200), SORSG(200), ES(900), PI(900)

THIS SUBROUTINE CALCULATES GAMMA SPECTRA AND GAMMA ENERGY SPECTRA.

NRG = NUMBER OF GROUP BOUNDARIES.
NEP = NUMBER OF ENERGY GROUPS.
EBDG = ENERGIES OF GROUP BOUNDARIES.
SPEGAM = GAMMA SPECTRUM.
SORSG = GAMMA ENERGY SPECTRUM.

NGPS=NRDG-1
DO 10 J=1,NEP
   DO 12 I=1,NEPD
      K=I+1
      IF(EBDG(I) .GE. ES(J)) 12,13,13
   CONTINUE
   SPEGAM(K)=SPEGAM(K)+PI(J)
   SORSG(K)=SORSG(K)+PI(J)*ES(J)
10 CONTINUE
PI
PRINT 20
20 FORMAT(1H5,5AX, *GAMMA SPECTRUM*)
PRINT 35,(SPEGAM(K), K=1, NGPS)
55 FORMAT(1H5,5AX, 6E12.4)
PRINT 50
50 FORMAT(1H5,5AX, *GAMMA ENERGY SPECTRUM*)
PRINT 35,(SORSG(K), K=1, NGPS)
RETURN
END
APPENDIX B  LASL Identification No. LP-477.

LISTING OF THE FPSPEC PROGRAM

PROGRAM FPSPEC(INP,OUT,PUN,FSET5,FSET6,FILM)
DIMENSION ERDN(200),EBDG(200),SPEGAM(200),SORSG(200),BETAS(200),
BSBTAES(200),TSBP(200),TSPER(200),TSPG(200),TSPESG(200),DUM1(500),
DUM2(500),HL(50)
DIMENSION ERDMH(200),EBGHM(200),GAMEXP(200),NEEXP(200)
DIMENSION GMEXP1(200),TSPEC1(200)
DIMENSION GAMFR(200),GAMPER(200),GAMHFR(200)
DIMENSION BETFR(200),BETPER(200),BETHFR(200)
DIMENSION XEN(3),YSP(3),EBX(200),EGX(200),EGXM(200)
DIMENSION EBDG(200)
DIMENSION TI(10),ABSIS(10),ORDIN(10)

EBOB = BETA ENERGY GROUP BOUNDARIES
EBDG = GAMMA ENERGY GROUP BOUNDARIES
SPEGAM = GAMMA SPECTRUM
SORSG = GAMMA ENERGY SPECTRUM
BETAS = BETA SPECTRUM
BSBTAES = BETA ENERGY SPECTRUM
TSBP = TOTAL BETA SPECTRUM
TSPER = TOTAL BETA ENERGY SPECTRUM
TSPG = TOTAL GAMMA SPECTRUM
TSPESG = TOTAL GAMMA ENERGY SPECTRUM
IF NPUN 1, SOME DATA ARE PUNCHED
NAPLT = NUMBER OF BETA GROUPS PLOTTED
NAPL = NUMBER OF GAMMA GROUPS PLOTTED
IF NL = 1, PLOTTING IS DONE.
IF ICOMP = 1, COMPARISON OF BETA SPECTRA WITH EXPERIMENT
IF ICMEPG = 1, COMPARISON OF GAMMA SPECTRA WITH EXPERIMENT
GAMEXP = EXPERIMENTAL GAMMA SPECTRUM FOR COMPARISON
GAMEXP = EXPERIMENTAL GAMMA SPECTRUM
BETEXP = EXPERIMENTAL BETA SPECTRUM FOR COMPARISON
NGEXP = NUMBER OF EXPERIMENTAL BETA GROUPS
NREXP = NUMBER OF EXPERIMENTAL GAMMA GROUPS
ID AND IOE ARE MAT IDENTIFICATION NUMBERS
IF STYP' = 0, GAMMA SPECTRUM IS PROVIDED ON INPUT TAPE
IF STYP = 1,9 GAMMA SPECTRUM IS PROVIDED ON INPUT TAPE
NSP IS THE NUMBER OF SPECTRA PER NUCLIDE ON INPUT TAPE
IF NSBET = 1, BETA SPECTRA ARE INPUT FOR EACH ISOTOPE
IF NGBAS = 1, GAMMA SPECTRA ARE INPUT FOR EACH ISOTOPE
GPS = GAMS F.P. SECOND (181 F.P.)
BPS = BETAS PER SECOND (181 F.P.)
GMVPS = GAMMA MEV PER SECOND (181 F.P.)
BMVPS = BETA MEV PER SECOND (181 F.P.)
CGMVP = CINDER GAMMA MEV PER SECOND (181 F.P.)
CBMVP = CINDER BETA MEV PER SECOND (181 F.P.)
GMVPE = GAMMA MEV/FISSION (181 F.P.)
BMVPE = BETA MEV/FISSION (181 F.P.)
CGMVPF = CINDER GAMMA MEV/FISSION (181 F.P.)
CBMVPF = CINDER BETA MEV/FISSION (181 F.P.)
TTOT = TOTAL TIME (IN-FLUX AND SHUTDOWN)
TDCY = TIME SINCE LAST POWER STEP
DENS = ISOTOPE ATOMIC DENSITY
BETE = TOTAL CINDER MEV/FISSION (BETA) INCLUDING DENSITY
GAME = TOTAL CINDER MEV/FISSION (GAMMA) INCLUDING DENSITY
RPGE = RETA PLUS GAMMA TOTAL CINDER MEV/FISSION INCL. DENS.
IF NGAS = 1, GASEOUS F. P. ARE CALCULATED
JRT = BETA ISOTOPE COUNT (181 F.P.)
IGCT = GAMMA ISOTOPE COUNT (181 F.P.)
IGASR = RETA GAS ISOTOPE COUNT (181 F.P.)
CALL EXPH
READ 10, NRUN, NGAS
READ 10, NPLOT, TOPT
READ 10, ICOMPB, ICOMPB
IF(NPLOT.EQ.1) READ 10, NBPLT, NGPLT
IF(ICOMPB.EQ.1) READ 10, NBEXP
IF(ICOMPGB.EQ.1) READ 10, NGEXP
IF(ICOMPGB.EQ.1, AND, NPLOT.EQ.1) READ 10, NBXPLT
IF(ICOMPGB.EQ.1, AND, NPLOT.EQ.1) READ 10, NGXPLT
IF(NPLOT.EQ.1) READ 20, QLMPLT
IOPT=0
IF(ICOMPGB NE.1) GO TO 3
READ 20, (EGX(I), I=1, NGEXP)
DO 7421 I=1, NGEXP
7421 EGX(I)=EGX(I)*1.0E+6
NGEXM1=NGEXP-1
DO 7321 I=1, NGEXM1
7321 CONTINUE
NGEXP=NGEXM1
READ 20, (GAFEXP(I), I=1, NGEXP)
READ 20, (GAMERR(I), I=1, NGEXP)
DO 2 I=1, NGEXP
GAMERR(I)=ARS(GAMERR(I))
GAMPER(I)=GAFEXP(I)+GAMERR(I)
GAFMRR(I)=GAFEXP(I)-GAMFRR(I)
2 CONTINUE
SMEXP=0
3 CONTINUE
IF(ICOMPGB NE.1) GO TO 4
READ 20, (EBX(I), I=1, NREXP)
NREXM1=NREXP-1
DO 7121 I=1, NREXP
7121 CONTINUE
NREXP=NREXM1
READ 20, (HETEXP(I), I=1, NREXP)
READ 20, (RETERR(I), I=1, NREXP)
DO 6101 I=1, NREXP
6101 CONTINUE
NREXP=NREXM1
READ 20, (HETXP(I), I=1, NREXP)
READ 20, (RET(EXP(I), I=1, NREXP)
DO 6101 I=1, NREXP
6101 CONTINUE
SMEXP=0
4 CONTINUE
READ(S, 101N8ETS#NGAMS
10 FORMAT(21I1)
FACTR=1.0E+06
IBCT=0
READ(5, 20) (EBDR(I), I=1, NBDR)
20 FORMAT(6E12.4)
    DENR=ERDR(2)-ERDR(1)
    DO 6100 I=1, NBDG
       BETEXP(I)=BETEXP(I)/1.0E+6*DENR
       BETERR(I)=BETERR(I)/1.0E+6*DENR
       BETPER(I)=BETPER(I)/1.0E+6*DENR
    6100 CONTINUE
    PRINT 2001
2001 FORMAT(1H30,35X,*BETA ENERGY BOUNDARIES (EV)*/*)
    PRINT 220, (EBX(I), I=1, NREXP)
5101 FORMAT(1H30,35X,*BETA ENERGY BOUNDARIES (EV)*/*)
    IF(NPUN.EQ.1) PRINT 5101
5001 FORMAT(1H30,35X,*EXPERIMENTAL BETA ENERGY POINTS (EV)*/*)
    IF(NPUN.EQ.1) PRINT 5001
5102 FORMAT(1H30,35X,*EXPERIMENTAL BETA ENERGY POINTS (EV)*/*)
    IF(NPUN.EQ.1) PUNCH 873, (EBX(I), I=1, NREXP)
    IF(220-EQ.1) PRINT 2202
2202 FORMAT(1H30,35X,*GAMMA ENERGY BOUNDARIES (EV)*/*)
    IF(NPUN.EQ.1) PRINT 2202
5103 FORMAT(1H30,35X,*GAMMA ENERGY BOUNDARIES (EV)*/*)
    IF(NPUN.EQ.1) PUNCH 5103
5002 FORMAT(1H30,35X,*EXPERIMENTAL GAMMA ENERGY POINTS (MEV)*/*)
    IF(NPUN.EQ.1) PRINT 5002
5104 FORMAT(1H30,35X,*EXPERIMENTAL GAMMA ENERGY POINTS (MEV)*/*)
    IF(NPUN.EQ.1) PUNCH 5104
    GMEXP1(I)=SMEXP(I)*(EGX(I+1)-EGX(I))/DENR
    GMEXP1(I)=GMEXP1(I)*1.0E+6
    GO TO 21
21 CONTINUE
    IF(220-EQ.1) GO TO 22
\[ \text{DO } 7 \ i=1, \text{NRXP} \]
\[ \text{SMEXPR=SMEXPB+RETEXP(I)*(ERX(I+1)-ERX(I))/DENB} \]
\[ \text{CONTINUE} \]
\[ \text{DO } 105 \ i=1, \text{NBDM1} \]
\[ \text{TSPR(I)=0.} \]
\[ \text{105 TSPLD(I)=0.} \]
\[ \text{DO } 106 \ i=1, \text{NBDM1} \]
\[ \text{TSPG(I)=0.} \]
\[ \text{106 TSPEG(I)=0.} \]
\[ \text{IF(NGAS.NE.1) GO TO 1001} \]
\[ \text{DO } 1002 \ i=1,7 \]
\[ \text{READ(6,110) DUM} \]
\[ \text{1002 CONTINUE} \]
\[ \text{READ(6,120)(HL(I),I=1,10)} \]
\[ \text{READ(6,120)(HL(I),I=1,10)} \]
\[ \text{READ(6,120)(HL(I),I=1,10)} \]
\[ \text{1003 CONTINUE} \]
\[ \text{READ(6,132)IN, GAS, AIN, OENS, ACT, BETE, GAMS, RBGE} \]
\[ \text{IF(EOF,6) READ(1001)} \]
\[ \text{1004 IF(GAS.NE.5H GAS) GO TO 1003} \]
\[ \text{NGSRT=NGSRT+1} \]
\[ \text{NGSST=NGSST+1} \]
\[ \text{TGASB=TGASB+PETE} \]
\[ \text{TGASG=TGASG+GAMS} \]
\[ \text{GO TO 1003} \]
\[ \text{1001 CONTINUE} \]
\[ \text{READ(5,30)STYP, I=1,10) \]
\[ \text{READ(6,110)TDCV} \]
\[ \text{READ(6,110)FNS} \]
\[ \text{READ(6,110)DEL} \]
\[ \text{READ(6,110)DET} \]
\[ \text{READ(6,110)GAM} \]
\[ \text{READ(6,110)SUM} \]
\[ \text{READ(6,120)(HL(I),I=1,10)} \]
\[ \text{READ(6,120)(HL(I),I=1,10)} \]
\[ \text{READ(6,120)(HL(I),I=1,10)} \]
\[ \text{120 CONTINUE} \]
\[ \text{100 FORMAT(10A8)} \]
\[ \text{30 FORMAT(2A5,4T10)} \]
\[ \text{40 FORMAT(F6,2)} \]
\[ \text{IF(NBETS.EQ.1.AND.STYP.EQ.1,A) GO TO 80} \]
\[ \text{GO TO 90} \]
\[ \text{80 READ(5,20)(BETAS(I),I=1,NBOM1)} \]
\[ \text{READ(5,20)(BETAS(I),I=1,NBOM1)} \]
\[ \text{READ(5,20)EBA, SUMRA} \]
\[ \text{DO 81 I=1,NBDM1} \]
\[ \text{81 BETAS(I)=BETAS(I)/1.0E+06} \]
\[ \text{1RCT=IBCT+1} \]
\[ \text{TMP=0.} \]
\[ \text{DO 83 I=1,NRDM1} \]
\[ \text{83 TMP=TMP+2B+2AES(I)} \]
\[ \text{GO TO 100} \]
\[ \text{90 DO 95 I=1,NBOM1} \]
\[ \text{BETAS(I)=0.} \]
\[ \text{95 BETAES(I)=0.} \]
\[ \text{THPSB=0.} \]
\[ \text{100 CONTINUE} \]
IF(STYP.EQ.1,0,AND,NSP,NE.2) GO TO 60
IF(STYP.EQ.0,0,AND,NSP,NE.2) GO TO 107
READ(5,40)STYP
107 IF(NGAMX.EQ.0,1,AND,STYP,EQ.0,0) GO TO 50
GO TO 60
50 READ(5,20)(SPF,GM1(I),I=1,NRDGM1)
READ(5,20)(SORSG(I),I=1,NBDGM1)
READ(5,20)(TSG,GM1)
DO 52 I=1,NRDGM1
52 SORSG(I)=SORSG(I)/1.0E+06
ICT=IGCT+1
TMSG=0.
DO 53 I=1,NRDGM1
53 TMSG=TMSG+SORSG(I)
GO TO 70
60 DO 65 I=1,NBDGM1
SPF,GM1(I)=R.
65 SORSG(I)=SORSG(I)/1.0E+06
IGCT=IGCT+1
TMSG=0.
DO 70 I=1,NBDGM1
70 CONTINUE
125 READ(6,130)ID,GAS,AIO,DENS,ACT,RETEN,GAME,BPGE
130 FORMAT(1X,17,AS,A5,A2,5(1X,E12.6))
IF(ID.NE.IDE) GO TO 125
IF(IDP.NE.1) GO TO 139
IF(ACT.LT.1.0E-35) GO TO 139
BETEN=RETEN/ACT
GAME=GAME/ACT
IF(BETEN.F0.0) GO TO 130
ABDG=ARS(I)*TMSG/BETEN*100.
IF(ABDG.GT.0.0) PRINT 131,SYM1,SYM2,IDE,ABDG,TMSG,RETEN
131 FORMAT(1X,5X,ISOTOPE,*A5,A5,* ID = *,I7,* HAS *,F9.3,* PERCENT
1T DIFFERENCE IN BETA ENERGY, I.E. *,E12.4,* VS. *,E12.4)
130 CONTINUE
IF(GAME.EQ.0,0) GO TO 130
ABDG=ARS(I)*TMSG/GAMEE*100.
IF(ABDG.GT.0.0) PRINT 132,SYM1,SYM2,IDE,ABDG,TMSG,GAMEE
132 FORMAT(1X,5X,ISOTOPE,*A5,A5,* ID = *,I7,* HAS *,F9.3,* PERCENT
1T DIFFERENCE IN GAMMA ENERGY, I.E. *,E12.4,* VS. *,E12.4)
139 CONTINUE
IF(NGAS,0,1,AND,GAS,NE.5,H GAS ) GO TO 199
IF(NGAS,NE.1) GO TO 169
IGASB=IGASB+1
IGASG=IGASG+1
SMGASB=SMGASB+RETEN
SMGASG=SMGASG+GAME
169 CONTINUE
BSUM1=BSUM1+PETE
GSUM1=SUM1+GAME
DO 140 I=1,NRDH1
TSPR(I)=TSPR(I)+RETAS(I)*ACT
140 TSPF(I)=TSPF(I)+METAES(I)*ACT
DO 150 I=1,NRDH1
TSPG(I)=TSPG(I)+SPF,GM1(I)*ACT
150 TSPEG(I)=TSPEG(I)+SORSG(I)*ACT
199 CONTINUE
REWIND 6
GO TO 1
200 GPS=R.
BPS=0.
GMEVPS=R.
BMPFVS=0.
DO 30A I=1, NBDM1
BPS=APS+TSPB(I)
30A BMPFVS=RMPFVS+TSPF(I)
DO 31A I=1, NBDM1
GPS=GPS+TSPG(I)
31A GMPFVS=GMFVS+TSPG(I)
BMFPS=RMPFVS/FPS
GMFPS=GMFVS/FPS
GPF=GPS/FPS
RPF=GPS/FPS
PRET=100.*(1.-RMFVPF/BETOT)
PGM=100.*(1.-GMFVPF/GAMT0T)
CRMVPS=100.1
CMMVPS=100.1
CMMFVPF=CMMVPS/FPS
GMVPS=GMVPS/FPS
PBC=100.*(1.-BMFVPF/CHMVPF)
PBC=100.*(1.-GMFVPF/CMVMPF)
PRINT 210, TTOT, TDCY
210 FORMAT(1H5, 5X, "TOTAL BETA SPECTRUM AT *,E12.6,* SEC, TOTAL AND *,
1E12.6,* SEC, DECAY (BETAS/SEC)*/
PRINT 220, (TSPR(I), I=1, NBDM1)
220 FORMAT(1H5, 6F15.5)
PRINT 230, TTOT, TDCY
230 FORMAT(1H5, 5X, "TOTAL BETA ENERGY SPECTRUM AT *,E12.6,* SEC, TOTAL
1ANG *,E12.6,* SEC, DECAY (MEV/SEC)*/
PRINT 240, (TSPR(I), I=1, NBDM1)
240 FORMAT(1H5, 5X, "TOTAL GAMMA SPECTRUM AT *,E12.6,* SEC, TOTAL AND *
1E12.6,* SEC, DECAY (GAMMAS/SEC)*/
PRINT 250, (TSPG(I), I=1, NBDM1)
250 FORMAT(1H5, 5X, "TOTAL GAMMA ENERGY SPECTRUM AT *,E12.6,* SEC, TOTAL
1ANG *,E12.6,* SEC, DECAY (MEV/SEC)*/
PRINT 260, (TSPG(I), I=1, NBDM1)
PRINT 270, TTOT, TDCY
270 FORMAT(1H5, 6F15.5)
PRINT 280, (TSPR(I), I=1, NBDM1)
280 FORMAT(1H5, 6F15.5)
PRINT 290, TTOT, TDCY
290 FORMAT(1H5, 6F15.5)
PRINT 300, TTOT, TDCY
300 FORMAT(1H5, 6F15.5)
PRINT 310, TTOT, TDCY
310 FORMAT(1H5, 6F15.5)
PRINT 320, TTOT, TDCY
320 FORMAT(1H5, 6F15.5)
PRINT 330, TTOT, TDCY
330 FORMAT(1H5, 6F15.5)
PRINT 340, TTOT, TDCY
340 FORMAT(1H5, 6F15.5)
PRINT 350, TTOT, TDCY
350 FORMAT(1H5, 6F15.5)
PRINT 251
PRINT 400,FPS
400 FORMAT(1H1,2'X,*FISSIONS / SEC = *,E12,6)
PRINT 401,FPS
401 FORMAT(1H1,2'X,*RETAS / SEC = *,E12,6)
PRINT 410,BPF
410 FORMAT(1H1,2'X,*FISSION / FISSION = *,E12,6)
PRINT 420,MEVPS
420 FORMAT(1H1,2'X,*BETA MEV / SEC = *,E12,6)
IF(ICONPB.NE.1) GO TO 422
PRINT 421,SMFSPS
421 FORMAT(1H1,2'X,*EXPERIMENTAL BETA MEV / FISSION = *,E12,6)
422 CONTINUE
PRINT 430,MEVPS
430 FORMAT(1H1,2'X,*BETA MEV / FISSION = *,E12,6)
PRINT 435,CMVPF,PCR
435 FORMAT(1H1,2'X,*CINDER BETA MEV / FISSION = *,E12,6,
1* PERCENT DIFFERENCE = *,E12,6)
PRINT 510,GPS
510 FORMAT(1H1,2'X,*GAMMAS / SEC = *,E12,6)
PRINT 520,GPF
520 FORMAT(1H1,2'X,*CINDER GAMMA MEV / FISSION = *,E12,6)
PRINT 530,GMEVPS
530 FORMAT(1H1,2'X,*GAMMA MEV / SEC = *,E12,6)
IF(ICONPG.NE.1) GO TO 532
PRINT 531,SMEXPG
531 FORMAT(1H1,2'X,*EXPERIMENTAL GAMMA MEV / FISSION = *,E12,6)
532 CONTINUE
PRINT 540,GMEVPS
540 FORMAT(1H1,2'X,*GAMMA MEV / FISSION = *,E12,6)
PRINT 550,CMVPF,PGC
550 FORMAT(1H1,2'X,*CINDER GAMMA MEV / FISSION = *,E12,6,
1* PERCENT DIFFERENCE = *,E12,6)
PRINT 610,BETOT,PBT
610 FORMAT(1H1,2'X,*TOTAL BETA MEV / FISSION = *,E12,6,
1* PERCENT DIFFERENCE = *,E12,6)
PRINT 620,GAMMINT,PGAM
620 FORMAT(1H1,2'X,*TOTAL GAMMA MEV / FISSION = *,E12,6,
1* PERCENT DIFFERENCE = *,E12,6)
PRINT 630,INCT,ICT
630 FORMAT(1H1,2'X,*TOTAL GAMMA COUNT = *,I3,* ,GAMMA COUNT = *,I3)
IF(NGAS.NE.1) GO TO 671
PRINT 670,NGAS,TGASG
670 FORMAT(1H1,2'X,*TOTAL GAS COUNT = *,I3,* ,GAMMA GAS COUNT = *,I3)
PRINT 680,NGGB,NGGT
680 FORMAT(1H1,2'X,*TOTAL GAS COUNT = *,I3,* ,GAMMA TOTAL GAS C
1DUNT = *,I3)
SMGAS=SMGAS/FPS
SMGAS=SMGAS/FPS
TGASB=TGASB/FPS
TGAS=TGAS/FPS
PRINT 674,SMGASB
PRINT 675,SMGAS
PRINT 672,TGASR
PRINT 673,TGAS
672 FORMAT(1H1,2'X,*CINDER TOTAL GAS BETA MEV / FISSION = *,E12,6)
673 FORMAT(1H1,2'X,*CINDER TOTAL GAS GAMMA MEV / FISSION = *,E12,6)
674 FORMAT(1H1,2'X,*CINDER GAMMA BETA MEV / FISSION = *,E12,6)
675 FORMAT(1H1,2'X,*CINDER GAMMA GAMMA MEV / FISSION = *,E12,6)
671 CONTINUE
RATB=RHEVPF/RETOT
RATBC=GMVPF/RETOT
RATG=GHEVPF/GAMTOT
RATGC=GMVPF/GAMTOT
IF(ICOMPNE,1) GO TO 631
RATEXG=SEMEXPG/GAMTOT
RATXG1 = SEMEXPG/GHEVPF
RATXEC = RATEXG*GMVPF*GMVFP

631 CONTINUE
IF(ICOMPNE,1) GO TO 632
RATEXB = SEMEXPR/REMVFP*RATBC

632 CONTINUE
PRINT 710, RATB
710 FORMAT (1H0, 5X, **RATIO OF BETG MEV / FISSION TO TOTAL CINDER BETG ME
IV/FISSION = **E12.6)
PRINT 720, RATBC
720 FORMAT (1H0, 5X, **RATIO OF CINDER BETG MEV / FISSION TO TOTAL CINDER
1BETG MEV / FISSION = **E12.6)
PRINT 730, RATG
730 FORMAT (1H0, 5X, **RATIO OF GAMMA MEV / FISSION TO TOTAL CINDER GAMMA
1MEV / FISSION = **E12.6)
PRINT 740, RATGC
740 FORMAT (1H0, 5X, **RATIO OF CINDER GAMMA MEV / FISSION TO TOTAL CINDER
1 GAMMA MEV / FISSION = **E12.6)
IF(ICOMPNE,1) GO TO 742
PRINT 741, RATEXG
741 FORMAT (1H0, 5X, **RATIO OF EXPERIMENTAL GAMMA MEV / FISSION TO TOTAL
CINDER GAMMA MEV / FISSION = **E12.6)
PRINT 747, RATXEC
747 FORMAT (1H0, 5X, **RATIO OF EXPERIMENTAL GAMMA MEV / FISSION TO TOTAL
1CINDER GAMMA MEV / FISSION (EXCLUDING CONVERSION ELECTRONS) = **
E12.6)
PRINT 746, RATXG1
746 FORMAT (1H0, 5X, **RATIO OF EXPERIMENTAL GAMMA MEV / FISSION TO TOTAL
1MEV / FISSION = **E12.6)
742 CONTINUE
IF(ICOMPNE,1) GO TO 744
PRINT 743, RATEXB
743 FORMAT (1H0, 5X, **RATIO OF EXPERIMENTAL BETG MEV / FISSION TO TOTAL B
ETG MEV / FISSION = **E12.6)
744 CONTINUE
PRINT 793
793 FORMAT (1H0, 5X, **NB, TOTAL REFERS TO ALL 825 FISSION PRODUCTS,
THE REST REFER TO THE 181 FISSION PRODUCTS*)
PRINT 794
794 FORMAT (1H0, 5X, **THE FOLLOWING SPECTRA ARE NORMALIZED TO THE TOTAL C
INDER-CALCULATED GAMMA AND BETG MEV/FISSION**, 5X, ** FOR ALL 825 FI
SSION PRODUCTS**/)
IF(NGAS, EQ, 1) RATR = TGASB/SMGASB
IF(NGAS, EQ, 1) RATGC = TGASG/SMGASG
DO 810 I = 1, NRDGM1
EBDG(I) = 0.5 * (EBDG(I) + EBDG(I+1))/1.0E+06
TSPG(I) = TSPG(I)/RATR
810 TSPEG(I) = TSPEG(I)/RATB
SMGCS = 0.
DO 820 I = 1, NRDGM1
EBDG(I) = 0.5 * (EBDG(I) + EBDG(I+1))/1.0E+06
TSPG(I) = TSPG(I)/RATGC
TSPEG(I) = TSPEG(I)/RATGC
SMGCS = SMGCS + TSPEG(I)

44
820 TSPEG1(I) = SMGCS
PRINT 830, TTOT, TDY
830 FORMAT(1H1, 5X, 'NORMALIZED BETA SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (MEV/FISSION*) /)
PRINT 220, (TSPBR(I), I=1, NBDM1)
PRINT 840, TTOT, TDY
840 FORMAT(1H10, 5X, 'NORMALIZED BETA ENERGY SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (MEV/FISSION*) /)
PRINT 220, (TSPEG(I), I=1, NBDM1)
IF(NPUN, EQ, 1) PUNCH 4010, TTOT, TDY
4010 FORMAT(1H10, 5X, 'BETAC MEV/FISSION AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY*)
IF(NPUN, EQ, 1) PUNCH 873, (TSPEG(I), I=1, NBDM1)
IF(ICMPB, NE, 1) GO TO 841
PRINT 842, TTOT, TDY
842 FORMAT(1H10, 5X, 'EXPERIMENTAL BETA ENERGY SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (MEV/FISSION*) /)
PRINT 220, (BETEXP(I), I=1, NBEXP)
PRINT 4963
4963 FORMAT(6E12.6)
PRINT 850, TTOT, TDY
850 FORMAT(1H10, 5X, 'NORMALIZED GAMMA SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (GAMMAS/FISSION*) /)
PRINT 220, (TSPGM(I), I=1, NBGDM1)
872 FORMAT(1H10, 5X, 'GAMMAS/FISSION AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY*)
873 FORMAT(6E12.6)
PRINT 860, TTOT, TDY
860 FORMAT(1H10, 5X, 'NORMALIZED GAMMA ENERGY SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (MEV/FISSION*) /)
IF(NPUN, EQ, 1) PUNCH 7836, TTOT, TDY
7836 FORMAT(1H10, 5X, 'NORMALIZED SUM GAMMA ENERGY SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (GAMMAS/FISSION*) /)
PRINT 220, (TSPGM(I), I=1, NBGDM1)
PRINT 859, TTOT, TDY
859 FORMAT(1H10, 5X, 'NORMALIZED SUM GAMMA ENERGY SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (GAMMAS/FISSION*) /)
PRINT 220, (TSPGM(I), I=1, NBGDM1)
IF(ICMPG, NE, 1) GO TO 862
PRINT 861, TTOT, TDY
861 FORMAT(1H10, 5X, 'EXPERIMENTAL GAMMA ENERGY SPECTRUM AT \times \times12.6, \star SEC, TOTAL AND \times \times12.6, \star SEC, DECAY (MEV/FISSION*) /)
PRINT 220, (GAMEXP(I), I=1, NGEXP)
IF(NPUN, EQ, 1) PUNCH 3001
3001 FORMAT(1H10, 5X, 'EXPERIMENTAL GAMMA MEV/FISSION*)
IF(NPUN, EQ, 1) PUNCH 873, (GAMEXP(I), I=1, NGEXP)
IF(NPUN, EQ, 1) PUNCH 3002
3002 FORMAT(1H10, 5X, 'EXPERIMENTAL GAMMA ERRORS*)
IF(NPUN, EQ, 1) PUNCH 873, (GAMEXP(I), I=1, NGEXP)
PRINT 858, TTOT, TDY
858 FORMAT(1H10, 5X, 'EXPERIMENTAL SUM GAMMA ENERGY SPECTRUM AT \times \times12.6, \star
1 SEC. TOTAL AND *E12.6* SEC. DECAY (MEV/FISSION)*/
PRINT 220, (GMEEXP(1), I=1, NGEXP)
PRINT 857, TTOT, TDCY
857 FORMAT((HEX5X,*ERRORS OF EXPERIMENTAL GAMMA ENERGY SPECTRUM AT *,
*E12.6* SEC. TOTAL AND *E12.6* SEC. DECAY (MEV/FISSION*))
PRINT 220, (GAMERR(I), I=1, NGEXP)
862 CONTINUE
IF(NPLOT.NE.1) GO TO 901
DO 957 I=1, NGEXP
957 ERX(I)=ERX(I)
957 ENCONF(10,5511,ATTOT)TTOT
5511 FORMAT(1PE10.3)
5511 ENCODE(10,5511,ATDCY)TDCY
DO 6553 I=1, NGEXP
6553 ERX(I)=ERX(I)/1.0E+06
BMN=QLMPLT
DO 910 I=1, NBDGM1
IF(TSB(I),LT,REMIN) TSB(I)=BMN
910 CONTINUE
BMN=QLMPLT
DO 920 I=1, NBDGM1
IF(TSPE(I),LT,BEMIN) TSPE(I)=BEMIN
IF(13COMB.NE.1) GO TO 911
911 CONTINUE
920 CONTINUE
IF(13COMB.NE.1) GO TO 993
DO 964 I=1, NGEXP
IF(BETM(I),LT,REMIN) BETM(I)=REMIN
IF(BETMP(I),LT,REMIN) BETMP(I)=REMIN
IF(BET(1),LT,REMIN) BET(I)=REMIN
993 CONTINUE
964 CONTINUE
GMIN=QLMPLT
DO 930 I=1, NBDGM1
IF(TSG(I),LT,GMIN) TSG(I)=GMIN
930 CONTINUE
GMIN=QLMPLT
GMIN1=QLMPLT
DO 940 I=1, NBDGM1
IF(TSPG(I),LT,GMIN) TSPG(I)=GMIN
IF(TSPG(I),LT,GMIN1) TSPG(I)=GMIN1
940 CONTINUE
IF(13COMPG.NE.1) GO TO 931
DO 946 I=1, NGEXP
IF(GAMEXP(I),LT,GMIN) GAMEXP(I)=GMIN
IF(GMEEXP1(I),LT,GMIN) GMEEXP1(I)=GMEN1
IF(GAMMER(I),LT,GMEN) GAMMER(I)=GMIN
IF(GAMPER(I),LT,GMEN) GAMPER(I)=GMEN
946 CONTINUE
931 CONTINUE
TI(1)=1FBFTAS PER
TI(2)=1PFIISSION AT
TI(3)=ATTOT
TI(4)=10H S. TOTAL,
TI(5)=ATDCY
TI(6)=10H S. DECAY
ABRIS(1)=3HEV
ORDIN(1)=$H$SPECTRUM
CALL PLOSB(EDRM, TSPB, +NRPLT, -1,+1,+47R,0,0,0,
,1TI,60, ARBIS,3,ORDIN,8)
942 CONTINUE
  TI(2)=10H SUM GAMMA
  TI(3)=10H MEV/FIS.
  TI(4)=10H CALCULATED
  IF( ICONPG,NE,1 ) GO TO 961
  TI(5)=10H (*) AND E
  TI(6)=10H EXPERIMENTAL
  TI(7)=5HL (*)
  CALL PLOTM(ERDG,M,TPSLG1,+NGPLT,=1,0,10,0,10,10)
  CALL PLOTM(EGX,GMEXP,1,+NGPLX,=1,1,103,0,10,10)
  GO TO 962
961 CALL PLOTM(ERDG,M,TPSLG1,+NGPLT,=1,0,10,3,0,10,10)
962 CONTINUE
901 CONTINUE
END

SUBROUTINE EXL
CALL VBFS(1,205005B)
RETURN
END

SUBROUTINE EXH
CALL VBFS(1,205007B)
RETURN
END
# APPENDIX C

## SAMPLE OUTPUT FROM THE FPDCYS PROGRAM

### METHOD 4 FOR BETA SPECTRA

### METHOD 2 FOR GAMMA SPECTRA

#### BETA ENERGY BOUNDARIES (EV)

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<thead>
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<th>Energy (EV)</th>
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<tbody>
<tr>
<td>0.0</td>
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<tr>
<td>1E+07</td>
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<tr>
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<tr>
<td>5E+07</td>
</tr>
<tr>
<td>6E+07</td>
</tr>
<tr>
<td>7E+07</td>
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</table>

#### GAMMA ENERGY BOUNDARIES (EV)

<table>
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<th>Energy (EV)</th>
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<td>6.5E+07</td>
</tr>
<tr>
<td>7E+07</td>
</tr>
<tr>
<td>7.5E+07</td>
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</tbody>
</table>
E-BETA = 3211E+07
E-GAMMA = 2881E+06
E-ALPHA = 9
HALFLIFE = 1900E+02
BRANCHINGS = 100E+01
Q-VALUE(S) = 7200E+07
WEIGHTED Q = 7200E+07(+/- 2000E+06)

BETA SPECTRUM

NORMALIZATION FACTOR = 1000E+01
NO. OF POINTS = 5

E-BETA REL INTENSITY

1 2700E+07 1000E+01

BETA SPECTRUM

1830E-01 2452E-01 3082E-01 3686E-01 4247E-01 4751E-01
5185E-01 5541E-01 5811E-01 5990E-01 6073E-01 6061E-01
5954E-01 5755E-01 5470E-01 5105E-01 4671E-01 4197E-01
3642E-01 3076E-01 2498E-01 1929E-01 1389E-01 9025E-02
4949E-02 1938E-02 2884E-03 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0

BETA ENERGY SPECTRUM

9606E+03 3728E+04 7755E+04 1295E+05 1915E+05 2617E+05
3374E+05 4159E+05 4941E+05 5691E+05 6377E+05 6972E+05
7441E+05 7767E+05 7929E+05 7910E+05 7704E+05 7309E+05
6734E+05 5994E+05 5117E+05 4143E+05 3121E+05 2117E+05
1210E+05 4923E+04 7575E+03 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0


\[ \text{AVERAGE BETA ENERGY} = 1.136 \times 10^7 \]

\[ \begin{array}{cccccccc}
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
\end{array} \]

\[ \text{BETA SPECTRUM} \]

\[ \begin{array}{cccccccc}
9.194E-01 & 9.916E-01 & 1.059E+00 & 1.095E+00 & 1.124E+00 & 1.137E+00 \\
9.135E+00 & 1.117E+00 & 1.083E+00 & 1.038E+00 & 9.744E-01 & 9.013E-01 \\
9.234E-01 & 1.516E-01 & 8.277E-02 & 3.229E-02 & 4.789E-03 & 0. \\
\end{array} \]

\[ \text{BETA ENERGY SPECTRUM} \]

\[ \begin{array}{cccccccc}
1.637E+04 & 6.384E+04 & 1.336E+05 & 2.244E+05 & 3.343E+05 & 4.620E+05 \\
5.983E+05 & 7.442E+05 & 8.932E+05 & 1.040E+06 & 1.180E+06 & 1.308E+06 \\
1.418E+06 & 1.507E+06 & 1.570E+06 & 1.605E+06 & 1.607E+06 & 1.577E+06 \\
1.512E+06 & 1.415E+06 & 1.288E+06 & 1.133E+06 & 9.577E+05 & 7.680E+05 \\
5.736E+05 & 3.860E+05 & 2.189E+05 & 8.848E+04 & 1.353E+04 & 0. \\
\end{array} \]

\[ \text{AVERAGE BETA ENERGY} = 1.232 \times 10^7 \]

\[ \begin{array}{cccccccc}
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0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
0. & 0. & 0. & 0. & 0. & 0. & 0. & 0. \\
\end{array} \]

\[ \text{BETA SPECTRUM} \]

\[ \begin{array}{cccccccc}
1.102E+00 & 1.169E+00 & 1.234E+00 & 1.295E+00 & 1.350E+00 & 1.408E+00 \\
1.403E+00 & 1.416E+00 & 1.512E+00 & 1.537E+00 & 1.554E+00 & 1.565E+00 \\
1.569E+00 & 1.566E+00 & 1.557E+00 & 1.540E+00 & 1.517E+00 & 1.487E+00 \\
\end{array} \]
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<th>Beta Emission</th>
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<tr>
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<tr>
<td>0.2146E+03</td>
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BETA ENERGY SPECTRUM

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AVERAGE BETA ENERGY = 0.2494E+07

BETA SPECTRUM

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AVERAGE BETA ENERGY = 0.2494E+07

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BETA ENERGY SPECTRUM

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<td>0.9958E+06</td>
</tr>
<tr>
<td>1.083E+07</td>
<td>1.087E+07</td>
</tr>
<tr>
<td>Beta Energy</td>
<td>Beta Spectrum</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1.040E+07</td>
<td>1.016E+07</td>
</tr>
<tr>
<td>0.828E+06</td>
<td>0.775E+06</td>
</tr>
<tr>
<td>0.494E+06</td>
<td>0.435E+06</td>
</tr>
<tr>
<td>0.151E+06</td>
<td>0.108E+06</td>
</tr>
</tbody>
</table>

**Average Beta Energy =** 0.3033E+07

<table>
<thead>
<tr>
<th>Beta Spectrum</th>
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</thead>
<tbody>
<tr>
<td>1.339E+00</td>
</tr>
<tr>
<td>0.523E+00</td>
</tr>
<tr>
<td>0.100E+01</td>
</tr>
<tr>
<td>0.1439E+01</td>
</tr>
<tr>
<td>0.1767E+01</td>
</tr>
<tr>
<td>0.1933E+01</td>
</tr>
<tr>
<td>0.1915E+01</td>
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<tr>
<td>0.1719E+01</td>
</tr>
<tr>
<td>0.1374E+01</td>
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<tr>
<td>0.9367E+00</td>
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<tr>
<td>0.4875E+00</td>
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<tr>
<td>0.1324E+00</td>
</tr>
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**Average Beta Energy =** 0.3328E+07

<table>
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<tbody>
<tr>
<td>2.242E+00</td>
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<td>0.832E+00</td>
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<td>0.1465E+01</td>
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<tr>
<td>0.1956E+01</td>
</tr>
<tr>
<td>0.2254E+01</td>
</tr>
<tr>
<td>0.2395E+01</td>
</tr>
<tr>
<td>0.2324E+01</td>
</tr>
<tr>
<td>0.2039E+01</td>
</tr>
<tr>
<td>Energy (MeV)</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>0.00-0.04</td>
</tr>
<tr>
<td>0.05-0.09</td>
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<tr>
<td>0.10-0.14</td>
</tr>
<tr>
<td>0.15-0.19</td>
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<tr>
<td>0.20-0.24</td>
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<tr>
<td>0.25-0.29</td>
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<tr>
<td>0.30-0.34</td>
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<td>0.35-0.39</td>
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<tr>
<td>0.50-0.54</td>
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<td>0.55-0.59</td>
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<td>0.60-0.64</td>
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<td>0.65-0.69</td>
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<tr>
<td>0.70-0.74</td>
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<tr>
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<tr>
<td>1.65-1.69</td>
</tr>
<tr>
<td>1.70-1.74</td>
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<tr>
<td>1.75-1.79</td>
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</table>

The sum of the beta energy spectrum is 3187E+09.
<table>
<thead>
<tr>
<th>E = GAMMA</th>
<th>REL. INTENSITY</th>
<th>ICC</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>654E+06</td>
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</tr>
<tr>
<td>2</td>
<td>1076E+07</td>
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</tr>
<tr>
<td>3</td>
<td>1731E+07</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>2514E+07</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>2590E+07</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>2605E+07</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>2634E+07</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>3149E+07</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>3666E+07</td>
<td>0</td>
</tr>
</tbody>
</table>

**GAMMA SPECTRUM**

(1 - E = BETA / ENERGY = SPECTRUM = SUM) x 100 = 7458E+00

**NORMALIZATION FACTOR** = 1142E+00

**NO. OF POINTS** = 9

**TOTAL BETA ENERGY EQUALS** = 3187E+07

E = BETA = 3111E+07
E = BETA = 6912E+07
E = NEUTRINO = 3701E+07
Q0 = 6912E+07

\[
\text{TOTAL BETA ENERGY EQUALS} = 3187E+07
\]

**E = GAMMA REL. INTENSITY**

<table>
<thead>
<tr>
<th>E = GAMMA</th>
<th>REL. INTENSITY</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>654E+06</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1076E+07</td>
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<td>3</td>
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<td>0</td>
</tr>
<tr>
<td>9</td>
<td>3666E+07</td>
<td>0</td>
</tr>
</tbody>
</table>

**GAMMA SPECTRUM**

(1 - E = BETA / ENERGY = SPECTRUM = SUM) x 100 = 7458E+00

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**NO. OF POINTS** = 9

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E = BETA = 6912E+07
E = NEUTRINO = 3701E+07
Q0 = 6912E+07

\[
\text{TOTAL BETA ENERGY EQUALS} = 3187E+07
\]
### GAMMA ENERGY SPECTRUM

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Intensity (Counts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2285E+08</td>
<td>0.4225E+08</td>
</tr>
<tr>
<td>0.2760E+01</td>
<td>0.6928E+04</td>
</tr>
<tr>
<td>0.5696E+01</td>
<td>0.3123E+04</td>
</tr>
<tr>
<td>0.7994E+06</td>
<td>0.1422E+05</td>
</tr>
<tr>
<td>0.1658E+07</td>
<td>0.7143E+07</td>
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<tr>
<td>0.1988E+07</td>
<td>0.5424E+07</td>
</tr>
<tr>
<td>0.7554E+06</td>
<td>0.3629E+07</td>
</tr>
<tr>
<td>0.7254E+05</td>
<td>0.3251E+04</td>
</tr>
<tr>
<td>0.7468E+07</td>
<td>0.9327E+07</td>
</tr>
<tr>
<td>0.1740E+04</td>
<td>0.4500E+02</td>
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</tbody>
</table>

The sum of the gamma energy spectrum is 0.2523E+09

### NORMALIZED GAMMA SPECTRUM

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Intensity (Counts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4195E-01</td>
<td>0.7170E-01</td>
</tr>
<tr>
<td>0.3407E-08</td>
<td>0.8114E-05</td>
</tr>
<tr>
<td>0.5309E-08</td>
<td>0.</td>
</tr>
</tbody>
</table>
NORMALIZED GAMMA ENERGY SPECTRUM

TOTAL GAMMA ENERGY EQUALS 2881E+06
ETG = 2881E+06
EICC = 0
ETR = 2881E+06
Qo = 7200E+07

CALCULATED ENERGIES (ENDF/B)
AVE BETA = 3211E+07 (3211E+07)
AVE TRANSITION E = 2881E+06 (2881E+06)
TOT GAMMA = 2881E+06
E=NEUTRINO = 3701E+07
CE = 0
FRAC CONV E OF TOT TRAN = 0
Q = 7200E+07 (+/- 2,7778 PCT)
FQ = 1225E+04

Q difference is within uncertainty

================================================================================

5
33-4S = 82M
MAT = 76
NDK = 1
NSP = 2
IDE = 3308210

E=BETA = 1819E+07
E=GAMMA = 2995E+07
E=ALPHA = 0
HALFLIFE = 1330F+02
BRANCHINGS = 1000E+01
Q=VALUE(S) = 7200E+07
WEIGHTED Q = 7200E+07 (+/- 2000E+06)

BETA SPECTRUM
---------------
NORMALIZATION FACTOR = 1000E+01
NO. OF POINTS = 4
E=BETA REL INTENSITY
1 3100E+07 1400E+02

BETA SPECTRUM
1872E+00 2535E+00 3222E+00 3899E+00 4550E+00 5162E+00
5721E+00 6216E+00 6639E+00 6983E+00 7241E+00 7409E+00
7485E+00 7469E+00 7361E+00 7163E+00 6880E+20 6517E+00
6082E+00 5584E+00 5033E+00 4440E+00 3621E+00 3190E+00
2563E+00 1959E+00 1397E+00 9001E-01 4896E-01 1903E-01
2815E+02 0 0 0 0 0
The table contains columns labeled BETA ENERGY SPECTRUM and BETA SPECTRUM, with values in scientific notation. There is also a calculation for the AVERAGE BETA ENERGY. The values range from 1.12E+05 to 6.34E+06.
<table>
<thead>
<tr>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.714E+00</td>
<td>1.498E+00</td>
<td>1.267E+00</td>
<td>1.055E+00</td>
<td>8.532E+00</td>
<td>6.655E+00</td>
<td>4.945E+00</td>
<td>3.435E+00</td>
<td>2.157E+00</td>
<td>1.146E+00</td>
</tr>
</tbody>
</table>

**Beta Energy Spectrum**

<table>
<thead>
<tr>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.578E+04</td>
<td>1.037E+05</td>
<td>2.246E+05</td>
<td>3.918E+05</td>
<td>6.773E+05</td>
<td>8.721E+05</td>
<td>1.136E+06</td>
<td>1.849E+06</td>
<td>3.631E+06</td>
<td>6.319E+06</td>
</tr>
</tbody>
</table>

**Average Energy** = 2.445E+07

**Total Beta Spectrum**

<table>
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<tr>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.882E+05</td>
<td>1.538E+06</td>
<td>3.277E+06</td>
<td>5.617E+06</td>
<td>8.546E+06</td>
<td>1.204E+07</td>
<td>1.604E+07</td>
<td>2.949E+07</td>
<td>5.685E+07</td>
<td>8.415E+07</td>
</tr>
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</table>

**Total Beta Spectrum**

<table>
<thead>
<tr>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
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<th>Value</th>
<th>Value</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.882E+05</td>
<td>1.538E+06</td>
<td>3.277E+06</td>
<td>5.617E+06</td>
<td>8.546E+06</td>
<td>1.204E+07</td>
<td>1.604E+07</td>
<td>2.949E+07</td>
<td>5.685E+07</td>
<td>8.415E+07</td>
</tr>
</tbody>
</table>
THE SUM OF THE BETA ENERGY SPECTRUM IS \( 1.813 \times 10^9 \)

NORMALIZED TOTAL BETA SPECTRUM

<table>
<thead>
<tr>
<th>( E )</th>
<th>( E )</th>
<th>( E )</th>
<th>( E )</th>
<th>( E )</th>
<th>( E )</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.371 \times 10^{-2}</td>
<td>1.011 \times 10^{-1}</td>
<td>1.392 \times 10^{-1}</td>
<td>1.598 \times 10^{-1}</td>
<td>1.894 \times 10^{-1}</td>
<td>2.184 \times 10^{-1}</td>
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<tr>
<td>2.464 \times 10^{-1}</td>
<td>2.729 \times 10^{-1}</td>
<td>2.977 \times 10^{-1}</td>
<td>3.202 \times 10^{-1}</td>
<td>3.403 \times 10^{-1}</td>
<td>3.577 \times 10^{-1}</td>
</tr>
<tr>
<td>3.772 \times 10^{-1}</td>
<td>3.937 \times 10^{-1}</td>
<td>3.926 \times 10^{-1}</td>
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<td>3.991 \times 10^{-1}</td>
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<tr>
<td>3.933 \times 10^{-1}</td>
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<tr>
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<tr>
<td>1.787 \times 10^{-1}</td>
<td>1.767 \times 10^{-1}</td>
<td>1.389 \times 10^{-1}</td>
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<tr>
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<tr>
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<tr>
<td>4.946 \times 10^{-3}</td>
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<td>2.157 \times 10^{-3}</td>
<td>1.146 \times 10^{-3}</td>
<td>4.036 \times 10^{-4}</td>
<td>6.319 \times 10^{-5}</td>
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</tbody>
</table>

NORMALIZED TOTAL BETA ENERGY SPECTRUM

<table>
<thead>
<tr>
<th>( E )</th>
<th>( E )</th>
<th>( E )</th>
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<th>( E )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.882 \times 10^{-3}</td>
<td>1.538 \times 10^{-4}</td>
<td>3.277 \times 10^{-4}</td>
<td>5.617 \times 10^{-4}</td>
<td>8.546 \times 10^{-4}</td>
<td>1.214 \times 10^{-5}</td>
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<tr>
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<td>7.793 \times 10^{-5}</td>
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<tr>
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<td>7.970 \times 10^{-5}</td>
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<td>3.978 \times 10^{-5}</td>
<td>3.486 \times 10^{-5}</td>
<td>3.808 \times 10^{-5}</td>
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<tr>
<td>2.567 \times 10^{-5}</td>
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<td>1.468 \times 10^{-5}</td>
<td>1.165 \times 10^{-5}</td>
<td>9.179 \times 10^{-6}</td>
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<tr>
<td>7.448 \times 10^{-6}</td>
<td>6.470 \times 10^{-6}</td>
<td>5.637 \times 10^{-6}</td>
<td>4.797 \times 10^{-6}</td>
<td>3.966 \times 10^{-6}</td>
<td>3.168 \times 10^{-6}</td>
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<tr>
<td>2.397 \times 10^{-6}</td>
<td>1.699 \times 10^{-6}</td>
<td>1.089 \times 10^{-6}</td>
<td>5.894 \times 10^{-7}</td>
<td>2.283 \times 10^{-7}</td>
<td>3.366 \times 10^{-8}</td>
</tr>
</tbody>
</table>

TOTAL BETA ENERGY EQUALS \( 1.813 \times 10^9 \)

\( E = \text{BETA} + \text{NWUT} = 4.099 \times 10^7 \)
\( E = \text{BETA} = 1.819 \times 10^7 \)
\( E = \text{NEUTRINO} = 2.280 \times 10^7 \)
\( QQ = 4.099 \times 10^7 \)

\( (1 - \frac{E - \text{BETA}}{\text{ENERGY-SPECTRUM-SUM}}) \times 100 = 9.356 \times 10^7 \)
**Gamma Spectrum**

**Normalization Factor:** 0.712E+00
**No. of Points:** 13

<table>
<thead>
<tr>
<th>E (Gamma)</th>
<th>Rel. Intensity</th>
<th>ICC</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>3.435E+06</td>
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<tr>
<td>2</td>
<td>5.605E+06</td>
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<tr>
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<td>6.548E+06</td>
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</tr>
<tr>
<td>4</td>
<td>8.155E+06</td>
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</tr>
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**THE SUM OF THE GAMMA ENERGY SPECTRUM IS** 4201E+09

**NORMALIZED GAMMA SPECTRUM**

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NORMALIZED GAMMA ENERGY SPECTRUM

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| 0.1635E+06 | 0.3012E+06 | 0.2197E+04 | 0.4194E+05 | 0.2053E+06 | 0.2267E+05 |
| 0.1136E+05 | 0.6772E+03 | 0.4705E+05 | 0.2953E+06 | 0.8695E+05 | 0.1202E+04 |
| 0.7809E+00 | 0.0000E+00 | 0.1129E+01 | 0.3105E+03 | 0.1179E+05 | 0.1179E+05 |
| 0.6175E+05 | 0.4475E+05 | 0.1167E+05 | 0.1116E+06 | 0.3189E+06 | 0.1711E+06 |
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| 0.1947E+00 | 0.2295E+02 | 0.6520E+03 | 0.9961E+04 | 0.3668E+05 | 0.4254E+05 |

| 0.1554E+05 | 0.1789E+04 | 0.6483E+02 | 0.7402E+00 | 0.0000E+00 | 0.0000E+00 |
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |

TOTAL GAMMA ENERGY EQUALS 2995E+07
ETG = 2.995E+07
EICC = 0
ETR = 2.995E+07
Q0 = 7.094E+07

CALCULATED ENERGIES (ENDF/B)
AVE BETA = 1.819E+07 ( 1.819E+07)
AVE TRANSITION E = 2.995E+07 ( 2.995E+07)
TOT GAMMA = 2.995E+07
E=NEUTRINO = 2.28E+07
CE = 0
FRAC CONV E OF TOT TRANS = 0
Q = 7.094E+07 ( 7.200E+07 +/- 2.778 PCT)
FQ0 = 1.477E+01

Q DIFFERENCE IS WITHIN UNCERTAINTY
### APPENDIX D

**SAMPLE OUTPUT FROM THE FPSPEC PROGRAM**

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#### GAMMA ENERGY BOUNDARIES (EV)

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### Experimental Gamma Energy Points (MeV)

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<td>7129E+13</td>
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TOTAL BETA ENERGY SPECTRUM AT 19470E+03 SEC. TOTAL AND 18470E+03 SEC. DECAY (MEV/SEC)

| 1032E+18 | 3326E+18 | 5736E+18 | 8331E+18 | 1007E+19 | 1188E+19 |
| 1342E+18 | 1477E+19 | 1670E+19 | 1711E+19 | 1801E+19 | 1866E+19 |
| 1912E+18 | 1937E+19 | 1942E+19 | 1935E+19 | 1912E+19 | 1882E+19 |
| 1845E+18 | 1802E+19 | 1766E+19 | 1716E+19 | 1662E+19 | 1604E+19 |
| 1541E+19 | 1473E+19 | 1426E+19 | 1337E+19 | 1264E+19 | 1190E+19 |
| 1113E+19 | 1331E+19 | 9513E+18 | 8660E+18 | 7819E+18 | 6978E+18 |
| 6156E+18 | 5373E+18 | 4641E+18 | 3977E+18 | 3377E+18 | 2853E+18 |
| 2422E+18 | 2897E+18 | 1845E+18 | 1630E+18 | 1436E+18 | 1254E+18 |
| 1095E+18 | 9365E+17 | 7969E+17 | 6654E+17 | 5443E+17 | 4359E+17 |
| 3432E+17  | 2676E+17 | 2054E+17 | 1546E+17 | 1112E+17 | 7514E+16 |
| 47695E+16 | 29616E+16 | 1882E+16 | 1456E+16 | 1216E+16 | 9875E+15 |
| 7723E+15  | 5748E+15 | 4013E+15 | 2526E+15 | 1341E+15 | 6081E+14 |
| 73695E+13 | 1142E+06 | 3904E+05 |            |            |            |

TOTAL GAMMA SPECTRUM AT 19470E+03 SEC. TOTAL AND 18470E+03 SEC. DECAY (GAMMAS/SEC)

| 1734E+19 | 2413E+19 | 9663E+18 | 2897E+19 | 1907E+19 | 2365E+19 |
| 2415E+19 | 1594E+19 | 1910E+19 | 1970E+19 | 6999E+18 | 2533E+19 |
| 2064E+19 | 1213E+19 | 2397E+19 | 7582E+18 | 2289E+19 | 1712E+19 |
| 1707E+19 | 1108E+19 | 1138E+19 | 1012E+19 | 1106E+19 | 7277E+18 |
| 6981E+18 | 1125E+19 | 1586E+19 | 1134E+19 | 189E+19  | 1047E+19 |
| 5429E+18 | 4235E+18 | 3599E+18 | 3653E+18 | 3628E+18 | 3092E+18 |
| 2499E+18 | 2341E+18 | 2572E+18 | 3435E+18 | 3092E+18 | 2032E+18 |
| 1916E+18 | 1942E+18 | 2213E+18 | 2394E+18 | 2094E+18 | 1555E+18 |
| 1891E+18 | 1885E+18 | 2797E+18 | 3124E+18 | 2141E+18 | 1555E+18 |
| 1752E+18 | 1719E+18 | 1324E+18 | 1195E+18 | 8204E+17 | 5905E+17 |
| 5699E+17  | 5539E+17 | 4996E+17 | 4447E+17 | 4952E+17 | 8596E+17 |
| 1402E+18 | 1632E+18 | 1381E+18 | 1211E+18 | 1421E+18 | 1755E+18 |
| 1516E+18 | 9425E+17 | 5519E+17 | 4312E+17 | 3909E+17 | 3299E+17 |
| 2739E+17  | 3285E+17 | 6037E+17 | 1037E+17 | 1251E+18 | 1039E+18 |
| 7259E+17  | 6423E+17 | 8453E+17 | 8744E+17 | 6262E+17 | 5248E+17 |
| 1775E+17  | 1761E+17 | 2159E+17 | 1991E+17 | 1211E+17 | 9384E+16 |
| 1757E+16  | 1393E+16 | 2171E+16 | 3117E+16 | 4049E+16 | 5779E+16 |
| 8789E+16  | 1160E+17 | 1202E+17 | 1086E+17 | 9332E+16 | 8148E+16 |
| 68623E+16 | 5368E+16 | 3837E+16 | 2367E+16 | 4434E+13 | 4165E+15 |
| 1962E+15  | 1917E+14 | 2449E+13 | 8395E+12 | 2256E+14 | 5443E+15 |
| 84463E+14 | 2284E+15 | 4509E+15 | 6612E+15 | 7019E+15 | 1375E+13 |
| 38834E+15 | 1278E+15 | 38599E+14 | 85254E+13 | 1375E+13 | 16224E+12 |
### Total Gamma Energy Spectrum at 194700E+03 Sec, Total and 184700E+03 Sec, Decay (MeV/Sec)

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<th>194700E+03 Sec</th>
<th>184700E+03 Sec</th>
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<td>21215E+17</td>
<td>1839E+18</td>
<td>42397E+18</td>
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<td>77999E+18</td>
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<td>12922E+19</td>
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<td>54991E+18</td>
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<td>2444E+18</td>
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<td>87341E+17</td>
<td>9948E+17</td>
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<td>84032E+16</td>
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<td>61716E+15</td>
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<td>50644E+15</td>
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<td>19580E+16</td>
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### Total Beta Spectrum at 194700E+03 Sec, Total and 184700E+03 Sec, Decay (Betas/Fission)

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### TOTAL BETA ENERGY SPECTRUM AT 194700E+03 SEC. TOTAL AND 184700E+03 SEC. DECAY (MEV/FISSION)

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### TOTAL GAMMA SPECTRUM AT 194700E+03 SEC. TOTAL AND 184700E+03 SEC. DECAY (GAMMAS/FISSION)

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Count</th>
<th>Energy (MeV)</th>
<th>Count</th>
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Note: The values are in scientific notation and represent counts per unit of energy.
<table>
<thead>
<tr>
<th>TOTAL GAMMA ENERGY SPECTRUM AT ( \cdot 194700E+03 ) SEC. TOTAL AND ( \cdot 194700E+03 ) SEC. DECAY (MEV/FISSION)</th>
</tr>
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<tbody>
<tr>
<td>( \cdot 85707E+05 )</td>
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<td>( \cdot 31511E+03 )</td>
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<td>( \cdot 34272E+05 )</td>
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<td>( \cdot 24712E+06 )</td>
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<td>( \cdot 29461E+06 )</td>
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<tr>
<td>( \cdot 73789E+06 )</td>
</tr>
</tbody>
</table>

FISSIONS / SEC = \( \cdot 24752AE+22 \)

RETAS / SEC = \( \cdot 428766E+20 \)

BETAS / FISSION = \( \cdot 173219E+01 \)

BETA MEV / SEC = \( \cdot 536854E+20 \)

BETA MEV / FISSION = \( \cdot 216886E+01 \)

CINDER BETA MEV / FISSION = \( \cdot 220944E+01 \)

PERCENT DIFFERENCE = \( \cdot 183656E+01 \)

GAMMAS / SEC = \( \cdot 580429E+20 \)

GAMMAS / FISSION = \( \cdot 234490E+01 \)

GAMMA MEV / SEC = \( \cdot 580977E+20 \)

EXPERIMENTAL GAMMA MEV / FISSION = \( \cdot 294231E+01 \)

GAMMA MEV / FISSION = \( \cdot 234712E+01 \)
CINDER GAMMA MEV / FISSION = 234867E-01 PERCENT DIFFERENCE = 660528E-01
CINDER TOTAL BETA MEV / FISSION = 296158E-01 PERCENT DIFFERENCE = 267668E+02
CINDER TOTAL GAMMA MEV / FISSION = 298372E-01 PERCENT DIFFERENCE = 213359E+02
BETA COUNT = 163 GAMMA COUNT = 172
RATIO OF BETA MEV / FISSION TO TOTAL CINDER BETA MEV / FISSION = 732332E+00
RATIO OF CINDER BETA MEV / FISSION TO TOTAL CINDER BETA MEV / FISSION = 746034E+00
RATIO OF GAMMA MEV / FISSION TO TOTAL CINDER GAMMA MEV / FISSION = 786641E+00
RATIO OF CINDER GAMMA MEV / FISSION TO TOTAL CINDER GAMMA MEV / FISSION = 787161E+00
RATIO OF EXPERIMENTAL GAMMA MEV / FISSION TO TOTAL CINDER GAMMA MEV / FISSION = 986122E+00
RATIO OF EXPERIMENTAL GAMMA MEV / FISSION TO TOTAL CINDER GAMMA MEV / FISSION
(EXCLUDING CONVERSION ELECTRONS) = 986774E+00
RATIO OF EXPERIMENTAL GAMMA MEV / FISSION TO TOTAL MEV / FISSION = 125359E+01

NB. TOTAL REFERS TO ALL 825 FISSION PRODUCTS. THE REST REFER TO THE 181 FISSION PRODUCTS.

THE FOLLOWING SPECTRA ARE NORMALIZED TO THE TOTAL CINDER-CALCULATED GAMMA AND BETA MEV/FISSION
FOR ALL 825 FISSION PRODUCTS

NORMALIZED BETA SPECTRUM AT 194700E+03 SEC. TOTAL AND 184700E+03 SEC. DECAY (BETAS/FISSION)

| 11292E-02 | 12194E-02 | 12656E-02 | 12663E-02 | 12356E-02 | 11922E-02 |
| 11493E-02 | 10878E-02 | 10393E-02 | 99422E-03 | 94667E-03 | 89591E-03 |
| 84926E-03 | 79259E-03 | 74073E-03 | 68910E-03 | 63948E-03 | 59359E-03 |
| 55955E-03 | 51170E-03 | 47541E-03 | 44656E-03 | 41782E-03 | 37660E-03 |
| 34720E-03 | 31946E-03 | 29330E-03 | 26837E-03 | 24478E-03 | 22265E-03 |
| 28748E-03 | 18828E-03 | 16131E-03 | 14266E-03 | 12506E-03 | 10849E-03 |
| 93499E-04 | 79065E-04 | 68530E-04 | 55564E-04 | 46922E-04 | 37944E-04 |
| 31456E-04 | 26690E-04 | 22880E-04 | 19779E-04 | 17045E-04 | 14575E-04 |
| 12377E-04 | 10439E-04 | 87840E-05 | 71399E-05 | 57219E-05 | 44970E-05 |
| 34753E-05 | 26608E-05 | 20863E-05 | 14840E-05 | 10530E-05 | 69706E-06 |
| 43529E-06 | 26582E-06 | 18626E-06 | 12654E-06 | 10404E-06 | 83178E-07 |
| 64150E-07 | 47119E-07 | 32359E-07 | 28054E-07 | 10505E-07 | 39278E-08 |

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### Normalized Beta Energy Spectrum at 194700e+03 sec. Total and 184700e+03 sec. Decay (MeV/Fission)

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<th>Energy (MeV)</th>
<th>Beta Activity (%)</th>
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### Normalized Gamma Spectrum at 194700e+03 sec. Total and 184700e+03 sec. Decay (Gammas/Fission)

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**NORMALIZED GAMMA ENERGY SPECTRUM AT 194700E+03 SEC. TOTAL AND 184700E+03 SEC. DECAY (MEV/FISSION)**

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**NORMALIZED SUM GAMMA ENERGY SPECTRUM AT 194700F+03 SEC. TOTAL AND 184700F+03 SEC. DECAY (MEV/FISSION)**

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Note: The table values are in units of energy (E+03 or E+05) and count. The table represents normalized gamma energy spectrum at different time intervals.
<p>| $2.837E+05$ | $1.497E+04$ | $3.167E+04$ | $4.731E+04$ | $7.389E+04$ | $9.131E+04$ |
| $1.163E+03$ | $1.374E+03$ | $1.631E+03$ | $1.903E+03$ | $2.167E+03$ | $2.464E+03$ |
| $3.131E+03$ | $4.051E+03$ | $4.924E+03$ | $5.756E+03$ | $6.397E+03$ | $7.828E+03$ |
| $7.994E+03$ | $8.104E+03$ | $9.977E+03$ | $1.115E+04$ | $1.211E+04$ | $1.307E+04$ |
| $1.413E+02$ | $1.523E+02$ | $1.655E+02$ | $1.818E+02$ | $1.970E+02$ | $2.111E+02$ |
| $2.252E+02$ | $2.382E+02$ | $2.483E+02$ | $2.565E+02$ | $2.647E+02$ | $2.744E+02$ |
| $2.169E+02$ | $2.307E+02$ | $3.119E+02$ | $3.627E+02$ | $3.981E+02$ | $4.086E+02$ |
| $4.233E+02$ | $4.422E+02$ | $4.780E+02$ | $5.029E+02$ | $5.328E+02$ | $5.569E+02$ |
| $5.788E+02$ | $6.934E+02$ | $6.343E+02$ | $6.797E+02$ | $7.061E+02$ | $7.378E+02$ |
| $7.669E+02$ | $7.993E+02$ | $8.293E+02$ | $8.715E+02$ | $9.127E+02$ | $9.486E+02$ |
| $9.749E+02$ | $1.005E+03$ | $1.043E+03$ | $1.064E+03$ | $1.097E+03$ | $1.129E+03$ |
| $1.152E+03$ | $1.189E+03$ | $1.218E+03$ | $1.249E+03$ | $1.302E+03$ | $1.339E+03$ |
| $1.335E+01$ | $1.434E+01$ | $1.559E+01$ | $1.585E+01$ | $1.595E+01$ | $1.618E+01$ |
| $1.615E+01$ | $1.659E+01$ | $1.713E+01$ | $1.745E+01$ | $1.778E+01$ | $1.808E+01$ |
| $1.847E+01$ | $1.874E+01$ | $1.986E+01$ | $2.034E+01$ | $2.096E+01$ | $2.132E+01$ |
| $2.911E+01$ | $2.964E+01$ | $2.863E+01$ | $2.834E+01$ | $2.824E+01$ | $2.867E+01$ |
| $2.156E+01$ | $2.176E+01$ | $2.246E+01$ | $2.223E+01$ | $2.248E+01$ | $2.267E+01$ |
| $2.299E+01$ | $2.327E+01$ | $2.357E+01$ | $2.384E+01$ | $2.413E+01$ | $2.433E+01$ |
| $2.458E+01$ | $2.475E+01$ | $2.491E+01$ | $2.502E+01$ | $2.515E+01$ | $2.527E+01$ |
| $2.563E+01$ | $2.559E+01$ | $2.573E+01$ | $2.596E+01$ | $2.619E+01$ | $2.636E+01$ |
| $2.633E+01$ | $2.687E+01$ | $2.703E+01$ | $2.715E+01$ | $2.726E+01$ | $2.733E+01$ |
| $2.710E+01$ | $2.752E+01$ | $2.762E+01$ | $2.774E+01$ | $2.786E+01$ | $2.842E+01$ |
| $2.833E+01$ | $2.845E+01$ | $2.857E+01$ | $2.861E+01$ | $2.864E+01$ | $2.867E+01$ |
| $2.891E+01$ | $2.893E+01$ | $2.908E+01$ | $2.928E+01$ | $2.939E+01$ | $2.935E+01$ |
| $2.938E+01$ | $2.940E+01$ | $2.940E+01$ | $2.948E+01$ | $2.949E+01$ | $2.949E+01$ |
| $2.942E+01$ | $2.942E+01$ | $2.942E+01$ | $2.942E+01$ | $2.942E+01$ | $2.942E+01$ |</p>
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Gamma MEV/Fission at 1.947E+02 s, Total, 1.847E+02 s, Decay