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A FORTRAN IV/63 PROGRAM PACKAGE FOR CALCULATING THE TIME CHANNEL RESPONSE FUNCTION IN NEUTRON TIME-OF-FLIGHT SPECTROSCOPY

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GESTI PRICES

Abstract

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Three computer programs - PTIME, TWALK, and CØNVØL - for computing the time-channel response function for a neutron time-of-flight spectrometer are described. PTIME computes the time-jitter smeared physical flight-time distribution for the target detector configuration where the incident beam and the detected neutrons are along the cylindrical axes of the target and detector, respectively. The flight-time resolution and spectrometer efficiency are computed and plotted results are provided. TWALK computes the neutron pulse-height spectrum and generates the time-slewing response function with the aid of the time-slewing curve. CØNVØL performs the integral over the time-analyzer response function of the convolution of the physical flight-time distribution and the time-slewing response function. Instructions on the use of these codes with the CDC-1604 computer are described along with input card formats required for execution. The methods of entabulation and interpolation of graphic data are included. Complete program listings are presented in appendices.

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I. INTRODUCTION

This report describes three computer programs, PTIME, TWALK, and CONVOL which are used in combination to compute the time-channel response function for a neutron time-of-flight spectrometer. The detailed derivation of the equations and the discussion leading to the time-channel response function are given elsewhere¹ and, in this report, only the principle equations for which the programs provide a solution are given.

Figure 1 shows the simplified spectrometer for which the calculations are made and Fig. 2 shows the target and detector in a typical experimental configuration. The coordinate systems and the various parameters shown in the figures are discussed as they are introduced.

Secondary neutrons are produced in homogeneous slab targets by the interactions of monoenergetic charged particles (or neutrons) with the target nuclei. (In this report, the incident particles are taken to be monoenergetic 160-MeV protons which react in the target to produce secondary neutrons in the energy region between 2- and 100-MeV.) The time-channel response function, $S_k(v_p; v_n, \theta)$, is the probability per incident proton that a secondary neutron of speed v_n produced in the target is detected in channel k of the multichannel time analyzer. $S_k(v_p; v_n, \theta)$ is obtained from the integral over analyzer response function of the convolution of the physical flight-time distribution of detected neutrons and the time-slewing (walk) response function given by

$$S_k(v_p; v_n, \theta) = \int_{t_m} A_k(t_m) T(v_p; v_n, t_m) dt_m, \quad (1)$$

where

$$A_k(t_m) = \text{the analyzer response function; the probability that a neutron of measured flight time } t_m \text{ produces a count in channel } k \text{ of the multichannel time analyzer, and}$$

$$T(v_p; v_n, t_m) dt_m = \text{the probability per incident proton per MeV of neutron energy that a neutron has a measured flight time within } dt_m \text{ at } t_m.$$

¹R. T. Santoro, System Response Functions for Flight-Time Spectrometry of Secondary Fast Neutrons, ORNL-4114 (1967).

Fig. 1. Simplified Block Diagram of the Neutron Time-of-Flight Spectrometer.

Fig. 2. The Target and Detector Coordinate Systems.

$T(v_p; v_n, t_m)$ is obtained from the convolution

$$T(v_p; v_n, t_m) dt_m = dt_m \int_{t_i} C(v_p; v_n, t_i) W(t_m - t_i, v_n) dt_i, \quad (2)$$

where $t_m - t_i = t_w(h)$,

$C(v_p; v_n, t_i) dt_i$ = the jitter-smeared physical flight-time distribution; the probability per incident proton per MeV of neutron energy that a neutron of speed v_n has a jitter smeared apparent flight time within dt_i at t_i and,

$W[t_w(h), v_n]$ = the time-slewing response function; the probability per nsec that a neutron of velocity v_n produces a pulse-amplitude dependent time slewing $t_w(h)$.

The time-slewing response function is normalized such that

$$\int_{t_w(h)} W[t_w(h), v_n] dt_w(h) = 1. \quad (3)$$

The jitter-smeared physical flight-time distribution function is obtained from the convolution

$$dt_i C(v_p; v_n, t_i) = dt_i \int G(v_p; v_n, t) J(t_i - t) dt, \quad (4)$$

where $t_j = t_i - t$, $J(t_j)$ is the time-jitter distribution, and $G(v_p; v_n, t)$ is the flight-time density function of detected neutrons. $J(t_j)$ is approximated by a normal frequency function with zero mean jitter time, t_j , and constant standard deviation σ_j .

Program PTIME computes the jitter-smeared physical flight-time distribution given by Eq. (4) and program TWALK computes the time-slewing response function given by Eq. (3). The output data from these programs are used as input to CONVOL which performs the integrations shown in Eqs. (1) and (2). These programs and their associated subprograms will be described. Instructions on the use of these codes on the ORNL CDC-1604 computer will be discussed and typical results presented.

II. PROGRAM PTIME

The physical flight-time distribution function $C(v_p; v_n, t_i)$ is derived assuming the following: (1) the neutron emission from the target is independent of the azimuthal scattering angle and the polar angle over the angular region subtended by the detector, (2) neutron detection may be treated in the first collision approximation with the light being emitted uniformly from the interaction point and collected uniformly from all points within the detector volume, (3) the beam distribution perpendicular to the scattering plane may be ignored, (4) the instrumental timing jitter can be approximated by a Gaussian distribution independent of pulse height from the scintillation detector. The physical flight time distribution function is obtained by defining the geometric response function for neutron interaction events in the detector as a function of the neutron flight time from a point in the target and then summing over the target volume.

A. Derivation of the Flight-Time Density Function

The flight-time density function of detected neutrons is the probability per incident proton of speed v_p per MeV of neutron energy per nsec that a secondary neutron of speed v_n has an apparent flight time t , and is given by

$$G(v_p; v_n, t) dt = dt \iiint N(y, z) B(\ell_p, \vec{\Omega}) E_\theta(t, \ell_p, x, v_n) dx dy dz, \quad (5)$$

where $dx dy dz$ is an element of target volume and

$dy dz N(y, z)$ = the probability that a beam particle has a displacement from the beam axis within dy at y and dz at z ,

$dx B(\ell_p, \vec{\Omega})$ = the probability per unit solid angle per MeV of neutron energy that the proton interacts in the target within dx at a penetration $\ell_p = x + y \tan \psi - \tau_1 \sec \psi$ to produce a neutron which is emitted in the direction $\vec{\Omega}$, and

$E_\theta(t, \ell_p, x, v_n) dt$ = the detector geometric response function: The probability that a neutron of velocity v_n born at x, y in the target and emitted in a solid

angle toward the detector is detected within
dt at t.

The detector geometric response function is given by

$$E_{\theta}(t, \ell_p, x, v_n) dt = dt \int_{A_D} I(t, \ell_p, x, v_n, \vec{\Omega}) d\vec{\Omega},$$

where the integration is performed over the area of the detector face, A_D . $d\vec{\Omega} = [(\hat{i}' \cdot \vec{\Omega})/\ell_f^3] dA_D$ is the element of solid angle subtended by an element of detector front surface at the interaction point in the target P_T . ℓ_f is the distance from P_T to face of the detector and $\hat{i}'$ is the unit vector along the detector axis x' . The integrand, the probability that a neutron of velocity v_n born in the target at x, y and emitted in the direction $\vec{\Omega}$ is detected within dt at t, is given by

$$I(t, \ell_p, x, v_n, \vec{\Omega}) dt = \begin{cases} \exp\left(-\Sigma_{TN}^{\text{eff}} \ell_T\right) \Sigma(v_n) \exp\left[-\Sigma_D^{\text{eff}} \ell_D(t)\right] d\ell_D(t); & \text{provided the neutron} \\ & \text{interacts at a detec-} \\ & \text{tor penetration dis-} \\ & \text{tance } \ell_D(t) \text{ along the} \\ & \text{direction } \vec{\Omega}, \quad (6) \\ 0 & ; \text{ for } \ell_D(t) \text{ inconsistent} \\ & \text{with neutron interac-} \\ & \text{tions in the detector,} \end{cases}$$

where

- Σ_{TN}^{eff} = effective macroscopic absorption cross section for neutrons in the target,
- $\Sigma(v_n)$ = macroscopic "efficiency" cross section for neutron detection,
- Σ_D^{eff} = effective macroscopic absorption cross section for neutrons in the detector,
- v_n = neutron velocity,
- ℓ_T = pathlength traveled by the neutron in the target,
- $\ell_D(t)$ = pathlength traveled by the neutron in the detector expressed in terms of the apparent flight time,
- $d\ell_D(t)$ = differential distance traveled by the neutron in time dt.

To obtain the complete flight-time distribution given by Eq. (5), we now integrate over the target volume taking into consideration all possibilities for proton interactions. In that equation,

$$B(\ell_p, \vec{\Omega}) \, dx = \begin{cases} \Sigma_p(v_p; v_n, \vec{\Omega}) \exp(-\Sigma_{TP}^{\text{eff}} \ell_p) \, dx & ; \, x, y \text{ within target,} \\ 0 & ; \, x, y \text{ outside target,} \end{cases} \quad (7)$$

where

$\Sigma_p(v_p; v_n, \vec{\Omega})$ = the differential macroscopic cross-section per MeV per unit solid angle in the direction $\vec{\Omega}$ for the production of neutrons of speed v_n ,
 Σ_{TP}^{eff} = the effective macroscopic cross section for absorption of protons in the target.

[Experiments are normally designed to make $\Sigma_p(v_p; v_n, \vec{\Omega})$ sufficiently constant over the detector face so that $\Sigma_p(\vec{\Omega}) \cong \Sigma_p(\theta)$].

It has been assumed that the z-component of the beam typically introduces negligible flight-path variations. $E_\theta(t, \ell_p, x, v_n)$ and $B(\ell_p, \vec{\Omega})$ were considered independent of z, and since $N(y, z)$ is the only term in which z is contained explicitly, it is integrated immediately over all values of z. $N(y)$ is then approximated by a Gaussian distribution with mean value equal to zero, given by

$$N(y) = \frac{1}{\sigma\sqrt{2}} e^{(-1/2)(y/\sigma)^2}, \quad (8)$$

where

σ = the standard deviation of the proton beam distribution about the x-z plane.

B. The Numerical Calculation of $C(v_p; v_n, t_i)$

The numerical calculation of the jitter-smeared physical flight-time distribution was accomplished by completing the integration shown in Eq. (4) and evaluating the results at values of t_i for which the distribution is nonzero. The integration is performed using Gaussian quadratures.

This method of integration was chosen since it yields an accurate approximation to the integral and requires fewer computational steps than other methods. Detailed discussions of the Gaussian quadrature procedure are given by Lanczos² and Kuo.³

C. Cross Sections

The effective macroscopic cross section for neutrons in the detector [see Eq. (6)] is obtained from

$$\Sigma_D^{\text{eff}} = N_H \sigma_H + N_C \sigma_{C,ne} \quad , \quad (9)$$

where N_H and N_C are the atomic densities of hydrogen and carbon in the detector, σ_H is the microscopic total cross section for hydrogen, and $\sigma_{C,ne}$ is the nonelastic microscopic cross section for carbon.

The macroscopic efficiency cross section $\Sigma(v_n)$ [see Eq. (6)] is taken from Schuttler.⁴ These data are based on first collision calculations of the detector efficiency for bias values of 180-keV electron equivalent. This corresponds to 1 MeV for neutrons. Schuttler's data extend up to 50 MeV. For higher neutron energies, the efficiency cross section is inferred from the hydrogen and carbon total cross sections.

The macroscopic absorption cross section for protons in the target Σ_{TP}^{eff} is estimated using the nonelastic cross section for neutrons in carbon from the data of Bertini.⁵

Σ_{TN}^{eff} is set equal to zero in the program listed here. This is not unreasonable for the case of thin targets ($T < 1$ cm) since the mean free path for neutrons is usually much greater than T . For example, for carbon targets, $\lambda = 7.5$ cm at $E_N = 2.0$ MeV.

²Cornelius Lanczos, Applied Analysis, (Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1956).

³Shan S. Kuo, Numerical Methods and Computers, (Addison-Wesley, Reading, Massachusetts, 1965).

⁴R. S. Schuttler, Efficiency of Organic Scintillators to Fast Neutrons, ORNL-3888, July 1966.

⁵H. Bertini, Phys. Rev. **131**, 1801 (1963).

D. Reduction of the Integral to Quadratures

The evaluation of Eq. (4) requires the solution of a four fold integral evaluated at the values of the jitter-smeared apparent flight-times t_i for which the distribution is nonzero. The range of flight times for which the distribution is nonzero is implied by the conditions of Eq.

(6). The values of t_i used in the evaluation of the integral are determined from the extremum flight paths for the neutron for the particular target-detector geometry being studied. The minimum and maximum flight times are defined by $(t_i)_{\min} = (\ell_f)_{\min} / v_n - 2.5\sigma_j$ and $(t_i)_{\max} = (\ell_f)_{\max} / v_n + 2.5\sigma_j$, where $(\ell_f)_{\min}$ and $(\ell_f)_{\max}$ are the extremum flight paths for the neutron between the target and the detector. The addition and subtraction of $2.5\sigma_j$ insures that the values of t_i are defined well into the region of the tails of the jitter smeared distribution. The time mesh is then taken in equal intervals between $(t_i)_{\min}$ and $(t_i)_{\max}$.

The integral over the face of the detector is evaluated by expressing the element of detector area in terms of the cylindrical coordinates on the face of the detector.

The integration over the face of the detector was broken down into two regions in order to take into account the effects of the detector edges. The contributions to the flight-time distribution are then added according to their respective weights and the integral is evaluated over ρ and α as follows

$$2 \int_{-\pi/2}^{\pi/2} \int_0^{R_D} \rho d\rho d\alpha = 2 \int_{-\pi/2}^{\pi/2} d\alpha \left[\int_0^{R'_D(\alpha)} \rho d\rho + \int_{R'_D(\alpha)}^{R_D} \rho d\rho \right], \quad (10)$$

where ρ and $d\rho$ are the radial components, $d\alpha$ is the element of azimuthal angle, and R'_D is the value of the radius at the detector front face along the ray for which the projected flight-path of the neutron along $\vec{\Omega}$ just intercepts the point where the rear surface and the cylindrical surface intersect.

E. Program Glossary

Program PTIME consists of the following subprograms and auxiliary

subprogram packages. Complete listings of the programs are given in the appendices as indicated.

	<u>APPENDIX</u>
MAIN PROGRAM - PTIME	1
<u>Subprograms for computing cross sections</u>	
XSECTN	2
XSECTP	3
XSEC	4
XSECD	5
<u>Subprograms for computing distances and flight times</u>	
FL	6
TL	7
TERMLY	8
TMAX	9
<u>Subprograms for setting up the Gaussian quadrature weights and associated points</u>	
WT	10
AP	11
<u>Subprograms for miscellaneous calculations and plotting</u>	
CDEDX	12
RTSDRAW	13
RTSYSCL	14
EXTREMUM	15
<u>Subprograms for entabulation and interpolation</u>	
TABUL8	16
TERP SYSTEM PACKAGE ⁶	
PLOTTING PACKAGE ⁷	

⁶D. I. Putzulu, P. Aebersold, and W. R. Burrus, Description of the TERP System, A FORTRAN II/63, IV/63, 360 System for Efficient Interpolation, ORNL-TM-1706 (December 1966).

⁷D. K. Trubey and M. B. Emmett, A CDC-1604-Subroutine Package for Making Linear, Logarithmic and Semilogarithmic Graphs Using the Calcomp Plotter, ORNL-3447 (June 1963).

F. Entabulation of Cross Sections and the Error Function

In addition to the subprograms listed in the program glossary, three additional function subprograms are required; XSECHT, XSECNE, and ERFX. Function subprograms XSECHT and XSECNE contain the tabular data of the total microscopic cross section for hydrogen and the nonelastic microscopic cross section for carbon, respectively. Subprogram ERFX tabulates the error function for values of the argument from 0 to 5.0.

These subprograms are used in conjunction with the TERP system to perform the necessary interpolation to yield the value for the cross section as a function of the neutron energy and the error function as a function of the argument. The techniques for generating these decks from tabular data (or plotted data) are described fully by Putzulu *et al.*⁶

G. Input Cards

PTIME is the main calling program. The following input cards are required to complete the execution of the program. Reference to Fig. 2 will aid in identifying some of these parameters.

Input Card 1

```
READ EP, EN
FORMAT (2F8.4)
```

EP = proton energy (MeV),

EN = neutron energy (MeV).

For the subroutines listed in this report, EP = 160-MeV proton. To change this value or the incident particle type, the following subroutines must be revised: XSECTP - Appendix 3, CDEDX - Appendix 13. XSECTP returns the value for the effective macroscopic cross section for absorption of protons in the target [see Eq. (7)] and CDEDX returns the value for the incremental energy loss for these particles in the target.

Input Card 2

```
READ PSI, THETA
FORMAT (2F8.4)
```

PSI = the target rotation angle, (deg) $|\psi| \leq \pi/2$,
 THETA = the angle between the beam axis and the normal to
 the face of the detector (deg).

Input Card 3

```
READ  TAU1, TAU2, RD, D, PL, SIG, SIGJ
FORMAT (7F8.4)
```

TAU1 = element of target thickness along $(-\xi)$, (cm),

TAU2 = element of target thickness along $(+\xi)$, (cm),

Note: The target thickness, $T = \text{TAU2} - \text{TAU1}$.

TAU1 is a negative number.

RD = detector radius, (cm),

D = detector thickness, (cm),

PL = the normal distance from $x-y-z = 0$ to the face of
 the detector, (cm). This corresponds to $\vec{L}$ in Fig. 2.

SIG = the standard deviation of the beam distribution, (cm),
 [see Eq. (8)], and

SIGJ = the standard deviation of the instrumental time
 jitter distribution, (nsec).

Input Card 4

```
READ  TSPACE
FORMAT (F8.4)
```

TSPACE = sets the time mesh, that is, the number of points
 along t_1 at which distribution is evaluated. For
 optimum results, $\text{TSPACE} \geq 20$.

Input Card 5

```
READ  IPNT, JPNT, KPNT, LPNT
FORMAT (4I4)
```

These parameters set the number of quadrature points for
 approximating y , x , ρ , and α integrals respectively. The
 program will approximate the integrals using 2, 4, 8, 12,
 16, or 20 point quadratures. Different values may be

assigned to each parameter. The weights and associated points are set by subprograms: WT - Appendix 10, AP - Appendix 11.

Input Card 6

```
READ  KPLOT, KPUNCH
FORMAT (2I4)
```

KPLOT = sets up a linear plot of the physical flight-time distribution function,

KPLOT = 0, no plot is produced,

KPLOT = 1, plot is produced.

Preparation of the data for plotting is performed in sub-routines: RTSDRAW - Appendix 14, RTSYSCL - Appendix 15, EXTREMUM - Appendix 16. In the resulting plots, the abscissa gives values of t_i and the ordinate gives $[C(v_p; v_n, t_i) / (\Omega_{\text{eff}} \times T_{\text{eff}})]$ where

Ω_{eff} = the effective solid angle subtended by the detector at the origin of x-y-z. $\Omega_{\text{eff}} = A_D / (|\vec{L}|)^2$,
and,

T_{eff} = the effective target thickness.

KPUNCH = controls the output of punched card data,

KPUNCH = 0, no punched cards produced,

KPUNCH = 1, punch cards produced.

The following information is punched on the output cards

Output Card 1

```
EN, TAU1, TAU2, RD, D, PL, SIG, SIGJ
FORMAT (8F8.4)
```

Output Card 2

```
THETA, PSI, TSPACE, GTMIN
FORMAT (4F8.4)
```

GTMIN = minimum value of the jitter-smeared flight time, t_i .

Output Cards 3 ... 3 + TSPACE

TI, CTIVN, ACTIVN, BCTIVN
FORMAT (4E11.4)

TI = value of t_i
CTIVN = $C(v_p; v_n, t_i)$
ACTIVN = $CTIVN / (\Omega_{eff} \times T_{eff})$
BCTIVN = $ACTIVN / (\text{zero bias efficiency})$

Input Card 7

READ TITLE
FORMAT (7A8)

Card 7 is used only when $KPLOT = 1$. If $KPLOT = 0$, this card is omitted. This puts a title on the plot. Up to 56 alpha characters may be used.

Input Card 8

READ KCYCLE
FORMAT (I4)

KCYCLE = 0, stop program,

KCYCLE = 1, restart program with a new set of input data.

H. Warning Messages

This program makes wide use of the TERP system⁶ which enables the user to make rapid, accurate numerical approximations to functions which are not normally provided in the computer library. All of the cross-section curves and the tables of the error function were approximated using this system. The system yields specific values for these approximated functions by parabolic interpolation within the tabulated values supplied to the system.

Occasionally, a "wiggle" warning message will precede the published results. A wiggle is defined as the change in the sign of the slope within a parabola. The causes of the wiggle message are described fully in ref. 6.

If σ_j (SIGJ) is small compared to t_i and one or more of the number of quadrature points IPNT, JPNT, KPNT, LPNT (card 5) are improperly set for an accurate approximation, the computed distribution may be nonmonotonically increasing to its peak value and/or nonmonotonically decreasing. This leads to an improper computation of the full width at half maximum of the distribution and an error message of the type (TONIC = 0N. MON IN BTERP) will result and the program execution may terminate before all the cases have been run. In general, the nonmonotonicity can be eliminated by increasing the value σ_j , or, if this is not practical, by increasing the number of quadrature points. The trial and error approach may be required for optimum results.

SAMPLE OUTPUT FROM PROGRAM PTIME

(PROGRAM PRINTOUT AND CALCOMP PLOT)

RESULTS OF THE CALCULATIONS

NEUTRON ENERGY (MEV)	=	14.5000
NEUTRON VELOCITY (CM/NSEC)	=	5.2097
PROTON ENERGY (MEV)	=	160.0000
PROTON VELOCITY (CM/NSEC)	=	15.5874
STANDARD DEVIATION OF THE BEAM DISTRIBUTION	=	.2500
AREA UNDER THE GAUSSIAN BEAM DISTRIBUTION	=	.9748
TARGET THICKNESS ALONG THE BEAM AXIS	=	.5774
ANGLE BETWEEN THE BEAM AXIS AND THE TARGET NORMAL (PSI)	=	30.0000
TAU1, COMPONENT OF TARGET THICKNESS ALONG (-) XI	=	-.2500
TAU2, COMPONENT OF TARGET THICKNESS ALONG (+) XI	=	.2500
TARGET COMPOSITION	CARBON	
DEUX, INCREMENTAL ENERGY LOSS FOR 160-MEV PROTONS (MEV-CM**2/GM)	=	-4.5186
REMOVAL CROSS-SECTION FOR PROTONS (CM-1)	=	.0205
REMOVAL CROSS-SECTION FOR NEUTRONS (CM-1)	=	0
DETECTOR RADIUS (CM)	=	6.0000
DETECTOR THICKNESS (CM)	=	6.0100
DISTANCE FROM X,Y=0 TO THE FACE OF THE DETECTOR, PL (CM)	=	70.0000
INDEX OF REFRACTION OF THE DETECTOR, REFR	=	1.4300
ANGLE BETWEEN THE BEAM AXIS AND THE DETECTOR NORMAL, THETA	=	60.0000
REMOVAL CROSS-SECTION FOR NEUTRONS (CM-1)	=	.0543
EFFICIENCY CROSS-SECTION (CM-1)	=	.0383
AREA OF THE DETECTOR FRONT SURFACE	=	113.0972
DETECTOR SOLID ANGLE (AREA/PL**2)	=	.0231
ZERO BIAS EFFICIENCY FOR NEUTRONS	=	.2783
STANDARD DEVIATION OF THE JITTER DISTRIBUTION	=	.4300

.EVALUATION OF THE FLIGHT-TIME DISTRIBUTION

MAXIMUM POSSIBLE FLIGHT TIME (NSEC)	=	15.8366
MINIMUM POSSIBLE FLIGHT TIME (NSEC)	=	12.2010
NUMBER OF POINTS TAKEN BETWEEN TMAX AND TMIN FOR INTEGRATION	=	30
NUMBER OF QUADRATURE POINTS		

X =	4
Y =	4
RHO =	4
ALPHA =	4

JITTER-SMEARED FLIGHT TIME	CTIVN/DIFF XSEC (CTIVN)	ACTIVN	BCTIVN
12.201	5.6675e-07	4.2782e-05	1.5372e-04
12.326	1.6464e-06	1.2428e-04	4.4658e-04
12.452	4.4205e-06	3.3369e-04	1.1990e-03
12.577	1.0969e-05	8.2801e-04	2.9752e-03
12.702	2.5173e-05	1.9002e-03	6.0279e-03
12.828	5.3467e-05	4.0360e-03	1.4502e-02
12.953	1.0520e-04	7.9408e-03	2.8533e-02
13.079	1.9195e-04	1.4489e-02	5.2063e-02
13.204	3.2923e-04	2.4550e-02	8.8214e-02
13.329	5.1248e-04	3.8685e-02	1.3900e-01
13.455	7.5223e-04	5.6783e-02	2.0403e-01
13.580	1.0304e-03	7.7783e-02	2.7949e-01
13.705	1.3198e-03	9.9625e-02	3.5797e-01
13.831	1.5837e-03	1.1954e-01	4.2955e-01
13.956	1.7837e-03	1.3464e-01	4.8379e-01
14.081	1.8887e-03	1.4257e-01	5.1228e-01
14.207	1.8825e-03	1.4210e-01	5.1060e-01
14.332	1.7674e-03	1.3342e-01	4.7939e-01
14.458	1.5632e-03	1.1800e-01	4.2401e-01
14.583	1.3018e-03	9.8268e-02	3.5310e-01
14.708	1.0196e-03	7.6966e-02	2.7655e-01
14.834	7.4992e-04	5.6609e-02	2.0341e-01
14.959	5.1703e-04	3.9028e-02	1.4024e-01
15.084	3.3349e-04	2.5174e-02	9.0453e-02
15.210	2.0085e-04	1.5161e-02	5.4477e-02
15.335	1.1274e-04	8.5100e-03	3.0578e-02
15.461	5.8876e-05	4.4443e-03	1.5969e-02
15.586	2.8565e-05	2.1562e-03	7.7477e-03
15.711	1.2857e-05	9.7053e-04	3.4873e-03
15.837	5.3626e-06	4.0480e-04	1.4545e-03

MEAN =	14.1450	VARIANCE =	.0047	STANDARD DEVIATION =	.0689
FWHM =	1.1999	SPREAD =	.6443		
AREA UNDER ACTIVN =	.1811				

EFFICIENCY FROM THE DISTRIBUTION OF FLIGHT-TIMES = .1812

TOTAL RESOLUTION (PER-CENT) = 8.4827

GEOMETRIC RESOLUTION (PER-CENT) = 4.5549

ACTIVN = CTIVN/DETECTOR SOLID ANGLE X TARGET THICKNESS
 BCTIVN = ACTIVN/ZERO BIAS EFFICIENCY

III. PROGRAM TWALK

Program TWALK computes the time-slewing response function given by Eq. (3). To determine the response function, the pulse-height spectrum from the neutron interactions in the detector and the time-slewing curve must be known.

The pulse-height spectrum is calculated here using a first collision approximation to obtain the macroscopic cross section. Conversion to pulse height units is achieved using the fast-light output curves for the charged particle interactions in the detector.⁸ The pulse height spectrum is computed at $4*EN$ energy values in equal energy intervals. These data are then converted to the slewing response function using the walk curve of Peelle et al.⁹ The slewing curve gives the time shift in terms of the ratio of the pulse height to the amplitude of the photomultiplier tube output pulse which just triggers the time analyzer. The analytical methods leading to the differential cross section and subsequent computations which yield $W[t_w(h), v_n]$ are described fully in ref. 1.

PTIME computes the slewing response function for neutrons in the energy region $2\text{-MeV} \leq EN \leq 100 \text{ MeV}$. The code produces punched card output of $W[t_w(h), v_n]$ and $t_w(h)$ for a time analyzer discriminator bias setting of 90 keV electron equivalent.

A. Program Glossary

Program TWALK consists of the following programs and program sub-routines.

APPENDIX

MAIN PROGRAM - TWALK

Auxiliary Programs

TABUL8	16
TERP SYSTEM PACKAGE - (see ref. 6)	

⁸J. B. Birks, Proc. Phys. Soc. A64, 74, 1952.

⁹R. W. Peelle et al., Differential Cross-Sections for the Production of Protons in the Reactions of 160-MeV Protons on Complex Nuclei, ORNL-3887, Sept. 1966.

Note: All of the necessary reaction cross sections, light tables and the time-slewing curve are contained in TWALK in data statements of the form

$$\text{DATA } (I_1 = \text{LIST}), (I_2 = \text{LIST}) ,$$

where I is an identifier representing the array name in which the data is stored.

To modify the program to operate using another walk curve or different detector, all that is required is to change the appropriate DATA statements and perhaps their associated DIMENSIONS.

If the dimension and list length are unchanged, interpolation and entabulation is performed by means of the TERP system.⁶ If longer or shorter tables are used, then arguments in TABUL8 which initiate the call for the TERP package must also be suitably modified.

B. Input Cards

Two input cards are required for executing the program.

Card 1

```
READ EN
FORMAT (F8.4)
```

EN = neutron energy ($2 \text{ MeV} \leq \text{EN} \leq 100 \text{ MeV}$).

Card 2

```
READ KNTR
FORMAT (I4)
```

KNTR controls the recycling of the program if successive cases are to be run,

KNTR = 0, program stops,

KNTR = 1, program recycles and a new set of input cards are required.

C. Output Cards

The following information is punched on output cards.

Output Card 1

EN, XNORM
FORMAT (F8.4, E10.5)

EN = neutron energy (MeV),
XNORM = normalization of the time-slewing distribution.

Output Cards 2 ... 2 + (4EN - 3)

XT, YT
FORMAT (2E11.4)

XT = slewing time (nsec),
YT = probability for slewing time (nsec^{-1})

D. Warning Messages

TWALK also makes use of the TERP system package. Several "wobble" warnings may be published along with the final results. The sources of these warning messages have been studied and they have no effect on the final results.

SAMPLE OUTPUT FROM PROGRAM TWALK

PULSE-HEIGHT SPECTRUM
AND
TIME-SLEWING RESPONSE FUNCTION

PULSE-HEIGHT SPECTRUM		TIME-SLEWING RESPONSE FUNCTION	
*****		*****	
PULSE-HEIGHT (MEV)		TIME (NSEC)	
PROBABILITY (MEV-1 CM-1)		PROBABILITY (NSEC-1)	
3.6839E-02	4.4048E-02	1.314E-03	1.2497E+00
7.9295E-02	4.1154E-02	1.0266E-02	1.2361E+00
1.2719E-01	5.6323E-02	2.2036E-02	1.2220E+00
1.8052E-01	4.9271E-02	3.4001E-02	1.2074E+00
2.3928E-01	4.4856E-02	4.6168E-02	1.1922E+00
3.0349E-01	2.5069E-02	5.8544E-02	1.1763E+00
3.7312E-01	1.4486E-02	7.1137E-02	1.1598E+00
4.4820E-01	1.1181E-02	8.3954E-02	1.1425E+00
5.2871E-01	9.1981E-03	9.7004E-02	1.1220E+00
6.1466E-01	8.1760E-03	1.1036E-01	1.1005E+00
7.0605E-01	7.2299E-03	1.2447E-01	1.0837E+00
8.0287E-01	6.5305E-03	1.3908E-01	1.0667E+00
9.0532E-01	5.9718E-03	1.5422E-01	1.0494E+00
1.0129E+00	5.5320E-03	1.6995E-01	1.0317E+00
1.1222E+00	5.2338E-03	1.8631E-01	1.0134E+00
1.2333E+00	4.9620E-03	2.0337E-01	9.9438E-01
1.3462E+00	4.7218E-03	2.2120E-01	9.7439E-01
1.4609E+00	4.5260E-03	2.3988E-01	9.5320E-01
1.5774E+00	4.3627E-03	2.5953E-01	9.3055E-01
1.6956E+00	4.2302E-03	2.7850E-01	9.0248E-01
1.8157E+00	4.1119E-03	2.9550E-01	8.7299E-01
1.9375E+00	4.0092E-03	3.1367E-01	8.4299E-01
2.0611E+00	3.9255E-03	3.3068E-01	8.1288E-01
2.1865E+00	3.8518E-03	3.4882E-01	7.8310E-01
2.3137E+00	3.7858E-03	3.6843E-01	7.5414E-01
2.4425E+00	3.7169E-03	3.9008E-01	7.2603E-01
2.5742E+00	3.6255E-03	4.1477E-01	6.9879E-01
2.7087E+00	3.5434E-03	4.4405E-01	6.7344E-01
2.8461E+00	3.4683E-03	4.7426E-01	6.4980E-01
2.9863E+00	3.4001E-03	5.0464E-01	6.2766E-01
3.1294E+00	3.3376E-03	5.3522E-01	6.0695E-01
3.2753E+00	3.2808E-03	5.6600E-01	5.8779E-01
3.4241E+00	3.2297E-03	5.9701E-01	5.6995E-01
3.5757E+00	3.1829E-03	6.4332E-01	5.5322E-01
3.7301E+00	3.1393E-03	6.9008E-01	5.3726E-01
3.8874E+00	3.0995E-03	7.3558E-01	5.2266E-01
4.0475E+00	3.0301E-03	7.8099E-01	5.0959E-01
4.2322E+00	3.0005E-03	8.3076E-01	4.9677E-01
4.4175E+00	2.9737E-03	8.8592E-01	4.8414E-01
4.6011E+00	2.9495E-03	9.4811E-01	4.7266E-01
4.7829E+00	2.9279E-03	1.0117E+00	4.6222E-01
4.9630E+00	2.9087E-03	1.0753E+00	4.5282E-01
5.1414E+00	2.8919E-03	1.1675E+00	4.4444E-01
5.3180E+00	2.8773E-03	1.2618E+00	4.3700E-01
5.4929E+00	2.8649E-03	1.3729E+00	4.3059E-01
5.6660E+00	2.8547E-03	1.4935E+00	4.2511E-01
5.8374E+00	2.8466E-03	1.6428E+00	4.2055E-01
6.0071E+00	2.8404E-03	1.7819E+00	4.1690E-01
6.1750E+00	2.8363E-03	1.9729E+00	4.1415E-01
6.3389E+00	2.8342E-03	2.1731E+00	4.1231E-01
6.5013E+00	2.8312E-03	2.4327E+00	4.1149E-01

6.6629 _# +00	2.8231 _# -03	2.7271 _# +00	9.1521 _# -02
6.8236 _# +00	2.8159 _# -03	3.1208 _# +00	9.7974 _# -02
6.9835 _# +00	2.8095 _# -03	3.6330 _# +00	1.0443 _# -01
7.1425 _# +00	2.8038 _# -03	4.2931 _# +00	8.1935 _# -02
7.3007 _# +00	2.7990 _# -03	0	0
7.4580 _# +00	2.7949 _# -03	0	0
7.6144 _# +00	2.7917 _# -03	0	0
<hr/>			
<hr/>			
<hr/>			

IV. PROGRAM CØNVØL

Program CØNVØL computes the time-channel response function from the convolution of the physical flight-time distribution (from program PTIME) and the time-slewing response function (from program TWALK), given by Eq. (2), and the integral over the time-analyzer response function given by Eq. (1).

The convolution is performed using trapezoidal quadratures. The time-slewing response function is divided into equal time intervals such that the initial and final time-slewing values form the lower and upper time limits. The physical flight-time distribution is then divided into intervals of the same size. Forming the time intervals in this manner insures that the sharp edges of the slewing distribution are properly represented in the quadrature.

The analyzer response function is approximated by a rectangular distribution over the width of a time channel by

$$A_k(t_m) = \begin{cases} 1; & n(k - \frac{1}{2}) < t_m \leq n(k + \frac{1}{2}), \\ 0; & \text{otherwise,} \end{cases}$$

where n is the analyzer conversion gain in nsec per channel (taken here to be 0.5 nsec per channel) and k is the time-channel number. The time-channel response function is integrated over all time channels and the area under the distribution is shown to be equal to the spectrometer efficiency. A more detailed discussion of this analysis is given in ref. 1.

Plotted results of the convolution given by Eq. (2) and the time-channel response function are also produced by the program.

A. Program Glossary

Program CØNVØL consists of the following main program and subroutines.

	<u>APPENDIX</u>
MAIN PROGRAM - CØNVØL	18
<u>Subprograms for tabulation and interpolation</u>	
TABUL8	16
TERP SYSTEM - (see ref. 6)	

Subprograms for plotting results

DRAW1		19
YSCL1		20
DRAW2		21
YSCL2		22
EXTREMUM		15
PLOT PACKAGE	- (see ref. 6)	

B. Input Cards

The following input cards are required to execute program ~~C~~ONV~~O~~L. These cards are produced by programs PTIME and TWALK. The only exception is the title card used with the plotted results.

First Deck - generated by TWALK

```

READ  EN, XNORM
FORMAT (F8.5,E10.5)

```

EN = neutron energy (MeV),

XNORM = normalization of the time-slewing distribution
computed in TWALK.

```

READ  (TW(I), XW(I), I = 1, IMAX)
FORMAT (2E11.4)

```

TW = walk time (nsec),

XW = probability per MeV of having walk time TW,

IMAX = the number of cards in the time slewing deck,
(4*EN-3).

Second Deck - generated by PTIME

```

READ  ENEUT, TAU1, TAU2, RD, D, PL, SIG, SIGJ†
FORMAT (8F8.4)

```

[†]These cards are explained in the description of the output cards generated by program PTIME.

ENEUT = neutron energy (MeV) corresponds to EN in program
PTIME.

```
READ THETA, PSI, TINT, GTMIN†
FORMAT (4F8.4)
```

TINT = TSPACE in description of PTIME,

GTMIN = the minimum value of the jitter-smeared physical
flight time.

```
READ (TP(I), GP(I), AP(I), BP(I), I = 1, JMAX)†
FORMAT (4E11.4)
```

JMAX
TINT } = the number of input cards in the second deck.
TSPACE }

```
READ TITLE
FORMAT (7A8)
```

Two plots are produced by this program. Both have the
same title which is read in with this card. The maximum
number of letters or symbols in the title is 56.

```
READ KNTR
FORMAT (I4)
```

KNTR = (-1) start the program with a new energy value.

In this case, a new slewing function deck "first
deck" and physical flight-time distribution "second
deck" must be read into the program,

KNTR = (0) stop the program. No more cases are required,

KNTR = (+1) continue the program using the same neutron
energy. In this case, all that is required are
additional "second decks" (physical flight-time
distribution). The slewing response function is
the same for a given neutron energy.

SAMPLE OUTPUT FROM CONVOL

RESULTS FROM CONVOL

INPUT DATA

```

NEUTRON ENERGY      = 14.5000
DETECTOR ANGLE       = 60.0000
DETECTOR THICKNESS   = 6.0100
DETECTOR RADIUS      = 6.0000
FLIGHT PATH          = 70.0000
STD. DEV. OF BEAM DISTR. = .2500
TARGET ANGLE         = 30.0000
TARGET THICKNESS     = .5000
    TAU1              = -.2500
    TAU2              = .2500

```

```

STD. DEV. OF JITTER  = .4300
SPECTROMETER EFFICIENCY = .1812

```

SLEWING RESPONSE FUNCTION (EQUAL TIME UNITS)

WALK TIME	W(TW(H), VN)	WALK TIME	W(TW(H), VN)
1.3149e-03	1.2497e+00	1.3149e-03	6.2486e-01
1.0266e-02	1.2361e+00	7.8211e-02	1.1500e+00
2.2036e-02	1.2220e+00	1.5774e-01	1.0458e+00
3.4001e-02	1.2074e+00	2.3726e-01	9.5589e-01
4.6168e-02	1.1922e+00	3.1679e-01	7.6155e-01
5.8544e-02	1.1763e+00	3.9632e-01	6.0437e-01
7.1137e-02	1.1598e+00	4.7584e-01	5.2442e-01
8.3954e-02	1.1425e+00	5.5537e-01	4.2465e-01
9.7004e-02	1.1220e+00	6.3489e-01	3.5204e-01
1.1036e-01	1.1005e+00	7.1442e-01	3.5961e-01
1.2447e-01	1.0837e+00	7.9395e-01	3.1335e-01
1.3908e-01	1.0667e+00	8.7347e-01	2.8504e-01
1.5422e-01	1.0494e+00	9.5300e-01	2.7856e-01
1.6995e-01	1.0317e+00	1.0325e+00	2.3961e-01
1.8631e-01	1.0134e+00	1.1121e+00	1.9800e-01
2.0337e-01	9.9439e-01	1.1916e+00	1.9457e-01
2.2129e-01	9.7440e-01	1.2711e+00	1.8278e-01
2.3988e-01	9.5321e-01	1.3506e+00	1.7407e-01
2.5953e-01	9.3056e-01	1.4302e+00	1.6227e-01
2.7850e-01	8.9249e-01	1.5097e+00	1.4604e-01
2.9550e-01	8.2996e-01	1.5892e+00	1.3928e-01
3.1367e-01	7.6955e-01	1.6687e+00	1.3725e-01
3.3068e-01	7.2885e-01	1.7483e+00	1.3231e-01
3.4882e-01	6.8310e-01	1.8278e+00	1.2766e-01
3.6843e-01	6.4146e-01	1.9073e+00	1.2406e-01
3.9008e-01	6.0503e-01	1.9868e+00	1.2061e-01
4.1477e-01	5.7627e-01	2.0664e+00	1.1623e-01
4.4405e-01	5.5694e-01	2.1459e+00	1.1127e-01
4.7426e-01	5.3055e-01	2.2254e+00	1.0702e-01
5.0464e-01	4.9801e-01	2.3049e+00	1.0398e-01
5.3522e-01	4.5879e-01	2.3845e+00	1.0160e-01
5.6600e-01	4.1210e-01	2.4640e+00	9.9482e-02
5.9701e-01	3.5726e-01	2.5435e+00	9.6963e-02
6.4332e-01	3.6095e-01	2.6230e+00	9.4544e-02
6.9008e-01	3.6464e-01	2.7026e+00	9.2140e-02

7.3553e-01	3.4820e-01	2.7821e+00	9.1154e+02
7.8099e-01	3.1959e-01	2.8616e+00	9.1352e+02
8.3076e-01	2.9677e-01	2.9412e+00	9.2411e+02
8.8592e-01	2.8314e-01	3.0207e+00	9.4332e+02
9.4811e-01	2.8004e-01	3.1002e+00	9.7046e+02
1.0117e+00	2.5942e-01	3.1797e+00	9.8829e+02
1.0753e+00	2.1008e-01	3.2593e+00	9.9936e+02
1.1675e+00	1.9856e-01	3.3388e+00	1.0099e+01
1.2618e+00	1.8387e-01	3.4183e+00	1.0199e+01
1.3729e+00	1.7280e-01	3.4978e+00	1.0294e+01
1.4935e+00	1.4776e-01	3.5774e+00	1.0390e+01
1.6423e+00	1.3893e-01	3.6569e+00	1.0419e+01
1.7819e+00	1.3010e-01	3.7364e+00	1.0320e+01
1.9729e+00	1.2145e-01	3.8159e+00	1.0167e+01
2.1731e+00	1.0947e-01	3.8955e+00	9.9642e+02
2.4327e+00	1.0049e-01	3.9750e+00	9.7108e+02
2.7271e+00	9.1521e-02	4.0545e+00	9.4070e+02
3.1203e+00	9.7974e-02	4.1340e+00	9.0529e+02
3.6330e+00	1.0443e-01	4.2136e+00	8.6484e+02
4.2931e+00	8.1935e-02	4.2931e+00	4.0968e+02

NORMALIZATION OF THE TIME-SLEWING RESPONSE FUNCTION = 1.0000

INPUT DATA FROM PTIME

TI (NSEC)	CTIVN	ACTIVN	BCTIVN
12.20100	.00000	.00004	.00015
12.32600	.00000	.00012	.00045
12.45200	.00000	.00033	.00120
12.57700	.00001	.00083	.00298
12.70200	.00003	.00190	.00683
12.82800	.00005	.00404	.01450
12.95300	.00011	.00794	.02853
13.07900	.00019	.01449	.05206
13.20400	.00033	.02455	.08821
13.32900	.00051	.03869	.13900
13.45500	.00075	.05678	.20403
13.58100	.00103	.07778	.27949
13.70500	.00132	.09963	.35797
13.83100	.00158	.11954	.42955
13.95600	.00178	.13464	.48379
14.08100	.00189	.14257	.51228
14.20700	.00188	.14210	.51060
14.33200	.00177	.13342	.47939
14.45800	.00156	.11800	.42401
14.58300	.00130	.09827	.35310
14.70800	.00102	.07697	.27655
14.83400	.00075	.05661	.20341
14.95900	.00052	.03903	.14024
15.08400	.00033	.02517	.09045
15.21000	.00020	.01516	.05448
15.33500	.00011	.00851	.03058
15.46100	.00006	.00444	.01597
15.58600	.00003	.00216	.00775
15.71100	.00001	.00097	.00349
15.83700	.00001	.00040	.00145

TM(NSEC),	T(VP,VN,TM)
24.3994	1.06297*-06
24.5584	5.93576*-06
24.7175	1.74652*-05
24.8765	3.87845*-05
25.0356	7.71481*-05
25.1946	1.44800*-04
25.3537	2.56849*-04
25.5127	4.40201*-04
25.6718	7.31172*-04
25.8308	1.17552*-03
25.9899	1.84181*-03
26.1489	2.80643*-03
26.3080	4.15723*-03
26.4671	5.99552*-03
26.6261	8.41670*-03
26.7852	1.15010*-02
26.9442	1.53075*-02
27.1033	1.98730*-02
27.2623	2.51710*-02
27.4214	3.11237*-02
27.5804	3.75895*-02
27.7395	4.43558*-02
27.8985	5.12042*-02
28.0576	5.78741*-02
28.2166	6.40808*-02
28.3757	6.95658*-02
28.5347	7.40999*-02
28.6938	7.75003*-02
28.8528	7.96602*-02
29.0119	8.05552*-02
29.1709	8.02039*-02
29.3300	7.87037*-02
29.4890	7.62154*-02
29.6481	7.29157*-02
29.8072	6.90191*-02
29.9662	6.47350*-02
30.1253	6.02567*-02
30.2843	5.57686*-02
30.4434	5.14174*-02
30.6024	4.73064*-02
30.7615	4.35050*-02
30.9205	4.00579*-02
31.0796	3.69760*-02
31.2386	3.42522*-02
31.3977	3.18682*-02
31.5567	2.97909*-02
31.7158	2.79710*-02
31.8748	2.63859*-02
32.0339	2.50219*-02
32.1929	2.38449*-02
32.3520	2.28296*-02
32.5110	2.19503*-02
32.6701	2.11872*-02
32.8291	2.05282*-02
32.9882	1.99611*-02
33.1473	1.94755*-02
33.3063	1.90669*-02

33.4654	1.87282e-02
33.6244	1.84530e-02
33.7835	1.82355e-02
33.9425	1.80678e-02
34.1016	1.79396e-02
34.2606	1.78404e-02
34.4197	1.77576e-02
34.5787	1.76764e-02
34.7378	1.75807e-02
34.8968	1.74527e-02
35.0559	1.72739e-02
35.2149	1.70267e-02
35.3740	1.66946e-02
35.5330	1.62640e-02
35.6921	1.57236e-02
35.8511	1.50683e-02
36.0102	1.42984e-02
36.1692	1.34206e-02
36.3283	1.24487e-02
36.4874	1.13999e-02
36.6464	1.02966e-02
36.8055	9.16538e-03
36.9645	8.03356e-03
37.1236	6.92806e-03
37.2826	5.87408e-03
37.4417	4.89279e-03
37.6007	3.99962e-03
37.7598	3.20653e-03
37.9188	2.51935e-03
38.0779	1.93772e-03
38.2369	1.45797e-03
38.3960	1.07210e-03
38.5550	7.69741e-04
38.7141	5.39227e-04
38.8731	3.67976e-04
39.0322	2.43980e-04
39.1912	1.56752e-04
39.3503	9.74249e-05
39.5093	5.80661e-05
39.6684	3.27052e-05
39.8275	1.69800e-05
39.9865	7.44591e-06
40.1456	1.92239e-06
40.3046	6.4765e-07

TYPE-CHANNEL RESPONSE FUNCTIONS

CHANNEL NUMBER	PROBABILITY PER MEV
24	1.68621e-06
25	1.06555e-04
26	1.71784e-03
27	1.01767e-02
28	2.68616e-02
29	3.73037e-02
30	3.14889e-02
31	2.01064e-02
32	1.31258e-02
33	1.01674e-02
34	9.09509e-03
35	8.51991e-03

36	6.91916E-03
37	3.96732E-03
38	1.35492E-03
39	2.31042E-04
40	2.97055E-05

NOTE***** PLOT AS HISTOGRAMS

THE SUM OVER ALL CHANNELS = 0.18117

ACKNOWLEDGMENTS

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APPENDIX I
PROGRAM PTIME

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PROGRAM PTIME	0000
C.....	0005
C.....COMMON	0010
C.....	0015
COMMON NI,N0,NP	0020
COMMON PSI,THETA,PSIR,THETAR,PL,RD,D,RT,T,TAU1,TAU2,DEDX,SECPS1	0025
COMMON SIG,SIGJ,DECCN,DECOND,REFR,VLITE,EP,EN,VP,VN,TI,TSPACE	0030
COMMON QX,QY,QR,QA,XLO,XHI,YLO,YHI,ALPHLO,ALPHHI,RH0LO,RH0HI	0035
COMMON CONAM,CONCAP,CONX,CONY,CONFL	0040
COMMON P1,SQ2P1,P102,GTMIN,GTMAX	0045
COMMON CLT,CTMAX,CTMIN,CTP	0050
COMMON CSECTN,CSECD	0055
COMMON SITHET,C0THET,TANPS1	0060
COMMON TAU1S,TAU2S	0065
COMMON ACTIVN,BCTIVN	0070
C.....	0075
C.....DIMENSION	0080
C.....	0085
DIMENSION DX(20),SX(20)	0090
DIMENSION TI(100)	0095
DIMENSION CTIVN(100)	0100
DIMENSION YNUMER5(100),P0M5(100),TERM6(100),FUNCT(100)	0105
DIMENSION ANS3(100),ANS2(100),ANS1(100),ANS(100),RES(100)	0110
DIMENSION TITLE(8)	0115
DIMENSION APX(20),APY(20),APR(20),APA(20)	0120
DIMENSION WTX(20),WTY(20),WTR(20),WTA(20)	0125
DIMENSION PR0D(100),SUMSQ(100)	0130
DIMENSION TSMEAR(200)	0135
DIMENSION ACTIVN(100),BCTIVN(100)	0140
DIMENSION CITIVN(100),C2TIVN(100),TI1(100),TI2(100),FIRST(109)	0145
DIMENSION SECOND(109)	0150
DIMENSION SMEARC(200)	0155
C.....	0160
C.....TAPE NUMBERS 1604	0165
C.....	0170
NI = 50	0175
N0 = 51	0180
NP = 52	0185
C THE PLOTTING TAPE IS LOGICAL 48.	0190
C.....	0195
CALL TAD(-1)	0200
C.....	0205
C SET THE PROTON AND NEUTRON ENERGY	0210
C.....	0215
100 CONTINUE	0220
C.....	0225
READ(NI,8015) EP, EN	0230
C.....	0235
C EP = PROTON ENERGY (MEV)	0240
C EN = NEUTRON ENERGY (MEV)	0245
C RELATIVISTIC CORRECTIONS FOR THE NEUTRON AND PROTON VELOCITIE	0250
ERM = 931.478	0255
RMN = ERM*1.008982	0260
RMP = ERM*1.008142	0265
WN = RMN+EN	0270
WP = RMP+EP	0275

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CONVER = 3.E+10*1.E-09	0280
C VN = NEUTRON VELOCITY (CM/NSEC)	0285
VN = CONVER*SQRT(1. + (RMN**2/WM**2))	0290
C VP = PROTON VELOCITY (CM/NSEC)	0295
VP = CONVER*SQRT(1. + (RMP**2/WP**2))	0300
C	0305
C EVALUATE ALL CROSS-SECTIONS	0310
C	0315
CSECTN = XSECTN(DUMMY)	0320
CSECD = XSECD(EN)	0325
CSEC = XSEC(EN)	0330
C	0335
C SET THE TARGET AND DETECTOR GEOMETRY	0340
C	0345
C	0350
READ(NI,8020) PSI, THETA	0355
C	0360
C PSI = THE ANGLE BETWEEN THE BEAM AXIS AND THE TARGET NORMAL (DEG	0365
C PSIR = THE ANGLE BETWEEN THE BEAM AXIS AND THE TARGET NORMAL (RAD	0370
C THETA = THE ANGLE BETWEEN THE BEAM AXIS AND THE DETECTOR NORMAL (DEG	0375
C THETAR = THE ANGLE BETWEEN THE BEAM AXIS AND THE DETECTOR NORMAL (RAD	0380
C	0385
C	0390
READ(NI,8025) TAU1,TAU2,RD,D,PL,SIG,SIGJ	0395
C	0400
C SIG = THE STANDARD DEVIATION OF THE PROTON BEAM DISTRIBUTION	0405
C SIGJ = THE STANDARD DEVIATION OF THE TIME JITTER DISTRIBUTION	0410
C PL = THE DISTANCE FROM X-Y = 0 TO THE FACE OF THE DETECTOR	0415
C RD = RADIUS OF THE NEUTRON DETECTOR	0420
C D = THICKNESS OF THE NEUTRON DETECTOR	0425
C RT = RADIUS OF THE TARGET	0430
C T = THICKNESS OF THE TARGET	0435
C TAU1 IS A NEGATIVE NUMBER	0440
C	0445
C ISET SETS THE INNER AND OUTER INTEGRATION OVER RHO.	0450
C ISET = 2 INNER REGION ONLY. ISET = 2 OUTER REGION.	0455
C ISET = 2	0460
C	0465
PSIR = PSI/57.29578	0470
THETAR = THETA/57.29578	0475
SECPSI = 1./COS(PSIR)	0480
TAU2S = TAU2*SECPSI	0485
TAU1S = TAU1*SECPSI	0490
T = TAU2S - TAU1S	0495
SITHET = SIN(THETAR)	0500
COTHET = COS(THETAR)	0505
TANPSI = ATAN(PSIR)	0510
C	0515
C CALCULATE DEDX.	0520
DEDX = CDIDX(EP,TAU1,TAU2,SECPSI)	0525
C	0530
C	0535
C SET ALL CONSTANTS IN THE ANALYSIS	0540
C	0545
EPS = 0.001	0550
PI = 3.14159	0555

04=28=67

	SQ2PI = SORT(2,*PI)	0560
	PI02 = PI/2.	0565
C	REFR = INDEX OF REFRACTION OF THE NEUTRON DETECTOR	0570
	REFR = 1.43	0575
C	VLITE = THE SPEED OF LIGHT (CM/NSEC)	0580
	VLITE = 3.E+10/1.E+09	0585
	DECON = REFR*VN/VLITE	0590
	DECOND = DECON*D	0595
	FACTOR = 1./(2.*SIGJ**2)	0600
C	.....	0605
C	FLIGHT-TIME INITIALIZATION	0610
C	.....	0615
	YT = 2.5*SIG	0620
C	.....	0625
C	DETERMINE IF TARGET IS IN TRANSMISSION OR REFLECTION,	0630
C	.....	0635
	ANGLE = ABSF(THETAR - PSIR)	0640
	IF(ANGLE - PI02) 110,110,105	0645
105	CONTINUE	0650
	PLMINP = PL-(YT*TANPSI+TAU1S)*COTHET-YT*SITHET	0655
	PLMINN = PL-(-YT*TANPSI+TAU1S)*COTHET-(-YT)*SITHET	0660
C	GTMIN IS THE MINIMUM POSSIBLE FLIGHT-TIME FROM THE GEOMETRY	0665
	GTMIN = MINIF(PLMINP,PLMINN)/VN - 2.5*SIGJ	0670
	PLD = PL + D	0675
	AT=YT*TANPSI+TAU1S	0680
	PLMAX1 = FL(TAU2S,+AT,+RD,PI02,PLD,THETAR)	0685
	PLMAX2 = FL(TAU2S,+AT,-RD,PI02,PLD,THETAR)	0690
	PLMAX3 = FL(TAU2S,-AT,+RD,PI02,PLD,THETAR)	0695
	PLMAX4 = FL(TAU2S,-AT,-RD,PI02,PLD,THETAR)	0700
C	GTMAX IS THE MAXIMUM POSSIBLE FLIGHT TIME FROM THE GEOMETRY	0705
	GTMAX = MAXIF(PLMAX1,PLMAX2,PLMAX3,PLMAX4)/VN + 2.5*SIGJ	0710
	GO TO 115	0715
110	CONTINUE	0720
	PLMINP = PL-(YT*TANPSI+TAU2S)*COTHET-YT*SITHET	0725
	PLMINN = PL-(-YT*TANPSI+TAU2S)*COTHET-(-YT)*SITHET	0730
C	GTMIN IS THE MINIMUM POSSIBLE FLIGHT-TIME FROM THE GEOMETRY	0735
	GTMIN = MINIF(PLMINP,PLMINN)/VN - 2.5*SIGJ	0740
	PLD = PL + D	0745
	BT=YT*TANPSI+TAU2S	0750
	PLMAX1 = FL(TAU1S,+BT,+RD,PI02,PLD,THETAR)	0755
	PLMAX2 = FL(TAU1S,+BT,-RD,PI02,PLD,THETAR)	0760
	PLMAX3 = FL(TAU1S,-BT,+RD,PI02,PLD,THETAR)	0765
	PLMAX4 = FL(TAU1S,-BT,-RD,PI02,PLD,THETAR)	0770
C	GTMAX IS THE MAXIMUM POSSIBLE FLIGHT TIME FROM THE GEOMETRY	0775
	GTMAX = MAXIF(PLMAX1,PLMAX2,PLMAX3,PLMAX4)/VN + 2.5*SIGJ	0780
C	.....	0785
115	READ(NI,0030) TSPACE	0790
C	.....	0795
C	.....	0800
C	SET THE TIME MESH FOR T1.	0805
C	.....	0810
	ISPACE = TSPACE	0815
	IGTMAX = GTMAX	0820
	IGTMIN = GTMIN	0825
	GTMAX = IGTMAX	0830
	GTMIN = IGTMIN	0835

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	DELT = (GTMAX - GTMIN)/(TSPACE - 1.)	0840
	TI(1) = GTMIN	0845
	DO 120 M = 2, TSPACE	0850
	TI(M) = TI(M-1) + DELT	0855
120	CONTINUE	0860
C	.....	0865
C	BEGIN THE INTEGRATION WITH GAUSS QUADRATURES	0870
C	.....	0875
C	.....	0880
	READ(NI, 8035) JPNT, KPNT, LPNT	0885
C	.....	0890
C	SET THE WEIGHTS AND ASSOCIATED POINTS FOR THE QUADRATURE.	0895
	DO 125 I = 1, IPNT	0900
	APX(I) = AP(IPNT/4+1, I)	0905
	WTX(I) = WT(IPNT/4+1, I)	0910
125	CONTINUE	0915
	DO 130 J = 1, JPNT	0920
	APX(J) = AP(JPNT/4+1, J)	0925
	WTX(J) = WT(JPNT/4+1, J)	0930
130	CONTINUE	0935
	DO 135 K = 1, KPNT	0940
	APX(K) = AP(KPNT/4+1, K)	0945
	WTK(K) = WT(KPNT/4+1, K)	0950
135	CONTINUE	0955
	DO 140 L = 1, LPNT	0960
	APX(L) = AP(LPNT/4+1, L)	0965
	WTL(L) = WT(LPNT/4+1, L)	0970
140	CONTINUE	0975
	ANST1 = 0.0	0980
	FIAT2 = 0.0	0985
C	.....	0990
C	SET THE UPPER AND LOWER LIMITS ON EACH INTEGRAL.	0995
C	THE ORDER OF INTEGRATION IS Y, X, RHO, ALPHA	1000
C	.....	1005
C	LIMITS ON THE Y INTEGRATION	1010
C	YT DEFINES THE UPPER AND LOWER LIMITS OF INTEGRATION FOR Y	1015
C	IT DEFINES THE REGION OF THE INCIDENT BEAM DISTRIBUTION TO PLUS	1020
C	AND MINUS 2.5 STANDARD DEVIATIONS.	1025
C	.....	1030
	YLO = -YT	1035
	YHI = +YT	1040
C	LIMITS ON THE RHO INTEGRATION	1045
C	.....	1050
C	RHOLO = LOWER LIMIT OF INTEGRATION IN RHO. RHOHI = UPPER LIMIT OF	1055
C	INTEGRATION ON THE FIRST REGION OF THE DETECTOR. RHOHI2 = UPPER	1060
C	LIMIT OF INTEGRATION ON THE SECOND REGION OF THE DETECTOR.	1065
C	.....	1070
	RHOLO = 0.0	1075
	RHOHI = RD*(1. + D/PL)	1080
	RHOHI2 = RD	1085
C	LIMITS ON THE ALPHA INTEGRATION	1090
	ALPHLO = -PI/2.	1095
	ALPHHI = PI/2.	1100
C		1105
	DY = (YHI - YLO)/2.	1110
	SY = (YHI + YLO)/2.	1115

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	DRH0 = (RH0H1 - RH0L0)/2.	1120
	SRH0 = (RH0H1 + RH0L0)/2.	1125
	DRH01 = RD/2.	1130
	SRH01 = RD/2.	1135
	DRH02 = (RH0H12 - RH0H1)/2.	1140
	SRH02 = (RH0H12 + RH0H1)/2.	1145
	DALF = (ALPHH1 - ALPHL0)/2.	1150
	SALF = (ALPHH1 + ALPHL0)/2.	1155
C	.....	1160
C	AREA UNDER THE GAUSSIAN BEAM DISTRIBUTION	1165
C	.....	1170
	AGAUSS = 0.0	1175
	DO 145 I=1,IPNT	1180
	QY = DY*APY(I) + SY	1185
	FGAUSS = EXP(-(QY**2/(2.*SIG**2)))	1190
	AGAUSS = AGAUSS + FGAUSS*WTY(I)	1195
145	CONTINUE	1200
	GAUSS = DY*AGAUSS*(1./((SQRT(2.*3.14159)*SIG))	1205
C	.....	1210
C	TEST FOR AREA OF THE DETECTOR FRONT SURFACE	1215
C	.....	1220
	TESTC=0.0	1225
	TESTC1 = 0.0	1230
	TESTC2 = 0.0	1235
	AREA1 = 0.0	1240
	AREA2 = 0.0	1245
	DO 175 K=1,KPNT	1250
	IF(2 - ISET) 150,150,155	1255
150	QR2 = DRH02*APR(K) + SRH02	1260
155	QR1 = DRH0*APR(K) + SRH0	1265
	TESTB=0.0	1270
	DO 160 L=1,LPNT	1275
	QA = DALF*APA(L) + SALF	1280
	FUNCTA = 1.0	1285
	TESTB = FUNCTA*WTA(L) + TESTB	1290
160	CONTINUE	1295
	IF(2 - ISET) 165,165,170	1300
165	TESTC2 = TESTC2 + TESTB*QR2*WTR(K)	1305
170	TESTC1 = TESTC1 + TESTB*QR1*WTR(K)	1310
175	CONTINUE	1315
	AREA1 = 2.*DRH0*DALF*TESTC1	1320
	AREA2 = 2.*DRH02*DALF*TESTC2	1325
	AREA = AREA1 + AREA2	1330
C	.....	1335
C	.....	1340
C	START THE QUADRATURE OVER THE Y COORDINATES OF THE TARGET	1345
C	.....	1350
	DO 180 M = 1,ISPACE	1355
	ANS(M) = 0.0	1360
180	CONTINUE	1365
	EFFI = 0.0	1370
	EFFIP = 0.0	1375
	FINANS = 0.0	1380
	DO 375 I = 1,IPNT	1385
	QY = DY*APY(I) + SY	1390
C	NOTE XLIM = F(Y)	1395

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	DX(1) = ((TAU2S - QY*TANPSI) - (TAUIS - QY*TANPSI))/2.	1400
	SX(1) = ((TAU2S - QY*TANPSI) + (TAUIS - QY*TANPSI))/2.	1405
C	*****	1410
C	START THE QUADRATURE OVER THE X COORDINATES OF THE TARGET	1415
C	*****	1420
	DO 185 M = 1, ISPACE	1425
	ANS1(M) = 0.0	1430
185	CONTINUE	1435
	EFF2 = 0.0	1440
	EFF2P = 0.0	1445
	ANSX = 0.0	1450
	DO 365 J = 1, JPNT	1455
	QX = DX(1)*APX(J) + SX(J)	1460
	FUNCTY = TERMIY(QX, QY, PSIP, TAU1, SECP1, SIG)	1465
	CONX = PL = QX*COTHET = QY*SITHET	1470
	CAPXA = QX + QY*TANPSI - TAU1S	1475
	CONST = 1./((4.*EP*VN)	1480
	CTP = QX/VP - CONST*(CAPXA**2)* DEDX	1485
C	*****	1490
C	START THE QUADRATURE OVER THE ALPHA COORDINATES OF THE DETECTOR	1495
C	*****	1500
	DO 190 M = 1, ISPACE	1505
	ANS2(M) = 0.0	1510
190	CONTINUE	1515
	EFF3 = 0.0	1520
	EFF3P = 0.0	1525
	DO 355 L = 1, LPNT	1530
	QA = DALF*APA(L) + SALF	1535
C	*****	1540
C	START THE QUADRATURE OVER THE RHO COORDINATES OF THE DETECTOR	1545
C	*****	1550
	DO 195 M = 1, ISPACE	1555
	ANS3(M) = 0.0	1560
195	CONTINUE	1565
	EFF4 = 0.0	1570
	EFF4P = 0.0	1575
	DO 345 INTEG = 1, ISET	1580
	DO 345 K = 1, KPNT	1585
	IF(2 - INTEG) 205, 205, 200	1590
200	QR = DRH0*APR(K) + SRH0	1595
	TERM7 = QR	1600
	GA TO 210	1605
205	QR = DRH02*APR(K) + SRH02	1610
	TERM7 = QR	1615
210	CONTINUE	1620
C	*****	1625
	IF(2 - INTEG) 220, 220, 215	1630
215	CONTINUE	1635
	CONFI = FL(QX, QY, QR, QA, PL, THETAR)	1640
	CONY = QR*SIN(QA) + QX*SITHET - QY*COTHET	1645
	CONOM = (PL - QX*COTHET - QY*SITHET)/CONFI	1650
C	*****	1655
C	*****	1660
C	THIS VERSION INCLUDES CORRECTIONS FOR THE DETECTOR EDGES.	1665
C	*****	1670
C	*****	1675

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CTMIN = CONFL/VN + CTP + REFR*D/VLITE	1680
CTMAX = CTMIN + (D/CONOM)/VN + REFR*D/VLITE	1685
C*****	1690
GO TO 225	1695
220 CONFL = FL(QX,QY,QR,QA,PL,THETAR)	1700
CONY = QR*SIN(QA) + QX*SITHET - QY*COTHET	1705
CONOM = (PL - QX*COTHET - QY*SITHET)/CONFL	1710
CTMIN = CONFL/VN + CTP + REFR*D/VLITE	1715
CTMAX = TMAX(DUMMY)	1720
225 CONTINUE	1725
CLT = TL(DUMMY)	1730
PON2 = CLT*CSECTN	1735
TERM3 = CONOM/CONFL**2	1740
CONST3 = (1. - DECON*CONOM)	1745
PON4 = ((DECON*CONFL+CTP*VN)/CONST3)*CSECD	1750
IF(2-INTEG) 235,235,230	1755
230 EFF5=(CSEC/CSECD)*(1.-EXP(-CSECD*(CTMAX-CTMIN+REFR*D/VLITE)*VN))	1760
I*TERM3*TERM7	1765
GO TO 240	1770
235 EFF5=(CSEC/CSECD)*(1.-EXP(-CSECD*(CTMAX-CTMIN+REFR*D/VLITE-CONCAP	1775
I)*VN))*TERM3*TERM7	1780
240 CONTINUE	1785
C*****	1790
C EVALUATION OF THE INTEGRAND OVER THE JITTER SMEARED FLIGHT-TIMES.	1795
C CTIVN IS THE DISTRIBUTION FUNCTION EVALUATED AT THESE TIME PRINTS.	1800
C*****	1805
DO 315 M = 1, ISPACE	1810
XNUMER5(M) = TI(M) - ((SIGJ**2)*VN/CONST3)*CSECD	1815
PON5(M) = FACTOR*(TI(M)**2 - XNUMER5(M)**2)	1820
A = (CTMAX - XNUMER5(M))/SIGJ	1825
B = (CTMIN - XNUMER5(M))/SIGJ	1830
IF (A) 245,245,260	1835
245 A = -A	1840
IF(5.-A)250,250,255	1845
250 AX = -0.5000	1850
GO TO 275	1855
255 AX = -ERFX(A)	1860
GO TO 275	1865
260 IF(5.-A) 265,265,270	1870
265 AX = 0.5000	1875
GO TO 275	1880
270 AX = ERFX(A)	1885
275 IF(B) 280,280,295	1890
280 B = -B	1895
IF(5.-B)285,285,290	1900
285 BX = -0.5000	1905
GO TO 310	1910
290 BX=-ERFX(B)	1915
GO TO 310	1920
295 IF(5.-B) 300,300,305	1925
300 BX = 0.5000	1930
GO TO 310	1935
305 BX = ERFX(B)	1940
310 TERM6(M) = AX - BX	1945
FUNCT(M) = EXP(-PON2 + PON4 - PON5(M))*TERM3*TERM6(M)*TERM7/CONST3	1950
315 CONTINUE	1955

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C.....	1980
DO 330 M = 1, ISPACE	1965
IF(2-INTG) 325,325,320	1970
320 ANS3(M) = ANS3(M) + FUNCT(M)*WTR(K)*DRH0	1975
GO TO 330	1980
325 ANS3(M) = ANS3(M) + FUNCT(M)*WTR(K)*DRH02	1985
330 CONTINUE	1990
IF(2-INTG) 340,340,335	1995
335 EFF4 = EFF4 + EFF5*WTR(K)*DRH0	2000
GO TO 345	2005
340 EFF4 = EFF4 + EFF5*WTR(K)*DRH02	2010
345 CONTINUE	2015
DO 350 M = 1, ISPACE	2020
ANS2(M) = ANS2(M) + ANS3(M)*WTA(L)	2025
350 CONTINUE	2030
EFF3 = EFF3 + 2.*EFF4*WTA(L)*DALF	2035
355 CONTINUE	2040
DO 360 M = 1, ISPACE	2045
ANS1(M) = ANS1(M) + ANS2(M)*WTX(J)*FUNCTY	2050
360 CONTINUE	2055
EFF2 = EFF2 + EFF3*WTX(J)	2060
EFF2P = EFF2P + WTX(J)	2065
365 CONTINUE	2070
DO 370 M = 1, ISPACE	2075
ANS(M) = ANS(M) + WTY(I)*ANS1(M)*DX(I)	2080
370 CONTINUE	2085
EFF1 = EFF1 + EFF2*WTY(I)	2090
EFF1P = EFF1P + EFF2P*WTY(I)	2095
375 CONTINUE	2100
DO 380 M = 1, ISPACE	2105
CTIVN(M) = ((ANS(M)*DY*DALF*2.*VN)/(SQ2PI*SIG))*CSEC/GAUSS	2110
380 CONTINUE	2115
C.....	2120
C..... EFF = THE EFFICIENCY FROM THE DISTRIBUTION OF FLIGHT-TIMES.	2125
EFF = (EFF1/EFF1P)*(PL**2/AREA)	2130
C.....	2135
CALL TABUL8(TI,CTIVN,ISPACE,2*ISPACE+8,SMEARC)	2140
XTMIN = TI(1)	2145
XTMAX = TI(ISPACE)	2150
EFFYC = TERFI(XTMIN,XTMAX,SMEARC)	2155
C.....	2160
C CALCULATION OF THE ZERO BIAS EFFICIENCY.	2165
C	2170
EO = 1. - EXP(-CSECD*D)	2175
C	2180
C.....	2185
C	2190
C CALCULATION OF THE MEAN, VARIANCE, AND STANDARD DEVIATION	2195
C	2200
C.....	2205
SUM = 0.0	2210
SUMC = 0.0	2215
DO 385 M = 1, ISPACE	2220
PROD(M) = TI(M)	2225
SUM = SUM + PROD(M)*CTIVN(M)	2230
SUMC = SUMC + CTIVN(M)	2235

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385	CONTINUE	2240
	AVG = SUM/SUMC	2245
C		2250
	SUM2 = 0.0	2255
	DO 390 M = 1, ISPACE	2260
	SUMSQ(M) = ((ABS(TI(M) - AVG))**2)*CTIVN(M)	2265
	SUM2 = SUM2 + SUMSQ(M)	2270
390	CONTINUE	2275
	VAR = SUM2	2280
	STDDEV = SQRT(VAR)	2285
C	.....	2290
C		2295
C	CONVERT CTIVN TO ACTIVN AND BCTIVN.	2300
C		2305
C	.....	2310
	SIGMA = XSECTP(EP)	2315
	ATTEN = 1. - EXP(-SIGMA*T)	2320
	SOLANG = AREA/PL**2	2325
	DO 395 M = 1, ISPACE	2330
	ACTIVN(M) = CTIVN(M)*(PL**2/AREA)*SIGMA/ATTEN	2335
	BCTIVN(M) = ACTIVN(M)/E0	2340
395	CONTINUE	2345
C	.....	2350
C	.....	2355
C		2360
C	CALCULATION OF THE EFFICIENCY BY INTEGRATION OF THE DISTRIBUTION	2365
C		2370
C	.....	2375
	CALL TABJL9(TI, ACTIVN, ISPACE, 2*ISPACE+8, TSMEAR)	2380
	XTMIN = TI(1)	2385
	XTMAX = TI(ISPACE)	2390
	EFFY = TERP1(XTMIN, XTMAX, TSMEAR)	2395
C	.....	2400
C		2405
C	CALCULATION OF FWHM AND RESOLUTION OF THE SPECTROMETER.	2410
C		2415
C	.....	2420
	AXAMP = CTIVN(1)	2425
	DO 410 M = 2, ISPACE	2430
	IF(CTIVN(M) - AXAMP) 405, 405, 400	2435
400	AXAMP = CTIVN(M)	2440
405	CONTINUE	2445
410	CONTINUE	2450
	HAFAMP = 0.5*AXAMP	2455
	DO 425 K = 1, ISPACE	2460
	IF(AXAMP - CTIVN(M)) 420, 415, 420	2465
415	K = M	2470
	MAXVAL = K	2475
420	CONTINUE	2480
425	CONTINUE	2485
	DO 430 M = 1, K	2490
	CTIVN(M) = CTIVN(M)	2495
	TI(M) = TI(M)	2500
430	CONTINUE	2505
	J = K + 1	2510
	DO 435 M = J, ISPACE	2515

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	C2TIVN(M+1-J) = CTIVN(M)	2520
	TI2(M+1-J) = TI(M)	2525
435	CONTINUE	2530
	LENGTH = (3*(K-1))/2 + 7	2535
	K = (LENGTH - 7)/3*2+1	2540
	CALL TABSET(TI1,TI1(K),LENGTH,K,FIRST)	2545
	X = TI1(1)	2550
	DO 440 LL = 1,K	2555
	CALL TABX(X,CTIVN(LL),LL,FIRST)	2560
440	CONTINUE	2565
	POINT1 = BTEFP(HAFAMP,FIRST)	2570
	LENGTH = (3*(ISPACE - MAXVAL - 1))/2 + 7	2575
	K = (LENGTH - 7)/3*2+1	2580
	CALL TABSET(TI2,TI2(K),LENGTH,K,SECOND)	2585
	X = TI2(1)	2590
	DO 445 LL = 1,K	2595
	CALL TABX(X,C2TIVN(LL),LL,SECOND)	2600
445	CONTINUE	2605
	POINT2 = BTEFP(HAFAMP,SECOND)	2610
	FWHM = POINT2 - POINT1	2615
	SPRED = SQRT(FWHM**2 = (2.354*SIGJ)**2)	2620
	RESSIG = (FWHM/AVG)*100.	2625
	RESGEOM = (SPRED/AVG)*100.	2630
	C.....	2635
	C	2640
	C KPL0T DECIDES WHETHER PLOTTING WILL BE DONE	2645
	C KPL0T = 1 PLOT RESULTS	2650
	C KPL0T = 0 NO PLOTS	2655
	C KPUNCH DECIDES PUNCHING OF THE OUTPUT CARDS.	2660
	C KPUNCH = 0 NO CARDS PUNCHED.	2665
	C KPUNCH = 1 CARDS WILL BE PUNCHED.	2670
	C.....	2675
	C READ(NI,8040) KPL0T,KPUNCH	2680
	C.....	2685
	C IF(1 - KPL0T) 450,450,455	2690
	450 CONTINUE	2695
	C.....	2700
	C READ(NI,8045) (TITLE(I),I=1,7)	2705
	C.....	2710
	C TITLE(8) = GETDATE(DUMMY)	2715
	C CALL RTSDRAW(ACTIVN,TITLE)	2720
	455 CONTINUE	2725
	C.....	2730
	C....	2735
	C WRITE OUT THE RESULTS.	2740
	C....	2745
	C WRITE(NO,8065)	2750
	C WRITE(NO,8070) EN,VN,EP,VP,SIG,GAUSS,T,PSI,TAU1,TAU2,DEDX,SIGMA,	2755
	C CSECTN,RD,D,PL,REFR,THETA,CSECD,CSEC,AREA,SOLANG,ED	2760
	C WRITE(NO,8095) SIGJ	2765
	C WRITE(NO,8075) GTMAX,GTMIN,ISPACE,IPNT,JPNT,KPNT,LPNT	2770
	C WRITE(NO,8080) (TI(M),CTIVN(M),ACTIVN(M),BCTIVN(M), M = 1,ISPACE)	2775
	C WRITE(NO,8055)	2780
	C WRITE(NO,8085) AVG,VAR,STDDEV,FWHM,SPRED,EFFY	2785
	C WRITE(NO,8090) EFF	2790
	C WRITE(NO,8105) RESSIG,RESGEOM	2795

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WRITE(N0,8100)	2800
WRITE(N0,8060)	2805
C****	2810
IF (I-KPUNCH) 460,460,465	2815
C PUNCH OUT CARDS.	2820
460 PUNCH 8000,EN,TAU1,TAU2,RO,D,PL,SIG,SIGJ	2825
PUNCH 8005,THETA,PSI,ISPACE,GTMIN	2830
PUNCH 8010,(TI(M),CTIVN(M),ACTIVN(M),BCTIVN(M), M=1,ISPACE)	2840
465 CONTINUE	2845
C*****	2850
CALL TAD(0)	2855
C KCYCLE = THE PROGRAM RESTART CONTROL CARD	2860
C KCYCLE = 1, RESTART PROGRAM WITH NEW PARAMETERS.	2865
C KCYCLE = 0, NO CHANGE. ALL PARAMETERS HAVE BEEN RUN,	2870
C*****	2875
READ(N1,8050) KCYCLE	2880
C*****	2885
IF(1-KCYCLE) 100,100,470	2890
C*****	2895
C LOCATION OF ALL FORMAT STATEMENTS	2900
8000 FORMAT(8F8.4)	2905
8005 FORMAT(4F8.4)	2910
8010 FORMAT(4E11.4)	2915
8015 FORMAT(2F8.4)	2920
8020 FORMAT(>F8.4)	2925
8025 FORMAT(7F8.4)	2930
8030 FORMAT(F9.4)	2935
8035 FORMAT(4I4)	2940
8040 FORMAT(2I4)	2945
8045 FORMAT(7A8)	2950
8050 FORMAT(I4)	2955
8055 FORMAT(I40)	2960
8060 FORMAT(I41)	2965
8065 FORMAT(I41)	2970
8070 FORMAT(50X,27HRESULTS OF THE CALCULATIONS/50X,27H*****	2975
2*****//25X,24HNEUTRON ENERGY (MEV),41X,3H= ,F8.4/25X,28H	2980
3NEUTRON VELOCITY (CM/NSEC),37X,3H= ,F8.4/25X,19HPROTON ENERGY	2985
4(MEV),46X,3H= ,F8.4/25X,25HPROTON VELOCITY (CM/NSEC),40X,3H= ,F8	2990
5.4/25X,43HSTANDARD DEVIATION OF THE BEAM DISTRIBUTION,22X,3H= ,F8	2995
6.4/25X,41HAREA UNDER THE GAUSSIAN BEAM DISTRIBUTION,24X,3H= ,F8.4	3000
7//25X,36HTARGET THICKNESS ALONG THE BEAM AXIS,29X,3H= ,F8.4/25X,	3005
855HANGLE BETWEEN THE BEAM AXIS AND THE TARGET NORMAL (PSI),10X,3H=	3010
9 ,F8.4/25X,43HTAU1, COMPONENT OF TARGET THICKNESS ALONG (+) XT,17	3015
AX,3H= ,F8.4/25X,48HTAU2, COMPONENT OF TARGET THICKNESS ALONG (+)	3020
8XI,17X,3H= ,F8.4/25X,48HTARGET COMPOSITION	3025
C CARRON /25X,69HDEDX, INCREMENTAL ENERGY LOSS FOR 16	3030
00-MEV PROTNS (MEV-CM**2/GM) = ,F8.4/25X,41HREMOVAL CROSS-SECTION	3035
FOR PROTNS (CM=1),24X,3H= ,F8.4/25X,41HREMOVAL CROSS-SECTION FO	3040
OR NEUTRONS (CM=1),24X,3H= ,F8.4/25X,20HDETECTOR RADIUS (CM),45X,	3045
03H= ,F8.4/25X,23HDETECTOR THICKNESS (CM),42X,3H= ,F8.4/25X,69HDI	3050
STANCE FROM X,Y=0 TO THE FACE OF THE DETECTOR,PL (CM)	3055
1,F8.4/25X,40HINDEX OF REFRACTION OF THE DETECTOR,REFR,25X,3H= ,F8	3060
J.4/25X,69HANGLE BETWEEN THE BEAM AXIS AND THE DETECTOR NORMAL, THE	3065
KTA = ,F8.4/25X,41HREMOVAL CROSS-SECTION FOR NEUTRONS (CM=1)	3070
L,24X,3H= ,F8.4/25X,32HEFFICIENCY CROSS-SECTION (CM=1),33X,3H= ,	3075
MF8.4/25X,34HAREA OF THE DETECTOR FRONT SURFACE,31X,3H= ,F8.4/25X,	3080

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L,24X,3H= ,F8.4/25X,32HEFFICIENCY CROSS-SECTION (CM-1),33X,3H= , 3075
MF8.4/25X,34HAREA OF THE DETECTOR FRONT SURFACE,31X,3H= ,F8.4/25X, 3080
*TAPE PARITY ERROR NEXT LINE(S)*
N34HDETECTOR SOLID ANGLE (AREA/PI**2),31X,3H= ,F8.4/25X,34HZERO B 3085
BIAS EFFICIENCY FOR NEUTRONS ,31X,3H= ,F8.4) 3090
8075 FORMAT(141,40X,42HEVALUATION OF THE FLIGHT-TIME DISTRIBUTION/40X,4 3095
22H*****//25X,35HMAXIMUM POSSI 3100
3RLF FLIGHT TIME (NSEC),30X,3H= ,F8.4/25X,35HMINIMUM POSSIBLE FLIG 3105
4HT TIME (NSEC),30X,3H= ,F8.4/25X,67HNUMBER OF POINTS TAKEN BETWEE 3110
5N TMAX AND TMIN FOR INTEGRATION = ,14/25X,27HNUMBER OF QUADRAT 3115
V 6URE POINTS/63X,5HX = ,14/63X,5HY = ,14/61X,7HRRH = ,14/59X,9HAL 3120
7PHA = ,14/25X,14HJITTER-SMEARED,3X,15HCTIVN/DIFF XSEC,6X,6HACTIV 3125
8N,13X,6HACTIVN/26X,11HFLIGHT TIME,9X,7H(CTIVN)/25X,14H***** 3130
9*,3V,15H***** ,3X,15H***** ,3X,15H***** 3135
A**) 3140
8080 FORMAT(29X,F8.3,9X,E10.5,7X,E10.5,9X,E10.5) 3145
8085 FORMAT(25X,9HMEAN = ,F8.4,4X,13HVARIANCE = ,F8.4,4X,23HSTANDAR 3150
2D DEVIATION = ,F8.4/25X,9HFWHM = ,F8.4,4X,10HSPREAD = ,F8.4/ 3155
325X,22HAREA UNDER ACTIVN = ,F8.4) 3160
8090 FORMAT(140,25X,51HEFFICIENCY FROM THE DISTRIBUTION OF FLIGHT-TIMES 3165
1 = ,F8.4) 3170
8095 FORMAT(140,24X,45HSTANDARD DEVIATION OF THE JITTER DISTRIBUTION,20 3175
1X,3H= ,F8.4) 3180
8100 FORMAT(140,25X,68H***** 3185
1 *****//25X,56HACTIVN = CTIVN/DETECTOR SOLID ANGLE 3190
2X TARGET THICKNESS/25X,36HACTIVN = ACTIVN/ZERO BIAS EFFICIENCY) 3195
8105 FORMAT(25X,30HTOTAL RESOLUTION (PER-CENT) = ,F8.4/ 3200
125X,34HGEOMETRIC RESOLUTION (PER-CENT) = ,F8.4) 3205
470 CONTINUE 3210
CALL TAD(+1) 3215
CALL EXIT 3220
END 3225

```

APPENDIX II

SUBPROGRAM XSECTN(EN)

04-28-67

FUNCTION XSECTN(EN)	0000
C THIS SUBPROGRAM RETURNS THE VALUE OF THE EFFECTIVE REMOVAL CROSS	0005
C SECTION FOR NEUTRONS IN THE TARGET. SEE EQUATION (6).	0010
C*****	0015
C FOR THIN TARGETS IN WHICH THE NEUTRON MEAN FREE PATH IS MUCH	0020
C GREATER THEN THE DISTANCE TRAVELLED BY THE NEUTRON FROM THE INTER-	0025
C ACTION POINT IN THE TARGET TO THE POINT OF EXIT FROM THE TARGET.	0030
C XSECTN = 0. FOR EXAMPLE, THE TOTAL CROSS-SECTION IN CARBON IS	0035
C 1.7 BARN AND THE CORRESPONDING MEAN FREE PATH IS 7.5 CM.	0040
C*****	0045
XSECTN = 0.0	0050
RETURN	0055
END	0060

APPENDIX III

SUBPROGRAM XSECTP(EP)

04-28-67

FUNCTION XSECTP(EP)	0000
C THIS SUBPROGRAM RETURNS THE VALUE FOR THE EFFECTIVE MACROSCOPIC	0005
C CROSS-SECTION FOR THE ABSORPTION OF PROTONS IN THE TARGET.	0010
C*****	0015
C SIGTP = MICROSCOPIC CROSS-SECTION.	0020
C*****	0025
C THE VALUE FOR SIGTP GIVEN IN THIS VERSION IS FOR 160-MEV PROTONS	0030
C IN CARBON. FROM H. BERTINI, PHYS REV 131, 1800.	0035
C*****	0040
C NOTE	0045
C IF THE TARGET, INCIDENT PARTICLE ENERGY, OR INCIDENT	0050
C PARTICLE IS CHANGED, THIS SUBPROGRAM MUST BE	0055
C REVISED ACCORDINGLY.	0060
C*****	0065
C XN = AVOGADROS NUMBER	0070
C P = THE DENSITY OF THE TARGET IN GM/CM**3	0075
C*****	0080
XN = 6.024E+23	0085
SIGTP = 233.0E-27	0090
P = 1.75	0095
A = 12.	0100
XSECTP = (XN*P*SIGTP)/A	0105
100 RETURN	0110
END	0115

APPENDIX IV

SUBPROGRAM XSEC(EN)

04-28-67

 FUNCTION XSEC(EN)

 DIMENSION E0(30),MACRO(30),SECTAB(60)

 DATA(E0=2.0,3.0,4.0,5.0,6.0,7.0,8.0,9.0,10.,12.0,15.0,20.,25.,
 30.,35.,40.,45.,50.,55.,60.,65.,70.,75.,80.,85.,90.,95.,100.)

 DATA(MACRO=.070,.063,.057,.054,.0515,.0480,.043,.042,.0415,.040,
 1.038,.035,.0315,.028,.025,.023,.0215,.0195,.0192,.0183,.0178,
 2.017,.0166,.0162,.0159,.0156,.014,.0122)

 C*****

 C THIS SUBPROGRAM RETURNS THE VALUE FOR THE MACROSCOPIC
 C EFFICIENCY CROSS-SECTION FOR 2- TO 100-MEV NEUTRONS IN A NE-213
 C LIQUID SCINTILLATOR DETECTOR. THESE DATA ARE FROM
 C R. J. SCHUTTLE, ORNL-3888.

 C*****

 CALL TABJL8(E0,MACRO,28,56,SECTAB)

 XSEC = TERPT(EN,SECTAB)

 RETURN

 END

APPENDIX V
SUBPROGRAM XSECD(EN)

04-28-67

FUNCTION XSECD(EN)	0000
C.....	0005
C THIS SUBPROGRAM RETURNS THE VALUE FOR THE MACROSCOPIC REMOVAL	0010
C CROSS-SECTION FOR NEUTRONS IN THE DETECTOR.	0015
C THE DETECTOR IS NE-213 WHICH IS COMPOSED CHIEFLY OF HYDROGEN AND	0020
C AND CARBON. XSECNE IS THE NON-ELASTIC CROSS-SECTION FOR	0025
C CARBON AND XSECHT IS THE TOTAL CROSS-SECTION FOR HYDROGEN.	0030
C XSECNE AND XSECHT ARE INCLUDED IN THE PROGRAM PACKAGE AS AUXILIARY	0035
C DECKS AND WERE MADE USING THE TECHNIQUES FOR PRODUCING A TERP	0040
C DECK REPORTED BY PUTZULU, ET. AL. THE VALUES FOR THE	0045
C CROSS-SECTIONS WERE TAKEN FROM BNL-325.	0050
C.....	0055
C H IS THE NUMBER OF HYDROGEN ATOMS PER GRAM	0060
C C IS THE NUMBER OF CARBON ATOMS PER GRAM	0065
ENLOG = ALOG(EN*1.E+06)	0070
IF(EN-4.92) 100,100,105	0075
100 XCNE = 0.0	0080
GO TO 110	0085
105 CONTINUE	0090
XNELOG = XSECNE(ENLOG)	0095
XCNE = EXP(XNELOG)	0100
110 CONTINUE	0105
XHTLOG = XSECHT(ENLOG)	0110
XHT = EXP(XHTLOG)	0115
H = 0.04826E+24	0120
C = 0.03986E+24	0125
XSECD = (XHT*H + XCNE*C)*1.E+24	0130
RETURN	0135
END	0140

APPENDIX VI

SUBPROGRAM FL(X,Y,RH ϕ ,ALPHA,PL,THETAR)

04-28-67

	FUNCTION FL(X,Y,RHO,ALPHA,PL,THETA)	0000
C	THIS SUBPROGRAM RETURNS THE VALUE FOR THE DISTANCE FROM THE	0005
C	NEUTRON BIRTH POINT IN THE TARGET TO THE FACE OF THE DETECTOR.	0010
	FLA=PL**2+X**2+Y**2+RHO**2	0015
	FLE=SIN(THETA)*(2.*X*RHO*SIN(ALPHA)-2.*PL*Y)	0020
	FLC=COS(THETA)*(2.*Y*RHO*SIN(ALPHA)+2.*PL*X)	0025
	FL=SQRT(FLA+FLR+FLC)	0030
	RETURN	0035
	END	0040

APPENDIX VII
SUBPROGRAM TL(DUMMY)

04-28-67

```

      FUNCTION TL(DUMMY)                                0000
C .....                                              0005
C                                     COMMON              0010
C .....                                              0015
      COMMON NI,NC,NP                                0020
      COMMON PSI,THETA,PSIR,THETAR,PL,RD,D,RT,T,TAU1,TAU2,DEDX,SECPSI 0025
      COMMON SIG,SIGJ,DECON,DECOND,REFP,VLITE,EP,EN,VP,VN,VI,TSPACE 0030
      COMMON QX,QY,QR,QA,XL0,XHI,YL0,YHI,ALPHL0,ALPHHI,RH0L0,RH0HI 0035
      COMMON CONNM,CONCAP,CONX,CONY,CONF1            0040
      COMMON P1,SQ2P1,P102,GTMIN,GTMAX                0045
      COMMON CLT,CTMAX,CTMIN,CTP                      0050
      COMMON CSECTN,CSECD                             0055
      COMMON STHET,COTHET,TANPSI                      0060
      COMMON TAU1S,TAU2S                              0065
      COMMON ACTIVN,ACTIVN                            0070
C .....                                              0075
C                                     DIMENSION          0080
C .....                                              0085
      DIMENSION TI(100)                              0090
C .....                                              0095
C  THIS SUBPROGRAM RETURNS THE VALUE FOR THE DISTANCE TRAVELLED BY
C  THE NEUTRON IN THE TARGET.                         0100
C .....                                              0105
C .....                                              0110
      DIMENSION ACTIVN(100),ACTIVN(100)               0115
      ANGLE = ABS(THETAR-PSIR)                         0120
      DIFANG = THETAR-PSIR                             0125
      DENOM = (1./CONF1)*(CONX*CHS(DIFANG)+CONY*SIN(DIFANG)) 0130
      IF(ANGLE-P102) 110,110,115                      0135
      100 CONTINUE                                    0140
C  TARGET IN TRANSMISSION.                            0145
      XNUMER=(TAU2S - QX - QY*TANPSI)*(1./SECPSI)      0150
      TL = XNUMER/DENOM                                0155
      GO TO 110                                         0160
      105 CONTINUE                                    0165
C  TARGET IN REFLECTION.                              0170
      XNUMER = (QX+QY*TANPSI-TAU1S)*(1./SECPSI)        0175
      TL = XNUMER/DENOM                                0180
      110 RETURN                                       0185
      END                                              0190
*TAPE PARITY ERROR NEXT LINE(S)*

```

APPENDIX VIII

SUBPROGRAM TERMLY(X,Y,PSIR,TAU1,SECPSI,SIG)

04-28-67

FUNCTION TERMIY(X,Y,PSIR,TAU,SECPSI,SIG)	0000
SECTP = XSECTP(EP)	0005
TERMIY=EXP(-((Y**2/(2.*SIG**2))+ SECTP*(X+Y*ATAN(PSIR)-TAU)*SECPSI	0010
)))	0015
100 RETURN	0020
END	0025

APPENDIX IX

SUBPROGRAM TMAX(DUMMY)

04-28-67

```

FUNCTION TMAX(NUMMY)                                0000
C                                                     0005
C.....COMMON.....                                0010
COMMON NI,N0,NP                                     0015
COMMON PSI,THETA,PSIR,THETAR,PL,RD,D,RT,T,TAU1,TAU2,DEDX,SECPSI 0020
COMMON SIG,SIGJ,DECON,DECOND,REFR,VLITE,EP,EN,VP,VN,TI,TSPACE 0025
COMMON QX,QY,QR,QA,XL0,XHI,YL0,YHI,ALPHL0,ALPHHI,RH0L0,RH0HI 0030
COMMON CONOM,CONCAP,CONX,CONY,CONFL                 0035
COMMON PI,SQ2PI,P102,GTMIN,GTMAX                   0040
COMMON CLT,CTMAX,CTMIN,CTP                           0045
COMMON CSECTN,CSECD                                   0050
COMMON SITHET,COTHET,TANPSI                         0055
COMMON TAU1S,TAU2S                                   0060
COMMON ACTIVN,ACTIVN                                0065
C.....DIMENSION.....                                0070
C.....DIMENSION TI(100).....                        0075
C.....0080
C.....0085
C      THIS SUB-PROGRAM RETURNS THE MAXIMUM VALUE OF THE FLIGHT-TIME 0090
C      FOR THE PARTICULAR SET OF POINTS IN X, Y, RH0, AND ALPHA. 0095
C.....0100
      YY = -(QY*SITHET) + QY*COTHET                 0105
      A=QR**2-2.*QR*SIN(QA)*YY+YY**2                 0110
      B=2.*YY*(QR*SIN(QA)-YY)                         0115
      C=RD**2-YY**2                                    0120
      ROOT = SQRT(B**2 + 4.*A*C)                       0125
      RATIO = (-B+ROOT)/(2.*A)                        0130
      TTMIN = CONFL/VN                                0135
      TMAXC = RATIO*CONFL/VN                          0140
      CONCAP = (D-CONFL*(RATIO-1.)*CONOM)*REFR/VLITE 0145
100 TMAX = TMAXC+(D-CONFL*(RATIO-1.)*CONOM)*REFR/VLITE + CTP 0150
      RETURN                                           0155
      ENC                                              0160

```

APPENDIX X
SUBPROGRAM WT(N,M)

04-28-67

	FUNCTION WT(N,M)	0000
	DIMENSION WT(6,10)	0000
C	THIS SUBPROGRAM SETS THE WEIGHTS FOR THE GAUSSIAN QUADRATURE.	0005
C	VALUES ARE FOR 2, 4, 8, 12, 16, AND 20 POINT QUADRATURE.	0010
	IF (11-137) 100, 105, 100	0015
100	11 = 137	0020
	WT(1,1) = 1.	0025
	WT(1,2) = 0.	0030
	WT(1,3) = 0.	0035
	WT(1,4) = 0.	0040
	WT(1,5) = 0.	0045
	WT(1,6) = 0.	0050
	WT(1,7) = 0.	0055
	WT(1,8) = 0.	0060
	WT(1,9) = 0.	0065
	WT(1,10) = 0.	0070
	WT(2,1) = 0.6521451549	0075
	WT(2,2) = 0.3478548451	0080
	WT(2,3) = 0.	0085
	WT(2,4) = 0.	0090
	WT(2,5) = 0.	0095
	WT(2,6) = 0.	0100
	WT(2,7) = 0.	0105
	WT(2,8) = 0.	0110
	WT(2,9) = 0.	0115
	WT(2,10) = 0.	0120
	WT(3,1) = 0.3626837834	0125
	WT(3,2) = 0.3137066459	0130
	WT(3,3) = 0.2223810345	0135
	WT(3,4) = 0.1612285363	0140
	WT(3,5) = 0.	0145
	WT(3,6) = 0.	0150
	WT(3,7) = 0.	0155
	WT(3,8) = 0.	0160
	WT(3,9) = 0.	0165
	WT(3,10) = 0.	0170
	WT(4,1) = 0.2491470458	0175
	WT(4,2) = 0.2334925365	0180
	WT(4,3) = 0.2031674267	0185
	WT(4,4) = 0.1600783285	0190
	WT(4,5) = 0.1069393260	0195
	WT(4,6) = 0.0471753364	0200
	WT(4,7) = 0.	0205
	WT(4,8) = 0.	0210
	WT(4,9) = 0.	0215
	WT(4,10) = 0.	0220
	WT(5,1) = 0.1894506105	0225
	WT(5,2) = 0.1826034150	0230
	WT(5,3) = 0.1691565194	0235
	WT(5,4) = 0.1495959888	0240
	WT(5,5) = 0.1246289713	0245
	WT(5,6) = 0.0951585117	0250
	WT(5,7) = 0.0622535239	0255
	WT(5,8) = 0.0271524594	0260
	WT(5,9) = 0.	0265
	WT(5,10) = 0.	0270

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WTI(6,1) = .1527533871	0275
WTI(6,2) = .1491729865	0280
WTI(6,3) = .1420961093	0285
WTI(6,4) = .1316886384	0290
WTI(6,5) = .1181945320	0295
WTI(6,6) = .1019301198	0300
WTI(6,7) = .0832767415	0305
WTI(6,8) = .0626720483	0310
WTI(6,9) = .0406014298	0315
WTI(6,10) = .0176140071	0320
105 I = N	0325
J = N	0330
DO 115 K=1,10	0335
IF (WTI(I,K)) 110, 120, 110	0340
110 KK = K	0345
115 CONTINUE	0350
120 IF (J-KK) 130, 130, 125	0355
125 WT = WTI(1,2*KK+1-J)	0360
RETURN	0365
130 WT = WTI(1,J)	0370
RETURN	0375
END	0380

APPENDIX XI
SUBPROGRAM AP(N,M)

04-28-67

	FUNCTION AP(N,M)	0000
	DIMENSION API(6,10)	0005
C	THIS SUBPROGRAM SETS THE ASSOCIATED POINTS FOR THE GUASSIAN	0010
C	QUADRATURE. VALUES ARE INCLUDED FOR 2, 4, 8, 12, 16, AND	0015
C	20 POINT QUADRATURE.	0020
	IF (II-137) GO, 105, 100	0025
100	II = 137	0030
	API(1,1) = 0.5773502692	0035
	API(1,2) = 0.	0040
	API(1,3) = 0.	0045
	API(1,4) = 0.	0050
	API(1,5) = 0.	0055
	API(1,6) = 0.	0060
	API(1,7) = 0.	0065
	API(1,8) = 0.	0070
	API(1,9) = 0.	0075
	API(1,10) = 0.	0080
	API(2,1) = 0.3399810436	0085
	API(2,2) = 0.8611363116	0090
	API(2,3) = 0.	0095
	API(2,4) = 0.	0100
	API(2,5) = 0.	0105
	API(2,6) = 0.	0110
	API(2,7) = 0.	0115
	API(2,8) = 0.	0120
	API(2,9) = 0.	0125
	API(2,10) = 0.	0130
	API(3,1) = 0.1834346425	0135
	API(3,2) = 0.5255324099	0140
	API(3,3) = 0.7966664774	0145
	API(3,4) = 0.9602898565	0150
	API(3,5) = 0.	0155
	API(3,6) = 0.	0160
	API(3,7) = 0.	0165
	API(3,8) = 0.	0170
	API(3,9) = 0.	0175
	API(3,10) = 0.	0180
	API(4,1) = 0.1252334085	0185
	API(4,2) = 0.3678314990	0190
	API(4,3) = 0.5873179543	0195
	API(4,4) = 0.7699026742	0200
	API(4,5) = 0.9041172564	0205
	API(4,6) = 0.9815606342	0210
	API(4,7) = 0.	0215
	API(4,8) = 0.	0220
	API(4,9) = 0.	0225
	API(4,10) = 0.	0230
	API(5,1) = 0.0950125098	0235
	API(5,2) = 0.2816035508	0240
	API(5,3) = 0.4580167777	0245
	API(5,4) = 0.6178762444	0250
	API(5,5) = 0.7554044084	0255
	API(5,6) = 0.8656312024	0260
	API(5,7) = 0.9445750231	0265
	API(5,8) = 0.9894009350	0270
	API(5,9) = 0.	0275

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API(5,10) = 0.	0280
API(6,1) = .0765265211	0285
API(6,2) = .2277858511	0290
API(6,3) = .3737060887	0295
API(6,4) = .5108670019	0300
API(6,5) = .6360536807	0305
API(6,6) = .7463319065	0310
API(6,7) = .8391169718	0315
API(6,8) = .9122344283	0320
API(6,9) = .9639719273	0325
API(6,10) = .9931285991	0330
105 I = N	0335
J=M	0340
DO 115 K=1,10	0345
IF(API(I,K))110,120,110	0350
110 KK = K	0355
115 CONTINUE	0360
120 IF(J-KK)130,130,125	0365
125 KKK = 2*KK + 1 *J	0370
AP = -API(I,KKK)	0375
RETURN	0380
130 AP = API(I,1)	0385
RETURN	0390
END	0395

APPENDIX XII

SUBPROGRAM CDEDX(EP,TAU1,TAU2,SECPSI)

04-28-67

FUNCTION CDEDX(EP,TAU1,TAU2,SECPSI)	0005
C	0010
C THIS FUNCTION SUBPROGRAM RETURNS THE VALUE FOR THE INCREMENTAL ENE	0015
C LOSS OF 160-MEV PROTONS IN CARBON. THE ROTATION OF THE TARGE	0020
C THROUGH PSI IS CONSIDERED,	0025
C	0030
DIMENSION SP(12),PE(12),TDEDX(24)	0035
DATA(PE=100.,110.,120.,130.,140.,150.,160.,170.,180.,190.,200.)	0040
DATA(SP=6.084,5.711,5.3925,5.1173,4.8772,4.6658,4.4783,4.3109,	0045
14.1604,4.0444,4.001)	0050
CALL TABUL8(PE,SP,11,24,TDEDX)	0055
XDEDX = TERPT(EP,TDEDX)	0060
XT = TAU2*SECPSI - TAU1*SECPSI	0065
C THE DENSITY OF CARBON IS 1.75 GM/CM3.	0070
ELOSS = 1.75*XT*XDEDX	0075
EBACK = EP - ELOSS	0080
EMID = EBACK + ELOSS/2.	0085
CCDEDX = TERPT(EMID,TDEDX)	0090
CDEDX = - CCDEDX	0095
RETURN	0100
END	0105

APPENDIX XIII

SUBPROGRAM RTSDRAW(Y,TITLE)

04-28-67

SUBROUTINE RTSDRAW(Y,TITLE)	0000
COMMON NI,N0,NP	0005
COMMON PSI,THETA,PSIR,THETAR,PL,RD,D,RT,T,TAU1,TAU2,DEDX,SECPSI	0010
COMMON SIG,SIGJ,DECON,DECOND,REFR,VLITE,EP,EN,VP,VN,TI,ISPACE	0015
COMMON QX,QY,QR,QA,XL0,XHI,YL0,YHI,ALPHL0,ALPHHI,RH0L0,RH0HI	0020
COMMON CON0M,CONCAP,CONX,CONY,CONFL	0025
COMMON PI,SQ2PI,P102,GTMIN,GTMAX	0030
COMMON CLT,CTMAX,CTMIN,CTP	0035
COMMON CSECTN,CSECD	0040
COMMON SITHET,COTHET,TANPSI	0045
COMMON TAU1S,TAU2S	0050
COMMON ACTIVN,ACTIVN	0055
C.....	0060
DIMENSION TI(100)	0065
DIMENSION TITLE(8),A(6)	0070
DIMENSION Y(200)	0075
C.....	0080
C THIS SUBPROGRAM IS THE CALLING ROUTINE AND INITIALIZING PROGRAM	0085
C FOR THE PLOTS CALCULATED BY PROGRAM PTIME. IT CALLS THE ROUTINES	0090
C TO SET THE X AND Y AXES AND DETERMINES THE KIND OF POINTS TO BE	0095
C USED. CHANGES IN THE TITLES OF THE X AND Y AXES ARE MADE	0100
C IN THIS PROGRAM.	0105
C.....	0110
ISPACE = ISPACE	0115
CALL EXTREMUM(TI,XUP,ISPACE,1)	0120
CALL EXTREMUM(TI,XL0,ISPACE,0)	0125
X = YUP - XL0	0130
IF(X-7.) 105,105,100	0135
100 DELX = 2.0	0140
GO TO 110	0145
105 DELX = 1.0	0150
110 IX0 = XL0 + X/2. + 3.5	0155
XXL0 = IX0	0160
CALL RTSYSCL(Y,YZER0,DELY,ISPACE)	0165
CALL LINEAR(0.0,DELY,10,XXL0,DELX,7.,7.0,48,A)	0170
CALL LETTER(2.47,47HCTIVN/(DETECTOR SOLID ANGLE X TARGET THICKNESS	0175
1),A)	0180
CALL LETTER(1.38,38HFLIGHT-TIME (JITTER-SMEARED) (NSEC),A)	0185
CALL LETTER(0.54,TITLE,A)	0190
DO 115 I = 1,ISPACE	0195
X = TI(I)	0200
YI = Y(I)	0205
CALL POINT(1,X,YI,3.0,08,0.0,1,A)	0210
115 CONTINUE	0215
CALL ADVANCE(A)	0220
RETURN	0225
END	0230

APPENDIX XIV

SUBPROGRAM RTSYSCL(SET,ALØWY,DELY,DUMMY)

04-28-67

SUBROUTINE RTSYSCL(SET,ALOWY,DELY,DUMMY)	0000
C	0005
C THIS SUBPROGRAM SETS THE Y SCALE FOR THE PLOTS GENERATED BY	0010
C PROGRAM PTIME.	0015
C	0020
COMMON NI,NO,NP	0025
COMMON PSI,THETA,PSIR,THETAR,PL,RD,D,RY,T,TAU1,TAU2,DEDX,SECPSI	0030
COMMON SIG,SIGJ,DECON,DECOND,REFR,VLITE,EP,EN,VP,VN,T1,TSPACE	0035
COMMON QX,QY,QR,QA,XLO,XHI,YLO,YHI,ALPHLO,ALPHHI,RHLO,RHHI	0040
COMMON CONOM,CONCAP,CONX,CONY,CONFL	0045
COMMON PI,SQ2PI,PI02,GTMIN,GTMAX	0050
COMMON CLT,CTMAX,CTMIN,CTP	0055
COMMON CSECTN,CSECD	0060
COMMON SITHET,COTHET,TANPSI	0065
COMMON TAU1S,TAU2S	0070
COMMON ACTIVN,ACTIVN	0075
C	0080
DIMENSION TI(100)	0085
DIMENSION SET(100)	0090
ISPACE = TSPACE	0095
ALOWY = 0.0	0100
C*** FIND UPPER LIMIT	0105
CALL EXTREMUM(SET,GREAT,ISPACE,1)	0110
C*** SET SCALE MAXIMUM	0115
J = 0	0120
IF(GREAT,GE,1.) 100,120	0125
100 IGREAT = GREAT	0130
105 IF(IGREAT) 115,115,110	0135
110 IGREAT = IGREAT/10.	0140
J = J+1	0145
GO TO 105	0150
115 IGREAT = GREAT/(10.** (J-1))	0155
DELY = (IGREAT+1)*10.** (J-2)	0160
RETURN	0165
120 J = J+1	0170
IGREAT = GREAT*10.**J	0175
IF(IGREAT) 125,120,125	0180
125 DELY = (IGREAT + 1)/10.** (J+1).	0185
RETURN	0190
END	0195

APPENDIX XV

SUBPROGRAM EXTREMUM(SET,EXT,N,K)

04-28-67

SUBROUTINE EXTREMUM(SET,EXT,N,K)	0000
C*** ROUTINE FINDS THE EXTREMUM OF A SET OF NUMBERS.	0005
C IF K .EQ. 0, ROUTINE FINDS MINIMUM.	0010
C IF K .NE. 0, ROUTINE FINDS MAXIMUM.	0015
C*** COMPILED IN FORTRAN 63 FOR THE 1604 ON 27 MAY 1964.	0020
DIMENSION SET(777)	0025
EXT = SET(1)	0030
IF (K) 100, 135	0035
C*** FIND MAXIMUM	0040
100 DO 130 I=2,N	0045
IF (EXT) 105, 115, 120	0050
105 IF (SET(I)) 110, 125, 125	0055
110 IF (SET(I) - EXT) 130, 130, 125	0060
115 IF (SET(I)) 130, 130, 125	0065
120 IF (SET(I)) 130, 130, 110	0070
125 EXT = SET(I)	0075
130 CONTINUE	0080
RETURN	0085
C*** FIND MINIMUM	0090
135 DO 165 I=2,N	0095
IF (EXT) 140, 150, 155	0100
140 IF (SET(I)) 145, 165, 165	0105
145 IF (SET(I) - EXT) 160, 165, 165	0110
150 IF (SET(I)) 160, 165, 165	0115
155 IF (SET(I)) 160, 160, 145	0120
160 EXT = SET(I)	0125
165 CONTINUE	0130
RETURN	0135
END	0140

APPENDIX XVI

```
SUBPROGRAM TABUL8(XX,YY,IMAX,LENGTH,TNAME)
```


04-28-67

	SUBROUTINE TABUL8 (XX,YY,IMAX,LENGTH,TNAME)	0000
	DIMENSIONXX(77),YY(77),TNAME(88)	0005
C	<i>ADDON</i>	0010
C	TABUL8 SETS UP TERP8 TABLES IN CONJUNCTION WITH THE TERP DECK.	0015
C	XX = NAME OF THE X-AXIS,	0020
C	YY = NAME OF THE Y-AXIS,	0025
C	IMAX = NUMBER OF POINTS IN X AND Y.	0030
C	LENGTH = DESIRED LENGTH OF THE TERP TABLE. USUALLY 2 X IMAX.	0035
C	TNAME = THE NAME OF THE TABLE TO BE GENERATED BY THE TERP SYSTEM.	0040
C		0045
	100 CALLTARSET(XX,XX(IMAX),LENGTH,LOOP,TNAME)	0050
	X=XX	0055
	DO10K=1,LOOP	0060
	Y=TERPU(X,XX,YY,IMAX)	0065
	105 CALL TABX (X,Y,K,TNAME)	0070
	110 CONTINUE	0075
	RETURN	0080
	END	0085

APPENDIX XVII

PROGRAM TWALK

05-03-67

PROGRAM TWALK

0000

C**** DIMENSION CARDS

C*****

DIMENSION EPRT(400),WHEP(400),EPRT(60),EPLITE(60),PTABLE(120)

DIMENSION XEXP(400),DXP(400),WEP(400)

DIMENSION ENUT(12),XCSEC(12),EBIAS(30),CPH(30),CTABLE(24)

DIMENSION CCTAB(60)

DIMENSION ENA(14),XMACNA(14),ATABLE(28),WEA(30),EMIN(30)

DIMENSION WEC(400),AEN(60),ALITE(60)

DIMENSION NTABLE(120)

DIMENSION XAEN(200),DXAEN(200),WAEN(200)

DIMENSION PROTEN(200),CASCAD(200),NALFA(200)

DIMENSION ENER(200),SPECAS(200),SPECHY(200),SPECAL(200)

DIMENSION SPECT(200)

DIMENSION DAEN(30),DALITE(30),DEPRT(30),DPLITE(30),DATAB(60)

DIMENSION DPTAB(60)

DIMENSION PSPEC(400),CSPEC(400),ASPEC(50)

DIMENSION SPECTRUM(400)

DIMENSION TSLEW(75),FTWALK(150),RTWALK(150),SLEWORD(75)

DIMENSION TIME(75),DTSLEW(75),DTWALK(150),RMAG(400)

DIMENSION WALK(400),XNSCM(400)

DIMENSION ORN(400)

DIMENSION TABLE(2000)

DIMENSION WPBS(400),WNEG(400)

DIMENSION DELTA(1000),SORO(1000)

DIMENSION WFUNCT(400)

DIMENSION XT(1000),YT(1000)

DIMENSION WAKTAB(1000),WAKTAB2(1000)

C*****

C**** DATA CARDS

C*****

C****

C**** VALUES FOR THE PROTON LIGHT CURVE.

C****

DATA(EPRT=,2,.25,.3,.35,.4,.45,.5,.55,.6,.65,.7,.75,.8,.85,.9,.95

1,.1,.15,.2,.25,.3,.35,.4,.45,.5,.55,.6,.65,.7,.75,.8,.85,.9,.95,

210,.15,.20,.25,.30,.35,.40,.45,.50,.55,.60,.65,.70,.75,.80,.85,.9

390,.95,.100,)

DATA(EPLITE=.0290,.0352,.0420,.0488,.0563,.0638,.0745,.0808,.0901,

1.0996,.110,.119,.129,.141,.153,.163,.175,.302,.450,.615,.800,1.02,

21.24,.146,.170,.195,.218,.246,.274,.300,.326,.360,.388,.423,.460,

37.90,.115,.152,.192,.232,.276,.315,.360,.402,.448,.490,.540,.586,

463,.167,.873,.078,.782,5)

C*****

C****

C**** ALPHA PARTICLE LIGHT TABLE.

C****

DATA(AEN=,2,.25,.3,.35,.4,.45,.5,.55,.6,.65,.7,.75,.8,.85,.9,.95

1,.1,.15,.2,.25,.3,.35,.4,.45,.5,.55,.6,.65,.7,.75,.8,.85,.9,.95,

210,.15,.20,.25,.30,.35,.40,.45,.50,.55,.60,.65,.70,.75,.80,.85,.9

390,.95,.100,)

DATA(ALITE=.0225,.0238,.0251,.0266,.0279,.0292,.0305,.0318,.0333,

1.0345,.0358,.0370,.0385,.0397,.0413,.0428,.0445,.0613,.0805,

2.104,.130,.156,.188,.220,.256,.293,.335,.375,.424,.470,.515,.568,

3.626,.675,.730,.140,.222,.324,.440,.560,.690,.830,.995,.116,.134,

415.3,.174,.193,.214,.233,.255,.274,.295)

```

C****
C****
C**** CASCADE PRODUCT CROSS-SECTIONS.
C****
DATA(ENUT=10,,12,,14,,15,,19,,19.5,20,,20.5,21,,22,,25,,30,)
DATA(XCSEC=65,,112,,160,,185,,285,,300,,308,,311,,314,,316,,320,,
1323,1)
C****
C****
C**** STANDARD ENERGY SPECTRUM FOR CASCADE PRODUCTS,
C****
DATA(EBIAS=3,,35,,4,,45,,5,,55,,6,,7,,8,,9,,10,,11,,12,,13,,14
1,,15,,16,,17,,18,,19,2,0,2.5,3,0,3.5,4,0)
DATA(CPH=1,,62,,1,,61,,86,,66,,52,,42,,36,,25,,19,,14,,11,
1,,93,,078,,064,,054,,046,,04,,036,,032,,028,,026,,016,,010,,007,
2,,005)
C****
C****
C**** CARBON (N,ALPHA) CROSS-SECTIONS,
C****
DATA(ENA=9,,10,,11,,11.5,12,,13,,14,,16,,18,,18.5,20,,25,,30,,50.)
DATA(XMACNA=2,E=04,1,E=03,2,E=03,2,6E=03,3,1E=03,3,E=03,2,6E=03,
1,7,E=04,8,E=04,6,E=04,4,E=04,3,E=04,2,E=04,2,E=04)
C****
C****
C**** DERIVATIVES OF THE PROTON AND ALPHA PARTICLE LIGHT TABLES,
C****
DATA(DAEN=2,,3,,4,,5,,6,,7,,8,,9,,1,,2,,3,,4,,5,,6,,7,,8,,9,,10,,
115,,20,,30,,40,,50,,60,,70,,80,,90,,100,)
DATA(DALITE=0270,,0270,,0270,,0270,,0270,,0270,,0270,,0290,,0300,
1,0427,,0520,,0640,,0730,,0820,,0950,,0980,,1070,,1150,,1490,,1840,
2,2360,,2700,,3300,,3700,,4000,,4000,,4000,,4000)
DATA(DEPRT=2,,3,,4,,5,,6,,7,,8,,9,,1,,2,,3,,4,,5,,6,,7,,8,,9,,10,,
115,,20,,30,,40,,50,,60,,70,,80,,90,,100,)
DATA(DPLITE=120,,140,,160,,179,,191,,205,,218,,230,,240,,325,
1,385,,420,,480,,521,,560,,600,,640,,660,,740,,780,,820,,850,,880,
2,900,,920,,940,,950,,960)
C****
C****
C**** THE TIME-SLEWING CURVE,
C****
DATA(TSLEW=6,,5,9,5,8,5,7,5,6,5,5,5,4,5,3,5,2,5,1,5,,4,9,4,8,4,7,
14,6,4,5,4,4,4,3,4,2,4,1,4,,3,9,3,8,3,7,3,6,3,5,3,4,3,3,3,2,3,1,3,
22,9,2,8,2,7,2,6,2,5,2,4,2,3,2,2,2,1,2,,1,9,1,8,1,7,1,6,1,5,1,4,1,3
3,1,2,1,1,1,,9,8,7,6,5,4,3,2,,1,0,0,,1,,2,,3,,4,,5,
4,,6,,7,,8,,1,0,,1,1,,1,2)
DATA(SLEW0R=1,490,1,495,1,50,1,505,1,51,1,53,1,55,1,56,1,58,1,6,
11,65,1,70,1,75,1,80,1,85,1,90,1,95,2,0,2,1,2,2,2,3,2,4,2,48,
22,58,2,7,2,8,2,95,3,09,3,25,3,4,3,6,3,8,4,,4,2,4,45,4,75,
35,1,5,4,5,75,6,25,6,7,7,2,7,7,8,5,9,2,10,,11,12,13,3,14,5,
4,16,5,18,5,21,,24,,27,,32,,37,,47,,57,5,70,,84,5,,100,,120,,180,,190
5,,228,,280,,330,,420,,800,,900,,1075,)
C****
C****
C**** CALL TAD(-1)
C****

```

05-03-67

C****	COMPUTE ALL CONSTANTS.	0015
C****		0020
	PI = 3.14159	0025
	HN = 0.04286E+24	0030
	CN = 0.03986E+24	0035
	A2=938.256	0040
	A3=0.0769	0045
	A4=0.9231	0050
	A5=5.71	0055
	A6=0.6923	0060
	A7=3730.	0065
	CALL TABUL8(EPRT,EPLITE,53,106,PTABLE)	0070
	CALL TABUL8(DEPRT,DPLITE,28,56,DPTAB)	0075
C****		0080
C****	SET TAPE NUMBERS (7604)	0085
C****		0090
	NI = 50	0095
	NO = 51	0100
	NP = 52	0105
C****		0110
C****	.....	0115
C****		0120
C****	READ IN THE NEUTRON ENERGY.	0125
C****		0130
	100 CONTINUE	0135
	READ(NI,8000) EN	0140
	READ(NI,8005) KNTR	0145
	8000 FORMAT(F8,4)	0150
	8005 FORMAT(I4)	0155
C****		0160
C****	COMPUTE THE TOTAL CROSS-SECTION FOR HYDROGEN.	0165
C****		0170
	SIGTOT = 3.*PI/((1.206*EN*(-1.86+0.09415*EN+0.00013*EN**2)**2) +	0175
	PI/((1.206*EN+(0.423*0.1300*EN)**2)	0180
C****		0185
C****	COMPUTE THE ENERGY SPECTRUM FOR PROTON RECOILS.	0190
C****		0195
	RATIO = (EN/90.0)**2	0200
	IEN = 4.*EN	0205
	EPROT(1) = EN/(4.*EN)	0210
	XYXY = 1.0E+24	0215
	DO 110 I = 2,IEN	0220
	EPROT(I) = EPROT(I-1) + EPROT(1)	0225
105	SI = ACOSF(1. - 2.*(EPROT(1)/EN))	0230
	SIGSI = (1.+2.*RATIO*(COS(SI)**2))/(1.+(2./3.)*RATIO)	0235
	WHEP(1) = HN*SIGTOT*SIGSI/EN*XYXY	0240
	WHEP(1) = WHEP(2)	0245
110	CONTINUE	0250
C****		0255
C****	READ THE LIGHT CURVE FOR PROTONS AND CONVERT THE ENERGY SPECTRUM.	0260
C****		0265
	DO 115 I = 1,IEN	0270
	XEXP(I) = TERPT(EPROT(I),PTABLE)	0275
	DXP(I) = TERPT(EPROT(I),DPTAB)	0280
	WEP(I) = WHEP(I)/DXP(I)	0285
115	CONTINUE	0290

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C*****	0295
C*****	0300
C*** COMPUTE THE PULSE-HEIGHT SPECTRUM FOR CASCADE PRODUCTS IN CARBON.	0305
C*****	0310
DO 120 I=1, IEN	0315
WEC(I) = 0.0	0320
120 CONTINUE	0325
IF(10. = EN) 130, 130, 125	0330
125 GO TO 175	0335
130 CALL TABUL8(ENUT, XCSEC, 12, 24, CTABLE)	0340
IF(EN = 40.) 135, 135, 140	0345
135 CRSEC = TERPT(EN, CTABLE)	0350
CRSEC = CRSEC/1000.	0355
GO TO 145	0360
140 CRSEC = 0.331	0365
145 CALL TABUL8(EBIAS, CPH, 25, 50, CCTAB)	0370
DO 170 J=1, IEN	0375
XEPROT = XEXP(I)	0380
IF(0.3 = XEPROT) 155, 150, 150	0385
150 WEC(I) = 4.05*CRSEC*CN*1.E=24	0390
GO TO 170	0395
155 IF(4.0 = XEPROT) 165, 165, 160	0400
160 WEC(I) = TERPT(XEPROT, CCTAB)*(CRSEC*CN*1.E=24)	0405
GO TO 170	0410
165 WEC(I) = 0.0000	0415
170 CONTINUE	0420
C*****	0425
C*****	0430
C*** COMPUTE THE CARBON (N, ALPHA) BERYLLIUM PULSE-HEIGHT SPECTRUM.	0435
C*****	0440
C*** COMPUTE THE MAXIMUM AND MINIMUM ALPHA PARTICLE ENERGIES.	0445
C*****	0450
175 CONTINUE	0455
IF(EN=9.0) 180, 180, 185	0460
180 GO TO 220	0465
185 CONTINUE	0470
E0M=EN/A2	0475
E0M=E0M*2.	0480
PCM=(E0M*(EN/A2))**.5	0485
BETACM=PCM*A3	0490
XXX=A4*EN*A5	0495
XX=A6*XXX	0500
X=2.*XX/A7	0505
YYY=X**.5	0510
XMAXV=YYY*BETACM	0515
XMINV=YYY*BETACM	0520
XMAXVS=XMAXV**2	0525
XMINVS=XMINV**2	0530
EMAXA=.5*XMAXVS*A7	0535
EMINA=.5*XMINVS*A7	0540
C*****	0545
C*** COMPUTE THE ENERGY SPECTRUM FOR ALPHA PARTICLES	0550
C*****	0555
IF(EN = 9.0) 220, 220, 190	0560
190 IF(EN = 50.0) 195, 195, 220	0565
195 ACSEC = 0.069*0.0398	0570

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EMIN(I) = EMINA	0575
DO 210 I = 2,25	0580
IF(I = 1) 205,200,205	0585
200 WEA(I) = ACSEC/EMIN(I)	0590
GO TO 210	0595
205 CONTINUE	0600
EMIN(I) = EMIN(I-1) * EMINA/25.	0605
WEA(I) = ACSEC/EMIN(I)	0610
WEA(I) = WEA(2)	0615
210 CONTINUE	0620
CALL TABUL8(AEN,ALITE,53,106,NTABLE)	0625
CALL TABUL8(DAEN,DALITE,28,56,DATAB)	0630
DO 215 I=1,25	0635
XAEN(I)=TERPT(EMIN(I),NTABLE)	0640
DXAEN(I) = TERPT(EMIN(I),DATAB)	0645
WAEN(I)=WEA(I)/DXAEN(I)	0650
215 CONTINUE	0655
CALL TABUL8(XAEN,WAEN,25,50,ASPEC)	0660
220 CONTINUE	0665
C*****	0670
C*****	0675
C CALCULATION OF THE TOTAL SPECTRUM.	0680
C*****	0685
C*****	0690
DO 260 I = 1,IEN	0695
IF(EN=9,0) 225,225,230	0700
225 GO TO 250	0705
230 IF(EN=50,0) 235,235,225	0710
235 CONTINUE	0715
IF(XEXP(I) = XAEN(1)) 250,250,240	0720
240 IF(XEXP(I) = XAEN(25)) 245,245,250	0725
245 ALPHA = TERPT(XEXP(I),ASPEC)	0730
GO TO 255	0735
250 ALPHA = 0,0	0740
255 SPECTRUM(I) = ALPHA * WEC(I) * WEP(I)	0745
260 CONTINUE	0750
C*****	0755
C*****	0760
C CONSTRUCTION OF THE TIME-SLEWING CURVE.	0765
C*****	0770
C*****	0775
CALL TABUL8(TSLEW,SLEWORD,72,140,FTWALK)	0780
DO 265 I=1,69	0785
ORD(I)=SLEWORD(I)*.090	0790
265 CONTINUE	0795
CALL TABUL8(TSLEW,ORD,72,140,RTWALK)	0800
TIME(I) = 6,0	0805
DO 270 I = 2,69	0810
TIME(I) = TIME(I-1) + 0,1	0815
DTSLEW(I) = * (TERPT(TIME(I),RTWALK)-TERPT(TIME(I-1),RTWALK))/0,10	0820
I	0825
DTSLEW(I) = DTSLEW(2)	0830
270 CONTINUE	0835
CALL TABUL8(TSLEW,DTSLEW,72,140,DTWALK)	0840
DO 285 I = 1,IEN	0845
RMAG(I) = XEXP(I)/0,090	0850

05=03=67

	IF(RMAG(I) = 1.490) 275,280,280	0855
275	WALK(I) = 0.0	0860
	XNSCH(I) = 0.0	0865
	GO TO 285	0870
280	CONTINUE	0875
	WALK(I) = BTERP(RMAG(I),FTWALK)	0880
	XNSCH(I) = TERPT(WALK(I),DTWALK)*SPECTRUM(I)	0885
285	CONTINUE	0890
	DO 300 I = 1,IEN	0895
	IF(IEN = 1) 300,300,290	0900
290	CONTINUE	0905
	IF(XNSCH(I+1) = XNSCH(I)) 295,300,300	0910
295	XNSCH(I) = (XNSCH(I+1) - XNSCH(I-1))/2. + XNSCH(I-1)	0915
300	CONTINUE	0920
	XNORM = 0.0	0925
C	.....	0930
C	.....	0935
C	 NORMALIZATION OF THE TIME SLEWING RESPONSE FUNCTION,	0940
C	.....	0945
C	.....	0950
	XNORM = 0.0	0955
	XNORM2 = 0.0	0960
	J = IEN = 1	0965
	KKK = IEN = 3	0970
	DO 305 I = 1,IEN	0975
	XT(I) = WALK(IEN + I = 1)	0980
	YT(I) = XNSCH(IEN + I = 1)	0985
305	CONTINUE	0990
	CALL TABUL8(XT,YT,KKK,2*KKK,WAKTAB)	0995
	XNORM = TERPI(XT(I),XT(KKK),WAKTAB)	1000
	DO 310 I = 1,IEN	1005
	YT(I) = YT(I)/XNORM	1010
310	CONTINUE	1015
	CALL TABUL8(XT,YT,KKK,2*KKK,WAKTAB2)	1020
	XNORM2 = TERPI(XT(I),XT(KKK),WAKTAB2)	1025
	WRITE(N0,8010) XNORM,XNORM2	1030
8010	FORMAT(1H,10X,8HXNORM = F10.5/10X,18HNORMALIZED AREA = F10.5)	1035
C	.....	1040
C	.....	1045
C	 PUBLICATION OF THE RESULTS AND CARD PUNCHING FORMATS,	1050
C	.....	1055
C	.....	1060
	WRITE(N0,8015)	1065
8015	FORMAT(1H,50X,2HPULSE-HEIGHT SPECTRUM/59X,3HAND/45X,30HTIME=SLEW	1070
	ING RESPONSE FUNCTION/55X,10H*****)	1075
	WRITE(N0,8020) EN	1080
8020	FORMAT(45X,21HNEUTRON ENERGY ,F5.1,4H=MEV)	1085
	WRITE(N0,8025)	1090
8025	FORMAT(25X,2HPULSE=HEIGHT SPECTRUM,24X,30HTIME=SLEWING RESPONSE F	1095
	UNCTION/25X,21H*****24X,30H*****	1100
	2*****/19X,12HPULSE=HEIGHT,8X,11HPROBABILITY,22X,4HTIME,12X,11HP	1105
	ROBABILITY/22X,5H(MEV),11X,13H(MEV-1 CM-1),20X,6H(NSEC),12X,8H(NSE	1110
	4C=1))	1115
	WRITE(N0,8030) (XEXP(I),SPECTRUM(I),XT(I), YT(I), I=1,IEN)	1120
8030	FORMAT(19X,E10.5,10X,E10.5,20X,E10.5,9X,E10.5)	1125
	PUNCH 8035,EN,XNORM2	1130

n5=03=67

8035	FORMAT(F8,4,E10,5)	1135
	PUNCH 8040,(XT(I),YT(I), I = 1,KKK)	1140
8040	FORMAT(2E11,4)	1145
	IF(1=KNTR) 100,100,315	1150
315	CONTINUE	1155
320	CALL EXIT	1160
	CALL TAD(*1)	1165
	END	1170

APPENDIX XVIII

PROGRAM CONVØL

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PROGRAM CONVOL	0000
C*****	0005
C COMMON	0010
C*****	0015
COMMON NI,NO,NP,TPROB,JJ,TIME	0020
COMMON INDEX,CRES,TCHAN,IDCHAN	0025
C*****	0030
C DIMENSION	0035
C*****	0040
DIMENSION TITLE(8)	0045
DIMENSION TW(400),XW(400),WALK(825),XT(400),YT(400),TP(100),CP(100)	0050
1,BP(100),AP(100),PTIME(200),XP(1000),YP(1000),TIME(1000),TPROB(100	0055
20),CONV(1000)	0060
DIMENSION TM(1000),CRES(1000)	0065
DIMENSION INDEX(1000)	0070
DIMENSION ANALYZ(1000),NAME(1000),TCHAN(1000)	0075
C*****	0080
C TAPE NUMBERS 1604	0085
NI = 50	0090
NO = 51	0095
NP = 52	0100
C*****	0105
100 CONTINUE	0110
C*****	0115
C READ IN THE TIME SLEWING RESPONSE FUNCTION.	0120
C*****	0125
READ(NI,8000) EN,XNORM	0130
C*****	0135
8000 FORMAT(F8.4,E10.5)	0140
IMAX = 4,EN=3,	0145
MAX = IMAX	0150
C*****	0155
READ(NI,8005) (TW(I),XW(I), I=1,IMAX)	0160
C*****	0165
8005 FORMAT(2E11.4)	0170
TWMAX = TW(IMAX)	0175
TWONE = TW(1)	0180
CALL TABUL8(TW,XW,IMAX,2*IMAX,WALK)	0185
WNORM = TERPI(TW(1),TW(IMAX),WALK)	0190
IF(1.0-WNORM) 105,115,105	0195
105 DO 110 I=1, IMAX	0200
XW(I) = XW(I)/WNORM	0205
CALL TABUL8(TW,XW,IMAX,2*IMAX,WALK)	0210
WNORM=TERPI(TW(1),TW(IMAX),WALK)	0215
110 CONTINUE	0220
115 CONTINUE	0225
C*****	0230
C PUT SLEWING RESPONSE FUNCTION INTO EQUAL TIME BINS.	0235
C*****	0240
IF(EN = 5.0) 120,120,125	0245
120 DENOM = 2*IMAX = 1	0250
IMAX = 2*IMAX	0255
DELTA = (TWMAX - TWONE)/DENOM	0260
GO TO 130	0265
125 DENOM = IMAX = 1	0270
DELTA = (TWMAX - TWONE)/DENOM	0275

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130	CONTINUE	0280
	XT(1) = TW(1)	0285
	YT(1) = XW(1)	0290
	DO 135 I = 2,IMAX	0295
	XT(I) = XT(I-1) + DELTA	0300
	YT(I) = TERPT(XT(I),WALK)	0305
135	CONTINUE	0310
C*****		0315
C	READ IN THE PHYSICAL FLIGHT-TIME DISTRIBUTION,	0320
C*****		0325
140	CONTINUE	0330
C*****		0335
	READ(N1,8010) ENEUT,TAU1,TAU2,RD,D,PL,SIG,SIGJ	0340
	READ(N1,8015) THETA,PSI,TINT,GTMIN	0345
8010	FORMAT(8F8,4)	0350
8015	FORMAT(4F8,4)	0355
C*****		0360
	JMAX = TINT	0365
C*****		0370
	READ(N1,8020) (TP(I),CP(I),AP(I),BP(I), I=1,JMAX)	0375
C*****		0380
8020	FORMAT(4E11,4)	0385
C	CONSTRUCT A TERP TABLE FOR TP + AP	0390
	CALL TABUL8(TP,AP,JMAX,2*JMAX,PTIME)	0395
	PNORM = TERPI(TP(1),TP(JMAX),PTIME)	0400
	KMAX = IMAX + JMAX	0405
	XP(1) = TP(1)	0410
	YP(1) = AP(1)	0415
	DO 155 J = 2,KMAX	0420
	XP(J) = XP(J-1) + DELTA	0425
	IF(TP(JMAX) - XP(J)) 150,145,145	0430
145	YP(J) = TERPT(XP(J),PTIME)	0435
	KKKK = J	0440
	GO TO 155	0445
150	YP(J) = 0.0	0450
155	CONTINUE	0455
C*****		0460
C	SET UP THE TIME SCALE ,	0465
	TIME(1) = XP(1) + XT(1)	0470
	JJ = KKKK + IMAX	0475
	DO 160 M=2,JJ	0480
	TIME(M) = TIME(M-1) + DELTA	0485
160	CONTINUE	0490
C*****		0495
C	START THE CONVOLUTION	0500
C*****		0505
	YT(1) = YT(1)*0.5	0510
	YT(IMAX) = YT(IMAX)*0.5	0515
	YP(1) = 0.5*YP(1)	0520
	YP(KMAX) = YP(KMAX)*0.5	0525
	KK = IMAX + JMAX	0530
	DO 165 I = 1,JJ	0535
	TPROB(I) = 0.0	0540
165	CONTINUE	0545
	DO 180 I = 1,IMAX	0550
	DO 180 J = 1,KKKK	0555

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	IF(YP(J))170,170,175	0560
170	TPROB(I+J) = 0.0	0565
	GO TO 180	0570
175	CONTINUE	0575
	TPROB(I+J) = TPROB(I+J) + DELTA*YT(I)*YP(J)	0580
180	CONTINUE	0585
	DO 185 I=1,JJ	0590
	TPROB(I) = TPROB(I+1)	0595
185	CONTINUE	0600
	CALL TABUL8(TIME,TPROB,JJ,2*JJ,CONV)	0605
	AREA = TERP1(TIME(I),TIME(JJ),CONV)	0610
	READ(NI,8025) (TITLE(I),I=1,7)	0615
8025	FORMAT(7A8)	0620
	TITLE(8)=GETDATE(DUMMY)	0625
	CALL DRAW1(TPROB,TITLE)	0630
	CALIB=0.500	0635
	DO 190 I=1,JJ	0640
	TIME(I)=TIME(I)/CALIB	0645
190	CONTINUE	0650
	CALL TABUL8(TIME,TPROB,JJ,2*JJ,NAME)	0655
C*****		0660
C	BIN THE CONVOLUTED DISTRIBUTION.	0665
C*****		0670
C	FIND THE MINIMUM CHANNEL,	0675
C*****		0680
	MINCHAN = TIME(I)	0685
	CHANMIN = MINCHAN * 0.5	0690
	IF(TIME(I) = CHANMIN) 195,200,200	0695
195	CHANMIN = CHANMIN * 0.5	0700
	GO TO 205	0705
200	CHANMIN = CHANMIN * 0.5	0710
205	CONTINUE	0715
C*****		0720
C	FIND THE MAXIMUM CHANNEL,	0725
C*****		0730
	MAXCHAN = TIME(JJ)	0735
	CHANMAX = MAXCHAN * 0.5	0740
	IF(TIME(JJ) = CHANMAX) 210,215,215	0745
210	CHANMAX = CHANMAX * 0.5	0750
	GO TO 220	0755
215	CHANMAX = CHANMAX * 0.5	0760
220	CONTINUE	0765
	DCHAN = CHANMAX - CHANMIN	0770
	IDCHAN = DCHAN	0775
	ICHAN = IDCHAN * 1	0780
	TCHAN(I) = CHANMIN	0785
	DO 225 I=2,IDCHAN	0790
	TCHAN(I) = TCHAN(I-1) + 1.0	0795
225	CONTINUE	0800
	DO 230 I=2,ICHAN	0805
	TL0 = TCHAN(I) * 0.5	0810
	TH1 = TL0 * 1.0	0815
	CRS(I) = 0.5*(TERPT(TL0,NAME) + TERPT(TH1,NAME))/2.0	0820
	INDEX(I) = TCHAN(I)	0825
230	CONTINUE	0830
	A = TCHAN(I) * 0.5	0835

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      B = TCHAN(IDCHAN) = 0.5                                0840
      INDEX(1) = TCHAN(1)                                    0845
      INDEX(IDCHAN) = TCHAN(IDCHAN)                          0850
      C                                                        0855
      C                                                        0860
      CRES(1) = TERPT(A,NAME)/2,                              0865
      CRES(IDCHAN) = TERPT(B,NAME)/2,                        0870
      C                                                        0875
      C                                                        0880
      C                                                        0885
      SCHAN=0                                                 0900
      DO 235 I=1,JJ                                           0905
      SCHAN=SCHAN+CRES(I)                                     0910
235  CONTINUE                                                 0915
      CALL DRAW2(CRES,TITLE)                                  0920
      C*****                                                  0935
      C      PUBLICATION OF RESULTS                          0940
      C*****                                                  0945
      T = TAU2=TAU1                                           0950
      WRITE(N0,8040)                                          0955
      8040 FORMAT(1H)                                          0960
      WRITE(N0,8045) EN,THETA,D,RD,PL,SIG,PSI,T,TAU1,TAU2,SIGJ,PNORM 0965
      8045 FORMAT(50X,19HRESULTS FROM CONVOL/50X,18H*****//10X, 0970
      117H INPUT DATA/10X,24H*****//10X,28HNEUTRO 0975
      2N ENERGY = ,F8,4/10X,28HDETECTOR ANGLE = ,F8 0980
      3,4/10X,28HDETECTOR THICKNESS = ,F8,4/10X,28HDETECTOR RADIUS 0985
      4 = ,F8,4/10X,28HFLIGHT PATH = ,F8,4/10X,2 0990
      58HSTD. DEV. OF BEAM DISTR. = ,F8,4/10X,27HTARGET ANGLE 0995
      6 = ,F8,4/10X,28HTARGET THICKNESS = ,F8,4/15X,23HTAU1 1000
      7 = ,F8,4/15X,23HTAU2 = ,F8,4//10X, 1005
      828HSTD. DEV. OF JITTER = ,F8,4/10X,28HSPECTROMETER EFFICIEN 1010
      9CY = ,F8,4) 1015
      IF(EN=5.0) 245,245,240 1020
      240 WRITE(N0,8070) 1025
      WRITE(N0,8050) 1030
      8050 FORMAT(50X,44HSLEWING RESPONSE FUNCTION (EQUAL TIME UNITS)// 1035
      110X,9HWALK TIME,10X,11HW(TW(H),VN),17X,9HWALK TIME,9X,11HW(TW(H), 1040
      2VN)/11X,6H(NSEC),13X,8H(NSEC=1),20X,6H(NSEC),12X,8H(NSEC=1)) 1045
      WRITE(N0,8055) (TW(I),XW(I),XT(I),YT(I),I=1,IMAX) 1050
      8055 FORMAT(8X,E11,4,11X,E11,4,18X,E11,4,10X,E11,4) 1055
      GO TO 250 1060
      245 WRITE(N0,8070) 1065
      WRITE(N0,8060) 1070
      8060 FORMAT(10X,9HWALK TIME,10X,11HW(TW(H),VN)/11X,6H(NSEC),13X, 1075
      18H(NSEC=1)) 1080
      WRITE(N0,8065) (TW(I),XW(I), I=1, MAX) 1085
      8065 FORMAT(8X,E11,4, 8X,E11,4) 1090
      WRITE(N0,8070) 1095
      8070 FORMAT(1H0) 1100
      WRITE(N0,8075) 1105
      8075 FORMAT(12X,44HSLEWING RESPONSE FUNCTION (EQUAL TIME UNITS)/ 1110
      110X,9HWALK TIME,9X,11HW(TW(H),VN)/11X,6H(NSEC),13X,8H(NSEC=1)) 1115
      WRITE(N0,8080) (XT(I),YT(I),I=1,IMAX) 1120
      8080 FORMAT(8X,E11,4, 8X,E11,4) 1125
      250 CONTINUE 1130
      WRITE(N0,8085) WNORM 1135

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8085	FORMAT(1H0.8X,54HNORMALIZATION OF THE TIME-SLEWING RESPONSE FUNCTI	1140
	ON = ,F8.4)	1145
	WRITE(NO,8090)	1150
8090	FORMAT(1H0.8X,21HINPUT DATA FROM PTIME/9X,21H*****	1155
	/,19X,2HT1,18X,5HCTIVN,14X,6HACTIVN,14X,6HBCIVN/,8X,6H(NSEC))	1160
	WRITE(NO,8095) (TP(I),CP(I),AP(I),BP(I), I=1,JMAX)	1165
	WRITE(NO,8070)	1170
8095	FORMAT(10X,4(F15.5,5X))	1175
	WRITE(NO,8070)	1180
	WRITE(NO,8100)	1185
8100	FORMAT(16X,9HTM(NSEC),4X,11HT(VP,VN,TM)/16X,24H*****	1190
	1*****)	1195
	WRITE(NO,8105) (TIME(I),TPROB(I), I = 1,JJ)	1200
8105	FORMAT(16X,F8.4,5X,E11.5)	1205
	WRITE(NO,8110)	1210
8110	FORMAT(44X,31HTIME-CHANNEL RESPONSE FUNCTIONS/44X,31H*****	1215
	1*****//33X,14HCHANNEL NUMBER,20X,19HPROBABILITY PER M	1220
	2EV)	1225
	WRITE(NO,8115) (INDEX(I),CRES(I), I=1,IDCHAN)	1230
8115	FORMAT(38X,13.31X,E11.5)	1235
	WRITE(NO,8120) 60HAN	1240
8120	FORMAT(20X,28HNOTE***** PLOT AS HISTOGRAMS/20X,28HTHE SUM OVER ALL	1245
	1 CHANNELS = ,F10.5)	1250
	READ(NI,8125)KNTR	1255
8125	FORMAT(14)	1260
C	(-1) --- START WITH NEW ENERGY VALUE	1265
C	(0) --- STOP PROGRAM	1270
C	(+1) --- CONTINUE WITH THE SAME ENERGY	1275
8130	FORMAT(10X,F8.4,5X,E10.5)	1280
	IF(KNTR) 100,255,140	1285
255	CONTINUE	1290
	CALL EXIT	1295
	END	1300

APPENDIX XIX

SUBPROGRAM DRAW1(Y,TITLE)

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SUBROUTINE DRAW(Y,TITLE)		0000
C		0005
	COMMON NI,NO,NP,TPROB,JJ,TIME	0010
	COMMON INDEX,CRES,TCHAN,IDCHAN	0015
	DIMENSION TPROB(1000),TIME(1000),CRES(1000),TCHAN(1000),INDEX(1000)	0020
	1)	0025
	DIMENSION TITLE(8),A(6)	0030
	DIMENSION Y(200)	0035
C	.....	0040
C	THIS SUBPROGRAM IS THE CALLING ROUTINE AND INITIALIZING PROGRAM	0045
C	FOR THE PLOTS CALCULATED BY PROGRAM CONVOL. IT CALLS THE ROUTINES	0050
C	TO SET THE X AND Y AXES AND DETERMINES THE KIND OF POINTS TO BE	0055
C	USED. CHANGES IN THE TITLES OF THE X AND Y AXES ARE MADE	0060
C	IN THIS PROGRAM,	0065
C	.....	0070
	ISPACE = JJ	0075
	CALL EXTREMUM(TIME,XUP,ISPACE,1)	0080
	CALL EXTREMUM(TIME,XLO,ISPACE,0)	0085
	X = XUP - XLO	0090
	IF(X=7,) 105,105,100	0095
100	DELX = 2.0	0100
	GO TO 110	0105
105	DELX = 1.0	0110
110	IX0 = XLO + X/2, = 3.5	0115
	XXLO = IX0	0120
	CALL YSCL(Y,YZER0,DELY,ISPACE)	0125
	CALL LINEAR(0,0,DELY,10,XXLO,DELX,7,=7.0,48,A)	0130
	CALL LETTER(1,34,34HMEASURED FLIGHT-TIME = TM = (NSEC),A)	0135
	CALL LETTER(2,44,44HPROBABILITY PER MEV PER NSEC FOR FLIGHT-TIME,A)	0140
	1)	0145
	CALL LETTER(0,64,TITLE,A)	0150
	DO 115 I = 1,ISPACE	0155
	X = TIME(I)	0160
	YI = Y(I)	0165
	CALL POINT(1,X,YI,3,0.08,0.0,1,A)	0170
115	CONTINUE	0175
	CALL ADVANCE(A)	0180
	RETURN	0185
	END	0190

APPENDIX XX

```
SUBPROGRAM YSCL1(SET,ALØWY,DELY,DUMMY)
```

06-13-67

SUBROUTINE YSCL(SET,ALOWY,DELY,DUMMY)		0000
C	THIS SUBPROGRAM SETS THE Y SCALE FOR THE PLOTS GENERATED BY	0005
C	PROGRAM CONVOL	0010
C		0015
C		0020
C		0025
	COMMON NI,NO,NP,TPROB,JJ,TIME	0030
	COMMON INDEX,CRES,TCHAN,TDCHAN	0035
	DIMENSION TPROB(1000),TIME(1000),CRES(1000),TCHAN(1000),INDEX(1000)	0040
	1) DIMENSION SET(100)	0045
	ISPACE = JJ	0050
	ALOWY = 0.0	0055
		0060
C**	FIND UPPER LIMIT	0065
	CALL EXTREMUM(SET,GREAT,ISPACE,1)	0070
C**	SET SCALE MAXIMUM	0075
	J = 0	0080
	IF(GREAT.GE.1.) 100,120	0085
100	IGREAT = GREAT	0090
105	IF(IGREAT) 115,115,110	0095
110	IGREAT = IGREAT/10	0100
	J = J+1	0105
	GO TO 105	0110
115	IGREAT = GREAT/(10.**J)	0115
	DELY = (IGREAT+1)*10.**J	0120
	RETURN	0125
120	J = J + 1	0130
	IGREAT = GREAT*10.**J	0135
	IF(IGREAT) 125,120,125	0140
125	DELY = (IGREAT + 1)/10.**J	0145
	RETURN	0150
	END	0155

APPENDIX XXI

SUBPROGRAM DRAW2(Y,TITLE)

06-13-67

SUBROUTINE DRAW2(Y,TITLE)		0000
C	.....	0005
	COMMON N1,N0,NP,TPR08,JJ,TIME	0010
	COMMON INDEX,CRES,TCHAN,IDCHAN	0015
	DIMENSION TPR08(1000),TIME(1000),CRES(1000),TCHAN(1000),INDEX(1000)	0020
	1)	0025
	DIMENSION TITLE(8),A(6)	0030
	DIMENSION Y(200)	0035
C	.....	0040
C	THIS SUBPROGRAM IS THE CALLING ROUTINE AND INITIALIZING PROGRAM	0045
C	FOR THE PLOTS CALCULATED BY PROGRAM CONVOL. IT CALLS THE ROUTINES	0050
C	TO SET THE X AND Y AXES AND DETERMINES THE KIND OF POINTS TO BE	0055
C	USED. CHANGES IN THE TITLES OF THE X AND Y AXES ARE MADE	0060
C	IN THIS PROGRAM.	0065
C	.....	0070
	ISPACE = IDCHAN	0075
	CALL EXTREMUM(TCHAN,XUP,ISPACE,1)	0080
	CALL EXTREMUM(TCHAN,XLB,ISPACE,0)	0085
	X = XUP - XLB	0090
	IF(X=7.) 105,105,100	0095
100	DELX = 4.0	0100
	GO TO 110	0105
105	DELX = 1.0	0110
110	IXC = XLB - 1.0	0115
	XXLB = IXC	0120
	CALL YSCL2(Y,YZER0,DELY,ISPACE)	0125
	CALL LINEAR(0,0,DELY,10,XXLB,DELX,7,-7.0,48,A)	0130
	CALL LETTER(1,14,14HCHANNEL NUMBER,A)	0135
	CALL LETTER(2,23,23HPROBABILITY PER CHANNEL,A)	0140
	CALL LETTER(0,64,TITLE,A)	0145
	X1 = TCHAN(1) - 0.5	0150
	X2 = X1 + 1.0	0155
	DO 125 I = 1,ISPACE	0160
	YI = Y(I)	0165
	IF(I=1) 120,120,115	0170
115	X1 = X2	0175
	X2 = X1 + 1.0	0180
120	CALL CURVE(1,X1,YI,A)	0185
	CALL CURVE(2,X2,YI,A)	0190
125	CONTINUE	0195
	CALL ADVANCE(A)	0200
	RETURN	0205
	END	0210

APPENDIX XXII

SUBPROGRAM YSCL2(SET,ALØWY,DELY,DUMMY)

06-13-67

SUBROUTINE YSCL2(SET,ALOWY,DELY,DUMMY)		0000
C	THIS SUBPROGRAM SETS THE Y SCALE FOR THE PLOTS GENERATED BY	0005
C	PROGRAM CONVOL	0010
C		0015
C		0020
C		0025
	COMMON N1,N0,NP,TPROB,JJ,TIME	0030
	COMMON INDEX,CRES,TCHAN,IDCHAN	0035
	DIMENSION TPROB(1000),TIME(1000),CRES(1000),TCHAN(1000),INDEX(1000)	0040
	1) DIMENSION SET(100)	0045
	ISPACE = IDCHAN	0050
	ALOWY = 0.0	0055
C***	FIND UPPER LIMIT	0060
	CALL EXTREMUM(SET,GREAT,ISPACE,1)	0065
C***	SET SCALE MAXIMUM	0070
	J = 0	0075
	IF(GREAT,GE,1,) 100,120	0080
100	IGREAT = GREAT	0085
105	IF(IGREAT) 115,115,110	0090
110	IGREAT = IGREAT/10	0095
	J = J+1	0100
	GO TO 105	0105
115	IGREAT = GREAT/(10,**(J-1))	0110
	DELY = (IGREAT+1)*10,**(J-2)	0115
	RETURN	0120
120	J = J + 1	0125
	IGREAT = GREAT*10,**J	0130
	IF(IGREAT) 125,120,125	0135
125	DELY = (IGREAT + 1)/10,**(J+1)	0140
	RETURN	0145
	END	0150
		0155

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