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Fortran Programs for (p, γ) Yield Calculations Based on Vavilov's Theory of Energy Loss Distributions

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ABSTRACT

Two Fortran programs have been written to provide a method for the analysis of (p,γ) resonance yield curves for targets that may be thick compared to resonance width but which have a total energy loss small compared to the energy of the incident particle. For the sake of definiteness, (p,γ) reactions are discussed but the programs may be used for some other incident particles as well.

The programs are designed for several kinds of inview usage; in each, calculated and experimental yield curves are to be compared. A subprogram for plotting yield curves on a Calcomp plotter facilitates this comparison. Other subprograms provide plots that are useful in insuring that suitable parameters have been chosen as input data. Among the uses envisioned are: (1) the extraction of resonance widths and energies from experimental (p,γ) yield data from homogeneous targets and for targets that have a layer of inert matter or matter that contributes to the yield but which is different from that of the target; (2) the determination of the energy loss characteristics of a layer of matter on a target which produces a reaction with a sharp resonance of known properties; (3) the determination of target thickness, e.g., for solid targets used in neutron production; (4) the determination of the atomic composition of certain kinds of thin films; (5) the calculation of energy loss distributions; and (6) the calculation of the beam energy distributions after the beam has passed through a slab of matter.

The necessary energy loss distributions for the target are calculated by means of a theory due to P.V. Vavilov which gives a mathematically rigorous solution of an integro-differential equation for the many-collision energy loss fluctuations experienced by a charged particle as it penetrates matter. This solution is based on a free-electron single-collision energy loss probability density; the consequences of this assumption are discussed.

PROBLEM STATUS

This is a final report on this phase of the problem.

AUTHORIZATION

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FORTRAN PROGRAMS FOR (p,γ) YIELD CALCULATIONS BASED ON VAVILOV'S THEORY OF ENERGY LOSS DISTRIBUTIONS

INTRODUCTION

Mathematical descriptions of resonant (p,γ) yield curves provide a means of extracting the resonance energy and the resonance full width at half maximum (FWHM) from experimental data. Since such descriptions depend on the average energy loss and energy loss fluctuations of charged particle beams as they penetrate matter, valuable insight and understanding of the theories of energy loss and energy loss fluctuations may be had by correlating measured yields with calculated yields. The work herein described is concerned chiefly with yield curves taken from narrow isolated resonances in nuclear reactions with incident charged particle beams of small energy inhomogeneity. For the sake of definiteness, (p,γ) reactions are discussed but the results can be applied to some other kinds of incident particles as well.

The yield from a (p,γ) reaction for a homogeneous target is described by the formula

$$Y(E_b,t) = N_i N_t \int_E \int_{E_i} \int_0^t \sigma(E,E_r) g(E_i,E_b) f(E_i - E,x)\, dE dE_i dx, \qquad (1)$$

$Y(E_b,t)$ = number of reactions at an average bombarding energy E_b

N_i = number of incident beam particles

N_t = number of target particles per cubic centimeter of the kind contributing to the yield

E_r = resonance energy

$\sigma(E,E_r)$ = cross section per atom at energy E

$g(E_i,E_b)\, dE_i$ = probability that a beam particle in free space will be in energy interval dE_i at E_i if the average beam energy is E_b

$f(E_i - E,x)\, dE$ = probability that a particle which has an energy in dE_i at E_i before entering the target will be degraded into dE at E as it penetrates the target and loses energy through many collisions with the atomic electrons along the path with a length in the range x to x+dx (measured in cm along the beam direction)

t = target thickness in cm.

The integration with respect to dE and dE_i is to be carried out over energy regions where the cross-section function and beam energy distribution function $g(E_i,E_b)$ have nonnegligible values.

Since the concern here is only with the relative yields, the constants N_i and N_t will be dropped. The energy loss E_i - E will be designated by Δ. Since the loss is assumed to be proportional to the path length, the average energy loss $\bar{\Delta}$ will be taken as the target-penetration-depth variable, and the energy loss distribution function f will be written $w(\Delta,\bar{\Delta})$. The yield formula then becomes

$$Y(E_b,T) = \int_E \int_{E_i} \int_0^T \sigma(E,E_r) g(E_i,E_b) w(\Delta,\bar{\Delta})\, dE dE_i d\bar{\Delta}, \qquad (2)$$

where T is the target thickness in keV.

Two Fortran programs, named WINTGRL7 and YIELD6, for calculating and plotting the relative (p,γ) yields according to Eq. (2), have been written. Some results obtained with the programs, a brief discussion of Vavilov's theory, and a discussion of related work appear in Ref. 1. Preliminary versions of these programs appear in Ref. 2.

The energy loss distributions $w(\Delta,\bar{\Delta})$ are calculated by program WINTGRL7 according to the Vavilov formula (1,3,4):

$$f(\Delta,s) = \frac{\kappa}{\pi\xi}\, e^{\kappa(1+\beta^2\gamma)} \int_0^\infty e^{\kappa f_1} \cos(y\lambda_v + \kappa f_2)\, dy, \tag{3}$$

where

$\kappa = \xi\epsilon_{max}$

$\xi = 0.30058\ (mc^2/\beta^2)(Z/A)s$, in which m = rest mass of the electron, c = velocity of light, β = ratio of the velocity of the incident particle to the velocity of light, Z = number of electrons per target atom (molecule), A = atomic (molecular) weight of the target, s = target depth variable in grams/cm^2

$\lambda_v = \frac{\Delta - \bar{\Delta}}{\epsilon_{max}} - \kappa(1 + \beta^2 - \gamma)$

$\gamma = 0.577216$, which is Euler's constant

$f_1(y) = \beta^2[\log y - Ci(y)] - \cos y - y\, Si(y)$ and

$f_2(y) = y[\log y - Ci(y)] + \sin y + \beta^2\, Si(y)$, in which $Si(y) = \int_0^y \frac{\sin u}{u} du$, the sine integral and $Ci(y) = \int_\infty^y \frac{\cos u}{u} du$, the cosine integral.

Formula (3) gives a family of energy loss distribution functions each labeled by a value of κ. The subroutines that calculate these functions are based on a program listing kindly furnished by Seltzer and Berger (4). WINTGRL7 also integrates with respect to $\bar{\Delta}$ and punches the integrals on cards.

Program YIELD6 reads the set of integrals punched by WINTGRL7 and other data from punched cards and calculates the (p,γ) yield. This program will also modify the free-space beam energy distribution for the case where the beam passes through a layer of matter (in general different from that of the target) which may or may not contribute to the yield.

The cross-section function $\sigma(E_r,E)$ may be supplied as data to program YIELD6; alternatively, this program will calculate a cross-section function according to the single-level Breit-Wigner formula if the resonance energy and width are supplied as data.

The beam energy distribution $g(E_i,E_b)$ is calculated by YIELD6 if E_b is supplied. The shape is Gaussian. However, a modification could be readily made to accommodate a function of arbitrary shape.

Although Vavilov's development (3,4) is based on the free-electron single-collision energy loss probability density, he diminishes the effect of this approximation on his result by substituting for the first moment of this distribution the average energy loss given by Bethe's theory (5). The present work replaces this first moment by an experimental value of average energy loss (1,2). However, the theory depends to a degree on the single-collision spectrum, and this dependence causes the lack of agreement between experimental and calculated yields for targets containing atoms of atomic weight much

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greater than about 25. In the present work, agreement with experiment for targets containing atoms of intermediate atomic weight is improved by replacing Z, the number of electrons per target molecule, with Z_{eq}, the "equivalent number of free electrons," in the single-collision energy loss spectrum (1). Z_{eq} may be found for a given target material by treating it as a parameter of variation for one target. The extent of the usefulness of this concept will not be entirely clear until more experience with it is gained.

The programs have been written in Fortran-63 (a Control Data Corporation version of Fortran). They have been run on the NRL CDC 3800 which has 77777_8 memory locations in bank one and about 54000_8 in bank two available for the user's program. Each of the programs described in this report occupies nearly all of the available memory.

METHOD OF CALCULATION

To evaluate formula (2), the target is divided into slabs by equally spaced planes perpendicular to the beam direction. The energy loss distributions are calculated by WINTGRL7 for each plane near the face of the target, for every other plane somewhat deeper in the target, and less frequently for other planes still deeper in the target. The manner in which the target planes are selected must be chosen by the user. The integral variable I labels the planes; I = 1 labels the face of the target; the energy loss distribution for the target face is set equal to zero for all energy losses. In Vavilov's notation (1,3,4) the distributions are labeled by the set κ and in the programs they are labeled by the set D(I). Many of the more important names for the Fortran programs are listed in Appendixes A and C. Since there is no significant difference between the Vavilov distributions and the Landau distributions (6) for small κ (i.e., for small average energy loss), WINTGRL7 will produce Landau distributions in lieu of Vavilov distributions for the first ILAN values of I, where the value of ILAN is set by the user. This reduces computation time. The Landau functions are derived from a stored tabulation due to Börsch-Supan (7).

Formula (2) is evaluated for a chosen set of bombarding energies, E_b = EB(M), sufficient in number and distributed so as to facilitate comparison of calculated and experimental yields. Provision is made for the plotting of selected loss distributions, calculated yield, and experimental yield by means of a Calcomp plotter.

All energies at which the functions of the integrand of formula (2) are evaluated must belong to a "basic set;" all energy differences must be differences between members of this set. The interval on the basic set is named DEI and should be chosen so that the density of points is adequate to represent the most rapidly varying function of the integrand; for sharp resonances, this is the cross-section function. For example, if the resonance FWHM is estimated to be no smaller than 0.020 keV and DEI is chosen to be 0.004 keV, there will be at least 5 points on the cross-section representation above half height. The values of the basic set are fixed by requiring that E_r be a member and the range of the set must be sufficient to represent the greatest energy loss that may occur with nonnegligible probability. The set EB(M) must be a subset of the basic set.

Program WINTGRL7 calculates the distribution function at each target plane for a set of energy losses Δ_j = EIE(J5). The interval on this set, DE, must be an integral multiple of DEI so that the set Δ_j will be a subset of basic energy set differences. This is done so that the energy interval on the distribution functions may be coarser than that required to represent the cross-section function and beam energy distribution. The function W(J5), consisting of the integrals over the target depth variable, is interpolated to obtain values at losses corresponding to the basic energy set in program YIELD6, which integrates over the beam energy distribution and cross-section function.

The average energy loss between target planes, DKX, is related to DE by the relation DKX = DE * NDKX/A6, where A6 is a constant near unity and NDKX is a small integer; the origin of this formula will be discussed later. Typically, for a narrow resonance, DE might be chosen to be 0.020 keV and NDKX = 2 so that the average energy loss between target planes would be about 0.040 keV. The quantities DE and NDKX must be chosen small enough so that a further reduction will have a negligible effect on the resonance parameters deduced from the calculation.

Ten or fewer distributions may be specified by the I value on a data card read by WINTGRL7 for plotting. These plots are an aid in assuring that a resonable choice of parameters for the calculation has been made.

After calculating the energy loss distributions at selected target planes, WINTGRL7 integrates with respect to $\bar{\Delta}$ = KX(I), that is, it calculates the set of integrals

$$W(J5) = W_j = \int_0^T w(\Delta_j, \bar{\Delta}) d\bar{\Delta}; \tag{4}$$

there will be as many integrals plus one as there are energy loss increments Δ_j. These integrals represent the probability that, somewhere in the target, a particle will suffer an energy loss J5*DE where J5 = 1, 2, 3 . . . J3STØP and J3STØP=HILØSS/DE+1; HILØSS is the maximum loss any particle will suffer in the target with nonnegligible probability. The function W(J5) is plotted if selected energy loss distributions are plotted. The set W(J5) and other parameters are punched on cards for input to program YIELD6.

Program YIELD6 has three modes of operation, depending on data constants NSLA and NSLP. If there is no surface layer on the target, NSLA and NSLP are set equal to zero. If there is a surface layer which does not contribute to the yield (for example, a layer of carbon on an aluminum target used to produce the $^{27}Al(p,\gamma)^{28}Si$ reaction), NSLA is set equal to zero and NSLP is set equal to unity. The program then broadens and shifts the peak energy of the free-space energy distribution to take into account the effect of the layer. To accomplish this, the Vavilov distribution at the layer-target interface is calculated by subroutine BEAM1. To accommodate the case where a layer on the target contributes to the yield (for example a layer of Al_2O_3 on an aluminum target for the reaction cited above), the yield from the layer is computed in the usual manner by means of WINTGRL7 and YIELD6 (with NSLA = NSLP = 0) and punched on cards by YIELD6. The yield from the target proper is then calculated by means of the two programs with NSLA set equal to unity and NSLP set equal to zero; the layer yield is read from cards by YIELD6 and added to that of the target proper after being multiplied by a constant named YLDFAC.

As an aid in the use of program YIELD6, subroutine GRAPHB is provided to plot the free-space beam energy distribution, the energy loss distribution at the layer-target interface, and the interface beam energy distribution. A subroutine GRAPHA is provided to plot the experimental yield which is read from data and to plot the calculated yield so that judgements may be made as to the choice of resonance parameters read from data. If agreement between experiment and calculated yield is not satisfactory, these parameters are varied and another calculation made.

More detailed descriptions of the programs and subprograms are given in subsequent sections.

PROGRAM WINTGRL7

Program WINTGRL7 and its subprograms W6, VAV6, TRIGEX, LAN1, GRAPH5, and NØRM2 produce the distribution functions at specified target planes, integrate with respect

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to the target depth variable KX(I) = $\bar{\Delta}$, print certain quantities, graph certain distributions (specified in data) and the integrals W(J5) =W(Δ_j) = $\int w(\Delta_j, \bar{\Delta})d\bar{\Delta}$, and punch the set of integrals W(J5) on cards which are to be read by program YIELD6; J5 is an integer variable labeling the set of energy losses for a yield calculation. A nomenclature list which gives the meaning of most of the important quantities in the program appears in Appendix A; a program listing, a sample print-out, and a sample plot appear in Appendix B. All energies are in keV unless otherwise stated.

The main program statements numbered 96 and below are FØRMAT statements. Statements with numbers between 100 and 120 specify the data to be read from cards (Table 1). Certain constants and arrays are then computed. Although there are definitions and explanations in the nomenclature list, a few points are worth considering in greater detail.

Table 1
Data Cards for Program WINTGRL7

Cards	Format	Data
1	–	Comment in columns 2-70
2	–	Comment in columns 2-70
3	8F10.4	Z, A, DE, DEI, ZIP, TT, HILØSS, CUTFAC
4	8F10.4	RM, SEL, ERA
5	8I10	NMAX, NCØMP, LCØMP, LCØUNT, LCØUNT2, NDKX, NLANDAU, ILAN
6	8F10.4	DYMAX, CØMP, SLØ, PCUT, CUTFAC
7	8I10	NTWØS, NFØURS, NEIGHTS, KSIZE(2), KSIZE(3), KSIZE(4), KSIZE(5)
8	I5, 10I5	NPMAX, NP(I), I=1,2 ... N;N<11
9	8I10	NPRINT1, NPRINT2, NØPLØT, ICTLØW, INRM, IQUIT
10	8I10	IPRINT(I), I=1, ... IM, IM<11
11	8I10	KPRINT(K), K=1 ... KM, KM<11
12	8F10.4	SFX, SFY, SFXLØW, SFYLØW
13-111*	5(F6.1,3X, E10.4,6X)	486 pairs of values specifying the Landau distribution.

*These cards may be omitted if the program is never required to produce Landau distribution.

The parameter Z is not always the actual number of electrons per target molecule as in Vavilov's theory but is equal to the number of "equivalent free electrons" Z_{eq}, which determines (to a good approximation) the set of distribution functions appropriate to the target, i.e., those labeled by the set D(I) = κ leading to a yield curve which agrees with experiment. For targets of low atomic number, Z will be equal to or nearly equal to the actual number of electrons per atom (molecule) but for targets composed of elements of intermediate and high atomic number, Z will be substantially less than the actual number. The integer variable I labels the planes of the target and the parameter set κ = D(I). D(I) is the parameter set that labels the distribution functions in the Vavilov formula, where I = 1 for the face of the target and I = IMAX for the back surface of the target.

There is an option in the program that permits the low-loss distribution functions to be determined from the Landau distribution function which is stored on data cards. This saves computation time and is feasible because the Landau and Vavilov functions (plotted as a function of the Landau parameter λ) are essentially identical for $\kappa < 0.01$ — see, for example, Fig. 1 of Ref. 4. This option is entered (not entered) if the control constant NLANDAU is set equal to unity (zero) in data. Values of the Landau $\lambda = (\lambda_v/\kappa) - \log \kappa =$ GL(LL) and Landau distribution function $\varphi =$ GPH(LL) were taken from the table of Ref. 7 and are entered in data, 5 pairs to a card, for values of $\lambda = -3.5, -3.4 \ldots 99.5$. These cards need not be present if the Landau option is never used. If NLANDAU = 1, the distribution functions labeled by I = 1, 2, 3 ... ILAN will be determined from the Landau table and the remaining distribution functions will be obtained by means of formula (3).

For very small values of κ (i.e., for the low-loss distributions) for a target subdivided into very thin slabs, the functions determined either from the Landau function $\varphi(\lambda)$ or the Vavilov formula (3) would have nonnegligible amplitudes for some negative values of energy loss; this is judged to be physically unrealistic and the lowest loss permitted is zero. For very small values of κ, this means that the functions are cut off at $\lambda \approx 0$. These functions are then renormalized so that they envelop an area of unity. This, in effect, changes their shape so that they are more asymmetric than the Vavilov functions and more nearly resemble the single-collision loss distribution given by Eq. (9) of Ref. 1.

The target thickness (in keV) is read from data but is recomputed after IMAX is obtained from it so that the target thickness will be exactly equal to the sum of the average energy losses in all of the target slabs. This is done as follows. The average energy loss between target planes is DKX:

$$\text{IMAX} = \text{TT/DKX} + 1. \tag{5}$$

The integer IMAX is then compared with the real value TT/DKX + 1 and set equal to the integer nearest it. Then TT is recomputed by

$$\text{TT} = (\text{IMAX} - 1)*\text{DKX}. \tag{5'}$$

Often, the target thickness is not known to within an uncertainty of size DKX. In fact, the most probable value of target thickness is usually judged to be that which leads to agreement between calculated and experimental yields. Both the set of distribution functions and the target thickness must be correct to obtain the correct shape for a yield curve that is taken over a bombarding energy range greater than the target thickness.

Although the energy interval DEI is not used in program WINTGRL7, it is read from the data cards and together with other parameters is repunched on data cards for transmission to program YIELD6. The energy interval DE gives the spacing of points on the distribution functions and, hence, the spacing of set W(J5); DE must be an integral multiple of DEI. The set W(J5) is later interpolated to obtain a set with energy loss interval DEI prior to integration over the beam energy distribution and the resonance shape.

The quantity DKX cannot be chosen independently but is obtained in the following way so that one set, $\lambda_v =$ PV(K), can be used for the calculation of all distribution functions obtained from the Vavilov formula, where K = 1, 2, 3 ... KMAX:

$$\lambda_v = \frac{\Delta - \bar{\Delta}}{\epsilon_{max}} - \kappa B = \text{PV(K)} = \frac{\text{EIE(J5)} - \text{KX(I)}}{\text{GEMAX}} - \text{D(I)}*\text{B}, \tag{6}$$

where EIE(J5) is the set of energy losses for the problem at hand, GEMAX $= \epsilon_{max}$, the maximum energy that an incident particle of resonance energy can transfer to a free

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electron, and $B = 1 + \beta^2 - \gamma$, where β is the ratio of the incident particle velocity at resonance energy to the velocity of light and $\gamma = 0.577216$, which is Euler's constant. There is a discussion in Ref. 1 of the manner in which the experimental value of the average energy loss per unit length for the target matter enters the calculation; Eq. (14) of Ref. 1 is rewritten here as

$$\kappa = \frac{\bar{\Delta}}{L\,\epsilon_{max}} = D(I) = \frac{KX(I)}{KX2*GEMAX}, \tag{7}$$

where L = KX2 in Fortran notation. Now let

$$\bar{\Delta} = KX(I) = (I - 1)*DKX, \text{ where } I = 1, 2, 3 \ldots IMAX, \tag{8}$$

and

$$EIE(J5) = (J3STØP - J5)*DE, \text{ where } J5 = 1, 2, 3 \ldots J3STØP. \tag{9}$$

If Eqs. (7), (8), and (9) are substituted into Eq. (6), we have

$$PV(K) = (DE/GEMAX)*(J3STØP - J5) - (I - 1)*DKX*A6/GEMAX, \tag{10}$$

where A6 = 1 + B/KX2. Now introduce a new integer variable

$$K = J5 + (I - 1)*NDKX, \tag{11}$$

where NDKX is a small integer, and let

$$DKX = DE*NDKX/A6 \tag{12}$$

to get

$$PV(K) = (DE/GEMAX)*(J3STØP - K), \tag{13}$$

where K = 1, 2, 3 ... KMAX; KMAX = J3STØP + (I - 1)*NDKX. NDKX is approximately the ratio of the energy loss interval between target planes to the interval between points on the energy loss distributions.

The energy loss distribution functions have negligible amplitudes for losses which are large compared to $\bar{\Delta}$; and values of a given function need not be calculated for losses greater than a few times $\bar{\Delta}$. Therefore, calculations are cut off at values of J5 = J5CUTHI (I) according to the empirical formula

$$J5CUTHI(I) = J3STØP - CUTC/DE - CUTFAC*J3STØP*I/IMAX, \tag{14}$$

where the values of CUTC and CUTFAC are read from data and can be determined from experience with the aid of plotted distribution functions.

Some of the other quantities computed in the main program will be discussed in descriptions of its subroutines.

Subroutine W6

Subroutine W6 is called by the main program. Its function is to set parameters so that it may call subroutine VAV6 to calculate a pair of distribution functions. Upon RETURN, W6 integrates over two target-plane intervals by means of Simpson's rule along the target depth axis $\bar{\Delta}$ for each value of J5 to get partial sums for the set W(J5).

For large values of target penetration (large average energy loss), the distribution functions become more nearly alike and more nearly Gaussian; therefore, the intervals along the target depth axis may be larger than DKX and fewer than IMAX distribution functions need be calculated. The intervals used are under the control of the user through the constants NØNES, NTWØS, NFØURS, and NEIGHTS, which are given values in data; NØNES is the number of pairs of distributions separated by DKX; NTWØS is the number of pairs separated by 2*DKX; NFØURS is the number of pairs separated by 4*DKX; and NEIGHTS is the number of pairs separated by 8*DKX.

If IMAX is even, there will be an odd number of bins for integration over $\bar{\Delta}$. Therefore, provision is made so that integration over the last bin is carried out by means of the trapezoidal rule if IMAX is even.

Subroutine VAV6

Subroutine VAV6 is based on a program listing kindly furnished by Seltzer and Berger (4) of the National Bureau of Standards. This subroutine is called by W6, and, if NLANDAU = 0, it computes a pair of distribution functions on each call (except possibly on the last call). If NLANDAU = 1, distribution functions labeled by I = 2, 3, ... ILAN are derived from the table of the Landau function $\varphi(\lambda)$ stored in data by calling subroutine LAN1. For $\kappa \leq 0.01$ and somewhat larger, there is no significant difference between the distributions derived from the Landau table and those computed by means of the Vavilov formula.

The distribution functions calculated by means of the Vavilov formula are calculated as a function of λ_v = PV(K) and stored in SUM(K). However, they must be expressed as a function of the energy loss variable Δ = EIE(J5) and renormalized. Once this is done, they are stored in WLC1(I6,J6).

Some of the relationships in this subroutine can be better understood by picturing a fictitious rectangular array with the columns labeled by I = 1, 2 ... IMAX. The first column should be labeled with I = 1. If NDKX = 2, the third column should be labeled with I = 2, the fifth with I = 3, etc.; if NDKX = 3, the fourth column should be labeled with I = 2 and the seventh with I = 3, etc. The rows should be labeled with K = 1, 2 ... KMAX. The diagonals (upper left to lower right) should be labeled with J5 = 1, 2 ... J3STØP where they project from the left side of the array. The relationship between J5 and K is: K = J5 + (I - 1)*NDKX; KMAX = J3STØP + (IMAX - 1)*NDKX. The locations in the first column from 1 through J3STØP represent the energy loss distribution function at the face of the target and should be filled with zeros. The first time VAV6 is called, it will compute values for columns 3 and 5 (assuming NDKX = 2) between diagonals 1 through J3STØP. The numbers in the first three columns filled are divided by $\xi = \bar{\Delta}/L$ = KX(I)/KX2 (to provide distributions that envelop unit area when plotted as a function of Δ) and stored in array WLC1(I6,J6), where I6 = 1, 2, 3 and J6 = J5. Upon RETURN to subroutine W6, integration by Simpson's rule with respect to $\bar{\Delta}$ over the first two slabs of the target takes place. On the next call of VAV6 (assuming NØNES > 1), the locations in columns labeled with I = 4 and I = 5 that are pierced by the J3STØP diagonals will be filled, renormalized, and the contents of 3rd, 4th and 5th columns to be filled will be transferred to array WLC1(I6,J6) for partial integration. The partial integrals are accumulated in array W(J6). This procedure constructs energy loss distributions $w(\Delta,\bar{\Delta})$ for each target plane and integrates with respect to $\bar{\Delta}$ over lines of constant Δ. In regions of the fictitious

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array where I > 2*NØNES, not every column will be filled and the bin width for integration over the target depth variable will be increased correspondingly. The goal is to obtain "fine-grained" integration near the face of the target where the distribution functions are rapidly varying functions of $\bar{\Delta}$ and to use coarser intervals to save computer time deeper in the target.

Not every value obtained in the Vavilov mode of VAV6 is obtained by means of formula (3). Where the distribution functions are slowly varying, functions of Δ, some values are supplied by interpolating between nearby values that are obtained by numerical integration. The manner in which this is done is controlled by the contents of array KSIZE(M), M = 1, 2, 3, 4, which is stored in data. For example, if KSIZE(4) = 50, K will be advanced with an increment of 4 for the first 4*KSIZE(4) = 200 values of each distribution. This is the high-loss region of the distribution functions (near the top of the fictitious array). The next 3*KSIZE(3) values will be computed with a K increment of 3. The values not computed are supplied by interpolation from nearby values that are computed. This procedure also saves computer time. The extent to which such approximations can be made is a matter of experience; a criterion for increasing the degree of approximation is that its effect on the final yield curve shall be essentially negligible.

The integrand of formula (3) oscillates about a line lying parallel to the y axis and above it. The amplitude of the oscillations decreases as y increases; the integrand takes on values of both signs except for large y. Care must be taken to choose DY small enough so that there will be several bins per quarter cycle of the integrand and yet large enough so that there is a reasonable compromise between accuracy of numerical integration and computation time. DY(I) is different for each distribution and is given by

$$\mathrm{DY(I)} = \mathrm{DYMAX}*\frac{\mathrm{GKMIN}}{\mathrm{D(I)}}*\mathrm{SQRTF(RI - 1.0)}, \tag{15}$$

where GKMIN is the smallest value of κ = D(I) for a particular yield calculation (this occurs for I = 2), RI is the real representation of I, and DYMAX is the value of DY(2) and is the largest value DY(I) will assume for all I. DYMAX is specified in data.

The number of bins per quarter cycle of the integrand for a given I value and DY(I) tends to decrease as y nears the region where convergence occurs. The number of bins per quarter cycle for the Vavilov integrand is given approximately by

$$\mathrm{NPQC(I)} = 1.57/[\mathrm{PV(K)}*\mathrm{DY(I)}]. \tag{16}$$

The largest value of λ_v = PV(K) for the Ith distribution occurs at

$$\mathrm{KCUT(I)} = \mathrm{J5CUTHI(I)} + (\mathrm{I} - 1)*\mathrm{NDKX}. \tag{17}$$

The array NPQC(I) is evaluated for K = KCUT(I) in the main program and printed. This array aids in choosing DYMAX sufficiently small; DYMAX $\approx$ 1.0 is typical.

The numerical evaluation of the Vavilov integral, formula (3), must be carried out to obtain each value of the Ith distribution function unless this value is obtained by interpolating between nearby values so calculated. Simpson's rule is employed, and the partial sums for pairs of bins, each of width DY, are stored in array S(M) of VAV6; a maximum of 1250 partial sums (2500 bins) may be stored. The values of these partial sums oscillate about the exact value of the integral, and, for small values of y, the partial sums are often negative.

In the analysis of (p,γ) yield curves, it is sometimes useful to calculate the low-loss distributions at closely spaced energy loss intervals where the average loss may be of the order of 10 eV. The Vavilov integral converges slowly for such cases and the convergence criterion of Seltzer and Berger has been modified. Subroutine VAV6 approximates the Vavilov integral as follows. Let us define convergence criterion one as that for which

$$\left| \frac{S(M) - S(M-1)}{S(M)} \right| < \text{CØMP}, \quad M = 1, 2 \ldots \tag{18}$$

(where CØMP $\approx 10^{-5}$) is satisfied for NCØMP successive values of M (where NCØMP $\approx$ 10) This is the convergence criterion used by Seltzer and Berger and in the present method is tested for after each partial sum is computed—even though other tests are also applied. If convergence criterion one is not satisfied after LCØUNT/2 partial sums (LCØUNT $\approx$ 500), a test is made to see if $|S(M)|$ is less than SLØ, where SLØ $\approx$ 0.3. If this inequality is satisfied for LCØMP $\approx$ 10 successive partial sums, condition two has been satisfied. If condition two is satisfied, the accumulation of the subsequent partial sums is begun in location ACCS. If after the accumulation of 100 partial sums in ACCS, convergence has not been obtained via condition one, the value of the distribution function is calculated from the average value of the accumulation. If convergence is not obtained through condition two after (LCØUNT + LCØUNT2)/2 partial sums (where LCØUNT2 $\leq$ 2000), the value of the distribution function is computed from the average value of the next 100 partial sums.

Up to ten distribution functions can be printed from VAV6 by specifying the number desired in NPMAX and the I values of the desired functions in NP(M). These functions will also be graphed by subroutine GRAPH5 except that if one or more of the functions requested is skipped due to computation in the modes specified by NTWØS, NFØURS, or NEIGHTS, these functions will not be printed or graphed.

By storing the I values of up to six distributions in IPRINT(N), N = 5, 6, 7, 8, 9, 10, a table will be printed from VAV6. The following quantities will be printed: Landau lambda, Vavilov lambda, the distribution (normalized to have unit area when plotted as a function of the Landau lambda), the number of terms (i.e., the number of times the integrand was evaluated) to achieve convergence, the maximum value of K, the maximum value of J6 (stored in J6SV), the value of ACCS (stored in KACCS(K)), the value of I and the value of I6. If this table is not desired, some or all of the array IPRINT(N) may be filled with zeros or left empty.

Certain other quantities may be printed or not from VAV6 depending on whether certain control constants (described in the nomenclature list of Appendix A) are one or zero.

Subroutine TRIGEX

Subroutine TRIGEX is called by VAV6 and computes certain functions used in the calculation of the Vavilov integral.

Subroutine GRAPH5

Subroutine GRAPH5 causes the CALCOMP plotter to graph distribution functions against energy loss if NGRAPH5 in data is equal to one. No graphs are plotted if NGRAPH5 = 0. Functions W, the integrals over the distribution functions with respect to the target depth variable, are also plotted against energy loss if NGRAPH5 = 1. There are control constants in data that determine the size of the plots; these constants are

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defined in the nomenclature list of Appendix A. Appendix B contains a plot from this subroutine (Fig. B1) of a few energy loss distribution functions and of the integrals with respect to $\bar{\Delta}$ for the 992-keV resonance in the $^{27}Al(p,\gamma)^{28}Si$ reaction; the aluminum target was 4.923 keV thick at resonance energy.

Subroutine NØRM2

Subroutine NØRM2 normalizes the distribution functions labeled by I = 2, 3, ... INØRM. This is necessary for the low-loss distribution functions whether they are derived from the Landau table in data or calculated by means of the Vavilov formula. When entry point NØRM2 is called by VAV6, the areas of the distributions printed from VAV6 are calculated, stored in array AREAC(10), and printed by the main program.

Subroutine LAN1

Subroutine LAN1 is called by VAV6 when I ≤ ILAN and causes the distribution function for the current value of I to be derived from the Landau distribution function stored in data rather than to be calculated from the Vavilov formula. The values of λ are stored in GL(LL): the least value of λ is -3.5, which is less than any value of λ needed in the program. The values of Landau function $\varphi(\lambda)$ were taken from Ref. 7 and are stored in GPH(LL). The value of λ corresponding to the current value of J5 is calculated and stored in P(J5); the value of LL is then increased from 1 until GL(LL) exceeds P(J5) and a linear interpolation is made between GPH(LL) and GPH(LL - 1) for the value of $\varphi(\lambda)$ corresponding to the energy loss labeled by J5.

PROGRAM YIELD6

Program YIELD6 reads constants and arrays from cards, including the W function which is punched by program WINTGRL7. The quantities read and their assignment to data cards may be ascertained from statements 102 through 132 in the YIELD6 listing in Appendix D (also see Table 2). A nomenclature list defining some of the more important names that appear in YIELD6 and its subprograms appears in Appendix C.

This program and its subprograms calculate the (p,γ) yield according to formula (2) by integrating over the beam energy distribution and the cross-section function and provide for certain plots. Operation may be said to occur in any one of three modes: (a) target with no surface layer, (b) target with a passive surface layer which does not contribute to the yield and, (c) target with an active surface layer which does contribute to the yield. Operation is in the first mode if data constants NSLP and NSLA are set equal to zero. Operation will be in the second mode if NSLP = 1 and NSLA = 0. In this mode, the energy loss distribution at the interface of the layer and the target is calculated and the free-space energy distribution is modified to take into account the broadening and the shift in average energy which occurs as the beam traverses the layer. Operation is in the third mode when NSLP = 0 and NSLA = 1. The surface layer yield must now contribute to the total yield. The surface layer yield is first obtained from a separate calculation with WINTGRL7 and YIELD6 (in mode 1) in which the layer is treated as a separate target but with NPNCH = 1. The set of bombarding energies must be the same in the layer yield calculation and the calculation for the yield from the target proper plus that of the layer.

The subprograms of YIELD6 are named SETS5, BEAM1, TRIGEX, G7, YM4, YM5, GRAPHA, and GRAPHB. Brief descriptions of the subprograms follow.

Table 2
Data Cards for Program YIELD6

Cards	Format	Data
1	—	Comment in columns 2 - 70
2	—	Comment in columns 2 - 70
3	8I10	NPRINT1, NPRINT2, NPRINT3, NGRAPHA, NGRAPHB, NSLA, NSLP
4	8I10	MPRINT1, MPRINT2, LPRINT1, LPRINT2, LPNCH, NSIGMA
5	3(F10.4,I10)	DEB1, NEB1, DEB2, NEB2, DEB3, NEB3
6	10F10.4	EBNRM, SFN, YLDFAC
L1*	10F10.4	ZSL, ASL, SLT, SELSL, HILØSSL, SLØ, PMIN
L2*	8I10	LCØUNT, LCØMP, NCØMP, LCØUNT2
YSL†	10F8.5	NEB3 values of surface layer yield 10 to a card
W1‡	5F10.3,F10.5, F10.3	Z, ZIP, A, TT, SEL, DYFAC, HILØSS
W2‡	3I5, 5F12.6	IMAX, J3STØP, KMAX, DE, DEI, BSQ, GEMAX, A7
W(J5)‡	10F8.5	J3STØP integrals W(J5)
EXP1	I3	NEXP
EXP(N)	4(I3,F9.2, F8.2)	NEXP triads of experimental yield data
7	4F20.10	SFAX, SFAY, SFBX, SFBY
8	4F10.3,3I10	ER, GAMMA, BFWHM, EB(1), NBW, NGAM, LMX
E(L)§	6E12.5	LMX values of cross-section function energy
BW(L)§	6E12.5	LMX values of the cross-section function

*Omit unless the calculation is for a target which has a surface layer.
†Omit unless this calculation is for a target with an active surface layer.
‡From program WINTGRL7.
§Omit these cards if the cross-section function is to be generated internally.

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Subroutine SETS5

SETS5 is called by YIELD6. It generates a set of bombarding energies at which the yield is to be calculated; these values are stored in array EB(M). It generates a free-space Gaussian beam distribution and stores it in GLC(L2).

The set EB(M) is computed with three different intervals DEB1, DEB2, and DEB3, which are specified in the input data. There are NEB1 values of EB(M) with interval DEB1; there are NEB2 - NEB1 values of EB(M) with interval DEB2, etc. If DEB1, etc., are entered into data with values which make the set EB(M) nonmembers of the basic set of energies, DEB1, etc., are recomputed so that EB(M) will belong to the basic set. ER is a member of set EB(M).

If LMX = 0 in data, SETS5 generates a set of energy values at which the cross-section function is defined and stores them into E(L). These values will be spaced by NBW*DEI for the eight values on each side of the resonance energy; the interval will be doubled for the next outlying eight values, on each side of resonance, etc. The set will continue to be generated, in groups of 16 until $|E(L) - ER| \geq$ NGAM*GAMMA. If the cross-section function extends to about 100*GAMMA on either side of resonance, the area under the Breit-Wigner resonance curve defined will be within a few tenths percent of the true area under such a curve. The resonance function is then generated and stored in BW(L).

If LMX > 0, functions E(L) and EW(L) will be read from data cards; L = 1, 2, 3 ... LMX. In constructing arbitrary sets E(L), they must be members of the basic set of energies for the problem. LRES, the value of L at resonance, must also be read from data for the case of external E(L) and BW(L).

Subroutines BEAM1 and TRIGEX

Subroutines BEAM1 and TRIGEX calculate the energy loss distribution at the layer-target interface by means of the Vavilov formula (3). Values of this function are calculated at energy loss intervals DE at all loss values where the loss probability density is significant. No values are obtained by interpolation as was done in VAV6. This distribution function is stored in array WLC2(K).

The second task of these subroutines is to calculate the shape of the beam energy distribution after the beam has passed through the surface layer using WLC2(K). This "distorted" beam energy distribution is first calculated at energy interval DE and then, by interpolation, values are supplied so that the final energy interval is DEI. The calculation is made by selecting a value on the distorted distribution energy axis and computing the probability density that a beam particle will exist at some higher energy on the free-space distribution and will be degraded to the selected value. The sum of such probability densities gives the probability density for the distorted distribution at one of the selected energies which are separated by the interval DEI. Subroutine TRIGEX is called by BEAM1 to calculate certain functions.

Subroutine G7

Subroutine G7 integrates over the beam energy distribution by means of Simpson's rule for each value of the cross-section function BW(L). These integrals are stored in array H(L). This integration is performed for each value of the bombarding energy EB(M); M and L are set in YIELD6 which then calls G7. The set EB(M) belongs to the basic set of energies.

The function W(J5) was computed by WINTGRL7 and transferred to YIELD6 by means of punched cards. It was computed at energy loss points DE apart. The beam and cross-section functions are computed at energies DEI apart; DE must be greater than DEI. The function W(J5) is interpolated to interval DEI and stored in array WINT(L2); only those values needed for integration for a given M and L are stored in this array at one time. Interpolation is facilitated by the introduction of a set of parameters J2 = J2A ... J2P ... J2MAX. Where J2A corresponds to the largest loss needed for a given M and L, J2P corresponds to the loss required to degrade the particles in the peak of the beam to energy E(L), and J2MAX corresponds to zero loss in the target.

For each M and L setting, the appropriate limits LI and LF on the beam energy distribution independent variable L2 (which is also the independent variable for array WINT (L2)) as well as the parameters J2A and J2P are computed by three different strings of statements, depending on whether EB(M) is less than, equal to, or greater than E(L). If EB(M) > EBLOW = E(L) - 2*BFWHM, there is a jump past the integration routines since there is no yield under this condition. Precautions are taken to assure that the indices LI and LF and J2A do not take on values less than unity.

For diagnostic purposes, certain sets of parameters used in G7 may be printed out for selected values of M and L under the control of constants MPRINT1, MPRINT2, and LPRINT1, and LPRINT2 which are entered in data. It should be noted that the beam energy decreases with increasing values of L2 and the energy loss decreases with increasing values of J2 and L2.

Subroutine YM4; Function YM5

Subroutine YM4 and function YM5 integrate over the cross-section function BW(L), where L = 1, 2, 3 ... LMØX by means of Simpson's rule. The subroutine YM4 sets limits on the integer variable L and calls YM5 to sum products BW(L)*H(L) over eight intervals per call. The partial sums are multiplied by the appropriate bin width in YM4, and the final sum (for a given value of M) is multiplied by YLDFAC, a factor which accounts for the generally lower atomic density of contributing atoms in a surface layer than in the "target proper."

Because of the structure of YM4, care must be taken to construct external functions BW(L) and E(L) with the same interval scheme as is used for these functions when generated internally.

Subroutine GRAPHA

Subroutine GRAPHA causes the Calcomp plotter to plot the experimental points (stored in data) and the calculated yield if NGRAPHA (in data) is equal to one. If there is a layer on the target which contributes to the yield (NSLA = 1), the yield for the layer (which is calculated in a preliminary run by YIELD6 with NSLA = NSLP = 0) is plotted separately and the total yield (layer plus target proper) is also plotted.

The ordinates of the experimental points may be adjusted so that the areas under the experimental yield curve and calculated yield curve will be equal out to the bombarding energy of some experimental point named EBNRM; EBNRM must be specified in the input data and must lie in the energy range bounded by NEB1*DEB1 and NEB1*DEB1 + (NEB2 - NEB1)*DEB2. This leaves the fraction of the areas to be matched to the user's choice. It is often desirable to compare the early parts of the calculated and experimental yield curves since the shape of the high-energy part of the experimental yield curve is affected by target thickness inhomogeneities. For sufficiently thick targets, the value of ER and

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GAMMA determined by comparing curves are independent of the high-energy part of the yield curve. In fact, if the target is sufficiently thick, ER and GAMMA may be determined without calculating the high-energy part of the yield curve.

If it is desirable to plot the experimental yield curve to an arbitrary vertical scale, set EBNRM = 0.0 and specify constant SFN in the input data. The experimental yield curve will then be plotted according to YX = YEXP(N)*SFAY*SFN*6.0, where YX is the height in inches and SFAY is a scale factor (of the order of 1.0) in data. Figure D1, Appendix D, illustrates a plot by GRAPHA for the 992-keV resonance in the $^{27}Al(p,\gamma)^{28}Si$ reaction. The target consists of 4.934 keV of aluminum with an 0.156-keV layer of Al_2O_3.

Subroutine GRAPHB

If NGRAPHB = 1 in data, subroutine GRAPHB will cause the Calcomp plotter to plot the energy loss distribution at a layer-target interface, the free-space beam energy distribution, and the beam energy distribution at the layer-target interface. Figure D2, Appendix D, shows plots for proton beam with 0.198-keV FWHM incident on an aluminum target with an Al_2O_3 layer 0.156 keV thick at resonance energy.

Area Under Yield Curve

The area under the yield curve should be numerically equal to the target thickness (when there is no yield from a surface layer and YLDFAC is 1.0) since the beam energy distribution, the cross-section function, and the energy loss distributions are all normalized to unity. This area is named AYLD and is computed and printed in YIELD6. If there is a surface layer which contributes to the yield, the numerical value of the yield curve area will be increased over the target thickness by an amount computed for AYLD in the preliminary yield calculation for the layer.

The value of AYLD is usually less than TT due to truncation of distribution functions and approximations in intergration routines. Typically, the difference is within 2 percent.

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Appendix A

NOMENCLATURE FOR PROGRAM WINTGRL7

A (read from data) is the molecular weight of the target matter.

A7 = 0.30058 mc^2/β^2, where the nomenclature is that of formula (3).

ACCS is a location in which the partial sums representing the Vavilov integral are accumulated in connection with convergence criterion two—for the current distribution function calculated in VAV6.

BSQ = β^2 is the square of the ratio of the velocity of the incident particle to that of light at resonance energy.

CØMP (read from data) is a positive number of the order of 10^{-6} used to test for convergence of the Vavilov integral formula. If the absolute value of the fractional change from the partial sum M - 1 to the Mth (representing the integral in VAV6) is less than CØMP for NCØMP $\approx$ 10 successive values of M, convergence criterion one is said to be satisfied.

LCØUNT (read from data) is an integer such that if the number of partial sums formed in the integration of the Vavilov formula exceeds LCØUNT, the second convergence criterion is applied to all subsequent partial sums representing the current integral.

CUTC (read from data) is a constant that appears in the formula J5CUTHI(I) = J3STØP - CUTC/DE - CUTFAC*J3STØP*I/IMAX. A typical value for this parameter is 0.8. It insures that no distribution function will be cut off at less than a loss of CUTC keV.

CUTFAC (read from data) is a constant (on the order of unity) that determines the I dependence of the way in which the energy loss distribution functions are cut off in the high-loss region through the formula J5CUTHI(I) = J3STØP - CUTC/DE - CUTFAC* J3STØP*I/IMAX.

DE (read from data) is the energy loss interval for the calculation of the Vavilov distribution functions. It must be an integral multiple (greater than one) of DEI so that these functions can be conveniently interpolated to intervals of size DEI. Thus, the probability densities computed will be for losses which are equal to exact differences between particle energies and energies at which the cross-section function is represented. Typically, the size of DE will be about 0.020 keV. DKX is computed, is dependent on the size of DE, and is approximately NDKX*DE. Therefore, the choice of DE fixes the thickness and number of target subdivisions and the time required for integration over the target depth variable $\bar{\Delta}$.

DEI (read from data) is the smallest energy interval (in keV) in the basic set of energies which contains all energy differences that enter the calculation. Energy loss increments are also eventually reduced to size DEI, although the energy loss distribution functions are initially calculated on interval DE which must always be greater than DEI and is an integral multiple of DEI. Choose DEI by first estimating the smallest value of GAMMA = (Γ)(in keV) that is likely to be assumed for the resonance under consideration; then make DEI $\approx \Gamma/5.0$. This will cause the program to represent the cross-section function with 5 points above half height for the smallest Γ assumed and with more if Γ is larger. If DEI is not an integral submultiple of DE (in data), it will be recalculated to be such.

D(I) = κ is the parameter that labels the Ith distribution in Vavilov's theory.

DKX is the average energy loss in keV between target planes.

DY(I) is an array in which are stored the values of bin width DY for the Vavilov formula which calculates the energy loss distribution labeled by I.

DYMAX (read from data) is the largest bin width (DY) that will be used in the integration of the Vavilov formula. Since the integrand is oscillatory, a value of DY that is large compared to the period of oscillation will result in meaningless integration. Typically, this parameter will be unity.

EIE(J5) is the energy loss Δ labeled by the integer variable J5 = 1, 2, 3 . . . J3STØP.

ERA (read from data) is the first estimate of the resonance energy in keV and is used to compute a value for β^2.

GEMAX = ϵ_{max} is the maximum energy in keV that can be transferred in a collision between an incident particle and a free electron.

GL(LL) (read from data if NLANDAU = 1) is the set of Landau lambdas, λ, paired with values of the Landau distribution function in data.

GPH(LL) (read from data if NLANDAU = 1) is the set of values for the Landau distribution function stored in data. Each value is paired with a value of λ on the data cards. This array is read and printed from SUBRØUTINE LAN1 if NLANDAU = 1. There are 486 values.

HILØSS (read from data) is the maximum loss in keV that any incident particle will suffer (with nonnegligible probability) while traversing the entire target thickness. A value for this parameter can be obtained by inspecting plots of the energy loss distribution functions for various target thicknesses.

I is an integer variable that labels the planes which subdivide the target (I = 1 labels the target face). Hence, I also labels the set D(I) = κ and the set of energy loss distributions.

ICØUNT is a location in which is stored the ordinal number of the distribution function about to be plotted and printed; ICØUNT = 1, 2, 3 . . . NPMAX. If the maximum value of ICØUNT that appears in the printout is less than NPMAX, this means that not all the distribution functions designated in NP(10) were actually calculated.

ICTLØW (read from data) is an integer which controls the height of the plots of the low-loss distribution functions which tend to be sharp. The first ICTLØW distribution functions plotted by GRAPH5 will be plotted according to Y = SFYLØW*10.0*WLC1(I6,J6). Y is in inches.

ILAN is an integer that determines the I value of the last distribution function derived from the Landau table in data. If I > ILAN, the distribution functions are calculated from the Vavilov formula.

IMAX is the I value labeling the final target plane (back face). If IMAX exceeds 400, the program is stopped and an abort message printed.

KPRINT(10) (read from data) stores values of K for which certain parameters may be printed. See IPRINT(10).

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KSIZE(NBLØCK) is an array that governs the manner in which the values of the distribution labeled by I6 and I are calculated in the K loop of VAV6 and stored in array WLC1 (I6,J6). NBLØCK = 1, 2, 3, 4, 5 is the ordinal number of a block of values. J6 = J5 = 1, 2, ... J3STØP labels the distribution values; J6 = K - (I6 - 1)*NDKX. If KSIZE(5) $\neq$ 0, the calculation of the Ith distribution function begins with KSIZE(5) blocks with interval MK = 16, then the KSIZE(4) blocks with interval MK = 8 are determined—then KSIZE(2) blocks with interval MK = 2. Only the first and last values of each block are calculated by means of the Vavilov formula; the intervening values are obtained by linear interpolation from the first and last. If KSIZE(5) = 0, the calculation begins with blocks of the 4th kind, etc.; KSIZE(N) may be zero provided KSIZE (N + 1) = 0. If K is less than J5CUTHI(I) + (I - 1)*NDKX or greater than J5CUTLO(I) + (I - 1)*NDKX zeros will appear in array WLC1(I6,J6). The distribution values in blocks of the first kind (NBLOCK = 1) are all calculated by the Vavilov formula unless I $\leq$ ILAN; then they are supplied by interpolation from the values of the Landau function stored in data. KSIZE(5)—KSIZE(2) are read from data; KSIZE(1) is calculated according to KSIZE(1) = J3STØP - 1 - 2*KSIZE(2) - 4*KSIZE(3) - 8*KSIZE(4) - 16*KSIZE(5). Thus, the user may determine the degree of approximation with which the distributions are calculated by specifying KSIZE(NBLOCK) NBLOCK = 2, 3, 4, 5—and by specifying ILAN in data.

KSTØP contains the final value of K in the K loop of VAV6.

KSTØPSV stores the value of KSTØP before entry is made to the K loop in VAV6 for the first time for the current I value.

KSTRT contains the starting value of K in the K loop of VAV6 where the values of the Vavilov distribution are calculated.

KSTRTSV stores the value of KSTRT before entry is made to the K loop of VAV6 for the first time—for the current I value; these numbers are used as a basis for calculating KSTRT for the next I value.

KX(I) is the average energy loss $\bar{\Delta}$ (in keV) of an incident particle that has penetrated to the Ith plane of the target.

KX2 is the ratio SEL/ξ, where SEL is the experimental specific energy loss in units of keV-cm^2/gram and $\xi = z^2(mc^2/\beta^2)$ (Z/A)s; z is the number of electron charges on the incident particle; mc^2 is the electron rest mass in keV; Z/A is the number of electrons per target molecule; β is the ratio of the velocity of the incident particle to that of light; and s is the penetration depth in grams/cm^2 and is set equal to one when KX2 is calculated.

LCØMP (read from data). See LCØUNT.

LCØUNT (read from data) is a positive integer of the order of 500. If convergence criterion one in VAV6 is not satisfied after LCØUNT/2 partial sums, a test is made to see if the absolute value of the Mth partial sum is less than SLØ $\approx$ 0.3. If this test is satisfied LCØMP $\approx$ 10 successive times, convergence criterion two is said to be satisfied.

INØRM (read from data) contains an integer such that if I $\leq$ INØRM, the distributions will be renormalized so as to envelop unit areas.

IPRINT(10) (read from data) is an array whose contents control the printing of certain quantities from VAV6 (see listing of WINTGRL7). If I = IPRINT(M), this printout can occur. The first location of this array, in conjunction with the first two locations of array KPRINT(10), controls the printing of certain quantities in the integrand of the Vavilov formula for the stored values of I and K. The second location of IPRINT(10) and the third and fourth locations of KPRINT(10) are similarly associated.

IQUIT (read from data) is an integer that will cause the calculation of distribution functions to be stopped at I = IQUIT and a plot made by SUBRØUTINE GRAPH5. This feature shortens the computation time if only distribution functions are desired.

ISTØP is the value of I labeling the second distribution of a pair calculated in VAV6 prior to partial integration (in Subroutine W6) over the target-depth variable.

ISTRT is the value of I labeling the first distribution of a pair calculated in VAV6 prior to partial integration (in subroutine W6) over the target-depth variable.

J5 is an integer variable that labels the set of energy losses when they are spaced at interval DE. J = 1 corresponds to the greatest energy loss of the set.

J5CUTHI(I) contains the value of J5 corresponding to the value of K contained in KCUT(I). Low values of J5 correspond to large loss values.

J5CUTLO(I) stores the value of J5 at which the computation of the Ith distribution function is cut off at the low-loss end. This corresponds to cut-off specified by PCUT. This array is printed as a diagnostic aid.

J3STØP = HILØSS/DE is the maximum value of the integer variable J5 that labels the energy loss values separated by DE. J5 = J3STØP is the value of J5 associated with zero energy loss, i.e., the energy loss associated with the face of the target.

J6SV stores the value of J6 corresponding to the value of K stored in KSTRTSV.

K is an integer variable that labels members of the set P(K) = λ and PV(K) = λ_v.

KCUT(I) contains the value of K at which the computation of the energy loss distribution will be cut off in the high-loss region. Low values of K correspond to high values of loss.

KMAX = J3STØP + (IMAX - 1)*NDKX is the maximum value of the integer variable K that labels values of the distribution function and the Landau λ, P(K). If KMAX exceeds 1700, arrays P(K) and PV(K) would overflow; the calculation is stopped and an abort message is printed.

LCØUNT2 (read from data) is a positive integer on the order of 10^3 and less than 2×10^3. If convergence is not achieved in VAV6 after the computation of (LCØUNT + LCØUNT2)/2 partial sums, the value of the integral is computed from the average value of the next 100 partial sums.

MI is the increment in I between distribution functions of the pair calculated by VAV6 prior to partial integration (in subroutine W6) with respect to the target-depth variable.

MK contains the increment in K for the K loop of VAV6.

MAXT(K) is the value of the number of bins spanned in the integration to obtain the Kth value of the current Vavilov distribution function. These quantities are printed in a table under the control of IPRINT(M).

NBLØCK denotes the subscript for the array KSIZE(NBLØCK), where NBLØCK = 1, 2, 3, 4, 5.

NCALL is an integer denoting the number of times subroutine VAV6 has been executed. The last statement in VAV6 causes NCALL to be increased by unity. If NPRINT2 = 1, the statement "END OF PRINTOUT FROM CALL M OF SUBROUTINE VAV6" has the value of NCALL for M.

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NCØMP (read from data). See CØMP

NDKX (read from data) is a small integer (usually 2 or 3) that determines whether the distribution functions are calculated for every I value (NDKX = 1), every other I value (NDKX = 2), etc. Since DKX is always approximately equal to DE, a choice of NDKX allows the average energy loss between target planes at which distributions are calculated to be substantially greater than the loss interval on the distribution functions.

NEIGHTS (read from data) is the number of pairs of distribution functions (in the region of large $\bar{\Delta}$) for which the bin width for integration with respect to the target-depth variable ($\bar{\Delta}$) is 8.0*DKX.

NFØURS (read from data) is the number of pairs of distribution functions (in region of moderate $\bar{\Delta}$) for which the bin width for integration with respect to the target-depth variable ($\bar{\Delta}$) is 4.0*DKX.

NLANDAU (read from data). If NLANDAU = 1, the first ILAN distribution functions will be derived from the table of Landau distribution values that is stored in data. If NLANDAU $\neq$ 1, all distribution functions will be calculated by means of the Vavilov formula.

NMAX (read from data) is the maximum number of partial sums that can be stored in the numerical evaluation of the Vavilov integral in VAV6.

NØNES is the number of pairs of distribution functions (in the region of small $\bar{\Delta}$) for which the bin width for integration with respect to $\bar{\Delta}$ is DKX. NØNES = (IMAX - 1 - 4*NTWØS - 8*NFØURS - 16*NEIGHTS)/2.

NØPLØT (read from data). If NØPLØT = 1 ($\neq$1), GRAPH5 will (will not) be called by the main program.

NØPRINT1 is an integer controlling the printing of the Landau table stored in data. If NØPRINT1 = 1 ($\neq$1), the table will (will not) be printed.

NØPRINT2 (read from data) controls the printing of the following quantities from VAV6: ISTRT, ISTØP, NCALL, KSTRT, KSTØP, MK, and LCØUNT. If NØPRINT2 = 1 ($\neq$1), these quantities will (will not) be printed every time there is a change in KSTRT and KSTØP.

NP(10) (read from data) may contain NPMAX I values which designate the energy loss distribution functions that the user wishes to be plotted by subroutine GRAPH5. Those distribution functions will be plotted and printed only if they are calculated by VAV6. Recall that the distribution functions labeled by some values of I are not calculated, i.e., in the region of the target where the integration with respect to target-depth variable has a bin width greater than DKX*NDKX. The actual number of distribution functions plotted and printed is given by an integer stored in ICØUNT.

NPMAX (read from data) is an integer equal to or less than 10 that indicates the number of distribution functions that are designated for plotting by subroutine GRAPH5 and printing by VAV6.

NPQC (I) is approximately the number of bins per quarter cycle of the integrand of the Vavilov formula for the Ith distribution function. If DYMAX is chosen too large, the numerical evaluation of the Vavilov formula will give misleading results. The array NPQC(I), I = 1, IMAX is printed as an aid to insure meaningful integration.

NTWØS (read from data) is the number of pairs of distribution functions for which the bin width for integration with respect to the target-depth variable ($\bar{\Delta}$) is 2.0*DKX.

PCUT (read from data) is the value of λ at which the calculation of the Vavilov distribution is cut off at the low-loss end.

P(K) is the set of Landau parameters λ.

PV(K) is the set of Vavilov parameters λ_v.

RM (read from data) is the rest mass of the incident particle in keV.

SEL (read from data) is the specific average energy loss of the target in keV-cm^2/gram.

SFX (read from data) is a scale factor that governs the abscissas of the plotted distribution functions whose ordinal numbers are greater than ICTLØW. SFX is typically of the order of 1.0.

SFXLØW (read from data) is a scale factor that governs the abscissas of the plotted distribution functions whose ordinal numbers 1, 2, 3—are ICTLØW or less. SFXLOW is typically of the order of 5.0.

SFY (read from data) is a scale factor governing the heights of the distribution functions plotted by GRAPH5 which have ordinal numbers greater than ICTLOW. Typically, SFY is of the order of unity.

SFYLØW (read from data) is a scale factor (typically on the order of 0.02) that governs the height of the first ICTLOW distribution functions plotted by GRAPH5.

SLØ (read from data). See LCØUNT.

SUM(K) is the Kth value of the current Vavilov distribution function as calculated in VAV6 and printed out under control of IPRINT(M), where M = 1, 2, 3, 4, 5 in a table. These values are normalized to unit area when the distribution functions are expressed as a function of λ = P(K).

TT (read from data) is the target thickness in keV.

W(1700) is an array in which the integrals W(J5) of the distribution functions over the target-depth variable are stored.

WLC1(3,1700) is an array into which are stored (temporarily) the values of three distribution functions for the purpose of integrating with respect to $\bar{\Delta}$ over two adjacent bins—by means of Simpson's rule.

Z (read from data) is the number of equivalent-free electrons per target molecule.

ZIP (read from data) is the number of electron charges on the incident particle.

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Appendix B
LISTING OF PROGRAM WINTGRL7 AND SAMPLE RUN

```
      PROGRAM WINTGRL7
      TYPE REAL KX,KX2
      COMMON/1/Z,A,DE,DEI,RM,SEL,ERA,TT,HILOSS,NDKX,NLANDAU,ILAN
      COMMON/2/NMAX ,NCOMP,LCOMP,LCOUNT,LCOUNT2,DYMAX,COMP,SLO,PCUT
      COMMON/3/CUTC,CUTFAC,NONES,NTWOS,NFOURS,NEIGHTS,NPMAX,ICOUNT,I,I6
      COMMON/4/ISTRT,ISTOP,MI,MK,KSTRT,KSTOP,NCALL,IQUIT,NBLOCK
      COMMON/5/KSIZE(5),NP(10),IPRINT(10),KPRINT(10)
      COMMON/6/NOPRINT1,NOPRINT2
      COMMON/7/SFX,SFY,SFXLOW,SFYLOW,ICTLOW,INORM,J5CUTLO(400)
      COMMON/8/KX(400),DY(400),D(400),KCUT(400),NPOC(400),J5CUTHI(400)
      COMMON/9/EIE(1700),PV(1900),DIF(1700),P(1900)
      COMMON/10/A3,A4,A5,A6,A7,GEMAX,KX2,IMAX,J3STOP,KMAX,DKX,BSQ
      COMMON/11/WLC1(3,1700),W(1700),AREA(10),WA(1700),GL(500),GPH(500)
    6 FORMAT(1H1)
    8 FORMAT(72H
     2                    )
   10 FORMAT(72H
     2                    )
C
C     FIRST TWO DATA CARDS MAY CONTAIN COMMENTS,
C
   12 FORMAT(8F10.4)
   13 FORMAT(8F10.7)
   14 FORMAT(4F15.5)
   15 FORMAT(10I10)
   16 FORMAT(8I10)
   17 FORMAT(10I5)
   18 FORMAT(I5,10I5)
   19 FORMAT(10F8.5)
   21 FORMAT(//* QUANTITIES READ FROM DATA CARDS.*)
   30 FORMAT(/* Z=*,F5.1,13X,*ZIP=*,F4.1,12X,*A=*,F7.2,11X,*RM=*,F10.2,
     27X,*NLANDAU=*,I3,9X,*ILAN=*,I3)
   32 FORMAT( * SEL=*,F10.1,6X*ERA=*,F8.2,8X,*DE=*,F6.3,11X,*DEI=*,F9.6,
     2 7X,*TT=*,F7.3,10X,*NDKX=*,I2)
   34 FORMAT( * NMAX=*,I5,10X,*NCOMP=*,I3,11X,*LCOMP=*,I4,10X,*LCOUNT2=*
     2I5,7X,*DYMAX=*,F6.3,8X,*HILOSS=*,F6.2)
   36 FORMAT( * COMP=*,F8.5,7X,*SLO=*,F5.2,11X,*PCUT=*,F5.2, 9X,* CUTC=*
     2,F6.2,9X,*CUTFAC=*,F5.1)
   38 FORMAT( * NONES=*,I3,11X,*NTWOS=*,I3,11X,*NFOURS=*,I3,10X,*NEIGHTS
     2=*,I3,9X,*IQUIT=*,I4,10X,*INORM=*,I3)
   40 FORMAT( * SFX=*,F5.2,11X,*SFY=*,F5.2,11X,*SFXLOW=*F5.2,8X,*SFYLOW=
     2*,F5.2,8X,*ICTLOW=*,I3,10X,*NOPLOT=*,I3)
```

```
 42 FORMAT( * NOPRINT1=*I3,8X*NOPRINT2=*,I3,8X,*LCOUNT=*,I4)
 44 FORMAT(/* KSIZE(M), M=1,5*)
 46 FORMAT(/* NPMAX          NP(M),  M=1,NPMAX*)
 48 FORMAT(I5,10X,10I5)
 50 FORMAT(/* IPRINT(I), I=1,10*)
 52 FORMAT(/* KPRINT(K), K=1,10*)
 60 FORMAT(//* QUANTITIES COMPUTED IN MAIN PROGRAM,*)
 62 FORMAT(/ * A3=*,E12.5,5X,*A4=*,E12.5,5X,*A5=*,E12.5,5X,*A6=*,E12.5
   2,5X,*A7=*,E12.5,4X,*NONES=*,I4)
 64 FORMAT ( * GEMAX=*,E12.5,2X,*KX2=*,E12.5,4X,*IMAX=*,I4,11X,*J3STOP
   2=*,I4,9X,*KMAX=*,I4,11X,*DKX=*,F10.5)
 70 FORMAT(/ * KX(I), I=1,*I4)
 72 FORMAT(/(1X,10E12.5))
 74 FORMAT(/ * DY(I), I=1,*,I4)
 76 FORMAT(/ * D(I), I=1,*,I4)
 78 FORMAT(/ * KCUT(I),I=1,*,I4)
 80 FORMAT(/ * NPQC(I), I=1,*,I4)
 81 FORMAT(/* J5CUTLO(I), I=1,*,I4)
 82 FORMAT(/ * J5CUTHI(I), I=1,*,I4)
 84 FORMAT(/ * EIE(J5), J5=1,*I4)
 86 FORMAT(/ * PV(K), K=1,*,I4)
 88 FORMAT(//* QUANTITIES PRINTED FROM SUBROUTINES LAN1 AND VAV6,*)
 90 FORMAT(//* FINAL PRINTOUT FROM MAIN PROGRAM,*)
 91 FORMAT(/ I3, *DIST FCTNS REQUESTED,*,2X,I3,* DIST FCTNS SAVED,*,/)
 92 FORMAT(  I5,* INTEGRALS W(J5) OVER VARIABLE KX FOLLOW,*)
 93 FORMAT(/* AREAS OF PLOTTED DISTRIBUTION FUNCTIONS     1,ICOUNT*)
 94 FORMAT(4F10.3,F10.1,F10.5,F10.4)
 95 FORMAT(3I5,4F12.6,F12.2)
 96 FORMAT( *NEXT TWO CARDS CONTAIN CONSTANTS FROM WINTGRL7,*)
 97 FORMAT(* J3STOP EXCEEDS 1700 OR KMAX EXCEEDS 1900,  ABORT*)
 98 FORMAT(* IMAX EXCEEDS 400,  ABORT,*)
 99 FORMAT(* KSIZE(1) OR NONES IS ZERO OR NEGATIVE,  ABORT,*)
100 READ 8  $ READ 10
102 READ 12,Z,A,DE,DEI,ZIP,TT,HILOSS,CUTC
104 READ 12,RM,SEL,ERA
106 READ 16,NMAX ,NCOMP,LCOMP,LCOUNT,LCOUNT2,NDKX,NLANDAU,ILAN
108 READ 12,DYMAX,COMP,SLO,PCUT,CUTFAC
110 READ 16,NTWOS,NFOURS,NEIGHTS,KSIZE(2),KSIZE(3),KSIZE(4),KSIZE(5)
112 READ 18,NPMAX,(NP(L),L=1,NPMAX)
116 READ 16,NOPRINT1,NOPRINT2,NOPLOT,ICTLOW,INORM,IQUIT
118 READ 17,(IPRINT(I),I=1,10) $ READ 17, (KPRINT(K),K=1,10)
120 READ 12,SFX,SFY,SFXLOW,SFYLOW
C
C     COMPUTE CONSTANTS,
C
150 BSQ=2*ERA/RM $  A3=1.0/SQRTF(1-BSQ)  $  ERM=510.976
152 A4=2.0*ERM*BSQ*A3**2 $ EMOPM=ERM/RM
154 A5=1.0/(1.0+2*EMOPM*A3+EMOPM**2) $ GEMAX=A4*A5
156 A7=0.30058*ZIP**2*ERM/BSQ $ KX2=SEL/(A7*Z/A)
158 B=1.0+BSQ-0.577216 $ A6=1.0+B/KX2 $ DKX=DE*NDKX/A6
160 IMAX=TT/DKX+1 $ RIMAX=TT/DKX+1.0 $ DIFF=RIMAX-IMAX
161 IF(DIFF.LT.0.5 ) GO TO 162 $ IMAX=IMAX+1
162 IF(IMAX.GT.400) 163,164
```

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  163 WRITE(61,98) $ STOP
  164 TT=DKX*(IMAX-1)
  165 J3STOP=HILOSS/DE $ KMAX=J3STOP*(IMAX-1)*NDKX
  166 IF(J3STOP.GT.1700.OR.KMAX.GT.1900) 167,169
  167 WRITE(61,97) $STOP
  169 NONES=(IMAX-1-4*NTWOS-8*NFOURS-16*NEIGHTS)/2
  170 KSIZE(1)=J3STOP-1-2*KSIZE(2)-4*KSIZE(3)-8*KSIZE(4)-16*KSIZE(5)
  171 IF(KSIZE(1).LT.1.OR.NONES.LT.1) 172,190
  172 WRITE(61,99) $ STOP
C
C     COMPUTE CERTAIN ARRAYS.
C
  190 DEN=KX2*GEMAX
  193 DO195 I=1,IMAX
  194 KX(I)=(I-1)*DKX $ D(I)=KX(I)/DEN
  195 CONTINUE
  210 DO 218 J5= 1,J3STOP
  214 EIE(J5)=(J3STOP-J5)*DE
  218 CONTINUE
  220 GKMIN=DKX/DEN $ DYFAC=DYMAX*GKMIN
  222 DO 228 I=2,IMAX
  224 RI=I $ DY(I)=DYFAC*SQRTF(RI-1.0)/D(I)
  226 J5CUTHI(I)=J3STOP-CUTC/DE-CUTFAC*J3STOP*I/IMAX
      IF(J5CUTHI(I).LT.1)J5CUTHI(I)=1
  227 KCUT(I)=J5CUTHI(I)+(I-1)*NDKX
  228 CONTINUE
  230 DO 238 K=1,KMAX
  232 PV(K)=(J3STOP-K)*DE/GEMAX
  238 CONTINUE
  250 DO 258 I=2,IMAX
  252 K=KCUT(I) $ NPQC(I)=1.57/(PV(K)*DY(I))
  258 CONTINUE
C
C     PRINT QUANTITIES READ FROM DATA CARDS.
C
  400 WRITE (61,8) $  WRITE (61,10) $ WRITE(61,21)
  402 WRITE (61,30) Z,ZIP,A,RM,NLANDAU,ILAN
  404 WRITE (61,32) SEL,ERA,DE,DEI,TT,NDKX
  406 WRITE (61,34) NMAX,NCOMP,LCOMP,LCOUNT2,DYMAX,HILOSS
  408 WRITE (61,36) COMP,SLO,PCUT, CUTC,CUTFAC
  410 WRITE(61,38) NONES,NTWOS,NFOURS,NEIGHTS,IQUIT,INORM
  412 WRITE (61,40) SFX,SFY,SFXLOW,SFYLOW,ICTLOW,NOPLOT
  414 WRITE (61,42) NOPRINT1,NOPRINT2,LCOUNT
  416 WRITE (61,44)
  418 WRITE (61,16) (KSIZE(M), M=1,5)
  420 WRITE (61,46) $ WRITE (61,48) NPMAX,(NP(M), M=1,NPMAX)
  422 WRITE (61,50) $ WRITE (61,17) (IPRINT(I), I=1,10)
  424 WRITE (61,52) $ WRITE (61,17) (KPRINT(K), K=1,10)
C
C     PRINT QUANTITIES COMPUTED IN MAIN PROGRAM.
C
  430 WRITE (61,60)
  432 WRITE (61,62) A3,A4,A5,A6,A7,NONES
```

```
  434 WRITE (61,64) GEMAX,KX2,IMAX,J3STOP,KMAX,DKX
  436 WRITE (61,70) IMAX $ WRITE (61,72) (KX(I),I=1,IMAX)
  438 WRITE (61,74) IMAX $ WRITE (61,72) (DY(I),I=1,IMAX)
  440 WRITE (61,76) IMAX $ WRITE (61,72) (D(I), I=1,IMAX)
  442 WRITE (61,78) IMAX $ WRITE (61,15) (KCUT(I), I=1,IMAX)
  444 WRITE (61,80) IMAX $ WRITE (61,15) (NPOC(I), I=1,IMAX)
  446 WRITE (61,82) IMAX $ WRITE (61,15) (J5CUTHI(I), I=1,IMAX)
  448 WRITE (61,84) J3STOP $ WRITE (61,72) (EIE(J5), J5=1,J3STOP)
  450 WRITE (61,86) KMAX   $ WRITE (61,72) (PV(K), K=1,KMAX)
  460 WRITE (61,88)
C
C     CALL W6 TO INTEGRATE THE ENERGY LOSS DISTRIBUTION FUNCTIONS
C     OVER THE TARGET DEPTH VARIABLE.
C
  500 CALL W6
C
C     FINAL PRINTOUT AND PUNCHOUT FROM MAIN PROGRAM.
C
  600 WRITE (61,90)
  601 WRITE(61,81)IMAX $ WRITE(61,15) (J5CUTLO(I), I=1, IMAX)
  602 WRITE (61,91) NPMAX,ICOUNT
  604 WRITE (61,92) J3STOP
  606 WRITE (61,72) (W(J5), J5=1,J3STOP)
  608 WRITE (61,93)
  610 WRITE (61,72) (AREA(IC),  IC=1,ICOUNT)
C
C     PUNCH NUMBERS FOR PROGRAM YIELD6.
C
  700 WRITE (62,96)
  702 WRITE (62,94) Z,ZIP,A,TT,SEL,DYFAC,HILOSS
  704 WRITE (62,95) IMAX,J3STOP,KMAX,DE,DEI,BSQ,GEMAX,A7
  706 WRITE(62,92) J3STOP
  708 WRITE (62,19) (W(J5), J5=1,J3STOP)
  710 CALL GRAPH5B
  800 END


      SUBROUTINE W6
      COMMON/1/Z,A,DE,DEI,RM,SEL,ERA,TT,HILOSS,NDKX,NLANDAU,ILAN
      COMMON/3/CUTC,CUTFAC,NONES,NTWOS,NFOURS,NEIGHTS,NPMAX,ICOUNT,I,I6
      COMMON/4/ISTRT,ISTOP,MI,MK,KSTRT,KSTOP,NCALL,IQUIT,NBLOCK
      COMMON/5/KSIZE(5),NP(10),IPRINT(10),KPRINT(10)
      COMMON/8/KX(400),DY(400),D(400),KCUT(400),NPOC(400),J5CUTHI(400)
      COMMON/9/EIE(1700),PV(1900),DIF(1700),P(1900)
      COMMON/10/A3,A4,A5,A6,A7,GEMAX,KX2,IMAX,J3STOP,KMAX,DKX,BSQ
      COMMON/11/WLC1(3,1700),W(1700),AREA(10),WA(1700),GL(500),GPH(500)
    5 ISTRT=2$ ISTOP=3 $ MI=1 $ NCALL=0 $ ASSIGN 40 TO NS
    6 KSTRT=1 $ KSTOP=1+16*KSIZE(5) $ MK=16 $ NBLOCK=5
    7 MKSV=MK $ NBLOCKSV=NBLOCK $ IF(KSIZE(NBLOCK).EQ.0) 8,20
    8 NBLOCK=NBLOCK-1 $ MK=MK/2
    9 KSTOP=1+MK*KSIZE(NBLOCK) $ GO TO 7
```

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```
   20 MK=MKSV $ NBLOCK=NBLOCKSV $ CALL VAV6
   22 J6S=J5CUTHI(I)
C
C     PIECEWISE INTEGRATION OF WLC1(I6,J6)
C
   24 DO 28 J6=J6S,J3STOP
   26 WA(J6)=WA(J6)+WLC1(1,J6)+4.0*WLC1(2,J6)+WLC1(3,J6)
   28 WLC1(1,J6)=WLC1(3,J6)
   30 GO TO NS,(40,50,60,70,140)
   40 IF(NCALL=NONES) 80,42,50
   42 ASSIGN 50 TO NS $ NOT=NONES+NTWOS $ WID=0.3333*DKX $ GO TO 100
   50 IF(NCALL=NOT)80,52,60
   52 IF(NTWOS.EQ.0) 140,53
   53 ASSIGN 60 TO NS $ NOTF=NOT+NFOURS $ WID=0.66666*DKX $ GO TO 100
   60 IF(NCALL=NOTF)80,62,70
   62 IF(NFOURS.EQ.0) 140,63
   63 ASSIGN 70 TO NS $ NOTFE=NOTF +NEIGHTS $ WID=1.3333*DKX $ GO TO 100
   70 IF(NCALL=NOTFE)80,72,140
   72 IF(NEIGHTS.EQ.0) 140,73
   73 ASSIGN 140 TO NS $ WID=2.6666*DKX $ GO TO 100
   80 ISTRT=ISTOP+MI $ ISTOP=ISTRT+MI
   82 IF(ISTRT.GT.IQUIT)100,20
  100 DO 104 J6=J6S,J3STOP
  102 W(J6)=W(J6)+WA(J6)*WID
  104 WA(J6)=0.0
  110 MI=2*MI
  125 IF(ISTRT.GT.IQUIT) 200,130
  130 GO TO NS,(40,50,60,70,140)
C
C     IF IMAX IS EVEN, DO TRAPEZOIDAL INTEGRATION OVER THE LAST BIN,
C
  140 IODD=IMAX-(IMAX/2)*2
  142 IF(IODD.EQ.1)GO TO 200
  144 ISTRT=ISTOP+1 $ ISTOP =ISTRT $ MI=1
  146 MK=MKSV $ NBLOCK=NBLOCKSV $ CALL VAV6
  148 DO 150 J6=1,J3STOP
  150 W(J6)=W(J6)+(WLC1(1,J6)+WLC1(2,J6))*0.5 *DKX
  200 END


      SUBROUTINE VAV6
      TYPE REAL KX,KX2
      COMMON/1/Z,A,DE,DEI,RM,SEL,ERA,TT,HILOSS,NDKX,NLANDAU,ILAN
      COMMON/2/NMAX ,NCOMP,LCOMP,LCOUNT,LCOUNT2,DYMAX,COMP,SLO,PCUT
      COMMON/3/CUTC,CUTFAC,NONES,NTWOS,NFOURS,NEIGHTS,NPMAX,ICOUNT,I,I6
      COMMON/4/ISTRT,ISTOP,MI,MK,KSTRT,KSTOP,NCALL,IQUIT,NBLOCK
      COMMON/5/KSIZE(5),NP(10),IPRINT(10),KPRINT(10)
      COMMON/6/NOPRINT1,NOPRINT2
      COMMON/7/SFX,SFY,SFXLOW,SFYLOW,ICTLOW,INORM,J5CUTLO(400)
      COMMON/8/KX(400),DY(400),D(400),KCUT(400),NPOC(400),J5CUTHI(400)
      COMMON/9/EIE(1700),PV(1900),DIF(1700),P(1900)
      COMMON/10/A3,A4,A5,A6,A7,GEMAX,KX2,IMAX,J3STOP,KMAX,DKX,BSQ
```

```
      COMMON/11/WLC1(3,1700),W(1700),AREA(10),WA(1700),GL(500),GPH(500)
      DIMENSION F1F(2500),F2F(2500),FAC1(2500),
     1FAC2(2500),FAC3(2500),G(2500),MAXT(1900),
     2S(1300),SI(2500),SUM(1900),Y(2500),KACCS(1900)
C
   10 FORMAT (1H0)
   11 FORMAT(/* ISTRT=*I4,5X,*ISTOP=*,I4,5X,*MI=*,I3,9X,*NCALL=*,I4)
   12 FORMAT( * KSTRT=*I4,5X,*KSTOP=*I4,5X,*MK=*I3,9X,*ICOUNT=*I3)
   30 Y(1)=0.0 $ S(1)=0.0 $ KEN=1 $ MKSV=MK $ NBLOCKSV=NBLOCK $ I6=2
C
   40 DO 450 I=ISTRT,ISTOP,MI
   41 KSTOP=KSTOP*MI*NDKX $ KSTRT=KSTRT+MI*NDKX $ KEY=0.0
      DO 42 J6=1,J3STOP
   42 WLC1(I6,J6)=0.0
      IF(NLANDAU.NE.1)GO TO 45 $ IF(I.GT.ILAN) GO TO 45
      IF(I.EQ.2) 43,44
   43 CALL LAN1 $ GO TO 605
   44 CALL LAN11 $ GO TO 605
   45 KSTRTSV=KSTRT $ KSTOPSV=KSTOP $ J6STRT=KSTRTSV-(I-1)*NDKX
   46 MK=MKSV $ NBLOCK=NBLOCKSV
  100 FORMAT(1X,10E12.5)
  110 LMAX=NMAX     $ MAXY=0 $ MAXB=0
C
  115 DL=LOGF(D(I)) $ KPSTOP=KSTRT+J3STOP
  117 DO 118 K=KSTRT,KPSTOP
  118 P(K) = PV(K)/D(I) - DL
  148 G(1)=EXPF(-D(I)*(1.0+0.5772157*BSQ    ))
      C=D(I)*DY(I)/(3.0*3.141593*G(1))
C
C     IF NOPRINT2=1, NCALL ETC.WILL BE PRINTED BY VAV6.
C
  149 IF(NOPRINT2.EQ.0) GO TO 150
      PRINT 11,ISTRT,ISTOP,MI,NCALL  $ PRINT 12,KSTRT,KSTOP,MK,ICOUNT
C
  150 DO 320 K=KSTRT,KSTOP,MK
  152 IF(K.LT.KCUT(I)) GO TO 320
  156 IF(P(K).GT.PCUT) GO TO 180
  158 IF(KEY.EQ.1) GO TO 320
  160 J5CUTLO(I)=K-(I-1)*NDKX $ KEY=1 $ GO TO 320
  180 NCOUNT=0 $ MCOUNT=0 $ ACCS=0.0 $ NACCS=0 $ LFLAG=0
      DO 255 L=2,LMAX
  182 IF(MAXY-L) 190,200,200
  190 Y(L)=Y(L-1)+DY(I)
  195 CALL TRIGEX (Y(L),SI(L),CI)
      FAC1(L)=LOGF(Y(L))-CI
      FAC2(L)=COSF(Y(L))+Y(L)*SI(L)
      FAC3(L)=Y(L)*FAC1(L)+SINF(Y(L))
  200 IF(MAXB-L) 210,220,220
  210 F1F(L)=EXPF(D(I)*(BSQ    *FAC1(L)-FAC2(L)))
      F2F(L)=D(I)*(FAC3(L)+BSQ    *SI(L))
  220 G(L)=F1F(L)*COSF(Y(L)*PV(K) + F2F(L))
  225 IF (FLOATF(L)-2.0*FLOATF(L/2)) 255,255,230
  230 M=(L+1)/2
```

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  231 S(M)=S(M-1)+G(L-2)+4.0*G(L-1)+G(L)
  232 IF(L.LT.LCOUNT)GO TO 239 $ IF(L.GT.LCOUNT2)GO TO 235
      IF(LFLAG.EQ.1) GO TO 235
  233 IF(ABSF(S(M)).LT.SLO) GO TO 234 $ MCOUNT=0 $ ACCS=0.0 $ NACCS=0
      GO TO 239
  234 MCOUNT=MCOUNT+1 $ IF(MCOUNT.LT.LCOMP) GO TO 239 $ LFLAG=1
  235 ACCS=ACCS+S(M) $ NACCS=NACCS+1
  236 IF(NACCS.LT.100) GO TO 239
  237 S(M)=ACCS/NACCS $ KACCS(K)=NACCS $ GO TO 260
  239 IF (ABSF((S(M)-S(M-1))/S(M))-COMP) 240,250,250
  240 NCOUNT=NCOUNT+1
  241 IF (NCOUNT-NCOMP) 255,260,260
  250 NCOUNT=0
  255 CONTINUE
  260 MAXT(K)=L
      MAXTY=MAXT(K)
      MMAX=M
      IF (MAXTY-MAXY) 275,275,270
  270 MAXY=MAXTY
  275 IF (MAXTY-MAXB) 285,285,280
  280 MAXB=MAXTY
  285 SUM(K)=C*S(MMAX)
  286 J6=K-(I-1)*NDKX
  288 WLC1(I6,J6) = (KX2/KX(I))*SUM(K)
C
C     IPRINT(J), J=1,2 AND KPRINT(K) K=1,4 GOVERN PRINTING OF G(L)
C     AND S(M), THE SEQUENCE OF VAVILOV INTEGRALS FOR A GIVEN K=VALUE,
C
  289 IF(I.EQ.IPRINT(1)) GO TO 290 $ IF(I=IPRINT(2)) 320,291,320
  290 IF(K.LT.KPRINT(1)) GO TO 320 $ IF(K=KPRINT(2)) 295,295,320
  291 IF(K.LT.KPRINT(3)) GO TO 320 $ IF(K=KPRINT(4)) 295,295,320
C
  295 PRINT 300,MAXTY,I,K
  300 FORMAT(/* G(L),  L=1,*I4,10X,*I=*,I4,10X,*K=*,I4)
      PRINT 100,(G(L),L=1,MAXTY)
  305 PRINT 310,MMAX,I,K
  310 FORMAT(/* S(M)=,  M=1,*,I4,10X,*I=*,I4,10X,*K=*I4)
      PRINT 100,(S(M),M=1,MMAX)
      PRINT 10
  320 CONTINUE
C
C     IPRINT(J), J=3,4 AND KPRINT(K), K=5,8 GOVERN PRINTING OF C, Y(L),
C     F1F(L), F2F(L), AND F3F(L),
C
  322 IF(I.EQ.IPRINT(3)) GO TO 323 $ IF(I.EQ.IPRINT(4)) 324,499
  323 IF(K.LT.KPRINT(5)) GO TO 499 $ IF(K.GT.KPRINT(6)) 499,338
  324 IF(K.LT.KPRINT(7)) GO TO 499 $ IF(K.GT.KPRINT(8)) 499,338
  338 PRINT 340,C
  340 FORMAT (3H C=1PE11.4)
      PRINT 10
      PRINT 350,MAXB
  350 FORMAT (10H Y(L),L=1,I4)
      PRINT 100,(Y(L),L=1,MAXB)
```

```
      PRINT 10
      PRINT 360,MAXB
  360 FORMAT (12H F1F(L),L=1,I4)
      PRINT 100,(F1F(L),L=1,MAXB)
      PRINT 10
      PRINT 370,MAXB
  370 FORMAT (12H F2F(L),L=1,I4)
      PRINT 100,(F2F(L),L=1,MAXB)
      PRINT 10
C
C  THE 500 SERIES OF STATEMENTS DIVIDES ARRAY WLC1 INTO 5 BLOCKS WITH
C  DIFFERENT K-INTERVALS SO THAT SOME VALUES IN THE REGIONS OF HIGH ENERGY
C  LOSS ARE NOT CALCULATED BUT ARE SUPPLIED BY INTERPOLATION. KSIZE(5)
C  IS THE NBR OF STEPS OF 16 IN THE 5TH BLOCK WHICH IS IN THE HIGHEST LOSS
C  REGION (LOW J5). NBLOCK IS THE BLOCK INDEX. BLOCK 4 HAS KSIZE(4) STEPS OF
C  8 K-VALUES EACH, ETC.
C
  499 IF(NBLOCK.GT.1) 501,601
  501 IF(KEN.EQ.1) 502,503
  502 J6STRT=KSTRT-(I-1)*NDKX $ J6STOP=KSTOP-(I-1)*NDKX-MK $ KEN=0
  503 J6STRT=KSTRT-(I-1)*NDKX-MK      $ J6STOP=KSTOP-(I-1)*NDKX-MK
  505 DO 550 J6= J6STRT,J6STOP,MK
  515 J7=J6+1
  520 DIF(J6) = (WLC1(I6,J6+MK)      - WLC1(I6,J6))/MK
  522 KA=1
  523 KAEND=MK-1
  525 WLC1(I6,J7)=WLC1(I6,J6)  + KA* DIF(J6)
  530 KA=KA+1
  532 J7=J7+1
  535 IF(KA-KAEND)525,525,550
  550 CONTINUE
C
  560 NBLOCK=NBLOCK-1
  565 IF(NBLOCK.EQ.0) GO TO 601
  570 MK=MK/2
  575 IF(MK.EQ.0)GO TO 601
  580 KSTRT=KSTOP+MK $ KSTOP=KSTOP+MK*KSIZE(NBLOCK)
  585 GO TO 149
C
  600 FORMAT (I5,5I10)
  601 KSTOPSVP=KSTOP
  602 KSTRT=KSTRTSV $ KSTOP=KSTOPSV
  605 I6SAVE=I6
  610 FORMAT (10E12.5)
C
C
C
  612 IF(I-INORM) 614,614,650
  614 CALL NORMA
```

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```
650 IF(ICOUNT-NPMAX)651,385,385
651 IF(I.EQ.NP(1 ))GO TO 690
652 IF(I.EQ.NP(2 ))GO TO 690
653 IF(I.EQ.NP(3 ))GO TO 690
654 IF(I.EQ.NP(4 )) GO TO 690
655 IF(I.EQ.NP(5 ))GO TO 690
656 IF(I.EQ.NP(6 ))GO TO 690
657 IF(I.EQ.NP(7 ))GO TO 690
658 IF(I.EQ.NP(8 ))GO TO 690
659 IF(I.EQ.NP(9 ))GO TO 690
660 IF(I.EQ.NP(10))GO TO 690
661 GO TO 385
675 FORMAT(2I4,(10F12.8))
687 GO TO 651
690 ICOUNT=ICOUNT+1
691 IF(ICOUNT.EQ.1)692,693
692 CALL GRAPH5      $ GO TO 694
693 CALL GRAPH5A      $ GO TO 694
694 PRINT 695
    PRINT 675, ICOUNT,I, (WLC1(I6SAVE,J6),J6=1,J3STOP) $ PRINT 10
695  FORMAT(/* ICOUNT,I,  WLC1(I6SAVE,J6),J6=1,J3STOP*)
696 IF(NLANDAU.NE.1)GO TO 385 $ IF(I=ILAN) 430,430,385
C
385 IF(I.EQ.IPRINT(5)) GO TO 390 $ IF(I.EQ.IPRINT(6)) GO TO 390
386 IF(I.EQ.IPRINT(7)) GO TO 390 $ IF(I.EQ.IPRINT(8)) GO TO 390
387 IF(I.EQ.IPRINT(9)) GO TO 390 $ IF(I.EQ.IPRINT(10))GO TO 390
388 GO TO 425
390 PRINT 400,I
391 FORMAT(I10)
392 KC=KCUT(I)
400 FORMAT (/ *     LANDAU      VAVILOV    DIFFERENTIAL    TERMS FOR*,
   27X,*K*,10X,*KACCS*,13X,*I=*,I4)
    PRINT 410,I6
410 FORMAT (  *      LAMBDA       LAMBDA    DISTRIBUTION     RESULT*,
   248X,*I6=*,I4)
    PRINT 420,(P(K),PV(K),SUM(K),MAXT(K),K,KACCS(K), K=KC
   2,KSTOPSVP)
420 FORMAT(3E13.4,I11,2I12)
421 FORMAT(/* END OF PRINTOUT FROM CALL*,I4,* OF SUBROUTINE VAV6,*)
425 DO 427 K=KSTRTSV,KSTOPSVP
426 SUM(K)=0.0 $ MAXT(K)=0 $ KACCS(K)=0.0 $ P(K)=0.0
427 CONTINUE
430 I6=I6+1
450  CONTINUE
460 NCALL=NCALL+1 $ PRINT 421,NCALL
    END
```

```
      SUBROUTINE TRIGEX(X,SI,CI)
      X2=X*X
      IF (X2-100.0) 10,40,40
   10 SI=0.0
      CI=0.57721566+0.5*LOGF(X2)
      T=X
      A=1.0
   20 SI=SI+T
      A=A+1.0
      T=-T*(X*(A-1.0)/(A**2))
      IF(ABSF(T)-(1.0E-09))80,30,30
   30 CI=CI+T
      A=A+1.0
      T=T*(X*(A-1.0)/(A**2))
      IF(ABSF(T)-(1.0E-09))80,20,20
   40 AMAX=0.5*(X+1.0)
      P=1.0
      Q=0.0
      S=1.0/X
      A=1.0
   50 Q=Q+S
      A=A+1.0
      IF(A-AMAX)60,60,70
   60 S=-S*(A/X)
      P=P+S
      IF (ABSF(S)-(1.0E-12)) 70,62,62
   62 A=A+1.0
      IF(A-AMAX)65,65,70
   65 S=S*(A/X)
      GO TO 50
   70 CX=COSF(X)/X
      SX=SINF(X)/X
      SI=1.5707963-P*CX-Q*SX
      CI=P*SX-Q*CX
   80 RETURN
      END
```

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```
      SUBROUTINE GRAPH5
      COMMON/1/Z,A,DE,DEI,RM,SEL,ERA,TT,HILOSS,NDKX,NLANDAU,ILAN
      COMMON/3/CUTC,CUTFAC,NONES,NTWOS,NFOURS,NEIGHTS,NPMAX,ICOUNT,I,I6
      COMMON/5/KSIZE(5),NP(10),IPRINT(10),KPRINT(10)
      COMMON/7/SFX,SFY,SFXLOW,SFYLOW,ICTLOW,INORM,J5CUTLO(400)
      COMMON/8/KX(400),DY(400),D(400),KCUT(400),NPOC(400),J5CUTHI(400)
      COMMON/9/EIE(1700),PV(1900),DIF(1700),P(1900)
      COMMON/10/A3,A4,A5,A6,A7,GEMAX,KX2,IMAX,J3STOP,KMAX,DKX,BSQ
      COMMON/11/WLC1(3,1700),W(1700),AREA(10),WA(1700),GL(500),GPH(500)
      DIMENSION PLTARRAY(254)
      CALL PLOTS(PLTARRAY,254,1)
C
C     LETTER UNITS OF THE X AXIS,  DRAW X AXIS,
C
  110 XLABEL=0.0 $ JJ6=HILOSS+1
  120 DO 160 J6=1,JJ6
  130 X=(J6-1)*SFX*2.0
  140 CALL NUMBER(X-0.20 ,-0.2,0.105,XLABEL,0.0,4HF4.1)
  150 XLABEL= XLABEL+1.0
  160 CONTINUE
  165 CALL PLOT(X,0.0, 3) $ CALL PLOT(0.0,0.0,0.2)
C
C     NAME AXES,
C
  170 X=HILOSS*SFX $ Y=-0.42 $ H=0.105
  180 CALL SYMBOL(X,Y,H,22H EIE (KEV ENERGY LOSS),0.0,22)
  190 X=-0.4    $ Y=4.5*SFY$ H=0.105
  195 CALL SYMBOL(X,Y,H,19HPROBABILITY PER KEV,90.0,19)
C
C     LETTER UNITS OF THE Y AXIS,  DRAW Y AXIS,
C
  200 YLABEL=0.0
  210 DO 260 J6 =1,11,2
  220 Y=(J6-1)   *SFY
  230 X=-0.2*SFX$ H=0.105
  240 CALL NUMBER (X,Y-0.105,H,YLABEL,90.0,4HF3.1)
  250 YLABEL =YLABEL+0.2
  256 CALL PLOT(0.0,Y,3) $ CALL PLOT(0.0,0.0,0.2)
  260 CONTINUE
C
C     PLOT POINTS,
C
  290 NUM=1
      ENTRY GRAPH5A
  300 NODD=NUM-(NUM/2)*2
  302 IF(NODD.EQ.0)GO TO 312
  303 J6=J3STOP $ KEY=1
  304 IF(J6.LT.J5CUTHI(I))GO TO 350
  306 IF(ABSF(WLC1(I6,J6))-0.001) 343,343,308
  308 IF(NUM.GT.ICTLOW)320,310
  310 Y=SFYLOW*10.0*WLC1(I6,J6) $ GO TO 322
  312 J6=J5CUTHI(I) $ KEY=1
  314 IF(J6.GT.J3STOP) GO TO 350
  316 IF(ABSF(WLC1(I6,J6))-0.001)344,344,318
  318 IF(NUM.GT.ICTLOW) 320,310
```

```
  320 Y=SFY*10.0*WLC1(I6,J6)
  322 IF(Y.GT.0.0) GO TO 326 $ Y=-0.3 $ GO TO 328
  326 IF(Y.LT.10.0) GO TO 328 $ Y=10.0
  328 IF(NUM.GT.ICTLOW) GO TO 332
  330 X=2.0*SFXLOW*EIE(J6) $ GO TO 334
  332 X=2.0*SFX*EIE(J6)
  334 IF(X.GT.0.0) GO TO 336 $ IF(J6.EQ.J3STOP) GO TO 336 $ X=-0.3
  335 GO TO 338
  336 IF(X.LT.25.0) GO TO 338 $ X=25.0
  338 IF(KEY.NE.1) GO TO 340 $ KEY=0 $ CALL PLOT(X,Y,3)
  340 CALL SYMBOL(X,Y,0.08,NUM,0.0,-2)
  342 IF(NODD.EQ.0) GO TO 344
  343 J6=J6-1 $ GO TO 304
  344 J6=J6+1 $ GO TO 314
  350 CALL NORM2 $ NUM=NUM+1 $ RETURN
C
C     PLOT INTEGRALS W(J6)
C
      ENTRY GRAPH5B
  500 J6=1
  505 Y=5.0*W(J6)    *SFY
  510 IF(Y.GT.0.0)GO TO 520
  515 Y=0.0
  520 CONTINUE
  525 X=(2.0*EIE(J6))*SFX
  530 IF(X.GT.0.0)GO TO 540
  535 X=0.0
  540 IF(X.LT.25.0) GO TO 550
  545 X=25.0
  550 IF(Y.LT.10.0) GO TO 560
  555 Y=10.0*SFY
  560 NUM=0
      IF(J6.GT.1)GO TO 570
  565 CALL PLOT(X,Y,3)
  570 CALL SYMBOL(X,Y,0.08,NUM,0.0,-2)
  575 J6=J6+1
  580 IF(J6.GT.J3STOP)GO TO 590
  585 GO TO 505
  590 CALL PLOTS(20.0,0.0,3)
  600 CALL STOPPLOT
  620 END
```

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```
      SUBROUTINE NORM2
      COMMON/1/Z,A,DE,DEI,RM,SEL,ERA,TT,HILOSS,NDKx,NLANDAU,ILAN
      COMMON/3/CUTC,CUTFAC,NONES,NTWOS,NFOURS,NEIGHTS,NPMAX,ICOUNT,I,I6
      COMMON/5/KSIZE(5),NP(10),IPRINT(10),KPRINT(10)
      COMMON/8/KX(400),DY(400),D(400),KCUT(400),NPOC(400),J5CUTHI(400)
      COMMON/10/A3,A4,A5,A6,A7,GEMAX,KX2,IMAX,J3STOP,KMAX,DKX,BSQ
      COMMON/11/WLC1(3,1700),W(1700),AREA(10),WA(1700),GL(500),GPH(500)
C
C     INTEGRATE OVER PLOTTED DISTRIBUTION FUNCTIONS TO TEST NORMALITY.
C
    1 FORMAT(10F8.4)
   25 IC=I6
   30 SUM=0.0 $ J6=J3STOP-1
   32 SUM=SUM+WLC1(IC,J6-1)+4.0*WLC1(IC,J6)+WLC1(IC,J6+1)
   34 J6=J6-2 $ IF(J6-J5CUTHI(I)) 36,32,32
   36 AREA(ICOUNT)=DE*0.33333*SUM
   38 RETURN
C
C     RENORMALIZE LOW-LOSS DISTRIBUTION FUNCTIONS
C
      ENTRY NORMA
  101 J6=J3STOP-1 $ SUM=0.0
  102 SUM=SUM+WLC1(I6,J6-1)+4.0*WLC1(I6,J6)+WLC1(I6,J6+1)
  104 J6=J6-2 $ IF(J6-J5CUTHI(I)) 106,102,102
  106 ADF=DE*SUM*0.33333 $ SF=1.0/ADF $ J6S=J5CUTHI(I)
  112 DO 114 J6=J6S,J3STOP
  114 WLC1(I6,J6)=WLC1(I6,J6)*SF
  118 END
```

```
      SUBROUTINE LAN1
      TYPE REAL KX,KX2
      COMMON/1/Z,A,DE,DEI,RM,SEL,ERA,TT,HILOSS,NDKX,NLANDAU,ILAN
      COMMON/2/NMAX ,NCOMP,LCOMP,LCOUNT,LCOUNT2,DYMAX,COMP,SLO,PCUT
      COMMON/3/CUTC,CUTFAC,NONES,NTWOS,NFOURS,NEIGHTS,NPMAX,ICOUNT,I,I6
      COMMON/6/NOPRINT1,NOPRINT2
      COMMON/8/KX(400),DY(400),D(400),KCUT(400),NPOC(400),J5CUTHI(400)
      COMMON/9/EIE(1700),PV(1900),DIF(1700),P(1900)
      COMMON/10/A3,A4,A5,A6,A7,GEMAX,KX2,IMAX,J3STOP,KMAX,DKX,BSQ
      COMMON/11/WLC1(3,1700),W(1700),AREA(10),WA(1700),GL(500),GPH(500)
    5 FORMAT(5(F6.2,E10.4))
    6 FORMAT(5(F6.1,3X,E10.4,6X))
    7 FORMAT(/* GL(LL),GPH(LL),     LL=1,LLMAX*)
    8 LLMAX=486
   10 READ 5,(GL(LL),GPH(LL),LL=1,LLMAX)
   12 IF(NOPRINT1.EQ.1) 16,20
   16 WRITE(61,7)
   18 WRITE(61,6)(GL(LL),GPH(LL),LL=1,LLMAX)
   20 DEN=KX2*GEMAX
      ENTRY LAN11
   30 GX=KX(I)/KX2 $ J5END=J5CUTHI(I) $ B=1.0*BSQ=0.577216
   40 J5=J3STOP
   50 P(J5)=((EIE(J5)-KX(I))/GX)-B-LOGF(KX(I)/DEN)
   52 IF(P(J5).LT.PCUT) GO TO 74
   55 LL=1
   60 IF(GL(LL).GT.P(J5)) 63,62
   62 LL=LL+1 $ GO TO 60
   63 IF(GL(LL).GT.20.0) GO TO 64 $ DGL=0.1 $ GO TO 70
   64 IF(GL(LL).GT.50.0) GO TO 66 $ DGL=0.2 $ GO TO 70
   66 DGL=0.5
   70 WLC1(I6,J5)=((GPH(LL)-GPH(LL-1))*(P(J5)-GL(LL-1))/DGL
     2GPH(LL-1))/GX
   74 J5=J5-1 $ IF(J5.LT.J5END) 80,50
   80 END
```

992 KEV RESONANCE IN AL=27(P,GAMMA), 4.934=KEV TARGET,

QUANTITIES READ FROM DATA CARDS,

```
Z= 13.0              ZIP= 1.0             A=  26.98            RM= 938256.00        NLANDAU=  1          ILAN= 13
SEL=175582.0         ERA=  992.20         DE= 0.020            DEI= 0.004000        TT=  4.923           NDKX= 3
NMAX= 2500           NCOMP= 10            LCOMP=  10           LCOUNT2= 1000        DYMAX= 0.900         HILOSS=  9.00
COMP= 0.00005        SLO= 0.30            PCUT=3.30            CUTC=  1.00          CUTFAC=  1.4
NONES= 12            NTWOS= 10            NFOURS=  3           NEIGHTS=  0          IQUIT= 401           INORM= 40
SFX= 0.25            SFY= 0.50            SFXLOW= 2.50         SFYLOW= 0.03         ICTLOW=  2           NOPLOT=  1
NOPRINT1=  0         NOPRINT2=  0         LCOUNT= 500

KSIZE(M), M=1,5
      47        17        20        12        12

NPMAX          NP(M),  M=1,NPMAX
   4              2   10   51   89

IPRINT(I), I=1,10
  -0   =0   =0   -0   -0   =0   =0   =0   =0   =0

KPRINT(K), K=1,10
  -0   =0   =0   -0   -0   =0   =0   =0   =0   =0
```

QUANTITIES COMPUTED IN MAIN PROGRAM,

```
A3= 1.00106+000      A4= 2.16600+000      A5= 9.98911-001      A6= 1.08468+000      A7= 7.26194+004      NONES=  12
GEMAX= 2.16364+000   KX2= 5.01794+000     IMAX=  90            JSTOP= 450           KMAX= 717            DKX=   0.05532

KX(I), I=1,  90

 0.00000+000 5.53161=002 1.10632=001 1.65948=001 2.21264=001 2.76580=001 3.31896=001 3.87212-001 4.42529=001 4.97845-001
 5.53161=001 6.08477=001 6.63793=001 7.19109=001 7.74425=001 8.29741=001 8.85057=001 9.40373-001 9.95689=001 1.05101+000
 1.10632+000 1.16164+000 1.21695+000 1.27227+000 1.32759+000 1.38290+000 1.43822+000 1.49353+000 1.54885+000 1.60417+000
 1.65948+000 1.71480+000 1.77011+000 1.82543+000 1.88075+000 1.93606+000 1.99138+000 2.04669+000 2.10201+000 2.15733+000
 2.21264+000 2.26796+000 2.32327+000 2.37859+000 2.43391+000 2.48922+000 2.54454+000 2.59985+000 2.65517+000 2.71049+000
 2.76580+000 2.82112+000 2.87644+000 2.93175+000 2.98707+000 3.04238+000 3.09770+000 3.15302+000 3.20833+000 3.26365+000
 3.31896+000 3.37428+000 3.42960+000 3.48491+000 3.54023+000 3.59554+000 3.65086+000 3.70618+000 3.76149+000 3.81681+000
 3.87212+000 3.92744+000 3.98276+000 4.03807+000 4.09339+000 4.14870+000 4.20402+000 4.25934+000 4.31465+000 4.36997+000
 4.42529+000 4.48060+000 4.53592+000 4.59123+000 4.64655+000 4.70187+000 4.75718+000 4.81250+000 4.86781+000 4.92313+000

DY(I), I=1,  90

 0.00000+000 9.00000=001 6.36396=001 5.19615=001 4.50000=001 4.02492=001 3.67423=001 3.40168=001 3.18199=001 3.00000-001
 2.84605=001 2.71360=001 2.59808=001 2.49615=001 2.40535=001 2.32379=001 2.25000=001 2.18282=001 2.12132=001 2.06474-001
 2.01246=001 1.96396=001 1.91881=001 1.87663=001 1.83712=001 1.80000=001 1.76505=001 1.73205-001 1.70084=001 1.67126-001
 1.64317=001 1.61645=001 1.59099=001 1.56670=001 1.54349=001 1.52128=001 1.50000=001 1.47959-001 1.45999=001 1.44115-001
 1.42302=001 1.40556=001 1.38873=001 1.37249=001 1.35680=001 1.34164=001 1.32698=001 1.31278-001 1.29904=001 1.28571-001
 1.27279=001 1.26025=001 1.24808=001 1.23625=001 1.22474=001 1.21356=001 1.20268=001 1.19208-001 1.18176=001 1.17170-001
 1.16190=001 1.15233=001 1.14300=001 1.13389=001 1.12500=001 1.11631=001 1.10782=001 1.09952-001 1.09141=001 1.08347-001
 1.07571=001 1.06810=001 1.06066=001 1.05337=001 1.04623=001 1.03923=001 1.03237=001 1.02565-001 1.01905=001 1.01258-001
 1.00623=001 1.00000=001 9.93884-002 9.87878-002 9.81981=002 9.76187=002 9.70495=002 9.64901-002 9.59403=002 9.53998-002
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UNCLASSIFIED

D(I), I=1, 90

0.00000+000	5.09496-003	1.01899-002	1.52849-002	2.03798-002	2.54748-002	3.05698-002	3.56647-002	4.07597-002	4.58547-002
5.09496-002	5.60446-002	6.11395-002	6.62345-002	7.13295-002	7.64244-002	8.15194-002	8.66144-002	9.17093-002	9.68043-002
1.01899-001	1.06994-001	1.12089-001	1.17184-001	1.22279-001	1.27374-001	1.32469-001	1.37564-001	1.42659-001	1.47754-001
1.52849-001	1.57944-001	1.63039-001	1.68134-001	1.73229-001	1.78324-001	1.83419-001	1.88514-001	1.93609-001	1.98704-001
2.03798-001	2.08893-001	2.13988-001	2.19083-001	2.24178-001	2.29273-001	2.34368-001	2.39463-001	2.44559-001	2.49653-001
2.54748-001	2.59843-001	2.64938-001	2.70033-001	2.75128-001	2.80223-001	2.85318-001	2.90413-001	2.95509-001	3.00603-001
3.05698-001	3.10793-001	3.15888-001	3.20983-001	3.26078-001	3.31173-001	3.36267-001	3.41362-001	3.46457-001	3.51552-001
3.56647-001	3.61742-001	3.66837-001	3.71932-001	3.77027-001	3.82122-001	3.87217-001	3.92312-001	3.97407-001	4.02502-001
4.07597-001	4.12692-001	4.17787-001	4.22882-001	4.27977-001	4.33072-001	4.38167-001	4.43262-001	4.48357-001	4.53452-001

KCUT(I),I=1, 90

0	389	385	381	377	373	369	365	361	357
353	349	345	341	337	333	329	325	321	317
313	309	305	301	297	293	289	285	281	277
273	269	265	261	257	253	249	245	241	237
233	229	225	221	217	213	209	205	201	197
193	189	185	181	177	173	169	172	175	178
181	184	187	190	193	196	199	202	205	208
211	214	217	220	223	226	229	232	235	238
241	244	247	250	253	256	259	262	265	268

NPQC(I), I=1, 90

0	3	4	4	5	5	5	5	5	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	6	6	6	6
6	6	6	7	7	7	7	7	7	7
8	8	8	8	8	8	9	9	9	9

J5CUTHI(I), I=1, 90

0	386	379	372	365	358	351	344	337	330
323	316	309	302	295	288	281	274	267	260
253	246	239	232	225	218	211	204	197	190
183	176	169	162	155	148	141	134	127	120
113	106	99	92	85	78	71	64	57	50
43	36	29	22	15	8	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1

EIE(J5), J5=1, 450

8.98000+000	8.96000+000	8.94000+000	8.92000+000	8.90000+000	8.88000+000	8.86000+000	8.84000+000	8.82000+000	8.80000+000
8.78000+000	8.76000+000	8.74000+000	8.72000+000	8.70000+000	8.68000+000	8.66000+000	8.64000+000	8.62000+000	8.60000+000
8.58000+000	8.56000+000	8.54000+000	8.52000+000	8.50000+000	8.48000+000	8.46000+000	8.44000+000	8.42000+000	8.40000+000
8.38000+000	8.36000+000	8.34000+000	8.32000+000	8.30000+000	8.28000+000	8.26000+000	8.24000+000	8.22000+000	8.20000+000
8.18000+000	8.16000+000	8.14000+000	8.12000+000	8.10000+000	8.08000+000	8.06000+000	8.04000+000	8.02000+000	8.00000+000
7.98000+000	7.96000+000	7.94000+000	7.92000+000	7.90000+000	7.88000+000	7.86000+000	7.84000+000	7.82000+000	7.80000+000
7.78000+000	7.76000+000	7.74000+000	7.72000+000	7.70000+000	7.68000+000	7.66000+000	7.64000+000	7.62000+000	7.60000+000
7.58000+000	7.56000+000	7.54000+000	7.52000+000	7.50000+000	7.48000+000	7.46000+000	7.44000+000	7.42000+000	7.40000+000
7.38000+000	7.36000+000	7.34000+000	7.32000+000	7.30000+000	7.28000+000	7.26000+000	7.24000+000	7.22000+000	7.20000+000

7.18000+000	7.16000+000	7.14000+000	7.12000+000	7.10000+000	7.08000+000	7.06000+000	7.04000+000	7.02000+000	7.00000+000
6.98000+000	6.96000+000	6.94000+000	6.92000+000	6.90000+000	6.88000+000	6.86000+000	6.84000+000	6.82000+000	6.80000+000
6.78000+000	6.76000+000	6.74000+000	6.72000+000	6.70000+000	6.68000+000	6.66000+000	6.64000+000	6.62000+000	6.60000+000
6.58000+000	6.56000+000	6.54000+000	6.52000+000	6.50000+000	6.48000+000	6.46000+000	6.44000+000	6.42000+000	6.40000+000
6.38000+000	6.36000+000	6.34000+000	6.32000+000	6.30000+000	6.28000+000	6.26000+000	6.24000+000	6.22000+000	6.20000+000
6.18000+000	6.16000+000	6.14000+000	6.12000+000	6.10000+000	6.08000+000	6.06000+000	6.04000+000	6.02000+000	6.00000+000
5.98000+000	5.96000+000	5.94000+000	5.92000+000	5.90000+000	5.88000+000	5.86000+000	5.84000+000	5.82000+000	5.80000+000
5.78000+000	5.76000+000	5.74000+000	5.72000+000	5.70000+000	5.68000+000	5.66000+000	5.64000+000	5.62000+000	5.60000+000
5.58000+000	5.56000+000	5.54000+000	5.52000+000	5.50000+000	5.48000+000	5.46000+000	5.44000+000	5.42000+000	5.40000+000
5.38000+000	5.36000+000	5.34000+000	5.32000+000	5.30000+000	5.28000+000	5.26000+000	5.24000+000	5.22000+000	5.20000+000
5.18000+000	5.16000+000	5.14000+000	5.12000+000	5.10000+000	5.08000+000	5.06000+000	5.04000+000	5.02000+000	5.00000+000
4.98000+000	4.96000+000	4.94000+000	4.92000+000	4.90000+000	4.88000+000	4.86000+000	4.84000+000	4.82000+000	4.80000+000
4.78000+000	4.76000+000	4.74000+000	4.72000+000	4.70000+000	4.68000+000	4.66000+000	4.64000+000	4.62000+000	4.60000+000
4.58000+000	4.56000+000	4.54000+000	4.52000+000	4.50000+000	4.48000+000	4.46000+000	4.44000+000	4.42000+000	4.40000+000
4.38000+000	4.36000+000	4.34000+000	4.32000+000	4.30000+000	4.28000+000	4.26000+000	4.24000+000	4.22000+000	4.20000+000
4.18000+000	4.16000+000	4.14000+000	4.12000+000	4.10000+000	4.08000+000	4.06000+000	4.04000+000	4.02000+000	4.00000+000
3.98000+000	3.96000+000	3.94000+000	3.92000+000	3.90000+000	3.88000+000	3.86000+000	3.84000+000	3.82000+000	3.80000+000
3.78000+000	3.76000+000	3.74000+000	3.72000+000	3.70000+000	3.68000+000	3.66000+000	3.64000+000	3.62000+000	3.60000+000
3.58000+000	3.56000+000	3.54000+000	3.52000+000	3.50000+000	3.48000+000	3.46000+000	3.44000+000	3.42000+000	3.40000+000
3.38000+000	3.36000+000	3.34000+000	3.32000+000	3.30000+000	3.28000+000	3.26000+000	3.24000+000	3.22000+000	3.20000+000
3.18000+000	3.16000+000	3.14000+000	3.12000+000	3.10000+000	3.08000+000	3.06000+000	3.04000+000	3.02000+000	3.00000+000
2.98000+000	2.96000+000	2.94000+000	2.92000+000	2.90000+000	2.88000+000	2.86000+000	2.84000+000	2.82000+000	2.80000+000
2.78000+000	2.76000+000	2.74000+000	2.72000+000	2.70000+000	2.68000+000	2.66000+000	2.64000+000	2.62000+000	2.60000+000
2.58000+000	2.56000+000	2.54000+000	2.52000+000	2.50000+000	2.48000+000	2.46000+000	2.44000+000	2.42000+000	2.40000+000
2.38000+000	2.36000+000	2.34000+000	2.32000+000	2.30000+000	2.28000+000	2.26000+000	2.24000+000	2.22000+000	2.20000+000
2.18000+000	2.16000+000	2.14000+000	2.12000+000	2.10000+000	2.08000+000	2.06000+000	2.04000+000	2.02000+000	2.00000+000
1.98000+000	1.96000+000	1.94000+000	1.92000+000	1.90000+000	1.88000+000	1.86000+000	1.84000+000	1.82000+000	1.80000+000
1.78000+000	1.76000+000	1.74000+000	1.72000+000	1.70000+000	1.68000+000	1.66000+000	1.64000+000	1.62000+000	1.60000+000
1.58000+000	1.56000+000	1.54000+000	1.52000+000	1.50000+000	1.48000+000	1.46000+000	1.44000+000	1.42000+000	1.40000+000
1.38000+000	1.36000+000	1.34000+000	1.32000+000	1.30000+000	1.28000+000	1.26000+000	1.24000+000	1.22000+000	1.20000+000
1.18000+000	1.16000+000	1.14000+000	1.12000+000	1.10000+000	1.08000+000	1.06000+000	1.04000+000	1.02000+000	1.00000+000
9.80000-001	9.60000-001	9.40000-001	9.20000-001	9.00000-001	8.80000-001	8.60000-001	8.40000-001	8.20000-001	8.00000-001
7.80000-001	7.60000-001	7.40000-001	7.20000-001	7.00000-001	6.80000-001	6.60000-001	6.40000-001	6.20000-001	6.00000-001
5.80000-001	5.60000-001	5.40000-001	5.20000-001	5.00000-001	4.80000-001	4.60000-001	4.40000-001	4.20000-001	4.00000-001
3.80000-001	3.60000-001	3.40000-001	3.20000-001	3.00000-001	2.80000-001	2.60000-001	2.40000-001	2.20000-001	2.00000-001
1.80000-001	1.60000-001	1.40000-001	1.20000-001	1.00000-001	8.00000-002	6.00000-002	4.00000-002	2.00000-002	0.00000+000

PV(K), K=1, 717

4.15042+000	4.14117+000	4.13193+000	4.12269+000	4.11344+000	4.10420+000	4.09496+000	4.08571+000	4.07647+000	4.06723+000
4.05798+000	4.04874+000	4.03949+000	4.03025+000	4.02101+000	4.01176+000	4.00252+000	3.99328+000	3.98403+000	3.97479+000
3.96554+000	3.95630+000	3.94706+000	3.93781+000	3.92857+000	3.91933+000	3.91008+000	3.90084+000	3.89159+000	3.88235+000
3.87311+000	3.86386+000	3.85462+000	3.84538+000	3.83613+000	3.82689+000	3.81765+000	3.80840+000	3.79916+000	3.78991+000
3.78067+000	3.77143+000	3.76218+000	3.75294+000	3.74370+000	3.73445+000	3.72521+000	3.71596+000	3.70672+000	3.69748+000
3.68823+000	3.67899+000	3.66975+000	3.66050+000	3.65126+000	3.64202+000	3.63277+000	3.62353+000	3.61429+000	3.60504+000
3.59580+000	3.58655+000	3.57731+000	3.56807+000	3.55882+000	3.54958+000	3.54033+000	3.53109+000	3.52185+000	3.51260+000
3.50336+000	3.49412+000	3.48487+000	3.47563+000	3.46639+000	3.45714+000	3.44790+000	3.43865+000	3.42941+000	3.42017+000
3.41092+000	3.40168+000	3.39244+000	3.38319+000	3.37395+000	3.36470+000	3.35546+000	3.34622+000	3.33697+000	3.32773+000
3.31849+000	3.30924+000	3.30000+000	3.29075+000	3.28151+000	3.27227+000	3.26302+000	3.25378+000	3.24454+000	3.23529+000
3.22605+000	3.21681+000	3.20756+000	3.19832+000	3.18907+000	3.17983+000	3.17059+000	3.16134+000	3.15210+000	3.14286+000
3.13361+000	3.12437+000	3.11512+000	3.10588+000	3.09664+000	3.08739+000	3.07815+000	3.06891+000	3.05966+000	3.05042+000
3.04118+000	3.03193+000	3.02269+000	3.01344+000	3.00420+000	2.99496+000	2.98571+000	2.97647+000	2.96723+000	2.95798+000
2.94874+000	2.93949+000	2.93025+000	2.92101+000	2.91176+000	2.90252+000	2.89328+000	2.88403+000	2.87479+000	2.86554+000
2.85630+000	2.84706+000	2.83781+000	2.82857+000	2.81933+000	2.81008+000	2.80084+000	2.79160+000	2.78235+000	2.77311+000
2.76386+000	2.75462+000	2.74538+000	2.73613+000	2.72689+000	2.71765+000	2.70840+000	2.69916+000	2.68991+000	2.68067+000
2.67143+000	2.66218+000	2.65294+000	2.64370+000	2.63445+000	2.62521+000	2.61597+000	2.60672+000	2.59748+000	2.58823+000
2.57899+000	2.56975+000	2.56050+000	2.55126+000	2.54202+000	2.53277+000	2.52353+000	2.51428+000	2.50504+000	2.49580+000

UNCLASSIFIED

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2,48655+000 2,47731+000 2,46807+000 2,45882+000 2,44958+000 2,44034+000 2,43109+000 2,42185+000 2,41260+000 2,40336+000
2,39412+000 2,38487+000 2,37563+000 2,36639+000 2,35714+000 2,34790+000 2,33865+000 2,32941+000 2,32017+000 2,31092+000
2,30168+000 2,29244+000 2,28319+000 2,27395+000 2,26470+000 2,25546+000 2,24622+000 2,23697+000 2,22773+000 2,21849+000
2,20924+000 2,20000+000 2,19076+000 2,18151+000 2,17227+000 2,16302+000 2,15378+000 2,14454+000 2,13529+000 2,12605+000
2,11681+000 2,10756+000 2,09832+000 2,08907+000 2,07983+000 2,07059+000 2,06134+000 2,05210+000 2,04286+000 2,03361+000
2,02437+000 2,01513+000 2,00588+000 1,99664+000 1,98739+000 1,97815+000 1,96891+000 1,95966+000 1,95042+000 1,94118+000
1,93193+000 1,92269+000 1,91344+000 1,90420+000 1,89496+000 1,88571+000 1,87647+000 1,86723+000 1,85798+000 1,84874+000
1,83950+000 1,83025+000 1,82101+000 1,81176+000 1,80252+000 1,79328+000 1,78403+000 1,77479+000 1,76555+000 1,75630+000
1,74706+000 1,73781+000 1,72857+000 1,71933+000 1,71008+000 1,70084+000 1,69160+000 1,68235+000 1,67311+000 1,66386+000
1,65462+000 1,64538+000 1,63613+000 1,62689+000 1,61765+000 1,60840+000 1,59916+000 1,58992+000 1,58067+000 1,57143+000
1,56218+000 1,55294+000 1,54370+000 1,53445+000 1,52521+000 1,51597+000 1,50672+000 1,49748+000 1,48823+000 1,47899+000
1,46975+000 1,46050+000 1,45126+000 1,44202+000 1,43277+000 1,42353+000 1,41429+000 1,40504+000 1,39580+000 1,38655+000
1,37731+000 1,36807+000 1,35882+000 1,34958+000 1,34034+000 1,33109+000 1,32185+000 1,31260+000 1,30336+000 1,29412+000
1,28487+000 1,27563+000 1,26639+000 1,25714+000 1,24790+000 1,23865+000 1,22941+000 1,22017+000 1,21092+000 1,20168+000
1,19244+000 1,18319+000 1,17395+000 1,16471+000 1,15546+000 1,14622+000 1,13697+000 1,12773+000 1,11849+000 1,10924+000
1,10000+000 1,09076+000 1,08151+000 1,07227+000 1,06302+000 1,05378+000 1,04454+000 1,03529+000 1,02605+000 1,01681+000
1,00756+000 9,98319-001 9,89075-001 9,79832-001 9,70588-001 9,61344-001 9,52100-001 9,42857-001 9,33613-001 9,24369-001
9,15126-001 9,05882-001 8,96638-001 8,87395-001 8,78151-001 8,68907-001 8,59663-001 8,50420-001 8,41176-001 8,31932-001
8,22689-001 8,13445-001 8,04201-001 7,94958-001 7,85714-001 7,76470-001 7,67227-001 7,57983-001 7,48739-001 7,39495-001
7,30252-001 7,21008-001 7,11764-001 7,02521-001 6,93277-001 6,84033-001 6,74790-001 6,65546-001 6,56302-001 6,47059-001
6,37815-001 6,28571-001 6,19327-001 6,10084-001 6,00840-001 5,91596-001 5,82353-001 5,73109-001 5,63865-001 5,54622-001
5,45378-001 5,36134-001 5,26891-001 5,17647-001 5,08403-001 4,99159-001 4,89916-001 4,80672-001 4,71428-001 4,62185-001
4,52941-001 4,43697-001 4,34454-001 4,25210-001 4,15966-001 4,06723-001 3,97479-001 3,88235-001 3,78991-001 3,69748-001
3,60504-001 3,51260-001 3,42017-001 3,32773-001 3,23529-001 3,14286-001 3,05042-001 2,95798-001 2,86554-001 2,77311-001
2,68067-001 2,58823-001 2,49580-001 2,40336-001 2,31092-001 2,21849-001 2,12605-001 2,03361-001 1,94118-001 1,84874-001
1,75630-001 1,66386-001 1,57143-001 1,47899-001 1,38655-001 1,29412-001 1,20168-001 1,10924-001 1,01681-001 9,24369-002
8,31932-002 7,39495-002 6,47059-002 5,54622-002 4,62185-002 3,69748-002 2,77311-002 1,84874-002 9,24369-003 0,00000+000
-9,24369-003-1,84874-002-2,77311-002-3,69748-002-4,62185-002-5,54622-002-6,47059-002-7,39495-002-8,31932-002-9,24369-002
-1,01681-001-1,10924-001-1,20168-001-1,29412-001-1,38655-001-1,47899-001-1,57143-001-1,66386-001-1,75630-001-1,84874-001
-1,94118-001-2,03361-001-2,12605-001-2,21849-001-2,31092-001-2,40336-001-2,49580-001-2,58823-001-2,68067-001-2,77311-001
-2,86554-001-2,95798-001-3,05042-001-3,14286-001-3,23529-001-3,32773-001-3,42017-001-3,51260-001-3,60504-001-3,69748-001
-3,78991-001-3,88235-001-3,97479-001-4,06723-001-4,15966-001-4,25210-001-4,34454-001-4,43697-001-4,52941-001-4,62185-001
-4,71428-001-4,80672-001-4,89916-001-4,99159-001-5,08403-001-5,17647-001-5,26891-001-5,36134-001-5,45378-001-5,54622-001
-5,63865-001-5,73109-001-5,82353-001-5,91596-001-6,00840-001-6,10084-001-6,19327-001-6,28571-001-6,37815-001-6,47059-001
-6,56302-001-6,65546-001-6,74790-001-6,84033-001-6,93277-001-7,02521-001-7,11764-001-7,21008-001-7,30252-001-7,39495-001
-7,48739-001-7,57983-001-7,67227-001-7,76470-001-7,85714-001-7,94958-001-8,04201-001-8,13445-001-8,22689-001-8,31932-001
-8,41176-001-8,50420-001-8,59663-001-8,68907-001-8,78151-001-8,87395-001-8,96638-001-9,05882-001-9,15126-001-9,24369-001
-9,33613-001-9,42857-001-9,52100-001-9,61344-001-9,70588-001-9,79832-001-9,89075-001-9,98319-001-1,00756+000-1,01681+000
-1,02605+000-1,03529+000-1,04454+000-1,05378+000-1,06302+000-1,07227+000-1,08151+000-1,09076+000-1,10000+000-1,10924+000
-1,11849+000-1,12773+000-1,13697+000-1,14622+000-1,15546+000-1,16471+000-1,17395+000-1,18319+000-1,19244+000-1,20168+000
-1,21092+000-1,22017+000-1,22941+000-1,23865+000-1,24790+000-1,25714+000-1,26639+000-1,27563+000-1,28487+000-1,29412+000
-1,30336+000-1,31260+000-1,32185+000-1,33109+000-1,34034+000-1,34958+000-1,35882+000-1,36807+000-1,37731+000-1,38655+000
-1,39580+000-1,40504+000-1,41429+000-1,42353+000-1,43277+000-1,44202+000-1,45126+000-1,46050+000-1,46975+000-1,47899+000
-1,48823+000-1,49748+000-1,50672+000-1,51597+000-1,52521+000-1,53445+000-1,54370+000-1,55294+000-1,56219+000-1,57143+000
-1,58067+000-1,58992+000-1,59916+000-1,60840+000-1,61765+000-1,62689+000-1,63613+000-1,64538+000-1,65462+000-1,66386+000
-1,67311+000-1,68235+000-1,69160+000-1,70084+000-1,71008+000-1,71933+000-1,72857+000-1,73781+000-1,74706+000-1,75630+000
-1,76555+000-1,77479+000-1,78403+000-1,79328+000-1,80252+000-1,81176+000-1,82101+000-1,83025+000-1,83950+000-1,84874+000
-1,85798+000-1,86723+000-1,87647+000-1,88571+000-1,89496+000-1,90420+000-1,91344+000-1,92269+000-1,93193+000-1,94118+000
-1,95042+000-1,95966+000-1,96891+000-1,97815+000-1,98739+000-1,99664+000-2,00588+000-2,01513+000-2,02437+000-2,03361+000
-2,04286+000-2,05210+000-2,06134+000-2,07059+000-2,07983+000-2,08907+000-2,09832+000-2,10756+000-2,11681+000-2,12605+000
-2,13529+000-2,14454+000-2,15378+000-2,16302+000-2,17227+000-2,18151+000-2,19076+000-2,20000+000-2,20924+000-2,21849+000
-2,22773+000-2,23697+000-2,24622+000-2,25546+000-2,26470+000-2,27395+000-2,28319+000-2,29244+000-2,30169+000-2,31092+000
-2,32017+000-2,32941+000-2,33865+000-2,34790+000-2,35714+000-2,36639+000-2,37563+000-2,38487+000-2,39412+000-2,40336+000
-2,41260+000-2,42185+000-2,43109+000-2,44034+000-2,44958+000-2,45882+000-2,46807+000
```

QUANTITIES PRINTED FROM SUBROUTINES LAN1 AND VAV6.

```
ICOUNT,I,  WLC1(I6SAVE,J6),J6=1,J3STOP
  1   2  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0,00000000  0,01352474  0,01404559  0,01459493  0,01517889  0,01573824  0,01645554
 0,01715481  0,01789878  0,01869298  0,01954006  0,02044658  0,02141737  0,02245783  0,02357555  0,02477996  0,02607688
 0,02747804  0,02899546  0,03064020  0,03242896  0,03437798  0,03650519  0,03883693  0,04139682  0,04421552  0,04733284
 0,05078451  0,05462973  0,05891881  0,06373179  0,06915423  0,07529241  0,08227520  0,09026674  0,09946504  0,11012615
 0,12257337  0,13721918  0,15462112  0,17548888  0,20079476  0,23187622  0,27060623  0,31965119  0,38292607  0,46636689
 0,57922764  0,73660033  0,96413033  1,30784701  1,85597738  2,78910783  4,50598072  7,91842570 14,74295757 22,51297709
```

END OF PRINTOUT FROM CALL 1 OF SUBROUTINE VAV6.

END OF PRINTOUT FROM CALL 2 OF SUBROUTINE VAV6.

END OF PRINTOUT FROM CALL 3 OF SUBROUTINE VAV6.

END OF PRINTOUT FROM CALL 4 OF SUBROUTINE VAV6.

UNCLASSIFIED

```
ICOUNT,I,  WLC1(I6SAVE,J6),J6=1,J3STOP
 2  10  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000
 0,00000000  0,00000000  0,00000000  0.00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,00000000  0,02676518
 0,02728253  0,02781397  0,02836137  0,02892503  0,02950494  0,03010207  0,03071751  0,03135138  0,03200367  0,03267707
 0,03337034  0,03408636  0,03482502  0,03558655  0,03637388  0,03718617  0,03802447  0,03889195  0,03979874  0,04071491
 0,04167359  0,04266586  0,04369185  0,04475479  0,04585567  0,04699676  0,04818011  0,04940602  0,05067870  0,05199925
 0,05336987  0,05479403  0,05627373  0,05781301  0,05941272  0,06107775  0,06281136  0,06461712  0,06643833  0,06845972
 0,07050603  0,07264197  0,07487126  0,07720150  0,07963668  0,08218483  0,08485085  0,08764298  0,09056884  0,09363604
 0,09685441  0,10023327  0,10378243  0,10751264  0,11143561  0,11557395  0,11992906  0,12451824  0,12935949  0,13447557
 0,13987674  0,14558870  0,15164398  0,15805374  0,16485051  0,17206412  0,17971944  0,18786799  0,19653210  0,20576816
 0,21561385  0,22611886  0,23734474  0,24935702  0,26220942  0,27598082  0,29075538  0,30661039  0,32366410  0,34200554
 0,36176462  0,38306242  0,40605684  0,43089610  0,45774378  0,48678762  0,51822265  0,55228116  0,58913088  0,62919299
 0,67254315  0,71951896  0,77037849  0,82540005  0,88481330  0,94883829  1,01761214  1,09119839  1,16944479  1,25218194
 1,33880131  1,42828819  1,51926517  1,60980193  1,69701328  1,77721519  1,84575021  1,89691703  1,92398780  1,91982847
 1,87725299  1,79017154  1,65525721  1,47335474  1,25178883  1,00442991  0,75143542  0,51600140  0,31909944  0,17362787

END OF PRINTOUT FROM CALL   5 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL   6 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL   7 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL   8 OF SUBROUTINE VAV6,
```

```
END OF PRINTOUT FROM CALL   9 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  10 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  11 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  12 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  13 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  14 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  15 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  16 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  17 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  18 OF SUBROUTINE VAV6,

ICOUNT,I,  WLC1(I6SAVE,J6),J6=1,J3STOP
  3  51  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
 0.00000000  0.00000000  0.00000000  0.00005022  0.00010043  0.00015065  0.00020086  0.00025108  0.00030129  0.00035151
 0.00040173  0.00045194  0.00050216  0.00055237  0.00060259  0.00065280  0.00070302  0.00075323  0.00080345  0.00083559
 0.00086772  0.00089986  0.00093200  0.00096413  0.00099627  0.00102840  0.00106054  0.00109268  0.00112481  0.00115695
 0.00118909  0.00122122  0.00125336  0.00128549  0.00131763  0.00136877  0.00141992  0.00147106  0.00152220  0.00157335
 0.00162449  0.00167563  0.00172678  0.00177792  0.00182906  0.00188021  0.00193135  0.00198249  0.00203364  0.00208478
 0.00213592  0.00221637  0.00229682  0.00237727  0.00245772  0.00253817  0.00261862  0.00269907  0.00277953  0.00285998
 0.00294043  0.00302088  0.00310133  0.00318178  0.00326223  0.00334268  0.00342313  0.00354810  0.00367307  0.00379805
 0.00392302  0.00404799  0.00417297  0.00429794  0.00442291  0.00454788  0.00467286  0.00479783  0.00492280  0.00504778
 0.00517275  0.00529772  0.00542269  0.00561395  0.00580521  0.00599647  0.00618772  0.00637898  0.00657024  0.00676149
 0.00695275  0.00714401  0.00733526  0.00752652  0.00771778  0.00790903  0.00810029  0.00829155  0.00849281  0.00877048
 0.00905815  0.00934582  0.00963349  0.00992116  0.01020883  0.01049650  0.01078417  0.01107184  0.01135951  0.01164719
 0.01193486  0.01222253  0.01251020  0.01279787  0.01308554  0.01350941  0.01393327  0.01435714  0.01479101  0.01520488
 0.01562874  0.01605261  0.01647648  0.01690035  0.01732421  0.01774808  0.01817195  0.01859582  0.01901968  0.01944355
 0.01986742  0.02047853  0.02108964  0.02170075  0.02231187  0.02292298  0.02353409  0.02414520  0.02475631  0.02536743
 0.02597854  0.02658965  0.02720076  0.02781187  0.02842299  0.02903410  0.02964521  0.03050912  0.03137302  0.03223693
 0.03310083  0.03396474  0.03482864  0.03569255  0.03655645  0.03742036  0.03828426  0.03914817  0.04001208  0.04087598
 0.04173989  0.04260379  0.04346770  0.04457200  0.04567631  0.04678062  0.04788492  0.04898923  0.05009354  0.05119785
 0.05230215  0.05359587  0.05488958  0.05618329  0.05747700  0.05877072  0.06006443  0.06135814  0.06265186  0.06415984
 0.06566783  0.06717582  0.06868380  0.07019179  0.07169977  0.07320776  0.07471575  0.07645625  0.07819676  0.07993727
 0.08167778  0.08341829  0.08515879  0.08689930  0.08863981  0.09062730  0.09261479  0.09460228  0.09659976  0.09857725
 0.10056474  0.10255223  0.10453972  0.10678327  0.10902682  0.11127037  0.11351392  0.11575747  0.11800102  0.12024457
 0.12248812  0.12497572  0.12746332  0.12995092  0.13243853  0.13492613  0.13741373  0.13990134  0.14239894  0.14510710
 0.14782526  0.15054341  0.15326157  0.15597973  0.15869789  0.16141605  0.16413421  0.16705130  0.16996839  0.17288548
 0.17580258  0.17871967  0.18163676  0.18455385  0.18747095  0.19054944  0.19362794  0.19670643  0.19978493  0.20286342
 0.20594192  0.20902041  0.21209891  0.21532251  0.21854610  0.22176970  0.22499330  0.22821690  0.23144050  0.23466410
 0.23788770  0.24124251  0.24459732  0.24795214  0.25130695  0.25466176  0.25801657  0.26137139  0.26472620  0.26817746
 0.27162872  0.27507998  0.27853124  0.28204417  0.28555710  0.28907003  0.29258296  0.29615426  0.29972556  0.30329686
 0.30686816  0.31047835  0.31408853  0.31769872  0.32130890  0.32492971  0.32855051  0.33217132  0.33579213  0.33938558
 0.34297904  0.34657250  0.35016596  0.35366646  0.35716697  0.36066747  0.36416798  0.36752742  0.37088687  0.37424631
 0.37760576  0.38073514  0.38386453  0.38699392  0.39012330  0.39292300  0.39572269  0.39852238  0.40132207  0.40370165
 0.40608122  0.40846080  0.41084038  0.41261937  0.41439836  0.41617735  0.41795635  0.41901917  0.42008200  0.42114483
 0.42220765  0.42240516  0.42260268  0.42280019  0.42299770  0.42214040  0.42128311  0.42042582  0.41956852  0.41760203
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UNCLASSIFIED

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 0.41563553  0.41366903  0.41170254  0.40845510  0.40520766  0.40196021  0.39871277  0.39410858  0.38950438  0.38490019
 0.38029599  0.37431246  0.36832892  0.36234539  0.35636185  0.34909449  0.34182713  0.33455977  0.32729242  0.31905492
 0.31081743  0.30205480  0.29329217  0.28407422  0.27485628  0.26526598  0.25567568  0.24580814  0.23594059  0.22590135
 0.21586211  0.20576658  0.19567106  0.18564028  0.17560951  0.16576410  0.15591868  0.14633811  0.13675754  0.12767816
 0.11859878  0.11003477  0.10147076  0.09352052  0.08557028  0.07831095  0.07105162  0.06453642  0.05802122  0.05228088
 0.04654053  0.04158001  0.03661948  0.03223473  0.02822358  0.02457483  0.02127490  0.01832168  0.01565618  0.01330022
 0.01122491  0.00940845  0.00782965  0.00646757  0.00530136  0.00431083  0.00347637  0.00277943  0.00220240  0.00172910
 0.00134447  0.00103520  0.00078897  0.00059474  0.00044335  0.00032669  0.00023784  0.00017100  0.00000000  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000  0.00000000

END OF PRINTOUT FROM CALL  19 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  20 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  21 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  22 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  23 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL  24 OF SUBROUTINE VAV6,

ICOUNT,I,  WLC1(I6SAVE,J6),J6=1,J3STOP
  4  89  0.01189340  0.01219901  0.01250462  0.01281023  0.01311584  0.01342144  0.01372705  0.01403266  0.01433827  0.01464388
 0.01494949  0.01525510  0.01556071  0.01586632  0.01617193  0.01647754  0.01678315  0.01719561  0.01760806  0.01802051
 0.01843297  0.01884542  0.01925787  0.01967033  0.02008278  0.02049523  0.02090769  0.02132014  0.02173259  0.02214504
 0.02255750  0.02296995  0.02338240  0.02392947  0.02447653  0.02502359  0.02557066  0.02611772  0.02666478  0.02721185
 0.02775891  0.02830597  0.02885304  0.02940010  0.02994716  0.03049423  0.03104129  0.03158835  0.03213541  0.03284710
 0.03355879  0.03427048  0.03498217  0.03569386  0.03640555  0.03711724  0.03782893  0.03854062  0.03925231  0.03996399
 0.04067568  0.04138737  0.04209906  0.04281075  0.04352244  0.04442932  0.04533619  0.04624307  0.04714994  0.04805682
 0.04896369  0.04987057  0.05077745  0.05168432  0.05259120  0.05349807  0.05440495  0.05531183  0.05621870  0.05712558
 0.05803245  0.05916026  0.06028808  0.06141589  0.06254370  0.06367151  0.06479932  0.06592713  0.06705494  0.06818275
 0.06931057  0.07043838  0.07156619  0.07269400  0.07382181  0.07494962  0.07607743  0.07744450  0.07881156  0.08017863
 0.08154569  0.08291275  0.08427982  0.08564688  0.08701394  0.08838101  0.08974807  0.09111514  0.09248220  0.09384926
 0.09521633  0.09658339  0.09795046  0.09955582  0.10116119  0.10276656  0.10437192  0.10597729  0.10758266  0.10918802
 0.11079339  0.11239876  0.11400412  0.11560949  0.11721486  0.11882022  0.12042559  0.12203096  0.12363632  0.12545656
 0.12727680  0.12909705  0.13091729  0.13273753  0.13455777  0.13637801  0.13819825  0.14001849  0.14183873  0.14365897
 0.14547921  0.14729946  0.14911970  0.15093994  0.15276018  0.15472750  0.15669482  0.15866214  0.16062947  0.16259679
 0.16456411  0.16653143  0.16849875  0.17046607  0.17243340  0.17440072  0.17636804  0.17833536  0.18030268  0.18227001
 0.18423733  0.18624009  0.18824286  0.19024563  0.19224839  0.19425116  0.19625393  0.19825669  0.20025946  0.20226223
 0.20426499  0.20626776  0.20827053  0.21027329  0.21227606  0.21427883  0.21628159  0.21815846  0.22003532  0.22191218
 0.22378904  0.22566590  0.22754276  0.22941962  0.23129649  0.23317335  0.23505021  0.23692707  0.23880393  0.24068079
 0.24255765  0.24443452  0.24631138  0.24796823  0.24962508  0.25128193  0.25293878  0.25459563  0.25625249  0.25790934
 0.25956619  0.26100585  0.26244551  0.26388517  0.26532482  0.26676448  0.26820414  0.26964380  0.27108346  0.27225118
 0.27341889  0.27458661  0.27575433  0.27692205  0.27808977  0.27925748  0.28042520  0.28126066  0.28209611  0.28293156
 0.28376702  0.28460247  0.28543793  0.28627338  0.28710884  0.28755352  0.28799821  0.28844290  0.28888758  0.28933227
 0.28977696  0.29022164  0.29066633  0.29065837  0.29065041  0.29064245  0.29063450  0.29062654  0.29061858  0.29061062
 0.29060266  0.29007782  0.28955299  0.28902816  0.28850332  0.28797849  0.28745365  0.28692882  0.28640398  0.28531808
 0.28423218  0.28314627  0.28206037  0.28097447  0.27988857  0.27880267  0.27771676  0.27602649  0.27433621  0.27264593
 0.27095565  0.26926537  0.26757510  0.26588482  0.26419454  0.26188722  0.25957991  0.25727259  0.25496527  0.25265796
 0.25035064  0.24804333  0.24573601  0.24284785  0.23995968  0.23707152  0.23418336  0.23129520  0.22840703  0.22551887
 0.22263071  0.21922306  0.21581542  0.21240778  0.20900013  0.20559249  0.20218484  0.19877720  0.19536955  0.19166605
 0.18796256  0.18425906  0.18055556  0.17671364  0.17287171  0.16902979  0.16518787  0.16126043  0.15733299  0.15340555
 0.14947811  0.14552312  0.14156813  0.13761314  0.13365815  0.12973684  0.12581552  0.12189421  0.11797290  0.11414726
 0.11032163  0.10649600  0.10267036  0.09899218  0.09531400  0.09163581  0.08795763  0.08450809  0.08105855  0.07760900
 0.07415946  0.07096954  0.06777962  0.06458970  0.06139979  0.05851071  0.05562164  0.05273257  0.04984349  0.04728422
 0.04472494  0.04216566  0.03960638  0.03739233  0.03517828  0.03296422  0.03075017  0.02888272  0.02701527  0.02514783
```

0.02328038	0.02174770	0.02021502	0.01868234	0.01714966	0.01592979	0.01470992	0.01349005	0.01227018	0.01132501
0.01037983	0.00943465	0.00848947	0.00778570	0.00708193	0.00637816	0.00567439	0.00516859	0.00466280	0.00415700
0.00365120	0.00330195	0.00295270	0.00260345	0.00225420	0.00202329	0.00179239	0.00156148	0.00133058	0.00116728
0.00100397	0.00087595	0.00074794	0.00064899	0.00055005	0.00047446	0.00039888	0.00034200	0.00028513	0.00024296
0.00020079	0.00016999	0.00013920	0.00006960	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

END OF PRINTOUT FROM CALL 25 OF SUBROUTINE VAV6,

END OF PRINTOUT FROM CALL 26 OF SUBROUTINE VAV6,

FINAL PRINTOUT FROM MAIN PROGRAM,

J5CUTL0(I), I=1, 90

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	450	0	449	0	447	0
446	0	445	0	443	0	442	0	440	0
438	0	437	0	435	0	433	0	431	0
429	0	427	0	425	0	423	0	421	0
419	0	417	0	414	0	0	0	410	0
0	0	405	0	0	0	401	0	0	0
397	0	0	0	391	0	0	0	385	385

4DIST FCTNS REQUESTED, 4 DIST FCTNS SAVED,

450 INTEGRALS W(J5) OVER VARIABLE KX FOLLOW,

7.61274-003	7.83740-003	8.06206-003	8.28672-003	8.51138-003	8.73605-003	8.96071-003	9.18537-003	9.41003-003	9.63469-003
9.85935-003	1.00840-002	1.03087-002	1.05333-002	1.07580-002	1.09827-002	1.12073-002	1.15239-002	1.18405-002	1.21571-002
1.24737-002	1.27903-002	1.31069-002	1.34235-002	1.37401-002	1.40567-002	1.43733-002	1.46899-002	1.50065-002	1.53231-002
1.56396-002	1.59562-002	1.62728-002	1.67198-002	1.71667-002	1.76136-002	1.80605-002	1.85075-002	1.89544-002	1.94013-002
1.98482-002	2.02952-002	2.07421-002	2.11890-002	2.16359-002	2.20829-002	2.25298-002	2.29767-002	2.34236-002	2.40378-002
2.46520-002	2.52662-002	2.58804-002	2.64946-002	2.71088-002	2.77231-002	2.83373-002	2.89515-002	2.95657-002	3.01799-002
3.07941-002	3.14083-002	3.20225-002	3.26367-002	3.32509-002	3.40925-002	3.49341-002	3.57757-002	3.66172-002	3.74588-002
3.83004-002	3.91420-002	3.99836-002	4.08252-002	4.16668-002	4.25084-002	4.33500-002	4.41916-002	4.50332-002	4.58747-002
4.67163-002	4.78393-002	4.89624-002	5.00854-002	5.12084-002	5.23314-002	5.34544-002	5.45774-002	5.57004-002	5.68234-002
5.79465-002	5.90695-002	6.01925-002	6.13155-002	6.24385-002	6.35615-002	6.46845-002	6.61727-002	6.76745-002	6.91695-002
7.06645-002	7.21595-002	7.36544-002	7.51494-002	7.66444-002	7.81394-002	7.96344-002	8.11294-002	8.26243-002	8.41193-002
8.56143-002	8.71093-002	8.86043-002	9.05330-002	9.24617-002	9.43904-002	9.63191-002	9.82478-002	1.00177-001	1.02105-001
1.04034-001	1.05963-001	1.07891-001	1.09820-001	1.11749-001	1.13678-001	1.15606-001	1.17535-001	1.19464-001	1.21905-001
1.24345-001	1.26786-001	1.29227-001	1.31668-001	1.34109-001	1.36549-001	1.38990-001	1.41431-001	1.43872-001	1.46313-001
1.48754-001	1.51194-001	1.53635-001	1.56076-001	1.58517-001	1.61560-001	1.64604-001	1.67648-001	1.70692-001	1.73735-001
1.76779-001	1.79823-001	1.82866-001	1.85910-001	1.88954-001	1.91998-001	1.95041-001	1.98085-001	2.01129-001	2.04173-001
2.07216-001	2.10894-001	2.14572-001	2.18249-001	2.21927-001	2.25604-001	2.29282-001	2.32960-001	2.36638-001	2.40315-001
2.43993-001	2.47670-001	2.51348-001	2.55026-001	2.58703-001	2.62381-001	2.66059-001	2.70413-001	2.74769-001	2.79123-001
2.83477-001	2.87832-001	2.92187-001	2.96542-001	3.00897-001	3.05252-001	3.09606-001	3.13961-001	3.18316-001	3.22671-001
3.27025-001	3.31380-001	3.35735-001	3.40570-001	3.45404-001	3.50239-001	3.55074-001	3.59909-001	3.64744-001	3.69578-001

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3.74413-001	3.79499-001	3.84586-001	3.89672-001	3.94758-001	3.99844-001	4.04931-001	4.10017-001	4.15103-001	4.20543-001
4.25984-001	4.31424-001	4.36865-001	4.42305-001	4.47745-001	4.53186-001	4.58626-001	4.64238-001	4.69851-001	4.75463-001
4.81076-001	4.86688-001	4.92300-001	4.97913-001	5.03526-001	5.09330-001	5.15135-001	5.20939-001	5.26743-001	5.32548-001
5.38352-001	5.44158-001	5.49962-001	5.55862-001	5.61761-001	5.67661-001	5.73561-001	5.79460-001	5.85361-001	5.91260-001
5.97160-001	6.03137-001	6.09114-001	6.15091-001	6.21068-001	6.27046-001	6.33023-001	6.39001-001	6.44979-001	6.50893-001
6.56807-001	6.62722-001	6.68637-001	6.74552-001	6.80467-001	6.86382-001	6.92297-001	6.98115-001	7.03933-001	7.09752-001
7.15570-001	7.21388-001	7.27207-001	7.33025-001	7.38844-001	7.44390-001	7.49937-001	7.55483-001	7.61029-001	7.66576-001
7.72122-001	7.77669-001	7.83215-001	7.88502-001	7.93788-001	7.99075-001	8.04361-001	8.09647-001	8.14934-001	8.20220-001
8.25508-001	8.30296-001	8.35084-001	8.39871-001	8.44659-001	8.49447-001	8.54235-001	8.59026-001	8.63815-001	8.68105-001
8.72395-001	8.76685-001	8.80975-001	8.85052-001	8.89131-001	8.93209-001	8.97288-001	9.00933-001	9.04579-001	9.08222-001
9.11867-001	9.15406-001	9.18932-001	9.22454-001	9.25997-001	9.28961-001	9.31924-001	9.34888-001	9.38880-001	9.41479-001
9.44079-001	9.46680-001	9.49281-001	9.51494-001	9.53707-001	9.57959-001	9.60210-001	9.62074-001	9.63940-001	9.65808-001
9.67677-001	9.69144-001	9.71618-001	9.73107-001	9.74599-001	9.75715-001	9.76834-001	9.77955-001	9.79079-001	9.81801-001
9.82591-001	9.83384-001	9.84182-001	9.84665-001	9.85152-001	9.85645-001	9.87104-001	9.87367-001	9.87637-001	9.87913-001
9.88195-001	9.88316-001	9.88444-001	9.90436-001	9.90619-001	9.90659-001	9.90708-001	9.90768-001	9.90839-001	9.90811-001
9.91681-001	9.91698-001	9.91728-001	9.91683-001	9.91653-001	9.91638-001	9.91638-001	9.93235-001	9.93223-001	9.93242-001
9.93277-001	9.93267-001	9.93279-001	9.93316-001	9.94136-001	9.94180-001	9.94252-001	9.94356-001	9.94490-001	9.94603-001
9.94751-001	9.96203-001	9.96457-001	9.96700-001	9.96988-001	9.97267-001	9.97596-001	9.97901-001	9.98804-001	9.99230-001
9.99723-001	1.00016+000	1.00067+000	1.00121+000	1.00183+000	1.00242+000	1.00311+000	1.00377+000	1.00454+000	1.00530+000
1.00619+000	1.00696+000	1.00802+000	1.00896+000	1.01107+000	1.01213+000	1.01339+000	1.01457+000	1.01593+000	1.01730+000
1.01888+000	1.02033+000	1.02209+000	1.02383+000	1.02559+000	1.02751+000	1.02954+000	1.03177+000	1.03392+000	1.03625+000
1.03878+000	1.04128+000	1.04419+000	1.04708+000	1.05014+000	1.05345+000	1.05686+000	1.06057+000	1.06451+000	1.06858+000
1.07297+000	1.07771+000	1.08267+000	1.08799+000	1.09372+000	1.09983+000	1.10646+000	1.11356+000	1.12127+000	1.12952+000
1.13852+000	1.14852+000	1.15935+000	1.17145+000	1.18478+000	1.19949+000	1.21631+000	1.23511+000	1.25661+000	1.28161+000
1.31091+000	1.34582+000	1.38845+000	1.44162+000	1.51047+000	1.60386+000	1.74055+000	1.96050+000	2.33150+000	2.57807+000

AREAS OF PLOTTED DISTRIBUTION FUNCTIONS 1,ICOUNT

1.00000+000 1.00000+000 9.99982-001 9.90296-001

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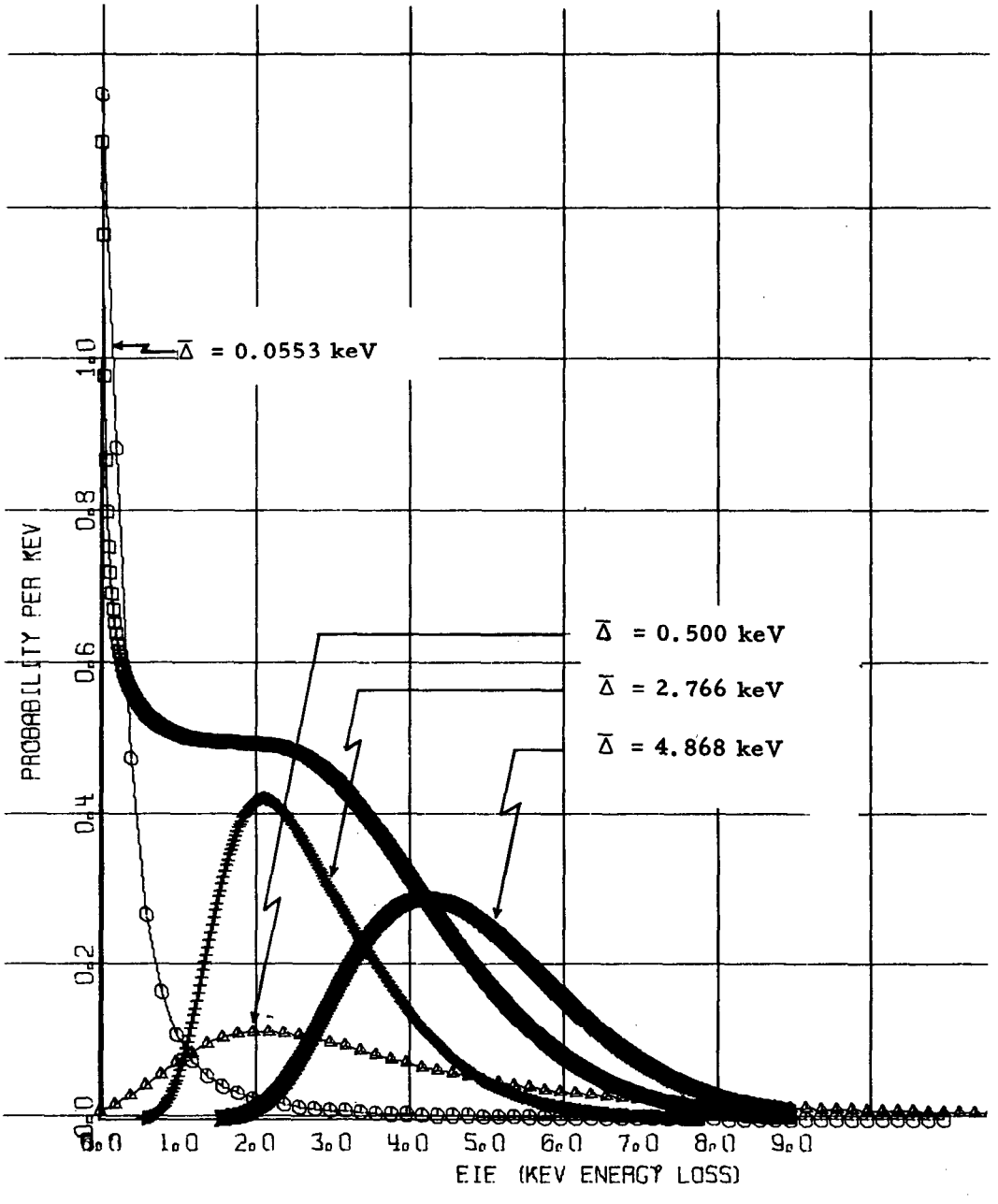

Fig. B1 - Plot by subroutine GRAPH5 for the 992-keV resonance in the $^{27}Al(p,\gamma)^{28}Si$ reaction. The target was 4.934 keV thick at resonance energy. The squares (Calcomp symbol 0) represent the integrals with respect to $\bar{\Delta}$. The four energy-loss distributions are labeled with their average energy loss and are represented by Calcomp symbols 1, 2, 3, and 4. Note that the first two distributions have scalefactors SFXLOW = 2.5 and SFYLOW = 0.03.

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Appendix C

NOMENCLATURE LIST FOR PROGRAM YIELD6

Names defined in program WINTGRL7 that have the same meaning in program YIELD6 will not be redefined here. All energies and energy intervals are in keV.

AGLC is the area under the free-space beam energy distribution GLC(L2).

AGLCD is the area under the interface beam energy distribution.

ASL (read from data if there is a surface layer) is the molecular weight of the target surface layer.

AWLC2 is the area under the interface energy loss distribution.

AYLD is the area under the yield function YLD(M).

BFWHM (read from data) is the full width at half maximum in keV of the beam energy distribution; it is assumed to be of Gaussian shape.

BW(100) is an array in which are stored the values which represent the cross-section function.

DEB1 (read from data) is the approximate value of the first NEB1 - 1 intervals between bombarding energies at which the yield is calculated. The exact value is adjusted to be the largest integral multiple of DEI that is equal to or less than the value of DEB1 stored in data.

DEB2 (read from data) is the size of the interval for bombarding energies between EB(NEB1) and EB(NEB2).

DEB3 (read from data) is the size of the interval for bombarding energies between EB(NEB2) and EB(NEB3).

E(200) is an array in which the values of energy (in keV) at which the cross section is defined are stored.

EB(100) (EB(1) is read from data) is the array in which the bombarding energies at which the yield is calculated are stored. These values are calculated so as to be members of the basic energy set. If EB(1) is not a member of the basic energy set, it will be recalculated to be so.

EBEXP(100) (read from data) is an array containing the values of bombarding energy (in keV) at which the yield was measured.

EBLØW is an energy 2*BFWHM below the current value of E(L). If EB(M) < EBLØW, there is a jump past the statements that cause integration over the beam energy distribution.

EBNRM (read from data) is a value of experimental bombarding energy lying within the range EB(NEB1) to EB(NEB2). The ordinates of the experimental yield curve are adjusted before plotting so that the areas under the experimental and calculated curves up to EBNRM are equal unless EBNRM = 0.0.

ENEW(200) is an array in which are stored energy values ENEW(L) = EB(M) - MDEI*DEI. Since MDEI = (EB(M) - E(L))/DEI, if EB(M) and E(L) belong to the basic set with interval DEI, ENEW(L) should be exactly equal to E(L). Therefore, a comparison of the two arrays provides a check on the condition that EB(M) and E(L) shall belong to the basic energy set. This array is printed if M = MPRINT1 or M = MPRINT2. And if LPRINT1 or LPRINT2 have appropriate values.

ER (read from data) is the resonance energy E_r in keV.

FLAG1 is set equal to 1.0 in subroutine G7 if the current value of EB(M) lies below the current value of E(L) by twice the full width at half maximum of the free-space beam energy distribution.

GAMMA (read from data) is the full width at half maximum Γ of the resonance.

GLC(2000) is an array in which the free-space beam energy distribution GLC(L2) is stored after being calculated in subprogram SETS5.

GLCD(5041) is an array in which the values representing the layer-target-interface beam energy distribution are stored.

J2A labels the value of loss required to degrade the most energetic particle in the beam energy distribution to the current value of E(L).

H(200) is an array in which the integrals with respect to the beam energy variable are stored.

HILØSSL (read from data if there is a surface layer) is the greatest loss in the surface layer which any beam particle will suffer with nonnegligible probability.

J2 is an integer variable which labels the set of losses spaced by interval DEI. J2 = 1 corresponds to HILØSS; J2 = J2MAX corresponds to zero loss.

J2MAX is the value of J2 corresponding to zero energy loss.

J2P is the value of J2 that corresponds to the loss necessary to degrade a particle of energy EB(M) to energy E. If EB(M) < E(L), this corresponds to a value of J2P > J2MAX and, therefore, to an energy gain. However, in integrating over the beam energy, only true energy losses are used.

KZERØLØS is the value of K corresponding to zero energy loss on the interface energy loss distribution; KZERELØS = (HILOSSL/DE) + 1. If KZERØLØS exceeds 2510, the program will stop and an abort message will be printed.

L2B is the value of L2 corresponding to the highest energy point on the free-space beam energy distribution GLC(L2). The lowest energy point corresponds to L2 = 1. If L2B exceeds 2000, the program will stop and an abort message will be printed.

L2F is the value of L2 corresponding to the smallest loss at which W(J5) is interpolated to obtain WINT(L2).

L2I is the value of L2 corresponding to the greatest loss at which W(J5) is interpolated to obtain WINT(L2).

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L2MAX is the number of values that will be calculated for the interface beam energy distribution. L2MAX = L2B + HILØSSL/DEI + 1. Thus, there will be as many values as there are in the free-space beam energy distribution plus the number required for the least energetic beam particle to be degraded by HILOSSL. L2MAX is calculated in SETS5. If L2MAX exceeds 5041, the program will stop and an abort message will be printed.

L2P is the value of L2 that corresponds to the peak of the free-space beam energy distribution GLC(L2).

LMX (read from data) is the number of values of E(L) and BW(L), if these are external functions read from data.

LMØX is the maximum value of L for internally generated functions E(L) and BW(L). If external functions are read from data (LMX > 0), LMØX is set equal to LMX.

LPNCH (read from data). If LPNCH = 1 ($\neq$1), the values of calculated yield will (will not) be punched on cards.

L2PP is the number of intervals of size DEI in half the total beam energy distribution.

LPRINT1 (read from data); if LPRINT1 = 1 certain L-dependent parameters are printed from subprogram G7 for the value of bombarding energy stored in EB(MPRINT1) and EB(MPRINT2).

LPRINT2 (read from data) has the same function as LPRINT1.

LRES (Read from data if BW(L) is an external function) is the value of L at resonance energy.

LSTØP is the maximum value of L for a particular M value. LSTØP is set equal to L in the main program just before YM4 is called.

MDEI is the number of units of size DEI by which the current value of EB(M) differs from the current value of E(L).

MPRINT1 (read from data) is a control constant which if set equal to some value of M will cause certain parameters to be printed from subroutine G7 when the bombarding energy is EB(M).

MPRINT2 (read from data) has the same function as MPRINT1.

NBW (read from data) determines the minimum energy interval for representations of E(L) and BW(L); the eight intervals on either side of resonance energy have size NBW*DEI.

NDE is the ratio DE/DEI rounded to the nearest whole number. DE is to be chosen as an integral multiple of DEI in program WINTGRL 7 and transmitted to program YIELD6 via punched cards. If DEI is not an integral submultiple of DE, it will be altered by the program to be such and a statement will be printed stating that DEI has been changed. NDE must be at least 2.

NEB1 (read from data) is the number of bombarding energies separated by interval DEB1.

NEB2 (read from data) is the sum of NEB1 and the number of bombarding energy increments of size DEB2. NEB2 must be at least one greater than NEB1.

NEB3 (read from data) is the sum of NEB1, NEB2, and the number of bombarding energy increments of size DEB3. NEB3 must be at least one greater than NEB2 + NEB1.

NEXP (read from data) is the number of pairs of experimental yield data.

NGAM (read from data) determines the energy range over which BW(L) will be represented when it is generated within the program. This range will lie between energy values NGAM*GAMMA and (NGAM + 1)*GAMMA keV.

NGRAPHA (read from data) is to be set equal to one (zero) if a plot of the calculated and experimental yield is (is not) desired.

NGRAPHB (read from data) is to be set equal to one (zero) if plots of the layer-target-interface energy loss distribution, the free-space beam energy distribution, and the interface beam energy distribution are (are not) desired.

NPRINT1 (read from data). If NPRINT1 = 1 ($\neq$1), a set of constants will (will not) be printed; see program listing.

NPRINT2 (read from data). If NPRINT2 = 1 ($\neq$1), certain arrays (see program listing) will (will not) be printed.

NPRINT3 (read from data). If NPRINT3 = 1 ($\neq$1), certain arrays (see program listing) will (will not) be printed.

NSLA (read from data) is to be set equal to one (zero) if there is (is not) an "active" layer on the front surface of the target, i.e., a layer which contributes to the yield. Prior to a calculation in which NSLA = 1, a separate calculation of the yield from the layer with the bombarding energies EB(M) must have been made with NPNCH = 1 to obtain data cards for the layer yield which are read when NSLA = 1.

NSLP (read from data) is to be set equal to one (zero) if there is (is not) a "passive" layer on the front surface of the target, i.e., a layer which broadens the beam energy distribution and reduces its average energy but which contributes nothing to the yield.

PMIN (read from data if there is a surface layer) is a value of the Landau lambda below which the value of the interface beam energy distribution will be negligible and will not be calculated.

SELSL (read from data if there is a surface layer) is the specific energy loss (at resonance energy) of the target surface layer in keV-cm^2/gram.

SFAX (read from data) is a scale factor (of order unity) governing the widths of the yield plots.

SFAY (read from data) is a scale factor (of order unity) governing the heights of the yield plots.

SFBX (read from data) is a scale factor (of order unity) governing the width of the plots by subroutine GRAPHB.

SFBY (read from data) is a scale factor (of order unity) governing the heights of the plots by subroutine GRAPHB and should not exceed unity.

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SFN (read from data) is a scale factor for plotting the experimental yield when EBNRM = 0.0 in data. If EBNRM $\neq$ 0.0, SFN is computed internally (see EBNRM). The experimental yield curve is plotted according to YX = YEXP(N) *SFAY*SFN*6.0, where YX is the ordinate height in inches.

ZSL (read from data if there is a surface layer) is the equivalent number of free electrons per molecule which has the same effective stopping power as the number of bound electrons per molecule of the surface layer on the target.

SLT (read from data if there is a surface layer) is the thickness of the target surface layer in keV (at resonance energy).

WINT (6000) is an array in which the current interpolated values of the W function are stored.

YEXP (100) (read from data) is an array in which the values of experimental yield are stored. The units are arbitrary since the values are adjusted so that the areas under the experimental and calculated yield plots will be equal out to EBNRM.

YLDFAC (read from data) is a factor which takes into account the fact that the number of atoms per cm^3 in a surface layer which contributes to the yield may be different from the same quantity for the target proper. This factor is to be calculated as follows:

$$\text{YLDFAC} = \frac{\text{F (layer)}}{\text{F (target)}} * \frac{\text{A (target)}}{\text{ASL (layer)}} * \frac{\text{SEL (target)}}{\text{SELSL (layer)}} ,$$

where F is the fraction of atoms per molecule that contribute to the yield; A and ASL are molecular weights; SEL and SELSL are specific energy loss values.

YSL(100) (read from data if NSLA = 1) is an array containing the values of yield of the surface layer, if any. If NSLA = 1, these values will be added to the yield of the target proper.

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Appendix D
LISTING OF PROGRAM YIELD6 AND SAMPLE RUN

```
      PROGRAM YIELD6
      TYPE INTEGER FLAG1
      COMMON/A/NSLA,NSLP,BFWHM,HILOSS,PMIN,HILOSSL,JSTOP
      COMMON/B/ ER,GAMMA,DEB1,NEB1,DEB2,NEB2,DEB3,NEB3,ERNRM,MTOP,NBW
      COMMON/C/YSL(100),W(1700),NEXP,EREXP(100),YEXP(100),M,L,H(200)
      COMMON/E/SFAX,SFAY,SFBX,SFBY,PLTARRAY(255 ),LPRINT2,SFN
      COMMON/F/DE,NDE,DEI,L2P,L2R,GEMAX,LPRINT1,A7,TT,YLDFAC,LMOX,LRES
      COMMON/H/L2PP,J2MAX,AGLC,AGLCD,AWLC2,FLAG1,LSTOP
      COMMON/K/SLT,SELSL,ZSL,ASL,BSQ,A10
      COMMON/L/WLC2(2510),NCOMP,LCOMP,LCOUNT,LCOUNT2,SLO,DYFAC
      COMMON/1/EB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
      COMMON/2/GLC(2000),GLCD(5041), ENEW(200),L2MAX ,LMX
      COMMON/3/WINT(6000),Y(2400),KZEROLOS
C
    1 FORMAT(1X,9F8.5,F7.4)
    2 FORMAT(1H0)
    4 FORMAT(1H1)
    6 FORMAT(*
     2                 *)
    7 FORMAT(*
     2                 *)
    8 FORMAT(4F10.3,4I10)
    9 FORMAT(10F10.4)
   10 FORMAT(3(F10.4,I10))
   11 FORMAT(10F12.6)
   12 FORMAT(8I10)
   14 FORMAT(10F8.5)
   15 FORMAT(5F10.3,F10.5,F10.3)
   16 FORMAT(I3)
   18 FORMAT(4(I3,F9.2,F8.2))
   19 FORMAT(3I5,5F12.6)
   20 FORMAT( * NPRINT1=*,I2,10X,*NPRINT2=*,I2,10X,*NPRINT3=*,I2,10X,
     2*LPNCH=*,I2)
   21 FORMAT(/* ER=*,E12.5,5X,*GAMMA=*,E12.5,2X,*BFWHM=*,E12.5)
   22 FORMAT( * NGRAPHA=*,I2,10X,*SFAX=*,F4.2,11X,*SFAY=*,F4.2,11X,
     2*NBW=*,I5)
   24 FORMAT( * NGRAPHB=*,I2,10X,*SFBX=*,F4.2,11X,*SFBY=*,F4.2,11X,
     2*NGAM=*,I5)
   26 FORMAT( * NSLA=*,I2,13X,*NSLP=*,I2,13X,*L2MAX=*,I4,10X,*KZEROLOS=*
     2I4)
   28 FORMAT( * EB(1)=*,F10.4,4X,*DEB1=*,F7.4,8X,*NEB1=*,I3,12X,*LMX=*,
     2I4)
   29 FORMAT(/* DE=*,E12.5,5X,*DEI=*,E12.5,4X,*PMIN=*,F6.2,9X,*NDE=*,I2)
   30 FORMAT( * DEB2=*,F7.4,8X,*NEB2=*,I3,12X,*DEB3=*,F7.4, 8X,*NEB3=*,
     2I3)
   32 FORMAT( * MPRINT1=*,I2,10X,*MPRINT2=*,I2,10X,*LPRINT1=*,I2,10X,
     2*LPRINT2=*,I2)
```

```
   40 FORMAT( * J3STOP=*,I4,9X,*KMAX=*I4,11X,*IMAX=*,I4,11X,*LMOX=*,I5)
   41 FORMAT( * L2P=*I4,12X,*L2B=*,I4,12X,*J2MAX=*,I4,10X,*EBNRM=*,F8,2)
   42 FORMAT(/* Z=*,F6,2,12X,*ZIP=*,F4,1)
   44 FORMAT( * TT=*,F8,4,9X,*A=*,F9,4,9X,*SEL=*,E12.5,4X,*LRES=*,I5)
   46 FORMAT( * GEMAX=*,E12.5)
   47 FORMAT( * ZSL=*,F6,2,10X,*ASL=*,F10,5,6X,*SLO=*,F10,5)
   48 FORMAT( * SLT=*,F6,3,10X,*SELSL=*,F10,2,4X,*HILOSSL=*,F5,2)
   49 FORMAT( * BSO=*,F8,5,8X,*A7=*F10,2,7X,*DYFAC=*,F10.5,4X,*HILOSS=
     2*,F7,3,6X,*YLDFAC=*,F6,3)
   50 FORMAT(/* NEXP=*,I4,10X,*N,EBEXP(N), YEXP(N), N=1,NEXP*)
   52 FORMAT(/* YSL(M), M=1,MTOP*)
   54 FORMAT(/* W(J5), J5=1,J3STOP*)
   55 FORMAT(/* E(L),  L=1,LMOX*)
   57 FORMAT (/* EBL(L2), 1,L2B*)
   58 FORMAT(/* EB(M), M=1,MTOP*)
   60 FORMAT(/* BW(L), L=1,LMOX*)
   62 FORMAT(/* GLC(L2), L2=1,L2B*)
   64 FORMAT(/* GLCD(L2),L2=1,L2MAX*)
   80 FORMAT(/* YLD(M) ,  M=1,100*)
   82 FORMAT( *     VALUES OF SURFACE LAYER YIELD, YSL(L), FOLLOW.*)
   86 FORMAT(/* WLC2(KCOMP),  KCOMP=1,KZEROLOS*)
   87 FORMAT(* LCOUNT=*,I6,7X,*LCOMP=*I5,8X,*NCOMP=*,I6,8X,*LCOUNT2=*I6)
   88 FORMAT( * AGLC=*F10,7,5X,*AGLCD=*,F10,7,4X,*AWLC2=*,F10,7,4X,
     2*AYLD=*,F10,7)
   90 FORMAT(/* KZEROLOS EXCEEDS 2510, ARRAY WLC2 WILL OVERFLOW, ABORT*)
   92 FORMAT(* DEI HAS BEEN CHANGED TO *,F7,4)
   94 FORMAT(6E12,5)
C
C     FIRST TWO DATA CARDS CONTAIN COMMENTS,
C
  102 READ(60,6)
  103 READ(60,7)
  104 READ(60,12) NPRINT1,NPRINT2,NPRINT3,NGRAPHA,NGRAPHB,NSLA,NSLP
  105 READ(60,12) MPRINT1,MPRINT2,LPRINT1,LPRINT2,LPNCW
  106 READ(60,10) DEB1,NEB1,DEB2,NEB2,DEB3,NEB3
  107 READ(60,9) EBNRM,SFN,YLDFAC
      MTOP=NEB3
  108 IF(NSLP.EQ.1) GO TO 109 $ IF(NSLA.EQ.1) GO TO 109 $ GO TO 114
C
C     READ YIELD AND CONSTANTS FOR SURFACE LAYER, IF ANY.
C
  109 READ(60,9) ZSL,ASL,SLT,SELSL,HILOSSL,SLO,PMIN
  110 READ(60,12) LCOUNT,LCOMP,NCOMP,LCOUNT2
  111 IF(NSLA.NE.1)GO TO 114
  112 READ(60,14) (YSL(M),M=1,MTOP)
C
C     READ CONSTANTS FROM WINTGRAL7,
C
  114 READ(60,15) Z,ZIP,A,TT,SEL,DYFAC,HILOSS
  115 READ(60,19) IMAX,J3STOP,KMAX,DE,DEI,BSO,GEMAX,A7
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```
C
C     READ INTEGRALS W(J5) FROM WINTGRL7.
C
  116 READ(60,14) (W(J5),J5=1,J3STOP)
C
C
C     READ EXPERIMENTAL YIELD DATA.
C
  122 READ(60,16) NEXP
  124 READ(60,18) (N,EBEXP(N),YEXP(N),N=1,NEXP)
  126 READ(60,8)  SFAX,SFAY,SFBX,SFBY
  128 READ(60,8) ER,GAMMA,BFWHM,EB(1),N3W,NGAM,LMX,LRES
  132 IF(LMX.GT.0) 134,138
  134 READ(60,94)(E(L), L=1,LMX)
  136 READ(60,94)(BW(L), L=1,LMX)
  138 LMOX=LMX $ GO TO 182
C
C     COMPUTE CONSTANTS
C
  182 NN=DEB1/DEI  $ DEB1=NN*DEI
  183 NN=DEB2/DEI  $ DEB2=NN*DEI
  184 NN=DEB3/DEI  $ DEB3=NN*DEI
  185 NN=(ER-EB(1))/DEI $ EB(1)=ER-NN*DEI
  188 NN=HILOSSL/DE  $ HILOSSL=NN*DE
  190 KZEROLOS=NN+1
  192 IF((NSLA.EQ.1.OR.NSLP.EQ.1).AND.KZEROLOS.GT.2510) 194,202
  194 WRITE(61,90) $ STOP
  202 NDE=DE/DEI $ RNDE=DE/DEI $ DIF=RNDE-NDE
  203 IF(DIF.LT.0.5) GO TO 205 $ NDE=NDE+1
  205 IF(DIF.EQ.0.0) 210,206
  206 DEI=DE/NDE $ WRITE(61,92) DEI
  210 J2MAX=(J3STOP-1)*NDE+1
C
  251 CALL SETS5
  255 IF(NSLP.EQ.1) GO TO 274
  258 IF(NSLA.EQ.1) GO TO 274
  272 GO TO 300
  274 CALL BEAM1
C
C     CALCULATE YIELD
C
  300 M=1
  302 L=1
  304 CALL G7
  312 IF(FLAG1.EQ.1) GO TO 318
  314 IF(L-LMOX)316,318,318
  316 L=L+1 $ GO TO 304
  318 LSTOP=L $ CALL YM4 $ IF(NSLA.EQ.1) YLD(M)=YLD(M)+YSL(M)
  320 IF(M-MTOP) 322,350,350
```

```
  322 M=M+1
  324 DO 326 L=1,93
  326 ENEW(L)=0.0
  328 GO TO 302
C
C     COMPUTE AREA UNDER YIELD CURVE
C
  350 MI=1 $ MF=NEB1 $ BIN=DEB1 $ AYLD=0.0 $ ASSIGN 380 TO NEXT
  355 YSM=(YLD(MI)+YLD(MF)) *BIN/2.0 $ AYLD=AYLD+YSM $ YSM=0.0 $ M=MI
  365 M=M +1 $ IF(M.LT.MF)370,375
  370 YSM=YSM+YLD(M) $ GO TO 365
  375 AYLD=AYLD+YSM*BIN $ GO TO NEXT,(380,390,400)
  380 MI=NEB1 $ MF=NEB2 $ BIN=DEB2 $ ASSIGN 390 TO NEXT $ GO TO 355
  390 MI=NEB2 $ MF=NEB3 $ BIN=DEB3 $ ASSIGN 400 TO NEXT $ GO TO 355
C
C     WRITE.
C
  400 WRITE(61,2) $ WRITE(61,6) $ WRITE(61,7)
  402 WRITE(61,21) ER,GAMMA,BFWHM
  403 IF(NPRINT1.NE.1) GO TO 500
  404 WRITE(61,20) NPRINT1,NPRINT2,NPRINT3,LPNCH
  405 WRITE(61,22) NGRAPHA,SFAX,SFAY,NBW
  406 WRITE(61,24) NGRAPHB,SFBX,SFBY,NGAM
  408 WRITE(61,26) NSLA,NSLP,L2MAX,KZEROLOS
  409 WRITE(61,29) DE,DEI,PMIN,NDE
  410 WRITE(61,28) EB(1),DEB1,NEB1,LMX
  412 WRITE(61,30)  DEB2,NEB2,DEB3,NEB3
  414 WRITE(61,32) MPRINT1,MPRINT2,LPRINT1,LPRINT2
  420 WRITE(61,40) J3STOP,KMAX,IMAX,LMOX
  421 WRITE(61,41) L2P,L2B,J2MAX,EBNRM
  422 WRITE(61,42) Z,ZIP
  424 WRITE(61,44) TT,A,SEL,LRES
  426 WRITE(61,46) GEMAX
  427 WRITE(61,47) ZSL,ASL,SLO
  428 WRITE(61,48) SLT,SELSL,HILOSSL
  429 WRITE(61,49) BSO,A7 ,DYFAC,HILOSS,YLDFAC
  430 WRITE(61,87) LCOUNT,LCOMP,NCOMP,LCOUNT2
  432 WRITE(61,88) AGLC,AGLCD,AWLC2,AYLD
  500 IF(NPRINT2.NE.1) GO TO 525
  501 WRITE(61,50) NEXP
  502 WRITE(61,18) (N,EBEXP(N),YEXP(N), N=1,NEXP)
  504 IF(NSLA.NE.1) GO TO 510
  506 WRITE(61,52)
  508 WRITE(61,11) (YSL(M), M=1,MTOP)
  510 WRITE(61,54)
  512 WRITE(61,14) (W(J5),J5=1,J3STOP)
  525 IF(NPRINT3.NE.1) GO TO 604
  530 WRITE(61,55) $ WRITE(61,9) (E(L), L=1,LMOX)
  532 WRITE(61,58)
  534 WRITE(61, 9) (EB(M), M=1,MTOP)
```

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```
538 WRITE(61,60)
539 WRITE(61,11) (BW(L), L=1,LMOX)
540 WRITE(61,62)
542 WRITE(61,11) (GLC(L2), L2=1,L2B)
550 IF(NSLA.EQ.1) GO TO 553
552 IF(NSLP.NE.1) GO TO 604
553 WRITE(61,64)
554 WRITE(61,11) (GLCD(L3), L3=1,L2MAX)
556 WRITE (61,86) $ WRITE(61,9) (WLC2(K),K=1,KZEROLOS)
604 WRITE(61,80)
606 WRITE(61,14) (YLD(M), M=1,100)
700 IF(LPNCH.NE.1) GO TO 750
702 WRITE(62,82)
704 WRITE(62,14) (YLD(M), M=1,MTOP)
750 IF(NGRAPHA.NE.1) GO TO 800 $ CALL GRAPHA
800 IF(NGRAPHB.NE.1) GO TO 810 $ CALL GRAPHB
810 CALL STOPPLOT
    END


    SUBROUTINE SETS5
    COMMON/A/NSLA,NSLP,BFWHM,HILOSS,PMIN,HILOSSL,J3STOP
    COMMON/B/ ER,GAMMA,DEB1,NEB1,DEB2,NEB2,DEB3,NEB3,ERNRM,MTOP,NBW
    COMMON/C/YSL(100),W(1700),NEXP,EBEXP(100),YEXP(100),M,L,H(200)
    COMMON/E/SFAX,SFAY,SFBX,SFBY,PLTARRAY(255 ),LPRINT2,SFN
    COMMON/F/DE,NDE,DEI,L2P,L2B,GEMAX,LPRINT1,A7,TT,YLDFAC,LMOX,LRES
    COMMON/H/L2PP,J2MAX,AGLC,AGLCD,AWLC2,FLAG1,LSTOP
    COMMON/1/EB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
    COMMON/2/GLC(2000),GLCD(5041), ENEW(200),L2MAX ,LMX
    COMMON/3/WINT(6000),Y(2400),KZEROLOS
  2 FORMAT(//* FROM SETS5,  L2P=*,I5,11X,*L2PP=*,I5,10X,*L2B=*,I5)
  3 FORMAT(/* BEAM ENERGY DIST EXCEEDS SIZE OF GLC(2000).  ABORT,*)
  4 FORMAT(/* BEAM ENERGY DIST EXCEEDS SIZE OF GLCD(5041).  ABORT,*)
  5 FORMAT(/* LMOX EXCEEDS 200. ABORT*)
C
C     GENERATE ARRAY EB(M).  NEB2 MUST BE ONE GREATER THAN NEB1 AND
C     NEB3 MUST BE AT LEAST ONE GREATER THAN NEB3.
C
 20 EBS=EB(1) $ MI=1 $ MF=NEB1 $ DEB=DEB1 $ ASSIGN 30 TO NEXT
 24 DO 26 M=MI,MF
 26 EB(M)=EBS+(M-MI)*DEB
 28 GO TO NEXT,(30,34,36)
 30 EBS=EB(NEB1)+DEB2 $ MI=NEB1+1 $ MF=NEB2 $ DEB=DEB2
 32 ASSIGN 34 TO NEXT $ GO TO 24
 34 EBS=EB(NEB2)+DEB3 $ MI=NEB2+1 $ MF=NEB3 $ DEB=DEB3
 35 ASSIGN 36 TO NEXT $ GO TO 24
 36 CONTINUE
```

```
C
C     GENERATE GAUSSIAN BEAM DISTRIBUTION.
C
   40 L2P=(2.0*BFWHM)/DEI $ L2PP=L2P-1 $ L2B=L2P+L2PP
   41 SIGB=BFWHM/(2.0*1.177) $ B7=1.0/(SIGB*SQRTF(2.0*3.1416))
   42 IF(L2B.GT.2000) 44,46
   44 WRITE(61,3) $ STOP
   46 L2MAX=L2B+HILOSSL/DEI+1$ EBLL2P=(L2P-1)*DEI $ A8=2.0*SIGB**2
   48 IF((NSLA.EQ.1.OR.NSLP.EQ.1).AND.L2MAX.GT.5041)49,52
   49 WRITE(61,4) $ STOP
   52 DO 60 L2=1,L2B
   54 EBL= (L2-1)*DEI $ VARB=(EBL-EBLL2P)**2
   56 GLC(L2)=B7*EXPF(-(VARB/A8))
   60 CONTINUE
   62 SUM=0.0
   64 DO 66 L2= 1,L2B
   66 SUM=SUM+GLC(L2)
   68 AGLC=SUM*DEI
   70 IF(LMX.GT.0) 160,100
C
C     GENERATE ARRAYS E(L) AND BW(L).
C
C     GENERATE UPPER HALF OF ARRAY E( ) AND STORE IN LOWER HALF.
C
  100 K=1 $ E(K)=ER $ KI=2 $ KF=9 $ D=NBW*DEI $ EMAX=ER+NGAM*GAMMA
  102 DO 104 K=KI,KF
  104 E(K)=E(K-1)+D
  108 KFSV=KF $ D=2.0*D $ KI=KF+1 $ KF=KI+7
  109 IF(E(KFSV)-EMAX) 102,110,110
C
C     TRANSFER TO UPPER HALF.
C
  110 LRES=KFSV $ LMOX=2*LRES-1 $ IF(LMOX.GT.200) 111,112
  111 WRITE(61,5) $ STOP
  112 DO 116 K=2,LRES
  114 L=LRES+K-1
  116 E(L)=E(K)
  118 E(LRES)=ER
C
C     GENERATE LOWER HALF OF E( )
C
  120 KF=LRES-1
  122 DO 124 K=1,KF
  124 E(LRES-K)=2.0*ER-E(LRES+K)
C
C     GENERATE BW(L)
C
  150 C7=GAMMA/(2.0*3.1416) $ A9=GAMMA**2/4.0
  152 DO 154 L=1,LMOX
  154 BW(L)=C7/((E(L)-ER)**2+A9)
  160 WRITE(61,2)L2P,L2PP,L2B
      END
```

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      SUBROUTINE TRIGEX(X,SI,CI)
      X2=X*X
      IF (X2-100.0) 10,40,40
   10 SI=0.0
      CI=0.57721566+0.5*LOGF(X2)
      T=X
      A=1.0
   20 SI=SI+T
      A=A+1.0
      T=-T*(X*(A-1.0)/(A**2))
      IF(ABSF(T)-(1.0E-09))80,30,30
   30 CI=CI+T
      A=A+1.0
      T=T*(X*(A-1.0)/(A**2))
      IF(ABSF(T)-(1.0E-09))80,20,20
   40 AMAX=0.5*(X+1.0)
      P=1.0
      Q=0.0
      S=1.0/X
      A=1.0
   50 Q=Q+S
      A=A+1.0
      IF(A-AMAX)60,60,70
   60 S=-S*(A/X)
      P=P+S
      IF (ABSF(S)-(1.0E-12)) 70,62,62
   62 A=A+1.0
      IF(A-AMAX)65,65,70
   65 S=S*(A/X)
      GO TO 50
   70 CX=COSF(X)/X
      SX=SINF(X)/X
      SI=1.5707963-P*CX-Q*SX
      CI=P*SX-Q*CX
   80 RETURN
      END
```

```
      SUBROUTINE G7
      TYPE INTEGER FLAG1
      COMMON/A/NSLA,NSLP,BFWHM,HILOSS,PMIN,HILOSSL,J3STOP
      COMMON/B/ ER,GAMMA,DEB1,NEB1,DEB2,NEB2,DEB3,NEB3,ERNRM,MTOP,NBW
      COMMON/C/YSL(100),W(1700),NEXP,EBEXP(100),YEXP(100),M,L,H(200)
      COMMON/E/SFAX,SFAY,SFBX,SFBY,PLTARRAY(255 ),LPRINT2,SFN
      COMMON/F/DE,NDE,DEI,L2P,L2B,GEMAX,LPRINT1,A7,TT,YLDFAC,LMOX,LRES
      COMMON/H/L2PP,J2MAX,AGLC,AGLCD,AWLC2,FLAG1,LSTOP
      COMMON/K/SLT,SELSL,ZSL,ASL,BSQ,A10
      COMMON/1/EB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
      COMMON/2/GLC(2000),GLCD(5041), ENEW(200),L2MAX ,LMX
      COMMON/3/WINT(6000),Y(2400),KZERO_OS
    4 L2I=0 $ L2F=0 $ MDEI=0 $ J2AA=0 $ J5A=0
    5 FLAG1=0 $ EBLOW=E(L)-2.0*BFWHM
C
C     IF EB(M) LIES BELOW EBLOW, CONTRIBUTIONS FROM ALL BEAM PARTICLES
C     ARE NEGLIGIBLE.
C
   12 IF(EB(M)-E(L)) 30,50,60
   30 IF(EB(M).GT.EBLOW) GO TO 32 $ FLAG1=1 $ GO TO 500
C
C     CASE WHERE EB(M) LIES BETWEEN EBLOW AND E(L).
C
   32 MDEI=(E(L)-EB(M))/DEI $ RDEI=E(L)-EB(M) $ DF=RDEI-MDEI
   34 IF(DF.GT.0.5) MDEI=MDEI+1 $ ENEW(L)=EB(M)+MDEI*DEI
   36 J2P=J2MAX+MDEI $ J2A=J2P-L2PP $ L2F=L2P-MDEI $ GO TO 140
C
C     CASE WHERE EB(M)=E(L)
C
   50 ENEW(L)=E(L) $ J2P=J2MAX $ J2A=J2MAX-L2PP $ L2F=L2P $ GO TO 140
C
C     CASE WHERE EB(M) LIES ABOVE E(L).
C
   60 MDEI=(EB(M)-E(L))/DEI $ RDEI=(EB(M)-E(L))/DEI $ DF=RDEI-MDEI
   62 IF(DF.GT.0.5) MDEI=MDEI+1 $  ENEW(L)=EB(M)-MDEI*DEI
C
   70 IF(NSLA.EQ.1) GO TO 80 $ GO TO 72
   72 IF(NSLP.EQ.1) GO TO 80
   74 IF(MDEI.LT.L2PP) GO TO 90 $ J2P=J2MAX-MDEI $ J2A=J2P-L2PP $L2F=L2B
   76 GO TO 140
   80 LIM2=L2MAX-L2PP $ IF(MDEI.LT.LIM2) GO TO 90
   84 J2P=J2MAX-MDEI $ J2A=J2P-L2PP $ L2F=L2MAX $ GO TO 140
   90 J2P=J2MAX-MDEI $ J2A=J2P-L2PP $ L2F=L2P +MDEI $ GO TO 140
C
C     INTERPOLATE W(J5) TO GET WINT(L2).
C
  140 IF(J2A.LT.1) 142,144
  142 L2I=-J2A+2 $ IF(L2I.GT.L2MAX)GO TO 500 $ J2A=1 $ GO TO 146
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  144 L2I=1
  146 J5A=(J2A-1)/NDE+1 $ IF(J5A.GT.J3STOP) GO TO 500
  148 J2AA=(J5A-1)*NDE+1 $ J5=J5A
  150 L2=L2I $ J2=J2A $ J2TEST=J5*NDE+1
  153 DW=(W(J5+1)-W(J5))/NDE
  154 WINT(L2)=W(J5)+DW*(J2-J2AA)$ L2=L2+1 $ J2=J2+1
  156 IF(J2.EQ.J2TEST) GO TO 160 $ GO TO 154
  160 J5=J5+1 $ WINT(L2)=W(J5)
  170 IF(J5.EQ.J3STOP)172,174
  172 L2F=L2 $ GO TO 200
  174 L2=L2+1 $ J2=J2+1 $ J2TEST=J2TEST+NDE
  175 IF(L2.GT.L2F) GO TO 200
  176 DW=(W(J5+1)-W(J5)) /NDE
  178 WINT(L2)=W(J5) +DW*(J2-J2TEST+NDE) $ L2=L2+1 $ J2=J2+1
  180 IF(J2-J2TEST) 178,160,160
C
C     INTEGRATE GLCD(L2)*WINT(L2) OR GLC(L2)*WINT(L2) OVER THE RANGE OF
C     INTERSECTION. USE SIMPSONS RULE.
C
  200 NBINS=L2F-L2I $ NODD=NBINS-(NBINS/2)*2  $ IF(NSLA.EQ.1.OR.
     2 NSLP.EQ.1) 201,212
  201 IF(NODD) 202,202,206
  202 SUM=0.0 $ L2S=L2I+1 $ L2HALT=L2F-1
  203 DO 204 L2=L2S,L2HALT,2
  204 SUM=SUM+GLCD(L2-1)*WINT(L2-1)+4.0*GLCD(L2)*WINT(L2)+GLCD(L2+1)*
     2WINT(L2+1)
  205 H(L)=SUM*DEI/3.0 $ GO TO 500
  206 SUM=0.0 $ L2S=L2I+1 $ L2HALT=L2F-2
  207 DO 208 L2=L2S,L2HALT,2
  208 SUM=SUM+GLCD(L2-1)*WINT(L2-1)+4.0*GLCD(L2)*WINT(L2)+GLCD(L2+1)*
     2WINT(L2+1)
  209 H(L)=SUM*DEI/3.0
  210 H(L)=H(L)+(GLCD(L2F-1)*WINT(L2F-1)+GLCD(L2F)*WINT(L2F))*DEI/2.0
  211 GO TO 500
  212 SUM=0.0 $ L2S=L2I+1 $ L2HALT=L2F-1 $ IF(NODD) 213,213,216
  213 DO 214 L2=L2S,L2HALT,2
  214 SUM=SUM+GLC(L2-1)*WINT(L2-1)+4.0*GLC(L2)*WINT(L2)+GLC(L2+1)*WINT
     2(L2+1)
  215 H(L)=SUM*DEI/3.0 $ GO TO 500
  216 SUM=0.0 $ L2S=L2I+1 $ L2HALT=L2F-2
  217 DO 218 L2=L2S,L2HALT,2
  218 SUM=SUM+GLC(L2-1)*WINT(L2-1)+4.0*GLC(L2)*WINT(L2)+GLC(L2+1)*WINT
     2(L2+1)
  219 H(L)=SUM*DEI/3.0
  220 H(L)=H(L)+(GLC(L2F-1)*WINT(L2F-1)+GLC(L2F)*WINT(L2F))*DEI/2.0

  500 IF(M.EQ.MPRINT1) GO TO 510
  505 IF(M.NE.MPRINT2) GO TO 800
  510 IF(L.EQ.LPRINT1) GO TO 520
  515 IF(L.NE.LPRINT2) GO TO 800
```

```
520 WRITE(61,604) M,L,FLAG1,LSTOP
522 WRITE(61,606)  EBLOW,J2P,J2MAX
524 WRITE(61,608) MDEI
526 WRITE(61,610) L2B,L2I,L2F,H(L)
528 WRITE(61,612) E(L),EB(M),ENEW(L)
531 WRITE (61,614)M $ WRITE(61,622) (ENEW(LT), LT=1,100)
600 FORMAT(1H0)
602 FORMAT(1H1)
604 FORMAT(/* M=*,I4,14X,*L=*,I4,14X,*FLAG1=*,I2,12X,*LSTOP=*,I4)
606 FORMAT( * EBLOW=*,E12.5,2X,*J2P=*,I5,11X,*J2MAX=*,I5)
608 FORMAT( * MDEI=*,I5)
610 FORMAT( * L2B=*,I5,11X,*L2I=*,I5,11X,*L2F=*,I5,5X,*H(L)=*,F10.7)
612 FORMAT( * E(L)=*,F10.4,5X,*EB(M)=*,F10.4,4X,*ENEW(L)=*,F10.4)
614 FORMAT(/* ENEW(L), L=1,100            M=*,I4)
615 FORMAT(/ 50X,*FROM G7,  L2MAX=*,I10)
616 WRITE(61,615) L2MAX
622 FORMAT(10F12.4)
628 FORMAT(10F10.5)
800 END
```

```
      SUBROUTINE BEAM1
      TYPE REAL KX2L
      COMMON/A/NSLA,NSLP,BFWHM,HILOSS,PMIN,HILOSSL,J3STOP
      COMMON/B/ ER,GAMMA,DEB1,NEB1,DEB2,NEB2,DEB3,NEB3,ERNRM,MTOP,NBW
      COMMON/C/YSL(100),W(1700),NEXP,EBEXP(100),YEXP(100),M,L,H(200)
      COMMON/E/SFAX,SFAY,SFBX,SFBY,PLTARRAY(255 ),LPRINT2,SFN
      COMMON/F/DE,NDE,DEI,L2P,L2B,GEMAX,LPRINT1,A7,TT,YLDFAC,LMOX,LRES
      COMMON/H/L2PP,J2MAX,AGLC,AGLCD,AWLC2,FLAG1,LSTOP
      COMMON/K/SLT,SELSL,ZSL,ASL,BSQ,A10
      COMMON/L/WLC2(2510),NCOMP,LCOMP,LCOUNT,LCOUNT2,SLO,DYFAC
      COMMON/1/FB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
      COMMON/2/GLC(2000),GLCD(5041), ENEW(200),L2MAX ,LMX
      COMMON/3/WINT(6000),Y(2400),KZEROLOS
      DIMENSION F1F(2400),F2F(2400),FAC1(2400),PV(2510),SUM(2510),
     2FAC2(2400),FAC3(2400),G(2400),MAXT(2510),S(1300),ST(2400)
      EQUIVALENCE (GLCD,F1F),(WINT,F2F)
   25 Y(1)=0.0 $ S(1)=0.0 $ LMAX=2400 $ MAXY=0 $ MAXB=0 $ COMP=0.00001
   28 KX2L=SELSL/(A7*ZSL/ASL) $ D=SLT/(KX2L*GEMAX)
   29 DY=(DYFAC/D)*SQRTF(SLT/DE)
   30 B1= SLT/GEMAX+D*(1+BSQ-0.5772157) $ B2=LOGF(D)
   31 DO 32 K=1,KZEROLOS
   32 PV(K)=(KZEROLOS-K)*DE /GEMAX-B1
  148 G(1)=EXPF(-D*(1.0+0.5772157*BSQ))
      C=D*DY/(3.0*3.141593*G(1))
  150  DO 300 K=1,KZEROLOS
  151 P=PV(K)/D-B2       $ IF(P.LT.PMIN) GO TO 286
  180 NCOUNT=0 $ MCOUNT=0 $ ACCS=0.0 $ NACCS=0 $ LFLAG=0
```

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      DO 255 L=2,LMAX
      IF (MAXY-L) 190,200,200
  190 Y(L)=Y(L-1)+DY
  195 CALL TRIGEX (Y(L),SI(L),CI)
      FAC1(L)=LOGF(Y(L))-CI
      FAC2(L)=COSF(Y(L))+Y(L)*SI(L)
      FAC3(L)=Y(L)*FAC1(L)+SINF(Y(L))
  200 IF(MAXB-L) 210,220,220
  210 F1F(L)=EXPF(D*(BSQ*FAC1(L)-FAC2(L)))
      F2F(L)=D*(FAC3(L)+BSQ*SI(L))
  220 G(L)=F1F(L)*COSF(Y(L)*PV(K)+F2F(L))
  225 IF (FLOATF(L)-2.0*FLOATF(L/2)) 255,255,230
  230 M=(L+1)/2
  231 S(M)=S(M-1)+G(L-2)+4.0*G(L-1)+G(L)
  232 IF(L.LT.LCOUNT) GO TO 239 $ IF(L.GT.1000) GO TO 235
      IF(LFLAG.EQ.1) GO TO 235
  233 IF(ABSF(S(M)).LT.SLO) GO TO 234 $ MCOUNT=0 $ ACCS=0.0 $ NACCS=0
      GO TO 239
  234 MCOUNT=MCOUNT+1 $ IF(MCOUNT.LT.LCOMP) GO TO 239 $ IFLAG=1
  235 ACCS=ACCS+S(M) $ NACCS=NACCS+1
  236 IF(NACCS.LT.100) GO TO 239
  237 S(M)=ACCS/NACCS $ GO TO 260
  239 IF (ABSF((S(M)-S(M-1))/S(M))-COMP) 240,250,250
  240 NCOUNT=NCOUNT+1
  241 IF (NCOUNT-NCOMP) 255,260,260
  250 NCOUNT=0
  255 CONTINUE
  260 MAXT(K)=L
      MAXTY=MAXT(K)
      MMAX=M
      IF (MAXTY-MAXY) 275,275,270
  270 MAXY=MAXTY
  275 IF (MAXTY-MAXB) 285,285,280
  280 MAXB=MAXTY
  285 SUM(K)=C*S(MMAX)
  286 WLC=(KX2L/SLT)*SUM(K) $ KCOMP=KZEROLOS+1-K
  300 WLC2(KCOMP)=WLC
  305 DO 308 K=1,KZEROLOS
  306 IF(WLC2(K).GT.0.0) GO TO 308
  307 WLC2(K)=0.0
  308 CONTINUE
C
C     COMPUTE DISTORTED BEAM FUNCTION GLCD(L3).
C
  500 L3TEST=SLT/DEI $ L3END=L2MAX
  504 DO 519 L3=1,L2MAX,NDE
  506 SUMA=0.0
  508 DO 512 L2=1,L3,NDE
  510 K=(L3-L2)/NDE+1
  512 SUMA=SUMA+GLC(L2)*WLC2(K)
```

```
514 GLCD(L3)=SUMA*DE
516 IF(L3.LT.L3TEST) 519,517
517 IF(GLCD(L3).LT.0.001) 518,519
518 L3END=L3 $ GO TO 520
519 CONTINUE
520 L4STOP=NDE-1
521 DO 530 L3=1,L3END,NDE
522 DIF=(GLCD(L3+NDE)-GLCD(L3))/NDE
524 DO 526 L4=1,L4STOP
526 GLCD(L3+L4)=GLCD(L3)+L4*DIF
530 CONTINUE
600 SUMB=0.0
602 DO 604 L3=1,L2MAX
604 SUMB=SUMB+GLCD(L3)
606 AGLCD=SUMB*DEI
610 SUMC=0.0
612 DO 614 L2=1,KZEROLOS
614 SUMC=SUMC+WLC2(L2)
616 AWLC2=SUMC*DE
620 END
```

```
    SUBROUTINE YM4
    COMMON/B/ ER,GAMMA,DEB1,NEB1,DEB2,NEB2,DEB3,NEB3,ERNRM,MTOP,NBW
    COMMON/C/YSL(100),W(1700),NEXP,EBEXP(100),YEXP(100),M,L,H(200)
    COMMON/F/DE,NDE,DEI,L2P,L2B,GEMAX,LPRINT1,A7,TT,YLDFAC,LMOX,LRES
    COMMON/1/EB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
  1 YLD(M)=0.0
  2 LC=LRES $ LB=LC+8 $ D=NBW*DEI $ IOD=0
  4 YLD(M)=YLD(M)+YM5(LC,LB,IOD)*D
  6 LC=LB $ LB=LC+8 $ D=2.0*D $ IF(LC.GT.LMOX)8,4
  8 LB=LRES $ LC=LB-8 $ D=NBW*DEI
 10 YLD(M)=YLD(M)+YM5(LC,LB,IOD)*D
 12 LB=LC $ LC=LB-8 $ D=2.0*D $ IF(LC.LT.1)14,10
 14 YLD(M)=YLD(M)*YLDFAC
    END
```

```
    FUNCTION YM5(LC,LB,IOD)
    COMMON/C/YSL(100),W(1700),NEXP,EBEXP(100),YEXP(100),M,L,H(200)
    COMMON/1/EB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
  5 SUM=0.0 $ SM=0.0 $ IF(IOD)8,6
  6 LA=LC+1 $ GO TO 10
  8 SM =(BW(LC)*H(LC)+BW(LC+1)*H(LC+1))/2.0 $ LA=LC+2
 10 SUM=SUM+BW(LA-1)*H(LA-1)+4.0*BW(LA)*H(LA)+BW(LA+1)*H(LA+1)
 12 LA=LA+2 $ IF(LA.LT.LB) GO TO 10
 14 YM5=SM+SUM/3.0
    END
```

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      SUBROUTINE GRAPHA
      COMMON/A/NSLA,NSLP,BFWHM,HILOSS,PMIN,HILOSSL,J3STOP
      COMMON/B/ ER,GAMMA,DEB1,NEB1,DEB2,NEB2,DEB3,NEB3,EBNRM,MTOP,NBW
      COMMON/C/YSL(100),W(1700),NEXP,EBEXP(100),YEXP(100),M,L,H(200)
      COMMON/E/SFAX,SFAY,SFBX,SFBY,PLTARRAY(255 ),LPRINT2,SFN
      COMMON/F/DE,NDE,DEI,L2P,L2B,GEMAX,LPRINT1,A7,TT,YLDFAC,LMOX,LRES
      COMMON/H/L2PP,J2MAX,AGLC,AGLCD,AW_C2,FLAG1,LSTOP
      COMMON/1/EB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
      COMMON/2/GLC(2000),GLCD(5041), ENEW(200),L2MAX ,LMX
      COMMON/3/WINT(6000),Y(2400),KZERO_OS
C
    1 CALL PLOTS(PLTARRAY,255,1)
C
C     LETTER UNITS OF THE X-AXIS.
    2 XLABEL=-2.0 $ JJ=8.0+2.0*TT+HILOSSL
C
      DO 8 J=1,JJ,2
    4 X=(J-1)*SFAX $ YN=-0.2 $ H=0.105
    6 CALL NUMBER (X-0.20,YN,H,XLABEL,0.0,4HF4.1)
    8 XLABEL=XLABEL+2.0
C
C     LETTER UNITS OF THE Y-AXIS.
C
   10 YLABEL=0.0
   12 DO 18 J=1,10,2
   14 YC= (J-1)*SFAY
   16 CALL NUMBER (-0.10,YC-0.24,0.105,YLABEL,90.0,4HF4.1)
   18 YLABEL=YLABEL+2.0
C
C     NAME AXES.
C
   20 X=(2.0+TT/2.0)*SFAX $ YS=-0.42 $ H=0.105
   22 CALL SYMBOL (X,YS,H,14H EB - ER (KEV),0.0,14)
   24 X=-0.3       $ YS=3.5*SFAY $ H=0.105
   26 CALL SYMBOL (X,YS,H,15H RELATIVE YIELD,90.0,15)
C
C     DRAW AXES.
C
   30 HT=10.0*SFAY $ XLTH=(JJ-1)*SFAX
   32 CALL PLOT (0.0,HT,3) $ CALL PLOT(0.0,0.0,2)
   34 CALL PLOT (XLTH,0.0,2)
   36 IF(EBNRM.EQ.0.0) GO TO 100
C
C     DETERMINE THE FACTOR FOR EQUALIZING THE AREAS OF THE CALCULATED
C     AND EXPERIMENTAL CURVES OUT TO EBNRM.
C
   50 SUM=(YLD(1)+YLD(NEB1))/2.0 $ MSTOP=NEB1-1
   52 DO 54 M=2,MSTOP
   54 SUM=SUM+YLD(M)
```

```
   56 M=NEB1+1 $ SM=0.0
   58 SM=SM+YLD(M)
   60 M=M+1 $ IF(EB(M).LT.EBNRM) 58,62
   62 SM=SM+(YLD(NEB1)+YLD(M))/2.0
   64 AREAC=SUM*DEB1+SM*DEB2-(YLD(M-1)+YLD(M))*(EB(M)-EBNRM)/2.0
   80 AREAX=0.0
   82 DO 84 N=2,NEXP
   83 IF(EBEXP(N).GT.EBNRM)  GO TO 90
   84 AREAX=AREAX+(YEXP(N)+YEXP(N-1))*(EBEXP(N)-EBEXP(N-1))*0.5
   90 SFN =AREAC/AREAX
C
C     PLOT EXPERIMENTAL CURVE.
C
  100 NUM=1 $ N=1 $ XLIM= 25.0       $ YLIM=10.0 $ H=0.08
  102 X=(EBEXP(N)-ER+2.0)*SFAX $ YX=YEXP(N)*SFAY*SFN*6.0
  104 IF(X.LT.XLIM) GO TO 106 $ X=XLIM
  106 IF(X.GT.-0.5) GO TO 108 $ X=-0.5
  108 IF(YX.LT.YLIM) GO TO 110 $ YX=YLIM
  110 IF(YX.GT.-0.25) GO TO 112 $ YX=-0.25
  112 IF(N.GT.1) GO TO 114 $ CALL PLOT(X,YX,3)
  114 CALL SYMBOL(X,YX,H,NUM,0.0,-1)
  116 N=N+1 $ IF(N.GT.NEXP) GO TO 200 $ GO TO 102
C
C     PLOT CALCULATED YIELD CURVE. IF NSLA=1. PLOT YSL(M).
C
  200 NUM=2 $ M=MTOP
  202 X=(EB(M)-ER+2.0)*SFAX $ YC=YLD(M)*SFAY*6.0
  204 IF(X.LT.XLIM) GO TO 206 $ X=XLIM
  206 IF(YC.LT.YLIM) GO TO 207 $ YC=YLIM
  207 IF(M.LT.MTOP) GO TO 209
  208 CALL PLOT(X,YC,3) $ CALL SYMBOL(X,YC,H,NUM,0.0,-1) $ GO TO 210
  209 CALL SYMBOL(X,YC,H,NUM,0.0,-1)
  210 M=M-1 $ IF(M.LT.1) GO TO 300  $ GO TO 202
  300 IF(NSLA.NE.1) GO TO 400
  302 M=1 $ NUM=3
  304 X=(EB(M)-ER+2.0)*SFAX $ YC=YSL(M)*SFAY*6.0
  306 IF(X.LT.XLIM) GO TO 308 $ X=XLIM
  308 IF(YC.LT.YLIM) GO TO 310 $ YC=YLIM
  310 IF(M.GT.1) GO TO 312 $ CALL PLOT (X,YC,3)
  312 IF(YC.LT.0.003)GO TO 314 $ CALL SYMBOL(X,YC,H,NUM,0.0,-1)
  314 M=M+1 $ IF(M.GT.MTOP) GO TO 400 $ GO TO 304
  400 NSTOP=XLTH+4.0 $ XSTOP=NSTOP $ CALL PLOT(XSTOP,0.0,-3)
  410 FORMAT(//* AREAC=*,F10.7,5X,*AREAX=*,E10.4,5X,*SFN=*,F10.7)
  420 WRITE(61,410) AREAC,AREAX,SFN
  500 END
```

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```
      SUBROUTINE GRAPHB
      COMMON/A/NSLA,NSLP,BFWHM,HILOSS,PMIN,HILOSSL,J3STOP
      COMMON/B/ ER,GAMMA,DEB1,NEB1,DEB2,NEB2,DEB3,NEB3,ERNRM,MTOP,NBW
      COMMON/C/YSL(100),W(1700),NEXP,EREXP(100),YEXP(100),M,L,H(200)
      COMMON/E/SFAX,SFAY,SFBX,SFBY,PLTARRAY(255 ),LPRINT2,SFN
      COMMON/F/DE,NDE,DEI,L2P,L2B,GEMAX,LPRINT1,A7,TT,YLDFAC,LMOX,LRES
      COMMON/H/L2PP,J2MAX,AGLC,AGLCD,AW_C2,FLAG1,LSTOP
      COMMON/K/SLT,SELSL,ZSL,ASL,BSQ,A10
      COMMON/L/WLC2(2510),NCOMP,LCOMP,LCOUNT,LCOUNT2,SLO,DYFAC
      COMMON/1/EB(100),MPRINT1,E(200),BW(200),YLD(100),MPRINT2,NGAM
      COMMON/2/GLC(2000),GLCD(5041), ENEW(200),L2MAX ,LMX
      COMMON/3/WINT(6000),Y(2400),KZEROLOS
C
C     DRAW AND LABEL AXES FOR ENERGY LOSS DISTRIBUTION PLOT.
C
    5 DO 10 M=1,100,2
    6 XLABEL=0.0+(M-1)       $ X=0.0+(M-1)*SFBX $ XSTOP=HILOSSL*SFBX+1.0
    8 IF(X.GT.XSTOP)12,9
    9 CALL NUMBER(X-0.2,-0.2,0.105,XLABEL,0.0,4HF4.1)
   10 CONTINUE
   12 CALL PLOT(X,0.0,3) $ CALL PLOT(0.0,0.0,2)
   20 X=2.0 $ Y=-0.42 $ H=0.105
   22 CALL SYMBOL(X,Y,H,18H ENERGY LOSS (KEV),0.0,18)
   24 X=-0.42 $ Y=2.5
   26 CALL SYMBOL(X,Y,H,20H PROBABILITY PER KEV,90.0,20) $ X=-0.20
   30 DO 34 M=1,11,2
   32 YLABEL=0.0+0.2*(M-1) $ Y=0.0+(M-1)*SFBY $ IF(Y.GT.10.0) 33,34
   33 Y=10.0  $  GO TO 35
   34 CALL NUMBER(X,Y-0.2,H,YLABEL,90.0,4HF4.1)
   35 CALL PLOT(0.0,Y,3) $ CALL PLOT(0.0,0.0,2)
C
C     DRAW AND LABEL BEAM ENERGY DISTRIBUTION AXES.
C
   59 N=4.0+HILOSSL+2.0*SLT+4.0*BFWHM $ X=N*SFBX+0.25 $ YLABEL=0.0
   60 DO 64 M=1,50
   61 Y=1.0+(M-1)*SFBY  $  IF(Y.GT.10.0) 65,62
   62 CALL NUMBER(X,Y-0.2,H,YLABEL,90.0,4HF4.1)
   64 YLABEL=YLABEL+0.1
   65 X=N*SFBX $ Y=10.0*SFBY $  IF(Y.GT.10.0) Y=10.0
   66 CALL PLOT(X,Y,3) $ CALL PLOT(X,1.0,2)
   68 X=N*SFBX+0.5 $ Y=2.0       $ CALL PLOT(X,Y,3)
   70 CALL SYMBOL(X,Y,H,20H PROBABILITY PER KEV,90.0,20)
   72 Y=0.75 $ NN=5.0*BFWHM
   73 XHLT=(N-2-HILOSSL)*SFBX
   74 DO 80 M=1,50
   75 X=(N-M+1)*SFBX-0.08 $ XLABEL=1.0+NN-(M-1)
   76 IF(X.LT.XHLT) 82,77
   77 CALL NUMBER(X-0.2,Y,H,XLABEL,0.0,4HF5.1)
   80 CONTINUE
```

```
   82 Y=1.0 $ CALL PLOT(X,Y,3) $ X=N*SFBX $ CALL PLOT(X,Y,2)
   84 X=N*SFBX-3.0 $ Y=0.50 $ CALL PLOT(X,Y,3)
   86 CALL SYMBOL(X,Y,H,12H EI-EB (KEV),0,0,12)
C
C     PLOT FREE-SPACE BEAM ENERGY DISTRIBUTION.
C
  200 NUM=1 $ H=0.08 $ XLIM=100.0*SFBX$ YLIM=10.0 $ SIGB=BFWHM/(2*1.177)
  201 B7=1.0/(SIGB*SQRTF(2.0*3.1416)) $ NDEN=2.0*B7 $ NNN=N-1-NN
  202 IF(NDEN.LT.1) 203,204
  203 NDEN=1 $ GO TO 205
  204 RDEN=2.0*B7 $ DF=RDEN-NDEN $ IF(DF.GT.0.5) NDEN=NDEN+1
  205 YFAC=10.0*SFBY/NDEN
  206 DO 214 L2=1,L2B,4
  208 X=(NNN+(L2P-L2)*DEI)*SFBX $ Y=YFAC*GLC(L2)+1.0
  210 IF(X.GT.XLIM) X=XLIM $ IF(Y.GT.YLIM) Y=YLIM $ IF(X.LT.2.0) X=2.0
  211 IF(L2.GT.1) 213,212
  212 CALL SYMBOL(X,Y,H,NUM,0,0,-1)
  213 CALL SYMBOL(X,Y,H,NUM,0,0,-2)
  214 CONTINUE
C
C     PLOT INTERFACE BEAM ENERGY DISTRIBUTION.
C
  300 NUM=2 $ L3TEST=2.0*SLT/DEI
  301 DO 303 L2=1,L2MAX
  302 DIFF=GLCD(L2+1)-GLCD(L2) $ IF(DIFF.LT.0.0) 304,303
  303 CONTINUE
  304 ND=2.0*GLCD(L2)       $ RND=2.0*GLCD(L2)       $ DF=RND-ND
  305 IF(ND) 306,306,307
  306 ND=1 $ GO TO 308
  307 IF(DF.GT.0.5) ND=ND+1
  308 YFAC=10.0*SFBY/ND
  309 INC=4*L2MAX/100
  310 DO 330 L3=1,L2MAX,INC
  312 X=(NNN+(L2P-L3)*DEI)*SFBX  $ Y=1.0+YFAC*GLCD(L3)
  314 IF(X.GT.XLIM) X=XLIM $ IF(Y.GT.YLIM) Y=YLIM $ IF(X.LT.2.0) X=2.0
  316 IF(L3.LT.L3TEST) GO TO 318 $ IF(Y.LT.0.005) 400,318
  318 IF(L3.LT.2) CALL SYMBOL(X,Y,H,NUM,0,0,-1)
  320 CALL SYMBOL(X,Y,H,NUM,0,0,-2)
  330 CONTINUE
C
C     PLOT INTERFACE ENERGY LOSS DISTRIBUTION.
C
  400 DO 410 KCOMP=1,KZEROLOS
  402 DIFF=WLC2(KCOMP+1)-WLC2(KCOMP) $ IF(DIFF.LT.0.0) 411,410
  410 CONTINUE
  411 NDN=0.75*WLC2(KCOMP) $ RDN=0.75*WLC2(KCOMP) $ IF(NDN.LT.1) 412,414
  412 NDN=1 $ GO TO 416
  414 DF=RDN-NDN $ IF(DF.GT.0.5) NDN=NDN+1
  416 YFAC=5.0*SFBY/NDN $ KTEST=4.0*SLT/DE $ NUM=3
  418 CALL PLOT(0.0,3)
  419 INC=1+KZEROLOS /200
```

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```
420 DO 430 KCOMP=1,KZEROLOS ,INC
422 X=SFBX*(KCOMP-1)*DE $ Y=WLC2(KCOMP)*YFAC
424 IF(KCOMP.LT.KTEST) GO TO 426 $ IF(Y.LT.0.005) GO TO 500
426 IF(X.LT.0.0) X=-0.25 $ IF(X.GT.XLIM) X=XLIM $ IF(Y.LT.0.0) Y=-0.25
428 IF(Y.GT.YLIM) Y=YLIM
430 CALL SYMBOL(X,Y,H,NUM,0,0,-2)
C
C     LETTER LEGEND
C
500 X=1.1 $ Y=9.7*SFBY+0.04 $ IF(Y.GT.10.0) Y=9.8      $ NUM=1
502 CALL SYMBOL(X,Y,0.08,NUM,0,0,-1) $ X=1.25 $ H=0.105
504 CALL SYMBOL(X,Y,H,41H FREE-SPACE BEAM ENERGY DISTRIBUTION X 1/,
   20,0,41)  $ X=4.95
506 CALL NUMBER(X,Y,H,NDEN,0,0,2HI2) $ X=1.1 $ Y=Y-0.3          $ NUM=2
508 CALL PLOT(X,Y,3) $ CALL SYMBOL(X,Y,0.08,NUM,0,0,-1) $ X=1.25
510 CALL SYMBOL(X,Y,H,40H INTERFACE BEAM ENERGY DISTRIBUTION X 1/,0.0,
   240) $ X=4.85
512 CALL NUMBER(X,Y,H,ND  ,0,0,2HI2) $ X=1.1 $ Y=Y-0.3          $ NUM=3
514 CALL SYMBOL(X,Y,0.08,NUM,0,0,-1) $ X=1.25
516 CALL SYMBOL(X,Y,H,30H ENERGY LOSS DISTRIBUTION X 1/,0.0,30)
518 X=3.95 $ CALL NUMBER(X,Y,H,NDN,0.0,2HI2)
519 X=N*SFBX $ CALL PLOT(X,Y,3)
600 END
```

```
)            L2PP=   78          L2R=  157

:   9              FLAG1= 0            LSTOP=  28
:P= 1045           J2MAX= 1797

:I=    1           L2F=  758     H(L)= 0.7530167
:(M)=  990.7000    ENEW(L)=  986.9400

     M=   3
:0     983.1000    983.7400    984.3800    985.0200    985.6600    986.3000    986.9400      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
:0       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

                          FROM G7,  L2MAX=       758

  10               FLAG1= 0            LSTOP=  28
:P= 1109           J2MAX= 1797

:I=    1           L2F=  758     H(L)= 0.8337337
:(M)=  990.7000    ENEW(L)=  987.2400

     M=   3
0      983.1000    983.7400    984.3800    985.0200    985.6600    986.3000    986.9400    987.2600
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0        0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

                          FROM G7,  L2MAX=       758

   9               FLAG1= 0            LSTOP=  33
P=  965            J2MAX= 1797

I=     1           L2F=  758     H(L)= 0.6405609
(M)=   991.1000    ENEW(L)=  986.9400
```

```
ENEW(L), L=1,100          M=   7
   981.8200    982.4600    983.1000    983.7400    984.3800    985.0200    985.6600    986.3000    986.9400       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000

                                                FROM G7,  L2MAX=        758

M=   7                L=  10                FLAG1= 0              LSTOP=  33
EBLOW= 9.86864+002    J2P= 1029             J2MAX= 1797
MDEI=  768
L2B=  157             L2I=    1             L2F=  758      H(L)= 0.7312423
E(L)=  987.2600       EB(M)=  991.1000      ENEW(L)=  987.2600

ENEW(L), L=1,100          M=   7
   981.8200    982.4600    983.1000    983.7400    984.3800    985.0200    985.6600    986.3000    986.9400    987.2600
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000
     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000       0.0000

                                                FROM G7,  L2MAX=        758


YIELD FROM A 4.95-KEV TARGET WITH A 0.156-KEV LAYER OF AL203,
YSLM IS FROM SEQUENCE 442-8-3-70, W FUNCTION IS FROM SEQUENCE 2715.

ER= 9.91900+002       GAMMA= 1.00000-001    BFWHM= 1.98000-001
NPRINT1= 1            NPRINT2= 1            NPRINT3= 1            LPNCH= 0
NGRAPHA= 1            SFAX=0.50             SFAY=1.00             NRW=    4
NGRAPHB= 1            SFBX=2.00             SFBY=0.50             NGAM=   90
NSLA= 1               NSLP= 0               L2MAX= 758            K7EROLOS= 151

DE= 2.00000-002       DEI= 5.00000-003      PMIN= -3.30           NDE= 4
EB(1)=  990.5000      DEB1= 0.1000          NEB1= 25              LMX=    0
DEB2= 0.3000          NEB2= 45              DEB3= 0.5000          NEB3= 50
MPRINT1= 3            MPRINT2= 7            LPRINT1= 9            LPRINT2=10
J3STOP= 450           KMAX= 717             IMAX=  90             LMOX=   97
L2P=  79              L2B= 157              J2MAX=1797            ERNRM=  997.71
```


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```
Z= 13,00              ZIP= 1,0
TT=  4,9230           A=  26,9800          SEL= 1,75582+005     LRES=   49
GEMAX= 2,16364+000
ZSL= 50,00            ASL= 101,96000       SL0=   0,30000
SLT= 0,156            SELSL= 199440,00     HILOSSL= 3,00
BSQ= 0,00212          A7=  72619,41        DYFAC=   0,00459     HILOSS=    9,000      YLDFAC= 1,000
LCOUNT=   500         LCOMP=    10         NCOMP=    10         LCOUNT2=  1000
AGLC= 0,9999958       AGLCD= 0,9889451     AWLC2= 0,9891571     AYLD= 4,8244975

NEXP=  23             N,EBEXP(N), YEXP(N), N=1,NEXP
 1   991,01    0,00  2   991,16    0,00  3   991,31    0,00  4   991,51    0,00
 5   991,61    0,01  6   991,75    0,06  7   991,91    0,14  8   992,11    0,20
 9   992,21    0,21 10   992,31    0,22 11   992,51    0,21 12   992,61    0,21
13   992,70    0,21 14   993,01    0,20 15   993,16    0,20 16   993,26    0,20
17   994,01    0,19 18   994,71    0,18 19   996,21    0,12 20   997,01    0,08
21   997,71    0,05 22   999,21    0,02 23  1000,76    0,00

YSL(M), M=1,MTOP
   0,000100    0,000120    0,000140    0,000160    0,000200    0,000240    0,000300    0,000390
   0,001200    0,002210    0,005860    0,017720    0,035290    0,034540    0,017980    0,008200
   0,001600    0,001140    0,000840    0,000640    0,000510    0,000270    0,000170    0,000110
   0,000030    0,000020    0,000010    0,000010    0,000010    0,000010    0,000010    0,000010
   0,000000    0,000000    0,000000    0,000000    0,000000    0,000000    0,000000    0,000000

W(J5), J5=1,J3STOP
0,00761 0,00784 0,00806 0,00829 0,00851 0,00874 0,00896 0,00919 0,00941 0,00963
0,00986 0,01008 0,01031 0,01053 0,01076 0,01098 0,01121 0,01152 0,01184 0,01216
0,01247 0,01279 0,01311 0,01342 0,01374 0,01406 0,01437 0,01469 0,01501 0,01532
0,01564 0,01596 0,01627 0,01672 0,01717 0,01761 0,01806 0,01851 0,01895 0,01940
0,01985 0,02030 0,02074 0,02119 0,02164 0,02208 0,02253 0,02298 0,02342 0,02404
0,02465 0,02527 0,02588 0,02649 0,02711 0,02772 0,02834 0,02895 0,02957 0,03018
0,03079 0,03141 0,03202 0,03264 0,03325 0,03409 0,03493 0,03578 0,03662 0,03746
0,03830 0,03914 0,03998 0,04083 0,04167 0,04251 0,04335 0,04419 0,04503 0,04587
0,04672 0,04784 0,04896 0,05009 0,05121 0,05233 0,05345 0,05458 0,05570 0,05682
0,05795 0,05907 0,06019 0,06132 0,06244 0,06356 0,06468 0,06617 0,06767 0,06917
0,07066 0,07216 0,07365 0,07515 0,07664 0,07814 0,07963 0,08113 0,08262 0,08412
0,08561 0,08711 0,08860 0,09053 0,09246 0,09439 0,09632 0,09825 0,10018 0,10211
0,10403 0,10596 0,10789 0,10982 0,11175 0,11368 0,11561 0,11754 0,11946 0,12190
0,12435 0,12679 0,12923 0,13167 0,13411 0,13655 0,13899 0,14143 0,14387 0,14631
0,14875 0,15119 0,15364 0,15608 0,15852 0,16156 0,16460 0,16765 0,17069 0,17374
0,17678 0,17982 0,18287 0,18591 0,18895 0,19200 0,19504 0,19809 0,20113 0,20417
0,20722 0,21089 0,21457 0,21825 0,22193 0,22560 0,22928 0,23296 0,23664 0,24032
0,24399 0,24767 0,25135 0,25503 0,25870 0,26238 0,26606 0,27041 0,27477 0,27912
0,28348 0,28783 0,29219 0,29654 0,30090 0,30525 0,30961 0,31396 0,31832 0,32267
0,32703 0,33138 0,33573 0,34057 0,34540 0,35024 0,35507 0,35991 0,36474 0,36958
0,37441 0,37950 0,38459 0,38967 0,39476 0,39984 0,40493 0,41002 0,41510 0,42054
0,42598 0,43142 0,43686 0,44230 0,44775 0,45319 0,45863 0,46424 0,46985 0,47546
0,48108 0,48669 0,49230 0,49791 0,50353 0,50933 0,51513 0,52094 0,52674 0,53255
0,53835 0,54416 0,54996 0,55586 0,56176 0,56765 0,57356 0,57946 0,58536 0,59126
0,59716 0,60314 0,60911 0,61509 0,62107 0,62705 0,63302 0,63900 0,64498 0,65089
0,65681 0,66272 0,66864 0,67455 0,68047 0,68638 0,69230 0,69821 0,70393 0,70975
0,71557 0,72139 0,72721 0,73303 0,73884 0,74439 0,74994 0,75548 0,76103 0,76658
0,77212 0,77767 0,78322 0,78850 0,79379 0,79907 0,80436 0,80965 0,81493 0,82022
```

0,82551	0,83030	0,83508	0,83987	0,84466	0,84945	0,85423	0,85903	0,86381	0,86810
0,87239	0,87668	0,88097	0,88505	0,88913	0,89321	0,89729	0,90093	0,90458	0,90822
0,91187	0,91540	0,91893	0,92246	0,92600	0,92995	0,93192	0,93489	0,93888	0,94148
0,94408	0,94668	0,94928	0,95149	0,95371	0,95795	0,96021	0,96207	0,96394	0,96581
0,96768	0,96914	0,97162	0,97311	0,97460	0,97572	0,97683	0,97796	0,97908	0,98180
0,98259	0,98338	0,98418	0,98466	0,98515	0,98564	0,98710	0,98737	0,98764	0,98791
0,98820	0,98832	0,98844	0,99044	0,99062	0,99065	0,99071	0,99077	0,99084	0,99081
0,99168	0,99170	0,99173	0,99168	0,99165	0,99164	0,99164	0,99324	0,99323	0,99324
0,99328	0,99327	0,99328	0,99332	0,99414	0,99418	0,99425	0,99436	0,99449	0,99460
0,99475	0,99620	0,99646	0,99670	0,99699	0,99727	0,99760	0,99790	0,99880	0,99923
0,99972	1,00016	1,00067	1,00121	1,00183	1,00242	1,00311	1,00377	1,00454	1,00530
1,00619	1,00696	1,00802	1,00896	1,01107	1,01213	1,01339	1,01457	1,01599	1,01730
1,01888	1,02033	1,02209	1,02383	1,02559	1,02751	1,02954	1,03177	1,03392	1,03625
1,03878	1,04128	1,04419	1,04708	1,05014	1,05345	1,05686	1,06057	1,06451	1,06858
1,07297	1,07771	1,08267	1,08799	1,09372	1,09983	1,10646	1,11356	1,12127	1,12952
1,13852	1,14852	1,15935	1,17145	1,18478	1,19949	1,21631	1,23511	1,25661	1,28161
1,31091	1,34582	1,38845	1,44162	1,51047	1,60386	1,74055	1,96050	2,33150	2,57807

E(L), L=1,LMOX

981,8200	982,4600	983,1000	983,7400	984,3800	985,0200	985,6600	986,3000	986,9400	987
987,5800	987,9000	988,2200	988,5400	988,8600	989,1800	989,5000	989,6600	989,8200	989
990,1400	990,3000	990,4600	990,6200	990,7800	990,8600	990,9400	991,0200	991,1000	991
991,2600	991,3400	991,4200	991,4600	991,5000	991,5400	991,5800	991,6200	991,6600	991
991,7400	991,7600	991,7800	991,8000	991,8200	991,8400	991,8600	991,8800	991,9000	991
991,9400	991,9600	991,9800	992,0000	992,0200	992,0400	992,0600	992,1000	992,1400	992
992,2200	992,2600	992,3000	992,3400	992,3800	992,4600	992,5400	992,6200	992,7000	992
992,8600	992,9400	993,0200	993,1800	993,3400	993,5000	993,6600	993,8200	993,9800	994
994,3000	994,6200	994,9400	995,2600	995,5800	995,9000	996,2200	996,5400	996,8600	997
998,1400	998,7800	999,4200	1000,0600	1000,7000	1001,3400	1001,9800			

EB(M), M=1,MTOP

990,5000	990,6000	990,7000	990,8000	990,9000	991,0000	991,1000	991,2000	991,3000	991
991,5000	991,6000	991,7000	991,8000	991,9000	992,0000	992,1000	992,2000	992,3000	992
992,5000	992,6000	992,7000	992,8000	992,9000	993,2000	993,5000	993,8000	994,1000	994
994,7000	995,0000	995,3000	995,6000	995,9000	996,2000	996,5000	996,8000	997,1000	997
997,7000	998,0000	998,3000	998,6000	998,9000	999,4000	999,9000	1000,4000	1000,9000	1001

BW(L), L=1,LMOX

0,000157	0,000179	0,000206	0,000239	0,000281	0,000336	0,000409	0,00050
0,000853	0,000995	0,001175	0,001409	0,001722	0,002150	0,002762	0,00317
0,005134	0,006211	0,007666	0,009699	0,012662	0,014681	0,017223	0,02048
0,038620	0,050349	0,068336	0,081160	0,097941	0,120480	0,151720	0,19673
0,566387	0,720157	0,941743	1,273237	1,788254	2,609091	3,881819	5,48808
3,881819	2,609092	1,788254	1,273237	0,941743	0,720157	0,566387	0,37448
0,151720	0,120480	0,097941	0,081160	0,068336	0,050349	0,038620	0,03055
0,017223	0,014681	0,012662	0,009699	0,007666	0,006211	0,005134	0,00431
0,002762	0,002150	0,001722	0,001409	0,001175	0,000995	0,000853	0,00073
0,000409	0,000336	0,000281	0,000239	0,000206	0,000179	0,000157	

GLC(L2), L2=1,L2B

0,000102	0,000134	0,000175	0,000229	0,000298	0,000386	0,000499	0,000643	0,000824	0,001054
0,001343	0,001704	0,002156	0,002717	0,003413	0,004271	0,005327	0,006620	0,008198	0,010116
0,012439	0,015241	0,018609	0,022642	0,027450	0,033162	0,039922	0,047891	0,057247	0,068189
0,080936	0,095728	0,112824	0,132503	0,155067	0,180832	0,210134	0,243324	0,280762	0,322817
0,369862	0,422269	0,480400	0,544607	0,615217	0,692530	0,776809	0,868272	0,967080	1,073332
1,187057	1,308200	1,436621	1,572083	1,714250	1,862680	2,016822	2,176018	2,339497	2,506387
2,675709	2,846395	3,017288	3,187159	3,354718	3,518630	3,677534	3,830055	3,974832	4,110530
4,235867	4,349628	4,450689	4,538035	4,610773	4,668151	4,709573	4,734602	4,742975	4,734602
4,709573	4,668151	4,610773	4,538035	4,450689	4,349628	4,235867	4,110530	3,974832	3,830055
3,677534	3,518630	3,354718	3,187159	3,017288	2,846395	2,675709	2,506387	2,339497	2,176018
2,016822	1,862680	1,714250	1,572083	1,436621	1,308200	1,187057	1,073332	0,967080	0,868272
0,776809	0,692530	0,615217	0,544607	0,480400	0,422269	0,369862	0,322817	0,280762	0,243324
0,210134	0,180832	0,155067	0,132503	0,112824	0,095728	0,080936	0,068189	0,057247	0,047891
0,039922	0,033162	0,027450	0,022642	0,018609	0,015241	0,012439	0,010116	0,008198	0,006620
0,005327	0,004271	0,003413	0,002717	0,002156	0,001704	0,001343	0,001054	0,000824	0,000643
0,000499	0,000386	0,000298	0,000229	0,000175	0,000134	0,000102			

GLCD(L2),L2=1,L2MAX

0,000006	0,000012	0,000017	0,000023	0,000029	0,000045	0,000062	0,000078	0,000095	0,000139
0,000182	0,000226	0,000270	0,000379	0,000489	0,000598	0,000708	0,000967	0,001226	0,001486
0,001745	0,002327	0,002909	0,003491	0,004072	0,005306	0,006540	0,007774	0,009007	0,011480
0,013953	0,016426	0,018899	0,023581	0,028264	0,032947	0,037630	0,046006	0,054383	0,062759
0,071135	0,085282	0,099429	0,113575	0,127722	0,150267	0,172812	0,195357	0,217902	0,251781
0,285659	0,319537	0,353415	0,401367	0,449319	0,497271	0,545223	0,609058	0,672892	0,736727
0,800561	0,880312	0,960063	1,039814	1,119565	1,212772	1,305979	1,399186	1,492393	1,593790
1,695187	1,796584	1,897981	1,999814	2,101647	2,203481	2,305314	2,398353	2,491392	2,584431
2,677470	2,752539	2,827608	2,902577	2,977746	3,027407	3,077068	3,126730	3,176391	3,196320
3,216250	3,236179	3,256109	3,245794	3,235479	3,225165	3,214850	3,177443	3,140035	3,102628
3,065220	3,006649	2,948077	2,889505	2,830933	2,758579	2,686224	2,613869	2,541515	2,462838
2,384162	2,305486	2,226810	2,148255	2,069701	1,991147	1,912592	1,838943	1,765294	1,691645
1,617996	1,552204	1,486412	1,420621	1,354829	1,298207	1,241586	1,184965	1,128343	1,080962
1,033580	0,986198	0,938816	0,899945	0,861074	0,822204	0,783333	0,751841	0,720349	0,688857
0,657365	0,632056	0,606646	0,581286	0,555927	0,535518	0,515110	0,494701	0,474293	0,457810
0,441327	0,424844	0,408361	0,394960	0,381560	0,368159	0,354758	0,343771	0,332783	0,321795
0,310808	0,301714	0,292621	0,283527	0,274434	0,266836	0,259239	0,251641	0,244043	0,237637
0,231230	0,224824	0,218417	0,212947	0,207517	0,202068	0,196618	0,191944	0,187271	0,182597
0,177923	0,173886	0,169848	0,165810	0,161772	0,158259	0,154747	0,151235	0,147722	0,144648
0,141573	0,138499	0,135424	0,132718	0,130011	0,127304	0,124598	0,122203	0,119808	0,117413
0,115018	0,112888	0,110758	0,108629	0,106499	0,104597	0,102695	0,100793	0,098890	0,097185
0,095479	0,093773	0,092067	0,090531	0,088995	0,087460	0,085924	0,084536	0,083149	0,081761
0,080374	0,079116	0,077858	0,076600	0,075343	0,074199	0,073055	0,071911	0,070768	0,069725
0,068682	0,067639	0,066596	0,065642	0,064688	0,063735	0,062781	0,061906	0,061032	0,060157
0,059283	0,058479	0,057676	0,056872	0,056068	0,055328	0,054588	0,053848	0,053107	0,052424
0,051741	0,051057	0,050374	0,049742	0,049109	0,048477	0,047845	0,047259	0,046673	0,046087
0,045501	0,044957	0,044413	0,043869	0,043325	0,042818	0,042312	0,041806	0,041300	0,040828
0,040356	0,039885	0,039413	0,038973	0,038533	0,038092	0,037652	0,037241	0,036829	0,036418
0,036006	0,035621	0,035236	0,034850	0,034465	0,034104	0,033743	0,033382	0,033020	0,032681
0,032342	0,032003	0,031664	0,031345	0,031027	0,030708	0,030390	0,030090	0,029790	0,029490
0,029190	0,028908	0,028625	0,028343	0,028060	0,027793	0,027527	0,027260	0,026994	0,026742
0,026490	0,026239	0,025987	0,025749	0,025511	0,025273	0,025035	0,024810	0,024585	0,024360
0,024134	0,023921	0,023708	0,023495	0,023281	0,023079	0,022877	0,022674	0,022472	0,022280
0,022088	0,021896	0,021704	0,021522	0,021340	0,021158	0,020975	0,020802	0,020629	0,020455
0,020282	0,020117	0,019952	0,019787	0,019622	0,019465	0,019308	0,019151	0,018994	0,018845
0,018695	0,018545	0,018396	0,018253	0,018110	0,017968	0,017825	0,017689	0,017552	0,017416
0,017280	0,017150	0,017020	0,016890	0,016760	0,016635	0,016511	0,016387	0,016263	0,016144

0,016025	0,015906	0,015787	0,015673	0,015559	0,015446	0,015332	0,015223
0,014896	0,014792	0,014687	0,014583	0,014479	0,014379	0,014279	0,014178
0,013886	0,013790	0,013694	0,013602	0,013510	0,013418	0,013326	0,013237
0,012972	0,012887	0,012802	0,012717	0,012632	0,012550	0,012469	0,012387
0,012148	0,012069	0,011991	0,011913	0,011839	0,011764	0,011688	0,011615
0,011397	0,011327	0,011257	0,011185	0,011116	0,011049	0,010981	0,010913
0,010716	0,010650	0,010585	0,010522	0,010459	0,010397	0,010334	0,010273
0,010091	0,010033	0,009974	0,009913	0,009857	0,009800	0,009744	0,009687
0,009521	0,009467	0,009412	0,009359	0,009306	0,009253	0,009201	0,009149
0,008996	0,008946	0,008896	0,008846	0,008797	0,008748	0,008700	0,008651
0,008507	0,008459	0,008411	0,008364	0,008316	0,008269	0,008221	0,008173
0,008029	0,007979	0,007929	0,007879	0,007829	0,007776	0,007723	0,007670
0,007500	0,007442	0,007384	0,007319	0,007254	0,007189	0,007124	0,007050
0,006830	0,006747	0,006664	0,006581	0,006497	0,006404	0,006311	0,006217
0,005918	0,005815	0,005712	0,005601	0,005490	0,005379	0,005268	0,005152
0,004802	0,004684	0,004565	0,004445	0,004328	0,004210	0,004093	0,003976
0,003634	0,003522	0,003409	0,003305	0,003200	0,003095	0,002990	0,002895
0,002610	0,002526	0,002441	0,002357	0,002273	0,002199	0,002126	0,002053
0,001854	0,001791	0,001729	0,001675	0,001622	0,001569	0,001516	0,001472
0,001338	0,001300	0,001263	0,001225	0,001188	0,001156	0,001125	0,001094
0,001009	0,000982	0,000956	0,000719	0,000482	0,000246	0,000009	0,000009
0,000008	0,000008	0,000008	0,000008	0,000008	0,000008	0,000008	0,000007
0,000007	0,000007	0,000007	0,000007	0,000006	0,000006	0,000006	0,000006
0,000006	0,000006	0,000005	0,000005	0,000005	0,000005	0,000005	0,000005
0,000005	0,000005	0,000004	0,000004	0,000004	0,000004	0,000004	0,000004
0,000004	0,000004	0,000004	0,000004	0,000003	0,000003	0,000003	0,000003
0,000003	0,000003	0,000003	0,000003	0,000003	0,000003	0,000003	0,000003
0,000003	0,000002	0,000002	0,000002	0,000002	0,000002	0,000002	0,000002
0,000002	0,000002	0,000002	0,000002	0,000002	0,000002	0,000002	0,000002
0,000002	0,000002	0,000002	0,000002	0,000002	0,000002	0,000001	0,000001
0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001
0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001
0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001
0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001
0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001	0,000001
0,000001	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000
0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000
0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000
0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000	0,000000

WLC2(KCOMP), KCOMP=1,KZEROLOS

2,9132	5,6325	6,5707	6.0329	4,9745	3,9258	3,0616	2,3953	1,8934	1,5162
1,2307	1,0124	0,8432	0.7105	0,6050	0,5201	0,4511	0,3943	0,3472	0,3077
0,2744	0,2460	0,2216	0,2006	0,1824	0,1664	0,1524	0,1401	0,1292	0,1194
0,1107	0,1029	0,0959	0,0896	0,0838	0,0786	0,0739	0,0695	0,0655	0,0619
0,0585	0,0554	0,0526	0,0499	0,0475	0,0452	0,0431	0,0411	0,0392	0,0375
0,0359	0,0344	0,0329	0,0316	0,0304	0,0292	0,0280	0,0270	0,0260	0,0250
0,0242	0,0233	0,0225	0,0217	0,0210	0,0203	0,0197	0,0190	0,0184	0,0179
0,0173	0,0168	0,0163	0,0158	0,0154	0,0149	0,0145	0,0141	0,0137	0,0134
0,0130	0,0127	0,0124	0,0120	0,0117	0,0114	0,0112	0,0109	0,0106	0,0104
0,0101	0,0099	0,0097	0.0095	0,0092	0,0090	0,0088	0,0086	0,0085	0,0083
0,0081	0,0079	0,0078	0,0076	0,0075	0,0073	0,0072	0,0070	0,0067	0,0062
0,0053	0,0045	0,0037	0,0031	0,0026	0,0022	0,0019	0,0017	0,0015	0,0013
0,0012	0,0011	0,0010	0,0009	0,0008	0,0007	0,0007	0,0006	0,0006	0,0005
0,0005	0,0005	0,0004	0,0004	0,0004	0,0004	0,0003	0,0003	0,0003	0,0003
0,0003	0,0003	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002
0,0002									

YLD(M) , M=1,100

0,00887	0,00967	0,01080	0,01197	0,01337	0,01519	0,01741	0,02032	0,02428	0,02987
0,03829	0,05308	0,08818	0,19540	0,45676	0,78700	0,99385	1,05407	1,05282	1,03856
1,02406	1,01182	1,00186	0,99388	0,98754	0,97529	0,97005	0,94775	0,96467	0,95411
0,92913	0,88718	0,82929	0,75809	0,67837	0,59497	0,51179	0,43233	0,35917	0,29354
0,23659	0,18766	0,14705	0,11373	0,08715	0,05457	0,03345	0,02027	0,01043	0,00341
0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000

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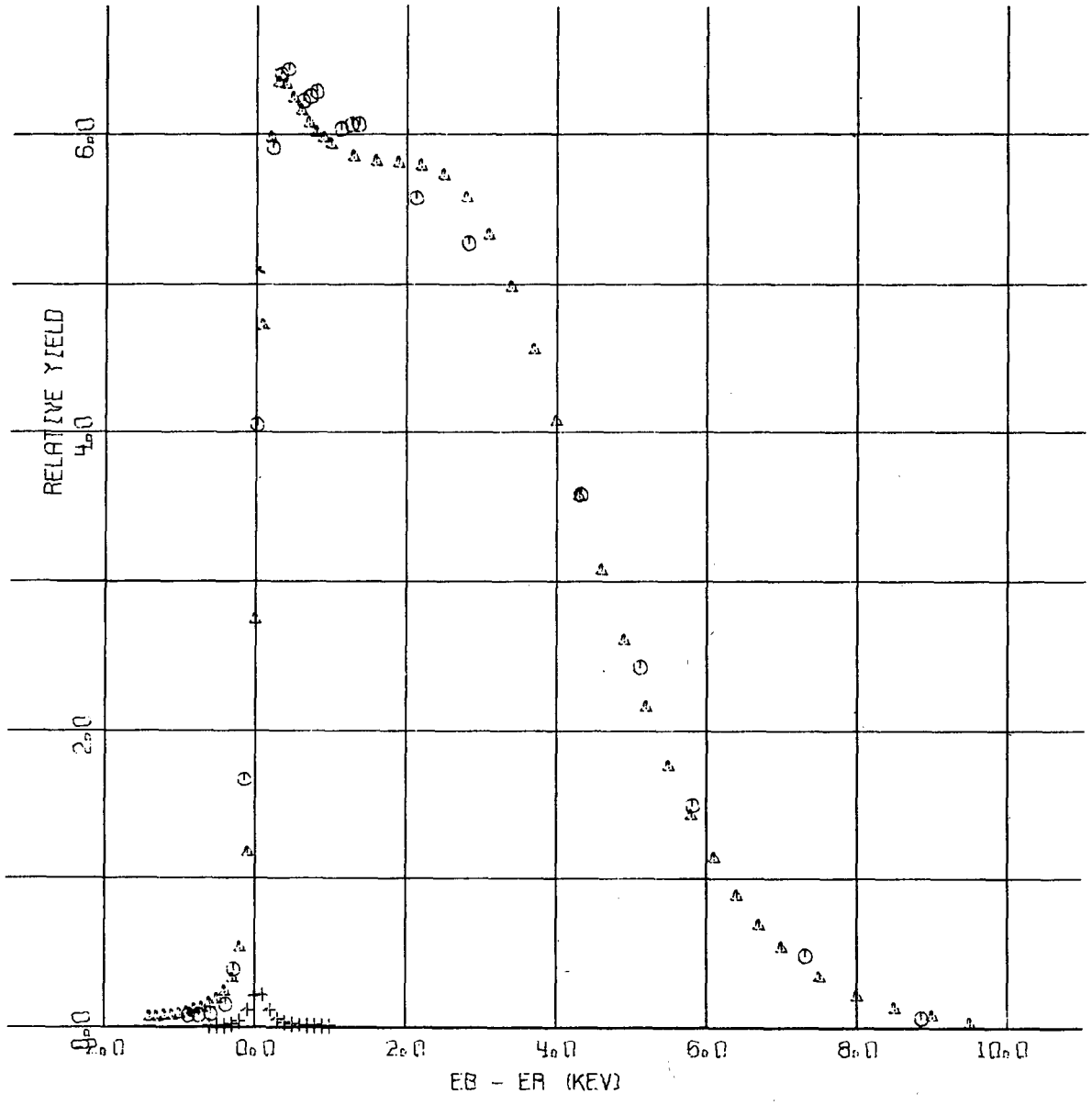

Fig. D1 - Plot from subroutine GRAPHA for the yield from the $^{27}Al(p,\gamma)^{28}Si$ reaction. The target consist of an 0.156 keV layer of Al_2O_3 on an aluminum target 4.934 keV thick. The experimental data are from Ref. 2.

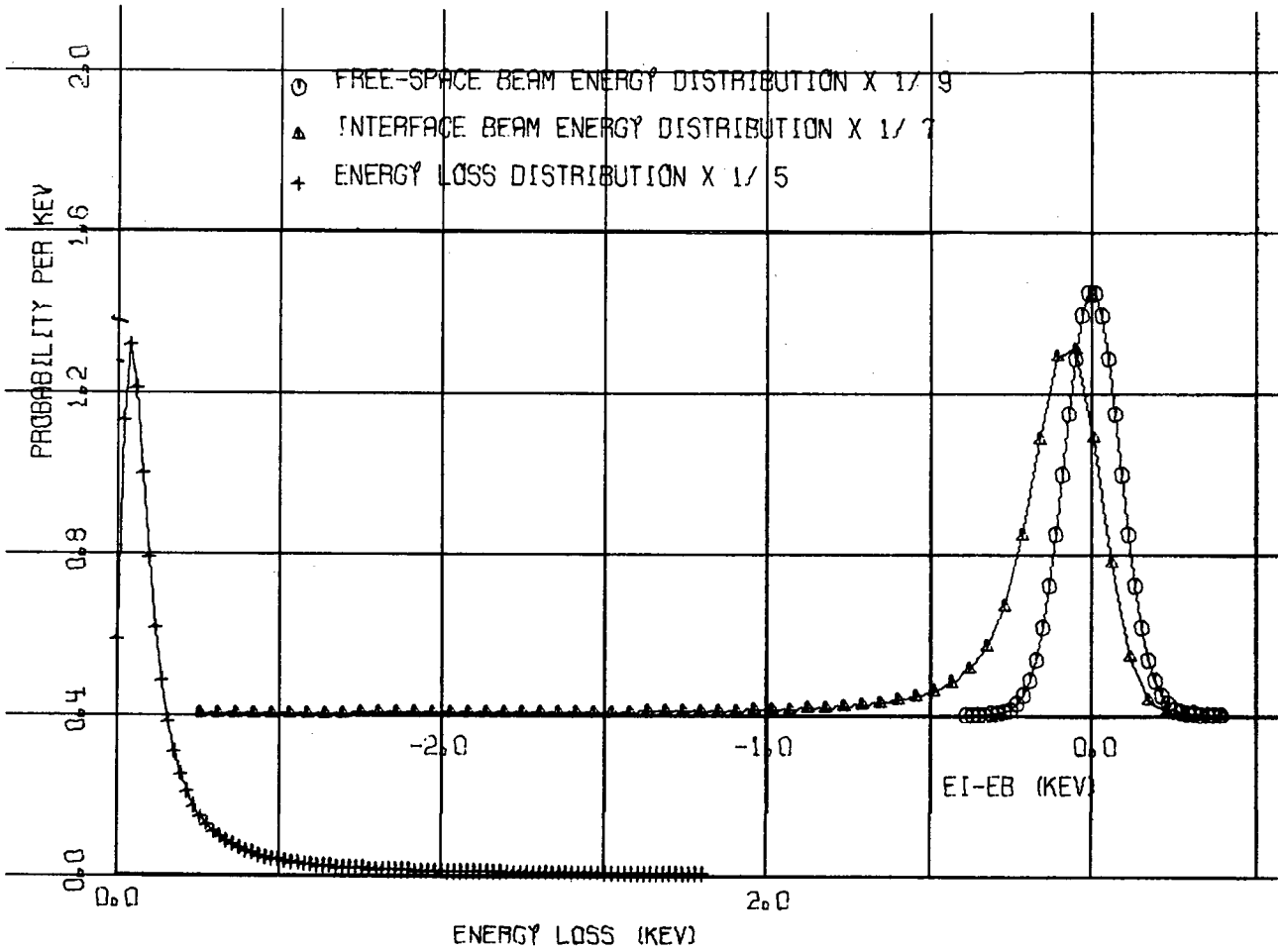

Fig. D2 - Plot from subroutine GRAPHB for a proton beam having a FWHM of 0.198 keV target of aluminum having a layer of Al_2O_3 0.156 keV thick at resonance energ

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FORTRAN PROGRAMS FOR (p,γ) YIELD CALCULATIONS BASED ON VAVILOV'S THEORY OF ENERGY LOSS DISTRIBUTIONS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

This is a final report on this phase of the work; work is continuing on other phases.

5. AUTHOR(S) *(First name, middle initial, last name)*

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13. ABSTRACT

Two Fortran programs have been written to provide a method for the analysis of (p,γ) resonance yield curves for targets that may be thick compared to resonance width but which have a total energy loss small compared to the energy of the incident particle. For the sake of definiteness, (p,γ) reactions are discussed but the programs may be used for some other incident particles as well.

The programs are designed with several kinds of usage in view; in each, calculated and experimental yield curves are to be compared. A subprogram for plotting yield curves on a Calcomp plotter facilitates this comparison. Other subprograms provide plots that are useful in insuring that suitable parameters have been chosen as input data. Among the uses envisioned are: (1) the extraction of resonance widths and energies from experimental (p,γ) yield data for homogeneous targets and for targets that have a layer of inert matter or matter that contributes to the yield but which is different from that of the target; (2) the determination of the energy loss characteristics of a layer of matter on a target which produces a reaction with a sharp resonance of known properties; (3) the determination of target thickness, e.g., for solid targets used in neutron production; (4) the determination of the atomic composition of certain kinds of thin films; (5) the calculation of energy loss distributions; and (6) the calculation of the beam energy distributions after the beam has passed through a slab of matter.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
(p,γ) Yield calculations Vavilov's Theory Fortran programs Nuclear resonances Energy loss fluctuations						

The necessary energy loss distributions for the target are calculated by means of a theory due to P.V. Vavilov which gives a mathematically rigorous solution of an integro-differential equation for the many-collision energy loss fluctuations experienced by a charged particle as it penetrates matter. This solution is based on a free-electron single-collision energy loss probability density; the consequences of this assumption are discussed.