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SIOB:* A FORTRAN CODE FOR LEAST-SQUARES SHAPE FITTING SEVERAL NEUTRON TRANSMISSION MEASUREMENTS USING THE BREIT-WIGNER MULTILEVEL FORMULA

G. de Saussure, D. K. Olsen, R. B. Perez

*("...seven in one blow...", R. L. Macklin)

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ABSTRACT

The FORTRAN-IV code SIOB was developed to least-square fit the shape of neutron transmission curves. Any number of measurements on a common energy scale for different sample thicknesses can be simultaneously fitted. The computed transmission curves can be broadened with either a Gaussian or a rectangular resolution function or both, with the resolution width a function of energy. The total cross section is expressed as a sum of single-level or multilevel Breit-Wigner terms and Doppler broadened using the fast interpolation routine QUICKW. The number of data points, resonance levels and variables which can be handled simultaneously is only limited by the overall dimensions of two arrays in the program and by the stability of the matrix inversion. In a test problem seven transmissions each with 3750 data points were simultaneously fitted using 74 resonances and 110 variable parameters. The problem took 47 min. of CPU time on an IBM-91, for 3 iterations.

I. INTRODUCTION

In order to improve the accuracy of the ^{238}U resonance parameters up to a few keV, Olsen *et al.* have recently completed two series of neutron-transmission measurements, using flight paths of 40 m and 150 m successively. In both series of measurements the transmissions were obtained through several ^{238}U sample thicknesses.[1]

Several existing computer codes were examined[2-5] but none was found entirely suitable for the simultaneous analysis of transmissions on the same energy scale through several thicknesses. The code described herein was primarily designed for this analysis, but it was also successfully applied to the analysis of transmission data through samples composed of medium and lightweight nuclei.[6]

In Section II of this memo we give an outline of the structure of the code, which may be helpful in understanding the other sections of this report and the program. Section III discusses the expression for the theoretical transmission and shows how it is resolution broadened. In Section IV we define several expressions for the total cross-section and outline how these are Doppler broadened. Section V briefly discusses the least-square-fit algorithm and Section VI indicates the relations between two critical array dimensions in the program and the size of the fitting problem. In Section VII we explain the operation of flags by which the user indicates which parameters should be held fixed or varied by the program.

In the Appendices we give a list of the input parameters and their functions, the input and output of a sample problem, and a complete FORTRAN listing of the program.

II. BRIEF DESCRIPTION OF THE PROGRAM

The subroutines and functions used with their arguments are listed in Table I. An outline of the program is given below:

1. The main program reads all input data. A list of these data and their function is given in Appendix I. Some of the input parameters are fixed and specify the problem, other input parameters are initial guesses for parameters which can be varied, and the last input parameters are flags which have a one to one correspondence to the parameters which can be varied. These flags specify which parameters are held fixed (flag is zero) and which parameters are varied (flag is one or two).
2. After reading the input, the main program calls the subroutine PHINEQ. In this subroutine the resolution-broadened theoretical transmissions are computed and compared with the experimental transmissions to obtain the initial χ^2 called PHIOLD. In addition the normal equations for the changes in the variable parameters are constructed before control is returned to the main program.
3. The main program then calls subroutine MVP. In this subroutine the normal equations are solved through a matrix inversion in the subroutine SLV. The variable parameters are altered through addition of the proper components of the solution vector. The

TABLE I. LIST OF SUBROUTINES AND FUNCTIONS USED BY SIOB

1. Subprograms called by MAIN

```
SUBROUTINE PHINEQ(JV)
SUBROUTINE MVP
```

2. Subprograms called by PHINEQ

```
FUNCTION   RES(E, JRES)
FUNCTION   BGR(E, NT)
FUNCTION   WEIGHT(NT, IE)
FUNCTION   SIG(E, JV)
```

3. Subprograms called by MVP

```
SUBROUTINE SLV(NV2)
SUBROUTINE PHINEQ(JV)
FUNCTION   PEN(LJ, RHO)
```

4. Subprograms called by SIG

```
FUNCTION   PHI2(LJ, RHO)
FUNCTION   DPH(LJ, RHO)
FUNCTION   SHF(LJ, RHO)
FUNCTION   DSHF(LJ, RHO)
FUNCTION   PEN(LJ, RHO)
FUNCTION   FNS(VE, E, N)
SUBROUTINE SVS(AX, YI, REW, AIMW)
```

5. Subprograms called by SVS

```
SUBROUTINE W(REZ, AIMI, REW, AIMW)
SUBROUTINE QUICKW(AX, Y, REW, AIMW)
```

changes in the variable parameters are printed at each iteration. A new value of χ^2 called PHI is then computed and control returned to the main program.

4. The new value of χ^2 is compared to the previous value determined in step 2. If χ^2 has significantly decreased and if the number of iterations has not exceeded a preset number of iterations IT2, the number-of-iterations counter is incremented and the program proceeds again with step 2; otherwise, the program is terminated.

III. CALCULATED RESOLUTION BROADENED TRANSMISSION

The number *NT*2 of experimental transmission curves are fitted simultaneously. The trial calculated transmissions are:

$$T_{NT}(E) = (1 - \varepsilon_{NT}) \cdot \int e^{-\tau_{NT}\sigma(E',\lambda_1,\lambda_2,\ \ldots)} P(E,E')dE' + \beta_{NT} \cdot BGR(E,NT)$$

$$NT = 1,2,\ldots NT2 \tag{1}$$

where the ε_{NT}, τ_{NT} and β_{NT} are variable parameters which can be searched. The Doppler-broadened cross-section $\sigma(E',\lambda_1,\lambda_2,\ldots)$ is a function of other variable parameters λ_i, which will be discussed in the next section. The τ_{NT}'s are the sample thicknesses, in atoms per barn, corresponding to the transmission curves $T_{NT}(E)$. If the experimental transmissions are properly normalized and if the backgrounds are properly substracted, the values of the ε_{NT} and β_{NT} should vanish; however because there are experimental uncertainties associated with the normalization and with the background substraction, it may be desirable to consider the ε_{NT} and β_{NT} as variables to be searched. An energy dependent background shape may be coded for each thickness, as desired, in the function $BGR(E,NT)$.

The resolution function is taken to be of the form:

$$P(E,E') = Ae^{-\left[\frac{E-E'}{R(E)}\right]^2} \qquad (2)$$

where A is a normalization constant such that

$$\int P(E,E')dE' = 1 \qquad (3)$$

and where the resolution width $R(E)$ may either be coded as desired in the function $RES(E,JRES)$ or, if $JRES = 0$, is taken as:

$$R(E) = \left[BE2 \cdot E^2 + CE3 \cdot E^3\right]^{1/2} \qquad (4)$$

where $BE2$ and $CE3$ are fixed input parameters. Expression (4) is appropriate for time-of-flight measurement;[7-11] in this case:

$$BE2 = \frac{2}{3}\left(\frac{\delta L}{L}\right)^2 \text{ and } CE3 = \frac{2}{3}\left(\frac{\delta t}{\mu L}\right)^2 \qquad (5)$$

where L is the flight-path length, δL is the total uncertainty in flight-path due to the finite thicknesses of the source and of the detector and to the "equivalent length" of the moderation spread; dt is the total uncertainty in timing and the constant $\mu = 72.3$ eV$^{1/2}$ μS/m. The factors 2/3 in (5) arise from the conversion of an assumed rectangular uncertainty to an equivalent Gaussian uncertainty. For more details on resolution functions, the references should be consulted.

The convolution of Eq. (1) is approximated by the Gauss-Hermite technique:

$$\int y(x)e^{-x^2}dx \simeq \sum_{NG=1}^{NG2} A_{NG} \cdot y\left(x_{NG}\right) \qquad (6)$$

The values of the coefficients A_{NG} and of the roots of the Hermite polynomials x_{NG} were taken from the paper of Salzer, Zucker and Capuano.[12] $NG2$ is an input parameter which can be selected as any odd integer between 1 and 19. The precision of the approximation increases as NG2 increases, but so does the run time of the program. Values of $NG2$ between 5 and 9 have been found adequate for most cases. If $NG2$ = 1 the calculated transmissions are not resolution broadened.

When the experimental transmission is measured over successive rectangular time-of-flight channels of nearly equal energy widths, the resolution broadening due to the finite width of the time-of-flight channels can efficiently be represented by fitting a parabola to the compared transmissions at the energies corresponding to the center of the channels i-1, i, and i+1, and integrating that parabola over the width of the ith channel. This procedure leads to the relation:

$$T_i^* = \frac{1}{24}(T_{i-1} + 22T_i + T_{i+1}) \qquad (7)$$

where T_i^* is the time-of-flight-broadened transmission in channel i, and T_i is the unbroadened transmission at the energy corresponding to the center of channel i. A "switch" *JPLY* = 1 allows the program to combine the rectangular broadening given by Eq. (7) with the Gaussian broadening given by Eq. (6).

IV. TOTAL CROSS-SECTION EXPRESSIONS

The Doppler broadened total cross-section and its derivatives with respect to the variable parameters are computed in the function *SIG*.

The basic formulae utilized are the single-level[13] and multi-level[14] Breit-Wigner formulae as defined in ENDF/B procedures.[15] These formulae and their parametrization are discussed below:

A. The Single-Level-Breit-Wigner Formula

The expression for the total cross section is given by

$$\sigma_{nt}(E) = \sum_{\ell} \sigma_{nt}^{\ell}(E) \ , \qquad (8)$$

where

$$\sigma_{nt}^{\ell}(E) = (2\ell + 1)\frac{4\pi}{k^2} \sin^2\phi\ell + \frac{\pi}{k^2} \sum_{J} g_J \sum_{r} \frac{\Gamma_{nr}\left[\Gamma_r \cos 2\phi\ell - 2(E-E_r')\sin 2\phi\ell\right]}{(E-E_r')^2 + \frac{1}{4}\Gamma_r^2} \qquad (9)$$

and where g_J is the usual spin statistical factor given by

$$g_J = \frac{2J+1}{2 \cdot (2I+1)} \qquad (10)$$

The quantity I is the spin of the target nucleus and J is the spin of the resonance state. The energy dependence of the neutron width is given by:

$$\Gamma_{nr}(E) = \frac{\Gamma_{nr}(|E_r|)}{P_{\ell}(|E_r|)} \cdot P_{\ell}(E) \qquad (11)$$

where Er is the resonance level energy. The total width is given by:

$$\Gamma_r(E) = \Gamma_{nr}(E) + \Gamma_{ar} \qquad (12)$$

where Γ_{ar} is the reaction width. The shifted resonance energy is given by:

$$E'_r = E_r + \frac{S_\ell(|E_r|) - S_\ell(E)}{2P_\ell(|E_r|)} \; ; \; \Gamma_{nr}(|E_r|) \tag{13}$$

The shift factors $S_\ell(ka)$, penetration factors $P_\ell(ka)$ and phase shifts $\phi_\ell(k\hat{a})$ are given in Table II for the angular momentum values $\ell = 0,1,2$ and 3. The quantity k is the neutron wave number, a the channel radius and $\hat{a}$ the effective scattering radius.

B. The Multilevel-Breit-Wigner Formula

The multilevel-Breit-Wigner expression for the cross section is the same as the single-level expression except that the level-level interference term is added; that is,

$$\left[\sigma_{nt}^{\ell}(E)\right]_{ML} = \left[\sigma_{nt}^{\ell}(E)\right]_{SL} + \frac{\pi}{k^2} \sum_J g_J \sum_r \sum_{s \neq r} \frac{\Gamma_{nr}\Gamma_{ns}\left[(E-E'_r)(E-E'_s) + 1/4\Gamma_r\Gamma_s\right]}{\left[(E-E'_r)^2 + \frac{1}{4}\Gamma_r^2\right] \cdot \left[(E-E'_s)^2 + \frac{1}{4}\Gamma_s^2\right]} \tag{14}$$

where $\left[\sigma_{nt}^{\ell}(E)\right]_{SL}$ represents the cross section given in Eq. (9). The level-level interference term in Eq. (14) can be recast in a form more suitable for Doppler broadening; that is,

$$\left[\sigma_{nt}^{\ell}(E)\right]_{ML} = \left[\sigma_{nt}^{\ell}(E)\right]_{SL} + \frac{\pi}{k^2} P_\ell(E) \sum_J g_J \sum_r \frac{\Gamma_{nr}\left[\Gamma_r G_r - 2(E-E'_r)H_r\right]}{(E-E'_r) + \frac{1}{4}\Gamma_r^2} \tag{15}$$

where

$$G_r = \sum_{s \neq r} \Gamma^\circ_{ns} \frac{g_{rs}}{g_{rs}^2 + h_{rs}^2} \; , \tag{16}$$

TABLE II. SHIFT FACTORS, PENETRATION FACTORS AND PHASE SHIFTS FOR ANGULAR MOMENTA $\ell = 0, 1, 2$ and 3

Angular Momentum ℓ	Shift-factor $S_\ell(\rho)$	Penetration Factor $P_\ell(\rho)$	Phase Shift $\phi_\ell(\rho)$
0	0	ρ	ρ
1	$-\frac{1}{1+\rho^2}$	$\frac{\rho^3}{1+\rho^2}$	$\rho - \tan^{-1}\rho$
2	$-\frac{18+3\rho^2}{9+3\rho^2+\rho^4}$	$\frac{\rho^5}{9+3\rho^2+\rho^4}$	$\rho - \tan^{-1}\left(\frac{3\rho}{3-\rho^2}\right)$
3	$-\frac{675+90\rho^2+6\rho^4}{225+45\rho^2+6\rho^4+\rho^6}$	$\frac{\rho^7}{225+45\rho^2+6\rho^4+\rho^6}$	$\rho - \tan^{-1}\left[\frac{\rho(\rho-15)}{6\rho^2-15}\right]$

For definitions, see text below Eq. (13).

$$H_r = \sum_{s \neq r} \Gamma^{\circ}_{ns} \frac{d_{rs}}{g^2_{rs} + h^2_{rs}} , \tag{17}$$

$$\Gamma^{\circ}_{ns} = \frac{\Gamma_{ns}(|E_s|)}{P_\ell(|E_s|)} , \tag{18}$$

$$g_{rs} = \frac{1}{2}(\Gamma_r + \Gamma_s) \text{ and } d_{rs} = E'_r - E'_s . \tag{19}$$

Through the penetration and shift factors of Eqs. (11) and (13), the terms g_{rs} and d_{rs}, and hence also G_r and H_r have a weak energy dependence; however, since the level-level interference is important only in the vicinity of a resonance level, the program evaluates G_r and H_r at the resonance energy E_r and neglects their energy dependence. This a very good approximation which results in a considerable saving in computer time since G_r and H_r need not be recomputed at each energy.

C. Truncation Effects

The sums over levels in Eqs. (9), (15), (16), and (17) extend over all levels of a given J-sequence. However, since the transmission is computed over a finite energy interval, only those levels within the interval and a few important levels near the boundaries of the interval are explicitly retained. The contribution of the other levels to the cross section may be approximated using a picket-fence model of uniformly spaced levels with average resonance parameters.[16,17] Using this model the contribution of the levels that are not retained in the sums in Eqs. (9), (15), (16) and (17) are estimated to be $F_1 \sin 2\phi\ell + F_2(\Gamma) \cos 2\phi\ell$, $\frac{1}{2}[F_1{}^2 + F_2(\Gamma)^2]$, $F_2(\Gamma + \Gamma_r)$ and F_1 respectively, where

$$F_1 = S \cdot P_\ell(E) \cdot \ell n\left(\frac{EH - E + \varepsilon D}{E - EL + \varepsilon D}\right) \tag{20}$$

$$F_2(\Gamma) = S \cdot P_\ell(E) \cdot \frac{EH - EL + D}{(EH - E + \frac{1}{2} D)(E - EL + \frac{1}{2} D)} \cdot \frac{\Gamma}{2} \qquad (21)$$

$$\Gamma = \Gamma_a + \langle\Gamma_n^\circ\rangle P_\ell(E) \qquad (22)$$

where $\langle\Gamma_n^\circ\rangle$ is the average value of the reduced neutron width, Γ_a is the average reaction width, D the average level spacing and S the strength function. The quantities EH and EL are the energies of the highest and lowest levels explicitly included in the sums, and $\varepsilon = (1 - e)^{-1} \simeq .582$. The approximations have been discussed in some detail in Ref. 17.

D. The Total Cross-Section Trial Function.

The total cross-section trial function used by the program is represented by:

$$\sigma = \sum_{NS=1}^{NS2} \eta_{NS} \cdot \frac{2\pi}{k_{NS}^2} \sum_{J=1}^{J2(NS)} \left[(2\ell+1) \cdot 2 \sin^2\phi\ell \cdot F_J + g_J P_J\right] \qquad (23)$$

$$+ \sum_{N=1}^{NAUX} \gamma_N \cdot f(E,N)$$

where $NS2$ nuclear species NS contribute to the cross section and the parameters η_{NS} allows the program to search for the isotopic concentrations of the species NS. The quantity k_{NS} represents the neutron wave number in the center-of-mass system for a collision with the species NS. For each species there are $J2(NS)$ level sequences for which an angular momentum ℓ and a spin statistical factor g_J are specified. The resonance term P_J will be discussed later. By setting $F_J = 0$ the user may make the contribution of a given sequence to the potential scattering vanish. The last sum in Eq. (23) describes an optional arbitrary function of energy with $NAUX$ parameters which can be searched. The functions $f(E,N)$

may be programmed as desired, and can be used to represent the contributions to the cross-section from far away levels, from isotopes not explicitly included in the first sum, or other sources.

The resonance term P_J vanishes if the number of levels $NR2(J)$ for the given J-sequence is zero; otherwise,

$$P_J = \sum_{NR=1}^{NR2} \Gamma_{nNR} \left[GR_{NR}U_{NR} - HR_{NR}V_{NR} \right] + F_2(\Gamma) \cos(2\phi_\ell) + F_1 \sin(2\phi_\ell) \quad (24)$$

where:

$$GR_{NR} = \cos(2\phi\ell) + \left[\sum_{S\neq NR} \Gamma^\circ_{ns} \frac{g_{NRS}}{g^2_{NRS} + d^2_{NRS}} + F_2(\Gamma + \Gamma_r) \right], \quad (25)$$

$$HR_{NR} = \sin(2\phi\ell) + \left[\sum_{S\neq NR} \Gamma^\circ_{ns} \frac{d_{NRS}}{g^2_{NRS} + d^2_{NRS}} + F_1 \right], \quad (26)$$

$$U_{NR} = \frac{\frac{1}{2}\Gamma_{NR}}{(E'_{NR}-E)^2 + (\frac{1}{2}\Gamma_{NR})^2}, \quad (27)$$

$$V_{NR} = \frac{E'_{NR} - E}{(E'_{NR}-E)^2 + (\frac{1}{2}\Gamma_{NR})^2}. \quad (28)$$

The bracketed terms in Eqs. (25) and (26) are included only when the multi-level formula is used. The terms Γ_{NR}, E'_{NR}, g_{NRS} and d_{NRS} have been defined previously by Eqs. 12, 13, and 19, respectively. In Eqs. 24, 25 and 26, the phase shift $\phi\ell$ is a function of $k_{NS} \cdot \hat{a}_{NS}$ and is given in Table II for different values of the angular momentum ℓ; $\hat{a}_{NS}$ is the effective scattering radius for the nuclear species NS.

The cross-section parameters which can be searched by the program are the isotopic concentrations n_{NS} and effective scattering radius $\hat{a}_{NS}$ for each nuclear species, the resonance energies E_{NR}, neutron widths Γ_{nNR} and reaction widths Γ_{aNR} of each level and the parameters γ_N of Eq. (23). Expressions (27) and (28) are used to compute the unbroadened cross-section. The Doppler broadening of those expressions is discussed in the next subsection.

E. Doppler Broadening.

The only rapidly varying functions of energy in the expression for the total cross section are the line-shape functions U_{NR} and V_{NR} of Eqs. 27 and 28; hence, the Doppler broadened cross section is obtained by replacing the functions U_{NR} and V_{NR} by their Doppler broadened expressions[18] U^*_{NR} and V^*_{NR} defined by

$$U^*_{NR}(E) = \frac{\Delta}{\sqrt{\pi}} \int U_{NR}(E')e^{-\left(\frac{E-E'}{\Delta}\right)^2} dE' , \tag{29}$$

and

$$V^*_{NR}(E) = \frac{\Delta}{\sqrt{\pi}} \int V_{NR}(E')e^{-\left(\frac{E-E'}{\Delta}\right)^2} dE' . \tag{30}$$

where Δ is the Doppler width. Expressions (29) and (30) are computed by the fast interpolation routine QUICKW developed at Argonne National Laboratory.[19]

V. LEAST-SQUARE-FIT ALGORITHM

The best values of the n variable parameters p_1, p_2, $\ldots p_n$ are obtained by minimizing

$$\phi = \sum_{ij} w_{ij}\left[T_{ij}^{(e)} - T_{ij}(E_i, N_j, p_1, \ldots p_n)\right]^2 \qquad (31)$$

with respect to the p_k's, with perhaps constraints on some of the p_k's; for example, resonance widths may not become negative. Equation (31) is a double sum where $T_{ij}^{(e)}$ is the measured transmission and T_{ij} the computed transmission at energy E_i for the sample thickness N_j. The quantity w_{ij} is the weight of the measured transmission and, in general, is the inverse square of the statistical uncertainty.

Usually the computed transmissions are not linear functions of the variable parameter p_k; hence, the minimization problem must be solved by an iterative technique. The program uses a variation of the Gauss-Newton-Marquardt technique[20] which has been found efficient and is outlined below. For a justification of the efficiency of the technique, references 20 and 21 should be consulted.

The minimization problem is linearized by expanding the computed transmissions in a Taylor series around guessed or previously iterated values of the parameters $p_k^{(o)}$. Keeping only the first term in the expansion gives

$$\langle\phi\rangle = \sum_{ij} w_{ij}\left[T_{ij}^{(e)} - T_{ij}\left(P_k^{(o)}\right) - \sum_k \frac{\delta T}{\delta P_k}\,\delta P_k\right]^2 . \qquad (32)$$

The linearized expression $\langle\phi\rangle$ is minimized by the solution of a system of linear equations which may be represented in matrix form as

$$M\vec{d} = \vec{v} \qquad (33)$$

where $d_k = p_k - p_k^{(0)}$ is a component of the correction vector $\vec{d}$

$$M_{k\rho} = \sum_{ij} w_{ij} \cdot \frac{\delta T_{ij}}{\delta p_k} \cdot \frac{\delta T_{ij}}{\delta p_\rho} \tag{34}$$

and

$$V_k = \sum_{ij} w_{ij} \left[T_{ij}^{(e)} - T_{ij}\left(p^{(0)}\right)\right] \frac{\delta T_{ij}}{\delta p_k} . \tag{35}$$

Equation (33) is solved by inversion of the matrix M:

$$\vec{d} = M^{-1}\vec{V} \tag{36}$$

The initial values of the variable parameters p_k are changed to the new values

$$p_k^{(1)} = p_k^{(0)} + \eta d_k \tag{37}$$

where η is gauged to insure that none of the parameters which are defined positive will become negative. If for one or several positive-defined parameters p_r we have

$$d_r \leq -p_r^{(0)} \tag{38}$$

then

$$\eta = -0.9\left[\frac{p_r^{(0)}}{d_r}\right]_{\text{min}} \tag{39}$$

where the bracketed term is the value of $\left(p_r^{(0)}/d_r\right)$ for which η is the smallest among the set of positive-defined parameters for which condition (38) holds. If condition (38) never holds for the positive-defined parameters, then η is unity.

There is no guarantee that the value of ϕ computed with the new values $p_k^{(1)}$ will be smaller than the value of ϕ computed with the old values $p_k^{(0)}$ since the minimization was derived for the linearized $\langle\phi\rangle$ of Eq. 37.

The algorithm used to minimize ϕ operates as follows: if $\phi\left[\vec{p}^{(1)}\right]$ is smaller or equal to $\phi\left[\vec{p}^{(0)}\right]$ then the old values $p_k^{(0)}$ of the parameters are replaced by their new estimates $p_k^{(1)}$ and a new iteration is initiated, unless the maximum number of allowed iterations has been reached. If $\phi\left[\vec{p}^{(1)}\right]$ is larger than $\phi\left[\vec{p}^{(0)}\right]$, Eq. (33) is replaced by:

$$(M + 2^n\, b\, I)\vec{d} = \vec{V} \tag{40}$$

where I is the identity matrix ($I_{k\ell} = \delta_{k\ell}$) and b is a constant defined by

$$b = 0.033\, \frac{(\vec{V}\, M\, \vec{V})}{(\vec{V}\, \vec{V})} \ . \tag{41}$$

The value of n in Eq. (40) is incremented by unit steps from zero to ten, until a value of $\vec{d}$ is found by solving Eq. (40) such that

$$\phi(\vec{p}^{(0)} + n\vec{d}) \leq \phi(\vec{p}_0) \ . \tag{42}$$

If inequality (42) cannot be satisfied for $n \leq 10$, the search is terminated.

The normal matrix M of Eq. (33) is symmetric and positive definite. To save computer space and time it is stored and used in triangular form. The matrix inversion is done by the Cholesky method which is particularly well-suited for this kind of problem.[22-24] The normal vector $\vec{V}$ and normal matrix M are stored in CØMMØN/VAR/, the inversion and the multiplication of Eq. (36) are performed in the subroutine SLV.

VI. DIMENSIONS OF THE PROGRAM

The number of data points, resonance levels, and variables which can be handled simultaneously is only limited by two critical dimensions which are set in the main part of the program and by the stability of the matrix inversion. In a test problem seven transmissions, each with 3750 data points were simultaneously fitted using 74 resonance levels and 110 variable parameters.

The critical dimensions which control the maximum size of the problem are the dimensions of blank COMMON and of the labeled COMMON/VAR/. These dimensions are referred to as $IG2P$ and $KG2P$ and their values should be inserted in a DATA statement in the main program as shown in the FORTRAN listing in Appendix D. The program will then verify that the critical dimensions are sufficiently large for the problem to be solved before going into the least square search routine. If the dimensions are not sufficiently large, a message is printed and the program stops. The values required for $IG2P$ and $KG2P$ are determined by the following inequalities:

$$IG2P \geq NDAT(3 \cdot NT2+1) + 2(3 \cdot NT2+3 \cdot NRT+2NS2+NAUX+NLS) \tag{43}$$

$$KG2P \geq \frac{NV2}{2}(NV2+19) + (1+NV2)NT2 \tag{44}$$

where $NDAT$ is the number of energy points at which transmissions for $NT2$ sample sizes are given, NRT is the total number of resonance levels, $NS2$ the total number of nuclear species, $NAUX$ the total number of auxiliary parameters (the γ_N's of Eq. 23), NLS the total number of levels which are treated by the Breit-Wigner-multilevel formula, and $NV2$ is the total number of variable parameters with a positive flag as described in the next section.

VII. VARIABLE PARAMETERS AND FLAGS

The variable parameters whose value can be searched on by the program are:

(1) the normalizations ε_{NT}, thicknesses τ_{NT} and background parameters β_{NT} defined in Eq. (1) and Section III;

(2) the isotopic concentrations η_{NS} and effective scattering radii $\hat{a}_{NS}$ discussed under Eq. (23) in Section IV D;

(3) the resonance energies E_{NR}, neutron widths at resonance $\Gamma_{nNR}(E_{NR})$, and reaction widths Γ_{aNR} discussed in Section IV A;

(4) and the cross-section background parameters γ_n defined in the last term of Eq. (23).

A flag is read for each variable parameter which allows the user to control how the variable parameter will be treated; the value of the flags should be set to 0, 1, or 2. Parameters with flags equal to 0 will be treated as constant and their values will not be searched by the program. For parameters with flags equal to 1, an optimum real value will be searched. If the flag is equal to 2 an optimum positive value will be searched. Hence it is advisable to assign a flag equal to 2 to those variable parameters which are defined positives.

It is important to note that varying simultaneously some combinations of parameters may result in an indeterminate problem; in such cases the normal matrix will have a zero determinant, cannot be inverted, and an error message will be printed. For example, if only one sample thickness and only one nuclear species are used, the product $\tau_{NT}\eta_{NS}$ determines the areal density and only one of the two parameters τ_{NT} or η_{NS} can be varied.

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APPENDIX I. INPUT DATA AND THEIR FUNCTIONS

Various versions of the program SIØB have been in use, which differ mostly by the input format. This appendix discusses the input data required by the version whose FORTRAN is listed in Appendix II.

The input data may be divided into four groups:

A. Fixed points input switches and floating point input constants which control the operation of the program, as will be explained below.

B. Transmission data.

C. Initial guesses.

D. Flags.

The structure and format of the input data cards is listed immediately below. After this listing the function of these input data will be discussed.

Structure and Format of Input Cards

A. Fixed point switches and floating point constants.

1st card:	Format (9A8)	Legend
2nd card:	Format (15I4)	*NT*2, *IT*2, *NGS*, *NAUX*, *JERR*, *JCAL*, *JRES*, *JPAR*, *LPAR*, *LMAT*, *MPAR*, *LPLT*, *LDAT*, *JPLY*, *JKEV*
3rd card:	Format (6F11.3)	*BE*2, *CE*3, *EH*, *EL*, *RATIØ*, *DTMIN*

B. Transmission data.

4. Format Card:	Format (9A8)	*FMDAT*

5. Data Cards: Format (FMDAT), read in 4.

$E, T, \delta T, T_2, \delta T_2 \ldots, T_{NT_2}, \delta T_{NT_2}$

6. Terminate transmission data with a blank card.

C. Initial guesses.

I. Transmission Parameters

7. Start with a blank card

8. Sample thicknesses: Format (8F10.5) $\tau_1, \tau_2, \ldots\tau_{NT_2}$

9. Normalisations: Format (8F10.5) $\varepsilon_1, \varepsilon_2, \ldots\varepsilon_{NT_2}$

10. Backgrounds: Format (8F10.5) $\beta_1, \beta_2, \ldots\beta_{NT_2}$

II. Resonance Parameters

8. Format-card: Format (9A8) *FMPAR*

9. Nuclear Species: Format (4E11.3) *FRS, AHAT, AWRI, TEMP*

10. J-Sequence: Format (2I11,5E11.3) *LJ, INT, GSJ, FR, STRF, GNA, GAV*

11. Level Parameters: Format (*FMPAR*), read in 8

E_0, Γ_n, Γ_j

12. Terminate each J sequence with a blank card.

13. Terminate each Nuclear Species with a blank card.

14. Terminate Resonance Parameters with a blank card.

III. Auxiliary Parameters

15. Auxiliary parameters: Format (7E11.3) $\gamma_1, \ldots\gamma_{NAUX}$

D. Flags

16. Start with a blank card.

17. Flags for thicknesses: Format (40F2.0) $F_{\tau_1}, \ldots F_{\tau NT_2}$

18. Flags for Normalizations: Format (40F2.0) $F\varepsilon_1, \ldots F\varepsilon_{NT_2}$

19. Flags for Backgrounds: Format (40F2.0) $F\beta_1, \ldots F\beta_{N^2}$

20. Flags of Nuclear Species: Format (2F2.0) *FFRS*, *FAHAT*

21. Flags of Level Parameters: Format (3F2.0) FE_0, $F\Gamma_n$, $F\Gamma_\gamma$

22. Terminate each J sequence with a blank card.

23. Terminate resonance parameters with a blank card.

24. Flags for auxiliary parameters: Format (40F2.0) $F\gamma_1, \ldots F\gamma_{NAUX}$

Functions of Input Data

Legend	This legend is printed at the head of the output print-out
*NT*2	Number of transmission samples
*IT*2	Maximum number of iterations
NGS	Number of terms in Gauss-Hermite convolution (see Eq. 6 of Section III)
NAUX	Number of auxiliary parameters (the γ_n's of Eq. 23 of Section IV D)
JERR=0	For usual options
JCAL=0	For usual options
JRES=0	The resolution function is computed by Eq. 4 of Section III
JRES≠0	The resolution function must be coded in the function *RES*(*E*, *JRES*)
JPAR=0	Level parameters are read in order E_0, Γ_n, Γ_γ
JPAR=1	Level parameters are read in order E_0, Γ_γ, Γ_n
LPAR=0	The initial guesses are printed before the iteration loop

LPAR=2	The initial guesses are printed before the iteration loop and the final values after the loop.
LPAR=-1	The initial guesses and final values are not printed.
LMAT$\leq$0	The parameter-covariance matrix is not printed
LMAT>0	The parameter-covariance matrix is printed
MPAR<0	The final values of the parameters are punched
MPAR$\geq$0	The final values of the parameters are not punched
LPLT<0	No plot-punched cards generated
LPLT$\geq$0	Final plot-punched cards generated
LPLT>0	Plot-punched cards generated at each iteration (These punched cards are used with a local utility program to generate plots)
LDAT$\leq$0	Calculated and measured transmissions not printed
LDAT>0	Final calc. and meas. transmissions printed
LDAT>1	Calc. and meas. transmissions printed at each iteration
JPLY$\neq$0	Transmissions are channel-broadened by Eq. 7 Section III
JPLY=0	Channel broadening is not done
JKEV=0	All energy inputs are in eV
JKEV$\neq$0	All energy inputs are in keV
*BE*2 and *CE*3	Parameters used in computing the resolution width of *JRES*=0; see Eq. 4 of Section III
EH, EL	Parameters used in computing the contribution of a picket-fence of levels, see Eq. 20 and 21 of Section IV D
RATIØ	Convergence parameters: the iteration loop is terminated if $\chi^2_{new} > RATI\emptyset * \chi^2_{old}$

DTMIN	A parameter used in function *WEIGHT*(*NT*,*JE*) to define a minimum error on the transmission data
FMDAT	Input format of transmission data
$E, T_1, \delta T_1, T_2, \delta T_2, \ldots$	Energy, transmission through first sample, error, transmission through second sample, error...
τ_i, i=1, *NT*2	Sample thickness, see Eq. 1, Section III
ε_i, i=1, *NT*2	Normalizations, see Eq. 1, Section III
β_i, i=1, *NT*2	Backgrounds, see Eq. 1, Section III
FMPAR	Input format of level parameters E_0, Γ_n, Γ_γ
FRS	Isotopic concentration of nuclear species (denoted η_{NS} in Eq. 23 Section IV D)
AHAT	Effective scattering radius of a nuclear species (denoted $\hat{a}_{NS}$ in Section IV D)
AWRI	Ratio of the mass of the isotope to that of a neutron
TEMP	Effective temperature for Doppler broadening
LJ	Orbital angular momentum ℓ of a given sequence
INT=0	The J-sequence is treated by the single level formula
INT=1	The J-sequence is treated by the multilevel formula
GSF	Spin statistical factor of a J-sequence
FR	Factor multiplying the potential scattering contribution of the J-sequence (Represented as $F\gamma$ in Eq. 23, Section IV D)
STRF, *GNA*, *GAV*	Parameters used in computing the contribution of a picket fence of levels, represented by S,$\langle\Gamma_n^\circ\rangle$ and Γ_a in Eq. 20, 21 and 22 of Section IV C. If STRF=0, the picket-fence contribution is ignored.

E_0, Γ_n, Γ_γ	Level parameters: resonance energy, neutron width at resonance, capture width. Given in eV if JKEV=0, otherwise in keV
$\gamma_1, \ldots \gamma_{NAUX}$	Auxiliary parameters defined in Eq. 23 Section IV D.
Flags	All the parameters τ_i, ε_i, β_i, are *FRS, AHAT,* E_0, Γ_n, $\Gamma\gamma$ and γ_i are associated with "flags" which are read in the same order as the parameters. The flag determines how the parameter is to be treated:
Flag=0	The parameter is not varied
Flag=1	The value of the parameter is adjusted to minimize χ^2
Flag=2	The value of the parameter is adjusted to minimize χ^2 but kept positive

(more detail on the operation of the flags are given in Section VII)

APPENDIX II. FORTRAN LISTING OF SIØB PROGRAM AND SUBPROGRAMS

```
**FTN,L,G,E,Y.
      REAL * 8 C
      REAL * 8 FM(9),LEGEND(9),FMAPB(9),FMDAT(9),FMPAR(9),FMFLG(9)
      DIMENSION C(1)
      COMMON F(2000)
      COMMON/VAR/G(700)
      DATA IG2P,KG2P/2000,700/
      COMMON/IAD/IP1,IPT2,IPN1,IPN2,IPB1,IPB2,IPS1,IP2,IF1,IFT2,IFN1,
     1IFN2,IFB1,IFB2,IFS1,IF2,IG1,IG2
      COMMON/KAD/LM1,LS1,MV1,MM1,MS1,MS2,KV1,KG1,KG2
      COMMON/NAD/NVT,NVN,NVB,NVP,NV2,NT2
      COMMON/INDX/JERR,JCAL,JRES,JPAR,LPAR,LMAT,MPAR,LPLT,LCAT,JPLY,JKEV
      COMMON/IEN/IE1,IE2,IE3,IEC1,IGS,NGT
      COMMON/LEV/JFLAG,NS2,NAUX,JL(10),NRL(10,10),MOM(10,10),INL(10,10)
      COMMON/FLT/BE2,CE3,EH,EL,PHI,DOFINV,DTMIN
      COMMON/FLD/AK0(10),CC(10),RAD(10),DELTA(10)
      COMMON/FL2/GSPIN(10,10),FRL(10,10),STRFL(10,10),GNAL(10,10),GAVL(10,10)
     110,10)
      EQUIVALENCE(C(1),G(1))
      DATA ITI,ITO,ITF,ITC/5,6,7,8/
      DATA FMAPB/8H(8F10.5),8*8H        /
      DATA FMCAT/8H(F10.5,1,8H4F5.3)  ,7*8H        /
      DATA FMPAR/8H(E11.5,2,8H2X,2E11.,8H5)      ,6*8H        /
      DATA FMFLG/8H(40F2.0),8*8H        /
      DATA NGSP,NAUXP,AKP,B4/1,1,.002196771,.00034465/
      DATA R0P,R1P,AWRIP/.123,.08,236.01/
      DATA PI/3.141593/
      DATA RATIO/.999/
      DATA IPLOT/0/
      DATA AKPCVT,B4CVT/31.62278,0.0010/
      DATA IRTN/0/
    1 READ(ITI,101) (LEGEND(I),I=1,9),IT
      WRITE(ITO,101)(LEGEND(I),I=1,9)
      IF(IT.NE.0)    GO TO 1
C     READ FIXED POINT INPUT
      READ(ITI,102)NT2,IT2,NGS,NAUX,JERR,JCAL,JRES,JPAR,LPAR,LMAT,MPAR,
     1LPLT,LDAT,JPLY,JKEV
C     READ FLOATING POINT INPUT
      READ(ITI,103)BE2,CE3,EH,EL,RATIO,DTMIN
      IF(JKEV.NE.0) AKP=AKP*AKPCVT
      IF(JKEV.NE.0) B4=B4*B4CVT
      IF(NT2.EQ.0)    NT2=7
      IE1=1
      IE3=NT2+1
      IF(JERR.EQ.0)    IE3=IE3+NT2
      IF(JCAL.EQ.0)    IE3=IE3+NT2
      IE=IE1-IE3
      IEC1=IE1+IE3-NT2
      IF(IT2.EQ.0)    IT2=10
      IF(RATIO.EQ.0.0)RATIO=0.9990
      IF(DTMIN.EQ.0.0) DTMIN=0.00010
      IF(NGS.EQ.0)    NGS=NGSP
      NGT=(NGS+1)/2
      IGS=(NGT*(NGT-1))/2
      IF(NAUX.EQ.0)    NAUX=NAUXP
      IF(LPAR.GE.0)    WRITE(ITO,222)NT2,IT2,NGS,NAUX,JERR,JCAL,JRES,JPAR
     1,LPAR,LMAT,MPAR,LPLT,LDAT,JPLY,JKEV

      IF(LPAR.GE.0)    WRITE(ITO,223)BE2,CE3,EH,EL,RATIO,DTMIN
C     READ FORMAT FOR TRANSMISSION DATA
      READ(ITI,101)(FM(I),I=1,9)
      IF(ICOMPARE(FM(1),8H        ,8).EQ.0)    GO TO 5
      DO 3 I=1,9
    3 FMDAT(I)=FM(I)
C     READ TRANSMISSION DATA
    5 IE=IE+IE3
      IF(JERR.EQ.0)    READ(ITI,FMDAT)F(IE),(F(IE+NT),F(IE+NT2+NT),NT=1,N
     1T2)
      IF(JERR.NE.0)    READ(ITI,FMDAT)F(IE),(F(IE+NT),NT=1,NT2)
      IF(F(IE).NE.0.)    GO TO 5
      IE2=IE-IE3
      NDAT=((IE-IE1)*NT2)/IE3
      IP1=IE
      IP0=IP1-1
      IE=IE+NT2
C     READ FORMAT FOR THICKNESSES
      READ(ITI,101)(FM(I),I=1,9)
      IF(ICOMPARE(FM(1),8H        ,8).EQ.0)    GO TO 9
      DO 7 I=1,9
    7 FMAPB(I)=FM(I)
C     READ SAMPLE THICKNESSES IN ATOMS PER BARN (APB)
    9 IPT2=IE-1
      READ(ITI,FMAPB)(F(IP),IP=IP1,IPT2)
C     READ TRANSMISSION-NORMALISATION ERRORS
      IPN1=IPT2+1
      IPN2=IPT2+NT2
      READ(ITI,FMAPB)(F(IP),IP=IPN1,IPN2)
```

```
C     READ TRANSMISSION BACKGROUNDS
      IPB1=IPN2+1
      IPB2=IPN2+NT2
      READ(ITI,FMAPB)(F(IP),IP=IPB1,IPB2)
      IE=IPB2+1
C     READ FORMAT FOR RESONANCE-PARAMETERS
      READ(ITI,101)(FM(I),I=1,9)
      IF(ICOMPARE(FM(1),8H         ,8).EQ.0)   GO TO 13
      DO 11 I=1,9
   11 FMPAR(I)=FM(I)
C     READ INITIAL GUESSES
   13 IPS1=IE
      NLS=0
      NS2=0
   14 NS2=NS2+1
      READ(ITI,104)FRS,AHAT,AWRI,TEMP,DEL,RN,AK
      IF(FRS.EQ.0.)   GO TO 19
      JL(NS2)=0
      F(IE)=FRS
      F(IE+1)=AHAT
      IE=IE+2
      IF(AWRI.EQ.0.)   AWRI=AWRIP
      IF(TEMP.NE.0.)   DEL=SQRT(B4*TEMP/AWRI)
      DELTA(NS2)=DEL
      IF(RN.EQ.0.)   RN=RCP*(AWRI**.333)+R1P
      RAD(NS2)=RN
      IF(AK.EQ.0.)   AK=AKP*AWRI/(1.+AWRI)
      AK0(NS2)=AK
      C0(NS2)=PI/(AK*AK)
      AKRN=AK*RN
   15 READ(ITI,106)LJ,INT,GSJ,FR,STRF,GNA,GAV
      IF(GSJ.EQ.0.)   GO TO 14
      J=JL(NS2)+1
      JL(NS2)=J
      MOM(NS2,J)=LJ
      GSPIN(NS2,J)=GSJ
      INL(NS2,J)=INT
      STRFL(NS2,J)=STRF
      GNAL(NS2,J)=GNA
      GAVL(NS2,J)=GAV
      FRL(NS2,J)=FR
      NRL(NS2,J)=0
   16 IF(JPAR.EQ.0)   READ(ITI,FMPAR)E0,GN,GG
      IF(JPAR.EQ.1)   READ(ITI,FMPAR)E0,GG,GN
      IF(E0.EQ.0.)   GO TO 15
      NRL(NS2,J)=NRL(NS2,J)+1
      IF(INT.NE.0)   NLS=NLS+1
      F(IE)=E0
      F(IE+1)=GG
      F(IE+2)=GN/PEN(LJ,AKRN*SQRT(ABS(E0)))
      IE=IE+3
      GO TO 16
   19 NS2=NS2-1
C     READ AUXILIARY PARAMETERS
      IP2=IE+NAUX-1
      READ(ITI,104)(F(IP),IP=IE,IP2)
C     READ FORMAT FOR FLAGS
      READ(ITI,101)(FM(I),I=1,9)
      IF(ICOMPARE(FM(1),8H         ,8).EQ.0)   GO TO 23
      DO 21 I=1,9
   21 FMFLG(I)=FM(I)
C     READ FLAGS TO VARY THICKNESSES
   23 IF1=IP2+1
      IFT2=IP2+NT2
      READ(ITI,FMFLG)(F(IF),IF=IF1,IFT2)
C     READ FLAGS TO VARY NORMALISATIONS
      IFN1=IFT2+1
      IFN2=IFT2+NT2
      READ(ITI,FMFLG)(F(IF),IF=IFN1,IFN2)
C     READ FLAGS TO VARY BACKGROUNDS
      IFB1=IFN2+1
      IFB2=IFN2+NT2
      READ(ITI,FMFLG)(F(IF),IF=IFB1,IFB2)
      IFS1=IFB2+1
      IF=IFB2
C     READ FLAGS TO VARY PARAMETERS
      DO 27 NS=1,NS2
      READ(ITI,FMFLG)F(IF+1),F(IF+2)
      IF=IF+2
      JL2=JL(NS)
      DO 27 J=1,JL2
      NR2=NRL(NS,J)
      IF(NR2.EQ.0) GO TO 26
      DO 25 NR=1,NR2
      READ(ITI,FMFLG)(F(IF+N),N=1,3)
```

```
   25 IF=IF+3
   26 CONTINUE
   27 READ(ITI,FMFLG)
      READ(ITI,FMFLG)
      IF2=IF+NAUX
      IF=IF+1
      READ(ITI,FMFLG)(F(I),I=IF,IF2)
C     SET EH AND EL IF EH=0.
      IF(EH.EQ.0.)    EL=F(IPS1+2)
      IF(EH.EQ.0.)    EH=F(IP2-NAUX-2)
C     IG1,IG2 SPACE FOR STORING INTERFERENCE
C        PARAMETERS  USED IN SIG.
      IG1=IF2+1
      IG2=IF2+NLS+NLS
C     COMPUTE THE NUMBER OF VARIABLES NV2
      NVT=0
      NVN=0
      NVB=0
      DO 29 NT=1,NT2
      IF(F(IP2+NT).NE.0.)    NVT=NVT+1
      IF(F(IFT2+NT).NE.0.)    NVN=NVN+1
      IF(F(IFN2+NT).NE.0.)    NVB=NVB+1
   29 CONTINUE
      NVP=0
      DO 31 IF=IFS1,IF2
      IF(F(IF).NE.0.)    NVP=NVP+1
   31 CONTINUE
      NV2=NVT+NVN+NVB+NVP
C     NUMBER OF DEGREES OF FREEDOM (FOR CHISQ)
      DOF=NCAT-NV2
      DOFINV=1./DOF
      LM1=NV2+1
      NM=(NV2*(NV2+1))/2
      LS1=LM1+NM
      MV1=LS1+NV2
      MM1=MV1+NV2
      MS1=MM1+NM
      MS2=MS1+NV2-1
      KV1=MS2+MS2+1
      KG1=KV1+NV2
      KG2=KG1+(1+NV2)*NT2-1
C     CHECK COMMON ARRAYS FOR SIZE
      NERR=0
      IF(IG2.GT.IG2P)    NERR=NERR+1
      IF(KG2.GT.KG2P)    NERR=NERR+1
      IF(NERR.EQ.0)    GO TO 33
      WRITE(ITO,201)IG2,IG2P,KG2,KG2P
      CALL ERROR
   33 CONTINUE
      WRITE(ITO,217)NCAT,IG2,KG2
      WRITE(ITO,216)EL,EH
      IF(LPAR.GE.0)    WRITE(ITO,225)
C     PRINT RESONANCE PARAMETERS
   34 IF(LPAR.LT.0)    GO TO 40
      IE=IPS1
      DO 37 NS=1,NS2
      AK=AKO(NS)

      RN=RAD(NS)
      DEL=DELTA(NS)
      JL2=JL(NS)
      WRITE(ITO,231)NS,AK,RN,DOP,JL2,F(IE),F(IE+1)
      IE=IE+2
      AKRN=AK*RN
      DO 37 J=1,JL2
      LJ=MOM(NS,J)
      INT=INL(NS,J)
      GSJ=GSFIN(NS,J)
      FR=FRL(NS,J)
      STRF=STRFL(NS,J)
      GNA=GNAL(NS,J)
      GAV=GAVL(NS,J)
      NR2=NRL(NS,J)
      WRITE(ITO,233)LJ,INT,GSJ,FR,STRF,GNA,GAV,NR2
      IF(NR2.EQ.0)    GO TO 37
      WRITE(ITO,236)
      DO 35 NR=1,NR2
      E0=F(IE)
      GG=F(IE+1)
      GN=F(IE+2)*PEN(LJ,AKRN*SQRT(ABS(E0)))
      IE=IE+3
   35 WRITE(ITO,235)E0,GG,GN
      WRITE(ITO,237)
   37 CONTINUE
   40 CONTINUE
      IF(IRTN.EQ.1)    GO TO 70
C     ITERATION LOOP
      DO 45 IT=1,IT2
      LM=LM1
      DO 41 LA=1,NV2
      D(LA)=0.
      DO 41 LB=LA,NV2
      D(LM)=0.
```

```
   41 LM=LM+1
      JFLAG=0
      PHI=0.
      JV=0
      CALL PHINEQ(JV)
      PHIOLD=PHI
C     PUNCH CARDS FOR PDP10 PLOTS
      IF(LPLT.LT.1)   GO TO 43
      IPLOT=IPLOT+1
      NE2=1+(IE2-IE1)/IE3
      DO 42 NT=1,NT2
      ISN=10*IPLOT+NT
      WRITE(ITP,301)ISN,NE2
      NTT=NT+NT2
      NTN=NTT+NT2
      DO 42 IE=IE1,IE2,IE3
      WRITE(ITP,301)F(IE),F(IE+NT),F(IE+NTT),F(IE+NTN)
   42 CONTINUE
   43 CONTINUE
C     PRINT TRANSMISSIONS
      IF(LDAT.LE.1)   GO TO 46
      WRITE(ITO,204)
      DO 44 IE=IE1,IE2,IE3
      IEA=IE+NT2
      IEB=IEA+NT2
      WRITE(ITO,205)F(IE),(F(IEB+NT),F(IE+NT),F(IEA+NT),F(IP0+NT),NT=1,N
     1T2)
   44 CONTINUE
   46 CONTINUE
      WRITE(ITO,208)IT
      CALL MVP
      IF(PHI.GT.RATIO*PHIOLD)   GO TO 47
   45 CONTINUE
      GO TO 49
   47 WRITE(ITO,202)
      JFLAG=0
      CALL PHINEQ(-1)
C     PUNCH CARDS FOR PDP10 PLOTS
   49 IF(LPLT.LT.0)   GO TO 55
      IPLOT=IPLOT+1
      NE2=1+(IE2-IE1)/IE3
      DO 51 NT=1,NT2
      ISN=10*IPLOT+NT
      WRITE(ITP,301)ISN,NE2
      NTT=NT+NT2
      NTN=NTT+NT2
      DO 51 IE=IE1,IE2,IE3
      WRITE(ITP,301)F(IE),F(IE+NT),F(IE+NTT),F(IE+NTN)
   51 CONTINUE
C     PRINT TRANSMISSIONS
   55 IF(LDAT.LE.0)   GO TO 59
      WRITE(ITO,204)
      DO 57 IE=IE1,IE2,IE3
      IEA=IE+NT2
      IEB=IEA+NT2
      WRITE(ITO,205)F(IE),(F(IEB+NT),F(IE+NT),F(IEA+NT),F(IP0+NT),NT=1,N
     1T2)
   57 CONTINUE
   59 CONTINUE
C     PUNCH FINAL PARAMETRES
      IF(MPAR.LE.0)   GO TO 69
      WRITE(ITC,101)(FMAPE(I),I=1,9)
      WRITE(ITC,FMAPB)(F(IP),IP=IP1,IPT2)
      WRITE(ITC,FMAPB)(F(IP),IP=IPN1,IPN2)
      WRITE(ITC,FMAPB)(F(IP),IP=IPB1,IPB2)
      WRITE(ITC,101)(FMPAR(I),I=1,9)
      IE=IPS1
      DO 63 NS=1,NS2
      FRS=F(IE)
      AHAT=F(IE+1)
      IE=IE+2
      DEL=DELTA(NS)
      RN=RAD(NS)
      AK=AKC(NS)
      AKRN=AK*RN
      AWRI=0.
      TEMP=0.
      WRITE(ITC,104)FRS,AHAT,AWRI,TEMP,DEL,RN,AK
      JL2=JL(NS)
```

```
      DO 62 J=1,JL2
      INT=INL(NS,J)
      GSJ=GSPIN(NS,J)
      FR=FRL(NS,J)
      STRF=STRFL(NS,J)
      GAV=GAVL(NS,J)
      WRITE(ITC,106)J,INT,GSJ,FR,STRF,GAV
      NR2=NRL(NS,J)
      IF(NR2.EQ.0)    GO TO 62
      DO 61 NR=1,NR2
      E0=F(IE)
      GG=F(IE+1)
      GN=F(IE+2)*PEN(J,AKRN*SQRT(ABS(E0)))
      IE=IE+3
      IF(JPAR.EQ.0)    WRITE(ITC,FMPAR)E0,GN,GG
      IF(JPAR.EQ.1)    WRITE(ITC,FMPAR)E0,GG,GN
   61 WRITE(ITC,101)
   62 WRITE(ITC,101)
   63 WRITE(ITC,101)
      WRITE(ITC,104)(F(IP),IP=IE,IP2)
   69 CONTINUE
      IF(LPAR.NE.2)    GO TO 71
      WRITE(ITO,239)
      IRTN=1
      GO TO 34
   70 IRTN=0
   71 CONTINUE
      READ(ITI,102)IGOTO
      IF(IGOTO.EQ.0)CALL EXIT
      IF(IGOTO.EQ.1)CALL ERROR
      IF(IGOTO.EQ.2)GO TO 1
  101 FORMAT(9A8,I8)
  102 FORMAT(20I4)
  103 FORMAT(7G11.3)
  104 FORMAT(7G11.3)
  105 FORMAT(2G11.3,5I11)
  106 FORMAT(2I11,5G11.3)
  201 FORMAT(1H1,'COMMON TOO SMALL',4I20)
  202 FORMAT(1H0,'STOP ITERATIONS BECAUSE CONVERGENCE IS TOO SLOW')
  203 FORMAT(1H ,08X,7(1X,F10.7,5H APB ))
  204 FORMAT(1H1,9X,'ENERGY',11X,'CALCULATION'   4X,'EXPERIMENT',
     1 8X,'ERROR',8X,'ATOMS PER BARN',//)
  205 FORMAT(1H ,G20.5,3F15.4,G20.5/(21X,3F15.4,G20.5))
  206 FORMAT(1H0,'J-STATE=',I2,'L-VALUE=',I2,'NUMBER OF LEVELS=',I3,'FG=
     1',G11.3,'AK=',G11.3,/ )
  207 FORMAT(1H ,3G20.5)
  208 FORMAT(1H1,'ITERATION NUMBER',I3)
  212 FORMAT(1H ,7G15.5)
  216 FORMAT(1H0,'TRUNCATION LIMITS',2G16.5)
  217 FORMAT(1H0,'NUMBER OF TRANSMISSION VALUES'I8,/,' MAXIMUM ADDRESS O
     1F F-ARRAY',I9,/,' MAXIMUM ADDRESS OF G-ARRAY',I9)
  222 FORMAT(1H0,'FIXED POINT INPUTS   ',20I4)
  223 FORMAT(1H ,'FLOATING POINT INPUTS   ',7G11.3)
  225 FORMAT(1H0,///////,15X,'INPUT RESONANCE PARAMETERS',///)
  231 FORMAT(1H0,2X,'NUCLEAR SPECIES =',I3,5X,
     1'REDUCED MOMENTUM='G12.5,5X,
     2'NUCLEAR RADIUS='G12.5,/,

     38X,'DOPPLER WIDTH='G12.5,5X,
     4'NUMBER OF ANGULAR MOMENTA='I3,/,
     58X,'FRACTIONAL ABUNDANCE='F7.4,5X
     6'EFFECTIVE RADIUS='F7.4,//)
  233 FORMAT(1H0,4X,'ANGULAR MOMENTUM='I2,5X,
     1'INTERFERENCE PARAMETER='I2,5X,
     2'SPIN STATISTICAL FACTOR='F6.3,5X,
     3'POTENTIAL SCATTERING FRACTION='F6.3,/,
     410X,'STRENGTH-FUNCTION='G12.5,5X,
     5'AVERAGE NEUTRON-WIDTH='G12.5,5X,
     6'AVERAGE CAPTURE-WIDTH='G12.5,//,10X,
     7'NUMBER OF LEVELS='I4)
  236 FORMAT(1H0,15X,'RESONANCE ENERGY',5X,'CAPTURE-WIDTH',5X,'NEUTRON-W
     1IDTH',//)
  235 FORMAT(14X,3G18.5)
  237 FORMAT(1H0)
  239 FORMAT(1H1,'FINAL RESONANCE PARAMETRES',///)
  301 FORMAT(20A4)
      END
```

```
      SUBROUTINE PHINEQ(JV)
C     REQUIRES RES(E,JRES),SIG(E,JV),BGR(E,NT),WEIGHT(NT,IE)
      REAL * 8 D
      DIMENSION C(1)
      DIMENSION A(55),X(45)
      COMMON F(1)
      COMMON/VAR/G(1)
      COMMON/IAD/IP1,IPT2,IPN1,IPN2,IPB1,IPB2,IPS1,IP2,IF1,IFT2,IFN1,
     1IFN2,IFB1,IFB2,IFS1,IF2,IG1,IG2
      COMMON/KAD/LM1,LS1,MV1,MM1,MS1,MS2,KV1,KG1,KG2
      COMMON/NAD/NVT,NVN,NVB,NVP,NV2,NT2
      COMMON/INDX/JERF,JCAL,JRES,JPAR,LPAR,LMAT,MPAR,LPLT,LDAT,JPLY,JKEV
      COMMON/IEN/IE1,IE2,IE3,IEC1,IGS,NGT
      COMMON/FLT/BE2,CE3,EH,EL,PHI,DOFINV,DTMIN
      EQUIVALENCE(C(1),G(1))
      DATA A/   1.0000E 00,6.6667E-01,1.6667E-01,5.3333E-01,2.2208E-01,
     2          1.1257E-02,4.5714E-01,2.4012E-01,3.0757E-02,5.4827E-04,
     3          4.0635E-01,2.4410E-01,4.9916E-02,2.7891E-03,2.2345E-05,
     4          3.6941E-01,2.4224E-01,6.6139E-02,6.7203E-03,1.9576E-04,
     5          8.1218E-07,3.4099E-01,2.3787E-01,7.9169E-02,1.1771E-02,
     6          6.8124E-04,1.1527E-05,2.7226E-08,3.1826E-01,2.3246E-01,
     7          8.9418E-02,1.7366E-02,1.5674E-03,5.6421E-05,5.9754E-07,
     8          8.5896E-10,2.9954E-01,2.2671E-01,9.7406E-02,2.3087E-02,
     9          2.8589E-03,1.6849E-04,4.0127E-06,2.8080E-08,2.5843E-11,
     A          2.8377E-01,2.2094E-01,1.0360E-01,2.8667E-02,4.5072E-03,
     B          3.7850E-04,1.5351E-05,2.5322E-07,1.2204E-09,7.4828E-13/
      DATA X/   1.22474480,0.95857251,2.02018261,0.81628788,1.67355156,
     2          2.65196133,0.72355098,1.46855259,2.26658058,3.19099331,
     3          0.65680963,1.32655716,2.02594757,2.78328991,3.66847134,
     4          0.60576391,1.22005463,1.85310841,2.51973629,3.24660873,
     5          4.10133839,0.56506962,1.13611603,1.71999264,2.32573223,
     6          2.96716595,3.66994953,4.49999142,0.53163302,1.06764889,
     7          1.61292362,2.17350292,2.75776291,3.37893200,4.06194687,
     8          4.87134457,0.50352019,1.01036835,1.52417088,2.04923153,
     9          2.59113407,3.15784931,3.76218700,4.42853260,5.22027206/
C     LOOP OVER ENERGIES
      IP0=IF1-1
      IEC=IEC1-1
      DO 69 IE=IE1,IE2,IE3
      E=F(IE)
      IF(JRES.EQ.0)   R=E*SQRT(BE2+CE3*E)
      IF(JRES.NE.0)   R=RES(E,JRES)
C     LOOP OVER GAUSS INTEGRATION INTERVALS
      ENG=E
      IG=IGS
      JG=IGS-NGT
      DO 59 NG=1,NGT
      ANG=A(IG+NG)
      IF(NG.EQ.1)   GO TO 53
      DE=R*X(JG+NG)
   51 ENG=E+DE
   53 CS=SIG(ENG,JV)
C     LOOP OVER TRANSMISSION-SAMPLES
      K=KG1

      DO 57 NT=1,NT2
      APN=F(IP0+NT)
      TR=ANG*EXP(-APN*CS)
      TN=(1.+F(IPT2+NT))*TR
      IF(NG.EQ.1)   G(K)=F(IPN2+NT)*BGR(E,NT)
      G(K)=G(K)+TN
C     LOOP OVER DERIVATIVES
      IF(JV.LT.0)   GO TO 57
      KNV=K+1
      NTC=1
      DO 54 IF=IF1,IFT2
      IF(F(IF).EQ.0.)   GO TO 54
      IF(NTC.NE.NT.OR.NG.EQ.1)   G(KNV)=0.
      IF(NTC.EQ.NT)   G(KNV)=G(KNV)-CS*TN
      KNV=KNV+1
   54 NTC=NTC+1
      NTC=1
      DO 55 IF=IFN1,IFN2
      IF(F(IF).EQ.0.)   GO TO 55
      IF(NTC.NE.NT.OR.NG.EQ.1)   G(KNV)=0.
      IF(NTC.EQ.NT)   G(KNV)=G(KNV)+TR
      KNV=KNV+1
   55 NTC=NTC+1
      KV=KV1
      KNV=KNV+NVB
      DO 56 NV=1,NVP
      IF(NG.EQ.1)   G(KNV)=0.
      G(KNV)=G(KNV)-APN*TN*G(KV)
      KNV=KNV+1
```

```
   56 KV=KV+1
   57 K=K+NV2+1
      IF(NG.EQ.1.OR.DE.LT.0.)    GO TO 59
      DE=-DE
      GO TO 51
   59 CONTINUE
C     LOOP OVER TRANSMISSION SAMPLES
      K=KG1
      DO 65 NT=1,NT2
C     STORE COMPUTED TRANSMISSIONS IF NEEDED
      IF(JCAL.EQ.0)    F(IEC+NT)=G(K)
C     CONTRIBUTIONS TO PHI AND NORMAL EQUATIONS
      W=WEIGHT(NT,IE)
      DTN=F(IE+NT)-G(K)
      DTNW=DTN*W
      PHI=PHI+DTN*DTNW
      IF(JV.LT.0)    GO TO 65
C     DERIVATIVES OF TRANSMISSION-BACKGROUNDS
      K1=K+NVT+NVN+1
      NTC=1
      DO 61 IF=IFB1,IFB2
      IF(F(IF).EQ.0.)    GO TO 61
      G(K1)=0.
      IF(NTC.EQ.NT)    G(K1)=BGR(E,NT)
      K1=K1+1
   61 NTC=NTC+1
C     NORMAL EQUATIONS
      L=LM1
      DO 63 NA=1,NV2
      GKNA=G(K+NA)
      D(NA)=D(NA)+DTNW*GKNA
      DO 63 NB=NA,NV2
      D(L)=D(L)+W*GKNA*G(K+NB)
   63 L=L+1
   65 K=K+NV2+1
   69 IEC=IEC+IE3
      IF(JPLY.EQ.0) RETURN
C     CORRECTION FOR CHANNEL WIDTHS
      PHI=0.0
      IE9=IE1+IE3+IE3
      IEC=IEC1-1
      DO 71 IE=IE1,IE2,IE3
      DO 70 NT=1,NT2
      IT=IEC+NT
      IF(IE.LE.IE9.OR.IE.EQ.IE2)  GO TO 70
      F(IT)=0.041667*(F(IT+IE3)+F(IT-IE3)+22.0*F(IT))
   70 PHI=PHI+WEIGHT(NT,IE)*(F(IE+NT)-F(IT))**2
   71 IEC=IEC+IE3
      RETURN
      END


      FUNCTION RES(E,JRES)
      RES=0.
      RETURN
      END


      FUNCTION BGR(E,NT)
      BGR=1.
      RETURN
      END


      FUNCTION WEIGHT(NT,IE)
      COMMON F(1)
      COMMON/NAD/NVT,NVN,NVE,NVP,NV2,NT2
      COMMON/FLT/BE2,CE3,EH,EL,PHI,DOFINV,DTMIN
      COMMON/INDX/JERR,JCAL,JRES,JPAR,LPAR,LMAT,MPAR,LPLT,LDAT,JPLY,JKEV
      DT=F(IE+NT+NT2)
      IF(DT.GE.DTMIN) GO TO 10
      DT =DTMIN
      F(IE+NT+NT2)=DTMIN
   10 WEIGHT=1.0/(DT*DT)
      RETURN
      END
```

```
      SUBROUTINE MVP
C     REQUIRES SLV(NV2)
C     MVP DOES A P-SEARCH IF NEEDED
C     SAVE OLD CHISQUARE
      REAL * 8 D
      DIMENSION D(1)
      COMMON F(1)
      COMMON/VAR/G(1)
      COMMON/IAD/IP1,IPT2,IPN1,IPN2,IPB1,IPB2,IPS1,IP2,IF1,IFT2,IFN1,
     1IFN2,IFB1,IFB2,IFS1,IF2,IG1,IG2
      COMMON/KAD/LM1,LS1,MV1,MM1,MS1,MS2,KV1,KG1,KG2
      COMMON/NAD/NVT,NVN,NVB,NVP,NV2,NT2
      COMMON/INDX/JERR,JCAL,JRES,JPAR,LPAR,LMAT,MPAR,LPLT,LCAT,JPLY,JKEV
      COMMON/IEN/IE1,IE2,IE3,IEC1,IGS,NGT
      COMMON/LEV/JFLAG,NS2,NAUX,JL(10),NRL(10,10),MOM(10,10),INL(10,10)
      COMMON/FLT/BE2,CE3,EH,EL,PHI,DOFINV,DTMIN
      COMMON/FLD/AK0(10),C0(10),RAD(10),DELTA(10)
      COMMON/FL2/GSPIN(10,10),GAVL(10,10),STRFL(10,10),FRL(10,10)
      EQUIVALENCE(D(1),G(1))
      DATA ITI,ITO/5,6/
      DATA EPP,NPSMAX/.033,10/
      CHIOLD=DOFINV*PHI
      NPS=0
C     SAVE NORMAL MATRIX AT MM1
      LM=LM1
      MM=MM1
      DO 11 LA=1,NV2
      DO 11 LB=LA,NV2
      D(MM)=D(LM)
      MM=MM+1
   11 LM=LM+1
C     SOLVE NORMAL EQUATIONS
   19 CALL SLV(NV2)
C     GAUGE ETA, IF NPS=0 SAVE ORIGINAL PARAMETERS
      ETA=1.
      IF=IF1
      LS=LS1
      MV=MV1
      DO 25 IP=IP1,IP2
      IF(F(IF).EQ.0)    GO TO 25
      IF(NPS.EQ.0)    D(MV)=F(IP)
      IF(F(IF).EQ.1.)    GO TO 23
      IF(D(MV)+ETA*D(LS).LE.0.)    ETA=-.9*D(MV)/D(LS)
   23 MV=MV+1
      LS=LS+1
   25 IF=IF+1
C     MODIFY VARIABLE PARAMETERS
      IF=IF1
      LS=LS1
      MV=MV1
      DO 27 IP=IP1,IP2
      IF(F(IF).EQ.0.)    GO TO 27
      F(IP)=D(MV)+ETA*D(LS)
      MV=MV+1
      LS=LS+1

   27 IF=IF+1
C     GET NEW VALUE OF CHI-SQUARE
      JFLAG=0
      PHI=0.
      JV=-1
      CALL FHINEQ(JV)
      CHISQ=DOFINV*PHI
C     IF NPS=0 STORE ERRORS IN D
      IF(NPS.GT.0)    GO TO 31
      LM=LM1
      MS=MS1
      DO 29 LA=1,NV2
      DO 29 LB=LA,NV2
      IF(LA.EQ.LB.OR.LMAT.GT.0)    D(LM)=CHISQ*D(LM)
      IF(LA.NE.LB)    GO TO 29
      D(MS)=DSQRT(D(LM))
      MS=MS+1
   29 LM=LM+1
C     IF LMAT.GT.0 PRINT CONVARIANCE-MATRIX
      LM2=LS1-1
      IF(LMAT.GT.0)    WRITE(ITO,204)(D(LM),LM=LM1,LM2)
   31 IF(CHISQ.GT.CHIOLD)    GO TO 51
      WRITE(ITO,201)
      WRITE(ITO,202)NPS,ETA,CHIOLD,CHISQ
C     PRINT SAMPLE THICKNESSES
      WRITE(ITO,221)
      WRITE(ITO,203)
      IF=IF1
      MS=MS1
      MV=MV1
      DO 33 IP=IP1,IPT2
      IF(F(IF).EQ.0.)    GO TO 32
      WRITE(ITO,204)D(MV),F(IP),D(MS)
      MV=MV+1
      MS=MS+1
      GO TO 33
```

```
   32 WRITE(ITO,204)F(IF)
   33 IF=IF+1
C     PRINT NORMALISATICN-ERRORS
      WRITE(ITO,226)
      WRITE(ITO,203)
      DO 82 IP=IPN1,IPN2
      IF(F(IF).EQ.0.)    GO TO 81
      WRITE(ITO,204)D(MV),F(IP),D(MS)
      MV=MV+1
      MS=MS+1
      GO TO 82
   81 WRITE(ITO,204)F(IF)
   82 IF=IF+1
C     PRINT TRANSMISSION BACKGROUNDS
      WRITE(ITO,222)
      WRITE(ITO,203)
      DO 35 IP=IPB1,IPB2
      IF(F(IF).EQ.0.)    GC TO 34
      WRITE(ITO,204)D(MV),F(IP),D(MS)
      MV=MV+1
      MS=MS+1

      GO TO 35
   34 WRITE(ITO,204)F(IP)
   35 IF=IF+1
C     PRINT RESONANCE PARAMETERS
      WRITE(ITO,230)
      IP=IPB2
      DO 46 NS=1,NS2
      AK=AKC(NS)
      RN=RAC(NS)
      AKRN=AK*RN
      JL2=JL(NS)
      WRITE(ITO,231)NS,JL2
      WRITE(ITO,224)
      WRITE(ITO,203)
      IF(F(IF).EC.0.)    GC TO 36
      WRITE(ITO,204)D(MV),F(IP+1),D(MS)
      MV=MV+1
      MS=MS+1
      GO TO 37
   36 WRITE(ITO,204)F(IF+1)
   37 IF=IF+1
      IF(F(IF).EQ.0.)    GC TO 38
      WRITE(ITO,204)D(MV),F(IP+2),D(MS)
      MV=MV+1
      MS=MS+1
      GO TO 39
   38 WRITE(ITO,204)F(IF+2)
   39 IF=IF+1
      IP=IP+2
      DO 46 J=1,JL2
      LJ=MCN(NS,J)
      NR2=NRL(NS,J)
      WRITE(ITO,232)LJ,NR2
      IF(NR2.EQ.0)    GC TO 46
      WRITE(ITO,225)
      WRITE(ITO,203)
      WRITE(ITO,227)
      DO 43 NR=1,NR2
      FLAG=F(IF)+F(IF+1)+F(IF+2)
      IF(FLAG.NE.0.)    WRITE(ITO,211)
      DO 43 M=1,3
      IP=IP+1
      IF(FLAG.EQ.0.)    GO TO 43
      T1=F(IP)
      IF(M.EQ.1)    PENR=PEN(LJ,AKRN*SQRT(ABS(T1)))
      IF(M.EQ.3)    T1=T1*PENR
      IF(F(IF).EQ.0.)    GO TO 42
      T2=D(MV)
      T3=D(MS)
      MV=MV+1
      MS=MS+1
      IF(M.NE.3)    GO TO 41
      T2=T2*PENR
      T3=T3*PENR
   41 WRITE(ITO,204)T2,T1,T3
      GO TO 43
   42 WRITE(ITO,204)T1
```

```
   43 IF=IF+1
   46 CONTINUE
C     AUXILIARY PARAMETERS
      WRITE(ITO,226)
      WRITE(ITO,203)
      DO 45 N=1,NAUX
      IP=IP+1
      IF(F(IF).EQ.0.)    GO TO 44
      WRITE(ITO,204)D(MV),F(IP),D(MS)
      MV=MV+1
      MS=MS+1
      GO TO 45
   44 WRITE(ITO,204)F(IF)
   45 IF=IF+1
      RETURN
C     PROCEED WITH P-SEARCH
   51 NPS=NPS+1
      IF(NPS.GT.NPSMAX)    GO TO 71
      IF(NPS.GT.1)    GO TO 61
C     COMPUTE PSC
      GMG=0.
      MM0=MM1-1
      GG=0.
      DO 55 LA=1,NV2
      SUM=0.
      NM=MM0+LA
      J=NV2-1
      DO 54 LB=1,NV2
      SUM=SUM+D(LB)*D(NM)
      IF(LB.GE.LA)    GO TO 53
      NM=NM+J
      J=J-1
      GO TO 54
   53 NM=NM+1
   54 CONTINUE
      GMG=GMG+SUM*D(LA)
   55 GG=GG+D(LA)*D(LA)
      PSC=EPP*GMG/GG
C     ADD PSC TO DIAGONAL ELEMENTS OF NORMAL MATRIX
C         AND RESTORE IN D(LM1)
   61 LM=LM1
      MM=MM1
      DO 63 LA=1,NV2
      DO 63 LB=LA,NV2
      D(LM)=D(MM)
      IF(LA.EQ.LB)    D(LM)=D(LM)+PSC
      LM=LM+1
   63 MM=MM+1
      PSC=PSC+PSC
      GO TO 19
   71 WRITE(ITO,205)
C     RESTORE OLD PARAMETERS AND CHIOLD
      CHISQ=CHIOLD
      IF=IF1
      MV=MV1
      DO 75 IP=IP1,IP2
      IF(F(IF).EQ.0.)    GO TO 75

      F(IP)=D(MV)
      MV=MV+1
   75 IF=IF+1
      GO TO 31
  201 FORMAT(1H0,8X,'NPS',17X,'ETA',15X,'CHIOLD',14X,
     1'CHINEW',/   )
  202 FORMAT(1H ,I10,6X,3G20.5,// )
  203 FORMAT(1H0,9X,'OLD VALUE',11X,'NEW VALUE',14X,
     1'ERROR',/    )
  204 FORMAT(1H ,6G20.5)
  205 FORMAT(1H0,'CAN DO NO GOOD, SORRY')
  211 FORMAT(1H )
  221 FORMAT(1H0,5X,'SAMPLE-THICKNESSES')
  222 FORMAT(1H0,5X,'TRANSMISSION-BACKGROUNDS')
  224 FORMAT(1H0,5X,'FRACTIONAL ABUNDANCE AND RADIUS')
  225 FORMAT(1H0,5X,'RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH')
  226 FORMAT(1H0,///////,15X,       'AUXILIARY PARAMETERS',///)
  227 FORMAT(1H0,7X,'(ONLY VARIED LEVELS ARE LISTED)')
  228 FORMAT(1H0,5X,'NORMALISATION-ERRORS')
  230 FORMAT(1H0,///////,15X,       'RESONANCE PARAMETERS',///)
  231 FORMAT(1H0,////,1X,'NUCLEAR SPECIES =',I3,5X,
     4'NUMBER OF ANGULAR MOMENTA =',I3)
  232 FORMAT(1H0,//,2X,'ANGULAR MOMENTUM =',I2,5X,
     7'NUMBER OF LEVELS=' I4)
      END
```

```
      SUBROUTINE SLV(N)
      IMPLICIT REAL * 8 (A-H,O-Y)
      COMMON/VAR/F(1)
      REAL * 8 F
      IF(N-1) 1,2,3
    1 WRITE(6,101)
  101 FORMAT (1H0,'NEGATIVE ARGUMENT IN SLV')
      RETURN
    2 F(2)=1./F(2)
      F(3)=F(2)*F(1)
      RETURN
    3 K=N+1
      DO 10 M=1,N
      M1=M-1
      DO 10 L=M,N
      A=0.
      IF(M1.LE.0)    GO TO 6
      KL=N+L
      KM=N+M
      DO 5 LM=1,M1
      A=A+F(KL)*F(KM)
      J=N-LM
      KL=KL+J
    5 KM=KM+J
    6 T=F(K)-A
      IF(L.GT.M)    GO TO 9
      IF(T.GT.0.)    GO TO 7
      WRITE(6,102)T
  102 FORMAT (1H0,'FAILURE IN SLV  T=',G20.5)
    7 D=DSQRT(T)
      F(K)=D
      GO TO 10
    9 F(K)=T/D
   10 K=K+1
      K=N+1
      F(K)=1./F(K)
      DO 12 L=2,N
      K=K+N-L+2
      T=1./F(K)
      F(K)=T
      L1=L-1
      KL=N+L
      KM=N
      DO 12 M=1,L1
      LK=KL
      A=0.
      DO 11 LM=M,L1
      I1=KM+LM
      A=A-F(KL)*F(I1)
   11 KL=KL+N-LM
      F(LK)=A*T
      J=N-M
      KL=LK+J
   12 KM=KM+J
      K=N+1
      DO 14 M=1,N
      KL=K
      DO 14 L=M,N
      KM=K
      A=0.
      I1=N-L+1
      DO 13 LM=1,I1
      A=A+F(KL)*F(KM)
      KL=KL+1
   13 KM=KM+1
      F(K)=A
   14 K=K+1
      DO 18 L=1,N
      A=0.
      IJ=N+L
      JI=0
      J=N-1
      DO 17 M=1,N
      JI=JI+1
      A=A+F(IJ)*F(JI)
      IF(M.GE.L)    GO TO 16
      IJ=IJ+J
      J=J-1
      GO TO 17
   16 IJ=IJ+1
   17 CONTINUE
      F(K)=A
   18 K=K+1
      RETURN
      END
```

```
      FUNCTION SIG(E,JV)
C     REQUIRES SVS(ZEC,ETA,U0,V0) AND FNS(VE,N)
C     FOR JV.GE.C COMPUTES DERIVATIVES
C     FOR JFLAG=C RECCMPUTES INTERFERENCE TERMS
      COMMCN F(1)
      COMMON/VAR/G(1)
      COMMON/IAC/IP1,IPT2,IPN1,IPN2,IPB1,IPB2,IPS1,IP2,IF1,IFT2,IFN1,
     1IFN2,IFB1,IFB2,IFS1,IF2,IG1,IG2
      COMMCN/KAC/LM1,LS1,MV1,MM1,MS1,MS2,KV1,KG1,KG2
      COMMON/NAD/NVT,NVN,NVB,NVP,NV2,NT2
      COMMON/INDX/JERR,JCAL,JRES,JPAR,LPAR,LMAT,MPAR,LPLT,LDAT,JPLY,JKEV
      COMMON/LEV/JFLAG,NS2,NAUX,JL(10),NRL(10,10),MOM(10,10),INL(10,10)
      COMMON/FLT/BE2,CE3,EH,EL,PHI,DOFINV,DTMIN
      COMMON/FLD/AKO(10),CO(10),RAD(10),DELTA(1C)
      COMMCN/FL2/GSPIN(10,10),FRL(10,10),STRFL(10,10),GNAL(10,10),GAVL(10,10)
     10,10)
      DATA SQPI,PI4/1.772454,12.5664/
      DATA EPSI/1.E-6/
      IF(JFLAG.NE.0)   GO TC 21
C     COMPUTATICN OF LEVEL-LEVEL-INTERFERENCES
C         (IF JFLAG=0)
      JFLAG=1
      IP=IPS1
      K=IG1
      DO 20 NS=1,NS2
      IP=IP+2
      JL2=JL(NS)
      AKRNS=AKO(NS)*RAD(NS)
      DO 20 J=1,JL2
      NR2=NRL(NS,J)
      IF(NR2.EQ.0)   GO TO 20
      INT=INL(NS,J)
      IF(INT.EQ.0)   GO TO 13
      LJ=MOM(NS,J)
      IPO=IP
   13 DO 19 NR=1,NR2
      IF(INT.EQ.C)   GO TO 19
      ER=F(IP)
      GAR=F(IP+1)
      GNR=F(IP+2)
      VER=SQRT(ABS(ER))
      RHOR=AKRNS*VER
      PENR=PEN(LJ,RHOR)
      SHFR=SHF(LJ,RHOR)
      F(K)=0.
      F(K+1)=0.
      GR=GNR*PENR
   14 IPS=IPO
      DO 17 MS=1,NR2
      IF(MS.EQ.NR)   GO TO 17
      ES=F(IPS)
      GNS=F(IPS+2)
      RHOS=AKRNS*SQRT(ABS(ES))
      GS=GNS*PENR

      DL=ER-ES-(SHF(LJ,RHOS)-SHFR)*GNS
      GH=.5*(GAR+F(IPS+1)+GR+GS)
      TEMP=GNS/(DL*DL+GH*GH)
      F(K)=F(K)+TEMP*GH
      F(K+1)=F(K+1)+TEMP*DL
   17 IPS=IPS+3
      K=K+2
   19 IP=IP+3
   20 CONTINUE
   21 CONTINUE
C     MAIN PART OF CROSS-SECTION
      IP=IPS1
      K=IG1
      VE=SQRT(E)
      SIG=0.
      IF(JV.LT.0)   GC TO 25
      IF=IFS1
      KV=KV1
C     SUM OVER NUCLEAR SPECIES
   25 DO 59 NS=1,NS2
      FRS=F(IP)
      AHAT=F(IP+1)
      IP=IP+2
      CNS=2.*CO(NS)/E
      AKONS=AKO(NS)
      AKNS=AKONS*VE
      RADNS=RAD(NS)
      AKRNS=AKONS*RADNS
      RHO=AKNS*RADNS
      RHOHAT=AKNS*AHAT
      CFNS=CNS*FRS
      JL2=JL(NS)
      DEL=DELTA(NS)
      IF(DEL.EQ.0.)   GC TO 27
      DE=1./(DEL*VE)
      SQPIDE=SQPI*DE
```

```
 27 SIGS=C.
    IF(JV.LT.0)    GC TO 33
    KVR=0
    KVN=0
    IF(F(IF).EC.C.)    GO TO 29
    KVN=KV
    KV=KV+1
 29 IF(F(IF+1).EC.0.)    GO TO 31
    KVR=KV
    GKVJ=0.
    KV=KV+1
 31 IF=IF+2
C   SUM CVER ANGULAR-MOMENTA
 33 DO 49 J=1,JL2
    LJ=MCM(NS,J)
    GSJ=GSPIN(NS,J)
    INT=INL(NS,J)
    NR2=NRL(NS,J)
    PHIL2=PHI2(LJ,RHCHAT)
    SIN2=SIN(PHIL2)
    COS2=COS(PHIL2)

    PENL=PEN(LJ,RHC)
    SHFL=SHF(LJ,RHC)
    CFG=CFNS*GSJ
    FR=FRL(NS,J)
    SIGJ=C.
    IF(FR.EQ.0.)    GO TO 34
    ALJ=2*LJ+1
    CCOS=1.-CCS2
    IF(COS2.GT..999)    CCOS=2.*(SIN(.5*PHIL2)**2)
    SIGJ=ALJ*CCOS*FR
 34 CONTINUE
    IF(KVR.NE.0)    GKVR=C.
C   PICKET-FENCE EXTENSIONS
    STRF=STRFL(NS,J)
    IF(STRF.EQ.0.)    GC TC 35
    GAV=GAVL(NS,J)
    GNA=GNAL(NS,J)
    GTA=GAV+GNA*PENL
    DBAR=GNA/STRF
    TEMP=STRF*PENL
    PFS=TEMP*.5*GTA*FNS(DBAR,E,2)
    PFA=-TEMP*FNS(DEAR,E,1)
    FENCE=PFS*COS2-PFA*SIN2
    IF(INT.NE.C)    FENCE=FENCE+.5*(PFS*PFS+PFA*PFA)
    SIGJ=SIGJ+GSJ*FENCE
 35 CONTINUE
    IF(NR2.EQ.0)    GO TO 48
C   CONTRIBUTION OF RESONANCES
    DO 47 NR=1,NR2
    ER=F(IP)
    GAR=F(IP+1)
    GNR=F(IP+2)
    IP=IP+3
    GN=GNR*PENL
    RHR=AKRNS*SQRT(ABS(ER))
    SHIFT=SHF(LJ,RHR)-SHFL
    EP=SHIFT*GNR+ER
    GR=COS2
    HR=SIN2
    GH=.5*(GAR+GN)
    DL=EP-E
    IF(INT.EQ.0)    GO TO 36
    GR=GR+F(K)*PENL
    HR=HR+F(K+1)*PENL
    K=K+2
    IF(STRF.EQ.0.)    GO TO 36
    PFT=PFS+TEMP*GH*FNS(DEAR,E,2)
    GR=GR+PFT
    HR=HR-PFA
 36 CONTINUE
    IF(JV.GE.0)    FLAG=F(IF)+F(IF+1)+F(IF+2)
    IF(DEL.NE.0.)    GC TO 37
    DENINV=1./(GH*GH+DL*DL)
    U=GH*DENINV
    V=DL*DENINV
    IF(FLAG.EQ.0.)    GO TO 39
    DP1=-(U+U)*V
```

```
      DP2=(U+V)*(U-V)
      GO TO 39
   37 ETA=GH*DE
      ZED=GL*DE
      CALL SVS(ZED,ETA,U0,V0)
      U=SQPIDE*U0
      V=SQPIDE*V0
      IF(FLAG.EQ.0.)    GO TO 39
      DP1=(DE+DE)*(ETA*V-ZED*U)
      DP2=(DE+DE)*(DE-ZED*V-ETA*U)
      IF(ABS(ETA*V-ZED*U).LT.EPSI)    DP1=-(U+U)*V
      IF(ABS(DE-ZED*V-ETA*U).LT.EPSI)    DP2=(U+V)*(U-V)
   39 UV=GR*U-HR*V
      SIGJ=SIGJ+GSJ*UV*GN
C     CALCULATION OF DERIVATIVES
      IF(JV.LT.0)    GO TO 47
C     W.R.T. EFFECTIVE RADIUS AHAT
      IF(KVR.NE.0)    GKVR=GKVR-GN*(V*COS2+U*SIN2)
      IF(FLAG.EQ.0.)    GO TO 45
C     W.R.T. RESONANCE ENERGY ER
      IF(F(IF).EQ.0.)    GO TO 41
      G(KV)=CFG*GN*(GR*DP1-HR*DP2)*(1.+GNR*DSHF(LJ,RHR)*.5*RHR/ER)
      KV=KV+1
C     W.R.T. CAPTURE WIDTH GAR
   41 IF(F(IF+1).EQ.0.)    GO TO 43
      G(KV)=-.5*CFG*GN*(GR*DP2+HR*DP1)
      KV=KV+1
C     W.R.T. REDUCED NEUTRON WIDTH GNR
   43 IF(F(IF+2).EQ.0.)    GO TO 45
      UN=DP1*SHIFT-.5*DP2*PENL
      VN=.5*DP1*PENL+DP2*SHIFT
      G(KV)=CFG*(PENL*UV+GN*(GR*UN-HR*VN))
      KV=KV+1
   45 IF=IF+3
   47 CONTINUE
   48 CONTINUE
      IF(JV.LT.0)    GO TO 49
      IF(KVR.NE.0)    GKVJ=GKVJ+(ALJ*SIN2*FR+GSJ*GKVR)*DPH(LJ,RHOHAT)
   49 SIGS=SIGS+SIGJ
      IF(JV.LT.0)    GO TO 59
      IF(KVR.NE.0)    G(KVR)=(CFNS+CFNS)*AKNS*GKVJ
      IF(KVN.NE.0)    G(KVN)=SIGS*CNS
   59 SIG=SIG+SIGS*CFNS
C     CONTRIBUTION OF AUXILIARY PARAMETRES
      DO 69 N=1,NAUX
      SIG=SIG+F(IP)*FNS(VE,E,N)
      IF(JV.LT.0)    GO TO 69
C     DERIVATIVES W.R.T. AUXILIARY PARAMETRES
      IF(F(IF).EQ.0.)    GO TO 67
      G(KV)=FNS(VE,E,N)
      KV=KV+1
   67 IF=IF+1
   69 IP=IP+1
      RETURN
      END

      FUNCTION PHI2(LJ,RHO)
      PHI2=RHO+RHO
      IF(LJ.EQ.0)    RETURN
      IF(LJ.NE.1)    GO TO 1
      PHI2=PHI2-2.*ATAN(RHO)
      RETURN
    1 IF(LJ.NE.2)    GO TO 2
      PHI2=2.*(RHO-ATAN(3.*RHO/(3.-RHO*RHO)))
      RETURN
    2 IF(LJ.NE.3)    CALL ERROR
      RHOSQ=RHO*RHO
      PHI2=2.*(RHO-ATAN(RHO*(RHOSQ-15.)/(6.*RHOSQ-15.)))
      RETURN
      END

      FUNCTION DPH(LJ,RHO)
      IF(LJ.NE.0)    GO TO 1
      DPH=1.
      RETURN
    1 RHOSQ=RHO*RHO
      IF(LJ.NE.1)    GO TO 2
      DPH=RHOSQ/(1.+RHOSQ)
      RETURN
    2 IF(LJ.NE.2)    GO TO 3
      DPH=9.*RHOSQ/(9.+RHOSQ*(3.+RHOSQ))
      RETURN
    3 IF(LJ.NE.3)    CALL ERROR
      RHO4=RHOSQ*RHOSQ
      DPH=(RHO4+RHO4)*(RHOSQ+2.)/
     1(225.+45.*RHOSQ+RHO4*(6.+RHOSQ))
      RETURN
      END
```

```
      FUNCTION SHF(LJ,RHO)
      IF(LJ.NE.0)   GO TO 1
      SHF=0.
      RETURN
    1 RHOSQ=RHO*RHO
      IF(LJ.NE.1)   GO TO 2
      SHF=-.5/(1.+RHOSQ)
      RETURN
    2 IF(LJ.NE.2)   GO TO 3
      SHF=-(9.+1.5*RHOSQ)/(9.+RHOSQ*(3.+RHOSQ))
      RETURN
    3 IF(LJ.NE.3)   CALL ERROR
      RHO4=RHOSQ*RHOSQ
      SHF=-(337.5+45.*RHOSQ+3.*RHO4)/(225.+45.*RHOSQ+6.*RHO4
     1+RHO4*RHOSQ)
      RETURN
      END


      FUNCTION DSHF(LJ,RHO)
      IF(LJ.NE.0)   GO TO 1
      DSHF=0.
      RETURN
    1 RHOSQ=RHO*RHO
      IF(LJ.NE.1)   GO TO 2
      DSHF=RHO/((1.+RHOSQ)**2)
      RETURN
    2 IF(LJ.NE.2)   GO TO 3
      TEMP=9.+RHOSQ*(3.+RHOSQ)
      DSHF=3.*RHO*(TEMP+9.*RHOSQ)/(TEMP*TEMP)
      RETURN
    3 IF(LJ.NE.3)   CALL ERROR
      RHO4=RHOSQ*RHOSQ
      RHO6=RHO4*RHOSQ
      TEMP=225.+45.*RHOSQ+6.*RHO4+RHO6
      DSHF=1687.5+900.*RHOSQ+382.5*RHO4+RHO6*(30.+RHOSQ)
      DSHF=6.*RHO*DSHF/(TEMP*TEMP)
      RETURN
      END


      FUNCTION PEN(LJ,RHO)
      PEN=RHO
      IF(LJ.EQ.0)   RETURN
      RHOSQ=RHO*RHO
      IF(LJ.NE.1)   GO TO 1
      PEN=PEN*RHOSQ/(1.+RHOSQ)
      RETURN
    1 RHO4=RHOSQ*RHOSQ
      IF(LJ.NE.2)   GO TO 2
      PEN=RHO*RHO4/(9.+3.*RHOSQ+RHO4)
      RETURN
    2 IF(LJ.NE.3)   CALL ERROR
      RHO6=RHO4*RHOSQ
      PEN=RHO*RHO6/(225.+45.*RHOSQ+6.*RHO4+RHO6)
      RETURN
      END


      FUNCTION FNS(VE,E,N)
      COMMON/FLT/BE2,CE3,EH,EL,PHI,DOFINV,DTMIN
      DATA EPS/.582/
      FNS=0.
      GO TO (21,22,23,24,25,26,27,28,29)N
   21 FNS=ALOG((EH-E+EPS*VE)/(E-EL+EPS*VE))
      RETURN
   22 FNS=(EH-EL+VE)/((EH-E+.5*VE)*(E-EL+.5*VE))
      RETURN
   23 FNS=1.
      RETURN
   24 FNS=E
      RETURN
   25 FNS=VE
      RETURN
   26 FNS=1./VE
      RETURN
   27 CONTINUE
   28 CONTINUE
   29 CONTINUE
      END
```

```
      SUBROUTINE SVS(AX,Y1,REW,AIMW)
      COMMON/TRTI/TR(62,62),TI(62,62),KI
      DATA K/0/
      IF(K.EQ.1)    GO TO 3
      K=1
      KI=1
      X=-.1
      DO 2  I=1,62
      Y=-.1
      DO 1  J=1,62
      CALL W(X,Y,TR(I,J),TI(I,J))
    1 Y=Y+.1
    2 X=X+.1
    3 CONTINUE
      CALL QUICKW    (AX,Y1,REW,AIMW)
      RETURN
      END


      SUBROUTINEW(REZ,AIM1,REW,AIMW)
      REW=0.
      AIMW=0.
      AIMZ=ABS (AIM1)
      IF(REZ)27,2001,27
 2001 IF(AIM1)27,2002,27
 2002 REW=1.
      RETURN
   27 R2=REZ*REZ
      AI2=AIMZ*AIMZ
      ABREZ=ABS (REZ)
      IF(ABREZ+1.25*AIMZ-5.0)102,102,100
  100 IF(ABREZ+1.1*AIMZ-6.6)117,117,116
  101 IF(ABREZ+1.43333*AIMZ-4.3)119,119,118
  102 IF(ABREZ+1.863636*AIMZ-4.1)111,111,104
  103 IF(AIMZ-1.5)110,120,120
  104 IF(AIMZ-1.4)115,115,101
  105 IF(ABREZ+1.07317*AIMZ-4.4)119,119,118
  106 IF(ABREZ-2.7)127,128,128
  107 IF(ABREZ-3.1)106,108,108
  108 IF(ABREZ-3.4)129,130,130
  109 IF(R2+1.18*AI2-5.76)103,107,107
  110 IF(R2+1.7227*AI2-4.41)125,126,126
  111 IF(R2+1.71*AI2-2.89)113,109,109
  112 IF(R2+1.69*AI2-1.69)123,124,124
  113 IF(R2+2.0408*AI2-1.0)114,112,112
  114 IF(R2+1.5625*AI2-.25)121,122,122
  115 IF(ABREZ+1.43333*AIMZ-4.3)120,120,105
  116 NMAX=1
      GO TO 15
  117 NMAX=2
      GO TO 15
  118 NMAX=3
      GO TO 15
  119 NMAX=4
      GO TO 15
  120 NMAX=6
      GO TO 15
  121 NMAX=2
      GO TO 20
  122 NMAX=3
      GO TO 20
  123 NMAX=4
      GO TO 20
  124 NMAX=5
      GO TO 20
  125 NMAX=6
      GO TO 20
  126 NMAX=7
      GO TO 20
  127 NMAX=8
      GO TO 20
  128 NMAX=9
      GO TO 20
  129 NMAX=10
      GO TO 20
```

```
  130 NMAX=11
   2) KW=2
      AIMZ=AIM1
      GO TC 200
   15 KW=1
      IF(AIM1)2000,15C,150
 2000 KW=2
      AIMZ=AIM1
      GO TC 200
C WA IS OBTAINEC FRCM ASYMTCTIC SERIES
  150 RV=2.*(R2-AI2)
      AK=4.*REZ*AIMZ
      EL=AK
      H=0.
      B=0.
      A=0.
      TEMPM=0.
      TEMEL=0.
      G=1.
      C=-1.1283792*AIMZ
      D=1.1283792*REZ
      AM=RV-1.
      AAK=1.
      K=0
   11 AJTEMP=2.*AAK
      TEMP4=(1.-AJTEMP)*AJTEMP
      AJP=RV-(4.*AAK+1.)
      GO TC 40
   41 AAK=AAK+1.
      K=K+1
      PR=REW
      PI=AIMW
   12 AMAGN=TEMPM**2+TEMEL**2
      REW=(TEMPC*TEMPM+TEMPD*TEMEL)/AMAGN
      AIMW=(TEMPM*TEMPD-TEMEL*TEMPC)/AMAGN
      IF(ABS (REW-PR)-1.E-6)665,11,11
  665 IF(ABS (AIMW-PI)-1.E-6)65,11,11
   65 RETURN
C WT IS OBTAINEC FRCM TAYLCR SERIES
  200 TEMP1=R2+AI2
      TEMP2=2.*TEMP1*TEMP1
      AJ=-(R2-AI2)/TEMP2
      AK=2.*REZ*AIMZ/TEMP2
      C=0.
      B=0.
      AJSIG=0.
      D=C.
      JSIG=C
      G=0.
      H=0.
      EL=0.
      A=1.
      AM=1.
      SIGP=1.5
      EXPON=EXP (TEMP2*AJ)
      EXPC=EXPON*CCS (TEMP2*AK)
      EXPS=-EXPON*SIN (TEMP2*AK)
      SIG2P=2.*SIGP
    4 AJ4SIG=4.*AJSIG
      AJ4SM1=AJ4SIG-1.
      TEMP3=1./(AJ4SM1*(AJ4SIG+3.))
      TT4=SIG2P*(2.*AJSIG-1.)
      TEMP4=TT4/(AJ4SM1*(AJ4SIG+1.)*(AJ4SIG-3.)*AJ4SM1)
      AJP=AJ+TEMP3
      GO TC 40
   42 AJSIG=AJSIG+1.
      JSIG=JSIG+1
    6 TEMP7=(AM*AM+EL*EL)*1.7724539
      REF=(AIMZ*(C*AM+D*EL)-REZ*(AM*D-C*EL))/
     1TEMP7/TEMP1
      AIMF=(AIMZ*(AM*D-C*EL)+REZ*(C*AM    +D*EL))/TEMP7/TEMP1
      PR=REW
      PI=AIMW
      REW=EXPC-REF
      AIMW=EXPS-AIMF
      IF(ABS (REW-PR)-1.E-6)664,7,7
  664 IF(ABS (AIMW-PI)-1.E-6)64,7,7
   64 RETURN
    7 SIG2P=2.*AJSIG
      GO TC 4
   40 TEMPC=AJP*C+TEMP4*A-AK*D
      TEMPD=AJP*D+TEMP4*B+AK*C
      TEMEL=AJP*EL+TEMP4*H+AK*AM
      TEMPM=AJP*AM+TEMP4*G-AK*EL
      A=C
      B=D
      G=AM
      H=EL
      C=TEMPC
      D=TEMPD
      AM=TEMPM
      EL=TEMEL
      IF(ABS (TEMPM)+ABS (TEMEL)-1.0E15)49,43,43
```

```
   43 C=1.0E-15*C
      D=1.0E-15*D
      AM=1.0E-15*AM
      EL=1.0E-15*EL
      TEMPC=1.0E-15*TEMPC
      TEMPD=1.0E-15*TEMPD
      TEMPM=1.0E-15*TEMPM
      TEMEL=1.0E-15*TEMEL
      GO TO 50
   49 IF(ABS (TEMPM)+ABS (TEMEL)-1.0E-15)44,44,50
   44 C=1.0E15*C
      D=1.0E15*D
      AM=1.0E15*AM
      EL=1.0E15*EL
      TEMPC=1.0E15*TEMPC
      TEMPD=1.0E15*TEMPD
      TEMPM=1.0E15*TEMPM
      TEMEL=1.0E15*TEMEL
   50 GO TO(41,42,12345),KW
12345 RETURN
      END
```

```
      SUBROUTINE QUICKW       (AX,Y ,REW,AIMW)
      COMMON/TRTI/TR(62,62),TI(62,62),KI
      AKI=SIGN(1.,AX)
      X=ABS(AX)
      TEST=X*X+Y*Y
      IF(TEST.LT.36.)GO TO 10
      IF(TEST.LT.144.)GO TO 2
      IF(TEST.LT.10000.)GO TO 3
      A1=1./(1.7724539*TEST)
      REW=Y*A1
      IF(KI.GT.0)AIMW=X*A1*AKI
      RETURN
   10 II=X*10.
      JJ=Y*10.
      I=II+2
      J=JJ+2
      N=J-1
      P=10.*X-II
      Q=10.*Y-JJ
   15 P2=P*P
      Q2=Q*Q
      PQ=P*Q
      HP=.5*P
      HQ=.5*Q
      HQ2=.5*Q2
      HP2=.5*P2
      A1=HQ2-HQ
      A2=HP2-HP
      A3=1.+PQ-P2-Q2
      A4=HP2-PQ+HP
      A5=HQ2-PQ+HQ
      REW=A1*TR(I,N    )+A2*TR(I-1,J)+A3*TR(I,J)+A4*TR(I+1,J)+A5*TR(I,J+1)
     1+PQ*TR(I+1,J+1)
      IF(KI.LE.0) GO TO 8
    5 AIMW=A1*TI(I,N    )+A2*TI(I-1,J)+A3*TI(I,J)+A4*TI(I+1,J)+A5*TI(I,J+1
     1)+PQ*TI(I+1,J+1)
      AIMW=AIMW*AKI
      GOTO8
    2 A1=X*X -Y*Y
      A2=2.*X*Y
      A3=A2*A2
      A4=A1-.2752551
      A5=A1-2.724745
      D1=.5124242/(A4*A4+A3)
      D2=.05176536/( A5*A5+A3)
      REW=D1*(A2*X-A4*Y)+D2*(A2*X-A5*Y)
      IF(KI.LE.0) GO TO 8
    7 AIMW=D1*(A4*X     +A2*Y)+D2*(A5*X+A2*Y)
      AIMW=AIMW*AKI
      GOTO8
    3 A1=(X*X -Y*Y )*2.
      A2=4.*X*Y
      A4=A1-1.
      D1=1.1283792/(A4*A4+A2*A2)
      REW=D1*(A2*X-A4*Y)
      IF(KI.LE.0) GO TO 8


    9 AIMW=D1*(A4*X+A2*Y)
      AIMW=AIMW*AKI
    8 RETURN
      END
```

APPENDIX III. SAMPLE PROBLEM

A. Listing of Input

```
STUB TEST PRØBLEM WITH 40M 238U DATA
  3    5    9    1    0    0    0    0    0    0    0   -1    1    1    0
  5.74E-07    7.40E-12 566.0       386.0        0.999           0.0030
(F10.3,6F6.3)
  458.136 0.864 0.025 0.536 0.017 0.149 0.005
  458.344 0.888 0.026 0.580 0.018 0.146 0.005
  458.552 0.901 0.026 0.550 0.017 0.138 0.004
  458.761 0.834 0.024 0.542 0.017 0.149 0.005
  458.970 0.869 0.025 0.580 0.018 0.143 0.004
  459.179 0.906 0.026 0.542 0.017 0.157 0.005
  459.388 0.866 0.025 0.582 0.018 0.141 0.004
  459.597 0.849 0.024 0.541 0.017 0.146 0.004
  459.806 0.862 0.025 0.558 0.017 0.150 0.005
  460.016 0.887 0.025 0.529 0.016 0.151 0.005
  460.225 0.843 0.024 0.535 0.017 0.153 0.005
  460.435 0.871 0.025 0.570 0.018 0.154 0.005
  460.645 0.893 0.025 0.604 0.019 0.152 0.005
  460.855 0.858 0.025 0.552 0.017 0.151 0.005
  461.065 0.871 0.025 0.577 0.018 0.154 0.005
  461.275 0.873 0.025 0.565 0.017 0.149 0.005
  461.486 0.878 0.025 0.559 0.017 0.160 0.005
  461.697 0.906 0.026 0.560 0.017 0.159 0.005
  461.907 0.862 0.024 0.563 0.018 0.155 0.005
  462.118 0.817 0.024 0.551 0.017 0.144 0.005
  462.329 0.806 0.023 0.453 0.015 0.103 0.003
  462.540 0.778 0.023 0.381 0.014 0.059 0.003
  462.752 0.665 0.021 0.242 0.010 0.020 0.002
  462.963 0.542 0.018 0.116 0.007 0.004 0.001
  463.175 0.501 0.017 0.066 0.005 0.003 0.001
  463.386 0.510 0.017 0.091 0.006 0.005 0.001
  463.598 0.635 0.020 0.167 0.008 0.013 0.001
  463.811 0.734 0.022 0.263 0.010 0.033 0.002
  464.023 0.782 0.023 0.403 0.014 0.062 0.003
  464.235 0.851 0.025 0.473 0.015 0.090 0.003
  464.448 0.843 0.024 0.489 0.016 0.107 0.004
  464.660 0.858 0.025 0.497 0.016 0.114 0.004
  464.873 0.854 0.024 0.560 0.018 0.115 0.004
  465.086 0.874 0.025 0.542 0.017 0.120 0.004
  465.299 0.846 0.025 0.501 0.016 0.128 0.004
  465.512 0.896 0.026 0.528 0.016 0.123 0.004
  465.726 0.916 0.027 0.531 0.017 0.127 0.004
  465.939 0.840 0.024 0.517 0.016 0.128 0.004
  466.153 0.826 0.024 0.529 0.017 0.122 0.004
  466.366 0.858 0.025 0.573 0.018 0.130 0.004
  466.581 0.853 0.024 0.546 0.017 0.130 0.004
  466.795 0.871 0.025 0.524 0.016 0.127 0.004
```

467.009	0.839	0.024	0.504	0.016	0.123	0.004
467.223	0.879	0.025	0.523	0.016	0.125	0.004
467.438	0.877	0.025	0.511	0.016	0.129	0.004
467.653	0.856	0.024	0.511	0.016	0.129	0.004
467.867	0.871	0.025	0.531	0.017	0.136	0.004
468.082	0.875	0.025	0.565	0.018	0.133	0.004
468.297	0.835	0.024	0.539	0.017	0.134	0.004
468.513	0.873	0.025	0.533	0.016	0.144	0.005
468.728	0.898	0.026	0.577	0.018	0.140	0.004
468.944	0.839	0.024	0.542	0.017	0.140	0.004
469.159	0.852	0.025	0.529	0.017	0.141	0.004
469.375	0.842	0.024	0.551	0.017	0.137	0.004
469.591	0.849	0.024	0.542	0.017	0.136	0.004
469.808	0.875	0.025	0.559	0.017	0.139	0.004
470.024	0.867	0.025	0.556	0.017	0.143	0.004
470.240	0.860	0.025	0.556	0.017	0.140	0.004
470.457	0.837	0.024	0.582	0.018	0.141	0.004
470.674	0.890	0.026	0.564	0.018	0.142	0.004
470.891	0.876	0.025	0.521	0.016	0.142	0.004
471.108	0.872	0.025	0.571	0.018	0.149	0.005
471.325	0.871	0.025	0.565	0.017	0.143	0.004
471.542	0.872	0.025	0.553	0.017	0.141	0.004
471.760	0.866	0.025	0.575	0.018	0.148	0.005
471.978	0.891	0.026	0.521	0.016	0.142	0.004
472.195	0.887	0.025	0.564	0.017	0.141	0.004
472.413	0.919	0.026	0.568	0.018	0.141	0.004
472.632	0.927	0.027	0.566	0.017	0.150	0.005
472.850	0.894	0.026	0.560	0.017	0.147	0.005
473.068	0.886	0.026	0.578	0.018	0.147	0.004
473.287	0.838	0.024	0.577	0.018	0.147	0.005
473.506	0.852	0.024	0.544	0.017	0.146	0.004
473.724	0.842	0.024	0.539	0.017	0.151	0.005
473.943	0.879	0.025	0.563	0.018	0.148	0.005
474.163	0.901	0.026	0.568	0.018	0.144	0.004
474.382	0.881	0.025	0.526	0.016	0.148	0.005
474.602	0.892	0.025	0.564	0.018	0.142	0.004
474.821	0.862	0.025	0.571	0.018	0.149	0.005
475.041	0.892	0.026	0.575	0.018	0.160	0.005
475.261	0.847	0.024	0.527	0.016	0.149	0.004
475.481	0.897	0.025	0.589	0.018	0.147	0.004
475.701	0.878	0.025	0.541	0.017	0.158	0.005
475.922	0.866	0.025	0.572	0.018	0.164	0.005
476.142	0.870	0.025	0.572	0.018	0.157	0.005
476.363	0.862	0.024	0.557	0.017	0.162	0.005
476.584	0.835	0.024	0.582	0.018	0.155	0.005
476.805	0.839	0.024	0.584	0.018	0.159	0.005

477.026	0.864	0.025	0.558	0.018	0.155	0.005
477.247	0.824	0.024	0.538	0.017	0.147	0.005
477.469	0.876	0.026	0.522	0.017	0.130	0.004
477.690	0.831	0.025	0.444	0.015	0.099	0.004
477.912	0.746	0.023	0.346	0.013	0.047	0.002
478.134	0.656	0.021	0.218	0.010	0.015	0.001
478.356	0.622	0.020	0.119	0.007	0.004	0.001
478.579	0.604	0.019	0.117	0.007	0.007	0.001
478.801	0.660	0.021	0.201	0.009	0.017	0.001
479.023	0.750	0.022	0.298	0.011	0.041	0.002
479.246	0.841	0.024	0.395	0.013	0.072	0.003
479.469	0.856	0.025	0.473	0.015	0.097	0.003
479.692	0.835	0.024	0.562	0.018	0.115	0.004
479.915	0.860	0.025	0.540	0.017	0.121	0.004
480.139	0.843	0.024	0.523	0.016	0.132	0.004
480.362	0.824	0.024	0.532	0.016	0.133	0.004
480.586	0.839	0.024	0.501	0.016	0.142	0.004
480.810	0.865	0.026	0.541	0.017	0.136	0.004
481.034	0.867	0.025	0.539	0.017	0.138	0.004
481.258	0.867	0.025	0.577	0.018	0.139	0.004
481.482	0.859	0.024	0.520	0.016	0.139	0.004
481.707	0.884	0.026	0.541	0.017	0.141	0.004
481.931	0.857	0.024	0.556	0.017	0.151	0.005
482.156	0.890	0.025	0.529	0.016	0.145	0.004
482.381	0.853	0.024	0.550	0.017	0.133	0.004
482.606	0.909	0.026	0.547	0.017	0.142	0.004
482.831	0.834	0.024	0.528	0.016	0.148	0.005
483.056	0.861	0.025	0.542	0.017	0.137	0.004
483.282	0.835	0.024	0.568	0.017	0.141	0.004
483.508	0.898	0.026	0.567	0.017	0.141	0.004
483.734	0.903	0.026	0.543	0.017	0.142	0.004
483.960	0.847	0.024	0.565	0.017	0.146	0.004
484.186	0.876	0.025	0.522	0.016	0.143	0.004
484.412	0.890	0.026	0.532	0.017	0.141	0.004
484.639	0.853	0.024	0.512	0.016	0.140	0.004
484.865	0.874	0.025	0.549	0.017	0.135	0.004
485.092	0.880	0.025	0.518	0.016	0.124	0.004
485.319	0.902	0.026	0.526	0.016	0.115	0.004
485.546	0.893	0.026	0.503	0.016	0.129	0.004
485.773	0.844	0.024	0.548	0.017	0.139	0.004
486.001	0.850	0.024	0.531	0.016	0.136	0.004
486.229	0.833	0.024	0.581	0.018	0.143	0.004
486.456	0.871	0.025	0.548	0.017	0.151	0.005
486.684	0.886	0.025	0.538	0.016	0.150	0.005
486.912	0.888	0.025	0.557	0.017	0.159	0.005
487.141	0.870	0.025	0.560	0.017	0.148	0.004
487.369	0.833	0.024	0.570	0.018	0.151	0.005
487.597	0.901	0.026	0.542	0.017	0.153	0.005
487.826	0.879	0.025	0.547	0.017	0.143	0.004

488.055	0.860	0.024	0.535	0.017	0.130	0.004
488.284	0.856	0.025	0.518	0.016	0.112	0.004
488.513	0.854	0.025	0.482	0.016	0.078	0.003
488.743	0.818	0.024	0.377	0.013	0.057	0.002
488.972	0.801	0.023	0.392	0.014	0.052	0.002
489.202	0.851	0.025	0.428	0.014	0.068	0.003
489.432	0.844	0.024	0.483	0.016	0.095	0.003
489.662	0.862	0.025	0.524	0.017	0.130	0.004
489.892	0.869	0.025	0.588	0.018	0.141	0.004
490.123	0.896	0.025	0.526	0.016	0.155	0.005
490.353	0.886	0.026	0.548	0.017	0.149	0.005
490.584	0.846	0.024	0.593	0.018	0.146	0.004
490.814	0.860	0.024	0.540	0.017	0.152	0.005
491.045	0.852	0.024	0.557	0.017	0.157	0.005
491.277	0.895	0.026	0.543	0.017	0.160	0.005
491.508	0.906	0.025	0.588	0.018	0.153	0.005
491.740	0.907	0.026	0.570	0.018	0.155	0.005
491.971	0.897	0.026	0.575	0.018	0.156	0.005
492.203	0.865	0.025	0.562	0.017	0.153	0.005
492.435	0.836	0.024	0.578	0.018	0.150	0.005
492.667	0.893	0.025	0.571	0.018	0.149	0.004
492.899	0.867	0.025	0.580	0.018	0.158	0.005
493.132	0.864	0.024	0.568	0.018	0.154	0.005
493.365	0.889	0.025	0.540	0.016	0.153	0.005
493.597	0.883	0.025	0.549	0.017	0.158	0.005
493.830	0.902	0.026	0.568	0.017	0.154	0.005
494.063	0.912	0.026	0.608	0.019	0.149	0.004
494.297	0.888	0.025	0.554	0.017	0.159	0.005
494.530	0.892	0.025	0.566	0.017	0.158	0.005
494.764	0.865	0.025	0.564	0.017	0.148	0.004
494.998	0.880	0.025	0.556	0.017	0.160	0.005
495.231	0.857	0.025	0.587	0.018	0.156	0.005

```
                                                                        BLANK CARD
                                                                        BLANK CARD
0.012395   0.05208    0.17536
0.0        0.0        0.0
0.0        0.0        0.0
(3F10.3)
1.000       0.9184      236.01      300.0
           0             1 1.0      1.0        0.04906     0.981       0.0230
397.4      0.00640    0.0252
410.2      0.02060    0.0226
```

```
433.7       0.00998     0.0235
462.8       0.00550     0.0235
478.3       0.00380     0.0235
518.3       0.05160     0.0244
535.2       0.04700     0.0235

            1            0 1.0       1.0                          BLANK CARD
466.8       0.00010     0.0236
485.0       0.00012     0.0236
488.2       0.00062     0.0241

                                                                  BLANK CARD
                                                                  BLANK CARD
0.0                                                               BLANK CARD

 0  0  0                                                          BLANK CARD
 1  1  0
 0  0  0
 0  2
 0  0  0
 0  0  0
 0  0  0
 2  0  2
 2  0  2
 0  0  0
 0  0  0

 2  0  2                                                          BLANK CARD
 2  0  2
 2  0  2

                                                                  BLANK CARD
 1                                                                BLANK CARD

                                                                  BLANK CARD
                                                                  BLANK CARD
```

B. Listing of Output

```
SIOB TEST PROBLEM WITH 40M 238U DATA

FIXED POINT INPUTS        3   5   9   1   0   0   0   0   0   0   0  -1   1   1   0
FLOATING POINT INPUTS     0.574E-06  0.740E-11   566.       386.      0.999      0.300E-02

NUMBER OF TRANSMISSION VALUES     907
MAXIMUM ADDRESS OF F-ARRAY       1788
MAXIMUM ADDRESS OF G-ARRAY        591

TRUNCATION LIMITS       386.00          566.00



            INPUT RESONANCE PARAMETERS


 NUCLEAR SPECIES =  1      REDUCED MOMENTUM= 0.21875E-02      NUCLEAR RADIUS= 0.83874
      DOPPLER WIDTH= 0.78633E 66     NUMBER OF ANGULAR MOMENTA=  2
      FRACTIONAL ABUNDANCE= 1.0000      EFFECTIVE RADIUS= 0.9184


   ANGULAR MOMENTUM= 0      INTERFERENCE PARAMETER= 1     SPIN STATISTICAL FACTOR= 1.000     POTENTIAL SCATTERING FRACTION= 1.000
        STRENGTH-FUNCTION= 0.49060E-01       AVERAGE NEUTRON-WIDTH= 0.98100            AVERAGE CAPTURE-WIDTH= 0.23000E-01

        NUMBER OF LEVELS=    7

             RESONANCE ENERGY      CAPTURE-WIDTH      NEUTRON-WIDTH

                  397.40           0.25200E-01        0.64000E-02
                  410.20           0.22600E-01        0.20600E-01
                  433.70           0.23500E-01        0.99800E-02
                  462.80           0.23500E-01        0.55000E-02
                  478.30           0.23500E-01        0.38000E-02
                  518.30           0.24400E-01        0.51600E-01
                  535.20           0.23500E-01        0.47000E-01

   ANGULAR MOMENTUM= 1      INTERFERENCE PARAMETER= 0     SPIN STATISTICAL FACTOR= 1.000     POTENTIAL SCATTERING FRACTION= 1.000
        STRENGTH-FUNCTION= 0.0                AVERAGE NEUTRON-WIDTH= 0.0               AVERAGE CAPTURE-WIDTH= 0.0

        NUMBER OF LEVELS=    3

             RESONANCE ENERGY      CAPTURE-WIDTH      NEUTRON-WIDTH

                  466.80           0.23600E-01        0.10000E-03
                  485.00           0.23600E-01        0.12000E-03
                  488.20           0.24100E-01        0.62000E-03
```

```
ITERATION NUMBER  1

        NPS               ETA              CHIOLD             CHINEW

         0              1.0000             29.000             4.8829


     SAMPLE-THICKNESSES

        OLD VALUE             NEW VALUE              ERROR

        0.12395E-01
        0.52080E-01
        0.17536

     NORMALISATION-ERRORS

        OLD VALUE             NEW VALUE              ERROR

        0.0                 -0.60741E-02          0.48846D-02
        0.0                 -0.29360E-01          0.53139D-02
        0.0

     TRANSMISSION-BACKGROUNDS

        OLD VALUE             NEW VALUE              ERROR

        0.0
        0.0
        0.0
```

RESONANCE PARAMETERS

NUCLEAR SPECIES = 1 NUMBER OF ANGULAR MOMENTA = 2

FRACTIONAL ABUNDANCE AND RADIUS

OLD VALUE	NEW VALUE	ERROR
1.0000		
0.91840	0.95370	0.12906D-02

ANGULAR MOMENTUM = 0 NUMBER OF LEVELS= 7

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

(ONLY VARIED LEVELS ARE LISTED)

OLD VALUE	NEW VALUE	ERROR
462.80	463.12	0.11517E-01
0.23500E-01		
0.55019E-02	0.39651E-02	0.21574E-03
478.30	478.42	0.12477E-01
0.23500E-01		
0.38005E-02	0.37049E-02	0.14500E-03

ANGULAR MOMENTUM = 1 NUMBER OF LEVELS= 3

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

(ONLY VARIED LEVELS ARE LISTED)

OLD VALUE	NEW VALUE	ERROR
466.80	466.91	0.12985
0.23600E-01		
0.10004E-03	0.49464E-04	0.24433E-04
485.00	485.26	0.11205
0.23600E-01		
0.12010E-03	0.78360E-04	0.24801E-04
488.20	488.69	0.27767E-01
0.24100E-01		
0.62093E-03	0.29111E-03	0.41450E-04

AUXILIARY PARAMETERS

OLD VALUE	NEW VALUE	ERROR
0.0	-0.33570	0.13253

ITERATICN NUMBER 2

NPS	ETA	CHIOLD	CHINEW
0	1.COCO	4.8829	2.0742

SAMPLE-THICKNESSES

OLC VALUE	NEW VALUE	ERROR
0.12395E-01		
0.52080E-01		
0.17536		

NCRMALISATION-ERRORS

OLC VALUE	NEW VALUE	ERROR
-0.60741D-02	-0.28567E-02	0.32031D-02
-0.29360D-01	-0.22132E-01	0.36255D-02
0.0		

TRANSMISSION-BACKGROUNDS

OLC VALUE	NEW VALUE	ERROR
0.0		
0.0		
0.0		

RESONANCE PARAMETERS

NUCLEAR SPECIES = 1   NUMEER CF ANGULAR MOMENTA = 2

FRACTICNAL ABUNCANCE ANC RACIUS

OLC VALUE	NEW VALUE	ERROR
1.0000		
0.95370	0.94888	0.92928D-03

ANGULAR MCMENTUM = 0   NUMEER CF LEVELS= 7

RESONANCE-ENERGY,CAPTURE-WICTH,NEUTRON-WIDTH

OLC VALUE	NEW VALUE	ERROR
(ONLY VARIED LEVELS ARE LISTED)		
463.12	463.17	0.74882E-02
0.23500E-01		
0.39653E-02	0.51063E-02	0.88958E-04
478.42	478.43	0.86925E-02
0.23500E-01		
0.37049E-02	0.39649E-02	0.96005E-04

ANGULAR MOMENTUM = 1 NUMBER OF LEVELS= 3

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

OLD VALUE	NEW VALUE	ERROR
(ONLY VARIED LEVELS ARE LISTED)		
466.91	467.15	0.18469
0.23600E-01		
0.49502E-04	0.52906E-04	0.16739E-04
485.26	485.33	0.12528
0.23600E-01		
0.78376E-04	0.12865E-03	0.17750E-04
488.69	489.15	0.33424E-01
0.24100E-01		
0.29152E-03	0.64901E-03	0.18594E-04

AUXILIARY PARAMETERS

OLD VALUE	NEW VALUE	ERROR
-0.33570	-0.22924E-01	0.99935D-01

ITERATION NUMBER 3

NPS	ETA	CHIOLD	CHINEW
0	1.0000	2.0742	1.0611

SAMPLE-THICKNESSES

OLD VALUE	NEW VALUE	ERROR
0.12395E-01		
0.52080E-01		
0.17536		

NORMALISATION-ERRORS

OLD VALUE	NEW VALUE	ERROR
-0.28567D-02	-0.21108E-02	0.23008D-02
-0.22132D-01	-0.21063E-01	0.26021D-02
0.0		

TRANSMISSION-BACKGROUNDS

OLD VALUE	NEW VALUE	ERROR
0.0		
0.0		
0.0		

RESONANCE PARAMETERS

NUCLEAR SPECIES = 1 NUMBER OF ANGULAR MOMENTA = 2

FRACTIONAL ABUNDANCE AND RADIUS

OLD VALUE	NEW VALUE	ERROR
1.0000		
0.94888	0.94863	0.66121D-03

ANGULAR MOMENTUM = 0 NUMBER OF LEVELS= 7

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

OLD VALUE	NEW VALUE	ERROR
(ONLY VARIED LEVELS ARE LISTED)		
463.17	463.17	0.50667E-02
0.23500E-01		
0.51063E-02	0.53836E-02	0.84385E-04
478.43	478.43	0.60386E-02
0.23500E-01		
0.39649E-02	0.39813E-02	0.72857E-04

ANGULAR MOMENTUM = 1 NUMBER OF LEVELS= 3

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

OLD VALUE	NEW VALUE	ERROR
(ONLY VARIED LEVELS ARE LISTED)		
467.15	467.18	0.12355
0.23600E-01		
0.52912E-04	0.55953E-04	0.11985E-04
485.33	485.30	0.55287E-01
0.23600E-01		
0.12864E-03	0.13023E-03	0.13155E-04
489.15	488.87	0.13038E-01
0.24100E-01		
0.64846E-03	0.72674E-03	0.18745E-04

AUXILIARY PARAMETERS

OLD VALUE	NEW VALUE	ERROR
-0.22924D-01	-0.17400E-01	0.70507D-01

ITERATICN NUMBER 4

NPS	ETA	CHIOLD	CHINEW
0	1.COCO	1.0611	0.97770

SAMPLE-THICKNESSES

OLD VALUE	NEW VALUE	ERROR
0.12395E-01		
0.52080E-01		
0.17536		

NCRMALISATION-ERRORS

OLD VALUE	NEW VALUE	ERROR
-0.21108D-02	-C.1S6C8E-02	0.22108D-02
-0.21063D-01	-0.2CES3E-C1	0.25023D-02
0.0		

TRANSMISSION-EACKGROUNCS

OLD VALUE	NEW VALUE	ERROR
0.0		
0.0		
0.C		

RESONANCE PARAMETERS

NUCLEAR SPECIES = 1 NUMBER OF ANGULAR MOMENTA = 2

FRACTICNAL ABUNCANCE ANC RACIUS

OLD VALUE	NEW VALUE	ERROR
1.0000		
0.S4863	0.94810	0.63565D-03

ANGULAR MCMENTUM = C NUMBER CF LEVELS= 7

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

OLC VALUE	NEW VALUE	ERROR
(ONLY VARIED LEVELS ARE LISTEC)		
463.17	463.17	0.48384E-02
0.235COE-01		
0.53836E-02	0.53979E-02	0.86178E-04
478.43	47E.43	0.57896E-02
0.23500E-01		
0.39813E-02	0.3SSC5E-C2	0.70193E-04

ANGULAR MCMENTUM = 1 NUMBER OF LEVELS= 3

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

OLD VALUE	NEW VALUE	ERROR
(ONLY VARIED LEVELS ARE LISTED)		
467.18	467.18	0.11257
0.23600E-01		
0.55954E-04	0.56053E-04	0.11568E-04
485.30	485.30	0.52450E-01
0.23600E-01		
0.13023E-03	0.13524E-03	0.12646E-04
488.87	488.91	0.11597E-01
0.24100E-01		
0.72682E-03	0.82565E-03	0.19243E-04

AUXILIARY PARAMETERS

OLD VALUE	NEW VALUE	ERROR
-0.17400D-01	0.55976E-01	0.67549D-01

ITERATION NUMBER 5

NPS	ETA	CHIOLD	CHINEW
0	1.0000	0.97770	0.97676

SAMPLE-THICKNESSES

OLD VALUE	NEW VALUE	ERROR
0.12395E-01		
0.52080E-01		
0.17536		

NORMALISATION-ERRORS

OLD VALUE	NEW VALUE	ERROR
-0.19608D-02	-0.19473E-02	0.22102D-02
-0.20693D-01	-0.20634E-01	0.25027D-02
0.0		

TRANSMISSION-BACKGROUNDS

OLD VALUE	NEW VALUE	ERROR
0.0		
0.0		
0.0		

RESONANCE PARAMETERS

NUCLEAR SPECIES = 1 NUMBER OF ANGULAR MOMENTA = 2

FRACTIONAL ABUNDANCE AND RADIUS

OLD VALUE	NEW VALUE	ERROR
1.0000		
0.94810	0.94810	0.63482D-03

ANGULAR MOMENTUM = 0 NUMBER OF LEVELS= 7

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

(ONLY VARIED LEVELS ARE LISTED)

OLD VALUE	NEW VALUE	ERROR
463.17	463.17	0.48367E-02
0.23500E-01		
0.53979E-02	0.53983E-02	0.86427E-04
478.43	478.43	0.57741E-02
0.23500E-01		
0.39905E-02	0.39907E-02	0.70242E-04

ANGULAR MOMENTUM = 1 NUMBER OF LEVELS= 3

RESONANCE-ENERGY,CAPTURE-WIDTH,NEUTRON-WIDTH

(ONLY VARIED LEVELS ARE LISTED)

OLD VALUE	NEW VALUE	ERROR
467.18	467.18	0.11233
0.23600E-01		
0.56053E-04	0.56062E-04	0.11565E-04
485.30	485.30	0.50458E-01
0.23600E-01		
0.13524E-03	0.13532E-03	0.12664E-04
488.91	488.91	0.10758E-01
0.24100E-01		
0.82584E-03	0.83286E-03	0.21053E-04

AUXILIARY PARAMETERS

OLD VALUE	NEW VALUE	ERROR
0.55976D-01	0.57396E-01	0.67436D-01

STOP ITERATIONS BECAUSE CONVERGENCE IS TOO SLOW

ENERGY	CALCULATION	EXPERIMENT	ERROR	ATOMS PER BARN
458.14	0.8700	0.8640	0.0250	0.12395E-01
	0.5500	0.5360	0.0170	0.52080E-01
	0.1433	0.1490	0.0050	0.17536
458.34	0.8702	0.8880	0.0260	0.12395E-01
	0.5505	0.5800	0.0180	0.52080E-01
	0.1438	0.1460	0.0050	0.17536
458.55	0.8704	0.9010	0.0260	0.12395E-01
	0.5510	0.5500	0.0170	0.52080E-01
	0.1442	0.1380	0.0040	0.17536
458.76	0.8706	0.8340	0.0240	0.12395E-01
	0.5516	0.5420	0.0170	0.52080E-01
	0.1447	0.1490	0.0050	0.17536
458.97	0.8708	0.8690	0.0250	0.12395E-01
	0.5521	0.5800	0.0180	0.52080E-01
	0.1452	0.1430	0.0040	0.17536
459.18	0.8710	0.9060	0.0260	0.12395E-01
	0.5528	0.5420	0.0170	0.52080E-01
	0.1457	0.1570	0.0050	0.17536
459.39	0.8713	0.8660	0.0250	0.12395E-01
	0.5534	0.5820	0.0180	0.52080E-01
	0.1463	0.1410	0.0040	0.17536
459.60	0.8716	0.8490	0.0240	0.12395E-01
	0.5541	0.5410	0.0170	0.52080E-01
	0.1470	0.1460	0.0040	0.17536
459.81	0.8719	0.8620	0.0250	0.12395E-01
	0.5549	0.5580	0.0170	0.52080E-01
	0.1477	0.1500	0.0050	0.17536
460.02	0.8722	0.8870	0.0250	0.12395E-01
	0.5558	0.5290	0.0160	0.52080E-01
	0.1485	0.1510	0.0050	0.17536
460.22	0.8726	0.8430	0.0240	0.12395E-01
	0.5568	0.5350	0.0170	0.52080E-01
	0.1494	0.1530	0.0050	0.17536
460.43	0.8730	0.8710	0.0250	0.12395E-01
	0.5579	0.5700	0.0180	0.52080E-01
	0.1504	0.1540	0.0050	0.17536
460.64	0.8735	0.8930	0.0250	0.12395E-01
	0.5592	0.6040	0.0190	0.52080E-01
	0.1516	0.1520	0.0050	0.17536
460.85	0.8740	0.8580	0.0250	0.12395E-01
	0.5607	0.5520	0.0170	0.52080E-01
	0.1529	0.1510	0.0050	0.17536
461.06	0.8747	0.8710	0.0250	0.12395E-01
	0.5625	0.5770	0.0180	0.52080E-01
	0.1546	0.1540	0.0050	0.17536
461.27	0.8754	0.8730	0.0250	0.12395E-01
	0.5646	0.5650	0.0170	0.52080E-01
	0.1565	0.1490	0.0050	0.17536
461.49	0.8763	0.8780	0.0250	0.12395E-01
	0.5670	0.5590	0.0170	0.52080E-01
	0.1588	0.1600	0.0050	0.17536
461.70	0.8769	0.9080	0.0260	0.12395E-01
	0.5687	0.5600	0.0170	0.52080E-01
	0.1605	0.1590	0.0050	0.17536
461.91	0.8753	0.8620	0.0240	0.12395E-01
	0.5650	0.5630	0.0180	0.52080E-01
	0.1582	0.1550	0.0050	0.17536
462.12	0.8648	0.8170	0.0240	0.12395E-01
	0.5418	0.5510	0.0170	0.52080E-01
	0.1436	0.1440	0.0050	0.17536
462.33	0.8315	0.8060	0.0230	0.12395E-01
	0.4761	0.4530	0.0150	0.52080E-01
	0.1094	0.1030	0.0030	0.17536
462.54	0.7601	0.7780	0.0230	0.12395E-01
	0.3586	0.3810	0.0140	0.52080E-01
	0.0632	0.0590	0.0030	0.17536
462.75	0.6539	0.6650	0.0210	0.12395E-01
	0.2191	0.2420	0.0100	0.52080E-01
	0.0257	0.0200	0.0030	0.17536
462.96	0.5510	0.5420	0.0180	0.12395E-01
	0.1126	0.1160	0.0070	0.52080E-01
	0.0069	0.0040	0.0030	0.17536
463.17	0.5015	0.5010	0.0170	0.12395E-01
	0.0691	0.0660	0.0050	0.52080E-01
	0.0017	0.0030	0.0030	0.17536
463.39	0.5309	0.5100	0.0170	0.12395E-01
	0.0916	0.0910	0.0060	0.52080E-01
	0.0032	0.0050	0.0030	0.17536
463.60	0.6195	0.6350	0.0200	0.12395E-01
	0.1726	0.1670	0.0080	0.52080E-01
	0.0124	0.0130	0.0030	0.17536
463.81	0.7201	0.7340	0.0220	0.12395E-01
	0.2885	0.2630	0.0100	0.52080E-01
	0.0329	0.0330	0.0030	0.17536
464.02	0.7940	0.7820	0.0230	0.12395E-01
	0.3958	0.4030	0.0140	0.52080E-01
	0.0619	0.0620	0.0030	0.17536

464.23	0.8333	0.8510	0.0250	0.12395E-01
	0.4655	0.4730	0.0150	0.52080E-01
	0.0884	0.0900	0.0030	0.17536
464.45	0.8499	0.8430	0.0240	0.12395E-01
	0.4998	0.4890	0.0160	0.52080E-01
	0.1056	0.1070	0.0040	0.17536
464.66	0.8561	0.8580	0.0250	0.12395E-01
	0.5142	0.4970	0.0160	0.52080E-01
	0.1146	0.1140	0.0040	0.17536
464.87	0.8588	0.8540	0.0240	0.12395E-01
	0.5209	0.5600	0.0180	0.52080E-01
	0.1194	0.1150	0.0040	0.17536
465.09	0.8604	0.8740	0.0250	0.12395E-01
	0.5249	0.5420	0.0170	0.52080E-01
	0.1225	0.1200	0.0040	0.17536
465.30	0.8615	0.8460	0.0250	0.12395E-01
	0.5278	0.5010	0.0160	0.52080E-01
	0.1247	0.1280	0.0040	0.17536
465.51	0.8624	0.8960	0.0260	0.12395E-01
	0.5300	0.5280	0.0160	0.52080E-01
	0.1265	0.1230	0.0040	0.17536
465.73	0.8631	0.9160	0.0270	0.12395E-01
	0.5318	0.5310	0.0170	0.52080E-01
	0.1280	0.1270	0.0040	0.17536
465.94	0.8636	0.8400	0.0240	0.12395E-01
	0.5333	0.5170	0.0160	0.52080E-01
	0.1291	0.1280	0.0040	0.17536
466.15	0.8640	0.8260	0.0240	0.12395E-01
	0.5341	0.5290	0.0170	0.52080E-01
	0.1298	0.1220	0.0040	0.17536
466.37	0.8639	0.8580	0.0250	0.12395E-01
	0.5340	0.5730	0.0180	0.52080E-01
	0.1297	0.1300	0.0040	0.17536
466.58	0.8633	0.8530	0.0240	0.12395E-01
	0.5324	0.5460	0.0170	0.52080E-01
	0.1284	0.1300	0.0040	0.17536
466.79	0.8621	0.8710	0.0250	0.12395E-01
	0.5294	0.5240	0.0160	0.52080E-01
	0.1261	0.1270	0.0040	0.17536
467.01	0.8611	0.8390	0.0240	0.12395E-01
	0.5268	0.5040	0.0160	0.52080E-01
	0.1240	0.1230	0.0040	0.17536
467.22	0.8610	0.8790	0.0250	0.12395E-01
	0.5266	0.5230	0.0160	0.52080E-01
	0.1238	0.1250	0.0040	0.17536
467.44	0.8622	0.8770	0.0250	0.12395E-01
	0.5295	0.5110	0.0160	0.52080E-01
	0.1261	0.1290	0.0040	0.17536
467.65	0.8639	0.8560	0.0240	0.12395E-01
	0.5340	0.5110	0.0160	0.52080E-01
	0.1298	0.1290	0.0040	0.17536
467.87	0.8655	0.8710	0.0250	0.12395E-01
	0.5381	0.5310	0.0170	0.52080E-01
	0.1332	0.1360	0.0040	0.17536
468.08	0.8665	0.8750	0.0250	0.12395E-01
	0.5408	0.5650	0.0180	0.52080E-01
	0.1354	0.1330	0.0040	0.17536
468.30	0.8671	0.8350	0.0240	0.12395E-01
	0.5422	0.5390	0.0170	0.52080E-01
	0.1366	0.1340	0.0040	0.17536
468.51	0.8674	0.8730	0.0250	0.12395E-01
	0.5430	0.5330	0.0160	0.52080E-01
	0.1373	0.1440	0.0050	0.17536
468.73	0.8676	0.8980	0.0260	0.12395E-01
	0.5436	0.5770	0.0180	0.52080E-01
	0.1378	0.1400	0.0040	0.17536
468.94	0.8678	0.8390	0.0240	0.12395E-01
	0.5441	0.5420	0.0170	0.52080E-01
	0.1382	0.1400	0.0040	0.17536
469.16	0.8680	0.8520	0.0250	0.12395E-01
	0.5446	0.5290	0.0170	0.52080E-01
	0.1386	0.1410	0.0040	0.17536
469.38	0.8681	0.8420	0.0240	0.12395E-01
	0.5450	0.5510	0.0170	0.52080E-01
	0.1390	0.1370	0.0040	0.17536
469.59	0.8683	0.8490	0.0240	0.12395E-01
	0.5455	0.5420	0.0170	0.52080E-01
	0.1394	0.1360	0.0040	0.17536
469.81	0.8684	0.8750	0.0250	0.12395E-01
	0.5459	0.5590	0.0170	0.52080E-01
	0.1397	0.1390	0.0040	0.17536
470.02	0.8686	0.8670	0.0250	0.12395E-01
	0.5463	0.5560	0.0170	0.52080E-01
	0.1401	0.1430	0.0040	0.17536
470.24	0.8688	0.8600	0.0250	0.12395E-01
	0.5467	0.5560	0.0170	0.52080E-01
	0.1404	0.1400	0.0040	0.17536
470.46	0.8689	0.8370	0.0240	0.12395E-01
	0.5471	0.5820	0.0180	0.52080E-01
	0.1408	0.1410	0.0040	0.17536

470.67	0.8691	0.8900	0.0260	0.12395E-01
	0.5475	0.5640	0.0180	0.52080E-01
	0.1411	0.1420	0.0040	0.17536
470.89	0.8692	0.8760	0.0250	0.12395E-01
	0.5479	0.5210	0.0160	0.52080E-01
	0.1415	0.1420	0.0040	0.17536
471.11	0.8694	0.8720	0.0250	0.12395E-01
	0.5483	0.5710	0.0180	0.52080E-01
	0.1418	0.1490	0.0050	0.17536
471.32	0.8695	0.8710	0.0250	0.12395E-01
	0.5487	0.5650	0.0170	0.52080E-01
	0.1421	0.1430	0.0040	0.17536
471.54	0.8697	0.8720	0.0250	0.12395E-01
	0.5491	0.5530	0.0170	0.52080E-01
	0.1425	0.1410	0.0040	0.17536
471.76	0.8698	0.8660	0.0250	0.12395E-01
	0.5495	0.5750	0.0180	0.52080E-01
	0.1428	0.1480	0.0050	0.17536
471.98	0.8699	0.8910	0.0260	0.12395E-01
	0.5499	0.5210	0.0160	0.52080E-01
	0.1432	0.1420	0.0040	0.17536
472.19	0.8701	0.8870	0.0250	0.12395E-01
	0.5503	0.5640	0.0170	0.52080E-01
	0.1435	0.1410	0.0040	0.17536
472.41	0.8702	0.9190	0.0260	0.12395E-01
	0.5507	0.5680	0.0180	0.52080E-01
	0.1439	0.1410	0.0040	0.17536
472.63	0.8704	0.9270	0.0270	0.12395E-01
	0.5511	0.5660	0.0170	0.52080E-01
	0.1442	0.1500	0.0050	0.17536
472.85	0.8706	0.8940	0.0260	0.12395E-01
	0.5515	0.5600	0.0170	0.52080E-01
	0.1446	0.1470	0.0050	0.17536
473.07	0.8707	0.8860	0.0260	0.12395E-01
	0.5519	0.5780	0.0180	0.52080E-01
	0.1450	0.1470	0.0040	0.17536
473.29	0.8709	0.8380	0.0240	0.12395E-01
	0.5524	0.5770	0.0180	0.52080E-01
	0.1454	0.1470	0.0050	0.17536
473.51	0.8711	0.8520	0.0240	0.12395E-01
	0.5528	0.5440	0.0170	0.52080E-01
	0.1458	0.1460	0.0040	0.17536
473.72	0.8712	0.8420	0.0240	0.12395E-01
	0.5533	0.5390	0.0170	0.52080E-01
	0.1462	0.1510	0.0050	0.17536
473.94	0.8714	0.8790	0.0250	0.12395E-01
	0.5538	0.5630	0.0180	0.52080E-01
	0.1467	0.1480	0.0050	0.17536
474.16	0.8716	0.9010	0.0260	0.12395E-01
	0.5544	0.5680	0.0180	0.52080E-01
	0.1472	0.1440	0.0040	0.17536
474.38	0.8718	0.8810	0.0250	0.12395E-01
	0.5549	0.5260	0.0160	0.52080E-01
	0.1477	0.1480	0.0050	0.17536
474.60	0.8721	0.8920	0.0250	0.12395E-01
	0.5555	0.5640	0.0180	0.52080E-01
	0.1482	0.1420	0.0040	0.17536
474.82	0.8723	0.8620	0.0250	0.12395E-01
	0.5562	0.5710	0.0180	0.52080E-01
	0.1488	0.1490	0.0050	0.17536
475.04	0.8726	0.8920	0.0260	0.12395E-01
	0.5568	0.5750	0.0180	0.52080E-01
	0.1494	0.1600	0.0050	0.17536
475.26	0.8728	0.8470	0.0240	0.12395E-01
	0.5576	0.5270	0.0160	0.52080E-01
	0.1501	0.1490	0.0040	0.17536
475.48	0.8732	0.8970	0.0250	0.12395E-01
	0.5585	0.5890	0.0180	0.52080E-01
	0.1509	0.1470	0.0040	0.17536
475.70	0.8735	0.8780	0.0250	0.12395E-01
	0.5594	0.5410	0.0170	0.52080E-01
	0.1517	0.1580	0.0050	0.17536
475.92	0.8739	0.8660	0.0250	0.12395E-01
	0.5605	0.5720	0.0180	0.52080E-01
	0.1527	0.1640	0.0050	0.17536
476.14	0.8744	0.8700	0.0250	0.12395E-01
	0.5617	0.5720	0.0180	0.52080E-01
	0.1539	0.1570	0.0050	0.17536
476.36	0.8749	0.8620	0.0240	0.12395E-01
	0.5632	0.5570	0.0170	0.52080E-01
	0.1552	0.1620	0.0050	0.17536
476.58	0.8756	0.8350	0.0240	0.12395E-01
	0.5650	0.5820	0.0180	0.52080E-01
	0.1569	0.1550	0.0050	0.17536
476.80	0.8762	0.8390	0.0240	0.12395E-01
	0.5668	0.5840	0.0180	0.52080E-01
	0.1586	0.1590	0.0050	0.17536

477.03	0.8763	0.8640	0.0250	0.12395E-01
	0.5671	0.5580	0.0180	0.52080E-01
	0.1591	0.1550	0.0050	0.17536
477.25	0.8730	0.8240	0.0240	0.12395E-01
	0.5593	0.5380	0.0170	0.52080E-01
	0.1537	0.1470	0.0050	0.17536
477.47	0.8583	0.8760	0.0260	0.12395E-01
	0.5266	0.5220	0.0170	0.52080E-01
	0.1334	0.1300	0.0040	0.17536
477.69	0.8190	0.8310	0.0250	0.12395E-01
	0.4490	0.4440	0.0150	0.52080E-01
	0.0947	0.0990	0.0040	0.17536
477.91	0.7471	0.7460	0.0230	0.12395E-01
	0.3278	0.3460	0.0130	0.52080E-01
	0.0496	0.0470	0.0030	0.17536
478.13	0.6596	0.6560	0.0210	0.12395E-01
	0.2046	0.2180	0.0100	0.52080E-01
	0.0182	0.0150	0.0030	0.17536
478.36	0.5986	0.6220	0.0200	0.12395E-01
	0.1304	0.1190	0.0070	0.52080E-01
	0.0051	0.0040	0.0030	0.17536
478.58	0.5995	0.6040	0.0190	0.12395E-01
	0.1303	0.1170	0.0070	0.52080E-01
	0.0044	0.0070	0.0030	0.17536
478.80	0.6591	0.6600	0.0210	0.12395E-01
	0.1995	0.2010	0.0090	0.52080E-01
	0.0143	0.0170	0.0030	0.17536
479.02	0.7399	0.7500	0.0220	0.12395E-01
	0.3090	0.2980	0.0110	0.52080E-01
	0.0372	0.0410	0.0030	0.17536
479.25	0.8047	0.8410	0.0240	0.12395E-01
	0.4135	0.3950	0.0130	0.52080E-01
	0.0694	0.0720	0.0030	0.17536
479.47	0.8407	0.8580	0.0250	0.12395E-01
	0.4819	0.4730	0.0150	0.52080E-01
	0.0984	0.0970	0.0030	0.17536
479.69	0.8559	0.8350	0.0240	0.12395E-01
	0.5147	0.5620	0.0180	0.52080E-01
	0.1164	0.1150	0.0040	0.17536
479.91	0.8619	0.8600	0.0250	0.12395E-01
	0.5280	0.5400	0.0170	0.52080E-01
	0.1252	0.1210	0.0040	0.17536
480.14	0.8638	0.8430	0.0240	0.12395E-01
	0.5337	0.5230	0.0160	0.52080E-01
	0.1295	0.1320	0.0040	0.17536
480.36	0.8650	0.8240	0.0240	0.12395E-01
	0.5369	0.5320	0.0160	0.52080E-01
	0.1321	0.1330	0.0040	0.17536
480.59	0.8659	0.8390	0.0240	0.12395E-01
	0.5391	0.5010	0.0160	0.52080E-01
	0.1340	0.1420	0.0040	0.17536
480.81	0.8665	0.8850	0.0260	0.12395E-01
	0.5409	0.5410	0.0170	0.52080E-01
	0.1355	0.1360	0.0040	0.17536
481.03	0.8671	0.8670	0.0250	0.12395E-01
	0.5423	0.5390	0.0170	0.52080E-01
	0.1367	0.1380	0.0040	0.17536
481.26	0.8676	0.8670	0.0250	0.12395E-01
	0.5435	0.5770	0.0180	0.52080E-01
	0.1377	0.1390	0.0040	0.17536
481.48	0.8680	0.8590	0.0240	0.12395E-01
	0.5446	0.5200	0.0160	0.52080E-01
	0.1386	0.1390	0.0040	0.17536
481.71	0.8683	0.8840	0.0260	0.12395E-01
	0.5455	0.5410	0.0170	0.52080E-01
	0.1394	0.1410	0.0040	0.17536
481.93	0.8686	0.8570	0.0240	0.12395E-01
	0.5463	0.5560	0.0170	0.52080E-01
	0.1401	0.1510	0.0050	0.17536
482.16	0.8689	0.8900	0.0250	0.12395E-01
	0.5471	0.5290	0.0160	0.52080E-01
	0.1407	0.1450	0.0040	0.17536
482.38	0.8691	0.8530	0.0240	0.12395E-01
	0.5477	0.5500	0.0170	0.52080E-01
	0.1413	0.1330	0.0040	0.17536
482.61	0.8694	0.9090	0.0260	0.12395E-01
	0.5483	0.5470	0.0170	0.52080E-01
	0.1418	0.1420	0.0040	0.17536
482.83	0.8696	0.8340	0.0240	0.12395E-01
	0.5489	0.5280	0.0160	0.52080E-01
	0.1423	0.1480	0.0050	0.17536
483.06	0.8698	0.8610	0.0250	0.12395E-01
	0.5494	0.5420	0.0170	0.52080E-01
	0.1428	0.1370	0.0040	0.17536
483.28	0.8700	0.8350	0.0240	0.12395E-01
	0.5499	0.5680	0.0170	0.52080E-01
	0.1432	0.1410	0.0040	0.17536
483.51	0.8701	0.8980	0.0260	0.12395E-01
	0.5504	0.5670	0.0170	0.52080E-01
	0.1436	0.1410	0.0040	0.17536

483.73	0.8703	0.9030	0.0260	0.12395E-01
	0.5508	0.5430	0.0170	0.52080E-01
	0.1440	0.1420	0.0040	0.17536
483.96	0.8704	0.8470	0.0240	0.12395E-01
	0.5510	0.5650	0.0170	0.52080E-01
	0.1442	0.1460	0.0040	0.17536
484.19	0.8702	0.8760	0.0250	0.12395E-01
	0.5506	0.5220	0.0160	0.52080E-01
	0.1439	0.1430	0.0040	0.17536
484.41	0.8695	0.8900	0.0260	0.12395E-01
	0.5486	0.5320	0.0170	0.52080E-01
	0.1421	0.1410	0.0040	0.17536
484.64	0.8675	0.8530	0.0240	0.12395E-01
	0.5435	0.5120	0.0160	0.52080E-01
	0.1378	0.1400	0.0040	0.17536
484.86	0.8643	0.8740	0.0250	0.12395E-01
	0.5352	0.5490	0.0170	0.52080E-01
	0.1310	0.1350	0.0040	0.17536
485.09	0.8611	0.8800	0.0250	0.12395E-01
	0.5269	0.5180	0.0160	0.52080E-01
	0.1242	0.1240	0.0040	0.17536
485.32	0.8599	0.9020	0.0260	0.12395E-01
	0.5239	0.5260	0.0160	0.52080E-01
	0.1218	0.1150	0.0040	0.17536
485.55	0.8618	0.8930	0.0260	0.12395E-01
	0.5285	0.5030	0.0160	0.52080E-01
	0.1255	0.1290	0.0040	0.17536
485.77	0.8653	0.8440	0.0240	0.12395E-01
	0.5378	0.5480	0.0170	0.52080E-01
	0.1332	0.1390	0.0040	0.17536
486.00	0.8686	0.8500	0.0240	0.12395E-01
	0.5465	0.5310	0.0160	0.52080E-01
	0.1404	0.1360	0.0040	0.17536
486.23	0.8707	0.8330	0.0240	0.12395E-01
	0.5518	0.5810	0.0180	0.52080E-01
	0.1449	0.1430	0.0040	0.17536
486.46	0.8716	0.8710	0.0250	0.12395E-01
	0.5542	0.5480	0.0170	0.52080E-01
	0.1470	0.1510	0.0050	0.17536
486.68	0.8719	0.8860	0.0250	0.12395E-01
	0.5551	0.5380	0.0160	0.52080E-01
	0.1478	0.1500	0.0050	0.17536
486.91	0.8721	0.8880	0.0250	0.12395E-01
	0.5555	0.5570	0.0170	0.52080E-01
	0.1482	0.1590	0.0050	0.17536
487.14	0.8722	0.8700	0.0250	0.12395E-01
	0.5558	0.5600	0.0170	0.52080E-01
	0.1484	0.1480	0.0040	0.17536
487.37	0.8721	0.8330	0.0240	0.12395E-01
	0.5557	0.5700	0.0180	0.52080E-01
	0.1484	0.1510	0.0050	0.17536
487.60	0.8716	0.9010	0.0260	0.12395E-01
	0.5544	0.5420	0.0170	0.52080E-01
	0.1473	0.1530	0.0050	0.17536
487.83	0.8695	0.8790	0.0250	0.12395E-01
	0.5489	0.5470	0.0170	0.52080E-01
	0.1428	0.1430	0.0040	0.17536
488.05	0.8630	0.8600	0.0240	0.12395E-01
	0.5326	0.5350	0.0170	0.52080E-01
	0.1306	0.1300	0.0040	0.17536
488.28	0.8491	0.8560	0.0250	0.12395E-01
	0.4990	0.5180	0.0160	0.52080E-01
	0.1078	0.1120	0.0040	0.17536
488.51	0.8288	0.8540	0.0250	0.12395E-01
	0.4518	0.4820	0.0160	0.52080E-01
	0.0793	0.0780	0.0030	0.17536
488.74	0.8109	0.8180	0.0240	0.12395E-01
	0.4114	0.3770	0.0130	0.52080E-01
	0.0572	0.0570	0.0030	0.17536
488.97	0.8071	0.8010	0.0230	0.12395E-01
	0.4029	0.3920	0.0140	0.52080E-01
	0.0528	0.0520	0.0030	0.17536
489.20	0.8201	0.8510	0.0250	0.12395E-01
	0.4321	0.4280	0.0140	0.52080E-01
	0.0683	0.0680	0.0030	0.17536
489.43	0.8411	0.8440	0.0240	0.12395E-01
	0.4802	0.4830	0.0160	0.52080E-01
	0.0962	0.0950	0.0030	0.17536
489.66	0.8586	0.8620	0.0250	0.12395E-01
	0.5219	0.5240	0.0170	0.52080E-01
	0.1233	0.1300	0.0040	0.17536
489.89	0.8683	0.8690	0.0250	0.12395E-01
	0.5459	0.5880	0.0180	0.52080E-01
	0.1408	0.1410	0.0040	0.17536

490.12	0.8721	0.8960	0.0250	0.12395E-01
	0.5558	0.5260	0.0160	0.52080E-01
	0.1487	0.1550	0.0050	0.17536
490.35	0.8734	0.8860	0.0260	0.12395E-01
	0.5590	0.5480	0.0170	0.52080E-01
	0.1514	0.1490	0.0050	0.17536
490.58	0.8737	0.8460	0.0240	0.12395E-01
	0.5600	0.5930	0.0180	0.52080E-01
	0.1523	0.1460	0.0040	0.17536
490.81	0.8739	0.8600	0.0240	0.12395E-01
	0.5605	0.5400	0.0170	0.52080E-01
	0.1527	0.1520	0.0050	0.17536
491.04	0.8740	0.8520	0.0240	0.12395E-01
	0.5608	0.5570	0.0170	0.52080E-01
	0.1530	0.1570	0.0050	0.17536
491.28	0.8742	0.8950	0.0260	0.12395E-01
	0.5612	0.5430	0.0170	0.52080E-01
	0.1533	0.1600	0.0050	0.17536
491.51	0.8743	0.9060	0.0250	0.12395E-01
	0.5615	0.5880	0.0180	0.52080E-01
	0.1536	0.1530	0.0050	0.17536
491.74	0.8744	0.9070	0.0260	0.12395E-01
	0.5618	0.5700	0.0180	0.52080E-01
	0.1539	0.1550	0.0050	0.17536
491.97	0.8745	0.8970	0.0260	0.12395E-01
	0.5621	0.5750	0.0180	0.52080E-01
	0.1542	0.1560	0.0050	0.17536
492.20	0.8746	0.8650	0.0250	0.12395E-01
	0.5624	0.5620	0.0170	0.52080E-01
	0.1545	0.1530	0.0050	0.17536

492.43	0.8747	0.8360	0.0240	0.12395E-01
	0.5627	0.5780	0.0180	0.52080E-01
	0.1547	0.1500	0.0050	0.17536
492.67	0.8748	0.8930	0.0250	0.12395E-01
	0.5630	0.5710	0.0180	0.52080E-01
	0.1550	0.1490	0.0040	0.17536
492.90	0.8750	0.8670	0.0250	0.12395E-01
	0.5633	0.5800	0.0180	0.52080E-01
	0.1553	0.1580	0.0050	0.17536
493.13	0.8751	0.8640	0.0240	0.12395E-01
	0.5636	0.5680	0.0180	0.52080E-01
	0.1556	0.1540	0.0050	0.17536
493.36	0.8752	0.8890	0.0250	0.12395E-01
	0.5639	0.5400	0.0160	0.52080E-01
	0.1558	0.1530	0.0050	0.17536
493.60	0.8753	0.8830	0.0250	0.12395E-01
	0.5642	0.5490	0.0170	0.52080E-01
	0.1561	0.1580	0.0050	0.17536
493.83	0.8754	0.9020	0.0260	0.12395E-01
	0.5645	0.5680	0.0170	0.52080E-01
	0.1564	0.1540	0.0050	0.17536
494.06	0.8755	0.9120	0.0260	0.12395E-01
	0.5648	0.6080	0.0190	0.52080E-01
	0.1567	0.1490	0.0040	0.17536
494.30	0.8756	0.8880	0.0250	0.12395E-01
	0.5651	0.5540	0.0170	0.52080E-01
	0.1570	0.1590	0.0050	0.17536
494.53	0.8757	0.8920	0.0250	0.12395E-01
	0.5654	0.5660	0.0170	0.52080E-01
	0.1573	0.1580	0.0050	0.17536
494.76	0.8759	0.8650	0.0250	0.12395E-01
	0.5657	0.5640	0.0170	0.52080E-01
	0.1576	0.1480	0.0040	0.17536
495.00	0.8760	0.8800	0.0250	0.12395E-01
	0.5660	0.5560	0.0170	0.52080E-01
	0.1579	0.1600	0.0050	0.17536
495.23	0.8761	0.8570	0.0250	0.12395E-01
	0.5663	0.5870	0.0180	0.52080E-01
	0.1582	0.1560	0.0050	0.17536

C. Plots, generated by local utilities

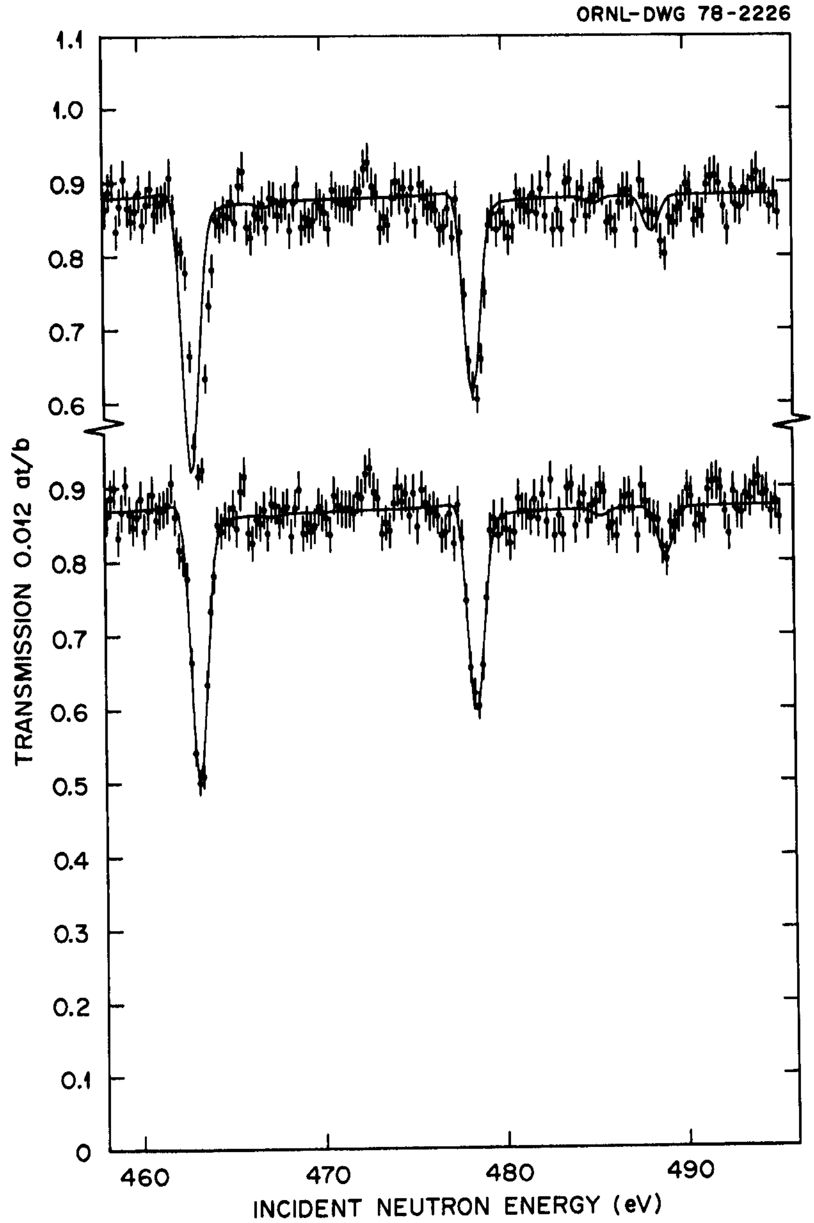

Fig. 1. Transmission of a 0.012 at/b sample of ^{238}U. This figure is generated in connection of the sample problem discussed in the appendix. The upper curve represents the transmission curve computed with the initial guesses. The lower curve is computed with the parameters obtained from the simultaneous fit to three sample thicknesses. The data fitted were obtained from reference 1.

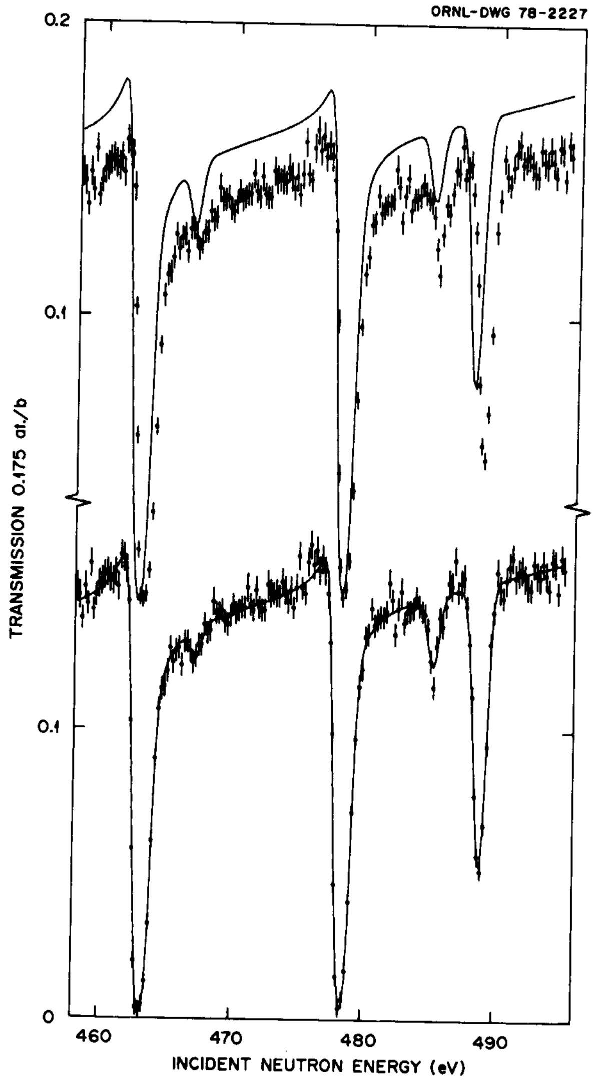

Fig. 2. Transmission of a 0.052 at/b sample of ^{238}U. This figure is generated in connection of the sample problem discussed in the appendix. The upper curve represents the transmission curve computed with the initial guesses. The lower curve is computed with the parameters obtained from the simultaneous fit to three sample thicknesses. The data fitted were obtained from reference 1.

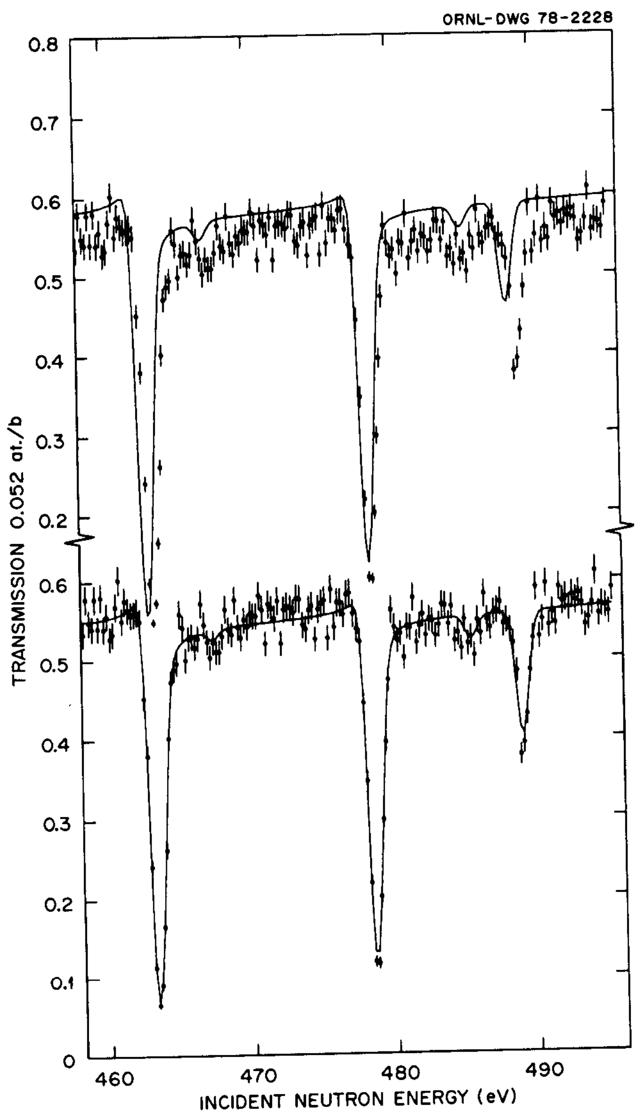

Fig. 3. Transmission of a 0.175 at/b sample of ^{238}U. This figure is generated in connection of the sample problem discussed in the appendix. The upper curve represents the transmission curve computed with the initial guesses. The lower curve is computed with the parameters obtained from the simultaneous fit to three sample thicknesses. The data fitted were obtained from reference 1.

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