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EXPANDED FORTRAN IV PROGRAM FOR ELASTIC SCATTERING ANALYSES

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16. Abstract

SCATLE is a FORTRAN IV nuclear optical model program which is a revision and extension of program SCAT4 (published by a UCLA group in 1962). This report describes program SCATLE and serves as a user's guide. SCATLE calculates elastic scattering cross sections, polarizations, phase shifts, and triple scattering values. An automatic search varies the nuclear parameters to improve agreement between calculated and experimental cross sections and polarizations. Several nuclear potential forms are available.

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SUMMARY

SCATLE is a FORTRAN IV program which uses the nuclear optical model to calculate elastic scattering cross sections and polarizations. The version presented herein was written for an IBM 7094 II/7044 direct couple system at Lewis. This report describes program SCATLE and serves as a user's guide. SCATLE contains several options for calculating the central nuclear potential. Some options allow the real central, imaginary central, and spin-orbit potentials to have independent parameters. The parameters of the nuclear potential can be varied by a search option to improve the agreement between calculated and experimental values of cross sections and polarizations. Any one of the several chi-square functions calculated by SCATLE can be minimized by the search option. Plots of cross sections and polarizations as a function of scattering angle are furnished as part of the program output. Calculations of nuclear phase shifts and triple scattering values are available. The input description includes a listing of seven example input cases. Selected output from these examples is presented.

INTRODUCTION

Program SCATLE is the result of extensive revisions and additions made to the program SCAT4 (ref. 1).

Both SCAT4 and SCATLE solve the Schrodinger wave equation, using a given scattering energy and nuclear interaction potential. The solutions to the wave equation are used to calculate scattering cross sections and polarizations as a function of scattering angle. These calculated values are compared to experimentally measured values. A chi-square function is evaluated to furnish a numerical basis for the comparison. The calculated values depend on the chosen form of the nuclear interaction potential, which is a function of several parameters. SCATLE contains an automatic search option which minimizes chi-square by varying these parameters. SCATLE also provides an increased number of options for choosing the nuclear interaction potential.

In SCAT4, a nuclear potential is defined by specifying real and imaginary strength parameters (which represent the depths of the attractive potential wells) and real shape parameters (which define the nuclear size and surface diffuseness). When a Woods-Saxon form is used for the central potential, both the real and imaginary terms of the central nuclear potential are functions of the same two shape parameters. When a Gaussian form is chosen for the imaginary potential well, it is a function of two additional shape parameters. The nuclear potential can also have a spin-orbit term which is multiplied by real and imaginary strength parameters representing the depths of the spin-orbit potential wells. The shape parameters for the spin-orbit term are those used for the real central potential. These parameters can be incremented in uniform steps to provide a grid of points in the parameter space. Program SCAT4 then calculates scattering cross sections, polarizations, and chi-squares at each grid point.

The program SCATLE is basically an extension of SCAT4. All the SCAT4 calculations are included in SCATLE, although some of them have been revised. Several new calculations have been added, and some of the old calculations have been used in new ways. For example, one section of SCATLE is a merger of the basic SCAT4 calculations with a search program (ref. 2) from Argonne National Laboratory. SCATLE is arranged so that the parameter values at each grid point are input to the search program. The parameters are changed to give better agreement (in a least-squares sense) between calculated and experimental values for cross section and polarization. This process continues until a local minimum of the chi-square function is reached.

New options are also available for calculating the central-nuclear-potential form factors. The real central potential is always of the Woods-Saxon form, but can have different parameters than the imaginary potential (the decoupled case). The imaginary term may be a derivative of Woods-Saxon form, a Gaussian plus Woods-Saxon form, or a derivative of Woods-Saxon plus Woods-Saxon form.

SCATLE also has options to calculate phase shifts and triple scattering parameters. Additional output is available in printed and plotted forms.

The primary purpose of this report is to document SCATLE. The sections of this report which describes data preparation and available options will serve as a user's guide. The SCATLE calculations, input, and output are explained in detail. Some calculations are essentially unchanged from the original SCAT4 calculations. In these cases, the appropriate references will be made to the UCLA report (ref. 1).

MATHEMATICAL DESCRIPTION

The program SCATLE contains several calculations and options which are not available in SCAT4. These are described in detail in the following sections. SCATLE also contains calculations which are essentially the same as the corresponding ones in SCAT4. Because those calculations are presented in reference 1, they are not discussed in this report.

Nuclear Potential Options

The Schrodinger equation solved by SCATLE can be written as

$$\left[\frac{-\hbar^2}{2\mu}\nabla^2 + V_1(r) + V_2(r)\bar{S}\cdot\bar{L}\right]\psi = E\psi \tag{1}$$

using the symbols of reference 1. (All symbols are defined in appendix A.) The interactions represented in equation (1) by $V_1(r)$ and $V_2(r)$ can be rewritten as

$$V_1(r) + V_2(r)\bar{S}\cdot\bar{L} = V_{CN} + V_{coul} + V_{SO} + V_{coul,SO} \tag{2}$$

where V_{CN} is the nuclear central potential, V_{coul} is the coulomb potential, V_{SO} is the nuclear spin-orbit potential, and $V_{coul,SO}$ is the coulomb spin-orbit potential.

Although equation (1) is expressed in terms of the variable r, it is convenient to represent the potentials in terms of the dimensionless variable ρ where

$$\rho = kr \tag{3}$$

The wave number k is given by

$$k = \sqrt{\frac{2\mu E}{\hbar^2}} = 0.218739\sqrt{\mu E} \quad \mathrm{fm}^{-1} \tag{4}$$

The constant factor in equation (4) is slightly different from the constant factor in equation (8) of reference 1. A similar difference occurs in the definition of the coulomb parameter η, where

$$\eta = \frac{\mu(ZZ')e^2}{\hbar^2 k} = 0.157481\ ZZ'\sqrt{\frac{m_i}{E_{LAB}}} \tag{5}$$

corresponds to equation (43) of reference 1. The constants used in equations (4) and (5) were computed using values of the fundamental constants $\hbar$ and e from reference 3. The reduced mass μ is given by

$$\mu = \frac{m_i \cdot m_b}{m_i + m_b} \tag{6}$$

Options for computing spin-orbit potential. - The standard form for the spin-orbit term in equation (2) uses the strength parameters VS and WS, and the shape parameters AS and RS. The spin-orbit scattering potential V_{SO} is then given by

$$V_{SO} = \frac{2}{M_\pi^2 c^2}\left\{\frac{k^2}{\rho}\frac{d}{d\rho}\left[\frac{-VS - i \cdot WS}{1 + \exp\left(\frac{\rho - \rho_S}{k \cdot a_S}\right)}\right]\right\}\bar{S} \cdot \bar{L} \qquad KL(1) \neq 2 \tag{7}$$

where

$$\rho_S = k \cdot RS \cdot (m_b)^{1/3} \tag{8}$$

In equation (8), m_b represents the mass number of the target nucleus. When the square-well form is chosen for the real central potential, VS and WS must be set to zero (KL(1) = 2).

There are also several special options available for computing V_{SO}. These are described on pages 20 through 24 of reference 1 as form A and form B. They are obtained by setting KL(9) $\neq$ 0 or KL(10) $\neq$ 0. SCATLE provides an option for introducing a space-exchange form for the real spin-orbit potential. In that option, VS is the strength of the real spin-orbit term when the angular momentum number l is an even number, and VSODD is the strength when l is odd (KX(6) = 1).

Options for computing central nuclear potential. - SCATLE contains several options for computing the central nuclear potential which is represented as V_{CN} in equation (2); V_{CN} can be expressed as a function of ρ by

$$V_{CN}(\rho) = V_{CN,\mathcal{R}} + i \cdot V_{CN,\mathcal{J}} \tag{9}$$

where $V_{CN,\mathcal{R}}$ is the real part of V_{CN} and $V_{CN,\mathcal{J}}$ is the imaginary part.

There are two primary options for computing the real central potential $V_{CN,\mathcal{R}}$ in

SCATLE. Both options use a Woods-Saxon form with strength parameter VO. The first option uses the shape parameters AS and RS, which are identical to those in the spin-orbit term (coupled spin-orbit case). Then $V_{CN,\mathcal{R}}$ is given by

$$V_{CN,\mathcal{R}} = -VO \frac{1}{1 + \exp\left(\dfrac{\rho - \rho_S}{k \cdot a_S}\right)} \qquad KX(7) = 1 \tag{10}$$

This option is also available in SCAT4. The second option uses the shape parameters AO and RO. These are independent of the shape parameters in the spin-orbit term (decoupled spin-orbit case). Then $V_{CN,\mathcal{R}}$ is given by

$$V_{CN,\mathcal{R}} = -VO \frac{1}{1 + \exp\left(\dfrac{\rho - \rho_O}{k \cdot a_O}\right)} \qquad KX(7) = 2 \tag{11}$$

where

$$\rho_O = k \cdot RO \cdot (m_b)^{1/3} \tag{12}$$

SCATLE contains five primary options for computing the imaginary part of the central potential $V_{CN,\mathcal{I}}$:

(1) Standard Woods-Saxon

$$V_{CN,\mathcal{I}} = -WI \frac{1}{1 + \exp\left(\dfrac{\rho - \rho_S}{k \cdot a_S}\right)} \qquad KL(1) = 0 \tag{13}$$

(2) Gaussian absorption

$$V_{CN,\mathcal{I}} = -WI \cdot \exp\left[-\left(\frac{\rho - \rho_I}{k \cdot a_I}\right)^2\right] \qquad KL(1) = 1, \; KX(1) = 0 \tag{14}$$

where

$$\rho_I = k \cdot RI \cdot (m_b)^{1/3} \tag{15}$$

(Options (1) and (2) are also available in SCAT4.)

(3) Derivative of Woods-Saxon

$$V_{CN,\mathscr{I}} = -WI \frac{4 \cdot \exp\left(\frac{\rho - \rho_I}{k \cdot a_I}\right)}{\left[1 + \exp\left(\frac{\rho - \rho_I}{k \cdot a_I}\right)\right]^2} \qquad \begin{array}{l} KL(1) = 1, \\ KX(1) = 1 \end{array} \tag{16}$$

(4) Gaussian plus Woods-Saxon

$$V_{CN,\mathscr{I}} = -WI \cdot \exp\left[-\left(\frac{\rho - \rho_I}{k \cdot a_I}\right)^2\right] - WVI \frac{1}{1 + \exp\left(\frac{\rho - \rho_I}{0.69\, k \cdot a_I}\right)} \qquad \begin{array}{l} KL(1) = 1, \\ KX(1) = 2 \end{array} \tag{17}$$

(5) Derivative of Woods-Saxon plus Woods-Saxon

$$V_{CN,\mathscr{I}} = -WI \frac{4 \cdot \exp\left(\frac{\rho - \rho_I}{k \cdot a_I}\right)}{\left[1 + \exp\left(\frac{\rho - \rho_I}{k \cdot a_I}\right)\right]^2} - WVI \frac{1}{1 + \exp\left(\frac{\rho - \rho_I}{k \cdot a_I}\right)} \qquad \begin{array}{l} KL(1) = 1, \\ KX(1) = 3 \end{array} \tag{18}$$

There are 10 ways to combine the two primary options for $V_{CN,\mathscr{R}}$ and the five primary options for $V_{CN,\mathscr{I}}$ to calculate $V_{CN}(\rho)$ by equation (9). Table I shows how these combinations are formed and lists the parameters used for $V_{CN,\mathscr{R}}$, $V_{CN,\mathscr{I}}$, and V_{SO}.

TABLE I. - SHAPE PARAMETERS FOR REAL CENTRAL NUCLEAR, IMAGINARY CENTRAL NUCLEAR, AND SPIN-ORBIT POTENTIALS

Real central nuclear potential, $V_{CN,\mathcal{R}}$	Imaginary central nuclear potential, $V_{CN,\mathcal{I}}$	Spin-orbit potential, V_{SO}
Shape parameters		
AS, RS (eq. (10))	AS, RS (eq. (13))	AS, RS
AS, RS (eq. (10))	AI, RI (eqs. (14), (16), (17), (18))	AS, RS
AO, RO (eq. (11))	AS, RS (eq. (13))	AS, RS
AO, RO (eq. (11))	AI, RI (eqs. (14), (16), (17), (18))	AS, RS

The square well form of V_{CN} is given by

$$V_{CN,\mathcal{R}} = V_{CN,\mathcal{I}} = 1 \qquad \text{for } \rho \leq \rho_S \tag{19a}$$

and KL(1) = 2

$$V_{CN,\mathcal{R}} = V_{CN,\mathcal{I}} = 0 \qquad \text{for } \rho > \rho_S \tag{19b}$$

There are several options available which vary the shape of the Woods-Saxon form of V_{CN} by including a dip or bump at the origin, or by varying the shape of the knee or tail of the potential curve. These options are described on pages 18 through 20 of reference 1 as form A and form B. They are obtained by setting KL(7) $\neq$ 0 or KL(8) $\neq$ 0.

Grid and Search Procedures

The nuclear potential calculations depend on the following 12 parameters: VS, WS, AS, RS, VO, AO, RO, WI, WVI, AI, RI, and VSODD. Determining good values for these parameters requires three steps. The first step is to make initial guesses for the parameters. The next step is to vary the parameters in some systematic manner. The final step is to compare the results of calculations which are based on different sets of parameter values.

In SCATLE, the initial guesses are the input values of the parameters. The calculations are compared on the basis of a chi-square function associated with each set of parameter values. This chi-square function measures the deviation (in a least-squares sense) of the calculated values from the experimental values for cross section and polarization. There are several variations for calculating the chi-square function. These are described in a later section.

SCATLE provides three options for the systematic variation of the parameters. The grid option (KT(1) = 2) calculates results at several predetermined sets of parameter values. The search option (KT(1) = 4) begins from a single set of parameter values and automatically varies these parameters to give successively smaller values of chi-square. Each parameter set in the grid option can also be used as the starting point for a search (KT(1) = 3).

Each set of parameter values can be considered as defining a point in an n-dimensional parameter space. The points used in the grid option are defined as grid points. The initial grid point consists of the input values of the 12 parameters listed previously. Each parameter selected for the grid variation is then incremented for a specified number of uniform steps. The remaining grid points are then formed by taking all possible combinations of the generated parameter values. Cross sections and polarizations are calculated at each grid point. Chi-square functions are then calculated and written out at each grid point, along with the parameter values. The variable names of the grid increments and of the number of grid steps corresponding to each parameter are found in table IV. (Tables II through V are grouped at the end of the section Input requirements.)

SCATLE contains an automatic search option which utilizes the subroutines described in reference 2. For any given search, the parameters to be varied are defined as search parameters. These n search parameters can be any selected subset of the 12 parameters listed previously. Each search begins from the point in the n-dimensional parameter space which is defined by the input values of the search parameters. A specified chi-square function is then calculated at this point. The partial derivatives of the chi-square function with respect to each of the search parameters are also calculated, and they define the gradient of the function at this point. Increments for the search parameters are then calculated by using the gradient and a matrix (H-matrix) which is used as a metric in the parameter space. The search parameters are varied simultaneously and in such a way that the next iteration produces a smaller chi-square value. These calculations are repeated until a local minimum of the chi-square function is determined.

The number of iterations required to locate a minimum depends on how accurately the H-matrix at each point describes the gradient at that point. A search converges faster with a good approximation for the initial H-matrix than with a poor approximation. There are three ways to set up the initial H-matrix in SCATLE. These options are described in table III. A standard diagonal matrix can be constructed by using the elements found in column 5 of table IV. Experience has shown that these values are appropriate.

The normal search output for each iteration includes the current values of the search parameters, the partial derivatives of chi-square with respect to each of the search parameters, and the value of the chi-square function to be minimized. At the end of a search, the final H-matrix is written out and the final values of the search parameters are used to generate the output for a SCATLE single case.

When the grid and search options are combined, each grid point becomes the starting point for a search. The initial H-matrix for the first grid point is specified according to the options described in table III. The initial H-matrix for any subsequent grid point is set equal to the final H-matrix from the previous grid point. This procedure generally leads to a more rapid convergence than occurs when a standard or arbitrary initial H-matrix is used.

Additional Calculations

The program SCATLE computes and outputs several quantities which were not computed in SCAT4. This section presents a brief description of the mathematical expressions for these calculations.

Double and triple scattering calculations. - The quantities $\delta^+_{l,\mathcal{R}}$, $\delta^+_{l,\mathcal{I}}$, $\delta^-_{l,\mathcal{R}}$, $\delta^-_{l,\mathcal{I}}$, η^+_l, and η^-_l are computed and written out in subroutine OUTPT4. These quantities are also plotted in the subroutine PTETDL. The absorption coefficients η^+_l and η^-_l are expressed in terms of the imaginary parts of the complex phase shifts δ^+_l and δ^-_l by

$$\eta^+_l = \exp\left(-2\delta^+_{l,\mathcal{I}}\right) \tag{20a}$$

$$\eta^-_l = \exp\left(-2\delta^-_{l,\mathcal{I}}\right) \tag{20b}$$

The phase shifts are related to the complex coefficients C^+_l and C^-_l by the following equation (see eq. (57) of ref. 1):

$$C^{\pm}_{l,\mathcal{R}} + iC^{\pm}_{l,\mathcal{I}} = \frac{1}{2i}\left\{\exp\left[2i\left(\delta^{\pm}_{l,\mathcal{R}} + i\delta^{\pm}_{l,\mathcal{I}}\right)\right] - 1\right\} \tag{21}$$

C^+_l and C^-_l are related to the scattering amplitudes $A(\theta)$ and $B(\theta)$. The spin-independent amplitude $A(\theta)$ is given by

$$A(\theta) = f_c(\theta) + \frac{1}{k}\sum_{l=0}^{\infty} \exp(2i\sigma_l)\left[(l+1)C^+_l + lC^-_l\right]P_l(\cos\theta) \tag{22a}$$

The spin-dependent scattering amplitude is

$$B(\theta) = \frac{-i}{k} \sum_{l=0}^{\infty} \exp(2i\sigma_l)\left(C_l^+ - C_l^-\right)P_l^1(\cos\theta) \tag{22b}$$

Equation (22) appears as equation (60) in reference 1. The coulomb scattering amplitude $f_c(\theta)$ appearing in equation (22a) is given by (see eq. (47) of ref. 1)

$$f_c(\theta) = \frac{-\eta}{2k \sin^2\left(\frac{\theta}{2}\right)} \exp\left\{-i\eta \ln\left[\sin^2\left(\frac{\theta}{2}\right)\right] + 2i\sigma_0\right\} \tag{23}$$

The coulomb phase shift σ_l is defined by (see eq. (49) of ref. 1)

$$\sigma_l = \arg \Gamma(l + 1 - i\eta) \tag{24}$$

Calculations and output for the triple scattering parameters R, β, and -R' are provided in subroutine TRIPS. The rotation angle β is defined in terms of the scattering amplitudes, cross section, and polarization by

$$\cos\beta = \frac{|A(\theta)|^2 - |B(\theta)|^2}{\sigma(\theta)\left[1 - P^2(\theta)\right]^{1/2}} \tag{25a}$$

$$\sin\beta = \frac{A(\theta)B^*(\theta) - A^*(\theta)B(\theta)}{\sigma(\theta)\left[1 - P^2(\theta)\right]^{1/2}} \tag{25b}$$

For an unpolarized incident beam, the cross section and polarization are given in terms of the scattering amplitudes $A(\theta)$ and $B(\theta)$ as follows:

$$\sigma(\theta) = |A(\theta)|^2 + |B(\theta)|^2 \tag{26}$$

$$\overline{P}(\theta) = \frac{A^*(\theta)B(\theta) + A(\theta)B^*(\theta)}{\sigma(\theta)} \overline{n} \tag{27}$$

The rotation parameter R is defined by

$$R = \left[1 - P^2(\theta)\right]^{1/2} \cos(\beta - \theta_{LAB}) \tag{28}$$

The parameter $-R'$, often denoted in the literature by the symbol A, is given as

$$-R' = \left[1 - P^2(\theta)\right]^{1/2} \sin(\beta - \theta_{LAB}) \tag{29}$$

The output from subroutine TRIPS includes a table of θ, tan β, β, θ_{LAB}, R, and $-R'$ values along with a plot of R and $-R'$ as a function of θ.

The polarization $\overline{P}(\theta)$ is usually obtained from a double scattering experiment. When the incident beam is unpolarized, the polarization $\overline{P}(\theta)$ of the scattered beam is along the direction of the unit vector $\overline{n}_1$ of equation (30) and figure 1.

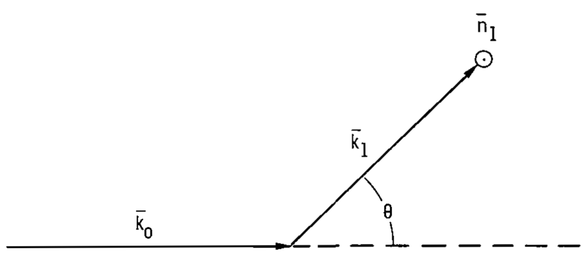


Figure 1. - Polarization direction in double scattering.

$$\overline{n}_1 = \frac{\overline{k}_0 \times \overline{k}_1}{|\overline{k}_0 \times \overline{k}_1|} \tag{30}$$

Consider a triple scattering experiment with a 100-percent-polarized beam of spin 1/2 particles. Let the polarization vector be normal to the incident beam in the plane of scattering, as shown in figure 2.

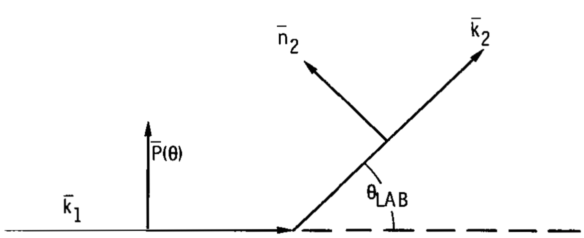


Figure 2. - Polarization directions in triple scattering.

The rotation of polarization R can be defined as

$$R = \frac{2}{\hbar} \langle \overline{S} \rangle \cdot \overline{n}_2 \tag{31}$$

where the direction of $\overline{n}_2$ is given by

$$\overline{n}_2 = \frac{(\overline{k}_1 \times \overline{k}_2) \times \overline{k}_2}{\left| (\overline{k}_1 \times \overline{k}_2) \times \overline{k}_2 \right|} \tag{32}$$

The direction of n_2 defines the sign convention used to define R, β, and -R'.

Chi-square calculations. - The various chi-square functions computed in subroutine CHISQ are presented in this section. The function minimized by the search subroutines can be selected from any of the chi-square functions given by equations (33) and (34) or by equations (37) through (42). (See explanation of KX(3) in table III.) The search subroutines will also minimize the sum $\chi_\sigma^2 + \chi_P^2$ over any one of the restricted angular ranges. (See explanation of KX(12) in table III.)

The value of the chi-square deviation for the polarization is computed just as in SCAT4 (eq. (139) of ref. 1)

$$\chi_P^2 = \sum_\theta \chi_P^2(\theta) = \sum_\theta \left[\frac{P^{th}(\theta) - P^{ex}(\theta)}{\Delta P^{ex}(\theta)} \right]^2 \tag{33}$$

The total chi-square is (eq. (137) of ref. 1)

$$\chi_T^2 = \chi_\sigma^2 + \chi_P^2 \tag{34}$$

where χ_σ^2 is computed from the cross-section calculations and data.

The absolute normalization of the experimental cross-section data is usually uncertain. When fitting calculated cross sections, the experimental data can be normalized by a constant N, as described in reference 4. The equation for χ_σ^2 then becomes

$$\chi_\sigma^2 = \sum_\theta \chi_\sigma^2(\theta) = \sum_\theta \left[\frac{\sigma^{th}(\theta) - N \cdot \sigma^{ex}(\theta)}{N \cdot \Delta\sigma^{ex}(\theta)} \right]^2 \tag{35}$$

In SCATLE, there are three options for choosing the value of N. When KX(5) = 0, N is set equal to 1 so that χ^2_σ is computed just as in SCAT4. In this case, $\sigma^{ex}(\theta)$ and $\Delta\sigma^{ex}(\theta)$ are not normalized in the χ^2_σ calculation. When KX(5) = 1, N is set equal to the input variable XNORM. Finally, when KX(5) = 2, N is set equal to N_E which is given by

$$N_E = \frac{\displaystyle\sum_\theta \left[\frac{\sigma^{th}(\theta)}{\Delta\sigma^{ex}(\theta)}\right]^2}{\displaystyle\sum_\theta \frac{\sigma^{th}(\theta)\sigma^{ex}(\theta)}{\left[\Delta\sigma^{ex}(\theta)\right]^2}} \tag{36}$$

In this case, N is recomputed for each set of $\sigma^{th}(\theta)$ values and is such that the corresponding χ^2_σ value is as small as possible. The value of N_E is always printed out along with values of the various chi-square functions.

The coulomb cross section $\sigma^{th}_{coul}(\theta)$ can be used in place of $\Delta\sigma^{ex}(\theta)$ as the weight factor in the χ^2_σ calculation. This option requires KX(3) = 1. Then χ^2_σ is given by

$$\chi^2_\sigma = \sum_\theta \left[\frac{\sigma^{th}(\theta) - \sigma^{ex}(\theta)}{\sigma^{th}_{coul}(\theta)}\right]^2 \tag{37}$$

In addition, it is possible to compute a chi-square function over restricted angular ranges. This is useful when trying to fit a particular portion of an experimental curve. The ranges of angles are controlled by input controls KT(4) through KT(14) which correspond to the indices NF, NR, N1, IN1, N2, IN2, N3, IN3, N4, IN4 as used in equations (38) through (42).

The computations using NF and NR are

$$\chi^2_{\sigma,F} = \sum_{j=1}^{NF} \chi^2_\sigma(\theta_j) \tag{38a}$$

$$\chi^2_{P,F} = \sum_{j=1}^{NF} \chi^2_P(\theta_j) \tag{38b}$$

$$\chi^2_{\sigma,M} = \sum_{j=NF+1}^{NR} \chi^2_{\sigma}(\theta_j) \tag{39a}$$

$$\chi^2_{P,M} = \sum_{j=NF+1}^{NR} \chi^2_{P}(\theta_j) \tag{39b}$$

$$\chi^2_{\sigma,R} = \sum_{j=NR+1}^{JMAX} \chi^2_{\sigma}(\theta_j) \tag{40a}$$

$$\chi^2_{P,R} = \sum_{j=NR+1}^{JMAX} \chi^2_{P}(\theta_j) \tag{40b}$$

where J_{max} is the index of the last angle of the set.

If we let K equal 1, 2, 3, and 4, the values of chi-square are computed for NK and INK as follows:

$$\chi^2_{\sigma,K} = \sum_{j=NK}^{NK+INK} \chi^2_{\sigma}(\theta_j) \tag{41a}$$

$$\chi^2_{P,K} = \sum_{j=NK}^{NK+INK} \chi^2_{P}(\theta_j) \tag{41b}$$

For K equal to 3 and 4, the following chi-squares can be computed:

$$\chi^2_{\sigma,34} = \chi^2_{\sigma,3} + \chi^2_{\sigma,4} \tag{42a}$$

$$\chi^2_{P,34} = \chi^2_{P,3} + \chi^2_{P,4} \tag{42b}$$

Adjusted chi-square values are also calculated to furnish additional output. These adjusted values are the chi-square functions just described divided by the factor JMAX - NP, where JMAX is the number of experimental data points and NP is an input variable.

Effective potential calculations. - The effective potential for a given l-value is computed and plotted in subroutine PTFFRI. The effective potential V_{EFF} is given by

$$V_{EFF} = -\frac{V_{CN,\mathcal{R}}}{E} + \frac{V_{coul}}{E} + \frac{l(l+1)}{\rho^2} \tag{43}$$

The value of l in equation (43) is equal to the input parameter KX(9). The effective potential V_{EFF} is plotted as a function of ρ for those values of ρ which lie in the range

$$(\rho_S - k \cdot l_{lim}) < \rho < (\rho_S + k \cdot l_{lim}) \tag{44}$$

This plot then presents the detailed behavior of the effective potential near the nuclear surface. The value of l_{lim} in equation (44) is set internally to be an integer in the interval [0, 8], which produces a suitable plotting range.

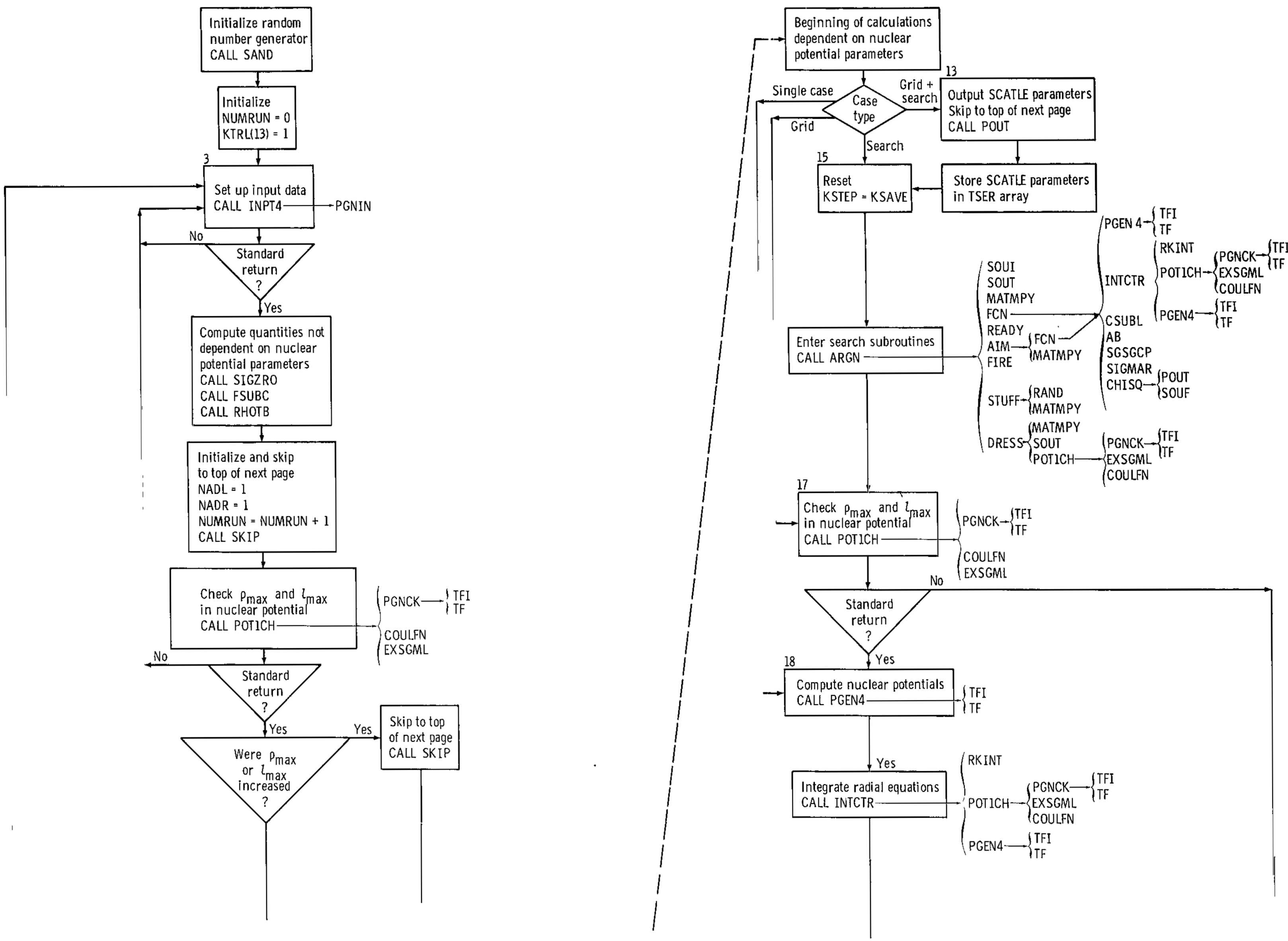
PROGRAM DESCRIPTION

General Program Organization

Each subroutine of the FORTRAN program SCATLE is assigned a subroutine number, and each card is assigned a card number. The card numbers are punched in columns 73 through 80 and appear in the FORTRAN listing at the end of this main section. The first two digits of each card number are the corresponding subroutine number. In this section of the report, the subroutine numbers are given in parentheses following each subroutine name.

Subroutines essentially unchanged from SCAT4. - The calculations in the following subroutines are essentially unchanged from SCAT4, although the common statements have been completely revised and the subroutines have been rewritten in the FORTRAN IV language:

SIGZRO (04)	EXSGML (09)
FSUBC (05)	CSUBL (16)
RHOTB (06)	SGSGCP (18)
SKIP (07)	SIGMAR (19)



Initialize random number generator CALL SAND
Initialize NUMRUN = 0 KTRL(13) = 1
3
Set up input data CALL INPT4
PGNIN
No
Standard return ?
Yes
Compute quantities not dependent on nuclear potential parameters CALL SIGZRO CALL FSUBC CALL RHOTB
Initialize and skip to top of next page NADL = 1 NADR = 1 NUMRUN = NUMRUN + 1 CALL SKIP
Check ρmax and lmax in nuclear potential CALL POT1CH
PGNCK
TFI
TF
COULFN
EXSGML
No
Standard return ?
Yes
Were ρmax or lmax increased ?
Yes
Skip to top of next page CALL SKIP
Beginning of calculations dependent on nuclear potential parameters
Single case
Grid
Case type
Grid + search
Search
13
Output SCATLE parameters Skip to top of next page CALL POUT
Store SCATLE parameters in TSER array
15
Reset KSTEP = KSAVE
Enter search subroutines CALL ARGN
SOUI
SOUT
MATMPY
FCN
READY
AIM
FIRE
FCN
MATMPY
STUFF
RAND
MATMPY
DRESS
MATMPY
SOUT
POT1CH
PGNCK
TFI
TF
EXSGML
COULFN
PGEN 4
TFI
TF
INTCTR
RKINT
POT1CH
PGNCK
EXSGML
COULFN
TFI
TF
PGEN4
TFI
TF
CSUBL
AB
SGSGCP
SIGMAR
CHISQ
POUT
SOUF
17
Check ρmax and lmax in nuclear potential CALL POT1CH
PGNCK
TFI
TF
COULFN
EXSGML
No
Standard return ?
Yes
18
Compute nuclear potentials CALL PGEN4
TFI
TF
Yes
Integrate radial equations CALL INTCTR
RKINT
POT1CH
PGNCK
EXSGML
COULFN
TFI
TF
PGEN4
TFI
TF

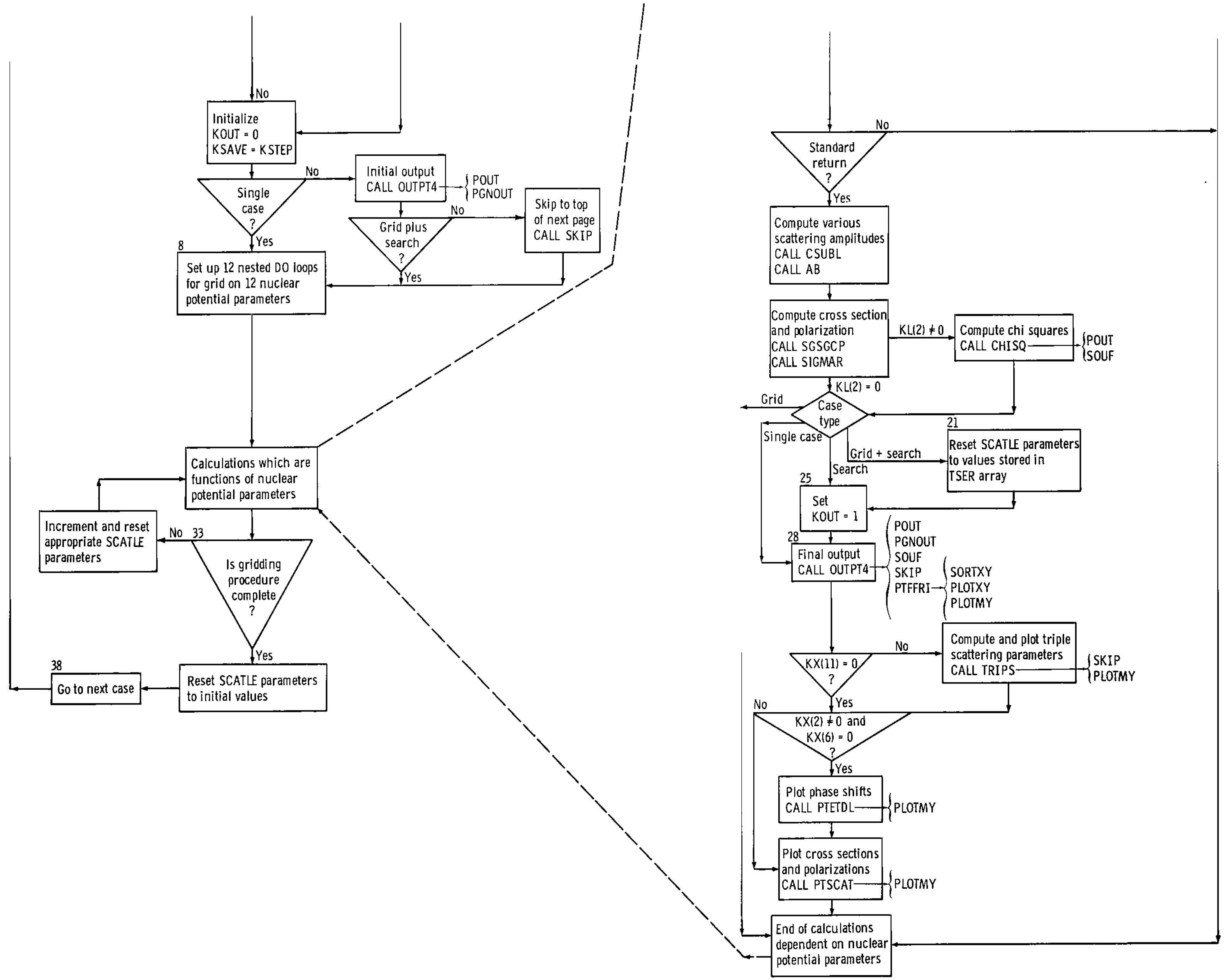


Figure 3. - Flow chart of main routine CTRL4 and overall program organization.

Subroutines modified from SCAT4. - The calculations in the following subroutines have been modified from SCAT4:

CTRL4 (01)	PGEN4 (12)
INPT4 (03)	INTCTR (14)
POT1CH (08)	RKINT (15)
COULFN (10)	AB (17)
OUTPT4 (11)	CHISQ (20)

CTRL4 (01): The main routine CTRL4 controls the flow of the program. Since the flow is different from that of SCAT4, a general flow chart is shown in figure 3.

INPT4 (03): Subroutine INPT4 controls the data input and performs several initial calculations. Standard values for the program controls and for other input variables are set automatically in INPT4. These standard values can be overwritten by means of input statements referring to NAMELIST statements. The SCATLE input is less complicated and requires fewer data cards than the corresponding SCAT4 input. A detailed description of the SCATLE input is contained in the next subsection.

POT1CH (08): The purpose of subroutine POT1CH is to make sure that l_{max} and ρ_{max} are sufficiently large. The value of l_{max} must be large enough so that all the partial waves sensibly affected by the nuclear potential are included in the computation. The value of ρ_{max} determined by this subroutine must be so large that the non-coulomb part of the potential is negligible at $\rho = \rho_{max}$. The flow chart of POT1CH (fig. 4) outlines the details of the procedure for checking and increasing l_{max} and ρ_{max}. The quantities which are tested are expressed in terms of the variables TCR, TCI, TSR, and TSI, where TCR and TCI are defined by

$$TCR = -\frac{V_{CN,\mathcal{R}}}{E} \tag{45a}$$

$$TCI = -\frac{V_{CN,\mathcal{I}}}{E} \tag{45b}$$

Equation (6) can be rewritten as

$$V_{SO} = V_{SO,\mathcal{R}} + i \cdot V_{SO,\mathcal{I}} \tag{46}$$

where

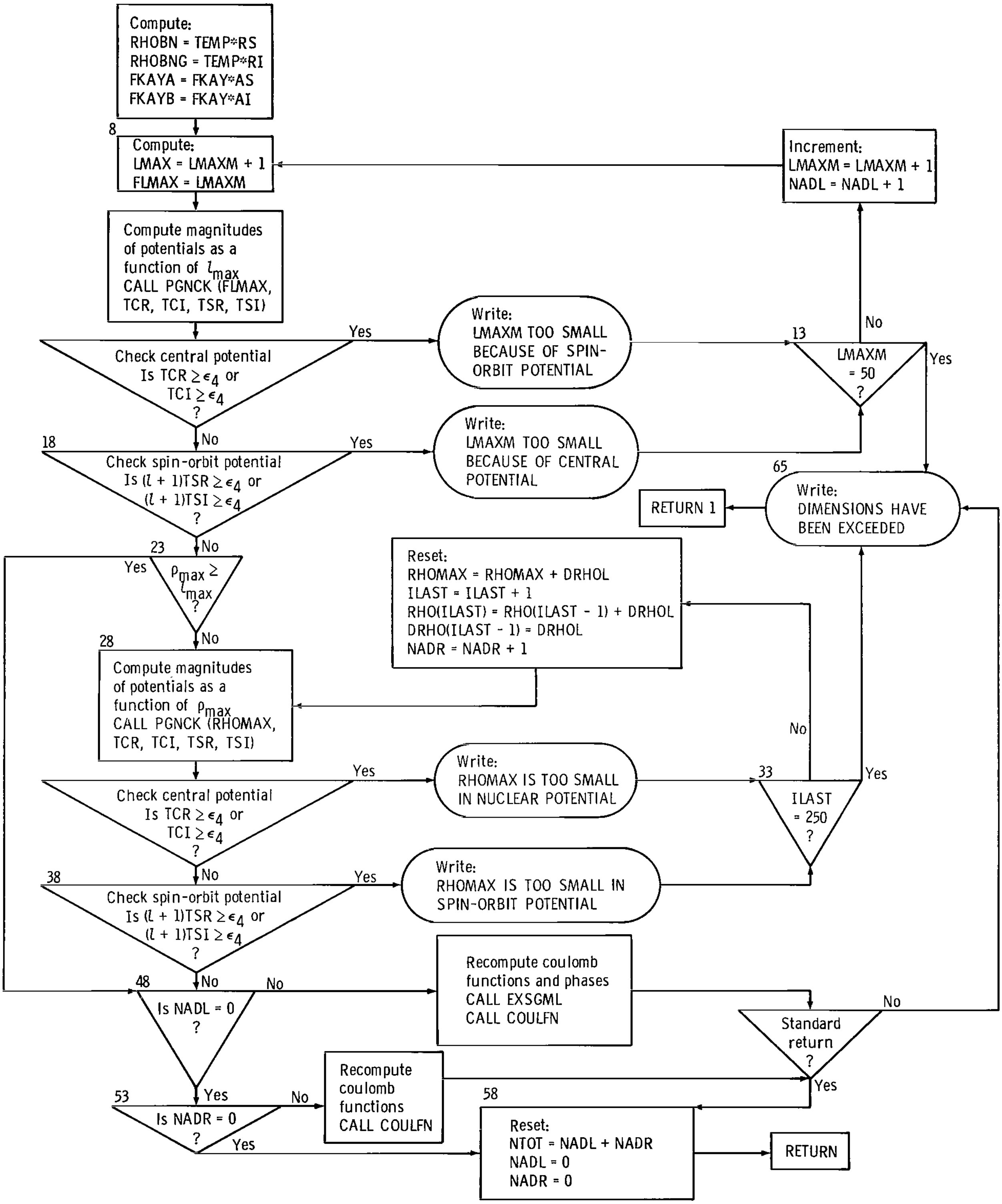


Figure 4. - Flow chart of subroutine POT1CH.

$$V_{SO,\mathcal{R}} = -VS \frac{2 \cdot k \cdot S_l \cdot \exp\left(\frac{\rho - \rho_S}{k \cdot a_S}\right)}{\left[1 + \exp\left(\frac{\rho - \rho_S}{k \cdot a_S}\right)\right]^2} \tag{47a}$$

and

$$V_{SO,\mathcal{I}} = -WS \frac{2 \cdot k \cdot S_l \cdot \exp\left(\frac{\rho - \rho_S}{k \cdot a_S}\right)}{\left[1 + \exp\left(\frac{\rho - \rho_S}{k \cdot a_S}\right)\right]^2} \tag{47b}$$

and where S_l is given by

$$S_l = l \quad \text{when} \quad |\overline{S}| = \frac{\hbar}{2} \tag{48a}$$

$$S_l = -l - 1 \quad \text{when} \quad |\overline{S}| = -\frac{\hbar}{2} \tag{48b}$$

The variables TSR and TSI are defined by

$$TSR = -\frac{V_{SO,\mathcal{R}}}{E \cdot S_l} \tag{49a}$$

$$TSI = -\frac{V_{SO,\mathcal{I}}}{E \cdot S_l} \tag{49b}$$

COULFN (10): Subroutine COULFN has been modified from the SCAT4 version by adding the calculations of the SCAT4 subroutine RMXINC. The table of ρ values is now extended directly in subroutine COULFN when necessary.

OUTPT4 (11): Subroutine OUTPT4 includes the statements for SCATLE initial and final output. This subroutine also includes the calculations for $\delta^+_{l,\mathcal{R}}$, $\delta^+_{l,\mathcal{I}}$, $\delta^-_{l,\mathcal{R}}$, $\delta^-_{l,\mathcal{I}}$, η^+_l, and η^-_l defined by equations (20) and (21). OUTPT4 has been expanded from the

SCAT4 version to include additional printouts and calculations. A detailed description of output options is presented in the section Typical output listings.

PGEN4 (12): The SCATLE version of subroutine PGEN4 is an extensive revision of the SCAT4 subroutine. The SCAT4 version of PGEN4 computes values for the nuclear potential at the beginning and middle of the integration mesh points. The SCATLE version of PGEN4 contains the following revisions:

(1) The potential V_{CN} can be computed using several new options as described in the section Options for computing central nuclear potential.

(2) PGEN4 is now called directly by POT1CH and furnishes values for the potential at $l = l_{max}$ and $\rho = \rho_{max}$.

(3) The two separate computations of the potential at the beginning and middle of an integration step interval have been combined in the coding.

(4) The computations for the knee and tail variations of the form factors as described in reference 1 are now found in the function TF.

(5) PGEN4 contains the following entry points:

(a) The normal entry point at the beginning of PGEN4 is used for calculating the nuclear potential at the beginning and middle of the integration mesh points.

(b) PGNCK is the entry point called by POT1CH.

(c) PGNIN is an entry point called from INPT4. It provides for the input of data used by function TF for the knee and tail variation calculations.

(d) PGNOUT is an entry point called from OUTPT4. It provides for the initial output of the knee and tail variation parameters.

A flow chart of subroutine PGEN4 is shown in figure 5.

INTCTR (14): This subroutine controls the Runge-Kutta integration procedure. When KX(6) = 1, the strength of the real spin-orbit term in the nuclear potential is VS if l is an even integer and VSODD if l is an odd integer.

RKINT (15): Subroutine RKINT carries out the numerical integration of the radial wave equation. The integration is carried out by operating with two coupled differential equations for the real and imaginary parts of the radial wave function. For convenience, this set of two equations is solved for the case $j = l + 1/2$ and $j = l - 1/2$ at the same time. When VS = WS = 0, these two cases are identical. In order to speed up the integration procedure, RKINT calculates only one of these cases when VS = WS = 0.

AB (17): Subroutine AB calculates the scattering coefficients $A(\theta)$ and $B(\theta)$. The Legendre polynomials $P_l(\cos\theta)$ and the associated Legendre polynomials $P_l^1(\cos\theta)$ are also calculated in this subroutine. To economize on computer storage space, the quantities $P_l(\cos\theta)$ and $P_l^1(\cos\theta)$ are recomputed each time $A(\theta)$ and $B(\theta)$ are computed.

CHISQ (20): Subroutine CHISQ computes the chi-square functions and the normalization constant given in equations (33) through (42). During a grid case, this subroutine provides for the output of the parameter and chi-square values.

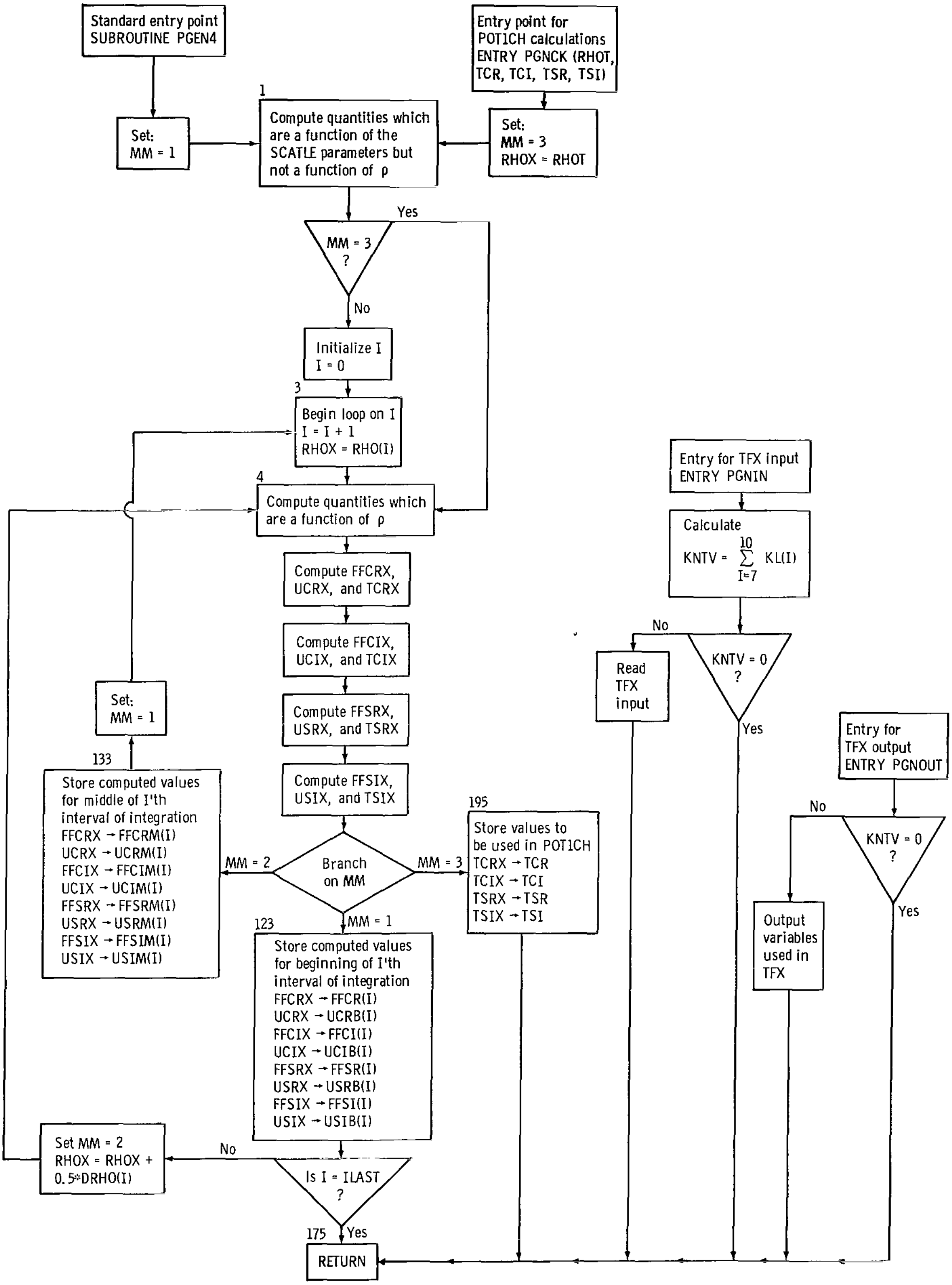


Figure 5. - Flow chart of subroutine PGEN4.

New subroutines. - The following subroutines were written for program SCATLE:

POUT(02)	PTETDL(23)
TFX(13)	PTSCAT(24)
PTFFRI(21)	SOUI(26)
TRIPS(22)	SCTBD(34)

POUT(02): Subroutine POUT outputs values of the nuclear potential parameters, along with proper labels, during search and grid procedures.

TFX(13): Function TFX contains the calculations for the special variations of the potential form factors referred to as knee and tail variations in reference 1.

PTFFRI(21): Subroutine PTFFRI is called only when KL(12) = 1. It computes and plots the effective potential as a function of ρ near the nuclear surface. The potential as given by equations (43) and (44) is calculated for a single given l-value. The form factors for the real and imaginary parts of the central nuclear and spin-orbit potentials are also plotted as a function of ρ. These form factors are the coefficients of -VO, -WI, -WVI, -VS, and -WS in the equations for the nuclear potential. The spin-orbit form factors are multiplied by the factor $4 \cdot \rho_S$ before plotting, and all four form factors appear on a single plot.

TRIPS(22): Subroutine TRIPS is called when $KX(11) \neq 0$. When KX(11) equals 1 or 2, the triple scattering parameters R, β, and R' of equations (25), (28), and (29) are calculated. The values of θ, tan β, β, θ_{LAB}, R, and -R' are then written out in table form. Subroutine TRIPS also produces a plot of R and -R' as a function of θ. When KX(11) = 2, a table of the quantities $f_c(\theta)$ and $[A(\theta) - f_c(\theta)]$ is generated in polar form. These quantities are given by equations (22a) and (23). A table of σ_l values as given by equation (24) is also written out.

PTETDL(23): Subroutine PTETDL is called when $KX(2) \neq 0$ and $KL(6) \neq 1$. This subroutine produces a plot of η_l^+ and η_l^- as a function of l (see eq. (20)). It also produces a plot of the quantities $\delta^\pm_{l,\mathcal{R}}$, $\delta^\pm_{l,\mathcal{R}} - \pi$, $\delta^\pm_{l,\mathcal{R}} + \pi$, and $\delta^\pm_{l,\mathcal{R}} + 2\pi$ as a function of l. The real phase shifts $\delta^\pm_{l,\mathcal{R}}$ are defined in equation (21).

PTSCAT(24): This subroutine produces plots of polarization and/or cross-section data when $KL(4) \neq 0$. When KL(4) = 1, a plot of $P^{ex}(\theta)$ and $P^{th}(\theta)$ as a function of θ is produced. A plot of $\sigma^{ex}(\theta)$ and $\sigma^{th}(\theta)$ as a function of θ is produced when KL(4) = 2. A plot of $N \cdot \sigma^{ex}(\theta)$ and $\sigma^{th}(\theta)$ as a function of θ is also produced when the experimental cross sections are normalized in equation (35) ($KX(5) \neq 0$ and KL(4) = 2). When KL(4) = 3, the combined results of KL(4) = 1 and KL(4) = 2 are produced.

SOUI(26): Subroutine SOUI outputs and labels values of the search parameters and their partial derivatives during a search. The value of the reaction cross section and the values of the normalization and chi-square functions given by equations (33) through (42) are also written out. Subroutine SOUI contains two nonstandard entry points which are labeled ENTRY SOUF and ENTRY SOUT.

SCTBD(34): Subroutine SCTBD is a BLOCK DATA subprogram. The convergence limits ϵ_1, ϵ_2, ϵ_3, and ϵ_4 are entered into COMMON block CONV in SCTBD. The names of the SCATLE parameters are entered into COMMON block PARA.

Search subroutines. - The SCATLE search subroutines are unchanged from the corresponding subroutines of reference 2 in the sense that the searching procedure is the same. There are several new cutoff options which are controlled by the input variables NMLR, NPCT, and PCT (table III). The SCATLE search subroutines are changed from those of reference 2 in the sense that the input, output, and COMMON statements have been modified.

ARGN(25): The SCATLE subroutine ARGN corresponds to the main program of reference 2, and controls the search procedure. The SCATLE search variables are input in subroutine INPT4 by referring to NAMELIST SCHI. Table III contains a detailed description of the search input.

The following subroutines are described in reference 2:

READY(27)	DRESS(30)
AIM(28)	STUFF(31)
FIRE(29)	MATMPY(32)

FCN(33): Subroutine FCN is called by several search subroutines. It calculates the value of the chi-square function to be minimized and its gradient, given a set of values for the n search parameters. Let $f_{\chi^2}(x_1, x_2, \ldots, x_n)$ be the chi-square function designated by the controls KX(4) and KX(12) (see table III). The n components of the gradient of f_{χ^2} are given by

$$G_j = \frac{\partial f_{\chi^2}}{\partial x_j} = \frac{f_{\chi^2}(x_1, \ldots, x_j + \Delta x_j, \ldots, x_n) - f_{\chi^2}(x_1, \ldots, x_j, \ldots, x_n)}{\Delta x_j} \tag{50}$$

for $j = 1$ to $j = n$, where $x_1, x_2, \ldots, x_n$ are the current values of the n search parameters. The values of Δx_j corresponding to each SCATLE parameter are found in column 6 of table IV. The value of $f_{\chi^2}(x_1, x_2, \ldots, x_n)$ is the current value of the function to be minimized by the search subroutines, and the gradient of this function is defined by the n values of G_j.

Program Operating Instructions

Machine specifications. - Program SCATLE is written in FORTRAN IV programming language (version 13). It is currently being run at Lewis on an IBM 7094 II direct couple system with 32 768 core storage locations. The monitor system is a modified version of the IBM-distributed IBSYS Version 13. SCATLE utilizes several options which are not part of the IBM monitor system. Table V includes descriptions of these options and indicates where they are used in SCATLE.

Detailed description of required input. - The form of the data cards is specified by either FORMAT statements or NAMELIST statements. There are nine sets of data cards. Four sets are required for every case; the other five sets may be required depending on the options chosen. The nine input sets are listed in table II. The card number listed refers to the READ statement for that data set. The NAMELIST or FORMAT for each set is listed in the column labeled Description.

Table III lists and describes all SCATLE input variables which appear in NAMELIST statements. The standard input values also appear in table III. The glossary of FORTRAN variables (appendix B) may also be helpful in interpreting the SCATLE input variables.

Table IV lists the variable names of the grid increment and number of grid points corresponding to each SCATLE parameter. The values of the corresponding elements in the standard H-matrix are also tabulated. The values of Δx_j in column 6 are those used to calculate the partial derivatives of f_{χ^2} for the search subroutines (eq. (50)). These values are internal and cannot be read in.

The dimension specifications of the FORTRAN variables impose three limitations on the input values: JMAX must be less than or equal to 150; LMAXM must be less than or equal to 50; the RHOIN and DRHOIN arrays cannot take on values which cause the resulting RHO array to have more than 250 elements.

In general, the SCATLE user need input a NAMELIST variable only if he wants its value to differ from the value already stored in the computer. The flow diagram of figure 6 shows how a set of input values for any given case is defined.

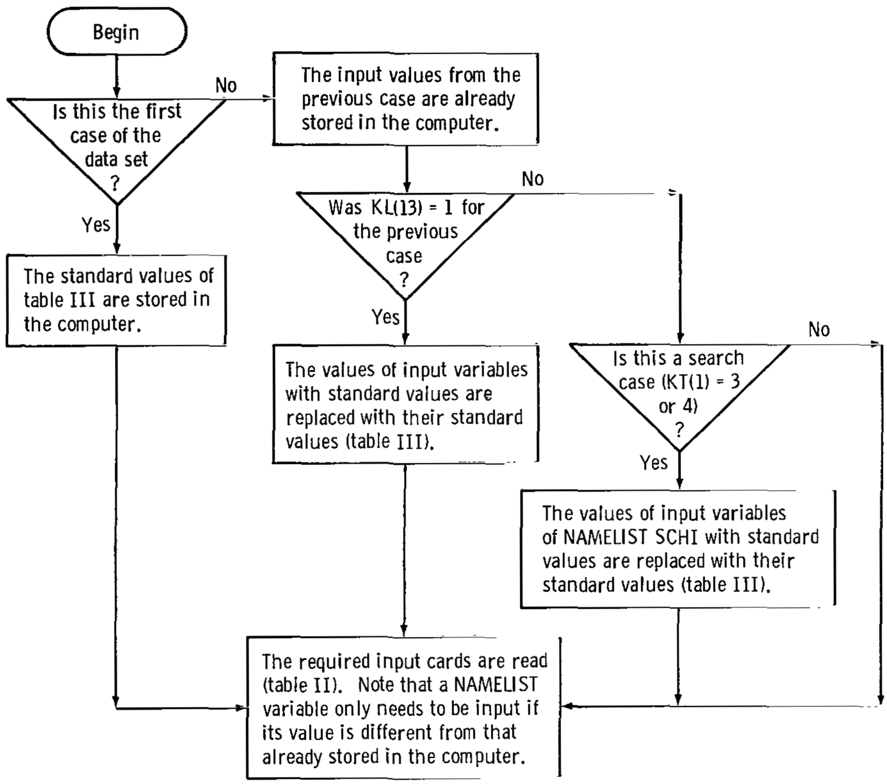


Figure 6. - Schematic flow diagram showing how a set of input values is defined.

The data cards for a single case with standard controls and with no experimental data are listed below. The potential is a Woods-Saxon real central potential, a Gaussian imaginary central potential, and a derivative of Woods-Saxon spin-orbit potential.

```
        STANDARD POTENTIAL CASE WITHOUT EXPERIMENTAL DATA

$KTK KL(2)=0 $

$PEI FMI=1.00783,FMB=27.97693,ELAB=18.82 ,ZZ=14,RC=1.25,VO=60,AS=.6,RS=1.0,
WI=6,AI=.8,RI=1.2,VS=6,   $

$RFI $

$TSP DTH=5,THI=5,THF=175 $
```

Card 1 is the title card. Card 2 contains the nonstandard value KL(2) = 0 so that chi-square values (meaningless here without experimental data) will not be computed. Card 3 and Card 4 contain the parameters describing the specific nucleus and interaction. The first four variables are the incident and target nucleus masses, laboratory energy, and charge product. The coulomb charge radius parameter is denoted by RC; VO, AS, and RS are parameters for the real central potential; WI, AI, and RI are parameters for the imaginary central potential; and VS is the real spin-orbit potential strength. Card 5 must be read in, but since standard values are used for the integration data, the data field is left blank. Card 6 contains values needed to generate the set of center-of-mass angles at which cross sections and polarizations are calculated.

Input cards for typical data sets. - This section lists the input cards for six example cases which compute results for scattering of 18.82-MeV protons from ^{28}Si. Data set 1 consists of the input cards for examples 1 and 2. The input cards for examples 3 through 6 have been combined to form data set 2. These two data sets illustrate the input requirements described in the previous section.

Example 1 of data set 1 is a six-parameter search case with search parameters VO, WI, VS, AO, AI, and AS. The real central potential $V_{CN,\mathcal{R}}$ uses a Woods-Saxon form factor, the imaginary central potential $V_{CN,\mathcal{I}}$ uses a derivative of Woods-Saxon form factor, and the spin-orbit potential contains only a real part.

Example 2 of data set 1 is a combination grid and search case which uses the same options for V_{CN} and V_{SO} as example 1. The grid parameters are AO and AS; and each grid point is the starting point for a four-parameter search on VO, WI, VS, and AI.

DATA SET 1

```
EXAMPLE 1      SILICON 28 (P,P) E=18.82      SINGLE CASE SEARCH

 $KTR KL(4)=2, KX(1)=1, KX(7)=2, KT(1)=4, NP=10$

 $PEI FMI=1.00783, FMB=27.97693, ELAB=18.82, ZZ=14., RC=1.25,
 VO=60., WI=6., VS=6., AO=.8, AI=.8, AS=.5, RO=1.05, RI=1.2, RS=.95$

 $RHI LMAXM=15, NMAX=4, RHOIN(3)=5., 15., DRHOIN(2)=.1, .2$

 $SCFI N=6, SRCH='VO', 'WI', 'VS', 'AO', 'AI', 'AS'$

 $TSP CSIG=T, JMAX=44, JOPT=1$

   5.18      1.57 +5    1.57 +4    1.0        1.0 +30
   7.77      2.35 +4    2.35 +3    1.0        1.0 +30
  12.95    2623.70    262.37       1.0        1.0 +30
  15.53    1350.16    135.02       -.077       .020
  18.12     870.77     87.08       1.0        1.0 +30
  20.71     649.43     64.94       1.0        1.0 +30
  23.30       1.0        1.0 +30   -.187       .025
  25.87     204.06     20.41       1.0        1.0 +30
  31.03      90.89      9.09       -.266       .020
  36.18      27.12      3.71       1.0        1.0 +30
  38.80       1.0        1.0 +30    -.617      .028
  41.33       5.47      0.55       1.0        1.0 +30
  46.46      10.11      1.01        .400       .039
```

51.58	25.09	2.51	1.0	1.0 +30
54.10	1.0	1.0 +30	.161	.021
56.69	36.32	3.63	1.0	1.0 +30
61.79	37.42	3.74	-.118	.040
66.87	32.14	3.21	1.0	1.0 +30
69.40	1.0	1.0 +30	-.236	.022
71.94	23.06	2.31	1.0	1.0 +30
76.99	13.63	1.36	-.404	.049
82.03	7.55	0.76	1.0	1.0 +30
84.50	1.0	1.0 +30	-.451	.027
87.06	4.78	0.48	1.0	1.0 +30
92.06	4.54	0.45	-.143	.036
97.06	5.19	0.52	1.0	1.0 +30
99.50	1.0	1.0 +30	.580	.038
102.03	5.82	0.58	1.0	1.0 +30
106.99	6.07	0.61	.610	.034
111.94	5.24	0.52	1.0	1.0 +30
114.40	1.0	1.0 +30	.579	.028
116.87	4.30	0.43	1.0	1.0 +30
121.79	3.42	0.34	.340	.040
126.69	2.85	0.29	1.0	1.0 +30
129.10	1.0	1.0 +30	.080	.046
131.58	2.69	0.27	1.0	1.0 +30
136.46	2.69	0.27	-.034	.051
141.33	2.80	0.28	1.0	1.0 +30
143.80	1.0	1.0 +30	.098	.044
146.18	2.84	0.28	1.0	1.0 +30
151.03	2.91	0.29	.434	.039
155.87	2.65	0.27	.680	.050
160.71	2.53	0.25	1.0	1.0 +30
165.53	2.55	0.26	.740	.050

```
EXAMPLE 2      SILICON 28 (P,P) E=18.82      SEARCH WITH GRID ON AO AND AS
 $KTR KT(1)=3$
 $PEI AU=.7$
 $GRI NAU=2, DAU=.1, NAS=2, DAS=.05$
 $RFI $
 $SCHI N=4, SRCH='VU', 'WI', 'VS', 'AI'$
```

Example 3, the first case of data set 2, is a single case which uses the same options for V_{CN} and V_{SO} as examples 1 and 2. The values of the SCATLE parameters are the values at the end of the search of example 1.

Example 4 is also a single case. This case is exactly the same as example 3 except that it uses the normalization N_E in the calculation of X_σ^2.

Example 5 is a grid case which uses the same computing options as example 3. The grid points of this example bracket the point in the parameter space used as input for example 3.

Example 6 is a single case where $V_{CN,\mathcal{R}}$ uses a Woods-Saxon form factor, $V_{CN,\mathcal{I}}$ uses a knee and tail variation form factor, and the spin-orbit potential contains only a real part. Input values for the SCATLE parameters which yield reasonable chi-square values were chosen.

Data set 1 ran on an IBM 7094 II direct couple system at Lewis with an execution time of 11.76 minutes. The execution time for data set 2 was 0.82 minute.

DATA SET 2

```
EXAMPLE 3      SILICON 28 (P,P) E=18.82      SINGLE CASE

 $KTR KL(4)=3, KL(6)=2, KL(12)=1, KX(1)=1, KX(7)=2, NP=10$

 $PEI FM1=1.00783, FMB=27.97693, ELAB=18.82, ZZ=14., RC=1.25,
 V0=59.78, WI=6.294, VS=6.217, A0=.7642, AI=.8455, AS=.5134, R0=1.05, RI=1.2,
 RS=.95$

 $RFI LMAXM=15, NMAX=4, RHOIN(3)=5., 15., DRHOIN(2)=.1, .2$

 $TSP CSIG=T, JMAX=44, JOPT=1$

   5.18       1.57 +5    1.57 +4    1.0        1.0 +30
   7.77       2.35 +4    2.35 +3    1.0        1.0 +30
  12.95    2623.76     262.37       1.0        1.0 +30
  15.53    1350.16     135.02      -.077        .020
  18.12     870.77      87.08       1.0        1.0 +30
  20.71     649.43      64.94       1.0        1.0 +30
  23.30       1.0        1.0 +30   -.187        .025
  25.87     204.06      20.41       1.0        1.0 +30
  31.03      90.89       9.09      -.266        .020
  36.18      37.12       3.71       1.0        1.0 +30
  38.80       1.0        1.0 +30    -.617       .028
  41.33       5.47       0.55       1.0        1.0 +30
  46.46      10.11       1.01        .400       .039
  51.58      25.09       2.51       1.0        1.0 +30
  54.10       1.0        1.0 +30     .161       .021
  56.69      36.32       3.63       1.0        1.0 +30
  61.79      37.42       3.74      -.118        .040
  66.87      32.14       3.21       1.0        1.0 +30
  69.40       1.0        1.0 +30   -.236        .022
  71.94      23.06       2.31       1.0        1.0 +30
  76.99      13.63       1.36      -.404        .049
  82.03       7.55       0.76       1.0        1.0 +30
  84.50       1.0        1.0 +30   -.451        .027
```

```
  87.06       4.78       0.48       1.0        1.0 +30
  92.06       4.54       0.45        .143       .036
  97.06       5.19       0.52       1.0        1.0 +30
  99.50       1.0        1.0 +30     .580       .038
 102.03       5.82       0.58       1.0        1.0 +30
 106.99       6.07       0.61        .610       .034
 111.94       5.24       0.52       1.0        1.0 +30
 114.40       1.0        1.0 +30     .579       .028
 116.87       4.30       0.43       1.0        1.0 +30
 121.79       3.42       0.34        .340       .040
 126.69       2.85       0.29       1.0        1.0 +30
 129.10       1.0        1.0 +30     .080       .048
 131.58       2.69       0.27       1.0        1.0 +30
 136.46       2.69       0.27       -.034       .051
 141.33       2.80       0.28       1.0        1.0 +30
 143.80       1.0        1.0 +30     .098       .044
 146.18       2.84       0.28       1.0        1.0 +30
 151.03       2.91       0.29        .434       .039
 155.87       2.65       0.27        .680       .050
 160.71       2.53       0.25       1.0        1.0 +30
 165.53       2.55       0.26        .740       .050

EXAMPLE 4      SILICON 28 (P,P) E=18.82      SINGLE CASE, ENORM NORMALIZATION
 $KTR KX(5)=2$
 $PEI $
 $RHI $

EXAMPLE 5      SILICON 28 (P,P) E=18.82      GRID ON VO, VS, AND WI
 $KTR KL(13)=1, KT(1)=2, KX(5)=0$
 $PEI VO=50., VS=4., WI=4.$
 $GRI NVO=2, DVO=10., NWI=2, DWI=2., NVS=3, DVS=2.$
 $RHI $

EXAMPLE 6      SILICON 28 (P,P) E=18.82      SINGLE CASE, KNEE AND TAIL VCNI
 $KTR KL(1)=0, KL(4)=3, KL(6)=1, KL(8)=1, KX(7)=2, NP=11$
 $PEI VO=51.9, WI=30.08, VS=10.37, AO=.75, AS=.85, RO=1.161, RS=.861$
 $RHI LMAXM=15, NMAX=4, RHOIN(3)=5., 15., DRHOIN(2)=.1, .2$
-1.        0.        1.        0.        1.        0.        .7        0.
 $TSP $
```

Tables describing input. - Tables II, III, and IV contain details of SCATLE input options. Table V lists the nonstandard FORTRAN IV programming options used in SCATLE.

TABLE II. - INPUT SETS

Input set	Required for-	Card number	Description
1	All cases	03--0950	Title card (FORMAT 13A6)
2	All cases	03--0970	Controls: NAMELIST/KTR/KL, KT, KX, XNORM, NP
3	All cases	03--1200	SCATLE parameters (energy, mass, and charge values): NAMELIST/PEI/FMI, FMB, ELAB, ZZ, RC, VO, AO, RO, WI, WVI, AI, RI, VS, WS, AS, RS, VSODD
4	KT(1) = 2 or KT(1) = 3	03--1330	Grid variables: NAMELIST/GRI/DRI, DRS, DVO, DWI, DAS, DVS, DWS, DAI, DWVI, DAO, DRO, DVSODD, NRI, NRS, NVO, NWI, NAS, NVS, NWS, NAI, NWVI, NAO, NRO, NVSODD
5	All cases	03--1350	Integration variables and LMAXM: NAMELIST/RHI/NMAX, LMAXM, RHOIN, DRHOIN
6	$\sum_{I=7}^{10} KL(I) \neq 0$	12--1630	Input for knee and tail variations (FORMAT 8E10.0):[a] TH(1), TH(2), TN1(1), TN1(2), TN2(1), TN2(2), PMA, PMB
7	KT(1) = 3 or KT(1) = 4	03--1520	Search variables: NAMELIST/SCHI/C, DELTA, E, FAC, H, KSTEP, N, NC, NHP, NSSW1, NMLR, NPCT, PCT, SRCH, VP
8	KL(3) $\neq$ 0	03--1790	Experimental data: NAMELIST/TSP/CSIG, DPOLEX, DSGMEX, DTH, JMAX, JOPT, POLEX, SGMAEX, THETAD, THI, THF
9	JOPT $\neq$ 0	03--1880 03--1890	Experimental data (FORMAT 8E10.0):[a] THETAD(J), SGMAEX(J), DSGMEX(J), POLEX(J), DPOLEX(J); one card for each J from 1 to JMAX

[a]When data are input using E-conversion, the exponent is read as 0 whenever the characters Exx are omitted from the data card. Thus, data which are punched on cards according to the specifications for F-conversion will aso be input correctly by E-conversion. (See listing of data cards for example data sets.)

TABLE III. - SCATLE INPUT VARIABLES APPEARING IN NAMELIST STATEMENTS

Namelist name	Variable name	Standard values	Description
KTR	KL(1)	1	0 - $V_{CN,\mathcal{R}}$, Woods-Saxon; $V_{CN,\mathcal{I}}$, Woods-Saxon 1 - $V_{CN,\mathcal{R}}$, Woods-Saxon; $V_{CN,\mathcal{I}}$, determined by KX(1) 2 - Square well form of V_{CN} (eq. (19)): When KL(1) = 2, KX(7) is set to 1. If KL(1) = 2, set VS = WS = 0.
	KL(2)	1	0 - Chi-square not computed. 1 - Compute chi-square.
	KL(3)	1	0 - Use experimental values from previous case. 1 - Read NAMELIST/TSP/. (KL(3) is set equal to 0 after Read.)
	KL(4)	0	0 - No plot. 1 - Plot polarizations. 2 - Plot sigmas. 3 - Plot sigmas and polarizations.
	KL(5)	0	Not used
	KL(6)	0	0 - Normal output. 1 - Minimum output (η_l^+, η_l^-, $\delta_{l,\mathcal{R}}^+$, $\delta_{l,\mathcal{R}}^-$ are not computed, printed, or plotted.) 2 - Normal output plus AR, AI, BR, BI
	KL(7)	0	0 - Standard form for $V_{CN,\mathcal{R}}$ 1 - Form A for $V_{CN,\mathcal{R}}$ } Ref. 1 2 - Form B for $V_{CN,\mathcal{R}}$ } Ref. 1
	KL(8)	0	0 - Standard form for $V_{CN,\mathcal{I}}$ 1 - Form A for $V_{CN,\mathcal{I}}$ } Ref. 1 2 - Form B for $V_{CN,\mathcal{I}}$ } Ref. 1
	KL(9)	0	0 - Standard form for $V_{SO,\mathcal{R}}$ 1 - Derivative of form A for $V_{SO,\mathcal{R}}$ } Ref. 1 2 - Form B for $V_{SO,\mathcal{R}}$ } Ref. 1
	KL(10)	0	0 - Standard form for $V_{SO,\mathcal{I}}$ 1 - Derivative of form A for $V_{SO,\mathcal{I}}$ } Ref. 1 2 - Form B for $V_{SO,\mathcal{I}}$ } Ref. 1
	KL(11)	0	0 - No coulomb spin-orbit term } Eq. (2) 1 - Includes coulomb spin-orbit } Eq. (2)
	KL(12)	0	0 - Do not print and plot form factors (ref. 1) 1 - Print and plot form factors; plot effective potential for l = KX(9) (eq. (43)).
	KL(13)	0	0 - Save current input values for next case. 1 - Initialize input to standard values before next case. (KL(3) is reset to 1.)

TABLE III. - Continued. SCATLE INPUT VARIABLES APPEARING IN NAMELIST STATEMENTS

Namelist name	Variable name	Standard values	Description
KTR	KT(1)	1	1 - Single case, no search 2 - Grid, no search 3 - Grid, plus search 4 - Single case with search
	KT(2)	0	Not used
	KT(3)	0	Not used
	KT(4)	0	NF $\quad$ $\mathrm{SUMFS} = \sum_{j=1}^{NF} \chi_{\sigma}^{2}(\theta_j)$; $\mathrm{SUMFP} = \sum_{j=1}^{NF} \chi_{P}^{2}(\theta_j)$
	KT(5)	0	NR $\quad$ $\mathrm{SUMMS} = \sum_{j=NF+1}^{NR} \chi_{\sigma}^{2}(\theta_j)$; $\mathrm{SUMMP} = \sum_{j=NF+1}^{NR} \chi_{P}^{2}(\theta_j)$
	KT(6)	0	N1 $\quad$ $\mathrm{SUMRS} = \sum_{j=NR+1}^{JMAX} \chi_{\sigma}^{2}(\theta_j)$; $\mathrm{SUMRP} = \sum_{j=NR+1}^{JMAX} \chi_{P}^{2}(\theta_j)$
	KT(7)	0	IN1 $\quad$ $\mathrm{SUM1S} = \sum_{j=N1}^{N1+IN1} \chi_{\sigma}^{2}(\theta_j)$; $\mathrm{SUM1P} = \sum_{j=N1}^{N1+IN1} \chi_{P}^{2}(\theta_j)$
	KT(8)	0	N2 $\quad$ $\mathrm{SUM2S} = \sum_{j=N2}^{N2+IN2} \chi_{\sigma}^{2}(\theta_j)$; $\mathrm{SUM2P} = \sum_{j=N2}^{N2+IN2} \chi_{P}^{2}(\theta_j)$
	KT(9)	0	IN2
	KT(10)	0	N3 $\quad$ $\mathrm{SUM3S} = \sum_{j=N3}^{N3+IN3} \chi_{\sigma}^{2}(\theta_j)$; $\mathrm{SUM3P} = \sum_{j=N3}^{N3+IN3} \chi_{P}^{2}(\theta_j)$
	KT(11)	0	IN3
	KT(12)	0	N4 $\quad$ $\mathrm{SUM4S} = \sum_{j=N4}^{N4+IN4} \chi_{\sigma}^{2}(\theta_j)$; $\mathrm{SUM4P} = \sum_{j=N4}^{N4+IN4} \chi_{P}^{2}(\theta_j)$
	KT(13)	0	IN4 $\quad$ SUM34S = SUM3S + SUM4S SUM34P = SUM3P + SUM4P
	XNORM	1	Normalization factor for $\sigma^{ex}(\theta)$ and $\Delta\sigma^{ex}(\theta)$; SNORM = XNORM when KX(5) = 1
	NP	0	All chi-square values are divided by (JMAX - NP) and printed out along with the unadjusted chi-square values.
	KX(1)	0	0 - Gaussian form for $V_{CN,\mathcal{J}}$ (eq. (14)) 1 - Derivative of Woods-Saxon form for $V_{CN,\mathcal{J}}$ (eq. (16)) 2 - Gaussian plus Woods-Saxon form for $V_{CN,\mathcal{J}}$ (eq. (17)) 3 - Derivative of Woods-Saxon plus Woods-Saxon form for $V_{CN,\mathcal{J}}$ (eq. (18))
	KX(2)	0	0 - Do not plot η_l^{+}, η_l^{-}, $\delta^{+}_{l,\mathcal{R}}$, $\delta^{-}_{l,\mathcal{R}}$ (eqs. (20) and (21)). 1 - Plot η_l^{+}, η_l^{-}, $\delta^{+}_{l,\mathcal{R}}$, $\delta^{-}_{l,\mathcal{R}}$ } KL(6) $\neq$ 1. 2 - Plot and punch η_l^{+}, η_l^{-}, $\delta^{+}_{l,\mathcal{R}}$, $\delta^{-}_{l,\mathcal{R}}$ } KL(6) $\neq$ 1.

TABLE III. - Continued. SCATLE INPUT VARIABLES APPEARING IN NAMELIST STATEMENTS

Namelist name	Variable name	Standard values	Description
KTR	KX(3)	0	0 - $\Delta\sigma^{ex}(\theta)$ used in χ^2_σ 1 - $\Delta\sigma^{ex}(\theta)$ replaced by $\sigma^{th}_{coul}(\theta)$ in $\chi^2\sigma$; when KX(3) = 1, KX(5) is set equal to 0.
	KX(4)	3	Determines what function will be minimized by search: 1 - CHI2ST 8 - SUM3S 15 - SUMMP 2 - CHI2PT 9 - SUM3P 16 - SUMRS 3 - CHI2T 10 - SUM4S 17 - SUMRP 4 - SUM1S 11 - SUM4P 18 - SUM34S 5 - SUM1P 12 - SUMFS 19 - SUM34P 6 - SUM2S 13 - SUMFP 7 - SUM2P 14 - SUMMS When KX(12) = 1, CHISQ(KX(4)) + CHISQ(KX(4) + 1) will be minimized.
	KX(5)	0	0 - SNORM = 1 1 - SNORM = XNORM 2 - SNORM = ENORM KX(5) is set equal to 0 when KX(3) = 1.
	KX(6)	0	0 - Normal integration procedure 1 - Exchange potential in integration routine: If l is even, VS = VS. If l is odd, VS = VSODD.
	KX(7)	1	1 - AS and RS used to compute Woods-Saxon form of $V_{CN,\Re}$ (eq. (10)) 2 - AO and RO used to compute Woods-Saxon form of $V_{CN,\Re}$ (eq. (11)) KX(7) is set equal to 1 when KL(1) = 2.
	KX(8)	0	Not used
	KX(9)	0	l-value used in angular momentum term when plotting effective potential (eq. (43)); this option is used only when KX(12) = 1.
	KX(10)	0	Not used
	KX(11)	0	0 - Do not call TRIPS 1 - Call TRIPS (standard output) 2 - Call TRIPS (standard output plus scattering amplitudes and $\sigma^{th}_{coul}(\theta)$ output)
	KX(12)	0	$\neq$1 - Search on CHISQ(KX(4)) 1 - Search on CHISQ(KX(4)) + CHISQ(KX(4) + 1)
	KX(13)	0	Not used
PEI	FMI, FMB, ELAB, ZZ, RC	None	Mass, energy, charge product, coulomb radius
	VO, AO, RO, WI, WVI, AI RI, VS, WS, AS, RS, VSODD	0	SCATLE parameters (nuclear potential parameters)
GRI	DVO, DAO, DRO, DWI, DWVI, DAI, DRI, DVS, DWS, DAS, DRS, DVSODD	0	Grid increments (table IV)
	NVO, NAO, NRO, NWI, NWVI, NAI, NRI, NVS, NWS, NAS, NRS, NVSODD	1	Number of grid values (table IV)

TABLE III. - Concluded. SCATLE INPUT VARIABLES APPEARING IN NAMELIST STATEMENTS

Namelist name	Variable name	Standard values	Description
RHI	LMAXM	25	l_{max}
	NMAX	3	Number of RHOIN values (≤10)
	RHOIN(I) for I = 1 to 10	0.05, 0.5, 25.	RHO(1)=RHOIN(1) RHO(I)=RHO(I-1)+DRHOIN(1); RHOIN(1)<RHO(I)≤RHOIN(2)
	DRHOIN(I) for I = 1 to 9	0.05, 0.5	RHO(I)=RHO(I-1)+DRHOIN(NMAX-1); RHOIN(NMAX-1)<RHO(I)≤RHOIN(NMAX)
SCHI	C(I, J) for I = 1 to 12 J = 1 to 10	0	Constraint matrix
	DELTA	None for FAC = 0 H(1, 1)·H(2, 2)···H(N, N) for FAC ≠ 0	Determinant of H-matrix
	E	0.1	Criteria for search cutoff
	FAC	-1	Controls input of H-matrix
	H(I, J), I = 1 to 12	FAC < 0: Diagonal matrix composed of standard elements from table IV FAC = 0: None FAC > 0: FAC × Identity matrix	Symmetric matrix used by search routines; when FAC = 0, only elements on diagonal and to right of diagonal are input.
	KSTEP	0	Number of random steps to be taken at end of search
	N	None	Number of parameters to be searched on
	NC	0	Number of constraints
	NHP	5	H-matrix is printed out every NHP iterations during search
	NSSW1	1	Output control: NSSW1 ≥ 1 gives normal search output. NSSW1 < 1 gives minimum search output.
	NMLR	5	A search will be cut off after NMLR move left or move right output messages.
	NPCT	5	A search will terminate after NPCT iterations with less than PCT percent change.
	PCT	0.5	
	SRCH(I), I = 1 to 12	None	This array must contain the FORTRAN names of the N parameters to be searched on. Literal constants must be enclosed by apostrophies when read into NAMELIST (e.g., SRCH = 'VO', 'RS').
	VP	0	Factor for determining the length of random steps (card 31--0220.)
TSP	CSIG	FALSE	$\sigma^{ex}(\theta)$ and $\Delta\sigma^{ex}(\theta)$ are converted from mb/sr to fm^2/sr when CSIG = .TRUE.
	JMAX	None	Number of experimental data points.
	JOPT	0	When JOPT ≠ 0, experimental data will be read with FORMAT 8E10.0 (table II).
	DTH	0	When DTH ≠ 0, the THETAD array is generated from THI to THF in steps of DTH.
	THI	None	
	THF	None	
	THETAD-array	None	θ
	DPOLEX-array	None	Δp^{ex}
	DSGMEX-array	None	$\Delta\sigma^{ex}$
	POLEX-array	None	p^{ex}
	SGMAEX-array	None	σ^{ex}

TABLE IV. - SCATLE PARAMETERS - SEARCH AND GRID INFORMATION

1	2	3	4	5	6
SCAT4 parameter name	SCATLE parameter name	Grid increment	Number of grid values	Corresponding element in standard diagonal H-matrix	Increment for parameter for x_j in equation (50), Δx_j
V	VO	DVO	NVO	0.005	0.001
W	WI	DWI	NWI	.005	.001
	AO	DAO	NAO	.00001	.0001
	RO	DRO	NRO	.00001	.0001
	WVI	DWVI	NWVI	.001	.001
BG	AI	DAI	NAI	.00001	.0001
RG	RI	DRI	NRI	.00001	.0001
VS	VS	DVS	NVS	.001	.001
WS	WS	DWS	NWS	.001	.001
A	AS	DAS	NAS	.00001	.0001
R0	RS	DRS	NRS	.00001	.0001
	VSODD	DVSODD	NVSODD	.001	.001

TABLE V. - NONSTANDARD FORTRAN IV PROGRAMMING OPTIONS USED IN SCATLE

Option	Card numbers where used			Description
G-type format	02--0140	11--0940	22--0360	Output format option which causes each number to be examined to determine whether it fits I, E, or F format. If the number fits one of these formats, it is printed in that format. All other numbers are printed in O-type format.
	02--0150	11--1060	22--0520	
	11--0580	11--1100	22--0590	
	11--0620	11--1190	22--1120	
	11--0630	11--1360	25--0930	
	11--0640	11--1550	25--0940	
	11--0650	11--1970	26--0230	
	11--0670	20--0850	26--0250	
	11--0780	20--0860	26--0320	
	11--0790	20--0910	26--0330	
	11--0870	20--0920	26--0390	
	11--0880		26--0460	
Input of literal (BCD) constants on NAMELIST data cards		03--1520		This option permits the names of the SCATLE parameters to be entered into the SRCH-array on NAMELIST data cards. This is accomplished by enclosing the parameter names in apostrophes. Since these literal constants have less than six characters, they are left adjusted with the remaining characters set to blanks, for example, $TSP N=3, SRCH='RI', 'VO', 'WVI' $ will cause the SRCH-array to appear in the machine as SRCH(1) RIbbbb SRCH(2) VObbbb SRCH(3) WVIbbb
Generate random numbers		01--0290		CALL SAND(X) initializes the procedure for generating random numbers.
		31--0140		Each CALL RAND(Y) generates a new random number.
Printed plots		21--0740		Each CALL PLOTXY(XDOWN, YACROS, KODE, P) generates a single curve plot. (Ref. 5)
	21--1160	23--0390	24--0590	Each CALL PLOTMY(XDOWN, YACROS, KKK, P) generates a multiple curve plot. (Ref. 5)
	22--1080	23--0610	24--0940	
		21--0720		Each CALL SORTXY(V, W, NPTS) rearranges the NPTS of the V-array in order of increasing size. The elements of the W-array are moved to maintain the original pair-relation. (Ref. 5)

Typical output listings. - The SCATLE output presented in this section is a portion of the output generated by running the standard potential case and the six example cases of the previous section. The first four pages of output from example 1 are shown. Values for the input variables and several initial calculations are listed on the first page, and the second through fourth pages contain all output from the search procedure. The last six pages of output from example 1 are not included since they correspond to the second page and to the last five pages of output from example 3.

Example 2 produces 40 pages of output. The portion presented here includes the initial page, and the initial and final parameters for each search procedure.

All 12 pages of output from example 3 are listed. The input potential parameters of this example agree to four figures with the final values of the search of example 1. Therefore, the final output values from example 1 are quite similar to the output values from example 3. The output from examples 4, 5, and 6, which consists of 21 pages, is not listed herein.

```
RUN NUMBER  1                 STANDARD POTENTIAL CASE WITHOUT EXPERIMENTAL DATA

                                            CONTROLS
                  N =    1    2    3    4    5    6    7    8    9   10   11   12   13

              KL(N)=     1    0    0    0    0    0    0    0    0    0    0    0    0
              KT(N)=     1    0    0    0    0    0    0    0    0    0    0    0    0
              KX(N)=     0    0    0    3    0    0    1    0    0    0    0    0    0

                                       BASIC INPUT DATA

   FMI=    1.00783          FMB=  27.97693          ELAB=  18.820            ZZ=  14.

 XNORM= 1.0000000          SNORM=  1.               JMAX=  35                NP=  0

                                  NUCLEAR POTENTIAL PARAMETERS

    VO= 60.000C00           WI= 6.0000000           AO= 0                    RO= 0
                           WVI= 0                   AI= 0.8000000            RI= 1.2000000
    VS= 6.0000000           WS= 0                   AS= 0.6000000            RS= 1.0000000
 VSODD= 0                                                                    RC= 1.2500000

                                   BASIC COMPUTED QUANTITIES

 RHORO= 0               RHORI= 3.3497156        RHORS= 2.7914296        RHORC= 3.4892870

   ECM= 18.165609           K= 0.9195175         KAS= 0.5517105          KAI= 0.7356140

   ETA= 0.5101995
                                       INTEGRATION DATA

 RHOMAX= 25.000000             LMAXM=25                          NMAX= 3

 RHOIN=        0.0500      0.5000      25.0000

 DRHOIN=              0.0500      0.5000
```

```
RUN NUMBER  1                 STANDARD POTENTIAL CASE WITHOUT EXPERIMENTAL DATA
         THETA                   SIGMATH              SIG/SIGC                 POL TH
       5.0000000                19502.611            0.9172991             1.6765503E-03
       10.000000                1066.8035            0.7997761             1.2657248E-02
       15.000000                230.55717            0.8694993             1.5116542E-02
       20.000000                96.579293            1.1409455            -1.6100620E-02
       25.000000                50.409868            1.4373500            -7.3879237E-02
       30.000000                26.120771            1.5228981            -0.1570987
       35.000000                11.937901            1.2682216            -0.2856010
       40.000000                4.2748480            0.7600241            -0.5127966
       45.000000                1.0820086            0.3015014            -0.8231835
       50.000000                0.7001327            0.2901839             0.2469563
       55.000000                1.7489625            1.0330060             0.4659013
       60.000000                3.2012861            2.5995876             0.3104368
       65.000000                4.4103024            4.7756708             0.1785101
```

70.000000	5.0628741	7.1197093	6.9308369E-02
75.000000	5.1076718	9.1140505	-2.6157600E-02
80.000000	4.6556681	10.326472	-0.1097795
85.000000	3.8846824	10.514505	-0.1769103
90.000000	2.9837244	9.6916710	-0.2157031
95.000000	2.1152926	8.1207087	-0.2042394
100.00000	1.3936460	6.2354569	-0.1051392
105.00000	0.8831912	4.5459146	0.1279789
110.00000	0.6042636	3.5349597	0.4517522
115.00000	0.5408755	3.5556094	0.5669629
120.00000	0.6502372	4.7521958	0.3688893
125.00000	0.8742473	7.0315315	0.1591130
130.00000	1.1498138	10.079298	7.4726537E-02
135.00000	1.4179195	13.421867	0.1040219
140.00000	1.6318933	16.532366	0.2156623
145.00000	1.7625985	18.946604	0.3835882
150.00000	1.8008391	20.368075	0.5825254
155.00000	1.7560279	20.728001	0.7800936
160.00000	1.6520144	20.189225	0.9302291
165.00000	1.5210953	19.095482	0.9704754
170.00000	1.3970447	17.876693	0.8344227
175.00000	1.3094758	16.948968	0.4914119

RUN NUMBER 1 STANDARD POTENTIAL CASE WITHOUT EXPERIMENTAL DATA

L	REAL C(L+1/2)	IMAG C(L+1/2)	REAL C(L-1/2)	IMAG C(L-1/2)
0	0.4108870	0.5872918	0.4158149	0.5329699
1	0.1612435	0.2797029	4.7274854E-03	0.2355706
2	-0.2608620	0.1779562	-0.4199165	0.3899489
3	-0.2886678	0.4682251	0.1319349	0.4436573
4	0.1623717	0.1346650	7.0444219E-02	4.4456440E-02
5	3.0956736E-02	7.5457897E-03	1.1048209E-02	4.1612677E-03
6	3.1027100E-03	5.1497504E-04	-7.9829085E-04	3.7459059E-04
7	-1.9256093E-03	3.9758640E-05	-2.7292777E-03	3.6686320E-05
8	-2.5147565E-03	8.5630705E-06	-2.6822239E-03	9.1137080E-06
9	-2.2513660E-03	5.1906080E-06	-2.2862279E-03	5.3355428E-06
10	-1.8607633E-03	3.4660762E-06	-1.8680033E-03	3.4963492E-06
11	-1.4754299E-03	2.1772815E-06	-1.4769507E-03	2.1809079E-06
12	-1.1506343E-03	1.3242082E-06	-1.1509994E-03	1.3236396E-06
13	-8.7950244E-04	7.7337465E-07	-8.7961549E-04	7.7345572E-07
14	-6.3914633E-04	4.0864590E-07	-6.3918725E-04	4.0775446E-07
15	-4.5268404E-04	2.0605891E-07	-4.5271553E-04	2.0506866E-07
16	-3.2030407E-04	1.0182136E-07	-3.2031742E-04	1.0288596E-07
17	-2.0949129E-04	4.4049870E-08	-2.0949131E-04	4.4741154E-08
18	-1.1748969E-04	1.3565904E-08	-1.1750402E-04	1.3254814E-08
19	-6.1564481E-05	3.8641117E-09	-6.1572863E-05	3.7338010E-09
20	-3.7483953E-05	1.0725489E-09	-3.7488161E-05	1.3887664E-09
21	-2.5147821E-05	5.8122986E-10	-2.5166588E-05	2.6101841E-10
22	-1.3541272E-05	3.4524781E-10	-1.3554924E-05	1.4652123E-10
23	-3.6835778E-06	4.0009485E-11	-3.6806699E-06	2.1660470E-10
24	1.6714246E-06	8.0880384E-11	1.6714222E-06	1.9599967E-10
25	2.8766948E-06	8.7511669E-11	2.8766967E-06	-4.1383439E-12

RUN NUMBER 1 STANDARD POTENTIAL CASE WITHOUT EXPERIMENTAL DATA

L	ETA1	ETA2	DELR1-DELPR	DELPI	DELR2-DELMR	DELMI
0	0.8401144	0.8342400	0.8900657	8.7108624E-02	0.8249604	9.0617098E-02
1	0.5460046	0.5289432	0.3159200	0.3025639	8.9380804E-03	0.3184371
2	0.8288815	0.8681960	2.8011822	9.3839015E-02	2.4843516	7.0668893E-02
3	0.5808226	0.2869239	2.4110109	0.2716549	0.5835958	0.6242692
4	0.7995855	0.9219161	0.2091128	0.1118309	7.6711250E-02	4.0650533E-02
5	0.9868525	0.9919236	3.1389777E-02	6.6173484E-03	1.1139087E-02	4.0545914E-03
6	0.9989893	0.9992521	3.1058690E-03	5.0559862E-04	3.1407938	3.7409572E-04
7	0.9999279	0.9999415	3.1396669	3.6054659E-05	3.1388632	2.9240658E-05
8	0.9999955	0.9999962	3.1390779	2.2426297E-06	3.1389104	1.9222535E-06
9	0.9999997	0.9999998	3.1393413	1.2665988E-07	3.1393065	1.1175872E-07
10	1.0000000	1.0000000	3.1397319	7.4505806E-09	3.1397247	1.1175871E-08
11	1.0000000	1.0000000	3.1401173	3.7252903E-09	3.1401157	-0
12	1.0000000	1.0000000	3.1404421	3.7252903E-09	3.1404417	-0
13	1.0000000	1.0000000	3.1407132	-0	3.1407131	-0
14	1.0000000	1.0000000	3.1409535	-0	3.1409535	-0
15	1.0000000	1.0000000	3.1411400	3.7252903E-09	3.1411400	3.7252903E-09
16	1.0000000	1.0000000	3.1412724	-0	3.1412724	-0
17	1.0000000	1.0000000	3.1413832	-0	3.1413832	7.4505806E-09
18	1.0000000	1.0000000	3.1414752	-0	3.1414752	-0
19	1.0000000	1.0000000	3.1415311	3.7252903E-09	3.1415311	3.7252903E-09
20	1.0000000	1.0000000	3.1415552	3.7252903E-09	3.1415552	3.7252903E-09
21	1.0000000	1.0000000	3.1415676	3.7252903E-09	3.1415675	3.7252903E-09
22	1.0000000	1.0000000	3.1415792	3.7252903E-09	3.1415792	3.7252903E-09
23	1.0000000	1.0000000	3.1415890	3.7252903E-09	3.1415890	3.7252903E-09
24	1.0000000	1.0000000	1.6714246E-06	3.7252903E-09	1.6714222E-06	3.7252903E-09
25	1.0000000	1.0000000	2.8766948E-06	3.7252903E-09	2.8766967E-06	-0

```
RUN NUMBER  1          EXAMPLE 1     SILICON 28 (P,P) E=18.82      SINGLE CASE SEARCH

                                                CONTROLS
                    N =    1    2    3    4    5    6    7    8    9   10   11   12   13

                 KL(N)=    1    1    0    3    0    0    0    0    0    0    0    0    0
                 KT(N)=    4    0    0    0    0    0    0    0    0    0    0    0    0
                 KX(N)=    1    0    0    3    0    0    2    0    0    0    0    0    0

                                             BASIC INPUT DATA

   FMI=   1.00783           FMB=  27.97693          ELAB=  18.820              ZZ=  14.

 XNORM= 1.0000000          SNORM=  1.               JMAX=  44                  NP= 10

                                         NUCLEAR POTENTIAL PARAMETERS

    VO= 60.000000            WI= 6.0000000            AO= 0.8000000            RO= 1.0500000
                            WVI= 0                    AI= 0.8000000            RI= 1.2000000
    VS= 6.0000000            WS= 0                    AS= 0.5000000            RS= 0.9500000
 VSODD= 0                                                                      RC= 1.2500000

                                          BASIC COMPUTED QUANTITIES

RHORO= 2.9310011        RHORI= 3.3497156        RHORS= 2.6518582        RHORC= 3.4892870

  ECM= 18.165609            K= 0.9195175          KAS= 0.4597588          KAI= 0.7356140

  ETA= 0.5101995
                                              INTEGRATION DATA

RHOMAX= 15.000000              LMAXM=15                               NMAX= 4

RHOIN=      0.0500     0.5000     5.0000     15.0000

DRHOIN=           0.0500     0.1000     0.2000




RUN NUMBER  1          EXAMPLE 1     SILICON 28 (P,P) E=18.82      SINGLE CASE SEARCH

VARIABLE METRIC MINIMIZATION

N= 6  K= 0  E=    1.00000E-01  P=    0.           DELTA=    2.50000E-23
NHP= 5     NMLR= 5     NPCT= 5      PCT= 0.5000
       VO             WI             VS            AO            AI            AS
X=    60.0000       6.00000       6.00000       0.80000       0.80000       0.50000

H

   5.0C000E-03  0.            0.            0.            0.            0.

   0.           5.00000E-03   0.            0.            0.            0.

   0.           0.            1.00000E-03   0.            0.            0.

   0.           0.            0.            1.00000E-05   0.            0.

   0.           0.            0.            0.            1.00000E-05   0.

   0.           0.            0.            0.            0.            1.00000E-05

IT     0  STEP     0  F=    8.24182E 02
       VO             WI             VS            AO            AI            AS
X=    60.0000       6.00000       6.00000       0.80000       0.80000       0.50000
G=    52.5208      -860.764      -49.7360      6317.90      -5573.81       299.988
ENORM=  1.34307          SIGMAR(TH)=   95.4705          CHI2T=  824.182          CHI2ST=   536.556          CHI2PT=   287.626

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IT     1  STEP     0  F=    5.00752E 02   GS=   -4.43157E 03

DELTA=    5.15794E-24
       VO             WI             VS            AO            AI            AS
X=    59.9574       6.69885       6.00808       0.78974       0.80905       0.49951
G=   -0.33951       31.1241      -35.8391      2025.79       354.729       253.906
ENORM=  1.15326          SIGMAR(TH)=   99.7806          CHI2T=  500.752          CHI2ST=   311.254          CHI2PT=   189.498

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IT     2  STEP     0  F=    4.78168E 02   GS=   -4.81788E 01

DELTA=    4.85679E-24
       VO             WI             VS            AO            AI            AS
X=    59.9575       6.60671       6.04225       0.77005       0.80651       0.49711
G=   -0.45776       5.70679      -22.8806      -42.9916      -149.574       46.7300
ENORM=  1.16026          SIGMAR(TH)=   98.2166          CHI2T=  478.168          CHI2ST=   282.282          CHI2PT=   195.886

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UNDERSHOT

IT    3  STEP    0  F=    4.76723E 02  GS=  -8.96794E-01

DELTA=    9.71357E-24
      VO              WI              VS              AO              AI              AS
X=   59.9614        6.57218         6.08883         0.76997         0.80976         0.49609
G=  -0.78201       -1.23215       -12.1346          3.70026       -182.610        -13.8855
ENORM=  1.16164          SIGMAR(TH)=  98.3731           CHI2T=  476.723           CHI2ST=  280.158          CHI2PT=  196.565

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UNDERSHOT

IT    4  STEP    0  F=    4.75603E 02  GS=  -7.66493E-01

DELTA=    1.94271E-23
      VO              WI              VS              AO              AI              AS
X=   59.9719        6.53323         6.14188         0.76961         0.81487         0.49569
G=   0.37384       -0.19836        -0.98419        14.7247        -130.577        -70.7245
ENORM=  1.16142          SIGMAR(TH)=  98.6894           CHI2T=  475.603           CHI2ST=  277.742          CHI2PT=  197.861

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UNDERSHOT

IT    5  STEP    0  F=    4.74988E 02  GS=  -3.98690E-01

DELTA=    3.88543E-23
      VO              WI              VS              AO              AI              AS
X=   59.9739        6.49360         6.17759         0.76908         0.82017         0.49669
G=   1.52969        1.75476         4.82559        23.8037         -79.8416        -98.8770
ENORM=  1.16131          SIGMAR(TH)=  99.0121           CHI2T=  474.988           CHI2ST=  276.564          CHI2PT=  198.423

ERROR MATRIX

   5.04116E-03  -1.65115E-04   2.80492E-04  -6.19368E-06   2.81032E-05  -1.58117E-06

  -1.65115E-04   3.41031E-03  -2.06964E-03   5.26835E-05  -2.82769E-04  -8.86554E-06

   2.80492E-04  -2.06964E-03   3.34332E-03  -2.73925E-05   2.48465E-04   1.20495E-06

  -6.19368E-06   5.26835E-05  -2.73925E-05   9.54302E-06  -2.76653E-06  -1.74292E-07

   2.81032E-05  -2.82769E-04   2.48465E-04  -2.76653E-06   3.80278E-05   1.67708E-06

  -1.58117E-06  -8.86554E-06   1.20495E-06  -1.74292E-07   1.67708E-06   1.09893E-05

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UNDERSHOT

IT    6  STEP    0  F=    4.74410E 02  GS=  -3.42403E-01

DELTA=    7.77086E-23
      VO              WI              VS              AO              AI              AS
X=   59.9608        6.45270         6.19294         0.76825         0.82521         0.49917
G=   3.14713        0.89264         5.29099        27.1988         -50.3159        -86.3266
ENORM=  1.16185          SIGMAR(TH)=  99.2832           CHI2T=  474.410           CHI2ST=  276.579          CHI2PT=  197.831

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UNDERSHOT

IT    7  STEP    0  F=    4.73741E 02  GS=  -3.94979E-01

DELTA=    1.55417E-22
      VO              WI              VS              AO              AI              AS
X=   59.9200        6.40765         6.19710         0.76707         0.83076         0.50301
G=   3.28445        0.22888         2.38419        14.6866         -33.3023        -61.5692
ENORM=  1.16227          SIGMAR(TH)=  99.5622           CHI2T=  473.741           CHI2ST=  277.513          CHI2PT=  196.227

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UNDERSHOT

IT    8  STEP    0  F=    4.73141E 02  GS=  -4.24909E-01

DELTA=    3.10834E-22
      VO              WI              VS              AO              AI              AS
X=   59.8513        6.34207         6.20859         0.76545         0.83893         0.50854
G=   2.78473       -1.94550         0.15259         7.82013        -17.6620        -30.0980
ENORM=  1.16285          SIGMAR(TH)=  99.9777           CHI2T=  473.141           CHI2ST=  278.962          CHI2PT=  194.179

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UNDERSHOT

IT    9  STEP    0  F=    4.72937E 02  GS=  -1.91945E-01

DELTA=    6.21668E-22
      VO              WI              VS              AO              AI              AS
X=   59.7770        6.29418         6.21655         0.76418         0.84546         0.51340
G=   0.51117       -0.40817        -2.03705        -6.17981          1.71661        -10.3760
ENORM=  1.16243          SIGMAR(TH)= 100.329            CHI2T=  472.937           CHI2ST=  280.560          CHI2PT=  192.377
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H

1.61791E-02	8.67207E-03	-1.20793E-03	2.20589E-04	-1.12486E-03	-8.18465E-04
8.67207E-03	1.14332E-02	-3.58654E-03	2.52970E-04	-1.31386E-03	-7.09034E-04
-1.20793E-03	-3.58654E-03	3.68662E-03	-6.39499E-05	4.42508E-04	1.26851E-04
2.20589E-04	2.52970E-04	-6.39499E-05	1.45785E-05	-2.85654E-05	-1.78690E-05
-1.12486E-03	-1.31386E-03	4.42508E-04	-2.85654E-05	1.70831E-04	9.22064E-05
-8.18465E-04	-7.09034E-04	1.26851E-04	-1.78690E-05	9.22064E-05	7.36106E-05

FINAL VALUES

ERROR MATRIX

1.61791E-02	8.67207E-03	-1.20793E-03	2.20589E-04	-1.12486E-03	-8.18465E-04
8.67207E-03	1.14332E-02	-3.58654E-03	2.52970E-04	-1.31386E-03	-7.09034E-04
-1.20793E-03	-3.58654E-03	3.68662E-03	-6.39499E-05	4.42508E-04	1.26851E-04
2.20589E-04	2.52970E-04	-6.39499E-05	1.45785E-05	-2.85654E-05	-1.78690E-05
-1.12486E-03	-1.31386E-03	4.42508E-04	-2.85654E-05	1.70831E-04	9.22064E-05
-8.18465E-04	-7.09034E-04	1.26851E-04	-1.78690E-05	9.22064E-05	7.36106E-05

DELTA= 6.21668E-22 F= 4.72937E 02 GS= -2.14612E-02

	VO	WI	VS	AO	AI	AS
X=	59.7770	6.29418	6.21655	0.76418	0.84546	0.51340
G=	0.51117	-0.40817	-2.03705	-6.17981	1.71661	-10.3760

ENORM= 1.16243 SIGMAR(TH)= 100.329 CHI2T= 472.937 CHI2ST= 280.560 CHI2PT= 192.377

SUM OF CHI SQUARES / 34. CHI2T= 13.9099 CHI2ST= 8.25177 CHI2PT= 5.65814

RUN NUMBER 2 EXAMPLE 2 SILICON 28 (P,P) E=18.82 SEARCH WITH GRID ON AO AND AS

CONTROLS

N =	1	2	3	4	5	6	7	8	9	10	11	12	13
KL(N)=	1	1	0	3	0	0	0	0	0	0	0	0	0
KT(N)=	3	0	0	0	0	0	0	0	0	0	0	0	0
KX(N)=	1	0	0	3	0	0	2	0	0	0	0	0	0

BASIC INPUT DATA

FMI= 1.00783 FMB= 27.97693 ELAB= 18.820 ZZ= 14.

XNORM= 1.0000000 SNORM= 1. JMAX= 44 NP= 10

NUCLEAR POTENTIAL PARAMETERS

VO= 60.000000 WI= 6.0000000 AO= 0.7000000 RO= 1.0500000
WVI= 0 AI= 0.8000000 RI= 1.2000000
VS= 6.0000000 WS= 0 AS= 0.5000000 RS= 0.9500000
VSODD= 0 RC= 1.2500000

BASIC COMPUTED QUANTITIES

RHORO= 2.9310011 RHORI= 3.3497156 RHORS= 2.6518582 RHORC= 3.4892870

ECM= 18.165609 K= 0.9195175 KAS= 0.4597588 KAI= 0.7356140

ETA= 0.5101995

INTEGRATION DATA

RHOMAX= 15.000000 LMAXM=15 NMAX= 4

RHOIN= 0.0500 0.5000 5.0000 15.0000

DRHOIN= 0.0500 0.1000 0.2000

VO= 60.000000 WI= 6.0000000 AO= 0.7000000 RO= 1.0500000
WVI= 0 AI= 0.8000000 RI= 1.2000000
VS= 6.0000000 WS= 0 AS= 0.5000000 RS= 0.9500000
VSODD= 0

VARIABLE METRIC MINIMIZATION

N= 4 K= 0 E= 1.00000E-01 P= 0. DELTA= 2.50000E-13
NHP= 5 NMLR= 5 NPCT= 5 PCT= 0.5000

	VO	WI	VS	AI
X=	60.0000	6.00000	6.00000	0.80000

```
H

   5.0C000E-03   0.             0.             0.

   0.            5.00000E-03    0.             0.

   0.            0.             1.00000E-03    0.

   0.            0.             0.             1.00000E-05

IT     0  STEP     0  F=     8.39127E 02
      VO             WI             VS             AI
X=    60.0000        6.00000        6.00000        0.80000
G=    18.7988        -545.662       -6.73676       -4952.93
ENORM=  1.29809        SIGMAR(TH)=   91.3161        CHI2T=   839.127        CHI2ST=   438.634        CHI2PT=   400.492

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UNDERSHOT

IT     8  STEP     0  F=     6.09582E 02   GS=  -2.03440E-01

DELTA=    5.49510E-13
      VO             WI             VS             AI
X=    58.9726        5.28248        6.02324        1.00881
G=    9.15527E-02   -2.31934        5.39398        -0.45776
ENORM=  1.15287        SIGMAR(TH)=   108.857        CHI2T=   609.582        CHI2ST=   286.220        CHI2PT=   323.362

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    VO= 60.000000              WI= 6.0000000              AO= 0.8000000              RO= 1.0500000
                              WVI= 0                      AI= 0.8000000              RI= 1.2000000
    VS= 6.0000000              WS= 0                      AS= 0.5000000              RS= 0.9500000
 VSODD= 0

VARIABLE METRIC MINIMIZATION

N= 4   K= 0   E=    1.00000E-01   P=    0.             DELTA=    5.49510E-13
NHP= 5      NMLR= 5      NPCT= 5      PCT= 0.5000
      VO             WI             VS             AI
X=    6C.0000        6.00000        6.00000        0.80000

H

   8.46098E-03   2.22449E-03   -1.36860E-03   -5.17742E-04

   2.22449E-03   2.45093E-03   -5.73725E-04   -3.98457E-04

  -1.36860E-03  -5.73725E-04    1.88324E-03    1.67550E-04

  -5.17742E-04  -3.98457E-04    1.67550E-04    9.15804E-05

IT     0  STEP     0  F=     8.24182E 02
      VO             WI             VS             AI
X=    60.0000        6.00000        6.00000        0.80000
G=    52.5208        -860.764       -49.7360       -5570.22
ENORM=  1.34307        SIGMAR(TH)=   95.4705        CHI2T=   824.182        CHI2ST=   536.556        CHI2PT=   287.626

- - - - - - - - - -


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COLINEAR

IT     5  STEP     0  F=     5.19893E 02   GS=  -5.06950E-01

DELTA=    5.58919E-13
      VO             WI             VS             AI
X=    60.2413        6.96744        6.19267        0.77580
G=   -1.57928        -2.81525       -1.43433       -31.4331
ENORM=  1.15890        SIGMAR(TH)=   98.1721        CHI2T=   519.893        CHI2ST=   307.338        CHI2PT=   212.555

    VO= 60.000000              WI= 6.0000000              AO= 0.7000000              RO= 1.0500000
                              WVI= 0                      AI= 0.8000000              RI= 1.2000000
    VS= 6.0000000              WS= 0                      AS= 0.5500000              RS= 0.9500000
 VSODD= 0

VARIABLE METRIC MINIMIZATION

N= 4   K= 0   E=    1.00000E-01   P=    0.             DELTA=    5.58919E-13
NHP= 5      NMLR= 5      NPCT= 5      PCT= 0.5000
      VO             WI             VS             AI
X=    60.0000        6.00000        6.00000        0.80000

H

   6.78425E-03   1.70795E-03   -7.69296E-04   -3.42263E-04

   1.70795E-03   5.15069E-03    4.09421E-04   -6.01555E-04
```

```
  -7.69296E-04   4.09421E-04   1.72424E-03  -1.20906E-05

  -3.42263E-04  -6.01555E-04  -1.20906E-05   8.48659E-05

IT     0  STEP     0  F=    8.29891E 02
      VO              WI              VS              AI
X=   60.0000         6.00000         6.00000         0.80000
G=   32.6233        -542.244        -57.2357        -4910.58
ENORM=  1.30165          SIGMAR(TH)=  91.3337          CHI2T=   829.891         CHI2ST=  448.990         CHI2PT=  380.901

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RICOCHET

IT     4  STEP     0  F=    5.89731E 02  GS=  -1.08734E-01

DELTA=    5.58886E-13
      VO              WI              VS              AI
X=    58.8634        5.25787         6.23021         1.01314
G=  -0.64087         1.31989        -1.92261        -0.99182
ENORM=  1.15455          SIGMAR(TH)=  109.168          CHI2T=   589.731         CHI2ST=  289.685         CHI2PT=  300.047

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    VO= 60.000000              WI= 6.0000000             AO= 0.8000000            RO= 1.0500000
                              WVI= 0                     AI= 0.8000000            RI= 1.2000000
    VS= 6.0000000              WS= 0                     AS= 0.5500000            RS= 0.9500000
 VSODD= 0

VARIABLE METRIC MINIMIZATION

N= 4  K= 0  E=    1.00000E-01  P=    0.           DELTA=    5.58886E-13
NHP= 5     VMLR= 5     NPCT= 5      PCT= 0.5000
      VO              WI              VS              AI
X=    60.0000        6.00000         6.00000         0.80000

H

   8.67082E-03   3.27192E-03  -1.09463E-03  -6.87075E-04

   3.27192E-03   4.12951E-03  -5.04715E-04  -6.34927E-04

  -1.09463E-03  -5.04715E-04   1.56702E-03   1.04119E-04

  -6.87075E-04  -6.34927E-04   1.04119E-04   1.18829E-04

IT     0  STEP     0  F=    8.47453E 02
      VO              WI              VS              AI
X=   60.0000         6.00000         6.00000         0.80000
G=   63.6749        -858.528        -86.1053        -5461.43
ENORM=  1.34704          SIGMAR(TH)=  95.4813          CHI2T=   847.453         CHI2ST=  551.122         CHI2PT=  296.331

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RICOCHET

IT     5  STEP     0  F=    5.31088E 02  GS=  -4.27264E-01

DELTA=    9.33008E-13
      VO              WI              VS              AI
X=    60.2372        7.01321         6.47004         0.76998
G=  -0.69427         2.74658         3.73077        -3.96729
ENORM=  1.16036          SIGMAR(TH)=  97.8084          CHI2T=   531.088         CHI2ST=  307.648         CHI2PT=  223.440



RUN NUMBER  1          EXAMPLE 3     SILICON 28 (P,P) E=18.82      SINGLE CASE

                                                CONTROLS
                   N =    1    2    3    4    5    6    7    8    9   10   11   12   13

                KL(N)=    1    1    0    3    0    2    0    0    0    0    0    1    0
                KT(N)=    1    0    0    0    0    0    0    0    0    0    0    0    0
                KX(N)=    1    0    0    3    0    0    2    0    0    0    0    0    0

                                           BASIC INPUT DATA

  FMI=    1.00783          FMB=   27.97693          ELAB=  18.820              ZZ=  14.

 XNORM= 1.0000000          SNORM=   1.              JMAX=  44                  NP= 10
```

NUCLEAR POTENTIAL PARAMETERS

VO= 59.780000	WI= 6.2940000	AO= 0.7642000	RO= 1.0500000
	WVI= 0	AI= 0.8455000	RI= 1.2000000
VS= 6.2170000	WS= 0	AS= 0.5134000	RS= 0.9500000
VSODD= 0			RC= 1.2500000

BASIC COMPUTED QUANTITIES

RHORO= 2.9310011	RHORI= 3.3497156	RHORS= 2.6518582	RHORC= 3.4892870
ECM= 18.165609	K= 0.9195175	KAS= 0.4720803	KAI= 0.7774521
ETA= 0.5101995			

INTEGRATION DATA

RHOMAX= 15.000000 LMAXM=15 NMAX= 4

RHOIN= 0.C500 0.5000 5.0000 15.0000

DRHOIN= 0.0500 0.1000 0.2000

SUM OF CHI SQUARES

CHISQ SIGMA= 280.52768 CHISQ POL= 192.41044 CHISQ TOTAL= 472.93813

SUM OF CHI SQUARES / 34.

CHISQ SIGMA= 8.2508142 CHISQ POL= 5.6591307 CHISQ TOTAL= 13.909945

REACTION CROSS SECTION AND DATA NORMALIZATION FACTOR

SIGMAR(TH)= 100.33423 ENORM= 1.1624686

RUN NUMBER 1 EXAMPLE 3 SILICON 28 (P,P) E=18.82 SINGLE CASE

THETA	SIGMA TH	SIGTH/SIGC	POL TH	SIGMA EX	SIGEX/SIGC	POL EX
5.180	15679.710	0.8494833	1.3878863E-03	15700.000	0.8505825	1.0000000
7.770	2666.1137	0.7299965	2.5145114E-03	2350.0000	0.6434428	1.0000000
12.950	339.09003	0.7124991	-1.2503671E-02	262.37600	0.5513068	1.000000C
15.530	193.01440	0.8356875	-3.1285520E-02	135.01600	0.5845739	-7.6999999E-02
18.120	126.24218	1.0085123	-5.2990013E-02	87.076999	0.6956330	1.0000000
20.710	86.685940	1.1756859	-7.6033229E-02	64.942999	0.8807953	1.0000000
23.3C0	59.235816	1.2797077	-0.1013589	0.1000000	2.1603614E-03	-0.1870000
25.870	39.155144	1.2772691	-0.1309221	20.406000	0.6656585	1.0000000
31.030	13.803928	0.9181994	-0.2197211	9.0890000	0.6045753	-0.2660000
36.180	2.7465358	0.3317344	-0.4195832	3.7120000	0.4483459	1.000000C
38.8C0	0.7360464	0.1164127	-0.5821097	0.1000000	1.5815947E-02	-0.617000C
41.330	0.2475967	4.9896246E-02	0.3617011	0.5470000	0.1102327	1.0000000
46.460	1.5288198	0.4807349	0.3994871	1.0110000	0.3179073	0.4000000
51.580	3.4064788	1.5858350	0.1692597	2.5090000	1.1680272	1.0000000
54.1C0	4.0447513	2.2477649	0.1075874	0.1000000	5.5572388E-02	0.1610000
56.690	4.4045787	2.9078532	5.6533065E-02	3.6320000	2.3978055	1.000000C
61.790	4.2878773	3.8724900	-3.0094878E-02	3.7420000	3.3794944	-0.1180000
66.870	3.4453608	4.1258313	-0.1160490	3.2140000	3.8487759	1.000000C
69.4C0	2.9169364	3.9804220	-0.1622959	0.1000000	0.1364590	-0.2360000
71.940	2.3880696	3.6929128	-0.2114980	2.3060000	3.5660003	1.0000000
76.990	1.4857117	2.8976247	-0.3095006	1.3630000	2.6582967	-0.404000C
82.030	0.8912685	2.1478465	-0.3556238	0.7550000	1.8194562	1.0000000
84.5C0	0.7130025	1.8932853	-0.3218145	0.1000000	0.2655370	-0.451000C
87.060	0.5936940	1.7356793	-0.2286860	0.4780000	1.3974448	1.000000C
92.060	0.4984139	1.7374185	7.0789014E-02	0.4540000	1.5825962	0.1430000
97.060	0.4978162	2.0389090	0.3360890	0.5190000	2.1256716	1.0000000
99.5C0	0.5068773	2.2347560	0.4199099	0.1000000	0.4408870	0.5800000
102.030	0.5137956	2.4370749	0.4788090	0.5820000	2.7605874	1.0000000
106.990	0.5078257	2.7543385	0.5325628	0.6070000	3.2922389	0.6100000
111.940	0.4733559	2.9011540	0.5226408	0.5240000	3.2115465	1.0000000
114.4C0	0.4486754	2.9101862	0.4946923	0.1000000	0.6486172	0.579000C
116.870	0.4214045	2.8857124	0.4499449	0.4300000	2.9445730	1.0000000
121.790	0.3668571	2.7778288	0.3097377	0.3420000	2.5896114	0.3400000
126.690	0.3206657	2.6580683	0.1185059	0.2850000	2.3624276	1.000000C
129.100	0.3024719	2.6125239	2.0539314E-02	0.1000000	0.8637245	8.0000000E-02
131.580	0.2869613	2.5798543	-7.0468131E-02	0.2690000	2.4183773	1.000000C
136.460	0.2648081	2.5591511	-0.1827467	0.2690000	2.5996619	-3.4000000E-02
141.330	0.2510328	2.5857115	-0.1651732	0.2800000	2.8840823	1.000000C
143.8C0	0.2462748	2.6119042	-0.1033306	0.1000000	1.0605648	9.8000000E-02
146.180	0.2427934	2.6433458	-1.4842476E-02	0.2840000	3.0919714	1.000000C
151.030	0.2386700	2.7250951	0.2219047	0.2910000	3.3225909	C.434000C
155.870	0.2384857	2.8337388	0.4635839	0.2650000	3.1487874	0.6800000
160.710	0.2421985	2.9726298	0.6239240	0.2530000	3.1052019	1.000000C
165.530	0.2489115	3.1322618	0.6461486	0.2550000	3.2088786	0.7400000

RUN NUMBER 1 EXAMPLE 3 SILICON 28 (P,P) E=18.82 SINGLE CASE

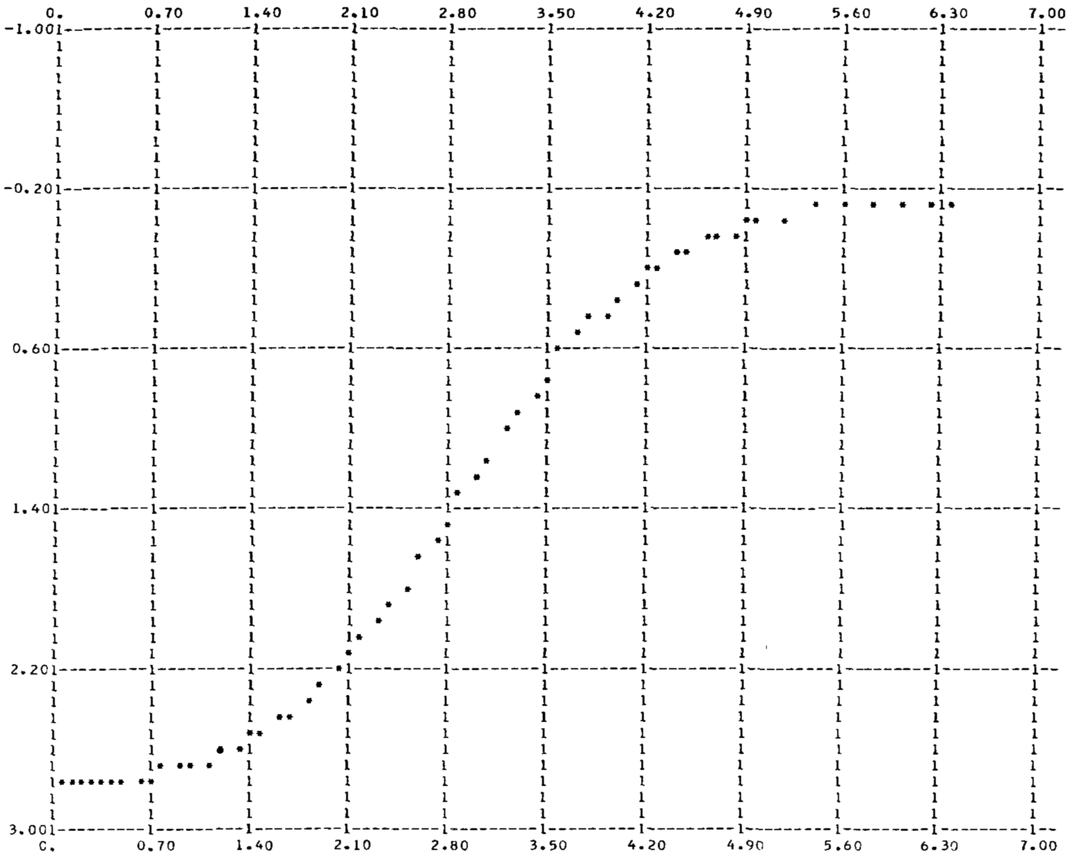
AR	AI	BR	BI
110.89297	-58.158817	-0.1066592	-1.6281780E-02
28.684781	-42.933341	-0.1571137	-2.6897145E-02
-4.4477044	-17.867395	-0.2467559	-5.7223670E-02
-7.4116112	-11.747162	-0.2837676	-7.7985012E-02
-8.0776906	-7.8027890	-0.3145912	-0.1029910
-7.7054700	-5.2134228	-0.3382819	-0.1321368
-6.8529771	-3.4813522	-0.3541798	-0.1651236
-5.7992061	-2.3136658	-0.3617489	-0.2011009
-3.5643085	-0.9476917	-0.3510967	-0.2797219
-1.5654698	-0.2704655	-0.3060035	-0.3592358
-0.7086644	-5.6611151E-02	-0.2706070	-0.3967471
1.1170655E-03	0.1037110	-0.2292403	-0.4292881
1.0768472	0.3515894	-0.1271914	-0.4789854
1.6900079	0.5484719	-8.4916171E-03	-0.4994584
1.8419744	0.6342305	5.2941335E-02	-0.4968207
1.9092615	0.7147209	0.1162452	-0.4847271
1.8252724	0.8446249	0.2356366	-0.4328305
1.5354735	0.9236042	0.3385726	-0.3464188
1.3427649	0.9398961	0.3808843	-0.2923032
1.1308299	0.9393402	0.4160517	-0.2320222
0.6903431	0.8867367	0.4613636	-9.9899782E-02
0.2741723	0.7697713	0.4712799	3.8019395E-02
9.2433609E-02	0.6922601	0.4630767	0.1038965
-7.5164065E-02	0.6006489	0.4458346	0.1688100
-0.3322382	0.3983853	0.3886201	0.2798129
-0.4903354	0.1827994	0.3053906	0.3615360
-0.5323327	7.9092240E-02	0.2576258	0.3884231
-0.5533283	-2.4104075E-02	0.2045954	0.4064272
-0.5361774	-0.2051836	9.4762875E-02	0.4114112
-0.4591263	-0.3467726	-1.5269644E-02	0.3769279
-0.4055650	-0.3996956	-6.7573149E-02	0.3462221
-0.3454292	-0.4402976	-0.1173013	0.3073460
-0.2176284	-0.4830369	-0.2050890	0.2100211
-9.5982666E-02	-0.4768410	-0.2739569	9.4990802E-02
-4.3192271E-02	-0.4574650	-0.3001632	3.5130587E-02
4.1713044E-03	-0.4275293	-0.3216287	-2.6787462E-02
7.2572336E-02	-0.3435374	-0.3476012	-0.1438640
0.1046149	-0.2348674	-0.3530480	-0.2455258
0.1070159	-0.1735779	-0.3486922	-0.2882827
0.1010939	-0.1122627	-0.3404299	-0.3226112
6.7286364E-02	1.4721980E-02	-0.3128545	-0.3688466
1.1834987E-02	0.1368083	-0.2737513	-0.3803805
-5.4751443E-02	0.2465954	-0.2262742	-0.3566392
-0.1210144	0.3375969	-0.1734201	-0.3003678

RUN NUMBER 1 EXAMPLE 3 SILICON 28 (P,P) E=18.82 SINGLE CASE

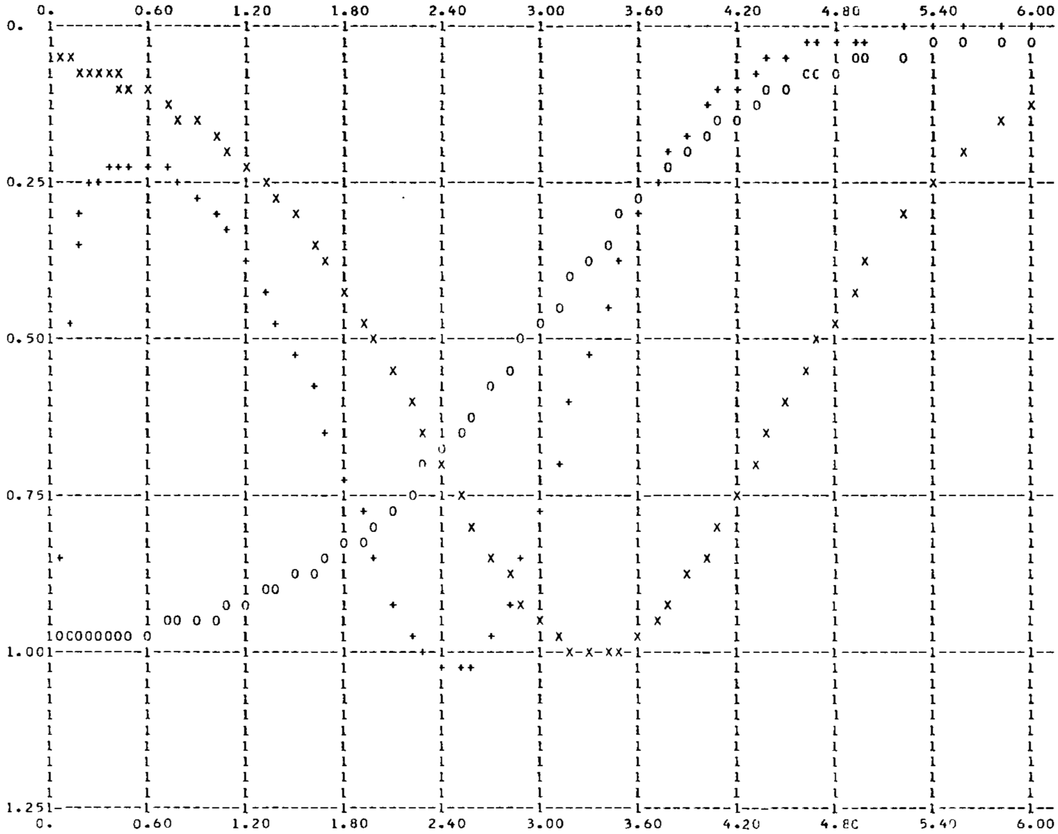
RHO(I)	FFCR	FFCI	FFSR	FFSI
4.9999999E-02	0.9836964	5.5773134E-02	8.0154006E-02	8.0154006E-02
0.1000000	0.9825150	5.9366311E-02	4.4514633E-02	4.4514633E-02
0.1500000	0.9812497	6.3183208E-02	3.2959121E-02	3.2959121E-02
0.2000000	0.9798948	6.7236732E-02	2.7450663E-02	2.7450663E-02
0.2500000	0.9784440	7.1540345E-02	2.4384012E-02	2.4384012E-02
0.3000000	0.9768911	7.6108165E-02	2.2559364E-02	2.2559364E-02
0.3500000	0.9752291	8.0954888E-02	2.1464311E-02	2.1464311E-02
0.4000000	0.9734508	8.6095843E-02	2.0844365E-02	2.0844365E-02
0.4500000	0.9715486	9.1546956E-02	2.0559780E-02	2.0559780E-02
0.5000000	0.9695143	9.7324777E-02	2.0528306E-02	2.0528306E-02
0.6000000	0.9650152	0.1099296	2.1039957E-02	2.1039957E-02
0.7000000	0.9598795	0.1240539	2.2155285E-02	2.2155285E-02
0.8000000	0.9540258	0.1398492	2.3782535E-02	2.3782535E-02
0.9000000	0.9473649	0.1574732	2.5890141E-02	2.5890141E-02
1.0000000	0.9397999	0.1770871	2.8477027E-02	2.8477027E-02
1.0999999	0.9312264	0.1988522	3.1557773E-02	3.1557773E-02
1.1999999	0.9215340	0.2229251	3.5153228E-02	3.5153228E-02
1.2999999	0.9106066	0.2494512	3.9282745E-02	3.9282745E-02
1.3999999	0.8983255	0.2785579	4.3956224E-02	4.3956224E-02
1.4999999	0.8845709	0.3103443	4.9165028E-02	4.9165028E-02
1.5999999	0.8692265	0.3448707	5.4871450E-02	5.4871450E-02
1.6999999	0.8521832	0.3821458	6.0997011E-02	6.0997011E-02
1.7999999	0.8333445	0.4221124	6.7410705E-02	6.7410705E-02
1.8999999	0.8126329	0.4646328	7.3919279E-02	7.3919279E-02
1.9999999	0.7899958	0.5094737	8.0262785E-02	8.0262785E-02
2.0999999	0.7654134	0.5562918	8.6119311E-02	8.6119311E-02
2.1999999	0.7389044	0.6046230	9.1122676E-02	9.1122676E-02
2.2999999	0.7105327	0.6538741	9.4894992E-02	9.4894992E-02
2.3999999	0.6804115	0.7033225	9.7092385E-02	9.7092385E-02
2.4999999	0.6487056	0.7521221	9.7457039E-02	9.7457039E-02
2.5999998	0.6156311	0.7993198	9.5864356E-02	9.5864356E-02
2.6999998	0.5814518	0.8438825	9.2352284E-02	9.2352284E-02
2.7999998	0.5464722	0.8847341	8.7123209E-02	8.7123209E-02
2.8999998	0.5110276	0.9208025	8.0516179E-02	8.0516179E-02
2.9999998	0.4754718	0.9510731	7.2956217E-02	7.2956217E-02
3.0999998	0.4401630	0.9746451	6.4893907E-02	6.4893907E-02
3.1999998	0.4054494	0.9907860	5.6749653E-02	5.6749653E-02
3.2999998	0.3716560	0.9989784	4.8873274E-02	4.8873274E-02
3.3999998	0.3390729	0.9989549	4.1523312E-02	4.1523312E-02
3.4999998	0.3079464	0.9907163	3.4864455E-02	3.4864455E-02

3.5999998	0.2784734	0.9745315	2.8977959E-02	2.8977959E-02
3.6999998	0.2507989	0.9509192	2.3879015E-02	2.3879015E-02
3.7999998	0.2250170	0.9206129	1.9535873E-02	1.9535873E-02
3.8999998	0.2011738	0.8845143	1.5887324E-02	1.5887324E-02
3.9999998	0.1792726	0.8436386	1.2856827E-02	1.2856827E-02
4.0999997	0.1592803	0.7990579	1.0362841E-02	1.0362841E-02
4.1999997	0.1411342	0.7518483	8.3257185E-03	8.3257185E-03
4.2999997	0.1247486	0.7030424	6.6718152E-03	6.6718152E-03
4.3999996	0.1100217	0.6535929	5.3355553E-03	5.3355553E-03
4.4999996	9.6840918E-02	0.6043451	4.2601188E-03	4.2601188E-03
4.5999995	8.5088283E-02	0.5560210	3.3972589E-03	3.3972589E-03
4.6999995	7.4644069E-02	0.5092129	2.7066355E-03	2.7066355E-03
4.7999995	6.5390212E-02	0.4643844	2.1549143E-03	2.1549143E-03
4.8999994	5.7212653E-02	0.4218779	1.7148030E-03	1.7148030E-03
4.9999994	5.0003048E-02	0.3819263	1.3641142E-03	1.3641142E-03
5.1999994	3.8089118E-02	0.3101560	8.6275637E-04	8.6275637E-04
5.3999994	2.8927412E-02	0.2492933	5.4558054E-04	5.4558054E-04
5.5999994	2.1919187E-02	0.1987222	3.4511169E-04	3.4511169E-04
5.7999994	1.6579851E-02	0.1573676	2.1842833E-04	2.1842833E-04
5.9999993	1.2524479E-02	0.1239691	1.3834852E-04	1.3834852E-04
6.1999993	9.4515034E-03	9.7257215E-02	8.7698380E-05	8.7698380E-05
6.3999993	7.1270635E-03	7.6054716E-02	5.5638407E-05	5.5638407E-05
6.5999993	5.3711812E-03	5.9324243E-02	3.5328551E-05	3.5328551E-05
6.7999993	4.0461296E-03	4.6182923E-02	2.2451173E-05	2.2451173E-05
6.9999993	3.0469625E-03	3.5897449E-02	1.4279202E-05	1.4279202E-05
7.1999993	2.2939652E-03	2.7869371E-02	9.0888244E-06	9.0888244E-06
7.3999993	1.7267341E-03	2.1616641E-02	5.7894372E-06	5.7894372E-06
7.5999992	1.2995802E-03	1.6754708E-02	3.6904180E-06	3.6904180E-06
7.7999992	9.7799071E-04	1.2979068E-02	2.3540257E-06	2.3540257E-06
7.9999992	7.3592195E-04	1.0049920E-02	1.5025522E-06	1.5025522E-06
8.1999992	5.5373597E-04	7.7792279E-03	9.5966017E-07	9.5966017E-07
8.3999991	4.1663346E-04	6.0200213E-03	6.1328548E-07	6.1328548E-07
8.5999991	3.1346628E-04	4.6577113E-03	3.9215102E-07	3.92151C2E-07
8.7999990	2.3583943E-04	3.6031290E-03	2.5088716E-07	2.5088716E-07
8.9999989	1.7743269E-04	2.7869873E-03	1.6059334E-07	1.6059334E-07
9.1999989	1.3348871E-04	2.1555093E-03	1.0284684E-07	1.0284684E-07
9.3999988	1.0042706E-04	1.6669925E-03	6.5896065E-08	6.5896065E-08
9.5999987	7.5553298E-05	1.2891200E-03	4.2240065E-08	4.2240065E-08
9.7999986	5.6839914E-05	9.9686047E-04	2.7088075E-08	2.7088075E-08
9.9999986	4.2761348E-05	7.7083432E-04	1.7378512E-08	1.7378512E-08
10.199998	3.2169758E-05	5.9604154E-04	1.1153746E-08	1.1153746E-08
10.399998	2.4201547E-05	4.6087531E-04	7.1613673E-09	7.1613673E-09
10.599998	1.8206966E-05	3.5635566E-04	4.5997231E-09	4.5997231E-09
10.799998	1.3697188E-05	2.7553626E-04	2.9554400E-09	2.95544C0E-09
10.999998	1.0304448E-05	2.1304427E-04	1.8995974E-09	1.8995974E-09
11.199998	7.7520704E-06	1.6472437E-04	1.2213622E-09	1.2213622E-09
11.399998	5.8319045E-06	1.2736307E-04	7.8553579E-10	7.8553579E-10
11.599998	4.3873556E-06	9.8475296E-05	5.0538352E-10	5.0538352E-10
11.799998	3.3006173E-06	7.6139446E-05	3.2524108E-10	3.25241C8E-10
11.999998	2.4830610E-06	5.8869584E-05	2.0936997E-10	2.0936997E-10
12.199998	1.8680114E-06	4.5516769E-05	1.3481684E-10	1.3481684E-10
12.399998	1.4053080E-06	3.5192586E-05	8.6834143E-11	8.6834143E-11
12.599998	1.0572155E-06	2.7210121E-05	5.5943534E-11	5.5943534E-11
12.799998	7.9534493E-07	2.1038235E-05	3.6051124E-11	3.6051124E-11
12.999997	5.9833920E-07	1.6266265E-05	2.3237728E-11	2.3237728E-11
13.199997	4.5013148E-07	1.2576686E-05	1.4982056E-11	1.4982056E-11
13.399997	3.3863453E-07	9.7239863E-06	9.6615942E-12	9.6615942E-12
13.599997	2.5475525E-07	7.5183473E-06	6.2319365E-12	6.2319365E-12
13.799997	1.9165274E-07	5.8129991E-06	4.0206018E-12	4.0206018E-12
13.999997	1.4418063E-07	4.4944660E-06	2.5944808E-12	2.59448C8E-12
14.199997	1.0846729E-07	3.4750082E-06	1.6745510E-12	1.6745510E-12
14.399997	8.1600083E-08	2.6867889E-06	1.0810171E-12	1.0810171E-12
14.599997	6.1387864E-08	2.0773573E-06	6.9799198E-13	6.9799198E-13
14.799997	4.6182171E-08	1.6061600E-06	4.5076471E-13	4.5076471E-13
15.000000	3.4742750E-08	1.2418371E-06	2.9115590E-13	2.9115590E-13

PLOT OF UCRB VS RHO   FLPT= 0.



PLOT OF FFSR, FFSI, FFCR, AND FFCI VS RHO



* FFSR + FFSI 0 FFCR X FFCI

RUN NUMBER 1 EXAMPLE 3 SILICON 28 (P,P) E=18.82 SINGLE CASE

THETA	DSIGMA EX	DPOL EX	CHI SQUARE SIGMA	CHI SQUARE POL	CHI SQUARE TOTAL
5.1800000	1570.0000	1.0000000E 30	1.6701521E-04	0	1.6701521E-04
7.7700000	235.00000	1.0000000E 30	1.8094685	0	1.8094685
12.950000	26.237000	1.0000000E 30	8.5491178	0	8.5491178
15.530000	13.502000	2.0000000E-02	18.451677	5.2245340	23.676211
18.120000	8.7079999	1.0000000E 30	20.228483	0	20.228483
20.710000	6.4939999	1.0000000E 30	11.210165	0	11.210165
23.300000	9.9999999E 28	2.5000000E-02	0	11.735032	11.735032
25.870000	2.0410000	1.0000000E 30	84.387260	0	84.387260
31.030000	0.9090000	2.0000000E-02	26.904341	5.3543460	32.258686
36.180000	0.3710000	1.0000000E 30	6.7721179	0	6.7721179
38.800000	9.9999999E 28	2.8000000E-02	0	1.5527248	1.5527248
41.330000	5.4999999E-02	1.0000000E 30	29.633835	0	29.633835
46.460000	0.1010000	3.9000000E-02	26.285394	1.7292219E-04	26.285567
51.580000	0.2510000	1.0000000E 30	12.785007	0	12.785007
54.100000	9.9999999E 28	2.1000000E-02	0	6.4691650	6.4691650
56.690000	0.3630000	1.0000000E 30	4.5297294	0	4.5297294
61.790000	0.3740000	4.0000000E-02	2.1303302	4.8295689	6.9598990
66.870000	0.3210000	1.0000000E 30	0.5194812	0	0.5194812
69.400000	9.9999999E 28	2.2000000E-02	0	11.223739	11.223739
71.940000	0.2310000	1.0000000E 30	0.1262237	0	0.1262237
76.990000	0.1360000	4.9000000E-02	0.8141308	3.7193409	4.5334716
82.030000	7.5999999E-02	1.0000000E 30	3.2148749	0	3.2148749
84.500000	9.9999999E 28	2.7000000E-02	0	22.892849	22.892849
87.060000	4.7999998E-02	1.0000000E 30	5.8095114	0	5.8095114
92.060000	4.4999999E-02	3.6000000E-02	0.9741228	4.0234771	4.9975998
97.060000	5.1999999E-02	1.0000000E 30	0.1659592	0	0.1659592
99.500000	9.9999999E 28	3.8000000E-02	0	17.748503	17.748503
102.03000	5.7999999E-02	1.0000000E 30	1.3828310	0	1.3828310
106.99000	6.0999999E-02	3.4000000E-02	2.6432534	5.1873049	7.8305584
111.94000	5.1999999E-02	1.0000000E 30	0.9485278	0	0.9485278
114.40000	9.9999999E 28	2.8000000E-02	0	9.0660667	9.0660667
116.87000	4.3000000E-02	1.0000000E 30	3.9958048E-02	0	3.9958048E-02
121.79000	3.3999999E-02	4.0000000E-02	0.5344959	0.5723782	1.1068741
126.69000	2.8999999E-02	1.0000000E 30	1.5125345	0	1.5125345
129.10000	9.9999999E 28	4.8000000E-02	0	1.5345369	1.5345369
131.58000	2.7000000E-02	1.0000000E 30	0.4425374	0	0.4425374
136.46000	2.7000000E-02	5.1000000E-02	2.4103834E-02	8.5065722	8.5306760
141.33000	2.8000000E-02	1.0000000E 30	1.0702793	0	1.0702793
143.80000	9.9999999E 28	4.4000000E-02	0	20.936991	20.936991
146.18000	2.8000000E-02	1.0000000E 30	2.1657975	0	2.1657975
151.03000	2.8999999E-02	3.9000000E-02	3.2561616	29.575546	32.831707
155.87000	2.7000000E-02	4.9999999E-02	0.9643456	18.734368	19.698714
160.71000	2.5000000E-02	1.0000000E 30	0.1866749	0	0.1866749
165.53000	2.6000000E-02	4.9999999E-02	5.4837246E-02	3.5232337	3.5780709

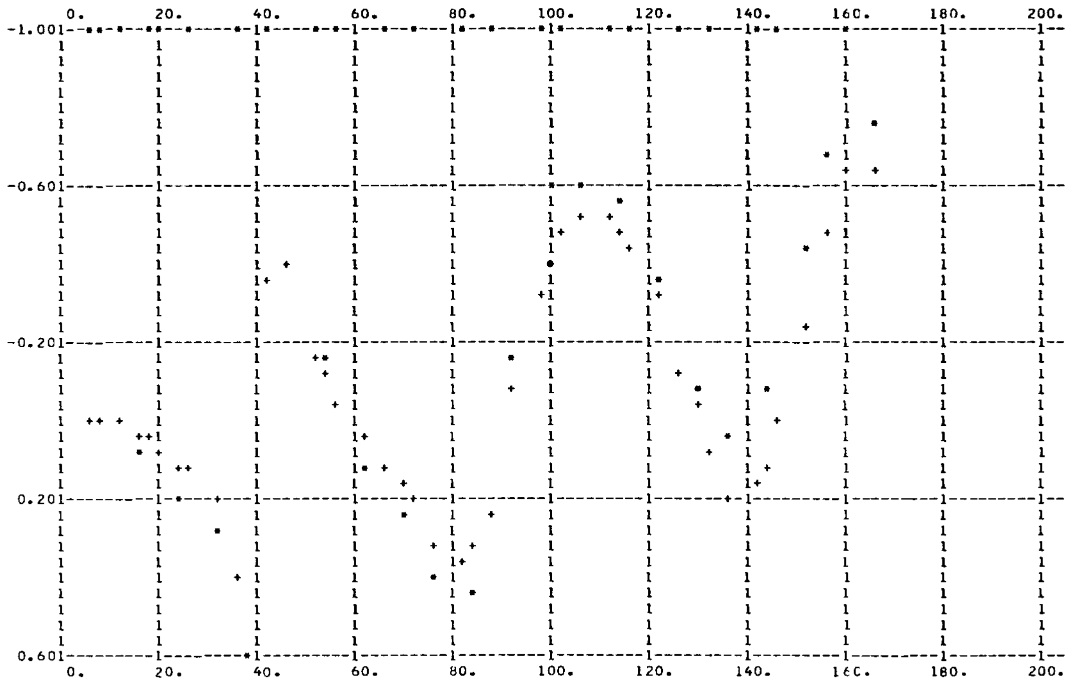
RUN NUMBER 1 EXAMPLE 3 SILICON 28 (P,P) E=18.82 SINGLE CASE

L	REAL C(L+1/2)	IMAG C(L+1/2)	REAL C(L-1/2)	IMAG C(L-1/2)
0	0.1797416	0.6337050	0.1993897	0.6043705
1	0.2075140	0.4301398	0.1424520	0.3554857
2	-2.0074445E-02	0.3233131	-0.1707857	0.3970086
3	-0.2027441	0.3759233	-6.9572725E-02	0.5679760
4	5.3130092E-02	0.3786884	0.1061343	0.2836448
5	6.7871674E-02	0.1004405	5.8032002E-02	8.8889067E-02
6	2.1710433E-02	2.7823952E-02	1.9809761E-02	2.7045244E-02
7	6.2823109E-03	8.4491352E-03	5.9807702E-03	8.3943006E-03
8	1.7717289E-03	2.6271696E-03	1.7235118E-03	2.6231314E-03
9	4.9349798E-04	8.1922075E-04	4.8564087E-04	8.1891522E-04
10	1.3623820E-04	2.5487865E-04	1.3494133E-04	2.5485352E-04
11	3.6857079E-05	7.8806739E-05	3.6632877E-05	7.8803394E-05
12	9.6379640E-06	2.3940782E-05	9.5954361E-06	2.3939455E-05
13	2.5497706E-06	6.9950169E-06	2.5415491E-06	6.9958642E-06
14	7.9680026E-07	1.9177817E-06	7.9584671E-07	1.9186472E-06
15	3.2539769E-07	4.8349122E-07	3.2022431E-07	4.8272232E-07

RUN NUMBER 1 EXAMPLE 3 SILICON 28 (P,P) E=18.82 SINGLE CASE

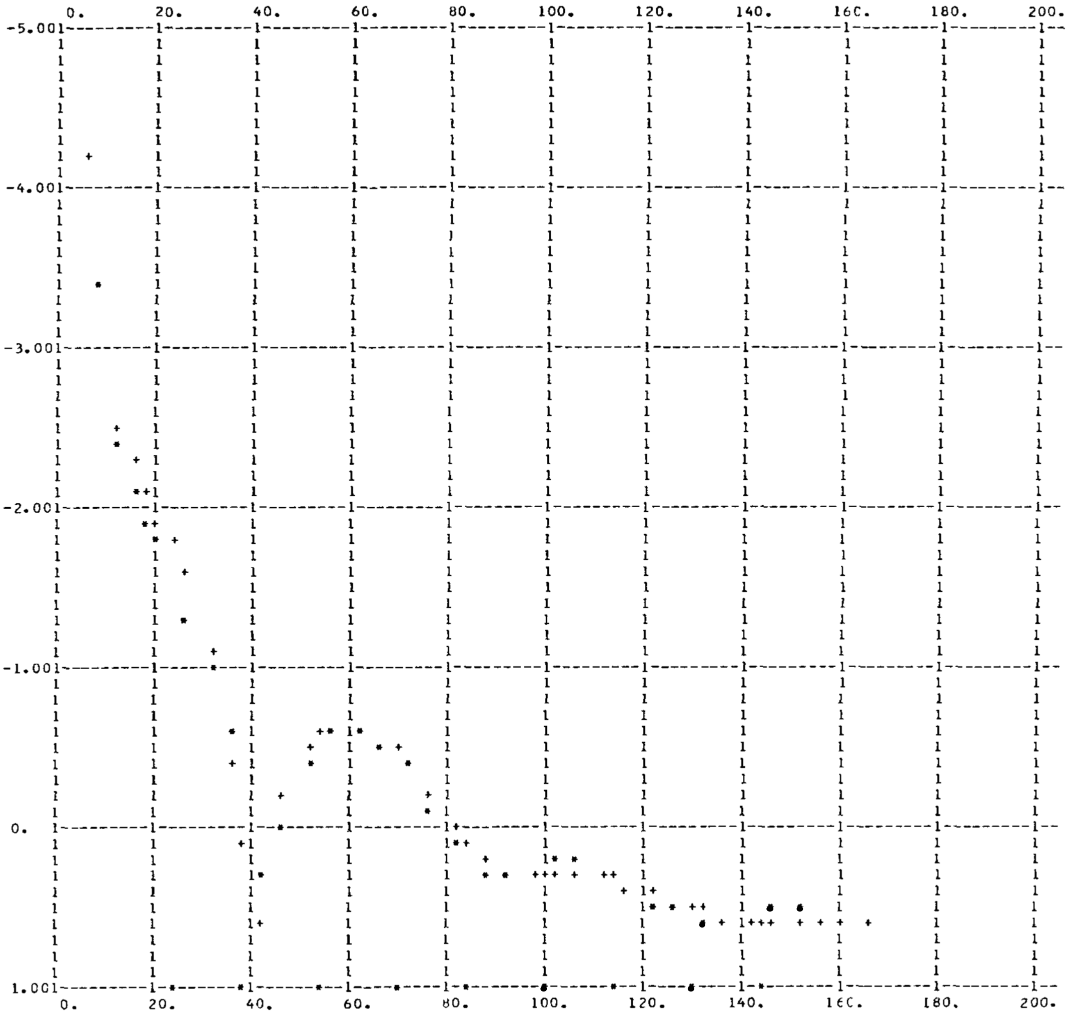
L	ETA1	ETA2	DELR1-DELPR	DELPI	DELR2-DELMR	DELMI
0	0.4480361	0.4501087	1.1051825	0.4014407	1.0265136	0.3991330
1	0.4379155	0.4058420	0.6230305	0.4128646	0.3891059	0.4508957
2	0.3556473	0.3988733	3.0850273	0.5169078	2.6275221	0.4595557
3	0.4753954	0.1945364	2.6307878	0.3718042	1.9692993	0.8185679
4	0.2648722	0.4819713	0.2063998	0.6642540	0.2280319	0.3649354
5	0.8105661	0.8303732	8.4130075E-02	0.1050112	7.0116233E-02	9.2940025E-02
6	0.9453498	0.9467389	2.2973585E-02	2.8100132E-02	2.0930320E-02	2.7365980E-02
7	0.9831820	0.9832842	6.3899479E-03	8.4805076E-03	6.0825934E-03	8.4285667E-03
8	0.9947520	0.9947597	1.7810798E-03	2.6309259E-03	1.7325945E-03	2.6270387E-03
9	0.9983620	0.9983626	4.9430771E-04	8.1965046E-04	4.8643740E-04	8.1935194E-04
10	0.9994903	0.9994903	1.3630768E-04	2.5493071E-04	1.3501014E-04	2.5490462E-04
11	0.9998424	0.9998424	3.6862889E-05	7.8814727E-05	3.6638651E-05	7.8811001E-05
12	0.9999521	0.9999521	9.6384255E-06	2.3943013E-05	9.5958955E-06	2.3943013E-05
13	0.9999860	0.9999860	2.5498063E-06	6.9961441E-06	2.5415847E-06	6.9961441E-06
14	0.9999962	0.9999962	7.9680331E-07	1.9185281E-06	7.9584977E-07	1.9222535E-06
15	0.9999990	0.9999990	3.2539800E-07	4.8428797E-07	3.2022462E-07	4.8428797E-07

PLOT OF POLEX AND POLTH VS THETA (DEG)



• POLEX   + POLTH

PLOT OF SGMAEX AND SGMATH VS THETA (DEG)



• SGMAEX   + SGMATH

SCATLE FORTRAN Listing

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$IBFTC CTRL4    LIST,DECK
C.....PAGE TITLING INFORMATION
      COMMON/PTI/NUMRUN, TITLE(13)
C.....INDICATORS FOR INCREASES IN RHOMAX AND LMAXM
      COMMON/PCH/ NADL, NADR, NTOT
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, MI, MS, N, NC, NS, NSSW1, NSSW2, Q, RSS,S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12),Z
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)
C.....GRID VARIABLES
      COMMON/GDV/TRI, TRS, TVO, TWI, TAS, TVS, TWS, TAI, TWVI, TAO, TRO,
     1TVSODD,NRI, NRS, NVO, NWI, NAS, NVS, NWS, NAI, NWVI, NAO, NRO,
     2NVSODD,DRI, DRS, DVO, DWI, DAS, DVS, DWS, DAI, DWVI, DAO, DRO,
     3DVSODD
C.....SCATLE PARAMETERS
      COMMON/PARA/RI, RS, VO, WI, AS, VS, WS, AI, WVI, AO, RO, VSODD,
     1NAME(12)
      COMMON/LIND/LMAX, LMAXM
C.....VARIABLES TO BE PLOTTED IN PTETDL
      COMMON/PTPL/AETA1(51), AETA2(51), DELR1(51), DELR2(51)
      DIMENSION SER(12), TSER(12),TPAR(12)
      EQUIVALENCE (RI,SER), (TRI,TPAR)
      CALL SAND(IX)
      NUMRUN=0
      KTRL(13)=1
C.....SET UP INPUT DATA
    3 CALL INPT4($38)
C.....COMPUTE QUANTITIES NOT DEPENDENT ON NUCLEAR POTENTIAL PARAMETERS
      CALL SIGZRO
      CALL FSUBC
      CALL RFUTB
      NADL=1
      NADR=1
      NUMRUN= NUMRUN+1
      CALL SKIP
C.....CHECK RHO AND L IN NUCLEAR POTENTIAL
      CALL PCTICH($38)
      IF(NTOT.GT.2)CALL SKIP
      KOUT=0
      KSAVE= KSTEP
      IF(KSEND.EQ.1) GO TO 8
C.....INITIAL OUTPUT
      CALL OUTPT4
      IF(KSEND.NE.3)CALL SKIP
    8 CONTINUE
C.....SET UP DO LOOPS FOR GRID ON NUCLEAR POTENTIAL PARAMETERS
      RI= TRI
      DO 33 IRI=1,NRI
      IF(IRI.GT.1) RI= RI+DRI
      RS= TRS
      DO 33 IRS=1,NRS
      IF(IRS.GT.1)RS= RS+DRS
      VO= TVO
      DO 33 IVO=1,NVO
      IF(IVO.GT.1) VO= VO+DVO
      WI= TWI
      DO 33 IWI= 1,NWI
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```
      IF(IWI.GT.1) WI= WI+DWI
      AS= TAS
      DO 33 IAS= 1,NAS
      IF(IAS.GT.1) AS= AS+DAS
      VS= TVS
      DO 33 IVS=1,NVS
      IF(IVS.GT.1) VS= VS+DVS
      WS= TWS
      DO 33 IWS=1,NWS
      IF(IWS.GT.1) WS= WS+DWS
      AI= TAI
      DO 33 IAI= 1,NAI
      IF(IAI.GT.1) AI=AI+DAI
      WVI= TWVI
      DO 33 IWVI= 1,NWVI
      IF(IWVI.GT.1)WVI= WVI+DWVI
      AO= TAO
      DO 33 IAO=1,NAO
      IF(IAO.GT.1) AO= AO+DAO
      RO= TRO
      DO 33 IRO=1,NRO
      IF(IRO.GT.1) RO= RO+DRO
      VSODD= TVSODD
      DO 33 IVSODD=1,NVSODD
      IF(IVSODD.GT.1) VSODD = VSODD+DVSODD
      GO TO (18,17,13,15), KSEND
C.....OUTPUT PARAMETERS FOR COMBINATION GRID AND SEARCH
   13 WRITE(6,20)
   20 FORMAT(1H1)
      CALL POUT
      DO 14 I=1,12
   14 TSER(I)=SER(I)
   15 KSTEP= KSAVE
C.....ENTER SEARCH SUBROUTINES
      CALL ARGN
   17 CALL POTICH($33)
C.....COMPUTE NUCLEAR POTENTIALS
   18 CALL PCEN4
C.....INTEGRATE RADIAL EQUATIONS
      CALL INTCTR($33)
C.....COMPUTE VARIOUS SCATTERING AMPLITUDES
      CALL CSUBL
      CALL AB
C.....COMPUTE CROSS SECTIONS AND POLARIZATIONS
      CALL SGSGCP
      CALL SIGMAR
      IF(KTRL(2).NE.0) CALL CHISQ
      GO TO (28,33,21,25),KSEND
   21 DO 23 I=1,12
   23 SER(I)=TSER(I)
   25 KOUT=1
C.....FINAL OUTPUT
   28 CALL OUTPT4
C.....COMPUTE, OUTPUT, AND PLOT TRIPLE SCATTERING PARAMETERS
      IF(KTRLX(11).NE.0) CALL TRIPS
C.....PLOT PHASE SHIFTS
      IF(KTRLX(2).NE.0.AND.KTRL(6).NE.1)CALL PTETDL(AETA1,AETA2,DELR1,
     1DELR2,LMAX)
C.....PLOT CROSS SECTIONS AND POLARIZATIONS
      CALL PTSCAT
   33 CONTINUE
      DO 35 I=1,12
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```
   35 SER(I)=IPAR(I)
   38 GO TO 3
      END
```

```
$IBFTC POUT    LOST,DECK
      SUBROUTINE POUT
C.....SCATLE PARAMETERS
      COMMON/PARA/PAR(12), NAME(12)
      DIMENSION IPO(12), NAMO(12), PARO(12)
      DATA (IPO(I),I=1,12)/3,4,10,11,9,8,1,6,7,5,2,12/
      DATA (NAMO(I),I=1,12)/6H    VO,6H    WI,6H    AO,6H    RO,6H   WVI
     1,6H    AI,6H    RI,6H    VS,6H    WS,6H    AS,6H    RS,6H VSODD/
C.....OUTPUT SCATLE PARAMETERS
      DO 15 I=1,12
      J=IPO(I)
   15 PARO(I)=PAR(J)
      WRITE(6,10) (NAMO(I),PARO(I),I=1,12)
   10 FORMAT(1HK,A6,1H=1PG14.7,3(4X,A6,1H=G14.7),
     1/1HJ,21X,3(4X,A6,1H=G14.7),2(/1HJ,A6,1H=G14.7,3(4X,A6,1H=G14.7)))
      RETURN
      END
```

```
$IBFTC INPT4   LOST,DECK
      SUBROUTINE INPT4(*)
C.....PAGE TITLING INFORMATION
      COMMON/PTI/NUMRUN, TITLE(13)
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RSS,S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12),Z
C.....AUXILIARY SEARCH VARIABLES
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,
     1NPCT, NPCTP, PCT
C.....ENERGY, MASS, AND CHARGE INPUT VALUES
      COMMON/EMCV/ELAB, FMB, FMI, FMO, RC, ZZ
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMAO, SIGMA1, TEMP
      COMMON/LIND/LMAX, LMAXM
C.....GRID VARIABLES
      COMMON/GDV/TRI, TRS, TVO, TWI, TAS, TVS, TWS, TAI, TWVI, TAO, TRO,
     1TVSODD,NRI, NRS, NVO, NWI, NAS, NVS, NWS, NAI, NWVI, NAO, NRO,
     2NVSODD,DRI, DRS, DVO, DWI, DAS, DVS, DWS, DAI, DWVI, DAO, DRO,
     3DVSODD
C.....SCATLE PARAMETERS
      COMMON/PARA/RI, RS, VO, WI, AS, VS, WS, AI, WVI, AO, RO, VSODD,
     1NAME(12)
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)
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C.....VARIABLES USED IN RHOTB
      COMMON/RHO/DRHOIN( 9), NMAX, RHOIN(10)
C.....VARIABLES COMPUTED IN PGEN4 (NUCLEAR POTENTIAL TERMS)
      COMMON/PGO/FLPT,UCRB(250), UCIB(250), UCRM(250), UCIM(250),
     1USRB(250), USIB(250), USRM(250), USIM(250)
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS
      COMMON/SACS/AAI(150),AR(150), BI(150), BR(150), FCI(150), FCR(150)
     1,SGMAC(150), SIGTEM(150), SRATIO(150)
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),
     1CHI2P(150), C HI2(150), ENORM, SGMRTH, SNORM, XNORM,NP,CSNRM,NCSN
      INTEGER SRCH
      LOGICAL CSIG
      DIMENSION DELI(12), DPAR(12), HD(12), KL(13), KT(13), KX(13),
     1NPAR(12), PAR(12), SRCH(12), TPAR(12)
      EQUIVALENCE (KL,KTRL), (KT,KTRLT), (KX,KTRLX),
     1(PAR,RI), (TPAR,TRI), (NPAR,NRI), (DPAR,DRI)
      DATA(HD(I),I=1,12)/2*.00001,2*.005,.00001,2*.001,.00001,.001,
     12*.00001,.001/
      DATA(DELI(I),I=1,12)/2*.0001,2*.001,.0001,2*.001,.0001,.001,
     12*.0001,.001/
      NAMELIST/KTR/KL, KT, KX, XNORM, NP
      NAMELIST/PEI/FMI, FMB, ELAB, ZZ, RC, VO, AO, RO, WI, WVI, AI, RI,
     1VS, WS, AS, RS, VSODD
      NAMELIST/GRI/DRI, DRS, DVO, DWI, DAS, DVS, DWS, DAI, DWVI, DAO,
     1DRO, DVSODD,NRI, NRS, NVO, NWI, NAS, NVS, NWS, NAI, NWVI, NAO,
     2NRO, NVSODD
      NAMELIST/RHI/NMAX, LMAXM, RHOIN, DRHOIN
      NAMELIST/SCHI/C, DELTA, E, FAC, H, KSTEP, N, NC, NHP, NSSW1, NMLR,
     1INPCT, PCT, SRCH, VP
      NAMELIST/TSP/CSIG, DPOLEX, DSGMEX, DTH, JMAX, JOPT, POLEX, SGMAEX,
     1THETAD, THI, THF
      IF(KL(13).EQ.0) GO TO 11
C.....INITIALIZE INPUT VARIABLES
      DO 5 I=1,13
      KL(I)=0.
      KT(I)=0.
      KX(I)=0.
    5 CONTINUE
      KL(1)=1
      KL(2)=1
      KL(3)=1
      KT(1)=1
      KX(4)=3
      KX(7)=1
      DO 8 I=1,12
      PAR(I)=0.
      NPAR(I)=1
      DPAR(I)=0.
    8 CONTINUE
      JOPT=0
      CSIG= .FALSE.
      XNORM=1.
      NP=0
      NMAX= 3
      LMAXM=25
      RHOIN(1)= .05
      RHOIN(2)= .5
      RHOIN(3)=25.
      DRHOIN(1)=.05
      DRHOIN(2)=.5
      DTH=0.
```

```
C.....READ TITLE AND CONTROLS
   11 READ(5,10) TITLE
   10 FORMAT(13A6)
      READ(5,KTR)
C.....ELIMINATE INCONSISTENT USE OF KX(7)
      IF(KL(1) .EQ.2.AND.KX(7).EQ.2)KX(7)=1
C......REMOVE POSSIBILITY OF NORMALIZING SGMAC
      IF(KX(3).EQ.1) KX(5)=0
C......SET UP SIGMA NORMALIZATION
      SNORM=1.
      IF(KX(5).EQ.1)SNORM=XNORM
C.....SET UP INTERNAL PROGRAM CONTROLS
      KSEND= KT(1)
      FLPT = KX(9)
      KDLMAX=1
      KDLM=0
      NCSN=3
      DO 13 K=4,13
   13 KDLM=KDLM+KT(K)
      IF(KDLM.EQ.0) GO TO 18
      KDLMAX=2
      NCSN=19
      KDLM=KT(6)+KT(8)+KT(10)+KT(12)
      IF(KDLM.EQ.0) KDLMAX=3
   18 CONTINUE
C.....READ SCATLE PARAMETERS AND ENERGY, MASS, AND CHARGE VALUES
      READ(5,PEI)
      CO2 = FM1+FMB
      FMU= (FM1*FMB)/CO2
      ECM= ELAB*(FMB/CO2)
      FKAY=.218739 *SQRT(FMU*ECM)
      TEMP = FKAY*(FMB**.33333333)
      ETA=.157481  *ZZ*SQRT(FM1/ELAB)
      ETA2= ETA**2
      RHOBC= TEMP*RC
      DO 23 I=1,12
      TPAR(I)= PAR(I)
   23 CONTINUE
C.....READ GRID VARIABLES
      IF(KSEND.EQ.2.OR.KSEND.EQ.3) READ(5,GRI)
C.....READ INTEGRATION DATA
      READ(5,RHI)
C.....INPUT FOR KNEE AND TAIL VARIATIONS
      CALL PGNIN
C.....INITIALIZE AND READ IN SEARCH VARIABLES
      KDR=0
      IF(KSEND.LT.3) GO TO 48
      KSTEP=0
      NC=0
      NSSW1=1
      NHP=5
      NMLR=5
      NPCT=5
      PCT=.5
      E=.1
      VP =0.
      FAC= -1.
      DELTA=1.
      READ(5,SCHI)
      DO 45 I=1,N
      DO 33 K=1,12
      IF(NAME(K).EQ.SRCH(I)) GO TO 35
```

```
   33 CONTINUE
      WRITE(6,20) SRCH(I)
   20 FORMAT(1HKA6,44H IS NOT A SCATLE PARAMETER.  GO TO NEXT CASE)
      KDR=1
      GO TO 48
   35 ID(I)=K
      LABEL(I)=NAME(K)
      DEL(I)= DEL1(K)
      DO 38 J=I,N
      IF(FAC.NE.0.) H(I,J)=0.
   38 H(J,I)= H(I,J)
      IF(FAC) 41,45,43
   41 H(I,I)=HD(K)
      GO TO 44
   43 H(I,I)=FAC
   44 DELTA=DELTA*H(I,I)
   45 CONTINUE
      IF(NPCT.GT.10)NPCT=10
      NPCTP=NPCT+1
   48 CONTINUE
C.....READ EXPERIMENTAL DATA
      IF(KL(3).EQ.0) GO TO 63
      KL(3)=0
      READ(5,TSP)
      IF(DTH.EQ.0.)GO TO 53
      J=0
   51 J=J+1
      AJ=J-1
      THETAD(J)=THI+DTH*AJ
      IF(THETAD(J).LT.THF.AND.J.LT.175)GO TO 51
      JMAX=J
   53 DO 58 J=1,JMAX
      IF(JOPT.NE.0)READ(5,50) THETAD(J), SGMAEX(J), DSGMEX(J), POLEX(J),
     1DPOLEX(J)
   50 FORMAT(8E10.0)
      THETA(J)=.0174532925*THETAD(J)
C.....CONVERT FROM MILLIBARNS TO SQUARE FERMIS/STERAD
      IF(.NOT.CSIG) GO TO 58
      SGMAEX(J)=.1*SGMAEX(J)
      DSGMEX(J)= .1*DSGMEX(J)
   58 CONTINUE
      CSNRM=JMAX-NP
      CSIG= .FALSE.
   63 IF(KX(3).NE.0)GO TO 68
      DO 65 J=1,JMAX
   65 SIGTEM(J)=DSGMEX(J)
   68 IF(KDR.EQ.1)RETURN 1
      RETURN
      END
```

```
$IBFTC SIGZRO  LOST,DECK
      SUBROUTINE SIGZRO
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....COMPUTE COULOMB PHASE SHIFT FOR L=0,1
      SIGMA0=-(ETA/(12.0*(ETA**2+16.0)))*(1.0+(ETA**2-48.0)/(30.0*((ETA*
     1*2+16.0)**2))+(ETA**4-160.0*(ETA**2)+1280.0)/(((16.0+ETA**2)**4)*1
```

```
     1205.0))
      SIGMA0=SIGMA0-ETA+(ETA/2.0)*ALOG(ETA**2+16.0)+((7.0/2.0)*ATAN(ETA/
     14.0))-(ATAN(ETA)+ATAN(ETA/2.0)+ATAN(ETA/3.0))
      SIGMA1=SIGMA0+ATAN(ETA)
   11 RETURN
      END
```

```
$IBFTC FSUBC    LOST,DECK
      SUBROUTINE FSUBC
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR(150)
     1,SGMAC(150), SIGTEM(150), SRATIO(150)
C.....COMPUTE COULOMB SCATTERING AMPLITUDES
      DO 10 J=1,JMAX
      SN=(SIN(THETA(J)/2.0))**2
      FLN=ETA*(ALOG(SN))-2.0*SIGMA0
      FNU=ETA/(2.0*FKAY*(SN))
   23 FCR(J)=(-FNU*COS(FLN))
   10 FCI(J)=(FNU*SIN(FLN))
   27 RETURN
      END
```

```
$IBFTC RHOTB    LOST,DECK
      SUBROUTINE RHOTB
C.....VARIABLES USED IN RHOTB
      COMMON/RHO/DRHOIN( 9), NMAX, RHOIN(10)
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....GENERATE ARRAY OF RHO VALUES
      DRHO(1)=DRHOIN(1)
      RHO(1)=RHOIN(1)
      NN=1
      I=1
   20 RHO(I+1)=RHO(I)+DRHOIN(NN)
      IF (RHO(I+1)-RHOIN(NMAX))30,50,70
   30 IF(ABS(RHO(I+1)-RHOIN(NN+1))-.5*DRHOIN(NN))35,35,40
   35 NN=MINO(NN+1,NMAX-1)
   40 DRHO(I+1)=DRHOIN(NN)
      I=I+1
      GO TO 20
   50 ILAST=I+1
   60 RHO(ILAST)=RHOIN(NMAX)
      DRHO(ILAST-1)=RHO(ILAST)-RHO(ILAST-1)
      RHOMAX=RHOIN(NMAX)
      DRHOL=DRHOIN(NMAX-1)
   83 RETURN
```

```
70  IF((RHO(I+1)-RHOIN(NMAX))-.5*DRHOIN(NN))50,50,75
75  ILAST=I
    GO TO 60
    END
```

```
$IBFTC SKIP     LIST,DECK
      SUBROUTINE SKIP
C.....PAGE TITLING INFORMATION
      COMMON/PTI/NUMRUN, TITLE(13)
C.....SKIP TO NEXT PAGE, WRITE RUN NUMBER AND TITLE
      WRITE(6,650)NUMRUN,TITLE
  650 FORMAT(1H1,10HRUN NUMBERI3,10X,13A6)
      RETURN
      END
```

```
$IBFTC POTICH  LIST,DECK
      SUBROUTINE POTICH(*)
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....CONVERGENCE CRITERIA
      COMMON/CONV/EPS1, EPS2, EPS3, EPS4
      COMMON/LIND/LMAX, LMAXM
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
C.....INDICATORS FOR INCREASES IN RHOMAX AND LMAXM
      COMMON/PCH/ NADL, NADR, NTOT
      RHOBN=TEMP*RO
      RHOBNG=TEMP*RG
      FKAYA=FKAY*A
      FKAYB=FKAY*BG
    8 LMAX=LMAXM+1
      FLMAX=LMAXM
C.....COMPUTE MAGNITUDE OF POTENTIALS AS A FUNCTION OF LMAXM
      CALL PONCK(FLMAX,TCR,TCI,TSR,TSI)
C.....IF MAGNITUDE OF CENTRAL POTENTIAL TOO LARGE, INCREASE LMAXM
      IF(TCR.LT.EPS4.AND.TCI.LT.EPS4)GO TO 18
      WRITE(6,10) LMAXM
   10 FORMAT(7H0LMAXM=I5,3H +1,45H LMAXM TOO SMALL BECAUSE OF CENTRAL PO
     1TENTIAL)
C.....LMAXM GT 50 CAUSES DIMENSIONS TO BE EXCEEDED
   13 IF(LMAXM.EQ.50)GO TO 65
      LMAXM=LMAXM+1
      NADL=NADL+1
      GO TO 8
   18 TL=LMAX
C.....IF MAGNITUDE OF SPIN-ORBIT POTENTIAL TOO LARGE, INCREASE LMAXM
      IF(TL*TSR.LT.EPS4.AND.TL*TSI.LT.EPS4)GO TO 23
      WRITE(6,20) LMAXM
```

```
   20 FORMAT(7HJLMAXM=I5,3H +1,48H LMAXM TOO SMALL BECAUSE OF SPIN ORBIT
     1 POTENTIAL)
      GO TO 13
   23 IF(RHOMAX .GE.FLMAX)GO TO 48
C.....COMPUTE MAGNITUDE OF POTENTIAL AS A FUNCTION OF RHOMAX
   28 CALL PGNCK(RHOMAX,TCR,TCI,TSR,TSI)
C.....IF MAGNITUDE OF CENTRAL POTENTIAL TOO LARGE, INCREASE RHOMAX
      IF(TCR.LT.EPS4.AND.TCI.LT.EPS4)GO TO 38
      WRITE(6,30) RHOMAX, DRHOL
   30 FORMAT(8HJRHOMAX=E16.9,2H+ E16.9,41H RHOMAX IS TOO SMALL IN NUCLEA
     1R POTENTIAL)
C.....IF ILAST GT 250, RHO DIMENSIONS ARE EXCEEDED
   33 IF(ILAST.EQ.250) GO TO 65
      RHOMAX=RHOMAX+DRHOL
      ILAST=ILAST+1
      RHO(ILAST)=RHO(ILAST-1)+DRHOL
      DRHO(ILAST-1)=DRHOL
      NADR=NADR+1
      GO TO 28
C.....IF MAGNITUDE OF SPIN-ORBIT POTENTIAL TOO LARGE, INCREASE RHOMAX
   38 IF(TL*TSR.LT.EPS4.AND.TL*TSI.LT.EPS4)GO TO 48
      WRITE(6,40) RHOMAX,DRHOL
   40 FORMAT(8HJRHOMAX=E16.9,2H+ E16.9,44H RHOMAX IS TOO SMALL IN SPIN O
     1RBIT POTENTIAL)
      GO TO 33
C.....IF LMAXM HAS BEEN INCREASED, RECOMPUTE COULOMB FUNCTIONS, PHASES
   48 IF(NADL.EQ.0)GO TO 53
      CALL EXSGML
      CALL COULFN($65)
      GO TO 58
C.....IF RHOMAX HAS BEEN INCREASED, RECOMPUTE COULOMB FUNCTIONS
   53 IF(NADR.GT.0)CALL COULFN($65)
   58 CONTINUE
      NTOT=NADL+NADR
      NADL=0
      NADR=0
      RETURN
   65 WRITE(6,70)
   70 FORMAT(48HKDIMENSIONS HAVE BEEN EXCEEDED.  GO TO NEXT CASE)
      RETURN 1
      END
```

```
$IBFTC EXSGML  LIST,DECK
      SUBROUTINE EXSGML
C.....VARIABLES WHICH ARE CALCULATED AS FUNCTIONS OF L
      COMMON/VARL/CI1(51), CI2(51), CR1(51), CR2(51), EXSGMI(51),
     1EXSGMR(51), F(52), FBAR(91), FP(51), G(52), GP(51)
      COMMON/LIND/LMAX, LMAXM
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA,  FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....COMPUTE COULOMB PHASE SHIFTS
    1 FL=0.0
      EXSGMR(1)=COS(2.0*SIGMA0)
      EXSGMI(1)=SIN(2.0*SIGMA0)
      ETA2A=2.0*ETA
      DO 20 L=2,LMAX
      FL=FL+1.0
```

```
      TER0=FL**2
      TER1=TER0+ETA2
      TER2=(TER0-ETA2)/TER1
      TER3=(ETA2A*FL)/TER1
   13 EXSGMR(L)=(TER2*EXSGMR(L-1))-(TER3*EXSGMI(L-1))
   20 EXSGMI(L)=(TER2*EXSGMI(L-1))+(TER3*EXSGMR(L-1))
   17 RETURN
      END
```

```
$IBFTC COULFN  LIST,DECK
      SUBROUTINE COULFN(*)
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR( 150)
     1,SGMAC(150), SIGTEM(150), SRATIO(150)
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA,  FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....CONVERGENCE CRITERIA
      COMMON/CONV/EPS1, EPS2, EPS3, EPS4
      COMMON/LIND/LMAX, LMAXM
C.....VARIABLES WHICH ARE CALCULATED AS FUNCTIONS OF L
      COMMON/VARL/CI1(51), CI2(51), CR1(51), CR2(51), EXSGMI(51),
     1EXSGMR(51), F(52), FBAR(91), FP(51), G(52), GP(51)
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....COMPUTE COULOMB FUNCTIONS
      SQ=SQRT(1.0+ETA2)
    1 IJ=1
      AR( 1)=-ETA
      AI( 1)=0.0
      AR( 2)=-.5*ETA2
      AI( 2)=.5*ETA
    2 SI=0.0
      SR=0.0
      PR= RHOMAX
      DO 10  K=2,49
      TEM=PR*FLOAT(1-K)
      TR=AR(K)/TEM
      TI=AI(K)/TEM
   53 SQN=TR**2+TI**2
      IF(K-2) 4,4,3
    3 IF( SQN-SQO) 4,4,11
    4 TR=SR+TR
      TI=SI+TI
      IF( TR-SR) 6,5,6
    5 IF( TI-SI) 6,13,6
    6 SR=TR
      SI=TI
      AR(K+1)=0.0
      AI(K+1)=0.0
      KP=K/2
      DO 7 MM=1,KP
      KM=K+1-MM
      AR(K+1)=AR(K+1)-AR(MM)*AR(KM)+AI(MM)*AI(KM)
    7 AI(K+1)=AI(K+1)-AI(KM)*AR(MM)-AI(MM)*AR(KM)
      IF(K-2*KP) 8,9,8
```

```
  8    AR(K+1)=AR(K+1)-.5*(AR(KP+1)**2-AI(KP+1)**2)
       AI(K+1)=AI(K+1)-AR(KP+1)*AI(KP+1)
  9    FK=.5*FLOAT(K)
       AI(K+1)=AI(K+1)-FK*AR(K)
       AR(K+1)=AR(K+1)+FK*AI(K)
       PR= PR*RHOMAX
 10    SQO=SQN
       GO TO 101
  11 TEM=SR**2+SI**2
       IF(TEM)105,105,12
  12 IF(ABS(SQO/TEM)-EPS3)13,13,106
 13    GO TO (14,15),IJ
 14    PAR=RHOMAX-ETA*ALOG(2.0*RHOMAX)
       PHI0R=PAR+SIGMA0+SR
       PHI0I=SI
       AR(2)=-1.0+AR(2)
       IJ=2
       GO TO 2
 15    PHI1R=PAR+SIGMA1-.157079632E+01+SR
       PHI1I=SI
 25    T1=EXP(-PHI0I)
       T2=EXP(-PHI1I)
       G(1)=T1*COS(PHI0R)
       G(2)=T2*COS(PHI1R)
       F1=T1*SIN(PHI0R)
       F2=T2*SIN(PHI1R)
       IF(ABS(F1*G(2)-F2*G(1)-1.0/SQ)-EPS1)  31,31,102
 31    IDEC=11
 32    I=LMAX+IDEC
       FBAR(I)=.1
       FBAR(I+1)=0.0
       LIMIT=LMAXM+IDEC
       FL=LMAX+IDEC
       T1=SQRT((FL+1.0)**2+ETA2)
133    DO 33 I=1,LIMIT
       L=LMAX+IDEC-I
       FL=L
       T2=SQRT(FL**2+ETA2)
       FBAR(L)=((2.0*FL+1.0)*(ETA+FL*(FL+1.0)/RHOMAX)*FBAR(L+1)-FL*T1*FBA
      1R(L+2))/((FL+1.0)*T2)
 600 IF(ABS(FBAR(L))-1.E+30)33,33,601
 601 K=LMAX+IDEC
       FBAR(K)=FBAR(K)*0.1
       GO TO 133
 33    T1=T2
       ALPHA=1.0/((FBAR(1)*G(2)-FBAR(2)*G(1))*SQ)
 43    LMAXP=LMAX+1
       DO 34 I=1,LMAXP
 34    FBAR(I)=ALPHA*FBAR(I)
       IF(IDEC-11) 371,35,371
 371 IF(ABS(F1/FBAR(1)-1.0)-EPS2) 37,37,35
 35    DO 36 I=1,LMAXP
 36    F(I)=FBAR(I)
       IDEC=IDEC+5
       IF (IDEC-40) 32,32,103
37     DO 38 I=1,LMAXP
       IF(ABS(F(I)/FBAR(I)-1.0)-EPS2) 38,38,35
38     CONTINUE
       DO 381 I=1,LMAXP
381    F(I)=FBAR(I)
382    T1=SQ
       DO 40 L=1,LMAXM
```

```
      FL=L                                                              10--1120
      T2=SQRT((FL+1.0)**2+ETA2)                                         10--1130
      G(L+2)=((2.0*FL+1.0)*(ETA+FL*(FL+1.0)/RHOMAX)*G(L+1)-(FL+1.0)*T1*G10--1140
     1(L))/(FL*T2)                                                      10--1150
      TS=FL/T1                                                          10--1160
   45 IF(ABS(F(L)*G(L+1)-F(L+1)*G(L)-TS)-EPS1) 40,40,104               10--1170
   40 T1=T2                                                             10--1180
   41 DO 42 L=1,LMAX                                                    10--1190
      FL=L                                                              10--1200
      TEM=FL**2                                                         10--1210
      T1=TEM/RHOMAX+ETA                                                 10--1220
   46 T2=SQRT(TEM+ETA2)                                                 10--1230
      FP(L)=(T1*F(L)-T2*F(L+1))/FL                                      10--1240
   42 GP(L)=(T1*G(L)-T2*G(L+1))/FL                                      10--1250
   63 RETURN                                                            10--1260
  101 WRITE (6,121)RHOMAX,DRHOL                                         10--1270
      GO TO 110                                                         10--1280
  102 WRITE (6,122)RHOMAX,DRHOL                                         10--1290
      GO TO 110                                                         10--1300
  103 WRITE (6,123)RHOMAX,DRHOL                                         10--1310
      GO TO 110                                                         10--1320
  104 WRITE (6,124)RHOMAX,DRHOL ,L                                      10--1330
      GO TO 110                                                         10--1340
  105 WRITE (6,125)RHOMAX,DRHOL                                         10--1350
      GO TO 110                                                         10--1360
  106 WRITE (6,126)RHOMAX,DRHOL                                         10--1370
  110 IF(ILAST.EQ.250) RETURN 1                                         10--1380
      RHOMAX=RHOMAX+DRHOL                                               10--1390
      ILAST=ILAST+1                                                     10--1400
      RHO(ILAST)=RHO(ILAST-1)+DRHOL                                     10--1410
      DRHO(ILAST-1)=DRHOL                                               10--1420
      GO TO 1                                                           10--1430
  121 FORMAT(18H INCREASE RHO MAX=E11.4,2H+ E11.4,35H A OR B SERIES CONV10--1440
     1ERGES TOO SLOWLY)                                                 10--1450
  122 FORMAT(18H INCREASE RHO MAX=E11.4,2H+ E11.4,22H BAD INITIAL WRONSK10--1460
     1IAN)                                                              10--1470
  123 FORMAT(18H INCREASE RHO MAX=E11.4,2H+ E11.4,24H L TOO LARGE IN FBA10--1480
     1R (L))                                                            10--1490
  124 FORMAT(18H INCREASE RHO MAX=E11.4,2H+ E11.4,21H BAD WRONSKIAN FOR 10--1500
     1L=I3)                                                             10--1510
  125 FORMAT(67H SERIES IN PHI0 OR PHI1 IS ZERO, CHECK DATA, IF OK INCRE10--1520
     1ASE RHOMAX=E11.4,2H+ E11.4)                                       10--1530
  126 FORMAT(52H A OR B SERIES DIVERGES TOO QUICKLY INCREASE RHOMAX=E11.10--1540
     14,2H+ E11.4)                                                      10--1550
      END                                                               10--1560



$IBFTC OUTPT4  LIST,DECK                                                11--0010
      SUBROUTINE OUTPT4                                                 11--0020
C.....SCATLE PARAMETERS                                                 11--0030
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)       11--0040
C.....ENERGY,MASS, AND CHARGE INPUT VALUES                              11--0050
      COMMON/EMCV/ELAB, FMB, FMI, FMO, RC, ZZ                           11--0060
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION           11--0070
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),           11--0080
     1CHI2P(150), CHI2(150), ENORM, SGMRTH,SNORM,XNORM,NP,CSNRM,NCSN    11--0090
C.....SCATLE INPUT AND OUTPUT VARUABLES WHICH ARE FUNCTIONS OF THETA    11--0100
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),11--0110
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)                 11--0120
```

```
C.....VARIABLES COMPUTED IN PGEN4 (FORM FACTORS)
      COMMON/PGF/FFCI(250), FFCIM(250), FFCR(250), FFCRM(250), FFSI(250)
     1,FFSIM(250), FFSR(250), FFSRM(250)
C.....VARIABLES USED IN RHOTB
      COMMON/RHO/DRHOIN( 9), NMAX, RHOIN(10)
C.....VARIABLES WHICH ARE CALCULATED AS FUNCTIONS OF L
      COMMON/VARL/CI1(51), CI2(51), CR1(51), CR2(51), EXSGMI(51),
     1EXSGMR(51), F(52), FBAR(91), FP(51), G(52), GP(51)
      COMMON/LIND/LMAX, LMAXM
C.....VARIABLES TO BE PLOTTED IN PTETDL
      COMMON/PTPL/AETA1(51), AETA2(51), DELR1(51), DELR2(51)
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA,  FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR(150)
     1,SGMAC(150), SIGTEM(150), SRATIO(150)
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....AUXILIARY SEARCH VARIABLES
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,
     1NPCT, NPCTP, PCT
      DIMENSION   DELPI(51), DELMI(51)
      DIMENSION IDK(4),SNID(3), CHIQS(19)
      EQUIVALENCE (CHIQS(1),CHI2ST)
      DATA (IDK(I),I=1,4)/6H    N =,6HKL(N)=,6HKT(N)=,6HKX(N)=/
      DATA (SNID(I),I=1,3)/6H  1.   ,6H XNORM,6H ENORM/
C.....SCATLE OUTPUT
C.....INITIAL PAGE OUTPUT
      IF(KOUT.EQ.1)GO TO 11
      WRITE(6,10) IDK(1), (I,I=1,13),IDK(2), KTRL, IDK(3), KTRLT,
     1IDK(4), KTRLX
   10 FORMAT(1HK,46X,8HCONTROLS/1HJ,14X,A6,13I5/1HK,14X,A6,13I5,
     12(/1HJ,14X,A6,13I5))
      NRM=KTRLX(5) + 1
      WRITE(6,20) FMI, FMB, ELAB, ZZ,XNORM,SNID(NRM), JMAX, NP
   20 FORMAT(1HL,42X,16HBASIC INPUT DATA/8HK    FMI=F10.5,9X,
     16H   FMB=F10.5,9X,6H ELAB=F8.3,11X,6H    ZZ=F5.0/
     28HK XNORM=F10.7,9X,6HSNORM=A6,13X,6H JMAX=I4,15X,6H    NP=I3)
      WRITE(6,30)
   30 FORMAT(1HL,36X,28HNUCLEAR POTENTIAL PARAMETERS)
      CALL POUT
      WRITE(6,40) RC
   40 FORMAT(1H+,79X,3HRC=1PG14.7)
      RHORO=TEMP*DUMMY(3)
      WRITE(6,50) RHORO, RHOBNG, RHOBN, RHOBC, ECM, FKAY, FKAYA,
     1FKAYB, ETA
   50 FORMAT(1HK,37X,25HBASIC COMPUTED QUANTITIES/7HKRHORO=1PG14.7,5X,
     16HRHORI=G14.7,5X,6HRHORS=G14.7,5X,6HRHORC=G14.7/
     27HK   ECM=G14.7,5X,6H     K=G14.7,5X,6H   KAS=G14.7,5X,6H   KAI=G14.7/
     37HK   ETA=G14.7)
      WRITE(6,60) RHOMAX, LMAXM, NMAX, (RHOIN(I),I=1,NMAX)
   60 FORMAT(1HJ,42X,16HINTEGRATION DATA/8HKRHOMAX=1PG14.7,12X,
     16HLMAXM=I2,25X,5HNMAX=I2/7HKRHOIN=0P10F12.4)
      NMAXM=NMAX-1
      WRITE(6,70) (DRHOIN(I),I=1,NMAXM)
   70 FORMAT(8HKDRHOIN=6X,9F12.4)
      CALL PGNOUT
      IF(KSEND.GT.1)GO TO 121
   11 GO TO (15,121,21,21),KSEND
```

```
C.....INITIAL PAGE OUTPUT, SINGLE CASE ONLY
   15 IF(KTRL(2).NE.1)GO TO 35
      WRITE(6,80) CHI2ST, CHI2PT, CHI2T
   80 FORMAT(1HL,41X,18HSUM OF CHI  SQUARES/13HKCHISQ SIGMA=1PG14.7,7X,
     110HCHISQ POL=G14.7,9X,12HCHISQ TOTAL=G14.7)
      IF(KOLMAX.EQ.1)GO TO 16
      WRITE(6,90)
   90 FORMAT(1HJ)
      CALL SOUF
   16 DO 17 KK=1,NCSN
   17 CHIQS(KK)=CHIQS(KK)/CSNRM
      WRITE(6,280) CSNRM, CHI2ST, CHI2PT, CHI2T
  280 FORMAT(1HK,36X,20HSUM OF CHI  SQUARES /F5.0/13HKCHISQ SIGMA=1PG14.7
     1,7X,10HCHISQ POL=G14.7,9X,12HCHISQ TOTAL=G14.7)
      IF(KOLMAX.EQ.1)GO TO 18
      WRITE(6,90)
      CALL SOUF
   18 WRITE(6,100) SGMRTH, ENORM
  100 FORMAT(1HL,24X,52HREACTION CROSS SECTION AND DATA NORMALIZATION FA
     1CTOR/1HK,20X,11HSIGMAR(TH)=1PG14.7,19X,6HENORM=G14.7)
C.....OUTPUT EXPERIMENTAL,THEORETICAL CROSS SECTION, POLARIZATION
   21 CALL SKIP
      WRITE(6,110)
  110 FORMAT(1HJ,2X,5HTHETA,6X,8HSIGMA TH,8X,10HSIGTH/SIGC,9X,6HPOL TH,
     110X,8HSIGMA EX,8X,10HSIGEX/SIGC,9X,6HPOL EX)
      IF(KTRLX(5).NE.0)WRITE(6,120) SNID(NRM)
  120 FORMAT(1H+,111X,A6,7H*SGMAEX)
      DO 28 J=1,JMAX
      SIGXOC=SGMAEX(J)/SGMAC(J)
      WRITE(6,220) THETAD(J), SGMATH(J), SRATIO(J), POLTH(J), SGMAEX(J),
     1SIGXOC, POLEX(J)
  220 FORMAT(1HJ,F8.3,1P6G17.7)
      IF(KTRLX(5).EQ.0)GO TO 28
      SGMEXN=SNORM*SGMAEX(J)
      WRITE(6,130) SGMEXN
  130 FORMAT(1H+,110X,1PG17.7)
   28 CONTINUE
      GO TO 41
C.....OUTPUT THEORETICAL CROSS SECTION, POLARIZATION ONLY
   35 CALL SKIP
      WRITE(6,140)
  140 FORMAT(1HJ, 9X,5HTHETA,19X,7HSIGMATH,18X,8HSIG/SIGC,18X,6HPOL TH)
      DO 38 J=1,JMAX
   38 WRITE(6,150) THETAD(J), SGMATH(J), SRATIO(J), POLTH(J)
  150 FORMAT(1HJ,1PG20.7,4G25.7)
   41 IF(KTRL(6).EQ.1)GO TO 121
      IF(KTRL(6).NE.2)GO TO 48
C.....OUTPUT SCATTERING AMPLITUDES A,B
      CALL SKIP
      WRITE(6,160)
  160 FORMAT(1HJ,11X,2HAR,23X,2HAI,23X,2HBR,23X,2HBI)
      DO 43 J=1,JMAX
   43 WRITE(6,150) AR(J), AI(J), BR(J), BI(J)
   48 IF(KTRL(12).NE.1)GO TO 53
C.....OUTPUT AND PLOT FORM FACTORS
      CALL SKIP
      WRITE(6,170)
  170 FORMAT(1HJ,9X,6HRHO(I),15X,4HFFCR,16X,4HFFCI,16X,4HFFSR,16X,4HFFSI
     1)
      DO 51 I=1,ILAST
   51 WRITE(6,180) RHO(I), FFCR(I), FFCI(I), FFSR(I), FFSI(I)
```

```
  180 FORMAT(1HJ,1P6G20.7)
      CALL PTFFRI
   53 IF(KTRL(2).NE.1)GO TO 61
C.....OUTPUT CHISQ AND ERRORS FOR SIGMA AND POLARIZATION
      CALL SKIP
      WRITE(6,190)
  190 FORMAT(1HJ, 9X,5HTHETA,13X,9HDSIGMA EX,13X,7HDPOL EX, 8X,
     116HCHI SQUARE SIGMA,5X,14HCHI SQUARE POL,5X,16HCHI SQUARE TOTAL)
      DO 58 J=1,JMAX
   58 WRITE(6,180) THETAD(J), DSGMEX(J), DPOLEX(J), CHI2S(J), CHI2P(J),
     1CHI2(J)
C.....OUTPUT REAL AND IMAG PARTS OF C-COEFFICIENTS
   61 CALL SKIP
      WRITE(6,200)
  200 FORMAT(1HJ,11X,1HL,14X,13HREAL C(L+1/2),12X,13HIMAG C(L+1/ 2),12X,
     113HREAL C(L-1/2),12X,13HIMAG C(L-1/2))
      DO 63 L=1,LMAX
      L1=L-1
   63 WRITE(6,210) L1, CR1(L), CI1(L), CR2(L), CI2(L)
  210 FORMAT(1HJ,I11,1PG30.7,3G25.7)
C.....COMPUTE AND OUTPUT SCATTERING PHASE SHIFTS
      CALL SKIP
      WRITE (6,1399)
      DO 400 L=1,LMAX
      L1=L-1
      AETA1(L)=2.0*SQRT(CR1(L)**2+(.5-CI1(L))**2)
      AETA2(L)=2.0*SQRT(CR2(L)**2+(.5-CI2(L))**2)
      DELPI(L)=-.5*ALOG(AETA1(L))
      DELMI(L)=-.5*ALOG(AETA2(L))
      TEM=CI1(L)-.5
      IF(CR1(L)) 402,401,401
  401 IF(TEM) 403,403,404
  403 DELR1(L)=.5*ATAN(-CR1(L)/TEM)
      GO TO 410
  404 DELR1(L)= .5*(3.1415927 + ATAN(-CR1(L)/TEM))
      GO TO 410
  402 IF(TEM) 405,405,406
  405 DELR1(L)=3.1415927+.5*ATAN(-CR1(L)/TEM)
      GO TO 410
  406 DELR1(L)=.5*(3.1415927+ATAN(-CR1(L)/TEM))
  410 TEM=CI2(L)-.5
      IF(CR2(L))1402,1401,1401
 1401 IF(TEM) 1403,1403,1404
 1403 DELR2(L)=.5*ATAN(-CR2(L)/TEM)
      GO TO 1410
 1404 DELR2(L)=.5*(3.1415927+ATAN(-CR2(L)/TEM))
      GO TO 1410
 1402 IF(TEM) 1405,1405,1406
 1405 DELR2(L)=3.1415927+.5*ATAN(-CR2(L)/TEM)
      GO TO 1410
 1406 DELR2(L)=.5*(3.1415927+ATAN(-CR2(L)/TEM))
 1410 WRITE (6,1400)L1, AETA1(L),AETA2(L),DELR1(L),
     1DELPI(L),DELR2(L),DELMI(L)
  400 CONTINUE
      IF(KTRLX(2)-2)121,1415,121
 1415 WRITE(6,1420)
 1420 FORMAT(1HL)
 1425 WRITE(6,1430) (DELR1(I),DELPI(I),DELR2(I),DELMI(I),I=1,LMAX)
 1430 FORMAT(2H* 8F10.5)
 1399 FORMAT(5H    L, 9X,4HETA1,16X,4HETA2,13X,11HDELR1-DELPR,11X,
     15HDELPI,13X,11HDELR2-DELMR,11X,5HDELMI)
 1400 FORMAT(I5,1P6G20.7)
```

```
  121 RETURN
      END
```

```
$IBFTC PGEN     LOST,DECK
      SUBROUTINE PGEN4
C.....VARIABLES USED FOR KNEE AND TAIL VARIATIONS
      COMMON/SCNFF/TH(2), TN1(2), TN2(2), TRM(2),PMA, PMB
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA,  FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....VARIABLES COMPUTED IN PGEN4 (NUCLEAR POTENTIAL TERMS)
      COMMON/PGU/FLPT,UCRB(250), UCIB(250), UCRM(250), UCIM(250),
     1USRB(250), USIB(250), USRM(250), USIM(250)
C.....VARIABLES COMPUTED IN PGEN4 (FORM FACTORS)
      COMMON/PGF/FFCI(250), FFCIM(250), FFCR(250), FFCRM(250), FFSI(250)
     1, FFSIM(250), FFSR(250), FFSRM(250)
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....MM=1 DURING CALCULATIONS AT THE BEGINNINGS OF INTEGRATION INTERVAL
C.....MM=2 DURING CALCULATIONS AT THE MIDPOINTS OF INTEGRATION INTERVALS
C.....MM=3 DURING POTICH CALCULATIONS
      MM=1
    1 T1= V/ECM
      T2= W/ECM
      T3= 2.*FKAY/A
      T10=-VS/ECM
      T11=-WS/ECM
      T4= T3*T10
      T5 = T3*T11
      T6 = FKAYA
      IF(ABS(T6).LT.1.E-10) T6= SIGN(1.E-10,T6)
      T7 = ETA/RHOBC
      T8 = RHOBC**2
      T9 = 2.*ETA
      T12 = FKAYB
      IF(ABS(T12).LT.1.E-10) T12= SIGN(1.E-10,T12)
      IF(KNTV.NE.0)TEMX=TFI(A)
      TTWV=DUMMY(1)
      IF(KTRL(1).NE.1.OR.KTRLX(1).LT.2)TTWV=0.
      KDCI=0
      UCIX=0.
      FFCIX=0.
      IF(W.EQ.0..AND.TTWV.EQ.0.)KDCI=1
      IF(KTRLX(7).NE.2) GO TO 2
      RHOBRL = TEMP*DUMMY(3)
      T26 = FKAY*DUMMY(2)
      IF(ABS(T26).LT.1.E-10)T26=SIGN(1.E-10,T26)
    2 CONTINUE
      IF(MM.EQ.3)GO TO 4
C.....SET UP LOOP ON I
      I=0
    3 I=I+1
      RHOX = RHO(I)
```

```
    4 TEMX= (RHOX-RHOBN)/T6
      TEMX= AMIN1(TEMX,80.)
      EX= EXP(TEMX)
      IF(KTRL(1).NE.2) GO TO 7
      S1= 0.
      IF(RHOX.LT.RHOBN) S1=1.
      GO TO 8
    7 S1 = 1./(1.+EX)
    8 S2 = EX*S1**2
      IF(RHOX.GT.RHOBC) GO TO 9
      S3 = T7*(3.-RHOX**2/T8)
      GO TO 11
    9 S3 = T9/RHOX
   11 S4 = S2/RHOX
C.....COMPUTE FFCRX AND UCRX
      IF(KTRL(7).NE.0) GO TO 33
      IF(KTRLX(7).EQ.2) GO TO 19
      FFCRX= S1
      GO TO 58
   19 TEMX = (RHOX-RHOBRL)/T26
      TEMX = AMIN1(TEMX,80.)
      FFCRX= 1./(1.+EXP(TEMX))
      GO TO 58
   33 FFCRX = TF(1,KTRL(7),RHOX)
   58 TCRX=T1*FFCRX
      UCRX=-1.-TCRX+S3
C.....COMPUTE FFCIX AND UCIX
      IF(KTRL(8).NE.0) GO TO 83
      IF(KOC1.EQ.1)GO TO 88
      IF(KTRL(1).NE.1) GO TO 75
      TEM1= (RHOX-RHOBNG)/T12
      TEM1= AMIN1(TEM1,55.)
      IF(KTRLX(1).EQ.1.OR.KTRLX(1).EQ.3) GO TO 63
      S1= EXP(-TEM1**2)
      IF(KTRLX(1).EQ.0) GO TO 75
      S1V= 1./(1.+EXP(TEM1/.69))
      GO TO 75
   63 EX1 = EXP(TEM1)
      S1 =(4./(1.+EX1))*(EX1/(1.+EX1))
      IF(KTRLX(1).EQ.1)GO TO 75
      S1V = 1./(1.+EX1)
   75 UCIX = -T2*S1-S1V*TTWV/ECM
      FFCIX=(S1*W+S1V*TTWV)/(W+TTWV)
      GO TO 88
   83 FFCIX= TF(1,KTRL(8),RHOX)
      UCIX=-T2*FFCIX
   88 TCIX=-UCIX
C.....COMPUTE FFSRX AND USRX
      IF(KTRL(9).NE.0)GO TO 93
      FFSRX = S4
      USRX=T4*FFSRX
      GO TO 98
   93 FFSRX= TF(2,KTRL(9),RHOX)
      CN1 = .5
      IF(ITQ.EQ.2) CN1 = FKAYA
      USRX = CN1*T4*FFSRX
   98 TSRX=USRX
      IF(KTRL(11).EQ.0) GO TO 108
      T30 = .004927*ETA*ECM
      RHOY= AMAX1(RHOX,RHOBC)
      USRX=USRX+T30/RHOY**3
```

```
C.....COMPUTE FFSIX AND USIX
  108 IF(KTRL(10).NE.0) GO TO 113
      FFSIX = S4
      USIX=T5*FFSIX
      GO TO 118
  113 FFSIX = TF(2,KTRL(10),RHOX)
      CN1 = .5
      IF(ITQ.EQ.2) CN1=FKAYA
      USIX = CN1*T5*FFSIX
  118 TSIX=USIX
      GO TO (123,133,195),MM
  123 FFCR(I)= FFCRX
      UCRB(I)= UCRX
      FFCI(I)= FFCIX
      UCIB(I)= UCIX
      FFSR(I)= FFSRX
      USRB(I)= USRX
      FFSI(I)= FFSIX
      USIB(I)= USIX
      IF(I.EQ.ILAST)GO TO 175
      MM=2
      RHOX = RHOX+.5*DRHO(I)
      GO TO 4
  133 FFCRM(I)= FFCRX
      UCRM(I)= UCRX
      FFCIM(I)= FFCIX
      UCIM(I)= UCIX
      FFSRM(I)= FFSRX
      USRM(I)= USRX
      FFSIM(I)= FFSIX
      USIM(I)= USIX
      MM=1
      GO TO 3
  175 RETURN
C.....ENTRY FOR POTICH CALCULATIONS
      ENTRY PGNCK(RHOT,TCR,TCI,TSR,TSI)
      RHOX=RHOT
      MM=3
      GO TO 1
  195 TCR=TCRX
      TCI=TCIX
      TSR=TSRX
      TSI=TSIX
      GO TO 175
C.....ENTRY TO INITIALIZE PGEN4
      ENTRY PGNIN
      KNTV=KTRL(7)+KTRL(8)+KTRL(9)+KTRL(10)
      IF(KNTV.NE.0)READ(5,200)TH, TN1, TN2, PMA, PMB
  200 FORMAT(8E10.0)
      GO TO 175
C.....ENTRY FOR TFX INITIAL OUTPUT
      ENTRY PGNOUT
      IF(KNTV.NE.0)WRITE(6,250) TH(1), TRM(1), TN1(1), TN2(1), PMA,
     1TH(2), TRM(2), TN1(2), TN2(2), PMB
  250 FORMAT(7H1    HA=E16.9,7H    RMA=E16.9,7H    N1A=E16.9,7H    N2A=E16.9
     1,7H    PMA=E16.9/7H    HB=E16.9,7H    RMB=E16.9,7H    N1B=E16.9,7H
     2N2B=E16.9,7H    PMB=E16.9)
      GO TO 175
      END
```

```
$IBFTC TFX      LOST,DECK
      FUNCTION  TF(JTQ,KOD,RHOX)
C.....SPECIAL CENTRAL NUCLEAR FORM FACTOR
C.....VARIABLES USED FOR KNEE AND TAIL VARIATIONS
      COMMON/SCNFF/TH(2), TN1(2), TN2(2), TRM(2),PMA, PMB
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA,  FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
      ITQ=JTQ
      GO TO (3,6),ITQ
    3 IX=2
      IF(KOD.EQ.1) IX=1
      GO TO 9
    6 IX=1
      IF(KOD.LE.1)GO TO 9
      ITQ=1
      IX=2
    9 TTN= TN1(IX)
      IF(RHOX.GT.RHOBN) TTN= TN2(IX)
      T20= RHOX/RHOBN
      TF=0.
      IF(TTN*ALOG(T20).GT.80.) GO TO 35
      TEM= TTN*FKAY*A
      IF(TEM.NE.0.) GO TO 12
      TG = T20**(RHOBN/FKAY*A)
      GO TO 18
   12 TQ=(T20**TTN-1.)*RHOBN/TEM
      IF(TQ.GT.80.) GO TO 35
      TG = EXP(TQ)
   18 TF= 1./(1.+TG)
      IF(RHOX.GT.TRM(IX))GO TO (35,28),ITQ
      T21= RHOX/TRM(IX)
      THH = TH(IX)*(1.+2.*T21)*(1.-T21)**2
      IF(ITQ.EQ.2) GO TO 28
      TF = TF*(1.+THH)
      GO TO 35
   28 TFN = TF
      TF= RHOBN*T20**TTN*TG*(TFN/RHOX)**2/(FKAY*A)
      IF(RHOX.GT.TRM(IX))GO TO 35
      T24= 6.*TH(IX)*(1.-T21)/TRM(IX)**2
      TF = T24*TFN+ (1.+THH)*TF
   35 RETURN
      ENTRY TF1(DUM)
      TRM(1)=PMA*RHOBN
      TRM(2)=PMB*RHOBN
      TF=DUM
      GO TO 35
      END
```

```
$IBFTC INTCTR  LOST,DECK
      SUBROUTINE INTCTR(*)
C.....RADIAL WAVE FUNCTIONS AND THEIR FIRST DERIVATIVES DURING INTEGRATI
      COMMON/RWF/L, XC1, XCP1, XD1, XDP1, YC1, YCP1, YD1, YDP1
C.....FINAL RADIAL WAVE FUNCTIONS AND FIRST DERIVATIVES
      COMMON/RWFF/X1(51), X1P(51), X2(51), X2P(51), Y1(51), Y1P(51),
     1Y2(51), Y2P(51)
```

```
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
      COMMON/LIND/LMAX, LMAXM
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....CONTROL INTEGRATION OF RADIAL EQUATIONS
      IFIRST=1
      IDX=1
C.....KTRLX(6)=1 FOR EXCHANGE FORM IN SPIN-ORBIT POTENTIAL
      IF(KTRLX(6).EQ.1)IDX=2
      DO 2 KK=1,IDX
      DO 1 L=KK,LMAX,IDX
      TEM=RHO(IFIRST)**(L-1)
      XC1=TEM*RHO(IFIRST)
      XD1=XC1
      FL=L
      XCP1=FL*TEM
      XDP1=XCP1
      YC1=0.0
      YD1=0.0
      YCP1=0.0
      YDP1=0.0
      CALL RKINT
      X1(L)=XC1
      X2(L)=XD1
      Y1(L)=YC1
      Y2(L)=YD1
      X1P(L)=XCP1
      X2P(L)=XDP1
      Y1P(L)=YCP1
    1 Y2P(L)=YDP1
      IF(IDX.EQ.1)GO TO 2
      IF(KK.EQ.2)GO TO 2
      VSSAV=VS
      VS=DUMMY(4)
      CALL POTICH($15)
C.....GENERATE POTENTIAL FOR EXCHANGE TERM
      CALL PGEN4
    2 CONTINUE
      IF(IDX.EQ.2)VS=VSSAV
      RETURN
   15 RETURN 1
      END
```

```
$IBFTC RKINT    LOST,DECK
      SUBROUTINE RKINT
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....RADIAL WAVE FUNCTIONS AND THEIR FIRST DERIVATIVES DURING INTEGRATI
      COMMON/RWF/L, XC1, XCP1, XD1, XDP1, YC1, YCP1, YD1, YDP1
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....VARIABLES COMPUTED IN PGEN4 (NUCLEAR POTENTIAL TERMS)
      COMMON/PGU/FLPT,UCRB(250), UCIB(250), UCRM(250), UCIM(250),
     1USRB(250), USIB(250), USRM(250), USIM(250)
```

```
    1 FL=L-1
      F2L=-1.0-FL
      F3L=FL*(FL+1.0)
      TB=UCRB(IFIRST)+F3L/(RHO(IFIRST)**2)
C.....IF VS=WS=0, OMIT REDUNDANT INTEGRATION STEPS
      IF(KTRL(11).NE.0)GO TO 13
      IF(VS.EQ.0..AND.WS.EQ.0.)GO TO 413
   13 PCB=TB+USRB(IFIRST)*FL
      PDB=TB+USRB(IFIRST)*F2L
      QCB=UCIB(IFIRST)+USIB(IFIRST)*FL
      QDB=UCIB(IFIRST)+USIB(IFIRST)*F2L
      IK=ILAST-1
      DO 6 I=IFIRST,IK
    2 HDRHO=.5*DRHO(I)
      DRHO2=(DRHO(I)**2)*.5
      RHOM=RHO(I)+HDRHO
      TM=UCRM(I)+F3L/(RHOM**2)
   15 PCM=TM+USRM(I)*FL
      PDM=TM+USRM(I)*F2L
      QCM=UCIM(I)+USIM(I)*FL
      QDM=UCIM(I)+USIM(I)*F2L
      XCPP1=PCB*XC1-QCB*YC1
      YCPP1=QCB*XC1+PCB*YC1
      XDPP1=PDB*XD1-QDB*YD1
      YDPP1=QDB*XD1+PDB*YD1
      XC2=XC1+XCP1*HDRHO
      YC2=YC1+YCP1*HDRHO
      XD2=XD1+XDP1*HDRHO
      YD2=YD1+YDP1*HDRHO
      XCPP2=PCM*XC2-QCM*YC2
      YCPP2=QCM*XC2+PCM*YC2
      XDPP2=PDM*XD2-QDM*YD2
      YDPP2=QDM*XD2+PDM*YD2
      DRHO4=.5*DRHO2
      SDRHO=.33333333*HDRHO
      XC3=XC2+XCPP1*DRHO4
      YC3=YC2+YCPP1*DRHO4
      XD3=XD2+XDPP1*DRHO4
      YD3=YD2+YDPP1*DRHO4
      XCPP3=PCM*XC3-QCM*YC3
      YCPP3=QCM*XC3+PCM*YC3
      XDPP3=PDM*XD3-QDM*YD3
      YDPP3=QDM*XD3+PDM*YD3
      XC4=XC2+XCPP2*DRHO2+XCP1*HDRHO
      YC4=YC2+YCPP2*DRHO2+YCP1*HDRHO
      XD4=XD2+XDPP2*DRHO2+XDP1*HDRHO
      YD4=YD2+YDPP2*DRHO2+YDP1*HDRHO
      TB=UCRB(I+1)+F3L/(RHO(I+1)**2)
   17 PCB=TB+USRB(I+1)*FL
      PDB=TB+USRB(I+1)*F2L
      QCB=UCIB(I+1)+USIB(I+1)*FL
      QDB=UCIB(I+1)+USIB(I+1)*F2L
      XCPP4=PCB*XC4-QCB*YC4
      YCPP4=QCB*XC4+PCB*YC4
      XDPP4=PDB*XD4-QDB*YD4
      YDPP4=QDB*XD4+PDB*YD4
      SXC=XCPP2+XCPP3
      SYC=YCPP2+YCPP3
      SXD=XDPP2+XDPP3
      SYD=YDPP2+YDPP3
      TXC=SXC+XCPP1
      TYC=SYC+YCPP1
```

```
      TXD=SXD+XDPP1
      TYD=SYD+YDPP1
      TXC1=XC1+DRHO(I)*(XCP1+SDRHO*TXC)
      TYC1=YC1+DRHO(I)*(YCP1+SDRHO*TYC)
      TXD1=XD1+DRHO(I)*(XDP1+SDRHO*TXD)
      TYD1=YD1+DRHO(I)*(YDP1+SDRHO*TYD)
      TXCP1=XCP1+SDRHO*(TXC+SXC+XCPP4)
      TYCP1=YCP1+SDRHO*(TYC+SYC+YCPP4)
      TXDP1=XDP1+SDRHO*(TXD+SXD+XDPP4)
      TYDP1=YDP1+SDRHO*(TYD+SYD+YDPP4)
      TEM= AMAX1(ABS(XC1),ABS(YC1),ABS(XCP1),ABS(YCP1),
     1       ABS(XD1),ABS(YD1),ABS(XDP1),ABS(YDP1))
      IF(TEM-1.E+30)21,21,316
  316 RENORM=TEM
  320 XC1=XC1/RENORM
      YC1=YC1/RENORM
      XCP1=XCP1/RENORM
      YCP1=YCP1/RENORM
      XD1=XD1/RENORM
      YD1=YD1/RENORM
      XDP1=XDP1/RENORM
      YDP1=YDP1/RENORM
      WRITE (6,200)RENORM,L,RHO(I)
  200 FORMAT(24H RENORMALIZATION FACTOR=E16.9,22H IN RKINT FOR CODED L=I
     13,9H AND RHO=E16.9)
      JSPILL=0
      GO TO 2
   21 XC1=TXC1
      YC1=TYC1
      XD1=TXD1
      YD1=TYD1
      XCP1=TXCP1
      YCP1=TYCP1
      XDP1=TXDP1
      YDP1=TYDP1
    6 CONTINUE
    4 RETURN
C.....INTEGRATION STEPS FOR VS=WS=0, OMITS REDUNDANT EQUATIONS
  413 PCB=TB
      QCB=UCIB(IFIRST)
      IK=ILAST-1
      DO 46 I=IFIRST,IK
   42 HDRHO=.5*DRHO(I)
      DRHO2=(DRHO(I)**2)*.5
      RHOM=RHO(I)+HDRHO
      TM=UCRM(I)+F3L/(RHOM**2)
  415 PCM=TM
      QCM=UCIM(I)
      XCPP1=PCB*XC1-QCB*YC1
      YCPP1=QCB*XC1+PCB*YC1
      XC2=XC1+XCP1*HDRHO
      YC2=YC1+YCP1*HDRHO
      XCPP2=PCM*XC2-QCM*YC2
      YCPP2=QCM*XC2+PCM*YC2
      DRHO4=.5*DRHO2
      SDRHO=.33333333*HDRHO
      XC3=XC2+XCPP1*DRHO4
      YC3=YC2+YCPP1*DRHO4
      XCPP3=PCM*XC3-QCM*YC3
      YCPP3=QCM*XC3+PCM*YC3
      XC4=XC2+XCPP2*DRHO2+XCP1*HDRHO
      YC4=YC2+YCPP2*DRHO2+YCP1*HDRHO
      TB=UCRB(I+1)+F3L/(RHO(I+1)**2)
```

```
 417  PCB=TB
      QCB=QCIB(I+1)
      XCPP4=PCB*XC4-QCB*YC4
      YCPP4=QCB*XC4+PCB*YC4
      SXC=XCPP2+XCPP3
      SYC=YCPP2+YCPP3
      TXC=SXC+XCPP1
      TYC=SYC+YCPP1
      TXC1=XC1+DRHO(I)*(XCP1+SDRHO*TXC)
      TYC1=YC1+DRHO(I)*(YCP1+SDRHO*TYC)
      TXCP1=XCP1+SDRHO*(TXC+SXC+XCPP4)
      TYCP1=YCP1+SDRHO*(TYC+SYC+YCPP4)
      TEM=AMAX1(ABS(XC1),ABS(YC1),ABS(XCP1),ABS(YCP1))
      IF(TEM-1.E+30)421,421,4316
 4316 RENORM=TEM
 4320 XC1=XC1/RENORM
      YC1=YC1/RENORM
      XCP1=XCP1/RENORM
      YCP1=YCP1/RENORM
      WRITE (6,4200)RENORM,L,RHO(I)
 4200 FORMAT(24H RENORMALIZATION FACTOR=E16.9,22H IN RKINT FOR CODED L=I
     13,9H AND RHO=E16.9)
      GO TO 42
 421  XC1=TXC1
      YC1=TYC1
      XD1=XC1
      YD1=YC1
      XCP1=TXCP1
      YCP1=TYCP1
      XDP1=XCP1
      YDP1=YCP1
 46   CONTINUE
  44  RETURN
      END
```

```
$IBFTC CSUBL    LIST,DECK
      SUBROUTINE CSUBL
C.....FINAL RADIAL WAVE FUNCTIONS AND FIRST DERIVATIVES
      COMMON/RWFF/X1(51), X1P(51), X2(51), X2P(51), Y1(51), Y1P(51),
     1Y2(51), Y2P(51)
      COMMON/LIND/LMAX, LMAXM
C.....VARIABLES WHICH ARE CALCULATED AS FUNCTIONS OF L
      COMMON/VARL/CI1(51), CI2(51), CR1(51), CR2(51), EXSGMI(51),
     1EXSGMR(51), F(52), FBAR(91), FP(51), G(52), GP(51)
C.....COMPUTE C-COEFFICIENTS
      DO 40 L=1,LMAX
      XNORM1=AMAX1(ABS(X1(L)),ABS(Y1(L)),ABS(X1P(L)),ABS(Y1P(L)))
      TX1L=X1(L)/XNORM1
      TY1L=Y1(L)/XNORM1
      TX1PL=X1P(L)/XNORM1
      TY1PL=Y1P(L)/XNORM1
      FNORM=AMAX1(F(L),G(L),FP(L),GP(L))
      TFL=F(L)/FNORM
      TGL=G(L)/FNORM
      TFPL=FP(L)/FNORM
      TGPL=GP(L)/FNORM
      C01=TFL*TY1PL-TFPL*TY1L
      C02=TFPL*TX1L-TFL*TX1PL
```

```
      CO3=TY1L*TGPL-TY1PL*TGL+TX1L*TFPL-TX1PL*TFL                       16--0240
      CO4=TX1PL*TGL-TX1L*TGPL+TY1L*TFPL-TY1PL*TFL                       16--0250
      CO7=1.C/(CO3**2+CO4**2)                                           16--0260
   53 CR1(L)=(CO1*CO3+CO2*CO4)*CO7                                      16--0270
      CI1(L)=(CO2*CO3-CO1*CO4)*CO7                                      16--0280
      XNORM2=AMAX1(ABS(X2(L)),ABS(Y2(L)),ABS(X2P(L)),ABS(Y2P(L)))       16--0290
      TX2L=X2(L)/XNORM2                                                 16--0300
      TY2L=Y2(L)/XNORM2                                                 16--0310
      TX2PL=X2P(L)/XNORM2                                               16--0320
      TY2PL=Y2P(L)/XNORM2                                               16--0330
      CO1=TFL*TY2PL-TFPL*TY2L                                           16--0340
      CO2=TFPL*TX2L-TFL*TX2PL                                           16--0350
      CO3=TY2L*TGPL-TY2PL*TGL+TX2L*TFPL-TX2PL*TFL                       16--0360
      CO4=TX2PL*TGL-TX2L*TGPL+TY2L*TFPL-TY2PL*TFL                       16--0370
      CO7=1.C/(CO3**2+CO4**2)                                           16--0380
   55 CR2(L)=(CO1*CO3+CO2*CO4)*CO7                                      16--0390
   40 CI2(L)=(CO2*CO3-CO1*CO4)*CO7                                      16--0400
   59 RETURN                                                            16--0410
      END                                                               16--0420
```

```
$IBFTC AB       LOST,DECK                                               17--0010
      SUBROUTINE AB                                                     17--0020
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA    17--0030
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),17--0040
     1SGMAEX(15C), SGMATH(150), THETA(150), THETAD(150)                 17--0050
      COMMON/LIND/LMAX, LMAXM                                           17--0060
C.....VARIABLES WHICH ARE CALCULATED AS FUNCTICNS OF L                  17--0070
      COMMON/VARL/CI1(51), CI2(51), CR1(51), CR2(51), EXSGMI(51),       17--0080
     1EXSGMR(51), F(52), FBAR(91), FP(51), G(52), GP(51)                17--0090
C.....OTHER SCATLE VARIABLES                                            17--0100
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,     17--0110
     1RHOBNG, SIGMAO, SIGMA1, TEMP                                      17--0120
C.....SCATTERING AMPLITUDES AND ADDITICNAL CRCSS SECTIONS               17--0130
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR(150)17--0140
     1,SGMAC(15C), SIGTEM(150), SRATIO(150)                             17--0150
      DIMENSION P(52),PP(51)                                            17--0160
C.....COMPUTE SCATTERING AMPLITUDES A, B                                17--0170
      FKAYD=1.0/FKAY                                                    17--0180
    4 DO 20 J=1,JMAX                                                    17--0190
      ASUMR=C.0                                                         17--0200
      ASUMI=C.0                                                         17--0210
      BSUMR=C.0                                                         17--0220
      BSUMI=C.0                                                         17--0230
C.....COMPUTES LEGENDRE POLYNOMIALS                                     17--0240
      SI2=1.C/SIN(THETA(J))                                             17--0250
      CO=COS(THETA(J))                                                  17--0260
      P(1)=1.0                                                          17--0270
      P(2)=CO                                                           17--0280
      PP(1)=C.0                                                         17--0290
      TWOLP1=3.0                                                        17--0300
      FL=1.C                                                            17--0310
      DO 20C8 L=1,LMAXM                                                 17--0320
      TL=FL+1.0                                                         17--0330
      P(L+2)  =(TWOLP1*CO*P(L+1)  -FL*P(L)  )/TL                        17--0340
      PP(L+1)  =TL*SI2*(CO*P(L+1)  -P(L+2)  )                           17--0350
      TWOLP1=TWOLP1+2.0                                                 17--0360
 20C8 FL=TL                                                             17--0370
      DO 10 L=1,LMAX                                                    17--0380
```

```
      FL=L                                                              17--0390
      ATR1=FL*CR1(L)+(FL-1.0)*CR2(L)                                    17--0400
      ATI1=FL*CI1(L)+(FL-1.0)*CI2(L)                                    17--0410
      BTR1=CR1(L)-CR2(L)                                                17--0420
      BTI1=CI1(L)-CI2(L)                                                17--0430
      ATR2=ATR1*EXSGMR(L)-(ATI1*EXSGMI(L))                              17--0440
      ATI2=ATR1*EXSGMI(L)+(ATI1*EXSGMR(L))                              17--0450
      BTR2=BTR1*EXSGMR(L)-(BTI1*EXSGMI(L))                              17--0460
      BTI2=BTR1*EXSGMI(L)+(BTI1*EXSGMR(L))                              17--0470
      ASUMR=ASUMR+(ATR2*P(L   ))                                        17--0480
      ASUMI=ASUMI+(ATI2*P(L   ))                                        17--0490
      BSUMR=BSUMR+(BTR2*PP(L   ))                                       17--0500
   10 BSUMI=BSUMI+(BTI2*PP(L   ))                                       17--0510
      AR(J)= FCR(J)+(FKAYD*ASUMR)                                       17--0520
      AI(J)=FCI(J)+(FKAYD*ASUMI)                                        17--0530
      BR(J)= FKAYD*BSUMI                                                17--0540
   20 BI(J)= -FKAYD*BSUMR                                               17--0550
   33 RETURN                                                            17--0560
      END                                                               17--0570
```

```
$IBFTC SGSGCP  LOST,DECK                                                18--0010
      SUBROUTINE SGSGCP                                                 18--0020
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS               18--0030
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR( 150)18--0040
     1,SGMAC(150), SIGTEM(150), SRATIO(150)                             18--0050
C.....OTHER SCATLE VARIABLES                                            18--0060
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,     18--0070
     1RHOBNG, SIGMA0, SIGMA1, TEMP                                      18--0080
C.....SCATLE CONTROLS                                                   18--0090
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)           18--0100
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA    18--0110
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),18--0120
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)                 18--0130
C.....COMPUTE CROSS SECTION, POLARIZATION, RATIO(SIGMA/SIGMA-COUL)      18--0140
      DO 50 J=1,JMAX                                                    18--0150
      SGMATH(J) = AR(J)*AR(J)+AI(J)*AI(J) + BR(J)*BR(J)+BI(J)*BI(J)     18--0160
      POLTH(J)= -(2.0*(AR(J)*BR(J)+AI(J)*BI(J)))/SGMATH(J)              18--0170
   13 SGMAC(J) = FCR(J)*FCR(J) + FCI(J)*FCI(J)                          18--0180
      IF(ETA) 7,7,8                                                     18--0190
    8 SRATIO(J)=SGMATH(J)/SGMAC(J)                                      18--0200
   15 GO TO 5                                                           18--0210
    7 SRATIO(J)=0.0                                                     18--0220
    5 IF(KTRLX(3))1,50,1                                                18--0230
    1 IF(DSGMEX(J)-1.E+27)2,2,3                                         18--0240
    2 SIGTEM(J)=SGMAC(J)                                                18--0250
      GO TO 50                                                          18--0260
    3 SIGTEM(J)=DSGMEX(J)                                               18--0270
   50 CONTINUE                                                          18--0280
   19 RETURN                                                            18--0290
      END                                                               18--0300
```

```
$IBFTC SIGMAR  LOST,DECK                                                19--0010
      SUBROUTINE SIGMAR                                                 19--0020
```

```
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),
     1CHI2P(150), CHI2(150), ENORM, SGMRTH,SNORM,XNORM,NP,CSNRM,NCSN
C.....VARIABLES WHICH ARE CALCULATED AS FUNCTIONS OF L
      COMMON/VARL/CI1(51), CI2(51), CR1(51), CR2(51), EXSGMI(51),
     1EXSGMR(51), F(52), FBAR(91), FP(51), G(52), GP(51)
      COMMON/LIND/LMAX, LMAXM
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMA0, SIGMA1, TEMP
C.....COMPUTE REACTION CROSS SECTIONS
      FL=0.0
      SGMRTH=0.0
      CPI=(.12566370E+02)/(FKAY**2)
      DO 20 L=1,LMAX
      SGMRTH=SGMRTH+FL*(CI2(L)-(CI2(L))**2-(CR2(L))**2)
      FL=FL+1.0
   20 SGMRTH=SGMRTH+FL*(CI1(L)-(CI1(L))**2-(CR1(L))**2)
      SGMRTH=CPI*SGMRTH
   13 RETURN
      END
```

```
$IBFTC CHISQ    LIST,DECK
      SUBROUTINE CHISQ
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),
     1CHI2P(150), CHI2(150), ENORM, SGMRTH,SNORM,XNORM,NP,CSNRM,NCSN
C.....SCATLE CONTROLS
      COMMON/CNTR/KULT, KSEND, KTRL(13), KTRLT(3), NF, NR, N1, IN1,
     1N2, IN2, N3, IN3, N4, IN4, KTRLX(13)
C.....AUXILIARY SEARCH VARIABLES
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,
     1NPCT, NPCTP, PCT
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR(150)
     1,SGMAC(150), SIGTEM(150), SRATIO(150)
      DIMENSION CHIQS(19)
      EQUIVALENCE
     1(CHIQS(1),CHI2ST), (SUMS(1),SUM1S), (SUMS(2),SUM1P),
     2(SUMS(3),SUM2S), (SUMS(4),SUM2P), (SUMS(5),SUM3S),(SUMS(6),SUM3P),
     3(SUMS(7),SUM4S), (SUMS(8),SUM4P),(SUMS(9),SUMFS),(SUMS(10),SUMFP),
     4(SUMS(11),SUMMS),(SUMS(12),SUMMP),(SUMS(13),SUMRS),
     5(SUMS(14),SUMRP), (SUMS(15),SUM34S), (SUMS(16),SUM34P)
      ANUM=0.
      DEN=0.
      DO 20 J=1,JMAX
      TEM=SGMATH(J)/DSGMEX(J)
      ANUM=ANUM+TEM**2
   20 DEN=DEN+TEM*SGMAEX(J)/DSGMEX(J)
      ENORM=ANUM/DEN
      IF(KTRLX(5).EQ.2)SNORM=ENORM
      CHI2PT=0.
      CHI2ST=0.
      DO 28 J=1,JMAX
      CHI2P(J)=((POLTH(J)-POLEX(J))/DPOLEX(J))**2
      CHI2PT=CHI2PT+CHI2P(J)
```

```
      CHI2S(J)=SGMATH(J)-SNORM*SGMAEX(J)
      CHI2S(J)=(CHI2S(J)/(SNORM*SIGTEM(J)))**2
      CHI2(J)=CHI2S(J) + CHI2P(J)
   28 CHI2ST=CHI2ST+CHI2S(J)
      CHI2T=CHI2ST+CHI2PT
   32 GO TO (19,26,26),KDLMAX
   26 DO 40 I=1,14
   40 SUMS(I)=0.0
C.....CALCULATE SPECIAL CHI SQUARES
      IF(KDLMAX-3)1,16,1
    1 IF (N1) 2,3,2
    2 LIM = N1+IN1
      DO 101  J=N1,LIM
      SUM1S = SUM1S+CHI2S(J)
  101 SUM1P = SUM1P+CHI2P(J)
    3 IF (N2) 4,5,4
    4 LIM = N2+IN2
      DO 102  J=N2,LIM
      SUM2S = SUM2S+CHI2S(J)
  102 SUM2P=SUM2P+CHI2P(J)
    5 IF (N3) 6,7,6
    6 LIM = N3+IN3
      DO 103  J=N3,LIM
      SUM3S = SUM3S+CHI2S(J)
  103 SUM3P = SUM3P + CHI2P(J)
    7 IF(N4)14,15,14
   14 LIM = N4+IN4
      DO 104  J=N4,LIM
      SUM4S = SUM4S + CHI2S(J)
  104 SUM4P = SUM4P + CHI2P(J)
   15 SUM34S = SUM3S+SUM4S
      SUM34P = SUM3P+SUM4P
   16 DO 105  J=1,NF
      SUMFS = SUMFS+CHI2S(J)
  105 SUMFP=SUMFP+CHI2P(J)
      I = NF+1
      DO 106  J=I,NR
      SUMMS = SUMMS+CHI2S(J)
  106 SUMMP = SUMMP+CHI2P(J)
      I = NR+1
      DO 107  J=I,JMAX
      SUMRS = SUMRS+CHI2S(J)
  107 SUMRP=SUMRP+CHI2P(J)
   19 IF(KSEND.NE.2)GO TO 43
C.....OUTPUT SCATLE PARAMETERS
   30 CALL POUT
      WRITE(6,60) ENORM,CHI2ST,CHI2PT,CHI2T
   60 FORMAT(1H+,26X,6HENORM=1PG14.7,4X,7HCHI2ST=G14.7,4X,7HCHI2PT=G14.7
     1,5X,6HCHI2T=G14.7)
      CALL SOUF
      DO 38 KK=1, NCSN
   38 CHIQS(KK)=CHIQS(KK)/CSNRM
      WRITE(6,80) CSNRM, CHI2ST, CHI2PT, CHI2T
   80 FORMAT(1HK,10X,20HSUM OF CHI SQUARES /F5.0,15X,7HCHI2ST=G14.7,4X,7
     1HCHI2PT=G14.7,5X,6HCHI2T=G14.7)
      CALL SOUF
      WRITE(6,70)
   70 FORMAT(1HK,10(2H- ))
   43 RETURN
      END
```

```
$IBFTC PTFFRI  LIST,DECK
      SUBROUTINE PTFFRI
C.....VARIABLES COMPUTED IN PGEN4 (NUCLEAR POTENTIAL TERMS)
      COMMON/PGU/FLPT,UCRB(250), UCIB(250), UCRM(250), UCIM(250),
     1USRB(250), USIB(250), USRM(250), USIM(250)
C.....VARIABLES COMPUTED IN PGEN4 (FORM FACTORS)
      COMMON/PGF/FFCI(250), FFCIM(250), FFCR(250), FFCRM(250), FFSI(250)
     1,FFSIM(250), FFSR(250), FFSRM(250)
C.....VARIABLES COMPUTED IN RHOTB
      COMMON/RHT/DRHOL, DRHO(249), IFIRST, ILAST, RHO(250), RHOMAX
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMAO, SIGMA1, TEMP
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
      DIMENSION    KK(14), PT(11), YPLOT(1000), XPLOT(1000)
      EQUIVALENCE  (UCRB,XPLOT),(USRB,YPLOT)
C.....PLOT FORM FACTORS
C.....SET UP PLOT OF UCRB
      TESTA=1.50*V/ECM
      ANUM = FLPT*(FLPT + 1.)
      IF(FLPT) 7,6,7
    6 BN=8.
      CN=8.
      GO TO 9
    7 CN=0.
    8 CN=CN+1.
      DEN1=RHOBN-CN*FKAYA
      DEN1=DEN1*DEN1
      DEN2=RHOBN+CN*FKAYA
      DEN2=DEN2*DEN2
      TERM=ANUM/DEN1-ANUM/DEN2
      IF(TERM-TESTA)8,8,19
   19 BN=AMIN1(8.,CN)
    9 TESTB=RHOBN+BN*FKAYA
      TESTC=RHOBN-CN*FKAYA
      KNT=0
      DO 2 I=1,ILAST
      IF(TESTC-RHO(I))1,1,2
    1 IF(RHO(I)-TESTB)3,3,2
    3 TERM=ANUM/(RHO(I)*RHO(I))
    4 KNT=KNT+1
      UCRB(KNT)=UCRB(I)+TERM+1.
      UCRB(KNT)=-UCRB(KNT)
      YPLOT(KNT)=RHO(I)
    2 CONTINUE
      PT(1)=KNT
      KODE=48
      IX1=ABS(UCRB(1))
      X1=IX1+1
      JX1=SIGN(X1,UCRB(1))
      IXL=ABS(UCRB(KNT))
      XL=IXL+1
      JXL=SIGN(XL,UCRB(KNT))
      IXBEG=MIN0(JX1,JXL)
      XBEG=100*IXBEG
      IDELX=IABS(JXL-JX1)
      DELX=IDELX*2
      IRO1=YPLOT(1)
      RO1=100*IRO1
```

```
      IROF=YPLOT(KNT)
      IDELY=IROF-IRO1
      DELY=IDELY+1
      PT(6)=4.
      PT(7)=XBEG
      PT(8)=DELX
      PT(9)=4.
      PT(10)=RO1
      PT(11)=DELY
      CALL SORTXY(UCRB,YPLOT,KNT)
      WRITE(6,100)FLPT
      CALL PLOTXY(UCRB,YPLOT,KODE,PT)
      WRITE(6,101)
  100 FORMAT(33HPT PLOT OF UCRB VS RHO        FLPT=F4.0)
  101 FORMAT(2HPL)
C.....SET UP PLOT OF FFSR, FFSI, FFCR, FFCI
      TEST=RHOBN+7.5*FKAYA
      CNSR=4.*RHOBN
      CNSI=CNSR
      IF(KTRL(9).EQ.2)CNSR=1.
      IF(KTRL(10).EQ.2)CNSI=1.
      KNT=0
      DO 28 I=1,ILAST
      IF(RHO(I)-TEST)29,29,28
   29 KNT=KNT+1
   28 CONTINUE
      NPTS=KNT
      KNT=0
      DO 12 I=1,ILAST
      IF(RHO(I)-TEST)11,11,12
   11 KNT=KNT+1
      I2=NPTS+KNT
      I3=NPTS+I2
      I4=NPTS+I3
      XPLOT(KNT)=CNSR*FFSR(I)
      XPLOT(I2)=CNSI*FFSI(I)
      XPLOT(I3)=FFCR(I)
      XPLOT(I4)=FFCI(I)
      YPLOT(KNT)=RHO(I)
   12 CONTINUE
      KDEL=YPLOT(NPTS)
      DELF=KDEL+1
      KK(1)=48
      KK(2)=4
      KK(3)=NPTS
      PT(1)=3.
      PT(6)=3.
      PT(7)=0.
      PT(8)=25.
      PT(9)=4.
      PT(10)=0.
      PT(11)=DELF
      WRITE(6,200)
      CALL PLOTMY(XPLOT,YPLOT,KK,PT)
      WRITE(6,201)
      RETURN
  200 FORMAT(44HPT PLOT OF FFSR, FFSI, FFCR, AND FFCI VS RHO)
  201 FORMAT(42HPL * FFSR      + FFSI      0 FFCR      X FFCI)
      END
```

```
$IBFTC TRIPS   LIST,DECK
      SUBROUTINE TRIPS
C.....COMPUTE, OUTPUT, AND PLOT TRIPLE SCATTERING PARAMETERS
C.....SCAT-4 DIMENSIONS AND COMMON
C.....VARIABLES COMPUTED IN PGEN4 (NUCLEAR POTENTIAL TERMS)
      COMMON/PGU/FLPT,UCRB(250), UCIB(250), UCRM(250), UCIM(250),
     1USRB(250), USIB(250), USRM(250), USIM(250)
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)
      COMMON/LIND/LMAX, LMAXM
C.....PAGE TITLING INFORMATION
      COMMON/PTI/NUMRUN, TITLE(13)
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR(150)
     1,SGMAC(150), SIGTEM(150), SRATIO(150)
C.....VARIABLES WHICH ARE CALCULATED AS FUNCTIONS OF L
      COMMON/VARL/CI1(51), CI2(51), CR1(51), CR2(51), EXSGMI(51),
     1EXSGMR(51), F(52), FBAR(91), FP(51), G(52), GP(51)
C.....ENERGY, MASS, AND CHARGE INPUT VALUES
      COMMON/EMCV/ELAB, FMB, FMI, FMU, RC, ZZ
      DIMENSION PT(11),R(14),XSAV(150),YPLOT(150)
      EQUIVALENCE (UCRB,XSAV), (USRB,YPLOT)
      IF(KTRLX(11)-2)355,309,355
  309 CALL SKIP
      WRITE(6,310)
  310 FORMAT(1H0,6X,5HTHETA,13X,3HFCR,17X,3HFCI,16X,6HAR-FCR,14X,
     16HAI-FCI,14X,5HSGMAC)
      DO 325 J=1,JMAX
      XSAV(J)=AR(J)-FCR(J)
      YPLOT(J)=AI(J)-FCI(J)
C.....OUTPUT REAL AND IMAG PARTS OF F, COULOMB SCATTERING AMPLITUDE
  325 WRITE(6,320)THETAD(J),FCR(J),FCI(J),XSAV(J),YPLOT(J),SGMAC(J)
  320 FORMAT(1H ,G15.3,5G20.8)
      CALL SKIP
      WRITE(6,330)
  330 FORMAT(1H0,6X,5HTHETA,13X,4HCAMP,16X,4HCPHA,16X,4HNAMP,16X,
     14HNPHA,9X,1HL,8X,6HSGCOUL)
C.....COMPUTE AND OUTPUT MAGNITUDES OF F, A-F
      DO 335 J=1,JMAX
      CAMP=SQRT(FCR(J)*FCR(J)+FCI(J)*FCI(J))
      CPHA=ATAN2(FCI(J),FCR(J))
      ANAMP=SQRT(XSAV(J)*XSAV(J)+YPLOT(J)*YPLOT(J))
      ANPHA=ATAN2(YPLOT(J),XSAV(J))
      IF(J-LMAX)332,332,331
  331 WRITE(6,340)THETAD(J),CAMP,CPHA,ANAMP,ANPHA
      GO TO 335
  332 SGCOUL=.5*ATAN2(EXSGMI(J),EXSGMR(J))
      WRITE(6,340)THETAD(J),CAMP,CPHA,ANAMP,ANPHA,J,SGCOUL
  340 FORMAT(1H ,G15.3,4G20.8,I3,G20.8)
  335 CONTINUE
      IF(LMAX-JMAX)355,355,352
  352 LIN=JMAX+1
      DO 353 L=LIN,LMAX
      SGCOUL=.5*ATAN2(EXSGMI(L),EXSGMR(L))
  353 WRITE(6,354) L,SGCOUL
  354 FORMAT(1H ,95X,I3,G20.8)
  355 WRITE(6,1000) NUMRUN,TITLE
 1000 FORMAT(11H1RUN NUMBERI3,10X,13A6 ///8X,5HTHETA15X,6HTANBET
```

```
1         15X,4HBETA12X,10H THETA,LAB14X,3HROT18X,3H-R')
      DO 5 J=1,JMAX
      YPLOT(J)=THETAD(J)
      ASQ= AR(J)*AR(J) + AI(J)*AI(J)
      BSQ= BR(J)*BR(J) + BI(J)*BI(J)
      TANBET=-2.*(AI(J)*BR(J) - AR(J)*BI(J))/(ASQ-BSQ)
C.....CALCULATE LAB ANGLE IN TERMS OF TAN AND COS
      TNTHO= SIN(THETA(J))/(COS(THETA(J))+ FMI/FMB)
      SCTHO= SQRT(1. + TNTHO*TNTHO)
      IF(TNTHO)20,21,21
   20 CSTHO= -1./SCTHO
      GO TO 22
   21 CSTHO= 1./SCTHO
C.....COMPUTE ROTATION OF POLARIZATION
   22 XXX= (ASQ-BSQ)/SGMATH(J)
      ROT= XXX*CSTHO*(1.+TANBET*TNTHO)
      CC=XXX*CSTHO*(TANBET-TNTHO)
      BETA= ATAN(TANBET)
      IF(TANBET)30,31,31
   30 BETA= 180.+BETA/.01745329252
      GO TO 32
   31 BETA= BETA/.01745329252
   32 THO= ATAN(TNTHO)
      IF(TNTHO)23,24,24
   23 THO= 180.+THO/.01745329252
      GO TO 25
   24 THO= THO/.01745329252
   25 CONTINUE
C.....OUTPUT TRIPLE SCATTERING PARAMETERS
      WRITE (6,1001) THETAD(J),TANBET,BETA,THO,ROT,CC
      XSAV(J)=-CC
      JJ=J+JMAX
      XSAV(JJ)=-ROT
    5 CONTINUE
C.....SET UP FOR PLOT OF ROT AND R-PRIME
   19 K(1)=48
      K(2)=2
      K(3)=JMAX
      PT(1)=3.
      PT(6)=4.
      PT(7)=-100.
      PT(8)=4.
      PT(9)=6.
      PT(10)=0.
      PT(11)=2.
      WRITE (6,100)
      CALL PLOTMY(XSAV,YPLOT ,K,PT)
      WRITE (6,101)
  100 FORMAT(23HPT   PLOT OF -R' AND ROT)
  101 FORMAT(27HPL   * -R'            + ROT)
 1001 FORMAT(6G20.8)
      RETURN
      END
```

```
$IBFTC PTETDL  LOST,DECK
      SUBROUTINE PTETDL
C.....VARIABLES COMPUTED IN PGEN4 (NUCLEAR POTENTIAL TERMS)
      COMMON/PGU/FLPT,UCRB(250), UCIB(250), UCRM(250), UCIM(250),
```

```
     1USRB(250), USIB(250), USRM(250), USIM(250)
      COMMON/LIND/LMAX, YLMAXM
C.....VARIABLES TO BE PLOTTED IN PTETDL
      COMMON/PTPL/AETA1(51), AETA2(51), DELR1(51), DELR2(51)
      DIMENSION KK(14), PT(11)
      DIMENSION XPLOT(408), YPLOT(408)
      EQUIVALENCE (UCRB,XPLOT), (USRB,YPLOT)
C.....PLOTS ETA1,ETA2,DELP, DELM
C.....SET UP ABSCISSA FOR BOTH PLOTS
    1 DO 2 I=1,5
      IF((LMAX-1)-10*I)3,3,2
    2 CONTINUE
    3 IF(I-3)5,4,5
    4 I=4
    5 PT(9)=5.0
      PT(10)=0.0
      PT(11)=I
      YPLOT(1)=0.
      DO 6 I=2,LMAX
    6 YPLOT(I)=YPLOT(I-1)+1.0
C.....SET UP PLOT OF ETA
    7 KK(1)=48
      KK(2)=2
      KK(3)=LMAX
      PT(1)=3.0
      PT(6)=4.0
      PT(7)=-100.0
      PT(8)=2.0
      DO 8 I=1,LMAX
      XPLOT(I)=-AETA1(I)
      IP=I+LMAX
    8 XPLOT(IP)=-AETA2(I)
      WRITE (6,100)
      CALL PLOTMY(XPLOT,YPLOT,KK,PT)
      WRITE (6,101)
C.....SET UP PLOT OF DELTA, DELTA-PI, DELTA+PI, DELTA+2PI
    9 KK(1)=48
      KK(2)=2
      KK(3)=4*LMAX
      PT(1)=3.0
      PT(6)=5.0
      PT(7)=-100.0
      PT(8)=1.0
C.....COMPUTE NEGATIVE VALUES TO BE PLOTTED
      DO 10 J=1,4
      IN=(J-1)*LMAX
      IND=(J+3)*LMAX
      CON=FLOAT(J-2)*PI
      DO 10 I=1,LMAX
      II=IN+I
      XPLOT(II)=-(DELR1(I)+CON)
      IP=IND+I
      XPLOT(IP)=-(DELR2(I)+CON)
   10 YPLOT(II)=YPLOT(I)
      WRITE (6,102)
      CALL PLOTMY(XPLOT,YPLOT,KK,PT)
      WRITE (6,103)
   11 RETURN
  100 FORMAT(29HPT PLOT OF ETA1 AND ETA2 VS L)
  101 FORMAT(20HPL * ETA1    + ETA2 )
  102 FORMAT(31HPT PLOT OF DELR1 AND DELR2 VS L)
  103 FORMAT(20HPL * DELR1   + DELR2)
      END
```

```
$IBFTC PTSCAT  LIST,DECK
      SUBROUTINE PTSCAT
C.....SCATLE INPUT AND OUTPUT VARIABLES WHICH ARE FUNCTIONS OF THETA
      COMMON/THI/DPOLEX(150), DSGMEX(150), JMAX, POLEX(150), POLTH(150),
     1SGMAEX(150), SGMATH(150), THETA(150), THETAD(150)
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....SCATTERING AMPLITUDES AND ADDITIONAL CROSS SECTIONS
      COMMON/SACS/AI(150), AR(150), BI(150), BR(150), FCI(150), FCR(150)
     1,SGMAC(150), SIGTEM(150), SRATIO(150)
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),
     1CHI2P(150), CHI2(150), ENORM, SGMRTH,SNORM,XNORM,NP,CSNRM, NCSN
      DIMENSION PT(11), KK(14), PSAV(6)
      DIMENSION XPLOT(150), YPLOT(150)
      EQUIVALENCE (AR,XPLOT), (BR,YPLOT)
      DIMENSION FMTA(10), FMTA1(8), FMTA2(10), FMTB(6), FMTB1(5),
     1FMTB2(6)
      DATA FMTA1(1)/48H(43HPT PLOT OF SGMAEX AND SGMATH VS THETA (DEG))/
      DATA FMTA2(1)/56H(51HPT PLOT OF (SNORM*SGMAEX) AND SGMATH VS THETA
     1 (DEG))/
      DATA FMTB1(1)/28H(23HPL * SGMAEX      + SGMATH)/
      DATA FMTB2(1)/36H(31HPL * (ENORM*SGMAEX)      + SGMATH)/
C.....KTRL(4)=0       NO PLOT
C.....KTRL(4)=1       PLOT OF POLEX AND POLTH VS THETAD
C.....KTRL(4)=2       PLOT OF SGMAEX AND SGMATH VS THETAD
C.....KTRL(4)=3       PLOT POLARIZATIONS AND CROSS SECTIONS
C.....KTRLX(5).NE.0   IF CROSS SECTIONS ARE PLOTTED, ALSO PLOT SGMAEX*ENO
C.....                AND SGMATH VS THETAD
      IF(KTRL(4).EQ.0)GO TO 48
C.....SET UP YPLOT FOR ALL PLOTS
      TMAX=0.
      DO 7 J=1,JMAX
      IF(THETAD(J).GT.TMAX)TMAX=THETAD(J)
    7 YPLOT(J)=THETAD(J)
      KK(1)=48
      KK(2)=2
      KK(3)=JMAX
      PT(1)=3.
      PT(9)=5.
      PT(10)=0.
      I=1
   13 AI=I
      IF(TMAX.LE.50.*AI)GO TO 18
      I=I+1
      GO TO 13
   18 PT(11)=5*I
      IF(KTRL(4).EQ.2)GO TO 28
C.....PLOT POLEX AND POLTH VS THETAD
      PT(6)=4.
      PT(7)=-100.
      PT(8)=4.
      DO 21 J=1,JMAX
      XPLOT(J)=-POLEX(J)
      JJ=J+JMAX
   21 XPLOT(JJ)=-POLTH(J)
      WRITE(6,100)
  100 FORMAT(41HPT PLOT OF POLEX AND POLTH VS THETA (DEG))
      CALL PLOTMY(XPLOT,YPLOT,KK,PT)
      WRITE(6,101)
  101 FORMAT(22HPL * POLEX      + POLTH)
      IF(KTRL(4).EQ.1)GO TO 48
```

```
C.....PLOT SGMAEX AND SGMATH VS THETAD
   28 XMIN=1.E10
      XMAX=1.E-10
      DO 31 J=1,JMAX
      XPLOT(J)=-ALOG10(SGMAEX(J))
      JJ=J+JMAX
      XPLOT(JJ)=-ALOG10(SGMATH(J))
      IF(XPLOT(J).LT.XMIN)XMIN=XPLOT(J)
      IF(XPLOT(JJ).LT.XMIN)XMIN=XPLOT(JJ)
      IF(XPLOT(J).GT.XMAX)XMAX=XPLOT(J)
      IF(XPLOT(JJ).GT.XMAX)XMAX=XPLOT(JJ)
   31 CONTINUE
      KOD=1
      DO 33 I=1,8
      FMTA(I)=FMTA1(I)
      IF(I.GT.5)GO TO 33
      FMTB(I)=FMTB1(I)
   33 CONTINUE
   35 MIN=XMIN
      MIN=MIN-1
      MAX=XMAX
      MAX=MAX+1
      IF(MAX-MIN.LT.4)GO TO 36
      PT(6)=5.
      PT(7)=10*MIN
      PT(8)=1.
      GO TO 38
   36 PT(6)=4.
      PT(7)=100*MIN
      PT(8)=5.
   38 WRITE(6,FMTA)
      CALL PLOTMY(XPLOT,YPLOT,KK,PT)
      WRITE(6,FMTB)
      IF(KOD.EQ.2)GO TO 48
      IF(KTRLX(5).EQ.0)GO TO 48
C.....PLOT SNORM * SGMAEX AND SGMATH VS THETAD
      DO 43 J=1,JMAX
      XPLOT(J)=-ALOG10(SNORM*SGMAEX(J))
      IF(XPLOT(J).LT.XMIN)XMIN=XPLOT(J)
      IF(XPLOT(J).GT.XMAX)XMAX=XPLOT(J)
      JJ=J+JMAX
      XPLOT(JJ)=-ALOG10(SGMATH(J))
   43 CONTINUE
      DO 45 I=1,10
      FMTA(I)=FMTA2(I)
      IF(I.GT.6)GO TO 45
      FMTB(I)=FMTB2(I)
   45 CONTINUE
      KOD=2
      GO TO 35
   48 RETURN
      END
```

```
$IBFTC ARGN     LIST,DECK
      SUBROUTINE ARGN
C.....VARIABLE METRIC MINIMIZATION (MONITOR ADAPTATION)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
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     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
C.....AUXILIARY SEARCH VARIABLES
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,
     1NPCT, NPCTP, PCT
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),
     1CHI2P(150), CHI2(150), ENORM, SGMRTH,SNORM,XNORM,NP,CSNRM,NCSN
      DIMENSION SER(12)
      EQUIVALENCE (RG,SER)
      DIMENSION CHIQS(19)
      EQUIVALENCE (CHIQS(1),CHI2ST)
      DO 705 I=1,N
      J=ID(I)
  705 X(I)=SER(J)
  101 MS=0
  109 WRITE (6,5)
  111 WRITE(6,6)N,KSTEP,E,VP,DELTA
      WRITE(6,7) NHP, NMLR, NPCT, PCT
    7 FORMAT(5H0NHP=I2,5X,5HNMLR=I2,5X,5HNPCT=I2,5X,4HPCT=F7.4)
      CALL SOUT
 2860 IF (NC) 113, 113, 2861
 2861 WRITE (6,2013)
 2862 DO 2863 J=1,NC
 2863 WRITE (6,2014)(C(I,J),I=1,N)
  113 WRITE (6,8)
  114 DO 115 I=1,N
  115 WRITE (6,9)(H(I,J),J=1,N)
  117 CALL FCN(N,VG(1),VF,X(1))
      M1=0
      IIN=1
  118 LV = 1
 1185 IT=0
  119 WRITE (6,14)IT,MS,VF
      CALL SOUT
  120 WRITE (6,4)
 1201 IF (NC) 121,121,1202
 1202 DO 1209 J1=1,NC
 1203 CALL MATMPY(N,N,H(1,1),C(1,J1),T(1))
 1204 CALL MATMPY(1,N,T(1),C(1,J1),TO)
 2204 IF (M1-1) 1206, 1206, 1205
 1205 IF (TO-E) 1209, 1209, 1206
 1206 DO 1208 I=1,N
 1207 DO 1208 J=1,N
 1208 H(I,J)=H(I,J)-T(I)*T(J)/TO
 1209 CONTINUE
  121 CALL READY
  122 LV = LV
  123 GO TO (139,159,137,126),LV
  124 LV = 2
  125 GO TO 121
  126 CALL AIM
  127 LV = LV
  128 GO TO (129,135,137),LV
  129 CALL FIRE
      IF(M1.GE.NMLR)GO TO 1395
  130 LV = LV
  131 GO TO (135,132,126),LV
  132 LV = 1
```

```
  133 CALL DRESS($142)                                                    25--0680
 1335 LV = LV                                                             25--0690
  134 GO TO (124,156),LV                                                  25--0700
  135 LV = 2                                                              25--0710
  136 GO TO 133                                                           25--0720
  137 LV = 3                                                              25--0730
  138 GO TO 133                                                           25--0740
  155 LV = 4                                                              25--0750
  161 GO TO 133                                                           25--0760
  139 IF(NSSW1.LT.1)CALL SOUT                                             25--0770
 1395 WRITE(6,8)                                                          25--0780
      DO 1096 I=1,N                                                       25--0790
 1096 WRITE(6,9) (H(I,J),J=1,N)                                           25--0800
      CALL STUFF                                                          25--0810
  140 LV = LV                                                             25--0820
  141 GO TO (117,142),LV                                                  25--0830
  142 WRITE (6,10)                                                        25--0840
  143 WRITE (6,11)                                                        25--0850
  144 DO 145 I=1,N                                                        25--0860
  145 WRITE (6,9)(H(I,J),J=1,N)                                           25--0870
  146 WRITE (6,13)DELTA,VF,GS                                             25--0880
      CALL SOUT                                                           25--0890
      DO 148 KK=1,NCSN                                                    25--0900
  148 CHIQS(KK)=CHIQS(KK)/CSNRM                                           25--0910
      WRITE(6,15) CSNRM, CHI2T, CHI2ST, CHI2PT                            25--0920
   15 FORMAT(1HK,13X,20HSUM OF CHI SQUARES /F5.0,15X,6HCHI2T=G13.5,       25--0930
     15X,7HCHI2ST=G13.5,5X,7HCHI2PT=G13.5)                                25--0940
      CALL SOUF                                                           25--0950
  150 CALL FCN(N,VG(1),VF,X(1))                                           25--0960
  156 CONTINUE                                                            25--0970
      RETURN                                                              25--0980
 2013 FORMAT(12H0CONSTRAINTS)                                             25--0990
 2014 FORMAT(3H0  1P8E14.5)                                               25--1000
    4 FORMAT(20H0- - - - - - - - - -)                                     25--1010
    5 FORMAT(29H0VARIABLE METRIC MINIMIZATION)                            25--1020
    6 FORMAT(3H0N=I2,4H  K=I2,4H  E=1PE14.5,4H  P=E14.5,8H  DELTA=E14.5)25--1030
    8 FORMAT(2H0H)                                                        25--1040
    9 FORMAT(1H01P8E14.5/(1H08E14.5))                                     25--1050
   10 FORMAT(13H0FINAL VALUES)                                            25--1060
   11 FORMAT(13H0ERROR MATRIX)                                            25--1070
   13 FORMAT(7H0DELTA=1PE14.5,4H  F=E14.5,5H  GS=E14.5)                   25--1080
   14 FORMAT(4HCIT I4,7H  STEP I4,4H  F=1PE14.5)                          25--1090
      END                                                                 25--1100
```

```
$IBFTC SOUTT    LOST,DECK                                                 26--0010
      SUBROUTINE SOUT                                                     26--0020
C.....SEARCH OUTPUT OF PARAMETERS DERIVATIVES AND CHI SQUARES             26--0030
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM                            26--0040
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,    26--0050
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,                    26--0060
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,    26--0070
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z                  26--0080
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION             26--0090
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),             26--0100
     1CHI2P(150), CHI2(150), ENORM, SGMRTH,SNORM,XNORM,NP,CSNRM,NCSN      26--0110
C.....AUXILIARY SEARCH VARIABLES                                          26--0120
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,      26--0130
     1NPCT, NPCTP, PCT                                                    26--0140
      DIMENSION CSID(2)                                                   26--0150
      DATA (CSID(I),I=1,2)/5HSIGMA,5H POL /                               26--0160
      KOD=1                                                               26--0170
```

```
  3 IA=1
    IB=MIN0(N,9)
  8 WRITE(6,10) (LABEL(I),I=IA,IB)
 10 FORMAT(7X,A5,8(9X,A5))
    WRITE(6,20) (X(I),I=IA,IB)
 20 FORMAT(3HJX=1P9G14.5)
    IF(KOD.EQ.2)WRITE(6,30) (VG(I),I=IA,IB)
 30 FORMAT(3HJG=1P9G14.5)
    IF(IB.EQ.N)GO TO 23
    IA=10
    IB=N
    GO TO 8
 23 IF(KOD.EQ.1)GO TO 53
    WRITE(6,40) ENORM, SGMRTH, CHI2T, CHI2ST, CHI2PT
 40 FORMAT(1HJ,6HENORM=G13.5,5X,11HSIGMAR(TH)=G13.5,5X,6HCHI2T=G13.5,
   15X,7HCHI2ST=G13.5,5X,7HCHI2PT=G13.5)
    ENTRY SOUF
    GO TO (47,45,43),KDLMAX
 43 WRITE(6,50)
 50 FORMAT(1HJ,20X,4HSUMF,21X,4HSUMM,21X,4HSUMR)
    WRITE(6,60) CSID(1), (SUMS(KK),KK=9,13,2)
 60 FORMAT(1HJA5,3G25.8)
    WRITE(6,60) CSID(2), (SUMS(KK),KK=10,14,2)
    GO TO 47
 45 WRITE(6,70)
 70 FORMAT(1HJ,12X,4HSUM1,11X,4HSUM2,11X,4HSUM3,11X,4HSUM4,11X,
   14HSUMF,11X,4HSUMM,11X,4HSUMR,10X,5HSUM34)
    WRITE(6,80) CSID(1), (SUMS(KK),KK=1,15,2)
 80 FORMAT(1HJA6,8G15.5)
    WRITE(6,80) CSID(2), (SUMS(KK),KK=2,16,2)
 47 CONTINUE
 53 RETURN
    ENTRY SOUT
    KOD=2
    GO TO 3
    END
```

```
$IBFTC READY   LIST,DECK
      SUBROUTINE READY
C.....READY (MONITOR ADAPTATION)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
C.....AUXILIARY SEARCH VARIABLES
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,
     1NPCT, NPCTP, PCT
      DIMENSION FEX(12)
      LV = LV
      GO TO (200,201),LV
  200 IT=1
  201 CALL MATMPY (N,N,H(1,1),VG(1),S(1))
  202 DO 203 I=1,N
  203 S(I)=-S(I)
  204 M=1
  205 CALL MATMPY (M,N,S(1),VG(1),GS)
  206 IF(GS+E)207,227,227
  207 IF(IT.GT.NPCTP)GO TO 246
      FEX(IT)=VF
      IF(IT.EQ.NPCTP)GO TO 249
      GO TO 255
```

```
  246 FEX(NPCT+2)=VF
      DO 248 KK=1,NPCTP
  248 FEX(KK)=FEX(KK+1)
  249 TEST=.01*PCT*VF
      IF(FEX(1)-FEX(NPCTP).GT.TEST)GO TO 255
      WRITE(6,2)NPCT,PCT
    2 FORMAT(33HJTHE CHANGE IN F DURING THE LAST I2,
     125H ITERATIONS IS LESS THAN F7.4,9H PER CENT)
      GO TO 227
  255 TP1 = -2.0*(VF/GS)
  208 EL=AMIN1(2.0,TP1)
  209 SL=-GS
  210 DO 211 I=1,N
  211 XP(I)=X(I)+EL*S(I)
  213 CALL FCN(N,VGP(1),VFP,XP(1))
  214 M=1
  215 CALL MATMPY (M,N,S(1),VGP(1),GSP)
  216 IF(GSP)217,229,229
  217 IF (VFP-VF) 218,229,229
  218 WRITE (6,1)
  231 FB = VFP
  232 DO 234 I=1,N
  233 GB(I) = VGP(I)
  234 T(I)=XP(I)
  220 IF(EL-2.0)221,223,223
  221 LV = 3
  222 RETURN
  223 DELTA=2.0*DELTA
  224 TO=1.0/SL
  225 LV = 2
  226 GO TO 222
  227 LV = 1
  228 GO TO 222
  229 LV = 4
  230 GO TO 222
    1 FORMAT(10HOUNDERSHOT)
      END
```

```
$IBFTC AIM      LOST,DECK
      SUBROUTINE AIM
C.....AIM (MONITOR ADAPTATION)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
  300 Z = GS+GSP+3.0*(VF-VFP)/EL
  301 TO=GS/Z
      TI=GSP/Z
  302 Q=SQRT(1.0-TO*TI)
      Q = ABS(Q*Z)
      VA = (GSP+Q-Z)/(GSP-GS+2.0*Q)
  303 TO = (EL*(GSP+Z+2.0*Q)*VA**2)/3.0
  304 FO = VFP-TO
  305 CALL MATMPY (N,N,H(1,1),VGP(1),T(1))
  306 TP1=GSP/SL
  307 DO 308 I=1,N
  308 T(I)=-T(I)+TP1*S(I)
  309 M=1
  310 CALL MATMPY(M,N,T(1),VGP(1),GTP)
  311 IF(2.0*TO+GTP)317,312,312
  312 TP1 = 1.0-VA
```

```
  313 DO 314 I=1,N
  314 T(I) = VA*X(I)+TP1*XP(I)
  315 LV = 1
  316 RETURN
  317 IF (VF+GTP/2.0) 312,318,318
  318 DO 319 I=1,N
  319 T(I)=T(I)+XP(I)
  321 CALL FCN(N,GB(1),FB,T(1))
  322 IF(FB-FO)323,312,312
  323 WRITE (6,1)
  324 DO 325 I=1,N
  325 S(I)=T(I)-XP(I)
  326 M=1
  327 CALL MATMPY(M,N,S(1),GB(1),GTT)
  328 GTT=GTT-GTP
  329 IF(GTT)335,330,330
  330 GSS=GTT
  331 SL=-GTP
  332 EL=1.0
  333 LV = 2
  334 GO TO 316
  335 LV = 3
  336 GO TO 316
    1 FORMAT(9HORICOCHET)
      END
```

```
$IBFTC FIRE     LOST,DECK
      SUBROUTINE FIRE
C.....FIRE (MONITOR ADAPTATION)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON /AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
  401 CALL FCN(N,GB(1),FB,T(1))
  402 M=1
      IF(ABS(VA)-1.E-30)410,403,403
  403 CALL MATMPY(M,N,S(1),GB(1),GSB)
  404 TP1= AMIN1(VF,VFP)
  405 IF(TP1-FB+E)418,406,406
  406  TP1=VA/(1.0-VA)
  407 TP2 = (1.0-VA)/VA
  408 TO=GSB*(TP1-TP2)
  409 IF(ABS(TO)-Q)413,410,410
  410 GSS=2.0*Q
  411 LV = 1
      M1=0
  412 RETURN
  413 GSS=TO+2.0*Q
  414 DO 415 I=1,N
  415 VG(I) = (GB(I)-VG(I))*TP1+(VGP(I)-GB(I))*TP2
  416 LV = 2
      M1=0
  417 GO TO 412
  418 IF (VF-VFP) 419,428,428
  419 WRITE (6,1)
  420 EL = (1.0-VA)*EL
  421 VFP = FB
  422 GSP=GSB
  423 DO 425 I=1,N
  424 XP(I)=T(I)
  425 VGP(I) = GB(I)
```

```
  426 LV = 3
      M1=M1+1
  427 GO TO 412
  428 WRITE (6,2)
  429 EL = EL*VA
  430 VF = FB
  431 GS=GSB
  432 DO 434 I=1,N
  433 X(I)=T(I)
  434 VG(I) = GB(I)
  435 GO TO 426
    1 FORMAT(10HOMOVE LEFT)
    2 FORMAT(11HOMOVE RIGHT)
      END
```

```
$IBFTC DRESS   LOST,DECK
      SUBROUTINE DRESS(*)
C.....DRESS (MONITOR ADAPTATION)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
C.....AUXILIARY SEARCH VARIABLES
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,
     1NPCT, NPCTP, PCT
C.....VARIABLES NEEDED FOR POP1
      COMMON JMAX, LMAX, THETA(75)
C..... VARIABLES NEEDED FOR AB
      COMMON AR(75), AI(75),
     1         BR(75), BI(75),
     2         CR1(51), CR2(51), CI1(51), CI2(51),
     3         EXSGMR(51), EXSGMI(51),
     4         FKAY, FCR(75), FCI(75)
      LV = LV
      GO TO (500,525,519,510),LV
  500 CALL MATMPY(N,N,H(1,1),VG(1),X(1))
  501 M=1
  502 CALL MATMPY(M,N,X(1),VG(1),TO)
  503 TP1=SL-GSS**2/TO-E
  504 IF(TP1)524,505,505
  505 DO 507 I=1,N
  506 DO 507 J=1,N
  507 H(I,J)=H(I,J)-X(I)*X(J)/TO
  508 DELTA=DELTA*(EL*GSS/TO)
  509 TO=EL/GSS
  510 DO 512 I=1,N
  511 DO 512 J=1,N
  512 H(I,J)=H(I,J)+TO*S(I)*S(J)
  519 VF = FB
  520 DO 522 I=1,N
  521 VG(I) = GB(I)
  522 X(I)=T(I)
  513 WRITE (6,1)IT,MS,VF,GS
      IF(NSSW1.LT.1)GO TO 517
  516 WRITE (6,3)DELTA
      CALL SOUT
      IF(IIN.NE.NHP)GO TO 517
  560 IIN=0
      WRITE(6,7)
      DO 534 I=1,N
  534 WRITE(6,8) (H(I,J),J=1,N)
```

```
  517 WRITE (6,4)
      CALL POTICH($585)
  518 IT=IT+1
      IIN=IIN+1
 5185 LV = 1
  523 RETURN
  524 WRITE (6,5)
  525 TP1=EL*SL/GSS
  526 DELTA=DELTA*TP1
  527 TO=(TP1-1.0)/SL
  528 GO TO 510
  585 RETURN 1
    1 FORMAT(4HCIT I4,7H  STEP I4,4H  F=1PE14.5,5H  GS=E14.5)
    3 FORMAT(7H0DELTA=1PE14.5)
    4 FORMAT(20H0- - - - - - - - - -)
    5 FORMAT(9H0COLINEAR)
    7 FORMAT(13H0ERROR MATRIX)
    8 FORMAT(1H01P8E14.5/(1H08E14.5))
      END
```

```
$IBFTC STUFF   LIST,DECK
      SUBROUTINE STUFF
C.....STUFF(MONITOR ADAPTATION)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
  600 KSTEP=KSTEP-1
  601 IF(KSTEP)617,602,602
  602 MS=MS+1
  620 WRITE (6,1)MS,DELTA,GS
  603 DO 604 I=1,N
      CALL RAND(Y)
  604 T(I)=Y-.5
  605 CALL MATMPY(N,N,H(1,1),T(1),S(1))
  606 M=1
  607 CALL MATMPY(M,N,S(1),T(1),TP1)
  608 TP1=SQRT(TP1)
  609 EL = VP/TP1
  610 DO 611 I=1,N
  611 X(I)=X(I)+EL*S(I)
  614 LV = 1
  616 RETURN
  617 LV = 2
  618 MS=0
  619 GO TO 616
    1 FORMAT(13H0RANDOM STEP I4,8H  DELTA=1PE14.5,5H  GS=E14.5)
      END
```

```
$IBFTC MATMPY  LIST,DECK
      SUBROUTINE MATMPY(M,N,H,VG,S)
C.....MATRIX MULTIPLICATION (MONITOR ADAPTATION)
```

```
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
  702 DO 703 I=1,M
  7CC S(I)=0.0
      DO 703 J=1,N
  703 S(I)=H(J,I)*VG(J)+S(I)
  7C4 RETURN
      END
```

```
$IBFTC FCN      LOST,DECK
      SUBROUTINE FCN(N,VG,VF,X)
C.....VARIABLES USED IN ARGONNE SEARCH PROGRAM
      COMMON/AGN/C(12,10), DELTA, E, EL, FAC, FB, FO, GB(12), GS, GSB,
     1GSP, GSS, GTP, GTT, H(12,12), IT, KSTEP, LV, LS,
     2M, M1, MS, N, NC, NS, NSSW1, NSSW2, Q, RS, S(12), SL, T(12), TO,
     3VA, VF, VFP, VG(12), VGP(12), VP, X(12), XP(12), Z
C.....AUXILIARY SEARCH VARIABLES
      COMMON/ASV/DEL(12), ID(12), IIN, KDLMAX, LABEL(13), NHP, NMLR,
     1NPCT, NPCTP, PCT
C.....SCATLE PARAMETERS
      COMMON/PARA/RG, RO, V, W, A, VS, WS, BG, DUMMY(4), NAME(12)
C.....CHI SQUARES, NORMALIZATION CONSTANT, AND SIGMA REACTION
      COMMON/CSQ/CHI2ST, CHI2PT, CHI2T, SUMS(16), CHI2S(150),
     1CHI2P(150), CHI2(150), ENORM, SGMRTH,SNORM,XNORM,NP,CSNRM,NCSN
C.....SCATLE CONTROLS
      COMMON/CNTR/KOUT, KSEND, KTRL(13), KTRLT(13), KTRLX(13)
C.....OTHER SCATLE VARIABLES
      COMMON/MISC/ECM, ETA, ETA2, FKAY, FKAYA, FKAYB, RHOBC, RHOBN,
     1RHOBNG, SIGMAO, SIGMA1, TEMP
      DIMENSION SER(12)
      EQUIVALENCE (RG,SER)
      DIMENSION CHIQS(19), CHIQST(19)
      EQUIVALENCE (CHIQS(1),CHI2ST)
C.....CALCULATE FUNCTION AND PARTIAL DERIVATIVES TO BE USED BY SEARCH
      XX=0.
      IND = KTRLX(4)
      DO 802 I=1,N
      J=ID(I)
  802 SER(J)=X(I)
      KODE = 1
      DO 816 I=1,N
      J=ID(I)
      IF(I.NE.1)GO TO 813
  811 CONTINUE
      RHOBN=TEMP*RO
      RHOBNG = TEMP*RG
      FKAYA=FKAY*A
      FKAYB=FKAY*BG
      CALL PGEN4
      CALL INTCTR($825)
      CALL CSUBL
      CALL AB
      CALL SGSGCP
      CALL SIGMAR
      CALL CHISQ
```

```
      IF(KTRLX(12).EQ.1)XX=CHIQS(IND+1)
      IF(KODE.EQ.2)GO TO 815
      VF=CHIQS(IND)+XX
      DO 812 K=1,19
  812 CHIQST(K)=CHIQS(K)
      ENRMT=ENORM
      SGMT=SGMRTH
      KODE = 2
  813 SER(J)=SER(J)+DEL(I)
      GO TO 811
  815 VG(I) = (CHIQS(IND)+XX-VF)/DEL(I)
      SER(J) = SER(J)-DEL(I)
  816 CONTINUE
      DO 818 K=1,19
  818 CHIQS(K)=CHIQST(K)
      ENORM=ENRMT
      SGMRTH=SGMT
      RETURN
  825 WRITE(6,830)
  830 FORMAT(62HK NONSTANDARD RETURN FROM INTCTR IN FCN,  EXECUTION TERM
     1INATED)
      STOP
      END
```

```
$IBFTC SCTBD    LOST,DECK
      BLOCK DATA
C.....SCATLE PARAMETERS
      COMMON/PARA/RI, RS, VO, WI, AS, VS, WS, AI, WVI, AO, RO, VSODD,
     1NAME(12)
C.....CONVERGENCE CRITERIA
      COMMON/CONV/EPS1, EPS2, EPS3, EPS4
      DATA(NAME(I),I=1,12)/2HRI,2HRS,2HVO,2HWI,2HAS,2HVS,2HWS,2HAI,
     13HWVI,2HAO,2HRO,5HVSODD/
      DATA EPS1,EPS2,EPS3,EPS4 /3*.00001, .001/
      END
```

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, April 29, 1970,
129-02.

APPENDIX A

SYMBOLS

AI	diffuseness parameter in nuclear potential (eq. (15)), fm
AO	diffuseness parameter in nuclear potential (eq. (12)), fm
AS	diffuseness parameter in nuclear potential (eq. (7)), fm
$A(\theta)$	spin-independent scattering amplitude (eq. (22a))
a	diffuseness parameter in nuclear potential, fm
$B(\theta)$	spin-dependent scattering amplitude (eq. (22b))
$C_l^{\pm}$	coefficients used to compute scattering amplitudes (eq. (21))
c	velocity of light, m/sec
E	energy in center-of-mass system, MeV
e	electron charge, C
$f_c(\theta)$	coulomb scattering amplitude (eq. (23))
f_{χ^2}	chi-square function to be minimized by search
G_j	j^{th} component of gradient of f_{χ^2} (eq. (50))
H	matrix used as metric in search parameter space
$\hbar$	Planck constant, MeV-sec
IN1, IN2, IN3, IN4	number of angles in ranges 1 through 4 (eq. (41))
J_{max}	last angle in data set
j	total angular momentum quantum number
k	wave number in center-of-mass system, fm^{-1}
$\bar{k}$	wave vector, fm^{-1}
$\bar{L}$	orbital angular momentum operator
l	orbital angular momentum quantum number
l_{lim}	see eq. (44)
M_π	mass of pion, kg
m_b	mass of target nucleus, amu
m_i	mass of incident nucleus, amu
N	normalization constant for $\sigma^{ex}(\theta)$ (eq. (35))
NF	last forward angle
NR	last middle angle
N_E	normalization constant for $\sigma^{ex}(\theta)$ which gives smallest χ^2 for a given $\sigma^{th}(\theta)$ (eq. (36))
N1, N2, N3, N4	first angle of ranges 1 through 4 (eq. (41))
$\bar{n}$	unit normal vector

$P(\theta)$ polarization at angle θ (eq. (27))

$\overline{P}(\theta)$ polarization vector

$\Delta P^{ex}(\theta)$ uncertainty in experimental polarization at angle θ

$P_l(\cos\theta)$ Legendre polynomial

$P_l^1(\cos\theta)$ associated Legendre polynomial

R rotation parameter (eq. (28))

R' rotation parameter (eq. (29))

RC coulomb charge radius parameter

RI radius parameter in nuclear potential (eq. (15)), fm

RO radius parameter in nuclear potential (eq. (12)), fm

RS radius parameter in nuclear potential (eq. (7)), fm

r radial coordinate, fm

$\overline{S}$ spin angular momentum operator

S_l orbital angular momentum number (eqs. (48a) and (48b))

TCI see eq. (45b)

TCR see eq. (45a)

TSI see eq. (49b)

TSR see eq. (49a)

V scattering potential, MeV

VO strength parameter for real central nuclear potential, MeV

VS strength parameter for real spin-orbit nuclear potential, MeV

VSODD strength parameter for real spin-orbit nuclear potential, for odd values of l, MeV

V_{EFF} dimensionless effective potential for given l (eq. (43))

$V_1(r)$ spin-independent potential (eq. (2)), MeV

$V_2(r)$ spin-dependent potential (eq. (2)), MeV

WI strength parameter for imaginary central nuclear potential, MeV

WS strength parameter for imaginary spin-orbit nuclear potential, MeV

WVI strength parameter for imaginary central nuclear potential, MeV

x_j current values of j^{th} search parameter

Δx_j increment for x_j in eq. (50)

Z dimensionless charge number of incident nucleus

Z' dimensionless charge number of target nucleus

β rotation angle (eqs. (25a) and (25b)), deg

$\delta_l^{\pm}$ phase shifts (eq. (21))

$\left.\begin{matrix}\epsilon_1, \epsilon_2, \\ \epsilon_3, \epsilon_4\end{matrix}\right\}$ convergence parameters

η	coulomb parameter (eq. (5))
$\eta_l^{\pm}$	absorption coefficients (eqs. (20a) and (20b))
θ	angular coordinate in center-of-mass system, deg
μ	reduced mass, amu
ρ	dimensionless radial coordinate (eq. (3))
$\sigma(\theta)$	elastic cross section at angle θ, fm^2
σ_l	coulomb phase shift (eq. (24))
σ_0	coulomb phase shift for $l = 0$
$\Delta\sigma^{ex}(\theta)$	uncertainty in experimental cross section at angle θ, fm^2
χ^2	sum of chi-squares for a range of angles
$\chi^2(\theta)$	chi-square at angle θ
ψ	wave function representing scattering particle

Subscripts:

CN	central nuclear
coul	coulomb
F	forward angles (eq. (38))
I	corresponds to input parameters AI and RI
$\mathscr{I}$	imaginary part of complex number
j	index denoting j^{th} parameter, 1, . . ., n
K	index denoting particular χ^2 function (eq. (41)), 1, . . ., 4
LAB	value as measured in laboratory system
l	orbital angular momentum
M	middle angles (eq. (39))
max	maximum
n	number of search parameters
O	corresponds to input parameters AO and RO
P	polarization
R	backward angles (eq. (40))
$\mathscr{R}$	real part of complex number
S	corresponds to input parameters AS and RS
SO	spin-orbit
T	total (polarization + cross section)
σ	cross section
0	incident
1	after single scattering
2	after double scattering

Superscripts:

ex	experimental values
th	theoretical or calculated values
+	total angular momentum, $j = l + 1/2$
-	total angular momentum, $j = l - 1/2$

APPENDIX B

GLOSSARY OF FORTRAN VARIABLES

The FORTRAN variables listed here are those appearing in the COMMON statements of program SCATLE. Some of the FORTRAN variables in COMMON block /AGN/ are omitted, since they are internal to the search subroutines of reference 2. When two or more FORTRAN names refer to the same variable, the alternate names are enclosed in brackets. Some of the mathematical symbols listed do not appear in appendix A. Those symbols correspond to symbols in references 1 and 2, and are defined in the last column.

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
AETA1(L), AETA2(L)	51	PTPL	η_l^+, η_l^-	absorption coefficients (eqs. (20a) and (20b))
AI, [BG]		PARA	a_I	diffuseness parameter for Gaussian absorption (eqs. (14), (16), (17), (18))
AO, [DUMMY(2)]		PARA	a_O	diffuseness parameter for decoupled potential (eq. (11))
AR(J), AI(J), [AAI(J)]	150	SACS	$A_{\mathcal{R}}(\theta)$, $A_{\mathcal{I}}(\theta)$	spin-independent scattering amplitude at angle θ (eq. (22a))
AS, [A]		PARA	a_S	diffuseness parameter, (eqs. (10) and (13))
BR(J), BI(J)	150	SACS	$B_{\mathcal{R}}(\theta)$, $B_{\mathcal{I}}(\theta)$	spin-dependent scattering amplitude at angle θ (eq. (22b))
C(K, M)	(12, 10)	AGN		constraint coefficients for search procedure
CHI2(J)	150	CSQ	$\chi_T^2(\theta)$	total chi-square at angle θ
CHI2T, [CHISQ(3)]		CSQ	χ_T^2	total chi-square summed over J_{max} angles (eq. (34))
CHI2P(J)	150	CSQ	$\chi_P^2(\theta)$	chi-square for polarization at angle θ (eq. (33))
CHI2PT, [CHISQ(2)]		CSQ	χ_P^2	chi-square for polarization summed over J_{max} angles (eq. (33))
CHI2S(J)	150	CSQ	$\chi_\sigma^2(\theta)$	chi-square for cross section at angle θ (eqs. (35) and (37))
CHI2ST, [CHISQ(1)]		CSQ	χ_σ^2	chi-square for cross section summed over J_{max} angles (eq. (35))
CR1(L), CI1(L)	51	VARL	$C_{l,\mathcal{R}}^+$, $C_{l,\mathcal{I}}^+$	see eqs. (21), (22a), and (22b)
CR2(L), CI2(L)	51	VARL	$C_{l,\mathcal{R}}^-$, $C_{l,\mathcal{I}}^-$	see eqs. (21), (22a), and (22b)

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
CSNRM		CSQ		JMAX - NP
DAI, DAO, DAS, DRI, DRO, DRS, DVO, DVS, DVSODD, DWI, DWS, DWVI		GDV		parameter increments used for grid procedure (table IV)
DEL(K)	12	ASV	Δx_j	increment for search parameter x_j (eq. (50))
DELR1(L), DELR2(L)	51	PTPL	$\delta^+_{l,\mathcal{R}}$, $\delta^-_{l,\mathcal{R}}$	see eq. (21)
DELTA		AGN		determinant of H-matrix used in search procedure
DPOLEX(J)	150	THI	$\Delta P^{ex}(\theta)$	standard deviation in experimental polarization at angle θ (eq. (33))
DRHO(I)	249	RHT	$\Delta\rho$	numerical integration step for I^{th} integration interval
DRHOL		RHT		last interval to be used in numerical integration
DRHOIN(K)	9	RHU		numerical integration step size for all DRHO(I), where RHOIN(K) < RHO(I) ≤ RHOIN(K+1)
DSGMEX(J)	150	THI	$\Delta\sigma^{ex}(\theta)$	standard deviation in experimental cross section at angle θ (eq. (35))
E		AGN	ϵ	twice the fractional accuracy to which f_{χ^2} is to be minimized
ECM		MISC	E	incident energy in center-of-mass system
EPS1, EPS2, EPS3		CONV	ϵ_1, ϵ_2, ϵ_3	error thresholds in calculations of coulomb functions
EPS4		CONV	ϵ_4	error threshold used in POT1CH subroutine
ELAB		EMCV	E_{LAB}	energy of incident particle in laboratory system
ENORM		CSQ	N_E	normalization constant (eq. (36))
ETA, ETA2		MISC	η, $(\eta)^2$	coulomb parameter (eq. (5))
EXSGMR(L), EXSGMI(L)	51	VARL		real and imaginary parts of $\exp(2i\sigma_l)$

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
F(L)	52	VARL	F_l	regular coulomb function
FAC		AGN		factor which controls the form of the initial H-matrix for a search (table III)
FBAR(L)	91	VARL	$F_l^{(n)}$	n^{th} trial value of regular coulomb function used in iterative computation of F
FCR(J), FCI(J)	150	SACS	$f_{C,\Re}(\theta)$, $f_{C,\Im}(\theta)$	coulomb scattering amplitude (eq. (23))
FFCI(I), FFCIM(I)	250	PGF	$f_{CI}(\rho)$, $f_{CI}\left(\rho + \frac{\Delta\rho}{2}\right)$	form factors for the imaginary central potential
FFCR(I), FFCRM(I)	250	PGF	$f_{CR}(\rho)$, $f_{CR}\left(\rho + \frac{\Delta\rho}{2}\right)$	form factors for real central potential
FFSI(I), FFSIM(I)	250	PGF	$f_{SI}(\rho)$, $f_{SI}\left(\rho + \frac{\Delta\rho}{2}\right)$	form factors for imaginary spin-orbit potential
FFSR(I), FFSRM(I)	250	PGF	$f_{SR}(\rho)$, $f_{SR}\left(\rho + \frac{\Delta\rho}{2}\right)$	form factors for real spin-orbit potential
FKAY		MISC	k	wave number (eq. (4))
FKAYA		MISC	$k \cdot a_S$	wave number times diffuseness constant
FKAYB		MISC	$k \cdot a_I$	wave number times diffuseness constant
FMB		EMCV	m_b	mass number of target nucleus
FLPT		PGU	l	value of l in eq. (43)
FMI		EMCV	m_i	mass number of incident nucleus
FMU		EMCV	μ	reduced mass of incident particle
FP(L)	51	VARL	F_l'	derivative of regular coulomb function
G(L)	52	VARL	G_l	irregular coulomb function
GP(L)	51	VARL	G_l'	derivative of irregular coulomb function
H(K, M)	(12, 12)	AGN	$H_{k,m}$	element of matrix used as a metric during search procedure

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
ID(K)	12	ASV		internal control used for initializing search parameter array
IFIRST		RHT		initial value of index I referring to RHO(I)
IIN		ASV		internal counter used to regulate printout of H-matrix
ILAST		RHT		final value of index I referring to RHO(I)
JMAX		THI	J_{max}	total number of angles (JMAX $\leq$ 150)
KDLMAX		ASV		internal control used to initiate calculation of restricted χ^2 functions as given in eqs. (38) through (42)
KL(K), [KTRL(K)]	13	CNTR		input controls (table III)
KOUT		CNTR		internal control used to select proper output mode
KSEND		CNTR		KSEND set to KT(1), see description of KT(1) in table III
KSTEP		AGN		number of random changes in variables to test minimum after a search
KT(K), [KTRLT(K)]	13	CNTR		input controls (table III)
KX(K), [KTRLX(K)]	13	CNTR		input controls (table III)
L		RWF	$l + 1$	index of partial waves
LABEL(K)	13	ASV		array containing search parameter labels
LMAX		LIND	$l_{max} + 1$	index of maximum partial wave
LMAXM		LIND	l_{max}	maximum number of partial waves
N		AGN	n	number of search parameters
NADL		PCH		internal control which is increased by 1 each time l_{max} is increased in POT1CH

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
NADR		PCH		internal control which is increased by 1 each time ρ_{max} is increased in POT1CH
NAI, NAO, NAS, NRI, NRO, NRS, NVO, NVS, NVSODD, NWI, NWS, NWVI		GDV		number of increments used for parameters in grid (table IV)
NAME(K)	12	PARA		array of output labels for nuclear potential parameters
NC		AGN		number of constraints on search parameters
NCSN		CSQ		number of values to be divided by CSNRM
NHP		ASV		H-matrix is printed out every NHP iterations during a search
NMAX		RHU		number of RHOIN(I) values to be input
NMLR		ASV		search is cut off after NMLR move left or move right output messages
NP		CSQ		chi-square adjustment factor
NPCT		ASV		search is terminated after NPCT iterations with less than PCT percent change
NPCTP		ASV		not used
NSSW1		AGN		input variable which controls search output (table III)
NTOT		PCH		NTOT = NADL + NADR
NUMRUN		PTI		index identifying cases of a data set
PCT		ASV		search will terminate after NPCT iterations with less than PCT percent change
PMA, PMB		SCNFF	$\frac{\rho_{mA}}{\rho_S}, \frac{\rho_{mB}}{\rho_S}$	parameters for knee and tail variations (eqs. (86) and (87) of ref. 1)

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
POLEX(J)	150	THI	$P^{ex}(\theta)$	experimental value of polarization for angle θ
POLTH(J)	150	THI	$P^{th}(\theta)$	calculated value of polarization for angle θ
RC		EMCV		uniform charge radius constant used to compute ρ_{coul}
RHO(I)	250	RHT	ρ	value of ρ at I^{th} integration interval
RHOBC		MISC	ρ_{coul}	value of ρ at which uniform charge density ends, $\rho_{coul} = k \cdot RC\ (m_b)^{1/3}$
RHOBN		MISC	ρ_S	value of ρ corresponding to RS (eq. (7))
RHOBNG		MISC	ρ_I	value of ρ corresponding to RI (eq. (15))
RHOIN(K)	10	RHU		values of ρ for which integration interval changes
RHOMAX		RHT	ρ_{max}	value of ρ for last integration interval
RI, [RG]		PARA	RI	Gaussian radius constant (eq. (15))
RO, [DUMMY(3)]		PARA	RO	radius constant for decoupled potential (eq. (12))
RS, [R0]		PARA	RS	radius constant (eq. (7))
SGMAC(J)	150	SACS	$\sigma_{coul}(\theta) = \|f_c(\theta)\|^2$	coulomb scattering cross section for angle θ
SGMAEX(J)	150	THI	$\sigma^{ex}(\theta)$	experimental value of cross section for angle θ
SGMATH(J)	150	THI	$\sigma^{th}(\theta)$	calculated value of cross section for angle θ
SGMRTH		CSQ	σ_R	calculated value of reaction cross section
SIGMA0, SIGMA1		MISC	σ_0, σ_1	coulomb phase shifts (eq. (24))
SIGTEM(J)	150	SACS		internal temporary storage for weight factors in computing $\chi^2_\sigma(\theta)$ (eqs. (35) and (37))

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
SNORM		CSQ	N	normalization constant for experimental cross section (eq. (35))
SRATIO(J)	150	SACS	$\sigma^{th}(\theta)/\sigma_{coul}(\theta)$	ratio of scattering cross section to coulomb cross section for angle θ
SUMS(K)	16	CSQ		χ^2 for a restricted range of angles (see next 16 variables)
SUM1S, [SUMS(1)], [CHISQ(4)]		CSQ	$\chi^2_{\sigma,1}$	see eq. (41a)
SUM1P, [SUMS(2)], [CHISQ(5)]		CSQ	$\chi^2_{P,1}$	see eq. (41b)
SUM2S, [SUMS(3)], [CHISQ(6)]		CSQ	$\chi^2_{\sigma,2}$	see eq. (41a)
SUM2P, [SUMS(4)], [CHISQ(7)]		CSQ	$\chi^2_{P,2}$	see eq. (41b)
SUM3S, [SUMS(5)], [CHISQ(8)]		CSQ	$\chi^2_{\sigma,3}$	see eq. (41a)
SUM3P, [SUMS(6)], [CHISQ(9)]		CSQ	$\chi^2_{P,3}$	see eq. (41b)
SUM4S, [SUMS(7)], [CHISQ(10)]		CSQ	$\chi^2_{\sigma,4}$	see eq. (41a)
SUM4P, [SUMS(8)], [CHISQ(11)]		CSQ	$\chi^2_{P,4}$	see eq. (41b)
SUMFS, [SUMS(9)], [CHISQ(12)]		CSQ	$\chi^2_{\sigma,F}$	see eq. (38a)
SUMFP, [SUMS(10)], [CHISQ(13)]		CSQ	$\chi^2_{P,F}$	see eq. (38b)
SUMMS, [SUMS(11)], [CHISQ(14)]		CSQ	$\chi^2_{\sigma,M}$	see eq. (39a)
SUMMP, [SUMS(12)], [CHISQ(15)]		CSQ	$\chi^2_{P,M}$	see eq. (39b)
SUMRS, [SUMS(13)], [CHISQ(16)]		CSQ	$\chi^2_{\sigma,R}$	see eq. (40a)
SUMRP, [SUMS(14)], [CHISQ(17)]		CSQ	$\chi^2_{P,R}$	see eq. (40b)
SUM34S, [SUMS(15)], [CHISQ(18)]		CSQ	$\chi^2_{\sigma,34}$	see eq. (42a)
SUM34P, [SUMS(16)], [CHISQ(19)]		CSQ	$\chi^2_{P,34}$	see eq. (42b)
TEMP		MISC	$k(m_b)^{1/3}$	auxiliary constant used in calculating various ρ values (eq. (7))
TH(K)	2	SCNFF	h_{0A}, h_{0B}	parameters for knee and tail variations (eq. (88) of ref. 1)
THETA(J)	150	THI	θ	center-of-mass scattering angle in radians
THETAD(J)	150	THI	θ	center-of-mass scattering angle in degrees

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
TITLE(K)	13	PTI		title information (78 characters)
TN1(K)	2	SCNFF	nA_1, nB_2	parameters for knee and tail variations
TN2(K)	2	SCNFF	nA_2, nB_2	(eq. (90) of ref. 1)
TAI, TAO, TAS, TRI, TRO, TRS, TVO, TVS, TVSODD, TWI, TWS, TWVI		GDV		storage for initial parameter values during grid
TRM(K)	2	SCNFF	ρ_{mA}, ρ_{mB}	parameters for knee and tail variations (eqs. (86) and (87) of ref. 1)
UCIB(I), UCIM(I)	250	PGU	$U_{CI}(\rho)$, $U_{CI}\left(\rho + \frac{\Delta\rho}{2}\right)$	l-independent part of imaginary central potential
UCRB(I), UCRM(I)	250	PGU	$U_{CR}(\rho)$, $U_{CR}\left(\rho + \frac{\Delta\rho}{2}\right)$	l-independent part of real central potential
USRB(I), USRM(I)	250	PGU	$U_{SR}(\rho)$, $U_{SR}\left(\rho + \frac{\Delta\rho}{2}\right)$	l-independent part of real spin-orbit potential
USIB(I), USIM(I)	250	PGU	$U_{SI}(\rho)$, $U_{SI}\left(\rho + \frac{\Delta\rho}{2}\right)$	l-independent part of imaginary spin-orbit potential
VO, [V]		PARA	VO	depth of real central potential
VP		AGN		input number to determine size of random step taken at end of search (see card 31--0220.)
VS		PARA	VS	depth of real spin-orbit potential
VSODD, [DUMMY(4)]		PARA	VSODD	real spin-orbit strength for odd l in exchange option
WI, [W]		PARA	WI	depth of imaginary central potential
WS		PARA	WS	depth of imaginary spin-orbit potential
WVI, [DUMMY(1)]		PARA	WVI	depth of imaginary central potential
XNORM		CSQ	N	input value of normalization constant (eq. (35))

FORTRAN symbol	Dimension	COMMON block	Mathematical symbol	Description
XC1, XCP1		RWF	$x_l^+(\rho)$, $\dot{x}_l^+(\rho)$	real parts of radial wave function and first derivative for $l + 1/2$
XD1, XDP1		RWF	$x_l^-(\rho)$, $\dot{x}_l^-(\rho)$	as above for real part, $l - 1/2$
YC1, YCP1		RWF	$y_l^+(\rho)$, $\dot{y}_l^+(\rho)$	as above for imaginary part, $l + 1/2$
YD1, YDP1		RWF	$y_l^-(\rho)$, $\dot{y}_l^-(\rho)$	as above for imaginary part, $l + 1/2$
X1(L), X1P(L)	51	RWFF	$x_l^+(\rho_{max})$, $\dot{x}_l^+(\rho_{max})$	value of XC1 and XCP1 at end of numerical integration
X2(L), X2P(L)	51	RWFF	$x_l^-(\rho_{max})$, $\dot{x}_l^-(\rho_{max})$	value of XD1 and XDP1 at end of numerical integration
Y1(L), Y1P(L)	51	RWFF	$y_l^+(\rho_{max})$, $\dot{y}_l^+(\rho_{max})$	value of YC1 and YCP1 at end of numerical integration
Y2(L), Y2P(L)	51	RWFF	$y_l^-(\rho_{max})$, $\dot{y}_l^-(\rho_{max})$	value of YD1 and YDP1 at end of numerical integration
ZZ		EMCV	ZZ'	product of atomic numbers of target and incident nuclei

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