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UNICORN – A PROGRAM TO CALCULATE POINT CROSS SECTIONS FROM RESONANCE PARAMETERS

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PHYSICS

UNICORN – A PROGRAM TO CALCULATE POINT CROSS SECTIONS FROM RESONANCE PARAMETERS

By

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NAA-SR-11980, Vol IV "Compilation, Evaluation and Reduction of Neutron Differential Scattering Data"

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ABSTRACT

Unbroadened cross sections for $\ell = 0$ neutrons are calculated at energy points from resonance parameters using the Breit-Wigner line shape. The interference between resonance and potential scattering for multiple resonances is properly treated. Provision is made for spin-dependent potential scattering and adjustment to 2200 m/s cross-section values.

The energy grid is optimized to provide a best representation using a specified number of points for an isolated resonance. The optimization is based on a symmetric line shape and is designed for use with logarithmic interpolation in the cross section and linear interpolation in energy. Under these conditions the magnitude of the error in the integral of the cross section in each interval is a constant percentage of the total integral. A calculation of the resonance integral in up to 50 groups is provided.

UNICORN will accommodate a maximum of 100 resonances, 100 energy points per resonance, and 3900 total energy points. The energies and cross sections may be obtained on cards and in graphical displays. The code is written in FORTRAN IV. Execution time on the IBM 7094 is about 10 millisec/resonance/point including punched cards and graphs.

I. INTRODUCTION

The growing use of point cross sections in nuclear reactor analysis provides the motivation for efficient, flexible codes to generate point data in the resonance region. A coupled set of three programs which produce Doppler-broadened point cross sections for a mixture of isotopes has been developed. UNICORN produces unbroadened point cross sections from resonance parameter data. These cross sections are used by the DOPCRS[1] program, which Doppler broadens them using the heat equation. The third program folds together cross sections of different isotopes with proper weighting and presents the results in formats suitable for other codes.

UNICORN uses resolved resonance parameters for $\ell = 0$ resonances in a Breit-Wigner line shape formulation which includes resonance-resonance scattering interference and energy dependent potential scattering. The treatment is thus accurate at high energies and for scattering resonances of light isotopes.

II. BREIT-WIGNER FORMULAS

The Breit-Wigner one-level formula for the (α, β) reaction with $\ell = 0$ neutrons is

$$\sigma(\alpha, \beta) = \sum_J g_J \pi \lambda\!\!\!^{-2} \frac{\Gamma_{\alpha J} \Gamma_{\beta J}}{\left(E - E_J^r\right)^2 + \left(\frac{1}{2} \Gamma_J\right)^2}, \qquad \ldots(1)$$

where J is the spin of the compound nucleus, and the other symbols are standard notation. (Since $\ell = 0$, the channel is uniquely characterized by J as well as by the channel spin $S = |J + \ell|$.)

Equation 1 does not apply to elastic scattering because of the interference effects between re-emission of the incident particle (resonance scattering) and scattering by the nuclear potential (potential scattering). The expression for elastic scattering is:

$$\sigma_s = \sum_J g_J \pi \lambda\!\!\!^{-2} \left| A_J^{res} + A_J^{pot} \right|^2 . \qquad \ldots(2)$$

The first term is the resonance scattering amplitude

$$A_J^{res} = \frac{i\Gamma_{nJ}}{\left(E - E_J^r\right) + i \frac{1}{2} \Gamma_J} = 2Y_J + 2ix_J Y_J$$

$$Y_J = \frac{\frac{\Gamma_{nJ}}{\Gamma_J}}{1 + x_J^2}$$

$$x_J = \frac{2\left(E - E_J^r\right)}{\Gamma_J}$$

The second term is the potential scattering amplitude

$$A_J^{pot} = \exp(2ikR_J) - 1$$

where R_J is the potential scattering radius.[2]

When multiple resonances are involved, the resonance effects must be summed over the resonances.

$$\sigma_\gamma = \sum_m \sum_J g_J \pi \lambda\!\!\!^{-2} \frac{\Gamma_{nJm}\, \Gamma_{\gamma Jm}}{\left(E - E_{Jm}^r\right)^2 + \left(\frac{1}{2}\Gamma_{Jm}\right)^2}$$

$$= \sum_m \sum_J 4\pi g_J \lambda\!\!\!^{-2}\, Y_{Jm}\, \Gamma_{\gamma Jm} / \Gamma_{Jm}$$

$$\sigma_s = \sum_J 4\pi g_J \lambda\!\!\!^{-2} \left\{ \left(\sum_m Y_{Jm}\right)^2 + \left(\sum_m x_{Jm}\, Y_{Jm}\right)^2 - 2 \sin^2(kR_J) \cdot \left(\sum_m Y_{Jm}\right) + \sin(2kR_J) \cdot \left(\sum_m x_{Jm}\, Y_{Jm}\right) + \sin^2(kR_J) \right\}$$

$$4\pi\lambda\!\!\!^{-2} = 4\pi \left(\frac{\hbar}{m_n v_n}\right)^2 = \frac{2.6035 \times 10^6}{E} \left(1 + \frac{1.0090}{A}\right)^2$$

A = atomic weight.

The term $(1 + 1.0090/A)^2$ is included because it is assumed that laboratory-system parameters are used.[3]

III. SCATTERING INTERFERENCE FOR MULTIPLE RESONANCES

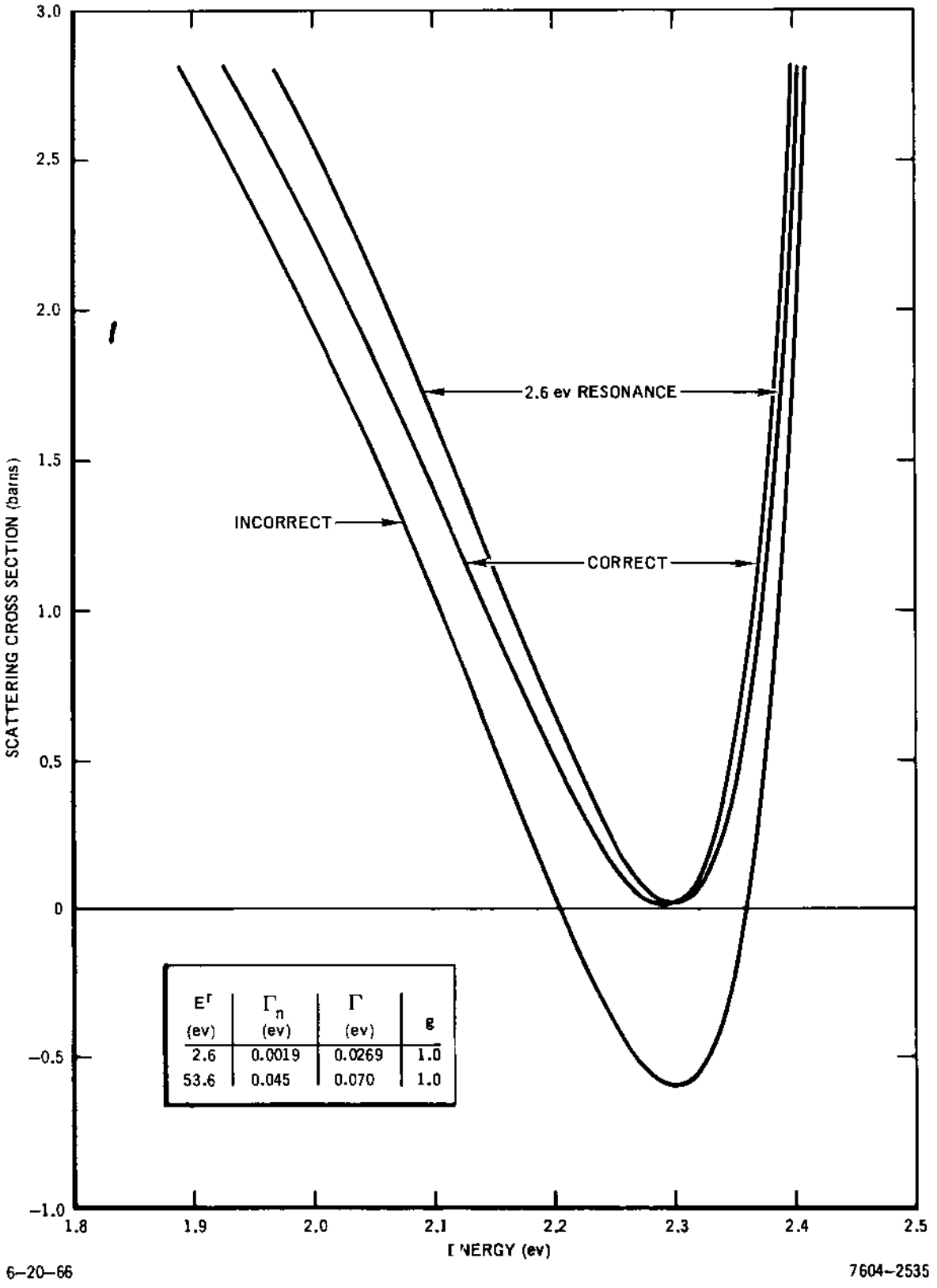
The summation of the resonance scattering amplitude over the resonances can be important even for widely spaced resonances. Also the summation over the resonances must be made inside the absolute value brackets in Equation 2 or the resonance-resonance scattering interference will be over estimated and negative cross sections can occur. The above considerations are illustrated in the case of the two lowest resonances of Pu^{238} in Figure 1. At the interference minimum below the 2.6 ev resonance the incorrect procedure gives -0.6b, whereas the correct procedure gives 0.015b.

For resonances where the value of J is not known, the statistical weight factor, g, is usually taken to be 1/2. However, in order to correctly use the formula which includes resonance-resonance scattering interference, a physically possible value of g must be employed. Theory predicts that the number of resonances with a particular value of J is proportional to 2J + 1. The possible J states are I + 1/2 and I - 1/2, so the possible values of g are

$$g_J = \frac{1}{2}\left(\frac{2J+1}{2I+1}\right) = \frac{1}{2}\left(1 \pm \frac{1}{2I+1}\right) .$$

Consequently, the code assigns J = I + 1/2 to the first 2(I + 1/2) + 1 resonances with unknown J(g = 1/2) and J = I - 1/2 to the next 2(I - 1/2) + 1 resonances alternately. The values of Γ_n are changed to preserve $g\Gamma_n$.

$$\Gamma_n(g = g_J) = \frac{1}{2}\Gamma_n \left(g = \frac{1}{2}\right) \Big/ g_J$$



E_r (ev)	Γ_n (ev)	Γ (ev)	g
2.6	0.0019	0.0269	1.0
53.6	0.045	0.070	1.0

Figure 1. Scattering Cross Section of Pu-242 from 1.9 to 2.4 ev for Two Resonances

IV. ADJUSTMENT TO 2200 m/s VALUES

UNICORN will adjust the calculated cross sections to force agreement to input 2200 m/s values. The adjustment is made only when a nonzero capture cross section is entered. In that case, both the capture and fission cross sections are adjusted, but the scattering cross section is adjusted only if a nonzero value is also entered for it. The adjustment is made according to the following formula:

$$\sigma_k = \sigma_k^{\text{calc.}} + \left(\sigma_k^{\text{input}} - \sigma_k^{\text{calc.}}\right)\left(\frac{E_{2200}}{E}\right)^{\frac{1}{2}}$$

k = Y, f, s (capture, fission, or scattering)

The scattering cross section includes the potential scattering. The calculated 2200 m/s cross sections are printed as the first point and labelled 3900 when the adjustment option is used.

V. ENERGY GRID

An energy grid is calculated which, under some simplifying assumptions, gives the most accurate representation of the resonance for a given number of points. Logarithmic interpolation in the cross section and linear interpolation in energy is assumed. The calculation assumes the simplified line shape $(1 + x^2)^{-1}$. The points are chosen so that between any two points the magnitude of the difference between the exact integral and the integral calculated using interpolation is a constant. The percent error in the integral over an isolated resonance is less than 1000/ (No. of points)^2. The energy grid is determined by using the x values calculated from the closest (in x value) resonance. Thus, the entire set is normally not used for any resonance. The midpoint between resonances and the upper and lower energies of the case are included in the grid. The values $x_m = 0$ ($E_m = E_m^r$) are regular points in the grid. The details of the calculation are set forth in the Appendix.

Sometimes energy points are desired which are not a part of the normal grid. Such points can be obtained by including resonances at those points with $\Gamma_n = 0$. $\Gamma = \Gamma_\gamma$ can be set to provide the desired spacing or the point where the next resonance takes over. A dummy resonance of this type can be used to obtain more closely spaced points at the lower energy bound of the case by suitable selection of E^r and Γ_γ values (see Appendix).

VI. RESONANCE INTEGRALS

Optionally, the code will integrate the pointwise cross sections over a 1/E spectrum within input energy groups. A parabolic (subscript p) fit to each three points is used between the two midpoints of the set (with appropriate modification at the case limits).

$$\sigma_{pm} = \sigma_m + (E - E_m)\left[E_{m+1}, E_m\right] + (E - E_{m+1})\left[E_{m+2}, E_{m+1}, E_m\right]$$

$$E_L \equiv \frac{1}{2}(E_m + E_{m-1}) \leq E \leq \frac{1}{2}(E_m + E_{m+1}) \equiv E_U \ ,$$

where

$$\left[E_i, E_j\right] \equiv \frac{\sigma_i - \sigma_j}{E_i - E_j}$$

$$\left[E_i, E_j, E_k\right] \equiv \frac{\left[E_i, E_k\right] - \left[E_i, E_j\right]}{E_i - E_j}$$

$$\int_{E_L}^{E_U} \sigma_{pm}\, dE = \left(\sigma_{m-1} - \left[E_m, E_{m-1}\right] E_{m-1} + \left[E_{m+1}, E_m, E_{m-1}\right] E_m E_{m-1}\right) \ln\left(\frac{E_U}{E_L}\right)$$
$$+ \left\{\left[E_m, E_{m-1}\right] - (E_{m-1} + E_m)\left[E_{m+1}, E_m, E_{m-1}\right]\right\}(E_U - E_L)$$
$$+ \frac{1}{2}\left[E_{m+1}, E_m, E_{m-1}\right]\left(E_U^2 - E_L^2\right) .$$

Double precision arithmetic is used. The group limits for integration (50 maximum) are arbitrary as long as they fall in the range of the case.

VII. PUNCHED CARDS

Options are available in UNICORN to punch cards containing the energy points, and the scattering, capture, fission, and total cross sections. The data is punched in separate decks for each item. Six points are punched per card with increasing energy in 1PE12.5 format. The identification columns 73-76 contain the symbols NRG1, SCT2, CPT3, FSN4, or TOT5 respectively. The cards are sequenced in columns 77-80 with the number of the first point on the card (1, 7, 13, etc.).

VIII. GRAPHICAL DISPLAY

The point cross sections can be displayed graphically using North American Aviation routines. Nine-inch-square graphs and 35-mm film are produced. A maximum of 100 plots per cross section (scattering, capture, fission) can be obtained. Each plot has an equal energy width. The code automatically adjusts the grid for each cross section to produce as large a plot as possible. Examples are shown for the sample problem in Section X.

IX. INPUT DATA

The input data are as follows (see sample problem, Section X):

1) The first card of each case is a title card in format 12A6. The first half of the title is printed on each graph produced.

2) The second card has the format I12, 5E12.8 and contains the following data:

NR	No. of resonances	
S22G	Capture	2200 m/s cross sections. See Section IV
S22W	Fission	
S22S	Scattering	
PNTPR	No. of points to describe isolated resonance See Section V	
DLCRT	Energy width of graphs ≥ (EMAX-EMIN)/100	

3) The third card has the format 6E12.8 and contains the following data:

EMIN	Minimum energy of case
EMAX	Maximum energy of case
ATW	Atomic weight of isotope
SPIN	Spin (I) of target nucleus
PSM	Potential scattering cross section for J = I - 1/2
PSP	Potential scattering cross section for J = I + 1/2

At E = 0 the potential scattering cross section is defined by

$$\sigma_{pot\ J} \equiv 4\pi R_J^2 \times 10^{24}.$$

4) The fourth card contains the following options in format 6I12:

IPU	Card punch option	0 = No +1 = γ, f, s -1 = γ, f, s, t
ICS	Scattering	Graphical display options 0 = No 1 = Yes
ICG	Capture	
ICW	Fission	

IX	Resonance parameter option	0 = Read 1 = Use values from previous case.
IPT	Energy grid options	0 = Calculate 1 = Use values from previous case.

5) The resonance integral options are chosen on the fifth card format 5I12. If any are chosen, the energy group breakpoints are listed in increasing energy, format 6E12.8, on successive cards (see IDRL below).

IRS	Scattering	Resonance integral option
IRC	Capture	0 = No
IRW	Fission	1 = Yes
NGL	Number of group limits = No. of groups + 1	
IDRL	Group limits option	0 = Use previous case. 1 = Read cards.

6) The last set of cards are the resonance parameters, one resonance per card in increasing energy, format 5E12.8. NR total cards are needed.

EO	Resonance energy E^r
GAMN	Γ_n Scattering
GAMG	Γ_γ Capture
GAMW	Γ_f Fission
	level widths at E^r
G	$g_J = 1/2(2J + 1)/(2I + 1)$, statistical weight

X. SAMPLE CASES

Input data and output for a sample case are shown on the following pages. It required 11 sec execution time on the IBM 7094.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. UNICORN PROGRAMMER JOHN OTTER DATE JUNE 1966 PAGE 1 of JOB NO.

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
UNICORN SAMP		ANGRT, GRAPH TITLE (6A6)
LE PROBLEM W		
183. 6-66		
LOW ENERGY		AN, TITLE (12A6)
FIT GAMMA GA		
MMA = 0.075	10	
27.		I12, NR, NUMBER OF RESONANCES
10.0		E12.8, S22G, CAPTURE } 2200 m/s CROSS SECTIONS TO
0.0		" , S22W, FISSION } WHICH CODE WILL ADJUST
0.0		" , S22S, SCATTERING } SEE SECTION
51.0		" , PNTPR, No. OF GRID POINTS FOR ISOLATED RESONANCE
40.0	20	" , DLGRT, ENERGY WIDTH OF GRAPHS → $\frac{EMAX-EMIN}{100}$
0.5		E12.8, EMIN, MINIMUM ENERGY
200.0		" , EMAX, MAXIMUM ENERGY
183.0		" , ATW, ATOMIC WEIGHT
0.5		" , SPIN, SPIN OF TARGET NUCLEUS
5.0		" , PSM, POTENTIAL SCAT XSEC FOR $J = I - \frac{1}{2}$
5.0	30	" , PSP, " " " " $J = I + \frac{1}{2}$
0		I12, IPU, CARD PUNCH OPTION, 0 = No, +1 = Yes, -1 = Yes &
1		" , ICS, SCATTERING } GRAPHICAL DISPLAY OPTION
1		" , ICG, CAPTURE } 0 = No
0		" , ICW, FISSION } 1 = Yes
0		" , IX, RESONANCE PARAMETER OPTION { 0 = READ, 1 = PREVIOUS CASE
0	40	" , IPT, GRID POINT OPTION { 0 = CALCULATE, 1 = PREVIOUS CASE

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. PROGRAMMER DATE PAGE 2 of JOB NO.

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1		I12, IRS, SCATTERING } RESONANCE INTEGRAL OPTION
1		" , IRG, CAPTURE } 0 = No
0		" , IRW, FISSION } 1 = YES
3		" , NGL, No. OF GROUP BOUNDARIES (= No. OF GROUPS + 1)
1		" , IDRL, GROUP BOUNDARIES OPTION { 1 = READ, 0 = PREVIOUS CASE
	50	
0.5		GROUP BOUNDARIES IN INCREASING ENERGY.
1.12.56.		6 PER CARD. FORMAT 6E12.8
10.0		
	60	
0.0253		E12.8, E0, RESONANCE ENERGY
0.0		" , GAMN, SCATTERING } LEVEL WIDTHS AT E0
0.5		" , GAMG, CAPTURE }
		" , GAMW, FISSION }
1.0		" , G, STATISTICAL WEIGHT = $\frac{2J+1}{2(I+1)}$
	70	
7.68		NR TOTAL RESONANCE CARDS NEEDED AS
174 -2		ABOVE
75 -1		
75 -0		
	80	

UNICORN SAMPLE PROBLEM W183 6-66 LOW ENERGY FIT GAMMA GAMMA = 0.075

INPUT DATA

NUMBER OF RESONANCES = 27
2200 M/S XSEC - CAPTURE = 0.10000000E 02
2200 M/S XSEC - FISSION = -0.00000000E-38
2200 M/S XSEC - SCATTERING = -0.00000000E-38
POINTS ACROSS RESONANCE = 0.51000000E 02
ENERGY WIDTHS OF CRT PLOTS = 0.40000000E 02
MINIMUM ENERGY = 0.50000000E 00
MAXIMUM ENERGY = 0.20000000E 03
ATOMIC WEIGHT = 0.18300000E 03
SPIN OF TARGET NUCLEUS = 0.50000000E 00
POT. SCAT. XSEC J=I-0.5 = 0.50000000E 01
POT. SCAT. XSEC J=I+0.5 = 0.50000000E 01
PUNCHED CARDS (1=YES,0=NO) = 0

RESONANCE PARAMETERS

NUMBER	ENERGY	NEUTRON WIDTH	GAMMA WIDTH	FISSION WIDTH	STATISTICAL WEIGHT
1	0.25300E-01	0.00000E-38	0.50000E 00	-0.00000E-38	0.10000E 01
2	0.76800E 01	0.17400E-02	0.75000E-01	-0.00000E-38	0.75000E 00
3	0.27100E 02	0.43300E-01	0.75000E-01	-0.00000E-38	0.75000E 00
4	0.40600E 02	0.17000E-02	0.75000E-01	-0.00000E-38	0.75000E 00
5	0.46100E 02	0.15400E 00	0.75000E-01	-0.00000E-38	0.75000E 00
6	0.47800E 02	0.11500E 00	0.75000E-01	-0.00000E-38	0.25000E 00
7	0.66000E 02	0.16000E-02	0.75000E-01	-0.00000E-38	0.75000E 00
8	0.10080E 03	0.10000E 00	0.75000E-01	-0.00000E-38	0.75000E 00
9	0.10360E 03	0.12000E-01	0.75000E-01	-0.00000E-38	0.25000E 00
10	0.13790E 03	0.40000E-02	0.75000E-01	-0.00000E-38	0.75000E 00
11	0.14420E 03	0.10000E 00	0.75000E-01	-0.00000E-38	0.25000E 00
12	0.15480E 03	0.40000E 00	0.75000E-01	-0.00000E-38	0.25000E 00
13	0.15710E 03	0.67000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
14	0.17370E 03	0.13000E 00	0.75000E-01	-0.00000E-38	0.75000E 00
15	0.19210E 03	0.33000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
16	0.23550E 03	0.22000E-01	0.75000E-01	-0.00000E-38	0.25000E 00
17	0.24040E 03	0.14000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
18	0.24340E 03	0.19000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
19	0.25900E 03	0.66000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
20	0.28020E 03	0.30000E 00	0.75000E-01	-0.00000E-38	0.75000E 00
21	0.29760E 03	0.44000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
22	0.32340E 03	0.20000E 00	0.75000E-01	-0.00000E-38	0.75000E 00
23	0.33720E 03	0.35000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
24	0.34830E 03	0.17000E 00	0.75000E-01	-0.00000E-38	0.75000E 00
25	0.36140E 03	0.39000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
26	0.39160E 03	0.43000E-01	0.75000E-01	-0.00000E-38	0.75000E 00
27	0.41870E 03	0.57000E-01	0.75000E-01	-0.00000E-38	0.75000E 00

THE SPACING FOR A PIECEWISE LOGARITHMIC REPRESENTATION OF 1/(1+X**2) IS DETERMINED IN WHICH, FOR EACH INTERVAL,THE ERROR IN THE AREA IS (PI/2)*DELTA

1	-0.98700E 04	51	0.98700E 04
2	-0.16423E 04	50	0.16423E 04
3	-0.51491E 03	49	0.51491E 03
4	-0.22091E 03	48	0.22091E 03
5	-0.11364E 03	47	0.11364E 03
6	-0.65908E 02	46	0.65908E 02
7	-0.41517E 02	45	0.41517E 02
8	-0.27804E 02	44	0.27804E 02
9	-0.19506E 02	43	0.19506E 02
10	-0.14193E 02	42	0.14193E 02
11	-0.10629E 02	41	0.10629E 02
12	-0.81549E 01	40	0.81549E 01
13	-0.63770E 01	39	0.63770E 01
14	-0.50626E 01	38	0.50626E 01
15	-0.40657E 01	37	0.40657E 01
16	-0.32911E 01	36	0.32911E 01
17	-0.26746E 01	35	0.26746E 01
18	-0.21709E 01	34	0.21709E 01
19	-0.17456E 01	33	0.17456E 01
20	-0.13660E 01	32	0.13660E 01
21	-0.78744E 00	31	0.78744E 00
22	-0.56609E 00	30	0.56609E 00
23	-0.39870E 00	29	0.39870E 00
24	-0.25572E 00	28	0.25572E 00
25	-0.12509E 00	27	0.12509E 00
26	0.00000E-38	26	0.00000E-38

OUTPUT DATA

NO.	ENERGY	CAPTURE	FISSION	SCATTERING	TOTAL
3900	0.253000E-01	0.889325E 01	0.000000E-38	0.182381E 01	0.107171E 02
1	0.500000E 00	0.236295E 01	-0.000000E-38	0.179580E 01	0.415874E 01
2	0.568031E 00	0.223352E 01	-0.000000E-38	0.179168E 01	0.402520E 01
3	0.693956E 00	0.204939E 01	-0.000000E-38	0.178399E 01	0.383337E 01
4	0.848082E 00	0.188706E 01	-0.000000E-38	0.177444E 01	0.366150E 01
5	0.104172E 01	0.174264E 01	-0.000000E-38	0.176223E 01	0.350486E 01
6	0.129094E 01	0.161544E 01	-0.000000E-38	0.174613E 01	0.336156E 01
7	0.161954E 01	0.150796E 01	-0.000000E-38	0.172419E 01	0.323214E 01
8	0.206402E 01	0.142795E 01	-0.000000E-38	0.169305E 01	0.312100E 01
9	0.268247E 01	0.139616E 01	-0.000000E-38	0.164631E 01	0.304247E 01
10	0.357349E 01	0.148059E 01	-0.000000E-38	0.156943E 01	0.305002E 01
11	0.490192E 01	0.205055E 01	-0.000000E-38	0.141729E 01	0.346785E 01
12	0.666148E 01	0.932683E 01	-0.000000E-38	0.970793E 00	0.102976E 02
13	0.693154E 01	0.163740E 02	-0.000000E-38	0.825075E 00	0.171991E 02
14	0.713542E 01	0.298499E 02	-0.000000E-38	0.713509E 00	0.305634E 02
15	0.727218E 01	0.520208E 02	-0.000000E-38	0.716983E 00	0.527378E 02
16	0.736710E 01	0.868191E 02	-0.000000E-38	0.920178E 00	0.877393E 02
17	0.743532E 01	0.139607E 03	-0.000000E-38	0.144020E 01	0.141047E 03
18	0.748575E 01	0.217330E 03	-0.000000E-38	0.243479E 01	0.219765E 03
19	0.752400E 01	0.328970E 03	-0.000000E-38	0.411307E 01	0.333083E 03
20	0.755372E 01	0.486138E 03	-0.000000E-38	0.675142E 01	0.492889E 03
21	0.757737E 01	0.704032E 03	-0.000000E-38	0.107191E 02	0.714751E 03
22	0.759670E 01	0.100326E 04	-0.000000E-38	0.165267E 02	0.101979E 04
23	0.761302E 01	0.141439E 04	-0.000000E-38	0.249429E 02	0.143933E 04
24	0.762759E 01	0.199516E 04	-0.000000E-38	0.374217E 02	0.203258E 04
25	0.764079E 01	0.352396E 04	-0.000000E-38	0.726552E 02	0.359661E 04
26	0.765828E 01	0.432092E 04	-0.000000E-38	0.923736E 02	0.441330E 04
27	0.766470E 01	0.492084E 04	-0.000000E-38	0.108118E 03	0.502896E 04
28	0.767019E 01	0.535099E 04	-0.000000E-38	0.120345E 03	0.547133E 04
29	0.767520E 01	0.561112E 04	-0.000000E-38	0.128910E 03	0.574003E 04
30	0.768000E 01	0.569705E 04	-0.000000E-38	0.133574E 03	0.583063E 04
31	0.76848CE 01	0.560747E 04	-0.000000E-38	0.134169E 03	0.574163E 04
32	0.768981E 01	0.534387E 04	-0.000000E-38	0.130593E 03	0.547446E 04
33	0.76953CE 01	0.491067E 04	-0.000000E-38	0.122807E 03	0.503348E 04
34	0.770172E 01	0.430831E 04	-0.000000E-38	0.110680E 03	0.441699E 04
35	0.771021E 01	0.350974E 04	-0.000000E-38	0.934122E 02	0.360316E 04
36	0.773241E 01	0.198138E 04	-0.000000E-38	0.577771E 02	0.203516E 04
37	0.774698E 01	0.140198E 04	-0.000000E-38	0.433619E 02	0.144534E 04
38	0.776330E 01	0.992360E 03	-0.000000E-38	0.327523E 02	0.102511E 04
39	0.778263E 01	0.694644E 03	-0.000000E-38	0.247223E 02	0.719367E 03
40	0.780628E 01	0.478190E 03	-0.000000E-38	0.186214E 02	0.496812E 03
41	0.783600E 01	0.322351E 03	-0.000000E-38	0.140040E 02	0.336355E 03
42	0.787425E 01	0.211989E 03	-0.000000E-38	0.105342E 02	0.222443E 03
43	0.792468E 01	0.135244E 03	-0.000000E-38	0.794985E 01	0.143194E 03
44	0.799290E 01	0.833759E 02	-0.000000E-38	0.604375E 01	0.854197E 02
45	0.808782E 01	0.493622E 02	-0.000000E-38	0.465159E 01	0.540137E 02
46	0.822458E 01	0.278494E 02	-0.000000E-38	0.364204E 01	0.314915E 02
47	0.842846E 01	0.149121E 02	-0.000000E-38	0.291737E 01	0.178295E 02
48	0.874682E 01	0.755776E 01	-0.000000E-38	0.239633E 01	0.995409E 01
49	0.927302E 01	0.367389E 01	-0.000000E-38	0.201453E 01	0.568842E 01
50	0.102089E 02	0.182159E 01	-0.000000E-38	0.171431E 01	0.353590E 01
51	0.120403E 02	0.108936E 01	-0.000000E-38	0.142428E 01	0.251364E 01
52	0.153209E 02	0.102810E 01	-0.000000E-38	0.106501E 01	0.209311E 01
53	0.203783E 02	0.195993E 01	-0.000000E-38	0.572887E 00	0.253282E 01
54	0.232016E 02	0.470335E 01	-0.000000E-38	0.812608E 00	0.551596E 01
55	0.246443E 02	0.108147E 02	-0.000000E-38	0.270021E 01	0.135149E 02
56	0.254554E 02	0.230967E 02	-0.000000E-38	0.773265E 01	0.308293E 02
57	0.259462E 02	0.458665E 02	-0.000000E-38	0.183038E 02	0.641703E 02
58	0.262605E 02	0.854272E 02	-0.000000E-38	0.379693E 02	0.123396E 03
59	0.264713E 02	0.150689E 03	-0.000000E-38	0.717979E 02	0.222487E 03
60	0.266176E 02	0.253321E 03	-0.000000E-38	0.126482E 03	0.379804E 03
61	0.267226E 02	0.409235E 03	-0.000000E-38	0.211157E 03	0.620393E 03
62	0.268005E 02	0.639052E 03	-0.000000E-38	0.337702E 03	0.976754E 03
63	0.268595E 02	0.969434E 03	-0.000000E-38	0.521518E 03	0.149095E 04
64	0.269053E 02	0.143467E 04	-0.000000E-38	0.782568E 03	0.221744E 04
65	0.269418E 02	0.208051E 04	-0.000000E-38	0.114704E 04	0.322755E 04
66	0.269716E 02	0.296757E 04	-0.000000E-38	0.165053E 04	0.461810E 04
67	0.269967E 02	0.418690E 04	-0.000000E-38	0.234594E 04	0.653283E 04
68	0.270192E 02	0.591002E 04	-0.000000E-38	0.333315E 04	0.924317E 04
69	0.270534E 02	0.104482E 05	-0.000000E-38	0.595131E 04	0.163995E 05
70	0.270665E 02	0.128150E 05	-0.000000E-38	0.732698E 04	0.201420E 05
71	0.270764E 02	0.145970E 05	-0.000000E-38	0.836962E 04	0.229666E 05
72	0.270849E 02	0.158751E 05	-0.000000E-38	0.912459E 04	0.249997E 05
73	0.270926E 02	0.166487E 05	-0.000000E-38	0.959038E 04	0.262391E 05
74	0.271000E 02	0.169052E 05	-0.000000E-38	0.975877E 04	0.266640E 05
75	0.271074E 02	0.166409E 05	-0.000000E-38	0.962646E 04	0.262673E 05
76	0.271151E 02	0.158602E 05	-0.000000E-38	0.919506E 04	0.250553E 05
77	0.271236E 02	0.145763E 05	-0.000000E-38	0.847103E 04	0.230473E 05
78	0.271335E 02	0.127904E 05	-0.000000E-38	0.745406E 04	0.202445E 05
79	0.271466E 02	0.104222E 05	-0.000000E-38	0.609644E 04	0.165187E 05
80	0.271808E 02	0.588797E 04	-0.000000E-38	0.347744E 04	0.936541E 04
81	0.272033E 02	0.416813E 04	-0.000000E-38	0.247719E 04	0.664531E 04

82	0.272284E 02	0.295177E 04	-0.000000E-38	0.176658E 04	0.471835E 04
83	0.272582E 02	0.206734E 04	-0.000000E-38	0.124747E 04	0.331481E 04
84	0.272947E 02	0.142399E 04	-0.000000E-38	0.867881E 03	0.229187E 04
85	0.273405E 02	0.960543E 03	-0.000000E-38	0.592729E 03	0.155327E 04
86	0.273995E 02	0.631872E 03	-0.000000E-38	0.396105E 03	0.102798E 04
87	0.274772E 02	0.403523E 03	-0.000000E-38	0.258173E 03	0.661697E 03
88	0.275824E 02	0.248858E 03	-0.000000E-38	0.163565E 03	0.412423E 03
89	0.277287E 02	0.147282E 03	-0.000000E-38	0.100368E 03	0.247650E 03
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91	0.282538E 02	0.440795E 02	-0.000000E-38	0.337688E 02	0.778483E 02
92	0.287446E 02	0.219183E 02	-0.000000E-38	0.183874E 02	0.403057E 02
93	0.295557E 02	0.101515E 02	-0.000000E-38	0.949851E 01	0.196500E 02
94	0.309984E 02	0.452068E 01	-0.000000E-38	0.449834E 01	0.901902E 01
95	0.338217E 02	0.241605E 01	-0.000000E-38	0.156522E 01	0.358127E 01
96	0.352900E 02	0.233001E 01	-0.000000E-38	0.835613E 00	0.316562E 01
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98	0.380724E 02	0.319469E 01	-0.000000E-38	0.779680E-01	0.327265E 01
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106	0.404058E 02	0.446731E 02	-0.000000E-38	0.295333E 01	0.476264E 02
107	0.404441E 02	0.652949E 02	-0.000000E-38	0.382081E 01	0.691157E 02
108	0.404738E 02	0.943181E 02	-0.000000E-38	0.491607E 01	0.992341E 02
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110	0.405167E 02	0.185834E 03	-0.000000E-38	0.804718E 01	0.197882E 03
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116	0.405902E 02	0.994600E 03	-0.000000E-38	0.256337E 02	0.102023E 04
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127	0.407026E 02	0.134571E 03	-0.000000E-38	0.857621E 00	0.135428E 03
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137	0.419799E 02	0.964424E 01	-0.000000E-38	0.314093E 01	0.127852E 02
138	0.429165E 02	0.144787E 02	-0.000000E-38	0.905498E 01	0.235337E 02
139	0.438665E 02	0.277207E 02	-0.000000E-38	0.271157E 02	0.548364E 02
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141	0.448830E 02	0.877768E 02	-0.000000E-38	0.125203E 03	0.212980E 03
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145	0.456345E 02	0.547726E 03	-0.000000E-38	0.989634E 03	0.153736E 04
146	0.457232E 02	0.808121E 03	-0.000000E-38	0.149805E 04	0.230617E 04
147	0.457938E 02	0.116906E 04	-0.000000E-38	0.221093E 04	0.337999E 04
148	0.458514E 02	0.166473E 04	-0.000000E-38	0.319930E 04	0.486403E 04
149	0.459001E 02	0.234587E 04	-0.000000E-38	0.456080E 04	0.691467E 04
150	0.459436E 02	0.330824E 04	-0.000000E-38	0.651902E 04	0.982726E 04
151	0.460098E 02	0.584212E 04	-0.000000E-38	0.117151E 05	0.175572E 05
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164	0.463486E 02	0.166001E 04	-0.000000E-38	0.360467E 04	0.526468E 04
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174	0.474873E 02	0.342084E 03	-0.000000E-38	0.566738E 03	0.908822E 03
175	0.475459E 02	0.462721E 03	-0.000000E-38	0.740270E 03	0.120299E 04
176	0.475938E 02	0.631686E 03	-0.000000E-38	0.988720E 03	0.162041E 04
177	0.476342E 02	0.866149E 03	-0.000000E-38	0.133838E 04	0.220453E 04
178	0.476702E 02	0.119915E 04	-0.000000E-38	0.184034E 04	0.303550E 04
179	0.477252E 02	0.207909E 04	-0.000000E-38	0.318482E 04	0.526391E 04
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187	0.478379E 02	0.287603E 04	-0.000000E-38	0.451706E 04	0.739309E 04
188	0.478538E 02	0.252780E 04	-0.000000E-38	0.399439E 04	0.652219E 04
189	0.478748E 02	0.206612E 04	-0.000000E-38	0.329380E 04	0.535993E 04
190	0.479098E 02	0.118175E 04	-0.000000E-38	0.193459E 04	0.311634E 04
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193	0.480541E 02	0.433987E 03	-0.000000E-38	0.763085E 03	0.119707E 04
194	0.481127E 02	0.306987E 03	-0.000000E-38	0.559554E 03	0.866540E 03
195	0.481862E 02	0.214728E 03	-0.000000E-38	0.409486E 03	0.624214E 03
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203	0.517441E 02	0.564813E 01	-0.000000E-38	0.282804E 02	0.339286E 02
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207	0.616477E 02	0.738183E 00	-0.000000E-38	0.906135E 01	0.979954E 01
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217	0.658443E 02	0.353905E 02	-0.000000E-38	0.420700E 01	0.395975E 02
218	0.658739E 02	0.522049E 02	-0.000000E-38	0.374642E 01	0.559514E 02
219	0.658976E 02	0.755355E 02	-0.000000E-38	0.336241E 01	0.788980E 02
220	0.659169E 02	0.107598E 03	-0.000000E-38	0.312778E 01	0.110726E 03
221	0.659331E 02	0.151677E 03	-0.000000E-38	0.316008E 01	0.154837E 03
222	0.659477E 02	0.213984E 03	-0.000000E-38	0.368360E 01	0.217668E 03
223	0.659698E 02	0.378145E 03	-0.000000E-38	0.698784E 01	0.385133E 03
224	0.659783E 02	0.463807E 03	-0.000000E-38	0.980011E 01	0.473607E 03
225	0.659847E 02	0.528353E 03	-0.000000E-38	0.126436E 02	0.540997E 03
226	0.659902E 02	0.574692E 03	-0.000000E-38	0.154386E 02	0.590130E 03
227	0.659952E 02	0.602794E 03	-0.000000E-38	0.180723E 02	0.620866E 03
228	0.660000E 02	0.612197E 03	-0.000000E-38	0.204204E 02	0.632617E 03
229	0.660048E 02	0.602751E 03	-0.000000E-38	0.223690E 02	0.625120E 03
230	0.660098E 02	0.574609E 03	-0.000000E-38	0.238120E 02	0.598421E 03
231	0.660153E 02	0.528235E 03	-0.000000E-38	0.246440E 02	0.552879E 03
232	0.660217E 02	0.463658E 03	-0.000000E-38	0.247537E 02	0.488412E 03
233	0.660302E 02	0.377975E 03	-0.000000E-38	0.239382E 02	0.401913E 03
234	0.660523E 02	0.213814E 03	-0.000000E-38	0.202911E 02	0.234105E 03
235	0.660669E 02	0.151520E 03	-0.000000E-38	0.181765E 02	0.169697E 03
236	0.660831E 02	0.107458E 03	-0.000000E-38	0.163427E 02	0.123801E 03
237	0.661024E 02	0.754122E 02	-0.000000E-38	0.147508E 02	0.901630E 02
238	0.661260E 02	0.520973E 02	-0.000000E-38	0.133794E 02	0.654766E 02
239	0.661557E 02	0.352969E 02	-0.000000E-38	0.122073E 02	0.475042E 02
240	0.661939E 02	0.233779E 02	-0.000000E-38	0.112132E 02	0.345911E 02
241	0.662442E 02	0.150926E 02	-0.000000E-38	0.103755E 02	0.254681E 02
242	0.663123E 02	0.947618E 01	-0.000000E-38	0.967314E 01	0.191493E 02
243	0.664071E 02	0.578277E 01	-0.000000E-38	0.908561E 01	0.148684E 02
244	0.665436E 02	0.343650E 01	-0.000000E-38	0.859140E 01	0.120279E 02
245	0.667471E 02	0.201470E 01	-0.000000E-38	0.817070E 01	0.101854E 02
246	0.670649E 02	0.119415E 01	-0.000000E-38	0.779752E 01	0.899167E 01
247	0.675901E 02	0.745096E 00	-0.000000E-38	0.743755E 01	0.818265E 01
248	0.685243E 02	0.508259E 00	-0.000000E-38	0.703715E 01	0.754541E 01
249	0.703523E 02	0.377528E 00	-0.000000E-38	0.650127E 01	0.687880E 01
250	0.744610E 02	0.290670E 00	-0.000000E-38	0.563577E 01	0.592644E 01
251	0.769949E 02	0.272636E 00	-0.000000E-38	0.526385E 01	0.553649E 01
252	0.814700E 02	0.268155E 00	-0.000000E-38	0.448770E 01	0.475585E 01
253	0.908567E 02	0.515015E 00	-0.000000E-38	0.275848E 01	0.327350E 01
254	0.950331E 02	0.126198E 01	-0.000000E-38	0.146287E 01	0.272485E 01
255	0.971672E 02	0.296851E 01	-0.000000E-38	0.778476E 00	0.374698E 01
256	0.983672E 02	0.642353E 01	-0.000000E-38	0.155730E 01	0.798083E 01
257	0.990932E 02	0.128467E 02	-0.000000E-38	0.526920E 01	0.181159E 02

258	0.995581E 02	0.240227E 02	-0.000000E-38	0.141541E 02	0.381768E 02
259	0.998700E 02	0.424767E 02	-0.000000E-38	0.314459E 02	0.739226E 02
260	0.100086E 03	0.719181E 02	-0.000000E-38	0.614781E 02	0.132996E 03
261	0.100242E 03	0.115466E 03	-0.000000E-38	0.110171E 03	0.225831E 03
262	0.100357E 03	0.180752E 03	-0.000000E-38	0.185276E 03	0.366028E 03
263	0.100444E 03	0.274359E 03	-0.000000E-38	0.296891E 03	0.571250E 03
264	0.100512E 03	0.406263E 03	-0.000000E-38	0.458157E 03	0.864420E 03
265	0.100566E 03	0.589277E 03	-0.000000E-38	0.686392E 03	0.127967E 04
266	0.100610E 03	0.840766E 03	-0.000000E-38	0.100521E 04	0.184598E 04
267	0.100647E 03	0.118652E 04	-0.000000E-38	0.144985E 04	0.263637E 04
268	0.100680E 03	0.167520E 04	-0.000000E-38	0.208681E 04	0.376201E 04
269	0.100731E 03	0.296263E 04	-0.000000E-38	0.379937E 04	0.676200E 04
270	0.100750E 03	0.363430E 04	-0.000000E-38	0.471233E 04	0.834662E 04
271	0.100765E 03	0.414024E 04	-0.000000E-38	0.541304E 04	0.955328E 04
272	0.100778E 03	0.450332E 04	-0.000000E-38	0.592941E 04	0.104327E 05
273	0.100789E 03	0.472334E 04	-0.000000E-38	0.625918E 04	0.109825E 05
274	0.100800E 03	0.479670E 04	-0.000000E-38	0.639551E 04	0.111922E 05
275	0.100811E 03	0.472226E 04	-0.000000E-38	0.633488E 04	0.110571E 05
276	0.100822E 03	0.450128E 04	-0.000000E-38	0.607700E 04	0.105783E 05
277	0.100835E 03	0.413744E 04	-0.000000E-38	0.562473E 04	0.976217E 04
278	0.100850E 03	0.363101E 04	-0.000000E-38	0.497642E 04	0.860743E 04
279	0.100869E 03	0.295923E 04	-0.000000E-38	0.409920E 04	0.705843E 04
280	0.100920E 03	0.167246E 04	-0.000000E-38	0.238161E 04	0.405408E 04
281	0.100953E 03	0.118426E 04	-0.000000E-38	0.171689E 04	0.290115E 04
282	0.100990E 03	0.838914E 03	-0.000000E-38	0.124063E 04	0.207955E 04
283	0.101034E 03	0.587774E 03	-0.000000E-38	0.889703E 03	0.147748E 04
284	0.101088E 03	0.405057E 03	-0.000000E-38	0.630604E 03	0.103566E 04
285	0.101156E 03	0.273409E 03	-0.000000E-38	0.440683E 03	0.714092E 03
286	0.101243E 03	0.180025E 03	-0.000000E-38	0.303123E 03	0.483148E 03
287	0.101358E 03	0.115133E 03	-0.000000E-38	0.205002E 03	0.320135E 03
288	0.101514E 03	0.711762E 02	-0.000000E-38	0.136263E 03	0.207439E 03
289	0.101730E 03	0.423253E 02	-0.000000E-38	0.890708E 02	0.131396E 03
290	0.102042E 03	0.241116E 02	-0.000000E-38	0.573107E 02	0.814223E 02
291	0.102507E 03	0.134223E 02	-0.000000E-38	0.364640E 02	0.498863E 02
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293	0.102951E 03	0.991878E 01	-0.000000E-38	0.268082E 02	0.367270E 02
294	0.103183E 03	0.102176E 02	-0.000000E-38	0.235367E 02	0.337543E 02
295	0.103338E 03	0.123521E 02	-0.000000E-38	0.218225E 02	0.341745E 02
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302	0.103706E 03	0.136398E 03	-0.000000E-38	0.330217E 02	0.169419E 03
303	0.103724E 03	0.190660E 03	-0.000000E-38	0.405477E 02	0.231208E 03
304	0.103741E 03	0.267387E 03	-0.000000E-38	0.517921E 02	0.319179E 03
305	0.103766E 03	0.469611E 03	-0.000000E-38	0.837170E 02	0.553328E 03
306	0.103775E 03	0.575148E 03	-0.000000E-38	0.101627E 03	0.676775E 03
307	0.103783E 03	0.654674E 03	-0.000000E-38	0.115940E 03	0.770614E 03
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315	0.103834E 03	0.469256E 03	-0.000000E-38	0.102360E 03	0.571616E 03
316	0.103859E 03	0.266907E 03	-0.000000E-38	0.697290E 02	0.336636E 03
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318	0.103894E 03	0.135764E 03	-0.000000E-38	0.466923E 02	0.182456E 03
319	0.103916E 03	0.962210E 02	-0.000000E-38	0.392330E 02	0.135454E 03
320	0.103943E 03	0.674250E 02	-0.000000E-38	0.335052E 02	0.100930E 03
321	0.103977E 03	0.466436E 02	-0.000000E-38	0.290936E 02	0.757372E 02
322	0.104020E 03	0.318589E 02	-0.000000E-38	0.256798E 02	0.575387E 02
323	0.104077E 03	0.215279E 02	-0.000000E-38	0.230083E 02	0.445361E 02
324	0.104155E 03	0.144537E 02	-0.000000E-38	0.208673E 02	0.353210E 02
325	0.104262E 03	0.970711E 01	-0.000000E-38	0.190765E 02	0.287836E 02
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332	0.113410E 03	0.335493E 00	-0.000000E-38	0.631817E 01	0.665366E 01
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335	0.133411E 03	0.325888E 00	-0.000000E-38	0.315683E 01	0.348271E 01
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341	0.137480E 03	0.648395E 01	-0.000000E-38	0.131993E 01	0.780388E 01
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349	0.137831E 03	0.170543E 03	-0.000000E-38	0.299104E 01	0.173534E 03
350	0.137846E 03	0.240623E 03	-0.000000E-38	0.575845E 01	0.246381E 03
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354	0.137890E 03	0.646426E 03	-0.000000E-38	0.320777E 02	0.678503E 03
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358	0.137910E 03	0.646391E 03	-0.000000E-38	0.419755E 02	0.688366E 03
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367	0.138061E 03	0.397196E 02	-0.000000E-38	0.974466E 01	0.496642E 02
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370	0.138222E 03	0.106831E 02	-0.000000E-38	0.590994E 01	0.165930E 02
371	0.138320E 03	0.653917E 01	-0.000000E-38	0.511819E 01	0.116574E 02
372	0.138461E 03	0.391783E 01	-0.000000E-38	0.449653E 01	0.841437E 01
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385	0.143844E 03	0.643258E 02	-0.000000E-38	0.874155E 02	0.151741E 03
386	0.143912E 03	0.950545E 02	-0.000000E-38	0.128514E 03	0.223569E 03
387	0.143966E 03	0.137691E 03	-0.000000E-38	0.185518E 03	0.323209E 03
388	0.144010E 03	0.196280E 03	-0.000000E-38	0.263819E 03	0.460099E 03
389	0.144047E 03	0.276831E 03	-0.000000E-38	0.371433E 03	0.648264E 03
390	0.144080E 03	0.390678E 03	-0.000000E-38	0.523470E 03	0.914148E 03
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407	0.144556E 03	0.642032E 02	-0.000000E-38	0.859761E 02	0.150179E 03
408	0.144643E 03	0.424398E 02	-0.000000E-38	0.570012E 02	0.994410E 02
409	0.144758E 03	0.273169E 02	-0.000000E-38	0.368696E 02	0.641864E 02
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RESONANCE INTEGRAL - SCATTERING

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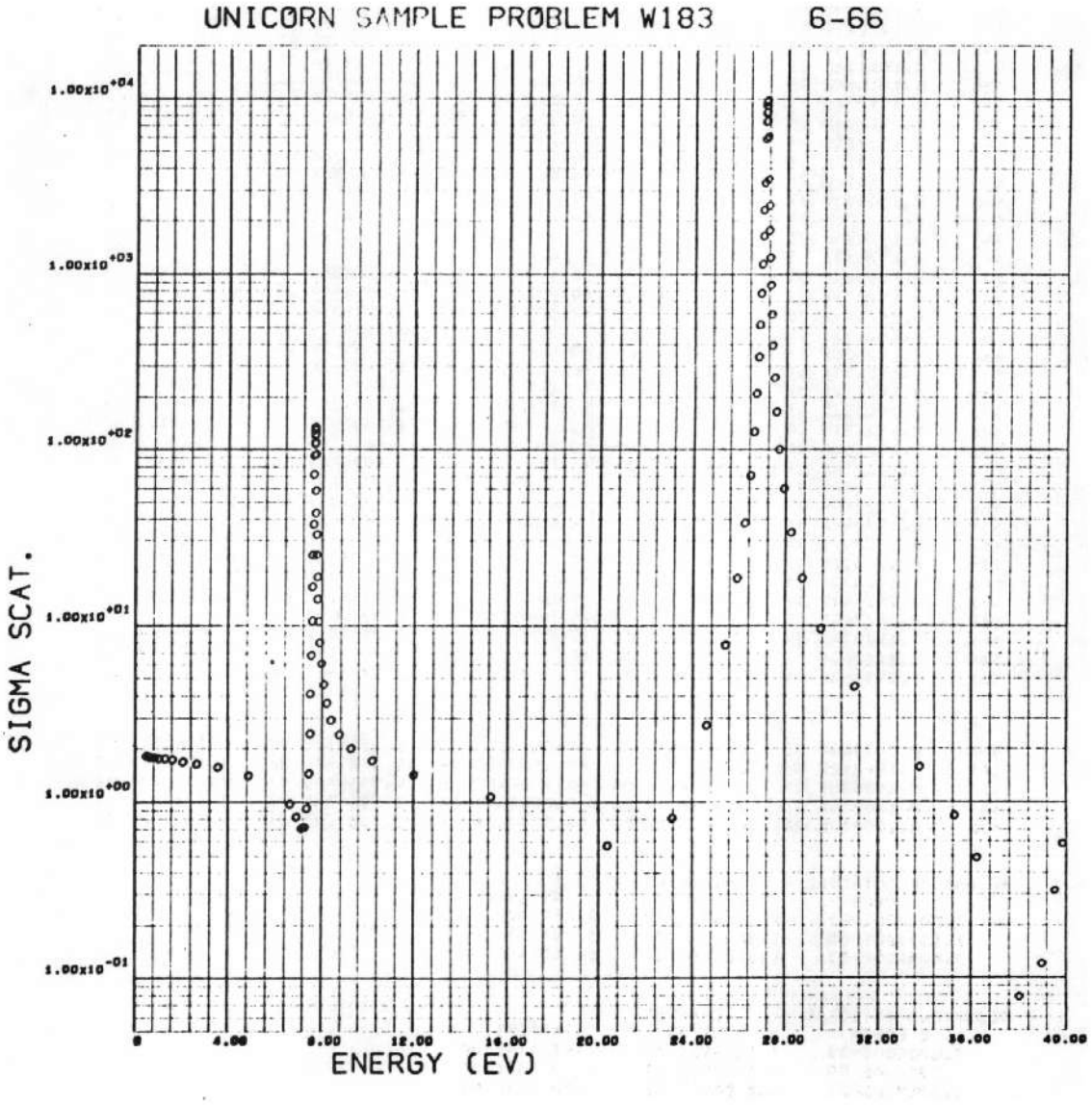
1.125600E 00	1.000000E 01	5.493943E 00
5.000000E-01	1.000000E 01	6.937645E 00

RESONANCE INTEGRAL - CAPTURE

E LOWER	E UPPER	INTEGRAL
5.000000E-01	1.125600E 00	1.621718E 00
1.125600E 00	1.000000E 01	9.102202E 01
5.000000E-01	1.000000E 01	9.264374E 01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1.00x10+02
1.00x10+01
1.00x10+00
1.00x10-01
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12.00
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20.00
24.00
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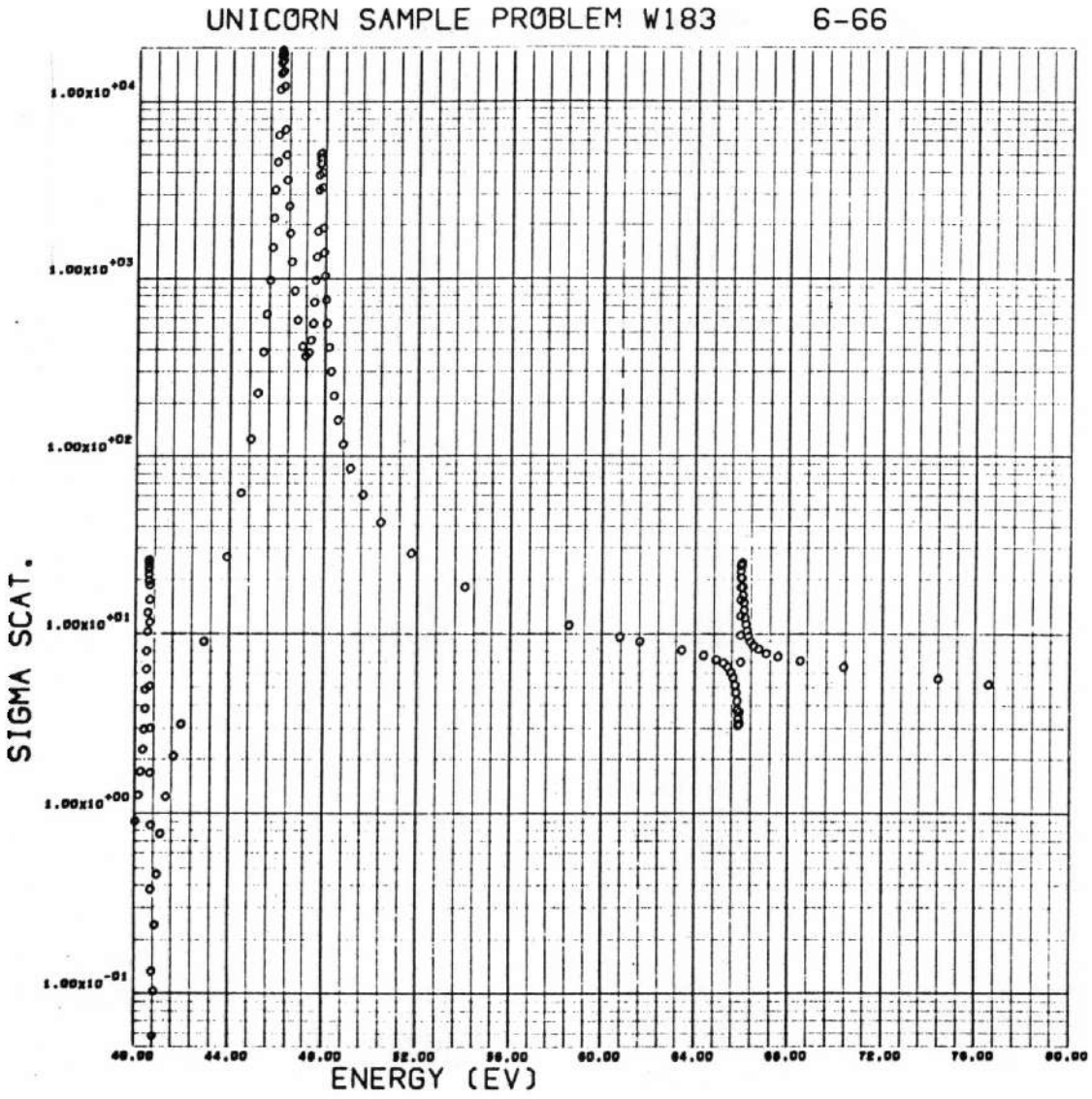
32.00
36.00
40.00
ENERGY (EV)


UNICORN SAMPLE PROBLEM W183 6-66
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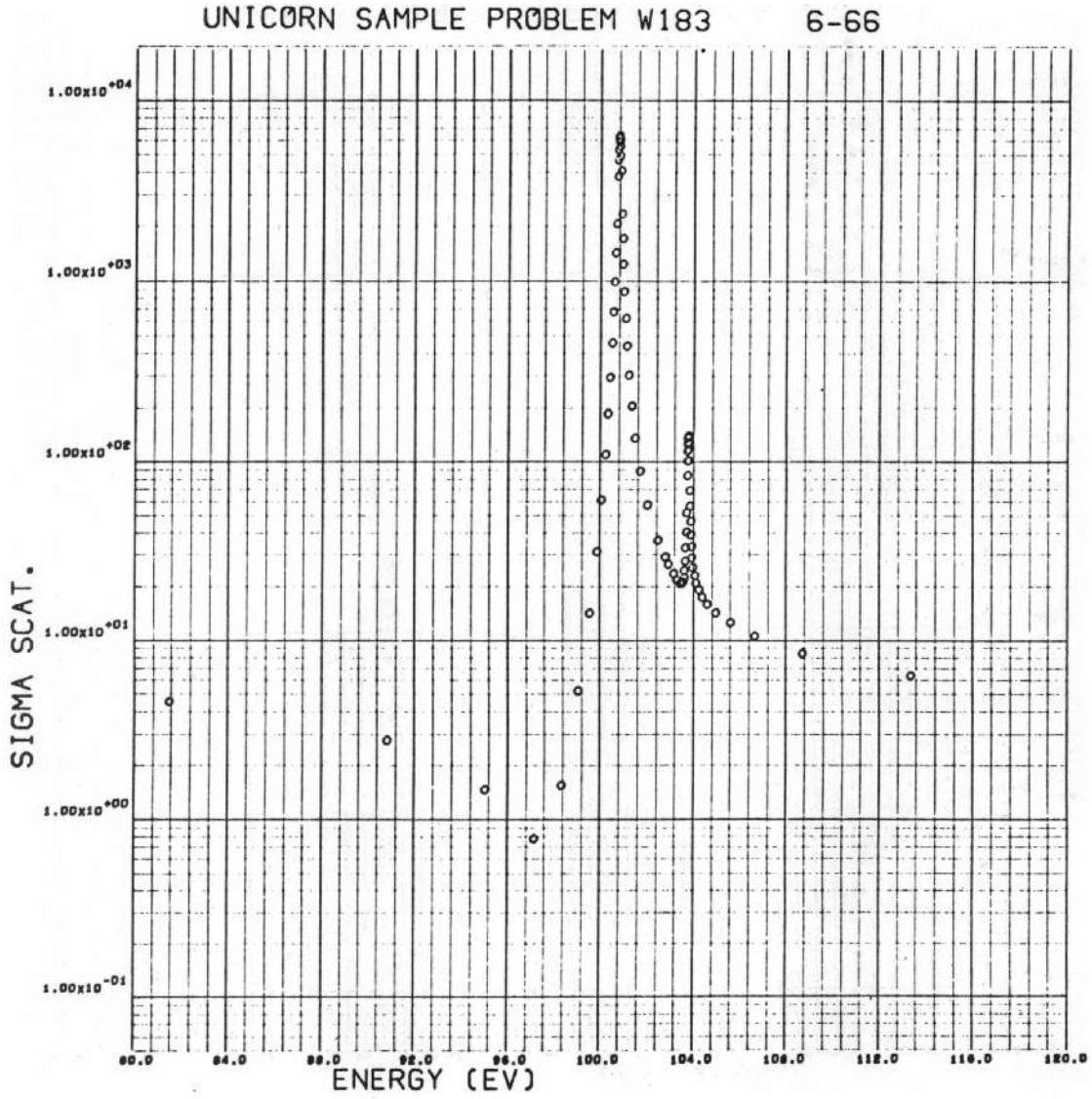
72.00
76.00
80.00
ENERGY (EV)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1.00x10-01
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92.0
96.0
100.0
104.0
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112.0
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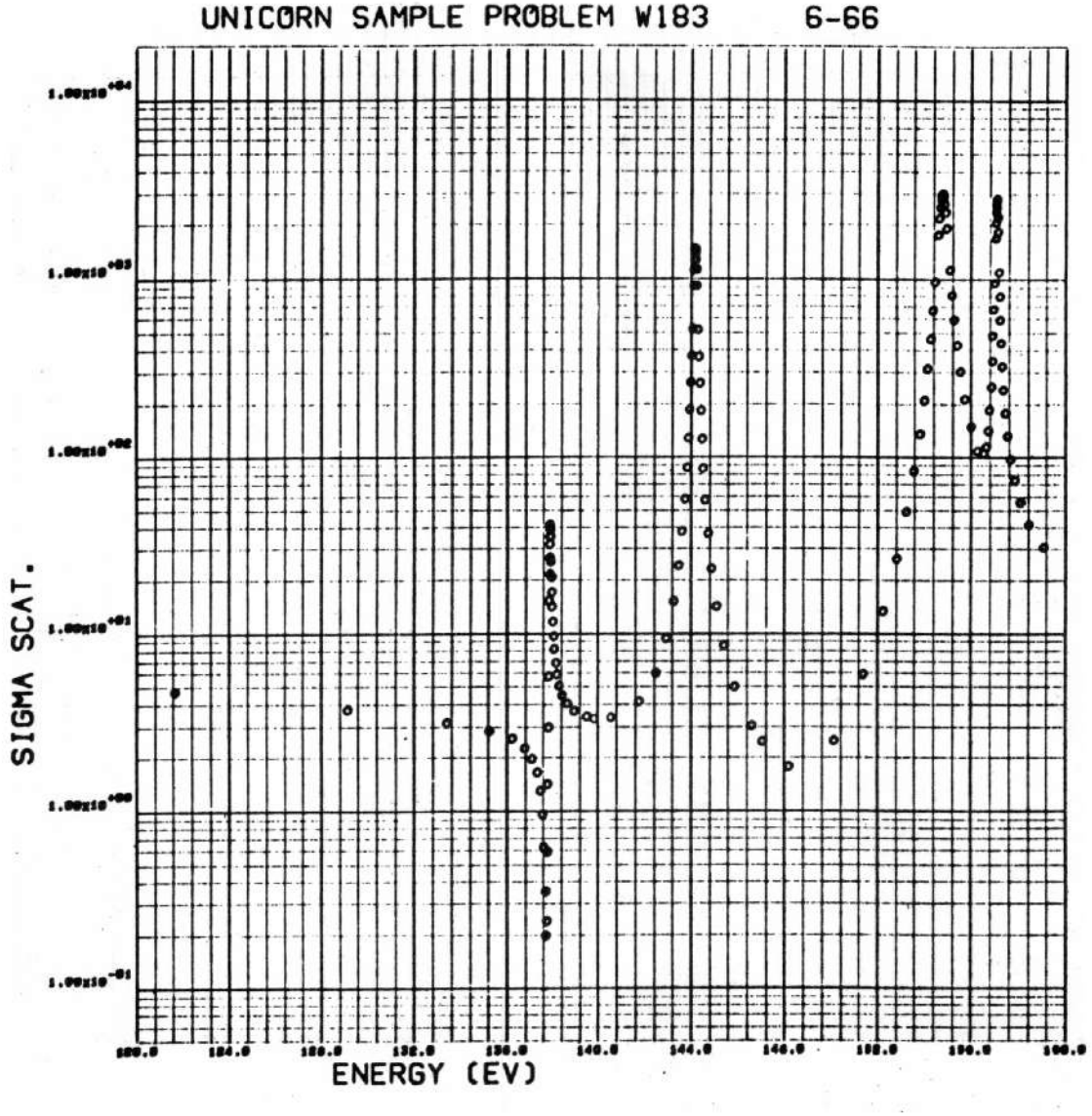
120.0
ENERGY (EV)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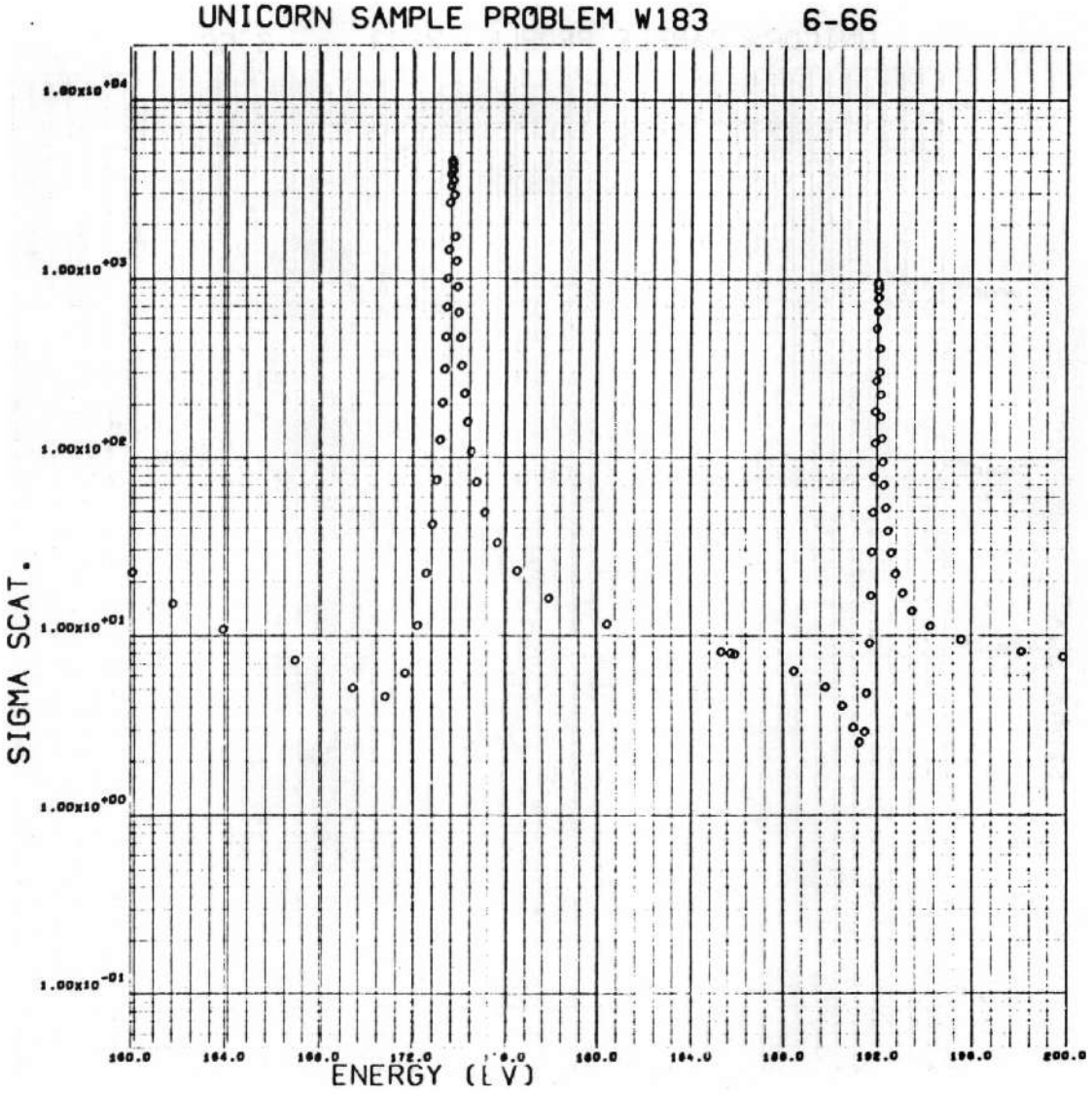
SIGMA SCAT.
ENERGY (EV)


UNICORN SAMPLE PROBLEM W183 6-66
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1.00x10-01
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172.0
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180.0
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192.0
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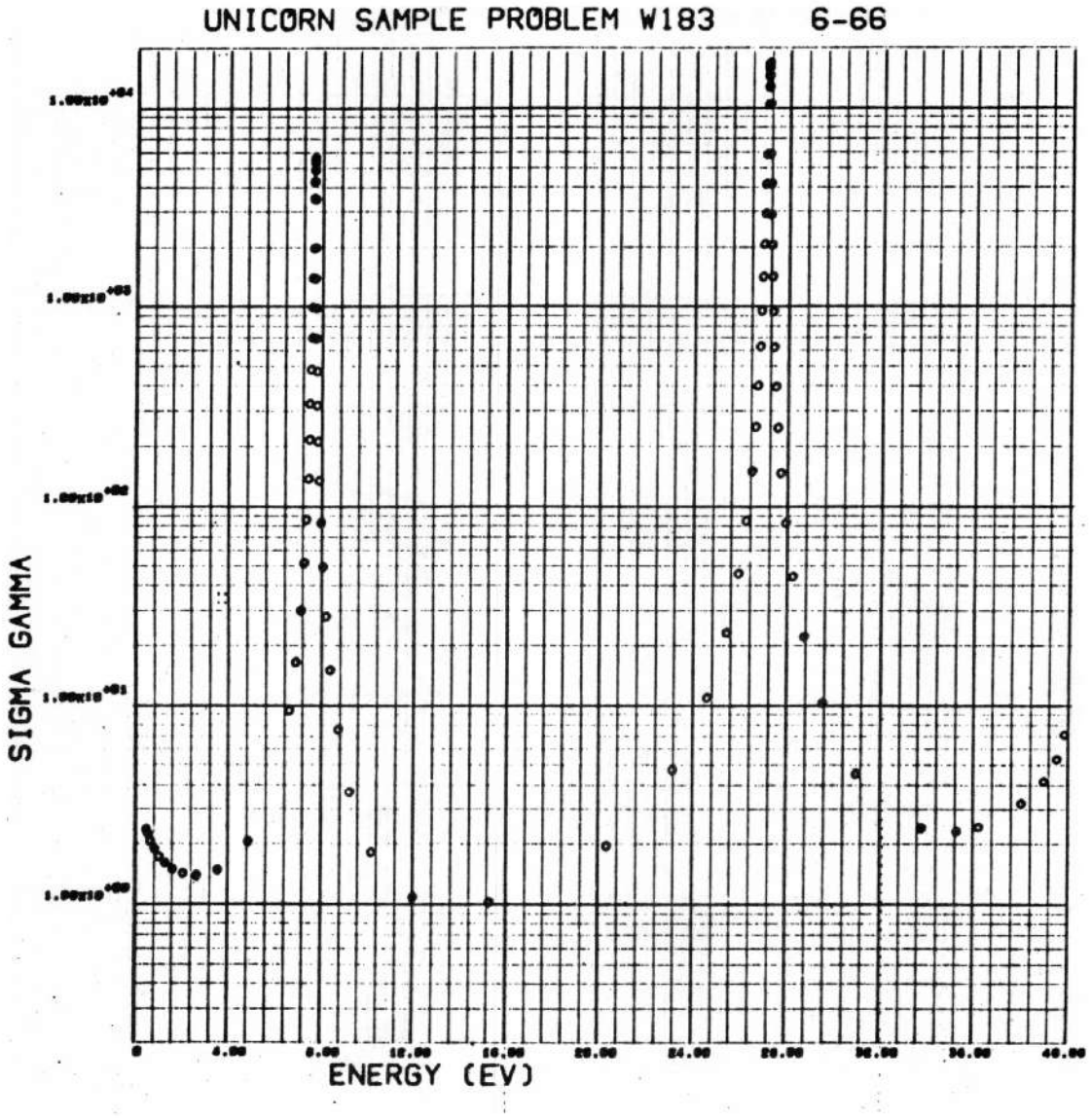
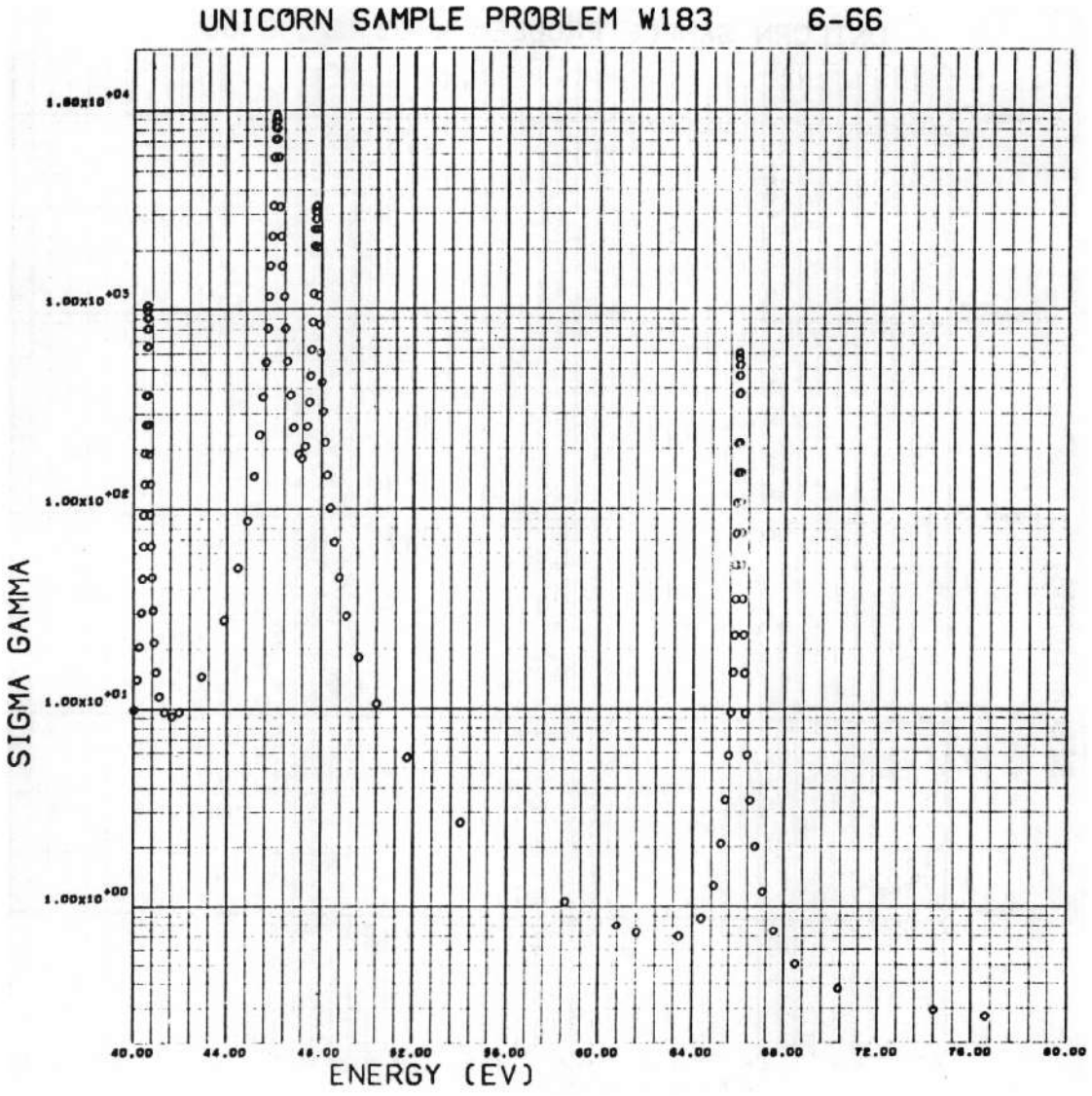
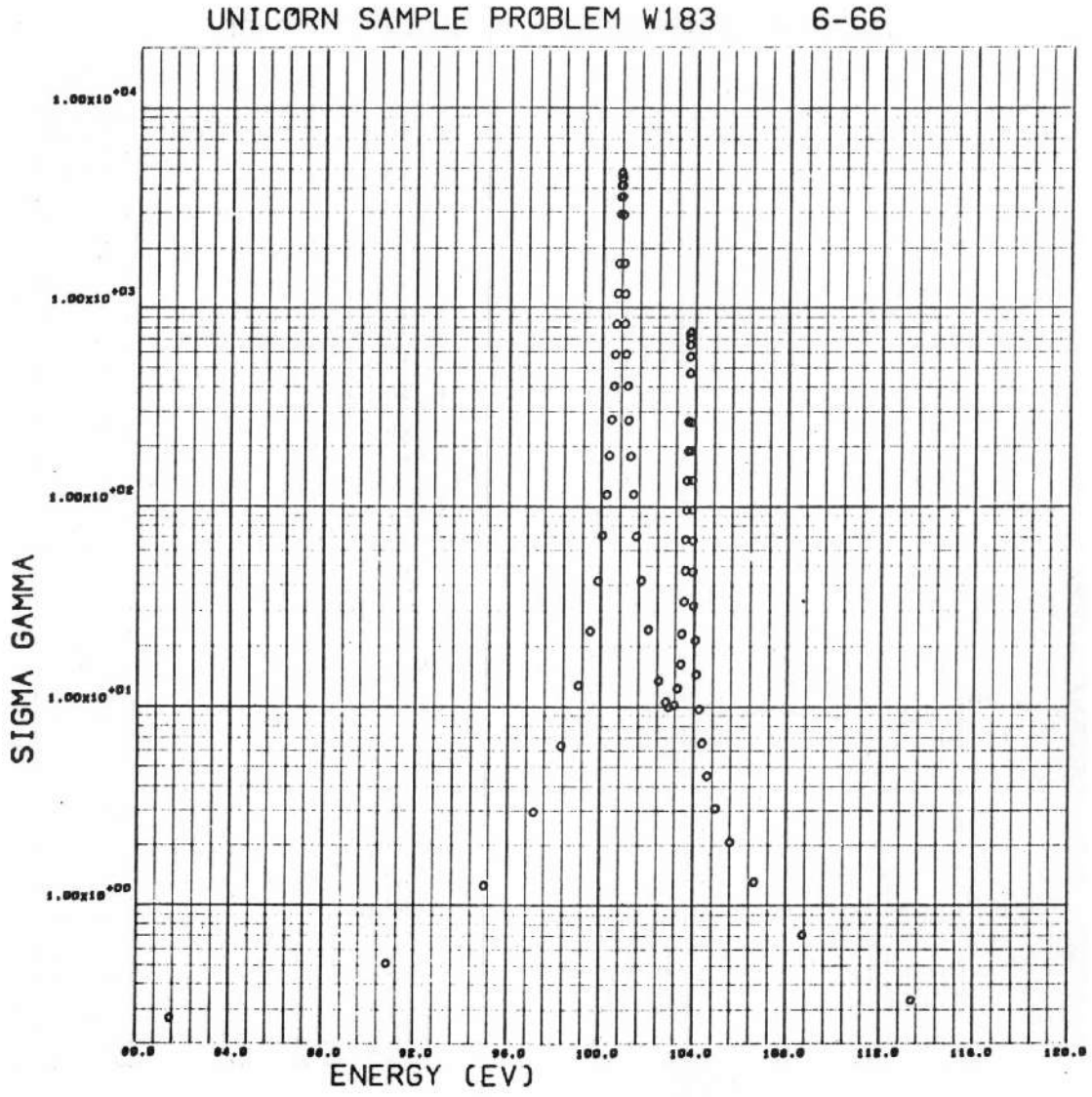
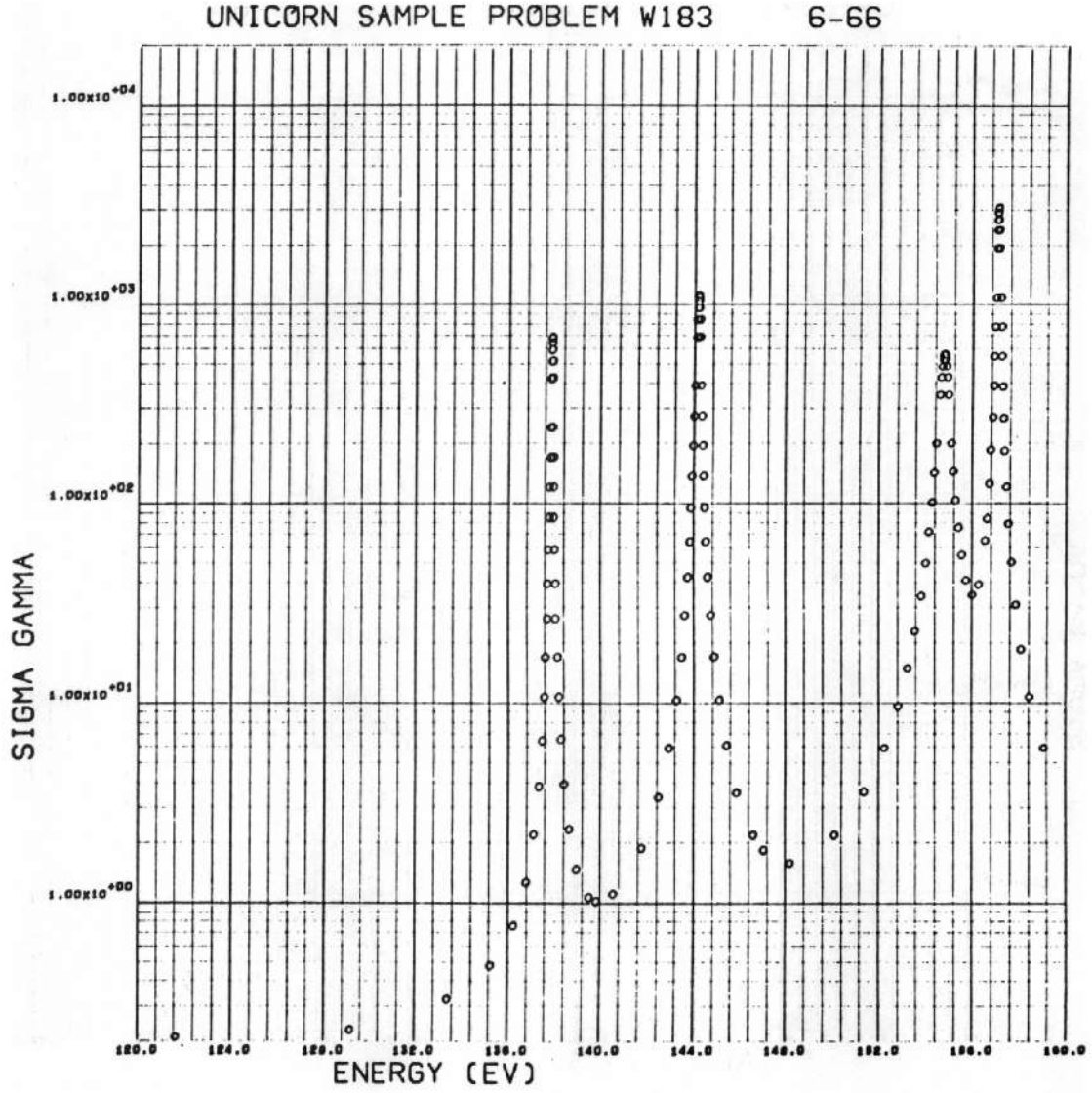
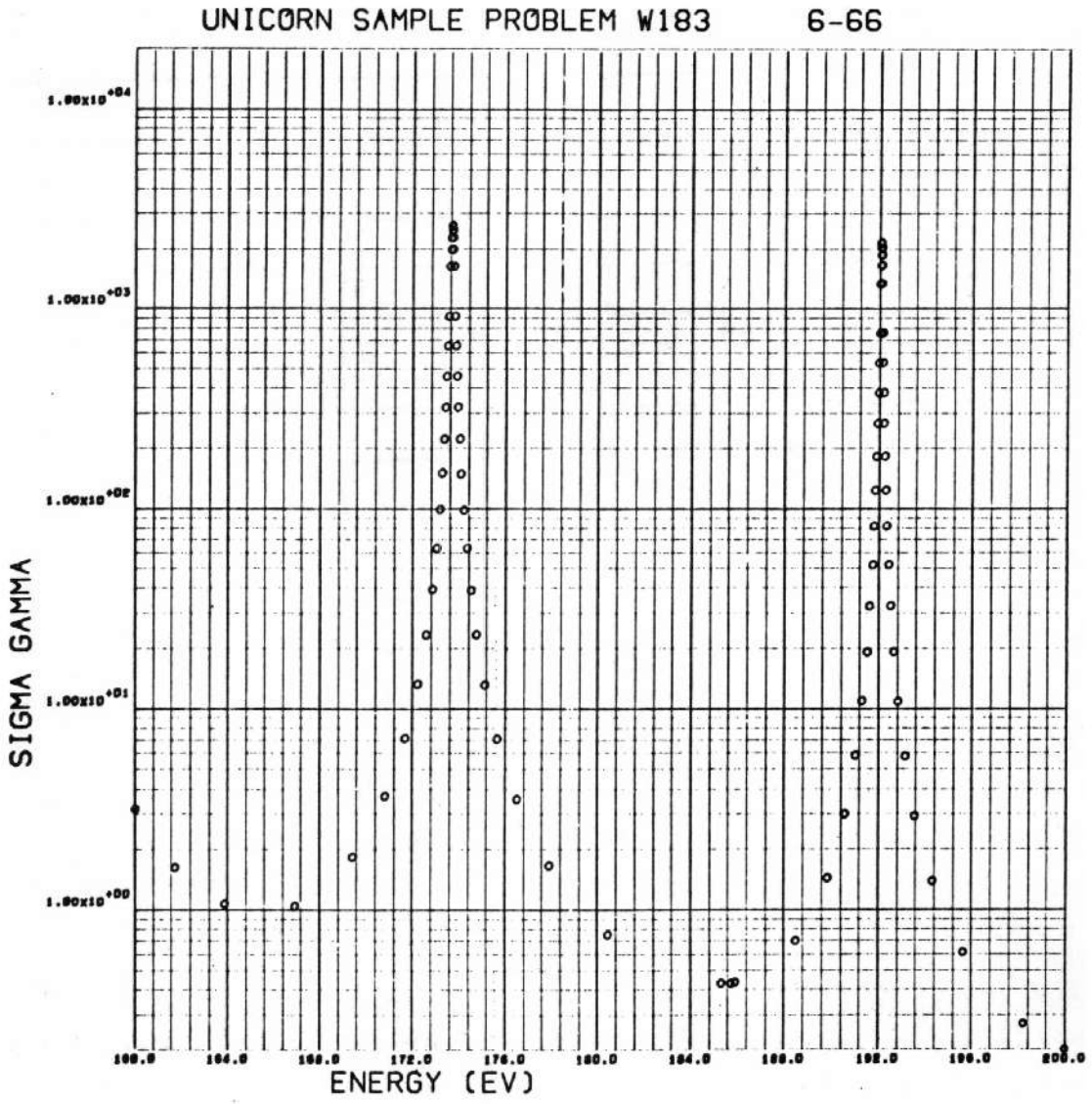
ENERGY (EV)


UNICORN SAMPLE PROBLEM W183 6-66
SIGMA GAMMA
ENERGY (EV)


UNICORN SAMPLE PROBLEM W183 6-66
SIGMA GAMMA
1.00x10+04
1.00x10+03
1.00x10+02
1.00x10+01
1.00x10+00
40.00
44.00
48.00
52.00
56.00
60.00
64.00
68.00
72.00
76.00
80.00
ENERGY (EV)

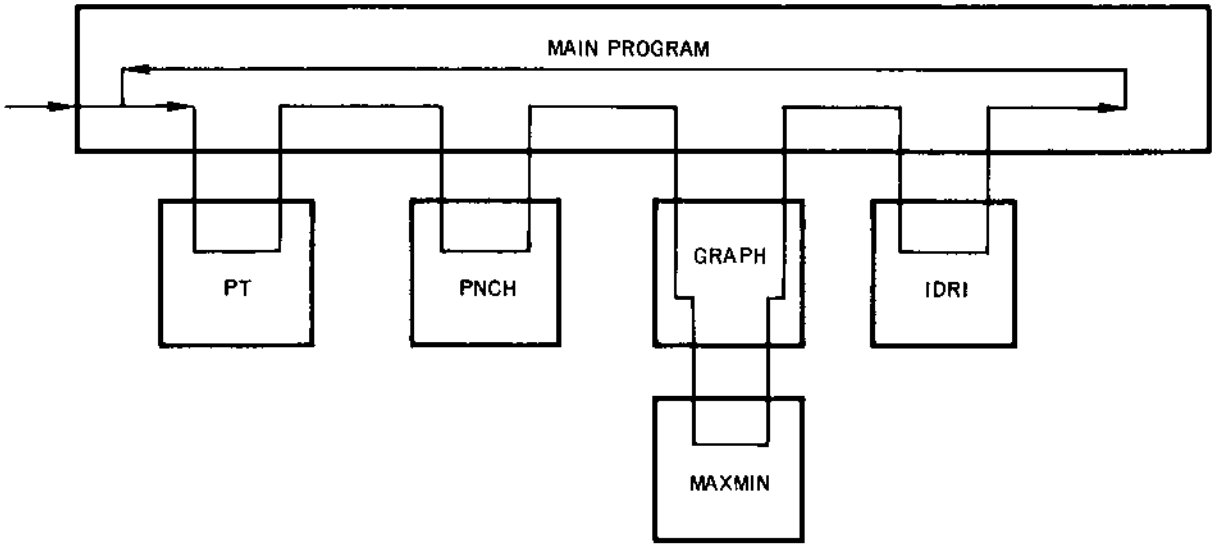

UNICORN SAMPLE PROBLEM W183 6-66
SIGMA GAMMA
ENERGY (EV)


UNICORN SAMPLE PROBLEM W183 6-66
SIGMA GAMMA
1.00x10+04
1.00x10+03
1.00x10+02
1.00x10+01
1.00x10+00
120.0
124.0
128.0
132.0
136.0
140.0
144.0
148.0
152.0
156.0
160.0
ENERGY (EV)


UNICORN SAMPLE PROBLEM W183 6-66
SIGMA GAMMA
ENERGY (EV)

XI. FLOW CHARTS AND SUBROUTINE DESCRIPTIONS

The flow of logic among subroutines is shown below followed by descriptive statements of each subroutine. Following these are more detailed flow diagrams of each subroutine.



6-20-66 Figure 2. Subroutine Flow Chart 7604-2536

Main Program: Reads and writes input data, assigns statistical weights for g = 0.5 resonances, writes output titles, calculates cross sections and 2200 m/s adjustments, writes cross sections and determines energy points using data from subroutine PT, directs flow to PNCH, GRAPH, and IDRI subroutines.

Subroutine PT: Calculates the optimized point representation of the line shape $(1 + x^2)^{-1}$ for use with a semilogarithmic interpolation scheme as described in both Section V and the Appendix.

Subroutine PNCH: Prepares output for punched cards.

Subroutine GRAPH: Prepares output for graphical display of cross sections.

Subroutine MAXMIN: Calculates the best limits for the cross-section scale of graphical displays.

Subroutine IDRI: Integrates point cross sections over 1/E spectrum within specified energy groups.

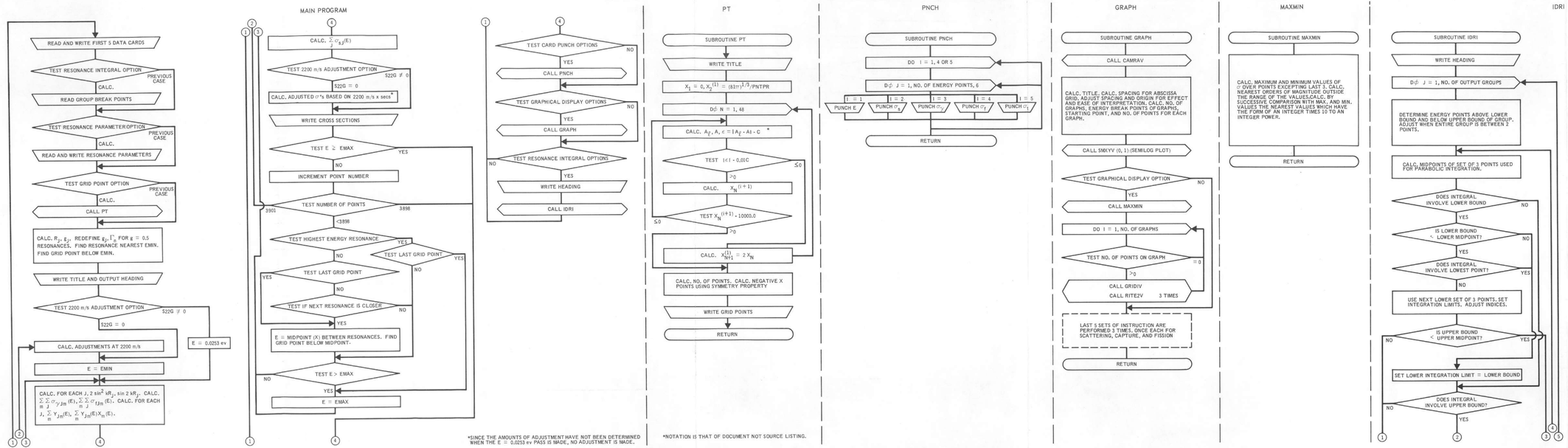


Figure 3. Subroutine Flow Chart (Detailed)

XII. UNICORN LISTING

UNICORN is coded in FORTRAN IV, version 13, for the IBM 7094. The graphical display routine uses functions written by North American Aviation, Inc. A source listing is given on the following pages.

```
C     SINGLE-LEVEL BREIT-WIGNER LINE SHAPE AT 0 DEG K FOR L=0 NEUTRONS. UNEK0010
C     POINT SPACING IS A FUNCTION OF 2ND + 3RD DERIVATIVES WR TO ENERGY.UNEK0020
C     SCATTERING INTERFERENCE ASSUMED AMONG ALL RESONANCES WITH SAME G. UNEK0025
C                                                                      UNEK0030
      DIMENSION AN(12),E0(100),GAMN(100),GAMG(100),GAMW(100),G(100),   UNEK0040
     XGG1(100),EP(3900),XGR(3900),XWR(3900),XSR(3900),GAMS(100),GRL(50),UNEK0050
     XGAT0(100),XP(100),AA(2),BB(2),GG(2),R(2),SKR2(2),S2KR(2),       UNEK0055
     XASC(2),ACP(2),AFS(2)                                            UNEK0060
      COMMON XP,NPT,DELTA                                             UNEK0065
      DATA ASC,ACP,AFS/6H  SCAT,6HTERING,6H     C,6HAPTURE,6H     F,6HISUNEK  67
     XSION/                                                           UNEK  68
   35 DO 32 I=1,3900                                                  UNEK  70
      XSR(I) = 0.0                                                    UNEK0072
      XGP(I) = 0.0                                                    UNEK0074
   32 XWR(I) = 0.0                                                    UNEK0076
C                                                                     UNEK0078
C     READ AND WRITE INPUT DATA                                       UNEK0080
C                                                                     UNEK0090
      READ (5,1000) AN,NR,S22G,S22W,S22S,PNTPR,DLCRT,EMIN,EMAX,ATW,SPIN,UNEK0100
     XPSM,PSP,IPU,ICS,ICG,ICW,IX,IPT,IRS,IRG,IRW,NGL,IDRL             UNEK0110
 1000 FORMAT (12A6/I12,5E12.8/6E12.8/6I12/5I12)                       UNEK0120
      WRITE (6,2000) AN,NR,S22G,S22W,S22S,PNTPR,DLCRT,EMIN,EMAX,ATW,SPINUNEK0130
     X,PSM,PSP,IPU                                                    UNEK0140
 2000 FORMAT (1H1,12A6//// 40X,10HINPUT DATA///29H NUMBER OF RESONANCES UNEK0150
     X       =I5/29H 2200 M/S XSEC - CAPTURE     =F16.8/29H 2200 M/S XSEC UNEK0160
     X- FISSION     =F16.8/29H 2200 M/S XSEC - SCATTERING =F16.8/29H POINUNEK0170
     XTS ACROSS RESONANCE     =F16.8/29H ENERGY WIDTHS OF CRT PLOTS =F16.UNEK0180
     X8/29H MINIMUM ENERGY              =E16.8/29H MAXIMUM ENERGY        UNEK0190
     X      =E16.8/29H ATOMIC WEIGHT                 =F16.8/29H SPIN OF TARGUNEK0200
     XET NUCLEUS      =E16.8/29H POT. SCAT. XSEC J=I-0.5     =E16.8/29H POUNEK0210
     XT. SCAT. XSEC J=I+0.5     =F16.8/29H PUNCHED CARDS (1=YES,0=NO) =I5UNEK0215
     X)                                                               UNEK0216
      IF (IDRL) 33,33,29                                              UNEK0217
   29 READ (5,1002) (GRL(I),I=1,NGL)                                  UNEK0218
 1002 FORMAT (6E12.8)                                                 UNEK0219
      IF (IX) 33,33,34                                                UNEK0220

   33 DO 30 I=1,100                                                   UNEK0221
   30 E0(I) = 0.0                                                     UNEK0223
      READ (5,1001) (E0(I),GAMN(I),GAMG(I),GAMW(I),G(I),I=1,NR)       UNEK0225
 1001 FORMAT (5E12.8)                                                 UNEK0230
   34 WRITE (6,2001)                                                  UNEK0240
 2001 FORMAT (1H-35X,20HRESONANCE PARAMETERS/7HONUMBER,5X,6HENERGY,6X,13UNEK0250
     XHNEUTRON WIDTH,5X,11HGAMMA WIDTH,5X,13HFISSION WIDTH,2X,14HSTATISTUNEK0260
     X[CAL WEIGHT)                                                    UNEK0270
      WRITE (6,2002) (J,E0(J),GAMN(J),GAMG(J),GAMW(J),G(J),J=1,NR)    UNEK0280
 2002 FORMAT (I5,4X,E12.5,3X,E17.5,5X,E12.5,5X,E12.5,5X,E12.5)        UNEK0300
C                                                                     UNEK0310
C     INITIALIZATION, CONSTANTS, AND REDEFINITION OF STATISTICAL WEIGHTSUNEK0320
C                                                                     UNEK0330
      IF (IPT) 36,36,31                                               UNEK0331
   36 DELTA = 42.4115/PNTPR**3                                        UNEK0332
      CALL PT                                                         UNEK0338
   31 DO 37 I=1,4000                                                  UNEK0345
      XGP(I) = 0.0                                                    UNEK0350
   37 XWR(I) = 0.0                                                    UNEK0355
      D22G = 0.0                                                      UNEK0360
      D22W = 0.0                                                      UNEK0365
      D22S = 0.0                                                      UNEK0370
      CMTL = (1.0+1.0090/ATW)**2                                      UNEK0375
      R(1) = 6.1977E-4*SQRT(PSM/CMTL)                                 UNEK0380
      R(2) = 6.1977E-4*SQRT(PSP/CMTL)                                 UNEK0382
      DEN = 2.0*SPIN+1.0                                              UNEK0385
      GG(1) = SPIN/DEN                                                UNEK0390
      GG(2) = (SPIN+1.0)/DEN                                          UNEK0395
      L = 0                                                           UNEK0400
      LDEN = DEN                                                      UNEK0405
      DO 44 J=1,NR                                                    UNEK0410
      IF (G(J)-0.5) 43,38,43                                          UNEK0415
   38 L = L+1                                                         UNEK0420
      IF (L-LDEN-1) 39,39,40                                          UNEK0425
   39 G(J) = GG(2)                                                    UNEK0430
      GO TO 41                                                        UNEK0435
   40 G(J) = GG(1)                                                    UNEK0440
```

```
   41 GAMN(J) = GAMN(J)/2.0/ G(J)                                        UNEK0443
      IF (L-2*LOEN) 43,42,42                                             UNEK0445
   42 L = 0                                                              UNEK0450
   43 GG1(J) = GAMG(J)+GAMW(J)                                           UNEK0455
      GAT0(J) = GG1(J)+GAMN(J)                                           UNEK0457
   44 GAMS(J) = GAMN(J)/SQRT(ABS(E0(J)))                                 UNEK0460
      EP(1) = EMIN                                                       UNEK0465
      NRM = MAX0(NR-1,1)                                                 UNEK0470
    5 DO 10 M=1,NRM                                                      UNEK0480
      M = M                                                              UNEK0485
      IF (2.0*EP(1)-E0(M)-E0(M+1)) 15,10,10                              UNEK0490
   10 CONTINUE                                                           UNEK0495
   15 X1 = 2.0*(EP(1)-E0(M))/GAT0(M)                                     UNEK0500
      DO 20 K=1,NPT                                                      UNEK0520
      N = MAX0(K-1,1)                                                    UNEK0525
      IF (X1-XP(K)) 25,20,20                                             UNEK0530
   20 CONTINUE                                                           UNEK0535
C                                                                        UNEK0540
C     WRITE TITLES                                                       UNEK0550
C                                                                        UNEK0560
   25 WRITE (6,2003) AN                                                  UNEK0570
 2003 FORMAT (1H1,12A6////37X,11HOUTPUT DATA/)                           UNEK0580
      WRITE (6,2005)                                                     UNEK0590
 2005 FORMAT ( 5HO NO.7X,6HENERGY ,8X,7HCAPTURE,8X, 7HFISSION,7X,10HSCATUNEK0600
     XTERING,7X,5HTOTAL )                                                UNEK0610
C                                                                        UNEK0620
C     CALC. 1/V XSEC ADJUSTMENT                                          UNEK0630
C                                                                        UNEK0635
      IF (S22G) 55,55,45                                                 UNEK0640
   45 I = 3900                                                           UNEK0650
      EP(3900) = 0.0253                                                  UNEK0660
      GO TO 60                                                           UNEK0670
   50 D22G = (S22G-XGR(3900))*0.15906                                    UNEK0680
      D22W = (S22W-XWR(3900))*0.15906                                    UNEK0690
      IF (S22S) 55,55,51                                                 UNEK0700
   51 D22S = (S22S-XSR(3900))*0.15906                                    UNEK0710
C                                                                        UNEK0730
C     CALC XSECS                                                         UNEK0740
C                                                                        UNEK0750
   55 I = 1                                                              UNEK0760
   60 XX = 0.0                                                           UNEK0762
      SQRTEP = SQRT(EP(I))                                               UNEK0763
      DO 65 K=1,2                                                        UNEK0765
      WL = SQRTEP*R(K)                                                   UNEK0767
      SKR2(K) = 2.0*SIN(WL)**2                                           UNEK0768
      S2KR(K) = SIN(2.0*WL)                                              UNEK0769
      AA(K) = 0.0                                                        UNEK0771
   65 BB(K) = 0.0                                                        UNEK0772
      CON = 2.6035E+6*CMTL/EP(I)                                         UNEK0777
      DO 80 J=1,NR                                                       UNEK0790
      GAN = GAMS(J)*SQRTEP                                               UNEK0795
      GAT = GAN+GG1(J)                                                   UNEK0796
      X = 2.0*(EP(I)-E0(J))/GAT                                          UNEK0800
      OPX = GAT*(1.0+X**2)                                               UNEK0802
      SOX = GAN/OPX                                                      UNEK0805
      CNSX = CON*G(J)*SOX                                                UNEK0810
      XGR(I) = XGR(I)+CNSX*GAMG(J)/GAT                                   UNEK0815
      XWR(I) = XWR(I)+CNSX*GAMW(J)/GAT                                   UNEK0820
      IF (G(J)-0.5) 70,700,72                                            UNEK0827
   70 AA(1) = AA(1)+SOX                                                  UNEK0824
      BB(1) = BB(1)+SOX*X                                                UNEK0826
      GO TO 80                                                           UNEK0828
   72 AA(2) = AA(2)+SOX                                                  UNEK0830
      BB(2) = BB(2)+SOX*X                                                UNEK0832
   80 CONTINUE                                                           UNEK0840
      DO 78 K=1,2                                                        UNEK0877
   78 XX = XX+GG(K)*(AA(K)**2+BB(K)**2-SKR2(K)*(AA(K)-.5)+S2KR(K)*BB(K))UNEK0878
      XSR(I) = CON*XX                                                    UNEK0879
C                                                                        UNEK0880
C     MAKE 1/V ADJUSTMENT                                                UNEK0890
C                                                                        UNEK0900
      IF (S22G) 90,90,85                                                 UNEK0910
   85 XGR(I) = XGR(I)+D22G/SQRTEP                                        UNEK0920
      XWR(I) = XWR(I)+D22W/SQRTEP                                        UNEK0930
```

```
      XSR(I) = XSR(I)+D22S/SQRTEP                                       UNEK0940
C                                                                       UNEK0950
C     WRITE XSEC, CALC NEXT ENERGY POINT                                UNEK0960
C                                                                       UNEK0970
   90 XTR = XGR(I)+XWR(I)+XSR(I)                                        UNEK0990
      WRITE (6,2006) I,EP(I),XGR(I),XWR(I),XSR(I),XTR                   UNEK1000
 2006 FORMAT (1H ,I4,1X,5E15.6)                                         UNEK1010
      I = I+1                                                           UNEK1020
      IF (EP(I-1)-EMAX) 86,95,95                                        UNEK1030
   86 IF (I-3898) 88,95,50                                              UNEK1040
   88 N = N+1                                                           UNEK1042
      EP(I) = XP(N)*GATO(M)/2.0+EO(M)                                   UNEK1044
      IF (M-NR) 93,87,95                                                UNEK1045
   87 IF (N-NPT) 94,94,96                                               UNEK1046
   93 XMO = 2.0*(EO(M+1)-EO(M))/(GATO(M+1)+GATO(M))                     UNEK1047
      IF (N-NPT) 97,97,89                                               UNEK1048
   97 IF (XP(N)-XMO) 94,89,89                                           UNEK1049
   89 M = M+1                                                           UNEK1050
      DO 91 K=1,NPT                                                     UNEK1052
      N = MAXO(K-1,1)                                                   UNEK1054
      IF (-XMO-XP(K)) 92,91,91                                          UNEK1056
   91 CONTINUE                                                          UNEK1058
   92 EP(I) = -XMO*GATO(M)/2.0+EO(M)                                    UNEK1060
   94 IF (EP(I)-EMAX) 60,60,96                                          UNEK1062
   96 EP(I) = EMAX                                                      UNEK1063
      GO TO 60                                                          UNEK1065
   95 IUR = I-1                                                         UNEK1070
C                                                                       UNEK1080
C     PUNCH ENERGY POINTS AND CROSS SECTIONS                            UNEK1090
C                                                                       UNEK1100
      IP = 4                                                            UNEK1105
      IF (IPU) 99,300,100                                               UNEK1110
   99 IP = 5                                                            UNEK1115
  100 CALL PNCH(IP,IUR,EP,XSR,XGR,XWR)                                  UNEK1117
C                                                                       UNEK1270
C     OBTAIN CRT OF DESIRED INFORMATION                                 UNEK1280
C                                                                       UNEK1290

  300 IF (ICS+ICG+ICW) 600,600,310                                      UNEK1295
  310 CALL GRAPH    (OLCRT,IUR,ICS,ICG,ICW,EP,XSR,XGR,XWR,AN)           UNEK1297
C                                                                       UNEK1300
C     INTEGRATE POINT CROSS SECTIONS BY GROUP, 1/E FLUX, PARABOLIC FIT. UNEK1310
C                                                                       UNEK1312
  600 IF (IRS) 620,620,610                                              UNEK1610
  610 WRITE (6,2007) ASC                                                UNEK1620
      CALL IDRI(NGL,GRL,EP,XSR,IUR)                                     UNEK1630
 2007 FORMAT (21H-RESONANCE INTEGRAL - 2A6/)                            UNEK1635
  620 IF (IRG) 640,640,630                                              UNEK1640
  630 WRITE (6,2007) ACP                                                UNEK1650
      CALL IDRI(NGL,GRL,EP,XGR,IUR)                                     UNEK1660
  640 IF (IRW) 700,700,650                                              UNEK1670
  650 WRITE (6,2007) AFS                                                UNEK1680
      CALL IDRI(NGL,GRL,EP,XWR,IUR)                                     UNEK1690
  700 GO TO 35                                                          UNEK1700
      END                                                               UNEK1710
```

```
C     OPTIMIZED PIECEWISE LOGARITHMIC REPRESENTATION OF 1/(1+X**2)      10X20010
      SUBROUTINE PT                                                     10X20030
      DIMENSION XP(100),XPT(50)                                         10X20040
      COMMON XP,NPT,DELTA                                               10X20050
      WRITE (6,100)                                                     10X20060
  100 FORMAT (103H-THE SPACING FOR A PIECEWISE LOGARITHMIC REPRESENTATIO10X20070
     XN OF 1/(1+X**2) IS DETERMINED IN WHICH, FOR EACH /55H INTERVAL,THE10X20080
     X ERROR IN THE AREA IS (PI/2)*DELTA        //)                     10X20090
      XPT(1) = 0.0                                                      10X20100
      XPT(2) = 1.417121*DELTA**(1.0/3.0)                                10X20110
      XT = 0.0                                                          10X20120
      DO 25 N=1,48                                                      10X20130
      OPX = 1.0+XPT(N)**2                                               10X20140
   10 C = OPX/(1.0+XPT(N+1)**2)                                         10X20150
      CLN = ALOG(C)                                                     10X20155
      XIN = XPT(N+1)-XPT(N)                                             10X20160
      ULO = XIN*(C-1.0)/CLN/OPX                                         10X20170
      VXT = ATAN(XPT(N+1))                                              10X20180
      UXT = VXT-XT                                                      10X20190
      CRI = ABS(ULO-UXT)-DELTA                                          10X20200
      IF (ABS(CRI)-0.01*DELTA) 20,20,15                                 10X20210
   15 XPT(N+1) = XPT(N+1)-CRI/(ULO*ABS(2.0*XPT(N+1)*C/OPX+CLN/XIN)*(C/  10X20220
     X(C-1.0)-1.0/CLN))+ABS(CRI/XPT(N+1))                               10X20225
      NS = N                                                            10X20228
      IF (XPT(N+1)-10000.0) 10,10,30                                    10X20230
   20 XT = VXT                                                          10X20240
   25 XPT(N+2) = XPT(N+1)*2.0                                           10X20260
   30 NPT = 2*NS-1                                                      10X20290
      DO 35 I=1,NS                                                      10X20300
      J = NS-I+1                                                        10X20310
      XP(I) = -XPT(J)                                                   10X20320
      M = NPT-I+1                                                       10X20330
      XP(M) = XPT(J)                                                    10X20340
   35 WRITE (6,200) I,XP(I),M,XP(M)                                     10X20380
  200 FORMAT (1H 2(I12,E14.5))                                          10X20390
      NPTP1 = NPT+1                                                     10X20393

      DO 40 I=NPTP1,100                                                 10X20395
   40 XP(I) = 0.0                                                       10X20397
      RETURN                                                            10X20400
      END                                                               10X20410
```



```
C     PUNCH ENERGY POINTS AND CROSS SECTIONS                            PNCH0020
      SUBROUTINE PNCH(IP,IUR,EP,XSR,XGR,XWR)                            PNCH0030
      DIMENSION  EP(6),XSR(6),XGR(6),XWR(6),XTL(6)                      PNCH0040
  100 DO 135 I=1,IP                                                     UNEK1120
      DO 130 J=1,IUR,6                                                  UNEK1130
      K = J+5                                                           UNEK1140
      GO TO (105,125,110,115,128),I                                     UNEK1150
  105 PUNCH 3000, (EP(L),L=J,K),I,J                                     UNEK1160
 3000 FORMAT (1P6E12.5,3HNRG,I1,I4)                                     UNEK1170
      GO TO 130                                                         UNEK1180
  110 PUNCH 3001, (XGR(L),L=J,K),I,J                                    UNEK1190
 3001 FORMAT (1P6E12.5,3HCPT,I1,I4)                                     UNEK1200
      GO TO 130                                                         UNEK1210
  115 IF (XWR(1)) 135,135,120                                           UNEK1220
  120 PUNCH 3002, (XWR(L),L=J,K),I,J                                    UNEK1230
 3002 FORMAT (1P6E12.5,3HFSN,I1,I4)                                     UNEK1240
      GO TO 130                                                         UNEK1250
  125 PUNCH 3003, (XSR(L),L=J,K),I,J                                    UNEK1260
 3003 FORMAT (1P6E12.5,3HSCT,I1,I4)                                     UNEK1270
      GO TO 130                                                         UNEK1271
  128 DO 129 M=1,6                                                      UNEK1272
      N = J+M-1                                                         UNEK1273
  129 XTL(M) = XGR(N)+XSR(N)+XWR(N)                                     UNEK1274
      PUNCH 3004, (XTL(L),L=1,6),I,J                                    UNEK1275
 3004 FORMAT (1P6E12.5,3HTOT,I1,I4)                                     UNEK1276
  130 CONTINUE                                                          UNEK1280
  135 CONTINUE                                                          UNEK1290
      RETURN                                                            PNCH1990
      END                                                               PNCH2000
```

```
C     CRT DISPLAYS                                                      GRAF0020
      SUBROUTINE GRAPH   (DLCRT,IUR,ICS,ICG,ICW,EP,XSR,XGR,XWR,AN)     GRAF0030
      DIMENSION          EP(1),XSR(1),XGR(1),XWR(1),AN(1),              GRAF0040
     XECRT(100),ECRT(100),ITN(100),ANCRT(6)                            GRAF0050
  300 CALL CAMRAV(1)                                                    UNEK1313
      DO 301 I=1,6                                                      UNEK1314
  301 ANCRT(I) = AN(I)                                                  UNEK1315
      IF (DLCRT) 302,302,304                                            UNEK1316
  302 DLCRT = 10000.0                                                   UNEK1318
  304 DX = DLCRT/50.0                                                   UNEK1320
      IF (DX-1.0)  306,306,308                                          UNEK1321
  306 DX = 0.1*AMAX0(IFIX(10.001*DX),1)                                 UNEK1322
      GO TO 314                                                         UNEK1323
  308 IF (DX-10.0) 310,310,312                                          UNEK1324
  310 DX = IFIX(DX+0.01)                                                UNEK1325
      GO TO 314                                                         UNEK1326
  312 DX = 10*IFIX(0.1001*DX)                                           UNEK1327
  314 ECRT(1) = AINT (EP(1)/DX)*DX+0.00001                              UNEK1328
      LCRT(1) = 1                                                       UNEK1332
      K = 1                                                             UNEK1333
      DO 325 I=2,100                                                    UNEK1334
      ECRT(I) = ECRT(I-1)+DLCRT                                         UNEK1335
      DO 315 J=K,IUR                                                    UNEK1336
      IF (EP(J)-ECRT(I)) 315,315,320                                    UNEK1337
  315 L = J+1                                                           UNEK1338
  320 LCRT(I) = L                                                       UNEK1340
      K = L                                                             UNEK1341
      ITN(I-1) = LCRT(I)-LCRT(I-1)                                      UNEK1342
      IF (ECRT(I)-EP(IUR)) 325,330,330                                  UNEK1343
  325 CONTINUE                                                          UNEK1344
  330 ICRT = I-1                                                        UNEK1345
      CALL SMXYV(0,1)                                                   UNEK1346
  400 IF (ICS) 500,500,410                                              UNEK1370
  410 CALL MAXMIN(XSR,IUR,SL,SU)                                        UNEK1372
      DO 420 I=1,IUR                                                    UNEK1375
      IF (XSR(I)) 415,415,420                                           UNEK1380
  415 XSR(I) = SU                                                       UNEK1385
  420 CONTINUE                                                          UNEK1390
      DO 490 I=1,ICRT                                                   UNEK1395
      IF (ITN(I)) 490,490,440                                           UNEK1396
  440 L = LCRT(I)                                                       UNEK1397
      CALL GRID1V(1,ECRT(I),ECRT(I+1),SL,SU,DX,1.,5,5,5,5,5,-3)         UNEK1400
      CALL APLOTV(ITN(I),EP(L),XSR(L),1,1,1,38,IERR)                    UNEK1430
  450 CALL RITE2V (188,1010,1000,90,2,36,1,ANCRT,IERR)                  UNEK1440
      CALL RITE2V ( 10, 296,1000,180,2,12,-1,12H SIGMA SCAT.,IERR)      UNEK1450
      CALL RITE2V(296,10,1000,90,2,12,-1,12H ENERGY (EV),IERR)          UNEK1460
  490 CONTINUE                                                          UNEK1465
  500 IF (ICG) 600,600,510                                              UNEK1490
  510 CALL MAXMIN(XGR,IUR,GL,GU)                                        UNEK1492
      DO 520 I=1,IUR                                                    UNEK1495
      IF (XGR(I)) 515,515,520                                           UNEK1500
  515 XGR(I) = GU                                                       UNEK1505
  520 CONTINUE                                                          UNEK1510
      DO 590 I=1,ICRT                                                   UNEK1515
      IF (ITN(I)) 590,590,540                                           UNEK1516
  540 L = LCRT(I)                                                       UNEK1517
      CALL GRID1V(1,ECRT(I),ECRT(I+1),GL,GU,DX,1.,5,5,5,5,5,-3)         UNEK1520
      CALL APLOTV(ITN(I),EP(L),XGR(L),1,1,1,38,IERR)                    UNEK1550
  550 CALL RITE2V (188,1010,1000,90,2,36,1,ANCRT,IERR)                  UNEK1560
      CALL RITE2V ( 10, 296,1000,180,2,12,-1,12H SIGMA GAMMA,IERR)      UNEK1570
      CALL RITE2V(296,10,1000,90,2,12,-1,12H ENERGY (EV),IERR)          UNEK1580
  590 CONTINUE                                                          UNEK1585
  600 IF (ICW) 700,700,610                                              UNEK1600
  610 CALL MAXMIN(XWR,IUR,WL,WU)                                        UNEK1602
      DO 620 I=1,IUR                                                    UNEK1605
      IF (XGR(I)) 615,615,620                                           UNEK1610
  615 XWR(I) = WU                                                       UNEK1615
  620 CONTINUE                                                          UNEK1620
      DO 690 I=1,ICRT                                                   UNEK1625
      IF (ITN(I)) 690,690,640                                           UNEK1626
  640 L = LCRT(I)                                                       UNEK1628
      CALL GRID1V(1,ECRT(I),ECRT(I+1),WL,WU,DX,1.,5,5,5,5,5,-3)         UNEK1630
      CALL APLOTV(ITN(I),EP(L),XWR(L),1,1,1,38,IERR)                    UNEK1660
      CALL RITE2V(188,1010,1000,90,2,36,1,ANCRT,IERR)                   UNEK1670
      CALL RITE2V ( 10, 296,1000,180,2,12,-1,12H SIGMA FISS.,IERR)      UNEK1680
      CALL RITE2V(296,10,1000,90,2,12,-1,12H ENERGY (EV),IERR)          UNEK1690
  690 CONTINUE                                                          UNEK1695
  700 RETURN                                                            GRAF1700
      END                                                               GRAF1710
```

MXMN - EFN SOURCE STATEMENT - IFN(S) -

```
      SUBROUTINE MAXMIN(X,N,XL,XU)                                      MXMN0020
      DIMENSION X(1)                                                    MXMN0030
      XL = 10000.0                                                      MXMN0040
      XU = 0.0                                                          MXMN0050
      NM3 = N-3                                                         MXMN0055
      DO 40 I=1,NM3                                                     MXMN0060
      IF (XL-X(I)) 20,20,10                                             MXMN0070
   10 XL = X(I)                                                         MXMN0080
   20 IF (XU-X(I)) 30,40,40                                             MXMN0090
   30 XU = X(I)                                                         MXMN0100
   40 CONTINUE                                                          MXMN0110
      IL = INT(ALOG10(XL))                                              MXMN0120
      IU = INT(ALOG10(XU))                                              MXMN0130
      TL =10.0**(IL+(-1+ISIGN(1,IL))/2)                                 MXMN0140
      TU =10.0**(IU+(1+ISIGN(1,IU))/2)                                  MXMN0150
      DO 50 I=2,11                                                      MXMN0160
      EYE = I                                                           MXMN0170
      IF (EYE*TL-XL) 50,60,60                                           MXMN0180
   50 CONTINUE                                                          MXMN0190
   60 XL = (EYE-1.0)*TL                                                 MXMN0200
      DO 70 I=2,11                                                      MXMN0210
      EYE = I                                                           MXMN0220
      IF (EYE*TU*0.1-XU) 70,70,80                                       MXMN0230
   70 CONTINUE                                                          MXMN0240
   80 XU = EYE*TU*0.1                                                   MXMN0250
      RETURN                                                            MXMN0260
      END                                                               MXMN0270
```

```
C     RESONANCE INTEGRALS                                                    IDRI0020
      SUBROUTINE IDRI(NGL,GRL,X,Y,N)                                         IDRI0030
      DOUBLE PRECISION XL,XU,A21,A31,B321                                    IDRI0040
      DIMENSION X(3),Y(3),GRL(2),S(50)                                       IDRI0050
      GT = 0.0                                                               IDRI0052
      NG = NGL-1                                                             IDRI0054
      IUP = 1                                                                IDRI0056
      WRITE (6,2008)                                                         IDRI0057
 2008 FORMAT (47H        E LOWER          E UPPER          INTEGRAL)         IDRI0058
      DO 300 J=1,NG                                                          IDRI0059
      XLO = GRL(J)                                                           IDRI0060
      XUP = GRL(J+1)                                                         IDRI0062
      S(J) = 0.0                                                             IDRI0064
      DO 50 I=IUP,N                                                          IDRI0070
      ILO = I                                                                IDRI0080
      IF (XLO-X(I)) 60,50,50                                                 IDRI0090
   50 CONTINUE                                                               IDRI0100
   60 DO 70 I=ILO,N                                                          IDRI0110
      IUP = I-1                                                              IDRI0120
      IF (XUP-X(I)) 80,80,70                                                 IDRI0130
   70 CONTINUE                                                               IDRI0132
   80 IF (ILO-IUP) 90,90,85                                                  IDRI0135
   85 IUP = ILO                                                              IDRI0140
   90 I = ILO                                                                IDRI0145
   95 XU = (X(I+1)+X(I))/2.0                                                 IDRI0150
      XL = (X(I)+X(I-1))/2.0                                                 IDRI0155
      IF (I-ILO) 200,100,110                                                 IDRI0160
  100 IF (XLO-XL) 105,109,109                                                IDRI0165
  105 IF (ILO-2) 109,109,107                                                 IDRI0170
  107 XU = XL                                                                IDRI0175
      XL = XLO                                                               IDRI0180
      ILO = 0                                                                IDRI0185
      I = I-1                                                                IDRI0190
      IF (XUP-XU) 137,137,150                                                IDRI0195
  109 XL = XLO                                                               IDRI0200
  110 IF (I-IUP) 150,120,200                                                 IDRI0205
  120 IF (XUP-XU) 140,140,130                                                IDRI0210
  130 IF (IUP-N+1) 135,140,140                                               IDRI0215
  135 IUP = IUP+1                                                            IDRI0220
      GO TO 150                                                              IDRI0225
  137 IUP = I                                                                IDRI0227
  140 XU = XUP                                                               IDRI0230
  150 A21 = (Y(I)-Y(I-1))/(X(I)-X(I-1))                                      IDRI0250
      A31 = (Y(I+1)-Y(I-1))/(X(I+1)-X(I-1))                                  IDRI0260
      B321 = (A31-A21)/(X(I+1)-X(I))                                         IDRI0270
      S(J) = S(J)+(Y(I-1)-A21*X(I-1)+X(I-1)*X(I)*B321)*DLOG(XU/XL)+          IDRI0280
     X(A21-(X(I-1)+X(I))*B321)*(XU-XL)+B321*(XU**2-XL**2)/2.0                IDRI0290
      I = I+1                                                                IDRI0300
      IF (I-IUP) 95,95,200                                                   IDRI0310
  200 WRITE (6,2009) XLO,XUP,S(J)                                            IDRI0320
 2009 FORMAT ( 1H 1P3E16.6)                                                  IDRI0330
  300 GT = GT+S(J)                                                           IDRI0340
      WRITE (6,2009) GRL(1),GRL(NGL),GT                                      IDRI0350
      RETURN                                                                 IDRI0360
      END                                                                    IDRI0370
```

REFERENCES

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2. V. Blatt and V. Weisskopt, "Theoretical Nuclear Physics," Chapter 8 (John Wiley and Sons, New York and London, 1952)

3. J. J. Devaney, "The Approximate Doppler Broadening of an Isolated Nuclear Resonance," LA 3315, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, p. 15

APPENDIX
ENERGY GRID CALCULATION

Optimized point spacing for pointwise representation of $(1 + x^2)^{-1} \equiv y$ using logarithmic interpolation. The criterion used is that between any two points the magnitude of the difference between the exact integral, A, and the integral assuming logarithmic interpolation, A_ℓ, be within 1% of a constant, C, determined by the number of points selected to represent an isolated resonance.

$$|\epsilon| < .01\ C \qquad\qquad \epsilon = |A_\ell - A| - C$$

$$A_\ell = \int_{x_i}^{x_{i+1}} y_\ell\, dx = \int_{x_i}^{x_{i+1}} y_i \left(\frac{y_{i+1}}{y_i}\right)^{\frac{x-x_i}{x_{i+1}-x_i}} = y_i \frac{\alpha - 1}{\beta \ln \alpha} \ ,$$

where

$$\alpha = \frac{1 + x_i^2}{1 + x_{i+1}^2}$$

$$\beta = (x_{i+1} - x_i)^{-1}$$

$$C = \frac{\pi}{2}\left[3/(\text{No. of points/resonance})\right]^3 \ .$$

Since y is symmetrical, only the positive x values are calculated.

$x_1 = 0.0$ $\quad (E = E^r)$ is taken to be a point of the grid.

Then, for each successive point a value is guessed and an iteration procedure is followed to converge the point. In the following treatment superscripts denote the iteration.

A first guess for x_2 is obtained by solving $\epsilon(x_2) = 0$ approximately using series expansions which retain only cubic and lower terms.

$$x_2^{(1)} = (6C)^{\frac{1}{3}} .$$

For $j > 2$,

$$x_j^{(1)} \equiv 2x_{j-1}$$

$$x_j^{(i+1)} = x_j^{(i)} + \Delta x_j^{(i)} ,$$

where

$$\Delta x_j^{(i)} = \frac{-\epsilon^{(i)}}{\left| \frac{d\epsilon^{(i)}}{dx_j} \right| + \zeta} ,$$

where

$$\zeta = \frac{|\epsilon(i)|}{x_j} ,$$

so that the magnitude of the maximum step taken is $\left| x_j^{(i)} \right|$.

After some manipulation, we find

$$\frac{d\epsilon^{(i)}}{dx_j} = -G^{(i)} A_{\ell}^{(i)} \left(\frac{\beta^{(i)}}{\beta^{(i)} - 1} - \frac{1}{\ln \beta^{(i)}} \right) ,$$

where

$$G^{(i)} \equiv 2x_j^{(i)} \; y_j^{(i)} + \frac{\ln \beta^{(i)}}{x_j^{(i)} - x_{j-1}} .$$

No values of $x > 10000.0$ are calculated. x is related to energy through

$$x_m = \frac{2(E - E_m^r)}{\Gamma_m} .$$


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