PINSTECH-147

A COMPUTER PROGRAMS PACKAGE FOR THE KINEMATICAL ANALYSIS OF ELASTIC HEAVY ION REACTIONS

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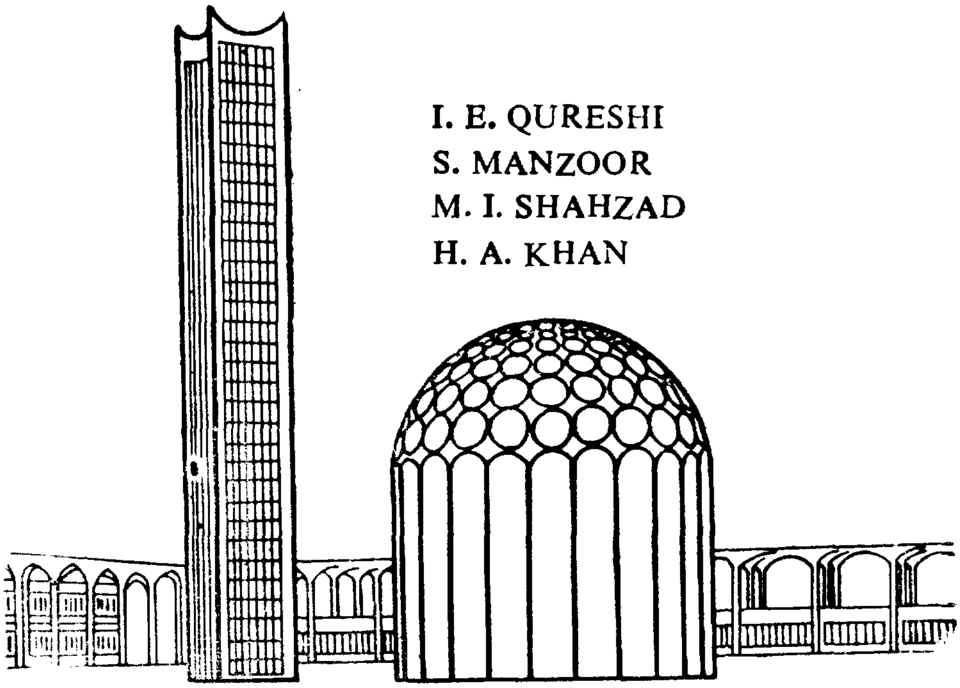

Radiation Physics Division
Pakistan Institute of Nuclear Science & Technology
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NOTICE

The computer programs described in this report have been written in FORTRAN by Dr. I.E. Qureshi. These can be copied freely, converted to other computer languages and used by all for their research work. However whenever results based on these programs are presented in seminars, theses, reports or papers, a proper acknowledgment must be made.

ABSTRACT

Kinematical correlations of nuclear fragments in a binary nuclear reaction can be studied with the help of suitable experimental data. When dielectric track detectors are used to register the reaction events, the primary experimental data consists of track parameters. Typically there are thousands of binary events each of which is characterized by five experimental data values. The sifting and analysis of data is usually very tedious and time-consuming if it is done manually. It has been felt for some time that the separation of elastic and different inelastic channels may be automated by using appropriate computer codes. For this purpose a package of programs, described in this report have been developed at PINSTECH. This package is being used to convert primary data into lengths and angular bins, assign uncertainties to these values, evaluate theoretically expected values for elastic events, and finally compare theoretical and experimental values to select elastic events. Using these selected events, the ratio of differential elastic cross section and Rutherford cross section is calculated, as a function of scattering angle. This quantity is of interest for the determination of total reaction cross section as well as nuclear size parameters.

CONTENTS

INTRODUCTION

It has been reported by Fleischer et al.[1] (1991) that the use of dielectric track detectors (DTD) in Nuclear Physics research has declined over the last two decades. This situation has arisen partly because of the development of electronic detectors with almost 4π angular coverage, and partly because of the laborious nature of manual data collection and analysis done in the case of track detectors. The attractive features of dielectric detectors are well known[2]. The above mentioned shortcomings can be overcome by making use of automatic measuring systems and by computerized data analysis. Some laboratories have now access to sophisticated image analysis systems which enormously increase the data taking efficiency, if track diameters are the main object of measurements. There is no hardware available as yet for complete three dimensional measurement of a track formed inside a detector material. Even if the data is taken manually, it is still necessary to make subsequent analysis in a well-prescribed manner using computer programs. For this purpose different laboratories have developed their own codes. At PINSTECH, we have developed software for analysing the track data collected with the help of an optical microscope. The final quantity of interest is the ratio of elastic differential cross section to Rutherford cross section which falls to 1/4th of its central value at an angle of scattering called quarter-point-angle, $\theta_{1/4}$. The total cross section of the given heavy ion reaction is related to $\theta_{1/4}$ which also determines the interaction radius[3].

The complete description of the experimental set-up, exposure geometry, etching process and measurement process is given in different publications of R.P.D. e.g. ref. 4.

In the present write-up we only describe the procedure used for the computational analysis. In order to make this document helpful for practical use, a detailed description of input/output files alongwith specimen data is included. The report describes the main program ELASTIC.FOR and two subsidiary programs ROW2.FOR and IRE.FOR.

1- R.L. Fleischer Nucl. Tracks Radiat. Meas. 19 (1991) 847.

2- I.E. Qureshi, Nucl. Track Radiat. Meas. 15 (1988) 411.

3- I.E. Qureshi and H.A. Khan, Nucl. Track Radiat. Meas. 15 (1988) 423.

4. I.E. Qureshi, M. I. Shahzad, S. Manzoor and H.A. Khan, Nucleus 31 (1994) 25.

PURPOSE

The program 'ELASTIC' is meant for calculating the ratio of $(d\sigma/d\Omega)_{exp.}$ and $(d\sigma/d\Omega)_{Rutherford}$ using a set of elastic events measured with SSNTDs in the case of nucleus-nucleus collisions. The first step for doing so is to select the 'elastic' events out of the total set of binary events.

The selection is based on two criteria :

C1- The event satisfies the elastic scattering angular correlation

$$\theta_1 = \arctan\left[\sin 2\theta_2 \,/\, \left\{\left(m_P / m_T\right) - \cos 2\theta_2\right\}\right] \tag{1}$$

where θ_1 and θ_2 are scattering angles of projectile and target respectively while m_P and m_T are their respective masses.

C2- The measured projectile track length is 'close' to the length 'expected' for the energy of an elastically scattered particle (corresponding to the measured projectile scattering angle θ_1) given by

$$E_1 = \left[E_0 m_P^2 / (m_P + m_T)^2\right]\left\{\cos\theta_1 \pm \sqrt{(m_T / m_P)^2 - \sin^2\theta_1}\right\}^2 \tag{2}$$

where E_o is the energy of the projectile before interaction.

The events selected on the basis of first criterion only are designated as 'ELASTIC' events while those satisfying both criteria have been called 'SPECIAL ELASTIC' events.

PROCEDURE

In order to apply criterion *C1*, it is first necessary to estimate the experimental uncertainties in angles θ_1 and θ_2. Since these angles are not measured directly, rather they are calculated from the measurements of the 'projected length' and the 'depth' of a given track, therefore the uncertainties in primary measurements are propagated to angular uncertainties. The quadratic formulae used for this purpose are

$$\delta\theta / \text{degrees} = \left[\sqrt{(l_P\delta d)^2 + (d\delta l_P)^2} \,/\, l_o^2\right] \times 180/\pi$$
$$l_o = \sqrt{l_P^2 + d^2} \tag{3}$$

where 'l_p'is the projected length of a prong and 'd' is the depth of its end-point, δl_p and δd are the corresponding uncertainties. It is obvious from the above expression that for fixed values of δd and δl_p, each prong of an event would have different values of $\delta\theta$.

For a particular event first the upper and lower limits of target scattering angle i.e. $\theta_2 + \delta\theta_2$ and $\theta_2 - \delta\theta_2$ are calculated by using measured values of 'lp' and 'd' and by using eq (3).

With the help of eq (1) theoretically predicted limits of θ_l values are calculated i.e $\theta_1^U(th)$ and $\theta_l^L(th)$. It is then checked whether the range $[\theta_l^L(th) - \theta_l^U(th)]$ has an overlap with the range $(\theta_l^{exp.} - \delta\theta_l) - (\theta_l^{exp.} + \delta\theta_2)$. If so, then the event is categorized as elastic .

The application of criterion $C2$ is based on the comparison of experimental length of projectile track and the 'expected' value of its range corresponding to energy E_l of eq. (2). The expected values are the theoretical predictions based on some range energy formula. For the present program a table of range values corresponding to wide range of projectile energies (in fact energy/nucleon in equally spaced intervals) is created after running an appropriate range-energy program. This reference table is accessed through ELASTIC. For the measured projectile scattering angle of a specific event, say θ_l we calculate E_l (eq. 2) and then using the reference table mentioned above, the range corresponding to energy E_l is found with the help of 3-point Lagrange interpolation formula, i.e.

$$f(x_o + ph) = \frac{p(p-1)}{2} f(x_o - h) + (1 - p^2) f(x_2) + \frac{p(p+1)}{2} f(x_o + h) \qquad (4)$$

where 'h' is the step-length of independent variable (energ/nucleon 'ε' in our case) and $x=(x_o+ph)$ is the specific value at which the function is required. Thus $p = (x-x_o)/h$. Making an allowance for various uncertainties, an event would be picked up as special elastic if its length is close to the theoretical value by a predetermined magnitude. In practice the measured lengths are always smaller than the expected values. Therefore, the program applies the length criterion by adding 'DL' (see input card 3) to the measured values.

THE INPUT REQUIREMENTS AND CONVERSION OF DATA

The general input regarding the geometrical parameters of the binary events has two possible forms. One can either specify the raw measurements of projected lengths, depths and the gap values for each event or the true lengths (in μm) and scattering angles (degrees) and gap values may be given. In the first case, the true lengths and angles are calculated by multiplying projected lengths with a calibration factor (CF) and depths with refractive index (RI). The values of CF and RI are read along with the other data. The total lengths and angles are calculated by using the formulae (see also fig. 1).

$$\begin{aligned} l_i &= \sqrt{(l'_{p_i} + (d'_i)^2} \\ \theta_i &= \arctan(l'_{p_i} / d'_i) \end{aligned} \qquad i = 1, 2 \qquad (5)$$

where l'_{p_i} and d'_i are derived from the measurements of projected lengths (lp), depths (d) and gap values (G) using

$$\begin{aligned} l'p_1 &= lp_1 + \Delta l_1 \quad ; \quad d'_1 = d_1 + \Delta d \\ l'p_2 &= lp_2 + \Delta l_2 \quad ; \quad d'_2 = d_2 + \Delta d \\ \Delta l_i &= \frac{lp_i}{d_i} \times \Delta d \quad ; \quad \Delta d = G \Big/ \left(\frac{lp_1}{d_1} + \frac{lp_2}{d_2} \right) \end{aligned} \qquad (6)$$

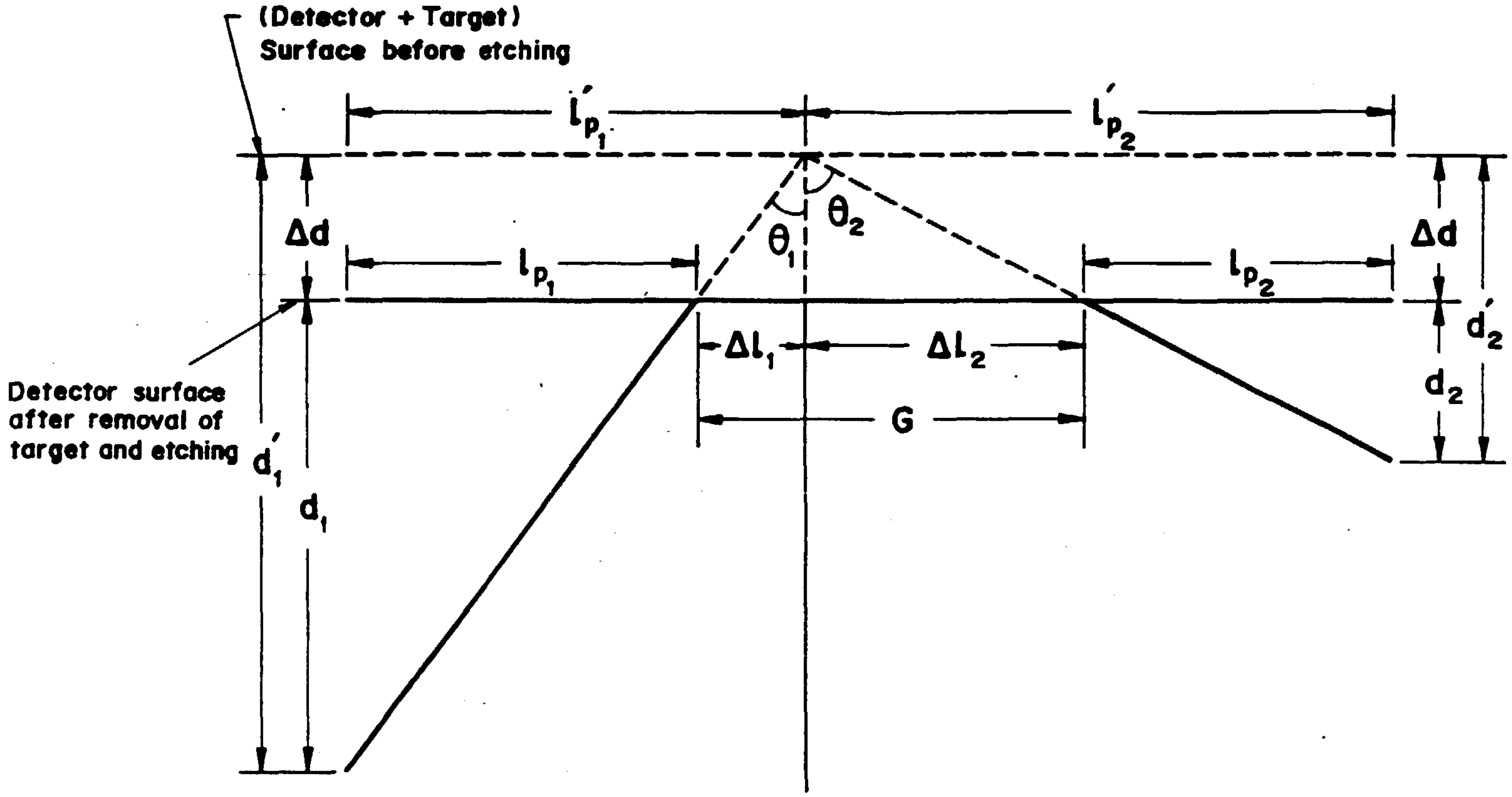

FIG: 1

Fig. 1. The track geometry of a binary event registered in DTD.

The values of *lp*, *d* and *G* used in the above relation are the real values (usually in microns i.e. the raw values have been properly multiplies by CF and RI).

It is sometimes convenient to read the actual total track lengths and angles directly. For this option it is still necessary to specify the gap value (in microns) used initially to reconstruct the event. The reason for this is as follows. For the selection of elastic events it may be necessary to reduce the depth slightly as explained in the next section. It is, therefore necessary that the original values of projected lengths and depths are first retrieved and then modified in order to keep the geometry unperturbed (see fig. 2). The recovery of original data from computed values of lengths and angles can be done by using the eqs. (given below) which need the information on gap value

$$
\begin{aligned}
l'_{p_i} &= l_i \sin^{-1}(\theta_i) \quad &;\quad d'_i &= l_i \cos^{-1}(\theta_i) \\
l_{p_i} &= l'_{p_i} - \Delta l_i \quad &;\quad d_i &= d'_i - \Delta d \\
d_i &= d'_i - \Delta d \\
\Delta l_i &= (l'_{p_i} / d_i) * \Delta d \\
\Delta d &= G \Big/ \left(\frac{lp'_1}{d'_1} + \frac{lp'_2}{d'_2} \right)
\end{aligned}
\qquad (7)
$$

REFINEMENT OF MEASUREMENTS

It has been observed that the recoiling target in a binary event makes a very shallow track causing considerable difficulties in its depth measurement. The instruments measuring the depth have usually inherent limitation of resolution i.e. the depths can be measured only in steps of 0.5 μm and for some instruments, in steps of 1 μm. A real depth of 0.6 micron may therefore be incorrectly noted as 1 μm. Considering this possibility, the program is allowed to decrease the depth of a given prong by a specified number of times in steps of 0.1 μm. After each reduction, the entire geometry of the event is reconstructed and the angular criterion applied each time to see if the modification has resulted in the selection of the event as elastic. The events which satisfy elastic scattering angular criterion after using this procedure are indication by a '*' in the output.

CALCULATION OF CROSS SECTIONS

Rutherford Cross Section

The denominaor in the ratio $(d\sigma)_{exp} / (d\sigma)_{Rutherford}$ is the differential elastic cross section corresponding to pure Coulomb scattering or Rutherford scattering. This cross section is calculated for a given scattering angle ξ (in c.m. frame) from the expression

$$(d\sigma / d\Omega)_{Rutherford} = \left(\eta^2 / 4k^2\right) \mathrm{cosec}^4(\zeta / 2) \qquad (8)$$

where η is the Sommerfeld parameter given by,

$$\eta = \mu Z_1 Z_2 e^2 / \hbar^2 k \qquad (9)$$

and the wave number k can be written as,

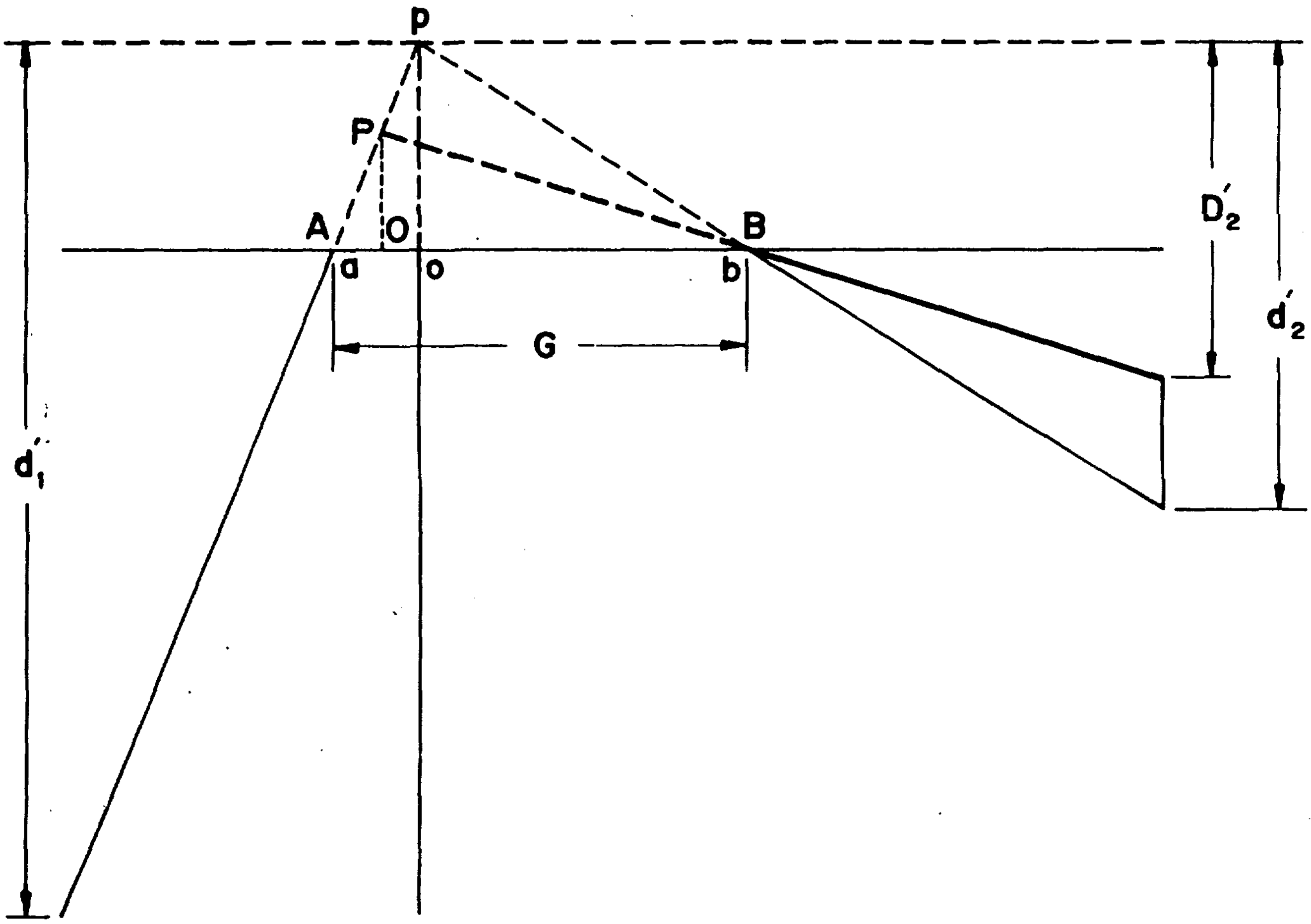

FIG: 2

Fig. 2. The geometry of a binary event reconstructed after depth modification.

$$k = \frac{1}{\hbar}\sqrt{2\,\mu\,E_{c.m}} \qquad (10)$$

The symbols used in the above equations are defined as,

$\hbar$	=	Reduced Planck's constant
e	=	Charge on an electron
$Z_1(Z_2)$	=	Charge of the projectile (target)
μ	=	Reduced mass of the interacting nuclei
$E_{c.m.}$	=	Pre interaction energy of the projectile in c.m. frame

Usually we take $E_{c.m.} \simeq \varepsilon A_{red}$
and $\mu \simeq A_{red}$

Here ε is the energy/nucleon of the projectile and A_{red} is define in terms of mass numbers of projectile (A_1) and mass number of target (A_2) as;

$$A_{red} = A_1A_2/(A_1 + A_2) \qquad (11)$$

In practice, the value of Rutherford cross section is required not for a specific angle θ but for a specific angular bin ($\theta_i - \theta_i'$). The cross section integrated over the bin is obtained after converting lab. angles (θ) to angles in c.m frame (ζ) and by using

$$(d\sigma)_{Rutherford}\Big|_{\xi_1}^{\xi_1'} = \int_{\xi_1}^{\xi_1'} (d\sigma / d\Omega).2\pi \sin\xi\, d\xi$$
$$= 4\pi C\left[\operatorname{cosec}^2\left(\frac{\xi_1}{2}\right) - \operatorname{cosec}^2\left(\frac{\xi_1'}{2}\right)\right] \qquad (12)$$

where

$$C = (\eta^2 / 4k^2) = \left(\frac{Z_1 Z_2 e^2}{4E_{c.m}}\right)^2$$

The quantity 4πC is written in the program in such a way that its units are cm^2.

Experimental Differential Cross Section

As in the case of Rutherford cross sections, the experimental elastic differential cross sections are also obtained for a given angular bin. The general expression for cross section calculation is used to obtain this value as,

$$(d\sigma)_{exp.}\Big|_{\xi_1}^{\xi_1'} = \frac{\delta R}{N\,\Phi} \qquad (13)$$

where

δR	=	No. of two pronged elastic events in a chosen area α having projectile scattering angles within the bin $(\xi_1 - \xi_1')$
N	=	No. of target nuclei = N_{av} (ρt) α/A where N_{av} = Avogadros number (= 6.02 x 10^{20} / mg.mole) ρt = Specific thickness (mg/cm^2)
Φ	=	Fluence (#/cm^2)

The relative error in $(d\sigma)_{exp.}$ is given by

$$\frac{\Delta(d\sigma)_{exp}}{(d\sigma)_{exp}} = \sqrt{\left(\frac{\Delta R}{R}\right)^2 + \left[\frac{\Delta(\delta t)}{(\delta t)}\right]^2 + \left(\frac{\Delta\alpha}{\alpha}\right)^2 + \left(\frac{\Delta\Phi}{\Phi}\right)^2} \tag{14}$$

Since $\Delta R = \sqrt{R}$, therefore if the %age error of each quantity is used, then

$$\Delta(d\sigma)_{exp} = \frac{(d\sigma)_{exp}}{100}\sqrt{\left(\frac{1}{\sqrt{R}}*100\right)^2 + [\Delta'(\delta t)]^2 + [\Delta'(\alpha)]^2 + [\Delta'(\Phi)]^2} \tag{15}$$

Where $\Delta'(X)$ is the percentage error in the quantity X. Typical values of $\Delta'(\rho t)$ and $\Delta'(\Phi)$ are 0.1. For well-defined areas $\Delta'(\alpha)$ may be zero.

Normalized Cross Section

The experimental elastic differential cross sections (eq. 13) are divided by their corresponding Rutherford values (eq. 12) to obtain normalized cross sections $(d\sigma)_{exp}/(d\sigma)_{Rutherford}$. In order to obtain the distribution of this quantity as a function of scattering angle ξ (in c.m. frame), it is necessary to organize $(d\sigma)_{exp.}$ values in ascending orders of corresponding c.m. angles. It is then easier to collect all events lying in ranges $(\xi_1 - \xi_1')$ etc.

The expression used for converting laboratory angles (θ) into c.m. angles (ξ) is,

$$\xi = \cos^{-1}\left[\frac{-R\tan^2\theta \pm \sqrt{1+\tan^2\theta(1-R^2)}}{1+\tan^2\theta}\right] \tag{16}$$

where $R = m_P/m_T$

In the case of inverted kinematics i.e. for $R > 1$ there is an upper limit of θ given by

$$\theta_{max} = \tan^{-1}\sqrt{\frac{1}{R^2-1}} \tag{17}$$

INPUT/OUTPUT SPECIFICATIONS FOR THE PROGRAM ELASTIC.FOR

INPUT FILES

3 Input files (Channels: FOR001, FOR002, FOR003)
3 Output files (Channels: FOR004, FOR007, FOR008)

	Directory
System A:	[KJAMIL.EHSAN]
System B:	[KJAMIL.MANZOOR]

DATA FILE 1 : INPUT CHANNEL FOR001
File NAME convention : EL [proj.][target].DAT

PURPOSE : Specifications of the reaction and data input/output options

Card 1 : IC, ID1, ID2, ID3, IP1, IP2, IP3, IP4, IP5, IP6, IP7, IP8 (12I2)

IC = n where '*n*' is the number of times, the given depth of the target track is reduced in steps of 0.1 μm.

ID1 = 0 Card 5′ is read (see below)
= 1 Card 5 is read (see below)

ID2 = 0 The track data is read from channel 2 in the form of total lengths, angles and gap values. (corrected final values)

= 1 The track data is read from channel 2 in the form of projected lengths, depths and gap values. (uncorrected raw values)

ID3 = 1 The depth of the target track is reduced in steps of 0.1 μm, in order to see if the event becomes elastic after modification. This is done IC times (see above)
= 0 No depth modification is performed

IP1 = IP2 = ... IP8 = 0 Only minimal ouput is printed on channel 4, comprising of the echo of Data File 1, number of elastic and special elastic events selected by the program and the ratio $(d\sigma)_{exp} / (d\sigma)_{Rutherford}$

IP1 = 1 Special elastic events are written in PRONGY format (The Field-of-View and Event Number are also printed)

IP2 = 1 The values of theoretical E_l (corresponding to angles θ_l), theoretical L_l and experimental L_l are written.

IP3 = 1 The events selected as elastic on the basis of angular correlation are written in the form.

I	l_{p1}	d_1	l_{p2}	d_2	G	l_1	θ_1	l_2	θ_2

where

I	=	event no.
l_{p1}	=	projected length of projectile track
d_1	=	depth of projectile track
l_{p2}	=	projected length of target track
G	=	value of the gap between two projected tracks
l_1	=	total length of the projectile track
θ_1	=	polar angle of the projectile track
l_2	=	total length of the target track
θ_2	=	polar angle of the target track

IP4 = 1 The inelastic events on the basis of angular correlation are written in the form given under IP3 = 1

IP5 = 1 The values of angles θ_1 and θ_2 in the elastic selection loop are written after each adjustment of target track depth. Each event is written twice giving the upper and lower values of θ_1 and θ_2. [Caution : If this switch is on for large number of events, the output can be very large. Use only for diagnosis]

IP6 = 1 The complete input is written in the form given under IP3=1. [This may be printed only once with a given set of data].

IP7 = 1 The scattering angles θ_1 and θ_2 for inelastic and elastic events respectively, are written on channel 7 for plotting with Harvard Graphics. Also the lengths and scattering angles of elastic events are written.

IP8 = 1 The scattering angles θ_1 and θ_2 for elastic events and special elastic events respectively, are written on channels 8 for plotting with Harvard Graphics.
Also the lengths and angles l_1, θ_1 followed by l_2, θ_2 are written in the case of special elastic events.

Card 2 : XMP, ZP, XMT, ZT, EBM (5F10.3)

XMP : Mass no. of the projectile

ZP : Charge no. of the projectile

XMT : Mass no. of the target

ZT : Charge no. of the target

EBM : Initial energy per nucleon of the projectile in MeV/u

Card 3 : UNCD1, UNCD2, UNCP1, UNCP2, DL (5F10.3)

UNCD1 : Uncertainty in the depth measurement (in microns) of larger tracks (i.e. projectile) given in the same units as that of track lengths

UNCD2 : Uncertainty in the depth measurement of shorter tracks (i.e. target) given in the same units as that of track lengths.

UNCP1 : Uncertainty (in microns) in the projected length measurement of longer track

UNCP2 : Uncertainty (in microns) in the projected length measurement of shorter track.

DL : Deficit in the experiment length of projectile track as compared to the theoretically expected length .If the condition L_1 (experimental) + DL ≥ L_1 (theoretical) is satisfied the event is confirmed as elastic event. Such an event is previously already selected as elastic on the basis of angular correaltion.

Card 4 : BF, BW, BL, B1, B2 (5F10.3)

BF/BL : First/Last value of the angular range within which the ratios $(d\sigma)_{exp.}/(d\sigma)_{Rutherford}$ is calculated

BW : The width of each bin within the range BF-BL. The number of angular bins are defined by (BL-BF)/BW.

B1/B2 : Not used at Present.

Card 5: AN, THE, ARE, FL, FLE, DUM (6G12.3)

AN : No. of target atoms
(This input option is used when the thickness of the target is not known. However, the number of target atoms was calculated previously).

THE : Percent error in thickness.

ARE : Percent error in scanned area

FL : Fluence of the projectile beam (# / cm^2)

FLE : Percent error in fluence.

Card 5' : TH, THE, AR, ARE, FL, FLE (6G12.3)

TH : Thickness of the target (mg/cm^2)

THE : Percent error in thickness

AR : Scanned area of the detector (cm^2)

ARE : Percent error in area

FL : Fluence of the projectile beam ($\#/cm^2$)

FLE : Percent error of the fluence

[Note: If Card 5' is read, then AN is calculated from

$N = N_{av}\ (\rho t)\ \alpha/A$

where
N_{av} = Avogadro's no. (6.022×10^{20}/mg.mole)
α = scanned area (cm^2).
ρt = Specific thickness (mg/cm^2)
A = Mass number of the target.

DATA FILE 2 :INPUT CHANNEL : FOR002

File NAME Convention : 1) [Proj.][Target][no. of Prongs][Id].DAT (if the data is in the form of total lengths and angles i.e. the output of ROW2).

2) [Proj.][Target][Id][no. of Prongs].DAT (if the data is in the form of projected lengths, depths and gap values etc. i.e. input to ROW2).

PURPOSE : The track data given in this file is the total binary data. This is used to select elastic events.

If ID2 = 0 (see card 1 of DATA FILE 1)

NE Cards : XL1 (I), A1 (I), XL2 (I), A2 (I), GAP (I), FOV (I) (1X, 5F6.1, F7. 3)

[**Note** : This data set must be followed by an empty line since the data END condition is used to determine the number of events (= NE). This data must be in form of output from program ROW2.]

XL1 : Actual length (in microns) of the longer track (i.e. projectile)

A1 : Scattering angle (degrees) corresponding to XL1

XL2 : Actual length (in microns) of the shorter track (i.e. target)

A2 : Scattering angle (degrees) corresponding to XL2

GAP : Length of the gap (in microns) between the projected lengths of binary track

FOV : Field-of-view, specified as the coordinates on the grid used for scanning events with microscope. The position should be given as: (ROW NUMBER).(COLUMN NUMBER) e.g. 037.103 would mean that the event lies within the box specified by 37th row and 103rd column

If ID2 = 1 (see card 1 of DATA FILE 1)

Card 1: CF, RI (10X, 2F10.3)

CF: Calibration Factor used for converting the projected lengths in millimeters to microns i.e. A projected length traced out on paper and measured to be 10 mm. would correspond to 15 μm if CF = 1.5.

RI: Refractive Index of the detector material. (The depths of the track ends measured in microns are multiplied by RI to determine true depths of the tracks).

NE Cards: XLP1 (I), XLD1 (I), XLP2 (I), XLD2(I), GAP (I), FOV (I) (IX, 5F6.1, F7.3)

(**Note**: This set of data (inducing card 1, above)should be exactly in the same from as required for INPUT to ROW2)

XLP1 : Projected length of the first track. The first track could be any of the two binary tracks and the lengths may be in millimeters. If true lengths in microns are written them CF should be specified as 1.

XLD1 : Depths of the track ends corresponding to XLP1. The depth may or may not be corrected w.r.t. refractive index. If corrected depth is given then RI should be specified as 1.

XLP2 : Projected length of the second track (see also under XLP1)

XLD2 : Depth of the second track (see also under XLD2)

GAP : The length of the gap between projected lengths. The gap should be input in millimeters if calibration factor is not 1.

FOV : See under ID2 = 0 data set.

DATA FILE 3 :INPUT CHANNEL FOR003
File NAME Convention :IRE [Proj.][Medium] DAT
PROPOSE :This is a table of theoretical energy (MeV/u)-range (microns) values. The value of range for a specific energy is determined by interpolation using this table.

NAE Cards: AE(I), AL(I) (2F10.3)

AE : Values of the energy (MeV/u)
(The range of energy values should cover the energy region of interest)

AL : The value of the range of projectile corresponding to energy AE travelling in the detector material.

This file containing reference data is created as follows:

- First the program DEDXH.FOR is run for a given projectile and a given medium. The step length for energy values should be fixed.
- Then the program RAW. FOR is run which selects the required section of DEDXH output and creates a file on channels 2. This file should be given the name IRE [Proj.] [Detector].DAT

OUTPUT FILES

Channel : FOR004

General output is written on this channel in accordance with the options IP1 - IP6 (see card 1, data file - 1

Channels : FOR007, FOR008

The outputs on these channels are written if IP7 = 1 and IP8 = 1. This output is used for plotting graphs with "Harvard Graphics". The arrangement of the output data is as follows.

Target scattering angle for inelastic events	**Projectile scattering angle for inelastic events**	(1X, 2F10.1)
⋮	⋮	
Target scattering angle for elastic events	**Proj. scattering angle for elastic events**	(1X, F10.1, 10X, F10.1)

The set of angles is followed by two blank lines and then the track lengths and scattering angles of the elastic events are written for projectiles followed (immediately) by those of target in the format (1X, 2F10.1) i.e.

Track length of Projectile	**Scattering angle of Projectile**
⋮	⋮
Track length of target	**Scattering angle of target**
⋮	⋮

On channel 8, the angles θ_2, θ_1, for the elastic events not selected as "special elastic" (i.e. those which satisfy angular criterion but do not satisfy length criterion) are written first, followed by θ_2, θ_1 of special elastic events. This set is followed by track lengths and angles of special elastic events. First the projectile values are written and immediately below this target values are written in the format described for channel FOR007.

ROW2.FOR

Purpose: This program is basically meant to prepare histograms for length distributions and angular distributions in the case of binary events of heavy ion reactions. The program can be used in two modes.

Mode 1- Given the actual total lengths (in microns) and scattering angles (in degrees), the program simply rearranges the data and frequencies are calculated as a funtion of length and angular bins.

Mode 2- The program can also be used to calculate actual lengths and angles of two prong events using raw data, which comprises of projected lengths and depths of boths tracks. This elementary data is modified in the following manner.

Projected length (usually in millimeters measured with a tracing tube of the microscope)	→	**Projected length × CF** (CF is the calibration factor. After multipliation with this factor the projected length is obtained in microns)
Depth (measured with depth measuring instrument attached to microscope stage. The values are in microns)	→	**Depth × RI** (RI is the refractive index of the detector material. After multiplication the true depth is obtained in microns)
GAP (in mm)	→	**GAP × CF**

GAP is the value of 'gap' between two projected lengths traced out on the paper while viewing a two-prong event through the microscope.

GAP
←→
____________ ____________

The multiplication with CF gives the true value of gap in microns
The actual lengths and polar angles of the prongs are obtained by using the following eqs. (see also Fig. 1)

$$l'_{p_1} = l_{p_1} + \frac{l_{p_1}}{d_1} \Delta d$$

$$l'_{p_2} = l_{p_2} + \frac{l_{p_2}}{d_1} \Delta d$$

$$\Delta d = G \left[\frac{l_{p_1}}{d_1} + \frac{l_{p_{2_1}}}{d_2} \right]$$

$$d'_1 = d_1 + \Delta d$$

$$d'_2 = d_2 + \Delta d$$

(Note: In the above eqs. lp_1, lp_2, d_1, d_2 and G are the quantities which have been obtained after multiplying with the Calibration factor (CF) and Refractive index (RI).

The actual lengths and angles are given by :

$$l_i = \sqrt{l'^2_{p_i} + d_i^2}$$

$$\theta_i = \tan^{-1}\left(\frac{l'_{p_i}}{d'_i}\right)$$

Bins and Frequencies: In order to find the number of events having their lengths in a given range of values, the following data re-ordering is done by the program.

The longer of the two lengths in each event is written in the first column, followed by its corresponding angle in the second column. The shorter track length and its corresponding angle go to third and fourth column for each event.

For each of the four quantities, the programme separately looks for the events lying in specific length and angle bins. These numbers are stored and later used for plotting histograms.

INPUT / OUTPUT FOR ROW2.FOR

INPUT FILE:
(Conventional Name) [Proj.][Target][Id.][No. of Prongs].DAT
Channel : FOR 001

OUTPUT : FOR002
[Note: If the program is used in mode 2, the first part of the output, displaying computed lengths and angles is used directly for input to ELASTIC.FOR]

Card 1: NP, NE, CF, RI (2I5, 2F10.3)

NP : No. of Prongs (Although presently the prog. is applicable for binary events, it may
be extended for use in the case of higher multiplicity events)
NE : No. of Events
CF : Calibration Factor
RI : Refractive Index

Card 2: XF, XL, XW, YF, YL, YW, AF, AL, AW, BF, BL, BW

(1X, 3F10.3, /1X, 3F10.3, /1X, 3F10.3, /1X, 3F10.3)

XF / XL: First / Last value of the first length (which is always the longer length) for which bins are made.

XW : Width of each bin between XF and XL.

(The no. of bins are calcualted by $\frac{XL - XF}{XW}$)

:

YF / YL : First / Last value of the second length

YW : Width of each bin between YF and YL.

AF / AL : First / Last value of the angle corresponding to the first length (which is always longer length)

AW : Width of the angular bin.

BF / BL : First / Last value of the angles corresponding to the second track length.

BW : Width of the angular bin

Mode 1: For this mode, it is necessary that CF = 0

NE Cards : (Y(J), J= 1, N), FOV [1X, <N> F6.1, F7.3]

Note : Each of the NE cards is read in a loop I. The number N is equal to 5 for two prong events)

Y(1) : First track length (true total length in microns after applying all necessary correction)

Y(2) : Angle corresponding to first track length

Y(3) : Second track length (true total length, with all corrections)

Y(4) : Angle corresponding to second track length

Y(5) : Value of the gap between projected length (in microns)

FOV: The field-of-view for the observed event. (The specification is made as a real number using the convention ROW.COLUMN where ROW is the row number and COLUMN is the column number of the grid. This is optional input and is not used in calculations)

Mode 2 : This mode is activated for CF ≠ 0

NE Cards : (X(J), J= 1,N), FOV (I) [1X, <N> F6.1, F7.3]

X(2)/X(3) : Projected length of the first/second track (raw value in mm as traced on the paper)

X(2)/X(4) : Depth of the first / second track (uncorrected for Refractive Index)

X(5) : Gap between the projected lengths (in mm as traced on the paper)

IRE.FOR

PURPOSE: To calculate the range corresponding to a given energy by interpolating a range energy table

METHOD: Step 1: A standard range-energy program (e.g. VRHBD or DEDXH) is used to creat a table of range values corresesopnding to equi-spaced energies for a given charged particle incident on a given (detector) material.

Step 2: The required values are separated from the general output of standard programs in order to store it in two-column arays (AE(1000), AL(1000)). If in step 1, the program DEDXH is used, then RAW.FOR (Input FOR001. Output FOR002) may be used for this purpose.

Step 3: The interpolation is done by a 3pt. Langrangian formula.

$$f(x_o + ph) = \frac{p(p-1)}{2} f_{-1} + (1 - p^2) f_o + \frac{p(p+1)}{2} f_1$$

The above formula is quite accurate for closely spaced continuous array for ` f ' without rapid fluctuations. The independent variable has to equi-spaced (Normally the energies are given MeV/u). In order to increase the speed of retrieved interpulated value: a skip step method is introduced which transfers control to the region of interest. For example if the value of energy at which the range is required is 10.56 MeV, while a table of energy values 1-20 MeV in steps of 0.1 MEV is given, then the difference of first energy in the array AE(I) and the reference energy RE(I) = 10.56 is calculated. The program control is then moved to the region of 10 MeV energy.

INPUT / OUTPUT FOR IRE.FOR

INPUT FILE 1: Channel : FOR001 (RE (I), I= 1, 100) [1X, F10.3].
where RE are the set of values at which the range is required.

INPUT FILE 2: Channel: FOR002

INPUT Filename Convention :IRE [Proj.][detector].DAT

Note: Since this file containing the array of energy and range values is created by running RAW.FOR which uses standard output of DEDXH as input and produces the required array on FOR002, therefore either FOR002.DAT is directly used in IRE or it is renamed according to the above convention for later use.

OUTPUT: Channel : FOR003 (RE (I), RLL (I), I= 1, NE) [1X, 2F10.3]
The energy (MeV/u) and range (microns) is written for the values specified under RE in File 1.

OUTPUT DATA FILE OF ROW2.FOR
USED AS
INPUT DATA FILE FOR ELASTIC.FOR

AUAUB2.OUT

182.1	12.6	13.7	73.4	2.4	92.150
179.5	10.9	13.7	65.1	2.1	92.160
165.4	10.2	20.0	74.3	1.4	92.310
179.4	10.4	17.6	75.9	4.3	92.390
174.7	8.1	11.8	61.5	1.5	92.400
182.1	6.0	22.1	66.1	2.0	92.230
167.5	13.4	18.6	73.3	1.7	92.130
177.9	6.8	12.9	53.2	1.8	92.150
180.3	6.5	12.7	72.8	1.7	91.270
181.7	9.3	12.4	79.2	3.8	91.330
180.4	11.0	10.0	49.0	2.2	91.330
190.7	11.0	8.8	53.2	3.1	91.200
182.2	10.1	13.8	66.0	1.8	91.160
178.3	9.3	12.4	72.2	1.8	91.160
183.9	10.4	20.1	64.2	1.4	91.120
179.7	7.3	12.6	69.2	3.4	91.110
175.4	10.0	18.9	83.3	5.2	90.090
181.4	11.4	12.6	71.2	2.5	90.110
85.0	16.4	20.1	79.9	1.7	90.110
180.8	11.1	22.6	80.7	2.7	90.160
170.0	12.5	17.1	78.0	1.5	90.160
180.1	14.3	22.0	75.3	2.8	90.190
181.4	9.2	19.5	79.1	2.4	90.230
160.7	15.3	18.3	61.3	1.4	90.300
180.2	9.5	13.4	72.6	2.5	90.330
169.9	16.6	18.7	73.4	1.7	89.280
182.1	12.0	11.3	58.2	2.0	89.280
154.4	14.0	21.2	80.2	2.2	89.240
172.7	5.5	10.1	79.2	1.4	89.240
183.2	10.4	8.7	56.5	2.7	89.110
176.2	8.1	11.8	70.4	2.1	89.100
188.5	5.9	11.9	78.5	3.8	88.060
187.8	7.3	8.7	59.9	2.1	88.090
153.3	12.5	14.3	75.6	1.3	88.130
183.2	11.9	11.5	70.1	2.0	88.150
176.6	15.9	23.3	58.0	1.8	88.210
159.0	12.8	22.9	71.4	2.5	88.240
166.6	10.4	8.8	69.5	4.2	88.270
179.1	13.5	16.0	50.4	5.3	88.280
180.6	15.4	20.1	74.9	1.4	88.300
168.3	14.5	20.5	74.8	2.0	87.930
163.1	8.8	13.7	74.4	1.7	87.410
181.6	8.7	9.2	63.7	1.8	87.410
164.8	9.1	14.7	75.9	1.4	87.380
173.3	13.9	17.6	70.6	2.9	87.370
168.1	9.6	17.2	84.2	1.1	87.320
178.9	9.5	9.2	50.4	1.4	87.300
167.0	13.1	20.6	80.1	1.7	87.300
170.3	12.9	12.5	81.0	2.2	87.300
51.8	19.5	13.8	82.6	1.3	87.300
154.3	14.2	12.3	82.2	1.4	87.180
174.0	13.0	21.5	65.8	1.7	87.160
172.8	14.0	16.1	76.9	1.8	87.140
180.7	13.6	22.3	80.9	1.8	87.100
172.9	14.3	16.5	80.6	1.7	87.090
172.6	15.9	12.8	74.9	1.3	87.070

INPUT DATA FILE FOR ELASTIC.FOR

ELAUAUC.DAT

```
8 0 0 1 1 1 1 1 1 1 1 1
   1.10          5.00          54.6          5.00          0.795E+06     5.00
  197.000      79.000      197.000      79.000      15.900
    1.864        1.481        1.650        1.550       40.000
    1.000        1.000       90.000        0.000        0.000
 NO. OF EVENTS =    193
 MASS RATIO =  1.000
 A M A X =200.000
```

E.NO.	LP1	D1	LP2	D2	GAP	L1	A1	L2	A2	FDV
1	39.7	177.7	13.1	3.9	2.4	182.1	12.6	13.7	73.4	92.150
2	33.9	176.3	12.4	5.8	2.1	179.5	10.9	13.7	65.1	92.160
3	29.3	162.8	19.3	5.2	1.4	165.4	10.2	20.0	74.8	92.310
4	32.4	176.5	17.1	4.3	4.3	179.4	10.4	17.6	75.9	92.390
5	24.6	173.0	10.4	5.6	1.5	174.7	8.1	11.8	61.5	92.400
6	19.0	181.1	20.2	9.0	2.0	182.1	6.0	22.1	66.1	92.230
7	38.8	162.9	17.8	5.3	1.7	167.5	13.4	18.6	73.3	92.130
8	21.1	176.6	10.3	7.7	1.8	177.9	6.8	12.9	53.2	92.150
9	20.4	179.1	12.1	3.8	1.7	180.3	6.5	12.7	72.8	91.270
10	29.4	179.3	12.2	2.3	3.8	181.7	9.3	12.4	79.2	91.330
11	34.4	177.1	7.5	6.6	2.2	180.4	11.0	10.0	49.0	91.330
12	36.4	187.2	7.0	5.3	3.1	190.7	11.0	8.8	53.2	91.200
13	32.0	179.4	12.6	5.6	1.8	182.2	10.1	13.8	66.0	91.160
14	28.8	176.0	11.8	3.8	1.8	178.3	9.3	12.4	72.2	91.160
15	33.2	180.9	18.1	8.7	1.4	183.9	10.4	20.1	64.2	91.120
16	22.8	178.2	11.8	4.5	3.4	179.7	7.3	12.6	69.2	91.110
17	30.5	172.7	18.8	2.2	5.2	175.4	10.0	18.9	83.3	90.090
18	35.9	177.8	11.9	4.1	2.5	181.4	11.4	12.6	71.2	90.110
19	24.0	81.5	19.8	3.5	1.7	85.0	16.4	20.1	79.9	90.110
20	34.8	177.4	22.3	3.7	2.7	180.8	11.1	22.6	80.7	90.160
21	36.8	166.0	16.7	3.6	1.5	170.0	12.5	17.1	78.0	90.160
22	44.5	174.5	21.3	5.6	2.8	180.1	14.3	22.0	75.3	90.190
23	29.0	179.1	19.1	3.7	2.4	181.4	9.2	19.5	79.1	90.230
24	42.4	155.0	16.1	8.8	1.4	160.7	15.3	18.3	61.3	90.300
25	29.7	177.7	12.8	4.0	2.5	180.2	9.5	13.4	72.6	90.330
26	48.5	162.8	17.9	5.3	1.7	169.9	16.6	18.7	73.4	89.280
27	37.9	178.1	9.6	6.0	2.0	182.1	12.0	11.3	58.2	89.280
28	37.4	149.8	20.9	3.6	2.2	154.4	14.0	21.2	80.2	89.240
29	17.2	178.9	9.9	1.9	1.4	179.7	5.5	10.1	79.2	89.240
30	33.1	180.2	7.3	4.8	2.7	183.2	10.4	8.7	56.5	89.110
31	24.8	174.4	11.1	4.0	2.1	176.2	8.1	11.8	70.4	89.100
32	19.4	187.5	11.7	2.4	3.8	188.5	5.9	11.9	78.5	88.060
33	23.9	186.3	7.5	4.4	2.1	187.8	7.3	8.7	59.9	88.090
34	33.2	149.7	13.9	3.6	1.3	153.3	12.5	14.3	75.6	88.130
35	37.8	179.3	10.8	3.9	2.0	183.2	11.9	11.5	70.1	88.150
36	48.4	169.8	19.8	12.3	1.8	176.6	15.9	23.3	58.0	88.210
37	35.2	155.0	21.7	7.3	2.5	159.0	12.8	22.9	71.4	88.240
38	30.1	163.9	8.2	3.1	4.2	166.6	10.4	8.8	69.5	88.270
39	41.8	174.2	12.3	10.2	5.3	179.1	13.5	16.0	50.4	88.280
40	48.0	174.1	19.4	5.2	1.4	180.6	15.4	20.1	74.9	88.300
41	42.1	162.9	19.8	5.4	2.0	168.3	14.5	20.5	74.8	87.930
42	25.0	161.2	13.2	3.7	1.7	163.1	8.8	13.7	74.4	87.410
43	27.5	179.5	8.2	4.1	1.8	181.6	8.7	9.2	63.7	87.410
44	26.1	162.7	14.3	3.6	1.4	164.8	9.1	14.7	75.9	87.380
45	41.6	168.2	16.6	5.8	2.9	173.3	13.9	17.6	70.6	87.370
46	28.0	165.7	17.1	1.7	1.1	168.1	9.6	17.2	84.2	87.320
47	29.5	176.4	7.1	5.9	1.4	178.9	9.5	9.2	50.4	87.300
48	37.9	162.7	20.3	3.5	1.7	167.0	13.1	20.6	80.1	87.300
49	38.0	166.0	12.3	2.0	2.2	170.3	12.9	12.5	81.0	87.300

OUTPUT DATA FILE OF ELASTIC.FOR

IF IP6 = 1

OUTPUT DATA FILE OF ELASTIC.FOR

IF IP3=1 WITH ID3=1

NO. OF ELASTIC EVENTS 145 OUT OF 193

	E.NO.	LP1	D1	LP2	D2	GAP	L1	A1	L2	A2	FOV
	1	39.7	177.7	13.1	3.9	2.4	182.1	12.6	13.7	73.4	92.150
*	3	29.3	162.8	19.3	5.1	1.4	165.4	10.2	20.0	75.1	92.310
	4	32.4	176.5	17.1	4.3	4.3	179.4	10.4	17.6	75.9	92.390
	7	38.8	162.9	17.8	5.3	1.7	167.5	13.4	18.6	73.3	92.130
*	9	20.4	179.0	12.1	2.9	1.7	180.2	6.5	12.5	76.4	91.270
	10	29.4	179.3	12.2	2.3	3.8	181.7	9.3	12.4	79.2	91.330
*	14	28.8	175.9	11.8	3.4	1.8	178.3	9.3	12.3	73.8	91.160
	17	30.5	172.7	18.8	2.2	5.2	175.4	10.0	18.9	83.3	90.090
*	18	35.9	177.8	11.9	3.9	2.5	181.4	11.4	12.6	71.7	90.110
	20	34.8	177.4	22.3	3.7	2.7	180.8	11.1	22.6	80.7	90.160
	21	36.8	166.0	16.7	3.6	1.5	170.0	12.5	17.1	78.0	90.160
	22	44.5	174.5	21.3	5.6	2.8	180.1	14.3	22.0	75.3	90.190
	23	29.0	179.1	19.1	3.7	2.4	181.4	9.2	19.5	79.1	90.230
*	25	29.7	177.7	12.8	3.8	2.5	180.2	9.5	13.3	73.6	90.330
	26	48.5	162.8	17.9	5.3	1.7	169.9	16.6	18.7	73.4	89.280
	28	37.4	149.8	20.9	3.6	2.2	154.4	14.0	21.2	80.2	89.240
	29	17.2	178.9	9.9	1.9	1.4	179.7	5.5	10.1	79.2	89.240
*	31	24.8	174.3	11.1	3.1	2.1	176.1	8.1	11.6	74.4	89.100
	32	19.4	187.5	11.7	2.4	3.8	188.5	5.9	11.9	78.5	88.060
	34	33.2	149.7	13.9	3.6	1.3	153.3	12.5	14.3	75.6	88.130
*	35	37.8	179.2	10.8	3.8	2.0	183.2	11.9	11.5	70.7	88.150
*	37	35.2	155.0	21.7	6.6	2.5	158.9	12.8	22.7	73.0	88.240
	38	30.1	163.9	8.2	3.1	4.2	166.6	10.4	8.8	69.5	88.270
	40	48.0	174.1	19.4	5.2	1.4	180.6	15.4	20.1	74.9	88.300
	41	42.1	162.9	19.8	5.4	2.0	168.3	14.5	20.5	74.8	87.930
*	42	24.9	161.2	13.2	3.6	1.7	163.1	8.8	13.7	74.9	87.410
	44	26.1	162.7	14.3	3.6	1.4	164.8	9.1	14.7	75.9	87.380
*	45	41.6	168.2	16.6	5.7	2.9	173.3	13.9	17.6	71.0	87.370
	46	28.0	165.7	17.1	1.7	1.1	168.1	9.6	17.2	84.2	87.320
	48	37.9	162.7	20.3	3.5	1.7	167.0	13.1	20.6	80.1	87.300
	49	38.0	166.0	12.3	2.0	2.2	170.3	12.9	12.5	81.0	87.300
	53	41.8	167.7	15.7	3.6	1.8	172.8	14.0	16.1	76.9	87.140
	55	42.7	167.5	16.3	2.7	1.7	172.9	14.3	16.5	80.6	87.090
	56	47.3	166.0	19.1	5.2	1.3	172.6	15.9	19.8	74.8	87.070
	57	30.5	167.9	10.8	3.1	2.4	170.7	10.3	11.2	74.1	87.080
	58	30.5	169.8	11.2	3.3	3.1	172.5	10.2	11.7	73.6	86.100
	59	40.5	162.6	16.9	2.6	1.4	167.6	14.0	17.1	81.1	86.100
	61	23.0	159.6	16.1	3.6	1.7	161.2	8.2	16.5	77.3	86.210
	62	26.4	179.0	9.2	2.0	1.7	180.9	8.4	9.4	77.9	86.250
	64	33.7	162.8	7.3	2.1	1.7	166.3	11.7	7.6	74.2	86.320
	65	39.8	170.9	15.4	2.8	2.2	175.5	13.1	15.7	79.6	86.340
	67	37.2	162.6	18.5	3.5	1.1	166.8	12.9	18.8	79.4	86.410
*	68	20.1	179.4	7.9	2.3	2.8	180.5	6.4	8.3	73.6	85.410
	70	30.2	180.7	15.9	2.9	2.4	183.2	9.5	16.2	79.8	85.380
*	71	32.0	168.0	12.1	3.8	2.2	171.0	10.8	12.7	72.4	86.320
	74	42.6	154.7	21.4	7.0	1.5	160.5	15.4	22.5	72.0	85.210
*	75	26.5	169.4	6.7	2.6	1.3	171.4	8.9	7.2	68.7	85.210
*	76	29.6	159.7	18.5	5.1	1.8	162.4	10.5	19.2	74.7	85.190
	78	27.7	169.1	15.1	2.7	1.3	171.4	9.3	15.3	80.0	84.170
	79	39.4	162.7	19.0	3.6	2.0	167.4	13.6	19.3	79.2	84.230
	80	35.6	165.8	16.7	3.5	1.1	169.6	12.1	17.1	78.3	84.280
	81	30.7	138.3	19.4	3.5	1.4	141.7	12.5	19.7	79.8	84.290
	82	34.2	172.6	12.4	3.6	1.4	175.9	11.2	12.9	73.6	84.380
	83	40.7	182.2	15.6	3.6	1.5	186.7	12.6	16.0	77.1	83.400
	84	38.3	165.8	19.6	3.5	1.5	170.2	13.0	19.9	79.8	83.390
	85	27.5	164.4	12.4	2.8	1.7	166.7	9.5	12.7	77.3	83.380
*	86	27.7	170.9	11.3	3.4	1.4	173.2	9.2	11.8	73.5	83.300
	87	31.0	136.6	18.9	3.5	1.3	140.1	12.8	19.2	79.6	83.290
	88	35.1	162.5	10.7	1.8	1.3	166.3	12.2	10.9	80.3	83.200
	89	21.5	70.3	18.0	5.4	1.8	73.5	17.0	18.8	73.4	83.180
	90	31.5	178.8	13.7	1.8	1.5	181.6	10.0	13.8	82.4	83.130
	91	35.1	174.0	11.3	2.7	1.1	177.5	11.4	11.6	76.6	84.110
	93	38.2	161.5	5.7	2.4	2.0	166.0	13.3	6.2	67.5	82.110
	94	34.7	161.7	8.6	2.5	3.2	165.4	12.1	9.0	73.8	82.110
	95	19.8	165.9	9.5	2.7	1.0	167.1	6.8	9.9	74.1	82.120
*	96	23.6	168.0	14.0	3.5	2.7	169.6	8.0	14.4	75.9	82.200
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

OUTPUT DATA FILE OF ELASTIC.FOR

IF ID3 = I

	5	8.6429	32.904	57.096							
	5	7.5571	18.016	71.984							
	5	8.6429	32.410	57.590							
	5	7.5571	17.466	72.534							
	5	8.6430	31.910	58.090							
	5	7.5570	16.911	73.089							
*	5	24.6	172.8	10.4	4.7	1.5	174.6	8.1	11.4	65.6	92.400
	6	6.5199	27.770	62.230							
	6	5.4801	20.030	69.970							
	6	6.5200	27.514	62.486							
	6	5.4800	19.761	70.239							
	6	6.5200	27.258	62.742							
	6	5.4800	19.491	70.509							
	6	6.5200	27.000	63.000							
	6	5.4800	19.220	70.780							
	6	6.5201	26.742	63.258							
	6	5.4799	18.947	71.053							
	6	6.5201	26.482	63.518							
	6	5.4799	18.674	71.326							
	6	6.5201	26.221	63.779							
	6	5.4799	18.400	71.600							
	6	6.5201	25.959	64.041							
	6	5.4799	18.124	71.876							
	6	6.5202	25.696	64.304							
	6	5.4798	17.848	72.152							
*	6	19.0	181.0	20.2	8.1	2.0	182.0	6.0	21.8	68.2	92.230
	7	13.969	21.280	68.720							
	7	12.831	12.120	77.880							
	8	7.3324	43.489	46.511							
	8	6.2676	30.111	59.889							
	8	7.3325	43.097	46.903							
	8	6.2675	29.651	60.349							
	8	7.3325	42.700	47.300							
	8	6.2675	29.187	60.813							
	8	7.3326	42.298	47.702							
	8	6.2674	28.719	61.281							
	8	7.3327	41.892	48.108							
	8	6.2673	28.246	61.754							
	8	7.3327	41.480	48.520							
	8	6.2673	27.768	62.232							
	8	7.3328	41.064	48.936							
	8	6.2672	27.285	62.715							
	8	7.3328	40.643	49.357							
	8	6.2672	26.797	63.203							
	8	7.3329	40.216	49.784							
	8	6.2671	26.305	63.695							
*	8	21.0	176.5	10.3	6.8	1.8	177.8	6.8	12.4	56.7	92.150
	9	7.0253	23.909	66.091							
	9	5.9747	10.491	79.509							
	9	7.0253	23.425	66.575							
	9	5.9747	9.9756	80.024							
	9	7.0254	22.937	67.063							
	9	5.9746	9.4582	80.542							
	9	7.0254	22.447	67.553							
	9	5.9746	8.9387	81.061							
	9	7.0254	21.954	68.046							
	9	5.9746	8.4171	81.583							
	9	7.0255	21.457	68.543							
	9	5.9745	7.8935	82.107							
	9	7.0255	20.958	69.042							
	9	5.9745	7.3679	82.632							

OUTPUT DATA FILE OF ELASTIC.FOR

IF IP2=1

	FXP.-A1	TH.-E1	EXP.-L1	TH.-L1
1	12.600	15.143	182.100	182.648
3	10.200	15.401	165.393	186.332
4	10.400	15.382	179.400	185.184
7	13.400	15.046	167.500	181.411
9	6.500	15.696	180.193	188.956
10	9.300	15.485	181.700	186.436
14	9.300	15.485	178.251	186.436
17	10.000	15.421	175.400	186.356
18	11.400	15.279	181.377	183.935
20	11.100	15.311	180.800	185.095
21	12.500	15.155	170.000	182.662
22	14.300	14.930	180.100	180.155
23	9.200	15.494	181.400	186.447
25	9.500	15.467	180.156	186.414
26	16.600	14.602	169.900	176.426
28	14.000	14.969	154.400	180.204
29	5.500	15.754	179.700	190.160
31	8.100	15.584	176.051	187.688
32	5.900	15.732	188.500	190.132
34	12.500	15.155	153.300	182.662
35	11.900	15.224	183.180	183.867
37	12.800	15.120	158.931	182.618
38	10.400	15.382	166.600	185.184
40	15.400	14.779	180.600	177.749
41	14.500	14.903	168.300	180.122
42	8.800	15.528	163.086	187.617
44	9.100	15.502	164.800	187.585
45	13.900	14.982	173.282	180.220
46	9.600	15.458	168.100	186.402
48	13.100	15.033	167.000	181.457
49	12.900	15.108	170.300	182.603
53	14.000	14.969	172.800	180.204
55	14.300	14.930	172.900	180.155
56	15.900	14.707	172.600	177.660
57	10.300	15.392	170.700	185.196
58	10.200	15.401	172.500	186.332
59	14.000	14.969	167.600	180.204
61	8.200	15.577	161.200	187.678
62	8.400	15.561	180.900	187.658
64	11.700	15.246	166.300	183.894
65	13.100	15.083	175.500	181.457
67	12.900	15.108	166.800	182.603
68	6.400	15.702	180.549	190.095
70	9.500	15.467	183.200	186.414
71	10.800	15.342	170.980	185.134
74	15.400	14.779	160.500	177.749
75	8.900	15.519	171.436	187.606
76	10.500	15.372	162.371	185.172
78	9.300	15.485	171.400	186.436
79	13.600	15.021	167.400	181.380
80	12.100	15.201	169.600	183.839
81	12.500	15.155	141.700	182.662
82	11.200	15.300	175.900	185.082
83	12.600	15.143	186.700	182.648
84	13.000	15.095	170.200	181.472

OUTPUT DATA FILE OF ELASTIC.FOR

IF IPI=1

NO. OF SPECIAL EL. EVENTS 132 OUT OF TOTAL 193

L1	A1	L2	A2	FOV	E.NO.
182.1	12.6	13.7	73.4	92.150	1
165.4	10.2	20.0	75.1	92.310	3
179.4	10.4	17.6	75.9	92.390	4
167.5	13.4	18.6	73.3	92.130	7
180.2	6.5	12.5	76.4	91.270	9
181.7	9.3	12.4	79.2	91.330	10
178.3	9.3	12.3	73.8	91.160	14
175.4	10.0	18.9	83.3	90.090	17
181.4	11.4	12.6	71.7	90.110	18
180.8	11.1	22.6	80.7	90.160	20
170.0	12.5	17.1	78.0	90.160	21
180.1	14.3	22.0	75.3	90.190	22
181.4	9.2	19.5	79.1	90.230	23
180.2	9.5	13.3	73.6	90.330	25
169.9	16.6	18.7	73.4	89.280	26
154.4	14.0	21.2	80.2	89.240	28
179.7	5.5	10.1	79.2	89.240	29
176.1	8.1	11.6	74.4	89.100	31
188.5	5.9	11.9	78.5	88.060	32
153.3	12.5	14.3	75.6	88.130	34
183.2	11.9	11.5	70.7	88.150	35
158.9	12.8	22.7	73.0	88.240	37
166.6	10.4	8.8	69.5	88.270	38
180.6	15.4	20.1	74.9	88.300	40

OUTPUT DATA FILE OF ELASTIC.FOR

IF IP1 = IP2 = ···· IP8 = 0

BIN		EVENTS	NORM X-SEC	ABSOL ERR	SIGE	SIGR
1(	1.0- 2.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
2(	2.0- 3.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
3(	3.0- 4.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
4(	4.0- 5.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
5(	5.0- 6.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
6(	6.0- 7.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
7(	7.0- 8.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
8(	8.0- 9.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
9(	9.0- 10.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
10(	10.0- 11.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
11(	11.0- 12.0)	4	0.0061	0.0031	0.448E-23	0.274E-25
12(	12.0- 13.0)	6	0.0118	0.0049	0.349E-23	0.411E-25
13(	13.0- 14.0)	3	0.0074	0.0043	0.277E-23	0.205E-25
14(	14.0- 15.0)	1	0.0031	0.0031	0.223E-23	0.685E-26
15(	15.0- 16.0)	8	0.0300	0.0109	0.183E-23	0.543E-25
16(	16.0- 17.0)	4	0.0181	0.0092	0.151E-23	0.274E-25
17(	17.0- 18.0)	9	0.0486	0.0167	0.127E-23	0.615E-25
18(	18.0- 19.0)	10	0.0638	0.0209	0.107E-23	0.685E-25
19(	19.0- 20.0)	7	0.0523	0.0203	0.917E-24	0.479E-25
20(	20.0- 21.0)	14	0.1215	0.0341	0.789E-24	0.959E-25
21(	21.0- 22.0)	7	0.0701	0.0272	0.684E-24	0.479E-25
22(	22.0- 23.0)	11	0.1262	0.0396	0.597E-24	0.753E-25
23(	23.0- 24.0)	5	0.0654	0.0298	0.524E-24	0.342E-25
24(	24.0- 25.0)	8	0.1136	0.0432	0.462E-24	0.543E-25
25(	25.0- 26.0)	10	0.1671	0.0548	0.410E-24	0.685E-25
26(	26.0- 27.0)	7	0.1313	0.0509	0.365E-24	0.479E-25
27(	27.0- 28.0)	6	0.1258	0.0525	0.327E-24	0.411E-25
28(	28.0- 29.0)	4	0.0933	0.0474	0.293E-24	0.274E-25
29(	29.0- 30.0)	2	0.0518	0.0369	0.265E-24	0.137E-25
30(	30.0- 31.0)	3	0.0858	0.0501	0.239E-24	0.205E-25
31(	31.0- 32.0)	1	0.0315	0.0316	0.217E-24	0.685E-26
32(	32.0- 33.0)	1	0.0346	0.0347	0.198E-24	0.685E-26
33(	33.0- 34.0)	1	0.0379	0.0381	0.181E-24	0.685E-26
34(	34.0- 35.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
35(	35.0- 36.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
36(	36.0- 37.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
37(	37.0- 38.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
38(	38.0- 39.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
39(	39.0- 40.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
40(	40.0- 41.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
41(	41.0- 42.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
42(	42.0- 43.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
43(	43.0- 44.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
44(	44.0- 45.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
45(	45.0- 46.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
46(	46.0- 47.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
47(	47.0- 48.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
48(	48.0- 49.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
49(	49.0- 50.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
50(	50.0- 51.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
51(	51.0- 52.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
52(	52.0- 53.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
53(	53.0- 54.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
54(	54.0- 55.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
55(	55.0- 56.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
56(	56.0- 57.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
57(	57.0- 58.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
58(	58.0- 59.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
59(	59.0- 60.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
60(	60.0- 61.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
61(	61.0- 62.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
62(	62.0- 63.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
63(	63.0- 64.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
64(	64.0- 65.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
65(	65.0- 66.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
66(	66.0- 67.0)	0	0.0000	0.0000	0.000E+00	0.000E+00
67(	67.0- 68.0)	0	0.0000	0.0000	[illegible]	[illegible]

OUTPUT DATA FILE OF ELASTIC.FOR

IF IP7 = 1

73.6	9.5
73.4	16.6
80.2	14.0
79.2	5.5
74.4	8.1
78.5	5.9
75.6	12.5
70.7	11.9
73.0	12.8
69.5	10.4
74.9	15.4
74.8	14.5
74.9	8.8
75.9	9.1
71.0	13.9
84.2	9.6
80.1	13.1
81.0	12.9
76.9	14.0
80.6	14.3
74.8	15.9
74.1	10.3
73.6	10.2
81.1	14.0
77.3	8.2
77.9	8.4
74.2	11.7
79.6	13.1
79.4	12.9
73.6	6.4
79.8	9.5
72.4	10.8
72.0	15.4
68.7	8.9
74.7	10.5
80.0	9.3
79.2	13.6
78.3	12.1
79.8	12.5
73.6	11.2
77.1	12.6
79.8	13.0
77.3	9.5
73.5	9.2
79.6	12.8
80.3	12.2
73.4	17.0
82.4	10.0
76.6	11.4
67.5	13.3
73.8	12.1
74.1	6.8
75.9	8.0
79.9	13.3
73.2	10.1
68.7	12.2
80.9	14.1
79.9	12.4
84.2	8.8
80.0	5.7
75.6	14.1

OUTPUT DATA FILE OF ELASTIC.FOR

IF IP8 = 1

80.0	9.3
79.2	13.6
78.3	12.1
73.6	11.2
77.1	12.6
79.8	13.0
77.3	9.5
73.5	9.2
80.3	12.2
82.4	10.0
76.6	11.4
67.5	13.3
73.8	12.1
74.1	6.8
75.9	8.0
79.9	13.3
73.2	10.1
68.7	12.2
80.9	14.1
79.9	12.4
84.2	8.8
80.0	5.7
75.6	14.1
65.1	9.1
72.7	6.3
75.4	12.3
74.9	11.4
73.4	8.9
78.0	15.4
80.0	10.9
77.7	12.0
78.9	9.6
79.9	8.3
83.8	10.0
71.9	10.3
79.7	9.0
77.2	7.6
70.7	11.0
75.6	9.6
80.5	10.7
80.3	11.0
78.8	14.6
76.0	9.6
81.7	11.8
79.2	6.8
75.6	7.9
83.3	11.0
81.2	13.2
73.8	6.5
72.4	9.1
59.9	11.3
70.2	16.1
79.9	11.6
81.7	7.6
82.4	8.8
76.7	10.8
81.1	10.9
80.0	10.9
83.9	10.3
76.1	5.3
81.9	11.6

INPUT DATA FILE FOR ROW2.FOR

AUAUB2.DAT

```
 2 1379   1.401     1.604
 0.0      200.0     5.0
 0.0       50.0     5.0
 0.0       90.0     5.0
 0.0       90.0     5.0
 7.8    2.0   28.2 109.0    1.7 92.15
 7.5    3.0   24.2 108.0    1.5 92.16
12.8    3.0   20.9 100.0    1.0 92.31
 9.2    2.0   23.0 108.0    3.1 92.39
 6.4    3.0   17.5 106.0    1.1 92.40
13.1    5.0   13.6 111.0    1.4 92.23
11.6    3.0   27.7 100.0    1.2 92.13
 6.2    4.0   14.9 108.0    1.3 92.15
 7.5    2.0   14.6 110.0    1.2 91.27
 6.1    1.0   20.9 110.0    2.7 91.33
 4.0    3.0   24.3 108.0    1.6 91.33
 3.1    2.0   25.7 114.0    2.2 91.20
 7.8    3.0   22.6 110.0    1.3 91.16
 7.2    2.0   20.6 108.0    1.3 91.16
12.0    5.0   23.7 111.0    1.0 91.12
 6.1    2.0   16.1 109.0    2.4 91.11
 9.8    1.0   21.7 106.0    3.7 90.09
 6.8    2.0   25.5 109.0    1.8 90.11
13.0    2.0   17.1  50.0    1.2 90.11
14.1    2.0   24.8 109.0    1.9 90.16
10.9    2.0   26.2 102.0    1.1 90.16
13.3    3.0   31.7 107.0    2.0 90.19
12.0    2.0   20.7 110.0    1.7 90.23
10.6    5.0   30.2  95.0    1.0 90.30
 7.4    2.0   21.1 109.0    1.8 90.33
11.7    3.0   34.5 100.0    1.2 89.28
 5.6    3.0   26.9 109.0    1.4 89.28
13.4    2.0   26.6  92.0    1.6 89.24
 6.1    1.0   12.2 110.0    1.0 89.24
 3.5    2.0   23.5 110.0    1.9 89.11
 6.5    2.0   17.6 107.0    1.5 89.10
 5.7    1.0   13.8 115.0    2.7 88.06
 4.0    2.0   16.9 114.0    1.5 88.09
 9.0    2.0   23.6  92.0    0.9 88.13
 6.4    2.0   26.9 110.0    1.4 88.15
13.0    7.0   34.3 104.0    1.3 88.21
13.8    4.0   25.1  95.0    1.8 88.24
 3.1    1.0   21.3 100.0    3.0 88.27
 5.6    4.0   29.2 105.0    3.8 88.28
12.9    3.0   34.1 107.0    1.0 88.30
12.8    3.0   30.0 100.0    1.4 87.93
 8.3    2.0   17.7  99.0    1.2 87.41
 4.7    2.0   19.5 110.0    1.3 87.41
 9.2    2.0   18.5 100.0    1.0 87.38
 9.9    3.0   29.6 103.0    2.1 87.37
11.4    1.0   20.1 102.0    0.8 87.32
 4.2    3.0   20.9 108.0    1.0 87.30
13.3    2.0   27.0 100.0    1.2 87.30
 7.3    1.0   27.0 102.0    1.6 87.30
 3.9    1.0   12.3  30.0    0.9 87.30
12.7    1.5   26.9  92.0    1.0 87.18
12.9    5.0   27.8 104.0    1.2 87.16
10.0    2.0   29.7 103.0    1.3 87.14
14.5    2.0   30.2 108.0    1.3 87.10
10.5    1.5   30.4 103.0    1.2 87.09
12.8    3.0   33.7 102.0    0.9 87.07
```

INPUT DATA FILE FOR IRE.FOR

IREAUC.DAT

0.100	6.052
0.200	8.907
0.300	11.199
0.400	13.203
0.500	15.026
0.600	16.721
0.700	18.322
0.800	19.848
0.900	21.315
1.000	22.733
1.100	24.110
1.200	25.452
1.300	26.764
1.400	28.051
1.500	29.315
1.600	30.559
1.700	31.786
1.800	32.997
1.900	34.194
2.000	35.380
2.100	36.551
2.200	37.711
2.300	38.862
2.400	40.005
2.500	41.140
2.600	42.268
2.700	43.391
2.800	44.507
2.900	45.619
3.000	46.727
3.100	47.830
3.200	48.930
3.300	50.027
3.400	51.121
3.500	52.213
3.600	53.302
3.700	54.389
3.800	55.475
3.900	56.560
4.000	57.643
4.100	58.725
4.200	59.807
4.300	60.889
4.400	61.969
4.500	63.050
4.600	64.131
4.700	65.212
4.800	66.294
4.900	67.376
5.000	68.458
5.100	69.542
5.200	70.626
5.300	71.711
5.400	72.797
5.500	73.885
5.600	74.973
5.700	76.063
5.800	77.155
5.900	78.248
6.000	79.343
6.100	80.440