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**"HIFI"
A Computer Code for Projectile
Fragmentation Accompanied
by Incomplete Fusion**

J. R. Wu

**OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY**

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ACCOMPANIED BY INCOMPLETE FUSION

J. R. Wu

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It is subject to revision or correction and therefore does not represent a
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I. INTRODUCTION

In this report, a brief summary of a model proposed to describe projectile fragmentation accompanied by incomplete fusion and the instructions for the use of the computer code "HIFI" are given. The code "HIFI" calculates single inclusive spectra, coincident spectra and excitation functions resulting from particle-induced reactions (see Section II). It is a multi-purpose program which can calculate any type of coincident spectra as long as the reaction is assumed to take place in the two steps described below.

The program is written for use on the ORNL IBM 360 and 370 computers. A core of 350 K bytes is required to run this code. However, the amount of core can be reduced by modifying the arrays YSEC (15, 10, 200) and PYYY (13, 10, 200) to smaller dimensions (see Section IV).

Execution time depends strongly on the input parameters. For the reaction $^{160}\text{Gd}(^{12}\text{C}, \alpha\gamma)$ at $E = 200$ MeV, where α energy windows $122 \leq E_\alpha \leq 160$ MeV were chosen with 2 MeV steps and θ_α was fixed at 20° , the program required ~ 30 seconds to calculate 6 particle (n,p,d,t, ^3He and α) spectra in coincidence with alpha particles for 15 angle pairs. However, ~ 15 minutes were required when alpha energy windows of $26 \leq E_\alpha \leq 160$ MeV were used. Most of the computing time is used in the calculation of the evaporation cascade.

A summary of the model and types of calculations allowed are described in Section II. Section III lists the required input cards. In Section IV, a complete listing of the program is given. A sample input and output is given in Section V.

II. MODEL

The model, which is based on projectile fragmentation, pre-equilibrium emission and evaporation mechanisms, is formulated to describe particle-particle angular correlations and particle- γ correlations in complex projectile induced reactions. The reaction is assumed to take place in two steps. The projectile, p , breaks up in the first step producing a fast beam-velocity ejectile, x , while the remainder of the projectile fuses with the target, A . In the second step, the composite nucleus, R^* , decays via particle and γ emission, i.e. $p + A \rightarrow x + R^*$, $R^* \rightarrow y + \text{anything}$, where y can decay by particle or γ -ray emission. A schematic diagram describing this projectile breakup mechanism and the associated velocity diagram in which the recoil effect due to multiparticle emission is neglected is shown on figure 1. A simple planewave projectile breakup model is employed to describe the production of fast beam-velocity particles (lower vertex). In this model, the projectile breakup is described as a fast process governed by the distribution of nucleon momenta in the projectile before the collision. The fragment emitted is produced from the coupling of the internal Fermi momentum $\vec{p}'$ and the c.m. momentum $\frac{m_x}{m_p} \vec{p}_p$. Here, $\vec{p}_p$ is the momentum of the incident projectile, and m_x and m_p are masses of fragment x and the projectile, respectively. The deexcitation of the recoiling nucleus (upper vertex) is described by pre-equilibrium particle emissions (exciton model) followed by evaporation where multiparticle emissions are allowed. The laboratory differential cross section for the fragment x and the decay particle y in coincidence is given by¹

FIGURE 1

$$\begin{aligned}
\frac{d^4 \sigma}{d\Omega_x d\Omega_y dE_x dE_y} &= \frac{d^2 \sigma}{d\Omega_x dE_x} \frac{d^2 P(U, \vec{q})}{d\Omega_y dE_y} \delta(\vec{p}_p - \vec{p}_x - \vec{q}) \delta(E_p - E_x - E_R - U - Q) \\
&= N_x P_x m_x \left| \phi(\vec{p}_x - \frac{m_x}{m_p} \vec{p}_p) \right|^2 \sigma_R(U) \frac{d^2 P(U, \vec{q})}{d\Omega_y dE_y} \\
&\quad \delta(\vec{p}_p - \vec{p}_x - \vec{q}) \delta(E_p - E_x - E_R - U - Q)
\end{aligned} \tag{1}$$

where $\vec{q}$ is the momentum of recoiling nucleus R, E_p , E_x , E_R , U and Q are, respectively, the incident energy, the energy of observed fragment x , K.E. of the recoiling nucleus, excitation energy of the recoiling nucleus and the reaction Q -value. Two δ functions are to assure conservation of linear momentum and energy. $\sigma_R(U)$ is the fusion cross section for the transferred fragment f and the target nucleus at excitation energy U . N_x is a normalization constant which may contain the information about the angular momentum window (or range of impact parameters) for projectile breakup. The momentum distribution of x in the rest frame of projectile is assumed to be of the form²

$$\begin{aligned}
\left| \phi(\vec{p}') \right|^2 &= \left| \phi(\vec{p}_x - \frac{m_x}{m_p} \vec{p}_p) \right|^2 \\
&= \left(\frac{1}{\sqrt{2\pi} \sigma} \right)^3 \exp \left(- \frac{p'^2}{2\sigma^2} \right)
\end{aligned} \tag{2}$$

$$\text{with } \sigma^2 = \sigma_0^2 \frac{(m_p - m_x) m_x}{m_p - 1} \tag{3}$$

here σ_0 is related to the Fermi momentum of the projectile or nuclear temperature T by $\sigma_0^2 = mT \left(\frac{m_p - 1}{m_p} \right)$ where m is nucleon mass. The laboratory energy distributions of the decay particles $\frac{d^2 P(U, \vec{q})}{d\Omega_y dE_y}$ is transformed from

the c.m. distribution of the recoiling system, $\frac{d^2 P'(U, \vec{q})}{d\Omega' y_R dE' y_R}$, calculated at an excitation energy U and recoil momentum $\vec{q}$ using pre-equilibrium and evaporation models. The details of these models can be found in ref. 3. In the pre-equilibrium calculations, the initial particle-hole configuration (P_0, h_0) is taken to be $(f+1, 1)$. For the sake of simplicity, we have assumed that the angular distribution of the decay particle is isotropic in the c.m. frame of the recoiling system. Further we have ignored the angular momentum effect and the small recoil effect due to multiparticle emissions. The fusion cross section σ_R and inverse reaction cross sections needed are calculated using the model of ref. 4. Reaction Q -values and particle separation energy are calculated from mass table of ref. 5. In the following, a summary is given for a few selected reactions that can be calculated with this code.

1. Angular correlations between a fast projectile-like fragment and particles decaying from the recoiling system R^* .
2. Correlations of the final residual nuclear products and the fast projectile-like fragment. The final residual nuclear products are identified from fragment- γ coincident measurements. Note that the decay can be either by pre-equilibrium emission only or by pre-equilibrium emission plus evaporation.
3. Single inclusive pre-equilibrium emission spectra.
4. Single inclusive pre-equilibrium emission plus evaporation spectra.
5. Excitation functions.

The code "HIFI" uses the projectile fragmentation model² to calculate the

distribution of fast beam-velocity fragment³ which must be lighter than projectile. However, $d\sigma^2/d\Omega_X dE_X$ may be provided by user, if the fragment is heavier than the projectile or the fragment is produced by other process (see Section III INPUT for details). The decay channels may include up to a maximum of 10 particle types (See INPUT).

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REFERENCES

1. J. R. Wu and I. Y. Lee, submitted to Phys. Rev. Lett., and reference therein.
2. H. Feshbach and K. Kuang, Phys. Lett. 47B, 300 (1973); A. S. Goldhaber, Phys. Lett. 53B, 306 (1974); D. K. Scott, LBL preprint (1978).
3. J. R. Wu and C. C. Chang, Phys. Rev. C 16, 1812 (1977); Phys. Rev. C 17, 1540 (1978).
4. T. D. Thomas, Phys. Rev. 116, 703 (1959); J. R. Huizenga and G. Igo, Nucl. Phys. 29, 462 (1962); D. B. Beard and A. McClellan, Phys. Rev. 140, B888 (1965).
5. J. H. Mattauch, W. Thiele and A. H. Wapstra, Nucl. Phys. 67, 32 (1965); G. T. Garvey et al., Rev. Mod. Phys. 41, 51 (1969).

III. INPUT

Card Set No. 1 (175 cards)

Mass Table: This set of data is read in only once and stored in the common block / com7 /, unless the program is reloaded.

* { The following cards can be repeated in different ways if more than one type of calculation is requested. These cards are to be provided by the user.

Card Set No. 2 (1 card)

Read (5,5) [IOP(I0), I0=1,20], [Name(I1), I1 = 1, 60]

5 FØRMAT (20I1,60A1)

IOP(1): Stop execution, if IOP(1) = 9.

IOP(2): Pauli-correction is included in pre-equilibrium calculation, if IOP(2) ≠ 0.

IOP(3): Coincidence spectra are calculated if IOP(3) = 0,
 { pre-equilibrium singles spectra are calculated for projectile plus target system if IOP(3) ≠ 0,
 { if IOP(3) = 2, provide initial particle-hole number (see card set No. 4), otherwise P_0 = projectile nucleon number + 1 h_0 = 1.

IOP(4): Maximum exciton number to be included in the calculation

$\bar{n} = \sqrt{2gE}$ if IOP(4) = 0

$\bar{n} = \sqrt{1.33gE}$ if IOP(4) = 1

$$\bar{n} = \sqrt{gE} \text{ if } IOP(4) = 2$$

$$\bar{n} = \sqrt{0.67gE} \text{ if } IOP(4) = 3$$

$$\bar{n} = 2 \times IOP(4) + P_0 + h_0 \text{ if } 4 \leq IOP(4) \leq 9.$$

IOP(5): Number of terms to be used for gaussian integration

$$IOP(5) = 1, N = 10 \text{ terms}$$

$$IOP(5) = 2, N = 20 \text{ terms}$$

$$IOP(5) = 3, N = 40 \text{ terms.}$$

IOP(6): Number of particle types to be included in the pre-equilibrium and equilibrium calculation. Maximum will be 10 if IOP(6) = 0, the particle types are arranged in the order of n, p, d, t, ^3He , α , ^5He , ^5Li , ^6Li , ^7Li .

Example: IOP(6) = 6, then n, p, d, t, ^3He and α emissions are calculated.

IOP(7): Number of partial waves $\ell = 50 \times IOP(7)$ (maximum $\ell = 200$ in this version) to be included in the calculation for reaction cross section σ_R for $A \geq 2$. The parabolic model is used for complex projectiles, while for n and p the method of ref. 4 is used.

IOP(8): The peripheral width (ΔR) for a fragment x that can emerge in two spherical nuclei collisions is calculated using the clean cut geometry of the fireball model and the spectra are multiplied by the factor $[2\pi R_t \Delta R / \pi(R_p + R_t)^2]$.

$$\frac{A!}{N!Z!} \left(\frac{Z_p}{A_p}\right)^Z \left(\frac{N_p}{A_p}\right)^N, \text{ if } IOP(8) \neq 0.$$

IOP(9): If the spectrum of fragment x is to be provided by user, set
IOP(9) $\neq$ 0 (see card set No. 6) otherwise set IOP(9) = 0.

IOP(10): Printout only final spectra and yields of residual nuclei
if IOP(10) = 0, print out everything if IOP(10) $\neq$ 0.

IOP(11): Number of protons to be emitted in the evaporation
calculations. Maximum number is 9.

IOP(12): Number of neutrons to be emitted in the evaporation
calculations. Maximum number is 12 if IOP(12) = 9.
When both IOP(11) = 0 and IOP(12) = 0, evaporation calcu-
lation is deleted.

IOP(13): Only B.E. effect is considered in the evaporation cascade,
if IOP(13) = 0.

Coulomb barrier effect is included to inhibit charge par-
ticle emission in the evaporation cascade, if IOP(13) $\neq$ 0.

IOP(14) to IOP(20): Not used, leave these blank.

NAME: Title

Card Set No. 3 (2 cards)

Read (5,4) ZP,AP,ZT,AT,ZX,AX,ELAB,SIGR,XK,ZETA,DE

4 FØRMAT(8F10.3)

ZP: Projectile charge number

AP: Projectile mass number

ZT: Target charge number

AT: Target mass number

ZX: Fragment X charge number } Fast ejectile x
 AX: Fragment X mass number } used for coincident
 calculation only
 ELAB: Incident lab. energy
 SGR: Total reaction cross section (barns) σ_R ,
 $\text{SGR} > 0$, provided by user
 $\text{SGR} \leq 0$ (any negative number), σ_R will be calculated inter-
 nally using parabolic model and $|\text{SGR}|$ will be used as a
 normalization if $\text{SGR} < 0$
 XK: Level density parameter $a = A/xK$, if $xK \leq 0$, $xK = 8$
 ZETA: Transition matrix element scaling factor used in the pre-
 equilibrium calculation
 if $\text{ZETA} < 0$, $\text{ZETA} = 200$
 DE: Energy step size to be used for spectra.

Card Set No. 4 (1 card)

* { Ignore this card, if $\text{IOP}(3) = 0$ and 1 options are chosen.
 { Provide this card only if $\text{IOP}(3)=2$,

 READ(5,4) Po, Ho

 Po: initial particle number

 Ho: initial hole number

*NOTE: If singles pre-equilibrium and evaporation spectra are to be
 calculated only, repeat card set Nos. 2, 3, and 4 (if needed) and
 ignore the card set Nos. 5 and 6.

Card Set No. 5 (1 card)

Read(5,4) ANGX, EXI, EXF, ANGI, ANGF, DANG, PPO, EYW

ANGX: Lab. angle of fast beam-velocity fragment x

EXI: Energy window for fragment x (low energy end)

EXF: Energy window for fragment x (high energy end)

AngI: Lab. angular range for decay particle y (low angle)

AngF: Lab. angular range for decay particle y (high angle)

(AngF must be greater than AngI in the region 0 to 360°)

DANG: Angular step size (maximum angle pairs are 15 in the present version)

ppo: Momentum distribution width parameter σ_0 (MeV/C)

EYW: Energy integrated yield for the decay particle y will be carried out for two regions; 1) over entire energy region, 2) over $E \geq EYW$.

Card Set No. 6 ($\text{INT}(\frac{NL-1}{8}) + 1$ cards)

* { Read this set only if IOP(9) ≠ 0, i.e. the spectrum of fragment x is provided by user, otherwise ignore this set.

Read (5,4) (XSEC(ML), ML=1, NL)

NL = (EXF-EXI)/DE + 1

XSEC: Energy spectrum of fragment X from $E = EXI$ to EXF with energy step DE.

NOTE: (1) Card Set Nos. 5 and 6 (if any) can be repeated for another set of input values.

(2) Set ANGX < 0 to return to card set No. 2 for a new case.

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IV. PROGRAM LISTING

```

C
C-----MAIN-----
C
ISN 0002      COMMON /CONT/PI,AMU,RAD,LEG,HB,POW
ISN 0003      COMMON /COM1/IOP(20),NBAR
ISN 0004      COMMON /COM2/AP,ZP,AT,ZT,AX,ZX,AF,ZF,AC,ZC,G,ZETA,P0,H0,Q(19),C(19)
ISN 0005      COMMON /COM3/A(19),Z(19),S(19),SYM(19)
ISN 0006      COMMON /COM4/PY(200),KED,YY(10,200)
ISN 0007      COMMON /COM5/SIGN(10,200),EN(200),NPT
ISN 0008      REAL*8 WI(20),XI(20)
ISN 0009      COMMON /COM6/WI,XI,NTERM
ISN 0010      COMMON /COM7/NMIN(100),NMAX(100),H(19,100),GN(154),GZ(100),GA(253)
ISN 0011      COMMON /COM8/SE(13,10,10),PS(10,200),YYY(10,200),DE,XK
ISN 0012      COMMON /COM9/RSIG(13,10),PYYY(13,10,200)
ISN 0013      COMMON /COM10/VCOU(10)
ISN 0014      REAL SIGC(200),YSEC(15,10,200),SIGF(200),XSEC(200),ZSEC(200)
ISN 0015      REAL EMASS(19),RMASS(19),THA(15),THB(15),XYSEC(15)
ISN 0016      REAL TRSIG(13,10)
ISN 0017      INTEGER MCME(19)
ISN 0018      LOGICAL*1 NAME(60)

C
C-----READ IN MASS TABLE AND STORED IN /COM7/-----
C
ISN 0019      READ (5,1) (NMIN(N0),N0=1,100)
ISN 0020      READ (5,1) (NMAX(N0),N0=1,100)
ISN 0021      1  FORMAT (20A4)
ISN 0022      DO 3 N0=1,100
ISN 0023      READ (5,1) (H(N1,N0),N1=1,19)
ISN 0024      3  CONTINUE
ISN 0025      READ (5,4) (GN(N4),N4=1,154)
ISN 0026      READ (5,4) (GZ(N4),N4=1,100)
ISN 0027      READ (5,4) (GA(N4),N4=1,253)
ISN 0028      4  FORMAT (8F10.3)

C
C-----END OF MASS TABLE INPUT-----
C-----
C
C-----INPUT DATA-----
C
ISN 0029      99999 CONTINUE
ISN 0030      READ (5,5) (IOF(I0),I0=1,20),(NAME(I1),I1=1,60)
ISN 0031      5  FORMAT (20I1,6CA1)

C
C-----NAME--TITLE

```

```

C-----IOP(1)--9, STOP
C-----IOP(2)--NOT 0, PAULI CORRECTION INCLUDED
C-----IOP(3)--NOT 0, DO PRE-EQ. EMISSION (SINGLES)
C-----IOP(4)--0,N=SQRT(2GE),1,N=SQRT(1.33GE),2,N=SQRT(GE),3,N=SQRT(0.67GE)
C-----IOP(5)--GAUSS INTEGRATION,1=10TERMS,2=20TERMS,3=40 TERMS
C-----IOP(6)--NO. OF PARTICLE TYPES TO BE CALCULATED FOR PRE-EQ. EMISSIONS
C
C          MAX. WILL BE 10 IF SET IOP(6)=0
C-----IOP(7)--NOT 0 USE PARABOLIC MODEL TO CALCULATE REACTION CROSS SECTION
C
C          1,L=50,2,L=100,3,L=150,4,L=200
C-----IOP(8)--NOT 0, CALCULATE DR FOR FRAGMENT X THAT CAN COME OUT
C-----IOP(9)--NOT 0, READ IN SINGLE SPECTRUM PROB. OR CROSS SEC.
C-----IOP(10)--NOT 0, PRINT ALL OUTPUTS, 0, PRINT ONLY FINAL SPECTRA
C-----IOP(11)--NO. OF PROTON MAX 9
C-----IOP(12)--NO. OF NEUTRONS IF 9 MAX. WILL BE 12
C-----IOP(13)--NOT 0, COULOMB BARRIER EFFECT IS CONSIDERED
C

```

ISN 0032

```

C-----
C          IF (IOP(1) .EQ. 9) STOP
C-----
C

```

ISN 0034

```

C          READ (5,4) ZP,AP,ZT,AT,ZX,AX,ELAB,SIGR,XK,ZETA,DE

```

```

C-----ZP--PROJECTILE CHARGE NO.
C-----AP--PROJECTILE MASS NO.
C-----ZT-- TARGET CHARGE NO.
C-----AT-- TARGET MASS NO.
C-----ZX-- OBSERVED FRAGMENT X CHARGE NO.
C-----AX-- OBSERVED FRAGMENT X MASS NO.
C-----ELAB--LAB. INCIDENT ENERGY
C-----SIGR--TOTAL REACTION CROSS SECTION (.GT. 0)
C
C          =0, CROSS SEC. CALCULATED INTERNALLY
C
C          .LT. 0, CROSS SEC. CALCULATED INTERNALLY AND ABS(SIGR) USED AS A
C
C          NORMALIZATION FACTOR
C-----XK-- LEVEL DENSITY PARAMETER(A/XK), IF .LT. 0, DEFAULT IS 8.
C-----ZETA--MATRIX ELEMENT SCALING FACTOR, IF .LT. 0, DEFAULT IS 200
C-----DE--ENERGY INCREMENT FOR CALCULATED SPECTRUM
C
C-----

```

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ISN 0035      LT=IOP(7)*50
ISN 0036      IOP6=IOP(6)
ISN 0037      IF (IOP(6) .EQ. 0) IOP6=10
ISN 0039      KED=DE
ISN 0040      IF (XK .LE. 0.) XK=8;
ISN 0042      IF (ZETA .LT. 0.) ZETA=200.
C-----PRINT OUT ALL INPUT DATA-----
ISN 0044      WRITE (6,6) (NAME(I1),I1=1,60),((I0,IOP(I0)),I0=1,20)
ISN 0045      6   FORMAT (1H1/1X1H*,13('---INPUT---'),1H*//30X60A1//5(5X'IOP(',I2,')=
                X',I1)))
ISN 0046      WRITE (6,7) ZP,AP,ZT,AT,ZX,AX,ELAB,SIGR,XK,ZETA,DE
ISN 0047      7   FORMAT (/5X'PROJECTILE Z=',F10.2,5X'PROJECTILE A=',F10.2/
                5X'TARGET Z=',F10.2,5X'TARGET A=',F10.2/5X'FRAGMENT-X Z=',F10.2,
                5X'FRAGMENT-X A=',F10.2/5X'LAB. INCIDENT ENERGY=',F10.2,'(MEV)'/
                5X'SIGR=',F10.4,5X'LEVEL DENSITY PARAMETER=A/',F5.1/5X'MATRIX ELEM
                ENT SCALING FACTOR=',F10.2/5X'ENERGY STEP SIZE FOR SPECTRUM=',F10.
                A2///)
ISN 0048      WRITE (6,8)
ISN 0049      8   FORMAT (1X8('---INPUT END---')//1X10('===OUTPUT===')//)
ISN 0050      IF (ICP(12) .EQ. 9) IOP(12)=12
ISN 0052      ECM=AT/(AP+AT)*ELAB
ISN 0053      IF (SIGR .GT. 0.) GO TO 10
ISN 0055      CALL PARAB(ZP,AP,ZT,AT,LT,ECM,ECM,NPS,SIGC)
ISN 0056      IF (SIGR .LT. 0.) SIGC(1)=ABS(SIGR)*SIGC(1)
ISN 0058      SIGR=SIGC(1)
ISN 0059      10  CONTINUE
ISN 0060      NTERM=5*IOP(5)
ISN 0061      IF (IOP(5) .EQ. 3) NTERM=20
ISN 0063      CALL GAUSS(IOP(5),WI,XI)
ISN 0064      CALL MASS(ZP,AP,PMASS,PDM)
ISN 0065      CALL MASS(ZT,AT,TMASS,TDM)
ISN 0066      IF (IOP(3) .EQ. 0) GO TO 11
ISN 0068      ZC=ZP+ZT
ISN 0069      AC=AP+AT
ISN 0070      ZF=ZP
ISN 0071      AF=AP
ISN 0072      P0=AP+1.
ISN 0073      H0=1.
ISN 0074      IF (IOP(3) .EQ. 2) READ (5,4) P0,H0
ISN 0076      CALL MASS(ZC,AC,CMASS,CDM)
ISN 0077      QF=(PMASS+TMASS-CMASS)*AMU
ISN 0078      UX=ECM+QF

```

```

ISN 0079      QQ=0.
ISN 0080      NQE=UX/DE
ISN 0081      IF (NQE .GT. 200) NQE=200
ISN 0083      GO TO 212
ISN 0084      11  CONTINUE
ISN 0085      CALL MASS(ZX,AX,XMASS,XDM)
ISN 0086      ZF=ZP-ZX
ISN 0087      AF=AP-AX
ISN 0088      ZC=ZF+ZT
ISN 0089      AC=AF+AT
ISN 0090      PO=AF+1.
ISN 0091      HO=1.
ISN 0092      IF (IOP(8) .EQ. 0 .OR. IOP(9) .NE. 0) GO TO 19
ISN 0094      IZP=ZX
ISN 0095      IAP=AX
ISN 0096      INP=IAP-IZP
ISN 0097      YIJ=1.
ISN 0098      DO 16 IJ=1,INP
ISN 0099      XIJ=FLOAT(IZP+IJ)/FLOAT(IJ)
ISN 0100      16  YIJ=YIJ*XIJ
ISN 0101      IF (IAP .LE. 1) YIJ=1.
ISN 0103      YIJ=YIJ*(ZP/AP)**IZP*((AP-ZP)/AP)**INP
ISN 0104      RP=1.2*AP**POW
ISN 0105      RT=1.2*AT**POW
ISN 0106      RMAX=RP+RT
ISN 0107      KBM=RMAX/0.1
ISN 0108      DO 17 KB=1,KBM
ISN 0109      BK=FLOAT(KBM+1-KB)*0.1
ISN 0110      CALL ZNUM(RP,RT,BK,F,DELF)
ISN 0111      BAP=AP*(1.-F)
ISN 0112      IF (BAP .LT. AX) GO TO 18
ISN 0114      17  CONTINUE
ISN 0115      18  DBR=RMAX-BK
ISN 0116      SIGR=SIGR*2.*DBR*RT/RMAX**2*YIJ
ISN 0117      WRITE (6,211) DBR,YIJ
ISN 0118      211  FORMAT (/5X'PERIPHERAL WIDTH FOR FRAGMENT-X=',F10.2,'(FM)',5X'PROB
X. OF BEING X=',1PE11.4)
ISN 0119      19  CONTINUE
ISN 0120      CALL MASS(ZF,AF,FMASS,FDM)
ISN 0121      CALL MASS(ZC,AC,CMASS,CDM)
ISN 0122      QQ=(XMASS+CMASS-(PMASS+TMASS))*AMU
ISN 0123      QF=(FMASS+TMASS-CMASS)*AMU
ISN 0124      IF (AF .LE. 0.) QF=0.
ISN 0126      212 CONTINUE
ISN 0127      CONST=2.656/(PI*1.0544)**2/HB
ISN 0128      G=6.*AC/XK/(PI*PI)

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ISN 0129      P00=SQRT(ELAB*(ELAB+2.*AMU*PMASS))
ISN 0130      IF (IOP(3) .NE. 0) GO TO 213
ISN 0132      IF (AF .LE. 0.) GO TO 213
ISN 0134      POX=XMASS/PMASS*PC0
ISN 0135      CALL PARAB(ZF,AF,ZT,AT,LT,ECM,DE,NPT,SIGF)
C-----CALCULATE B.E. AND INVERSE REACTION CROSS SEC.-----
ISN 0136      213 CONTINUE
ISN 0137      QMIN=100.
ISN 0138      DO 20 I=1,IOP6
ISN 0139      VCOU(I)=0.
ISN 0140      CALL MASS(Z(I),A(I),EMASS(I),EDM)
ISN 0141      CALL MASS(ZC-Z(I),AC-A(I),RMASS(I),RDM)
ISN 0142      Q(I)=(EMASS(I)+RMASS(I)-CMASS)*AMU
ISN 0143      IF (QMIN .GT. Q(I)) QMIN=Q(I)
ISN 0145      C(I)=(2.*S(I)+1.)*EMASS(I)*RMASS(I)/CMASS*CONST
ISN 0146      CALL PARAB(Z(I),A(I),ZC-Z(I),AC-A(I),LT,ECM,DE,NPT,SIGC)
ISN 0147      DO 20 J=1,NPT
ISN 0148      IF (I .EQ. 1) EN(J)=FLOAT(J)*DE
ISN 0150      SIGN(I,J)=SIGC(J)
ISN 0151      IF (SIGN(I,J) .LE. 0. .AND. IOP(13) .NE. 0) VCOU(I)=EN(J)
ISN 0153      20 CONTINUE
ISN 0154      IF (IOP(11) .EQ. 0 .AND. IOP(12) .EQ. 0) GO TO 2010
C-----CALCULATE ALL SEPARATION ENERGIES FOR DECAY CHAIN
ISN 0156      IOP11=IOP(11)+1
ISN 0157      IOP12=IOP(12)+1
ISN 0158      DO 2001 KA=1,IOP12
ISN 0159      XKA=KA-1
ISN 0160      DO 2001 KB=1,IOP11
ISN 0161      XKB=KB-1
ISN 0162      ZCC=ZC-XKB
ISN 0163      ACC=AC-XKA-XKB
ISN 0164      CALL MASS(ZCC,ACC,CCMAS,CCDM)
ISN 0165      DO 2001 I=1,IOP6
ISN 0166      CALL MASS(ZCC-Z(I),ACC-A(I),SMASS,SDM)
ISN 0167      SE(KA,KB,I)=(SMASS+EMASS(I)-CCMAS)*AMU
ISN 0168      2001 CONTINUE
ISN 0169      DO 2002 KA=1,13
ISN 0170      DO 2002 KB=1,10
ISN 0171      2002 TRSIG(KA,KB)=0.
ISN 0172      2010 CONTINUE
C
C-----PRINT OUT SOME OF USEFUL QUANTITIES CALCULATED ABOVE-----
ISN 0173      WRITE (6,21) P00,ECM,SIGR,QQ,QF,G,P0,H0,((I,Q(I)),I=1,IOP6)
ISN 0174      21 FORMAT (/5X'INCIDENT MOMENTUM=',F10.2,'(MEV/C)'/5X'C.M. ENERGY=',F
X10.2,5X'REACTION CROSS SEC.=',F10.4,'(BARN)'/5X'TWO-BODY Q-VALUE='
X,F10.4,'(MEV)'/5X'COMPOUND FORMATION Q-VALUE=',F10.4,'(MEV)'/
X5X'SINGLE PARTICLE STATE DENSITY=',F10.4/5X'INITIAL PARTICLE NO.=',
X,F5.0,5X'HOLE NO.=',F5.0/5X'*****B.E. FOR ALL EMITTED PARTICLES***
X*1/(5X'2*(1+10.3)=.F10.4)')

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ISN 0175      IF (IOP(10) .EQ. 0) GO TO 26
ISN 0177      IF (IOP(11) .EQ. 0 .AND. IOP(12) .EQ. 0) GO TO 92
ISN 0179      DO 29 I=1,IOP6
ISN 0180      WRITE (6,27) SYM(I)
ISN 0181      27  FORMAT (/5X'*****SEPARATION ENERGY FOR ',A3,' IN THE DECAY CHAIN**
                X****/)
ISN 0182      DO 29 KA=1,IOP12
ISN 0183      WRITE (6,28) (SE(KA,KB,I),KB=1,IOP11)
ISN 0184      28  FORMAT (1X10(1X1PE11.4))

ISN 0185      29  CONTINUE
ISN 0186      92  CONTINUE
ISN 0187      WRITE (6,22) EN(1),EN(NPT),DE
ISN 0188      22  FORMAT (/5X'*****CALCULATED REACTION CROSS SEC. IN BARN FOR ALL PA
                RICLES*****'/5X'FROM',F10.2,' MEV TO ',F10.2,' MEV WITH',F10.2,'
                XMEV STEP'//)
ISN 0189      DO 24 I=1,IOP6
ISN 0190      WRITE (6,23) SYM(I),(SIGN(I,J),J=1,NPT)
ISN 0191      23  FORMAT (/5X'-----',A3,'-----'/(10(1X1PE11.4)))
ISN 0192      24  CONTINUE
ISN 0193      IF (IOP(3) .NE. 0) GO TO 214
ISN 0195      IF (AF .LE. 0.) GO TO 26
ISN 0197      WRITE (6,25) (SIGF(J),J=1,NPT)
ISN 0198      25  FORMAT (/5X'REACTION CROSS SEC. FOR TRANSFERRED FRAGMENT AND TARGE
                XT'/(10(1X1PE11.4)))
ISN 0199      26  CONTINUE
C-----
C
ISN 0200      30  READ (5,4) ANGX,EXI,EXF,ANGI,ANGF,DANG,PP0,EYW
C
C-----THIS CARD MAY BE REPEATED FOR DIFFERENT ANGLE AND ENERGY WINDOW FOR X
C-----ANGX--LAB. ANGLE OF FRAGMENT X
C-----EXI--ENERGY WINDOW FOR X (LOW END)
C-----EXF--ENERGY WINDOW FOR X (HIGH END)
C-----ANGI--FIRST LAB. ANGLE FOR OTHER FRAGMENTS IN COINCIDENCE WITH X
C-----ANGF-- LAST LAB. ANGLE FOR OTHER FRAGMENTS IN COINCIDENCE WITH X
C-----DANG--ANGLE INCREMENT
C-----PP0--MOMENTUM DISTRIBUTION WIDTH PARAMETER
C
C-----
ISN 0201      IF (ANGX .LT. 0.) GO TO 99999
ISN 0203      DO 31 K=1,15
ISN 0204      DO 31 I=1,10
ISN 0205      DO 31 J=1,200
ISN 0206      31  YSEC(K,I,J)=0.

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ISN 0207      THX=ANGX*PI/180
ISN 0208      AA=1.+CMASS/XMASS
ISN 0209      BB=P00*COS(THX)
ISN 0210      CC=P00*P00+2.*CMASS*AMU*(QQ-ELAB)
ISN 0211      DD=BB*BB-AA*CC
ISN 0212      IF (DD .LT. 0.) GO TO 30
C-----MAX. ALLOWED MOMENTUM FOR FRAGMENT X AT ANGLE X-----
ISN 0214      PMAX=(BB+SQRT(BB*BB-AA*CC))/AA
ISN 0215      EXMAX=SQRT(PMAX*PMAX+(XMASS*AMU)**2)-XMASS*AMU
ISN 0216      UMAX=(1.-PMASS/CMASS)*E_A3-QQ
ISN 0217      IF (EXF .GT. EXMAX) EXF=EXMAX
ISN 0219      NL=(EXF-EXI)/DE
ISN 0220      NL=NL+1
ISN 0221      IF (IOP(9) .NE. 0) READ (5,4) (XSEC(ML),ML=1,NL)
C-----START CALCULATING RECOILING NUCLEUS EXCITATION ENERGY, RECOLI ANGLE
C      VELOCITY AND DEEXCITATION USING EXCITON MODEL WITH ENERGY WINDOW EXI-EX
C
ISN 0223      PP0=PP0*SQRT((AF-AX)*AX/(AP-1.))
ISN 0224      NQE=0
ISN 0225      WA=(ANGF-ANGI)/DANG
ISN 0226      WA=WA+1
ISN 0227      DO 40 MA=1,NA
ISN 0228      THA(MA)=ANGI+FLOAT(MA-1)*DANG

ISN 0229      THB(MA)=THA(MA)
ISN 0230      IF (THB(MA) .GT. 180.) THB(MA)=THB(MA)-360.
ISN 0232      THA(MA)=THA(MA)*PI/180
ISN 0233      40 CONTINUE
ISN 0234      WRITE (6,509) ANGX,EXI,EXF,DE,PP0
ISN 0235      509 FORMAT (/1X120('=')/5X'FRAGMENT-X AT ANGLE=',F10.2,'(DEG)'/5X'ENER
XGY WINDOW FROM',F10.2,'(MEV) TO ',F10.2,'(MEV) WITH ',F10.2,'(M
XEV) STEP'/5X'MOMENTUM DISTRIBUTION WIDTH=',F10.2,'(MEV/C)'/
5X'*****CROSS SEC. PROJECTED ON FRAGMENT-X IN COINCIDENCE WITH OTH
XER FRAGMENT-Y AT VARIOUS ANGLE*****')
ISN 0236      DO 1000 ML=1,NL
ISN 0237      TLX=EXI+FLOAT(ML-1)*DE
ISN 0238      EYMAX=ELAB-TLX-3Q
ISN 0239      MAXEY=EYMAX
ISN 0240      NPE=MAXEY/KED
ISN 0241      IF (NPE .GT. 200) NPE=200
ISN 0243      IF (NQE .LT. NPE) NQE=NPE
ISN 0245      PLX=SQRT(TLX*(TLX+2.*XMASS*AMU))
ISN 0246      PLQ=SQRT(P00*P00-2.*BB*PLX+PLX*PLX)
ISN 0247      TLQ=SQRT(PLQ*PLQ+(CMASS*AMU)**2)-CMASS*AMU
ISN 0248      BCM=PLQ/(TLQ+CMASS*AMU)
ISN 0249      GCM=1./SQRT(1.-BCM*BCM)

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C-----EXCITATION ENERGY OF RECOILING NUCLEUS
ISN 0250      UX=ELAB-QQ-TLX-TLO
ISN 0251      ECMR=UX-QF
ISN 0252      IF (UX .GT. UMAX .OR. UX .LE. 0. .OR. ECMR .LE. 0.) GO TO 1000
C-----RECOILING ANGLE
ISN 0254      ARG=PLX/PLQ*SIN(THX)
ISN 0255      IF (ARG .GT. 1.) ARG=1.
ISN 0257      THQ=ARSIN(ARG)
ISN 0258      IF (IOP(9) .NE. 0) GO TO 507
C-----C.M. MOMENTUM IN THE PROJECTILE FRAME
ISN 0260      PCX=SQRT(PLX*PLX-2.*PLX*POX*COS(THX)+POX*POX)
C-----FIND THE REACTION CROSS SEC. FOR TRANSFERRED FRAGMENT AND TARGET
ISN 0261      N=5
ISN 0262      CALL YLG(EN,SIGF,NPT,ECMR,N,XSIGF,IER)
ISN 0263      IF (XSIGF .LE. 0.) GO TO 1000
C-----PROBABILITY OF FRAGMENT X(OR Y) AT C.M. FRAME OF PROJECTILE
ISN 0265      PPX=0.634936/PP0**3*EXP(-PCX*PCX*0.5/(PP0*PP0))
ISN 0266      PPX=PPX*100.
ISN 0267      XNORM=PPX*XSIGF*SIGR
C-----CALCULATE SINGLES SPECTRUM FOR FRAGMENT X-----
ISN 0268      XSEC(ML)=PLX*SQRT(PCX*PCX+(XMASS*AMU)**2)*XNORM
ISN 0269      507 CONTINUE
ISN 0270      IF (UX .LT. QMIN) TRSIG(1,1)=TRSIG(1,1)+XSEC(ML)*DE
ISN 0272      IF (XSEC(ML) .LE. 0.) GO TO 1000
ISN 0274      IF (UX .LT. QMIN) GO TO 1000
C-----CALCULATE PRE-EQ. EMISSION-----
ISN 0276      IF (IOP(4) .EQ. 0) NBAR=SQRT(2.*G*UX)
ISN 0278      IF (IOP(4) .EQ. 1) NBAR=SQRT(1.33*G*UX)
ISN 0280      IF (IOP(4) .EQ. 2) NBAR=SQRT(G*UX)
ISN 0282      IF (IOP(4) .EQ. 3) NBAR=SQRT(0.67*G*UX)
ISN 0284      IF (IOP(4) .GT. 3) NBAR=2*IOP(4)+INT(P0+H0)
ISN 0286      CALL PREQQ(UX,MCME)
C-----USE SAME REACTION CROSS FOR ALL DECAY CHAIN TO SPEED UP CALCULATIONS
ISN 0287      IF (IOP(11) .NE. 0 .OR. IOP(12) .NE. 0) CALL EVAPOR(UX,MCME)
C-----START CALCULATING LAB. SPECTRUM AND MAKE TRANSFORMATION-----
C-----ANGLE OF FRAGMENT -X IS DEFINED AS POSITIVE(COUNTERCLOCKWISE)-----

C-----RECOIL ANGLE IS DEFINED AS POSITIVE (CLOCKWISE)
C-----ANGLE OF FRAGMENT Y IS DEFINED AS POSITIVE(COUNTERCLOCKWISE)

ISN 0289      THQQ=THQ*DEG
ISN 0290      WRITE (6,508) THQQ,UX
ISN 0291      508 FORMAT (/20X'*****RECOIL ANGLE=',F7.2,'(DEG)*****EXCITATION ENERGY
                X=',F7.2,'(MEV)*****')

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ISN 0292      WRITE (6,510) TLX,(THB(MA),MA=1,NA)
ISN 0293      510  FORMAT (//1X111(' - ')/1X,'I',1XF7.2,' MEV I',30X'LAB. ANGLE FOR EMI
                XTTED PARTICLE Y ',31X'I'/1X111(' - ')/1X'I',2X'PARTICLE',3X'I',8(2XF
                X7.2,2X'I')/1X'I',13X'I',8(11(' - '),'I')/1X'I',4X'TYPE',5X'I',8(2XF7
                X.2,2X'I'))
ISN 0294      WRITE (6,512)
ISN 0295      512  FORMAT (1X111(' - '))
ISN 0296      DO 400 I=1,IOP6
ISN 0297      IF (MCME(I) .LT. 1) GO TO 400
ISN 0299      DO 298 MMA=1,15
ISN 0300      298  XYSEC(MMA)=0.
ISN 0301      DO 299 J=1,200
ISN 0302      ZSEC(J)=0.
ISN 0303      IF (J .LE. MCME(I)) ZSEC(J)=YY(I,J)
ISN 0305      299  CONTINUE
ISN 0306      DO 500 MA=1,NA
ISN 0307      THL=THA(MA)+THG
ISN 0308      SUM=0.
ISN 0309      DO 300 J=1,NPE
ISN 0310      YKE=J*KED
ISN 0311      PLY=SQRT(YKE*(YKE+2.*EMASS(I)*AMU))
ISN 0312      YEC=GCM*(YKE+EMASS(I)*AMU-BCM*PLY*COS(THL))-EMASS(I)*AMU
ISN 0313      IF (YEC .LE. 0.) GO TO 300
ISN 0315      PCY=SQRT(YEC*(YEC+2.*EMASS(I)*AMU))
ISN 0316      YCHE=CMASS/RMASS(I)*YEC
ISN 0317      IF (YCHE .GT. UX-Q(I) .OR. YCHE .LE. 0.) GO TO 300
ISN 0319      N=5
ISN 0320      CALL YLG(EN,ZSEC,MCME(I),YCHE,N,ZSIG,IER)
ISN 0321      IF (ZSIG .LE. 0.) GO TO 300
ISN 0323      SPEC=ZSIG*XSEC(ML)*PLY/PCY*0.25/PI*DE
ISN 0324      YSEC(MA,I,J)=YSEC(MA,I,J)+SPEC
ISN 0325      SUM=SUM+SPEC*DE
ISN 0326      300  CONTINUE
ISN 0327      XYSEC(MA)=SUM
ISN 0328      500  CONTINUE
ISN 0329      WRITE (6,511) (XYSEC(MA),MA=1,8),SYM(I),(XYSEC(MMA),MMA=9,NA)
ISN 0330      511  FORMAT (1X'I',13X'I',8(1PE11.4,'I')/1X'I',5XA3,5X'I',8(11(' - '),'I'
                X)/1X'I',13X'I',8(1PE11.4,'I'))
ISN 0331      WRITE (6,512)
ISN 0332      400  CONTINUE
ISN 0333      IF (IOP(11) .EQ. 0 .AND. IOP(12) .EQ. 0) GO TO 1000
ISN 0335      DO 2100 KA=1,13
ISN 0336      DO 2100 KB=1,13

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ISN 0337      2100  TRSIG(KA,KB)=TRSIG(KA,KB)+RSIG(KA,KB)*XSEC(ML)*DE
ISN 0338      1000  CONTINUE
C-----
ISN 0339      WRITE (6,1001) (XSEC(ML),ML=1,NL)
ISN 0340      1001  FORMAT (/5X'*****'((SINGLES ENERGY SPECTRUM FOR FRAGMENT-X))*****'
                X//((10(1X1PE11.4)))
ISN 0341      DO 1100 I=1,IOP6
ISN 0342      WRITE (6,1002)
ISN 0343      1002  FORMAT (/1X120(' '))
ISN 0344      WRITE (6,1003) SYM(I),DE,DE
ISN 0345      1003  FORMAT (/5X'*****',A3,'*****INCOINCIDENCE WITH X*****'/5X'*****EN
                XERGY SPECTRUM FROM',F5.1,' (MEV) WITH ',F5.1,' (MEV) STEP*****'/)
ISN 0346      DO 1100 MA=1,NA
ISN 0347      THAA=THA(MA)*DEG
ISN 0348      WRITE (6,1004) THAA,(YSEC(MA,I,J),J=1,NQE)
ISN 0349      1004  FORMAT (/5X'(((LAB. ANGLE=',F5.1,' (DEG)))')//((10(1X1PE11.4)))
ISN 0350      TOTAL=0.
ISN 0351      TOTAL=0.
ISN 0352      DO 1005 J=1,NQE
ISN 0353      WSEC=YSEC(MA,I,J)*DE
ISN 0354      IF (FLOAT(J)*DE.GT.EYW) TOTALW=TOTALW+WSEC
ISN 0355      1005  TOTAL=TOTAL+WSEC
ISN 0356      WRITE (6,1006) TOTAL,EYW,TOTALW
ISN 0357      1006  FORMAT (5X'*****INTEGRATED YIELD=',1XE11.4,'*****INTEGRATED YIELD
ISN 0358      XABOVE ',F5.1,' MEV=',1PE11.4,'*****')
ISN 0359      1100  CONTINUE
ISN 0360      IF (IOP(3) .EQ. 0) GO TO 220
ISN 0362      214  CONTINUE
ISN 0363      IF (IOP(4) .EQ. 0) NRAR=SQRT(2.*G*UX)
ISN 0365      IF (IOP(4) .EQ. 1) NRAR=SQRT(1.33*G*UX)
ISN 0367      IF (IOP(4) .EQ. 2) NRAR=SQRT(G*UX)
ISN 0369      IF (IOP(4) .EQ. 3) NRAR=SQRT(0.67*G*UX)
ISN 0371      IF (IOP(4) .GT. 3) NRAR=2*IOP(4)+INT(P0+H0)
ISN 0373      CALL PREQQ(UX,MCME)
ISN 0374      IF (IOP(11) .NE. 0 .OR. IOP(12) .NE. 0) CALL EVAPOR(UX,MCME)
ISN 0376      DO 216 KA=1,13
ISN 0377      DO 216 KB=1,10
ISN 0378      216  TRSIG(KA,KB)=RSIG(KA,KB)*SIGR
ISN 0379      DO 219 I=1,IOP6
ISN 0380      DO 217 J=1,NQE
ISN 0381      217  YY(I,J)=YY(I,J)*SIGR
ISN 0382      WRITE (6,218) SYM(I),DE,DE,(YY(I,J),J=1,NQE)
ISN 0383      218  FORMAT (/5X'*****',A3,' ENERGY SPECTRUM FROM',F5.1,' (MEV) WITH '
                X,F5.1,' (MEV) STEP*****'//((10(1X1PE11.4)))

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ISN 0002      SUBROUTINE PREQQ(E,MCME)
ISN 0003      COMMON /COM1/IOP(20),NBAR
ISN 0004      COMMON/COM2/AP,ZP,AT,ZT,AX,ZX,AF,ZF,AC,ZC,G,ZETA,P0,H0,Q(19),C(19)
ISN 0005      COMMON /COM3/A(19),Z(19),S(19),SYM(19)
ISN 0006      COMMON /COM4/PY(200),KED,YY(10,200)
ISN 0007      DIMENSION MCME(19),RATE(19)
ISN 0008      REAL WS(50),XLN(50),XLP(50),TPP(50),DELP(50),DELN(50),DELE(50)
ISN 0009      IMAX=(NBAR-INT(P0+H0))/2
ISN 0010      IF (IMAX .GT. 50) IMAX=50
ISN 0012      IOP6=IOP(6)
ISN 0013      IF (IOP(6) .EQ. 0) IOP6=10
ISN 0015      DO 2 L=1,IMAX
ISN 0016      P4=P0+FLOAT(L-1)
ISN 0017      H4=H0+FLOAT(L-1)
ISN 0018      WS(L)=0.
ISN 0019      DO 1 I=1,IOP6
ISN 0020      MCME(I)=0
ISN 0021      WY=0.
ISN 0022      CALL PREQ(E,P4,H4,I,WY,MAX,MIN,1)
ISN 0023      1 WS(L)=WS(L)+WY
ISN 0024      CALL XT(P4,H4,XLN(L),XLP(L),WS(L),TPP(L),E)
ISN 0025      DELP(L)=0.
ISN 0026      DELN(L)=0.
ISN 0027      DELE(L)=0.
ISN 0028      2 CONTINUE
ISN 0029      DELP(1)=1.
ISN 0030      DO 11 L=1,IMAX
ISN 0031      IF (TPP(L) .LE. 0.) TPP(L)=1.
ISN 0033      DELP(L+1)=DELP(L)*XLP(L)/TPP(L)
ISN 0034      DELN(L)=DELP(L)*XLN(L)/TPP(L)
ISN 0035      DELE(L)=DELP(L)*WS(L)/TPP(L)
ISN 0036      11 CONTINUE
ISN 0037      DO 31 L=1,IMAX
ISN 0038      31 DELP(L)=DELP(L)/TPP(L)
ISN 0039      DO 70 I=1,IOP6
ISN 0040      RATE(I)=0.
ISN 0041      DO 40 KE=1,200
ISN 0042      40 YY(I,KE)=0.
ISN 0043      DO 42 L=1,IMAX
ISN 0044      P4=P0+FLOAT(L-1)
ISN 0045      H4=H0+FLOAT(L-1)
ISN 0046      CALL PREQ(E,P4,H4,I,WY,MAX,MIN,0)
ISN 0047      IF (MAX .LT. 1) GO TO 42
ISN 0049      DO 41 KE=1,MAX

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ISN 0050      41      YY(I,KE)=YY(I,KE)+PY(KE)*DELP(L)
ISN 0051      RATE(I)=RATE(I)+WY*DELP(L)
ISN 0052      IF (MCME(I) .LT. MAX) MCME(I)=MAX
ISN 0054      42      CONTINUE
ISN 0055      IF (IOP(10) .LE. 1) GO TO 70
ISN 0057      MAXI=KED
ISN 0058      MAXF=MAX*KED
ISN 0059      WRITE (6,44) SYM(I)
ISN 0060      44      FORMAT (/10X'*****ENERGY SPECTRUM FOR ',A3,'*****'//)

ISN 0061      WRITE (6,45) MAXI,MAXF,(YY(I,KE),KE=1,MAX)
ISN 0062      45      FORMAT (/10X'*****ENERGY FROM',I5,' MEV TO ',I5,' MEV*****'//
      .10X'*****PROBABILITY*****'//((10(1X1PE11.4)))

ISN 0063      WRITE (6,46) RATE(I)
ISN 0064      46      FORMAT (/10X'*****TOTAL PROBABILITY=',1PE11.4,'*****'//)
ISN 0065      70      CONTINUE
ISN 0066      RETURN
ISN 0067      END

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ISN 0002      SUBROUTINE PARAB(ZI, AI, ZT, AT, LT, EF, DE, NPS, SIG)
ISN 0003      COMMON /CONT/PI, AMU, RAD, DEG, HB, POW
ISN 0004      REAL SIG(200), HW(200), BL(200)
ISN 0005      IF (AI .LT. 1.99) GO TO 200
ISN 0007      ZIT=ZI*ZT
ISN 0008      AM=AI*AT/(AI+AT)
ISN 0009      XMU=41.859/AM
ISN 0010      CXP=67.*EXP(2.03833*AI**POW)
ISN 0011      IF (AI .LT. 4.001) CXP=1100.
ISN 0013      RT=1.17*(AI**POW+AT**POW)
ISN 0014      IF (AI .LT. 4.001) RT=1.17*AT**POW
ISN 0016      DO 10 NE=1,200
ISN 0017      SIG(NE)=0.
ISN 0018      HW(NE)=0.
ISN 0019      BL(NE)=0.
ISN 0020      10  CONTINUE
ISN 0021      DO 30 NN=1,LT
ISN 0022      N=NN-1
ISN 0023      XN=N
ISN 0024      NLT=0
ISN 0025      XR=RT
ISN 0026      11  DR=(XR-RT)/0.574
ISN 0027      IF (DR .LE. -174.) GO TO 100
ISN 0029      FR=-1.44*ZIT/(XR*XR)-XN*(XN+1.)/XR**3*XMU+CXP/0.574*EXP(-DR)
ISN 0030      IF (ABS(FR) .LE. 0.00001) GO TO 20
ISN 0032      DFR=2.88*ZIT/XR**3+XN*(XN+1.)/XR**4*3.*XMU-CXP/0.574**2*EXP(-DR)
ISN 0033      DELTA=-FR/DFR
ISN 0034      IF (ABS(DELTA) .LE. 0.00001) GO TO 20
ISN 0036      XR=XR+DELTA
ISN 0037      NLT=NLT+1
ISN 0038      IF (XR .LE. 0.) XR=-XR
ISN 0040      GO TO 11
ISN 0041      20  DV2=2.88*ZIT/XR**3+XN*(XN+1.)*3.*XMU/XR**4-CXP/0.574**2*EXP(-DR)
ISN 0042      HW2=XMU*DV2
ISN 0043      HW(NN)=SQRT(ABS(HW2))
ISN 0044      BL(NN)=1.44*ZIT/XR+XN*(XN+1.)/XR**2*XMU*0.5-CXP*EXP(-DR)
ISN 0045      30  CONTINUE
ISN 0046      NPS=ABS(EF)/DE+0.01
ISN 0047      DO 40 NE=1,NPS
ISN 0048      EX=FLOAT(NE)*DE
ISN 0049      IF (EF .LT. 0.) EX=EX*AT/(AI+AT)
ISN 0051      FACT=0.
ISN 0052      DO 39 M=1,LT
ISN 0053      MM=M-1

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ISN 0054      XM=MM
ISN 0055      FAC=2.*(BL(M)-EX)/HW(M)*PI
ISN 0056      IF (FAC .GT. 30.) GO TO 39
ISN 0058      TL=1.
ISN 0059      IF (FAC .LT. -20.) GO TO 38
ISN 0061      TL=1./(1.+EXP(FAC))
ISN 0062      38  CONTINUE
ISN 0063      FACT=FACT+TL*(2.*XM+1.)
ISN 0064      IF (M .GT. 25 .AND. FACT-FACTT .LE. 1.E-06) GO TO 399

ISN 0066      FACTT=FACT
ISN 0067      39  CONTINUE
ISN 0068      399 CONTINUE
ISN 0069      SIG(NE)=PI*1.0544**2/(5.312*AM*EX)*FACT
ISN 0070      IF (SIG(NE) .LT. 1.E-03) SIG(NE)=0.
ISN 0072      40  CONTINUE
ISN 0073      100 RETURN
ISN 0074      200 CONTINUE
ISN 0075      I=ZI+AI
ISN 0076      XR=1.35*AT**POW
ISN 0077      NPS=ABS(EF)/DE+0.01
ISN 0078      GO TO (1000,2000),I
ISN 0079      1000 CONTINUE
ISN 0080      XN=0.7834-0.0414*AT**POW
ISN 0081      B=-2.144-0.0813*AT**POW
ISN 0082      DO 1001 NE=1,NPS
ISN 0083      EX=FLOAT(NE)*DE
ISN 0084      IF (EF .LT. 0.) EX=EX*AT/(AI+AT)
ISN 0086      XX=XR+4.55517/SQRT(EX)
ISN 0087      SIG(NE)=PI*0.01*XX*XX*(1.-EXP(B*EX**XN))
ISN 0088      1001 CONTINUE
ISN 0089      RETURN
ISN 0090      2000 CONTINUE
ISN 0091      ALPHA=1.5+0.289*ZT
ISN 0092      DO 2001 NE=1,NPS
ISN 0093      EX=FLOAT(NE)*DE
ISN 0094      IF (EF .LT. 0.) EX=EX*AT/(AI+AT)
ISN 0096      SIG(NE)=PI*XR*XR*(1.+(1.+10./ZT)*(ALPHA/EX)**1.5)*EXP(-(ALPHA/EX)*
X*1.5)*0.01
ISN 0097      IF (SIG(NE) .LT. 1.E-03) SIG(NE)=0.
ISN 0099      2001 CONTINUE
ISN 0100      RETURN
ISN 0101      END

```

```

ISN 0002      BLOCK DATA
ISN 0003      COMMON /CONT/PI,AMU,RAD,DEG,HB,POW
ISN 0004      COMMON /COM3/A(19),Z(19),S(19),SYM(19)
ISN 0005      DATA A/1.,1.,2.,3.,3.,4.,5.,5.,6.,7.,7.,8.,9.,9.,10.,11.,11.,12.,1
X3./
ISN 0006      DATA Z/0.,1.,1.,1.,2.,2.,2.,3.,3.,3.,4.,4.,4.,5.,5.,5.,6.,6.,6./
ISN 0007      DATA S/0.5,0.5,1.,0.5,0.5,0.,1.5,1.5,1.,1.5,1.5,0.,1.5,1.5,3.,1.5,
X1.5,0.,0.5/
ISN 0008      DATA SYM/' N',' P',' D',' T','3HE','4HE','5HE','5LI','6LI','7L
X1','7BE','8BE','9BE',' 9H','10B','11B','11C','12C','13C'/
ISN 0009      DATA PI/3.1415926/,AMU/931.478/,RAD/0.0174533/,DEG/57.2958/
ISN 0010      DATA HB/6.582/,POW/.3333333/
ISN 0011      END

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```

ISN 0002      SUBROUTINE XT(P,H,XLN,XLP,WS,TP,E)
ISN 0003      COMMON /CONT/PI,AMU,RAD,DEG,HB,POW
ISN 0004      COMMON /COM1/IOP(20),NBAR
ISN 0005      COMMON/COM2/AP,ZP,AT,ZT,AX,ZX,AF,ZF,AC,ZC,G,ZETA,P0,H0,Q(19),C(19)
ISN 0006      Y=0.
ISN 0007      IF (IOP(2) .NE. 0) Y=0.5*((P+1.)**2+(H+1.)**2)/G
ISN 0009      CONST=PI/HB*ZETA/AC**3/E
ISN 0010      XLN=CONST*G*P*H*(P+H-2.)
ISN 0011      XLP=CONST*G**3*(E-Y)*(E-Y)/(P+H+1.)
ISN 0012      IF (E .LE. Y) XLP=0.
ISN 0014      TP=XLP+XLN+WS
ISN 0015      RETURN
ISN 0016      END

```

```

ISN 0002      SUBROUTINE PREQ(EE,P,H,I,WS,MU,MI,KOP)
ISN 0003      COMMON /COM1/ICP(20),NBAR
ISN 0004      COMMON/COM2/AP,ZP,AT,ZT,AX,ZX,AF,ZF,AC,ZC,G,ZETA,P0,H0,Q(19),C(19)
ISN 0005      COMMON /COM3/A(19),Z(19),S(19),SYM(19)
ISN 0006      COMMON /COM4/PY(200),KED,YY(10,200)
ISN 0007      COMMON /COM5/SIGN(10,200),EN(200),NPT
ISN 0008      REAL*8 WI(20),XI(20)
ISN 0009      COMMON /COM6/WI,XI,NTERM
ISN 0010      REAL XSEC(200),X(2)
ISN 0011      DO 1 J=1,200
ISN 0012      PY(J)=0.
ISN 0013      1 XSEC(J)=SIGN(I,J)
ISN 0014      WS=0.
ISN 0015      AR=AC-A(I)
ISN 0016      ZR=ZC-Z(I)
ISN 0017      MI=0
ISN 0018      MU=0
ISN 0019      IF (EE .LE. Q(1)) RETURN
ISN 0021      LH=H
ISN 0022      LP=P
ISN 0023      LB=A(I)
ISN 0024      IF (A(I) .GT. P .OR. A(I) .EQ. P+H) RETURN
ISN 0026      LPH=LP+LH
ISN 0027      LPH1=LPH-1
ISN 0028      LPH2=LPH-LB
ISN 0029      LB1=LB-1
ISN 0030      NPH=LPH2-1
ISN 0031      A1=0.
ISN 0032      A2=0.
ISN 0033      A3=0.
ISN 0034      IF (ICP(2) .EQ. 0) GO TO 2
ISN 0036      A1=0.25*((P-A(I))*2+H*P+(P-A(I))-3.*H)/G
ISN 0037      A2=0.25*(P*P+H*H+P-3.*H)/G
ISN 0038      A3=0.25*(A(I)*A(I)+A(I))/G
ISN 0039      IF (A1 .LT. 0.) A1=0.
ISN 0041      IF (A2 .LT. 0.) A2=0.
ISN 0043      IF (A3 .LT. 0.) A3=0.
ISN 0045      A4=A3
ISN 0046      2 CONTINUE
ISN 0047      TMAX=EE-Q(1)-A1
ISN 0048      TMIN=KED
ISN 0049      IF (TMAX .LE. TMIN) RETURN
ISN 0051      EEX=EE-A2
ISN 0052      IF (EEX .LE. 0.) RETURN

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ISN 0054      FACT1=1.
ISN 0055      FACT2=1.
ISN 0056      FACT3=1.
ISN 0057      FACT4=1.
ISN 0058      FACT5=1.
ISN 0059      DO 3 I1=1,LB
ISN 0060      XXI=P+1.-FLOAT(I1)
ISN 0061      YYI=P+H-FLOAT(I1)
ISN 0062      ZZI=I1
ISN 0063      FACT1=FACT1*XXI
ISN 0064      FACT2=FACT2*YYI
ISN 0065      FACT3=FACT3*ZZI
ISN 0066      3  CONTINUE
ISN 0067      RBP=RB(P,H,A(I),Z(I))
ISN 0068      IF (KOP .EQ. 1) GO TO 100
ISN 0070      MI=1
ISN 0071      MU=INT(TMAX)/KED
ISN 0072      IF (MU .GT. 200) MU=200
ISN 0074      DO 4 J=MI,MU
ISN 0075      T=J*KED
ISN 0076      U=EE-Q(I)-T-A1
ISN 0077      IF (U .LE. 0.) GO TO 4
ISN 0079      N=5
ISN 0080      CALL YLG(EN,XSEC,NPT,T,N,SG,IER)
ISN 0081      IF (SG .LT. 0.) SG=0.
ISN 0083      PY(J)=C(I)*SG*FACT1*FACT2*FACT4*(U/EE)**LPH1/(G*U)**LB*T*RBP
ISN 0084      4  CONTINUE
ISN 0085      IF (KOP .EQ. 2) RETURN
ISN 0087      200 CONTINUE
ISN 0088      C1=C(I)*FACT1*FACT2*FACT5*RBP/(G*EE)**LB
ISN 0089      DELTA=(TMAX+TMIN)*0.5
ISN 0090      FAC=(TMAX-TMIN)*0.5
ISN 0091      FUNP=0.
ISN 0092      DO 200 K=1,NTERM
ISN 0093      X(1)=FAC*SNGL(XI(K))+DELTA
ISN 0094      X(2)=-FAC*SNGL(XI(K))+DELTA
ISN 0095      DO 200 K1=1,2
ISN 0096      N=5
ISN 0097      CALL YLG(EN,XSEC,NPT,X(K1),N,SG,IER)
ISN 0098      IF (SG .LT. 0.) SG=0.
ISN 0100      FUNP=FUNP+SNGL(WI(K))*SG*X(K1)*((TMAX-X(K1))/EE)**NPH
ISN 0101      200 CONTINUE
ISN 0102      WS=C1*FUNP*FAC
ISN 0103      RETURN
ISN 0104      END

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ISN 0002      SUBROUTINE EVAPOR(UX,MCME)
ISN 0003      COMMON /COM1/IOP(20),NBAR
ISN 0004      COMMON/COM2/AP,ZP,AT,ZT,AX,ZX,AF,ZF,AC,ZC,G,ZETA,P0,H0,Q(19),C(19)
ISN 0005      COMMON /COM3/A(19),Z(19),S(19),SYM(19)
ISN 0006      COMMON /COM4/PY(200),KED,YY(10,200)
ISN 0007      COMMON /COM5/SIGN(10,200),EN(200),NPT
ISN 0008      COMMON /COM8/SE(13,10),PS(10,200),YYY(10,200),DE,XK
ISN 0009      COMMON /COM9/RSIG(13,10),PYYY(13,10,200)
ISN 0010      COMMON /COM10/VCOU(10)
ISN 0011      DIMENSION ZSEC(200),MCME(19),MPT(13,10)
ISN 0012      ACC=AC
ISN 0013      ZCC=ZC
ISN 0014      IOP11=IOP(11)+1
ISN 0015      IOP12=IOP(12)+1
ISN 0016      IOP6=ICP(6)
ISN 0017      IF (IOP(6) .EQ. 0) IOP6=10
ISN 0019      DO 3 KA=1,13
ISN 0020      DO 3 KE=1,10
ISN 0021      DO 2 KC=1,200
ISN 0022      2   PYYY(KA,KE,KC)=0.
ISN 0023      MPT(KA,KB)=0
ISN 0024      3   RSIG(KA,KE)=0.
ISN 0025      PTT=0.
ISN 0026      DO 10 I=1,IOP6
ISN 0027      DO 4 KC=1,200
ISN 0028      4   ZSEC(KC)=YY(I,KC)
ISN 0029      IF (UX-Q(I) .LT. 1.) GO TO 10
ISN 0031      IUMAX=INT((UX-Q(I)-10.)/DE)+10
ISN 0032      IF (UX-Q(I) .LE. 10.) IUMAX=UX-Q(I)
ISN 0034      IF (IUMAX .GT. 200) IUMAX=200
ISN 0036      IF (IUMAX .LE. 0) GO TO 10
ISN 0038      KB=INT(Z(I))+1
ISN 0039      KA=INT(A(I))-INT(Z(I))+1
ISN 0040      MPT(KA,KB)=IUMAX
ISN 0041      DO 5 IU=1,IUMAX
ISN 0042      IF (IU .LE. 10) UI=IU
ISN 0044      IF (IU .GT. 10) UI=(IU-10)*KED+10
ISN 0046      N=5
ISN 0047      CALL YLG(EN,ZSEC,MCME(I),UX-Q(I)-UI,N,USIG,IER)
ISN 0048      IF (USIG .LT. 0.) USIG=0.
ISN 0050      PYYY(KA,KE,IU)=LSIG
ISN 0051      IF (IU .LE. 10) PTT=PTT+USIG
ISN 0053      IF (IU .GT. 10) PTT=PTT+USIG*DE
ISN 0055      5   CONTINUE

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ISN 0056      10  CONTINUE
ISN 0057      PTT=1.-PTT
ISN 0058      IN=2
ISN 0059      IF (PTT .LT. 0.00001) GO TO 20
ISN 0061      CALL WIDTH(ZCC,ACC,UX,1,1)
ISN 0062      DO 14 I=1,IOP6
ISN 0063      IF (UX-Q(I) .LT. 1.) GO TO 14
ISN 0065      IUMAX=INT((UX-Q(I)-10.)/DE)+10
ISN 0066      JUMAX=(UX-Q(I))/DE

ISN 0067      IF (UX-Q(I) .LT. 10.) IUMAX=UX-Q(I)
ISN 0069      IF (IUMAX .GT. 200) IUMAX=200
ISN 0071      IF (JUMAX .GT. 200) JUMAX=200
ISN 0073      IF (IUMAX .LE. 0) GO TO 14
ISN 0075      KB=INT(Z(I))+1
ISN 0076      KA=INT(A(I))-INT(Z(I))+1
ISN 0077      DO 13 IU=1,IUMAX
ISN 0078      PYYY(KA,KB,IU)=PYYY(KA,KB,IU)+YYY(I,IU)*PTT
ISN 0079      IF (IU.LE. JUMAX) YY(I,IU)=YY(I,IU)+PS(I,IU)*PTT
ISN 0081      13  CONTINUE
ISN 0082      14  CONTINUE
ISN 0083      20  CONTINUE
ISN 0084      DO 300 KA=1,IOP12
ISN 0085      DO 200 KB=IN,IOP11
ISN 0086      ZCC=ZC-FLOAT(KB-1)
ISN 0087      ACC=ZC-FLOAT(KB-1)-FLOAT(KA-1)
ISN 0088      IF (ZCC .LE. 3. .OR. ACC .LE. 6.) GO TO 300
ISN 0090      QMIN=100.
ISN 0091      DO 100 I=1,IOP6
ISN 0092      100 IF (QMIN .GT. SE(KA,KB,I)+VCOU(I)) QMIN=SE(KA,KB,I)+VCOU(I)
ISN 0094      MCUT=INT(QMIN-9.)/KEB+10
ISN 0095      IF (QMIN .LE. 10.) MCUT=QMIN+0.6
ISN 0097      MCUS=MCUT+1
ISN 0098      MSTOP=MPT(KA,KB)
ISN 0099      IF (MCUT .GT. 200) MCUT=200
ISN 0101      IF (MCUS .LE. 0) MCUS=1
ISN 0103      IF (MSTOP .GT. 200) MSTOP=200
ISN 0105      IF (MSTOP .LE. 0) GO TO 200
ISN 0107      IF (MSTOP .LE. MCUT) MCUT=MSTOP
ISN 0109      IF (MCUT .LE. 0) GO TO 111
ISN 0111      DO 110 J=1,MCUT
ISN 0112      IF (J .LE. 10) RSIG(KA,KB)=RSIG(KA,KB)+PYYY(KA,KB,J)
ISN 0114      IF (J .GT. 10) RSIG(KA,KB)=RSIG(KA,KB)+PYYY(KA,KB,J)*DE
ISN 0116      110 CONTINUE

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ISN 0117      111  CONTINUE
ISN 0118      IF (MCUS .GE. 200) GO TO 200
ISN 0120      IF (MSTOP .LE. MCUT .OR. MSTOP .LE. 0) GO TO 200
ISN 0122      DO 120 J1=MCUS,MSTOP
ISN 0123      IF (J1 .LE. 10) UUX=J1
ISN 0125      IF (J1 .GT. 10) UUX=(J1-10)*KED+10
ISN 0127      IF (PYYY(KA,KB,J1) .LT. 0.00001) GO TO 120
ISN 0129      CALL WIDTH(ZCC,ACC,UUX,KA,KB)
ISN 0130      DO 115 I=1,IOP6
ISN 0131      IF (UUX-SE(KA,KB,I) .LT. 1.) GO TO 115
ISN 0133      IUMAX=INT((UUX-SE(KA,KB,I)-10.)/DE)+10
ISN 0134      JUMAX=(UUX-SE(KA,KB,I))/DE
ISN 0135      IF (UUX-SE(KA,KB,I) .LE. 10.) IUMAX=UUX-SE(KA,KB,I)
ISN 0137      IF (IUMAX .GT. 200) IUMAX=200
ISN 0139      IF (JUMAX .GT. 200) JUMAX=200
ISN 0141      IF (IUMAX .LE. 0) GO TO 115
ISN 0143      KZ=KB+INT(Z(I))
ISN 0144      KN=KA+INT(A(I))-INT(Z(I))
ISN 0145      IF (J1 .LE. 10) DDE=1.
ISN 0147      IF (J1 .GT. 10) DDE=DE
ISN 0149      DO 114 IU=1,IUMAX
ISN 0150      IF (KZ .GT. 10 .OR. KN .GT. 13) GO TO 113
ISN 0152      PYYY(KN,KZ,IU)=PYYY(KN,KZ,IU)+YYY(I,IU)*PYYY(KA,KB,J1)*DDE
ISN 0153      113  CONTINUE

ISN 0154      IF (IU .LE. JUMAX) YY(I,IU)=YY(I,IU)+PS(I,IU)*PYYY(KA,KB,J1)*DDE
ISN 0156      114  CONTINUE
ISN 0157      IF (KZ .GT. 10 .OR. KN .GT. 13) GO TO 115
ISN 0159      IF (MPT(KN,KZ) .LT. JUMAX) MPT(KN,KZ)=IUMAX
ISN 0161      115  CONTINUE
ISN 0162      120  CONTINUE
ISN 0163      200  CONTINUE
ISN 0164      IN=1
ISN 0165      300  CONTINUE
ISN 0166      RETURN
ISN 0167      END

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ISN 0002      SUBROUTINE WIDTH(ZCC,ACC,UU,I1,I2)
ISN 0003      COMMON /CONT/PI,AMU,RAD,DEG,HB,POW
ISN 0004      COMMON /COM1/IOP(20),NBAR
ISN 0005      COMMON /COM3/A(19),Z(19),S(19),SYM(19)
ISN 0006      COMMON /COM5/SIGN(10,200),EN(200),NPT
ISN 0007      COMMON /COM8/SE(13,10,10),PS(10,200),YYY(10,200),DE,XK
ISN 0008      INTEGER MAXX(10),MAYY(10)
ISN 0009      A0=ACC/XK
ISN 0010      CCC=AMU/(HB*HB*PI*PI*9.)
ISN 0011      IOP6=IOP(6)
ISN 0012      IF (IOP(6) .EQ. 0) IOP6=10
ISN 0014      DO 1 I=1,IOP6
ISN 0015      DO 1 J=1,200
ISN 0016      PS(I,J)=0.
ISN 0017      1 YYY(I,J)=0.
ISN 0018      TW1=0.
ISN 0019      TW2=0.
ISN 0020      DO 100 I=1,IOP6
ISN 0021      CS=(2.*S(I)+1.)*A(I)*(ACC-A(I))/ACC*CCC
ISN 0022      AN=(ACC-A(I))/XK
ISN 0023      A0N=(A0/AN)**0.25
ISN 0024      IF (UU .LE. SE(I1,I2,I)) GO TO 100
ISN 0026      XX=2.*SQRT(A0*UU)
ISN 0027      IUCR=INT(1.5625/AN)+1
ISN 0028      YIUCR=IUCR+1
ISN 0029      XIUCR=IUCR+2
ISN 0030      FF1=A0N*(UU/YIUCR)**1.25*EXP(2.*SQRT(AN*YIUCR)-XX)
ISN 0031      FF2=A0N*(UU/XIUCR)**1.25*EXP(2.*SQRT(AN*XIUCR)-XX)
ISN 0032      XMAX=UU-SE(I1,I2,I)
ISN 0033      MAX=XMAX/DE
ISN 0034      IF (MAX .GT. 200) MAX=200
ISN 0036      MAXX(I)=MAX
ISN 0037      IF (MAX .LE. 0) GO TO 80
ISN 0039      DO 70 J=1,MAX
ISN 0040      T=FLOAT(J)*DE
ISN 0041      YE=XMAX-T
ISN 0042      YYE=SQRT(AN*YE)*2.
ISN 0043      IF (YE .LE. 1.5625/AN) GO TO 60
ISN 0045      W=A0N*(UU/YE)**1.25*EXP(YYE-XX)
ISN 0046      GO TO 61
ISN 0047      60 W=ALOG10(FF2)-(ALOG10(FF2)-ALOG10(FF1))*(XIUCR-YE)
ISN 0048      W=10.**W
ISN 0049      61 PS(I,J)=W*CS*T*SIGN(I,J)
ISN 0050      70 TW1=TW1+PS(I,J)*DE

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ISN 0051      80    MAY=INT((XMAX-10.)/DE)+10
ISN 0052      IF (XMAX .LE. 10.) MAY=XMAX
ISN 0054      IF (MAY .GT. 200) MAY=200
ISN 0056      MAYY(I)=MAY
ISN 0057      IF (MAY .LE. 0) GO TO 100
ISN 0059      DO 90 J=1,MAY
ISN 0060      IF (J .LE. 10) YE=FLOAT(J)
ISN 0062      IF (J .GT. 10) YE=FLOAT(J-10)*DE+10.
ISN 0064      T=XMAX-YE

ISN 0065      JL=T/DE+0.5
ISN 0066      IF (JL .LT. 1) JJ=1
ISN 0068      IF (JL .GT. 200) JJ=200
ISN 0070      YYE=SQRT(AN*YE)*2.
ISN 0071      IF (YE .LE. 1.5625/AN) GO TO 81
ISN 0073      W=AON*(UU/YE)*#1.25*EXP(YYE-XX)
ISN 0074      GC TO 82
ISN 0075      81    W=ALOG10(FF2)-(ALOG10(FF2)-ALOG10(FF1))* (XIUCR-YE)
ISN 0076      W=10.**W
ISN 0077      82    YYY(I,J)=W*CS*T*SIGN(I,JJ)
ISN 0078      IF (J .LE. 10) TW2=TW2+YYY(I,J)
ISN 0080      IF (J .GT. 10) TW2=TW2+YYY(I,J)*DE
ISN 0082      90    CONTINUE
ISN 0083      100   CONTINUE
ISN 0084      IF (TW1 .LE. 0.) TW1=1.
ISN 0086      IF (TW2 .LE. 0.) TW2=1.
ISN 0088      DO 300 I=1,IOP6
ISN 0089      JJ=MAXX(I)
ISN 0090      IF (JJ .LE. 0) GO TO 209
ISN 0092      DO 200 J=1,JJ
ISN 0093      200   PS(I,J)=PS(I,J)/TW1
ISN 0094      209   CONTINUE
ISN 0095      IF (JJ .LE. 0) GO TO 300
ISN 0097      JJ=MAYY(I)
ISN 0098      DO 210 J=1,JJ
ISN 0099      210   YYY(I,J)=YYY(I,J)/TW2
ISN 0100      300   CONTINUE
ISN 0101      RETURN
ISN 0102      END

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ISN 0002      FUNCTION RE(P,H,PB,P1B)
ISN 0003      COMMON /COM1/IOP(20),NBAR
ISN 0004      COMMON/COM2/AP,ZP,AT,ZT,AX,ZX,AI,ZI,AC,ZC,G,ZETA,P0,H0,Q(19),C(19)
ISN 0005      RB=0.
ISN 0006      IP0=P0
ISN 0007      N=INT(P)+INT(H)
ISN 0008      NMAX=NBAR
ISN 0009      IP=P
ISN 0010      Z=ZT
ISN 0011      A=AT
ISN 0012      PA=AI
ISN 0013      PIA=ZI
ISN 0014      NMIN=INT(P0)+INT(H0)
ISN 0015      XN=A-Z
ISN 0016      NUB=INT(PB)-INT(P1B)
ISN 0017      XNUB=NUB
ISN 0018      IMAX=IP-INT(PA)
ISN 0019      MAXP=(NMAX+INT(P0-H0))/2
ISN 0020      IPA=PA
ISN 0021      IPIA=PIA
ISN 0022      IPB=PB
ISN 0023      IPIB=P1B
ISN 0024      IPIBB=IPB+IPIB
ISN 0025      IF (IP .GT. MAXP .OR. IP .GT. 20) GO TO 1000
ISN 0027      RBP1=0.
ISN 0028      IMAX=IMAX+1
ISN 0029      DO 500 I=1,IMAX
ISN 0030      XI=I-1
ISN 0031      II=I-1
ISN 0032      TERM1=1.
ISN 0033      IF (II .EQ. 0) GO TO 101
ISN 0035      DO 100 II=1,II
ISN 0036      XI1=II
ISN 0037      100 TERM1=TERM1*(P-PA-XI1+1.)/(XI-XI1+1.)
ISN 0038      101 TERM2=1.
ISN 0039      IF ((IPIA+II) .LT. IPIB) GO TO 700
ISN 0041      IF (IPIB .EQ. 0) GO TO 201
ISN 0043      DO 200 I2=1,IPIB
ISN 0044      XI2=I2
ISN 0045      200 TERM2=TERM2*(PIA+XI-XI2+1.)/(PIB+1.-XI2)
ISN 0046      201 TERM3=1.
ISN 0047      IF (IP .LT. (IPIA+NUB+II)) GO TO 700
ISN 0049      IF (NUB .EQ. 0) GO TO 301
ISN 0051      DO 300 I3=1,NUB

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ISN 0052      XI3=I3
ISN 0053      300  TERM3=TERM3*(P-PIA-XI-XI3+1.)/(XNUB-XI3+1.)
ISN 0054      301  ZANA=(Z/A)**I*(XN/A)**(IP-IPA-II)
ISN 0055      GO TO 302
ISN 0056      700  ZANA=0.
ISN 0057      302  RBP1=TERM1*TERM2*TERM3*ZANA+RBP1
ISN 0058      500  CONTINUE
ISN 0059      TERM4=1.
ISN 0060      IF (IP .LT. IPB) RBP1=0.

ISN 0062      DO 400 I4=1,IPB
ISN 0063      XI4=I4
ISN 0064      400  TERM4=TERM4*(P-XI4+1.)/(PB-XI4+1.)
ISN 0065      600  RB=RBP1/TERM4
ISN 0066      RETURN
ISN 0067      1000 TERM5=1.
ISN 0068      DO 1001 I5=1,IPE
ISN 0069      XI5=I5
ISN 0070      1001 TERM5=TERM5*XI5
ISN 0071      TERM6=1.
ISN 0072      IF (IPB .EQ. 0) GO TO 1003
ISN 0073      DO 1002 I6=1,IPB
ISN 0074      XI6=I6
ISN 0075      1002 TERM6=TERM6*XI6
ISN 0076      1003 TERM7=1.
ISN 0077      IF (NUB .EQ. 0) GO TO 1005
ISN 0078      DO 1004 I7=1,NUB
ISN 0079      XI7=I7
ISN 0080      1004 TERM7=TERM7*XI7
ISN 0081      1005 RB=TERM5/TERM6/TERM7*(Z/A)**IPB*(XN/A)**NUB
ISN 0082      RETURN
ISN 0083      END
ISN 0084
ISN 0085

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ISN 0002      SUBROUTINE MASS(Z,A,AMU,DM)
ISN 0003      COMMON /COM7/NMIN(100),NMAX(100),H(19,100),GN(154),GZ(100),GA(253)
ISN 0004      IF (Z .EQ. 0) GO TO 300
ISN 0006      IZ=INT(Z)
ISN 0007      IN=INT(A)-INT(Z)
ISN 0008      IF (Z .EQ. 89.) NMAX(89)=142
ISN 0010      IF (IN .GT. NMAX(IZ) .OR. IN .LT. NMIN(IZ)) GO TO 200
ISN 0012      I=IN-NMIN(IZ)+1
ISN 0013      DM=-H(I,IZ)
ISN 0014      IF (Z .EQ. 89. .AND. A .EQ. 231.) DM=35.915
ISN 0015      IF (Z .EQ. 89. .AND. A .EQ. 230.) DM=33.76498
ISN 0016      IF (Z .EQ. 89. .AND. A .EQ. 229.) DM=30.59
ISN 0020      IF (Z .EQ. 52. .AND. A .EQ. 120.) DM=-89.4
ISN 0022      AMU=A+DM/931.478
ISN 0023      RETURN
ISN 0024      200 CONTINUE
ISN 0025      IA=A
ISN 0026      AMU=(1.0078252*Z+1.008665*(A-Z))-(110.7824+GN(IN)+GZ(IZ)+GA(IA))/
                X931.478
ISN 0027      DM=(AMU-A)*931.478
ISN 0028      RETURN
ISN 0029      300 AMU=1.008655
ISN 0030      DM=8.07144
ISN 0031      RETURN
ISN 0032      END

```

ISN 0002	SUBROUTINE YLG(X,Y,N,XBAR,NPTS,YLGINT,IER)		
	VERSION OF 72/256		
	C-----	YLG	2
	C LAGRANGE INTERPOLATION	YLG	3
	C-----	YLG	4
	C ARGUMENT DEFINITION	YLG	5
	C X -- ARRAY OF N INDEPENDENT VARIABLE VALUES%INPUT<	YLG	6
	C Y -- ARRAY OF N DEPENDENT VARIABLE VALUES %INPUT<	YLG	7
	C N -- NUMBER OF DATA POINTS %INPUT<	YLG	8
	C XBAR -- INDEPENDENT VARIABLE VALUE FOR WHICH YLGINT IS THE	YLG	9
	C INTERPOLANT %INPUT<	YLG	10
	C NPTS -- NUMBER OF DATA POINTS TO BE USED IN INTERPOLATION%INPUTYLG	YLG	11
	C \$ -- ERROR EXIT IF N IS LESS THAN 2, OR IF OVERFLOW IS	YLG	12
	C DETECTED.	YLG	13
	C-----	YLG	14
	C REFERENCE	YLG	15
	C K. S. KUNZ, NUMERICAL ANALYSIS, MCGRAW-HILL BOOK COMPANY, 1957.YLG	YLG	16
ISN 0003	DIMENSION X(N),Y(N)		
	C-----	YLG	17
ISN 0004	IER=0	YLG	19
	C-----	YLG	20
	C CHECK ARGUMENTS N AND NPTS	YLG	21
	C IF NPTS IS OUT OF RANGE, USE ALL POINTS	YLG	22
	C-----	YLG	23
ISN 0005	IF(N.LT.2)GO TO 14	YLG	24
ISN 0007	IF(NPTS.GT.1.AND.NPTS.LT.N) GO TO 2	YLG	25
ISN 0009	DO 41 JH=1,N	YLG	26
ISN 0010	IF (XBAR-X(JH)) 41,12,41	YLG	27
ISN 0011	41 CONTINUE	YLG	28
ISN 0012	NPTS=N	YLG	29
ISN 0013	1 JL=1	YLG	30
ISN 0014	JH=NPTS	YLG	31
ISN 0015	GO TO 9		
	C-----	YLG	33
	C DETERMINE POSITION OF XBAR WITHIN X ARRAY	YLG	34
	C UPON EXIT FROM LOOP 3, %JH-1< LT XBAI-3N& %JH@	YLG	35
	C-----	YLG	36
ISN 0016	2 DO 3 JH=1,N	YLG	37
ISN 0017	IF(XBAR-X(JH)) 5,12,3	YLG	38
ISN 0018	3 CONTINUE	YLG	39
ISN 0019	* JH=N	YLG	40
ISN 0020	JL=N-NPTS+1	YLG	41
ISN 0021	GO TO 9	YLG	42
	C-----	YLG	43

C	DETERMINE WHICH POINTS USED IN INTERPOLATION	YLG	44
C	THE POINTS CHOSEN ARE THE ONES WHOSE ABSCISSAS ARE CLOSEST TO XB198C7	YLG	45
C	JL IS LOWEST SUBSCRIPT OF POINTS USED, JH IS HIGHEST SUBSCRIPT	YLG	46
C	-----	YLG	47
ISN 0022	5 JL=JH	YLG	48
ISN 0023	D2=X(JH)-XBAR		
ISN 0024	6 JL=JL-1	YLG	50
ISN 0025	IF(JL.LE.1) GO TO 1		
ISN 0027	D1=XBAR-X(JL)	YLG	52
ISN 0028	7 IF(JH-JL+1.EQ.NPTS) GO TO 8	YLG	53
ISN 0030	IF(XBAR-X(JL-1).LT.D2) GO TO 6	YLG	54
ISN 0032	JH=JH+1	YLG	55
ISN 0033	IF(JH.GT.N) GO TO 4	YLG	56
ISN 0035	D2=X(JH)-XBAR		
ISN 0036	GO TO 7	YLG	58
ISN 0037	8 INDCT=0	YLG	59
ISN 0038	IF(JL.GT.1.AND.XBAR-X(JL-1).LT.D2) INDCT=-1	YLG	60
ISN 0040	IF(JH.LT.N.AND.X(JH+1)-XBAR.LT.D1) INDCT=1	YLG	61
ISN 0042	JL=JL+INDCT		
ISN 0043	JH=JH+INDCT		
C	-----	YLG	64
C	DETERMINE INTERPOLATING POLYNOMIAL VALUE	YLG	65
C	INNER LOOP COMPUTES PRODUCT	YLG	66
C	OUTER LOOP COMPUTES SUM	YLG	67
C	ERROR RETURN FOR DETECTED OVERFLOW	YLG	68
C	-----	YLG	69
ISN 0044	9 YLGINT=0.	YLG	70
ISN 0045	RNUM=1.	YLG	71
ISN 0046	DO 13 J=JL,JH	YLG	72
ISN 0047	13 RNUM=RNUM*(XBAR-X(J))	YLG	73
ISN 0048	DO 11 K=JL,JH	YLG	74
ISN 0049	DEN=1.	YLG	75
ISN 0050	DO 10 J=JL,JH		
ISN 0051	IF(K.EQ.J) GO TO 10	YLG	77
ISN 0053	DEN=DEN*(X(K)-X(J))	YLG	78
ISN 0054	CALL OVERFL(INDCT)	YLG	79
ISN 0055	IF(INDCT.EQ.1) GO TO 14	YLG	80
ISN 0057	10 CONTINUE	YLG	81
ISN 0058	DEN=DEN*(XBAR-X(K))	YLG	82
ISN 0059	YLGINT=YLGINT+Y(K)*RNUM/DEN	YLG	83
ISN 0060	CALL OVERFL(INDCT)	YLG	84
ISN 0061	IF(INDCT.EQ.1) GO TO 14	YLG	85
ISN 0063	11 CONTINUE	YLG	86
ISN 0064	RETURN	YLG	87

	C-----	YLG	83
	C XBAR EQUAL TO AN ELEMENT OF THE X ARRAY	YLG	83
	C-----	YLG	90
ISN 0065	12 YLGINT=Y(JH)	YLG	91
ISN 0066	RETURN	YLG	92
ISN 0067	14 IER=1	YLG	93
ISN 0068	RETURN	YLG	94
ISN 0069	END	YLG	95

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ISN 0002      SUBROUTINE ZNUM(R1,R2,B,F,DELTA)
ISN 0003      F=0.
ISN 0004      DELTA=1.
ISN 0005      IF (B .GE. R1+R2) RETURN
ISN 0007      XNU=R1/(R1+R2)
ISN 0008      BETA=B/(R1+R2)
ISN 0009      XMU=R2/R1
ISN 0010      IF (R1 .GE. R2 .AND. B+R2 .LE. R1) IE=1
ISN 0012      IF (R1 .GE. R2 .AND. B+R2 .GT. R1) IE=2
ISN 0014      IF (R2 .GT. R1 .AND. B+R1 .GT. R2) IE=3
ISN 0016      IF (R2 .GT. R1 .AND. B+R1 .LE. R2) IE=4
ISN 0018      GO TO (10,20,30,40),IE
ISN 0019      10 F=(1.-(1.-XMU**2)**1.5)*SQRT(1.-(BETA/XNU)**2)
ISN 0020      RETURN
ISN 0021      20 F=0.75*SQRT(1.-XNU)*((1.-BETA)/XNU)**2-0.125*(3./XMU*SQRT(1.-XNU)-
X(1.-(1.-XMU**2)**1.5)*SQRT(1.-(1.-XMU)**2)/XMU**3)*((1.-BETA)/XNU)
X**3
ISN 0022      RETURN
ISN 0023      30 F=0.75*SQRT(1.-XNU)*((1.-BETA)/XNU)**2-0.125*(3.*SQRT(1.-XNU)-1.)*
X((1.-BETA)/XNU)**3
ISN 0024      RETURN
ISN 0025      40 F=1.
ISN 0026      RETURN
ISN 0027      END

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ISN 0002      SUBROUTINE GAUSS(NGAUSS,WI,XI)
ISN 0003      IMPLICIT REAL*8(A-H,O-Z)
ISN 0004      DIMENSION WI(20),XI(20)
ISN 0005      IF( NGAUSS .GT.3) GO TO 50
ISN 0007      GO TO (10,20,30),NGAUSS
ISN 0008      10  CONTINUE
ISN 0009      WI(1)=0.666713443D-01
ISN 0010      WI(2)=0.149451349D0
ISN 0011      WI(3)=0.219086363D0
ISN 0012      WI(4)=0.269266719D0
ISN 0013      WI(5)=0.295524225D0
ISN 0014      XI(1)=0.973906529D0
ISN 0015      XI(2)=0.865063367D0
ISN 0016      XI(3)=0.679409568D0
ISN 0017      XI(4)=0.433395394D0
ISN 0018      XI(5)=0.148874339D0
ISN 0019      RETURN
ISN 0020      20  CONTINUE
ISN 0021      WI(1)=0.176140071D-01
ISN 0022      WI(2)=0.406014298D-01
ISN 0023      WI(3)=0.626720483D-01
ISN 0024      WI(4)=0.832767415D-01
ISN 0025      WI(5)=0.1019301198D0
ISN 0026      WI(6)=0.118194532D0
ISN 0027      WI(7)=0.1316886384D0
ISN 0028      WI(8)=0.1420961093D0
ISN 0029      WI(9)=1.491729864D-01
ISN 0030      WI(10)=0.1527533871D0
ISN 0031      XI(1)=0.993128599D0
ISN 0032      XI(2)=0.963971927D0
ISN 0033      XI(3)=0.912234428D0
ISN 0034      XI(4)=0.839116972D0
ISN 0035      XI(5)=0.746331906D0
ISN 0036      XI(6)=0.636053681D0
ISN 0037      XI(7)=0.510867002D0
ISN 0038      XI(8)=0.373706089D0
ISN 0039      XI(9)=0.227785851D0
ISN 0040      XI(10)=0.765265211D-01
ISN 0041      RETURN
ISN 0042      30  CONTINUE
ISN 0043      WI(1)=0.452127709D-02
ISN 0044      WI(2)=0.104982845D-01
ISN 0045      WI(3)=0.164210583D-01
ISN 0046      WI(4)=0.222458491D-01

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ISN 0047	WI(5)=0.279370069D-01
ISN 0048	WI(6)=0.334601952D-01
ISN 0049	WI(7)=0.387821679D-01
ISN 0050	WI(8)=0.438709081D-01
ISN 0051	WI(9)=0.486956076D-01
ISN 0052	WI(10)=0.532278469D-01
ISN 0053	WI(11)=0.574397691D-01
ISN 0054	WI(12)=0.613062425D-01
ISN 0055	WI(13)=0.648040134D-01
ISN 0056	WI(14)=0.679120458D-01
ISN 0057	WI(15)=0.706110473D-01
ISN 0058	WI(16)=0.728865824D-01
ISN 0059	WI(17)=0.74723169D-01
ISN 0060	WI(18)=0.761103619D-01
ISN 0061	WI(19)=0.770398181D-01
ISN 0062	WI(20)=0.775059479D-01
ISN 0063	XI(1)=0.998237710C0
ISN 0064	XI(2)=0.990726238C0
ISN 0065	XI(3)=0.977259950C0
ISN 0066	XI(4)=0.957916819C0
ISN 0067	XI(5)=0.932812808C0
ISN 0068	XI(6)=0.902098807C0
ISN 0069	XI(7)=0.865959503C0
ISN 0070	XI(8)=0.824612231C0
ISN 0071	XI(9)=0.778305051C0
ISN 0072	XI(10)=0.727318255D0
ISN 0073	XI(11)=0.671956684D0
ISN 0074	XI(12)=0.612553889D0
ISN 0075	XI(13)=0.549467125D0
ISN 0076	XI(14)=0.483075802D0
ISN 0077	XI(15)=0.413779204D0
ISN 0078	XI(16)=0.341994091D0
ISN 0079	XI(17)=0.268152185D0
ISN 0080	XI(18)=0.192697581D0
ISN 0081	XI(19)=0.116084071D0
ISN 0082	XI(20)=0.387724175D-01
ISN 0083	RETURN
ISN 0084	50 PRINT 51
ISN 0085	51 FORMAT (/5X,'NUMBER NOT IN THE TABLE!')
ISN 0086	RETURN
ISN 0087	END

V. EXAMPLE

INPUT cards:

Card No. 2. 00012621012910000000 $^{160}\text{Gd}(^{12}\text{C},\text{Ax})$ E = 200 MeV

Card No. 3. 6., 12., 64., 160., 1., 4., 200., 1., -1., -1., 2.

Card No. 5. 20., 26., 38., 15., 345., 30., 52.5., 30.

Followed by two cards (1)-1.(2)9 to stop the program

OUTPUTS:

INPUTINPUT***INPUT***INPUT***INPUT***INPUT***INPUT***INPUT***INPUT***INPUT***

16GGD(12C,AX) E=200 MEV

IOP(1)=0	IOP(2)=0	IOP(3)=0	IOP(4)=1	IOP(5)=2
IOP(6)=6	IOP(7)=2	IOP(8)=1	IOP(9)=0	IOP(10)=1
IOP(11)=2	IOP(12)=9	IOP(13)=1	IOP(14)=0	IOP(15)=0
IOP(16)=0	IOP(17)=0	IOP(18)=0	IOP(19)=0	IOP(20)=0

PROJECTILE Z= 6.00 PROJECTILE A= 12.00
 TARGET Z= 64.00 TARGET A= 160.00
 FRAGMENT-X Z= 2.00 FRAGMENT-X A= 4.00
 LAB. INCIDENT ENERGY= 200.00(MEV)
 SIGR= 1.0000 LEVEL DENSITY PARAMETER=A/ 8.0
 MATRIX ELEMENT SCALING FACTOR= 200.00
 ENERGY STEP SIZE FOR SPECTRUM= 2.00

---INPUT END-----INPUT END-----INPUT END-----INPUT END-----INPUT END-----INPUT END

===OUTPUT=====OUTPUT=====OUTPUT=====OUTPUT=====OUTPUT=====OUTPUT=====OUTPUT===

PERIPHERAL WIDTH FOR FRAGMENT-X= 3.66(FM) PROB. OF BEING X= 3.7500E-01

INCIDENT MOMENTUM= 2123.93(MEV/C)
 C.M. ENERGY= 166.05 REACTION CROSS SEC.= 0.2086(BARN)
 TWO-BODY Q-VALUE= 7.3198(MEV)
 COMPOUND FORMATION Q-VALUE= 0.0234(MEV)
 SINGLE PARTICLE STATE DENSITY= 12.7665
 INITIAL PARTICLE NO.= 9. HOLE NO.= 1.

*****B.E. FOR ALL EMITTED PARTICLES*****

Q(1)= 7.7604	Q(2)= 7.9878	Q(3)= 13.0477	Q(4)= 13.1188	Q(5)= 14.3980
Q(6)= -0.5401	Q(			

*****SEPARATION ENERGY FOR N IN THE DECAY CHAIN*****

7.7604E+00	7.2630E+00	7.1350E+00
6.4244E+00	6.3249E+00	5.6284E+00
8.5421E+00	8.0305E+00	7.6325E+00
6.6234E+00	6.5381E+00	6.2395E+00
8.7838E+00	8.3858E+00	8.2010E+00
6.8366E+00	6.8366E+00	6.4386E+00
9.1817E+00	8.9401E+00	8.5706E+00
7.2345E+00	7.0782E+00	6.8366E+00
9.6508E+00	9.0823E+00	8.8264E+00
7.5188E+00	7.3198E+00	6.8081E+00
9.8356E+00	9.5371E+00	9.8782E+00
7.5756E+00	7.5188E+00	6.6376E+00
9.8213E+00	9.1817E+00	9.3523E+00

*****CALCULATED REACTION CROSS SEC. IN BARN FOR ALL PARTICLES*****
FROM 2.00 MEV TO 186.00 MEV WITH 2.00 MEV STEP

----- N -----							
3.2715E+00	2.8872E+00	2.6860E+00	2.5583E+00	2.4688E+00	2.4020E+00	2.3500E+00	2.3082E+00
2.2194E+00	2.1977E+00	2.1786E+00	2.1617E+00	2.1465E+00	2.1328E+00	2.1204E+00	2.1090E+00
2.0802E+00	2.0719E+00	2.0642E+00	2.0570E+00	2.0503E+00	2.0439E+00	2.0379E+00	2.0323E+00
2.0171E+00	2.0125E+00	2.0081E+00	2.0039E+00	1.9999E+00	1.9961E+00	1.9925E+00	1.9890E+00
1.9792E+00	1.9762E+00	1.9733E+00	1.9705E+00	1.9678E+00	1.9652E+00	1.9627E+00	1.9603E+00
1.9534E+00	1.9512E+00	1.9491E+00	1.9471E+00	1.9451E+00	1.9432E+00	1.9413E+00	1.9395E+00
1.9343E+00	1.9326E+00	1.9310E+00	1.9295E+00	1.9279E+00	1.9264E+00	1.9250E+00	1.9236E+00
1.9195E+00	1.9182E+00	1.9169E+00	1.9156E+00	1.9144E+00	1.9132E+00	1.9120E+00	1.9108E+00
1.9075E+00	1.9064E+00	1.9054E+00	1.9044E+00	1.9033E+00	1.9023E+00	1.9014E+00	1.9004E+00
1.8976E+00	1.8967E+00	1.8958E+00					

2.2736E+00	2.2444E+00
2.0986E+00	2.0890E+00
2.0269E+00	2.0219E+00
1.9856E+00	1.9824E+00
1.9579E+00	1.9556E+00
1.9377E+00	1.9360E+00
1.9222E+00	1.9208E+00
1.9097E+00	1.9086E+00
1.8995E+00	1.8985E+00

REACTION CROSS SEC. FOR TRANSFERRED FRAGMENT AND TARGET							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	4.9933E-03	6.6569E-02	3.3435E-01	6.6905E-01	9.6714E-01	1.2275E+00	1.4562E+00
1.9998E+00	2.1447E+00	2.2757E+00	2.3945E+00	2.5026E+00	2.6014E+00	2.6920E+00	2.7752E+00
2.9884E+00	3.0493E+00	3.1060E+00	3.1587E+00	3.2080E+00	3.2540E+00	3.2971E+00	3.3376E+00
3.4448E+00	3.4765E+00	3.5064E+00	3.5347E+00	3.5614E+00	3.5866E+00	3.6106E+00	3.6333E+00
3.6947E+00	3.7132E+00	3.7308E+00	3.7476E+00	3.7635E+00	3.7788E+00	3.7933E+00	3.8072E+00
3.8452E+00	3.8567E+00	3.8678E+00	3.8784E+00	3.8885E+00	3.8983E+00	3.9076E+00	3.9165E+00
3.9411E+00	3.9487E+00	3.9559E+00	3.9629E+00	3.9696E+00	3.9760E+00	3.9822E+00	3.9881E+00
4.0045E+00	4.0096E+00	4.0145E+00	4.0192E+00	4.0237E+00	4.0280E+00	4.0321E+00	4.0361E+00
4.0473E+00	4.0507E+00	4.0540E+00					

0.0	0.0
1.6585E+00	1.8386E+00
2.8519E+00	2.9228E+00
3.3755E+00	3.4112E+00
3.6548E+00	3.6753E+00
3.8204E+00	3.8331E+00
3.9251E+00	3.9333E+00
3.9938E+00	3.9993E+00
4.0400E+00	4.0437E+00

=====

FRAGMENT-X AT ANGLE= 20.00(DEG)

ENERGY WINDOW FROM 26.00 (MEV) TO 38.00 (MEV) WITH 2.00 (MEV) STEP

MOMENTUM DISTRIBUTION WIDTH= 89.54 (MEV/C)

*****CROSS SEC. PROJECTED ON FRAGMENT-X IN COINCIDENCE WITH OTHER FRAGMENT-Y AT VARIOUS ANGLE*****

*****RECOIL ANGLE= 5.04(DEG)*****EXCITATION ENERGY= 157.31(MEV)*****

I 26.00 MEV I		LAB. ANGLE FOR EMITTED PARTICLE Y							
I	PARTICLE	I 15.00	I 45.00	I 75.00	I 105.00	I 135.00	I 165.00	I -165.00	I
I		I-----I	I-----I	I-----I	I-----I	I-----I	I-----I	I-----I	I
I	TYPE	I -105.00	I -75.00	I -45.00	I -15.00	I			
I		I-----I	I-----I	I-----I	I-----I	I-----I	I-----I	I-----I	I
I		I 2.1082E-01	I 1.8932E-01	I 1.6081E-01	I 1.3550E-01	I 1.1832E-01	I 1.1057E-01	I 1.1214E-01	I
I	N	I-----I	I-----I	I-----I	I-----I	I-----I	I-----I	I-----I	I
I		I 1.4324E-01	I 1.7044E-01	I 1.9796E-01	I 2.1440E-01	I			I

*****((SINGLES ENERGY SPECTRUM FOR FRAGMENT-X))*****

1.3434E-01 2.1849E-01 3.3759E-01 4.9804E-01 7.0466E-01 9.5960E-01 1.2617E+00

***** N*****INCOINCIDENCE WITH X*****

*****ENERGY SPECTRUM FROM 2.0 (MEV) WITH 2.0 (MEV) STEP*****

((LAB. ANGLE= 15.0(DEG)))

1.0830E+00	7.3256E-01	4.7412E-01	2.9724E-01	1.8728E-01	1.1879E-01	7.6752E-02	5.1064E-02
1.9473E-02	1.5493E-02	1.2798E-02	1.0873E-02	9.4175E-03	8.2551E-03	7.2837E-03	6.4445E-03
4.4431E-03	3.9044E-03	3.4188E-03	2.9820E-03	2.5906E-03	2.2411E-03	1.9301E-03	1.6549E-03
1.0143E-03	8.5312E-04	7.1386E-04	5.9413E-04	4.9172E-04	4.0460E-04	3.3090E-04	2.6891E-04
1.3848E-04	1.0934E-04	8.5624E-05	6.6471E-05	5.1124E-05	3.8936E-05	2.9342E-05	2.1864E-05
8.3816E-06	5.9155E-06	4.1070E-06	2.8004E-06	1.8731E-06	1.2263E-06	7.8422E-07	4.8874E-07
9.8478E-08	5.3677E-08	2.8012E-08	1.3924E-08	6.5532E-09	2.8997E-09	1.1959E-09	4.5440E-10
1.2416E-11	2.6465E-12	4.1611E-13	1.3570E-12	6.7149E-13	3.0901E-13	1.3945E-13	0.0
0.0	0.0	0.0					

*****INTEGRATED YIELD= 0.6428E+01*****INTEGRATED YIELD ABOVE 30.0 MEV= 1.2832E-01*****

3.5338E-02	2.5604E-02
5.7033E-03	5.0401E-03
1.4125E-03	1.1998E-03
2.1708E-04	1.7402E-04
1.6096E-05	1.1697E-05
2.9605E-07	1.7376E-07
1.5651E-10	4.7726E-11
0.0	0.0

*****RESIDUAL NUCLEAR YIELDS (COMPOUND A= 168. Z= 68.)*****

```

*****
* N/Z*   Z-0   *   Z-1   *   Z-2   *   Z-3   *   Z-4   *   Z-5   *   Z-6   *   Z-7   *
*****
*N- 0* 0.0    * 8.6026E-11* 5.3351E-11* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 1* 9.4763E-11* 1.3580E-10* 2.7360E-09* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 2* 4.7925E-10* 6.7620E-08* 4.3638E-06* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 3* 2.8935E-08* 8.8698E-06* 2.4769E-05* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 4* 3.9405E-05* 2.0641E-03* 3.3265E-03* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 5* 2.3124E-03* 1.4288E-02* 2.3694E-02* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 6* 1.8514E-02* 8.5321E-02* 1.5037E-01* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 7* 5.2917E-02* 1.8966E-01* 3.0710E-01* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 8* 2.0337E-01* 4.2184E-01* 7.4660E-01* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
*N- 9* 3.2382E-01* 4.9680E-01* 5.9267E-01* 0.0    * 0.0    * 0.0    * 0.0    * 0.0    *
*      *      *      *      *      *      *      *      *      *
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