```
======================================================================= Virgin
                                                                        Virgin
     PROGRAM VIRGIN                                                     Virgin
     VERSION 76-1 (NOVEMBER 1976)                                       Virgin
     VERSION 84-1 (JUNE 1984)    *DOUBLE PRECISION ENERGY               Virgin
     VERSION 86-1 (JANUARY 1986)*FORTRAN-77/H VERSION                   Virgin
     VERSION 88-1 (JULY 1988)    *OPTION...INTERNALLY DEFINE ALL I/O    Virgin
                                  FILE NAMES (SEE, SUBROUTINE FILEIO    Virgin
                                  FOR DETAILS).                         Virgin
                                 *IMPROVED BASED ON USER COMMENTS.      Virgin
     VERSION 89-1 (JANUARY 1989)*PSYCHOANALYZED BY PROGRAM FREUD TO     Virgin
                                  INSURE PROGRAM WILL NOT DO ANYTHING   Virgin
                                  CRAZY.                                Virgin
                                 *UPDATED TO USE NEW PROGRAM CONVERT    Virgin
                                  KEYWORDS.                             Virgin
                                 *ADDED LIVERMORE CIVIC COMPILER        Virgin
                                  CONVENTIONS.                          Virgin
     VERSION 92-1 (JANUARY 1992)*COMPLETE RE-WRITE                      Virgin
                                 *OUTPUT IN PLOTTAB FORMAT              Virgin
                                 *UP TO 2000 THICKNESSES                Virgin
                                 *INCREASED INCORE PAGE SIZE TO 6000    Virgin
                                  CROSS SECTION POINTS                  Virgin
                                 *ADDED PHOTON CALCULATIONS             Virgin
                                 *ADDED BLACKBODY SPECTRUM              Virgin
                                 *ADDED MULTIPLE LAYERS                 Virgin
                                 *ADDED SPATIALLY DEPENDENT DENSITY     Virgin
                                 *ADDED FORTRAN SAVE OPTION             Virgin
                                 *COMPLETELY CONSISTENT I/O ROUTINES -  Virgin
                                  TO MINIMIZE COMPUTER DEPENDENCE.      Virgin
     VERSION 92-2 (MAY 1992)     *CORRECTED TO HANDLE MULTIGROUP CROSS  Virgin
                                  SECTIONS AS INPUT IN ENDF/B FORMAT.   Virgin
     VERSION 96-1 (JANUARY 1996) *COMPLETE RE-WRITE                     Virgin
                                 *IMPROVED COMPUTER INDEPENDENCE        Virgin
                                 *ALL DOUBLE PRECISION                  Virgin
                                 *ON SCREEN OUTPUT                      Virgin
                                 *UNIFORM TREATMENT OF ENDF/B I/O       Virgin
                                 *IMPROVED OUTPUT PRECISION             Virgin
                                 *DEFINED SCRATCH FILE NAMES            Virgin
     VERSION 99-1 (MARCH 1999)   *CORRECTED CHARACTER TO FLOATING       Virgin
                                  POINT READ FOR MORE DIGITS            Virgin
                                 *UPDATED TEST FOR ENDF/B FORMAT        Virgin
                                  VERSION BASED ON RECENT FORMAT CHANGE Virgin
                                 *GENERAL IMPROVEMENTS BASED ON         Virgin
                                  USER FEEDBACK                         Virgin
     VERS. 2000-1 (FEBRUARY 2000)*GENERAL IMPROVEMENTS BASED ON         Virgin
                                  USER FEEDBACK                         Virgin
     VERS. 2002-1 (MAY 2002)     *OPTIONAL INPUT PARAMETERS             Virgin
     VERS. 2004-1 (MARCH 2004)   *ADDED INCLUDE FOR COMMON              Virgin
                                 *UP TO 2000 THICKNESSES                Virgin
                                 *INCREASED INCORE PAGE SIZE TO 60,000  Virgin
     VERS. 2007-1 (JAN.  2007)   *CHECKED AGAINST ALL ENDF/B-VII.       Virgin
                                 *INCREASED INCORE PAGE SIZE TO         Virgin
                                  240,000 FROM 60,000.                  Virgin
     VERS. 2007-2 (DEC.  2007)   *72 CHARACTER FILE NAME.               Virgin
     VERS. 2010-1 (Apr.  2010)   *General update based on user feedback Virgin
                                 *INCREASED INCORE PAGE SIZE TO         Virgin
                                  600,000 FROM 240,000.                 Virgin
     VERS. 2012-1 (Aug.  2012)   *Added CODENAME                        Virgin
                                 *32 and 64 bit Compatible              Virgin
                                 *Added ERROR stop                      Virgin
     VERS. 2015-1 (Jan.  2015)   *Extended OUT9.                       Virgin
                                 *Replaced ALL 3 way IF Statements.     Virgin
                                 *Generalized TART Group Structures.    Virgin
                                 *Generalized SAND-II Group Structures. Virgin
                                 *Extended SAND-II to 60, 150, 200 MeV. Virgin
     VERS. 2015-2 (Apr.  2015)   *Changed ALL data to "D" instead of    Virgin
                                  "E" to insure it is REAL*8 and avoid  Virgin
                                  Truncation ERRORS.                    Virgin
     VERS. 2017-1 (May   2017)   *Added UKAEA 1102 Group Structure.     Virgin
                                 *Increased points to 3,000,000         Virgin
                                 *Increased groupd to 30,000            Virgin
```

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                          *Updated based on user feedback        Virgin
                          *Defintion of built-in group structure Virgin
                           using SUBROUTINE GROPE is identical   Virgin
                           for GROUPIE and VIRGIN.               Virgin
                          *All floating point parameters changed Virgin
                           to character inout + IN9 conversion.  Virgin
VERS. 2018-1 (Jan.  2018)  *Decreased PAGE size from 3,000,000   Virgin
                           to 1,500,000                          Virgin
                          *On-line output for ALL ENDERROR       Virgin
VERS. 2019-1 (June  2019)  *Additional Interpolation Law Tests   Virgin
                          *Checked Maximum Tabulated Energy to   Virgin
                           insure it is the same for all MTs -   Virgin
                           if not, print WARNING messages.       Virgin
                                                                 Virgin
2015-2 Acknowledgment                                            Virgin
=====================                                            Virgin
I thank Andrej Trkov (NDS, IAEA) for finding the problem with    Virgin
the "E" formatted DATA (this effected both VIRGIN and GROUPIE).  Virgin
I also thank Andrej for overseeing the entire PREPRO project     Virgin
at IAEA, Vienna; he is part of a truly International team who    Virgin
worked together to produce PREPRO-2015-2, and to make it         Virgin
available Internationally on-line for FREE to ALL users.         Virgin
                                                                 Virgin
OWNED, MAINTAINED AND DISTRIBUTED BY                             Virgin
-----------------------------------                              Virgin
THE NUCLEAR DATA SECTION                                         Virgin
INTERNATIONAL ATOMIC ENERGY AGENCY                               Virgin
P.O. BOX 100                                                     Virgin
A-1400, VIENNA, AUSTRIA                                          Virgin
EUROPE                                                           Virgin
                                                                 Virgin
ORIGINALLY WRITTEN BY                                            Virgin
-----------------------------------                              Virgin
Dermott E. Cullen                                                Virgin
                                                                 Virgin
PRESENT CONTACT INFORMATION                                      Virgin
---------------------------                                      Virgin
Dermott E. Cullen                                                Virgin
1466 Hudson Way                                                  Virgin
Livermore, CA 94550                                              Virgin
U.S.A.                                                           Virgin
Telephone  925-443-1911                                          Virgin
E. Mail    RedCullen1@Comcast.net                                Virgin
Website    RedCullen1.net/HOMEPAGE.NEW                           Virgin
                                                                 Virgin
PURPOSE                                                          Virgin
-------                                                          Virgin
THIS PROGRAM IS DESIGNED TO CALCULATE UNCOLLIDED (I.E. VIRGIN)   Virgin
FLUX AND REACTIONS DUE TO TRANSMISSION OF A MONODIRECTIONAL       Virgin
BEAM OF NEUTRONS THROUGH ANY THICKNESS OF MATERIAL. IN ORDER     Virgin
TO SIMULATE AN EXPERIMENTAL MEASUREMENT THE RESULTS ARE GIVEN    Virgin
AS INTEGRALS OVER ENERGY TALLY GROUPS (AS OPPOSED TO POINTWISE   Virgin
IN ENERGY). BY TAKING THE RATIO OF REACTIONS TO FLUX IN EACH      Virgin
GROUP AN EQUIVALENT SPATIALLY DEPENDENT GROUP AVERAGED CROSS     Virgin
SECTION IS CALCULATED BY THE PROGRAM.                            Virgin
                                                                 Virgin
EVALUATED DATA                                                   Virgin
--------------                                                   Virgin
THE EVALUATED DATA MUST BE IN THE ENDF/B FORMAT. HOWEVER IT      Virgin
MUST BE LINEAR-LINEAR INTERPOLABLE IN ENERGY-CROSS SECTION       Virgin
BETWEEN TABULATED POINTS. SINCE ONLY CROSS SECTIONS (FILE 3 OR 23) Virgin
ARE USED, THIS PROGRAM WILL WORK ON ANY VERSION OF ENDF/B        Virgin
(I.E. ENDF/B-I, II, III, IV, V OR VI).                           Virgin
                                                                 Virgin
RELATED COMPUTER CODES                                           Virgin
----------------------                                           Virgin
IN ORDER TO CONVERT ENDF/B DATA TO THE FORM REQUIRED BY THIS CODE Virgin
THE FOLLOWING COMPUTER CODES MAY BE USED,                        Virgin
                                                                 Virgin
LINEAR  - CONVERT FROM GENERAL ENDF/B INTERPOLATION TO LINEAR-   Virgin
          LINEAR INTERPOLATION.                                  Virgin
```

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RECENT  - ADD THE RESONANCE CONTRIBUTION TO TABULATED BACKGROUND   Virgin
          CROSS SECTIONS TO OBTAIN LINEAR-LINEAR INTERPOLABLE      Virgin
          RESULTS.                                                 Virgin
SIGMA1  - DOPPLER BROADEN CROSS SECTION TO OBTAIN LINEAR-LINEAR    Virgin
          INTERPOLABLE RESULTS.                                    Virgin
MIXER   - MIX INDIVIDUAL MATERIALS TOGETHER TO DEFINE COMPOSITE    Virgin
          MIXTURES, E.G., COMBINE MATERIALS TO DEFINE STAINLESS    Virgin
          STELL.                                                   Virgin
                                                                   Virgin
IN ORDER TO PLOT THE OUTPUT RESULTS OF THIS CODE USE PROGRAM       Virgin
PLOTTAB.                                                           Virgin
                                                                   Virgin
COPIES OF ANY OR ALL OF THESE CODES MAY BE OBTAINED FROM D.E.      Virgin
CULLEN AT THE ABOVE ADDRESS.                                       Virgin
                                                                   Virgin
OUTPUT FORMAT                                                      Virgin
-------------                                                      Virgin
FOR ALL VERSIONS OF THIS PROGRAM PRIOR TO VERSION 92-1 OUTPUT WAS  Virgin
IN TABULAR FORM.                                                   Virgin
                                                                   Virgin
FOR VERSION 92-1 AND LATER VERSIONS OF THIS CODE ALL OUTPUT IS IN  Virgin
THE PROGRAM PLOTTAB FORMAT TO ALLOW RESULTS TO BE EASILY PLOTTED.  Virgin
FOR A COPY OF PROGRAM PLOTTAB CONTACT D.E. CULLEN AT THE ABOVE     Virgin
ADDRESS.                                                           Virgin
                                                                   Virgin
TALLY GROUPS                                                       Virgin
------------                                                       Virgin
THE TALLY GROUP STRUCTURE MAY BE ANY SET OF MONONTONICALLY         Virgin
INCREASING ENERGY BOUNDARIES. THERE MAY BE UP TO 2000 TALLY        Virgin
GROUPS. BY USING THE INPUT PARAMETERS THE USER MAY SPECIFY ANY     Virgin
ARBITRARY TALLY GROUP STRUCTURE OR SELECT ONE OF THE FOLLOWING     Virgin
BUILT-IN GROUP STRUCTURES.                                         Virgin
                                                                   Virgin
 (0) TART 175 GROUPS                                               Virgin
 (1) ORNL  50 GROUPS                                               Virgin
 (2) ORNL 126 GROUPS                                               Virgin
 (3) ORNL 171 GROUPS                                               Virgin
 (4) SAND-II 620 GROUPS - 1.0D-4 eV UP TO 18 MEV                   Virgin
 (5) SAND-II 640 GROUPS - 1.0D-4 eV UP TO 20 MEV                   Virgin
 (6) WIMS 69 GROUPS                                                Virgin
 (7) GAM-I 68 GROUPS                                               Virgin
 (8) GAM-II 99 GROUPS                                              Virgin
 (9) MUFT 54 GROUPS                                                Virgin
(10) ABBN 28 GROUPS                                                Virgin
(11) TART 616 GROUPS TO  20 MeV                                    Virgin
(12) TART 700 GROUPS To   1 GeV                                    Virgin
(13) SAND-II 665 GROUPS - 1.0D-5 eV UP TO 18 MEV                   Virgin
(14) SAND-II 685 GROUPS - 1.0D-5 eV UP TO 20 MEV                   Virgin
(15) TART 666 GROUPS TO 200 MeV                                    Virgin
(16) SAND-II 725 GROUPS - 1.0D-5 eV UP TO  60 MEV                  Virgin
(17) SAND-II 755 GROUPS - 1.0D-5 eV UP TO 150 MEV                  Virgin
(18) SAND-II 765 GROUPS - 1.0D-5 eV UP TO 200 MEV                  Virgin
(19) UKAEA  1102 GROUPS - 1.0D-5 eV UP TO 1 GeV                    Virgin
                                                                   Virgin
INCIDENT SPECTRUM                                                  Virgin
-----------------                                                  Virgin
THE INCIDENT SPECTRUM MAY BE ANY TABULATED FUNCTION THAT IS        Virgin
GIVEN BY A SET OF POINTS THAT IS MONOTONICALLY INCREASING IN       Virgin
ENERGY AND LINEAR-LINEAR INTERPOLABLE IN ENERGY-SPECTRUM           Virgin
BETWEEN TABULATED POINTS. THERE IS NO LIMIT TO THE NUMBER OF       Virgin
POINTS USED TO DESCRIBE THE SPECTRUM. THERE ARE FIVE BUILT-IN      Virgin
OPTIONS FOR THE SPECTRUM.                                          Virgin
                                                                   Virgin
(1) CONSTANT...ENERGY INDEPENDENT (INPUT 0)                        Virgin
(2) 1/E (INPUT 1)                                                  Virgin
(3) BLACKBODY - PHOTON SPECTRUM                                    Virgin
(4) BLACKBODY - ENERGY SPECTRUM (E TIMES THE PHOTON SPECTRUM)      Virgin
(5) TRANSMITTED SPECTRUM FROM PREVIOUS CASE                        Virgin
                                                                   Virgin
NORMALIZATION OF SPECTRUM                                          Virgin
-------------------------                                          Virgin
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ANY INCIDENT SPECTRUM, EITHER READ AS INPUT OR ONE OF THE BUILT-IN SPECTRA, WILL BE NORMALIZED TO UNITY WHEN INTEGRATED OVER THEIR ENTIRE ENERGY RANGE.

TRANSMITTED SPECTRA WILL NOT BE RE-NORMALIZED, SINCE IT ALREADY INCLUDES THE NORMALIZATION OF THE INCIDENT SPECTRUM.

NOTE, INCIDENT SPECTRA IS NORMALIZED TO UNITY OVER THEIR ENTIRE ENERGY RANGE - NOT OVER THE ENERGY RANGE OF THE GROUPS. IF THE ENERGY RANGE OF THE GROUPS IS LESS THAN THAT OF THE SPECTRUM ONLY THAT PORTION OF THE SPECTRUM WILL BE USED AND THIS WILL NOT BE RE-NORMALIZED TO UNITY.

COMPOSITION OF A LAYER

YOU MAY RUN PROBLEMS INVOLVING

1) A LAYER OF UNIFORM DENSITY - DENSITY FOR ATTENUATION IS THAT OF THE TOTAL. DENSITY FOR REACTIONS IS THAT OF THE REACTION.
2) A LAYER OF UNIFORM DENSITY - DENSITY IS THE SUM OF THE TOTAL AND REACTION DENSITIES - THE SUM OF THE CROSS SECTIONS IS USED FOR ATTENUATION AND REACTIONS.
3) A LAYER OF VARYING DENSITY BASED ON A UNIFORM TOTAL DENSITY PLUS A VARIATION BETWEEN 0 AND A MAXIMUM BASED ON THE REACTION DENSITY - 0 AT 0 THICKNESS AND MAXIMUM AT MAXIMUM THICKNESS. IN THIS CASE THE AVERAGE REACTION DENSITY IS EQUAL TO THE INPUT REACTION DENSITY. THE VARIATION IN REACTION DENSITY CAN BE LINEAR, SQUARE OR CUBIC.
4) A LAYER OF VARYING DENSITY BASED ON A TOTAL DENSITY WHICH VARYING FROM MAXIMUM AT 0 THICKNESS TO 0 AT MAXIMUM THICKNESS PLUS A REACTION DENSITY WHICH VARIES FROM 0 AT 0 THICKNESS TO MAXIMUM AT MAXIMUM THICKNESS. IN THIS CASE THE AVERAGE DENSITY OF THE TOTAL AND REACTION WILL BOTH BE EQUAL TO THE INPUT TOTAL AND REACTION DENSITIES. THE VARIATION IN TOTAL AND REACTION DENSITY CAN BE LINEAR, SQUARE OR CUBIC.

IN THE FIRST CASE THE TWO REQUESTED CROSS SECTIONS ARE CONSIDERED TO BE INDEPENDENT - THE TOTAL CROSS SECTION IS USED TO CALCULATE ATTENUATION AND THE REACTION CROSS SECTION IS USED TO CALCULATE REACTIONS, E.G., TRANSMISSION THROUGH NATURAL URANIUM (THE TOTAL CROSS SECTION SHOULD BE THAT OF NATURAL URANIUM) AND REACTIONS IN A U-235 DETECTOR (THE REACTION CROSS SECTION SHOULD BE THAT OF U-235).

IN THE OTHER THREE CASES THE TWO REQUESTED CROSS SECTIONS ARE TREATED AS TWO CONSTITUENTS OF A MIXTURE OF TWO MATERIALS AND THE TWO CROSS SECTIONS ARE USED BOTH TO DEFINE A TOTAL CROSS SECTION FOR ATTENUATION AND A REACTION CROSS SECTION TO DEFINE REACTIONS. IN THESE CASES THE MIXTURE WILL VARY CONTINUOUSLY, E.G., IN CASE 4) HALF WAY THROUGH THE LAYER THE COMPOSITION WILL BE 1/2 THE MATERIAL DEFINED BY THE TOTAL AND 1/2 THE MATERIAL BASED ON THE REACTION. IN THESE CASES RATHER THAN THINKING OF THE TWO CROSS SECTIONS AS A TOTAL AND REACTION CROSS SECTION, IT IS BETTER TO THINK OF THEM AS THE TOTAL CROSS SECTIONS FOR MATERIALS A AND B AND THE CALCULATED REACTIONS WILL BE BASED ON THESE TWO TOTAL CROSS SECTIONS.

MULTIPLE LAYERS

THIS CODE MAY BE USED TO RUN EITHER A NUMBER OF INDEPENDENT PROBLEMS, EACH INVOLVING TRANSMISSION THROUGH A SINGLE LAYER OF MATERIAL, OR TRANSMISSION THROUGH A NUMBER OF LAYERS ONE AFTER THE OTHER.

IN THE CASE OF MULTIPLE LAYERS, ONE LAYER AFTER ANOTHER, THE TRANSMITTED ENERGY DEPENDENT SPECTRUM IS USED AS THE INCIDENT SPECTRUM FOR THE NEXT LAYER. THERE IS NO LIMIT TO THE NUMBER OF LAYERS WHICH MAY BE USED - EACH LAYER IS TREATED AS A COMPLETELY INDEPENDENT PROBLEM WITH A DEFINED INCIDENT SOURCE, AND AS SUCH THE CYCLE OF TRANSMISSION THROUGH EACH LAYER AND USING THE TRANSMITTED SPECTRUM AS THE INCIDENT SPECTRUM FOR THE NEXT LAYER MAY BE REPEATED ANY NUMBER OF TIMES.

```
                                                                      Virgin
REMEMBER - THE INCIDENT SPECTRUM IS ASSUMED TO BE LINEARLY            Virgin
INTERPOLABLE IN ENERGY AND SPECTRUM BETWEEN THE ENERGIES AT           Virgin
WHICH IT IS TABULATED. THE TRANSMITTED SPECTRUM WILL BE TABULATED     Virgin
AT THE UNION OF ALL ENERGIES OF THE INCIDENT SPECTRUM AND CROSS       Virgin
SECTIONS (TOTAL AND REACTION). IN ORDER TO INSURE THE ACCURACY        Virgin
OF THE RESULT WHEN PERFORMING MULTIPLE LAYER CALCULATION BE SURE      Virgin
TO SPECIFY THE INCIDENT SPECTRUM ON THE FIRST LAYER TO SUFFICIENT     Virgin
DETAIL (ENOUGH ENERGY POINTS CLOSELY SPACED TOGETHER) IN ORDER TO     Virgin
ALLOW THE TRANSMITTED SPECTRUM TO BE ACCURATELY REPRESENTED BY        Virgin
LINEAR INTERPOLATION BETWEEN SUCCESSIVE ENERGY POINTS - THERE IS      Virgin
NO LIMIT TO THE NUMBER OF POINTS ALLOWED IN THE INCIDENT SPECTRUM,    Virgin
SO IF YOU ARE IN DOUBT, SIMPLY USE MORE ENERGY POINTS TO SPECIFY      Virgin
THE INCIDENT SPECTRUM.                                                Virgin
                                                                      Virgin
RESULT OUTPUT UNITS                                                   Virgin
------------------                                                    Virgin
FLUX      = EXACTLY AS CALCULATED                                     Virgin
REACTIONS = 1/CM OR 1/GRAM                                            Virgin
AVERAGE   = 1/CM - MACROSCOPIC UNITS                                  Virgin
CROSS                                                                 Virgin
SECTION                                                               Virgin
                                                                      Virgin
THICKNESS AND DENSITY                                                 Virgin
---------------------                                                 Virgin
THE UNCOLLIDED CALCULATION ONLY DEPENDS ON THE PRODUCT OF             Virgin
THICKNESS AND DENSITY (I.E. GRAMS PER CM SQUARED). THIS FACT          Virgin
MAY BE USED TO SIMPLIFY INPUT BY ALLOWING THE THICKNESS AND           Virgin
DENSITY TO BE GIVEN EITHER AS CM AND GRAMS/CC RESPECTIVELY            Virgin
OR ELSE TO GIVE THICKNESS IN GRAMS/(CM*CM) AND INPUT A                Virgin
DENSITY OF 1.0 - OR IN ANY OTHER CONVENIENT UNITS AS LONG AS          Virgin
THE PRODUCT OF THICKNESS AND DENSITY IS IN THE CORRECT GRAMS          Virgin
PER CENTIMETER SQUARED.                                               Virgin
                                                                      Virgin
GRAMS/(CM*CM) ARE RELATED TO ATOMS/BARN THROUGH THE RELATIONSHIP      Virgin
                                                                      Virgin
GRAMS/(CM*CM)=(ATOMS/BARN)*(GRAMS/MOLE)*(MOLE/ATOM)                   Virgin
                                                                      Virgin
OR...                                                                 Virgin
                                                                      Virgin
GRAMS/(CM*CM)=(ATOMS/BARN)*(ATOMIC WEIGHT)/0.602                      Virgin
                                                                      Virgin
CROSS SECTIONS AT A SPACE POINT AND OPTICAL THICKNESS                 Virgin
-----------------------------------------------------                 Virgin
THIS PROGRAM ALLOWS LAYERS OF EITHER UNIFORM DENSITY OR               Virgin
CONTINUOUSLY VARYING DENSITY. THE DENSITY CAN BE ONE OF THE           Virgin
FOLLOWING FORMS,                                                      Virgin
1) C                    = UNIFORM DENSITY                             Virgin
2) C*2*(X/T)            = LINEAR VARIATION FROM 0 TO C                Virgin
3) C*(2-2*(X/T))        = LINEAR VARIATION FROM C TO 0                Virgin
4) C*3*(X/T)**2         = SQUARE VARIATION FROM 0 TO C                Virgin
5) C*(3-3*(X/T)**2)/2   = SQUARE VARIATION FROM C TO 0                Virgin
6) C*4*(X/T)**3         = CUBIC VARIATION FROM 0 TO C                 Virgin
7) C*(4-4*(X/T)**3)/3   = CUBIC VARIATION FROM C TO 0                 Virgin
                                                                      Virgin
IN ORDER TO CALCULATE REACTIONS AT A POINT THE MICROSCOPIC            Virgin
REACTION CROSS SECTION NEED MERELY BE SCALED BY THESE DENSITIES.      Virgin
                                                                      Virgin
IN ORDER TO CALCULATE TRANSMISSION WE MUST DEFINE THE OPTICAL         Virgin
PATH LENGTH WHICH MAY BE DEFINED BY INTEGRATING EACH OF THE           Virgin
ABOVE DENSITY FORMS TO FIND,                                          Virgin
1) C*X                                                                Virgin
2) C*X*(X/T)                                                          Virgin
3) C*X*(2-(X/T))                                                      Virgin
4) C*X*(X/T)**2                                                       Virgin
5) C*X*(3-(X/T)**2)/2                                                 Virgin
6) C*X*(X/T)**3                                                       Virgin
7) C*X*(4-(X/T)**3))/3                                                Virgin
                                                                      Virgin
IN ORDER TO CALCULATE TRANSMISSION TO A POINT THE MICROSCOPIC         Virgin
TOTAL CROSS SECTION NEED MERELY BE SCALED BY THESE DENSITIES          Virgin
```

TO DEFINE THE OPTICAL PATH LENGTH.

THE VARIATION OF THE DENSITY THROUGH THE LAYER MAY BE DEFINED BY SETTING X = 0 OR X = T TO FIND,

	X = 0	X = T
1)	C	C
2)	0	2*C
3)	2*C	0
4)	0	3*C
5)	3*C/2	0
6)	0	4*C
7)	4*C/3	0

THE OPTICAL PATH THROUGH A LAYER OF THICKNESS T MAY BE DEFINED FROM THE ABOVE EXPRESSIONS BY SETTING X=T TO FIND THAT IN ALL CASES THE ANSWER WILL BY C*T. THE CONSTANTS IN THE ABOVE EXPRESSIONS HAVE BEEN INTRODUCED IN ORDER TO FORCE THIS RESULT. WITH THESE FACTORS THE OPTICAL PATH LENGTH THROUGH THE LAYER WILL EXACTLY CORRESPOND TO AN AVERAGE DENSITY CORRESPONDING TO THAT INPUT FOR THE TOTAL AND/OR REACTION, I.E., C CORRESPONDS TO THE INPUT DENSITY.

NOTE - FOR THE SAME OPTICAL PATH LENGTHS THROUGH THE LAYER THE TRANSMISSION WILL BE EXACTLY THE SAME. HOWEVER, VARYING THE DENSITY WILL ALLOW YOU TO MODIFY THE REACTION RATES AT SPECIFIC DEPTHS INTO THE LAYER.

COMPUTATION OF INTEGRALS

STARTING FROM TOTAL CROSS SECTIONS, REACTION CROSS SECTIONS AND A SOURCE SPECTRUM ALL OF WHICH ARE GIVEN IN TABULAR FORM WITH LINEAR INTERPOLATION BETWEEN TABULATED POINTS ALL REQUIRED INTEGRALS CAN BE DEFINED BY ANALYTICAL EXPRESSIONS INVOLVING NOTHING MORE COMPLICATED THAN EXPONENTIALS. THE INTEGRALS THAT MUST BE EVALUATED ARE OF THE FORM...

FLUX

$$\int_{EK}^{EK+1} S(E)\, e^{-XCT(E)\,Z}\, dE$$

REACTIONS

$$\int_{EK}^{EK+1} S(E)\, XCR(E)\, e^{-XCT(E)\,Z}\, dE$$

WHERE..

- EK TO EK+1 = LONGEST ENERGY INTERVAL OVER WHICH S(E), XCT(E) AND XCR(E) ARE ALL LINEARLY INTERPOLABLE.
- S(E) = ENERGY DEPENDENT WEIGHTING SPECTRUM
- XCR(E) = REACTION CROSS SECTION
- XCT(E) = OPTICAL PATH LENGTH (BASED ON TOTAL CROSS SECTION)
- Z = MATERIAL THICKNESS

S(E), XCR(E) AND XCT(E) ARE ALL ASSUMED TO BE GIVEN IN TABULAR FORM WITH LINEAR INTERPOLATION USED BETWEEN TABULATED POINTS. IN OTHER WORDS BETWEEN TABULATED POINTS EACH OF THESE THREE IS DEFINED BY A FUNCTION OF THE FORM...

$$F(E)=((E - EK)*FK+1 + (EK+1 - E)*FK)/(EK+1 - EK)$$

EACH OF THESE THREE CAN BE CONVERTED TO NORMAL FORM BY THE CHANGE OF VARIABLES....

$$X=(E - 0.5*(EK+1 + EK))/(EK+1 - EK)$$

IN WHICH CASE X WILL VARY FROM -1 (AT EK) TO +1 (AT EK+1) AND EACH FUNCTION REDUCES TO THE NORMAL FORM...

$$F(X)=0.5*(FK*(1 - X) + FK+1*(1 + X))$$
$$=0.5*(FK+1 + FK) + 0.5*(FK+1 - FK)*X$$

```
BY DEFINING THE AVERAGE VALUE AND 1/2 THE CHANGE ACROSS THE        Virgin
INTERVAL.                                                          Virgin
                                                                   Virgin
AVF=0.5*(FK+1 + FK)                                                Virgin
DF= 0.5*(FK+1 - FK)                                                Virgin
DE= 0.5*(EK+1 - EK)                                                Virgin
                                                                   Virgin
EACH OF THE THREE FUNCTIONS REDUCES TO THE SIMPLE FORM...          Virgin
                                                                   Virgin
F(X)=AVF+DF*X                                                      Virgin
                                                                   Virgin
AND THE TWO REQUIRED INTEGRALS REDUCE TO...                        Virgin
                                                                   Virgin
FLUX                                                               Virgin
----                                                               Virgin
DE*EXP(-AVXCT*Z) * (INTEGRAL -1 TO +1)                             Virgin
((AVS+DS*X)*EXP(-DXCT*Z*X)*DX)                                     Virgin
                                                                   Virgin
REACTION                                                           Virgin
--------                                                           Virgin
DE*EXP(-AVXCT*Z) * (INTEGRAL -1 TO +1)                             Virgin
((AVS*AVXCR+(AVS*DXCR+AVXCR*DS)*X+DS*DXCR*X*X)*EXP(-DXCT*Z*X)*DX)  Virgin
                                                                   Virgin
WHERE                                                              Virgin
                                                                   Virgin
AVXCT   = AVERAGE VALUE OF THE TOTAL CROSS SECTION                 Virgin
AVXCR   = AVERAGE VALUE OF THE REACTION CROSS SECTION              Virgin
AVS     = AVERAGE VALUE OF THE SOURCE                              Virgin
DXCT    = 1/2 THE CHANGE IN THE TOTAL CROSS SECTION                Virgin
DXCR    = 1/2 THE CHANGE IN THE REACTION CROSS SECTION             Virgin
DS      = 1/2 THE CHANGE IN THE SOURCE                             Virgin
DE      = 1/2 THE CHANGE IN THE ENERGY                             Virgin
                                                                   Virgin
NOTE THAT IN THIS FORM THE ENERGY ONLY APPEARS IN FRONT OF THE     Virgin
INTEGRALS AND THE INTEGRALS ARE EXPRESSED ONLY IN TERMS OF THE     Virgin
TABULATED VALUES OF S(E), XCT(E) AND XCR(E). IN PARTICULAR NO      Virgin
DERIVATIVES ARE USED, SO THAT THERE ARE NO NUMERICAL INSTABILITY   Virgin
PROBLEMS IN THE VACINITY OF DISCONTINUITIES IN S(E), XCT(E) OR     Virgin
XCR(E). INDEED, SINCE (EK+1 - EK) APPEARS IN FRONT OF THE INTEGRAL Virgin
POINTS OF DISCONTINUITY AUTOMATICALLY MAKE ZERO CONTRIBUTION TO    Virgin
THE INTEGRALS.                                                     Virgin
                                                                   Virgin
THE REQUIRED INTEGRALS CAN BE EXPRESSED IN TERMS OF THE THREE      Virgin
INTEGRALS IN NORMAL FORM....                                       Virgin
                                                                   Virgin
F(A,N) = (INTEGRAL -1 TO 1) (X**N*EXP(-A*X)*DX), N=0,1 AND 2.      Virgin
                                                                   Virgin
THESE THREE INTEGRALS CAN BE EVALUATED TO FIND...                  Virgin
                                                                   Virgin
N=0                                                                Virgin
---                                                                Virgin
F(A,0) = (EXP(A)-EXP(-A))/A                                        Virgin
                                                                   Virgin
N=1                                                                Virgin
---                                                                Virgin
F(A,1) = ((1-A)*EXP(A)-(1+A)*EXP(-A))/(A*A)                        Virgin
                                                                   Virgin
N=2                                                                Virgin
---                                                                Virgin
F(A,2) = ((2-2*A+A*A)*EXP(A)-(2+2*A+A*A)*EXP(-A))/(A*A*A)          Virgin
                                                                   Virgin
HOWEVER THESE EXPRESSIONS ARE NUMERICALLY UNSTABLE FOR SMALL       Virgin
VALUES OF A. THEREFORE FOR SMALL A THE EXPONENTIAL IN THE          Virgin
INTEGRALS ARE EXPANDED IN A POWER SERIES...                        Virgin
                                                                   Virgin
EXP(-AX)=1.0-(AX)+(AX)**2/2-(AX)**3/6+(AX)**4/24-.....             Virgin
        =(SUM K=0 TO INFINITY) (-AX)**K/(K FACTORIAL)              Virgin
                                                                   Virgin
AND THE INTEGRAL REDUCES TO THE FORM....                           Virgin
                                                                   Virgin
(SUM K=0 TO INFINITY) ((-A)**K/(K FACTORIAL)) *                    Virgin
```

```
(INTEGRAL -1 TO 1) (X**(N+K))*DX                                        Virgin
                                                                        Virgin
WHICH CAN BE ANALYTICALLY EVAULATED TO FIND....                         Virgin
(K(N) = K FACTORIAL)                                                    Virgin
                                                                        Virgin
N=0                                                                     Virgin
---                                                                     Virgin
F(A,0) = 2*(1+(A**2)/K(3)+(A**4)/K(5)+(A**6)/K(7)+....                  Virgin
                                                                        Virgin
N=1                                                                     Virgin
---                                                                     Virgin
F(A,1) = -2*A*(2/K(3)+4*(A**2)/K(5)+6*(A**4)/K(7)+8*(A**6)/K(9)+..      Virgin
                                                                        Virgin
N=2                                                                     Virgin
---                                                                     Virgin
F(A,2) = 2*(2/K(3)+3*4*(A**2)/K(5)+5*6*(A**4)/K(7)+                     Virgin
         7*8*(A**6)/K(9)+....                                           Virgin
                                                                        Virgin
THESE EXPANSIONS ARE USED WHEN THE ABSOLUTE VALUE OF A IS LESS          Virgin
THAN 0.1. BY TRUNCATING THE ABOVE SERIES BEFORE A**8 THE ERROR          Virgin
RELATIVE TO THE LEADING TERM OF THE SERIES WILL BE 10**(-10),           Virgin
YIELDING 10 DIGIT ACCURACY.                                             Virgin
                                                                        Virgin
AFTER EVALUATING THE ABOVE FUNCTIONS, EITHER DIRECTLY OR BY USING       Virgin
THE EXPANSION THE TWO REQUIRED INTEGRALS CAN BE WRITTEN AS...           Virgin
                                                                        Virgin
FLUX                                                                    Virgin
----                                                                    Virgin
DE*EXP(-AVXCT*Z)*(AVS*F(A,0) + DS*F(A,1))                               Virgin
                                                                        Virgin
REACTIONS                                                               Virgin
---------                                                               Virgin
DE*EXP(-AVXCT*Z)*                                                       Virgin
(AVS*AVXCR*F(A,0) + (AVS*DXCR+AVXCR*DS)*F(A,1) + DS*DXCR*F(A,2))        Virgin
                                                                        Virgin
INPUT FILES                                                             Virgin
-----------                                                             Virgin
FILENAME  UNIT  DESCRIPTION                                             Virgin
--------  ----  -----------                                             Virgin
INPUT       2   INPUT LINES                                             Virgin
ENDFIN     10   EVALUATED DATA IN ENDF/B FORMAT                         Virgin
                                                                        Virgin
OUTPUT FILES                                                            Virgin
------------                                                            Virgin
FILENAME  UNIT  DESCRIPTION                                             Virgin
--------  ----  -----------                                             Virgin
OUTPUT      3   OUTPUT LISTING                                          Virgin
                                                                        Virgin
SCRATCH FILES                                                           Virgin
-------------                                                           Virgin
FILENAME  UNIT  DESCRIPTION                                             Virgin
--------  ----  -----------                                             Virgin
SCR1       12   REACTION, FLUX AND CROSS SECTION RESULTS (BCD)          Virgin
                (SORTED AT END OF RUN AND OUTPUT SEPARATELY)            Virgin
SCR2       13   TALLY GROUP ENERGY BOUNDARIES (BINARY)                  Virgin
SCR3       14   SOURCE SPECTRUM (BINARY)                                Virgin
SCR4       15   TOTAL CROSS SECTION (BINARY)                            Virgin
SCR5       16   REACTION CROSS SECTION (BINARY)                         Virgin
                                                                        Virgin
OPTIONAL STANDARD FILE NAMES (SEE SUBROUTINE FILIO1 AND FILEIO2)        Virgin
-------------------------------------------------------------------     Virgin
UNIT  FILE NAME   FORMAT                                                Virgin
----  ----------  ------                                                Virgin
  2   VIRGIN.INP   BCD                                                  Virgin
  3   VIRGIN.LST   BCD                                                  Virgin
 10   ENDFB.IN     BCD                                                  Virgin
11-15  (SCRATCH)   BINARY                                               Virgin
 16   PLOTTAB.CUR PLOTTAB OUTPUT FORMAT DATA                            Virgin
                                                                        Virgin
INPUT LINES                                                             Virgin
-----------                                                             Virgin
```

```
ANY NUMBER OF CASES MAY BE RUN ONE AFTER THE OTHER. AFTER THE      Virgin
FIRST CASE HAS BEEN RUN THE FOLLOWING CASES MAY USE THE SAME       Virgin
THICKNESSES, GROUP STRUCTURE AND SPECTRUM AS THE PRECEDING CASE.   Virgin
IN ADDITION THE TRANSMITTED SPECTRUM FROM ONE CASE MAY BE USED     Virgin
AS THE INCIDENT SPECTRUM IN THE NEXT CASE, TO ALLOW MULTIPLE       Virgin
LAYERS OF DIFFERENT MATERIALS.                                     Virgin
                                                                   Virgin
LINE  COLS.  FORMAT  DESCRIPTION                                   Virgin
----  -----  ------  ----------                                    Virgin
   1   1-60   ENDF/B INPUT DATA FILENAME                           Virgin
                (STANDARD OPTION = ENDFB.IN)                       Virgin
                                                                   Virgin
LEAVE THE DEFINITION OF THE FILENAMES BLANK - THE PROGRAM WILL     Virgin
THEN USE STANDARD FILENAMES.                                       Virgin
                                                                   Virgin
 2-3   1-72   18A4   TWO LINE TITLE DESCRIBING PROBLEM             Virgin
   4   1- 6    I6    ZA (1000*Z+A) OF TARGET FOR TOTAL             Virgin
       7-11    I5    MT OF TOTAL                                   Virgin
      12-22   E11.4  DENSITY FOR TOTAL                             Virgin
      23-28    I6    ZA (1000*Z+A) OF TARGET FOR REACTION          Virgin
      29-33    I5    MT OF REACTION                                Virgin
                     = 0 - NO REACTION CALCULATION (ONLY FLUX).    Virgin
                     = GREATER THAN 0 - CALCULATE REACTIONS.       Virgin
      34-44   E11.4  DENSITY FOR REACTION                          Virgin
      45-50    I6    NUMBER OF TARGET THICKNESSES                  Virgin
                     = GREATER THAN 0 = READ FROM INPUT            Virgin
                       (1 TO 2000 ALLOWED)                         Virgin
                     =  0 = SAME AS LAST CASE                      Virgin
      51-55    I5    NUMBER OF TALLY GROUPS                        Virgin
                     (REMEMBER NUMBER OF GROUP BOUNDARIES          Virgin
                     IS ONE MORE THAN THE NUMBER OF GROUPS)        Virgin
                     UP TO 2000 GROUPS ARE ALLOWED                 Virgin
                     BUILT-IN GROUP STRUCTURES.                    Virgin
                     = GREATER THAN 0 = READ FROM INPUT            Virgin
                     =  0 TART 175 GROUPS                          Virgin
                     = -1 ORNL  50 GROUPS                          Virgin
                     = -2 ORNL 126 GROUPS                          Virgin
                     = -3 ORNL 171 GROUPS                          Virgin
                     = -4 SAND-II 620 GROUPS..1.0D-4 eV TO 18 MEV  Virgin
                     = -5 SAND-II 640 GROUPS..1.0D-4 eV TO 20 MEV  Virgin
                     = -6 WIMS 69 GROUPS                           Virgin
                     = -7 GAM-I 68 GROUPS                          Virgin
                     = -8 GAM-II 99 GROUPS                         Virgin
                     = -9 MUFT 54 GROUPS                           Virgin
                     =-10 ABBN 28 GROUPS                           Virgin
                     =-11 TART 616 GROUPS TO  20 MeV               Virgin
                     =-12 TART 700 GROUPS TO   1 GeV               Virgin
                     =-13 SAND-II 665 GROUPS..1.0D-5 eV TO 18 MEV  Virgin
                     =-14 SAND-II 685 GROUPS..1.0D-5 eV TO 20 MEV  Virgin
                     =-15 TART 666 GROUPS TO 200 MeV               Virgin
                     =-16 SAND-II 725 GROUPS..1.0D-5 eV TO  60 MEV Virgin
                     =-17 SAND-II 755 GROUPS..1.0D-5 eV TO 150 MEV Virgin
                     =-18 SAND-II 765 GROUPS..1.0D-5 eV TO 200 MEV Virgin
                     =-19 UKAEA  1102 GROUPS..1.0D-5 eV to   1 GeV Virgin
      56-60    I5    NUMBER OF POINTS IN SOURCE SPECTRUM            Virgin
                     (MUST BE AT LEAST TWO POINTS)                 Virgin
                     = GREATER THAN 1 = READ FROM INPUT            Virgin
                     =  0 = SAME AS LAST CASE                      Virgin
                     = -1 = CONSTANT (ENERGY INDEPENDENT)          Virgin
                     = -2 = 1/E                                    Virgin
                     = -3 = BLACKBODY - PHOTON SPECTRUM            Virgin
                     = -4 = BLACKBODY - ENERGY SPECTRUM            Virgin
                     = -5 = TRANSMITTED SPECTRUM FROM LAST CASE    Virgin
                     NOTE, ALL SPECTRA, EXCEPT THE TRANSMITTED     Virgin
                     SPECTRUM FROM THE LAST CASE, WILL BE          Virgin
                     NORMALIZED SUCH THAT ITS INTEGRAL OVER        Virgin
                     ENERGY WILL BE UNITY.                         Virgin
      61-64  1X,3I1  SPATIALLY DEPENDENT OUTOUT                    Virgin
                     = 0 = NO                                      Virgin
                     = 1 = YES                                     Virgin
                     FOR THE 3 QUANTITIES                          Virgin
```

```
                    COLUMN 67 FLUX                                  Virgin
                           68 REACTIONS                             Virgin
                           69 AVERAGE CROSS SECTION                 Virgin
      65-65    I1    ENERGY DEPENDENT OUTOUT                        Virgin
                     = 0 = NONE                                     Virgin
                     = 1 = INCIDENT SPECTRUM                        Virgin
                     = 2 = TRANSMITTED SPECTRUM                     Virgin
                     = 3 = INCIDENT REACTIONS                       Virgin
                     = 4 = TRANSMIITED REACTIONS                    Virgin
                     = 5 = TOTAL CROSS SECTION                      Virgin
                     = 6 = REACTION CROSS SECTION                   Virgin
   5   1-11   E11.4  BLACKBODY TEMPERATURE IN eV                    Virgin
      12-22   E11.4  FLUX NORMALIZATION                             Virgin
      23-33   E11.4  REACTION NORMALIZATION                         Virgin
                     CALCULATIONS WILL BE BASED ON THE SPECTRUM     Virgin
                     AND CROSS SECTIONS AS READ. AT OUTPUT THE      Virgin
                     RESULTS WILL BE MULTIPLIED BY THESE            Virgin
                     NORMALIZATION FACTORS.                         Virgin
      34-44    I11   DENSITY PROFILE                                Virgin
                     = 0 - UNIFORM - BASED ON TOTAL DENSITY         Virgin
                     = 1 - UNIFORM - TOTAL + REACTION DENSITY       Virgin
                     = 2 - TOTAL + LINEAR REACTION                  Virgin
                     = 3 - LINEAR (TOTAL + REACTION)                Virgin
                     = 4 - TOTAL + SQUARE REACTION                  Virgin
                     = 5 - SQUARE (TOTAL + REACTION)                Virgin
                     = 6 - TOTAL + CUBIC REACTION                   Virgin
                     = 7 - CUBIC (TOTAL + REACTION)                 Virgin
 6-N   1-66  6E11.4  TARGET THICKNESSES IN CM                       Virgin
                     IF SAME AS LAST CASE THIS SECTION IS NOT       Virgin
                     INCLUDED IN THE INPUT.                         Virgin
VARY   1-66  6E11.4  TALLY GROUP ENERGY BOUNDARIES                  Virgin
                     (NUMBER OF BOUNDARIES IS ONE MORE THAN         Virgin
                     THE NUMBER OF TALLY GROUPS)                    Virgin
                     IF THE STANDARD OPTION (-14 TO 0) IS           Virgin
                     SELECTED THIS SECTION IS NOT INCLUDED          Virgin
                     IN THE INPUT                                   Virgin
VARY   1-66  6E11.4  SOURCE SPECTRUM IN ENERGY (eV)-SOURCE PAIRS    Virgin
                     (MUST BE AT LEAST TWO POINTS)                  Virgin
                     IF STANDARD OPTION (-5 TO 0) IS SELECTED THIS  Virgin
                     SECTION IS NOT INCLUDED IN THE INPUT           Virgin
                                                                    Virgin
ANY NUMBER OF CASES MAY BE RUN ONE AFTER ANOTHER.                   Virgin
                                                                    Virgin
EXAMPLE INPUT NO. 1                                                 Virgin
-------------------                                                 Virgin
CALCULATE THE UNCOLLIDED FLUX AND CAPTURE (MT=102) THROUGH          Virgin
30 CM OF IRON (DENSITY 7.87 G/CC). TALLY THE RESULTS USING          Virgin
THE TART 175 GROUP STRUCTURE. THE SOURCE WILL BE CONSTANT           Virgin
FROM 1 KEV TO 20 MEV. USE THE STANDARD ENDF/B INPUT DATA            Virgin
FILENAME.                                                           Virgin
                                                                    Virgin
ENDFB.IN                                                            Virgin
IRON 0 TO 30 CM THICK.                                              Virgin
CONSTANT SOURCE FROM 1 KEV TO 20 MEV.                               Virgin
 26000    1 7.8700D+ 0 26000  102 7.8700D+ 0     2    0    2 1100  Virgin
 0.0000D+ 0 1.0000D+ 0 1.0000D+ 0          0 0.0000D+00             Virgin
 0.0000D+00 3.0000D+01                                              Virgin
 1.0000D+03 1.0000D+00 2.0000D+07 1.0000D+00                        Virgin
                                                                    Virgin
EXAMPLE INPUT NO. 2                                                 Virgin
-------------------                                                 Virgin
CALCULATE THE UNCOLLIDED PHOTON FLUX THROUGH A MIXTURE OF SILICON   Virgin
AND IRON FOR 100 MEV PHOTONS INCIDENT. THE TRANSMISSION WILL BE     Virgin
CALCULATED FOR 21 THICKNESSES VARYING BETWEEN 0 AND 1 CM. THERE     Virgin
WILL BE ONLY 1 TALLY GROUP SPANNING A VERY NARROW ENERGY RANGE      Virgin
NEAR 100 MEV, AND THE SOURCE SPECTRUM WILL BE CONSTANT OVER THE     Virgin
SAME ENERGY RANGE. USE THE STANDARD ENDF/B INPUT DATA FILENAME      Virgin
BY LEAVING THE FIRST INPUT LINE BLANK.                              Virgin
                                                                    Virgin
(THIS IS A BLANK LINE TO USE THE STANDARD INPUT FILENAME)           Virgin
100 MEV PHOTONS                                                     Virgin
```

```
     SILICON + 5 % IRON                                                 Virgin
      14000  521 2.30000+ 0 26000  521 1.15000- 1    21    1    2 1000  Virgin
      0.00000+ 0 1.00000+ 0 1.00000+ 0          1 0.00000+00            Virgin
      0.00000+00 5.00000-01 1.00000+00 1.50000+00 2.00000+00 2.50000+00 Virgin
      3.00000+00 3.50000+00 4.00000+00 4.50000+00 5.00000+00 5.50000+00 Virgin
      6.00000+00 6.50000+00 7.00000+00 7.50000+00 8.00000+00 8.50000+00 Virgin
      9.00000+00 9.50000+00 1.00000+01                                  Virgin
      9.99000+ 7 1.00100+ 8                                             Virgin
      9.99000+ 7 1.00000+ 4 1.00100+ 8 1.00000+ 4                       Virgin
                                                                        Virgin
 ======================================================================= Virgin
```