```
======================================================================= Sigma1
                                                                        Sigma1
     PROGRAM SIGMA1                                                      Sigma1
     ==============                                                      Sigma1
     VERSION 73-1 (MARCH 1973)                                          Sigma1
     VERSION 76-1 (FEBRUARY 1976)                                       Sigma1
     VERSION 76-2 (OCTOBER 1976)                                        Sigma1
     VERSION 77-1 (JANUARY 1977)                                        Sigma1
     VERSION 78-1 (JULY 1978)                                           Sigma1
     VERSION 79-1 (JULY 1979)    CDC-7600 AND CRAY-1 VERSION.           Sigma1
     VERSION 80-1 (MAY 1980)     IBM, CDC AND CRAY VERSION              Sigma1
     VERSION 80-2 (DECEMBER 1980)IMPROVED BASED ON USER COMMENTS.       Sigma1
     VERSION 81-1 (MARCH 1981)   DOUBLE PRECISION IBM VERSION           Sigma1
     VERSION 81-2 (AUGUST 1981)  IMPROVED IBM SPEED AND STABILITY       Sigma1
     VERSION 82-1 (JANUARY 1982) IMPROVED COMPUTER COMPATIBILITY        Sigma1
     VERSION 83-1 (JANUARY 1983)*MAJOR RE-DESIGN.                       Sigma1
                                *PAGE SIZE INCREASED - 1002 TO 2004.    Sigma1
                                *ELIMINATED COMPUTER DEPENDENT CODING.  Sigma1
                                *NEW, MORE COMPATIBLE I/O UNIT NUMBER.  Sigma1
                                *ADDED STANDARD ALLOWABLE ERROR OPTION  Sigma1
                                  (CURRENTLY 0.1 PER-CENT).             Sigma1
                                *UNRESOLVED RESONANCE REGION COPIED.    Sigma1
                                *1/V EXTENSION OF CROSS SECTIONS        Sigma1
                                  OUTSIDE OF TABULATED ENERGY RANGE AND Sigma1
                                  INTO UNRESOLVED ENERGY RANGE.         Sigma1
     VERSION 83-2 (OCTOBER 1983)*IMPROVED BASED ON USER COMMENTS.       Sigma1
     VERSION 84-1 (APRIL 1984)  *IMPROVED NUMERICAL STABILITY.          Sigma1
                                *PARTIAL EVALUATION TREATMENT.          Sigma1
     VERSION 85-1 (APRIL 1985)  *ITERATE TO CONVERGENCE (USING THE SAME Sigma1
                                  ENERGY GRID FOR HOT CROSS SECTION AS  Sigma1
                                  COLD CROSS SECTIONS WAS FOUND TO BE   Sigma1
                                  INACCURATE).                          Sigma1
                                *NEW FASTER HIGH ENERGY BROADENING.     Sigma1
                                *UPDATED FOR ENDF/B-VI FORMATS.         Sigma1
                                *SPECIAL I/O ROUTINES TO GUARANTEE      Sigma1
                                  ACCURACY OF ENERGY.                   Sigma1
                                *DOUBLE PRECISION TREATMENT OF ENERGY   Sigma1
                                  (REQUIRED FOR NARROW RESONANCES).     Sigma1
     VERSION 85-2 (AUGUST 1985) *FORTRAN-77/H VERSION                   Sigma1
     VERSION 86-1 (JANUARY 1986)*ENERGY DEPENDENT SCATTERING RADIUS     Sigma1
     VERSION 88-1 (JULY 1988)   *OPTION...INTERNALLY DEFINE ALL I/O     Sigma1
                                  FILE NAMES (SEE, SUBROUTINE FILEIO    Sigma1
                                  FOR DETAILS).                         Sigma1
                                *IMPROVED BASED ON USER COMMENTS.       Sigma1
     VERSION 89-1 (JANUARY 1989)*PSYCHOANALYZED BY PROGRAM FREUD TO     Sigma1
                                  INSURE PROGRAM WILL NOT DO ANYTHING   Sigma1
                                  CRAZY.                                Sigma1
                                *UPDATED TO USE NEW PROGRAM CONVERT     Sigma1
                                  KEYWORDS.                             Sigma1
                                *ADDED LIVERMORE CIVIC COMPILER         Sigma1
                                  CONVENTIONS.                          Sigma1
     VERSION 90-1 (JUNE 1990)   *UPDATED BASED ON USER COMMENTS         Sigma1
                                *ADDED FORTRAN SAVE OPTION              Sigma1
                                *NEW MORE CONSISTENT ENERGY OUTPUT      Sigma1
                                  ROUTINES                              Sigma1
     VERSION 91-1 (JULY 1991)   *WARNING...INPUT PARAMETER FORMAT       Sigma1
                                  HAS BEEN CHANGED - SEE BELOW FOR      Sigma1
                                  DETAILS.                              Sigma1
                                *ADDED CHARGED PARTICLE PROJECTILES     Sigma1
                                *OUTPUT ENERGY RANGE IS ALWAYS AT       Sigma1
                                  LEAST AS LARGE AS INPUT ENERGY RANGE. Sigma1
                                *NO 1/V EXTENSION OF CROSS SECTIONS     Sigma1
                                  FROM UNRESOLVED ENERGY RANGE.         Sigma1
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VERSION 92-1 (JANUARY 1992)*INSURE MINIMUM AND MAXIMUM CROSS       Sigma1
                             SECTIONS ARE ALWAYS KEPT (NOT THINNED) Sigma1
                            *MT=19 (FIRST CHANCE FISSION) TREATED   Sigma1
                             THE SAME AS FISSION.                   Sigma1
                            *VARIABLE MINIMUM CROSS SECTION OF      Sigma1
                             INTEREST - TO ALLOW SMALL CROSS        Sigma1
                             SECTIONS NEAR THRESHOLDS TO BE         Sigma1
                             TREATED PROPERLY.                      Sigma1
                            *ALL ENERGIES INTERNALLY ROUNDED PRIOR  Sigma1
                             TO CALCULATIONS.                       Sigma1
                            *COMPLETELY CONSISTENT I/O AND ROUNDING Sigma1
                             ROUTINES - TO MINIMIZE COMPUTER        Sigma1
                             DEPENDENCE.                            Sigma1
VERSION 92-2 (JULY 1992)    *CORRECTED BUG ASSOCIATED WITH         Sigma1
                             THRESHOLD REACTIONS.                   Sigma1
                            *UNRESOLVED REGION COPIED WITHOUT       Sigma1
                             THINNING (IT SHOULD BE EXACTLY THE     Sigma1
                             SAME AT ALL TEMPERATURES).             Sigma1
                            *NO THINNING OF REACTIONS (MT) THAT     Sigma1
                             WERE NOT BROADENED.                    Sigma1
VERSION 93-1 (APRIL 1993)   *INCREASED PAGE SIZE FROM 2004         Sigma1
                             TO 24000 ENERGY PONTS.                 Sigma1
VERSION 94-1 (JANUARY 1994)*VARIABLE ENDF/B DATA FILENAMES         Sigma1
                             TO ALLOW ACCESS TO FILE STRUCTURES     Sigma1
                             (WARNING - INPUT PARAMETER FORMAT      Sigma1
                             HAS BEEN CHANGED)                      Sigma1
                            *CLOSE ALL FILES BEFORE TERMINATING     Sigma1
                             (SEE, SUBROUTINE ENDIT)               Sigma1
VERSION 96-1 (JANUARY 1996) *COMPLETE RE-WRITE                     Sigma1
                            *IMPROVED COMPUTER INDEPENDENCE         Sigma1
                            *ALL DOUBLE PRECISION                   Sigma1
                            *ON SCREEN OUTPUT                       Sigma1
                            *UNIFORM TREATMENT OF ENDF/B I/O        Sigma1
                            *IMPROVED OUTPUT PRECISION              Sigma1
                            *DEFINED SCRATCH FILE NAMES             Sigma1
                            *ALWAYS INCLUDE THERMAL VALUE           Sigma1
VERSION 97-1 (APRIL 1997)   *OPTIONALLY SET NEGATIVE CROSS         Sigma1
                             SECTIONS = 0 ON INPUT AND              Sigma1
                             OUTPUT.                                Sigma1
                            *INCREASED PAGE SIZE FROM 24000         Sigma1
                             TO 60000 ENERGY POINTS.                Sigma1
VERSION 99-1 (MARCH 1999)   *CORRECTED CHARACTER TO FLOATING       Sigma1
                             POINT READ FOR MORE DIGITS             Sigma1
                            *UPDATED TEST FOR ENDF/B FORMAT         Sigma1
                             VERSION BASED ON RECENT FORMAT CHANGE Sigma1
                            *TREAT LOW ENERGY INITIAL CROSS         Sigma1
                             SECTIONS AS LOG-LOG INTERPOLABLE       Sigma1
                            *CONSTANT (RATHER THAN 1/V) EXTENSION   Sigma1
                             TO HIGHER ENERGY.                      Sigma1
                            *UPDATED CONSTANTS BASED ON CSEWG       Sigma1
                             SUBCOMMITTEE RECOMMENDATIONS           Sigma1
                            *GENERAL IMPROVEMENTS BASED ON          Sigma1
                             USER FEEDBACK                          Sigma1
VERSION 99-2 (JUNE 1999)    *EXTENDED RANGE OF INTEGRALS FROM 4     Sigma1
                             TO 5 UNITS ON EACH SIDE OF ENERGY      Sigma1
                             POINT TO ALLOW FOR LARGER VARIATION    Sigma1
                             IN THE LOCAL CROSS SECTION             Sigma1
                            *ASSUME ENDF/B-VI, NOT V, IF MISSING    Sigma1
                             MF=1, MT-451.                          Sigma1
VERSION 99-3 (OCTOBER 1999))*IMPROVED ERFC FUNCTION DEFINITION.    Sigma1
                             I THANK BOB MACFARLANE (LANL) FOR      Sigma1
                             SUPPLYING A MORE ACCURATE ERFC         Sigma1
                             FUNCTION.                              Sigma1
```

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VERS. 2000-1 (FEBRUARY 2000)*CORRECTED LOW ENERGY INTERPOLATION    Sigma1
                             FOR NON-POSITIVE CROSS SECTIONS       Sigma1
                            *GENERAL IMPROVEMENTS BASED ON         Sigma1
                             USER FEEDBACK                         Sigma1
VERS. 2002-1 (MAY 2002)     *OPTIONAL INPUT PARAMETERS             Sigma1
VERS. 2004-1 (JAN. 2004)    *OPTIONALLY IGNORE UNRESOLVED REGION   Sigma1
                            *CORRECTED PROBLEM AT THE RESOLVED/    Sigma1
                             UNRESOLVED ENERGY BOUNDARY.           Sigma1
                            *CORRECTED HIGH ENERGY CONSTANT CROSS  Sigma1
                             SECTION EXTENSION.                    Sigma1
                            *TIGHTER CRITERIA FOR INITIAL ENERGY   Sigma1
                             POINT SPACING                         Sigma1
                            *TEMPERATURE DEPENDENT ENERGY POINT    Sigma1
                             SPACING.                              Sigma1
                            *ADDED NEW REICH-MOORE (LRF=7) TO      Sigma1
                             FILE2 TO ALLOW COPY TO FIND ANY       Sigma1
                             FOLLOWING UNRESOLVED PARAMETERS       Sigma1
VERS. 2005-1 (JUNE 2005)    *CORRECTED ERROR IN EHOT3 EQUIVALENCE  Sigma1
                             TO EHOT - THIS ONLY EFFECTS VERY BIG  Sigma1
                             OUTPUT FILES.                         Sigma1
VERS. 2007-1 (JAN. 2007)    *CHECKED AGAINST ALL ENDF/B-VII.       Sigma1
                            *INCREASED PAGE SIZE FROM 60,000       Sigma1
                             TO 360,000 ENERGY POINTS.             Sigma1
VERS. 2008-1 (APRIL 2008)   *1/2 INITIAL ENERGY POINT SPACING      Sigma1
                            *72 CHARACTER FILE NAMES.              Sigma1
VERS. 2010-1 (Apr. 2010)    *ASSUME LOW ENERGY LOG-LOG VARIATION   Sigma1
                             UP TO 1/A (eV) FOR ALL BUT TOTAL AND  Sigma1
                             ELASTIC.                              Sigma1
                            *CHANGED DEFAULT UNCERTAINTY TO 0.01%   Sigma1
                             FROM 0.1%                             Sigma1
                            *ALLOW MULTIPLE, ADJACENT UNRESOLVED   Sigma1
                             RESONANCE REGIONS = COMBINE INTO ONE  Sigma1
                             LARGER ENERGY RANGE TO COPY.          Sigma1
                            *DO NOT BROADEN SECTIONS THAT START    Sigma1
                             ABOVE 1 MILLION KT - PREVIOUSLY IT    Sigma1
                             WAS ASSUMED TOTAL, ELASTIC, CAPTURE   Sigma1
                             AND FISSION, AND LARGE SECTIONS (OVER Sigma1
                             10,000 ENERGY POINTS) WOULD BROADEN.  Sigma1
VERS. 2012-1 (Aug. 2012)    *CHANGE COPY CRITERIA TO HANDLE NEW    Sigma1
                             (N,N') DATA = THRESHOLD MAY BE VERY   Sigma1
                             HIGH (OLD CRITERIA) BUT INCLUDES MANY Sigma1
                             TABULATED ENERGY POINTS (NEW ADDED    Sigma1
                             CRITERIA).                            Sigma1
                            *ADDED STOP IF INCIDENT PARTICLE DATA  Sigma1
                             CANNOT BE DOPPLER BROADENED, E.G.,    Sigma1
                             PHOTON INCIDENT.                      Sigma1
                            *Added CODENAME                        Sigma1
                            *32 and 64 bit Compatible              Sigma1
                            *Added ERROR stop                      Sigma1
VERS. 2013-1 (Nov. 2013)    *Added NO broadening above 10 MeV -    Sigma1
                             this is to handle newer evaluations   Sigma1
                             that extend to higher energies and    Sigma1
                             may do "strange" things to stop one   Sigma1
                             MT and then include it as part of     Sigma1
                             a sum at higher energies, e.g. this   Sigma1
                             change will copy ALL points above     Sigma1
                             10 MeV, thus avoiding problems near   Sigma1
                             transistion energies at 20. 30, etc.  Sigma1
                             MeV or higher energies.               Sigma1
VERS. 2015-1 (Jan. 2015)    *Replaced ALL 3 way IF Statements.     Sigma1
                            *Replaced ALL LOGICAL by INTEGER.      Sigma1
                            *Extended OUT9.                        Sigma1
VERS. 2017-1 (May  2017)    *For MF=2 only use MT=151 = Defines    Sigma1
```

```
                                    Unresolved Resonance Region (URR).    Sigma1
                                     Ignore - NJOY created MT=152 and 153. Sigma1
                                    *Increased page size to 1,2000,000.    Sigma1
                                    *All floating input parameters changed Sigma1
                                     to character input + IN9 conversion.  Sigma1
                                                                           Sigma1
OWNED, MAINTAINED AND DISTRIBUTED BY                                       Sigma1
------------------------------------                                       Sigma1
THE NUCLEAR DATA SECTION                                                   Sigma1
INTERNATIONAL ATOMIC ENERGY AGENCY                                         Sigma1
P.O. BOX 100                                                               Sigma1
A-1400, VIENNA, AUSTRIA                                                    Sigma1
EUROPE                                                                     Sigma1
                                                                           Sigma1
ORIGINALLY WRITTEN BY                                                      Sigma1
------------------------------------                                       Sigma1
Dermott E. Cullen                                                          Sigma1
                                                                           Sigma1
PRESENT CONTACT INFORMATION                                                Sigma1
---------------------------                                                Sigma1
Dermott E. Cullen                                                          Sigma1
1466 Hudson Way                                                            Sigma1
Livermore, CA 94550                                                        Sigma1
U.S.A.                                                                     Sigma1
Telephone  925-443-1911                                                    Sigma1
E. Mail    RedCullen1@Comcast.net                                          Sigma1
Website    RedCullen1.nedt/HOMEPAGE.NEW                                    Sigma1
                                                                           Sigma1
Acknowledgement 2004                                                       Sigma1
--------------------                                                       Sigma1
Currently almost all improvements to this code are based upon              Sigma1
feedback from code users who report problems. This feedback                Sigma1
benefits ALL users of this code, and ALL users are encouraged              Sigma1
to report problems.                                                        Sigma1
                                                                           Sigma1
Improvements on the 2004 version of this code based on user                Sigma1
feedback including,                                                        Sigma1
1) Bret Beck  - reported a problem at the resolved/unresolved              Sigma1
                energy boundary.                                           Sigma1
2) S. Ganesan - reported a problem for small temperature changes.          Sigma1
                                                                           Sigma1
AUTHORS MESSAGE                                                            Sigma1
---------------                                                            Sigma1
THE REPORT DESCRIBED ABOVE IS THE LATEST PUBLISHED DOCUMENTATION           Sigma1
FOR THIS PROGRAM. HOWEVER, THE COMMENTS BELOW SHOULD BE CONSIDERED Sigma1
THE LATEST DOCUMENTATION INCLUDING ALL RECENT IMPROVEMENTS. PLEASE Sigma1
READ ALL OF THESE COMMENTS BEFORE IMPLEMENTATION, PARTICULARLY            Sigma1
THE COMMENTS CONCERNING MACHINE DEPENDENT CODING.                          Sigma1
                                                                           Sigma1
AT THE PRESENT TIME WE ARE ATTEMPTING TO DEVELOP A SET OF COMPUTER Sigma1
INDEPENDENT PROGRAMS THAT CAN EASILY BE IMPLEMENTED ON ANY ONE            Sigma1
OF A WIDE VARIETY OF COMPUTERS. IN ORDER TO ASSIST IN THIS PROJECT Sigma1
IT WOULD BE APPECIATED IF YOU WOULD NOTIFY THE AUTHOR OF ANY              Sigma1
COMPILER DIAGNOSTICS, OPERATING PROBLEMS OR SUGGESTIONS ON HOW TO         Sigma1
IMPROVE THIS PROGRAM. HOPEFULLY, IN THIS WAY FUTURE VERSIONS OF           Sigma1
THIS PROGRAM WILL BE COMPLETELY COMPATIBLE FOR USE ON YOUR                Sigma1
COMPUTER.                                                                  Sigma1
                                                                           Sigma1
PURPOSE                                                                    Sigma1
-------                                                                    Sigma1
THIS PROGRAM IS DESIGNED TO DOPPLER BROADEN NEUTRON INDUCED                Sigma1
CROSS SECTIONS. EACH SECTION OF CROSS SECTIONS (FILE 3) IS READ           Sigma1
FROM THE ENDF/B FORMAT. THE DATA IS DOPPLER BROADENED, THINNED            Sigma1
```

AND OUTPUT IN THE ENDF/B FORMAT.

IN THE FOLLOWING DISCUSSION FOR SIMPLICITY THE ENDF/B TERMINOLOGY
---ENDF/B TAPE---WILL BE USED. IN FACT THE ACTUAL MEDIUM MAY BE
TAPE, CARDS, DISK OR ANY OTHER MEDIUM.

ENDF/B FORMAT

THIS PROGRAM ONLY USES THE ENDF/B BCD OR CARD IMAGE FORMAT (AS
OPPOSED TO THE BINARY FORMAT) AND CAN HANDLE DATA IN ANY VERSION
OF THE ENDF/B FORMAT (I.E., ENDF/B-I, II, III, IV OR V FORMAT).

IT IS ASSUMED THAT THE DATA IS CORRECTLY CODED IN THE ENDF/B
FORMAT AND NO ERROR CHECKING IS PERFORMED. IN PARTICULAR IT IS
ASSUMED THAT THE MAT, MF AND MT ON EACH CARD IS CORRECT. SEQUENCE
NUMBERS (COLUMNS 76-80) ARE IGNORED ON INPUT, BUT WILL BE
CORRECTLY OUTPUT ON ALL CARDS. THE FORMAT OF SECTION MF=1, MT=451
AND ALL SECTIONS OF MF=3 MUST BE CORRECT. THE PROGRAM COPIES ALL
OTHER SECTION OF DATA AS HOLLERITH AND AS SUCH IS INSENSITIVE TO
THE CORRECTNESS OR INCORRECTNESS OF ALL OTHER SECTIONS.

ALL CROSS SECTIONS THAT ARE USED BY THIS PROGRAM MUST BE TABULATED
AND LINEARLY INTERPOLABLE IN ENERGY AND CROSS SECTION (ENDF/B
INTERPOLATION LAW 2). FILE 3 CROSS SECTIONS MAY BE MADE LINEARLY
INTERPOLABLE BY USING PROGRAM LINEAR (UCRL-50400, VOL.17, PART A).
FILE 2 RESONANCE PARAMETERS MAY BE USED TO RECONSTRUCT ENERGY
DEPENDENT CROSS SECTIONS AND ADD IN FILE 3 BACKGROUND CROSS
SECTIONS TO DEFINE LINEARLY INTERPOLABLE CROSS SECTIONS BY USING
PROGRAM RECENT (UCRL-50400, VOL. 17, PART C). IF THIS PROGRAM
FINDS THAT THE FILE 3 CROSS SECTIONS ARE NOT LINEARLY INTERPOLABLE
THIS PROGRAM WILL TERMINATE EXECUTION.

UNRESOLVED RESONANCE REGION

IN THE UNRESOLVED RESONANCE REGION IT IS NOT POSSIBLE TO EXACTLY
DEFINE THE ENERGY DEPENDENCE OF THE CROSS SECTIONS. THE AVERAGE
WIDTHS AND SPACINGS GIVEN IN ENDF/B ARE ONLY ADEQUATE TO DEFINE
AVERAGE VALUES OF THE CROSS SECTIONS. THEREFORE ALL CROSS SECTIONS
IN THE ENDF/B FORMAT FOR THE UNRESOLVED REGION ARE REALLY AVERAGE
VALUES WHICH CANNOT BE DOPPLER BROADENED USING THE SIGMA1 METHOD
(WHICH REQUIRES TABULATED, LINEARLY INTERPOLABLE, ENERGY DEPENDENT
CROSS SECTIONS.

THEREFORE,
(1) ALL TABULATED POINTS WITHIN THE UNRESOLVED RESONANCE REGION
WILL BE COPIED, WITHOUT MODIFICATION OR BROADENING. ADOPTION OF
THIS CONVENTION WILL ALLOW SUBSEQUENT PROGRAMS TO PROPERLY DEFINE
SELF-SHIELDED, DOPPLER BROADENED CROSS SECTIONS IN THE UNRESOLVED
RESONANCE REGION.
(2) CROSS SECTIONS WILL BE EXTENDED AS 1/V ABOVE THE UPPER ENERGY
LIMIT OF THE RESOLVED RESONANCE REGION AND BELOW THE LOWER ENERGY
LIMIT OF THE CONTINUUUM REGION (I.E. INTO THE UNRESOLVED
RESONANCE REGION). THIS CONVENTION WILL GUARANTEE A SMOOTH
BEHAVIOR CLOSE TO THE UNRESOLVED RESONANCE REGION BOUNDARIES.

OUTPUT FORMAT

IN THIS VERSION OF SIGMA1 ALL FILE 3 ENERGIES WILL BE OUTPUT IN
F (INSTEAD OF E) FORMAT IN ORDER TO ALLOW ENERGIES TO BE WRITTEN
WITH UP TO 9 DIGITS OF ACCURACY. IN PREVIOUS VERSIONS THIS WAS AN
OUTPUT OPTION. HOWEVER USE OF THIS OPTION TO COMPARE THE RESULTS
OF ENERGIES WRITTEN IN THE NORMAL ENDF/B CONVENTION OF 6 DIGITS
TO THE 9 DIGIT OUTPUT FROM THIS PROGRAM DEMONSTRATED THAT FAILURE

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TO USE THE 9 DIGIT OUTPUT CAN LEAD TO LARGE ERRORS IN THE DATA     Sigma1
JUST DUE TO TRANSLATION OF THE ENERGIES TO THE ENDF/B FORMAT.      Sigma1
                                                                   Sigma1
CONTENTS OF OUTPUT                                                 Sigma1
------------------                                                 Sigma1
ENTIRE EVALUATIONS ARE OUTPUT, NOT JUST THE BROADENED FILE 3       Sigma1
CROSS SECTIONS, E.G. ANGULAR AND ENERGY DISTRIBUTIONS ARE ALSO     Sigma1
INCLUDED.                                                          Sigma1
                                                                   Sigma1
DOCUMENTATION                                                      Sigma1
-------------                                                      Sigma1
THE FACT THAT THIS PROGRAM HAS OPERATED ON THE DATA IS DOCUMENTED  Sigma1
BY THE ADDITION OF THREE COMMENTS CARDS AT THE END OF EACH         Sigma1
HOLLERITH SECTION IN THE FORM                                      Sigma1
                                                                   Sigma1
***************** PROGRAM SIGMA1 (2017-1) ***************          Sigma1
DATA DOPPLER BROADENED TO 300.0   KELVIN AND                       Sigma1
DATA THINNED TO WITHIN AN ACCURACY OF  0.1 PER-CENT                Sigma1
                                                                   Sigma1
THE ORDER OF ALL SIMILAR COMMENTS (FROM LINEAR,RECENT AND GROUPY)  Sigma1
REPRESENTS A COMPLETE HISTORY OF ALL OPERATIONS PERFORMED ON       Sigma1
THE DATA.                                                          Sigma1
                                                                   Sigma1
THESE COMMENT CARDS ARE ONLY ADDED TO EXISTING HOLLERITH SECTIONS, Sigma1
I.E., THIS PROGRAM WILL NOT CREATE A HOLLERITH SECTION. THE FORMAT Sigma1
OF THE HOLLERITH SECTION IN ENDF/B-V DIFFERS FROM THE THAT OF      Sigma1
EARLIER VERSIONS OF ENDF/B. BY READING AN EXISTING MF=1, MT=451    Sigma1
IT IS POSSIBLE FOR THIS PROGRAM TO DETERMINE WHICH VERSION OF      Sigma1
THE ENDF/B FORMAT THE DATA IS IN. WITHOUT HAVING A SECTION OF      Sigma1
MF=1, MT=451 PRESENT IT IS IMPOSSIBLE FOR THIS PROGRAM TO          Sigma1
DETERMINE WHICH VERSION OF THE ENDF/B FORMAT THE DATA IS IN, AND   Sigma1
AS SUCH IT IS IMPOSSIBLE FOR THE PROGRAM TO DETERMINE WHAT FORMAT  Sigma1
SHOULD BE USED TO CREATE A HOLLERITH SECTION.                      Sigma1
                                                                   Sigma1
REACTION INDEX                                                     Sigma1
--------------                                                     Sigma1
THIS PROGRAM DOES NOT USE THE REACTION INDEX WHICH IS GIVEN IN     Sigma1
SECTION MF=1, MT=451 OF EACH EVALUATION.                           Sigma1
                                                                   Sigma1
THIS PROGRAM DOES NOT UPDATE THE REACTION INDEX IN MF=1, MT=451.   Sigma1
THIS CONVENTION HAS BEEN ADOPTED BECAUSE MOST USERS DO NOT         Sigma1
REQUIRE A CORRECT REACTION INDEX FOR THEIR APPLICATIONS AND IT WAS Sigma1
NOT CONSIDERED WORTHWHILE TO INCLUDE THE OVERHEAD OF CONSTRUCTING  Sigma1
A CORRECT REACTION INDEX IN THIS PROGRAM. HOWEVER, IF YOU REQUIRE  Sigma1
A REACTION INDEX FOR YOUR APPLICATIONS, AFTER RUNNING THIS PROGRAM Sigma1
YOU MAY USE PROGRAM DICTIN TO CREATE A CORRECT REACTION INDEX.     Sigma1
                                                                   Sigma1
SECTION SIZE                                                       Sigma1
------------                                                       Sigma1
SINCE THIS PROGRAM USES A LOGICAL PAGING SYSTEM THERE IS NO LIMIT  Sigma1
TO THE NUMBER OF POINTS IN ANY SECTION, E.G., THE TOTAL CROSS      Sigma1
SECTION MAY BE REPRESENTED BY 200,000 DATA POINTS.                 Sigma1
                                                                   Sigma1
SELECTION OF DATA                                                  Sigma1
-----------------                                                  Sigma1
THE PROGRAM SELECTS MATERIALS TO BE BROADENED BASED EITHER ON      Sigma1
MAT (ENDF/B MAT NO.) OR ZA. THE PROGRAM ALLOWS UP TO 100 MAT OR    Sigma1
ZA RANGES TO BE SPECIFIED. THE PROGRAM WILL ASSUME THAT THE        Sigma1
ENDF/B TAPE IS IN EITHER MAT OR ZA ORDER, WHICHEVER CRITERIA IS    Sigma1
USED TO SELECT MATERIALS, AND WILL TERMINATE WHEN A MAT OR ZA      Sigma1
IS FOUND THAT IS ABOVE THE RANGE OF ALL REQUESTS.                  Sigma1
                                                                   Sigma1
ENERGY GRID OF BROADENED DATA                                      Sigma1
```

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------------------------------                              Sigma1
```
THE ENERGY GRID FOR THE DOPPLER BROADENED CROSS SECTIONS IS
SELECTED TO INSURE THAT THE BROADENED DATA IS LINEAR-LINEAR
INTERPOLABLE. AS SUCH THE ENERGY GRID FOR THE BROADENED DATA
MAY NOT BE THE SAME AS THE ENERGY GRID FOR THE ORIGINAL
UNBROADENED DATA. GENERALLY AFTER BROADENING THERE WILL BE
FEWER DATA POINTS IN THE RESONANCE REGION, BUT AT LOW ENERGY
THERE MAY BE MORE POINTS, DUE TO THE 1/V LOW ENERGY EFFECT
CREATED BY DOPPLER BROADENING.

EFFECTIVE TEMERATURE INCREASE
```
------------------------------
```
IF THE ORIGINAL DATA IS NOT AT ZERO KELVIN THE PROGRAM WILL
BROADEN THE DATA BY THE EFFECTIVE TEMPERATURE DIFFENCE TO THE
FINAL TEMPERATURE. IF THE DATA IS ALREADY AT A TEMPERATURE THAT
IS HIGHER THAN THE FINAL TEMPERATURE DOPPLER BROADENING IS
NATURALLY NOT PERFORMED AND THE TEMPERATURE IN THE SECTION IS LEFT
AT ITS ORIGINAL VALUE.

MULTIPLE FINAL TEMPERATURES
```
--------------------------
```
THE PRESENT VERSION ONLY DOPPLER BROADENS TO ONE FINAL TEMPERATURE
(IF THERE IS SUFFICIENT INTEREST EXPRESSED BY USERS FUTURE
VERSION MAY BROADEN TO MULTIPLE TEMPERATURES. PLEASE
CONTACT THE AUTHOR IF YOU ARE INTERESTED IN A MULTIPLE
TEMPERATURE OPTION).

PROGRAM OPERATION
```
-----------------
```
EACH SECTION OF FILE 3 DATA IS CONSIDERED SEPERATELY. THE DATA
IS READ AND DOPPLER BROADENED A PAGE AT A TIME (ONE PAGE IS
60000 DATA POINTS). UP TO THREE PAGES OF DATA MAY BE IN THE CORE
AT ANY GIVEN TIME, THE PAGE BEING BROADENED, THE PAGE BELOW IT
IN ENERGY AND THE PAGE ABOVE IT IN ENERGY. AFTER A PAGE HAS BEEN
BROADENED IT IS THINNED, IF THE ENTIRE SECTION CONTAINS ONLY
ONE PAGE OR LESS, IT WILL STILL BE CORE RESIDENT AND WILL BE
WRITTEN DIRECTLY FROM CORE TO THE OUTPUT TAPE. IF THE BROADENED,
THINNED SECTION IS LARGER THAN A PAGE, AFTER A PAGE HAS BEEN
BROADENED AND THINNED IT IS WRITTEN TO A SCRATCH FILE. AFTER THE
ENTIRE SECTION HAS BEEN BROADENED AND THINNED THE DATA IS READ
FROM SCRATCH TO CORE, ONE PAGE AT A TIME, THE OUTPUT TO THE OUTPUT
TAPE.

ALLOWABLE ERROR
```
---------------
```
AFTER DOPPLER BROADENING THE CROSS SECTION IN THE RESONANCE REGION
WILL GENERALLY BE MUCH SMOOTHER THAN THE UNBROADENED DATA AND CAN
BE REPRESENTED TO THE SAME ACCURACY BY A SMALLER NUMBER OF ENERGY
POINTS. THEREFORE AFTER DOPPLER BROADENING THE DATA CAN BE THINNED
WITH ESSENTIALLY NO LOSE OF INFORMATION.

THE ALLOWABLE ERROR MAY BE ENERGY INDEPENDENT (CONSTANT) OR ENERGY
DEPENDENT. THE ALLOWABLE ERROR IS DESCRIBED BY A TABULATED
FUNCTION OF UP TO 20 (ENERGY,ERROR) PAIRS AND LINEAR INTERPOLATION
BETWEEN TABULATED POINTS. IF ONLY ONE TABULATED POINT IS GIVEN THE
ERROR WILL BE CONSIDERED CONSTANT OVER THE ENTIRE ENERGY RANGE.
WITH THIS ENERGY DEPENDENT ERROR ONE MAY OPTIMIZE THE OUTPUT FOR
ANY GIVEN APPLICATION BY USING A SMALL ERROR IN THE ENERGY RANGE
OF INTEREST AND A LESS STRINGENT ERROR IN OTHER ENERGY RANGES.

INPUT FILES
```
-----------
```
UNIT DESCRIPTION

```
 ----  -----------                                          Sigma1
   2  INPUT CARDS (BCD - 80 CHARACTERS/RECORD)              Sigma1
  10  ORIGINAL ENDF/B DATA (BCD - 80 CHARACTERS/RECORD)     Sigma1
                                                            Sigma1
OUTPUT FILES                                                Sigma1
------------                                                Sigma1
UNIT  DESCRIPTION                                           Sigma1
----  -----------                                          Sigma1
   3  OUTPUT REPORT (BCD - 120 CHARACTERS/RECORD)           Sigma1
  11  FINAL ENDF/B DATA (BCD - 80 CHARACTERS/RECORD)        Sigma1
                                                            Sigma1
SCRATCH FILES                                               Sigma1
------------                                                Sigma1
UNIT  DESCRIPTION                                           Sigma1
----  -----------                                          Sigma1
  12  SCRATCH FILE FOR BROADENED DATA                       Sigma1
      (BINARY - 180000 WORDS/RECORD - DOUBLE PRECISION/     Sigma1
                 42000 WORDS/RECORD - SINLGE PRECISION)     Sigma1
                                                            Sigma1
OPTIONAL STANDARD FILE NAMES (SEE SUBROUTINE FILEIO)        Sigma1
----------------------------------------------------        Sigma1
UNIT  FILE NAME                                             Sigma1
----  ----------                                           Sigma1
   2  SIGMA1.INP                                            Sigma1
   3  SIGMA1.LST                                            Sigma1
  10  ENDFB.IN                                              Sigma1
  11  ENDFB.OUT                                             Sigma1
  12  (SCRATCH)                                             Sigma1
                                                            Sigma1
INPUT CARDS                                                 Sigma1
----------                                                 Sigma1
CARD  COLS.  DESCRIPTION                                    Sigma1
----  -----  -----------                                   Sigma1
   1  1-11   SELECTION CRITERIA (0=MAT, 1=ZA)               Sigma1
      12-22  MONITOR MODE SELECTOR                          Sigma1
             = 0 - NORMAL OPERATION                         Sigma1
             = 1 - MONITOR PROGRESS OF DOPPLER BROADENING OF DATA. Sigma1
                   EACH TIME A PAGE OF DATA POINTS IS WRITTEN TO    Sigma1
                   THE SCRATCH FILE PRINT OUT THE TOTAL NUMBER OF   Sigma1
                   POINTS ON SCRATCH AND THE LOWER AND UPPER        Sigma1
                   ENERGY LIMITS OF THE PAGE (THIS OPTION MAY BE    Sigma1
                   USED IN ORDER TO MONITOR THE EXECUTION SPEED     Sigma1
                   OF LONG RUNNING JOBS).                           Sigma1
      23-33  KELVIN TEMPERATURE                             Sigma1
      34-44  MINIMUM CROSS SECTION OF INTEREST              Sigma1
             (DEFAULT VALUE = 1.0E-10 BARNS).               Sigma1
      45-55  NEGATIVE CROSS SECTION TREATMENT               Sigma1
             = 0 - O.K.                                     Sigma1
             = 1 - SET = 0                                  Sigma1
      56-66  UNRESOLVED RESONANCE REGION TREATMENT          Sigma1
             = 0 - COPY (NO BROADENING)                     Sigma1
             = 1 - IGNORE (BROADEN)                         Sigma1
   2  1-72   ENDF/B INPUT DATA FILENAME                     Sigma1
             (STANDARD OPTION = ENDFB.IN)                   Sigma1
   3  1-72   ENDF/B OUTPUT DATA FILENAME                    Sigma1
             (STANDARD OPTION = ENDFB.OUT)                  Sigma1
 4-N  1-11   LOWER MAT OR ZA LIMIT                          Sigma1
      12-22  UPPER MAT OR ZA LIMIT                          Sigma1
             UP TO 100 MAT OR ZA RANGES MAY BE SPECIFIED, ONE  Sigma1
             RANGE PER CARD. THE LIST OF RANGES IS TERMINATED BY  Sigma1
             A BLANK CARD. IF THE UPPER LIMIT IS LESS THAN THE  Sigma1
             LOWER LIMIT THE UPPER LIMIT WILL BE SET EQUAL TO THE  Sigma1
             LOWER LIMIT. IF THE FIRST REQUEST CARD IS BLANK IT  Sigma1
```

```
                WILL TERMINATE THE LIST OF REQUESTS AND CAUSE ALL       Sigma1
                DATA TO BE RETRIEVED (SEE EXAMPLE INPUT).                Sigma1
     VARY  1-11  ENERGY FOR ERROR LAW                                   Sigma1
          12-22  ERROR FOR ERROR LAW                                    Sigma1
                THE ACCEPTABLE LINEARIZING ERROR CAN BE GIVEN AS AN     Sigma1
                ENERGY DEPENDENT FUNCTION SPECIFIED BY UP TO 20         Sigma1
                (ENERGY,ERROR) PAIRS AND LINEAR INTERPOLATION           Sigma1
                TABULATE POINTS. ENERGIES MUST BE IN ASCENDING ORDER.   Sigma1
                THE ERROR LAW IS TERMINATED BY A BLANK CARD. IF THE     Sigma1
                FIRST ERROR LAW CARD IS BLANK IT WILL TERMINATE THE     Sigma1
                ERROR LAW AND THE ERROR WILL BE TREATED AS ENERGY       Sigma1
                INDEPENDENT, EQUAL TO ZERO, WHICH INDICATES THAT THE    Sigma1
                BROADENED DATA SHOULD NOT BE THINNED.                   Sigma1
                                                                        Sigma1
     EXAMPLE INPUT NO. 1                                                Sigma1
     -------------------                                                Sigma1
     BROADEN ALL URANIUM ISOTOPES AND THORIUM-232 TO 300 KELVIN. FROM   Sigma1
     0 TO 100 EV THIN OUTPUT DATA TO 0.1 PER-CENT ACCURACY. FROM 100 EV Sigma1
     TO 1 KEV VARY THE ERROR BETWEEN 0.1 AND 1 PER-CENT. ABOVE 1 KEV    Sigma1
     USE 1 PER-CENT ACCURACY.                                          Sigma1
                                                                        Sigma1
     EXPLICITLY SPECIFY THE STANDARD FILENAMES.                        Sigma1
                                                                        Sigma1
     THE FOLLOWING 11 CARDS ARE REQUIRED                               Sigma1
                                                                        Sigma1
         1            0 3.00000+ 2                                      Sigma1
ENDFB.IN                                                                Sigma1
ENDFB.OUT                                                               Sigma1
    92000     92999                                                     Sigma1
    90232                  (UPPER LIMIT WILL AUTOMATICALLY BE DEFINED)  Sigma1
                           (BLANK CARD INDICATES END OF REQUEST LIST)   Sigma1
0.00000+ 0 1.00000-03                                                   Sigma1
1.00000+ 2 1.00000-03                                                   Sigma1
1.00000+ 3 1.00000-02                                                   Sigma1
1.00000+ 9 1.00000-02                                                   Sigma1
                           (BLANK CARD INDICATES END OF ERROR LAW)      Sigma1
                                                                        Sigma1
     EXAMPLE INPUT NO. 2                                                Sigma1
     -------------------                                                Sigma1
     BROADEN ALL DATA TO 300 KELVIN AND DO NOT THIN THE BROADEN DATA.   Sigma1
     ALL OF THE STANDARD OPTION MAY BE INVOKED MERELY BY SPECIFYING     Sigma1
     THE KELVIN TEMPERATURE ON THE FIRST CARD. ALL OTHER FIELDS MAY     Sigma1
     BE LEFT BLANK.                                                     Sigma1
                                                                        Sigma1
     LEAVE THE DEFINITION OF THE FILENAMES BLANK - THE PROGRAM WILL     Sigma1
     THEN USE STANDARD FILENAMES.                                       Sigma1
                                                                        Sigma1
     THE FOLLOWING 5 CARDS ARE REQUIRED                                Sigma1
                                                                        Sigma1
                3.00000+ 2                                              Sigma1
                   (USE STANDARD FILENAME = ENDFB.IN)                   Sigma1
                   (USE STANDARD FILENAME = ENDFB.OUT)                  Sigma1
                   (RETRIEVE ALL DATA, TERMINATE REQUEST LIST)          Sigma1
                   (0.0 ALLOWABLE ERROR, TERMINATE ERROR LAW)           Sigma1
                                                                        Sigma1
     EXAMPLE INPUT NO. 3                                                Sigma1
     -------------------                                                Sigma1
     THE SAME AS ABOVE, ONLY DEFINE THE MINIMUM CROSS SECTION OF        Sigma1
     INTEREST TO BE 1.0E-30 BARNS (INSTEAD OF THE DEFAULT VALUE OF      Sigma1
     1.0E-10).                                                          Sigma1
                                                                        Sigma1
     READ ENDF/B DATA FROM \ENDFB6\RECENT\ZA092238 AND WRITE ENDF/B     Sigma1
     DATA TO \ENDFB\SIGMA1\ZA092238                                     Sigma1
```

```
                                                                    Sigma1
        THE FOLLOWING 5 CARDS ARE REQUIRED                          Sigma1
                                                                    Sigma1
                        3.00000+ 2 1.00000-30                       Sigma1
 \ENDFB6\RECENT\ZA092238                                            Sigma1
 \ENDFB6\SIGMA1\ZA092238                                            Sigma1
                    (RETRIEVE ALL DATA, TERMINATE REQUEST LIST)     Sigma1
                    (0.0 ALLOWABLE ERROR, TERMINATE ERROR LAW)      Sigma1
                                                                    Sigma1
 ================================================================== Sigma1
```