```
====================================================================== 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
    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
        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
                             *Added NRO = energy dependent scatter Sigma1
                              radius to copying FILE2 parameters   Sigma1
                              to define unresolved energy range.   Sigma1
                             *Corrected energy dependent scattering Sigma1
                              radius for all resonance types (see, Sigma1
                              the above comments).                Sigma1
VERS. 2018-1 (Jan. 2018)     *Added on-line report for ALL ENDERROR 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.                         Sigma1
                                                         Sigma1
IN THE FOLLOWING DISCUSSION FOR SIMPLICITY THE ENDF/B TERMINOLOGY Sigma1
---ENDF/B TAPE---WILL BE USED. IN FACT THE ACTUAL MEDIUM MAY BE   Sigma1
TAPE, CARDS, DISK OR ANY OTHER MEDIUM.                   Sigma1
                                                         Sigma1
ENDF/B FORMAT                                            Sigma1
------------                                             Sigma1
THIS PROGRAM ONLY USES THE ENDF/B BCD OR CARD IMAGE FORMAT (AS    Sigma1
OPPOSED TO THE BINARY FORMAT) AND CAN HANDLE DATA IN ANY VERSION  Sigma1
OF THE ENDF/B FORMAT (I.E., ENDF/B-I, II, III, IV OR V FORMAT).   Sigma1
                                                         Sigma1
IT IS ASSUMED THAT THE DATA IS CORRECTLY CODED IN THE ENDF/B      Sigma1
FORMAT AND NO ERROR CHECKING IS PERFORMED. IN PARTICULAR IT IS    Sigma1
ASSUMED THAT THE MAT, MF AND MT ON EACH CARD IS CORRECT. SEQUENCE Sigma1
NUMBERS (COLUMNS 76-80) ARE IGNORED ON INPUT, BUT WILL BE         Sigma1
CORRECTLY OUTPUT ON ALL CARDS. THE FORMAT OF SECTION MF=1, MT=451 Sigma1
AND ALL SECTIONS OF MF=3 MUST BE CORRECT. THE PROGRAM COPIES ALL  Sigma1
OTHER SECTION OF DATA AS HOLLERITH AND AS SUCH IS INSENSITIVE TO  Sigma1
THE CORRECTNESS OR INCORRECTNESS OF ALL OTHER SECTIONS.  Sigma1
                                                         Sigma1
ALL CROSS SECTIONS THAT ARE USED BY THIS PROGRAM MUST BE TABULATED Sigma1
AND LINEARLY INTERPOLABLE IN ENERGY AND CROSS SECTION (ENDF/B     Sigma1
INTERPOLATION LAW 2). FILE 3 CROSS SECTIONS MAY BE MADE LINEARLY  Sigma1
INTERPOLABLE BY USING PROGRAM LINEAR (UCRL-50400, VOL.17, PART A). Sigma1
```

FILE 2 RESONANCE PARAMETERS MAY BE USED TO RECONSTRUCT ENERGY   Sigma1
DEPENDENT CROSS SECTIONS AND ADD IN FILE 3 BACKGROUND CROSS   Sigma1
SECTIONS TO DEFINE LINEARLY INTERPOLABLE CROSS SECTIONS BY USING   Sigma1
PROGRAM RECENT (UCRL-50400, VOL. 17, PART C). IF THIS PROGRAM   Sigma1
FINDS THAT THE FILE 3 CROSS SECTIONS ARE NOT LINEARLY INTERPOLABLE Sigma1
THIS PROGRAM WILL TERMINATE EXECUTION.   Sigma1
                                                                   Sigma1
UNRESOLVED RESONANCE REGION   Sigma1
---------------------------   Sigma1
IN THE UNRESOLVED RESONANCE REGION IT IS NOT POSSIBLE TO EXACTLY   Sigma1
DEFINE THE ENERGY DEPENDENCE OF THE CROSS SECTIONS. THE AVERAGE   Sigma1
WIDTHS AND SPACINGS GIVEN IN ENDF/B ARE ONLY ADEQUATE TO DEFINE   Sigma1
AVERAGE VALUES OF THE CROSS SECTIONS. THEREFORE ALL CROSS SECTIONS Sigma1
IN THE ENDF/B FORMAT FOR THE UNRESOLVED REGION ARE REALLY AVERAGE Sigma1
VALUES WHICH CANNOT BE DOPPLER BROADENED USING THE SIGMA1 METHOD   Sigma1
(WHICH REQUIRES TABULATED, LINEARLY INTERPOLABLE, ENERGY DEPENDENT Sigma1
CROSS SECTIONS.   Sigma1
                                                                   Sigma1
THEREFORE,   Sigma1
(1) ALL TABULATED POINTS WITHIN THE UNRESOLVED RESONANCE REGION   Sigma1
WILL BE COPIED, WITHOUT MODIFICATION OR BROADENING. ADOPTION OF   Sigma1
THIS CONVENTION WILL ALLOW SUBSEQUENT PROGRAMS TO PROPERLY DEFINE Sigma1
SELF-SHIELDED, DOPPLER BROADENED CROSS SECTIONS IN THE UNRESOLVED Sigma1
RESONANCE REGION.   Sigma1
(2) CROSS SECTIONS WILL BE EXTENDED AS 1/V ABOVE THE UPPER ENERGY Sigma1
LIMIT OF THE RESOLVED RESONANCE REGION AND BELOW THE LOWER ENERGY Sigma1
LIMIT OF THE CONTINUUUM REGION (I.E. INTO THE UNRESOLVED   Sigma1
RESONANCE REGION). THIS CONVENTION WILL GUARANTEE A SMOOTH   Sigma1
BEHAVIOR CLOSE TO THE UNRESOLVED RESONANCE REGION BOUNDARIES.   Sigma1
                                                                   Sigma1
OUTPUT FORMAT   Sigma1
-------------   Sigma1
IN THIS VERSION OF SIGMA1 ALL FILE 3 ENERGIES WILL BE OUTPUT IN   Sigma1
F (INSTEAD OF E) FORMAT IN ORDER TO ALLOW ENERGIES TO BE WRITTEN   Sigma1
WITH UP TO 9 DIGITS OF ACCURACY. IN PREVIOUS VERSIONS THIS WAS AN Sigma1
OUTPUT OPTION. HOWEVER USE OF THIS OPTION TO COMPARE THE RESULTS   Sigma1
OF ENERGIES WRITTEN IN THE NORMAL ENDF/B CONVENTION OF 6 DIGITS   Sigma1
TO THE 9 DIGIT OUTPUT FROM THIS PROGRAM DEMONSTRATED THAT FAILURE Sigma1
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 (2018-1) ***************   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

REACTION INDEX

THIS PROGRAM DOES NOT USE THE REACTION INDEX WHICH IS GIVEN IN
SECTION MF=1, MT=451 OF EACH EVALUATION.

THIS PROGRAM DOES NOT UPDATE THE REACTION INDEX IN MF=1, MT=451.
THIS CONVENTION HAS BEEN ADOPTED BECAUSE MOST USERS DO NOT
REQUIRE A CORRECT REACTION INDEX FOR THEIR APPLICATIONS AND IT WAS
NOT CONSIDERED WORTHWHILE TO INCLUDE THE OVERHEAD OF CONSTRUCTING
A CORRECT REACTION INDEX IN THIS PROGRAM. HOWEVER, IF YOU REQUIRE
A REACTION INDEX FOR YOUR APPLICATIONS, AFTER RUNNING THIS PROGRAM
YOU MAY USE PROGRAM DICTIN TO CREATE A CORRECT REACTION INDEX.

SECTION SIZE

SINCE THIS PROGRAM USES A LOGICAL PAGING SYSTEM THERE IS NO LIMIT
TO THE NUMBER OF POINTS IN ANY SECTION, E.G., THE TOTAL CROSS
SECTION MAY BE REPRESENTED BY 200,000 DATA POINTS.

SELECTION OF DATA

THE PROGRAM SELECTS MATERIALS TO BE BROADENED BASED EITHER ON
MAT (ENDF/B MAT NO.) OR ZA. THE PROGRAM ALLOWS UP TO 100 MAT OR
ZA RANGES TO BE SPECIFIED. THE PROGRAM WILL ASSUME THAT THE
ENDF/B TAPE IS IN EITHER MAT OR ZA ORDER, WHICHEVER CRITERIA IS
USED TO SELECT MATERIALS, AND WILL TERMINATE WHEN A MAT OR ZA
IS FOUND THAT IS ABOVE THE RANGE OF ALL REQUESTS.

ENERGY GRID OF BROADENED DATA

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.                                                            Sigma1
                                                                Sigma1
ALLOWABLE ERROR                                                 Sigma1
--------------                                                  Sigma1
AFTER DOPPLER BROADENING THE CROSS SECTION IN THE RESONANCE REGION Sigma1
WILL GENERALLY BE MUCH SMOOTHER THAN THE UNBROADENED DATA AND CAN  Sigma1
BE REPRESENTED TO THE SAME ACCURACY BY A SMALLER NUMBER OF ENERGY  Sigma1
POINTS. THEREFORE AFTER DOPPLER BROADENING THE DATA CAN BE THINNED Sigma1
WITH ESSENTIALLY NO LOSE OF INFORMATION.                        Sigma1
                                                                Sigma1
THE ALLOWABLE ERROR MAY BE ENERGY INDEPENDENT (CONSTANT) OR ENERGY Sigma1
DEPENDENT. THE ALLOWABLE ERROR IS DESCRIBED BY A TABULATED       Sigma1
FUNCTION OF UP TO 20 (ENERGY,ERROR) PAIRS AND LINEAR INTERPOLATION Sigma1
BETWEEN TABULATED POINTS. IF ONLY ONE TABULATED POINT IS GIVEN THE Sigma1
ERROR WILL BE CONSIDERED CONSTANT OVER THE ENTIRE ENERGY RANGE. Sigma1
WITH THIS ENERGY DEPENDENT ERROR ONE MAY OPTIMIZE THE OUTPUT FOR Sigma1
ANY GIVEN APPLICATION BY USING A SMALL ERROR IN THE ENERGY RANGE Sigma1
OF INTEREST AND A LESS STRINGENT ERROR IN OTHER ENERGY RANGES.  Sigma1
                                                                Sigma1
INPUT FILES                                                     Sigma1
-----------                                                     Sigma1
UNIT  DESCRIPTION                                               Sigma1
----  -----------                                               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
```