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======================================================================== 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
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                          *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
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                          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 (Nov. 2018)  *Added on-line report for ALL ENDERROR Sigma1
VERS. 2019-1 (June 2019)  *Terminate if MF=3 Point Count and    Sigma1
                          Interpolation Law do not agree.       Sigma1
                          *Terminate if MF=3 Background         Sigma1
                          Interpolation is NOT Linear.          Sigma1
                          *Terminate if MF/MT=1/451 Input       Sigma1
                          temperature exceeds requested         Sigma1
                          Temperature - otherwise the output    Sigma1
                          by this code to MF=3 would appear     Sigma1
                          to be at the WRONG temperature.       Sigma1
                          *Additional Interpolation Law Tests   Sigma1
                          *Check consistency of Maximum         Sigma1
                          Tabulated cross sections for ALL MT   Sigma1
```

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                            processed - print WQARNING if NOT     Sigma1
                            the same for ALL MTs.                 Sigma1
                                                                  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
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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 (2019-1) ***************          Sigma1
DATA DOPPLER BROADENED TO 300.0   KELVIN AND                      Sigma1
DATA THINNED TO WITHIN AN ACCURACY OF  0.1 PER-CENT                Sigma1
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                                                                      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
-----------------------------                                         Sigma1
THE ENERGY GRID FOR THE DOPPLER BROADENED CROSS SECTIONS IS           Sigma1
SELECTED TO INSURE THAT THE BROADENED DATA IS LINEAR-LINEAR           Sigma1
INTERPOLABLE. AS SUCH THE ENERGY GRID FOR THE BROADENED DATA          Sigma1
MAY NOT BE THE SAME AS THE ENERGY GRID FOR THE ORIGINAL               Sigma1
UNBROADENED DATA. GENERALLY AFTER BROADENING THERE WILL BE            Sigma1
FEWER DATA POINTS IN THE RESONANCE REGION, BUT AT LOW ENERGY          Sigma1
THERE MAY BE MORE POINTS, DUE TO THE 1/V LOW ENERGY EFFECT            Sigma1
CREATED BY DOPPLER BROADENING.                                        Sigma1
                                                                      Sigma1
EFFECTIVE TEMERATURE INCREASE                                         Sigma1
-----------------------------                                         Sigma1
IF THE ORIGINAL DATA IS NOT AT ZERO KELVIN THE PROGRAM WILL           Sigma1
BROADEN THE DATA BY THE EFFECTIVE TEMPERATURE DIFFENCE TO THE         Sigma1
FINAL TEMPERATURE. IF THE DATA IS ALREADY AT A TEMPERATURE THAT       Sigma1
IS HIGHER THAN THE FINAL TEMPERATURE DOPPLER BROADENING IS            Sigma1
NATURALLY NOT PERFORMED AND THE TEMPERATURE IN THE SECTION IS LEFT    Sigma1
AT ITS ORIGINAL VALUE.                                                Sigma1
                                                                      Sigma1
MULTIPLE FINAL TEMPERATURES                                           Sigma1
---------------------------                                           Sigma1
THE PRESENT VERSION ONLY DOPPLER BROADENS TO ONE FINAL TEMPERATURE     Sigma1
(IF THERE IS SUFFICIENT INTEREST EXPRESSED BY USERS FUTURE            Sigma1
VERSION MAY BROADEN TO MULTIPLE TEMPERATURES. PLEASE                  Sigma1
CONTACT THE AUTHOR IF YOU ARE INTERESTED IN A MULTIPLE                Sigma1
TEMPERATURE OPTION).                                                  Sigma1
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                                                                      Sigma1
PROGRAM OPERATION                                                     Sigma1
-----------------                                                     Sigma1
EACH SECTION OF FILE 3 DATA IS CONSIDERED SEPERATELY. THE DATA        Sigma1
IS READ AND DOPPLER BROADENED A PAGE AT A TIME (ONE PAGE IS           Sigma1
60000 DATA POINTS). UP TO THREE PAGES OF DATA MAY BE IN THE CORE      Sigma1
AT ANY GIVEN TIME, THE PAGE BEING BROADENED, THE PAGE BELOW IT        Sigma1
IN ENERGY AND THE PAGE ABOVE IT IN ENERGY. AFTER A PAGE HAS BEEN      Sigma1
BROADENED IT IS THINNED, IF THE ENTIRE SECTION CONTAINS ONLY          Sigma1
ONE PAGE OR LESS, IT WILL STILL BE CORE RESIDENT AND WILL BE          Sigma1
WRITTEN DIRECTLY FROM CORE TO THE OUTPUT TAPE. IF THE BROADENED,      Sigma1
THINNED SECTION IS LARGER THAN A PAGE, AFTER A PAGE HAS BEEN          Sigma1
BROADENED AND THINNED IT IS WRITTEN TO A SCRATCH FILE. AFTER THE      Sigma1
ENTIRE SECTION HAS BEEN BROADENED AND THINNED THE DATA IS READ        Sigma1
FROM SCRATCH TO CORE, ONE PAGE AT A TIME, THE OUTPUT TO THE OUTPUT Sigma1
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
```

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          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
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    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
```