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BNL325 - Nuclear Reaction Data Display Program

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Abstract: A computer code for the graphical display of nuclear reaction data is described. The code, which works on a computer with VMS operating system, can overlay experimental data from an EXFOR/CSISRS table-computation format with evaluated data from ENDF formatted data libraries. Originally, this code has been used at the U.S. National Nuclear Data Center to produce the well-known neutron cross-section atlas published as report BNL-325.

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BNL325
Nuclear Reaction Data Display Program

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IAEA Nuclear Data Section

November 27, 1994

The BNL325 program is designed to prepare graphical displays of nuclear reaction cross section experimental data and overlay data curves in both a simple display mode and a more complex publication mode. The program has a long and revered history in the NNDC. This version of the program was designed for the production of the 1987 edition of the Neutron Data Atlas. It borrows heavily from its predecessor written by D. Garber and modified by R. Kinsey between 1970 and 1975. The starting point for this program was PLOTED written by a summer student, Ed Blucher in 1982.

Contents

1 Features and Restrictions

The basic features of this program include:

- ability to plot experimental cross section data from input DATA and BIB files in NNDC table-computation format,
- overlay up to six evaluated data curves in a single plot including direct access to the major evaluated data files; the order in which the keywords CURVE, ENDF, ENDFB, JEF, JENDL, CENDL, BROND and OVERLAY occur in a control file will determine the order (and line type) in the legend,
- ability to suppress plotting symbols which overlap and suppress points on an overly dense plot,
- ability to lay out multiple plots on either horizontal or vertical pages,
- automatic production of bibliographic pages describing the plotted data,
- both interactive and control file input modes,
- output to any NNDC graphical output device.

Only the control file mode contains all the layout instruction features required for a publication.

The major restrictions of the program are

1. only single variable data such as σ(E) or $\bar{\nu}$(E) may be plotted,
2. the input BIB and DATA tables must be in in the computation TABLE format,
3. the data for overlay curves must be in ENDF "section" format,
4. no more than 200 references in a single data table can be processed.

2 Operation

The BNL325 program is initiated on the VAX with the user defined DCL command `BNL325` which should be defined as

```
BNL325 :== $EXE:BNL325.EXE
```

where the parameter for the command line has the format

input_file/output_file/output_device/information_flag

If either the input file or the output file is not specified in the command line parameter or if the program is executed with the RUN command, then the program will prompt for the input and output file specifications.

The *input_file* is just the input control file specification. If this value is given as TT, then the user can specify interactively data required to construct a control file. Not all of the features of the control file form of the input specification are accessible in this dialog mode (see Table I for details).

The output_file is the name of the output graphics file. The output file contains PostScript instructions for plotting on a laser printer. It the output graphics file is TT then the output will be displayed on the user's terminal. The default mode is **REGIS** for DEC-VT240 or X-Windows terminals or for terminals which emulate this graphics instruction format.

In the case of terminal output, the default REGIS mode can be overridden by specifying the *device* field. In this case, 1 means **Tektronix 4014** mode; 2 means **PostScript**; and 3 means **REGIS**. Finally, the *information_flag* is used to suppress informational output if the value NO is given. These two fields are only available when BNL325 is started by the command BNL325.

3 KEYWORD Instructions

The keywords which can be used to specify the details of the operation of the BNL325 program in the control file are listed in Table I. A single plot is defined by all of the keywords between a PLOT and an ENDPLOT keyword. In the default operating mode, this series of keywords will produce 2 pages. The first page will be a data plot and the second a reference table. All data references from the data table, unless enumerated in an IGNORE keyword, will be included in the output reference table. In publication mode, all plots between a PAGE and an ENDPAGE keyword will appear on the same output page. The references for these plots are cumulated so that all the references are output on one or more pages when a REFTABLE keyword is given.

A keyword may be followed by one or more data records which give further information required by the keyword. The format of these records is a free format with fields separated by a comma.

Table I
Summary of BNL325 Keywords

Keyword	Location	Data Record Format*	Use	Terminal Input Equivalent
DEFAULT	First keyword in instruction file	none	Redefine program defaults	Yes
PUBLICATION	Between DEFAULT and ENDDEFAULT only	I	Define Publication mode	No
A4		none	Set or reset default parameters	No
NOA4		none		No
HORIZONTAL		none		Default
VERTICAL		none		Yes
SYMBOLS		none		Default
DOTS		none		Yes
ERRORS		none		Default
NOERRORS		none		Yes
GRID		none		Yes
NOGRID		none		Default
ID		none		Yes
CULL		I		No
ENDDEFAULT	Immediately following default parameters	none	Indicate end of default parameter setting	No
PAGE	Not between PLOT and ENDPLOT	none	Define pages in publication mode	No
ENDPAGE		none		No
REFTABLE		none or E		No
PLOT	Between PLOT and ENDPLOT only	none	Define a plot	Yes
ENDPLOT		none		Yes
NOPLOT		none	Define input data	No
NOREFERENCE		none		No
VERTICAL**		none		No
HORIZONTAL**		none		No
LOCATION		A5/A5	Publication mode only	No
BIB		A50		Yes
DATA		A50		Yes
NODATA		none		Yes
TABLE		5I		Yes
REACTION		A80		No

Table I (continued)
Summary of BNL325 Keywords

Keyword	Location	Data Record Format*	Use	Terminal Input Equivalent
CURVE		A30		Yes
ENDF		A40		No
OVERLAY		A30/A20	Define	No
ENDFB		none	overlay	Yes
JEF		none	curve	Yes
JENDL		none	data	Yes
CENDL		none		Yes
BROND		none		Yes
IGNORE		20I	Select	No
REMOVE		20I	data	No
EQUAL		20I	plotted	No
ANNOTATE	Between	none	Publication	No
NOANNOTATE		none	mode only	No
X-RANGE	PLOT	2E		Yes
SCALE	and	A10		Yes
X-LIMITS		3E		No
X-UNITS	ENDPLOT	I		Yes
Y-LIMITS		3E		No
Y-UNITS		I	Describe	Yes
LEGEND	only	2E,I		No
CULL ***		I	plot	No
NOCULL		none		No
GRID ***		none		No
NOGRID ***		none		No
ERRORS ***		none		No
NOERRORS ***		none		No
DOTS ***		none		No
SYMBOLS ***		none		No

* none no record required
I an integer
E a floating point number
A character string

a preceding integer is number of such fields

a trailing integer is the length of the character string

a / indicates a new record

** May appear only in the first plot definition on a page in publication mode.

*** May also be placed in the DEFAULT section.

4 KEYWORD Explanations

4.1 Job Defaults

DEFAULT	This keyword must be the first keyword in the control file if it is used. The keyword indicates the beginning of default definitions which will apply to all plots and tables generated during the current run of the program. Some of the defaults can be overridden on a plot by plot basis. The override condition is in effect for only the plot for which the counter keyword is given.
ENDDEFAULT	This keyword indicates the end of the default definition section.
PUBLICATION	This keyword located within the default definition section changes the program from normal to publication mode of operation. This permits more than one plot to appear on a page and enables those keywords such as ANNOTATE which apply only to the publication mode. The accompanying data record contains an integer which will be the starting page number for the first output page. Subsequent pages are numbered in increasing numerical order.
A4	Laser printer output is formated for A4 paper. This is the default if the symbol, HOME_BASE is set to anything. Then use NOA4 to override.
NOA4	Laser printer output is formated for American 8.5x11 inch paper. This is the default if the symbol, HOME_BASE is not set. Then use A4 to override.
HORIZONTAL	Tall pages are generated. This is the program default unless the keyword, VERTICAL is given in the DEFAULT section.
VERTICAL	Wide pages are generated. This can be made the program default by giving this keyword in the DEFAULT section.
SYMBOLS	This keyword causes all plotted points to be displayed with symbols unique to each data set. Only a dot will be plotted if the symbol would physically overlap another symbol already plotted. This is the program default unless the DOTS keyword is given in the DEFAULT section.

DOTS	This keyword causes all data points in a plot to be drawn as DOTS. This can be made the program default by giving this keyword in the DEFAULT section.
ERRORS	This keyword causes a error bars to be drawn for each data point on the plot if such information exists in the experimental data file. This is the program default unless the NOERRORS keyword is given in the DEFAULT section .
NOERRORS	This keyword results in no error bars being drawn on a plot. This keyword may be given in the DEFAULT section to suppress error bar plotting on all plots.
GRID	This keyword causes a grid to be drawn on a plot. The default is no grid unless the GRID keyword is given in the DEFAULT section.
NOGRID	This keyword causes the grid to be omitted from a plot. This is the program default unless the GRID keyword is given in the DEFAULT section .
ID	In normal mode, this keyword instructs the program to add a notation to both the plots and the reference tables giving the experimental data table (see TABLE) from which the page was derived. In publication mode, the program will add each laboratory code encountered in a reference table to the file LABS.ALL and each reference code to the file REFS.ALL instead of the table notation.
CULL	When the density of data points on a plot is too great, this keyword can cause the program to suppress plotting points. The suppression is done randomly. The keyword requires a following data record which contains the maximum number of points to be plotted from any single data set. If a data set contains fewer points than this value, no points in that set are skipped. The default is no cull unless the CULL keyword is given in the DEFAULT section.

4.2 Publication Mode Page Definitions

These keywords are used only in publication mode. They are used to define the beginning and end of pages and to force out reference pages which are cumulated in this mode.

PAGE	A new page in publication mode is signalled via this keyword. It may not be placed between a PLOT and an ENDPLOT keyword.
ENDPAGE	This keyword signals the end of a page in publication mode.
REFTABLE	This keyword instructs the program to produce one or more reference pages from the current cumulation of references from previous plots. The current cumulation is then set to zero to prevent possible later duplication when the keyword is issued again. If the cumulated reference file is empty, the keyword has no effect. The keyword is simulated at the end of a control file to insure that any remaining references are output. If the keyword follows an ENDPAGE keyword, then no following data record is required; however if the keyword immediately precedes the ENDPAGE, then a data record is required giving the distance from the bottom of the page up to the beginning of the table in inches or in centimeters if the A4 paper format has been selected.

4.3 Plot Definition

PLOT	A plot definition is initiated with this keyword. The remaining keywords defined below will be ignored unless they appear between the PLOT and the ENDPLOT keyword or unless they are permitted in the DEFAULT definition section.
ENDPLOT	This keyword signals the end of the definition of a plot. The program then produces the plot according to the keywords.
NOPLOT	This keyword will suppress the generation of the current plot. However, the corresponding reference table will be generated. In publication mode, the references will be added to the cumulated reference table for later output and a page annotation will be prepared with the notation (see BIB).
NOREFERENCE	Reference table generation of the current plot will be suppressed if this keyword is used. This feature is particularly useful when more than one plot is generated from a data table and you do not wish to have repeated information in the reference tables.
HORIZONTAL	Tall pages are generated. This is the program default unless the contra keyword, VERTICAL is given in the default section. In PUBLICATION mode, this keyword may appear only in the first plot on a page, otherwise it will be ignored.
VERTICAL	Wide pages are generated. This can be made the program default if VERTICAL is given in the default section. In PUBLICATION mode, this keyword may appear only in the first plot on a page, otherwise it will be ignored.
LOCATION	This keyword is used in PUBLICATION mode to specify the location of a plot on the page. The following two records contain keywords selected from Table II which indicates the horizontal and vertical locations of the plot on the page. The default assumed if the keyword is not used is that the plot occupies the entire page.

Table II

Descriptors for the LOCATION keyword

HORIZONTAL Descriptors

WHOLE	–	entire page
L-CENTER	–	left 2/3 page
R-CENTER	–	right 2/3 page
L-HALF	–	left 1/2 page
R-HALF	–	right 1/2 page
LEFT	–	left 1/3 of page
CENTER	–	center 1/3 page
RIGHT	–	right 1/3 page

VERTICAL Descriptors

WHOLE	–	entire page
T-MIDDLE	–	upper 2/3 page
B-MIDDLE	–	lower 2/3 page
UPPER	–	upper 1/2 page
LOWER	–	lower 1/2 page
TOP	–	upper 1/3 page
MIDDLE	–	middle 1/3 page
BOTTOM	–	bottom 1/3 page

BIB

This keyword is used to give the input file specification of the bibliographic information for the experimental data being plotted. The following record should give the complete file specification. The file must be in the format generated by the "table" option of the CSISRS computation format program. Generally files output from the computation format program are not suitable for "random access". If the BIB file does not contain 80-character fixed-length characters, the program will do the conversion automatically. This keyword need not be repeated in successive plot definitions if the bibliographic file to be used remains unchanged. The default file name is `EXFOR.BIB`.

DATA

This keyword is used to give the file specification for the experimental data being plotted. The following record should give the complete file specification. The file must be in the format generated by the "table" option of the CSISRS computation format program. Generally files output from the computation format program are not suitable for "random access". If the DATA file does not contain 80-character fixed-length characters, the program will do the conversion automatically.This keyword need not be repeated in successive plot definitions if the experimental data file to be used remains unchanged. The default file name is `EXFOR.TABLE`.

TABLE

The table or tables in the experimental data file to be used in the plot are selected with this keyword. Data from up to five tables can be merged together in a single plot. The tables are given as a list of table numbers separated by commas. If this keyword is not given, table 1 is assumed. If tables are merged, the reference numbers within the second and successive tables are reassigned to insure uniqueness within a plot. The reference numbers in the first table remain unchanged. The numbers in the successive tables are reassigned by adding to each number, the total number of references in preceding tables.

NODATA

This command instructs the program ignore any experimental data when generating the display. Only evaluated date overlays will be plotted. This is equivalent to giving blank specifications for both the BIB and DATA keywords.

REACTION

The nuclear reaction specification can be given with this keyword. The reaction specification is used to generate the plot title. It should be entered on the following record in the EXFOR reaction format including the surrounding parentheses. If the keyword is not given, the program first looks for the REACTION keyword in the bibliographic file for the first table in the table selection list. If no experimental data is being plotted, then the program attempts to construct a reaction string from the ENDF/B data file for an overlay curve. If neither of these conditions exist and the REACTION is not given, then the plot will not be generated.

CURVE

This keyword will cause a curve to be displayed on the plot. The curve will be labeled "Eyeguide". The following record should give the complete input file specification. The file must be in the format of an ENDF section preceded by a "tape label" record. If the data file is not found, the keyword is ignored.

ENDF

An evaluated data curve from any of the major evaluated data files, ENDF/B, JEF, JENDL, CENDL or BROND can be overlaid on a plot if this keyword is used. The data is retrieved directly from the ENDF/B data base. The following record has 8 fields to specify the data section required. The fields are

NLIB, NSUB, Z, A, LIS, MF, MT, LDRV

where	NLIB	is the library number or the library name
	NSUB	is the sublibrary number (projectile)
	Z	is the target chemical symbol or the proton number
	A	is target mass number
	LIS	is the target isomer state number
	MF	is the ENDF file number
	MT	is the ENDF section number
	LDRV	is the derived library number

If Z, A, LIS, MF or MT are zero, the program uses the CSISRS format reaction string to derive appropriate values. If the section cannot be found, an error message is output and the keyword ignored.

OVERLAY	This keyword will cause an additional curve to be drawn on a plot. The keyword can be used at most two times for each plot. The following record should give the complete file specification. The second record gives the curve label which will appear in the legend box. The label string must end with a dollar sign, **$**. The file must be in the format of an ENDF section preceded by a "tape label" record. If the data file is not found, the keyword is ignored.
ENDFB	Overlay the appropriate section from the ENDF/B-VI evaluated data library. The full reaction string must be available from the experimental data file or the REACTION keyword. Otherwise an error message is given and the keyword ignored.
JEF	Overlay the appropriate section from the JEF-2 evaluated data library. The full reaction string must be available from the experimental data file or the REACTION keyword. Otherwise an error message is given and the keyword ignored.
JENDL	Overlay the appropriate section from the JENDL-3 evaluated data library. The full reaction string must be available from the experimental data file or the REACTION keyword. Otherwise an error message is given and the keyword ignored.
CENDL	Overlay the appropriate section from the CENDL-2 evaluated data library. The full reaction string must be available from the experimental data file or the REACTION keyword. Otherwise an error message is given and the keyword ignored.
BROND	Overlay the appropriate section from the BROND evaluated data library. The full reaction string must be available from the experimental data file or the REACTION keyword. Otherwise an error message is given and the keyword ignored.

IGNORE

This keyword instructs the program to ignore selected data sets, that is, the data sets will be neither plotted nor included in the reference tables. This is accomplished by specifying either the reference number for a data set or the EXFOR data set identification (AN/SAN) for each data set to be ignored separated by commas on the following records. The reference numbers must be the internal reference numbers. See TABLE keyword if more than one table is selected for a plot.

REMOVE

This keyword instructs the program to remove selected data sets from a plot. However, the references will be included in the reference table. This is accomplished by specifying either the reference number for a data set or the EXFOR data set identification (AN/SAN) for each data set to be removed separated by commas on the following records. The reference numbers must be the internal reference numbers. See TABLE keyword if more than one table is selected for a plot.

EQUAL

This keyword instructs the program to merge two data sets together on the selected plot. This is accomplished by specifying pairs of either the reference numbers for a data set or the EXFOR data set identification (AN/SAN) numbers for each data set separated by an =, each number pair separated by commas, on the following records. The first number of a pair is the reference number of the data set to be merged and the second is the set into which the first will be merged. The reference numbers must be the internal reference numbers. See TABLE keyword if more than one table is selected for a plot.

ANNOTATE — This keyword, valid only in PUBLICATION mode, is used to instruct the program to include an annotation in the page margin for the current plot. The annotation consists of the target nucleus and reaction symbol. This keyword is issued automatically by the program if the keyword NOPLOT is used.

NOANNOTATE — This keyword may be combined with the NOPLOT keyword in PUBLICATION mode to suppress the production of a page margin annotation for the plot.

X-RANGE — The range of the independent variable for the data included in the plot can be limited with this keyword. The range of values is given as two floating point numbers in the following record separated by commas. The values are given in eV. The references in the reference table will not be restricted to those which have data in the restricted energy range. If the keyword is not used, the entire energy range of the data in the selected tables is used.

SCALE — The program will automatically select to the scaling for each axis (LOG or LINEAR) unless this keyword is used. The following record must contain one of the following descriptors:

LIN-LIN - linear in X and Y
LOG-LIN - log in X and linear in Y
LIN-LOG - linear in X and log in Y
LOG-LOG - log in X and Y .

X-LIMITS

This keyword sets the x-axis parameters for the plot. If the x-axis scale is linear, the following record contains three floating point numbers, first the lower value for the axis, second the upper value for the axis, and third the step between annotated divisions on the axis. If the axis scale is log then only the first two values are required. The units for these limits must be in the standard data units for the axis (energy in eV). If this keyword is not given, the program will provide reasonable values for the data to be plotted.

X-UNITS

This keyword will instruct the program to scale the x-axis units relative to the default data units for the axis. The following record contains an integer which is a multiple of 3. It may be negative. The integer represents the power of ten by which the data will be scaled. For example, the natural energy units are eV. If you wish to plot in MeV, then the record should have a value of 6.

Y-LIMITS

This keyword sets the y-axis parameters for the plot. If the y-axis scale is linear, the following record contains three floating point numbers, first the lower value for the axis, second the upper value for the axis, and third the step between annotated divisions on the axis. If the axis scale is log then only the first two values are required. The units for these limits must be in the standard data units for the axis (cross section in barns). If this keyword is not given, the program will provide reasonable values for the data to be plotted.

Y-UNITS

This keyword will instruct the program to scale the y-axis units relative to the default data units for the axis. The following record contains an integer which is a multiple of 3. It may be negative. The integer represents the power of ten by which the data will be scaled. For example, the natural cross section units are barns. If you wish to plot in millibarns, then the record should have a value of -3.

LEGEND

The location of the legend box within the plot can be specified with this keyword. The following record contains two floating point numbers and one integer. The first two numbers are the x- and y-coordinates of the lower left corner of the legend box in inches from the plot origin (centimeters if the A4 paper option has been selected). The third number is the number of columns in the legend(default is 1). If the value of 0.0 is given for either coordinate, the program will place the legend at the extreme lower value of the axis; a value of 100.0 will place the legend at the upper extreme of the axis. Either the absence of this keyword or the use of 0.0 for both coordinates will cause the program to attempt to locate a place for the legend by examining the data plotted. Therefore, to locate the legend in the lower left corner of the plot, use 0.05,0.05 (.13,.13 in A4 mode) for the coordinates. If you know where you want to locate the legend, use of this keyword will save execution time.

CULL

When the density of data points on a plot is too great, this keyword can cause the program to suppress plotting points. The suppression is done randomly. The keyword requires a following data record which contains the maximum number of points to be plotted from any single data set. If a data set contains fewer points than this value, no points in that set are skipped. This keyword may also be given in the DEFAULT section, otherwise the program default is not to cull experimental data points.

NOCULL

This keyword instructs the program not to cull any points from the data sets being plotted. This is only needed if the CULL keyword has been given in the DEFAULT section and you wish to override it for the current plot.

GRID

This keyword causes a grid to be drawn on the current plot. The default is no grid unless the GRID keyword is given in the DEFAULT section.

NOGRID

This keyword causes the grid to be omitted from the current plot. This is only needed if the GRID keyword has been given in the DEFAULT section and you wish to override it for the current plot.

ERRORS	This keyword causes a error bars to be drawn for each data point on the plot if such information exists in the experimental data file. This is the default so need not be given unless the NOERRORS keyword is given in the DEFAULT section and you wish to override it for the current plot.
NOERRORS	This keyword results in no error bars being drawn on the current plot. This keyword may be given in the DEFAULT section to suppress error bar plotting on all plots.
SYMBOLS	This keyword causes all plotted points to be displayed with symbols unique to each data set. Only a dot will be plotted if the symbol would physically overlap another symbol already plotted. This is the default and so need not be used unless the DOTS keyword is given in the DEFAULT section and you wish to override it for the current plot.
DOTS	This keyword causes all data points in the current plot to be drawn as DOTS. It may be given in the DEFAULT section to suppress symbol plotting on all plots.

Table III
Sample Control File

```
   DEFAULT
   PUBLICATION
*  31
   HORIZONTAL
   GRID
   ENDDEFAULT
   PAGE
   PLOT
*  WHOLE
*  UPPER
   BIB
*  92238.BIB
   DATA
*  92238.DAT
   ENDF
*  ENDFB,10,92,238,0
   OVERLAY
*  92238NG.DAT
*  ENDF/B-V
   JENDL
   TABLE
*  37,39
   REACTION
*  (92-U-238(N,G),,SIG)
   IGNORE
*  10,23,50,42
   EQUAL
*  15=12,14=12,13=12,
*  20176.003=20176.004
   REMOVE
*  22,13794.006,37
   ANNOTATE
   X-RANGE
*  1.0E+4,1.0E+5
   SCALE
*  LIN-LOG
   X-LIMITS
*  1.0E+4,1.0E+5,1.0E+4
   X-UNITS
*  3
   Y-LIMITS
*  .01,.5
   LEGEND
*  100.,100.,3
   CULL
*  500
   NOERRORS
   ENDPLOT
   PLOT
   TABLE
*  20
   NOPLOT
   IGNORE
*  3,7,8
   ENDPLOT
   REFTABLE
*  4.5
   ENDPAGE
```

* Indicates a data record; no *, a keyword record.

5 Related Programs

There are three auxiliary programs which work with the BNL325 program. They are briefly described in the following list.

ZEROP – Analyzes a computation format BIB and DATA file to generate a simple control file for the BNL325 program which will plot all the data tables.

B35BLD – Interactive program to aid in developing the initial instruction files for a publication format run of the BNL325 program.

B35APP – Prepares Lab and Reference Code appendices for the BNL325 publication. The input is a lab code list in a file LABS.ALL and a reference code list in a file REFS.ALL. The code expansions are obtained directly from the CSISRS dictionary system DANIEL. The output of the program is the file, APP.ALL, which is ready for input to the PRINTS program.