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RESONANCETABLES-1.0

Database for thermal cross sections, MACS and average resonance parameters

Arjan Koning

International Atomic Energy Agency
P.O. Box 100, A-1400 Vienna
AUSTRIA

and

Dimitri Rochman

Paul Scherrer Institut
CH-5232 Villigen
SWITZERLAND

Nuclear Data Section
International Atomic Energy Agency
P.O. Box 100
A-1400 Vienna
Austria

E-mail: NDS.Contact-Point@iaea.org
Fax: (43-1)26007
Telephone: (43-1)2600-21725
Web: <http://www-nds.iaea.org>

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Arjan Koning and Dimitri Rochman

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About the author



Arjan Koning is a nuclear physicist with a Masters Degree in Theoretical physics at the Univ. of Amsterdam, a PhD in the Natural Sciences on Multi-step direct reactions at the Univ. of Groningen, and a professorship at the Univ. of Uppsala on theoretical nuclear reactions.

Arjan is currently Head of the Nuclear Data Section at the IAEA in Vienna. Before that, he has worked at ECN/NRG Petten, the Netherlands, on nuclear reaction data for science and technology, and as guest scientist at CEA/Bruyeres-le-Chatel and Los Alamos National Laboratory on the development of nuclear reaction models. He has led various students to PhD degrees, has coordinated and chaired various international nuclear data projects such as the OECD/NEA JEFF and WPEC projects, and has advised governments and international organisations on nuclear research and development. Among his scientific accomplishments are innovations in nuclear reaction physics, especially the optical model and pre-equilibrium reactions, the TALYS nuclear model code, Total Monte Carlo uncertainty propagation and the TENDL nuclear data library. As of end-2020, his h-index is 52 with more than 14 000 citations.

Although Arjan has finally accepted leadership offers that he could no longer refuse, he aims to keep his scientific creativity alive by maintaining and extending TALYS + all products that emerge from that. Pleas from his friends to also spend time on other things are sometimes honored.

Preface

RESONANCETABLES is a directory-structured database with compiled and evaluated data for experimental thermal cross sections, resonance integrals, Maxwellian-averaged cross sections (MACS) and other average quantities in the resonance range.

RESONANCETABLES is, along with its counterparts ENDFTABLES and EXFORTABLES, another initiative which is deemed necessary for a future with efficient nuclear data evaluation, in which machine learning and automation will play a large role. The objective is to have all important fundamental nuclear data readily available for direct inclusion in software. This is rather normal for codes like e.g. MCNP, which requires a complete processed nuclear data library such as ENDF/B or JEFF for all nuclides, ready to use. For some reason, for software and data that produce evaluated nuclear data libraries this is generally not seen as necessary. Here nuclides are evaluated and formatted one by one, and retrieval of experimental data by e.g. a graphical web interface is seen as sufficient for evaluation purposes. Manual insertion of values in an evaluated data file is still being done. It is probably not surprising that the production of the TENDL library relies strongly on the availability of 'fundamental' databases as the ones presented here, but we think they can also be helpful for the other libraries, which are still produced by manual evaluation. Also, these databases can help assessing the overall quality of a nuclear data library, not only TENDL, and be used to validate nuclear model codes, or fine-tune the parameters of nuclear models. In that sense, this initiative can be seen as a modest extension of IAEA's RIPL project, which was a major step forward in efficient nuclear data evaluation. Ideally RESONANCETABLES should be replaced by a versatile API in the future.

License, contact and reference

As mentioned on the first page, in the source code and detailed in the last Appendix, RESONANCETABLES falls in the category of GNU General Public License software.

In addition to the GNU GPL *terms* I have a *request*:

- When RESONANCETABLES is used for your reports, publications, etc., please make a proper reference to the code. At the moment this is:

When you refer to the application of this software:

D. Rochman, A.J. Koning, J.-Ch. Sublet, A statistical analysis of evaluated neutron resonances with TARES for JEFF-3.3, JENDL-4.0, ENDF/B-VIII.0 and TENDL-2019, Nuclear Data Sheets 163, 163 (2020).

When you refer to something particular of this tutorial:

A.J. Koning and D. Rochman, RESONANCETABLES-1.0: Database for thermal cross sections, MACS and average resonance parameters, IAEA NDS Document Series IAEA(NDS)-234, December 2020

- Please inform me about, or send, extensions you have built into RESONANCETABLES. Of course, proper credit will be given to the authors of such extensions in future versions of the code.
- Informing me about your use of RESONANCETABLES in reports and publications will help me to maintain the RESONANCETABLES-bibliography.

Although I have invested a lot of effort in the validation of our code, I will not make the mistake to guarantee perfection. Therefore, in exchange for the free use of RESONANCETABLES: If you find any errors, or in general have any comments, corrections, extensions, questions or advice, I would like to hear about it at **A.Koning@iaea.org**. The webpage for RESONANCETABLES is **nds.iaea.org/talys**.

Acknowledgements

I wish to thank a few persons who have contributed to the present state of RESONANCETABLES:

- Dimitri Rochman for providing the numerical tables of some of the input data for this database and helpful advice.
- Jura Kopecky for information on the various original source files used for this database.
- Andrej Trkov for providing the Kayzero database
- Anatoli Ignatyuk and other RIPL members for constructing the starting databases

Arjan Koning

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1. Introduction

Neutron reaction data in and below the resonance range are crucial parts of neutron data libraries, especially for low-energy neutron applications. Therefore, resonance analyses are often performed on raw reaction data to produce resonance parameter evaluations. A proper evaluation reproduces, apart from the experimental resonances, the experimental value of the thermal cross section for all open channels as well as average resonance properties. Often, these evaluations are performed and published for a single nuclide, mostly when new experimental data comes available. Compilations, and in some cases evaluations of such data for all nuclides exist, with probably the various versions of the Atlas of Neutron Resonances by Mughabghab [1] as the most famous example.

These databases of resonance parameters were often made manually, i.e. numbers read from publications were inserted one by one with a word processor, unavoidably leading to errors. Also the evaluator could decide that not one, but the average of several measured values would end up in the database, without any documentation on why and how this average was obtained. Actually, it is often difficult to distinguish between a compilation (adoption of raw data without any further evaluation) or an evaluation, especially if in the evaluation one compiled value among a few alternative values is chosen as 'the' answer.

In an ideal world, there should exist one mother database, with EXFOR as the best candidate, which contains all the experimental values. An evaluated compilation of all relevant data of one type would be produced by a script which discards, includes, corrects and averages various data from EXFOR to come to a final evaluated value with an uncertainty margin. Unfortunately, we are not in that situation. There is probably consensus about what are valuable and reasonably complete evaluations (the latest version of the Atlas is an obvious candidate) but HOW the final numbers in such databases were produced remains a secret to the author, although sometimes one can recognize a one-to-one correspondence with the original published values. The same is true for high-quality evaluated data available in ENDF formatted libraries. The process to create such an evaluation may be documented in a publication, in which claims may have been made why the used value for e.g. the thermal capture cross section is the best to date. Again, this detailed info exists for several

nuclides but one needs to dig through many publications and reports. Often, after reproducing the data file in pointwise format, one can guess which data was adopted.

Besides repeating the evaluation consistently for the entire nuclide chart, which is a huge task and one may wonder whether there is an individual left with both the knowledge and willingness to do that, all we can do on short term is to collect these data and compare it with other compilations and perhaps try to create a 'best' database for each type of data.

RESONANCETABLES is merely a start to this and is restricted to important nuclear data values at only a few important energies (thermal energy, 30 keV) or an average over the entire resonance range. Individual resonances and their parameters are not considered here (yet).

The databases presented here are entirely based on previous compilations (e.g. RIPL), evaluations (e.g. Mughabghab's various versions of the Atlas of Neutron Resonances), and raw experimental data sets (EXFOR). A Fortran code *resonancetables.f90* has been written which reads in the entire collection of mother databases, performs some operations, and produces the RESONANCETABLES database. During this database translation, statistical tests are performed on the various mother databases and the results of these tests are written to various diagnostic files, revealing possible outliers, which can be taken into account for correction of the data of the mother databases. The most important output is a logical directory structure for all relevant data in an easy readable and unified format.

Hence, RESONANCETABLES is a directory-structured database, derived from the basic files mentioned above. In a different project, ENDFTABLES, which concerns the production of all ENDF data libraries in tabular format together with its statistical analysis, the values from those ENDF libraries are compared with the adopted values from this project. These ENDF values are included in our tables as well.

Eventually, this database could be replaced by an API which allows users to extract specific data at command-line level. That does not yet exist however. Also at some point we may also provide the output in JSON, YAML etc format if this is deemed useful.

1.1 This tutorial

After this Introduction, you will find the following,

Chapter 2: Installation guide for RESONANCETABLES. A general outline of the contents of the RESONANCETABLES database, and also an explanation on how to (optionally) regenerate the database yourself.

Chapter 3: A description of the input to RESONANCETABLES: The mother database with compilations and evaluations by others.

Chapter 4: A description of the priority rules for processing the mother database into the final database

Chapter 5: The final database.

Chapter 6: Outlook and conclusions.

2. Installation and getting started

2.1 The RESONANCETABLES package

In what follows we assume RESONANCETABLES will be installed on a Linux operating system. In total, you will need about 20 Mb of free disk space to install RESONANCETABLES. If you obtain the entire package as a tar file, you should do

- `tar xzf resonancetables.tar`

and the total package will be automatically stored in the *resonancetables/* directory. It contains the following directories and files:

- *source/* is the Fortran source of the code that performs the entire database creation and checking of the data. Most users will however only need the results already provided by us and not want to rerun the code.
- *files/* the mother database, i.e. the input files to *resonancetables.f90*
- *doc/* contains the documentation: this manual in pdf format.
- *thermal/* the produced thermal cross section database
- *macs/* the produced Maxwellian-averaged cross section (MACS) database
- *resonance/* the produced average resonance parameter database
- *libs/* contains the comparison of the database values with those of the major evaluated nuclear data libraries. These files are not produced by RESONANCETABLES but imported from another project.

Most users may only be interested in the contents of the database. **Thus, you do not need to further install or run anything and can use the database directly.** However, if you want to regenerate the database yourself with the *resonancetables.f90* code, continue with the following section.

2.2 The `resonancetables.f90` code

Although most users will only be interested in the final RESONANCETABLES database, there may be reasons to regenerate the entire database from scratch again, such as:

- your local changes in `resonancetables.f90` which improve or extend the database, (of course I advise to share that with the author),
- newer versions of the mother databases,
- etc.

The code `resonancetables.f90` has so far been tested on various Linux and Mac systems systems. The installation for a Linux system proceeds as follows

- Go into the `source/` directory,
- In `machine.f90` you should change the pathname called 'home'
- **`gfortran -c *.f90; gfortran *.o -o resonancetables`**

If you run the RESONANCETABLES code, it will overwrite all existing directories. Note that RESONANCETABLES has no input file, it only has one task: to produce a complete collection of resonance quantities. Hence you may type

resonancetables

A run will take about 30 seconds.

3. The mother database

3.1 Compiled and evaluated databases

The input files for RESONANCETABLES, the so-called mother databases, come in a variety of completeness, readability and formats, from different contributors. They are stored in the directory *files/*. Often these are multi-column files (some *very* multi) with many different quantities, blanks for cases where there are no data, etc. and quite some effort was invested to properly read these input files.

At the moment, the following files in the mother database are processed:

- *thermal.mugh06*: Mughabghab 2006 Atlas of neutron resonances [2], including many corrections by Dimitri Rochman
 - Thermal (n,el) , (n,γ) , (n,f) , (n,α) cross sections, total, prompt, and delayed nubar
- *thermal.mugh18*: Mughabghab 2018 Atlas of neutron resonances [1], including many corrections by Dimitri Rochman
 - Thermal (n,tot) , (n,el) , (n,γ) , (n,f) , (n,p) , (n,α) cross sections, total, prompt, and delayed nubar
 - Maxwellian-averaged cross sections (MACS)
 - Thermal (n,γ) , (n,f) resonance integrals
 - Average neutron resonance spacings D_0 , neutron strength functions S_0 , and average radiative widths Γ_γ
- *sukhoruchkin.txt*: Sukhoruchkin 2015 Neutron resonance parameters [3], digitized by Dimitri Rochman
 - Thermal (n,γ) , (n,f) , (n,p) , (n,α) cross sections
 - Thermal (n,γ) , (n,f) resonance integrals
 - MACS
- Reference Input Parameter Library (RIPL) [4]
 - *thermal.ripl*: Thermal cross section database compiled by Jura Kopecky,
 - *resonance.ripl*: Average resonance parameters D_0 , S_0 , Γ_γ , compiled and evaluated by

Anatoli Ignatyuk.

- Other compilations and evaluations
 - *kayzero.txt*: Kay-zero database for thermal (n, γ) cross sections, obtained from Andrej Trkov [5]
 - *resint.juko*: Resonance Integral database by Jura Kopecky [6]
 - *macs_kadonis.ng*: KADONIS database for MACS [7]
- EXFOR database [8]
 - *thermal_exfor.tot*: thermal (n,tot) cross sections
 - *thermal_exfor.el*: thermal (n,el) cross sections
 - *thermal_exfor.nf*: thermal (n,f) cross sections
 - *thermal_exfor.ng*: thermal (n, γ) cross sections
 - *thermal_exfor.np*: thermal (n,p) cross sections
 - *thermal_exfor.na*: thermal (n, α) cross sections
 - *thermal_exfor.nu*: thermal total nubar cross sections
 - *thermal_exfor.nup*: thermal prompt nubar cross sections
 - *thermal_exfor.nud*: thermal delayed nubar cross sections
 - *macs_exfor.ng*: MACS
 - *RI_exfor.ng*: (n, γ) resonance integral

3.2 Values from evaluated nuclear data libraries

To get a complete overview of all possible values, we have also included the values extracted from the evaluated nuclear data libraries, TENDL-2019 [9], ENDF/B-VIII [10], JEFF-3.3 [11], JENDL-4.0 [12] and CENDL-3.1 [13]. The values for the thermal cross sections, resonance integrals and MACS have been calculated using the INTER code [14] on the nuclear data files in pointwise form, produced with PREPRO's RECENT module [15] and have been put in tables in the *libs/* directory. Hence, for thermal cross sections we have

- *cendl3.1.therm*
- *endfb8.0.therm*
- *jeff3.3.therm*
- *jendl4.0.therm*
- *tendl.2019.therm*

and similarly for MACS and RI (resonance integral). These tables have been produced with the script *libmaker* which is used to analyze the world's nuclear data libraries and to put the data in tabular format. The actual C/E validation of the world's nuclear data libraries with the RESONANCETABLES database is done in that process, which produces the so-called *libraries/* directory needed for several of our codes. The results are however available in the files in the *libs/* directory.

4. Processing the mother database

The largest challenge in a project like this is to determine the *best* value for each case. This is what is part of nuclear data evaluation and this has only been done to a restricted extent here as most, if not all, of that is done by the evaluator of the mother databases. By intercomparing databases we could at least filter out the most obvious errors and make a correction table which acts on the mother database to produce the final values. (For example, this had to be done for the thermal cross sections from RIPL).

4.1 Priorities for the final database

The priority for adopting values from the various databases is based on date ("newer is better"), experience and proven impact (e.g. Kayzero database). For thermal cross sections and resonance integrals, the order of adoption is

1. Kayzero database
2. Mughabghab 2018 Atlas
3. Sukhoruchkin 2015 Atlas
4. Mughabghab 2006 Atlas
5. RIPL or Kopecky database
6. EXFOR (the most recent value)

For MACS, the order of adoption is

1. Mughabghab 2018 Atlas
2. Sukhoruchkin 2015 Atlas
3. KADONIS database
4. EXFOR (the most recent value)

For D_0 , the order of adoption is

1. RIPL
2. Mughabghab 2018 Atlas
3. EXFOR (the most recent value)

For S_0 and Γ_γ , the order of adoption is

1. Mughabghab 2018 Atlas
2. RIPL
3. EXFOR (the most recent value)

So the procedure is as follows, if a value exists in 1, it is adopted, if not, if a value exists in 2, it is adopted, etc. In future versions of the code these priorities can be changed if appropriate, also on a nuclide-by-nuclide basis. For that, we need input from experts.

4.2 Ratios between databases

To compare different mother databases for the same quantity, it is helpful to define a ratio,

$$R = \frac{\text{value of mother database}}{\text{value of final database}} \quad (4.1)$$

i.e. the mother database is one of the individual databases mentioned in the previous Section and the final database is the one obtained via the aforementioned priority rules. Obviously, one would expect many cases with R equal to or very close to 1. Nevertheless, important deviations exist. For every database, such a table with ratios is made, see the next Chapter.

5. The final database

5.1 The RESONANCETABLES

We have stored the final data directory-wise per reaction type. RESONANCETABLES consists of directories *thermal/*, for thermal cross sections, *macs/*, for Maxwellian-averaged cross sections (MACS) and *resonance/*, for average resonance parameters (and integrals), respectively. These directories contain all reaction data which **so far** could be processed from the mother database.

We first outline the classification of the filename extensions used in the database, You may look in e.g. *thermal/ng* to see a set of these files.

- *.final*, probably the most important file, since this file contains what we at the moment consider to be the best choice for each entry, and it is also the most complete. This file is the result of the priority rules set before. Note that for all these files, the reference for each entry is given in the last column. Occasionally, this is a reference to an EXFOR entry, which shows that not all existing data have been taken into account in some compilations and evaluations. Whether such cases are overlooked or left out on purpose (because e.g. the values are unreliable) is not known.
- *.ripl*, *.mugh06*, *.mugh18*, *.kayzero*, *.sukhoruchkin*, *.exfor*. These are the data taken straight from the respective mother databases and simply returned in the unified format of this database.
- *.ripl.ratio*, *mugh18.ratio*, etc. These files contain the ratio of the data from the mother database with respect to the *.final* (i.e. recommended) database. This helps to uncover errors and to determine whether there is a large variation among databases in general.
- *.all*. These files give all available data per nuclide, i.e. from all evaluations and EXFOR. Here, one can determine how many different data points there are per nuclide, and the position of the final selected value among the alternatives.
- Distinction between total, ground state and isomers. Note that some files come with an extension '*_g*', '*_m*', or '*_n*'. This means the datafile concerns data for the *residual* ground state or isomer only.

- *.capratio*. These files only exist for thermal cross sections other than (n,γ) . If one wants to discover trends (we have not found any so far) in e.g. the ratio of the thermal (n,p) cross section and the thermal (n,γ) cross section, then these files are available for such studies.
- The *nuc/* directory. In this directory, all EXFOR entries per nuclide are given, sorted by year of publication. This allows for easy examination, and plotting, of the evolution of measured values over time.

5.1.1 Thermal cross sections

The directory *thermal/* contains subdirectories

- *tot/*: thermal total cross section
- *el/*: thermal elastic cross section
- *nf/*: thermal (n,f) cross section
- *ng/*: thermal (n,γ) cross section
- *np/*: thermal (n,p) cross section
- *na/*: thermal (n,α) cross section
- *nu/*: thermal total nubar
- *nup/*: thermal prompt nubar
- *nud/*: thermal delayed nubar
- *nuc/*: experimental thermal cross sections per nuclide

Each directory contains the files described earlier. Each line of a cross section file contains charge number of target (Z), mass number of target (A), isomer of target ($Tiso$), cross section in barn (xs), uncertainty of cross section in barn (dxs), reference (Ref). The (Fortran) format is (4i4, 2Es15.5, 3x, a). If we take *thermal/ng/thermal_ng.final* as an example we see that entries for a natural nuclide, i.e. $A=0$, have been commented out with a '#' to allow for e.g. easy A -dependent plotting. Note also that the target ground state is denoted by $Tiso=0$. The production of the ground state and isomers are considered to be a cross section of different type, such cases are given in *thermal_ng.final_g*, etc.

The format for the ratio files is similar, see e.g. *thermal_ng.rtpl.ratio* although now instead of only cross section values we give the ratio and the values of the current database ($xs(this)$) and the final database ($xs(final)$).

5.1.2 Maxwellian-averaged cross sections

The directory *macs/* contains subdirectories with 30 keV data

- *ng/*: MACS (n,γ)
- *nuc/*: experimental MACS cross sections per nuclide

5.1.3 Average resonance data

The directory *resonance/* contains subdirectories with average resonance data

- *Ig/*: (n,γ) resonance integrals
- *If/*: (n,f) resonance integrals
- *D0/*: average neutron resonance spacings
- *S0/*: average neutron strength functions
- *gamgam/*: average neutron radiative widths

5.2 Comparison with nuclear data libraries

Outside this database, we have all world nuclear data libraries available in pointwise format. This allows to give a numerical and graphical comparison of the values of the data libraries and the current database, where we take our 'final' database, i.e. the one chosen according to the priority rules, as reference.

The files in the *libs/* directory also contain the root-mean-square values and a few other statistical measures for the deviation of nuclear data libraries from the database. The files with *_bin* in their filename contain a histogram with the C/E values as well as the F-value (root-mean-square), the chi-2 value, the number of experimental values that could be compared with the library *N*, as well as the number of cases inside a certain range from experiment.

For thermal capture cross sections the statistical summary is

```
==> cendl3.1_bin.therm <==
# F= 1.036 Chi-2= 8.319 N = 207 N inside 5%: 132 (0.638) N inside 20%: 181
  (0.874) N inside 50%: 191 (0.923)
```

```
==> endfb8.0_bin.therm <==
# F= 1.022 Chi-2= 2.095 N = 387 N inside 5%: 291 (0.752) N inside 20%: 340
  (0.879) N inside 50%: 360 (0.930)
```

```
==> jeff3.3_bin.therm <==
# F= 1.024 Chi-2= 3.803 N = 451 N inside 5%: 334 (0.741) N inside 20%: 396
  (0.878) N inside 50%: 418 (0.927)
```

```
==> jendl4.0_bin.therm <==
# F= 1.025 Chi-2= 4.209 N = 367 N inside 5%: 275 (0.749) N inside 20%: 326
  (0.888) N inside 50%: 340 (0.926)
```

```
==> tendl.2019_bin.therm <==
# F= 1.008 Chi-2= 4.772 N = 486 N inside 5%: 454 (0.934) N inside 20%: 470
  (0.967) N inside 50%: 473 (0.973)
```

for MACS this is

```
==> cendl3.1_bin.MACS <==
# F= 1.073 Chi-2= 10.967 N = 176 N inside 5%: 29 (0.165) N inside 20%: 78
  (0.443) N inside 50%: 101 (0.574)
```

```
==> endfb8.0_bin.MACS <==
# F= 1.083 Chi-2= 15.120 N = 332 N inside 5%: 56 (0.169) N inside 20%: 158
  (0.476) N inside 50%: 211 (0.636)
```

```
==> jeff3.3_bin.MACS <==
# F= 1.078 Chi-2= 19.841 N = 350 N inside 5%: 68 (0.194) N inside 20%: 178
  (0.509) N inside 50%: 211 (0.603)
```

```
==> jendl4.0_bin.MACS <==
# F= 1.070 Chi-2= 13.464 N = 292 N inside 5%: 59 (0.202) N inside 20%: 149
  (0.510) N inside 50%: 187 (0.640)
```

```
==> tendl.2019_bin.MACS <==
# F= 1.077 Chi-2= 12.531 N = 368 N inside 5%: 76 (0.207) N inside 20%: 203
  (0.552) N inside 50%: 240 (0.652)
```

and for the resonance integrals

```
==> cendl3.1_bin.RI <==
# F= 1.056 Chi-2= 1.891 N = 198 N inside 5%: 75 (0.379) N inside 20%: 129
  (0.652) N inside 50%: 161 (0.813)
```

```
==> endfb8.0_bin.RI <==
# F= 1.060 Chi-2= 1.747 N = 391 N inside 5%: 139 (0.355) N inside 20%: 252
  (0.645) N inside 50%: 303 (0.775)
```

Thermal Cross Sections

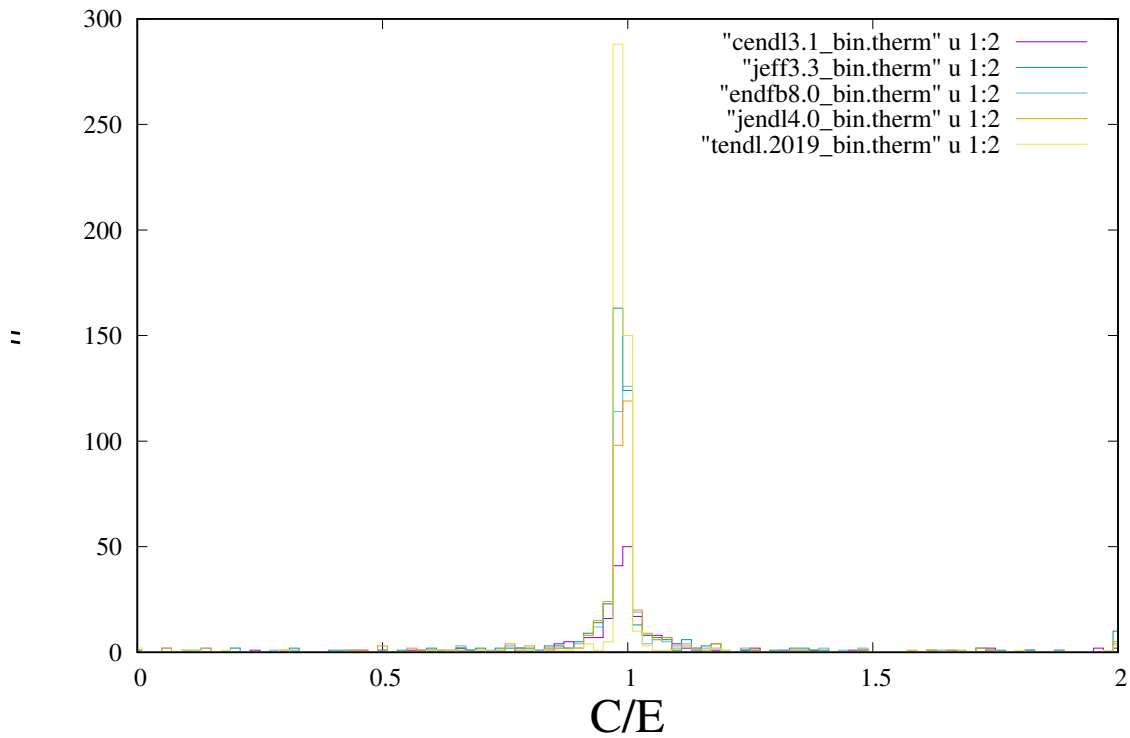


Figure 5.1: C/E histogram for thermal cross sections

```

==> jeff3.3_bin.RI <==
# F= 1.059 Chi-2= 10.286 N = 406 N inside 5%: 136 (0.335) N inside 20%: 262
  (0.645) N inside 50%: 317 (0.781)

==> jendl4.0_bin.RI <==
# F= 1.054 Chi-2= 1.657 N = 339 N inside 5%: 135 (0.398) N inside 20%: 235
  (0.693) N inside 50%: 277 (0.817)

==> tendl.2019_bin.RI <==
# F= 1.058 Chi-2= 37.314 N = 491 N inside 5%: 149 (0.303) N inside 20%: 271
  (0.552) N inside 50%: 333 (0.678)

```

Below are comparisons as histograms for C/E values as well as scatter plots as a function of A.

Maxwellian-Averaged Cross Sections

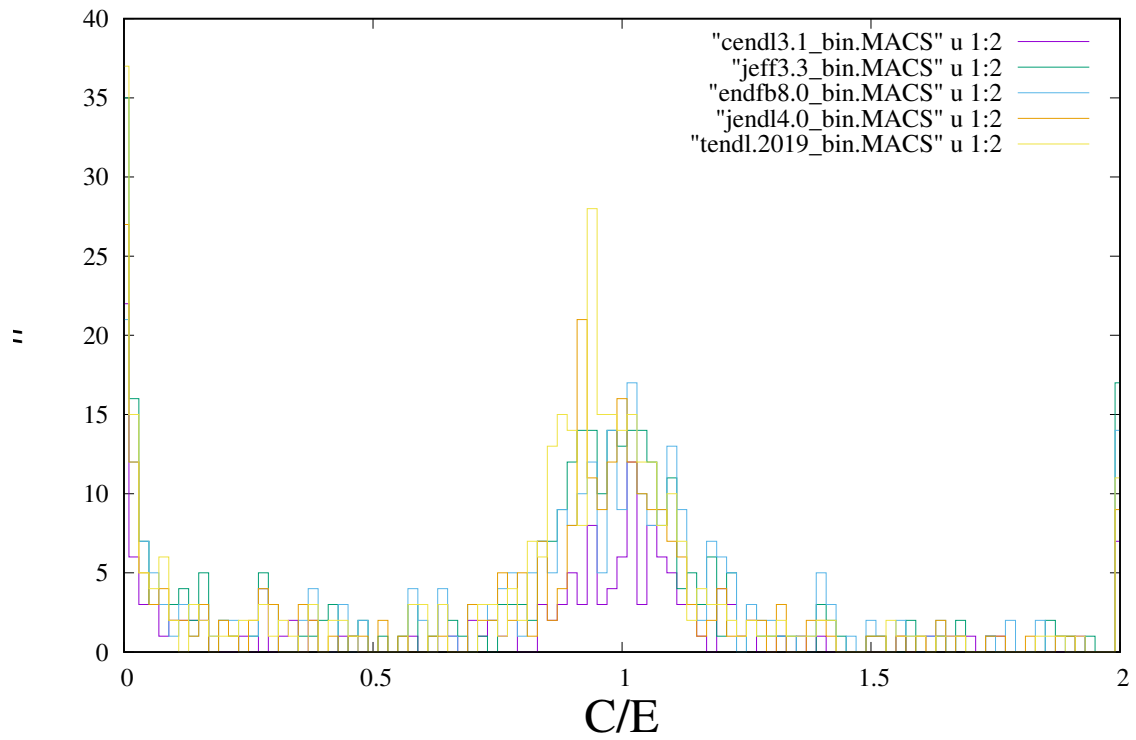


Figure 5.2: C/E histogram for MACS

Resonance Integral

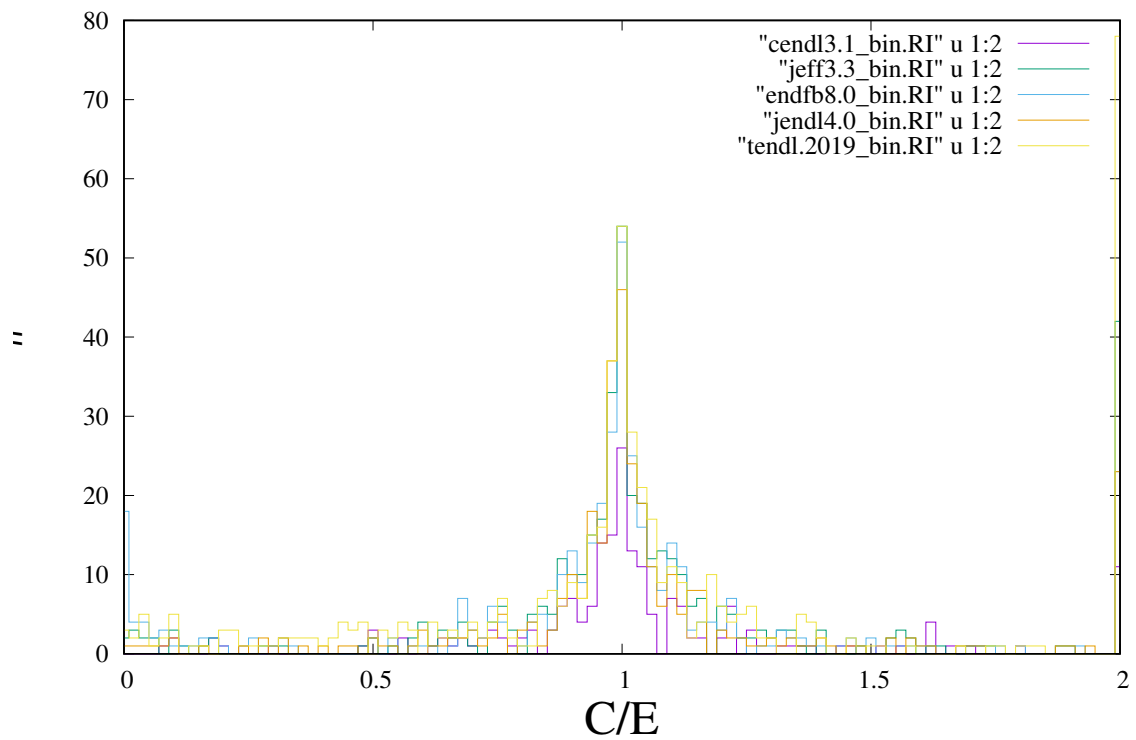


Figure 5.3: C/E histogram for Resonance Integral

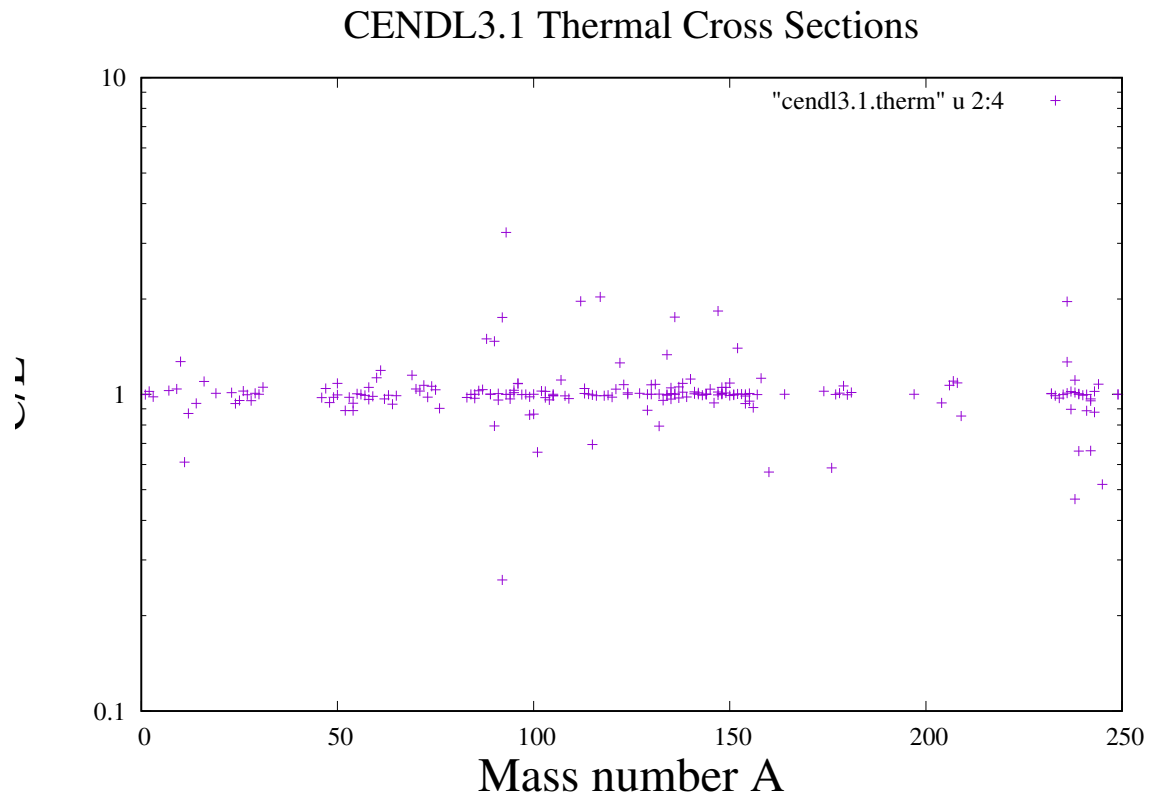


Figure 5.4: C/E values for thermal cross sections for CENDL-3.1

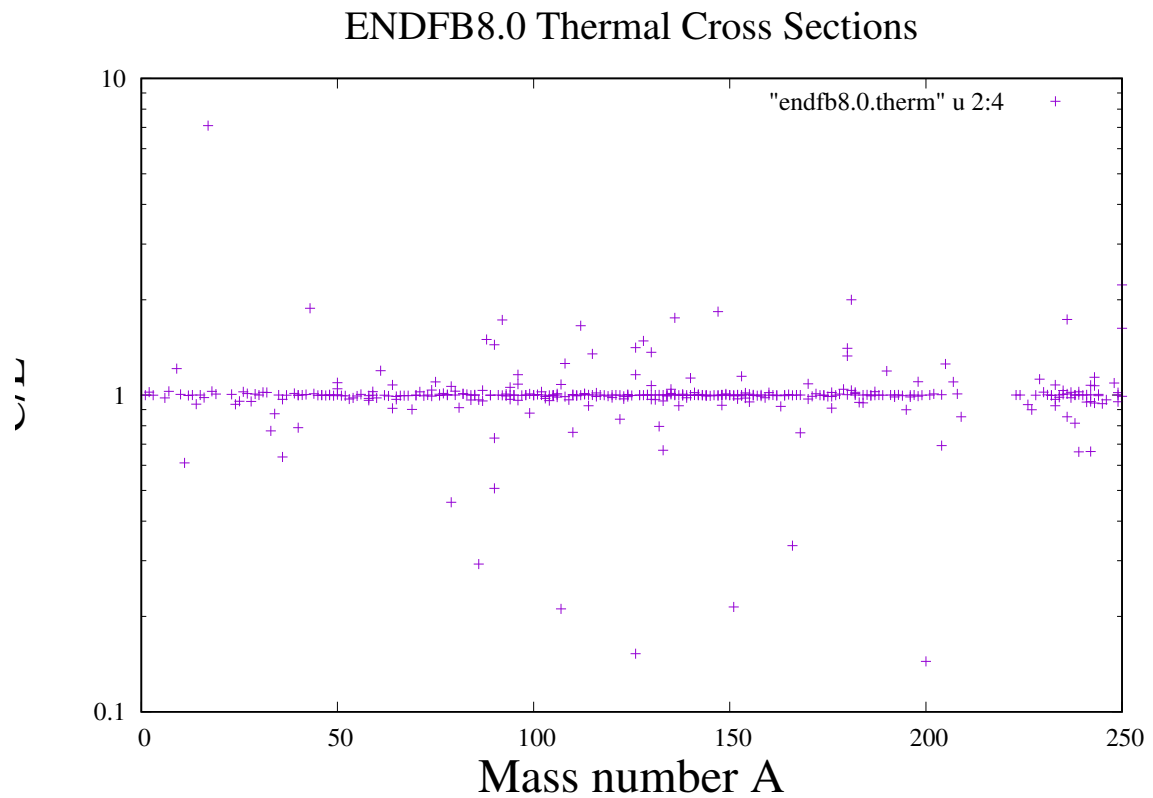


Figure 5.5: C/E values for thermal cross sections for ENDF/B-VIII

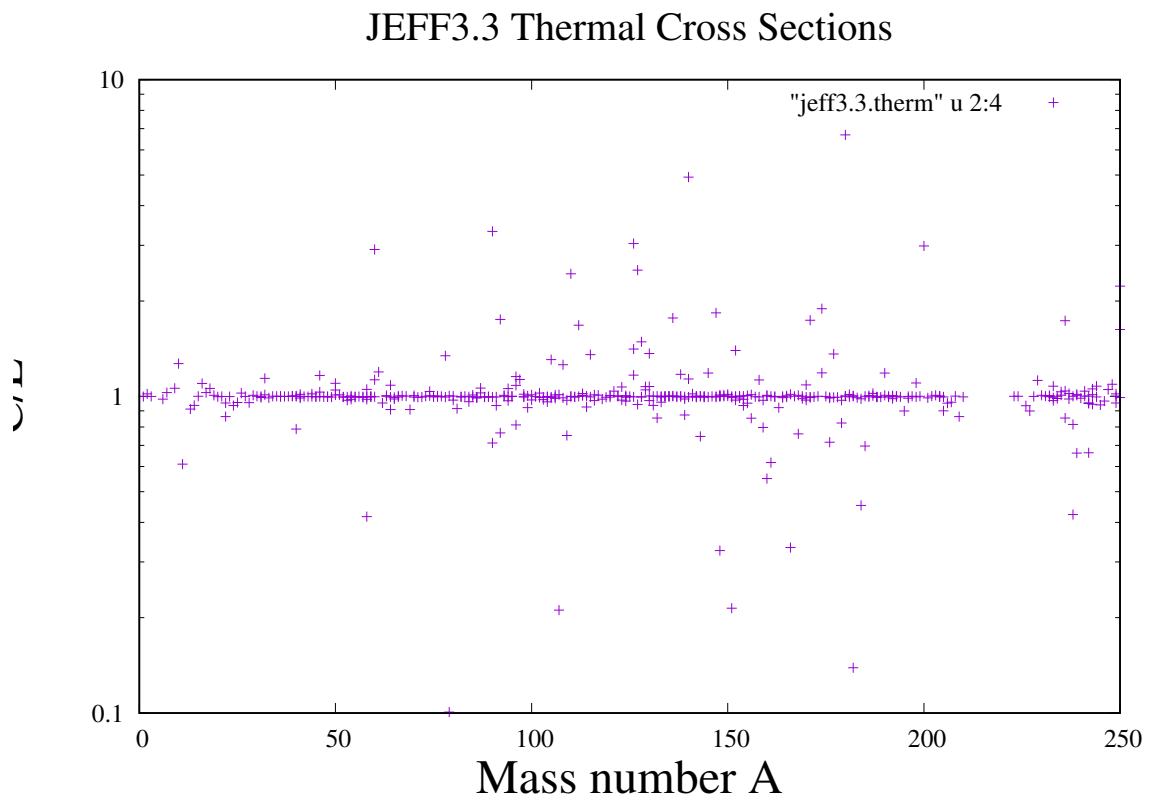


Figure 5.6: C/E values for thermal cross sections for JEFF-3.3

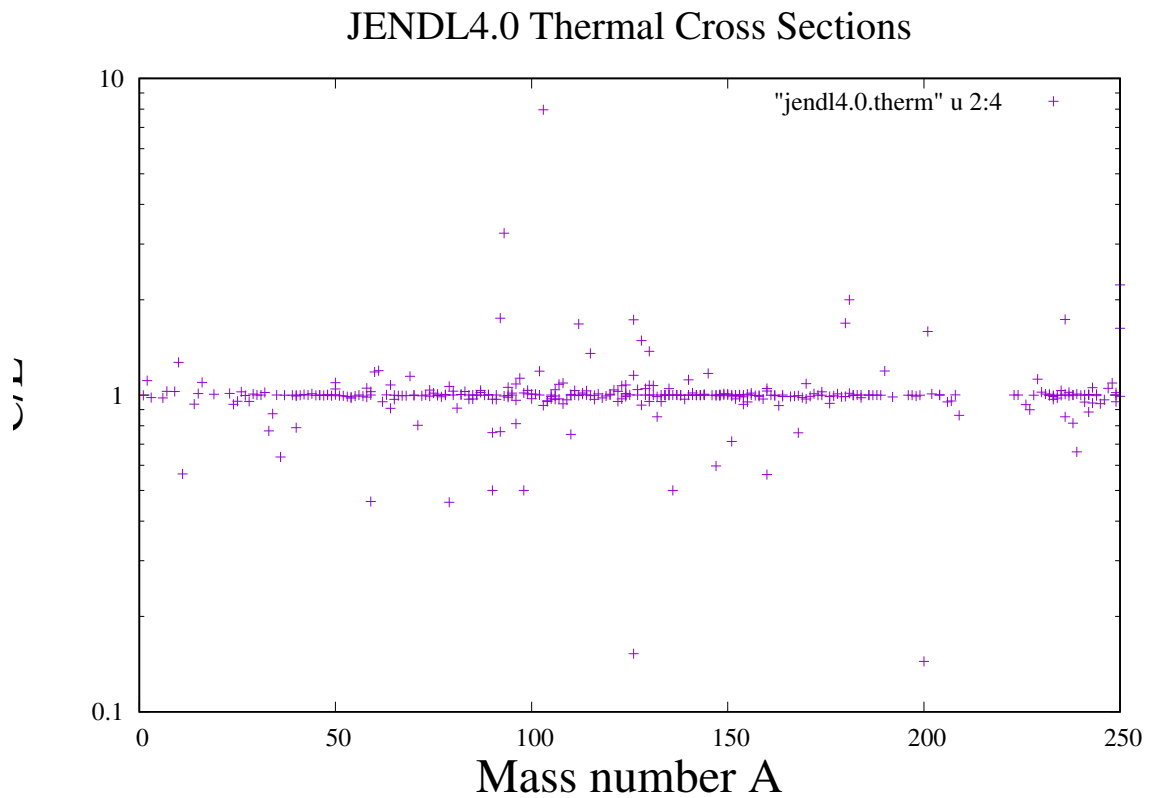


Figure 5.7: C/E values for thermal cross sections for JENDL-4.0

TENDL.2019 Thermal Cross Sections

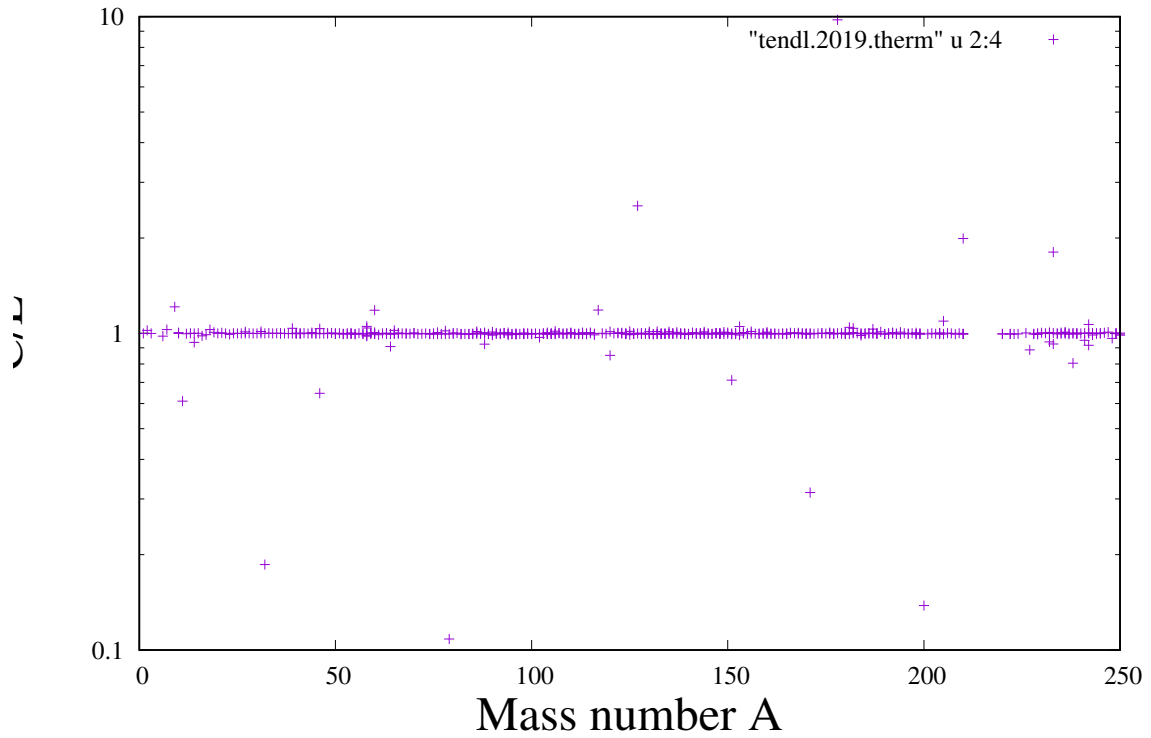


Figure 5.8: C/E values for thermal cross sections for TENDL-2019

CENDL3.1 Maxwellian-Averaged Cross Sections

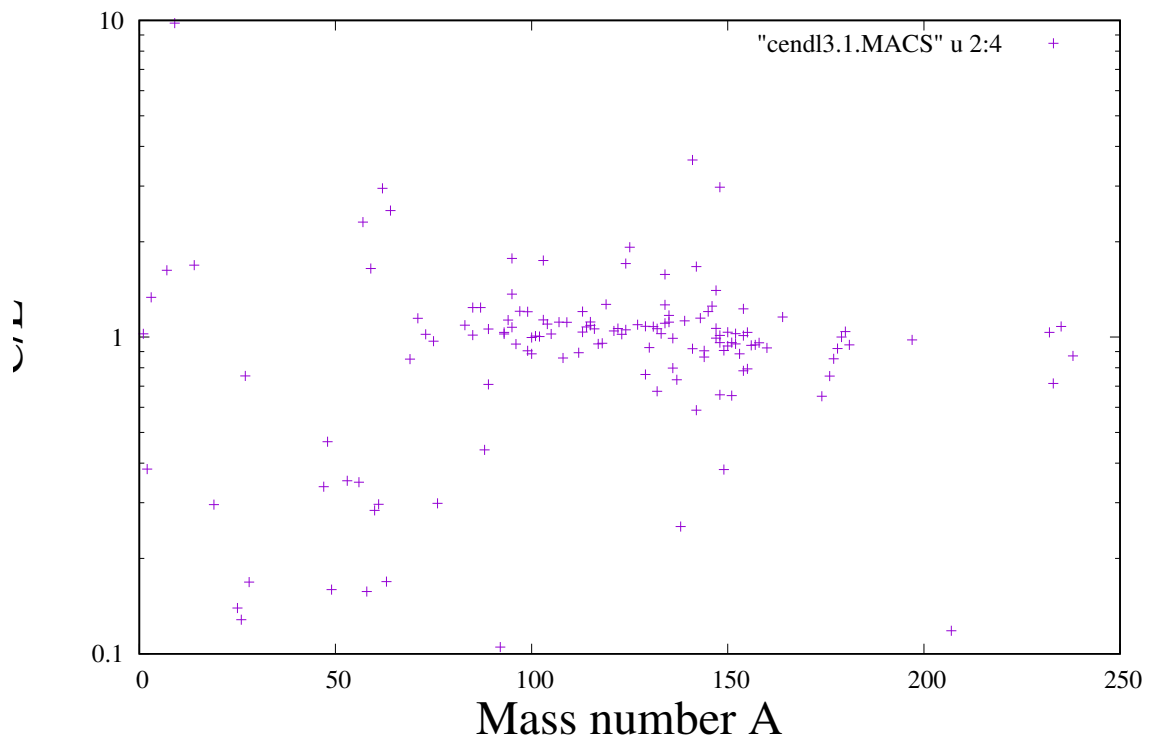


Figure 5.9: C/E values for MACS for CENDL-3.1

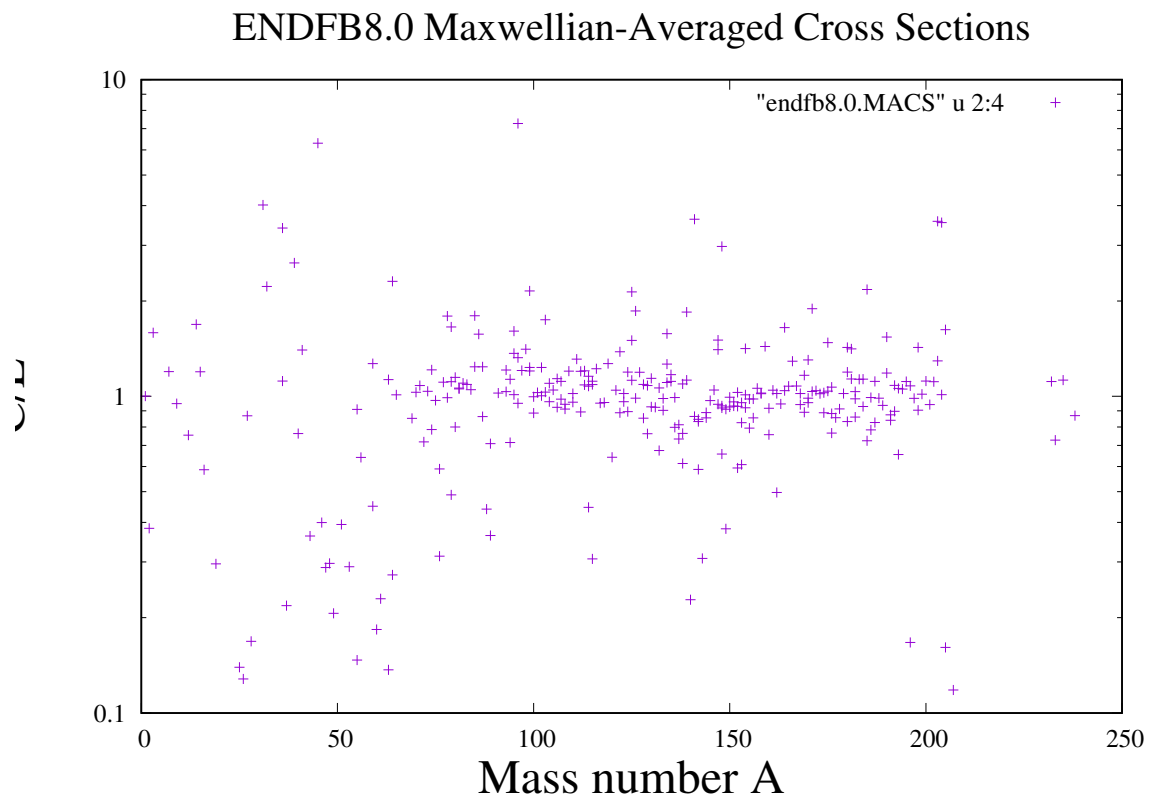


Figure 5.10: C/E values for MACS for ENDF/B-VIII

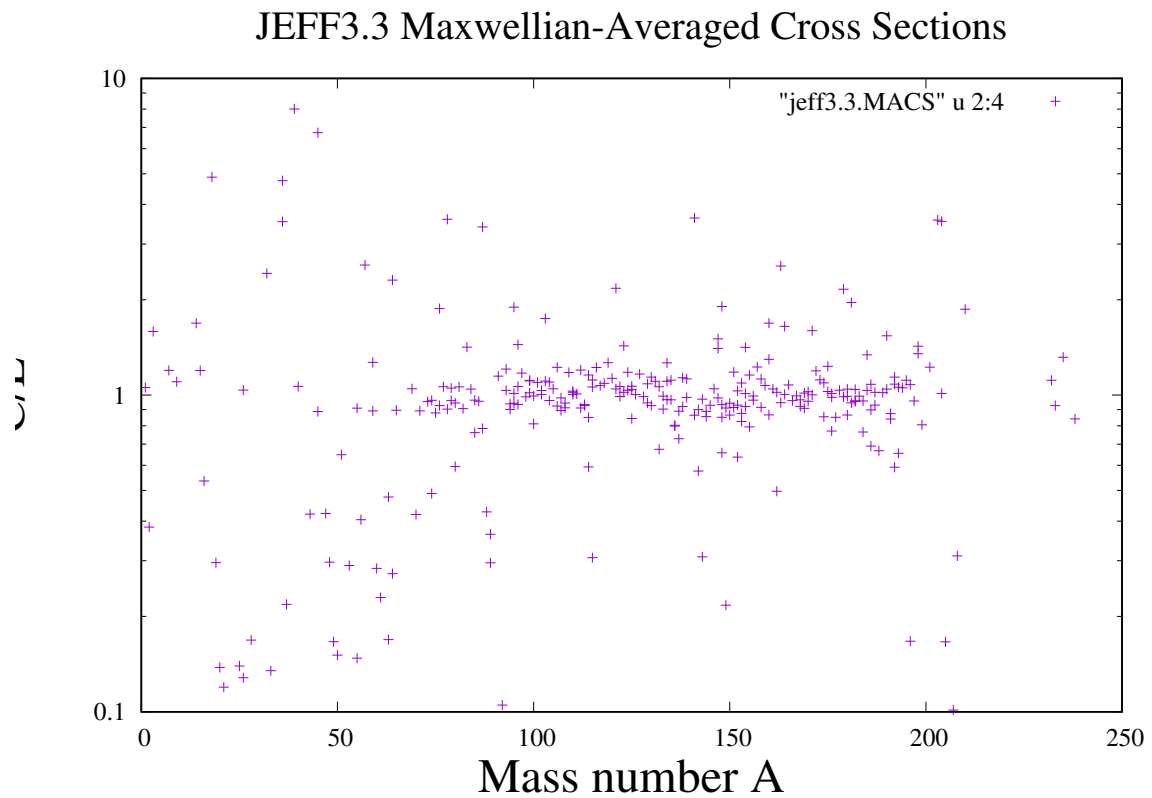


Figure 5.11: C/E values for MACS for JEFF-3.3

JENDL4.0 Maxwellian-Averaged Cross Sections

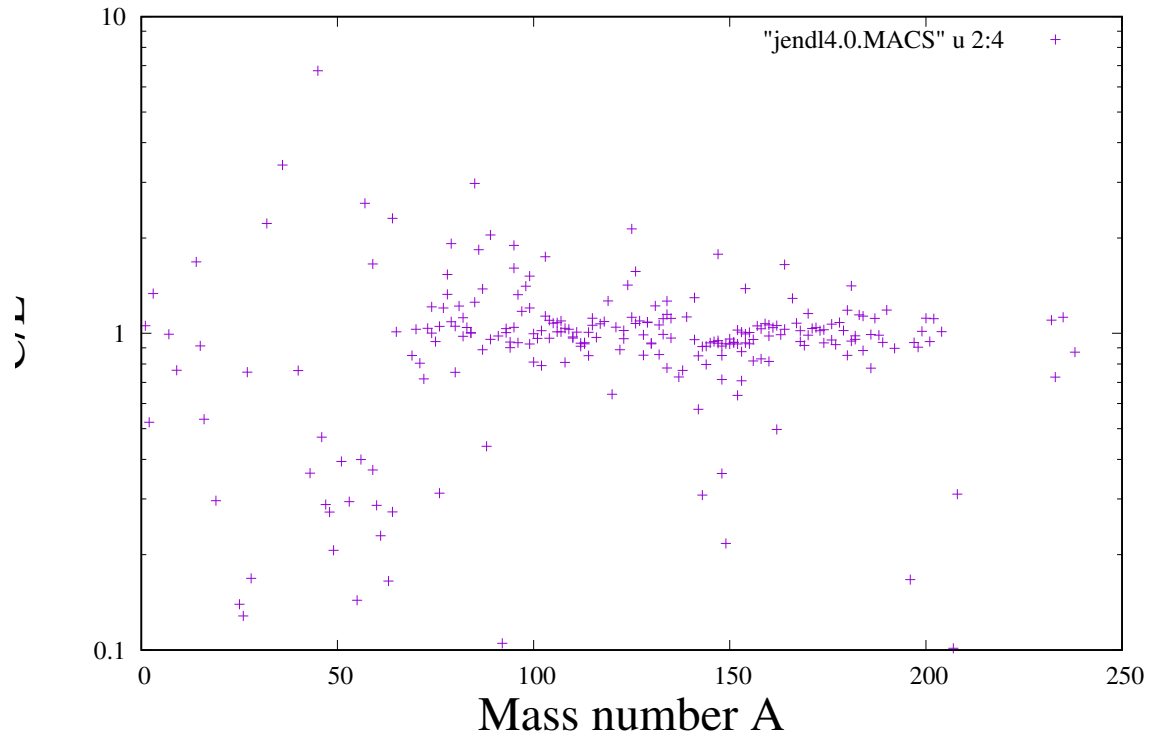


Figure 5.12: C/E values for MACS for JENDL-4.0

TENDL.2019 Maxwellian-Averaged Cross Sections

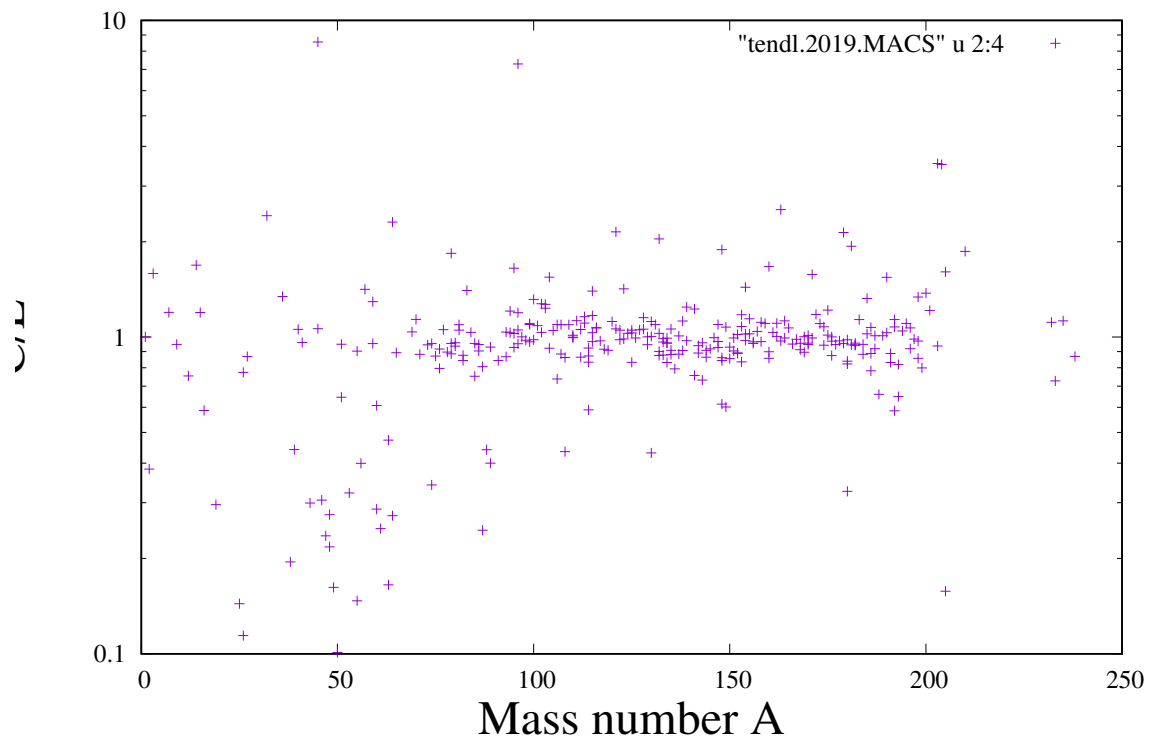


Figure 5.13: C/E values for MACS for TENDL-2019

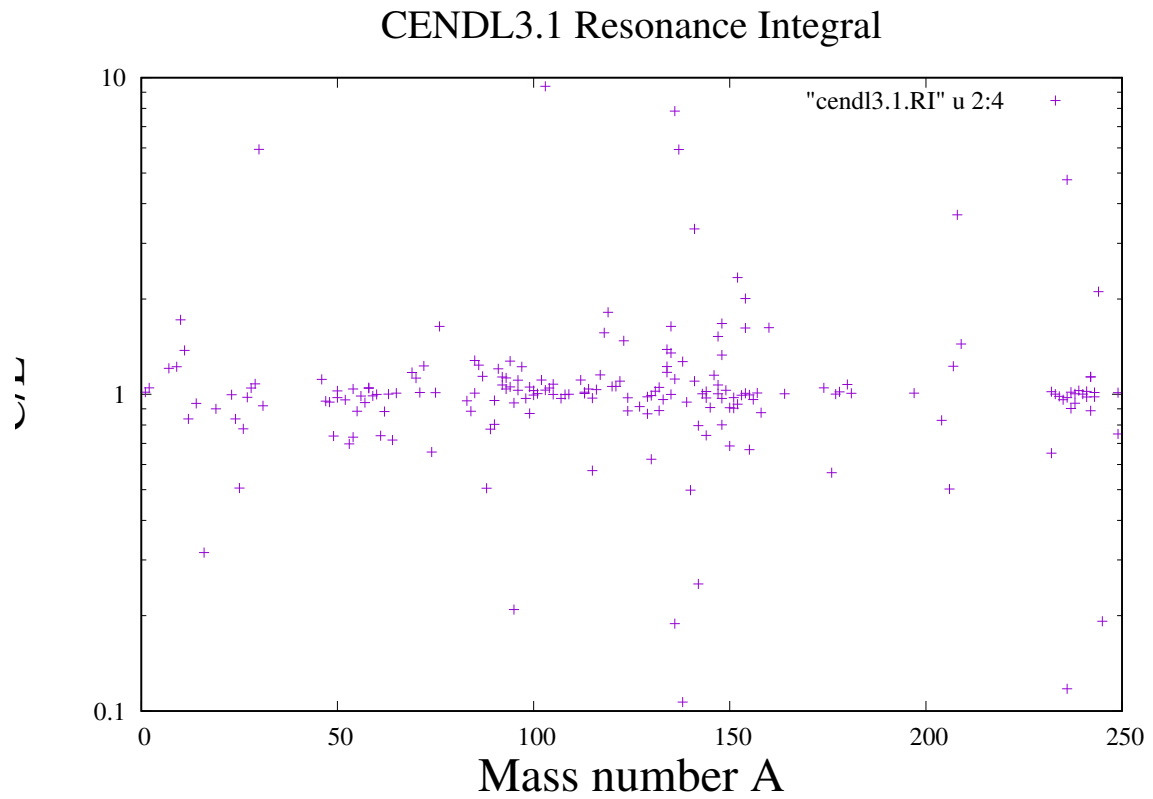


Figure 5.14: C/E values for resonance integrals for CENDL-3.1

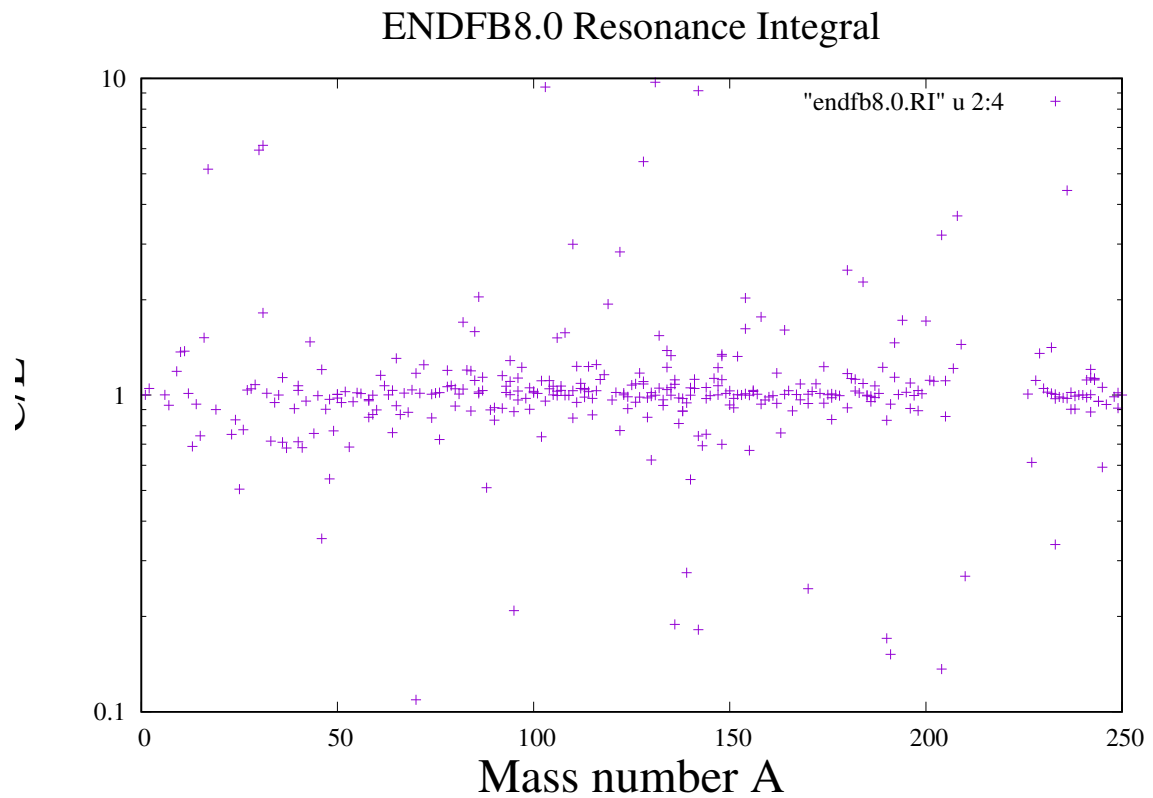


Figure 5.15: C/E values for resonance integrals for ENDF/B-VIII

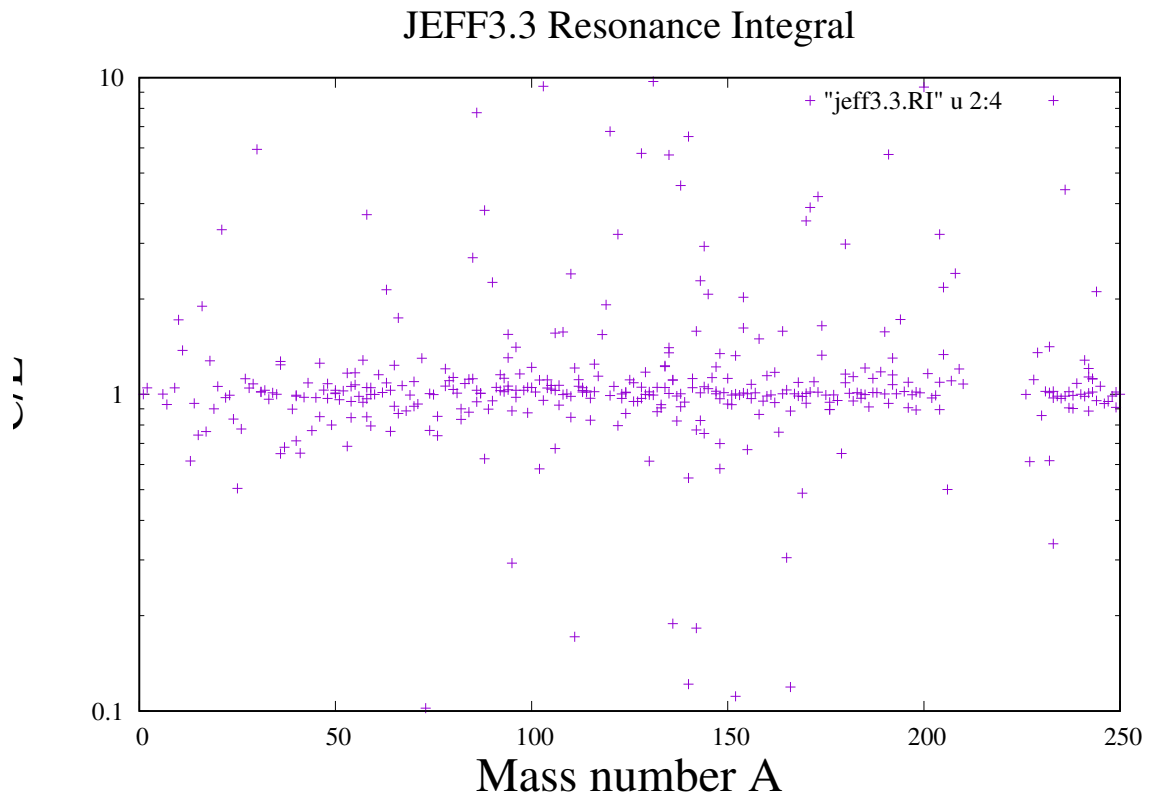


Figure 5.16: C/E values for resonance integrals for JEFF-3.3

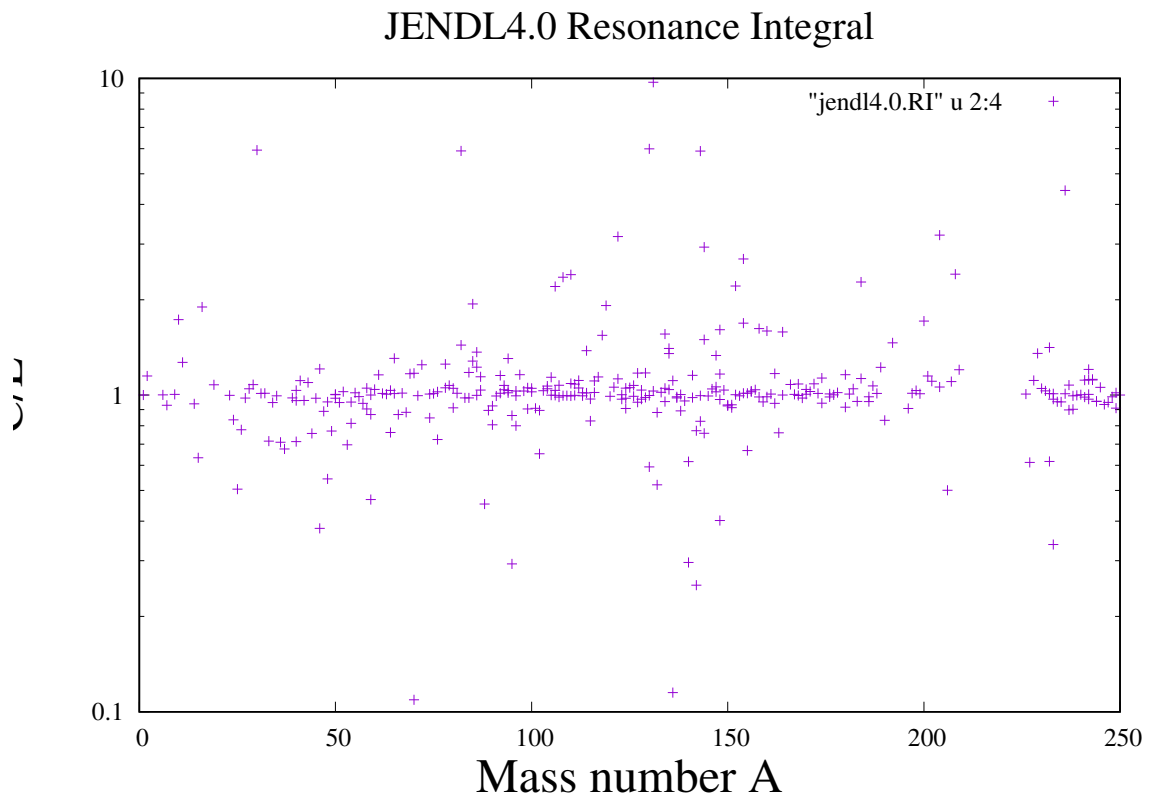


Figure 5.17: C/E values for resonance integrals for JENDL-4.0

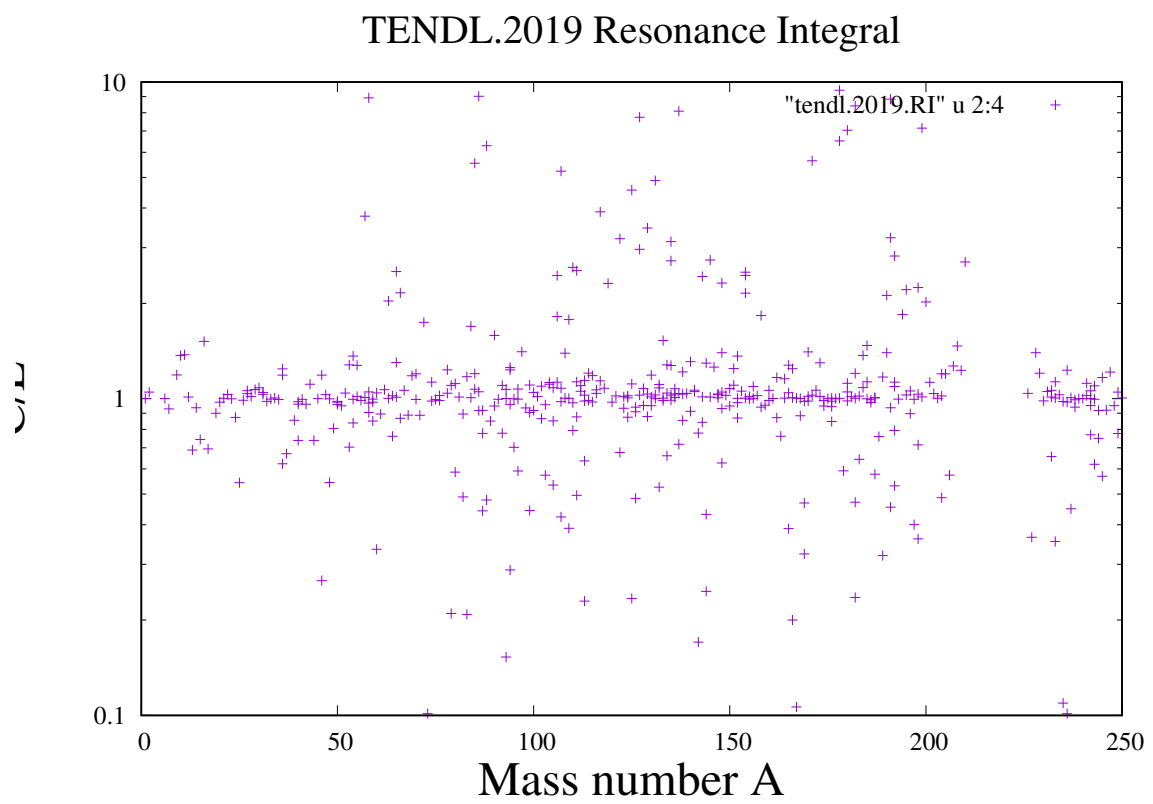


Figure 5.18: C/E values for resonance integrals for TENDL-2019

6. Outlook and conclusions

This manual describes RESONANCETABLES, a directory structured database derived from other databases, containing thermal cross sections, MACS and average resonance data. All data are presented in unified x-y-dy tables, and classified according to target nucleus and reaction.

This is supposed to be a first step towards a modern evaluation of these quantities whereby the final databases are completely reproducible from the original data and are retrievable by API's. "First step" here means that ideally an API would be available which would retrieve these data according to user-specific requests on command line level. Instead we have here produced the entire database.

The current 'final' databases have been constructed according to simple priority rules. It would be very useful to have an international working group to come to a well-evaluated database for these quantities, possible including the complete set of known resonance parameters.

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