UCRL-TR-202284

POINT 2004
A Temperature Dependent ENDF/B-VI, Release 8 Cross Section Library

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Point 2004 versus Point 2003

Both the current Point 2004 and the previously published Point 2003 are based on exactly the same ENDF/B-VI, Release 8 data. The difference between them is the accuracy to which the reconstructed data is presented and the media on which they are distributed.

When Point 2003 was released constraints on the size of the data files to conveniently fit onto CDs resulted in my having to construct the cross section to a looser tolerance than I would have liked, and certainly looser than I routinely use in my applications. Even with this limitation Point 2003 contained about 1.8 Gigabytes of data, distributed on three CDs.

Point 2004 is distributed on a single DVD, rather than a series of CDs. This has allowed me to tighten the tolerance on the data to reconstruct cross sections at all energies and temperatures to 0.1 % accuracy, which is what I routinely use in my applications. The result is a single DVD containing 4.3 Gigabyte of data. Note, that this library is almost two and a half times the size of the Point 2003 library, which should give you some idea of how much detail is added by tightening the tolerance; or if you prefer, how much detail was missing in earlier versions of this data.

For those familiar with the Point 2003 documentation, I will try to save you some time by pointing out that the remaining of this document is identical to the Point 2003, except where it refers to the difference in the contents of Point 2004 versus Point 2003. To help guide you through the remainder of this report, all changes are in red.

Introduction

The ENDF/B data library has recently been updated and is now freely available through the National Nuclear Data Center (NNDC), Brookhaven National Laboratory. This most recent library is identified as ENDF/B-VI, Release 8. Release 8 completely supersedes all preceding releases. Release 8 will be the last release of ENDF/B-VI; the next release of ENDF/B data will be for the new ENDF/B-VII library.

As distributed the ENDF/B-VI, Release 8 data includes cross sections represented in the form of a combination of resonance parameters and/or tabulated energy dependent cross sections, nominally at 0 Kelvin temperature.

For use in applications this library has been processed into the form of temperature dependent cross sections at eight neutron reactor like temperatures, between 0 and 2100 Kelvin, in steps of 300 Kelvin. It has also been processed to five astrophysics like temperatures, 1, 10, 100 eV, 1 and 10 keV. For reference purposes, 300 Kelvin is approximately 1/40 eV, so that 1 eV is approximately 12,000 Kelvin. At each temperature the cross sections are tabulated and linearly interpolable in energy.

All results are in the computer independent ENDF/B-VI character format [1], which allows the data to be easily transported between computers. In its processed form this library is approximately 4.3 gigabyte in size and is distributed on a single DVD.

Earlier Versions of ENDF/B-VI

Between the original distribution (Release 0) and Release 2 libraries, 74 evaluations were updated and distributed in July 1994 (see, UCRL-ID-117797). Between Release 2 and 3 libraries, 18 evaluations were updated and distributed in January 1996 (see, UCRL-ID-124171). Between Release 0 and 3 no completely new evaluations were added to the library. Between Release 3 and 4(see, UCRL-ID-127776), 87 evaluations were updated and five completely new evaluations were added, namely for Gd^{152}, Gd^{154}, Ir^{191}, Ir^{193} and Pu^{236}. In additional the evaluation for natural Cd was deleted and replaced by evaluations for the individual isotopes. Between Release 4 and 7, 68 materials were modified; mostly to extend the cross sections from 20 to 150 MeV, and three new evaluations were added (14-Si-28, 14-Si-29, 14-Si-30). The result was a library of 324 evaluations.

For details, see the above mentioned three reports: UCRL-ID-117797, UCRL-ID-124171, and UCRL-ID-127776 and its revisions.

ENDF/B-VI, Release 8 Data

Note that the following comments refer to both Point 2003 and Point 2004. Between the earlier version of this library (POINT2000), which was based on release 7 data, and the current version (POINT2003 now Point 2004), which is based on release 8 data, a direct cross section by cross section comparison will show minor (fraction of a %) differences in many cross sections, mainly due to improvements in the precision of the PREPRO2002 codes; these differences are not listed here. There are also many changes to the data that are not processed by PREPRO, this includes delayed neutron data, and neutron induced photon production data, that were not included in earlier versions of these evaluations; these changes are widespread throughout the library are also not listed here.

The following lists only significant changes to the evaluated neutron interaction cross sections (listed below in ascending ZA order),

Material	**Changes**
4-Be-9	(n,t) 12 to 20 MeV
8-O-16	New cross sections
16-S –Nat	I removed bogus "fission widths" from resonance parameters (note that this is the same correction I made for Release 7???)
17-Cl-35	New evaluation
17-Cl-37	New evaluation
42-Mo-95	New elastic and capture
43-Tc-99	New elastic and capture
44-Ru-101	New elastic and capture
45-Rh-103	New elastic and capture
46-Pd-105	New elastic and capture
47-Ag-109	New elastic and capture
50-Sn-120	New above 10 keV
50-Sn-122	New above 10 keV
50-Sn-124	New above 10 keV
51-Sb-121	New elastic, capture and inelastic
51-Sb-123	New elastic, capture and inelastic
54-Xe-131	New elastic and capture
60-Nd-143	New elastic and capture
60-Nd-145	New elastic and capture
62-Sm-147	New elastic and capture
62-Sm-150	New elastic and capture
62-Sm-151	New elastic and capture
62-Sm-152	Minor changes at upper end of resolved resonance region
64-Gd-155	New elastic and capture
64-Gd-157	New elastic and capture
91-Pa-232	New evaluation
92-U- 232	New elastic, inelastic, fission and capture
93-Np-236	New evaluation

The result is a library of 328 evaluations.

PREPRO2002 Codes

In addition to the changes in the ENDF/B-VI evaluations, it should be noted that between the last version of this report, where the PREPRO2000 codes were used, and the current version, where the PREPRO2002 codes were used, there have been major improvements in the ENDF/B Pre-processing codes. The major improvements were both in terms of improving the basic methods used by the codes and in terms of incorporating the latest ENDF/B-VI Formats and Procedures used by the current evaluations. The result is more accurate cross section data throughout the POINT2003 library.

WARNING – due to recent changes in ENDF/B-VI Formats and Procedures only the latest version of the ENDF/B Pre-processing codes, namely PREPRO2002, can be used to accurately process all current ENDF/B-VI evaluations. If you fail to heed this warning and you use any earlier versions of these codes the results will be inaccurate.

The PREPRO2002 codes run on virtually any computer, and are now available FREE on-line from the Nuclear Data Section, IAEA, Vienna, Austria, website at,

http://www-nds.iaea.or.at/ndspub/endf/prepro/

Requesting this Data

Please do not contact the author of this report to request this data; I do not have the resources necessary to directly respond to requests for this data. This data has been distributed to and is Internationally available from nuclear data/code centers throughout the World,

1) Within the United States: contact the National Nuclear Data Center, Brookhaven National Laboratory, Vicki McLane at services@bnlnd2.dne.bnl.gov
2) Within Western Europe: contact the OECD Nuclear Energy Agency/ Data Bank (NEA/DB), Paris, France, Enrico Sartori at sartori@nea.fr
3) Otherwise: contact the Nuclear Data Section, international Atomic Energy Agency, Vienna, Austria, Vladimir Pronyaev at v.pronyaev@iaea.org

Data Processing

As distributed the original evaluated data includes cross sections represented in the form of a combination of resonance parameters and/or tabulated energy dependent cross sections, nominally at 0 Kelvin temperature. For use in applications, this data has been processed using the 2002 version of the ENDF/B Pre-processing codes (PREPRO2002) to produce temperature dependent, linearly interpolable in energy, tabulated cross sections, in the ENDF/B-VI format.

For use in applications this library has been processed into the form of temperature dependent cross sections at eight neutron reactor like temperatures, between 0 and 2100 Kelvin, in steps of 300 Kelvin. It has also been processed to five astrophysics like temperatures, 1, 10, 100 eV, 1 and 10 keV. For reference purposes, 300 Kelvin is approximately 1/40 eV, so that 1 eV is approximately 12,000 Kelvin. At each temperature the cross sections are tabulated and linearly interpolable in energy.

The steps required and codes used to produce room temperature, linearly interpolable tabulated cross sections, in the ENDF/B-VI format, are described below (the name of each code in given in parenthesis; for details of each code see reference [2]).

Here are the steps, and PREPRO2002 codes, used to process the data, in the order in which the codes were used.

1) Linearly interpolable, tabulated cross sections (**LINEAR**)
2) Including the resonance contribution (**RECENT**)
3) Doppler broaden all cross sections to temperature (**SIGMA1**)
4) Check data, define redundant cross sections by summation (**FIXUP**)
5) Update evaluation dictionary in MF/MT=1/451 (**DICTIN**)

For the "cold" (0 Kelvin) data steps 1), 2) and 4), 5) were used. For the data at other temperatures, after steps 1) and 2), the data was Doppler broadened to each temperature using step 3), and the results were then made consistent with the ENDF/B formats and conventions using steps 4) and 5), to produce the final distributed data.

The result is linearly interpolable in energy, tabulated, temperature dependent cross sections, in the ENDF/B-VI format, ready to be used in applications.

Note - this processing only involved the energy dependent neutron cross sections. All other data in the evaluations, e.g., angular and energy distributions, was not affected by this processing, and is identical in all versions of the final results, i.e., it is the same in all of the directories, ORIGINAL, as well as K0 through K2100, and 1ev through 10kev, on the DVD.

Accuracy of Results

Each of the codes described above that was used to process data to obtain tabulated, linearly interpolable in energy cross sections, processed the data to within a user defined accuracy, or allowable uncertainty. The ENDF/B Pre-processing codes (PREPRO2002) are self-documenting, in the sense that the ENDF/B formatted output data that each code produces includes comments at the beginning of each evaluation defining the accuracy to which the cross sections were calculated. The combination of comments added by all of the codes defines the sequence and accuracy used by all of them. The accuracy is the same for all evaluations. Therefore, for exact details of the accuracy of the data, see the comments at the beginning of any evaluation. For use in Point 2004 all cross sections were reconstructed to within an accuracy of 0.1 % at all energies and temperatures; this is beyond the accuracy to which we physically know this data, so that we can assume that the data processing does not add any significant additional error to the inherent error of the data.

Contents of the Library

This library **contains** all of the evaluations in the ENDF/B-VI general purpose library. The following table summarizes the contents of the ENDF/B-VI general purpose library. This library contains evaluations for 328 materials (isotopes or naturally occurring elemental mixtures of isotopes).

This library **does not contain** data from special purpose ENDF/B-VI libraries, such as fission products, thermal scattering, photon interaction data. To obtain any of these special purpose libraries contact the National Nuclear Data Center, Brookhaven National Laboratory,

ENDF@bnlnd2.dne.bnl.gov

In this library each evaluation is stored as a separate file. The following table defines each material and the corresponding filename. The entire library is in the computer independent ENDF/B-VI character format, which allows the data to be easily transported between computers. The entire library requires approximately 4.3 gigabyte of storage and is distributed on a single DVD; see below for details of the DVD.

This library contains data for some metastable materials, which are indicated by an "M" at the end of their descriptions.

The majority of these evaluations are complete, in the sense that they include all cross sections over the energy range 10^{-5} eV to at least 20 MeV. However, the following are only partial evaluations that either only contain single reactions and no total cross section (Mg^{24}, K^{41}, Ti^{46}, Ti^{47}, Ti^{48}, Ti^{50} and Ni^{59}), or do not include energy dependent cross sections above the resonance region (Ar^{40}, Mo^{92}, Mo^{98}, Mo^{100}, In^{115}, Sn^{120}, Sn^{122} and Sn^{124}).

DVD Format and Layout

The DVD were written using DVD-R format that can be read on almost any computer that has a DVD reader.

The DVD is divided into fifteen (15) directories,

DOCUMENT	- A copy of this report in MSWord and PDF formats.
ORIGINAL	- The original ENDF/B data before it was processed.
K0	- 0 Kelvin cross sections
K300	- 300 Kelvin cross sections
K600	- 600 Kelvin cross sections
K900	- 900 Kelvin cross sections
K1200	- 1200 Kelvin cross sections
K1500	- 1500 Kelvin cross sections
K1800	- 1800 Kelvin cross sections
K2100	- 2100 Kelvin cross sections
1eV	- 1 eV cross sections
10eV	- 10 eV cross sections
100eV	- 100 eV cross sections
1keV	- 1 keV cross sections
10keV	- 10 keV cross sections

With the exception of DOCUMENT, each of these directories contains 328 files, one file for each evaluation. Each file is a complete ENDF/B "tape" [1], including a starting "tape" identification line, and ending with a "tape" end line [1]. In this form, each file can be used by a wide variety of available computer codes that treat data in the ENDF/B format, e.g., all of the PREPRO codes.

The Effects of Temperature and Doppler Broadening

For those readers who are not familiar with the effects of temperature and Doppler broadening on neutron cross sections and transport, I suggest that you read references [3] and [4], listed below.

Users of neutron cross sections should be aware that there are several important effects of temperature and Doppler broadening,

1) There is the well known effect in the neutron resonance region, where as the temperature increases resonances become broader, hence the name Doppler broadening. Figure 1 illustrates the effect of temperature on the U^{238} capture cross section for neutron reactor like temperatures, and figure 2 illustrates this effect for astrophysical like temperatures. These figures each contain four sub-figures, with each sub-figure comparing cross sections at two progressively higher temperatures. In both figure 1 and 2 each sub-figure shows exactly the same energy and cross section range. From these figures we can see that as temperature increases the peaks of the resonances become lower, and the minima between resonances become higher. At extremely high temperature the entire resonance structure disappears and the cross sections approaches a simple 1/v shape (where v is the neutron speed). This temperature effect will have a very important effect on resonance self-shielding in any neutron transport calculation. You should note from these figures that due to the large resonance spacing in U^{238} the resonance structure can still be seen up to surprisingly high temperatures.

To understand the importance of considering temperature we should consider reaction rates, such as captures/second, in various systems. In optically thin systems (few mean free paths dimensions) the flux will be unshielded, and our reaction rates will be defined by a simple cross section average,

Unshielded Capture = $\int_{E1}^{E2} [\Sigma c(E)\phi(E)] dE$ = capture cross section times neutron flux

In optically thick systems (many mean free paths dimensions) the flux will be shielded (the flux is suppressed by the total cross section) and our reaction rates must include the effect of self-shielding on the cross section average,

Shielded Capture = $\int_{E1}^{E2} [\Sigma c(E)\phi(E)/\Sigma t(E)] dE$ = including one over total cross section

Consider for example the U238 capture cross section between 1 and 10 keV as shown in fig. 1 and 2. If we calculate the unshielded and shielded average capture cross section for the energy interval over the range of temperatures shown in figs. 1 and 2, we obtain the results shown below in table 1.

What we see from these results is that the unshielded average capture cross section is virtually independent of temperature, being about 1 barn over the entire temperature range. In contrast the shielded average cross section varying by over a factor of three between the 0 K average (0.293 barns) and the 10 keV average (0.939 barns). **The point to learn from this is that without including the effect of self-shielding in multi-group calculations, temperature has very little effect on the average cross sections, which is quite simply wrong for optically thick systems.**

Table 1: Effect of Temperature on Average Cross Sections

Temp.	Unshielded (barns)	Shielded (barns)
0 K	0.996	0.293
300 K	0.966	0.526
600 K	0.996	0.576
1,200 K	0.996	0.630
12,000 K (1 eV)	0.996	0.799
10 eV	0.998	0.905
100 eV	1.000	0.933
1 keV	1.004	0.935
10 keV	1.007	0.939

2) Another, less well known, effect of Doppler broadening is at lower energies where as temperature increases the low energy constant scattering cross section increases and at very low energies approaches a simple 1/v shape (where v is the neutron speed); this effect is explained in detail in ref [3]. Figure 3 illustrates the effect of temperature on the hydrogen total cross section. From this figure we can see that starting from a "cold" (0 Kelvin) cross section that is constant at about 20 barns, as temperature increases the cross section increases. Compared to the "cold" 20 barn cross section, at thermal energy the Doppler broadened cross section is about 30 barns, i.e., 50 % higher. Note also from this figure that this effect extends well above thermal energy. For example, at 300 Kelvin the thermal energy is 0.0253 eV, but we can see this effect up to about 1 eV. From the lower half of figure 2 we can see that at very low energy the cross section approaches a simple 1/v shape (where v is the neutron speed) and the cross sections at various temperatures become proportional to one another. This effect on the cross sections at low energy is very important for thermal and low energy neutron systems.

3) Yet another important effect of temperature is that at lower energies neutrons do not slow down in energy as quickly and neutron scatter can even result in the upscatter of neutrons, i.e., when neutrons scatter they can gain, rather than lose, energy. This is a well known effect at low energies, where thermal scattering law data or a free gas model is used to model the interaction of neutrons with target atoms that are moving about with thermal motion. This effect can also be important at higher energies, particularly near narrow resonances, where thermal motion of the target atoms can cause neutrons to slightly upscatter, but even slight upscatter can cause a neutron to scatter from below to above the energy of a very narrow resonance. See reference [4], below for a routine

designed to be used in conjunction with the SIGMA1 method of Doppler broadening [3], to handle neutron thermal scattering. This routine [4] is completely compatible for use with the cross sections included here, since these cross sections were Doppler broadened using the SIGMA1 method [3]. The combination of SIGMA1 [3] Doppler broadened cross sections and THERMAL [4] to handle thermal scattering, is currently used in the TART Monte Carlo transport code [5].

Acknowledgments

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References

[1] Data Formats and Procedures for the Evaluated Nuclear Data File ENDF-6, BNL-NCS-44945, Rev. 11/95, edited by V. McLane, et.al. National Nuclear Data Center, Brookhaven National Lab. http://www.nndc.bnl.gov/nndcscr/documents/endf/endf102/

[2] "PREPRO2002: The 2002 ENDF/B Pre-Processing Codes," by D.E. Cullen, Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria, IAEA-NDS-39, Rev. 11, April 1, 2002. http://www-nds.iaea.or.at/ndspub/endf/prepro/

[3] "Exact Doppler Broadening of Tabulated Cross Sections," by D.E. Cullen and C.R. Weisbin, Nuclear Science and Engineering 60, p. 199 (1975)

[4] "THERMAL: A Routine Designed to Calculate Neutron Thermal Scattering," by D.E. Cullen, Lawrence Livermore National Laboratory, UCRL-ID-120560-Rev-1, Sept. 1995. http://www.llnl.gov/cullen1/thermal.htm

[5] “TART2002: A Coupled Neutron-Photon 3-D, Time Dependent, Combinatorial Geometry Monte Carlo Transport Code," by D.E. Cullen, Lawrence Livermore National Laboratory, UCRL-ID-126455, Rev. 4, Nov. 2002. http://www.llnl.gov/cullen1/mc.htm

ENDF/B-VI Release 8 Library (Z = 1 to 51) New Release 8 Evaluations in RED

Filename	Material	Filename	Material	Filename	Material
ZA001001	1-H -1	ZA028062	28-Ni-62	ZA042099	42-Mo-99
ZA001002	1-H -2	ZA028064	28-Ni-64	ZA042100	42-Mo-100
ZA001003	1-H -3	ZA029063	29-Cu-63	ZA043099	43-Tc-99
ZA002003	2-He-3	ZA029065	29-Cu-65	ZA044096	44-Ru-96
ZA002004	2-He-4	ZA031000	31-Ga-Nat	ZA044098	44-Ru-98
ZA003006	3-Li-6	ZA032072	32-Ge-72	ZA044099	44-Ru-99
ZA003007	3-Li-7	ZA032073	32-Ge-73	ZA044100	44-Ru-100
ZA004009	4-Be-9	ZA032074	32-Ge-74	ZA044101	44-Ru-101
ZA005010	5-B -10	ZA032076	32-Ge-76	ZA044102	44-Ru-102
ZA005011	5-B -11	ZA033075	33-As-75	ZA044103	44-Ru-103
ZA006000	6-C -Nat	ZA034074	34-Se-74	ZA044104	44-Ru-104
ZA007014	7-N -14	ZA034076	34-Se-76	ZA044105	44-Ru-105
ZA007015	7-N -15	ZA034077	34-Se-77	ZA044106	44-Ru-106
ZA008016	8-O -16	ZA034078	34-Se-78	ZA045103	45-Rh-103
ZA008017	8-O -17	ZA034080	34-Se-80	ZA045105	45-Rh-105
ZA009019	9-F -19	ZA034082	34-Se-82	ZA046102	46-Pd-102
ZA011023	11-Na-23	ZA035079	35-Br-79	ZA046104	46-Pd-104
ZA012000	12-Mg-Nat	ZA035081	35-Br-81	ZA046105	46-Pd-105
ZA012024	12-Mg-24	ZA036078	36-Kr-78	ZA046106	46-Pd-106
ZA013027	13-Al-27	ZA036080	36-Kr-80	ZA046107	46-Pd-107
ZA014000	14-Si-Nat	ZA036082	36-Kr-82	ZA046108	46-Pd-108
ZA014028	14-Si-28	ZA036083	36-Kr-83	ZA046110	46-Pd-110
ZA014029	14-Si-29	ZA036084	36-Kr-84	ZA047107	47-Ag-107
ZA014030	14-Si-30	ZA036085	36-Kr-85	ZA047109	47-Ag-109
ZA015031	15-P -31	ZA036086	36-Kr-86	ZA047111	47-Ag-111
ZA016000	16-S -Nat	ZA037085	37-Rb-85	ZA048106	48-Cd-106
ZA016032	16-S -32	ZA037086	37-Rb-86	ZA048108	48-Cd-108
ZA017000	17-Cl-Nat	ZA037087	37-Rb-87	ZA048110	48-Cd-110
ZA017035	17-Cl-35	ZA038084	38-Sr-84	ZA048111	48-Cd-111
ZA017037	17-Cl-37	ZA038086	38-Sr-86	ZA048112	48-Cd-112
ZA018040	18-Ar-40	ZA038087	38-Sr-87	ZA048113	48-Cd-113
ZA019000	19-K -Nat	ZA038088	38-Sr-88	ZA048114	48-Cd-114
ZA019041	19-K -41	ZA038089	38-Sr-89	ZA048115.M	48-Cd-115m
ZA020000	20-Ca-Nat	ZA038090	38-Sr-90	ZA048116	48-Cd-116
ZA021045	21-Sc-45	ZA039089	39-Y -89	ZA049000	49-In-Nat
ZA022000	22-Ti-Nat	ZA039090	39-Y -90	ZA049113	49-In-113
ZA022046	22-Ti-46	ZA039091	39-Y -91	ZA049115	49-In-115
ZA022047	22-Ti-47	ZA040000	40-Zr-Nat	ZA050112	50-Sn-112
ZA022048	22-Ti-48	ZA040090	40-Zr-90	ZA050114	50-Sn-114
ZA022050	22-Ti-50	ZA040091	40-Zr-91	ZA050115	50-Sn-115
ZA023000	23-V -Nat	ZA040092	40-Zr-92	ZA050116	50-Sn-116
ZA024050	24-Cr-50	ZA040093	40-Zr-93	ZA050117	50-Sn-117
ZA024052	24-Cr-52	ZA040094	40-Zr-94	ZA050118	50-Sn-118
ZA024053	24-Cr-53	ZA040095	40-Zr-95	ZA050119	50-Sn-119
ZA024054	24-Cr-54	ZA040096	40-Zr-96	ZA050120	50-Sn-120
ZA025055	25-Mn-55	ZA041093	41-Nb-93	ZA050122	50-Sn-122
ZA026054	26-Fe-54	ZA041094	41-Nb-94	ZA050123	50-Sn-123
ZA026056	26-Fe-56	ZA041095	41-Nb-95	ZA050124	50-Sn-124
ZA026057	26-Fe-57	ZA042000	42-Mo-Nat	ZA050125	50-Sn-125
ZA026058	26-Fe-58	ZA042092	42-Mo-92	ZA050126	50-Sn-126
ZA027059	27-Co-59	ZA042094	42-Mo-94	ZA051121	51-Sb-121
ZA028058	28-Ni-58	ZA042095	42-Mo-95	ZA051123	51-Sb-123
ZA028059	28-Ni-59	ZA042096	42-Mo-96	ZA051124	51-Sb-124
ZA028060	28-Ni-60	ZA042097	42-Mo-97	ZA051125	51-Sb-125
ZA028061	28-Ni-61	ZA042098	42-Mo-98		

ENDF/B-VI Release 8 Library (Z = 51 to 99) New Release 8 Evaluations in RED

Filename	Material	Filename	Material	Filename	Material
ZA051126	51-Sb-126	ZA060148	60-Nd-148	ZA074186	74-W -186
ZA052120	52-Te-120	ZA060150	60-Nd-150	ZA075185	75-Re-185
ZA052122	52-Te-122	ZA061147	61-Pm-147	ZA075187	75-Re-187
ZA052123	52-Te-123	ZA061148	61-Pm-148	ZA077191	77-Ir-191
ZA052124	52-Te-124	ZA061148.M	61-Pm-148m	ZA077193	77-Ir-193
ZA052125	52-Te-125	ZA061149	61-Pm-149	ZA079197	79-Au-197
ZA052126	52-Te-126	ZA061151	61-Pm-151	ZA082206	82-Pb-206
ZA052127.M	52-Te-127m	ZA062144	62-Sm-144	ZA082207	82-Pb-207
ZA052128	52-Te-128	ZA062147	62-Sm-147	ZA082208	82-Pb-208
ZA052129.M	52-Te-129m	ZA062148	62-Sm-148	ZA083209	83-Bi-209
ZA052130	52-Te-130	ZA062149	62-Sm-149	ZA090230	90-Th-230
ZA052132	52-Te-132	ZA062150	62-Sm-150	ZA090232	90-Th-232
ZA053127	53-I -127	ZA062151	62-Sm-151	ZA091231	91-Pa-231
ZA053129	53-I -129	ZA062152	62-Sm-152	ZA091232	91-Pa-232
ZA053130	53-I -130	ZA062153	62-Sm-153	ZA091233	91-Pa-233
ZA053131	53-I -131	ZA062154	62-Sm-154	ZA092232	92-U -232
ZA053135	53-I -135	ZA063151	63-Eu-151	ZA092233	92-U -233
ZA054124	54-Xe-124	ZA063152	63-Eu-152	ZA092234	92-U -234
ZA054126	54-Xe-126	ZA063153	63-Eu-153	ZA092235	92-U -235
ZA054128	54-Xe-128	ZA063154	63-Eu-154	ZA092236	92-U -236
ZA054129	54-Xe-129	ZA063155	63-Eu-155	ZA092237	92-U -237
ZA054130	54-Xe-130	ZA063156	63-Eu-156	ZA092238	92-U -238
ZA054131	54-Xe-131	ZA063157	63-Eu-157	ZA093236	93-Np-236
ZA054132	54-Xe-132	ZA064152	64-Gd-152	ZA093237	93-Np-237
ZA054133	54-Xe-133	ZA064154	64-Gd-154	ZA093238	93-Np-238
ZA054134	54-Xe-134	ZA064155	64-Gd-155	ZA093239	93-Np-239
ZA054135	54-Xe-135	ZA064156	64-Gd-156	ZA094236	94-Pu-236
ZA054136	54-Xe-136	ZA064157	64-Gd-157	ZA094237	94-Pu-237
ZA055133	55-Cs-133	ZA064158	64-Gd-158	ZA094238	94-Pu-238
ZA055134	55-Cs-134	ZA064160	64-Gd-160	ZA094239	94-Pu-239
ZA055135	55-Cs-135	ZA065159	65-Tb-159	ZA094240	94-Pu-240
ZA055136	55-Cs-136	ZA065160	65-Tb-160	ZA094241	94-Pu-241
ZA055137	55-Cs-137	ZA066160	66-Dy-160	ZA094242	94-Pu-242
ZA056134	56-Ba-134	ZA066161	66-Dy-161	ZA094243	94-Pu-243
ZA056135	56-Ba-135	ZA066162	66-Dy-162	ZA094244	94-Pu-244
ZA056136	56-Ba-136	ZA066163	66-Dy-163	ZA095241	95-Am-241
ZA056137	56-Ba-137	ZA066164	66-Dy-164	ZA095242	95-Am-242
ZA056138	56-Ba-138	ZA067165	67-Ho-165	ZA095242.M	95-Am-242m
ZA056140	56-Ba-140	ZA068166	68-Er-166	ZA095243	95-Am-243
ZA057139	57-La-139	ZA068167	68-Er-167	ZA096241	96-Cm-241
ZA057140	57-La-140	ZA071175	71-Lu-175	ZA096242	96-Cm-242
ZA058140	58-Ce-140	ZA071176	71-Lu-176	ZA096243	96-Cm-243
ZA058141	58-Ce-141	ZA072000	72-Hf-Nat	ZA096244	96-Cm-244
ZA058142	58-Ce-142	ZA072174	72-Hf-174	ZA096245	96-Cm-245
ZA058143	58-Ce-143	ZA072176	72-Hf-176	ZA096246	96-Cm-246
ZA058144	58-Ce-144	ZA072177	72-Hf-177	ZA096247	96-Cm-247
ZA059141	59-Pr-141	ZA072178	72-Hf-178	ZA096248	96-Cm-248
ZA059142	59-Pr-142	ZA072179	72-Hf-179	ZA097249	97-Bk-249
ZA059143	59-Pr-143	ZA072180	72-Hf-180	ZA098249	98-Cf-249
ZA060142	60-Nd-142	ZA073181	73-Ta-181	ZA098250	98-Cf-250
ZA060143	60-Nd-143	ZA073182	73-Ta-182	ZA098251	98-Cf-251
ZA060144	60-Nd-144	ZA074000	74-W -Nat	ZA098252	98-Cf-252
ZA060145	60-Nd-145	ZA074182	74-W -182	ZA098253	98-Cf-253
ZA060146	60-Nd-146	ZA074183	74-W -183	ZA099253	99-Es-253
ZA060147	60-Nd-147	ZA074184	74-W –184		

Fig.1: Effect of Doppler Broadening on Resonance Cross Sections

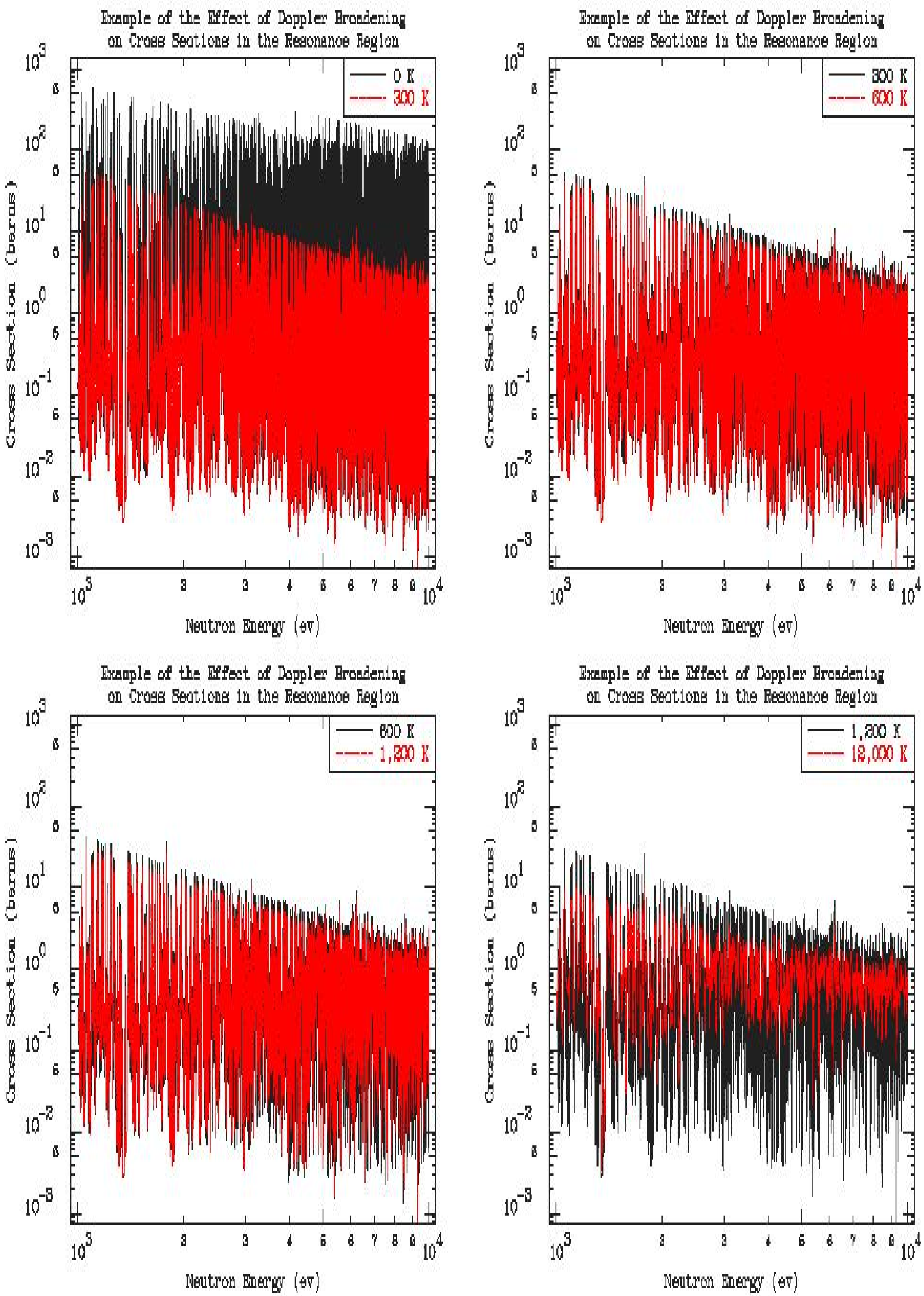


Fig.2: Effect of Doppler Broadening on Resonance Cross Sections

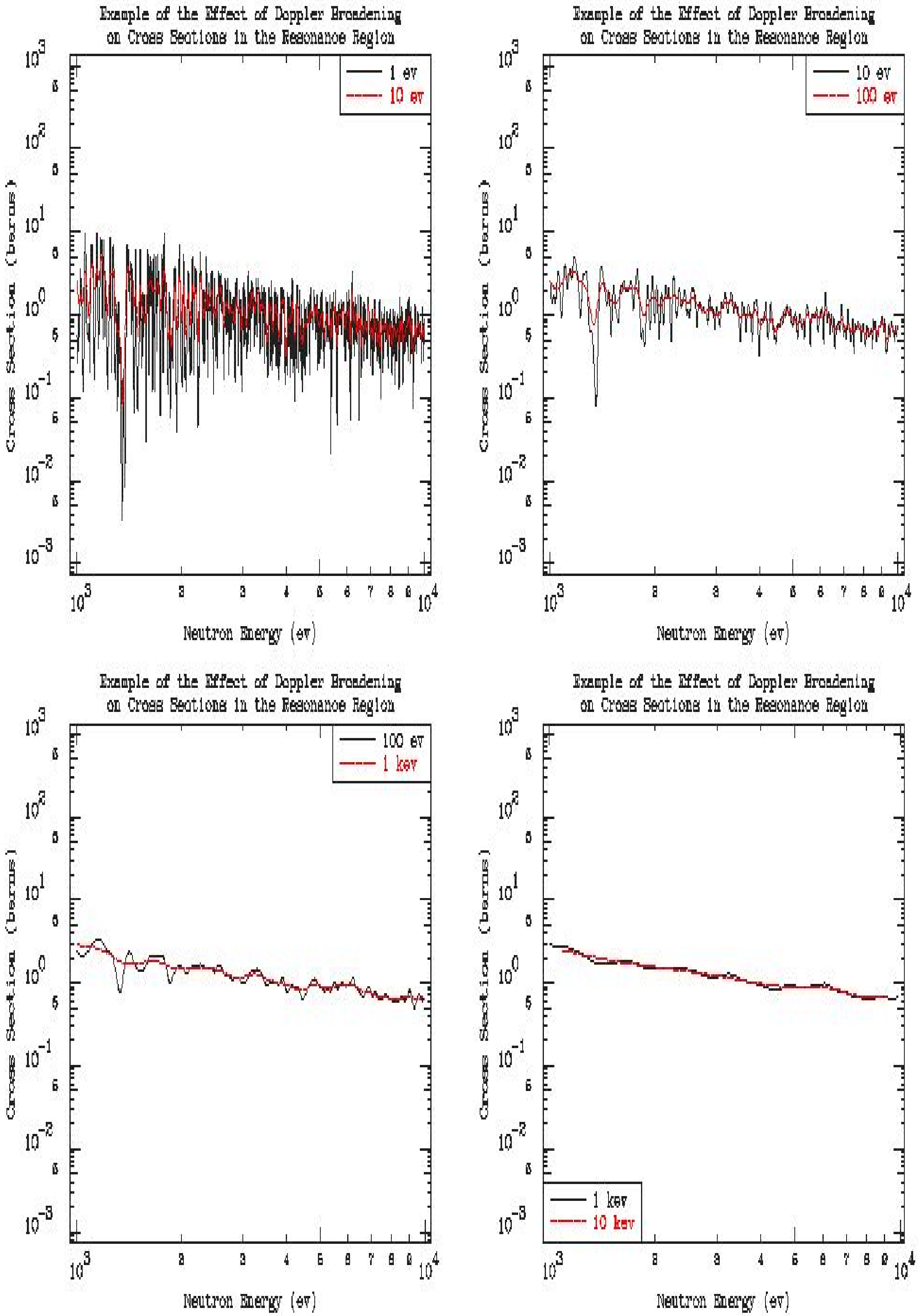
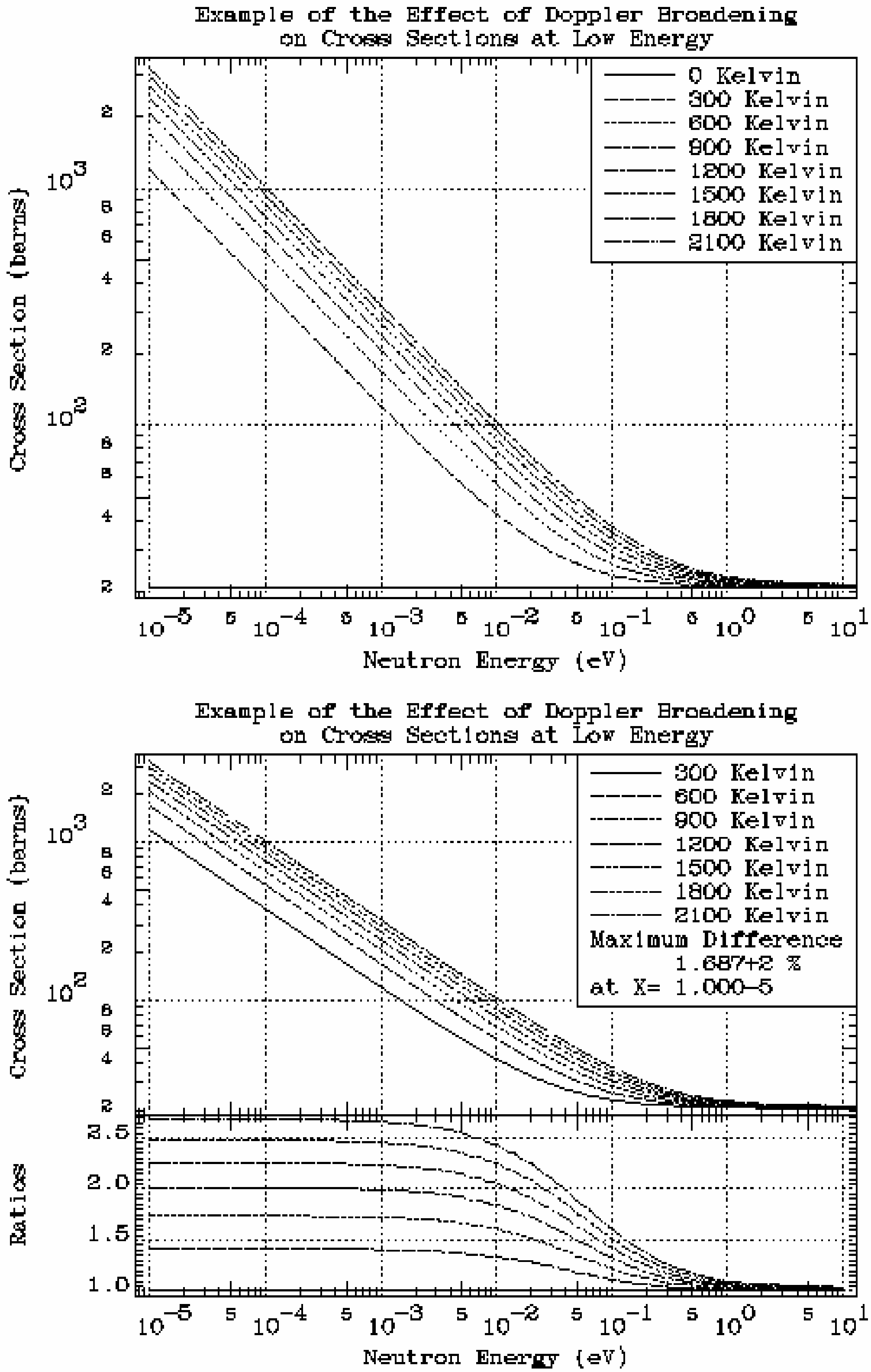


Fig.3: Effect of Doppler Broadening on Low Energy Cross Sections



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