LA-UR-14-21878
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Title: Release of Continuous Representation for S(,ß) ACE Data

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Intended for: Documentation, internal and on open website.

Issued: 2014-03-20

Release of Continuous Representation for $S(\alpha, \beta)$ ACE Data

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March 19, 2014

ATTENTION: This document is long and not intended to be printed. If you do print, please do not print the *many* pages of plots—which begin on page 20—which are best viewed on a computer screen.

1. Background

For low energy neutrons, the default free gas model for scattering cross sections is not always appropriate. Molecular effects or crystalline structure effects can affect the neutron scattering cross sections. These effects are included in the $S(\alpha, \beta)$ thermal neutron scattering data and are tabulated in `file 7` of the ENDF6 format files. S stands for scattering. α is a momentum transfer variable and β is an energy transfer variable.

The $S(\alpha, \beta)$ cross sections can include coherent elastic scattering (no E change for the neutron, but specific scattering angles), incoherent elastic scattering (no E change for the neutron, but continuous scattering angles), and inelastic scattering (E change for the neutron, and change in angle as well). Every $S(\alpha, \beta)$ material will have inelastic scattering and may have either coherent or incoherent elastic scattering (but not both). Coherent elastic scattering cross sections have distinctive jagged-looking Bragg edges, whereas the other cross sections are much smoother.

The evaluated files from the NNDC are processed locally in the `THERMR` module of NJOY. Data can be produced either for continuous energy Monte Carlo codes (using `ACER`) or embedded in multi-group cross sections for deterministic (or even multi-group Monte Carlo) codes (using `GROUPR`).

Currently, the $S(\alpha, \beta)$ files available for MCNP use discrete energy changes for inelastic scattering. That is, the scattered neutrons can only be emitted at specific energies—rather than across a continuous spectrum of energies. The discrete energies are chosen to preserve the average secondary neutron energy, i.e., in an integral sense, but the discrete treatment does not preserve any differential quantities in energy or angle.

2. New $S(\alpha, \beta)$ Libraries for MCNP

A new data library for $S(\alpha, \beta)$ materials for MCNP has been released. It is the first thermal scattering library for MCNP that includes continuous secondary energy data. The new continuous option was processed with the `IWT=2` flag on card `9` of the `ACER` input in NJOY. (The previous discrete representations used `IWT=0` or `1`.) See Appendix B for sample NJOY input decks.

ACE files for MCNP have been produced (along with the appropriate entries for the xsdir file) for each of the S(α, β) materials and at each of the given temperatures. Version 99.336 of NJOY was used on yellow-rail to process the thermal scattering evaluation files. The new continuous ACE files are considerably larger ($\sim$10x) than the previous discrete ACE files.

The new library contains all of the same materials as the most recent S(α, β) library [4], endf70sab, as well as the latest thermal scattering evaluation addition to ENDF/B-VII.1, SiO_2. Most of the scattering files are to be used as isotopic replacements in an MCNP run (using the MT card). However, two of the S(α, β) files (benzene and SiO_2) are to be used as whole material replacements in MCNP.

Most of the S(α, β) files have a maximum energy $E_{\max} = 10\,\text{eV}$—which is a THERMR input in NJOY. The exceptions are cryogenic materials like liquid and solid methane, para and ortho D and H, or the reactor material, UinUO2. The UinUO2 has a 1 eV maximum—so that the S(α, β) does not obscure a low-lying scattering resonance in the uranium at a few eV. MCNP uses the free gas scattering model above E_{max} and S(α, β) scattering below it.

The new files have been installed at /usr/projects/data/nuclear/mc/type1 on the open and secure ICN networks at Los Alamos and should be distributed soon to RSICC with the new version of MCNP 6.

2.1. New Naming Convention for Diatomic S(α, β) Materials

A new naming convention has been adopted for the diatomic S(α, β) materials. These materials and their new naming scheme are:

- be-o beryllium in beryllium oxide,
- o-be oxygen in beryllium oxide,
- h-zr hydrogen in zirconium hydride,
- zr-h zirconium in zirconium hydride,
- o2-u oxygen in uranium oxide,
- u-o2 uranium in uranium oxide.

The new names are reflected in Table 1. The previous convention was to use a slash (/) where now we are using a dash (-). The new naming convention for these materials is intended to avoid filename problems on Unix-like operating systems; i.e., Unix filenames can't have a slash in them.

The new continuous energy representation is released using both the new and traditional convention; this is done to preserve backwards compatibility. In the future, all S(α, β) data releases will only use the new convention and will not use slashes in the ZAIDs. Be aware that if you simply ask for the ZAID without the extension (e.g., be/o instead of be/o.10t) you *will* get the continuous energy representation as those come first on the xsdir file.

For this release of the S(α, β) data, both the new names (e.g., o2-u) and the traditional names (e.g., o2/u) will work. Future releases are not guaranteed to include the traditionally named ZAIDs.

In the previous S(α, β) data release [4], the ZAID extension for the S(α, β) materials were like 1xt where x ranged from 0–8 and represented an evaluated temperature. The new, continuous representation has similar extensions, 2xt. Both the discrete (1xt) and continuous (2xt) representations are available in this release. The lone exception is the sio2 data tables which are only available in the continuous representation.

A complete listing of the $S(\alpha, \beta)$ data tables available for this release is listed in Table 1.

2.2. Cross Section Plots

Cross section plots representative of each set of $S(\alpha, \beta)$ files are given in Appendix D. The `MCPLOT` option of MCNP 5 was used to plot the $S(\alpha, \beta)$ cross sections against the free gas cross sections for the identical isotope or material. A typical `MCPLOT` command would be

```
xs lwtr.10t mt 1 coplot xs 1001.70c mt -3
```

The intention of these plots was to verify that the higher energy $S(\alpha, \beta)$ cross sections asymptote into the free gas cross sections.

2.3. Update: March 2014

The original $S(\alpha, \beta)$ data tables for uranium in uranium oxide (`u-o2` and `u/o2`), zirconium in zirconium hydride (`zr-h` and `zr/h`), and silicon dioxide (`sio2`) had some problems in the header of those files. Updated and corrected versions of those files have been provided with a ZAID extension of `3xt`; `2xt` is the extension of the originally released files. Table 1 lists the new data tables as well as the original ones. The new/corrected data tables are the default tables.

3. Testing the New $S(\alpha, \beta)$ Data Files

The deficiencies in the old, discrete $S(\alpha, \beta)$-representation was noted by Cullen, et al. [3]. In their paper they show a series of calculations in what they call the "broomstick" problem to show that the secondary energy and angular distribution is discrete instead of continuous as one would expect.

The broomstick problem consists of a very long (10^5 cm) and very narrow (10^{-8} cm radius) cylinder filled with the scattering material and surrounded by a vacuum. A thermal monoenergetic ($E = 0.0253$ eV) source is placed in the middle of the broomstick. The energy and angular distribution of neutrons are tallied on planes perpendicular to the ends of the broomstick. With this geometry, any neutron that scatters will leave the broomstick and stream until it is tallied on the planes perpendicular to the ends of the cylinder.

As a test of our $S(\alpha, \beta)$ data files we have performed the broomstick calculations for all of our continuous and discrete representations of the $S(\alpha, \beta)$ thermal scattering data. For comparison, we have also performed the broomstick calculation with the thermal scattering treatment turned off; accomplished in MCNP by having no `MT` card. The secondary neutron energy and angular distributions were plotted and are included in Appendix C.

4. Archival Information

All of the files used to create these new $S(\alpha, \beta)$ data tables have been archived in `/hpss/nucldata/mc/type1/endf71sab` If you have need of this data, please contact a member of the Nuclear Data Team at Los Alamos National Laboratory `nucldata@lanl.gov`.

Table 1: S(α, β) cross section libraries available in MCNP.

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
				Aluminum-27 (13027)				
al27.22t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
al27.23t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
al27.24t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
al27.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
al27.20t	ENDF/B-VII.0	ENDF71SaB	2005	20	22	80	coh	
al27.21t	ENDF/B-VII.0	ENDF71SaB	2005	80	22	80	coh	
al27.12t	ENDF/B-VII.0	endf70sab	2005	293.6	20	80	coh	
al27.13t	ENDF/B-VII.0	endf70sab	2005	400	20	80	coh	
al27.14t	ENDF/B-VII.0	endf70sab	2005	600	20	80	coh	
al27.15t	ENDF/B-VII.0	endf70sab	2005	800	20	80	coh	
al27.10t	ENDF/B-VII.0	endf70sab	2005	20	20	80	coh	
al27.11t	ENDF/B-VII.0	endf70sab	2005	80	20	80	coh	
				Beryllium Metal (4009)				
be.20t	ENDF/B-VII.0	ENDF71SaB	1993	293.6	22	80	coh	
be.21t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	coh	
be.22t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	coh	
be.23t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	coh	
be.24t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	coh	
be.25t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	coh	
be.26t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	coh	
be.27t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	coh	
be.10t	ENDF/B-VII.0	endf70sab	1993	293.6	20	80	coh	
be.11t	ENDF/B-VII.0	endf70sab	1993	400	20	80	coh	
be.12t	ENDF/B-VII.0	endf70sab	1993	500	20	80	coh	
be.13t	ENDF/B-VII.0	endf70sab	1993	600	20	80	coh	
be.14t	ENDF/B-VII.0	endf70sab	1993	700	20	80	coh	
be.15t	ENDF/B-VII.0	endf70sab	1993	800	20	80	coh	
be.16t	ENDF/B-VII.0	endf70sab	1993	1000	20	80	coh	
be.17t	ENDF/B-VII.0	endf70sab	1993	1200	20	80	coh	
be.60t	endf6.3	sab2002	1993	294	16	64	coh	
be.61t	endf6.3	sab2002	1993	400	16	64	coh	
be.62t	endf6.3	sab2002	1993	600	16	64	coh	
be.63t	endf6.3	sab2002	1993	800	16	64	coh	
be.64t	endf6.3	sab2002	1993	1000	16	64	coh	
be.65t	endf6.3	sab2002	1993	1200	16	64	coh	
be.69t	endf6.3	sab2002	1993	77	16	64	coh	
be.01t	endf5	tmccs	1964	300	8	20	coh	
be.04t	endf5	tmccs	1964	600	8	20	coh	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
be.05t	endf5	tmccs	1964	800	8	20	coh	
be.06t	endf5	tmccs	1964	1200	8	20	coh	
		Beryllium in Beryllium Oxide (4009)						
be-o.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
be-o.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
be-o.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
be-o.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
be-o.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
be-o.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
be-o.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
be-o.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
		Beryllium in Beryllium Oxide (4009)						
be/o.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
be/o.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
be/o.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
be/o.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
be/o.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
be/o.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
be/o.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
be/o.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
be/o.10t	ENDF/B-VII.0	endf70sab	2005	293.6	20	80	coh	
be/o.11t	ENDF/B-VII.0	endf70sab	2005	400	20	80	coh	
be/o.12t	ENDF/B-VII.0	endf70sab	2005	500	20	80	coh	
be/o.13t	ENDF/B-VII.0	endf70sab	2005	600	20	80	coh	
be/o.14t	ENDF/B-VII.0	endf70sab	2005	700	20	80	coh	
be/o.15t	ENDF/B-VII.0	endf70sab	2005	800	20	80	coh	
be/o.16t	ENDF/B-VII.0	endf70sab	2005	1000	20	80	coh	
be/o.17t	ENDF/B-VII.0	endf70sab	2005	1200	20	80	coh	
		Benzene (1001, 6000, 6012)						
benz.20t	ENDF/B-VII.0	ENDF71SaB	1969	293.6	22	80	none	
benz.21t	ENDF/B-VII.0	ENDF71SaB	1969	350	22	80	none	
benz.22t	ENDF/B-VII.0	ENDF71SaB	1969	400	22	80	none	
benz.23t	ENDF/B-VII.0	ENDF71SaB	1969	450	22	80	none	
benz.24t	ENDF/B-VII.0	ENDF71SaB	1969	500	22	80	none	
benz.25t	ENDF/B-VII.0	ENDF71SaB	1969	600	22	80	none	
benz.26t	ENDF/B-VII.0	ENDF71SaB	1969	800	22	80	none	
benz.27t	ENDF/B-VII.0	ENDF71SaB	1969	1000	22	80	none	
benz.10t	ENDF/B-VII.0	endf70sab	1969	293.6	20	80	none	
benz.11t	ENDF/B-VII.0	endf70sab	1969	350	20	80	none	
benz.12t	ENDF/B-VII.0	endf70sab	1969	400	20	80	none	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
benz.13t	ENDF/B-VII.0	endf70sab	1969	450	20	80	none	
benz.14t	ENDF/B-VII.0	endf70sab	1969	500	20	80	none	
benz.15t	ENDF/B-VII.0	endf70sab	1969	600	20	80	none	
benz.16t	ENDF/B-VII.0	endf70sab	1969	800	20	80	none	
benz.17t	ENDF/B-VII.0	endf70sab	1969	1000	20	80	none	
benz.60t	endf6.3	sab2002	1969	294	16	64	none	
benz.61t	endf6.3	sab2002	1969	400	16	64	none	
benz.62t	endf6.3	sab2002	1969	600	16	64	none	
benz.63t	endf6.3	sab2002	1969	800	16	64	none	
benz.01t	endf5	tmccs	<1969	300	8	32	none	
benz.02t	endf5	tmccs	<1969	400	8	32	none	
benz.03t	endf5	tmccs	<1969	500	8	32	none	
benz.04t	endf5	tmccs	<1969	600	8	32	none	
benz.05t	endf5	tmccs	<1969	800	8	32	none	
Beryllium Oxide (4009, 8016)								
beo.60t	endf6.3	sab2002	1993	294	16	64	coh	
beo.61t	endf6.3	sab2002	1993	400	16	64	coh	
beo.62t	endf6.3	sab2002	1993	600	16	64	coh	
beo.63t	endf6.3	sab2002	1993	800	16	64	coh	
beo.64t	endf6.3	sab2002	1993	1000	16	64	coh	
beo.65t	endf6.3	sab2002	1993	1200	16	64	coh	
beo.01t	endf5	tmccs	<1969	300	8	32	coh	
beo.04t	endf5	tmccs	<1969	600	8	32	coh	
beo.05t	endf5	tmccs	<1969	800	8	32	coh	
beo.06t	endf5	tmccs	<1969	1200	8	32	coh	
Ortho Deuterium (1002)								
dortho.20t	ENDF/B-VII.0	ENDF71SaB	1993	19	22	80	none	
dortho.10t	ENDF/B-VII.0	endf70sab	1993	19	20	80	none	
dortho.60t	endf6.3	sab2002	1993	19	16	64	none	
dortho.01t	lanl89	therxs	<1969	20	8	8	none	
Para Deuterium (1002)								
dpara.20t	ENDF/B-VII.0	ENDF71SaB	1993	19	22	80	none	
dpara.10t	ENDF/B-VII.0	endf70sab	1993	19	20	80	none	
dpara.60t	endf6.3	sab2002	1993	19	16	64	none	
dpara.01t	lanl89	therxs	<1969	20	8	8	none	
Iron-56 (26056)								
fe56.22t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
fe56.23t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
fe56.24t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
fe56.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
fe56.20t	ENDF/B-VII.0	ENDF71SaB	2005	20	22	80	coh	
fe56.21t	ENDF/B-VII.0	ENDF71SaB	2005	80	22	80	coh	
fe56.12t	ENDF/B-VII.0	endf70sab	2005	293.6	20	80	coh	
fe56.13t	ENDF/B-VII.0	endf70sab	2005	400	20	80	coh	
fe56.14t	ENDF/B-VII.0	endf70sab	2005	600	20	80	coh	
fe56.15t	ENDF/B-VII.0	endf70sab	2005	800	20	80	coh	
fe56.10t	ENDF/B-VII.0	endf70sab	2005	20	20	80	coh	
fe56.11t	ENDF/B-VII.0	endf70sab	2005	80	20	80	coh	
			Graphite (6000,6012)					
grph.20t	ENDF/B-VII.0	ENDF71SaB	1993	293.6	22	80	coh	
grph.21t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	coh	
grph.22t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	coh	
grph.23t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	coh	
grph.24t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	coh	
grph.25t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	coh	
grph.26t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	coh	
grph.27t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	coh	
grph.28t	ENDF/B-VII.0	ENDF71SaB	1993	1600	22	80	coh	
grph.29t	ENDF/B-VII.0	ENDF71SaB	1993	2000	22	80	coh	
grph.10t	ENDF/B-VII.0	endf70sab	1993	293.6	20	80	coh	
grph.11t	ENDF/B-VII.0	endf70sab	1993	400	20	80	coh	
grph.12t	ENDF/B-VII.0	endf70sab	1993	500	20	80	coh	
grph.13t	ENDF/B-VII.0	endf70sab	1993	600	20	80	coh	
grph.14t	ENDF/B-VII.0	endf70sab	1993	700	20	80	coh	
grph.15t	ENDF/B-VII.0	endf70sab	1993	800	20	80	coh	
grph.16t	ENDF/B-VII.0	endf70sab	1993	1000	20	80	coh	
grph.17t	ENDF/B-VII.0	endf70sab	1993	1200	20	80	coh	
grph.18t	ENDF/B-VII.0	endf70sab	1993	1600	20	80	coh	
grph.19t	ENDF/B-VII.0	endf70sab	1993	2000	20	80	coh	
grph.60t	endf6.3	sab2002	1993	294	16	64	coh	
grph.61t	endf6.3	sab2002	1993	400	16	64	coh	
grph.62t	endf6.3	sab2002	1993	600	16	64	coh	
grph.63t	endf6.3	sab2002	1993	800	16	64	coh	
grph.64t	endf6.3	sab2002	1993	1000	16	64	coh	
grph.65t	endf6.3	sab2002	1993	1200	16	64	coh	
grph.01t	endf5	tmccs	1965	300	8	32	coh	
grph.04t	endf5	tmccs	1965	600	8	32	coh	
grph.05t	endf5	tmccs	1965	800	8	32	coh	
grph.06t	endf5	tmccs	1965	1200	8	32	coh	
grph.07t	endf5	tmccs	1965	1600	8	32	coh	
grph.08t	endf5	tmccs	1965	2000	8	32	coh	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
			Hydrogen in Zirconium Hydride (1001)					
h-zr.20t	ENDF/B-VII.0	ENDF71SaB	1993	293.6	22	80	inco	
h-zr.21t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	inco	
h-zr.22t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	inco	
h-zr.23t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	inco	
h-zr.24t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	inco	
h-zr.25t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	inco	
h-zr.26t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	inco	
h-zr.27t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	inco	
			Hydrogen in Zirconium Hydride (1001)					
h/zr.20t	ENDF/B-VII.0	ENDF71SaB	1993	293.6	22	80	inco	
h/zr.21t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	inco	
h/zr.22t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	inco	
h/zr.23t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	inco	
h/zr.24t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	inco	
h/zr.25t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	inco	
h/zr.26t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	inco	
h/zr.27t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	inco	
h/zr.10t	ENDF/B-VII.0	endf70sab	1993	293.6	20	80	inco	
h/zr.11t	ENDF/B-VII.0	endf70sab	1993	400	20	80	inco	
h/zr.12t	ENDF/B-VII.0	endf70sab	1993	500	20	80	inco	
h/zr.13t	ENDF/B-VII.0	endf70sab	1993	600	20	80	inco	
h/zr.14t	ENDF/B-VII.0	endf70sab	1993	700	20	80	inco	
h/zr.15t	ENDF/B-VII.0	endf70sab	1993	800	20	80	inco	
h/zr.16t	ENDF/B-VII.0	endf70sab	1993	1000	20	80	inco	
h/zr.17t	ENDF/B-VII.0	endf70sab	1993	1200	20	80	inco	
h/zr.60t	endf6.3	sab2002	1993	294	16	64	inco	
h/zr.61t	endf6.3	sab2002	1993	400	16	64	inco	
h/zr.62t	endf6.3	sab2002	1993	600	16	64	inco	
h/zr.63t	endf6.3	sab2002	1993	800	16	64	inco	
h/zr.64t	endf6.3	sab2002	1993	1000	16	64	inco	
h/zr.65t	endf6.3	sab2002	1993	1200	16	64	inco	
h/zr.01t	endf5	tmccs	<1969	300	8	20	inco	
h/zr.02t	endf5	tmccs	<1969	400	8	20	inco	
h/zr.04t	endf5	tmccs	<1969	600	8	20	inco	
h/zr.05t	endf5	tmccs	<1969	800	8	20	inco	
h/zr.06t	endf5	tmccs	<1969	1200	8	20	inco	
			Ortho Hydrogen (1001)					
hortho.20t	ENDF/B-VII.0	ENDF71SaB	1993	20	22	80	none	
hortho.10t	ENDF/B-VII.0	endf70sab	1993	20	20	80	none	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
hortho.60t	endf6.3	sab2002	1993	19	16	64	none	
hortho.61t	endf6.3	sab2002	1993	20	16	64	none	
hortho.62t	endf6.3	sab2002	1993	21	16	64	none	
hortho.63t	endf6.3	sab2002	1993	22	16	64	none	
hortho.64t	endf6.3	sab2002	1993	23	16	64	none	
hortho.65t	endf6.3	sab2002	1993	24	16	64	none	
hortho.66t	endf6.3	sab2002	1993	25	16	64	none	
hortho.01t	lanl89	therxs	<1969	20	8	8	none	
Para Hydrogen (1001)								
hpara.20t	ENDF/B-VII.0	ENDF71SaB	1993	20	22	80	none	
hpara.10t	ENDF/B-VII.0	endf70sab	1993	20	20	80	none	
hpara.60t	endf6.3	sab2002	1993	19	16	64	none	
hpara.61t	endf6.3	sab2002	1993	20	16	64	none	
hpara.62t	endf6.3	sab2002	1993	21	16	64	none	
hpara.63t	endf6.3	sab2002	1993	22	16	64	none	
hpara.64t	endf6.3	sab2002	1993	23	16	64	none	
hpara.65t	endf6.3	sab2002	1993	24	16	64	none	
hpara.66t	endf6.3	sab2002	1993	25	16	64	none	
hpara.01t	lanl89	therxs	<1969	20	8	8	none	
Deuterium in Heavy Water (1002)								
hwtr.20t	ENDF/B-VII.0	ENDF71SaB	2004	293.6	22	80	none	
hwtr.21t	ENDF/B-VII.0	ENDF71SaB	2004	350	22	80	none	
hwtr.22t	ENDF/B-VII.0	ENDF71SaB	2004	400	22	80	none	
hwtr.23t	ENDF/B-VII.0	ENDF71SaB	2004	450	22	80	none	
hwtr.24t	ENDF/B-VII.0	ENDF71SaB	2004	500	22	80	none	
hwtr.25t	ENDF/B-VII.0	ENDF71SaB	2004	550	22	80	none	
hwtr.26t	ENDF/B-VII.0	ENDF71SaB	2004	600	22	80	none	
hwtr.27t	ENDF/B-VII.0	ENDF71SaB	2004	650	22	80	none	
hwtr.10t	ENDF/B-VII.0	endf70sab	2004	293.6	20	80	none	
hwtr.11t	ENDF/B-VII.0	endf70sab	2004	350	20	80	none	
hwtr.12t	ENDF/B-VII.0	endf70sab	2004	400	20	80	none	
hwtr.13t	ENDF/B-VII.0	endf70sab	2004	450	20	80	none	
hwtr.14t	ENDF/B-VII.0	endf70sab	2004	500	20	80	none	
hwtr.15t	ENDF/B-VII.0	endf70sab	2004	550	20	80	none	
hwtr.16t	ENDF/B-VII.0	endf70sab	2004	600	20	80	none	
hwtr.17t	ENDF/B-VII.0	endf70sab	2004	650	20	80	none	
hwtr.60t	endf6.3	sab2002	1969	294	16	64	none	
hwtr.61t	endf6.3	sab2002	1969	400	16	64	none	
hwtr.62t	endf6.3	sab2002	1969	600	16	64	none	
hwtr.63t	endf6.3	sab2002	1969	800	16	64	none	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
hwtr.64t	endf6.3	sab2002	1969	1000	16	64	none	
hwtr.01t	endf5	tmccs	1969	300	8	20	none	
hwtr.02t	endf5	tmccs	1969	400	8	20	none	
hwtr.03t	endf5	tmccs	1969	500	8	20	none	
hwtr.04t	endf5	tmccs	1969	600	8	20	none	
hwtr.05t	endf5	tmccs	1969	800	8	20	none	
Hydrogen in Liquid Methane (1001)								
lmeth.20t	ENDF/B-VII.0	ENDF71SaB	1993	100	22	80	none	
lmeth.10t	ENDF/B-VII.0	endf70sab	1993	100	20	80	none	
lmeth.60t	endf6.3	sab2002	1993	100	16	64	none	
lmeth.01t	lanl89	therxs	<1969	100	8	8	none	
Hydrogen in Light Water (1001)								
lwtr.20t	ENDF/B-VII.0	ENDF71SaB	2006	293.6	22	80	none	
lwtr.21t	ENDF/B-VII.0	ENDF71SaB	2006	350	22	80	none	
lwtr.22t	ENDF/B-VII.0	ENDF71SaB	2006	400	22	80	none	
lwtr.23t	ENDF/B-VII.0	ENDF71SaB	2006	450	22	80	none	
lwtr.24t	ENDF/B-VII.0	ENDF71SaB	2006	500	22	80	none	
lwtr.25t	ENDF/B-VII.0	ENDF71SaB	2006	550	22	80	none	
lwtr.26t	ENDF/B-VII.0	ENDF71SaB	2006	600	22	80	none	
lwtr.27t	ENDF/B-VII.0	ENDF71SaB	2006	650	22	80	none	
lwtr.28t	ENDF/B-VII.0	ENDF71SaB	2006	800	22	80	none	
lwtr.10t	ENDF/B-VII.0	endf70sab	2006	293.6	20	80	none	
lwtr.11t	ENDF/B-VII.0	endf70sab	2006	350	20	80	none	
lwtr.12t	ENDF/B-VII.0	endf70sab	2006	400	20	80	none	
lwtr.13t	ENDF/B-VII.0	endf70sab	2006	450	20	80	none	
lwtr.14t	ENDF/B-VII.0	endf70sab	2006	500	20	80	none	
lwtr.15t	ENDF/B-VII.0	endf70sab	2006	550	20	80	none	
lwtr.16t	ENDF/B-VII.0	endf70sab	2006	600	20	80	none	
lwtr.17t	ENDF/B-VII.0	endf70sab	2006	650	20	80	none	
lwtr.18t	ENDF/B-VII.0	endf70sab	2006	800	20	80	none	
lwtr.60t	endf6.3	sab2002	1993	294	16	64	none	
lwtr.61t	endf6.3	sab2002	1993	400	16	64	none	
lwtr.62t	endf6.3	sab2002	1993	500	16	64	none	
lwtr.63t	endf6.3	sab2002	1993	800	16	64	none	
lwtr.64t	endf6.3	sab2002	1993	1000	16	64	none	
lwtr.01t	endf5	tmccs	<1969	300	8	20	none	
lwtr.02t	endf5	tmccs	<1969	400	8	20	none	
lwtr.03t	endf5	tmccs	<1969	500	8	20	none	
lwtr.04t	endf5	tmccs	<1969	600	8	20	none	
lwtr.05t	endf5	tmccs	<1969	800	8	20	none	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
Oxygen in Beryllium Oxide (8016, 8017, 8018)								
o-be.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
o-be.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
o-be.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
o-be.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
o-be.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
o-be.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
o-be.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
o-be.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
Oxygen in Beryllium Oxide (8016, 8017, 8018)								
o/be.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
o/be.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
o/be.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
o/be.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
o/be.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
o/be.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
o/be.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
o/be.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
o/be.10t	ENDF/B-VII.0	endf70sab	2005	293.6	20	80	coh	
o/be.11t	ENDF/B-VII.0	endf70sab	2005	400	20	80	coh	
o/be.12t	ENDF/B-VII.0	endf70sab	2005	500	20	80	coh	
o/be.13t	ENDF/B-VII.0	endf70sab	2005	600	20	80	coh	
o/be.14t	ENDF/B-VII.0	endf70sab	2005	700	20	80	coh	
o/be.15t	ENDF/B-VII.0	endf70sab	2005	800	20	80	coh	
o/be.16t	ENDF/B-VII.0	endf70sab	2005	1000	20	80	coh	
o/be.17t	ENDF/B-VII.0	endf70sab	2005	1200	20	80	coh	
Oxygen in UO2 (8016, 8017, 8018)								
o2-u.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
o2-u.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
o2-u.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
o2-u.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
o2-u.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
o2-u.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
o2-u.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
o2-u.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
Oxygen in UO2 (8016, 8017, 8018)								
o2/u.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
o2/u.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
o2/u.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
o2/u.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
o2/u.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
o2/u.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
o2/u.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
o2/u.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
o2/u.10t	ENDF/B-VII.0	endf70sab	2005	293.6	20	80	coh	
o2/u.11t	ENDF/B-VII.0	endf70sab	2005	400	20	80	coh	
o2/u.12t	ENDF/B-VII.0	endf70sab	2005	500	20	80	coh	
o2/u.13t	ENDF/B-VII.0	endf70sab	2005	600	20	80	coh	
o2/u.14t	ENDF/B-VII.0	endf70sab	2005	700	20	80	coh	
o2/u.15t	ENDF/B-VII.0	endf70sab	2005	800	20	80	coh	
o2/u.16t	ENDF/B-VII.0	endf70sab	2005	1000	20	80	coh	
o2/u.17t	ENDF/B-VII.0	endf70sab	2005	1200	20	80	coh	
Hydrogen in Polyethylene (1001)								
poly.20t	ENDF/B-VII.0	ENDF71SaB	1969	293.6	22	80	inco	
poly.21t	ENDF/B-VII.0	ENDF71SaB	1969	350	22	80	inco	
poly.10t	ENDF/B-VII.0	endf70sab	1969	293.6	20	80	inco	
poly.11t	ENDF/B-VII.0	endf70sab	1969	350	20	80	inco	
poly.60t	endf6.3	sab2002	1969	294	16	64	inco	
poly.01t	endf5	tmccs	1969	300	8	20	inco	
Silicon and oxygen in SiO2 (8016, 14028, 14029)								
sio2.30t	ENDF/B-VII.1	ENDF71SaB	2010	293.6	22	80	coh	
sio2.31t	ENDF/B-VII.1	ENDF71SaB	2010	350	22	80	coh	
sio2.32t	ENDF/B-VII.1	ENDF71SaB	2010	400	22	80	coh	
sio2.33t	ENDF/B-VII.1	ENDF71SaB	2010	500	22	80	coh	
sio2.34t	ENDF/B-VII.1	ENDF71SaB	2010	800	22	80	coh	
sio2.35t	ENDF/B-VII.1	ENDF71SaB	2010	1000	22	80	coh	
sio2.36t	ENDF/B-VII.1	ENDF71SaB	2010	1200	22	80	coh	
sio2.20t	ENDF/B-VII.1	ENDF71SaB	2010	293.6	22	80	coh	
sio2.21t	ENDF/B-VII.1	ENDF71SaB	2010	350	22	80	coh	
sio2.22t	ENDF/B-VII.1	ENDF71SaB	2010	400	22	80	coh	
sio2.23t	ENDF/B-VII.1	ENDF71SaB	2010	500	22	80	coh	
sio2.24t	ENDF/B-VII.1	ENDF71SaB	2010	800	22	80	coh	
sio2.25t	ENDF/B-VII.1	ENDF71SaB	2010	1000	22	80	coh	
sio2.26t	ENDF/B-VII.1	ENDF71SaB	2010	1200	22	80	coh	
Hydrogen in Solid Methane (1001)								
smeth.20t	ENDF/B-VII.0	ENDF71SaB	1993	22	22	80	inco	
smeth.10t	ENDF/B-VII.0	endf70sab	1993	22	20	80	inco	
smeth.60t	endf6.3	sab2002	1993	22	16	64	inco	
smeth.01t	lanl89	therxs	<1969	22	8	8	inco	
Uranium-238 in UO2 (92238)								

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
u-o2.30t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
u-o2.31t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
u-o2.32t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
u-o2.33t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
u-o2.34t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
u-o2.35t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
u-o2.36t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
u-o2.37t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
u-o2.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
u-o2.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
u-o2.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
u-o2.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
u-o2.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
u-o2.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
u-o2.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
u-o2.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
			Uranium-238 in UO2 (92238)					
u/o2.30t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
u/o2.31t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
u/o2.32t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
u/o2.33t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
u/o2.34t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
u/o2.35t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
u/o2.36t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
u/o2.37t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
u/o2.20t	ENDF/B-VII.0	ENDF71SaB	2005	293.6	22	80	coh	
u/o2.21t	ENDF/B-VII.0	ENDF71SaB	2005	400	22	80	coh	
u/o2.22t	ENDF/B-VII.0	ENDF71SaB	2005	500	22	80	coh	
u/o2.23t	ENDF/B-VII.0	ENDF71SaB	2005	600	22	80	coh	
u/o2.24t	ENDF/B-VII.0	ENDF71SaB	2005	700	22	80	coh	
u/o2.25t	ENDF/B-VII.0	ENDF71SaB	2005	800	22	80	coh	
u/o2.26t	ENDF/B-VII.0	ENDF71SaB	2005	1000	22	80	coh	
u/o2.27t	ENDF/B-VII.0	ENDF71SaB	2005	1200	22	80	coh	
u/o2.10t	ENDF/B-VII.0	endf70sab	2005	293.6	20	80	coh	
u/o2.11t	ENDF/B-VII.0	endf70sab	2005	400	20	80	coh	
u/o2.12t	ENDF/B-VII.0	endf70sab	2005	500	20	80	coh	
u/o2.13t	ENDF/B-VII.0	endf70sab	2005	600	20	80	coh	
u/o2.14t	ENDF/B-VII.0	endf70sab	2005	700	20	80	coh	
u/o2.15t	ENDF/B-VII.0	endf70sab	2005	800	20	80	coh	
u/o2.16t	ENDF/B-VII.0	endf70sab	2005	1000	20	80	coh	
u/o2.17t	ENDF/B-VII.0	endf70sab	2005	1200	20	80	coh	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

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Table 1: S(α,β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
Zirconium in Zirconium Hydride (40000, 40090, 40091, 40092, 40094, 40096)								
zr-h.30t	ENDF/B-VII.0	ENDF71SaB	1993	293.6	22	80	inco	
zr-h.31t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	inco	
zr-h.32t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	inco	
zr-h.33t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	inco	
zr-h.34t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	inco	
zr-h.35t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	inco	
zr-h.36t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	inco	
zr-h.37t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	inco	
zr-h.20t	ENDF/B-VII.0	ENDF71SaB	1993	293.6	22	80	inco	
zr-h.21t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	inco	
zr-h.22t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	inco	
zr-h.23t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	inco	
zr-h.24t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	inco	
zr-h.25t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	inco	
zr-h.26t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	inco	
zr-h.27t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	inco	
Zirconium in Zirconium Hydride (40000, 40090, 40091, 40092, 40094, 40096)								
zr/h.30t	ENDF/B-VII.0	ENDF71SaB	1993	293.6	22	80	inco	
zr/h.31t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	inco	
zr/h.32t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	inco	
zr/h.33t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	inco	
zr/h.34t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	inco	
zr/h.35t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	inco	
zr/h.36t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	inco	
zr/h.37t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	inco	
zr/h.21t	ENDF/B-VII.0	ENDF71SaB	1993	400	22	80	inco	
zr/h.22t	ENDF/B-VII.0	ENDF71SaB	1993	500	22	80	inco	
zr/h.23t	ENDF/B-VII.0	ENDF71SaB	1993	600	22	80	inco	
zr/h.24t	ENDF/B-VII.0	ENDF71SaB	1993	700	22	80	inco	
zr/h.25t	ENDF/B-VII.0	ENDF71SaB	1993	800	22	80	inco	
zr/h.26t	ENDF/B-VII.0	ENDF71SaB	1993	1000	22	80	inco	
zr/h.27t	ENDF/B-VII.0	ENDF71SaB	1993	1200	22	80	inco	
zr/h.10t	ENDF/B-VII.0	endf70sab	1993	293.6	20	80	inco	
zr/h.11t	ENDF/B-VII.0	endf70sab	1993	400	20	80	inco	
zr/h.12t	ENDF/B-VII.0	endf70sab	1993	500	20	80	inco	
zr/h.13t	ENDF/B-VII.0	endf70sab	1993	600	20	80	inco	
zr/h.14t	ENDF/B-VII.0	endf70sab	1993	700	20	80	inco	
zr/h.15t	ENDF/B-VII.0	endf70sab	1993	800	20	80	inco	
zr/h.16t	ENDF/B-VII.0	endf70sab	1993	1000	20	80	inco	

[a] All of the S(α,β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

Continued on next page

Table 1: S(α, β) cross section libraries available in MCNP (continued).

Discrete ZAID	Continuous ZAID	Library Name	Source	Eval Date	Temp (K)	Num of Angles	Num of Energies	Elastic Data
zr/h.17t	ENDF/B-VII.0	endf70sab	1993	1200	20	80	inco	
zr/h.60t	endf6.3	sab2002	1993	294	16	64	inco	
zr/h.61t	endf6.3	sab2002	1993	400	16	64	inco	
zr/h.62t	endf6.3	sab2002	1993	600	16	64	inco	
zr/h.63t	endf6.3	sab2002	1993	800	16	64	inco	
zr/h.64t	endf6.3	sab2002	1993	1000	16	64	inco	
zr/h.65t	endf6.3	sab2002	1993	1200	16	64	inco	
zr/h.01t	endf5	tmccs	<1969	300	8	32	inco	
zr/h.02t	endf5	tmccs	<1969	400	8	32	inco	
zr/h.04t	endf5	tmccs	<1969	600	8	32	inco	
zr/h.05t	endf5	tmccs	<1969	800	8	32	inco	
zr/h.06t	endf5	tmccs	<1969	1200	8	32	inco	

[a] All of the S(α, β) data is taken from the ENDF/B-VII.0 [1] release. The lone exception is `sio2` which comes from ENDF/B-VII.1 [2].

References

[1] M. B. Chadwick, P. Obložinský, M. Herman, N. M. Greene, R. D. McKnight, D. L. Smith, P. G. Young, R. E. MacFarlane, G. M. Hale, S. C. Frankle, A. C. Kahler, T. Kawano, R. C. Little, D. G. Madland, P. Moller, R. D. Mosteller, P. R. Page, P. Talou, H. Trellue, M. C. White, W. B. Wilson, R. Arcilla, C. L. Dunford, S. F. Mughabghab, B. Pritychenko, D. Rochman, A. A. Sonzogni, C. R. Lubitz, T. H. Trumbull, J. P. Weinman, D. A. Brown, D. E. Cullen, D. P. Heinrichs, D. P. McNabb, H. Derrien, M. E. Dunn, N. M. Larson, L. C. Leal, A. D. Carlson, R. C. Block, J. B. Briggs, E. T. Cheng, H. C. Huria, M. L. Zerkle, K. S. Kozier, A. Courcelle, V. Pronyaev, and S. C. van der Marck. ENDF/B-VII.0: Next generation evaluated nuclear data library for nuclear science and technology. *Nuclear Data Sheets*, 107(12):2931–3059, December 2006.

[2] M.B. Chadwick, M. Herman, P. Obložinský, M.E. Dunn, Y. Danon, A.C. Kahler, D.L. Smith, B. Pritychenko, G. Arbanas, R. Arcilla, R. Brewer, D.A. Brown, R. Capote, A.D. Carlson, Y.S. Cho, H. Derrien, K. Guber, G.M. Hale, S. Hoblit, S. Holloway, T.D. Johnson, T. Kawano, B.C. Kiedrowski, H. Kim, S. Kunieda, N.M. Larson, L. Leal, J.P. Lestone, R.C. Little, E.A. McCutchan, R.E. MacFarlane, M. MacInnes, C.M. Mattoon, R.D. McKnight, S.F. Mughabghab, G.P.A. Nobre, G. Palmiotti, A. Palumbo, M.T. Pigni, V.G. Pronyaev, R.O. Sayer, A.A. Sonzogni, N.C. Summers, P. Talou, I.J. Thompson, A. Trkov, R.L. Vogt, S.C. van der Marck, A. Wallner, M.C. White, D. Wiarda, and P.G. Young. ENDF/B-VII.1 nuclear data for science and technology: Cross sections, covariances, fission product yields and decay data. *Nuclear Data Sheets*, 112(12):2887 – 2996, 2011.

[3] D. E. Cullen, L. F. Hansen, E. M. Lent, and E. F. Plechaty. Thermal scattering law data: Implementation and testing using the monte carlo neutron transport codes cog, mcnp and tart. Technical Report UCRL-ID-153656, Lawrence Livermore National Laboratory, May 17 2003.

[4] Holly R. Trellue and Robert C. Little. Release of new mcnp s(alpha,beta) library ENDF70SAB based on ENDF/B-VII.0. Technical Report LA-UR-08-3628, Los Alamos National Laboratory, 2008.

A. Sample MCNP Input File

```
test of ENDF/B-VII data
1  1 -1.0 -1 2 -3  imp:n=1
2  0       -2:3    imp:n=0
3  0     1 -4 2 -3  imp:n=1

1    cx 1.0e-8
2    px 0
3    px 1.0e5
4    cx 1.0e99

print
nps 1E10
sdef pos=5.0e4 0 0 erg=0.0253e-6 vec=1 0 0 nrm=1  dir=1
tmp 2.53e-08 2.53e-08 2.53e-08
ctme 15.0
m1  1001.70c    2.0   8016.70c 1.0
mt1    lwtr.20t
f1:n 1
f11:n 2
c11   -1.0 199I 1.0
e11   1.0e-6
f21:n 3
c21   -1.0 199I 1.0
e21   1.0e-6
e0  1.0e-10 300ilog 1.0e-6
f31:n 2
c31   -1.0 499I 0.90 249I 0.99 100I 1.0
e31   1.0e-6
f41:n 3
c41   -1.0 499I 0.90 249I 0.99 100I 1.0
e41   1.0e-6
```

B. Sample NJOY Input Files

B.1. Temperature Independent NJOY Input

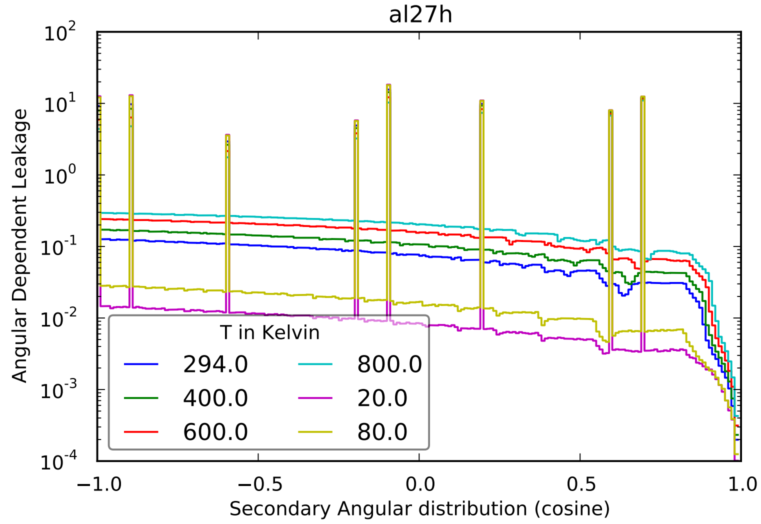
```
moder
20 -21
reconr
-21 -22
'pendf tape for ENDF/B-VII 1-H-1'/
125 14 0/
.001/
'1-H-1 from ENDF/B-VII'/
'processed with njoy at 0.1%'/
'the following reaction types are added'/
'     mt20x   gas production'/
'     mt221   free thermal scattering'/
'     mt222   h in h2o thermal scattering'/
'     mt223   h in poly inelastic thermal scattering'/
'     mt224   h in poly elastic thermal scattering'/
'     mt225   h in zrh inelastic thermal scattering'/
'     mt226   h in zrh elastic thermal scattering'/
'     mt227   h in benzine thermal scattering'/
'     mt301   total heating kerma factor'/
'     mt443   kinematic kerma'/
'     mt444   total damage energy production'/
0/
broadr
-21 -22 -23
125 9/
.001/
293.6  350  400  450  500  550  600  650  800 /
0/
heatr
-21 -23 -24/
125 4/
302 402 443 444 /
thermr
30 -24 -25
1 125 20 9 4 0 2 222 1/
293.6  350  400  450  500  550  600  650  800
.001 10./
gaspr
-21 -25 -27
moder
-27 28
stop
```

B.2. Temperature Dependent Input for ACER Module

```
acer
30 28 0 31 32
2 0 1 .28/
'H in h2o at 800K from ENDF/B-VII'/
125 800 'lwtr'/
1001/
222 80 0 0 1 10.1 2/
acer
0 31 35 33 34/
7 1/
'H in h2o at 800K from ENDF/B-VII'/
stop
```

C. Secondary Distributions Plots

C.1. Continuous



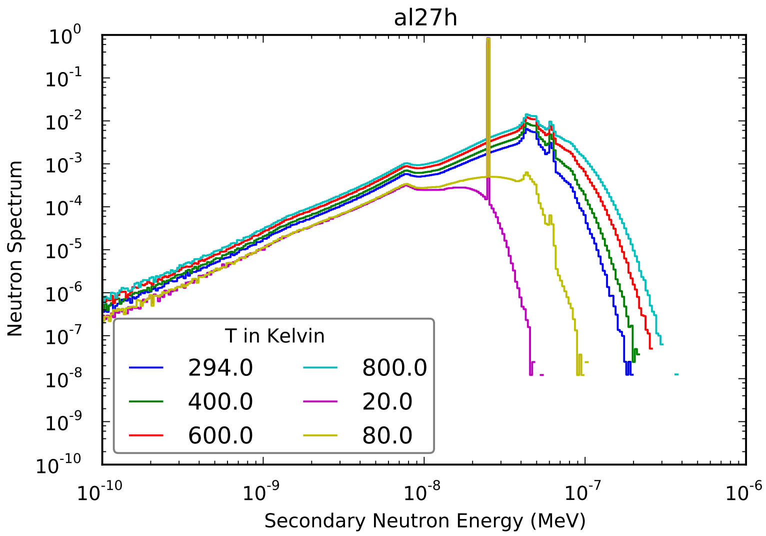


Figure 1: Continuous al27h

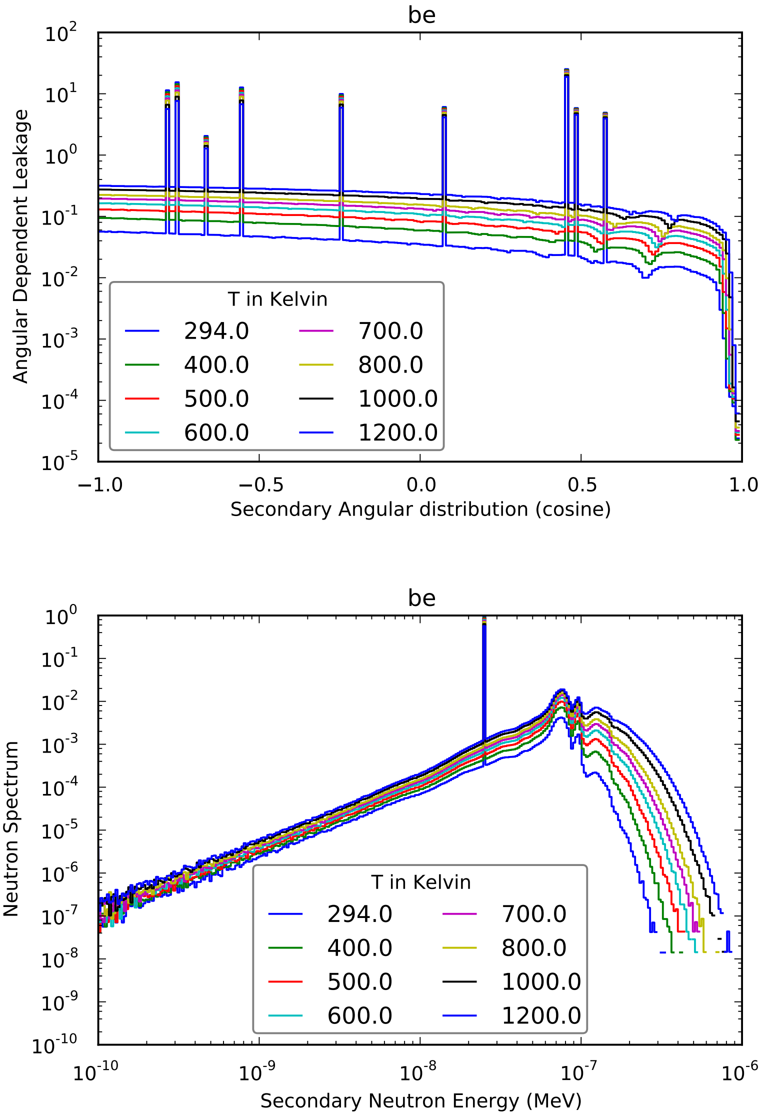


Figure 2: Continuous be

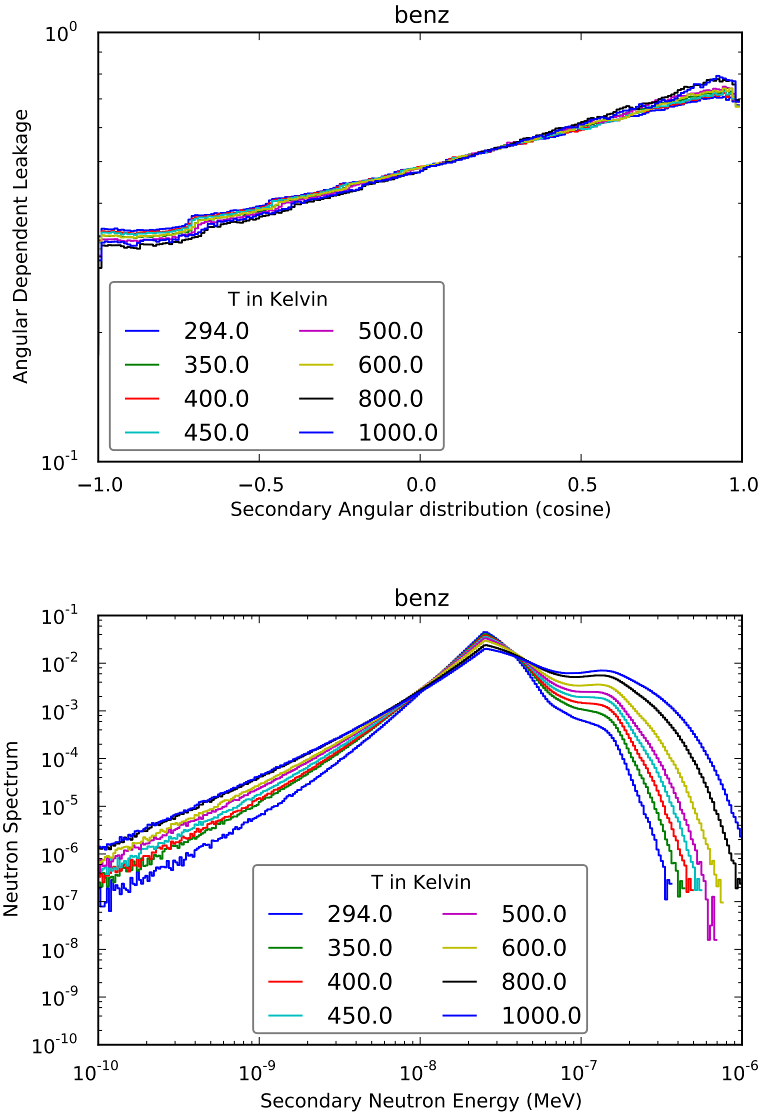


Figure 3: Continuous benz

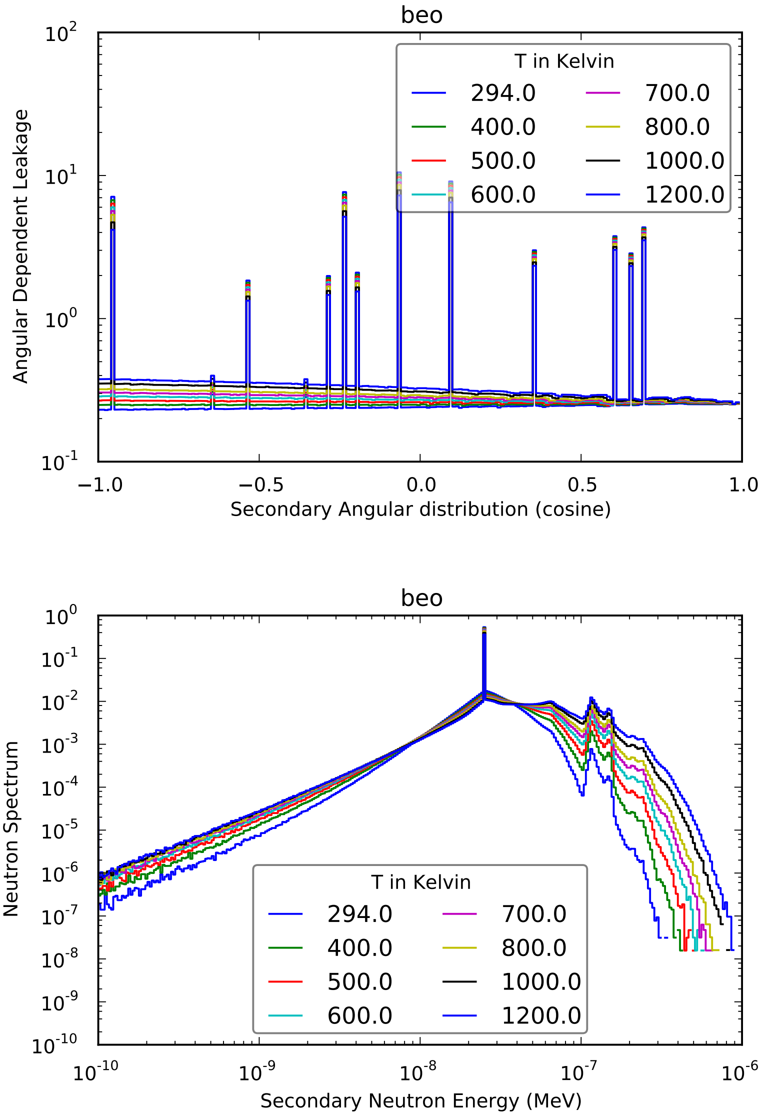


Figure 4: Continuous beo

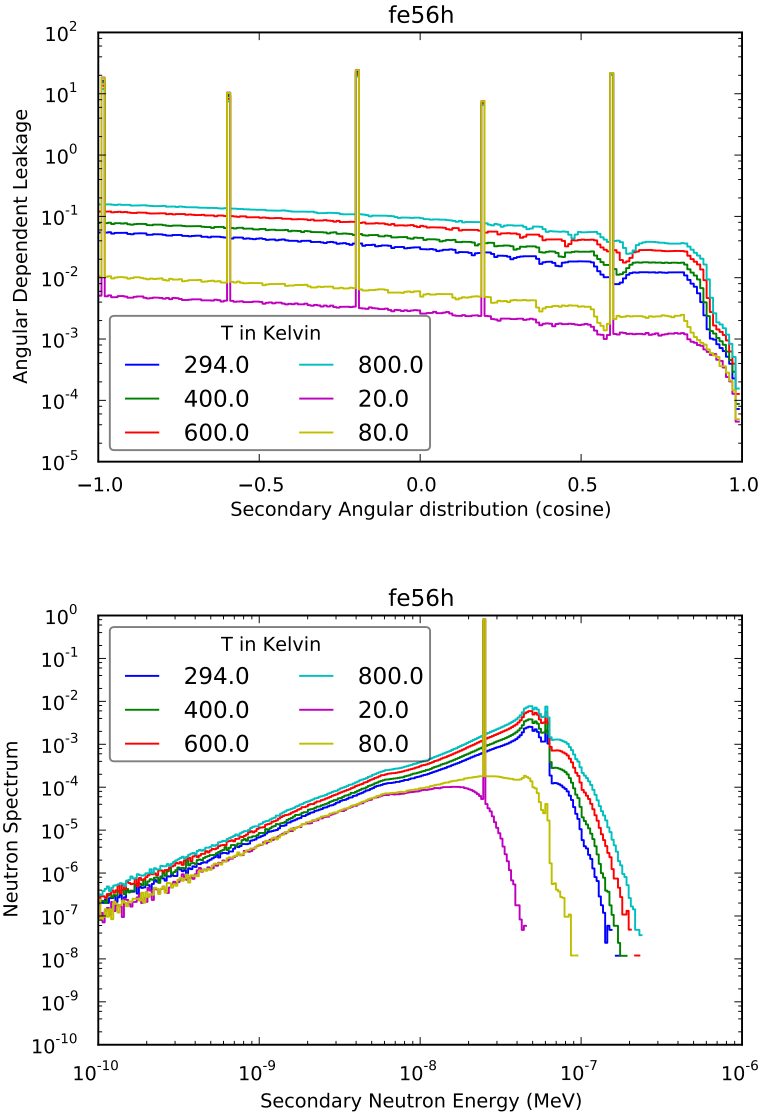


Figure 5: Continuous fe56h

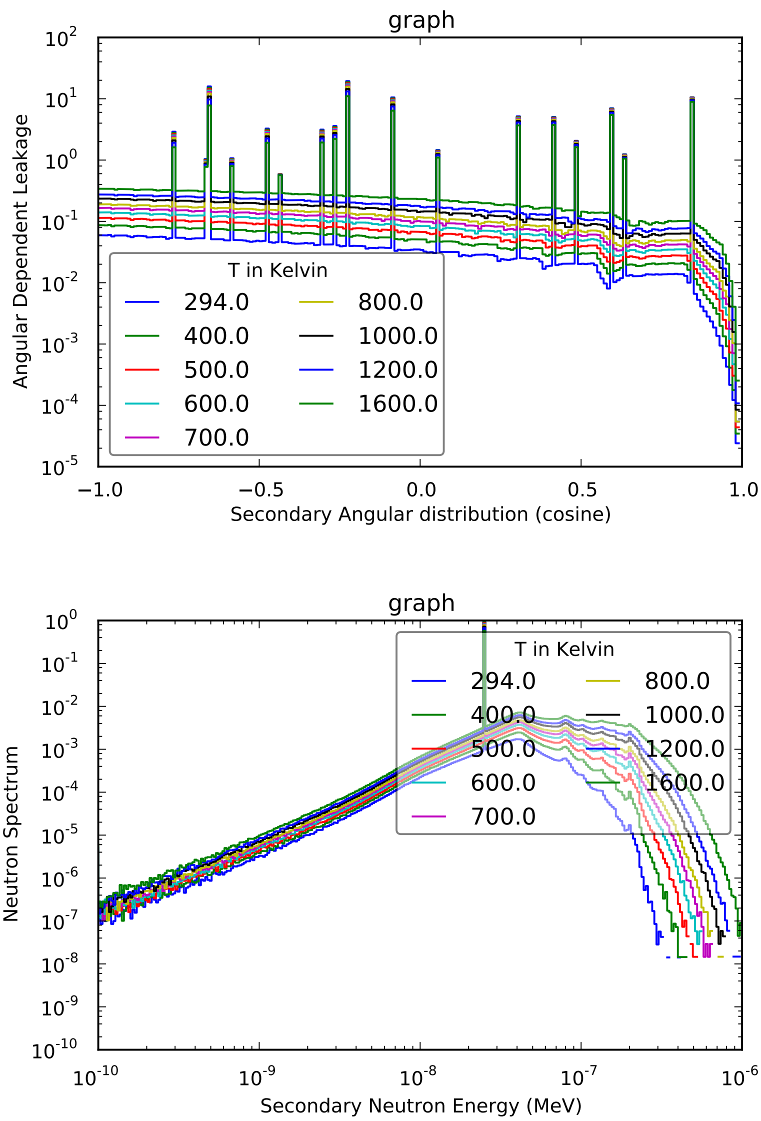


Figure 6: Continuous graph

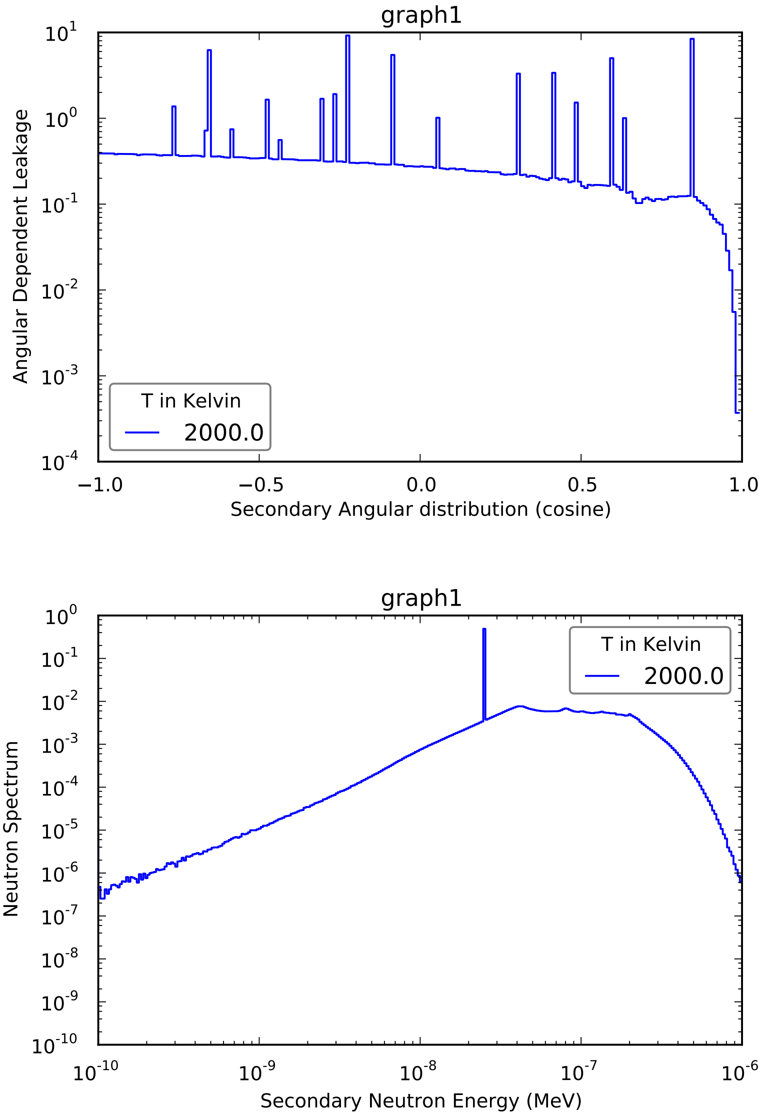


Figure 7: Continuous graph1

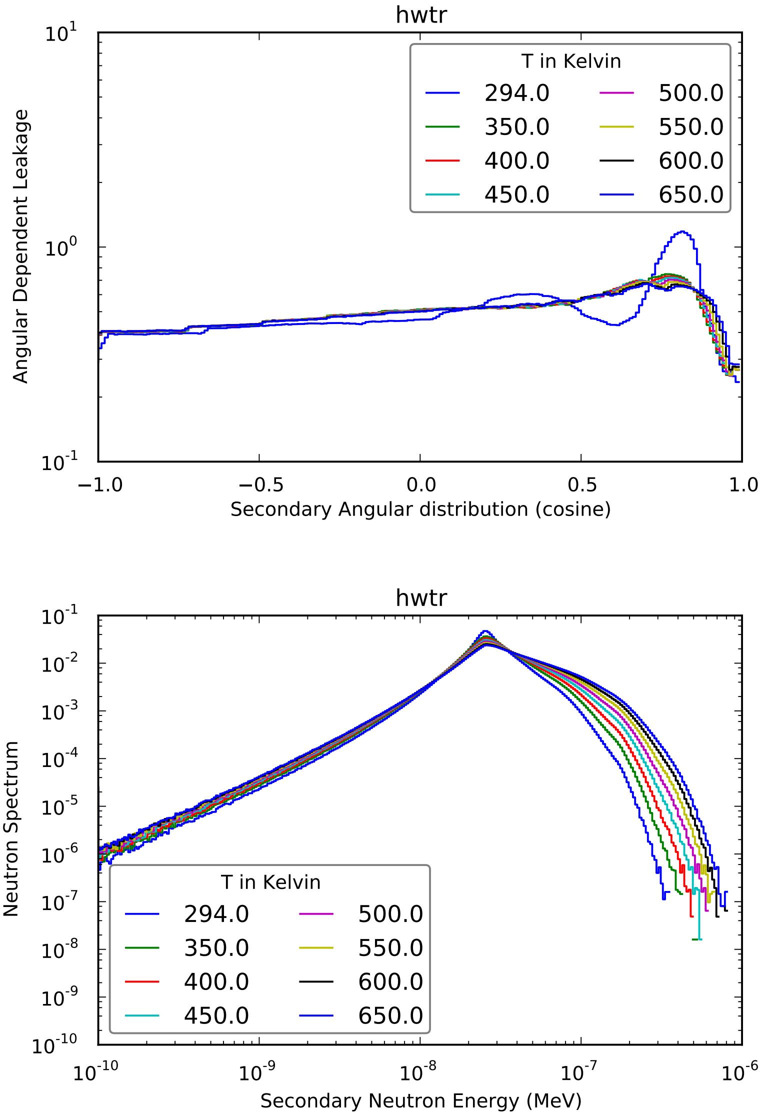


Figure 8: Continuous hwtr

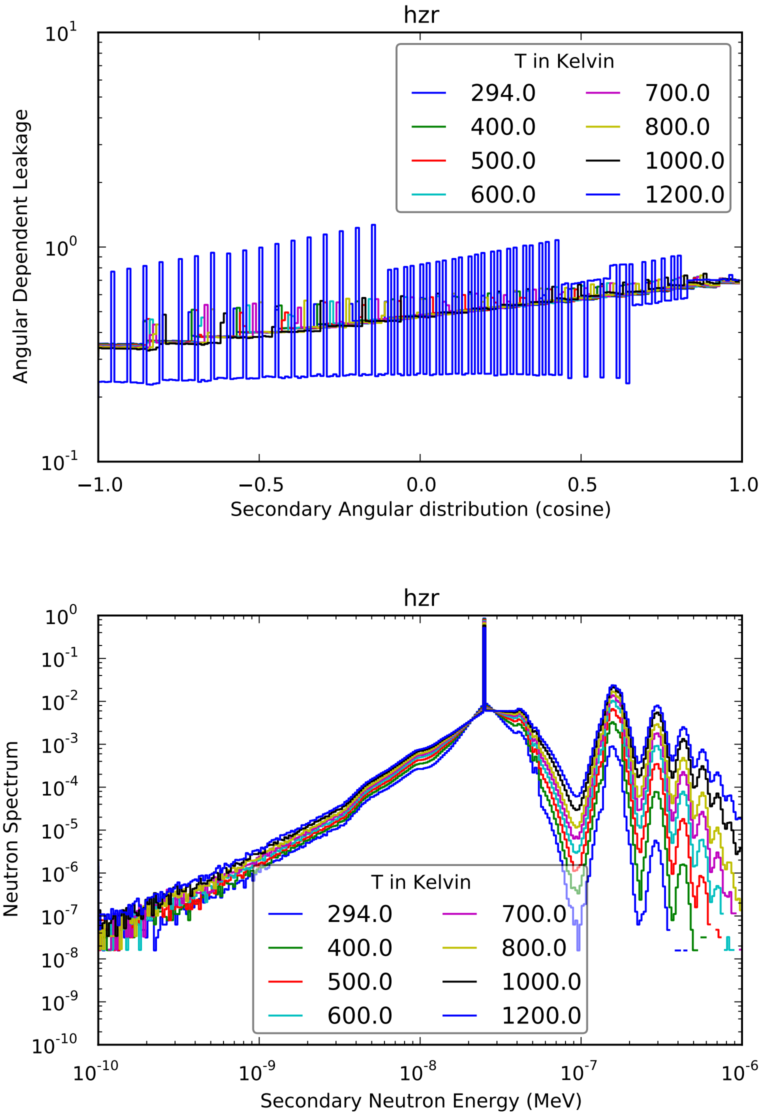


Figure 9: Continuous hzr

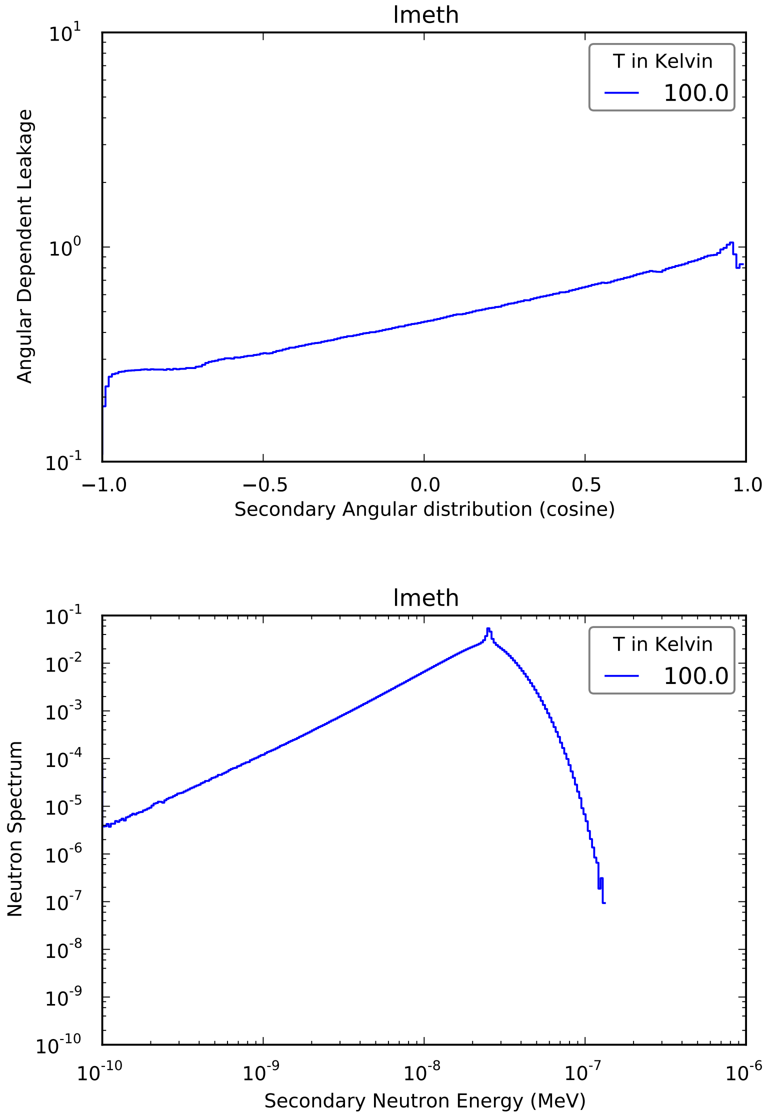


Figure 10: Continuous lmeth

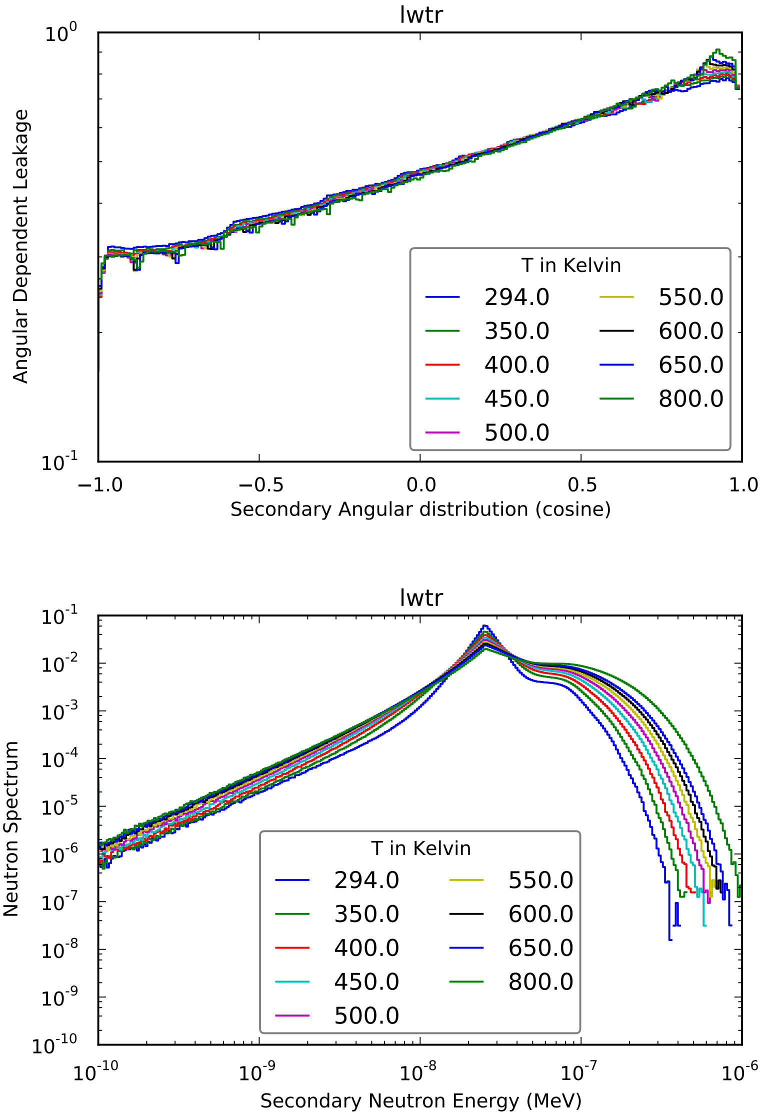


Figure 11: Continuous lwtr

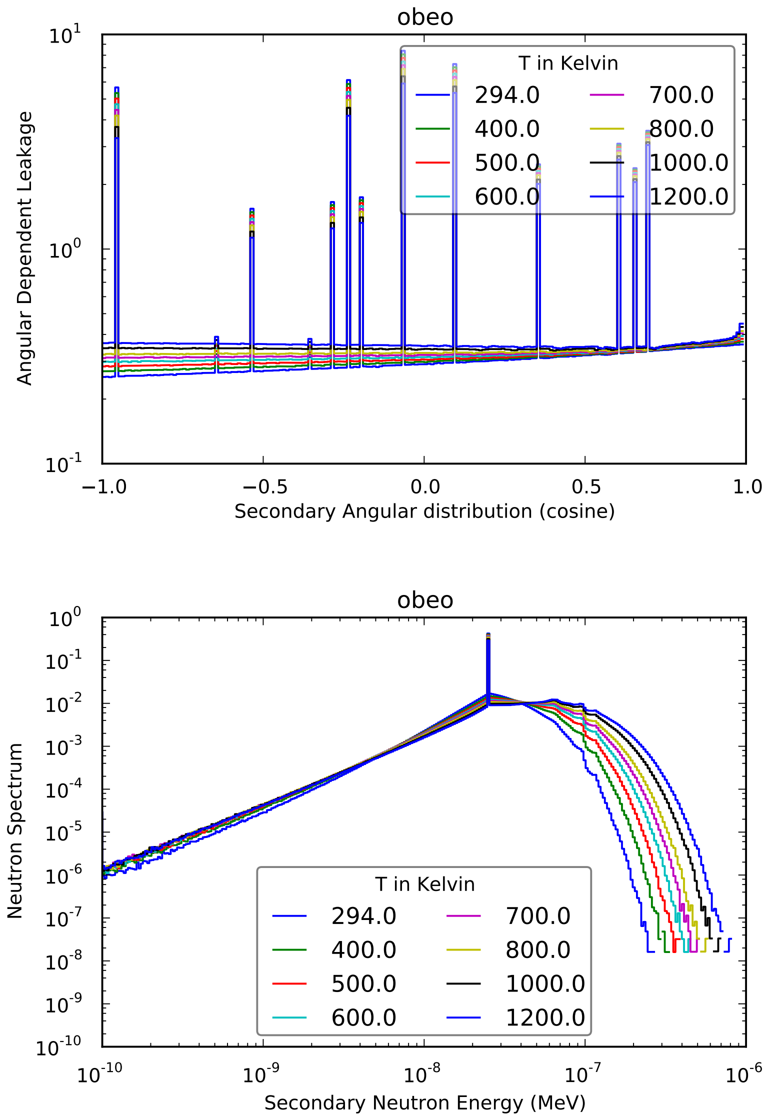
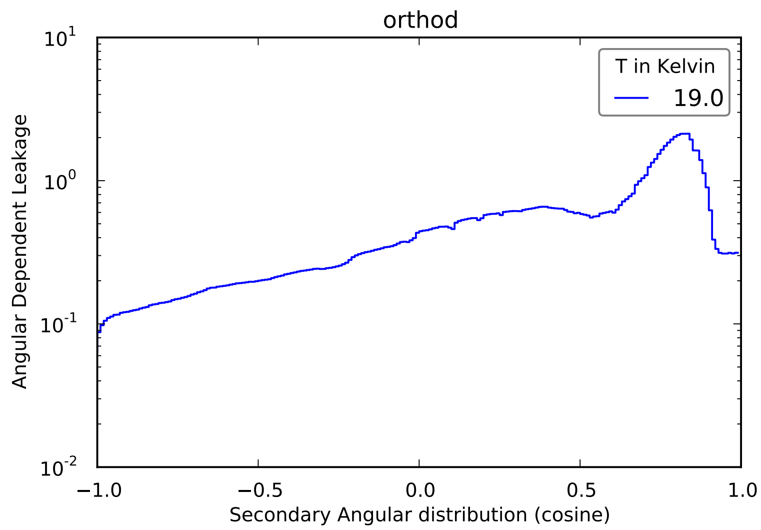


Figure 12: Continuous obeo



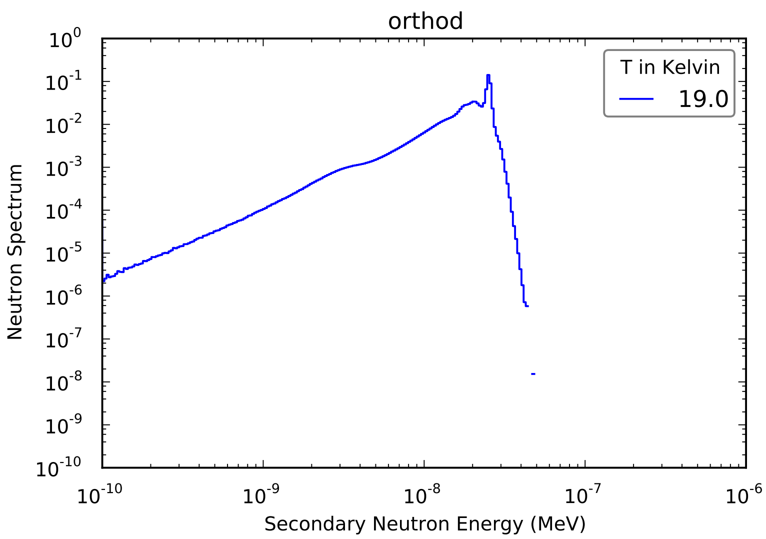


Figure 13: Continuous orthod

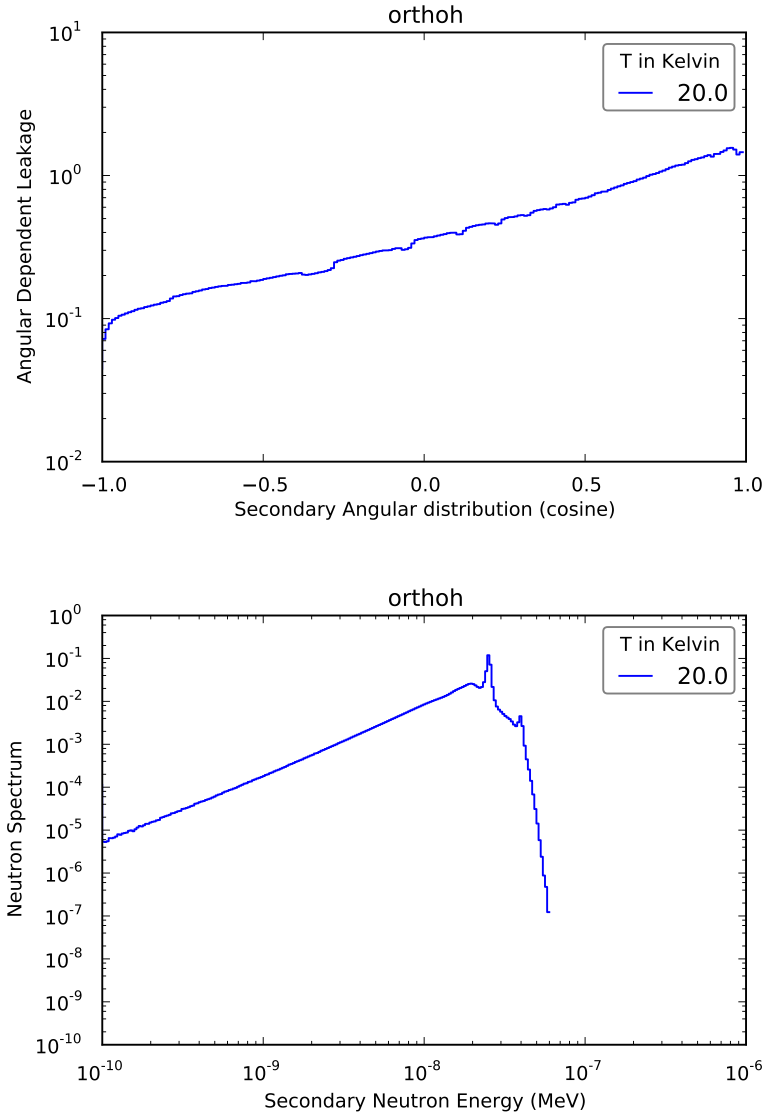


Figure 14: Continuous orthoh

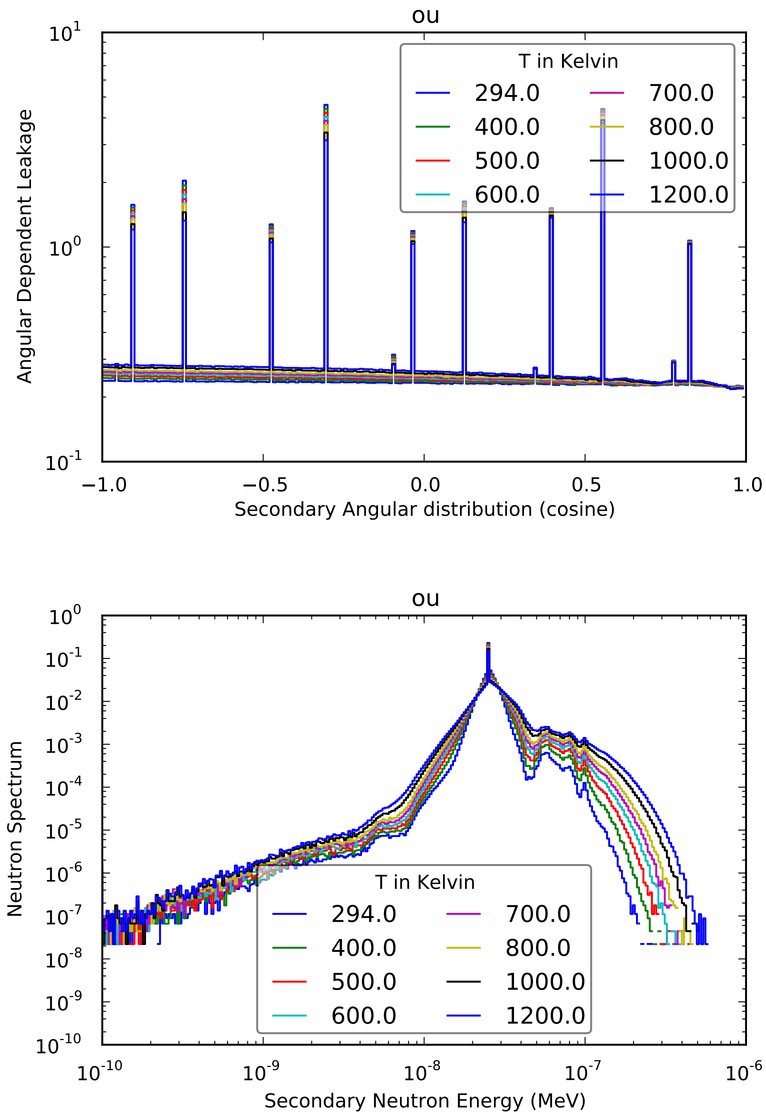
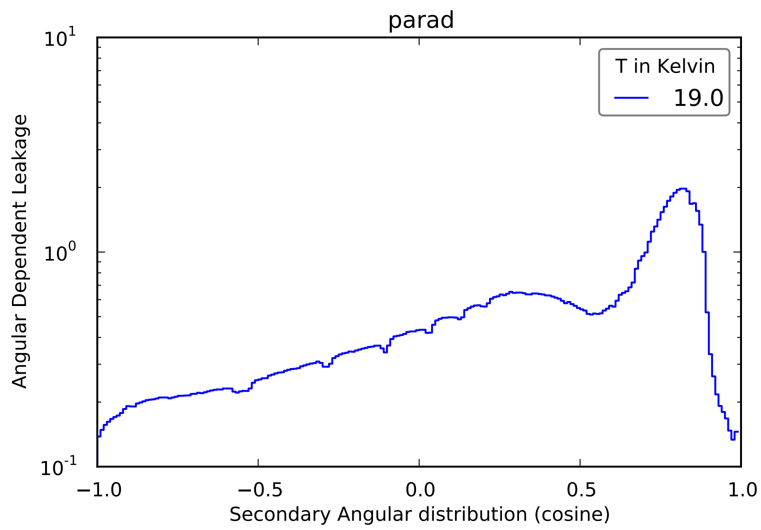


Figure 15: Continuous ou



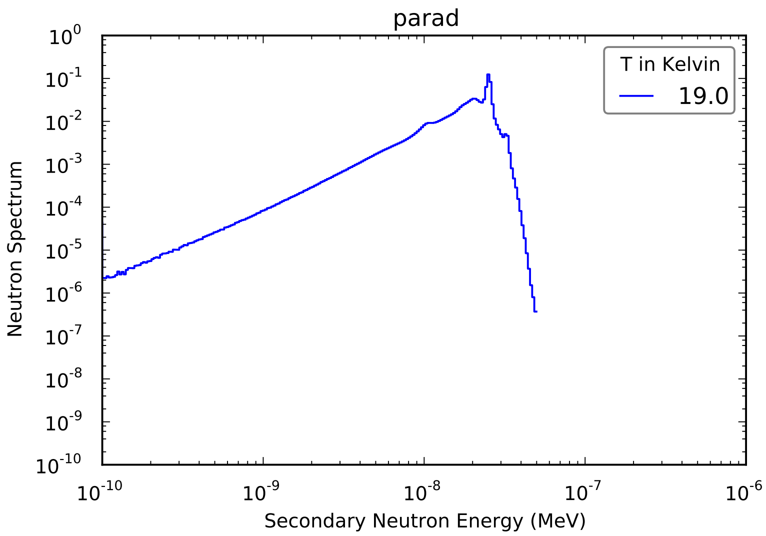
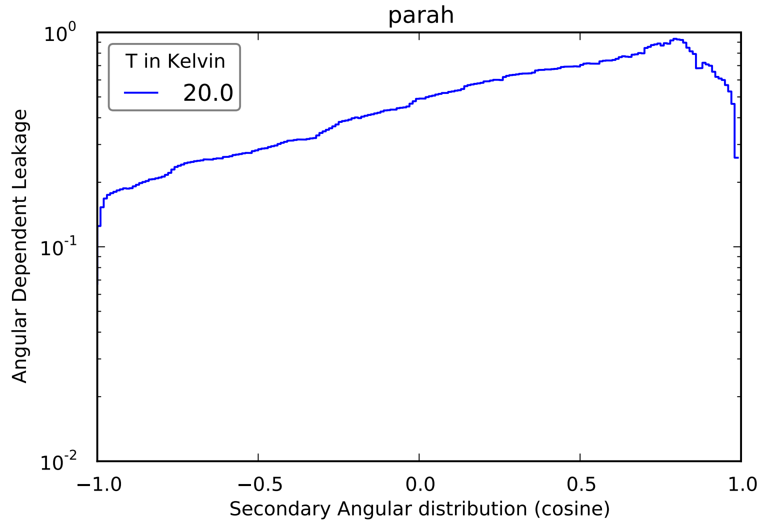


Figure 16: Continuous parad



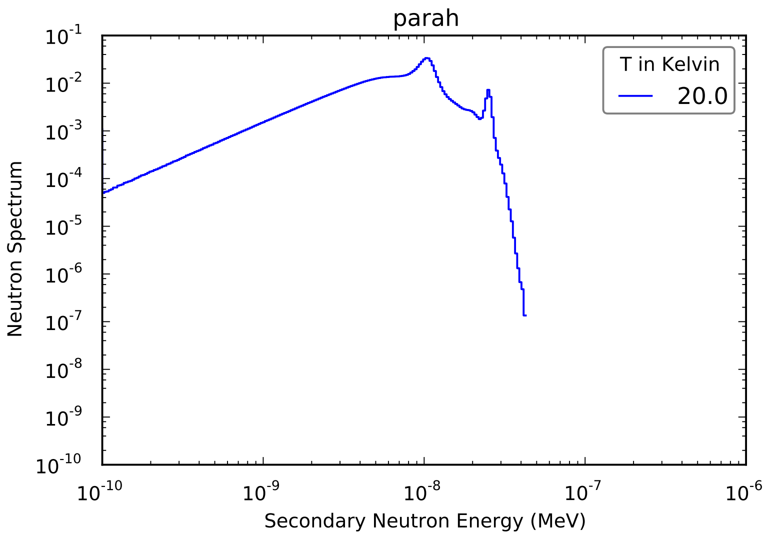
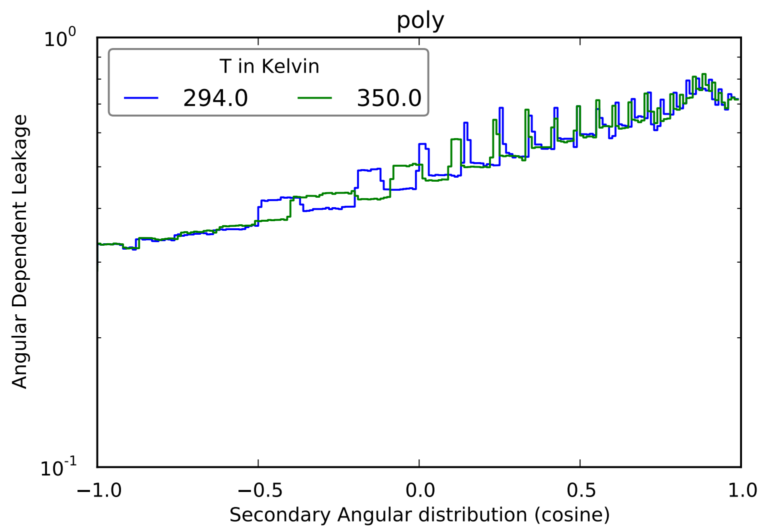


Figure 17: Continuous parah



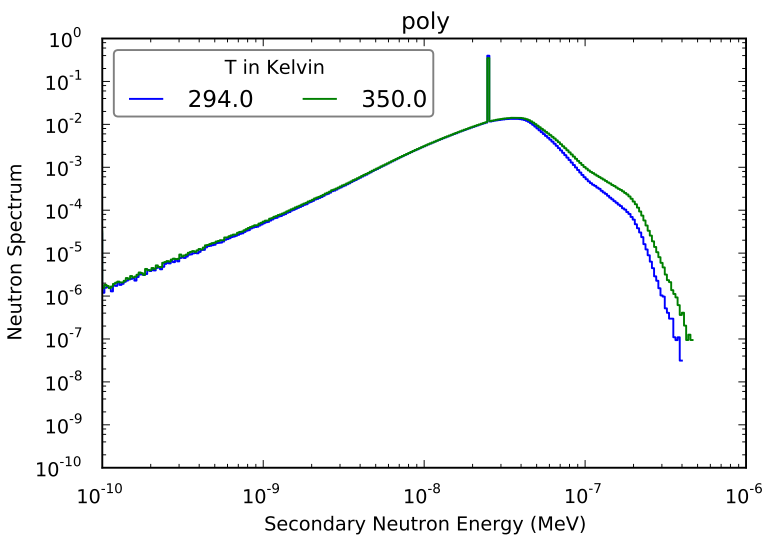


Figure 18: Continuous poly

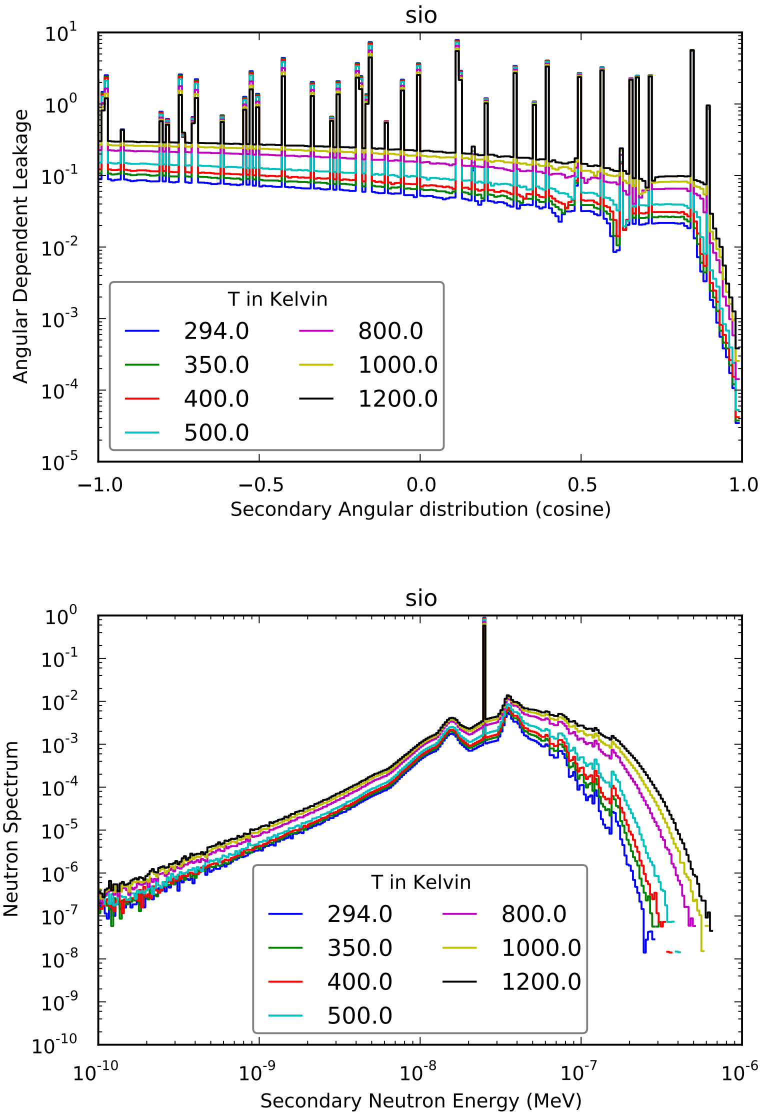


Figure 19: Continuous sio

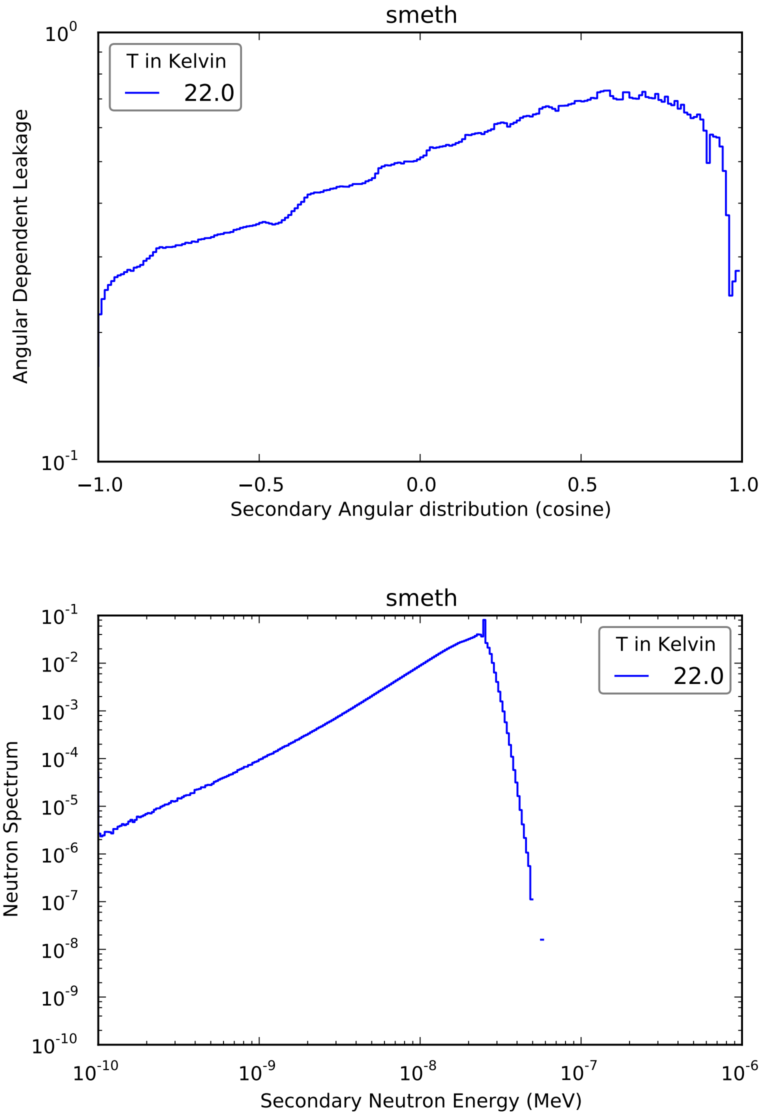


Figure 20: Continuous smeth

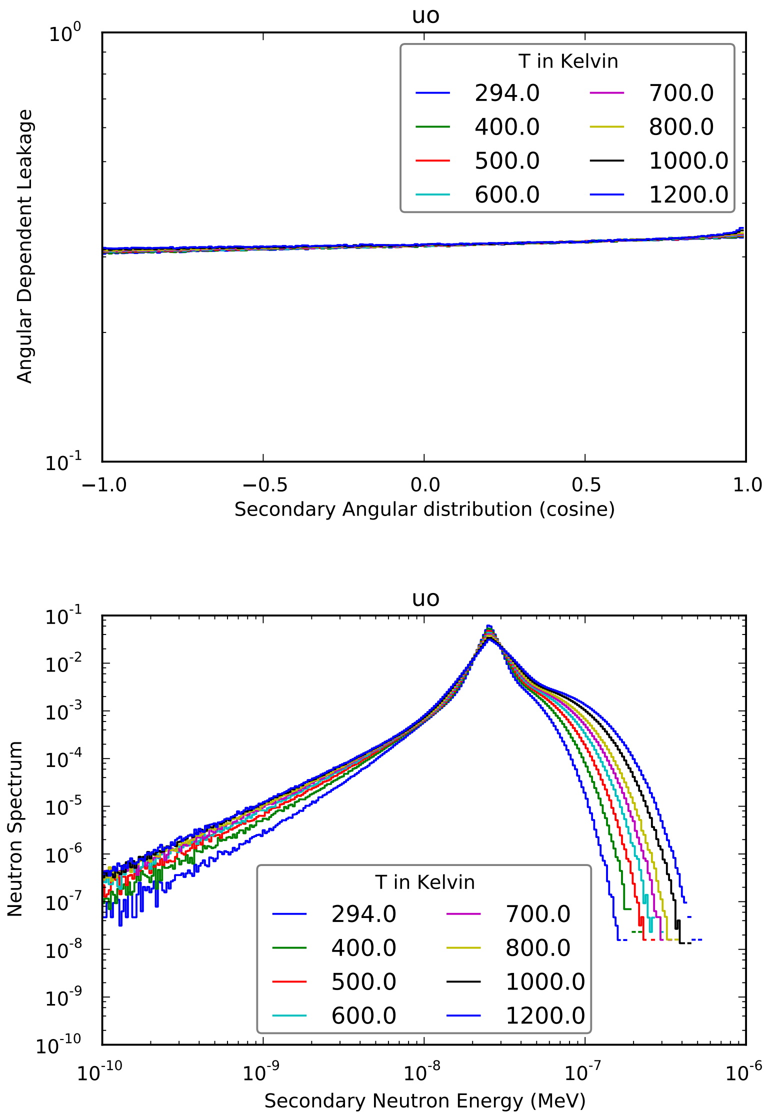


Figure 21: Continuous uo

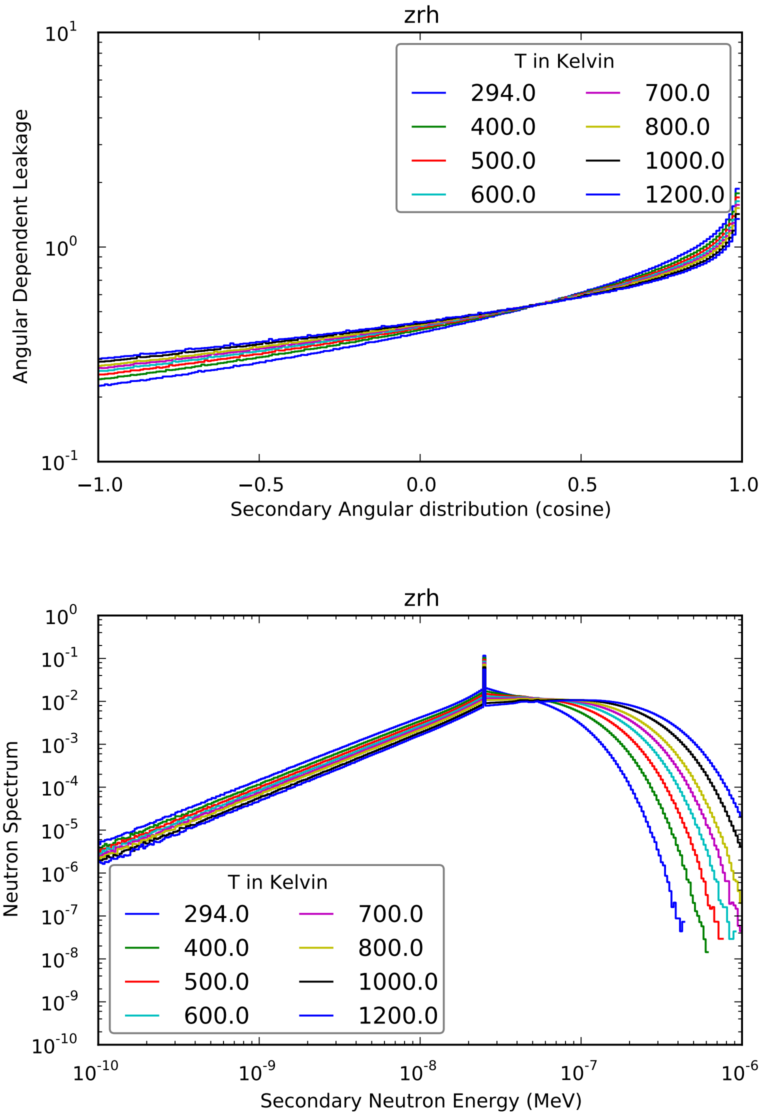


Figure 22: Continuous zrh

C.2. Discrete

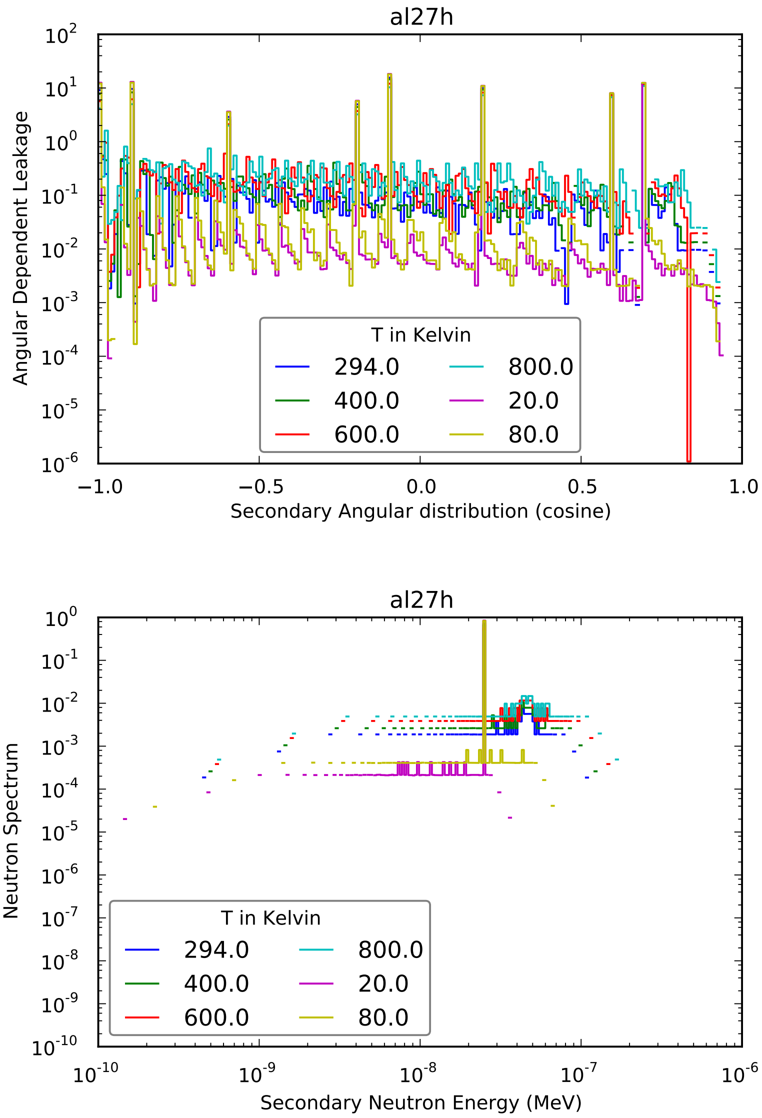


Figure 23: Discrete al27h

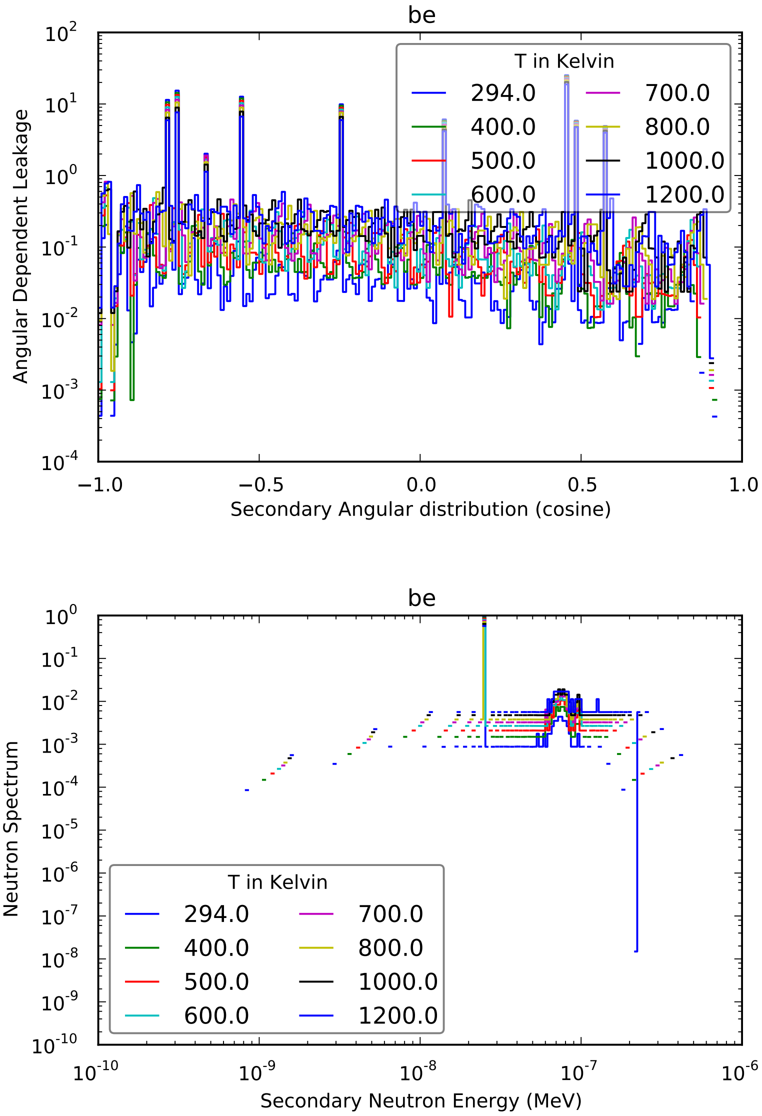


Figure 24: Discrete be

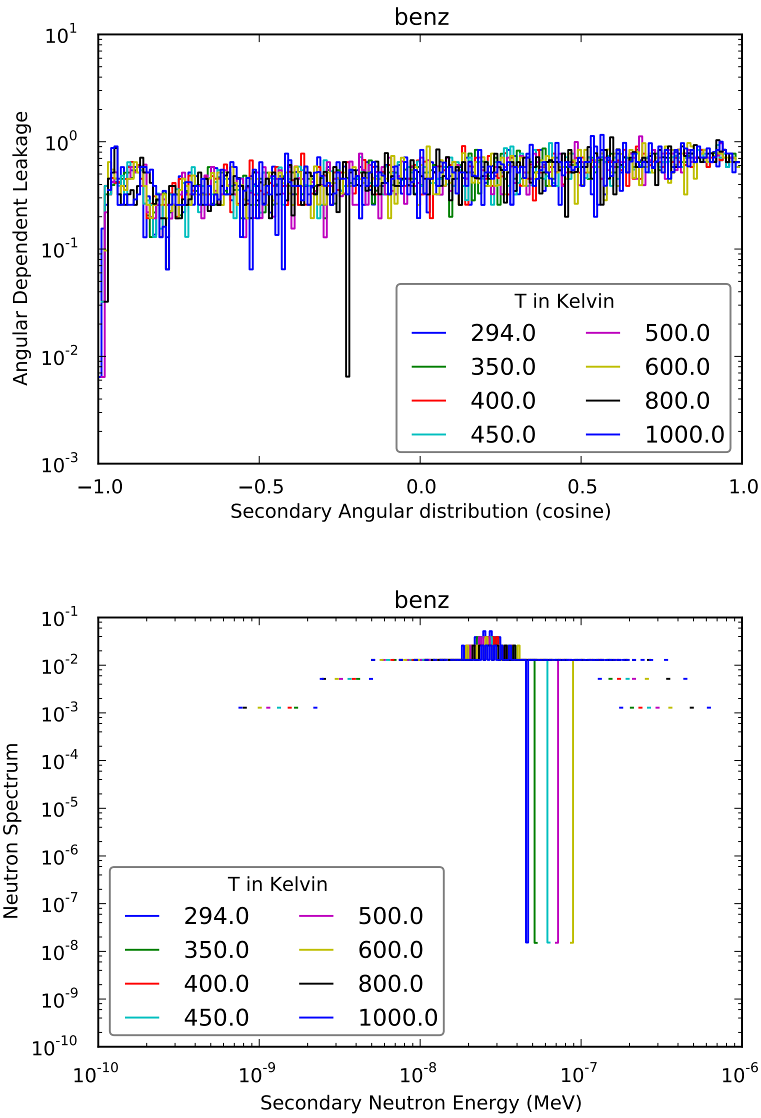


Figure 25: Discrete benz

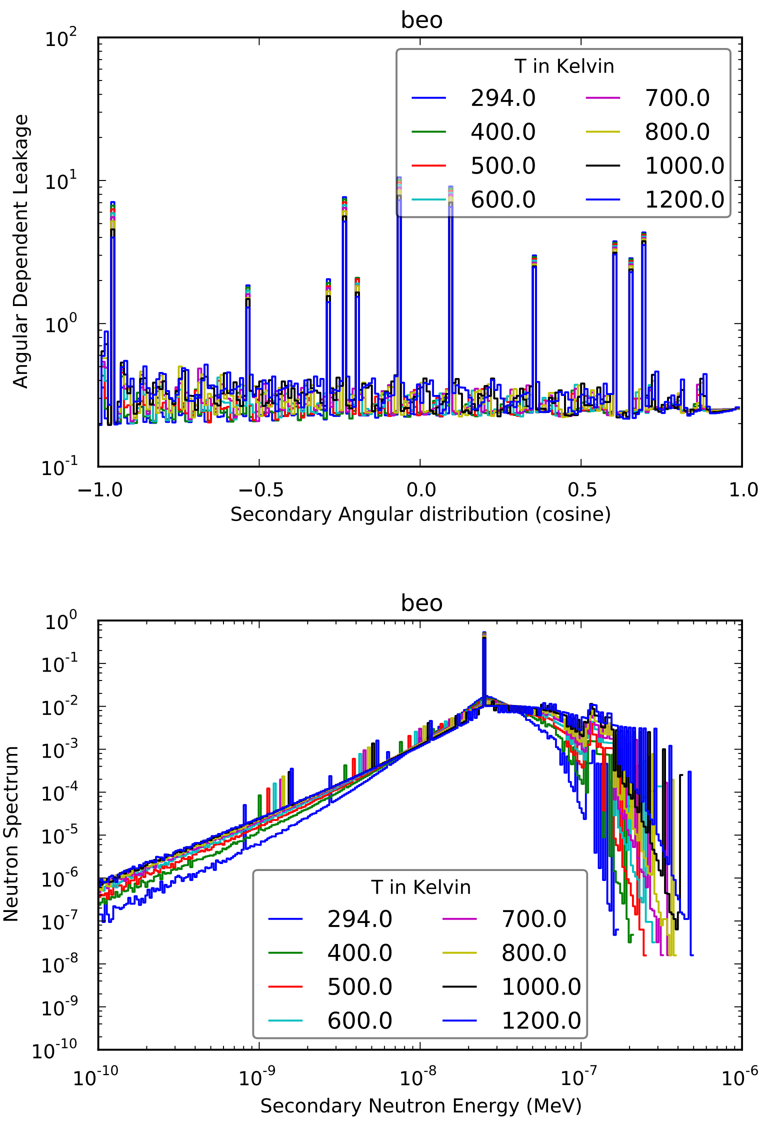


Figure 26: Discrete beo

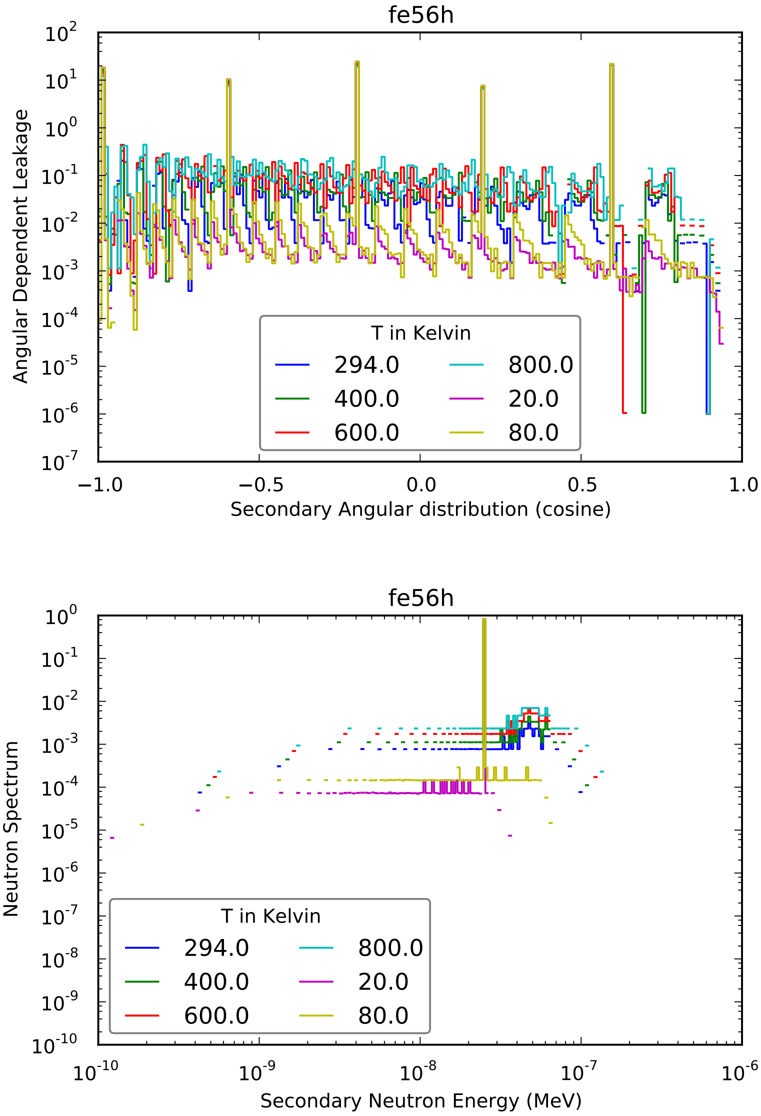


Figure 27: Discrete fe56h

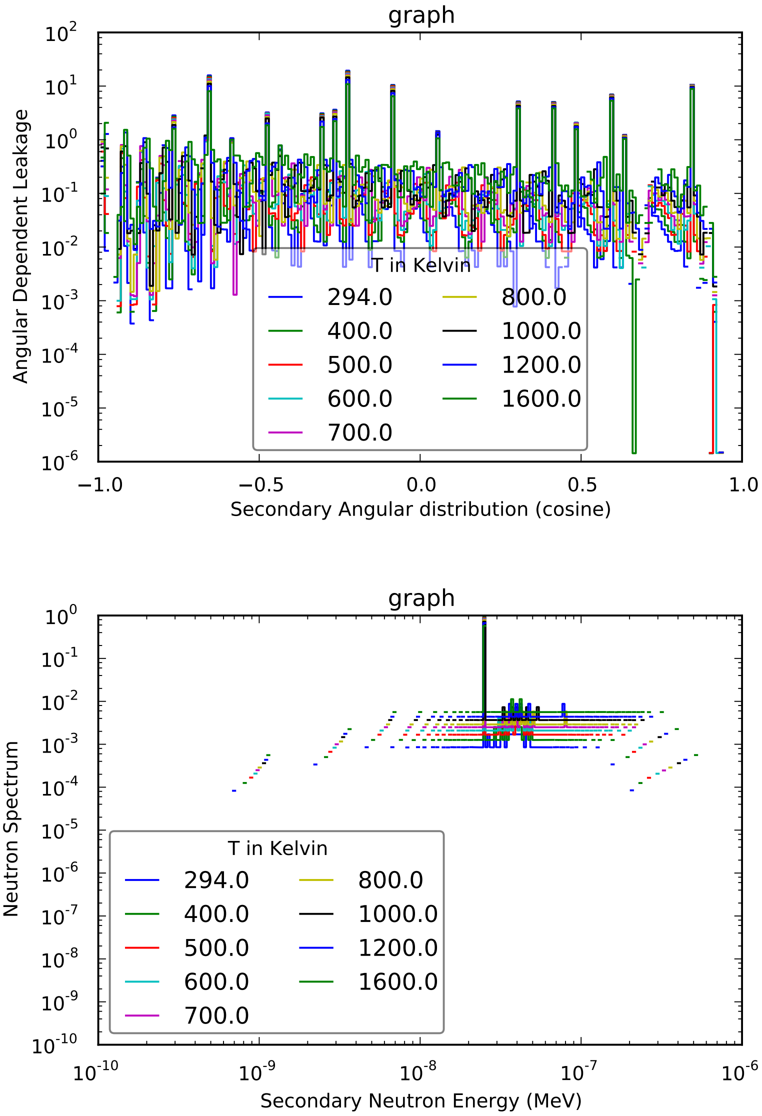


Figure 28: Discrete graph

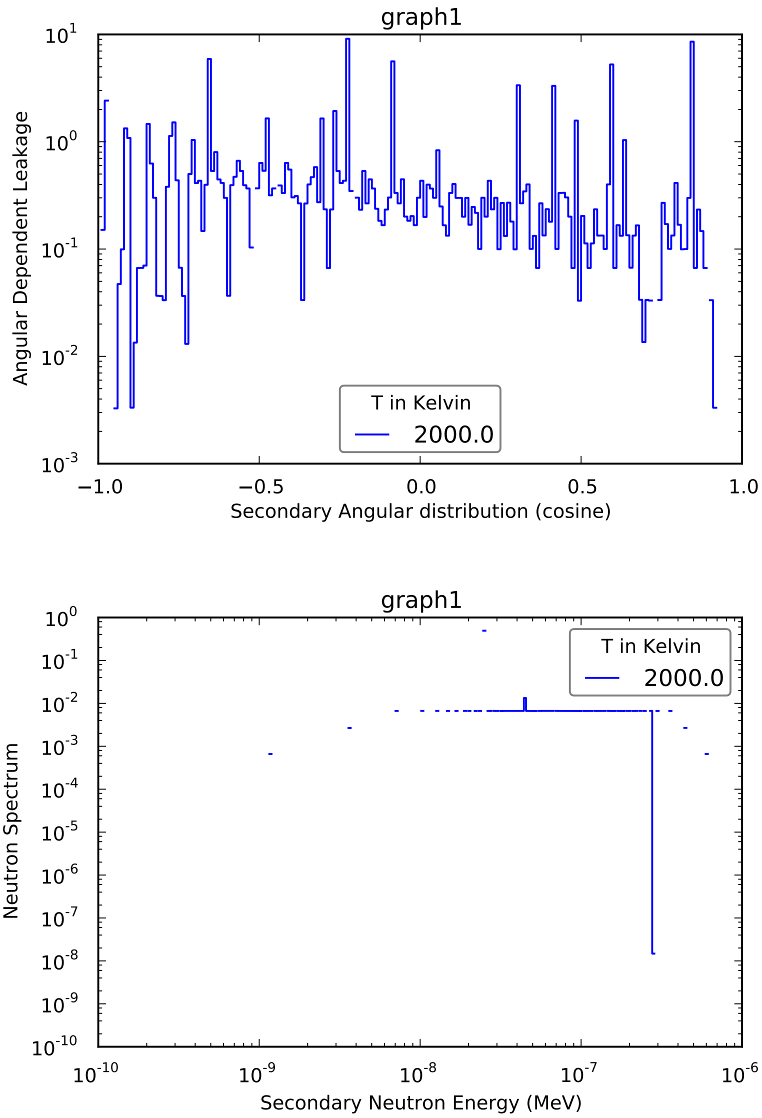


Figure 29: Discrete graph1

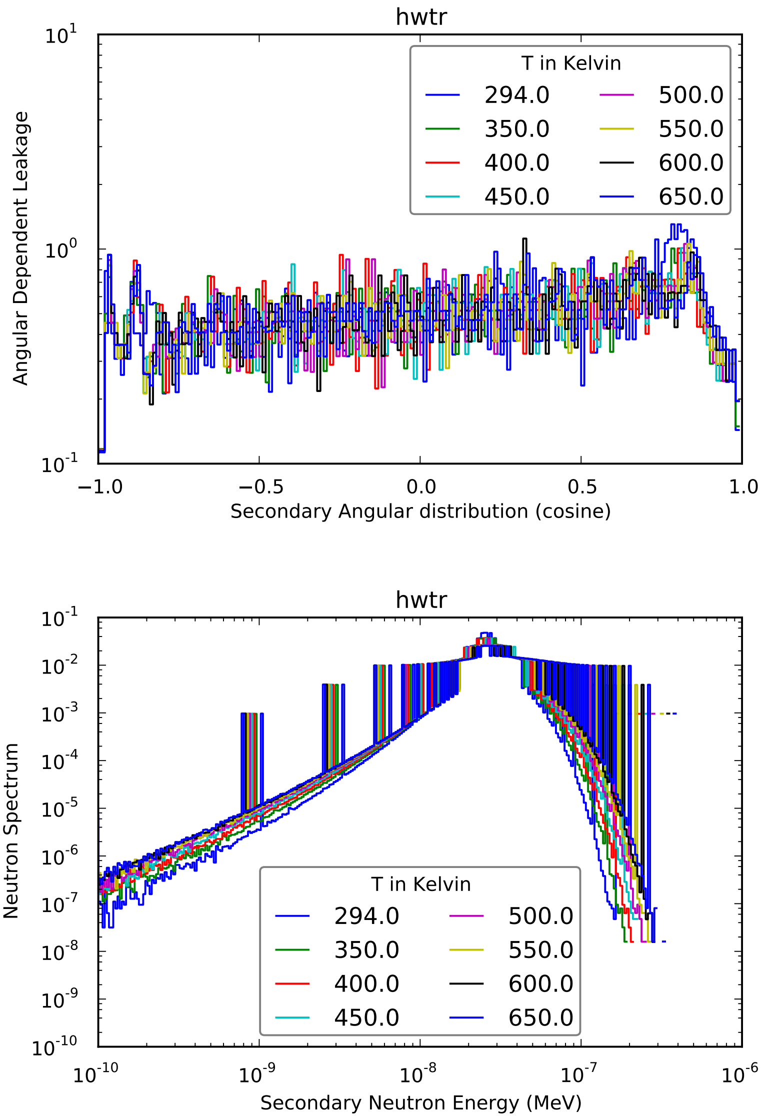
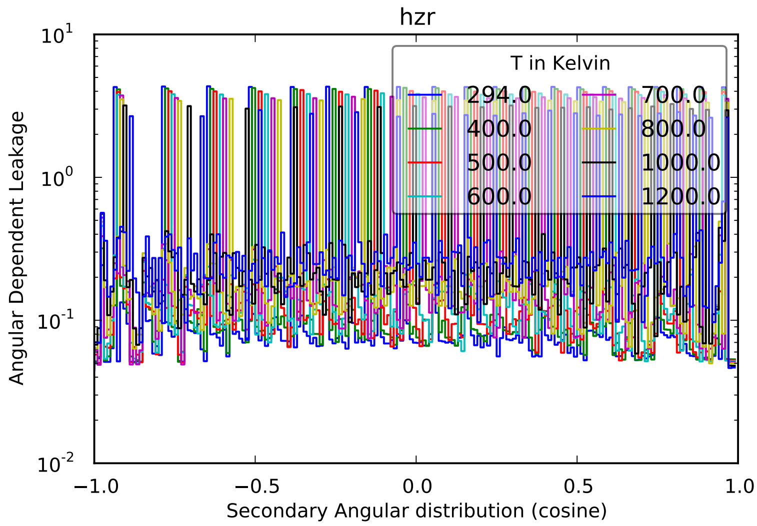


Figure 30: Discrete hwtr



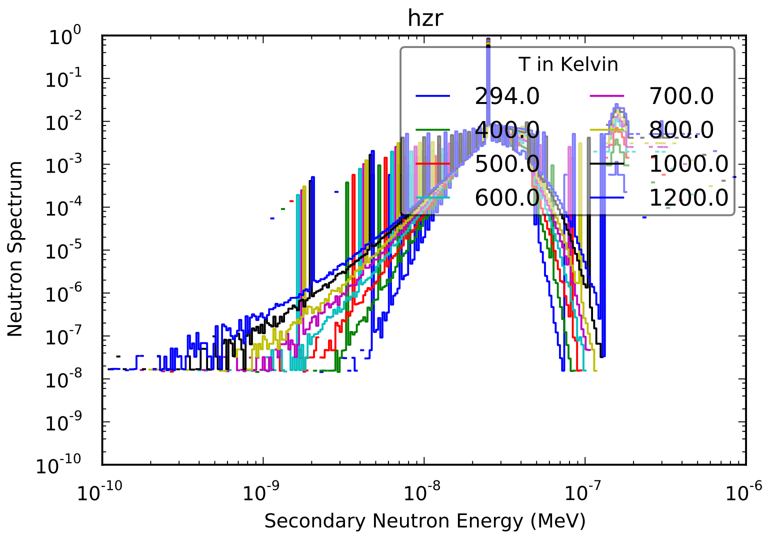
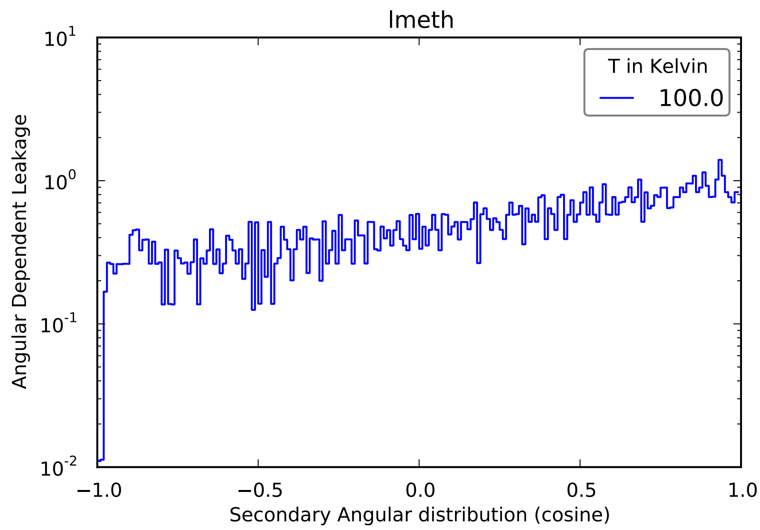


Figure 31: Discrete hzr



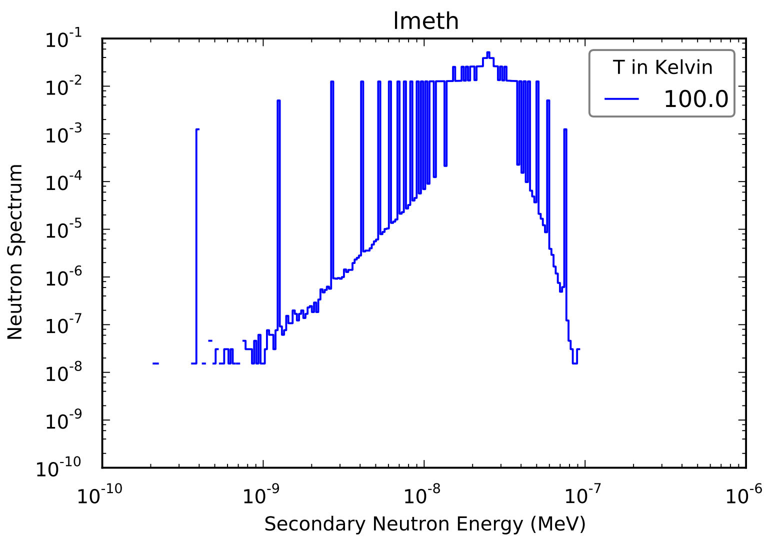


Figure 32: Discrete lmeth

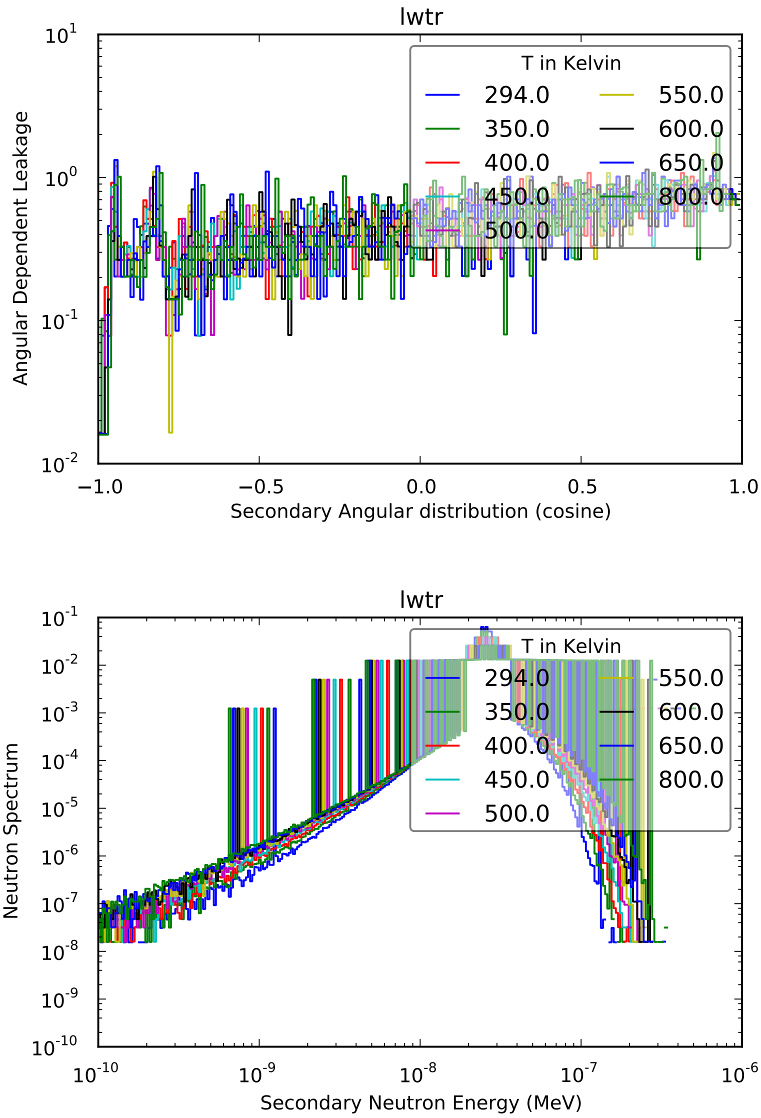


Figure 33: Discrete lwtr

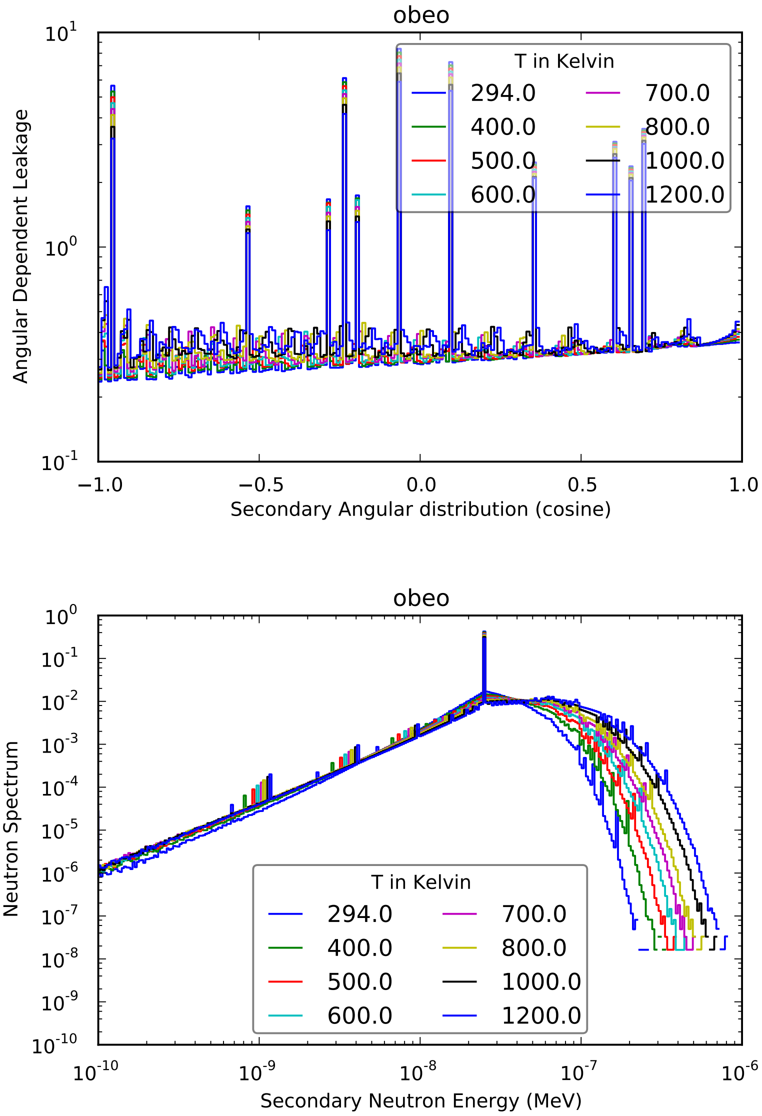


Figure 34: Discrete obeo

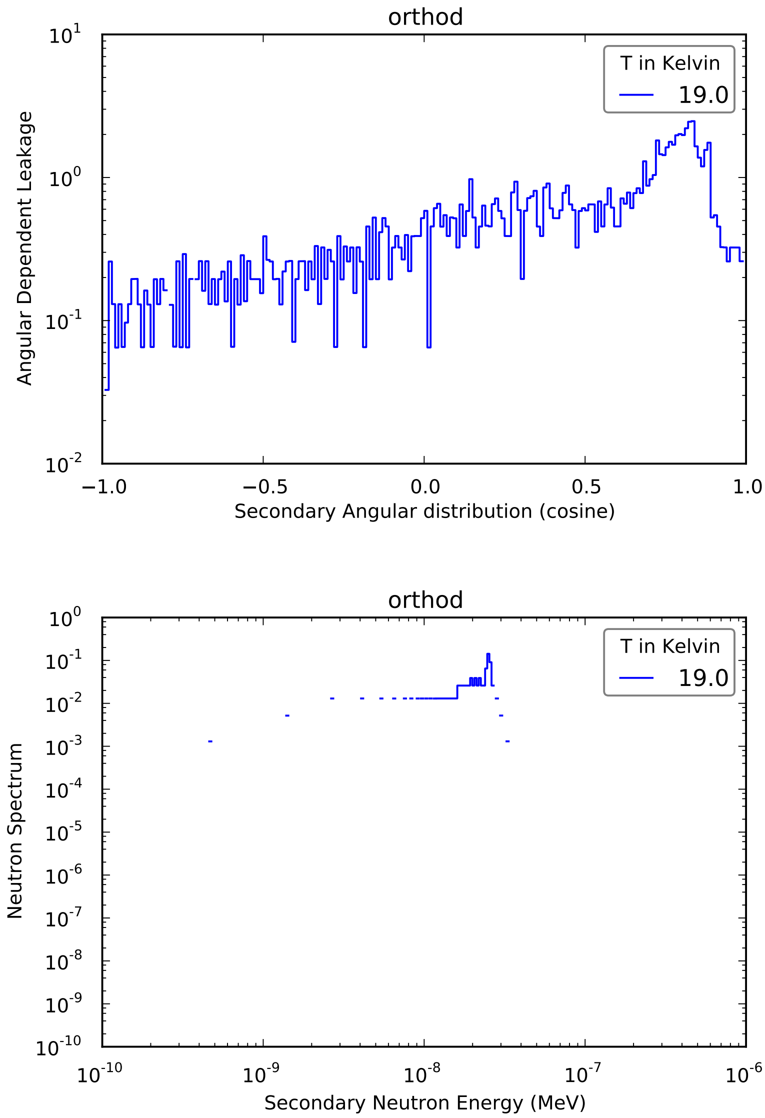
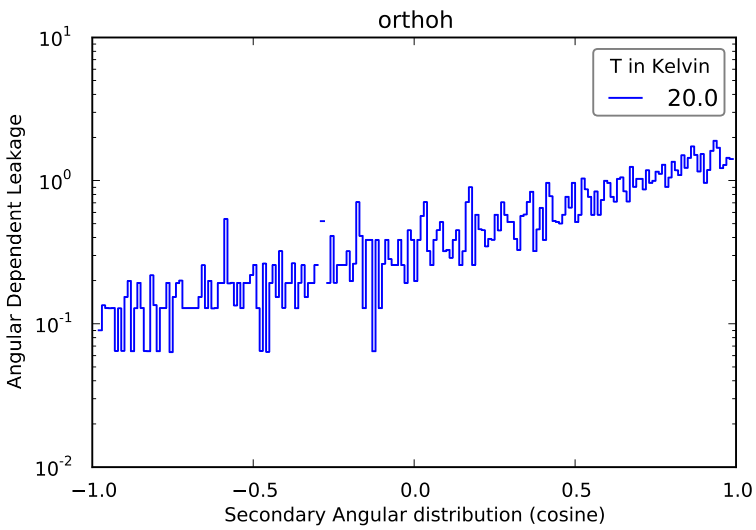


Figure 35: Discrete orthod



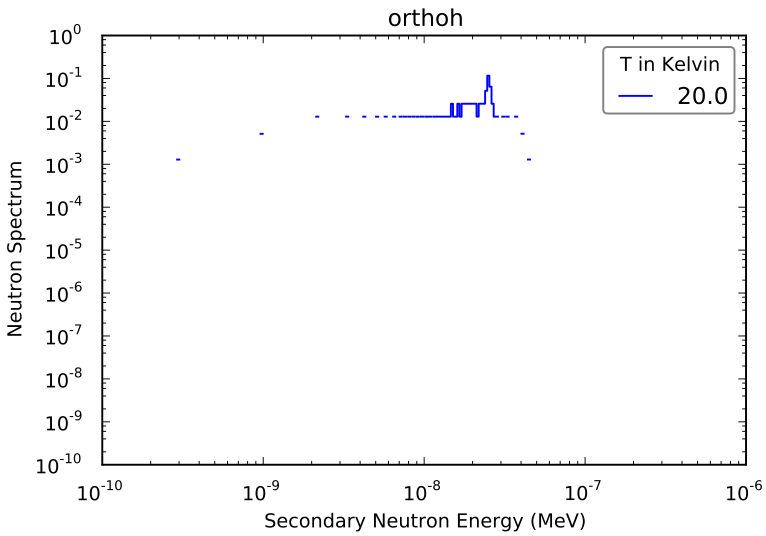
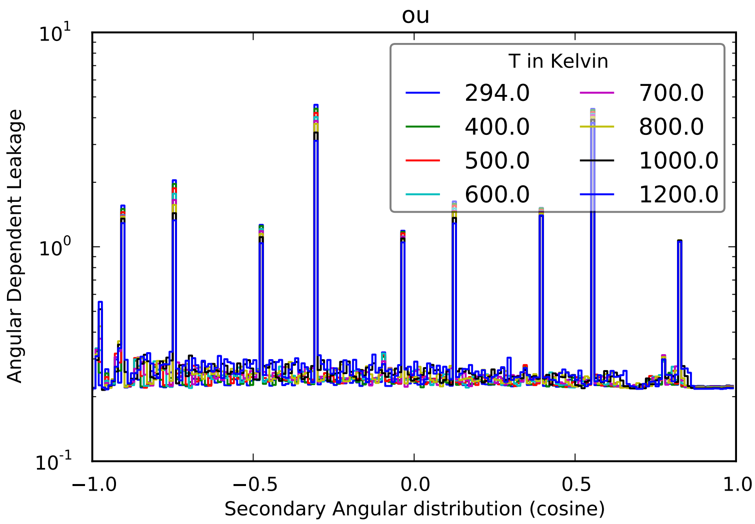


Figure 36: Discrete orthoh



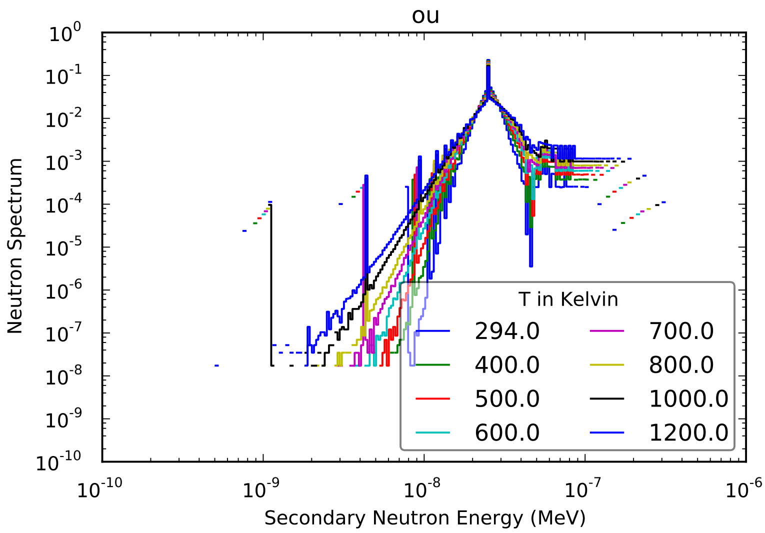


Figure 37: Discrete ou

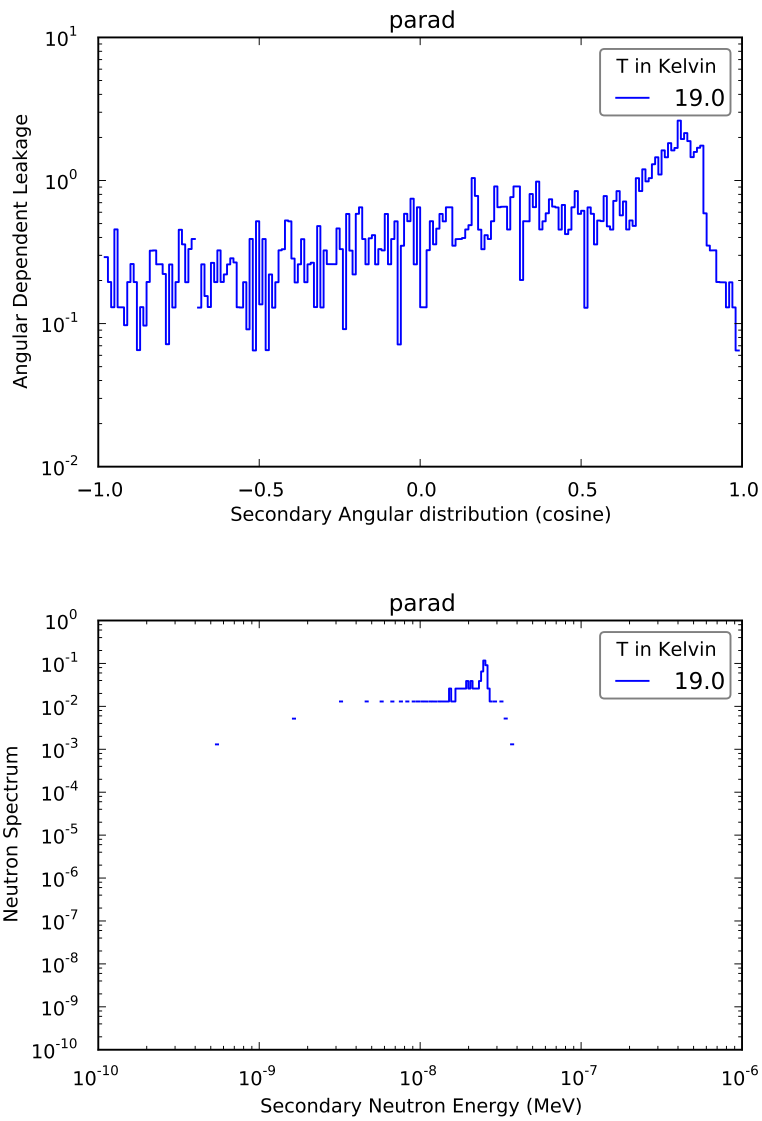
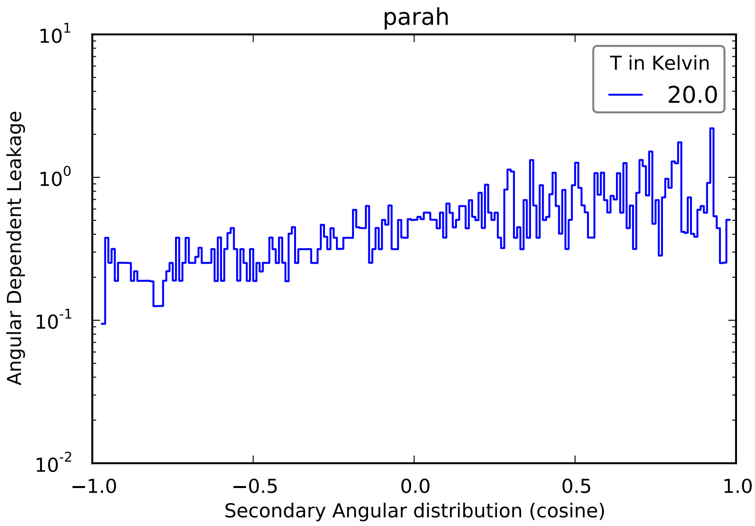


Figure 38: Discrete parad



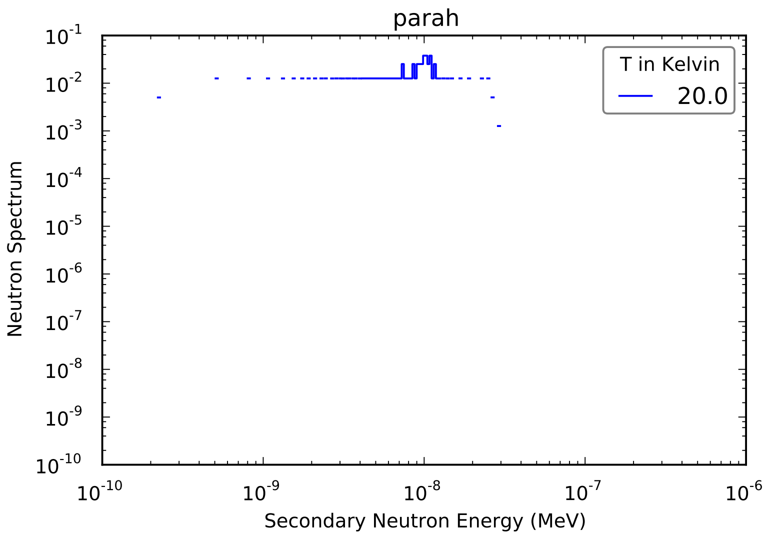


Figure 39: Discrete parah

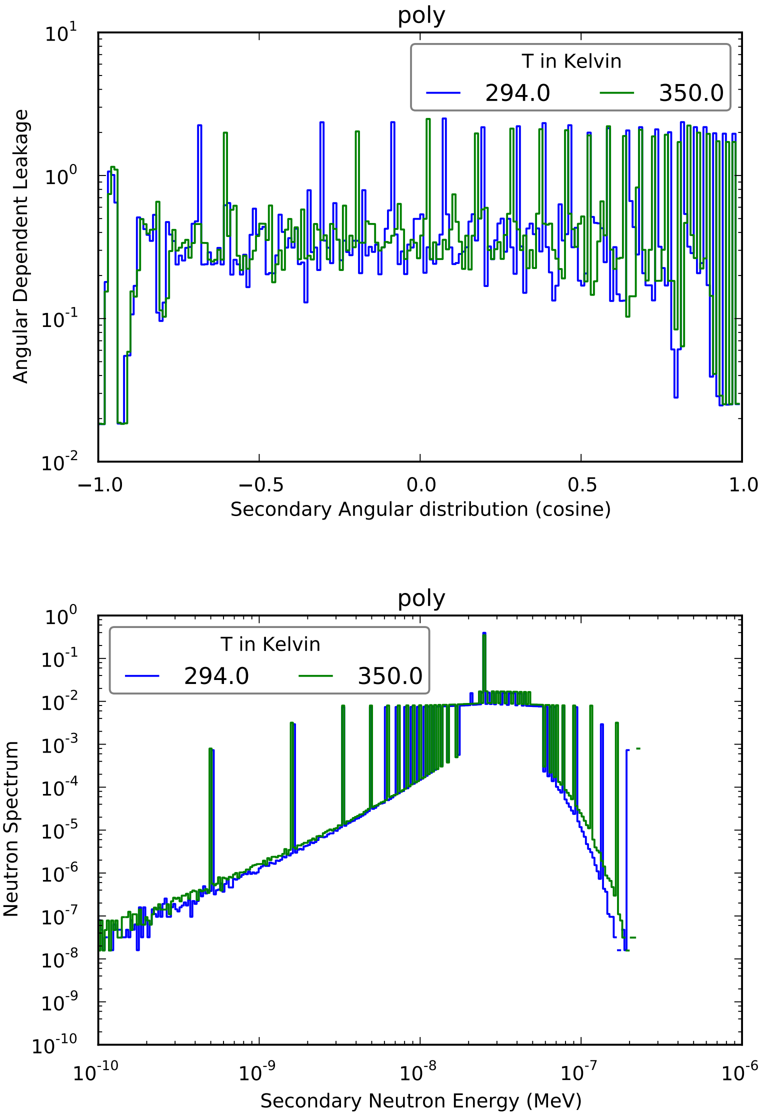


Figure 40: Discrete poly

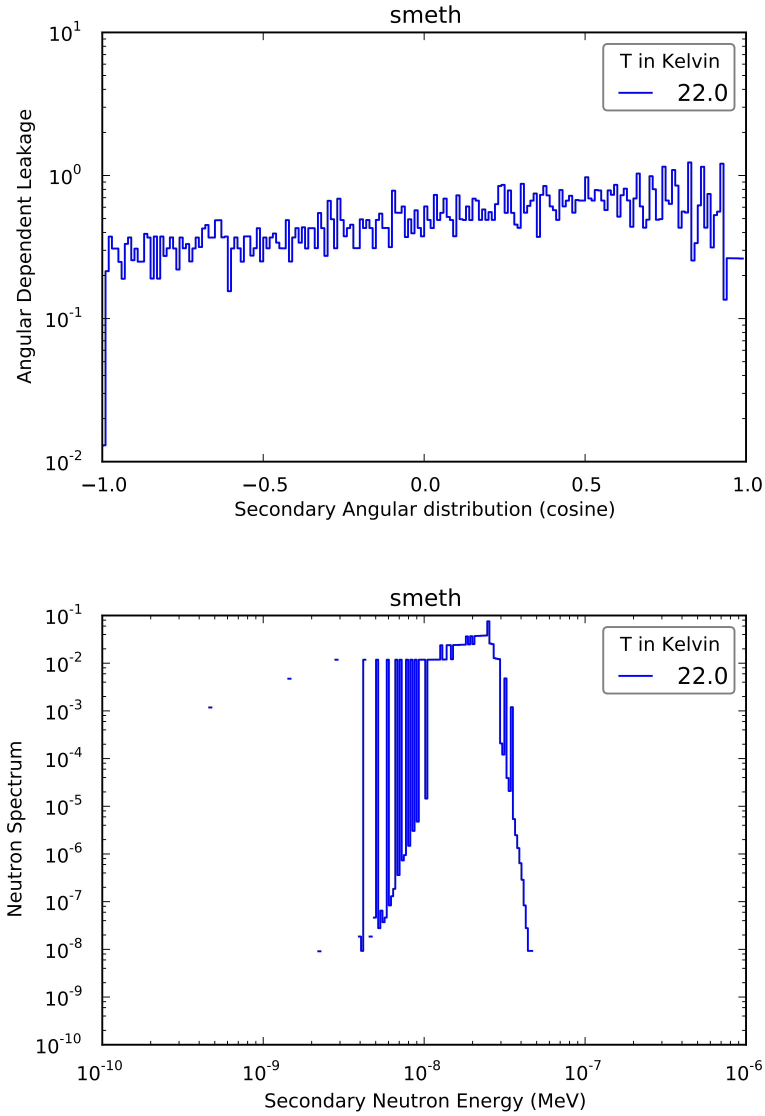
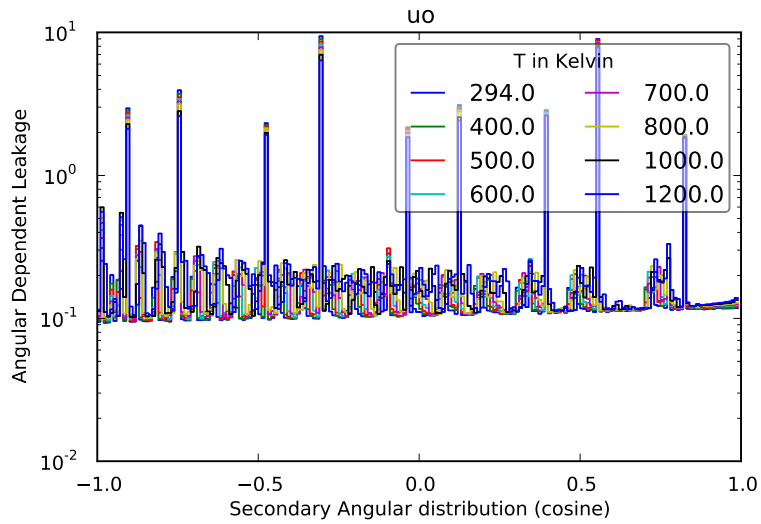


Figure 41: Discrete smeth



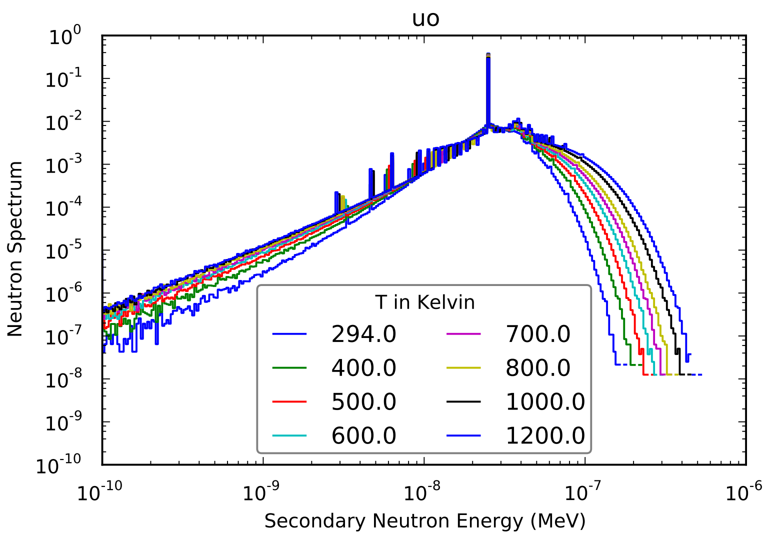


Figure 42: Discrete uo

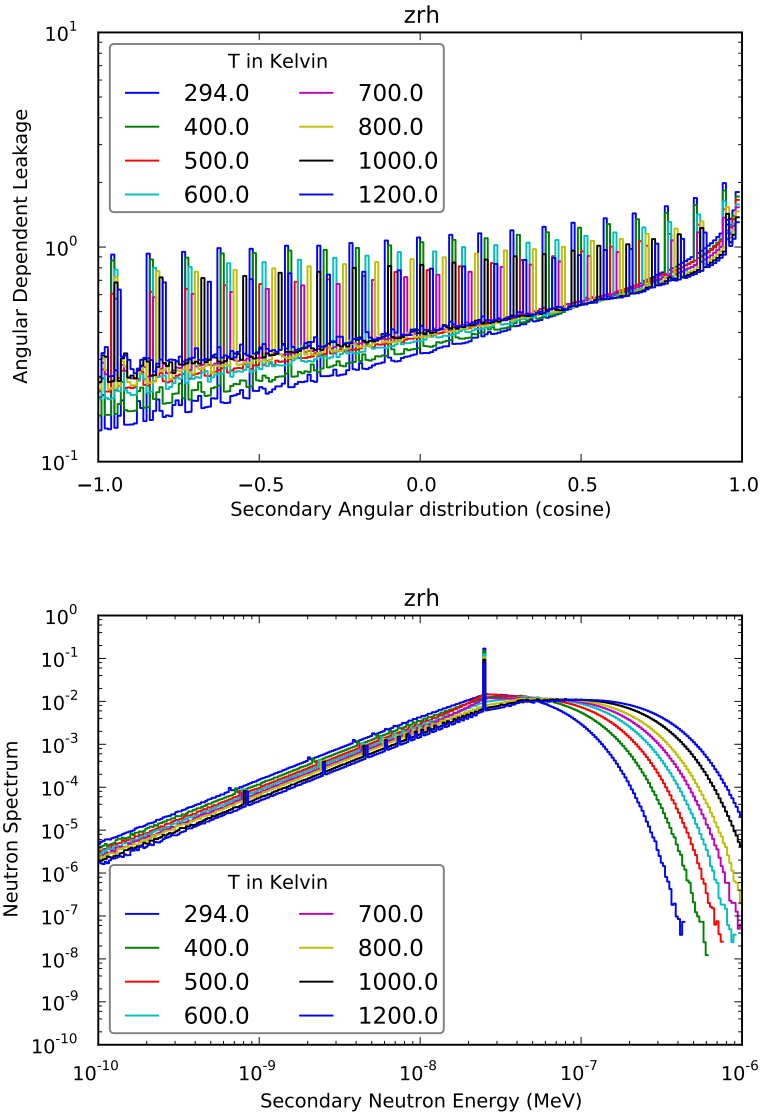
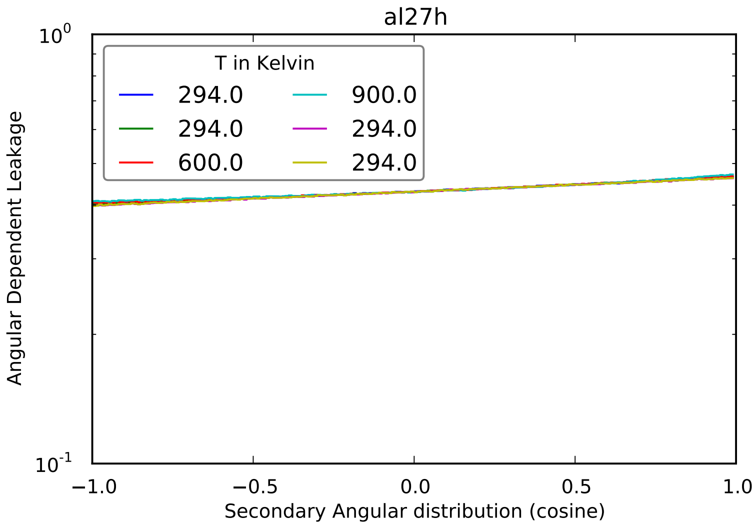


Figure 43: Discrete zrh

C.3. FreeGas



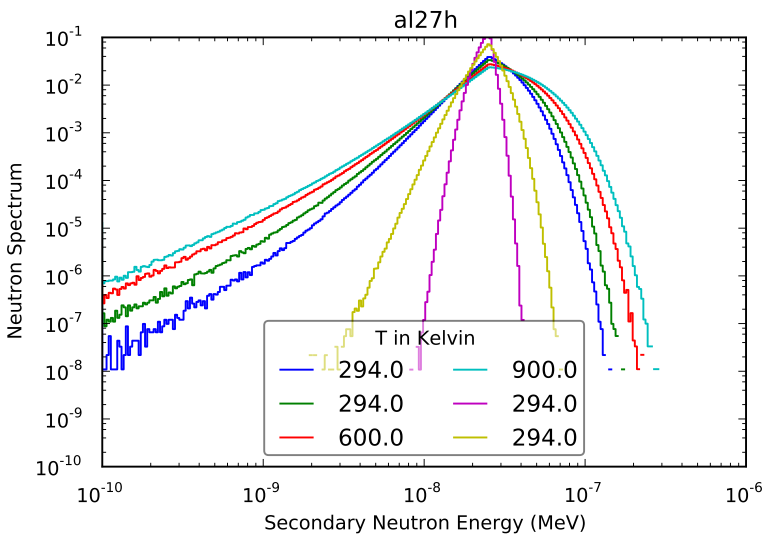


Figure 44: FreeGas al27h

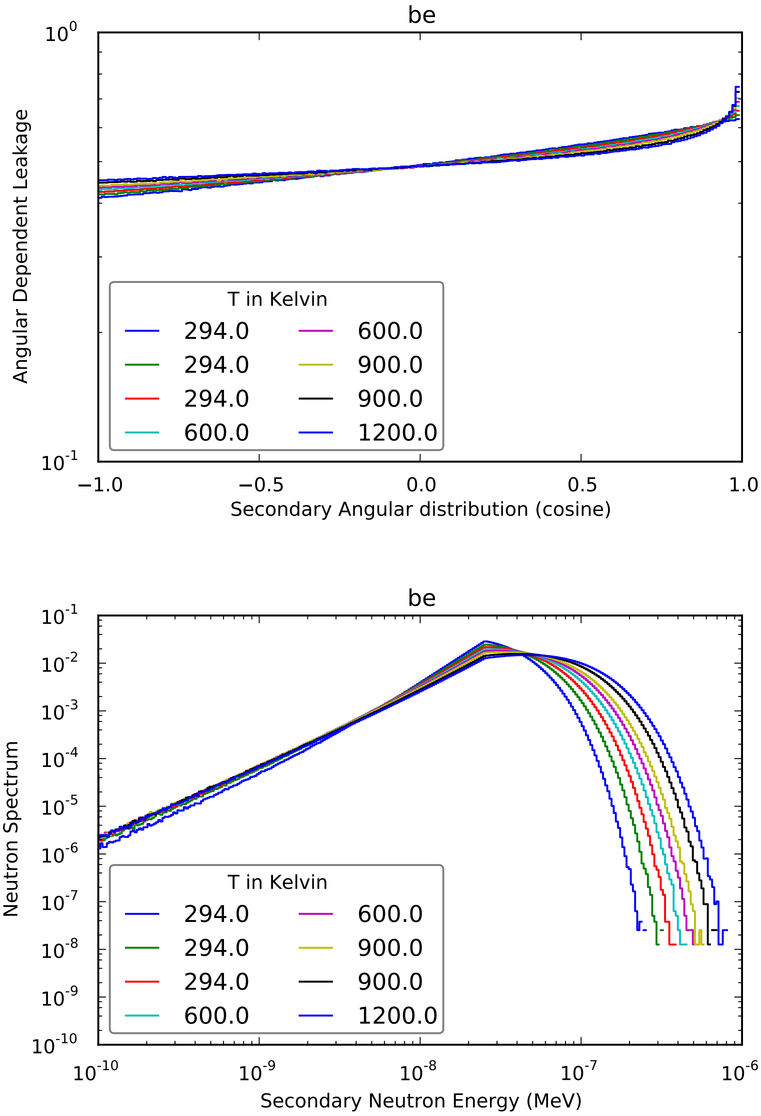


Figure 45: FreeGas be

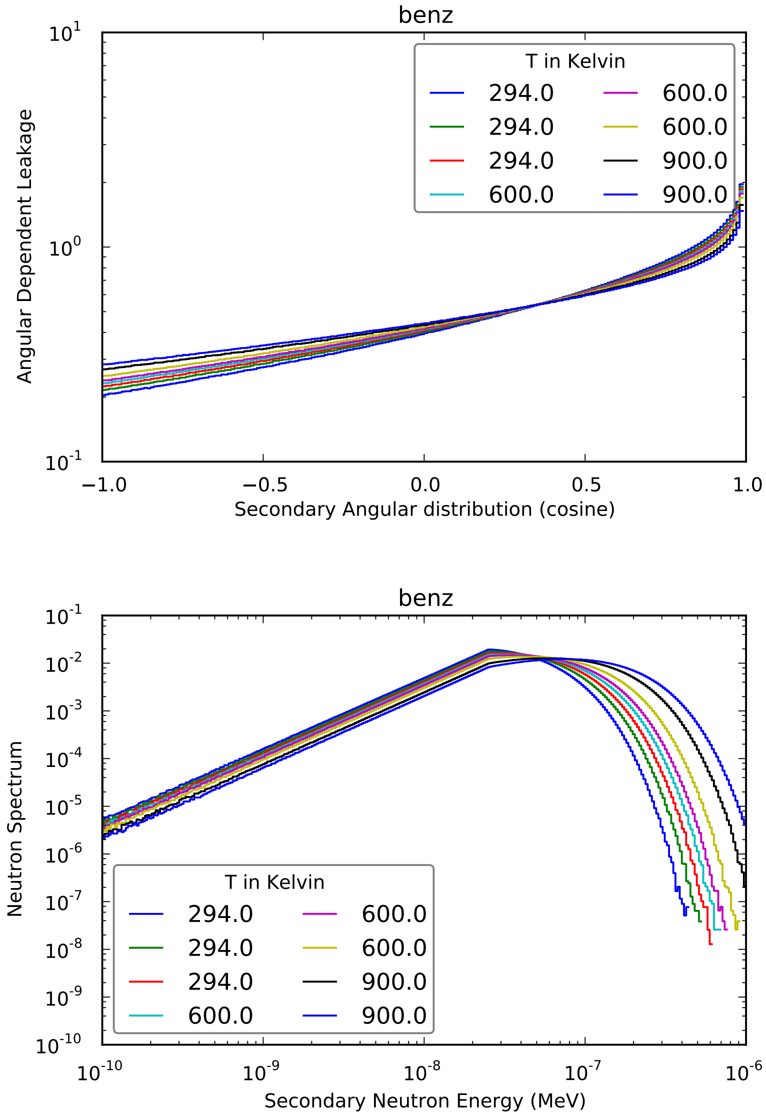


Figure 46: FreeGas benz

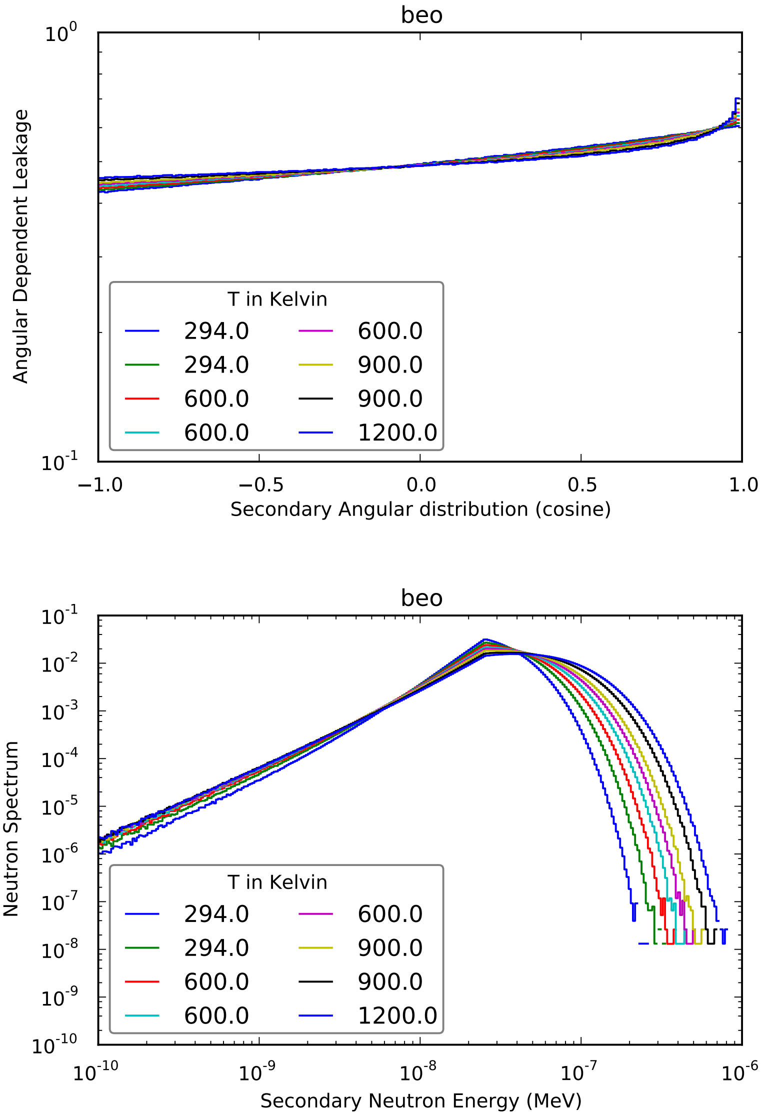


Figure 47: FreeGas beo

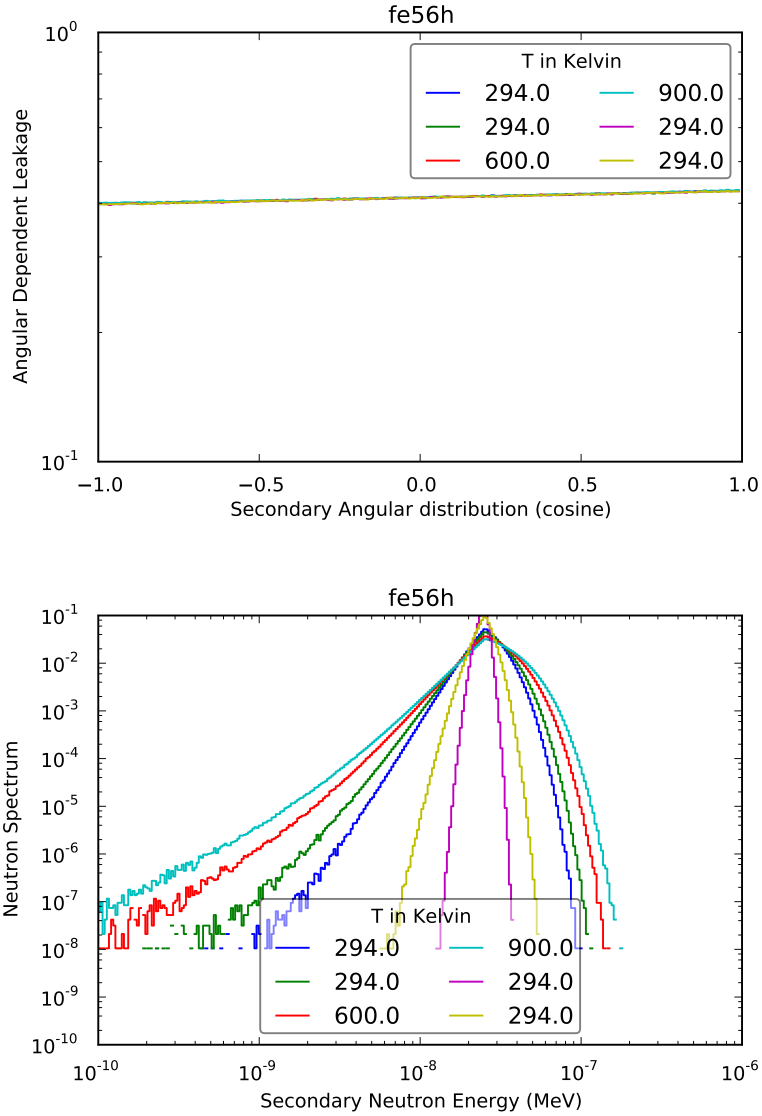


Figure 48: FreeGas fe56h

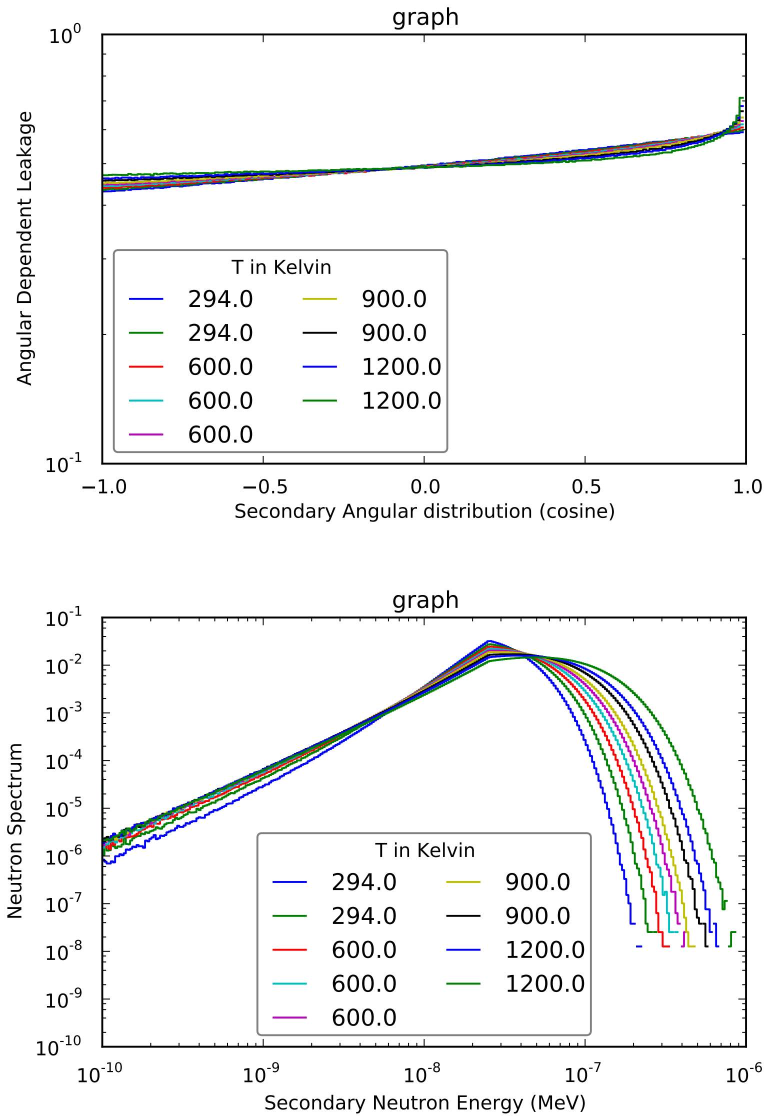


Figure 49: FreeGas graph

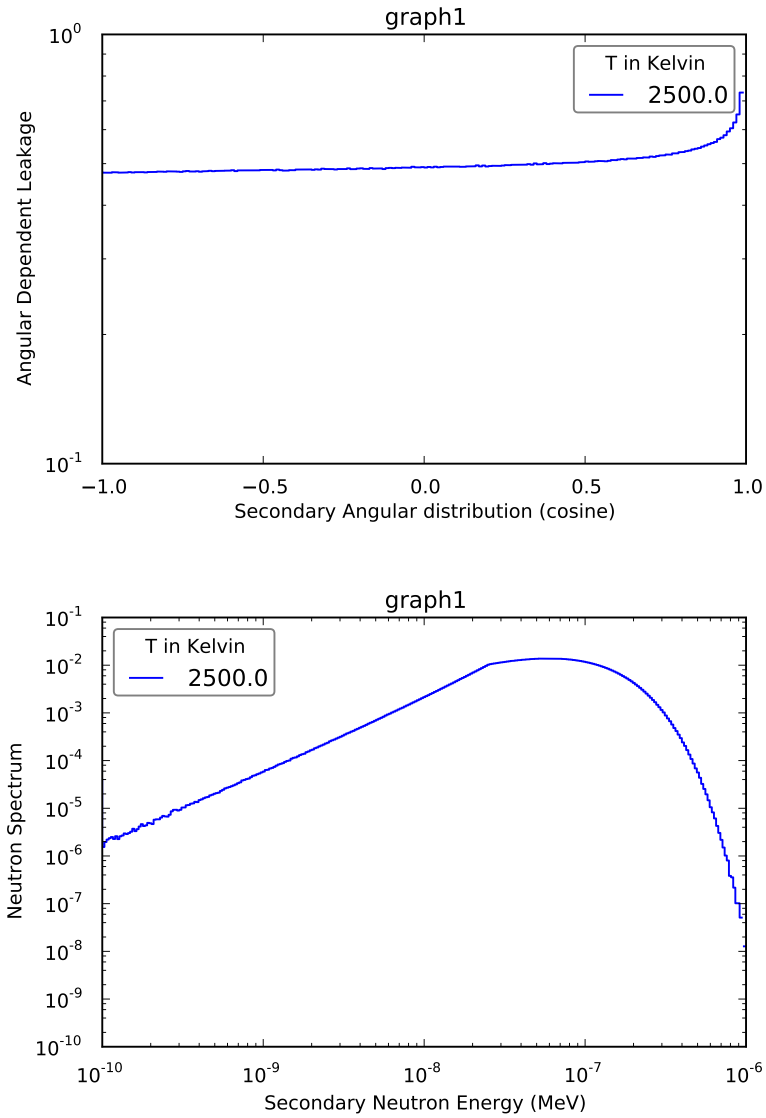
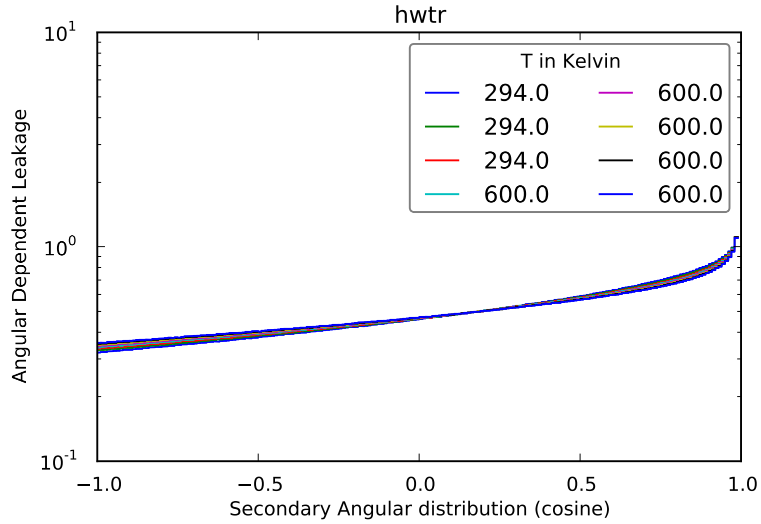


Figure 50: FreeGas graph1



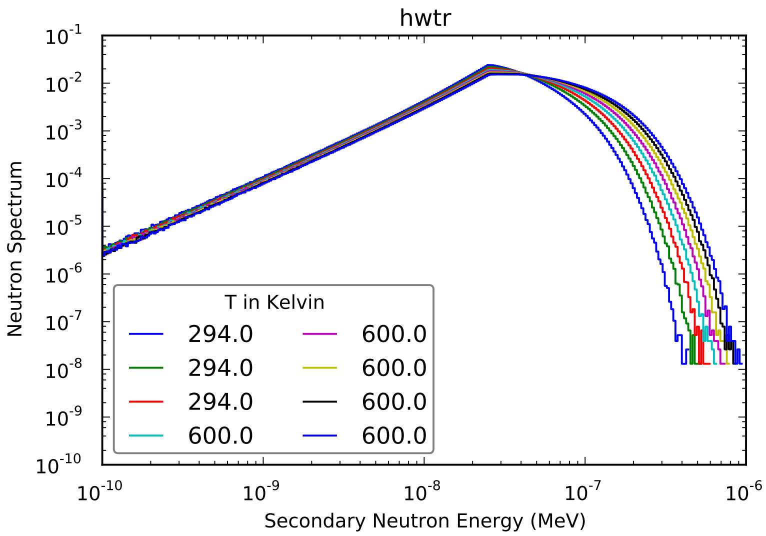


Figure 51: FreeGas hwtr

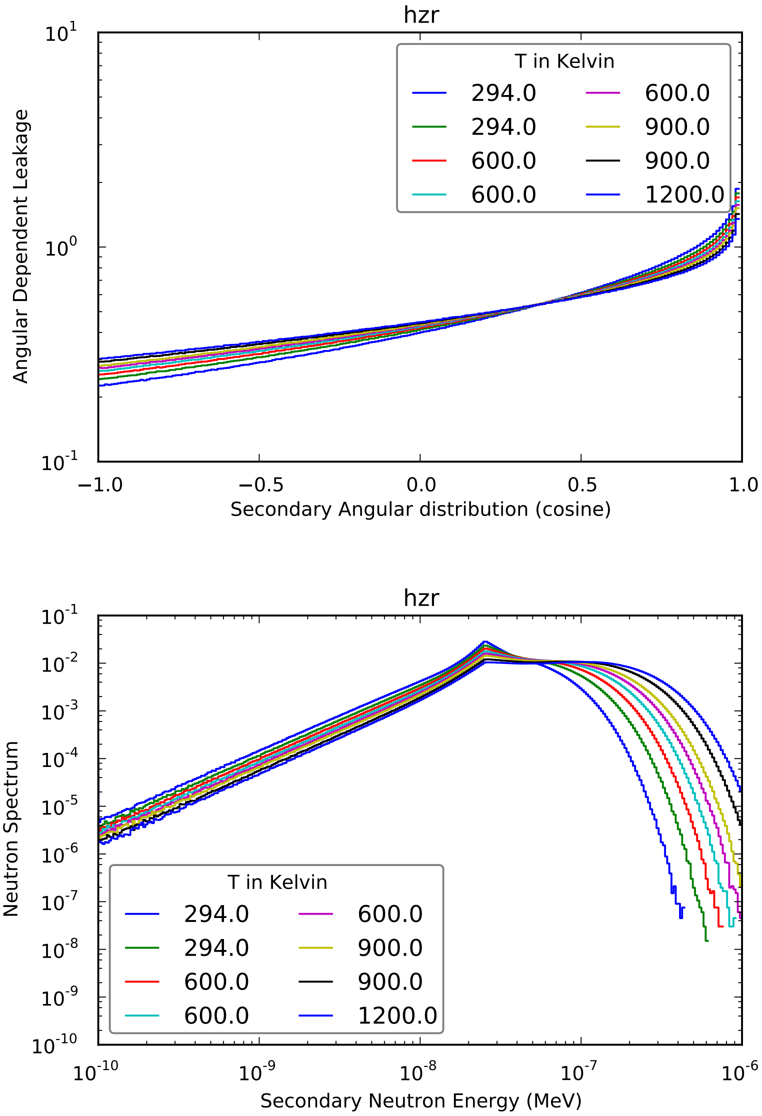
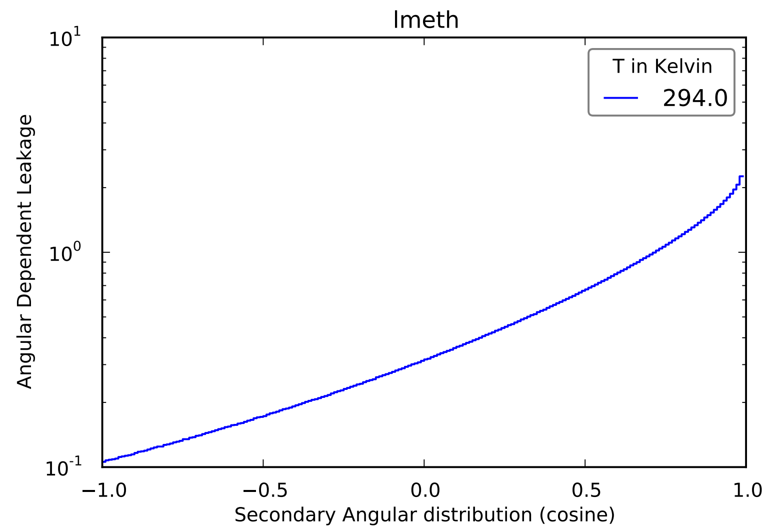


Figure 52: FreeGas hzr



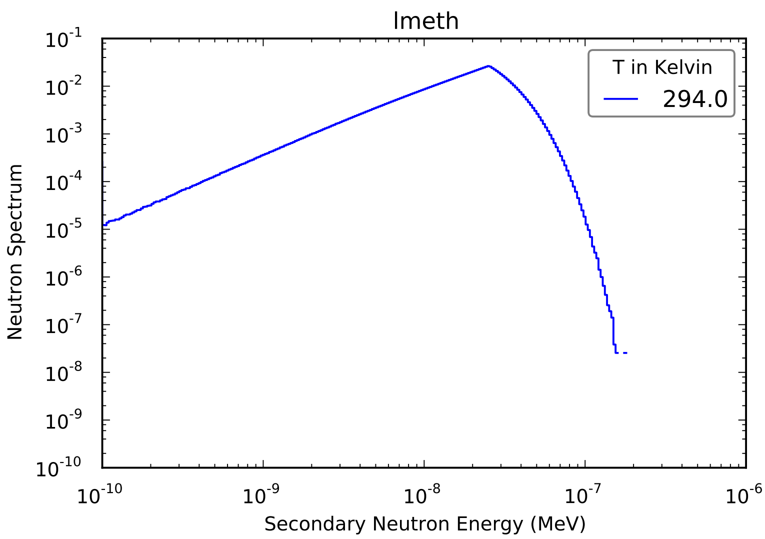
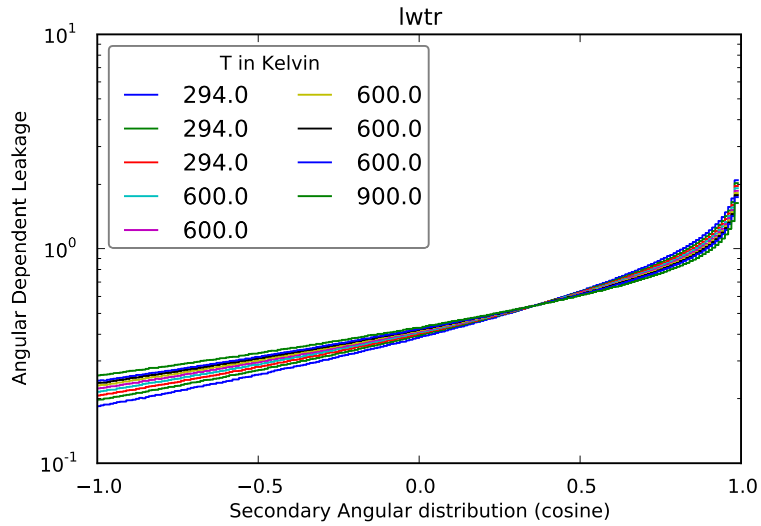


Figure 53: FreeGas lmeth



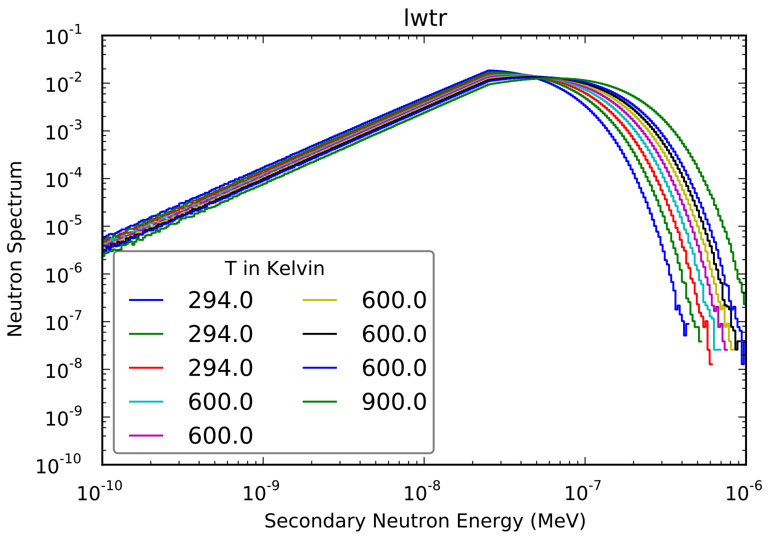


Figure 54: FreeGas lwtr

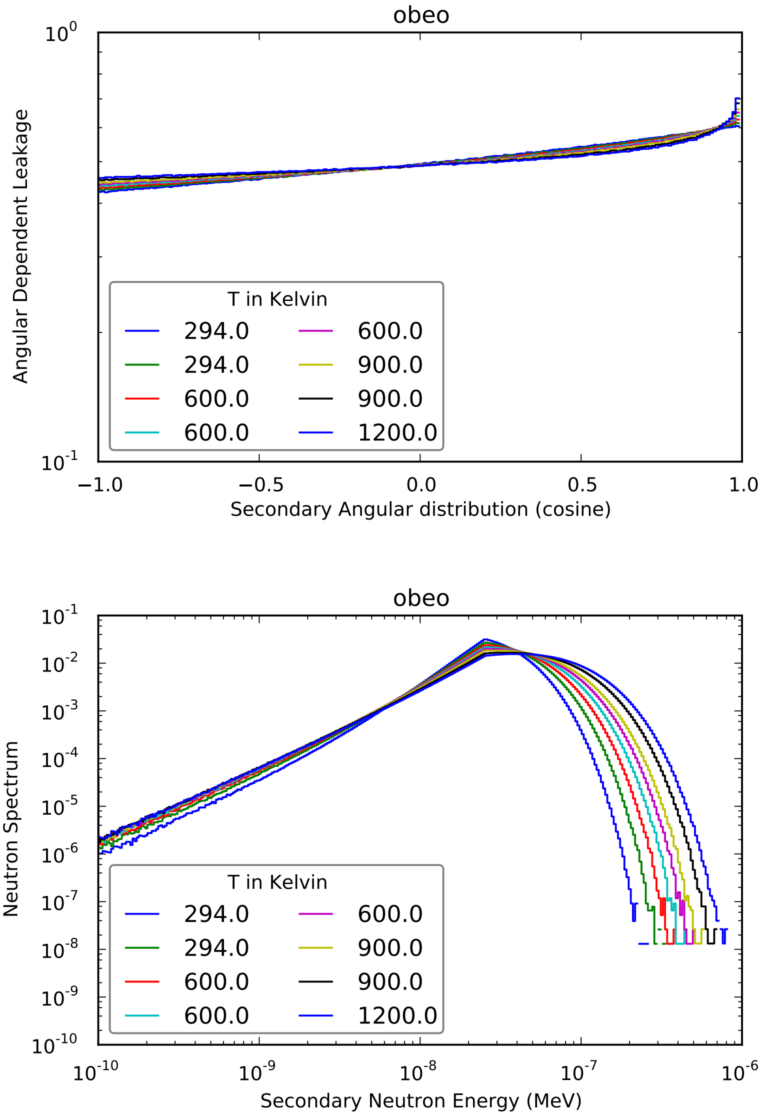


Figure 55: FreeGas obeo

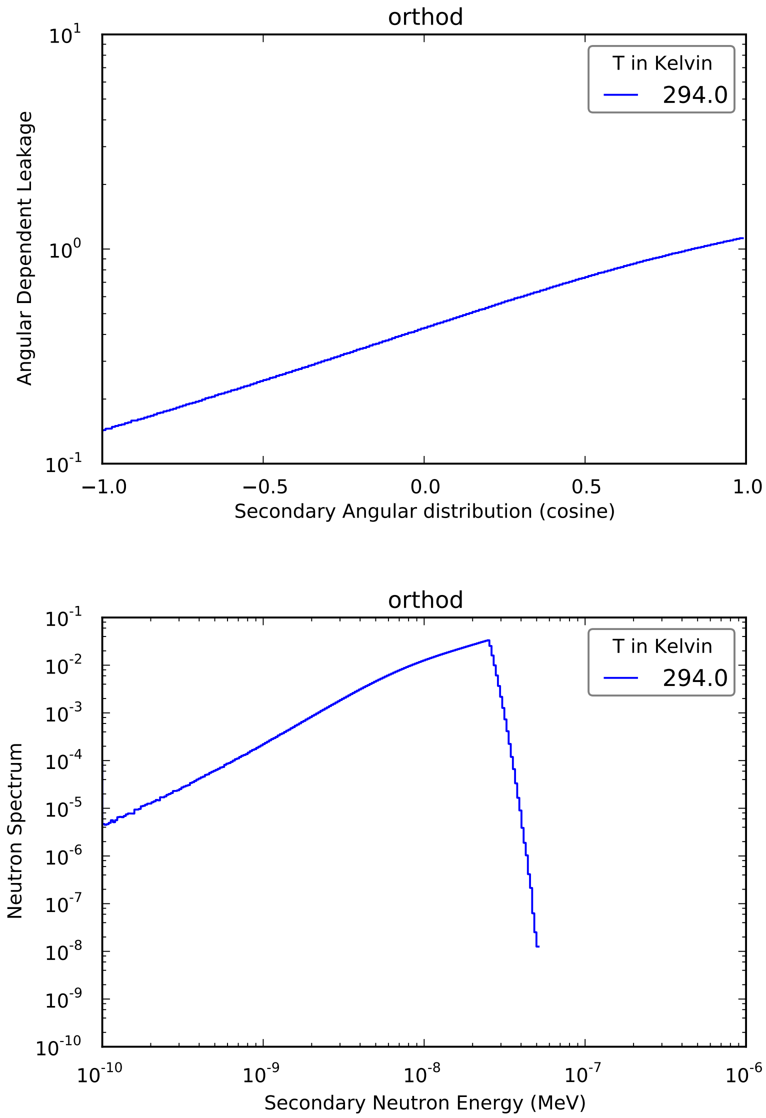


Figure 56: FreeGas orthod

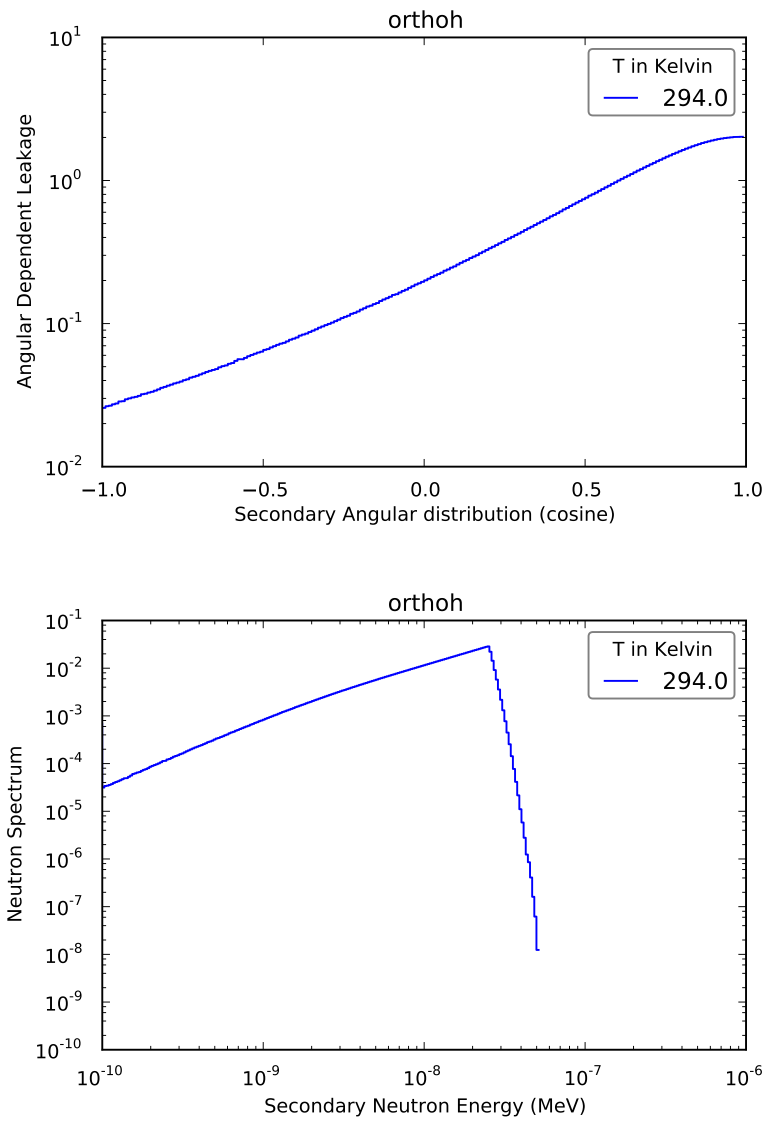


Figure 57: FreeGas orthoh

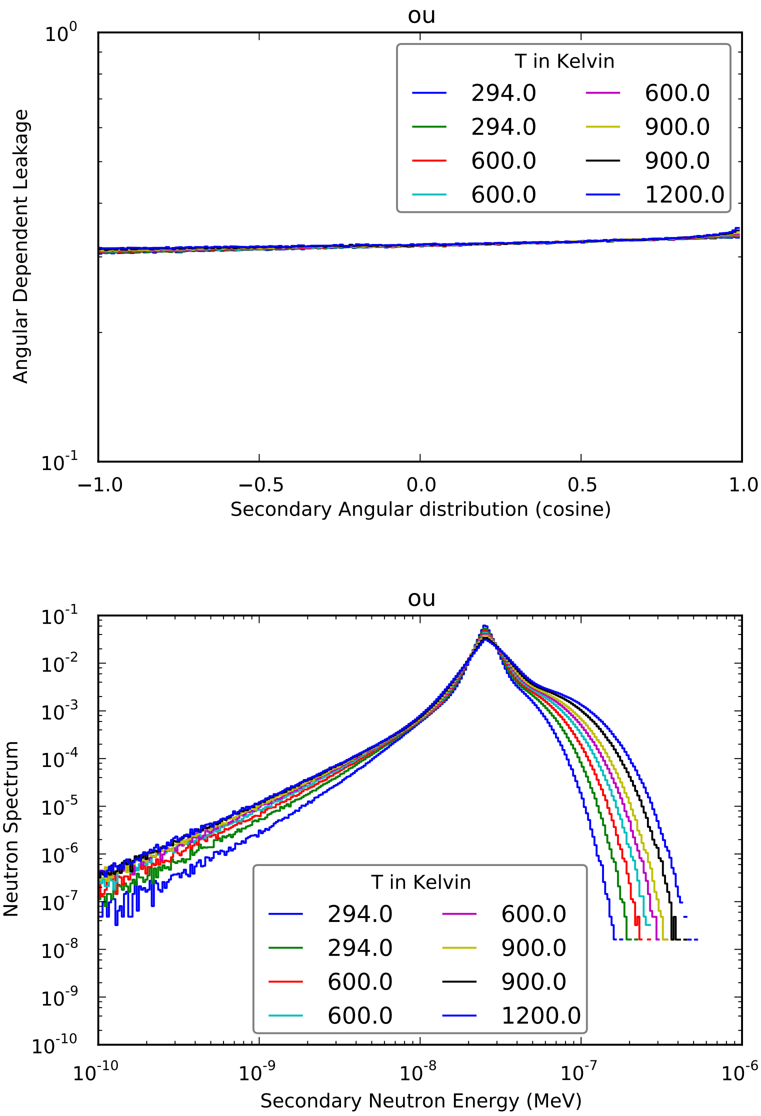
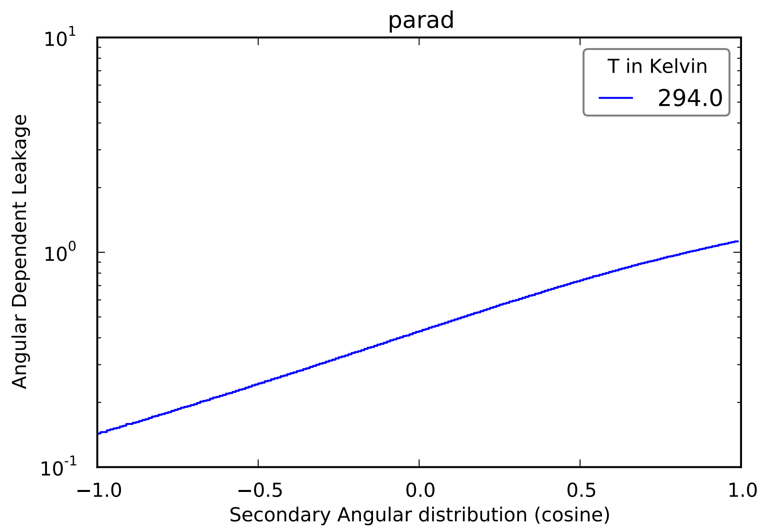


Figure 58: FreeGas ou



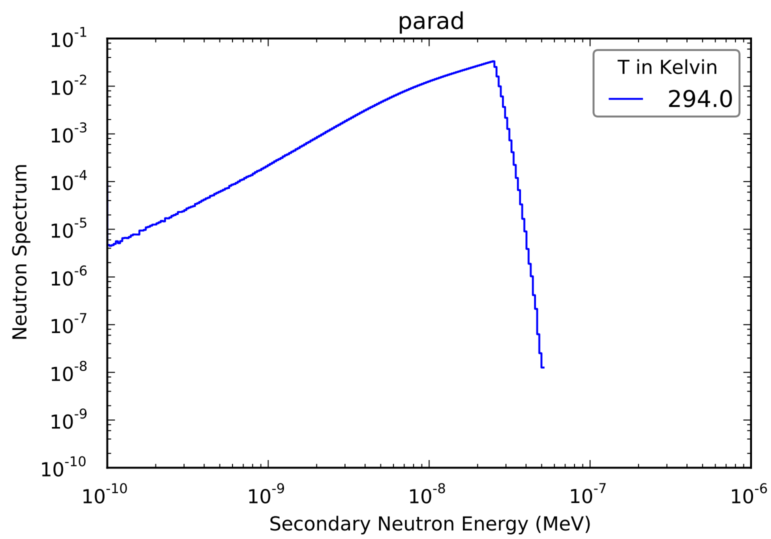
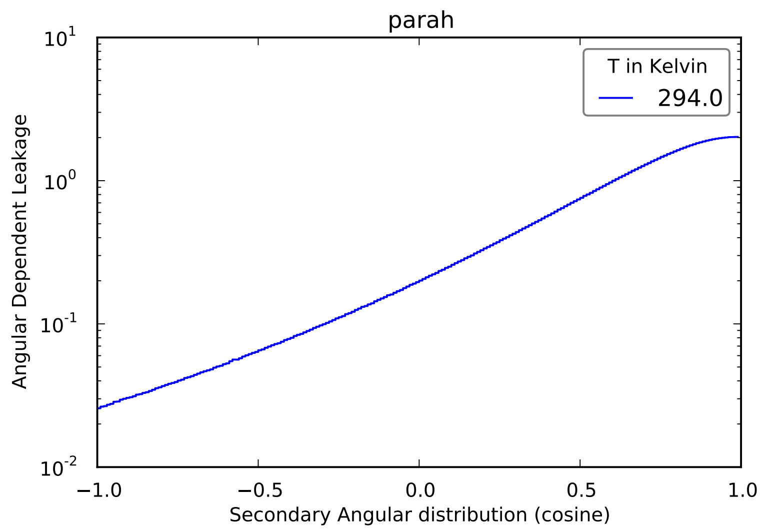


Figure 59: FreeGas parad



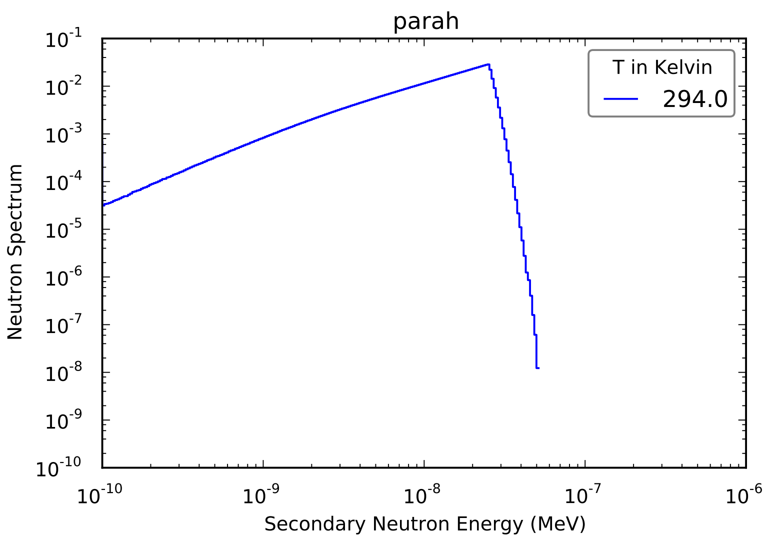


Figure 60: FreeGas parah

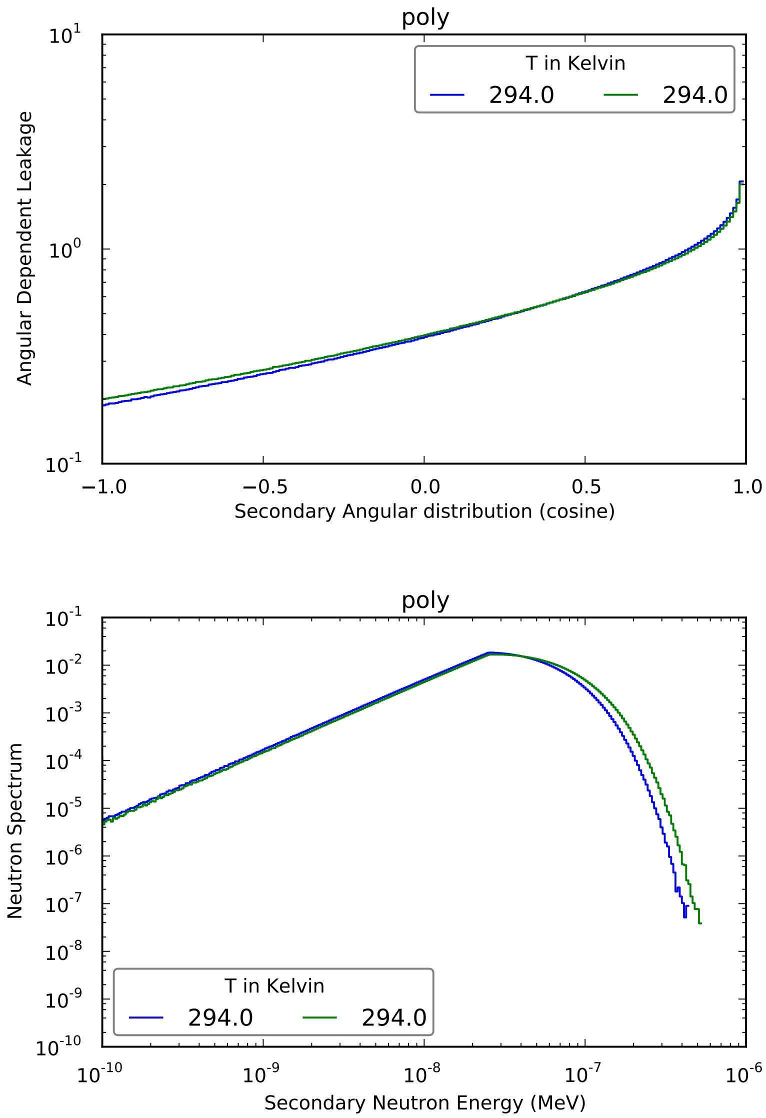


Figure 61: FreeGas poly

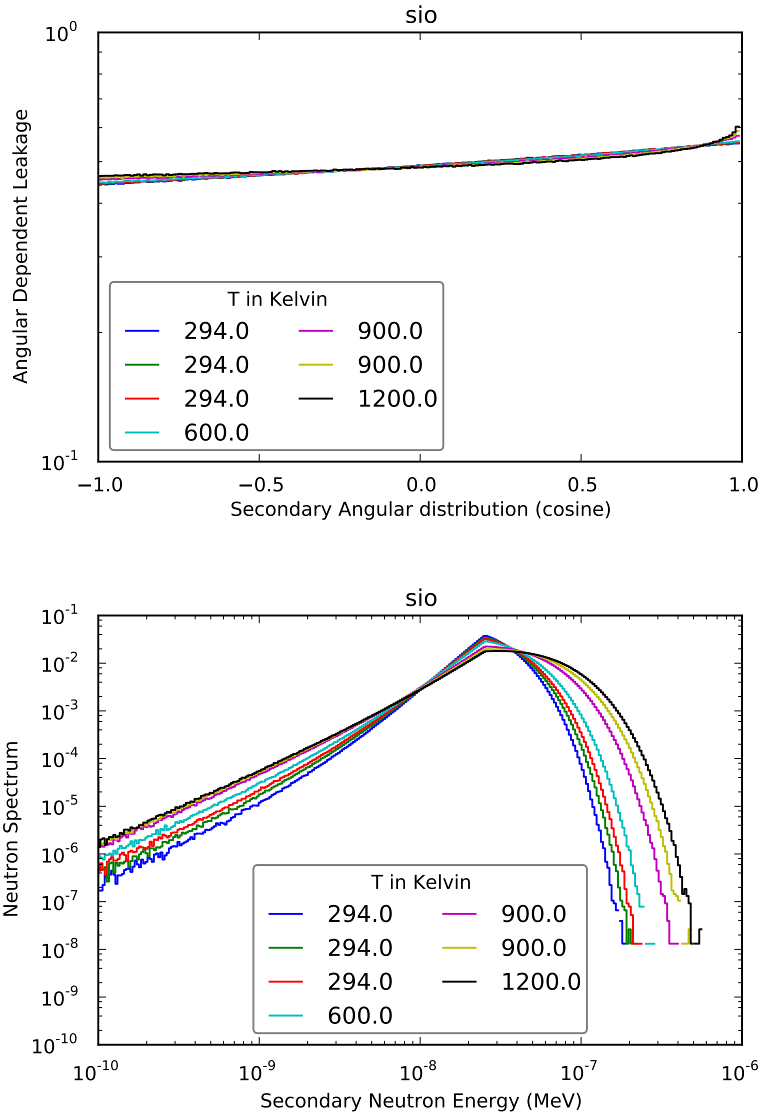


Figure 62: FreeGas sio

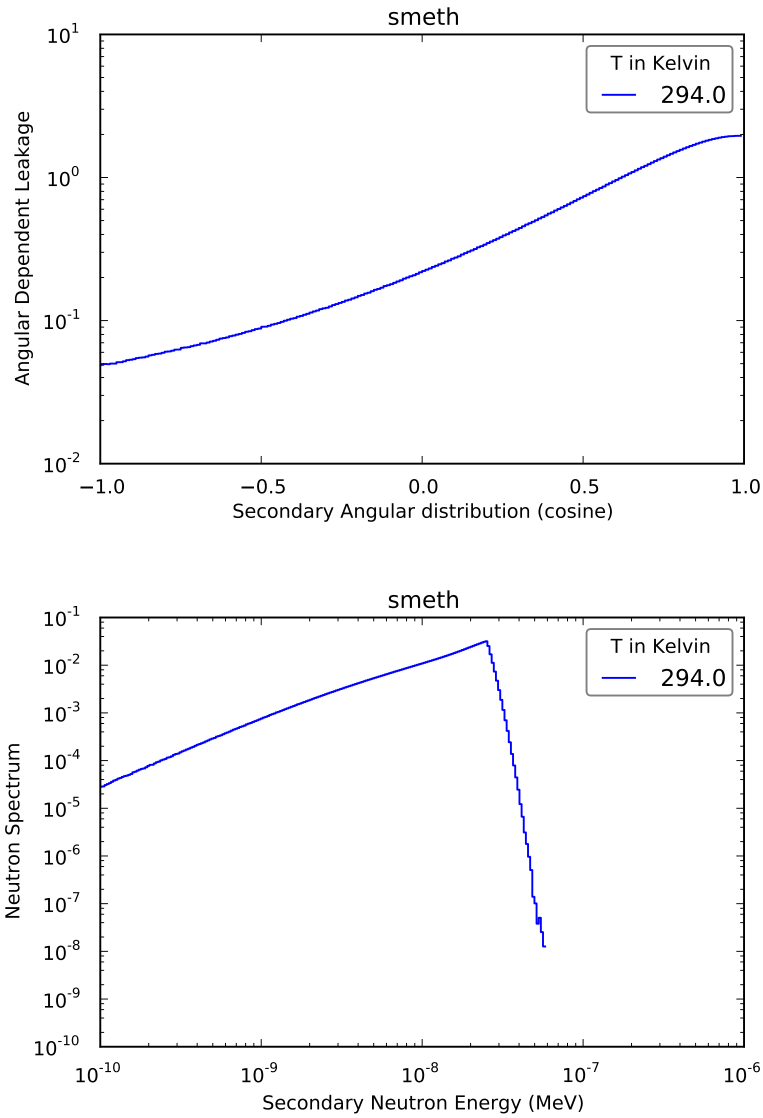
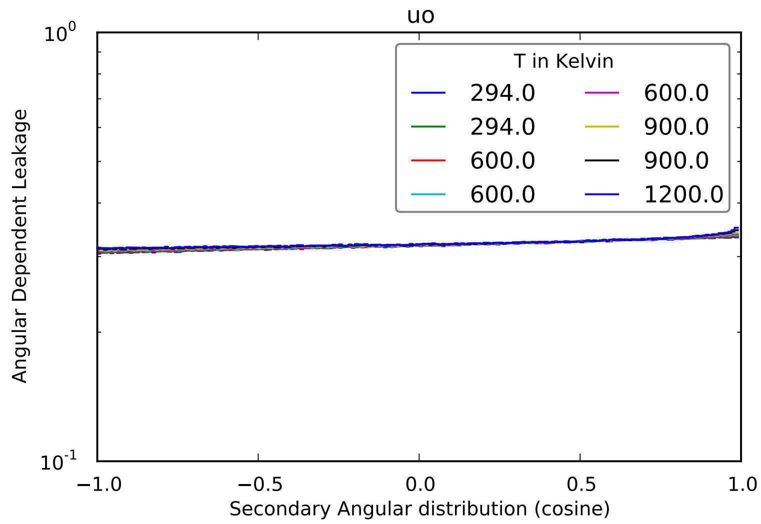


Figure 63: FreeGas smeth



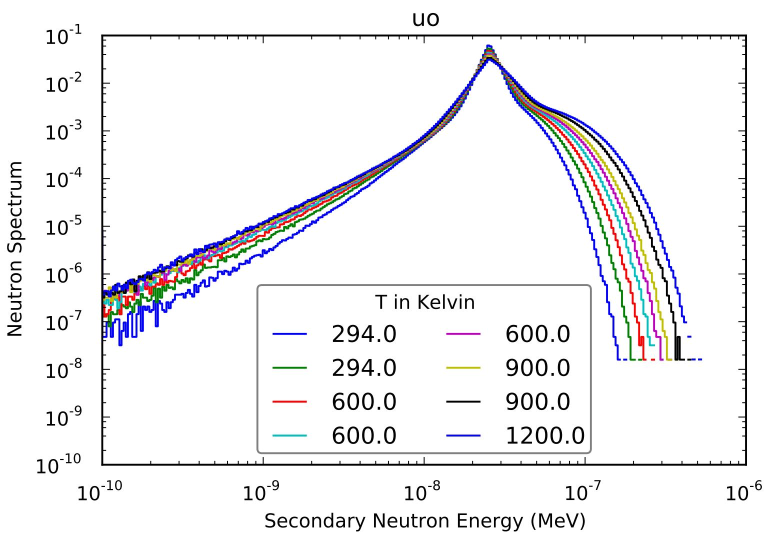
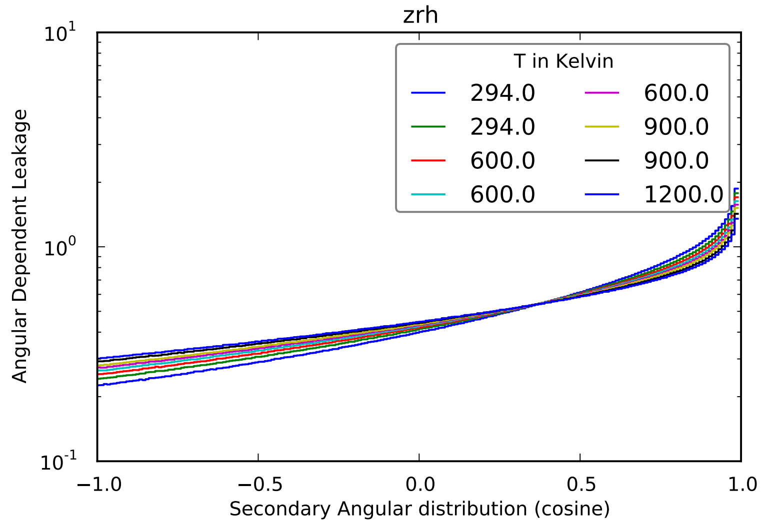


Figure 64: FreeGas uo



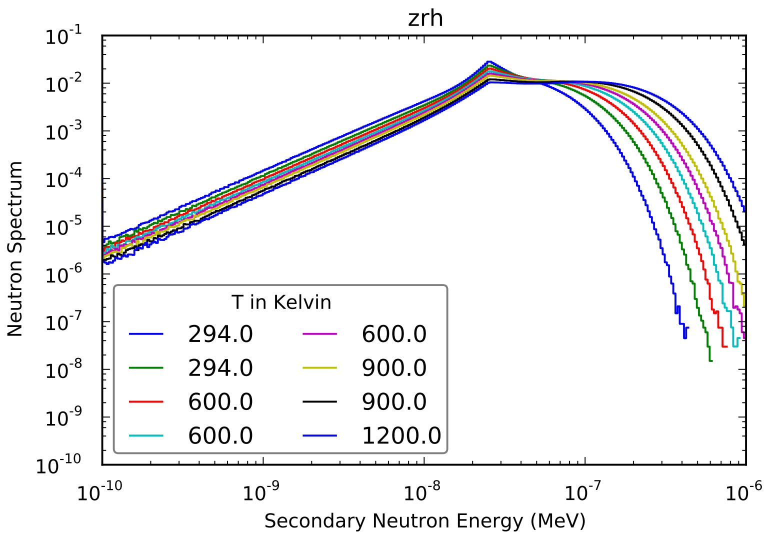


Figure 65: FreeGas zrh

D. Plots of the $S(\alpha, \beta)$ Cross Sections

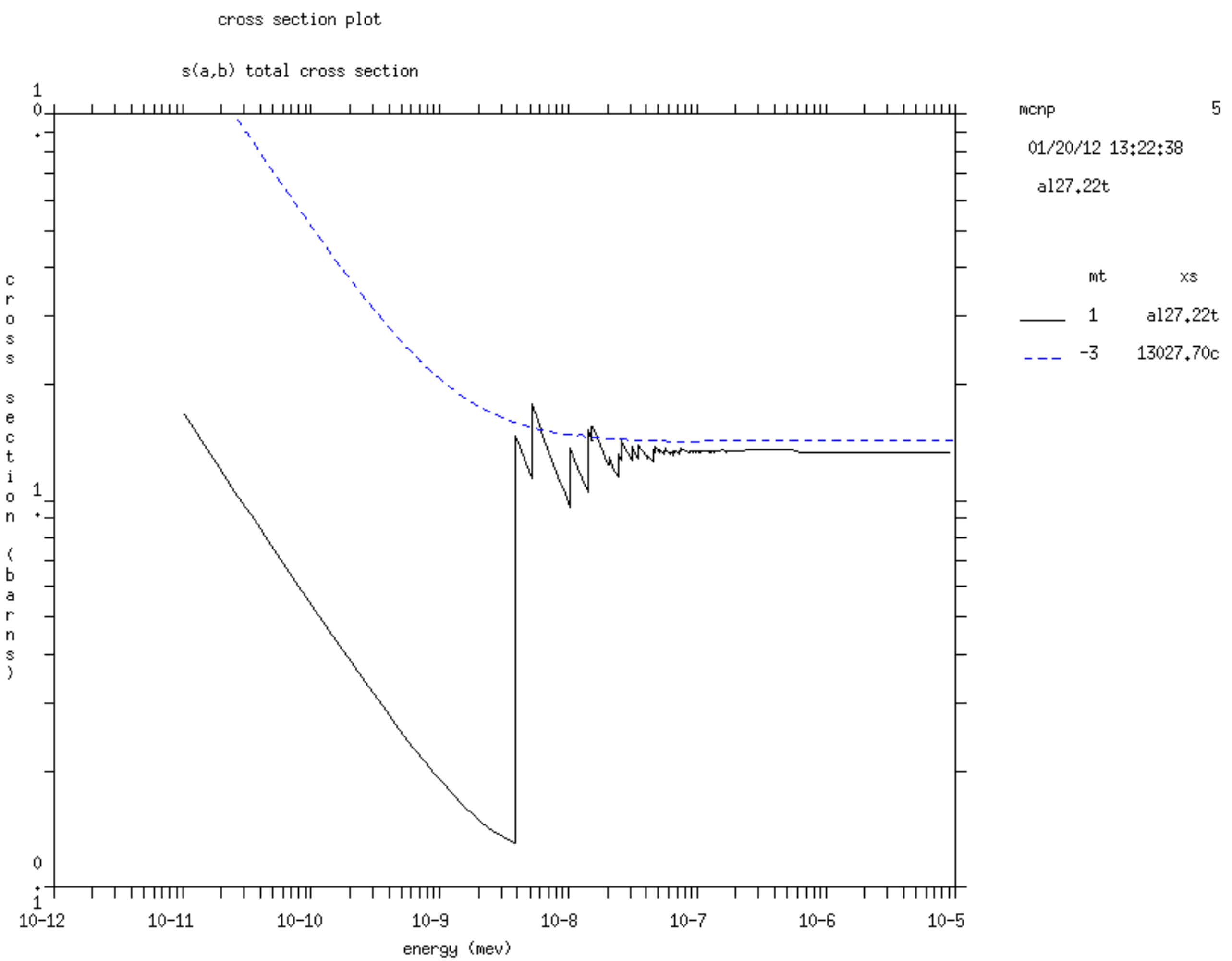


Figure 66: Plot of cross section for S(α, β) material: `al27`

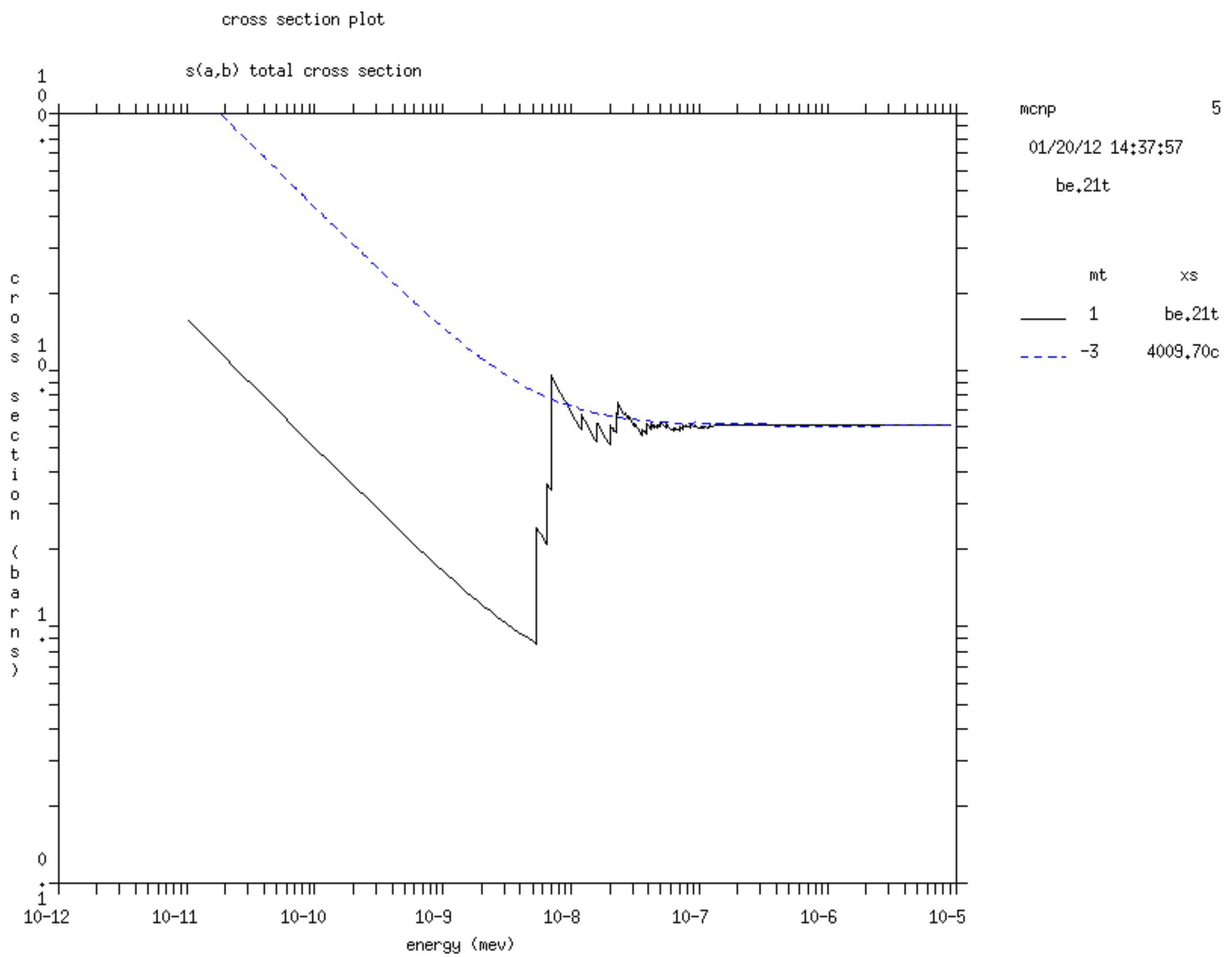


Figure 67: Plot of cross section for S(α, β) material: `be`

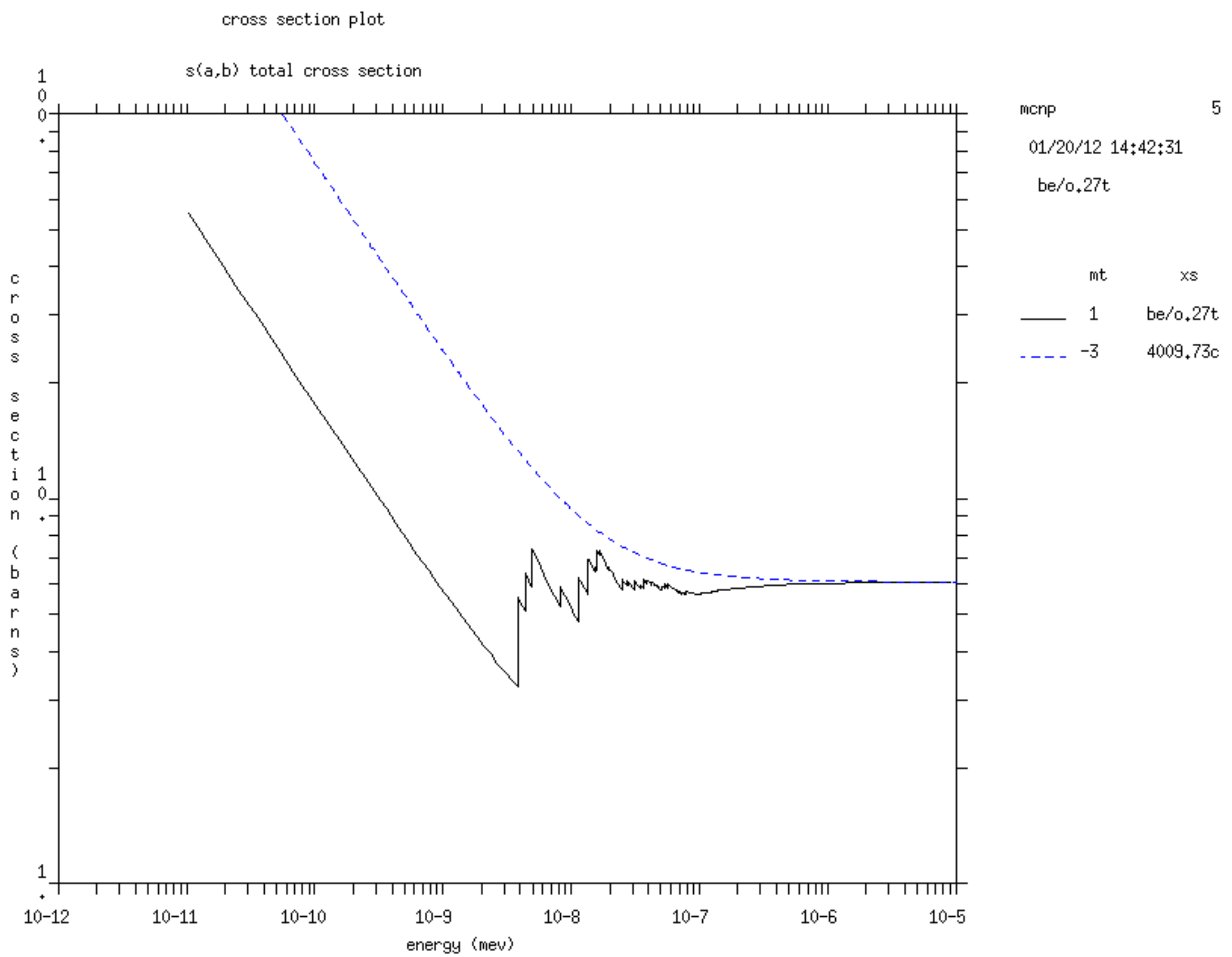


Figure 68: Plot of cross section for S(α, β) material: `beo`

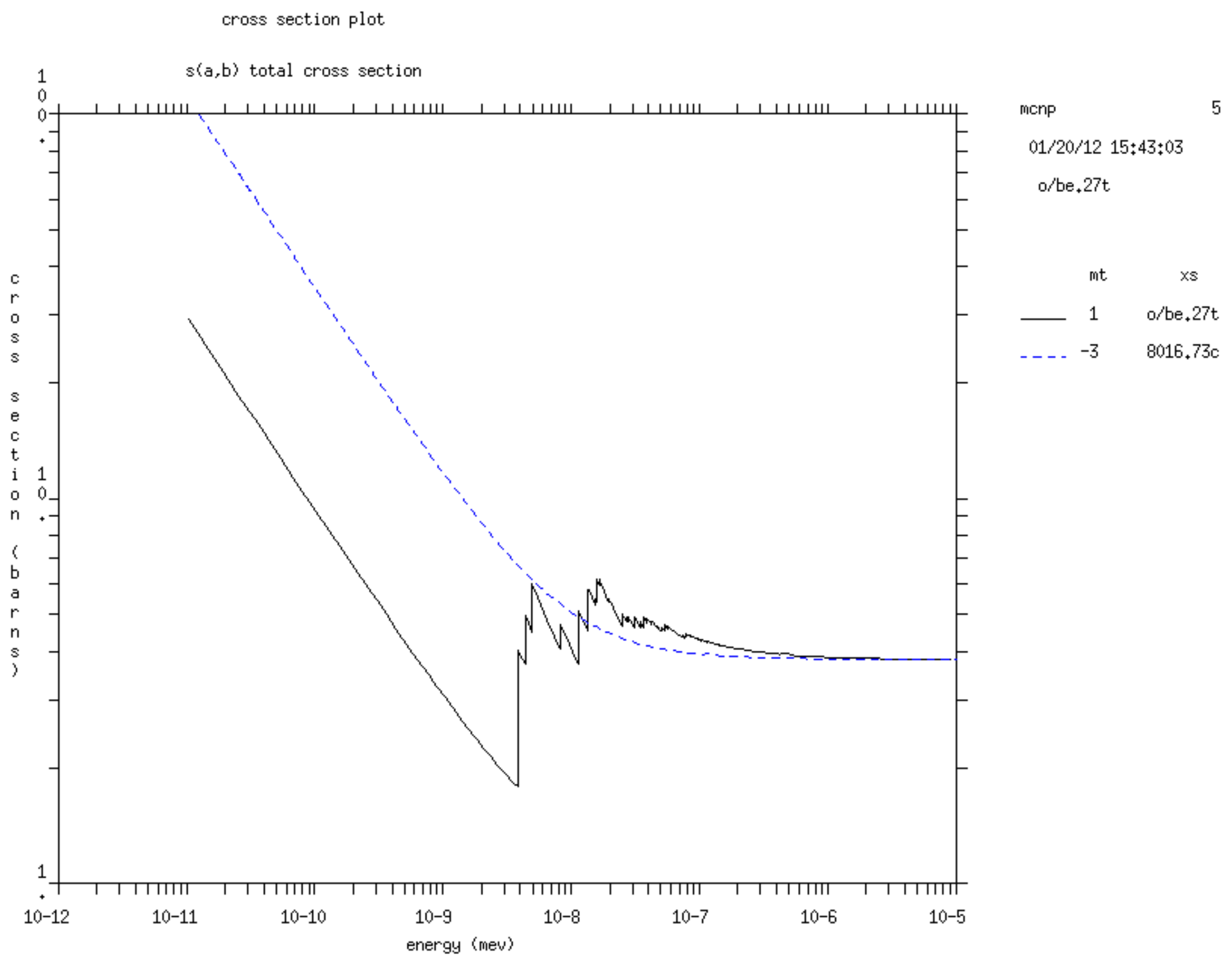


Figure 69: Plot of cross section for S(α,β) material: `obe`

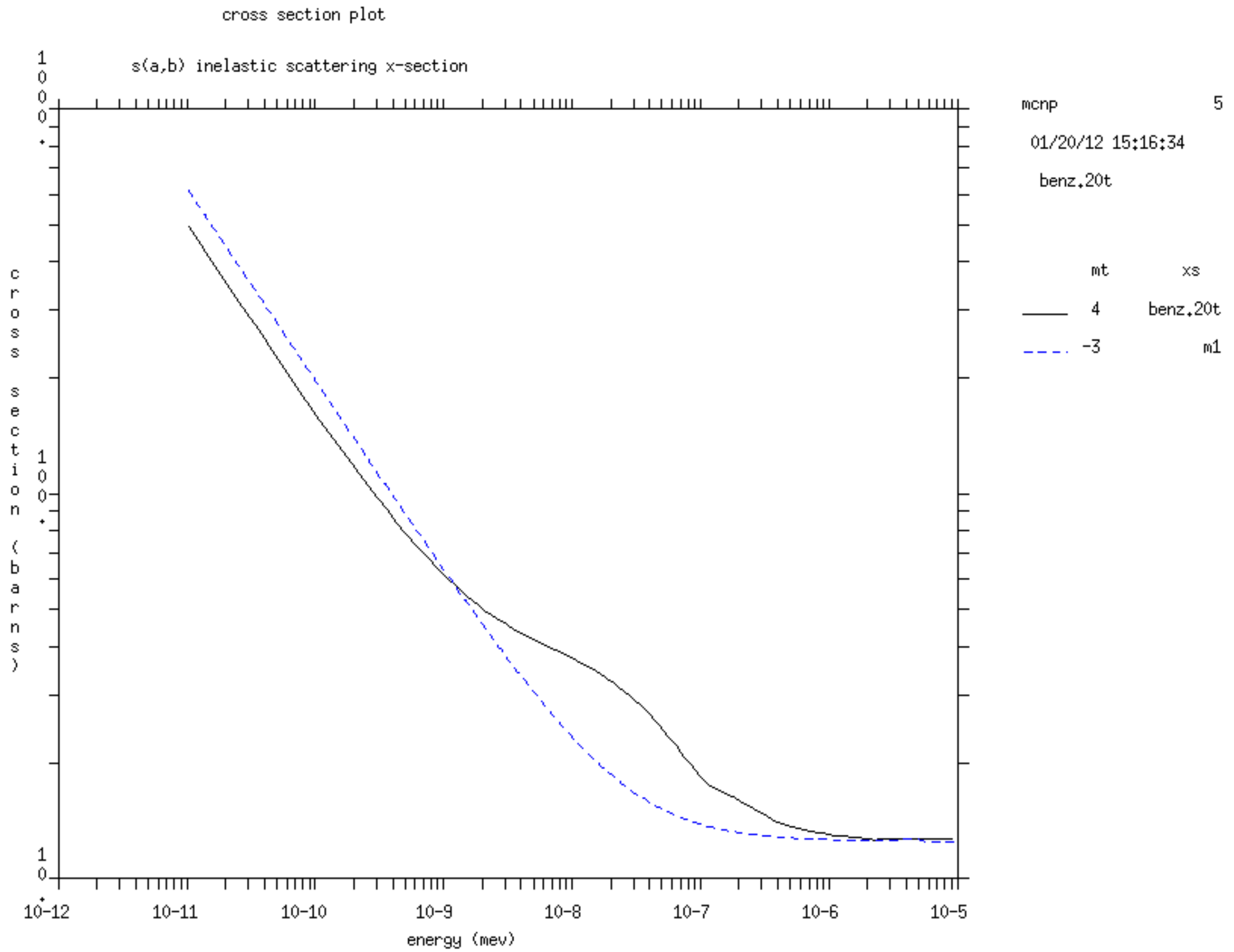


Figure 70: Plot of cross section for $S(\alpha, \beta)$ material: `benz`

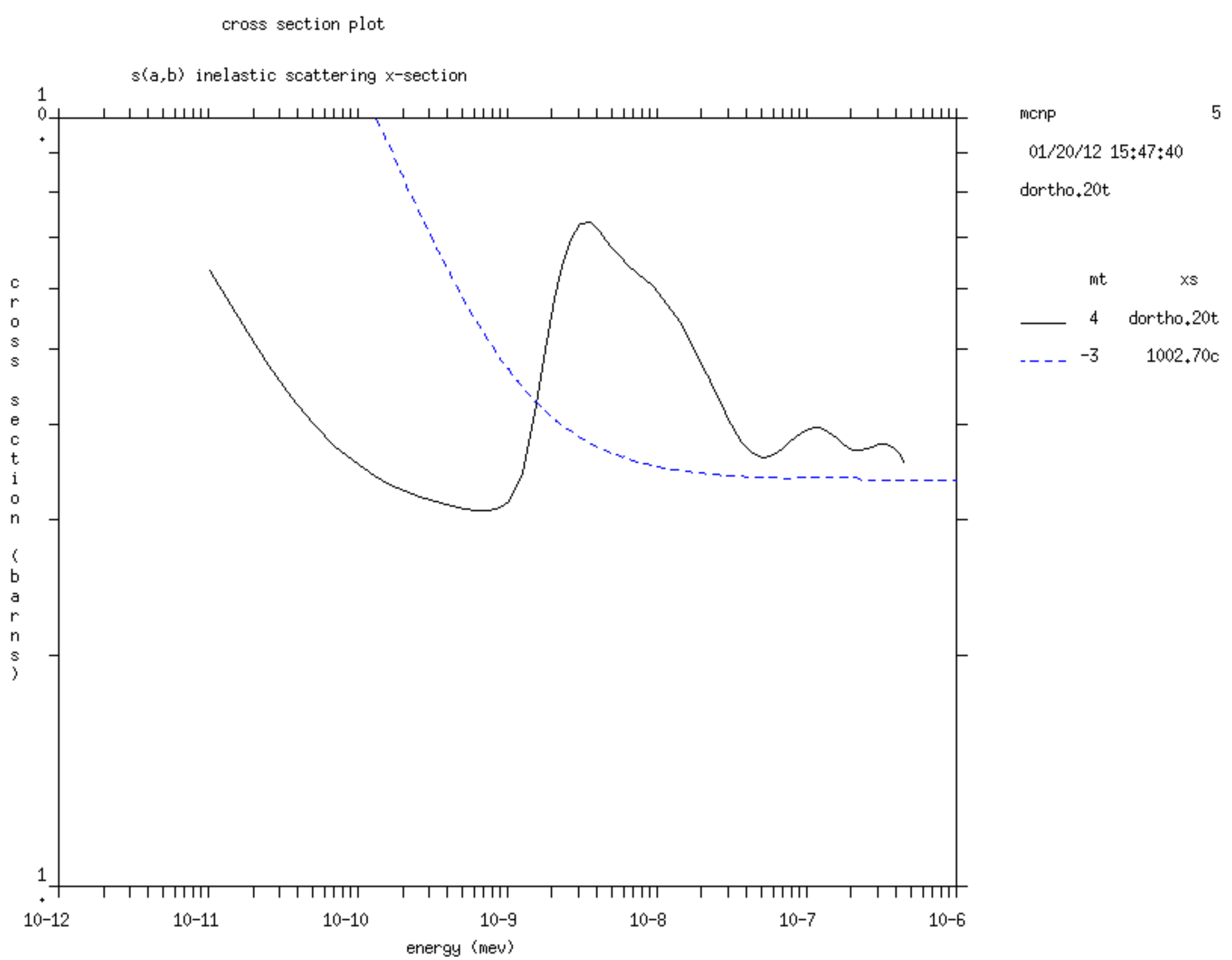


Figure 71: Plot of cross section for S(α,β) material: `dortho`

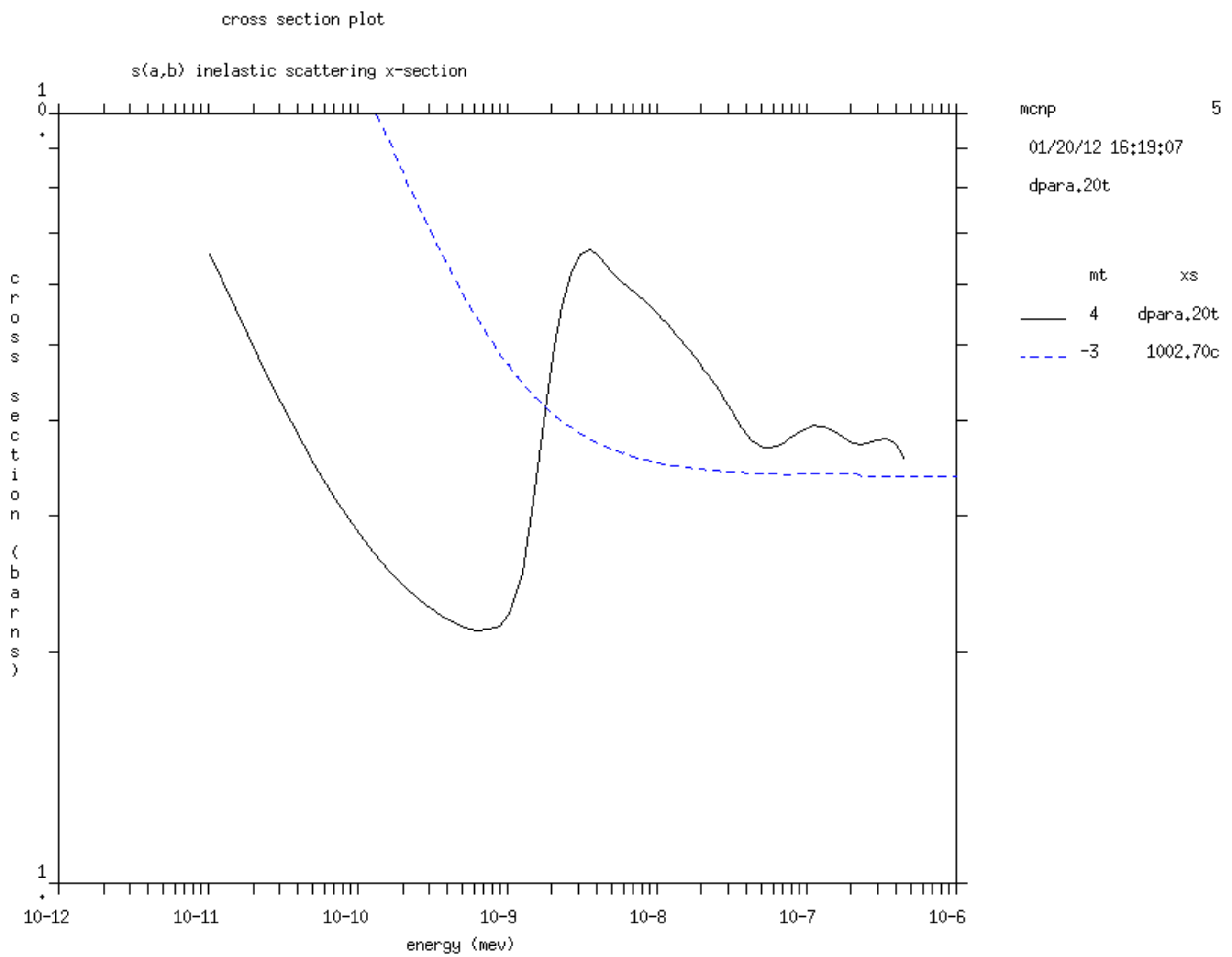


Figure 72: Plot of cross section for S(α, β) material: `dpara`

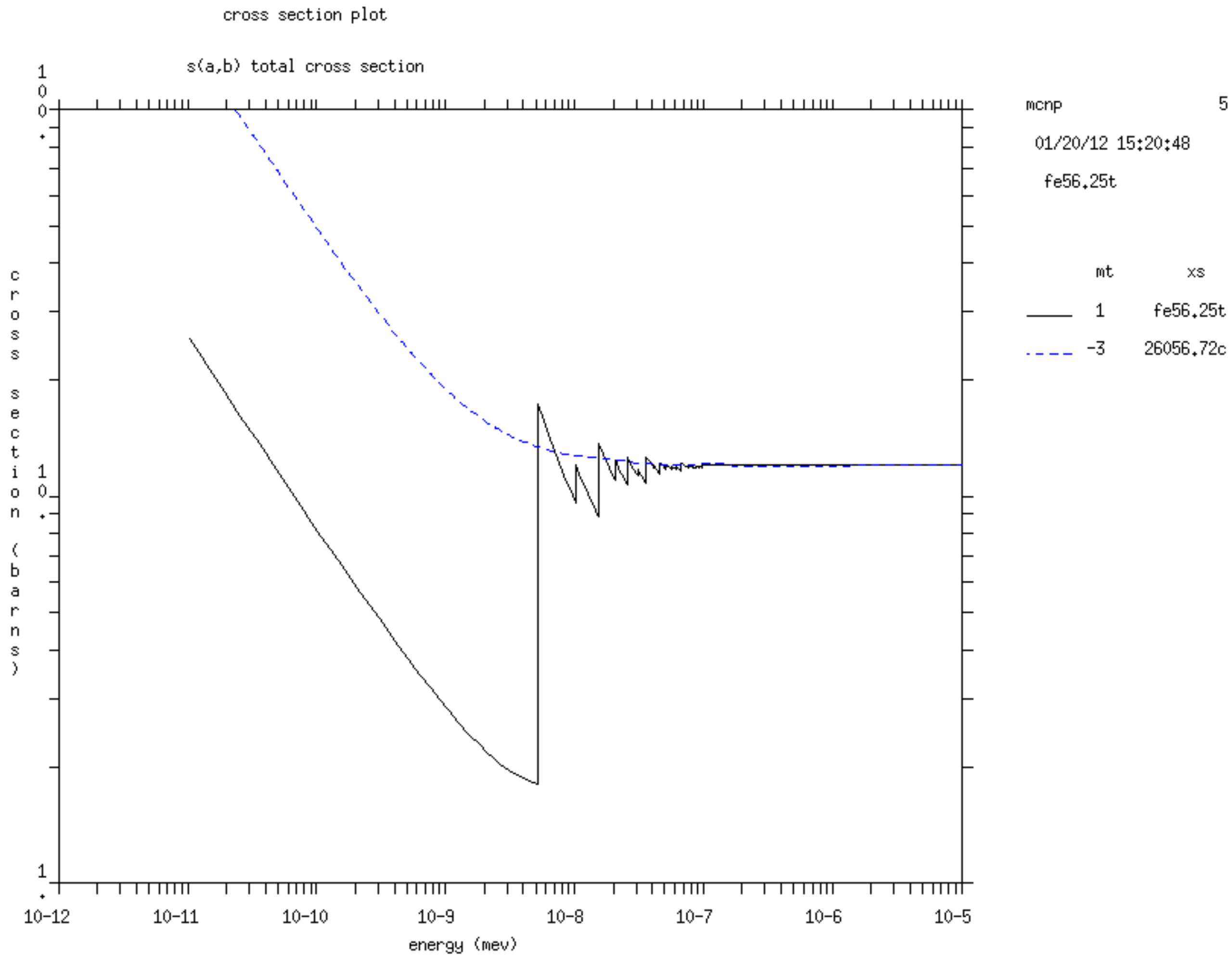


Figure 73: Plot of cross section for $S(\alpha, \beta)$ material: `fe56`

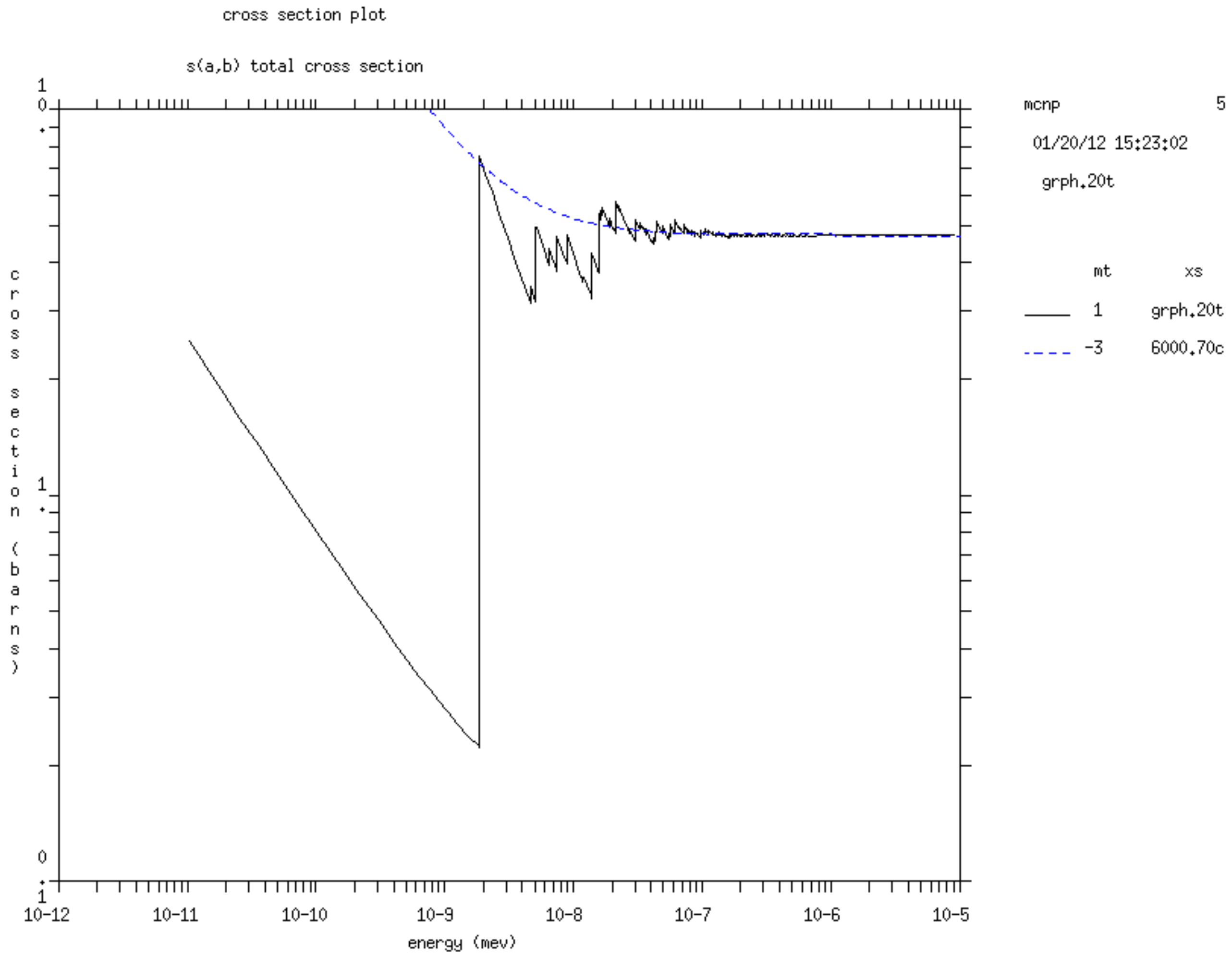


Figure 74: Plot of cross section for S(α,β) material: `graph`

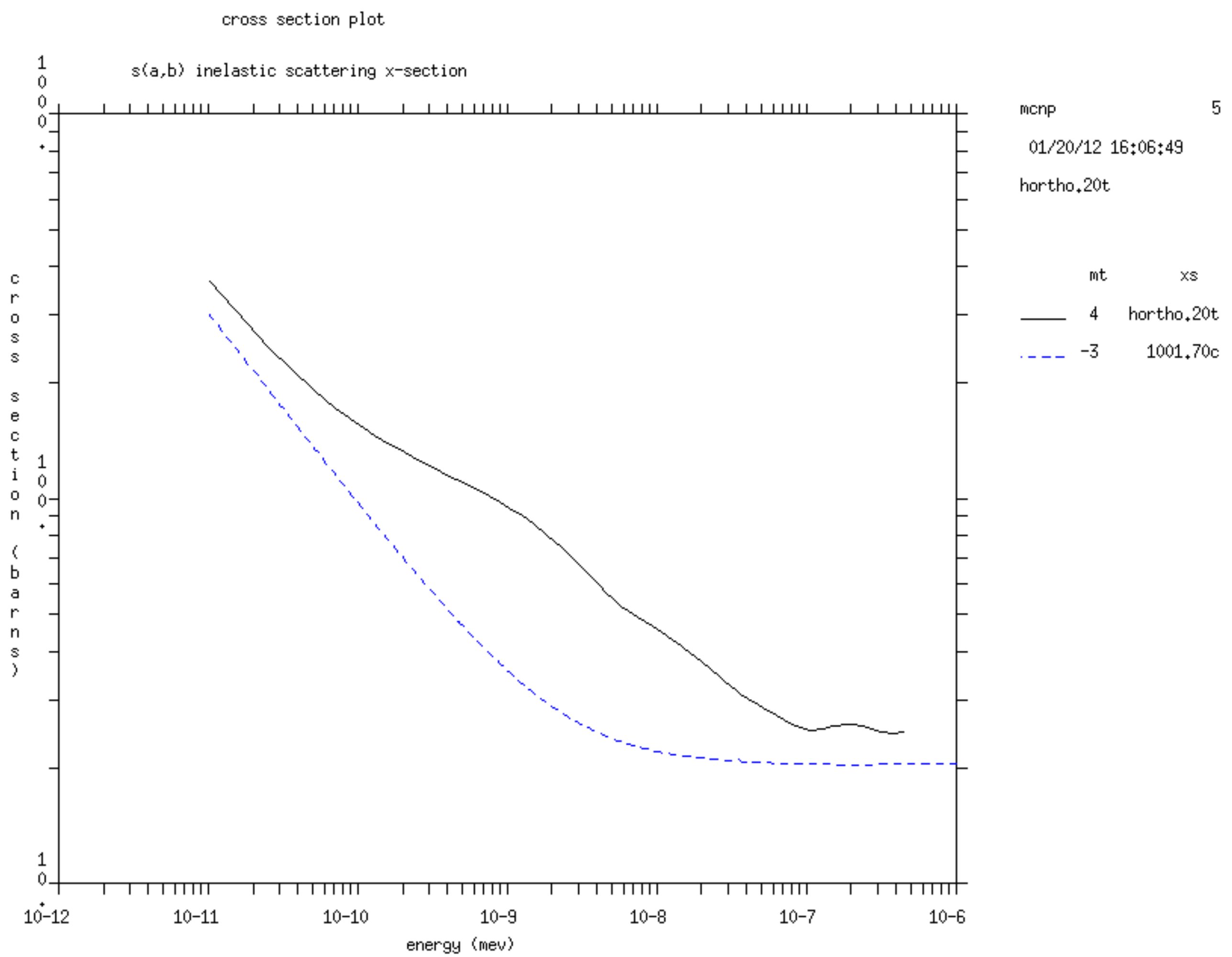


Figure 75: Plot of cross section for S(α,β) material: `hortho`

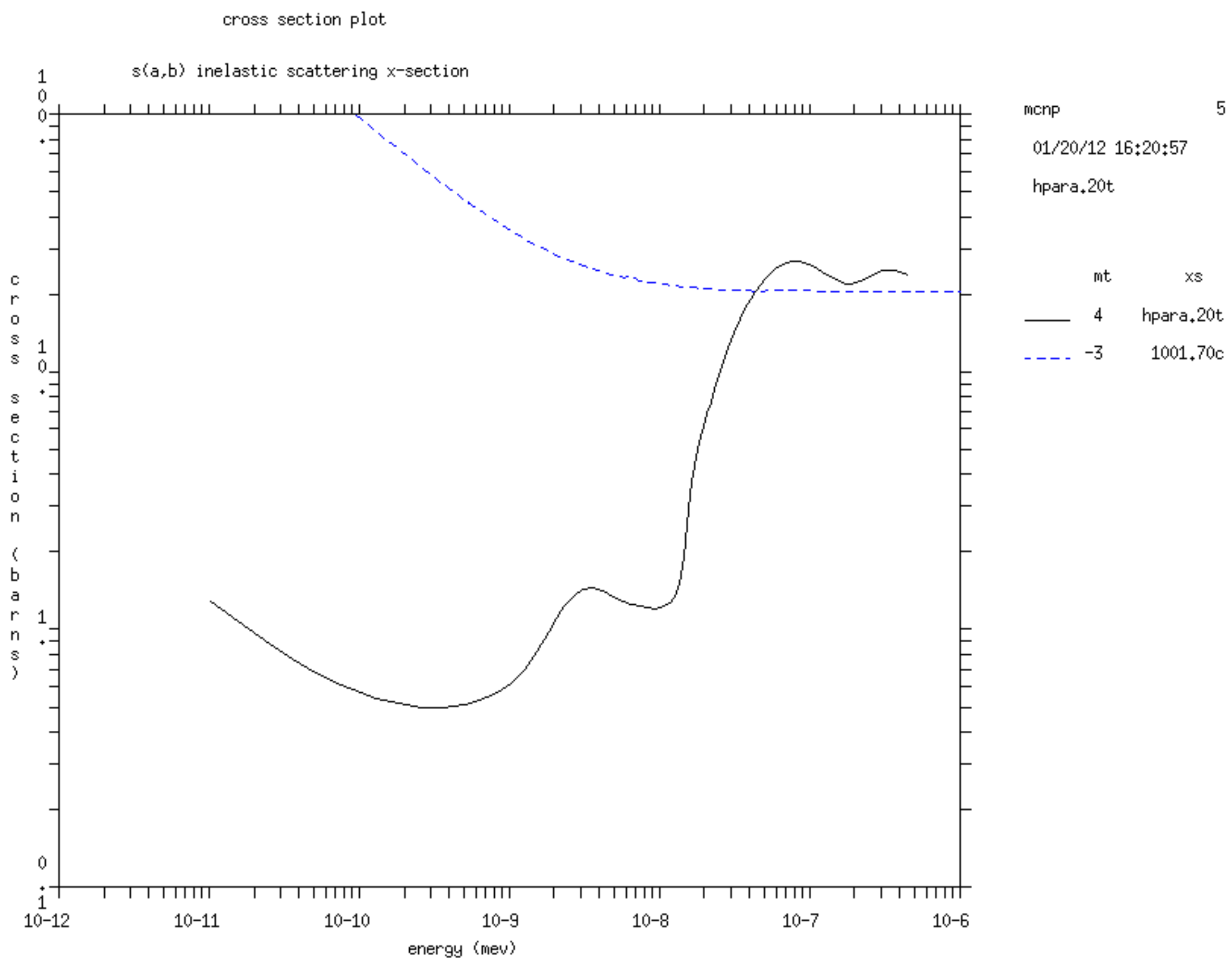


Figure 76: Plot of cross section for S(α, β) material: `hpara`

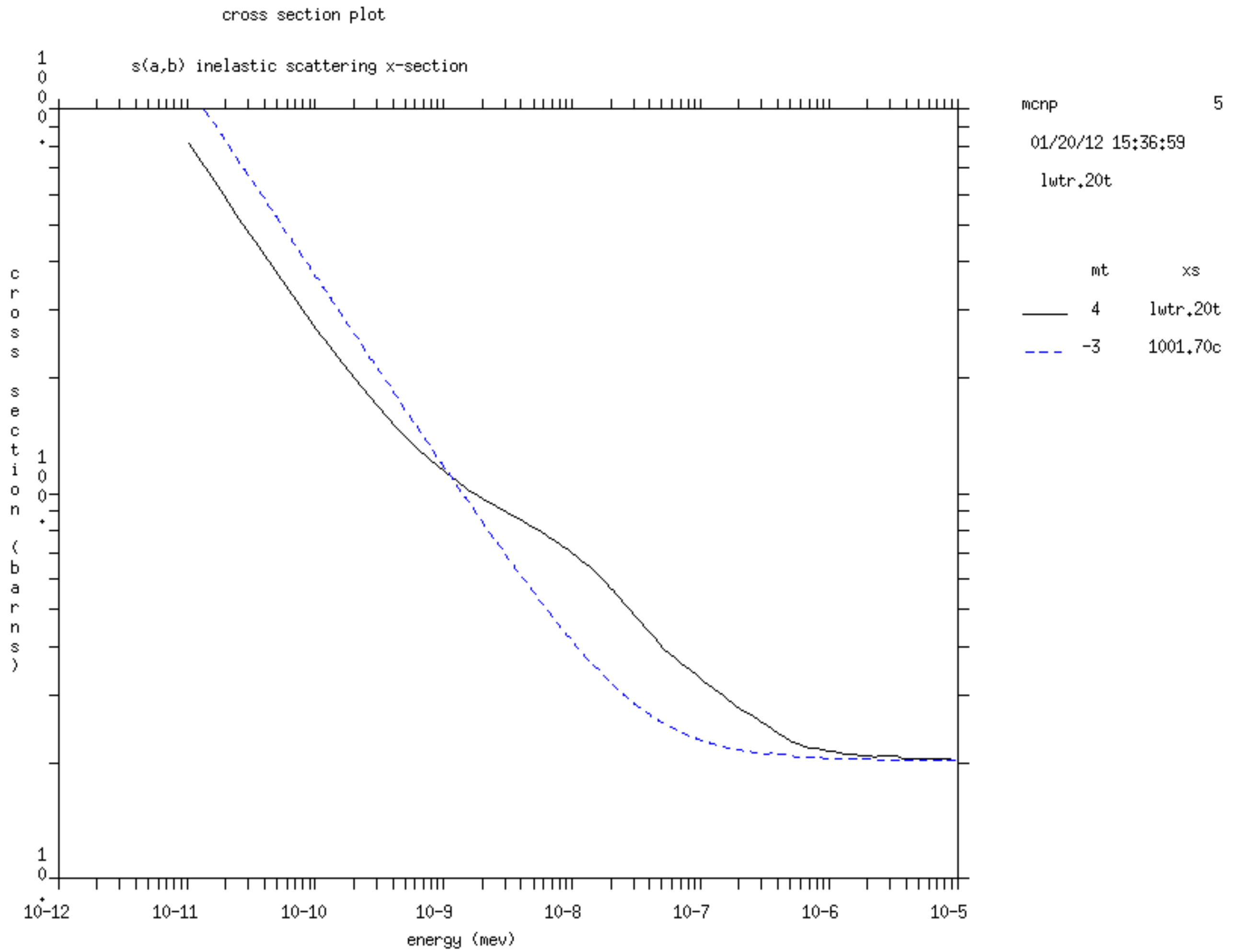


Figure 77: Plot of cross section for S(α, β) material: `lwtr`

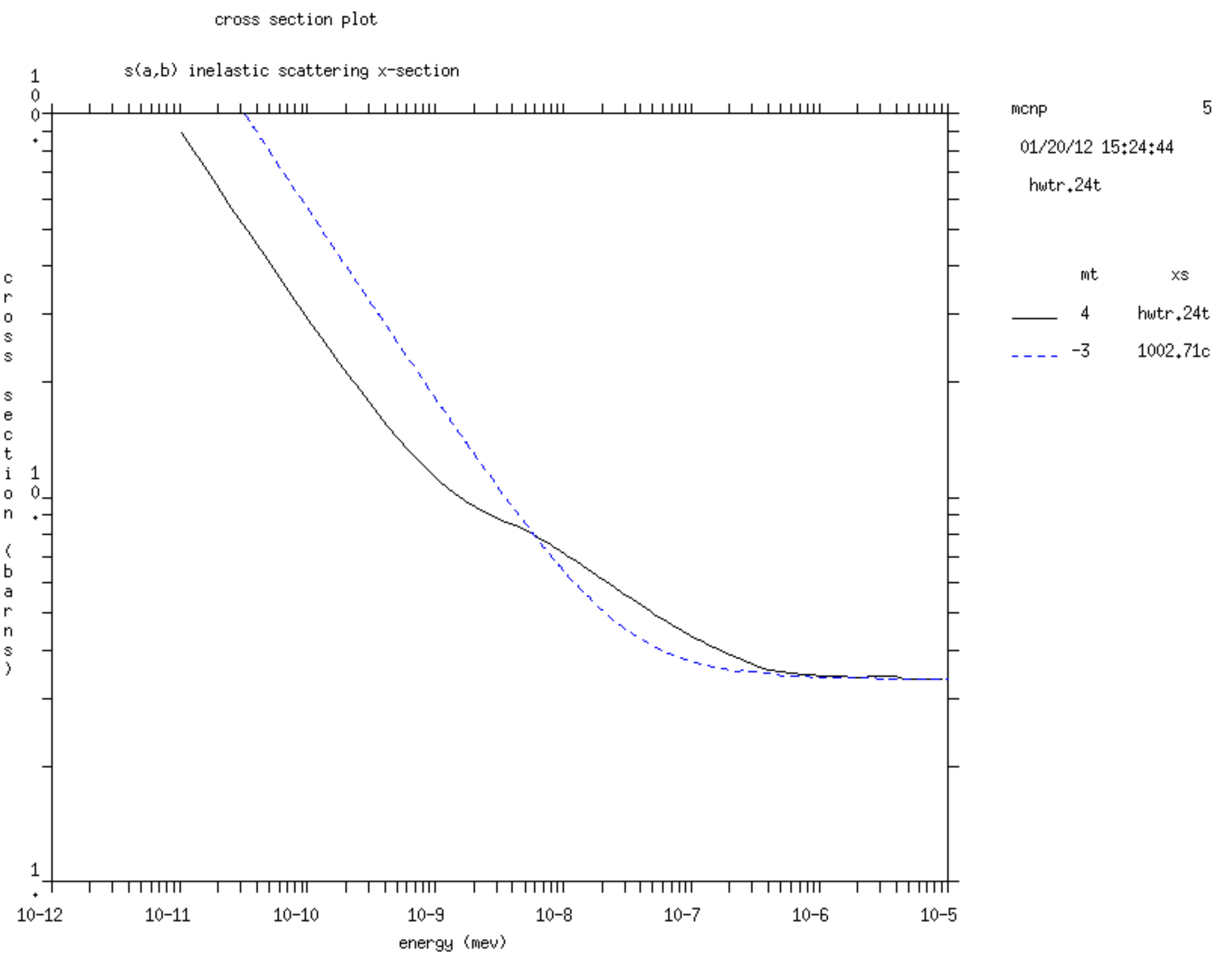


Figure 78: Plot of cross section for S(α, β) material: `hwtr`

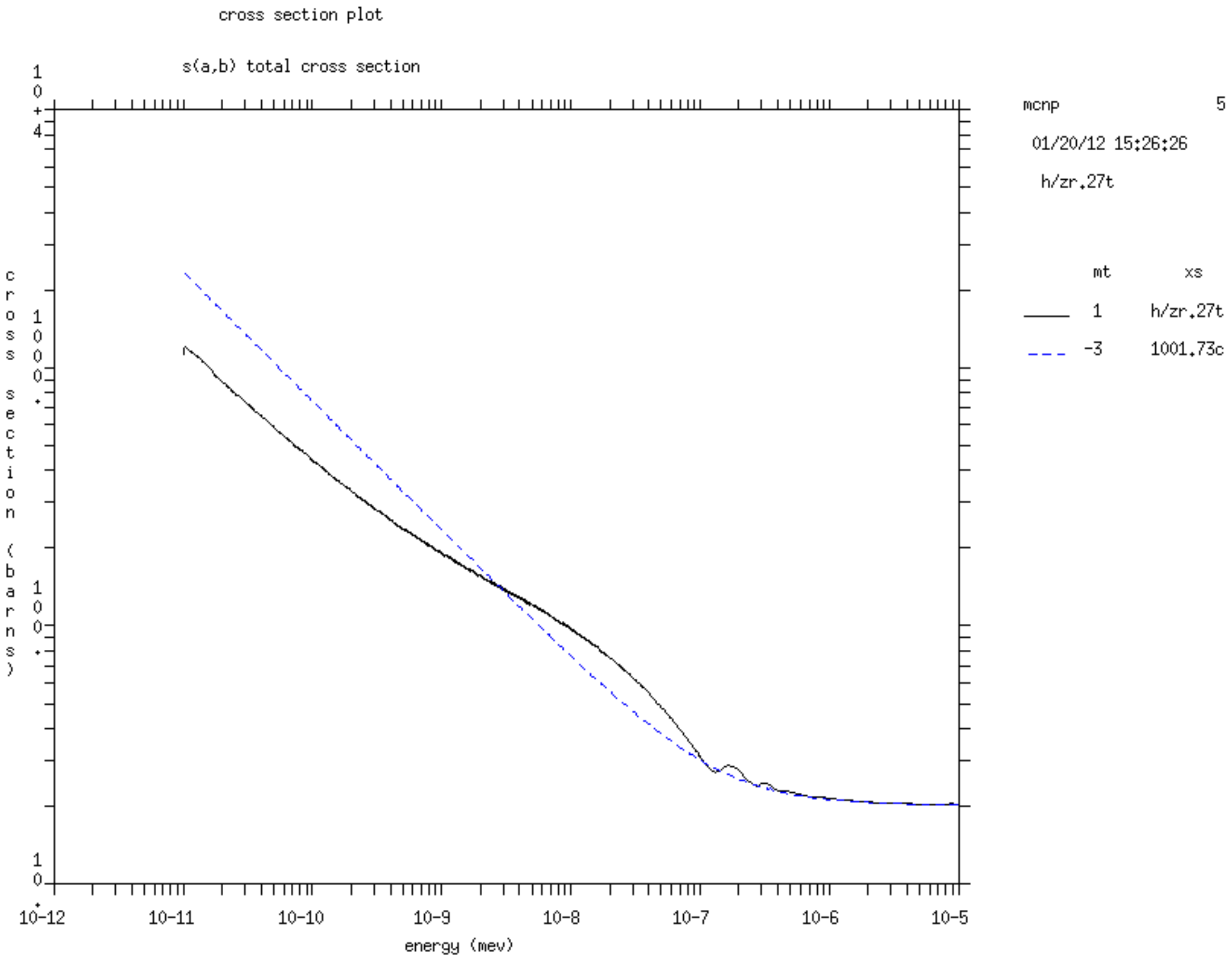


Figure 79: Plot of cross section for S(α,β) material: `hzr`

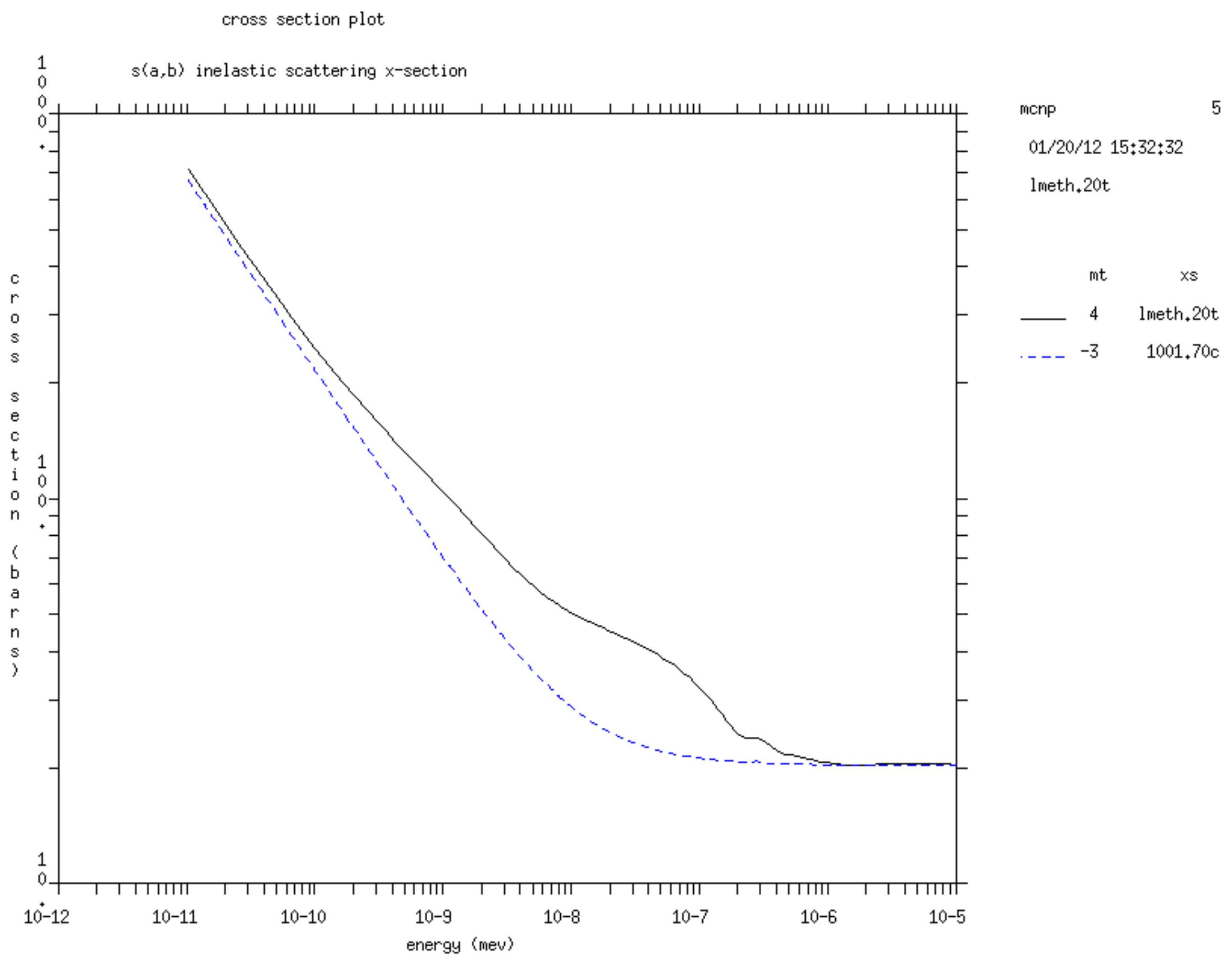


Figure 80: Plot of cross section for S(α,β) material: `lmeth`

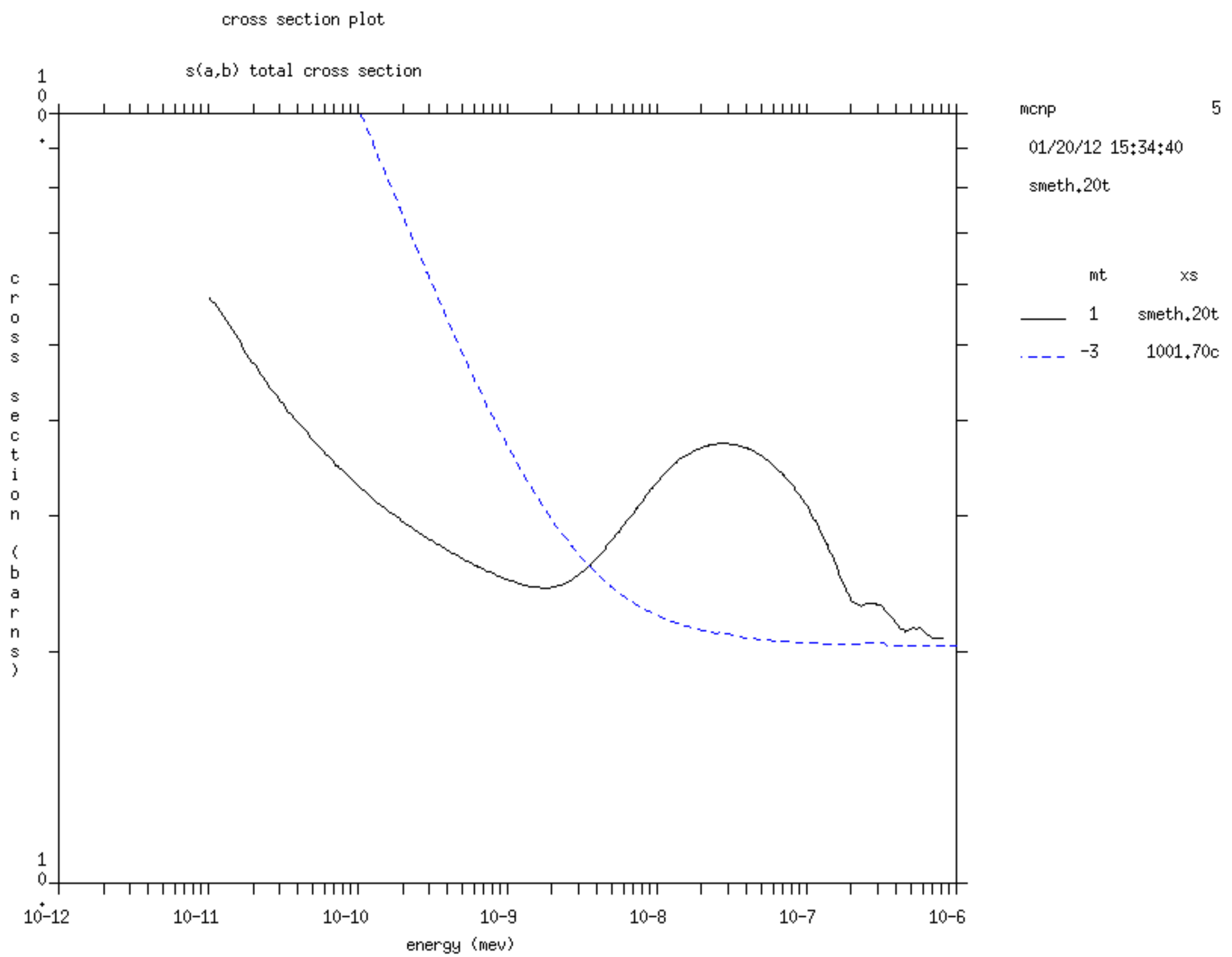


Figure 81: Plot of cross section for S(α, β) material: `smeth`

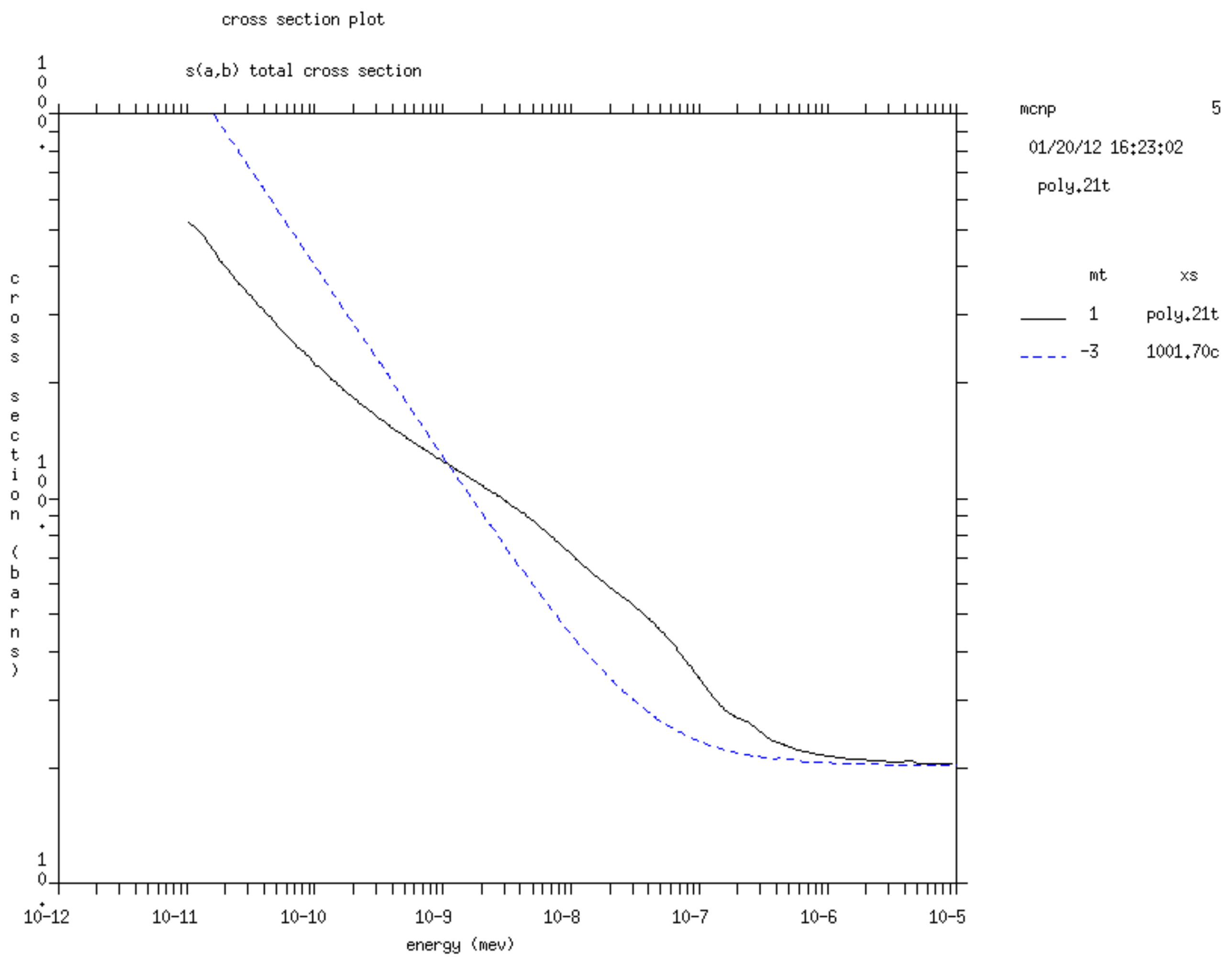


Figure 82: Plot of cross section for S(α, β) material: `poly`

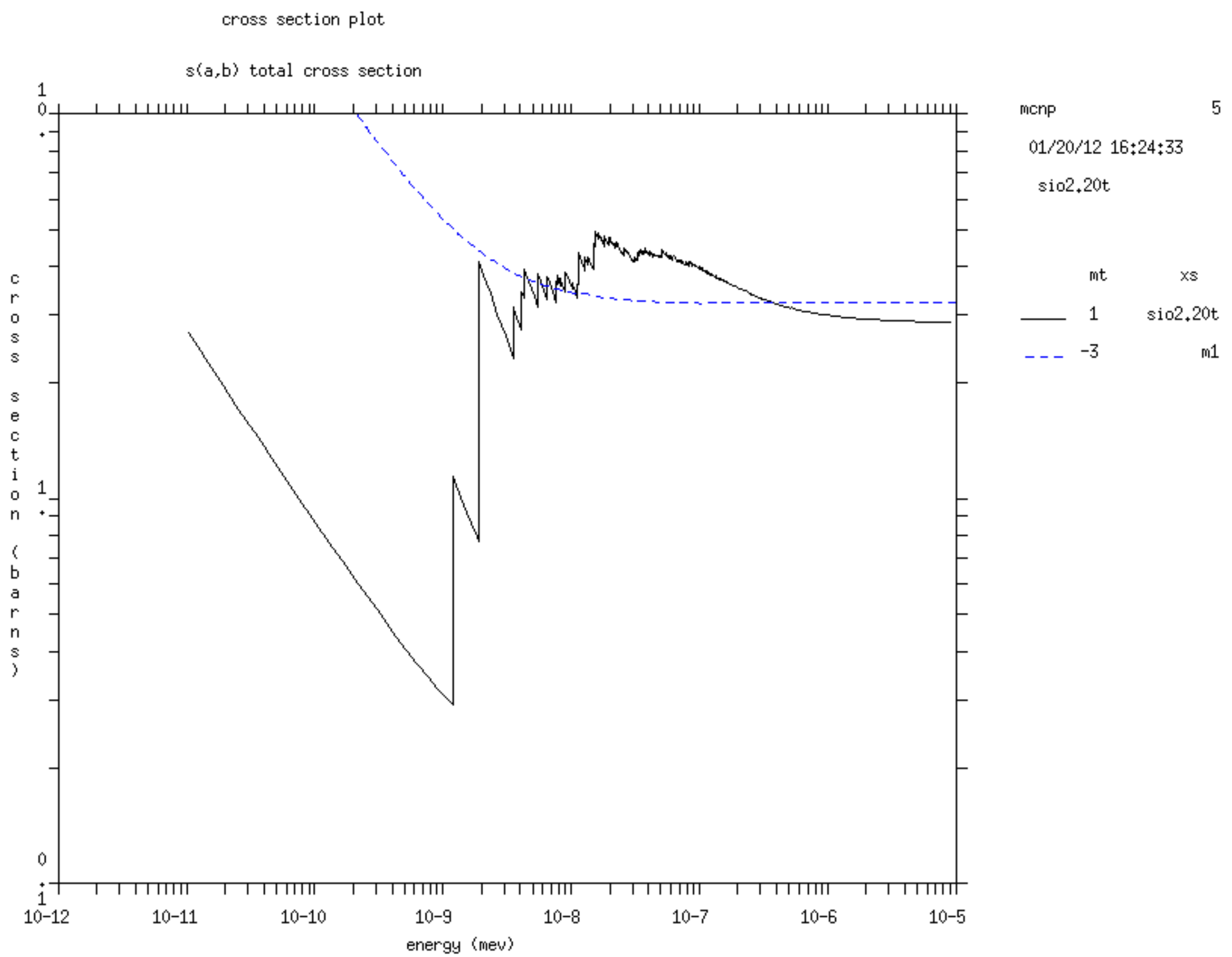


Figure 83: Plot of cross section for S(α, β) material: `si02`

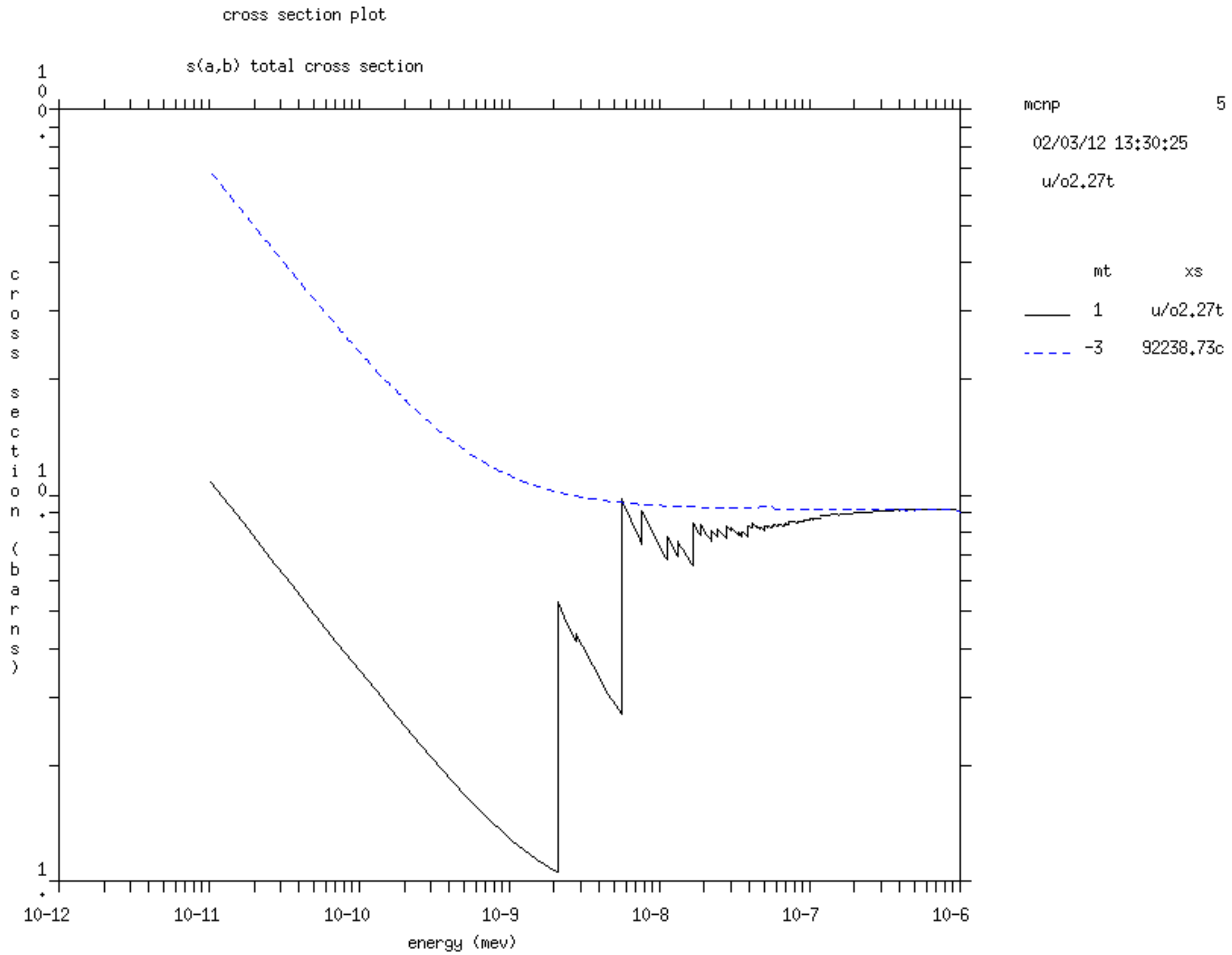


Figure 84: Plot of cross section for S(α, β) material: `uo2`

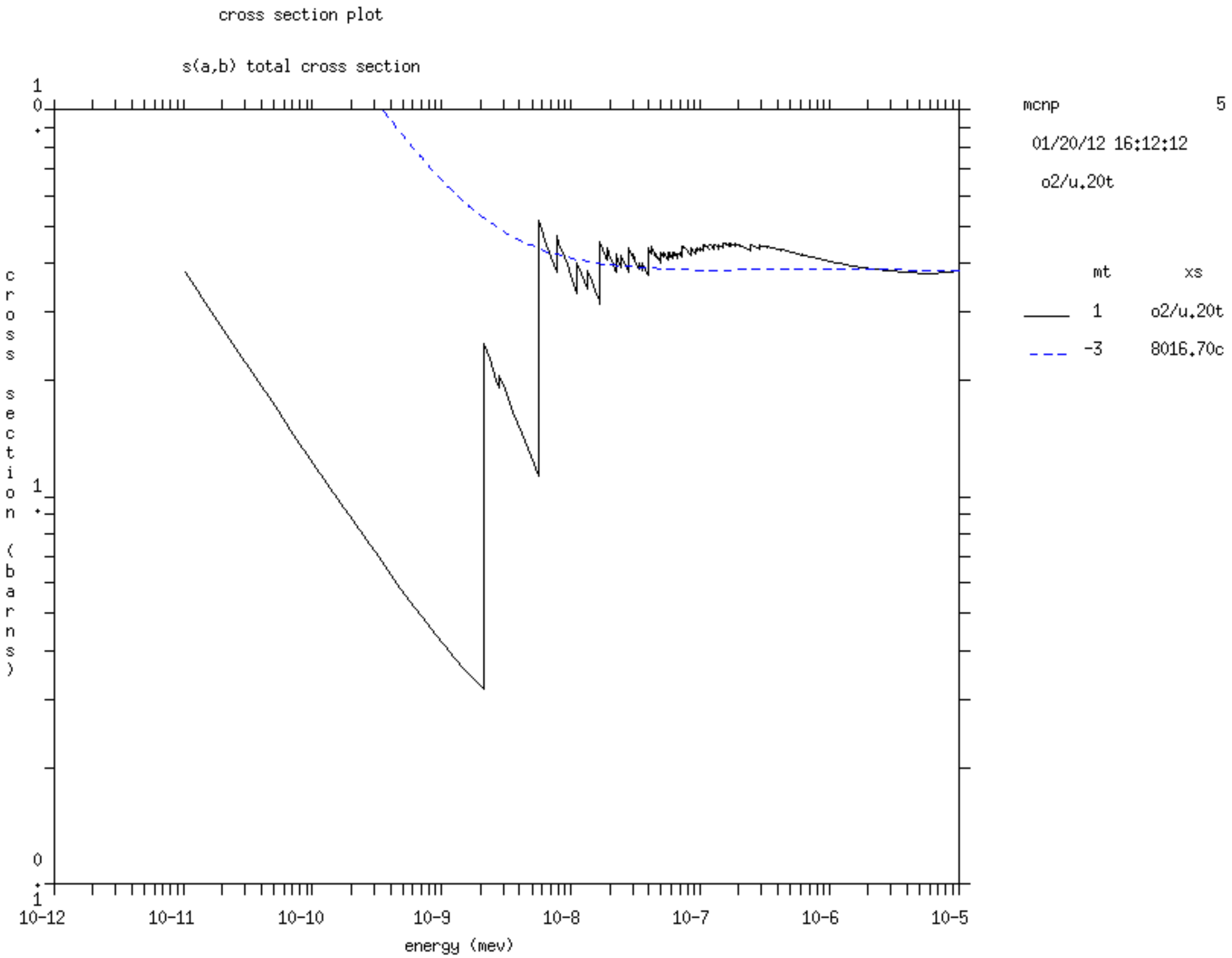


Figure 85: Plot of cross section for S(α, β) material: `o2u`