Comment to Unresolved Resonance Data in JENDL-3.3

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It is found out that the self-shielding correction for the unresolved resonances of many nuclei in JENDL-3.3 is too large around the upper energy of the unresolved resonance region. Probably the average reduced neutron widths or the upper energy of the unresolved resonance region in many nuclei in JENDL-3.3 are not appropriate. All the unresolved resonance data in JENDL-3.3 should be rechecked and revised by considering self-shielding correction in the next version.

1. Introduction

JENDL (JENDL-3.1 ~ JENDL-3.3) tends to use unresolved resonance data more than other evaluated nuclear data libraries. Not only heavy nuclei such as uranium, but also fission products such as niobium in JENDL include unresolved resonance data. However, these unresolved resonance data were not often used in neutronics calculations since the previous MCNP code Could not deal with unresolved resonance data so far.

At ND2001, the international conference on nuclear data for science and technology in 2001, it was pointed out that the leakage neutron spectrum from a niobium sphere of 0.5 m in radius with a 20 MeV neutron in the center, which was calculated with ANISN [1], MCNP4C [2] (this version can treat unresolved resonance data) and JENDL-3.3 [3], had a large strange bump around 100 keV as shown in Fig. 1, which originated from self-shielding correction for the unresolved resonance data.[4] It is considered that the unresolved resonance data of ^{93}Nb in JENDL-3.3 have some problems. Causes of this phenomenon are examined in this paper.

2. Self-shielding correction for unresolved resonance region of ^{93}Nb in JENDL-3.3

In order to check cross section data of ^{93}Nb in JENDL-3.3, the following multigroup libraries of pure ^{93}Nb in JENDL-3.3 were produced with self-shielding correction of the resolved resonance region;

1) multigroup library with self-shielding correction of the unresolved resonance region,
2) multigroup library without self-shielding correction of the unresolved resonance region.

The first multigroup library was generated with the TRANSX code [5] from MATXSLIB-J33 [6]. The second multigroup library were made with the TRANSX code from a MATXS file which was produced from JENDL-3.3 with the NJOY99.67 code [7] modified for JENDL-3.3 [6] in the same condition as MATXSLIB-J33 except for skipping self-shielding correction for unresolved resonance data. These multigroup libraries include response data such as elastic scattering cross section and (n,γ) reaction cross section. Since the unresolved resonance data are given for elastic scattering and (n,γ) reaction, self-shielding correction for the elastic scattering and (n,γ) cross section data was investigated in the unresolved resonance region. Figures 2 and 3 show the elastic scattering and (n,γ) cross section data deduced from the above multigroup libraries, respectively. It is found out that the elastic scattering cross sections of ^{93}Nb with self-shielding correction have a large ramp at the upper energy of the unresolved resonance region. The self-shielding correction of elastic scattering in the unresolved resonance region is too large

around the upper energy [100 keV] of the unresolved resonance region, while that for (n,γ) reaction is small. It is considered that this large self-shielding correction around the upper energy [100 keV] of the unresolved resonance region for elastic scattering causes the large bump around 100 keV in Fig. 1.

3. Unresolved resonance data of ^{93}Nb in JENDL-3.3

Then why is the self-shielding correction too large around the upper energy of the unresolved region of ^{93}Nb in JENDL-3.3? Next the unresolved resonance data, particularly average reduced neutron widths, of ^{93}Nb in JENDL-3.3 were checked. The average reduced neutron widths of ^{93}Nb in JENDL-3.3 are the following,

$\overline{\Gamma}^0_{n,l=0,j=4}$ = 0.0085323 eV at 7 ~ 100 keV,
$\overline{\Gamma}^0_{n,l=0,j=5}$ = 0.006981 eV at 7 ~ 100 keV,
$\overline{\Gamma}^0_{n,l=0,j=4}$ = 0.1832 eV at 7 ~ 100 keV,
$\overline{\Gamma}^0_{n,l=0,j=4}$ = 0.14249 eV at 7 ~ 100 keV,
$\overline{\Gamma}^0_{n,l=0,j=4}$ = 0.11658 eV at 7 ~ 100 keV,
$\overline{\Gamma}^0_{n,l=0,j=4}$ = 0.098646 eV at 7 ~ 100 keV.

The average reduced neutron widths are the same at both the lower energy [7 keV] and upper energy [100 keV] of the unresolved energy region. Probably the average reduced neutron widths are too large around the upper energy of the unresolved energy region. The larger average reduced neutron widths are required to reproduce average elastic scattering cross sections in the unresolved resonance region, but they case larger self-shielding correction.

Another view is also considered. The upper energy of the unresolved resonance region for all fission products is impartially set to 100 keV in JENDL. The upper energy [100 keV] of the unresolved resonance region may be too small.

The average reduced neutron widths and/or the upper energy of the unresolved resonance region of ^{93}Nb in JENDL-3.3 should be revised.

4. Other nuclei with unresolved resonance data in JENDL-3.3

Do other nuclei with unresolved resonance data in JENDL-3.3 have the same problem as ^{93}Nb? The elastic scattering cross sections with self-shielding correction for each nuclei [100 % abundance] with unresolved resonance data in JENDL-3.3 were deduced with TRANSX from MATXSLIB-J33 and plotted. As a result, it is found that elastic scattering cross sections in many nuclei have a similar strange ramp at the upper energy of the unresolved resonance region as shown in Figs. 4 and 5. Table 1 summarizes all the nuclei with unresolved resonance data in JENDL-3.3 and the nuclei which have the same problem as ^{93}Nb.

5. Summary

Causes for a strange bump around 100 keV appeared in calculated leakage neutron spectra from a niobium sphere of 0.5 m in radius with a 20 MeV neutron in the center were examined. As a result, it is found out that the self-shielding correction for the unresolved resonances is too large around the upper energy of the unresolved resonance region in ^{93}Nb of JENDL-3.3 . The following reasons for this problem are pointed out.

1) The average reduced neutron widths are larger around the upper energy of the unresolved resonance region.

and/or

2) The upper energy of the unresolved resonance region are smaller.

The above problem appears for many nuclei with unresolved resonance data in JENDL-3.3. All the unresolved resonance data in JENDL-3.3 should be rechecked and revised by considering self-shielding correction in the next version.

This time I focused on JENDL-3.3, but probably other nuclear data libraries such as ENDF/B-VI also have the same problem for unresolved resonance data as JENDL-3.3. In the near future unresolved resonance data of other nuclear data libraries will be investigated.

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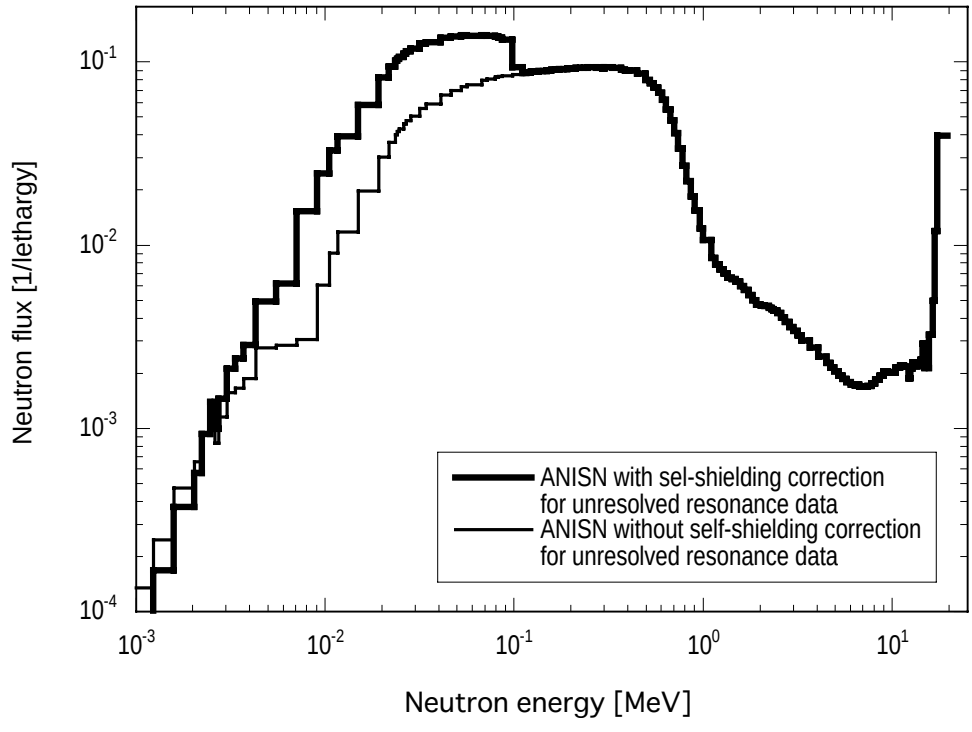
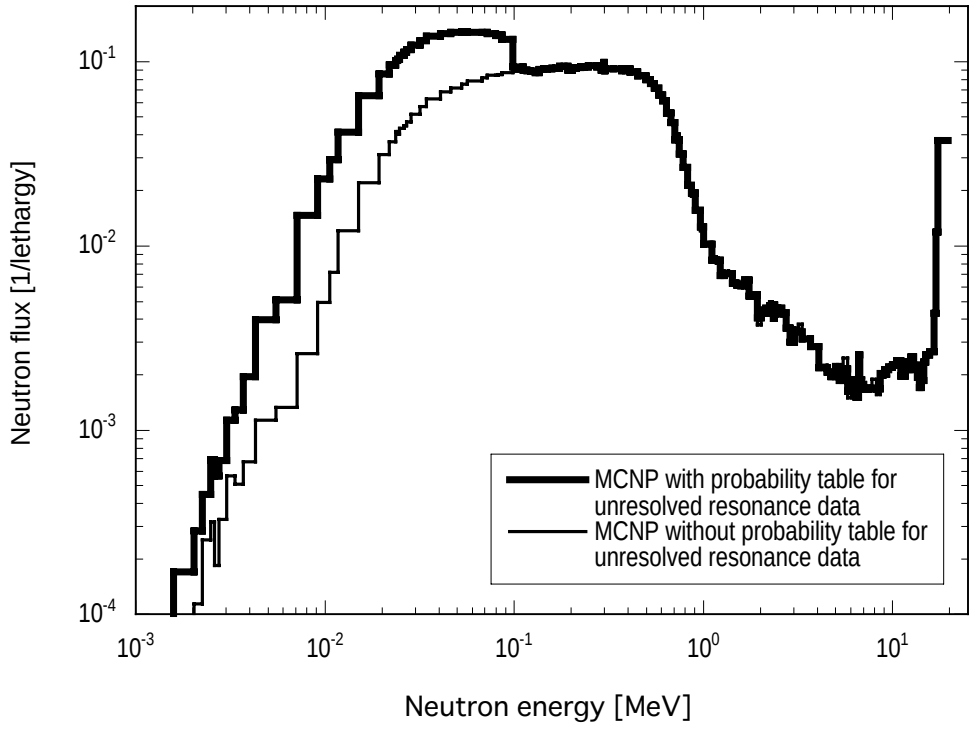
Table 1 Nuclei with unresolved resonance data in JENDL-3.3.

As-75, Se-74, -76, -77, -78, -79, **-80, -82,** Br-79, **-81, Kr-78, -80, -82, -83, -84, -85, Rb-85, -87, Sr-86, -87, -89, -90, Y-89, -91, Zr-91, -92, -93, -94, -95, Nb-93, -94, -95, Mo-92, -94, -95,-96, -97, -98, -100,** Tc-99, **Ru-96, -98, -99, -100, -101, -102, -103, -104, -106,** Rh-103, -105, **Pd-102, -104, -105, -106,** -107, **-108, -110,** Ag-107, -109, **Cd-106, -108, -110, -111, -112,** -113, **-114,-116,** In-113, -115, **Sn-112, -114, -115, -116, -117, -118, -119, -120, -122, -123, -124, -126, Sb-121, -123,** -124, **-125, Te-120, -122,** -123, **-124,** -125, **-126, -128, -130,** I-127, **-129, -131,** Xe-124, **-126, -128,** -129, **-130,** -131, **-132,-133, -134, -135,** Cs-133, -134, **-135, -136, -137,Ba-130,** -132, **-134,** -135, **-136,** -137, **-140,** La-138, **-139,** Ce-141, **-142, -144, Pr-141, -143, Nd-142, -143, -144, -145, -146,** -147, **-148, -150, Pm-147,** -148, **-149, Sm-144, -147, -148,** -149, **-150,** -151, **-152,** -153, **-154,** Eu-151, -152, -153, -154, -155, **-156, Gd-152, -154,** -155, **-156,** -157, **-158, -160,** Tb-159, Er-167, Hf-174, -176, -177, **-178,** -179, **-180,** Ta-181, Pa-231,-233, U-233, -234, -235, -236, -237, -238, Np-237, Pu-236, -238, -239, -240, -241, **-242,** Am-241, -242, -243, **Cm-240,** -241, **-242,** -243, **-244,** -245, **-246,** -247, **-248, -249, -250,** Bk-249, -250, Cf-249, **-250, -252**

Bold : Strange ramp appears in the elastic scattering cross section.



(a) ANISN calculation



(b) MCNP calculation

Fig. 1 Calculated leakage neutron spectra from a niobium sphere of 0.5 m in radius with a 20 MeV neutron in the center.

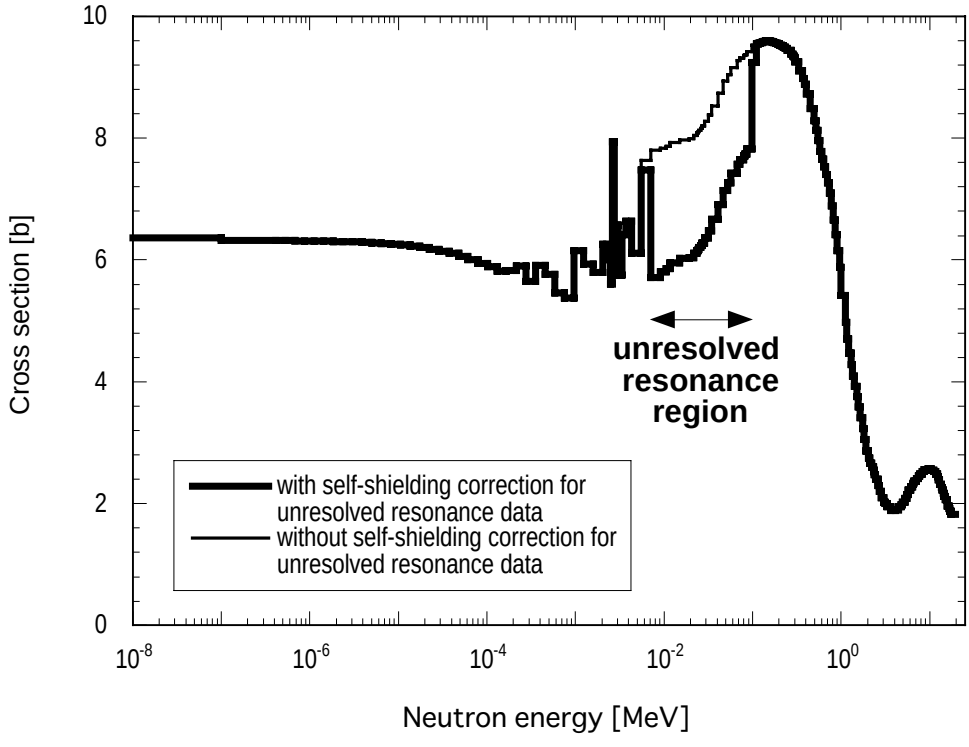


Fig. 2 Self-shielding corrected elastic scattering cross section of ^{93}Nb in JENDL-3.3.

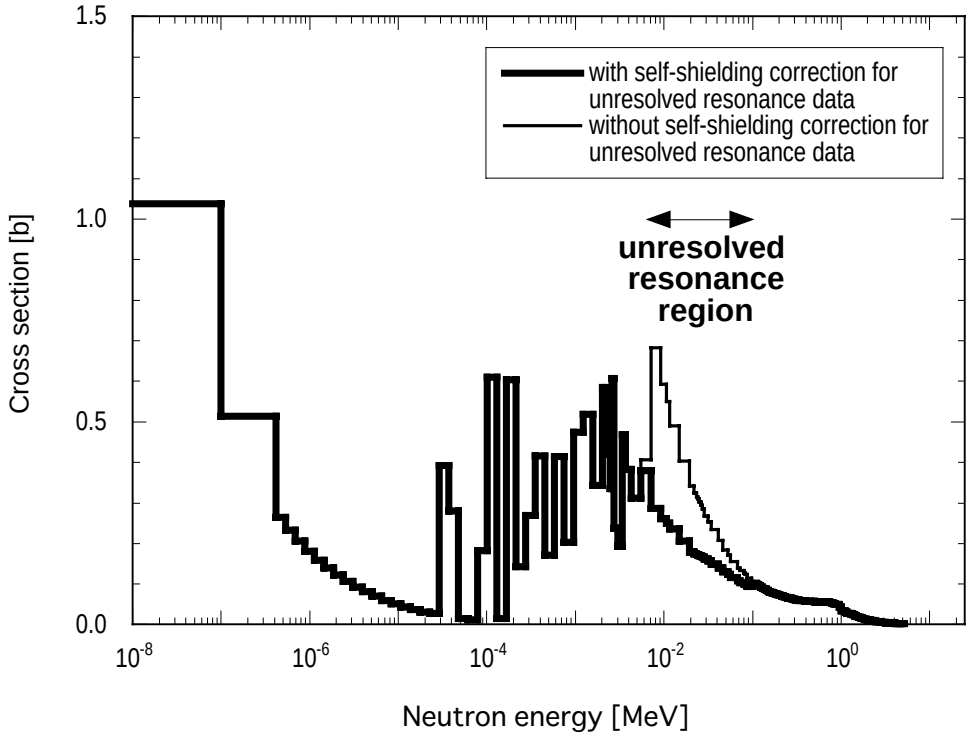


Fig. 3 Self-shielding corrected (n,γ) cross section of ^{93}Nb in JENDL-3.3.

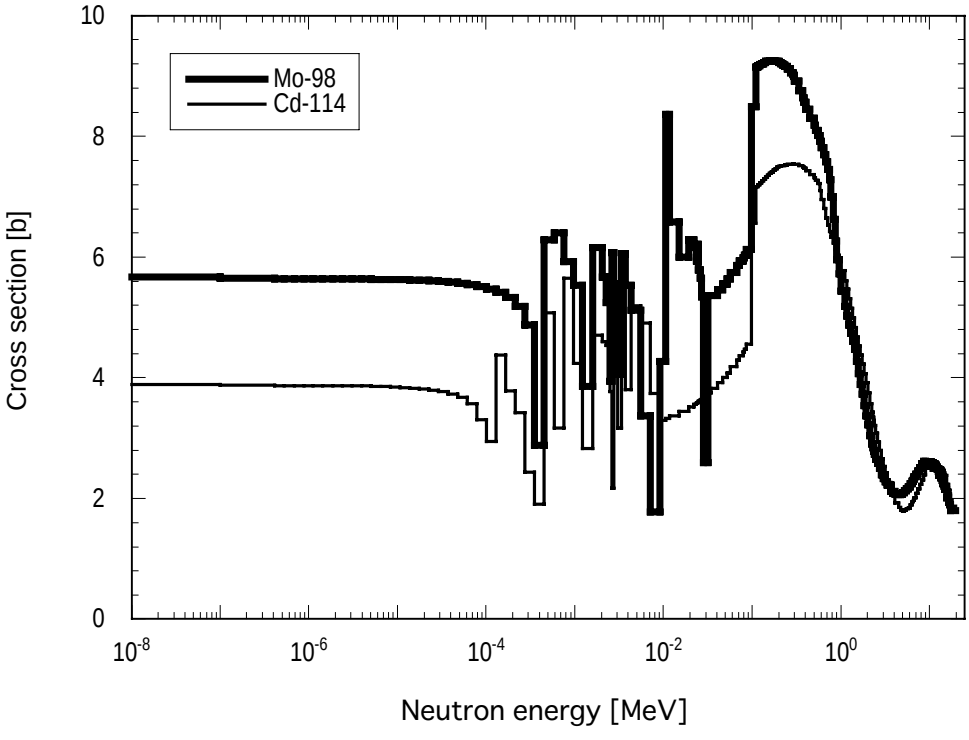


Fig. 4 Self-shielding corrected elastic scattering cross section of ^{98}Mo and ^{114}Cd in JENDL-3.3.

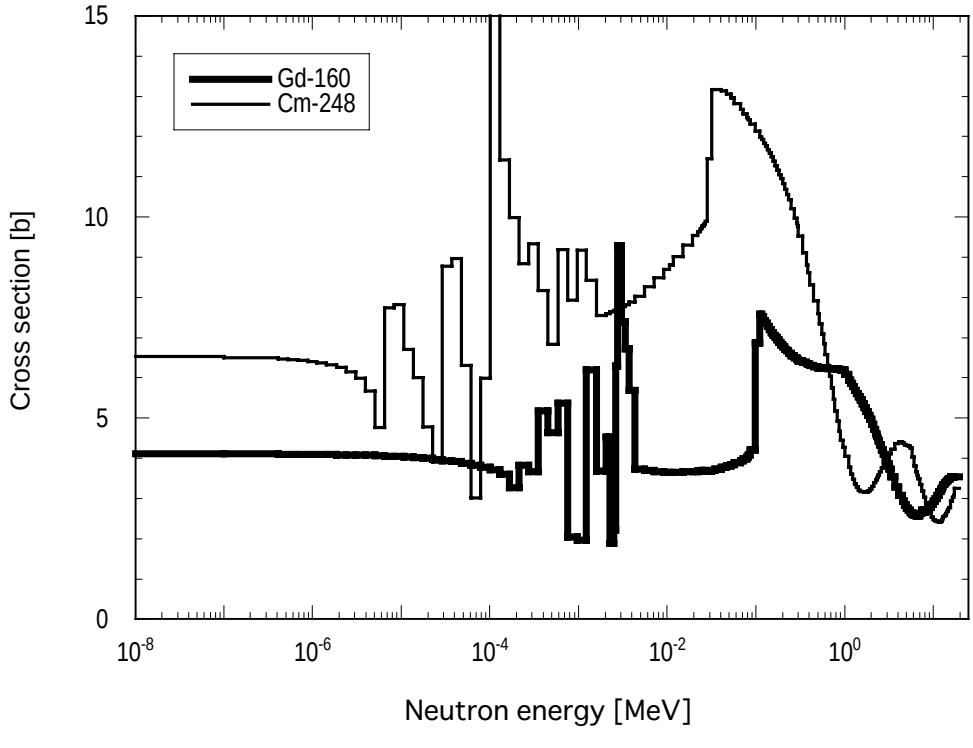


Fig. 5 Self-shielding corrected elastic scattering cross section of ^{160}Gd and ^{248}Cm in JENDL-3.3.