Some Comments to JSSTDL-300

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The effects of the problems (weighting function independent on Legendre order and f-table) of JSSTDL-300 for self-shielding correction were examined through a simple benchmark test. The following results were obtained;

1) The effect of inappropriate transport approximation originating from weighting function independent on Legendre order is large if the self-shielding correction is large.
2) The effect of incomplete f-table is dependent on each nucleus. Particularly it is very large for copper.

1. Introduction

The self-shielding correction in multigroup libraries is essential in order to obtain appropriate results in Sn calculations. The Bondarenko method [1] by using f-table is often used as the self-shielding correction and gives good results. Recently it is pointed out that the transport approximation with a weighting function (WF) dependent on Legendre order is important for appropriate self-shielding correction.[2]

JSSTDL-300 [3], a common multigroup library of neutron 300 groups and gamma 104 groups for shielding applications produced from JENDL-3.2 [4] with the PROF-GROUCH-G/B [5] code by Japanese Nuclear Data Committee, is widely applied in Japan. However, the self-shielding correction in JSSTDL-300 is probably inadequate due to the following two reasons.

1) The weighting function independent on Legendre order is adopted.
2) The f-table of elastic scattering is used as that of scattering matrix for elastic scattering.

Effects of the above problems are examined through a simple benchmark test in this paper.

2. Review of Transport Approximation

The transport approximation (consistent-P approximation) [6] for a group g with the Bondarenko method is the following approximation;

$$\sigma_{l\ g\leftarrow g}^{SN} = \sigma_{l\ g\leftarrow g}^{PN} - (\sigma_{ltg}^{PN} - \sigma_{0tg}^{PN}), \tag{1}$$

$$\sigma_{g}^{SN} = \sigma_{0tg}^{PN}, \tag{2}$$

$$\sigma_{ltg}^{PN} = \frac{\int_g \sigma_t(E) W_l(E) dE}{\int_g W_l(E) dE}, \tag{3}$$

$$\sigma_{l\ g\leftarrow g}^{PN} = \frac{\int_g dE' \int_g dE \sigma_l(E' \to E) W_l(E')}{\int_g dE' W_l(E')}, \tag{4}$$

$$W_l(E) = \frac{C(E)}{[\sigma_0 + \sigma_t(E)]^{l+1}}, \tag{5}$$

where *PN* means PN cross sections, *SN* means SN cross sections, *l* is Legendre order, $\sigma_t(E)$ is the energy-dependent total cross section, $\sigma_l(E' \rightarrow E)$ is the energy-dependent scattering cross section, $W_l(E)$ is a weighting function, $C(E)$ is a smooth function of neutron energy E, and s_0 is the background cross section. It should be noted that the denominator of the weighting function in Eq. (5) is not $(\sigma_0+\sigma_t\,(E))$, but $(\sigma_0+\sigma_t\,(E))^{l+1}$, i.e. dependent on Legendre order. Thus the term in parentheses in the right side of Eq. (1) is not always zero, though it is zero if the weighting function is independent on Legendre order. The NJOY [7] and TRANSX [6] code system adopts the following weighting function,

$$W_0(E) = \frac{C(E)}{[\sigma_0 + \sigma_t(E)]}, \qquad (6)$$

$$W_{l\geq 1}(E) = \frac{C(E)}{[\sigma_0 + \sigma_t(E)]^2}. \qquad (7)$$

Reference 2 shows that the transport approximation with this weighting function gives appropriate self-shielding correction, though the weighting function is different from Eq. (5) for Legendre order of ≥ 2.

The weighting function of Eq. (6) is used independently on Legendre order in JSSTDL-300. Hence the term in parentheses in the right side of Eq. (1) is automatically zero. As described later, this is not appropriate.

If the self-shielding effect is small, the term in parentheses in the right side of Eq. (1) is very small, which lead to no problem, since $W_l(E)$ is a smooth function of neutron energy E and σ^{PN}_{ltg} is almost the same as σ^{PN}_{0tg}.

3. Simple Benchmark Test

A simple benchmark test was carried out in order to examine whether the self-shielding correction in JSSTDL-300 is appropriate or not. The calculation model of this benchmark test consisted of a natural aluminum, iron, nickel or copper sphere of 1 m in radius with a 20 MeV neutron source in the center. Neutron spectra and integrated neutron fluxes in the sphere were calculated with the Sn code ANISN [8]. The following multigroup libraries of neutron 175 groups (VITAMIN-J [9]) with self-shielding correction were adopted for ANISN,

1) multigroup library generated from JSSTDL-300 (abbreviation : JSSTDL),
2) multigroup library with the weighting function of Eq. (6) independent on Legendre order generated from JENDL-3.2 by using the NJOY99.67 and TRANSX codes (abbreviation : NJOY, $WF_{L\geq 1}=WF_{L=0}$),
3) multigroup library with the weighting function of Eqs. (6) and (7) dependent on Legendre order and no transport approximation (the term in parentheses in the right side of Eq. (1) is neglected) generated from JENDL-3.2 by using the NJOY99.67 and TRANSX codes (abbreviation : NJOY, $WF_{L\geq 1}\neq WF_{L=0}$, No transport approximation)],
4) multigroup library with the weighting function of Eqs. (6) and (7) dependent on Legendre order and transport approximation [Consistent-P] generated from JENDL-3.2 by using NJOY99.67 and TRANSX (abbreviation : NJOY, $WF_{L\geq 1}\neq WF_{L=0}$, Transport approximation [consistent-P]).

The difference between ANISN calculations with the fist and second libraries indicates the effect due to incomplete f-table in JSSTDL-300. That between ANISN calculations with the second and third libraries corresponds to the effect due to weighting function only except for transport approximation. That between ANISN calculations with the third and fourth libraries reflects the effect due to transport approximation. These calculated results were compared with those obtained with MCNP4C [10] and FSXLIB-J3R2 [11] generated from JENDL-3.2.

Figure 1 shows calculated neutron spectra at 10 cm from the center in aluminum, iron, nickel and copper spheres. Since the self-shielding effect is small in aluminum, all the ANISN calculations for the aluminum sphere show almost the same results, which agree with the MCNP calculation well. On the contrary, the ANISN calculations are different each other for the iron, nickel and copper spheres.

In order to investigate the difference among the ANISN calculations in details along the distance from the center of the sphere, ratios of integrated neutron fluxes calculated with ANISN to those with MCNP are plotted in Figs. 2 ~ 5 for aluminum, iron, nickel and copper spheres, respectively. All the ANISN calculations for the aluminum sphere show almost the same results up to 90 cm from the center, which agree with the MCNP calculation within 30 %. The effect of the inadequate f-table in JSSTDL is small in iron, while it is large for integrated neutron flux from 10 to 100 keV in the nickel sphere and neutron fluxes below 1 MeV in the copper sphere. The effect of the weighting function not including transport approximation is small. The effect of the transport approximation is large in the iron, nickel and copper spheres. The ANISN calculations with the fourth multigroup library, which adopted appropriate transport approximation, agree with the MCNP calculations best. However, the agreement between the ANISN calculation with the fourth multigroup library and the MCNP calculation is not so good in the copper sphere. The reason of this disagreement is probably due to group structure as described in Ref. 12.

The P_1 coefficients of in-group scattering matrix of the four multigroup libraries are plotted in Fig. 6 for natural aluminum, iron, nickel and copper. It is demonstrated that they are very different between JSSTDL and the fourth multigroup library, which leads to the difference of neutron fluxes in Figs. 2 ~ 5.

4. Summary

The effects of the below problems of JSSTDL-300 for self-shielding correction were examined through a simple benchmark test.

1) The weighting function independent on Legendre order is adopted.
2) The f-table of elastic scattering is used as that of scattering matrix for elastic scattering.

The following results were obtained.

1) The effect of inappropriate transport approximation originating from a weighting function independent on Legendre order is large if the self-shielding correction is large.
2) The effect of incomplete f-table depends on each nucleus. Particularly it is very large for copper.

The JSSTDL-300 library should be modified for the weighting function (appropriate transport approximation) and f-table.

Acknowledgments

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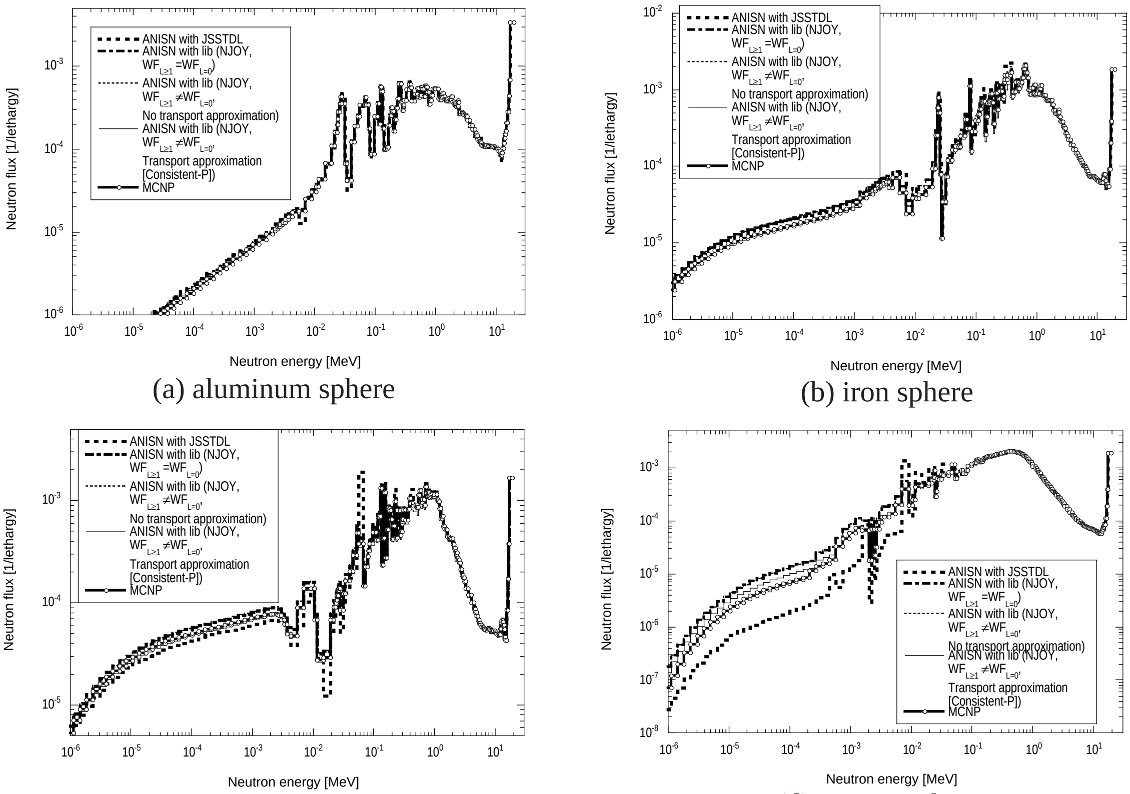


(a) aluminum sphere (b) iron sphere

(c) nickel sphere (d) copper sphere

Fig. 1 Calculated neutron spectra at 10 cm from the center.

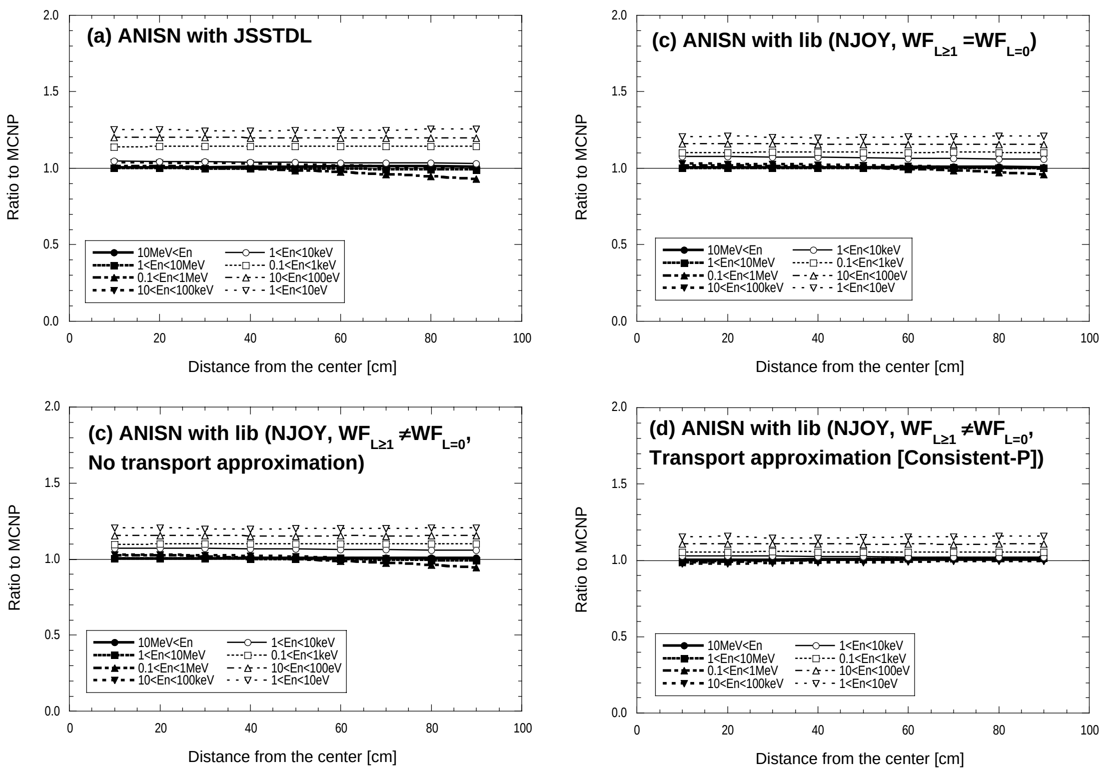


Fig. 2 Ratio of integrated neutron fluxes calculated with ANISN to those with MCNP in aluminum sphere.

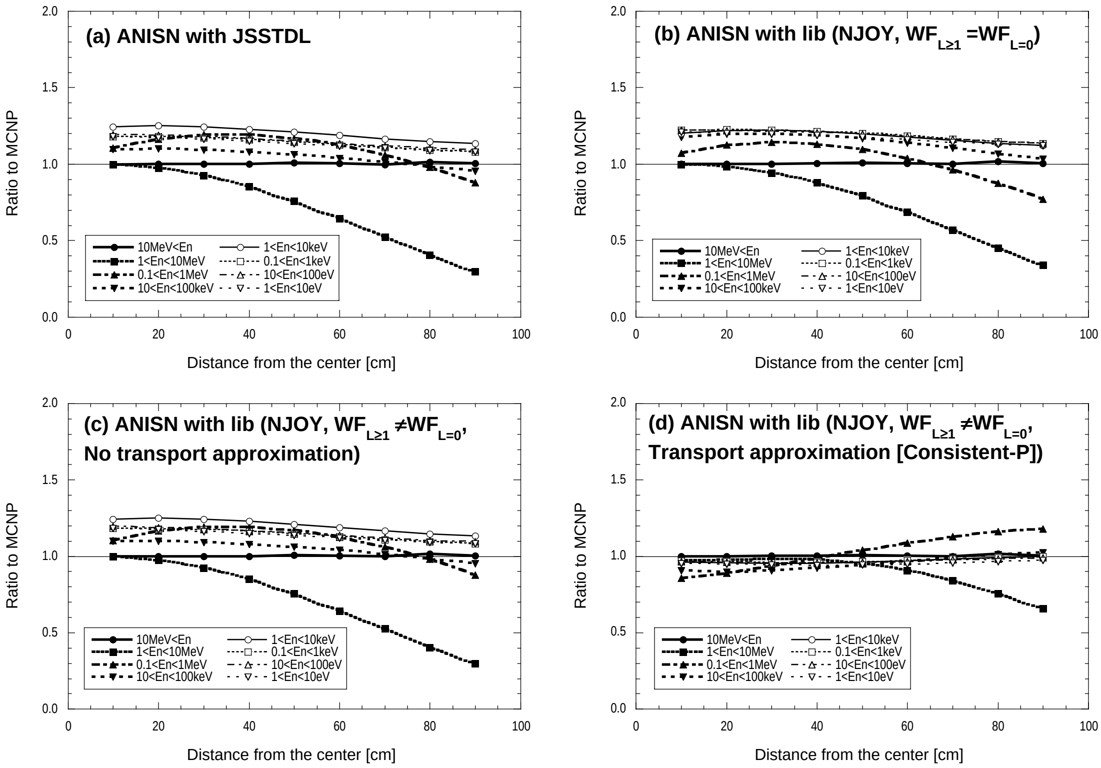


Fig. 3 Ratio of integrated neutron fluxes calculated with ANISN to those with MCNP in iron sphere.

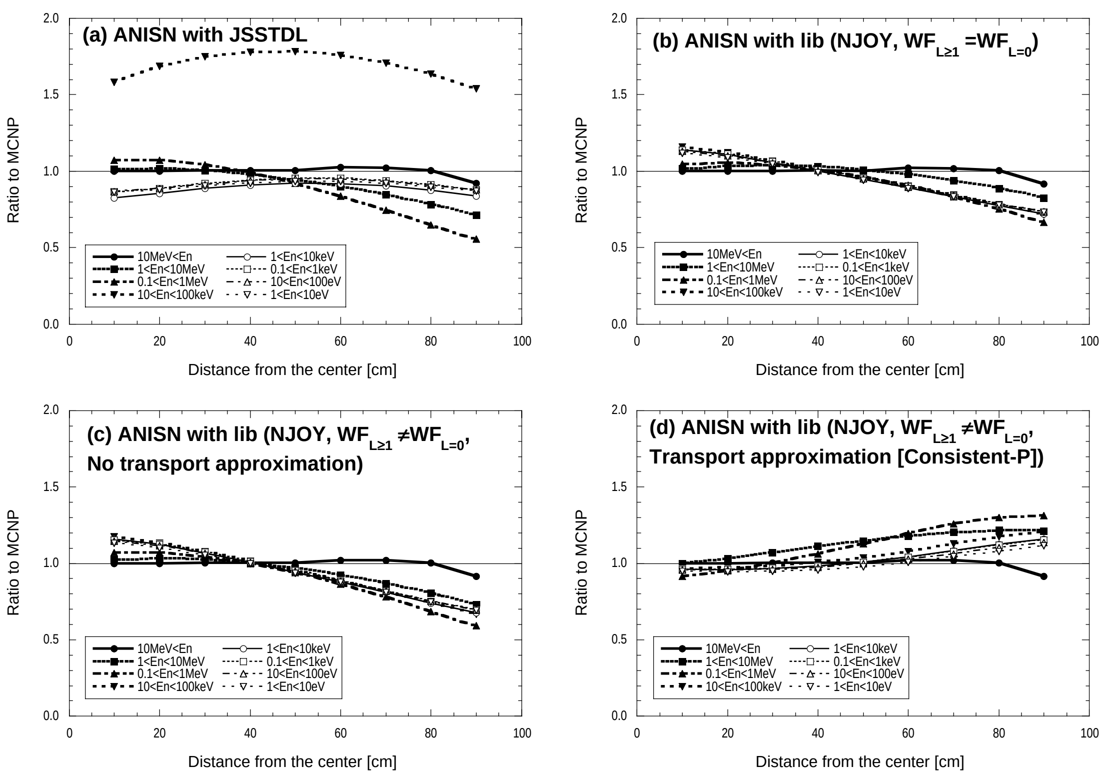


Fig. 4 Ratio of integrated neutron fluxes calculated with ANISN to those with MCNP in nickel sphere.

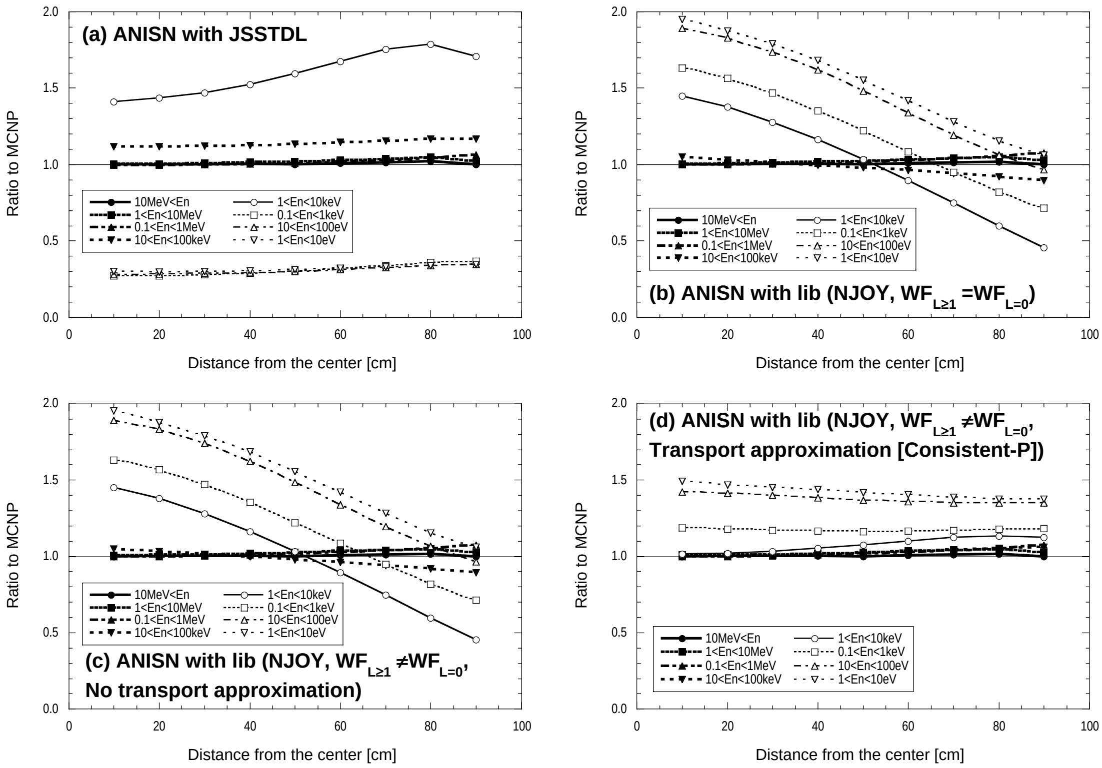
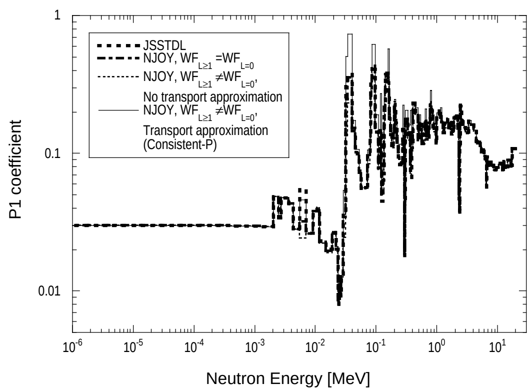
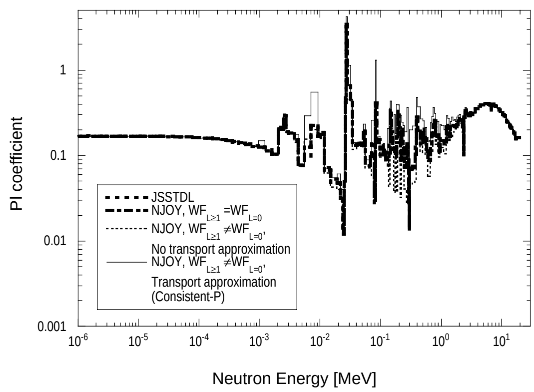


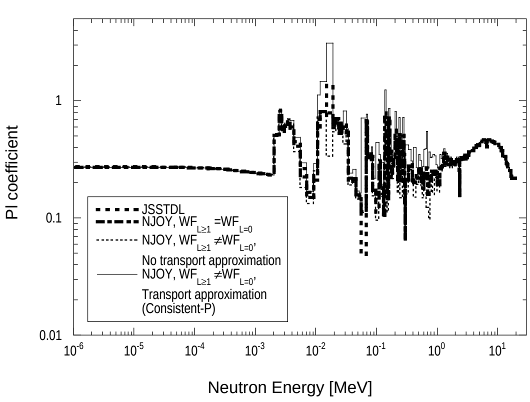
Fig. 5 Ratio of integrated neutron fluxes calculated with ANISN to those with MCNP in copper sphere.



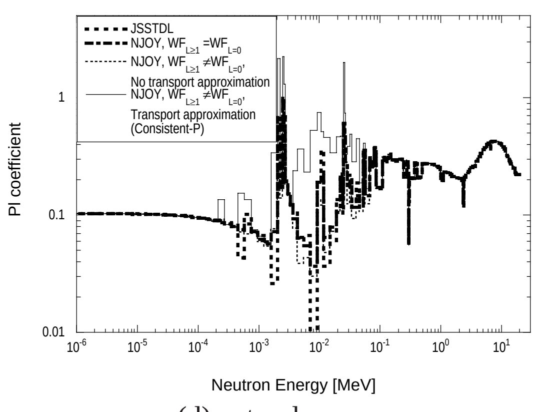
(a) natural aluminum



(b) natural iron



(c) natural nickel



(d) natural copper

Fig. 6 P_1 coefficients of in-group scattering matrix of the four multigroup libraries.