A Preliminary Study on a Method for Generating Self-shielded Multi-group Cross Sections in an Unresolved Resonance Region

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1. Introduction

The unresolved resonance region (URR) begins at an energy where it is difficult to measure individual resonances and extends to an energy where the effects of fluctuations in the resonance cross sections become unimportant for practical calculations.

The fluctuations in the cross section in this energy range lead to important effects, such as self-shielding, in some applications (e.g., fast reactors).

For a ^{239}Pu, URR is 2.5keV~30keV and its range is shown with a total cross section in Fig. 1.

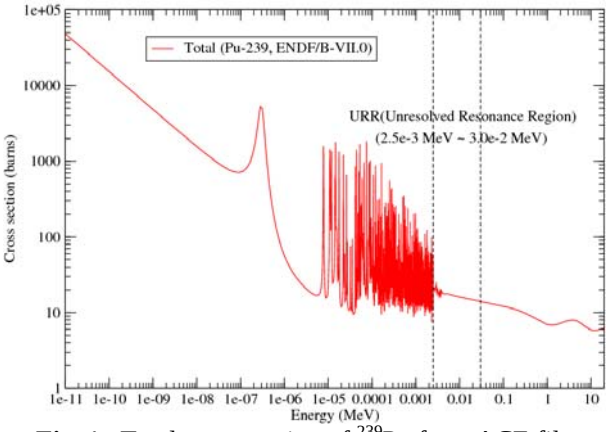

Fig. 1. Total cross section of ^{239}Pu from ACE file (ENDF/B-VII.0).

In ENDF-format evaluations, this "unresolved range" is handled by giving average values for the resonance spacing and the various partial widths, together with their probability distributions. These unresolved resonance parameters are used two ways in view of transport solver.

For a deterministic method, the self-shielded multi-group cross sections are generated by UNRESR and GROUPR modules of NJOY code [1] which use Bondarenko method.

For a Monte Carlo method, so-called Bondarenko method is not very useful for continuous-energy Monte Carlo codes like MCNP [2]. The natural approach for treating unresolved-resonance self-shielding for Monte Carlo codes is the "Probability Table" method. The PURR module produces probability tables that can be used in versions of MCNP from 4B on to treat unresolved-resonance self-shielding.

2. Method and results

2.1 Method

In this paper, we present a method to generate self-shielded multi-group cross sections in URR for easy numerical integration.

Main idea is that, in URR, we generate statistical resonances on given energy points by random sampling based on the probability table and combine these statistical resonances with smooth cross sections.

Figure 2 shows two sets of pointwise cross sections; smooth cross section (black color) and combined cross section (smooth + statistical resonance, red color).

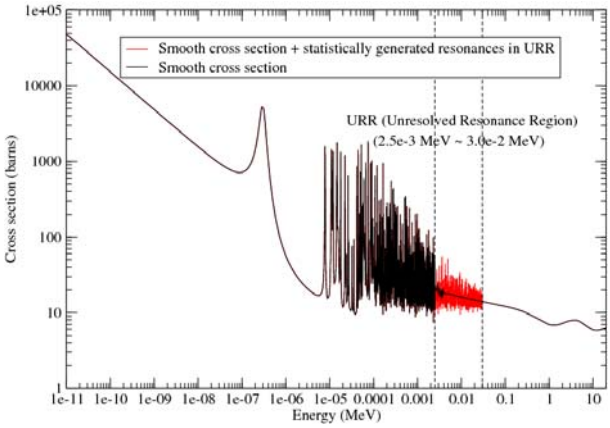

Fig. 2. Two sets of pointwise cross sections with/without statistically generated resonances in URR.

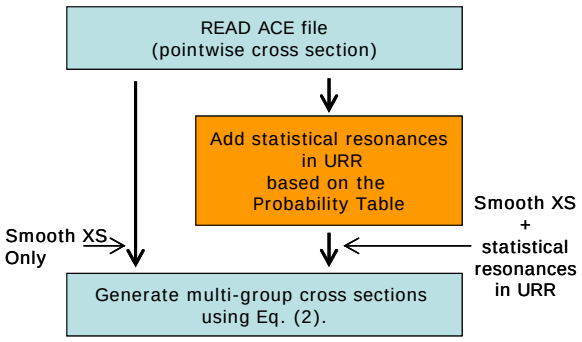

Fig. 3. Diagram of this method.

The self-shielded multi-group cross sections are determined by the numerical integration of pointwise cross sections based on the NR approximation [3] as

$$\bar{\sigma}_{xg}^{i} = \int_{\Delta E_g} \sigma_x^i(E)\frac{\Sigma_p(E)}{\Sigma_t(E)}dE \Big/ \int_{\Delta E_g} \frac{\Sigma_p(E)}{\Sigma_t(E)}dE \quad (1)$$

where

$\overline{\sigma}^{i}_{xg}$: effective cross section of group g for reaction type x of isotope i,

$\Sigma_t(E)$: total macroscopic cross sectons of mixture,

$\Sigma_p(E)$: potential cross sections.

Since the potential cross sections, $\Sigma_p(E)$, are almost constant in the resonance energy range, Eq. (1) is simplified to

$$\overline{\sigma}^{i}_{xg} = \int_{\Delta E_g} \sigma^{i}_{x}(E)\frac{1}{\Sigma_t(E)}dE \Big/ \int_{\Delta E_g}\frac{1}{\Sigma_t(E)}dE. \quad (2)$$

With pointwise cross sections included statistical resonances, numerical integration is performed with Eq. (2) to generate self-shielded multi-group cross sections.

2.2 Results

As a first step, we tested our method to generate multi-group total cross section of 94-Pu-239. The used parameters are listed in Table I. 10,000 energy points in URR (2.5keV~30keV) are added and atomic density for macroscopic total cross section is set to 1.0. For multi-group structure, 25 groups are set in URR.

Table I: Parameters for numerical test

Information of nuclide	
Name	94-Pu-239
Temperature (K)	293.6
URR range	2.5e-3 MeV ~ 3.0e-2 MeV
Library	ENDF/B-VII.0
Atomic density (atoms/b-cm)	1.0
URR data	
Number of energy points in URR for generating statistical resonances	10,000
Group structure data	
Energy group range (MeV) / Number of energy group	1.0e-3 ~ 2.5e-3 / 10 2.5e-3 ~ 3.0e-2 / 25 3.0e-2 ~ 5.0e-2 / 10

Generated multi-group total cross sections are compared in Fig. 4. Black and red ones are generated by numerical integration with smooth cross section and smooth + statistically generated resonances in URR, respectively.

In URR (between two dashed line), total cross section with statistical resonances gives less cross section than that with smooth cross section only. In the outside of URR, they give same results since they use identical pointwise cross sections.

To check the results, we compared it with PDF plots which can be downloaded from LANL T2 site [4]. This may not be an appropriate way. However, the tendency that self-shielded cross section gives less value than that of smooth or infinite diluted cross sections can be confirmed.

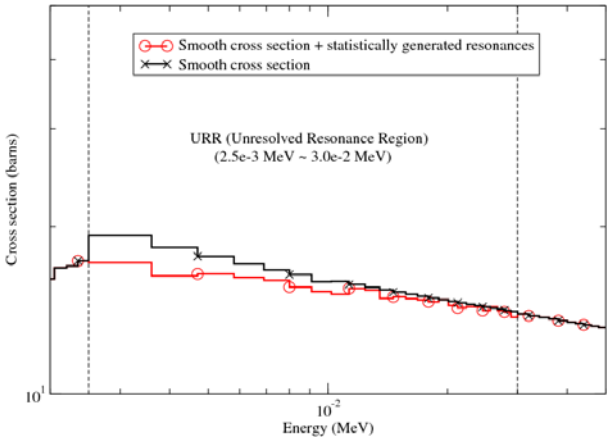

Fig. 4. Comparisons of generated self-shielded multi-group total cross sections of ^{239}Pu.

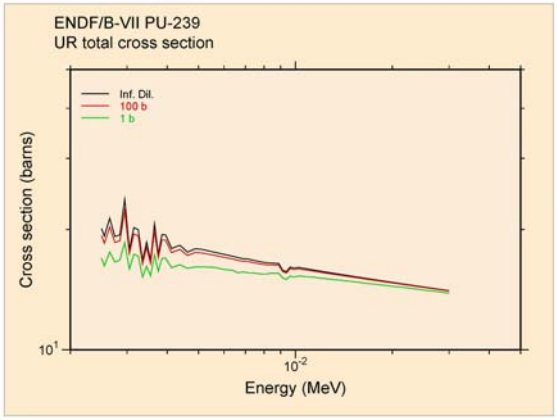

Fig. 5. Unresolved total cross section (in PDF plots of the data that were generated during processing for an MCNP library) [4].

3. Conclusions

We present a method to generate self-shielded multi-group cross sections in URR for easy numerical integration and tested on the total cross section of ^{239}Pu.

This is the first phase of study and the effects of statistical resonances in URR are identified by comparing generated multi-group cross sections.

Test will be performed on several other nuclides and this method might be used as a one of items for developing multi-group cross section generation code for fast reactor analysis.

Acknowledgement

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