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ON THE IMPORTANCE OF THE NEUTRON SCATTERING ANGULAR DISTRIBUTIONS FOR THE LWR FAST NEUTRON DOSIMETRY

A. Vasiliev[1], D. Rochman[1], M. Pecchia[1], H. Ferroukhi[1]

[1]Paul Scherrer Institut (PSI), Villigen PSI, Switzerland
alexander.vasiliev@psi.ch, dimitri-alexandre.rochman@psi.ch, marco.pecchia@psi.ch,
hakim.ferroukhi@psi.ch

ABSTRACT

Despite the significant progress achieved in the nuclear data uncertainties quantification techniques for neutron transport calculations, some parts of the nuclear data uncertainties are still not investigated in sufficient details. Particularly, the impact of the neutron scattering angular distributions in application to the fast neutron fluence (FNF) assessment for light water reactor pressure vessels can be named. At present time not only the calculation techniques need further developments for such investigations, but also the nuclear data libraries in general lack the uncertainty information which should be associated with the angular distributions of the scattered neutrons. At such circumstances it is not really possible to accurately evaluate the uncertainties associated with the differential neutron scattering cross-sections and commonly only the uncertainties of the angular integrated scattering cross-sections can be propagated in the neutronic calculations. However, at the same time it can be seen that the neutron scattering angular distributions can differ significantly between different evaluations and thus should be actually quite uncertain in the modern nuclear data libraries. Therefore, it is proposed in the given paper to make a preliminary quantitative assessment of importance of the neutron scattering angular distributions, e.g. with respect to the FNF predictions, before moving towards more sophisticated studies. Results of such an assessment are presented in the paper, underlying some noticeable differences particularly between the ENDF/B-VII.1 and JENDL-4.0 libraries and specifically for the elastic scattering angular distributions of emitted neutrons for O-16 isotope.

KEYWORDS: differential neutron scattering cross-sections, uncertainty, fast neutron flux, ENDF, MCNP

1. INTRODUCTION

A significant progress has been achieved in the past decade regarding the nuclear data uncertainties quantification techniques for the neutronic calculations of different types. Both the deterministic and stochastic options are being explored for the uncertainties propagation, as well in combination with both deterministic and Monte Carlo based neutron transport simulation codes. To a great extent the achieved progress is based on the considerable improvement of the uncertainties evaluations in the modern nuclear data libraries.

Nevertheless, the modern nuclear data libraries, obviously even covering the forthcoming releases of JEFF(3.3), TENDL(2017) and ENDF/B(VIII), still cannot provide sufficient information on some of the nuclear data, such as the scattering distributions of the secondary neutrons for all important isotopes.

It can be commented that for the scattering reactions the format of the data given for the angular distributions themselves and for their uncertainties can significantly differ, complicating the uncertainty propagation procedures. For instance, tabulated pointwise probabilities for the angular distributions can be used in ENDF file MF4, while file MF34 is designed to only contain the covariances of Legendre coefficients; furthermore, file MF34 data can be given in the laboratory system of coordinates, while the data in file MF4 is normally given for the center of mass system [1]. But even apart from the above complications, the modern libraries like ENDF/B-VIII.b5 or JENDL-4.0 contain the covariances only for the first order Legendre coefficients (i.e. for the average scattering angle, mu-bar), which is not sufficient for complete uncertainty quantification assessments.

However, at the same time it can be seen that the neutron scattering angular distributions may differ significantly between different evaluations (this will be demonstrated with certain examples in Section 2) and therefore shall actually be quite uncertain in the present-day nuclear data libraries. Thus, it is proposed in the given paper, before moving to more sophisticated studies, to make a preliminary quantitative assessment of the importance of the neutron scattering angular distributions, e.g. with respect to the fast neutron fluence (FNF), with the simple means available at hand. That can be done, for example, by comparing the calculations performed with a Monte Carlo code, e.g. MCNP® [2] used in the present study (also older code MCNPX-2.4.0 was employed for some test calculations), with the same nuclear data libraries in the ACE format, but with the particular scattering angular distributions taken from different evaluations (for which the raw ENDF files shall be processed with the NJOY code to produce required ACE files). Furthermore, for the first test assessments a simpler procedure can be utilized which even does not require the NJOY code usage and this option is discussed at first in the following study presented in Section 3.

It should be mentioned that the relevance of discrepancies between the existing independent evaluations of the angular distributions for the O-16 elastic scattering had already been illustrated and discussed in [3,4], at that time for the ENDF/B-VII.0 and JENDL-3.3 libraries. Recently, a similar work was reported for a similar application [5]. It shall be also noted that the methodologies for the nuclear data uncertainties propagation, in particular with MCNP calculations, have been under development at the Paul Scherrer Institute within the last decade and significant progress has been achieved with the in-house tool NUSS [6] which is capable to stochastically sample the nuclear data including cross-sections, but which is not yet applicable for sampling the secondary neutron angular distributions. It would however be reasonable at first to assess for which applications the angular distributions' uncertainties might be relevant and this problem is considered in the given study.

2. BACKGROUND ON THE ANGULAR DISTRIBUTIONS INFORMATION IN THE MODERN NUCLEAR DATA LIBRARIES

To illustrate the discrepancies in the angular distributions data provided in the different libraries, few figures are collected in this section as examples, but at first some general illustrations on the angular distribution shapes are provided for the readers' convenience (Figs. 1,6 were borrowed from the LANL webpages; http://t2.lanl.gov). To start, the elastic scattering angular distribution of O-16 is concerned, which has a rather irregular dependence on the incident neutron energy, as demonstrated below on Fig. 1 (note that the graph corresponds to the center of mass system of coordinates, but in the laboratory system the anisotropy will be even more pronounced).

It should be noted that in many cases the existing modern nuclear data libraries share the same evaluations and therefore cannot be always used for libraries inter comparisons, especially for the angular distributions. However, the ENDF/B-VII.1 (the same data are kept for ENDF/B-VIII.b5) and JENDL-4.0 have clearly different and independent evaluations and therefore the differences between the scattering data from these libraries shall give an idea on how the available evaluations are certain or uncertain.

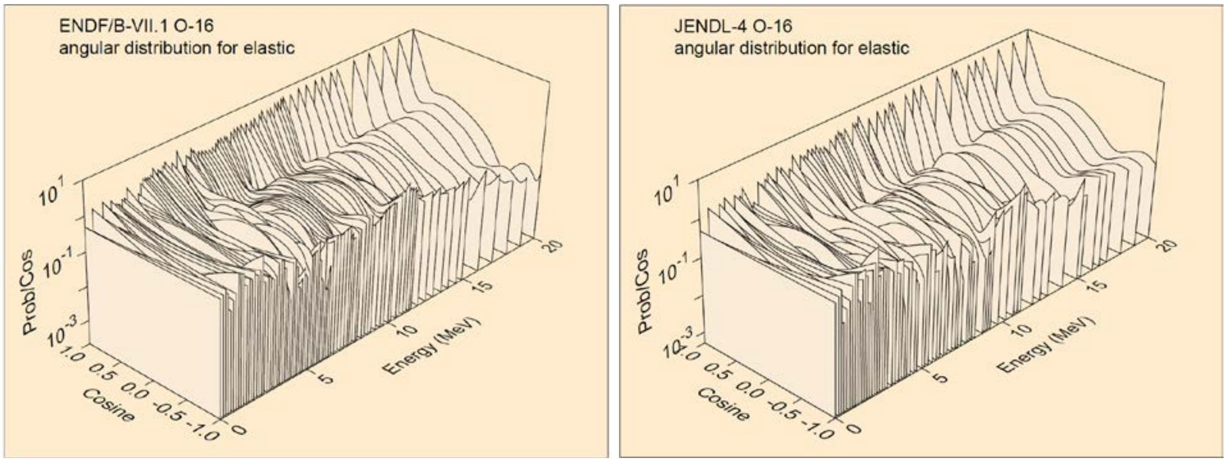

Figure 1. O-16 elastic scattering angular distribution

For completeness of the presentation, Fig. 2 demonstrates differences in the elastic scattering cross-section itself between the two libraries, produced with the JANIS software of OECD/NEA [7] (the energies above 10 MeV are marginally relevant for the topic of the paper).

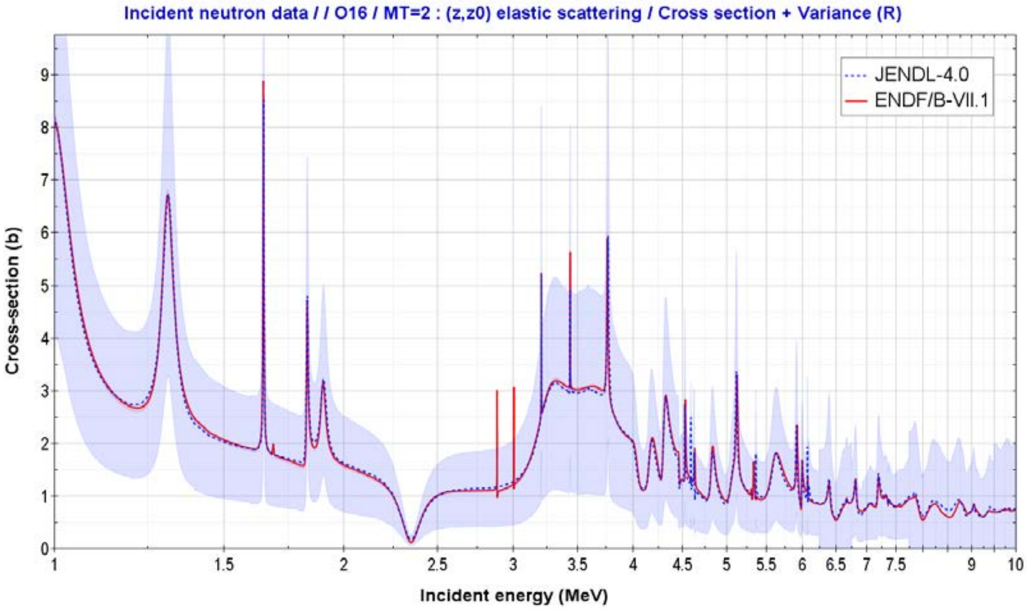

Figure 2. O-16 elastic scattering cross-section.

Some representative examples on the comparison of the scattering characteristics between ENDF/B-VII.1 and JENDL-4.0, produced with JANIS, are shown below on Figs. 3 and 4. In addition, Fig. 5 compares the angular distributions at selected neutron incident energy from different libraries. One can see that both TENDL-2015 and JEFF-3.2 have adopted the O-16 elastic scattering (n,n) angular distributions from ENDF/B (the same actually applies to other existing libraries, e.g. CENDL-3.1, BROND-3.1, etc.) and only JENDL-4.0 has an independent evaluation.

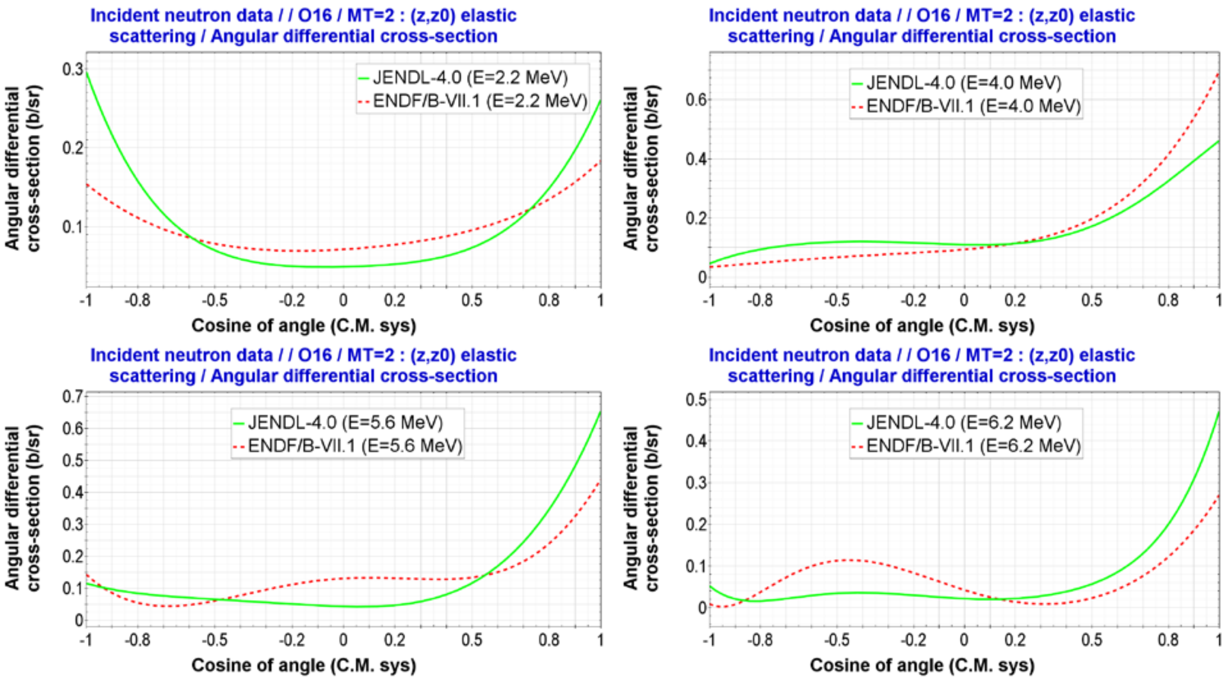

Figure 3. Comparison of ENDF/B-VII.1 and JENDL-4.0 angular distributions for O-16 elastic scattering for some incident neutron energies: 2.2MeV, 4.0MeV, 5.6MeV and 6.2MeV.

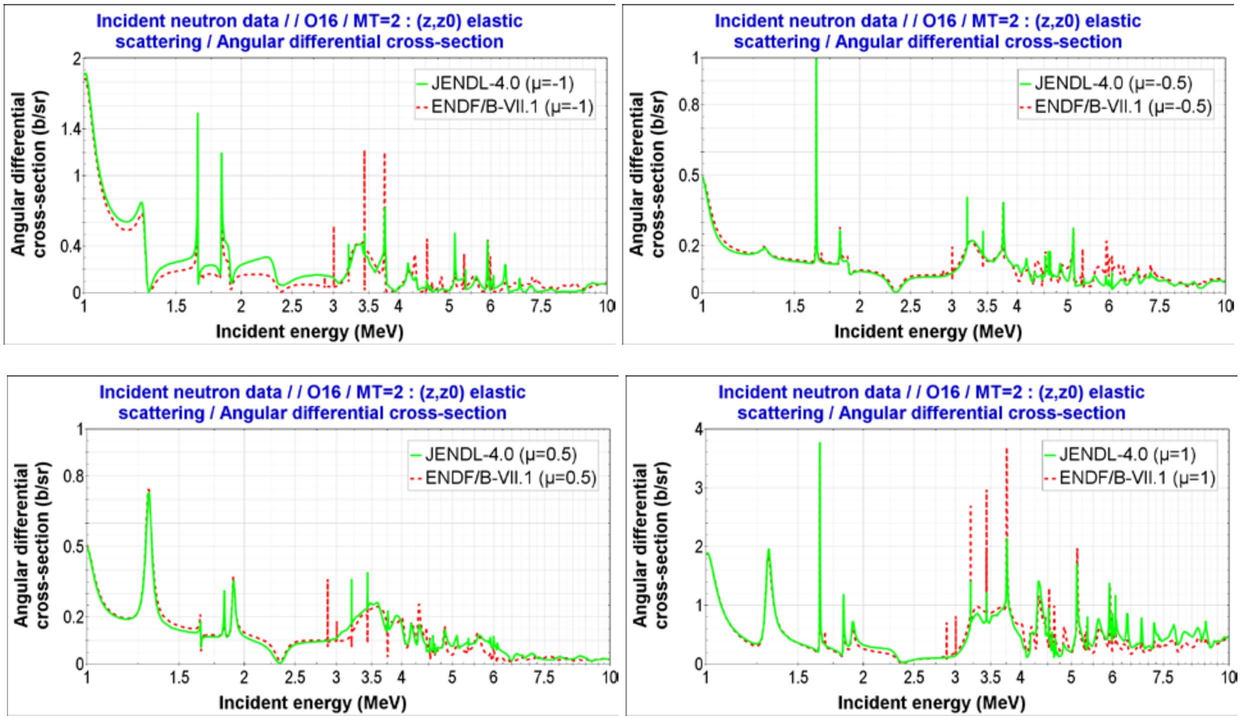

Figure 4. Comparison of ENDF/B-VII.1 and JENDL-4.0 angular differential elastic scattering cross-sections for O-16 for different cosines of the scattering angles: -1, -0.5, 0.5 and 1.

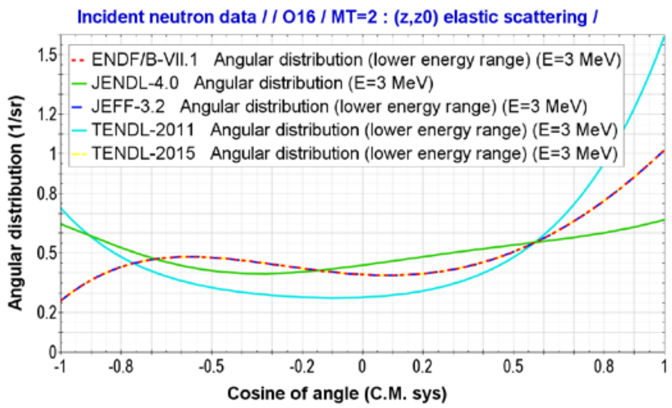

Figure 5. Illustration on the elastic scattering angular distributions.

As for the inelastic scattering of O-16, at first it is less anisotropic and secondly it has the threshold above 6.5 MeV, so the anisotropy of the inelastic scattering of O-16 is less important for the reactor dosimetry as compared with the elastic scattering reaction. Fig. 6 shows the first and the forth levels of the O-16 inelastic scattering as an illustration (the pictures were taken from http://t2.lanl.gov).

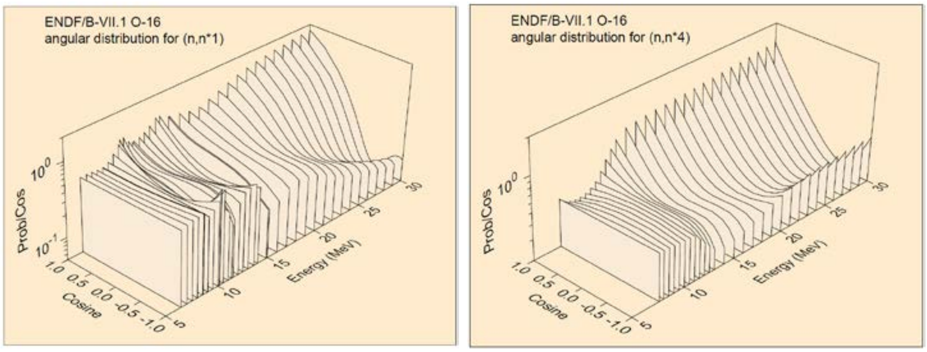

Figure 6. O-16 inelastic scattering angular distributions.

Next, Fig. 7 illustrates the angular distributions for selected neutron incident energies, this time for Fe-56 elastic scattering. It suggests that the nuclides constituting reactor structure materials potentially also can contribute to the calculation uncertainties due to the angular distributions of the scattered neutrons.

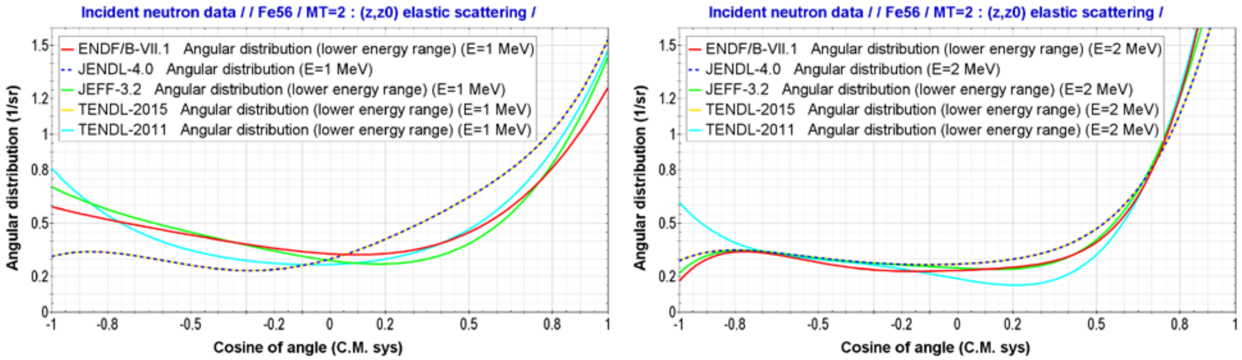

Figure 7. Angular distributions of Fe-56 elastic scattering for selected incident neutron energies.

The given examples clearly demonstrate differences between the differential elastic scattering cross-sections from the available evaluations for important isotopes.

3. CALCULATION MODELS AND TECHNIQUES

In order to preliminary check a potential importance of the scattering angular distributions with respect to the fast neutron flux and reactor dosimetry applications, at first an MCNP model of a Swiss PWR for calculations of the reactor pressure vessel (RPV) FNF [8,9] has been used for the given study. Note that the fast neutron flux levels at PWR RPV are higher as compared to the BWR case and therefore the case of PWR was selected for the initial assessment of the scattering cross-sections effects. However, in the case of BWR, although the FNF values themselves are generally lower, their uncertainties can be higher because of several reasons, among which is the fact that the volume of coolant in the reactor bypass and down comer can be relatively bigger. For illustration, Fig. 8 demonstrates MCNP models of the Swiss PWR and BWR reactors which are considered in the given paper.

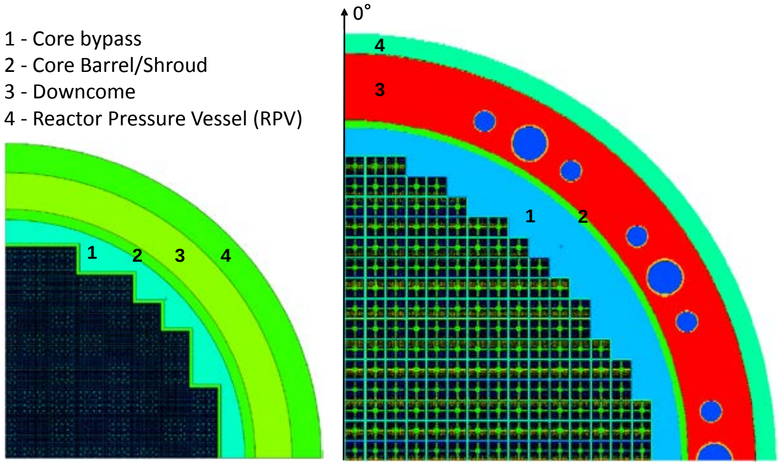

Figure 8. Illustration on MCNP models for Swiss PWR and BWR reactors; the models are scaled proportionally to the real reactors' dimensions.

Therefore, the detailed analysis of the PWR case will be at the end followed with an assessment of the selected most relevant nuclear data effects for the case of the BWR model [8,10] as well. In all calculation cases the total fast neutron fluxes (E>1MeV) at the RPV inner and outer surfaces of both reactors are considered. For simplicity, the same abbreviation 'FNF' is used for both the fast neutron flux and the fast neutron fluence, since in the context of the given paper the time integration of the flux is not relevant for discussion.

To simplify the test calculations, the following processing-efficient approach was chosen at the first stage: the ACE files with nuclear data for the selected nuclides were modified manually by deactivating the anisotropic scattering specifications. Namely, for O-16, Cr-52, Fe-56 and U-238 both elastic and inelastic scattering reactions were (one at a time) artificially changed from anisotropic to isotropic. With this simple operation it became possible to

1) assess the overall impact of the scattering anisotropy for the fast neutron flux calculations,
2) compare the impact of the scattering anisotropy between different libraries.

The neutron transport calculations were performed in the fixed-source mode and therefore the changes of the angular distributions did not affect the neutron source distributions.

After the identification of the most relevant cross-sections, the above described simplified assessments with the manually modified ACE files have been compared for a selected case with calculations with the test ACE files properly produced with NJOY, when the angular distributions under analysis were taken from the different libraries while all the rest nuclear data was kept the same as in the original cases.

4. CALCULATION RESULTS

At the beginning, the differences in the FNF results as obtained with the nominal ENDF/B-VII.1 and JENDL-4.0 libraries used for all nuclides in the models are reported in Table I (note that the difference in the FNF results between ENDF/B-VII.0 and JENDL-3.3 was about ~10% for the same PWR case analyzed in [4]). The abbreviations *RPV-in* and *RPV-out* stand for the inner and outer RPV surfaces (the results are integrated azimuthally and over the core height). The uncertainties given in the paper are based on the relative standard deviations of the MCNP calculation results reported in the output files. The uncertainties for the relative differences between two calculations are approximated as $\sqrt{\sigma_1^2 + \sigma_2^2}$ where $\sigma_{i=1,2}$ is respectively the MCNP uncertainty of an individual calculation.

Table I. Differences in the RPV FNF results obtained for the PWR and BWR cases with ENDF/B-VII.1 and JENDL-4.0; (FNF(JENDL-4.0)/FNF(ENDF/B-VII.1)-1).

Reactor model	RPV-in	RPV-out
PWR	**7.9**%±0.1%	**8.8**%±0.3%
BWR	16.6%±0.2%	16.8%±0.3%

Next, the results of the test calculations for the PWR model with the manually modified ACE files are shown in Table II. Here (n,n) means elastic scattering and (n,n') - inelastic scattering. The isotopes Cr-52 and Fe-56 were selected as representative for the steel composition since they are present in steel with highest concentrations. The level of the currently achieved statistical uncertainty of the data in Table II is, similar to the data in Table I, about ~0.1% for *RPV-in* and ~0.3% for *RPV-out* locations respectively. As it could be expected, the change of the inelastic scattering basically does not affect the results and therefore in the following only the elastic scattering will remain under consideration. Next, the effect of the elastic scattering in both ENDF/B-VII.1 and JENDL-4.0 ACE files is shown with Table III, where also the differences between the effects obtained with both ENDF/B-VII.1 and JENDL-4.0 libraries are assessed.

Table II. Relative change of RPV FNF due to changing the scattering laws in ENDF/B-VII.1 ACE files to isotropic.

Isotope	Reaction	RPV-in	RPV-out
O-16	n,n	**-20%**	**-20%**
	n,n'	0%	0%
Cr-52	n,n	**-14%**	**-29%**
	n,n'	0%	0%
Fe-56	n,n	**-38%**	**-63%**
	n,n'	0%	-1%
U-238	n,n	**-8%**	**-8%**
	n,n'	0%	-1%

Table III. Relative change of RPV FNF due to removing the elastic scattering anisotropy (the reference values correspond to the ENDF/B-VII.1 results).

	ENDF/B-VII.1		JENDL-4.0		ENDF/B-VII.1 vs. JENDL-4.0	
	RPV-in	RPV-out	RPV-in	RPV-out	RPV-in	RPV-out
O-16	-20.3%	-20.3%	-27.9%	-28.8%	**7.6%**±0.1%	**8.5%**±0.4%
Cr-52	-13.8%	-28.7%	-15.0%	-30.5%	1.2%±0.1%	1.9%±0.4%
Fe-56	-38.4%	-62.9%	-42.3%	-70.0%	3.8%±0.1%	7.1%±0.4%

It can be seen that the largest effect found for the FNF results is associated with O-16 elastic scattering angular distributions. The observed importance of the elastic scattering angular distribution for the FNF modelling may be associated with two additive effects: at first, the forward-peaked anisotropy increases chances of fast neutrons to reach RPV when traveling outwards the core and, at second, the smaller scattering angles correspond to smaller losses of energy at the scattering reaction, thus again increasing the chance of the fast neutrons to reach RPV before losing their energy below the FNF cut off of 1MeV. Next, in order to verify if the main effect from the O-16 cross-sections is related to the coolant material and not to the UO2 fuel, a test calculation was done when O-16 in the fuel was kept unchanged, while the modified ACE file was used for O-16 in coolant. It was confirmed that ~92% of the effect from the O-16 angular distributions is associated with water coolant in the case of the PWR reactor modeling.

In order to further verify the impact of the O-16 nuclear data differences between the ENDF/B-VII.1 and JENDL-4.0 files, a test calculation with the ENDF/B-VII.1 library but when the single O-16 isotope is fully taken from JENDL-4.0 was done, as reported below in Table IV. In this case the results for the PWR FNF at both RPV surfaces were basically identical to the results of JENDL-4.0 (within 0.2%). At the same time the FNF values computed with both ENDF/B-VII.1 and JENDL-4.0 libraries for the cases when the O-16 elastic scattering anisotropy was removed also agreed between together within 0.3%. To finalize the study of the O-16 data, a new ACE file was produced with NJOY code when all nuclear data files were taken from ENDF/B-VII.1 but the angular distribution file MF4 for the considered cross-section (elastic scattering, MT2) was replaced by the file taken from JENDL-4.0. The results are given in the last row of Table IV. Note that the last exercise allowed to quantify the effect related to the replacement of the angular distributions without any other changes in the nuclear data.

Table IV. Differences in the RPV FNF results obtained with different cross-sections vs. the reference case obtained with the nominal ENDF/B-VII.1 library.

Cross-sections modification	RPV-in	RPV-out
ENDF/B-VII.1 for all isotopes, but O-16 from JENDL-4.0	7.9%±0.1%	8.2%±0.3%
ENDF/B-VII.1 for all isotopes, but O-16 MF4/MT2 from JENDL-4.0	7.1%±0.1%	7.1%±0.3%

Noticeably, the results of Table IV are quite close to the results originally given in Table I and also reported in Table III (see highlighted values), taking into account the corresponding statistical uncertainties. The fact that the values of the last exercise do slightly differ from the data of Table III apparently can be partially explained by non-linear nature of the involved effects. Recall that in the case of the study reported in Table III the scattering anisotropy was deactivated in the ACE files while keeping all cross-sections unchanged in both libraries. In the case of the new ACE file compilation with NJOY the ENDF/B-VII.1 cross-sections were kept unchanged but the angular distributions were replaced by the

JENDL-4.0 data. It can be realized that the 'importance' of the angular distributions at different incident energies depends on the neutron spectra and on the main cross-sections, including the O-16 elastic cross-section itself, but not only. Therefore, the same angular distributions may play different role in the calculations with different basic cross-sections and thus the results of Tables I, III and IV may differ due to such natural reasons.

Finally, by comparison of the calculation results obtained with the modified ACE files with the elastic scattering anisotropy switched off, it is possible to assess the solo influence of the nominal cross-sections from the ENDF/B-VII.1 and JENDL-4.0 files MF3 (angular integral) on the PWR FNF results, as reported in Table V.

Table V. Effects in the RPV FNF results associated with the differences between ENDF/B-VII.1 and JENDL-4.0 elastic cross-sections, ignoring the angular distributions.

Isotope	RPV-in	RPV-out
O-16	0.4%±0.1%	0.0%±0.3%
Cr-52	1.3%±0.1%	4.1%±0.3%
Fe-56	-1.1%±0.1%	-3.3%±0.3%

The most noticeable effects can be seen for the FNF at the outer RPV vessel surface in association with Cr-52 and Fe-56 elastic scattering cross-sections. It can be expected that cross-sections of other steel isotopes may have similarly noticeable effects, which as well shall be taken into account for the comprehensive uncertainty evaluation studies.

The so far performed exercises may require further verifications and refinements and especially the statistical precision for the results for the outer RPV surface could be further improved. Nevertheless, the presently obtained results already indicate that at least the O-16 elastic scattering angular distribution alone brings the difference up to 9% in the FNF RPV calculations for PWR. Furthermore, based on the above findings obtained with the PWR model, a test calculation has been finally done for assessment of the O-16 elastic scattering angular distribution effect on the BWR RPV FNF. The same ACE file prepared with NJOY based on the ENDF/B-VII.1 data and the angular distribution file taken from JENDL-4.0, as was described above, was used. In this case the difference with the reference calculation with ENDF/B-VII.1 was found much higher as compared to the PWR model and also rather consistent with the *RPV-in* and *RPV-out* results from Table I: **18.3**% and **18.1**% (±0.2%) respectively.

Note, however, that the uncertainty in the FNF results due to the uncertainties of O-16 angular distribution can be even higher than just the difference between the two libraries' results and it needs therefore detailed assessment[1]. Furthermore, not only the FNF predictions are affected by the angular distribution uncertainties, but, naturally, also the reaction rates of the dosimetry detectors which are commonly used for the calculation methodologies validation. For instance, the difference between the Fe-54 (n,p) reactions calculated with the abovementioned ACE files with the angular distributions taken from ENDF/B-VII and JENDL-4.0 files was also assessed in the given study for both BWR and PWR models

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[1] It can be noted that with respect to the nuclear data uncertainties, the contribution of another coolant isotope, H-1, was previously found dominating with respect to the RPV FNF results for the same BWR (one standard deviation in FNF equals to ~**13**%) [8], which can be explained by the strong moderation property of H-1 in combination with the thick coolant volume between the BWR core and RPV.

and for the typical locations of the dosimetry measurements or scrapping tests performed respectively at both types of reactors, i.e. close to the RPV inner surface. The correspondingly found results are: **12.7%** (±0.2%) for PWR and **21.1** (±0.3%) for BWR models.

It can be noted in passing that the observed effects associated with the O-16 angular distributions of the elastically scattered neutrons are much higher if compared with the uncertainties of the FNF or the dosimetry reaction rates, associated with the uncertainties of the elastic cross-section itself (corresponding to ENDF data in MF33/MT2). The later uncertainties from the O-16 (n,n) reaction cross-section were evaluated in the past using ENDF/B-VII.1 data for the discussed here MCNP models and were found around ~1% only.

Note that for the neutron dosimetry applications it is desired to keep the overall uncertainty in the FNF predictions below 20% and also to avoid systematic biases [11]. It is therefore suggested that the findings reported in the given paper should deserve further attention from the nuclear data evaluators.

5. DISCUSSIONS

2.1. Outlook on the Currently Available Data on the O-16 Angular Distributions Uncertainties

As it was mentioned in the Introduction, the uncertainties of the angular distributions for, e.g., neutron scattering on O-16, cannot be accurately quantified at present due to the lack of relevant information. It is possible, however, to compare, for example, the average scattering angles (mu-bars) produced on the basis of JENDL-4.0 and newest ENDF/B-VIII.b5 data files and assess the obtained results with respect to the uncertainty information provided in these libraries for the L=1 elastic scattering Legendre coefficient (MF34). This is demonstrated here with Fig. 9. The results were obtained by processing ENDF formatted files MF4 and MF34 for O-16 with NJOY code.

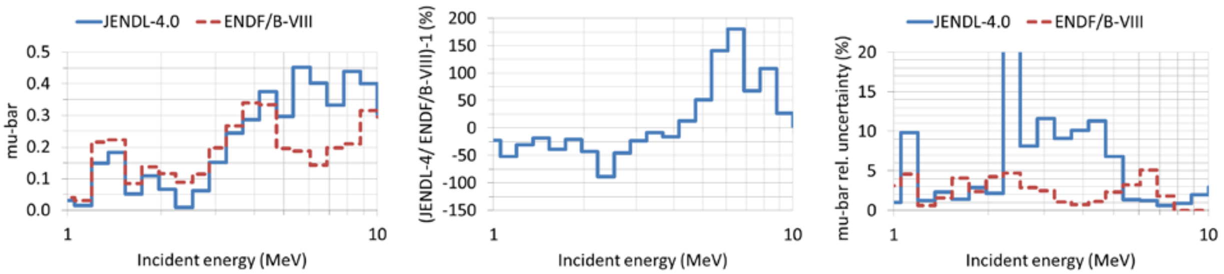

Figure 9. Information provided in ENDF/B-VIII.b5 and JENDL-4.0; left - mu-bar values; center – ration of the mu-bar values; right – reported mu-bar uncertainties.

On the one hand, it is seen that the differences between the data from ENDF/B-VIII.b5 and JENDL-4.0 libraries are significantly higher than the evaluated uncertainties for the same data. That may mean that the reported uncertainties are underestimated, although one cannot make any confident statements by only comparing two libraries. On the other hand, that may mean that the demonstrated in this paper comparison between the calculations with the two libraries gives a reasonably representative assessment (at least regarding mu-bar) of potential uncertainties in the FNF predictions, associated with the scattering angular distributions.

2.1. Relevance of the O-16 Angular Distributions for Criticality Calculations with LWR Fuel

The relevance of the scattering angular distribution uncertainties for the criticality calculations had been already examined for certain types of the systems in the works [12,13] and no significant influence of these data on the overall uncertainty results for the effective neutron multiplication factor, k_{eff}, could be found. For the sake of generality, the influence of the O-16 elastic scattering distributions has been also assessed in this work with the help of the ACE file based on the ENDF/B-VII.1 data with replaced MF4/MT2 section, as it was described above. Two criticality benchmark cases were calculated: LCT-001-01 and LCT-001-02 from [14], which represent water-moderated $U(2.35\%)O_2$ fuel rods in 2.032-cm square-pitched arrays. LCT-001-01 case consists of a single array of fuel rods, while case LCT-001-02 consists of three arrays in a row, having ~12cm distance between the central and the side arrays.

The obtained difference in the k_{eff} results between the nominal ENDF/B-VII.1 library and the case with MF4/MT2 data from JENDL-4.0 were 75pcm and 79pcm respectively for LCT-001-01 and LCT-001-02 cases, while the k_{eff} standard deviations equal to 4-5pcm. These results indicate that there is some non-negligible impact of the O-16 elastic scattering distributions' differences between ENDF/B-VII.1 and JENDL-4.0 data. In other words, the scattering angular distributions can be responsible for certain calculation biases in the criticality calculations. At the same time, obviously the uncertainties of the k_{eff} associated with the O-16 elastic scattering angular distributions should be practically negligible with respect to the typical values of the k_{eff} uncertainties associated with other nuclear data like the cross-sections, neutron multiplicity and fission neutron spectra, which in total can be in the order of ~500-1000pcm for the LCT benchmarks [15].

6. CONCLUSIONS

For a comprehensive evaluation of accuracy of the calculation results in neutronics calculations, it is necessary to consider all potential sources of uncertainties associated with nuclear data. For completeness this shall include the scattered neutron angular distributions. However, the uncertainties of such distributions are not yet completely characterized and also they are difficult for propagation in practice. Therefore, some preliminary quantification assessments have been done in the present study to analyze the potential importance of the angular distribution uncertainties, with respect to the particular case of the neutron transport calculations, namely for the FNF predictions.

Based on the currently obtained results for the PWR and BWR RPV FNF simulations, it became possible to identify that the differences in the angular distributions for O-16 elastic scattering between the JENDL-4.0 and ENDF/B-VII.1 libraries seem to be non-negligible and may lead to the differences in the FNF and dosimeters activation results in the order of ~10% for PWRs and ~20% for BWRs. In principle the uncertainties of the O-16 angular distributions may be even larger than the observed effects. For comparison, the typical levels of uncertainties of FNF at RPV inner surface, associated with uncertainties of all other nuclear data, except the angular distributions, were found around ~10% for the same PWR model and ~15% for the same BWR model, as considered in the given study [8].

As well, the differences in the elastic scattering cross-sections of the steel composition between the JENDL-4.0 and ENDF/B-VII.1 libraries can also be noticeable, and consequently it can be recommended that the associated uncertainties should be also taken into account in the FNF modeling. Since it is desired to keep the overall uncertainty in the FNF predictions below ~20% and also to avoid systematic biases [11], the discussed effects and uncertainties, primary the one associated with the O-16 elastic scattering angular distributions, seem significant from the viewpoint of the reactor dosimetry applications (for both the FNF calculation prediction and the FNF calculation methodology validation aspects) and therefore it can be suggested to the nuclear data evaluators to pay attention to the mentioned nuclear data.

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