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International Cooperation in Nuclear Data Evaluation

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The OECD Nuclear Energy Agency (NEA) is organising a co-operation between the major nuclear data evaluation projects in the world. The co-operation involves the ENDF, JEFF, and JENDL projects, and, owing to the collaboration with the International Atomic Energy Agency (IAEA), also the Russian BROND and the Chinese CENDL projects. The Working Party on international nuclear data Evaluation Cooperation (WPEC), comprised of about 20 core members, manages this co-operation and meets annually to discuss progress in each evaluation project and also related experimental activities. The WPEC assesses common needs for nuclear data improvements and these needs are then addressed by initiating joint evaluation efforts. The work is performed in specially established subgroups, consisting of experts from the participating evaluation projects. The outcome of these subgroups is published in reports, issued by the NEA.

Current WPEC activities comprise for example a number of studies related to nuclear data uncertainties, including a review of methods for the combined use of integral experiments and covariance data, as well as evaluations of some of the major actinides, such as ^{235}U and ^{239}Pu. This paper gives an overview of current and planned activities within the WPEC.

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I. INTRODUCTION

In 1989, the OECD Nuclear Energy Agency (NEA) established the Working Party on international nuclear data Evaluation Cooperation (WPEC) to provide a forum for a co-operation between the major nuclear data evaluation projects. The collaboration started between the US ENDF, the Western European JEFF and the Japanese JENDL projects and was subsequently extended to include the Russian BROND, the Chinese CENDL projects thanks to the support of the International Atomic Energy Agency (IAEA).

The main objectives of the cooperation are to:

- improve the quality and completeness of the evaluated nuclear data libraries by means of an international co-operation, and to
- coordinate the nuclear data measurements required within this framework.

During the annual meetings, the WPEC reviews the status of the major nuclear data evaluation libraries, as well as the associated nuclear data measurement efforts. The WPEC assesses the needs for nuclear data improvements, and establishes subgroups to address these needs. So far this cooperation has resulted in the completion of 24 studies covering many different issues, as can be seen from the WPEC webpage at http://www.nea.fr/html/science/wpec/.

The outcome and recommendations of the WPEC subgroups are published in reports (Fig. 1) that can be obtained from the NEA or downloaded directly from the WPEC webpage.

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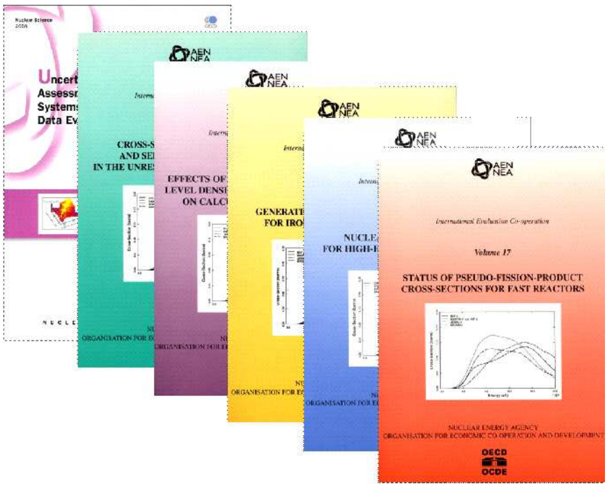

Fig. 1. (Color online) Examples of published WPEC reports.

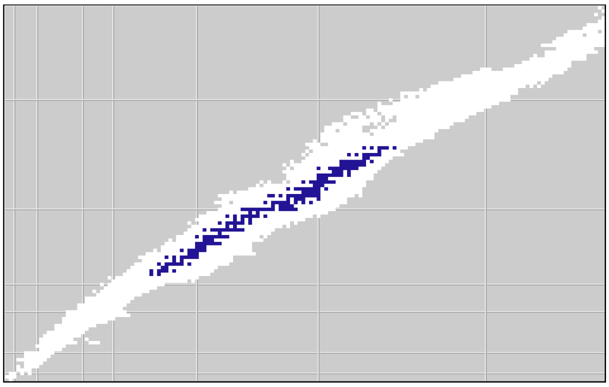

Fig. 2. (Color online) Chart of the 219 fission product isotopes evaluated by WPEC Subgroups 21 and 23.

II. RECENTLY PUBLISHED STUDIES

1. Evaluated Data Library for the Bulk of Fission Products

WPEC Subgroup 21 was formed to assess and make recommendations for fission product neutron cross sections by reviewing all available evaluations, as well as experimental and theoretical information. As a follow-up activity, the WPEC established Subgroup 23 to produce a fission product cross section library as recommended by Subgroup 21 and to perform an initial validation of this library.

The new fission product library was created in two steps. An initial version of the library was put together and made available for review and comments. Feedback was collected and numerous fixes were applied. The final version was assembled in the fall of 2006. The library, which contains evaluation for 219 fission products, has been adopted in full by ENDF/B-VII.0.

Validation of the library has been performed by the Cross Section Evaluation Working Group (CSEWG) and the Oak Ridge national Laboratory (ORNL) in the United States, as well as by Serco Assurance in the UK.

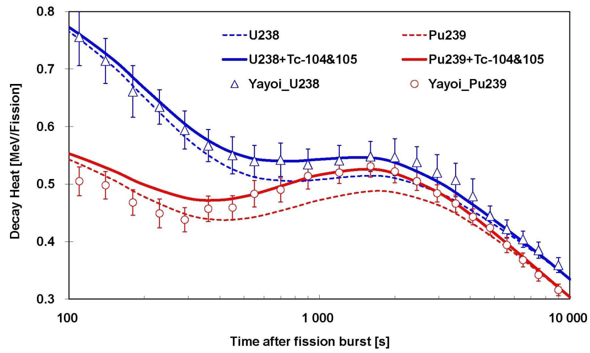

Fig. 3. (Color online) Gamma components of ^{238}U and ^{239}Pu fission product decay heat showing the effect of introducing preliminary TAGS results for ^{104,105}Tc compared to experimental data from Yayoi.

A detailed description of the compilation and validation of the fission product library is given in the WPEC subgroup report [1].

2. Assessment of Fission Product Decay Data for Decay Heat Calculations

The question why different national and international decay data libraries do not generate good estimates of radioactive decay heat without the introduction of theoretical data has been investigated by WPEC Subgroup 25. Although the theoretical data have sound bases for their adoption, it is considered that calculations based on mean decay data derived from total absorption gamma-ray spectroscopy (TAGS) are able to describe better the total decay heat, although the beta and gamma contributions may differ significantly when compared with measured data and decay heat standards.

The Subgroup reviewed the availability of TAGS data, and plans for additional TAGS measurements. The published report [2] contains recommendations on particular fission-product radionuclides that merit measurement by TAGS in order to improve decay heat calculations without the need to resort to theory. An example is given in Fig. 3.

Progress made by the experimentalists over the period 2006 - 2008 was monitored at an IAEA meeting in 2009 [3], which aimed at reviewing the availability of additional TAGS data for inclusion in current decay data sub-libraries.

3. Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations

Nuclear data needs for advanced reactor systems have been and are being discussed in many fora. The WPEC made a significant contribution to this discussion by establishing Subgroup 26 with the goal of developing a systematic approach consisting of a comprehensive sensitivity and uncertainty study to evaluate the impact of

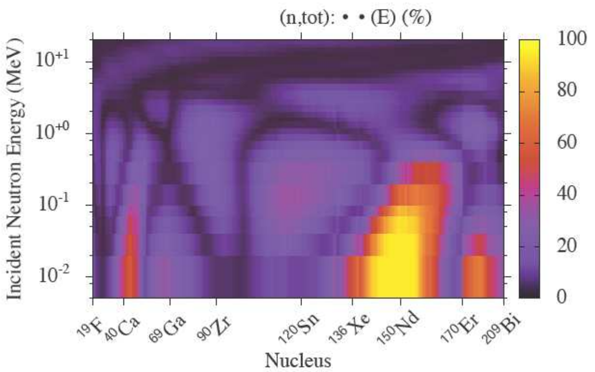

Fig. 4. (Color online) Uncertainty fluctuations in optical model calculations.

neutron cross-section uncertainties on the most significant integral core and fuel cycle parameters of a wide range of innovative systems.

Integral parameter uncertainties were calculated using a specifically developed library of covariance matrices. One significant result of the study was the strong impact of correlation data on the uncertainty assessment, indicating that any credible uncertainty analysis should include the best available covariance data accounting for energy correlations, possibly cross-correlations among reactions, and even cross correlation among isotopes.

A compilation of preliminary “design target accuracies” has been put together and a target accuracy assessment has been performed to provide an quantitative evaluation of required nuclear data improvements by isotope, nuclear reaction and energy range, in order to meet the design target accuracies. An example is given in Table 1. The complete results of the study are given in the published Subgroup report [4].

III. ALMOST COMPLETED STUDIES

A number of WPEC Subgroups have completed their work and are about to publish the results. This section provides a brief description of each of these activities.

1. Covariance Data in the Fast Neutron Region

The WPEC established Subgroup 24 to develop a methodology for generating covariances in fast neutron region, and to implement covariance capabilities in the major nuclear reaction codes.

A number of different methods, including deterministic, stochastic and hybrid methods, have been compared and advantages and disadvantages of the different methods have been evaluated.

It was noted that, for some nuclei, strong fluctuations are observed in the lower MeV energy region (Fig. 4), but there was no consensus, nor any clear guidelines on how such cases should be treated, if covariances are based on model calculations.

It was noted that unrealistically low uncertainties were frequently obtained when using deterministic methods in the presence of a large amount of experimental data, but methods have been proposed to help avoiding these very low uncertainties.

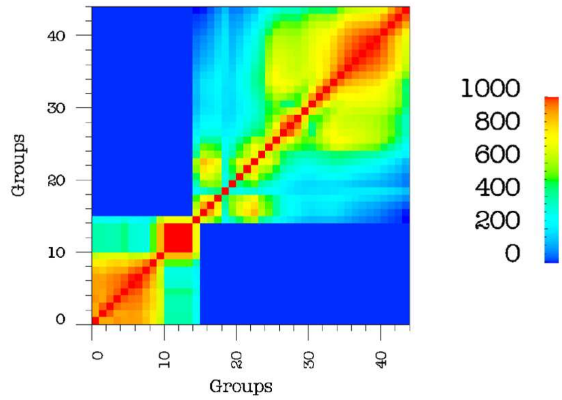

Fig. 5. (Color online) ^{235}U 44 group correlation.

However, it was noted that the preparation of covariances is affected by the subjective judgement of the evaluator and recommended uncertainties may sometimes differ by as much as factor 2.

2. Processing of Covariance Data

Following recent efforts to include covariance data in evaluated nuclear data libraries, as well as the development of Sensitivity/Uncertainty (S/U) analysis tools able to use these covariance data, the WPEC felt the need to verify that these tools were able to correctly propagate cross-section uncertainty data to calculated quantities of interest.

Subgroup 28 was set up to produce resonance cross-section evaluations with covariance data for important nuclides, such as ^{235}U, ^{238}U, and ^{239}Pu, and to implement methods to process and test covariance data.

All of the initially planned work has been performed and it shows that the investigated S/U analysis tools correctly propagate the uncertainty information in the calculations. However, differences between results obtained by the processing codes NJOY and PUFF needs to be further investigated.

3. Assessment of the Unresolved Resonance Treatment for Cross-section and Covariance Representation

The objectives of WPEC Subgroup 32 were to review existing unresolved resonance parameter formalisms, generate unresolved resonance parameters for ^{235}U and ^{238}U, and compare the results when calculating cross-sections with the resolved and unresolved formalisms. The subgroup should also make recommendations for a more rigorous treatment of the unresolved resonance region within the ENDF format based on the calculation results.

Table 1. Example of target accuracies for fast reactors.

Isotope	Reac.	Current Accuracy (%)	Target Accuracy (%)
^{238}U	$\sigma_{\rm inel}$	10 ∼ 20	2 ∼ 3
^{238}U	$\sigma_{\rm capt}$	3 ∼ 9	1.5 ∼ 2
^{241}Pu	$\sigma_{\rm fiss}$	8 ∼ 20	2 ∼ 3 (SFR,GFR,LFR) 5 ∼ 8 (ABTR, EFR)
^{239}Pu	$\sigma_{\rm capt}$	7 ∼ 15	4 ∼ 7

Table 2. Isotopes with missing photon production data.

Isotope	Rank	% Contribution @60GWd/Te over 4 Years
^{135}Xe	1	10.842
^{147}Pm	11	3.370
^{155}Eu	12	3.278
^{154}Eu	13	2.940
^{148m}Pm	21	1.145
^{107}Pd	23	0.838
^{93}Zr	24	0.727

The Subgroup has calculated infinitely dilute and self-shielded cross sections from the generated resonance parameters to determine differences in the formalisms, assuming that such a dense set of resolved resonances reasonably mimics the unresolved resonance region. As the observed cross section differences are small, it is not obvious that a more complex representation is required for practical calculations in the unresolved resonance region. However, the Subgroup needs to perform similar tests on lighter nuclides to verify that the conclusions obtained with heavy nuclides are applicable to all masses.

4. Prompt Photon Production from Fission Products

The recognised gaps and inconsistencies in gamma production data for fission products, as well as its importance for heating predictions in reactors, has led the WPEC to start an activity to identify and review suitable gamma source data.

Subgroup 27, in charge of this activity, has selected and ranked the fission products that contribute most to the gamma heating in a reactor. The Subgroup has limited its work to the top 26 fission products in the list, corresponding to about 90% of the absorption. It was noted that for several important isotopes there were no data at all available in the major evaluated data libraries (Table 2).

The Subgroup is currently reviewing alternative sources of photon production data, including data from model calculations, and will soon start assembling the data files and perform consistency checks.

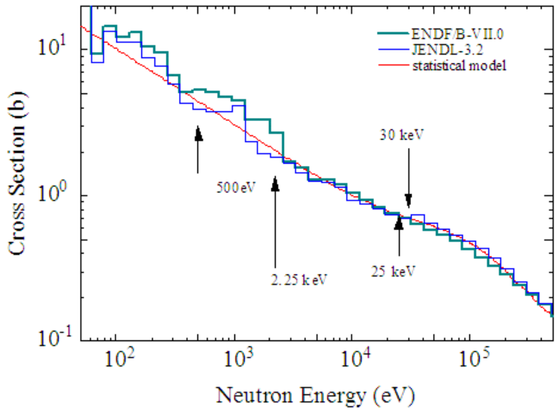

Fig. 6. (Color online) ^{235}U capture cross-section.

5. ^{235}U Capture Cross-section in the keV to MeV Energy Range

Following the investigation by WPEC Subgroup 18 of the epithermal energy region of the ^{235}U capture cross-section [5] and the subsequent re-evaluation of the ^{235}U resonance parameters, it was discovered that some of the evaluated data libraries have difficulties in modelling selected fast-neutron critical experiments at BFS (IPPE, Russia) and FCA (JAEA, Japan) using UO2 fuels. The most likely reason for these discrepancies was a too high ^{235}U capture cross section around 1 keV (Fig. 6).

Benchmark specifications for the FCA experiments in question were prepared for a more detailed analysis of the problem. The consensus was that the ^{235}U capture cross section in recent JENDL, ENDF/B, JEFF evaluations is slightly overestimated in the 500 eV to 2.5 keV range. The magnitude of this overestimation could be ∼10% or more.

However, only a change of the capture cross-section around 1 keV cannot explain the discrepancies. It was therefore decided to perform a new FCA sodium-void reactivity experiment to help solving the problem.

The final conclusions of WPEC Subgroup 29 will be published in mid 2010.

6. Improvement of the Accessibility and the Quality of the EXFOR Database

Nuclear data evaluators need to have easy and reliable access to experimental nuclear data, and the internation-

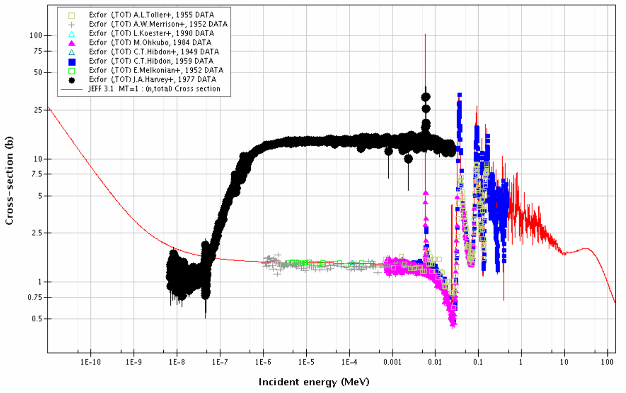

Fig. 7. (Color online) Graphical comparison of evaluated data with experimental data from EXFOR for the total neutron cross section of ^{27}Al.

ally maintained EXFOR database is the main source of such data. WPEC Subgroup 30 was set up to investigate whether the EXFOR data could be more easily accessible and whether the accessed data were correctly compiled.

The Subgroup focused on the following two activities:

- attempting to translate the entire EXFOR database into computational format,
- identifying and correcting the most obvious errors, using checking codes, plotting packages and comparisons with model codes.

The first step towards more user-friendly output from the EXFOR database was to investigate the possibility to translate from the original EXFOR format to a computational format. A global picture is now available showing which EXFOR data can and cannot be automatically translated.

A large number of errors in the EXFOR database have been discovered by graphically comparing the experimental data with either evaluated and calculated data. An example is given in Fig. 7.

IV. ON-GOING ACTIVITIES

1. High Priority Request List for Nuclear Data

The WPEC has established a long-term Subgroup charged with the task of maintaining a high priority request list for nuclear data. The purpose of this list is to provide a guide for those planning measurement, nuclear theory and evaluation programmes.

The requests in the list are divided in two main categories:

High priority requests

General requests

In order to be considered as a high priority, a request need to be justified by quantitative sensitivity studies (or the equivalent) and sufficiently documented.

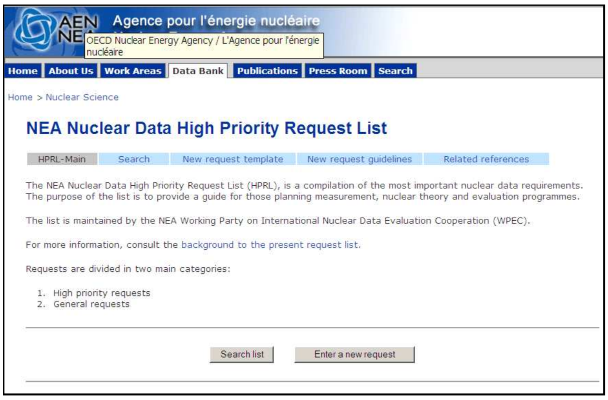

Fig. 8. (Color online) The webpage for the NEA High Priority Request List.

The recently completed WPEC Subgroup on "Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations" provided a number of new high priority requests.

The current high priority request list for nuclear data can be consulted at *http://www.nea.fr/dbdata/hprl*.

2. Methods for the Combined Use of Integral Experiments and Covariance Data

Following the work of WPEC Subgroup 26 on "Nuclear Data Needs for Advanced Reactor Systems", it was noted that many of the target accuracies, which have been defined to satisfy reactor design requirements for many integral neutronic parameters, are very tight and are not likely to be achieved with current experimental measurement techniques. It was therefore decided to start Subgroup 33 to investigate whether the combined use of integral experiments and differential information (*e.g.*, experimental and uncertainty data) would make it possible to provide designers with improved nuclear data that would meet design target accuracies for a wide range of innovative reactor and fuel cycle systems.

The Subgroup has started to study methods and issues on how to best exploit existing integral experiments, define new ones if needed, provide trends and feedbacks to nuclear data evaluators and measurers. A three-stage benchmark exercise, based on a limited set of integral experiments (Jezebel, Flattop, ZPR6-7, ZPPR-9, and Joyo), has been launched to test different methods of nuclear data adjustment/assimilation and different sets of covariance data, for the purpose of reducing the design uncertainties of reference sodium-cooled fast reactors. In the three stages the participants will use:

1. own initial cross sections and own covariances,
2. own initial cross sections and same covariances,
3. same initial cross sections and same covariances.

Fig. 9. (Color online) The ZPPR facility at Argonne National laboratory, USA.

V. PLANNED ACTIVITIES

The WPEC has currently established two new Subgroups, which are described below. It is foreseen that additional Subgroups could be started following the annual WPEC meeting in the beginning of June 2010.

1. Meeting Nuclear Data Needs for Advanced Reactor Systems

It has been decided to launch Subgroup 31 to investigate possibilities to meet nuclear data needs for advanced reactor systems.

The Subgroup will review the scope of the nuclear data needs identified by WPEC Subgroup 26 on "Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations", and consider the practicality of meeting those data needs. In addition, Subgroup 31 will evaluate existing experimental data accuracies versus requirements for new measurements, identify gaps in existing worldwide capabilities to meet these needs and recommend collaborative ways forward.

The Subgroup will start working in mid 2010.

2. Evaluation of ^{239}Pu in the Resonance Region

The ENDF and JEFF projects have adopted the same evaluation for the ^{239}Pu resonance region, largely based on work from ORNL, USA, and the CEA, France. A general over-prediction of about 0.5% for thermal Pu solution assemblies has been noted when using these evaluated data.

In recent years, the JEFF community has developed an updated ^{239}Pu file for JEFF-3.1.1 with modifications at thermal energies, which has improved some of the above mentioned discrepancies.

A new set of resonance parameters for ^{239}Pu has also been developed at ORNL. This evaluation is more consistent with the cross section resonance data and believed by the evaluators to be the best representation of these data to date. Nonetheless, this new evaluation does not improve the poor integral performance of the ENDF/B-VII.0 file, and in fact most of the discrepancies have become slightly worse.

The WPEC has agreed to establish Subgroup 34 with the goal of bringing together the experts in this area to see if a new evaluation can be developed that uses the most accurate fundamental cross section data with nuclear theory constraints, and also better models the relevant integral criticality data.

It is hoped this proposed collaboration will lead to the type of improvements obtained previously by WPEC Subgroup 22 on "Nuclear Data for Improved LEU-LWR Reactivity Predictions", mainly devoted to ^{238}U [6].

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