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NEUTRON DATA STANDARDS

Summary Report of the IAEA Consultants' Meeting

IAEA Headquarters, Vienna, Austria
6 – 10 December 2021
(virtual event)

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Vienna, Austria

November 2022

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ABSTRACT
The latest IAEA Neutron data standards were released in January 2018 (nds.iaea.org/standards/). This meeting was organized by the IAEA Nuclear Data Section to review the status of ongoing work for the development of the next version of the Neutron Data Standards. This meeting was conducted virtually during the week of 6-10 December 2021. There were 21 registered participants. Eighteen talks informed about ongoing measurement campaigns, interpretation of past measurements, ongoing evaluation work and developments regarding uncertainty quantification and evaluation methodology. Several new measurements were presented that were recommended to be included in the neutron standards database. Discussions on evaluation methodology comprised the consideration of spectrum averaged fission cross sections, the treatment of unrecognized sources of uncertainties, the development and application of uncertainty templates and extensions of the energy range of evaluations.

November 2022

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1. INTRODUCTION

The meeting was opened by Arjan Koning, Head of the IAEA Nuclear Data Section, who welcomed all the participants to this important virtual meeting on the topic of the Neutron Data Standards. Roberto Capote, co-host of the meeting, summarized previous work and highlighted important topics to be addressed within this meeting, such as the utility of SACS measurements as an ingredient in the Standards evaluation process and the treatment of Unrecognized Sources of Uncertainty (USU). Georg Schnabel, who served as the IAEA meeting host, briefly went through the proposed agenda. He asked participants for their consent to record the meeting to help with the preparation of the meeting report; the consent was given unanimously.

Allan Carlson was appointed Chair of the meeting and Denise Neudecker and Vladimir Pronyaev agreed to act as rapporteurs.

The virtual meeting took place 6-10 October with convening times 2pm to 6pm CET each day. The adopted agenda can be found in Appendix I, the participants' list in Appendix II and links to participants' presentations in Appendix III.

2. PRESENTATION SUMMARIES

Summaries of participants' presentations are given below, including their most important statements and conclusions. Full versions of the individual presentations are available in Appendix III of this report.

2.1. History of the standards evaluation process, A.D. Carlson (NIST, USA)

A presentation was given on the work leading from ENDF/B-I to the present-day standards showing the evolution of the evaluation process from its infancy to the present very improved process. Also, many of the problems regarding some of the evaluations were described.
For the full presentation refer to: History of the Standards Evaluation Process

2.2. Problems of neutron data standards evaluation and their possible solution, V. Pronyaev (Russia)

Solutions for the following problems, which may improve the standards cross section evaluations and presentation were considered:

- reprogramming of major modules of the standards evaluation codes GMAP and DAT using the modern programming language Python (G. Schnabel) that allows to remove possible bugs and extend the capabilities in the GLSQ data fitting;
- revision of experimental data using developed templates for accessing the components of data uncertainties and correlations between measurements done with the same methods (D. Neudecker);
- increasing of the number of bins for better presentation of the wide structure in the cross sections for neutrons with an energy below 100 keV (V. Pronyaev);
- analysis of possible reasons in data discrepancy measured with different methods (A. Carlson, P. Schillebeeckx, V. Pronyaev).

It is proposed to use 20 equal spacings on lethargy scale bins per energy decade between 100 eV and 100 keV as probably the most convenient for data presentation in the region where a broad structure can be observed in the cross sections. This allows usage of the high resolution TOF data in the combined fit, reduced to the typical resolution of measurements relying on constant energy neutron beams, which are mostly used in standards measurements.

There is a large difference between the results of ^{238}U(n, γ)/^{197}Au(n, γ)) measurements, carried out with the activation method with constant energy neutron beam and results obtained earlier in TOF measurements with prompt gamma registration. W. Poenitz, who used both methods in his measurements [1], suggested that the possible reason for this discrepancy might be the large difference in the prompt gamma ray spectra for the two reactions. The results of prompt gamma measurements appeared 10 % higher than the results of the activation measurements in the tenth keV range. The best way to exclude the unrecognized uncertainty of the measurement method is the separate evaluation of results obtained by different methods followed by an analysis of the differences in the evaluations. With the comparison of the results of different measurement methods and an analysis of reasons for the discrepancy, it is possible to estimate the additional uncertainty of the measurement methods, which were not described by the authors.

[1] W.P. Poenitz, L.R. Fawcett, Jr., D.L. Smity, Measurements of the $^{238}U(n, \gamma)$ Cross Section at Thermal and Fast Neutron Energies, Nucl. Sci. Engineering **78** (1981) 239.

2.3. GMAP modernization and new possibilities, G. Schnabel (IAEA)

Wolfang Pönitz started the development of the GMA code in the early eighties [1]. This code was later adopted in the neutron data standards project for the simultaneous evaluation of neutron standards cross sections and evolved to a flexible and powerful evaluation tool. Noteworthy, the code was extended by Donald Smith and Vladimir Pronyaev [2] to alleviate distortions due to an effect first demonstrated by Peelle [3], now referred to as Peelle's Pertinent Puzzle (PPP) effect. Due to this extension, the name of the code was changed to GMAP. Notwithstanding the great value and sophistication of the GMAP code, new requirements with the neutron standards project, such as the consideration of ratios of reaction rates in a californium spectrum, are beyond its capabilities. To address new requirements and to make the code better maintainable and accessible to researchers who are more familiar with the currently dominant data science centric programming languages, the GMAP code has been translated into a Python program. As the neutron standards serve as reference in many experiments to convert cross sections measured relative to standard reactions to absolute ones, the transition to a new code must be performed with the utmost care. Every difference in results based on the same input data between the Fortran and Python code must be explainable. For this reason, the first Python version was a line-by-line translation of the Fortran code. It was subsequently checked whether the Python code produces the same results as the Fortran code when using the neutron data standards database as input. After this validation exercise, readability and maintainability of the Python code were improved in a large number of small incremental modifications. After each modification, the functional equivalence to the Fortran code was checked. The new Python code is open source and available on the IAEA NDS Github account [4].

[1] Poenitz, W.P., Data Interpretation, Objective Evaluation Procedures and Mathematical Techniques for the Evaluation of Energy-Dependent Ratio, Shape and Cross Section Data, In: *Proceedings of the Conference on Nuclear Data Evaluation Methods and Procedures*, Sept. 22-25 1980, INDC(USA)-85, Vol. 1, 1981, pp. 249-285
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[3] Peelle, R.W., Peelle's Pertinent Puzzle, Informal ORNL memorandum, 1987.
[4] https://github.com/iaea-nds/gmapy

2.4. ^{235}U(n,f) cross section measurements for En < 29 eV by Deruytter and Wagemans, P. Schillebeeckx (EC-JRC, Geel)

Contributors: S. Kopecky, A. Plompen, P. Schillebeckx and C. Wagemans

An overview of neutron induced fission cross section measurements for incident neutron energies below 20 eV that were carried out by A.J. Deruytter and C. Wagemans is given. This includes the absolute experiments performed at the SCK CEN in Mol (BE) and the relative experiments at GELINA in Geel (BE).

Absolute measurements at SCK CEN

Two absolute measurements to determine the fission cross section at thermal energy for ^{235}U were carried out. The cross section in the thermal energy region was derived from results of time-of-flight experiments with a slow chopper at the BR1 and BR2 reactors of the SCK CEN in Mol, Belgium.

The absolute measurement of Deruytter [1], which was the subject of his PhD thesis, was carried out in 1960 at the BR1 reactor. The energy dependence of the neutron fluence rate was based on the ^{10}B(n,α) cross section. The absolute incident neutron fluence rate was determined by additional activation measurements with a gold foil. The total number of ^{235}U nuclides in the fission target was determined by low geometry α-counting. The α-counting system was calibrated by measurements in the same geometry using a set of reference samples. These samples were produced from the same batch of material and analysed by mass spectrometry for their total amount of ^{235}U. The reported value is σ(n,f) = 586.5 (60) b. Based on the experimental details provided in the paper we re-analysed the data using σ(n,γ) = 97.7 (5) b for the 1/v part of the ^{197}Au(n,γ) cross section as given in [2]. The result for the cross section at thermal energy σ(n,f) = 586.7 (70) b deviates by 0.5 % from the value σ(n,f) = 589.4 (78) b that is used in the database of Axton [3].

The measurements reported by Deruytter et al. [4] in 1973 were carried out in the early seventies at the BR2 reactor. The energy distribution of the incident neutron beam together with the absolute fluence rate were determined based on the ^{10}B(n,α) reaction. The ^{10}B(n,α) cross section at thermal energy was taken as σ(n,α) = 3835 (5) b. The total number of ^{235}U nuclides was determined by low geometry α-counting, however, without the use of reference materials. For the analysis of the data the ^{234}U half-life was taken as $T_{1/2}$ = 2.446 (4) x 10^5 a. The reported value is σ(n,f) = 587.6 (26) b. In addition, a resonance integral I_f[0.026, 0.06239] = 19.26 (8) b eV for energies between 20.26 meV and 62.39 meV is given. Based on the experimental details provided we re-analysed the data using $T_{1/2}$ = 2.455 (6) x 10^5 a for ^{234}U and a ^{10}B(n,α) cross section of σ(n,α) = 3838 (6) b. This resulted in a cross section at thermal energy of σ(n,f) = 585.4 (25) b and a resonance integral I_{f1}'[0.02026, 0.06239] = 19.19 (8) b eV. We also derived an integral between 20 meV and 60 meV of I_{f1}[0.02, 0.06] = 18.75 (8) b eV using the same reference values. The ratio of the cross section at thermal energy and I_{f1} is 31.23 (6) eV^{-1}. Evidently, this ratio is not affected by systematic effects such as the half-life of ^{234}U. The cross section at thermal energy is close to the value σ(n,f) = 586.4 (26) b adapted in the database of Axton [3], which was derived with a ^{10}B(n,α) cross section of σ(n,α) = 3838 (6) b and $T_{1/2}$ = 2.457 (3) x 10^5 for ^{234}U.

The weighted average of the re-analysed values from Deruytter [1] and Deruytter et al. [4] is σ(n,f) = 585.5 (24) b. This value is very close to the final value derived by Axton [3], which is 585.1 (16) b. The values recommended by the neutron standards project in 2009 [5] and 2018 [6] are 584.3 (10) b and 587.3 (14) b, respectively. These data are compared in Figure 1.

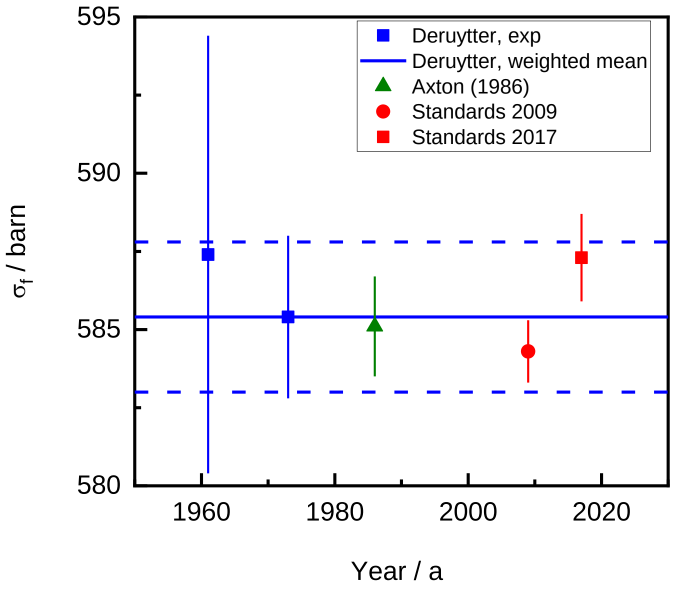

FIG. 1. Comparison of the neutron induced fission cross section of ^{235}U derived from the results of absolute measurements performed by Deruytter [1] and Deruytter et al. [4] with those resulting from the evaluation of Axton [3] and the neutron standards project [5][6].

Note that the uncertainty for the ^{235}U fission cross section in the standard evaluation of Ref. [6] is about 0.2 %, while the one for the ^{10}B(n,α) cross section is 0.8%. The value recommended for the ^{10}B(n,α) cross section σ(n,α) = 3844 (32) b in the latest standard evaluation [6] is increased by 0.15% and its uncertainty by more than a factor 5, without including any additional experimental data in the evaluation procedure. This should be investigated.

Relative cross section measurements at GELINA

An overview of the experiments carried out at GELINA by Deruytter and Wagemans to study the cross section of the ^{235}U(n,f) reaction in the energy region below 20 eV is given in TABLE 1. The measurements reported in 1971 [7], 1979 [8] and 1984 [9] were optimized to determine the resonance integral from 7.8 eV to 11 eV relative to the cross section in the thermal energy region. Unfortunately, the data of Ref. [9] are not available in EXFOR. The experiments reported in 1988 [10] were optimized to determine the energy dependence of the cross section in the sub-thermal energy region.

The cross section data resulting from all these experiments were derived by normalizing the data to the cross section integral $I_{f1'}$. Therefore, these data can only be used to determine ratios of cross section integrals. They cannot be used to evaluate independent values for the cross section at thermal energy and cross section integrals.

The adapted cross section at thermal energy and some cross section integrals are reported in TABLE 2. The integrals are: $I_{f1'}$[0.02026, 0.06239], I_{f1}[0.02, 0.06], and I_{f3}[7.8, 11], with the energies expressed in eV. The values reported in the original papers are compared with those derived in this work using the data reported in the EXFOR data library and those of Ref. [11]. The values of Ref. [11] and those derived in this work are fully consistent. They are also consistent with the data reported in Refs. [8], [9] and [10]. For the 1971 data of Ref. [7] the adapted cross section at thermal energy reported in Ref. [7] deviates by more than 0.5 % from the one derived in this work and in Ref. [11]. This suggests a problem with the normalisation of the data in Ref. [7], as also indicated in a footnote of Ref. [9].

The original data of Refs. [8], [9] and [10] were used to derive ratios of cross section integrals. This results in I_{f3}/I_{f1} = 13.06 (8) and $I_{f3}/I_{f'1}$ = 12.76 (8). Using the value for $I_{f1'}$ = 19.19(8) b eV derived from the absolute measurements of Deruytter et al. [4], this results in a value a resonance integral I_{f3} = 244.7 (20) b eV.

TABLE 1. OVERVIEW OF ^{235}U(n,f) CROSS SECTION EXPERIMENTS CARRIED OUT AT GELINA BY DERUYTTER AND WAGEMANS COVERING THE ENERGY REGION BELOW 20 eV

Reference		Frequency	Pulse Width	Moderator	FP length	Energy region	EXFOR
Deruytter 1971	[7]	40 Hz	1000 /40ns	2.8 cm PI	8.0 m	0.01 – 20 eV	20131
Wagemans 1979	[8]	40 Hz	30 ns	2.8 cm PI	7.8 m	0.02 – 3000 eV	21522
Wagemans 1984	[9]	100 Hz	14 ns	H_2O	8.2 m	0.02 – 3000 eV	
Wagemans 1988	[10]	40 Hz	2000 ns	CH_4 (77 °K)	8.2 m	0.002 – 20 eV	22080

TABLE 2. THE ^{235}U(n,f) CROSS SECTION AT THERMAL ENERGY THAT WAS USED TO NORMALISE THE DATA TOGETHER WITH INTEGRALS I_{f1} AND I_{f3}. The integrals are specified in the text. The values reported in the paper are compared with the values reported in this work and those reported by Duran et al. [11].

Raf.	Original			Re-analysis				Duran et al.		
	$\sigma_{0,f}$/b	$I_{f1'}$/(b eV)	I_{f3} /(b eV)	$\sigma_{0,f}$/b	$I_{f1'}$/(b eV)	I_{f1} /(b eV)	I_{f3} /(b eV)	$\sigma_{0,f}$/b	I_{f1} /(b eV)	I_{f3} /(b eV)
[7]	587.9	19.27	240.2 (21)	583.8	19.04	18.51	237.4	584.6	18.60	239.5
[8]	587.6	19.26	247.0 (30)	587.3	19.26	18.80	246.2	586.9	18.83	246.3
[9]	587.6	19.26	246.1							
[10]	584.25	19.15	242.5 (20)	584.3	19.15	18.71	244.1	584.3	18.71	244.2

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[1] A.J. Deruytter, J. Nucl. Energy **15** (1961) 165-175.
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[3] E.J. Axton, European Applied Research Reports, Nuclear Science and Technology Sec. 5 (1984) 609-676.
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[8] C. Wagemans, G. Coddens and A.J. Deruytter, Proceedings of the International Conference on Nuclear Cross Sections for Technology, Knoxville (US), 22 – 26 October 1979, pp. 961 – 965.
[9] Nuclear Standard Reference Data, Proceedings of an advisory group meeting, Geel, Belgium, 12-16 November 1984, IAEA TECDOC-335, pp. 156 – 161.
[10] C. Wagemans, P. Schillebeeckx, A.J. Deruytter and R. Barthélémy, Proceedings of the International Conference on Nuclear Data for Science and Technology, Mito, Japan, 30 May-3 June 1988, pp. 91 – 995.
[11] I. Duran, R. Capote and P. Cabanelas, Integral References for TOF (n,f) Measurements in Fissile Targets (submitted to Nucl. Data Sheets).

2.5. Integral references for TOF (n,f) measurements in fissile targets reactions and its relations with the Standard Thermal Neutron Constants, I. Duran (FICA-USC, Spain)

The primary standards in the TNC (Thermal Neutron Constants) table are defined as corresponding to neutrons having a kinetical energy of 0.0253 eV, equivalent to a velocity of 2200 m/s, this velocity being the mean value of a Maxwellian thermal distribution for neutrons in equilibrium with the target nuclei at 293.58 K (20.43 ºC). This historical definition is grounded on the unambiguity of the so-called *thermal point* (0.0253 eV), assuming that data from those experiments performed with Maxwellian neutron sources can be analytically reduced to the thermal point just by knowing the behavior of the neutron reaction cross section that was supposed to follow the 1/v law. As a matter of fact, the behavior of the reaction cross section differs from the 1/v law and from one nuclide to the other. This effect was studied by Wescott (Ref. [1]) who introduced the so-called g-factor (Wescott factor) in order to correct the cross section shift obtained when the neutron source has a Maxwellian velocity distribution, compared with a mono-energetic source. For lighter nuclides the 1/v law is very closely followed, and the g-factor is very close to unity. For the actinides cross sections, the negative effect of its bound levels and the positive effect of its resonances around 200-300 meV makes the g-factor deviate from unity. Moreover, there is a noticeable temperature dependence (Ref. [2]). Those cross section data experimentally obtained from Maxwellian neutron sources must be corrected to be comparable with mono-energetic measurements (0.0253 eV), thus introducing an important systematic bias (Ref. [3]).

For many experimental setups it is not possible to run at neutron energies around the thermal point; however even for experiments that can run with neutron energies around the thermal point often the neutron energy is not precisely known. As a result, most of the experimental datasets, even coming from good experiments, suffer of either bad data normalization or bad energy calibration, or even both. To overcome these problems, we are presenting in this work the values of integral mean values to be used as reference for normalization purposes. After defining the energy intervals of the (n,f) reaction cross section for the four main fissile nuclei included in the TNC table, as well as for the ^{10}B(n,α) reaction that is very often used as neutron beam monitor, we deal with cross section datasets from experiments done with white sources where the neutron energy is known by its time-of-flight (ToF) from the source to the target. The use of data acquisition systems with high time resolution in ToF experiments, helps to get an accurate knowledge of the impinging neutron velocity event by event. Furthermore, they are performed at room temperature close to 20ºC, and so do not require corrections by the Westcott factor, even when the cross section behavior is far from following the 1/v law.

Defining the energy intervals

The energy intervals proposed to define secondary standards have been discussed in several IAEA meetings. The thermal energy interval was agreed to be from 20 meV to 60 meV, the same for every nucleus, in order to easily obtain its ratios to each other and to ^{10}B(n,α); the thermal integral values are called I1. For the RRR (Resolved Resonance Range), the integral limits have been defined in order to meet the following two conditions: first to include resonances high enough to get high statistics; and second that these limits fall in cross-section valleys close to the selected resonances. By meeting these two conditions the integral values, termed as I3, will have both low statistical uncertainty and insensitivity to errors in the neutron energy calibration.

For the ^{10}B(n,α) reaction the integral value between limits 20 and 60 meV can be obtained directly from the standard cross section value at thermal point, as its energy dependence follows the 1/v law very accurately from 10 meV and up to 20 eV, with a deviation below 0.5%. The obtained analytical value of I1=127.1(0.5) b·eV is in perfect agreement with the integral values obtained from both ENDF/B-VIII.0 and JEFF-3.3 evaluated libraries.

For every four fissile nuclei ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu, a set of good quality (n,f) reaction experiments has been selected from the EXFOR data-base, as having high-energy-resolution data running from thermal energies up to the RRR, being so well suited to get cross-section integrals in the chosen energy intervals with very low statistical uncertainty.

Results

Least-square fits of consistent experimental ToF datasets of fission cross sections in the thermal region from 20 meV up to 60 meV allowed to derive independent values of the thermal point values in excellent agreement with the Standards TNC table, within one-sigma uncertainties. Such agreement guarantees the reliability of this new evaluation based on the selected database of consistent experimental ToF data. Recommended (reference) values of fission cross-section integrals I1 and I3 with low uncertainties are provided. The ^{235}U normalization integral I3 derived in this work of 245.7(4.1) b·eV is in good agreement with the neutron standards value of 247.5(3.0) b·eV [3].

Recommended (reference) ratios σ_f/I1 and I3/I1 with low uncertainties are also provided. Derived ratios are independent of the data normalization and feature reduced uncertainties due to strong positive correlations between the numerator and the denominator (which were assumed to be fully correlated). The σ_f /I1 and I3/I1 ratios made the data normalization traceable to the Standard Thermal Neutron Constants and also the slope of the fission cross section at the thermal point, to be used by evaluators as an additional constraint in their R-matrix analysis of experimental fission yield data.

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[3] V.G. Pronyaev, R. Capote, A. Trkobv, G. Noguere, A. Wallner, New fit of thermal neutron constants (TNC) for ^{233,235}U, ^{239,241}Pu and ^{252}Cf(sf): Mocroscopic vs. Maxwellian data, EPJ web Conf. **146** (2017) 02045.

2.6. Measurement of the ^{238}U/^{235}U fission cross section ratio at CSNS-Back-n, Z. Ren (China Academy of Engineering Physics)

Jie Wen[1], Yiwei Yang[1], Zhongwei Wen[1], Rong Liu[1*], Xingyan Liu[1], Zijie Han[1], Qi-Ping Chen[1], Zhizhou Ren[1], The Back-n collaboration

[1]Institute of Nuclear Physics and Chemistry, China Academy of Engineering Physics, Mianyang 621900, China

Based on the China Spallation Neutron Source (CSNS) – Back-streaming white neutron source (Back-n), the measurement of the ^{238}U/^{235}U fission cross section ratio in the 1–20 MeV neutron energy region has been carried out by a multi-cell fast fission ionization chamber using the time-of-flight method.

Two ^{235}U cells and three ^{238}U cells were mounted in the detector. The flight distance was calibrated as 76 m by the resonance peak of the ^{235}U(n, f) reaction at 8.77 eV, and the flight time of neutron was calculated through Gamma-Flash and the constant fraction timing method. The influences of the backing and collector were explored. The effect of the nonuniformity of white neutron beam, the attenuation of neutron flux, and the isotope impurity were all considered, and the relevant corrections were made.

The measured six groups of the ^{238}U/^{235}U fission cross section ratios in the 1–20 MeV neutron energy region agree with those of the ENDF/B-VIII.0 database in trend, and the average discrepancies between experiment and database are from 1.9% to 2.6%. The relative experimental uncertainties are 2.3%-3.6% (1.4–20 MeV), and the measured data agree with those of the database within experimental uncertainties at most energy points. The measured ^{238}U/^{235}U fission cross section ratios could provide information and data support in relevant nuclear data evaluation.

2.7. Fission TPC cross-section ratio results: ^{239}Pu(n,f)/^{235}U(n,f), L. Snyder (LLNL, USA)

The ^{239}Pu(n,f)/^{235}U(n,f) cross-section ratio has been measured with the fission Time Projection Chamber (fissionTPC) from 100 keV to 100 MeV. The fissionTPC provides three-dimensional reconstruction of fission-fragment ionization profiles, allowing for a precise quantification of measurement uncertainties. The measurement was performed at the Los Alamos Neutron Science Center (LANSCE). Numerous validation studies were undertaken and have provided a high degree of confidence in the results, there is however a ~2% disagreement with ENDF evaluations. The apparent systematic nature of the discrepancy and some circumstantial evidence indicate that the absolute normalization measurement may be the culprit. We therefore conclude that the data reported here can be utilized as precision shape data in any future evaluation until further measurements can be completed to validate the normalization.

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344.

LLNL-PRES-829707

2.8. Absolute measurements of ^{239}Pu(n,f) and ^{235}U(n,f) cross sections in the GMA database, D. Neudecker (LANL, USA)

LANL-Report LA-UR-21-31829 (2021)

I was asked by the standard chairs to review all absolute experimental data on the ^{239}Pu(n,f) and ^{235}U(n,f) cross sections in the GMA database that is the database underlying the Neutron Data Standards evaluation [1]. Absolute means in this context that the normalization of the data was experimentally determined. The aim was to set up a discussion on possible unrecognized and missing uncertainties in the database.
Sixteen ^{239}Pu(n,f), 44 ^{235}U(n,f), and 15 ^{239}Pu(n,f)/^{235}U(n,f) absolute cross sections exist in the GMA database. The ^{239}Pu(n,f), and ^{239}Pu(n,f)/^{235}U(n,f) absolute cross sections were already revised via templates of expected measurement uncertainties by D. Neudecker [2] and, therefore, the uncertainties are reasonable in size, however, ^{235}U(n,f) cross sections were not reviewed and low uncertainties can be found for individual measurement. Questions were raised on the normalization uncertainties for some of these measurements. In fact, the same group reported several measurements, in some instances with normalization uncertainties as low as 0.3%, while for another measurement (by the same group) with 1.1%. This triggered looking at these data sets into more detail. It was also highlighted that the normalization was determined with only five different techniques across a total of 75 data sets which could lead to correlations across measurements. This could be one potential explanation for unrecognized systematic uncertainties.

[1] A.D. Carlson et al., Nucl. Data Sheets **148** (2018) 143.
[2] D. Neudecker et al., Nucl. Data Sheets **163** (2020) 228.

2.9. The benefit of adjusting with criticality and reaction rate data, R. Casperson (LLNL)

LLNL-ABS-841050

Fission ratios measured at the center of a critical assembly are integral quantities which are sensitive to both the cross sections of the fission ratios and the neutron spectrum of the assembly. These ratios are referred to as spectral indices due to their spectral sensitivity and include a number of different cross section thresholds and shapes: ^{238}U/^{235}U, ^{237}Np/^{235}U, ^{233}U/^{235}U, and ^{239}Pu/^{235}U. Although these spectral indices can inform nuclear properties such as neutron scattering cross sections and prompt fission neutron spectra, a systematic discrepancy across multiple assemblies for a given fission ratio may indicate an issue in the fission cross section itself or in the measurement process.

Adjustment was performed on the ENDF/B-VIII.0 evaluation using data from the spectral indices data from the ENDF/B-VIII.0 validation table. This table includes seven critical assemblies and the four ratios mentioned above. Many of the C/E ratios were systematically low, and unsurprisingly adjustment reduced the ^{235}U(n,f) cross section by ~0.9%. The ^{235}U(n,f) unidentified source of uncertainty (USU) was not removed from the evaluation prior to adjustment and provided additional flexibility in the adjustment process; removing it and adding back after adjustment would have reduced the impact on ^{235}U(n,f).

Critical assembly keff can be dramatically impacted by adjustment with fission ratio data. To maintain consistency with past criticality measurements, the adjustment can additionally include keff data for the seven critical assemblies. The impact on the ^{235}U(n,f) cross sections is nearly the same as without the keff data, but the ^{235}U(n,f) uncertainties are significantly reduced when keff data is included.

Adjustment with critical assembly fission ratios relies on the data having credible uncertainties. Historically, when this data was analyzed, corrections were made for impact of the fission chamber on the neutron spectrum. This could have been impacted by the quality of the nuclear data for the fission chamber materials available at the time. Additionally, since that time concerns have been raised about fission chamber USUs, and these additional uncertainties were not included in the spectral indices uncertainty estimate. Finally, a considerable fraction of the spectral indices uncertainties may be correlated, which has not been estimated or included in the adjustment described here. Quantifying these uncertainties and correlations is an essential first step towards including such integral data in the neutron standards.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

2.10. Evaluation of fission cross section of major actinides, N. Otuka (IAEA)

The neutron-induced fission cross sections were simultaneously evaluated for the JENDL-5 library for $^{233;235}$U and $^{239;241}$Pu from 10 keV to 200 MeV and for ^{238}U and ^{240}Pu from 100 keV to 200 MeV. The evaluation was performed by least-squares fitting of the Schmittroth's roof function to the logarithms of the experimental cross sections and cross section ratios in the EXFOR library. A simultaneous evaluation code SOK was used with its extension to deal with data in arbitrary units. The outputs of the code were adopted as the evaluated cross sections without any further corrections. The newly obtained evaluated cross sections were compared with the evaluated cross sections in the JENDL-4.0 library and the IAEA Neutron Data Standards 2017. The evaluated cross sections were also validated against the californium-252 spontaneous fission neutron spectrum averaged cross sections, ΣΣ (coupled thermal/fast uranium and boron carbide spherical assembly) neutron spectrum averaged cross sections, and small-sized LANL fast system criticalities. The changes in the obtained evaluated cross sections from those in the JENDL-4.0 library are within 4% (^{241}Pu), 3% (^{233}U, ^{240}Pu), or 2% (^{235}U, ^{239}Pu). The newly evaluated ^{235}U, ^{238}U and ^{239}Pu cross sections agree with the IAEA Neutron Data Standards 2017 within 2% with some exceptions. For further details of the evaluation see Ref. [1].

[1] Naohiko Otuka, Osamu Iwamoto, EXFOR-based simultaneous evaluation of neutron-induced uranium and plutonium fission cross sections for JENDL-5, J. Nucl. Sci. Technol. 59 (2022) 1004 (http://doi.org/10.1080/00223131.2022.2030259).

2.11. Standard evaluation potential issues? SACS and absolute cross sections, R. Capote (IAEA)

The TPC measurement identified a 2% discrepancy in the ^{239}Pu/^{235}U fission cross section ratio, if TPC measured ratio data were normalized at 14 MeV. ^{239}Pu/^{235}U reaction rate ratio measured in several very well studied fast assemblies (Godiva, Flaptops, Jezebel, etc – see Section 2.9) also shows a 2% discrepancy compared to measured reaction rates. Additionally, a similar 2% discrepancy was identified between the spectrum averaged cross section (SACS) measured in the Cf spectrum (and evaluated by Mannhart (Ref. [1])) and those derived from the current standards. SACS input data used in the GMA input and in the Mannhart evaluation are reviewed and differences in evaluation-input data were identified. A need to consider the measured SACS ratios in the standard (GMA) fit is discussed. A much larger spread of 14 MeV absolute fission cross section in ^{239}Pu is highlighted. SACS ratios measured in ^{235}U(n_{th},f) neutron field are also suggested to be added to the GMA fit as input. A programme of action is discussed to improve the GMA-py code aimed at generating updated standard cross sections.

[1] A. Trkov, P.J. Griffin, S.P. Simakov, et al., IRDFF-II: A New Neutron Metrology Library. Special issue of Nucl. Data Sheets **163 (2020)** 1-108.

2.12. Progress on light-element standard cross sections at Los Alamos, G. Hale, M. Paris (LANL, USA)

We discussed recent R-matrix work on three of the light-element standard cross sections: n-p scattering up to 100 MeV, ^{6}Li(n,t)^{4}He up to 8 MeV, and n+^{12}C scattering up to 7 MeV. The n-p cross sections come from a charge-independent analysis of the N-N system that includes, in addition to the n-p data, measurements for p+p and n+n scattering, as well as for n+p capture and γ+d photo-disintegration, having a $\chi 2$ per degree of freedom of 1.02. The ^{6}Li(n,t)^{4}He cross section comes from an analysis of the ^{7}Li system that includes 6 channels and experimental data for 9 of the possible reactions among them, with a preliminary value for $\chi 2$ per degree of freedom of 1.65. This value does not correspond to a fully converged solution so a lower value for $\chi 2$ per degree of freedom will be obtained eventually. The data set includes an extensive recent measurement of the ^{6}Li(n,t)^{4}He differential cross section at neutron energies up to 3 MeV by Bai et al., which on the whole is quite well represented by the analysis. The cross sections for n+^{12}C scattering come from an R-matrix analysis of reactions in the ^{13}C system that includes also data for inelastic scattering to the first excited state of ^{12}C, and n+^{12}C capture, having a $\chi2$ per degree of freedom of 1.52. New measurements by Vanhoy of n+^{12}C elastic and inelastic angular distributions are being added to the analysis. All of these analyses need continuing effort in the coming year, as well as new work on the ^{11}B (n+^{10}B) system.

2.13. Alpha scattering experiments to improve and extend the ^{10}B(n,α)^{7}Li neutron cross section standard, M. Anastasiou (LLNL)

We propose to take new measurements of the ^{7}Li+α elastic- and inelastic-scattering reaction cross sections and angular distributions using the active-target detector ANASEN with a ^{7}Li beam on a ^{4}He gas target. With this experimental set-up, we will overcome the drawbacks of earlier experiments and obtain simultaneous measurements of the elastic and inelastic channel, with common beam normalization. We will quantify the systematic uncertainties for the analyzed reaction channels and provide results that are appropriate for inclusion in the evaluations. Collaborating evaluators will include the new data in the multi-channel R-matrix analysis used within the GMAP generalized least square fit of the neutron standards. The multi-channel R-matrix analyses of the ^{11}B system (n+^{10}B, α+^{7}Li) will be performed with the LLNL codes Fresco and Rflow, and the LANL R-matrix code edaf90. The new experimental data will constrain and inform current and future evaluations of the ^{10}B(n,α)^{7}Li neutron standard reaction cross section. They will also extend this standard's energy range higher than the current 1 MeV neutron energy. Improving the quality of neutron cross section standards impacts all nuclear data measurements that have been made or will be made relative to that standard, addressing nuclear data needs that cover multiple scientific or engineering disciplines.

2.14. Investigation of the p+ ^{10}Be system, T. Massey (Ohio Univ.)

The Ohio University group reported studies of the ^{11}B system. This is to support the R-Matrix analysis of the ^{10}B(n,alpha) standard. The results of initial results on ^{10}Be + p reactions were presented. Excitation functions were measured from 2 – 7 MeV and angular distributions at 2.4 and 3.5 MeV. Both neutrons and gamma rays were measured. Future plans include completing the analysis of this data and measurement of the integrated neutron cross sections at lower energies with a long counter.

2.15. Motivation and existing data for ^{235}U(n,γ)^{236}U, A. Wallner (HZDR, Germany)

Update on AMS experiments: (1) ^{235}U(n,g) at thermal and sub-thermal energies, (2) systematic difference between AMS & TOF

(1) A new method to measure the neutron capture cross section of ^{235}U and ^{238}U for thermal and cold energies using accelerator mass spectrometry (AMS) was presented. Goal of the project is to achieve an uncertainty of order 2-3% for the cross-section value. Besides the previously presented neutron irradiations at BR-1 (Mol, Belgium) with thermal neutrons, at FRM-II, Munich with cold neutrons (2 activations) and at ILL, Grenoble with very cold neutrons, we presented new additional activations at ILL. Two proposals for activations under well-defined conditions allow additional measurements of the ^{235}U and ^{238}U neutron capture reaction for cold neutrons. All these different activations will allow to explore the energy-dependence of the cross section in the energy range from 0.05 to 25 meV. Natural Uranium-oxide samples are used which allows also to study in the same samples the capture cross section of ^{238}U and ^{235}U. AMS directly counts the reaction products, ^{236}U and ^{239}Pu (decay product of ^{238}U). AMS is performed at the VERA laboratory in Vienna for the quantification of the reaction products ^{236}U and ^{239}Pu (as the longer-lived decay product of ^{239}U). Special consideration is taken to minimize systematic uncertainties in the measurements. The AMS measurements of the Mol and FRM-II activations are finished and first results were presented. Still pending is the measurement of the ILL samples and, as well, a cross calibration of reference samples used for ^{236}U and ^{239}Pu counting to new reference materials ordered from JRC Geel.

Preliminary outcome of the experiment: thermal values were reproduced; for cold and ultra-cold energies we found an indication for a deviation from 1/v for ^{235}U; however, an accuracy in the experimental data of <2% requires several AMS beamtimes and sophisticated reproducibility checks, i.e. unrecognized sources of uncertainties are important - therefore independent results from different AMS facilities will strengthen confidence;

The advent of new compact AMS systems can achieve required accuracy - a new dedicated AMS facility at HZDR with special focus on actinide measurements was presented.

(2) A second topic addressed was the potential indication of a systematic difference in the Maxwellian-Averaged Cross Section (MACS) values at 25 keV for the lighter isotopes. AMS seems to generate systematically lower cross section values compared to TOF data. The reason is not clear at this stage, but new measurements have been scheduled to confirm the AMS data. We recently studied the two reactions ^{35}Cl(n,g) and ^{54}Fe(n,g) for the MACS at ca. 25 keV, which is of interest to nuclear astrophysics. Here, an independent neutron irradiation and the use of different AMS facilities should clarify whether some systematic uncertainties plague the AMS method for these reactions. Part of the experiments are finished and for those the previous AMS results were confirmed. Therefore, the discrepancy between the two methods remains and is considered an open issue.

2.16. n_TOF high accuracy and resolution ^{235}U(n,f) cross section from thermal to 170 keV: preliminary results, P. Finocchiaro (INFN, Italy)

The ^{235}U(n,f) cross section was measured in a wide energy range (25 meV – 170 keV) at n_TOF relative to ^{6}Li(n,t) and ^{10}B(n,alpha), with high resolution and accuracy, with a setup based on a stack of six samples and six silicon detectors placed in the neutron beam. Preliminary higher resolution results are reported in the region between thermal and 10 keV neutron energy. A resonance analysis has been performed up to 200 eV, with the code SAMMY. The resulting fission kernels were compared with the ones extracted on the basis of the resonance parameters of the most recent major evaluated data libraries, showing that some discrepancies are still present. The new dataset with its unprecedented resolution and accuracy, can help improving the evaluations in the Resolved Resonance Region and reduce the uncertainties that affect this region.

2.17. Applying various templates to the neutron data standards, D. Neudecker (LANL, USA)

LANL Report LA-UR-21-31906 (2021)

An update on the effort on establishing templates of expected measurement uncertainties was provided. These templates list all pertinent uncertainty sources encountered for typical measurements, and give estimated values (based on literature, past measurements, expert judgement) for these missing uncertainties. Templates were already developed for (n,f) cross sections and applied to ^{239}Pu(n,f) cross sections in the GMA database in Ref. [1]. Templates were also developed for total and capture cross sections (lead: A. Lewis), average prompt fission neutron multiplicity and spectrum (lead: D. Neudecker), charged-particle cross sections (lead: D. Neudecker), (n,xn) cross sections and angular distributions (J. Vanhoy) and fission yields (lead: E. Matthews). Many of them could be applied to counter-check experimental uncertainties in the GMA database, and suggestions were given how to do this.

[1] D. Neudecker et al., Nucl. Data Sheets **163** (2020) 228.

2.18. ^{352}Cf(s.f.) γ-ray spectra: proposal of new reference, S. Simakov (KIT, Germany)

The prompt γ-ray spectra from spontaneous fission of ^{252}Cf(s.f.) was proposed as a reference γ-ray spectra in the energy range from 0.1 to 20 MeV. The importance of such data was demonstrated for the neutron-gamma transport evaluated data validation in the shielding benchmarks with ^{252}Cf-source. From the physics point of view, the disintegration of ^{252}Cf includes several processes: prompt and delayed neutron and γ-ray following the spontaneous fission, γ- and X-ray emission after α-decay. It was shown that the prompt and delayed ^{252}Cf(s.f.)γ-rays are not represented at all or with insufficient accuracy in the major evaluated libraries. Thus JEFF-3.3 has adopted the data measured only in the single experiment, ENDF/B-VIII.0 has no ^{252}Cf(s.f.)γ-spectrum.

On the other hand, the prompt ^{252}Cf(s.f.)γ-ray spectra have been measured in 21 independent experiments since 1956. Various detectors and measuring techniques were used that increase the reliability of the accumulated experimental data. The preliminary GLS fit to these measurements by the GMA code has shown the possibility of reference prompt ^{252}Cf(s.f.)γ-ray spectra production in the energy domain 0.1 – 20 MeV with uncertainty 10 – 50%. The latter was currently estimated from the uncertainties reported by the most precise experiments. Extension of the GMA fit above 20 MeV is presently not possible since the amplitude and energy shape of the γ-ray spectrum there are not established yet, neither experimentally nor theoretically.

Besides the GMA evaluation of the prompt ^{252}Cf(s.f.)γ-spectrum the continued collection of the delayed and total γ-rays data to complete the analysis of all γ-ray emission pathways would be useful.

3. ACTIONS AND RECOMMENDATIONS

This section lists actions and recommendations resulting from the discussion during the meeting. They are grouped by reaction. If pertinent, comments of participants regarding specific reactions and ongoing work are included as complementary information to the recommendations and action items.

3.1. H(n,n)

It is recommended that the data analysis by Mark Paris should be extended as high as reasonably possible but at least to 200 MeV. This analysis should also take into account experimental data obtained at the CSNS facility.

***ACTION**: Mark Paris and Gerry Hale will deliver an evaluation with uncertainties by fall 2022. If feasible, they will also explore procedures to obtain values above the highest energy limit of the Standards. They will also consider the issue of matching ranges in dealing with cross section uncertainties to preserve continuity and smoothness.*

***ACTION**: Vladimir Pronyaev will explore how Standard CS can be included as ratios to Hydrogen in GMAP, also considering potential difficulties with the handling of angular distributions.*

3.2. ^{3}He(n,p)

Gerry Hale is currently undertaking an evaluation of this reaction.

***ACTION**: Gerry Hale will contribute an evaluation of ^{3}He(n,p) to the Standards project.*

3.3. ^{6}Li(n,t),

Evaluation work is ongoing using the EDA code. New TPC data of ^{6}Li(n,t)/^{235}U(n,f) may be available in time for this new evaluation. Also, NIST sub-thermal data will be used if available and the experiment is completed.

***ACTION**: Luke Snyder will select TPC ratio data sets from the n-TOF experiment, which are to be included in the GMAP analysis. Deadline for doing this is fall 2022.*

***ACTION**: It should be decided how high in energy this evaluation will go. If differences occur between an analysis with the EDA and RAC R-matrix of these data, they should be resolved. Importantly, the same energy range in both analyses should be used.*

3.4. ^{10}B(n,α),^{10}B(n,α1)

It was recommended to include several datasets into a new evaluation:

- Paolo Finocchiaro's ratio data;
- Thomas Massey's data from an experiment at LANL;
- Thomas Massey's p+^{10}Be when available;
- Maria Anastasiou's alpha +^{7}Li data when available.

***ACTION**: Gerry Hale will acquire data from Thomas Massey's experiment at LANL and include it in the EDA evaluation. He will determine whether it is possible to extend the evaluation to higher energies.*

***ACTION:** Situation will be reviewed again in 6 months – Roberto will call a small meeting at that time. Roberto to check on AZURE results for evaluations of B using latest data from Massey.*

***ACTION**: Gerry Hale will take into consideration Peter Schillebeeckx's observation about higher ^{10}B(n,alpha) cross sections in his analyses with EDA.*

3.5. natC

The carbon total and angular distribution measurements of Jeff Vanhoy et al. appear to be consistent with the previous evaluation. They do not substantiate the differences seen by Yaron Danon. The difference is about 1% for the total cross section. There is also a concern about the angular distribution data at RPI that indicate differences with both recent standards evaluations at back angles (about 156 degrees) in the standards energy region. Apparently no new ^{13}C data have been obtained by Vanhoy. ^{13}C material is now available for him to use.

ACTION*: The reason for the difference between the standards evaluation and results for natural carbon obtained by Yaron Danon should be investigated.*

ACTION: *Mark Paris will perform an evaluation for the full energy range up to 8 MeV including new available datasets and explore the influence of ^{13}C on the result to help clarify whether the current carbon standard is isotopic or elemental.*

3.6. ^{197}Au Capture:

The participants were not aware of recent measurement campaigns relevant to this standard. People seem to be satisfied with the existing evaluation.

It was recommended to add any new ^{197}Au capture data, if relevant, and otherwise use SACS data to validate the existing evaluation.

3.7. ^{235}U(n,f)

It was recommended that the absolute ^{235}U(n,f) cross section data by Pirovano et al. for 30 to 150 MeV (and higher) should be included in the evaluation. It was also recommended to include the NIST absolute measurement of the ^{235}U(n,f) cross section at a sub-thermal energy to the evaluation. It was further recommended to add the Finochiaro ^{235}U(n,f) cross section data obtained relative to the ^{6}Li(n,t) and ^{10}B(n,α) cross sections. It was assessed that this data agrees with the standard in the standards energy region but from 918 keV neutron energy range it is lower by almost 5%. It was recommended that the focus should be put on the standards energy region.

ACTION*: The CSNS data will be included in the GMAP evaluation. Ralf Nolte will provide data up to 150 MeV, and possibly higher energies if available. Cutoff date should be end of October 2022. The status of the NIST cold neutron data is uncertain due to reactor shutdown.*

ACTION*: Determine how to include SACS ratio data in GMAP. There are about 10 data sets that are very precise. Minimum level is to include only Cf and U5 SACS data. The next level would be to include U5 and Pu SACS data as well. The third level would be to further include SACS data for U8. Lastly, explore energy-dependent USU uncertainties.*

3.8. ^{238}U(n,f)

It was recommended to include CSNS ^{238}U(n,f)/^{235}U(n,f) cross section ratio data of Zhizhou Ren in the evaluation. It was confirmed that TPC data has already been included in the GMA database.

ACTION*: Vladimir Pronyaev will add the data from CSNS to the GMA database.*

3.9. ^{239}Pu(n,f)

An evaluation was completed by Denise Neudecker. It was suggested that TPC data may be treated as absolute once the targets are improved.

ACTION*: It will be ensured that Denise Neudecker's final evaluation is included in the GMA database.*

ACTION*: It will be decided whether data sets 631 and 600 are to be treated as shape ratio data.*

ACTION*: Include Tovesson data properly in the evaluation, as far as the energy range is concerned.*

ACTION*: Ratio data relative to Hydrogen for the Lisowski data set will be obtained so it can be converted to cross sections using the latest H Standard values.*

3.10. Thermal constants

It was recommended to reevaluate the thermal neutron constants if new data become available or the evaluation method changes. It was emphasized that it is important to use the latest evaluation of ^{234}U half life for the mass determination. It was noted that the ^{235}U(n,f) cross section value at thermal of Deruytter 1973 can be used alone, not as a product of ^{234}U half life times the ^{235}U(n,f) cross section at thermal.
It was recommended to include cross sections relative to gold capture and ^{10}B(n,α) in the GMA fitting rather than treating them as constants.
It was recommended to include ^{235}U(n,γ) by Wallner in the evaluation.
It was recommended to include the proposed work by Stephen Croft, and Robert McElroy at ORNL for nubar ^{252}Cf when finalized as well as nubar results by Hansell for ^{252}Cf when finalized.
It was recommended to consider the need for integral references for TOF measurements of fission cross sections.
The neutron energy standards were discussed during the last meeting and the question was raised whether there is still interest in this and it was remarked that not much has been done since the 1991 NEANDC/INDC Nuclear Standards File work.

ACTION*: Some issues related to the thermal constant data, as discussed during the meeting, will be further examined by some of the participants at this meeting. Perhaps the CONRAD analysis values will be implemented in the GMAP analysis rather than doing a new evaluation.*

ACTION*: The possibility and benefits of including integral ratio values involving sigma0 (thermal), I1, and I3 for fission cross sections in the GMAP analysis (based on Ignacio Duran's suggestions that were discussed earlier in this meeting) will be explored. This will principally involve the ratios of sigma0 to I1 and I3/I1. Direct traceability to the evaluated thermal constants will be assured.*

3.11. Reference cross sections

It was agreed that no changes will be made to Cf(s.f.) spectrum representation in the new Standards since no new data of sufficiently good quality are available to affect the evaluation.

ACTION*: The possibility of including Cf(s.f.) gamma spectrum as a reference spectrum will be explored (proposed by Stanislav Simakov).*

3.12. Improved evaluation codes

It was recommended to investigate the impact of the number of nodes for GMA, to determine a good number of nodes, and to examine possible problems that may occur because of a changed number of nodes. It was emphasized that data at sub-thermal energies (e.g., 4 meV) need to be properly handled. Georg Schnabel's presentation elaborated on the progress to translate the GMAP code to Python and it is anticipated that this code can be very soon used in lieu of the original GMAP Fortran version. It was also mentioned that EDA improvements are underway for improved handling of uncertainties.

ACTION*: Georg Schnabel will use GMAP-Python in performing the evaluations for the new Standards since it is well validated through comparison with the original Fortran version from Poenitz, also including the fix for PPP introduced by Vladimir Pronyaev about 20 years ago.*

ACTION*: Georg Schnabel and Roberto Capote will consider an extension of GMAP-Python to include certain high-quality SACS ratio data for the Cf and U5 thermal neutron spectra.*

ACTION*: Ignacio Duran and Vladimir Pronyaev will investigate the impact of the number of nodes on the evaluation. They will investigate whether an increased number of nodes is beneficial and explore* *whether the use of a log-log energy representation allows for an extension of energy bins to avoid problems due to changing scales at the limits of neighboring energy regions. Georg Schnabel will implement the findings of this investigation.*

3.13. Adjustments

The question was raised whether criticality and reaction-rate data can be included in an evaluation as initial work by Robert Casperson suggests a lower ^{235}U(n,f) and a higher ^{239}Pu(n,f) cross section.

No recommendations were made, nor actions defined for this point.

3.14. SACS

It was agreed that results in the Standards project should be compared to the SACS evaluation by Mannhart.

3.15. USU

It was recommended that more work should be done on Unrecognized Sources of Uncertainties (USU) with an emphasis on improving them by providing its energy dependence for appropriate standards.

ACTION*: Roberto Capote, Denise Neudecker, Vladimir Pronyaev and Georg Schnabel will explore together the broad energy ranges and reactions that should be considered for defining the USU energy dependences. They will also investigate possible constructions of a USU covariance matrix and decide whether USU should be treated inside or outside the GMA Generalized Least Squares method.*

ACTION*: Tentative choices of energy groups mentioned in discussions at this meeting should be explored for the treatment of USU. Short virtual meetings in the future to assess progress on this matter as well as others discussed during the meeting.*

3.16. Templates

Denise Neudecker reported on templates for a very large range of data. It was recommended to continue work on the templates and especially, to check experiments with charged-particles (same compound nucleus) that often have very high weight in R-Matrix evaluations. Are those weights justifiable?

ACTION*: Denise Neudecker and Vladimir Pronyaev will discuss this point further as required.*

APPENDIX I: ADOPTED AGENDA

TM on Neutron Data Standards, 6-10 December 2021 (virtual event)

Monday 6 December (2:00 – 6:00 pm, open 1:45pm Vienna time)

2:00	**Opening of the meeting**	
	Election of Chair and Rapporteur(s), discussion/adoption of Agenda	
2:20	**Participants' Presentations**	
	A. Carlson	Review of the standards evaluation process *(25')*
	V. Pronyaev	Problems of neutron data standards evaluation and their possible solution *(25')*
	G. Schnabel	GMAP modernization and new possibilities *(25')*
Break		
	P. Schillebeeckx	^{235}U(n,f) cross section measurements for En < 12 eV by Deruytter and Wagemans *(25')*
	I. Duran	Integral references for ToF (n,f) measurements in fissile targets *(25')*
	Discussion	

Tuesday 7 December (2:00 – 6:00 pm, open 1:45pm Vienna time)

2:00	**Participants' Presentations (cont'): FISSION**	
	Z. Ren	Measurement of the ^{238}U/^{235}U fission cross section ratio at CSNS–Back-n *(25')*
	L. Snyder	Fission TPC ^{239}Pu(n,f)/^{235}U(n,f) Cross-Section Ratio Results *(25')*
	D. Neudecker	Absolute measurements of ^{239}Pu(n,f) and ^{235}U(n,f) cross sections in the GMA database *(25')*
Break		
	R. Casperson	The benefit of adjusting with criticality and reaction rate data *(25')*
	N. Otsuka	Evaluation of fission cross section of actinides *(25')*
	R. Capote	Standard evaluation potential issues? SACS and absolute cross sections *(20')*
	Discussion	

Wednesday 8 December (2:00 – 6:00 pm, open 1:45pm Vienna time)

2:00	**Participants' Presentations (cont'): LIGHT ELEMENTS**	
	G. Hale, M. Paris	Progress on light-element standard cross sections at Los Alamos *(30')*
	M. Anastasiou	Alpha-scattering experiments to improve and extend the ^{10}B(n,α)^{7}Li neutron cross section standard *(25')*
	T. Massey	^{11}B compound nucleus: ^{10}Be(p,n), ^{10}Be(p,n gamma), ^{10}Be(p, alpha gamma) reactions
Break		
	A. Wallner	Motivation and existing data for ^{235}U(n,gamma)^{236}U (25')
	Discussion	

Thursday 9 December (starting 2pm, open 1:45pm Vienna time)

2:00	**Participants' Presentations (cont'): VARIOUS**	
	P. Finochiaro	n_TOF high accuracy and resolution ^{235}U(n,f) cross section from thermal to 170 keV: preliminary results (25')
	D. Neudecker	Applying various templates to the Neutron Data Standards *(25')*
Break		
	S. Simakov	^{252}Cf(s.f.) g-ray spectra: proposal of new reference (25')
	Discussion	

Friday 10 December (starting 2pm, open 1:45pm Vienna time)

2:00	**Drafting of the meeting summary report**
	Agreement of actions, discussion of the new release and schedule

APPENDIX II: PARTICIPANTS

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APPENDIX III: PRESENTATION LINKS

#	Author	Title	Link
1	A. Carlson	History of the standards evaluation process	PDF
2	V.G. Pronyaev	Problems of neutron data standards evaluation and their possible solution	PDF
3	G. Schnabel	GMA modernization and new possibilities	PDF
4	P. Schillebeeckx	^{235}U(n,f) cross section measurements for En < 12 eV by Deruytter and Wagemans	PPTX
5	I. Duran	Integral references for ToF (n,f) measurements in fissile targets reactions and its relations with the standard TNC	PDF
6	Z. Ren	Measurement of the ^{238}U/^{235}U fission cross section ratio at CSNS-Back-n	PDF
7	L. Snyder	FissionTPC cross-section ratio results	PDF
8	D. Neudecker	Absolute measurements of ^{239}Pu(n,f) and ^{235}U(n,f) cross sections in the GMA database	PDF
9	R. Casperson	The benefit of adjusting with criticality and reaction rate data	PDF
10	N. Otsuka	Evaluation of fission cross section of major actinides	PDF
11	R. Capote	Standard evaluation potential issues? SACS and absolute cross sections	PPTX
12	G. Hale	Progress on light-element standard cross sections at Los Alamos	PDF
13	M. Anastasiou	Alpha scattering experiments to improve and extend the ^{10}B(n,alpha)^{7}Li neutron cross section standard	PDF
14	T.N. Massey	^{11}B compound nucleus: ^{10}Be(p,n), ^{10}Be(p,n gamma), ^{10}Be(p, alpha gamma) reactions	PDF
15	A. Wallner	Motivation and existing data for ^{235}U(n,gamma)^{236}U	PDF
16	P. Finocchiaro	n_TOF high accuracy and resolution ^{235}U(n,f) cross section from thermal to 170 keV: preliminary results	PDF
17	S. Simakov	^{252}Cf(s.f) gamma-ray spectra: proposal of new reference	PDF
18	D. Neudecker	Applying various templates to the neutron data standards	PDF

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