National Institute of Standards and Technology
Neutron Cross Section and Fluence Standards Program

PROGRESS REPORT

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USNDP 2023 Meeting

Activities

- Measurements of Neutron Cross Section Standards
  - Needed for improvement of standards evaluations
- Evaluation of Standards
  - Most cross sections are relative to the standards
  - An improvement in a standard leads to improvements in all measurements relative to that standard
- Other work

Nuclear Reaction Activities- Measurements

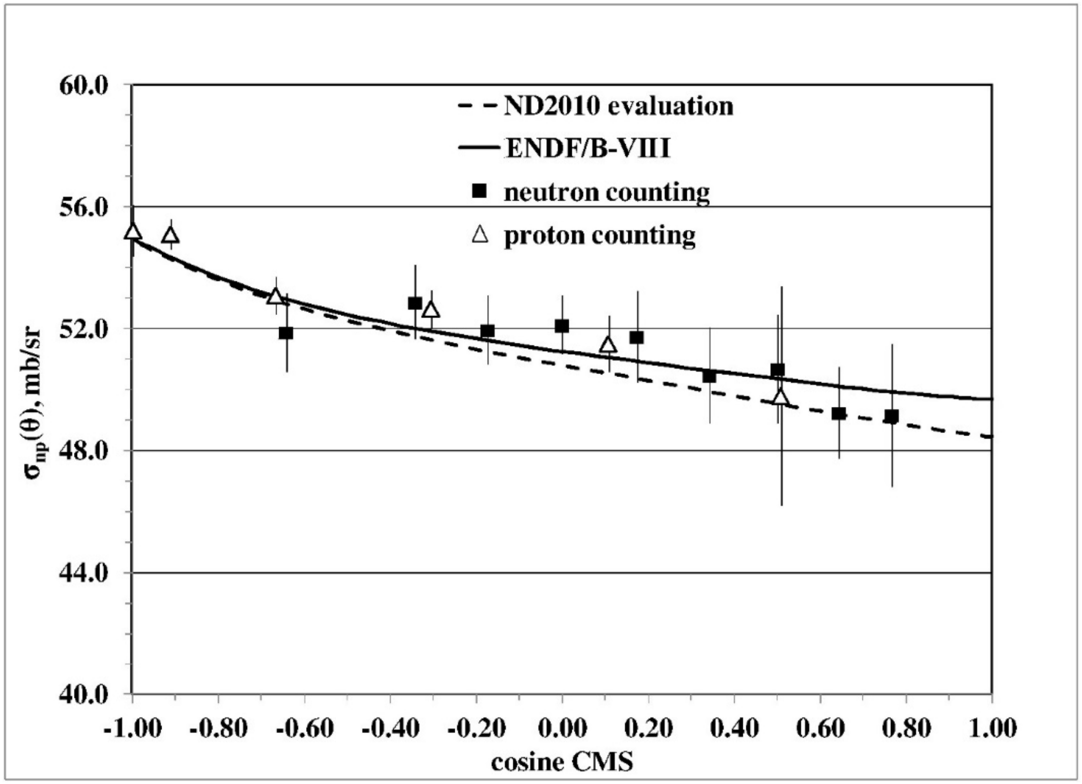
Comparison of measurements of neutron source emission rate CRR(III)-K9.Cf 2016

- **NIST is a participant in an international project measuring source intensity**
- **A single ^{252}Cf is sent to a number of laboratories throughout the world**
  - **Brazil, Canada, China, England, France, Italy, Russia, S. Korea and USA**
- **The measured rate at each laboratory using their techniques is sent to a pilot institute**
  - **The results are being tabulated leading to a publication in Metrologia**
- **Such work is valuable to ensure that each laboratory is obtaining consistent results**
  - **Results that deviate from the mean require investigation to find sources of error**

Nuclear Reaction Activities: H(n,n)H Standard Angular Distribution Work

This work was initiated to resolve problems with the hydrogen database.
The latest results were with neutron counting at 14.9 MeV to allow small CMS angles to be obtained.
The results and the ENDF/B-VIII evaluation are all in excellent agreement but there is a trend toward lower values at small CMS angles.

- (collaboration of NIST with Ohio University, Lincoln Memorial University and the University of Guelma)
  - **Results published in Nuclear Science and Enginering**



Nuclear Reaction Activities: Standards Measurements, $^{6}Li(n,t)$ Cross Section

- At the NIST Neutron Center for Neutron Research a measurement was made of the $^{6}Li(n,t)$ cross section standard. This is the first direct and absolute measurements of this cross section in this neutron energy range using monoenergetic neutrons (3.3 meV).

  - A primary effort was focused on measuring the neutron fluence accurately. It was determined with an uncertainty of 0.06%.

  - There is concern about the IRMM mass determination of the sample. That value yields a cross section value with an uncertainty of 0.3% that is 1% lower than the ENDF/B-VIII value.

  - Most of the uncertainty is from uncertainty in the ^{6}Li mass.

  - Though significant amounts of data were obtained, additional data will be obtained when the reactor is at full power. The previously obtained data has been analyzed. **A better determination of the mass must be done.**

(collaboration of NIST with the University of Tennessee and Tulane University)

Nuclear Reaction Activities: Standards Measurements, ^{6}Li(n,t) Cross Section

- For a better determination of the mass the following must be done:
- To start the process, a sample from the same batch as that used in the experiment is compared, by neutron counting using reactor neutrons, to the one used in the experiment.
- That sample should be submitted for mass determination using the NIST Isotope Dilution Mass Spectrometry (IDMS). The pandemic severely limited activity at that facility and they now have a reduction in staffing. So we await work at that facility. A new IDMS facility has beenestablished in our Division, but it presently can't satisfy the accuracy requirement. Note-to do this work that sample (not the original ome) is sacrificed.
- From the IDMS result and the ratio from the neutron counting experiment, the amount of ^{6}Li in the sample used in the experiment will be determined.
- Complications may come if there are questions about the NIST standard reference sample used for the IDMS.

Nuclear Reaction Activities- Measurements

- A measurement is underway at NIST of the $^{235}U(n,f)$ cross section at 3.3 meV. This is the same monoenergetic neutron energy using the same basic setup used for the $^{6}Li(n,t)$ measurement.
    - A well characterized $^{235}U(n,f)$ sample was obtained. It has a well defined mass with a 1% uncertainty obtained by comparison with various samples.
        - Plans are underway to measure the mass by alpha counting to improve the accuracy of the $^{235}U(n,f)$ sample. It involves using the well known ^{234}U half life and the established $^{235}U/^{234}U$ atom ratio.
    - However the areal uniformity of the mass distribution is not known well.
        - Studies are underway on that distribution.
    - Initial data were obtained but more data are required. Final data should provide about a percent uncertainty. Progress has stopped since the reactor is now running at 5% of normal power.
    - Very few absolute low energy monoenergetic measurements have been made of this cross section. They were all done in the 1950s and 1960s.

Nuclear Reaction Activities- Measurements

Previous $^{235}U(n,f)$ cross section measurements at about 25 meV (No Maxwellian Data)

Author	Date	CS (b)	DCS (b)	Reference
Saplakoglu	1959	593.17	13	*2nd Geneva Conf.**4**, 157*
Raffle	1959	581.97	18	*AERE/R-2998*
Deruytter	1961	589.73	8	*J. Nucl. Energy **15**, 165*
Maslin	1965	583.71	8	*Phys. Rev. **139**, 852*
NIST	~2024		~ *6*	(at 3.3 meV)
ENDF/B-VIII		587.29		

Nuclear Reaction Activities- Measurements

National Repository for Fissionable Isotope Mass Standards

- These are well characterized samples that have been obtained from various labs that no longer are in the nuclear measurement field. They are routinely monitored.
  - These samples are available for loan in physics and nuclear engineering applications.

Nuclear Reaction Activities- Measurements

Nubar Measurement

- Work done with the PROSPECT study that led to a measurement of nubar for ^{252}Cf.

- The measurement was made with a large bank of ^{6}Li loaded liquid scintillation detectors. There were 154 individual segments (detectors) with a total of 4 tons of ^{6}Li.

  - It differs from the scintillation tank type measurements since gamma-rays from a ^{252}Cf source near the detector start the detection process instead of neutrons. Detection of fission fragments in a fission chamber is not used. The neutrons are detected using the ^{6}Li(n,t) reaction.

  - There is high efficiency for neutron detection, about 70%. The understanding of neutron detector efficiency is being studied thoroughly to hopefully reduce the uncertainty in the absolute measurement that was previously large (2.2%).

- NIST collaborative work from the PROSPECT experiment headed by Hansell

Nuclear Reaction Activities: - Evaluations

- Experimental data in the standards database have been improved as a result of NIST involvement or encouragement.

- These data will be used in the evaluation of the neutron cross section standards.

- Work is continuously done to investigate new experiments for improvements that may be needed.

- Close cooperation with the groups at the China Spallation Neutron Source (CSNS) using the back-streaming white neutron source (Back-n WNS) has led to major sources of neutron standards data.

Nuclear Reaction Activities: - Evaluations

- Attended the virtual ND2022 conference on July 25-29,2022
  - Gave a paper on the **status of the experimental database for the new evaluation of the neutron standards.**
  - The paper has data that is a starting point for that needed for the new evaluation of the neutron standards.

Nuclear Reaction Activities: - Evaluations

- Attended the Covariance Workshop CW2022, Sept. 25-29, 2022 and chaired a session
- Co-authored a paper on **Experimental spectrum average cross sections in ^{252}Cf(sf) neutron field and its impact on evaluation of neutron standards**
  - This work investigates differences between different groups on the determination of these important spectrum averaged cross sections that have a large impact on the normalization of the standards.
  - A new Python based code was written by Schnabel (GMA-py) so ratios of spectrum averaged cross sections in the ^{252}Cf(sf) neutron field can now be used in standard cross section determinations.

Nuclear Reaction Activities: - Evaluations

A hybrid IAEA standards meeting was held on Oct.9-13, 2023 in Vienna

- I chaired the meeting and gave a presentation on the only primary standard - hydrogen scattering.

BELOW IS FOR MEASUREMENT ACTIVITY ONLY

- Final results were given for CSNS work on ^{6}Li(n,t) and ^{10}B(n,α) cross sections
- ^{239}Pu(n,f)/^{235}U(n,f), ^{6}Li(n,t)/^{235}U(n,f) and ^{239}Pu(n,f)/^{6}Li(n,t) cross section ratio work by the NIFFTE collaboration were discussed
- Near final absolute measurements for the ^{235}U(n,f) cross section obtained at the n_TOF facility up to 450 MeV were presented.
- CSNS measurements of the ^{235}U(n,f) cross section relative to hydrogen scattering from 10 to 70 MeV were shown
- Carbon scattering angular distributions from 1 to 8 MeV made at GELINA in a CEA collaboration were given

Nuclear Reaction Activities: - Evaluations

- Attended the CSEWG meeting Oct 31-Nov.4, 2022
  - Gave a paper on **Recent Standards Work**
  - Many of the measurements in this report will be used in the new evaluation of the neutron standards.

Nuclear Reaction Activities: - Evaluations

- Co-authored several papers on templates used in updating uncertainties of cross-section data in the neutron standards database.
  - These templates can help evaluators in identifying missing or suspiciously low uncertainties for a specific uncertainty source and missing correlations between uncertainties of the same and different experiments, when estimating covariances for measurements entering their evaluation.
    - Introduction to Templates of Expected Measurement Uncertainties
    - Templates of Expected Measurement Uncertainties for Total Cross Section Observables
    - Templates of Expected Measurement Uncertainties for Average Prompt and Total Fission Neutron Multiplicities
    - Templates of Expected Measurement and Uncertainties for Capture and Charged-Particle Production Cross Section Observables

Nuclear Reaction Activities: - Program Involvement

- Member of the Program Committees of the 17th and 18th International Symposium on Reactor Dosimetry (ISRD-17, 18). Due to covid, ISRD-17 was held in 2023 in Lausanne Switzerland and the ISRD-18 will be in the USA in 2025.

- Member of the International Program Committee of the 15th International Conference on Nuclear Data for Science and Technology, ND-2022.

- Member of the International Advisory Board for the 5th International Workshop on Nuclear Data Covariances (CW2020 now changed to CW2022).

Proposed Work

- ➢Pursue improvements in the experimental database so they are available for the next evaluation of the standards.

- ➢In an effort to continually improve the standards, continue to recommend and encourage new measurements and perform examinations of the data from them for use in future evaluations of the standards. Continue USU and Template work.

- ➢Calibrate NBS-I using an absolutely calibrated source based on the α-γ coincidence system.

- ➢Continue to acquire and monitor samples in the National Repository for Fissionable Isotope Mass Standards. Make these samples available for loan in experiments

- ➢Determine the mass of the ^{6}Li sample used for the ^{6}Li(n,t) cross section by Isotope Dilution Mass Spectrometry and consistency measurements. Then finalize the ^{6}Li(n,t) cross section data.

- ➢Measure the ^{235}U(n,f) cross section at 3.3 meV with high accuracy.

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