Remarks on LLNL pulsed sphere work

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… in June 2019

UPM aims to contribute to WPEC/SG47 in two objectives …

1. Collection of TOF Shielding Benchmarks for Nuclear Data validation

" … To participate in establishing the priority list of relevant benchmarks according to the needs of the nuclear data community, in particular among new and more recent benchmarks…"

2. Sensitivity Analysis

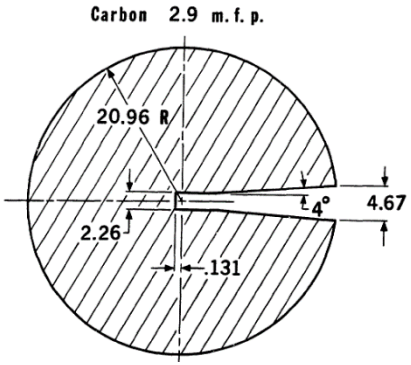
"… promote including the selected benchmarks in SINBAD;

contribute the available sensitivity profiles to be included in the database;"

1. LLNL pulsed spheres within MCNP6-TOF Suite

Leakage neutrons from

- ❑ LLNL: Pulsed sphere

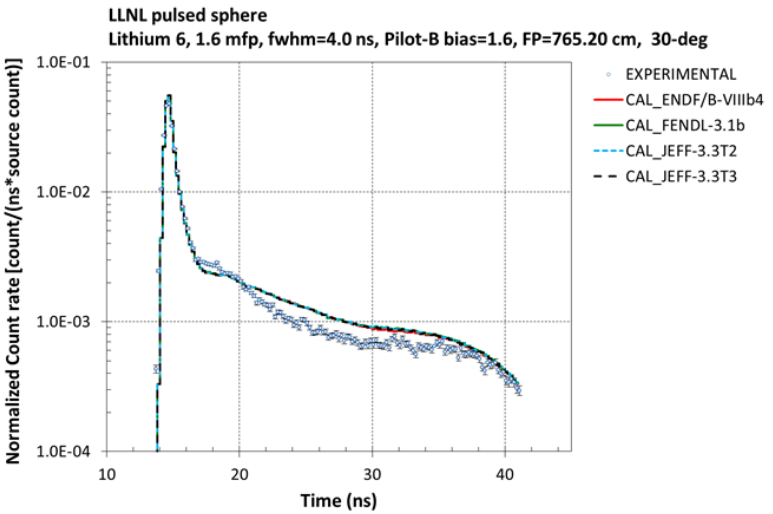


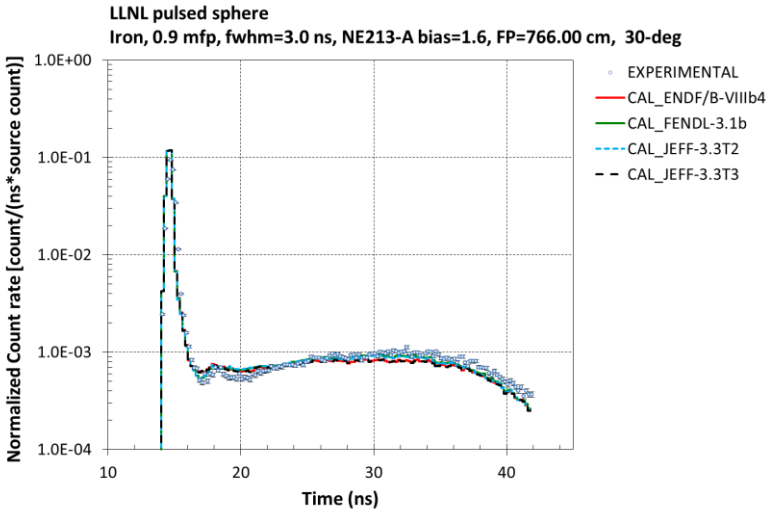
LLNL pulsed spheres		
	Beryllium	: 0.8 mfp, fwhm=4.0 ns, Pilot-B bias=1.6, FP=765.20 cm, 30-deg
	Carbon	: 2.9 mfp, fwhm=4.0 ns, NE213-A bias=1.6, FP=766.00 cm, 30-deg
	Concrete	: 2.0 mfp, fwhm=3.0 ns, NE213-A bias=1.6, FP=975.40 cm, 120-deg
	Iron	: 0.9 mfp, fwhm=3.0 ns, NE213-A bias=1.6, FP=766.00 cm, 30-deg
	Lead	: 1.4 mfp, fwhm=3.0 ns, NE213-A bias=1.6, FP=766.00 cm, 30-deg
	Lithium	: 1.6 mfp, fwhm=4.0 ns, Pilot-B bias=1.6, FP=765.20 cm, 30-deg
	Nitrogen	: 3.1 mfp, fwhm=4.0 ns, Pilot-B bias=1.6, FP=765.20 cm, 30-deg
	Pu-239	: 0.7 mfp, fwhm=3.0 ns, NE213-A bias=1.6, FP=766.00 cm, 30-deg
	U-235	: 0.7 mfp, fwhm=3.0 ns, NE213-A bias=1.6, FP=766.00 cm, 30-deg
	U-238	: 0.8 mfp, fwhm=4.0 ns, Pilot-B bias=1.6, FP=765.20 cm, 30-deg
	Water	: 1.9 mfp, fwhm=5.0 ns, Pilot-B bias=1.6, FP=754.00 cm, 30-deg

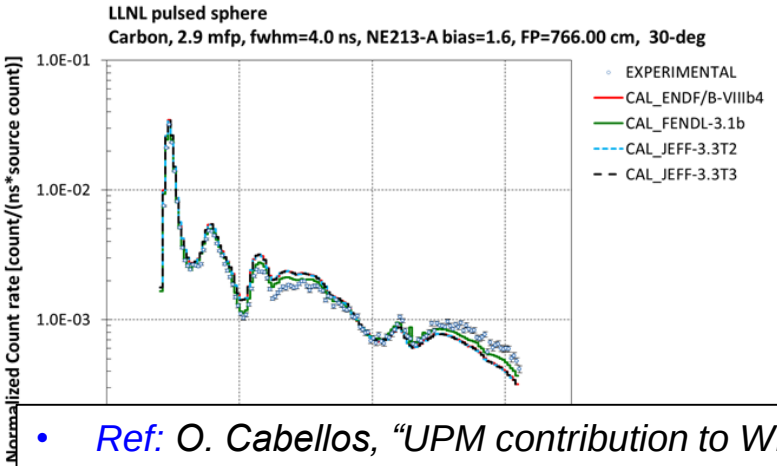
Ref. MCNP6 Benchmark suite

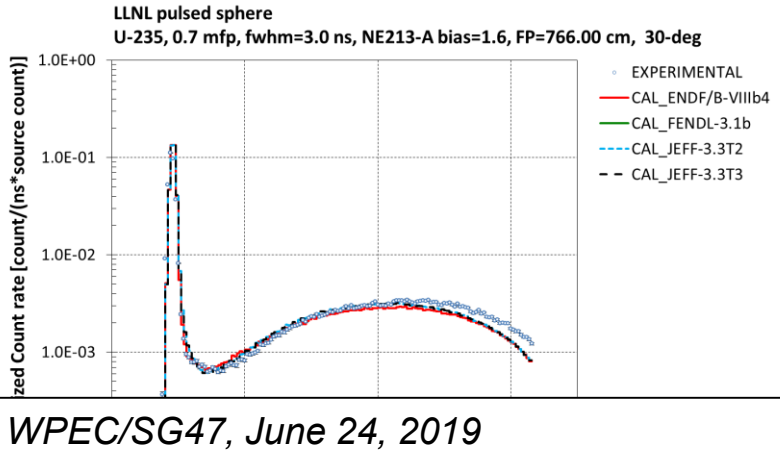
See presentation: *O. Cabellos "UPM contribution to WPEC/SG47", WPEC/SG47, June 24, 2019.*

1. LLNL Pulsed Spheres: Calculations with MCNP-6.1







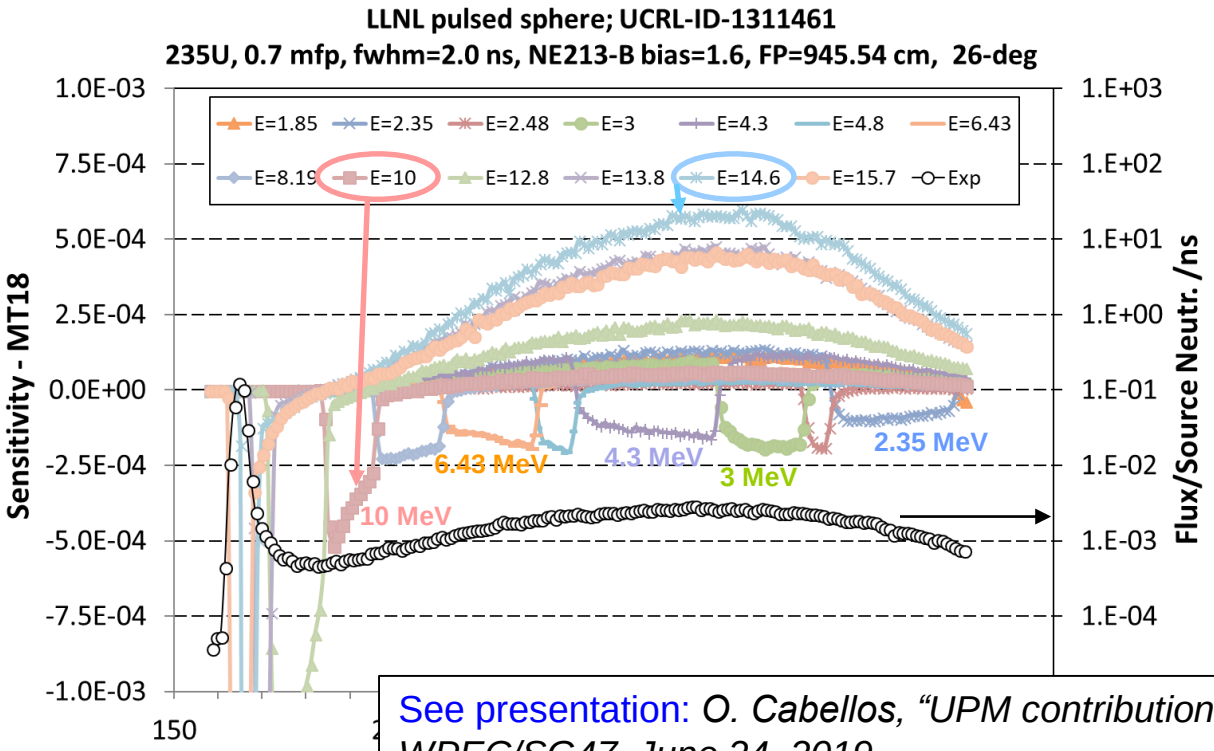


- *Ref: O. Cabellos, "UPM contribution to WPEC/SG47", WPEC/SG47, June 24, 2019*
- *Ref: A. Plompen et al., "The joint evaluated fission and fusion nuclear data library, JEFF-3.3", EPJ/A, 2020*

2. Sensitivity Analysis in LLNL pulsed spheres

- Sensitivity Analysis : "LLNL- 235U" pulsed sphere
  - **Fission** mainly around 14 MeV, other terms with lower values

Note: Sensitivities predicted with MCSEN code

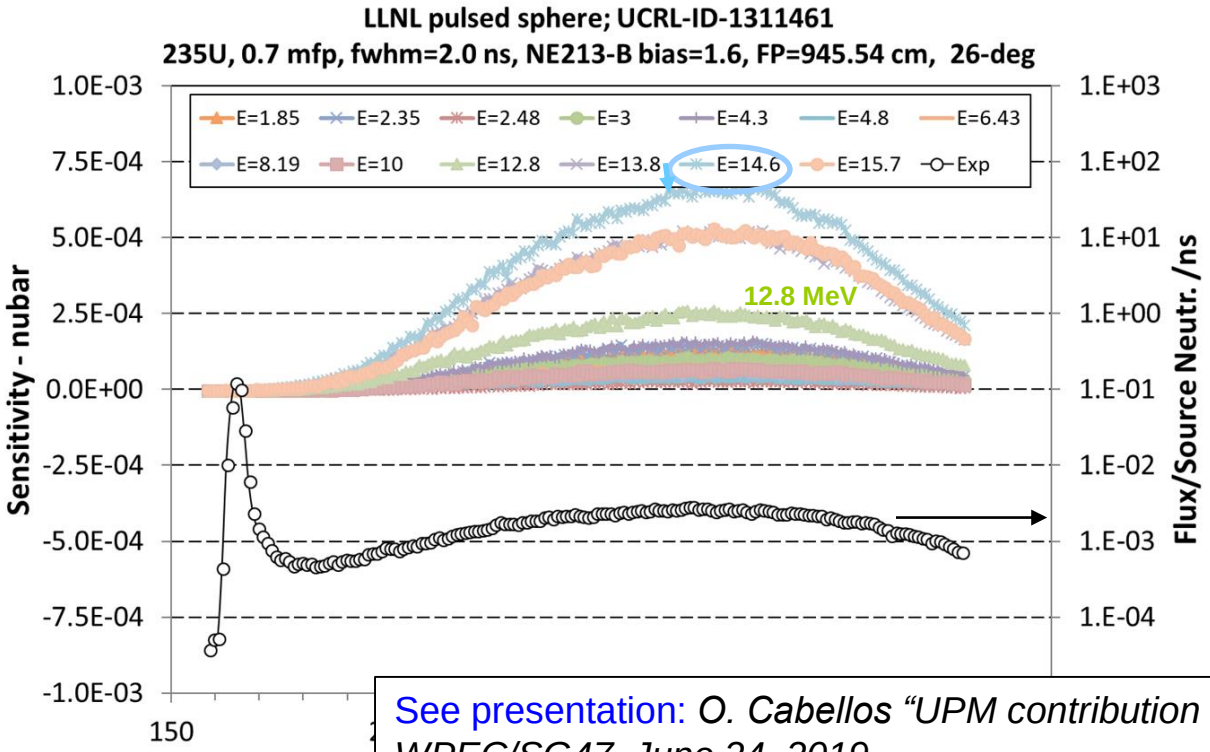


See presentation: *O. Cabellos, "UPM contribution to WPEC/SG47", WPEC/SG47, June 24, 2019.*

2. Sensitivity Analysis in LLNL pulsed spheres

- Sensitivity Analysis : "LLNL- 235U" pulsed sphere
  - **Nu-bar** mainly 14 MeV

Note: Sensitivities predicted with MCSEN code

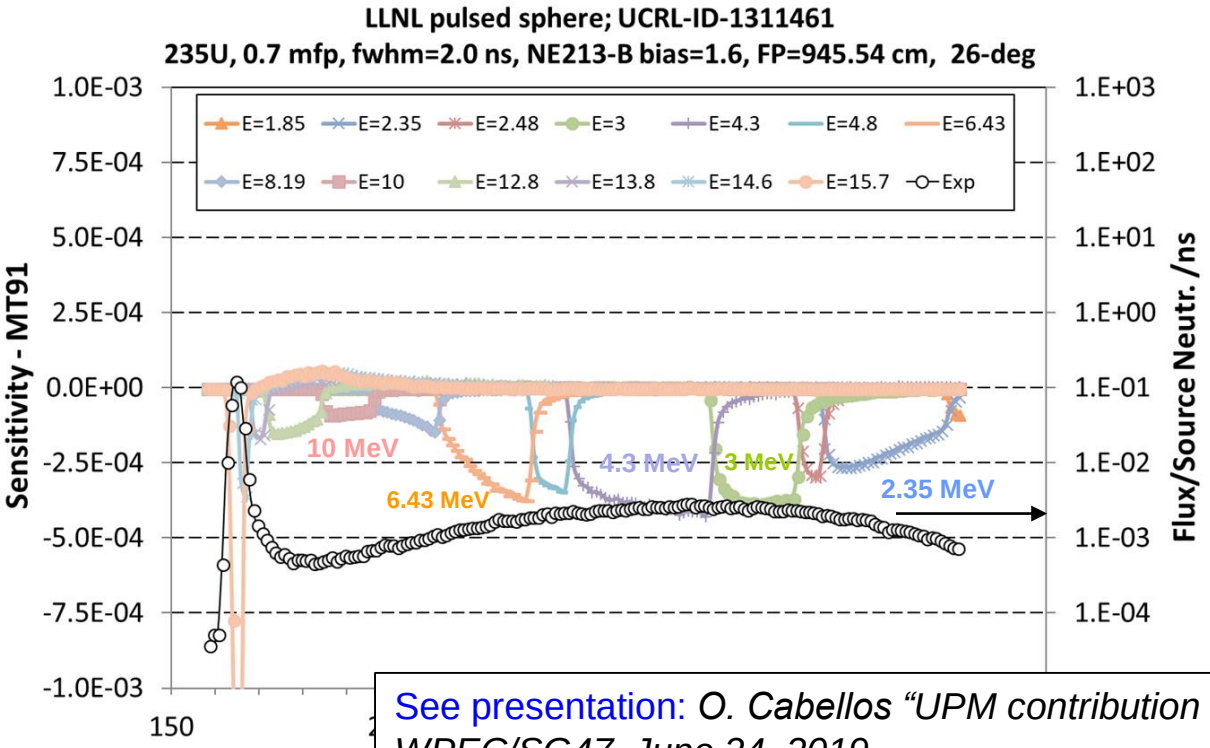


See presentation: *O. Cabellos "UPM contribution to WPEC/SG47", WPEC/SG47, June 24, 2019.*

2. Sensitivity Analysis in LLNL pulsed spheres

- Sensitivity Analysis : "LLNL- 235U" pulsed sphere
  - **MT91**, between 1.8-14 MeV

Note: Sensitivities predicted with MCSEN code



See presentation: *O. Cabellos "UPM contribution to WPEC/SG47", WPEC/SG47, June 24, 2019.*

Conclusion… in June 2019

- Collection of MCNP inputs/exp.data: FNS and Oktavian
  - Problems/errors in some inputs … **additional efforts are needed in the refining of the inputs**
    - MCNP4 → MCNP6
    - Neutron source spectra
  - Inputs and experimental data
    - Experimental data normalization

- **Important Benchmarks for ND validation… that are not yet in SINBAD**
  - LLNL pulsed spheres

- **Sensitivity Analysis using MCSEN5 code for LLNL pulsed spheres**
  - MCSEN5 -> MCNP5.1.30 (**some restrictions for new Nuclear Data**)
    - Ref. : R.L. Perel, J.J. Wagschal, Y. Yeivin, "Monte Carlo Calculation of Point-Detector Sensitivities to Material Parameters", Nuclear Science and Engineering, 124 (1), 197–209 (1996)
    - Ref.: R.L. Perel, "Upgrading of the MCSEN sensitivity software to comply with the current standard of the MCNP-5 Monte Carlo code", F4E-GRT-168.01, March 2014

See presentation: *O. Cabellos "UPM contribution to WPEC/SG47", WPEC/SG47, June 24, 2019.*

… in December 2020

UPM is collaborating with LANL, IAEA/NDS and JSI …

1. Collection of TOF Shielding Benchmarks for Nuclear Data validation

- **LANL** is working to understand which nuclear-data observables can be validated with pulsed spheres…
  - *See presentation in WPEC/SG47 May 2020, "Using LLNL Pulsed Spheres for Nuclear Data Validation" , D. Neudecker.*
  - ➢ ***75 LLNL pulsed-sphere neutron-leakage spectra for 20 different materials***.

2. Sensitivity Analysis… in LLNL pulsed spheres

- ***… LA-UR-20-26735 (2020-08-31)***

  "Sensitivity Analysis of Neutron-leakage Spectra for a Small Suite of LLNL Pulsed Spheres to MF = {1, 3, 5} Nuclear Data". O. Cabellos, D. Neudecker

- ***… paper to be published in Annals of Nuclear Energy***

  "Which nuclear data can be validated with LLNL pulsed-sphere experiments ?" D. Neudecker, O. Cabellos, A.R. Clark, W. Haeck, M. C. White, R. Capote, A. Trkov, M. Rising

  Alexander R. Clark will give more detailed info on this work at the WPEC/SG47-2021

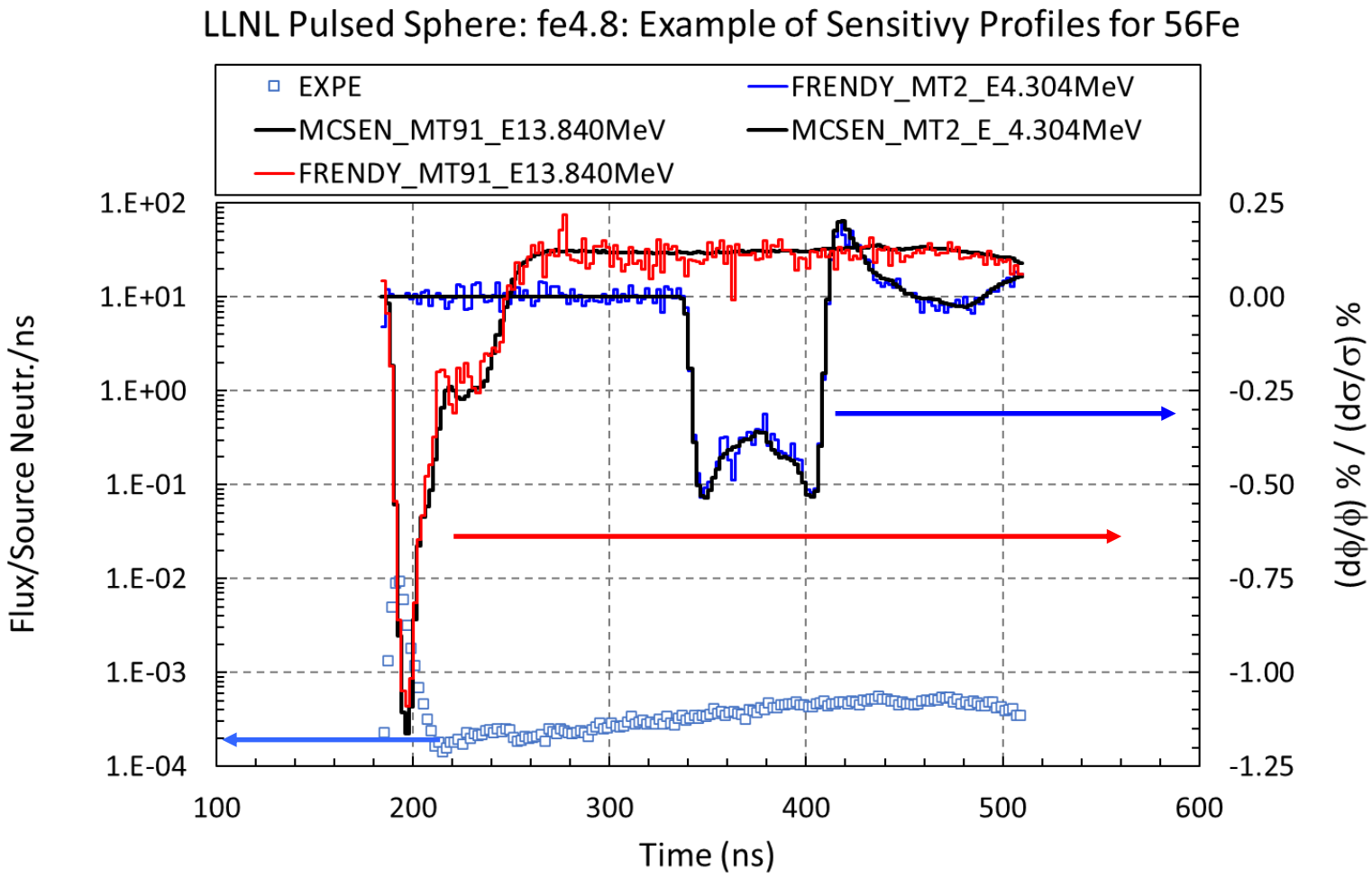
… in December 2020

Methodology for providing sensitivity profiles

- **MCSEN code with ENDF60 nuclear data libraries**
  - **MCSEN:** cross-sections, nubar, CHI and MF4 and MF6

- **SANDY and FRENDY codes using perturbation capabilities**
  - **In ENDF/PENDF files…SANDY:** cross-sections, nubar, CHI and MF4… MF6?
  - **In ACE files …FRENDY:** cross-sections, nubar and CHI

… in December 2020

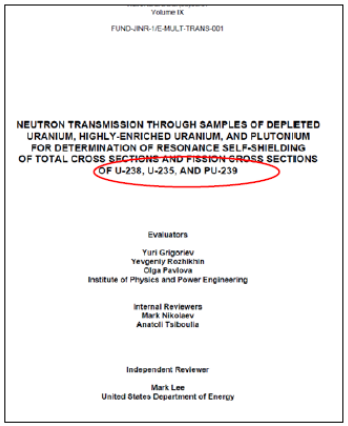


… using FRENDY/SANDY perturbation capability in Transmission Benchmarks

3. Neutron transmission experiments: Indications on ^{235}U evaluation

- **Indications on ^{235}U: 4.65eV – 21.5 keV**

ICSBEP/FUND-JINR-1/E-MULT-TRANS-001



Volume IX

FUND-JINR-1/E-MULT-TRANS-001

NEUTRON TRANSMISSION THROUGH SAMPLES OF DEPLETED URANIUM, HIGHLY-ENRICHED URANIUM, AND PLUTONIUM FOR DETERMINATION OF RESONANCE SELF-SHIELDING OF TOTAL CROSS SECTIONS AND FISSION CROSS SECTIONS OF U-238, U-235, AND PU-239

Evaluators

Yuri Grigoriev
Yevgeniy Rozhikhin
Olga Pavlova
Institute of Physics and Power Engineering

Internal Reviewers
Mark Nikolaev
Anatoli Tsiboulia

Independent Reviewer
Mark Lee
United States Department of Energy

*"The explicit product of the experiments was **the measurement of the energy-dependent self-shielded total and fission cross sections**, as characterized by various self-shielded and unshielded total neutron count rates as well as self-shielded and unshielded fission rates performed using the time-of-flight technique. Self-shielding was varied systematically through the use of **samples of different thicknesses**"*

Table 1.3-2. Samples of Highly Enriched Uranium.

Sample No.	1	2	3	4	5	6	7	8
Composition	2× U(90)_t	3× U(90)_t	4× U(90)_t	8× U(90)_t	1× U(90)	2× U(90)	4× U(90)	8× U(90)
Thickness, mm	~0.6	~0.9	~1.2	~2.4	~5	~10	~20	~40
Thickness, atoms/barn (Reference 2)	0.002574	0.003861	0.005148	0.01029	0.02145	0.0429	0.0858	0.1716

T. Ivanova, "IPPE transmission experiments" WPEC/SG39, 2014

"Observed experimental data on 235U α -value ($\alpha = \sigma_\gamma / \sigma_f$) has demonstrated the need for increasing the 235U capture cross-section in the energy range from 500 to 2500 eV in comparison with the recent evaluations."

O. Andrianova, "Impact of uncertainties in the 235U cross-section resonance structure on characteristics measured in the BFS-79 critical assemblies", EPJ Web of Conferences 146, 06013 (2017) ND2016

See presentation: O. Cabellos, "The importance of using different integral benchmarks to provide valuable feedbacks to the evaluation process". JEFDOC-2015, November 24-27,2020

… using FRENDY/SANDY perturbation capability in Transmission Benchmarks

3. Neutron transmission experiments: Indications on ^{235}U evaluation

- **IPPE ^{235}U-Transmission Benchmark:** Sample 7= 0.17160 atm/b

Figure. Values (C/E-1) in % of 235U-Total Transmission Function for sample 7(0.17160 atm/b)

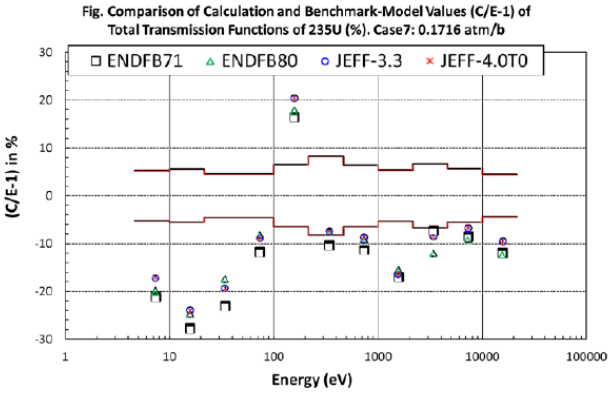
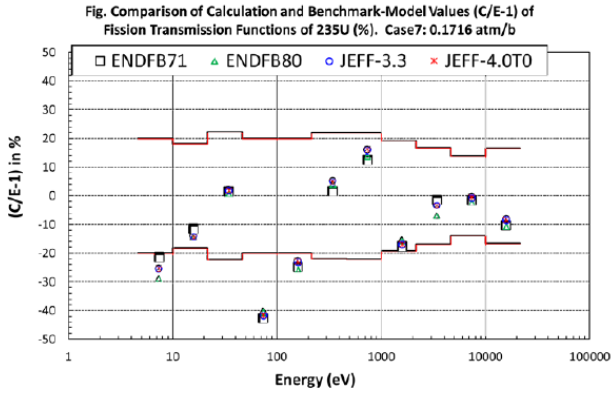


Figure. Values (C/E-1) in % of 235U-Fission Transmission Function for sample 7(0.17160 atm/b)



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… using FRENDY/SANDY perturbation capability in Transmission Benchmarks

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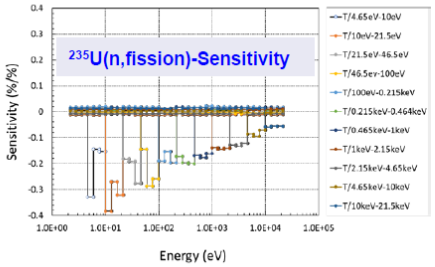
- **Sensitivities in IPPE ^{235}U-Transm. Benchm.:**
  Sample 7= 0.17160 atm/b

Figure. ^{235}U(n,fission)-Sensitivity (%/%) to 235U-Total Transmission Function in Sample 7.



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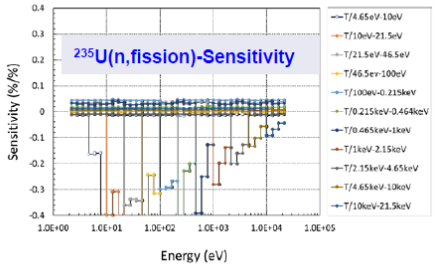


Figure. ^{235}U(n,γ)-Sensitivity (%/%) to 235U-Total Transmission Function in Sample 7.

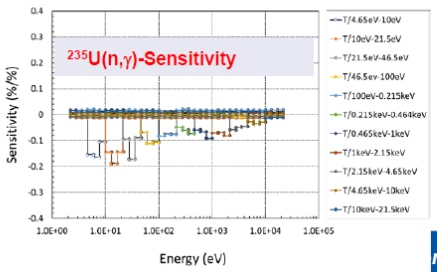
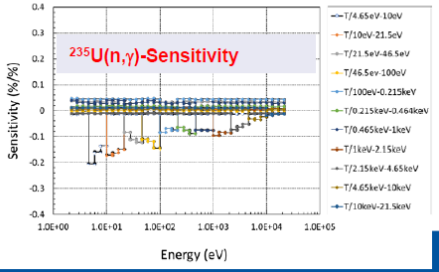


Figure. ^{235}U(n,γ)-Sensitivity (%/%) to 235U-Fission Transmission Function in Sample 7.



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Conclusion

- **Important Benchmarks for ND validation… that are not yet in SINBAD**
  - LLNL pulsed spheres
- **Sensitivity Analysis using different techniques:**
  - MCSEN
  - SANDY and FRENDY
- **Now… we already have sensitivity profiles**
  - Forward Propagation: **“impact of nuclear data changes” …** useful for ND evaluation
  - **Could NEA develop a new tool for SINBAD equivalent to NDaST code?**

Thank you for your attention!

Acknowledgments

This work is part of the SANDA project (Supplying Accurate Nuclear Data for energy and non-energy Applications) that has received funding from the European Union's H2020/Euratom under grant agreement No. 847552