LANL Nuclear Data for NCSP

Ionel Stetcu
T-2, Los Alamos National Laboratory

Collaborators: P. Talou, T. Kawano, G. Hale, M. Paris
D. Neudecker (XCP-5)

Outline

- ENDF/B-VIII.0 library officially released on Feb. 2, 2018
- Evaluations of light nuclei
- Evaluations of actinides
  - Prompt fission neutron spectrum (PFNS)
  - Prompt fission gamma spectrum (PFGS), average multiplicity, average total gamma ray energy
  - Probability distributions
  - TKE
- Performance in benchmarks
- Summary

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ENDF/B-VIII.0: The 8^{th} Major Release of the Nuclear Reaction Data Library with CIELO-project Cross Sections, New Standards and Thermal Scattering Data

D. A. Brown,[1] M. B. Chadwick,[2,*] R. Capote,[3] A. C. Kahler,[2] A. Trkov,[3] M. W. Herman,[1] A. A. Sonzogni,[1] Y. Danon,[4] A. D. Carlson,[5] M. Dunn,[6] D. L. Smith,[7] G. M. Hale,[2] G. Arbanas,[8] R. Arcilla,[1] C.R. Bates,[2] B. Beck,[9] B. Becker,[10] F. Brown,[2] R. J. Casperson,[9] J. Conlin,[2] D. E. Cullen,[9] M.-A. Descalle,[9] R. Firestone,[11] T. Gaines,[12] K. H. Guber,[8] A. I. Hawari,[13] J. Holmes,[14] T. D. Johnson,[1] T. Kawano,[2] B. C. Kiedrowski,[15] A. J. Koning,[3] S. Kopecky,[16] L. Leal,[17] J. P. Lestone,[2] C. Lubitz,[18] J. I. Márquez Damián,[19] C. M. Mattoon,[9] E. A. McCutchan,[1] S. Mughabghab,[1] P. Navratil,[20] D. Neudecker,[2] G. P. A. Nobre,[1] G. Noguere,[21] M. Paris,[2] M. T. Pigni,[8] A. J. Plompen,[16] B. Pritychenko,[1] V. G. Pronyaev,[22] D. Roubtsov,[23] D. Rochman,[24] P. Romano,[7] P. Schillebeeckx,[16] S. Simakov,[25] M. Sin,[26] I. Sirakov,[27] B. Sleaford,[9] V. Sobes,[8] E. S. Soukhovitskii,[28] I. Stetcu,[2] P. Talou,[2] I. Thompson,[9] S. van der Marck,[29] L. Welser-Sherrill,[2] D. Wiarda,[8] M. White,[2] J. L. Wormald,[13] R. Q. Wright,[8] M. Zerkle,[14] G. Žerovnik,[16] and Y. Zhu[13]

[1] *Brookhaven National Laboratory, Upton, NY 11973-5000, USA*
[2] *Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[3] *International Atomic Energy Agency, PO Box 100, A-1400 Vienna, Austria*
[4] *Rensselaer Polytechnic Institute, Troy, NY 12180, USA*
[5] *National Institute of Standards and Technology, Gaithersburg, MD 20899-8463, USA*
[6] *Spectra Tech, Inc., Oak Ridge, TN 37830, USA*
[7] *Argonne National Laboratory, Argonne, IL 60439-4842, USA*
[8] *Oak Ridge National Laboratory, Oak Ridge, TN 37831-6171, USA*
[9] *Lawrence Livermore National Laboratory, Livermore, CA 94551-0808, USA*
[10] *Gesellschaft für Anlagen und Reaktorsicherheit, Schwertnergasse 1, D-50667 Köln, Germany*
[11] *Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA*
[12] *AWE plc, Reading RG7 4PR, United Kingdom*
[13] *North Carolina State University, Raleigh, NC 27695, USA*
[14] *Naval Nuclear Laboratory, West Mifflin, PA 15122, USA*
[15] *University of Michigan, Ann Arbor, MI 48109, USA*
[16] *EC-JRC, B-2440 Geel, Belgium*
[17] *Institut de Radioprotection et de Sûreté Nucléaire, 92262 Fontenay aux Roses, Cedex, France*
[18] *Naval Nuclear Laboratory, Niskayuna, NY 12309, USA*
[19] *Centro Atómico Bariloche, S. C. de Bariloche, Argentina*
[20] *TRIUMF, Vancouver, BC V6T 2A3, Canada*
[21] *CEA, DEN, DER, SPRC, Cadarache, 13108 Saint-Paul-lèz-Durance, France*
[22] *PI Atomstandart at SC Rosatom, Moscow, Russian Federation*
[23] *Canadian Nuclear Laboratories, Chalk River, Ontario, Canada*
[24] *Paul Scherrer Institut, 5232 Villigen, Switzerland*
[25] *Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz, 1 76344 Eggenstein-Leopoldshafen, Germany*
[26] *University of Bucharest, Bucharest-Magurele, RO-077125, Romania*
[27] *Institute for Nuclear Research and Nuclear Energy, BAS, BG-1784 Sofia, Bulgaria*
[28] *Joint Institute for Energy and Nuclear Research, Minsk, Belarus*
[29] *NRG, Westerduinweg 3, 1755 LE Petten, The Netherlands*

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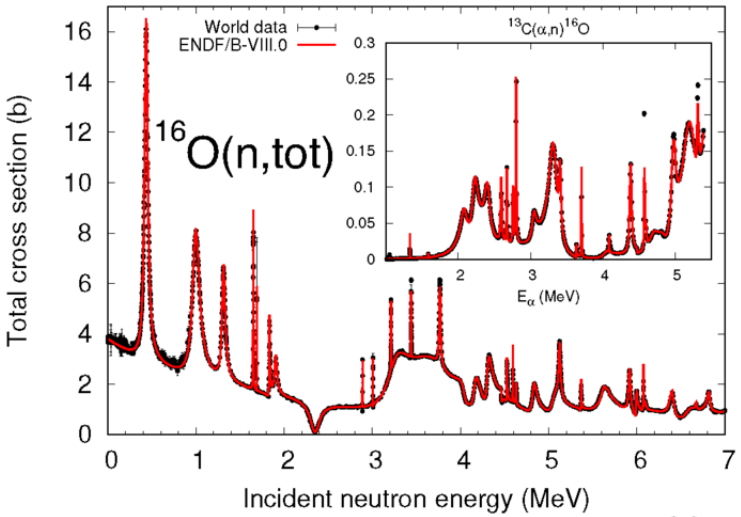
We describe the new ENDF/B-VIII.0 evaluated nuclear reaction data library. ENDF/B-VIII.0 fully incorporates the new IAEA standards, includes improved thermal neutron scattering data and uses new evaluated data from the CIELO project for neutron reactions on ^{1}H, ^{16}O, ^{56}Fe, ^{235}U, ^{238}U and ^{239}Pu described in companion papers in the present issue of *Nuclear Data Sheets*. The evaluations benefit from recent experimental data obtained in the U.S. and Europe, and improvements in theory and simulation. Notable advances include updated evaluated data for light nuclei, structural materials, actinides, fission energy release, prompt fission neutron and γ-ray spectra, thermal neutron scattering data, and charged-particle reactions. Integral validation testing is shown for a wide range of criticality, reaction rate, and neutron transmission benchmarks. In general, integral validation performance of the library is improved relative to the previous ENDF/B-VII.1 library.

https://doi.org/10.1016/j.nds.2018.02.001
0090-3752/

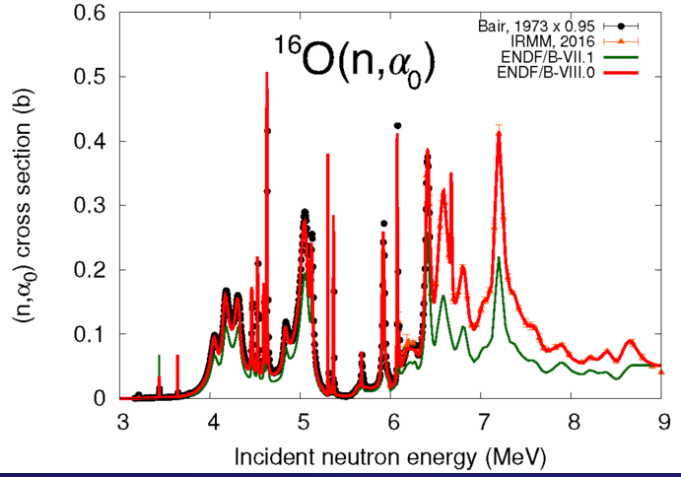
Light element evaluations (G. Hale & M. Paris)

- R-matrix approach gives consistent, simultaneous description of multiple reactions
- We contributed to improved ENDF/B-VIII.0 evaluations for ^{1}H, ^{2}H, ^{3}He, ^{6}Li, ^{9}Be, ^{10}B, ^{12}C, ^{13}C, ^{16}O, ^{18}O

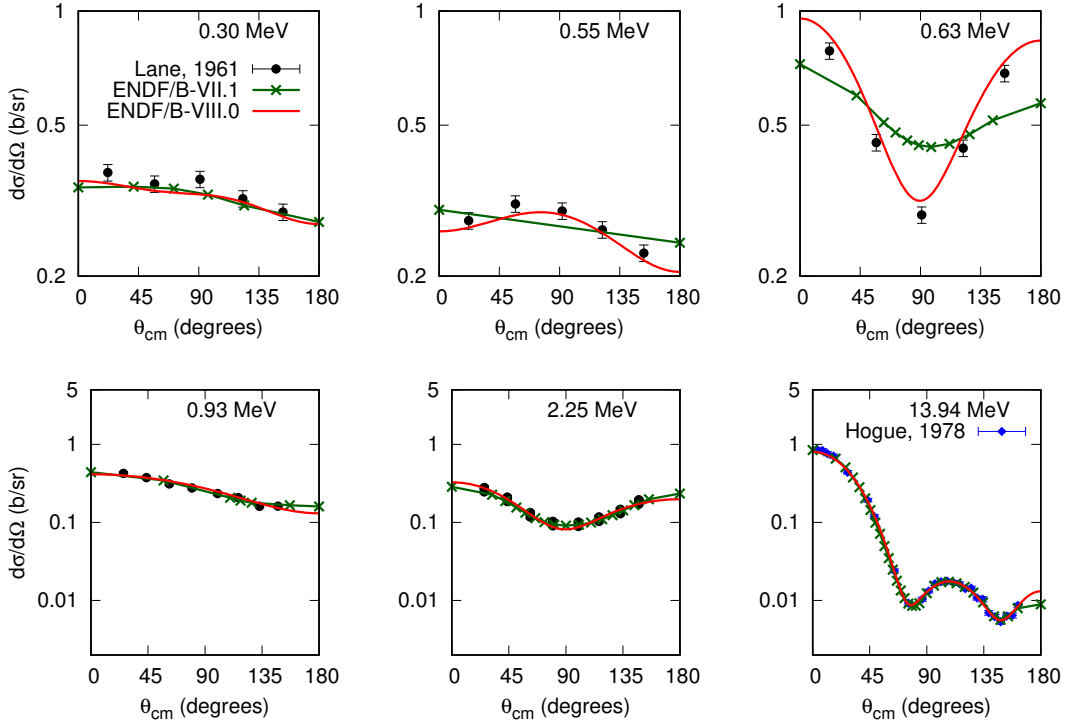


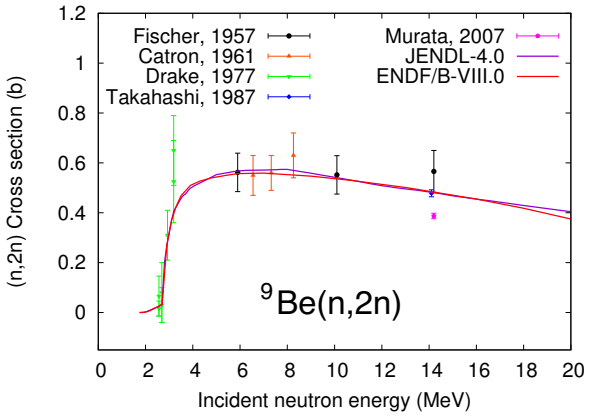
Criticality studies motivated changes in ^{235}U capture; ^{16}O elastic and (n,α) (consistent with much earlier ENDF/B-V.0 analysis!)

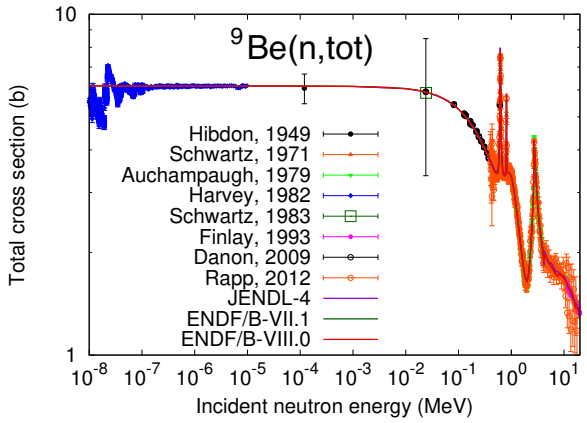
Ongoing work will focus on improved multiparticle spectra to allow precision evaluations for fast regime



^{9}Be(n,el) angular dist.

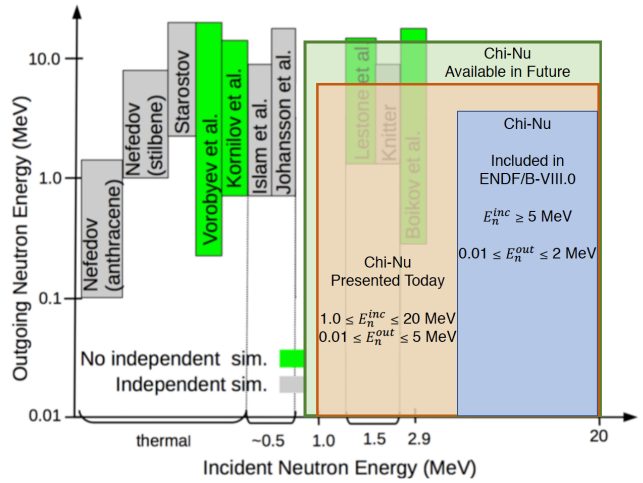




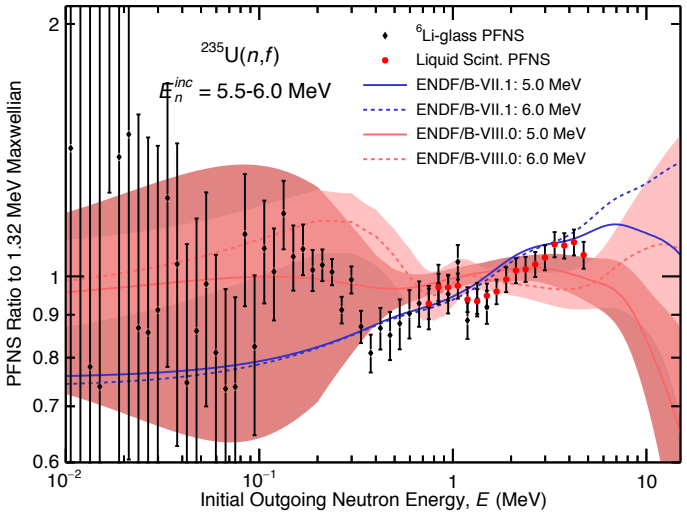


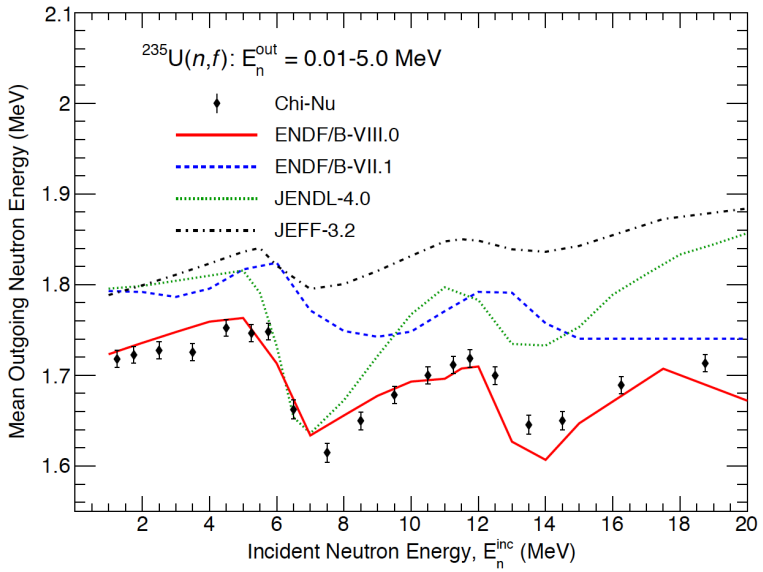
^{235}U(n,f) PFNS evaluation for ENDF/B-VIII.0

- Data from Chi-Nu included in the evaluation above 5 MeV incident neutron energy
- Changes in ENDF/B-VIII.0: evaluation procedure, physical models and Chi-Nu data
- Clear signatures of multi-chance fission



Second-chance fission





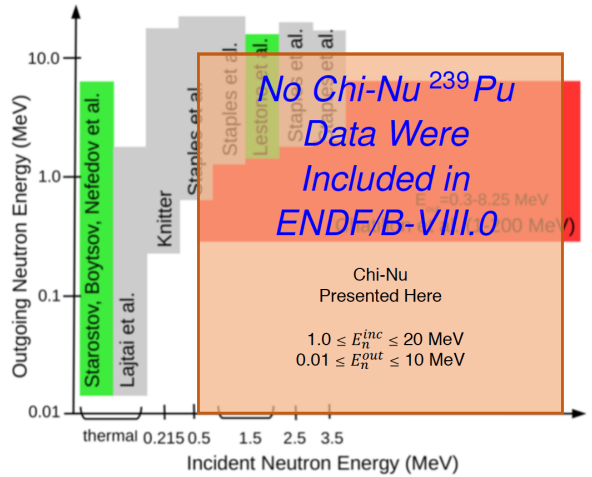
Evaluation: D. Neudecker et al., NDS 148, p. 293 (2018).
Chi-Nu data: M. Devlin et al., NDS 148, p. 322 (2018).
Experimental data: D. Neudecker et al., NDS 131 p. 289 (2016)

Chi-Nu data is preliminary

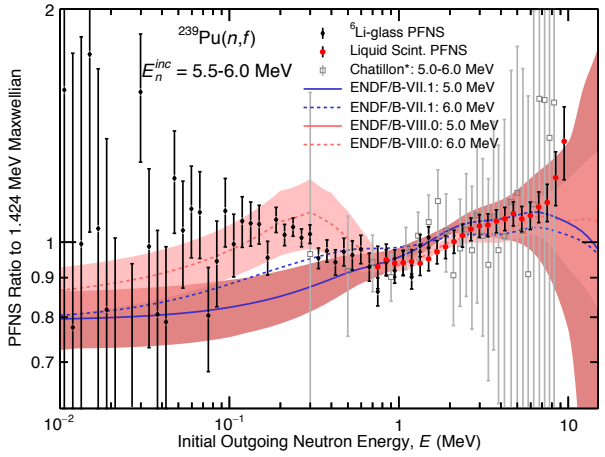
Plots courtesy K.J. Kelly

^{239}Pu(n,f) PFNS evaluation for ENDF/B-VIII.0

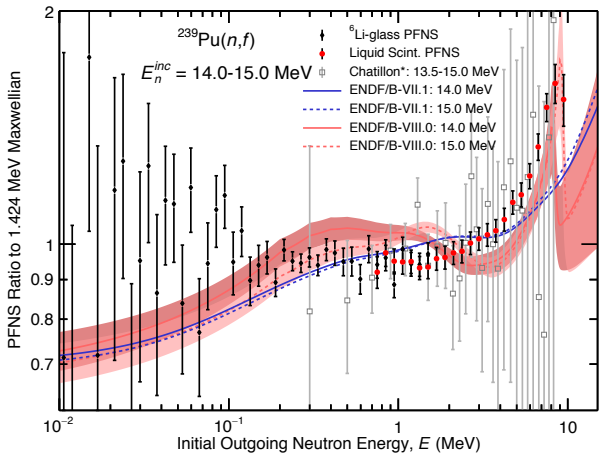
- Changes in ENDF evaluation: procedure and models
- Chi-Nu data will be included in the next evaluation
- Pre-equilibrium component clearly observed at several incident energies
- Third-chance fission not as drastic in Chi-Nu data (no dip in average neutron energy)

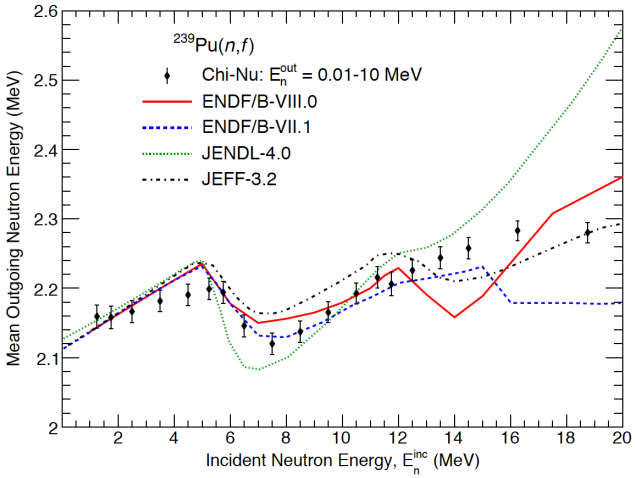


Second-chance fission



Pre-equilibrium neutrons





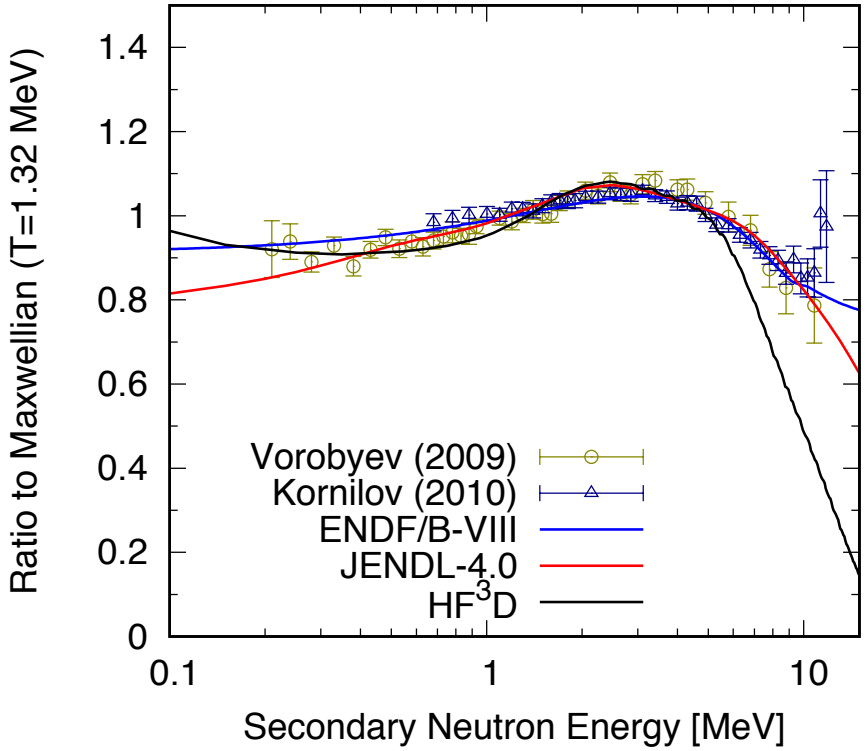
Chi-Nu data is preliminary

Plots courtesy K.J. Kelly

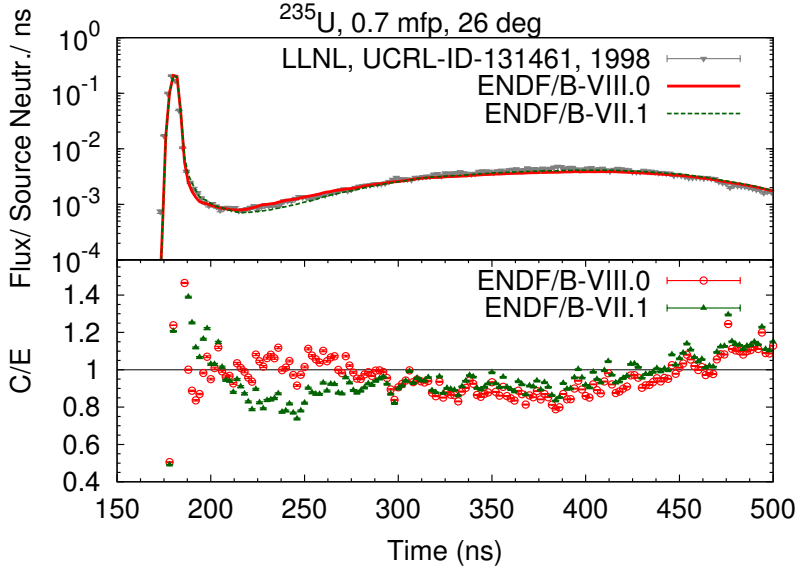
Prompt Fission Neutron Spectrum Calculated with Fully Deterministic Method, HF^{3}D

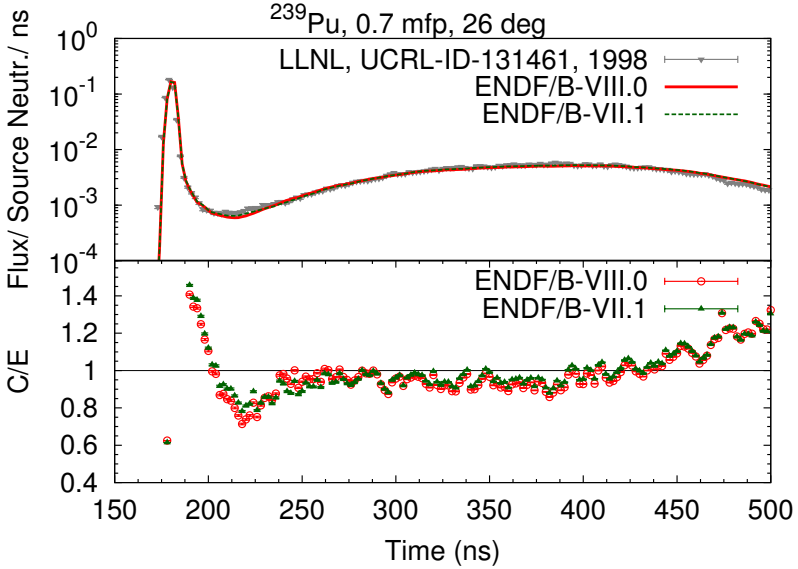
HF^{3}D: Hauser-Feshbach Fission Fragment Decay model

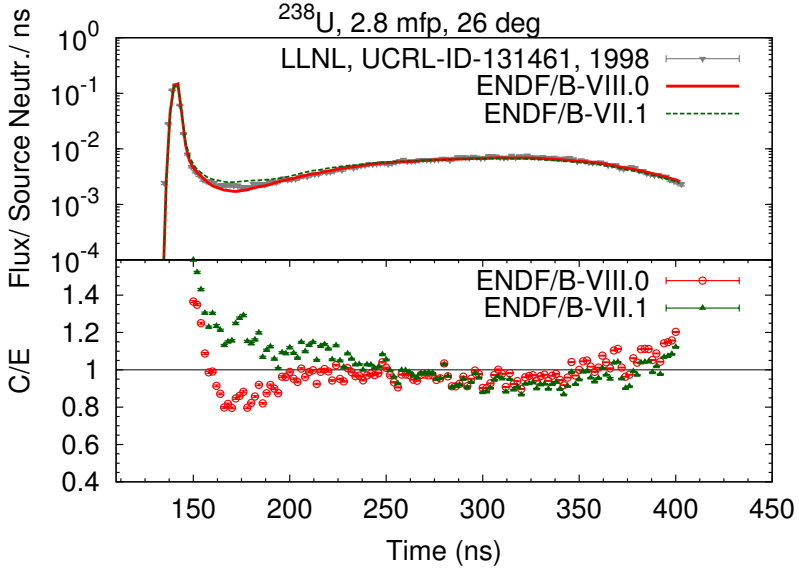
- New capability to be used in future evaluations of:
  - PFNS at low outgoing neutron energies
  - Fission fragment yields (independent and cumulative)
- Shape below 1 MeV different from Madland-Nix model
- HF^{3}D result drops quickly above 5 MeV
  - already seen in our previous Monte Carlo works
    - Becker, PRC **87** 014617 (2013)
    - Kawano, NPA **913**, 51 (2013)



Validating with LLNL pulsed sphere measurements







Pulsed sphere measurements help validate elastic, inelastic scattering and PFNS evaluated data.

Many important changes in evaluations, the quality of the description remains good.

Benchmarks recommended by S. Frankle, LA-UR-05-5879 (2005).

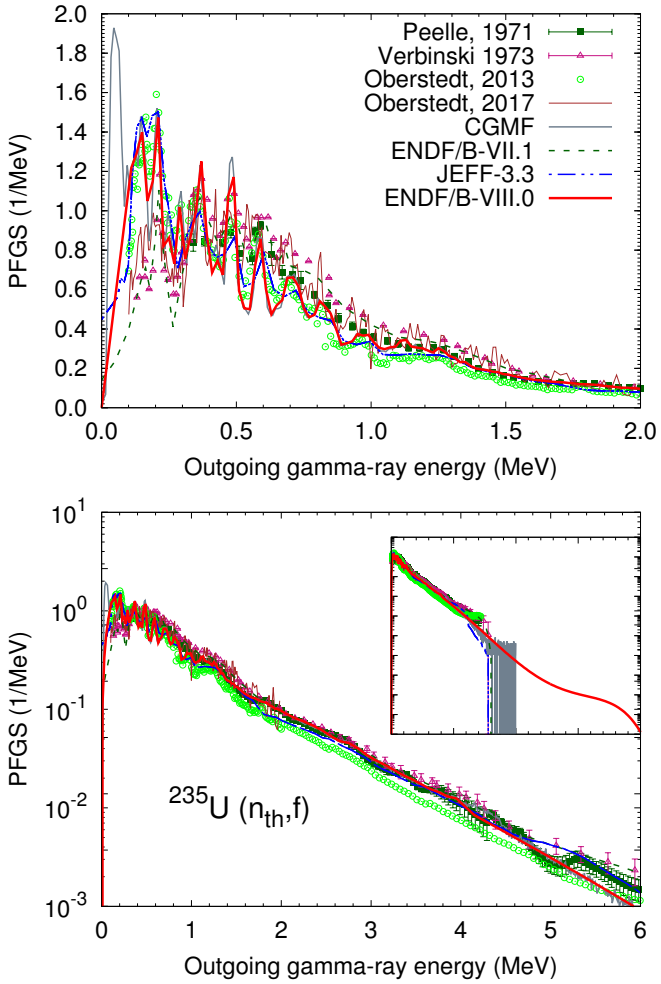
Simulations: D. Neudecker
Processing: J.L. Conlin

Validating with ICSBEP criticality benchmarks

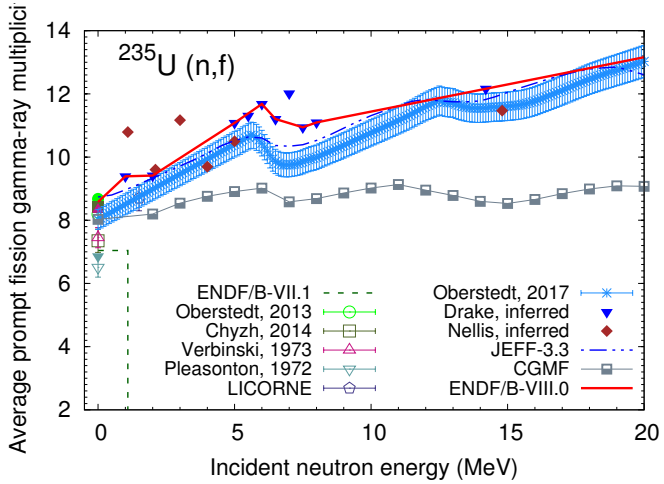
Benchmark	Experiment	ENDF/B-VII.1	ENDF/B-VIII.0	Comment
PMF001 (Rev. 2)	1.000(2)	0.99978(8)	0.99978(8)	Jezebel
PMF002	1.000(2)	1.00013(8)	1.00139(8)	Dirty Jezebel
PMF006	1.0000(30)	1.00085(10)	0.99985(10)	Flattop-Pu
PMF008	1.0000(6)	0.99762(9)	0.99756(9)	Thor
HMF001	1.000(1)	1.00002(8)	0.99991(8)	Godiva
HMF028	1.0000(16)	1.00299(9)	1.00061(9)	Flattop
IMF001.1	0.9988	1.00025(9)	0.99884(9)	Jemima (1)
IMF007.d	1.0045(7)	1.00447(7)	1.00439(7)	Big ten

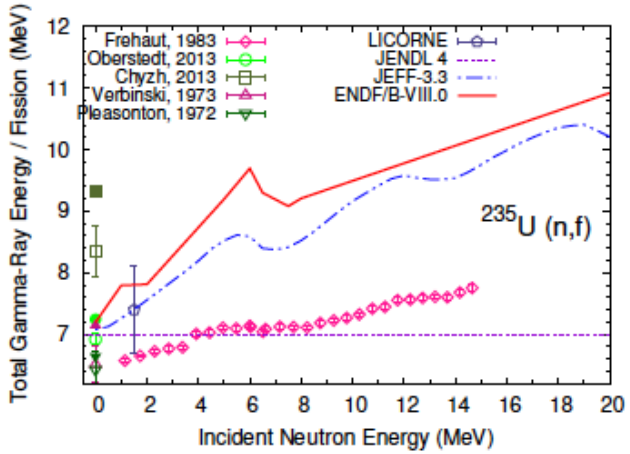
Benchmark input decks written by A.C. Kahler, simulated by D. Neudecker

Prompt fission gamma evaluations for major actinides in ENDF/B-VIII.0



- **Updated PFGS and multiplicity for all ^{235}U(n,f), ^{238}U(n,f), ^{239}Pu(n,f)**
- ENDF/B-VII.1 discontinuity at 1.09 MeV removed in ENDF/B-VIII.0
- PFGS independent on incident energy
- Evaluation based on old and new measurements (thermal)
- All gamma-producing channels explicitly given in ENDF/B-VIII.0
- **New information on multiplicity probability distribution included in the evaluation**



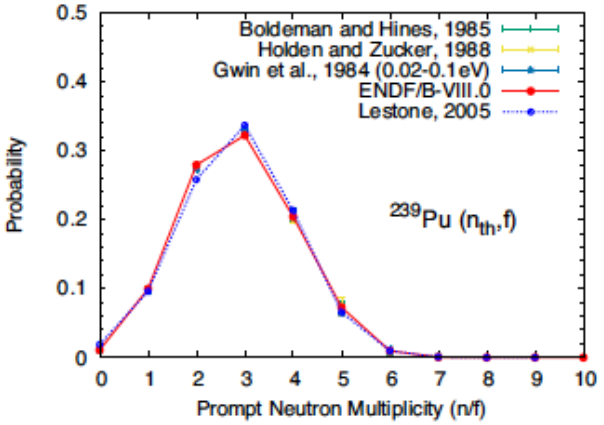


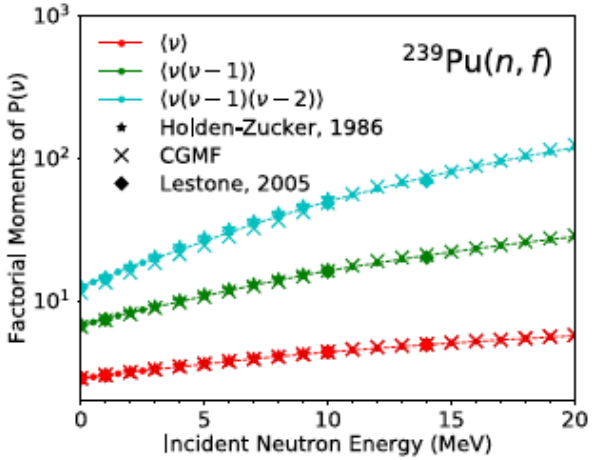
CGMF code (used in evaluations):

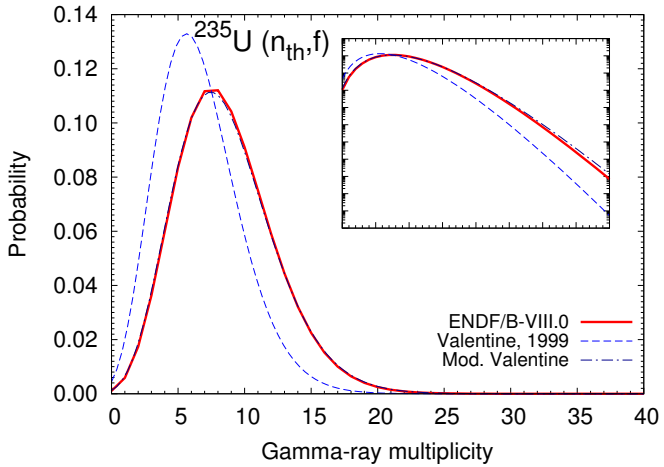
- Statistical treatment of decaying FFs
- Very good agreement with measured PFGS, especially at low energies
- Incident neutron energies from thermal to 20 MeV
- Integration into MCNP will provide correlated fission data

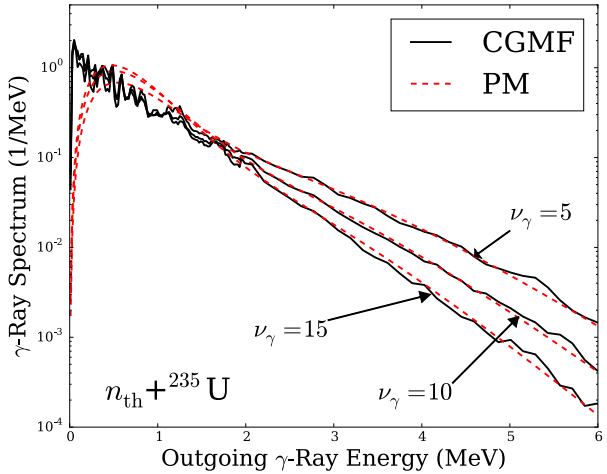
New feature: multiplicity distributions for prompt fission neutrons and gamma rays

- New ENDF format to accommodate P(ν), multiplicity-dependent spectra (neutrons and gammas)
- Based on empirical models for neutrons, CGMF+negative binomial model for gammas









- Strong dependence of the multiplicity-dependent PFGS
- Multiplicity-dependent spectra not yet included in the evaluation

Summary

- New evaluation released with significant improvements:
  - Total and exclusive cross sections
  - PFNS, nubar
  - PFG properties (explicit channel by channel evaluation)
  - PFN and PFG multiplicity probability distributions
- Improved physics models and improved data have been used
- Criticality benchmark quality preserved despite important changes in evaluations of PFNS, nubar, (fission) cross sections
- CGMF/FREYA integration in MCNP will provide alternatives for correlation data missing from ENDF
- Ongoing work on evaluations for:
  - nubar (resonance region) and PFNS (thermal) for ^{235}U, ^{239}Pu
  - Capture cross sections for ^{234}U, ^{236}U
- Machine learning for nuclear data

Acknowledgements

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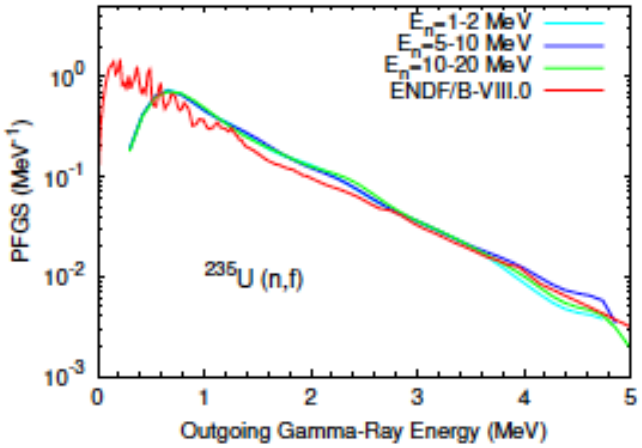
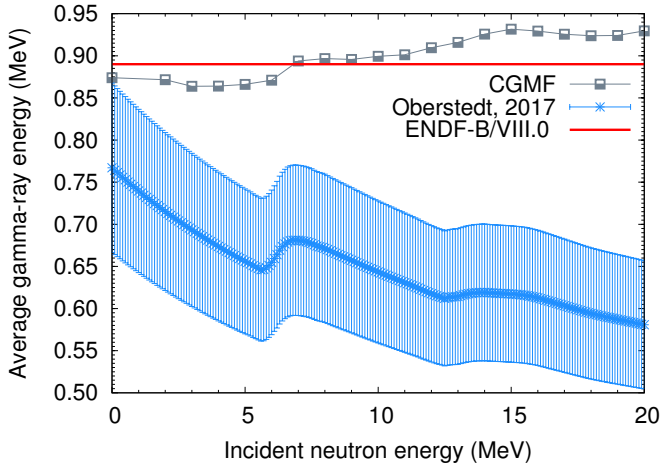
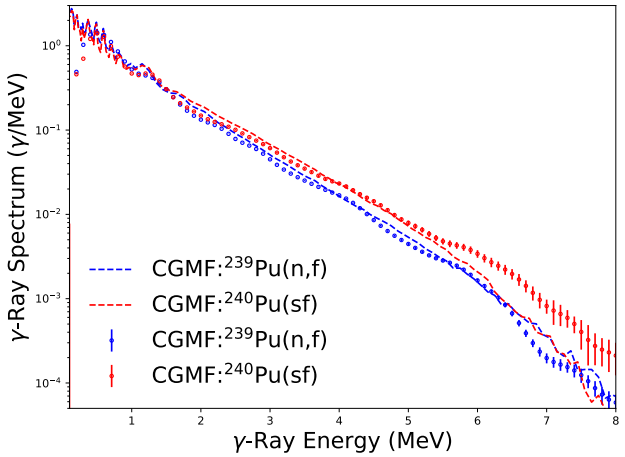
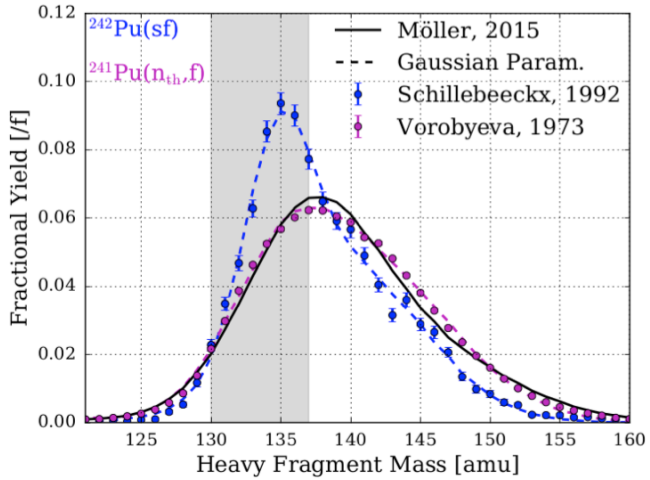
Additional slides

No incident neutron energy dependence of the PFGS in ENDF/B-VIII.0





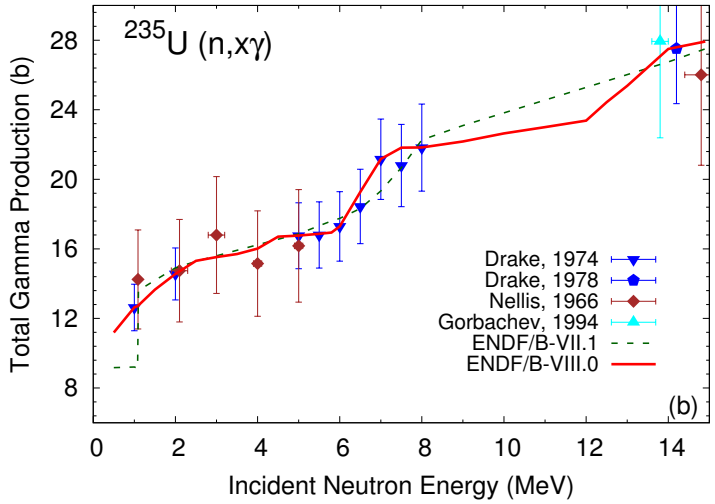


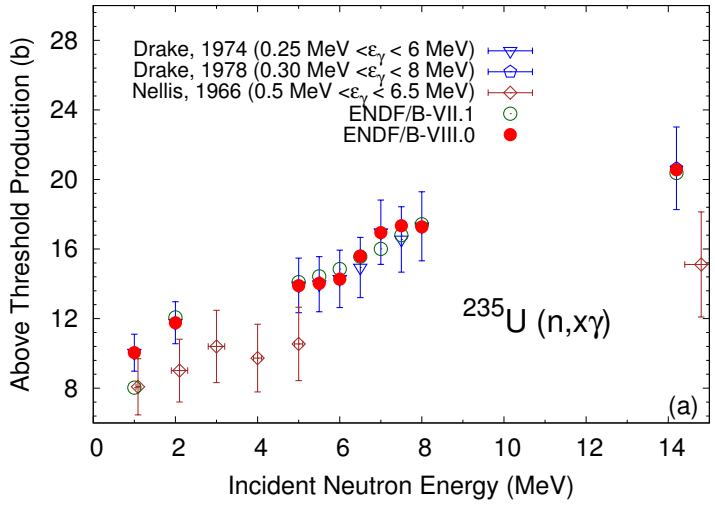


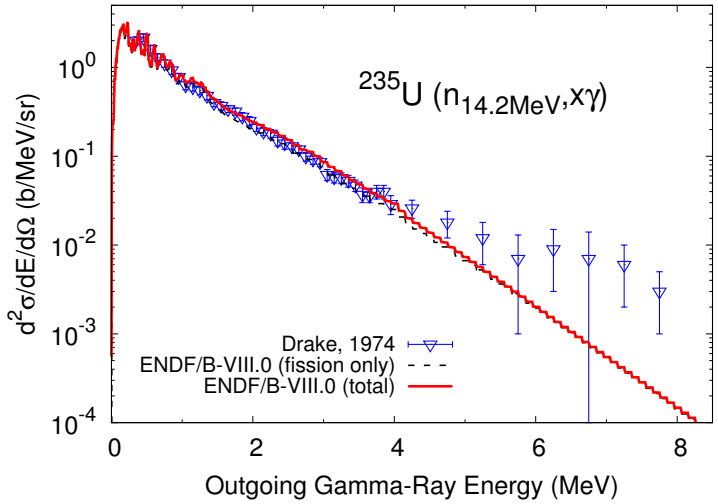
- Very little data available for fast neutrons
- CGMF shows a small dependence of neutron incident energy

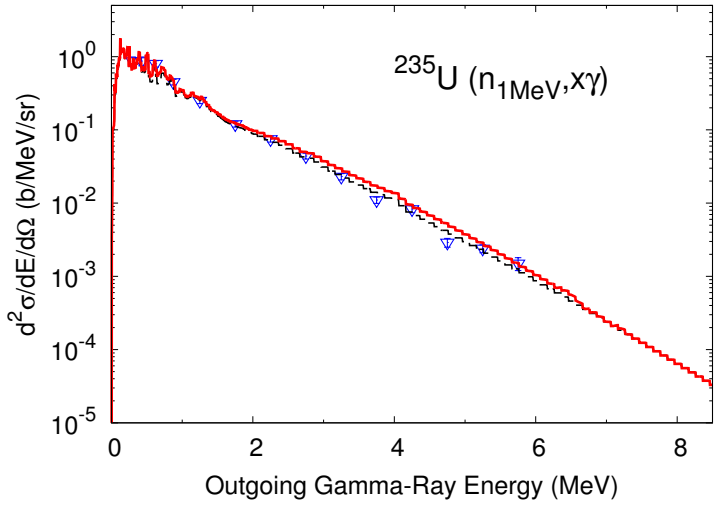
- Change in PFGS for SF vs neutron induced fission understood in terms of nuclear structure

Total gamma production





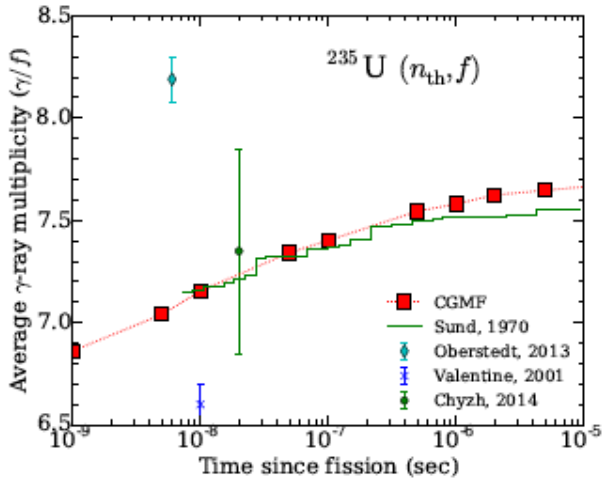




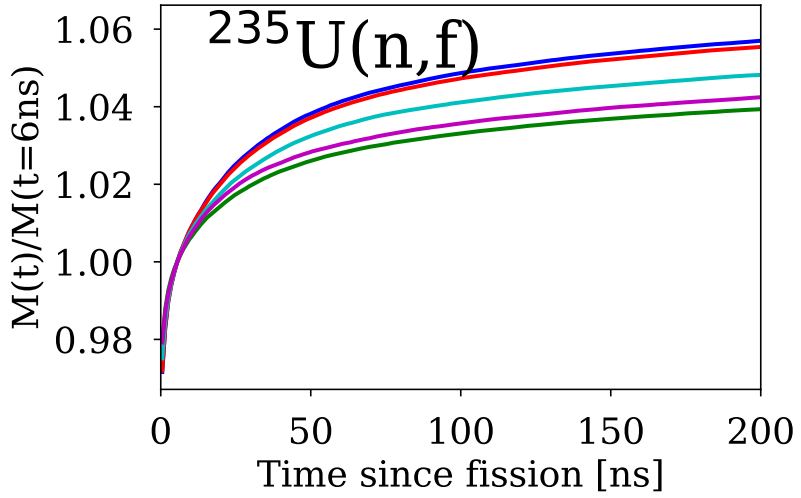
- Used to extract average PFG multiplicity for fast neutrons
- Improved evaluation with respect to ENDF/B-VII.1
- Similar results for ^{238}U(n,f) and ^{239}Pu(n,f)
- More data for fast neutrons would be very helpful

Time-Dependence of Prompt γ-Ray Emissions

- ns to μs isomers in fission fragments
- Time information not included in evaluated data files
- Model calculations for ^{252}Cf, ^{235}U, ^{239}Pu
- To investigate: the dependence of the average multiplicity as a function of time for different incident energies (will be soon available in MCNP)



Talou et al, PRC **94**, 064613 (2016)



New results with the energy dependence of the shape; thermal incident neutrons produce the strongest dependence of time