OAK RIDGE National Laboratory

Resolved Resonance Region Evaluation of n+^{140,142}Ce

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Outline

- Overview
- R-matrix Analysis
- Validation
- Conclusions

Overview

- ORNL has completed new resolved resonance region (RRR) evaluations for ^{140,142}Ce
- Carried out using Reich-Moore formalism instead of MLBW
- RRR covariance (File 32) included for both evaluations
- Added levels & changed spin assignments based on χ^2 metric
- ^{142}Ce RRR range increased from 13 to 26 keV
- ^{142}Ce resonances included up to 200 keV in agreement with experimental data

Overview – History and Motivation

- ENDF/B-VII.0 release based on recommendations of WPEC Subgroup 23 [1]
- Primarily adopted from compilation of resonances widths found in the ATLAS [2]
- Evaluations requested by Hanford Plutonium Finishing plant for nuclear criticality safety applications
  - Used as a catalyst or additive for chemical applications (e.g., glass polishing powder)
  - ^{140}Ce stable secondary fission product via β^- decay from ^{140}Xe, ^{140}Cs, and ^{140}Ba
  - ^{140}Ce important isotope in s-process stellar nucleosynthesis

Overview – Isotopic Properties

- Primarily ^{140,142}Ce (88.45% ^{140}Ce, 11.11% ^{142}Ce), <0.5% ^{136,138}Ce
- ^{140}Ce has closed neutron shell, so capture cross section relatively small
  - Potential for direct capture contribution
- RRR upper limit of 200 keV for ^{140}Ce and 13 keV for ^{142}Ce
- Inelastic threshold of 1596 keV for ^{140}Ce and 641.3 keV for ^{142}Ce
- No unresolved resonance region (URR) for ^{140}Ce, URR for ^{142}Ce from 13 – 100 keV

Overview – Experimental Datasets

- Only 2 previous high resolution experimental datasets found in EXFOR:
  - Hacken et. al. (1974) [3]
  - Ohkubo et. al. (1993) [4]
- Both datasets had issues precluding them from being used to fit data
  - Were both total cross section measurements; transmission highly preferred when performing fit
  - Hacken dataset has possible aluminum contamination and no published experimental uncertainties
  - Ohkubo dataset is a compilation of multiple samples with different thicknesses not labeled in the EXFOR entry or source publication

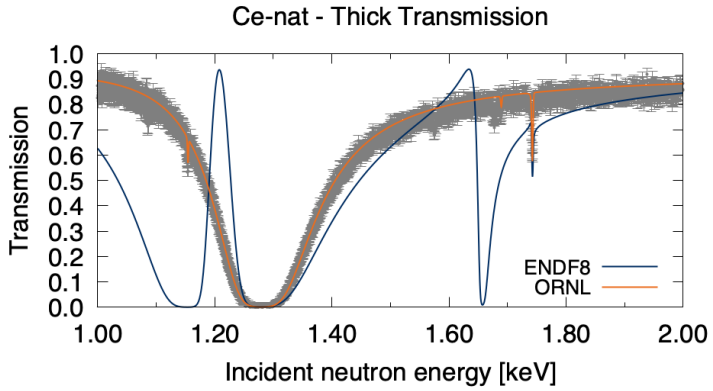
Overview – Experimental Datasets

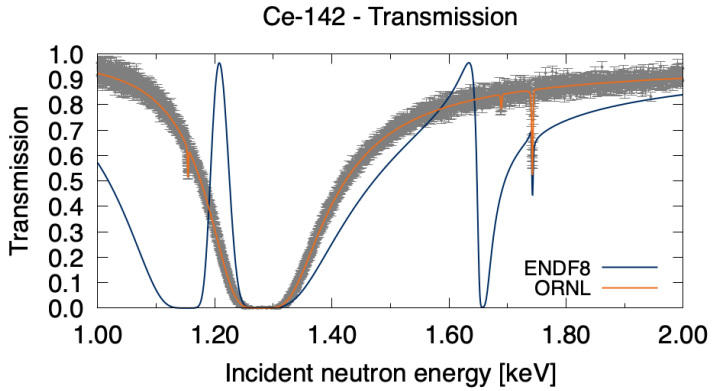
- New experimental data (transmission and capture yield) of ^{nat}Ce and 92% enriched ^{142}Ce measured at GELINA by Guber et. al. [5] were used for this fit
- Data evaluated from 1-200 keV
- Data corrected for
  - Doppler Broadening
  - Resolution Broadening
  - Oxygen parameters for oxide samples
    - Parameters do not exist in ENDF, compiled from [6]
  - Multiple scattering for capture yield measurements

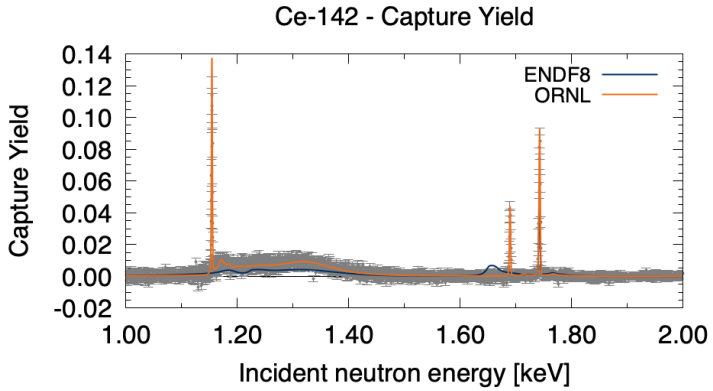
Sample (form)	Data Type	Sample Thickness (10^{-3} a/b)
^{nat}Ce (metallic)	Transmission	5.53
		28.71
	Capture yield	5.341
^{142}Ce (oxide)	Transmission	4.523
	Capture yield	4.523

R-matrix Analysis – 1-2 keV

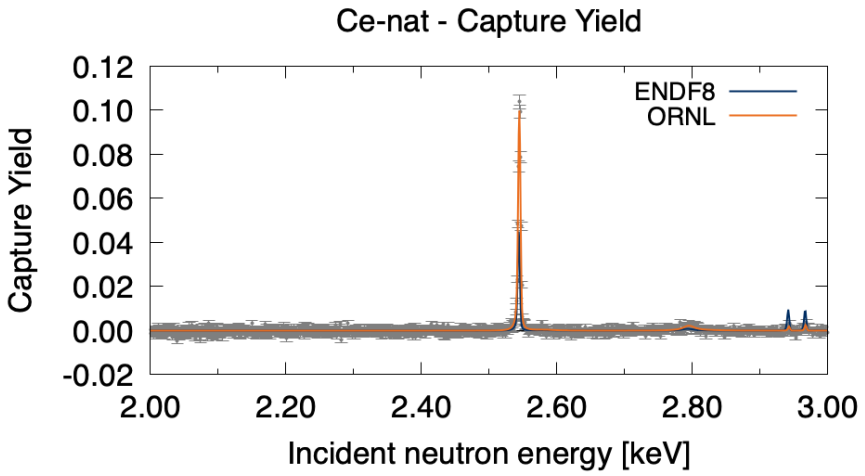
- Significant discrepancy in 1-2 keV region
- 2 misrepresented resonances believed to be transcription errors from source publication to Atlas of Neutron Resonances and, subsequently, to ENDF library
  - E_r=1.15 keV: Γ_n=50 eV s-wave -> Γ_n=50 meV p-wave
  - E_r=1.68 keV: Γ_n=10 eV s-wave -> Γ_n=10 meV p-wave

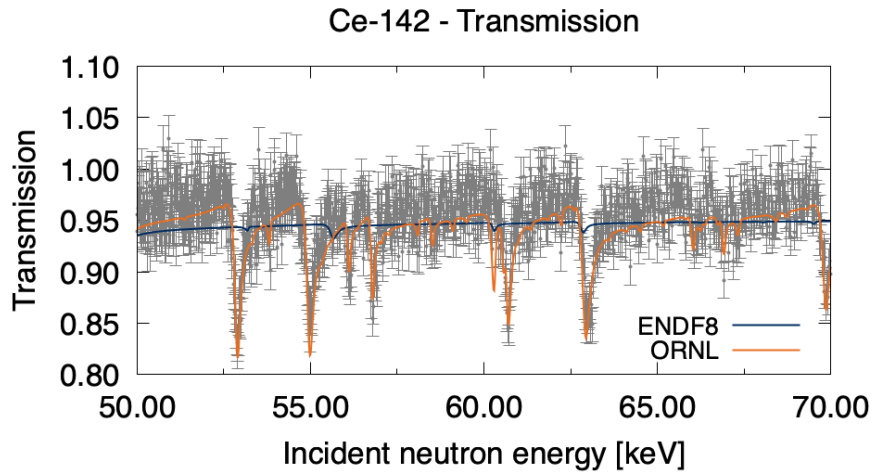


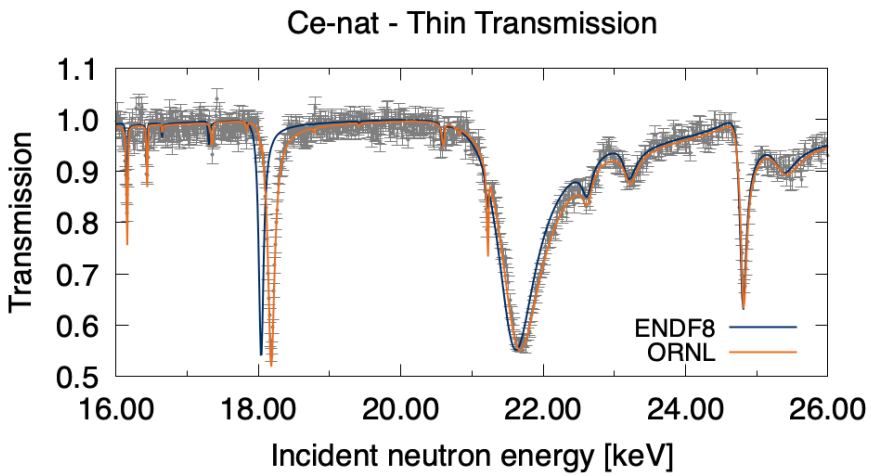


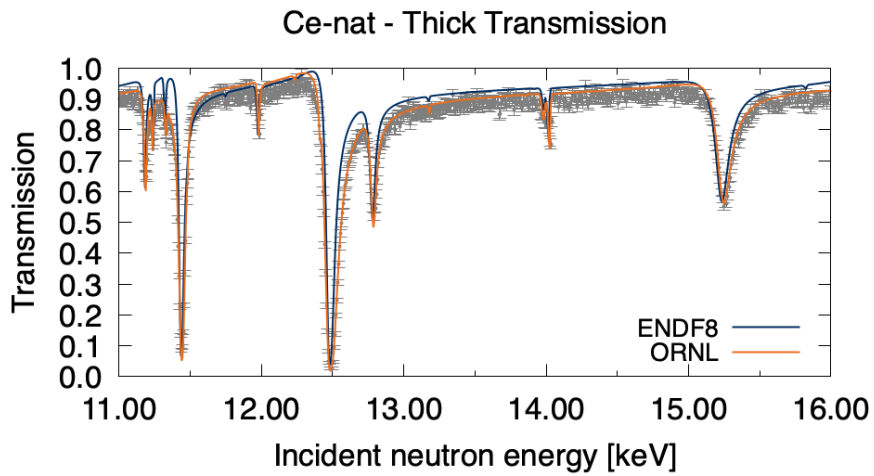


R-matrix Analysis

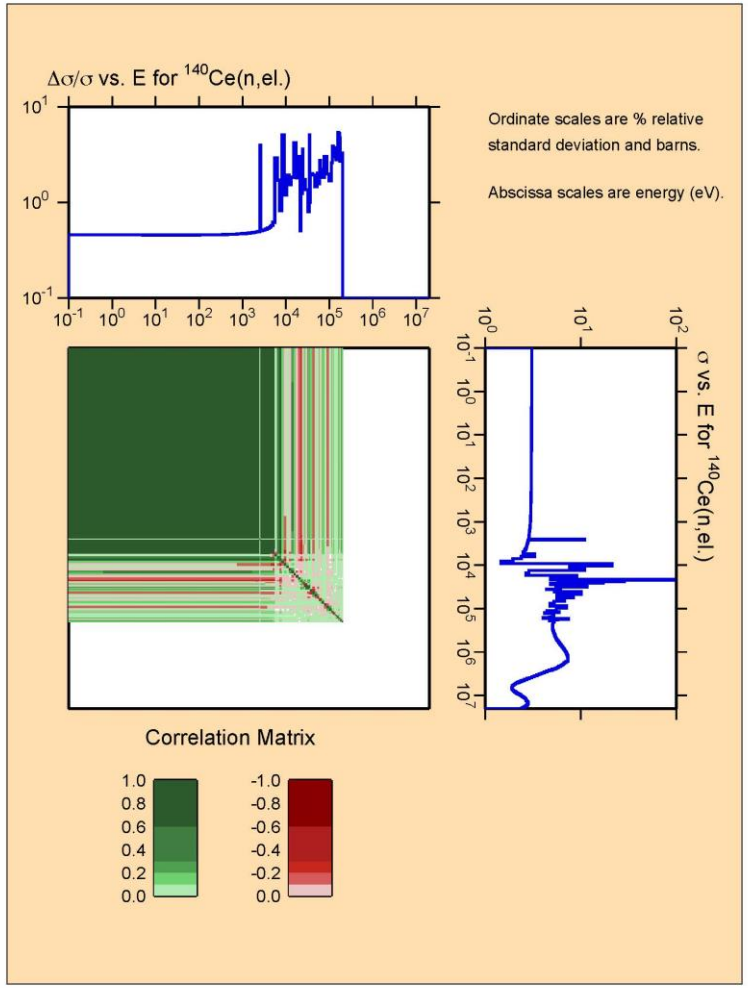


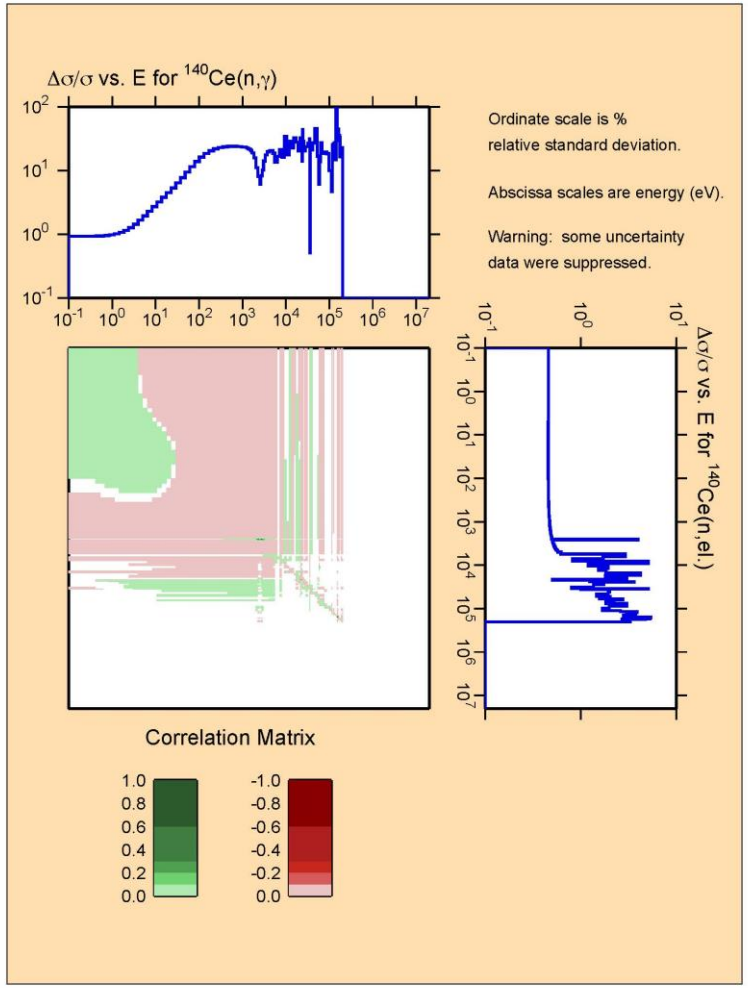


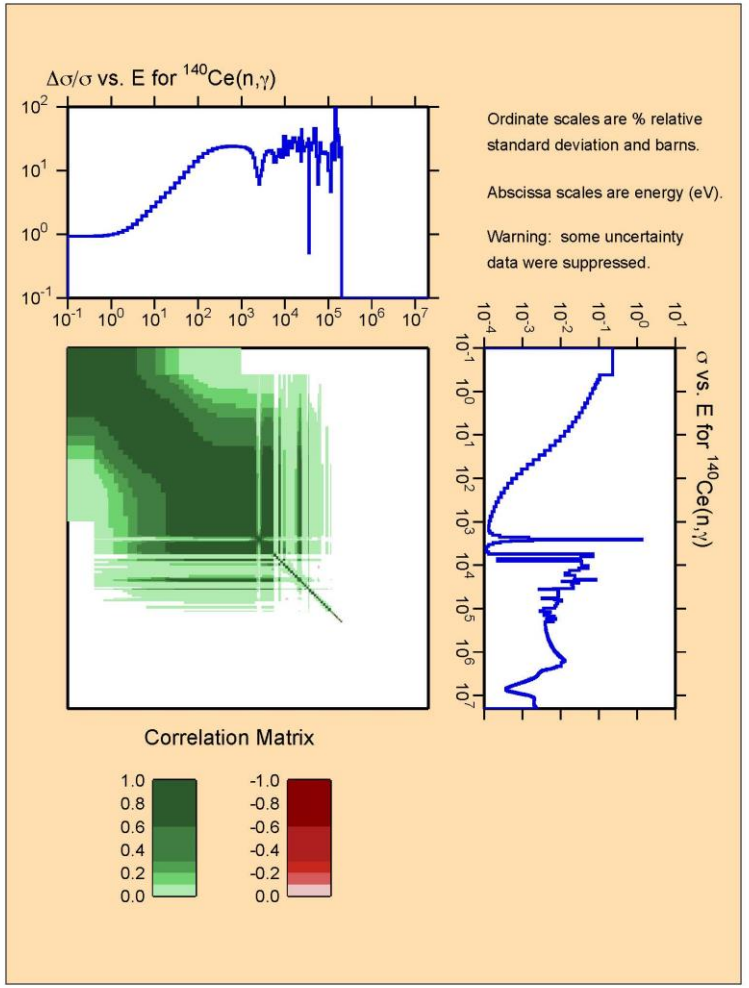




R-matrix Analysis – Uncertainties and Covariances







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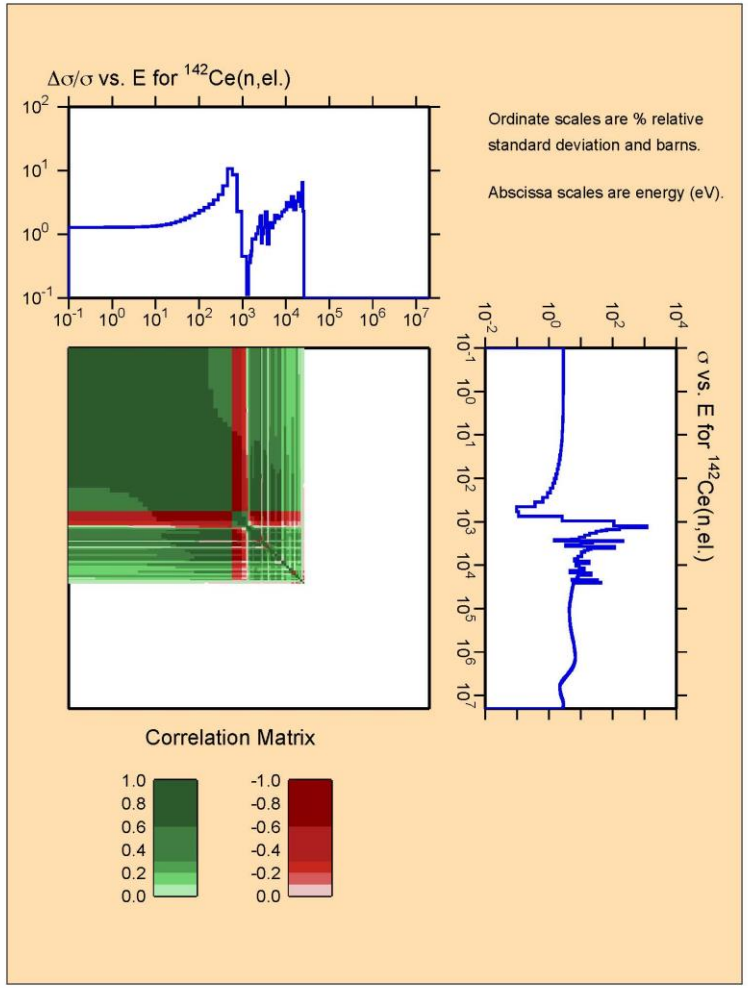

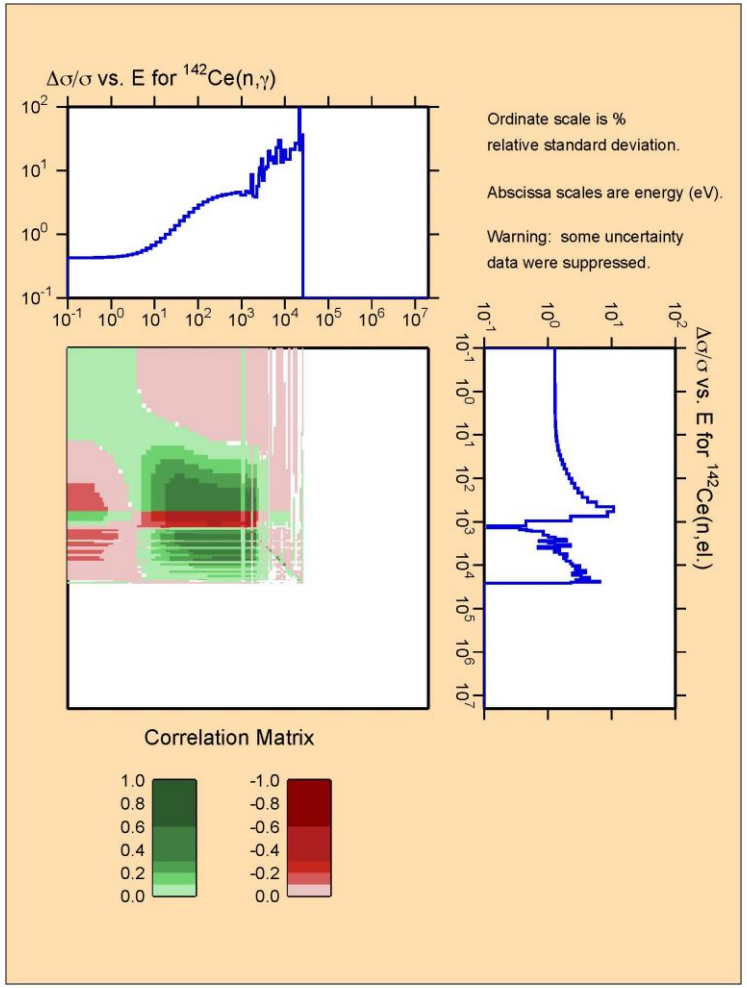

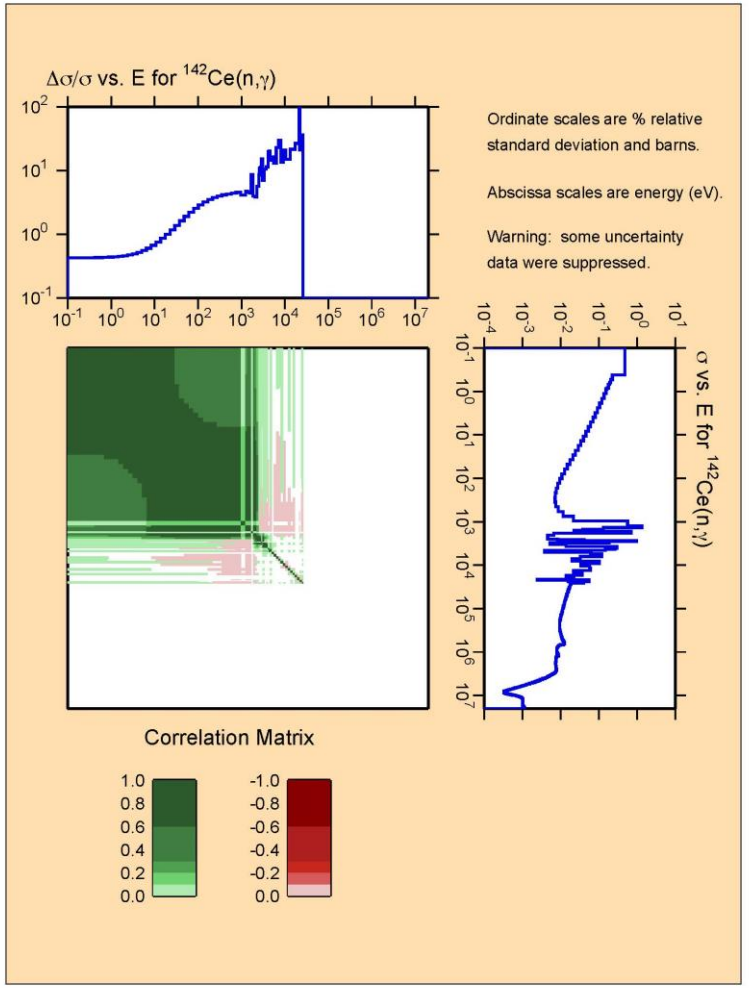

Validation – MACS

- No integral benchmarks found in ICSBEP or IRPhE that contained appreciable amounts of Ce
- Maxwellian-Averaged Cross Section (MACS) used as validation

$$\langle \sigma(E)\sqrt{E} \rangle_{kT} = \frac{2}{\sqrt{\pi}(kT)^2} \int_0^\infty \sigma_\gamma(E) E e^{-E/kT} dE$$

Library	^{140}Ce [mb]*	^{142}Ce [mb]*
KADONIS	11.73 ± 0.44	29.9 ± 1.0
ENDF8	7.80	20.08
ORNL	14.45	23.05

Conclusions

- ORNL has completed new resolved resonance region (RRR) evaluations for ^{140,142}Ce
- Lack of integral measurements makes validation difficult, but difference from Kadonis values suggest more investigation of capture cross section warranted

- Complete file (with updated File2 & File32) submitted to NNDC repository for inclusion in next release of ENDF
- Sponsor report and journal publication in progress

Acknowledgements

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- JRC-GEEL instrument scientists for their work in conducting the experiment and making the data available

References

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- [2] S. Mughabghab, Atlas of Neutron Resonances (Sixth Edition), Part A. Amsterdam: Elsevier, 2018.
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