New Resonance Evaluation for Cerium to Support Nuclear Criticality Safety Applications

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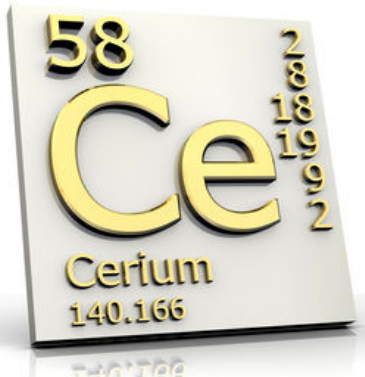
NCSP Nuclear Data Request for Hanford Plutonium Finishing Plant

- General Applications of Cerium:
  - Used commercially as a catalyst or additive in chemical applications (e.g., glass polishing powder).
  - High-yield fission product.
- The target uncertainty requested by NCSP in the resolved resonance region:
  - Total cross section: 1–2%.
  - Capture cross section: less than 6%.
- New cerium resonance evaluations will:
  - Significantly improve radiation transport calculations for systems involving cerium in processes in the DOE Complex.
  - Provide much-needed evaluated covariance data to support sensitivity/uncertainty analyses.
  - Submitted for inclusion in ENDF/B-VIII+

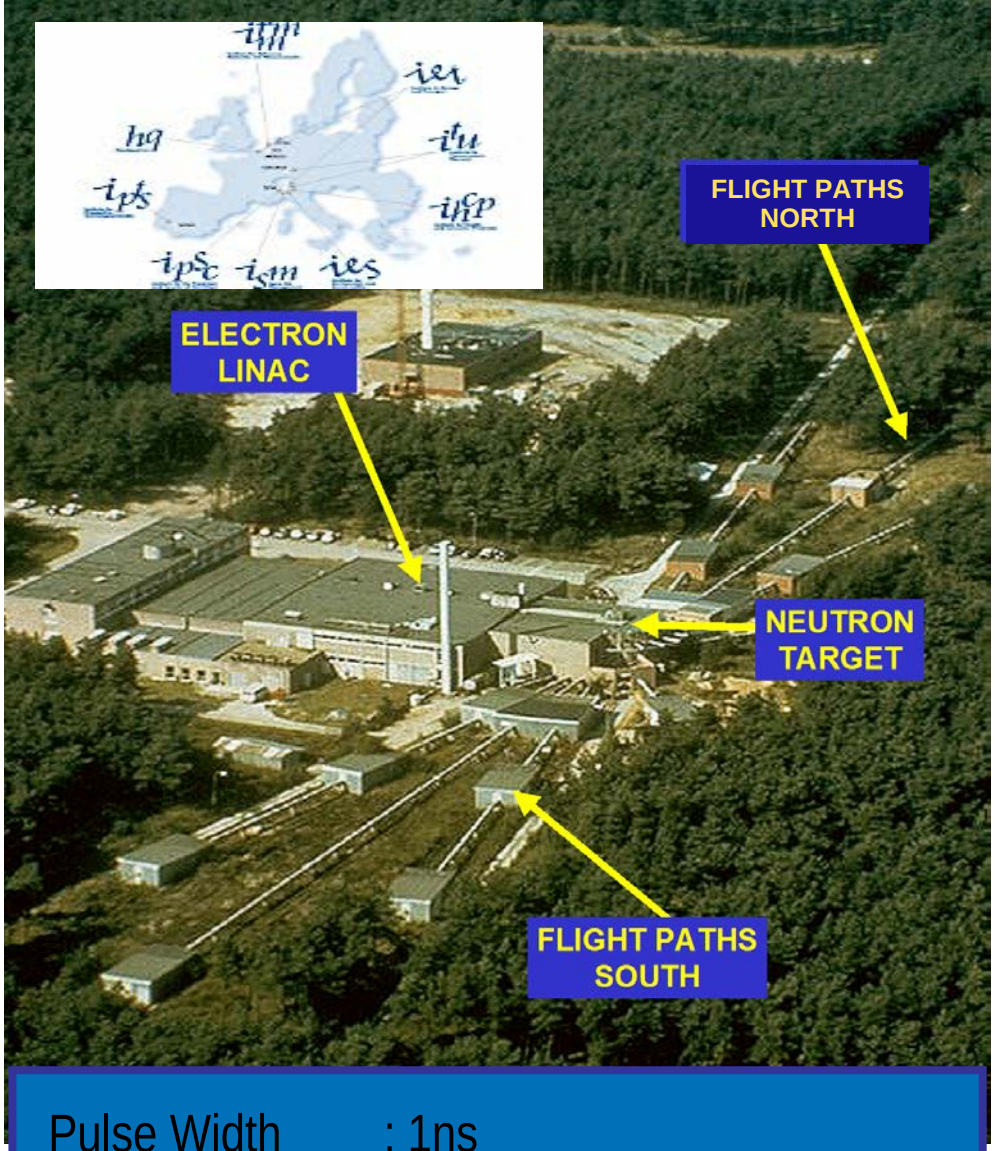


History of ENDF/B-VII.1 Evaluation for Isotopes of Ce

- Part of the WPEC: NEA Working Party on Evaluation Cooperation Subgroup-23 on the International Library of Fission Product Evaluations in 2004–2005.
- Prior, ENDF had adopted the JENDL resonance evaluation based on the experimental data of
  - Hacken, et al.
  - Camarda
  - Musgrove
- The ENDF/B-VII.1 (to be ENDF/B-VIII.0) resonance parameters for cerium are provided for the MLBW approximation.
- ENDF/B-VII.1 does not include the covariance data needed to support sensitivity/uncertainty analyses of systems involving cerium.

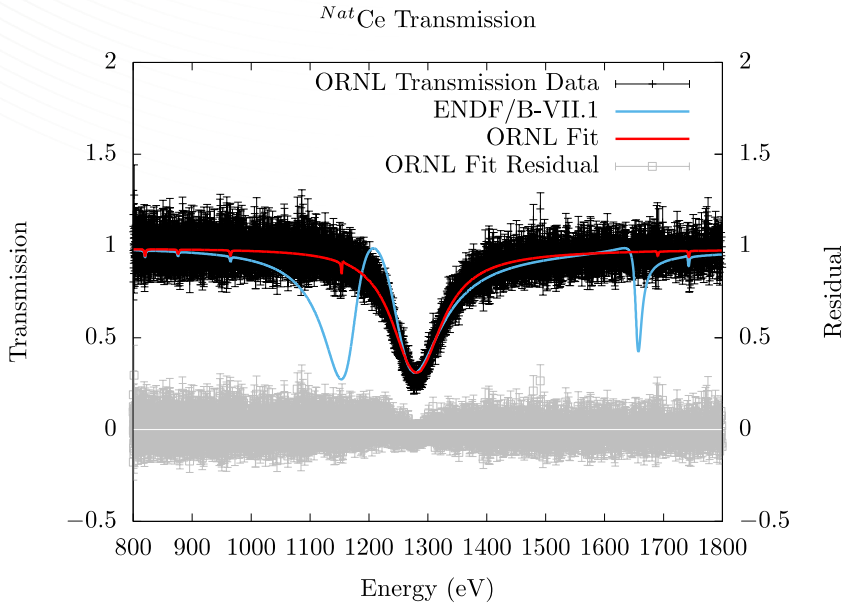
ORNL Measurement and Evaluation Efforts to Improve the Cerium Resonance Cross Section Evaluation

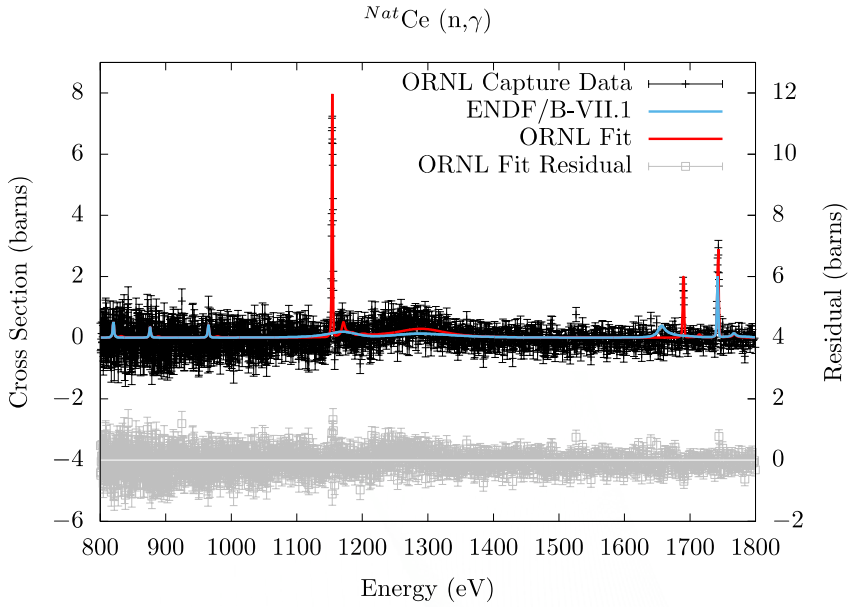
- ORNL has completed new differential measurements on natural samples at the European Commission Joint Research Center in Geel, Belgium.
- With the current resolution of GELINA, it should be possible to resolve resonances to high neutron energies, however the extremely small cross sections hinder that significantly.
- Measurements of an enriched ^{142}Ce sample are planned.



Pulse Width : 1ns
Frequency : 40 Hz – 800 Hz
Average Current : 4.7 μA – 75 μA
Neutron intensity : $1.6\ 10^{12}$ – $2.5\ 10^{13}$ n/s

Highlights of Improvements





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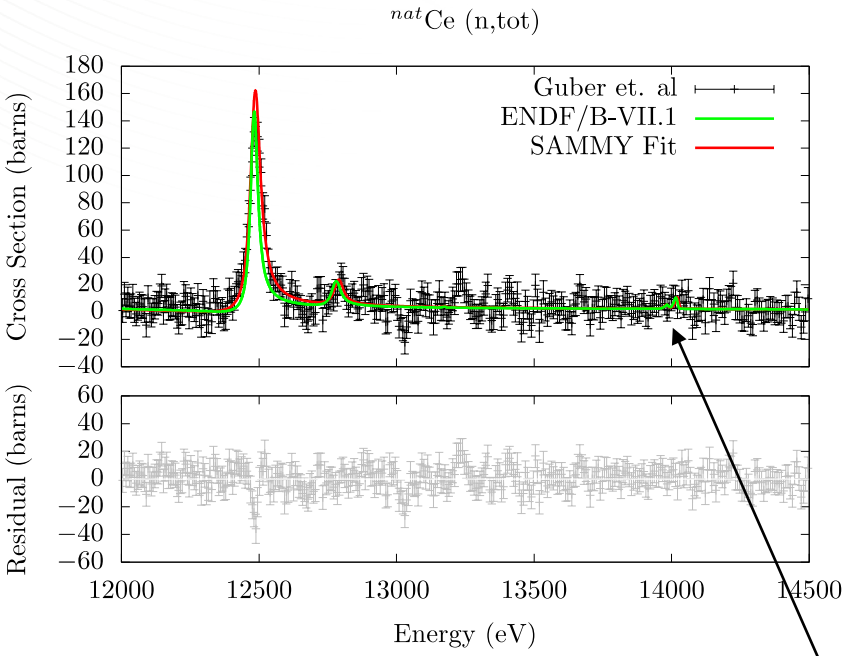
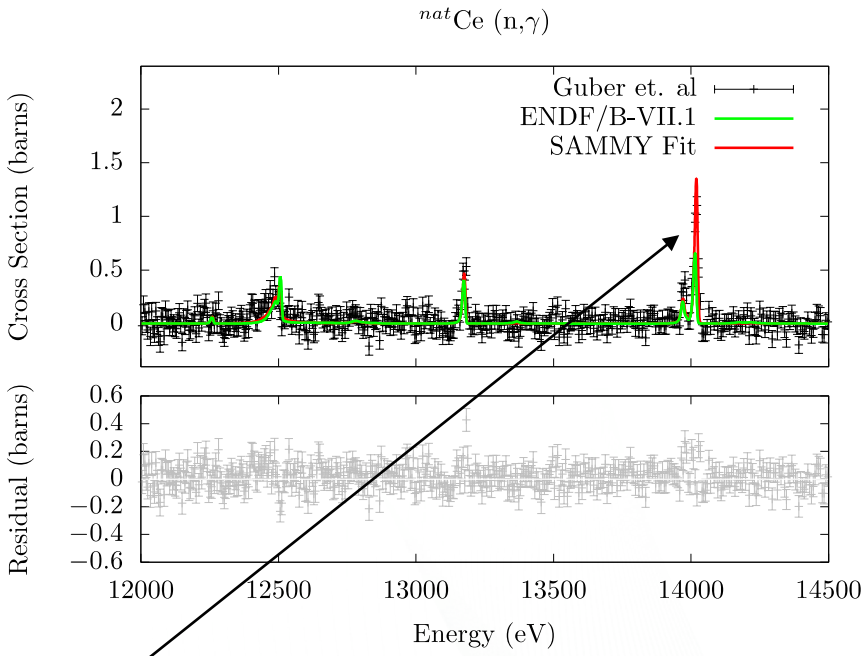
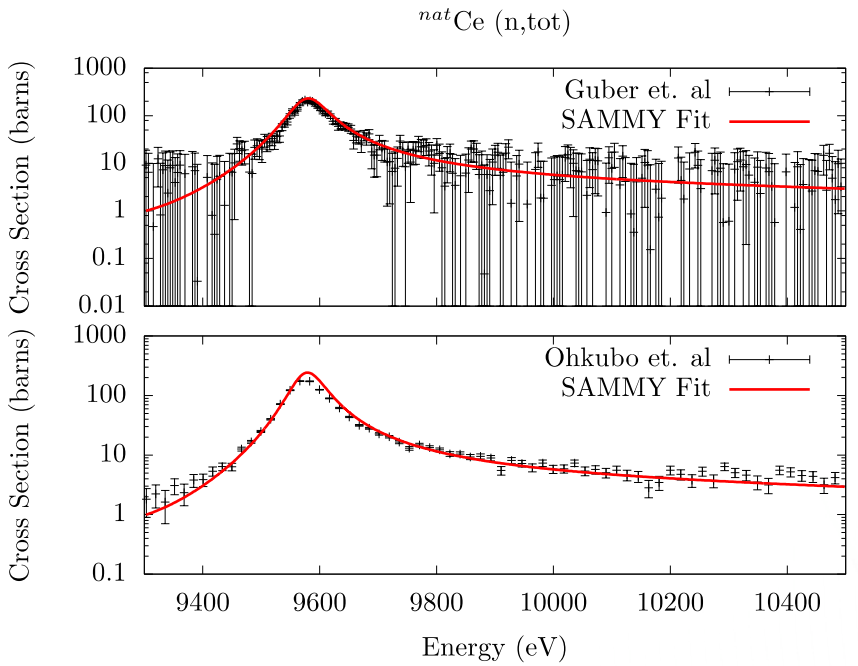
Complementarity of Capture Data





Experimental capture data allows to identify resonance widths for resonances barely observed in transmission data

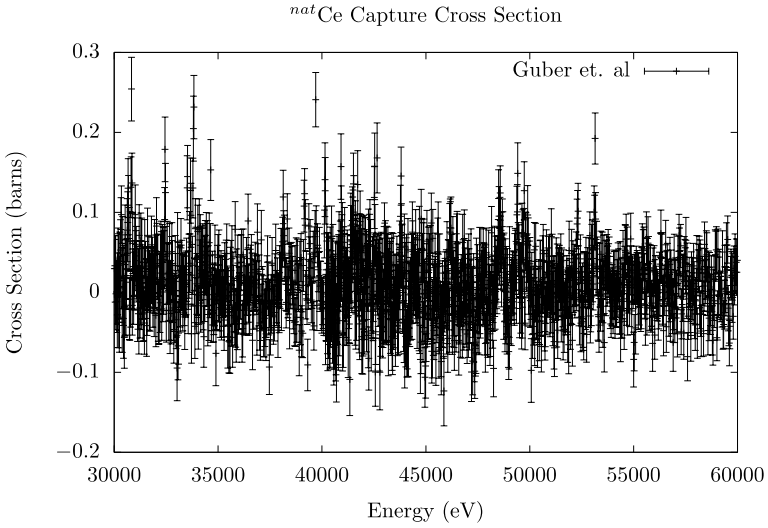
Agreement Between Independent Transmission Measurements

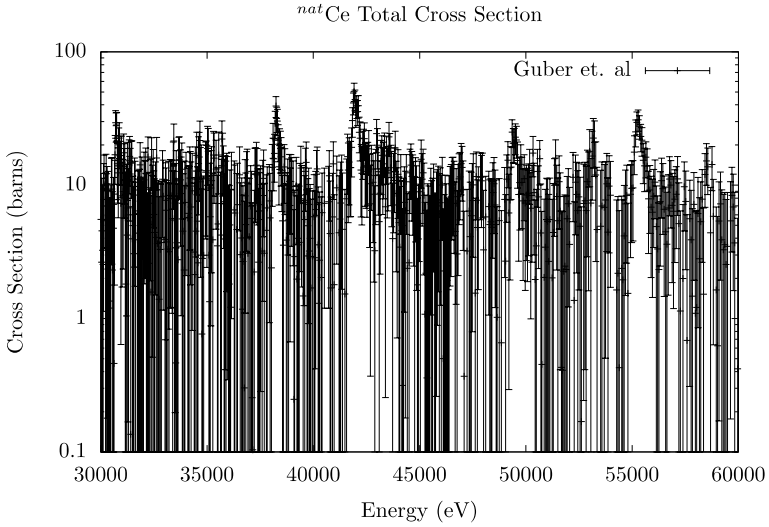


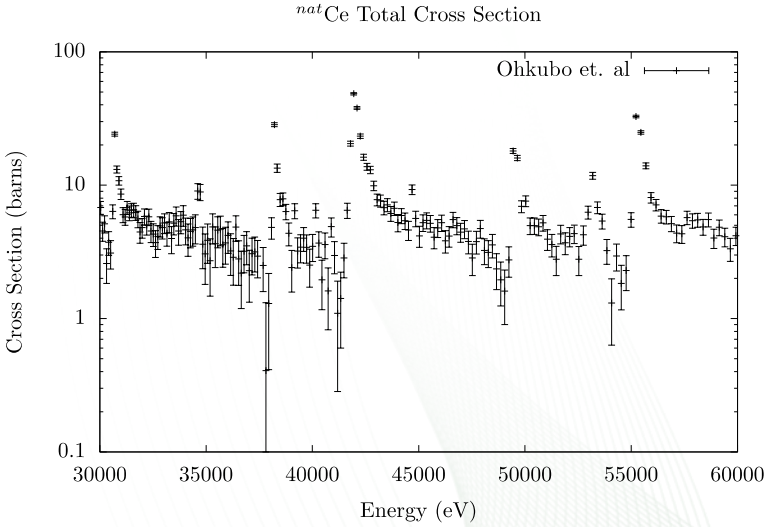
Low fidelity experimental uncertainty information

Experimental Data Above 30 keV

- Ce-140 has a closed neutron shell and is unlikely to absorb additional neutrons.
  - Capture cross section is very small
- Limited resolved experimental cross section data above 30 keV.
- Guber is planning to carry out new measurements to extend upper limit of resolved data.

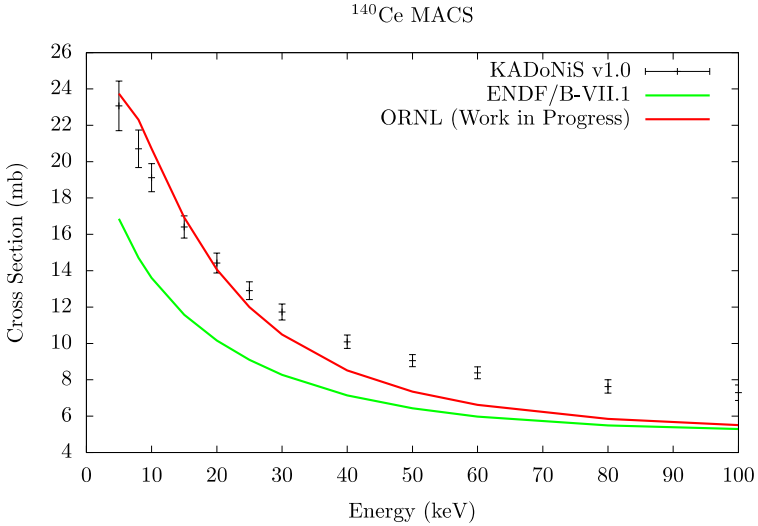


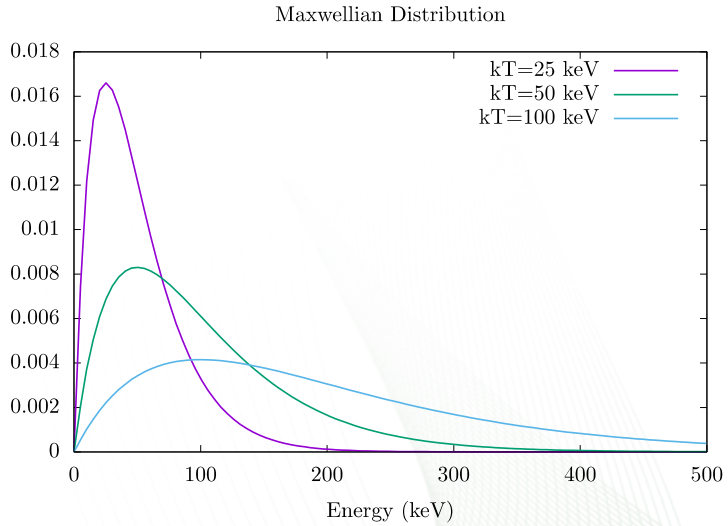




Validation/Benchmarking New Evaluation?

- No integral benchmarks found with significant sensitivity to resonance region of Cerium.
- The Maxwellian-Averaged Capture Cross Sections (MACS) from the Karlsruhe Astophysical Database of Nucleosynthesis in Stars (KADoNiS) is one limited validation case.
- Evaluated cross sections above RRR for Cerium have an increasing impact for MACS values at kT > 30 keV.





Conclusions

- New resonance evaluations for ^{140}Ce and ^{142}Ce are currently being developed at ORNL in support of the Hanford Plutonium Finishing Plant as part of the NCSP nuclear data request.
- The new evaluation is significantly improved by new differential measurements but is still grounded in historical measurements.
- The new evaluation seeks to improve the assumptions of the resolved resonance region by using the more rigorous Reich-Moore R-Matrix approximation.
- Resonance parameter covariance data will be generated to support sensitivity/uncertainty analysis efforts.
- To be submitted for inclusion in ENDF/B-VIII+ (post ENDF/B-VIII.0)
- Acknowledgements to the experimental measurements team:
  - ORNL: Klaus Guber, Clint Ausmus
  - IRMM: Peter Schillebeeckx, Carlos Paradela, Stefan Kopecky, Peter Siegler, Ruud Wynats