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Title: Prototype of a New Fixed-source Sensitivity Tally Capability

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Prototype of a New Fixed-source Sensitivity Tally Capability

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Overview

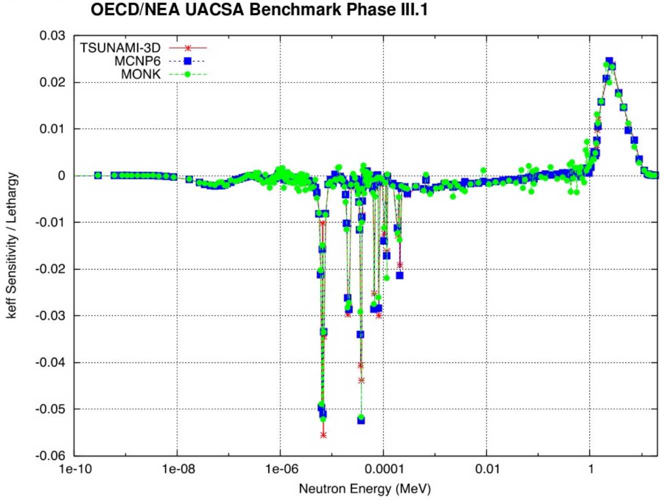
- Overview of Sensitivities
- Practical Uses of Sensitivities
  - Uncertainty quantification
  - Nuclear data library differences
  - Nuclear data adjustment
  - Similarity assessment
- Fixed-source Sensitivities
  - Methods
  - Verification
  - Current and Future Work

Overview of Sensitivities

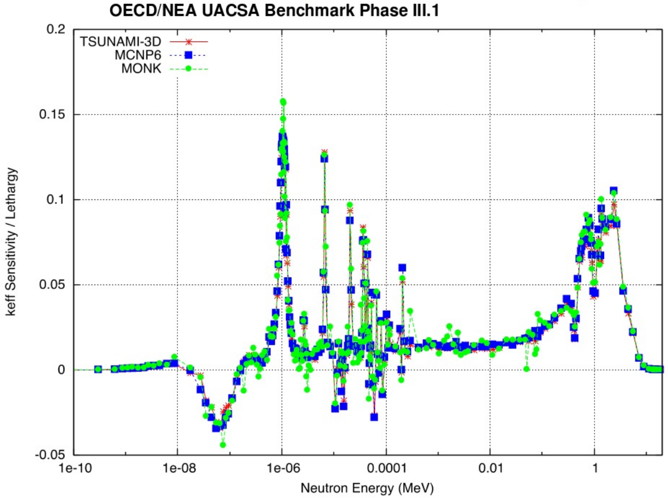
$$S_{k,\sigma} = \frac{\Delta k / k}{\Delta \sigma / \sigma}$$

- Use MCNP6 k-eigenvalue sensitivities as an example
  - Can compute profiles of k_{eff} – nuclear data sensitivity profiles through KSEN card
  - How does a relative change in the cross section impact k_{eff} of the system?
  - For a single system, these (isotope-reaction-energy-dependent) profiles are unique

U-238: total cross-section sensitivity

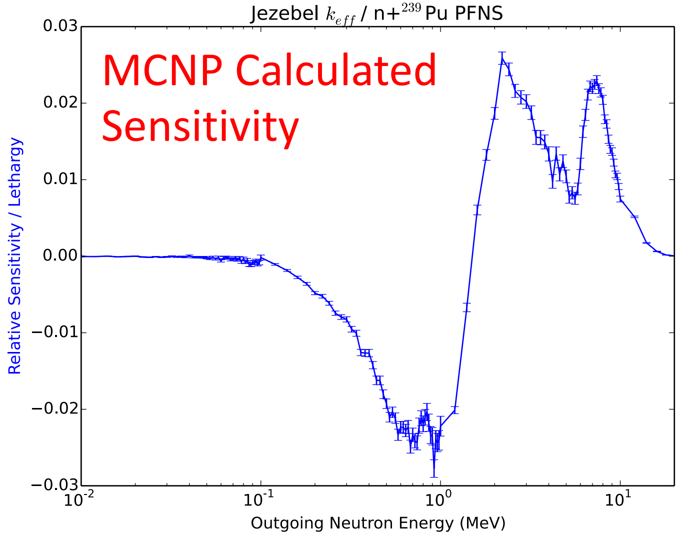


H-1: elastic scattering cross-section sensitivity



Practical Uses of Sensitivities

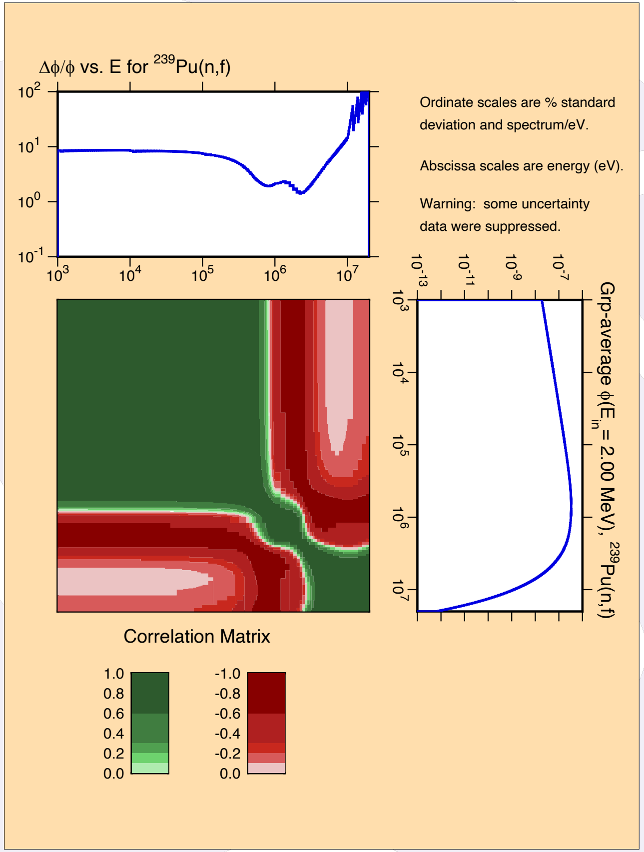
- Uncertainty Quantification



Uncertainty in Jezebel k_{eff} due to ^{239}Pu PFNS only

$$\sigma_k^2 = \vec{S}\,\mathbf{C}_X\,\vec{S}^T, \quad \frac{\sigma_k}{k} \cong 0.160\%$$

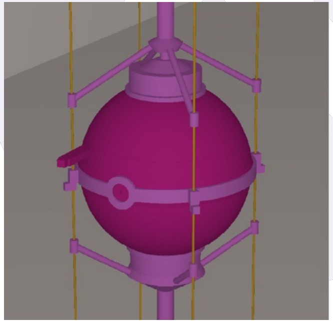
Nuclear Data Uncertainties

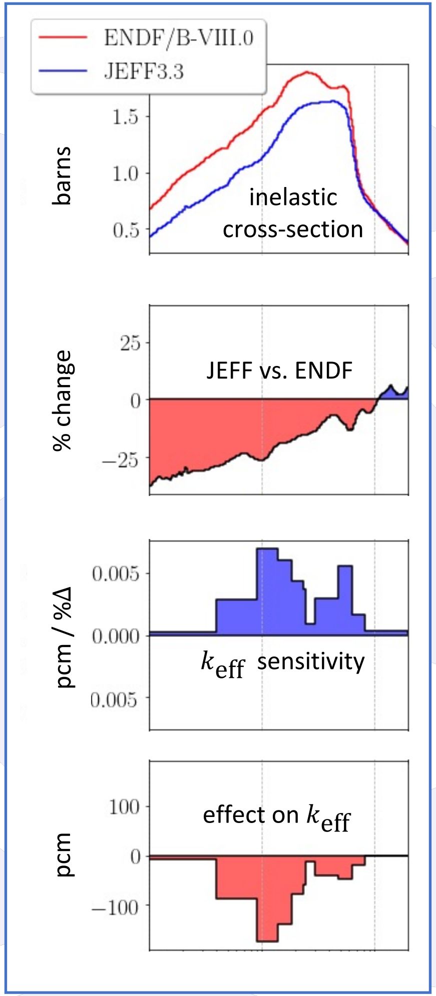


Practical Uses of Sensitivities

- Nuclear data library differences
- Differences in nuclear data libraries, such as ENDF/B-VIII.0 and JEFF3.3, can be studied for individual applications through sensitivity profiles
- Sensitivity profiles provide the link between nuclear data and predictive application simulations

Jezebel





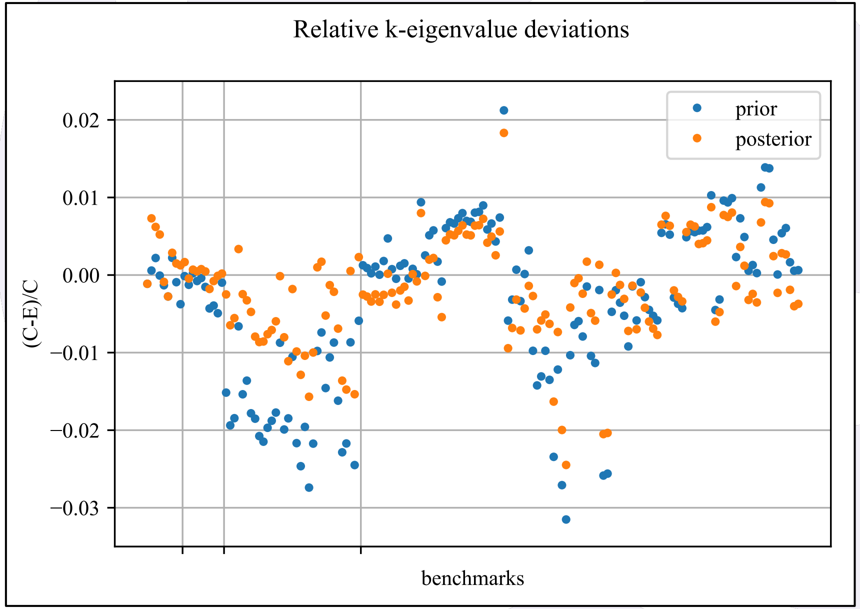
Practical Uses of Sensitivities

$$\mathbf{\Delta k = C_{mm} C_{dd}^{-1} d}$$

Sensitivities for each benchmark baked into the right-hand-side

- Nuclear Data Adjustment
  - Can apply generalized linear-least squares (GLLS) or other methods to optimize nuclear data to select criticality benchmarks
  - Sensitivities key ingredient
  - With the nuclear data adjusted through the GLLS method, posterior bias is reduced as compared to the prior bias and the nuclear data are then tuned / calibrated to specific applications

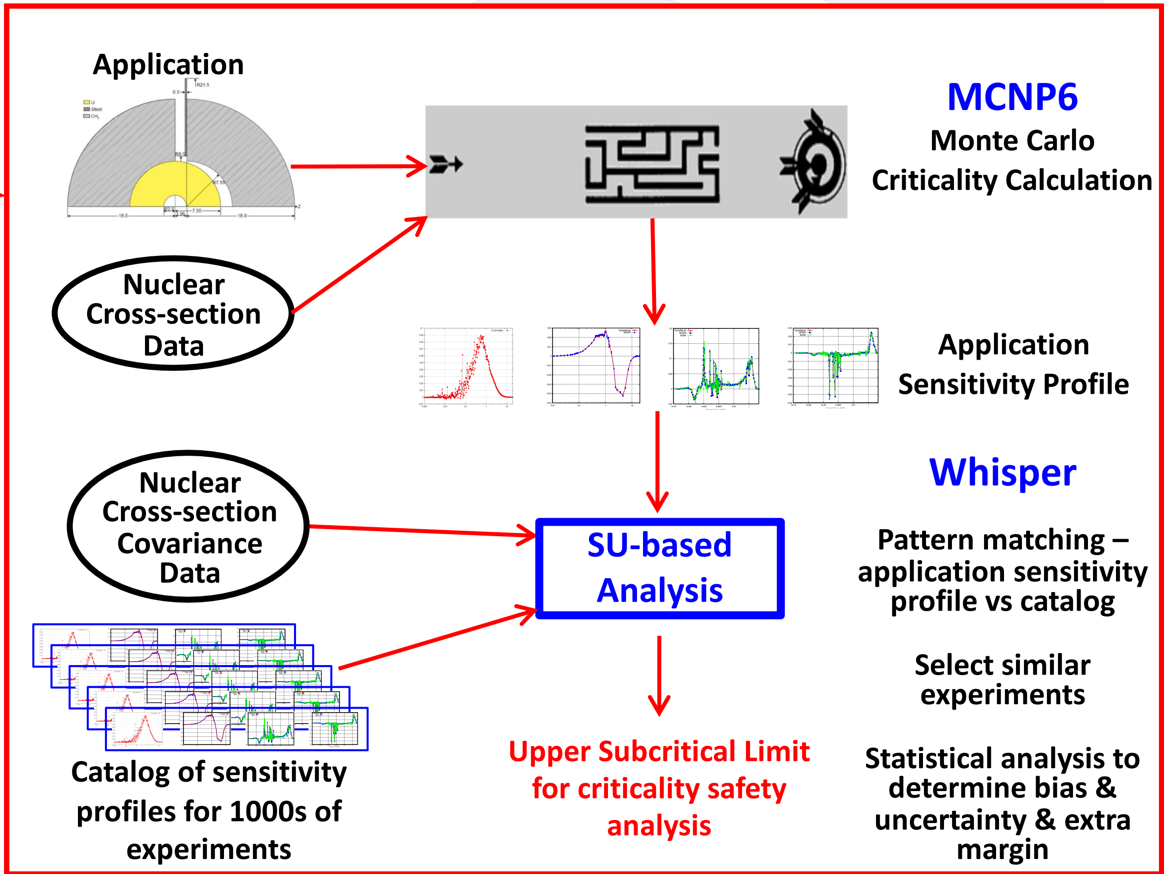
	Prior	Posterior
χ^2	4.61	2.06
RMS	0.0106	0.0066



Practical Uses of Sensitivities

- Similarity Assessment
  - Finding similar applications
  - Bias assessment
  - Experimental design

Goal of the EUCLID LDRD project is to design small-scale experiments that address needs and deficiencies in nuclear data



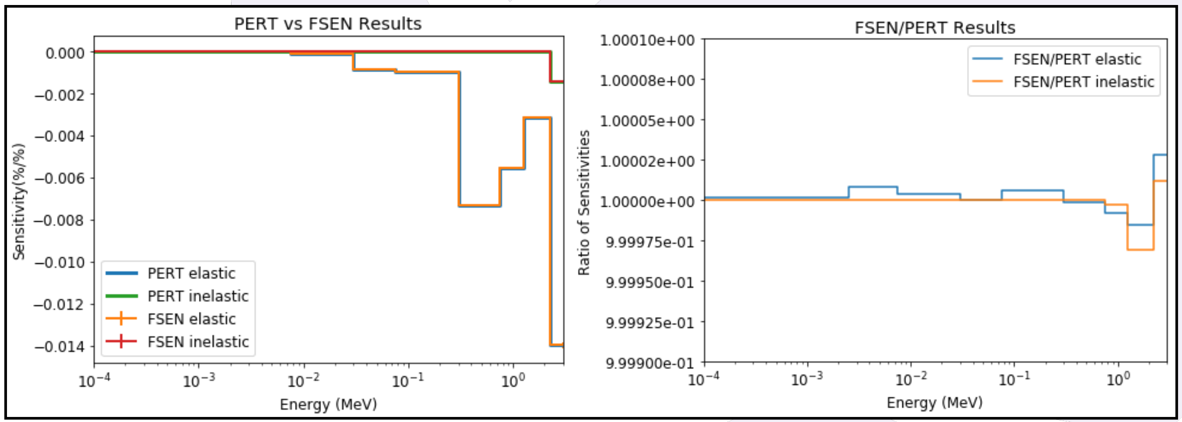
Fixed-source Sensitivities

- Methods
  - Central difference, brute force calculations (FRENDY/SANDY codes)
    - Direct modification of ENDF/ACE files (outside of MCNP)
    - Computationally expensive
    - Can be difficult to distinguish Monte Carlo statistics from small perturbations
  - Differential operator (PERT card)
    - Differentiating each part of the Monte Carlo random walk
  - **Adjoint-weighting (under development)**
    - **With an accurate adjoint estimate, very accurate results**
    - **Successful for k-eigenvalue calculations (KSEN card)**

Fixed-source Sensitivities

- Verification
  - Comparing adjoint-weighted approach to other methods
  - Central difference
    - Simple problem
    - Density perturbation on cell card
    - Analogous to total cross section perturbation
  - Differential operator (PERT)
    - Also a simple problem
    - Energy / reaction binning
    - Excellent agreement between PERT and adjoint-weighted sensitivity method!

	Sensitivity
Direct perturbation – central difference	-0.1257(1)
Adjoint-weight fixed-source method	-0.1251(5)

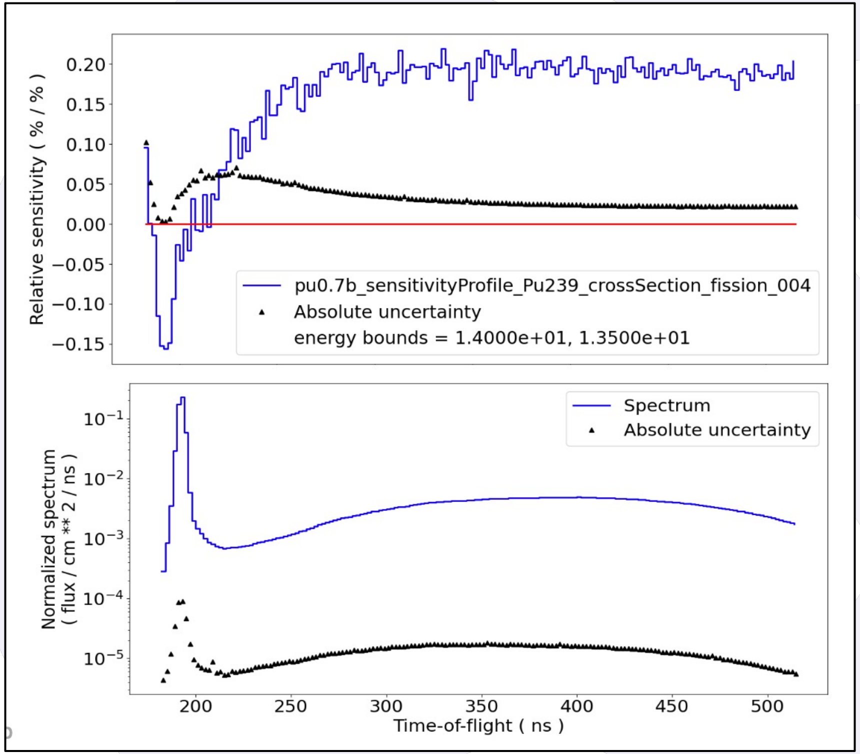


Fixed-source Sensitivities

- Current Work
  - Finish verification of adjoint-weighted sensitivity method
    - Comparison to brute force (central difference)
    - Comparison to differential operator
  - Improved output format (HDF5)
  - Extend to point detectors

- Future Work
  - Extensions to non-Boltzmann responses
    - Pulse-height tallies
    - Coincident/multiplicity analysis
  - More responses and particle types
  - Connect to new tally backend

LLNL Pulsed Sphere sensitivities calculated and available for additional verification of the new fixed-source sensitivity method under development



Acknowledgements

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LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Questions?

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