NC STATE UNIVERSITY

RADIANS

Subcritical Neutron Multiplicity Counting Experiments Applied to Nuclear Data Adjustment

John Mattingly

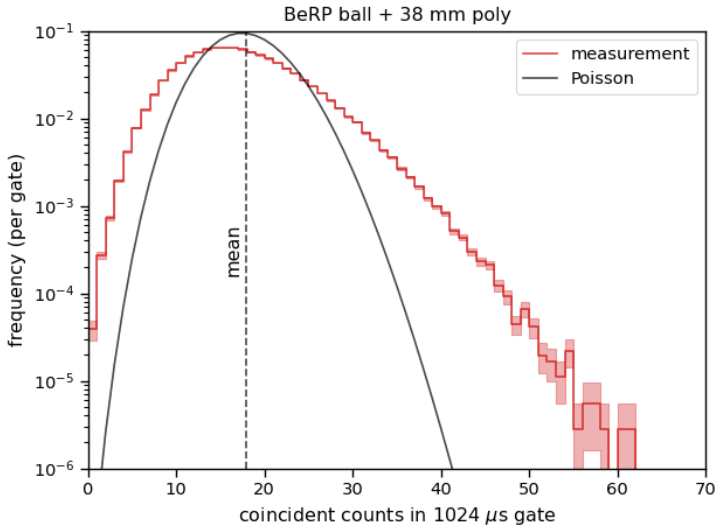
North Carolina State University

Subcritical neutron multiplicity counting

- Neutron multiplicity counting (NMC) accumulates the distribution of coincident neutron counts

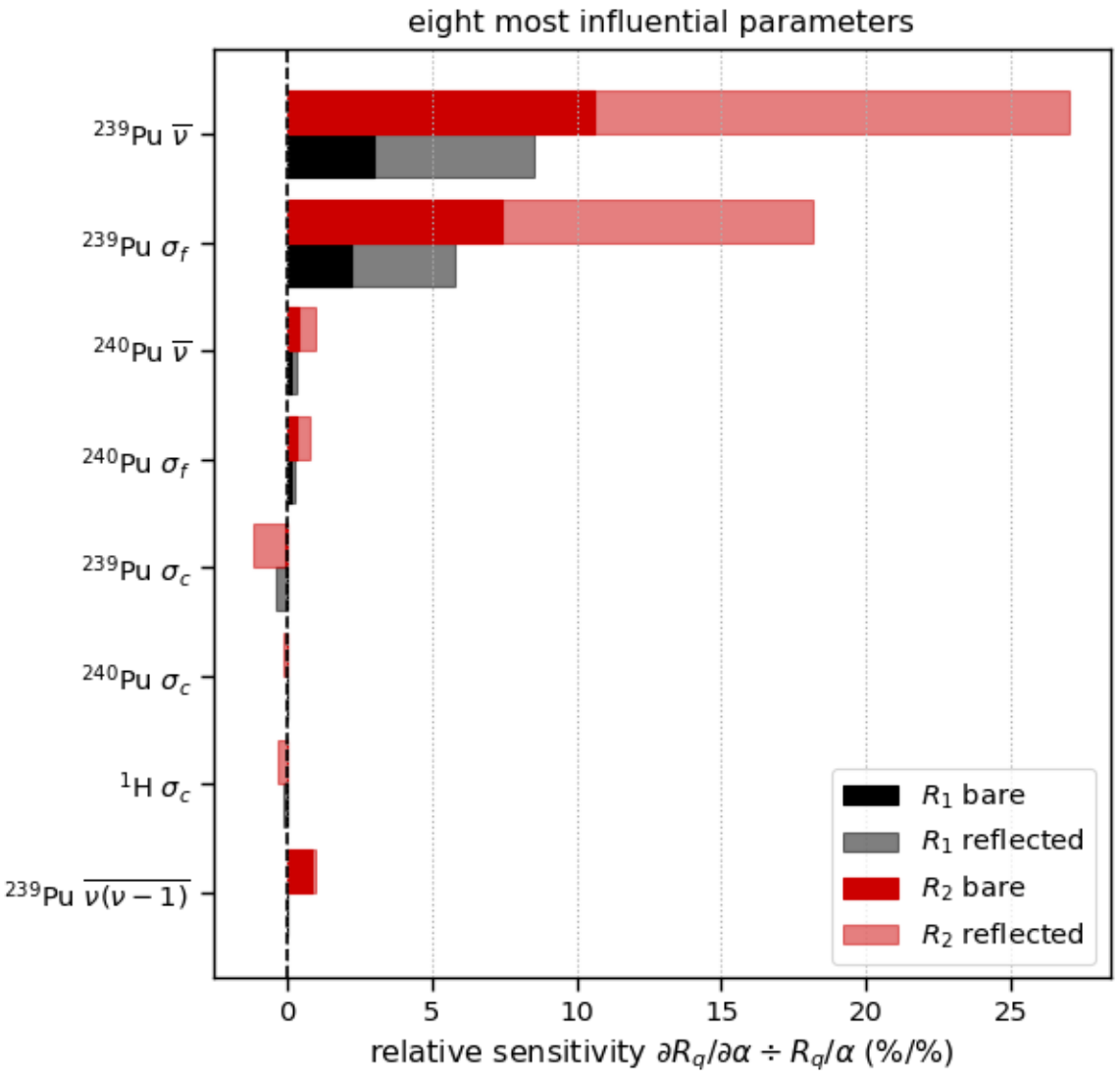
- The example used in this talk is a measurement of the BeRP ball reflected by polyethylene
  - 4.4-kg weapons-grade plutonium (WGPu) metal
  - Bare and reflected by polyethylene up to 150 mm thick
  - Measured using LANL nPod ^{3}He neutron multiplicity counter
  - Available in the Shielding and Integral Benchmark Archive and Database (SINBAD package no. NEA-1517/92)

- The NMC distribution measured from a multiplying system is broader than a Poisson distribution
- The higher moments (variance, skewness, kurtosis…) are more sensitive than the mean to changes in the nuclear cross sections (σ_f, σ_c, and σ_s) and other parameters (χ, $\bar{\nu}$, $\overline{\nu(\nu-1)}$, etc.)



Adjoint sensitivity analysis

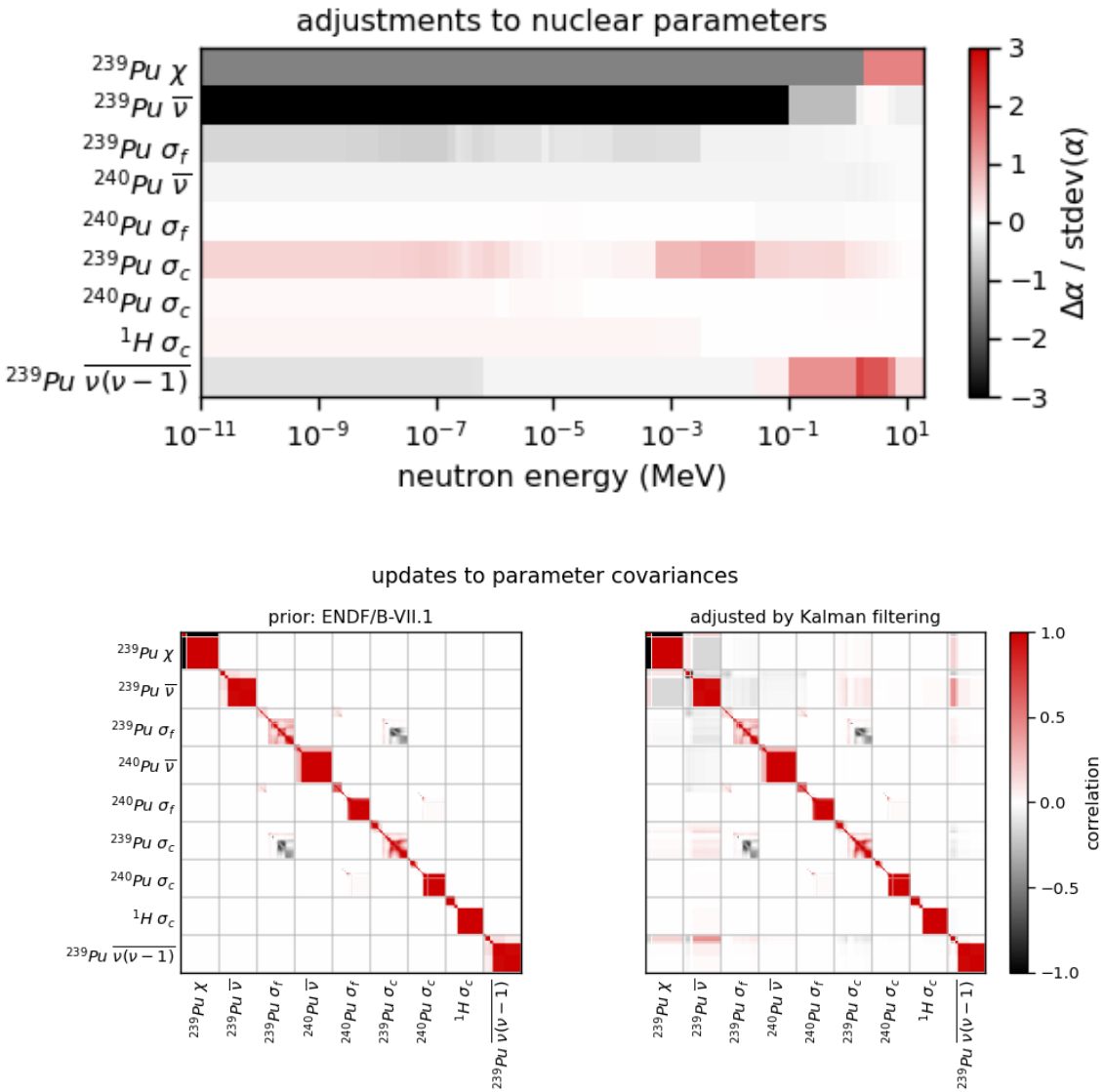
- NMC measurements have not been previously used for nuclear data evaluation because there was no efficient method to estimate their sensitivity to energy-dependent cross sections and other transport parameters
- Recently, NCSU developed a new adjoint-based first-order sensitivity analysis method to estimate sensitivities for higher-order NMC moments
- This also enables propagation of covariances in nuclear data onto uncertainties in the calculated moments
- Finally, it enables nuclear data adjustment using NMC measurements



Nuclear data adjustment

- Bayesian methods can be used with NMC measurements for nuclear data adjustment
  - An existing nuclear data evaluation is treated as a prior estimate of the mean value and covariance of the transport parameters
  - A Bayesian method updates the parameter values and covariances to minimize the error between the measured and calculated NMC moments

- The example shown at right used extended Kalman filtering (EKF), but there are many alternative methods for data adjustment



Summary

- Subcritical NMC measurements accumulate the frequency distribution of coincident neutron counts
- Their higher-order moments are more sensitive than the mean count rate to variations in nuclear cross sections and other transport parameters

- It is now possible to estimate the moments' sensitivity to energy-dependent nuclear data using first-order adjoint sensitivity analysis
- Nuclear data values and covariances can be adjusted using Bayesian inference to minimize error between measured and calculated NMC moments

- Existing subcritical NMC benchmark measurements are plentiful, and new benchmarks are relatively simpler than critical benchmarks to plan and execute
- The benchmarks do not easily fit into the International Criticality Safety Benchmark Experiment Program (ICSBEP) framework, which is principally structured to evaluate uncertainties in k_{eff}