LA-UR-16-23757

MCNP-WHISPER Methodology for Nuclear Criticality Safety Validation

This work supports:

US DOE Nuclear Criticality Safety Program

US DOE Stockpile Stewardship Program

LANL Nuclear Criticality Safety Division

LANL PF4 Restart

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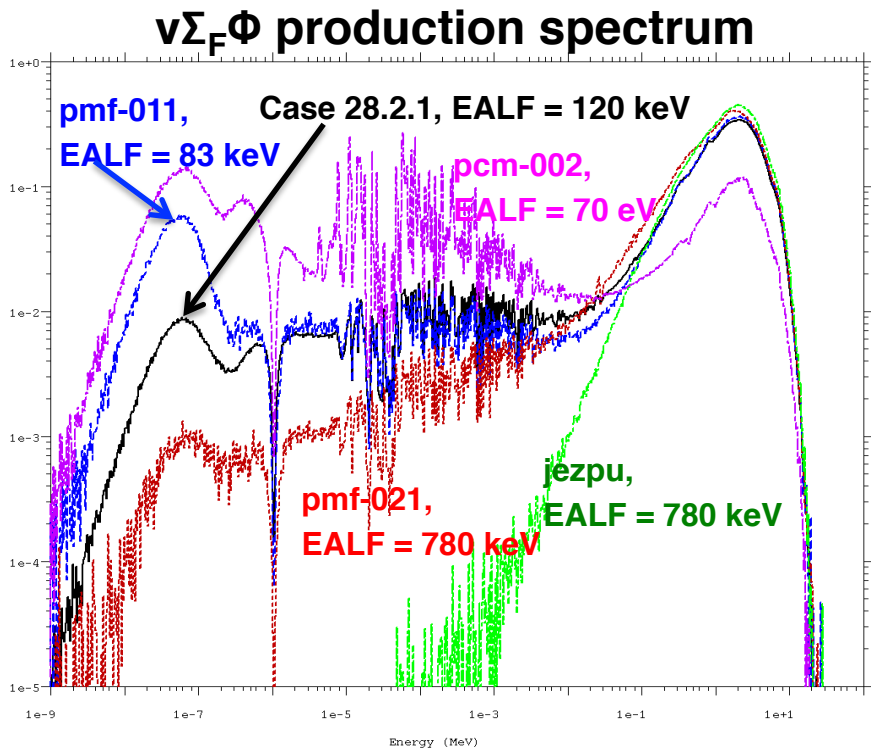
NCSP NUCLEAR CRITICALITY SAFETY PROGRAM

MCNP-WHISPER Methodology for Nuclear Criticality Safety Analysis (1)

- Nuclear Criticality Safety requires validation of computational methods
- Validation involves comparing calculation vs experiment for many benchmarks similar to the application of interest
- Neutron spectra are complex functions of geometry, materials, nuclear cross-sections, etc.
- Simple metrics cannot capture the complexity of a fissile system
- During the past 20 years, a powerful set of tools has been developed based on sensitivity-uncertainty methods



MCNP-WHISPER Methodology for Nuclear Criticality Safety Validation

- **MCNP determines sensitivity profiles to characterize the neutronics of an application or benchmark, S(energy, reaction, isotope), S = (dk/k) / (dσ/σ)**
- **WHISPER uses sensitivity profiles & data covariances to select similar benchmarks, determine bias, bias-uncertainty, & margin-of-subcriticality for setting the Upper-Subcritical-Limit (USL)**

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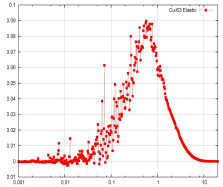
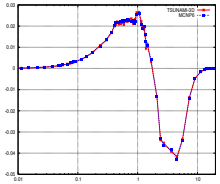
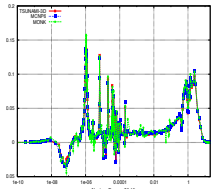
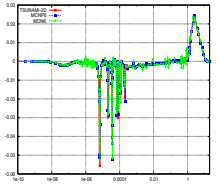
MCNP-WHISPER Methodology for Nuclear Criticality Safety Analysis (2)

- The **sensitivity coefficient** is the ratio of relative change in k-effective to relative change in a system parameter:

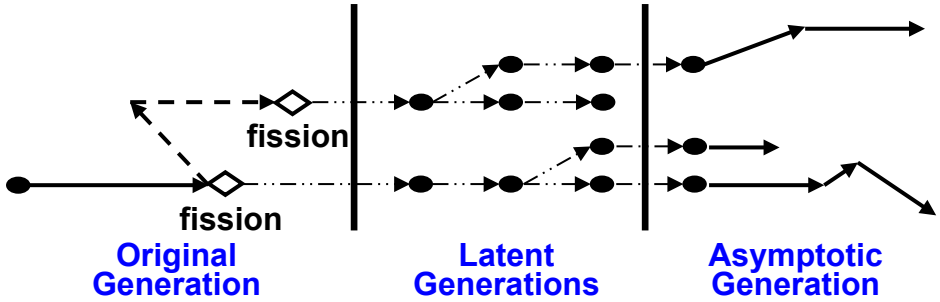
$$S_{k,x} = \frac{dk/k}{dx/x} = -\frac{\left\langle \psi^{\dagger}, \left(\Sigma_x - \mathrm{S}_x - k^{-1}\mathrm{F}_x\right)\psi \right\rangle}{\left\langle \psi^{\dagger}, k^{-1}\mathrm{F}\psi \right\rangle}$$

- $S_{k,x}(E)$ is the **sensitivity profile**, that includes all isotopes, reactions, & energies for a system:

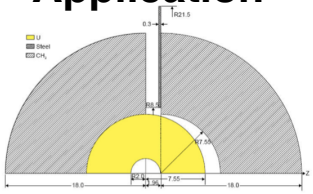
etc.

- **MCNP Monte Carlo** uses the Iterated Fission Probability method to compute adjoint-weighted integrals for the sensitivity profiles
  - Tally scores are collected in original generation, adjoint-weighting is based on the progeny in the asymptotic generation



MCNP-WHISPER Methodology for Nuclear Criticality Safety Analysis (3)

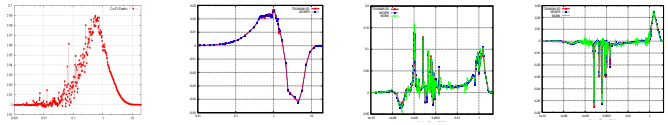
Application



Nuclear Cross-section Data

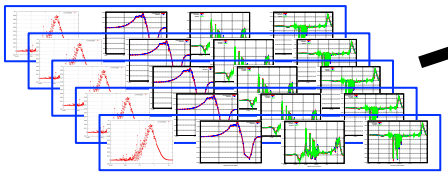
MCNP6

MCNP Monte Carlo Criticality Calculation



Application Sensitivity Profile

Nuclear Cross-section Covariance Data



Catalog of sensitivity profiles for 1100+ experiments

WHISPER analysis

WHISPER

Pattern matching – application sensitivity profile vs catalog

Select similar experiments

Statistical analysis to determine bias & uncertainty & extra margin

USL
Upper Subcritical Limit
for criticality safety analysis

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