Improved Deterministic Modeling for Safeguards Measurements

MTV Kickoff Meeting

May 21, 2019

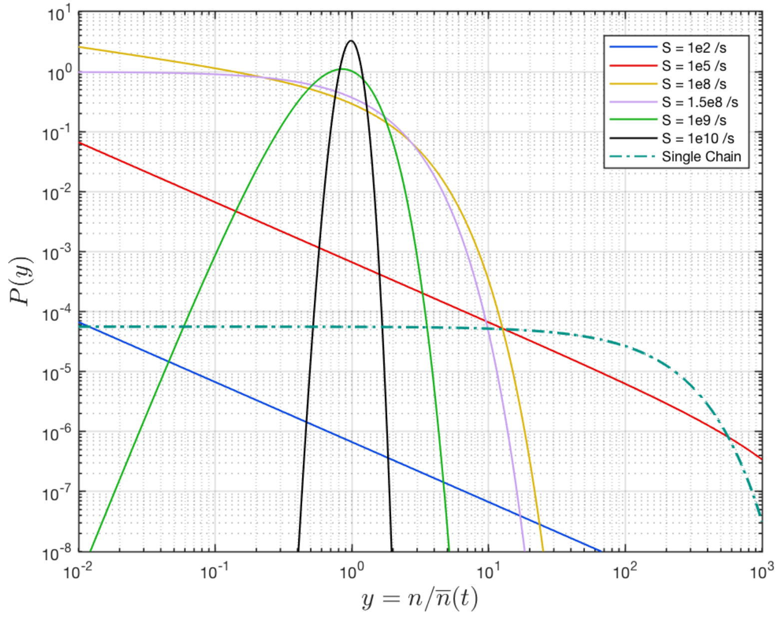
A.K. Prinja
University of New Mexico

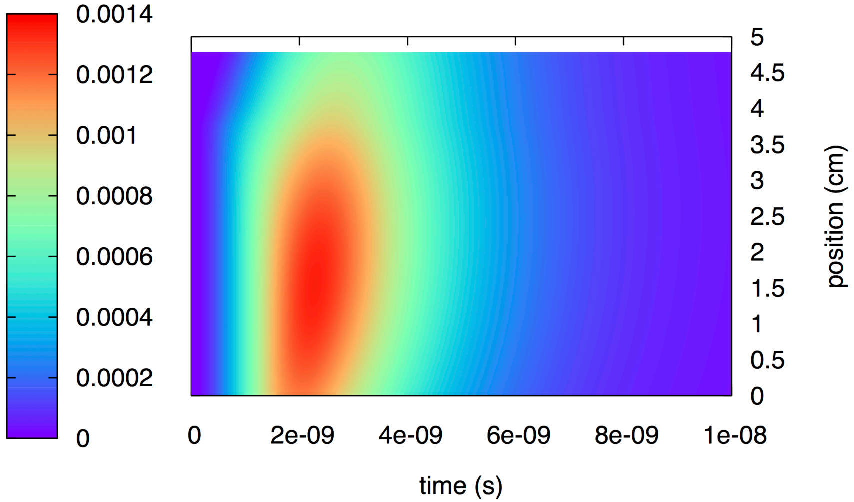
Introduction and Motivation

- Ensure nuclear materials and technology intended for civilian use is not diverted for nuclear weapons development
    - Monitoring and verification by implementing safeguards measures
    - Methods for nuclear materials identification and characterization
- Neutron fingerprinting by neutron multiplicity measurement (singles, doubles, triples)
    - Proven technique to establish unique signatures for tight identification of nuclear fuel composition
    - Enables accountability and control of nuclear material at every stage of the fuel cycle
- Theory, modeling and simulation provides a vital complement to experiments
    - Fundamental distributions (nuclear physics)
    - Lumped or point kinetic models for rapid estimation of gross features
    - Phase-space deterministic methods for more refined solutions (stochastic transport theory)
    - Monte Carlo methods for highly refined solutions and benchmarking (MCNP6, MCNP-PoliMi)

Introduction and Motivation

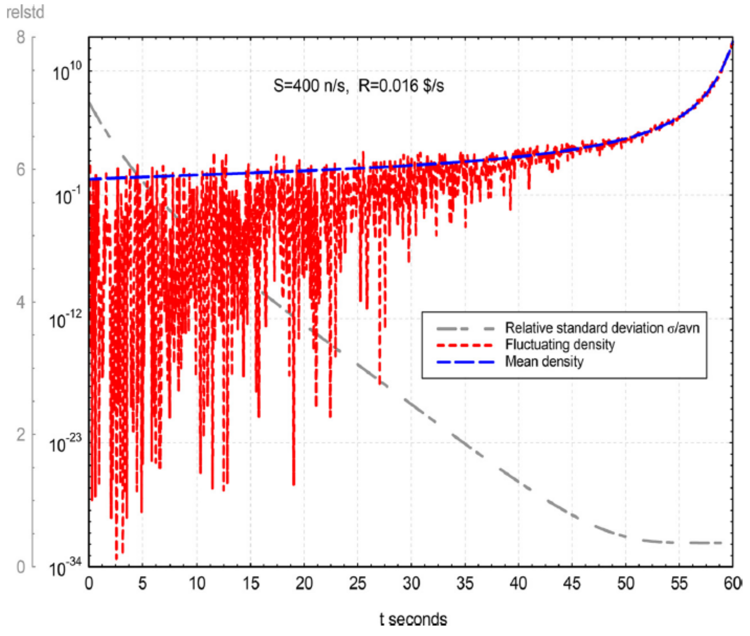
- Develop high fidelity deterministic transport models
- Comprehensive, hierarchical approach based on forward/ backward Master equations
  - ➢ Lumped model; phase-space dependence
  - ➢ Material heterogeneities, neutron slowing down
  - ➢ Region-specific moments (external detectors)
  - ➢ Leakage neutron and gamma multiplicity distribution
  - ➢ Fission neutron energy and angular correlation effects (FREYA, CGMF)
  - ➢ Benchmark against Monte Carlo and subcritical experiments





Introduction and Motivation

- Statistically unconverged signals
  - Real-world scenarios require rapid evaluation of the statistics of the particle field
  - Short detector dwell times $\Rightarrow$ incomplete statistical convergence
  - Low order statistical moments not sufficient
- Stochastic simulator
  - Time histories of random radiation signal, accounting for suboptimal detector dwell times
  - Kinetic Monte Carlo
  - Lumped stochastic differential equation models: Poisson, Gaussian noise



Mission Relevance

- Mitigating proliferation pathways through modeling and simulation advances to support nuclear material detection
- Expanding and making accessible to the community advances in predictive science capabilities in the nuclear security space
- Preparing future experts in nuclear security through: pedagogy, defining and solving innovative research problems, and developing advanced technical skills in theory, modeling and simulation
- Establishing targeted and sustained collaborations with national laboratories, taking advantage of unique educational and research capabilities and facilities at respective institutions

Technical Work Plan

- 5 year plan for the work
  - Years 1-2: Investigate lumped models for leakage neutron, gamma distributions; develop and implement deterministic moments model for spherically symmetric system (LANL Pu-sphere) with external detectors incorporating correlated emission
  - Years 2-3: Implement moments-model in PARTISN, benchmark against Monte Carlo; develop deterministic methodology to obtain number or multiplicity distributions at external detector locations
  - Years 3-4: Implement deterministic multiplicity model in PARTISN, begin benchmarking with Monte Carlo and experiments; formulate stochastic simulator model
  - Years 4-5: Complete benchmarking of deterministic multiplicity model; implement kinetic Monte Carlo to simulate time histories in lumped geometry; construct, solve and benchmark stochastic differential equation approximations; consider phase-space extensions
- National Lab connections:
  - LANL: Matthew Marcath, Avneet Sood, (XCP) − MCNP6, MCNP-PoliMi (Freya, CGMF);
    Jesson Hutchinson (NEN) experiments to validate code results
    Erin Davis (CCS) - PARTISN
  - LLNL: Manoj Prasad - stochastic theory and interpretation

Expected Impact

- Enable computation of neutron and gamma multiplicity distributions using hierarchy of models and novel deterministic formulations
- Provide a deeper understanding of the statistical uncertainties of radiation signals from weak sources
- Train next generation experts in theory, advanced modeling and simulation in nuclear safeguards and nonproliferation

MTV Impact

- Create linkages with MTV partner universities through workshop participation
- Strengthen national lab connections in nuclear security areas through joint research and internship opportunities for undergraduate and graduate students
- Develop new specialized graduate-level course material and potentially MS NE Concentration or Certificate Program in Nuclear Safeguards and Nonproliferation

➢ Consolidating MTV effort at UNM with existing established relevant experiment-based and computational research programs NE Department will facilitate establishment of Center for Nuclear Safety and Security

Conclusion

- Refined stochastic models and efficient computational tools for neutron and gamma multiplicity distributions will result in improved capability for detecting and identifying nuclear materials
- Training of next generation experts in nuclear security R&D area will contribute to manpower pipeline
- Collaborations with national laboratory staff will lead to specialized offerings in nuclear engineering academic programs to support the national nuclear security enterprise and recruit undergraduate and graduate students

Acknowledgements

The Consortium for Monitoring, Technology, and Verification would like to thank the NNSA and DOE for the continued support of these research activities.

This work was funded by the Consortium for Monitoring, Technology, and Verification under Department of Energy National Nuclear Security Administration award number DE-FOA-0001875

National Nuclear Security Administration

Your Logo