

01249

LA-UR-11-XXXX

Approved for public release;
distribution is unlimited.

Title: Current Capabilities for Generating List-Mode Data for
Simulated Subcritical Neutron Measurements Using MCNP

Author(s): Avneet Sood, XCP-7
Jesson D. Hutchinson, N-2
William L. Myers, N-2
Clell J. Solomon, XCP-7

Intended for: NCSP Review



Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

Current Capabilities for Generating List-Mode Data for Simulated Subcritical Neutron Measurements Using MCNP

Avneet Sood, J. Hutchinson, W. Myers,
C.J. Solomon

Los Alamos National Laboratory

Los Alamos, NM 87545



EST. 1943
Operated by Los Alamos National Security, LLC for NNSA

UNCLASSIFIED



Abstract

- This presentation briefly describes the following topics:
 - Review of sub-critical multiplication and measurements,
 - Current MCNP simulation capabilities,
 - MCNP modeling needs for comparisons with sub-critical multiplication measurements
 - Summary of FY10 work, Progress on FY11 work



EST. 1943
Operated by Los Alamos National Security, LLC for NNSA

UNCLASSIFIED

Slide 2



Relevant Physics for Sub-Critical Multiplication

- (Source) Passive neutrons from fissionable material emitted from:
 - Spontaneous fission neutron sources:
 - Correlated in time and location of fission
 - Examples: Cf-252, Pu-240
 - (α, n) reactions:
 - Produced when α particle is absorbed and neutron is emitted
 - Not correlated in time and location
 - Examples: Am-Be
- (Induced) Neutron multiplication dominated by two physical processes:
 - ($n, 2n$)
 - Occurs mostly above 7 MeV
 - Does not contribute significantly to most scenarios
 - Neutron-induced Fission

Simulations need to be "microscopically" correct for comparisons with measured data.

Sub-critical Measurements

- Neutron multiplication measurements (passive and active) designed to separate the correlated emission events, e.g., SF, from the uncorrelated events, e.g., (α, n),
 - Record time of neutron capture in a neutron detector over a large collection time (e.g. 300 sec)
 - Group these capture times in a large number (e.g. 1 M) smaller time sub-intervals (e.g. 250 μ sec)
 - These time sub-intervals are larger than typical neutron detection and lifetimes ($\sim 50 \mu$ sec)
 - Multiplicity histogram is constructed
 - Obeys Poisson statistics if system is non-multiplying (i.e. neutrons are emitted randomly in time)
 - Data analysis begins...Feynman Variance-to-Mean, CSDNA, etc

Data recorded is neutron detector location and time: list-mode data

Simulations need to produce list-mode data for comparisons

MCNP Simulations of Sub-Critical Measurement

- **MCNP – well suited for comparing results of sub-critical measurements**
 - Calculates relevant quantities for fixed-source, eigenvalue problems
 - How faithfully is MCNP simulating fission process and what we measure?
 - Correct for averaged values but not microscopically correct
- **MCNP simulation of neutron sources and detection**
 - User can define location, direction, energy, time, and intensity of SF, (α, n) neutron sources
 - User cannot define fission events
 - e.g. sample number of neutrons emitted from v_{bar}
 - User cannot define correlated (time, location) neutron sources
 - MCNP samples these values from user's input
 - User cannot (easily) record location and time of detection.
 - Possible using MCNP's PTRAC capability and a user-created external script to extract this information

Standard MCNP is not microscopically correct enough to compare with current sub-critical measurements:



Operated by Los Alamos National Security, LLC for NNSA

UNCLASSIFIED

Slide 5



FY10 Proposal to NCSP

- **Upgrade an existing (unreleased) capability for MCNP**
 - Use of Terrell (Lestone - new) data to statistically sample the actual number of neutrons ν released when **induced fissions** occurred in a calculation.
 - MCNP can do this for induced fissions, but not starting sources
 - Add capability to have a fixed source problem that started fission events (correlated) rather than individual neutron histories (independent samples).
 - Add capability to allow for a non-fissioning interrogating source (eg. AmBe), and
 - Add capability to write a special output file that contained the location and time at which each neutron was captured (list-mode data)
 - Resulting list-mode data can be evaluated by any analysis technique
 - **Capability has existed separately for over 25 years (internally V&V'd)**
 - **Difficult to maintain separately**
 - Make use of MCNP's user-defined subroutines SOURCE/TALLYX
 - Compare to existing benchmarks
- **FY10 proposal leveraged on-going experiments and equipment improvements to record list-mode data (e.g. PATRM/PMC)**



Operated by Los Alamos National Security, LLC for NNSA

UNCLASSIFIED

Slide 6



Deliverables for FY10

- **(1) Update the list-mode/fission source capability to current MCNP.**
 - Implement this capability as a routine that can be applied to any future version of MCNP through the SOURCEX and TALLYX routines provided with MCNP.
 - Produce MCNP5.1.51 executable (sequential, OpenMPI) with standard features plus correlated sources and list-mode capability.
- **(2) Compare and document simulated results with previous experimental results performed.**
- **(3) Compare and document simulated results with experiments to be performed at LANL or other ICSBEP experiments**
 - (a,n) sources with poly, SS shells, etc
 - SUB-PU-MET-FAST-001,002,and 003
- **(4) Begin R&D for application of variance reduction techniques to accelerate convergence of problems (current simulations are performed in analog mode)**
- **(5) Compare and document our simulation results using currently available codes MCNP-DSP and MCNP-Polimi (code-to-code verification)**
 - UNLV sub-task



UNCLASSIFIED

Slide 7



FY10 Q4 Results

- **Internally-developed multiplication patch to MCNP has been updated to current version of MCNP**
 - Coding existed in internal (much older) version of MCNP
 - Initial testing indicates code is working as expected. Comparison with experiments begun.
 - Still working on developing an independent SOURCE and TALLYX subroutine
- **Validation experiments performed at NTS/DAF**
 - Diagnostics included 2 NPODS, SNAP, 140% HPGe.
 - List-mode data taken, MCNP models developed/improved
 - **May 2010:** BeRP ball (bare), BeRP ball moderated with increasingly thick shells, BeRP ball moderated with fixed outer dimension and variable thickness
 - BeRP ball supported with hemi-shell – no longer a 1-D problem!
 - Two different moderators
 - **July 2010:** BeRP with different moderator, Active interrogation with D-T source
 - **September 2010:** Rocky Flat Shells (HEU) with Cf-252 source and multiple poly configurations



UNCLASSIFIED

Slide 8



FY11 Q1 - progress

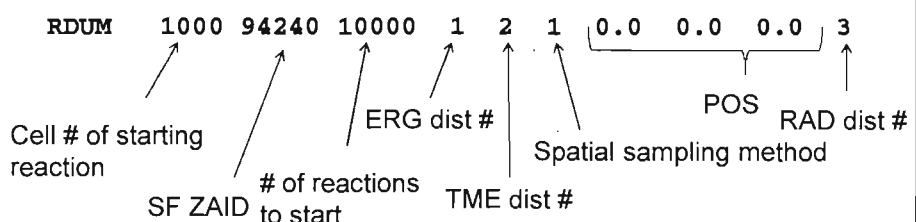
- **SOURCE/TALLYX subroutines written**
 - Subroutines intended for user-defined source and tally
 - Independent of MCNP – no modification of MCNP is required
 - Works with MCNP5.1.60 (current release)
- **SOURCE—modifies definition of starting particle to be a starting reaction, e.g., spontaneous fission, samples starting particles from that reaction**
- **TALLYX—modifies a type 4 tally to produce a file of absorption times in tally cell, a.k.a. list-mode data**
- **Tally output can be processed to analyze inferred multiplication**

We plan to submit SOURCE/TALLYX routines to MCNP code development team for adaptation into MCNP6 with documentation, validation benchmarks, etc

SOURCE Input Uses RDUM Card

- Input for the source is specified on the RDUM card

EXAMPLE:



- Multiple cells and SF ZAID combinations may be specified—sampled based on the # of starting reactions

Tally Modification Requires FU Card

- The FU card modifies the tally to score captures

- Requires analog simulation

- Sample induced fission multiplicity

phys:n 4j 1 or phys:n 4j 2

- Turn off default implicit capture

cut:n 2j 0

- EXAMPLE:

F4:n 1001 \$ Tally on cell 4

FU4 2003 \$ Score captures by ZAID 2003 (He-3)

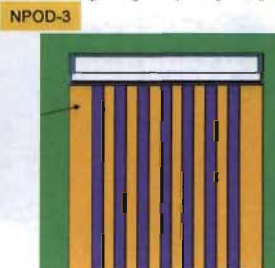
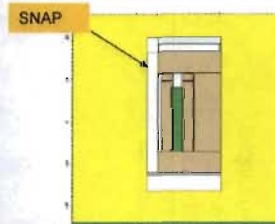
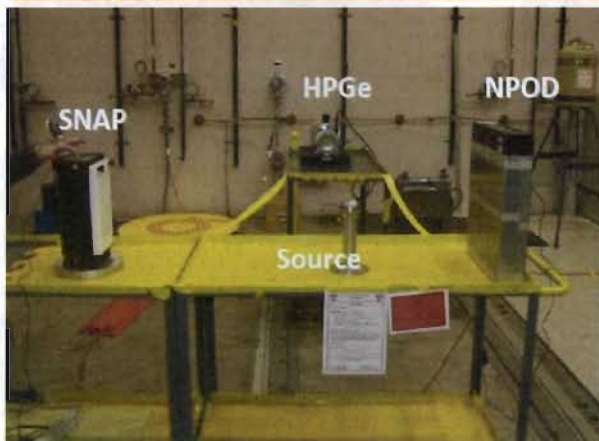
Example Tally List-Mode Output

3050	2902347683.93636
3049	25617701923.43888
3052	28074609346.68214
3050	20857333210.41721
3052	16140211088.86106
3053	24770874466.83554
3047	24759462750.29287
3049	15567786730.17038
3052	21217419855.78508
3052	21217402172.59257
3061	21217406407.25473
3048	21217404433.38023
3049	5437041302.96633

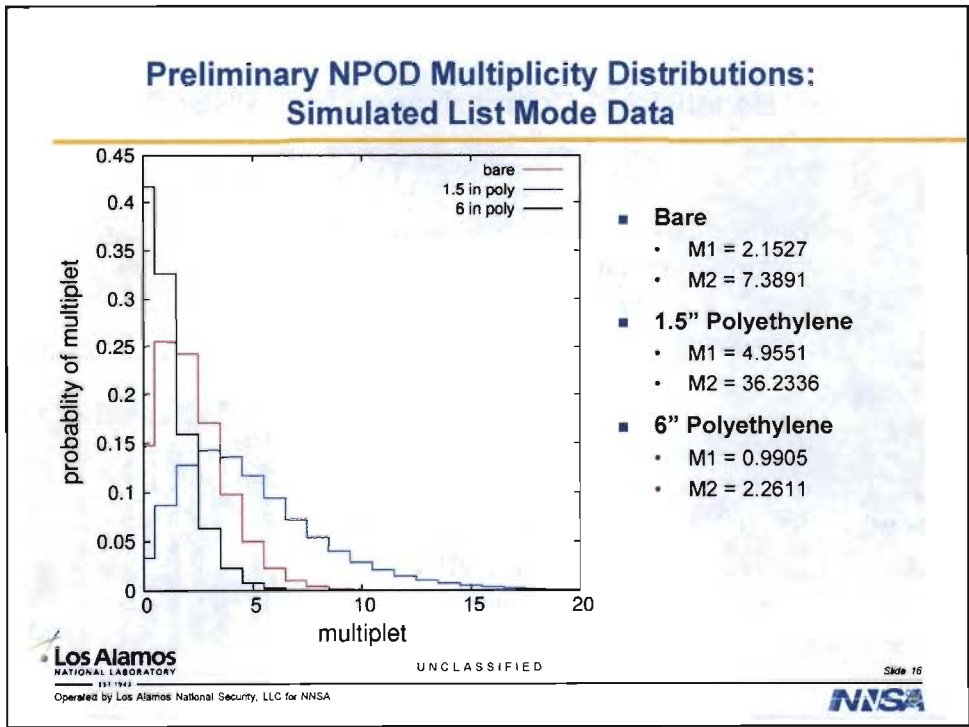
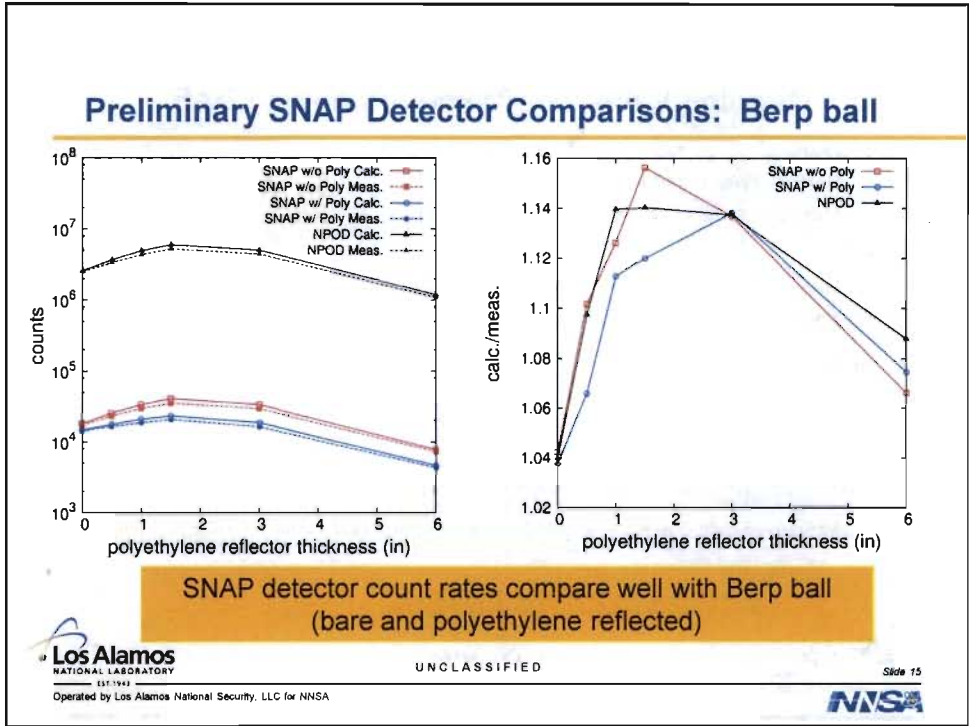
Ongoing Validation Measurements at DAF

- **WGPu**
 - Berp ball with different moderators
 - Measurements are done, simulations are in progress
- **HEU**
 - Rocky Flats shells with different moderators and interrogating sources (SF, (a,n))
 - Measurements are done, simulations are in progress
- **SF and (a,n) Sources:**
 - Multiple moderators
- **Active Sources**
 - D-T generator source
 - WGPu, HEU
 - Measurements are done, simulations are in progress

1st "Benchmark" Comparison: SNL - SINBAD



-J. Mattingly, "Polyethylene-Reflected Pu metal Sphere," SAND2009-5804



Status and Future of NCSP Work

■ FY11 proposed work:

- Continue comparison of MCNP simulations' list-mode output to relevant sub-critical benchmark experiments for code validation
- Simultaneously we wish to perform neutron leakage and neutron spectra measurements for additional points of comparison for our MCNP list-mode simulations.
 - Comparison of non-integral results for same neutron sources/scattering environments will give further confidence in the MCNP simulation results
 - Additional measurements will allow us to characterize room return as well as determine neutron detector efficiency.



EST. 1943
Operated by Los Alamos National Security, LLC for NNSA

UNCLASSIFIED

Slide 17

