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MCNP6 Shielding Validation Suite: Past, Present, and Future

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Abstract

MCNP6 is a general radiation transport software package used for a variety of applications including criticality and radiation detection and shielding, which are important for the design of criticality accident alarm systems. As part of MCNP6's software quality assurance, the development team produces validation suites for specific application. The MCNP6 shielding validation suite dates back to the 1990's, and updated with more detailed geometry and more resolution in the tally results, and now is included as part of the automated testing. Additions to the suite are currently being proposed.

Roadmap

- Review of validation in MCNP
- The old MCNP Shielding Suite
- Upgrades within the last couple years
- Future expansion plans

Validation of MCNP

- **Validation:**

  Does a particular simulation software and its associated data produce results that are sufficiently predictive of reality?

- **MCNP Development Team**
  - Attempts to provide a broad range of applications to assess overall software performance
- **End Users**
  - Must assess whether the software meets their needs

Validation of MCNP

- **Validation suites included with MCNP6**
  - **Criticality (k-effective and Rossi-alpha)**
  - **Shielding**
  - **High Energy Physics**

- **MCNP validation suites have received steady improvement**

- **The shielding suite has (largely) been neglected in the last several years until now**

Shielding Suite Overview

- **Prepared in the 1990s**
- **Focuses several neutron and photon transport through materials of interest for shielding applications**
  - Concrete, lead, water, etc.
- **Neutron/photon energies typically several MeV (fusion sources common)**
- **Previously was not automated and did not compare to experimental data – simply regression tests!**

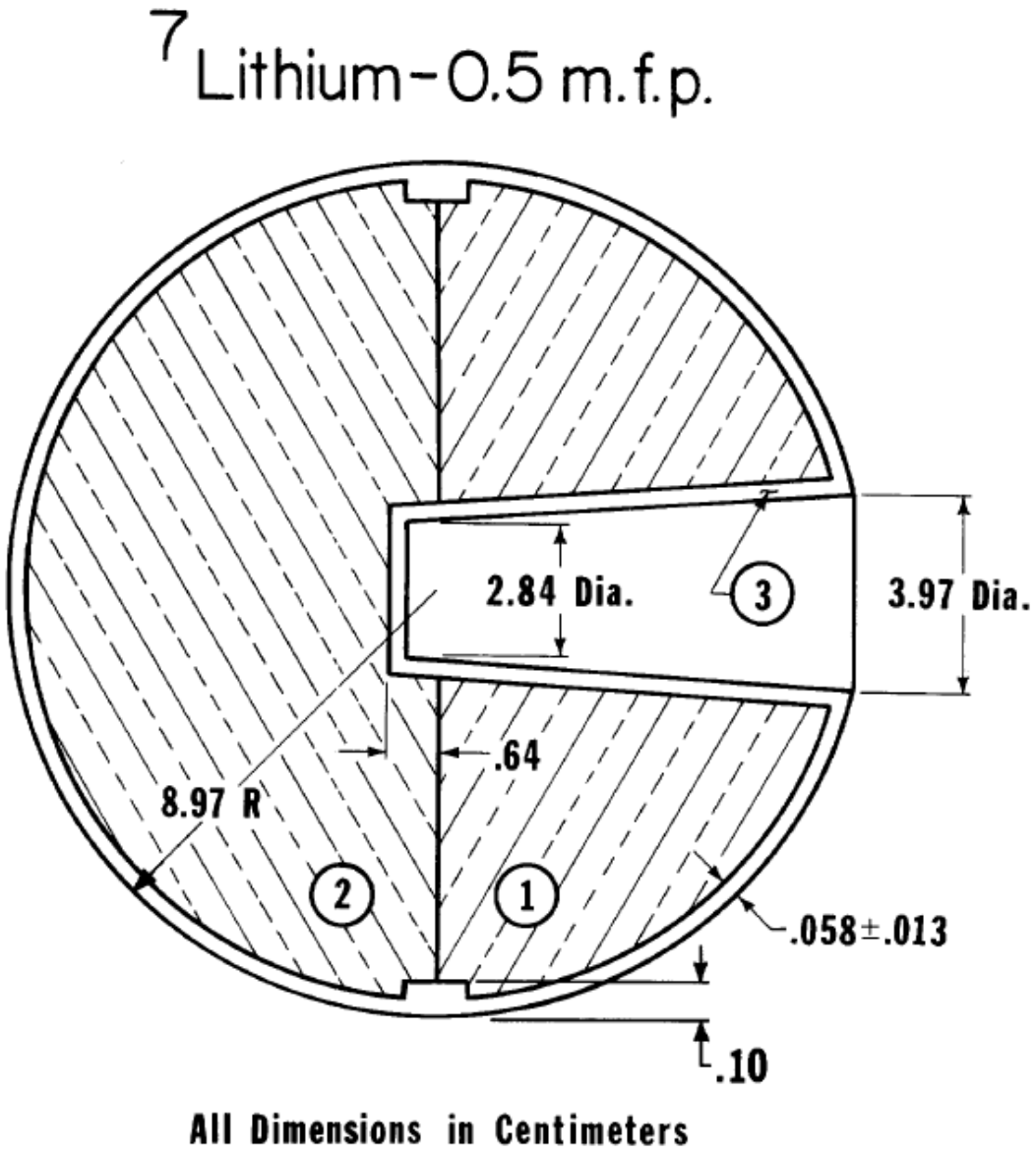
The Legacy Suite

Type	Material/Description
Pulsed Sphere	Lithium-6 Beryllium Carbon Nitrogen Iron Lead Water Concrete
Fusion Shielding	Config. 1, Neutron, On-Axis Config. 3, Neutron, Off-Axis Config. 3, Photon, On-Axis Config. 7, Neutron, On-Axis Config. 7, Photon, Off-Axis
Photon Dose	Co-60 Skyshine Co-60 Air Over Ground Co-60 Through Air Co-60 Through Teflon Sm K_α Through Air Sm K_α Through Teflon

LLNL Pulsed Spheres

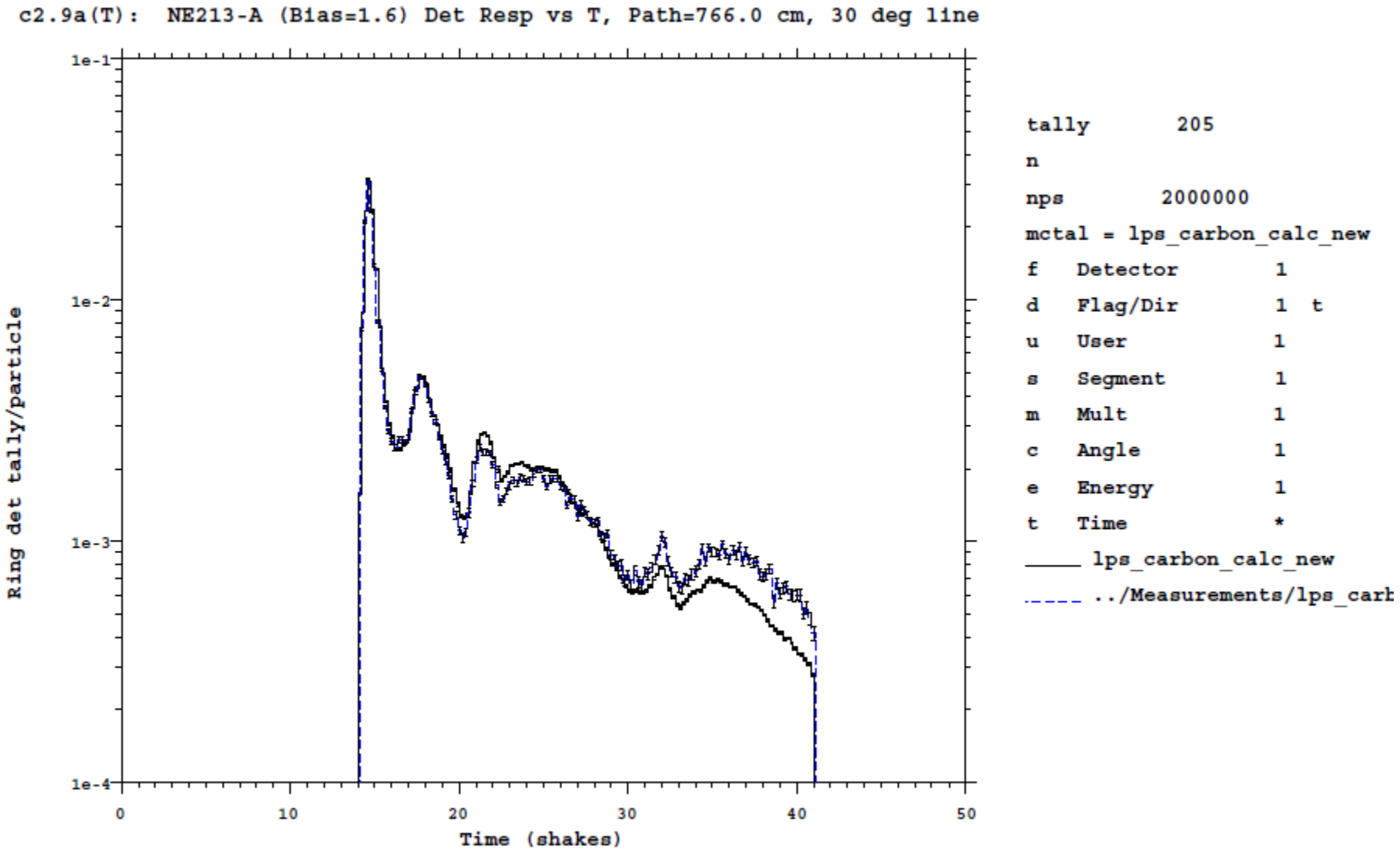
- **LLNL Pulsed Sphere models were very simple**
- **Improvements made**
  - **Detailed models by Stephanie Frankle incorporated**
  - **More materials added (U-235, U-238, Pu-239)**
  - **Details of time spectra matches experimental measurements for higher fidelity comparisons**
- **More configurations and materials available**

LLNL Pulsed Spheres



Carbon Sphere Result (ENDF/B-VII.0)

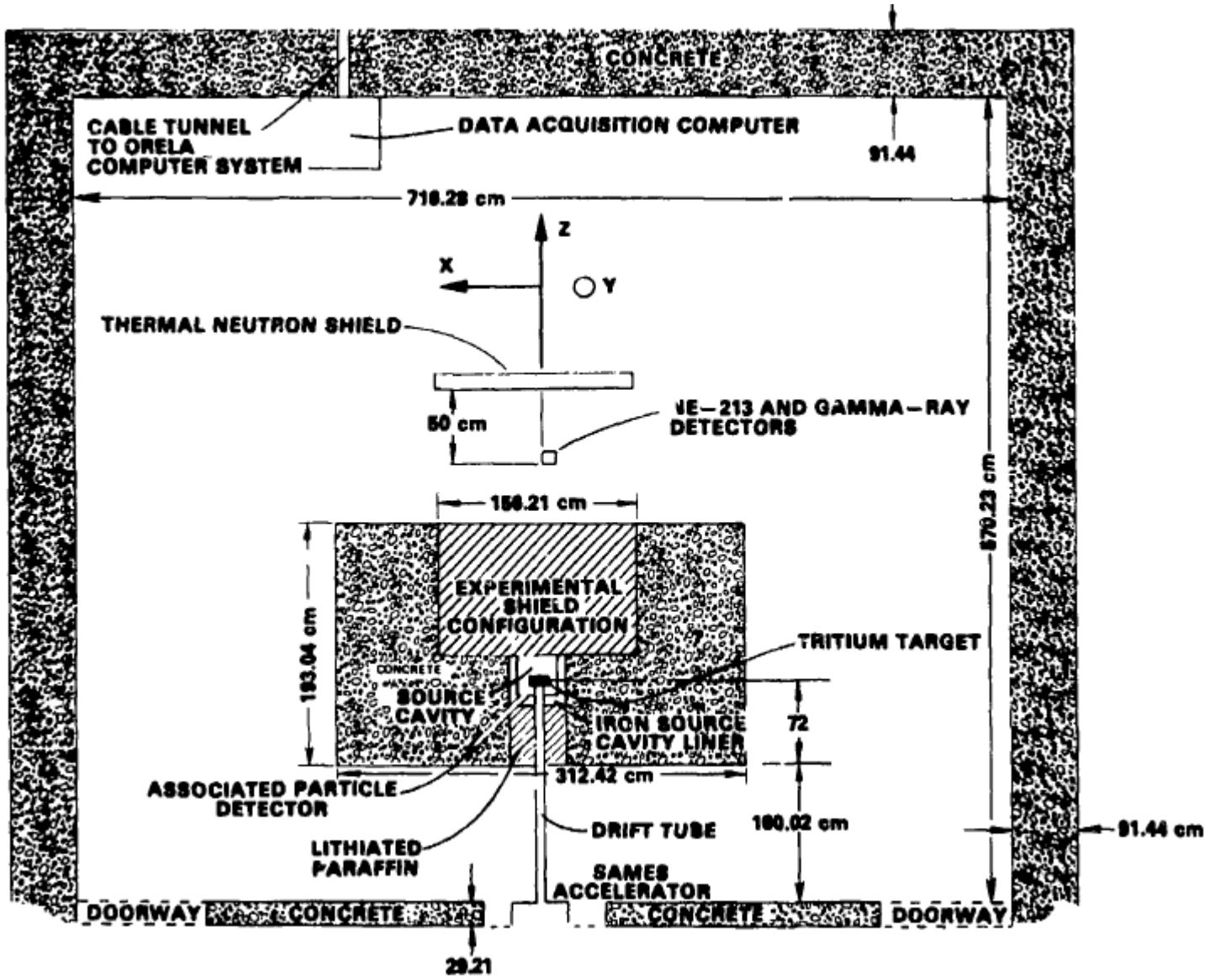
X-Computational
Physics Div.
XCP-3, LANL



Fusion Shielding

- Experiment where deuterons are aimed at a tritiated target.
- Measurements of neutron and gamma doses for various shield configurations and detector positions.
- Assesses neutron/photon transport, as well as gamma production cross sections.

Fusion Shielding



Fusion Shielding Result (ENDF/B-VII.0)

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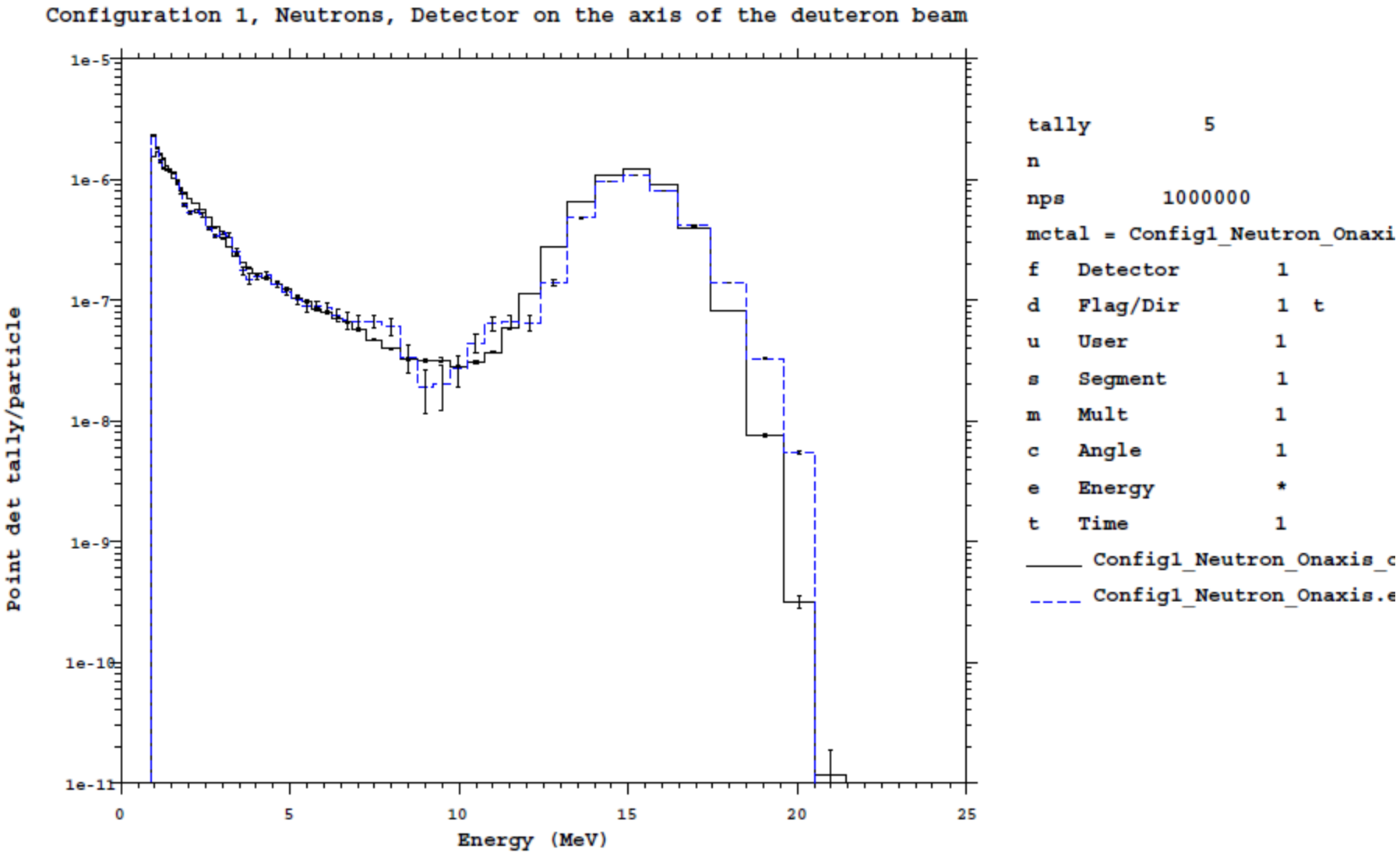

Photon Dose

- **Two experiments left (others have no experimental data still available!)**

- **Skyshine**
  - Assesses predictive capability of angular scattering off air from a Co-60 source in an open field.
  - Detectors placed at various distances away from the source.

- **Co-60 air over ground**
  - “Infinite” disk source of Co-60 on ground
  - Kerma in air measured ~1 meter above ground as function of angle

Skyshine Results (ENDF/B-VII.0)

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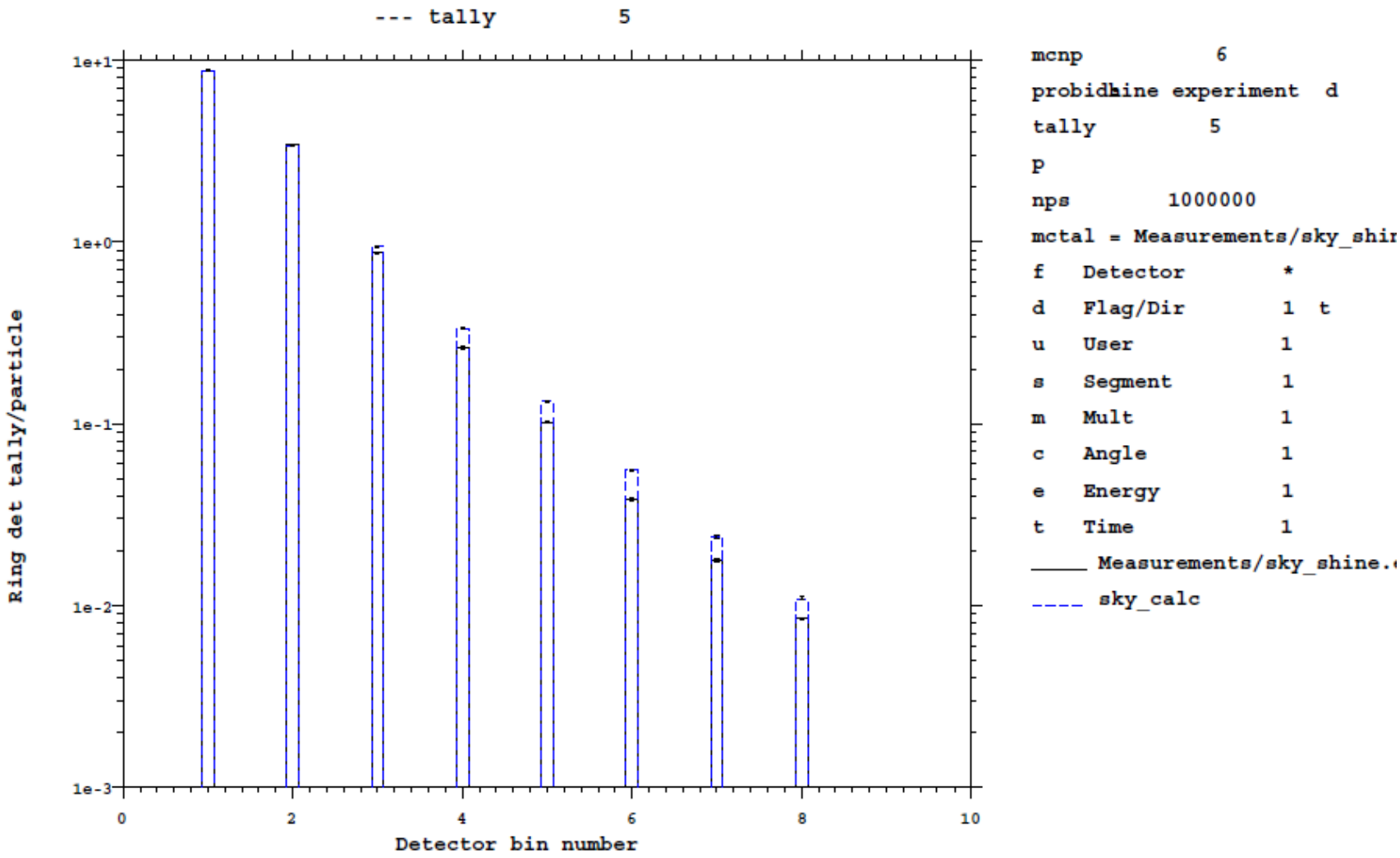

Co-60 Air/Ground Results (ENDF/B-VII.0)

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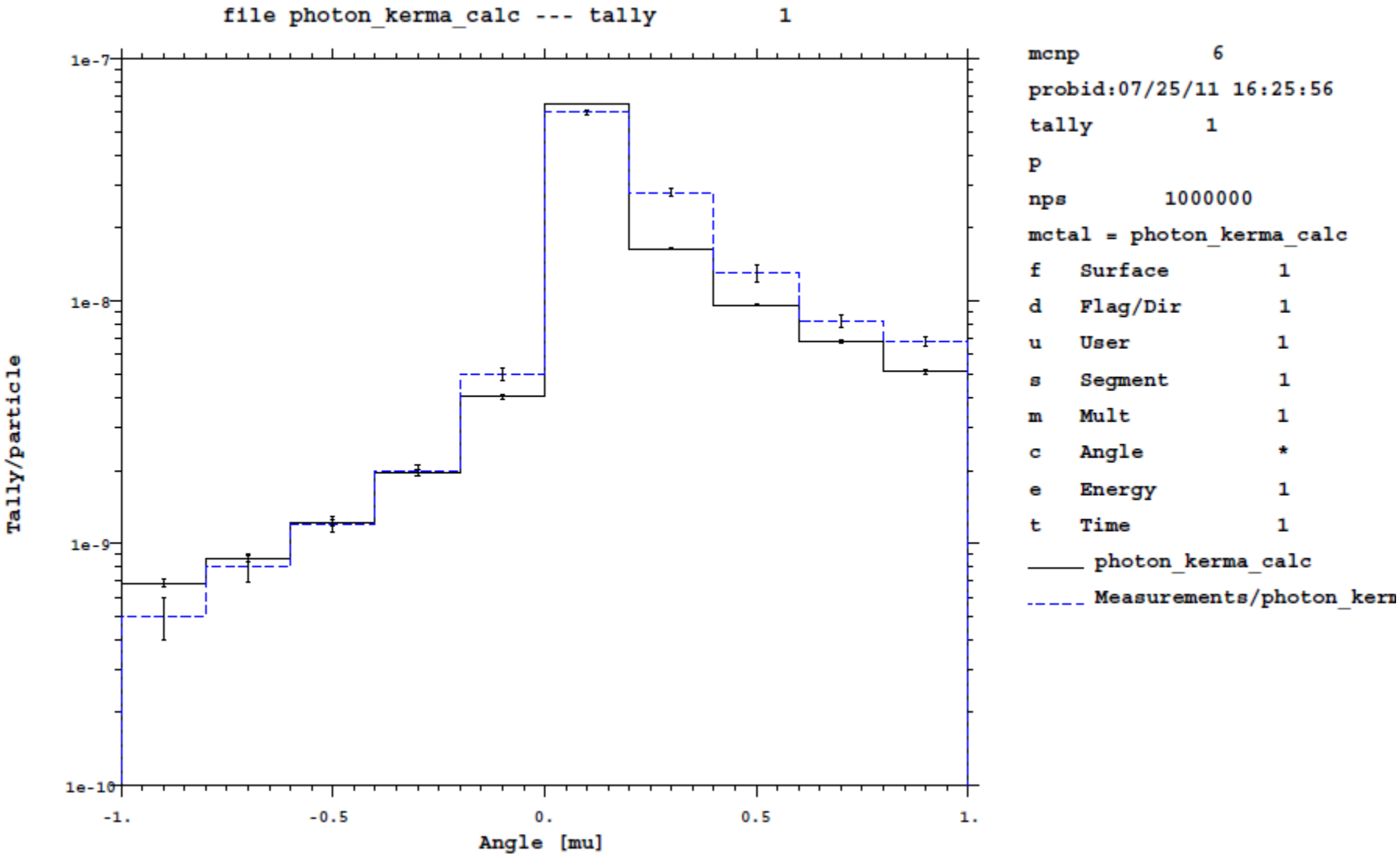
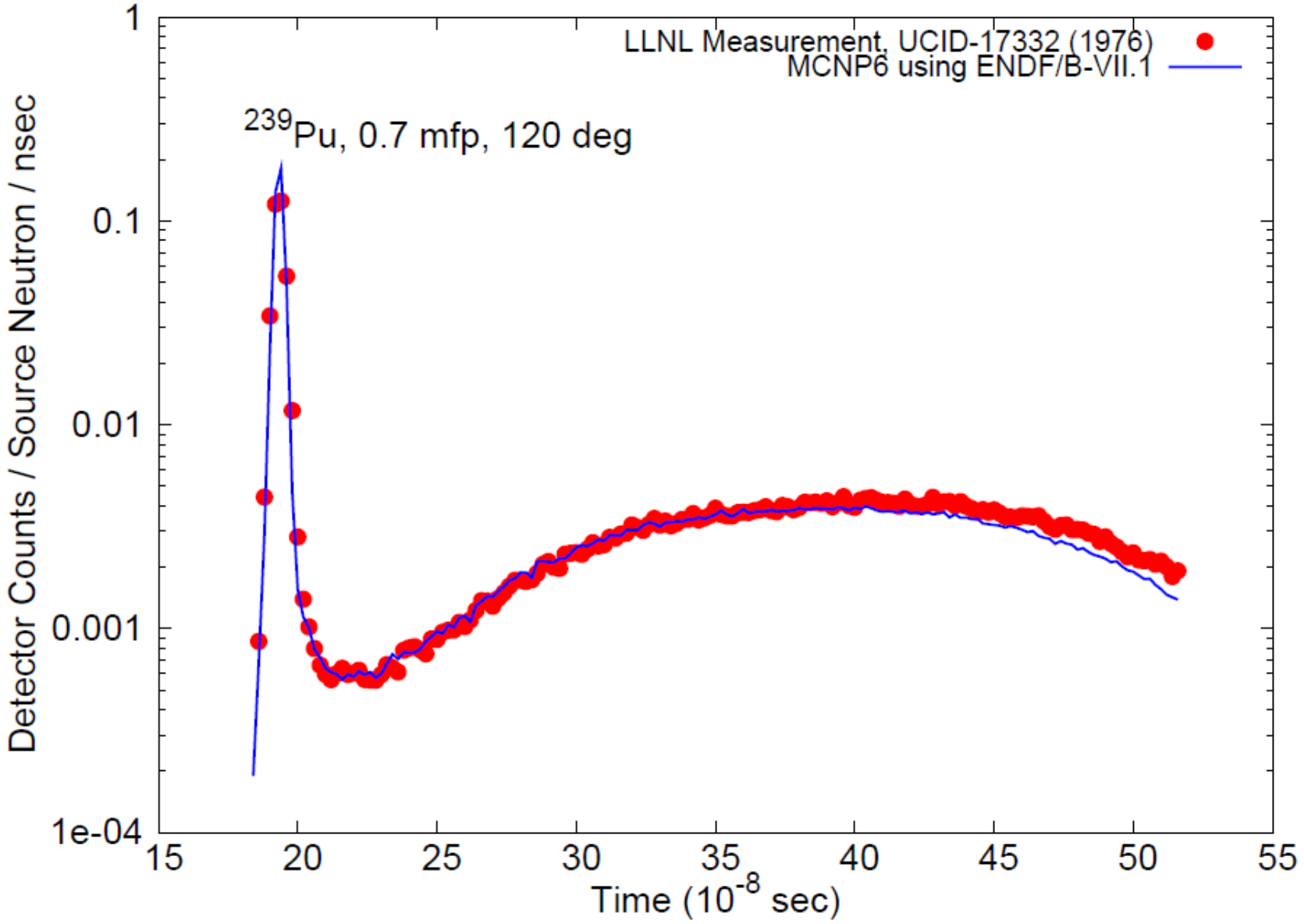


Automation

- **Work by summer students to collect and normalize MCNP tallies to experimental data**
  - **We want to do validation, not just regression!**
- **Batch submission scripts allow the suite to be run easily, and results are collected**
- **Results are available on the XCP-division LAN, in both tabular and gnuplot generated images for visual comparison**
  - **This is how we assess quality of MCNP6 in shielding**

Example Plot



Metrics for Assessment

- **Both the software and the data undergo steady improvements.**
- **Visualization of results useful for understanding spectra**
- **Often times, an overall "score" is useful to assess relative improvements of nuclear data**
  - Average relative error (with respect to experiment)
  - 90th percentile of relative errors

LLNL Pulsed Sphere ENDF/B-VII.0 Results

Material	Average	90-Percentile
Li-6	0.183	0.356
Be	0.114	0.224
C	0.150	0.247
N (liquid)	0.134	0.246
Fe	0.155	0.280
Pb	0.122	0.221
Water	0.292	0.610
Concrete	0.129	0.235

Future Additions

- **ICSBEP Handbook, Vol VIII has applicable benchmarks**
  - Shielding type with a Cf-252 source (assess fission neutron portions of cross sections)
  - Two “labyrinth” problems for concrete duct-streaming
- **One-, Two-, and Three-Legged Duct Problems by Maerker and Muckenthaler**
  - Test neutron albedo off concrete
- **Recent CALIBAN and Silene exercises by NCSP**

Summary

- Software tools must be validated to the applications of interests for their predictions to be credible

- The MCNP Shielding Suite has undergone various improvements in the quality of inputs and representative outputs, and is automated

- Future work is to expand the zone of applicability for the shielding validation suite to incorporate the needs to the criticality accident alarm design community

Questions?