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Comparison of MAVRIC/Monaco and TRIPOLI-4® Simulations of the LLNL Pulsed Spheres Benchmark Experiments

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Introduction

Oak Ridge National Laboratory and the Commissariat à l'Énergie Atomique et aux Énergies Alternatives – Centre de Saclay performed simulations of the Lawrence Livermore Pulses Spheres (LPS) benchmark experiments[1] to add these results to the suite of validation problems of MAVRIC/Monaco[2] and TRIPOLI-4®[3,4]. By the middle of 1971, the LPS experiments measured the neutron emission spectra for 17 isotopic, elemental, and compound spherical targets via time-of-flight techniques. These spherical targets varied in thickness from 0.5 to 5 mean free paths for 14-MeV neutrons. The source in each measurement was 14-MeV neutrons born from deuterium-tritium fusion reactions at the center of each sphere. These neutrons were born at times that resulted in a Gaussian distribution with a mean and full-width-at-half-maximum of 0 and 4 ns, respectively. The time-of-flight measurements were made along two different flight paths, 30° (Pilot B plastic or NE213 liquid scintillator) and 120° (NE213). These angles were measured with respect to the direction of travel of the deuterons.

Description of Work

The benchmark measurement data provided by Wong[1] are the time-dependent neutron count rates at the different detector locations. MAVRIC/Monaco and TRIPOLI-4® simulation results are compared to the measured data for some of the LPSs. Additionally, a comparison of calculated neutron energy spectra is presented at a few different times after neutrons begin to arrive at the detectors. The comparison of neutron spectra simplifies the interpretation of discrepancies between the codes. Finally, the calculated gamma flux on the surface of each LPS are compared. The calculated gamma flux is the integral over the entire neutron measurement time. Both Monte Carlo codes use cross sections based on ENDF/B-VII.1 for these simulations. However, TRIPOLI-4® results with cross sections based on JEFF-3.1.1 are also presented.

Results

Figure 1 provides a sample of the results presented in the full paper. This figure compares the measured and calculated neutron count rate in the 30° detector for the beryllium sphere that is 0.8 mean free paths thick. The measured data are bracketed by the two blue curves. The TRIPOLI-4® results agree with the measurement very well at all times. The MAVRIC/Monaco results are very good after 270 ns. MAVRIC/Monaco slightly overpredicts the data between 170 ns and 270 ns and does not reproduce the 145 ns peak. This discrepancy in the peak is due to Monaco not having a time-dependent source, i.e., all source neutrons are born at time 0 seconds. The calculated data in Figure 1 has 2-sigma error bars.

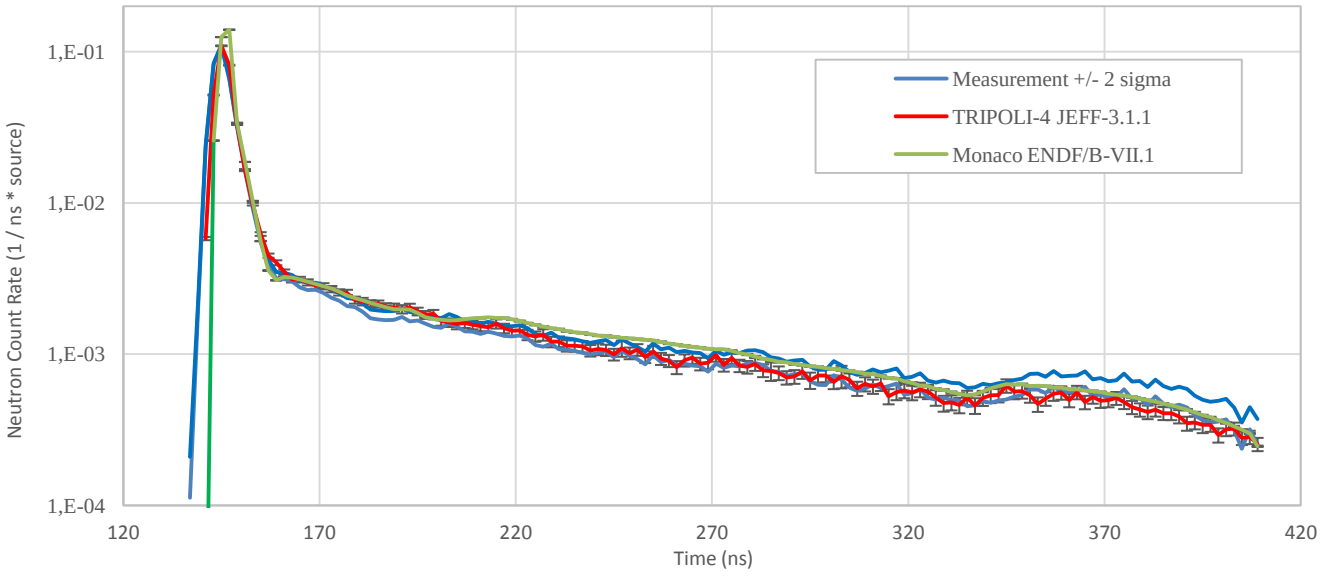

Figure 1. Livermore pulsed sphere: 0.8 mean free paths Be at 30 degrees.

References

1. C. WONG, et al., "Livermore Pulses Sphere Program: Program Summary through July 1971," UCRL-51144, Rev. 1. Lawrence Livermore Laboratory (1972).

2. SCALE Development Team, "SCALE: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design," ORNL/TM-2005/39, Version 6.2.2, Oak Ridge National Laboratory (2017).

3. TRIPOLI-4® Project Team, "TRIPOLI-4® CEA, EDF and AREVA reference Monte Carlo code," *Ann. Nucl. Energy*, **82** (2015) 151–160.

4. TRIPOLI-4® is a registered trademark of CEA.