

Task 6

Neutron Multiplicity Measurements of Target/Blanket Materials

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BACKGROUND

To optimize the performance of accelerator-driven sub-critical (ADS) transmutation systems, engineers will need to design the system to operate with a neutron multiplication factor just less than that of a critical, or self-sustaining, system. This design criterion requires particle transport codes that instill the highest level of confidence with minimal uncertainty, because larger uncertainties in the codes require larger safety margins in the design and result in a lower efficiency of the ADS transmuter. For current design efforts in the U.S., a Monte Carlo particle transport code MCNPX is used to model neutron production and transport for spallation neutron systems.

While providing a very useful research and modeling tool, uncertainties in MCNPX and associated data libraries, particularly at higher energies, require engineers to increase the safety margin in the designs of the ADS transmuter. Much of the uncertainty associated with MCNPX is thought to be due to the escape of multiple high-energy particles from the target (multiple scattering), along with uncertainties in the predictions of source term volume measurements. Determining a reliable method that measures, validates, and benchmarks the calculations of such a volumetric source term is necessary.

The primary goal of this research is to develop a detector system for the measurement of neutron production in spallation targets, to test the system in a variety of calibrated beam lines, and to produce precise, position-sensitive measurements of the volumetric neutron source term to provide data for validation of ADS design codes.

RESEARCH OBJECTIVES AND METHODS

A prototype modular neutron detector system with $64\ ^3\text{He}$ gas counting tubes was developed in conjunction with collaborators at the V.G. Khlopin Radium Institute (KRI) in St. Petersburg, Russia to measure the neutron multiplicity of scaled lead accelerator targets. The system, which has been named the Neutron Multiplicity Detector System (NMDS) was fabricated by KRI and shipped to UNLV. Its modularity allows it to be configured for a variety of experiments to measure neutron multiplicity from different sources: protons, electrons, high-energy neutrons, or even cosmic particles such as muons.

The NMDS is constructed from lead bricks that may be arranged in a $30\ \text{x}\ 30\ \text{x}\ 30\ \text{cm}$ cubic configuration for cosmic ray measurements or as an elongated accelerator target, either $15\ \text{x}\ 15\ \text{x}\ 120\ \text{cm}$ or $20\ \text{x}\ 20\ \text{x}\ 60\ \text{cm}$ (smaller arrangements are also possible). This system may be used to measure neutron production in a variety of configurations, on a variety of targets, with a variety of source particles, and over a range of energies (10 to 800 MeV) to produce a large data base that may be used to validate neutron multiplicity predictions.



View of detector system aligned with accelerator vacuum tube and window. The beam height had not been adjusted in this photograph. The AmBe source can be seen in the opening in the polyethylene bricks of the NMDS.

Time-dependent measurements of neutron production in the NMDS were intended to provide a systematic set of precise data that will enable direct comparison with code calculations, such as MCNPX and its accompanying data libraries. Comparison of results from the NMDS with calculations may decrease uncertainties. In addition, discrepancies that were discovered with this system could contribute to the improvement of the codes and data libraries. Improved models of beam line experiments, accelerator targets, and detector designs should result from these code improvements.

RESEARCH ACCOMPLISHMENTS

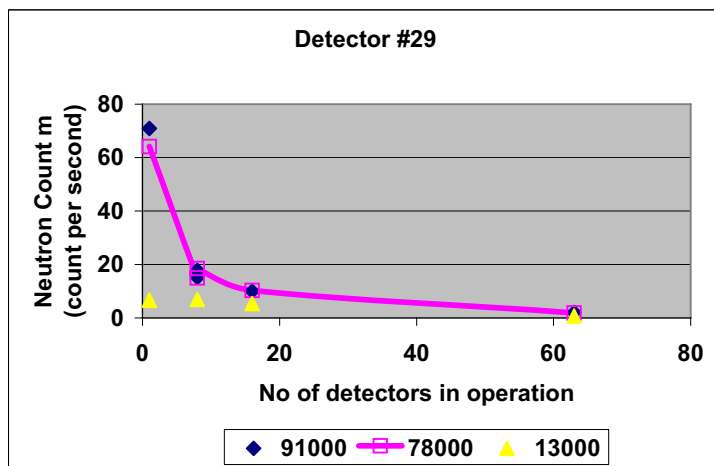
To evaluate its usefulness for measurement of spallation neutrons, the NMDS was transported to the Idaho Accelerator Center at Idaho State University where it was used in conjunction with an accelerator to determine its performance. This involved disassembling the system, packing it in its shipping crates, transporting it to ISU, reassembling it, and conducting a series of accelerator-driven experiments. At the IAC the electron beam was pointed at one face of the Pb (see picture above). After the experiments were completed, the system was returned to UNLV and reassembled there.

Several different cubic and rectangular configurations were examined, and all configurations were modeled in MCNPX prior to the experiments. The rectangular configurations were created in anticipation of conducting neutron multiplicity experiments on high-energy proton linear accelerators (linac) at the Los Alamos Neutron Science Center or at Brookhaven National Laboratory.

An AmBe source with a neutron production rate of $2500 \pm 10\%$ n/s was placed against the face of the Pb in all 5 configurations to measure the overall efficiency of the system. This weak source exceeded the counting capacity of the NMDS, such that its efficiency was reduced to 3.5% compared to earlier values at UNLV of 20-30% with a source strength of ~ 600 n/s.

An attempt to de-tune the accelerator was made by adjusting the electron beam to low current at frequencies of 15, 30, and 120 Hz. At 120 Hz, the deadtime of the detectors caused the system to acquire data for only 20-25% of the pulses. After the initial test runs, the frequencies were restricted to 15 Hz and 30 Hz for data acquisition, which allowed data to be acquired for 82-99% of the pulses received from the accelerator. However, excessive deadtime continued to reduce the counting efficiency. All results from the ISU-IAC accelerator-driven experiments were influenced by a count-rate limitation that is inherent in the NMDS hardware and software.

In an effort to determine system contributions to dead time, a deadtime measurement experiment was conducted at the Remote Sensing Laboratory (RSL) of the Nevada Test Site. The measurement was conducted using a cubic configuration and 64 detectors arranged in four banks of 16. Two ^{252}Cf neutron sources of 13,000 and 78,000 neutrons/second were used to perform two-source deadtime measurements. The data was analyzed and the deadtime coefficients were determined. Results indicated that the performance of individual detectors depends upon the number of detectors operating as well as the source strength (see figure below).



Performance of Detector #29 versus number of detectors in operation and source strength. The combined strength of the two sources is 91,000 n/s. The number of detectors were 1, 8, 16, and 64.

ACADEMIC YEAR HIGHLIGHTS

- ◆ T. Beller visited the ISU Idaho Accelerator Center and the NTS Remote Sensing Laboratory to work with others to conduct experiments with the NMDS. The NMDS was used with a 30-MeV Fast Pulse Linac electron accelerator at the IAC and with two ^{252}Cf sources at the RSL.
- ◆ S. Patil and T. Beller presented a poster at the Eighth Information Exchange Meeting on Actinide and Fission Product Partitioning & Transmutation, 9-11 November 2004, Las Vegas, NV. An accompanying paper, "The UNLV Neutron Multiplicity Detector System," was accepted for publication in the conference proceedings to be published by the OECD-NEA.
- ◆ S. Patil received a second place award in the Accelerator Applications track for her presentation of "Neutron Detector Characteristics in Deadtime Experiments," ANS Student Conference, Columbus, Ohio, April 15, 2005.

The individual detectors were determined to have a deadtime coefficient of a few ms, which would indicate a capability of the total system to count several thousand neutrons per second. However, the system has never counted more than 200 n/s, even with strong neutron sources. Each system component contributes to deadtime: ^3He tubes, pre-amps, signal processing boxes which support 8 detectors each, and the "special computer." In the final analysis, however, these experiments at ISU-IAC and NTS-RSL demonstrated that the performance of the system is critically limited because the "special computer" simply cannot process the data throughput during high count rates. In contrast, 50 or more counts from were measured from cosmic neutrons in a single 256 μs burst, a rate of 2×10^5 counts per second, but these events never happen even once a second. As a consequence of these experiments, a modern data acquisition system is being acquired that will support the maximum performance of each detector and all the detectors combined.

FUTURE WORK

The experiments conducted at the ISU-IAC and the NTS-RSL provided a much better understanding of the capabilities and limitations of the NMDS. The system is severely limited by deadtime. Subsequent to this determination, new data acquisition hardware and software were ordered for modification of the NMDS to count at much higher rates. After the system is modified, it may be tested with electron and proton accelerators. In addition, its use will be investigated in other projects, such as nuclear materials protection, control, and accountability for homeland security and proliferation resistance.

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