UNLV | University Libraries
University of Nevada, Las Vegas

Transmutation Sciences Physics (TRP) Transmutation Research Program Projects

2004

Neutron Multiplicity Measurements of Target/Blanket Materials

Denis Beller
University of Nevada, Las Vegas

Follow this and additional works at: https://digitalscholarship.unlv.edu/hrc_trp_sciences_physics

Part of the Nuclear Commons, Nuclear Engineering Commons, and the Oil, Gas, and Energy Commons

Repository Citation

Beller, D. (2004). Neutron Multiplicity Measurements of Target/Blanket Materials.
Available at: https://digitalscholarship.unlv.edu/hrc_trp_sciences_physics/9

This Annual Report is protected by copyright and/or related rights. It has been brought to you by Digital Scholarship@UNLV with permission from the rights-holder(s). You are free to use this Annual Report in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/or on the work itself.

This Annual Report has been accepted for inclusion in Transmutation Sciences Physics (TRP) by an authorized administrator of Digital Scholarship@UNLV. For more information, please contact digitalscholarship@unlv.edu.

Task 6

Neutron Multiplicity Measurements of Target/Blanket Materials

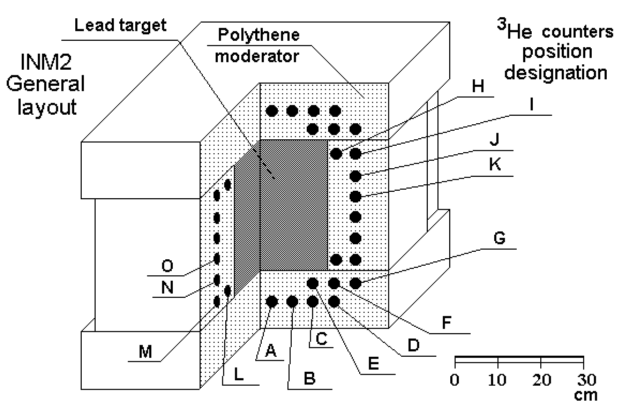
D. Beller

BACKGROUND

To optimize the performance of accelerator-driven transmutation subcritical systems (ADS), engineers will need to design the system to operate with a neutron multiplication factor just below 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.



NMDS in the INM2 ("CUBE") geometry.

RESEARCH OBJECTIVES AND METHODS

A prototype modular neutron detector system with 64 ^{3}He gas counting tubes was developed to measure the neutron multiplicity of scaled lead accelerator targets. The system has been named the Neutron Multiplicity Detector System, or NMDS. 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.

It is constructed from lead bricks that may be arranged in a 30 x 30 x 30 cm cubic configuration for cosmic ray measurements or as an elongated accelerator target, either 15 x 15 x 120 cm or 20 x 20 x 60 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.

This should enable the quantification of systematic errors in the latest version of MCNPX and its accompanying data libraries. Time-dependent measurements of neutron production in the NMDS should provide a systematic set of precise data that will enable direct comparison with code calculations. Comparison of results from the NMDS may decrease uncertainties and allow the derivation of relative measurements in the few percent range at the 95 percent confidence level. In addition, discrepancies that are discovered with this system can contribute to the improvement of the codes and data libraries. Improved models of beam line experiments, accelerator targets, and detector designs will result from these code improvements.

RESEARCH ACCOMPLISHMENTS

MCNPX models were developed to optimize the design of the NMDS for performing multiplicity measurements. Nuclear transport code models and calculations of neutron detection efficiency at various points in the target-detector assemblies were completed and interpreted prior to developing designs of the neutron detection systems needed to perform multiplicity measurements. Following completion of the modeling, a fabrication effort was initiated. A series of MCNPX models were developed at UNLV for a cylindrical target. Another generic model termed AS1 was created to examine response times, collection efficiencies, and escape probabilities. Colleagues at the V.G. Khlopin Radium Institute (KRI) completed preliminary nuclear transport modeling using the CONTROL code developed by KRI researchers.

The 60-element ^{3}He-detector-based system, developed in conjunction with collaborators at the Khlopin Radium Institute (KRI) in St. Petersburg, Russia, and fabricated by KRI, was completed and shipped to UNLV. It was assembled at UNLV in the "CUBE" geometry (30 cm x 30 cm x 30 cm of lead inside and 8 to 12 detectors on each of the 6 sides of the cube). A ^{252}Cf source was used to calibrate the NMDS. Detection efficiencies in ^{3}He as well as fractional capture in lead and polyethylene were calculated along with the percentage of neutrons lost. As expected, higher capture efficiencies for ^{3}He occurred with the source being placed in the center (because of reduced leakage). As the point source was moved from the center, the fraction of neutrons that escaped increased. These measured efficiencies were comparable to calculations and measurements done at KRI.

In addition, a series of MCNPX models was used to optimize the design for a prototype glass-fiber detector system. The models needed to finalize the Li glass fiber neutron multiplicity detector prototype design were verified by UNLV and the Pacific Northwest National Laboratory. However, this part of the project was terminated because of a change in scope of the project.

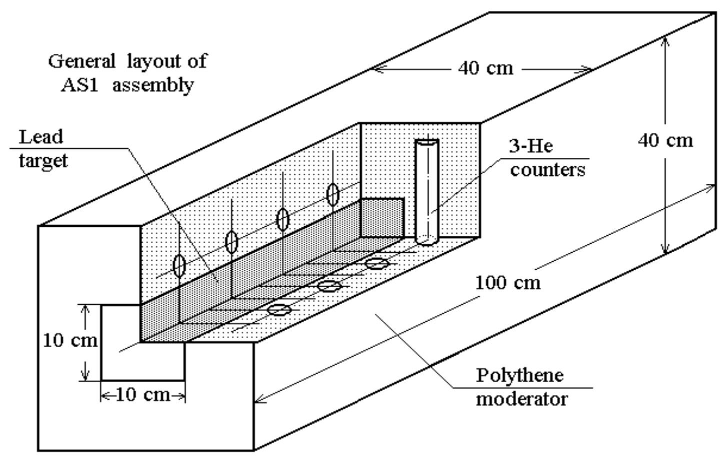
HIGHLIGHTS

- Undergraduate student Dean Curtis visited the Khlopin Radium Institute in the summer of 2003, where he worked side-by-side with KRI Director Dr. Alexander Rimsky-Korsakov. Mr. Curtis used MCNPX to model the performance of the NMDS and confirm measurement results, including the "lifetime" of neutrons produced in neutron multiplicity events.
- Fabrication of the ^{3}He-based neutron detector system was completed by KRI. The system was shipped to UNLV, was installed, and then was operated by the Russian collaborators to demonstrate its functionality. Efficiencies of ^{3}He detectors were determined with a ^{252}Cf standard. Since its installation the system has been used to take background measurements of cosmic rays, and performance has been compared to a similar system in St. Petersburg, Russia.
- Dean Curtis won an award for the best student poster for his presentation of "Modeling Neutron Multiplicities in a 60-Element ^{3}He Detector System" at the 2003 Annual Meeting of the American Nuclear Society, San Diego, CA, June 1-5, 2003.

FUTURE WORK

The experimental measurement of neutron production in scaled lead targets using the prototype neutron detector systems will be performed during the next year. Experiments are being planned to be performed with an electron accelerator at the Idaho State University, with a proton accelerator at UC Davis, and with a higher-energy system producing protons and/or neutrons at Los Alamos National Laboratory. Different configurations may be tested to increase the amount of neutron multiplicity data for analysis and comparison to computational models.

Results of measurements of neutron generation will be compared with MCNPX models of the experiments. The ongoing MCNPX modeling of high-energy neutron leakage from lead-bismuth targets will be coordinated with LANL and KRI. Modeling efforts will most likely be further refined subsequent to performing each set of neutron multiplicity measurements on the different accelerator systems.



General layout of test assembly "AS1," a 36-element ^{3}He detector system that was constructed at the Khlopin Radium Institute to verify the operation of the sysem.

Research Staff
Denis Beller, Principal Investigator, Research Professor, Mechanical Engineering Department

Students
Steven J. Curtis, Graduate Student, Department of Health Physics
Dean Curtis, Undergraduate Student, Computer Sciences
Timothy Beller, Undergraduate Student, Mechanical Engineering Department

Collaborators
Eric J. Pitcher, Lujan Center, Los Alamos National Laboratory
Michael Todosow, Brookhaven National Laboratory
Thomas Ward, Science Adviser, U.S. Department of Energy
Alexander Rimsky-Korsavok, Director, V.G. Khlopin Radium Institute