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Neutron Multiplicity Measurements of Target/Blanket Materials

Carter D. Hull
University of Nevada, Las Vegas

William H. Johnson
University of Nevada, Las Vegas

Task 6

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C.D. Hull and W.H. Johnson

GOAL AND BACKGROUND

The number of neutrons available from any transmutation system is the critical parameter in determining how quickly material can be transmuted. This means that maximizing neutron production while utilizing minimal power provides the most efficient transmutation system. For spallation neutron systems, neutron production and neutron use of the system may be determined using the MCNPX code package.

The LAHET Code system (LCS), part of the MCNPX package, provides simulation capabilities for a variety of particles in the higher energy regimes (which is the primary difference between the MCNPX package and the traditional MCNP package). Currently, the uncertainty associated with the neutron fluxes calculated using LCS for neutron proliferation simulation is 10-12% at the 95% confidence level. This uncertainty is thought to be due to the leakage of high-energy neutrons and protons, or multiple scattering, in the radial directions of thick targets. This uncertainty is unacceptable for most nuclear systems, and would result in significant limits on the operation of an accelerator-driven transmutation system.

One of the best methods for reducing uncertainty in modeling is to benchmark theoretical models, such as MCNPX (and the LAHET code within), against experimental observations. Unfortunately, the measurements of neutron production per unit volume necessary to validate and benchmark the code calculations for these source term volumes are lacking.

This research project plans to develop the technologies and experimental plans needed to address this data need. Initially, it involves the development of nuclear transport models and the acquisition of nuclear instrumentation necessary to perform neutron multiplicity measurements. By measuring neutron leakage from targets with various diameters, empirical measurements can be compared between detector systems and the MCNPX predictions. Additionally, precision position sensitive measurements of the source term volume for neutron production will permit systematic determination of major uncertainties in the LCS. This allows the performance of very low uncertainty measurements in the few percent range at the 95% confidence level. Finally, the acquisition of neutron multiplicity measurements on a variety of targets over a range of energies further validates and benchmarks the LCS.

Two neutron detector systems will be designed, fabricated, and deployed to collect experimental data in support of this effort. The first detector system uses ^{3}He (helium) gas tubes. Systems of this type have been used for many years. The second detector system is based on ^{6}Li (lithium) glass fibers. This newer, solid-state technology uses neutron sensitive scintillating glass fibers as detector elements. The two detector systems have been designed to measure the neutron multiplicity of large, complex lead and lead-bismuth targets.

OBJECTIVES

To begin developing the database necessary for the validation and benchmarking of the LAHET component of the MCNPX code suite, the UNLV research program has set forth the following objectives. First, the current MCNPX suite will be used to develop models of multi-element neutron detector systems. These models of the detector systems will be incorporated into the design of detailed models for the entire detector-target system. These models will first be used to help design the irradiation experiments, and then will be used to model the behavior of the system. Irradiation experiments corresponding to the detector-target system models will be performed, and measurements of the neutron leakage from the targets will be acquired. High spatial resolution and position sensitive measurements of the source term volume will also be acquired. The results of the experimental campaign will be compared with the simulated system to evaluate the performance of the MCNPX model. This database will also be made available to the code designers to allow them to benchmark the LAHET component of the MCNPX code.

RESEARCH ACCOMPLISHMENTS

Nuclear transport code models and calculations of neutron detection efficiency at various positions in the target-detector assembly were completed and interpreted prior to developing designs of the neutron detection systems needed to perform multiplicity measurements.

Colleagues at the Khlopin Radium Institute (KRI) finished preliminary nuclear transport codes using customized code developed by KRI researchers. These modeling efforts were coordinated with U.S. researchers and results indicate neutron production efficiencies of approximately 13%-19% in a lead target of 40 cm diameter and 1 m in length bombarded with a pulsed 1 GeV proton beam. These results are extremely simplified and represent only a “first cut” at the transport code models.

Numerical models performed at the Harry Reid Center using MCNPX Code were initiated following MCNPX training in January 2002 at UNLV. Dean Curtis, an undergraduate computer science student at UNLV, assisted with MCNPX model development for both the Russian ^{3}He and the American neutron glass fiber detector systems. Mr. Curtis assisted with the configuration and operation of the PC systems that will execute transport codes and archive modeling results. Mr. Curtis also collaborates with LANSCE and UNLV’s Mechanical Engineering department to further refine and augment modeling efforts.

KRI colleagues completed preliminary geometric models for the ^{3}He detector configuration. Carter Hull and Tom Ward approved one of the three models submitted by KRI. Completion of the model for the neutron glass fiber detector prototype permitted the initiation of detector design and fabrication studies. The ^{3}He target monitoring system, designed for U.S. laboratory needs and experimentation protocols, is in the final design and initial fabrication stages. It is suitable for prolonged, unattended operation. Data can be accessed via telecommunication lines such as direct cabling, modem, and high speed intranet/internet. Dr. Hull and Dr. Ward plan to approve the final design in Russia at KRI sometime after June 2002.

Researchers completed the American glass fiber detector prototype. It is ready to be tested in upcoming target experiments at LANSCE. Various limitations warrant that the experimental detector system not have the spatial resolution required for the actual target and blanket system. However, the proof-of-principle data provided will be invaluable.

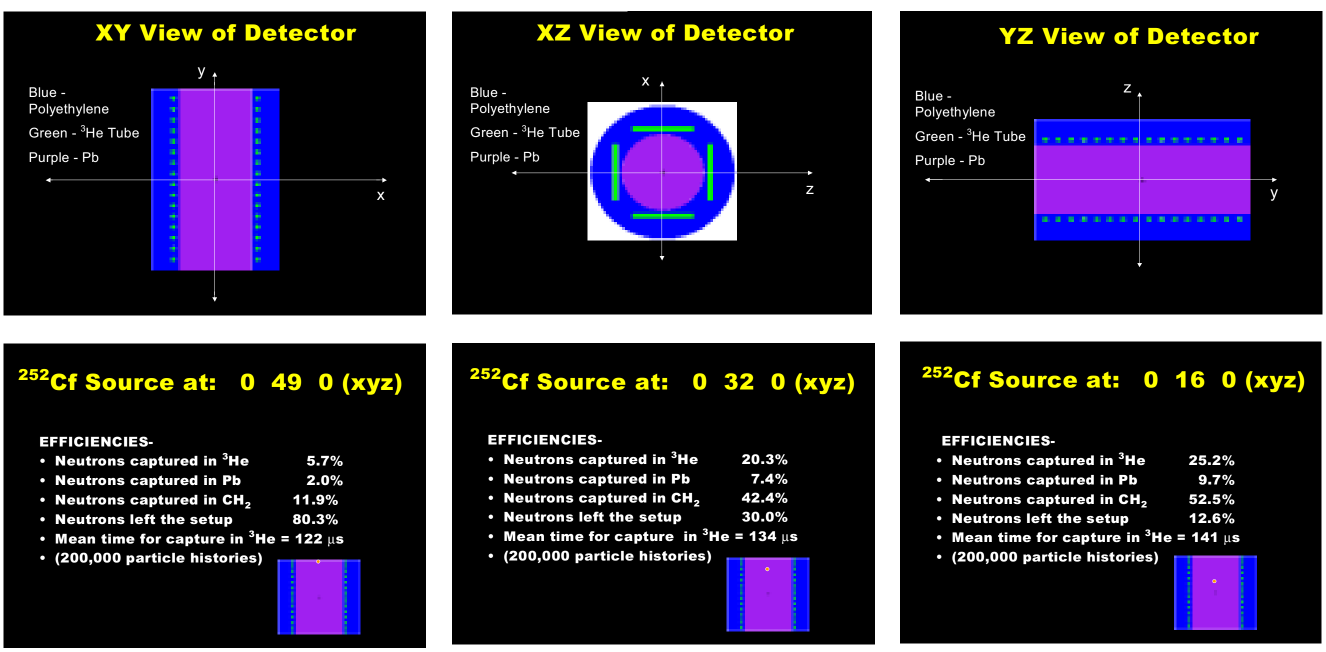
FUTURE WORK AND GOALS

Work in year two and subsequent work includes many tasks:

- refinement of MCNPX models of detector systems (various targets and beam energies);
- completion and modification of the glass fiber neutron detection system;
- integration and testing of the neutron fiber detector and electronics;
- acquisition of initial neutron multiplicity measurements; comparison of models with measurement results;
- review and modification of codes if indicated; and,
- review and validation of the data.

Project results will be submitted for publication in peer reviewed journals. Other goals include additional graduate research projects to refine these initial models and to perform neutron-multiplicity measurements on a variety of targets over a range of energies. These measurements are essential in validating and benchmarking the LCS modeling results of target materials. The neutron leakage measurements will provide a systematic set off precision data that will enable direct comparison with code calculations. These sets of measurements will enable the transmutation program to reduce the uncertainty and risk of design engineering and operation of the sub-critical multiplier system.

Future work may include measurements at the accelerator at Brookhaven National Lab. This accelerator produces beams of pions, kaons, and protons of appropriate energies that could be used to test the codes.



MCNPX Model of Target-Detector System

Research Staff

Carter D. Hull, Principal Investigator, Research Scientist, Harry Reid Center for Environmental Studies
William H. Johnson, Assistant Professor, Department of Health Physics

Students

Steven J. Curtis, Graduate Student. Dean Curtis, Undergraduate Student.

Collaborators

Michael Todosow, Division Head, Nuclear Science and Technology Division, Brookhaven National Laboratory
Eric J. Pitcher, Lujan Center, Los Alamos National Laboratory
Thomas Ward, Science Adviser, U.S. Department of Energy Consultant