Task 6

Neutron Multiplicity Measurements of Target/Blanket Materials

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BACKGROUND

To optimize the performance of accelerator driven transmutation 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 criteria requires particle transport codes that instill the highest level of confidence with minimal uncertainty, because the larger the uncertainties in the codes, the larger the safety margin required in the design and the lower the efficiency of the ADS transmuter. For current design efforts, the MCNPX code is used to determine neutron production and transport for spallation neutron systems.

While providing a very useful research and modeling tool, the uncertainties in MCNPX, 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 code calculations of such a volume source term is necessary.

The primary goal of this research is to develop and deploy the detector systems necessary for the measurement of neutron leakage from targets in calibrated beam lines, and to produce precise, position sensitive measurements of the source term volume for neutron production.

RESEARCH OBJECTIVES AND METHODS

Two prototype neutron detector systems utilizing different detection technologies, a ^{3}He gas tube system and a ^{6}Li glass optical fiber ("neutron glass fiber") system, will be developed to measure the neutron multiplicity of scaled lead accelerator targets (~4 cm diameter by 8 to 10 cm long). Performing measurements using both detector systems produces a consistent set of relative measurements. This should enable the quantification of systematic errors in the LAHET Code System (LCS) as incorporated in the latest MCNPX beta test version and library codes. Neutron leakage measurements should provide a systematic set of precision data that will enable direct comparison with code calculations. Comparison of results from the two detector systems may decrease uncertainties and allow the derivation of relative measurements in the few percent range at the 95 percent confidence level. A consistent set of relative measurements enables quantification of systematic errors within the MCNPX beta test versions and neutron cross-section data files. Improved models of beam line experiments, accelerator targets, and detector designs will result from these code improvements.

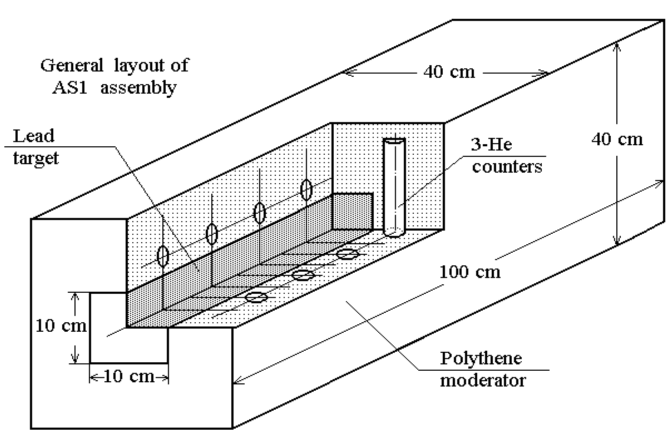
Producing precise, position sensitive measurements of the source term volume for neutron production allows systematic determination of major uncertainties in the code. This enables the performance of very low uncertainty measurements in the few percent range at 95% confidence level. High-resolution source volume measurements using the position sensitive detector permits a direct comparison of the code results with the neutron source term volume produced by the proton interaction in the target.

Additionally, these systems will be used to perform neutron-multiplicity measurements on a variety of targets over a range of energies (800-3,000 MeV), which should provide the data necessary to validate and benchmark the MNCPX code.

RESEARCH ACCOMPLISHMENTS

MCNPX models of neutron leakage from target systems were performed. Modeling efforts were refined prior to each set of neutron multiplicity measurements of ADS target and blanket materials. These dynamic models require review, revision, and refinement based on the results with the observed data of neutron leakage. Additional MCNP/MCNPX models were developed to optimize detector designs for performing multiplicity measurements for both the neutron glass fiber and ^{3}He detector systems.

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.



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.

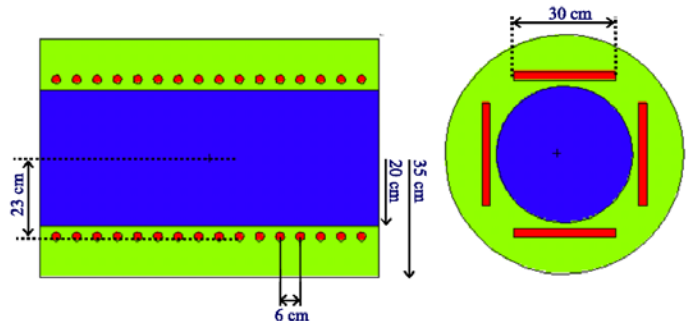
The 60-element ^{3}He-based system, developed in conjunction with collaborators at the Khlopin Radium Institute (KRI) in St. Petersburg, Russia, and fabricated by KRI, has been completed and is presently in transit. A series of MCNPX models were developed at UNLV for a cylindrical target. A generic model (termed AS1) was created to examine response times, collection efficiencies, and escape probabilities. Colleagues at the Khlopin Radium Institute (KRI) completed preliminary nuclear transport modeling using the CONTROL code developed by KRI researchers. A ^{252}Cf source was used to calibrate the KRI detector. Detection efficiencies in ^{3}He as well as fractional capture in Pb 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 efficiency values are comparable to calculations and measurements done at KRI.

Lead target configuration for the ^{3}He system was computationally changed to that of a rectangular block target and additional MCNPX models were constructed for this target/detector geometry. This difference between the UNLV prediction with MCNPX and the KRI measurement is most likely due to different detector configurations (geometry, numbers of counting tubes, source description and spectrum, and materials). These models will be repeated.

The glass fiber detector prototype is nearing completion in Oak Ridge, TN and will be ready to test in upcoming target experiments at the Crocker Nuclear Laboratory at the University of California, Davis. A series of MCNPX models was used to optimize the design for a Neutron Glass Fiber Detector for use in the calibrated proton beam line at the cyclotron facilities at UC Davis. Models also were developed to evaluate the optimal size and length of the detector and the position of the lead target within the detector element. The neutron glass fiber detector was re-designed after it became apparent from MCNPX modeling that internally moderated systems are not useful for determining the source term volume for neutron generation in the target; one of the long-term objectives of this project. The models needed to finalize the Li glass fiber neutron multiplicity detector prototype design were verified by UNLV and the Pacific Northwest National Laboratory.

HIGHLIGHTS

- "Modeling Neutron Multiplicities in a 60-element ^{3}He detector system" presented at the ANS Annual Meeting, San Diego, June 1-5, 2003. Dean Curtis won overall best student poster award.
- Fabrication of the ^{3}He-based neutron detector system has been completed by KRI. The system is in-transit to UNLV, with delivery and installation expected by the end of the summer.



2-D Cross Sections of the geometry used in this MCNPX model of the KRI 60-element ^{3}He detector system.

FUTURE WORK

The experimental measurement of neutron production in scaled Pb targets using the two prototype neutron detector systems will be performed over the next year. Initial measurements would best be performed at UC Davis, which may result in the ability to deploy a more robust system for target measurements to be performed at Los Alamos during the next academic year (early FY04). Other testing may be possible on beam lines at the Idaho National Laboratory.

These measurements of real time neutron leakage collected with these systems will be compared with the MCNPX models of the experiments. The ongoing MCNPX modeling of high-energy neutron leakage from Pb-Bi targets will be coordinated with Lujan Center at LANL and KRI. Modeling efforts will most likely be further refined subsequent to performing each set of neutron multiplicity measurements of target / blanket material materials. Additional MCNP/MCNPX models will be developed to optimize detector designs for performing multiplicity measurements for both the neutron glass fiber and ^{3}He detector systems.

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