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Evaluation of Polyethylene and Blank Pulsed Sphere Experiments Using Deuteron Transport Feature in COG

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INTRODUCTION

From the late 1960s to about 1985, LLNL undertook a series of 'pulsed sphere' experiments for 31 materials involving 148 different experiments using 75 different spheres. The purpose was to measure the neutron leakage spectra for different materials from 14-MeV neutrons generated by $^3H(d,n)^4He$ reactions induced by an incident D+ beam from the Insulated Core Transfer (ICT) accelerator at LLNL [1]. This deuteron beam was focused to impinge upon tritium loaded onto a titanium substrate within a low mass target assembly placed within the center of a spherical shell constructed from the material of interest.

COG [2] is a three-dimensional, continuous energy, Monte Carlo code, developed by Lawrence Livermore National Laboratory (LLNL). Recent additions to COG include alpha [3] and deuteron particle transport in order to directly calculate (α,n) and $^3H(d,n)^4He$ reactions, and resulting neutron emission spectra. Results of the direct deuteron transport calculation for the 0.8 MFP (mean free path) polyethylene sphere with PILOT B detector was previously [4] published. The purpose of this paper is to present expanded COG results showing the neutron peak from deuterium buildup ($^2H(d,n)^3He$) due to tritium decay in the target. Cross section data libraries used are ENDF/B-VIII.0 for neutrons and ENDF/B-VII.1 for deuterons, respectively.

COG MODELING

A schematic drawing [5] showing the target assembly, surrounding concrete wall, and detector assembly is shown in Fig. 1. In the figure, two collimator holes at 0° and 30° horizontal angles with respect to D+ beam line are shown. Two sets of experiments using different detector locations are evaluated. In the polyethylene sphere experiments, detectors are placed outside the collimator at the horizontal angle of 0° as to the D+ beam line. In the blank run, the detector is located outside the 30° angled collimator.

The COG model consists of the target assembly (see Fig. 2), polyethylene sphere, concrete walls, and collimator as shown in Fig. 3. The D+ beam is modeled as a 1.2 cm diameter cylinder of 400-keV ions impinging upon the tritium loaded titanium target.

The neutron time of flight is measured at a detector outside a collimator. The distance from the tritium target center to the detector modeled is 728 cm for the polyethylene sphere and 852.5 cm for the blank run. For the polyethylene run, the horizontal detector angle with respect to D+ beam is 0° while the vertical angle between the D+ beam lime and the detector is 26°. The angle between the beam line and the detector for the blank run is 38.9° [6]. The collimator for the blank run is therefore positioned at a 30° horizontal angle with respect to the beam line. The detectors used for the two experiments are NE213 scintillator detectors with a bias of 0.8 MeV, which are modeled as a 5.08 cm diameter × 5.08 cm long cylinder. The NE213 detector efficiency curve published in the later experiments [6] is used in the analysis.

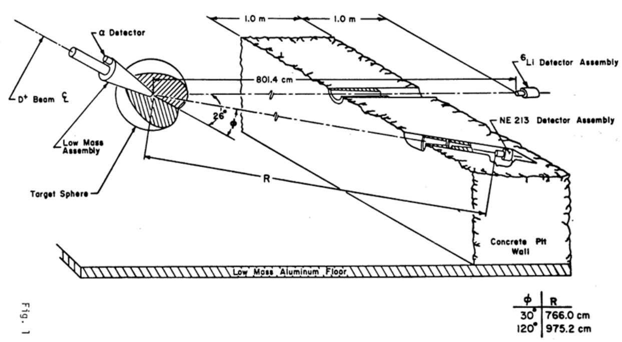

Fig. 1. Schematic Drawing of the Experimental Setup.

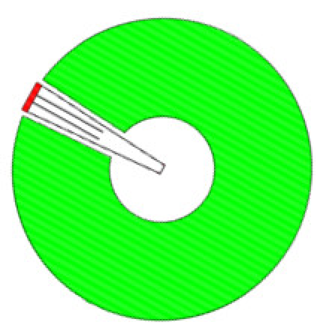

Fig.2. COG Model of Target Assembly and 1.8 MFP Thick Polyethylene Sphere.

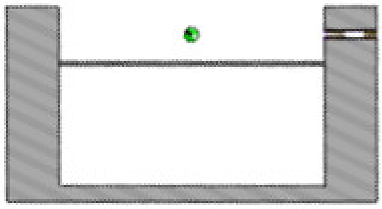

Fig. 3. COG XY View of Target Assembly, 1.8 MFP Polyethylene Sphere, Concrete Walls, Aluminum Floor, and 0° Collimator.

The collimator used in the polyethylene sphere experiment (0° collimator) is constructed from iron and borated paraffin and placed in a 32.386 cm diameter hole in the concrete wall. A 20.2 cm diameter iron collimator surrounded by a water liner that filled the annular space was used in the blank run (30° collimator).

The first case selected for simulation is a hollow polyethylene sphere, 1.8 mean free paths (MFP) or 16.56 cm thick. The tritium target is at the same elevation as the center of the collimator and detector. The inner and the outer diameters of the sphere are 17.88 and 52 cm, respectively. The blank run does not include the material sphere.

RESULTS

The experiments consist of recording the ratio of counts with the polyethylene sphere in to counts with the polyethylene out [1]. With this technique, the effects of the low mass target assembly, collimator, and the air in the flight path between the target and the detector cancel out resulting in insignificant effect on the experimental data. Note that the detector location for this blank run without the polyethylene sphere is outside the collimator angled at 0° with respect to the D+ beam line.

Polyethylene Sphere

Measured and calculated time of flight neutron spectra for the 1.8 mfp thick polyethylene hollow sphere are compared in Fig. 4. The detector times range from 121 to 663 nanoseconds corresponding to 19.5 to 0.63 MeV. The spectrum is given in units of normalized count rate, which is neutrons recorded at the detector per nanosecond per source neutron.

Measured and calculated spectra show a large and narrow peak at around 137 ns produced by the uncollided 14-MeV neutrons, with a broad decreasing distribution at later times due to the collided neutrons. Measurement data error varies with time ranging from less than 5% for 130 to 435 ns, 6 to 30% for 437 to 613 ns, 30 to 151% for 615 to 659 ns.

The error in the measured neutron time of flight spectra includes both the statistical counting error and the uncertainty in the detector efficiency [1]. The relative errors of the COG results are less than 5%. Good agreement is observed between the COG and the measurement data up to 540 ns. COG overpredicts the measurement data beyond 540 ns (below 1.31 MeV).

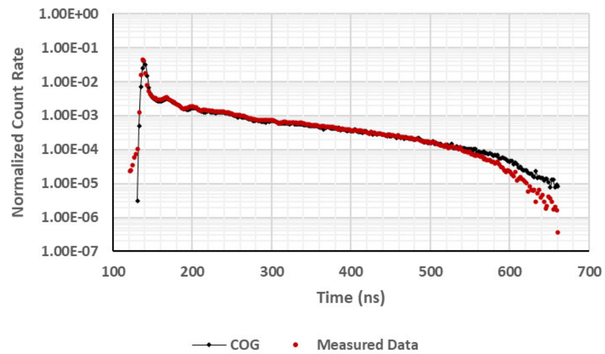

Fig. 4. COG Result of the Polyethylene Sphere.

Blank Run

Fig. 5 shows COG calculated count rates compared with the experimental data for the blank run. The detector times range from 147 ns (18.1 MeV) to 549 ns (1.26 MeV). As expected for the target without any material sphere, the count rate is nearly constant after the large and narrow peak at 159 ns. COG results show good agreement with measured data, clearly showing the small neutron peak at 350 ns from the deuterium buildup at the tritium target. Measurement errors are not reported but can be assumed not to exceed those reported for those reported for the polyethylene sphere in ratio to these measurements.

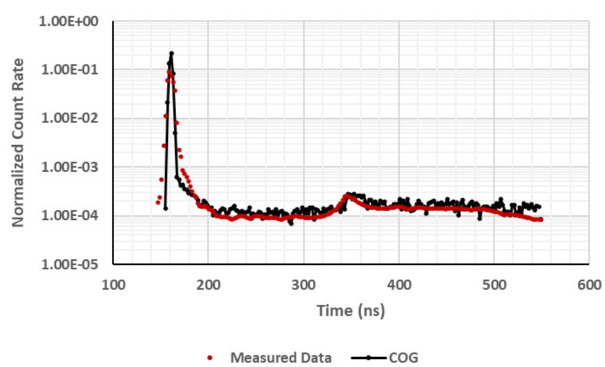

Fig. 5. COG Results of the Blank Run.

SUMMARY AND DISCUSSION

These COG results demonstrate that high-fidelity deuteron transport simulations can be performed for experiments using the $^{3}H(d,n)^{4}He$ 'source' reaction. By performing the direct deuteron transport simulation, the neutron peak due to the deuterium buildup can be identified.

Preparation of a complete report is on-going to provide to the Shielding Integral Benchmarks Archive and Database (SINBAD) [7] for information preservation and to facilitate access by the international user community. Evaluation of the other pulsed sphere experiments of interest are planned in the future.

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