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Development of Neutron Detector Arrays for Neutron-Induced Reaction Measurements

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Development of arrays of detectors for the detection of neutrons and γ rays produced in neutron-induced reactions at the Los Alamos Neutron Science Center (LANSCE) is ongoing, building on the solid foundation of past designs. Our current work is centered on the characterization of the types of neutron detectors that will be used in the arrays (liquid scintillators and ^{6}Li-glass detectors) and the construction of the detector supporting structures. These arrays will be used to measure the outgoing neutron spectra in experiments at the Weapons Neutron Research (WNR) facility at LANSCE on neutron-induced fission and inelastic neutron scattering. These experiments will provide improved data for nuclear energy and security applications. Precise measurements of the outgoing neutron spectra following neutron-induced fission impact the areas of nuclear energy, criticality safety, and global security. Similar measurements of the outgoing neutron spectra from inelastic neutron scattering provide nuclear structure information, such as energy-level densities in regions of high excitation energy. Various tests and considerations are in progress to understand the important contributing factors toward meeting our design goals. We present design considerations and test results.

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1 Supporting Material

1.1 Physics Motivations

The experimental data base of the prompt outgoing neutron spectra from neutron-induced fission is incomplete and, like in the case of ^{239}Pu, contains wildly discrepant measurements [Hai11]. The anticipated high quality data of the prompt fission neutron spectra will be used to validate theoretical fission models and to provide improved data for applications [Nod11]. Inelastic neutron scattering experiments will give information on nuclear structure such as the densities of nuclear energy levels [Roc04]. Such information for fission products is used as input to fission and other nuclear models.

1.2 WNR Facility

The Weapons Neutron Research (WNR) at the Los Alamos Neutron Science Center (LANSCE) provides pulsed neutron beams having a wide energy spectrum [Lis90]. These beams are produced via spallation reactions through the interaction of 800 MeV pulsed proton beams interacting in a tungsten target. The resulting neutron beam spectra range in energy from a few keV to approximately the proton beam energy of 800 MeV, with most of the neutron flux concentrated between 0.1 MeV and 100 MeV. Our neutron detector arrays will be assembled on the 15° left flight path that is being constructed currently as well.

1.3 Liquid-Scintillator Detectors

We will describe our tests on and design considerations for the array of liquid scintillators. We have selected large diameter (17.8 cm) scintillators filled with EJ309 liquid to increase the neutron detection efficiency. These scintillators are coupled to 12.5 cm diameter PMTs.

1.3.1 PMT and Light Guide Tests

We have made many tests of the uniformity of the response as a function of position on the face of the PMTs and scintillator cells coupled directly to the PMTs. In addition, we investigated the response uniformity with various light guides between the scintillators and PMTs.

1.3.2 Gain Stability Efforts

It has been demonstrated that PMT gain shifts are possible at high counting rates ($> 1-2$ kHz). Pulsed LED systems are commonly used to track gain shifts in scintillators during experiments. We will describe our LED pulser system and our initial tests of the system.

1.3.3 Efficiency Measurements

For an accurate determination of the shape of the prompt outgoing fission neutron spectrum, the neutron detection efficiency needs to be known very well. Three approaches are being employed: neutron spectrum from a ^{252}Cf fission chamber, well-studied neutron spectra produced at low energy accelerators, and tagged neutrons at the WNR facility.

1.3.4 Modeling Calculations

Efficiency measurements need to be correlated with detailed monte carlo calculations in order to extrapolate neutron detection efficiencies outside the energy ranges of the experiments. Geant4 and MCNP-PoliMi are being used to model the experimental configurations and calculate the neutron detection efficiencies. In addition to calculating efficiencies, Geant4 is being used to estimate backgrounds arising from neutron multiple scattering from neighboring detectors and supporting structures.

1.4 ^{6}Li-Glass Detectors

^{6}Li-glass detectors will be used to detect neutrons at lower energies where liquid scintillators have difficulty discriminating neutrons from γ rays (below 600 keV). These detectors are being characterized using ^{252}Cf spontaneous fission spectra, monte carlo model calculations, and ^{235}U(n,fission) neutron spectra. From preliminary analyses, it was determined that the detection of neutrons with energies as low as 50 keV is feasible with these detectors [Lee11].

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