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Creation of a Geant4 Muon Tomography Package for Imaging of Nuclear Fuel in Dry Cask Storage

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ABSTRACT

Nuclear waste management and non-proliferation is among the critical tasks to be addressed for the advancement of fission-based nuclear energy in the United States. Controlling nuclear material at its source is one of the main strategies to minimize the risks of nuclear proliferation and reduce potential homeland threats. Since the early 1950's, when the first nuclear power plant began to produce electricity, vast numbers of drums, containers and dry casks house, frequently unknown, waste that include spent nuclear fuel, concrete and voids. Storage of high level waste from a fission reactor typically involves placing PWR and BWR spent fuel assemblies in sealed dry casks. After the spent nuclear fuel has been placed inside the dry cask, the cask is welded, not allowing for visual inspection. The reason to monitor spent nuclear fuel dry casks stems from the need to investigate whether the stored content agrees with the declared content. Conventional methods for examining the interior of materials e.g., x-rays, are limited by the fact that they cannot penetrate very dense well-shielded objects.

Cosmic ray muon tomography has the potential to allow for non-destructive assessment of nuclear material accountancy with the aim to independently verify and identify weapons grade material, such as fuel pellets, fuel rods and fuel assemblies stored within sealed dense dry casks. Cosmic muons are relativistic charged particles continuously generated by high energy cosmic rays entering Earth's atmosphere. Energetic muons have the ability to penetrate high density material allowing the distribution of material within the object to be inferred from the muon tracks. The subsequent scattering and transmission of muons can provide a measurable signal about the structural and chemical composition of the stored materials. The proposed project focuses on the development of a simulation and analysis package to aid in the non-destructive assessment of sealed spent nuclear fuel dry casks using cosmic ray muons. The methodology will help the user to solve the inverse problem, i.e., determine presence, structure and geometry of spent nuclear fuel assemblies from muon transport measurements. Advantages of cosmic muon tomography include the utilization of the passive nature of muons, the lack of radiological sources and consequently the absence of any artificial radiological dose. Such a technique is in-line with the non-proliferation objectives of the Department of Energy, since using radiological sources for radiography could potentially pose the security risk in the case of source diversion.