Muon radiography verifies spent nuclear fuel in sealed casks

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International nuclear safeguard inspectors are tasked with monitoring the heavily shielded waste casks that store used plutonium produced as a byproduct of the nuclear fuel cycle. However, these inspectors have no immediate way to determine the amount of reactor fuel in a sealed cask if tamper-indicating seals on those casks are damaged. Compromised casks are typically sent elsewhere to be opened and reverified – a costly, time-consuming process. Los Alamos researchers and collaborators have investigated a method to "see" inside sealed casks using naturally occurring cosmic-ray muons. In research featured as an Editor's Choice in *Physical Review Applied*, the team showed that this method is sensitive enough to measure an entire storage cask and detect multiple missing fuel bundles.

Significance of the work

The research indicates that measurements of cosmic-ray muon scattering could be used as a stand-alone method to independently determine if fuel assemblies are missing from a sealed dry storage cask. Unlike more conventional radiographic probes, muons can penetrate the cask shielding and emerge with useful information about the contents of the cask. Moreover, muons are not subject to backgrounds from other casks and do not require any previous knowledge of the fuel history or opening the closed casks. Measurement times on the order of weeks to several months could provide sufficient data to draw conclusions about cask content and satisfy the requirements of the International Atomic Agency (IAEA). Thus muon radiography could be a solution to the longstanding problem of certifying that spent fuel casks – and by extension, the vast majority of the world's plutonium supplies – are accounted for under international nuclear safeguards and nonproliferation requirements.

Achievements

Researchers used a nuclear storage cask housed at the Idaho National Laboratory to test the method. The team measured the scattering angles of cosmic-ray muons that travel through a cask to verify the contents *in situ*. The investigators chose this particular cask as a test object because it is only partially loaded with 18 out of 24 possible fuel positions filled. Two identical muon-tracking detectors placed on opposite sides of the cask measured the trajectories of muons before and after passing through the cask. As muons passed through the cask, their amount of scattering was dependent on the path lengths of the cask shielding material and fuel encountered along their trajectory.

Muon radiography revealed multiple fuel bundles missing from the dry storage cask. The technique also demonstrated potential sensitivity to detect the removal of a single bundle of fuel. The team is now testing the sensitivity of muon radiography in more complicated scenarios, such as the removal of part of a single assembly or the replacement of a spent fuel assembly with a dummy.

The research team

Reference: "Verification of Spent Nuclear Fuel in Sealed Dry Storage Casks via Measurements of Cosmic-Ray Muon Scattering," *Physical Review Applied* 9, 044013 (2018); doi.org/10.1103/PhysRevApplied.9.044013.

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The National Nuclear Security Administration's Office of Defense Nuclear Nonproliferation Research and Development funded the work, which supports the Laboratory's Global Security mission area and the Science of Signatures and Nuclear and Particle Futures science pillars by applying technology and methods used in high-energy particle physics to solve a challenge in international nuclear safeguards. Los Alamos built the detectors and invented the muon scattering radiography technique used for this measurement.

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Caption for image below: *Schematic of the cask fuel bundle loading configuration and detector positions.*