Los Alamos Muon Detector Could Thwart Nuclear Smugglers

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Trillions of cosmic rays that constantly bombard Earth could help catch smugglers trying to bring nuclear weapons or materials into the United States.

Los Alamos National Laboratory scientists have developed a detector that can see through lead or other heavy shielding in truck trailers or cargo containers to detect uranium, plutonium or other dense materials. Their technique, muon radiography, is far more sensitive than x-rays, with none of the radiation hazards of x-ray or gamma-ray detectors now in use at U.S. borders.

Chris Morris of Los Alamos' Physics Division and Rick Chartrand of the Theoretical Division discussed recent improvements to the technique and their efforts to build a prototype detector today at the Annual Meeting of the American Association for the Advancement of Science during a symposium, "Detecting the Unseen with Cosmic-Ray Muons, scheduled for 9:45 - 11:15 a.m., EST.

Both 2004 U.S. presidential candidates declared nuclear terrorism the greatest threat facing the United States. National security experts have speculated that detonation of a nuclear weapon or radiological dispersion device on U.S. soil could create global chaos by shutting down trade. Existing radiographic methods are inefficient for detecting shielded nuclear materials and present radiation hazards to inspectors and vehicle passengers. Muon radiography uses the natural scattering of muons - produced by the decay of cosmic rays showering down on Earth - as a radiographic probe. In fact, efforts to shield nuclear materials with lead or similar heavy metals make a smuggled object easier to detect with muons.

"We believe we've worked through all of the major obstacles to building a prototype system for a range of security scenarios," Morris said.

Muon radiography works because muons are energetic enough to penetrate thick rock or heavy metals. Materials with large numbers of protons and tightly packed nuclei, such as plutonium and uranium or metals like lead and tungsten, produce stronger electromagnetic forces and therefore deflect muons more than less dense materials such as steel, aluminum or plastic.

A pair of detectors above and another pair beneath a truck, cargo container or other suspect object record each muon's path before and after it passes through the cargo. By analyzing changes in energy and trajectory, computer algorithms build a three-dimensional mathematical map of dense items in the cargo. In the 1960s, Luis Alvarez used muon counters to seek hidden chambers inside the Second Pyramid of Giza.

Muons strike the Earth from every angle, so the key to a workable detection system is to keep improving the computer algorithms for tomographic reconstruction. "If we measure the muon's path and energy with two detectors going in and two coming out, we have a straight line on either side that tells us how much the target deflects the muon, and we can locate highly dense objects, as well distinguishing between materials," said Larry Schultz, a member of the Los Alamos team.

One advantage of muon radiographs is their ability to discriminate between shielding materials and less dense metals. With an average energy of 3 billion electron volts, most muons can penetrate about six feet of lead. Gamma-ray detectors are far less penetrating, produce only cluttered, two-dimensional views that need additional interpretation and require hazardous materials such as cobalt.

One drawback of detection systems such as airport screeners is the need for people to interpret images and data. The automation built into the Los Alamos computer algorithm makes inspectors' jobs easier because it doesn't convert data from nearly a million detector coordinates into images, Chartrand explained. Instead, using machine learning techniques, the algorithm is trained with known examples until it can decide directly whether a bomb, nuclear materials or shielding are present.

"We've shown we can put the data through a machine-learning algorithm and train the system to spot objects of interest with a rate of false positives and false negatives that is less than 3 percent," Chartrand said. "We think we can continue to improve that."

Working at the Los Alamos Neutron Science Center, the team is building a prototype set of detectors big enough to radiograph in 60 seconds large metal objects such as auto engines or

transmissions. With refinement, inspectors could declare most vehicles harmless in a border setting with as little as 20 seconds of muon exposure.

Adapted from materials provided by Los Alamos National Laboratory.