Title: A Range Muon Tomography Performance Study for Detection of Explosives

Author(s): Leticia Cuellar, Konstantin Borozdin, Kiwhan Chung, Andrew J. Green, Nicolas Hengartner, Christopher Morris, Larry J. Schultz, Nathaniel P. Reimus, Jeffrey D. Bacon, Wendy Vogan-McNeil

A Range Muon Tomography Performance Study for the Detection of Explosives


Abstract—Soft cosmic ray tomography has been shown to successfully discriminate materials with various density levels due to their ability to deeply penetrate matter, allowing sensitivity to atomic number, radiation length and density. Because the multiple muon scattering signal from high Z- materials is very strong, the technology is well suited to the detection of the illicit transportation of special and radiological nuclear materials. In addition, a recent detection technique based on measuring the lower energy particles that do not traverse the material (range radiography), allows to discriminate low and medium Z-materials. This is shown in [4] using Monte Carlo simulations. More recently, using a mini muon tracker developed at Los Alamos National Laboratory, we performed various experiments to try out the radiation length technology. This paper presents the results from real experiments and evaluates the likelihood that soft cosmic ray tomography may be applied to detect high-explosives.

I. INTRODUCTION

Soft cosmic rays are subatomic particles that collide with the upper atmosphere to produce pions that decay to muons, electrons and positrons. Most muons reach the earth’s crust where they penetrate deeply into matter [3]. Electrons also reach the crust but because they are less energetic, they stop faster. These muons and electrons can serve as probes for tomographic imaging. Multiple muon scattering has been successfully applied to identify high Z- objects like shielding materials and special nuclear and radioactive materials. However, imaging of low-Z materials using multiple muon scattering are very noisy due to the low signal-to-noise ratio of these materials [5] and [6]. An alternative tomographic imaging technique, based on range radiography seems promising [4]. This technique exploits the fact that lower energy particles are more likely to stop while traversing an object. Image reconstruction with this technique on simple synthetic landscapes using data from Geant Monte Carlo simulations [1], [2] are encouraging.

The challenge is to mature this technology and transition it from working in Silico to enabling imaging of real scenes. To this end, Los Alamos National Laboratory has build a portable mini muon tracker (MMT). This muon tracker is constructed from sealed aluminum drift tubes, which are grouped into twenty-four 4 feet² squared planes. The MMT can be moved via a pallet jack or a fork lift. This paper presents the results of our first data collected from that instrument. The aim in each of the analyzed examples is to identify explosives hidden within the scene. The examples we consider range in complexity of the background clutter.

Fig. 1. Final Mini Muon Tracker mechanical design

Fig. 2. Completed Mini Muon Tracker to enable full track reconstruction of cosmic ray muons and electrons.

All authors are with the Los Alamos National Laboratory, Los Alamos, NM 87545. (emails: {leticia, kbor, kiwhan, a_green, nick, cmonis, schultz, neimms, jbacon, vegan}@lanl.gov).
II. EXPERIMENTS

All experiments performed are simple landscapes of various materials placed on top of a \( \frac{3}{4} \) plywood table. Materials include TNT, 9501, Lead, Tungsten, Aluminum, and water. Most common scenes are four two inches thick step wedges of different dimension: \( 12' \times 12'' \), \( 12'' \times 9'' \), \( 12'' \times 6'' \) and \( 12'' \times 3'' \), one three inches thick hemisphere of lead with spherical hollow, and a similar full lead sphere.

III. IMAGE RECONSTRUCTION

We are currently in the process to apply our image reconstruction technique based on stopping to all these scenes. Results should be available and ready to report by the time of the Nuclear Science Symposium.

REFERENCES