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Muon Tomography Passive Scanning of Occupied Passenger Vehicles

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Los Alamos National Laboratory and the [1]University of South Carolina

Abstract The threat of the detonation of a nuclear device in a major US city has prompted research aimed at providing more robust border surveillance for contraband nuclear material. The small amount of material needed to construct a nuclear device and the ease with which neutron and gamma ray signatures can be obscured with shielding makes this job difficult. We demonstrate a new technique which uses multiple scattering of cosmic ray muons to selectively detect high-z material in a background of normal clutter. The advantages of this technique are that it is passive, does not deliver any radiation dose above background, and is selective to high-z dense materials. The research that has lead to the development of this new radiography will be reviewed, and future extensions will be summarized

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LDC Review by A. Saunders 12/26/96

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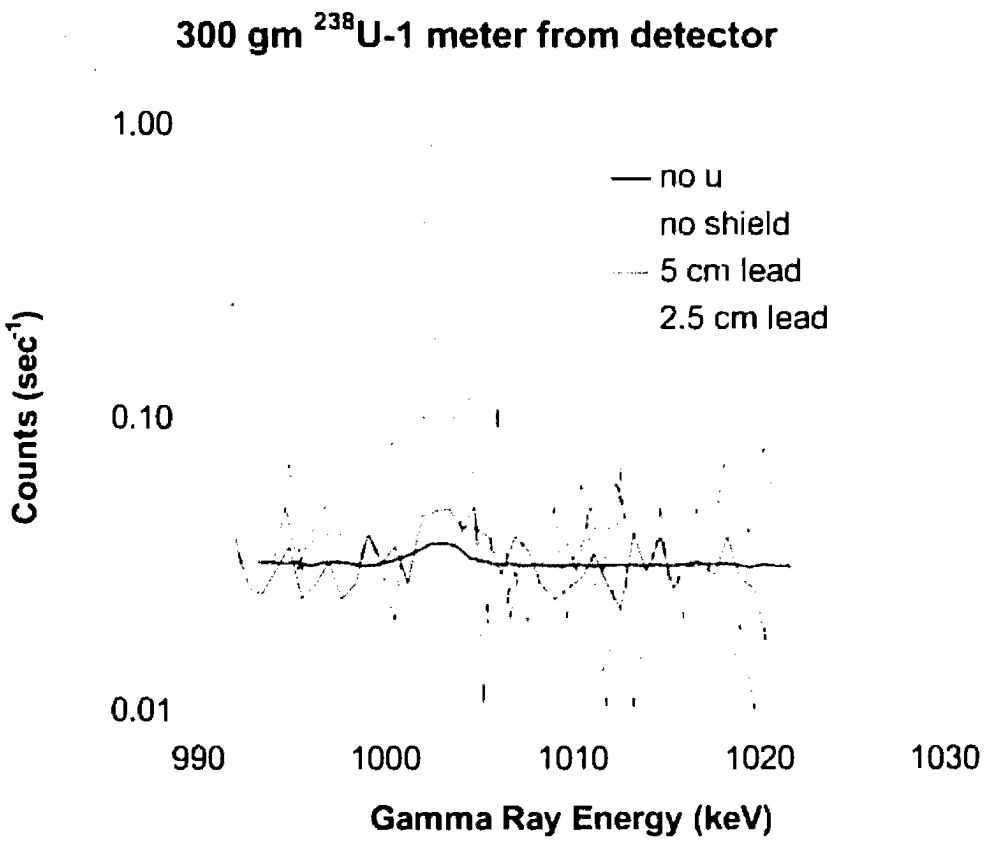
Conventional Technologies: High resolution γ-ray counting

Nuclear material is radioactive:

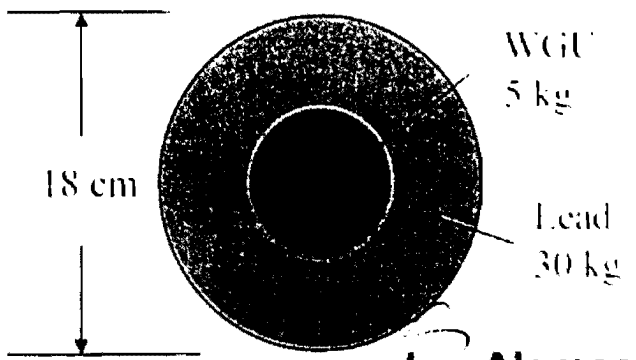
Weapon grade uranium (WGU): 10% ^{238}U 90% ^{235}U



Unshielded Kg quantities of highly enriched uranium can be detected with high reliability with 1 minute counting times by detecting γ's from the ^{238}U impurity.

Shielding threat object requires ~5 cm of lead, gold, tungsten, or other high-Z material

Small well shielded package



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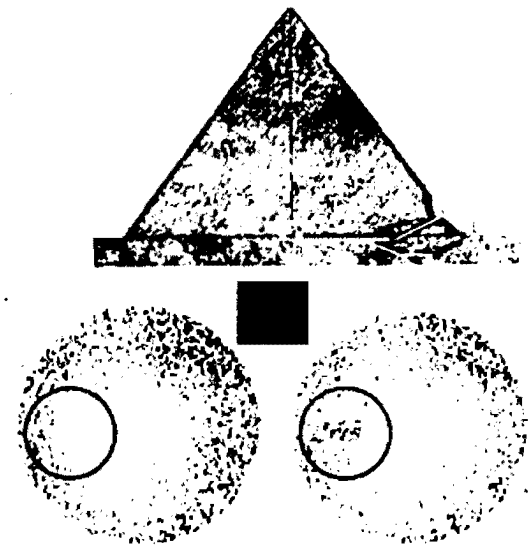
L. W. Alvarez, et al. used Range Radiography to look at a pyamid-this is *not* what we are doing.

Science, **167**, p. 832 (1970)
"Search for Hidden Chambers in the Pyramids"

Luis W. Alvarez *et al.*



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Provided by: Roy Schwitters

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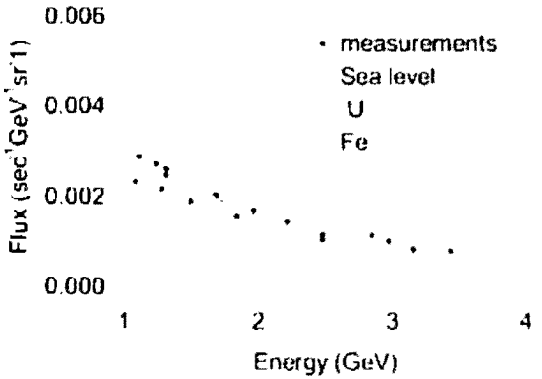
Charged particle radiography is a new LANL invention (1995) and is much more sensitive than range radiography.

How well can a 1000 cm^3 volume of uranium be measured in 1 minute

Range

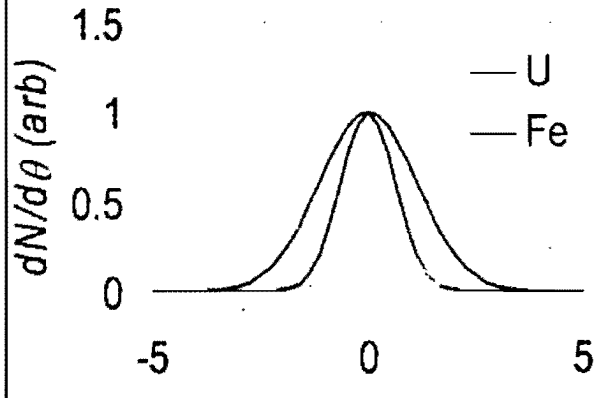


$$\Delta l = \frac{\lambda}{\sqrt{N}}$$

$$\lambda \approx 120\,\text{cm}$$

$$\frac{\Delta l}{l} \approx 1.2$$

Multiple Coulomb scattering



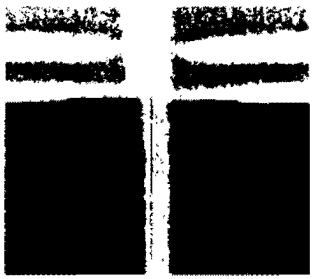
$$\Delta l = \frac{2}{\sqrt{2N}}$$

$$l = 10\,\text{cm}$$

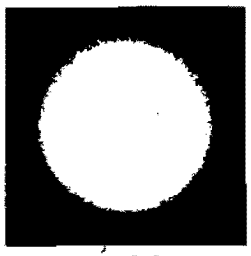
$$\frac{\Delta l}{l} = 0.14$$

30 MeV e

800 MeV



7.5 GeV p



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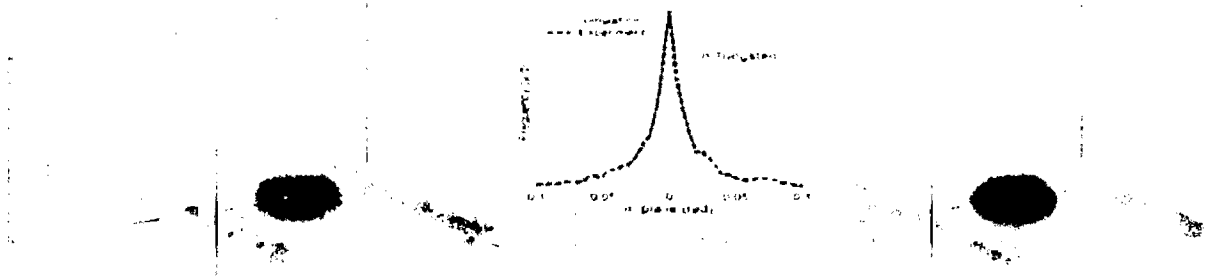
Tomography with cosmic ray muons has been shown to work

Experiment

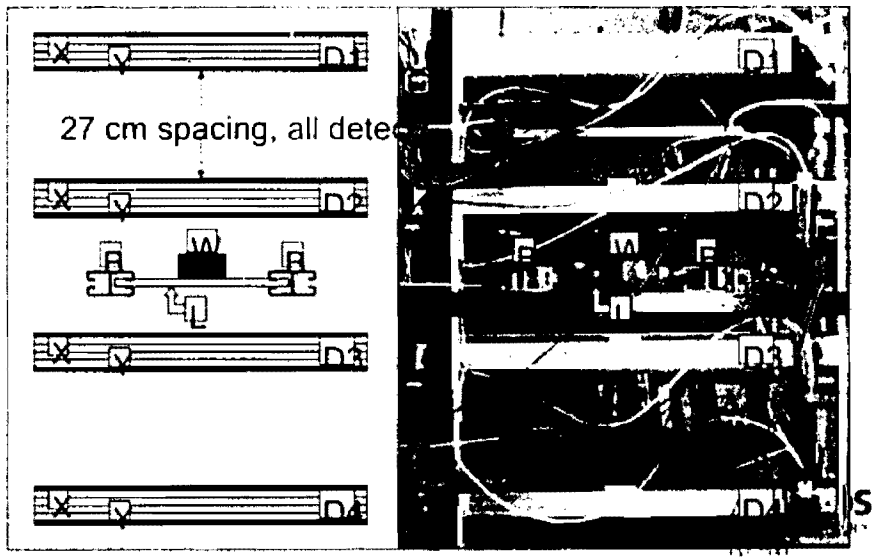
Simulation



Cosmic ray muon generator / multiple scattering simulation.

Good agreement with experiment.

Allows for extrapolation to larger, more complex scenes.



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Cosmic ray muons can provide information with no radiation dose above background and is especially sensitive to good shielding materials

Use tomography to localize scattering

$$\Delta x = \theta_{RMS} L$$
$$= 0.02 \times 200cm$$
$$= 4cm$$

Material	dE/dx	χ
	MeV-cm²/gm	cm
H_2O	2.06	36
Fe	1.87	1.76
Pb	1.54	0.56

Poisson statistics determine the sensitivity

$$\frac{\Delta\theta}{\theta} = \frac{1}{\sqrt{2N}}$$

$N = 100/\text{min}$

$\Delta\theta = 0.07\theta$ after 1 minute of counting

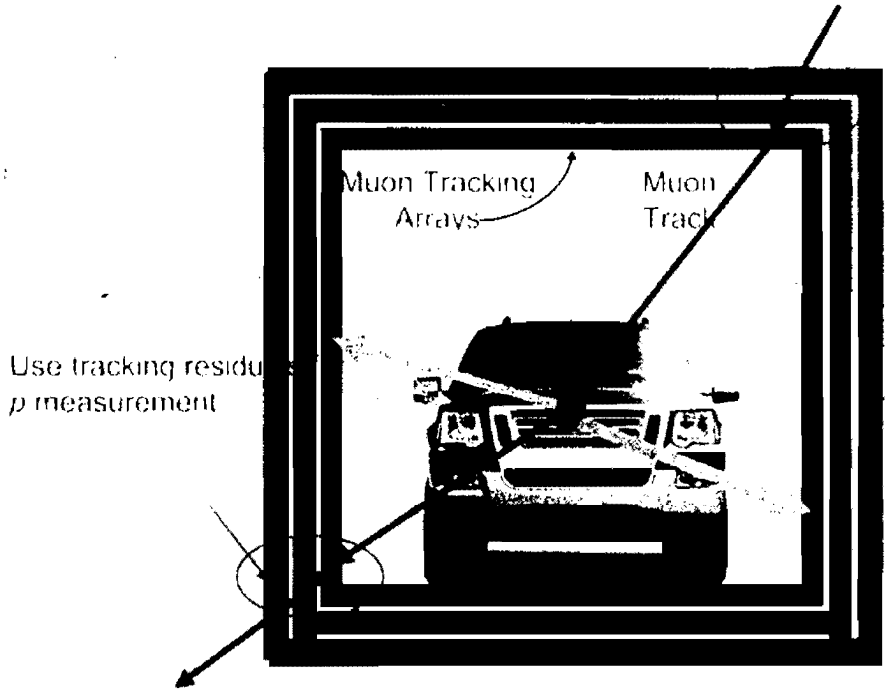
One minute of counting distinguishes a 10 cm cube of iron from a 10 cm cube of lead at 6 std deviations

Multifunction Occupied Passenger Vehicle Scanner

Three lays of drift chambers for robust cosmic ray tracking and tomographic reconstruction

Use track residuals to estimate momentum and reduce residuals

Measure gamma and neutron radiation with same detector



Cosmic ray muon tomography

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Time evolution of signal

15 sec

30 sec

60 sec

No threat

Threat object

Threat
1000 cc tungsten

1 hour exposure

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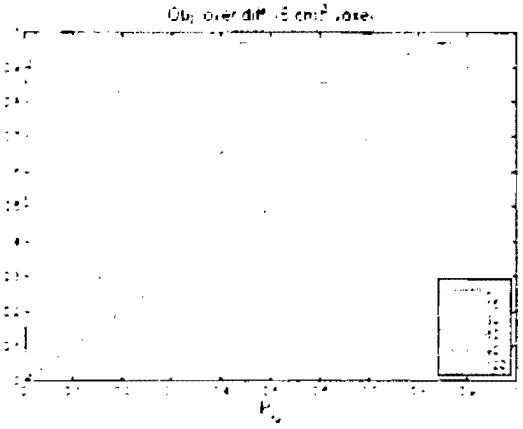
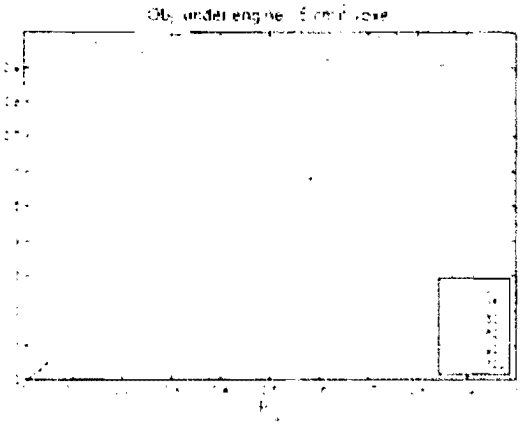
Receiver Operator Characteristic

Object over the differential

Object under the engine

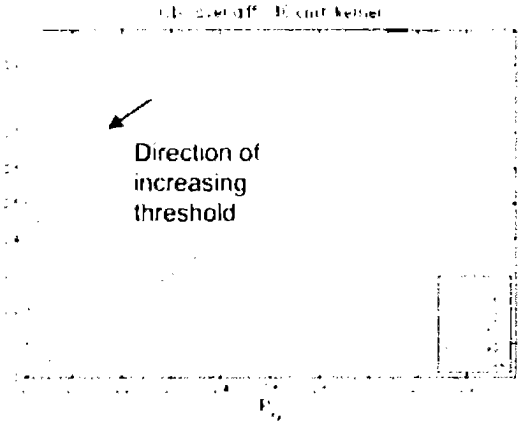
Single Voxel threshold
125 cc

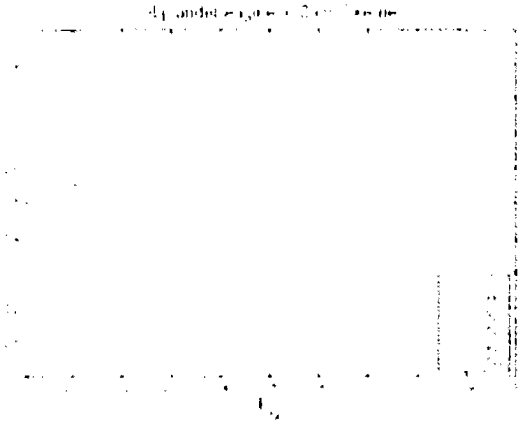




Time
0
15
30
60
120

8 voxel threshold
1000 cc





Direction of increasing threshold

$P_{detection}$

P_{false}

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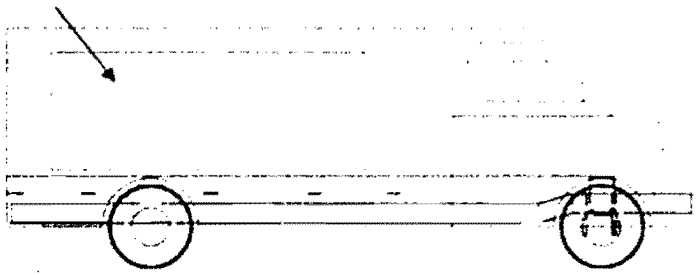
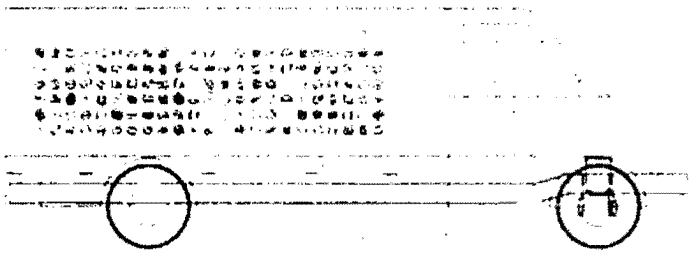
Cluttered scenes

Boreated plywood stack



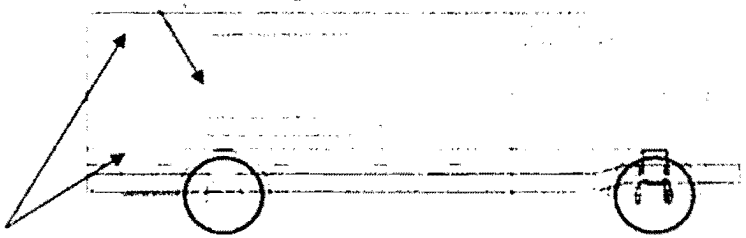
Plywood 4200 lbs

Cluttered cargo with steel aluminum, glass, AlBeMet



Total weight 7400 lbs

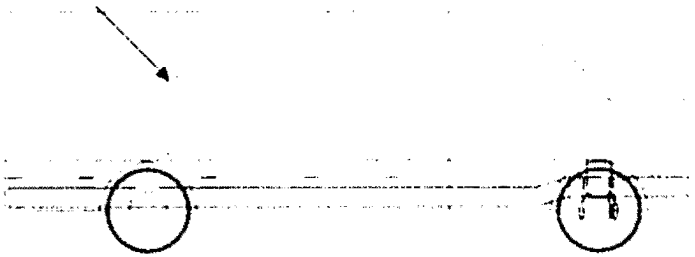
Welder with shielding



¼ " Steel plates

Welder 800 lbs
Plates 1000 lbs each
Total 2800 lbs

4" thick wall steel box
Filled with polyethylene



Steel 4300 lbs
Polyethylene 475 lbs

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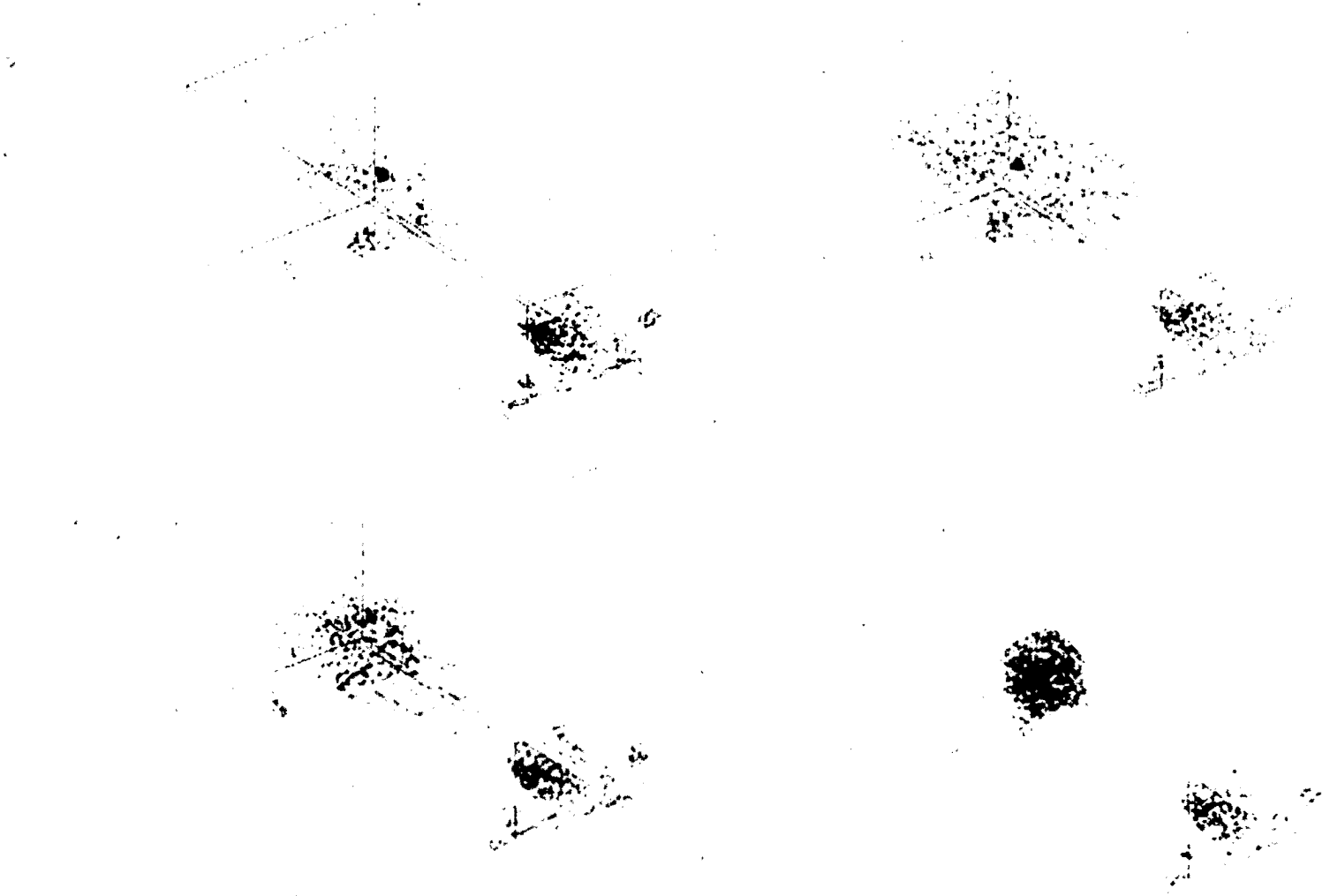
One Minute reconstructions



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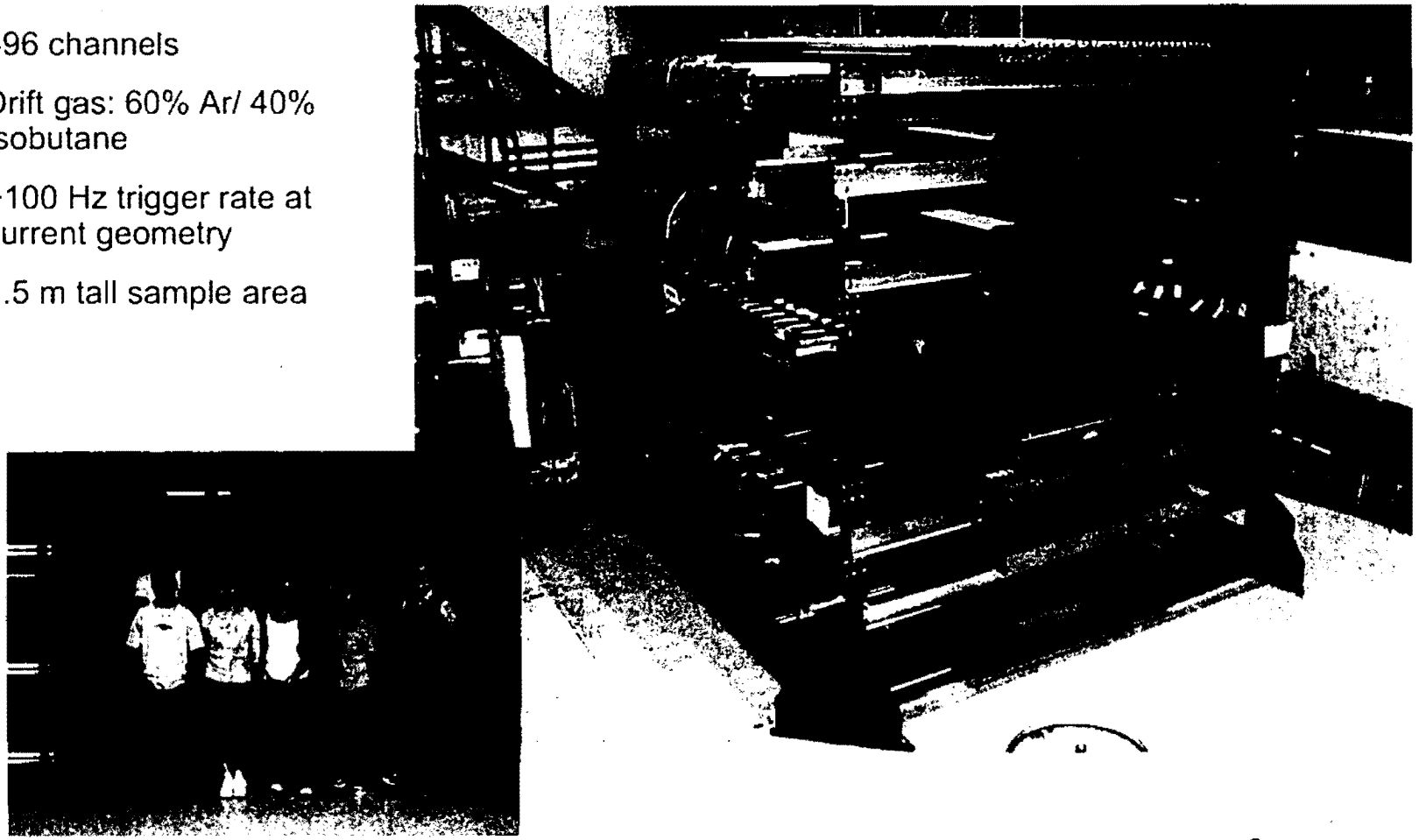
Large Muon Tracker at LANL

896 channels

Drift gas: 60% Ar/ 40% Isobutane

~100 Hz trigger rate at current geometry

1.5 m tall sample area



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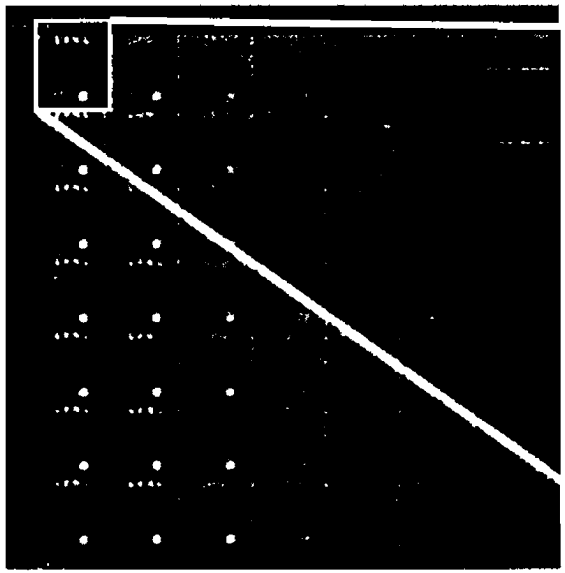
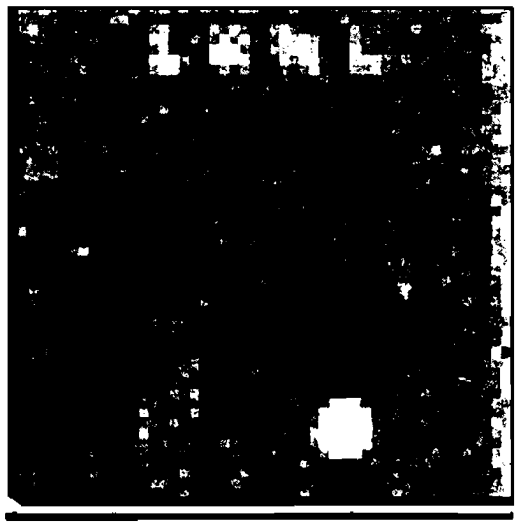
Objects on the LMT table





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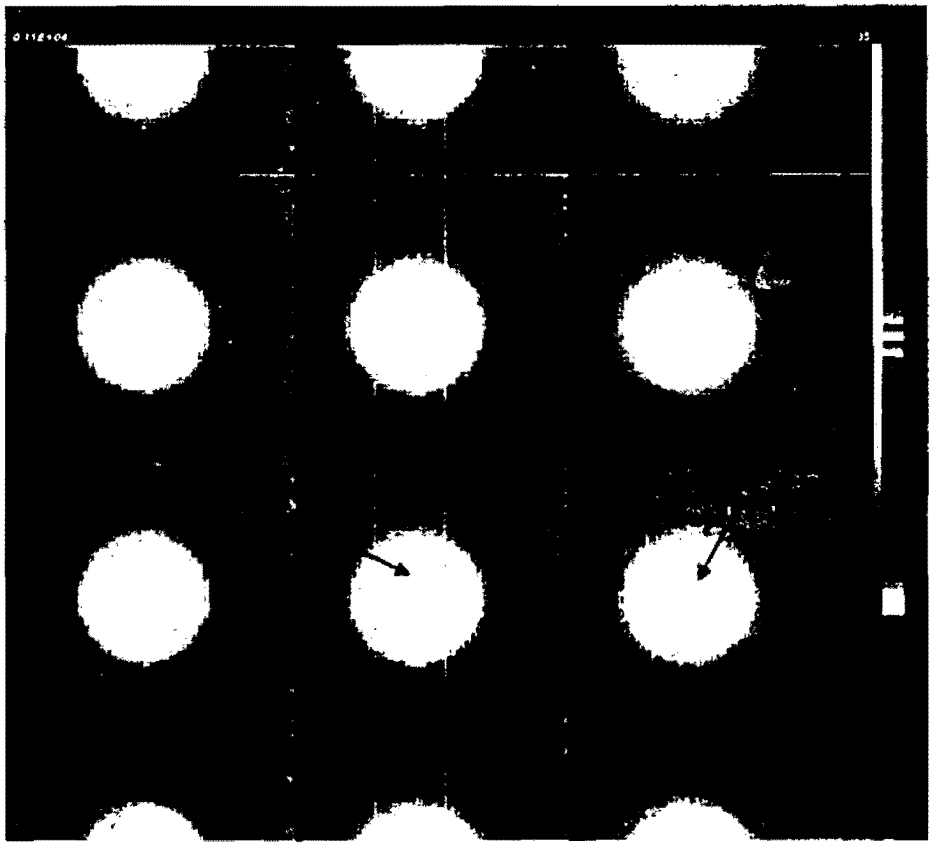
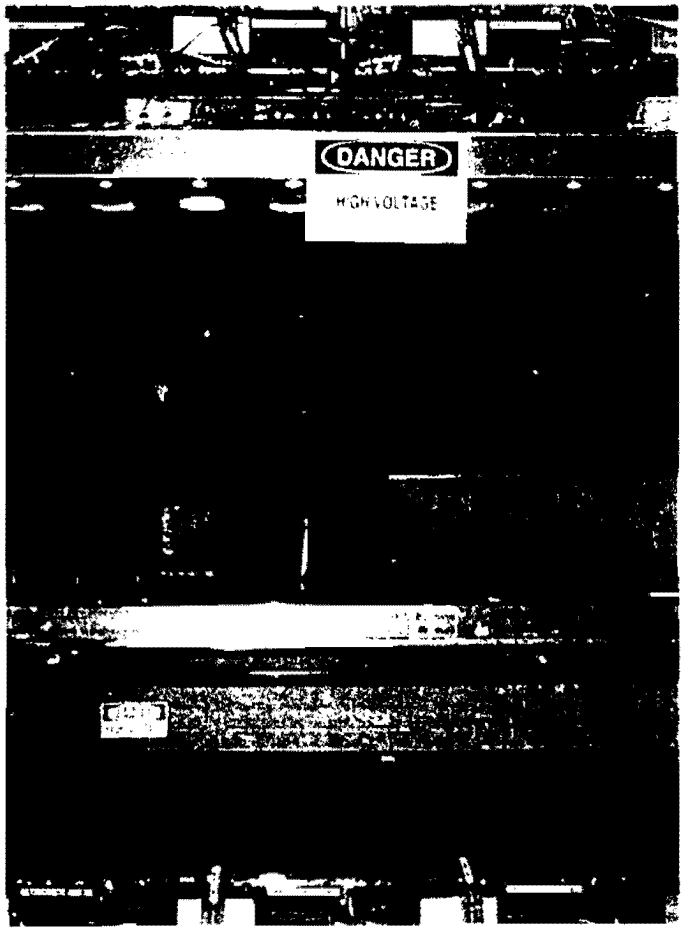
The same objects hidden in an 800 lb 40 gallon barrel of sand





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Conclusions

Simulations show muon tomography can provide sub-one minute threat object detection on occupied personal vehicles.

Experiments are being used to refine the technique and discover problems.

Cosmic ray tracking detectors can aslo be used for neutron and gamma ray counting.

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