The MUON CARGO project: maritime transport container and vehicle inspection by means of muon scattering tomography

Aitor Orio Alonso[1 3] Pablo Martínez Ruiz del Árbol[3] Carlos Díez González[1]
Pablo Gómez García[1]

[1]Muon Tomography Systems S.L - Bilbao, Spain

[2]Instituto de Física de Cantabria (IFCA) - Universidad de Cantabria - Santander, Spain

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Muographers, Naples
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Introduction

The challenge: automated inspection of containers and vehicles where goods and materials are carried

4-40 M TEU/year

2h/container

<5% inspections

150-300€/inspection

Current solutions

Canine units: efficient but affected by fatigue and mood swings of the animals.

X-rays: harmful for operators. Require large exclusion areas, long inspection time (>15 minutes per container), and are easily shielded.

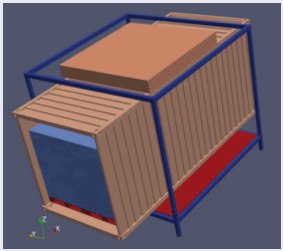
Neutron detectors: Only for radioactive materials, high false positive rate.

Introduction

MUON CARGO detection portal

A muon detection portal of 9 m² will be built, and installed in the Port of Santander (Cantabria, Spain).

MUON CARGO scanner



The MUON CARGO project

9m² prototype in 2024

The MUON CARGO project [3], is co-financed by **Puertos del Estado [1]** (public business entity under the Spanish Ministry of Transport, Mobility and Urban Agenda).

- **Budget: 650.000€**
- **In collaboration with IFCA** (Instituto de Física de Cantabria - Universidad de Cantabria)
- **Three main activties**: Software and algorithms (42.000€), manufacturing (420.000€), and field tests (188.000€)
- **Final result: 9m² muography scanner prototype** installed in the port of Santander

MWPC detectors

Modular MWPC (Multi-Wire proportional chambers)

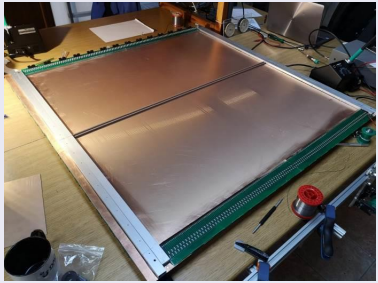
1m² MWPC detector

- 4 chambers (2D grids) per m²
- 4 mm separated wires
- $\sigma_{hits} = 1.15\ mm$
- 224 wires
- 89.6 x 89.6 cm² active detection surface

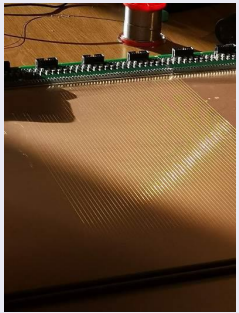
Manufacturing of 3x3 m² modular detector, based on previous designs

MWPC detectors

Details about manufacturing



Wire layer of a MWPC

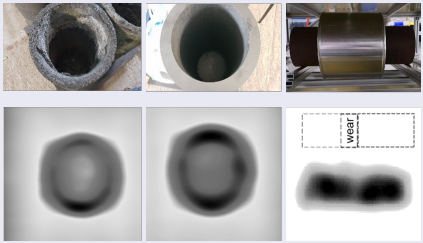


Wire soldering process

MWPC detectors

The technology has been matured over 5 years of work and research in the industry

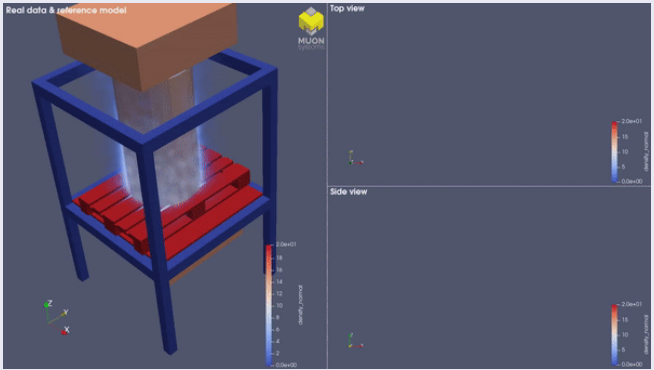
Crucible measurement



POCA reconstruction of damaged crucible (left), new crucible (centre), and insulated pipe with interior wear (right)

MWPC detectors

The technology has been matured over 5 years of work and research in the industry



MWPC detectors

Tested in the field: civil engineering

Measurements in a railway tunnel.
Absorption mode, checking tunnel overburden and voids. Recent measurements, one week campaign. Data analysis ongoing.

Software

Software and imaging techniques

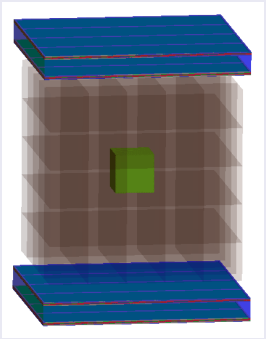
The project involves development of **AI and scattering muography algorithms, on the basis of previous work [2]**

POCA and other muography algorithms will be used to feed **autoencoders for anomaly detection**. The application of **variants of classic MLEM algorithm** are also considered. Ongoing work.

In addition to muography algorithm outputs, **complementary data** about the mass of the cargo, declared goods, and other available information will be exploited.

Preliminary results

Simplified scenarios



Simplified scenario

- Active detection surface = 268.8 x 268.8 cm^2
- Volume of the cargo = 250 x 250 x 250 cm^3
- Volume of the voxels = 50 x 50 x 50 cm^3
- Target allways in the central voxel (green)

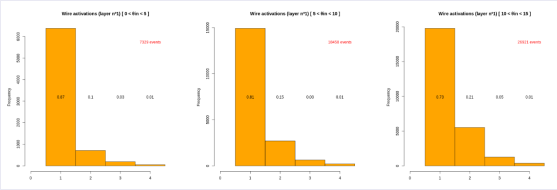
- All the voxels filled with base material
- Target voxel with different material (green)

- Base materials: Scrap (X0 = 8.833 cm), and Organic (X0 = 364.3 cm)
- Target materials: Guns (X0 = 3.533 cm), Cannabis (X0 = 145.7 cm)

Preliminary results

Simulation

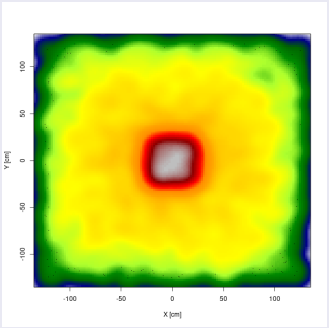
1. Cosmic muon flux has been generated with CRY.
2. Geant4 has been used to simulate the interaction of muons with matter.
3. Simulations consider the design of our MWPC: resolution, and materials.
4. Multiple wire activation depending on the incident angle of muons.



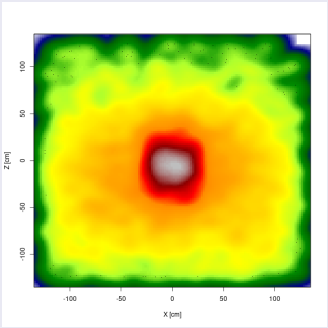
Real world HW data: wire activations depending on muon incidence angle (θ_{in})

Preliminary results

10 minute POCA muography: guns in the central voxel (50x50x50cm³) surrounded by organic material



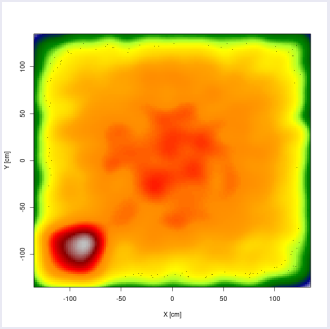
Top view



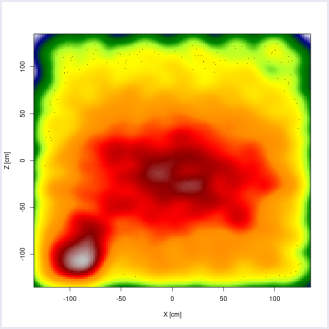
Side view

Preliminary results

10 minute POCA muography: guns in the bottom left corner (50x50x50cm³) surrounded by organic material



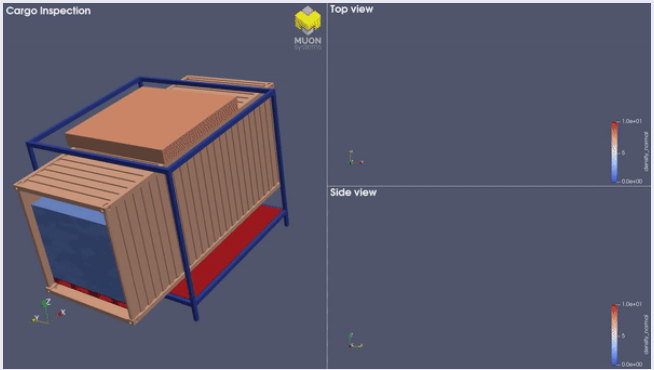
Top view



Side view

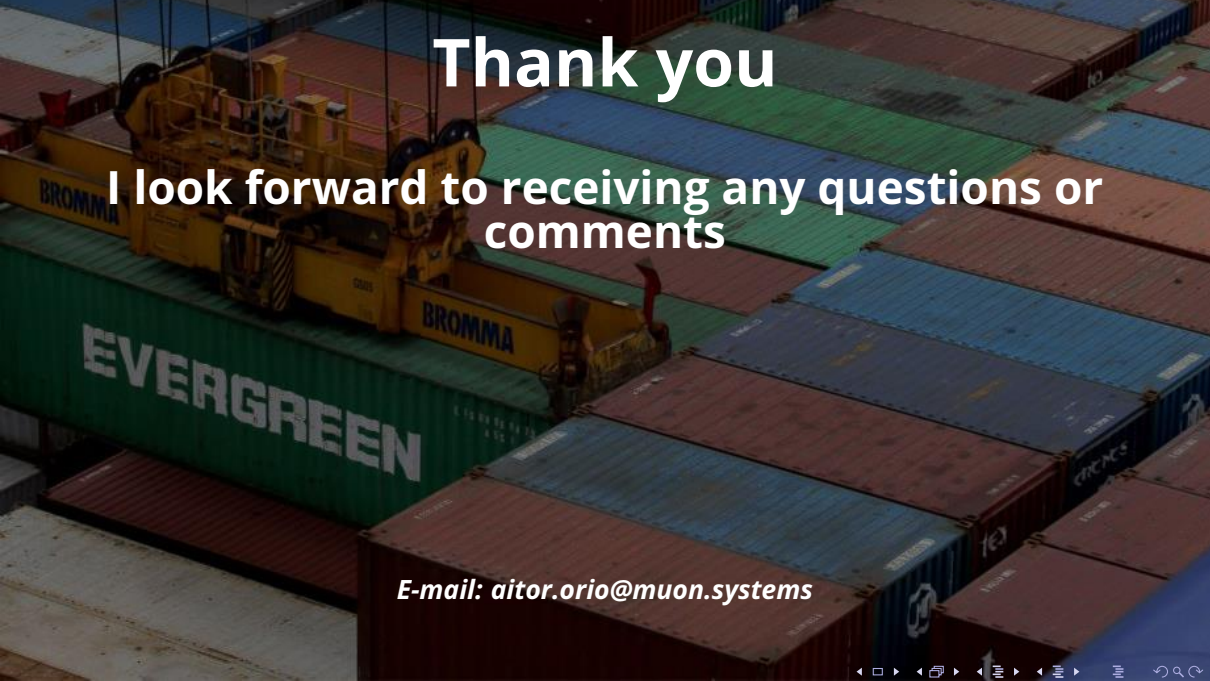
Preliminary results

Detailed scenarios



Conclusions

1. Muon Cargo is a project funded by the Spanish Government to install a **muography portal** for container inspection in the port of Santander (Cantabria, Spain).
2. The portal will have **9 m² of detectors using MWPC chambers** that have been widely tested in the industry sector.
3. From a software point of view several approaches are being developed: **from classic algorithms to new developments for anomaly detection**.
4. **The project will be finished by the end of 2024**, currently detectors are under construction. More results will come soon.



Thank you

I look forward to receiving any questions or comments

E-mail: aitor.orio@muon.systems

Materials used to simulate the base material of the cargoes and the targets.

Material	X0 (cm)	d (g/cm³)	Composition
Scrap	8.833	1.570	20% Steel + 80% Air
Organic	364.3	0.100	10% Organic + 90% Air
Guns	3.533	3.925	50% Steel + 50% Air
Cannabis	145.7	0.250	25% Organic + 75% Air

Table: Material definition.

References

Puertos del Estado
https://www.puertos.es/es-es

P. Martinez, A. Orio, C. Díez, and P. Garcıa (2022)
Applications of Muography to the Industrial Sector
Journal of Advanced Instrumentation in Science, vol. 2022, Apr. 2022. https://doi.org/10.31526/jais.2022.267

MUON CARGO project
https://muon.systems/en/muoncargo