MUON TOMOGRAPHY

FROM COSMIC RAYS TO THE LOUSAL MINE - PORTUGAL

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WHY ?

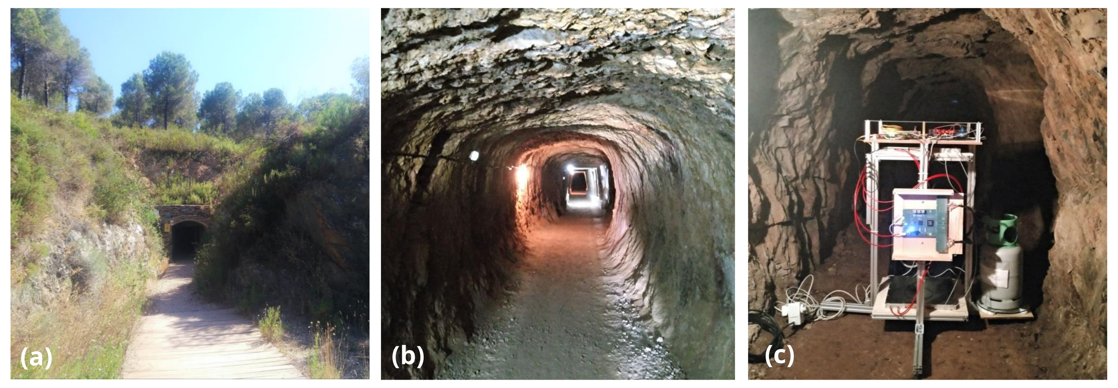
LIP and University of Évora share the vision of developing and implementing muon tomography in Portugal, applied to the field of geophysics. LIP is connected to CERN and focuses on particle physics research and development of particle detectors. U. Évora contributes with its vast experience in geophysics to shape the technique in its application. This is an ongoing project and its contribution serves to affirm muon tomography as an accessible geological mapping and prospecting method and as a complementary geophysical survey technique.

OBJECTIVES

The muon tomography will map the structures and masses of ore already known in the ground above the Lousal Mine and will improve the geological information with new data. A detailed gravimetric survey will also be performed in order to combine gravimetry and muography in a joint inversion of the data in order to obtain a 3D density profile.

LOUSAL MINE

The Lousal Mine is an inactive and well-mapped mine, located in the center of Portugal. Because of that, it is a good place to test the sensitivity of the telescopes. The observation will take place about 20 m below ground level, inside the Valdemar Gallery, where a muon telescope prototype was installed for testing and to collect preliminary information.



(a), (b) entrance and interior of the Valdemar Gallery; (c) muon telescope prototype built in the LIP and installed in the mine.

COSMIC RAYS

Most cosmic rays are protons traveling at nearly the speed of light. They hit the Earth coming from all directions, and when they collide with the atmosphere, they produce chain collisions that cause particle showers in which the muons are born.

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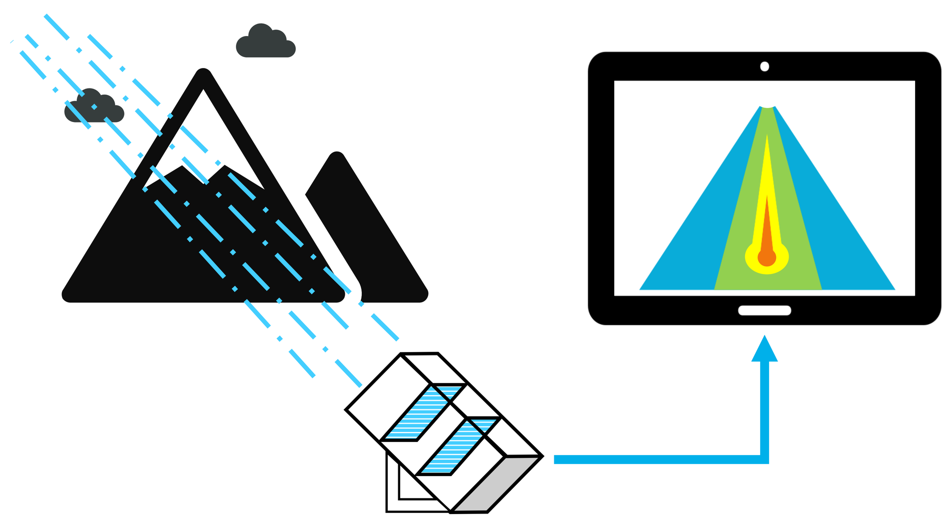
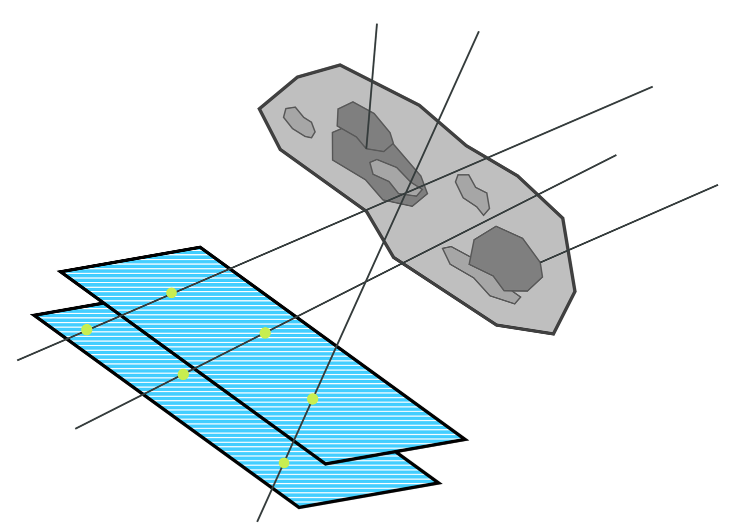


The telescope registers the muon flux coming from the direction of the observation. The observed flux reflects the transmission and absorption of the muons through matter. The set of detected particles produces muographs, that are radiographs of muons.



The denser the material, the more muons are absorbed in that direction. The muons transmitted to the detectors are those that have enough energy to pass through the entire column of matter in their path. The muon tomography thus allows determining the average density distribution based on the observed flux attenuation.

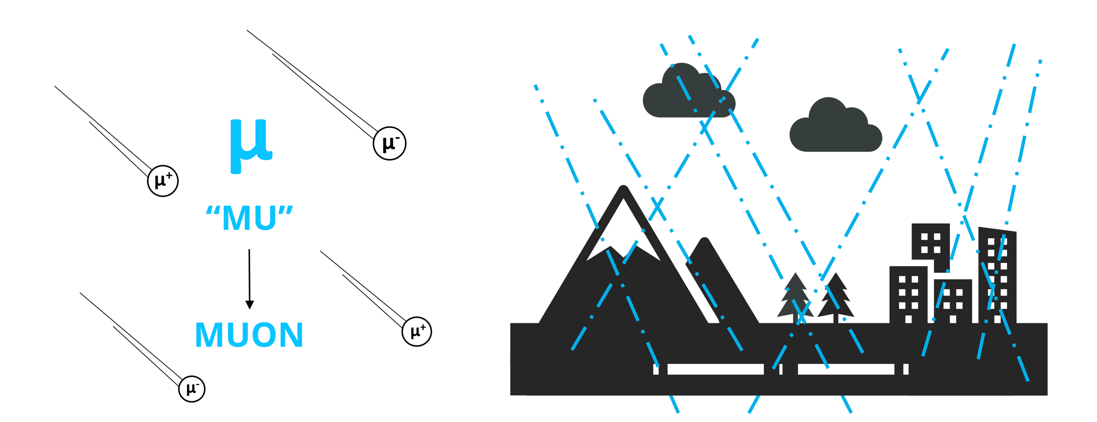
REFERENCE WORKS

Checchia, P. 2016. "Review of Possible Applications of Cosmic Muon Tomography." Journal of Instrumentation 11(12).

Procureur, S. 2018. "Muon Imaging: Principles, Technologies and Applications." Nuclear Instruments and Methods in Physics Research, A 878 (2018), 169–79.

Rhodes, Christopher J. 2015. "Muon Tomography: Looking inside Dangerous Places" Science Progress, 98(3), 291-299.

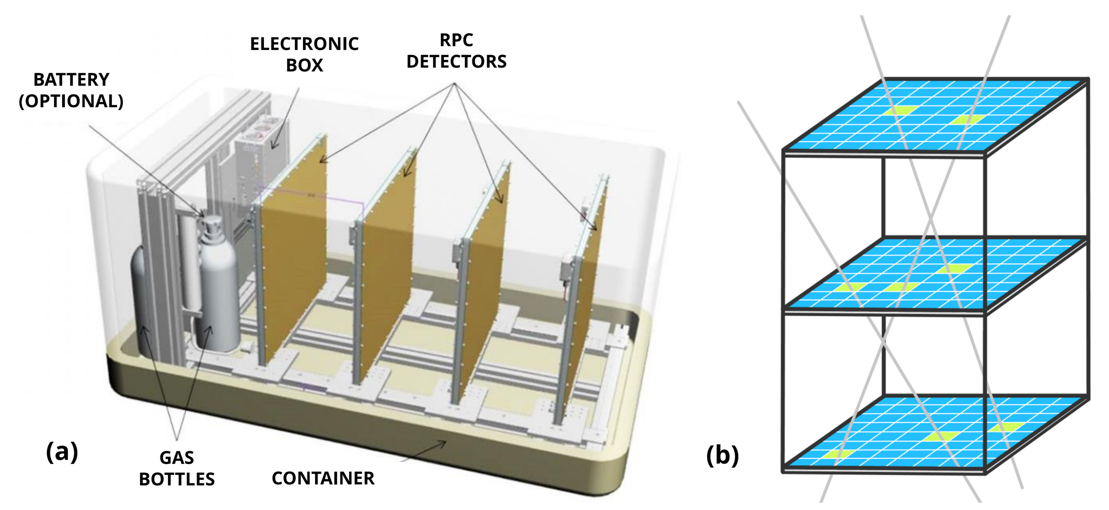
WHAT ARE MUONS ?



Muons are elemental particles like electrons, but with a mass 200 times greater. With the required kinetic energy, they can pass through huge amounts of matter and by interacting with other particles, they are easy to detect. Every square meter of Earth's surface is hit by roughly 250 muons per second from all directions.

MUON TELESCOPE

The telescopes built in the LIP use Resistive Plate Chambers (RPCs) as particle detectors. Each detector contains a mixture of an ionizing gas that produces a signal each time a muon passes through it. The detection of these particles in the different planes of the RPCs allows to determine the direction of its trajectory.



(a) IRFU-CEA telescope arrangement illustrating a muon telescope with RPCs; (b) example of the determination of the trajectories of muons from their detection along the RPC detectors.

ACKNOWLEDGEMENTS

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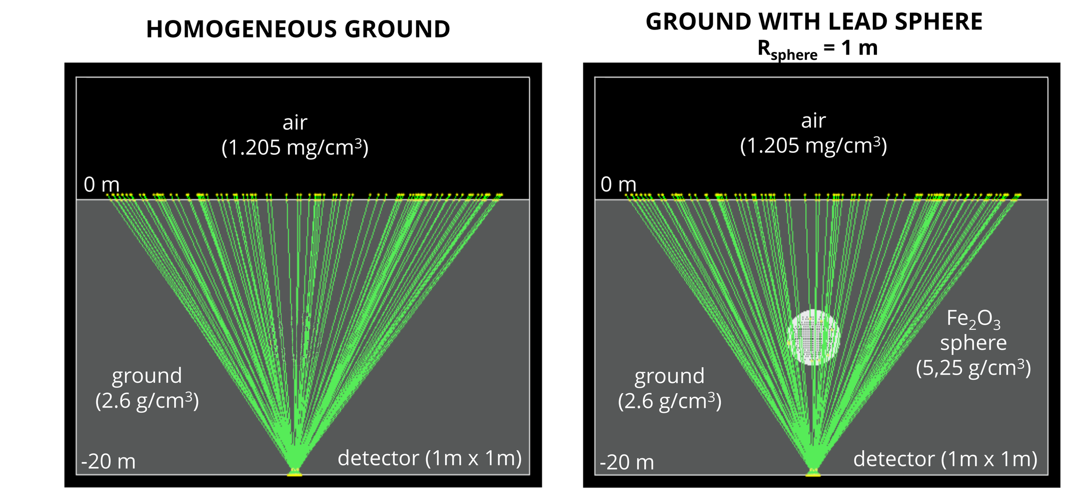
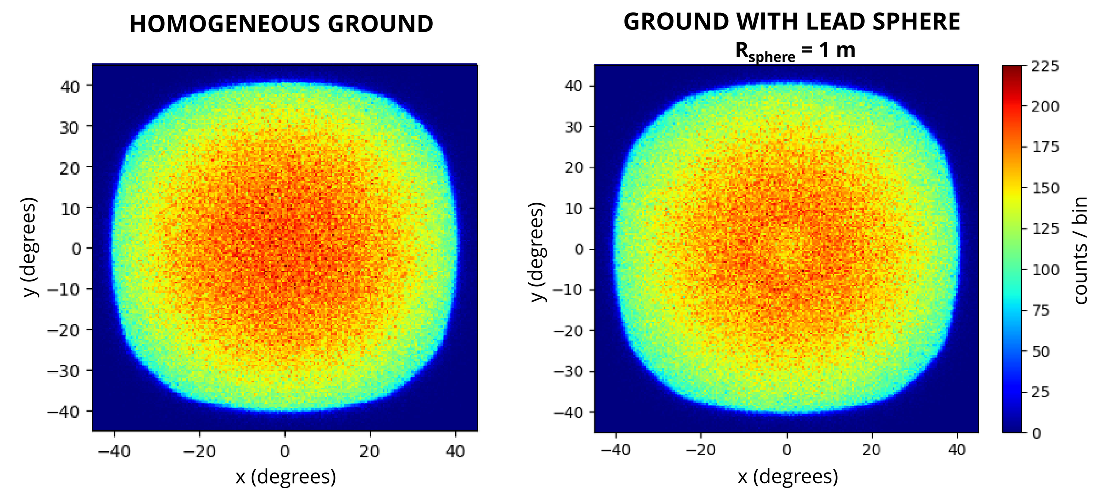
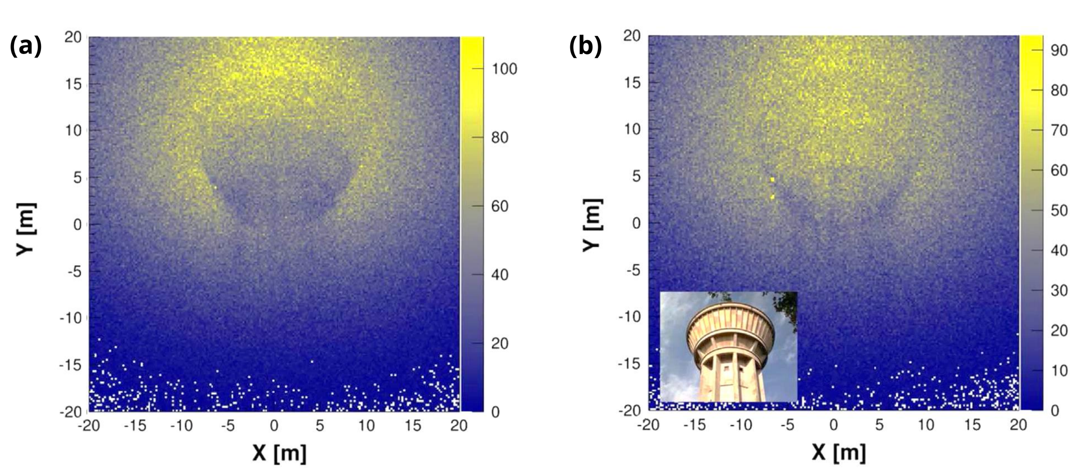
SIMULATIONS AND EXAMPLE



The path of the particles is simulated using GEANT4 software. The first simulated case presents a ground medium with homogeneous density and the second case presents the same medium but with a Fe_2O_3 sphere of greater density inside. The observation time for each one is 2 days. The muon flux arriving at a detector placed 20 meters below ground level is registered for each case. Only trajectories of detected muons are shown above.



The density of the materials present in the area under observation will determine the minimum required energy that a muon needs to be transmitted. By knowing the distribution of the muon flux, if the observed flux value is lower than expected, for a homogeneous medium as in the cases shown, this will correspond to a crossed material with a higher relative density, and vice versa. The presence of the lead sphere is reflected by a decrease of the measured flux in a circular area in its direction. This is the principle to obtain muographs with the average density distribution of sites with a more complex geology.



The example above are real muographs obtained by Boutille et al. (2016) while observing the Saclay water tower (France). The structure of the tower is easy to identify and, from (a) to (b), the tower water tank has a variation in its density, because in (a) it is full of water and in (b) it's empty. This example illustrates the sensibility of the muon tomography.

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