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Identification and three-dimensional localization of cavities at the Temperino mine (Tuscany-Italy) with the muon imaging technique

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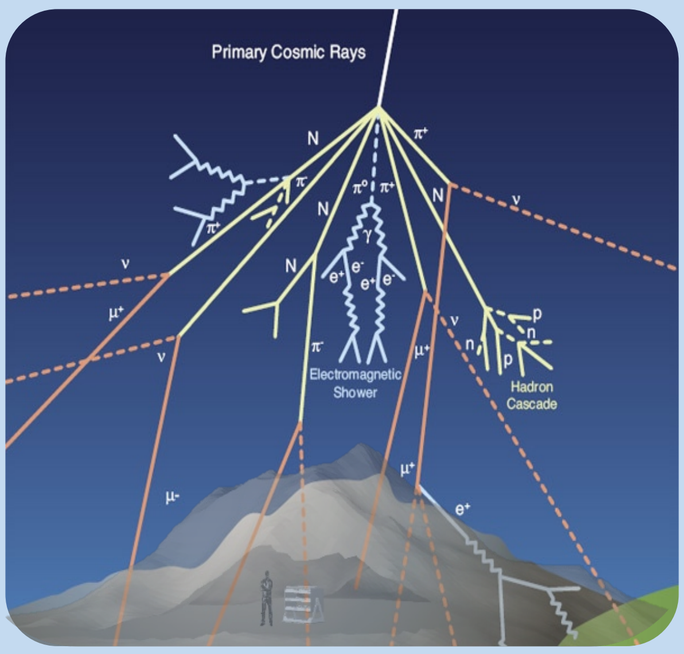
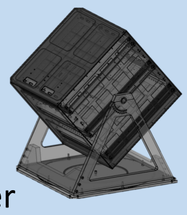
Muon radiography technique

Muon radiography is an ***imaging technique*** that allows to create 2D or 3D images of the internal density distribution of the object under study (target) through *transmission measurements of cosmic muons*. The detectors used are charged particle **trackers.**



✓ Non-invasive technique

✓ Various fields of application: archaeological, geological, civil engineering and nuclear safety, industrial field, monitoring of large structures



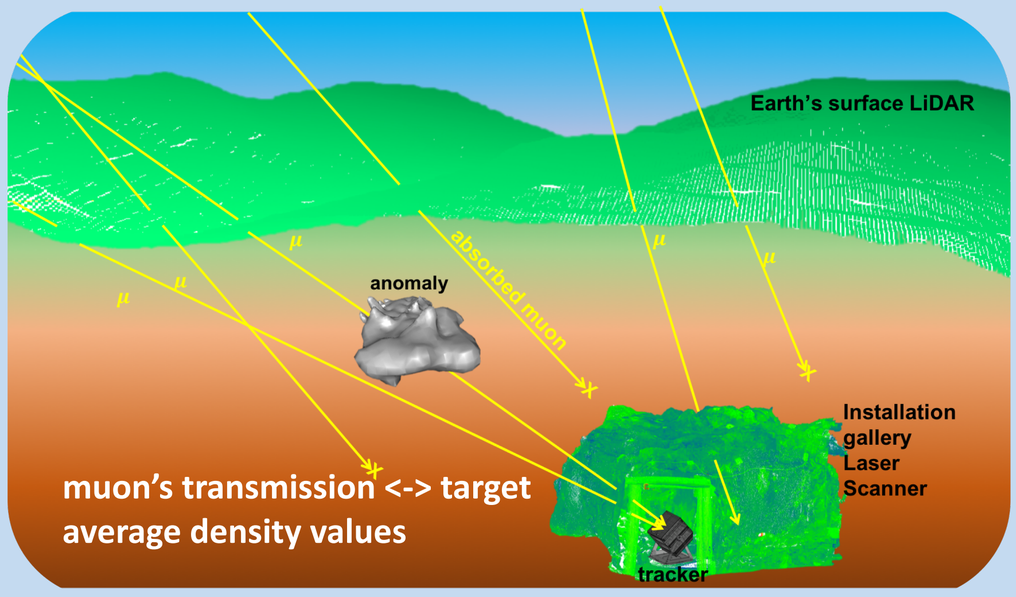
tracker

Muon radiography: geological field
Objective of the study: search for low density anomalies (cavities/tunnel) in a mine

✓ mapping of cavities in the areas already exploited

✓ important from an archaeological point of view

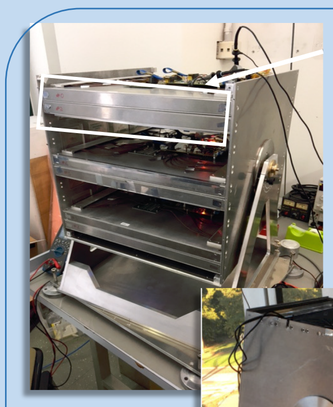
✓ possibility of securing the mine



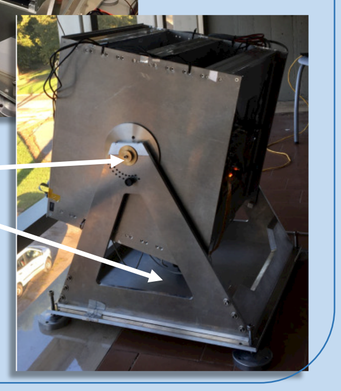
Detector

MIMA tracker (**M**uon **I**maging for **M**ining and **A**rchaeology)

- 3 X-Y tracking modules of plastic scintillator
- total dimensions approx. (50 x 50 x 50) cm³
- spatial resolution ~2mm, angular resolution 0.3-0.4 °
- altazimuth orientation system
- acceptance $\pm 65°$



module X-Y



altazimuth orientation system

MIMA at the Temperino mine

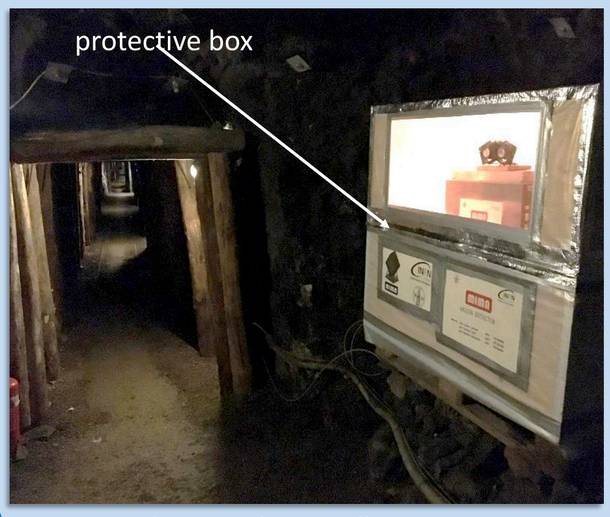
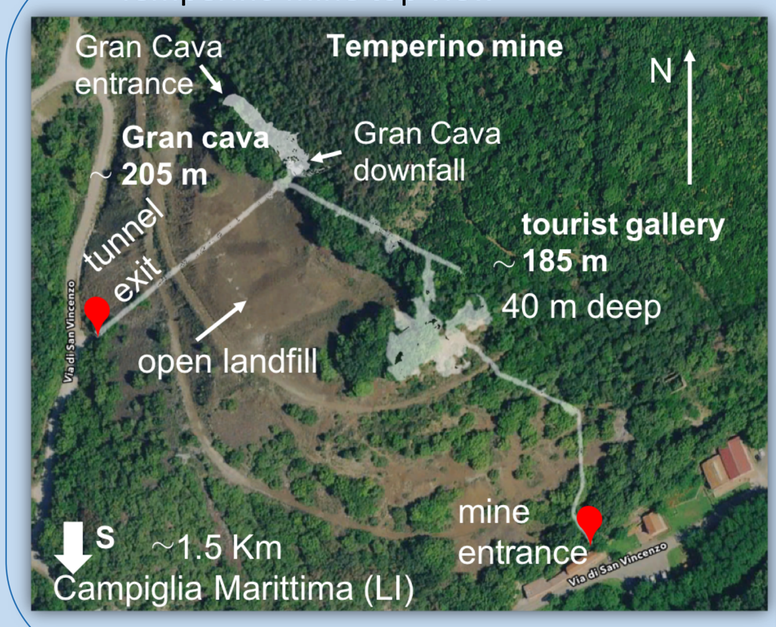


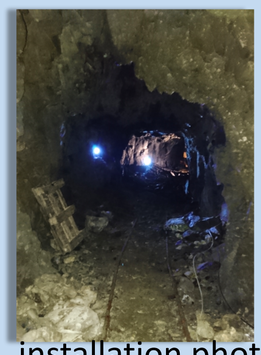
photo at the installation point

Temperino mine (Tuscany-LI)

- Situ: Archaeological Mines Park of San Silvestro in Campiglia Marittima (LI).
- Mining activity: Etruscan origins, medieval period, closing in 1980
- Mining material: Pb, Zn, Ag, Cu and Fe minerals concentrated in skarn

Temperino mine top view



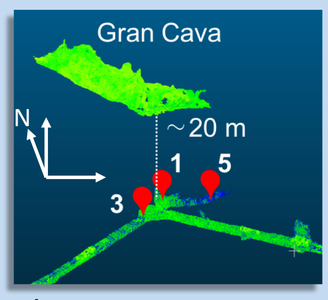


installation photos

3D reconstruction of the known cavity called Gran Cava and other low-density signals observed by MIMA

Triangulation technique for a first estimate of the 3D cavities development

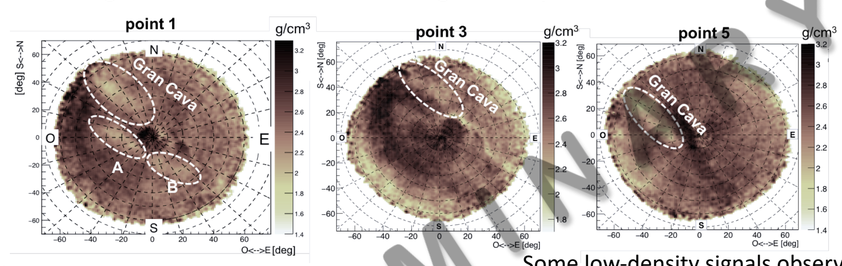
Three installation points



Laser scanner Point cloud

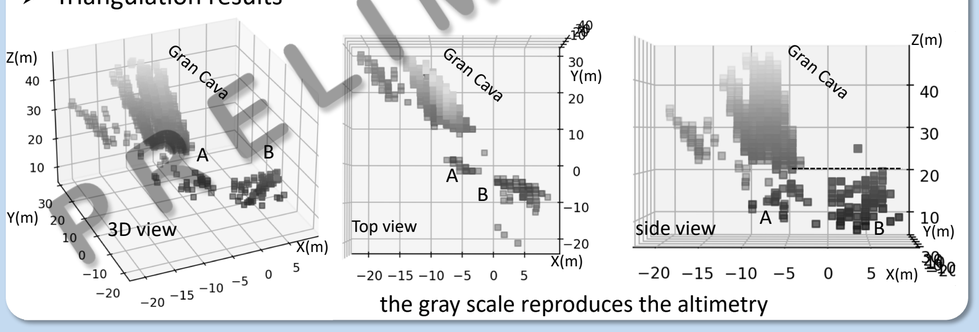
40 m below ground level

➢ 2D angular distribution of the average density



Some low-density signals observed

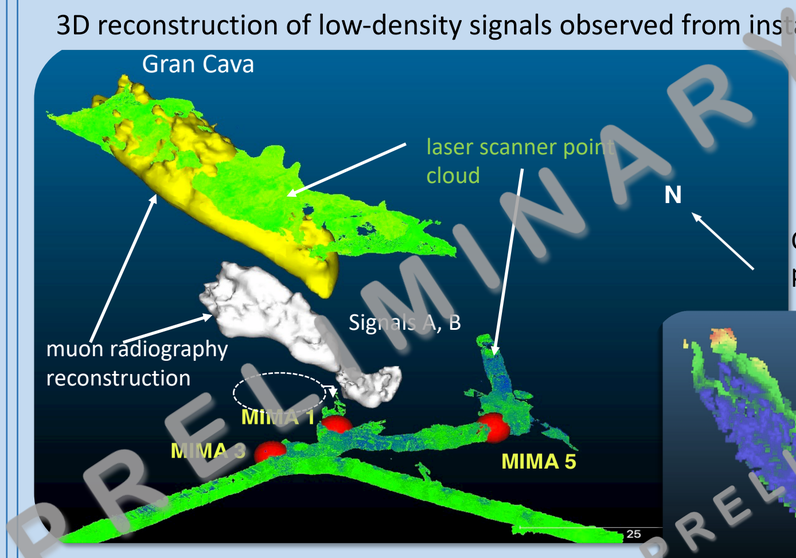
➢ Triangulation results



the gray scale reproduces the altimetry

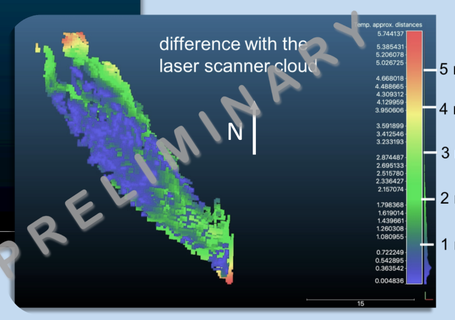
Innovative algorithm based on backprojection technique

3D reconstruction of low-density signals observed from installation 1



The Gran Cava case

CloudCompare point-point difference



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- Borselli D., Muographic study of the Temperino mine with the MIMA detector: development and test of an algorithm for identification and reconstruction of cavities in three dimensions, Master's degree thesis, UNIFI, AA 2018-2019.