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Title: Absorption muography as a support technique for non-invasive research and three-dimensional localization of tombs in archaeological sites: a case study from Palazzone Necropolis (Perugia - Italy)

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Absorption muography is a non-invasive imaging technique that exploits the penetrating power of atmospheric muons into matter to obtain two-dimensional muon transmission images of the monitored structure. The detectors used are charge particle trackers. Through comparison with simulations containing the known target structure, it is possible to generate density images and identify potential anomalies. Three-dimensional images of the anomalies are reconstructed using specialized algorithms. Absorption muography enables the monitoring of large structures and it is also particularly useful in the archaeological field for a mapping of low-density anomalies potentially related to unknown or inaccessible tombs or tunnels.

The necropolis of Palazzone, located South of Perugia (Italy), dating back to Etruscan times, contains about 200 known tombs, some of which, such as the Hypogeum of the Volumni, can be visited thanks to a touristic route. The eastern area of the necropolis, on the other hand, does not have a touristic path and is partially unknown. The objective of the muographic measurement campaign is to support the re-evaluation of this archaeological area by searching for new anthropic cavities and identifying them three-dimensionally.

Most of the techniques for 3D tomographic reconstruction are based on a combination of results from several measurements performed from different points of view within the site. One of the goals of this study is to obtain three-dimensional information starting from a single muographic measurement by exploiting an image focusing algorithm (the back-projection algorithm [1]). For this purpose, an area that contains a known large cavity called "tomb n.11" was used as the reference cavity for the three-dimensional reconstruction algorithm.

The measurement was carried out with a small (50x50x50) cm³ muon tracker called MIMA (Muon Imaging for Mining and Archeology) developed by the INFN section in Florence. The project is conducted by INFN FI, the University of Perugia and the direction of the Palazzone archaeological park.

The results of the three-dimensional reconstruction of the reference cavity and other low-density signals identified in the two-dimensional density map are presented, showing the potential of the algorithm in this field.

[1] Bonechi, L. *et al.* A projective reconstruction method of underground or hidden structures using atmospheric muon absorption data. *J. Instrum.* **10**, P02003. <https://doi.org/10.1088/1748-0221/10/02/p02003> (2015).