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Three years of muography at Mount Etna: results and future perspectives

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Mount Etna Volcano is characterized by the Summit Craters system which represents the crucial point of its persistent tectonic activity. The Muography of Etna Volcano project started in 2016 and the first muon-tracking telescope prototype has been installed on the slope of North-East Crater from August 2017 to October 2019 (Figure 1). The aim of the project was to find anomalies in the density of volcanic edifice and monitor their time evolution. In this work, the major results achieved by the project are presented, including the detection of an expanding underground cavity months before the collapse of the crater floor, but we also want to focus on our strategy and plans to realize a muography application at Mount Etna.
In designing the first telescope prototype of the MEV project, built at the Department of Physics and Astronomy (DFA) "E. Majorana" of the University of Catania, all common characteristics among detectors for an out-of-laboratory muography application were included: ruggedness and water-tightness to face every climatic condition at high altitude, power network independence (by means of solar panels and a battery pack) and low consumption, connection to the internet in order to remotely access and operate the telescope. The telescope is designed to work horizontally oriented with three X-Y position-sensitive tracking planes (TP) vertically placed and spaced in the horizontal direction. The distance D between the two external planes is 97 cm . The third TP is located in the middle between the two external planes. Particle detection and tracking are based on scintillating plastic bars technology, with two wavelength-shifting optical fibers (WLS) embedded in to transport the scintillation light to the sensor.
At the base of this design choice, there is the intention to measure at the same time the muon flux coming from the front and back sides of the detector. In this way, it is possible to measure the flux through the object of interest and the flux directly coming from the sky (not attenuated), or "open sky"flux. By comparing these two quantities, we have direct access to the spatial distribution of the absorption coefficient through the target object, which is a quantity related to its opacity, i.e. density integrated over the particle path along the direction of sight of the telescope.
Each TP is completed by a 64 channels Multi-Anode Photomultiplier (MAPMT, mod. Hamamatsu H8500) that allows us to read-out the scintillation light signal. Counting both WLS for each scintillating bars, there are 4 ⊠ N = 396 optical channels for each TP, but only 64 channels on the sensor. The coupling is made possible by a proper routing of the WLS that allows us to minimize the number of corresponding front-end channels by a factor 1/sqrt(N). The choice to develop custom electronic boards allowed to remove all the redundant components that can be found in an evaluation board and to keep only the ones required for the specific purpose. At the end of summer 2018, before the interruption of the second year of the data acquisition campaign, a module to measure particle time-of-flight (TOF) between the external tracking planes was installed. The purpose of this measurement is the correct discrimination of near-horizontal tracks.
The MEV telescope was installed and remained at the measurement site at the base of NE crater from 1st August 2017 till the end of September 2019, thus for more than two years. However, in 2017 and 2018, the whole detector, including solar panels, was buried under a huge snow coverage with the incoming winter. With solar panels covered, the detector went off after a short time and remained quiet during both winters. Only at the beginning of the summer, when the snow melted down, and the measurement site was again reachable by a car, it was possible to restore the power supply and start a new acquisition. However, the detector's design has demonstrated to be able to overcome exceptional weather conditions during winters at high altitudes without detriments to electronics and tracking modules. Only the components outside of the

box were partially damaged, i.e., solar panels and antennas for data transmission over the LTE network, and required to be repaired or substituted.

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