Geophysical Research Abstracts
Vol. 19, EGU2017-6335, 2017
EGU General Assembly 2017

Muon imaging of volcanoes with Cherenkov telescopes

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The quantitative understanding of the inner structure of a volcano is a key feature to model the processes leading to paroxysmal activity and, hence, to mitigate volcanic hazards. To pursue this aim, different geophysical techniques are utilized, that are sensitive to different properties of the rocks (elastic, electrical, density). In most cases, these techniques do not allow to achieve the spatial resolution needed to characterize the shallowest part of the plumbing system and may require dense measurements in active zones, implying a high level of risk.

Volcano imaging through cosmic-ray muons is a promising technique that allows to overcome the above shortcomings. Muons constantly bombard the Earth's surface and can travel through large thicknesses of rock, with an energy loss depending on the amount of crossed matter. By measuring the absorption of muons through a solid body, one can deduce the density distribution inside the target.

To date, muon imaging of volcanic structures has been mainly achieved with scintillation detectors. They are sensitive to noise sourced from (i) the accidental coincidence of vertical EM shower particles, (ii) the fake tracks initiated from horizontal high-energy electrons and low-energy muons (not crossing the target) and (iii) the flux of upward going muons.

A possible alternative to scintillation detectors is given by Cherenkov telescopes. They exploit the Cherenkov light emitted when charged particles (like muons) travel through a dielectric medium, with velocity higher than the speed of light. Cherenkov detectors are not significantly affected by the above noise sources. Furthermore, contrarily to scintillator-based detectors, Cherenkov telescopes permit a measurement of the energy spectrum of the incident muon flux at the installation site, an issue that is indeed relevant for deducing the density distribution inside the target.

In 2014, a prototype Cherenkov telescope was installed at the Astrophysical Observatory of Serra La Nave (southern flank of Mt. Etna, Italy; 1740m a.s.l.), in the framework of ASTRI, a flagship project of the Italian Ministry of Education, University and Research, led by the Italian National Institute of Astrophysics (INAF). This offers the opportunity to test the use of a Cherenkov telescope for imaging volcanic structures. Starting from this know-how, we plan to develop a new prototype of Cherenkov detector with suitable characteristics for installation in the summit zone of Etna volcano (around 3000m a.s.l.).