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End-to-end simulations of the MUon RAdiography of VESuvius experiment

Muon radiography is an imaging technique used to study the interior of large scale natural and man-made objects with the naturally occurring muons from cosmic showers. This technique exploits the penetration capability of muons and the imaging is performed from the measurements of the absorption profiles of muons as they pass through matter. The MUon RAdiography of VESuvius (MURAVES) project [1] aims at the study of the summital cone of Mt. Vesuvius, an active volcano near Naples, Italy. This muographic profile combined with the data from gravimetric and seismic measurement campaigns will be used for better defining the volcanic plug at the bottom of the crater. Figure 1 shows the Digital Terrain Model (DTM) of the Vesuvius crater, from [2]. The detection setup of MURAVES consists of three identical and independent tracking hodoscopes, constituted of scintillator bars coupled to SiPM, which are already installed on Mt. Vesuvius and fully operational. Each hodoscope includes four tracking stations, with a thick lead wall between the 3rd and the 4th that acts as a passive filter for low-momentum muons.

We report on a series of simulation studies that are being conducted to investigate the effects of the experimental constraints and to perform comparisons with the actual observations. The detector simulation setup is developed using Geant4 [3] and for the generation of cosmic showers, a study of particle generators (including CORSIKA [4] and CRY [5]) has been conducted to identify the most suitable one for our simulation framework. Figure 2 shows the interaction of a 1 GeV muon in the simulated geometry. To mimic the real data, Geant4 raw hits are converted to clusters through a simulated digitization: energy deposits are first summed per scintillator bar, and then converted to number of photoelectrons with a data-driven procedure. This is followed by the same clustering algorithm and thresholds as in real data. After application of the same tracking code as in real data, we quantify tracking inefficiencies, the effect of dark noise and other nuisances, and the effect of the lead wall in terms of absorption and scattering as a function of momentum. We also report on the examination of muon transport through the mountain using PUMAS [6] and Geant4. A brief summary of the simulation workflow is shown in Figure 3.

We will elaborate on the rationale for our technical choices, including trade-off between speed and accuracy, and on the lessons learned, which are of general interest for similar use cases in muon radiography.

Primary author: SAMALAN, Amrutha (Ghent University (BE))

Co-authors: GIAMMANCO, Andrea (Universite Catholique de Louvain (UCL) (BE)); RENDON, Cesar (Ghent University (BE)); SARACINO, Giiulio (Universita e sezione INFN di Napoli (IT)); Mr MACEDONIO, Giovanni (Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy); BONECHI, Lorenzo (Istituto Nazionale di Fisica Nucleare (INFN)); CIMMINO, Luigi (University of Naples "Federico II"); D'ERRICO, Mariaelena (Universita e INFN, Napoli (IT)); MOUSSAWI, Marwa (Catholic University of Louvain); TYTGAT, Michael (Ghent University (BE)); D'ALESSANDRO, Raffaello (Universita e INFN, Firenze (IT)); KARNAM, Raveendrababu (Universite Catholique de Louvain (UCL) (BE)); BASNET, Samip (Catholic University of Louvain)

Presenter: SAMALAN, Amrutha (Ghent University (BE))

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