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Analysis of muon tomography data sets: study of the geological layers above the Mont Terri underground rock laboratory

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The underground rock laboratory, parallel to the Mont Terri motorway tunnel, in north-western Switzerland, was created in a Mesozoic shale formation constituted by the Opalinus clay. This impermeable formation presents suitable properties for hosting repository sites of radioactive waste.
Our first muon telescope was placed in this laboratory in October 2009 to establish the feasibility of the muon tomography and to test the sensor performance in a calm environment, where we are protected from atmospheric noisy particles, before any field installation. The muon telescope was set up in the gallery in order to detect muons coming from above and reaching the detectors after crossing the overlying geological layers. The first data set allowed us to validate the development of the sensor and check the accuracy of our computer models: muon flux, attenuation through rock, telescope acceptance. The flux of muons measured goes from 8 events/day for directions where the rock thickness is minimum to 2 events/days for oblique directions. These variations are in perfect accordance with the topographic screening of the Mont Terri above the laboratory, the model densities are set at $2.45\ \mathrm{g/cm^3}$ for the clay layer and at $2.7\ \mathrm{g/cm^3}$ for the limestone layer as measured on samples.
From the first measurements, a muon densitometry experience has been established to realize a tomography which aims at determining the geometry of the geological layers overlying the Mont Terri underground laboratory. The telescope has been placed at different locations along the gallery to determine the geometry of the clay layer along a profile and evaluate the global rock mass above the laboratory. The flux of muons have been measured in five sites of detection with vertical or tilted configurations along 4805 ray paths which intersect them inside the volume of rock, the redundant informations allow the refinement of the results precision.
The sensor calibration has been realised by a bayesian dual inversion of the experimental telescope acceptance and the integrated flux of muons applied on data sets acquired with a vertical configuration on open sky, before and after the acquisitions inside the laboratory. The number of events detected is then corrected from eventual telescope's bars failures and compared to the model flux of muons underground. The inversion of the data sets is constrained by the topography, the geological map, the measured density and the observation of the intersection between the geological layers setting their positions and angles of tilt inside the gallery.