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Geological constraints for muon tomography: The world beyond standard rock

Alessandro Lechmann (1), David Mair (1), Akitaka Ariga (2), Tomoko Ariga (2), Antonio Ereditato (2), Samuel Käser (2), Ryuichi Nishiyama (2), Paola Scampoli (2,3), Mykhailo Vladymyrov (2), and Fritz Schlunegger (1)

(1) Institute of Geological Sciences, University of Bern, Baltzerstrasse 1+3, CH-3012, Bern, Switzerland, (2) Albert Einstein Center for Fundamental Physics, Laboratory for High-Energy Physics, University of Bern, Sidlerstrasse 5, CH-3012, Bern, Switzerland, (3) Dipartimento di Fisica "E. Pancini", Università di Napoli Federico II, Via Cintia, I-80126, Napoli, Italy

In present day muon tomography practice, one often encounters an experimental setup in which muons propagate several tens to a few hundreds of meters through a material to the detector. The goal of such an undertaking is usually centred on an attempt to make inferences from the measured muon flux to an anticipated subsurface structure. This can either be an underground interface geometry or a spatial material distribution. Inferences in this direction have until now mostly been done, thereby using the so called “standard rock” approximation. This includes a set of empirically determined parameters from several rocks found in the vicinity of physicist’s laboratories.

While this approach is reasonable to account for the effects of the tens of meters of soil/rock around a particle accelerator, we show, that for material thicknesses beyond that dimension, the elementary composition of the material (average atomic weight and atomic number) has a noticeable effect on the measured muon flux. Accordingly, the consecutive use of this approximation could potentially lead into a serious model bias, which in turn, might invalidate any tomographic inference, that base on this standard rock approximation.

The parameters for standard rock are naturally close to a granitic (SiO_2-rich) composition and thus can be safely used in such environments. As geophysical surveys are not restricted to any particular lithology, we investigated the effect of alternative rock compositions (carbonatic, basaltic and even ultramafic) and consequentially prefer to replace the standard rock approach with a dedicated geological investigation. Structural field data and laboratory measurements of density (He-Pycnometer) and composition (XRD) can be merged into an integrative geological model that can be used as an a priori constraint for the rock parameters of interest (density & composition) in the geophysical inversion.

Modelling results show that when facing a non-granitic lithology the measured muon flux can vary up to 20-30%, in the case of carbonates and up to 100% for peridotites, compared to standard rock data.