Muography and applications

Sébastien Procureur, CEA Paris-Saclay

(Sebastien.Procureur@cea.fr)

Muography is an imaging technique which makes use of the natural cosmic rays interacting with the Earth's atmosphere. These interactions produce showers of particles, and among them high energy muons which can travel several kilometers before decaying. Because the muon is a lepton with a relatively high mass, it is indeed very penetrating and at the sea level, muons largely dominate the charged particle flux. The electromagnetic interaction of the muon with matter essentially translates into two phenomena, namely a change of its direction through multiple scattering and energy loss eventually leading to its absorption. These two effects can be used to probe the internal structure of many objects. In the former case, detectors reconstruct the trajectories of muons upstream and downstream the object, and their combinations provide information on its 3D density. If the object is too large, the second method is used, in which the measurement of the muon flux in different directions through the object reveals its 2D density, integrated along the direction of observation.

Though applications of this technique have emerged more than 50 years ago, the progress made in the last decade on the precision and robustness of particle detectors has elicited strong interests in various disciplines. In particular, muography studies have been performed in volcanology and more recently on archeology, with the imaging of Egyptian pyramids. This technique has also been used successfully for the scan of nuclear reactors (Fukushima), and is expected to be developed in the coming years in many other fields, from nuclear waste imaging to civil engineering.

In parallel to this seminar, practical sessions will be organized with a muon imager made of 4 planes of Micromegas detectors. This instrument is actually very similar to the three telescopes deployed by the CEA in Egypt around the Great Pyramid of Giza. Live measurements in deviation and absorption modes will illustrate the interactions between muons and matter and provide training on how to operate such an instrument.

References:

- *Introductory muon science*, Nagamine (CUP, 2003), chapter 9
- *A Micromegas-based telescope for muon tomography: The WatTo experiment*, S. Bouteille *et al.*, Nucl. Instr. & Meth. A834 (2016), 223