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Bedrock topography beneath uppermost part of Aletsch glacier, Central Swiss Alps, revealed from cosmic-ray muon radiography

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In mountainous landscapes such as the Central Alps of Europe, the bedrock topography is one of the most interesting subjects of study since it separates the geological substratum (bedrock) from the overlying unconsolidated units (ice). The geometry of the bedrock topography puts a tight constraint on the erosional mechanism of glaciers. In previous studies, it has been inferred mainly from landscapes where glaciers have disappeared after the termination of the last glacial epoch. However, the number of studies with a focus on the structure beneath active glaciers is limited, because existing exploration methods have limitation in resolution and mobility.

The Eiger-μ project proposes a new technology, called muon radiography, to investigate the bedrock geometry beneath active glaciers. The muon radiography is a recent technique that relies on the high penetration power of muon components in natural cosmic rays. Specifically, one can resolve the internal density profile of a gigantic object by measuring the attenuation rate of the intensity of muons after passing through it, as in medical X-ray diagnostic. This technique has been applied to many fields such as volcano monitoring (eg. Ambrosino et al., 2015; Jourde et al., 2016; Nishiyama et al., 2016), detection of seismic faults (eg. Tanaka et al., 2011), inspection inside nuclear reactors, etc.

The first feasibility test of the Eiger-μ project has been performed at Jungfrau region, Central Swiss Alps, Switzerland. We installed cosmic-ray detectors consisting of emulsion films at three sites along the Jungfrau railway tunnel facing Aletsch glacier (Jungfraufirn). The detectors stayed 47 days in the tunnel and recorded the tracks of muons which passed through the glacier and bedrock (thickness is about 100 m). Successively the films were chemically developed and scanned at University of Bern with microscopes originally developed for the analysis of physics experiments on neutrino oscillation.

The analysis of muon absorption rate enabled us to image a three-dimensional boundary shape between dense granite bedrock ($\sim$ 2.7 g/cm^3) and light ice part ($\sim$ 0.8 g/cm^3) in the very uppermost part of Aletsch glacier. This is the first application of muon radiography to cryogenic science. Further measurements are presently ongoing to image inside a much larger edifice of Eiger glacier, which straddles on the western flank of the famous Eiger mountain.

References:

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