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Automatic readout for nuclear emulsions in muon radiography of volcanoes

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Nuclear emulsions are an effective choice in many scenarios of volcano radiography by cosmic-ray muons. They are cheap and emulsion-based detectors require no on-site power supply. Nuclear emulsion films provide sub-micrometric tracking precision and intrinsic angular accuracy better than 1 mrad. Imaging the inner structure of a volcano requires that the cosmic-ray absorption map be measured on wide angular range. High-absorption directions can be probed by allowing for large statistics, which implies a large overall flux, i.e. wide surface for the detector. A total area of the order of a few m^2 is nowadays typical, thanks to the automatic readout tools originally developed for high-energy physics experiments such as CHORUS, PEANUT, OPERA. The European Scanning System is now being used to read out nuclear emulsion films exposed to cosmic rays on the side of volcanoes. The structure of the system is described in detail with respect to both hardware and software. Its present scanning speed of 20 cm^2/h/side/microscope is suitable to fulfil the needs of the current exposures of nuclear emulsion films for muon radiograph, but it is worth to notice that applications in volcano imaging are among the driving forces pushing to increase the performances of the system.

Preliminary results for the Unzen volcano of a joint effort by research groups in Italy and Japan show that the current system is already able to provide signal/background ratio in the range 100÷10000:1, depending on the quality cuts set in the off-line data analysis. The size of the smallest detectable structures in that experimental setup is constrained by the available statistics in the region of highest absorption to about 50 mrad, or 22 m under the top of the mountain.

Another exposure is currently taking data at the Stromboli volcano. Readout of the exposed films is expected to begin in March 2012, and preliminary results will be available soon after.

An effort by several universities and INFN has already started to increase the scanning speed, to exceed 100 cm^2/h and approach the order of magnitude of 1000 cm^2/h. Muon radiography also demands high signal/background ratio to probe high absorption regions in volcanoes. A new camera, a new image acquisition device, an improved motion control board and extensive use of GPU-based processing are the keys to make a new leap in speed while even improving data quality. With most of the new hardware already finalised, software development is quickly progressing, and a stable, user-friendly and cheap prototype is expected to be ready to take data already this summer.

The amount of raw data collected is typically of the order of 10 TB/m^2. The operation of automatic microscopes is thus complemented with an automatic data management and processing system based on a distributed computing model. The processing power can be scaled up linearly by just increasing the number of available computers. An evolution is underway on this side too, and algorithms designed for GPU-based processing will soon help increase the available power while decreasing the overall cost of typical installations.