Technique to measure the cosmic muon flux at the old Canfranc Underground Laboratory

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Abstract. A technique to measure the cosmic muon flux distribution has been developed in the old Canfranc Underground Laboratory (2450 m.w.e.). This technique can determine the muon direction and it allows to obtain a three-dimensional distribution of the muon intensity which could be correlated to the mountain profile, as well. The experimental set-up, which has been taking data since November 2008, consists of a Time Projection Chamber (TPC) detector and a veto system composed of two plastic scintillators.

1. Introduction
Muon transport through matter has an important role in many areas of particle and astroparticle physics. Cosmic rays, which consist mostly of protons, interact in the atmosphere producing muons. Owing to their low energy loss, essentially by ionization, they can travel large distances and commonly reach the ground with a mean energy of 3 GeV. The average muon flux at the surface goes as \( \cos^2 \theta \). The rate in a thin horizontal detector is roughly 1 cm\(^{-2}\).min\(^{-1}\) [1]. Muon flux is effectively suppressed at large depths underground, for instance a previous measurement at the old Canfranc Underground Laboratory provided us with a muon flux of \((5.04 \pm 0.25) \times 10^{-3} \text{ m}^{-2}\text{s}^{-1}\) [2]. Also, their interaction with the rock or detector materials produces high-energy neutrons becoming an important source of background in experiments looking for rare events in underground sites.

The goal of the technique presented here is to measure the cosmic muon flux and determine the muon direction in the Canfranc Underground Laboratory using a Time Projection Chamber (TPC) detector. The features of this detector allow us to obtain information about several parameters of the muon flux, such as direction, length of its track, interaction angle, and energy deposition. It also permits to discriminate different particles like gammas, electrons and alphas.

2. Experimental set-up
The experimental set-up consists of two different components: a TPC detector and a veto system. The TPC detector used here was installed in the CAST Experiment where it achieved successful results [3]. The gas mixture, Ar (95%) + CH\(_4\) (5%), is located inside the TPC in a volume 10x15x30 cm\(^3\) with a 10 cm drift.

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The TPC working concept is simple: muon passing through the detector ionizes the gas liberating electrons, which produce secondary electrons with lower energy while drifting towards the amplification area. Here, the avalanche process takes place, due to the high electric field in the anode wires. Finally electric signals, that contain information about the location and charge production of initial interaction, are generated in the wires and recorded by the acquisition system. The detector has one anode plane and two cathodes planes. Each cathode plane has 96 wires, and the anode plane has 48 wires running perpendicular to the cathodes wires. These planes signals, combined with the trigger time, provide us three dimensional information for each event.

The veto system is located on top of the TPC detector, to obtain fast coincidence signals in time with the TPC trigger. It is made of two plastic scintillators BICRON BC 408 (80x40x5 cm³). A 6 µs veto time window has been chosen for identification of almost vertical muons.

3. Results
In a first phase, the set-up was installed in a sea level laboratory of the University of Zaragoza. There, it has been possible to check the proper operation of the detector and to measure the vertical muon flux in surface: 80 µ.m⁻².s⁻¹. From these data recorded in surface we have also obtained the software cuts necessary to distinguish different particles (see figure 1 left). For instance, to identify vertical muons and induced events by them. Some of the cuts used are: veto time less than 6 µs, good linear fit to a track (figure 1 right), number of touched anodes 48. Since November 2008, the detector has been recording data in the Canfranc Underground Laboratory.

Figure 1: Left: This plot shows clearly distinction of the particles depending on their charge collection in anodes and track length: vertical muons (on top), X-rays (on the left) and alphas (on the bottom). Right: these pictures show the muon track in anodes (left) and cathodes (right).

4. Outlook
This technique to measure muons provides us with the opportunity to know more deeply the features of the energy deposition of muons and to obtain a three dimensional map of their distribution. The measurements carried out in surface have proved the reliability of the detector and its capability to measure muons. The second phase, in the Canfranc Underground Laboratory is undergoing. We expect to have the first results from these measurements in the next future.

References
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