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Calculation of total muon flux observed by Muon Monitor experiment

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Abstract. An approach to calculate the flux of cosmicgenic muons detected by Muon Monitor experiment in lab LAB2400 of the Underground Laboratory in Canfranc (LSC) is described. The measuring apparatus consists of three layers of SC16 scintillation matrix detectors. The hardware function of the detector assembly was determined using computer simulation. Obtained value of the total muon flux turned out to be equal to $(4.35 \pm 0.2) \times 10^{-3}\ m^{-2}s^{-1}$.

1. Motivation

To eliminate background produced by cosmic rays, the experiments researching for rare processes are conducted in deep underground laboratories, where rock overburden attenuates flux of cosmogenic muons. Nevertheless, even such a small residual underground flux of cosmic muons produces background for physics experiments. The general goal of Muon Monitor project is to study muon background conditions in underground sites of Canfranc Underground Laboratory (LSC) and precisely measure muon flux taking into account considerable anisotropy of the flux because of complicated shape of mountains above the lab LAB2400 of LSC.

2. Experimental setup

The Muon Monitor consists of scintillation detecting assembly (SDA), data acquisition system (DAQ), and power supply system. The SDA has three layers consisting of the fast SC16 scintillation detectors: $3\times3 = 9$ detectors both in the top and in the bottom layers and $2\times2 = 4$ detectors in the middle layer (see figure 1). Effective square aperture is ~ 1 m^2. Maximum zenith angle of muon to be detected is approximately 80°. Each SC16 detector contains a 4×4 matrix of 16 independent, square pixel detectors of $122 \times 122 \times 30$ mm^3 [1,2]. The internal structure of the pixel, schematic view of the SC16 and connection layout is presented in the figure 2.

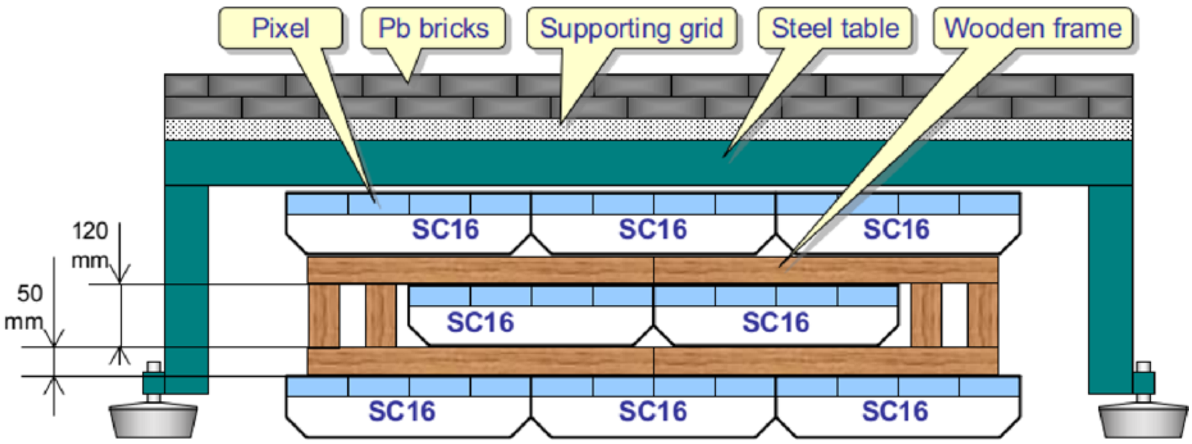

Figure 1. Schematic view of a detecting assembly

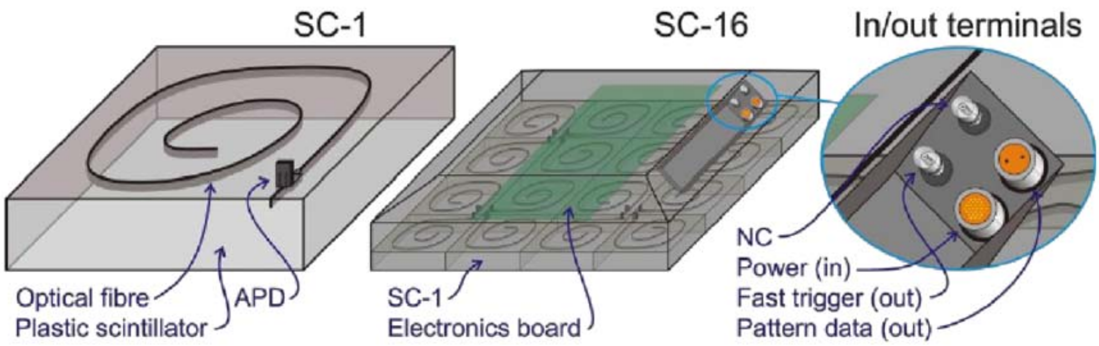

Figure 2. Schematic view of detector

3. Calculation of total muon flux

To calculate total muon flux with taking into account the geometrical response of SDA and individual efficiencies of subdetectors inside SC16 a Monte Carlo simulation was used. The simulation tool was written in Kotlin using Appache Commons Math for geometry description.

Only events that produce straight line tracks was selected to calculation. This was done using simulation program. Considering that simulation statistics of 10^7 is few orders of magnitude greater than the number of events in the experiment ($\sim 3 \times 10^5$), it is supposed that pixel combinations which do not appear in simulation, are not possible in the real data. Thus it was selected only events where set of pixels being hit exists in the simulation.

The efficiency for the given pixel set could be found from simulation with uniform initial distribution of muons in a following way:

$$R_i = \frac{N_{sim,i}}{N_{sim}}, \tag{1}$$

where $N_{sim,i}$ is the number of simulated muons that hit pixel set with index i and N_{sim} is the total number of simulated muons. The total flux for a given pixel set f_i can be found as:

$$f_i = \frac{g_i}{\int \varepsilon_i d(\Omega)} = \frac{g_i}{R_i}. \tag{2}$$

where g_i is experimental counts of given pixel combination. Each of f_i is not the estimate of the flux through the pixel set, but the flux through the monitor as a whole. If the initial distribution is uniform then all of f_i would give the same value and total flux could be found by simple averaging $f = \langle f_i \rangle$. In real experiment, the initial distribution is not uniform, but averaging still gives a consistent estimate of the total flux.

4. Results

This approach gives the total number of events $\langle f \rangle = \gamma \langle f \rangle_0 = 2.256 \cdot 10^5$ *events* observed by monitor during time of measurement equals to 51836385 seconds. The $\langle f \rangle_0$ has been calculated in assumption that average flux in unobservable large zenith angles region and detectable low ones is the same and γ is correction factor equals to the ratio between monitor angular coverage and total 2π solid angle. Uncertainties for calculation includes:

- uncertainties of pixels position: ~ 5 %
- statistical error: ~ 0.3 %
- uncertainties of total measurement time: less than 0.1%

With taking into account all uncertainties the total flux is:

$$\Phi = (4.35 \pm 0.2) \times 10^{-3} \; m^{-2} s^{-1}. \tag{3}$$

Paper containing overwiev of method, results and disciussion in detail is in progress[3].

Acknowledgments

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References

[1] Akhrameev E V *et al* 2009 Multi-pixel geiger-mode avalanche photodiode and wavelength-shifting fibre-optics readout of plastic scintillator counters for the emma underground experiment *Nucl. Inst. Meth. in Phys. Res.* A **610** 419–22

[2] Volchenko V I *et al* 2010 Background and muon counting rates in underground muon measurements with a plastic scintillator counter based on a wavelength shifting fibre and a multi-pixel avalanche photodiode readout *Centr.Eur.J.Phys.* **8** 445–47

[3] Bandac I *et al* Measurement of muon flux in the Canfranc Underground Laboratory *Unpublished paper*