Seize the weather with cosmic muons - Hexadecagon Muon Tracker (HMT)

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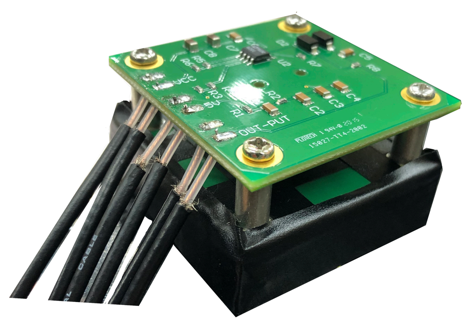
Cosmic muons(μ) are the decay product of the interaction between the cosmic rays and the substances in the atmosphere. Many factors can influence the process of the cosmic rays passing through the atmosphere so the muon flux differs. By using the self-designed Hexadecagon Muon Tracker (HMT), we aim to study effect of weather on the variation of the muon flux and the Muon flux as a function of zenith angular distribution. Scintillator and SiPM are employed in the HMT within our self-designed circuits to track muons. To have the most efficiency geometry to identify the muon from electron, the Geant4 simulation is used. The detail and the results are discussed in this presentation.

Introduction

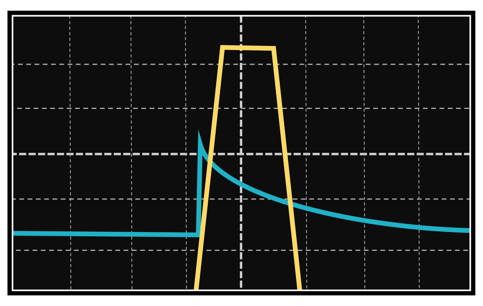
The cosmic rays interact with molecules in the atmosphere and generate the secondary particles, including muon, electron and etc. The muon flux is measured by two weeks in this experiment, attempting to study the relationship between the weather and muon flux.

How to detect the muon?

Scintillator	Generate the optical signal
SiPM	Transform into the electric signal
ADC	Amplify and delay the signal
Raspberry Pi	Read out the signal



Scintillator module unit

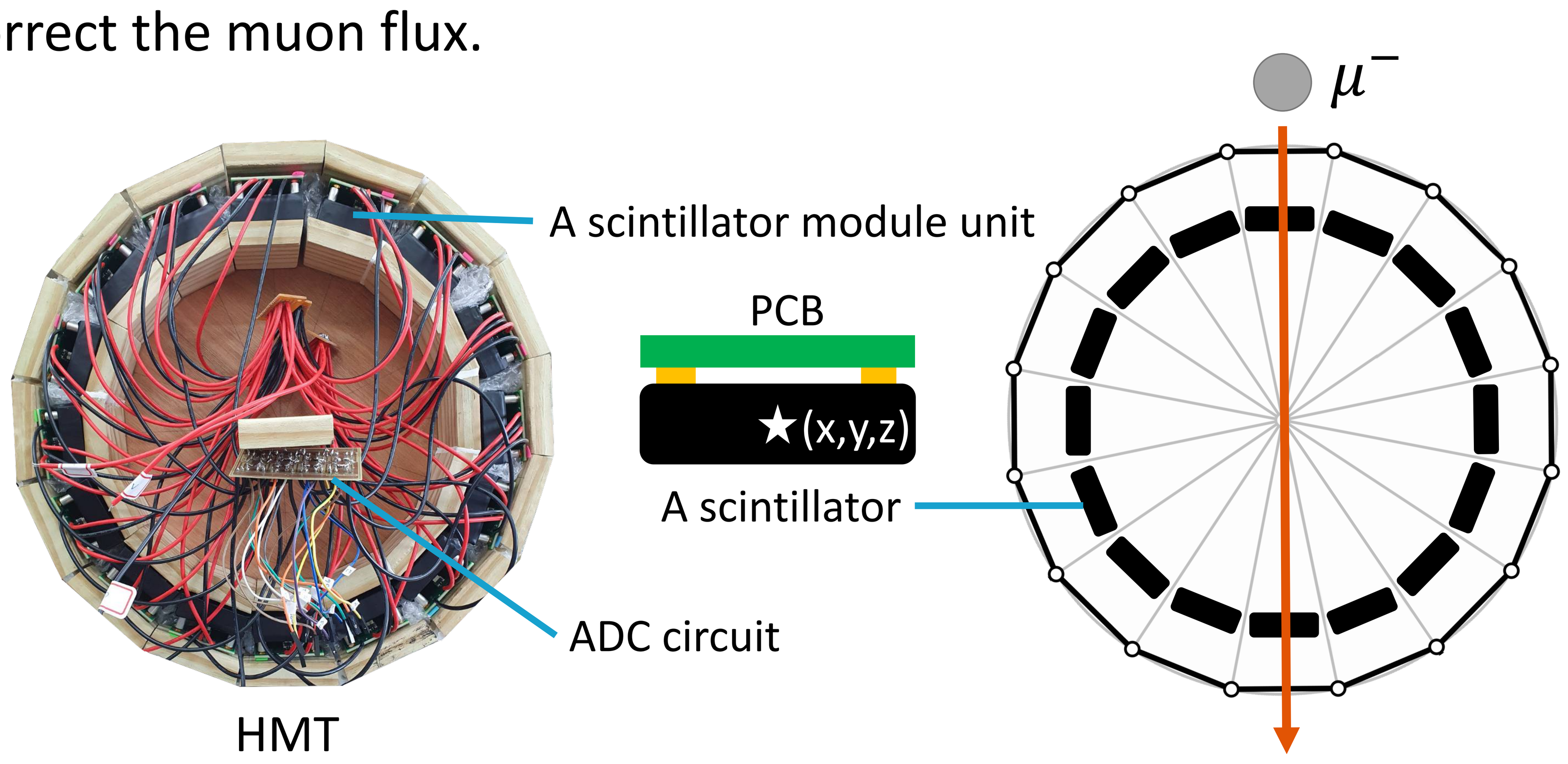


A muon signal
Green line: analog signal
Yellow line: digital signal

Experimental setup

The experimental setup is located at the rooftop of science 4 building (S4) to prevent the influence of the obstacles.

HMT is made of sixteen scintillator module units. If two scintillators receive the signals at the same time, the path of muon can be traced back. The HMT has the ability of full coverage on zenith angle. The efficiency of each unit was measured and hence can be used to correct the muon flux.



Theorem

Since the atmospheric temperature will change with the altitudes, we have to take whole atmosphere into account. The equation 1 ($Eq.1$) shows the function of effective temperature (T_{eff}).

$$T_{eff} = \frac{\sum_{n=1}^{37} \frac{dX_n}{X_n} T(X) W(X)}{\sum_{n=1}^{37} \frac{dX_n}{X_n} W(X)} \quad (Eq.1)$$

The X represents the different altitudes with the temperature $T(X)$, and $W(X)$ is the weighting factor. After processing the weather data, we compare with muon flux by the following formula.

$$\frac{\Delta R_\mu}{\langle R_\mu \rangle} = \propto_T \frac{\Delta T_{eff}}{\langle T_{eff} \rangle} \quad (Eq.2)$$

R_μ represents the muon flux. $\propto_T$is the effective temperature coefficient. The main goal of our experiment is to study the relationship between the muon flux and the atmospheric temperature.

Simulation

The veto rate of the electrons and the efficiency loss of the muons are also investigated by Geant4[1]. The result of blocking rate as a function of lead absorber is shown in **Fig.2**. The thickness of 1.5 cm is the best option.

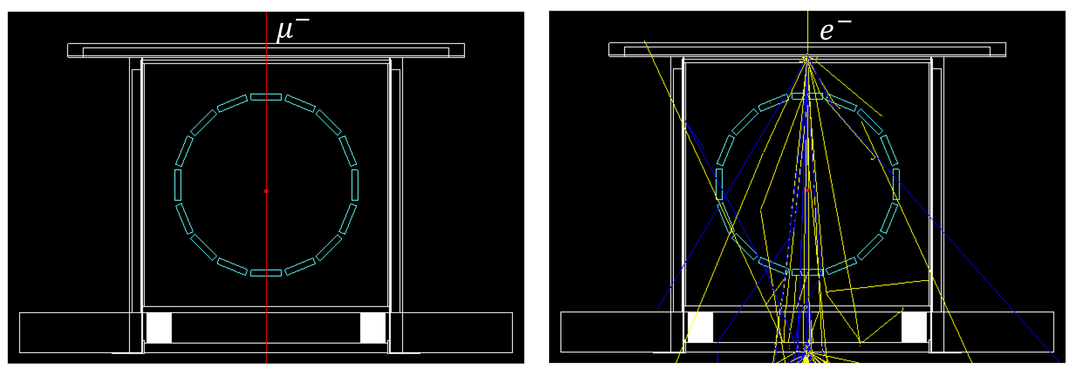


Fig.1 The event display of Geant4 simulation.
Left : a Muon event Right : an electron event

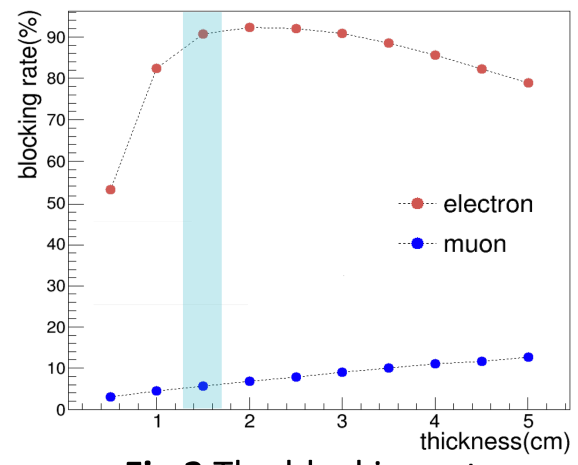


Fig.2 The blocking rate in different thicknesses.

Results

After tracing back the muon incidence angle by the HMT. The zenith angular distribution of the muon flux is shown in Fig.3, and the result is in a good agreement with the relation, $cos^2\theta$.

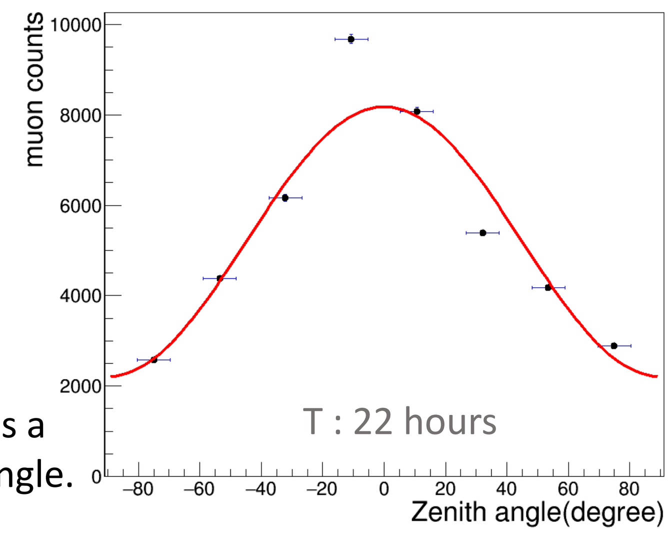


Fig.3 The muon flux as a function of the zenith angle.

The muon flux is expected to fluctuate with the period of 366 ± 3days[2]. However, our results shown in Fig.4 only present the measurements in 15 days. The duration is still too short to observe.

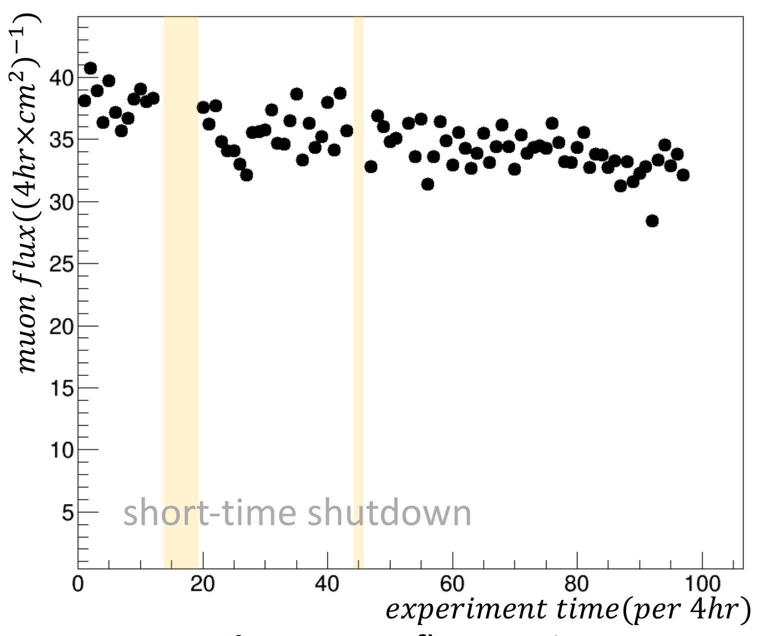


Fig.4 Muon flux vs. time

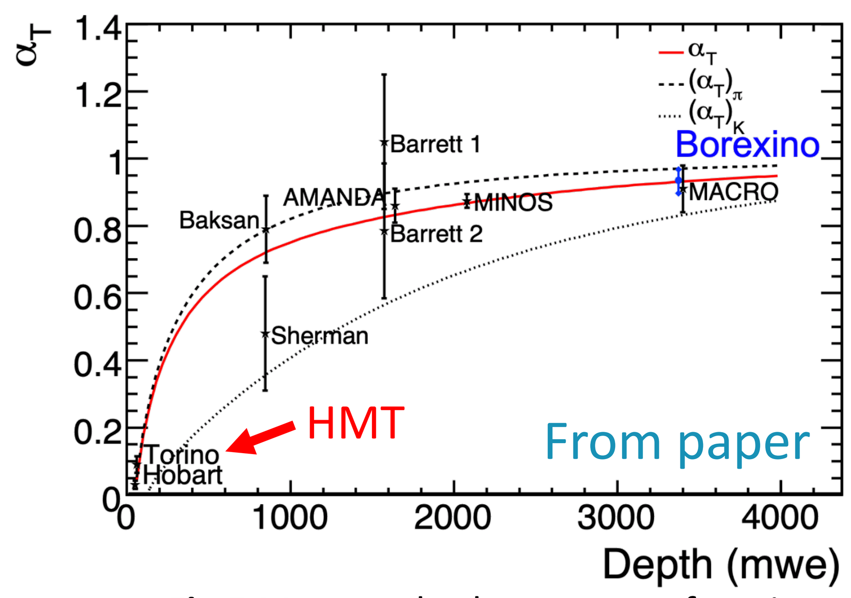


Fig.5 Measured values $\propto_T$ as a function of site depths[2].

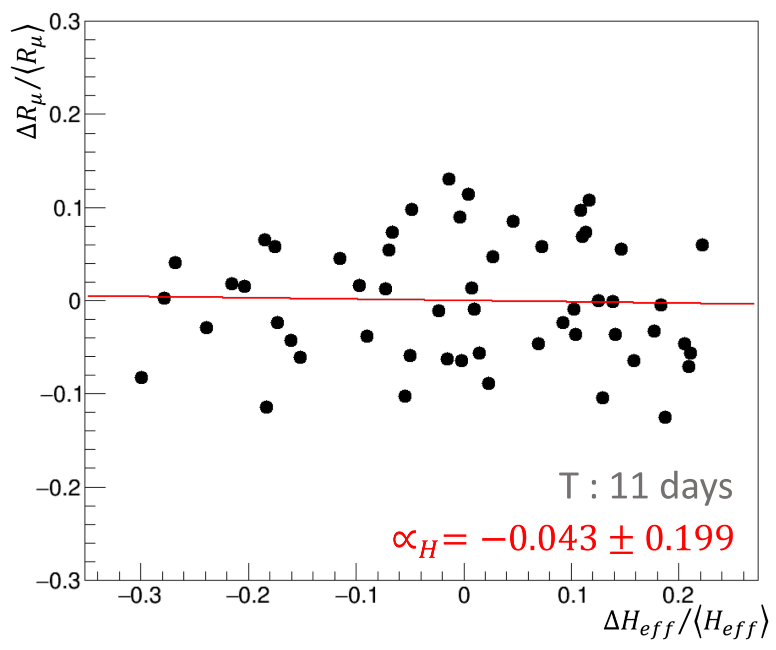


Fig.6(a) muon flux vs. humidity variation

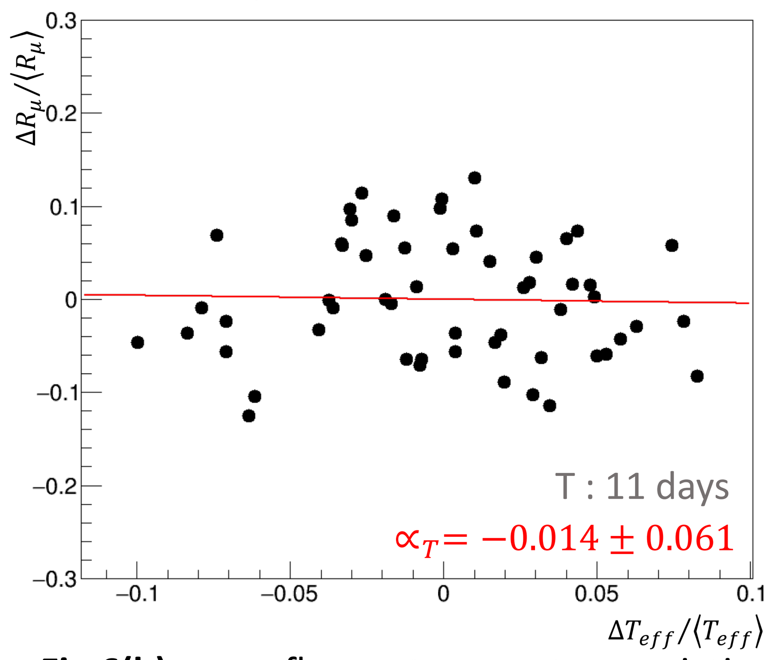


Fig.6(b) muon flux vs. temperature variation

The muon flux we measured shows the almost no correlation with the temperature(humidity) after taking into a account the atmospheric effects in different altitudes(**Fig.6**). Because the HMT is located on the ground and our site depth is merely zero after conversion, the measured value of α_T matches the previous measurements shown in **Fig.5**. In order to observe larger α_T, the underground experiment will be needed.

Conclusions

1. The angular distribution of muon flux is proportional to $cos^2\theta$.
2. The muon flux is independent of the temperature and humidity at the ground as presented in the previous experiments[2].

References

[1]https://geant4.web.cern.ch
[2]Borexino collaboration, Cosmic-muon flux and annual modulation in Borexino at 3800 m water-equivalent depth. Journal of Cosmology and Astroparticle Physics, 05(2012)015.