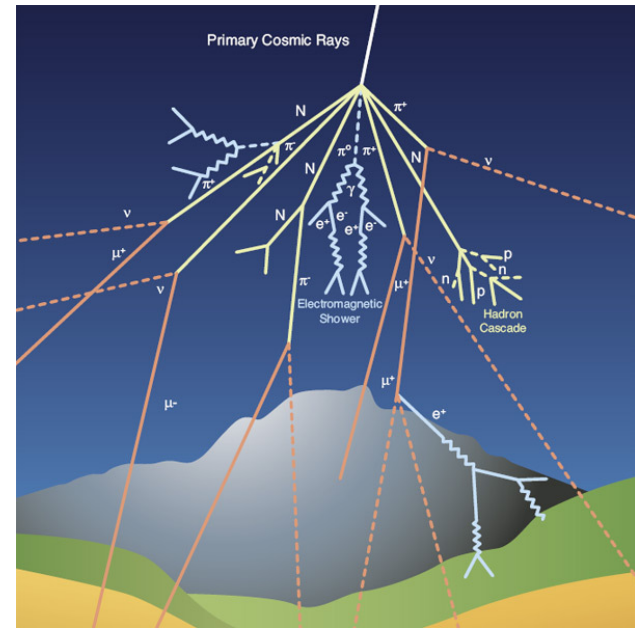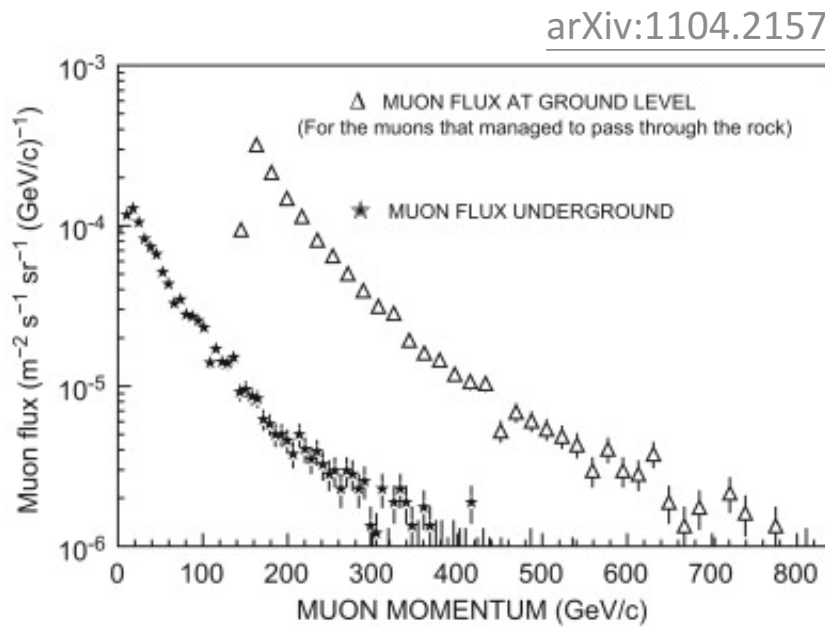# The angular distribution and flux variation of cosmic muons measured by the Hexadecagon Muon Tracker

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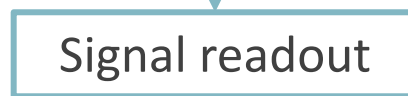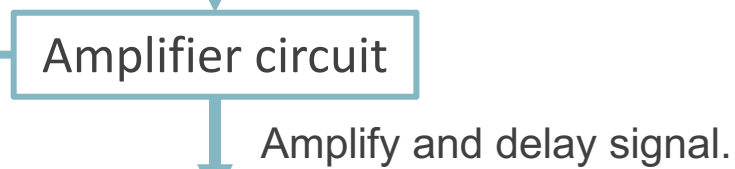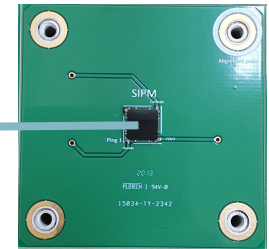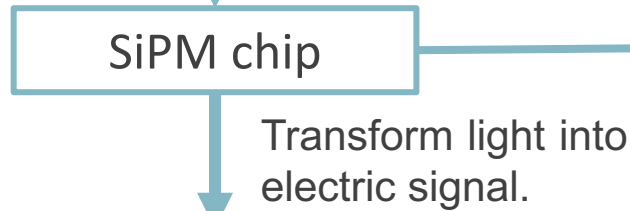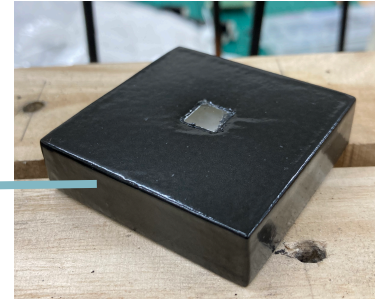
Introduction

- The cosmic rays interact with atmosphere and generate many secondary particles.

- The cosmic muons can be separated into soft muons and hard muons by their energy.

- The muon flux at the ground level is mainly contributed by soft muons.

arXiv:1104.2157

How to detect the cosmic muon

- When the muon enter…

μ^- → Scintillator

Generate light.

SiPM chip

Transform light into electric signal.

PCB

Amplifier circuit

Amplify and delay signal.

Scintillator

Scintillator module unit

Signal readout

Use the oscilloscope with digital analyzer.

Analysis method

- Weather data model: ERA5
- Take the whole atmosphere into account to study the weather effects on cosmic muon flux variations.
- For example: Effective temperature

$$T_{eff} = \frac{\sum_{n=1}^{10} \frac{dX_n}{X_n} T(X_n) W(X_n)}{\sum_{n=1}^{10} \frac{dX_n}{X_n} W(X_n)}$$

X: altitude T: temperature W: weighting factor
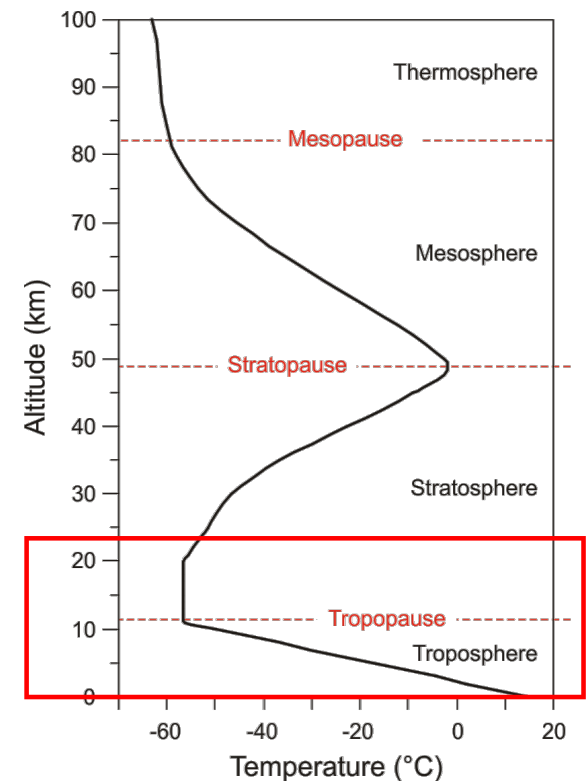
- Find out the Correlation coefficient α_T:

defined as ΔR_μ defined as ΔT_{eff}

$$\frac{R_\mu - \bar{R}_\mu}{\bar{R}_\mu} = \propto_T \frac{T_{eff} - \bar{T}_{eff}}{\bar{T}_{eff}}, \text{ then } \frac{\Delta R_\mu}{\bar{R}_\mu} = \propto_T \frac{\Delta T_{eff}}{\bar{T}_{eff}}$$

R_μ, T_{eff}: muon flux per day and daily temperature
$\bar{R}_\mu, \bar{T}_{eff}$: average muon flux and average daily temperature

- Other weather factors (humidity, the fraction of cloud cover) use the same way to analyze.
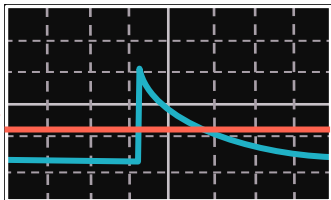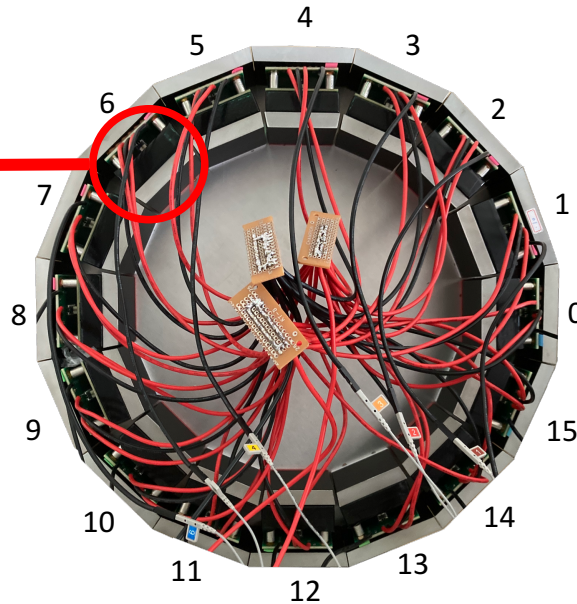
Experimental setup

- Location: The top floor of Science building 4 in NCU.
- The Hexadecagon Muon Tracker can detect the multiple incident angles at the same time.

Scintillator module unit

350mV
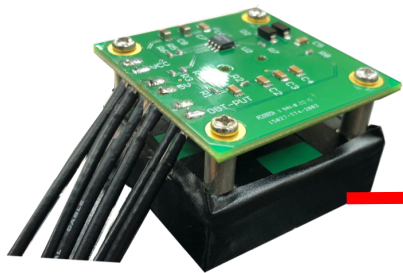
The muon signal after amplify and delay circuits.

Hexadecagon Muon Tracker
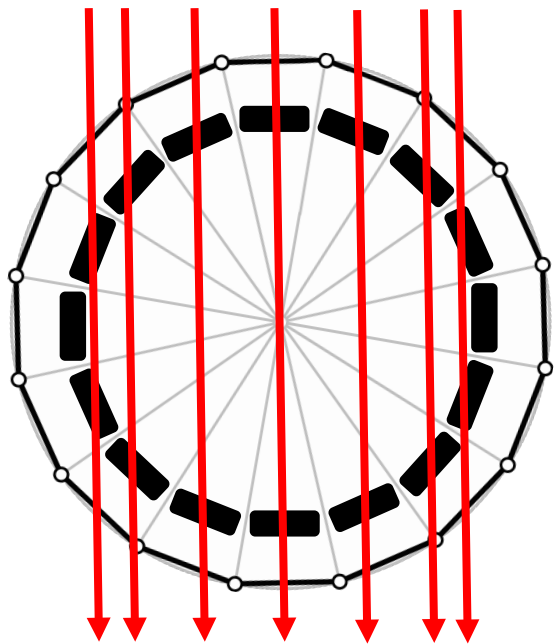(16 Scintillator modules)
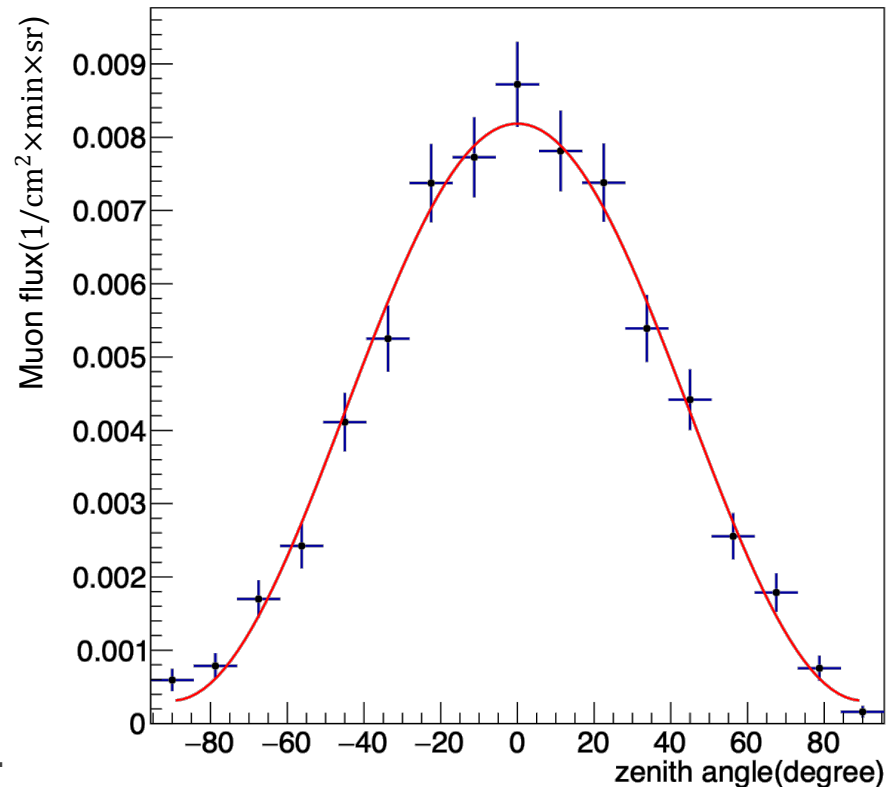

The screen of the oscilloscope

Results: Angular distribution

- Any two channels have signal at the same time can reconstruct the track of cosmic muon.

- experiment time: one week

- The angular distribution matches with the known $cos^2\theta$.

For 0 degree case:

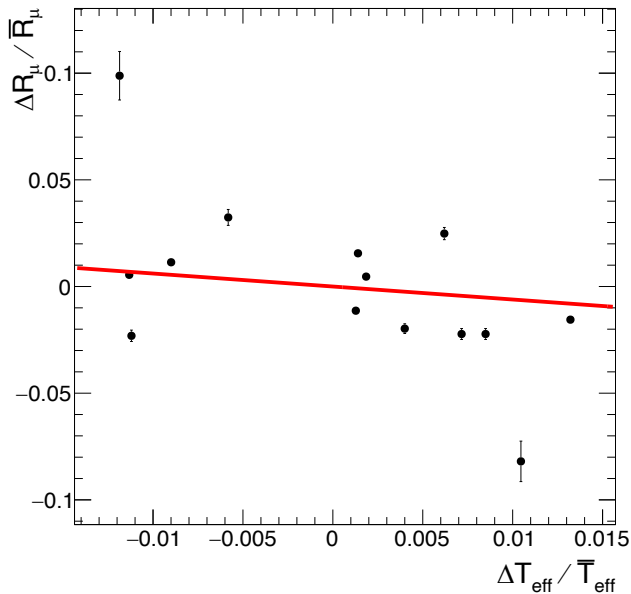All arrows trace back to zero degree.

Results: flux variation

- Compare the muon flux with temperature, relative humidity and the fraction of cloud cover.

- $\frac{\Delta R_\mu}{\bar{R}_\mu} = \propto_X \frac{\Delta X_{eff}}{\bar{X}_{eff}}$ Find out the $\propto_X$ by fitting. R_μ: muon flux per day (-11.25º~11.25º)
  X: weather factor

Temperature
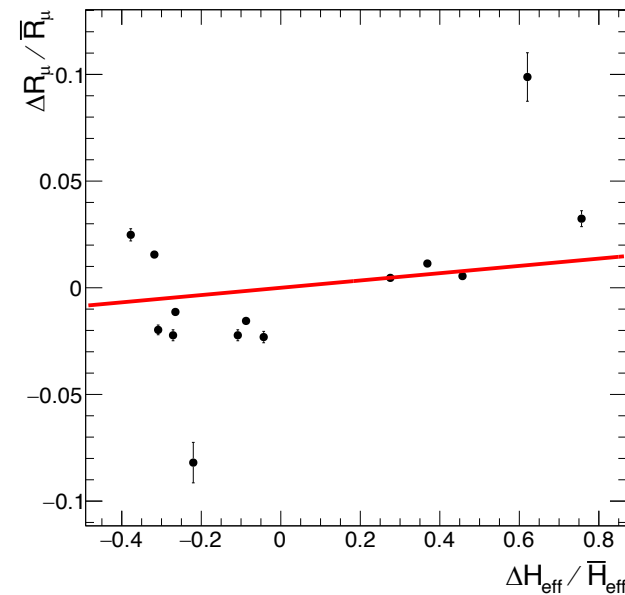$\propto_T = -0.6090 \pm 0.0452$

The fraction of cloud cover
$\propto_C = 0.0064 \pm 0.0004$
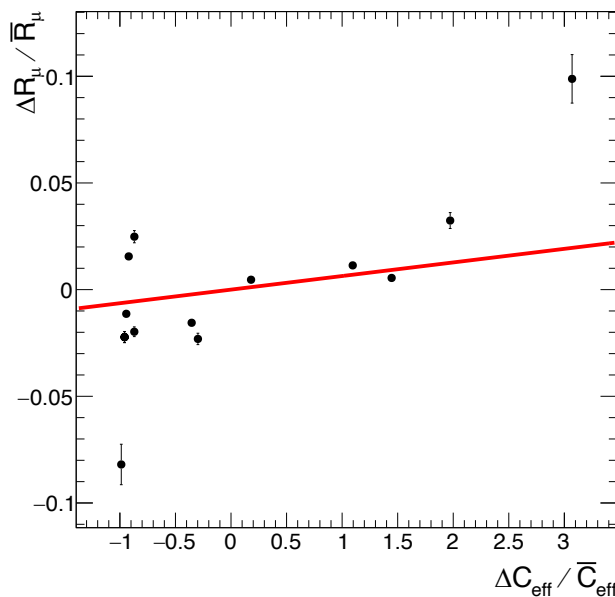
Relative humidity
$\propto_H = 0.0170 \pm 0.0009$

Conclusion

- A Hexadecagon Muon Tracker(HMT) with the scintillator and SiPM was built in NCU.

- So far the HMT has collected the 14 days data.

- The angular distribution of cosmic muon is proportional to $cos^2\theta$ as expected.

- There is a correlation between muon flux and weather factors (temperature, humidity and the fraction of cloud cover) base on current results.

- To-do List: Accumulate more data to verify their correlation.
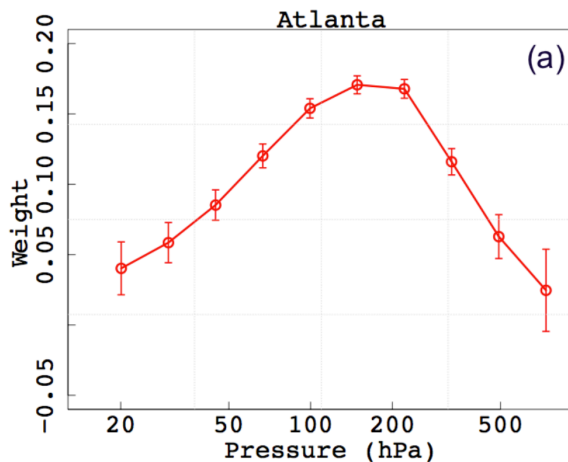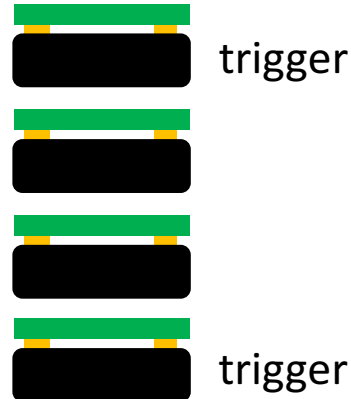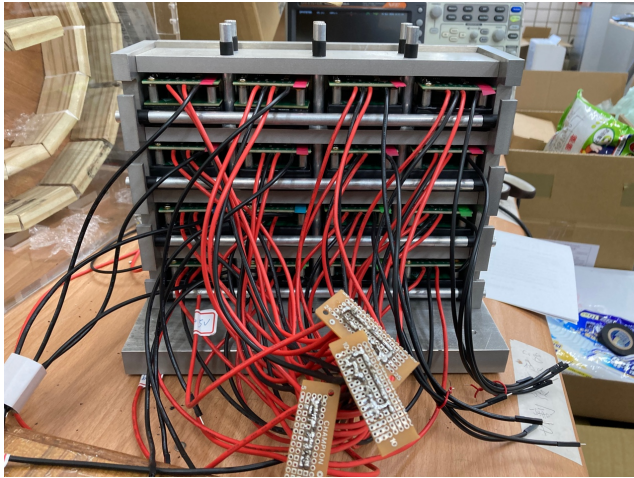
Back up

Angular distribution

- The angular distribution of muon is dependence of path muon walk in atmosphere.
- The angular distribution would follow the $cos\theta$ to the power of n.

Define 0 degree.

θ

45°
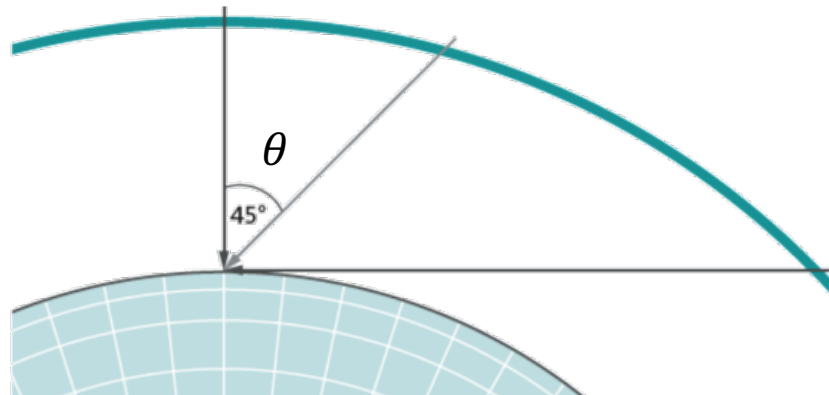
The efficiency test & weighting factor

- Measure each module efficiency.

	efficiency	event	top&bottom event
1	99.23%	1035	1043
2	99.55%	891	895
3	99.33%	1186	1194
4	99.54%	1501	1508
5	99.58%	952	956
6	98.00%	589	601
7	99.79%	962	964
8	99.72%	1063	1066
9	99.27%	957	964
10	98.87%	1054	1066
11	98.84%	594	601
12	99.06%	947	956
13	99.20%	1496	1508
14	99.16%	1184	1194
15	99.11%	887	895
16	98.75%	1030	1043

Angular distribution

- The all possible angles: