Muography-Cosmic Muon Scanner(CMS)

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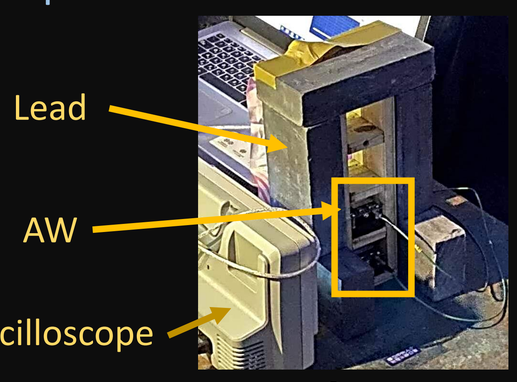
To know the inner structure of a building without invasion, the muon flux can be a great indicator of different density of the building structure. Our goal is to know the difference of muon flux in each floor in S4 and the influence of lead, and build a muon detector and try to restore the structure of the object without invading it. We use the scintillator as sensor which emits photons every time when a charge particle passes through. The detector is a 4-layer structure, and each layer is consisted of 25 sensors. The result will show the density of muon events on the cross section.

Introduction

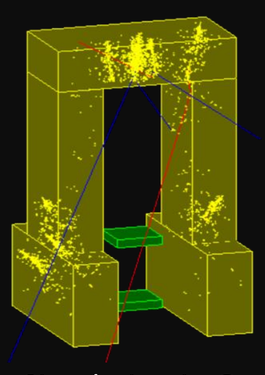
When cosmic rays impact the atmosphere, muons are produced. The muon is an elementary particle similar property to the electron and 200 times heavier than it. It can easily penetrate the dense object like building. Muography[1] is a technology to restore the inner structure of building without invading by detecting the muon flux behind a building.

Blocking Rate Experiment

Setup



Setup



Simulation in Geant4

In this experiment, we want to observe the flux difference of the setup with lead or without. The measurement was done on the roof.

Result

The measured flux is **8.55% less** when the lead brick is removed. The influence of lead and the composition of detected particles derived from the simulation and experiment are shown below.

Particle	Signal
Muon	-23.24%
Electron	-66.31%
Photon	+6.67%

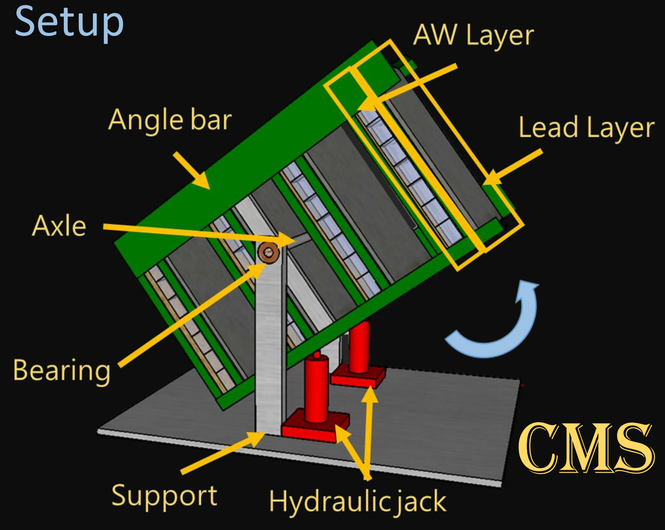
Simulation of signal affected by adding lead

Muon	Electron	Photon
63.66%	4.45%	31.88%

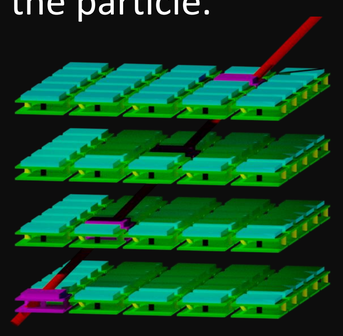
Detected particle's composition derived by the simulation and experimental result.

Muography Experiment

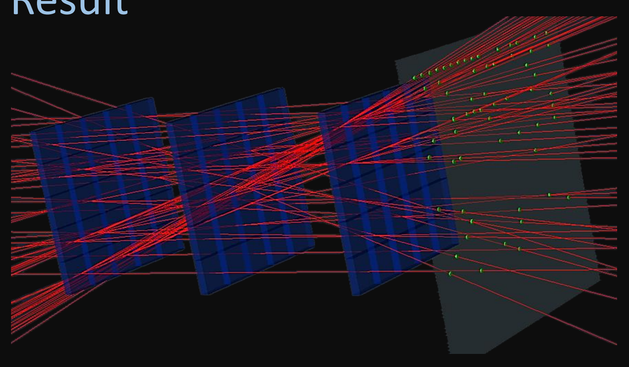
Setup

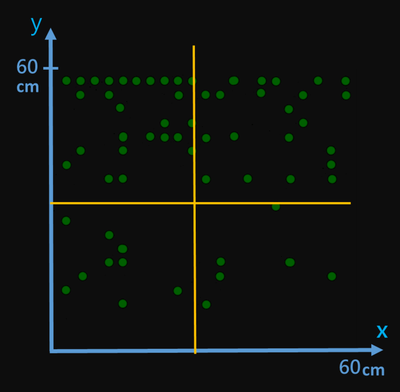


According to the signal on each layer, we can reconstruct the direction of the particle.



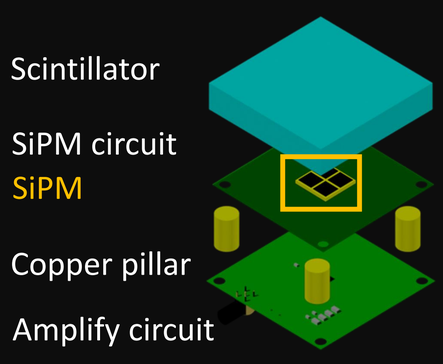
Result





The result shows that the detected muons in the upper part are more than the lower part. It fits the theory that the muon flux $\propto cos^2\theta$. But the difference between the left and the right is unclear. The higher statistics can be obtained by measuring in a longer time(current presented result was measured in 10 hours).

Detector

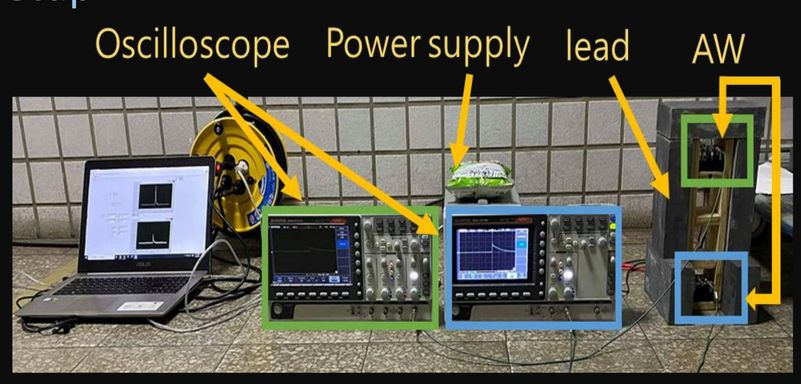


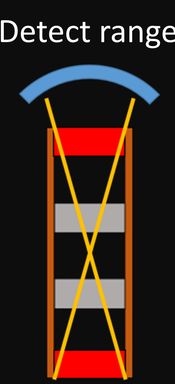
Our detector is made of a scintillator, a SiPM circuit, and an amplify circuit[2]. When charged particles hit the scintillator, it would emit photons and be caught by the SiPM, a light sensitive device, transforming the light signal into the electric signal. Since the original signal is in nano-second scale, a circuit of amplification and delay is necessary. For the sake of better expression, we name the detector, AW(阿瑋).

Muon Flux – Floor Experiment

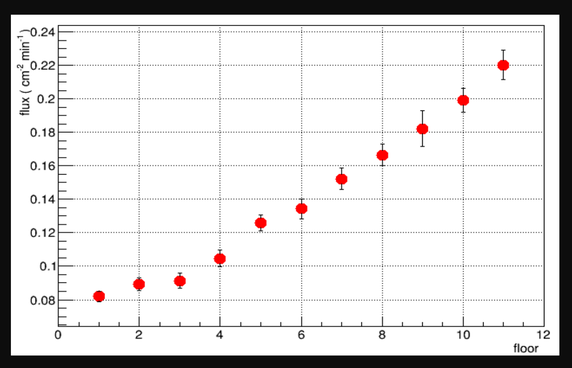
To know how the structure affects the muon flux, we measure the muon flux from ground to top floor of the S4 building. The detector points to zenith. The oscilloscope is used to read out the signal.

Setup



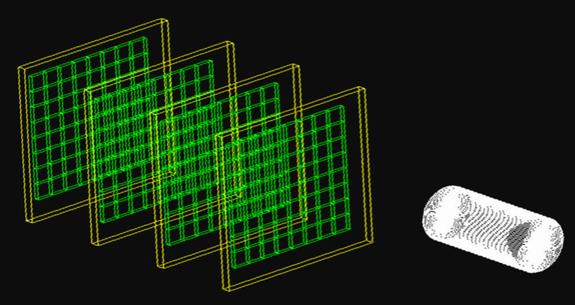


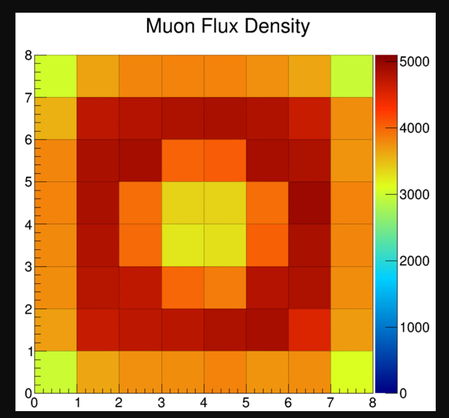
Result



The higher floor, the higher muon flux.

Simulation By Geant4





Providing the muon source with momentum spectrum and the electron, the result is shown in the right figure.

Conclusion

- ✓ Muon flux changes by the floor number. The muon flux decreases when it penetrates an object with larger density length.
- ✓ The result from the muon detection fits the theory that the muon flux changing by the elevation angle.
- ✓ Structure of the blocked part can be graphed by detecting in a longer time.

References

[1] Geosci. Instrum. Method. Data Syst., 4, 215–226, 2015

[2] S. N. Axani,a) J. M. Conrad,b) and C. Kirbyc) Physics Department, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139