# Cosmic-Ray Muons Detection by a Spark Chamber

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**Abstract.** Cosmic ray, originating from several galactic sources, bombards the Earth's atmosphere and produces lots of secondary particles. One of them is an unstable charged particle known as "muon" ($\mu^{\pm}$) with speed close to speed of light and lifetime about 2.2 microseconds before decaying into others. In this study, a spark chamber detector with a stack of 10 parallel electrode plates is constructed to detect the cosmic-ray muons which will lose their energies via ionization in the helium filled chamber. When muons passing through the chamber, they left their traces as the ionization paths. Sparks will occur immediately between each stack of parallel electrodes which are connected to a high voltage supply. The muon's trajectory can then be visualized by connecting the sparks in each stack. To construct this muon's path, two cameras are set to record the events from the two perpendicular planes on two sides of the chamber. The photos are analyzed using MATLAB to obtain the coordinates of the sparking tracks which then are used to determine the zenith angular distribution. The results show that a large number of muons arrived at our laboratory (Chulalongkorn University, Bangkok, Thailand 13° 44'09.5"N 100°31'49.6"E) with zenith angle about 30°

## 1. Introduction

Spark chamber is one of the first instruments used to demonstrate the existence of sub-atomic particles such as muons and also allows us to visualize the trajectory of charged particle as it passes through the detector in real time, as a result of ionization of filled gas molecule. Muon is a charged particle whose lifetime is about 2.2 microseconds [1]. It can travel with speed close to speed of light. With relativistic effect, those muons live long enough to reach the surface of the Earth. The aim of this project is to build a spark chamber for recording photos when cosmic-ray muons pass through the chamber. To record a video, we set two cameras facing two sides of the chamber and used the video analysis capability of MATLAB to analyze and to reconstruct the 3D tracks. The angular distribution of muons will then be determined.

## 2. Research Procedure

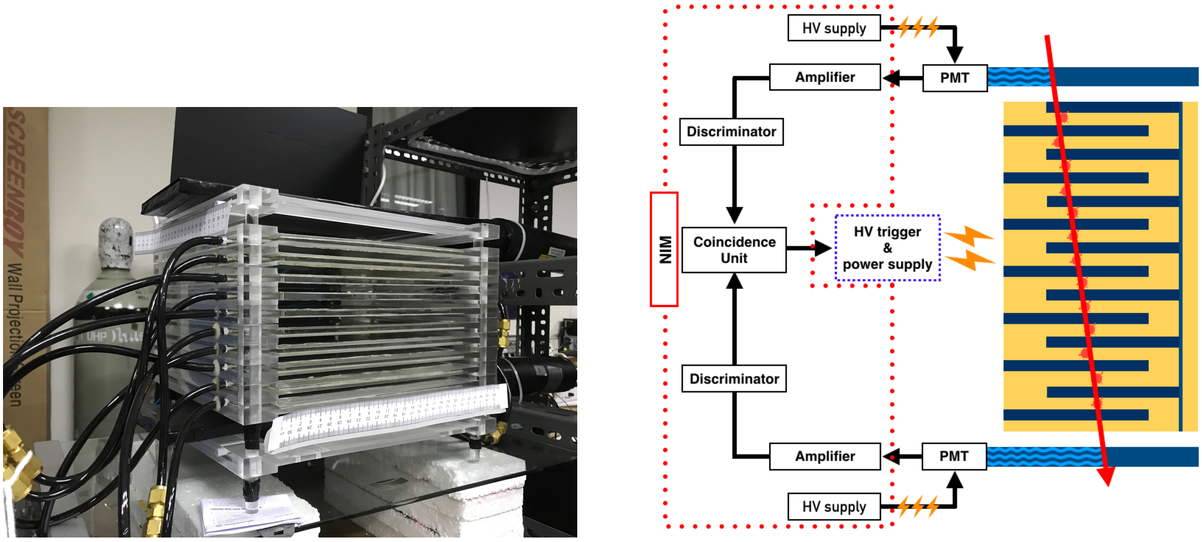
### *2.1. Detector and Experimental Setup*

A spark chamber is a particle detector consisting of a stack of aluminum plates separated by noble gases such as helium, neon or the mixture of the two. When a charged particle passes through the chamber, a control circuit supplies a high voltage between each adjacent pair of aluminum plates, generating a spark between each of the plates. The position where the particle passed through will form a line of sparks due to the ionization left by cosmic-ray muon. The traversing path of muon is thus revealed by the array or line of sparks, which may be seen through the chamber. It was most widely used as a research tool from 1930s to 1960s and has since been superseded by other detector technologies such as drift chambers and silicon detectors.

Our spark chamber constructed as shown in figure 1a. It consists of a stack of 10 parallel electrode plates which are connected to gas tubes for helium filling and also combined them vertically together. Two paddles of plastic scintillators connected to the photomultiplier tubes (PMTs) are placed above and below the chamber for event triggering. To detect particle, we use the Nuclear Instrument Modules (NIM) which consist of:

- two high voltage supply modules to supply the high voltage to PMTs
- two amplifier modules to multiply the signal from PMTs
- a discriminator module to set the threshold of the signal
- a coincidence unit to determine the events that pass through both scintillators
- a scaler module to count the number of detected particles

A schematic diagram of a spark chamber and the corresponding electronics system are shown in figure 1b.




**(a)** Our constructed spark chamber

**(b)** Schematic diagram

**Figure 1.** Experimental setup

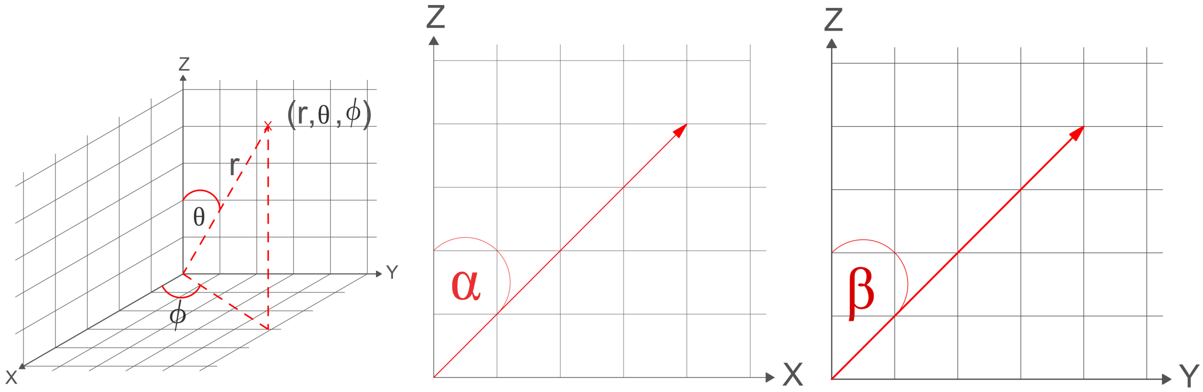
*2.2. Zenith Angle Determination*

We reconstructed the muon's trajectory from two cameras which record videos from two sides of the chamber. A particle's trajectory can be described using a spherical coordinate system as shown in figure 2a which can be described as follows:

$$x = r \sin\theta \cos\phi \qquad y = r \sin\theta \sin\phi \qquad z = r \cos\phi$$

The projection of muon's trajectory onto XZ and YZ planes are shown in figures 2b and 2c, we define the angles of the trajectory on each planes as $\alpha$ and $\beta$ with respect to z-axis on XZ and YZ planes, respectively. Thus, the relation between $\alpha$ and $\beta$ as a function of $\theta$ are as follows:

$$\tan\alpha = \tan\theta \cos\phi$$
$$\tan\beta = \tan\theta \sin\phi$$
$$\tan^2\theta = \tan^2\alpha + \tan^2\beta$$




**(a)** Spherical coordinate **(b)** XZ-plane **(c)** YZ-plane

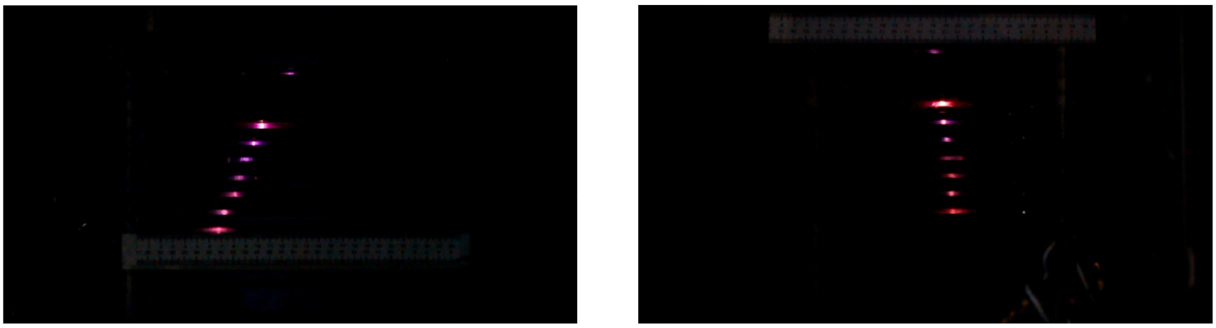
**Figure 2.** Spherical coordinate system and two projected planes

The zenith angle $\theta$, is bounded about 59° as a result of the detector's dimension. We can calculate the possible maximum angles of $\alpha$ and $\beta$ which are bounded by the plastic scintillators and chamber's dimension. The $\alpha_{max}$ and $\beta_{max}$ are 54.6° and 40.2°, respectively.

## 3. Results and Discussion

### *3.1. The Observed Events*

When muons passing through the chamber, they left their traces as ionization regions in which the high voltage is supplied immediately to electrodes. According to this operation, the traces are demonstrated as muon's trajectory as shown in figure 3. About 10,020 events has been taken for 275 hours, 10 January - 19 February 2018, and were categorized as good and bad events using the $\alpha_{max}$ and $\beta_{max}$ of each side as shown in figure 3. About 5,209 out of all events were analyzed as good events and were studied for the angular distribution of the cosmic-ray muons.



**(a)** Front view of the chamber **(b)** Side view of the chamber

**Figure 3.** An example of an observed event

### *3.2. Angular Distribution*

All events classified as good events are used to determine the cosmic-ray muon's angular distribution, represented in figure 4. Most muons penetrated through the chamber with zenith angle 30°. The histogram ends up at 59° which is a result of the chamber's dimension.

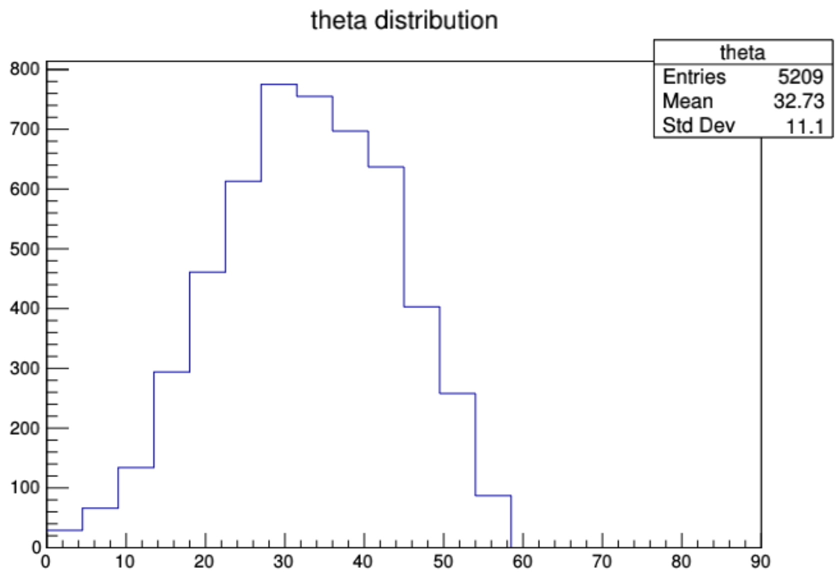



**Figure 4.** Angular distribution of muon

## 4. Conclusion

We have constructed a spark chamber to detect cosmic-ray muons. The muons angular distribution was determined by setting two cameras for recording videos which then were analyzed using MATLAB. Even though spark chamber was superseded by high resolution detectors, it is still an excellent device to reveal the existence of invisible cosmic-ray muon and to display their tracks.

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## References

[1] Patrignani C *et al* (Particle Data Group) 2016 Review of Particle Physics *Chin. Phys.* C **40** 100001 and 2017 update