

The Observation System of EAS Muon Component with the EAS Array and the Muon Spectrometer

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The observation system of muons associated with the compact extensive air shower (EAS) array and the solid iron magnet spectrometer (Okayama telescope) was at work in Okayama University. This telescope enables us to measure the atmospheric muon flux at sea level and the incident direction, the momentum and the charge sign of incident cosmic-ray muons. The EAS array which is a part of Large Area Air Shower experiment is also operated, and the telescope is located almost right under of this array. From January 2004, we started coincidence observation between the EAS array and Okayama telescope.

1. Introduction

The OU (plastic scintillator) array has been operating to observe extensive air showers (EAS) in the campus of Okayama University since September 1996 and belongs to the Large Area Air Shower experiment (LAAS) [1, 2]. The muon spectrometer (Okayama telescope) is also installed to measure the atmospheric muon flux in the building of Okayama University since April 1990 [3, 4].

The OU array is situated on rooftops of the building and the Okayama telescope under the same roof as shown in figure 2. The magnet spectrometer and the array of 8 scintillators have been used to measure the momentum spectrum of the muon component of EAS since January 2004. The ordinal atmospheric muons are initiated from the primary particles which energies are below $\sim 10^{12}$ eV. On the other hand, muons associated EAS are initiated from the primary particles which energies are $10^{14} \sim 10^{16}$ eV called the "knee" region.

This observation is able to study the muon component of EAS at sea level. Bennett and Greisen reported muon spectra using both the EAS array and the magnet spectrometer [5]. We have study muon flux associated with EAS using both the EAS array and the magnet spectrometer.

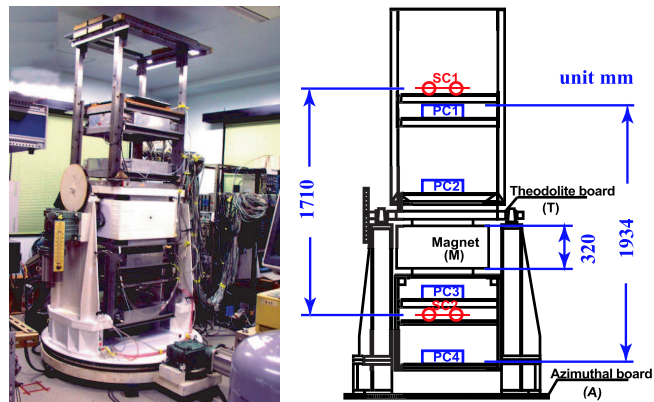


Figure 1. A photograph of Okayama telescope.

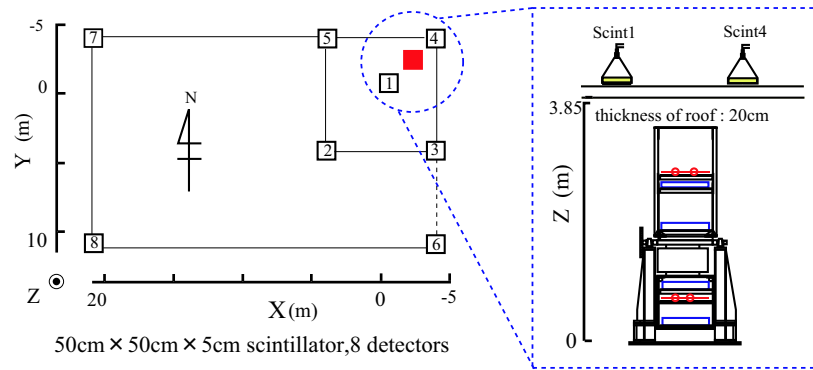


Figure 2. The arrangement of detectors. Left: Top view of detectors. The squares with numbers indicate positions of each scintillation counters. The filled square indicates the position of Okayama telescope. Right: Side view in the broken circle.

2. Observation system

The EAS array and the telescope are situated as shown in figure 2. The OU array is a part of Large Area Air Shower (LAAS) group arrays [1, 2]. The OU array is equipped with 8 detectors, each consist of a plastic scintillator ($50\text{ cm} \times 50\text{ cm} \times 5\text{ cm}$) and fast photomultiplier tube (PMT). The distance between the two triggering (No.1&No.4) is 5 m, and other detectors are located at 5-30 m from them. The array's angular resolution is evaluated at 7 degrees by the Monte Carlo simulation [2]. The arrangement is shown in figure 2. The OU array are put on the top of the building and the Okayama telescope are set up in the building. The angular resolution of the telescope is 1 mrad, MDM is about $150\text{ GeV}/c$. The geometrical acceptance is $21.5\text{ cm}^2\text{sr}$. The telescope consists of trigger counters (2 scintillation counters), position chambers (3 multi-wire proportional chamber sets used as drift chambers), an iron core magnet, and a theodolite and azimuthal boards. The main characteristics are summarized in the reference [4]. The OU array is put on the rooftops the building and the Okayama telescope is under the same roof. The OU array is used to observe EAS electrons and muons with the primary energy range $10^{14} \sim 10^{16}\text{ eV}$. The Okayama telescope is operated to observe atmospheric muons with the energy range $10^9 \sim 10^{11}\text{ eV}$. The majority of muons detected by the Okayama telescope are produced from the primary particle with the energy below $\sim 10^{12}\text{ eV}$. Each observation system is operated independently.

The trigger signal of the OU array circuit is sent to the Okayama telescope system as shown with the emphasized line in figure 3. The signal as the "coincidence" between the OU array and the telescope is recorded in the telescope data when the trigger signal of the OU array comes within $\pm 1\ \mu\text{sec}$ from the trigger signal of the telescope.

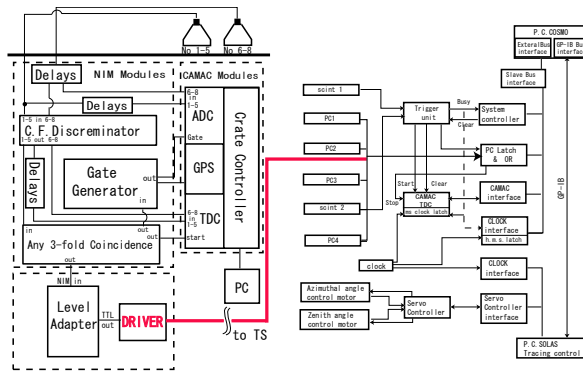


Figure 3. Block diagram of the observation system. Left side is shown the OU array system and right side is shown the Okayama telescope system. The emphasized line is connected both system to send the OU array coincidence signals to the Okayama telescope system.

3. Observation

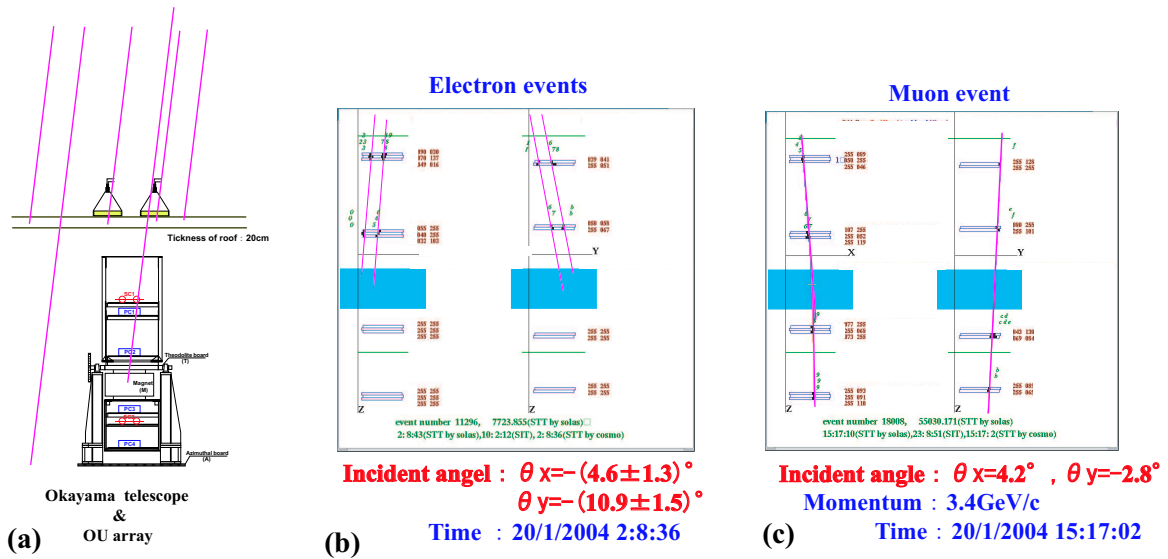


Figure 4. The particles of EAS fall in detectors. The events are shown in the track-checking system. Figure (b) shows two track events which are estimated electron events, since they do not penetrate the magnet. Figure (c) shows a single track event which is estimated single muon event, since it penetrates the magnet.

We have observed coincidence events between the OU array and the Okayama telescope from 18th January 2004 to 30th April 2005, total observation time is 380.2 days. Typical event tracks are shown in figure 4. Figure 4-(a) shows that particles in the air shower incident the OU array and the Okayama telescope. Figure 4-(b) and (c) show the track-checking system. Figure 4-(b) shows two track events. They are estimated to be electrons, since they do not penetrate the magnet. The thickness of

the iron core magnet is 32 cm. Figure 4-(c) shows the single track event. It is estimated to be a single track muon, since it penetrates the magnet. In case of single track muons, we can measure the momenta of them from bending in the magnet. The total number of coincidences and single muon events are shown in table 1.

The event rate of recorded all events in the telescope is 156,815 per day. The event rate of recorded all single

Table 1. Number of associated events.

	no.of events	rate / day
coincidence	299306	787.3
single muon	195	0.513

muon events is 10,732 per day. The coincidence event rate is 0.50 % and the associated single muon event rate is 3.3×10^{-4} % compared with recorded all events.

The physical results are presented as “Momentum Spectrum of Muons Associated with Cosmic-Ray Air Shower at Sea Level” in this conference [6].

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