# GRAPES III : A NEW LARGE EAS EXPERIMENT AT OOTY

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## ABSTRACT

A new large extensive air shower array, GRAPES III, is being installed at the mountain altitude laboratory at OOTY ($2200m$ *altitude*, $11°23'N, 76°39'E$) for a detailed study on the energy spectrum and composition of primary cosmic ray flux over the broad energy range, $3 \times 10^{13} \sim 3 \times 10^{16} eV$. We present here the details of the experiment including data taking and monitoring systems.

## INTRODUCTION

Direct measurements on the energy spectra for various nuclear groups in the primary cosmic ray flux have provided statistically significant results only for energies less than about $10^{14} eV$ (E.D. Olson et al 1995, M. Ichimura et al 1993). Information above this energy can be obtained mainly from indirect measurements on extensive air showers produced by ultra high energy cosmic rays (M. Amenomori et al 1996, M. Nagano et al 1984). Due to the complex nature of the shower phenomenon and various complexities of experimental techniques which give rise to some systematic errors in the results, it has not been possible to obtain satisfactory and consistent results on primary cosmic ray composition and its variation with energy at ultra high energies. The main motivation for the GRAPES ( *Gamma Ray Astronomy at PeV EnergieS* ) experiment is the understanding of the physical mechanism underlying the *knee* in the energy spectrum at $\sim 3 \times 10^{15} eV$ observed in several experiments (Amenomori et al 1996). For this purpose, detailed measurements on both the electron and the muon components are required on individual showers over a broad energy range around the *knee*. We present here details of an experiment being carried out at OOTY for a detailed study of the muon component of showers, using a very large area muon detector in association with a very dense air shower array.

## ELECTRON DENSITY/TIMING DETECTORS

It is desirable to make reliable measurements on the energy spectrum at lower energies, around $10^{13} \sim 10^{14}$ eV, with the air shower technique in order to have an overlap with direct measurements and to understand the systematics satisfactorily. A good agreement between direct and EAS measurements at these energies would provide the required confidence in measurements at ultra-high energies. Further, measurements over the entire energy range of interest, $3 \times 10^{13} \sim 3 \times 10^{16}$ eV, should be made with the same array to minimize possible systematic errors. The GRAPES III EAS array has been designed with these considerations in mind. With only 8 m separation between the adjacent detectors, the hexagonal shaped GRAPES III array has good triggering efficiency over the entire energy range of interest. Figure 1 shows the layout of the inner 217 detectors placed around the central laboratory, with muon detectors located towards the northern edge of the array. It is proposed to expand the array to 721 detectors in next 3 years, while collecting data with the smaller array for lower energy showers.

Each of these electron density/timing detectors is a 1 $m^2$ area, 5 cm thick plastic scintillation detector viewed by a fast 5 cm diameter photomultiplier (Burle 8575 / EMI 9807B) placed 65 cm above the scintillator, to achive uniform response over the entire scintillator area. All

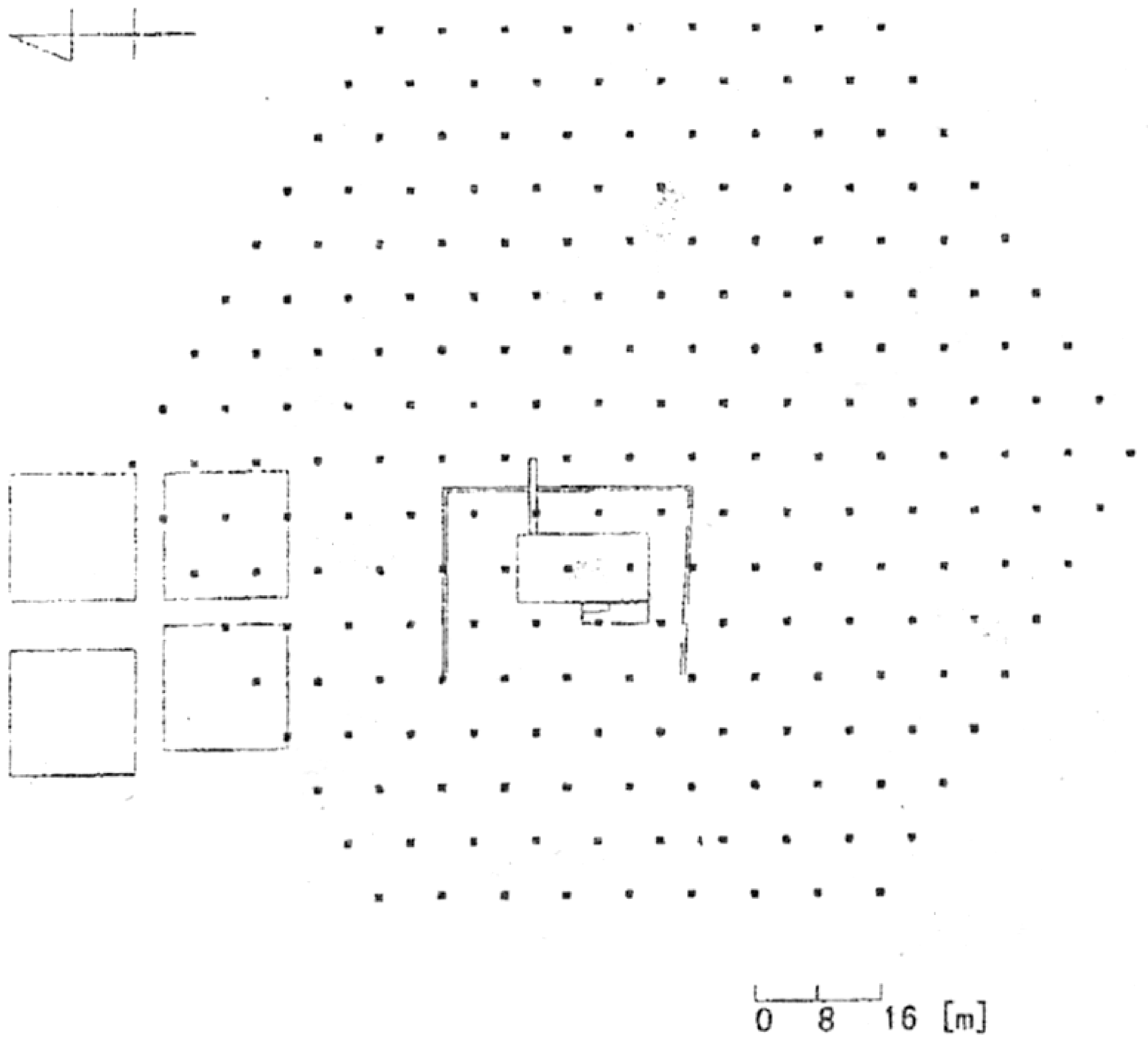

*Figure 1* : The layout of the inner 217 scintillation detectors and muon detectors

the electron detectors are instrumented for measurement of particle density for determination of shower size from the observed lateral density distribution, as well as relative arrival time for determination of the arrival angle, for individual showers. The shower selection requires generation of a trigger at two levels; the 'Level 0' requires a 3-fold fast coincidence between one of the detectors from each of the three adjacent rows. 'Level 1' trigger is generated by a slower coincidence between any 'N' detectors of the array with 'N' selectable over the range 6 ~ 20 depending on the energy range of interest. Results obtained from simulations for triggering efficiency as a function of primary energy and nuclear species, for the detector configuration of GRAPES III and trigger requirements, are discussed in another paper (OG 6.2.12) being presented at this Conference.

## MUON DETECTORS

It has been known for a long time that a simultaneous study on the electron and muon components of extensive air showers has good potential of yielding reliable results on the composition of primary flux. Keeping this in mind, we have installed a very large area ($\sim 560m^2$) muon detector in the GRAPES III array. The detector consists of 4 independent supermodules, each of $\sim 140m^2$ area, which are all located close to each other as shown in Figure 1. Each supermodule consists of 4 modules. The basic detector element is the $6m$ long proportional chamber with a cross sectional area of $10 \times 10cm^2$. Each module has 4 layers of proportional chambers, with alternate layers of chambers placed in orthogonal directions to permit satisfactory tracking of individual muons. Each of the 4 layers has 58 chambers placed side by side and adjacent chamber layers are separated by a layer of 15 cm thick concrete slabs. The concrete overburden above the 4th layer of chambers is 210 cm thick, giving a threshold energy of 1 GeV for near-vertical muons which traverse a minimum of 3 of the 4 layers. Laterally, the muon filter extends upto a zenith angle of 45° for muons traversing at least 3 of the 4 layers. The 4 modules of a supermodule share the muon filter as shown in Figure 2. Figure 3 shows a block diagram of the data recording system for a $\mu$-supermodule. Processing of data from chambers starts on receipt of a shower trigger from the EAS array. For all chambers recording a hit in coincidence with a shower, data on 'pulse-width' and relative arrival time are recorded. The 'pulse-width'

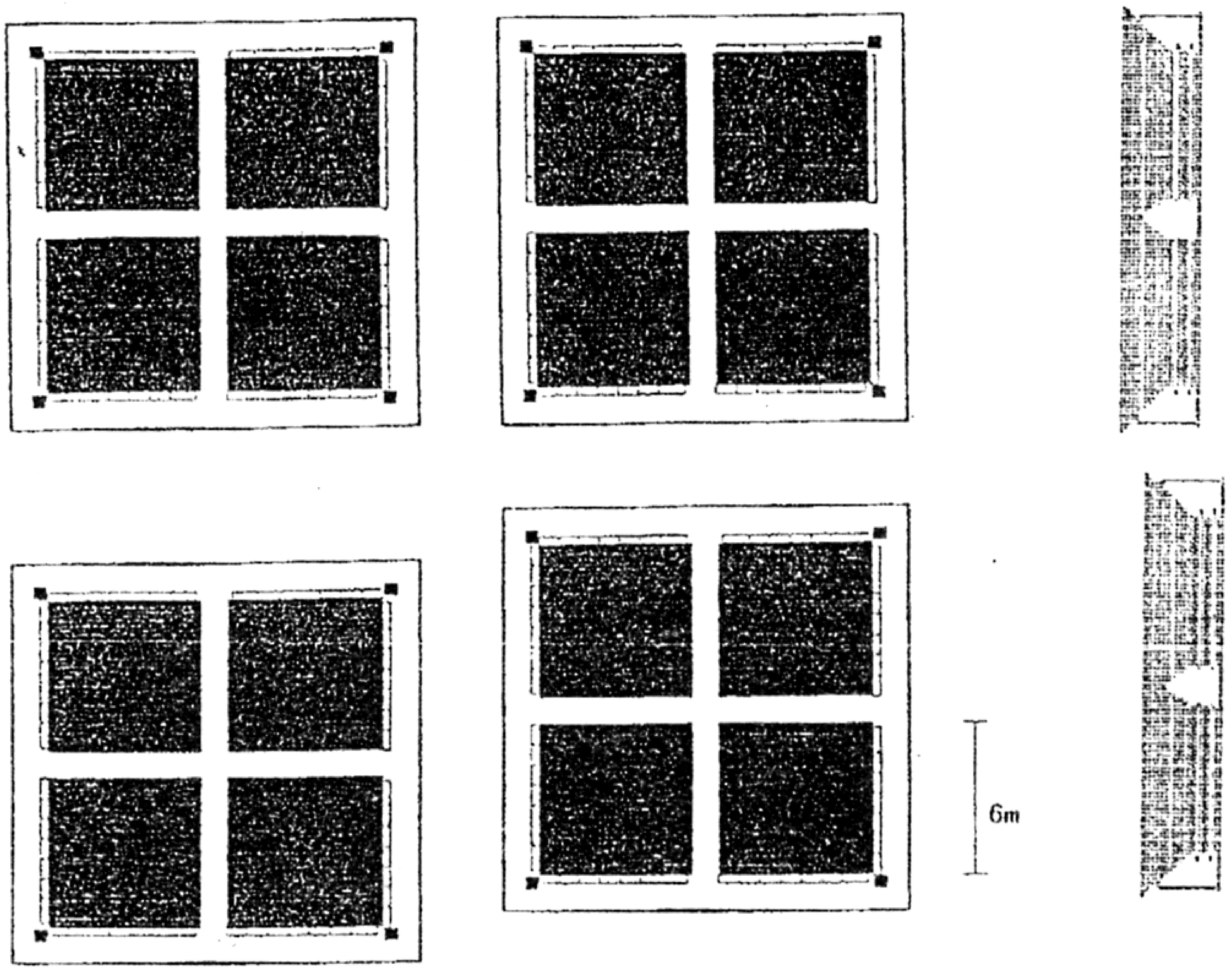

*Figure 2* : The 4 modules of a supermodules share the muon filter

is proportional to the logarithm of the amplitude of the pulse from the proportional chamber as the output of the charge-integrating-amplifier-shaper has an exponential shape with a decay time of $\sim 7\mu s$. The pulse-width and arrival time are digitized to give two bytes of data for each chamber. Only data from chambers which have recorded a hit are transferred to memory along with their addresses for each shower, along with the absolute time of the arrival of the shower as given by a precision clock controlled by GPS signals with an accuracy of $1\mu s$. Data are stored locally for each supermodule for a large number of showers before transfer to the Central Laboratory through ethernet connection. Each shower is uniquely identified at all supermodules as well as at the Central Laboratory by its absolute arrival time. To monitor and maintain high efficiency for all the muon chambers, we have designed and installed systems which monitor pulse-width distributions for each chamber as well as layer counting rates. Layer rate monitors look for stability of single layer rate as well as 3-layer and 4-layer rates. A pulse-width analyzer is used for calibration of all proportional chambers once every day. It has been observed that the 3-layer counting rate is about 4000 Hz for a module with $\geq 99\%$ efficiency for all chambers. Through this monitoring, we expect to be able to detect variations at the level of $\leq 1\%$ in muon intensity over time intervals of a seconds.

## DISCUSSION AND CONCLUSIONS

Using showers with well-defined characteristics, like shower size and core-location relative to muon detectors, we can study the properties of the muon component in two ways. Following the standard procedures as used by other groups for data obtained with smaller size muon detectors, we would be able to obtain a good measurement of lateral distribution for muons which would permit determination of the total number, $N_\mu$ for showers of average size $N_e$. This would permit a more precise study of $N_\mu - N_e$ relation than achieved so far due to better accuracy in determination of $N_\mu$ and $N_e$ with the GRAPES III array. However, more promising is the determination of the muon multiplicity distribution for showers of different size groups,

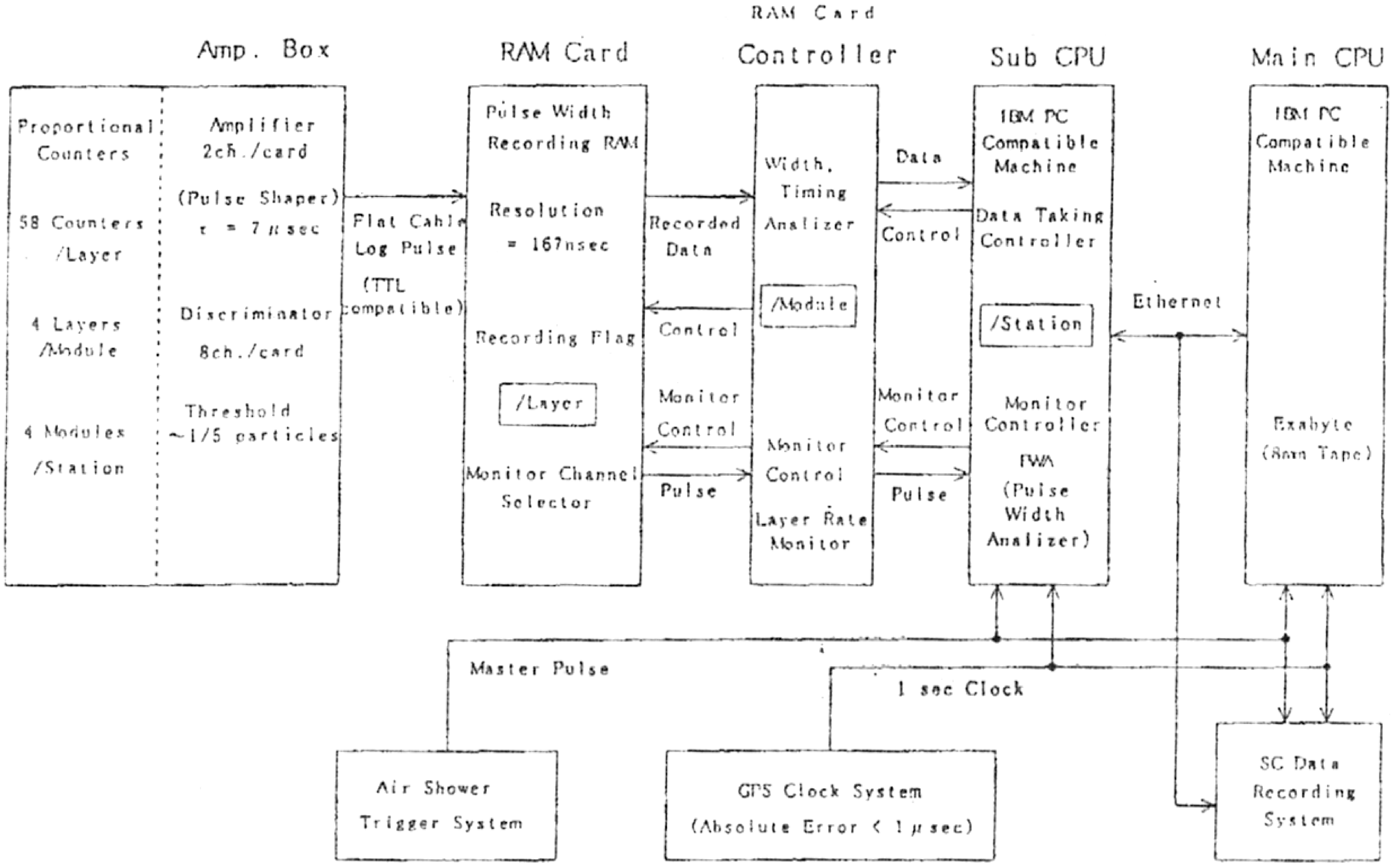

*Figure 3* : A block diagram of the muon data recording system

which has become possible for the first time with the GRAPES III array due to the very large area of the muon detector. Results expected from Monte Carlo simulations, carried out using COSMOS 4.0 (Kasahara 1995), for studies using both these methods are discussed in detail in another paper (OG 6.1.4) being presented at this Conference. These simulations show that detailed observations on the electron and muon components with the GRAPES III array would permit a good measurement of the composition of primary cosmic ray flux over the broad energy range, $3 \times 10^{13} \sim 3 \times 10^{16} eV$. These measurements would lead to a better understanding of the physical mechanism underlying the *knee* in the energy spectrum at $\sim 3 \times 10^{15} eV$.

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## REFERENCES

M. Amenomori et.al., Ap. J., 461, 408 (1996)
M. Ichimura et.al., Phys. Rev. D, 48, 1949 (1993)
K. Kasahara, Proc. 24th ICRC, 1, 399 (1995)
M. Nagano et.al., J. Phys. G, 10, 1295 (1984)
E.D. Olson, for the JACEE Collaboration, Proc. 24th ICRC, 2, 752 (1995)