A STUDY ON FINE FEATURES IN THE ENERGY SPECTRUM OF PRIMARY COSMIC RAYS OVER THE ENERGY RANGE $1 \times 10^{14} - 3 \times 10^{16} eV$ WITH THE GRAPES III EAS ARRAY AT OOTY

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ABSTRACT

New measurements on the fine features of the energy spectrum over the energy range, $1 \times 10^{14} - 3 \times 10^{16}$ eV, with better resolution than achieved so far, are required to improve our understanding of the physical mechanism underlying the *knee* at energy $\sim 3 \times 10^{15}$ eV. We present here the details of a new experiment, GRAPES III, being carried out at Ooty for a precision measurement of the energy spectrum of primary cosmic ray flux over a broad energy range, $1 \times 10^{14} - 3 \times 10^{16} eV$.

INTRODUCTION

Several experiments have reported observations (Amenomori et al 1996, Nagano et al 1984) on the steepening in the energy spectrum of primary cosmic ray flux at energy $\sim 3 \times 10^{15}$ eV from measurements on the shower size spectrum of extensive air showers. The presence of a bump just before the onset of steepening has also been suggested from a comparison of fluxes measured by satellite-borne detectors and air shower experiments. An understanding of these observed spectral feature, the *bump* and *knee*, has been attempted in terms of propagation effects of cosmic rays in the galactic disk and their leakage from the disk due to the larger Larmor radii at rigidities above some threshold rigidity, $\sim 1 - 3 \times 10^{14}$ GV/n. Alternatively, the *knee* has been interpreted in terms of changes in the accelerating mechanism in cosmic ray sources at energies around 10^{15-16} eV.

It has also been suggested (Erlykin and Wolfendale 1997) that these interesting spectral features at energies $\sim 10^{15-16}$ eV may be due to the occurrence of a supernova near the Solar system in not too distant past. It is felt that new precision measurements on the fine features of the energy spectrum over the broad energy range, $1 \times 10^{14} - 3 \times 10^{16}$ eV, with better resolution are necessary to improve our understanding of the physical mechanism underlying these spectral features. We present here the details of a new experiment, GRAPES III, being carried out at the mountain altitude laboratory at Ooty (2200 m altitude, 11° 23′ N, 76° 39′ E) for a new study on the the energy spectrum of primary cosmic ray flux over this energy range with better precision than achieved so far. The expected performance of the GRAPES III array obtained from Monte Carlo simulations is also discussed.

ELECTRON DENSITY/TIMING DETECTORS OF GRAPES III ARRAY

The layout of the inner 217 density/timing detectors, which are operational at present, is shown in Figure 1. In view of the necessity to have some overlap with the energy range of direct measurements with balloon/satellite borne detectors, the array has been designed to be dense with only 8 m separation between adjacent detectors. It is proposed to expand the

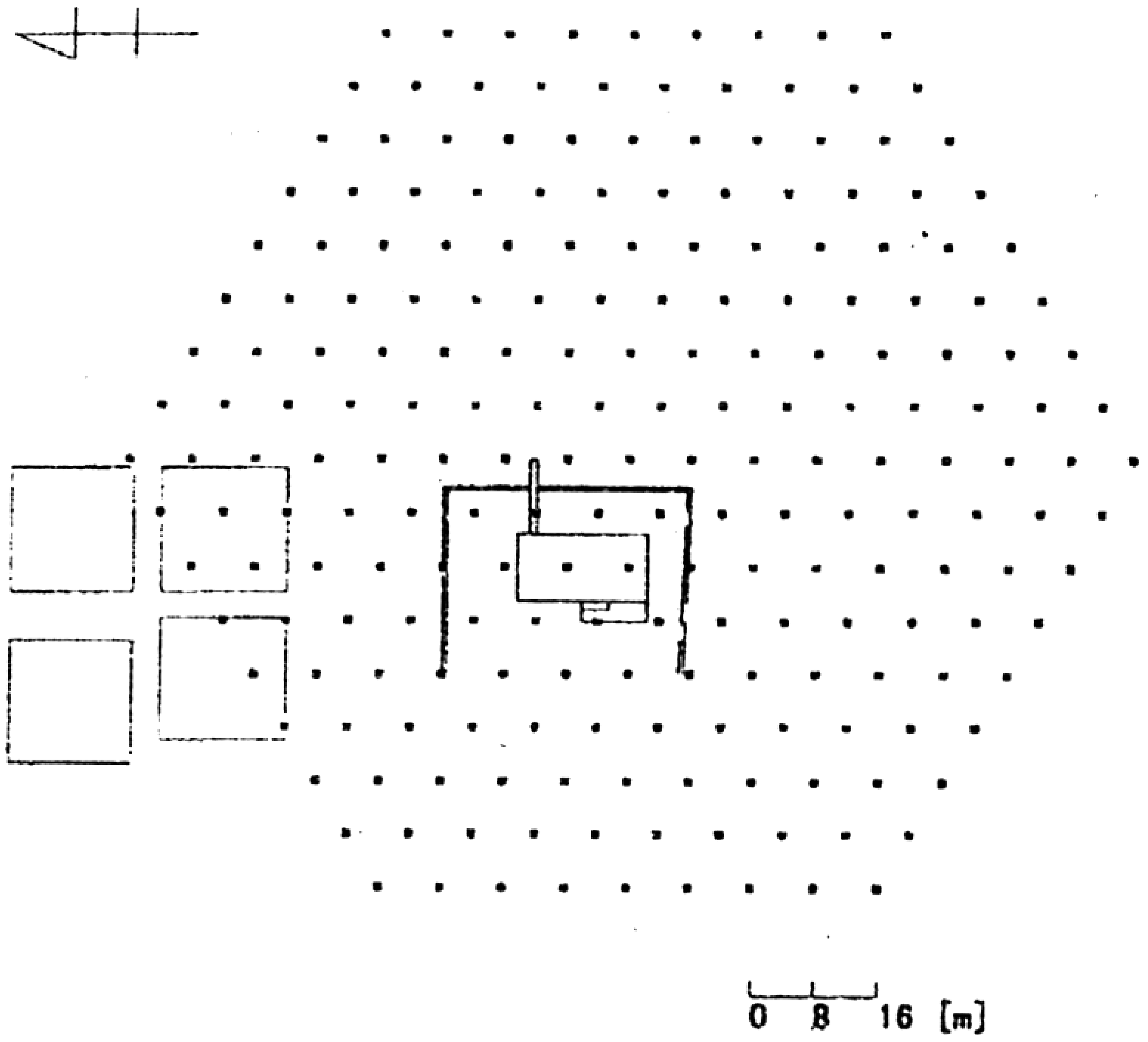

Figure 1 : The layout of the inner 217 scintillation detectors and muon detectors

array to 721 detectors in the next 3 years, while collecting data with the smaller array for lower energy showers. It is considered desirable to make reliable measurements on the energy spectrum at lower energies, around 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. It is also felt that measurements over the entire energy range of interest, $1 \times 10^{14} \sim 3 \times 10^{16}$ eV, should be made with the same array to minimise 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.

Each of the 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 achieve uniform response over the entire scintillator area. All 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. Monte Carlo simulations have been carried out to study the expected performance of the array for showers incident over the array, for various primary energies and different primary nuclear species. The variation of the 'detection efficiency' as a function of primary energy is shown in Figure 2 for showers initiated by different nuclei. GENAS (Kasahara and Torii 1991) program has been used to obtain these results. It is seen that efficiencies larger than 95% may be achieved for protons of energy $\geq$ 30 TeV, or $\alpha - particles$ of energy $\geq$ 40 TeV. However, for showers initiated by Fe nuclei, the efficiency becomes 95% only for energies $\geq$ 80 TeV. Figure 3 shows the variation in trigger rate as a function of primary energy for different nuclei. It may be concluded from

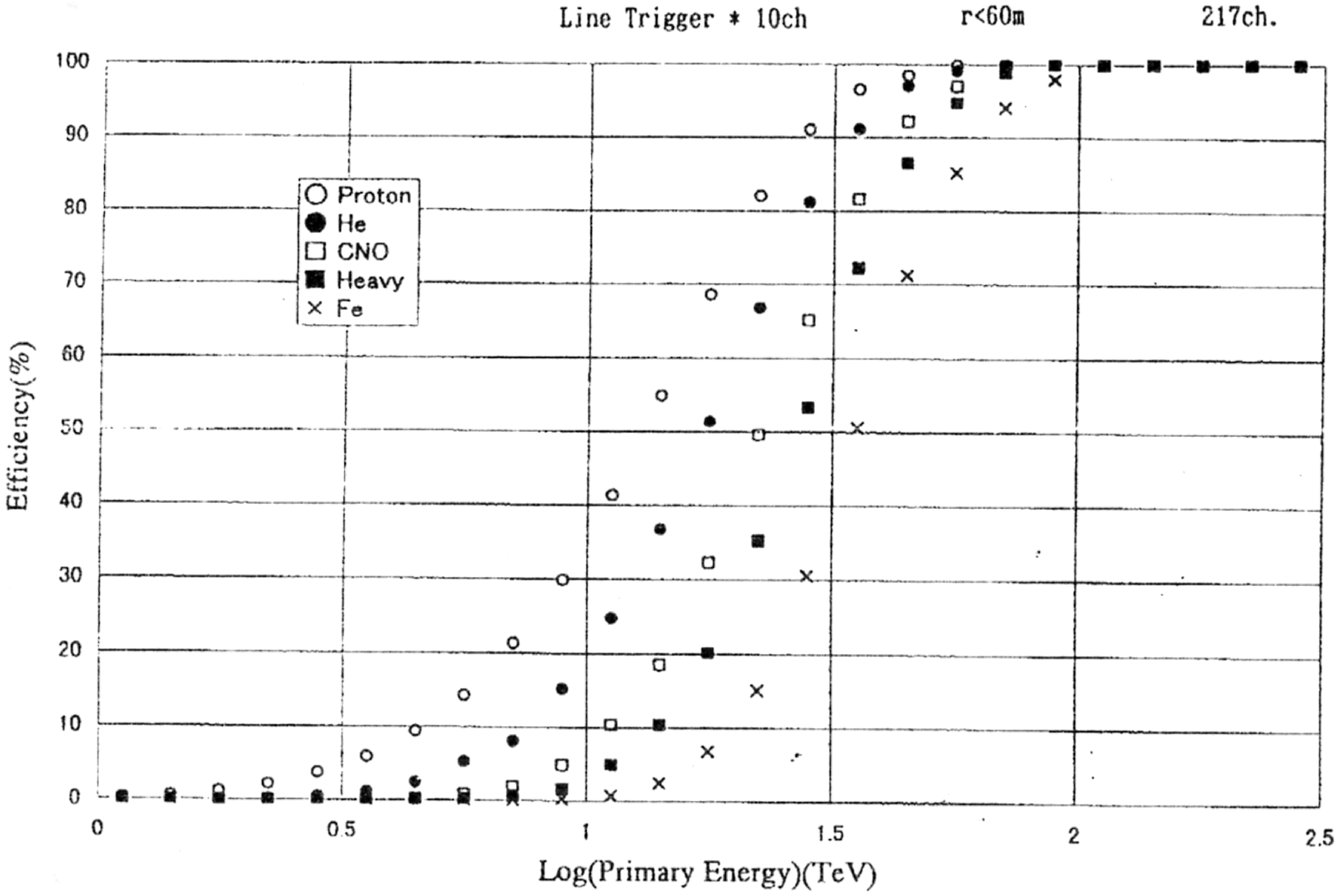

Figure 2 : Variation of Trigger Efficiency classified by primary energy for different nuclei

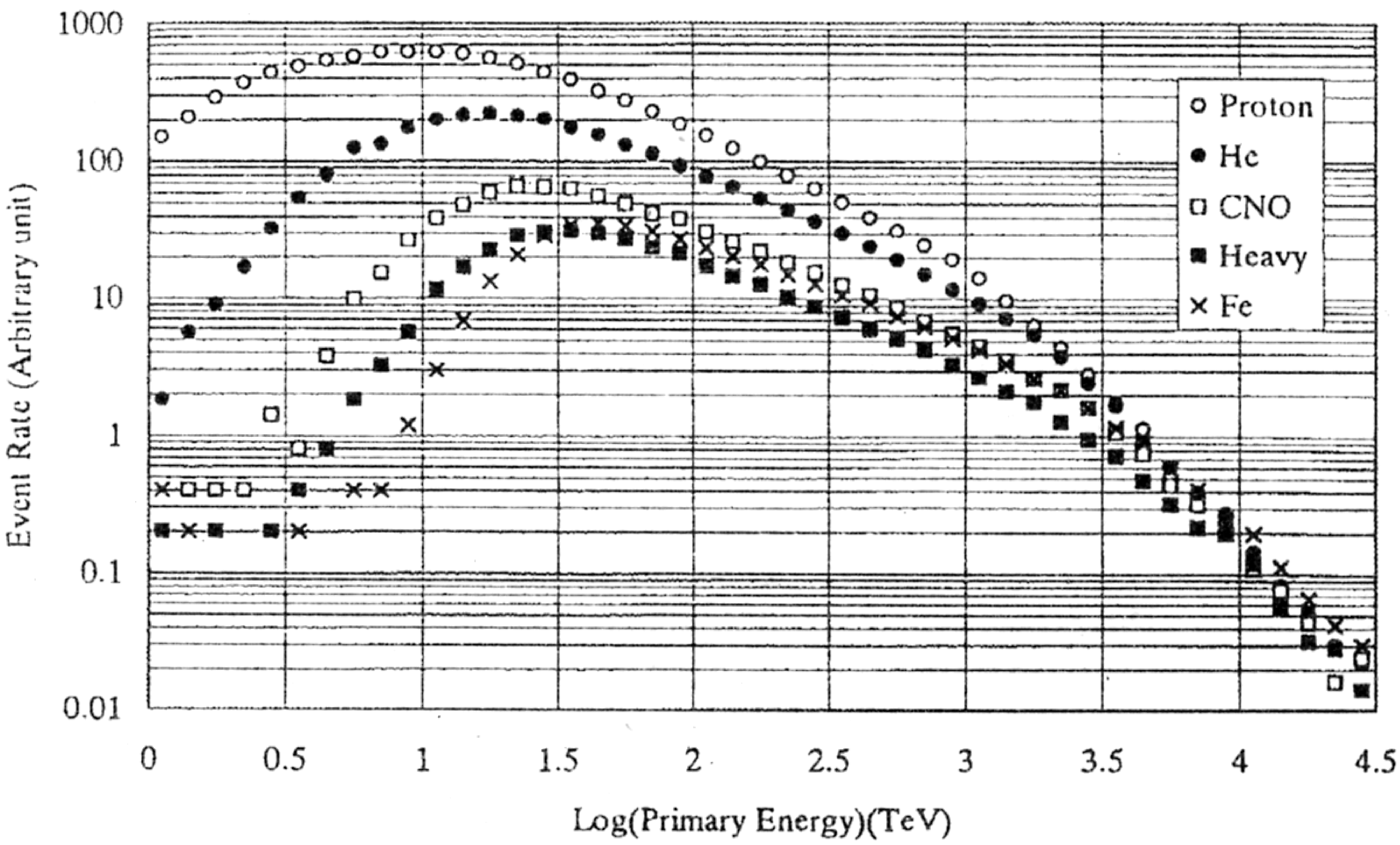

Figure 3 : Variation in trigger rate as a function of primary energy for different nuclei

this Figure that using data from the very large area muon detector to distinguish showers due to protons and lighter nuclei, it may be possible to compare the observed flux of showers due to these nuclei with flux values determined from observations with balloon or satellite borne detectors, at energies as low as 30 TeV.

MUON DETECTORS

As discussed in detail in another paper (OG 6.1.4) being presented at this Conference, one of the main objectives of the GRAPES III experiment is the measurement of the composition of primary cosmic ray flux over the broad energy range, $1 \times 10^{14} - 3 \times 10^{16}$ eV. For this purpose, a very large area ($\sim 560m^2$) muon detector has been installed in the GRAPES III array, which consists of 4 independent supermodules, each of $\sim 140m^2$ area, located close to each other as shown in Figure 1. Results expected from observations with this large detector are discussed in paper OG 6.1.4.

DISCUSSION AND CONCLUSIONS

With 721 electron density/timing detectors spread over an area of radius 120 m, the GRAPES III array is expected to provide data of very good quality on showers over the broad energy range, $1 \times 10^{14} - 3 \times 10^{16}$ eV. This would permit determination of the primary energy spectrum with better precision than achieved so far. It is expected that a detailed high statistics study may also permit observation of fine structure, if any, around the energy $\sim 3 \times 10^{15}$ eV where the spectrum has been observed to steepen (*knee*). These observations supplemented with information obtained from the large area muon detector are expected to provide insights into the physical mechanism underlying this spectral feature.

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