A NEW STUDY ON THE COMPOSITION OF PRIMARY COSMIC RAY FLUX OVER THE ENERGY RANGE $3 \times 10^{13} - 3 \times 10^{16} eV$ WITH THE GRAPES III EAS ARRAY AT OOTY

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ABSTRACT

A new extensive air shower array, GRAPES III, is being installed at OOTY for a study of the energy spectrum and composition of primary cosmic rays in the energy range, $3 \times 10^{13} \sim 3 \times 10^{16}$ eV. The array with 721 density/timing detectors and a 540 m^2 area muon detector is designed to measure the muon multiplicity distribution for showers of different size groups. We present here some details of the experiment and the results expected from Monte Carlo simulations on the sensitivity of the muon multiplicity distribution for showers initiated by primaries of different nuclear species. It is shown that observations with the large area muon detector in the GRAPES III array should provide a reliable determination of the composition of primary flux over a broad energy range, and particularly around the *knee* in the primary energy spectrum.

INTRODUCTION

Recent observations (Amenomori et al 1996, Nagano et al 1984) on the primary energy spectrum of cosmic ray flux have shown a so-called *knee* around 3×10^{15} eV, where the power law spectral index for the differential spectrum seems to change from ~ 2.6 to ~ 3.1 rather abruptly. The existence of the *knee* suggests either a significant change in the acceleration mechanism in cosmic ray sources around this energy or a change in the propagation and containment of cosmic rays in the galactic disk for more energetic particles. In order to improve our understanding of the physical processes responsible for this interesting spectral feature, it is necessary to study in greater detail the structure in the primary spectrum around the *knee* with better resolution than achieved so far. Also, it is very desirable to make more reliable measurements on the composition of primary flux at energies below and above the *knee*. With these considerations in mind, we are installing a new large extensive air shower array, GRAPES III, at the mountain altitude laboratory at OOTY (2200 m altitude, 11° 23′ N, 76° 39′ E). The main features of the GRAPES III experiment are (a) a very dense and large EAS array of 721 density/timing detectors, and (b) a very large area, 540 m^2, muon detector. We present here some details of the GRAPES III array with particular emphasis on the design of the muon detector and the results expected from observations on muons in this experiment as obtained from detailed Monte Carlo simulations.

GRAPES III EAS ARRAY

The new array consists of 721 unshielded electron density/timing detectors, arranged in an equilateral triangle configuration with inter-detector spacing of only $8m$, covering a 15-ring hexagonal pattern. Each detector consists of a 1 m^2 area, 5 cm thick plastic scintillator viewed by a fast 5 cm diameter photomultiplier (Burle 8575 / EMI 9807 B). The signal from each detector is used to measure both particle density and arrival time of the shower front. Only

217 detectors are operational at present and we plan to increase the number of detectors to 721 over the next 3 years. Details about the electron detector array, shower selection system and the expected trigger efficiency as a function of primary energy for different nuclear species are being presented separately in an accompanying paper (OG 6.2.12) at this Conference.

The basic detector element in the very large area, 540 m^2, muon detector is the $6m$ long proportional chamber with a cross sectional area of $10 \times 10cm^2$. In a module of the muon detector, 58 chambers are placed side by side on a concrete platform and covered with $15cm$ thick concrete slabs. Another layer of 58 chambers has been placed above this layer of concrete slabs in transverse direction relative to the first layer. The 2nd layer is followed by the 3rd and 4th layer, alternately in transverse directions and separated by 15 cm thick concrete slabs. This 4-layer structure has been designed to achieve satisfactory tracking of through-going muons and to permit rejection of counters fired by gamma ray photons either due to cosmic rays or background radioactivity.

There are 14 layers of 15 cm thick concrete slabs above the 4th layer of proportional chambers to provide the necessary thickness of absorber for removing low energy muons and other charged particles. The concrete overburden of 210 cm thick concrete above the 4th layer gives 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^o for muons traversing at least 3 of the 4 layers. Four nearby modules form a supermodule and share the muon filter. Four supermodules of the muon detector, located quite close to each other, provide a total sensitive area of 540 m^2 for studies on the muon component of showers of energies $\geq 10^{13}$ eV. The details of data recording and monitoring of the performance for the muon detector have been given in another paper (HE 6.1.9) being presented at this Conference.

MONTE CARLO SIMULATIONS AND DISCUSSION

We have carried out detailed simulations of air showers using GENAS and COSMOS 4.0 programs (Kasahara 1995) and studied the response of the electron and muon detectors as placed in the GRAPES III array. Results obtained for the expected performance for the electron component are discussed in detail in another paper (OG 6.2.12) presented at this conference. It may be noted that the 2-level shower trigger system would permit selection of showers of energy $\geq 10^{13}$ eV with high efficiency, permitting a good study of the muon content of these low energy showers. Figure 1 shows the expected lateral distribution expressed in terms of detected number of muons in the 540 m^2 detector for showers of size group, $10^{4.000} - 10^{4.125}$ over the distance range of 30-120 m for showers initiated by protons and iron nuclei. Figure 2 shows the $N^e - N^\mu$ plot for showers with cores located at 40 m from the centre of the muon detector, where N_μ again refers to the number of muons detected in the muon detector. It is clear from these figures that use of a very large area muon detector provides high quality data to make it possible to determine the composition of primary cosmic ray flux over the energy range of interest here, particularly around the *knee* in the energy spectrum. Simulations have also shown that it would also be quite easy to identify $\mu - poor$ showers with a strict criterion for $\mu - poor$ to search for showers produced by primary photons, particularly for showers of size $\geq 10^5$.

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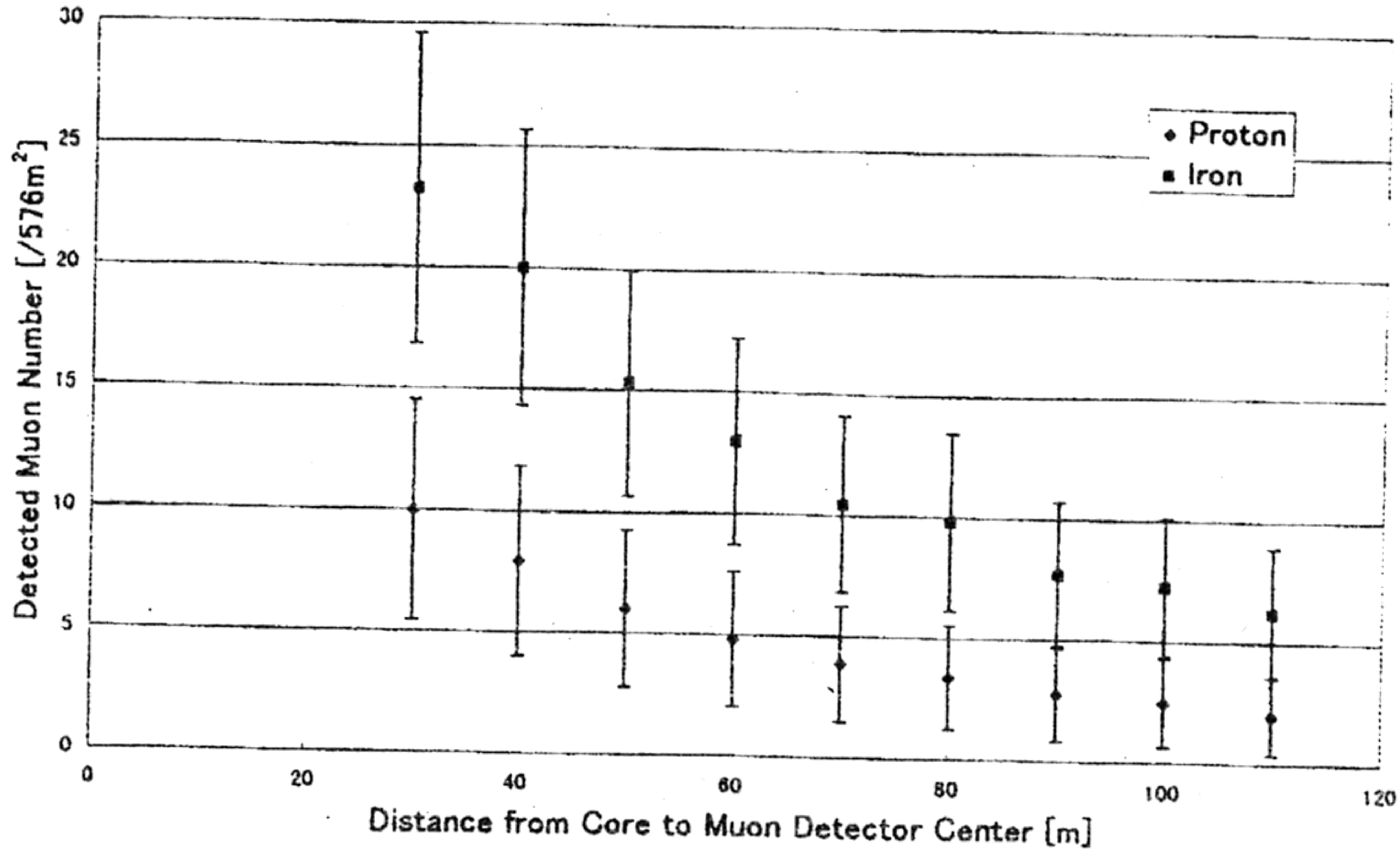

Figure 1 : Lateral distribution of Muons in EAS for $10^{4.00} < Size < 10^{4.25}$ (simulation)

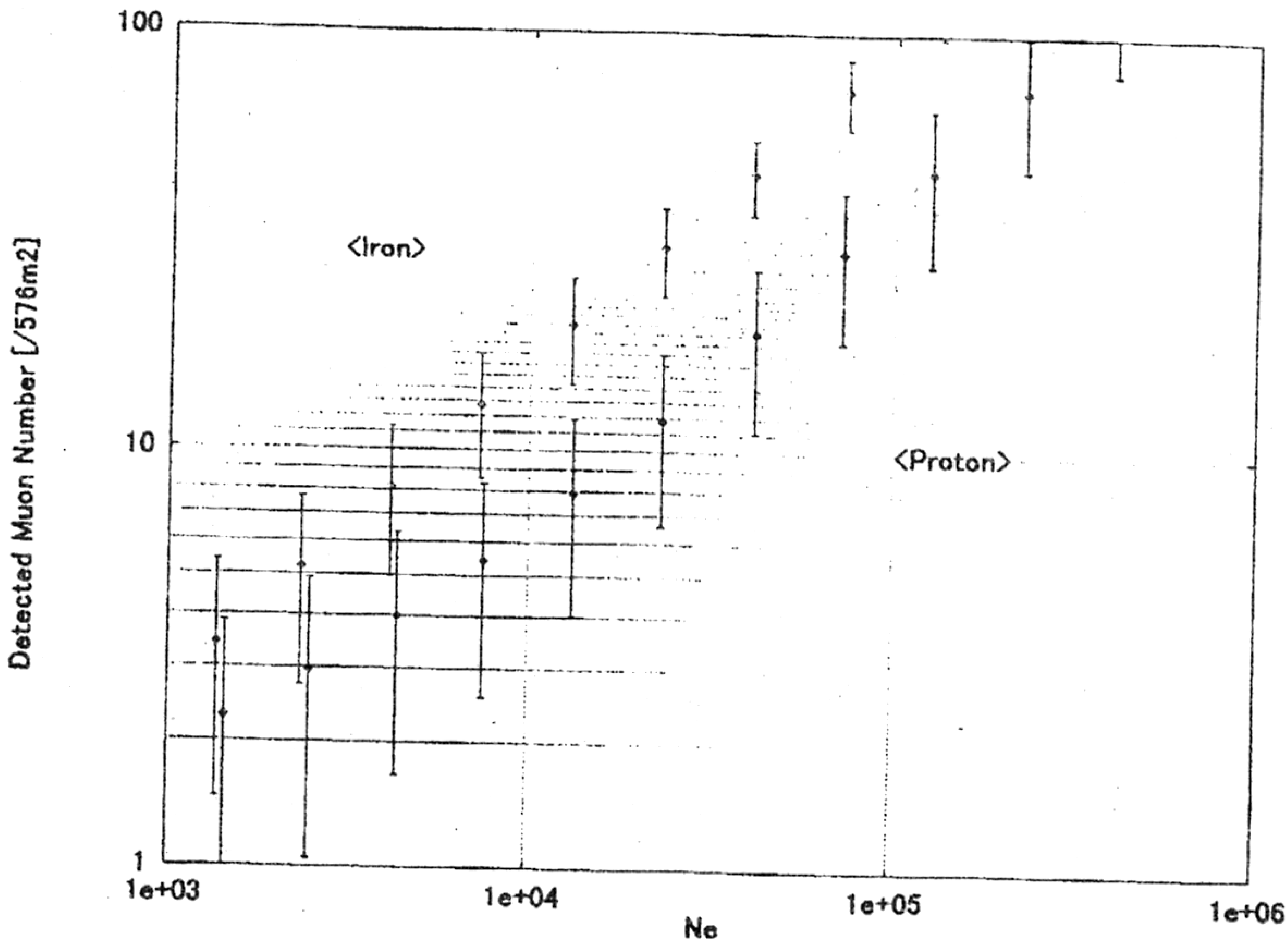

Figure 2 : $Ne - N_\mu$ plot for Core Distance = 40m (simulation)