Proceedings of ICRC 2001: 132

ICRC 2001

Study of UHE primary cosmic ray composition with atmospheric Cherenkov light observations

M. Cha[1], T. Cheung[2], X. Y. Gao[3], Q. X. Geng[2], C. L. Jing[1], G. R. Jing[1], C. Q. Liu[3], J. Liu[3], P. H. Ng[4], H. T. Yang[3], and Q. Q. Zhu[1]

[1]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, 100039, China.
[2]Department of Physics and Materials Science, City University of Hong Kong.
[3]Institute of Cosmic Rays, Yunnan University, Kunming, 650092, China.
[4]Department of Science and Mathematics,Hong Kong Institute of Education.

Abstract. An EAS array with capabilities of particle density detection, atmospheric Cherenkov light observation and muon number counting have been set up on Mt. Liang Wang $(24.7N, 102.9E, 2720m\ a.s.l.)$. It is located at the southeast of Kunming, (about 60km away from downtown) and the local climate is suitable for Cherenkov light observation. A comparison between the air Cherenkov data and our MC simulation with minijet model indicated that the mean mass of primary cosmic rays has no drastic changes below the knee,but a heavier tendency is clearly appeared above the knee.

1 Introduction

An EAS experiment with capabilities of particle density detection, atmospheric Cherenkov lights observation and muon number counting (Fig.1) have been set up on Mt. Liang Wang (24.7N,102.9E,2720m a.s.l.). Due to its multiple component measurement, it is hopeful to extract more reliable information on the primary cosmic ray composition with the aid of a MC simulation for different particle incidence.

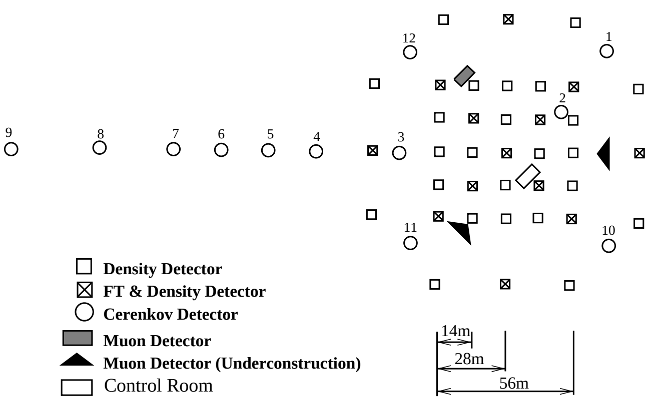

Fig. 1. The Liang Wang Mountain array

Correspondence to: Q. Q. Zhu (zhuqq@mail.ihep.ac.cn)

The experimental facility is shown in Fig.1. The density detector consists of 37 plastic scintillator counters which measure particle density distribution and particle arrival time for each shower. In addition, the central fast timing counters were used to provide trigger signals. Each Cherenkov detector equiped a photomultiplier directly viewing sky within an angular scope approximately 45 degree to the zenith. The muon detector is buried under 4m of solid and is sensitive to muons with surface energy $E_\mu \geq 2.5GeV$.

Fitting both lateral distributions of Cherenkov light and electron density, we infer the shower maximum depth x_{max}, shower size N_e and shower core position. Also we can measure the muon density ρ_μ. All of these $(x_{max}, N_e\ and\ \rho_\mu)$ are functions of secondary particle energy, distance to shower core, primary particle species and primary energy.

In this note we present preliminary result on the cosmic ray composition with the data of the density detector and Cherenkov light array.

2 Event Selection and Data Analysis

2.1 Criteria of good events

The data taking and the treatment of raw data (Gao 1991), for example event reconstruction, are similar to common EAS experiments. With our MC (Cheung 1999) samples, the accuracy of core position determination is about 3 meters. In the preliminary analysis we use only 1272 good events. All thess events satisfy following 6 criteria,

(1) the distance from each shower core to the array center ≤ 50 meters,

(2) zenith angle $\theta \leq 30^o$,

(3) $7.0 \cdot 10^4 \leq N_e \leq 1.0 \cdot 10^6$,

(4) $0.4 \leq s\ (shower\ \ age)\ \leq 2.0$,

(5) $\geq$ 6 Cherenkov detectors exceed the trigger threshold,

(6) the fitting goodness for the lateral distribution of Cherenkov lights is good enough.

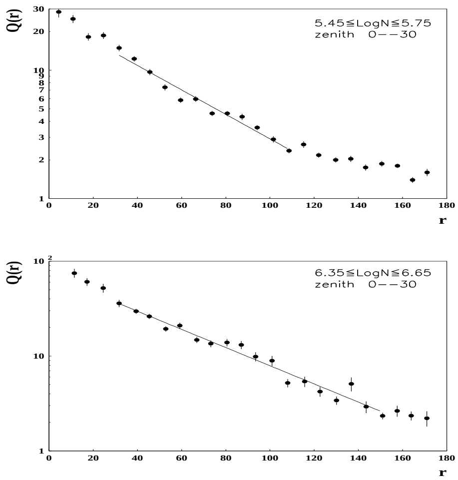

Fig. 2. Examples for the lateral distribution of Cherenkov light

2.2 Determination of shower maximum depth

The lateral distribution of Cherenkov light is fitted by function $Q(r) = a \cdot exp(-b \cdot r)$. here r is the radial distance of Cherenkov detector (r=0 means shower core), Q(r) the intensity of Cherenkov light at the region from r to r+dr, b the distribution parameter. In this work we take a cut of $40m \leq r \leq 140m$ in Q(r) fitting since our MC indicates the parameter b changes with r cut (see Fig.2). With the MC we also get the relation between shower maximum depth x_{max} and parameter b as the follows,

$$x_{max} = 1.14 \cdot 10^4 \cdot b + 287 \quad (g/cm^2)$$

2.3 Deternimation of shower's primary energy

With the MC, shower's primary energy is determined by the following formula,

$E_0 = 10^{8.83} \cdot N_e^{1.11}$ (eV), for primary protons
$E_0 = 10^{9.72} \cdot N_e^{1.03}$ (eV), for primary irons

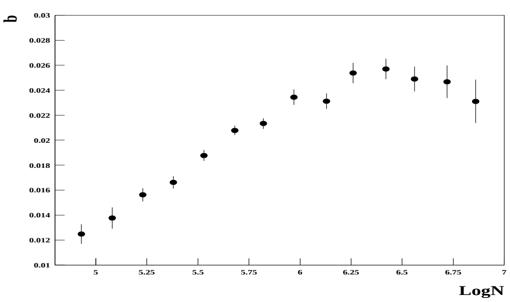

Fig. 3. parameter b vs shower size N_e

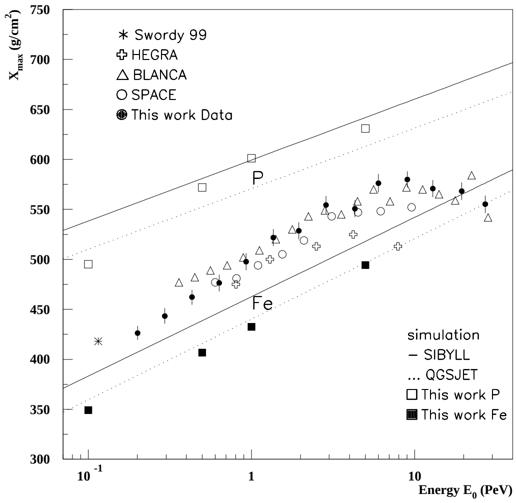

Fig. 4. x_{max} vs N_e and comparison with other data

3 Results and discusion

Fig.4 shows the change of x_{max} with shower size N_e. In the figure we combine our data with others (Fortson 1999, Dickison 1999,Arqueros 1999 and Swordy 1999) together for comparison. The figure indicates that the cosmic ray mass have no drasmetic changes before the "knee", but a heavier tendency is clearly appeared above the knee.

Our data also indicates that Q(100), the Cherenko light intensity at r=100 meters, is proportional to shower size $\log(N_e)$ (or primary energy) and it is independent of primary particle species(Fig.5). So it is expected to use Q(100) to deternime each shower's primary energy.

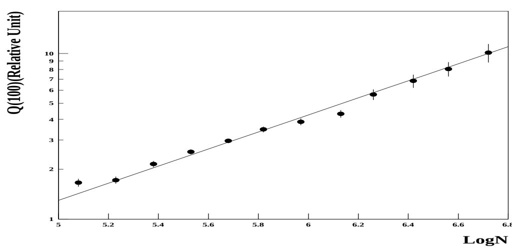

Fig. 5. Linear relation between Q(100) and $\log(N_e)$

References

Cheung T. and Zhu Q.Q.,1995, Proc. 24th ICRC, Roma, Vol.1, p143
Gao X.Y. et al., ,1991, Proc. 22th ICRC, Dublin, Vol.4, p472
Arqueros F. et al., 1999, e-Print Archive: astro-ph/9908202
Fortson L.F. et al., 1999, Proc. 26th ICRC,Salt Lake City, Vol.3, OG 1.2.02
Dickison J.E. et al., 1999,Proc. 26th ICRC,Salt Lake City, Vol.3, OG 1.2.05
Swordy S.P. and Kieda D.B. 1999,Proc. 26th ICRC,Salt Lake City, Vol.3, OG 1.2.07