Analysis of Emulsion Chambers in Tibet Hybrid Experiment Using the Image Scanner

The Tibet ASγ Collaboration

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Abstract

A hybrid experiment consisting of emulsion chambers and an air shower array was carried out by the Tibet ASγ collaboration to investigate primary proton spectrum in the knee region. A new method of automatic analysis of emulsion chamber using the image scanner was developed and applied to this experiment. In this paper, the result of analysis on emulsion chamber part in hybrid experiment is presented. It is shown sufficiently high efficiency of the γ-family detection is realized by automatic analysis both in energy and geometrical resolutions.

1. Introduction

Emulsion chamber is a powerful detector for γ-rays in TeV region with high spacial and energy resolution. The Tibet ASγ collaboration [2],[3] used it with combination of burst detectors and an air shower array for the purpose of measuring the energy flow characteristics of the air shower core in investigating the proton spectrum in the knee region. The total number of X-ray films of size 40 cm × 50 cm used for 3 years experiment with area of 80 m^2 amounts to 7200 sheets. It is a huge work to analyze them by traditional method where each

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shower spot is scanned by naked eyes and its optical density is measured by the photometer. We have developed a new method of analysis using conventional image scanner. * The results of analysis on Tibet hybrid experiment carried out at Tibet, Yangbajing (4300 m a.s.l.) in 1996-1999 are shown in this paper.

2. Experimental procedure

We have used a image scanner of A3 size (290mm × 420mm) to capture the graphic image of a X-ray film as 2 parts. The output of the scanner (TIFF format) contains the transparency data Z at each pixel by 12 bits data (0-4095). We examined the relation between Z and optical density D measured by photometer using a sample film which has artificial density steps. The result is shown in Fig.1, where solid line represents following formula.

$$\begin{aligned} D(Z) &= 99.60[1+(\tfrac{Z}{3.57})^{0.768}]^{-1} && Z < 1200 \\ &= 1.69[1+(\tfrac{Z}{1595})^{2.547}]^{-1} && Z > 1200 \end{aligned} \tag{1}$$

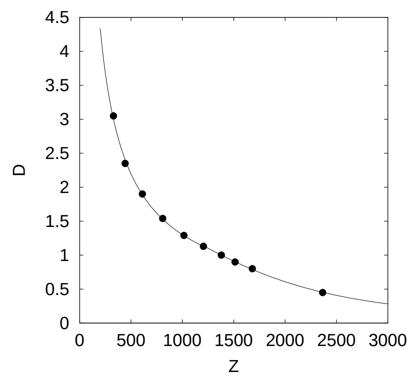

Fig. 1. Calibration curve between optical density D and transparency Z

The boundary following method is applied to the graphic image to detect the shower spots. In order to reject noises among detected spots, artificial neural network[6] was used effectively. The shower spot densities obtained by the scanner method are compared with the results from the photometric method in Fig.2. Fig.3 shows their relative error is about 16%. The transition curves of the cascade showers are fitted well with the theoretical curves as shown in Fig.4.

Since the graphic data of the X-ray films are taken by 600 DPI (pixel size of 42.3 μm × 42.3 μm), the spacial resolution for the shower spot is sufficiently good for the detection of γ-families. The γ-families are searched using a three dimensional (X,Y and D) pattern matching algorithm on successive layers of the X-ray films within the accuracy of 50 μm in geometry. The canonical correlation coefficient is calculated to reject the wrong pattern matching caused by noises. The distribution of the lateral spread of the γ-rays in a family is shown in Fig.5

*Preliminary results under development have been already reported in the last ICRC[9].

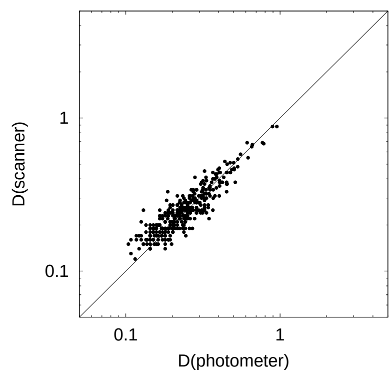

Fig. 2. Correlation between optical densities obtained by photometer and those by image scanner.

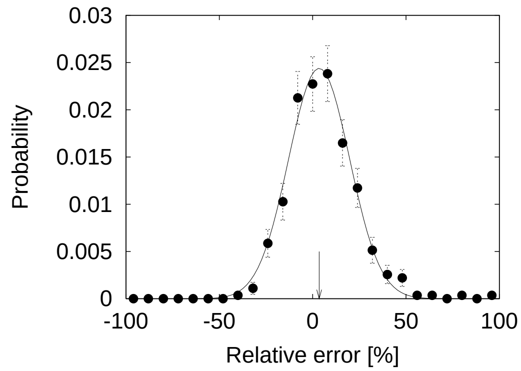

Fig. 3. Resolution of optical density. σ=16%

and compared with the simulation[5], where the roof effect is taken into account †.

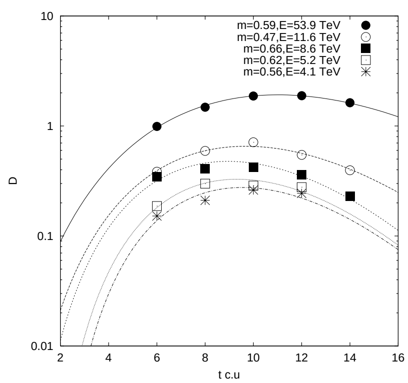

Fig. 4. Examples of transition curves of cascade showers obtained by the scanner method.

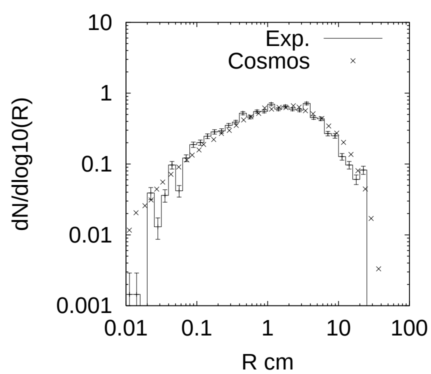

Fig. 5. The lateral spread of gamma families in comparison with the simulation taking into account of the roof effect.

Finally, graphical user interface was developed and used for reconstruction of the shower map.

3. Results

The differential energy spectrum of total γ-rays (which includes the isolated showers and the family members) is shown in Fig.6, which can be fitted by power law of the index -3.0 over $E_\gamma > 4$ TeV. The γ-families are detected under following criteria.
$E_\gamma \geq 4$ TeV, $N_\gamma \geq 4$ and $\sum E_\gamma \geq 16$ TeV,

†The problem of roof effect was discussed in the last ICRC paper[9].

where N_γ is the number of constituent showers in a γ-family and $\sum E_\gamma$ the sum energy of showers in a γ-family. The differential energy spectrum of γ-families is shown in Fig.7. The result is in a good agreement with the simulation indicating there is no serious biases for detection of the γ-families. The absolute intensity of total γ-ray spectrum and ΣE_γ spectrum are also consistent with Mt.Fuji[1] and Mt.Kanbala[7],[8] results.

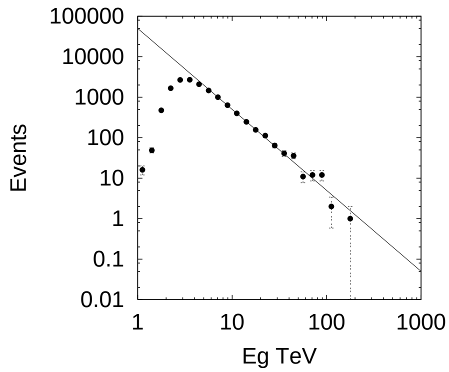

Fig. 6. Total γ-ray spectrum. Solid line represents power index -3.0

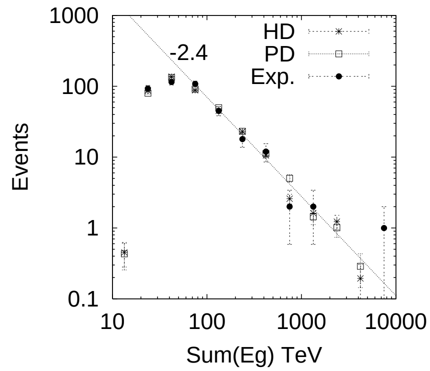

Fig. 7. ΣE_γ spectrum in comparison with the simulation, where HD and PD denote the assumption of heavy dominant composition and proton dominant one, respectively. Solid line represents power index -2.4.

4. Conclusion

The new method of emulsion chamber analysis using the image scanner is established and applied to the Tibet hybrid experiment. The detection threshold energy for γ-rays is 4 TeV. The detection of γ-families is made without serious biases.

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