A New Ultra High Energy Gamma Ray Telescope at Ōhya Mine

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1. Introduction

Search for the ultra high energy gamma rays coming from point sources is one of the main experimental aims of Ōhya project (Fig. 1)[1]. A fast air shower timing system has been constructed at ICRR for the study of the angular resolution of the system and operated approximately half a year. This paper describes the characteristics of the surface array of Ohya "air shower telescope".

2. Detail of the System

The array of the 24 channel scintillation counters situated at the campus of ICRR (Tanashi, Tokyo) is shown in Fig. 2. Each scintillator has an area of 0.25 m^2 and a thickness of 5 cm. The scintillation light is observed by the phtomultipliers located at 50 cm above the scintillator. Photomultipliers HAMAMATSU H1161 (R329) are used under a typical high voltage condition $\sim$1.4 KV. The output signal from the photomultiplier is sent to the preamplifire Le Croy 612A (gain x 10) via 100 m cable (71B/U). The output pulse height for the single particle is $\sim$30 mV and is discriminated by Le Croy 623B. The discriminator out-put signal is then sent to a coincidence circuit 380A. The delay time of the signal from the input of the preamplifire to the out-put of the coincidence circuit is 35 ns.

The out-put of the coincidence circuit is used for the start signal of the TDC 2228A. Meanwhile one of the out-put signals of each discriminator is delayed by 20 m cable and is used for the stop signal of the time digitizer. The start pulse arrives ∿15 ns before the stop signal. The time digitizer has a time resolution of 250 ps. The pulse height distribution is also recorded by ADC 2249W. The circuit diagram is shown in Fig. 3.

The liniarity of the phtomultiplier out-put and the time jittering was investigated by the photo-diode. As shown in Fig. 4, in the 3 decades of the pulse height range (from 3 mV to 3 V), the linearity is seen. Typical time jittering of the photomultiplier is given in Fig. 5. For the number of particles $N_e \geq 10$, time jittering becomes ∿1ns (catalogue value is 0.9 ns). The jittering of the electronics is less than 250 ps.

3. Angular Resolution of the Telescope

The trigger pulse is created when the air shower hits more than any 6 scintillation counters. The number of the fired scintillator is presented by the histogram of Fig. 6. The dotted line represents the data in which(digitizer)point deviates less than 3 standard deviation from the least-square fitting plane.

The air shower front is simply approximated by a plane: $Z = aX + bY + C$. For the vertical shower a and b take zero : a=b=0. The shower with zenith angle less than 15° is only used for the present data analysis. The plane determined by the least-square fitting is obtained by :

Define $\chi^2 = \frac{1}{\sigma^2}\Sigma(Z_i - aX_i - bY_i - c)^2$ and differentiate χ^2 by a,b,c. Then we get:

$$\begin{aligned}
\Sigma X_i Z_i &= a\cdot\Sigma X_i^2 + b\cdot\Sigma X_i Y_i + c\cdot\Sigma X_i \\
\Sigma Y_i Z_i &= a\cdot\Sigma X_i Y_i + b\cdot\Sigma Y_i^2 + c\cdot\Sigma Y_i \\
\Sigma Z_i &= a\cdot\Sigma X_i + b\cdot\Sigma Y_i + c\cdot N\ .
\end{aligned}$$

Parameters a,b and c are determined by

$$a = |A|/\Delta\ ,\ b = |B|/\Delta\ ,\ c = |C|/\Delta \quad \text{and}\ \Delta = \begin{vmatrix} \Sigma X_i^2 & \Sigma X_i Y_i & \Sigma X_i \\ \Sigma X_i Y_i & \Sigma Y_i^2 & \Sigma Y_i \\ \Sigma X_i & \Sigma Y_i & N \end{vmatrix}.$$

The statistical deviations in a,b and c σ_a, σ_b, and σ_c are given by

$$\sigma_a^2 = \sigma^2[N\Sigma Y_i^2 - (\Sigma Y_i)^2]/\Delta \quad , \quad \sigma_b^2 = \sigma^2[N\Sigma x_i^2 - (\Sigma X_i)^2]/\Delta \ .$$

The angular resolution of the system $\sqrt{\sigma_\theta^2}$ is defined by $\sqrt{\sigma_a^2 + \sigma_b^2}$.

Fig. 7 indicates the distribution of $\Delta Z_i = Z_i - (aX_i + bY_i + c)$ from the least-square fitting for the data of each scintillator. Fig. 7 shows the fluctuation of shower front σ_z is $\pm$ 2.5 m.

Figs. 8 and 9 represent the distribution of the angular resolution σ_θ of each shower. Each curve shows when we take the data with $Z_i \geqq 3$, 5 , and the number of total fired scintillators is greater than $\geqq$ 6, 10, 15 respectively. From these figures we conclude that our telescope has an angular resolution of 0.5° (at 1σ).

It is interesting to compare present result with the former measurement by Kiel group[2] with the use of 1 m^2 scntillators. Their data show on the angular resolution 1°. The data analysis is still continuing for the direction of the Cyg. X-3. The data will be presented at the conference.

References

1) Ōhya group : This conference proceeding, HE 5.1-7.

2) Kiel group : Proceed. of 12th ICRC,3,1038(1971).

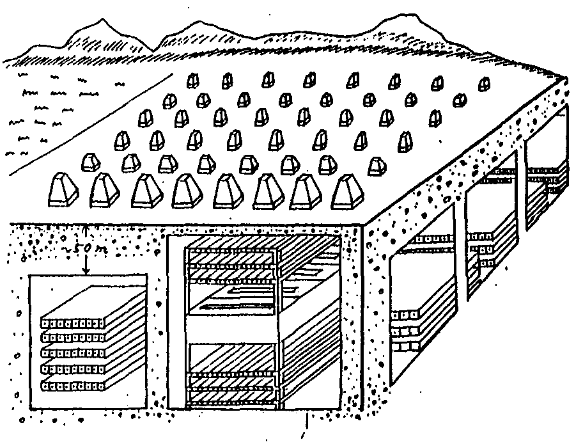


Fig. 1

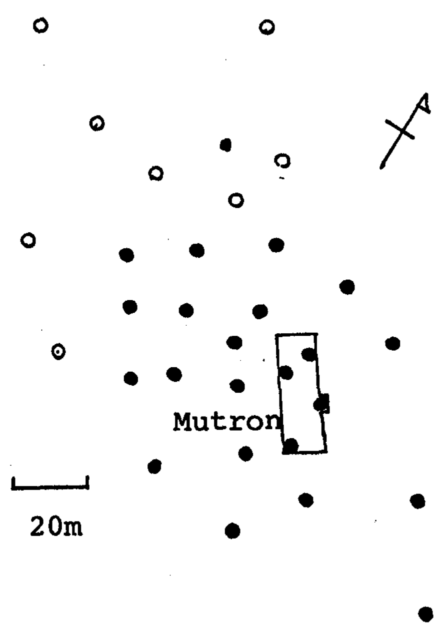


Fig. 2

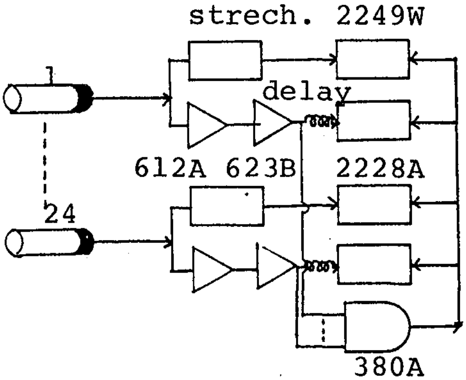


Fig. 3

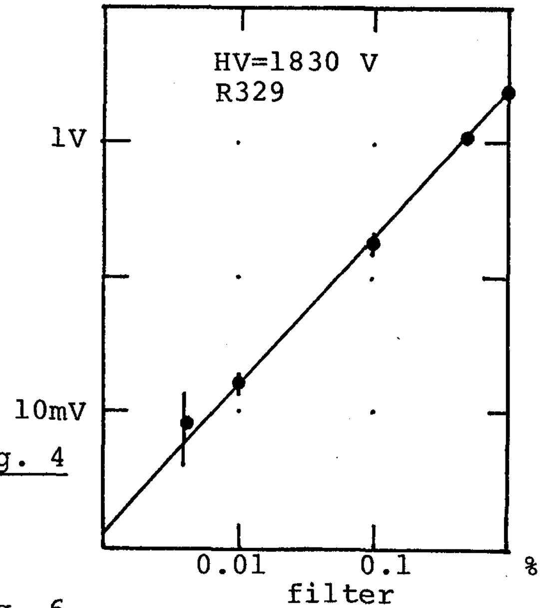


Fig. 4

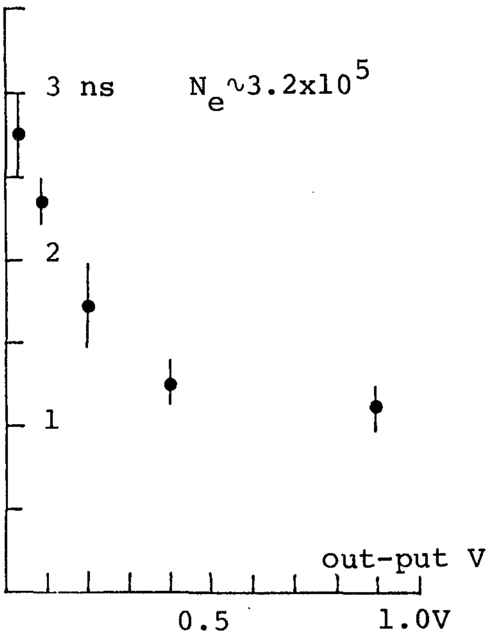


Fig. 5

Fig. 6

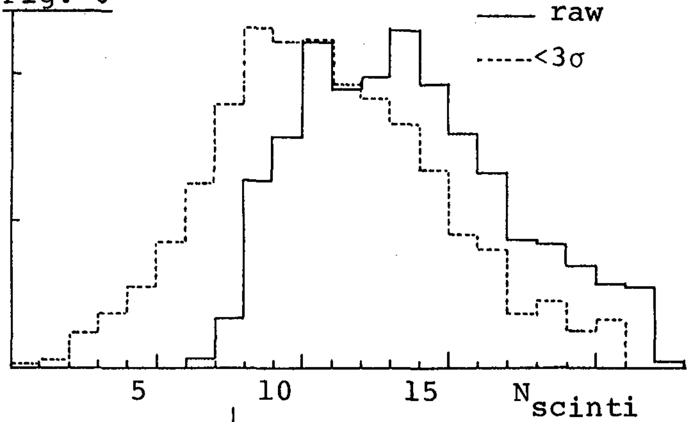
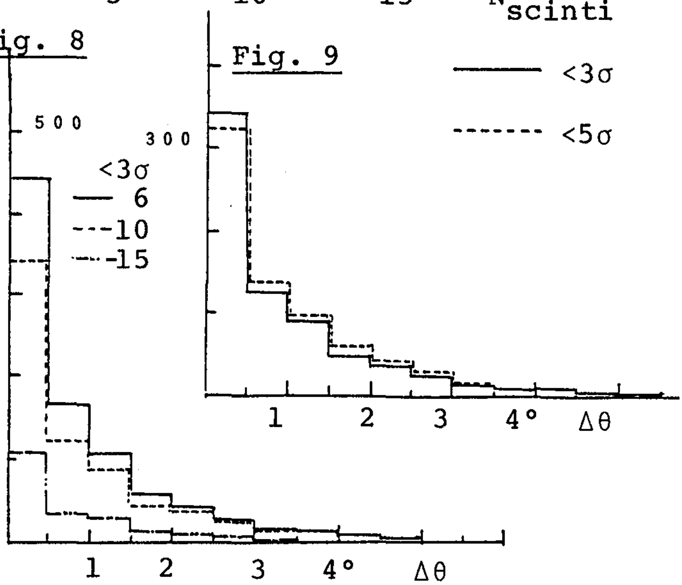


Fig. 8



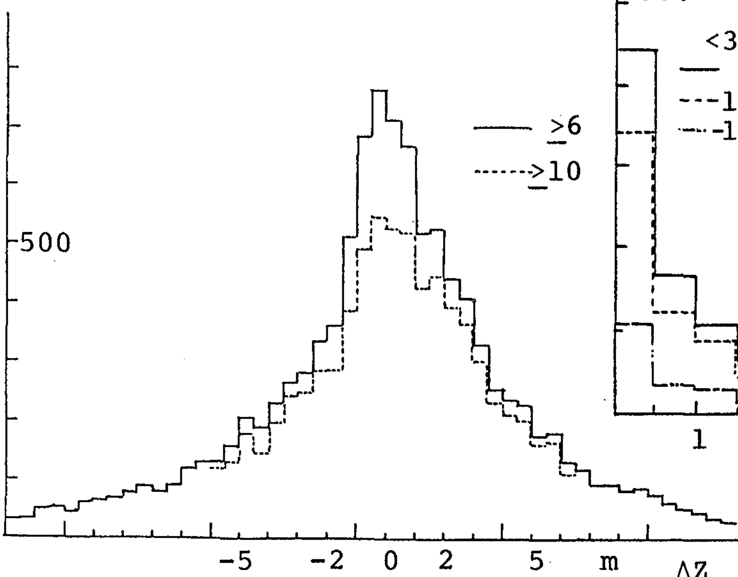


Fig. 7