DETECTION THRESHOLD ENERGY OF HIGH ENERGY CASCADE SHOWERS USING THERMOLUMINESCENCE PTFE-SHEET AND HOT-GAS READER

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ABSTRACT

New thermoluminescence(TL) sheet was developed as a detector for high energy components in air showers. For the investigation of detection threshold energy for cascade shower, TL sheets were exposed at Mt.Fuji with X-ray films in emulsion chambers and were scanned by a hot-gas reader. From the result of this experiment, it is concluded that if a γ ray whose energy is more than 6 TeV enters vertically into lead chambers, the cascade shower caused by this γ ray is securely detectable at the maximum development.

1. INTRODUCTION

From the viewpoints that TL powder has wide dynamic range and can be used repeatedly, it can be said that it has more excellent properties than the emulsion plate and the X-ray film which are widely used at present (1). Particularly in experiments for very high energy phenomenon in cosmic rays, these features are very desirable.

We have been developing a new detector using TL material as a new device for the plan to observe high energy particles in air showers (2). For this purpose, we developed a new TL sheet using a glasscloth as the base and a fluorocarbon resin as the binder.

The detection threshold energy of cascade shower using this TL sheet and a hot-gas reader was investigated by the experiment exposed to cosmic rays at Mt. Fuji.

2. TL SHEET and HOT-GAS READER

TL sheets so far developed have some defects of the low sensitivity and the easy exfoliation from the base plate and so on (3)(4). Therefore, they are not suitable for the practical application as they are.

At this time, we produced new TL sheet by the manufacturing method as shown in Figure 1. $BaSO_4$:Eu powder was adopted as TL material (4) and it was controlled so as to have the grain size of about several μm and to have the glow peak at 180 ^oC.

TL powder was mixed with fluorocarbon resin dispersion (PTFE = polytetrafluoroethylene) with weight ratio 1:1 and churned well. After the glasscloth belt was impregnated with this mixed dispersion, it was dried and sintered in an electric oven and rolled up. This process was repeated ten and several times until the thickness of coating became to be a certain

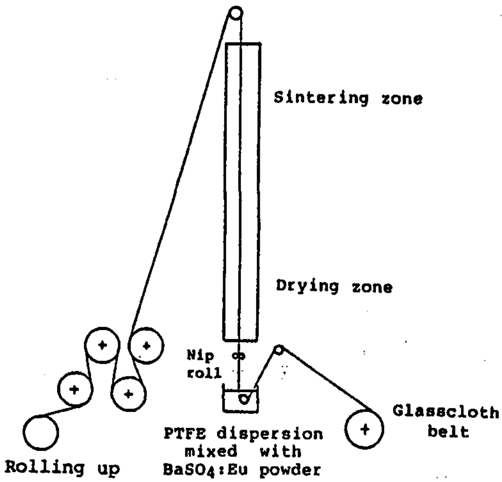

Fig.1. Schematic diagram of the manufacturing process of TL sheet.

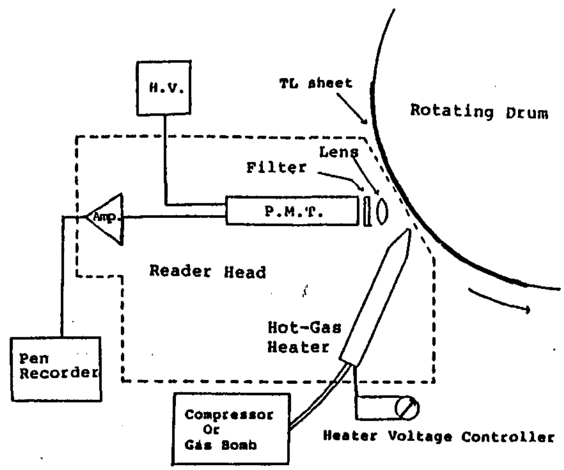

Fig.2. Basic scheme of scanning TL reader with hot-gas heating.

value.

Characteristics of this sheet are following.

1. High sensitivity. For example, 20 times higher than that of reference 3.
2. Flexibility. Free for bending and restoration.
3. TL coated layer is not cracked and does not come off by bending or hasty heating.

A readout system of this TL sheet is a scanning reader with hot-gas heating as shown in Figure 2. TL reader consists of a rotating drum on which TL sheet is fixed and a reader head at which thermoluminescence light is read out. The former is a cylinder made of steel and rotates with a constant velocity. The latter consists of a hot-gas heater and a photo-multiplier tube. As the drum makes one revolution, the reader head moves at a certain distance (3 mm) in the direction of axis of rotation of drum. The temperature of hot-gas stream is controlled by combination of the heater voltage and the rate of gas flow. In this experiment, to minimize the variation of flow rate, we used the nitrogen gas which is enclosed in high pressure gas bomb instead of air compressor.

The performance of new TL sheet was examined by means of this reader. Figure 3 shows the chart record of the reader soon after the irradiation by ^{90}Sr β source to TL sheet through 1 mm ϕ collimator. From this

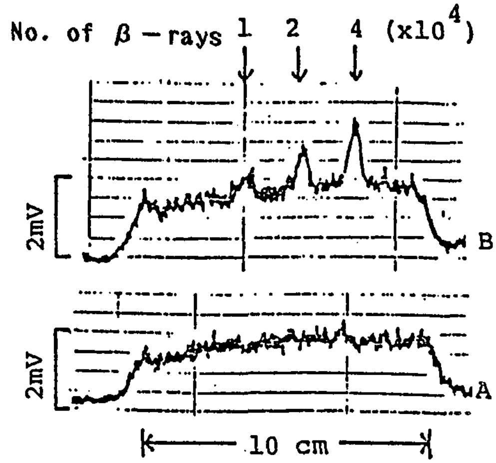

Fig.3. Scanning test of TL sheet.
(A):not irradiated.
(B):irradiated with ^{90}Sr.

result, the detection threshold seems to be about 1x10^4 β rays from ^{90}Sr source.

3. EXPRIMENTAL PROCEDURES AND RESULTS

For the investigation of the detection threshold energy of cascade shower using new TL sheet and hot-gas reader, we carried out an experiment by cosmic rays.

Chambers as shown in Figure 4 were constructed at Mt. Fuji (650 g/cm^2) in total area of 4 m^2 and exposed for a month. After development of X-ray films, cascade showers were picked up and each darkness was measured by photometry method. Figure 5 shows the energy spectrum of cascade showers induced by γ rays obtained from the transition of darkness. Since the present result agrees well with those obtained so far at Mt. Fuji (5), energy determination of cascade shower is appropriate.

On the other hand, TL sheets were scanned with hot-gas reader and it was examined whether TL signals appeared at the passing positions of cascade showers. The appearance frequency of TL signal is shown in Figure 6. The lower horizontal coordinate in the figure shows the darkness of X-ray film just above TL sheet, and the upper one shows the converted energy provided the darkness is the maximum darkness of a cascade shower which enters vertically. Figure 6(a) shows the appearance frequency of TL signal per sheet and Figure 6(b) shows the coincidence rate of TL signals between upper sheet and lower one at the same layer. The background noise in Figure 6 implys that the appearance frequency of TL signal at the position where cascade shower did not pass. This background noise is caused because the background level does not rise uniformly due to the ununiformity of sensitivity on TL sheet. The frequency of this background noise is therefore proportional to the period of exposure of TL sheet.

5. DISCUSSION

From the result of Figure 6, it is concluded that a cascade

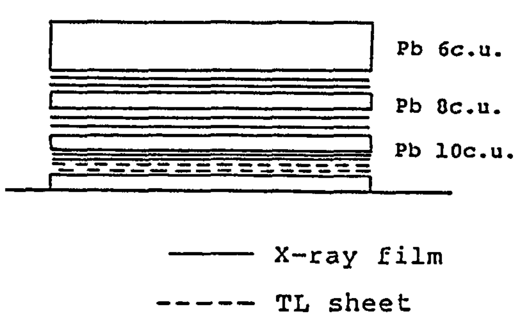

Fig.4. Design of the test chamber.

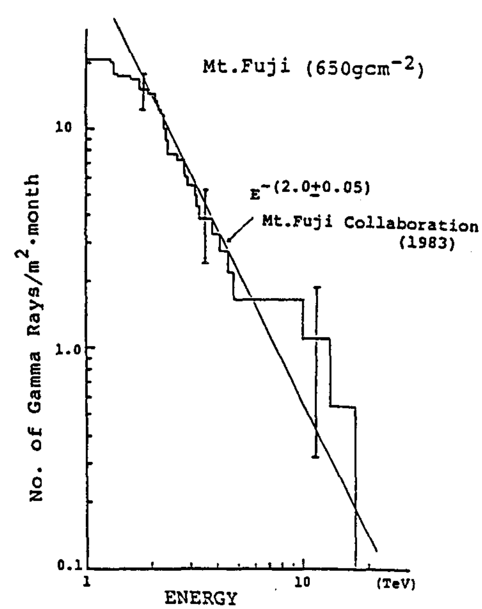

Fig.5. Integral energy spectrum of gamma rays.

shower of which energy is more than 6 TeV and incident angle is vertical is certainly detectable at its maximum development when we use new TL sheet and hot-gas reader. This threshold energy agrees with the evaluation from the comparison between the result of irradiation test by ^{90}Sr β source and the cascade calculation (6).

To lower the detection threshold energy, there are two methods. One is to use a more sensitive TL powder, and the other is to increase the sensitivity of TL sheet itself by increasing the proportion of TL powder or the thickness of coating. With regard to the latter, the present sheet is the best obtainable by the present manufacturing method. More sensitive TL powder of $BaSO_4$: Eu is available, but the ratio of sensitivity is limited to 1.5-2.0 at most. Another manufacturing method has to be developed to produce more sensitive sheet. One possible method is to compress the mixture of TL powder and fluorocarbon resin powder into a cylindrical form and to skive into a belt of a given thickness. The test sheet by this method is proved to have the sensitivity of about 3 times more than the present sheet.

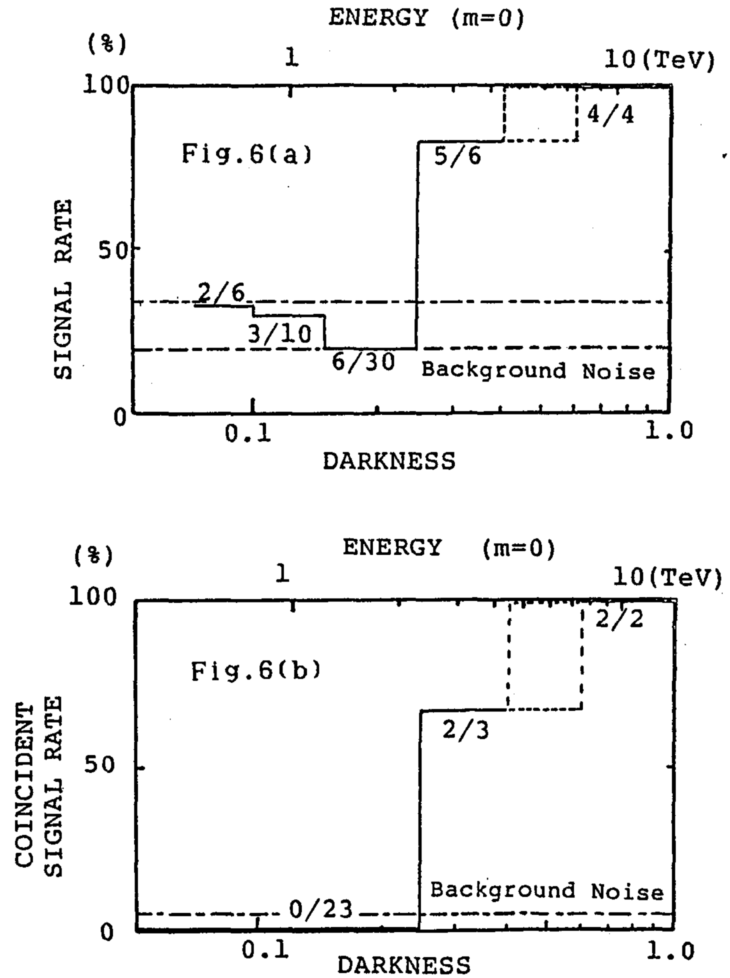

Fig.6. Appearance frequency of TL signal at the passing position of a cascade shower. (a):per sheet. (b): coincidence rate between two sheets.

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