1. Introduction

We have observed a high energy event of a bundle of electrons, γ rays and hadronic γ rays in an air shower core. This bundle were detected with an emulsion chamber with thickness of 15 cm lead installed in the central part of SYS air shower array at Mt. Chacaltaya. The size of air shower accompanying the bundle is $1.5 \times 10^7$ and the age parameter is determined 0.17 from the steepness of the lateral structure. This air shower is estimated to be initiated with a proton with energy around $10^{17}$ to $10^{18}$ eV at a altitude of around 100 gcm$^{-2}$ above Mt. Chacaltaya. We have determined lateral distributions of the electromagnetic component (for simplicity, we call this component as gamma ray) with energy above 2 TeV and also the hadronic component of energy above 6 TeV of this air shower core respectively. These lateral distributions may also ones at the very early stage of air shower development.

We have also studied so-called $E_R R_R$ distribution. Here $E_{\gamma}$, $E_H$ are the energy of each gamma ray and hadronic γ ray respectively. $R_{\gamma}$, $R_H$ are the radial distance from the center of the bundle of these particles. As well known, we can determine the transverse momentum from the product of energy and distance of a particle (ER) divided with a production height (H).

Since particles in the bundle are produced with process of the development of the nuclear cascade, we can not know the primary energy of each interaction in the cascade which produces these particles. In order to know the primary energy dependence of transverse momentum, we study the average products of energy and distance ($\langle E R \rangle$) for various average energies of secondary particle ($\langle E \rangle$).

2. Lateral distribution of gamma rays and hadrons

Centers of the bundle are determined from the energy weighted mean of positions of gamma rays and hadrons respectively. The deviation between two centers is only less than 1 mm and both are in agreement.

Lateral distributions of gamma rays and hadrons are shown in Fig.1 and Fig.2 for two different threshold energies. The slopes of these distributions are in agreement.
Distributions are represented by the power law of the form $r^{-n}$. The exponent ($n$) is about 1.8 for gamma rays and about 1.9 for hadrons.

3. ER distributions

ER is the parameter which reflect the transverse momentum of that particle. Fig. 3 and Fig. 4 show ER distribution for gamma rays and hadrons respectively. The distributions for hadrons with energy more than 10 TeV is flatter than others untill higher ER values.

The relation between the averages, $<\text{ER}>$ and $<\text{E}>$, are
shown in Fig.5 and Fig.6 for gamma rays and hadrons. The average \( \langle \text{ER} \rangle \) increase with increasing the mean energy \( \langle E \rangle \). This tendency is remarkable for high energy hadrons. This tendency is found in ER distributions of gamma rays and hadronic gamma rays of events Andromeda and M.A.ML. These events are the most high energy events among five families of the highest energy range, \( \Sigma E_\gamma > 1000 \text{ TeV} \) observed by Chacaltaya Emulsion Chamber Experiment of Brasil-Japan Collaboration.\(^{10}\)

4. Energy dependence of transverse momentum

Transverse momentum is determined from ER divided by production height. In the air shower, hadrons are not produced in a single interaction, but individual interactions at different stages in a nuclear cascade of air shower development. Radial distance \( R \), however, corresponds to radial deviation caused by final interaction in which that particle is produced. Therefore, we can estimate \( P_T \) with these \( R \) and an estimated most probable production height above the observation level. In the present case, we use 80 gcm\(^{-2}\) which is consistent to a height estimated from calculations of air shower development. We estimated \( P_T \) with \( P_T = \frac{E_r \times 3 \times R}{H} \) for hadron and \( P_T = \frac{E_r \times 2 \times R}{H} \) for gamma ray. Factor 3 comes from the charge symmetry in hadron interaction and factor 2 from two gamma decay of a neutral pion. Result are shown in Fig.7. In the figure, we show also data obtained from CERN experiments.\(^{2}\) In order to compare the accelerator results with present results, interaction energy in the laboratory system transfered from colliding particle energy is divided with the average multiplicity of secondary particles.\(^{3}\) Two points obtained from ISR and P\(P\) collider are connected with a dashed line. The present results are on the extrapolation of this line. In spite of uncertainty of air shower experiments, these data seem to be in good agreement. In the higher energy region, \( P_T \) increase much largely apart from the extrapolation of the energy dependence of lower energy region.

This figure shows that \( P_T \) increase with the power law of the average energy of shower particle of the form \( E^n \) of the
exponent $n=0.06$. However, in the extremely high energy region, the exponent increase to $n=0.44$.

In model calculations on the nuclear cascade of energy around $10^{17}$ eV, high energy hadrons can not be produced by secondary pion after passing through 80 g cm$^{-2}$. Consequently, hadrons with energy more than 100 TeV may be produced in fragmentation region of nucleon interaction.

We can conclude that this remarkable increase of $p_T$ for hadrons above 100 TeV with increasing average hadron energy may be a noteworthy characteristics of the energy dependence of transverse momentum especially in the fragmentation region.

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References

2) Arnison, G., et al, UA1 Collaboration,
3) Ward, D., et al, UA5 Collaboration,