

COMPARISON OF ABSOLUTE INTENSITY BETWEEN EAS WITH GAMMA-FAMILIES
AND GENERAL EAS AT MT. NORIKURA

Mitsumune, T., Nakatsuka, T., Nishikawa, K., Saito, To.,
Sakata, M., Shima, M. and Yamamoto, Y.

Konan University, Kobe, Japan.

Dake, S. and Kawamoto, M.

Kobe University, Kobe.

Kusunose, M., Ohmori, N. and Sasaki, H.

Kochi University, Kochi, Japan.

Hotta, N.

Utsunomiya University, Utsunomiya, Japan.

ABSTRACT

Gamma-families with total energy greater than 10 TeV, found in the EX chamber which was cooperated with the EAS array at Mt. Norikura, were combined with EAS triggered by big bursts. The absolute intensity of the size spectrum of these combined EAS was compared with that of general EAS obtained by AS trigger. EAS with sizes greater than 2×10^6 were always accompanied by gamma-families with $\Sigma E_{\gamma, H} \geq 10$ TeV, $n_{\gamma, H} \geq 2$ and $E_{\min} = 3$ TeV, although the rate of EAS accompanying such gamma-families decreases rapidly as their sizes decrease.

1. Introduction

The results of the cooperative experiment of the 20 m² iron EX (emulsion and/or X-ray film) chamber and the EAS array at Mt. Norikura (738 gcm⁻²) were reported once at Bangalore (Nakatsuka et al., 1983). Thereafter, the reanalysis of combination between gamma-families and EAS was done and a few new combined events were obtained. And, some of the old data were revised, especially the EAS size N_e and age parameter s were renewed by taking account of the transition effect of the materials over the scintillation counters and of the plastic scintillator itself for EAS density measurement. The data of general EAS obtained by the AS trigger in the same period of this experiment were analysed. In this report the EAS combined with gamma-families of total energy greater than 10 TeV is compared with the general EAS thus obtained with respect to the absolute intensities of EAS size spectrum.

2. Experiment

The experimental apparatus was described before (Yamamoto et al., 1981). The EAS data were taken by two kind of triggers. One was a burst trigger under the 14 r.l. thick EX chamber when any one of 72 burst scintillation counters responded to bursts greater than about 2000 particles per detector of 0.25 m² unit area. These EAS events with big bursts were provided for the analysis of combination with gamma-families. Another one was an AS trigger by four sets of four-fold coincidence of the nearest four out of the central nine non-covered scintillation counters.

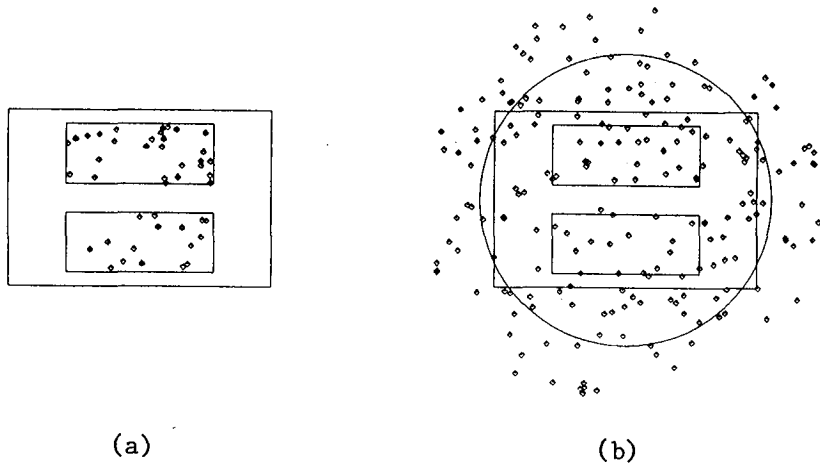


Fig. 1 Map of EAS axis locations.

(a): the EAS combined with gamma-families of $\Sigma E_{\gamma, H} \geq 10$ TeV. Two small rectangles indicate the EX chambers (10 m^2 each) and a big one is the spark area ($9 \times 6 \text{ m}^2$).

(b): the general EAS with $N_e \geq 2 \times 10^6$. Only the events hit the area within $r=5$ m were used for the analysis.

The period of the experiment was 302.5 days and the live time of recording system of EAS data was 292.2 days (95.7 %). The total number of EAS recorded by the burst trigger in this period was about 12000 events and the number of EAS obtained by the AS trigger was about 6000 events during about 240 days. The arrival angles of EAS, which are necessary for combining them with gamma-families and for deducing absolute intensity of EAS size spectrum, were detected by four sets of spark chambers. The live time of spark chamber system was a little higher than 80 %.

3. Selection of events

53 gamma-families with total energy $\Sigma E_{\gamma, H} \geq 10$ TeV and $n_{\gamma, H} \geq 2$ for $E_{\text{min}} = 3$ TeV were found in our EX chamber and 44 events out of them were combined with EAS triggered by big bursts. The rate of combination was 83 %. Nine gamma-families were not combined with EAS. This is mainly due to the lack of arrival angle data of EAS because of dead time of the spark chamber system. The data of these 44 combined events were used for deducing the absolute intensity of EAS with big gamma-families assuming that the residual nine unknown EAS have the same size distribution as the combined events. The EAS size N_e and age parameter s were determined by fitting the experimental shower particle density to the NKG lateral function with the Moliere unit 110 m, where the shower axis was put on the location of the gamma-family whose map was given in Fig. 1 (a). On the other hand, about 4200 EAS recorded during the last 170 days by the AS trigger were served for the size spectrum of general EAS. The axis locations of the general EAS whose axes hit the area within radius $r=7$ m from the array center are shown in Fig. 1 (b) for $N_e \geq 2 \times 10^6$. But, only the EAS whose axes hit the area of $r \leq 5$ m were employed for the analysis here.

4. Results

Using the experimental result about the transition effect of EAS shower particle density by thin materials (Saito et al., 1983) the corrections were made on the raw values of Ne and s for the response excesses of 3 cm thick plastic scintillator and also for the transition effect due to the roof and ceiling materials for indoor counters and due to the counter box material for all counters. As a result, the age parameter s was increased by the amount of 0.18 ~ 0.16 and the shower size Ne was multiplied by a factor 0.65 ~ 1.16 depending on the raw values of s from 0.4 to 1.2. The Ne-s scatter plot of the combined events after the correction is shown in Fig. 2. In this figure are also shown the Ne-dependences of average age parameters for combined events (crosses) and for the general EAS (open diamonds).

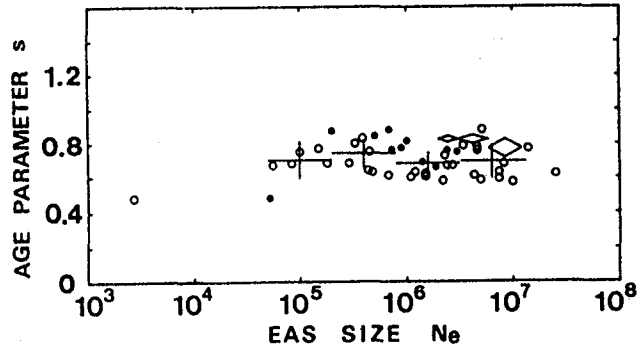


Fig. 2 Ne-s correlation for the combined EAS with gamma-families with $\Sigma E_{\gamma, H} \geq 10$ TeV (scatter plot and crosses) and for the general EAS with sizes $Ne \geq 2 \times 10^6$ (open diamonds).

In order to get the vertical intensity of size spectrum of EAS it is necessary to know the zenith angle distribution of them. In Fig. 3 (a) are shown the distributions for the combined EAS with gamma-families of $\Sigma E_{\gamma, H} \geq 10$ TeV (closed circles) and for the general EAS with $Ne \geq 2 \times 10^6$ (open circles). It is natural that the zenith angle distribution of the combined EAS is steeper than the general EAS but almost same as the gamma-families shown in Fig. 3 (b). Using the values of a factor x_0/Λ_{att} in the

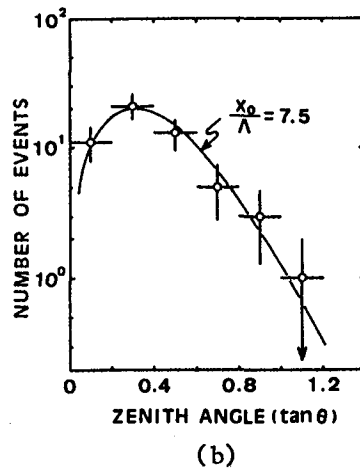
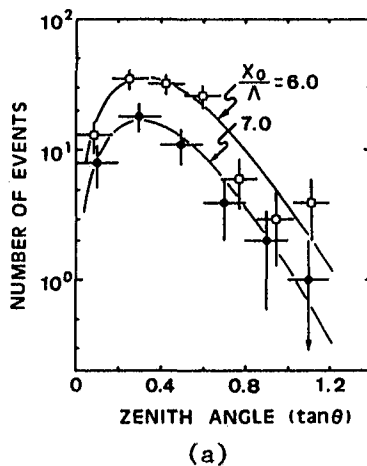


Fig. 3 Zenith angle distributions.

- (a): the general EAS with $Ne \geq 2 \times 10^6$ (open squares) and the combined EAS with gamma-families with $\Sigma E_{\gamma, H} \geq 10$ TeV (closed circles).
 (b): all gamma-families with $\Sigma E_{\gamma, H} \geq 10$ TeV, $n_{\gamma, H} \geq 2$ and $E_{min} = 3$ TeV.

theoretical zenith angle distribution fitted to the experimental data, we can easily get vertical intensity of EAS size spectrum as shown in Fig. 4. The spectrum of the general EAS, marked by open squares in this figure, is considered to be free from detection bias in the size region $N_{e \geq 2 \times 10^6}$. Closed circles and open triangles indicate the combined EAS with $\Sigma E_{\gamma, H} \geq 10$ TeV and ≥ 20 TeV, respectively. It is concluded from this figure that the EAS with $N_{e \geq 5 \times 10^6}$ are always associated with gamma-families with $\Sigma E_{\gamma, H} \geq 10$ TeV at the altitude of Mt. Norikura ($x_0 = 738 \text{ g cm}^{-2}$). This is consistent with the fact seen in Fig. 2 that both the average values of s agree each other for $N_{e \geq 5 \times 10^6}$ between the general EAS and the combined EAS with gamma-families with $\Sigma E_{\gamma, H} \geq 10$ TeV. Also, the figure 4 suggests that the EAS with $N_{e \geq 10^7}$ are always accompanied by gamma-families with $\Sigma E_{\gamma, H} \geq 20$ TeV at the same altitude. These results are important to study the absolute intensity of energy spectrum of the primary protons in the energy region $E_0 = 10^{15} \sim 10^{17}$ eV.

5. Conclusions

EAS with sizes greater than about 5×10^6 are always accompanied by gamma-families with $\Sigma E_{\gamma, H} \geq 10$ TeV, $n_{\gamma, H} \geq 2$ for $E_{\text{min}} = 3$ TeV at the altitude of Mt. Norikura. This size at Mt. Norikura is nearly equivalent to the primary proton's energy 10^{16} eV. The size of EAS which are always accompanied by gamma-families with $\Sigma E_{\gamma, H} \geq 20$ TeV seems to be greater than about 10^7 . Then, if the gamma-families with higher cutoff energy are observed together with EAS, the data will provide an available key to get the absolute intensity of the primary proton's spectrum up to 10^{17} eV.

6. Acknowledgements

The authors would like to express their thanks to the members of the Norikura Air Shower Group for kind offer of the EAS array and assistance and also to staffs of Norikura Observatory of the Institute for Cosmic Ray Research for kind offices and continuous support. This work is supported financially by a Grant-in-aid for Scientific Research from the Ministry of Education, Science and Culture.

7. References

- Nakatsuka et al., 1983; Conference Papers of the 18th ICRC (Bangalore), Vol. 11, 346.
 Saito et al., 1983; *ibid* Vol. 11, 217.
 Yamamoto et al., 1981; Conference Papers of the 17th ICRC (Paris), Vol. 11, 130.

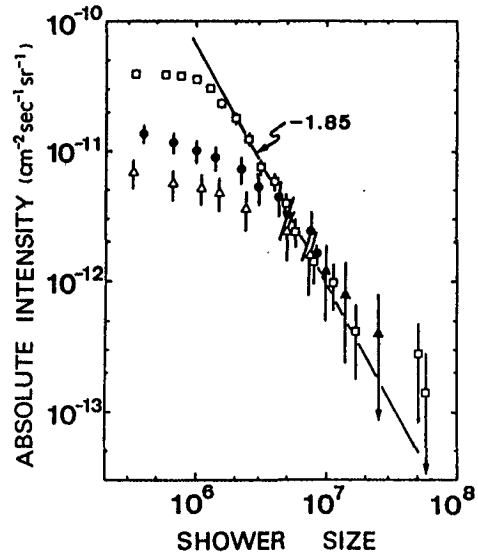


Fig. 4 Integral size spectra for the general EAS (open squares) and the combined EAS with gamma-families of $\Sigma E_{\gamma, H} \geq 10$ TeV (closed circles) and of $\Sigma E_{\gamma, H} \geq 20$ TeV (open triangles).