ON THE MEAN CHARACTERS OF FAMILY EVENTS OBSERVED AT MT.KANBALA

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ABSTRACT

General features of family events with $\Sigma E\gamma > 200$ TeV, observed by the emulsion chambers at Mt.Kanbala, are presented in comparison with the Monte Carlo simulation. The lateral and cluster structure, and the energy spectra of constituent gamma-rays and hadrons are shown to be consistent with the Monte Carlo results calculated under the assumption of heavy-enriched primary, scaling, QCD jets and increasing cross-section.

1. Introduction.

Upto now, the total amount of exposure of emulsion chambers(ECs) at Mt. Kanbala has reached about 420 m^2year. We already observed 10 big family events with energies $\Sigma E\gamma > 1000$ TeV. The main purpose of our experiment is to clarify what kinds of phenomena are new in the energy region beyond 10^{16} eV, though the problem of primary composition at these energies is inevitably interwined with this subject.

In this paper we present the average behaviour of the family events in comparison with the Monte Carlo simulation made by an assumption on primary and interaction. First, we discuss the flux of gamma-families at Mt.Kanbala, since this is known to be very sensitive to the model of both interaction and primary composition. Then the average features of family events are shown.

2. Experiment.

Two types of chambers are assembled on the Mt.Kanbala station. One is the Pb-EC, usually used at the mountain experiments, and the other the Fe-EC. The exposure list is shown in ref. 1).

In our data processing, hadrons are defined as showers with its starting point deeper than 6 c.u. and/or with accompanying successive interactions in the EC, and others are identified as gamma-rays. The minimum energy of showers accepted in our analysis is set to be 4 TeV. The detection efficiency of hadrons is estimated to be about 40 % for Pb-EC and about 80 % for Fe-EC in an average.

Here, we use only the data taken from the Pb-chambers

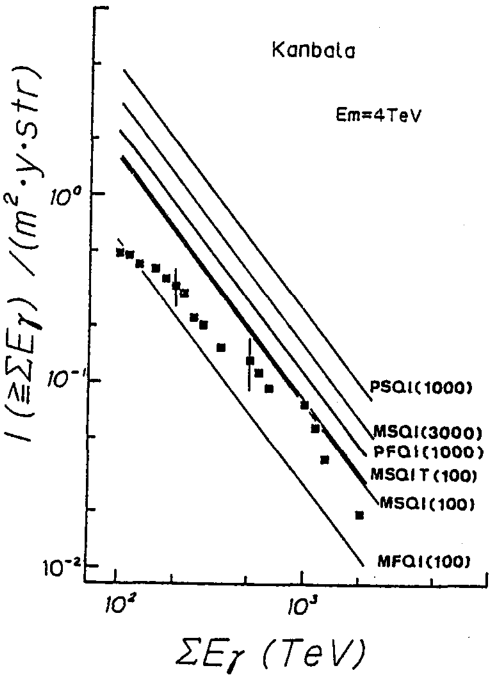

Fig. 1.

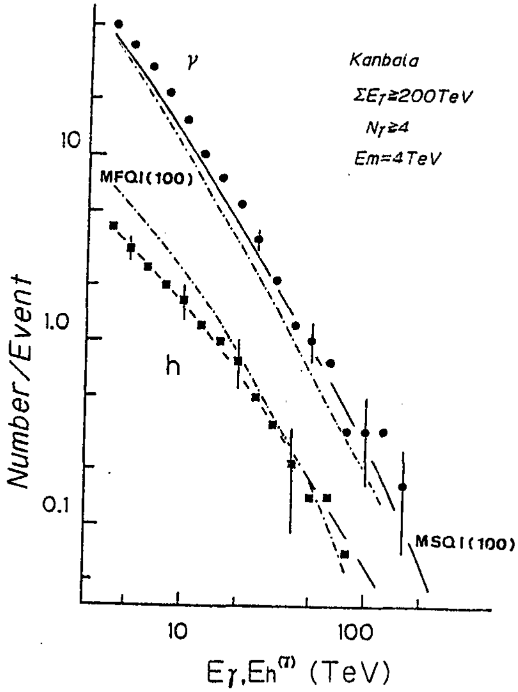

Fig. 2.

because the amount of exposure of the Fe-chambers is still insufficient to get quantitative results.

3. Monte Carlo simulation.

In order to make a standard picture on family phenomena and also to learn the size of its fluctuations, we have done the Monte Carlo simulations based on the conventional model of interaction and primary composition. Details of the simulation calculation are found in ref. 2). The meaning of the symbols appeared in this text is as follows ; M : Mixed chemical composition with a significant amount of heavy nuclei. The spectrum of Proton/He/L/M/H/VH/Fe becomes steeper at a bending energy (E_b) from 1.7/1.7/1.7/1.6/1.6/1.6/1.5 to 2.0 (all). The bending energy of proton spectrum is denoted in the bracket, and other nuclei steepen at energy of $Z*E_b$. P : Proton dominant primary (In both cases, the total flux is normarized to the Grigorov's total spectrum at 10^{15} eV). S : Scaling in the fragmentation region. F : Fire-ball model normalized at 150 TeV. Q : QCD-jet. I : Increasing cross-section as $E^{0.06}$. T : Increasing average P_t as $E^{0.04}$.

4. Results

4.1. Intensity of gamma-families at Mt.Kanbala.

The absolute flux of gamma-families is compared with the Monte Carlo calculations as shown in Fig. 1. As learned from

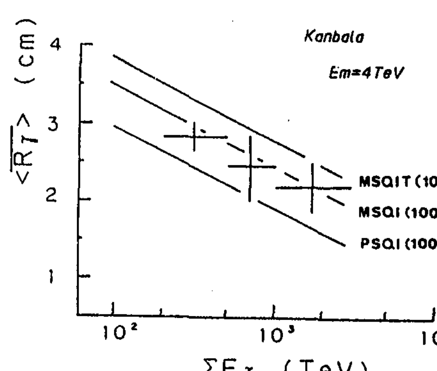

Fig. 3(a).

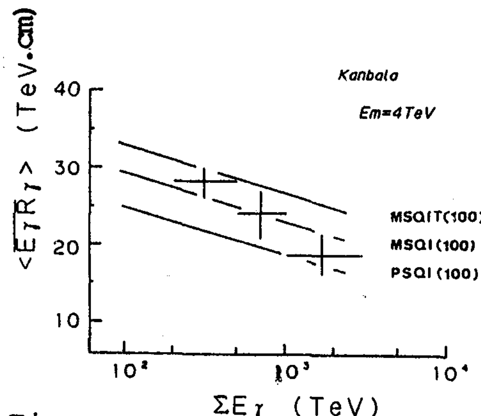

Fig. 3(b).

this figure, both cases of the model PSQI(1000) and MSQI(3000) give too high intensity compared with our data. In order to accord with the data, the proton spectrum must be bent at around 10^{14} eV. In this case, the fraction of protons and irons to the total is estimated to be about 20 % and 40 % at around 10^{15}eV, respectively. Even if we adopt the fire-ball model, the fraction of protons doesn't exceed 50 %.

4.2 Energy spectra of gamma-rays, hadrons.

Figure 2 shows the energy spectrum of gamma-rays and hadrons superposed in the energy interval of $\Sigma E_\gamma > 200$ TeV. The solid and dotted line corresponds to the model MSQI(100) and MFQI(100), respectively. No clear difference is found between the data and the model MSQI(100) both on the number of showers and the slope of spectrum. However, the fire-ball model (MFQI, heavy enriched primary and scaling break) gives steeper spectrum compared with the experiment. That is, strong scaling break is incompatible with the heavy enriched primary and requires the proton dominant primary.

4.3 Lateral structure of gamma-families.

The mean values of <R> and <ER> of gamma-rays averaged in the respective energy range are shown with the Monte Carlo results in Fig. 3(a), (b). Our data come between the model MSQIT(100) and PSQI(1000), and remain close to the MSQI(100). At accelerator energy regions, the mean P_t near central region seems to increase with energy as $E^{0.04}$. But, it is also well confirmed that the behaviour of

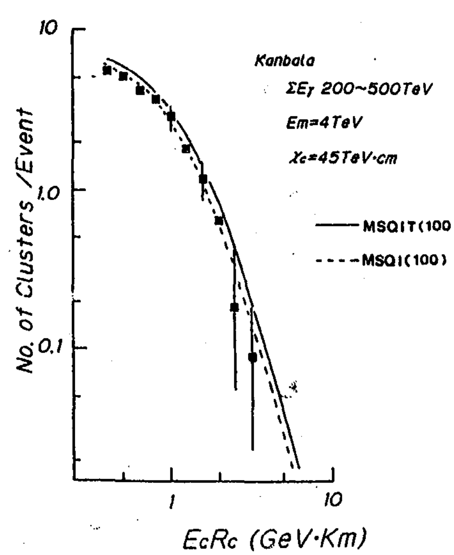

Fig. 4.

gamma-families is sensitive to the fragmentation region. If we take this into consideration, then we may say that the average P_t in the fragmentation region remains almost constant at least up to about 10^{15} eV (Here it should be noted that the QCD-jet effect is taken into account.).

The ER distribution of clusters in the gamma-families with ΣE_γ= 200-500 TeV is shown in Fig. 4, comparing with the results of the model MSQIT(100) and MSQI(100). This comparison tells us that the increasing mean P_t (smooth extrapolation from the accelerator energy region) gives merely a minor effect on the cluster structures.

5. Conclusions.

Our discussions are summarized as follows,

1) Scaling in the fragmentation region, increasing cross-section as E^δ , δ=0.04-0.06, and the heavy enriched primary spectrum can well explain our experimental data.

2) A fraction of protons and irons to the total flux takes a value of about 20 % and 40-60 % at around 10^{15} eV, respectively. The proton spectrum should steepen at around 10^{14} eV .

3) The energy dependence of average P_t is very weak in the fragmentation region.

These conclusions are compatible with other data, i.e., uncorrelated gamma-ray/hadron spectrum and the behaviour of super-families[3]. We also observed several family events with a peculiar structure, and some of these events are described in other paper[4].

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