HE 3.4-1

# A COSMIC RAY SUPER HIGH ENERGY MULTICORE FAMILY EVENT (I)
## EXPERIMENT AND GENERAL FEATURES

CHINA-JAPAN EMULSION CHAMBER COLLABORATION
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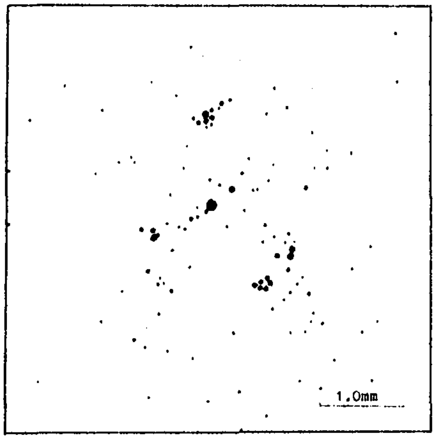
I. Introduction. Information on the fragmentation region in super high energy hadronic interactions can be obtained through the observations of $\gamma$-ray families produced by cosmic rays. $\gamma$-ray families with $\Sigma E_\gamma \geq 1000$ TeV are receiving increasing interests in emulsion chamber experiments. There exist some complications caused by the superposition of nuclear and electromagnetic cascades and the uncertainty in the nature of the primary particles. These complications usually make the conclusions drawn from various interesting phenomena observed in family events not so definite. Here we describe an interesting family event KO E19, which is likely to have suffered only very slight disturbances. It was found in Mt. Kambala emulsion chamber experiment. The production height of the event is determined to be H=(70±30)m and some conclusions are given.

II. Experiment. The event KO E19 was found in 14.8 m$^2$ of emulsion chamber (thickness 14 c.u.) exposed on Mt. Kambala during 1980.9-1981.9. The photosensitive materials of the emulsion chamber consist of x- ray films of Sakura N type and Fuji 100 type and nuclear emulsion plates of ET7C type. On the N type x-ray films, the central part of the event is completely blackened, forming a halo. The visible energies of the event are determined independently on the three kinds of photosensitive plates and crosschecked, yielding a consistent result.

The optical density distributions in the halo part are determined on all layers of N type films. From the variation of the density distributions on consecutive layers, we can determine the electron number densities $n_i$ and obtain the total number of electrons N and their total track length Z on the basis of the approximation B, thus giving the visible energy of the halo (1) $\Sigma E_\gamma$=1200 TeV. Every shower in the central part of the event are clearly separated from each other on the 100 type x-ray films and the ET7C type nuclear emulsion plates (Fig.1). On the 100 type films, we can make accruate measurements of the positions and optical densities, shower by shower, using the Mitaka-Hamamatzu automatic microphotometer. From the darkness-energy relation with Landau effect correction, we can determine the total visible energy(2), yielding $\Sigma E_\gamma$= 1300 TeV ($E_{min}$=2 TeV). On the ET7C emulsion plates, the electron track counting method is used for the energy determination of the majority of showers except those of very high energies, for which the photometric method is applied. The resultant visible energy is $\Sigma E_\gamma$= 1537 TeV ($E_{min}$=1.5 TeV), which is somewhat higher due to the lower threshold in the energy determination.

Fig.1



With the photometer system used, x and y distances can be measured accurate to about 1 $\mu$m and shower centers (points of maximum optical density) can be determined with a small aperture.

III. General Features of KO E19. The general statistical characteristics of the event are listed in Table I, where $N_\gamma$ is the number of $\gamma$-rays ($E_\gamma \geq 3$ TeV)and R the distance from the energy center of the event to the center of a shower. For families produced not too high above the detector, the electromagnetic cascades are usually not fully developed and thus $\langle ER \rangle$ will be small and $\langle E_\gamma \rangle$ large, while the energy spectrum will be exponential in form. This is the case for KO E19, as can be seen from Table I and Fig.2. Fig.3 shows the ER-R correlations of the showers in the event, points within the dashed circle representing those in the central part. It is this portion which is the least disturbed during the development and can provide interesting information about the super high energy hadronic interactions.

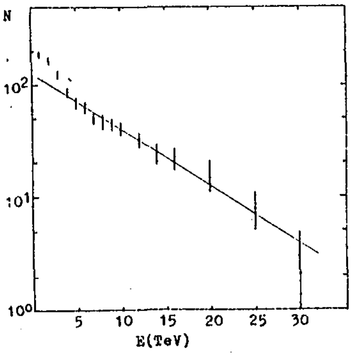


Fig.2

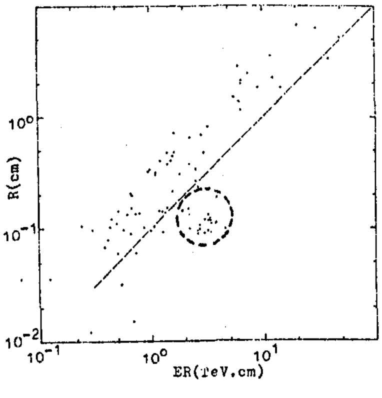


Fig.3

Table I. Statistical characteristics of KO E19

| $N_\gamma(E \geqslant 3\mathrm{TeV})$ | $\Sigma E_\gamma(\mathrm{TeV})$ | $\langle E_\gamma \rangle(\mathrm{TeV})$ | $\langle R \rangle(\mathrm{cm})$ | $\langle ER \rangle(\mathrm{TeV.cm})$ |
|---|---|---|---|---|
| 131 | 1083 | 8.3 | 0.39 | 3.23 |

IV.Production Height and Pseudorapidity Distribution. The exponential energy spectrum, the very low value of $\langle ER \rangle$ and the relatively high value of $\langle E_\gamma \rangle$ show some evidences of the small production height H of the main part of KO E19. For an accurate determination of H, a triangulation method is used. Among showers with $E_\gamma \geqq$ 10 TeV and penetrating through the whole thickness, 14 c.u., of the chamber, choose those with favorable measuring conditions. Take a pair of such showers i,j and determine the separations between them, $R_{ij}^{k}$ and $R_{ij}^{k+m}$ , on the k-th and the (k+m)-th layers respectively. Repeat the same for every pair. Then the production height H can be calculated from

$$H = (m\Delta H \sum_{ij} R_{ij}^{k}) \; / \sum_{ij}(R_{ij}^{k+m} - R_{ij}^{k})$$

where $\Delta$ H is the distance between two consecutive x-ray film layers. In our actual measurements, k=1, m=5 and $\Delta$H=1.3cm. The result is H=(70 ±30)m. As a rough check of this result, we make a mass distribution obtained from the coupling of the above showers pair by pair, where we take $m_{ij} = R_{ij}\sqrt{E_i E_j}/H$, with H=70m. This is compared with a simulation calculation shown in Fig.4. There are two peaks at $m_{ij}$ =150 MeV and 500 MeV in the experimental distribution, corresponding to the masses of $\pi^\circ$and $\eta^\circ$ respectively. and thus confirming the result from triangulation.

With H=70 m, calculate the pseudorapidity $\eta = -\ln\tan(\theta/2)$ where $\theta$ is the emmision angle of a secondary particle. The distribution of $\eta$ is shown in Fig.5. There is a hump near $\eta$ =12, which may be attributed to the showers in the cores of the central part. The magnitude of the plateau is roughly $\Delta N/\Delta\eta$ =40, a value about four times as large as that of the scaling extrapolation of accelerator results. The energy dependence of $\Delta N/\Delta\eta$ is shown in Fig.6, indicating a more rapid increase in $\Delta N/\Delta\eta$ above $10^{16}$ eV.

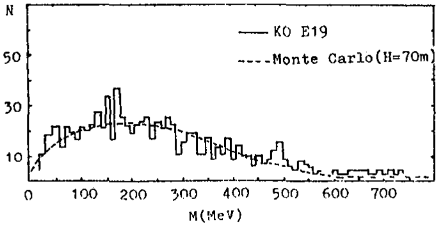


Fig.4

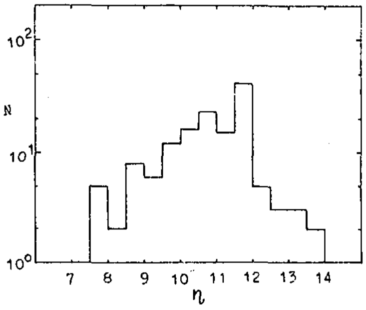


Fig.5

Taking H=70 m, the $p_t$ distribution in the family is shown in Fig.7, where "o" represent data of KO E19 ($E_{min}$=4 TeV) and "+" come from C-jets ($E_{min}$=0.5 TeV) . In the $p_t$<800 MeV/c region, the $p_t$ distribution of KO E19 is consistent with that of C-jets and both of them take the exponential form $e^{-5p_t}$ . The central portion of the family will be treated in (5).

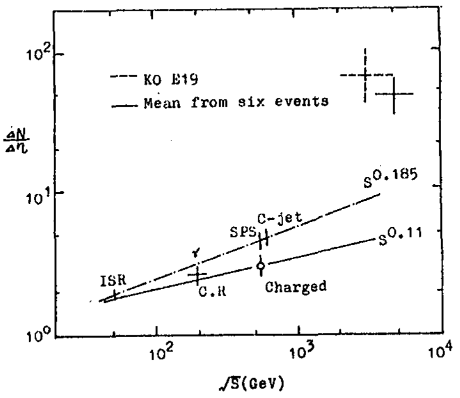


Fig.6

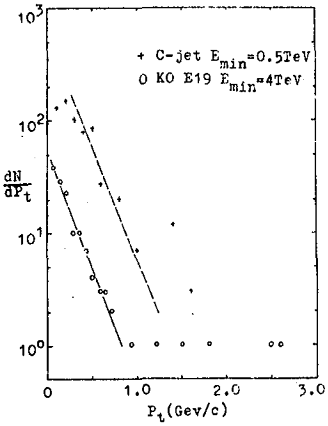


Fig.7

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