ON THE CHARACTERISTICS OF EMULSION CHAMBER FAMILY EVENTS PRODUCED IN LOW HEIGHTS

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1. Introduction.

The uncertainty of the primary cosmic ray composition at $10^{14}-10^{16}$ eV is well known to make the study of the nuclear interaction mechanism more difficult. Experimentally considering, if one can identify effectively the family events which are produced in low heights, then an event sample induced by primary protons might be able to be separated. It is undoubtedly very meaningful. In this paper we simulate the family events under the condition of mountain emulsion chamber experiments with a reasonable model. The aim is to search for the dependence of some experimentally observable quantities to the interaction height.

2. Method.

The model used is: proton incidence, total inelastic cross section rising with energies ($\sigma \propto E_0^{0.06}$), Feynman scaling in fragmentation region holding and mean transverse momentum increasing with energies ($\langle Pt \rangle \propto E_0^{0.05}$). The electromagnetic cascade and the multiple Coulomb scattering are also treated by Monte-Carlo method. Because the stress point is on the study of the qualitative charaters of the production height dependence on the transverse distribution of family events, the model used may be a suitable one.

The observation height is assumed at Mt. Kanbala (520 g/cm^2). The incident axis is taken uniformly on 40x50 cm^2 X-ray film, and the particle outside this area are ignored. Hadron showers are recorded by the same method as experiment with chamber thickness of 28 c.u. Pb. The criteria of a family are $\Sigma(E_\gamma+E_h^{(\gamma)})$ ($\equiv \Sigma E$) $\geqslant 30$ TeV, $n_\gamma \geqslant 4$ and $n_h \geqslant 0$ (all symbols are in the common meaning). 546 family events with $\Sigma E \geqslant 100$ TeV are analysed.

The $\langle R \rangle$ and $\langle ER \rangle$ of a group of testing events with $\langle Pt \rangle = 330$ MeV/c are shown in Table 1 to compare with M.Shibata's results (in parentheses) using model PRS[1]. The difference between them may be reasonable owing to the different observation levels. For families with $\Sigma E \geqslant 100$ Tev ($E_{min} = 4$ TeV), we have $\langle \overline{R} \rangle = 2.75$ cm which is close to the experimental value 2.5 cm[2].

Table 1 ⟨R⟩ and ⟨ER⟩ of family events

E (TeV)	30-50	50-100	100-200	200-500
⟨R⟩ (cm)	3.20 (3.3)	3.45 (3.1)	2.82 (2.5)	2.43 (2.3)
⟨ER⟩ (TeV.cm)	12.5 (13.6)	14.1 (13.7)	12.2 (11.7)	10.7 (10.6)

3. Average interaction times, mean interaction height and purity.

The average interaction times, N_{int}, for all observed particles of each family event is calculated. In Fig.1 is shown the N_{int} distribution with mean value 3.74. The relation between N_{int} and the first interaction height, H_{1st} is seen in Fig.2. It is obvious that the events having both single interaction only and low interaction height are very rare.

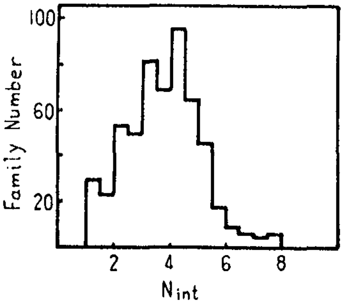
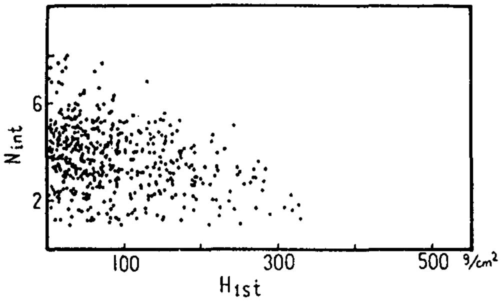


Fig.1

Fig.2



For each event with multi-time interactions, imagine that there exists a main interaction. We devide the 520 g/cm² atmosphere into 21 layers with step 25 g/cm². Define the layer in which the produced particles contributes the most fraction of family energy ΣE as the main interaction layer and the corresponding height as main interaction height (H_{main}). The fraction mentioned above is defined as purity of the family (abbreviate as p hereafter).

The distribution of main interaction height is rather flat, slight favorable to lower height (or larger H_{main}) (see Fig.3). It is noticed that the events with larger H_{main} are not always very pure (Fig.4). The low-height event which we are interested in, of caurse, should those with lower main interaction heights and high purities.

R and ER.

The analysis shows that ⟨R⟩ and ⟨ER⟩ of family events are significantly dependent on H_{1st} (Fig.5): events with larger ⟨R⟩ and ⟨ER⟩ have smaller H_{1st}, events with larger H_{1st} have smaller ⟨R⟩ and ⟨ER⟩, but incorrect inversely. As to the dependence of ⟨R⟩ and ⟨ER⟩ on H_{main}, it is insensi-

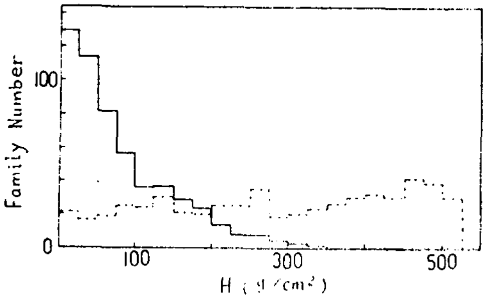


Fig.3 H_{1st} (real line) and H_{main} (dotted line) distribution

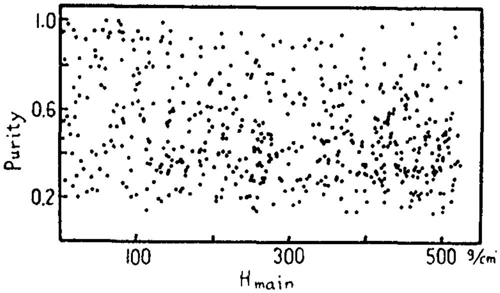


Fig.4 Purity vs. H_{main}

tive (Fig.6).

The rejuvenation treatment[3], or taking R as the distance to event axis, or taking ⟨R⟩ as the energy weighted mean R, all induce the ⟨R⟩ and ⟨ER⟩ with the same qualitative characters as shown in Fig.5 and 6.

"Decascading" treatment with full efficiency gives weak dependence of ⟨R⟩ on H_{main} (fig.7). Besides, ⟨ER⟩, mean energy ($\langle E_\gamma \rangle$) and maximum energy (E_γ^{max}) of γ-rays of a family event show the same tendency as ⟨R⟩. But at the other hand γ-ray number of a family, n_γ, shows opposite tendency. In

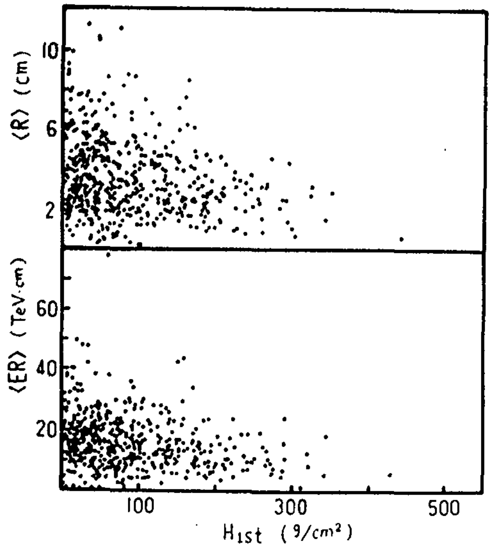


Fig.5

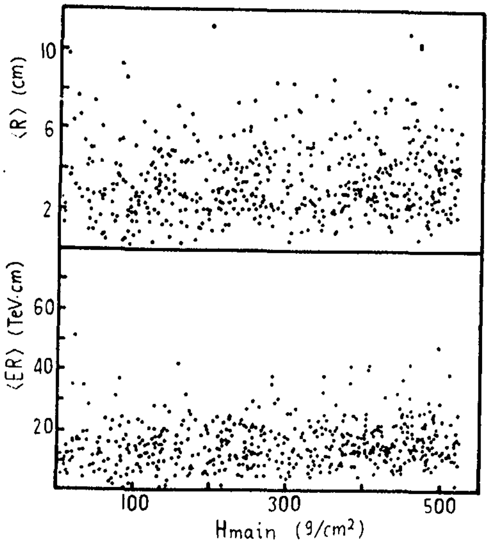


Fig.6

Fig.8 is shown the dependence of $\langle E_\gamma \rangle$ on H_{main}. When we analyse the relation between the composite quantity $C \equiv \langle R \rangle \cdot \langle E_\gamma \rangle E_\gamma^{max} / n_\gamma^2$ and H_{main} (Fig.9), it is seen that some low height events are condensed near C=0. Taking a C value cut (say C=5), the event sample selected will be dominant for low-height events.

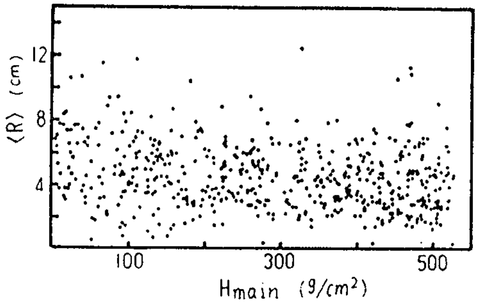


Fig.7

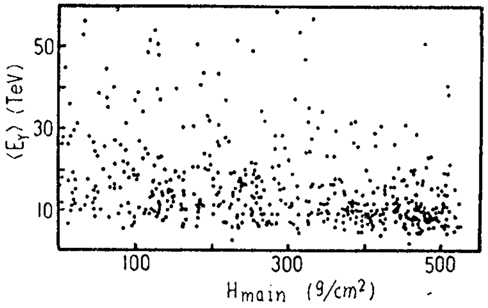


Fig.8

For the families not treated by decascading procedure, the composite quantity $A \equiv n_\gamma^2/(\langle R\rangle\cdot\langle ER\rangle\cdot\langle E_\gamma\rangle\cdot E_\gamma^{max})$ can also be used to separate the the concerned events. For example, there are 28 events satisfing the conditions $A<0.05$ and $\langle R\rangle<3$ cm, among which 12 have $H_{main}>450$ g/cm , 7 events have both $H_{main}>450$ g/cm and $p>0.7$. Considering the whole events satisfing these two conditions are not very rich (Fig. 4), this method may be useful.

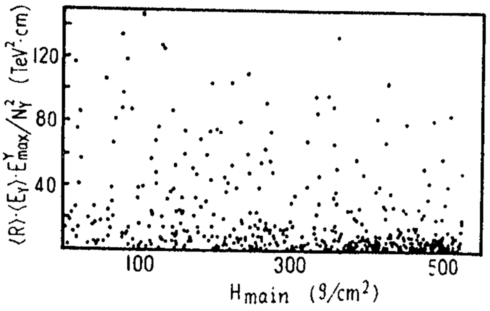


Fig.9

The condition $\langle ER\rangle<10$ TeV.cm and $\langle E_\gamma\rangle>12$ TeV can also separate about one half events having $H_{main}>450$ g/cm and $p>0.8$.

Summary.

Due mainly to the multi-interactions in thick atmosphere target above the mountain emulsion chamber, the dependence of the observable quantities of family events on the main interaction height H_{main} is strongly smearing. However, weak dependence on H_{main} still exists in $\langle R\rangle$, $\langle ER\rangle$, $\langle E_\gamma\rangle$, n_γ and E_γ^{max} etc. A small sample with low-height and high purity is not impossible to be separated by suitable composing and cutting of these quantities.

References.

1. M.Shibata, Phys. Rev., D24(1981)1847.
2. T.Yuda, 18th ICRC, Rapporteur talk on HE 5.
3. **Pamir** Collaboration, 14th ICRC, 7(1975)2370.