Atmospheric Interactions detected in both the Upper and the Lower Chambers at Chacaltaya

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1. Introduction

Brasil-Japan Collaboration has been studying the cosmic ray interactions in the energy region 10^{13} - 10^{17} eV by means of emulsion chambers exposed at Chacaltaya, 5220 m above sea-level, Bolivia[1]. The recent chambers have a two-storied structure, and the events which are observed both chambers have given us important informations on the phenomena. For example, the first Centauro event was detected as a small shower at the bottom of the upper chamber and as a big fraction of energy deposit in the lower chamber, which indicated a high contribution of hadronic showers[1].

We are almost finishing the complete analysis of the events of atmospheric interactions with such continuation for the Rio part of the 19th chamber. In this paper, we describe some results of the events with continuation in the rather low energy region which are often eliminated in the discussion only because of their low energy.

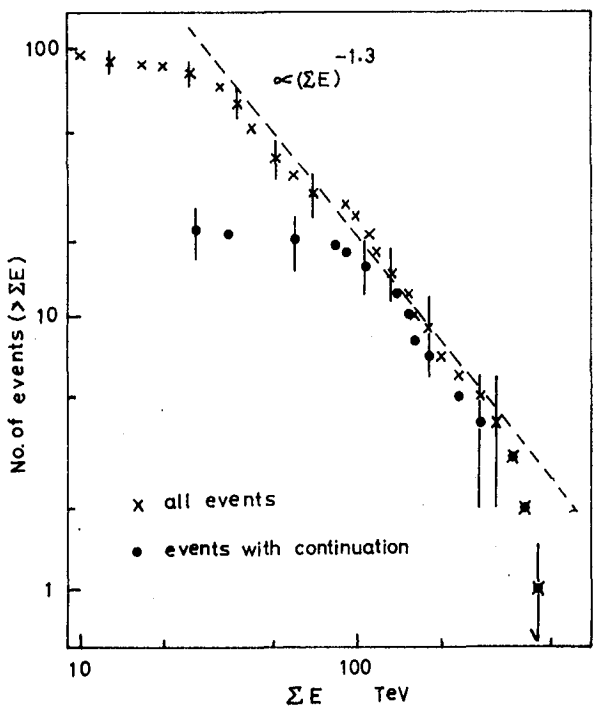

Fig.1 The integral distributions of total visible energy. (×) for all the events and (•) for the events with continuation.

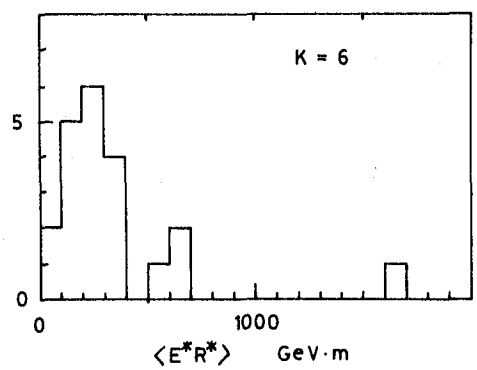

Fig.2 The histogram of $\langle E^*R^* \rangle$, where K=6 GeV·m is used for decascading.

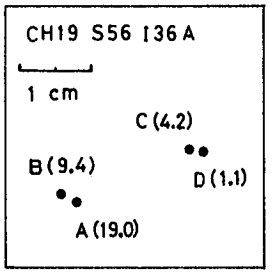

Fig.3 The target diagram of CH19 S56 I36 A. The name and energy of each core is shown.

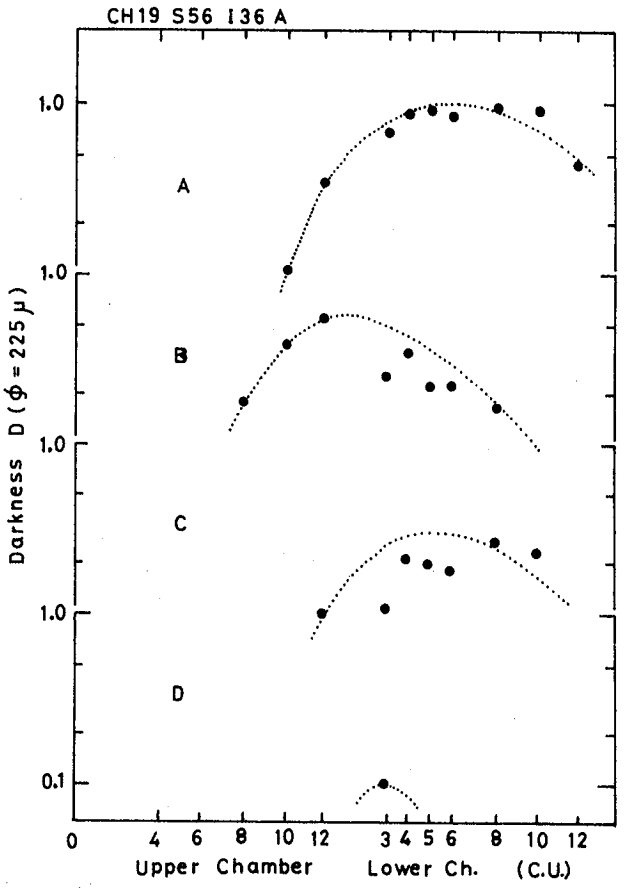

Fig.4 The transition of darkness D with slit diameter 225 μ for 4 cores in S56 I36 A. The fitting curves are also shown.

2. Experiment

The 19th chamber is two-storied, and for the whole upper and lower chambers, nuclear emulsion plates were inserted in sandwiches of lead plates together with X-ray films. The exposure time was 677 days. The upper chamber has total area of 44.2 m^2 and the lower chamber 32.4 m^2. They are formed by unit blocks of dimension 40 x 50 cm^2; in Rio de Janeiro have been analyzed 59 blocks of the upper chamber and 48 blocks of the lower chamber.

We must observe at least two penetrative shower cores in both the upper and the lower chambers, in order to determine the relative geometrical position of all the showers in both chambers. We have observed 21 events with such continuation. Fig.1 shows the integral distributions of the total energy visible in the form of electro-magnetic cascade showers for all the events and for the events with continuation. We notice that the distribution for all the events obeys $\propto(\Sigma E)^{-1.3}$, which is consistent with the previous measurements [1].

Fig.2 shows the distribution of average energy-weighted lateral spread, $\langle E^*R^* \rangle$, for the 21 events, where the so-called decascading constant K = 6 GeV·m was chosen [2]. We usually have a larger interest in the region of large ER, but in the following we describe three events in the small ER region.

3. Results

We have two events with continuation in the interval of

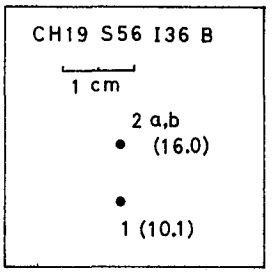

Fig.5 The target diagram of CH19 S56 I36 B.

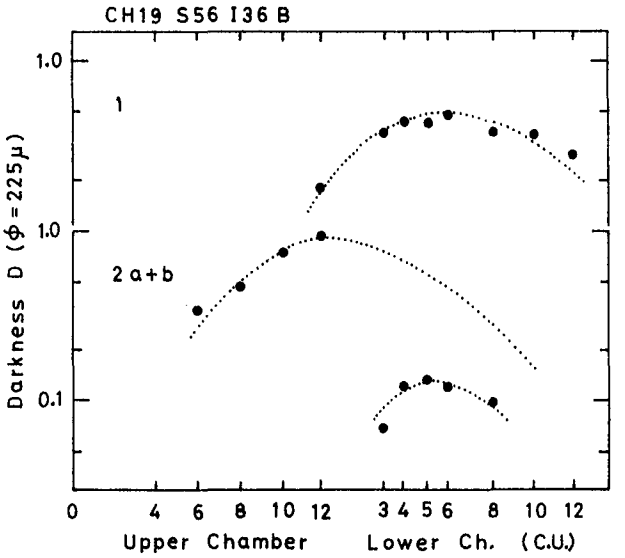

Fig.6 The transition of D for 2 spots in S56 I36 B.

$\langle E^*R^* \rangle$ less than 100 GeV·m. The names of the events are CH19 S56 I36 A and CH 19 S56 I36 B; it is a coincidence that these two events were observed in the same blocks.

CH19 S56 I36 A Fig.3 shows the target diagram of this event. The event consists of only four shower spots with the total visible energy 33.7 TeV. Fig.4 shows the transition of darkness D on the N-type X-ray films for the four spots of the event. The slit size is 225 μ in diameter. The depth of lead is indicated by the cascade unit of each chamber.

#A starts to be observed at the very deep layer, 8 cu on the emulsion plate and 10 cu on the X-ray film, as a sharply collimated shower core. #B starts to be observed at 8 cu and we can not find any track on the corresponding position at 6 cu. #C starts to be observed at 12 cu. #D is observed only in the lower chamber as a diffused small shower.

Down to 6 cu in the upper chamber, this event does not appear for detection, and the cores B, A, C and D start to appear, one by one, to form the event.

We can identify all the four cores as hadronic because of their deep penetration. This event is lacking in electromagnetic components at the entrance of the chamber within the limit of detection threshold (~1 TeV).

CH19 S56 I36 B Fig.5 shows the target diagram of this event. The event consists of two spots (#1 and #2) with the total visible energy 26.1 TeV. #2 consists of two constituent cores (a and b) with the very short mutual distance 33 μ. Both the two spots continue into the lower chamber.

Fig.6 shows the transition of spot darkness on the N-type X-ray films. #1 starts to appear at 12 cu in the upper chamber as a collimated core and in the lower chamber as multi-cores. #2 starts to be observed at 6 cu and the spacing effect of air-gap between the upper and the lower chambers is clearly seen in Fig.6.

We can identify #1 as a hadronic core, but we can not judge whether #2 contains hadronic nature.

CH19 S83 #200 This event is observed only in the upper chamber. Fig.7 shows the target diagram of this event. The event consists of two spots (#1 and #2) with the total visible energy ~30 TeV. #1 consists of two constituent cores (a and b) with the mutual distance 175 μ.

Fig.8 shows the transition of electron number counted on the nuclear emulsion plates in the area 78 x 78 μm^2. #1a appears as a normal shower, but #1b starts to appear at 8 cu and grows up remarkably down to 12 cu. #2 is observed only at 12 cu in the upper chamber.

We can identify #1a and #2 as hadronic cores. We can not judge #1b as a hadronic core.

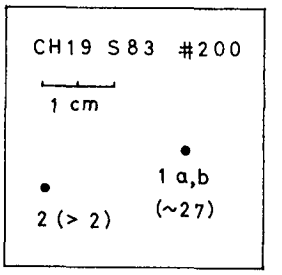

Fig.7 The target diagram of S83#200.

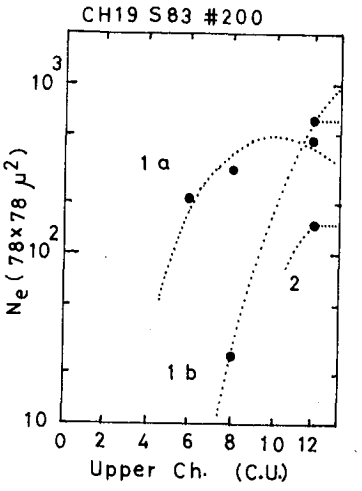

Fig.8 The transition of electron number inside the counting area 78 x 78 μm^2.

4. Discussions

We have encountered interesting (exotic) events in the high energy region, $\Sigma E > 80 - 100$ TeV [1,3]. But as shown in the previous section, we can pick up some events with an impressive character even in the lower energy region.

In the energy interval, 25 - 35 TeV, we have analyzed 18 events, among which 3 events showed a hadron-rich nature. If we use the power fit of $(\Sigma E)^{-1.3}$ in Fig.1, these 3 events are in the unbiased sample of ~40 events in that energy interval.

More details on the events with continuation will be presented at the Conference.

5. Acknowledgement

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