

STUDY OF HADRON BUNDLES OBSERVED IN CHACALTAYA
TWO-STORY EMULSION CHAMBER

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1. INTRODUCTION

The existence of hadron-rich families associated with few gamma-ray emission named Centauro and Mini-Centauro phenomena was reported by Brasil-Japan collaboration. (1) Since, it is important to make clear whether these are produced by the special type of interaction different from the ordinary pion multiple production or not, a number of studies have been made by various authors. (2)

We have already presented the result of the systematic study of hadron bundles, detected by Chacaltaya emulsion chamber No. 15, 17 and 18. (3)

In this paper the experimental results are compared with simulation calculation based on ordinary multiple pion production model.

2. EXPERIMENTAL PROCEDURE

We analyzed 172 blocks of the lower detector of each two-story emulsion chamber No. 15, 17 and 18.

Through the general scanning of X-ray films in the lower detector, we select parallel incident showers which pass through the upper chamber as hadron bundles, since such showers detected in lower chamber are originated by hadronic interactions in the chamber itself.

We studied core structure of showers in nuclear emulsion plates under microscope for all the detected X-ray film dark spots, and classify them into the following categories, (1) Pb-jet-upper with diffuse core structure, (2) C-jet with clean multi-core structure and (3) Pb-jet-lower with single collimated core structure.

We observed 90 hadron bundles in the present analysis. Among these hadron bundles, the following special events are included which were identified as Centauro I and IV, Mini-Centauro (7 events), and hadron-rich families (2 events).

Energies of showers are estimated by track-counting method for C-jets and by micro-photometry measurement for the others. The detection threshold energy was estimated around 2.0 TeV.

3. SIMULATION CALCULATION FOR HADRON BUNDLES.

In order to study hadron bundle phenomena originated from ordinary multiple pion production, a simulation calculation was carried out, based on the scaling model for nuclear interactions. (4)

Two kinds of primary particles are assumed for the contrast, (a) proton primary and (b) iron nucleus, respectively. In both cases, the energy spectrum of primary particles is assumed to be $F(\geq E_0) \propto E_0^{-\beta}$ and the power index β is given

as 1.8 in integral form. The minimum energy of primary particle in the calculation, E_{\min} , is chosen as 500 TeV for proton primary and 1000 TeV for iron nucleus. The structure and geometry of Chacaltaya chamber is taken into account exactly. The unit of detection for hadron bundles is taken to be the size of one block of chamber 40cm×50cm. In order to adjust to the experimental conditions, the family center is randomly moved inside the size of one unit block. 76 hadron bundles ($N_h \geq 2$, $E_h^{(s)} \geq 1$ TeV) are obtained from 600 proton primaries and 36 from 600 iron primary.

4. COMPARISON

Fig.1 shows the differential distribution of observed multiplicity, N_h , for all hadron bundles (90 events). Simulation results (76 events) are shown by the dotted line in the same figure.

Fig.2 shows the differential distribution of $\langle E_R \rangle$, and simulation results are shown by the dotted line in the same figure.

Fig.3 shows scattering plots of $\langle E_R^{(s)} \rangle$ v.s. N_h , where \bullet is simulation data based on proton primary, \times based on iron primary, \otimes is Centauro events, \circ is Mini-Centauro events, \odot is hadron-rich families and \bullet is the other observed events.

5. CONCLUSION.

As is seen in Fig.1, both hadron multiplicity distribution, obtained from the present observation and the simulation calculation, show almost the same distribution in the range $0 < N_h < 8$. It means that hadron bundles of such smaller multiplicities are considered to be originated from successive interactions of surviving nucleon with the nature of multiple production during passing through the atmosphere. One cannot find, however, larger multiplicity hadron bundles, $N_h > 9$, in the simulation data.

Especially, Centauro I ($N_h = 27$), Centauro IV ($N_h = 13$) seems to be far beyond the fluctuation which is expected from the ordinary pion multiple production originated from proton primary.

Fig.2 shows similar tendency between the $\langle E_R^{(s)} \rangle$ distribution obtained from the present observation and the simulation calculation in the range $0.80 < \langle E_R^{(s)} \rangle < 6.7 \times 10$ TeV.cm. One cannot find, however, smaller $\langle E_R^{(s)} \rangle$ hadron bundles, $\langle E_R^{(s)} \rangle < 0.80$ TeV.cm, in the simulation data.

The comparison of scattering plots of $\langle E_R^{(s)} \rangle$ v.s. N_h between the experimental results and the simulation data, based on proton and iron primary, shown in Fig.3 give the same conclusion. They are in the similar tendency for the events with $N_h < 13$.

6. ACKNOWLEDGMENT.

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Fig. / Differential Distribution
 of Multiplicity

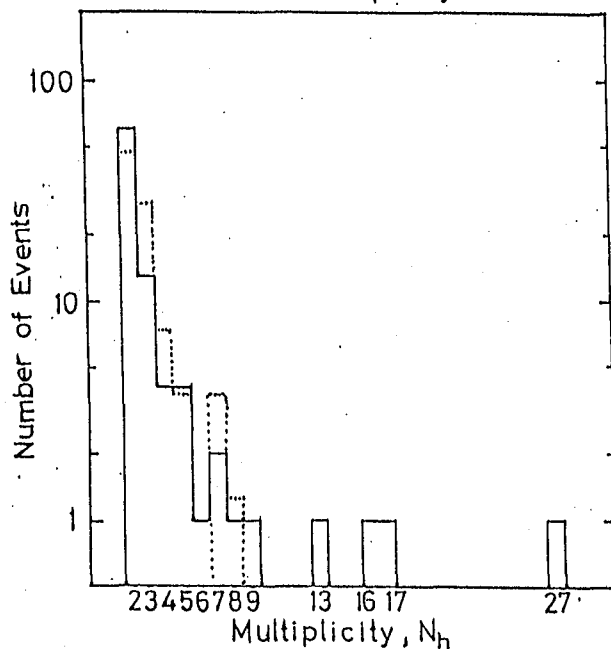


Figure shows the differential distribution of observed multiplicity, N_h .

———— is the experimental result for all hadron bundles (90 events).

..... is the simulation results (76 events from proton primary).

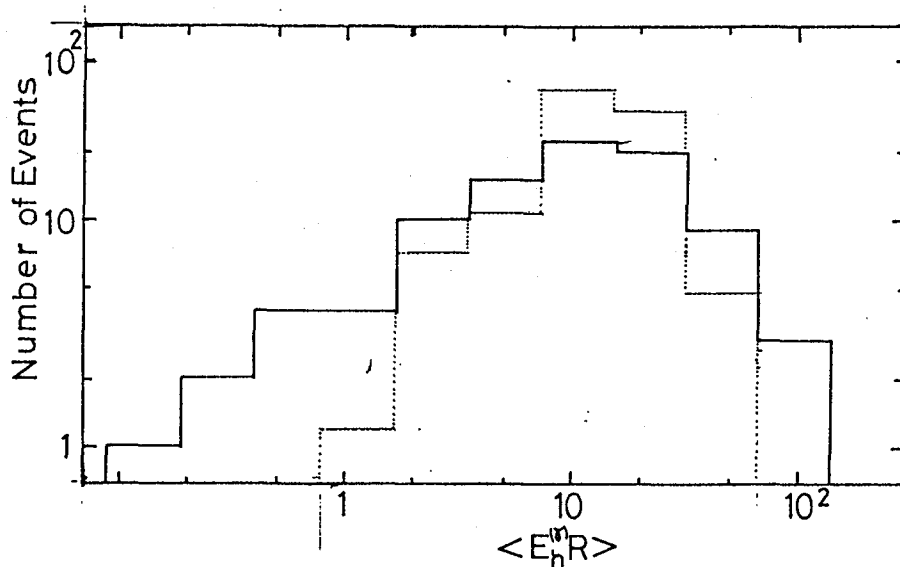


Figure 2; The differential distribution of $\langle E_h R \rangle$ is shown. is the experimental result for all hadron bundles (90 events).
 is the simulation results (76 events from proton primary).

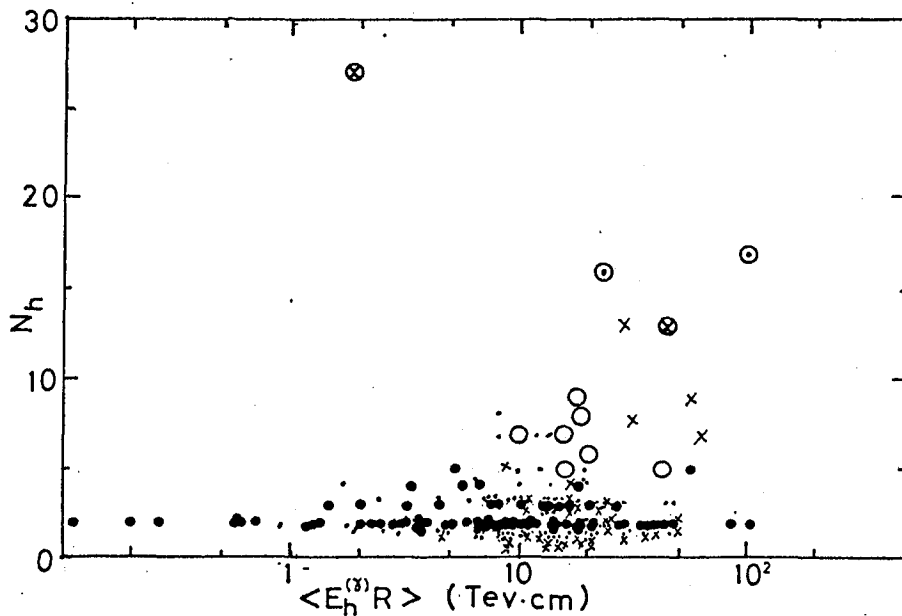


Figure 3; The scattering plots of $\langle E_h R \rangle$ v.s. N_h is shown.

- is simulation data based on proton primary.
- × based on iron primary.
- ⊗ is Centauro events.
- ⊙ is Mini-Centauro events.
- ⊙ is hadron-rich families.
- is the other observed events.