Comments on Centauro Events

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Abstract

The event "Centauro-I" is re-examined. It is shown that the previous upper-lower correspondence is not correct and then the description of the event must be changed in part. The new version of "Centauro-I" shows peculiar characteristics quite different from the cosmic-ray events, commonly observed, yet.

1. Introduction

Since the first report of Centauro-I many attempts have been made to understand peculiar characteristics of Centauro events from theoretical and experimental points of view. After the finding of Centauro-I, additional candidate events were looked for and eight candidate events are found through a series exposures of two-storey emulsion chambers at Mt. Chacaltaya. Those events are very hadron-rich but are not so spectacular as Centauro-I. That is, some of them are contaminated by the electron-photon component, due to the secondary interactions in the atmosphere, and some of them have no showers penetrating from the upper to the lower chamber and hence the upper-lower correspondence is not completely perfect. In other words, these candidate events can be interpreted as Centauro events which are produced at higher altitude, but are dependent crucially on the existence of Centauro-I. Centauro searches were done also by accelerator experiments, UA1 Collaboration and UA5 Collaboration at CERN SPS $\bar{p}p$ collider ($\sqrt{s}$ = 540 and 900 GeV) and CDF at FNAL Tevatron ($\sqrt{s}$ = 1800 GeV), but they did not find clean Centauro events to conclude that the upper limit of Centauro production probability is $10^{-5} \sim 10^{-6}$.

Based on the present status of Centauro, mentioned here, we thought that it is important to examine again Centauro-I critically.

2. Re-examination of Centauro-I

2.1. Chamber 15

Centauro-I is found in Chamber No.15 (C15) of two-storey structure. (See Table 1 for details.) Sensitive layers of lower (upper) chamber consist of a nuclear

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Table 1. Details of Chamber 15 of two-storey type

	Area	Thickness	Date(day/month/year)	
			Construction	Dismantle
Upper ch.	44.2 m^2	$1.3 \times 6 = 7.8$ cm Pb	4-5/10/69	29-30/07/70
Target layer	44.2 m^2	23 cm pitch		
Support		5 cm wood (spaced)		
Air gap		158 cm		
Lower ch.	33.0 m^2	$1.0 \times 8 = 8.0$ cm Pb	5-6/10/69	28-29/07/70

Table 2. Arrival directions of the families in S55 and I12

	Zenith angle $\tan\theta$	Azimuth angle φ
Family in S55	0.3 ± 0.1	$90° \pm 10°$
Family in I12	0.3 ± 0.1	$130° \pm 10°$

emulsion plate and X-ray films (only X-ray films). From the memos of construction and dismantle, it is sure with 100 % confidence that there was no chance that the lower detector was exposed to cosmic rays directly.

2.2. Critical examination of Centauro-I

Is the correspondence correct ?

According to the description of Centauro-I in Phys. Rep.[1] *"Among the showers due to Pb-jet-upper, there are several which have spots in both detectors and one pair of them, with distance apart of* ~ 7 *mm, gives a signal of angular divergence outside experimental error: the increase of the distance apart at the lower detector is found to be* 0.25 ± 0.05 *mm."* It came into our mind recently through our discussion that the former half of the above statement may not be consistent with the latter half. That is, these shower spots in the upper detector (S55) may not correspond to those in the lower detector (I12) (See Fig. 1.), because the both configurations are not the same exactly.

Hence we made re-measurement of shower directions for the families in S55 and I12 (We call shortly as "S55" instead of " the family in S55" hereafter.), which is given in Table 2. We conclude that S55 does not correspond to I12, (1) because the arrival directions of two families do not coincide with each other, and (2) because we could not find the same configurations of showers in S55 and I12 within the errors of 100 μm displacement. In the previous analysis the errors were estimated larger in shower direction and shower position measurements, which is the reason why we concluded the same configuration of showers in S55 and in I12. In the X-ray films, ~ 40 shower-spots are visible in I12 within the area of diameter ~ 1 cm by naked eye, and therefore the accidental coincidence of the configurations is possible if we allow the displacement ambiguity of 200 μm or more.

Did Centauro-I pass the upper detector ?

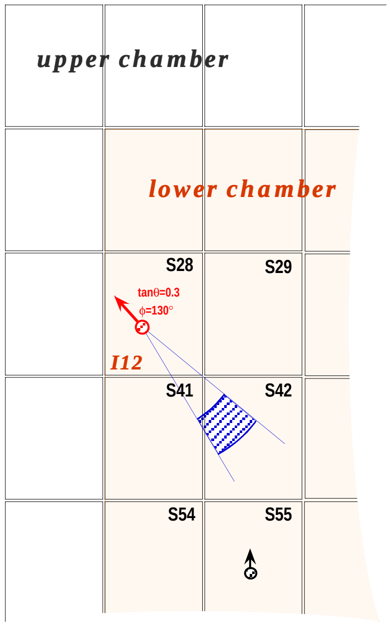

Fig. 1. Arrangement of the upper and lower blocks of the Chacaltaya chamber no.15. The hatched area is a position of upper chamber family expected from I12.

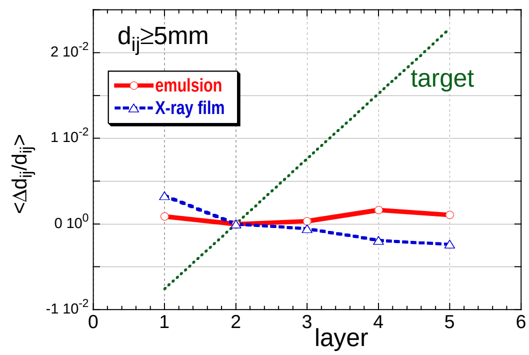

Fig. 2. Measurement of geometrical convergence of showers in lower chamber I12.

It is sure from the azimuth angle of I12 that it passed the upper detector. (There is no possibility that the block I12 is constructed upside down or in 180° rotation.)

Is there another family to correspond to I12 ?

We could not find a family with similar direction to I12 in blocks S29, S41 and S42, in which a family corresponding to I12 may exist approximately. (See Fig. 1.) There is a single shower of similar direction in S42, but we have no way to identify it as the upper part of I12. Consequently Centauro-I left a single or no shower in the upper chamber, although it passed the upper detector.

Did Centauro-I hit the lower chamber directly passing the gap of the upper ?

Each block (40 cm × 50 cm) of the emulsion chamber might be separated $\sim$ 1 cm from neighboring blocks, although we tried to put neighboring blocks as close as possible. Taking into account the inclination of Centauro-I, all the showers in I12 must have passed at least $\sim$ 3 cm Pb of the upper chamber. The structure of the electron showers in I12, which is observable in the nuclear emulsion plates by microscope, does not look to show the features that they have passed 3 cm Pb ($\sim$ 6 cascade unit). (Quantitative argument is not easy.)

Is I12 produced in the target ?

If so, we can observe displacement of the shower spots, $\sim$ 80 μm, in the

X-ray films and nuclear emulsion plates at different depths, 1.0 cm (Pb) + 0.3 cm (sensitive layer) apart, of the lower detector, because divergence angle of showers is $D/H = 1$ cm / 174 cm $= 6 \times 10^{-3}$ ($D:$ the lateral spread of showers in I12, H : the distance from the center of the target layer to the top surface of the lower detector).

We measured the divergence of shower spots at different depths in the lower detector using 353 pairs of showers in X-ray films and 73 pairs of high energy showers in nuclear emulsion plates. The results in Fig. 2 show that there is no divergence of shower positions.

3. Summary and discussion

(i) We made re-examination of Centauro-I, and we found that following points in the previous report [1] must be revised.
1. The family of 7 showers in S55 is the upper part of I12.
2. Centauro-I is produced at ~ 50 m above the chamber.

We should note, however, that the event is quite peculiar yet compared with high energy cosmic-ray events commonly observed. That is,
(1) Centauro-I passed the upper detector with leaving no (or a single) shower in the upper detector, while there are a lot of showers, 137 showers with detection threshold of 0.1 TeV, in the lower detector. Those are produced mainly in the target layer (and a few in the lower part of the upper detector).
(2) The family in I12 is *not* produced in the target layer by a single (or a small number of) hadron(s), because we could not observe the divergence of the showers in the lower detector.
(3) If the showers in I12 are produced by a number of hadrons, 10 $\sim$ 30 according to our analysis, a larger number of hadrons hit the upper detector and some of them must make showers in the upper detector. (But *no shower* !)

Centauro-I is not a sole event to show such strange characteristics. We have another event [2], though the number of showers and total energy, observed in the lower detector, is not large.
(ii) Bjorken et al.[3] proposed a model to describe the previous version of Centauro-I. That is, strange quark globs of meta-stable state among the primary cosmic rays heat up traversing the atmosphere and explode into hadrons. New version of Centauro-I can be described by this model, if we assume that large quark globs among the primary cosmic rays fragment into a number of small quark globs in the atmosphere and they hit the emulsion chamber.

[1] C.M.G.Lattes et al., *Phys. Rep.*, Vol.65 (1980) 151
[2] S.L.C.Barroso et al., *Proc. 25th ICRC, Durban*, Vol.6 (1997) 53
[3] J.D.Bjorken and L.D.MacLerran, *Phys. Rev*, D20 (1979) 2353