Centauro I: finding the answer

V. Kopenkin[1], Y. Fujimoto[2],
(1) Skobeltsyn Institute of Nuclear Physics of Moscow State University, 119992, Vorob'evy Gory, MSU, Moscow, Russia
(2) Advanced Research Center for Science and Engineering, Waseda University, Shinjuku-ku, Tokyo,169 Japan

Abstract

Since 1972 there have been many attempts to explain the mystery of Centauro species. A new analysis of the original Centauro I event shows that the solution lies with the details of the Chacaltaya detector. For a long time scientists believed that the Centauro I event consisted of two families. In summer 2002 we found that, contrary to the previous study, there is only one family related to Centauro I, and this is the family detected in the lower chamber. The new result indicates that it is not necessary to assume huge imbalance of hadron and electromagnetic components. The characteristic features of the event show that the most plausable candidate for the origin of Centauro I would be a glob of strange quark matter.

1. Introduction

The Japan-Brazil experiment[1] has been operating two-storied x-ray emulsion chambers at an altitude of 5220 m above sea level (an air pressure of about 540 mbar) on Mt Chacaltaya in the Bolivian Andes. In 1972 the Brazil-Japan collaboration found in the lower detector of the emulsion chamber No.15 a group of a few tens of shower spots (identified as 49 hadrons and 1 gamma) with energy $\sim 230\,TeV$ situated in a narrow region of 1.5 cm diameter[2]. The event was named "Centauro I". According to Greek mythology, a Centaur was highly asymmetric creature: with the top half of a man and the legs of a horse. The finding of the cosmic ray Centauro suggested that, perhaps, there was something wrong with either the theory of particle interactions, or the understanding of cosmic rays. A search for further Centauro type families were made on the successive Chacaltaya chambers, and several other candidates were found. Some of them showed not too small production height, as well as considerable fraction of electromagnetic component, another have been detected at the very edge of the films in the lower detector that did not allow to consider the complete picture of the event. However, the Centauro I event stands out completely from the sample

pp. 1587–1590

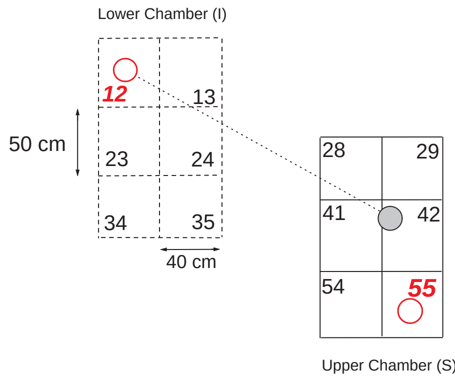

Fig. 1. The fragment of the Chacaltaya chamber $CH-15$. The position of Centauro I as determined in previous study is shown by open circles. The solid circle shows expected position in the upper chamber for the event $I-12$.

of experimental data from the same energy region. So far there was no positive result in Centauro search by accelerators[3], [4], [5].

2. The new picture of Centauro I

We found that the previously published data on the Centauro I event were insufficient for a rigorous test of the exact correspondence of the family pattern observed in the upper and the lower detectors. According to the original analysis, Centauro I consists of two groups of showers (see Figure 1): (1) the one is observed in the lower detector (block $I-12$), (2) and the other - in the upper detector (block $S-55$).

According to our analysis, the family in the lower chamber shows the arrival zenith angle $tan\theta \sim 0.3 \pm 0.1$. Thus, the expected place of arrival of Centauro I at the upper detector is estimated to be at the distance R in horizontal plane, measured from the center of the family in the lower detector: $R = H * tan\theta \sim 56 \pm 19$ cm, where $H = 10.8$ cm (upper detector) +23 cm (target) +5 cm (wood) +147 cm (air gap) = 185.8 cm. Nevertheless, the event observed in the block $S-55$, is located at the distance $R \sim 1$ m from the relative position of the lower part. The new measurements revealed that upper chamber family detected in the block $S-55$ shows different zenith angle: $tan\theta \sim 0.4 \pm 0.1$. The same situation has been found for the the azimuth angle of the event: $\phi \sim 130 \pm 10$ for the lower detector , and $\phi \sim 90 \pm 10$ for the upper detector . Thus, we found that the upper detector event found in block 55 has no relation to Centauro I. There is only one family related to Centauro I, and this is the family detected in the block I-12. With removal of the upper part family, the name "Centauro" in a sense of man-horse analogy, becomes redundant. There is only one event observed in the lower chamber. It is much closer in classification to the concept of the $C - jet$, or a jet from a target layer.

3. Discussion and Conclusion

In order to explain this result, we can consider interaction of the primary particle in the atmosphere with an air nucleus, or interaction of the primary particle in the target of the detector. It has been almost ruled out that Centauro I could be formed due to any kind of statistical fluctuations in the standard mechanism of hadron production. The flux of survivng heavy nuclei is too low at the mountain altitude (a factor $\sim 10^{-10}$) . The expected number of events, when primary is a heavy nucleus, has been estimated as $2.4 * 10^{-5}$ against 1 event observed[10]. It is generally thought that Centauro I can form one of two ways: exotic primaries[6], [7] or result of new features of hadron interactions[8], [9]. Our new finding shows that in any scenario under consideration, the new feature of the event had to be taken into account. For instance, the chance of 49 particles to penetrate without interaction and 1 particle to interact is $p \sim 10^{-8}$. Thus, any model that involves interaction of primary particle in the atmosphere (before entering the chamber), has to deal with this factor. In this situation an exotic particle, such as strange quark matter (SQM) would easily satisfy all the requests: deep penetration in the atmosphere, possibility of interaction in the target, high transverse momenta and large multiplicity of secondaries. Assuming that m.f.p. of SQM is similar to that of a proton (in fact, it could be much larger), and taking into account attenuation in the atmosphere, we can estimate probability to get the event at the lower chamber as $\sim 10^{-3}$. The only problem is the existence of SQM itself.

Since a single event is in question, we should not reject any mundane explanations that are perceived to be improbable. In evaluation of possible models, it is generally assumed that the Chacaltaya detector is ideal. In ideal detector the upper chamber covers the lower chamber without any "discontinuities" or gaps. The real situation in experiment is different. Previous investigation of Centauro I has almost never mentioned some specific features of the Chacaltaya detector, such as gaps[11] (comparable in size to the event) between neigboring blocks in the upper as well as lower chamber. Also in the real setup of the detector, there is no exact geometrical correspondence (in vertical direction) between every corner of each block in the upper and lower chamber. These factors would account for the possibility of an air family to pass through the gap between blocks in the upper chamber. Hence, if the detector had been ideal, then the most plausible explanation for the origin of Centauro-I , would have been SQM. In the real situation of the experiment, the most likely cause of the event $I - 12$ observed in the chamber $CH - 15$ would be the Chacataya detector problem.

We are grateful to Prof. A.Ohsawa for the opportunity to work with the original films of the Centauro I event. Without him the present work could not be realized. One of the authors (V.K.) is sincerely thankful to Prof. K.Kondo for the chance to work at Advanced Research Center of Waseda University.

References

[1] Lattes C. M. G. et al. , Suppl. Prog. Theor. Phys. 47, 1 (1971).

[2] Lattes C. M. G. et al., Phys. Rep. 65, 151 (1980).

[3] Alner G. J. et al. (UA5 collaboration), Phys. Lett. B 180, 415 (1986).

[4] Albajar C. et al. (UA1 collaboration), Nucl. Phys. B, 345, 1-21 (1990).

[5] Melese P. L. for the CDF collaboration, FERMILAB-Conf-96/205-E (1996).

[6] Witten E. Phys. Rev. D, 30, p.272 (1984).

[7] Panagiotou A. D. et al. Z. Phys. A333, 355-366, (1989).

[8] Hasegawa S. for the Brazil-Japan collaboration Prepared for talk at Fermilab CDF seminar. ICR-Report-151-87-5 (1987).

[9] Bjorken J. D., Kowalski K. L. & Taylor C. C. SLAC-PUB-6109 (1993).

[10] Acharya B. S. and Rao M. V. S., J. Phys. G: Nucl/ Part. Phys., 17, 759 (1991)

[11] Kopenkin V., Report on research activity to FAPESP (Fundacao de Amparo a Pesquisa do Estado de Sao Paulo), 1996.