tion in the water and also sound, by the thermoelastic effects associated with sudden energy release. Both the light and sound can be detected at considerable distance under suitable circumstances. Thus, very massive detectors become possible. The design of a DUMAND array is about 10^9 ton (gigaton detector) to obtain significant data on the fundamental weak interactions of cosmic ray neutrinos at energies of 1 TeV and above.

Acknowledgement

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References*

1. J. Benecke *et al.*: Phys. Rev. **188** (1969) 2159.
2. R. P. Feynman: Phys. Rev. Letters **23** (1969) 1415.
3. T. Yuda: private communication.
4. Brazil-Japan Collaboration: No. 435 in this Conference.
5. S. K. Machavariani *et al.*: 841 in this Conference.
6. Y. Takahashi, J. Iwai and I. Ohta: No. 839 in this Conference; A. P. Garyaka: No. 1032 in this Conference.
7. K. Kasahara and Y. Takahashi: Progr. theor. Phys. **55** (1976) 1896.
8. Y. Yamamoto *et al.*: No. 572 in this Conference.
9. M. R. Krishnaswamy *et al.*: 15th ICRC **6** (1977) p. 161.
10. Mutron group: No. 388 in this Conference.
11. S. Mikamo *et al.*: No. 410 in this Conference.
12. M. R. Krishnaswamy *et al.*: 15th ICRC **6** (1977) p. 85.
13. M. J. Ryan *et al.*: 12th ICRC **1** (1971) p. 178. N. L. Grigorov *et al.*: 12th ICRC **5** (1971) p. 1746.
14. L. M. Lederman: Phys. Reports **25c** (1976) 151.
15. S. Miyake *et al.*: 15th ICRC (1977).
16. M. R. Krishnaswamy *et al.*: Pramana **5** (1975) 259.
17. M. R. Krishnaswamy *et al.*: 15th ICRC **6** (1977) p. 137.
18. Utah University group: 15th ICRC **8** (1977) 258, 264, 270.
19. Dumand Symposium: 15th ICRC **6** (1977) p. 244–289.

* ICRC = International Cosmic Ray Conference

PROC. 19th INT. CONF. HIGH ENERGY PHYSICS
TOKYO, 1978

B 10 Centauro

Y. FUJIMOTO

Brasil-Japan Emulsion Chamber Collaboration

This is a short report of collaboration work on high energy nuclear interaction of 10^{14}–10^{15} eV with emulsion chambers exposed at Chacaltaya Observatory, Bolivia, 5200 m above sea level. Figure 1 gives structure of the chamber. The present results cover the data from four chambers of such type exposed successively for a period of one to two years each. Our apparatus consists of electron shower detectors, which are multi-layered sandwiches of Pb-plates, nuclear emulsion plates and X-ray films.

Figure 2 demonstrates how the chamber detects cosmic-ray electrons, gamma rays and hadrons. Figure 3 shows an example of cali-

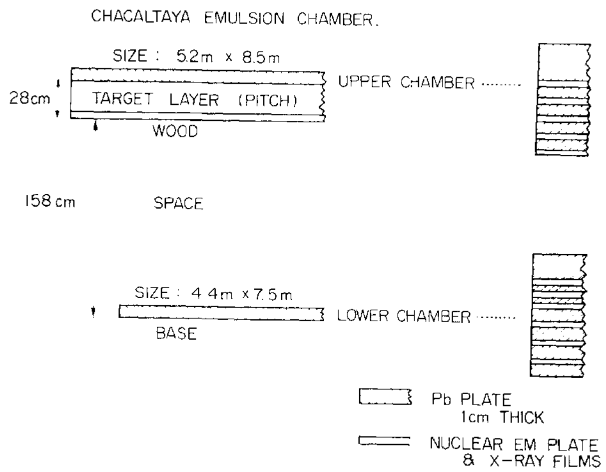

Fig. 1.

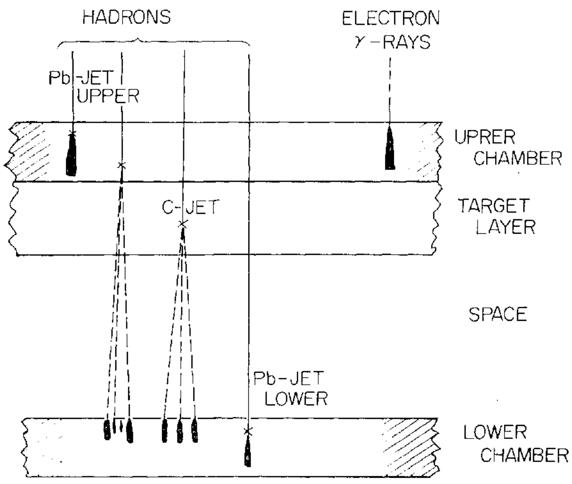

Fig. 2.

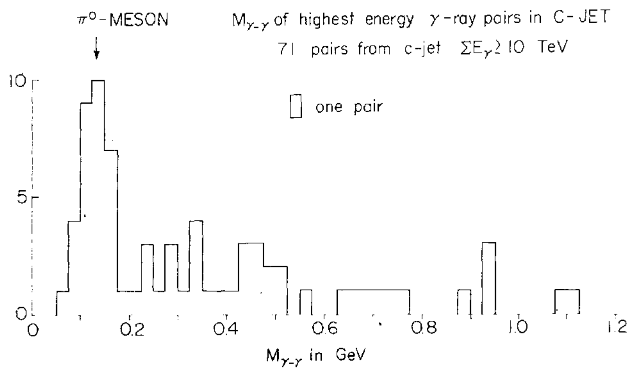

Fig. 3.

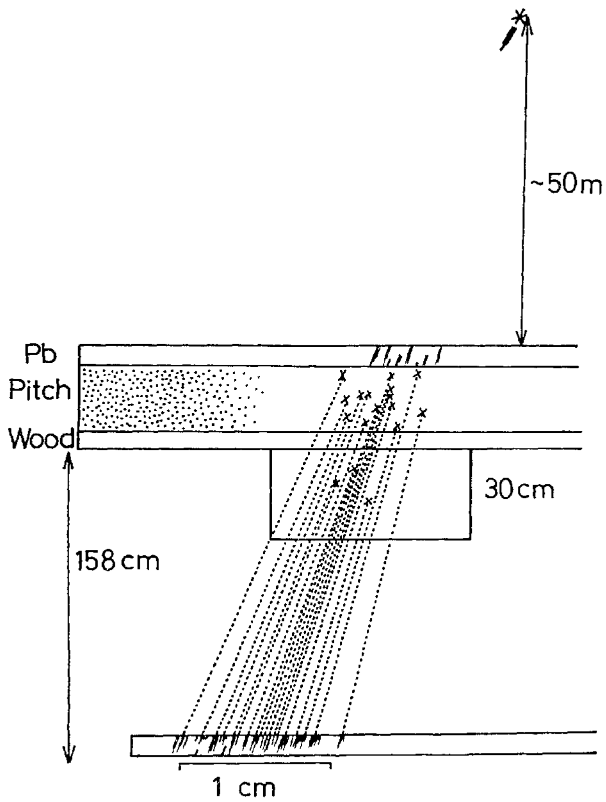

Fig. 4.

bration of our energy measurement through coupling of two gamma-rays into a pi-meson.

Figure 4 illustrates the first event of Centauro. Showers in the lower chamber are hadrons with collision mean free path of the usual value. Estimation shows that a bundle of 71 hadrons are arriving at the chamber with no association of electrons or gamma-rays above the detection threshold ($E_\gamma \gtrsim 2$ TeV). The geometry measurement in the upper and lower chamber tells that the bundle is divergent from a point at 50 ± 15 m above the chamber. Assuming it to be position of the parent interaction in atmosphere, the hadron multiplicity at production will be ~ 74.

We have at present four such examples, and the Table gives their outline. The common characteristic is that the event is large in the lower chamber showing presence of large number of hadrons. Estimations are given for multiplicity of hadrons and gamma-rays (or electrons) at the top of chamber and also at the point of parent nuclear interaction in atmosphere. The height of interaction is deter-

Table. Four Centauro events

Event number	I	II	III	IV
No. of showers in upper chamber	7	14	26	61
in lower chamber	43	23	16	15
Observed energy sum in upper chamber	28.1	75.6	150.1	195.5 TeV
in lower chamber	202.5	145.8	119.8	90.1 TeV
Observed hadron multiplicity	49	32	37	38
Estimated hadron multiplicity				
arriving at chamber	71	66	63	58
at interaction in air	74	71	76	90
Estimated height of interaction	50 ± 15	80	230	500
Multiplicity of electrons, gamma's				
arriving at chamber	none	none	17	51
at interaction in air	none	none	none	4

mined from the lateral spread referring to the event I, under assumption of constant p_T.

Distribution of p_T, fractional energy and rapidity of hadrons produced at interaction are given in Figs. 5, 6 and 7, which show that all the four events are of the same type, called Centauro. Interpretation is given as production of a fire-ball of rest energy ~ 200 GeV decaying into ~ 100 hadrons. Absence of neutral pi-meson indicates that pi-mesons are not significant numbers and the decay products are likely to be baryon pairs.

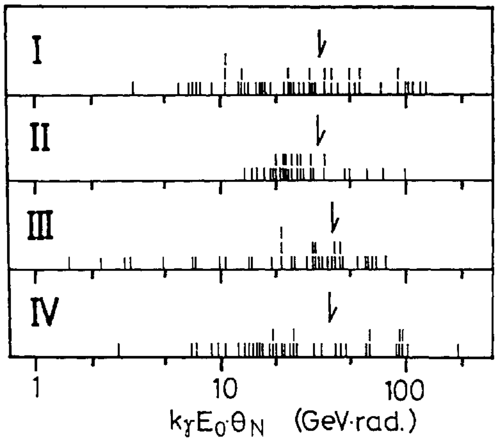

Fig. 7.

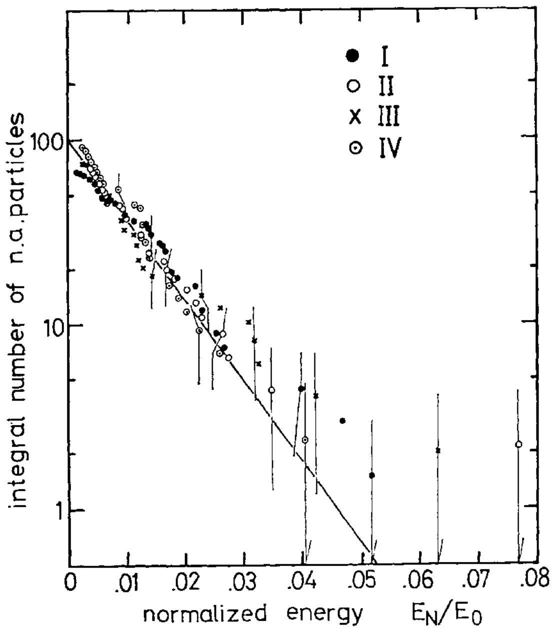

Fig. 5.

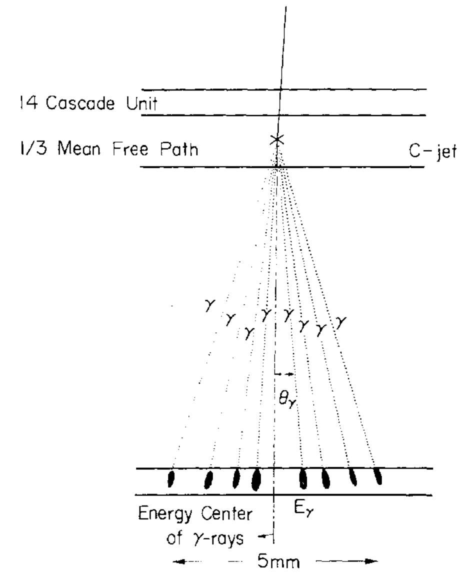

Fig. 8.

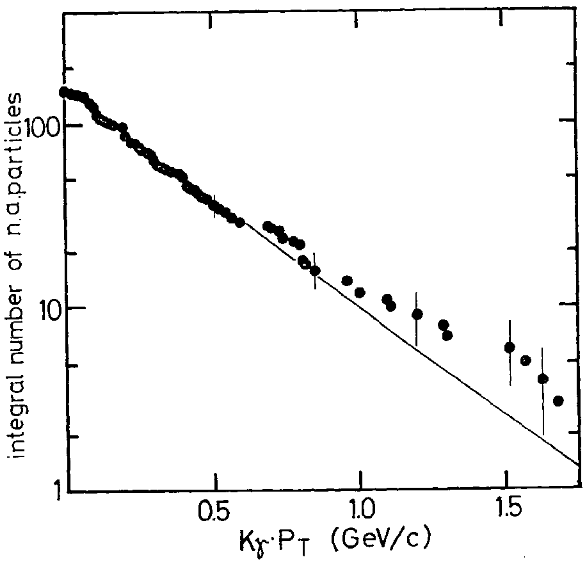

Fig. 6.

Centauro is one of typical nuclear interactions in energy range of $E_0 \sim 10^{15}$ eV. The study on interactions with $E_0 \sim 10^{14}$ eV is made through observation of C-jets, interactions in the target layer of 1/3 nuclear mean free path thick, as shown in Fig. 8. Figure 9 gives distribution of energy and emission angle of observed secondary gamma-rays in the C-jet events with $\Sigma E_\gamma \geqq 20$ TeV. Here we will present one diagram showing characteristics of those interactions. Figure 10 is the diagram of $\langle p_{T\gamma} \rangle$ and gamma-ray multiplicity per unit rapidity, n_γ, and each observed C-jet with $\Sigma E_\gamma \geqq 20$ TeV is represented by a dot. Nuclear interactions with energy of 10^{11}–10^{12} eV, which the accelerator experiments are observing, have $n_\gamma = 2 \sim 3$, and $p_{T\gamma} = 100 \sim 150$ MeV/c.

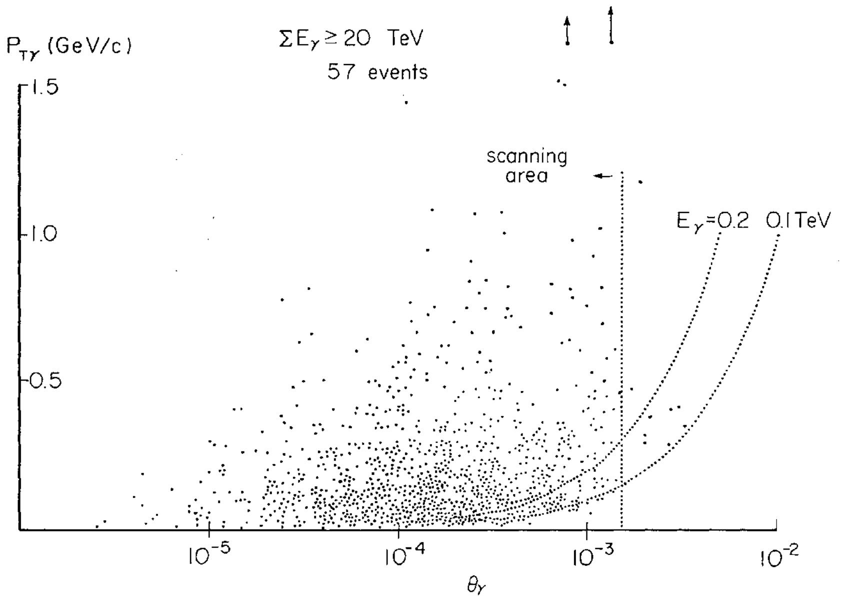

Fig. 9.

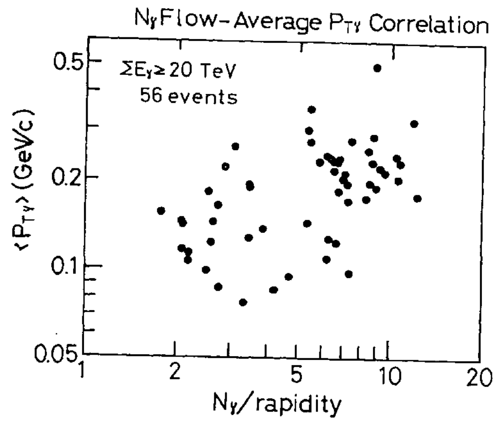

Fig. 10.

One sees a cluster of events with n_γ and $p_{T\gamma}$ consistent with the accelerator value, showing that the same type of events still exists in this 10^{14} eV range. There are seen another group of events which have significantly larger n_γ and $p_{T\gamma}$. Those are not observed in the accelerator experiments, and they appear now in this high energy region. We are calling the former as H-quantum type events and the latter as SH-quantum type.

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B 10 High Transverse Momenta in Collisions at Cosmic Ray Energies

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§1. Introduction

The first evidence of particles with high transverse momenta was obtained from observations on cosmic ray air shower cores.[1,2] The cosmic ray evidence up to 1975, is given in some detail in an issue of Physics Report in that year.[3]

§2. Observed Characteristics in Collisions Around 10^6 GeV

(a) Magnitude of p_t

In air shower cores values of p_t have been measured from "conventional" values around 0.5 GeV/c up to values as high as 120 GeV/