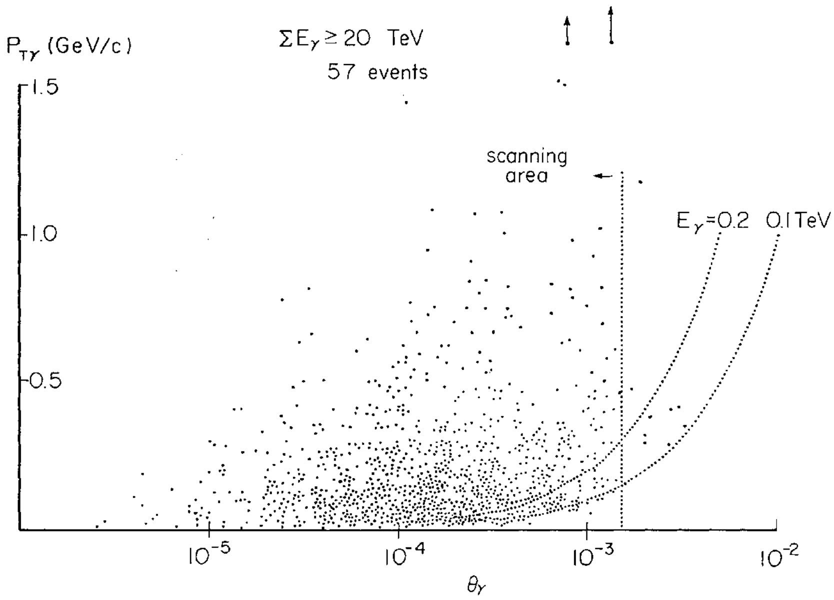

Fig. 9.

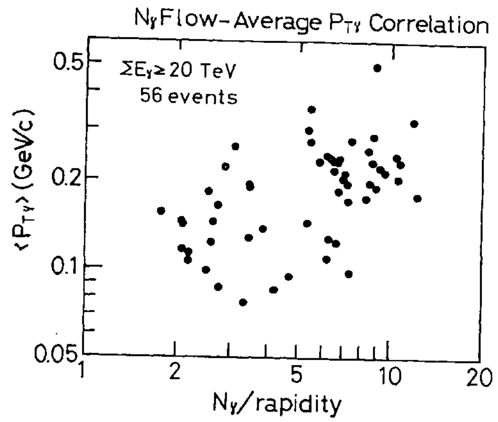

Fig. 10.

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/

c^4. At this conference the Konan–Kobe Group reports on a sub-core whose p_t is at least 40 GeV/c and probably >100 GeV/c^5.

(b) Cross section for production of high p_t

The showers observed are the results of complicated hadronic and electro-magnetic cascades through the atmosphere (vertical thickness= 1010 g/cm^2). There is some difficulty in estimating the total number of hadronic collisions occuring. But it can be estimated. Firstly the frequency of occurence of high p_t events have been determined by the Tokyo Air shower groups[6] who find that 3% of all showers of size $>10^5$ have sub cones with $p_t>2$ GeV/c. This figure is confirmed by the Sydney group[3]. Using the Sydney results, I have estimated that the fraction of collisions giving $p_t>2$ GeV/c, for energies between 10^5 and 10^7 GeV, lies between 0.17 and 0.012 (there two extremes come from two extreme assumptions concerning the nature of the primary particle incident in the atmosphere.) The coresponding fraction at the ISR (1500 GeV) is -6×10^{-4}. This considerable increase is at least qualitatively predicted by Q C D.[4]

(c) The p_t differential spectrum

The distribution of p_t in these high energy collisions is shown in Fig. 1.

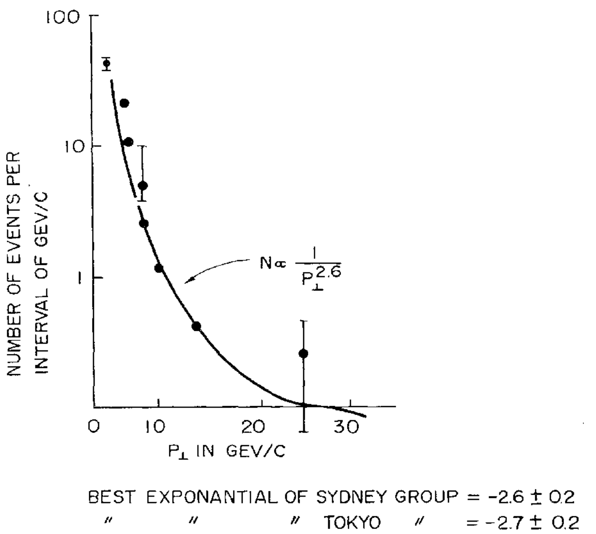

Fig. 1. This shows the number of showers per interval of p_t having a given p_t. The events were detected with the Sydney array. Details in ref. 3.

(d) The increase in cross section for high p_t in the range 10^5 to 10^8 GeV

Both the Sydney[3] and Leeds[8] groups find an increase in the fraction of air showers showing high p_t as the shower size (and hence, the primary energy) increases.

§3. Double Cored Showers

At shower sizes (sea level) of -10^5 particles we find that about 50% of all showers have an electron distribution function that shows a simple steep maximum and a radial fall of in electron density from that maximum (single cored showers). The remaining -50% are multicored showers with two or more maxima in the distribution. Two cored showers are sub-set of these. Such showers are observed both at sea level and mountain altitude. Examples are given in ref. 3. More recently the Japanese–Brasilian Emulsion group have observed examples of this type of shower in their Emulsion chambers at high mountain altitude ($\sim$500 g/cm^2 atmosphere depth). The core separation at these very high electron densities is generally only a few cm. However, some showers with separations up to 30 cm are seen (and correspondingly high p_t). Figure 2 shows a frequency distribution of these showers in the variable $\langle E\rangle\langle r\rangle$ where $\langle E\rangle$ is the mean energy in γ-rays in the two cores and $\langle r\rangle$ their mean distance from the centroid in cm. It seems possible that using this simple analysis one may be able to separate normal p_t showers rather sharply from high p_t showers and study the latter in detail. There may, for instance, be a correlation between the latter

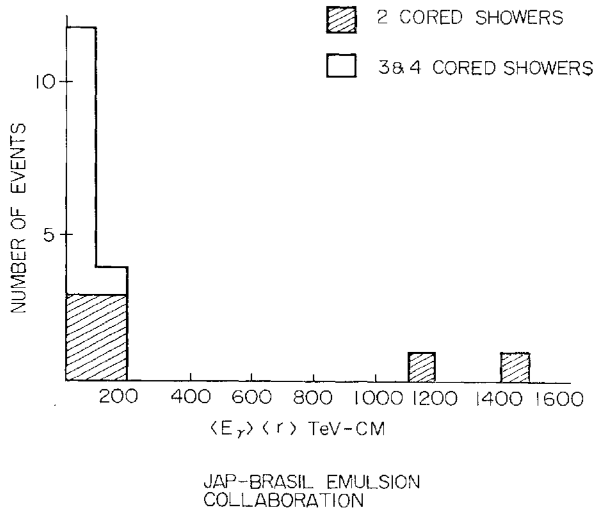

Fig. 2. A histogram of the number of double cored events with given $\langle E\rangle\langle r\rangle$ for the Japan-Brasilian Emulsion Collaboration experiments.

and 'Centauro' events.

§4. Rapid Development of Large Showers

A somewhat different (but possibly connected) phenomenon is the rapid loss of energy of very large cosmic ray air showers [$E_p \geq 10^{17}$ eV]. Figure 3 shows the development curves for showers of three different (muon) sizes as observed by the very large (60 km^2) Sydney air shower array. The curves give the change in the number of muons as the shower pass through it atmosphere. θ is the zenith angle of the shower axis. Hence sec $\theta=1$ means a shower at vertical incidence which at sea level was passed through 1010 g/cm^2 before reaching the detector. One can see that all the showers are declining in size from sec $\theta=1$ (*i.e.*, 1010 g/cm^2) to sec $\theta=1.8$ (*i.e.*, 1818 g/cm^2), *i.e.*, that even vertical showers are passed their maximum before they reach sea level. Monte Carlo simulations based on "ISR" reaction characteristics predict the opposite. It seems that even at very high energies new phenomena are occurring.

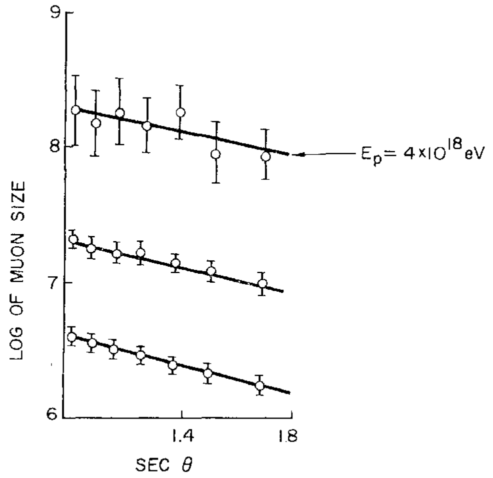

Fig. 3. Development curves for very large air showers. Each curves shows the change in the number of muons in showers of a given primary energy as the shower passes through the atmosphere. Details ref. 3.

Acknowledgement

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B 10 New Particles in Cosmic Ray Experiments

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Several years in advance the comencement of the 'charmed' age in high energy accelerator physics, a pioneering work on short-lived particle observation had been carried out in the cosmic ray field. In 1971, our group discovered one event[1] showing a pair creation of shortlived particles with life time around 10^{-13} sec and mass around 2 GeV, in the course of investigation of cosmic ray interactions. This particle was named by us as X particle. Es-