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III-7-12. A New Model for High Energy Nuclear Interaction

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Let us consider the hypothesis in which explosive production of mesons takes place through emission of a small number of the new quantum H[1,2]. The quantum H is supposed to convert into several mesons after the collision. Here, we show some typical example of clean jet shower recorded at Mt. Norikura.[3] Fig. 1 shows the angular distribution and energy spectrum of the jet shower, called "d-family". We notice very high energy π^0-meson, about $8 \cdot 10^{13}$ eV, appear in the very narrow angle, while other π^0-meson has smaller energy, about $* \cdot 10^{12}$eV. This could be considered as the fluctuation of the current two-fire-ball model. But, we would like to consider this situation as the basic characteristics of extreme high energy nuclear interaction, because we have several other evidence from Mt. Norikura experiment, for instance, general change of production spectrum of γ-rays from π^0-mesons,[4] as going to the higher energy.*

What is the situation of charged secondary particles? Fig. 2 and Fig. 3 show the angular distribution of typical jet showers collected by various laboratories.[5] We see very wide variety of the angular distribution. Then, we look for some kind of unit, which construct this wide variety of the angular distribution. Look at the event 0+6p of Bristol group.

One notices that all of shower particles group in a narrow region of the log tan θ plot, which suggests a strong correlation of the particles. Then, this grouping of shower particles found in 0+6p event will be identified as an example of the emission of one quantum H. Thus, one can find such grouping as that of 0+6p in almost all other events as in Fig. 2 and 3.

The general properties of this new quantum H is summarized briefly as follows.

Fig. 4 shows the distribution of number of shower particles in one quantum H collected from the data of various laboratories. The prong distribution of N-$\bar{N}$ annihilation event is also presented.

The angular distribution of shower parti-

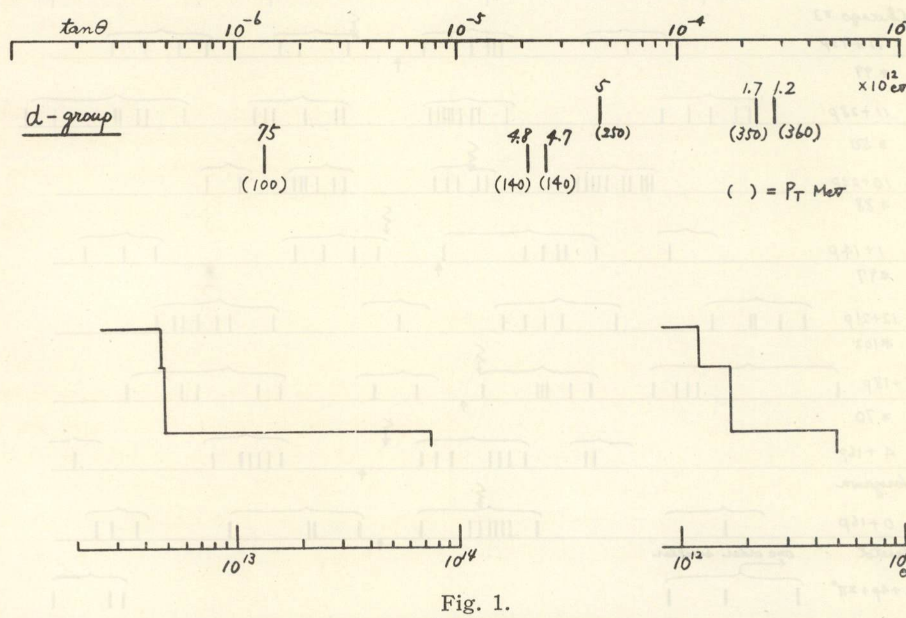

Fig. 1.

* Excited Baryon hypothesis is also proposed by the Japanese E.C.C. group of Mt. Norikura experiment.

cles in the rest system of the quantum H is investigated by the method of F-plot as in Fig. 5. The centre of the quantum is defined by $1/n_H \sum_i \log \tan \theta_i$. The angular distribution is not now isotropic, but rather, approximately, of the dipole type radiation, showing some polarization character of the emitted quantum H.

As well known, the transverse momentum of secondary pions of the jet shower is very

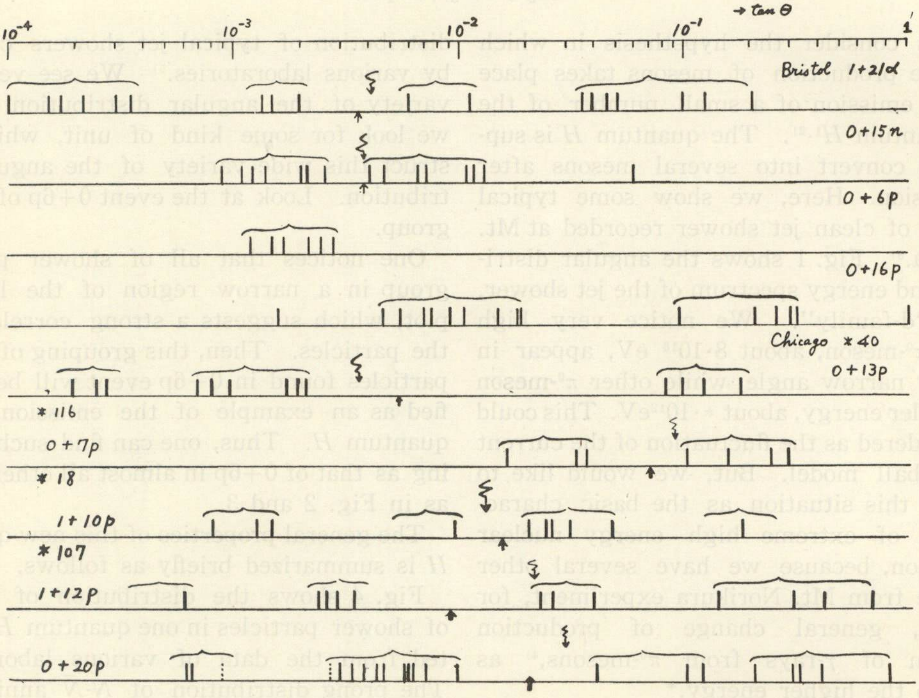

Fig. 2.

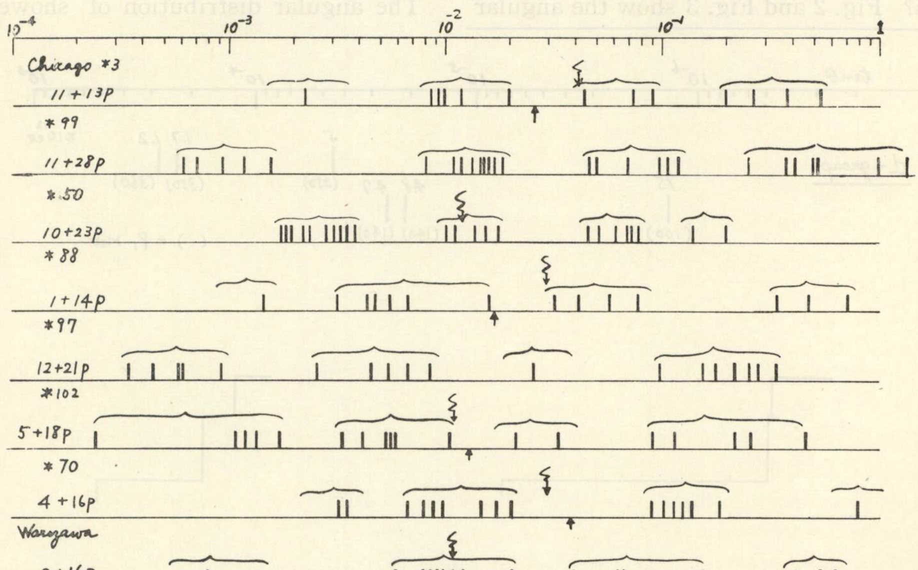

Fig. 3.

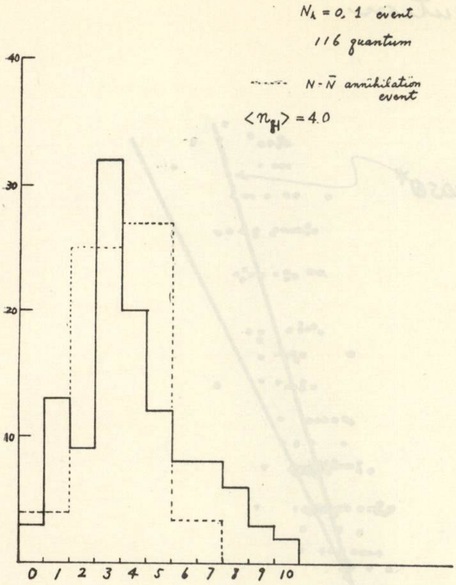

Fig. 4.

similar to the momentum spectrum of secondary pions from N-$\bar{N}$ annihilation event.

Thus, the following properties of the quantum H is found.

The properties of the quantum H is similar to the N-$\bar{N}$ annihilation event in various points. In fact, the mass of the quantum can be estimated as about $2Mc^2$, from the mean prong number of the quantum H and the mean transverse momentum of secondary K-meson, about 10% or so, it is better to say that the nature of new quantum H is something like that of the composite system of baryon and anti-baryon.

Next, we discuss briefly the mechanism of multiple meson production. As mentioned above, the basic characteristics of high energy nuclear collsion is not in the behavior of the individual pion or K-meson*, but in the production mechanism of our new quantum H.

First of all, Lorentz factor of quantum H in the high energy collision is important, because the internal energy of the new quantum H is definite, so the transferred energy at the high energy collision must appear in the form of Lorentz factor of the new quantum H. So the information of the details of the high energy interaction will come from the knowledge of this Lorentz factor. The symmetrical emission of the new quantum H in C.M.S. is observed in almost all cases of elementary processes, N_h=0, 1, within the experimental error of the angular distribution of jet showers. In the nucleus events, we see, in some cases, complicated emission of the new quantum H, and the large multiplicity.

The over-all distribuion of Lorentz factor of the quantum H is represented as, approximately, $1/\tilde{\gamma}_H$, $\tilde{\gamma}_H$ is the Lorentz factor of new quantum H in C. M. S. as shown in Fig. 6. The correlation of $\tilde{\gamma}_H$ to γ_c is represented in Fig. 7. So, if we go up to higher energy, we can expect the appearance of very high energy quantum H that can explain high energy secondary pion as observed in the experiment on Mt. Norikura.

The threshold energy for the production of this new qunatum H is estimated as about $\gamma_c \approx 5$. This correspond just to the point of change of normalized multiplicity observed by Kaneko and Okazaki.[6] Thus, the character of the nuclear interaction seems to change from this energy.

Finally, we ask, what is the role of this new quantum H for the nucleon physics? We remember that the nature of nucleus has been understood by introducing π-meson. If the nature of this new quantum H becomes clearer, we shall be, or rather, we hope to be able to solve the difficulty of pion physics, or in general, strongly interacting particle physics. This is because we may consider this new quantum H to be the matter constructing these strongly interacting particles.

* Momentum difference between initial and final state of colliding nucleon in C.M.S., $\Delta \bar{p}$, is order of, or large than 1 Bev/c irrespective of the model used, under the usual assumption on the transverse momentum of secondary pions.

References

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5) See ref. 1)
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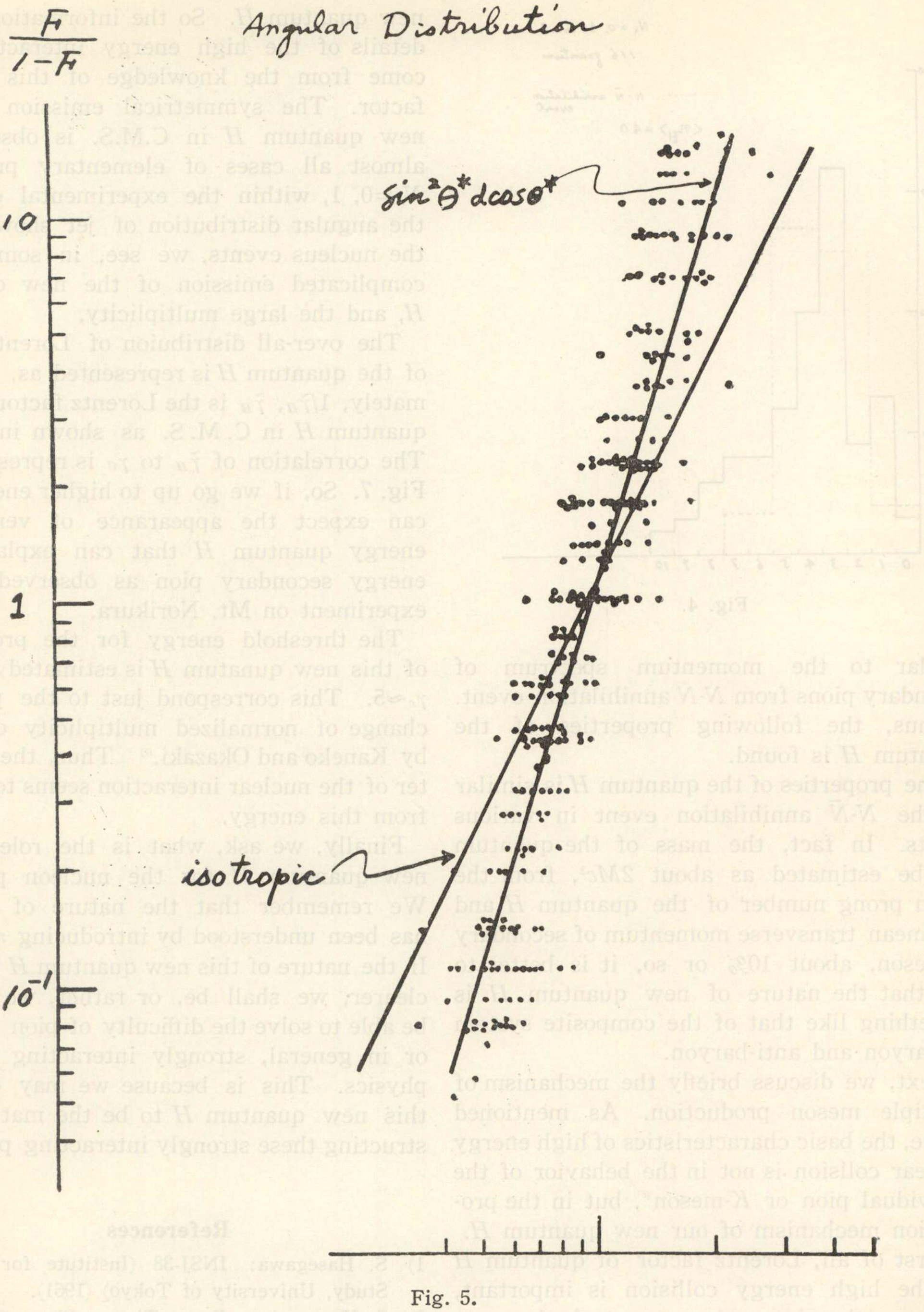

Fig. 5.

Discussion

Zatsepin, G.T.: Did you take into account, in rebuilding the angular distribution, the velocity distribution of π-mesons arising from one centre? If you did not take this into account, your distribution might be too steep. Also your method of combining particles into one "quantum" is a little arbitrary since it is quite possible that you may lose particles at big distances from the centre of the group. Again, this will cause the angular distribution to appear somewhat too steep.

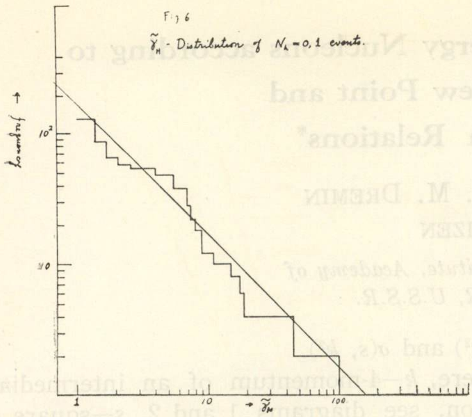

Fig. 6.

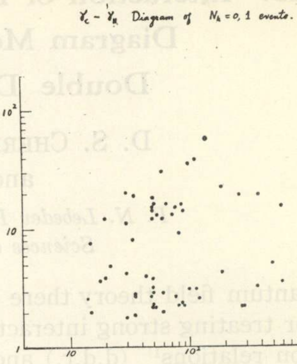

Fig. 7.

Hasegawa, S.: The effect of velocity distribution of secondary pions to the shape of angular distribution is large, as you say, as far as the velocity of the pions is not so large. But it is not so, in our case. Exact answer will come when the quanta H are collected more. The grouping of the particles into one quantum H seems to be a little arbitrary, but we have also to say that we have several, but not so many, typical examples which cannot be considered as mixing or missing of distant particles, and these typical examples of quantum H show the dipole type radiation, that is, narrow distribution within a factor $3\sim7$ in log tan θ plot, if the angular measurement of the data is correct. As for the typical example, we can point out such event as $0+6p$, $0+4p+2\pi^0$ of Bristol group and $*50$, $*99$, $*40$, and so on, of Chicago group shown in Fig. 2 and 3. The example shows that the angular distribution is too sharp to be considered isotropic.

Zhdanov, G.B.: I suppose that the statistics used is not sufficient to decide whether the shape of apparent angular distribution is connected with the true angular distribution or with the spread of particle velocities.

Hasegawa: It is true that the statistics is not enough to allow the final conclusion on the shape of angular distribution. It is urgently hoped to collect clean events more. (See discussion with Zatsepin.)

Miesowicz, M.: How do you collect the quantum H?

Hasegawa: At present we have not a definite way to collect the quantum H. But we have some typical examples which cannot be understood by the fluctuation from the current isotropic fire ball. (See discussion with Zatsepin.)

Taketani, M.: There are two types of phenomena, one is the type of, for example, "thermodynamics" in which the statistical fluctuation is smoothed out, and the other is the type of "Brownian motion" in which we can find the significant meaning in the fluctuation itself. We must look for also in the cosmic ray physics these two types of phenomena. Until now people usually paid attention to the first type of phenomena, but Dr. Hasegawa's work seems to belong to the second one. We, Japanese theoretical physicists, are now considering π-mesons, for example, not to be simple one, but very complicated things as is implied in Sakata's model. In this sense we must call attention to Dr. Hasegawa's work although I don't know whether it is true or not.