A New Model for the High Energy Nuclear Interaction

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The data on a large number of jet showers recently observed in nuclear emulsions and emulsion chambers have revealed the existence of a wide variety in the angular distribution and the energy spectrum of secondary particles.[1),2),3),4)] From an analysis of this wide variety of jet showers, one can find striking properties of the multiple meson production, which, consequently, suggest a new model which seems to indicate a fundamental feature of the elementary particles.

Fig. 1 illustrates several typical examples of the log-tan θ plots of the angular distributions of jet showers observed by the Bristol group[1)] and the Chicago group.[2),3)] Let us look for some kind of unit constituting the wide variety of the angular distribution observed. In the event $0+6p$ observed by the Bristol group, one notices that all shower particles are grouped in a narrow region of the log-tan θ plot; it suggests a strong correlation of secondary particles. Let us assume this grouping of secondary particles found in the event $0+6p$ as the typical example of the units which construct the angular distribution observed. Then, the distribution found in the other events in Fig. 1 is now interpreted as a composition of several groups of shower particles. More quantitatively, we define the unit according to the following criterion, a group of secondary particles distributing in a narrow region of about a factor of $3\sim5$ in the log-tan θ plot of the angular distribution. Fig. 1 shows identification of the unit made in this way.

On the basis of this grouping of secondary particles of the jet showers, various features of the unit are studied.* There is a close resemblance between the prong number distribution of the unit and of P-$\bar{P}$ annihilation events,[5)] though the unit has a slightly longer tail in the distribution. The angular distribution of the shower particles in the rest system of the unit shows roughly the dipole-type radiation, $\sin^2\theta^*\, d\cos\theta^*$ in the examination

* For the experimental data adopted for our analysis and the detailed results, see S. Hasegawa. INSJ No. 38. (1961) (Tokyo University).

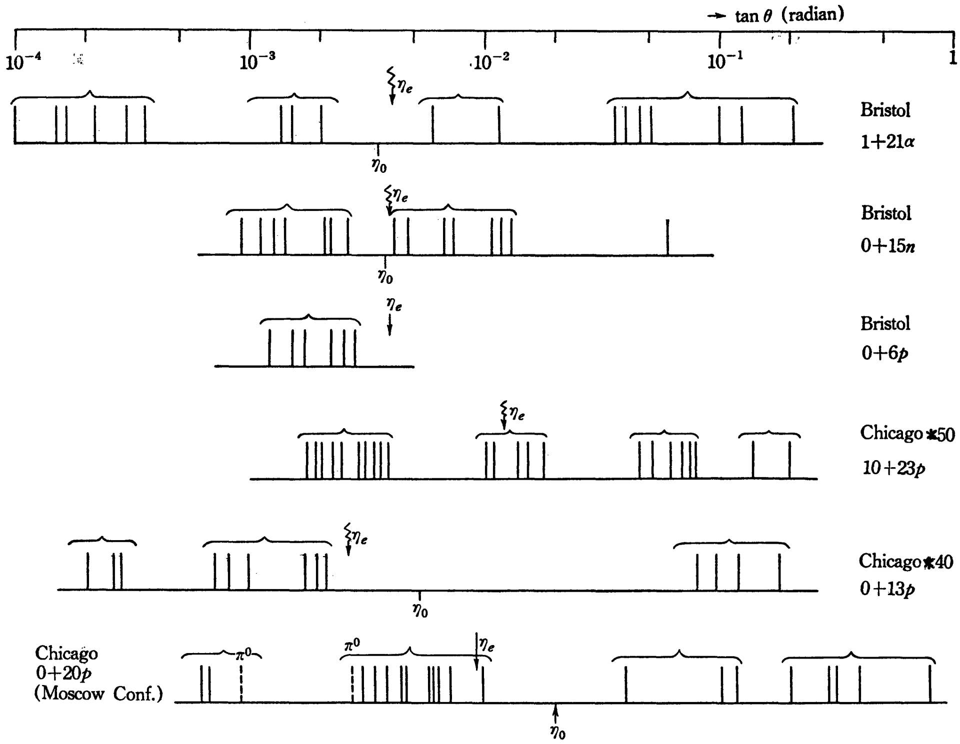

Fig. 1. Some interesting examples of the angular distribution which suggest the existence of the " quantum ".
η_e : Half angle determined with Castagonoli's method by each author.
η_0 : Determination of the half-angle from the hypothesis of the symmetrical emission of the " quantum ".

by the method of F-plot,[6] where θ^* is the angle in the rest system of the unit; this shows the polarization character of the unit with respect to the incident direction. One can also find that the distribution of the transverse momentum of secondary pions[7),8)] in jet showers is similar to the momentum spectrum of P-$\bar{P}$ annihilation events.[5)]

The above considerations suggest the " quantum " hypothesis of the unit in log-tan θ plot. An energy estimate for the mean internal energy of the " quantum " can be made by using the mean value of the transverse momentum observed, 0.3 Bev/c, and the mean prong number of a "quantum". The mean prong number in a " quantum " is found as 4.7. Correcting for missing π^0-mesons, we estimate that the mean number of emitted π-mesons from a "quantum" is about 6. Therefore, the mean internal energy of the " quantum " is about $2Mc^2$—M is the nucleon rest mass. Thus the "quantum" may be considered to be composed of a baryon and an anti-baryon. The experimental evidence that about 20% of the shower particles in jet showers are not pions[8)] shows that this baryon is not always a nucleon but sometimes a hyperon.

Thus, we can consider the following mechanism of the explosive meson production; at the moment of a violent collision of high energy, the emission of several polarized "quanta" takes place. This "quantum" can be identified as a composite of a fundamental baryon and an anti-baryon. Later the "quantum" will turn into several pions and possibly to *K*-mesons.

For the further study of the production mechanism of the "quantum" at a violent collision, one finds important information from the Lorentz factor of the "quantum". The symmetrical emission of "quanta" in forward and backward directions referring to the C.M. system is found for most of the experimental data. The overall distribution of Lorentz-factor of the "quantum" in the C.M. system, $\tilde{\gamma}_q$, is expressed approximately as $1/\tilde{\gamma}_q$.

This relation is consistent with our knowledge that the angular distribution of secondary particles averaged over all jet showers is $d\cos\tilde{\theta}/\sin\tilde{\theta}$,[8),9)] where $\tilde{\theta}$ is the emission angle in the C.M. system. The fine structure of the distribution of Lorentz-factor of the "quantum" will reveal some interesting unknown dynamics of the elementary particles.

Lastly, we examine the critical energy at which the emission of the polarized "quantum" takes place. A rough estimate shows that this critical energy is about $\gamma_c \sim 5$. We remember that the change of normalized multiplicity of secondary particles occurs at $\gamma_c \sim 8$, as studied by Kaneko and Okazaki.[10)] Detailed discussions of this new model will be published succesively.

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