of the internal motion of the particles?

**Nakamura:** In our scheme fermions are all described in terms of three kinds of 'charge spinors', and mesons are of 'charge vectors and scalars'. This enables us to resume that charge spins correspond to mechanical spins in the moving coordinates, which is a consequence of the rigid body models by Nakano and Fukutome.

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# III-7-3. Note on the Two-Centre of Jets

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One may try to describe inelastic nucleon-nucleon collisions in the high energy region-above 500 GeV-by a simple geometrical model on the basis of the two-centre conception,[1),2)] which in contrast to other workers assumes that angular momentum is conserved as orbital angular momentum. As in geometrical optics it is assumed that rays may be constructed according to the same laws that would be obeyed by particles in classical relativistic mechanics. To each ray a value "$b$" of impact parameter is attributed and predictions on the statistical distribution of observable quantities are derived from the equidistribution of $b^2$. This is a phenomenological model as no assumptions are made on the nature of what is called "centres" or "excited nucleons" here.

Conservation of energy and momentum requires:

$$m^2=\gamma^2\left(1-\frac{p'^2}{\gamma^2-(\Delta m)^2}\right) \qquad (1)$$

where $m$ is half of the sum of the rest masses of the excited nucleons, $\Delta m$ is half of the difference of the rest masses of them, $p'$ is the momentum of each of them in the CMS and $\gamma$ is the Lorentz factor of each of the colliding nucleons in the CMS. The velocity of light and the nucleon rest mass have been set equal to one. At inelastic collisions the impact parameter $b'$ after the collision is always greater than the impact parameter $b$ before the collision. Now, also a maximum value $a'$ is introduced for $b'$: $b\leq b'\leq a'$, which may be derived by Lorentz transformation from a length "$a$" defined by

$$\gamma^2(a'^2-b^2)=a^2-b^2\,. \qquad (2)$$

It is found then that there is a maximum value for the total rest masses in both centres, determined by

$$m=\frac{\gamma}{\sqrt{1+\xi^2(\gamma^2-1)}}\,, \qquad (3)$$

where $\xi=b/a$, According to this relation peripheral collisions are elastic. Completely inelastic collisions are possible only in the central region.

If maximum rest mass is transferred to the centres, the transverse momentum of each of them is found to be

$$P_t=\frac{\xi\gamma\sqrt{1-\xi^2}\,\sqrt{\gamma^2-1}}{1+\xi^2(\gamma^2-1)}\,. \qquad (4)$$

This model is not applicable if $P_t$ is comparable with the uncertainty of transverse momentum. This uncertainty, which is a consequence of the finite diameter of the nucleon, is about 1 GeV/$c$. Thus we must restrict our considerations to the region where $\xi$ is small. It is seen from the formula for $m$ that this is the region of high multiplicities of secondary particles.

We want to show now that some properties of inelastic nucleon-nucleon collisions may be described quite well by this simple model. This comparison is based on the maximum value for $m$ as given by (3). The mean total energy of a secondary particle in the rest system of a centre is considered as constant.

I. From (3) and (4) constancy of the mean transverse momentum of secondary particles is found in agreement with the observations of Nishimura[3] and many other authors.

II. If "$a$" is a constant independent of energy and impact parameter, the distribution of $\xi^2$-values should be the same in any sample of jets independent of the distribution of energies. And the distribution function should be found to be a straight line. This is confirmed by the following comparison:

From the papers of A. Barkow[5] and J. Gierula[6] we have taken all events with $\gamma > 23$, $N_h < 3$, $n_s > 11$. The distribution of $\xi^2$ for these events is shown in Fig. 1.

As may be seen from this diagram the distribution function may indeed be described quite well by a straight line.

In Fig. 2, a subsample is shown including 2/3 of all events only: 1/3 of all events with lowest energy and 1/3 of all events with highest energy.

Although the energy distribution is quite different in this sample the same distribution for $\xi^2$ is found. The same result was found for other subsamples with quite different energy distributions.

In Fig. 3, a $\gamma$-$n_s$ diagram is given including all events with $\gamma > 23$, $N_h < 3$. Between the lines $\xi^2 = \text{const.}$ equal numbers of events should be found. One finds 8, 12, 9.

Thus the differential cross section for particle production in the high energy, high multiplicity region, which according to this model is given by

$$\sigma(m)dm = 2\pi a^2 \frac{dm}{m^2} \qquad (5)$$

fits quite well into the experimental distribution.

Unfortunately the total number of events available in this region is still too small to apply a stringent test to this relation. It is hoped that soon much more primary cosmic

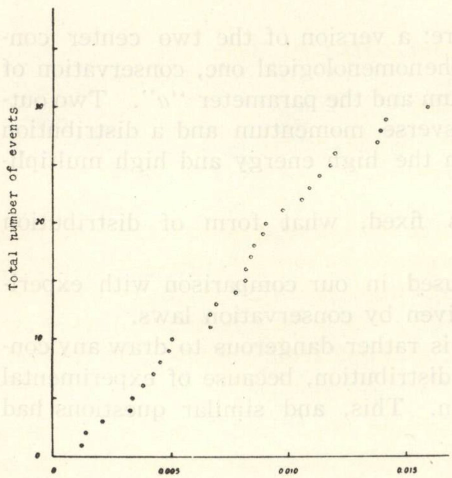


Fig. 1

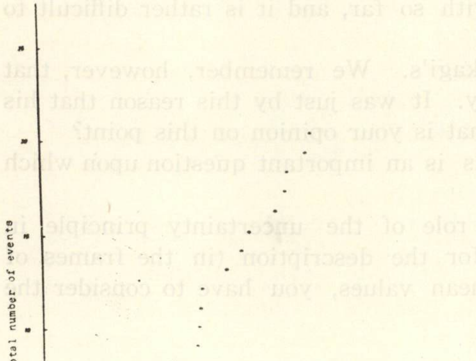


Fig. 2.

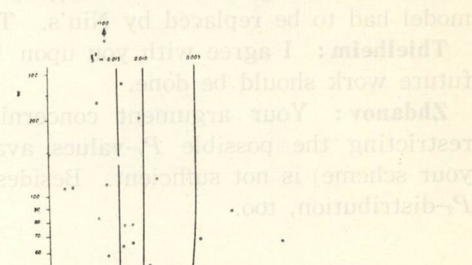

Fig. 3.

ray jets will have been observed. If this model is found then to give a good description of the observed distributions, it may be of heuristic value for the construction of a more comprehensive theory of jets.

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### *Discussion*

**Yamaguchi, Y.:** What are your inputs and outputs (the conclusions, which you would like to draw)? In particular, when you have talked about your results, are they in agreement with observation?

**Thielheim, K. O.:** The inputs in this model are: a version of the two center conception, which already makes this model a phenomenological one, conservation of energy, momentum and orbital angular momentum and the parameter "$a$". Two outputs of this model are: constancy of mean transverse momentum and a distribution function for multiplicities in the $\gamma$-$n_s$ diagram in the high energy and high multiplicity region.

**Yamaguchi:** When the impact parameter is fixed, what form of distribution has been used for the "mass" of a fire ball?

**Thielheim:** The value for $m=1/2\cdot(m_1+m_2)$ used in our comparison with experiments here is the maximum possible value as given by conservation laws.

**Miesowicz, M.:** I would like to stress that it is rather dangerous to draw any conclusions from the experimental $n_s$ frequency distribution, because of experimental biases which influence sharply this distribution. This, and similar questions had been discussed widely in "jet" sessions.

**Thielheim:** I agree with you.

**Zhdanov, G. B.:** If you make the comparison with the experiment for the multiplicity distribution and $P_T$-distribution in the same time, then I suppose you have also the possibility of comparison of the inelasticity coefficient $K$ with experiment.

**Thielheim:** This question was not dealt with so far, and it is rather difficult to derive a stringent condition on $K$ now.

**Ezawa, H.:** Your model is similar to Takagi's. We remember, however, that Takagi's model gave us a too large inelasticity. It was just by this reason that his model had to be replaced by Niu's. Then, what is your opinion on this point?

**Thielheim:** I agree with you upon that this is an important question upon which future work should be done.

**Zhdanov:** Your argument concerning the role of the uncertainty principle in restricting the possible $P_T$-values available for the description (in the frames of your scheme) is not sufficient. Besides the mean values, you have to consider the $P_T$-distribution, too.