the secondary charged particles with energy greater than 10^3 Bev; *i.e.* measure their energy from observations on the cascades which they produce with a precision of about 10%.

We shall begin with a paper by Prof. Miesowicz who will talk about the interpretation of some of the detailed features observed in the angular distribution of the secondary particles from nuclear collisions, and their interpretation in terms of the "two fire-ball" model of the interaction between nucleons.

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III-6-23. Recent Studies on the Fire Ball Model

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The coordinates $x=\log\tan\theta$ are now in general use in studying angular distribution of secondary particles generated in nuclear collisions of very high energy. These coordinates are very convenient because here the shape of angular distribution does not depend which system we use and therefore it does not depend on the energy estimation of the primary. In these coordinates the well known theories of multiple production, as Heisenberg or Landau theories, give more or less similar shape of angular distribution, approximately of Gaussian type. The standard deviation σ of the dN/dx distribution is now in general use as a measure of the anisotropy of the distribution in *CM*-system.

In 1956 we started to investigate systematically the problem of anisotropy of jets and we found that for energies higher than 10^{12} ev the shape of the angular distribution changes as compared with the normal distribution observed at lower energies.

Let us consider now only jets produced by singly charged or neutral primaries. We have observed for jets with small number of evaporation tracks and for energies higher than 10^{12} ev:

1. A very large spread of the anisotropy parameter σ of individual events. In our opinion the parameter σ of a given jet is a very important characteristics of the event. It depends not only on the primary energy, but is also connected with the type of collision which demonstrates itself by the shape of angular distribution of generated particles.

2. For high anisotropy and small multiplicity we have observed that the angular distribution dN/dx shows very often two maxima. We can say that there is a correlation of three characteristics of high energy jets:

$$\left.\begin{array}{l}\text{double maximum distribution}\\ \text{small multiplicity } (n_s)\\ \text{high anisotropy } (\sigma)\end{array}\right\}\text{are correlated.}$$

Events with typical 'two-maxima' distributions have well separated diffuse and narrow cones in laboratory system, so we were able in these cases to investigate the angular distributions in separate cones considered as separate jets.

For explaining these phenomena we suggested together with the Czechoslovakian Group (Dr. Pernegr)[1),3)] the two centre model in which the secondary particles are emitted from two centres moving in *CM*-system in opposite directions, roughly in the line of collision. We did not based on any theory but took the parameters of the model directly from the experiment. It had been in this way concluded that the emission in the system of the centre was isotropic, with energies of the secondaries in first approximation constant and independent on the primary energy. The last property corresponds to a constant value of transverse momentum observed in high energy collisions. Cocconi[2)] in his detailed analysis of this model introduced the name 'fire balls' for the emitting centres. Some months later Dr. Niu[4] published a proposal of a similar model, introducing additionally a new parameter to the model, the 'momentum of interaction'.

The two centre models of various forms had been proposed earlier by different authors in the time when the scarsity of experimental data for high energy jets did not allow to check these ideas experimentally. So far I know the first was Prof. Zatsepin. Recently this model has been discussed by many theoreticians, especially in this country. Several ideas have been suggested, the main point beeing the introduction of the nucleon structure into the problem of multiple production at these energies. But on the other hand the statistical significance of the experimental facts especially of the 'two maxima' distribution had been subject of discussion during the Moscow and Kiev conferences. Really very few people have worked experimentally in this subject. So, we found it necessary to perform a statistical analysis of the 'two maxima' distribution and to investigate the above mentioned correlations of this effect with other characteristics of jets. For this analysis we used all available data from our laboratory and from other laboratories.

I would like now to present some results of this analysis. It has been done in our laboratory by Gierula, Zielinski and myself[5] on 65 jets with $\gamma_c > 23$, what for symmetric *N-N* collisions corresponds to $E_p > 10^{12}$ ev. A

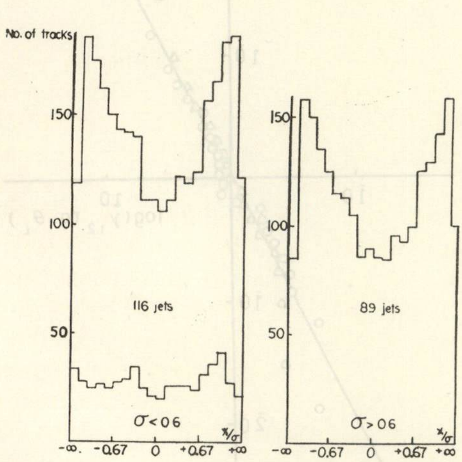

Fig. 1. Angular distribution of all jets from the analysis of the Polish group and of Chicago group. (See Ref. 7)

similar analysis on independent material of $\sim$50 jets has been done in Chicago by Gierula, Haskin and Lohrmann[6], so I shall show some results of our laboratory and some from both laboratories. Fig. 1[7] shows the main results for all the jets from both laboratories. We see here the composite angular distribution for 116 jets. As we are here interested only in the shape of the angular distribution we plot on the horizontal axis x/σ values normalizing in this way the angular distributions to $\sigma=1$. The intervals for x/σ values are so chosen that we expect in each interval the same number of tracks for normal distribution. It is represented in this type of diagram by horizontal straight line. We observe on the picture a very strong deviation of the observed distribution from the straight line. The deviation corresponds to about three standard dev.. In the left part of Fig. 1 we have indicated also the composite distribution for jets with small anisotropy ($\sigma < 0.6$). For small anisotropy we do not expect the 'two maxima' distribution according to two centre model with isotropic emission from two centres. The resulting anisotropy of a given jet in this model is a consequence of the movement of both centres in *CM*-system and depends on the Lorentz factor $\bar{\gamma}$ of the centre. We should expect the 'two maxima' distribution only for sufficient high $\bar{\gamma}$ values, that means for sufficient high anisotropy, roughly for $\sigma > 0.6$.

We are now going to present the experimental results concerning the correlation of the 'two maxima' distribution with other characteristics of jets. In this report I shall limit myself to jets with $N_h \leq 5$. Some problems of jets with high number of evaporation tracks and very high multiplicity I have presented in a paper of Gierula, Holynski and myself on one of the ordinary sessions. We consider now jets with $N_h \leq 5$ and $n_s < 20$. This group probably contains a considerable fraction of jets generated in collisions of primary nucleon with one of the nucleons of the target. The results for this group are shown in Fig. 2. We see on the first diagram all events with $N_h \leq 5$ for all n_s. The dashed line corresponds to events with $\sigma < 0.6$. On the diagram b) we collected only high anisotropy jets ($\sigma > 0.6$) and here the dashed line correspond to events with high multiplicity ($n_s>20$). The last diagram c) corresponds to $N_h\leq 5$ and $n_s<20$ in which we are interested now, with the condition $\sigma>0.6$. We have here very good evidence for two maxima distribution and its correlation with small multiplicity and high anisotropy. For comparison of the effect of multiplicity with an

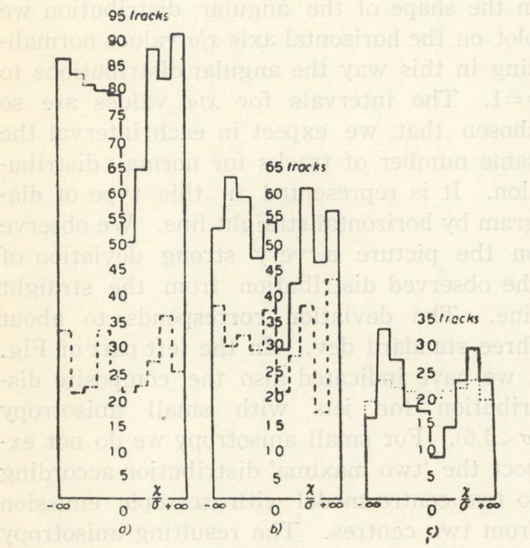

Fig. 2. Angular distributions for jets with $N_h\leq 5$ from the analysis of the Polish group. (see Ref. 5)

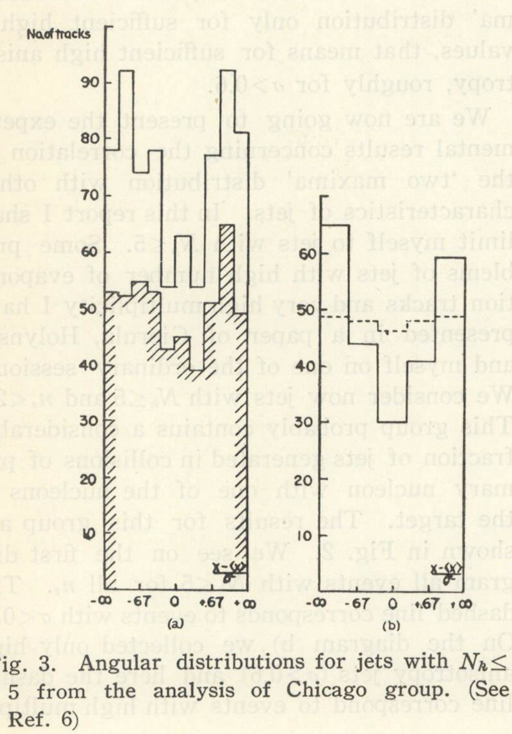

Fig. 3. Angular distributions for jets with $N_h\leq 5$ from the analysis of Chicago group. (See Ref. 6)

independent material, we show in Fig. 3 the results obtained in Chicago. In the diagram a) we see the composite distribution for all events with $N_h\leq 5$, and in the diagram b) events with $n_s<20$.

Of course by dividing the collection of our jets into groups with respect to anisotropy or multiplicity, we must take into account that this dividing of the collection might introduce some preference for 'two maxima' distribution. Although these correction is quite small it has been taken into account. We compared our experimental distribution in Fig. 2 c) and Fig. 3 b) not with a straight lines, but with the dashed lines indicated in these figures, where this corrections had been introduced.

Now I shall discuss the problem of isotropic emission from both centres. In our collection of jets in 1958 we could find only seven events proper for this analysis and we were not lucky to have new events of this type later. So I show in Fig. 4 our old result. But in Chicago analysis there are eight jets of this type. The total number of tracks in these events was 140. The results are:

Narrow cone: $\sigma=0.40\pm0.05$

Diffuse cone: $\sigma=0.43\pm0.05$.

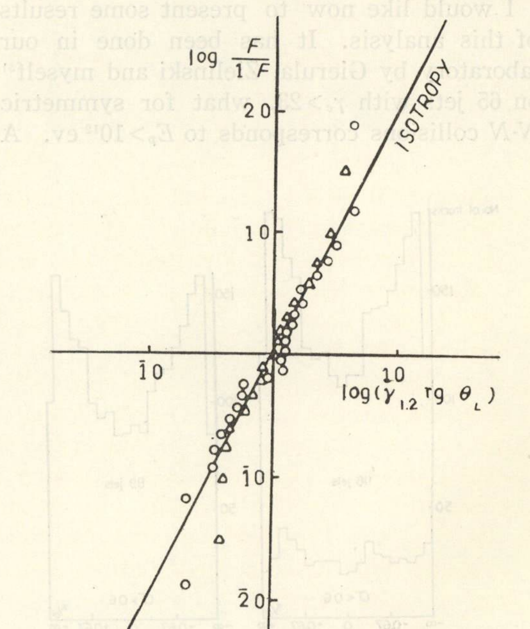

Fig. 4. Angular distributions in Duller-Walker plot for diffuse and narrow cones treated separately as independent jets. (See Ref. 1)

That is to compare with the value 0.39 for isotropy.

The last point which I would like to discuss very briefly concerns the correlation of inelasticity, transverse momentum and multiplicity. We can get information about the energy of particles in the system of the centre from the well known transverse momentum of secondaries. Estimating $\bar{\gamma}$ the Lorentz factor of the centre in *CM*-system for particular jet, we can estimate the energy bound in the centre and then the inelasticity K. The values obtained in this way are in reasonable agreement with K-values obtained for particular jets on other ways. In consequence of the small inelasticity the values of $\bar{\gamma}$ of the centres are considerably smaller than γ's of the nucleons after the collisions.

The question had been put many times, what fraction of the jets shows 'two-maxima' structure. Let we consider only jets with small number of evaporation tracks and small multiplicity. The 'two maxima' distribution appear practically in all cases for which the two centre model expects it, *i.e.* for jets with high anisotropy. But anisotropy is defined by $\bar{\gamma}$ and we experimentally do not know at present the unbiased frequency distribution of $\bar{\gamma}$ because high $\bar{\gamma}$ is correlated with small n_s. In the sample analysed in our laboratory about 1/2 of jets from the group $N_h \leq 5$ and $n_s < 20$ shows this type of the distribution. We shall now try to summarize these results.

1. Independently of any model the double maximum of the angular distribution of secondary particles is in our opinion a well established new feature of strongly anisotropic, high energy nuclear collisions.

2. The two centre model describes well the jets with $N_h \leq 5$ and $n_s < 20$, and the main arguments for the model are: 'two maxima' angular distribution, isotropy in separate cones and the correlation between n_s, $\bar{\gamma}$ and K (inelasticity).

3. The two centre model does not describe the group of jets with $N_h \leq 5$ and $n_s > 20$.

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Discussion

Menon, M. G. K.: In what fraction of an unbiassed sample of cases have you observed "double maxima"? Could you give the relative numbers of jets and the types looked at, the numbers with low multiplicity and the fraction of them which are anisotropic?

Miesowicz, M.: I can give the numbers from our own analysis. We analyzed altogether 65 jets. In these 65, I limited myself in this report only to this group of jets with $N_h \leq 5$. So we had 45 jets. From 45 jets we picked out 32 jets with $n_s < 20$. In these 32 jets we observed very good separation of group of tracks in half of all the jets, that means simply one half of jets has anisotropy higher than 0.6. Altogether we can say that, just as we said at the Moscow Conference, 20–30% of all jets show this behaviour. We see cases with very smaller anisotropy; we can say the isotropic cases with very high energy, for instance, Italian ICEF cases. They have some cases of this type and we have also these cases for which, of course, we can not expect double maxima distribution, and we can interpret this as the one fireball, for instance, like Prof. Dobrotin.