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CLUSTERS IN PERIPHERAL PROCESSES

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ABSTRACT

The main aim of this paper is to propose the criterion which gives the possibility to distinguish between the models with different mechanisms of cluster production. As an example we consider two multiperipheral models both of which fit the traditional distributions rather well even though they strongly differ in physical assumptions about the origin of clusters.

The newly proposed rapidity interval method helps to discriminate between them and to show that clusters are produced peripherally with rather large masses.

1. INTRODUCTION

Many models of multiple production have been proposed. To prove the vitality of any of them one should describe quantitatively a lot of experimental distributions. It means that the model should be well developed both from the theoretical point of view and for the computational purposes (i.e. the computer program should be elaborated).

Extensive investigation of the multiperipheral scheme [1,2] based on the Bethe-Salpeter equation has made it possible to compute [3] according to this scheme all distributions which could be obtained from many particle production experiment (it is briefly reviewed in [4]). Therefore the quantitative comparison of theory predictions with experimental data can be made.

Such a comparison confirms the previously derived conclusion [1] that particles are often created in inelastic processes via the intermediate stage of clusters' production. It is very difficult to reproduce in theory even such simplest experimental data as the multiplicity distribution if the clusterization of particles is not taken into account. The peripherally produced resonances give rise to the extremely narrow distribution with the low average multiplicity.

However, the theory does not propose the unique treatment of clusters. We have consider two versions of the multiperipheral scheme which strongly differ in the mechanism of production of clusters. Anticipating the conclusion we can say that both of them describe inclusive and semiinclusive one-particle distributions and two-particle correlations reasonably well but the rapidity interval distributions distinguish one from the other.

In the first version [2,4] clusters do not play any important role in peripheral processes but the single heavy non-peripheral cluster decaying according to hydrodynamical theory is produced. On the contrary, in the second version [5] all clusters are created in peripheral processes and no single non-peripheral cluster is formed. In spite of these remarkable physical differences both versions agree reasonably well with main experimental results for inelastic interactions of $\pi^- p$ at 40 GeV [5,8] and pp at 70 and 200 GeV [2,4,8] .

But the rapidity interval distributions (see [6] and references therein) differ appreciably in both the versions. They prefer the second version but show that it should be corrected to agree better with experiment. The role of clusters should increase in the developed scheme and their features should be slighly changed. We conclude that the rapidity interval method is very effective to study the clusterization phenomenon.

First, we describe and compare the two versions of the peripheral approach. Then we show in figures the quantitative agreement of both the versions with usual experimental distributions. Finally, we discuss the clusterization criteria and their indications for theoretical premises.

It is very simple in application and produces direct information about clusters. This method can be used to check any model of multiple production. We have used two multiperipheral models just as an example which reveals some of the possibilities of the rapidity interval method. It clearly exposes that any model, which pretends to describe experimental data, should fit not only traditional distributions but it should pass many correlation criteria to be convincing.

2. THEORETICAL MODELS

The multiperipheral scheme based on the Bethe-Salpeter equation [1,2,4] is aimed at describing all inelastic channels of reactions (i.e. the whole exclusive information) starting from the knowledge of elastic scattering and, first of all, of the energy behaviour of the total cross section which is connected to the elastic scattering amplitude by the optical theorem.

The approximate analytic solution of the multiperipheral equation helps to fix free adjustable parameters in the model. Eventually inealstic events are generated by a computer [3] and the various distributions are obtained in much the same way as it is usually done with bubble chamber data. A new method for Monte-Carlo calculation [3] is applied to multi-peripheral graphs with appropriate distribution of blobs' masses and enables us to consider properly all events (up to 16-charged particles ones). At present this is the only theoretical scheme which has been compared with all available experimental data for $\pi^- p$ at 40 GeV/c and for pp at E = 70 GeV/c and 200 GeV/c.

Fig. 1 shows the general structure of inelastic processes. All processes split up into the non-peripheral ones (the first term in the sum) at given energy and the peripheral ones which are described by the one-meson interactions of non-peripheral blobs at lower energies. The phenomenologically chosen non-peripheral processes are:

a) the $\pi\pi$ and πN resonances (similar to ones in ABFST-model [7]).

b) the elastic diffraction [x)]

c) the clusters.

The resonances and elastic diffraction are well known from experiment. The cluster can be described by different theoretical hypotheses. It is defined in the theory as a non-peripheral hadronic system having the mass beyond the prominent resonance region and decaying into more than two particles.

Many facets of the experimental data favour the clusters. Among them are the energy behaviour of average multiplicity, the multiplicity distribution, the two-particle correlations etc. (see [4]).

However, the theoretical definition of a cluster does not fix its properties completely. In particular, it does not say anything about its angular decay distribution. According to arguments stated in [9] we assume that a cluster is the

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[x)] Its parameters should coincide with that of shadow diffraction due to the inelastic processes under consideration.

statistical system which is described by Pomeranchuk' statistical theory at low masses ($M < 8$ Gev/c^2) and by Landau hydrodynamical theory at larger values of them. Such an assumption provides the scheme with the smallest possible numbdr of free adjustable parameters. In practice it means that at considered energies 40-200 GeV the inhomogeneous term of the equation (Fig. 1) is treated hydrodynamically and the clusters within the peripheral blobs are considered as statistical objects and decay isotropically.

The equation for the total cross section shown in Fig. 1 has a form:

$$\sigma(s) = \bar{\sigma}(s) + [\bar{\sigma}, \sigma] \tag{1}$$

where

$$[\bar{\sigma}, \sigma] = \frac{1}{16\pi^3 s \varkappa} \int \frac{dK^2 ds_1 ds_2}{(K^2+\mu^2)^2} \sqrt{(s_1+K^2-\mu^2)^2+4K^2\mu^2}\sqrt{(s_2+K^2-\mu^2)^2+4K^2\mu^2}\, \bar{\sigma}(s_1,K^2)\, \sigma(s_2,K^2)$$

s is a squared c.m.s. energy, μ is a mass of particles, K^2 is a squared four-momentum transferred, $\bar{\sigma}$ is a total cross section of non-peripheral processes.

This equation is well known from the early work in multiperipheralism [7] except for the coefficient $\varkappa$ which is usually equal to 1. One can try to take into account the rescattering effects considering the values of $\varkappa$ different from 1 (see in details in [5]). Our first version uses $\varkappa = 1$ but in the second version $\varkappa$ is equal to the ratio $(\sigma_{tot}/\sigma_{inel})^2 = 1.6$. We shall not go into the details (see

[5]) and want to stress another important feature which differ the versions one from the other.

The non-peripheral cross-section in the first version (the term $\bar{\sigma}$ in (1)) does not change appreciably at high energy and contributes about one third of the inelastic total cross section. But in the second version it is strongly suppressed for $\pi\pi$ and πN -processes and completely disappears from NN processes.

The off-mass-shell form-factors are also slightly changed.

All the modifications give rise to the physical consequences discussed above.

3. COMPARISON WITH EXPERIMENT

Most of the traditional inclusive and semiinclusive one-and two-particle distributions obtained for the two versions of the multiperipheral approach agree reasonably well with experiment. The agreement is slightly better for the second version but this difference is not decisive to choose it definitely.

The role of clusters is seen from Fig. 2 where the contributions of different graphs to the multiplicity distribution are shown. It is seen that the production of clusters contributes mostly to the high-multiplicity events. Peripheral resonances plus diffraction produce too narrow multiplicity distribution with the low average multiplicity. Let us note, however, that both the versions overestimate the low multiplicity events and should be slightly corrected. We shall get more decisive indications on it from the rapidity interval distributions.

To show weak dependence of other distributions on the model we compare semiinclusive rapidity distributions (Fig.3), the dependence of the average number of neutral pions on the number of negative pions (Fig. 4), semiinclusive distributions of the transverse momentum (Fig. 5).

It is impossible to discuss here all distributions compared with experimental data.

In general, about twenty distributions of such a type have been calculated for each of the processes: $\pi^- p$ at 40 GeV and pp at 70 and 200 GeV. The good agreement with experiment shows that the scheme is a workable and realistic one but one needs the refined correlation criteria to distinguish one version from the other.

4. THE CLUSTERIZATION CRITERION

In our opinion, the most effective way to distinguish cluster processes from the other ones is to use the rapidity interval method [6]. The rapidity intervals are defined in an n-prong event as the differences between the rapidities of any two particles

$$ {}^n r_k = y_{i+k} - y_i \quad , k = 0, 1 \dots n-2 \qquad (2) $$

containing the rapidities of some k particles in between. The distributions of the intervals with high enough values of n and k are very sensitive to the model proposed and, especially, to clusters' contribution.

The method permits the analytical consideration for simplest models to analyse qualitative effects and is easily applied in the multiperipheral scheme for quantitative comparison with experiment.

Fig. 6 shows strong shortage of clusters in the first version of the multiperipheral scheme and some shortage of them in the second version. It follows from the conclusions drawn from analytical treatment [6] which indicate that the maxima of rapidity interval distributions move to the lower values of intervals if the role of clusters increases.

The rapidity gap distribution (k=0) appears to be less sensitive to clusters than the distributions of intervals containing the large number of particles.

We conclude that clusters are produced peripherally with rather large masses (noticeably exceeding masses of resonances and larger than the average cluster size in the second version which is close to 3 GeV).

Although the second version does not differ strongly from experiment one can notice the irregularities in some theoretical distributions. At an energy 200 GeV (Fig. 6) the shoulders in distributions at large n and $k \geqslant 3$ are pronounced. The origin of them is known from the analysis of distributions produced by the definite graphs. They are initiated by the creation of two πN-clusters in a two-blob peripheral graph (Nova-type process [10]). It gives rise to the ptwo-bump-like structure of rapidity intervals (see Fig.8).

If this process exists one can separate it choosing the events with the slow secondary protons $|X_p| \leq 0.4$ (this condition diminishes the background due to peripherally produced resonances). The resulting distribution should show two-bump structure like the one shown in Fig.8.

The available preliminary experimental distributions do not possess any bump-like structure. Moreover, we failed to separate any bump-like contributions in them according to the above criteria.

Therefore, we conclude that the Nova-type process with two well separated clusters appears to be strongly suppressed.

5. CONCLUSION

Clustering phenomena in high-energy multiparticle final states were extensively studied for some years. There are three problems which should be solved,namely, the size of clusters, their origin (i.e. the mechanism of production) and their nature (in particular, the decay properties). One may argue [2,4, 11] that the clusters are noticeably larger than the commonly observed resonances. In this paper we tried to solve the next problem, namely, one of the origin of clusters. For this purpose, two models were considered. It was shown previously that both of them describe rather well the traditional characteristics of $\pi^- p$ -experiment at 40 GeV and pp at 70 and 200 GeV. But the models assume different origin of clusters. Using the newly proposed rapidity interval method we have been able to show that clusters should be produced peripherally with rather large masses. The results may provide a guide to more refined models.

We hope that the rapidity interval method may be useful for solving the problem of the nature of clusters, i.e. the question whether they can be described by the statistical approach, by the sequence of polyperipheral ladders or by gluonparton ideas.

FIGURE CAPTIONS

Fig. 1. The graph representation of equation (1) for total cross sections (A) and of its iteration solutions (B).

Fig. 2. The multiplicity distribution of charged particles at 70 GeV and its substructure according to the first version;

a) resonances + elastic diffraction + γ_s in the multiperipheral blobs, b) at least one of the blobs is a cluster (peripheral processes),

c) non-peripheral cluster, d) the total topological cross-section; e) only resonance production in multiperipheral blobs.

The total topological cross sections for the second version almost coincide with the ones given by the curve d).

Fig. 3. Inclusive and semiinclusive (4,6,8,10,12,14-prongs) rapidity distributions at 70 GeV.

A - the first version

B - the second version

Fig. 4. The dependence of the average number of neutral pions n_{π^0} on the number of negative pions n_- for the first version at 70 GeV (A) and for the second version at 40, 70, 200 GeV (B)

Fig. 5. Semiinclusive distributions of transverse momenta at 40 GeV according to the second version

Fig. 6. Rapidity interval distributions for two versions at 70 Gev ($n_{ch} = 10$)

Fig. 7. Rapidity interval distributions for the second version at 200 GeV (n_{ch} = 8)

Fig. 8. Rapidity interval distributions for different graphs at 200 GeV and n_{ch} = 10 (the second version)

a) a resonance + a cluster

b) a cluster + a cluster

c) two resonances + a cluster

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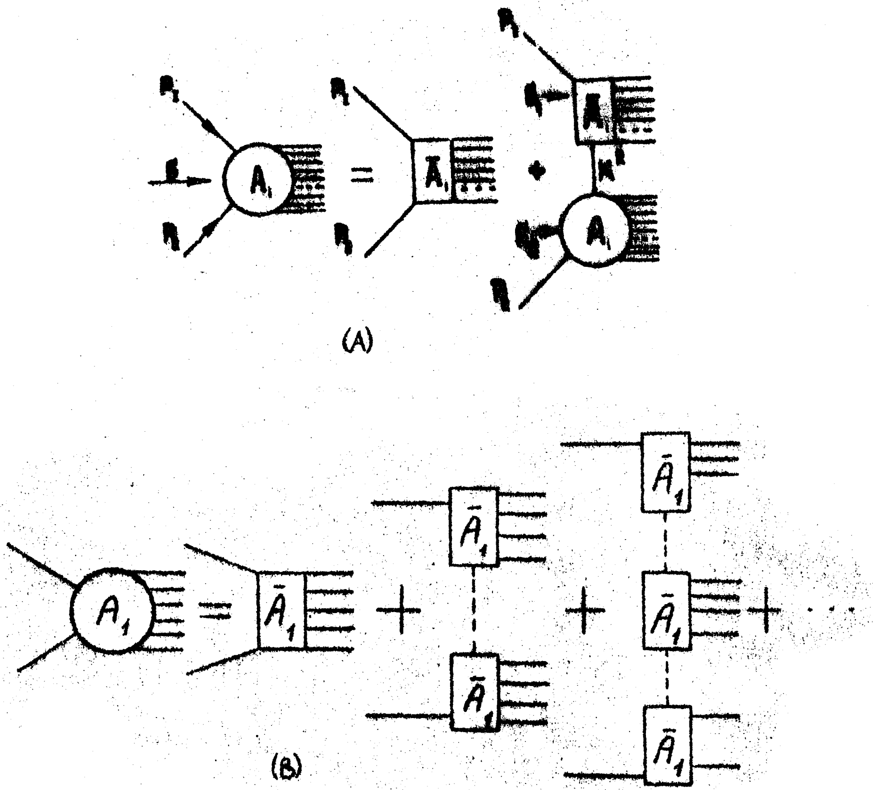


Fig. 1

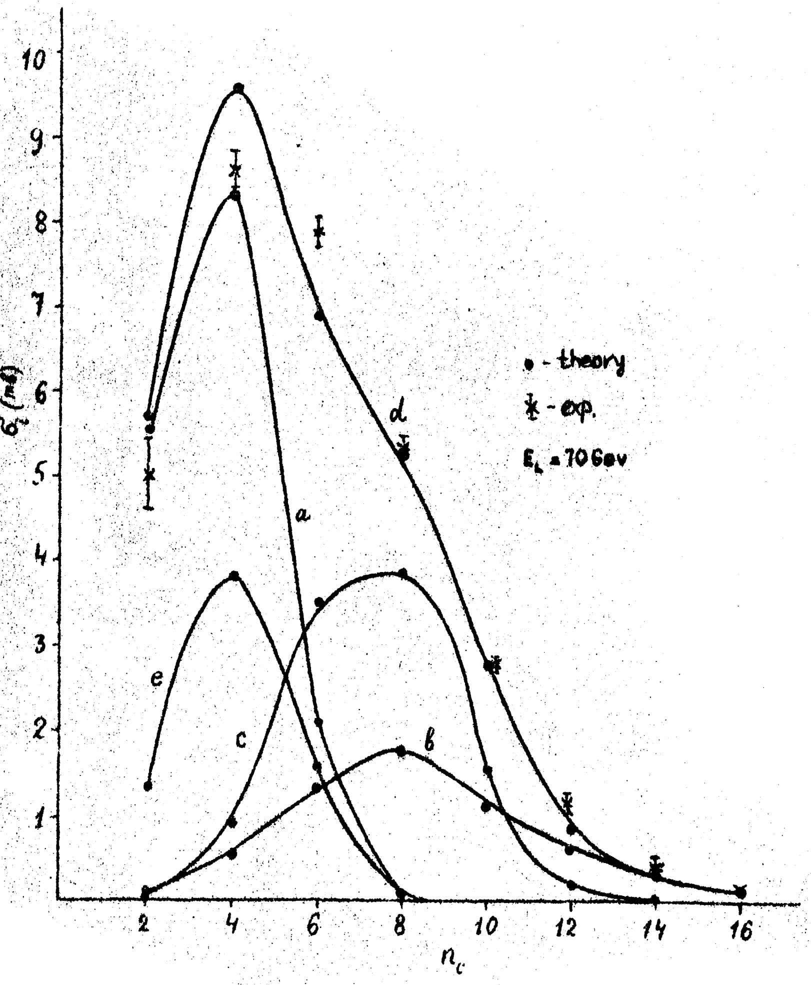

10
9
8
7
6
5
4
3
2
1
σ (mb)
2
4
6
8
10
12
14
16
n_c
a
b
c
d
e
• - theory
ǂ - exp.
E_L = 70 GeV

Fig. 2

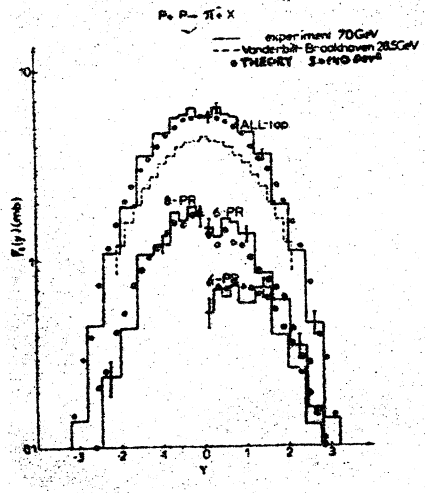

P + P → π + X
experiment 70GeV
Vanderbilt-Brookhaven 28.5GeV
THEORY
ALL-top
8-PR
6-PR
6-PR
Y

Fig. 3 (A)

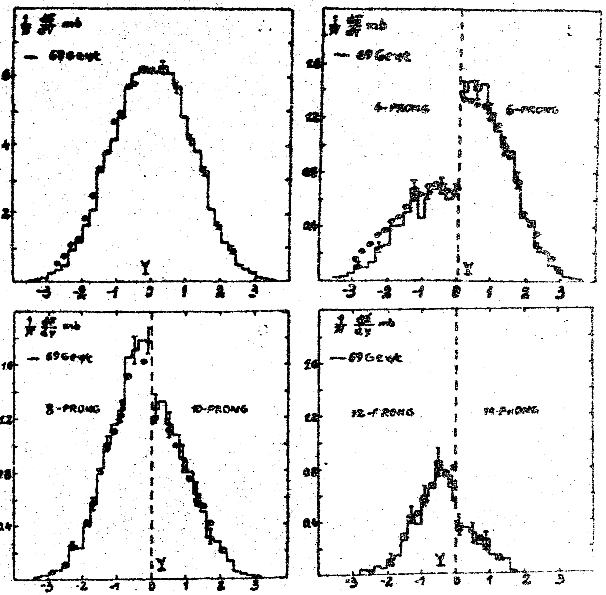
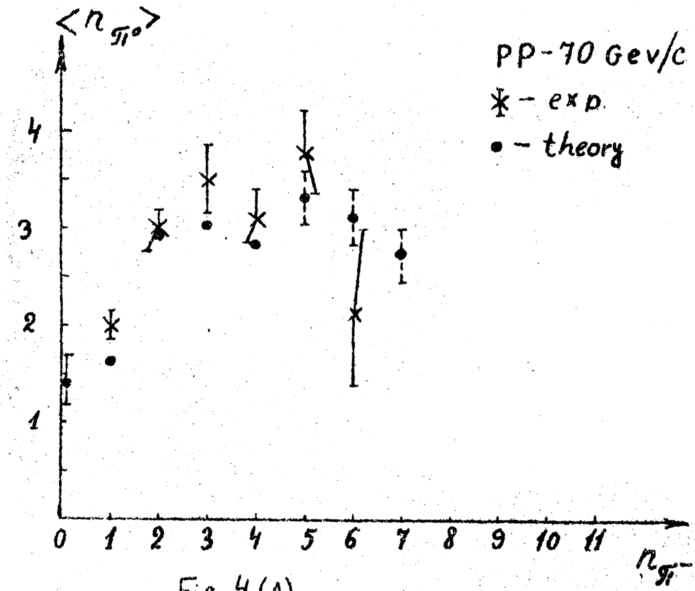
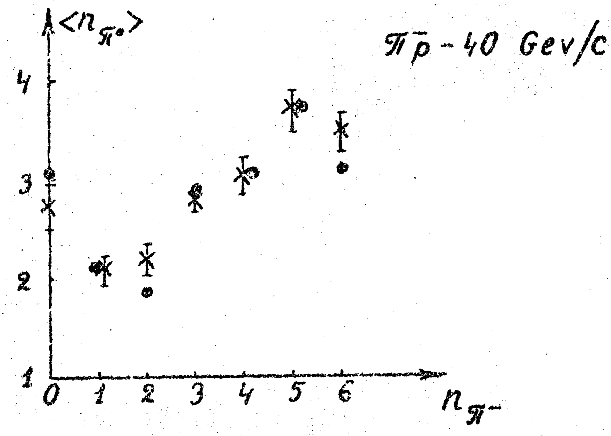

69 GeV/c
Y
6-PRONG
6-PRONG
8-PRONG
10-PRONG

Fig. 3 (B)



$\langle n_{\pi^0} \rangle$
PP - 70 Gev/c
- exp.
- theory
0 1 2 3 4 5 6 7 8 9 10 11
1 2 3 4
n_{π^-}

Fig. 4 (A)



$\langle n_{\pi^0} \rangle$
$\pi^- p$ - 40 Gev/c
0 1 2 3 4 5 6
1 2 3 4
n_{π^-}

Fig 4 (B)

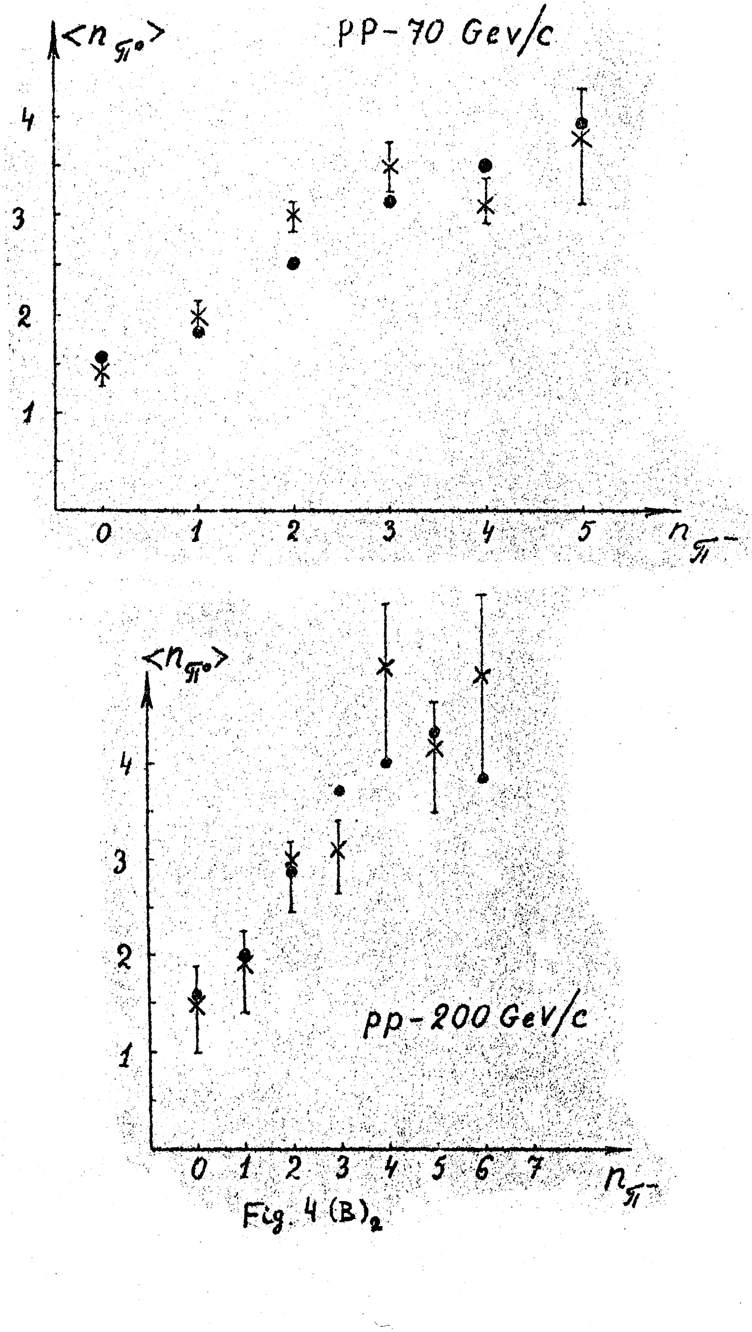

$\langle n_{\pi^0} \rangle$
PP- 70 Gev/c
4
3
2
1
0
1
2
3
4
5
n_{π^-}
$\langle n_{\pi^0} \rangle$
4
3
2
1
pp-200 GeV/c
0
1
2
3
4
5
6
7
n_{π^-}

Fig. 4 (B)$_2$

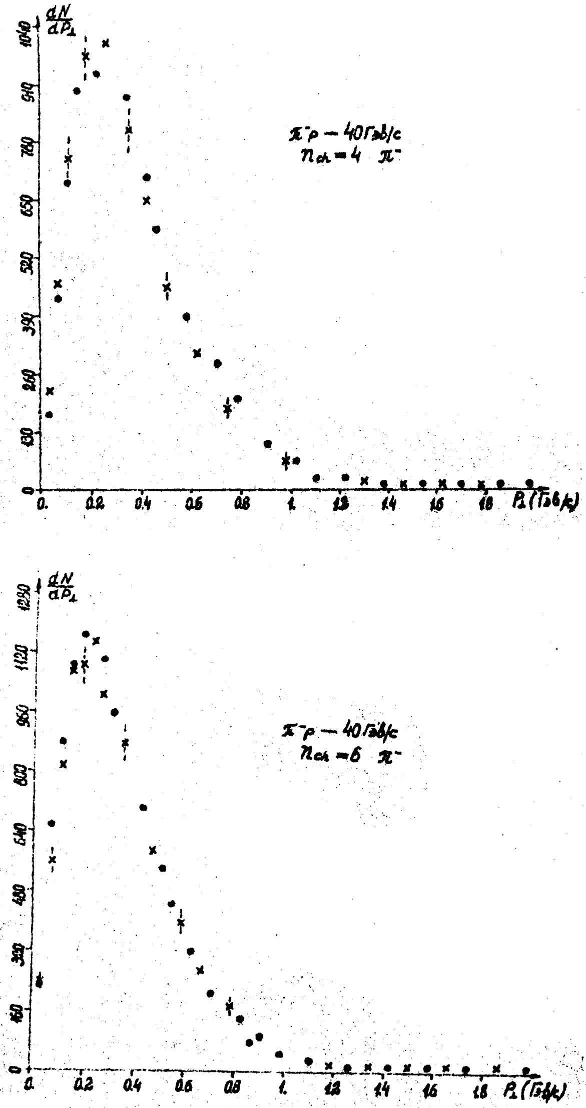


Fig. 5_1

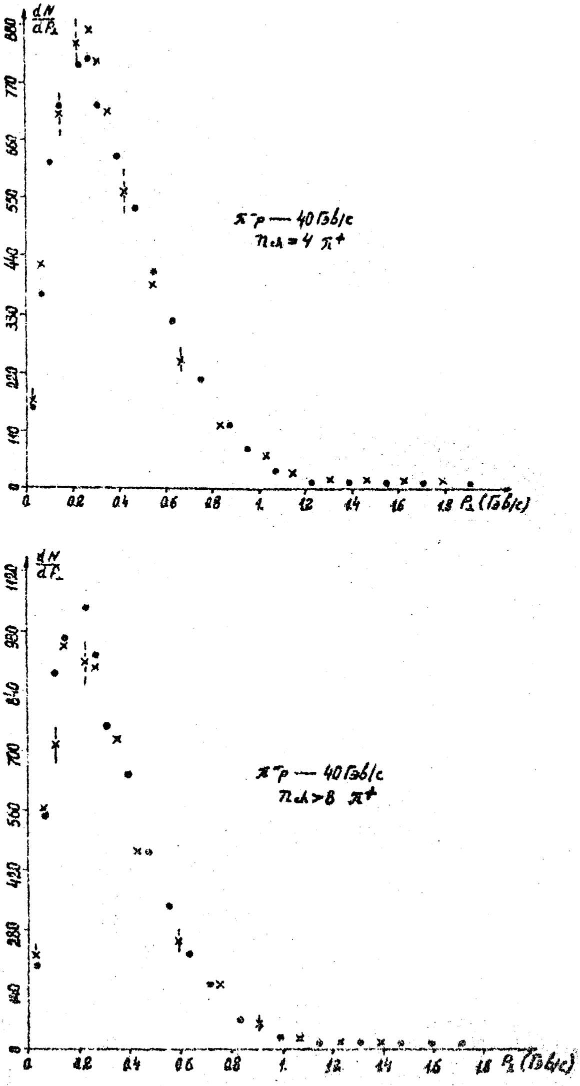

dN/dP⊥
880
770
660
550
440
330
220
110
0
0 0.2 0.4 0.6 0.8 1. 1.2 1.4 1.6 1.8
P⊥ (Гэв/с)
π⁻p — 40 Гэв/с
n_ch = 4 π⁺
dN/dP⊥
1120
980
840
700
560
420
280
140
0
0 0.2 0.4 0.6 0.8 1. 1.2 1.4 1.6 1.8
P⊥ (Гэв/с)
π⁻p — 40 Гэв/с
n_ch > 8 π⁺

Fig. 5_2

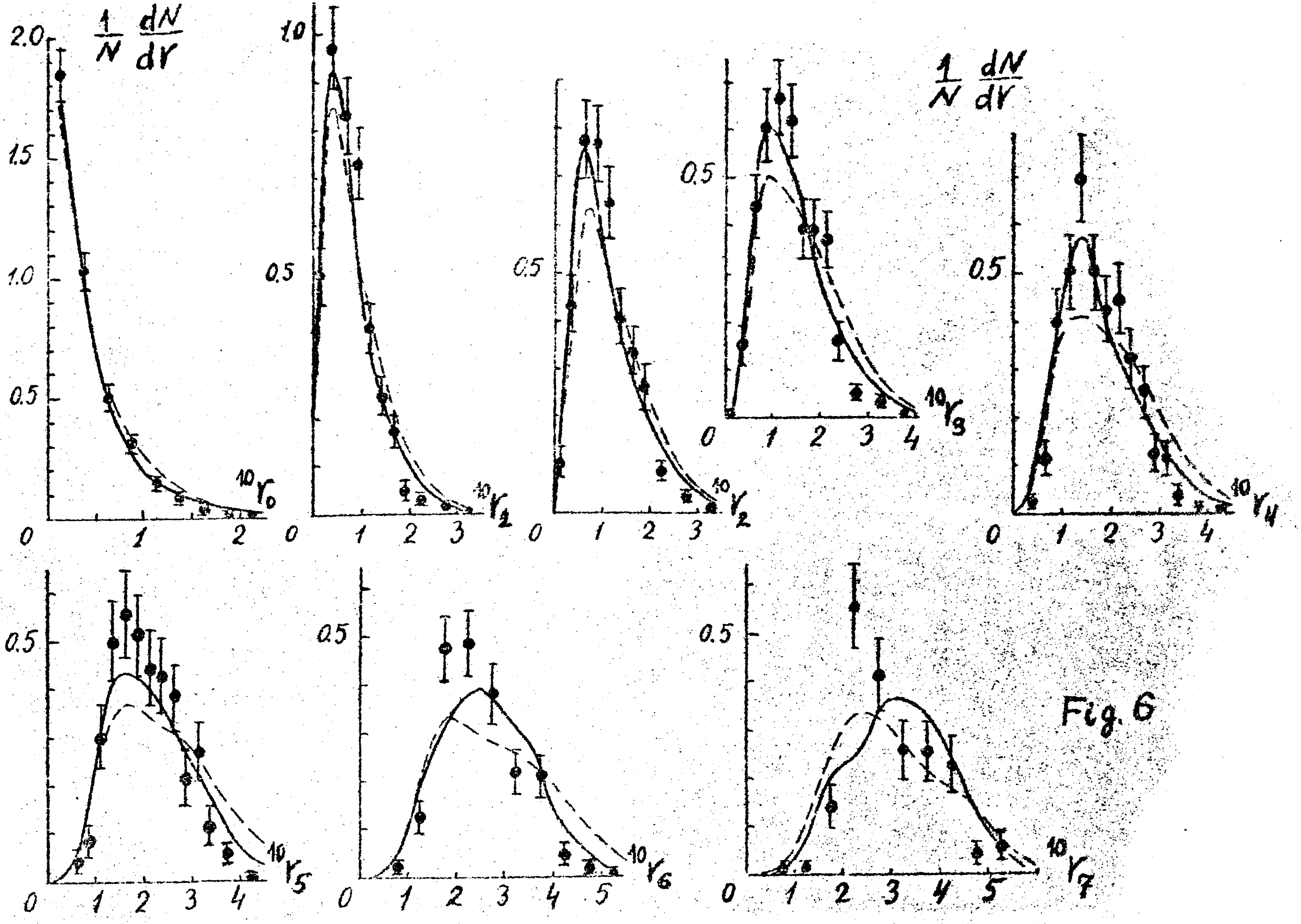


Fig. 6

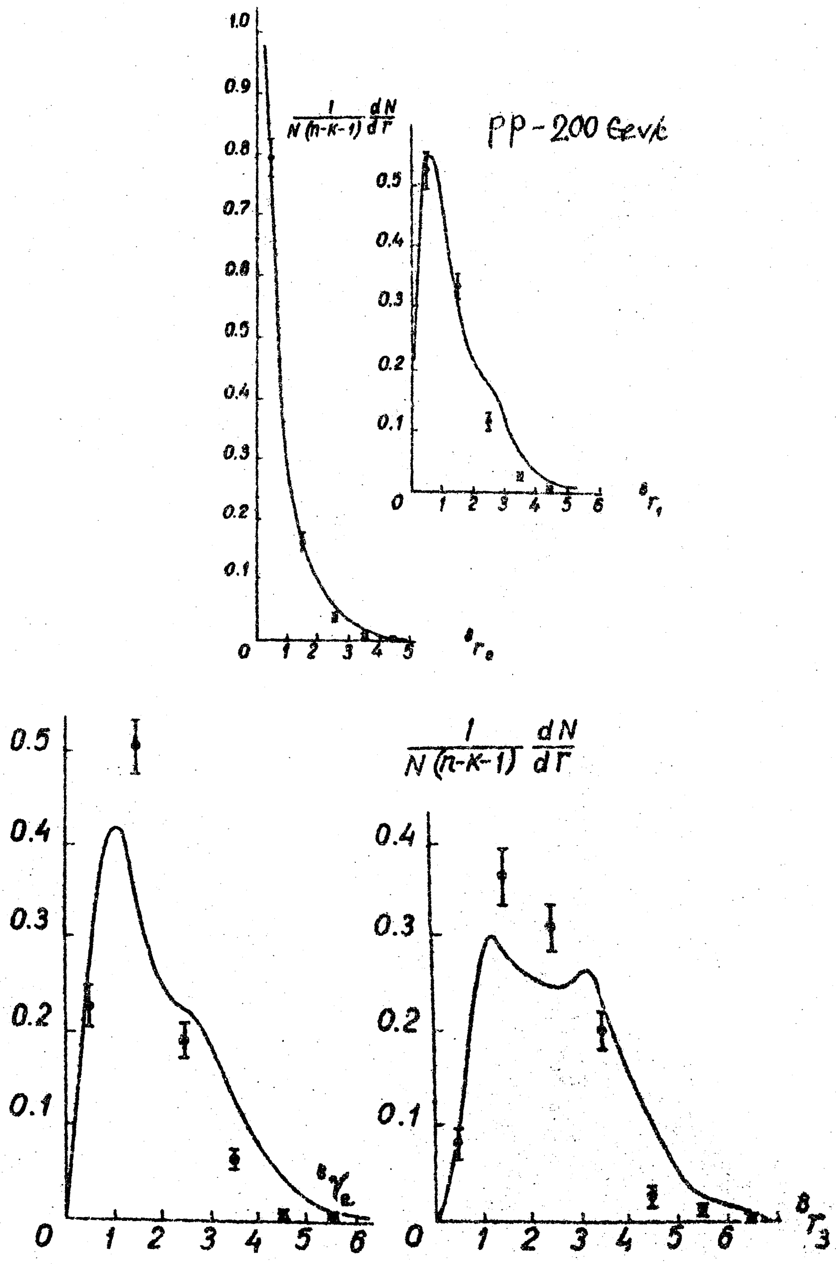
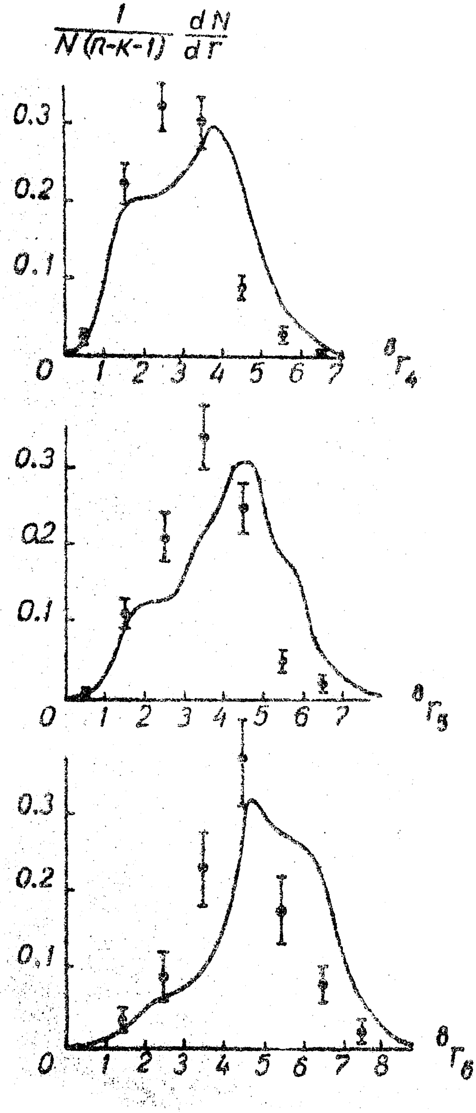

PP - 200 Gev/c
1/N(n-K-1) dN/dr
1/N(n-K-1) dN/dr
0
1
2
3
4
5
6
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Fig. 7_1



1/N(n-K-1) dN/dr
0.3
0.2
0.1
0
1 2 3 4 5 6 7
r_4
0.3
0.2
0.1
0
1 2 3 4 5 6 7
r_5
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8
r_6

Fig. 7_2

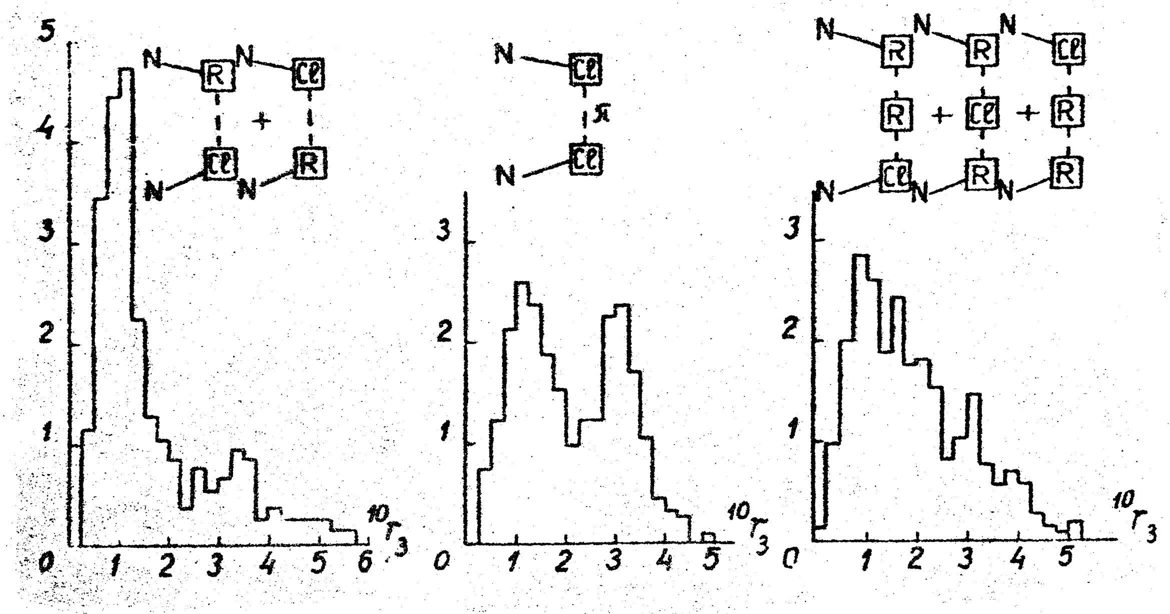


Fig. 8

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