ON MULTIPERIPHERAL MODELS

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A multiperipheral model, based on a quantum field theory approach (equations of the Bethe-Salpeter type) is discussed. Statistical processes are taken into account as an irreducible part of the Bethe-Salpeter equation. The fire-ball formation is obtained as a result of statistical processes of such a type.

Multiperipheral models are very close to the orthodox quantum field theory. The latter can explain some properties of the multiple production processes, but it is not able to give a full description of these processes. It is very important to separate the properties, which we can explain from those which cannot be explained from the point of view of the orthodox quantum field theory.

I would like to remind here the prayer quoted by Dale Carnegie (Dale Carnegie "*How to Stop Worrying and Start Living*") or rather to make a paraphrase of this prayer: "God, grant me

> the serenity to accept what I cannot change (or to give up what cannot be done);
> the courage to fight for what I can change (what can be done);
> the wisdom to distinguish between the two."

It seems to me that the multiperipheral theory offers these possibilities.

There are several various multiperipheral models; however, the differences between them decrease step by step. At present there is only one important difference. It concerns the existence (or non-existence) of the fire-balls (or clusters).

1. The general properties of multiperipheral models

The multiperipheral models are based on the diagram for the inelastic processes shown in Fig. 1. They correspond to the diagram for the imaginary part of the elastic scattering amplitude shown in Fig. 2. The vertices correspond to the emission of a single

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particle, or of a resonance, or to more complicated processes accompanied by the emission of many particles. The particles, exchanged in the process, can be pions, resonances, reggeons (in particular — Pomerons), and so on.

The general qualitative properties of the models are well known [1]. It is well known also that the multiperipheral models give the microscopic structure of the Pomeron, in

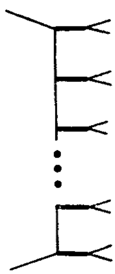

Fig. 1. Diagram defining multiperipheral model

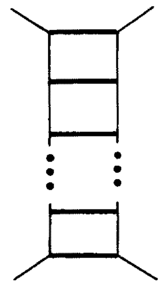

Fig. 2. Multiperipheral diagram for imaginary part of the elastic scattering amplitude

particular — the increase with energy of the interaction radius and of the transparence [2]. One can explain the physical meaning of this effect. Let us consider the target diagram, that is the plane, perpendicular to the collision line. The picture of the process in this plane has the form shown in Fig. 3. The average transverse component $K_\perp$ of the momentum (the transfer between the neighbouring vertices) is independent of the vertex

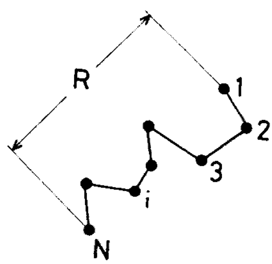

Fig. 3. The target diagram for the multiperipheral process

number and of the total energy s. The distances $r_\perp \sim 1/K_\perp$ have the same properties. The number of the vertices is proportional to ln s.

All directions of $\boldsymbol{K}_\perp$ (and $\boldsymbol{r}_\perp$) are equivalent. In this way we have a picture similar to that of the Brownian motion. In each vertex the secondary particles are emitted. These processes are going simultaneously, because the intervals are space-like.

The total radius $R_\perp$ is proportional to the square root of N: $R_\perp \sim \sqrt{N} \sim \sqrt{\ln s}$.

On the other hand, the width of the diffraction peak is proportional to the reciprocal of the radius squared, and — consequently — $b \sim R_\perp^{-2} \sim 1/\ln s$. It is also evident that the average density of the "matter" decreases with energy.

These characteristics of the multiperipheral processes are well known also in the Regge-pole approach.

2. *The apparatus of multiperipheral models*

Let us consider a homogeneous chain, consisting of the exchange of the identical particles of mass m (pions for example). One can write the equation of the Bethe-Salpeter type for the imaginary part of the amplitude A_1 at $t = 0$ (see Fig. 4):

$$A_1 = \bar{A}_1 + \frac{\varepsilon}{4\sqrt{|p|^2 s}} \int \bar{A}_1 A_1 D^2(k^2) ds_1 ds_2 dk^2. \tag{1}$$

Usually $p_1^2 = -m^2$. This equation is a direct consequence of the quantum field theory [3]. The term $\bar{A}_1$ is the irreducible part; it corresponds to diagrams without the two-particle intermediate state in the t-channel. The parameter $\varepsilon = 1/(2\pi)^3$ is much smaller than unity; this fact is very important.

In the t-channel the phase space has its natural form and ε is the natural normalizing factor. In the s-channel the phase space is transformed and it spreads out to large values of the dynamical variables. The "normal" region, where s_1, s_2, k^2 are of the order of m^2, corresponds to a very small fraction of this phase space. The appearance of such small numerical factors is a very interesting phenomenon in many problems of particle physics.

In the complex orbital momentum representation the equation (1) has the form

$$\varphi_l = \bar{\varphi}_l + \varepsilon \int \bar{\varphi}_l \varphi_l D^2(k^2)\,(k^2)^{l+1} dk^2 \,\frac{2^{2l-1}\Gamma(l+{}^3/_2)}{\Gamma(l+1)},$$

$$\varphi_l = \frac{2}{\pi(4pk)^l} \int A_1 Q_l(z) dz, \qquad z = \cos\theta_t = \frac{s+k^2+p^2}{4pk}. \tag{2}$$

By solving the equation (1) (or (2)) we get the amplitude A and its properties, namely: (1) The position of the poles in l-plane. (2) Their residua. (3) The slopes of the trajectories. (4) The properties of each of the iterations, that is the cross-sections of the processes with

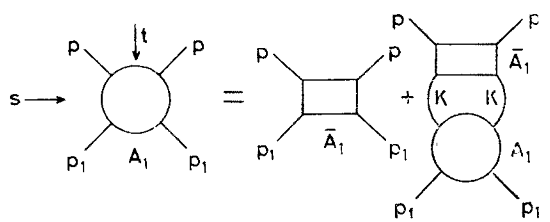

Fig. 4. Diagrammatic representation of Eq. (1)

a given number of the vertices. (5) If the characteristics of the inelastic processes are known, we can obtain a complete picture of the inelastic process. (6) If the value of $\bar{A}_1$ (or the value of $\bar{\varphi}_l$) is known for the t-channel, isospin $T = 1$, we get the corresponding values for the ϱ-trajectory.

If the chain is not homogeneous, then one can use two approaches:

One can calculate the properties of the inelastic processes directly (as it was done in CLA work [4], or in the paper of Levin and Ryskin [5]). Unfortunately, it is very difficult to obtain the analytical properties of the amplitude in this way.

One can use another method, let me call it "matroshka" (a Russian toy):

One can start from the equation (1), with pion exchange; one can write for $\bar{A}_1$ a similar equation with a ϱ meson exchange, and so on. Both methods can be used only if, in the final step, the irreducible part consists of the emission of a single particle (or a single resonance) only. It seems to me that there is no basis for optimistic expectations that the process is that simple. In the language of the Carnegie's prayer such an optimism is the result of the lack of "wisdom".

In reality there exist irreducible processes of the following type:

a) Interaction in the final state (see Fig. 5).

b) Interference processes (see Fig. 6). The relative contribution of these processes depends on the value of the momentum transfer, and increases for large k^2 (in particular, when the exchange of heavy particles takes place).

c) Many particle exchange, leading to a "statistical process". It is possible that the latter process is the result of the multiple interactions in the final state, that is — the process (c) can be considered as a result of the process (a) (see Fig. 7). Let me explain this.

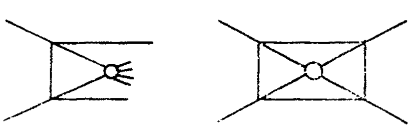

Fig. 5. Diagram representing interaction in the final state

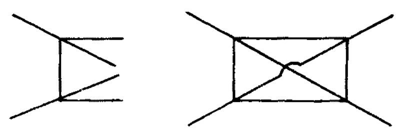

Fig. 6. Diagram representing interference processes

Let us assume that two resonances are created as a result of the peripheral interaction. Fig. 7 illustrates this process using the rapidity scale. The distance $\Delta y = |y_2 - y_3|$ is large. Consequently, the probability of interaction between particles 2 and 3 is small. (The probability of interaction between particles 3 and 4, or 1 and 2 is large because $|y_1 - y_2|$ and

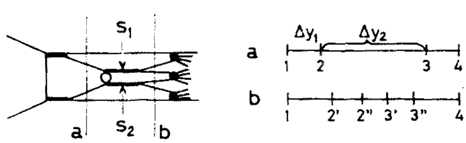

Fig. 7. Diagrams representing "statistical process"

$|y_3 - y_4|$ are small; however this interaction does not lead to an increase of the multiplicity, because the energy values s_1 and s_2 are low.) If nevertheless particles 3 and 4 interact then there appear two new resonances and the corresponding picture is such as shown on Fig. 7b. In this case all distances Δy have the values more close to each other than in the first case. This leads to an increase of the probability of interaction between particles belonging to various vertices. Besides, the interaction between particles which earlier belonged to one vertex, may now lead to the generation of new particles. This leads again to a further decrease of distances Δy and to an increase of the probability of the next interaction. It can be expected [6] that the process is dynamically instable, and, consequently, leads to a statistical object [7]. We are dealing now with a trigger-like process: if a first interaction in the final state does not take place then the process is a peripheral one. If, on the other hand, a first interaction occurs, then the process develops as a chain-like reaction, resulting in a statistical system [8].

3. The quantitative multiperipheral model

At present, in the Lebedev Physical Institute at Moscow, we try to undertake the quantitative work on this program [9][1].

The irreducible part of the $\pi\pi$ interaction consists of the following terms:

$$\bar{A} = \bar{A}_{\text{res}} + \bar{A}_{\text{diff}} + \bar{A}_{\text{c}}$$

or — in terms of the cross-sections ($\bar{A} = \sqrt{|2\boldsymbol{p}|^2 s\,\bar{\sigma}}$):

$$\bar{\sigma} = \bar{\sigma}_{\text{res}} + \bar{\sigma}_{\text{diff}} + \bar{\sigma}_{\text{c}}, \tag{3}$$

where $\bar{\sigma}_{\text{res}}$ = the cross-section for the resonance interaction, $\bar{\sigma}_{\text{diff}}$ = the diffractive interaction, $\bar{\sigma}_{\text{c}}$ = the so-called "central" interaction due to the many particle exchange (beyond the resonant peaks).

We choose the following form of the last term:

$$\bar{\sigma}_{\text{c}} = a\left(1 - \frac{z}{z_f}\right) F(k^2) F(p^2) \left(\frac{z}{z_0}\right)^{\bar{l}-1}. \tag{4}$$

In order to describe the dependence of $\bar{\sigma}_{\text{c}}$ on k^2 and p^2, we assume that the process is similar to a deep inelastic electromagnetic process, and we use the formula:

$$F(k^2) = \frac{\Delta}{\Delta + k^2} \cdot \frac{1}{1 + \beta k^2},$$

$$\Delta = 0.3\ \text{GeV}^2;\ \beta = 0.035\ \text{GeV}^{-2};\ \beta k^2 = \sigma_s/\sigma_t.$$

This formula was found as the result of a fitting procedure of the Bjorken scaling rule to the experimental data on the deep inelastic electromagnetic processes [11].

In this way we obtain values of free parameters given in Table I.

TABLE I

$a^{\pi\pi}$	The "cross-sections" of	4 mb
$a^{\pi N}$	the "central"	8 mb
a^{NN}	interactions	10 mb
$s_f^{\pi\pi}$	The threshold parameters	1.6 GeV^2
$s_f^{\pi N}$	of the "central" interactions (the "end" of the resonance region)	6 GeV^2
$\bar{l}$	The pole position of the "central" interactions	0.97
Δ_{res}	The parameters in the form factors of the resonance	1.5 GeV^2
Δ_{γ_5}	interactions and pseudoscalar-vertex	0.18 GeV^2

[1] The low-prong events were successfully described quantitatively by a multiperipheral scheme (without the term $\bar{A}_{\text{c}}$) developed in [10].

In order to determine them we used the experimental data on the elastic scattering and energy dependence of the total cross-sections of πN and NN interactions. More exactly, we used the two-pole parametrization of the amplitude [12, 13]:

$$A = \sigma_\infty \left[2 \left(\frac{s}{2M^2} \right)^{\alpha_P + \gamma_P t} \exp \varrho_P t + \sqrt{2}\, r \left(\frac{s}{2M^2} \right)^{\alpha_{P'} + \gamma_{P'} t} \exp \varrho_{P'} t \right], \tag{6}$$

where M is the nucleon mass.

For $t = 0$ it corresponds to:

$$\sigma = \sigma_\infty (1 + r/\sqrt{s}).$$

In Table II there are given the "experimental" values of the parameters (the result of fitting (6) to the experimental data).

TABLE II

			"Exper"	"Basic" (input)	"Calculated"
1	α_P	— the pole position of the Pomeron	1	1	
2	γ_P	— the slope of the Pomeron	0.2 GeV^{-2}	0.5	0.15 GeV^{-2}
3	$\alpha_{P'}$	— the pole position of the P′	0.5	0.5	
4	$\gamma_{P'}$	— its slope	0.5–1.0 GeV^{-2}		0.7 GeV^{-2}
5	$\sigma_\infty^{\pi N}$	— asymptotic cross-section for πN	23 mb	23 mb	
6	σ_∞^{NN}	— the same for NN	38 mb	38 mb	
7	$r^{\pi N}$	— the relation between the "residues" of the P′ and P poles in πN interaction	1	1	
8	r^{NN}	— the same in NN interaction	1	1	
9	$\varrho^{\pi N}$	— the logarithmic derivative of the residue of the πN amplitude	1 3.5 GeV^{-2}	1	3 GeV^{-2}
10	δ^{NN}	— the same of the NN amplitude	4.5	4.5	
11	α_ϱ	— the intercept	0.5		0.5
12	γ_ϱ	— the slope	0.5–1.0		0.9
13	β_ϱ	— the residue	140	140	

We have 8 "free parameters" and 13 "experimental" ones, some of them we choose as "basic" parameters and then calculate the remaining ones. The "calculated" values of the parameters are given in Table II. They are in a rather good agreement with the "experimental" values. Finally, we obtain the values of free parameters given in Table I. Let us make few comments on their values:

1) The pole of the "central" part is close to unity: $\bar{l} = 0.97$.

2) The value of the "central" $\pi\pi$ cross-section is relatively large. In the "reasonable" range of energies about 30% of the $\pi\pi$ collisions are nonperipheral. This is the result of the small value of the parameter ε.

3) The values of the "central" πN and NN cross-sections are also relatively large. This fact is very important from the point of view of the inelastic processes properties.

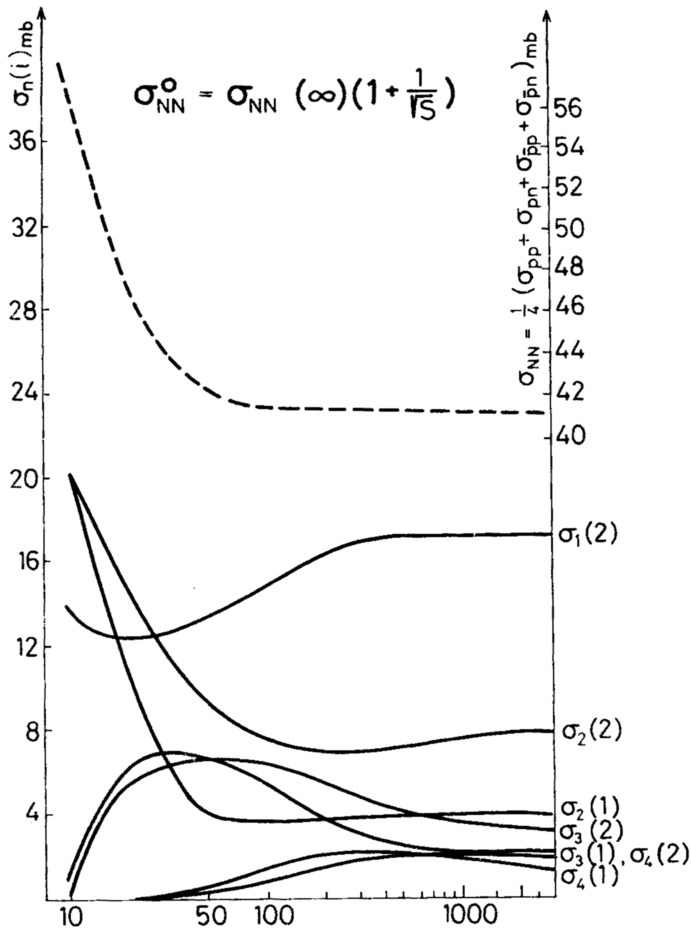

Fig. 8. The high energy behaviour of total cross-sections (the dashed line gives the total cross-section, the full lines represent iteration cross-section)

The large values of the above mentioned cross-sections have nothing to do with the parameter ε.

To achieve a better understanding of the situation we consider another model: without "central" πN and NN interactions at high energies. In this case it is possible to calculate the NN cross-section, if πN cross-section is known:

$$\sigma_{\rm NN} = \frac{1}{16\pi^3}\int F(k^2)D^2dk^2\int ds_1\bar{A}_{\pi N}(s_1, k^2)\left[\frac{1}{2}K^2+\frac{r}{\sqrt{s}}\frac{2}{3}K^{3/2}\right],$$

$$K = \frac{\sqrt{(s_1+k^2-M^2)^2+4k^2M^2}-(s_1+k^2-M^2)}{2M^2} \leqslant 1. \qquad (7)$$

One can see that the relative contribution of the P′ pole in the NN cross-section should be greater than that in the πN cross-section, due to the fact that $\frac{1}{2} < \frac{2}{3}$ and $K < 1$. This is the situation in all the multiperipheral models without "central" πN and NN parts.

This picture is in contradiction with the two-pole parametrization. When central parts $\bar{\sigma}_c^{\pi N}$ and $\bar{\sigma}_c^{NN}$ are present, then the two-pole parametrization can be satisfied due to the threshold behaviour of the central parts. This problem is closely connected with the recent experimental data on the cross-section increase with the energy. We shall discuss it later on.

4) The contributions corresponding to various iterations replace each other very slowly (see Fig. 8). This follows from the fact that $\bar{l}$ is close to unity. The result of it is the small value of $\gamma_P = 0.15$.

5) In the P′ pole the main contribution comes from the "resonance" irreducible part. Consequently the slope of the P′ trajectory is not small.

4. *Description of inelastic processes*

In order to describe inelastic interactions it is necessary to know the characteristics of the process in the vertices. These are well known for the "resonance" and "diffractive" parts.

For the central interaction we use a statistical approach in the Pomeranchuk form [14–16]. I would like to remind this approach. The process is considered as a statistical one. At the beginning (that is at the time of formation of the statistical system) we are dealing with a cloud of heated matter, characterised by the temperature T_{in} and the volume V_{in}. The size of the system is of the order of $\sqrt{\bar{\sigma}_c/\pi}$.

If the energy is high ($M^* > 10$ GeV), we use a hydrodynamical approach of Landau [17].

In the case of lower energy ($M^* \leqslant 10$ GeV) the hydrodynamical pressure does not play any important role, but the effects of viscosity are most essential. In this case the evolution of such a statistical system leads to a decrease of the temperature T, the matter density ϱ, the entropy production, and to an increase of size; it is assumed that the system at any time is in equilibrium. When the density ϱ and the temperature T become "critical" (*i. e.* $\varrho_{cr} \simeq m_\pi/1$ fm$)^3 \simeq m_\pi^4$, $T_{cr} = m_\pi$, these values being independent of the initial conditions), the interactions between the particles become weak enough and, in consequence, the system decays into free particles. Their angular distribution is quasi-isotropic and the average number of particles is $\langle n \rangle \simeq M^*/\bar{\varepsilon}$, $\bar{\varepsilon} \simeq 0.45$ GeV. From the point of view of the multiperipheral approach (for nucleon-nucleon interactions) only the final state properties are important.

However, the development of the system in time may be important for problems connected with the fireball transition through the nucleus. These are discussed by Zalewski [18]. The cross-section for the fireball-nucleon interaction may be time-dependent and small at the initial moment, as was suggested by Miesowicz [19]. Indeed, the cross-section of fireball-nucleon interaction is of the order of magnitude of its size squared (the system being a classical one). The size itself increases with time relatively slowly, because its expansion proceeds with the velocity of sound, ($C_s < 1$ (see Fig. 9)). It is possible that at high energy such a statistical system moves through the nucleus without interaction (due to its small dimensions).

Coming back to the proposed scheme we would like to remark that it is a combined one because the process is partly described by the quantum field theory and partly by

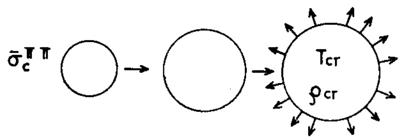

Fig. 9. Increase of the fireball radius

the statistical theory (the irreducible part). At this important point we hope to use the "wisdom to distinguish between the two". Let us stress that the phenomenological description of the statistical process does not introduce any new free parameters. Since all para-

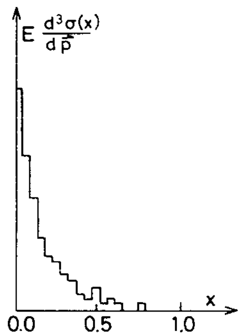

Fig. 10. The distribution $E \frac{d^3\sigma}{dp^3}(x)$ for π^- in interval $0.02 \leqslant p_\perp \leqslant 0.06$

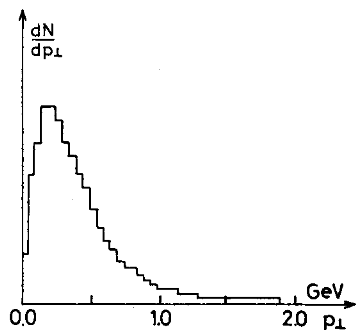

Fig. 11. The distribution $\frac{dN}{dp_\perp}$ for π^-

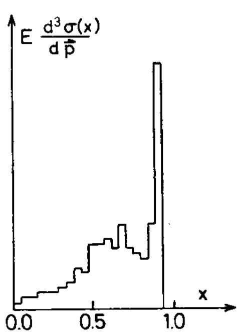

Fig. 12. The distribution $E \frac{d^3\sigma}{dp^2}(x)$ for protons in interval $0.14 \leqslant p_\perp \leqslant 0.18$

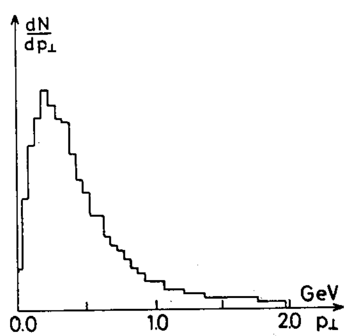

Fig. 13. The distribution $\frac{dN}{dp_\perp}$ for protons

meters discussed above are determined from the properties of elastic scattering, we start our description of inelastic processes practically without any free parameters.

We have simulated about 20000 events of pp collisions at the energy $E = 70$ GeV. All information on the events is stored on magnetic tape and ready for use in any kind of analysis.

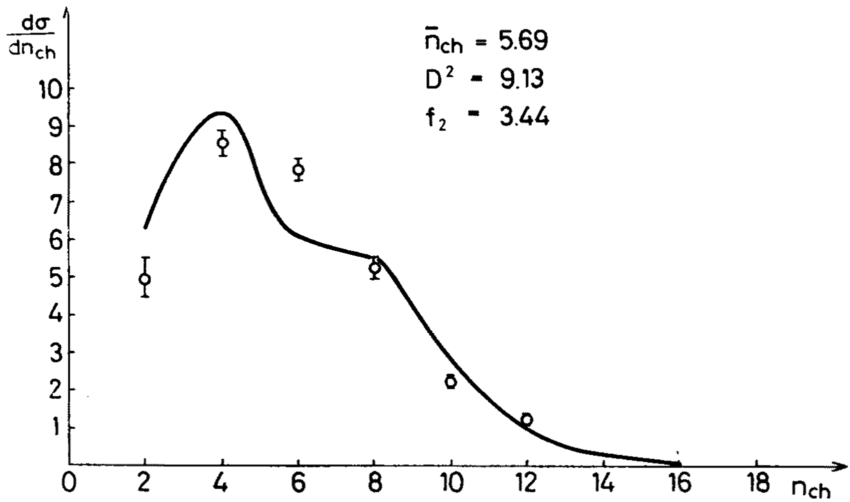

Fig. 14. The distribution $d\sigma/dn_{ch}$

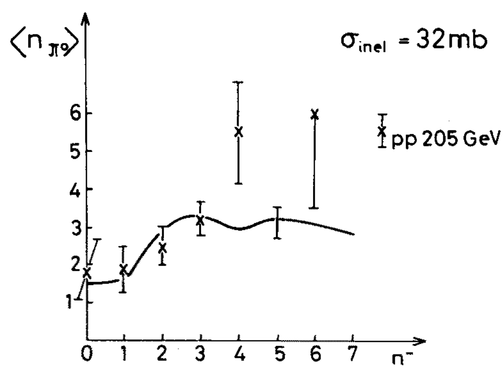

Fig. 15. The dependence $\langle n_{\pi^0} \rangle$ *vs* n_{π^-}

Figs 10–15 give some traditional distributions. The pion and nucleon distributions *vs* $p_\perp$ and "x" seem to be quite "natural" and we hope that they will agree with experiment. The distribution *vs* the multiplicity and the correlation of $\langle n_0 \rangle$ and n_- also agree with experimental data, but it can be simply the result of the "multiduality": the results of all the theoretical models are consistent with all the experimental data (Morrison).

5. *The modern problems*

The fireball (or: cluster) model

The first observation of the fireball effect was done by the Kraków group fifteen years ago. Formation of two groups of particles (two fireballs) from 5–7 charged pions without nucleons was observed at high energies [20]. Each group decays in its own system isotropically. At lower energies one fireball was observed [21]. At the present moment the question of creation of particles in groups (or clusters) is one of the most interesting problems and is widely discussed (in particular, at this School).

Now, the clusterization is defined in a wider sense *i. e.* by clusters one understands two different processes: (a) the formation of resonances (such a cluster consists of a small number of particles and can include a nucleon); (b) the formation of fireballs.

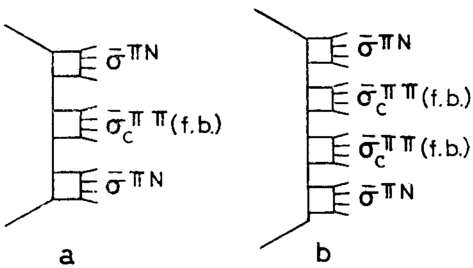

Fig. 16. Diagrams representing the production of fireballs

We shall discuss the second type of clusters. In the framework of the discussed scheme the formation of fireballs is due to the decay of the statistical system of the central $\pi\pi$ interaction. The creation of one or two fireballs is described by Fig. 16a and Fig. 16b respectively.

However, in the framework of our model the cross-section for such processes is small (about 1 mb). It increases with the energy, but very slowly, this is the result of large value of the πN "central" cross-section (the first and last vertices take too much of energy). It can be shown that the cross-section for the fire-ball formation is higher (about 10 mb) if the $\bar{\sigma}_c^{\pi N}$ is assumed to be equal to zero (or — very small [22]). Thus, the problem of the fireball formation and the problem of the cross-section dependence on energy are closely connected with each other.

At very high energies $E_L \simeq 10^{13}$–10^{15} eV there can appear in the framework of the model clusters of quite large masses. It follows from an extremely slow decrease of $\bar{\sigma}_c^{\pi\pi}$ and the contributions from iterations (see Fig. 16a, b) with increasing energy.

The problem of the cross-section dependence on energy

There are two different problems, namely:

a) Superasymptotic behaviour in the nonrealistic energy region.

b) An increase of the cross-section in a realistic energy region (preasymptotic behaviour).

We discuss only the second, more realistic problem.

ISR-data [23] demonstrate an increase of the pp cross-section at energies $E_L \simeq 10^{11}$–-10^{12} eV described by a fit [24]:

$$\sigma_{\mathrm{pp}} = 38.4 + 0.4\left(\ln \frac{s}{140}\right)^2 .$$

Such a fit corresponds to a pole of the third order at the point $l = 1$ or to three usual poles close to each other and to this point (the difference between these two possibilities is not important in the energy region under discussion).

Two remarks can be done about the relation of this fact to the multiperipheral theory.

First, the two-pole parametrization (6) should be corrected. Some parameters are changed. For example, such parameters as $\bar{l}$ and $\bar{\sigma}_c^{\pi\pi}$ are changed very slightly, the parameters Δ_r, Δ_{γ_5}, $\varrho_f^{\pi N}$ and $s_f^{\pi\pi}$ (also being changed) are of the same order of magnitude as in Table I. The most important effect is noticeable for parameters $a^{\pi N}$ and a^{NN} (*i.e.* $\bar{\sigma}_c^{\pi N}$ and $\bar{\sigma}_c^{NN}$) because they are very sensitive to the role of P′ trajectory. There are some arguments in favour of the statement that the values of $\bar{\sigma}_c^{\pi N}$ and $\bar{\sigma}_c^{NN}$ are negligibly small for the new parametrization. If it is the case, the role of fireball formation increases. Thus we hope that the new parametrization helps to make the model better.

Second, a new problem arises about the properties of a third order pole in the total partial wave amplitude. It is easy to show that the behaviour of $\bar{\sigma}_c^{\pi\pi}$ must be quite similar to the following one:

$$\bar{\sigma}_c^{\pi\pi} \sim (\ln s)^2 s^{\bar{l}-1}, \qquad \bar{l} < 1$$

i.e. in a wide energy interval $\bar{\sigma}_c^{\pi\pi}(s)$ must increase logarithmically and then slowly decrease in the asymptotic region. It is possible to explain this behaviour. I would like to remind the Heisenberg paper in which he used classical approach to the multiparticle production problem and got the result: $\sigma \sim \ln^2 E_L$ [25].

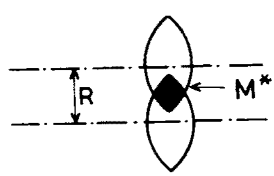

Fig. 17. The collision of the two classical objects

I repeat his arguments. Let us consider the collision of the classical objects with exponentially distributed densities (Fig. 17)

$$\varrho \sim l^{-rm_\pi}.$$

The particles do not interact if the impact parameter (radius of the interaction R) is so large, that the excitation is less than $M^* < 2m_\pi$. In this case radius R increases with energy logarithmically and

$$\sigma \sim R^2 \sim \ln^2 E_L.$$

At very large impact parameters ($R \gg m_\pi^{-1}$) this argument is hardly a correct one: one can say that here Heisenberg violates the Heisenberg uncertainty relation. However, at finite energies where the radius is still small enough ($R \lesssim m_\pi^{-1}$) the classical aproach to the "central" collisions is reasonable. Because of lack of time I shall discuss the second problem only.

The distribution of the transverse momentum of the secondaries

In the region of $p_\perp \lesssim 1.5$ GeV the differential cross-section is well described by the formula:

$$\frac{d\sigma}{dp_\perp} \sim e^{-6p_\perp} \sim e^{-p_\perp/T}.$$

In the statistical model this corresponds to the temperature equal to the pion mass $T = m_\pi$. At the large $p_\perp$ the distribution is proportional to $p_\perp^{-8}$. Moreover [27, 28]:

In the region of $2 < p_\perp < 3.5$ GeV the fraction of heavy particles (K, $\bar{\text{p}}$, p) is greater than the average.

The multiplicities are higher than the average ones.

There is an excess of the positive particles.

From the point of view of the multiperipheral model higher values of the transverse momenta of the secondaries are due to the contribution of a high momenta of the virtual exchanged

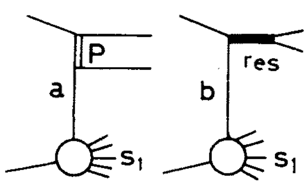

Fig. 18. Diagrams representing interaction with high transverse momentum

particles. Let us consider a diagram in which $k_\perp$ is high enough (Fig. 18a, b). This leads to the generation of real secondary particles with large $p_\perp$ in two cases:

a) The process in one of the vertices is of diffractive type. In this case $p_\perp \simeq k_\perp$ and the secondary particle is identical with the exchanged one.

b) There is a resonance formation in one of the blobs. In this case $p_\perp < k_\perp (p_\perp \simeq 0.5\, k_\perp)$ and the fraction of heavy secondary particles should be larger than usually. The calculation of the differential cross-section in the region of $2 \leqslant p_\perp$ was done on the basis of the formula (5) [29]. The results are shown in the Fig. 19. The dependence of the type $p_\perp^{-8}$ appears quite naturally, and the agreement is satisfactory.

One can easily explain the increase of the multiplicities. Namely, for higher values of k and, consequently, k^2, the distribution of the s_1 is shifted to larger values.

It seems possible that, if this picture is correct, the large fraction of heavy particles (and the positive particle excess as well) should be observed in the intermediate region of $p_\perp$ only. In the region $p_\perp > 5$ GeV the secondaries should be mainly pions. It would be interesting to test experimentally this suggestion.

The model developed above can be used to evaluate the triple Pomeron vertex. The inelastic processes with irreducible diffraction part shown in Fig. 20a correspond to the elastic scattering amplitude of the form shown in Fig. 20b. Because the multiperipheral chain produces Pomeron in the elastic process, one has to deal with the triple Pomeron

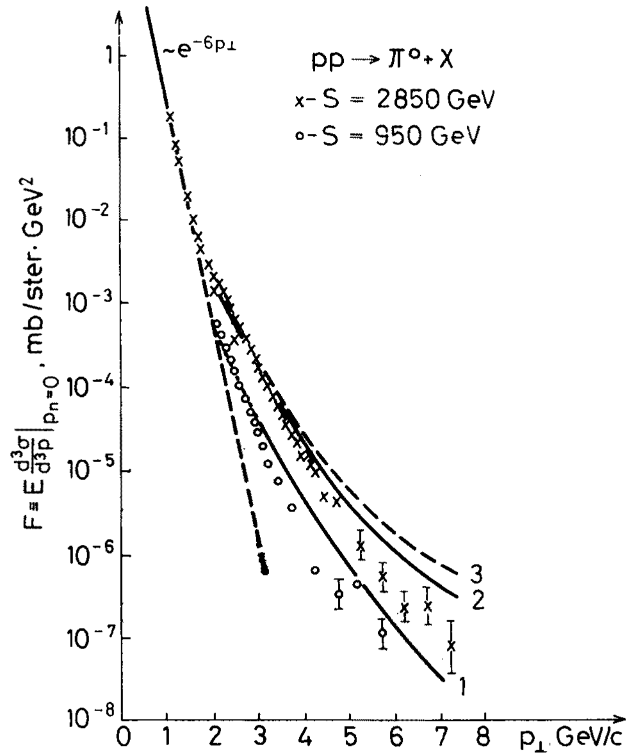

Fig. 19. Large transverse momentum distribution of π^0 at $\varrho_{||} = 0$ for different ISR-energies. Lower (1) and upper (2) theoretical bounds for $s = 2850\ \mathrm{GeV}^2$ are shown. The limiting form of the distribution at $s \to \infty$ is shown by the curve 3

vertex. The processes of Fig. 20a, can be calculated in the framework of the model. The triple Pomeron vertex is expressed through the parameters of the model [30]

$$g_P(0) \simeq \frac{6(\sigma_{\mathrm{tot}}^{\pi\pi})^2}{a}(1-\bar{l})^2 \simeq 0.15\ \mathrm{GeV}^{-1}.$$

It agrees quite well with the value of $g_P(0) \simeq 0.2\ \mathrm{GeV}^{-1}$ obtained from the peak of proton spectrum at $x \simeq 1$ at ISR energies [31]. As a result of such an agreement one can state that the contribution of inelastic diffraction processes is correctly reproduced by the model.

In conclusion I would like to make two remarks.

The first is a pleasant one

A multiperipheral model, which uses a relatively small number of free parameters, is able to give an almost complete description of inelastic processes.

The second remark is a sad one

The interaction radius increases with the energy and most of the information obtainable from the experiments on inelastic processes concerns only the interactions at relatively large distances. The information on the innermost structure of the elementary particles can be obtained only from the analysis of very rare events.

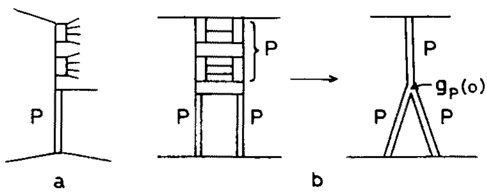

Fig. 20. Diagrams for calculation of the Triple-Pomeron vertex

Anyway one can hope to obtain new and interesting information from the study of clusterization. It may happen that many particle processes (in particular those of the statistical type) cannot be described by means of the contemporary quantum field theory [6, 7]. In that case one can expect that the investigation of clusterization processes will lead to the development of the theory itself.

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