New Indications of Changing the Regime of Multiple Production at Superhigh Energies

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PACS Ref: 96.40

Abstract

The effect of alignment of secondary particles (products of hadron interactions at superhigh energies $E^{\text{in}} \geq 5 \cdot 10^6$ GeV) as a "fan", which has been observed in cosmic rays, is analysed. It is shown that its main specific features are well described within the model that we proposed twenty years ago to explain sharp anomalies in the process of multiple production, which are observed in the same energy range. This model assumes that quarks have internal massive degrees of freedom. Some consequences of the used approach are discussed, which may be important for the multiple process in the above-mentioned region.

1 Introduction

In processes at superhigh energies ($E^{\text{in}} > 10^6 - 10^7$ GeV), earlier in cosmic rays [1] and now at new accelerators [2], there have been observed serious deviations from the particle production regime. First of all, it concerns a multiple process, which was observed at "accelerator" energies up to SPS energy and could successfully been described, for instance, in the framework of a phenomenological model of gluon dominance (MGD) for pp-, pA- and AA- collisions [3,4] or in its detailed version, a model of hadron strings (MHS) (see, in particular, [5]) as well as in the framework of a standard QCD approach.

These deviations imply a sharp increase in multiplicity, average transverse momentum $< p_{\perp} >$ of produced particles and a change of qualitative composition of secondary hadrons in favour of more massive ones [1]. And this is not the end of the chain of this kind of facts.

Recently [6], in studying the interactions of cosmic rays in stratosphere at "Concord" an event has been observed in which about 200 vigorous $\gamma$-quanta ($E_{\gamma} \geq 200$ GeV) with very small deviations turned out to be in the same plane, forming a "fan" (the term is from [6]).

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However, one cannot accept this observation as an exceptional or exotic one since similar events have already been observed in the experiment "Pamir" when studying $\gamma$-hadron superfamilies of particles generated by the primary hadron with energy around $10^7$ GeV and higher [7]. First important conclusions have been made in [7].

First, the effect of alignment of particles as a "fan" has a threshold nature and arises at primary energies exceeding $10^7$ GeV.

Second, at these energies a portion of events demonstrating the alignment of particles is not small and amounts to 20–40% of all inelastic collisions.

Third, in the process leading to the alignment, the central role should be played by heavy particles with mass of an order of hundreds GeV. Otherwise, as a result of cascading in the atmosphere the picture of alignment should be smeared.

Finally, attempts to explain the effect using traditional schemes based on the MHS representation of breaking of hadron strings which arise in the quark-quark interaction, did not give any positive results (for discussion see [7]).

Consequently, alongside with the earlier established sharp anomalies in the behaviour of secondary particles, which arise at superhigh energies [1,2], we face one more anomaly, qualitative change of the shape of their angular distribution.

2 Alignment effect - a new evidence for the qualitative change of regime of multiple production.

The problem arisen can be overcome either by making the above-mentioned approaches more complicated supplementing them with sophisticated superstructures or looking for a qualitatively new solution. Both the ways have right to exist. We choose the second way and give interpretation of events of the type of a "fan", which is based on the model of a new regime for an inelastic interaction of nucleons at superhigh energies, which we suggested 20 years ago [8]. According to it, violation of the standard MGD behaviour of characteristics of a multiple production process is due to the fact that at high energies in collisions close to head-on ones internal degrees of freedom of quarks are "defrosted", i.e., their internal structure manifests itself. This results in absorption of a great amount of collision energy by internal massive degrees of freedom, their excitation. As a result, there may be a situation when an ordinary "leading" effect, in complete correspondence with experiment [1,9], disappears and almost all the energy per valence quarks in colliding hadrons turns into excitation energy of a hadron object produced, on average resting in the center of mass system. This object was then called the Q-cluster. The proposed model allows one to explain (for details see [8]) basic of the observed anomalies in the behaviour of multiple production characteristics [1,2,9].

One can easily be convinced that the appearance of the effect of alignment of particles as a "fan" at superhigh energies can easily be explained in the framework of the model [8].
Indeed, if as a result of collision there appears a Q-cluster as a unified hadron system, from the conservation laws there automatically follows that besides excitation energy it must have an angular momentum as well. The fact that the unified hadron system may in principle possess an angular momentum was established by us almost 10 years ago while studying angular distribution of particles produced in cumulative reactions at smaller energies [10].

Let us estimate the angular momentum for the case of a "fan" effect. It is obvious that a unified system can be formed if the impact parameter "b" in a collision of nucleons does not exceed the value

\[ b_{\text{max}} \approx l \approx 0.5 \text{ fm} , \tag{1} \]

where \( l \) is the value of smearing the boundary of distribution of quarks in a nucleon, as in a quark bag. (This issue has in detail been considered in [10], and in [11] - relation (28)). Averaging over impact parameters in the interval \( 0 \leq b \leq b_{\text{max}} \) gives for the average value \( < b > \):

\[ < b > \approx \frac{2}{3} b_{\text{max}} \approx 0.33 \text{ fm} . \tag{2} \]

For the collision energy we take the value from [6], i.e.,

\[ E_{\text{in}}^p = 10^7 \text{ GeV} . \tag{3} \]

Then, an approximately average value of the angular momentum of the Q-cluster \( < L_Q > \) should be

\[ < L_Q > = \frac{< b > \sqrt{s}}{2\hbar} \approx 3 \cdot 10^3. \tag{4} \]

The allowance for energy carried away by the gluon fields of colliding nucleons would lead to a coefficient of an order of 0.7. This correction does not considerably change the result. Moreover, it is not obvious whether this correction is necessary or not.

A huge value of \( < L_Q > \) in (4) would certainly lead to a quasiclassical situation - particles and generators of jets leaving the Q-cluster should be arranged in the R plane normal to the angular momentum vector \( \vec{L}_Q \) and going through the collision axis. The situation in c.m.s. is shown in Fig.1. It is obvious that in the laboratory system this scheme of particle and jet dispersion qualitatively corresponds to the observed effect of a "fan" (especially if one takes into account that products with large energy, more than 200 GeV, are registered).

To verify a high degree of coplanarity of dispersion near the R plane, one has to show that the value of smearing the angular momentum distribution near \( \theta = \pi/2 \) is rather small due to the presence of quantum "q" corrections. It is known that the halfwidth \( \Delta \theta \) of distribution over \( \theta \) corresponding to the square of module of the wave function of the rotation motion |\( \Theta_R |^2 \) near \( \theta = \pi/2 \) in the quasiclassical approximation is equal to
\[ \Delta \theta_q \approx \sqrt{\frac{1}{2l}} \]  

(5)

If in the considered event one observes, for instance, 3 or 5 jets, each of them on average carries away from the Q-cluster the angular momentum \( L_Q/3 \) or \( L_Q/5 \), respectively. Then, on the basis of (4) and (5) we get for the smearing \( \Delta \theta \)

\[ \Delta \theta_q \approx \sqrt{\frac{1}{\frac{3}{3}L_Q}} \div \sqrt{\frac{1}{\frac{5}{5}L_Q}}. \]

(6)

Even for ten-jet events this smearing amounts to \( 1.7^\circ \).

The estimate (6) quantitatively confirms a high degree of coplanarity of jet and particle dispersion, according to the picture of the Q-cluster decay suggested by us in [8]. Consequently, the image of a "fan" in this sort of events is justified.

3 Interpretation of basic features of fan-type events within our model

So, in the framework of our model [8] the effect of alignment has a natural and quite transparent interpretation. Using it we can comment on the results [7] of experimental study of the effect in the order they are presented in paragraph 1.

First, the threshold nature of the effect automatically follows from the very essence of the model [8] as it is assumed that at sufficiently high energies internal degrees of quarks of colliding nucleons are "defrosted" (see paragraph 2).

Second, the adopted scene gives a considerable value for a portion of events with alignment to a total number of inelastic collisions \( \delta = \sigma_{\text{fan}}/\sigma_{\text{inel}} \). The lower estimate \( \delta_{\text{min}} \) can be obtained if for calculation of \( \sigma_{\text{fan}} \) we again use the quasiclassical approximation

\[ \sigma_{\text{fan}} \approx \pi (b_{\text{max}})^2 \approx 8 \text{ mb}. \]

(7)

Estimate (7) assumes that "transparency" (in terms of nuclear optics) is close to zero in this sort of collisions. This assumption is justified as, according to our model, collisions of nucleons with the impact parameters "\( b \)" in the interval \( 0 \leq b \leq b_{\text{max}} \) are relevant to destruction of all three pairs of quarks and disappearance of the leading effect. Assuming that \( \sigma_{\text{inel}} \approx 40 \text{ mb} \) at \( E_{\text{in}} = 10^7 \text{ GeV} \) (according to the data given in [1]) the increase in \( \sigma_{\text{inel}} \) in comparison with its value in the "accelerator" region may amount to 30% get \( \delta_{\text{min}} \) to be equal to

\[ \delta_{\text{min}} \approx 0.2. \]

(8)
It is obvious that the contribution to the effect may also come from collisions accompanied by destruction of two pairs of quarks, which correspond to somewhat larger values in $b_{\text{max}}$ and larger "transparency". Therefore, a real value of the portion of $\delta$ may turn out to be 1.5-2 times as large as the value (8). Consequently, there is no contradiction with experiment here as well.

Third, in our earlier paper [8], on the then available data [1] on the value of the threshold energy $E_{\text{th}}^{\text{in}}$ corresponding to transition to a new regime, and on the assumption that quark destruction can simply be represented as production of a pair of intermediate unstable particles (let us call them "H"-particles - heavy particles), we derived for their mass $M_{\text{H}} = \sqrt{s_{\text{qq}}}/2 \approx 50$ GeV. Consequently, the model [8] qualitatively (and automatically like above) agrees with the conclusions of [7]. However, at present a numerical estimate of mass $M_{\text{H}}$ has to be revised as in the recent [9,12] modern energy values are given starting from which a new regime acquires a stable character, namely $E_{\text{th}}^{\text{in}} \geq 5 \cdot 10^6 - 2 \cdot 10^7$ GeV. This value much larger than the one we used earlier [8]. Making calculation of [8] with a new value for $E_{\text{th}}^{\text{in}}$ we obtain

$$M_{\text{H}} \approx 400 \text{ GeV}.$$ (9)

The author of [7], following other reasonings, considers such a value for $M_{\text{H}}$ to be preferable.

### 3.1

Having the value for the mass of H-particles $M_{\text{H}} \approx 400$ GeV and for the Q-cluster temperature $T_{\text{Q}} \approx 3$ GeV, which has been obtained earlier in [8], one can roughly estimate a mean value of the angle $\Delta \theta_{\text{T}}$ of deflection of H-particles from the plane $R$ (see Fig.1) in the laboratory system of coordinates

$$\Delta \theta_{\text{T}} \approx (\arctan \frac{\langle p_{\perp}^{\text{H}} \rangle}{\langle p_{\parallel}^{\text{H}} \rangle})_{\text{lab}}.$$ (10)

Let us first note that kinetic energy of an H-particle in the rest frame of the excited Q-cluster in thermodynamical approximation is of an order of $E_{\text{kin}}^{\text{H}} \approx 3T/2 \approx 4.5$ GeV. Hence, for the velocity $v_{\text{H}}$ in the same system we get

$$\frac{v_{\text{H}}}{c} \approx 0.15.$$ (11)

Consequently, H-particles in the Q-system are extremely nonrelativistic. Taking into account that $M_{\text{H}} \gg T_{\text{Q}}$ one can easily obtain for $\langle p_{\perp}^{\text{H}} \rangle$:

$$\langle p_{\perp}^{\text{H}} \rangle \approx \sqrt{\frac{\pi M_{\text{H}} T_{\text{Q}}}{2}}.$$ (12)

For $\langle p_{\parallel}^{\text{H}} \rangle$ (neglecting a small velocity $v_{\text{H}}$ in the Q-system) we have

$$\langle p_{\parallel}^{\text{H}} \rangle_{\text{lab}} \approx M_{\text{H}} \cdot \gamma_{\text{Q}},$$ (13)

where $\gamma_{\text{Q}}$ is the Lorentz factor of the Q-cluster in the lab. system.
\[ \gamma_Q \approx 1.2 \cdot 10^3. \] (14)

Since \( < p^H \parallel > \gg < p^H \perp > \)

\[ \Delta \theta_T \approx \frac{< p^H \perp >}{< p^H \parallel >} \approx 9 \cdot 10^{-5} \approx 15'' . \] (15)

This value exceeds the quantum smearing \( (\Delta \theta_q)_{\text{lab}} \approx (\Delta \theta_q)_{\text{c.m.s}} / \gamma_Q \approx 1'' - 5'' \) (see paragraph 2).

For comparison with experiment let us use the data [6] on the dimension and mutual arrangement of halos from the groups of \( \gamma \)-quanta (see the figure therein) as well as the assumed distance (\( \approx 100 \) m) from the primary act to a registering set up. The estimate \( \Delta \theta \) from these data gives

\[ \Delta \theta_{\text{exp}} \approx 4'' - 6''. \] (16)

Indeed, for a realistic comparison of this value \( \Delta \theta \) with the model estimate \( \Delta \theta_T \) in eq.(15) one should take into account obvious facts.

First, limited accuracy of experimental determination of the distance between the point of a primary interaction (appearance of the Q-cluster) and a registering equipment. Moreover, selection of secondary registered particles by the criterion of a large value of their summed energy certainly decreases an average angle of particle dispersion near the plane of a "fan".

Second, it is obvious that the model estimate of the quantity \( \Delta \theta_T \) is rather rough. It is most probably an estimate from above as the allowance for a large value of the rest-mass of H-particles would lead to a noticeable decrease in the temperature value.

Therefore, one should expect agreement of \( \Delta \theta_{\text{exp}} \) with \( \Delta \theta_T \), in the best case, only in the order of magnitude. In this sense the result obtained can be considered satisfactory.

3.2

Important conclusions can be drawn from comparison of the results of "Pamir" experiments with those obtained on the "Concord". They correspond to distances \( h_Q \) between the point of primary interaction (by assumption, the point of production of a Q-cluster) and a recorder which are highly different in magnitude; for the "Pamir" \( h_Q \approx 3 \) km and for the "Concord" \( h_Q \approx 100 \) m.

We note that events recorded at the "Pamir" are characterized by three halo-spots from beams of \( \gamma \)-quanta. The event registered at the "Concord" consists of a double amount of aligned beams. Qualitatively, this ratio may happen to be not accidental. The chain length of \( \gamma \)-beams observed in the experiment "Concord" approximately equals 41 mm. If this "fan" was observed at a distance of 3 km from the point of primary interaction (i.e., in the conditions of the "Pamir"), the length of that chain would be 123 cm. This value is comparable with horizontal sizes of the "Pamir" recorder. Consequently, the probability for the
"Pamir" recorder to fix only separate fragments of the type "fan" discovered on the "Concord" is sufficiently large.

It is instructive to examine the situation in reverse order. The length of the chain of three halos in the "Pamir" experiment (at least, of those cited in [7]) equals $1.5 - 2.0$ cm. If these halos were registered at $h_Q \approx 100$ m (i.e. at the "Concord") rather than at $h_Q \approx 3$ km, all of them would be in an interval not larger than 0.7 mm. However, the accuracy of data reported in [6] does not exceed 1 mm. Therefore, the assumption that 5 beams of $\gamma$-quanta in the "Concord" event are produced not by 5 but a much larger number of H-particles (perhaps, 2 – 3 times) can be taken as realistic. Once the process of decay of initiators is completed, the picture with a large number (up to $10 - 15$) of hadron jets can be expected.

Since the events under consideration remain aligned up to distances $h_Q = 3$ km, it can be assumed that the lifetime of H-particles is of the order

$$\tau^H \approx 3 \text{ km} \div \gamma_Q \approx 0.8 \cdot 10^{-8} \text{ sec}$$

and, therefore, the mean free path of H-particles before decay, $< l_H >$, in experiments on colliding $pp$ and $p\bar{p}$ can be estimated as follows:

$$< l_H > \geq \tau^H \div v_H \approx 40 \text{ cm.}$$

As for the energetic $\gamma$-quanta of observed halos, they appear, as we think, from the energetic part (in accordance with the experimental conditions) of bremsstrahlung of $\pi^0$, $\rho^0$ and other mesons by H-particles with their subsequent decay containing the mode with $\gamma$-quanta.

3.3

There is a related problem of the appearance of "knee" in the spectrum of the photon-electron component observed experimentally at the same energies. The authors of ref. [9] have assumed that this knee is due to vanishing leading hadrons. In our opinion, this assumption is necessary but not sufficient. Indeed, when multiple processes go over to a new regime, the part of energy spent onto production of new particles (the "thermal" energy $W_T$) strongly increases, which can be seen in Fig.2. Curve 1 describes the behaviour of $W_T$ fitted to the experiment up to $E^{\text{in}} = (2 - 3) \cdot 10^5$ GeV (see reviews in [4]) and extrapolated onto the region of $E^{\text{in}} > 10^6 - 10^7$ GeV. Curve 2 is the dependence $W_T(E^{\text{in}})$ described by the model [8]. Curve 3 describes this dependence with the inclusion of the mechanism of breakdown of quarks, which demonstrates a strong growth of the energy release into the channel of multiple production at initial energies $E^{\text{in}} > 10^6$ GeV. Therefore, to coordinate the appearance of the knee in the $e, \gamma$-spectrum with the disappearance of leading hadrons, it is to be assumed that the energy losses of new H-particles (up to their decay), which take a huge part of the energy $W_T$, are much lower than those of usual primary baryons. This assumption is justified since H-particles being small in sizes and huge in mass can, only with a small cross section, transfer a small part of their energy to baryons in an atmospheric gaseous mixture.
It is possible that a quark consists of three superheavy fermions, H-particles, in analogy with the three-quark structure of a conventional baryon, nucleon. This idea is rather attractive, though speculative.

So, within the model [8], the assumption that the knee in the $e, \gamma$-spectrum appears due to disappearing leading hadrons becomes not only necessary but sufficient, as well.

4 Some consequences of the adopted picture

We complete the exposition of results obtained in [8] and in this paper with some important consequences from the model [8].

4.1

It was noted in [1] that the cross section of inelastic interaction grows when the new regime sets in. This means in terms of the hadron optics that the "transparency" of a nucleon-target decreases for an incident nucleon, but just this is, in accordance with the model [8], a consequence of "defreezing" of new degrees of freedom of quarks and formation of a Q-cluster followed by the disappearance of "leading" effect. Therefore, it is not surprising that a relative growth of $\sigma^{\text{inel}}$ at energies under consideration turns out to be close in magnitude to the part of aligned events $\sigma_{\text{fan}}$.

4.2

Approximately, it is not difficult to estimate the size of transition to a new regime in the energy scale $E^{\text{in}}$. In the c.m.s. a pair of quarks in colliding nucleons (start of a new regime $E^{\text{in}}_{\text{th}}$) to be broken requires an energy 3 times as low as that for breaking all 3 pairs of quarks and formation of a complete Q-cluster (full inclusion of a new regime $E^{\text{in}}_Q$). Therefore it is clear that the domain of transition in the lab. system should approximately cover an one-order interval, i.e. $\log(E^{\text{in}}_Q/E^{\text{in}}_{\text{th}}) \approx 1$. Boundaries of that domain should be slightly smoothed due to one-quark internal motion inside nucleons before collision, collective motion of the whole quark system with respect to the total gluon field, and due to possible excitation of quarks not followed by their decay.

This result of the model [8] is also in agreement with approximate data given in [1] on the size of transition to a new regime on the $E^{\text{in}}_{\text{lab}}$ scale. If modern data on a larger value of the initial energy, compared to its previous estimates were taken into consideration, the whole picture would only shift towards higher initial energies (qualitatively, it is shown in Fig.2).

4.3

Since an effective value of the rotational energy of a Q-cluster can be a half of its total internal energy, it can be assumed that the estimate of $M_H$ given by (9) is somewhat large and its realistic value can be half of that value. Therefore we expect $M_H$ to be in the interval
At present, it is difficult to make a more accurate estimation, however, a possible decrease of the estimate (19) will not essentially influence our results.

It is of interest to point to the following fact: in recent experiments on colliding beams of electrons and protons at HERA [13] an anomaly has been discovered in $e\,p$-scattering which testifies, in experimenters’ opinion, to the structure of a proton of order of 0.001 of its size, i.e. $\lambda_m \approx 10^{-3} < r_p >$. This observation does not contradict the assumption we have made in [8] concerning degrees of freedom of a nucleon deeper than quarks. The mass of the supposed structure is estimated to be

$$M \geq \frac{\hbar}{\lambda_m} \approx 250 \text{ GeV}.$$  \hspace{1cm} (20)

We see that estimates (19) and (20) obtained on the basis of qualitatively different processes provide close values for $M_H$. This comparison is sure to be tentative since the experiment [13] is not yet completed, and accidental elements are not excluded.

### 4.4

As a result, from our analysis we can make preliminary and speculative conclusions on the properties of H-particles:

- their mass is in the interval (19);
- the lifetime is of order $\tau^H_\alpha \approx 10^{-8} \text{ sec}$;
- H-particles are most likely fermions (heavy bosons with masses in the interval $610 \text{ GeV}/c^2 > m > m_W$ are not yet discovered [14]);
- H-particles are strongly interacting particles since the construction of a quark from them requires a huge mass defect (of an order of $400 - 800 \text{ GeV}$) and this is necessary for realization of a Q-cluster as an intermediate highly excited system that exists for a certain time (otherwise, the event with alignment becomes a mystery).

From the above properties of H-particles we may assume that they can be unstable superheavy baryons.

### 5 Conclusion

A number of sharp anomalies in the behaviour of characteristics of multiple production discovered in experiments with cosmic rays at ultrahigh energies and a striking effect of the “fan” with the highest degree of complanarity can be described within a unique mechanism formulated in [8,15].
The proposed scheme can be realized via the basic assumption made in [8] that quarks have internal structure constructed on massive degrees of freedom and in strong excitation they can destroy decaying into heavy unstable particles with a mass of hundreds of GeV. From a gnosiological standpoint, the assumption that quarks are not the latest indivisible elementary bricks in the structure of matter is not crazy, which follows from the whole history of physics.

Accuracy of the experiments under discussion and a qualitative estimate of the initial energy is not high, therefore, they should separately be estimated thoroughly. However, they together, at least, qualitatively can be given a common description and this testifies to the validity of the model proposed in [8]. In any case analysis of new data in [16] is not in conflict with our conclusions.

We hope that considerations we made in [8] and in this paper concerning the results available on the study of processes at ultrahigh energies will get further development; we mean progress in the experimental technique with cosmic rays (satellites of the Earth and stratospheric airplanes) and start-up of new accelerators (for example, LHG). Figure 2 illustrates a rapid decrease of the gap between energies attained at modern accelerators and the energy region of sharp anomalies observed in experiments with cosmic rays. As can be seen from Fig.2, energies at the FNAL tevatron in the scale of $E_p^{in}$ approach the threshold of new regime. In our opinion, a direct evidence for this statement comes from observed considerable deviations of the dependence of the yields of jets, $J/\Psi$- and $\Upsilon^0$-particles on $p_{\perp}$ at $\sqrt{s_{pp}} = 1.8 \, \text{TeV}$ [2] from the expected one. Spectra get much more hard, which in terms of thermodynamics corresponds to the start of anomalous growth of the temperature of an intermediate system. In the framework of the discussed picture, this situation is natural: pumping of the energy into an intermediate system begins fast growing as a result of defreezing the internal degrees of freedom of quarks leading first to their excitation and then to disintegration (earlier in [8], a behaviour like that was demonstrated for the distribution of extensive atmospheric shower "stems" over $p_{\perp}$).

Further experimental verification of the conception discussed in [8] and in this paper will support the idea of a quark as a structural object functionally analogous to a quasiparticle, an object widely used in different fields of physics. This perspective seems still more realistic in view of recent important results: for the first time, in semiconductors discovered are quasiparticles with fractional charges equal to 1/3 of the standard charge [17].

As we have mentioned in [8], the idea of quarks being quasiparticles can drastically change the view of the essence of confinement (quarks, quasiparticles cannot exist beyond a system, a hadron, whose local properties they express) and can impose the limits on the use of the asymptotic-freedom approximation (evidently, it is to be employed only in the subthreshold region of energies, i.e. at $\sqrt{s_{pp}} < 1 - 2 \, \text{TeV}$).

Acknowledgements
The authors are grateful to prof. V.A. Meshcheryakov for discussions.
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Figure captions

Fig. 1. The scheme of emission of decay products of a $Q$-cluster with a large angular momentum in the c.m.s.

Fig. 2. The $E_p^{in}$ - dependence of the energy spent for production of new particles in a $pp$-collision. Arrows denote values of $E_p^{in}$ equivalent in energies $\sqrt{s}$ reached at colliding beams of accelerators ISR, SPS and the FNAL tevatron: 60 GeV, 540 GeV and 1.8 TeV. Curve 1 - the $W_T(E^{in})$ dependence according MGD [4] up to $(2-3) \cdot 10^5$ GeV and extrapolation onto the region $E^{in} > 10^6 - 10^7$ GeV; Curve 2 - the $W_T(E^{in})$ dependence according Q-cluster model [8]; Curve 3 - the $W_T(E^{in})$ dependsence with the inclusion of the mechanism of breakdown of quarks.
