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UNIVERSAL FOUR-DIMENSIONAL HADRON JETS AND THE OBSERVABILITY OF COLOUR CHARGES

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1. INTRODUCTION

In the literature there exists an affirmation that colour objects, in particular, quarks and gluons, are not observed as they strongly interact with vacuum fluctuations and immediately transform to hadrons. However, let us consider the criteria of microobject observability. The observability of neutrons or neutrinos is beyond doubt because their secondary interactions (which are observed) take place at a large distance from the production point and due to the application of universal kinematic laws to the isolated systems. It is obvious that to measure the distance between the point of object production and the one of its secondary interaction or decay is not the necessary criterion of observability. There is no doubt about the observability of such unstable particles as η, J/ψ, ρ, ω mesons or Λ and other baryon resonances although the corresponding distances are not measurable for them. The observability of short-lived particles (besides kinematic laws) is based on two required criteria.

(A) The production cross section of really observed products of the secondary interaction (decay), σ, can be precisely presented as two factors

$$\sigma = \sigma_p \cdot W_d , \qquad (1)$$

where W_d is the probability of decay (or secondary interaction) of the supposed particle and σ_p the cross section of its production. This criterion characterizes both the independence of event production and decay (secondary interaction) and the isolation of a decaying system. The observability of the distance between the production and secondary interaction points is likely to be a particular case of this criterion.

(B) The universality of W_d, in other words, the similarity of its properties in various reactions, relativistic invariance of Wd (independence of the coordinate system) and the probability to assign definite quantum numbers to the decaying system including the mass belong to this criteria.

The aim of this paper is to show using various experimental material that the formulated criteria of microobject observability are executed for the objects having colour charges. In other words, quarks are as observable as unstable particles. Our analysis is based on a new relativistic invariant approach to the description of multiple particle process and on a new definition of jets [1]. The traditional analysis of the jet behaviour of secondary particles is performed with the aid of variables "sphericity", "thrust" and other which are not relativistic invariant quantities. The jet characteristics depend not only on the reference frame but also on the properties of colliding particles. Thus, traditionally identified jets do not satisfy the above criteria selecting independent objects. In the old approach jets represent only strong pecularities in angular distributions.

First applications to the description of jets of the relativistic invariant approach have discovered not only jet universal properties but also the similarity of quark and diquark fragmentation functions [1,2] considered to be different previously.

In the invariant method of analysing multiple particle production, the processes

$$I + II \longrightarrow 1 + 2 + 3 + \ldots \qquad (2)$$

are considered in a space the points of which are the four-velocities $u_i = P_i / m_i$, where P_i are the four-momenta; and m_i, the masses of particles.

The positive invariant quantities having the meaning of the squared distance in this space

$$b_{ik} = -(u_i - u_k)^2 = 2[(u_i u_k) - 1], \qquad (3)$$

where $i, k = I, II, 1, 2, 3, \ldots$, are basic variables describing the relative particle motion.

The idea of introducing the b_{ik} variables consists in that the interactions of quarks from objects i and k decrease monotonously and rather rapidly with increasing b_{ik} by analogy with a decrease of the Coulomb interaction between particles with increasing their relative velocity. This experimental fact can be formulated as a correlation depletion principle (CDP) in the relative velocity space by analogy with Bogolubov's principle of statistical Physics. The CDP leads to that the distributions, describing multiple particle processes, are

factorized in the four-velocity space b_{ik}, i.e. they decay into factors relating to different clusters in this space.

Using the CDP, a new approach to hadron jets has been formulated: the jet is considered as a cluster with relatively small b_{ik} values in the relative velocity space. The jet axis is determined as a single four-vector V that is extracted from the condition of minimum of the quantity:

$$\sum_k b_k = -\sum_k (V - u_k)^2. \qquad (4)$$

Summation is performed for all particles belonging to a separate group of particles. Quantity (4) is minimal for

$$V = \sum_k u_k / \sqrt{(\sum_k u_k)^2}. \qquad (5)$$

It should be stressed that in the traditional determination of jets the jet axis is not a four-vector but a single three-vector. Energetic variables do not take part in the old determination of jets.

The CDP shows that the cross sections of jet production, i.e. the cross sections of the processes:

$$I + II \longrightarrow \mathrm{Jet}^{\alpha} + \mathrm{Jet}^{\beta} + \ldots \qquad (6)$$

are factorized

$$\tau = \tau_p \cdot W^{\alpha}(b_k) \cdot W^{\beta}(b_k) \ldots \qquad (7)$$

Thus, the process of four-dimensional hadron jet productions satisfies the criterion (A).

The goal of the present paper is a further test of the universality of relativistic invariant quantities W^{α}, W^{β}, etc., i.e. the satisfaction of the criterion (B) for jets.

To prove the universality of W^{α} and W^{β}, i.e. the similarity of their properties in different reactions and the invariance of their properties is to show evidence for the observability of objects having colour charges.

The similarity of hadron jet properties studied even by traditional methods is shown in papers [2,4,5]. The hadron jet properties produced in soft $\pi^- p$ and cumulative $\pi^- C$ interactions at an incident pion momentum of 40 GeV/c are compared with similar data for e^+e^- annihilation and deep-inelastic $\nu(\bar{\nu})p$ scattering for equal energies in the c.m.s. Figure 1

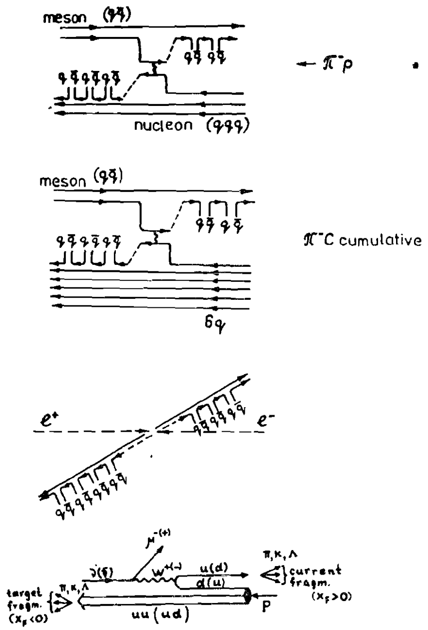


Fig. 1. The diagrams of different processes.

presents possible diagrams of hadron jet production in the processes in question. As shown in papers [2,4,5], in soft π^-p and cumulative π^-C interactions it is observed the production of two hadron jets emitted in the forward and backward hemispheres in the c.m.s., which can be due to the fragmentation of noninteracting quark from incident π^- meson and diquark from nucleons or a multiquark system of carbon nucleus.

The main conclusion of this analysis lies in that the fragmentation functions of quarks into hadrons are similar for these different processes. The same can be said of the fragmentation function of diquarks in the interactions under study. However, the fragmentation functions of quarks F_q and diquarks F_{qq} into hadrons are different [4]. The latter contradicts the representation that the jet properties are due to interactions of colour charges with vacuum. The results of comparison of soft hadron interactions at various energies have shown that the hadron jet properties depend on collision energy [4,5]. This fact is also in disagreement with the criterion (B). These differences in the jet characteristics are due to a relativistic nonvariant approach.

In this paper we present results of the study of hadron jet production by the new method in various processes ($\bar{p}p$, pp, π^-p, π^-C, pC, pTa and $\bar{\nu}N$) to prove the universality of W^α and W^β, i.e. to show that they reflect secondary interaction properties of the isolated objects. The present analysis was performed using different devices and accelerators over a wide energy range from 6 to 205 GeV/c*. The four-dimensional hadron jets are in full agreement with both (A) and (B) criteria, and it is the main result of this paper.

* *The four-dimensional jet production in soft and hard, specifically nuclear (cumulative) and annihilation processes, is under study.*

2. EXPERIMENTAL METHOD

The present analysis was performed using a set of experimental data on hadron-hadron, hadron-nucleus and $\tilde{\nu}N$ interactions. The types of interactions and event statistics are presented in Table 1.

Table 1.

Statistics of Events

NN	Type of collision	P_{lab} GeV/c	Statistics
1	pp	205	5025
2	π^-p	40	17376
3	π^-C	40	8791
4	$\bar{p}p$	22.4	44877
5	$\bar{p}p$	12	72099
6	$\bar{p}p$	5.7	68103
7	$p(C_3H_8)$	10	2732
	pTa	10	1913
8	$\tilde{\nu}N$	$\langle E_{\tilde{\nu}} \rangle = 35$ GeV	8000

The data on 40 GeV/c π^-p and π^-C interactions and 22.4 GeV/c $\bar{p}p$ collisions were obtained with the aid of a 2m propane and a 2m hydrogen ("Ludmila") bubble chambers exposed to π^- and $\bar{p}$ beams at the Serpukhov accelerator. The results for 10 GeV/c $p(C_3H_8)$ and pTa interactions were obtained by irradiating the 2m propane bubble chamber with Ta plates inside its working volume at the Synchrophasotron. The data on 205 GeV/c pp collisions and 5.7 and 12 GeV/c $\bar{p}p$ collisions were obtained with the help of the 76 cm hydrogen chamber (FNAL) and the 81 cm and 2m hydrogen chambers (CERN).

The data on $\tilde{\nu}N$ interactions were obtained with the aid of a 15-foot bubble chamber filled with a neon-hydrogen mixture (64% of Ne atoms) at the FNAL accelerator by the IHEP-ITEP-FNAL-Michigan University Collaboration. The chamber was exposed to a beam of muon antineutrinos with a broad energy spectrum. Altogether ~ 8000 interactions were measured.

$$\tilde{\nu} + N \longrightarrow \mu^+ + \sum_i h_i ,$$

in which $E_\mu \geq 4$ GeV and $E_{\tilde{\nu}} \geq 10$ GeV; in this case $\langle E_{\tilde{\nu}} \rangle = 35$ GeV [6].

The experimental details are described in refs. [6-13]. Data summary tapes containing information on the kinematical parameters of events were used in this analysis. Secondary protons were identified by ionization from 0.18 to 0.8 GeV/c in the propane chamber and from 0.1 to 1.5 GeV/c in the hydrogen chambers. The remaining charged particles were classified as π^+ mesons. In order to obtain the jet characteristics under identical experimental conditions, protons with $P_{lab} \geq 0.8$ GeV/c were taken to be π^+ mesons in all the experiments.

3. HADRON JET SELECTION

The selection of the particle belonging to the jet is made by means of relativistic invariant variables [14]:

$$x_p^i = \frac{m_i}{m_I}\,\frac{(u_i\, u_{II})}{(u_I\, u_{II})} \quad \text{and} \quad x_t^i = \frac{m_i}{m_{II}}\,\frac{(u_i\, u_I)}{(u_I\, u_{II})}, \qquad (8)$$

where index I denotes an incident particle, II a target and i secondary particles. For the case of nuclear collisions the atomic mass unit $m_0 = 931$ MeV is substituted for m_{II}.

The 4-momentum fraction of primary hadrons carried away by secondary particles is characterized by the x_p and x_t variables. Figure 2 illustrates a two-dimensional x_t and x_p diagram for $\pi^{\pm}$ mesons from π^-C interactions at P = 40 GeV/c that has a typical form for all the processes under investigation. The region of large x_t values corresponds to the target fragmentation and x_p the beam fragmentation. As is seen from Fig.2, already for $x_p(x_t) \geq 0.1$ and $x_t(x_p) < 0.1$ the beam and target fragmentation regions are rather well separated. Therefore the $\pi^{\pm}$ mesons, for which $x_t \geq 0.1$

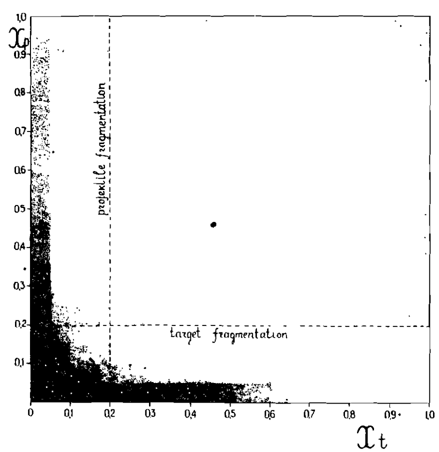


Fig. 2. The x_t and x_p distributions of secondary $\pi^{\pm}$ mesons in π^-C collisions at 40 GeV/c. The fragmentation region $x_{t,p} \geq 0.2$ is denoted by the broken line.

and $x_p < 0.1$, were attributed to the jet produced in the target fragmentation region; the pions with $x_p \geq 0.1$ and $x_t < 0.1$ were selected in the beam fragmentation region. Approximately 2% of particles are in the overlap region ($x_p > 0.1$ and $x_t > 0.1$) where the particles cannot be attributed to one or another jet. With larger probability these particles are due to hard processes as their average transverse momentum is 1.7±0.1 GeV/c. In addition, in the range $x_t < 0.1$ and $x_p < 0.1$ the quark-quark interaction is assumed to manifest itself significantly in hadron-hadron [3] and hadron-nucleus collisions, and hence it is excluded from the consideration.

For more strict selection criteria the $\pi^{\pm}$ mesons with $x_t \geq 0.2$ and $x_p < 0.2$ were attributed to the jet in the target fragmentation region and the ones with $x_p \geq 0.2$ and $x_t < 0.2$ in the beam fragmentation region.

Diffraction events were excluded from hadron-hadron collisions when comparing various types of interactions.

4. HADRON JET PROPERTIES IN SOFT HADRON-HADRON AND HADRON-NUCLEUS INTERACTIONS

Figures 3-6 show the $b_k(4)$ distributions of π^- mesons normalized to unit for π^-p, π^-C, $\bar{p}p$ [14] and pp interactions in the beam and target fragmentation regions. Table 2 presents the average values of $\langle b_k(\pi^-)\rangle$ in the jets for various types of interactions in the fragmentation regions of the beam ($x_p \geq 0.1$, $x_t < 0.1$) and the target ($x_t \geq 0.1$, $x_p < 0.1$). The distributions in Figs. 3-5 and the data of Table 2 imply that the b_k distribution of π^- mesons in the jets has a universal character and depends on neither the energy nor the type of interactions for $P_{lab} \geq 22$ GeV/c. Note that

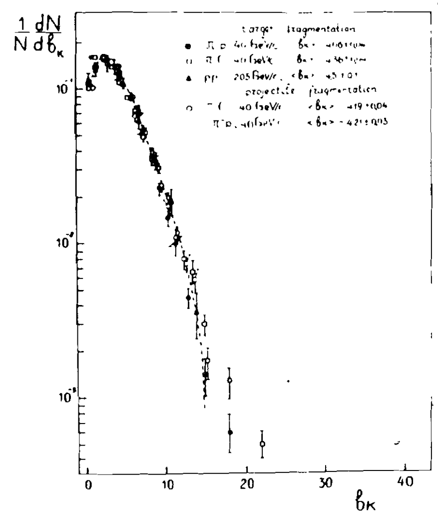


Fig. 3. The b_k distribution of π^- mesons for 40 GeV/c π^-p and π^-C and 205 GeV/c pp collisions in the fragmentation region of beam ($x_p \geq 0.1$ and $x_t < 0.1$) and targets ($x_t \geq 0.1$ and $x_p < 0.1$).

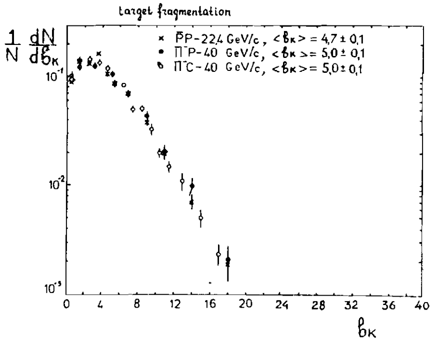
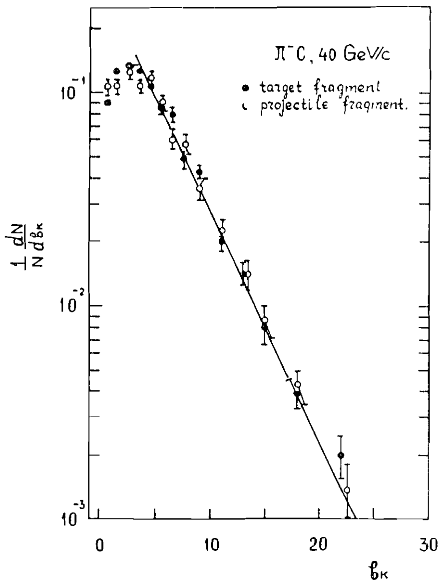


Fig. 4. The b_k distributions of π^- mesons for 22.4 GeV/c $\bar{p}p$ collisions, 40 GeV/c π^-p and π^-C collisions in the target fragmentation region.

Fig. 5. The b_k distributions of π^- mesons for 40 GeV/c π^-C interactions in the fragmentation region of target ($x_t \geq 0.2$, $x_p < 0.2$) and beam ($x_p \geq 0.2$, $x_t < 0.2$). The solid line is the approximation of the data by the exponential dependence.



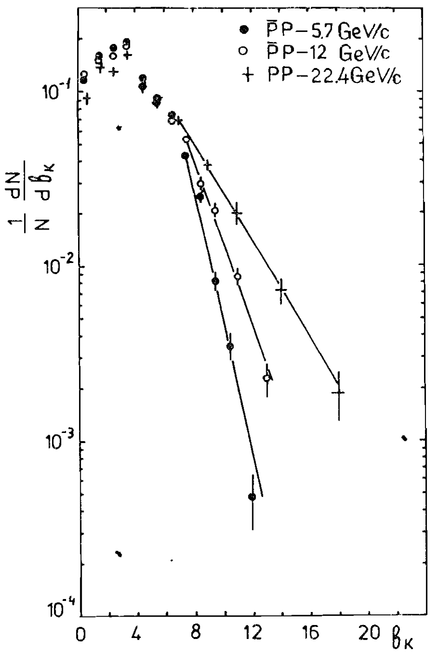


Fig. 6. The b_k distributions of π^- mesons for 5.7, 12 and 22 GeV/c $\bar{p}p$ collisions in the target fragmentation region ($x_t \geq 0.2$, $x_p < 0.2$).

this universality manifests itself more distinctly when the selection of the particles belonging to the fragmentation regions ($x_p \geq 0.2$ and $x_t \geq 0.2$) becomes more strict (see Figs. 4 and 5). The agreement of the distributions for π^-p and π^-C interactions in the beam and target fragmentation regions

Table 2.

The Average $\langle b_k \rangle$ Values for π^- Mesons

Type of collisions	P_{lab}, (GeV/c) W, GeV	Fragmentation region	$\langle b_k(\pi^-) \rangle$ *)
pp	205($\sqrt{s}$ = 19.7)	target fragment.	4.5 ± 0.1
π^-p	40($\sqrt{s}$ = 8.7)	beam fragment.	4.21 ± 0.03
π^-C	40	beam fragment.	4.19 ± 0.04
νN	<W>= 8	current fragment.	4.12 ± 0.17
π^-p	40($\sqrt{s}$ = 8.7)	target fragment.	4.06 ± 0.04
π^-C	40	target fragment.	4.36 ± 0.04
νN	<W> = 8	target fragment.	4.16 ± 0.30
$\bar{p}p$	22.4($\sqrt{s}$ = 6.6)	target fragment.	3.95 ± 0.03
νN	<W> = 4.9	current fragment.	3.68 ± 0.11
$\bar{\nu} N$	<W> = 3.5	current fragment.	3.17 ± 0.11
$\bar{\nu} N$	<W> = 4.9	target fragment.	3.45 ± 0.19
$p(C_3H_8)$+pTa	10	target fragment.	2.13 ± 0.04
$\bar{p}p$	12($\sqrt{s}$ = 4.9)	target fragment.	3.53 ± 0.01
$\bar{p}p$	5.7($\sqrt{s}$ = 3.6)	target fragment.	3.21 ± 0.01
$\bar{\nu} N$	<W> = 3.5	target fragment.	2.75 ± 0.15

* *Statistical errors are presented in the table. The systematic errors that are due to the incorrect identification of positive particles are 5÷10%.*

means that the fragmentation functions of quarks, diquarks and multiquark systems into pions in these variables have a universal character in contrast to their description by means of the traditional nonvariant variables [2,4,5]. From these data it also follows that the carbon nucleus has no influence on pion jet production which shows evidence for that it occurs outside the nucleus. From Fig. 6 and Table 2 it is also seen that at P_{lab} < 22 GeV/c the b_k distributions become much narrower and the average values of $\langle b_k \rangle$ decrease. This fact can be due to a limitation on the phase volume for lower energies that leads to narrowness of the b_k distributions. In addition, the fraction of annihilation processes increases (to 40%) in $\bar{p}p$ collisions at $P_{lab} <$ 22 GeV/c. According to the conventional notions /15/ , it can have a multijet character which also results in decreasing the $\langle b_k \rangle$ values.

Thus, the analysis of the b_k distributions of π^- mesons in the jets shows their universality which is independent of neither the collision energy at P_{lab} = 22 - 205 GeV/c nor the type of a fragmenting system (p, π^-, $\bar{p}$ and C). The squared mean 4-velocity of π^- mesons relative to the jet axis in the fragmentation of protons is characterized by $\langle b_k \rangle \simeq 4$.

The observed universality of the hadron jet b_k distributions in soft hadron-hadron and hadron-nucleus collisions at $P_{lab} \geq$ 22 GeV/c means that the hadronization of quarks, diquarks and multiquarks systems in these variables is the same at high energies in contrast to the traditional nonvariant variables which give substantial dependences on the energy and type of a quark system. The universality of the hadron jet properties can be interpreted as a characteristic of colour charge interaction with QCD-vacuum.

5. HADRON JET PROPERTIES IN DEEP INELASTIC $\tilde{\nu}$N COLLISIONS

Interest has been aroused in the invariant method of analysing hadron jets aplicable to hard processes, in which the jets are produced in the hadronization of colour objects in vacuum, and the comparison of their properties with the jet ones in soft hadron-hadron and hadron-nucleus collisions where we deal with colourless objects. It is of particular interest to analyse the hadron jet properties in deep inelastic lepton-nucleon collisions in which, according to the existing notations, the "isolated" (knocked-out) quark, hadronized in vacuum, and the diquark, whose hadronization is similar to the soft one of quarks and diquarks in hadron-hadron collisions, are produced.

For this purpose we have made the analysis of the hadron jet properties using the experimental material on $\tilde{\nu}$N interactions obtained by the IHEP-ITEP-FNAL and Michigan University Collaboration. The statistics of events and the average $\langle E_{\tilde{\nu}}$ value are presented in Table 1. The events with $Q^2 = -q^2 \geq 1$ (GeV/c)^2 and

$$x_B = \frac{Q^2}{2M\nu} \geq 0.1, \qquad (9)$$

have been selected to separate deep inelastic $\tilde{\nu}$N collisions with valent u-quarks, where q is the four-momentum transferred to the nucleon, m the nucleon mass and $\nu = E_{\tilde{\nu}} - E_{\mu^+}$ the energy of hadrons in the laboratory system. For separation of the multiple particle production region $W^2 \geq 9$ GeV^2 (W is the total hadron energy in the c.m.s.). According to these criteria, 2383 interactions are selected. The conditions $\sum_i e_i = 0$ or 1 and $n_N \leq 1$ (e_i is the charge of secondary particles and n_N the number of secondary nucleons in the interaction) are used to exclude nuclear effects that are due to cascade nucleon reproduction in the neon nucleus. As a result, we have selected for the analysis about 1000 events of deep inelastic $\tilde{\nu}$ collisions with valent u-quarks and $W \geq 3$ GeV.

According to the traditional conceptions in $\tilde{\nu}$N collisions, the particles with $y_i^* > 0$ (where y_i^* is the rapidity in the hadron c.m.s.) are attributed to the knocked-out quark jet and those with $y_i^* < 0$ to the jet produced by diquark from nucleon. For the pion jets selected in such a way (protons are not considered in this analysis) the jet axis is taken by formula (5) and the b_k distribution (4) of π^- mesons is obtained by analogy with the hadron-hadron and hadron-nucleus collisions considered earlier. In order to clear up the energy dependence of the pion b_k distributions, $\tilde{\nu}$N collisions are divided into three energy intervals:
1) W = 3÷4 GeV, 2) W = 4÷6 GeV and 3) W ≥ 6 GeV.
Figure 7 shows the b_k distributions of $\pi^{\pm}$ mesons (the π^+ and π^- meson b_k distributions are similar) in the jets produced in the fragmentation of knocked-out quark and diquark for the three energy intervals of the hadron system. In the $b_k \geq 2$ region all the distributions have an exponential character.

The average $\langle b_k \rangle$ value and B slope distributions obtained by approximating by the dependence

$$\frac{dN}{db_k} = A \exp(-b_k/B), \qquad (10)$$

are given in Table 3.

As is shown from the table, the average $\langle b_k \rangle$ and B values are similar within the experimental error for the quark and diquark fragmentation at the same W energy and grow with increasing W. In this case the average jet size is equal to $\langle b_k \rangle$ = 3÷4.

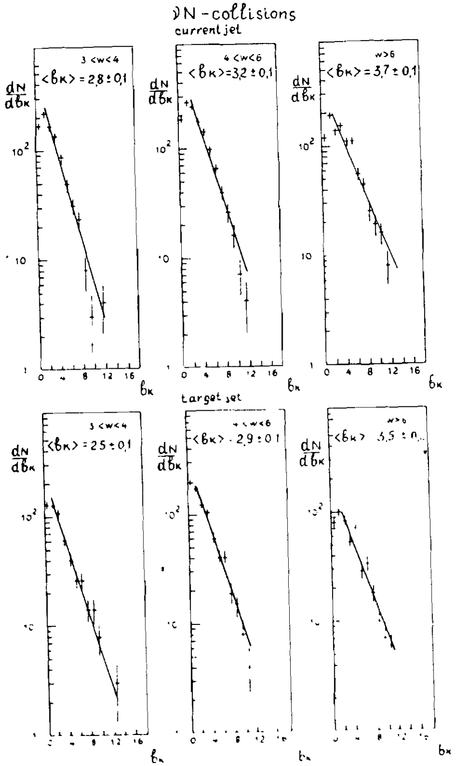


Fig. 7. The b_k distributions of $\pi^{\pm}$ mesons in $\tilde{\nu}N$ collisions in the fragmentation region of current and target in different W energy intervals. The solid lines show the results of approximating data by the exponential dependence.

For comparison with the data on hadron-hadron and hadron-nucleus collisions, the jets in $\tilde{\nu}N$ collisions are selected by X variable cutting similarly to jet selection in soft hadron-hadron and hadron-nucleus collisions. Denote the jet production process in $\tilde{\nu}N$ collisions as follows:

$$\tilde{\nu} + N \longrightarrow J_q + J_{qq} , \qquad (11)$$

where J_q is the knocked-out quark jet and J_{qq} the diquark jet. The particles, belonging to one or another jet, are selected with the aid of the invariant variables:

$$x_q^k = \frac{(P_{qq} \cdot P_k)}{(P_q \cdot P_{qq})} \geq 0.1 , \qquad (12)$$

$$x_{qq}^k = \frac{(P_q \cdot P_k)}{(P_q \cdot P_{qq})} \geq 0.1 , \qquad (13)$$

$$P_q = xP_N + q , \quad P_{qq} = (1 - x)P_N .$$

Here P_N, P_k are the four-momenta of a nucleon and a k-th particle; indices q(qq) show the particles belonging to the jet of knocked-out quark or diquark. In addition, in order to separate hadrons in the overlap jet region, the following condition is used: $y_k^* \geq 0$ for quark fragmentation and $y_k^* < 0$ for diquark one. The b_k values of π^- mesons obtained in this jet selection for the three energy intervals are presented in Table 2. As is seen from the Table, the $< b_k(\pi^-)>$ values for $\tilde{\nu}N$ interactions coincide, within a single error, with the $<b_k(\pi^-)>$ value for the soft jets in hadron-hadron and hadron-nucleus collisions at equal energies $\sqrt{s} = W$ in the c.m.s.

Table 3.
The Average $<b_k>$ Values and Slope B for π^- Mesons in $\tilde{\nu}N$ Collisions

W, GeV	Current Fragmentation		Target Fragmentation	
	$<b_k>$	B	$<b_k>$	B
3 - 4	2.8 ± 0.1	2.5 ± 0.3	2.54 ± 0.12	2.22 ± 0.26
4 - 6	3.22 ± 0.09	2.71 ± 0.20	2.91 ± 0.13	2.58 ± 0.25
≥ 6	3.71 ± 0.12	3.52 ± 0.26	3.47 ± 0.17	3.95 ± 0.66

Thus, these results imply that the hadronization of quarks and diquarks in soft and hard interactions in the 4-velocity space is universal in character and independent of neither the production nor the properties of the colour quark system. All these data show evidence that the jet properties are determined by the neutralization of colour charge in vacuum.

CONCLUSION

The analysis of hadron jet production in hadron-hadron, hadron-nucleus and $\tilde{\nu}N$ collisions in an energy range of P_{lab} = = 6÷205 GeV has been made in the frame of the new relativistic invariant approach [1,3]. The total statistics is approximately 228 thousand events.

Figure 8 shows the main results of this analysis: the average $<b_k>$ values of the squared four-velocity for pions relative to the axis of the jets produced in different ($\bar{p}p$, π^-p, π^-C, pp and $\tilde{\nu}N$) processes depending on the energy $\sqrt{s}$ = W in the c.m.s. . The figure also presents similar $<b_k>$ calculations for π^- mesons in the beam and target fragmentations for 40 and 360 GeV/c π^-p collisions simulated by the LUND-model [16]. The simulated distributions agree with the experimental π^-p

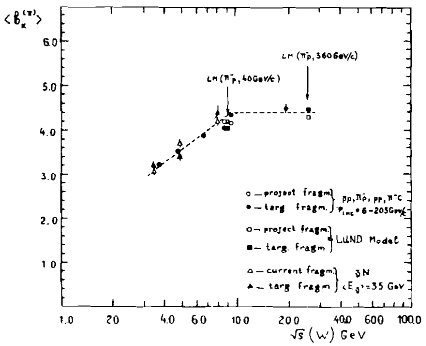


Fig. 8. The dependence of the average $\langle b_k \rangle$ *values of* π^- *mesons in jets of various processes on* $\sqrt{s} = W$ *in the c.m.s.*

data [17]. As seen from the figure, the average $\langle b_k \rangle$ values in the jets grow with increasing $\sqrt{s} = W$, and for $\sqrt{s} > 6$ GeV $(b_{J_1 J_2} = -(V_{J_1} - V_{J_2})^2 > 10)$ they reach the asymptotic regime. The average pion jets size is $\langle b_k \rangle \simeq 4$. This analysis has shown that the b_k distributions of hadrons in the jets have a universal character in soft and hard collisions independent of neither the type of a fragmentating system $(N, \pi^-, \bar{p}, C, q)$ nor the collision energy for $P_{lab} \geq 22$ GeV/c $(\sqrt{s} = W > 6$ GeV). This universality is due to the interaction properties of colour charges with vacuum and means that the colour charge hadronization in vacuum has a statistical character independent of the production method. It reaches the asymptotic regime at $E_q (E_{qq}) \geq 3$ GeV.

The QCD calculation of these distributions as universal parameters of strong interaction physics is of particular interest.

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17.	Theory of condenced matter
18.	Applied researches
19.	Biophysics

Балдин А.М. и др. E1-87-142

Универсальные четырехмерные струи и наблюдаемость цветных зарядов

На основе нового определения струй как кластеров в четырехмерном пространстве относительных скоростей проводится инвариантный анализ струйного рождения адронов в глубоконеупругих $\bar{\nu}N$ -взаимодействиях для трех интервалов энергий адронных систем: $\langle W \rangle$ = 3,5; 4,9; 8,0 ГэВ. Полученные результаты сравниваются с характеристиками четырехмерных струй в разных типах взаимодействий: pp, $\bar{p}p$, $\pi^- p$, $\pi^- C$, pC и pTa в области энергий 6÷205 ГэВ. Показано, что характеристики четырехмерных струй в мягких и жестких взаимодействиях универсальны, т.е. не зависят ни от типа фрагментирующей системы (π^-, p, $\bar{p}$, C, q), ни от первичной энергии $P_{лаб} \geq 22$ ГэВ/с ($\sqrt{s} = W > 6$ ГэВ).

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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Baldin A.M. et al. E1-87-142

Universal Four-Dimensional Hadron Jets and the Observability of Colour Charges

A new definition of the jets as clusters in the four-velocity space has been used to make an invariant analysis of the jet production processes in $\bar{\nu}N$ collisions for the three energy intervals of the hadron system: $\langle W \rangle$ = 3.5; 4.9; 8.0 GeV. The obtained results are compared with the characteristics of the four-dimensional jets in various types of interactions: pp, $\bar{p}p$, $\pi^- p$, $\pi^- C$, pC and pTa at energies from 6 to 205 GeV. The characteristics of the four-dimensional jets in soft and hard interactions are shown to be universal, i.e. independent of neither the type of the fragmenting system (p, $\bar{p}$, π^-, C, q) nor the collision energy for $P_{lab} \geq 22$ GeV/c ($\sqrt{s} = W > 6$ GeV). The obtained result means that the hadronization of the colour charges is determined by the dynamics of their interaction with vacuum.

The investigation has been performed at the Laboratory of High Energies, JINR.

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