объединенный
институт
ядерных
исследований
дубна

E1-84-317

A.M.Baldin, L.A.Didenko, V.G.Grishin,
A.A.Kuznetsov, Z.V.Metreveli*

HADRON JETS IN CUMULATIVE PROCESSES FOR π^-C INTERACTIONS AT P = 40 GeV/c

Submitted to the XXII International
Conference on High Energy Physics
(Leipzig, 1984)

* IHEP, Tbilisi State University, USSR

1984

1. INTRODUCTION

The analysis of multiple hadron production in different processes, such as e^+e^- annihilation, deep-inelastic lepton-hadron collisions and soft hadron-hadron interactions, has shown that the production of hadron jets, which have a number of universal properties, is observed in these interactions [1-10]. Collective characteristics of the jets, "sphericity", "thrust" and others, the multiplicity of hadrons and their momentum distributions in the jets coincide for these processes at equal energies in the c.m.s. The observed similarity of the properties of hadron jets is probably due to the existence of single mechanism of quark hadronization for soft and hard interactions.

It is of interest to study the properties of hadron jets produced in hadron-nucleus collisions which can give information on the influence of nuclear matter on their formation and will allow one to establish more general regularities of quark hadronization for different types of interactions.

Cumulative processes are of principal interest [11-14]. In this case quark-parton structure functions determined due to multiquark states in nuclei, are obtained from data on limiting nuclear fragmentation ($E \geq 3 \div 4$ GeV).

Quark hadronization from multiquark nuclear states is practically unstudied. Therefore it is particularly interesting to select jets in the region of nuclear fragmentation and to compare them with the properties of hadron jets in e^+e^- and hadron-hadron interactions.

This paper is devoted to the study of jet production in cumulative π^-C interactions at 40 GeV/c. The results obtained are compared with e^+e^- and π^-p data at $P = 40$ GeV/c.

Figure 1 presents possible diagrams of the fragmentation production of hadron jets for π^-p, e^+e^- and cumulative π^-C interactions. The analysis carried out in [8-10] has shown that the production of two hadron jets in π^-p interactions, collimated towards an incident pion and in an opposite direction, can be mainly considered as a result of the fragmentation of noninteracting $\bar{u}(d)$ quarks (forward hemisphere in the c.m.s.) and uu(ud) diquarks (backward hemisphere in the c.m.s.) from primary particles. Similarly, the production of secondary particle jets in the c.m.s. of π^-C interactions can be presented as a result of the fragmentation of noninteracting $\bar{u}(d)$ quarks from incident π^--meson in the forward hemisphere and

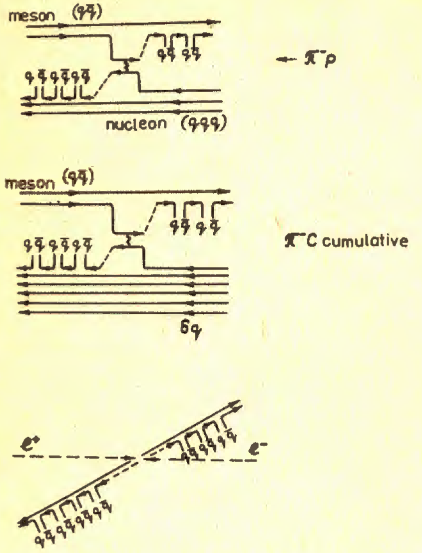

Fig.1. Schemes of π^-p, cumulative π^-C and e^+e^- interactions.

as a result of quark fragmentation from multiquark states of carbon nucleus in the backward hemisphere (region of target-nucleus fragmentation).

In this paper we study the fragmentation of quarks and diquarks into charged pions, neutral strange K^0-mesons and Λ-hyperons and collective characteristics of jets.

2. EXPERIMENT

Experimental data have been obtained using the 2m propane bubble chamber exposed to a beam of 40 GeV/c π^--mesons at the Serpukhov accelerator. The work was done on statistics of 6480 π^-C interactions* in which charged pions and protons were measured (the latter were identified over a momentum range of $200 \leq P_{lab} \leq 800$ MeV/c), 550 K^0_s-mesons ($K^0_s \to \pi^+\pi^-$) and 294 Λ-hyperons ($\Lambda \to p\pi^-$) were also used in the analysis. 11688 inelastic π^-p interactions with 753 K^0_s-mesons and 345 Λ-hyperons were used to compare with the π^-C data.

The method of selection of π^-p and π^-C interactions, the identification of neutral strange particles and a further processing of the events are described in detail in papers /15-20/.

Multinucleon π^-C interactions with the total charge of secondary particles $Q = N_+ - N_- = +1, +2, +3, +4$, where N_+ and N_- are the numbers of secondary positive and negative particles per interaction, were selected for the analysis. In this case the protons having $P_{lab} \leq 300$ MeV/c were excluded as in this region the fraction of spectator protons from the target-nucleus is large. For each group of multinucleon π^-C interactions with charge Q the analysis was performed in the c.m.s. of incident π^--meson and the corresponding number of nucleons (ν_n) involved in the interaction. In the events with Q = +1 there were two interacting protons, with Q = +2 three protons and so on. As neutrons also participate in these collisions, their number was estimated by the momentum conservation law for the events with given Q in the collision c.m.s. /21/.

*Pion interactions with quasi-free nucleons were excluded.

Table 1

Statistics of events

Type of interaction	Q	Average number of interacting nucleons	Energy $E_{c.m.s.}$ (GeV)	Number of events with given Q and $n_\pm \geq 4$	Fraction of events in % with given Q from all π^-C interactions
1	2	3	4	5	6
Multinucleon interactions	+1			2032	15
	+2			970	7
	+			395	3
	+4			138	1
	all			3535	28
Events with cumulative jets $\beta_0 \geq 1.0$	+1	3.0	15.3	1183	8.7
	+2	3.8	17.3	776	5.7
	+3	5.0	20.0	333	2.5
	+4	5.5	21.0	127	0.9
	all			2419	18
Events with cumulative jets $\beta_0 \geq 1.5$	+1	3.7	17.0	664	4.9
	+2	4.2	18.2	576	4.3
	+3	5.0	20.0	283	2.1
	+4	5.5	21.0	114	0.8
	all			1637	12.1

The energy of collision is defined by the formula

$$E_{c.m.s.} = \sqrt{S} = \sqrt{2\nu_n m_N E_\pi} \qquad (1)$$

with m_N the nucleon mass and E_π the energy of incident pion. Such an approach makes it possible to observe the change of the properties of hadron jets, produced on nuclei, with increasing the number of nucleons involved in the interaction what is somewhat similar to an investigation of the properties of hadron jets versus the atomic number of target-nucleus.

Table 1 presents the number of events selected with charge Q = +1, +2, +3, +4 and their fraction (in %) of the total cross section of π^-C interactions.

The cumulative events were selected using variable $\beta_i = \frac{E_i - P_{\parallel i}}{m_N}$, where E_i and $P_{\parallel i}$ are the energy and longitudinal momentum of secondary particles in the lab.system. According to the established selection criteria /22/, an event was assumed to be cumulative if a $\pi^\pm$-meson with $\beta_i \geq 0.6$ or a proton with

$\beta_i \geq 1$ was registrated in it. However, the hadronization of quarks from multiquark nuclear states can occur so that none of the particles has the value of β_i outside the kinematical limit of pion-nucleon collision whereas the sum of all β_i in a jet, produced in quark hadronization, is larger than 1.

$$\beta_0 = \sum_i \beta_i > 1,0 . \qquad (2)$$

As is shown [21], the events with cumulative particles incompletely reflect all cumulative processes and their configuration in momentum space. Thus, cumulative interactions were selected according to the condition (2): the events were selected in which the value of β_0 for a group (jet) of particles, moving backward in the c.m.s. $(\pi^- \nu_n)$, was larger than 1. A group of particles satisfying the condition (2) was assumed to be a cumulative jet.

Table 1 presents the number of cumulative events thus selected and their fraction of all π^-C interactions. The fraction of cumulative jets with K^0-mesons and Λ-hyperons was respectively ~8% and 10% of all cumulative jets.

3. JET STRUCTURE

The study of jet particle production in π^-C interactions has been performed using the standard variables: sphericity S and thrust T. Sphericity S is defined as follows:

$$S = \frac{3}{2} \min\left(\sum_i P_{\perp i}^2 / \sum_i |\vec{P}_i^*|^2\right) \qquad (3)$$

with $\vec{P}_i^*$ the momenta of secondary particles in the collision c.m.s. and $P_{\perp i}$ the transverse momenta of particle relative to some axis.

The axis, for which $\sum_i P_{\perp i}^2$ has a minimum value, is assumed to be a jet axis. Thrust T is found according to the formula:

$$T = \max\left(\sum_i |P_{\parallel i}^*| / \sum_i |\vec{P}_i^*|\right). \qquad (4)$$

Here $P_{\parallel i}^*$ is the projection of the momenta of secondary particles on some direction. The jet axis is defined as an axis which maximizes the sum $\sum |P_{\parallel i}^*|$. These variables are described in detail in paper [23]. It should be noted that variables S and T determine the jet cone opening angle.

Figure 2 shows the dependence of average values of sphericity <S> on collision energy $E_{c.m.s.}$ for e^+e^- annihilation [24-27]. An average value of S for π^-p interactions at $E_{c.m.s.} = 8.7$ GeV is also shown by an arrow. In the same figure are presented average values of <S> versus $E_{c.m.s.}$ for the jets

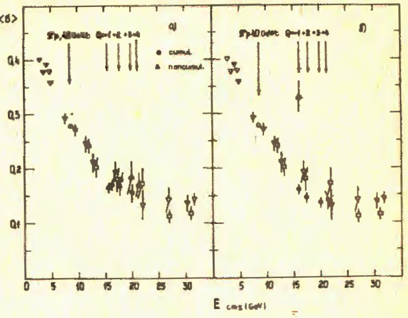

Fig.2. Average values of sphericity <S> for different types of interactions with $n_{\pm} \geq 4$ versus energy in the c.m.s. of colliding particles: ∇ , □ - for e^+e^- annihilations; ● - for cumulative π^-C interactions with $\beta_0 > 1.0$; ▲ - for noncumulative π^-C collisions; a) for jets of secondary particles with $x_i \geq 0.05$; b) for jets of secondary particles with $x_i \leq -0.05$.

of secondary particles collimated towards a primary pion and in an opposite direction in the cumulative ($\beta_0 > 1.0$) and noncumulative ($\beta_0 < 1.0$) events. The particles, having $|x_i| = \frac{2|P_{\parallel i}^*|}{E_{c.m.s.}} \geq 0.05$ refer to the jets. For comparison with the e^+e^- data the jets were selected in which the multiplicity of charged particles, $n_{\pm}$, was ≥ 4. As seen from the figure, the value of <S> for both jets in cumulative π^-C interactions agrees with the e^+e^- data at equal energies in the c.m.s. For the noncumulative events one can see a disagreement with similar data on e^+e^- interactions for the hadron jets produced in the fragmentation region of target-nucleus. An analogous picture is observed when comparing the values of variable T.

In order to rule out a possible influence of such nuclear effects as Fermi-motion and pion absorption in the nucleus which can lead to the production of particles and groups of particles with the value of $\beta_{i,0}$ outside the kinematical limit of pion-nucleon collision, we have selected jets with $\beta_0 \geq 1.5$. In Table 1 are presented the number of events satisfying this condition and their fraction of all π^-C interactions with $n_{\pm} \geq 4$.

For the cumulative jets thus selected the dependence of average values of <S> on energy $E_{c.m.s.}$ does not differ from that presented in fig.2.

4. MULTIPLICITY OF SECONDARY PARTICLES

1. Multiplicity of Charged Particles

It is known that in various types of hadron-hadron interactions and in e^+e^- annihilation the multiplicity of charged particles is different: e.g., in pp collisions the average va-

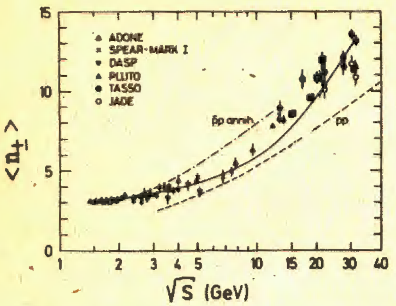

Fig.3. Average multiplicity of charged particles, $<n_{\pm}>$, versus energy in the c.m.s. for e^+e^- and cumulative π^-C interactions (■). Solid curve - QCD prediction for e^+e^- annihilation.

lues of $<n_{\pm}>$ are smaller than in e^+e^- annihilation at the same energies in the c.m.s. (fig.3), and in π^-p and K^-p interactions the values of $<n_{\pm}>$ coincide with the e^+e^- data at $\sqrt{S} \le 12$ GeV [3-6]. It is of interest to compare the multiplicity $<n_{\pm}>$ in e^+e^- annihilation and in cumulative processes.

Figure 3 depicts the average multiplicity of charged particles versus $\sqrt{S}$ in e^+e^- and cumulative π^-C collisions. It is seen that in cumulative processes the value of $<n_{\pm}>$ increases with increasing $E_{c.m.s.}$, and, within experimental errors, it coincides with the values of $<n_{\pm}>$ for e^+e^- annihilation at equal $E_{c.m.s.}$. However, the analysis has shown that this increase of $<n_{\pm}>$ in cumulative processes is greatly due to increasing the number of protons in the final state [21].

2. Multiplicities of Neutral Strange Particles

Table 2 shows the average multiplicities of K^n-mesons and Λ-hyperons in π^-p and cumulative π^-C interactions with charge $Q = +1, +2$. As is seen from the table, the multiplicities of K^n-mesons and Λ-hyperons in cumulative interactions are larger than in pion-proton collisions. Nevertheless, in π^-C events the multiplicity of neutral kaons increases proportionally to the average multiplicity of π^o-mesons, $<n_{\pi^o}>$, in these events* so that within the experimental errors, the ratio $\frac{<n_{K^n}>}{<n_{\pi^o}>}$ is similar for these interactions. Consequently, in cumulative processes no additional sources of strange meson production are observed as compared to neutral pions.

In comparison with the multiplicity of Λ-hyperons in pion-nucleon collisions, the multiplicity of Λ-hyperons in cumulative events increases approximately in proportion to the number of nucleons involved in the interaction.

* It is supposed that γ-quanta in the events are mainly produced from the decays of π^o-mesons, therefore $<n_{\pi^o}> = ½<n_{\gamma}>$.

Table 2

Multiplicities of K^n-mesons and Λ-hyperons in π^-p and cumulative π^-C interactions

Type of interaction	π^-p		π^-C, $Q = +1, +2$, $<\nu_n> \cong 3.3$	
Type of particles	K^n	Λ	K^n	Λ
$<n_{K,\Lambda}>$	0.23±0.01	0.065±0.006	0.34±0.02	0.16±0.01
$\frac{<n_{K,\Lambda}>}{<n_{\pi^o}>}$	0.090±0.006	0.025±0.002	0.098±0.006	0.045±0.004
$\frac{<n_{K,\Lambda}>}{<\nu_n>}$	0.23±0.01	0.065±0.006	0.102±0.006	0.047±0.004

Within the experimental errors, the ratio $\frac{<n_{\Lambda}>}{<\nu_n>}$ is similar for π^-p and π^-C interactions.

5. CHARACTERISTICS OF CHARGED PARTICLES IN JETS

Besides the analysis of the collective characteristics of the jets, sphericity and thrust, it is interesting to compare one-particle momentum distributions of secondary particles in the jets for cumulative π^-C and e^+e^- interactions.

In fig.4 is shown the transverse momentum squared distribution of all secondary particles in cumulative interactions with $Q = +1$ relative to the jet axis. The $P_{\perp}^2$ distributions of particles are similar, within the experimental errors, for the jets produced in the forward and backward hemisphere in the c.m.s. of $(\pi^-\nu_n)$ collisions. So figure 4 presents the summed distribution for both hemispheres. The transverse squared distribution of charged particles relative to the jet axis in e^+e^- annihilation for approximately close energies ($\sqrt{S}$ = = 13÷17 GeV) is given in the same figure for comparison. As seen, these distributions are similar for both types of the interactions considered.

Figure 5 illustrates the $x_{\parallel} = \frac{2P_{\parallel}}{E_{c.m.s.}}$ distributions of secondary particles in the forward and backward hemispheres in the c.m.s. of π^-C interactions with $Q = +1$, where $P_{\parallel}$ is the longitudinal momentum of particles relative to the jet axis. The data are compared with a similar distribution for e^+e^- annihilation at $\sqrt{S}$ = 7.4 GeV [28]. The distribution is normalized so that the area under it in the range $|x_{\parallel}| \ge 0.1$ is the same as in π^-C events.

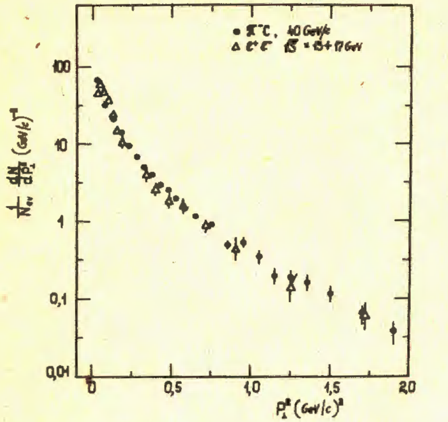

Fig.4. Transverse momentum squared distribution of charged particles relative to the jet axis in cumulative π^-C collisions at $\sqrt{S}$ = 15.3 GeV (●) and in e^+e^- annihilation at $\sqrt{S}$ = 13÷17 GeV.

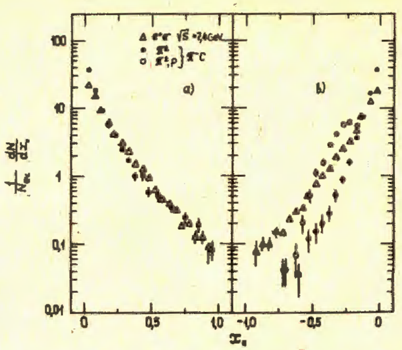

Fig.5. $x_{\parallel}$ distribution of charged particles relative to the jet axis in cumulative π^-C interactions at $\sqrt{S}$ = 15.3 GeV and in e^+e^- annihilation at $\sqrt{S}$ = 7.4 GeV; a) distribution of particles in jets flying in the c.m.s.; b) distribution of particles in jets flying backward in the c.m.s.

From the figure one can see that in cumulative π^-C collisions the distribution of particles in the jets, collimated towards an incident π^--meson, is in agreement with a similar distribution in e^+e^- interactions. For particles, produced in the fragmentation nuclear region in these events (both for pions and for protons), the $x_{\parallel}$ distribution relative to the jet axis differs from a similar distribution of charged particles in e^+e^- annihilation.

This difference can be due to variations of initial states of interacting objects which leads to various compositions of secondary particles in the final state and to distributions in their phase space distributions (in cumulative π^-C interactions with Q = +1 the average number of nucleons, $\langle\nu_n\rangle$, is 3.3 whereas in e^+e^- annihilations at $\sqrt{S}$ = 7.4 GeV the mean multiplicity of $p\bar{p}$ pairs per event $\langle n_{p\bar{p}}\rangle$ is < 0.1).

Therefore it would be more correct to compare identical systems of secondary particles in the final state (in this case meson ones) in their rest frame.

With this aim the events with two identified protons were selected from cumulative π^-C interactions with Q = +1. The protons were excluded from the analysis; the energy of the remaining meson system, $\langle M_0\rangle$, was 10 GeV. The value of $\langle M_0\rangle$ was decreased by 6% if the fraction of neutrons in the final state was accounted for.

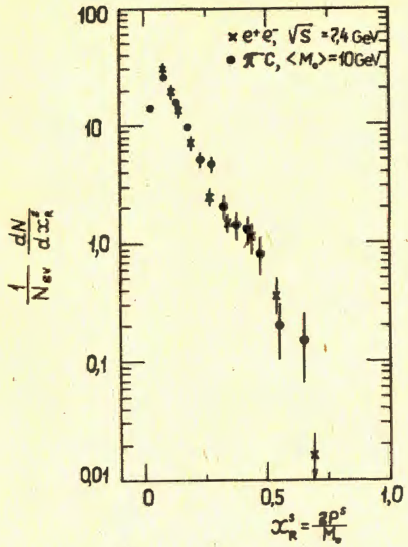

Fig.6. x_R^s distribution of pions in cumulative π^-C collisions for $\langle M_0\rangle \simeq 10$ GeV and in e^+e^- annihilation for $\sqrt{S}$ = 7.4 GeV.

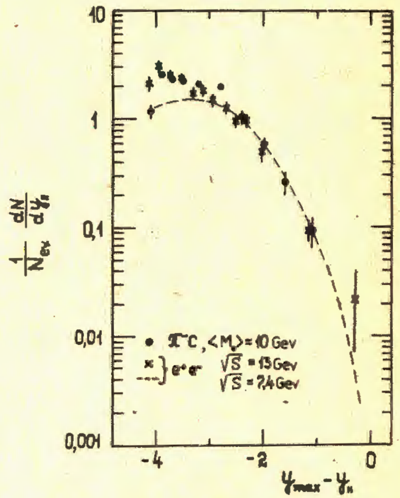

Fig.7. $y_{\parallel}^s$ distribution of pions for cumulative π^-C interactions at $\langle M_0\rangle = 10$ GeV and e^+e^- annihilation at $\sqrt{S}$ = 13 GeV and 7.4 GeV.

The $x_R^s = \frac{2P^s}{M_0}$ and $y_{\parallel}^s$ distributions of charged pions calculated in the rest frame of mesons (M_0), were analyzed. In this case P^s is the total momentum of pions in their rest frame M_0 and $y_{\parallel}^s$ the rapidity determined relative to the jet axis in the same system (the jet axis was reconstructed by variable T).

In such an approach the production of pion jets in the fragmentation region of target-nucleus can be interpreted as a result of the fragmentation of quarks from multiquark states of carbon nucleus.

Figures 6 and 7 compare the $\frac{dN}{dx_R^s}$ and $\frac{dN}{dy^s}$ distributions of charged pions, produced in the nuclear fragmentation region for cumulative π^-C events at $\langle M_0\rangle = 10$ GeV, with the x_R and $y_{\parallel}$ distributions of pions in e^+e^- annihilation for approximately equal energies $\sqrt{S}$. As seen from the figures, these distributions of pions are similar for both types of interaction.

6. QUARK AND DIQUARK FRAGMENTATION INTO STRANGE PARTICLES

1. Fragmentation Functions

Comparing the processes of quark and diquark fragmentation into neutral K^n-mesons and Λ-hyperons for various types of interaction, we use the scaling function $\frac{S}{\beta}\frac{d\sigma}{dx_E}$ in terms of which the e^+e^-data are analyzed. Here $x_E = 2E^*/\sqrt{S}$; $\beta = P^*/E^*$; P^* and E^* are the momentum and energy of the considered hadron in the collision c.m.s. According to quark-parton model predictions, for quark fragmentation this function depends only on variable x_E:

$$\frac{S}{\beta}\frac{d\sigma}{dx_E} \sim F_q(x_E). \qquad (5)$$

As taking into account factor S is important only for e^+e^- annihilation, we analyze the function $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ as in paper [10].

2. Fragmentation of U(d) Quarks into Strange Particles

Figures 8 and 9 present the $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ function versus x_E for neutral K^n-mesons and Λ-hyperons produced in the cumulative processes in the forward hemisphere in the c.m.s. of $\pi^-\nu_n$ collisions. Similar distributions for neutral strange particles in π^-p and e^+e^- interactions are given in the same figures [31,32]. From the figures one can see that, within the experimental errors, the dependence of the function $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ on x_E is similar for K^n-mesons and Λ-hyperons in cumulative π^-C, π^-p and e^+e^- interactions. The $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ distributions for K^n and Λ-particles can be approximated by the exponential dependence

$$\frac{1}{\beta}\frac{d\sigma}{dx_E} = A\exp(-Bx_E). \qquad (6)$$

The values of parameter B and the range of approximation in π^-p, cumulative π^-C and e^+e^- collisions are shown in Table 3. From the Table it is seen that, within the experimental errors, the slopes of the $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ distributions determined by parameter B coincide for K^n-mesons and Λ-hyperons, producted in quark fragmentation (forward hemisphere), in cumulative π^-C, π^-p and e^+e^- collisions.

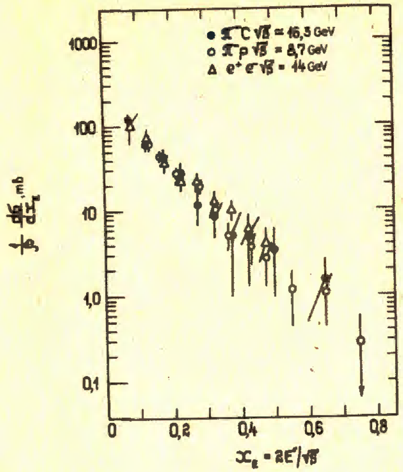

Fig.8. $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ distribution for K^n-mesons in the forward hemisphere in the c.m.s. for cumulative π^-C, π^-p and e^+e^- interactions. The distributions of K^n-mesons in π^-p and e^+e^- are normalized to the area under their $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ distribution in cumulative π^-C interactions.

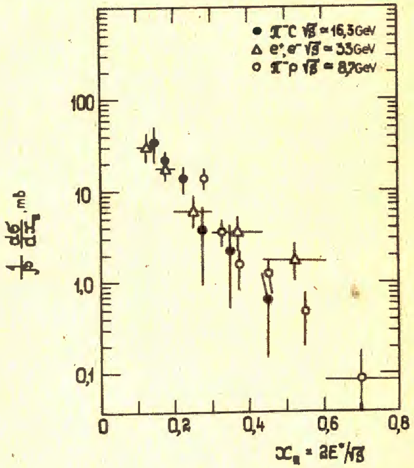

Fig.9. $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ distribution for Λ-hyperons in the forward hemisphere in the c.m.s. for cumulative π^-C, π^-p and e^+e^- collisions. Normalization is the same.

The average multiplicities of K^n-mesons and Λ-hyperons, produced in quark fragmentation in π^-p and cumulative π^-C interactions, are also similar:

$$\langle n_K\rangle_{\pi^-C} = 0.072 \pm 0.014; \quad \langle n_K\rangle_{\pi^-p} = 0.065 \pm 0.005 \quad \text{for } 0.2 \le x_E \le 0.5;$$

$$\langle n_\Lambda\rangle_{\pi^-C} = 0.006 \pm 0.003; \quad \langle n_\Lambda\rangle_{\pi^-p} = 0.006 \pm 0.001 \quad \text{for } 0.3 \le x_E \le 0.6.$$

These values of $\langle n_K\rangle$ and $\langle n_\Lambda\rangle$ are in approximate agreement with the average multiplicity of K^n-mesons and Λ-hyperons produced in e^+e^- collisions due to strange sea quarks [33,34] in the same x_E range.

Using the data obtained, we have made an attempt to evaluate a relative pickup probability of strange $s(\bar{s})$ quarks from the sea in comparison with $u(\bar{u})$ and $d(\bar{d})$ quarks. This probability can be determined by $\lambda_s = \frac{\langle n_K\rangle}{\langle n_\pi\rangle}$. The value of λ_s for

Table 3

Values of parameter B

Type of particles, type of events	Forward in the c.m.s.	Range of approximation	Backward in the c.m.s.	Range of approximation
K^n - mesons $\pi^- C$ - cumul.	9 ± 2	$x_E \geq$ 0,I	8 + 4	$x_E^s \geq$ 0,I5
K^n - mesons $\pi^- p$, 40 GeV/c	IO ± I	$x_E \geq$ 0,I5	9 + I	$x_E \geq$ 0,I5
Λ - hyperons $\pi^- C$ - cumul.	I8 ± 4	$x_E \geq$ 0,I5	5,2±0,7	$x_E^s \geq$ 0,2
Λ - hyperons $\pi^- p$, 40 GeV/c	3 ± 3	$x_E \geq$ 0,3	3,6±0,4	$x_E \geq$ 0,3
Λ - hyperons $\pi^- p$ 16 GeV/c	IO ± I	$x_E \geq$ 0,45	4,4 ±0,3	$x_E \geq$ 0,45
K^n, Λ particles e^+e^-	~ 8	$x_E \geq$ 0,I	-	-

cumulative $\pi^- C$ interactions turned out to be 0.18±0.03 what, within the experimental errors, agrees with that of λ_s obtained for $\pi^- p$ and e^+e^- collisions /10,33,34/. For quark fragmentation a relative pickup probability of diquarks from the sea determined by the relation $\lambda_{qq} = \frac{\langle n_\Lambda \rangle}{\langle n_K \rangle}$ was 0.11±0.06. The same value of λ_{qq} was obtained in $\pi^- p$ interactions (0.14±0.03)/10/ and e^+e^- annihilation (~0.08) /32/.

3. Diquark Fragmentation into Strange Particles

As is shown in the previous paragraph, in order to compare correctly the properties of hadron jets in various types of interactions, it is necessary to select identical systems of secondary particles in the final state. This is the reason why for comparison of the properties of K^n-mesons and Λ-hyperons, produced in the target-nucleus fragmentation region in cumulative processes, with the $\pi^- p$ and e^+e^- data, we have selected a system of secondary particles consisting of mesons and a baryon. Then the production of Λ-hyperons and K^n-mesons in the backward hemisphere in the rest frame of the selected subsystem can be considered as a result of the fragmentation of uu, ud or dd diquarks from multiquark states of carbon nucleus and other baryons as spectators. Cumulative $\pi^- C$ collisions with Q = +1 and one identified proton, with Q = +2 and two protons were selected for this comparison. These protons were excluded from the analysis. The energy of the remaining subsystem of secondary particles $\langle M_0 \rangle$, was 12.3 GeV.

Figures 10 and 11 show the $\frac{1}{\beta}\frac{d\sigma}{dx_E^s}$ function versus x_E^s for K^n-mesons and Λ-hyperons produced in the target-nucleus fragmentation region for cumulative $\pi^- C$ interactions with Q = +1, +2. Here $x_E^s = \frac{2E^s}{M_0}$ and E^s is the energy of particles in the rest frame of subsystem M_0. In the figures are also presented the $\frac{1}{\beta}\frac{d\sigma}{dx_E}$ distributions for neutral strange particles from e^+e^- and $\pi^- p$ collisions in the backward hemisphere in the c.m.s. As is seen from the figures, the $\frac{1}{\beta}\frac{d\sigma}{dx_E^s}$ distributions for K^n-mesons and Λ-hyperons agree, within the experimental errors, in the considered x_E^s range for these different processes. Table 3 displays the slopes B of the $\frac{1}{\beta}\frac{d\sigma}{dx_E^s}$ distribution for neutral strange particles produced in the backward hemisphere in the rest frame of subsystem M_0. The slopes can be obtained by approximating these distributions

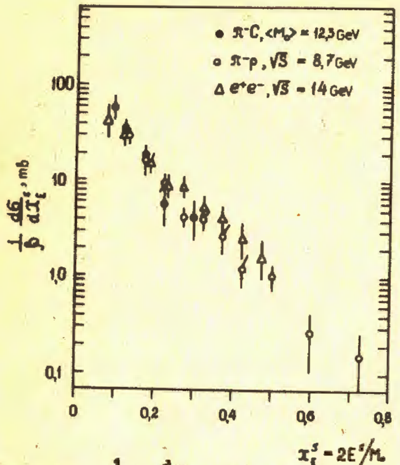

Fig.10. $\frac{1}{\beta}\frac{d\sigma}{dx_E^s}$ distribution for K^n-mesons in the backward hemisphere in the rest frame of subsystem M_0 for cumulative π^-C interactions. The comparison is made with the π^-p and e^+e^- data in the c.m.s.

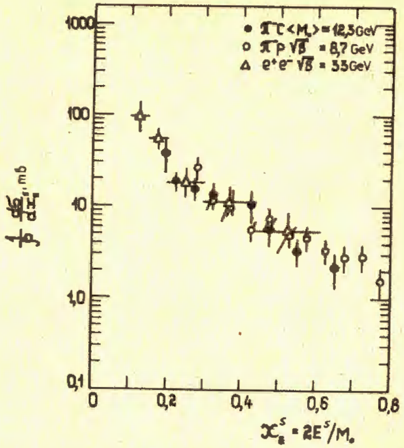

Fig.11. $\frac{1}{\beta}\frac{d\sigma}{dx_E^s}$ distribution for Λ-hyperons in the backward in the rest frame of subsysten M_0 for cumulative π^-C interactions. The comparison is made with the π^-p and e^+e^- data in the c.m.s.

by dependence (6). From the Table it is seen that the values of parameter B for K^n- and Λ-particles in cumulative events are consistent, within the errors, with the data. The value of slope B is also similar for K^n-mesons from cumulative events and e^+e^- annihilation. As for Λ-hyperons produced from diquark fragmentation in π^-p and cumulatice π^-C interactions, the slope B is smaller than in e^+e^- annihilation.

The results obtained mean that diquark fragmentation into neutral kaons and Λ-hyperons from multiquark states in light nuclei occurs in the same manner as diquark fragmentation into the same particles for soft hadron interactions.

7. MAIN CONCLUSIONS

Based on the analysis performed, the following main conclusions can be drawn:

1. In cumulative π^-C interactions with the number of interacting nucleons $\nu_n \leq 5$ the production of hadron jets is observed that are collimated towards an incident pion and in an opposite direction in the c.m.s. of $\pi^-\nu_n$ collisions. The value of sphericity for both jets coincide with the data for e^+e^- and hadron hadron interactions at equal energies in the c.m.s.

2. In π^-C interactions the longitudinal and transverse momentum distributions of pions for the cumulative jets and also for the jets collimated towards an incident pion agree with similar distributions of $\pi^{\pm}$-mesons in e^+e^- annihilation.

3. Within the experimental errors, the average multiplicity of charged particles in cumulative π^-C interactions is in agreement with the multiplicity $\langle n_{\pm}\rangle$ in e^+e^- annihilation for equal energies in the c.m.s.

4. The quark fragmentation functions $F_q^{K(\Lambda)}(x_E)$ for K^n-mesons and Λ-hyperons in cumulative π^-C, e^+e^- and soft π^-p collisions have a similar x_E-dependence. The mean multiplicities of K^n-mesons and Λ-hyperons produced in quark fragmentation due to the pickup of strange quarks from the sea, coincide, within the errors, in these interactions.

5. In cumulative π^-C interactions the diquark fragmentation functions $F_{qq}^{K(\Lambda)}(x_E)$ for K^n-mesons and Λ-hyperons from multiquark states of target-nucleus are consistent with similar π^-p data.

Within the errors, the fragmentation functions of diquarks $F_{qq}^K(x_E)$ in cumulative π^-C interactions and of quarks $F_q^K(x_E)$ in e^+e^- annihilation for K^n-mesons are similar in the range $x_E \leq 0.4$.

The results obtained indicate that the quark and diquark fragmentation into $\pi^{\pm}$-mesons and strange particles is universal in cumulative interactions on light nuclei, soft hadron collisions and e^+e^- annihilation.

The fragmentation of multiquark states on light nuclei is similar to that of quarks and diquarks in soft and hard collisions of particles.

REFERENCES

1. Basile M. et al. Phys.Lett., 1980, 92B, p.367; 95B, p.311; 1981, 99B, p.247.
2. Basile M. et al. Nuovo Cim., 1980, 58A, p.193; 1981, 65A, p.414; 1981, 65A, p.400; 1982, 67A, p.244; 1982, 67A, p.53.
3. Gottgens R. et al. Nucl.Phys., 1981, B178, p.392.
4. Grishin V.G. et al. Yad.Fiz., 1983, 37, p.915; JINR, P1-81-542, Dubna, 1981.
5. Barth M. et al. Nucl.Phys., 1981, B192, p.289.
6. Breakstrone A. et al. CERN/EP 81-68 Rev., Geneva, July, 1981.
7. Palmonary F. CERN-EP/82-176, Geneva, November, 1982.
8. Grishin V.G. et al. JINR, P1-83-306, Dubna, 1983.
9. Grishin V.G. et al. JINR, P1-83-823, Dubna, 1983.
10. Grishin V.G. et al. JINR, P1-84-79, Dubna, 1984.

11. Baldin A.M. ECHAYA, 1977, 8, p.429.
12. Baldin A.M. Proc. of IV Int.Seminar on High Energy Phys. Probl., JINR, D1-2-9227, Dubna, 1975.
13. Stavinsky V.S. ECHAYA, 1979, 10, p.949.
14. Baldin A.M. JINR, E1-80-545, Dubna, 1980.
15. BBCDSS TTU-BW. Collaboration. Phys.Lett., 1972, 39B, p.371.
16. Abdurakhimov A.U. et al. JINR, P1-6326, Dubna, 1972; Yad.Fiz., 1973, 18, p.545.
17. Angelov N. et al. JINR, P1-10324, Dubna, 1976; Yad.Fiz., 1977, 25, p.1013.
18. Abdurakhimov A.U. et al. JINR, P1-7267, Dubna, 1973; Yad.Fiz., 1973, 18, p.1251.
19. Angelov N. et al. JINR, P1-9648, Dubna, 1976; Yad.Fiz., 1977, 25, p.350; JINR, P1-9209, Dubna, 1975; Yad.Fiz., 1976, 24, p.732.
20. Angelov N. et al. JINR, P1-81-05, Dubna, 1981; Yad.Fiz., 1981, 34, p.1234.
21. Baldin A.M. et al. JINR, P1-83-483, Dubna, 1983.
22. Anoshin A.I. et al. Yad.Fiz., 1982, 36, p.409.
23. Brandt S., Dahman H.D. Z.Phys., 1979, C1, p.61.
24. Berger C. et al. Phys.Lett., 1979, 82B, p.449; 1978, 78B, p.176; 1979, 81B, p.410.
25. Brandelik R. et al. Phys.Lett., 1979, 83B, p.261.
26. Barber D. et al. Phys.Rev.Lett., 1979, 42, p.1113.
27. Günter W. DESY 80/85, Sept., 1980.
28. Hanson G.G. SLAC-Pub-1814, September, 1976.
29. Drell S.D. et al. Phys.Rev., 1969, 187, p.2159; 1970, D1, p.1617.
30. Wolf G. DESY 80/85, September, 1980.
31. Oberlack H. MPI-PAE/EXP, E1, 110, September, 1982.
32. Wolf G. DESY, 81-086, December, 1981.
33. Bartell W. et al. Z.Physik C., 1983, 20, p.187.

Received by Publishing Department
on May 4, 1984.

Балдин А.М. и др. E1-84-317

Струи адронов в кумулятивных процессах в π^-C-взаимодействиях при P = 40 ГэВ/с

Изучается образование струй адронов в кумулятивных π^-C-взаимодействиях при импульсе 40 ГэВ/с. Анализируются коллективные характеристики струй, множественности вторичных частиц, их импульсные распределения в струях. Изучаются функции фрагментации кварков $F_q^{K(\Lambda)}(x_E)$ и дикварков $F_{qq}^{K(\Lambda)}(x_E)$ из мультикварковых состояний ядра углерода в нейтральные странные частицы. Полученные результаты сравниваются с аналогичными данными для π^-p- и e^+e^--столкновений. Показано, что все изученные характеристики пионов в струях в кумулятивных π^-C-взаимодействиях и в e^+e^--аннигиляции одинаковы. Функция фрагментации кварков и дикварков в нейтральные странные частицы в кумулятивных π^-C-столкновениях и в π^-p-взаимодействиях совпадают. Совпадают также функции фрагментации кварков $F_q^{K(\Lambda)}(x_E)$ в странные частицы в кумулятивных π^-C-взаимодействиях и в e^+e^--аннигиляции.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1984

Baldin A.M. et al. E1-84-317

Hadron Jets in Cumulative Processes for π^-C Interactions at P = 40 GeV/c

The production of hadron jets is studied in cumulative π^-C interactions at 40 GeV/c. Collective characteristics, multiplicity and momentum distributions of secondary particles from the jets are analysed. The fragmentation functions of quarks $F_q^{K(\Lambda)}(x_E)$ and diquarks $F_{qq}^{K(\Lambda)}(x_E)$ from multiquark states for neutral strange particles are studied. The obtained results are compared with similar π^-p and e^+e^- data. It is shown that all pion characteristics studied from the jets in cumulative π^-C interactions and e^+e^- annihilation are simiiar. The quark and diquark fragmentation functions for neutral strange particles coincide, within the errors, in cumulative π^-C and π^-p collisions. The quark fragmentation functions $F_q^{K(\Lambda)}(x_E)$ for strange particles are also similar in cumulative π^-C interactions and e^+e^- annihilation.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1984