ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

E1-91-325

O.P.Gavrishchuk, V.F.Peresedov, L.S.Zolin

$K^{\pm}$ BACKWARD PRODUCTION IN pA INTERACTIONS AT 15-65 GeV

Submitted to "Nuclear Physics A"

1991

The production of high momentum mesons ($q \gtrsim 0.5$ GeV/c) at angles close to 180° in nuclear fragmentation under the influence of high energy beams is not an ordinary phenomenon because it cannot be explained within the framework of the simplified model of the nucleus with quasi free nucleons. One of the approaches used to explain this phenomenon arises from the hypothesis of interaction of a projectile with a density fluctuation of nuclear matter-flucton. This formation can be presented either as a multinucleon cluster |1| or as multiquark configuration |2,3| or as a few-nucleon correlation |4|. Constituent quarks of the flucton form a generalized multiquark system, and one of its quarks-partons can carry a momentum which is in the limit equal to the total momentum of all nucleons involved in such formation. We call hadrons, products of flucton fragmentation, "cumulative" according to |5|.

Using the model based on the hypothesis of the presence of multiquark configurations in nuclei, a successful quantitative reproduction of the spectra of cumulative pions has been made |6|. There has been no detailed comparision of model predictions with experimental data for kaons and antiprotons until recently. On the other hand, this was connected with insufficient data for K^- - and $\bar{p}$ -production at $\theta \simeq 180°$ and, on the other hand, cross section calculation for "sea" cumulative particles (K^-, $\bar{p}$) not containing valence quarks of the nucleus requires grounded notions about properties of the quark sea in nuclei.

In our experiment |7,8| we have measured differential production cross sections for positive and negative kaons at an angle of 159° (lab.system) in proton-nucleus collisions at a proton energy from 15 to 65 GeV. The experiment was carried out on an internal beam of the IHEP proton synchrotron (Serpukhov). 6 types of targets were used: Be, C, Al, Ti, Mo and W. The targets were prepared in the form of thin wires ($\varnothing < 100$ μ) to provide a multiple circulation of the internal proton beam across the target. This made it possible to take data on an increasing magnetic field of the accelerator and to have long runs without obstacles for the other users. The latter is important because of very small cross sections for backward cumulative particle production which is about I nb (at $q_k \simeq 0.8$ GeV/c) in the case of K^-. The momentum spectra of kaons were measured from 0.35 to 0.8 GeV/c which corresponds to the light front variable $\alpha=(E_k-q_k^{\parallel})/m_N$ from 1 to 1.9. The value of minimum target mass, x_m, measured in units of nucleon mass, m_N, is often used as a scaling variable to discribe cumulative data (x_m=1 corresponds to the kinematic limit for production on free nucleon at rest). The variable x_m coincides with and the Bjorken variable x at $E\to\infty$; x_m exceeds α by 5-10 % at our energies (15-65 GeV). The rise of the invariant cross sections for kaons is insignificant over an energy range from 15 to 65 GeV: it is on the average about 20 % as in the case of pions |8|. Further on we use the cross sections averaged over beam energy, E_p, with a mean value of $\bar{E}_o$ =40 GeV.

The normalized invariant cross sections of K^+- and K^- production, $\rho_k=(E_k/A)d\sigma/d^3q_k$, are presented in tables I and 2 and in figs.1 and 2. The indicated errors are statistical, the absolute normalization error is estimated to be 15 %. The invariant cross sections can be approximated by the exponents in the variables and T (kinetic energy of kaons): $\rho_k=C'\exp(-\alpha/\alpha_o)$ and $\rho_k=C\exp(-T/T_o)$. The dependences of the parameters α_o and T_o on mass number A are shown in fig.3. The slope of the spectra decreases with increasing A for K^+ and K^-, the "temperature" of the spectra, T_o, increases. However, the A-dependence of K^+ and K^- production is substantially different: as seen from fig.4, the ratio of the invariant cross sections for W and Be, ρ_W/ρ_{Be}, is equal to 10 for K^+ and about 2 for K^-. As a rule the A-dependence of particle production is cgaracterized by the power of mass number: $E_k d\sigma_{K^\pm}/dq_K^3 \sim A^{\alpha\pm}$. The dependence of $\pm$ on q_k is shown in fig.5; in the case of K^+ the A-dependence differs substantially (α^+ =1.6) from the volume type dependence, A^1.

It is shown |8| that main features of the EMC effect can be explaned if the nucleus is considered as a relativistic quantum system in which baryon number is conserved but the number of particles is not fixed. Due to vacuum polarization, the nucleus is not only the system of A nucleons but also the sea of particles-antiparticles which carries some part of nucleus momentum. As a consequence, an additional "collective" sea of $q\bar{q}$ - pairs as hard as the valence

TABLE I

Invariant cross section $(E/A)d\sigma/d^3q$ (mb $GeV^{-2}c^3$ sr^{-1}/nucleon) for the reaction $p+A\to K^+(159°)$ at $\bar{E}_p$ =40 GeV

q (GeV/c)	T (GeV)	Be	C	Al
0.350	0.111	(0.124±0.010)E-1	(0.198±0.039)E-1	(0.430±0.172)E-1
0.400	0.142	(0.640±0.045)E-2	(0.820±0.132)E-2	(0.280±0.084)E-1
0.450	0.174	(0.292±0.020)E-2	(0.390±0.062)E-2	(0.125±0.025)E-1
0.500	0.209	(0.105±0.010)E-2	(0.225±0.038)E-2	(0.680±0.340)E-2
0.550	0.245	(0.710±0.085)E-3	(0.660±0.185)E-3	(0.195±0.135)E-2
0.600	0.283	(0.262±0.016)E-3	(0.450±0.027)E-3	
0.650	0.322	(0.970±0.078)E-4	(0.181±0.015)E-3	(0.367±0.026)E-3
0.700	0.363	(0.436±0.048)E-4	(0.572±0.057)E-4	(0.172±0.016)E-3
0.750	0.404	(0.151±0.027)E-4	(0.197±0.032)E-4	(0.710±0.092)E-4
0.800	0.446		(0.750±0.180)E-5	(0.260±0.065)E-4

q (GeV/c)	T (GeV)	Ti	Mo	W
0.350	0.111	(0.560±0.168)E-1	(0.930±0.240)E-1	0.115±0.014
0.400	0.142	(0.300±0.087)E-1	(0.360±0.075)E-1	(0.525±0.058)E-1
0.450	0.174	(0.175±0.049)E-1	(0.173±0.075)E-1	(0.248±0.042)E-1
0.500	0.209	(0.660±0.250)E-2	(0.990±0.280)E-2	(0.910±0.136)E-2
0.550	0.245	(0.240±0.096)E-2	(0.330±0.155)E-2	(0.400±0.080)E-2
0.600	0.283	(0.172±0.012)E-2	(0.189±0.010)E-2	(0.206±0.012)E-2
0.650	0.322	(0.710±0.057)E-3	(0.750±0.045)E-3	(0.110±0.007)E-2
0.700	0.363	(0.263±0.031)E-3	(0.364±0.026)E-3	(0.447±0.027)E-3
0.750	0.404	(0.107±0.017)E-3	(0.114±0.012)E-3	(0.180±0.015)E-3
0.800	0.446	(0.290±0.087)E-4	(0.440±0.097)E-4	(0.880±0.088)E-4

TABLE II

Invariant cross section $(E/A)d\sigma/d^3q$ (mb $GeV^{-2}c^3$ sr^{-1}/nucleon) for the reaction $p+A \to K^-(159°)$ at $\bar{E}_p$ =40 GeV

q (GeV/c)	T (GeV)	Be	C	Al	Ti	Mo	W
0.350	0.111	(0.116±0.023)E-2		(0.250±0.150)E-2	(0.195±0.116)E-2	(0.220±0.100)E-2	(0.215±0.034)E-2
0.400	0.142	(0.700±0.105)E-3	(0.820±0.115)E-3	(0.500±0.500)E-3	(0.740±0.520)E-3	(0.133±0.040)E-2	(0.108±0.013)E-2
0.450	0.174	(0.353±0.049)E-3	(0.400±0.048)E-3	(0.102±0.061)E-2	(0.960±0.480)E-3	(0.450±0.148)E-3	(0.500±0.100)E-3
0.500	0.209	(0.118±0.029)E-3	(0.190±0.023)E-3		(0.410±0.246)E-3	(0.260±0.091)E-3	(0.182±0.045)E-3
0.550	0.245	(0.550±0.250)E-4	(0.112±0.022)E-3	(0.185±0.130)E-3	(0.150±0.150)E-3	(0.980±0.390)E-4	(0.760±0.230)E-4
0.600	0.283	(0.860±0.390)E-5	(0.213±0.055)E-4	(0.330±0.110)E-4	(0.670±0.200)E-4	(0.240±0.091)E-4	(0.500±0.080)E-4
0.650	0.322	(0.870±0.310)E-5	(0.107±0.029)E-4	(0.128±0.045)E-4	(0.167±0.075)E-4	(0.175±0.058)E-4	(0.157±0.031)E-4
0.700	0.363	(0.322±0.162)E-5	(0.590±0.114)E-5	(0.710±0.284)E-5	(0.700±0.490)E-5	(0.990±0.400)E-5	(0.113±0.025)E-5
0.750	0.404	(0.135±0.095)E-5	(0.354±0.114)E-5	(0.450±0.200)E-5	(0.880±0.530)E-5	(0.300±0.180)E-5	(0.380±0.113)E-5
0.800	0.446		(0.830±0.580)E-6		(0.450±0.450)E-5	(0.310±0.190)E-5	(0.270±0.135)E-5

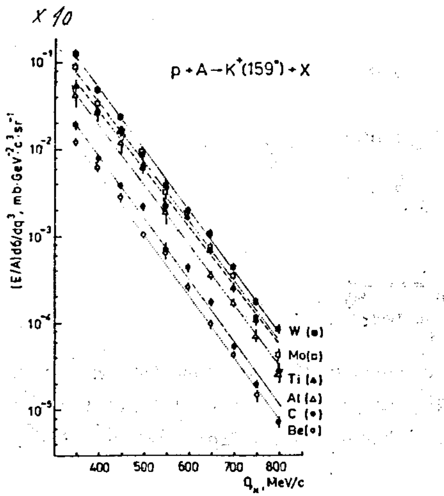

Fig.1. Invariant cross sections for the reaction $p+A \to K^+(159°)+X$.

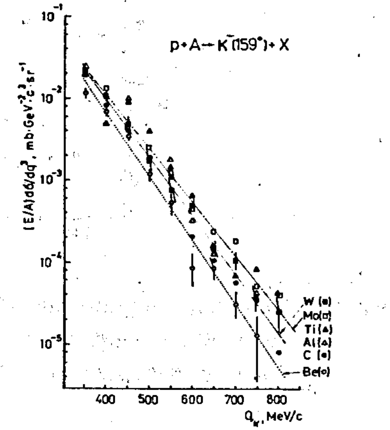

Fig.2. Invariant cross sections for the reaction $p+A \to K^-(159°)+X$, errors (statistical) are shown only for Be and W.

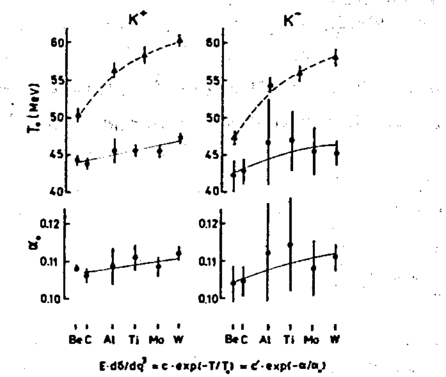

Fig.3. Dependence of the slope parameters, α_o and T_o, on A for the spectra of K^+(●) and K^-(o) at $\bar{E}_p$=40 GeV and θ_k=159°. ▲, △ -data for E_p=10 GeV and θ_k=119° |9|.

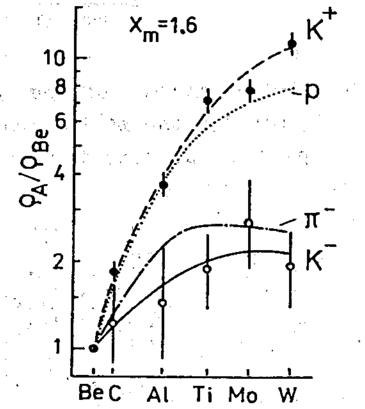

Fig.4. A-dependence of hadron production in the reaction $p+A \to h(159°)+X$ at $\bar{E}_p$ =40 GeV. The dependences for π and p are presented using the data from |8,10|.

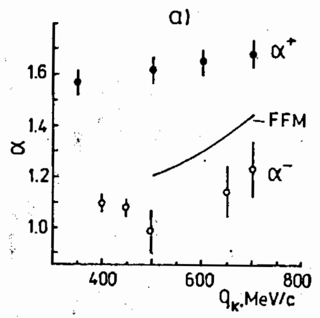

Fig.5. Momentum dependence of the power of mass number, $\alpha^{\pm}$, in case of presentation of $K^{\pm}$ cross section A-dependence in the form of $E d\sigma_{K^{\pm}}/d^3q \sim A^{\alpha\pm}$. Curve-prediction for K^+ |12|.

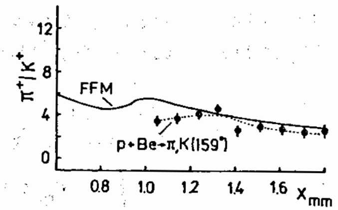

Fig.6. FFM-prediction of the quark model of flucton fragmentation |12| for the π^+/K^+-ratio in the reaction p+d→ π^+, K^+(180°). Points-our data for Be.

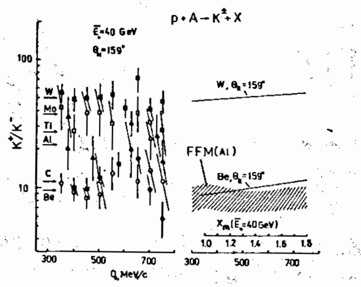

Fig.7. Ratio of the yields of K^+ - and K^- -mesons. Data for different A are depointed as in figs. 1,2. Arrows are mean values of K^+/K^- for separate A. Linear approximation of $K^+/K^-(x_m)$ and FFM-prediction for the reaction p+Al→ K^+(180°)+X are shown on the right.

quark distribution should exist in the nucleus along with the seas of quark-antiquarks and gluons in valence nucleons. This "collective" sea determines the spectrum of antiquarks at high x and also the spectrum of "sea" cumulative particles (K^-, $\bar{p}$). Proceeding from the assumtion of the concentration of the additional quark sea in fluctons, the authors of the Flucton Fragmentation Model (FFM) |12| have calculated the momentum spectrum of π^+ to K^+ in the reaction p+d→ π^+, K^+(180°). The reproduction of the experimental data was quite satisfactory for the flucton component in the deuteron (free parameter) equal to 3.6 %. The ratio π^+/K^+ calculated in this model is compared with our data for the Be nucleus (fig.6), the ratio and its x_m-dependences coincide well although the multiscattering effect in nuclei is not taken into account in this comparison.

The ratio of the K^+- and K^- yields must reflect a difference in the x-distribution of valence and sea quarks: this ratio should have a slight momentum dependence at $x > 0.5$ if the distribution of antiquarks in the "collective" sea is as hard as that of valence quarks |12|. The K^+/K^- ratio for our data is shown in fig.7. The observed dependence on x_m corresponds to the assumption of hardness of the quark sea in fluctons. Figure 7 also shows a quantitative FFM-prediction for the Al nucleus. In this case the observed x_m-dependence does not contradict the predicted one, but the predicted value of K^+/K^- is different. This distinction can be connected with the multiscattering effect as the cross sections of K^+N and K^-N differ substantially at $q_k < 1$ GeV/c.

Conclusion.

So, the momentum and A-dependences of $K^{\pm}$-production have been measured over a wide range of the cumulative variable x_m ($x_m \simeq \alpha$ =1-1.9) near 180° (at an angle of 159° where $q_k^{\perp}/q_k^{\parallel}$=0.35) and in an energy interval of 15-65 GeV where interactions of projectiles and target constituents take place mainly by far over confinement threshold and therefore quark-parton models of hadron production in nuclear fragmentation can be used as well-grounded ones. The spectra of "sea" hadrons (K^-, $\bar{p}$) make it possible to investigate the difference of the nucleus quark sea from the quark sea of free nucleons. Some predictions of the quark model of flucton fragmentation for cumulative kaons (x-dependences) are in accordance with our experimental data. However, correct taking into account distortions of the observed hadron spectra due to final state interactions in nuclei is required to compare quantitative model predictions with experimental data.

References

1) A.M.Baldin, Proc. of the 19-th Int.Conf. on High Energy Phys., Tokyo, 1978, p.155.
2) V.V.Burov, V.K.Lukyanov and A.I.Titov, Sov.J. Particles and Nuclei, vol.15, pp.558-579,1984 (publ. Amer.Inst.Phys.).
3) A.V.Efremov, Prog.Part.Nucl.Phys.,v.8, p. 345-365 (Pergamon, New York, 1982).
4) L.L.Frankfurt and M.I.Strikman, Phys.Rep. 86(1981)215.
5) A.M.Baldin, Sov.J.Particles and Nuclei, v.8(3), pp. 175-195, 1977 (publ. Amer.Inst. Phys.).
6) V.V.Burov, V.K.Lukyanov and A.I.Titov, Phys.Lett. B67(1977)46; JINR preprint E2-10680, Dubna (1977).
7) I.M.Belyaev et al., JINR Communication RI-88-34I and RI-88-342, Dubna (1988).
8) O.P.Gavrishchuk et al., Nucl.Phys. A253 (1991) 589.
9) S.V.Boyarinov et al., Sov.J.Nucl.Phys. 50 (1989) 1605.
10) I.M.Belyaev et al., JINR Communication RI-90-55I, Dubna (1990).
11) A.V.Efremov, Phys.Lett. B174 (1986) 776.
12) A.V.Efremov et al., Sov.J.Nucl.Phys.47 (1988) 868.

Received by Publishing Department
on July 12, 1991.

Гаврищук О.П., Переседов В.Ф., Золин Л.С. E1-91-325

Выход $K^{\pm}$ назад в pA взаимодействиях при 15-65 ГэВ

Измерены инвариантные сечения рождения K^+ и K^- мезонов под углом 159° на 6 ядерных мишенях (Be, C, Al, Ti, Mo, W) при энергии падающих протонов от 15 до 65 ГэВ. Импульсные спектры каонов измерены с использованием метода тонких внутренних мишеней на внутреннем пучке протонного синхротрона ИФВЭ (Серпухов). Спектры каонов исследованы в импульсном интервале от 350 до 800 МэВ/с, что соответствует интервалу значений переменной светового фронта $\alpha = 1 - 1{,}9$. А-зависимость сечений для K^+ и K^- существенно различна: $\sigma_k(W)/\sigma_k(Be)$ равно 10 для K^+ и около 2 для K^-. Отношение выходов K^+ и K^- демонстрирует слабую зависимость от α, но растет существенно с увеличением А: $R(Be) \cong 10$ и $R(W) \cong 50$. В рамках Модели Фрагментации Флуктонов $R(\alpha, A)$ может быть связано с перераспределением валентных и морских кварков в ядрах (в частности, с усилением кваркового моря во флуктонах).

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1991

Gavrishchuk O.P., Peresedov V.F., Zolin L.S. E1-91-325

$K^{\pm}$ Backward Production in pA Interactions at 15-65 GeV

The invariant cross sections of the yields of K^+ and K^- mesons are measured at an angle of 159° on 6 nuclear targets (Be, C, Al, Ti, Mo, W) at an incident proton energy from 15 to 65 GeV. The momentum spectra of kaons are measured by the method of thin target on an internal beam of the Serpukhov proton accelerator (IHEP). The kaon spectra are investigated in a momentum interval from 350 to 800 MeV/c what corresponds to the range of the light cone variable $\alpha = 1 \div 1.9$. The A-dependence of the K^+ and K^- cross sections is essentially different: $\sigma_k(W)/\sigma_k(Be)$ is equal to $\cong 10$ for K^+ and about 2 for K^-. The ratio R of the K^+ and K^- yields demonstrates a weak dependence on α, but it grows substantially with increasing A: $R(Be) \cong 10$ and $R(W) \cong 50$. In the frame of the Fluctuon Fragmentation Model $R(\alpha, A)$ can be connected with the redistribution of valent and sea quarks in the nucleus (in particular, with the reinforcement of the quark sea in fluctuons).

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1991