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CHARGED MULTIPLICITIES IN K^-p INTERACTIONS AT 110 GeV/c

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ABSTRACT

The charged multiplicity distribution is presented for K^-p interactions produced in the hydrogen bubble chamber, BEBC, using an RF separated, tagged K^- beam of 110 GeV/c momentum. A comparison with K^+p , πp and pp data at lower energies shows that the main features of the multiplicity distributions depend on energy and charge of the incident particles, but not on their strangeness. At high energies, only the energy is important.

The data were obtained from an exposure of the 3.7 m hydrogen bubble chamber BEBC to the RF separated, tagged K^- beam of 110 GeV/c momentum from the CERN SPS.

Tagging was necessary because at this energy the composition of the beam after the RF separation was $\sim 84\% K^-$, $10\% \bar{p}$ and $6\% \pi^-$ or μ^- .

The tagging system consisted of two threshold Cerenkov counters identifying incoming particles as K^- , $\bar{p}$ or π^-/μ^- , and two scintillation hodoscopes providing the horizontal position of the particles before entering and after traversing the two Cerenkov counters. After calibration, the hodoscopes allowed a prediction of the entrance position of beam particles in BEBC with an accuracy of ~ 1 cm in the horizontal plane. The vertical size of the beam was ~ 2 cm. Beam tracks were considered as K^- only if they were identified as kaons by the Cerenkov counters and if they matched unambiguously the hodoscope prediction. The tagging system is described more fully in ref. [1].

About 64% of beam tracks were labelled K^- : other incoming kaons were labelled $\bar{p}$ due to the Cerenkov inefficiency. In the kaon sample there was a 3% π/μ contamination and a negligible $\bar{p}$ contamination.

About 28 000 frames were triple scanned for all K^- interactions in a fiducial volume 3 m long. The combined scanning efficiency was practically 100% for events with four or more charged prongs and 90% for two prong events except for those with a short proton ($|t| < 0.05 \text{ GeV}^2$) which were mainly unseen. The missing cross section was estimated by extrapolating the t distribution of the observed two prong events to $t = 0$. For elastic events we used the differential cross section measured in ref. [2]; for inelastic events the loss at small $|t|$ was estimated to be $(0.05 \pm 0.03) \text{ mb}$.

A part of the film was scanned for all well-matched beam tracks labelled K^- , $\bar{p}$ or π^-/μ^- and their interactions. The corresponding cross sections were compatible with the beam composition calculated from the measured Cerenkov efficiency curves.

The topological cross sections were calculated by normalizing the corrected number of events to the total K^-p cross section at 110 GeV/c, $\sigma_T = (20.50 \pm 0.05)$ mb, deduced from ref. [3].

The observed multiplicity distribution was corrected for close V^0 and electron pairs, Dalitz pairs and close secondary interactions. The largest correction is due to unidentified electron pairs originating from the conversion of γ 's at small distances. The change of the average charged multiplicity due to all the corrections is smaller than one standard deviation.

Table 1 gives the numbers of events seen in scanning, the corrected number of events and the cross section for each topology.

The variation of the topological cross sections with the laboratory momentum p_{lab} is shown in fig. 1, where the curves are drawn to guide the eye. The data cover the range of p_{lab} up to 147 GeV/c, however the only experiment at momentum higher than ours is based on 481 events. At 110 GeV/c, the multiplicities 4, 6 and 8 account for approximately 2/3 of the total inelastic cross section. In this energy range the cross sections for multiplicities up to 4 are decreasing, the six and eight prong cross sections show little energy variation, and those for higher multiplicities rise rapidly with p_{lab} .

We find at 110 GeV/c that the average charged multiplicity $\langle n \rangle = 6.91 \pm 0.07$, the dispersion $D = \langle n^2 \rangle - \langle n \rangle^2 = 3.18 \pm 0.04$ and the correlation parameter for pairs of charged particles $f_2^{cc} = D^2 - \langle n \rangle = 3.18 \pm 0.28$.

The average charged multiplicity $\langle n \rangle$ is plotted in fig. 2(a) as a function of the square of the c.m. energy s . The data at other energies come from refs [4]-[8]. We parametrized the growth of $\langle n \rangle$ with energy by the formula

$$\langle n \rangle = a + b \ln s + c \ln^2 s \quad (1)$$

which gives a good fit to pp interactions [9].

The curve plotted in fig. 2(a) is the result of the best fit to the K^-p data which yields $a = 0.65 \pm 0.42$, $b = 0.61 \pm 0.22$, $c = 0.11 \pm 0.03$ and $\chi^2 = 9$ for 5 degrees of freedom.

A fit of eq. (1) with $c \equiv 0$ is poor, $\chi^2 = 24$ for 6 degrees of freedom. We conclude that the presence of a third term such as $\ln^2 s$ term is necessary to describe the growth of the multiplicity with s .

The parameter f_2^{cc} is plotted in fig. 2(b) as a function of s . At low energy f_2^{cc} is negative, it crosses zero at $s \approx 50$ GeV and then increases rapidly with $\ln s$. Eq. (1), but for f_2^{cc} instead of $\langle n \rangle$ fits the data of fig. 2(b) with a χ^2 of 4.2 for 5 degrees of freedom giving the results: $a = 3.6 \pm 1.4$, $b = -3.3 \pm 0.7$ and $c = 0.6 \pm 0.1$.

The energy variation of the multiplicity moments is remarkably similar for the non-annihilation reactions $K^\pm p$, $\pi^\pm p$ and pp . However, small systematic differences exist up to the highest momenta studied. For example, the average charged multiplicities for Kp are higher than for pp and lower than for πp interactions at the same value of s [10]. This is at least partly a kinematical effect due to the mass difference of the incident particles. Such effects are probably less important when a mutual variation of two multiplicity moments is studied, for example the dependence of the dispersion on the average charged multiplicity. Therefore we use the D versus $\langle n \rangle$ plot shown in fig. 3 to compare various reactions. For K^-p and K^+p the experimental points are plotted, including the results of recent high energy K^+p experiments [11]-[13]

It has been noticed [14] that in non-annihilation hadron-hadron collisions at high energy a linear relation holds between D and $\langle n \rangle$:

$$D = A \langle n \rangle + B = A (\langle n \rangle - \alpha) \quad (2)$$

with an universal slope $A \approx 0.55$ and an intercept $B \approx -0.5$. The parameter α was interpreted [15] as the average number of leading charged particles.

The lines in fig. 3 are the results of the fits with eq. (2) obtained in ref. [14], except for the low energy part of the π^-p curve which is drawn by hand through the π^-p data points.

At low incident momentum, the behaviour of negative (π^- or K^-) and positive (π^+ , K^+ or p) beam particles is clearly different. On the other hand, there is little difference between K^- and π^- as well as between K^+ and π^+ data. This implies that the charged particle multiplicity depends mainly on the charge and not on the strangeness of the incident particle.

At higher energy even the charge becomes unimportant. The straight lines for π^+p and π^-p in fig. 3 are compatible within errors [14] and agree with the K^+p experimental points.

A fit of eq. (2) to the five K^-p data points with $p_{\text{lab}} \geq 32$ GeV/c gives $A = 0.45 \pm 0.03$, $B = 0.06 \pm 0.14$. The slope is smaller than that for pp or πp interactions and the intercept is compatible with zero. The values obtained of A and B describe an average behaviour of the data at energies greater than 32 GeV, where the dependence of D on $\langle n \rangle$ may have some curvature due to a non-negligible contribution of the charge and hypercharge annihilation channels at 32 GeV.

The highest energy points at 70, 110 and 147 GeV are consistent with the universal slope and a non-zero intercept.

In terms of a simple quark model, the observed similarity of πp and Kp data at high energy means that multiparticle production is independent of quark flavours of the colliding particles.

A possible dependence on the number of constituent quarks at high energy is suggested by a small but significant difference between the pp and πp lines in the D versus $\langle n \rangle$ plot.

The charged multiplicity distributions for K^-p interactions at 110 GeV and at other energies are presented in fig. 4 in terms of the KNO variables $\langle n \rangle \sigma(n) / \sigma(\text{inel})$ versus $n / \langle n \rangle$ [16]. Within the statistical accuracy, the K^-p data in the energy range from 32 to 147 GeV lie on a single curve. This result seems to be in contrast with the pp case

where scaling is violated and the modified KNO variables $(\langle n \rangle - \alpha)\sigma(n)/\sigma(\text{inel})$ versus $(n - \alpha)/(\langle n \rangle - \alpha)$ describe the data more accurately [15],[17]. In fact, the observed agreement of the K^-p data with the KNO scaling may be accidental and limited to the energy range studied in which α happens to be zero. If the variation of D with $\langle n \rangle$ for K^-p has a non-zero intercept at higher energies, as suggested by fig. 3, then the KNO scaling law will be satisfied only approximately.

We conclude that the main features of the multiplicity distributions for meson-proton and proton-proton interactions depend primarily on the energy of the colliding particles. The quark content is important only at low energy ($p_{\text{lab}} \leq 30$ GeV/c), where the charge but not the strangeness plays a predominant role. At higher energies, charged particle multiplicities become independent of quark flavours. It would be interesting to check whether future $K^\pm p$ experiments at higher energies confirm this universality.

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TABLE 1

Number of events and the topological
cross sections at 110 GeV/c

Charged multiplicity	Number of events		Cross section mb
	seen	corrected	
0	5	10	0.03 ± 0.02
2 elastic inelastic	942	488	$2.51 \pm 0.12^{(a)}$
			1.50 ± 0.20
4	1302	1334	4.12 ± 0.13
6	1366	1367	4.22 ± 0.13
8	1248	1243	3.84 ± 0.13
10	781	763	2.35 ± 0.09
12	395	380	1.17 ± 0.06
14	187	180	0.55 ± 0.04
16	60	55	0.17 ± 0.03
18	13	11.3	0.035 ± 0.010
20	5	4.5	0.014 ± 0.007
total	6304		$20.50 \pm 0.05^{(b)}$

(a) From ref. [2].

(b) From ref. [3].

REFERENCES

- [1] I. Lehraus, CERN/EF/BEAM 76-3 (1976).
- [2] D.S. Ayres et al., Phys. Rev. D15 (1977) 3105.
- [3] A.S. Carroll et al., Phys. Lett. 61B (1976) 303.
- [4] K. Kuhn, Fortschritte der Physik 23 (1975) 541.
- [5] C. Louedec et al., Nuovo Cimento 41A (1977) 116.
- [6] C. Cochet et al., Nucl. Phys. B124 (1977) 61.
- [7] J.M. Lafaille et al., Saclay preprint D.Ph.P.E. 79-05 (1979).
- [8] D. Fong et al., Nucl. Phys. B102 (1976) 386.
- [9] W. Thome et al., Nucl. Phys. B129 (1977) 365.
- [10] J. Whitmore, Physics Reports 27C (1976) 187.
- [11] M. Barth et al., Cross sections and multiplicity distributions for K^+p at 70 GeV/c, CERN/EP 79-58.
- [12] V.E. Barnes et al., Phys. Rev. Lett. 34 (1975) 415.
- [13] D. Brick et al., Topological cross sections for K^+p interactions at 147 GeV/c, paper 616 submitted to the XIXth International Conference on High Energy Physics, Tokyo (1978).
- [14] A.K. Wroblewski, Proc. of VIIIth International Symposium on Multiparticle Dynamics, Kayserberg, June 1977.
- [15] A. Buras et al., Phys. Lett. 47B (1973) 251.
- [16] Z. Koba, H.B. Nielsen and P. Olesen, Nucl. Phys. B40 (1972) 317.
- [17] A.K. Wroblewski, Acta Physica Polonica B4 (1973) 857.

FIGURE CAPTIONS

Fig. 1 Topological cross sections as a function of the laboratory momentum.

Fig. 2 (a) Average charged multiplicity $\langle n \rangle$;
(b) the correlation parameter $f_2^{cc} = \langle n^2 \rangle - \langle n \rangle^2 - \langle n \rangle$ as a function of s . The curves are the results of fits with the formula $a + b \ln s + c \ln^2 s$.

The fitted values of a , b and c are given in the text.

Fig. 3 Dispersion D versus the average charged multiplicity $\langle n \rangle$ for K^-p and K^+p interactions. The straight lines are the results of fits [14] to the π^+p , π^-p and pp data. The curved line is hand-drawn through the π^-p data points.

Fig. 4 Charged multiplicity distributions for K^-p interactions at various incident momenta, plotted using the KNO variables.

Fig. 1

Fig. 2

Fig. 3

Fig. 4