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Hadronic ϕ production and the Lund model for low p_T interactions

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ABSTRACT

Experimental results on inclusive ϕ production are compared with the Lund model for low p_T hadronic interactions. The data is based on a sample of 600,000 ϕ mesons in the kinematic range $p_T < 1.0$ (GeV/c)² and $0.0 < x_F < 0.4$, produced in $\pi^\pm$, $K^\pm$, p and p Be interactions at 100 GeV/c and 120 GeV/c incident momentum. The Lund model reproduces the shapes of the longitudinal differential cross sections reasonably well, but the relative cross sections for incident π , K and p show a discrepancy with the data.

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The Lund model for low p_T hadronic interactions is described in ref. [1]. The interaction between an incident hadron and the target is pictured in the Lund model as a connection between a valence quark of the incident hadron and a valence quark of the target. The remaining valence quarks will continue to move apart and a colour flux tube is stretched between the valence quarks. Consequently one of the valence quarks of the incident hadron will be the leading quark at the end point of the string. The valence quarks of the interacting hadrons have an equal probability to be the interacting quark. Mesons are produced by the creation of pairs of quark and antiquark, which are pulled apart by the string. In particular ϕ mesons can be produced by the creation of $s\bar{s}$ -pairs. For incident non-strange beams two $s\bar{s}$ -pairs must be created to produce a ϕ meson. For incident kaons one $s\bar{s}$ -pair is sufficient in case the strange valence quark of the kaon is used to form a ϕ meson. The Lund model supplies only cross sections relative to the absorption cross section. For the evaluation of the absolute cross sections we have used the absorption cross sections determined by Carroll et al. [2]. The values for the absorption cross sections used are tabulated in table 1. The cross section per nucleon for inclusive ϕ production is obtained using a linear A-dependence, both for Lund and the data. We have used version JETSET 5.24 of the Lund model.

It should be noted that the Lund cross section for inclusive ϕ production is rather sensitive to the parameter which determines the relative creation probability of $s\bar{s}$ -pairs compared to $u\bar{u}$ - or $d\bar{d}$ -pairs. This parameter ($P(s\bar{s}/u\bar{u})$) is set at 0.3 in the program version we have used [3]. The effect of changing $P(s\bar{s}/u\bar{u})$ will be discussed at the end of this letter.

We have collected a high statistics sample of inclusively produced ϕ mesons between 100 and 200 GeV/c incident beam momentum [4]. In this letter we restrict ourselves to the data at 100 and 120 GeV/c, which represent the main features of our data. Table 2 lists the number of ϕ mesons which have been used for the evaluation of the differential cross sections $d\sigma/dp_T^2$, $d\sigma/dx_F$ and $d\sigma/d\Omega$. Due to the on-line trigger the data is restricted to the ranges $p_T^2 < 1.0 \text{ (GeV/c)}^2$ and $0.0 < x_F < 0.4$, where $x_F = (p_L/p_{Lmax})_{CM}$.

The $d\sigma/dp_T^2$ distributions have been parameterized with $e^{-bp_T^2}$. The values of slope parameter b are listed in table 3, both for the data and for the Lund model. The $d\sigma/dp_T^2$ distributions of the Lund model are significantly steeper than those measured.

The data [4] show that the decay angular distribution is not isotropic and varies with p_T , whereas the Lund program generates an isotropic decay angular distribution. A possible mechanism for p_T dependent vector meson polarization has been proposed [5] in the framework of the Lund model, using arguments analogous to those for hyperon polarization. However, this mechanism is not incorporated in the version of the Lund program [3] which we used.

In the comparison of the longitudinal differential cross sections for incident $\pi^-(\pi^+)$, $p(\bar{p})$ and $K^-(K^+)$ the systematic error should almost completely cancel at one given beam momentum. However the relative error in the normalization of the 100 GeV/c and 120 GeV/c data samples could be of the order of 10%. To eliminate a possible effect of a systematic shift in the cross sections we introduce two free parameters, which allow for a different normalization for the 100 GeV/c and 120 GeV/c data samples.

The measured longitudinal differential cross sections $d\sigma/dx_F$ are shown in figure 1 together with the Lund model predictions. The Lund cross sections are multiplied with fitted factors 0.80 ± 0.01 and 0.77 ± 0.01 for incident 120 GeV/c and 100 GeV/c respectively to obtain the minimal χ^2 . The χ^2 is large: 1060 for 98 data points and 2 parameters. We find that the Lund model does reproduce the general features of the data, i.e. steep distributions for incident $\pi^\pm$, p and $\bar{p}$ beams, which for incident $\pi^\pm$ are somewhat harder than for incident p and $\bar{p}$, and flat distributions for incident $K^\pm$ beams. However, the relative cross sections for different incident particle types deviate from the data, and the fit shows that the absolute cross section obtained by the Lund model is about 20% too large. In reference [4] it is shown that the measured total cross sections for incident K mesons compare well with results obtained in bubble chamber experiments, suggesting that the Lund model produces cross sections which are indeed too large.

If the parameter $P(s\bar{s}/u\bar{u})$ is reduced from 0.3 to 0.26, the Lund cross section in the interval $0.0 < x_F < 0.4$, decreases by 20%, 18% and 16% for incident π , p and K respectively. This reduction of $P(s\bar{s}/u\bar{u})$ leaves the shape of the $d\sigma/dx_F$ distributions unaltered for incident π and proton, but for incident K mesons the reduction in cross section is larger for small x_F values than for larger x_F . This effect is shown in figure 2, where the Lund prediction for inclusive ϕ production with incident 100 GeV/c K mesons is compared with the measured distribution. The solid curve is obtained with $P(s\bar{s}/u\bar{u})=0.3$ and has been multiplied with 0.82 ± 0.01 in a fit to these

data only to obtain the minimal χ^2 of 16.5 for 18 data points. Similarly, the dashed curve shows the Lund prediction with $P(s\bar{s}/u\bar{u})=0.26$ and gives $\chi^2=26.5$ with normalization factor 0.95 ± 0.01 . Hence reducing $P(s\bar{s}/u\bar{u})$ for obtaining a better agreement in absolute cross section, results in a worse description of the shape of the longitudinal differential cross section for incident K mesons in the x_F interval $0.0 < x_F < 0.4$.

Acknowledgements

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Table 1 : Absorption cross sections per nucleon for a Be target,
derived from Carroll et al. [3].

beam momentum and charge	σ (mb) for incident		
	$\pi^{\pm}$	$K^{\pm}$	p, $\bar{p}$
-100 GeV/c	15.4	13.9	22.2
+120 GeV/c	15.4	13.2	20.6

Table 2 : Number of ϕ mesons observed.

beam type GeV/c	$\pi^{\pm}$	p, $\bar{p}$	$K^{\pm}$
-100	270577 $\pm$ 1053	24574 $\pm$ 343	72191 $\pm$ 325
+120	121878 $\pm$ 717	78524 $\pm$ 622	9728 $\pm$ 184

Table 3 : Slope parameter b for data and Lund model,
obtained from fitting the $d\sigma/dp_T^2$ distributions with
 $e^{-bp_T^2}$ for two different ranges in p_T^2 .

Beam GeV/c	incident particle	$0.0 < p_T^2 < 0.5 \text{ (GeV/c)}^2$		$0.5 < p_T^2 < 1.0 \text{ (GeV/c)}^2$	
		b (GeV/c) $^{-2}$ data	b (GeV/c) $^{-2}$ Lund	b (GeV/c) $^{-2}$ data	b (GeV/c) $^{-2}$ Lund
100	π^-	3.1 $\pm$ 0.1	3.54 $\pm$ 0.04	2.8 $\pm$ 0.1	3.55 $\pm$ 0.09
	$\bar{p}$	3.2 $\pm$ 0.2	3.64 $\pm$ 0.04	2.9 $\pm$ 0.3	3.74 $\pm$ 0.10
	K^-	2.9 $\pm$ 0.1	4.47 $\pm$ 0.03	3.0 $\pm$ 0.1	3.82 $\pm$ 0.07
120	π^+	3.2 $\pm$ 0.1	3.60 $\pm$ 0.03	2.8 $\pm$ 0.1	3.57 $\pm$ 0.07
	p	3.0 $\pm$ 0.1	3.62 $\pm$ 0.03	2.8 $\pm$ 0.2	3.56 $\pm$ 0.08
	K^+	3.1 $\pm$ 0.15	4.37 $\pm$ 0.02	2.6 $\pm$ 0.3	3.69 $\pm$ 0.06

Figure captions

Figure 1 : The differential cross section $d\sigma/dx_F$ for hadronic production of ϕ mesons and the simultaneous fit with the Lund model as described in the text. The incident particles are indicated in each figure. The Lund model prediction has been multiplied in the fit with 0.80 and 0.77 to obtain the minimal χ^2 .

Figure 2 : The differential cross section $d\sigma/dx_F$ for hadronic ϕ production with 100 GeV/c incident K^- and the fit with the Lund model as described in the text. The solid/dashed curve is obtained with $P(s\bar{s}/u\bar{u})=0.3/0.26$. The normalization factors in the fit are 0.82 and 0.95 for $P(s\bar{s}/u\bar{u})=0.3$ and 0.26 respectively.

Figure 1.

Figure 2.