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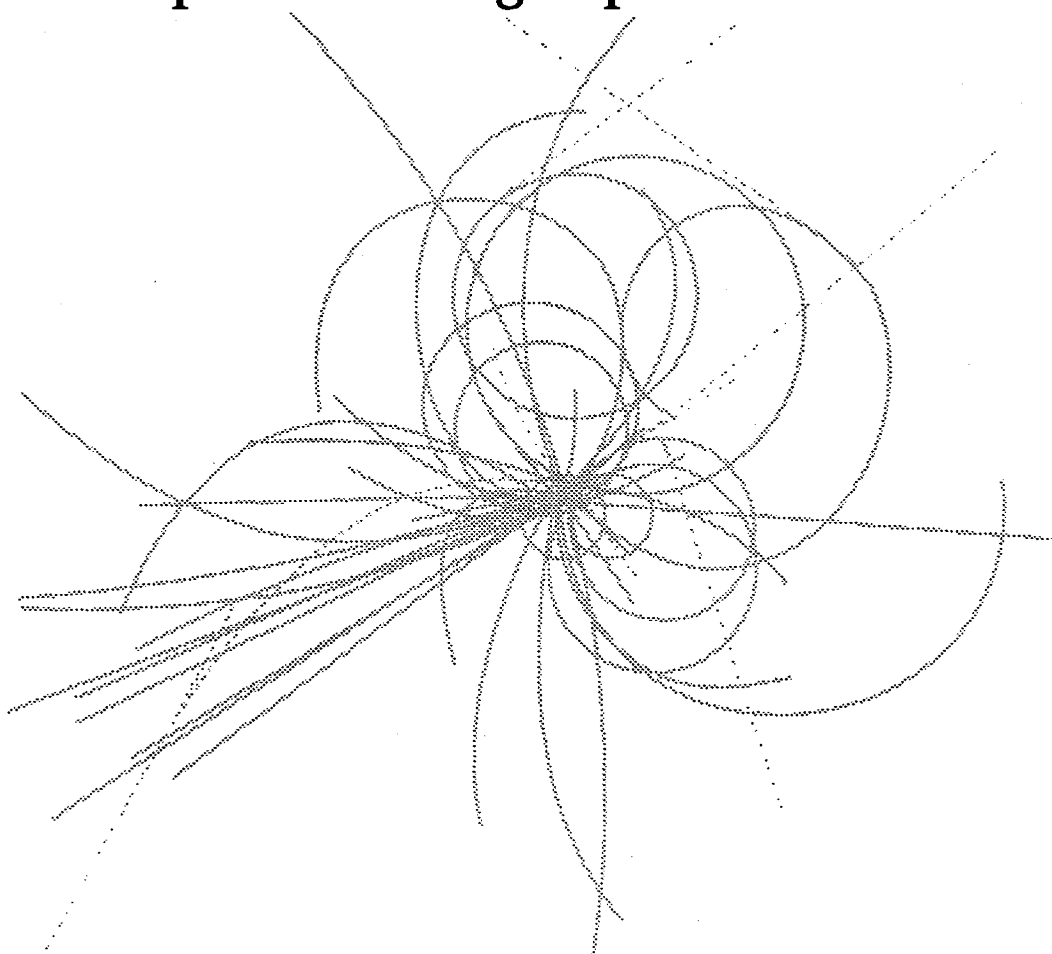

Total Cross Sections of Beauty and Charmed Mesons on Protons

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Using a simple scaling law we predict the values of the total cross sections $\sigma(B^{\pm}\,p)$, $\sigma(B^0_{d,s}\,p)$, $\sigma(\bar{B}^0_{d,s}\,p)$, $\sigma(D^{\pm}_{d,s}\,p)$, $\sigma(D^0\,p)$, $\sigma(\bar{D}^0\,p)$ from known total Kp cross sections. We assume that mesons with the same light valence quark, q, and differing only by their heavy valence quark content, Q, have total cross sections on protons which scale as the inverse of the nth power of the reduced mass of the meson. We predict that $\sigma\Big((Q\bar{q})\,p\Big) > \sigma\Big((\bar{Q}q)\,p\Big)$.

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I. INTRODUCTION

We now have prospects for having a copious supply of high energy B mesons produced at the SSCL and LHC multi-TeV hadron colliders. Even though the lifetime of B mesons is short ($\sim 10^{-12}$ sec), one may expect to observe some Bp interactions. We, therefore, attempt to estimate a variety of Bp total cross sections. Such cross sections are also important for estimating final state interactions involving B mesons and protons. Analagous estimates for Dp cross sections may also be made.

Using a simple scaling law we predict the values of the total cross sections

$$\sigma(B^{\pm}\,p), \sigma(B^0_{d,s}\,p), \sigma(\bar{B}^0_{d,s}\,p), \sigma(D^{\pm}_{d,s}\,p), \sigma(D^0\,p), \sigma(\bar{D}^0\,p)$$

from known meson-proton total cross sections [1]. We relate cross sections for projectiles with one common light valence antiquark (quark) but having different heavy valence quark (antiquark) content. For all of these processes the heavy quark can never annihilate with a valence quark of the target. In addition, inasmuch as the heavy quarks have no isospin, the meson projectiles,

$$K^-(s\bar{u}),\ D^0(c\bar{u}),\ B^-(b\bar{u}) \text{ and c.c.} \tag{1}$$

$$\bar{K}^0(s\bar{d}),\ D^+_d(c\bar{d}),\ \bar{B}^0_d(b\bar{d}) \text{ and c.c.} \tag{2}$$

differ only in their masses. Consequently we conjecture that the total cross sections scale as the inverse of some power n of the reduced mass

$$\mu(M) = \frac{m_q m_Q}{m_q + m_Q} \tag{3}$$

of the incident meson M. Here m_Q and m_q are the masses of the constituent heavy and light quarks. This assumption is equivalent to scaling the cross sections by a function of the size of the projectile. The heavier the projectile, the smaller is the cross section (for $n \geq 1$). For $n = 2$, the product $\mu^2\sigma$ is dimensionless. Table I gives the values of $\mu(M)$ for the mesons M used as projectiles.

DISCLAIMER

II. CROSS SECTION ESTIMATES

We consider a comparison of cross sections for projectiles having a light antiquark $\bar{u}$ and which differ by their heavy quark content e.g., $K^-(s\bar{u})$, $D^0(c\bar{u})$ and $B^-(b\bar{u})$. The scaling laws proposed for the total cross sections of these mesons on protons are:

$$\mu^n(K^-)\,\sigma(K^-\,p) = \mu^n(D^0)\,\sigma(D^0\,p) = \mu^n(B^-)\,\sigma(B^-\,p). \tag{4}$$

Similarly, for projectiles with a common light antiquark, $\bar{d}$

$$\mu^n(\bar{K}^0)\,\sigma(\bar{K}^0\,p) = \mu^n({D_d}^+)\,\sigma({D_d}^+\,p) = \mu^n({\bar{B}_d}^0)\,\sigma({\bar{B}_d}^0\,p). \tag{5}$$

From formulae (4) and (5), we obtain:

$$\sigma(D^0\,p) = (0.75)^n\,\sigma(K^-\,p), \quad \sigma(B^-\,p) = (0.64)^n\,\sigma(K^-\,p); \tag{6}$$

$$\sigma({D_d}^+\,p) = (0.75)^n\,\sigma(\bar{K}^0\,p), \quad \sigma({\bar{B}_d}^0\,p) = (0.64)^n\,\sigma(\bar{K}^0\,p). \tag{7}$$

To compare particle and antiparticle cross sections we use:

$$\mu^n(D)\,\sigma(D^0\,p) = \mu^n(K)\,\sigma(K^-\,p) \tag{8}$$

$$\mu^n(D)\,\sigma(\bar{D}^0\,p) = \mu^n(K)\,\sigma(K^+\,p) \tag{9}$$

and

$$\mu^n(B)\,\sigma(B^-\,p) = \mu^n(K)\,\sigma(K^-\,p) \tag{10}$$

$$\mu^n(B)\,\sigma(B^+\,p) = \mu^n(K)\,\sigma(K^+\,p). \tag{11}$$

Using the experimental result, $\sigma(K^-\,p) > \sigma(K^+\,p)$ we obtain:

$$\sigma\big(\bar{D}(\bar{c}u)\,p\big) < \sigma\big(D(c\bar{u})\,p\big) \tag{12}$$

$$\sigma\Big(B(\bar{b}u)\,p\Big) < \sigma\Big(\bar{B}(b\bar{u})\,p\Big). \tag{13}$$

These inequalities are independent of the precise value of n, for $n \geq 1$. Proceeding as above for projectiles containing a $\bar{d}$ antiquark and using the fact that $\sigma(\bar{K}^0\,p) = \sigma(K^-\,n)$, $\sigma(K^0\,p) = \sigma(K^+\,n)$ and $\sigma(K^-\,n) > \sigma(K^+\,n)$ we obtain:

$$\sigma\Big(\bar{D}(\bar{c}d)\,p\Big) < \sigma\Big(D(c\bar{d})\,p\Big) \tag{14}$$

$$\sigma\Big(B(\bar{b}d)\,p\Big) < \sigma\Big(\bar{B}(b\bar{d})\,p\Big). \tag{15}$$

Using the same approach we also obtain:

$$\mu^n(B_s)\,\sigma(\bar{B}^0_s\,p) = \mu^n(D_s)\,\sigma(D^+_s\,p) \tag{16}$$

$$\mu^n(B_s)\,\sigma(B^0_s\,p) = \mu^n(D_s)\,\sigma(D^-_s\,p). \tag{17}$$

The projectiles above have neither antiquarks that can annihilate with the valence quarks of the proton target nor do they have any light quark interactions with the proton. Therefore, we conjecture that

$$\sigma(B^0_s\,p) = \sigma(\bar{B}^0_s\,p) \text{ and } \sigma(D^+_s\,p) = \sigma(D^-_s\,p). \tag{18}$$

We do not know the value of n. As mentioned earlier, $n = 2$ gives an invariant scalar quantity. If we relax the requirement that one quark must be heavy, then we can relate $\sigma(K\,p)$ to $\sigma(\pi\,p)$. The scaling law applied to $\sigma(\pi\,p)$ and $\sigma(K\,p)$ works remarkably well for $n = 1$. For example, the experimental ratios $\sigma(K^-\,p)/\sigma(\pi^-\,p) \simeq 0.86$ and $\sigma(K^+\,p)/\sigma(\pi^+\,p) \simeq 0.83$ at 200 GeV/c incident momentum are very close to the ratio $\mu(\pi)/\mu(K) = 0.87$.

III. CONCLUSIONS

We have suggested a simple scaling law to relate total cross sections for heavy meson-proton interactions. Many of these cross sections are related to kaon-proton cross sections. We predict that $\sigma\Big((Q\bar{q})\,p\Big) > \sigma\Big((\bar{Q}q)\,p\Big)$.

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REFERENCES

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[1] "Review of Particles Properties," Phys. Lett. **B204**, 1 (1988).

[2] We use the following quark content for the mesons: $K^+ \equiv \bar{s}u$; $K^0 \equiv \bar{s}d$; $D^0 \equiv c\bar{u}$; $D_d^+ \equiv c\bar{d}$; $D_s^+ \equiv c\bar{s}$; $B^+ \equiv \bar{b}u$; $B_d^0 \equiv \bar{b}d$; $B_s^0 \equiv \bar{b}s$; $B_c^+ \equiv \bar{b}c$.

TABLES

TABLE I. Reduced masses (μ) of the various considered mesons using the following constituent quark masses: $m_u = m_d = 0.35$ GeV; $m_s = 0.5$ GeV; $m_c = 1.5$ GeV; $m_b = 5.2$ GeV.

meson	π	K	$D_{u,d}$	D_s	$B_{d,u}$	B_s	B_c
μ (GeV)	0.18	0.21	0.28	0.38	0.33	0.46	1.16