Chapter 1

Introduction

The absolute cross-section for charm production in high-energy hadronic interactions, despite more than twenty years of experimental activity, remains an issue of considerable interest. Early cross-section measurements are characterized by orders-of-magnitude discrepancies. Results from modern experiments (i.e., capable of full mass reconstruction and/or decay vertex detection) are relatively few in number and, although agreement among them has improved, still suffer from low statistics and large systematic errors [42]. The $c\bar{c}$ cross-sections for collisions of light hadrons (π, K, p) on nuclei are an independent test of assumptions underlying perturbative QCD predictions for heavy-quark production, which for even the heavier b system are not well-established [38]. Precise knowledge of the charm cross-section will improve understanding of leptonic backgrounds relevant to B physics and heavy-particle searches. In addition, it has been proposed that enhanced production of open charm above this baseline might be used as an indicator and probe of quark-gluon plasma formation in heavy-ion collisions [27].

Perturbative QCD provides a predictive framework in which we can calculate not only the amount of $c\bar{c}$ production in a given reaction, but also the momentum distributions of the charm quarks. These predictions depend, through the dominant gluon-gluon fusion process, on the momentum distributions of the gluons in the projectile and target particles [32]. Furthermore, the shapes of these differential cross-sections are relatively insensitive to theoretical uncertainties [33]. Although non-perturbative processes, particularly hadronization, additionally impact the x_F and p_T distributions of charm hadrons, these effects are reasonably assumed to be independent of initial-state gluon distributions. As a consequence, the shapes of these differential cross-sections should be sensitive to differences in beam-particle gluon distributions.

In this thesis, we present an analysis of Fermilab E769 data, some 400 million events collected during the 1987-88 fixed-target run. Inclusive reactions of the form

$$B\,N \rightarrow D\,X$$

are studied at a hadronic center-of-mass energy of 21.7 GeV, where the beam particle B is π^-, K^-, π^+, K^+, or p, the target is a nucleon N, and D is one of the charm mesons D^+, D^0, D_s, or D^{*+} (or a corresponding antimeson).[1] For each of these reactions, absolute and differential ($d\sigma/dx_F$ and $d\sigma/dp_T^2$) cross-sections are measured. For K and p beams, measurements of leading-particle asymmetries are also presented, addressing for the first time the effect of a leading strange quark. (A leading charm particle is defined, for $x_F > 0$, as one which shares at least one light valence quark or antiquark flavor with the beam particle.) With the exception of a few $d\sigma/dx_F$ measurements which extend to negative x_F, present results are confined to D mesons produced in the forward hemisphere (as measured in the hadronic center-of-mass frame).

Signals for these particles are obtained through full reconstruction of the following charged hadronic decay modes:

$$\begin{array}{lcll}
D^+ & \rightarrow & K^-\pi^+\pi^+, & (D^+ \rightarrow K\pi\pi) \\
D^0 & \rightarrow & K^-\pi^+, & (D^0 \rightarrow K\pi) \\
D_s^+ & \rightarrow & \left\{ \begin{array}{l} \phi\,\pi^+,\ \phi \rightarrow K^+K^- \\ \overline{K}^*(892)^0K^+,\ \overline{K}^{*0} \rightarrow K^-\pi^+, \end{array} \right. & \begin{array}{l} (D_s \rightarrow \phi\pi) \\ (D_s \rightarrow K^*K) \end{array} \\
D^{*+} & \rightarrow & D^0\pi^+,\ D^0 \rightarrow K^-\pi^+, & (D^* \rightarrow D^0\pi)
\end{array}$$

The righthand column above contains the shorthand names used to refer to these

[1]Throughout this text, names of charm particles (decays) generically denote the particles (decays) and their charge conjugates, unless otherwise stated or in contexts in which the sign of the D meson matters (e.g., in discussions of the leading-particle effect).

decay modes; combined $D_s \rightarrow \phi\pi$ and $D_s \rightarrow K^*K$ modes are referred to as "$D_s \rightarrow KK\pi$".

The central results presented in this thesis have appeared in two papers published concurrently in *Physical Review Letters* [10, 11].