CHARMED-HADRON PRODUCTION AND CHARM FRAGMENTATION AT ZEUS

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The procedures behind recent results on charm fragmentation fractions and associated derived variables obtained by the ZEUS collaboration are presented. Reconstruction of the D^{*+}, D^+, D^0 and D_s^+ mesons and Λ_c^+ baryons is outlined and related to their production cross sections which are in turn related to some associated variables also measured at ZEUS

1. Introduction

Charm quark production has been extensively studied at HERA[1,2]. The associated prediction assumes the universality of charm fragmentation and uses characteristics obtained in e^+e^- annihilation. However the production mechanisms are not the same as in the ZEUS eP collisions so it is important to test this assumption by making new measurements at HERA.

Details surrounding the measurement of the production of the weakly decaying charm ground states, the D^0, D^+, D_s^+ pseudo-scalar mesons and the Λ_c^+ baryon, are presented here. The production of the charm vector meson D^{*+} has also been studied along with it's respective anti-particle[a]. The measurement has been performed in eP scattering at HERA using an integrated luminosity of 79 pb^{-1}. It is made in the photoproduction regime with exchanged photon virtuality $Q^2 < 1$ GeV^2 and for photon proton centre of mass energies in the range $130 < W < 300$ GeV.

The production cross sections have been used to determine the ratio of neutral and charged D meson production rates, $R_{u/d}$, the strangeness

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[a]Hereafter, charge conjugation is implied

suppression factor, γ_s, and the fraction of D mesons produced in a vector state, P_v^d. The fractions of c quarks hadronising as a particular charm hadron, $f(c \to D, \Lambda_c)$, have been calculated in the accepted kinematic range.

2. Reconstruction of charmed hadrons and separation of D^0

The production of D^{*+}, D^0, D^+, D_s^+ and Λ_c^+ charm hadrons was measured in the range of transverse momentum $p_T(D, \Lambda_c) > 3.8$ GeV and pseudorapidity $|\eta(D, \Lambda_c)| < 1.6$. Charm hadrons were reconstructed using tracks measured in the CTD and assigned to the reconstructed event vertex.

The D^0 production cross section consists of two subsets: D^0 mesons that originate from a D^{*+} decay ($\sigma^{\rm tag}(D^0)$) and D^0 mesons that do not ($\sigma^{\rm untag}(D^0)$). For selected D^0 candidates, a search was performed for a track that could be a "soft" pion (π_s) in a $D^{*+} \to D^0\pi_s^+$ decay. The corresponding D^0 candidate was assigned to a class "with ΔM tag" if $0.143 < \Delta M < 0.148$ GeV where $\Delta M = M(K\pi\pi) - M(K\pi)$. The $D^{*+} \to D^0\pi_s^+$ cross section in the range $p_T(D^{*+}) > 3.8$ GeV and $|\eta(D^{*+})| < 1.6$ ($\sigma^{\rm kin}$) is a sum of two subsamples: events with the D^0 having $p_T(D^0) > 3.8$ GeV and $|\eta(D^0)| < 1.6$ ($\sigma^{\rm tag}$) and additional D^{*+} events with the D^0 outside of that kinematic range ($\sigma^{\rm add}$). The sum of the two components is given by

$$\sigma^{\rm kin}(D^{*+}) = \sigma^{\rm tag}(D^0)/B_{D^{*+}\to D^0\pi^+} + \sigma^{\rm add}(D^{*+}) \qquad (1)$$

where $B_{D^{*+}\to D^0\pi^+}$ is the branching ratio of the $D^{*+} \to D^0\pi^+$ decay [4].

3. Charm fragmentation fractions

The fraction of c quarks hadronising as a particular charm hadron $f(c \to D, \Lambda_c)$ is given by the ratio of the production cross section for the hadron to the sum of the production cross sections for all charm ground states that decay weakly $\sigma_{\rm gs}$, such that $f(c \to D, \Lambda_c) = \frac{\sigma_{D\Lambda_c}}{\sigma_{\rm gs}}$.

In addition to the measured D^0, D^+, D_s^+ and Λ_c^+ charm ground states, the production cross sections of the charm strange baryons Ξ_c^+, Ξ_c^0 and Ω_c^0 are included in the sum by assuming they contribute 14% of the Λ_c^+ cross section[5]. Overall the measurements made at ZEUS[3 4] are consistent with the world average which confirms the universality of charm fragmentation.

4. Derived variables

4.1. *Ratio of neutral to charged D-meson production rates*

The ratio of neutral to charged D-meson production rates is given by the ratio of the sum of D^{*0} and direct D^0 production cross sections to the sum of D^{*+} and direct D^+ production cross sections:

$$R_{u/d} = \frac{\sigma(D^{*0}) + \sigma^{\rm dir}(D^0)}{\sigma(D^{*+}) + \sigma^{\rm dir}(D^+)}, \qquad (2)$$

where $\sigma^{\rm dir}(D^0)$ and $\sigma^{\rm dir}(D^+)$ are those parts of the D^0 and D^+ inclusive cross sections which do not originate from D^{*0} and D^{*+} decays. Because $\sigma^{\rm dir}(D^+)$ and $\sigma^{\rm dir}(D^0)$ are not measured directly we must find a formalism for $R_{u/d}$ that is expressed in terms of quantities measured at ZEUS.

Since all D^{*0} decays produce a D^+ meson [5], the sum of $\sigma(D^{*0})$ and $\sigma^{\rm dir}(D^0)$ is the production cross section for D^0 mesons not originating from D^{*+} decays:

$$\sigma(D^{*0}) + \sigma^{\rm dir}(D^0) = \sigma^{\rm untag}(D^+). \qquad (3)$$

Subtracting from $\sigma(D^+)$ the contribution from D^{*+} decays gives

$$\sigma^{\rm dir}(D^+) = \sigma(D^+) - \sigma(D^{*+}) \cdot (1 - B_{D^{*+}\to D^0\pi^+}). \qquad (4)$$

Thus, the ratio of neutral and charged D-meson production rates can be calculated as

$$R_{u/d} = \frac{\sigma^{\rm untag}(D^0)}{\sigma(D^+) + \sigma(D^{*+}) \cdot B_{D^{*+}\to D^0\pi^+}} = \frac{\sigma^{\rm untag}(D^0)}{\sigma(D^+) + \sigma^{\rm tag}(D^0)}. \qquad (5)$$

The measured value of $R_{u/d}$ is

$$R_{u/d} = 1.100 \pm 0.078\,({\rm stat.})^{+0.038}_{-0.061}\,({\rm syst.})^{+0.047}_{-0.049}\,({\rm br.}). \qquad (6)$$

It agrees with unity and is thus consistent with isospin invariance, which implies that u and d quarks are produced equally in charm fragmentation.

4.2. *Fraction of charged D mesons produced in a vector state*

Vector mesons have a total of 3 spin states whereas pseudoscalar mesons (D^0, D^+) have only 1. By naïve spin counting we expect D mesons to be produced in a vector meson state three times more often than in a pseudoscalar state. Using expressions for $\sigma^{\rm kin}(D^{*+})$ and $\sigma^{\rm dir}(D^+)$, the fraction for charged charm mesons is given by

$$P_{\rm v}^d = \frac{\sigma^{\rm kin}(D^{*+})}{\sigma^{\rm kin}(D^{*+}) + \sigma^{\rm dir}(D^+)} = \frac{\sigma^{\rm tag}(D^0)/B_{D^{*+}\to D^0\pi^+} + \sigma^{\rm add}(D^{*+})}{\sigma(D^+) + \sigma^{\rm tag}(D^0) + \sigma^{\rm add}(D^{*+})}. \quad (7)$$

Using the measured cross sections we obtain a final measurement of

$$P_{\rm v}^d = 0.566 \pm 0.025\,({\rm stat.})^{+0.007}_{-0.022}\,({\rm syst.})^{+0.022}_{-0.023}\,({\rm br.}) \quad (8)$$

This value is smaller than the 0.75 as predicted by naïve spin counting and so we conclude that naïve spin counting does not work for charm.

4.3. *Strangeness-suppression factor*

The strangeness suppression factor is a parameter which determines the ratio of probabilities to create a s to u, d quark in the fragmentation process. Because all D^{*+} and D^{*0} decays produce either a D^+ or a D^0 meson, while all D_s^{*+} decays produce a D_s^+ meson[5] we may express γ_s in the form[3,4]

$$\gamma_s = \frac{2\,\sigma(D_s^+)}{\sigma^{\rm eq}(D^+) + \sigma^{\rm eq}(D^0)} \quad (9)$$

$$= \frac{2\,\sigma(D_s^+)}{\sigma(D^+) + \sigma^{\rm untag}(D^0) + \sigma^{\rm tag}(D^0) + \sigma^{\rm add}(D^{*+})\cdot(1+R_{u/d})} \quad (10)$$

The final measurement is

$$\gamma_s = 0.257 \pm 0.024\,({\rm stat.})^{+0.013}_{-0.016}\,({\rm syst.})^{+0.078}_{-0.049}\,({\rm br.}).$$

This is consistent with previous HERA results and with e^+e^- measurements, indicating universality of charm fragmentation.

5. Summary

Fragmentation fractions have been measured and found to be consistent with universality of charm fragmentation. The measured $R_{u/d}$ value agrees with unity and so is consistent with isospin invariance and the vector to pseudoscalar ratio has been measured and is found to be inconsistent with naïve spin counting. All are consistent with the world average.

References

1. ZEUS Collab., J. Breitweg et al., Eur. Phys. J. **C 6**, 67 (1999)
2. H1 Collab., C. Adloff et al., Nucl. Phys. J. **B 528**, 199 (2002)
3. L. Gladilin, these proceedings.
4. ZEUS Collab., Eur. Phys. J. C. **44**, 351-366 (2005)
5. Particle Data Group, S. Eidelman et al., Phys. Lett **B592**, 1 (2004)