EXPERIMENTAL RESULTS ON HEAVY QUARK FRAGMENTATION *

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Experimental results on c- and b-quark fragmentation are reviewed. The discussion is concentrated on measurements of heavy-quark fragmentation functions and fragmentation fractions. Measurements of various heavy-quark fragmentation ratios are also discussed. The experimental results are compared with theoretical expectations and model predictions.

1. Introduction

The initial stage of charm/bottom quark fragmentation can be described by perturbative QCD (pQCD) calculations [1]. A non-perturbative (NP) parameterisation is needed to describe the final heavy-quark transformation to a particular charmed or bottom hadron. Such parameterisation can include effects producing by the excited states decaying to a given hadron. The NP fragmentation parameterisation can be splited in two parts: fragmentation function and fragmentation fraction. Fragmentation functions are used to parameterise the transfer of the quark's energy to a given meson; they can be different for different pQCD calculations used to describe the initial fragmentation. Fragmentation fractions are the fractions of c/b quarks hadronising as a particular charmed/bottom hadron; they are expected to be universal for all pQCD calculations.

Measurements of the heavy quark fragmentation allow testing pQCD calculations and extracting fragmentation functions and fractions. A deeper phenomenological understanding of the heavy quark fragmentation can be obtained by measuring various heavy-quark fragmentation ratios. In partic-

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ular, we will discuss the ratio of neutral and charged D/B meson production rates, $R_{u/d}$, the strangeness-suppression factor, γ_s, and the fraction of D/B mesons produced in a vector state, $P_{\rm v}$.

2. Bottom quark fragmentation

The b-quark fragmentation function was measured at LEP [2,3,4] and SLD [5]. The measured spectra were compared with predictions of the leading-logarithmic (LL) JETSET 7.4 [6] Monte Carlo (MC) using different parametrisations for the fragmentation function. The best description of the data with a parametrisation with one free parameter was obtained using the parametrisation of Kartvelishvili et al. [7]. The Bowler [8] and symmetric LUND [9] parametrisations with two free parameters provided a better data description. The Peterson [10] and Collins-Spiller [11] parameterisations, and the HERWIG cluster model [12] predictions were found to be too broad to describe the data. The b-quark fragmentation function measurements were also used for fitting the NP parametrisation with the next-to-leading-order (NLO) calculations [13,14].

The b-quark fragmentation fractions were obtained by combining of all published LEP and CDF results on production of the weakly decaying B hadrons with measurements of the time-integrated mixing probabilities [15,16]. The isospin invariance, i.e. $R_{u/d} = 1$, was assumed in this procedure. Using the measured fragmentation fractions, the strangeness-suppression factor for bottom mesons is

$$\gamma_s = 2f(\bar{b} \to B_s^0)/[f(\bar{b} \to B^0) + f(\bar{b} \to B^+)] = 0.27 \pm 0.03.$$

Thus, bottom-strange meson production is suppressed by a factor ≈ 3.7. The combined LEP value for the fraction of B mesons, produced in a vector state, is $P_{\rm v} = 0.75 \pm 0.04$ [16], that is in perfect agreement with the naive spin counting expectation (0.75).

3. Charm quark fragmentation

The c-quark fragmentation function has been recently measured with high precision by the CLEO [17] and BELLE [18] collaborations. The data comparison with the JETSET MC predictions revealed the same picture as for the b-quark fragmentation. The best description of the data was obtained using the Bowler parametrisation with two free parameters, and the parametrisation of Kartvelishvili et al. with one free parameter.

A discrepancy between the NP parametrisations obtained with the CLEO/BELLE data and earlier ALEPH measurement [19] has been observed using the NLO initial conditions, next-to-leading logarithmic (NLL) evolution, NLO coefficient functions and NLL Sudakov resummation [1,13]. The difference, which was attributed to the evolution between the $\Upsilon(4S)$ and Z^0 energies, results in an additional uncertainty in predictions for $D^{*\pm}$ hadroproduction of the order 20%. To reduce the uncertainty direct measurements of the charm fragmentation function at hadronic machines would be useful. Such measurements were already performed in ep interactions at HERA by the ZEUS [20] and H1 [21] collaborations; their results were found to be in qualitative agreement with those obtained in e^+e^- annihilations.

Table 1. The fractions of c quarks hadronising as a particular charm hadron, $f(c \to D, \Lambda_c)$. The fractions are shown for the D^+, D^0, D_s^+ and Λ_c^+ charm ground states and for the D^{*+} state.

	ZEUS (γp) [22]	Combined e^+e^- data [24]	H1 (DIS) [23]
	stat. syst. br.	stat.$\oplus$syst. br.	total
$f(c \to D^+)$	$0.217 \pm 0.014\,^{+0.013}_{-0.005}\,^{+0.014}_{-0.016}$	$0.226 \pm 0.010\,^{+0.016}_{-0.014}$	0.203 ± 0.026
$f(c \to D^0)$	$0.523 \pm 0.021\,^{+0.018}_{-0.017}\,^{+0.022}_{-0.032}$	$0.557 \pm 0.023\,^{+0.014}_{-0.013}$	0.560 ± 0.046
$f(c \to D_s^+)$	$0.095 \pm 0.008\,^{+0.005}_{-0.005}\,^{+0.026}_{-0.017}$	$0.101 \pm 0.009\,^{+0.034}_{-0.020}$	0.151 ± 0.055
$f(c \to \Lambda_c^+)$	$0.144 \pm 0.022\,^{+0.013}_{-0.022}\,^{+0.037}_{-0.025}$	$0.076 \pm 0.007\,^{+0.027}_{-0.016}$	
$f(c \to D^{*+})$	$0.200 \pm 0.009\,^{+0.008}_{-0.006}\,^{+0.008}_{-0.012}$	$0.238 \pm 0.007\,^{+0.003}_{-0.003}$	0.263 ± 0.032

Table 1 compares the c-quark fragmentation fractions measured in ep interactions at HERA by the ZEUS [22] and H1 [23] collaborations with those obtained in e^+e^- annihilations. The latter values were compiled previously [24] and updated with the recent branching ratio values [16]. The measurements performed in e^+e^- and ep interactions are consistent. Measurements of the $R_{u/d}$ value in charm fragmentaion confirmed isospin invariance [22,23,24,25]. Meausurements of the strangeness-suppression factor in charm fragmentation showed that charmed-strange meson production is suppressed by a factor ≈ 3.9 (similar to the suppression in bottom fragmentation). The fraction of charged D mesons produced in a vector state, $P_{\rm v}^d$, was found to be ≈ 0.6[22,23,24,25] in both e^+e^- and ep interactions. The value is significantly smaller than that obtained in bottom fragmentation and does not agree with the naive spin counting expectation (0.75).

4. Summary

The b-qaurk fragmentation function and fractions were measured in e^+e^- annihilations, while the c-quark fragmenation was studied in both e^+e^- and

ep interactions. Comparison of the charm fragmentation characteristics, obtained in e^+e^- and ep interactions, generally supports the hypothesis that fragmentation proceeds independently of the hard sub-process.

The fraction of charged D mesons produced in a vector state, $P_{\rm v}^d$, in charm fragmentation was found to be ≈ 0.6 in both e^+e^- and ep interactions. The value is significantly smaller than that obtained in bottom fragmentation and does not agree with the naive spin counting expectation (0.75).

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