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 split 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, $\gamma_s$, and the fraction of $D/B$ mesons produced in a vector state, $P_v$.

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

$$\gamma_s = \frac{2f(\bar{b} \to B_0^0)/[f(\bar{b} \to B^0) + f(\bar{b} \to B^+)]}{f(\bar{b} \to B_0^0)} = 0.27 \pm 0.03.$$  

Thus, bottom-strange meson production is suppressed by a factor $\approx 3.7$. The combined LEP value for the fraction of $B$ mesons, produced in a vector state, is $P_v = 0.75 \pm 0.04$ $^{16}$, 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 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 fragmentation confirmed isospin invariance \(^{22,23,24,25}\). Measurements of the strangeness-suppression factor in charm fragmentation showed that charmed-strange meson production is suppressed by a factor \(\approx 3.9\) (similar to the suppression in bottom fragmentation). The fraction of charged \(D\) mesons produced in a vector state, \(P_{v}^d\), was found to be \(\approx 0.6\) \(^{22,23,24,25}\) 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 \(b\)-quark fragmentation function and fractions were measured in \(e^+e^-\) annihilations, while the \(c\)-quark fragmentation 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, $P^d_v$, in charm fragmentation was found to be $\approx 0.6$ 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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