Recent Results on Hadronic B Decay

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Abstract. In this paper we present recent results obtained by the CLEO Collaboration on hadronic and rare decays of B mesons. Highlights include an improved branching fraction for inclusive electro-magnetic penguin decays, a measurement of the photon spectrum in these decays as well as the first observation color-suppressed B decays to final states with open-charm mesons.

INTRODUCTION

Acknowledging the fact that in this area of electronic publishing conference proceedings have lost most of their original meaning we will not present a detailed description of the results reported at HF9. Instead we will provide a brief summary combined with a list of electronic references where the interested reader can find current and detailed information on our work. The transparencies shown during the conference are available in pdf format [1].

The data analyzed in these studies were collected at the Cornell Electron Storage Ring (CESR) with the CLEO detector. Three different configurations were used. The CLEO II (1990-1995) and CLEO II.V (1995-1999) data sample consists of 9.1 fb^{-1} collected on the $\Upsilon(4S)$ resonance and 4.4 fb^{-1} taken in the e^+e^- continuum just below the resonance. The CLEO III data sample includes 6.9 fb^{-1} of $\Upsilon(4S)$ and 2.3 fb^{-1} of continuum data. The two data samples correspond to 9.7×10^6 and 7.4×10^6 $B\bar{B}$ events, respectively. Details about CESR and the CLEO be found following the hyperlinks given in [2] and [3].

RARE DECAYS OF B MESONS

$b \to s\gamma$ Branching Fraction and Photon Energy Spectrum

We have measured the branching fraction and photon energy spectrum for the radiative penguin process $b \to s\gamma$ [4]. The branching fraction is found to be

$$\mathcal{B}(b \to s\gamma) \ = \ (3.21 \pm 0.43 \pm 0.27^{+0.18}_{-0.10}) \times 10^{-4}$$

The errors are statistical, systematic, and from theory corrections. Analyzing the shape of photon energy spectrum we obtain the first and second moment for photon energies above 2 GeV

$$< E_\gamma >= 2.346 \pm 0.032 \pm 0.011 \ GeV$$

and

$$< E_\gamma^2 > - < E_\gamma >^2 = 0.0226 \pm 0.0066 \pm 0.0020\, GeV^2$$

The measured branching fraction can be compared to recent theoretical calculations by Chetyrkin, Misiak, Munz and by Kagan and Neubert which predict

$$\mathcal{B}(b \to s\gamma) \ = \ (3.29 \pm 0.33) \times 10^{-4}$$

The window for new physics in this decay mode is closing.

Improved Upper Limits on the FCNC Decays $B \to K\ell^+\ell^-$ and $B \to K^*(892)\ell^+\ell^-$

Using the CLEO II and II.V data samples we have searched for the flavor-changing neutral current decays $B \to K\ell^+\ell^-$ and $B \to K^*(892)\ell^+\ell^-$ [5]. For the latter decay we require that the dilepton mass exceed 0.5 GeV. In none of the decay modes an indication of a signal is observed. We obtain the following 90% confidence level upper limits

$$\mathcal{B}(B \to K\ell^+\ell^-) < 1.7 \times 10^{-6}$$

and

$$\mathcal{B}(B \to K^*(892)\ell^+\ell^-) < 3.3 \times 10^{-6}.$$

In order to compare with theoretical prediction we calculate the upper limit on the weighted average

$$0.65\mathcal{B}(B \to K\ell^+\ell^-) + 0.35\mathcal{B}(B \to K^*(892)\ell^+\ell^-) < 1.5 \times 10^{-6}.$$

We note that the weighted-average limit is only 50% above the Standard Model prediction.

Rare Hadronic B Decay

Preliminary results on hadronic rare B decays such as $B \to \pi\pi$ and $B \to K\pi$ have been reported using about half of the CLEO III data sample. The results are consistent with previously published CLEO measurements of these decay modes. For detailed information see the branching ratio tables in reference [1].

UNDERSTANDING HADRONIC B DECAY

Most hadronic decays of B mesons can be described by external and internal spectator decay diagrams. For charged B meson decays these two amplitudes interfere while for neutral B mesons they lead to separate final states. Most theoretical work attempting a description of these decays is based on factorization - the assumptions that the quarks from the virtual W and the meson remnant hadronize independently [6]. Recent work has provided a more solid foundation for this hypothesis [7]. Furthermore, two phenomenological parameter, a_1 and a_2, are introduced to absorb non-perturbative contributions to the external and internal spectator decay amplitudes, respectively. These parameter are expected to be process dependent but current experimental data can be described with universal values $a_1 \approx 1.1$ and $a_2 \approx 0.25$. In the following sub-sections we provide new information on experimental tests of the factorization hypothesis and on the parameter a_2.

Factorization

Experimental tests of the factorization hypothesis have been performed by comparing branching fractions as well as as angular correlations between hadronic and semileptonic B meson decays. Within the experimental precision (10 - 30%) and over the limited q^2 range probed so far the measurements agree with factorization predictions. Using the recent CLEO observation of $\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^+\pi^-\pi^-\pi^0) = (1.72 \pm 0.14 \pm 0.24)\%$ [8], Ligeti, Luke and Wise compared the invariant 4π spectrum in $B \to D^*$ decays to $\tau^- \to \nu\pi^+\pi^-\pi^-\pi^0$ data [9]. Using factorization they find good agreement over the full accessible range up to $m^2_{4\pi} < 2.9\,GeV^2$. This provides a good factorization test if it can be demonstrated that $B \to D^* 4\pi$ transitions do not receive contributions from other decay diagrams. To answer this question, CLEO searched for the related decay mode $\bar{B}^0 \to D^{*0}\pi^+\pi^+\pi^-\pi^-$ which could proceed via D^{**} production or through an internal spectator decay. We find a branching ratio for this mode of $(0.30 \pm 0.07 \pm 0.06)\%$ [10]. We also observe a large $D^{**} \to D^{*0}\pi^+$ component indicating potential problems with the LLW factorization test. However, when we study the relative decay widths for $m^2_{4\pi} < 2.9\,GeV^2$ we find that there is almost no contribution to this part of the 4 pion spectrum (90 % C.L.):

$$\frac{\Gamma(\bar{B}^0 \to D^{*0}\pi^+\pi^-\pi^+\pi^-)}{\Gamma(\bar{B}^0 \to D^{*+}\pi^+\pi^-\pi^+\pi^0)} < 0.13$$

The LLW factorization test is still valid.

Color Suppression

Since in internal spectator decays the quarks from the virtual W decay have to match the color of the quarks in the decaying hadron it is expected that the amplitude for this process is suppressed compared to external spectator decays. In the decays of charm mesons, the effect of this color suppression is obscured by effects of final state interactions or reduced by non-factorizable contributions. Color suppression is, however, believed to be operative in the B meson system. The only color-suppressed B meson decay modes that have been observed so far are final states containing charmonium states, e.g. $B \to \psi K$. We have used the CLEO II and CLEO II.V data samples to study the color-suppressed hadronic decays of neutral B mesons into the final states $D^{(*)0}\pi^0$

[11]. Using 9.67 million B-pairs we find

$$\mathcal{B}(\bar{B}^0 \to D^0\pi^0) = (2.74^{+0.36}_{-0.32} \pm 0.55) \times 10^{-4}$$

and

$$\mathcal{B}(\bar{B}^0 \to D^{*0}\pi^0) = (2.20^{+0.59}_{-0.52} \pm 0.79) \times 10^{-4}$$

The first error is statistical and the second systematic. The statistical significance of the $D^0\pi^0$ signal is 12.1 sigma (5.9 sigma for $D^{*0}\pi^0$). Combining these results with previous measurements of other $B \to D^{(*)}\pi$ final states we determine the strong interaction phase δ_I between the isospin 1/2 and 3/2 amplitudes in the $D\pi$ and $D^*\pi$ final states to be $\cos\delta_I = 0.89 \pm 0.08$ and $\cos\delta_I = 0.89 \pm 0.08$, respectively.

Comparing our results to models of hadronic B decays allows us to estimate $|a_2|_{B \to D^{(*)0}\pi^0}$ to ≈ 0.4 - significantly larger than the values for a_2 obtained from $B \to$ Charmonium and charged B decays. The model dependence of a_2 begins to show.

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