Eur Phys J C **33**, s01, s232–s234 (2004)
Digital Object Identifier (DOI) 10.1140/epjcd/s2003-03-118-1

EPJ C direct
electronic only

Charmless B decays from CLEO: Rare and not-so-rare

Richard D. Ehrlich

Cornell University, Wilson Synchrotron Lab, Ithaca, NY 14853

Received: 14 October 2003 / Accepted: 12 November 2003 /
Published Online: 1 December 2003 – © Springer-Verlag / Società Italiana di Fisica 2003

Abstract. We present updated results from the CLEO collaboration from two studies of B meson decay to charmless hadronic final states. In the first analysis, we combine data from the CLEO II and CLEO III detectors to provide final measurements of thirteen two-body decay modes. In the second, the combined CLEO II and CLEO II.V data set is used to determine the η' momentum spectrum and branching ratio in the inclusive process $B \to \eta' X_{nc}$; with a more powerful analysis technique than was previously used. For the momentum range $2.0 < P_{\eta'} < 2.7$ GeV/c , we find a branching ratio, $\mathcal{B}(B \to \eta' X_{nc})$, of $[4.6 \pm 1.1 \pm 0.4 \pm 0.5] \times 10^{-4}$. The uncertainties are statistical, systematic, and due to subtraction of charm-decay background, respectively.

PACS. 13.25.Hw Decays of Bottom Mesons

1 Introduction: Rare two-body decays

The decay of the B meson to non-charmed final states signals the presence of processes involving the off-diagonal elements of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. They may proceed via $b \to u$, $b \to s$, or $b \to d$ transitions. The latter two, flavor changing neutral currents (penguin diagrams), are particularly sensitive to possible new particles within the loops as well as to new physics. $b \to u$ transitions have intrinsic interest through their explicit dependence on V_{ub} and its phase γ; they are obvious candidates for CP violating processes. The K^+K^- mode may occur via a W-exchange diagram and is suppressed by V_{ub}. It is expected to be very small.

It has been argued [1] that the branching ratio $\mathcal{B}(\to K^-\pi^+)$, together with other charmless modes can determine, or at least constrain, the CKM angleγ. It has futher been suggested the entire CKM triangle may be reconstructed from the study of charmless modes, independent of the methods which use B mixing, CP violation in K decay, and the $B \to J/\psi K^0{}_s$ CP asymmetry. Analyses of previously available data [2] find some inconsistency between the two approaches, which is further increased by the resulted presented here.

CLEO has previously published results [3] for many of the modes reported herein, using only the CLEO II detector. In the present work we add data from the new CLEO III experiment and report measurements which are based on the full, combined CLEO data sample; these supercede our previous results. More detail can be found in the recently published journal article [4].

2 CLEO detector(s) and datasets

CLEO is a general-purpose solenoidal magnet detector operating at the Cornell Electron Storage Ring (CESR). For the present work, CESR was operated at the center-of-mass energy of the $\Upsilon(4S)$ or at an energy 60 MeV below the resonance, where we can measure the four-flavor continuum background which underlies the $\Upsilon(4S)$. The resonant hadronic cross section is about 1 nb; the continuum cross section is about 3 nb. Between 1990 and 1999 the CLEO II and II.V experiments accumulated integrated luminosity of 9.13 fb^{-1} at the $\Upsilon(4S)$ and 4.35 fb^{-1} off resonance. Between July, 2000 and June, 2001, the CLEO III detector accumulated 6.18 fb^{-1} at the $\Upsilon(4S)$ and 2.24 fb^{-1} off resonance.

CLEO II and CLEO III are well-understood detectors with excellent calorimetry (CsI/Tl)) and charged particle tracking. The CLEO III detector [5] differs from its predecessor, CLEO II [6], principally by the presence of a RICH particle identifier, which can separate pions from kaons even at the highest momenta relevant to B decay. With the aid of specific ionization measurements in the 47-layer drift chamber,the separation exceeds 3 standard deviations at all momenta. The particle identification can be calibrated by using a sample of $D^{*\pm} \to \pi^{\pm}(slow) K^{\mp}\pi^{\pm}$ decays, where the charge of the slow pion (the “tag’) determines the identity of the other particles. For detection efficiencies near 90%, contamination by the undesired particle is < 10%.

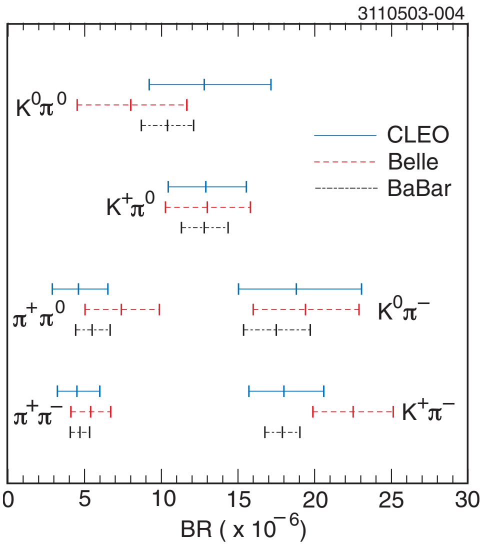

Fig. 1. The branching ratios for the well-measured two-body modes are compared with the results from the Babar and Belle collaborations

3 Features of analysis and two-body results

The modes to be considered , $\pi\pi, K\bar{K}, p\bar{p}, p\bar{\Lambda}$, and $\Lambda\bar{\Lambda}$ all feature two high-momentum, back-to-back particles. This topology occurs far more commonly in non-b hadronic events than in B decays, where the branching ratios are all of order 10^{-5} or less. Rejection of this so-called continuum background is key to the analysis. Both topological and kinematical features are used to distinguish among the various modes and to separate signal from background. Variables used include: M_B, the beam-constrained mass, ΔE, the energy difference between the beam and the candiadte B meson, θ_B, the angle between the candidate direction and the beam, $\mathcal{F}$, a Fisher discriminant formed from the candidate direction and energy-flows about the 2-body axis. After loose event selection cuts, an unbinned extended maximum-likelihood fit is performed for each mode with PDF's for signal, background, and "crossfeed" from misidentification.

The combined results are summarized in Table 1 and in Fig. 1, where it may be seen that all $K\pi$ and $\pi\pi$ modes (except for $\pi^0\pi^0$) have been measured with significance exceeding three standard deviations and are in general agreement with those of Babar and Belle. For the other modes we quote 90% confidence upper limits. The largest sources of systematic error are the number of $B\bar{B}$ pairs and the uncertainties in π^0 and Λ reconstruction efficiency. Note that the limit on decay to K^+K^- is below 10^{-6}.

4 Not-so-rare B decays: inclusive η' yields

In 1998 CLEO observed [7] copious inclusive production of high momentum η' in B decays, with $\mathcal{B} \sim 6. \times 10^{-4}$, as well as a large exclusive rate to $\eta' K$. Theorists have searched for the origin of this unexpected rate; favored explanations involve either the anomalous $gg^*\eta'$ coupling or the presence of intrinsic $c\bar{c}$ pairs in the η' wave function. Here we present a more refined analysis on the combined CLEO II/CLEO II.V dataset, with the added aim of clarifying the spectrum of states recoiling against the η'. More detail may be found in the recent journal publication [8].

Table 1. Branching ratios from the combined CLEO II/CLEO III dataset. The uncertainties are, respectively, statistical, and systematic

mode	significance(σ)	$\mathcal{B} \times 10^6$
$\pi^+\pi^-$	4.4	$4.5^{+1.4+0.5}_{-1.2-0.4}$
$\pi^+\pi^0$	3.5	$4.6^{+1.8+0.6}_{-1.6-0.7}$
$\pi^0\pi^0$	2.5	(< 4.4)
$K^+\pi^-$	> 7	$18.0^{+2.3+1.2}_{-2.1-0.9}$
$K^0\pi^+$	> 7	$18.8^{+3.7+2.1}_{-3.3-1.8}$
$K^+\pi^0$	> 7	$12.9^{+2.4+1.2}_{-2.2-1.1}$
$K^0\pi^0$	5.0	$12.8^{+4.0+1.7}_{-3.3-1.4}$
K^+K^-	-	(< 0.8)
K^0K^-	-	(< 3.3)
$K^0\bar{K}^0$	-	(< 3.3)
$p\bar{p}$	-	(< 1.4)
$\Lambda\bar{p}$	-	(< 1.5)
$\Lambda\bar{\Lambda}$	-	(< 1.2)

5 Outline of analysis technique for inclusive η' study

We take as signal the region $2.0 < P_{\eta'} < 2.7$ GeV/c , which excludes almost all B decays to charm. Any residual charm background will is determined from a Monte Carlo calculation, with the Monte Carlo "anchored" by the control region, $1.6 < P_{\eta'} < 1.9$ GeV/c , where the non-charmed contribution should be ignorable. Continuum contributions are removed by explicit subtraction of the scaled off-resonance data.

The analysis flow is as follows: 1)reconstruct η' in the mode $\eta' \to \pi^+\pi^-, \eta \to \gamma\gamma$ on the $\Upsilon(4S)$ and off-resonance, with the mass-difference between the η' candidate and the $\gamma\gamma$ mass required to be within 30 MeV of the nominal η', η mass difference, 2)for these η', perform "pseudo-reconstruction" of a B meson, combining with a kaon and up to 4 pions, 3)use a neural network, trained on Monte Carlo data to distinguish B-events from continuum (shape variables, $\Delta E, M_B$, and presence or absence of leptons are inputs to the net), 4)subtract scaled continuum and combinatorial backgrounds to get B decay yields, and 5)correct for the Monte Carlo determined charm contribution, which is scaled to agree in the control region. Each event is assigned a weight by the neural net. Combinatorial backgrounds are removed by fitting the mass difference distributions for $\Upsilon 4(S)$ and continuum data.

The resolution in M(X), the mass recoiling against the η', varies from 20 to 30 MeV when the decay products are all correctly identified (this ocurrs $\sim 50\%$ of the time) to between 200 and 300 MeV when particles are either missed or incorrectly added. Fig. 2 shows the comparison of the η' mass difference distributions in the signal region for on and off-resonance data. The continuum subtraction removes about 35 percent of the candidates. Fig. 3 shows the distribution in M(X),together with charm-related backgrounds as determined from the Monte Carlo simulation. Notable excesses above the estimated backgrounds are evident at $M(X) = M_K, M(X) \sim 1.4$ GeV, and at $M(X) \sim 2.3$ GeV.

5.1 η' results and discussion

Using an efficiency of $(6.81 \pm .56) \times 10^{-3}$ weights/event, we obtain:

$$\mathcal{B}(B \to \eta' X_{nc}) = [4.6 \pm 1.1 \pm 0.4 \pm 0.5] \times 10^{-4}$$

for 2.0< $P_{\eta'} < 2.7$ GeV/c. Here, the first uncertainty is statistical, the second systematic, and the third is due to the background. This rate may include a small contribution from $b \to dg$ gluonic penguins and from $b \to u$ tree processes. States with only u and d quarks have an efficiency of 0.79 relative to those that include kaons.

This result confirms the results of 7. Explanations for the unexpectedly large rate are, so far, unconvincing. Enhanced production via the QCD anomaly is disfavored by the recent CLEO measurements [9] of a small rate in $\Upsilon(1S) \to \eta' X$ Likewise, the intrinsic $c\bar{c}$ hypothesis predicts a $\mathcal{B}(B \to \eta' K^*)$ rate much larger than is observed.

We thank the dedicated CESR staff for their hard work and the Conference organizers for their hospitality and efficiency. This resesarch was supported by the National Science Foundation.

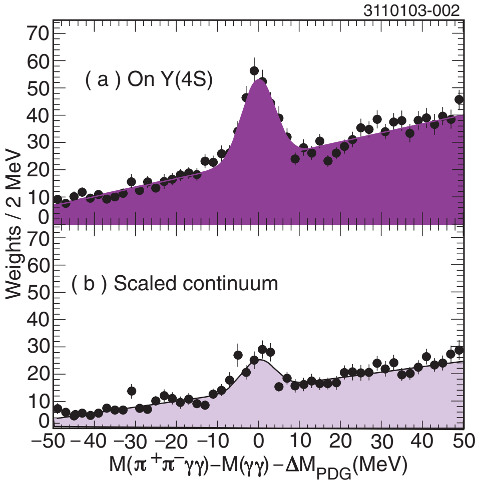

Fig. 2. The deviation of the mass difference beween the η' candidate and the $\gamma\gamma$ mass from the PDG η', η mass difference. a) $\Upsilon(4S)$ data, b) scaled continuum. The candidates have $2.0 < p_{\eta'} < 2.7$ GeV/c

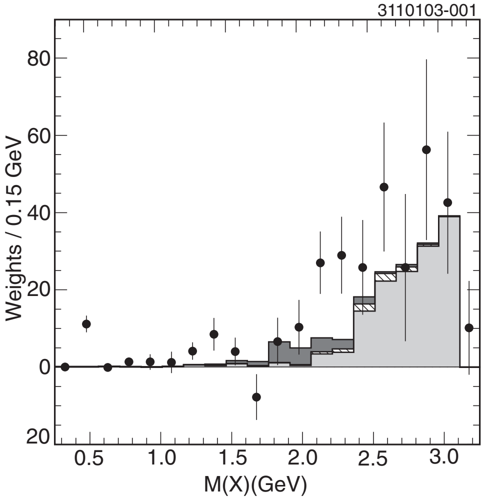

Fig. 3. The continuum and combinatorial background subtracted M(X)distribution (points with error bars) with estimated B-to-charm backgrounds. Cascade decays are shown as light grey, $B^0 \to \eta'(D^0 + D^{0*})$ is dark grey, and $B^0 \to \eta' D^{0**}$ in shown hatched. Neglecting the slight smearing due to B meson motion, the signal region corresponds to M(X) < 2.35 GeV; the control to M(X) > 2.5 GeV

References

1. Y.-Y. Keum, H.-N. Li, and A.I. Sanda: hep-ph/0201103; M. Neubert: J. High Energy Phys. **02**, 014 (1999); M. Neubert and J.L. Rosner: Phys. Rev. Lett. **81**, 5076 (1998); Phys. Lett. B **441**, 403 (1998); M. Neubert: *ibid.* **424**, 152 (1998); R. Fleischer and T. Mannel: Phys. Rev. D **57**, 2752 (1998)
2. M. Neubert: CLNS-02/1794 hep-ph 0207327; M. Beneke et al.: Nucl. Phys. B **606**, 245 (2001); M. Beneke et al.: Phys. Rev. Lett. **83**, 1914 (1999)
3. D.M. Asner et al. (CLEO): Phys. Rev. D **65**, 031103 (2002); R.A. Briere et al. (CLEO): Phys. Rev. Lett **86**, 3718 (2001) Earlier CLEO results are cited in the above
4. A. Bornheim et al. (CLEO): Phys. Rev. D **68**, 052002 (2003)
5. M. Artuso et al.: Nucl. Instrum. Meth. A **502**, 91 (2003); D. Peterson et al.: Nucl. Instrum. Meth. A **478**, 142 (2002)
6. Y. Kubota et al.: Nucl. Instrum. Meth. A **320**, (1992); T. S. Hill: *ibid.* **418**, 32 (1998)
7. T.E. Browder et al. (CLEO): Phys. Rev. Lett. **81**, 1786 (1998)
8. G. Bonvicini et al. (CLEO): Phys. Rev. D **68**, 011101 (2003)
9. M. Artuso et al. (CLEO): Phys. Rev. Lett. D **67**, 052003 (2003)