RADIATIVE $B$ DECAYS AT CLEO

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We report on the status of a variety of radiative $B$ decays studied by the CLEO detector with $9.7 \times 10^6$ $B\bar{B}$ pairs.

1 Introduction

Flavor changing neutral currents (FCNC) are well known to be forbidden at tree level in the Standard Model (SM). At higher order, however, loop diagrams (box and penguin diagrams) can generate effective flavor changing neutral currents, i.e., $b \rightarrow s$ and $b \rightarrow d$ transitions. The rates for such transitions in the SM are functions of the top quark mass and and $Z$ gauge bosons. Additionally, these rates are also sensitive to the exchange of heavy non-SM particles such as charged Higgs. Deviations from SM rates for $b \rightarrow s$ and $b \rightarrow d$ transitions are then a signature of physics beyond the SM. Hence, measurements of $b \rightarrow s$ and $b \rightarrow d$ transitions in the vicinity of the $\Upsilon(4S)$ resonance data, is $14 \times 10^7$.

Two observables are particularly useful for reconstructing $B$ candidates. The first is the difference in energy between a $B$ candidate and the beam energy, $\Delta E = E_B - E_{beam}$. The second is the beam-constrained $B$-mass, $M_B = \sqrt{E_{beam}^2 - p_B^2}$, where $p_B$ is the momentum of the $B$ candidate. Additionally, the shape of spherical $B\bar{B}$ events is used to distinguish them from jet-like continuum events.

3 Exclusive Modes

CLEO first observed the exclusive mode $B \rightarrow K^*\gamma$ and continues to collect statistics. The $K^*$ always decays to $K\pi$ and CLEO reconstructs four modes $(K^{\pm}\pi^\pm, K_S^0, K^{\pm}\pi^0, K_S^0\pi^0)$ to be consistent with the $K^*(890)$ resonance. No other $K^*$ resonances lie in this mass range. The $K\pi$ system and a hard photon are required to be consistent with the $B$ mass using the variables $\Delta E$ and $M_B$. The major background is from continuum $(e^+e^- \rightarrow q\bar{q})$ events accompanied by a hard photon from initial state radiation or events of the type $e^+e^- \rightarrow (\pi^0, \eta)X$ with $\pi^0, \eta \rightarrow \gamma\gamma$. Both backgrounds are suppressed with appropriate events shape and $\pi^0, \eta$ vetoes. Summed over all $K^*$ modes, the yield versus $M_B$ distribution is shown in figure .

Separated into neutral and charged $B$ modes, the measured branching fractions are: $B(B^+ \rightarrow K^{*+}\gamma) = (4.5 \pm 0.7 \pm 0.3) \times 10^{-5}$ and $B(B^0 \rightarrow K^{*0}\gamma) = (3.8 \pm 0.9 \pm 0.3) \times 10^{-5}$.

CLEO’s large sample of $B \rightarrow K^*\gamma$ de-
... that use relativistic form factors

These results imply 90% CL.

B and \( B \) fitting the ent helicity distributions and decay widths.

can be distinguished because of their differences.

B modes yields the branching fraction results:

Figure 1. The beam-constrained mass distribution for \( B \rightarrow K^\ast \gamma \) summed over the four \( K^\ast \) modes discussed in the text.

cays allows a search for direct CP violation by measuring the fractional CP asymmetry parameter \( A_{CP} = (B(b) - B(\bar{b})/(B(b) + B(\bar{b})) \), where \( B(b) \) is the branching fraction of \( B^- \) and \( B^0 \) into \( K^\ast \gamma \) and \( B(\bar{b}) \) is the branching fraction of \( B^+ \) and \( B^0 \) into \( K^\ast \gamma \). Here, self-tagging \( K^\ast \) decay modes are used to produce the result, summed over charged and neutral \( B \) decay modes, \( A_{CP} = +0.08 \pm 0.13 \pm 0.03 \).

CLEO has searched for resonances heavier than \( K^\ast(890) \), the \( K_2^\ast(1430) \) and the \( K^\ast(1410) \), each of which has an appreciable branching fraction to the final state \( K \pi \): \( B(K_2^\ast(1430) \rightarrow K \pi) = 50 \pm 1 \% \) and \( B(K^\ast(1410) \rightarrow K \pi) = 7 \pm 1 \% \). These modes can be distinguished because of their different helicity distributions and decay widths. Fitting the \( M_B \) distribution for both decay modes yields the branching fraction results:

\( B(B \rightarrow K_2^\ast(1430) \gamma) = (1.7 \pm 0.6 \pm 0.1) \times 10^{-5} \) and \( B(B \rightarrow K^\ast(1410) \gamma) < 12.7 \times 10^{-5} \) at 90% CL.

The likelihood contours for the fit are shown in figure 2. These results imply that \( R = B(B \rightarrow K^\ast(1430) \gamma)/B(B \rightarrow K^\ast(890) \gamma) = 0.4 \pm 0.1 \), favoring models that use relativistic form factors to predict these rates and disfavoring those with non-relativistic form factors.

CLEO has also searched for \( b \rightarrow d \gamma \) transitions of the form \( B \rightarrow \rho \gamma \) and \( B \rightarrow \omega \gamma \) which are a means to limit the CKM ratio \( |V_{td}/V_{ts}| \) through the ratio of branching fractions \( R \equiv B(B \rightarrow \rho(\omega) \gamma)/B(B \rightarrow K^\ast \gamma) = \xi |V_{td}/V_{ts}|^2 \), where \( \xi \) is the ratio of \( B \rightarrow \rho \) and \( B \rightarrow K^\ast \gamma \) form factors and lies in the range 0.6–0.9. The \( \Delta E \) vs. \( M(\pi\pi) \) distributions for \( B^0 \rightarrow \rho^0 \gamma \) and \( B^+ \rightarrow \rho^+ \gamma \) candidates are shown in figure 3. The branching fraction limits are \( B(B^0 \rightarrow \rho^0 \gamma) < 1.7 \times 10^{-5} \) and \( B(B^+ \rightarrow \rho^+ \gamma) < 1.3 \times 10^{-5} \) at the 90% CL. This corresponds to \( R < 0.32 \) at the 90% CL. For the choice \( \xi = 0.6 \), this implies \( |V_{td}/V_{ts}| < 0.72 \) at 90% CL. The search for \( B \rightarrow \omega \gamma \) yields the limit \( B(B^0 \rightarrow \omega \gamma) < 0.92 \times 10^{-5} \) at the 90% CL.

4 Inclusive Modes

CLEO has measured the inclusive branching fraction \( B(b \rightarrow s \gamma) \) by determining the hard photons energy spectrum and then performing an ON/OFF resonance subtraction. Backgrounds for this analysis are from continuum with initial state radiation and from continuum with a high energy \( \pi^0 \), \( \eta \), or \( \omega \),...
Figure 3. The $\Delta E$ vs. $M(\pi\pi)$ distribution for a) $B^0 \to \rho^0\gamma$ and for b) $B^+ \to \rho^+\gamma$ candidates. Dots above the slanted line have passed all cuts. The central dotted ovals are the limits that contain 90% of the $B \to \rho\gamma$ candidates. The partial ovals are the limits that contain 90% of the background $B \to K^*\gamma$ events.

where one of the daughter photons escapes detection. The ON-resonance background is suppressed by two methods. The first method uses a neural net (NN) technique based on event shape variables to separate $B\bar{B}$ events from non-$B\bar{B}$ events. The second technique uses a pseudo-reconstruction method and a second NN. The end result is that events are weighted by a NN output. Afterwards, OFF-resonance data is subtracted. Photon energies $E_\gamma$ between $2.1 \text{ GeV} < E_\gamma < 2.7 \text{ GeV}$ are used for the final result. Using only 3.1 fb$^{-1}$ of ON-resonance data, CLEO measures $B(b \to s\gamma) = (3.15 \pm 0.35 \pm 0.32 \pm 0.26) \times 10^{-4}$, consistent with SM calculations.

CLEO has searched for direct CP violation in $b \to s\gamma$ decays for the full data sample of $9.7 \times 10^6\ B\bar{B}$ events by constraining the fractional CP violation parameter $\Lambda_{CP}$. Although in the SM, $\Lambda_{CP}$ is expected to be less than 1%, some non-SM physics scenarios permit $\Lambda_{CP} < 10 - 40\%$. Events are flavor tagged using either the charge of a high momentum lepton from the “other” $B$ or by using a pseudo-reconstruction technique similar to the one used in the inclusive $b \to s\gamma$ analysis. The typical mis-tag rate is 10%. CLEO finds $-0.22 < \Lambda_{CP} < +0.09$ at the 90% CL.

5 Non-penguin Radiative Decays

Finally, CLEO has searched for radiative $B$ decays not mediated by electromagnetic diagrams, as shown in figure 4. In the SM such decays are expected to be small but their observation would permit the importance of $W$ exchange diagrams in $B$ decays to be gauged. Here, the $D^{*0}$ decays by $\pi^0$ or $\gamma$ emission and the $D^0$ is reconstructed in the $K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+$ final states. No events are found in $M_B - \Delta E$ space which leads to the branching fraction limit $B(\bar{B}^0 \to D^{*0}\gamma) < 5 \times 10^{-5}$ at the 90% CL.

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