SLAC-PUB-12085
August 2006

Recent Results in Electroweak B Decays from the *BABAR* Experiment

Karsten Köneke (representing the *BABAR* Collaboration)

Laboratory for Nuclear Science, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139, USA

Abstract. A review of the most recent *BABAR* results on electroweak penguin B decays is presented. The focus of this paper is on the measurement of observables in the decays $B \to X_s\gamma$, $B \to K^{(*)}l^+l^-$ $B \to K_S^0\pi^0\gamma$ (time–dependent analysis) and $B \to (\rho/\omega)\gamma$.

Keywords: Electroweak, Penguin, Rare B Decays, Photon Energy Spectrum, B meson
PACS: 11.30Hv, 13.25-k, 13.25Hw, 14.40Nd

INTRODUCTION

Rare decays are an excellent window for physics beyond the standard model (PBSM) to enter. The Feynman loop diagrams through which these decays proceed in the standard model (SM) could host additional particles from PBSM in the loop. Thus, the predictions from the SM of some of the observables (like branching fractions, CP-violating asymmetries and others) could differ from the measurements. This would indicate contributions from PBSM processes.

$B \to X_s\gamma$

The branching fraction is well known from experiment and agrees well with SM based calculations [1, 2]. Besides the measurement of the branching fraction, there are two major observables in this decay mode. The photon energy spectrum and the CP-violating charge asymmetry. The measurement of the photon energy spectrum can be used to obtain information about the b–quark mass and its kinetic energy inside the B–meson. The two decay products of a hypothetical free b–quark, the s–quark and the photon, would have a fixed momentum $m_b/2$. Due to the confinement of the b–quark inside the B–meson, the energy of the photon is not monoenergetic but instead has a distribution. The first moment (mean) of this distribution is expected to be $m_b/2$ and the second moment is a measurement of the kinetic energy of the b-quark inside the B–meson. The CP-violating charge asymmetry is expected to be less than 1% in the SM. A large non–zero measurement would therefore indicate PBSM.

BABAR has performed two independent analysis of this decay mode, a fully inclusive analysis and a sum–of–exclusive–modes analysis.

The fully inclusive analysis [3] uses a high–energy lepton (electron or muon) to identify the other B in the event. This analysis is based on 88.5 million $B\bar{B}$ pairs and the preliminary result for the branching fraction is $\mathscr{B}(B \to X_s\gamma)\left[E_\gamma > 1.9\,GeV\right] =$

Presented at Particles and Nuclei International Conference (PANIC 05), 24028 October 2005, Santa Fe, NM

Work supported in part by Department of Energy contract DE-AC02-76SF00515

$(3.67\pm0.29\pm0.34\pm0.29)\times10^{-4}$ where the first error is statistical, the second systematic and the third is the uncertainty due to model dependencies. The preliminary result for the first moment is $\langle E_\gamma\rangle\left[E_\gamma>1.9\,GeV\right]=(2.288\pm0.025\pm0.017\pm0.012)\,GeV$. For the CP-violating asymmetry, this analysis obtains $A_{CP}\left(B\to X_{(s+d)}\gamma\right)=-0.110\pm0.115\pm0.017$ (preliminary).

The sum–of–exclusive–modes analysis [4] reconstructs the X_s hadronic system explicitly in 38 final states. However, an additional uncertainty related to the hadronization of the X_s–system appears in this approach. This analysis is based on 88.9 million $B\bar{B}$ pairs and yields for the branching fraction (extrapolated from $E_\gamma>1.9\,GeV$) $\mathscr{B}(B\to X_s\gamma)\left[E_\gamma>1.6\,GeV\right]=\left(3.25\pm0.19^{+0.56+0.04}_{-0.41-0.09}\right)\times10^{-4}$. The first moment is determined as $\langle E_\gamma\rangle\left[E_\gamma>1.897\,GeV\right]=\left(2.321\pm0.038^{+0.017}_{-0.038}\right)\,GeV$ and the second moment is $\left\langle\left(E_\gamma-\langle E_\gamma\rangle\right)^2\right\rangle\left[E_\gamma>1.897\,GeV\right]=\left(0.0253\pm0.0101^{+0.0041}_{-0.0028}\right)\,GeV^2$. The CP-violating charge asymmetry $A_{CP}(B\to X_s\gamma)=0.025\pm0.050\pm0.015$ [5] is consistent with zero.

$B\to K^{(*)}l^+l^-$

In addition to the photon penguin diagram, two more Feynman diagrams contribute to this decay at leading order. The W–box diagram and the Z^0–penguin diagram. Thus, PBSM can manifest itself through different mechanisms in this decay. For example supersymmetric neutral Higgs bosons in models with large $\tan\beta$ could enhance the ratio of muon modes to electron modes $R_{K^{(*)}}=\mathscr{B}\left(B\to K^{(*)}\mu^+\mu^-\right)/\mathscr{B}\left(B\to K^{(*)}e^+e^-\right)$ [6]. Also, the CP-violating charge asymmetry is expected to be less than 1% in the SM [7]. On the other hand, PBSM could enhance this to order one [8].

The most recent BABAR analysis [9] is based on 229 million $B\bar{B}$ pairs and reconstructs only charged particles in the final state. For the charged leptons only muons and electrons are considered. The measured branching fractions $\mathscr{B}(B\to Kl^+l^-)=(0.34\pm0.07\pm0.03)\times10^{-6}$ and $\mathscr{B}(B\to K^*l^+l^-)=\left(0.78^{+0.19}_{-0.17}\pm0.12\right)\times10^{-6}$ agree well with theoretical predictions [10, 11]. Also the measured CP-violating charge asymmetries $A_{CP}(B^+\to K^+l^+l^-)=0.08\pm0.22\pm0.11$ and $A_{CP}(B\to K^*l^+l^-)=-0.03\pm0.23\pm0.12$ as well as the muon–to–electron ratios $R_K=1.06\pm0.48\pm0.05$ and $R_{K^*}=0.93\pm0.46\pm0.06$ agree well with SM expectations.

$B\to K^0_s\pi^0\gamma$

In this final state, the K^0_s and the π^0–mesons are CP–eigenstates. The photon is predominantly left (right) handed in the decay $b\to s\gamma$ ($\bar{b}\to\bar{s}\gamma$). Thus, the time–dependent CP–violation due to interference between direct decays and decays via $B^0-\bar{B}^0$ mixing is expected to be suppressed to less than 10% in the SM [12, 13]. Any measurement of a larger CP–violation would indicate PBSM.

Based on a data sample of 232 million $B\bar{B}$ pairs, the most recent BABAR analysis [14] searches for CP–violation in two meson–mass ranges. This analysis obtains in the K^* region ($0.8 < m_{K_S^0\pi^0} < 1.0\, GeV/c^2$) $S_{K^{*0}\gamma} = -0.21 \pm 0.40 \pm 0.05$ and $C_{K^{*0}\gamma} = -0.40 \pm 0.23 \pm 0.03$. The corresponding results for the non–K^* region ($1.1 < m_{K_S^0\pi^0} < 1.8\, GeV/c^2$) are $S_{K_S^0\pi^0\gamma} = 0.9 \pm 1.0 \pm 0.2$ and $C_{K_S^0\pi^0\gamma} = -1.0 \pm 0.5 \pm 0.2$.

$B \to (\rho/\omega)\,\gamma$

Besides the interests mentioned in the introduction, this rare decay is also interesting in constraining Cabibbo-Kobayashi-Maskawa (CKM) matrix elements. The ratio of branching fractions $\mathscr{B}(B \to (\rho/\omega)\,\gamma)\,/\,\mathscr{B}(B \to K^*\gamma)$ is in the SM related to the ratio of the CKM–matrix elements $|V_{td}|\,/\,|V_{ts}|$ and thus to the poorly known far side of the unitarity triangle [15, 16].

The most recent *BABAR* analysis [17] is based on a data set of 221 million $B\overline{B}$ pairs. No significant signal is seen and an upper limit at the 90% C.L. could be set for the ρ/ω combined branching fraction as $\mathscr{B}(B \to (\rho/\omega)\,\gamma) < 1.2 \times 10^{-6}$. The SM based range of $(0.8 - 1.8) \times 10^{-6}$ [15, 18] is already restricted by this measurement. A limit $|V_{td}|\,/\,|V_{ts}| < 0.19$ at 90% C.L. is obtained, ignoring theoretical uncertainties.

CONCLUSION

So far, no significant deviations from the SM have been seen. With *BABAR* continuing to take data, future updates of these measurements will significantly increase the precision of these measurements and further restrict the possible PBSM scenarios.

REFERENCES

1. A. J. Buras, A. Czarnecki, M. Misiak, and J. Urban, *Nucl. Phys.* **B631**, 219–238 (2002), hep-ph/0203135.
2. P. Gambino, and M. Misiak, *Nucl. Phys.* **B611**, 338–366 (2001), hep-ph/0104034.
3. B. Aubert, et al. (2005), hep-ex/0507001.
4. B. Aubert, et al. (2005), hep-ex/0508004.
5. B. Aubert, et al., *Phys. Rev. Lett.* **93**, 021804 (2004), hep-ex/0403035.
6. G. Hiller, and F. Kruger, *Phys. Rev.* **D69**, 074020 (2004), hep-ph/0310219.
7. F. Kruger, L. M. Sehgal, N. Sinha, and R. Sinha, *Phys. Rev.* **D61**, 114028 (2000), hep-ph/9907386.
8. F. Kruger, and E. Lunghi, *Phys. Rev.* **D63**, 014013 (2001), hep-ph/0008210.
9. B. Aubert, et al. (2005), hep-ex/0507005.
10. A. Ali, E. Lunghi, C. Greub, and G. Hiller, *Phys. Rev.* **D66**, 034002 (2002), hep-ph/0112300.
11. M. Zhong, Y.-L. Wu, and W.-Y. Wang, *Int. J. Mod. Phys.* **A18**, 1959–1989 (2003), hep-ph/0206013.
12. D. Atwood, M. Gronau, and A. Soni, *Phys. Rev. Lett.* **79**, 185–188 (1997), hep-ph/9704272.
13. B. Grinstein, Y. Grossman, Z. Ligeti, and D. Pirjol, *Phys. Rev.* **D71**, 011504 (2005), hep-ph/0412019.
14. B. Aubert, et al., *Phys. Rev.* **D72**, 051103 (2005), hep-ex/0507038.
15. A. Ali, E. Lunghi, and A. Y. Parkhomenko, *Phys. Lett.* **B595**, 323–338 (2004), hep-ph/0405075.
16. A. Ali, and A. Y. Parkhomenko, *Eur. Phys. J.* **C23**, 89–112 (2002), hep-ph/0105302.
17. B. Aubert, et al., *Phys. Rev. Lett.* **94**, 011801 (2005), hep-ex/0408034.
18. S. W. Bosch, and G. Buchalla, *Nucl. Phys.* **B621**, 459–478 (2002), hep-ph/0106081.