SLAC-PUB-13509
*BaBar*-PROC-08/156
0901.1263v1 [hep-ex]
January, 2009

# Rare $B$ Decays at *BaBar*

F. Palombo
Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
(for the *BABAR* Collaboration)

## Abstract

I present some of the most recent *BaBar* measurements for rare $B$ decays. These include rate asymmetries in the $B$ decays to $K^{(*)}l^+l^-$ and $K^+\pi^-$ and branching fractions in the $B$ decays to $l^+\nu_l$, $K_1(1270)^+\pi^-$ and $K_1(1400)^+\pi^-$. I also report a search for the $B^+$ decay to $K^0_S K^0_S \pi^+$.

Contributed to the Proceedings of the $18^{th}$ International Conference on Particles and Nuclei,
11/09/2008—11/14/2008, Eilat, Israel

*Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309*

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

# 1 Introduction

The study of rare $B$ decays plays a central role in the physics program of the *BABAR* [1] and Belle [2] experiments at the B-factories. Rare $B$ decays in fact provide sensitivity to the Standard Model (SM) parameters. They are also powerful probes for the presence of New Physics (NP).

# 2 Results

I present preliminary results of some of the latest *BABAR* analyses of electroweak, pure leptonic, and hadronic penguin B decays. Most of these improved measurements are based on the final *BABAR* dataset of about $465 \times 10^6$ $B\overline{B}$ pairs taken at the $\Upsilon(4S)$.

## 2.1 Electroweak $B$ Decays to $K^{(*)}l^+l^-$

Electroweak decays $B \to K^{(*)}l^+l^-$ ($l = e, \mu$) are mediated by flavor-changing neutral current processes, forbidden at tree level in the SM. These decays may proceed through a $\gamma$/Z loop (penguin) or a $W^-W^+$ box diagram. Contributions from NP may enter the loop and box diagrams at the same order as the SM ones and affect both rates and kinematic distributions [3]. In exclusive $B$ decay modes sensitivity to NP in the rates is limited by hadronic uncertainties. For this reason it is preferable to search for NP in rate asymmetries where part of these uncertainties cancels.

*BABAR* recently updated [4] measurements of direct *CP* asymmetry $\mathcal{A}_{CP}^{K^*}$, lepton flavor ratio $R_{K^{(*)}}$, and *CP*-averaged isospin asymmetry $\mathcal{A}_I^{K^{(*)}}$ . $\mathcal{A}_{CP}^{K^*}$ and $R_{K^{(*)}}$ , expected in SM at a level of $10^{-4}$ and 1 respectively, could be enhanced by NP contributions [5]. Results for both $\mathcal{A}_{CP}^{K^*}$ and $R_{K^{(*)}}$ are in agreement with SM expectations. $\mathcal{A}_I^{K^{(*)}}$ is expected at a level of 0.01 in SM [6]. In combined fit to $Kl^+l^-$ and $K^*l^+l^-$ in low dilepton mass squared region $0.1 < m_{ll}^2 < 7.02\ \mathrm{GeV}^2/c^4$, the fit result is $\mathcal{A}_I^{K^{(*)}} = -0.64^{+0.15}_{-0.14} \pm 0.03$. It is 3.9 standard deviations ($\sigma$) (systematic uncertainties included) from the null asymmetry. This effect is not seen in high $m_{ll}^2$ region ($> 10.24\ \mathrm{GeV}^2/c^4$).

## 2.2 Pure Leptonic $B^+$ Decays to $l^+\nu_l$

The purely leptonic $B$ decays to $l\nu_l$ ($l = \tau, \mu, e$) proceed in SM through $W$ boson annihilation with a branching fraction (BF): $\mathcal{B}(B^+ \to l^+\nu) = \frac{G_F^2 m_B}{8\pi} m_l^2 (1 - \frac{m_l^2}{m_B^2})^2 f_B^2 |V_{ub}|^2 \tau_{B^+}$ [7]. The SM estimate of the BF for $B \to \tau\nu_\tau$ is of the order of $10^{-4}$. BFs for modes with $\mu\nu_\mu$ and $e\nu_e$ are helicity suppressed ($\sim m_l^2$) by factors 225 and $10^7$, respectively. However contributions from NP scenarios [8] may enhance these SM expectations. *BABAR* studied these $B$ decays, searching signals with a semi-leptonic tagging method [7]. The measured BF $\mathcal{B}(B^+ \to \tau^+\nu_\tau)$ is $(1.8 \pm 0.8 \pm 0.1) \times 10^{-4}$ with a significance of $2.4\,\sigma$. The upper limit (UL) at 90% confidence level (CL) is $3.2 \times 10^{-4}$. Combining this with the other *BABAR* BF measurement of the same $B$ decay using an hadronic tag [9], we have $\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (1.8 \pm 0.6) \times 10^{-4}$ with a significance of $3.2\,\sigma$.

ULs at 90 % CL are set for the other two decay modes: $\mathcal{B}(B^+ \to \mu^+\nu_\mu) < 11 \times 10^{-6}$ and $\mathcal{B}(B^+ \to e^+\nu_e) < 7.7 \times 10^{-6}$. *BABAR* also searched for the $B^+ \to \mu^+\nu_\mu$ mode using an inclusive tag and set an UL of $1.3 \times 10^{-6}$ at 90 % CL [10].

### 2.3 Hadronic-Penguin $B$ Decays to K $\pi$, $K_1\pi$ and $K_S^0$ $K_S^0$ $\pi$

At the B-factories direct *CP* asymmetry has been observed in neutral $B$ decays to $\pi^+\pi^-$ and $K^+\pi^-$. *BABAR* has recently updated these measurements [11]. The measured direct *CP* asymmetry $\mathcal{A}_{K^\pm\pi^\mp}$ between $\overline{B}^0 \to K^-\pi^+$ and $B^0 \to K^+\pi^-$ is $-0.107 \pm 0.016^{+0.006}_{-0.004}$ with a significance of $6.1\,\sigma$. *BABAR* also measured the direct *CP* asymmetry $\mathcal{A}_{K^\pm\pi^0} = 0.030 \pm 0.039 \pm 0.010$ [12]. The difference of these two asymmetries, naively expected zero in SM, is: $\Delta\mathcal{A} = \mathcal{A}_{K^\pm\pi^0} - \mathcal{A}_{K^\pm\pi^\mp} = 0.137 \pm 0.044$ with a significance at a level of $3.1\,\sigma$. This result is consistent with Belle measurement [13]. Using the world average of existing (*BABAR*, Belle, CDF, CLEO) results [14] , we have $\Delta\mathcal{A} = 0.148 \pm 0.028$. with a significance at the level of $5.3\,\sigma$. Several approaches try to explain the large difference of $\mathcal{A}_{K^\pm\pi^0}$ and $\mathcal{A}_{K^\pm\pi^\mp}$ inside the SM as in [15] or with contributions from NP as in [16].

*BABAR* measured *CP* violating parameters in $B^0(\overline{B}^0) \to a_1(1260)^\pm\ \pi^\mp$ [17] for the extraction of the $\alpha$ angle of the unitary triangle. To determine by means of SU(3) flavor-symmetry [18] the uncertainties on this $\alpha$ measurement due to the presence of penguin contributions in the decay, *BABAR* measured the BF of $B^0$ to $K_1(1270)^+\pi^-$ and $K_1(1400)^+\pi^-$. Using a K-matrix formalism, a combined BF $\mathcal{B}(B^0 \to K_1(1270)^+\pi^- + K_1(1400)^+\pi^-) = (31.0 \pm 2.7 \pm 6.9) \times 10^{-6}$ is obtained with a significance $> 5.1\,\sigma$ [19].

The $B^+$ decay to $K_S^0 K_S^0 \pi^+$ is suppressed in SM with an expected BF of the order $10^{-6}$ [20]. An UL of $3.2 \times 10^{-6}$ at 90 % CL has been set by Belle [21]. The *BABAR* analysis, incorporating resonant and nonresonant intermediate states, finds no significant signal and sets an UL of $5.1 \times 10^{-7}$ at 90 % CL [22]. In the $B^+$ decay to $K^+K^-\pi^+$ *BABAR* has seen a peak at 1.5 GeV/$c^2$ (dub as $f_x(1500)$) in the $K^+K^-$ invariant mass [23]. Because there is no evidence of this peak in $K_S^0$ $K_S^0$ invariant mass spectrum, models in which $f_x(1500)$ has even spin and decays with isospin symmetry are disfavored.

## 3 Summary and Conclusions

I have presented a selection from the most recent *BABAR* results on rare $B$ decays. No significant deviations from the SM expectations have been seen (including also all those measurements on rare $B$ decays non presented here). The disagreement with SM found in a few cases may be explained either with improved calculations within the SM or with NP contributions. In conclusion, we need much more precise measurements to improve our sensitivity to SM deviations and to NP effects. This task, complementary to LHC NP search, can be accomplished at LHCb [24] and at a super B-factory [25].

## References


[1] *BABAR* Collaboration, B. Aubert *et al.*, Nucl. Instr. Meth. A **479**, 1 (2002).

[2] Belle Collaboration, S. Kurokawa *et al.*, Nucl. Instr. Meth. A **499**, 1 (2003).

[3] A. Ali *et al.*, Phys. Rev. D **66**, 034002 (2002).

[4] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:0807.4119v1, submitted to Phys. Rev. Lett. .

[5] C. Bobeth *et al.*, JHEP **0807**, 106 (2008); Q.-S. Yan *et al.*, Phys. Rev. D **62**, 094023 (2000).

[6] T. Feldmann and J. Matias, JHEP **0301**, 074 (2003).

[7] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:0809.4027v1.

[8] W.-S. Hou, Phys. Rev. D **48**, 2342 (1993).

[9] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **77**, 011107 (2008).

[10] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:0807.4187v1.

[11] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:0807.4226v2.

[12] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **76**, 091102 (2007).

[13] BELLE Collaboration, S.-W. Lin *et al.*, Nature **452**, 332 (2008).

[14] Heavy Flavor Averaging Group: http://www.slac.stanford.edu/xorg/hfag/.

[15] M. Gronau and J. L. Rosner, Phys. Lett. B **44**, 237 (2007); M. Ciuchini *et al.*, arXiv:0811.0341v1; M. Duraisamy and A. Kagan, arXiv:0812.3162v2.

[16] W.-S. How *et al.*, Eur. Phys. J. C **51**, 55 (2007); Q. Chang and Y-D. Yang, JHEP **0809**, 038 (2008).

[17] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **98**, 181803 (2007).

[18] M. Gronau and J. Zupan, Phys. Rev. D **73**, 057502 (2007).

[19] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:0807.4760v1.

[20] S. Fajfer *et al.*, Phys. Rev. D **60**, 054029 (1999); L. Guo *et al.*, Phys. Rev. D **75**, 014019 (2007).

[21] Belle Collaboration, A. Garmash *et al.*, Phys. Rev. D **69**, 012001 (2004).

[22] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:0811.1979v1, submitted to Phys. Rev. D (RC).

[23] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **99**,221801 (2007).

[24] LHCb website, http://public.web.cern.ch/public/en/LHC/LHCb-en.html

[25] SuperB Collaboration, A. Bona *et al.*, arXiv:0709.0451v2 (http://www.pi.infn.it/SuperB/); Super KEK B, A. G. Akeroyd *et al.*, arXiv: hep-ex/0406071v2 (http://superb.kek.jp/).