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Electroweak penguin B decays at Belle

Patrick Koppenburg[a]

KEK — High Energy Accelerator Research Organization, Tsukuba, Japan

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Abstract. We summarise the most recent results of the Belle experiment about flavour changing neutral current (FCNC) radiative and (semi-) leptonic B decays. In particular, we report about the first observation of the decays $B \to K^*\ell^+\ell^-$, $B \to \phi K\gamma$, the inclusive $B \to X_s\ell^+\ell^-$. We also report about searches for $B \to \ell^+\ell^-$ decay and for CP asymmetries in $B \to K^*\gamma$.

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1 Introduction

Since the first observation of a penguin decay ten years ago [1], radiative B decays have been a powerful tool to constrain physics beyond the Standard Model. Today we enter an era of precision measurements as the error on the $B \to K^*\gamma$ branching fraction is about to become systematics-dominated and as we start to observe more rare decays like $b \to s\bar{s}s\gamma$. In the future $b \to s\gamma$ transitions may be used to probe the kinematic properties the B decays, which is useful to understand the V_{ub} extraction from semileptonic decays, and may also provide a handle on V_{td} once the Cabbibo-suppressed $b \to d\gamma$ decays are seen.

At the price of an additional suppression by $\alpha_{\mathrm{e.m.}}$, one gets flavour-changing neutral current (FCNC) semileptonic $b \to s\ell\ell$ decays, where the lepton pair provides other observables, like the forward-backward charge asymmetry, which are much more powerful to constrain the Standard Model and its extensions.

In this report we summarise the latest results from Belle [2] about the above mentioned decays and also about purely leptonic $B \to \ell\ell$ decays.

2 Radiative decays

While we start to perform precise branching fraction and CP asymmetry measurements in the $B \to K^*\gamma$ decay, which cannot be considered as "rare" at B factories anymore, most of the partial width of $B \to X_s\gamma$ is yet still unknown. Thus the search for more exclusive final states is needed to achieve a better understanding of the hadronic structure of this decay.

[a] for the Belle Collaboration

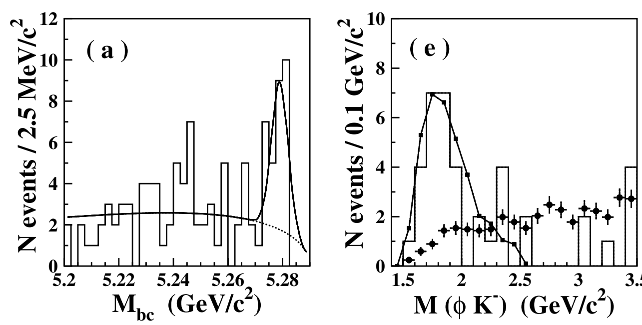

Fig. 1. m_{bc} fit (*left*) and $m_{\phi K}$ (*right*) for $K\phi\gamma$ final state. The measured (solid) $m_{\phi K}$ distribution is compared to MC simulations basing on a phase-space model (circles) or adjusted to follow the data (squares connected by a line)

2.1 First observation $B \to K\phi\gamma$

Using 90 fb^{-1}, we observe the decay $B^- \to \phi K^-\gamma$ [3]. This is the first observation of a radiative $b \to s\bar{s}s\gamma$ process. The decay is reconstructed using a high-energy photon, two oppositely charged kaons required to form the ϕ mass within 10 MeV ($\sim 3\sigma$), and one additional K^- or K^0_S. We observe 21.6 ± 5.6 events in the charged mode, (corresponding to a statistical significance of 5.5σ), and 5.8 ± 3.0 events in the neutral mode (3.3σ). The preliminary measured branching fractions are:

$$\mathcal{B}\left(B^- \to K^-\phi\gamma\right) = (3.4 \pm 0.9 \pm 0.4) \cdot 10^{-6}$$
$$\mathcal{B}\left(B^0 \to K^0\phi\gamma\right) = (4.6 \pm 2.4 \pm 0.6) \cdot 10^{-6}.$$

In the latter mode we also give an upper limit for the branching fraction at $8.3 \cdot 10^{-6}$ at 90% confidence level.

The beam-constrained mass fit for the charged mode is shown in Fig. 1 (left). The right hand side figure shows that the ϕK^- mass distribution differs from a naive three-body phase-space decay model. Yet the low statistics do not allow to draw any conclusion about the structure.

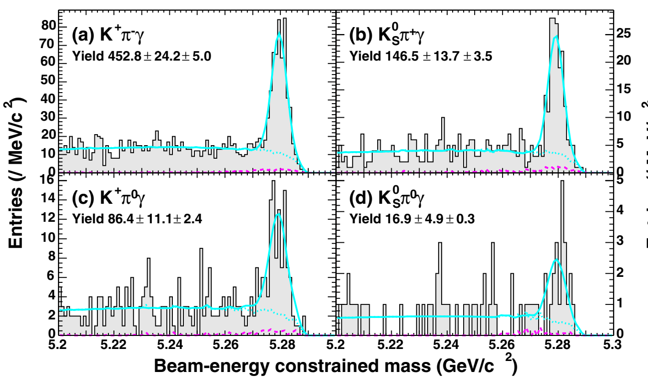

Fig. 2. Beam-constrained mass fits for $K^*\gamma$ final states

2.2 CP asymmetry in $B \to K^*\gamma$

Among radiative penguin decays, the $B \to K^*\gamma$ decay allows the most precise measurements. We observe 700 such decays [4], using a 78 fb^{-1} data sample and reconstructing the K^* in all visible final states $K^+\pi^-$, $K^0_S\pi^0$, $K^+\pi^0$, $K^0_S\pi^+$ (charge conjugation is implied throughout this report except where mentioned). The corresponding beam-constrained mass ($m_{\rm bc}$) distributions are shown in Fig. 2. The preliminary branching fractions are found to be

$$\mathcal{B}\left(B^0 \to K^{*0}\gamma\right) = (4.09 \pm 0.21 \pm 0.19) \cdot 10^{-5}$$
$$\mathcal{B}\left(B^+ \to K^{*+}\gamma\right) = (4.40 \pm 0.33 \pm 0.24) \cdot 10^{-5},$$

where the first error is statistical and the second systematic. Fitting the event yields separately for the two flavour eigenstates of the B meson (thus excluding the $K^0_S\pi^0\gamma$ final state) we get a measurement of the CP asymmetry:

$$A_{CP}\left(B \to K^*\gamma\right) = -0.001 \pm 0.044 \pm 0.008.$$

3 Semileptonic Penguin decays

Semileptonic FCNC decays $B \to X_s\ell^+\ell^-$ are known since the first observation of the $B \to K\ell^+\ell^-$ decay by Belle [5]. Here we report about the first observation of the long awaited $B \to K^*\ell^+\ell^-$ decay and about a semi-inclusive analysis.

3.1 First observation of $B \to K^*ll$

This analysis [6] searches for $B \to K^*ll$ and $B \to Kll$ using the full 140 fb^{-1} data sample available in Summer 2003. The candidates are formed using an oppositely-charged lepton pair (muons or electrons) and a K^+, K^0_S, or a K^* candidate formed formed as $K^+\pi^-$, $K^0_S\pi^+$ or $K^+\pi^0$. The lepton pair is vetoed if its mass is below 140 MeV/c^2, or compatible with the J/ψ or ψ' masses. In the eeK^* case, we also consider $ee\gamma$ and $ee\gamma\gamma$ combinations to suppress the $\psi^{(\prime)}$ background due to Bremsstrahlung. The fitted $m_{\rm bc}$ distributions are shown in Fig. 3. We observe

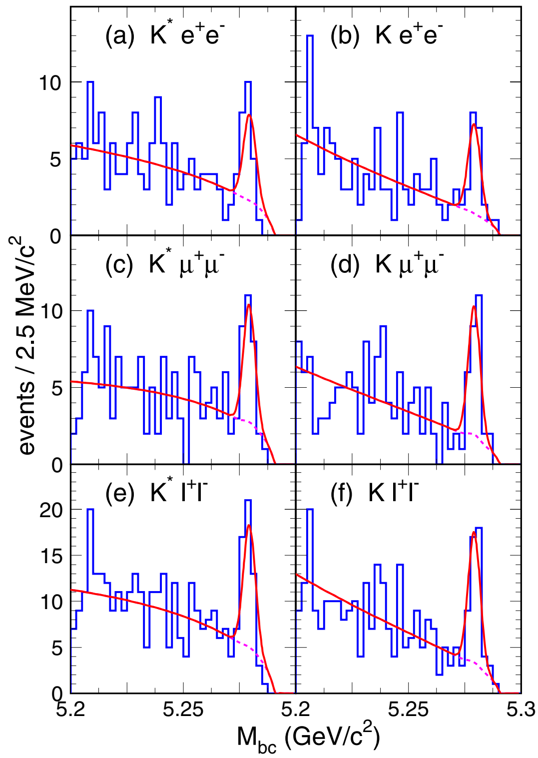

Fig. 3. $m_{\rm bc}$ fits for K^*ll and Kll final states

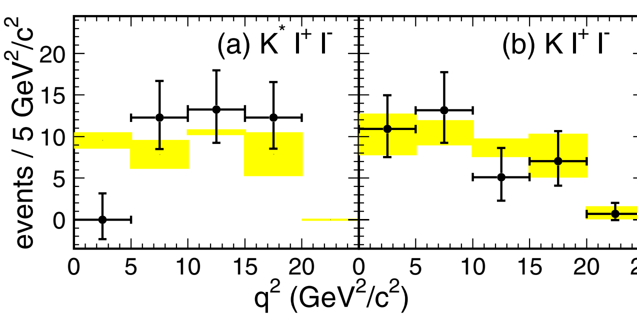

Fig. 4. q^2 distributions for Kll and K^*ll. Points show data while bands show the expectation range of various models [7]

36 ± 8 $B \to K^*\ell^+\ell^-$ and 38 ± 8 $B \to K\ell^+\ell^-$ events, with statistical significances of 5.7σ and 7.4σ respectively We extract the following preliminary branching fractions:

$$\mathcal{B}\left(B \to K^*\ell^+\ell^-\right) = \left(11.5\,^{+\,2.6}_{-\,2.4} \pm 0.8 \pm 0.2\right) \cdot 10^{-7}$$
$$\mathcal{B}\left(B \to K\ell^+\ell^-\right) = \left(\ 4.8\,^{+\,1.0}_{-\,0.9} \pm 0.3 \pm 0.1\right) \cdot 10^{-7}$$

where the third error is due to model-dependence. Figure 4 shows the measured squared dilepton mass (q^2) distributions compared to theoretical predictions [7].

3.2 Semi-inclusive analysis

We performed a semi-inclusive analysis using 60 fb^{-1} [8]. In this case the lepton pair is combined with any of 18

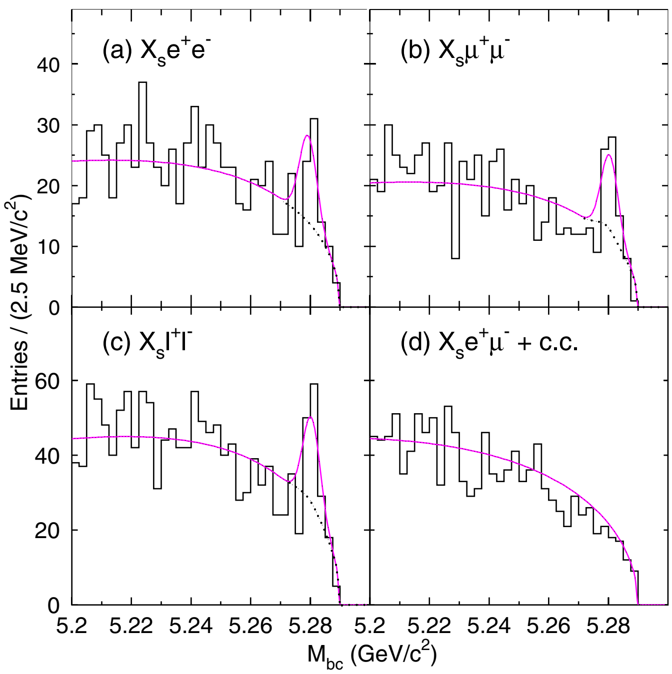

Fig. 5. $m_{\rm bc}$ fits for X_sll final states

combinations made of one kaon ($K^\pm$ or K^0_S) and up to four pions, one of which may be neutral. The so formed X_s system is required to have a mass below 2.6 GeV/c^2. The $m_{\rm bc}$ mass fits are shown in Fig. 5 for $B \to X_see$, $B \to X_s\mu\mu$ and the sum $B \to X_s\ell\ell$, where peaks are seen at the B mass. The forbidden $B \to X_se\mu$ mode is also shown as a control sample. We observe $60 \pm 14\,^{+\,9}_{-\,5}$ $B \to X_s\ell\ell$ events with a statistical significance of 5.4σ. The branching fractions are:

$$\mathcal{B}\left(B \to X_s\ell^+\ell^-\right) = \left(6.1 \pm 1.4\,^{+\,1.4}_{-\,1.1}\right)\cdot 10^{-6} \quad (5.4\sigma)$$
$$\mathcal{B}\left(B \to X_se^+e^-\right) = \left(5.0 \pm 2.3\,^{+\,1.3}_{-\,1.1}\right)\cdot 10^{-6} \quad (3.4\sigma)$$
$$\mathcal{B}\left(B \to X_s\mu^+\mu^-\right) = \left(7.9 \pm 2.1\,^{+\,2.1}_{-\,1.5}\right)\cdot 10^{-6} \quad (4.7\sigma).$$

4 Leptonic FCNC B decays

Finally, we report about the search for the FCNC decays $B \to ee$ $B \to \mu\mu$ and $B \to e\mu$, using a data sample of 78 fb^{-1} [9]. The Standard Model (SM) branching fractions predictions for the first two decays are about 10^{-10} and 10^{-15} respectively, but they could be enhanced by two order of magnitude in models including two Higgs doublets or Z-mediated FCNC. Apart from the negligibly small contribution form neutrino oscillations, the $B \to e\mu$ is forbidden in the SM, but could occur in some SUSY models or the Pati-Salam leptoquark model [10].

The selection is based on stringent requirements for the particle-identification of the two leptons and strong requirements for the $q\bar{q}$ ($q = u, d, s, c$) and $\tau\tau$ background rejections. In particular, to favour $B\bar{B}$ events, we require the presence of five charged tracks in the event.

We find no events in the signal box defined in the ΔE–$m_{\rm bc}$ plane, as shown in Fig. 6, while we expect about 0.2 to 0.3 events from background, depending on the mode. We set upper limits on the branching fractions as:

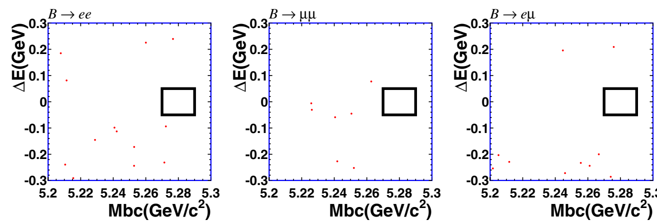

Fig. 6. ΔE versus m_{bc} for ee, $\mu\mu$ and $e\mu$ final states. The rectangles indicate the signal box

$$\mathcal{B}\left(e^+e^-\right) < 1.9 \cdot 10^{-7} \quad \text{(90\% CL)}$$
$$\mathcal{B}\left(\mu^+\mu^-\right) < 1.6 \cdot 10^{-7} \quad \text{(90\% CL)}$$
$$\mathcal{B}\left(e^\pm\mu^\pm\right) < 1.7 \cdot 10^{-7} \quad \text{(90\% CL).}$$

The latter allows to set a 90% CL lower limit on the mass of the Pati-Salam leptoquark [10,11] at 46 TeV/c^2. The details of the extraction are given in Ref. [9].

5 Conclusion

While radiative B decays become tools to understand the QCD structure of the B meson, semileptonic FCNC decays become hot candidates to test extensions of the Standard Model. After a long wait, we finally observed the decay $B \to K^*\ell\ell$, opening the road to measurements of the lepton forward-backward asymmetry.

References

1. S. Henderson et al. (CLEO Collaboration): Phys. Rev. Lett. **71**, 674 (1993)
2. A. Abashian et al. (Belle Collaboration): Nucl. Instr. and Meth. A **479**, 117 (2002)
3. A. Drutskoy et al. (Belle Collaboration): arXiv:hep-ex/0309006, submitted to Phys. Rev. Lett
4. K. Abe et al. (Belle Collaboration): BELLE-CONF-0319, EPS-abstract 537
5. K. Abe et al. (Belle Collaboration): Phys. Rev. Lett. **88**, 021801 (2002)
6. A. Ishikawa et al. (Belle Collaboration): arXiv:hep-ex/0308044, submitted to Phys. Rev. Lett
7. A. Ali, E. Lunghi, C. Greub, and G. Hiller: Phys. Rev. D **66**, 034002 (2002); E. Lunghi: arXiv:hep-ph/0210379; D. Meliikhow, N. Nikitin, and S. Simula: Phys. Lett. B **241**, 278 (1990); P. Colangelo, F. De Fazio, P. Santorelli, and E. Scrimieri: Phys. Rev. D **53**, 3672 (1996); Erratum, ibid. D **57**, 2186 (1998)
8. J. Kaneko et al. (Belle Collaboration): Phys. Rev. Lett. **90**, 021801 (2003)
9. M.-C. Chang, P. Chang, et al. (Belle Collaboration): arXiv:hep-ex/0309069, to appear in Phys. Rev. D (RC)
10. J.C. Pati and A. Salam: Phys. Rev. D **10**, 275 (1974)
11. A.V. Kuznetsov and N.V.Mikheev: Phys. Lett. B **329**, 295 (1994)