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Extrapolation of $B \to K^{(*)}\nu\bar{\nu}$ to the full Belle II dataset

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This memo briefly describes the extrapolation of $B \to K^{(*)}\nu\bar{\nu}$ at Belle II.

The expected branching fractions for exclusive $B \to K^{(*)}\nu\bar{\nu}$ decays have recently been calculated in the SM in Ref [2]. A numerical re-evaluation for B2TiP in late 2015 found that the expected branching ratios for these modes have slightly higher values. In contrast to $B \to K^{(*)}\ell^+\ell^-$ decays, the isospin asymmetries of the decays with neutrinos in the final state vanish identically, so the branching ratio of the B^0 and $B^\pm$ decays only differ due to the lifetime differences. A summary of the SM branching fractions is given in Table I.

TABLE I: SM $B \to K^{(*)}\nu\bar{\nu}$ branching fractions.

Mode	$\mathcal{B}$ $[10^{-6}]$ Ref. [2]	$\mathcal{B}$ $[10^{-6}]$ Ref. [1]
$B^+ \to K^+\nu\bar{\nu}$	$3.98 \pm 0.43 \pm 0.19$	4.68 ± 0.64
$B^0 \to K^0_S\nu\bar{\nu}$	$1.85 \pm 0.20 \pm 0.09$	2.17 ± 0.30
$B^+ \to K^{*+}\nu\bar{\nu}$	$9.91 \pm 0.93 \pm 0.54$	10.22 ± 1.19
$B^0 \to K^{*0}\nu\bar{\nu}$	$9.19 \pm 0.86 \pm 0.50$	9.48 ± 1.10

This Belle II sensitivity projection is based on a recent Belle measurement [3] with the hadron tag sample. To estimate the Belle II projections we assume the following improvement factors:

- The hadronic tag sample will have 100% higher efficiency.
- The reconstruction of K^0_S mesons will be 30% higher in efficiency.
- We consider a data taking scenario of 50 ab^{-1} of $\Upsilon(4S)$ data.

To extrapolate, we take the statistical uncertainty on a cut and count method up to E_{ECL}=0.4 GeV (this is reasonably indicative of the precision for a fit to the region up to 1.2 GeV). The signal yield is estimated from the SM branching fractions, and the efficiency in the Belle analysis, corrected for the above scale factors. We take the yield in data to derive the background component: in the case of the $B^+ \to K^+\nu\bar{\nu}$ mode, which has the largest background, we first subtract the expected signal component to estimate the background yield. In the other cases we conservatively consider the total yield to be attributed to the background - due to the negative fits for signal in the Belle analysis. Note that a toy MC method was used in a projection of $B \to K^+\nu\bar{\nu}$ at the 2013 KEK-FF workshop, which used the Belle tag efficiency and (now) outdated branching fraction calculations [4]. The results of that study are consistent with the cut and count approach used here (without the scaled factors above).

The multiplicative systematic uncertainties are approximately 7% in the Belle analysis, with a large additive background model uncertainty. Ultimately this systematic error may be around 8%, depending on the mode. In any case it should remain to be a statistics limited analysis even with the full Belle II data set.

TABLE II: Projections for the statistical uncertainties on the $B \to K^{(*)}\nu\bar{\nu}$ branching fractions.

Mode	$\mathcal{B}$ $[10^{-6}]$	Efficiency Belle $[10^{-4}]$	$N_{\text{Backg.}}$ 711 fb^{-1} Belle	$N_{\text{Sig-exp.}}$ 711 fb^{-1} Belle	$N_{\text{Backg.}}$ 50 ab^{-1} Belle II	$N_{\text{Sig-exp.}}$ 50 ab^{-1} Belle II	Statistical error 50 ab^{-1}	Total Error
$B^+ \to K^+\nu\bar{\nu}$	4.68	5.68	21	3.5	2960	245	20%	22%
$B^0 \to K^0_{\text{S}}\nu\bar{\nu}$	2.17	0.84	4	0.24	560	22	94%	94%
$B^+ \to K^{*+}\nu\bar{\nu}$	10.22	1.47	7	2.2	985	158	21%	22%
$B^0 \to K^{*0}\nu\bar{\nu}$	9.48	1.44	5	2.0	704	143	20%	22%
$B \to K^*\nu\bar{\nu}$ combined							15%	17%

[1] D. M. Straub, BELLE2-MEMO-2016-007.
[2] A. J. Buras, J. Girrbach-Noe, C. Niehoff and D. M. Straub, JHEP **1502**, 184 (2015) [arXiv:1409.4557 [hep-ph]].
[3] O. Lutz *et al.* [Belle Collaboration], Phys. Rev. D **87**, no. 11, 111103 (2013) [arXiv:1303.3719 [hep-ex]].
[4] T. Kuhr, "$B \to h^{(*)}\nu\bar{\nu}$" , KEK-FF Workshop (2013).