Rare B Decay potential of SuperB

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Rare B Decays Potential of SuperB

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On behalf of the SuperB Collaboration

The study of rare B-decays at SuperB provides unique opportunities to understand the Standard Model (SM) and constrains new physics (NP). It is discussed the new physics potential of the $B \to K\nu\overline{\nu}$ and $B \to K^{*}\nu\overline{\nu}$ system from the proposed SuperB experiment with 75ab^{-1} of data (5 nominal years of data taking).

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1. Introduction

Rare B decays with a $\nu\bar{\nu}$ pair in the final state are interesting probes of NP, since they allow one to transparently study contributions to Z and electroweak penguins. Furthermore, since the neutrinos escape the detector unmeasured, the $B \to K^{(*)} + E_{\rm miss}$ channel can also contain contributions from other light SM-singlet particles substituting the neutrinos in the decay. The $b \to s\nu\bar{\nu}$ decays are particularly interesting as it is possible to formulate model-independent phenomenological analysis. Out of the $B \to K\nu\bar{\nu}$ and $B \to K^*\nu\bar{\nu}$ decays, there are three observables accessible: the corresponding branching ratios and the K^* longitudinal polarization fraction $\langle F_L \rangle$ from $B \to K^*\nu\bar{\nu}$ decays. These three observables only depend on two combinations of the Wilson coefficients C_L^ν and C_R^ν [1] through the variables $\varepsilon = \frac{\sqrt{|C_L^\nu|^2+|C_R^\nu|^2}}{|(C_L^\nu)^{SM}|}$ and $\eta = \frac{-\mathrm{Re}(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2+|C_R^\nu|^2}$, ($\eta$ lies in the range $[-\frac{1}{2}, \frac{1}{2}]$). The discussed observables can be expressed in terms of ε and η as follows,

$$\mathrm{Br}(B \to K^*\nu\bar{\nu}) \;=\; 6.8 \times 10^{-6}(1+1.31\eta)\varepsilon^2 \;, \tag{1.1}$$

$$\mathrm{Br}(B \to K\nu\bar{\nu}) \;=\; 4.5 \times 10^{-6}(1-2\eta)\varepsilon^2 \;, \tag{1.2}$$

$$\langle \mathrm{F}_L(B \to K^*\nu\bar{\nu}) \rangle \;=\; 0.54\frac{(1+2\eta)}{(1+1.31\eta)} \;. \tag{1.3}$$

Table 1 shows the SM predictions and current experimental upper bounds on branching ratios (Br). The experimental bounds on the Br can then be translated in excluded areas on the $\varepsilon - \eta$ plane (green area on the rightmost plot of figure 1), where the SM corresponds to $(\varepsilon, \eta) = (1, 0)$.

Observable	SM prediction	Experiment
$\mathrm{Br}(B \to K\nu\bar{\nu})$	$(6.8^{+1.0}_{-1.1}) \times 10^{-6}$ [1]	$< 80 \times 10^{-6}$ [3]
$\mathrm{Br}(B \to K^*\nu\bar{\nu})$	$(4.5 \pm 0.7) \times 10^{-6}$ [1]	$< 14 \times 10^{-6}$ [4]
$\langle \mathrm{F}_L(B \to K^*\nu\bar{\nu}) \rangle$	0.54 ± 0.01 [1]	—

Table 1: *SM predictions and experimental* 90% C.L. *upper bounds for the three* $B \to K^{(*)}\nu\bar{\nu}$ *observables.*

2. The experimental technique and Expectations for SuperB

The recoil technique has been developed to search for rare B decays with undetected particles, like neutrinos, in the final states. Its consists on the reconstruction of one of the two B mesons ($B_{\rm tag}$), produced through the $e^+e^- \to \Upsilon(4S) \to B\bar{B}$ resonance, in a high purity hadronic or semi-leptonic final states, allowing to build a pure sample of $B\bar{B}$ events. Having identified the $B_{\rm tag}$, everything in the rest of the event (ROE) belongs by default to the signal B candidate ($B_{\rm sig}$), and so this technique provides a clean environment to search for rare decays. In this analysis, the $B_{\rm tag}$ is reconstructed in the hadronic modes $B \to D^{(*)}X$, where $X = n\pi + mK + pK^0_S + q\pi^0$ ($n+m+p+q < 6$), or semi-leptonic modes $B \to D^{(*)}\ell\nu$, ($\ell = e,\ \mu$). In the search for $B \to K\nu\bar{\nu}$ ($B \to K^*\nu\bar{\nu}$), the signal is given by a single track identified as a kaon (a K^* reconstructed in the $K^{*0} \to K^+\pi^-$, $K^{*+} \to K^+\pi^0/K^0_S\pi^+$ modes) in the ROE.

Even though the expected SuperB [2] increase in the instantaneous luminosity of a factor 100 already promises significant improvements on the before mentionned rare decays, additional activities for detector optimization are currently ongoing. The baseline SuperB detector configuration is very similar to BaBar but the boost ($\beta\gamma$) is reduced from 0.56 to 0.28. This boost reduction increases the geometrical acceptance and so the reconstruction efficiency. Additionally, it is considered the inclusion of a highly performant particle identification device (Fwd-PID) based on time-of-flight measurements in the forward region.

The SuperB fast simulation has been used to produce signal samples in the before mentionned detector configurations, BaBar, SuperB base-line and SuperB+Fwd-PID. This test showed a 15% to 20% increase in efficiency using the SuperB+Fwd-PID configuration with respect to the BaBar setup, depending on the final state, mainly due to the boost reduction. For the time being no generic $B\overline{B}$ samples has being produced. To be conservative it has been assumed that the background efficiency increases by the same factor as the signal in such a way that the signal to background ratio (S/B) stays constant. This global increase in efficiency provides a gain on $S/\sqrt{(S+B)}$, which would be interpreted as the signal significance for a cut and count analysis. The $S/\sqrt{(S+B)}$ ratio, for both $B \to K\nu\bar{\nu}$ and $B \to K^*\nu\bar{\nu}$ modes, as a function of the integrated luminosity for the three detector configurations is shown in the left and middle plots of figure 1 (BaBar (solid-black), SuperB (dotted-black) and SuperB+Fwd-PID (solid-red)). A sensitivity of 15% (17%) are expected for $B \to K\nu\bar{\nu}$ ($B \to K^*\nu\bar{\nu}$) at 75ab^{-1}. The rightmost plot of figure 1 shows the constraint at 68% (blue) and 95% (red) in the (ε,η) plane for the expected sensitivities on $\mathrm{Br}(B \to K\nu\bar{\nu})$ and $\mathrm{Br}(B \to K^*\nu\bar{\nu})$ at 75ab^{-1}.

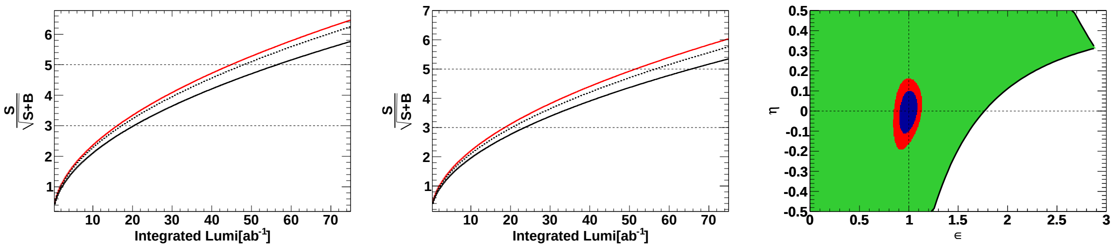

Figure 1: *Expected sensitivities for the* $\mathrm{Br}(B \to K\nu\bar{\nu})$ *(left) and* $\mathrm{Br}(B \to K^*\nu\bar{\nu})$ *(middle) as a function of the integrated luminosity; and expected constraint on the* (ε,η) *plane for the measurement of the before mentioned branching ratios at* 75ab^{-1} *(right).*

In summary, it has been investigated the reach of SuperB in the search of the $B \to K^{(*)}\nu\bar{\nu}$ decays with both the hadronic and semi-leptonic techniques. Preliminary results based on the SuperB fast simulation have shown a 15 to 25% increase in the global efficiency with respect to Babar. It has also been shown that SuperB will allow an unprecedent reduction of the NP parameter space, (ε,η) plane, given the expected sensitivities at 75ab^{-1} of data.

References

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