RARE DECAYS AT B FACTORIES

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Abstract

We will present a review of the most interesting results on rare B decays from the B Factories, based on the data collected by the BaBar [1] and Belle [2] detectors at asymmetric e^+e^- colliders at the center of mass energy of the $\Upsilon(4S)$ resonance.

1 Introduction

Rare B decays have always been a standard probe for New Physics (NP) searches as they offer a prolific ground where to look for deviations from the SM expectation. The very low SM rate of these decays often make them unaccessible with the present experimental datasets, unless NP effects enhance the rate up to the current experimental sensitivity. In this view, if a suppressed decay is observed, clear sign of NP can be claimed. On the other hand, if an upper limit (UL) is set, it can constraint NP scenarios. B Factories provide an unique environment where to investigate these processes. The high number of B mesons pairs produced often allows to approach the needed experimental sensitivity. Moreover, the clean environment and the closed kinematic of the initial state enable to obtain a very pure sample where to look for these decays.

In this work we are going to present a review of results from both BaBar and Belle collaboration on the B meson decays $B \to h^{(*)}\nu\bar{\nu}$, $B^+ \to l^+\nu_l$, $B^0 J/\psi\phi$ and $B^+ \to K^-\pi^+\pi^-/K^+K^-\pi^-$ [b].

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2 Analyses Overview

The analyses presented in this work exploit different reconstruction techniques, depending on the particles present in the final state. In the decays $B^0 J/\psi\phi$ and $B^+ \to K^-\pi^+\pi^-/K^+K^-\pi^-$ all particles decaying from the signal B are detectable, and thus a full kinematic reconstruction of the event is possible. On the other hand, $B^+ \to l^+\nu_l$ and $B \to h^{(*)}\nu\bar{\nu}$ decays possess one or more neutrinos in the final state, which clearly can not be detected. This particular characteristic calls for different analysis techniques, which allows to deal with the lack of information regarding these particles. Typically, the closed kinematic of an e^+e^- collision is exploited to constrain through energy and four-vector conservation the $B\bar{B}$ pairs, after both particles have been reconstructed. Different approaches can be employed in the selection of the B meson which is not decaying into the channel of interest (B_{tag}): a totally inclusive reconstruction is applied on the B_{tag} , without trying to identify its decay products, whenever the additional kinematic constraint coming from the two-body nature of the signal B (B_{sig}) can be exploited, as in $B^+ \to \mu^+\nu_l$ and $B^+ \to e^+\nu_l$ analyses. The high efficiency obtainable with this method has as drawback a poor energy resolution. On the other hand, when more than one neutrino is present in the event, a recoil technique is needed:first, the B_{tag} is reconstructed in either a semileptonic $B_{sl} \to D^{(*)}l\nu$ or hadronic $B_{had} \to DY$ ($Y = \pi, K$) system. Then, the channel of interest is searched in the rest of the event (ROE), defined as the set of tracks and calorimeter deposits not associated with the B_{tag} . The recoil method allows a very high resolution and purity, but has a low efficiency.

3 Search for $b \to s\nu\bar{\nu}$ processes

3.1 Theoretical Introduction

In the SM $b \to s\nu\bar{\nu}$ transitions occurs through Flavour Changing Neutral Current (FCNC) and are therefore forbidden at tree level. As these processes occurs via one-loop box or electroweak penguin diagrams, they are expected to be highly suppressed. The expected branching ratios ($\mathcal{B}$) are $\mathcal{B}$ $(B \to K * \nu\bar{\nu}) = (6.8^{+1.0}_{-1.1})\times10^{-6}$ and $\mathcal{B}$ $(B \to K\nu\bar{\nu}) = (4.5\pm0.7)\times10^{-6}$ [3]. However, this values can be enhanced in NP scenarios, where several mechanisms can contribute to the rate. For example, in Ref. [4], non-standard Z^0 coupling can give rise to an enhancement up to a factor 10. Moreover, new sources of missing energy, such as light dark matter [5] or unparticles [6,7], if accompanied by a K^*, would contribute to the total rate. The kinematic of the decay can be described in terms of $s_{\nu\bar{\nu}} = m^2_{\nu\bar{\nu}}/m^2_B$, where $m_{\nu\bar{\nu}}$ is the invariant mass of the neutrinos pair and m_B is the B meson mass. As NP can strongly affect the decay in terms of $s_{\nu\bar{\nu}}$ shape [3,7], it is important to not rely on any theoretical model when performing the analysis.

3.2 Analysis of $B \to h^{(*)}\nu\bar{\nu}$

The Belle collaboration analysis exploit the hadronic recoil technique and looks for final states with $h^{(*)} = K^+, K^0_S, K^{*0}, K^{*+}, \pi^+, \pi^0, \rho^+, \rho^0, \phi$, using a 492 fb^{-1} data sample [8]. B_{tag} candidates are reconstructed into a charged or neutral $D^{(*)}$ accompanied by a charged π or ρ or a_1 or $D^{(*)}_s$. The D^- mesons are reconstructed as $D^- \to K^0_S\pi^-, K^0_S\pi^-\pi^0, K^0_S\pi^-\pi^+\pi^-, K^+\pi^-\pi^-$ and $K^+\pi^-\pi^-\pi^0$, while $\bar{D}^{(*)0}$ as $\bar{D}^{(*)0} \to K^+\pi^-, K^+\pi^-\pi^0, K^+\pi^-\pi^+\pi^-, K^0_S\pi^0, K^0_S\pi^+\pi^-, K^+K^-$ and $K^0_S\pi^-\pi^+\pi^0$. The $D^{*-}(\bar{D}^{(*)0})$ mesons are reconstructed as $\bar{D}^0\pi^-(\bar{D}^0\pi^0$ and $\bar{D}^0\gamma)$ and the D^{*+}_s as $D^{*+}_s \to D^+_s\gamma$ and $D^+_s \to K^0_S K^+$ and $K^+K^-\pi^+$. No additional charged tracks or π^0 candidates are allowed in the event and thus B_{sig} candidates are selected using the variable $E_{\rm ECL} = E_{\rm tot} - E_{\rm rec}$, where $E_{\rm tot}$ and $E_{\rm rec}$ are the total visible energy measured by the calorimeter and the measured energy of reconstructed objects including the B_{tag} and the signal side $h^{(*)}$ candidate, respectively.

The dominant background comes from BB decays involving a $b \to c$ transition. In order to suppress such decays, the momentum of the $h^{(*)}$ candidate in the B_{sig} rest frame P^* is required to be 1.6 GeV/c $< P^* <$ 2.5 GeV/c. The cosine of the missing momentum in the lab frame is required to lie between -0.86 and 0.95 to rejects background events where particles are missing along the beam pipe. Given the fact that reconstruction efficiencies

Table 1: Observed number of events N_{obs}, expected background, N_b, reconstruction efficiencies ϵ and the UL at 90% of confidence level for $B \to h^{(*)}\nu\bar{\nu}$

Mode	N_{obs}	N_b	$\epsilon(\times 10^{-5})$	UL
$K^{*0}\nu\bar{\nu}$	7	4.2 ± 1.4	5.1 ± 0.3	$< 3.4 \times 10^{-4}$
$K^{*+}\nu\bar{\nu}$	4	5.6 ± 1.8	5.8 ± 0.7	$< 1.4 \times 10^{-4}$
$K^{+}\nu\bar{\nu}$	10	20.0 ± 4.0	26.7 ± 2.9	$< 1.4 \times 10^{-5}$
$K^{0}\nu\bar{\nu}$	2	2.0 ± 0.9	5.0 ± 0.3	$< 1.6 \times 10^{-4}$
$\pi^{+}\nu\bar{\nu}$	33	25.9 ± 3.9	24.2 ± 2.6	$< 1.7 \times 10^{-4}$
$\pi^{0}\nu\bar{\nu}$	11	3.8 ± 1.3	12.8 ± 0.8	$< 2.2 \times 10^{-4}$
$\rho^{0}\nu\bar{\nu}$	21	11.5 ± 2.3	8.4 ± 0.5	$< 4.4 \times 10^{-4}$
$\rho^{+}\nu\bar{\nu}$	15	17.8 ± 3.2	8.5 ± 1.1	$< 1.5 \times 10^{-4}$
$\phi\nu\bar{\nu}$	1	1.9 ± 0.9	9.6 ± 1.4	$< 5.8 \times 10^{-5}$

for the UL evaluation are estimated with MC simulation based on the SM, these two cuts introduce a SM dependence in the analysis results. The background $E_{\rm ECL}$ distributions are normalized by the number of events in the sideband region. None of the signal modes show a significant number of signal events. The observed number of events N_{obs}, expected background N_b, reconstruction efficiencies ϵ and the UL at 90% of confidence level obtained with an extension of the Feldman-Cousins method [9,10] are shown in Tab. 1.

3.3 Analysis of $B \to K^*\nu\bar{\nu}$

The $B \to K^*\nu\bar{\nu}$ from BaBar collaboration is performed in the recoil of both hadronic (HAD) and semileptonic (SL) system on a data sample of 413 fb^{-1} [11]. The two different tagging strategies provide non overlapping samples whose results can be combined as independent measurements. The event selection starts from the B_{tag} reconstruction: in the SL analysis, neutral D mesons are reconstructed in the $K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+$ and $K^0_S\pi^+\pi^-$ modes. Charged D mesons are reconstructed in the $K^-\pi^+\pi^+$ and $K^0_S\pi^+$ final states. In the HAD analysis, the $B_{\rm had}$ is reconstructed in $B_{\rm had} \to DY$ where $Y = n\pi + mK + rK^0_S + q\pi^0$ with $n+m+r+q < 6$ and D is a generic charmed meson. About 1000 different decay chains are considered. Charmed mesons are reconstructed in the same final states used in the SL analysis, along with the additional channels $D^+ \to K^+\pi^-\pi^+\pi^0, K^0_S\pi^+\pi^-\pi^+, K^0_S\pi^+\pi^0$. For each reconstructed tagging B, a K^* is searched in the ROE and reconstructed in the $K^+\pi^-$, $K^0_S\pi^+$ or $K^+\pi^0$ mode. Considering that signal events have no additional neutral particles produced in association with the K^*, one of the most discriminating variable between signal and background is, as in the Belle analysis, the extra neutral energy $E_{\rm extra}$, the sum of the energies of the calorimeter neutral clusters not used to reconstruct either the B_{sig} or the B_{tag} . In the SL analysis, the signal yield is extracted through a Maximum Likelihood (ML) fit to the final $E_{\rm extra}$ distribution, after selection criteria are applied to suppress the continuum background. In the HAD analysis, a loose selection is applied and all discriminants variables (including $E_{\rm extra}$) are used as inputs for a Neural Network (NN), whose output variable $NN_{\rm out}$ is fitted to extract the number of signal events. No significant signal is observed in the two analysis and a Bayesian approach is employed to set the UL at 90% of confidence level. The UL from the SL analysis are $\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu}) < 18 \times 10^{-5}$ and $\mathcal{B}(B^+ \to K^{*+}\nu\bar{\nu}) < 9 \times 10^{-5}$, the UL from the HAD analysis are $\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu}) < 11 \times 10^{-5}$ and $\mathcal{B}(B^+ \to K^{*+}\nu\bar{\nu}) < 21 \times 10^{-5}$. The combined UL are $\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu}) < 12 \times 10^{-5}$, $\mathcal{B}(B^+ \to K^{*+}\nu\bar{\nu}) < 8 \times 10^{-5}$ and $\mathcal{B}(B \to K^{*}\nu\bar{\nu}) < 8 \times 10^{-5}$.

These results are at the moment the most restrictive UL on these decay channels and are the first completely model independent measurement.

4 Search for $B^+ \to l^+\nu$ processes

4.1 Theoretical Introduction

In the SM the purely leptonic B decays $B^+ \to l^+\nu$ ($l = e, \mu, \tau$) proceed through the annihilation of the two quarks in the meson to form a virtual W boson. The branching ratio can be cleanly calculated in the SM and is sensitive to the Cabibbo Kobayashi Maskawa matrix element V_{ub} and the B decay constant f_B, which describes the overlap of the quark wave functions within the meson and which is currently the major source of uncertainty in the B calculation. Assuming $\tau_B = 1.638 \pm 0.011$ ps, V_{ub}=(4.39 $\pm$ 0.33) $\times 10^{-3}$ determined from inclusive charmless semileptonic B decays [12] and $f_B = 216{\pm}22$ MeV from lattice QCD calculation [13], the SM estimate of $\mathcal{B}(B^+ \to \tau^+\nu_l)$ is $(1.59 \pm 0.40) \times 10^{-4}$. Due to helicity suppression, $B^+ \to \mu^+\nu_l$ and $B^+ \to e^+\nu_l$ are suppressed by factors $m^2_{\mu,e}/m^2_\tau$ with respect to $B^+ \to \tau^+\nu_l$, leading to expected branching fractions of $\mathcal{B}(B^+ \to \mu^+\nu_l) = (5.6 \pm 0.4) \times 10^{-7}$ and $\mathcal{B}(B^+ \to e^+\nu_l) = (1.3 \pm 0.4) \times 10^{-11}$. Purely leptonic B decays are sensitive to physics beyond the SM, where additional heavy virtual particles contribute to the annihilation processes. Charged Higgs boson effects may greatly enhance or suppress the branching fraction in some two-Higgs-doublet models [14]. Moreover, in a SUSY scenario at large $\tan\beta$, non-standard effects in helicity-suppressed charged current interactions are potentially observable, being strongly $\tan\beta$-dependent and leading to [14]: $\frac{\mathcal{B}(B^+\to l^+\nu_l)_{\rm exp}}{\mathcal{B}(B^+\to l^+\nu_l)_{\rm SM}} \approx (1 - \tan^2\beta \frac{m^2_B}{M^2_H})^2$. These decays are also potential probes for Lepton Flavour Violation (LFV) in the ratios $R^{\mu/\tau}_B = \mathcal{B}(B^+ \to \mu^+\nu_l)/\mathcal{B}(B^+ \to \tau^+\nu_l)$ and $R^{e/\tau}_B = \mathcal{B}(B^+ \to \mu^+\nu_l)/\mathcal{B}(B^+ \to \tau^+\nu_l)$ [15].

4.2 Analysis of $B^+ \to l^+\nu_l$ in the SL Recoil

The $B^+ \to l^+\nu_l$ analysis from the BaBar collaboration is performed in the recoil of a semileptonic system on a data sample of 418 fb^{-1} [16]. The B_{tag} is reconstructed in the set of semileptonic B decay mode $B^- \to D^0 l^- \bar{\nu} X$, where $l = e, \mu$ and X can be either nothing or a transition particle from a higher mass charm state decay, which is not reconstructed (although tags consistent with a neutral B decay are vetoed). The D^0 is reconstructed in the same modes as in 3.3. Since τ decays before reaching active detector elements, the $B^+ \to \tau^+\nu_l$ signal is searched for in both leptonic and hadronic τ decay modes: $\tau^+ \to e^+\nu_e\bar{\nu}_\tau, \mu^+\nu_\mu\bar{\nu}_\tau, \pi^+\bar{\nu}_\tau$ and $\pi^+\pi^0\bar{\nu}_\tau$. The lepton momentum in the B_{sig} rest frame is used to separate electrons and muons from $B^+ \to \mu^+\nu_l$ or $B^+ \to e^+\nu_l$ and from τ decays. Backgrounds consists primarily of B^+B^- events in which the B_{tag} has been correctly reconstructed and the recoil side contains one signal candidate track and additional particles which are not reconstructed by the tracking detectors or calorimeter. Typically, these events contain K^0_L candidates and/or neutrinos. In addition, some excess events in data, most likely from two-photon and QED processes which are not modeled in the MC simulation, are also seen. Multiple variables are used to suppress backgrounds and are combined in two likelihood ratios (LHRs), which are probability distributions designed to produce maximum separation between signal and background. Among them, two of the most powerful are the ratio of the second and the zeroth Fox-Wolfram moment $R2$ [19] and the cosine of the angle between the B meson momenta and the $D^0 l$ candidate in the $\Upsilon(4S)$ frame. Also in this analysis, the total energy recorded in the detector and not assigned to either the B_{sig} or the B_{tag} $E_{\rm extra}$ is used to select signal decays. The number of expected background events is estimated from the $E_{rmextra}$ sidebands. The observed number of events N_{obs}, expected background N_b, reconstruction efficiencies ϵ and the branching ratio $\mathcal{B}$ or UL at 90% of confidence level obtained with the Feldman-Cousins method [9] are shown in Tab. 2.

Combined with the previous measurement in the HAD recoil [17], the $B^+ \to \tau^+\nu_l$ average from BaBar is $\mathcal{B}(B^+ \to \tau^+\nu) = (1.8 \pm 0.6) \times 10^{-4}$.

4.3 Inclusive Analyses of $B^+ \to l^+\nu_l$ ($l = e, \mu$)

$B^+ \to l^+\nu_l$ are two-body decays, so the lepton is produced mono-energetic in the B_{sig} rest frame. Thus, in inclusive analyses, the highest momentum lepton in the event is searched and assign to the signal side, and all other charged tracks and neutral clusters in the event

Table 2: Observed number of events N_{obs}, expected background N_b, reconstruction efficiencies ϵ and $\mathcal{B}$ or UL at 90% of confidence level for $B^+ \to l^+\nu_l$

Mode	N_{obs}	N_b	$\epsilon(\times 10^{-4})$	$\mathcal{B}$
$\tau^+\nu$	610	521 ± 31	10.54 ± 0.41	$(1.8 \pm 0.8 \pm 0.1)\times 10^{-4}$
$\mu^+\nu$	11	15 ± 10	27.1 ± 1.2	$< 11 \times 10^{-6}$ @ 90% CL
$e^+\nu$	17	24 ± 11	36.9 ± 1.5	$< 7.7 \times 10^{-6}$ @ 90% CL

are used to reconstruct the B_{tag} , without trying to identify the direct decay products of the B_{tag} . The momentum direction of the reconstructed B_{tag} is used to boost the lepton candidate in the B_{sig} rest frame and thus refine the estimate of the lepton momentum in this frame (p^*). The two most significant backgrounds are B semileptonic decays involving $B \to X_{u,c} l\nu$ transitions where the endpoint of the lepton spectrum approach that of the signal, and non-resonant $q\bar{q}$ events.

Belle analysis [18] is on a data sample of 253 fb^{-1} and applies tight cuts on lepton momentum in both CM frame ($p_{\rm CM}$) and B_{sig} rest frame p^* to remove $B \to X_{u,c} l\nu$ backgrounds, and exploit the combination of modified Fox-Wolfram moments [19,20] in a Fisher discriminant to suppress continuum events. A cut on the B_{tag} $\Delta E = E_B - E_{\rm beam}$, where E_B is the reconstructed energy of the B_{tag} and $E_{\rm beam}$ the beam energy in the CM frame, is applied to refine the selection. The final selection efficiency is $(2.2 \pm 0.1)\%$ for $B^+ \to \mu^+\nu_l$ and $(2.4 \pm 0.1)\%$ for $B^+ \to e^+\nu_l$. The yields are extracted from a ML fit to the beam-energy constrained mass $M_{bc} = \sqrt{E^2_{\rm beam} - p^2_B}$ distributions, where p_B is the reconstructed momentum of the B_{tag} , and 4.1 $\pm$ 3.1 signal events are observed for the muon mode and -1.8 $\pm$ 3.3 for the electron mode. The 90% confidence level for the upper limit on the branching fraction $\mathcal{B}_{90}$ are defined by $0.9 = \int_0^{\mathcal{B}_{90}} \mathcal{L}(\mathcal{B})d\mathcal{B} / \int_0^{\infty} \mathcal{L}(\mathcal{B})d\mathcal{B}$ and are $\mathcal{B}$ ($B^+ \to \mu^+\nu_l$)$< 1.7 \times 10^{-6}$ and $\mathcal{B}$ ($B^+ \to e^+\nu_l$) $< 9.8 \times 10^{-7}$

The 90% confidence level UL for the electron mode is currently the most stringent measurement available.

BaBar analysis [21] uses an integrated luminosity of 426 fb^{-1} and choose to combine five different topological and kinematical variables, optimized separately for each mode, in a Fisher discriminant for $q\bar{q}$ background suppression. A cut on the B_{tag} ΔE is applied for the muon mode in order to remove continuum background, while two linear combination of B_{tag} ΔE and B_{tag} p_T are used for the electron mode in order to reject also the background coming from two-photon events. The final selection efficiencies are $(6.1 \pm 0.2)\%$ for the muon mode and $(4.7 \pm 0.3)\%$ for the electron mode. The two-body nature of the decay is exploited by combining p^* and $p_{\rm CM}$ in a second Fisher discriminant, whose output $p_{\rm FIT}$ is used in combination with the B_{tag} $m_{ES} = \sqrt{E^2_{\rm beam} - |\vec{p}_B|^2}$ a ML fit to extract the yields. The number of observed signal events is 1.4 ± 17.2 for $B^+ \to \mu^+\nu_l$ and 17.9 ± 17.6 for $B^+ \to e^+\nu_l$. The 90% confidence level ULs are evaluated with a Bayesian approach and are $\mathcal{B}$ ($B^+ \to \mu^+\nu_l$)$< 1.0 \times 10^{-6}$ and $\mathcal{B}$ ($B^+ \to e^+\nu_l$)$< 1.9 \times 10^{-6}$

The 90% confidence level UL for the muon mode is more restrictive than any previous measurements.

5 Search for $B^0 \to J/\psi\phi$ decay

5.1 Theoretical Introduction

Studies of exclusive B meson decays to charmonium play an important role in exploring CP violation [22,23] and establish the Cabibbo-Kobayashi-Maskawa picture. The decay $B^0 \to J/\psi\phi$ is expected to proceed mainly via a Cabibbo-suppressed and a color-suppressed transition ($b \to c\bar{c}d$) with rescattering. In B decays, effects presumably due to rescattering have been seen in various decay processes, as $B^0 \to D_s^- K^+$ [24,25], and they may play an important role in understanding patterns of CP asymmetries in B decays to two charmless pseudoscalars [26].

5.2 Analysis of $B^0 \to J/\psi\phi$

The Belle analysis of $B^0 \to J/\psi\phi$ decay is performed on a data sample of 605 fb^{-1} [27]. Candidates for $B^0 \to J/\psi\phi$ decays are reconstructed from the decay $J/\psi \to l^+l^-(l = e, \mu)$ and $\phi \to K^+K^-$. B^0 are selected through the usual M_{bc} and ΔE variables and the signal yield is extracted through a ML fit to the ΔE distribution.

The dominant background comes from $B\bar{B}$ events with a B decays to a J/ψ, in particular $B^0 \to J/\psi K^{*0}(892)[\to K^-\pi^+]$ and $B^{0/-} \to J/\psi K_1(1270)[\to K^-\pi^+\pi^{0/-}]$. In both cases, a pion is misidentified as a kaon, and in the latter case the other pion is missed. The former has a peak at $\Delta E \sim 0.1$ GeV, while the latter has a broad peak in the negative ΔE region. These background are taken into account into the ML fit, as well as the remaining not-peaking combinatorial background. The number of observed signal events is $4.6^{+3.1}_{-2.5}$ with a significance of 2.3 σ and the 90% confidence UL, extracted by a frequentistic method using ensembles of pseudo-experiments, is $\mathcal{B}(B^0 \to J/\psi\phi) < 9.4 \times 10^{-7}$. The UL is the most restrictive up to date and improve of about one order of magnitude the previous result [28].

6 Search for $b \to qq\bar{d}/qq\bar{s}$ Processes

6.1 Theoretical introduction

$b \to qq\bar{d}/\bar{s}$ transitions are highly suppressed in the SM: compared with the penguin (loop) transition $b \to q\bar{q}d/s$, they are additionally suppressed by the small Cabibbo-Kobayashi-Maskawa matrix element factor $|V_{td}V_{ts}^*| \simeq 3\times10^{-4}$, leading to a predicted branching fractions of only $\mathcal{O}(10^{-14})$ and $\mathcal{O}(10^{-11})$, respectively [29,30]. These branching ratios can be significantly enhanced in SM extensions as the minimal supersymmetric standard model (MSSM) with or without conserved R parity, or models containing extra $U(1)$ gauge bosons [30]. Observation of the decays $B^- \to K^+\pi^-\pi^-$ and $B^- \to K^-K^-\pi^+$ would be clear experimental signature for $b \to dd\bar{s}$ and $b \to ss\bar{d}$ quark transitions, which have already been searched in these and other decay modes without success yet.

6.2 Analysis of $B^- \to K^+\pi^-\pi^-/K^-K^-\pi^+$

The BaBar $B^- \to K^+\pi^-\pi^-/K^-K^-\pi^+$ analysis uses 426 fb^{-1} of integrated luminosity [31]. $B^- \to K^+\pi^-\pi^-(K^-K^-\pi^+)$ candidates are selected by combining a charged kaon (pion) candidate with two charged pion (kaon), each of which has charge opposite to the kaon (pion). In order to avoid potentially large source of background arising from B decays mediated by the favored $b \to c$ transitions, B decays in which the pairs of daughter tracks have invariant mass combinations in the range $1.76 < m_{K\pi} < 1.94$ GeV/c^2, $2.85 < m_{K\pi} < 3.25$ GeV/c^2 and $3.65 < m_{K\pi} < 3.75$ GeV/c^2. These vetoes remove events containing the decays $D^0 \to K^-\pi^+$, $J/\psi \to l^+l^-$ and $\phi(2S) \to l^+l^-$, respectively, where the leptons in the J/ψ and $\phi(2S)$ decays are misidentified as pions and kaons. The final selection efficiencies are 21.6% for $B^- \to K^-\pi^+\pi^+$ and 17.8% for $B^- \to K^-K^-\pi^+$. Continuum events represent the dominant background: in order to discriminate against it, five variables, comprising topological quantities as well as the flavour properties of the recoiling B meson and the proper time difference between the two Bs, are combined into a NN. Residual backgrounds, arising from decays topologically similar to the signal but with some misreconstruction, can be divided in five categories, depending on their shape in m_{ES} and ΔE, and are taken into account in the fit to the yield. The number of signal events is extracted through a ML fit to m_{ES}, ΔE and the NN output NN_{out} and is found to be 22 ± 43 for $B^- \to K^-\pi^+\pi^+$ and -26 ± 19 for $B^- \to K^-K^-\pi^+$. A frequentistic Feldman-Cousins method is employed to obtain the 90% confidence level UL, which are $\mathcal{B}(B^- \to K^-\pi^+\pi^+) < 7.4 \times 10^{-7}$ and $\mathcal{B}(B^- \to K^-K^-\pi^+) < 4.2 \times 10^{-7}$ and improve of about a factor 3 previous measurements [32].

7 Conclusions

In this work we have presented a review of the most interesting results on rare B decays at the B Factories from BaBar and Belle experiments.

Rare decays posses high interest, as they are standard probe for NP searches, given the low decay rate expected in the SM. Their study is complementary to the direct exploration of the energy frontier and in some cases can access even higher energy scales. We have seen how the improved analysis techniques and the huge integrated luminosity from both BaBar and Belle experiments allow today to reach $\mathcal{O}(10^{-6} - 10^{-7})$ sensitivity and how, even if only UL, the results on these decay are already able to pose interesting constraints on various NP scenarios. Nonetheless, decays with undetectable particles in the final state will not be measurable at the LHC and a Super Flavour Factory will be needed in order to obtain improved measurements.

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