Prospects for $b \to s\nu\bar{\nu}$ and implications from b-anomalies

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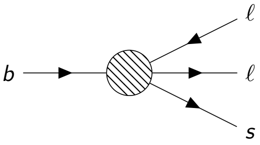
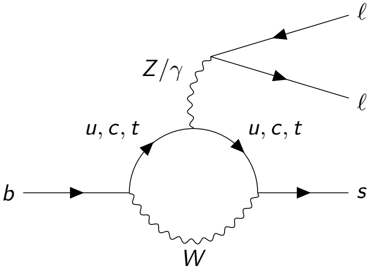
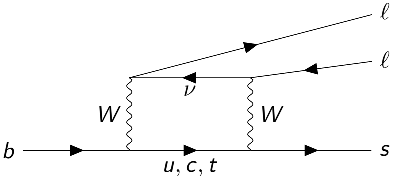
$b \to s\ell^+\ell^-$ transition



- FCNC process, which is loop supressed in the SM (potential sensitivity to NP)
- We don't actually see quarks, we see hadrons (mesons or baryons).
- Several studies have been done for this transition on the meson side ($B \to K^{(*)}\ell^+\ell^-$,$B_s \to \phi\ell^+\ell^-$).

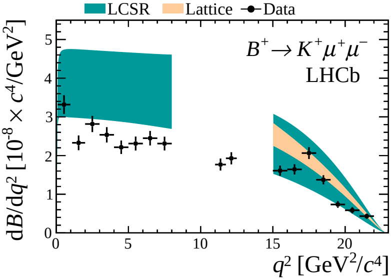




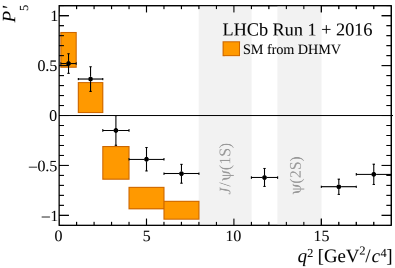
B-physics anomalies

Deviations from the SM expectations in $b \to s\ell^+\ell^-$:

- Around $2\sigma - 3\sigma$ for branching ratios and angular observables in $b \to s\mu\mu$ ($B \to K\mu\mu$, $B \to K^*\mu\mu$, $B_s \to \phi\mu\mu$)



[1403.8044]



[2003.04831]

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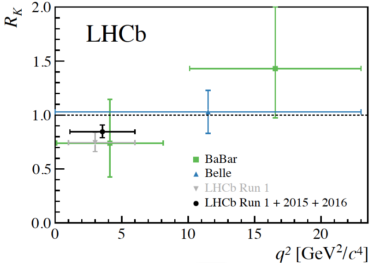
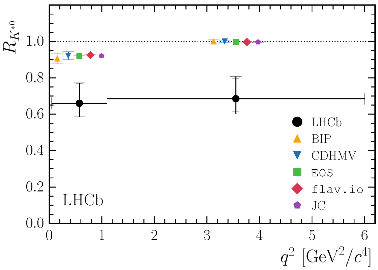
- Around 2.5σ for LFU ratio comparing $b \to s\mu\mu$ and $b \to see$ ($B \to K\ell^+\ell^-$, $B \to K^*\ell^+\ell^-$)

$$R_{K^{(*)}} = \frac{\mathcal{B}(B \to K^{(*)}\mu\mu)}{\mathcal{B}(B \to K^{(*)}ee)}$$



[1903.09252]



[1705.05802]

$b \to s\ell\ell$: Effective Hamiltonian

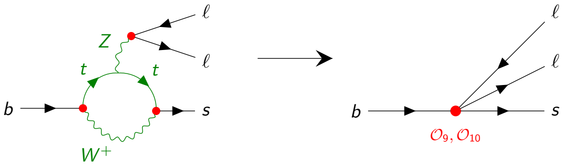
Local operator effective theory for $b \to s$ transitions. Non-local high energy processes are reduced to local operators as in Fermi Theory.

$$\mathcal{H}_{\text{eff}}(b \to s\ell^+\ell^-) = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i \mathcal{C}_i \mathcal{O}_i$$

With the SM operators relevant for this analysis

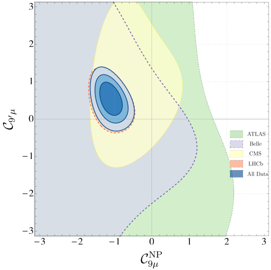
$$\mathcal{O}_7 = \frac{e}{g^2} m_b (\bar{s}\sigma_{\mu\nu} P_R b) F^{\mu\nu} \quad \mathcal{O}_9 = \frac{e^2}{g^2} (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \ell) \quad \mathcal{O}_{10} = \frac{e^2}{g^2} (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \gamma_5 \ell)$$

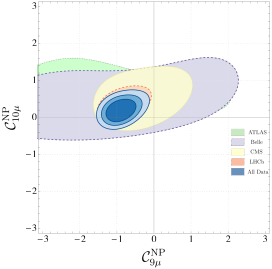
- Wilson coefficients ($\mathcal{C}_i$) contain short distance dynamics. They are accurately computed in SM and would deviate in presence of NP. Operators absent or suppressed in the SM, can be introduced by NP.
- We want to constrain these Wilson coefficients from data (done for mesons, now for baryons).
- We will also consider contributions in chirally flipped operators ($\mathcal{O}_{7'}, \mathcal{O}_{9'}, \mathcal{O}_{10'}$).



Global fits of $b \to s\ell\ell$

- (LFU) NP hints in rare semileptonic B decays indicate significant non-standard effects in muonic final states.
- Smaller effect in electrons is not excluded but not required to fit data.
- $b \to s\tau\tau$ transitions are at present only poorly constrained.





Main 1D scenarios for $b \to s\mu\mu$

These prefered scenarios show pulls from the SM of around 6σ

$$C_9^{\mu,\text{NP}} \qquad C_9^{\mu,\text{NP}} = -C_{10}^{\mu,\text{NP}}$$
$$C_9^{\mu,\text{NP}} = -C_{9'}^{\mu,\text{NP}}$$

Connecting $b \to s\ell\ell$ with $b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$

Based on: arXiv:2005.03734

S. Descotes-Genon, S. Fajfer, J. F. Kamenik, **M. Novoa-Brunet**

$b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$

- Why are these modes interesting?
  - Also FCNC!
  - Neutrinos and charged leptons in $SU(2)_L$ doublets in SM
  - Not affected by $c\bar{c}$ contributions.
  - Currently being measured and we expect soon future measurements! (NA62, Belle, KOTO, KLEVER, Belle 2)

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  - Dominated by long distances.
- Summation over neutrinos of all families (compared to processes with charged leptons of a single family).
- We can try to connect $b \to s\ell\ell$ with $b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$ following the work done for $b \to c\ell\nu$ [Bordone et al. 2017].

Connecting $b \to s\ell\ell$ with $b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$

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- If not, what are the most general assumptions we can make to connect them?

Connecting $b \to s\ell\ell$ with $b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$

- Can we do it in a model independent way?
- If not, what are the most general assumptions we can make to connect them?
- What are the implications of the $b \to s\ell\ell$ constraints on these modes?

NP from an EFT Lagrangian

Writting the operators in the down-quark and charged lepton mass basis $Q_L^i = (V_{ji}^{\mathrm{CKM}*} u_L^j, d_L^i)^T$ and $L_L^\alpha = (U_{\beta\alpha}^{\mathrm{PMNS}} \nu_L^\beta, \ell_L^\alpha)^T$

$$\mathcal{L}_{\text{eff.}} = \mathcal{L}_{\text{SM}} - \frac{1}{v^2} \lambda_{ij}^q \lambda_{\alpha\beta}^\ell \Big[C_T \left(\bar{Q}_L^i \gamma_\mu \sigma^a Q_L^i\right) \left(\bar{L}_L^\alpha \gamma^\mu \sigma^a L_L^\beta\right) + C_S \left(\bar{Q}_L^i \gamma_\mu Q_L^i\right) \left(\bar{L}_L^\alpha \gamma^\mu L_L^\beta\right) + C'_{RL} \left(\bar{d}_R^i \gamma_\mu d_R^i\right) \left(\bar{L}_L^\alpha \gamma^\mu L_L^\beta\right) + C'_{LR} \left(\bar{Q}_L^i \gamma_\mu Q_L^i\right) \left(\bar{\ell}_R^\alpha \gamma^\mu \ell_R^\beta\right) + C'_{RR} \left(\bar{d}_R^i \gamma_\mu d_R^i\right) \left(\bar{\ell}_R^\alpha \gamma^\mu \ell_R^\beta\right) \Big]$$

We assume that the same flavour structure encoded in λ_{ij}^q and $\lambda_{\alpha\beta}^\ell$ holds for all operators.

Quark Sector: $U(2)_q$ and (General) Minimal Flavour Violation

- We classify the NP flavour structure in terms of an approximate $U(2)_{q=Q,D}$ flavour symmetry.

$$\mathbf{q} \equiv (q_L^1, q_L^2) \sim (\mathbf{2}, \mathbf{1}) \qquad \mathbf{d} \equiv (d_R^1, d_R^2) \sim (\mathbf{1}, \mathbf{2}) \qquad d_R^3, q_L^3 \sim (\mathbf{1}, \mathbf{1})$$

- In the exact $U(2)_q$ limit only λ_{33}^q and $\lambda_{11}^q = \lambda_{22}^q$ are non-vanishing.
- Departures from the $U(2)_q$ limit manifest through non-diagonal terms ($\lambda_{i \neq j}^q$).
- We may impose the *leading* NP $U(2)_q$ breaking to be aligned with the SM Yukawas, yielding a (G)MFV structure [D'Ambrosio et al. 2002; Kagan et al. 2009]

$$d_L^3 = b_L + \theta_q e^{i\phi_q} \left(V_{td} d_L + V_{ts} s_L \right)$$

- In (G)MFV, the chirally flipped $\mathcal{C}_{i'}$ are suppressed.

Lepton Sector: $U(1)^3_\ell$ symmetry

We assume an approximate $U(1)^3_\ell$ symmetry (broken only by the neutrino masses) yielding $\lambda^\ell_{i\neq j} \simeq 0$ in order to fulfill LFV limits. We then consider three possible scenarios:

1. The simplest $\lambda^\ell_{\mu\mu} \neq 0$; $\lambda^\ell_{ee} = \lambda^\ell_{\tau\tau} = 0$
2. The anomaly-free assignment $\lambda^\ell_{\mu\mu} = -\lambda^\ell_{\tau\tau}$; $\lambda^\ell_{ee} = 0$
3. The hierarchical charge scenario $\lambda^\ell_{ee} \ll \lambda^\ell_{\mu\mu} \ll \lambda^\ell_{\tau\tau}$ (For concreteness we consider $\lambda^\ell_{\alpha\alpha}/\lambda^\ell_{\mu\mu} = m_\alpha/m_\mu$)

Relating (G)MFV Lagrangian with WET

Leading order in $U(2)_q$ breaking

$$b \to s\ell\ell \begin{cases} C_9^{\mu,\mathrm{NP}} & \propto & \lambda^\ell_{\mu\mu}\lambda^q_{33}\left((C_T + C_S) + C'_{LR}\right) + \mathcal{O}(\lambda^q_{23}) \\ C_{10}^{\mu,\mathrm{NP}} & \propto & \lambda^\ell_{\mu\mu}\lambda^q_{33}\left(-(C_T + C_S) + C'_{LR}\right) + \mathcal{O}(\lambda^q_{23}) \\ C_{9'}^{\mu,\mathrm{NP}} & \propto & \lambda^\ell_{\mu\mu}\lambda^q_{23}\left(C'_{RR} + C'_{RL}\right) \\ C_{10'}^{\mu,\mathrm{NP}} & \propto & \lambda^\ell_{\mu\mu}\lambda^q_{23}\left(C'_{RR} - C'_{RL}\right) \end{cases}$$

$$b \to s\nu\bar{\nu} \begin{cases} C_L^{\nu_\alpha,\mathrm{NP}} & \propto & \lambda^\ell_{\alpha\alpha}\lambda^q_{33}(C_T - C_S) + \mathcal{O}(\lambda^q_{23}) \\ C_R^{\nu_\alpha,\mathrm{NP}} & \propto & \lambda^\ell_{\alpha\alpha}\lambda^q_{23}C'_{RL} \end{cases}$$

$$s \to d\nu\bar{\nu} \left\{ C_{sd}^{\nu_\alpha,\mathrm{NP}} \quad \propto \quad \lambda^\ell_{\alpha\alpha}\lambda^q_{33}(C_T - C_S) + \mathcal{O}(\lambda^q_{23}) + \mathcal{O}(\lambda^q_{13}) \right.$$

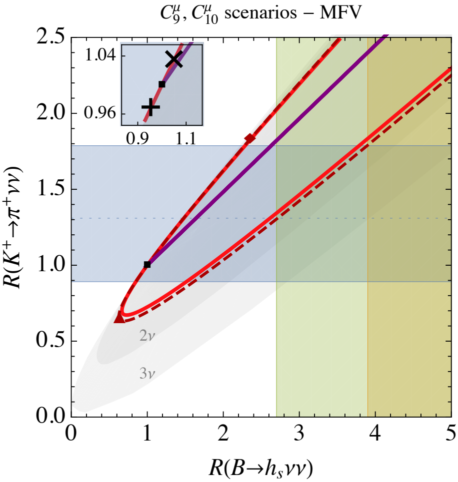
- A scenario for NP in $b \to s\ell\ell$ defines curves or regions in neutrino modes ($C_S - C_T$ vs $C_S + C_T$).

Constraints on $b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$ from $b \to s\ell\ell$

We consider the limit of (linear) MFV (only $\mathcal{C}_9$ and $\mathcal{C}_{10}$ allowed) in which $b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$ FCNC transitions are rigidly correlated driven by the combination of Wilson coefficients $C_S - C_T$. In this limit the NP contribution is the same for all $B \to h_s\nu\bar{\nu}$ modes.

$$R(X) = \frac{B(X)}{B(X)_{\text{SM}}}$$

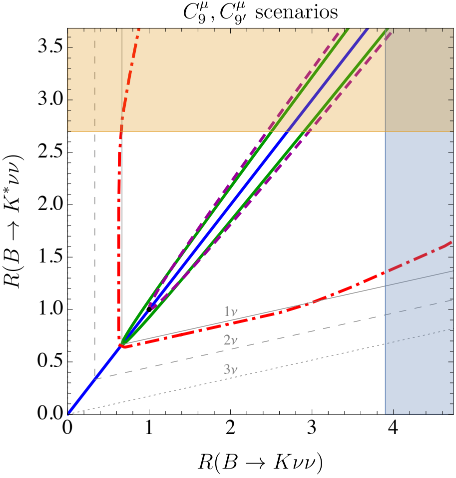
- Shaded: Completely free parameters affecting 2 or 3 neutrinos.
- Purple: Opposite sign $\lambda^{\ell}_{\mu\mu} = -\lambda^{\ell}_{\tau\tau}$
- Red: Only muons $\lambda^{\ell}_{\mu\mu}$
- Brown: Hierarchical ($\lambda^{\ell}_{\mu\mu} = \frac{m_\mu}{m_\tau}\lambda^{\ell}_{\tau\tau}$)



Constraints on $b \to s\nu\bar{\nu}$ from $b \to s\ell\ell$

Out of the (G)MFV limit we allow $\mathcal{C}_9$, $\mathcal{C}_{9'}$ NP and we take the other coefficients to 0. Deviations from the diagonal are driven by $C_{9'}$

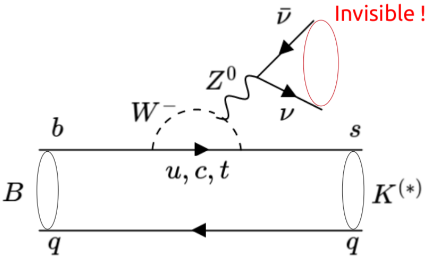
- Blue: (G)MFV Limit ($\mathcal{C}_{9'} = 0$)
- Purple: Opposite sign $\lambda^{\ell}_{\mu\mu} = -\lambda^{\ell}_{\tau\tau}$
- Green: Only muons $\lambda^{\ell}_{\mu\mu}$
- Red: Hierarchical ($\lambda^{\ell}_{\mu\mu} = \frac{m_\mu}{m_\tau}\lambda^{\ell}_{\tau\tau}$)
- Grey: Completely free parameters affecting 1, 2 or 3 neutrinos.



$b \to s\nu\bar{\nu}$: experimental prospects at Belle II

Experimental prospects : $B \to K^{(*)}\nu\bar{\nu}$

- B meson decay with $b \to s\nu\bar{\nu}$ transition
- This process has yet to be observed
- Actively searched for in the Belle II experiment.



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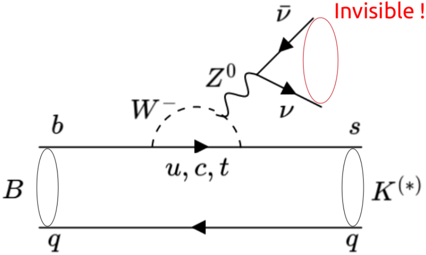

Main $b \to s\nu\bar{\nu}$ processes studied in Belle II:

- $B^+ \to K^+\nu\bar{\nu}$
- $B^0 \to K^0_S\nu\bar{\nu}$
- $B^+ \to K^{*+}\nu\bar{\nu}$
- $B^0 \to K^{*0}\nu\bar{\nu}$

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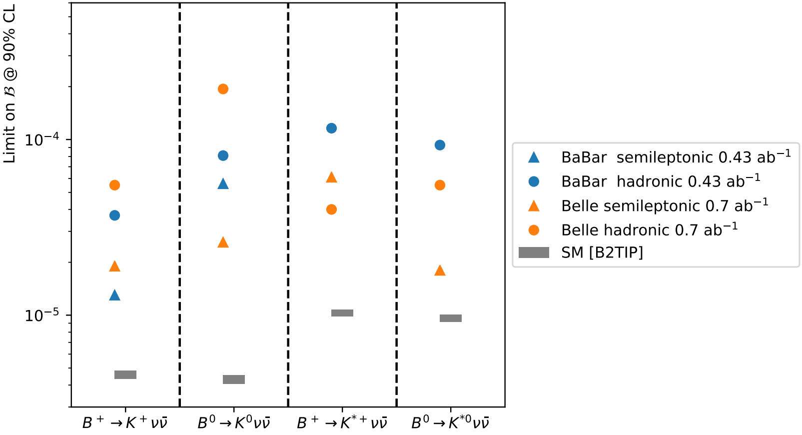


Experimental challenges

Two main challenges with the observation of $B \to K^{(*)}\nu\bar{\nu}$:

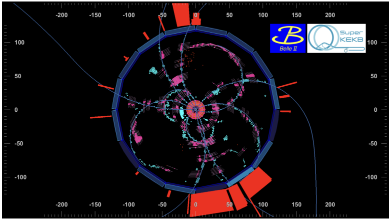
- Neutrinos do not interact with our detector
- Rare decay $\mathcal{B}(B \to K^{(*)}\nu\bar{\nu}) \simeq 10^{-6}/10^{-5}$

Experimental challenges

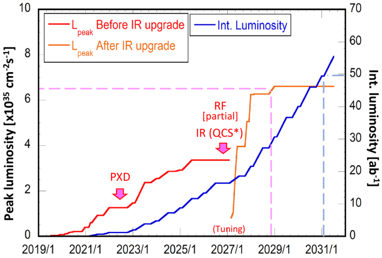
Two main challenges with the observation of $B \to K^{(*)}\nu\bar{\nu}$:

- Neutrinos do not interact with our detector
  $\to$ **Belle II** : e^+e^- collisions + clean environment + hermeticity

- Rare decay $\mathcal{B}(B \to K^{(*)}\nu\bar{\nu}) \simeq 10^{-6}/10^{-5}$
  $\to$ **Belle II** : highest instantaneous luminosity



Collision event @ Belle II

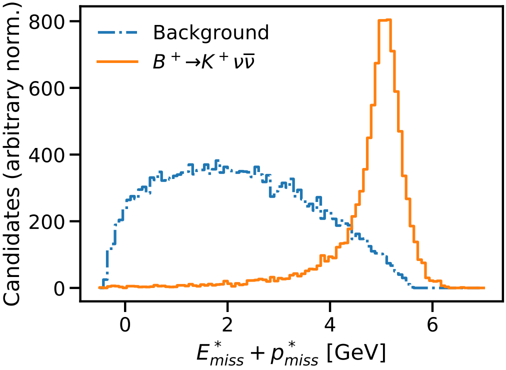


SuperKEKB luminosity calendar

Background rejection

A typical analysis consists of several selections :

- Reject non-$b\bar{b}$ events using mainly event shape variables
- To distinguish signal from $b\bar{b}$ background exploit mainly :
  - Presence of neutrinos (missing 4-momentum)
  - Absence of extra particles in the event (veto on extra tracks and cut or fit to extra energy in the calorimeter)



$B \to K^{(*)}\nu\bar{\nu}$ reconstruction

- In Belle II, collisions produce pairs of B mesons : B_{sig} and B_{tag}.
- Collisions of interest : $B_{sig} \to K^{(*)}\nu\bar{\nu}$ and $B_{tag} \to$ reconstructible final state.

How to "observe" B_{sig} ?

$B \to K^{(*)}\nu\bar{\nu}$ reconstruction

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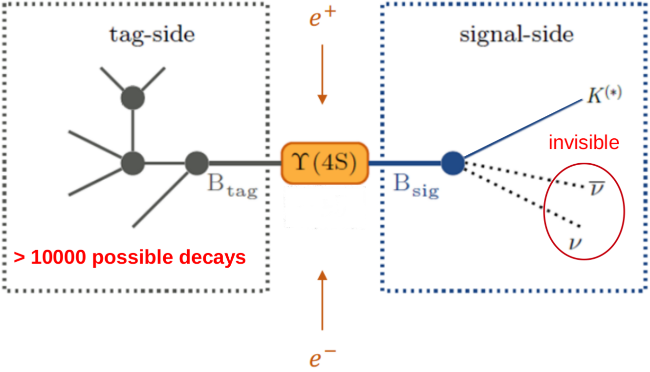
How to "observe" B_{sig} ?

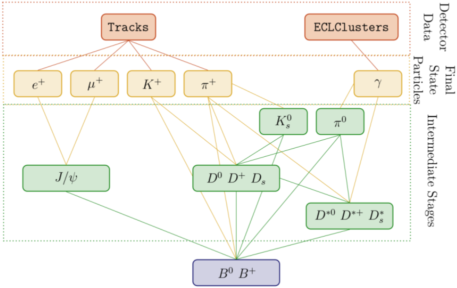
$\to$ **Reconstruct B_{tag} + $K^{(*)}$ and infer neutrino presence with missing 4-momentum.**

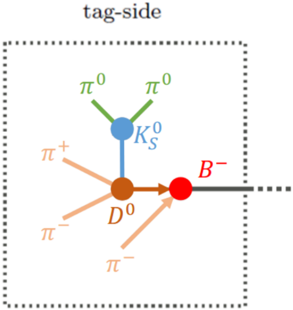


Full Event Interpretation

To reconstruct the **tag-side**, use of the Full Event Interpreation (FEI) algorithm.

- Key tool in the $B \to K^{(*)}\nu\bar{\nu}$ search.
- Sequential reconstruction of the exclusive B_{tag} decay chain.
- Trained on simulation.





Reconstruction efficiency

The total number of reconstructed candidates can be expressed as:

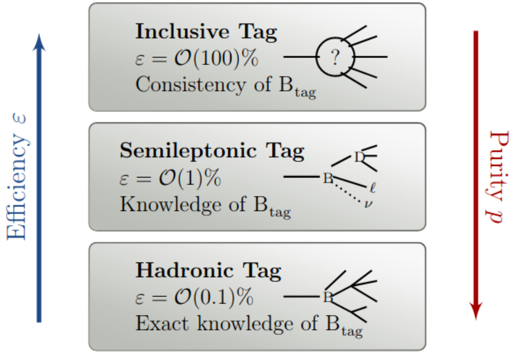
$$N = \mathcal{L} \times \sigma \times \mathcal{B}(B \to K^{(*)}\nu\bar{\nu}) \times \epsilon_{sig} \times \epsilon_{tag}$$

ϵ_{tag} = Tag-side reconstruction efficiency = $\Sigma_i \epsilon_i \times \mathcal{B}_i$ (sum over the $\mathcal{O}(10000)$ covered B_{tag} decay channels)
$\rightarrow$ main experimental challenge : enhancing ϵ_i and $\mathcal{B}_i$

Tagging methods

Two exclusive tagging methods :

- **Hadronic tag:** The B_{tag} is required to decay in a fully hadronic channel
- **Semileptonic tag:** The B_{tag} is required to decay in a semileptonic channel



In the Future

Several paths to continue looking for $b \to s$ processes in Belle II :

- Untagged analysis
- Refinement of standard tagged analysis
- Upgrades/replacements of the FEI algorithm (Deep learning)

Stay tuned !

Conclusions

Connecting $b \to s\ell\ell$ to neutrino modes

- Neutrino FCNC modes like $b \to s\nu\bar{\nu}$ and $s \to d\nu\bar{\nu}$ are interesting probes of NP.
- These modes can be related to and constrained by $b \to s\ell\ell$ through simple assumptions.

Prospects for $b \to s\nu\bar{\nu}$

- Specific methods developed to observe $b \to s\nu\bar{\nu}$ processes in Belle II
- Precise measurements expected by the end of Belle II data taking

Thank You!

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September 30, 2020

Back up

Possible Grossman-Nir bound violation at KOTO

- Cannot be explained without invoking isospin breaking NP (We can't explain it with (G)MFV) and additional long-lived neutral final states in the K_L decay beyond the three SM neutrinos.
- We note that new CP phases in $s \to d$ transitions only appear beyond the (G)MFV limit.
- Little can be said about the implications of $b \to s\mu\mu$ data model independently in this part of parameter space.
- A potential future experimental confirmation of $C_{9\prime}^{\mu,NP} \neq 0$ could at best provide circumstantial evidence for the presence of $U(2)_q$ breaking beyond (G)MFV

Relating (G)MFV Lagrangian with WET

The rare B decays $B \to K^{(*)}\nu\bar{\nu}$

$$\mathcal{B}(B \to K\nu\bar{\nu}) = (4.5 \pm 0.7) \times 10^{-6} \frac{1}{3} \sum_{\nu} (1 - 2\eta_\nu)\epsilon_\nu^2 \,,$$

$$\mathcal{B}(B \to K^*\nu\bar{\nu}) = (6.8 \pm 1.1) \times 10^{-6} \frac{1}{3} \sum_{\nu} (1 + 1.31\eta_\nu)\epsilon_\nu^2 \,,$$

$$\mathcal{B}(B \to X_s\nu\bar{\nu}) = (2.7 \pm 0.2) \times 10^{-5} \frac{1}{3} \sum_{\nu} (1 + 0.09\eta_\nu)\epsilon_\nu^2 \,,$$

where $\langle F_L \rangle$ is the longitudinal K^* polarisation fraction in $B \to K^*\nu\bar{\nu}$ decays. For each flavour of neutrino $\nu = \nu_e, \nu_\mu, \nu_\tau$, the two NP parameters can in turn be expressed as

$$\epsilon_\nu = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|C_{\mathrm{SM}}^\nu|} \,, \; \eta_\nu = \frac{-\mathrm{Re}(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2} \,,$$

where $C_{L,R}^\nu = C_{L,R}^{\nu,\mathrm{SM}} + C_{L,R}^{\nu,\mathrm{NP}}$ and $C_L^{\nu,\mathrm{SM}} = -6.38$ and $C_R^{\nu,\mathrm{SM}} = 0$ at $\mu = m_b$. Including leading $U(2)_q$ breaking effects we can write again

$$C_L^{\nu_\alpha,\mathrm{NP}} = -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\alpha\alpha}^\ell [V_{ts}^* \theta_q e^{-i\phi_q} + r_{23}][C_S - C_T] \,,$$

$$C_R^{\nu_\alpha,\mathrm{NP}} = -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\alpha\alpha}^\ell r_{23} C'_{RL} \,,$$

with $\alpha = e, \mu, \tau$.

Relating (G)MFV Lagrangian with WET

Similarly, the rare kaon decays $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$ can be conveniently expressed in presence of NP

$$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}(\gamma)) = (8.4 \pm 1.0) \times 10^{-11}$$

$$\times \frac{1}{3} \sum_\nu \left| 1 + \frac{C_{sd}^{\nu,\mathrm{NP}}}{V_{ts} V_{td}^* X_t + (X_c + \delta X_{c,u}) V_{cs} V_{cd}^*} \right|^2 ,$$

$$\mathcal{B}(K_L \to \pi^0 \nu\bar{\nu}) = (3.4 \pm 0.3) \times 10^{-11}$$

$$\times \frac{1}{3} \sum_\nu \left[1 + \mathrm{Im} \left(\frac{C_{sd}^{\nu,\mathrm{NP}}}{V_{ts} V_{td}^* X_t} \right) \right]^2 ,$$

Numerically, $X_t = 1.469(17)$ and $(X_c + \delta X_{c,u}) = 0.00106(6)$. For each neutrino flavour $\nu = \nu_e, \nu_\mu, \nu_\tau$, $C_{sd}^{\nu,\mathrm{NP}}$ receives contributions from three operators of the weak effective Hamiltonian yielding

$$C_{sd}^{\nu_\alpha,\mathrm{NP}} = \frac{\pi s_W^2}{\alpha_{em}} \lambda_{33}^q \lambda_{\alpha\alpha}^\ell [\theta_q^2 V_{ts} V_{td}^* (C_S - C_T)$$

$$+ \theta_q (V_{ts} e^{i\phi_q} r_{13}^* + V_{td}^* e^{-i\phi_q} r_{23}) (C_S - C_T)$$

$$+ r_{12} (C_S - C_T + C'_{RL})]$$

where $\alpha = e, \mu, \tau$

Relating (G)MFV Lagrangian with WET

Linear order in $U(2)_q$ breaking

$$b \to s\ell\ell \begin{cases} C_9^{\mu,\mathrm{NP}} &= -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\mu\mu}^\ell [V_{ts}^* \theta_q e^{-i\phi_q} + r_{23}] \\ & \qquad \times (C_T + C_S + C'_{LR}) \\ C_{10}^{\mu,\mathrm{NP}} &= -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\mu\mu}^\ell [V_{ts}^* \theta_q e^{-i\phi_q} + r_{23}] \\ & \qquad \times (-C_T - C_S + C'_{LR}) , \\ C_{9'}^{\mu,\mathrm{NP}} &= -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\mu\mu}^\ell r_{23} (C'_{RR} + C'_{RL}) \\ C_{10'}^{\mu,\mathrm{NP}} &= -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\mu\mu}^\ell r_{23} (C'_{RR} - C'_{RL}) \end{cases}$$

$$b \to s\nu\bar{\nu} \begin{cases} C_L^{\nu_\alpha,\mathrm{NP}} &= -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\alpha\alpha}^\ell [V_{ts}^* \theta_q e^{-i\phi_q} + r_{23}][C_S - C_T] \\ C_R^{\nu_\alpha,\mathrm{NP}} &= -\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{33}^q \lambda_{\alpha\alpha}^\ell r_{23} C'_{RL} \end{cases}$$

$$s \to d\nu\bar{\nu} \begin{cases} C_{sd}^{\nu_\alpha,\mathrm{NP}} &= \frac{\pi s_W^2}{\alpha_{em}} \lambda_{33}^q \lambda_{\alpha\alpha}^\ell [\theta_q^2 V_{ts} V_{td}^* (C_S - C_T) \\ &+ \quad \theta_q (V_{ts} e^{i\phi_q} r_{13}^* + V_{td}^* e^{-i\phi_q} r_{23}) (C_S - C_T) \\ &+ \quad r_{12} (C_S - C_T + C'_{RL})] \end{cases}$$

- A scenario for NP in $b \to s\ell\ell$ defines curves or regions in neutrino modes ($C_S - C_T$ vs $C_S + C_T$).

Expected sensitivities

Observables	Belle $0.71\,\mathrm{ab}^{-1}$ $(0.12\,\mathrm{ab}^{-1})$	Belle II $5\,\mathrm{ab}^{-1}$	Belle II $50\,\mathrm{ab}^{-1}$
$\mathrm{Br}(B^+ \to K^+ \nu\bar{\nu})$	$< 450\%$	30%	11%
$\mathrm{Br}(B^0 \to K^{*0} \nu\bar{\nu})$	$< 180\%$	26%	9.6%
$\mathrm{Br}(B^+ \to K^{*+} \nu\bar{\nu})$	$< 420\%$	25%	9.3%
$F_L(B^0 \to K^{*0} \nu\bar{\nu})$	–	–	0.079
$F_L(B^+ \to K^{*+} \nu\bar{\nu})$	–	–	0.077
$\mathrm{Br}(B^0 \to \nu\bar{\nu}) \times 10^6$	< 14	< 5.0	< 1.5
$\mathrm{Br}(B_s \to \nu\bar{\nu}) \times 10^5$	< 9.7	< 1.1	–

Figure 1: From The Belle II physics book