$B \to K \nu\nu$ measurements and new physics

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Key points

- Flavor changing neutral current transitions are suppressed in the standard model (SM) and thus are good place to look for new physics (NP) effects.
- Connections of $B \to K^{(*)}\nu\nu$ channel with neutral current (NC) $R_{B^{(*)}}$ [1] and charged current (CC) $R(D^{(*)})$ [2] anomalies in context of ‘simplified’ models are studied.
- Recently used inclusive tagging technique in Belle II increases possibility to observe events in $B^+ \to K^+\nu\nu\mu$ mode [3].

Introduction

The most general dimension-6 effective Hamiltonian contains (axial)vector, (pseudo)scalar and tensor operators when including light right-handed neutrinos (RHNS) in the final states.

$\mathcal{H}_{\text{eff}} = -\frac{4G_F\alpha_{\text{EM}}}{\sqrt{2}} V_{tb} V_{ts}^{\ast} \left( C_{1}^{\pm} \delta_{\alpha\beta} C_{\alpha \beta}^{\nu\nu} \right)^{\mu\nu} + \sum_{X=V,T} \left[ C_{X}^{\nu\nu} \delta_{\alpha\beta} C_{X}^{\nu\nu} \right]$

The SM contribution [4]:

$C_{1}^{\pm} = -2X_{t}/s_{W}^{2}$

$X_{t} = 1.469 \pm 0.017$

Ten four-fermion NP operators:

$C_{AB}^{\nu\nu} = \text{diag}(3, P_{\nu\nu})$

Observables: Branching ratios, differential distribution in $q^2$ for $B \to K^{(*)}\nu\nu$ channels and longitudinal polarisation fraction of $K^*$ only in the vector meson mode. The variation of all individual NP operators can achieve the expected range of $R_{K^*}$.

New Physics: Leptoquarks & Generic $Z'$

Leptoquark (LQ) arises in R-parity violating models, Grand Unified Theories, can turn a lepton into a quark and vice-versa. Differing in the SM gauge quantum numbers, the following six LQs contribute to $b \to s\nu\nu$. The SM contribution [4]:

$B_{\nu\nu}$ → $K^{(*)}\nu\nu$ channel with neutral current (NC) $R_{B^{(*)}}$ [1] and charged current (CC) $R(D^{(*)})$ [2] anomalies in context of ‘simplified’ models are studied.

Recently used inclusive tagging technique in Belle II increases possibility to observe events in $B^+ \to K^+\nu\nu\mu$ mode [3].

Is the anticipated enhancement correlated with $B$-anomalies?

Mediators Spin Interaction terms Operators

$S_3(3, 1, 1/3)$ 0 $+ Q_{L}^{\nu} Y_{t \alpha} \gamma_{\mu} \tau_{\nu} S_{B}^{\mu}$

$S_2(3, 2, 1/6)$ 0 $- \delta_{\alpha \beta} Y_{t \alpha} R_{B}^{\nu} \gamma_{\mu} \tau_{\nu} S_{B}^{\mu}$

$S_1(3, 2, 1/6)$ 0 $+ Q_{L}^{\nu} Y_{t \alpha} \gamma_{\mu} \tau_{\nu} S_{B}^{\mu}$

$U_{(3, 3/2, 1/3)}$ 1 $+ \delta_{\alpha \beta} Y_{t \alpha} \gamma_{\mu} \tau_{\nu} S_{B}^{\mu}$

$V_{(3, 2, 5/6)}$ 1 $+ \delta_{\alpha \beta} Y_{t \alpha} \gamma_{\mu} \tau_{\nu} S_{B}^{\mu}$

$O_{(1, 1, -1/3)}$ 1 $+ \delta_{\alpha \beta} Y_{t \alpha} \gamma_{\mu} \tau_{\nu} S_{B}^{\mu}$

The first generation entries in the LQ Yukawa coupling matrices are stringently constrained from Kaon and leptonic physics [5]. We choose minimal set of non-zero couplings relevant for one or both kind(s) of $B$-anomalies.

Summary

- Possibilities to connect the indicated excess in $B^+ \to K^+\nu\nu$ with both NC and CC $B$-anomalies in ‘simplified’ models.
- RHN explanations to $R(D^{(*)})$ are excluded for $S_1$ and $R_2$ LQs by $B \to K\nu\nu\mu$ data.
- Heavy $Z'$ explaining NC anomalies with minimal setup can not enhance $R_{K^*}$ value.
- $S_1$ explaining CC $B$-anomalies & $S_2$ in NC+CC framework can produce expected enhancement in $R_{K^*}$.
- Other links- Dark Matter connection?

Reference