Studying the NP chiral flip in the $B_{d(s)} \to K^{(*)}\bar{K}^{(*)}$ puzzle

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Outlines

- Motivation
- Model: RPV-MSSMIS
- $B_{d(s)} \to K^{(*)}\bar{K}^{(*)}$
- Relevant constraints
- Numerical discussions and conclusions

$B_{d(s)} \to K^{(*)}\bar{K}^{(*)}$ puzzle

$$L_{K^{(*)}\bar{K}^{(*)}} = \rho(m_{K^{(*)0}}, m_{K^{(*)0}})\mathcal{B}_{(\text{long})}(\bar{B}_s^0 \to K^{(*)0}\bar{K}^{(*)0})/\mathcal{B}_{(\text{long})}(\bar{B}_d^0 \to K^{(*)0}\bar{K}^{(*)0})$$

A. Biswas *et al.*, 2301.10542, M. Algueró *et al.*, 2011.07867

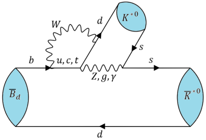
$$L^{\text{exp}}_{K^*\bar{K}^*} = 4.43 \pm 0.92 \qquad L^{\text{exp}}_{K\bar{K}} = 14.58 \pm 3.37$$

LHCb, R. Aaij *et al.*, 1995.06662, 2002.08229

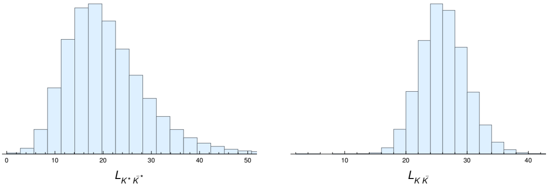
BaBar, B. Aubert *et al.*, 0708.2248, hep-ex/0608036

Belle, 1210.1348, 1512.02145

$$L^{\text{SM}}_{K^*\bar{K}^*} = 19.53^{+9.14}_{-6.64} \qquad L^{\text{SM}}_{K\bar{K}} = 26.00^{+3.88}_{-3.59}$$



show deviations with 2.6σ and 2.4σ, respectively

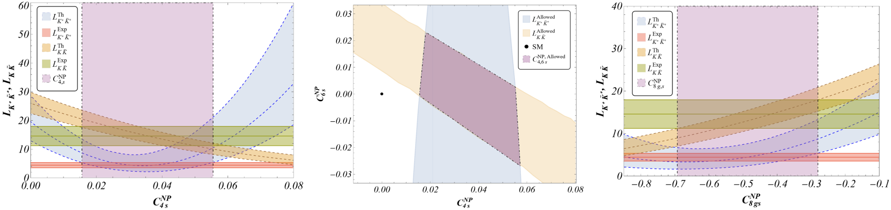


The model-independent global fit

$$\mathcal{L}_{\text{eff}} = \frac{4G_F}{\sqrt{2}} K_{tb} K_{tp}^{*} \sum_i C_i \mathcal{O}_i + \text{h.c.} \quad (p = s, d)$$

$$\mathcal{O}_{4p} = (\bar{p}_L^{\alpha} \gamma^{\mu} b_L^{\beta}) \sum_q (\bar{q}_L^{\beta} \gamma_{\mu} q_L^{\alpha}), \qquad \mathcal{O}_{6p} = (\bar{p}_L^{\alpha} \gamma^{\mu} b_L^{\beta}) \sum_q (\bar{q}_R^{\beta} \gamma_{\mu} q_R^{\alpha}),$$

$$\mathcal{O}_{7\gamma p} = \frac{-e m_b}{16\pi^2} (\bar{p}_L^{\alpha} \sigma^{\mu\nu} b_R^{\alpha}) F_{\mu\nu}, \qquad \mathcal{O}_{8gp} = \frac{-g_s m_b}{16\pi^2} (\bar{p}_L^{\alpha} \sigma^{\mu\nu} T_{\alpha\beta}^{a} b_R^{\beta}) G_{\mu\nu}^{a},$$



A. Biswas *et al.*, 2301.10542

RPV-MSSMIS

The superpotential:

$$\mathcal{W} = \mathcal{W}_{\text{MSSM}} + Y_\nu^{ij}\hat{R}_i\hat{L}_j\hat{H}_u + M_R^{ij}\hat{R}_i\hat{S}_j + \frac{1}{2}\mu_S^{ij}\hat{S}_i\hat{S}_j + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}_k,$$

$$\mathcal{W}_{\text{MSSM}} = \mu\hat{H}_u\hat{H}_d + Y_u^{ij}\hat{U}_i\hat{Q}_j\hat{H}_u - Y_d^{ij}\hat{D}_i\hat{Q}_j\hat{H}_d - Y_e^{ij}\hat{E}_i\hat{L}_j\hat{H}_d$$

The soft SUSY breaking terms:

$$-\mathcal{L}^{\text{soft}} = -\mathcal{L}^{\text{soft}}_{\text{MSSM}} + (m^2_{\tilde{R}})_{ij}\tilde{R}_i^*\tilde{R}_j + (m^2_{\tilde{S}})_{ij}\tilde{S}_i^*\tilde{S}_j + (A_\nu Y_\nu)_{ij}\tilde{R}_i^*\tilde{L}_jH_u + B^{ij}_{M_R}\tilde{R}_i^*\tilde{S}_j + \frac{1}{2}B^{ij}_{\mu_S}\tilde{S}_i\tilde{S}_j$$

In the (ν, R, S) basis,

$$\mathcal{M}_\nu = \begin{pmatrix} 0 & m_D^T(=\frac{1}{\sqrt{2}}v_uY_\nu) & 0 \\ m_D & 0 & M_R \\ 0 & M_R^T & \mu_S \end{pmatrix} = \mathcal{V}^\dagger \begin{pmatrix} m^{\text{diag}}_{\nu_l} & 0 \\ 0 & m^{\text{diag}}_{\nu_h} \end{pmatrix} \mathcal{V}^*$$

$$\Rightarrow \mu_S = (m_D^T)^{-1}M_RU_{\text{PMNS}}m_\nu^{\text{diag}}U^T_{\text{PMNS}}M_R^Tm_D^{-1}, \text{ when } \mu_S \ll m_D < M_R$$

RPV-MSSMIS

In the $(\tilde{\nu}_L^{\mathcal{I}(\mathcal{R})}, \tilde{R}^{\mathcal{I}(\mathcal{R})}, \tilde{S}^{\mathcal{I}(\mathcal{R})})$ basis,

$$\mathcal{M}^2_{\tilde{\nu}^{\mathcal{I}(\mathcal{R})}} = \begin{pmatrix} m^2_{\tilde{L}'} & (A_\nu - \mu\cot\beta)m_D^T & m_D^T M_R \\ (A_\nu - \mu\cot\beta)m_D & m^2_{\tilde{R}} + M_R M_R^T + m_D m_D^T & \pm M_R \mu_S + B_{M_R} \\ M_R^T m_D & \pm\mu_S M_R^T + B_{M_R}^T & m^2_{\tilde{S}} + \mu_S^2 + M_R^T M_R \pm B_{\mu_S} \end{pmatrix}$$

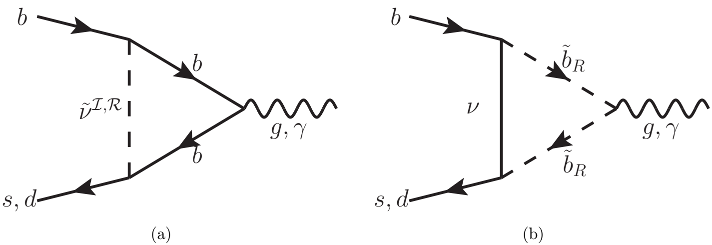
$$\approx \begin{pmatrix} m^2_{\tilde{L}'} & (A_\nu - \mu\cot\beta)m_D^T & m_D^T M_R \\ (A_\nu - \mu\cot\beta)m_D & m^2_{\tilde{R}} + M_R M_R^T + m_D m_D^T & B_{M_R} \\ M_R^T m_D & B_{M_R}^T & m^2_{\tilde{S}} + M_R^T M_R \pm B_{\mu_S} \end{pmatrix} \text{mass split}$$

In the context of mass eigenstates for d_i and l_i, other fields are rotated to mass eigenstates,

$$\mathcal{L}_{\text{LQD}} = \lambda'_{ijk}(\tilde{\nu}_{Li}\bar{d}_{Rk}d_{Lj} + \tilde{d}_{Lj}\bar{d}_{Rk}\nu_{Li} + \tilde{d}^*_{Rk}\bar{\nu}^c_{Li}d_{Lj}$$
$$- \tilde{l}_{Li}\bar{d}_{Rk}u_{Lj} - \tilde{u}_{Lj}\bar{d}_{Rk}l_{Li} - \tilde{d}^*_{Rk}\bar{l}^c_{Li}u_{Lj}) + \text{h.c.}$$
$$\Rightarrow$$
$$\mathcal{L}'_{\text{LQD}} = \lambda'^{\mathcal{I}(\mathcal{R})}_{vjk}\tilde{\nu}_v^{\mathcal{I}(\mathcal{R})}\bar{d}_{Rk}d_{Lj} + \lambda'^{\mathcal{N}}_{vjk}(\tilde{d}_{Lj}\bar{d}_{Rk}\nu_v + \tilde{d}^*_{Rk}\bar{\nu}^c_v d_{Lj})$$
$$- \tilde{\lambda}'_{ilk}(\tilde{l}_{Li}\bar{d}_{Rk}u_{Ll} + \tilde{u}_{Ll}\bar{d}_{Rk}l_{Li} + \tilde{d}^*_{Rk}\bar{l}^c_{Li}u_{Ll}) + \text{h.c.},$$

where $\lambda'^{\mathcal{I}(\mathcal{R})}_{vjk} = \lambda'_{ijk}\tilde{\mathcal{V}}^{\mathcal{I}(\mathcal{R})*}_{vi}$, $\lambda'^{\mathcal{N}}_{vjk} = \lambda'_{ijk}\mathcal{V}_{vi}$, and $\tilde{\lambda}'_{ilk} = \lambda'_{ijk}K^*_{lj}$

$B_{d(s)} \to K^{(*)}\bar{K}^{(*)}$ process (γ, g-penguin)

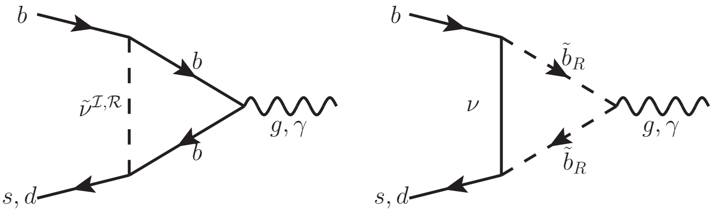


Gluon(phonton)-penguin diagrams in RPV-MSSMIS, within the single-value-k assumption, i.e. $\lambda'_{ij1} = \lambda'_{ij2} \approx 0$

$$\text{Fig.(a)}: \; C_{8gp}^{\text{NP}} = \frac{1}{48\sqrt{2}G_F\eta_t}\left\{ \frac{\lambda'^{\mathcal{I}*}_{vp3}\lambda'^{\mathcal{I}*}_{v33}}{m^2_{\tilde{\nu}^{\mathcal{I}}_v}}\left[8 + 6\log\left(\frac{m_b^2}{m^2_{\tilde{\nu}^{\mathcal{I}}_v}}\right)\right] - \frac{\lambda'^{\mathcal{R}*}_{vp3}\lambda'^{\mathcal{R}*}_{v33}}{m^2_{\tilde{\nu}^{\mathcal{R}}_v}}\left[8 + 6\log\left(\frac{m_b^2}{m^2_{\tilde{\nu}^{\mathcal{R}}_v}}\right)\right] + \frac{\lambda'^{\mathcal{I}*}_{vp3}\lambda'^{\mathcal{I}}_{v33}}{m^2_{\tilde{\nu}^{\mathcal{I}}_v}} + \frac{\lambda'^{\mathcal{R}*}_{vp3}\lambda'^{\mathcal{R}}_{v33}}{m^2_{\tilde{\nu}^{\mathcal{R}}_v}} \right\}$$

$$C_{7\gamma p}^{\text{NP}} = -\,C_{8gp}/3$$

$B_{d(s)} \to K^{(*)}\bar{K}^{(*)}$ process (γ, g-penguin)



(a) (b)

Gluon(phonton)-penguin diagrams in RPV-MSSMIS, within the single-value-k assumption, i.e. $\lambda'_{ij1} = \lambda'_{ij2} \approx 0$

$$L_{K\bar{K}}/L^{SM}_{K\bar{K}} \approx 1 + 1.13 C^{\rm NP}_{8gs}(\mu_{\rm EW}) + 0.34 C^{\rm NP}_{8gs}(\mu_{\rm EW})^2,$$
$$L_{K^*\bar{K}^*}/L^{SM}_{K^*\bar{K}^*} \approx 1 + 2.41 C^{\rm NP}_{8gs}(\mu_{\rm EW}) + 1.74 C^{\rm NP}_{8gs}(\mu_{\rm EW})^2,$$

where $\mu_{\rm EW} = 160$ GeV

We need $C^{\rm NP}_{8gs} \lesssim -0.08$ for 2σ-level explanation

Constraint: $B_s - \bar{B}_s$ mixing

$$\mathcal{L}_{\rm eff}^{b\bar{s}b\bar{s}} = (C_{\rm SM}^{\rm VLL} + C_{\rm NP}^{\rm VLL})(\bar{s}\gamma_\mu P_L b)(\bar{s}\gamma^\mu P_L b) + C_{\rm NP}^{\rm 1SRR}(\bar{s}P_R b)(\bar{s}P_R b) + \text{h.c.}$$

$$C_{\rm NP}^{\rm VLL} = \frac{1}{8i}\Big(\frac{1}{4}\Lambda_{vv'}^{\prime 1\mathcal{X}\mathcal{Y}} D_2[m_{\tilde{\nu}_v^{\mathcal{X}}}, m_{\tilde{\nu}_{v'}^{\mathcal{Y}}}, m_b, m_b] + \Lambda_{vv'}^{\prime\mathcal{N}} D_2[m_{\nu_v}, m_{\nu_{v'}}, m_{\tilde{b}_R}, m_{\tilde{b}_R}]\Big)$$

$$C_{\rm NP}^{\rm 1SRR} = \frac{1}{8i}\Big(\Lambda_{vv'}^{\prime 2\mathcal{X}\mathcal{Y}}(-1)^{\delta_{\mathcal{X}\mathcal{Y}}+1} m_b^2 D_0[m_{\tilde{\nu}_v^{\mathcal{X}}}, m_{\tilde{\nu}_{v'}^{\mathcal{Y}}}, m_b, m_b]$$
$$+ \Lambda_{vv'}^{\prime 3\mathcal{X}\mathcal{Y}}(\delta_{\mathcal{X}\mathcal{R}} - \delta_{\mathcal{X}\mathcal{I}}) m_b^2 D_0[m_{\tilde{\nu}_v^{\mathcal{X}}}, m_{\tilde{\nu}_{v'}^{\mathcal{Y}}}, m_b, m_b] - \frac{\lambda_{v23}^{\prime\mathcal{I}*2}}{2m_{\tilde{\nu}_v^{\mathcal{I}}}^2} + \frac{\lambda_{v23}^{\prime\mathcal{R}*2}}{2m_{\tilde{\nu}_v^{\mathcal{R}}}^2}\Big),$$

where

$$\Lambda_{vv'}^{\prime 1\mathcal{X}\mathcal{Y}} \equiv \lambda_{v33}^{\prime\mathcal{X}}\lambda_{v23}^{\prime\mathcal{X}*}\lambda_{v'33}^{\prime\mathcal{Y}}\lambda_{v'23}^{\prime\mathcal{Y}*} \qquad \Lambda_{vv'}^{\prime 2\mathcal{X}\mathcal{Y}} \equiv \lambda_{v33}^{\prime\mathcal{X}*}\lambda_{v23}^{\prime\mathcal{X}*}\lambda_{v'33}^{\prime\mathcal{Y}*}\lambda_{v'23}^{\prime\mathcal{Y}*}$$
$$\Lambda_{vv'}^{\prime 3\mathcal{X}\mathcal{Y}} \equiv \lambda_{v33}^{\prime\mathcal{X}*}\lambda_{v23}^{\prime\mathcal{X}*}\lambda_{v'33}^{\prime\mathcal{Y}}\lambda_{v'23}^{\prime\mathcal{Y}*} \qquad \Lambda_{vv'}^{\prime\mathcal{N}} \equiv \lambda_{v33}^{\prime\mathcal{N}}\lambda_{v23}^{\prime\mathcal{N}*}\lambda_{v'33}^{\prime\mathcal{N}}\lambda_{v'23}^{\prime\mathcal{N}*}$$

The recent experimental and SM results constrain

$$\mathcal{R}_{B_s} \equiv \frac{\Delta M_s}{\Delta M_s^{\rm SM}} = \left|1 + \frac{C_{\rm NP}^{\rm VLL}}{C_{\rm SM}^{\rm VLL}} - 2.38\frac{C_{\rm NP}^{\rm 1SRR}}{C_{\rm SM}^{\rm VLL}}\right|$$

in the range of $0.90 < \mathcal{R}_{B_s} < 1.04$

Relevant constraints

Tree-level

Observations	SM predictions	Experimental data
$\mathcal{B}(K^+ \to \pi^+ \nu \bar{\nu})$	$(9.24 \pm 0.83) \times 10^{-11}$ [1]	$(1.14^{+0.40}_{-0.33}) \times 10^{-10}$ [2]
$\mathcal{B}(D^0 \to \mu^+ \mu^-)$	$\lesssim 6 \times 10^{-11}$ [3]	$< 3.1 \times 10^{-9}$ [4]
$\mathcal{B}(\tau \to e \rho^0)$	-	$< 2.2 \times 10^{-8}$ [5]
$\mathcal{B}(\tau \to \mu \rho^0)$	-	$< 1.7 \times 10^{-8}$ [5]
$\mathcal{B}(B \to \tau \nu)$	$(9.47 \pm 1.82) \times 10^{-5}$ [6]	$(1.09 \pm 0.24) \times 10^{-4}$ [2]
$\mathcal{B}(D_s \to \tau \nu)$	$(5.40 \pm 0.30)\%$ [7]	$(5.36 \pm 0.10)\%$ [2]
$\mathcal{B}(\tau \to K \nu)$	$(7.15 \pm 0.026) \times 10^{-3}$ [8]	$(6.96 \pm 0.10) \times 10^{-3}$ [2]

[1] **J. Aebischer *et al.*, 1810.07698**
[2] **PDG2024**
[3] **LHCb, R. Aaij *et al.*, 1305.5059**
[4] **LHCb, R. Aaij *et al.*, 2212.11203**
[5] **Belle, N. Tsuzuki *et al.*, 2301.03768**
[6] **S. Nandi *et al.*, 1605.07191**
[7] **Q.-Y. Hu *et al.*, 2202.09875**
[8] **Q.-Y. Hu *et al.*, 1808.01419**

Loop-level

- $\pi \to \ell\nu(\gamma)$, $\tau \to e\gamma$, $\tau \to eee$, Z-pole data, $\mu \to e\bar{\nu}_e\nu_\mu$, $\tau \to \ell\bar{\nu}_\ell\nu_\tau$ etc.
- $B \to X_s\gamma$: $\mathcal{B}(B \to X_s\gamma) \times 10^4 = (3.40 \pm 0.17) - 8.25 C_{7\gamma s}(\mu_{\mathrm{EW}}) - 2.10 C_{8gs}(\mu_{\mathrm{EW}})$
  M. Misiak *et al.*, 2002.01548
- Set λ'_{2jk} negligible to avoid enlarging the Cabbibo anomaly
  A. M. Coutinho *et al.*, 1912.08823
  M. Blennow *et al.*, 2204.04559

Choice of input parameters

Parameters	Sets
$\tan\beta$	15
Y_ν	$\mathrm{diag}(0.28, 0.11, 0.10)$
M_R	$\mathrm{diag}(1, 1, 1)$ TeV
B_{M_R}	$\mathrm{diag}(0.5, 0.5, 0.5)$ TeV^2
B_{μ_S}	$\mathrm{diag}(0.66, 0.66, 0.66)$ TeV^2
$m_{\tilde{L}'_i}$	$\mathrm{diag}(1, 1, 1)$ TeV

provide $M_W \approx 80.385$ GeV, $m_{\tilde{l}_1} \approx 1$ TeV, and $m_{\tilde{\nu}_1} \approx 270$ GeV

ATLAS, G. Aad *et al.*, 2307.14759

$\sin^2\theta_{12}$	$\sin^2\theta_{23}$	$\sin^2\theta_{13}$
$0.304(12)$	$0.573^{+0.016}_{-0.020}$	$0.02219^{+0.00062}_{-0.00063}$
$\delta_{\mathrm{CP}}[^\circ]$	$\Delta m^2_{21}[10^{-5}\ \mathrm{eV}^2]$	$\Delta m^2_{31}[10^{-3}\ \mathrm{eV}^2]$
197^{+27}_{-24}	$7.42^{+0.21}_{-0.20}$	$2.517^{+0.026}_{-0.028}$

$$m_\nu^{\mathrm{diag}} \approx \mathrm{diag}(0, \sqrt{\Delta m^2_{21}}, \sqrt{\Delta m^2_{31}}) = \mathrm{diag}(0, 0.008, 0.05)\ \mathrm{eV}$$

I. Esteban *et al.*, 2007.14792

(S)neutrino mass spectrum

$\sin^2\theta_{12}$	$\sin^2\theta_{23}$	$\sin^2\theta_{13}$
$0.304(12)$	$0.573^{+0.016}_{-0.020}$	$0.02219^{+0.00062}_{-0.00063}$
$\delta_{CP}[^\circ]$	$\Delta m^2_{21}[10^{-5}\ \mathrm{eV}^2]$	$\Delta m^2_{31}[10^{-3}\ \mathrm{eV}^2]$
197^{+27}_{-24}	$7.42^{+0.21}_{-0.20}$	$2.517^{+0.026}_{-0.028}$

$$\mathcal{M}_\nu^{\mathrm{diag}} = \mathcal{V}\mathcal{M}_\nu\mathcal{V}^T$$

$$(\mathcal{M}^2_{\tilde{\nu}^{\mathcal{I}(\mathcal{R})}})^{\mathrm{diag}} = \tilde{\mathcal{V}}^{\mathcal{I}(\mathcal{R})}\mathcal{M}^2_{\tilde{\nu}^{\mathcal{I}(\mathcal{R})}}\tilde{\mathcal{V}}^{\mathcal{I}(\mathcal{R})\dagger}$$

$$\tilde{\mathcal{V}}^{\mathcal{I}} \approx \begin{pmatrix} -0.051 & 0 & 0 & -0.541 & 0 & 0 & 0.840 & 0 & 0 \\ 0 & -0.021 & 0 & 0 & -0.543 & 0 & 0 & 0.840 & 0 \\ 0 & 0 & -0.019 & 0 & 0 & -0.543 & 0 & 0 & 0.840 \\ 0.995 & 0 & 0 & -0.100 & 0 & 0 & -0.004 & 0 & 0 \\ 0 & 0.999 & 0 & 0 & -0.038 & 0 & 0 & 0 & 0 \\ 0 & 0 & -0.999 & 0 & 0 & 0.035 & 0 & 0 & 0 \\ -0.086 & 0 & 0 & -0.835 & 0 & 0 & -0.543 & 0 & 0 \\ 0 & -0.032 & 0 & 0 & -0.839 & 0 & 0 & -0.543 & 0 \\ 0 & 0 & -0.029 & 0 & 0 & -0.839 & 0 & 0 & -0.543 \end{pmatrix}$$

sneutrinos with
$\{269, 272, 272, 1010, 1000, 1000, 1129, 1127, 1127\}$ GeV

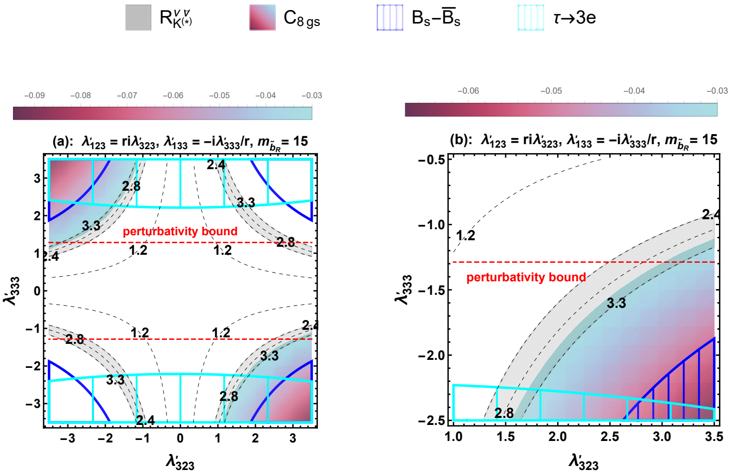
$$\mathcal{V}^T \approx \begin{pmatrix} 0.836 & 0.526 & -0.145 & 0.034i & 0 & 0 & -0.034 & 0 & 0 \\ -0.246 & 0.600 & 0.761 & 0 & 0.013i & 0 & 0 & 0.013 & 0 \\ 0.488 & -0.602 & 0.632 & 0 & 0 & 0.012i & 0 & 0 & 0.012 \\ 0 & 0 & 0 & -0.707i & 0 & 0 & -0.707 & 0 & 0 \\ 0 & 0 & 0 & 0 & -0.707i & 0 & 0 & 0.707 & 0 \\ 0 & 0 & 0 & 0 & 0 & -0.707i & 0 & 0 & 0.707 \\ -0.041 & -0.026 & 0.007 & 0.706i & 0 & 0 & -0.706 & 0 & 0 \\ 0.005 & -0.011 & -0.015 & 0 & 0.707i & 0 & 0 & 0.707 & 0 \\ -0.008 & 0.010 & -0.011 & 0 & 0 & 0.707i & 0 & 0 & 0.707 \end{pmatrix}$$

light neutrinos with $\{0, 0.008, 0.05\}$ eV and heavy ones with TeV

$$\tilde{\mathcal{V}}^{\mathcal{R}} \approx \begin{pmatrix} 0.076 & 0 & 0 & 0.834 & 0 & 0 & -0.545 & 0 & 0 \\ 0 & -0.032 & 0 & 0 & -0.839 & 0 & 0 & 0.544 & 0 \\ 0 & 0 & -0.029 & 0 & 0 & -0.839 & 0 & 0 & 0.544 \\ 0.996 & 0 & 0 & -0.094 & 0 & 0 & -0.003 & 0 & 0 \\ 0 & 0.999 & 0 & 0 & -0.038 & 0 & 0 & 0 & 0 \\ 0 & 0 & -0.999 & 0 & 0 & 0.035 & 0 & 0 & 0 \\ -0.054 & 0 & 0 & -0.542 & 0 & 0 & -0.838 & 0 & 0 \\ 0 & 0.021 & 0 & 0 & 0.543 & 0 & 0 & 0.839 & 0 \\ 0 & 0 & 0.019 & 0 & 0 & 0.543 & 0 & 0 & 0.839 \end{pmatrix}$$

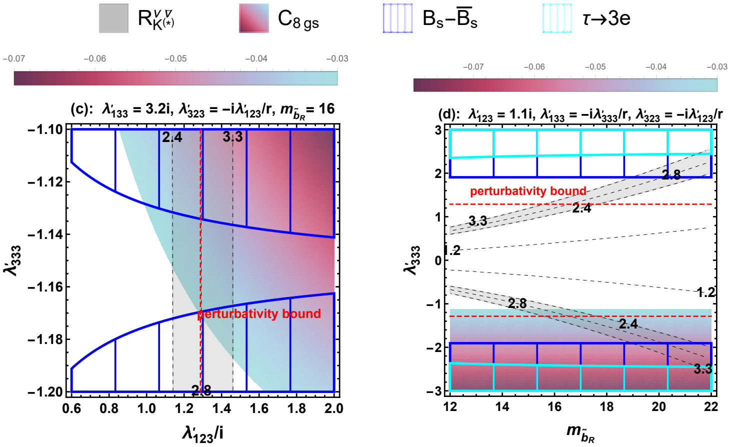
sneutrinos with
$\{854, 854, 854, 1010, 1000, 1000, 1389, 1388, 1388\}$ GeV

Puzzle explanation



The masses $m_{\tilde{b}_R}$ are given in units of TeV. The red dashed lines express the perturbativity limit, i.e. $\lambda' \leqslant \sqrt{4\pi}$. $r = 0.363$

Puzzle explanation



The masses $m_{\tilde{b}_R}$ are given in units of TeV. The red dashed lines express the perturbativity limit, i.e. $\lambda' \leqslant \sqrt{4\pi}$. $r = 0.363$

Benchmark Points

$m_{\tilde{b}_R}$	λ'_{123}	λ'_{133}	λ'_{323}	λ'_{333}	$C_{8gs}^{\rm NP}$	$L_{K\bar{K}}$	$L_{K^*\bar{K}^*}$	$\mathcal{B}_{VP}\times 10^5$
13 TeV	$1.1i$	$2.3i$	3.05	-0.81	-0.083	23.63	15.87	0.80
15 TeV	$1.15i$	$2.8i$	3.18	-1	-0.103	23.08	15.06	0.79
16 TeV	$1.15i$	$3.2i$	3.18	-1.14	-0.118	22.66	14.46	0.78

Here $\mathcal{B}_{VP}$ is the untagged branching ratio $\mathcal{B}(\bar{B}_s \to K^{*0}\bar{K}^0 + c.c.)$

For $m_{\tilde{b}_R}$ is 10 TeV:

$$C_{8gs}^{\rm NP} = 0.028\lambda'^{*}_{123}\lambda'^{*}_{133} + 0.004\lambda'^{*}_{323}\lambda'^{*}_{333} - 0.061\lambda'^{*}_{123}\lambda'_{133} - 0.062\lambda'^{*}_{323}\lambda'_{333}$$

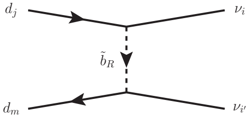
$$\mathcal{R}_{B_s} \approx \left|1 - 160.29\lambda'^{*2}_{123} - 20.91\lambda'^{*2}_{323} + 9\left(\lambda'^{*}_{123}\lambda'_{133} + \lambda'^{*}_{323}\lambda'_{333}\right)^2\right|$$

Conclusions

- RPV-MSSMIS framework connects the trilinear interaction $\lambda' \hat{L}\hat{Q}\hat{D}$ with the (s)neutrino chirality flip to make the unique contribution to $L_{K^{(*)}\bar{K}^{(*)}}$, through the gluon-penguin diagrams. The chiral-flip effects are expressed as the double-λ' terms in the Wilson coefficient $C_{8gs,d}^{\rm NP}$, which can be enhanced by the logarithm and make the related deviation explained.

- In the $B_s - \bar{B}_s$ mixing, there also exist chiral-flip contributions, and to fulfil the strict bound of experimental data, the scenario of imaginary λ'_{123}, λ'_{133} with real λ'_{323}, λ'_{333} is adopted.

Backup



$$\mathcal{L}_{\text{eff}}^{dd\nu\bar{\nu}} = (C_{mj}^{\text{SM}}\delta_{ii'} + C_{mj}^{\text{NP}})(\bar{d}_m\gamma_\mu P_L d_j)(\bar{\nu}_i\gamma^\mu P_L \nu_{i'}) + C_{mj}^{\text{1SRR}}(\bar{d}_m P_R d_j)(\bar{\nu}_i P_R \nu_{i'}) + C_{mj}^{\text{2SRR}}(\bar{d}_m \sigma_{\mu\nu} P_R d_j)(\bar{\nu}_i \sigma^{\mu\nu} P_R \nu_{i'}) + \text{h.c.}$$

$$C_{mj}^{\text{NP}} = \frac{\lambda'^{\mathcal{N}}_{i'j3}\lambda'^{\mathcal{N}*}_{im3}}{2m^2_{\tilde{b}_R}} = \frac{\mathcal{V}_{i'\alpha'}\mathcal{V}^*_{i\alpha}\lambda'_{\alpha'j3}\lambda'^*_{\alpha m3}}{2m^2_{\tilde{b}_R}}$$

New Belle II result induces that

$$\frac{\mathcal{B}(b\to s\nu\bar{\nu})}{\mathcal{B}(b\to s\nu\bar{\nu})_{\text{SM}}} = \frac{\sum_{i=1}^{3}\left|C_{23}^{\text{SM}} + C_{23}^{\text{NP}}\right|^2 + \sum_{i\neq i'}^{3}\left|C_{23}^{\text{NP}}\right|^2}{3\left|C_{23}^{\text{SM}}\right|^2} < 3.3$$

at 2σ level

Backup

$b \to se\tau$:

$$\Delta C_{9e\tau}^{4\lambda'} = -\Delta C_{10e\tau}^{4\lambda'} = -\frac{\sqrt{2}\pi^2 i}{2G_F\eta_t e^2}\Big(\tilde{\lambda}'_{1i3}\tilde{\lambda}'^{*}_{3i3}\lambda'^{\mathcal{N}}_{v33}\lambda'^{\mathcal{N}*}_{v23}D_2[m_{\nu_v}, m_{u_i}, m_{\tilde{b}_R}, m_{\tilde{b}_R}] + \tilde{\lambda}'_{1i3}\tilde{\lambda}'^{*}_{3i3}\lambda'^{\mathcal{I}}_{v33}\lambda'^{\mathcal{I}*}_{v23}D_2[m_{\tilde{\nu}^{\mathcal{I}}_v}, m_{\tilde{u}_{Li}}, m_b, m_b]\Big).$$

Extra imaginary part in $B_s - \bar{B}_s$ mixing: $\Lambda'^{\mathcal{N}}_{vv'}D_2[m_{\nu_v}, m_{\nu_{v'}}, m_{\tilde{b}_R}, m_{\tilde{b}_R}]$

Z boson partical decay: $\mathrm{Im}\,(\lambda'^{*}_{iJ3}\lambda'_{iJ'3}/\lambda'^{*}_{1J3}\lambda'_{1J'3})$

eEDM: $[(\cos^2\beta_{\lambda'_{1jk}} - \sin^2\beta_{\lambda'_{1jk}})\sin\alpha_{A_d} + \cos\beta_{\lambda'_{1jk}}\sin\beta_{\lambda'_{1jk}}\cos\alpha_{A_d})]|\lambda'_{1jk}|^2$