$B \to K^{(*)}\nu\bar{\nu}$ decays in the Standard Model and beyond

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in collaboration with A. Buras, J. Girrbach-Noe and D. Straub

based on 1409.4557

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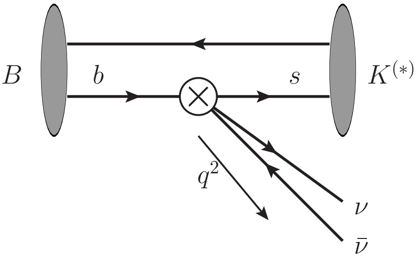
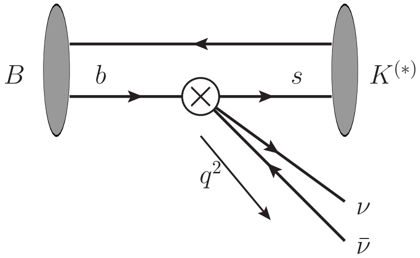
- New measurements on $B \to K^{(*)}\ell^+\ell^-$ allow to put strong constraints
- Hopefully, these decays will be accessible within the next few years

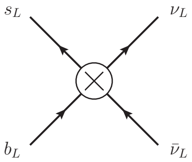
1. SM predictions
2. Model independent constraints
   - General remarks
   - Correlations with $B \to K^{(*)}\ell^+\ell^-$ decays
   - Beyond lepton flavour universality
3. Specific models
   - Z' models
   - Partial compositeness
   - MSSM
   - Leptoquarks
4. Conclusion



B
b
s
$K^{(*)}$
q^2
ν
$\bar{\nu}$



In the SM only one eff. operator contributes to $b \to s\nu\bar{\nu}$ transitions:



$$\mathcal{H}_{\text{eff}}^{\text{SM}} \propto C_L^{\text{SM}} \mathcal{O}_L + \text{h.c.}$$
$$\propto C_L^{\text{SM}} (\bar{s}\gamma_\mu P_L b)(\bar{\nu}\gamma^\mu P_L \nu) + \text{h.c.}$$

Since the ν's are invisible there are only three observables:

$$\frac{d\mathrm{BR}(B^+ \to K^+ \nu\bar{\nu})_{\mathrm{SM}}}{dq^2} = \tau_{B^+} 3|N|^2 \, [C_L^{\mathrm{SM}}]^2 \, \rho_K(q^2)$$

$$\frac{d\mathrm{BR}(B^0 \to K^{*0} \nu\bar{\nu})_{\mathrm{SM}}}{dq^2} = \tau_{B^0} 3|N|^2 \, [C_L^{\mathrm{SM}}]^2 \, \left[\rho_{A_1}(q^2) + \rho_{A_{12}}(q^2) + \rho_V(q^2)\right]$$

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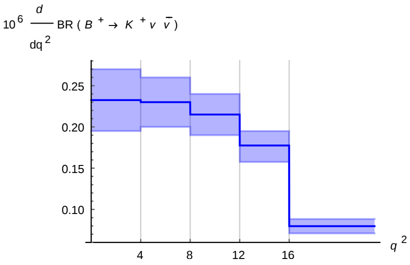
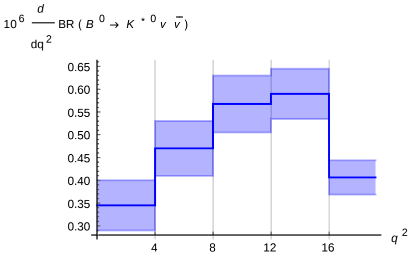
So, we have to control:

- Wilson coefficient C_L^{SM}
  $\to$ two-loop electroweak contributions (1009.0947)
- hadronic form factors $\rho(q^2)$
  $\to$ combined fit to LCSR and lattice results (Bharucha, Straub, Zwicky in prep.)

updated SM predictions





$BR(B^+ \to K^+\nu\bar{\nu})_{SM} =$
$(3.98 \pm 0.43 \pm 0.19) \times 10^{-6}$
$< 1.7 \times 10^{-5}$ (BaBar)

$BR(B^0 \to K^{*0}\nu\bar{\nu})_{SM} =$
$(9.19 \pm 0.86 \pm 0.50) \times 10^{-6}$
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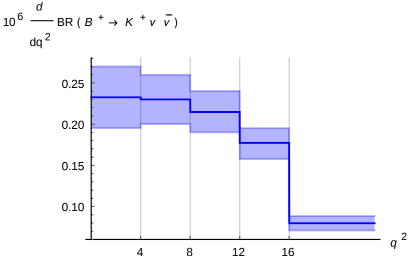

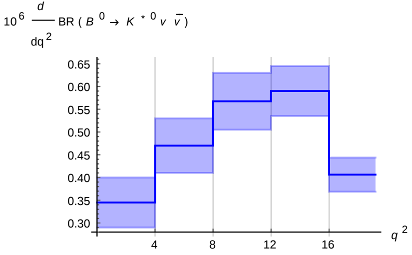

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We still need a factor of ~ 5 in experimental precision!

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General remarks

Beyond the SM, a second eff. operator can contribute (right-handed currents!):

$$\mathcal{H}_{\text{eff}} \propto C_L \mathcal{O}_L + C_R \mathcal{O}_R \ + \ \text{h.c.}\,,$$

$$\mathcal{O}_L \propto (\bar{s}\gamma_\mu P_L b)(\bar{\nu}\gamma^\mu P_L \nu)$$

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Reparametrize Wilson coefficients:

$$\epsilon = \frac{\sqrt{|C_L|^2 + |C_R|^2}}{|C_L^{\text{SM}}|}, \qquad \eta = \frac{-\text{Re}\,(C_L C_R^*)}{|C_L|^2 + |C_R|^2}$$

> 0

$\in [-\frac{1}{2}, \frac{1}{2}]$

$\neq 0$ only for right-handed currents!

Totally model-independent:

$$\mathcal{R}_K \equiv \frac{\mathrm{BR}(\to K)}{\mathrm{BR}(\to K)^{\mathrm{SM}}} = (1-2\,\eta)\epsilon^2, \quad \mathcal{R}_{K^*} \equiv \frac{\mathrm{BR}(\to K^*)}{\mathrm{BR}(\to K^*)^{\mathrm{SM}}} = (1+1.34\eta)\epsilon^2,$$

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$\Rightarrow$ new invisible particles in final state!

Correlations with $B \to K^{(*)}\ell^+\ell^-$ decays

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Use most general $\mathcal{G}_{\mathrm{SM}}$-invariant basis of dim6-operators. (1008.4884)

$$Q_{Hq}^{(1)} = \mathrm{i}(\bar{q}_L\gamma_\mu q_L)H^\dagger D^\mu H\,, \qquad Q_{ql}^{(1)} = (\bar{q}_L\gamma_\mu q_L)(\bar{l}_L\gamma^\mu l_L)\,,$$

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So, one finds a dictionary:

$$C_L = C_L^{\rm SM} + \widetilde{c}_{ql}^{(1)} - \widetilde{c}_{ql}^{(3)} + \widetilde{c}_Z\,, \qquad C_R = \widetilde{c}_{dl} + \widetilde{c}'_Z\,,$$
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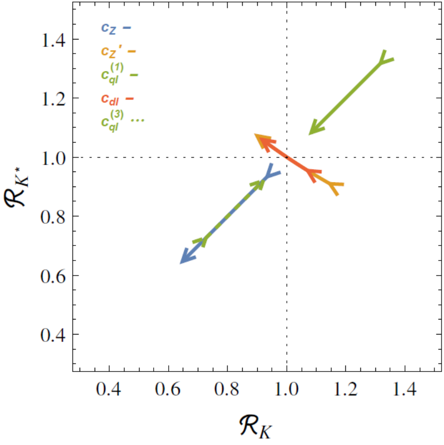
- Consider only certain scenarios of NP where only a subset of operators is active.

Individual Wilson Coefficients



2σ-constraints on individual operators

Current $b \to s\ell^+\ell^-$ data favour:

- If NP in $c_{ql}^{(1)}$: Enhancement up to $\sim 30\%$
- IF NP in c_Z (left-handed Z-penguins) or $c_{ql}^{(3)}$: suppression up to $\sim 40\%$
- If NP in right-handed currents (c_Z'): modification up to $\pm 10\%$

Non-agreement with SM due to tensions in $b \to s\mu^+\mu^-$ angular observables.

Two different scenarios

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NP dominated by:

- Modified (flavour changing) Z-couplings [e.g. MSSM, partial compositeness]

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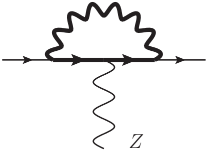

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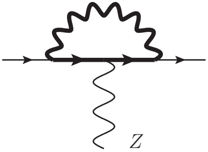

- 4-Fermion-Operators [e.g. exchange of heavy Z' boson]

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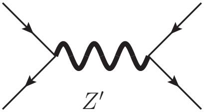

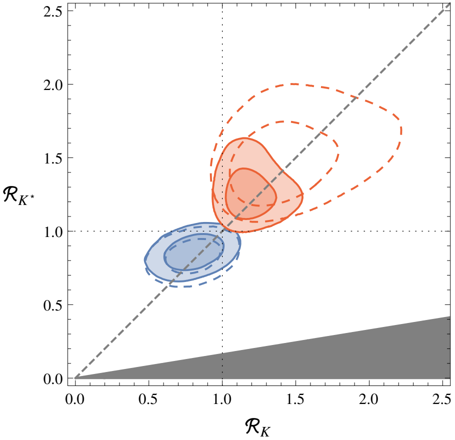

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solid: real
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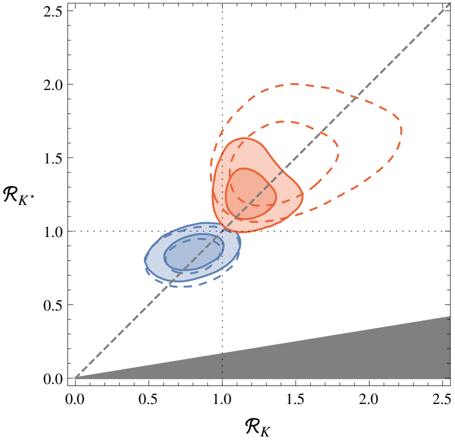

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Correlations between $\mathcal{R}_K$ and $\mathcal{R}_{K^*}$ allow to disentangle both scenarios, if tension in $b \to s\ell^+\ell^-$ stays.

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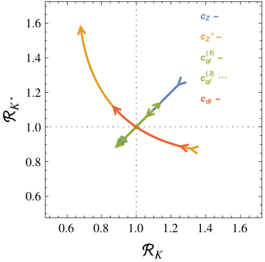

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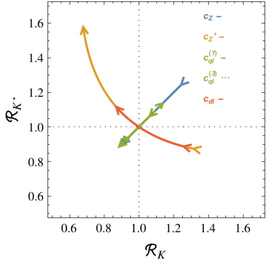

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1. SM predictions
2. Model independent constraints
   - General remarks
   - Correlations with $B \to K^{(*)}\ell^+\ell^-$ decays
   - Beyond lepton flavour universality
3. Specific models
   - Z' models
   - Partial compositeness
   - MSSM
   - Leptoquarks
4. Conclusion

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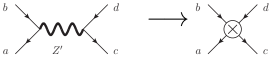

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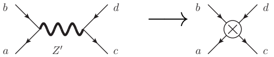

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- LEP2 searches for contact interaction
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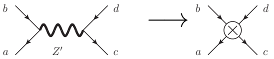

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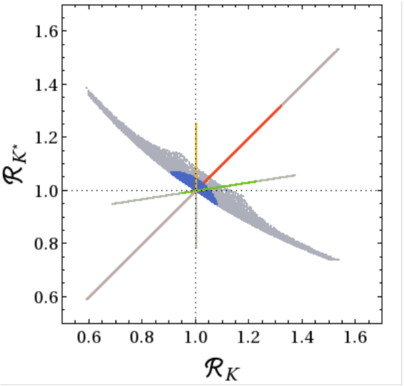

red: $\Delta_\mathrm{L}^{q_i q_j}$, ~~$\Delta_\mathrm{R}^{q_i q_j}$~~

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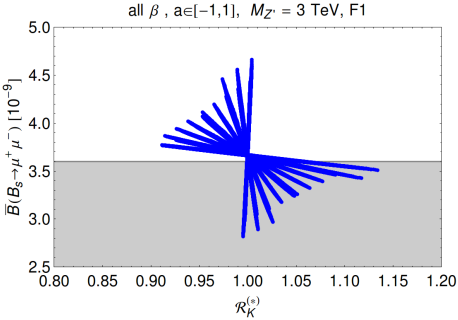

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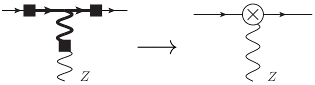

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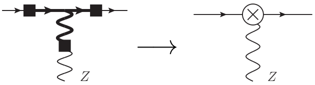

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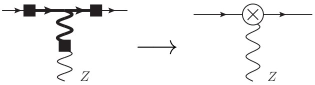

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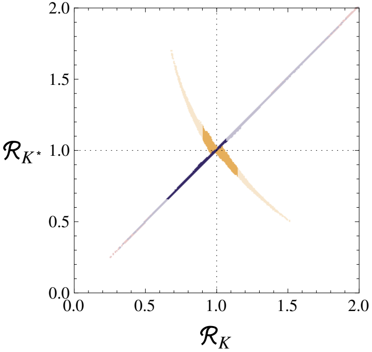

blue: Quarks in bidoublet repr
orange: Quarks in triplet repr

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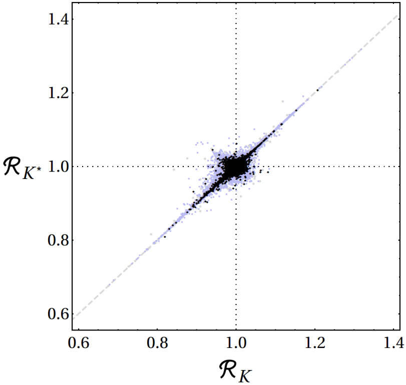

black points: correct Higgs mass

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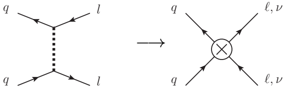

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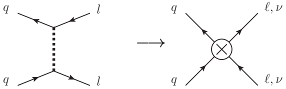

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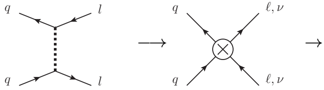

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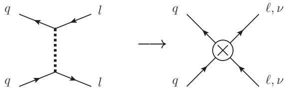

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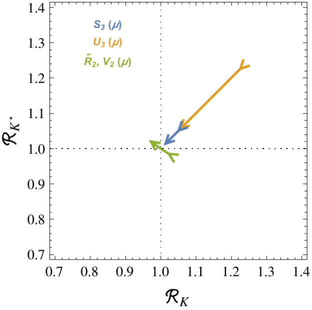

constraint by $b \to s\mu^+\mu^-$

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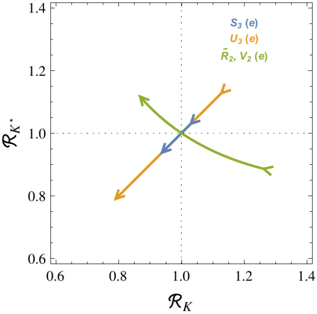

constraint by $b \to se^+e^-$

blue:	$(\bar{\mathbf{3}}, \mathbf{3})_{\frac{1}{3}}$	scalar
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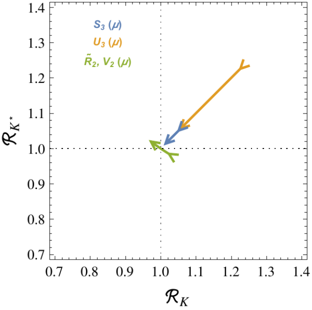

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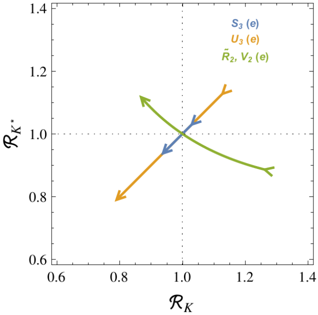

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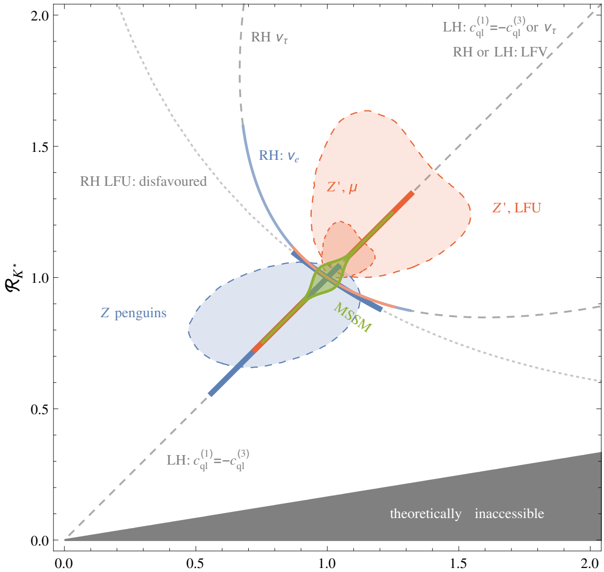
Summary



RH ν_τ
LH: $c_{ql}^{(1)}=-c_{ql}^{(3)}$ or ν_τ
RH or LH: LFV
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Z', μ
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theoretically inaccessible
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0.5
1.0
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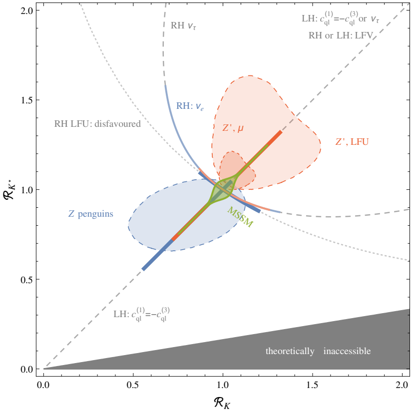

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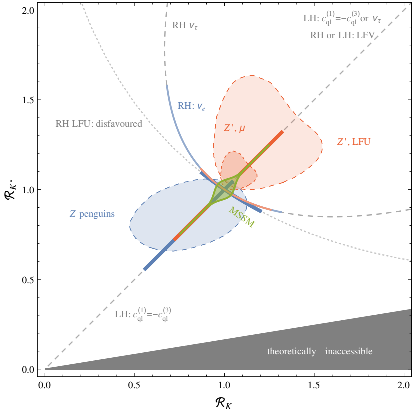

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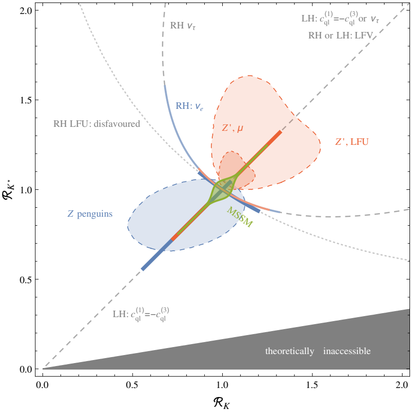

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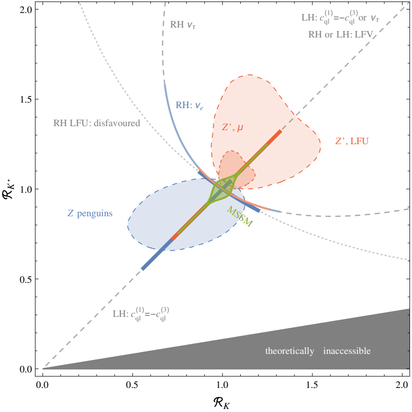

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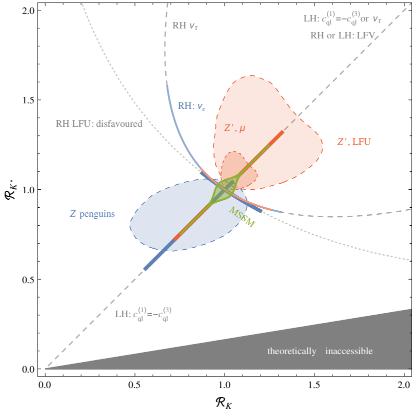

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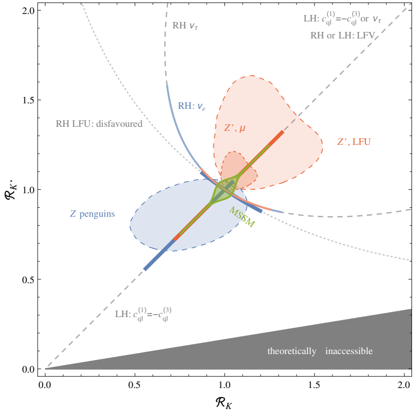

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