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

EPS Vienna

July 24, 2015

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- Recent theory progress allows to get much better SM predictions
- 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

3. Conclusion

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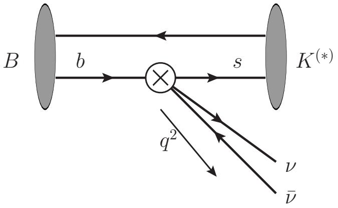
SM calculation



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

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

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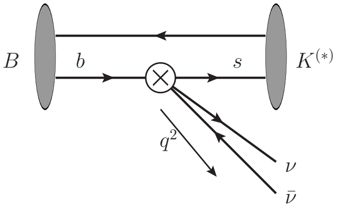

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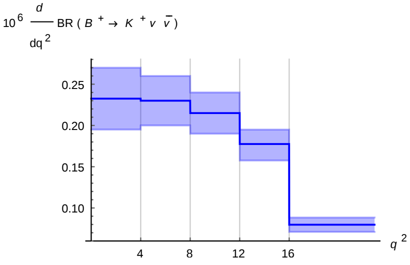
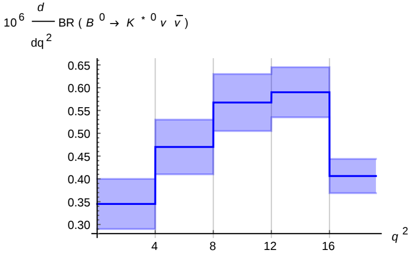
We have to control:

- Wilson coefficient C_L^{SM}
  $\to$ two-loop electroweak contributions (Brod,Gorbahn,Stamou 1009.0947)
- hadronic form factors $\rho(q^2)$
  $\to$ combined fit to LCSR and lattice results (Bharucha,Straub,Zwicky 1503.05534)]

updated SM predictions





$\mathrm{BR}(B^+ \to K^+\nu\bar{\nu})_{\mathrm{SM}} =$

$(3.98 \pm 0.43 \pm 0.19) \times 10^{-6}$

$< 1.7 \times 10^{-5}$ (BaBar)

$\mathrm{BR}(B^0 \to K^{*0}\nu\bar{\nu})_{\mathrm{SM}} =$

$(9.19 \pm 0.86 \pm 0.50) \times 10^{-6}$

$< 5.5 \times 10^{-5}$ (Belle)

$F_L^{\mathrm{SM}} =$

0.47 ± 0.03

General remarks

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

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

$$\begin{aligned} \mathcal{O}_L &\propto (\bar{s}\gamma_\mu P_L b)(\bar{\nu}\gamma^\mu P_L \nu) \\ \mathcal{O}_R &\propto (\bar{s}\gamma_\mu P_R b)(\bar{\nu}\gamma^\mu P_L \nu) \end{aligned}$$

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Reparametrize Wilson coefficients:

$$\epsilon = \frac{\sqrt{|C_L|^2 + |C_R|^2}}{|C_L^{\text{SM}}|}$$

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$$\mathcal{R}_{K^*} \equiv \frac{\text{BR}(\to K^*)}{\text{BR}(\to K^*)^{\text{SM}}} = (1 + 1.34\eta)\epsilon^2$$
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Correlations in $\mathcal{R}_K$, $\mathcal{R}_{K^*}$, $\mathcal{R}_{F_L}$

$\Rightarrow$ new invisible particles in final state?

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

Idea: Use $\mathrm{SU(2)_L}$ symmetry to connect $b \to s\nu\bar{\nu}$ decays to $b \to s\ell^+\ell^-$ decays, on which a lot of exp. data exists.

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

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\begin{aligned}
Q_{Hq}^{(1)} &= \mathrm{i}(\bar{q}_L\gamma_\mu q_L)H^\dagger D^\mu H\,, & 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:

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- Consider only certain scenarios of NP where only a subset of operators is active.

Two different scenarios

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NP dominated by:

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

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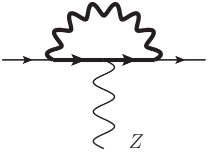

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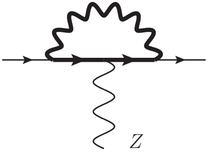

- 4-Fermion-Operators [e.g. exchange of heavy Z' boson]

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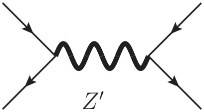
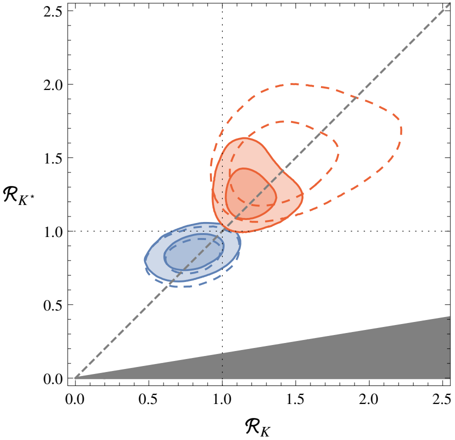


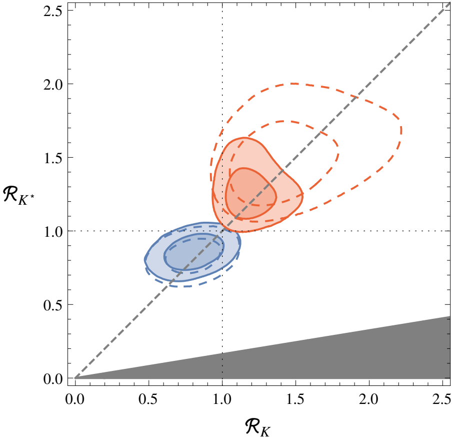


blue: modified Z couplings
red: 4-Fermion operators

solid: real
dashed: complex

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

- Suppression of $\mathcal{R}_{K^{(*)}}$ if NP mainly in modified Z couplings
- Enhancement of $\mathcal{R}_{K^{(*)}}$ if NP mainly in 4-Fermion operators



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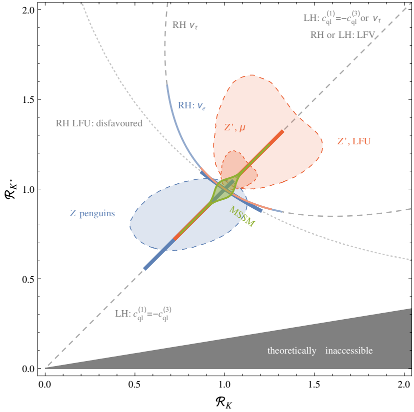
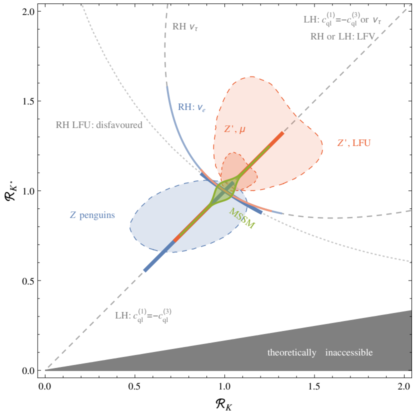
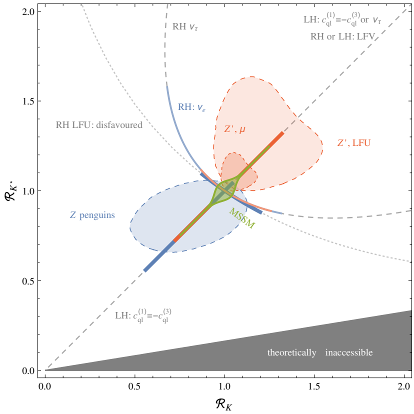
Correlations between $\mathcal{R}_K$ and $\mathcal{R}_{K^*}$ allow to disentangle both scenarios.
Due to tensions in $b \to s\ell^+\ell^-$.


RH ν_τ
LH: $c_{ql}^{(1)}=-c_{ql}^{(3)}$ or ν_τ
RH or LH: LFV
RH: ν_e
RH LFU: disfavoured
Z', μ
Z', LFU
Z penguins
MSSM
LH: $c_{ql}^{(1)}=-c_{ql}^{(3)}$
theoretically inaccessible
$\mathcal{R}_{K^*}$
$\mathcal{R}_K$
0.0
0.5
1.0
1.5
2.0



- $\mathcal{R}_K \neq \mathcal{R}_{K^*}$ problematic for
  - MFV
  - LH Z' couplings
  - certain PC scenarios
  - MSSM
  - $SU(2)_L$ singlet or triplet LQ



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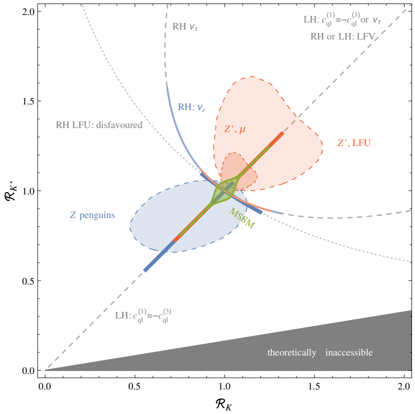

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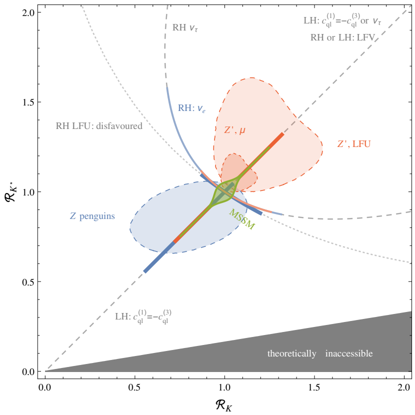

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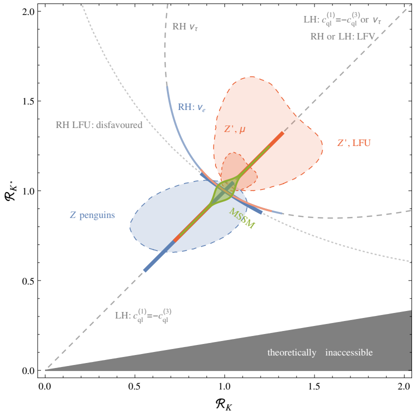

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- otherwise effects max. $\begin{cases} \pm 60\% \text{ LFU} \\ \pm 20\% \text{ only } \mu \end{cases}$

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- Correlations between $B \to K\nu\bar{\nu}$ and $B \to K^*\nu\bar{\nu}$ (and also $B \to K^{(*)}\ell\ell$ and $B_s \to \ell\ell$) can help to identify possible NP scenarios