Constraints on non-standard \( b \to s Z^0 \) couplings

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work in progress...
Starting point

Hint of a disagreement in $\sin 2\beta$ measurements between charmonium modes and s-penguins modes (beware of theoretical uncertainties)

- Maybe the sign of this long waited new physics
- What is the nature?

We investigate a class of models which may affect $b \rightarrow s\bar{q}q$ transitions

- Corrections?
- Which constraints on non-standard couplings may be given?
- Extension to $B_s$ sector?
Which kind of new physics?

A quite general scenario: Non-standard FCNC process in $b \rightarrow s q q$ transitions


- Mediated by a $Z^0$ exchange
  - non-standard $sZb$ coupling
  - standard $Zq\bar{q}$ coupling ($Z_V \bar{q} \gamma_\mu q + Z_A \bar{q} \gamma_\mu \gamma^5 q$)

- May arise from theory including exotic down-type heavy quarks

- Lagrangian of the non-standard $sZb$ coupling may be written as

$$\mathcal{L}_Z = \frac{g}{2\cos\theta_W} \left( \bar{b}_L \gamma_\mu s_L U_{sb}^L + \bar{b}_R \gamma_\mu s_R U_{sb}^R \right) Z^\mu + h.c$$

- Gives correlation between modes if the model is consistent (same non-standard $sZb$ coupling)
Effects in $B_d \rightarrow K_S(q\bar{q})$

For each decay amplitude, we propose the following parametrisation ($V_{ub}V_{us}^* \rightarrow 0$)

$$\mathcal{A}(MK_S) = V_{tb}V_{ts}^* T_{SM} + U_{sb}^L P_Z^L + U_{sb}^R P_Z^R$$

$$\overline{\mathcal{A}}(MK_S) = V_{tb}V_{ts}^* T_{SM} + U_{sb}^L P_Z^L + U_{sb}^R P_Z^R$$

It follows an exact relation between observables and non-standard coupling strengths for each mode (example given with $U_{sb}^R = 0$)

$$|U_{sb}^L|^2 \sin^2 \phi_Z = \Delta_{MK_S} \frac{BR(MK_S)}{|P_Z(MK_S)|^2} \frac{1}{(p_M/8\pi m_{B_d}^2 \Gamma_{B_d})}$$

- with $\Delta_{MK_S} \equiv \frac{1}{2} \left[ 1 - \sqrt{1 - C_{MK_S}^2} \cos 2\beta_{MK_S} \right]$ and $\Delta_{MK_S} \rightarrow 0$ when $\Delta\beta_{MK_S} \rightarrow 0$
- $P_Z(MK_S)$ is estimated using factorization hypothesis
- same relation exists at leading order with $|U_{sb}^L + U_{sb}^R|$ coupling strength involved
Non standard amplitude $P_Z$ estimation

Factorization formalism is used

\[ \mathcal{H}_{\text{eff}}^{Z} = -\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=1,7,8,9} (C_i^Z O_i + C_i^Z' O_i') \]

- Only Wilson coefficients are assumed affected by new physics
- At tree level, Z-penguin contribution take the form

\[ P_Z = \frac{G_F}{\sqrt{2}} [\overline{s}U_{sb}^L \gamma_\mu (1 - \gamma_5)b + \overline{s}U_{sb}^R \gamma_\mu (1 + \gamma_5)b][\overline{q} \gamma_\mu (Z_V + \gamma_5 Z_A)q] \]

- corresponding to the diagrams

We compute this for 6 modes: $\phi K_S, J/\psi K_S, \eta' K_S, \pi^0 K_S, \omega K_S, \rho^0 K_S$
We estimate non-standard $P_Z$ amplitude with naive factorization method

- Dominant in $\frac{1}{N_c}$, Wilson coefficients combination is stable between $Z$ scale and $b$ scale
- Dominant in $\frac{1}{m_b}$ for heavy to light transitions

Standard amplitude $T_{SM}$ is not estimated with factorization method

- Subdominant amplitude; penguin ($\phi K_S$) or color-suppressed ($J/\psi K_S, \pi^0 K_S...$)
- Numerically unstable; scale dependance of $C_W(\mu)$
- We use branching ratio instead, theoretical error is replaced by experimental error
Order of magnitude of $S_{MKs}$ at leading order

We take inclusive constraint on $U_{sb}$ in input for each mode

- Derived from BELLE data (ICHEP'04): $BR(B \rightarrow X_s l^+ l^-) = [4.11 \pm 0.83^{+0.74}_{-0.70}] \times 10^{-6}$, it follows $|U_{sb}^L + U_{sb}^R| \leq 1.4 \times 10^{-3}$

We define $U_{sb}^{eff} \equiv U_{sb}^L \sin \phi^L_Z + U_{sb}^R \sin \phi^R_Z$, so correlation relation becomes at leading order in factorization

$|U_{sb}^{eff}|^2 = \Delta_{MKs} \frac{BR(MKs)}{|P_Z(MKs)|^2} \frac{1}{(p_M/8\pi m_{Bd}^2 \Gamma_{Bd})}$

$S_{MKs}$ is obtained by scanning $U_{sb}^{eff}$ and $\beta_{SM}$ parameters

Other parameters ($BR$, Form factor,...) are fixed to their nominal value


**$S_{MKs}$ with Z-penguin contributions**

Input: Only inclusive bound on $U_{sb}^{\text{eff}}$

$S_{MKs}$ is computed, range of variation comes from $\beta_{SM}$ and $U_{sb}^{\text{eff}}|_{\text{incl}}$

<table>
<thead>
<tr>
<th>modes</th>
<th>$S_{MKs}$</th>
<th>$\phi_{K_s}$ 0.55 ± 0.27 (±0.18 $\beta_{SM}$ fixed ±0.08 $U_{sb}^{\text{eff}} = 0$)</th>
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Modes with bigger range are the most sensible to $U_{sb}$ and $P_Z$

A more global analysis is needed and will use correlation between all modes, we expect then stronger constraints on $S_{MKs}$
Global fit using correlation between modes

We want to predict $S_{MKs}$ for each mode with all other modes $M'Ks$ ($M \neq M'$) as input.

- Observables are $BR$, $S$, $C$ and only $BR$, $C$ for the mode we are looking at.
- In fact, each mode gives a constraint on $U_{sb}$ which is then used in the mode we want to predict the asymmetry.
- Factorization at leading order gives an exact correlation between modes with a single combination of right and left non-standard couplings involved; but $\frac{1}{N_c}$ corrections break these relations and left/right part must be estimated separately.
Corrections on $U_{sb}^{L}(U_{sb}^{R})$ constraints

Two main sources of corrections:

- $V_{ub}V_{us}^{*}$ correction estimated from dimensional arguments
  - improves CL @ $U_{sb} = 0$ (SM agreement with data)
  - see talk of M.Beneke: if $\Delta S_{SM}$ goes in the positive direction, the lower limit on $U_{sb}$ is conservative and conversely

- Factorization corrections
  - $\frac{1}{N_{c}}$ corrections to factorization
  - form factor error coming from $q^{2}$ parametrisation using lattice results (D.Becirevic, hep-ph/0211340)
  - modifies $CL(U_{sb})$ shape

We are still working on this global fit due to technical difficulties
Conclusion and prospects

A quite general scenario of NP is explored in various modes

- It gives correlations between modes at leading order in factorization
- Global fit for $S_{MK_S}$ computation is possible and on the way
- Analysis will include $B_s\bar{B}_s$ mixing

BUT

- $\frac{1}{N_c}$ corrections of factorization break the correlation; constraints on left and right non-standard couplings have to be given separately
- Global fit for $S_{MK_S}$ is technically difficult due to the number of parameters involved in the analysis