Z penguins & rare B decays

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Work done in collaboration with
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- FCNC Z penguins & low–energy SUSY
- Experimental bounds on the Zbs vertex
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- Conclusions

• Introduction

Flavour Changing Neutral Currents provide a powerful tool to search for physics beyond the Standard Model:

- No tree–level contributions within the SM
- Possible non–decoupling effects (= sizable deviations from the SM expectations even for $M_X \gg M_W$)

Basic types of FCNC amplitudes relevant to $b \to s\, l^+ l^-\, (\nu\bar{\nu})$:

A) Dim.–6 operators $\boxed{(\bar{b}\,\Gamma\, s)(\bar{l}\,\Gamma\, l)}$

Stong link ($\Rightarrow$ constraints) from ΔB=2 processes in most scenarios (i.e. when generated by box diagrams)

$$\text{SM} \Rightarrow \sim \frac{V_{ts}^* V_{tb}}{M_W^2} (\bar{b}_L \gamma_\mu s_L)(\bar{l}_L \gamma^\mu l_L)$$

$$\xrightarrow[\text{Physics}]{\text{New}} \sim \delta^X_{bs}/M_X^2 \quad \text{fast decoupling}$$

B) Magnetic operators $\boxed{(\bar{b}\,\sigma_{\mu\nu}\, s) F^{\mu\nu}}$

Stong direct constraints from $b \to s\gamma$ in any model

$$\text{SM} \Rightarrow \sim \frac{y_b V_{ts}^* V_{tb}}{M_W} (\bar{b}_R \sigma_{\mu\nu} s_L) F^{\mu\nu}$$

$(y_a = m_a/M_W)$ $\longrightarrow \sim \lambda^X_{bs}/M_X$ potential slow decoupling

C) FCNC Z couplings $\boxed{(\bar{b}\,\gamma_\mu\, s) Z^\mu}$

Not very constrained by exp. data at present !

$$\text{SM} \Rightarrow \sim (y_t^2 V_{ts}^* V_{tb})\, (\bar{b}_L \gamma_\mu s_L) Z^\mu$$

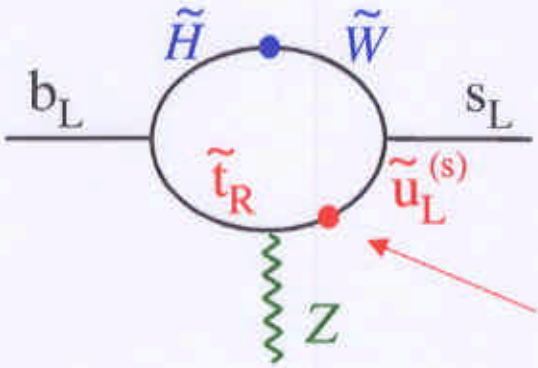
$$\longrightarrow \sim \xi^X_{bs}$$

potential non–decoupling ! (related to $SU(2)_L$ breaking)

• FCNC Z penguins & low–energy SUSY

Model with minimal particle content & generic flavour structure

Potentially dominant effect provided by chargino–stop loops
(large $SU(2)_L$ breaking in the up sector)



2nd order in the mass expansion

Colangelo, Isidori, '98

$$(\delta^U_{LR})_{23} = \frac{(\tilde{M}^2_U)_{s_L t_R}}{\langle \tilde{M}^2_U \rangle}$$

new source of flavor mixing

$$\left|\frac{A^Z_{SUSY}}{A^Z_{SM}}\right| \sim \left(\frac{500\ GeV}{\tilde{M}_\chi}\right)\left|(\delta^U_{LR})_{23}\right|$$

Lunghi *et al.* '99

The indirect bounds on $(\delta^U_{LR})_{23}$ are not very stringent

Best limit from $b\to s\gamma$: $\left|(\delta^U_{LR})_{23}\right| < 3\times\left(\frac{500\ GeV}{\tilde{M}_q}\right)^{-2}$ ← fast decoupling

Misiak, Pokorski, Rosiek '99

$O(1)$ deviations from SM expectations
in the Zbs vertex are possible !

• Experimental bounds on the *Zbs* vertex

General parameterization:

$$\mathscr{L}^{Z}_{FC} = \frac{G_F e^2}{\sqrt{2}\pi^2} M_Z^2 \frac{\cos\vartheta_W}{\sin\vartheta_W} Z^\mu \left(Z^L_{bs}\, \bar{s}_L \gamma_\mu b_L + Z^R_{bs}\, \bar{s}_R \gamma_\mu b_R \right)$$

$$\left(Z^L_{bs}\right)^{(SM)} = V^*_{ts} V_{tb} C_0(x_t) \sim 0.03$$

Possible bounds on Z_{bs} from:

$Z \to bs$	very weak	$\sim O(10)$
B – B mix.	weak	$\sim O(1)$
$b \to s l^+ l^-$	interesting	$\sim O(0.1)$

exclusive measurements

- ⊕ clear exp. signature
- ⊖ sizable th. error related to hadronic form factors

inclusive measurements

- ⊕ th. clean
- ⊖ weak exp. bounds

most stringent bound at present:

$$\mathrm{B}(B \to K^* \mu^+ \mu^-)^{(\mathrm{N.R.})} < 4.0\times10^{-6} \quad \Rightarrow \quad |Z^{L,R}_{bs}| < 0.13$$

[CDF '99]

$$\mathrm{B}(B \to K^* \mu^+ \mu^-)^{(\mathrm{N.R.})}_{SM} = \left(1.9\,^{+0.5}_{-0.3}\right)\times10^{-6}$$

decay mode	BR_{SM}	BR_{max}	BR_{exp}	
$B \to K^* \nu\nu$	$\approx 1.3\times10^{-5}$	$\lesssim 10^{-4}$	$< 7.7\times10^{-4}$	LEP
$B \to K \nu\nu$	$\approx 4\times10^{-6}$	$\lesssim 3\times10^{-5}$	$< 7.7\times10^{-4}$	LEP
$B \to K \mu^+\mu^-$	$\approx 6\times10^{-7}$	$\lesssim 2\times10^{-6}$	$< 5.2\times10^{-6}$	CDF
$B_s \to \mu^+\mu^-$	$\approx 3\times10^{-9}$	$\lesssim 3\times10^{-8}$	$< 2.6\times10^{-6}$	CDF

Enhancements up to ~ 10 possible in the modes where the single–photon exchange amplitude is forbidden

• The lepton FB asymmetry in $B \to K^* l^+ l^-$

An excellent probe of non–standard effects in Z^L_{bs}, including a possible ~~CP~~ phase, is provided by the forward–back asymmetry of the emitted leptons in $B \to K^* l^+ l^-$:

$$A_{FB}^{(B)}(s) = \frac{1}{d\Gamma(B\to K^*\mu^+\mu^-)/ds}\int d\cos\vartheta \frac{d^2\Gamma(B\to K^*\mu^+\mu^-)}{ds\, d\cos\vartheta} sgn(\cos\vartheta)$$

ϑ = angle between μ^+ & B momenta in the dilepton c.o.m. frame

$s = (p_{\mu^+} + p_{\mu^-})^2/m_B^2$

$A_{FB}^{(B)}(s) \neq 0$ $\longleftrightarrow$ interference between Vector and Axial–vector couplings to the lepton pair

$Q_7 \sim (\bar{s}_L \sigma_{\mu\nu} b_L) F^{\mu\nu}$
$Q_9 \sim (\bar{s}_L \gamma^\mu b_L)(\bar{l}\gamma_\mu l)$] Vector coupling (~ insensitive to Z^L_{bs})

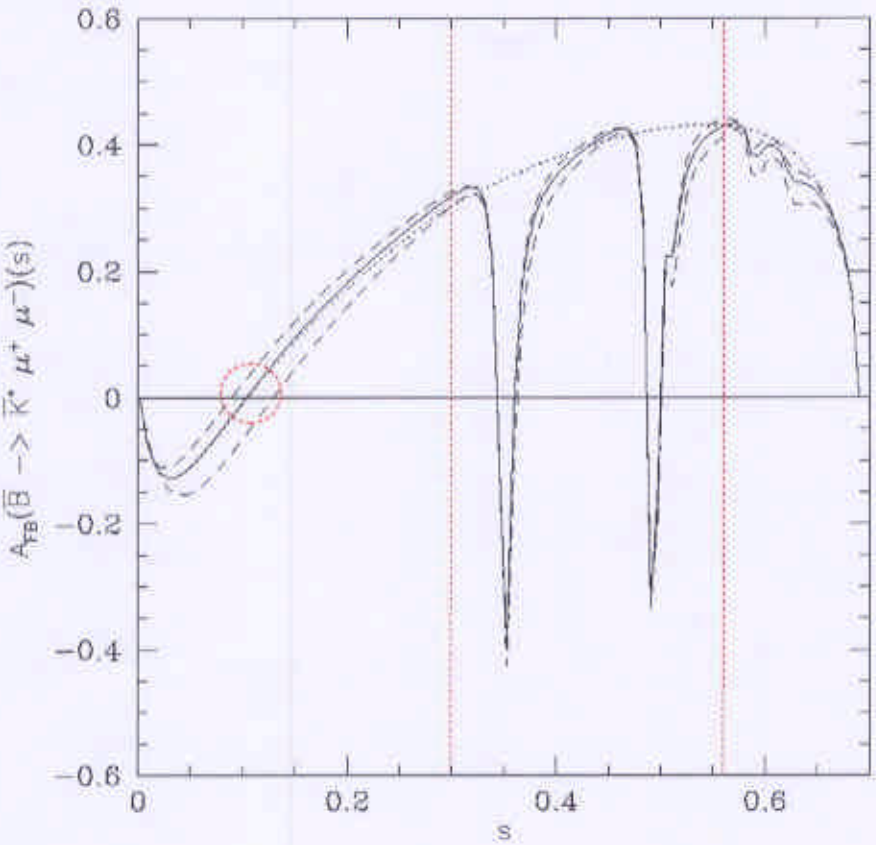
$Q_{10} \sim (\bar{s}_L \gamma^\mu b_L)(\bar{l}\gamma_\mu\gamma_5 l)$ Axial coupling (strongly sensitive to Z^L_{bs})

$$A_{FB}^{(B)}(s) \propto \Re\left[C_{10}^*\left(s\, C_9^{eff}(s) + r(s) C_7\right)\right]$$

Direct access to the relative phases of the Wilson Coefficients

~~CP~~ phase (beyond the SM)

absorptive (CP–cons.) phase due to intermediate $c\bar{c}$ states



$A_{FB}(s)$ within the SM for the $\bar{B} = |b\bar{d}\rangle$ mode

Properties of $A_{FB}(s)$ independent from the detailed structure of the hadronic form factors:

- $A_{FB}(s_0) = 0$ for $s_0 \simeq C_7/C_9$
  (unaffected by new physics in Z_{bs}) — Burdman '98
- $A_{FB}^{(\bar{B})}(s) < 0$ for $s < s_0$ within the SM
- $A_{FB}^{(B)}(s) = - A_{FB}^{(\bar{B})}(s)$ in absence of ~~CP~~ — Buchalla, Hiller & G.I. '00

clear tests of possible new physics effect in Z_{bs}

N.B.: several wrong statements in the literature about the sign of $A_{FB}(s)$!

• Conclusions

The generic New Physics scenario where the largest deviations from the SM, in the sector of FCNC $b \to s$ transitions, occurs via Z –boson exchange is

- theoretically well motivated
- phenomenologically allowed

Possible clear signatures of this scenario already observable within exclusive rare $B \to (K^*, K) + (l^+l^-, \nu\nu)$ decays:

- enhanced BR's
- sign and $\not{CP}$ effects in the lepton FB asymmetry of $B \to K^* \mu^+ \mu^-$