Electroweak penguins in isospin-violating B_s decays

A tool for New Physics searches

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Starting point

- ongoing discussions about signs for New Physics (NP) in $B \to K\pi$ data
- in particular [1]: $\Delta A_{CP} \equiv A_{CP}(B^- \to \pi^0 K^-) - A_{CP}(B^0 \to \pi^+ K^-) \overset{\text{exp.}}{=} (14.8 \pm 2.8)\%$ vs. $\Delta A_{CP} \overset{\text{SM}}{=} 1.9^{+6.0}_{-4.9}\%$
- points to violation of strong-isospin symmetry $\to$ **NP in electroweak penguins?**

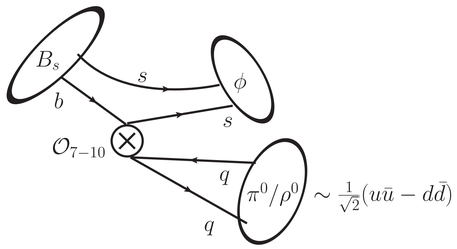
Our idea: Test isospin-violating NP at LHCb and future experiments with purely isospin-violating B decays [3]:

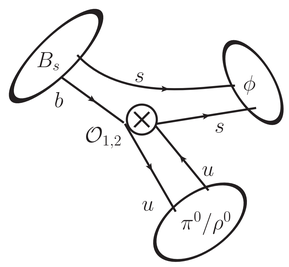
$$B_s \to \phi\rho^0 \text{ and } B_s \to \phi\pi^0$$

Basic analysis of $B_s \to \phi\rho^0, \phi\pi^0$

Consider effective low-energy theory

$$\mathscr{H}_{\text{eff}}^{\Delta B=1} = -\frac{4G_F}{\sqrt{2}} V_{tb}V_{ts}^* \sum_{i=1}^{10} C_i \mathscr{O}_i + h.c.$$





Contributions come from EW-penguin operators

$$\mathscr{O}_{7,9} = \tfrac{3}{2}(\bar{s}_\alpha \gamma_\mu P_L b_\alpha) \sum_q e_q (\bar{q}_\beta \gamma^\mu P_{R,L} q_\beta)$$
$$\mathscr{O}_{8,10} = \tfrac{3}{2}(\bar{s}_\alpha \gamma_\mu P_L b_\beta) \sum_q e_q (\bar{q}_\beta \gamma^\mu P_{R,L} q_\alpha)$$

and current-current operators

$$\mathscr{O}_{1,2} = (\bar{s}_\alpha \gamma_\mu P_L u_{\alpha,\beta})(\bar{u}_{\beta,\alpha} \gamma^\mu P_L b_\beta)$$

- we use *QCD factorization* to obtain operator matrix elements [2]
- in SM: EW penguins dominate, tree-level contribution is CKM- and colour-suppressed, weak annihilation contribution is OZI-suppressed
- main uncertainties come from $B_s \to \phi$ form factor, CKM angle γ and non-factorizeable spectator-scattering amplitudes

SM prediction:

$$\text{BR}(B_s \to \phi\rho^0) = (4.1^{+2.6}_{-1.0}) \cdot 10^{-7}$$
$$\text{BR}(B_s \to \phi\pi^0) = (1.4^{+1.0}_{-0.4}) \cdot 10^{-7}$$

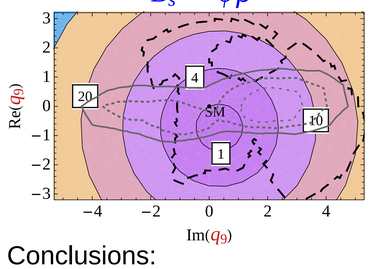
Isospin-violating NP can dramatically change these numbers, making both decay channels promising objects of study for experiments.

Model-independent NP analysis

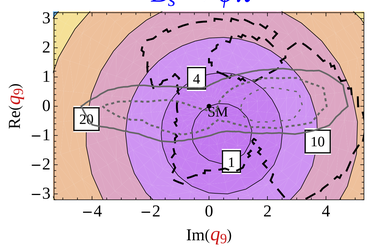
- we assume enhanced Wilson coefficients of $\mathscr{O}_7, \mathscr{O}_9$: $C_9 = C_9^{\text{SM}}(1 + q_9)$, $C_7 = C_7^{\text{SM}} + C_9^{\text{SM}} q_7$
- we calculate the enhancement of $\text{BR}(B_s \to \phi\rho^0)$ and $\text{BR}(B_s \to \phi\pi^0)$ w.r.t. their SM values (*coloured contours*) as a function of the q_i
- for a realistic prediction, we fit the q_i to $B \to K\pi$ data (*grey lines:* $1\sigma, 2\sigma, 3\sigma$) and calculate the 2σ-constraints from other hadronic B decays (allowed regions inside *black dashed lines*)

Example with $q_7 = 0$:

$B_s \to \phi\rho^0$



$B_s \to \phi\pi^0$



Conclusions:

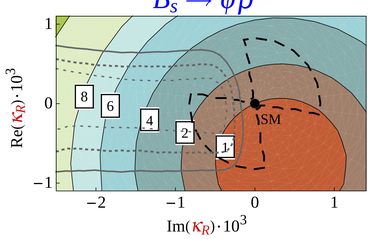
- NP in C_7 or C_9 can enhance both branching fractions by an order of magnitude
  $\to$ visible effect even if theory uncertainty is large
- q_7 and q_9 interfere constructively in $\phi\rho$-mode (two vector mesons), destructively in $\phi\pi$-mode (vector-pseudoscalar)
- similar results if NP creates a right-handed FCNC (contributions to the "mirror" operators $\mathscr{O}_7', \mathscr{O}_9'$)

Model 1: Z-boson FCNC

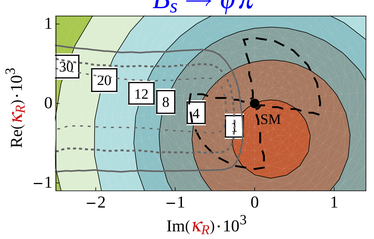
- we assume an effective flavour-violating Z-coupling [4] $\mathscr{L}_{\text{eff}} \supset -\frac{g}{2c_W} \bar{s} (\kappa_L \gamma_\mu P_L + \kappa_R \gamma_\mu P_R) b Z^\mu$
- analysis follows the pattern given above, constraints from $B_s - \overline{B}_s$ mixing and semileptonic B decays (*black*)

Example with $\kappa_L = 0$:

$B_s \to \phi\rho^0$



$B_s \to \phi\pi^0$



Conclusions:

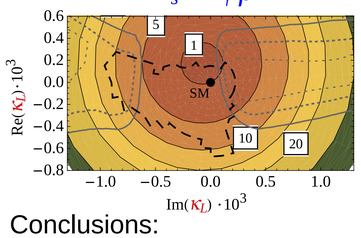
- constraints much tighter than favoured fit regions
- sizeable enhancement of branching fractions disfavoured if NP mainly left-handed
- enhancement up to a factor of 5 with right-handed NP (see plots), destructive interference of κ_L and κ_R for both modes

Model 2: FCNC from a Z' boson

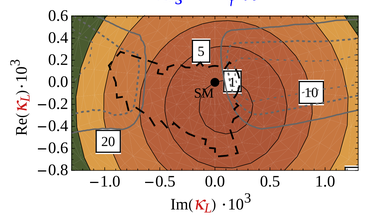
- SM gauge group extended by additional $U(1)'$, a heavy Z'-boson exists
- we assume a flavour-violating Z'-coupling in analogy to the Z coupling in model 1
- main difference: constraints are more model-dependent since $m_{Z'}$ and $U(1)'$-charges of leptons and quarks a priori unknown

Example with $\kappa_R = 0$, constraints only from hadronic B decays:

$B_s \to \phi\rho^0$



$B_s \to \phi\pi^0$



Conclusions:

- enhancement of branching fractions by an order of magnitude a priori possible if NP mainly left-handed (see plots)
- however, depending on $m_{Z'}$ and $U(1)'$-charges, semileptonic and $B_s - \overline{B}_s$ mixing constraints can become very tight
- destructive interference of κ_L and κ_R for both modes

Model 3: MSSM

- within Minimal Flavour Violation: very small SUSY contributions to EW penguins
- non-minimal contributions strongly constrained from data, in particular from $B \to X_s\gamma$
- we find that constraints leave no room for sizeable enhancement of $C_7^{(\prime)}$ and $C_9^{(\prime)}$, thus no large isospin-violation possible

References

[1] S. Baek, D. London, *Is there still a $B \to \pi K$ puzzle?*, Phys.Lett.B653:249-253,2007 ; [2] M. Beneke, M. Neubert, *QCD factorization for $B \to PP$ and $B \to PV$ decays*, Nucl.Phys.B675:333-415,2003; M. Beneke, J. Rohrer, D. Yang, *Branching fractions, polarisation and asymmetries of $B \to VV$ decays*, Nucl.Phys.B774:64-101,2007 ; M. Bartsch, G. Buchalla, C. Kraus, *$B \to V_L V_L$ decays at Next-to-Leading Order in QCD*, arXiv:0810.0249 [hep-ph] ; [3] L. Hofer, D. Scherer, L. Vernazza, *Search for New Physics in Electroweak Penguins via B_s Decays*, Acta Phys.Polon.B3:227-233,2010; [4] Y. Grossman, A. Kagan, M. Neubert, *Trojan penguins and isospin violation in hadronic B decays*, JHEP9910:029,1999;

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