On the recent anomalies in semileptonic B decays

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Abstract

In the LHC era, the discovery of New Physics (NP) signals is the major ambition of the high energy physics community and flavor physics can provide access to new heavy particles (Kaluza-Klein modes, supersymmetric particles ...) in complementary way with respect to direct searches. Signals of possible deviations with respect to the Standard Model (SM) have been recently claimed both by BABAR and LHCb through the analyses of specific semileptonic B meson decays. I'll focus on those decays with a τ lepton in the final state for which new BABAR measurements are available, showing a deviation from the SM at 3.4 σ level. I study the effects of new operators in the effective weak Hamiltonian on a set of observables, in semileptonic $B \to D^{(*)}$ modes as well as in semileptonic B and B_s decays to excited charmed mesons. Moreover, I'll discuss the phenomenology of the semileptonic decay $B \to K^* \mu^+ \mu^-$, in the framework of a warped extra-dimensional scenario. Since a complete set of form-factor independent observables have been recently measured by the LHCb collaboration, with few sizable deviations with respect to the SM in some of them, it'd be interesting to put constraints on NP models from the transition $b \to s\, \ell^+ \ell^-$.

1) Anomalous enhancement in B → $D^{(*)} \tau \nu_\tau$

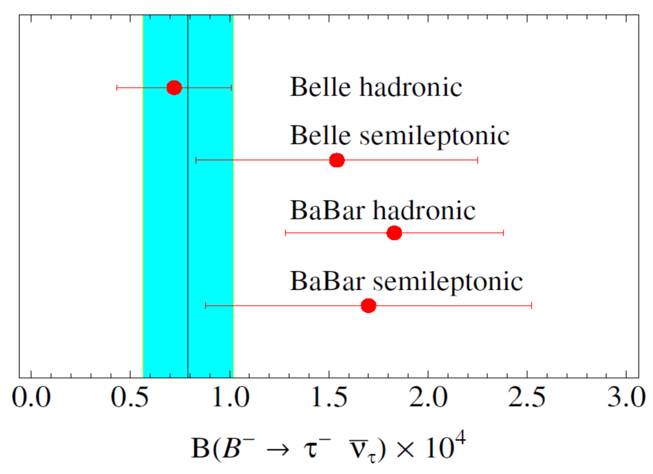
The BABAR Coll. reported the measurements of the ratio:

$$R(D^{(*)}) = \frac{Br(B \to D^{(*)} \ell \nu_\ell)}{Br(B \to D^{(*)} \tau \nu_\tau)}$$

$$R^-(D) = 0.429 \pm 0.082 \pm 0.052$$
$$R^-(D^*) = 0.322 \pm 0.0032 \pm 0.022$$
$$R^0(D^*) = 0.355 \pm 0.0039 \pm 0.021$$
$$R^0(D) = 0.469 \pm 0.084 \pm 0.053$$

- BABAR quotes 3.4 σ deviation from SM
- Is there a possible relation with $B \to \tau \nu_\tau$?

... however new measurements are much more compatible with the SM than the previous ones.



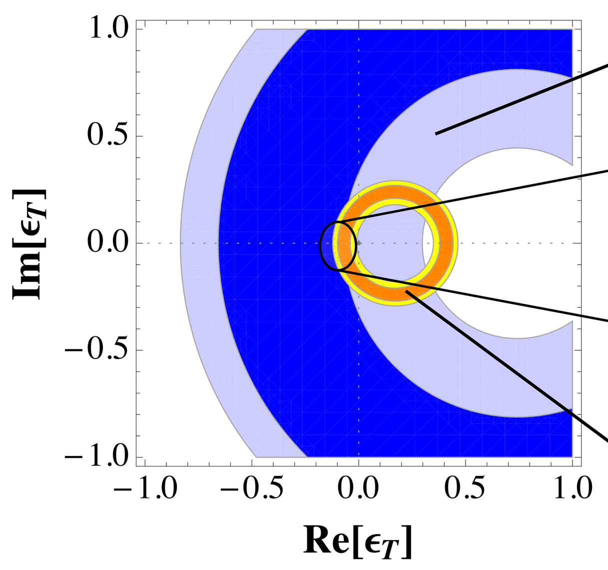
Let us consider a NP scenario in which:
- Only the semileptonic modes are enhanced but not the purely leptonic ones
- Can be tested in similar modes via suitable observables

$$H_{eff} = \frac{G_F}{\sqrt{2}}\left[\bar{c}\gamma_\mu(1-\gamma_5)b\,\bar{\ell}\gamma^\mu(1-\gamma_5)\nu_\ell + \varepsilon_T \bar{c}\sigma_{\mu\nu}(1-\gamma_5)b\,\bar{\ell}\sigma^{\mu\nu}(1-\gamma_5)\nu_\ell\right]$$

New tensorial coupling: $\varepsilon_T = 0$ ($\ell = e, \mu$) while $\varepsilon_T^\tau \equiv \varepsilon_T \neq 0$.

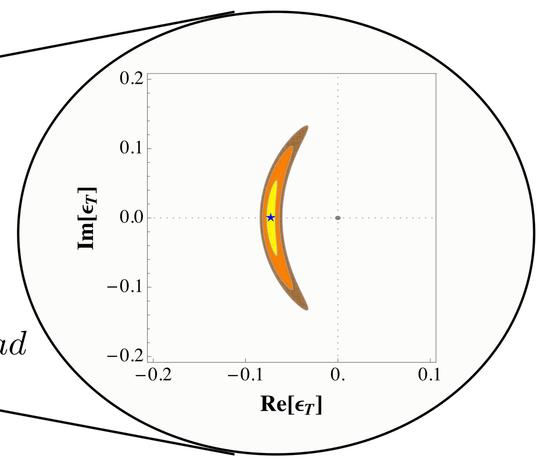
$$\frac{d\Gamma}{dq^2}(B \to M_c \ell \bar\nu_\ell) = C(q^2)\left[\frac{d\tilde\Gamma}{dq^2}\Big|_{SM} + \frac{d\tilde\Gamma}{dq^2}\Big|_{NP} + \frac{d\tilde\Gamma}{dq^2}\Big|_{INT}\right]$$

2) Phenomenology of a new tensorial coupling

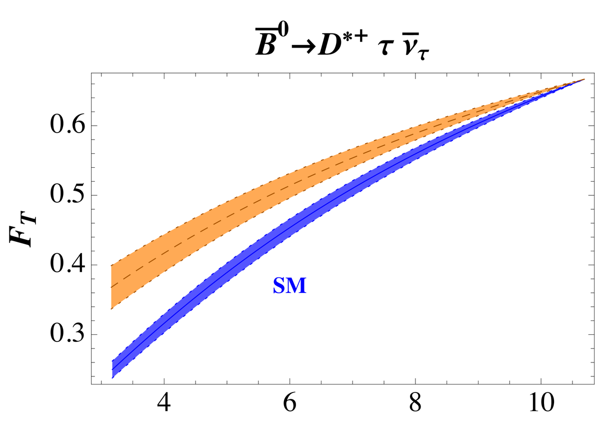


$$\epsilon_T = |a_T| e^{i\theta} + \epsilon_T^0$$

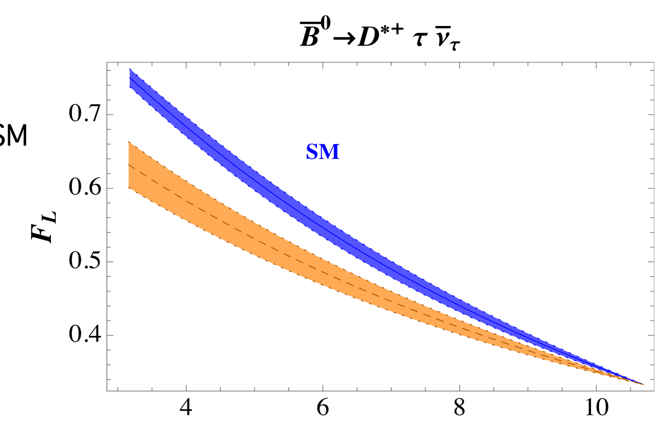
$$\mathrm{Re}[\epsilon_T^0] = 0.17, \quad \mathrm{Im}[\epsilon_T^0] = 0$$
$$|a_T| \in [0.24,\, 0.27]$$
$$\theta \in [2.6,\, 3.7]\, rad$$

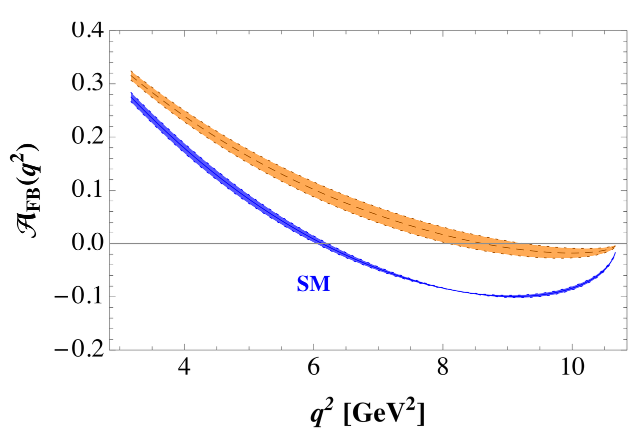


Varying ε_T in this range, predictions for several observables have been obtained

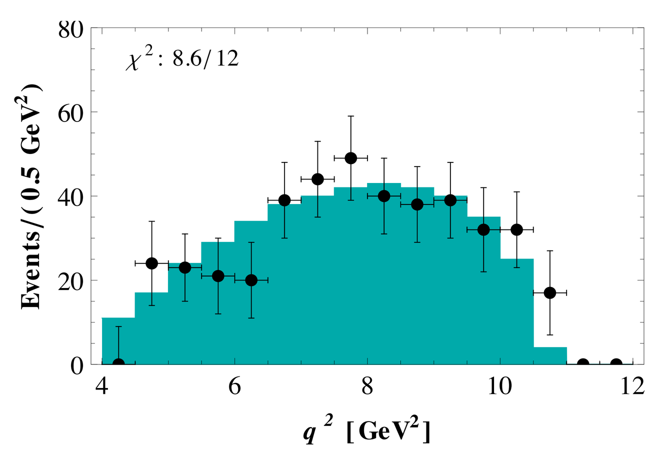


- @small q^2 -> F_L dominant in SM
- @ q^2~6 GeV^2 $F_L \sim F_T$ in the NP scenario

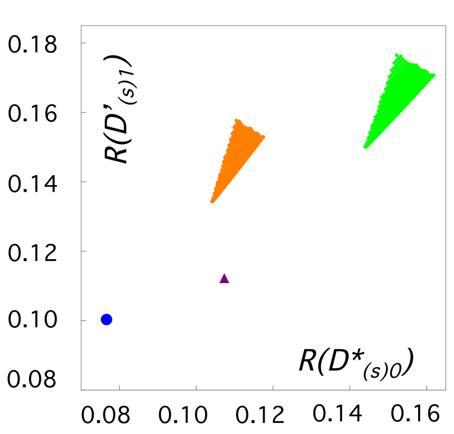




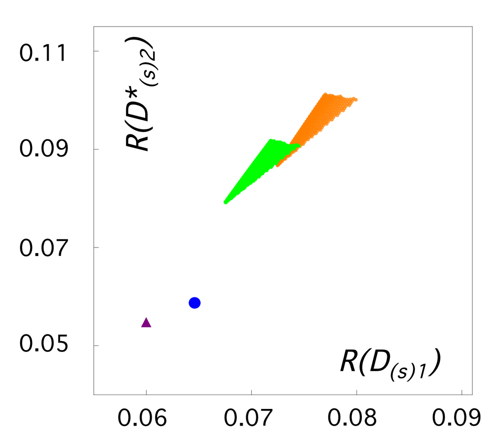
- SM predicts a zero of A_{FB} distrib. @ q^2~6.15 GeV^2
- in NP scenario the zero is shifted to $q^2 \in [8, 9]$ GeV^2
- BABAR differential q^2 decay distributions do not show a significant deviation with respect to SM



3) Predictions for D** states



- modes with strangeness
- modes without strangeness
- SM with strangeness
- SM without strangeness



4) Semileptonic decay B → K* $\ell^+\ell^-$

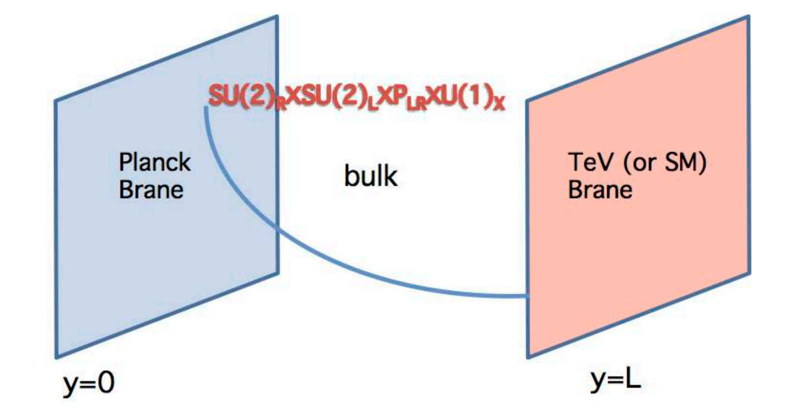
$b \to s\, \ell^+\ell^-$ effective hamiltonian:

$$\mathcal{H}^{eff} = -4\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \Big\{ C_1 \mathcal{O}_1 + C_2 \mathcal{O}_2 + \sum_{i=3,\dots,6} C_i \mathcal{O}_i + \sum_{i=7,\dots,10,P,S} [C_i \mathcal{O}_i + C'_i \mathcal{O}'_i] \Big\}$$

differ for chirality

- Hadronic uncertainties can be softened by using optimized observables
- New oustanding results from LHCb Coll. → a huge set of optimized observables P'_i measured
- Tensions with respect to SM in P'_5 @3.7σ in one q2 bin → a signal of New Physics?

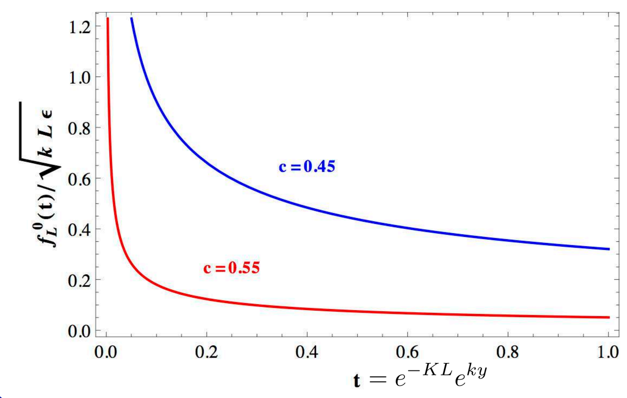
5) Randall-Sundrum model with custodial symmetry (RSc)



$$ds^2 = e^{-2k|y|}\eta_{\mu\nu} dx^\mu dx^\nu - dy^2$$

Planck scale

- All the gauge fields and the fermions are allowed to propagate in the bulk, Higgs field localized on the TeV brane → the EWSB scale depends on a geometric factor, only the Planck scale is physical
- Boundary conditions (Neumann vs Dirichlet) select the zero modes
- Gauge group: $SU(3)_C \times SU(2)_R \times SU(2)_L \times P_{LR} \times U(1)_X$ → flavor structure not trivial: new gauge bosons mediate FCNC at three level (to take under control !)
- Zbb coupling and the T parameter 'custodially protected'
- Several theoretical motivations.

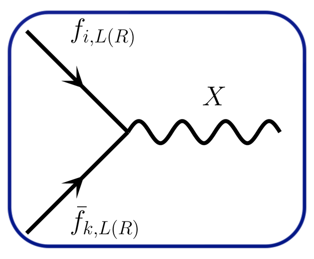


Fermion profile: $$f^{(0)}_{L,R}(y) = \sqrt{\frac{(1 \mp 2c)kL}{e^{(1\mp 2c)kL} - 1}}\, e^{(2\mp c)ky}$$

The c_i parameters determine the localization of the fermion along the extra dimensions → they must be constrained by EW precision data.

6) RSc contribution to B → K* $\ell^+\ell^-$

- Main contributions to $\Delta C^{(')}_{9,10}$ coefficients:



$$\Delta C_9 = \left[\frac{\Delta Y_s}{\sin^2(\theta_W)} - 4\Delta Z_s\right]$$

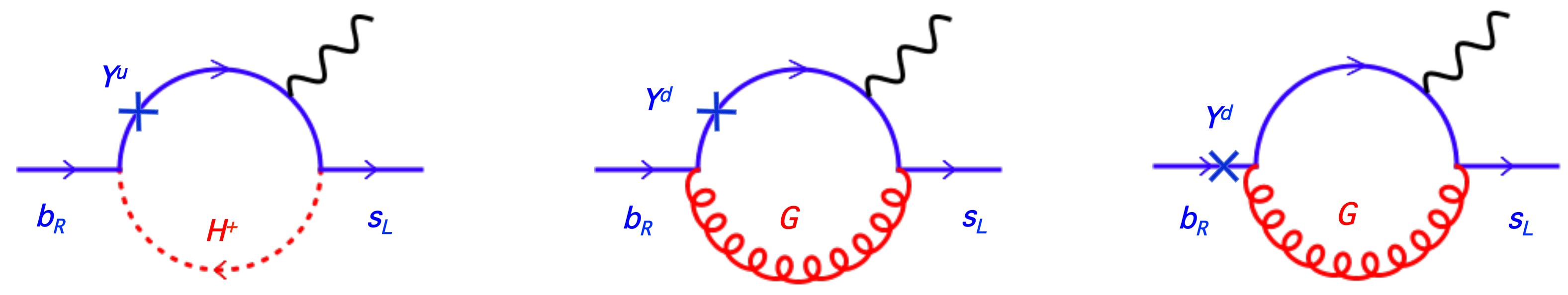
$$\Delta C_{10} = -\frac{\Delta Y_s}{\sin^2(\theta_W)}$$

$$\Delta Z_s = \frac{1}{V_{tb}V_{ts}^*}\sum_X \frac{\Delta_R^{\ell\ell}(X)}{8M_X^2 g_{SM}^2 \sin^2(\theta_W)}\Delta_L^{bs}(X)$$

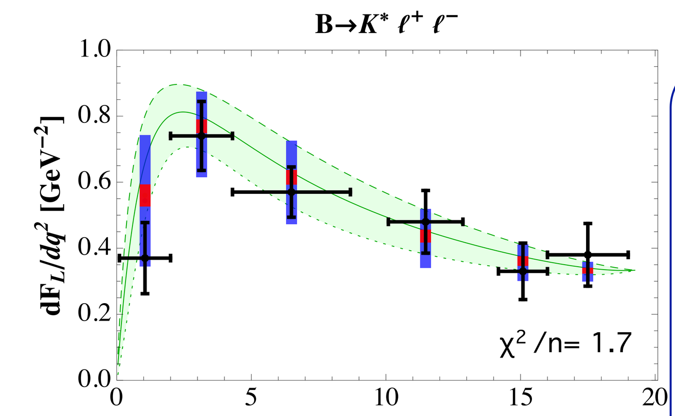
$$\Delta Y_s = -\frac{1}{V_{tb}V_{ts}^*}\sum_X \frac{\Delta_L^{\ell\ell}(X) - \Delta_R^{\ell\ell}(X)}{4M_X^2 g_{SM}^2}\Delta_L^{bs}(X)$$

X=Z, Z_H, Z' and A(1) → new neutral heavy gauge bosons

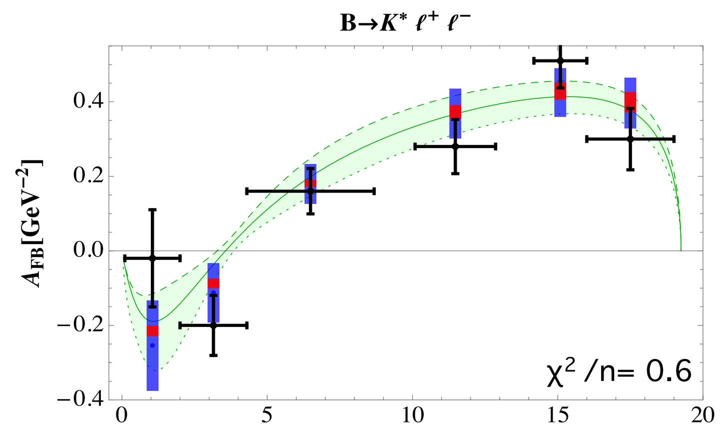
- Main contributions to $\Delta C^{(')}_7$ coefficients:

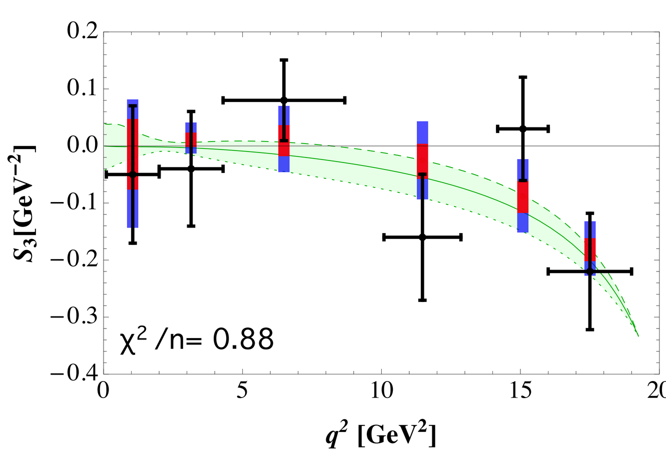


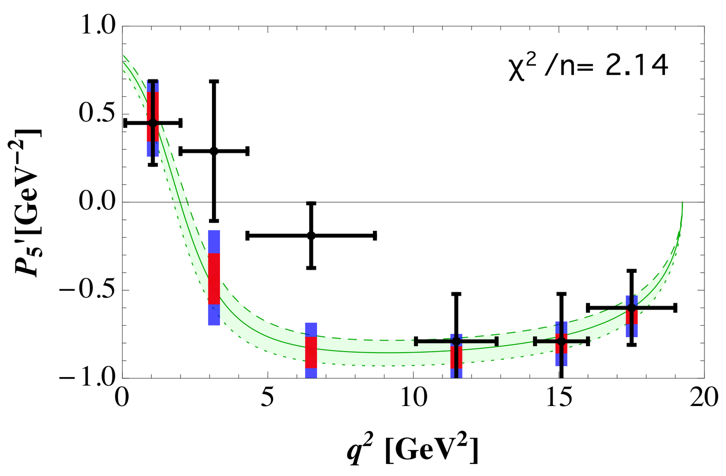
7) RSc predictions facing LHCb data



- SM predictions, with hadronic uncertaninties
- RSc predcitions
- RSc predictions with hadronic uncertainties
- LHCb data







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