Quark flavour observables in the flavor precision era:
331 models vs RSc

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Mainz, November 2014

Summary

- Experimental results that challenge SM predictions
- Anatomy of flavour observbles in 331 models
- deviations in angular observables in $B \to K^* \mu^+ \mu^-$

Based on works in collaborations with
- A.J. Buras, J. Girrbach
- P. Colangelo, P. Biancofiore

Recent results for flavour observables deviating from SM predictions

BR($B_s \to \mu^+ \mu^-$) close to SM while **BR($B_d \to \mu^+ \mu^-$)** higher than its SM value (LHCb + CMS)

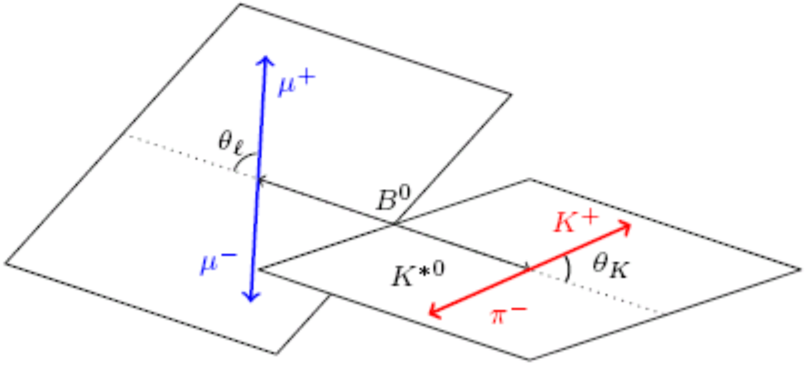
$$\bar{\mathcal{B}}(B_s \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$$
$$\mathcal{B}(B_d \to \mu^+\mu^-) = (3.6^{+1.6}_{-1.4}) \times 10^{-10}$$

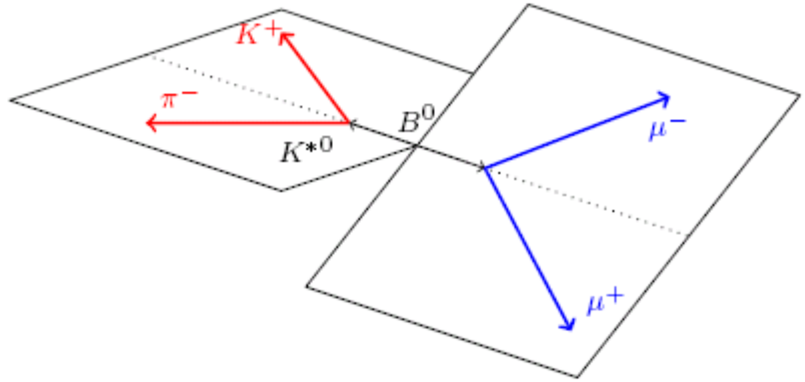
LHCb+ CMS

$$\bar{\mathcal{B}}(B_s \to \mu^+\mu^-)_{SM} = (3.65 \pm 0.23) \times 10^{-9}$$
$$\mathcal{B}(B_d \to \mu^+\mu^-)_{SM} = (1.06 \pm 0.09) \times 10^{-10}$$

Bobeth et al, 1311.0903

Bin analysis of angular observables in **B → K* μ⁺ μ⁻** deviate from SM (LHCb)





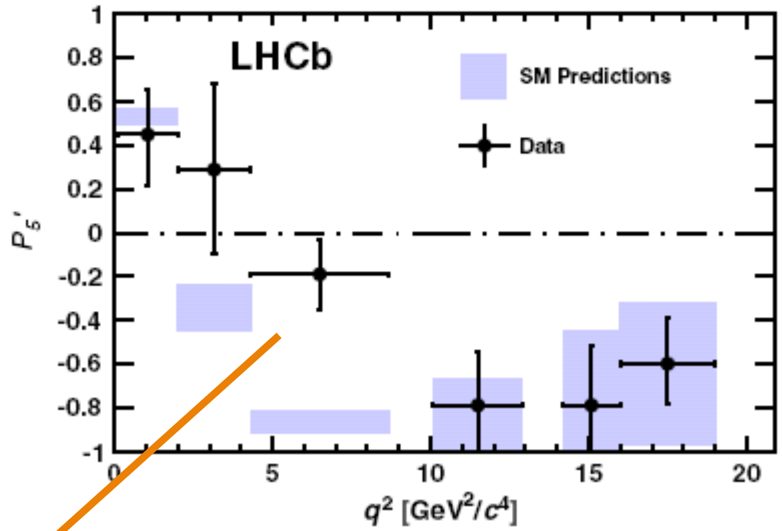
$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell\, d\cos\theta_K\, d\phi\, dq^2} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell$$
$$- F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi$$
$$+ S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi$$
$$+ S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big],$$

Form factor (almost) independent observables:

$$P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_L(1-F_L)}}.$$

Observables in B $\to K^* \mu^+ \mu^-$: LHCb results

LHCB Collab.
PRL 111 (2013) 191801



One measurement turns out to be discrepant

I discuss predictions for these observables

- in 331 models
- in comparison with RS model with custodial protection

A.J. Buras, J. Girrbach, M.V. Carlucci, FDF JHEP 1302 (2013) 023
A.J. Buras, J. Girrbach, FDF JHEP 1402 (2014) 112

P. Biancofiore, P, Colangelo, FDF PRD 89 (2014) 095018
& 1408.5614

331 Models: general features

P. Frampton, PRL 69 (92) 2889
F. Pisano & V. Pleitez, PRD 46 (92) 410

Gauge group:	$SU(3)_C \times SU(3)_L \times U(1)_X$
Spontaneously broken to	$SU(3)_C \times SU(2)_L \times U(1)_X$
Spontaneously broken to	$SU(3)_C \times U(1)_Q$

Fundamental relation:

$$Q = T_3 + \beta T_8 + X$$

Key parameter: defines the variant of the model

$\beta = \pm 1/\sqrt{3}, \pm 2/\sqrt{3}$

- lead to interesting phenomenology
- for $\beta = \pm 1/\sqrt{3}$ the new gauge bosons have integer charge

331 Model: new particle content

New Gauge Bosons

A new heavy Z' mediates
tree level FCNC in the quark sector

Extended Higgs sector

Three $SU(3)_L$ triplets, one sextet

New heavy fermions

D,S ,T new heavy quarks

$\mathbf{E}_l$ new heavy neutrinos (both L & R)

331 Models: quark mixing

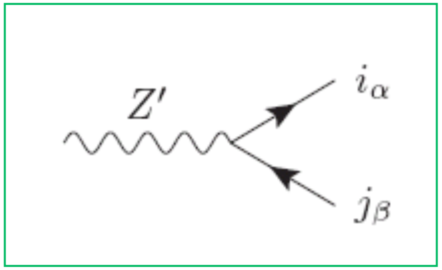
Quark mass eigenstates defined upon rotation through two unitary matrices $\mathbf{U_L}$ & $\mathbf{V_L}$

$$V_{\rm CKM} = U_L^\dagger V_L$$

In contrast to SM only one of them can be traded for VCKM, the other one enters in Z' couplings to quarks

$$V_L = \begin{pmatrix} \tilde{c}_{12}\tilde{c}_{13} & \tilde{s}_{12}\tilde{c}_{23}e^{i\delta_3} - \tilde{c}_{12}\tilde{s}_{13}\tilde{s}_{23}e^{i(\delta_1-\delta_2)} & \tilde{c}_{12}\tilde{c}_{23}\tilde{s}_{13}e^{i\delta_1} + \tilde{s}_{12}\tilde{s}_{23}e^{i(\delta_2+\delta_3)} \\ -\tilde{c}_{13}\tilde{s}_{12}e^{-i\delta_3} & \tilde{c}_{12}\tilde{c}_{23} + \tilde{s}_{12}\tilde{s}_{13}\tilde{s}_{23}e^{i(\delta_1-\delta_2-\delta_3)} & -\tilde{s}_{12}\tilde{s}_{13}\tilde{c}_{23}e^{i(\delta_1-\delta_3)} - \tilde{c}_{12}\tilde{s}_{23}e^{i\delta_2} \\ -\tilde{s}_{13}e^{-i\delta_1} & -\tilde{c}_{13}\tilde{s}_{23}e^{-i\delta_2} & \tilde{c}_{13}\tilde{c}_{23} \end{pmatrix}$$

331 Models: Z' couplings to quarks
The case of B_d,B_s,K systems



$$i\mathcal{L}_L(Z') = i\left[\Delta_L^{sd}(Z')(\bar{s}\gamma^\mu P_L d) + \Delta_L^{bd}(Z')(\bar{b}\gamma^\mu P_L d) + \Delta_L^{bs}(Z')(\bar{b}\gamma^\mu P_L s)\right] Z'_\mu$$

FCNC involve only left-handed quarks

depend only on four new parameters:

$$\tilde{s}_{13}, \quad \tilde{s}_{23}, \quad \delta_1, \quad \delta_2$$

B_d system → only on s_{13} and δ_1

B_s system → only on s_{23} and δ_2

K system → on s_{13} , s_{23} and δ_2 - δ_1

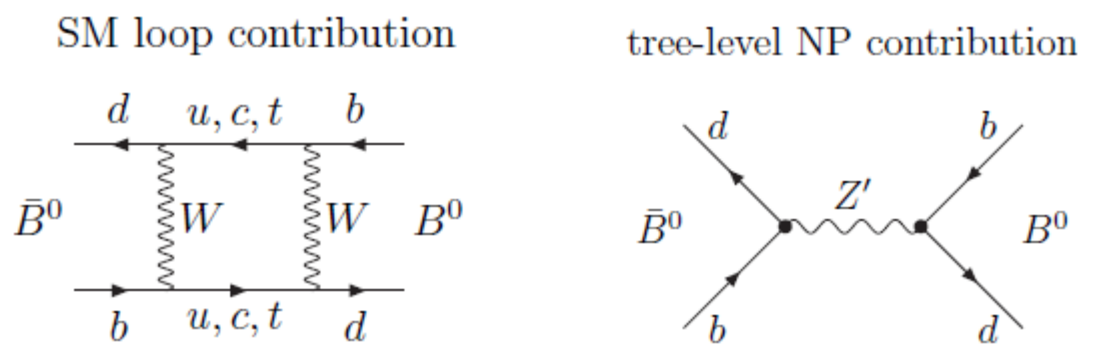
Specific feature of this model
Not true in general!

stringent correlations between observables expected

Oases in the parameter space from ΔF=2 observables

ΔM_d	$S_{\psi K_s}$	ΔM_s	$S_{\psi\phi}$
Mass difference in the $\bar{B}_d - B_d$ system	CP asymmetry in $B_d \to J/\psi\, K_s$	Mass difference in the $\bar{B}_s - B_s$ system	CP asymmetry in $B_s \to J/\psi\, \phi$

Example of NP contribution: The case of B_d mixing



Imposing the experimental constraints:

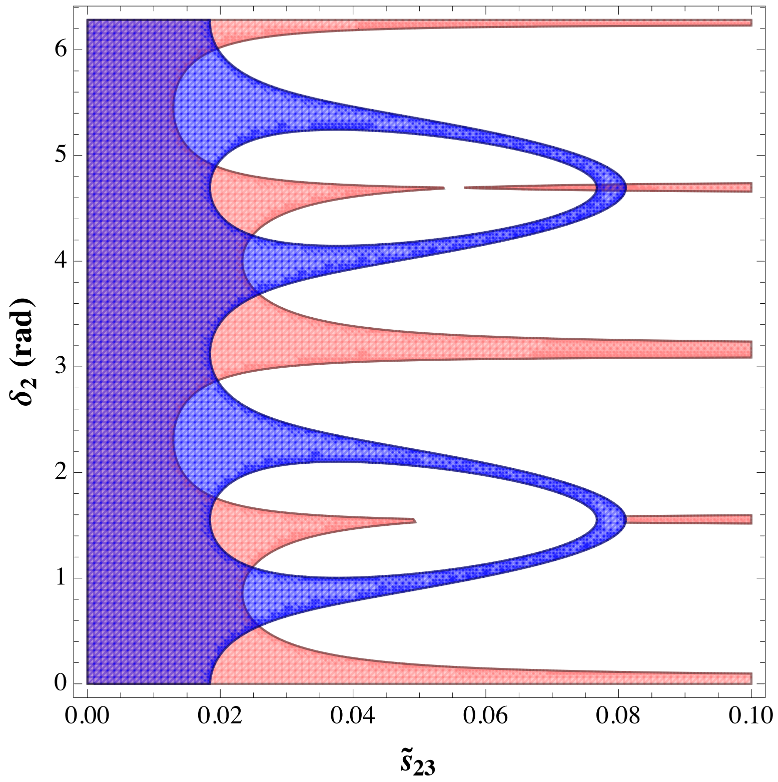
$$0.48/\text{ps} \le \Delta M_d \le 0.53/\text{ps}, \quad 0.64 \le S_{\psi K_S} \le 0.72,$$

$$16.9/\text{ps} \le \Delta M_s \le 18.7/\text{ps}, \quad -0.18 \le S_{\psi\phi} \le 0.18,$$

One finds the allowed oases for the parameters

s_{13} , $s_{23} > 0$ & $0 < \delta_{23} < 2\pi$ $0 < \delta_{13} < 2\pi$

Oases in the parameter space from ΔF=2 observables
Example for $\beta=-2/\sqrt{3}$



The decays $B_{s,d} \to \mu^+ \mu^-$

SM effective hamiltonian $\rightarrow$ one master function $Y_0(x_t)$

$$x_t = m_t^2/M_W^2$$

$$Y_0(x_t) = \frac{x_t}{8}\left(\frac{x_t-4}{x_t-1} + \frac{3x_t \log x_t}{(x_t-1)^2}\right)$$

$\rightarrow$ independent on the decaying meson and on the lepton flavour

Z' contribution modifies this function to:

$$Y(B_q) = Y(x_t) + \left[\frac{\Delta_A^{\mu\bar{\mu}}(Z')}{M_{Z'}^2 g_{\rm SM}^2}\right] \frac{\Delta_L^{qb}(Z')}{V_{tq}^* V_{tb}} \equiv |Y(B_q)|\, e^{i\theta_Y^q}$$

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The decay B $\rightarrow$ K* μ^+ μ^-

$$H^{eff} = -4\frac{G_F}{\sqrt{2}}V_{tb}V_{ts}^*\left\{C_1O_1 + C_2O_2 + \sum_{i=3,..,6} C_iO_i + \sum_{i=7,..,10,P,S}[C_iO_i + C_i'O_i']\right\}$$

Most relevant operators

$$O_7 = \frac{e}{16\pi^2}m_b(\bar{s}_{L\alpha}\sigma^{\mu\nu}b_{R\alpha})F_{\mu\nu}$$
$$O_7' = \frac{e}{16\pi^2}m_b(\bar{s}_{R\alpha}\sigma^{\mu\nu}b_{L\alpha})F_{\mu\nu}$$

→ Magnetic penguin operators

$$O_9 = \frac{e^2}{16\pi^2}(\bar{s}_{L\alpha}\gamma^\mu b_{L\alpha})\;\bar{\ell}\gamma_\mu\ell$$
$$O_9' = \frac{e^2}{16\pi^2}(\bar{s}_{R\alpha}\gamma^\mu b_{R\alpha})\;\bar{\ell}\gamma_\mu\ell$$
$$O_{10} = \frac{e^2}{16\pi^2}(\bar{s}_{L\alpha}\gamma^\mu b_{L\alpha})\;\bar{\ell}\gamma_\mu\gamma_5\ell$$
$$O_{10}' = \frac{e^2}{16\pi^2}(\bar{s}_{R\alpha}\gamma^\mu b_{R\alpha})\;\bar{\ell}\gamma_\mu\gamma_5\ell\,.$$

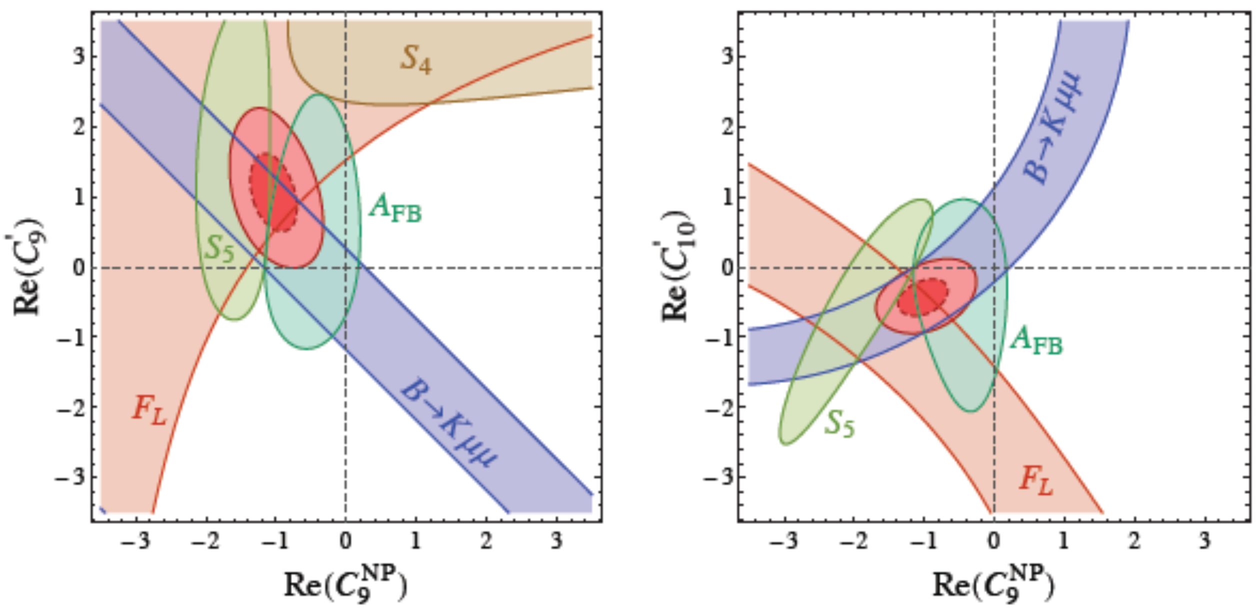
→ Semileptonic electroweak penguin operators

The decay $B \to K^* \mu^+ \mu^-$

How large should be the NP contributions to the relevant Wilson coefficients to explain the observed anomalies?

The result depends on how many coefficients are assumed to be affected by NP

W. Altmanshofer, D. Straub
EPJC73 (2013) 2646



Wilson coefficients C_9 and C_{10} in 331 models

$$C_9 = C_9^{\rm SM} + C_9^{\rm NP}, \qquad C_{10} = C_{10}^{\rm SM} + C_{10}^{\rm NP}$$

$$C_9^{\rm SM} \approx 4.1, \qquad C_{10}^{\rm SM} \approx -4.1$$

$$\sin^2\theta_W C_9^{\rm NP} = -\frac{1}{g_{\rm SM}^2 M_{Z'}^2}\frac{\Delta_L^{sb}(Z')\Delta_V^{\mu\bar\mu}(Z')}{V_{ts}^* V_{tb}}$$

$$\sin^2\theta_W C_{10}^{\rm NP} = -\frac{1}{g_{\rm SM}^2 M_{Z'}^2}\frac{\Delta_L^{sb}(Z')\Delta_A^{\mu\bar\mu}(Z')}{V_{ts}^* V_{tb}}$$

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The same coupling entering in ΔY governing $B_{s,d} \to \mu^+ \mu^-$

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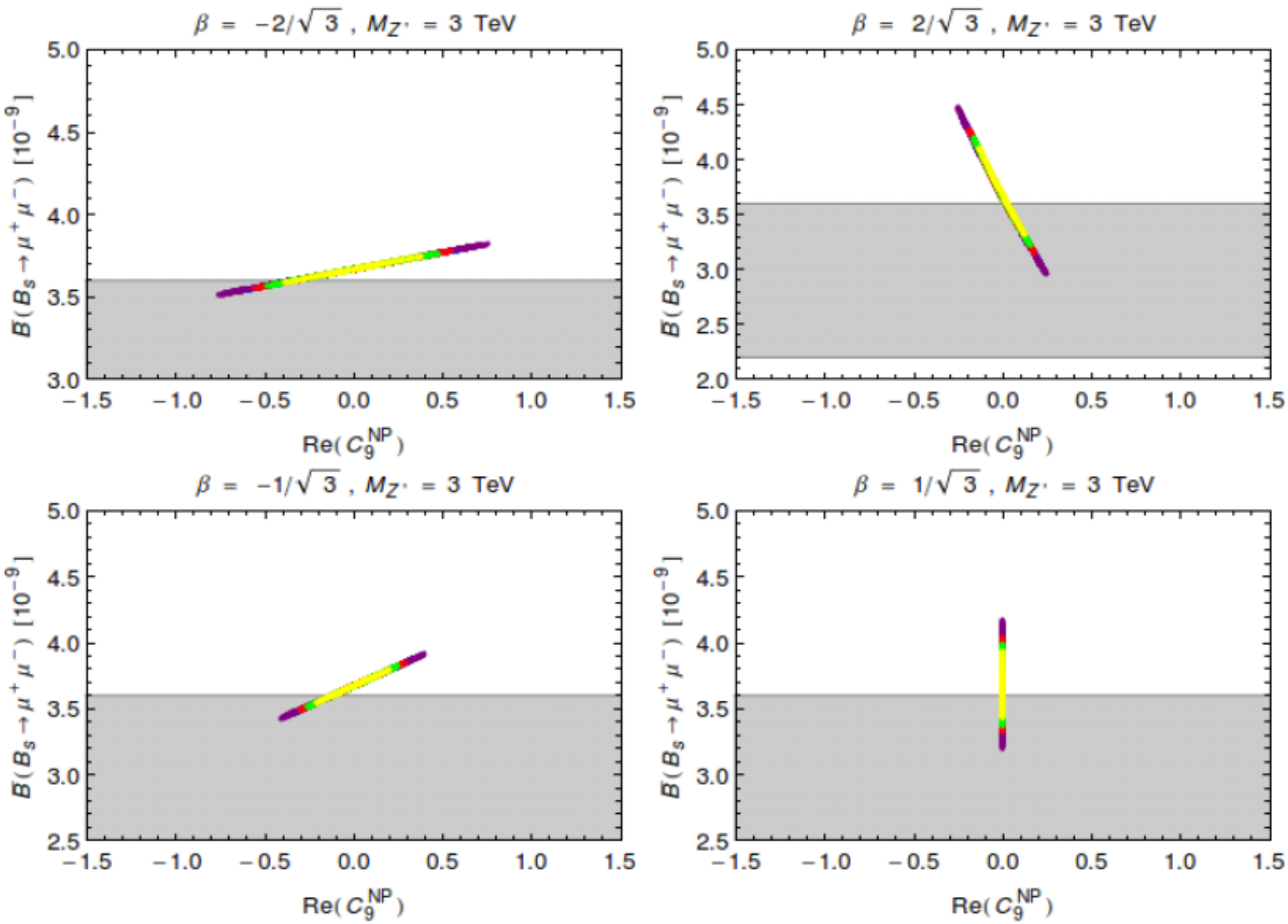
Requires the investigation of the ratio

$$R_1 = \frac{C_9^{\rm NP}}{C_{10}^{\rm NP}} = \frac{\Delta_V^{\mu\bar\mu}(Z')}{\Delta_A^{\mu\bar\mu}(Z')}$$

The same coupling entering in ΔY governing $B_{s,d} \to \mu^+ \mu^-$

Correlation between C_9 and BR($B_s \to \mu^+\mu^-$)



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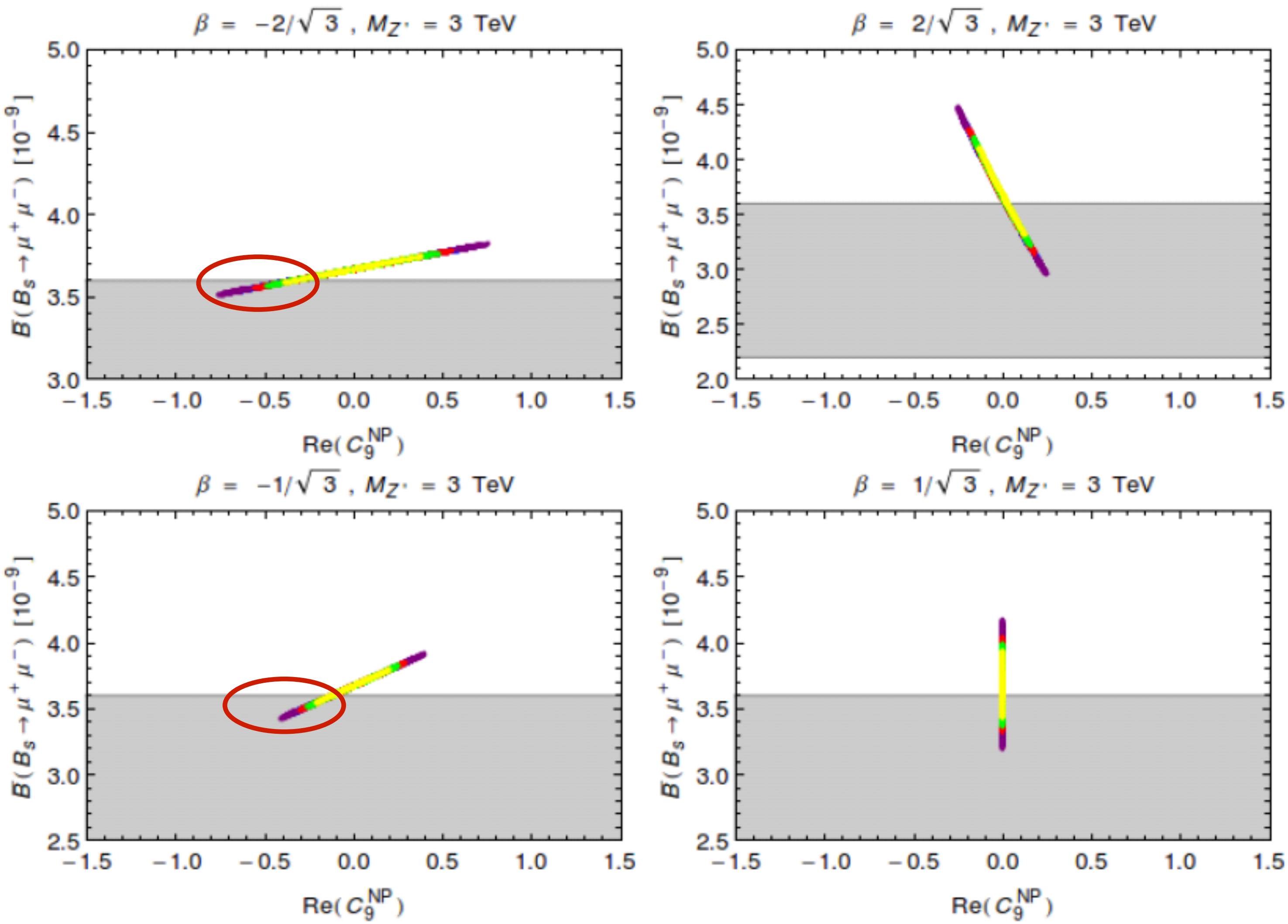
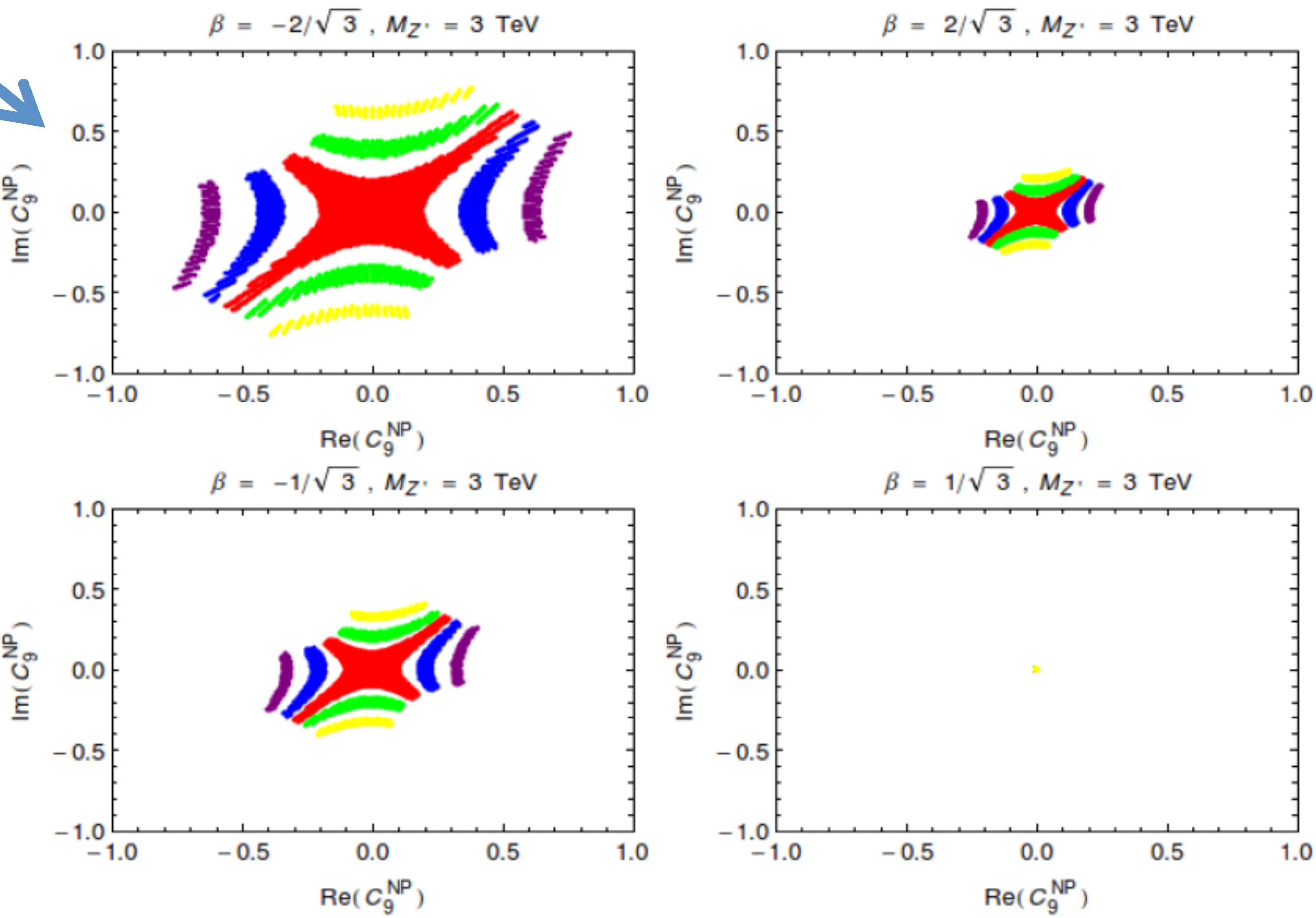


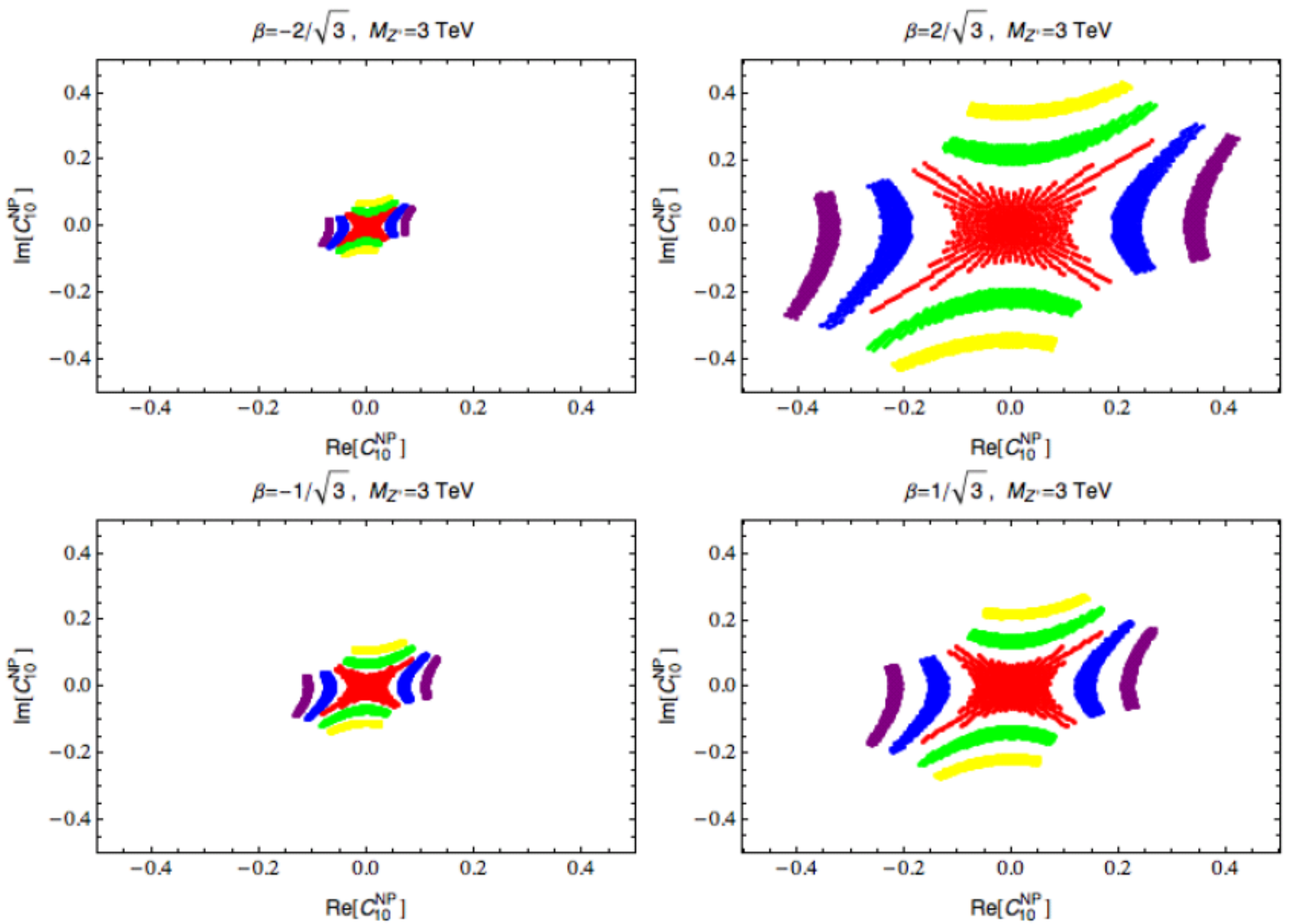
Scenario with the largest possible deviations from SM

C_9

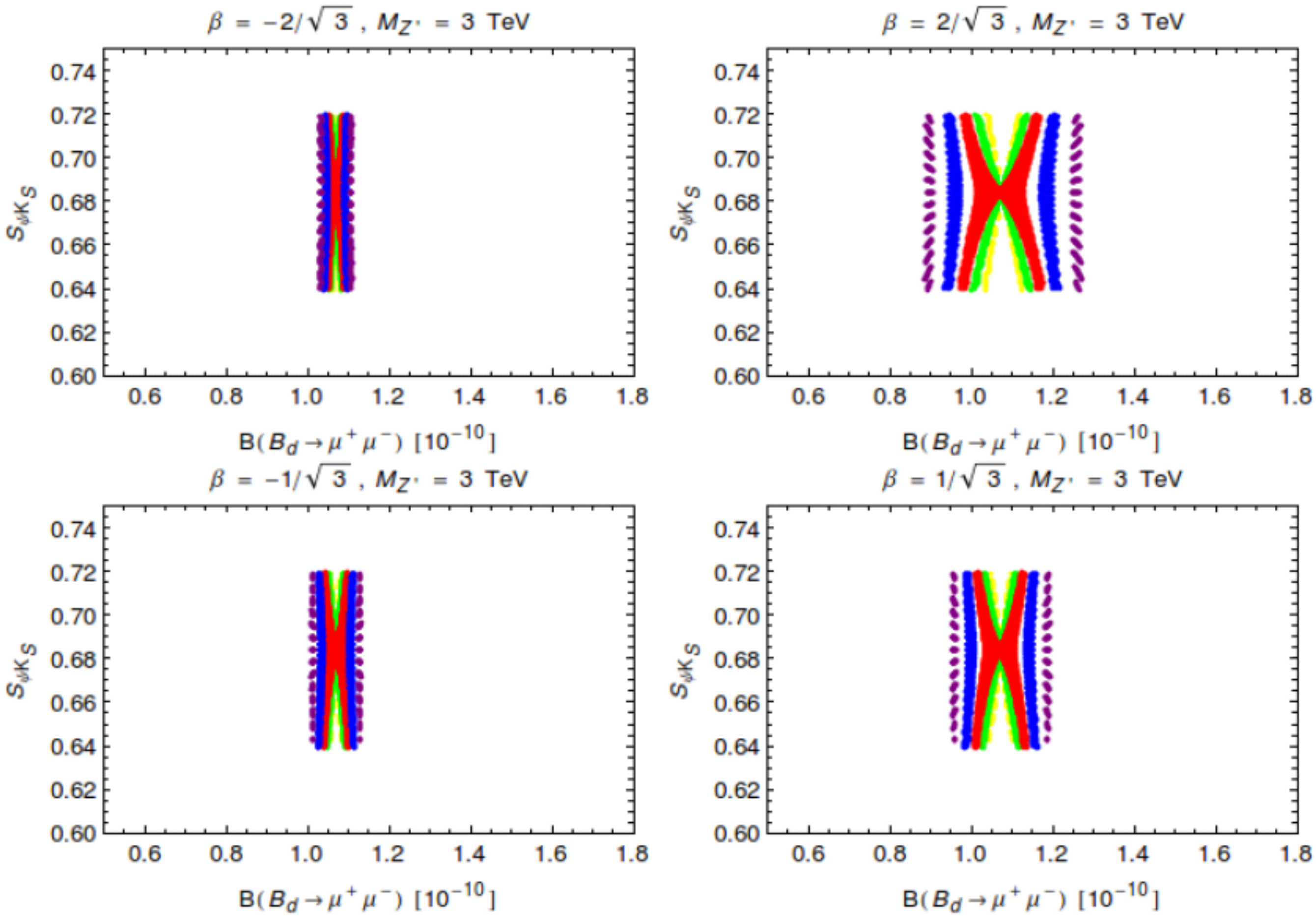


C$_{10}$

Scenario with the largest possible deviations from SM



$BR(B_d \to \mu^+\mu^-)$



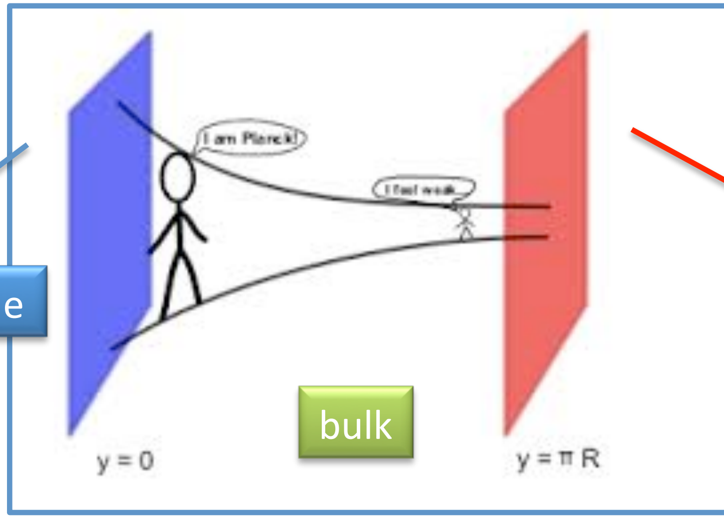
In this model independendently of β the large exp result for $BR(B_d \to \mu^+\mu^-)$ cannot be reproduced

The $B \to K^* \mu^+ \mu^-$ anomaly in another NP model: RS_c

Main features of the RS model

L. Randall, R. Sundrum, PRL83 (99) 8370

Planck (UV) brane



SM (IR) brane

$$ds^2 = e^{-2ky}\eta_{\mu\nu}dx^\mu dx^\nu - dy^2$$

$$k \simeq \mathcal{O}(M_{Planck})$$

- All fields propagate in the bulk, Higgs localized close to or on the IR brane
- possibility of solving the hierarchy problem
- Explaining the observed pattern in fermion masses and mixing

Custodially protected RS_c model

Agashe et al, PLB641 (06) 62
Carena et al.,NPB 759 (06) 202
Cacciapaglia et al PRD75 (07) 015003

Gauge group enlarged to $SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_X \times P_{L,R}$

Implies a mirror action of the two SU(2) groups

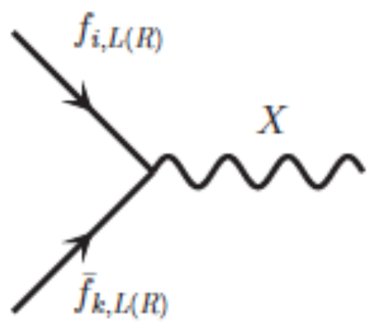
Benefits:

- Prevents large Z couplings to left-handed fermions
- Consitent with electroweak precision observables without large fine-tuning even for KK masses a a few TeV (LHC reach)

Particle content:

SM particles+ their KK excitations
New particles
Zero modes identified with SM fields
Boundary conditions distinuish fields with or without a zero mode

Tree level FCNC in RS_c model



$$-i\bar{f}_k \Delta^{ik}_{L(R)} \gamma_\mu P_{L(R)} f_i X^\mu$$

X= $A^{(1)}$ (1st KK of the γ)
Z, Z_H , Z' (from mixing of 0- and 1-modes)
$G^{(1)}$ (1st KK of the g)

does not contribute to decays to leptons

→ New contributions to the Wilson coefficients

Modified Wilson coefficients in RS_c model

Blanke et al, JHEP 0903 (09) 108
Albrecht et al, JHEP 0909 (09) 064

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

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

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

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

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

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

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Couplings to leptons

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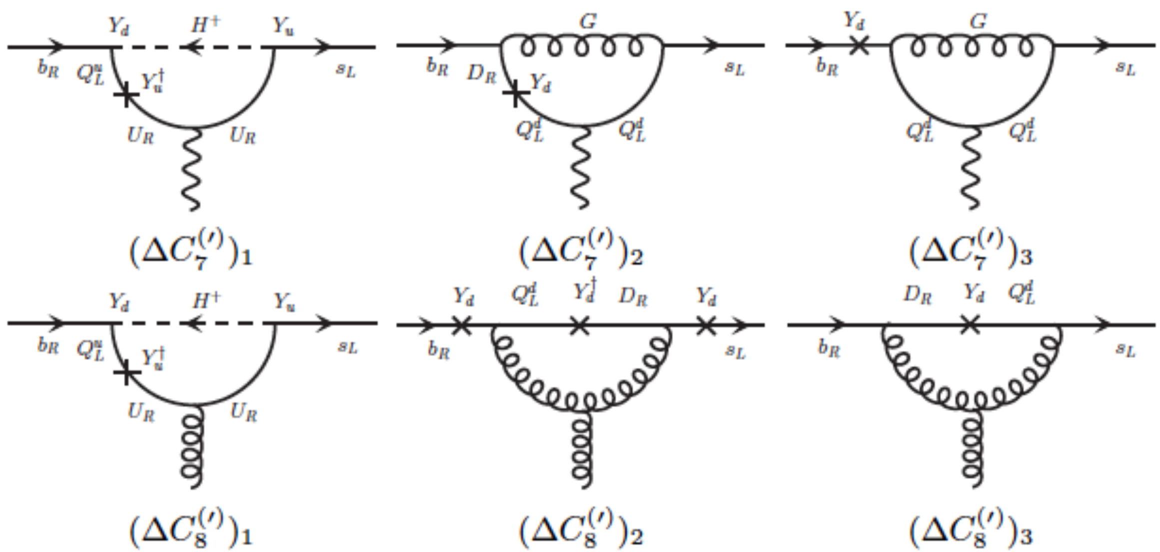
Couplings to leptons

Couplings to quarks

Modified Wilson coefficients in RS_c model

New contributions to $C_{7,8}$ are still loop induced



Parameters of the RS$_c$ model

KK decomposition for each field:

$$F(x,y) = \frac{1}{\sqrt{L}} \sum_k F^{(k)}(x) f^{(k)}(y)$$

$F^{(k)}(x)$: effective 4D fields

$f^{(k)}(y)$: 5D profiles

Fermion profiles (0-mode)

$$f^{(0)}(y,c) = \sqrt{\frac{(1-2c)kL}{e^{(1-2c)kL} - 1}} e^{-cky}$$

c: bulk mass

Bulk mass parameters are the same for left-handed fermions of the same generation:
$(u\ d)_L$ $(c\ s)_L$ $(t\ b)_L$ $(e\ \nu_e)_L$ $(\mu\ \nu_\mu)_L$ $(\tau\ \nu_\tau)_L$

Parameters of the RS$_c$ model

4D Yukawa coulings:

$$Y_{ij}^{u(d)} = \frac{1}{\sqrt{2}} \frac{1}{L^{3/2}} \int_0^L dy\, \lambda_{ij}^{u(d)} f^{(0)}_{q_L^i}(y) f^{(0)}_{u_R^j(d_R^j)}(y) h(y)$$

5D Yukawa matrices

Constraints: $\lambda^{u,d}$ should reproduce
- quark masses
- CKM elements

$$m_u = \frac{v}{\sqrt{2}} \frac{det(\lambda^u)}{\lambda^u_{33}\lambda^u_{22} - \lambda^u_{23}\lambda^u_{32}} \frac{e^{kL}}{L} f_{u_L} f_{u_R}$$

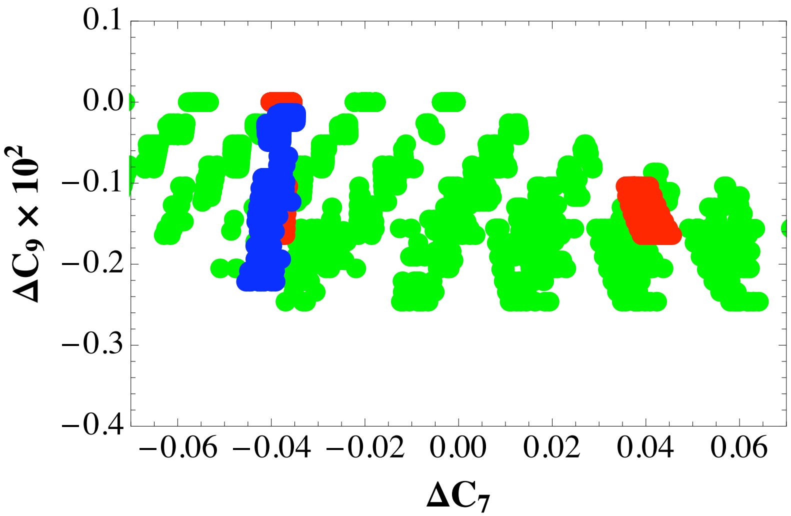
$$m_c = \frac{v}{\sqrt{2}} \frac{\lambda^u_{33}\lambda^u_{22} - \lambda^u_{23}\lambda^u_{32}}{\lambda^u_{33}} \frac{e^{kL}}{L} f_{c_L} f_{c_R}$$

$$m_t = \frac{v}{\sqrt{2}} \lambda^u_{33} \frac{e^{kL}}{L} f_{t_L} f_{t_R} \ ,$$

$$V_{CKM} = \mathcal{U}_L^\dagger \mathcal{D}_L$$

quark rotation matrices depend on the $\lambda^{u,d}$ elements

Results



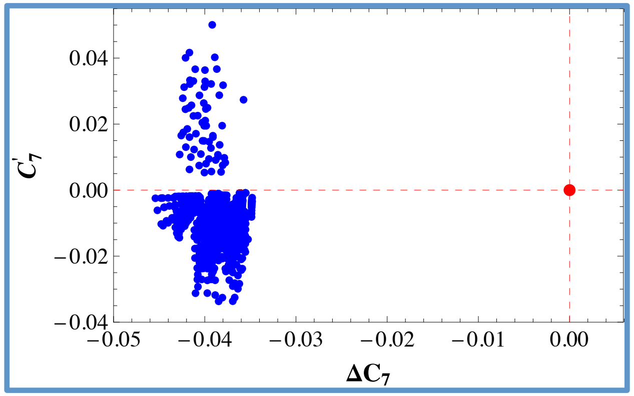
Constraints from V_{us} and V_{ub}

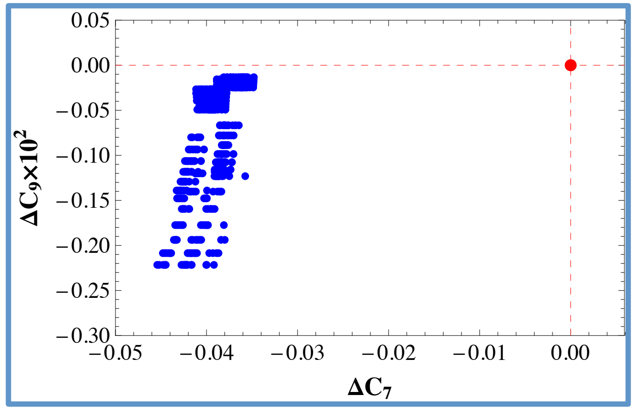
Constraints from V_{cb} and V_{ub}

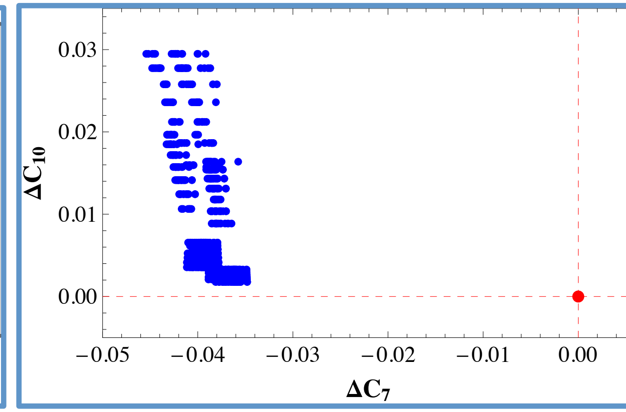
Constraints from Brs

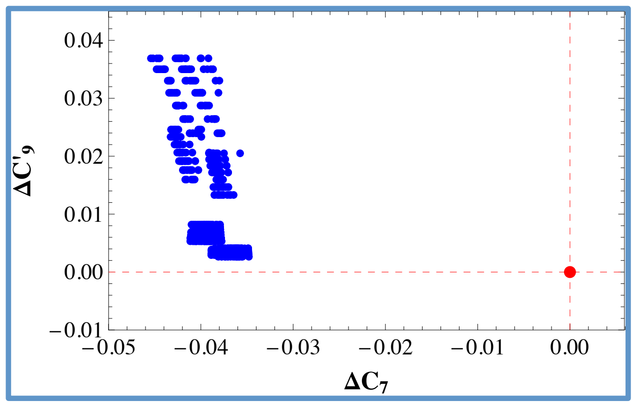
$$\mathcal{B}(B \to K^* \mu^+ \mu^-)_{exp} = (1.02 \pm^{0.14}_{0.13} \pm 0.05) \times 10^{-6} \,,$$
$$\mathcal{B}(B \to X_s \gamma)_{exp} = (3.55 \pm 0.24 \pm 0.09) \times 10^{-4}$$

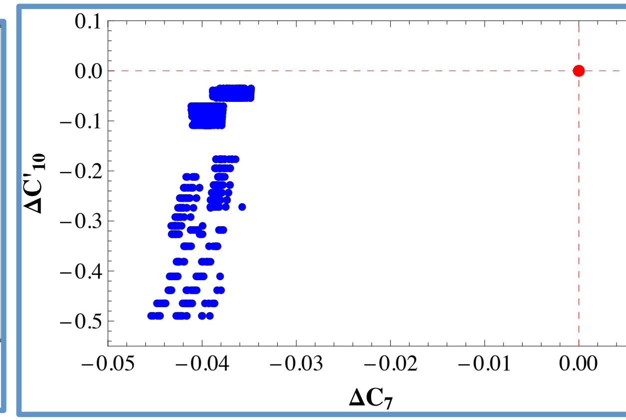
Results







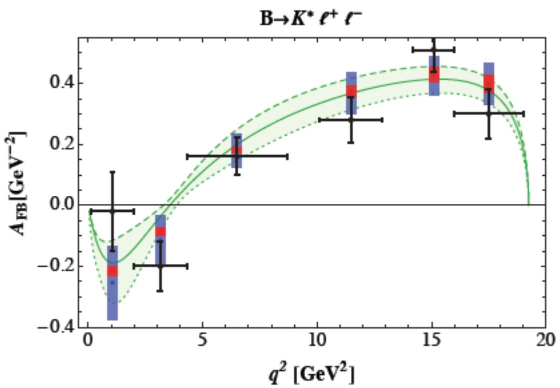


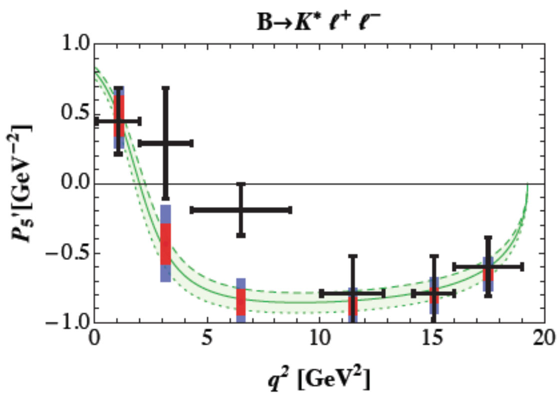


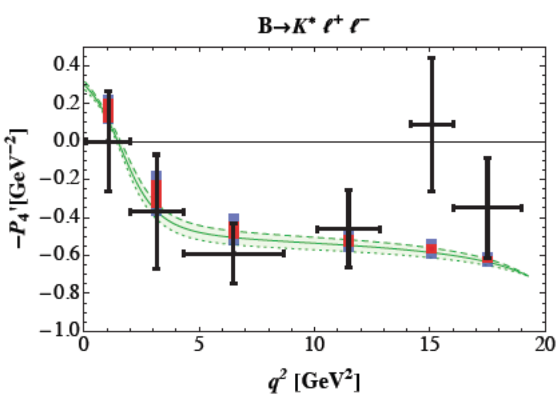
Largest deviations from SM results:

$$|\Delta C_7|_{max} \simeq 0.046$$
$$|\Delta C_7'|_{max} \simeq 0.05$$
$$|\Delta C_9|_{max} \simeq 0.0023$$
$$|\Delta C_9'|_{max} \simeq 0.038$$
$$|\Delta C_{10}|_{max} \simeq 0.030$$
$$|\Delta C_{10}'|_{max} \simeq 0.50$$

Results







SM result.
Uncertainty on FF taken into account

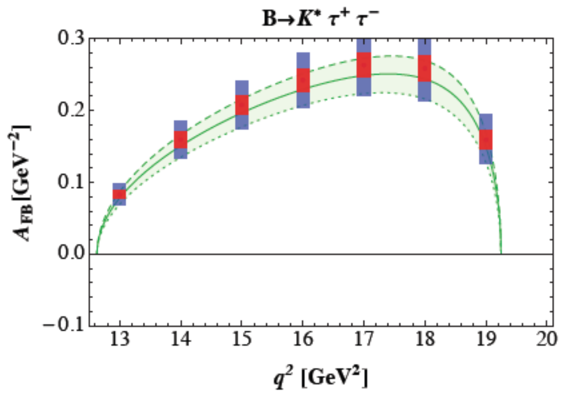
RS_c result.
Uncertainty reflects only the variation of input parameters

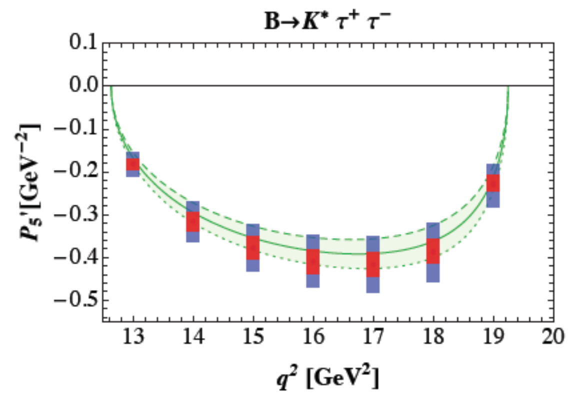
RS_c result.
Uncertainty reflects the variation of input parameters & FF errors

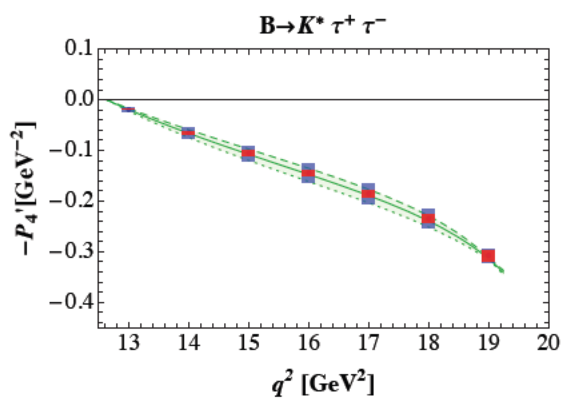
LHCb Data

- Deviations from SM results are possible
- Presently hidden by hadronic uncertainties
- Anomalies in data cannot be explained

Results: τ in the final state

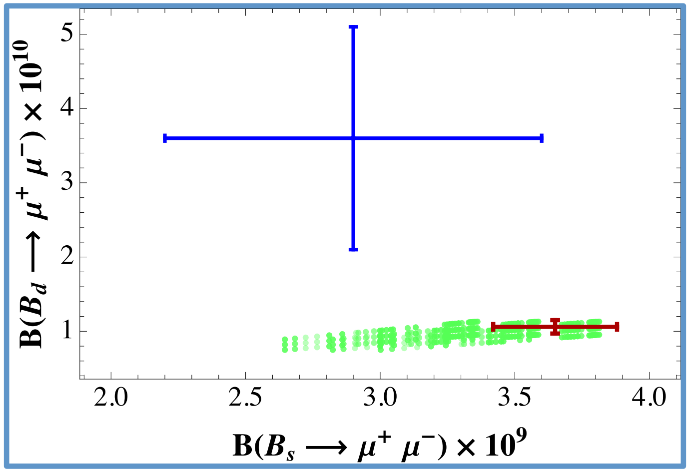






No measurements available yet to test SM

More results



Modification wrt the SM: C_{10} –> C_{10} - C_{10}'

- RS_c result
- SM result
- data

- In a region of the parameter space the SM result is reproduced
- The allowed range in RS_c is larger than in SM

$$\mathcal{B}(B_s \to \mu^+\mu^-)|_{RS} \in [2.64, 3.83] \times 10^{-9}$$

$$\mathcal{B}(B_d \to \mu^+\mu^-)|_{RS} \in [0.70, 1.16] \times 10^{-10}$$

- BR in the B_d case still lower than data

More results: decays B -> K$^{(*)}$ $\nu \bar{\nu}$

$$H_{eff} = C_L O_L + C_R O_R$$

$$O_L = (\bar{b}s)_{V-A}(\bar{\nu}\nu)_{V-A}$$

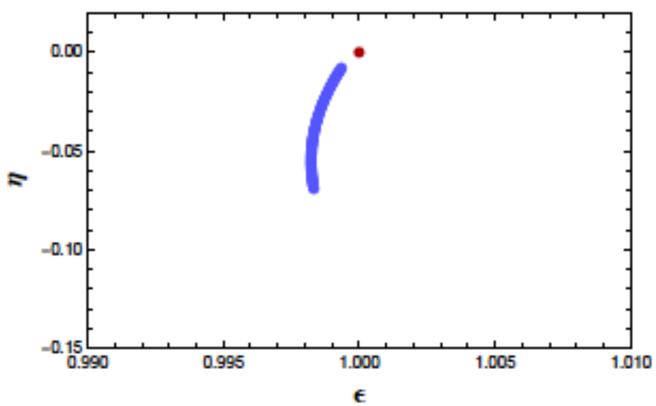
$$O_R = (\bar{b}s)_{V+A}(\bar{\nu}\nu)_{V-A}$$

their relative weight
can be assessed introducing:

$$\epsilon^2 = \frac{|C_L|^2 + |C_R|^2}{|C_L^{SM}|^2} \,, \qquad \eta = -\frac{\text{Re}\,(C_L C_R^*)}{|C_L|^2 + |C_R|^2}$$

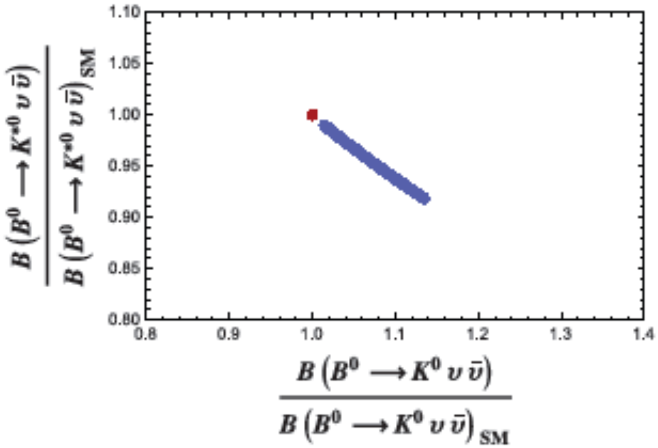
in the SM: $(\epsilon, \eta)_{SM} = (1, 0)$

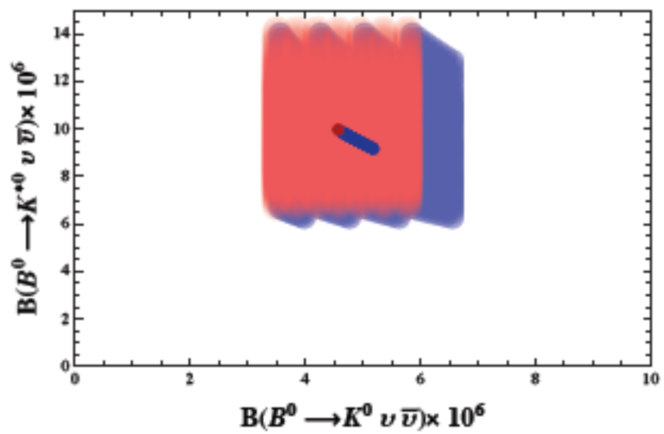
in RSc:



η deviates from 0

More results: decays B -> $K^{(*)} \nu \nu$





$$\mathcal{B}(B^0 \to K^0 \nu\bar{\nu})_{SM} = (4.6 \pm 1.1) \times 10^{-6}$$

$$\mathcal{B}(B^0 \to K^0 \nu\bar{\nu})_{RS} \in [3.45 - 6.65] \times 10^{-6}$$

$$\mathcal{B}(B^0 \to K^{*0} \nu\bar{\nu})_{SM} = (10.0 \pm 2.7) \times 10^{-6}$$

$$\mathcal{B}(B^0 \to K^{*0} \nu\bar{\nu})_{RS} \in [6.1 - 14.3] \times 10^{-6}$$

Belle

$$\begin{aligned} \mathcal{B}(B^+ \to K^+ \nu\bar{\nu}) &< 5.5 \times 10^{-5} \\ \mathcal{B}(B^0 \to K^0_S \nu\bar{\nu}) &< 9.7 \times 10^{-5} \\ \mathcal{B}(B^+ \to K^{*+} \nu\bar{\nu}) &< 4.0 \times 10^{-5} \\ \mathcal{B}(B^0 \to K^{*0} \nu\bar{\nu}) &< 5.5 \times 10^{-5} \,. \end{aligned}$$

BaBar

$$\begin{aligned} \mathcal{B}(B^+ \to K^+ \nu\bar{\nu}) &< 1.6 \times 10^{-5} \\ \mathcal{B}(B^0 \to K^0 \nu\bar{\nu}) &< 4.9 \times 10^{-5} \\ \mathcal{B}(B^+ \to K^{*+} \nu\bar{\nu}) &< 6.4 \times 10^{-5} \\ \mathcal{B}(B^0 \to K^{*0} \nu\bar{\nu}) &< 12 \times 10^{-5} \,, \end{aligned}$$

Observables in B -> K$^{(*)}$ ν ν

Integrated K* polarization fractions

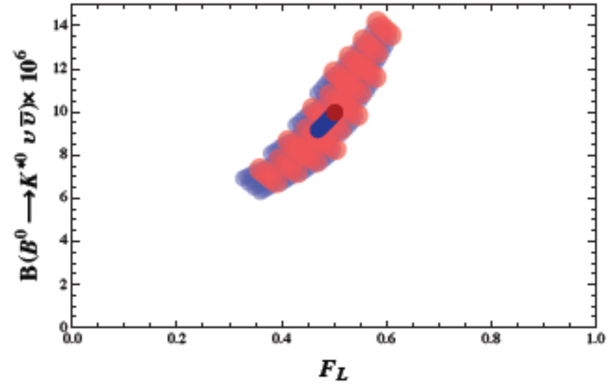
$$F_{L,T} = \frac{1}{\Gamma} \int_0^{1-\tilde{m}^2_{K^*}} ds_B \, \frac{dF_{L,T}}{ds_B} \, .$$

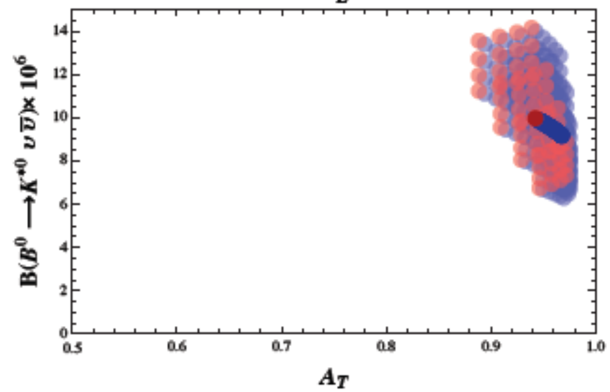
Ratio fo BRs of K mode and K* mode with transversely polarized K*

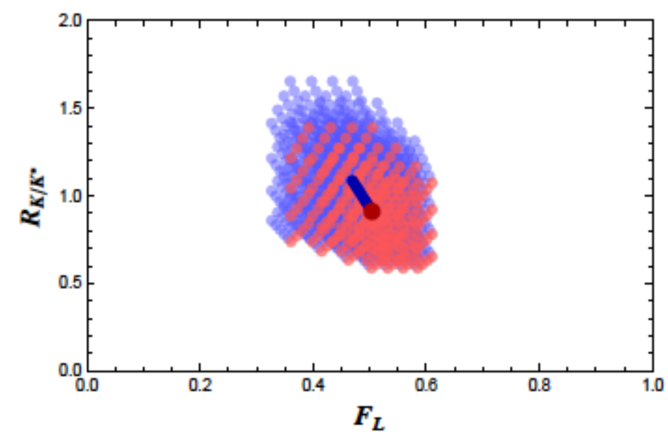
$$R_{K/K^*} = \frac{\mathcal{B}(B \to K \, \nu\bar{\nu})}{\mathcal{B}(B \to K^*_{h=-1} \, \nu\bar{\nu}) + \mathcal{B}(B \to K^*_{h=+1} \, \nu\bar{\nu})}$$

Transverse asymmetry

$$A_T = \frac{\mathcal{B}(B \to K^*_{h=-1} \, \nu\bar{\nu}) - \mathcal{B}(B \to K^*_{h=+1} \, \nu\bar{\nu})}{\mathcal{B}(B \to K^*_{h=-1} \, \nu\bar{\nu}) + \mathcal{B}(B \to K^*_{h=+1} \, \nu\bar{\nu})} \, ,$$







Observables in B -> K$^{(*)}$ ν ν

Integrated K* polarization fractions

$$F_{L,T} = \frac{1}{\Gamma}\int_0^{1-\tilde{m}_{K^*}^2} ds_B \, \frac{dF_{L,T}}{ds_B} \, .$$

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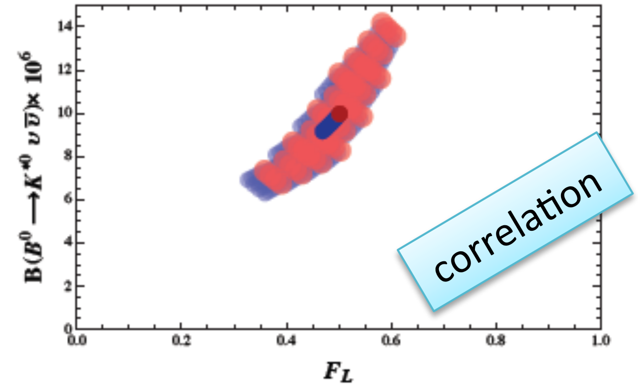
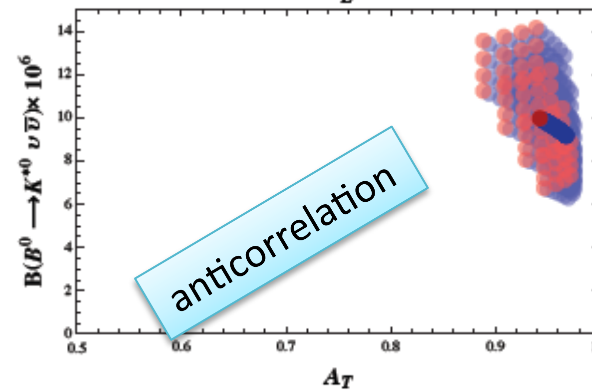
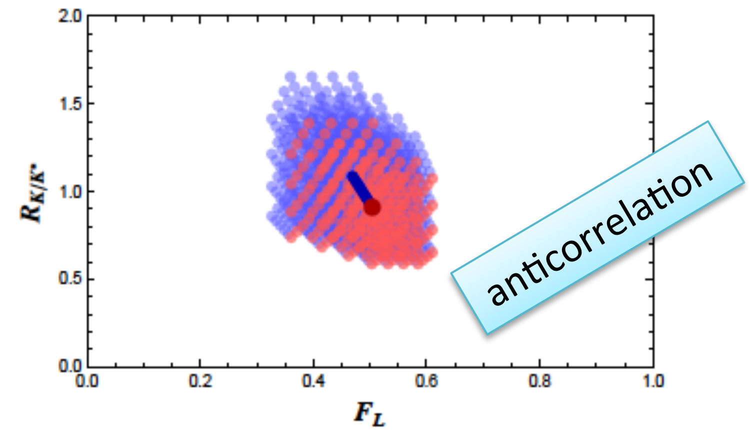
$$A_T = \frac{\mathcal{B}(B \to K^*_{h=-1}\, \nu\bar{\nu}) - \mathcal{B}(B \to K^*_{h=+1}\, \nu\bar{\nu})}{\mathcal{B}(B \to K^*_{h=-1}\, \nu\bar{\nu}) + \mathcal{B}(B \to K^*_{h=+1}\, \nu\bar{\nu})} \, ,$$







Conclusions

- 331 models might be in accordance with data but
  - $Re[C_9]$ cannot be smaller than -1
  - for $\beta<0$ the 1 bin -deviation in P_5' in $B \to K^* \mu^+ \mu^-$ can be softened and $BR(B_s \to \mu^+\mu^-)$ can be shifted closer to data
  - by no means the experimental datum for $BR(B_d \to \mu^+\mu^-)$ can be reproduced

- RS_c predicts Wilson coefficients that may deviate from SM ones
  Deviations are not enough to explain present puzzles
  τ modes represent interesting cross check of SM predictions vs NP scenarios
  multiple correlation pattern among observables exists in neutrino modes