U(2) and Minimal Flavour Violation in Supersymmetry

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arXiv:1105.2296 [hep-ph]

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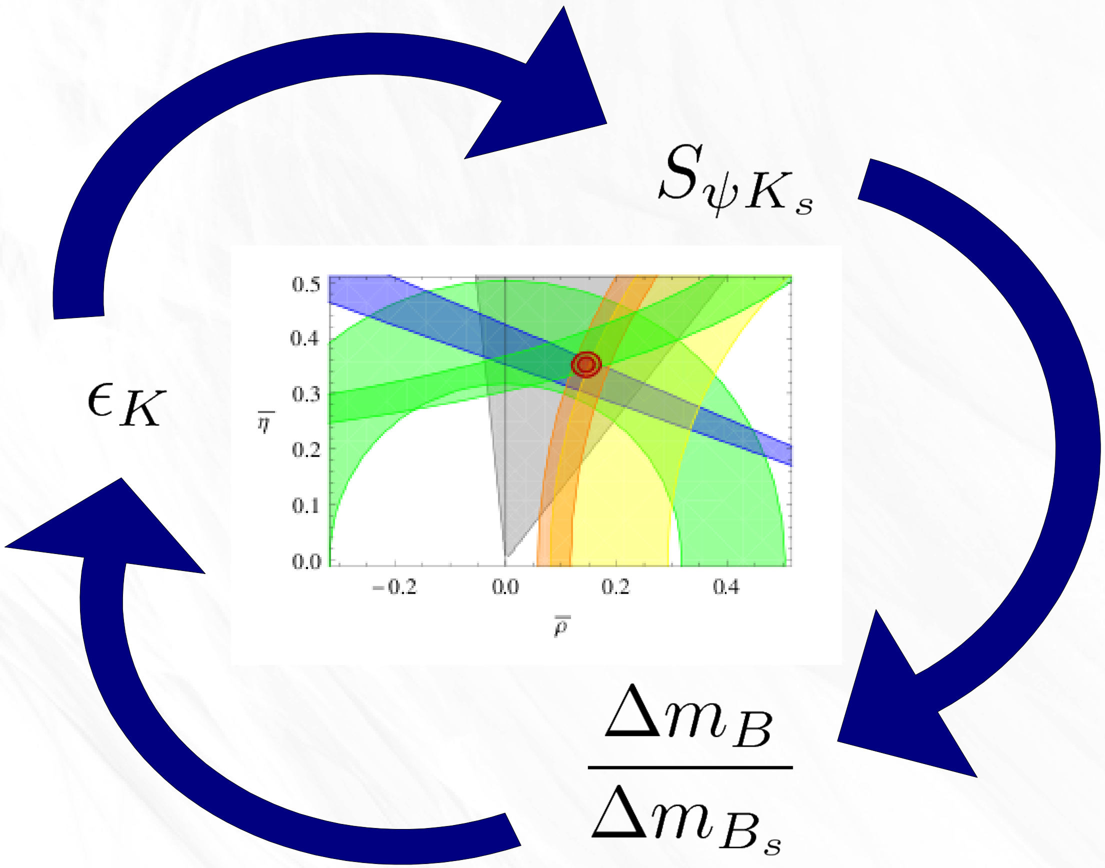
Minimal Flavour Violation Framework

- $U(3)^5$ framework built in order to suppress New Physics contributions to flavoured processes.
- SUSY masses are forced to be nearly degenerate.
- Flavour off-diagonal contributions are related to CKM and mass hierarchies: y_t, y_b.

D'Ambrosio, Giudice, Isidori, Strumia (hep-ph/0207036)

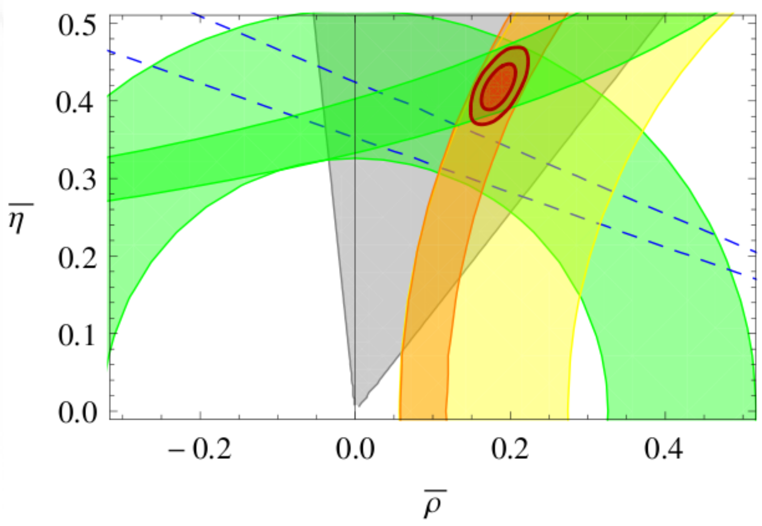
Flavour Tension in the SM

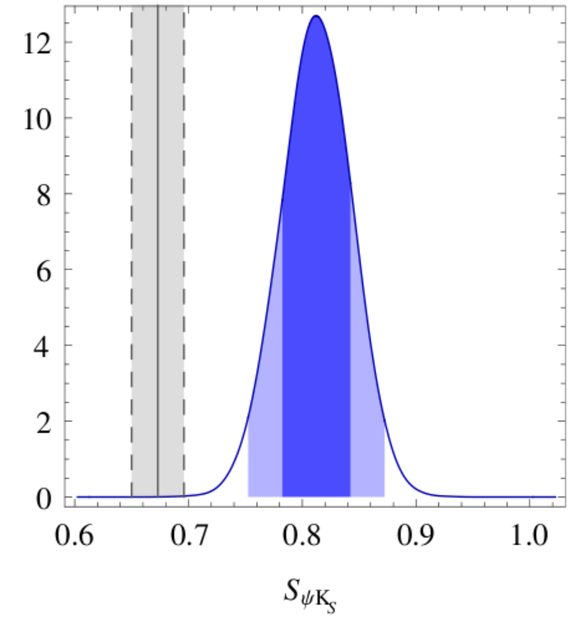


Buras, Guadagnoli (0901.2056 [hep-ph])
Altmannshofer *et al* (0909.1333 [hep-ph])

Flavour Tension in the SM

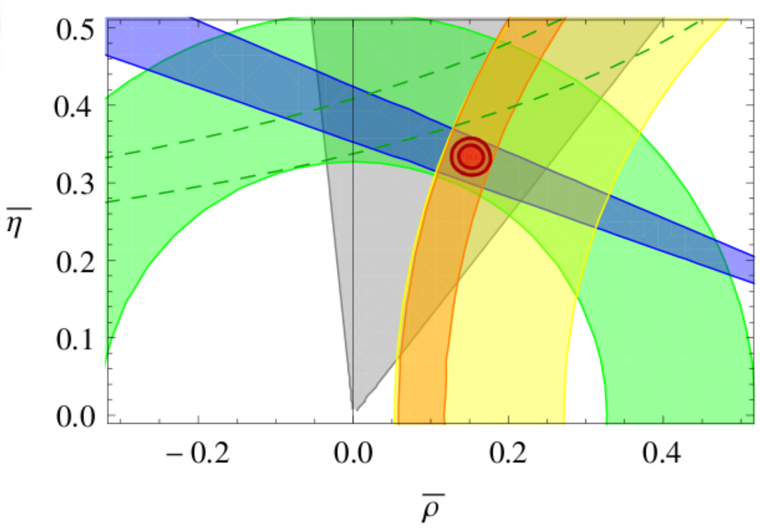
UT fit without $S_{\psi K_S}$:

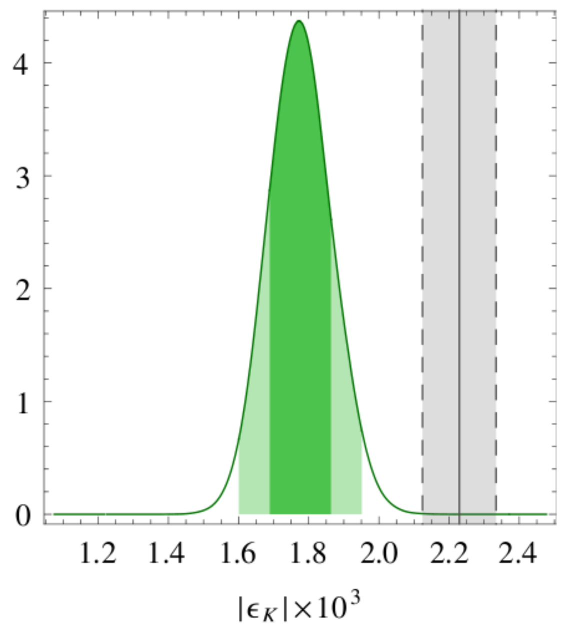




Flavour Tension in the SM

UT fit without ε_K:





U(2) Minimal Flavour Violation Framework

- We would like to establish a framework with the virtues of MFV, but with more liberty, such that flavour tension can be accommodated.
- Inspiration:
  - $U(3)^3$ expansion breaks down to $U(2)^3$ at large $\tan\beta$ Kagan, Perez, Volansky, Zapan (0903.1794 [hep-ph])
  - Flavour bounds do not strongly force the third generation squark masses to be degenerate. Giudice, Nardecchia, Romanino (0812.3610 [hep-ph])
  - U(2) SUSY flavour model Barbieri, Dvali, Hall (hep-ph/9512388)

Outline

- Construction of Framework I: Yukawas
- Construction of Framework II: Soft Masses
- Phenomenological Predictions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$U(2)^3$ Framework

$$U(2)_Q \otimes U(2)_u \otimes U(2)_d$$

$$\begin{aligned} Q^{(2)} &= (Q_1, \quad Q_2) \quad \sim \quad (\bar{2}, 1, 1) \\ u_R^{c(2)} &= (u^c_{R,1}, \quad u^c_{R,2})^T \quad \sim \quad (1, 2, 1) \\ d_R^{c(2)} &= (d^c_{R,1}, \quad d^c_{R,2})^T \quad \sim \quad (1, 1, 2) \end{aligned}$$

U(2)^3 Framework

$$U(2)_Q \otimes U(2)_u \otimes U(2)_d$$

$$\begin{aligned} Q^{(2)} &= (Q_1, \quad Q_2) &\sim& \quad (\bar{2}, 1, 1) \\ u_R^{c(2)} &= (u_{R,1}^c, \quad u_{R,2}^c)^T &\sim& \quad (1, 2, 1) \\ d_R^{c(2)} &= (d_{R,1}^c, \quad d_{R,2}^c)^T &\sim& \quad (1, 1, 2) \end{aligned}$$

$$W_q = y_t \, Q_3 \, t_R^c \, H_u + y_b \, Q_3 \, b_R^c \, H_d$$

$U(2)^3$ Spurions

$$V \quad \sim \quad (2,1,1)$$

$$Y_u = \begin{pmatrix} 0 & x_t\, V \\ 0 & 1 \end{pmatrix} y_t \qquad\qquad Y_d = \begin{pmatrix} 0 & x_b\, V \\ 0 & 1 \end{pmatrix} y_b$$

Hierarchy between V_{cb} and V_{tb} should be related to suppression in V.
(Hierarchy between V_{ub} and V_{tb} shall be understood later.)

$U(2)^3$ Spurions

$$\begin{aligned} V &\sim (2,1,1) \\ \Delta Y_u &\sim (2,\bar{2},1) \\ \Delta Y_d &\sim (2,1,\bar{2}) \end{aligned}$$

$$Y_u = \begin{pmatrix} \Delta Y_u & x_t V \\ 0 & 1 \end{pmatrix} y_t \qquad Y_d = \begin{pmatrix} \Delta Y_d & x_b V \\ 0 & 1 \end{pmatrix} y_b$$

Hierarchy between y_{f2} and y_{f3} should be related to suppression in ΔY_f.
(Hierarchy between y_{f1} and y_{f3} shall be commented later)

Explicit Parametrization

$$V = \epsilon\, U_V \underbrace{\begin{pmatrix} 0 \\ 1 \end{pmatrix}}_{\hat{s}_2} \qquad \epsilon \sim \lambda_{\mathrm{CKM}}^2$$

Explicit Parametrization

$$\begin{aligned} \Delta Y_u &= U_{Q_u}^{\dagger} \Delta Y_u^d U_U \\ \Delta Y_d &= U_{Q_d}^{\dagger} \Delta Y_d^d U_D \end{aligned}$$

$$\Delta Y_u^d = \begin{pmatrix} \lambda_{f1} & 0 \\ 0 & \lambda_{f2} \end{pmatrix} \qquad \begin{aligned} \lambda_{f1} &\sim y_{f1}/y_{f3} \\ \lambda_{f2} &\sim y_{f2}/y_{f3} \end{aligned}$$

Explicit Parametrization

$$\begin{aligned} \Delta Y_u &= U^\dagger_{Q_u} \Delta Y^d_u U_U \\ \Delta Y_d &= U^\dagger_{Q_d} \Delta Y^d_d U_D \end{aligned}$$

$$\Delta Y^d_u = \begin{pmatrix} \lambda_{f1} & 0 \\ 0 & \lambda_{f2} \end{pmatrix} \qquad \begin{aligned} \lambda_{f1} &\sim y_{f1}/y_{f3} \\ \lambda_{f2} &\sim y_{f2}/y_{f3} \end{aligned}$$

This framework does not justify the hierarchy between the first two generations.

A flavour model seeking this framework must provide some alignment mechanism in the (1-2) sector.

Explicit Parametrization

$$V = \epsilon U_V \hat{s}_2$$

$$\begin{aligned} \Delta Y_u &= U_{Q_u}^\dagger \Delta Y_u^d U_U \\ \Delta Y_d &= U_{Q_d}^\dagger \Delta Y_d^d U_D \end{aligned}$$

↓ Field redefinition

$$Y_u = \begin{pmatrix} U_{Q_u}^\dagger \Delta Y_u^d & x_t \, \epsilon \, \hat{s}_2 \\ 0 & 1 \end{pmatrix} y_t$$

$$Y_d = \begin{pmatrix} U_{Q_d}^\dagger \Delta Y_d^d & x_b \, \epsilon \, \hat{s}_2 \\ 0 & 1 \end{pmatrix} y_b$$

Explicit Parametrization

$$Y_f = \begin{pmatrix} U^\dagger_{Q_f} \Delta Y^d_f & x_f\,\epsilon\,\hat{s}_2 \\ 0 & 1 \end{pmatrix} y_f$$

$$U_{Q_f} = \begin{pmatrix} c_f & s_f\, e^{i\alpha_f} \\ -s_f\, e^{-i\alpha_f} & c_f \end{pmatrix}$$

Explicit Parametrization

$$Y_f = \begin{pmatrix} U^\dagger_{Q_f} \Delta Y^d_f & x_f \, \epsilon \, \hat{s}_2 \\ 0 & 1 \end{pmatrix} y_f$$

$$U_{Q_f} = \begin{pmatrix} c_f & s_f \, e^{i\alpha_f} \\ -s_f \, e^{-i\alpha_f} & c_f \end{pmatrix}$$

$$x_f \to x_f \, e^{i\phi_f}$$

We have **three** independent phases, we shall write down four just to keep matrices symmetric.

α_u ϕ_t α_d ϕ_b

Diagonalization Matrices

$$U_{fL} Y_f U_{fR}^\dagger = Y_f^{\rm diag}$$

$$U_{uL} = \begin{pmatrix} c_u & s_u\, e^{i\alpha_u} & -s_u s_t e^{i(\alpha_u+\phi_t)} \\ -s_u\, e^{-i\alpha_u} & c_u c_t & -c_u s_t e^{i\phi_t} \\ 0 & s_t e^{-i\phi_t} & c_t \end{pmatrix}$$

$$s_t/c_t = x_t \epsilon$$

Diagonalization Matrices

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$$s_t / c_t = x_t \epsilon$$

At the CKM level, we shall see that the hierarchy between V_{us} and V_{cs} is connected to the hierarchy between V_{ub} and V_{cb}.

Diagonalization Matrices

$$U_{fL} Y_f U_{fR}^{\dagger} = Y_f^{\rm diag}$$

$$U_{uL} = \begin{pmatrix} c_u & s_u\, e^{i\alpha_u} & -s_u s_t e^{i(\alpha_u + \phi_t)} \\ -s_u\, e^{-i\alpha_u} & c_u c_t & -c_u s_t e^{i\phi_t} \\ 0 & s_t e^{-i\phi_t} & c_t \end{pmatrix}$$

$$U_{uR} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & -\lambda_{u2} s_t e^{i\phi_t} \\ 0 & \lambda_{u2} s_t e^{-i\phi_t} & 1 \end{pmatrix}$$

CKM Matrix

$$V_{\mathrm{CKM}} = (U_{uL}^{\dagger} \cdot U_{dL})$$

$$\begin{pmatrix} c_u c_d + s_u s_d\, e^{i(\alpha_d - \alpha_u)} & -c_u s_d\, e^{-i\alpha_d} + s_u c_d\, e^{-i\alpha_u} & s_u s e^{-i(\alpha_u - \xi)} \\ c_u s_d\, e^{i\alpha_d} - s_u c_d\, e^{i\alpha_u} & c_u c_d + s_u s_d\, e^{i(\alpha_u - \alpha_d)} & c_u s e^{i\xi} \\ -s_d s\, e^{i(\alpha_d - \xi)} & -s c_d e^{-i\xi} & 1 \end{pmatrix}$$

$$(s/c)e^{i\xi} = \epsilon\, \left(x_b e^{-i\phi_b} - x_t e^{-i\phi_t}\right)$$

CKM Matrix

$$V_{\text{CKM}} = (U_{uL}^{\dagger} \cdot U_{dL})$$

$$\begin{pmatrix} c_u c_d + s_u s_d\, e^{i(\alpha_d - \alpha_u)} & -c_u s_d\, e^{-i\alpha_d} + s_u c_d\, e^{-i\alpha_u} & s_u s e^{-i(\alpha_u - \xi)} \\ c_u s_d\, e^{i\alpha_d} - s_u c_d\, e^{i\alpha_u} & c_u c_d + s_u s_d\, e^{i(\alpha_u - \alpha_d)} & c_u s e^{i\xi} \\ -s_d s\, e^{i(\alpha_d - \xi)} & -s c_d e^{-i\xi} & 1 \end{pmatrix}$$

CKM Matrix

$$V_{\text{CKM}} = (U^{\dagger}_{uL} \cdot U_{dL})$$

$$\begin{pmatrix} c_u c_d + s_u s_d \, e^{i(\alpha_d - \alpha_u)} & -c_u s_d \, e^{-i\alpha_d} + s_u c_d \, e^{-i\alpha_u} & s_u s e^{-i(\alpha_u - \xi)} \\ c_u s_d \, e^{i\alpha_d} - s_u c_d \, e^{i\alpha_u} & c_u c_d + s_u s_d \, e^{i(\alpha_u - \alpha_d)} & c_u s e^{i\xi} \\ -s_d s \, e^{i(\alpha_d - \xi)} & -s c_d e^{-i\xi} & 1 \end{pmatrix}$$

CKM Matrix

$$V_{\mathrm{CKM}} = (U_{uL}^{\dagger} \cdot U_{dL})$$

$$\begin{pmatrix} c_u c_d + s_u s_d\, e^{i(\alpha_d-\alpha_u)} & -c_u s_d\, e^{-i\alpha_d} + s_u c_d\, e^{-i\alpha_u} & s_u s e^{-i(\alpha_u-\xi)} \\ c_u s_d\, e^{i\alpha_d} - s_u c_d\, e^{i\alpha_u} & c_u c_d + s_u s_d\, e^{i(\alpha_u-\alpha_d)} & c_u s e^{i\xi} \\ -s_d s\, e^{i(\alpha_d-\xi)} & -s c_d e^{-i\xi} & 1 \end{pmatrix}$$

CKM Matrix

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$$\left(s_u c_d - c_u s_d\, e^{i(\alpha_u - \alpha_d)} \right) e^{-i\alpha_u}$$

CKM Matrix

$$V_{\mathrm{CKM}} = (U_{uL}^{\dagger} \cdot U_{dL})$$

$$\begin{pmatrix} c_u c_d + s_u s_d\, e^{i(\alpha_d - \alpha_u)} & -c_u s_d\, e^{-i\alpha_d} + s_u c_d\, e^{-i\alpha_u} & s_u s e^{-i(\alpha_u - \xi)} \\ c_u s_d\, e^{i\alpha_d} - s_u c_d\, e^{i\alpha_u} & c_u c_d + s_u s_d\, e^{i(\alpha_u - \alpha_d)} & c_u s e^{i\xi} \\ -s_d s\, e^{i(\alpha_d - \xi)} & -s c_d e^{-i\xi} & 1 \end{pmatrix}$$

$$\left(s_u c_d - c_u s_d\, e^{i(\alpha_u - \alpha_d)}\right) e^{-i\alpha_u}$$

$$\left(s_u c_d - c_u s_d\, e^{-i\phi}\right) e^{-i\alpha_u}$$

CKM Matrix

$$V_{\rm CKM} = (U_{uL}^{\dagger} \cdot U_{dL})$$

$$\begin{pmatrix} c_u c_d + s_u s_d\, e^{i(\alpha_d - \alpha_u)} & -c_u s_d\, e^{-i\alpha_d} + s_u c_d\, e^{-i\alpha_u} & s_u s e^{-i(\alpha_u - \xi)} \\ c_u s_d\, e^{i\alpha_d} - s_u c_d\, e^{i\alpha_u} & c_u c_d + s_u s_d\, e^{i(\alpha_u - \alpha_d)} & c_u s e^{i\xi} \\ -s_d s e^{i(\alpha_d - \xi)} & -s c_d e^{-i\xi} & 1 \end{pmatrix}$$

$$\left(s_u c_d - c_u s_d\, e^{i(\alpha_u - \alpha_d)}\right)\, e^{-i\alpha_u}$$

$$\left(s_u c_d - c_u s_d\, e^{-i\phi}\right)\, e^{-i\alpha_u}$$

$$\lambda\, e^{i\delta}\, e^{-i\alpha_u}$$

CKM Matrix

$$V_{\text{CKM}} = (U^{\dagger}_{uL} \cdot U_{dL})$$

$$\begin{pmatrix} 1-\lambda^2/2 & \lambda & s_u s e^{-i\delta} \\ -\lambda & 1-\lambda^2/2 & c_u s \\ -s_d s\, e^{i(\phi+\delta)} & -s c_d & 1 \end{pmatrix}$$

$$\begin{aligned} |s| &= 0.0410 \pm 0.0004 \\ s_u &= 0.0916 \pm 0.005 \\ s_d &= -0.22 \pm 0.02 \\ \cos\phi &= -0.13 \pm 0.2 \end{aligned}$$

What about SUSY?

Soft Masses: Unbroken Limit:

$$m_{\tilde{f}}^2 = \begin{pmatrix} m_{f_h}^2 & 0 & 0 \\ 0 & m_{f_h}^2 & 0 \\ 0 & 0 & m_{f_l}^2 \end{pmatrix}$$

Same spurions that generated the Yukawa structure shall generate the soft mass structure.

Soft Masses

$$m_{\tilde{u}}^2 = m_{u_h}^2 \begin{pmatrix} 1 + c_{uu} \Delta Y_u^T \Delta Y_u^* & x_u e^{-i\phi_u} \Delta Y_u^T V^* \\ x_u e^{i\phi_u} V^T \Delta Y_u^* & m_{u_l}^2 / m_{u_h}^2 \end{pmatrix}$$

Soft Masses

$$m_{\tilde{u}}^2 = m_{u_h}^2 \begin{pmatrix} 1 + c_{uu} \Delta Y_u^T \Delta Y_u^* & x_u e^{-i\phi_u} \Delta Y_u^T V^* \\ x_u e^{i\phi_u} V^T \Delta Y_u^* & m_{u_l}^2 / m_{u_h}^2 \end{pmatrix}$$

$$m_{\tilde{d}}^2 = m_{d_h}^2 \begin{pmatrix} 1 + c_{dd} \Delta Y_d^T \Delta Y_d^* & x_d e^{-i\phi_d} \Delta Y_d^T V^* \\ x_d e^{i\phi_d} V^T \Delta Y_d^* & m_{d_l}^2 / m_{d_h}^2 \end{pmatrix}$$

Soft Masses

$$m_{\tilde{u}}^2 = m_{u_h}^2 \begin{pmatrix} 1 + c_{uu}\Delta Y_u^T \Delta Y_u^* & x_u e^{-i\phi_u} \Delta Y_u^T V^* \\ x_u e^{i\phi_u} V^T \Delta Y_u^* & m_{u_l}^2 / m_{u_h}^2 \end{pmatrix}$$

$$m_{\tilde{d}}^2 = m_{d_h}^2 \begin{pmatrix} 1 + c_{dd}\Delta Y_d^T \Delta Y_d^* & x_d e^{-i\phi_d} \Delta Y_d^T V^* \\ x_d e^{i\phi_d} V^T \Delta Y_d^* & m_{d_l}^2 / m_{d_h}^2 \end{pmatrix}$$

$$m_{\tilde{Q}}^2 = m_{Q_h}^2 \begin{pmatrix} 1 + c_{Qv} V^* V^T + c_{Qu}\Delta Y_u^* \Delta Y_u^T + c_{Qd}\Delta Y_d^* \Delta Y_d^T & x_Q e^{-i\phi_Q} V^* \\ x_Q e^{i\phi_Q} V^T & m_{Q_l}^2 / m_{Q_h}^2 \end{pmatrix}$$

Squark Mixing Matrices

$$W_L^{d\dagger}\ m^2_{\tilde{Q}}\ W_L^d = (m^2_{\tilde{Q}})^{\rm diag}$$

$$W_L^d = \begin{pmatrix} c_d & \kappa^* & -\kappa^* s_L e^{i\gamma} \\ -\kappa & c_d & -c_d s_L e^{i\gamma} \\ 0 & s_L e^{-i\gamma} & 1 \end{pmatrix}$$

Squark Mixing Matrices

$$W_L^{d\dagger}\ m^2_{\tilde{Q}}\ W_L^d = (m^2_{\tilde{Q}})^{\rm diag}$$

$$W_L^d = \begin{pmatrix} c_d & \kappa^* & -\kappa^* s_L e^{i\gamma} \\ -\kappa & c_d & -c_d s_L e^{i\gamma} \\ 0 & s_L e^{-i\gamma} & 1 \end{pmatrix}$$

$$\kappa = c_d V_{td}/V_{ts}$$

No new phases on the (1-2) sector!

Squark Mixing Matrices

$$W_L^{d\dagger}\ m^2_{\tilde{Q}}\ W_L^d = (m^2_{\tilde{Q}})^{\rm diag}$$

$$W_L^d = \left(\begin{array}{ccc} c_d & \kappa^* & -\kappa^* s_L e^{i\gamma} \\ -\kappa & c_d & -c_d s_L e^{i\gamma} \\ 0 & s_L e^{-i\gamma} & 1 \end{array}\right)$$

$$\kappa = c_d V_{td}/V_{ts}$$

No new phases on the (1-2) sector!

$$s_L e^{i\gamma} \quad = \quad e^{-i\xi}(s_{x_b} e^{-i\phi_b} + s_Q e^{-i\phi_Q})$$

New phase on the (1-3) and (2-3) sectors!

Squark Mixing Matrices

$$W_L^{d\dagger}\ m^2_{\tilde{Q}}\ W_L^d = (m^2_{\tilde{Q}})^{\rm diag}$$

$$W_L^d = \begin{pmatrix} c_d & \kappa^* & -\kappa^* s_L e^{i\gamma} \\ -\kappa & c_d & -c_d s_L e^{i\gamma} \\ 0 & s_L e^{-i\gamma} & 1 \end{pmatrix}$$

New CPV in (1-3) sector is connected to CPV in (2-3) sector!

$$\kappa = c_d V_{td}/V_{ts}$$

No new phases on the (1-2) sector!

$$s_L e^{i\gamma} \quad = \quad e^{-i\xi}(s_{x_b} e^{-i\phi_b} + s_Q e^{-i\phi_Q})$$

New phase on the (1-3) and (2-3) sectors!

Squark Mixing Matrices

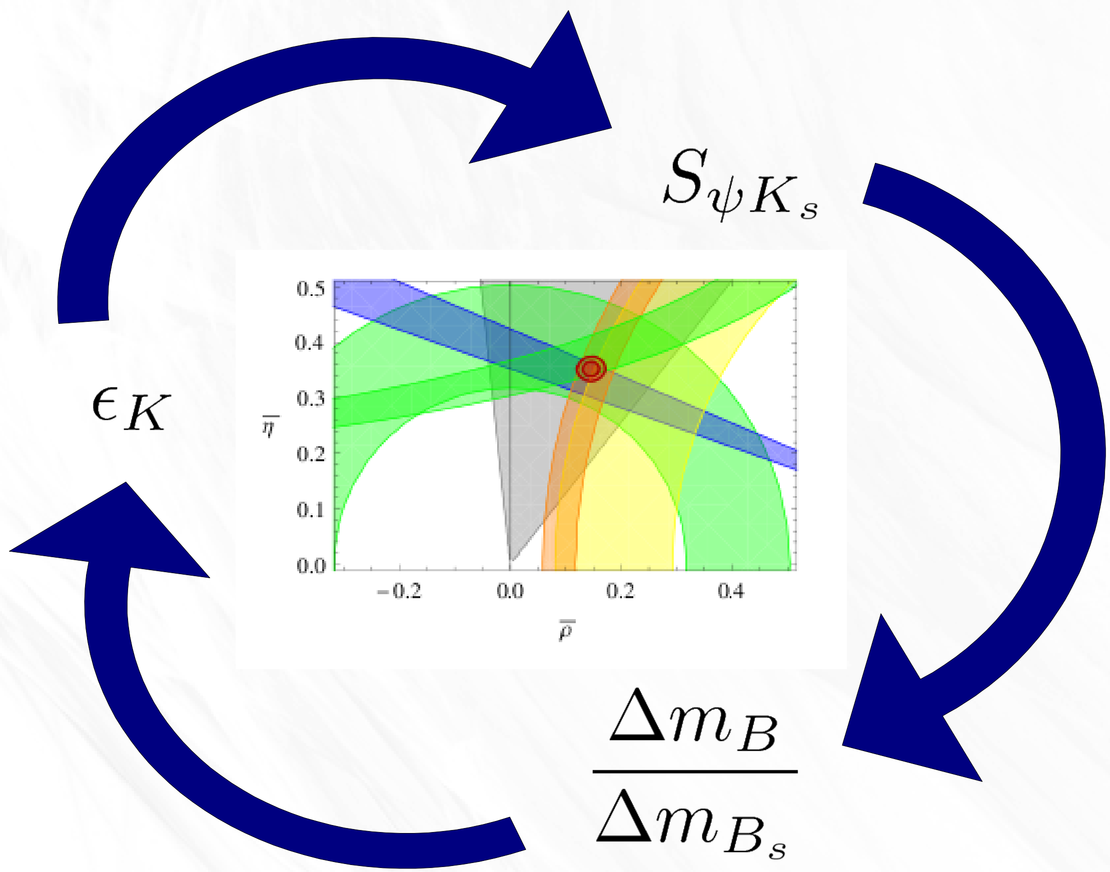
$$W_L^{d\dagger}\; m_{\tilde{Q}}^2\; W_L^d = (m_{\tilde{Q}}^2)^{\rm diag}$$

$$W_L^d = \begin{pmatrix} c_d & \kappa^* & -\kappa^* s_L e^{i\gamma} \\ -\kappa & c_d & -c_d s_L e^{i\gamma} \\ 0 & s_L e^{-i\gamma} & 1 \end{pmatrix}$$

$$W_R^d = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & \lambda_{d2}\, s_R^d\, e^{i\gamma_d} \\ 0 & -\lambda_{d2}\, s_R^d\, e^{-i\gamma_d} & 1 \end{pmatrix}$$

No large RR mixings

Flavour Tension in the SM



New SUSY Contributions

$$
\begin{aligned}
\epsilon_K &= \epsilon_K^{\mathrm{SM(tt)}} \times \left(1 + x^2 F_0\right) + \epsilon_K^{\mathrm{SM(tc+cc)}} \\
S_{\psi K_S} &= \sin\left(2\beta + \arg\left(1 + x F_0 e^{-2i\gamma}\right)\right) \\
\frac{\Delta M_d}{\Delta M_s} &= \frac{\Delta M_d^{\mathrm{SM}}}{\Delta M_s^{\mathrm{SM}}}
\end{aligned}
$$

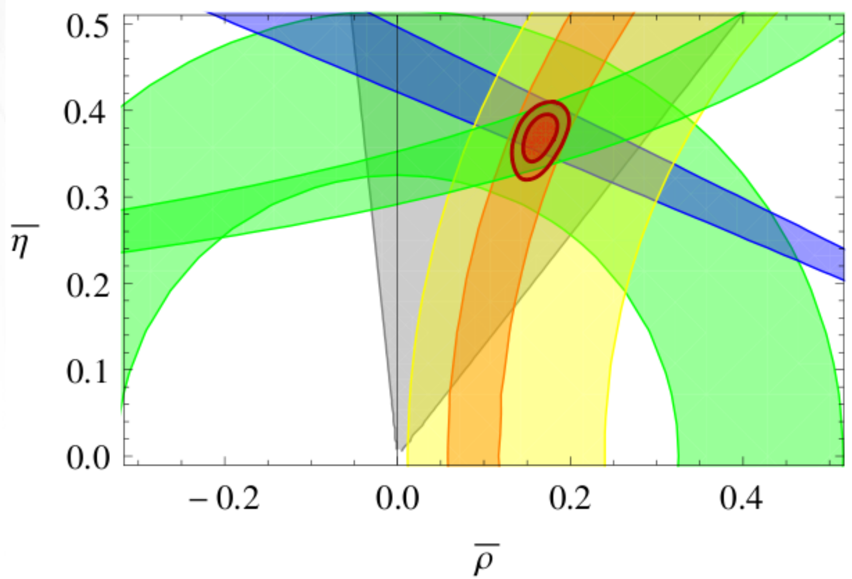
New SUSY Contributions

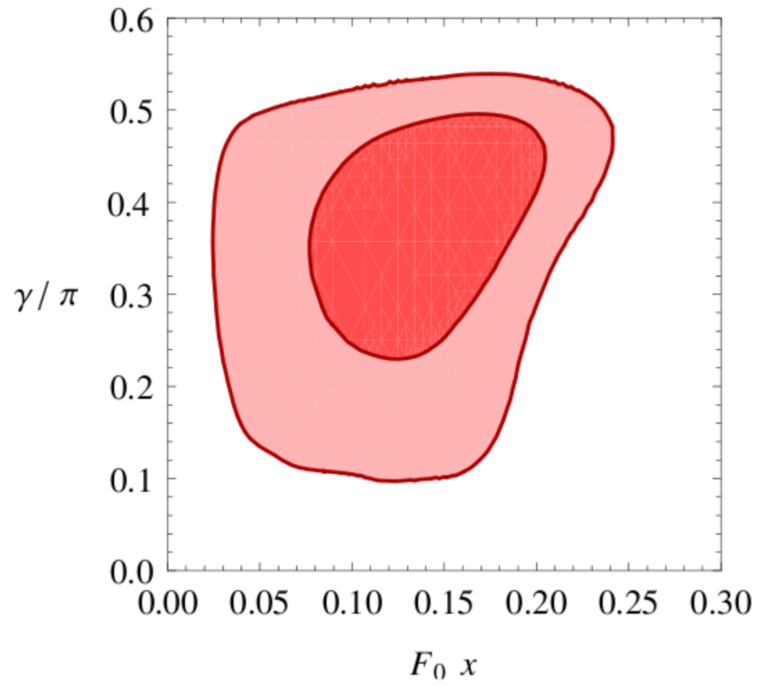
$$\begin{aligned}\epsilon_K &= \epsilon_K^{\mathrm{SM(tt)}} \times \left(1 + x^2 F_0\right) + \epsilon_K^{\mathrm{SM(tc+cc)}} \\ S_{\psi K_S} &= \sin\left(2\beta + \arg\left(1 + x F_0 e^{-2i\gamma}\right)\right) \\ \frac{\Delta M_d}{\Delta M_s} &= \frac{\Delta M_d^{\mathrm{SM}}}{\Delta M_s^{\mathrm{SM}}}\end{aligned}$$

$$F_0 = \frac{2}{3}\left(\frac{g_s}{g}\right)^4 \frac{m_W^2}{m_{Q_3}^2} \frac{1}{S_0(x_t)} \left[f_0(x_g) + \mathcal{O}\left(\frac{m_{Q_l}^2}{m_{Q_h}^2}\right)\right]$$

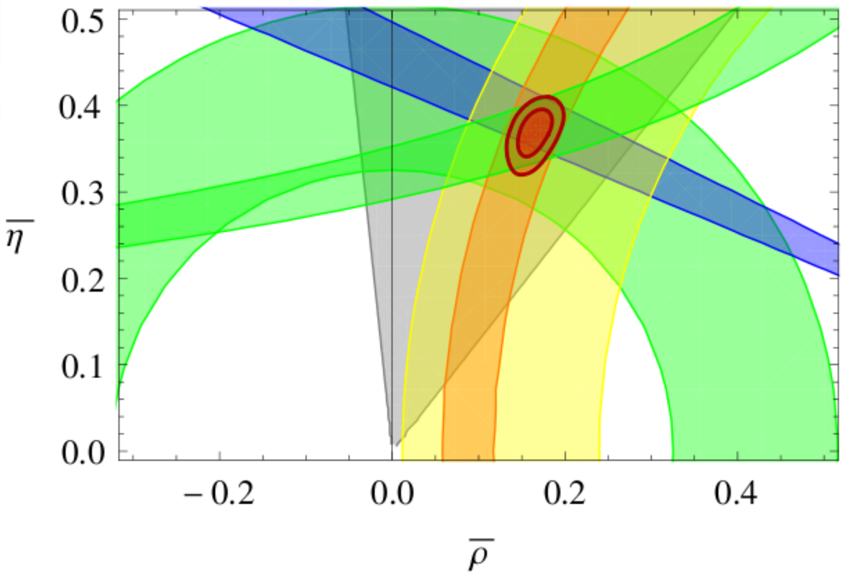
$$x = \frac{c_d^2 s_L^2}{|V_{ts}|^2} \qquad x_g = \frac{m_{\tilde{g}}^2}{m_{Q3}^2}$$

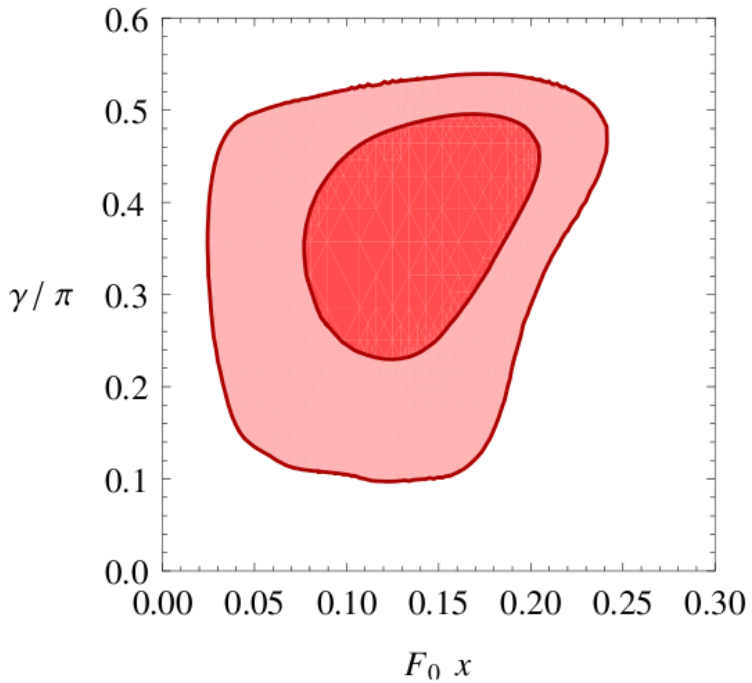
Fit with SUSY Contribution





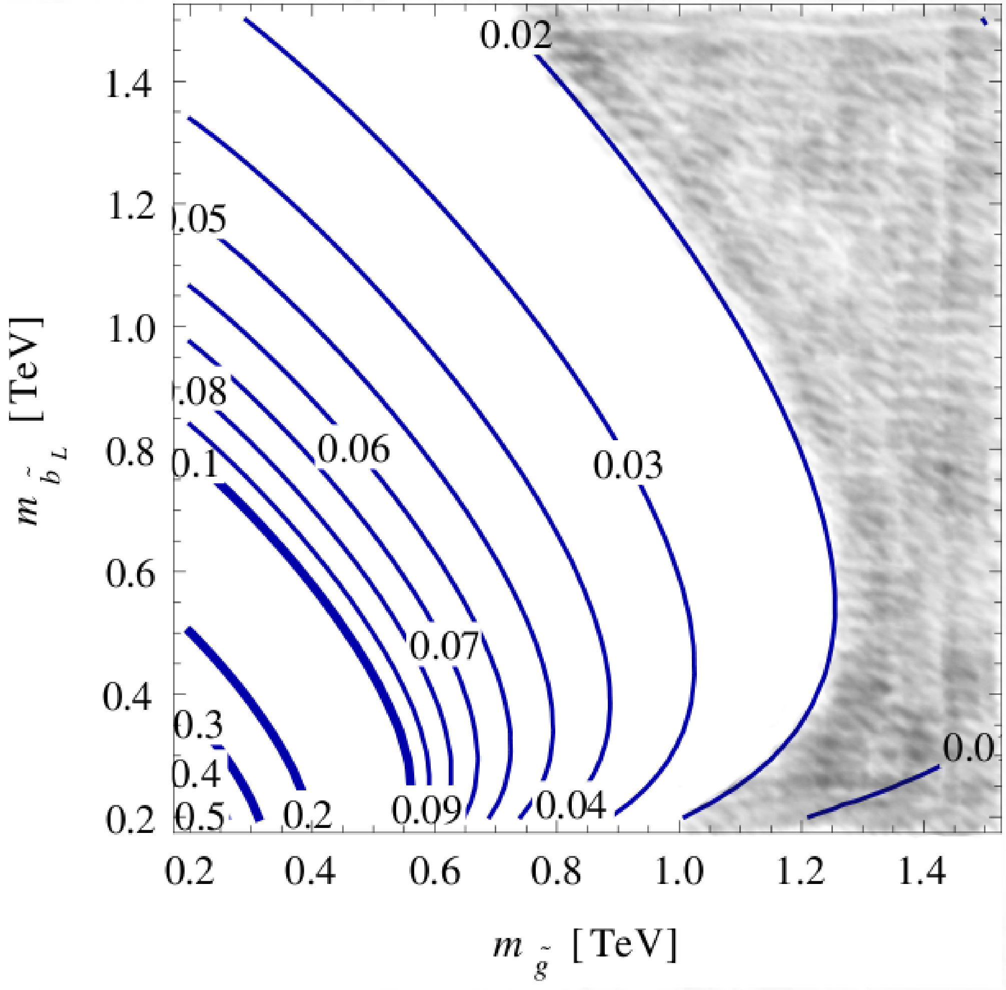
Fit with SUSY Contribution





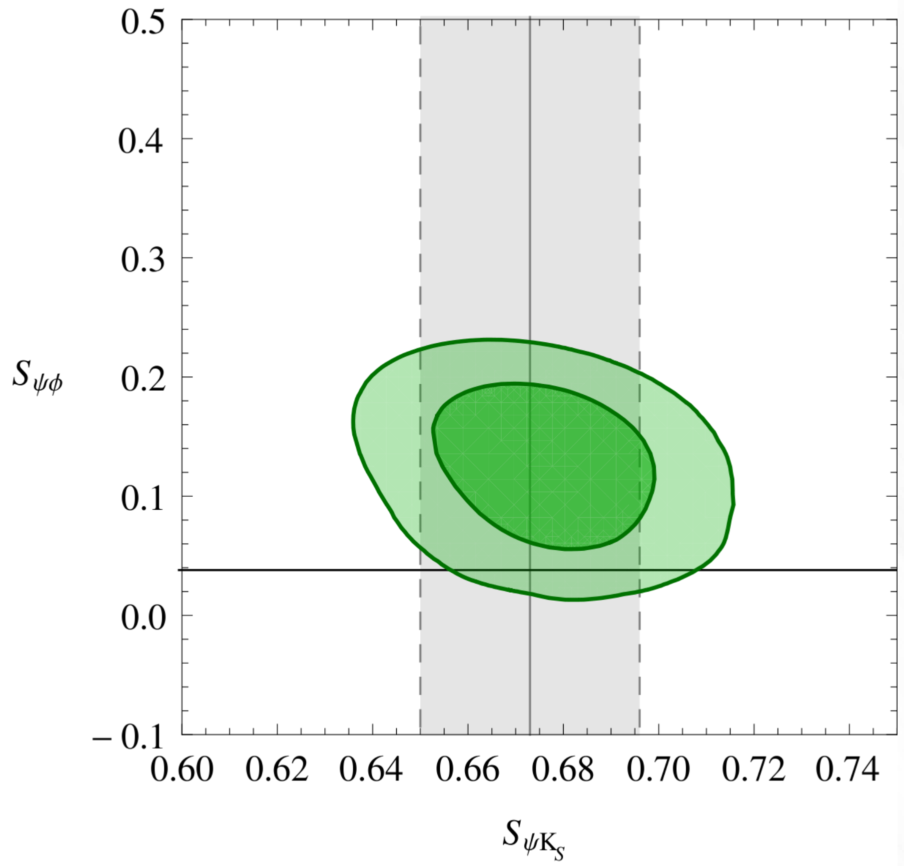
$$(\chi^2/N_{\mathrm{d.o.f.}})_{\mathrm{SM}} = 9.8/5 \qquad (\chi^2/N_{\mathrm{d.o.f.}})_{\mathrm{SUSY}} = 0.7/2$$

Predictions from Fit



Light spectrum for third generation sfermions!

Predictions from Fit



Large $S_{\psi\phi}$!!

Conclusions

- U(2)-based MFV is a new framework capable of building the Yukawa matrices.
- Allows more freedom than MFV at the moment of calculating the SUSY contributions.
- Freedom is not absolute: there exist correlations between contributions to different observables.

Conclusions

- Fit on flavoured CPV observables give two main predictions:
  - Masses of third generation squarks should be light.
  - Large deviation to $S_{\psi\phi}$ should be observed.

Backup Slides

$U(2)^3$ Framework for Small *tan*β

$$U(2)_Q \otimes U(2)_u \otimes U(2)_d \otimes U(1)_b$$

$$\begin{aligned} d_R^{c(2)} &\rightarrow e^{i\beta}\, d_R^{c(2)} \\ b_R^c &\rightarrow e^{i\beta}\, b_R^c \end{aligned}$$

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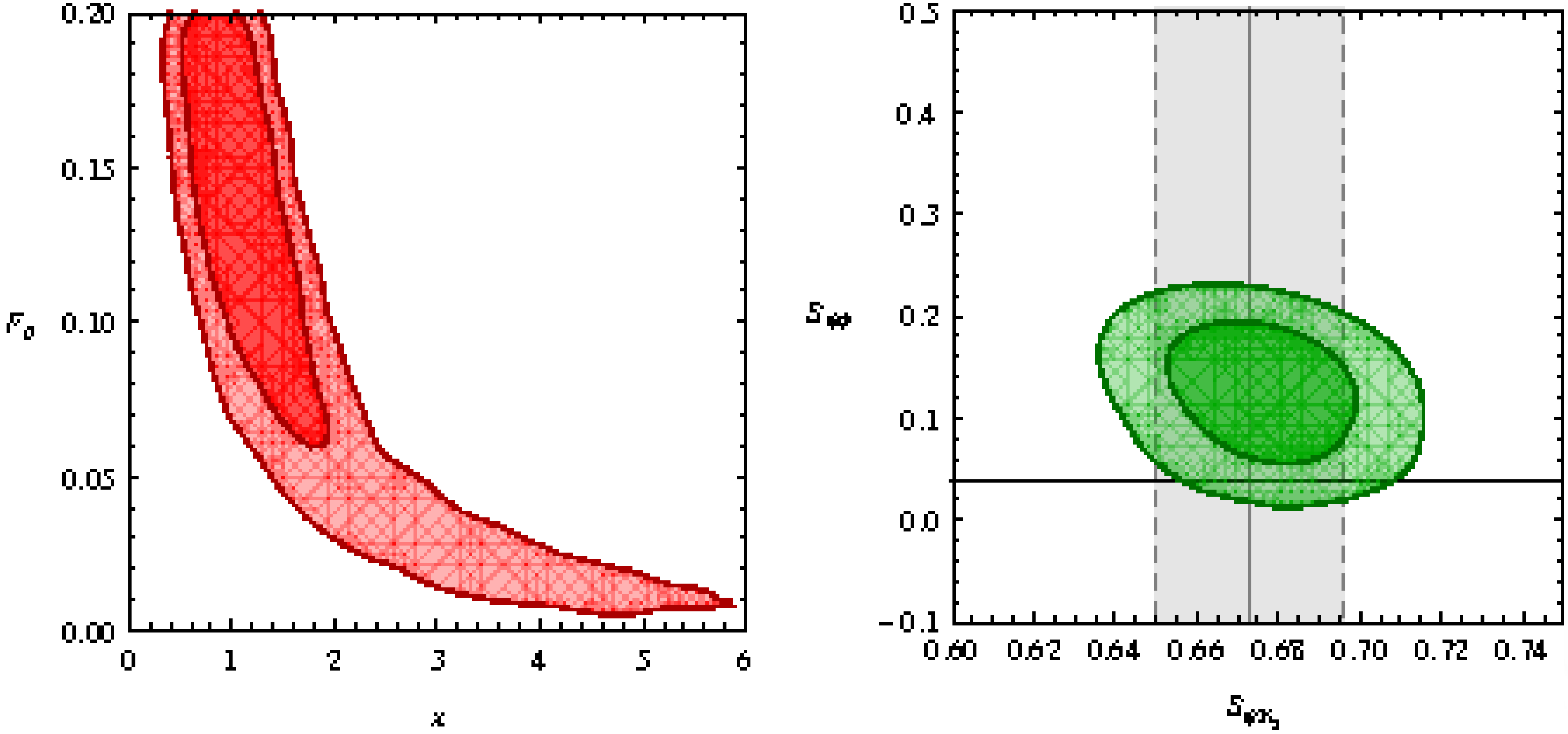
$$y_b \rightarrow e^{-i\beta}\, y_b$$

Small Spurion

Input to CKM Fit

$\|V_{ud}\|$	$0.97425(22)$	f_K	(155.8 ± 1.7) MeV
$\|V_{us}\|$	$0.2254(13)$	$\hat{B}_K$	0.724 ± 0.030
$\|V_{cb}\|$	$(40.89 \pm 0.70) \times 10^{-3}$	κ_ϵ	0.94 ± 0.02
$\|V_{ub}\|$	$(3.97 \pm 0.45) \times 10^{-3}$	$f_{B_s}\sqrt{\hat{B}_s}$	(291 ± 16) MeV
γ_{CKM}	$(74 \pm 11)^\circ$	ξ	1.23 ± 0.04
$\|\epsilon_K\|$	$(2.229 \pm 0.010) \times 10^{-3}$		
$S_{\psi K_S}$	0.673 ± 0.023		
ΔM_d	$(0.507 \pm 0.004)\,\mathrm{ps}^{-1}$		
ΔM_s	$(17.77 \pm 0.12)\,\mathrm{ps}^{-1}$		

Fit to F_0 and x



Dynamical Two-Site Model

$$G_1^{SM} \otimes G_2^{SM}$$

Third generation
Higgs

First + second generation

↓

U(2) symmetry

Dynamical Two-Site Model

Chiral field	G_1^{SM}	G_2^{SM}
χ_h	$(3, 2, \frac{1}{6})$	$(\bar{3}, 2, -\frac{1}{6})$
$\tilde{\chi}_h$	$(\bar{3}, 2, -\frac{1}{6})$	$(3, 2, \frac{1}{6})$
χ_ℓ	$(1, 2, \frac{1}{2})$	$(1, 2, -\frac{1}{2})$
$\tilde{\chi}_\ell$	$(1, 2, -\frac{1}{2})$	$(1, 2, \frac{1}{2})$

$$Y_u,\, Y_d \sim \begin{pmatrix} \epsilon_\ell & \epsilon_\ell & \epsilon_h \\ \epsilon_\ell & \epsilon_\ell & \epsilon_h \\ \epsilon_\ell \epsilon_h & \epsilon_\ell \epsilon_h & 1 \end{pmatrix}$$