Flavor Violation and Partial Compositeness

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Based on 1205.5803 in collaboration with
B. Keren-Zur, P. Lodone, D. Pappadopulo, R. Rattazzi , L. Vecchi

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Outline

- CP violation in D decays
- Partial Compositeness
- Composite Higgs with PC
- Supersymmetry with PC
- Conclusions

CP Asymmetry in D decays

$$A_{\text{raw}} = \frac{N(D^0 \to f) - N(\overline{D}^0 \to f)}{N(D^0 \to f) + N(\overline{D}^0 \to f)}$$

$$\Delta A_{CP} = A_{\text{raw}}(K^-K^+) - A_{\text{raw}}(\pi^-\pi^+) \approx A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+)$$

$$\Delta A_{CP} \approx \Delta a_{CP}^{\text{dir}}$$

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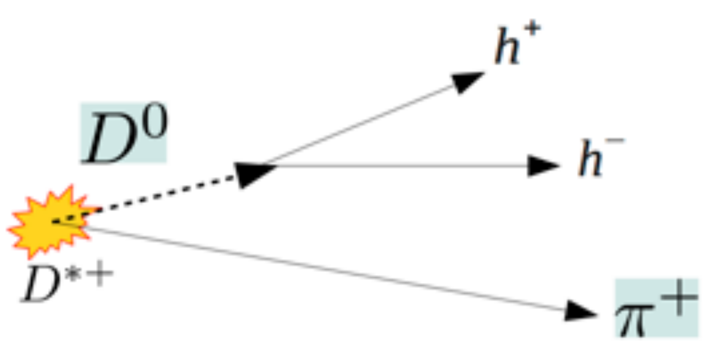

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LHCb 1112.0938

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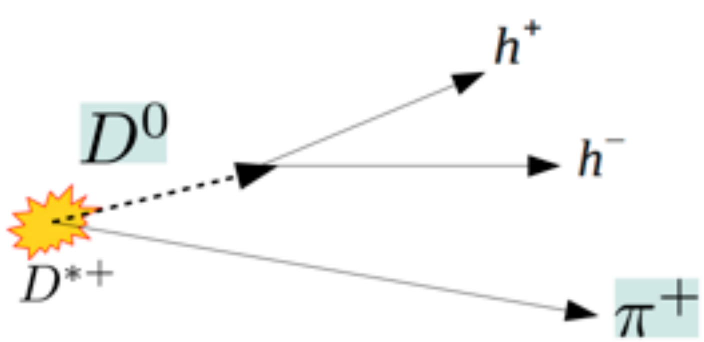

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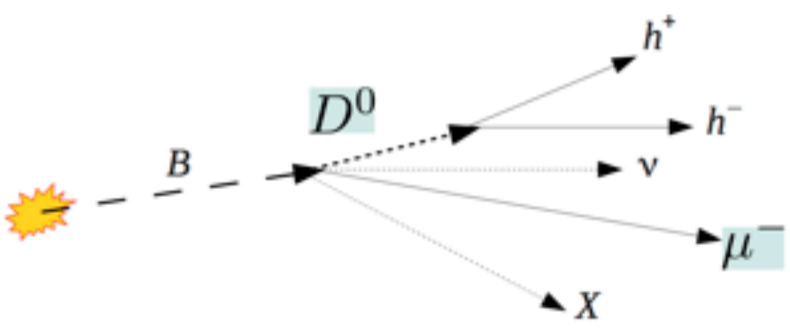


$$\Delta A_{CP} = (0.49 \pm 0.30 \pm 0.14)\%$$

LHCb 1303.2614

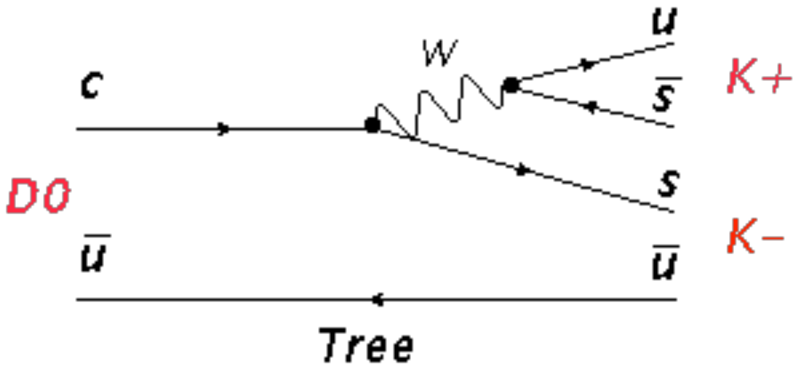
$$\Delta a_{CP}^{\text{dir}} = -(0.33 \pm 0.12)\%$$

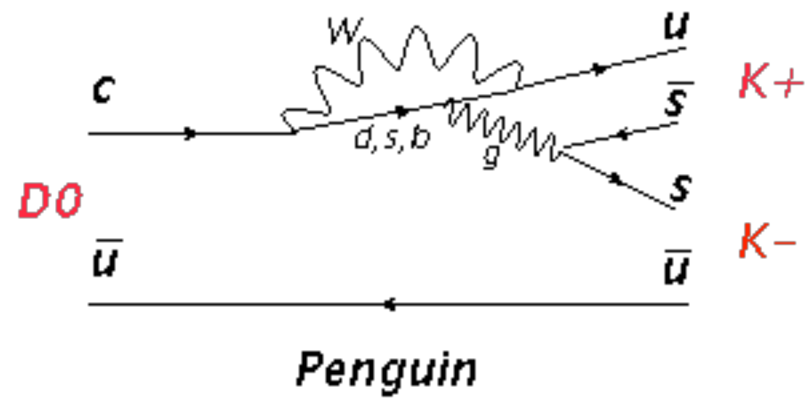
HFAG

CP Asymmetry in D decays

- Assumption 1: $\Delta A_{CP} = \mathcal{O}(0.5\%)$

Standard Model?





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$$\mathcal{O}\left(\frac{V_{cb}V_{ub}}{V_{cs}V_{us}}\frac{\alpha_s}{\pi}\right) \sim 10^{-4}$$

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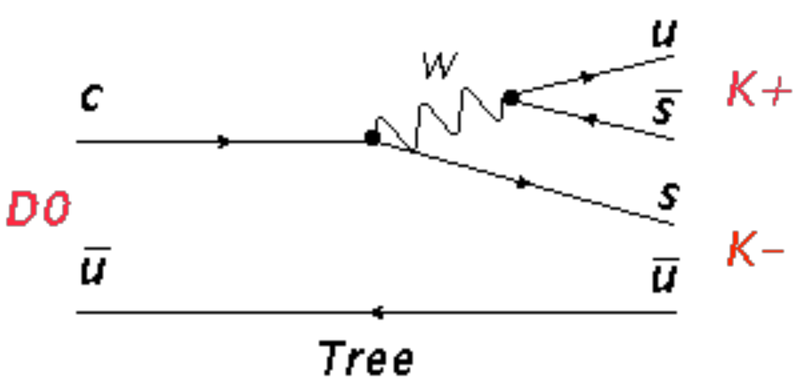

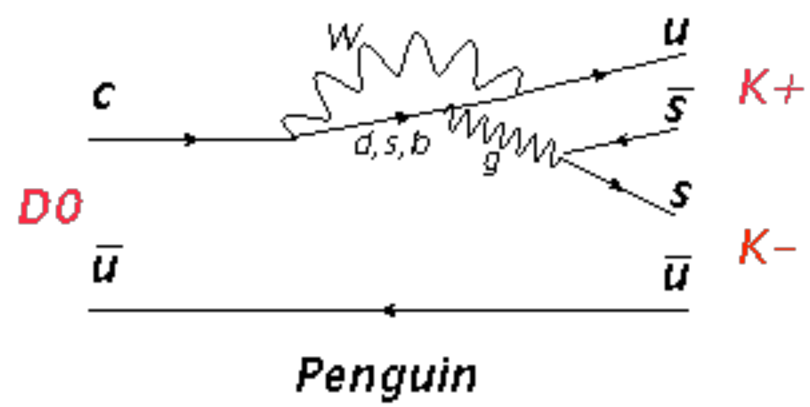

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- Assumption 2: New Physics (Non MFV!)

Model independent analysis

Isidori, Kamenik, Ligeti, Perez 1111.4987

- At the effective field theory level we have:

$$\mathcal{H}^{\text{eff}-\text{NP}}_{|\Delta c|=1} = \frac{G_F}{\sqrt{2}} \sum_i C_i^{\text{NP}} Q_i$$

$$\begin{aligned}
Q_1^q &= (\bar{u}q)_{V-A}\,(\bar{q}c)_{V-A} \\
Q_2^q &= (\bar{u}_\alpha q_\beta)_{V-A}\,(\bar{q}_\beta c_\alpha)_{V-A}\,, \\
Q_5^q &= (\bar{u}c)_{V-A}\,(\bar{q}q)_{V+A}\,, \\
Q_6^q &= (\bar{u}_\alpha c_\beta)_{V-A}\,(\bar{q}_\beta q_\alpha)_{V+A}\,, \\
Q_7 &= -\frac{e}{8\pi^2}\, m_c\, \bar{u}\sigma_{\mu\nu}(1+\gamma_5)F^{\mu\nu}\, c\,, \\
Q_8 &= -\frac{g_s}{8\pi^2}\, m_c\, \bar{u}\sigma_{\mu\nu}(1+\gamma_5)T^a G_a^{\mu\nu} c\,,
\end{aligned}$$

$$\Delta a_{CP} \approx (0.13\%)\text{Im}(\Delta R^{\text{SM}}) + 9\sum_i \text{Im}(C_i^{\text{NP}})\,\text{Im}(\Delta R_i^{\text{NP}})$$

keep track of the hadronic uncertainties...
0.1-0.2 as estimated using the tools in Kagan, etal. hep-ph/0609178

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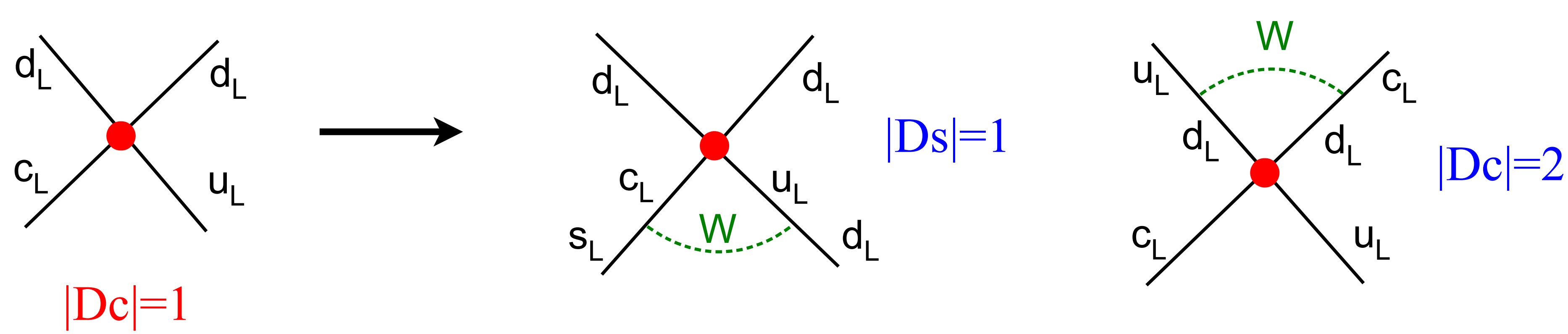
- Possible bounds from other observables: D mixing, CPV in kaon system,...



- Dipole operators are allowed $\quad Q_8 = -\frac{g_s}{8\pi^2}\, m_c\, \bar{u}\sigma_{\mu\nu}(1+\gamma_5)T^a G_a^{\mu\nu} c$

Partial Compositeness

- In TC theories techni-fermions break the EW dynamically $\langle TT^c \rangle \propto v^3$
- Fermion masses are generated by the ETC sector $\dfrac{f\,f^c\,TT^c}{\Lambda^2_{ETC}} \to m_f \propto \dfrac{v^3}{\Lambda^2}$

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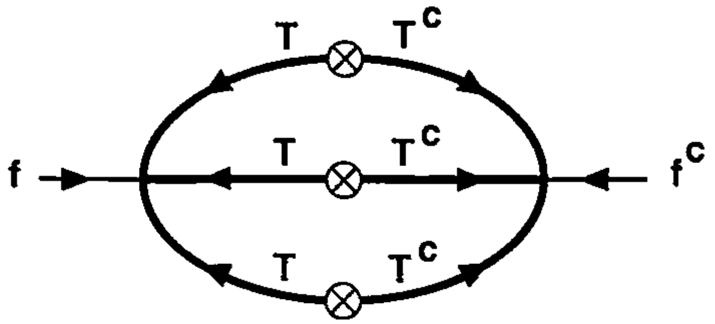
$$\mathcal{L} = \frac{g_L}{\Lambda_{ETC}^2} f \, TTT + \frac{g_R}{\Lambda_{ETC}^2} f^c \, T^c T^c T^c + h.c.$$



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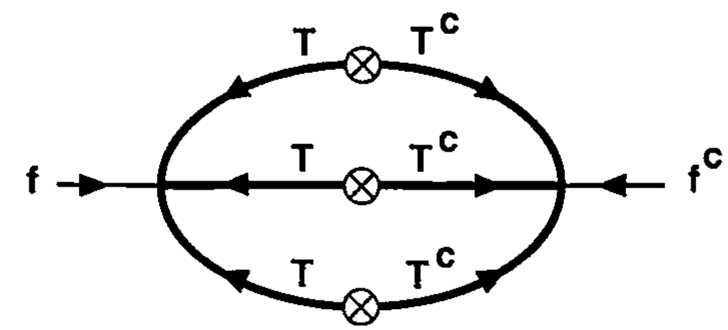
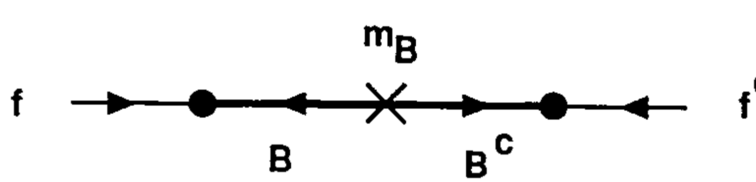


$$\mathcal{L}^{eff} = m_L f B + m_R f^c B^c + m_B B B^c$$



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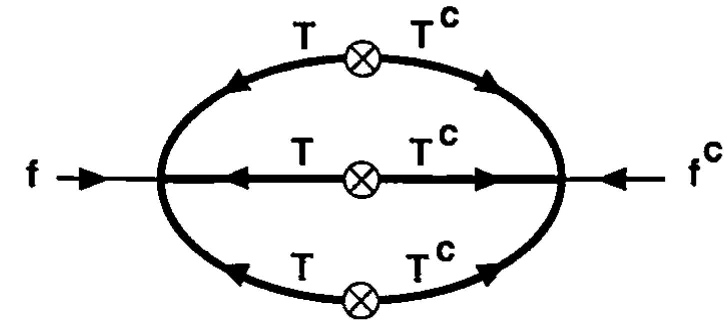

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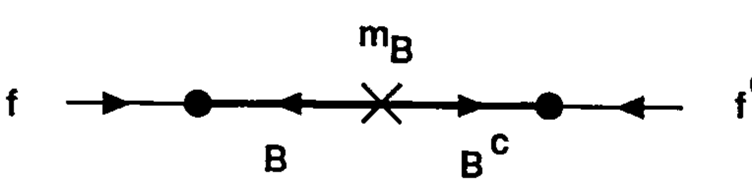

$$|SM\rangle = \cos\theta\, |f\rangle + \sin\theta\, |B\rangle$$

$$m_B \gg m_L, m_R \qquad m_f \approx \frac{m_L m_R}{m_B} = m_B \epsilon_L \epsilon_R \qquad \epsilon \approx \sin\theta$$

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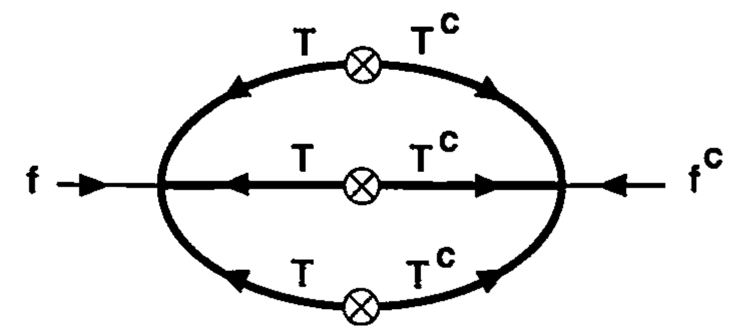

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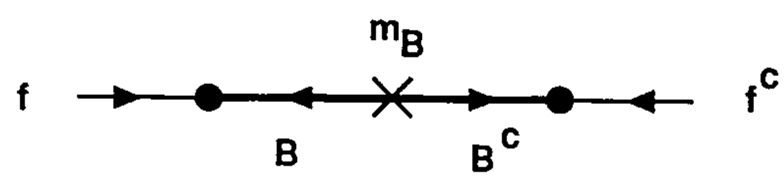

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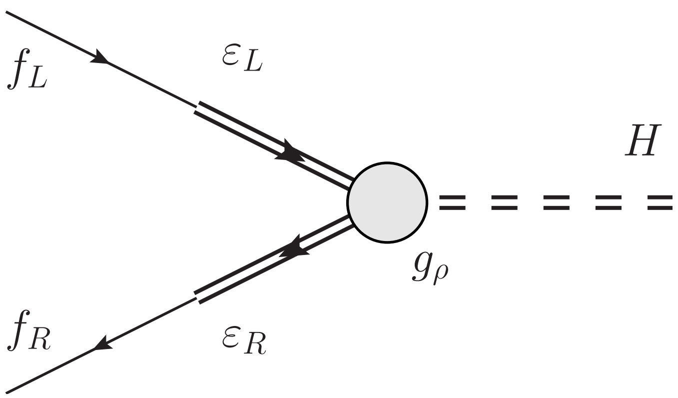
- We will apply this idea to the Composite Higgs scenario (Higgs=Pseudo NGB)

Partial Compositeness in CH models

- The idea of partial compositeness applied to the composite Higgs looks like:



$$\mathcal{L}_{\text{elem}} = i\overline{f}\gamma^\mu D_\mu f$$

$$\mathcal{L}_{\text{comp}} = \mathcal{L}_{\text{comp}}(g_\rho, m_\rho, H)$$

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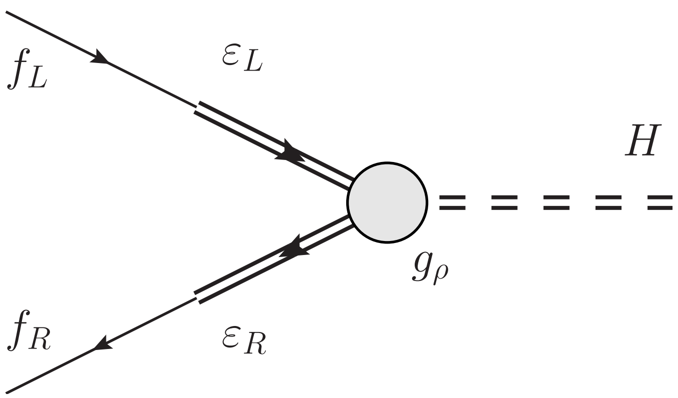

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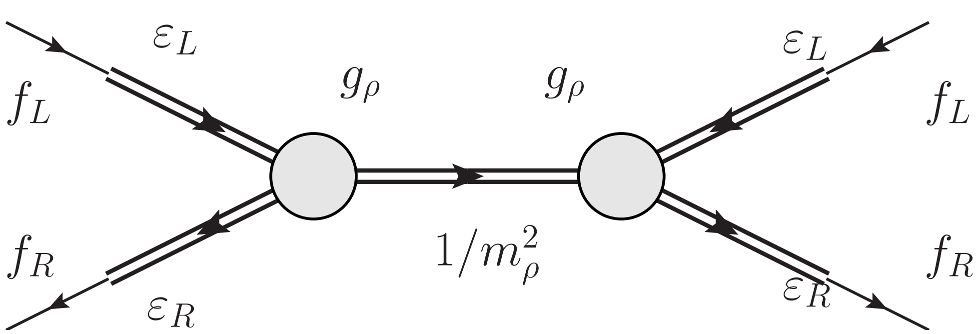

$$\sim \frac{g_\rho^2}{m_\rho^2} \epsilon_L^i \epsilon_R^i \epsilon_L^j \epsilon_R^j$$

FV related to the SM one but not in the Minimal FV way

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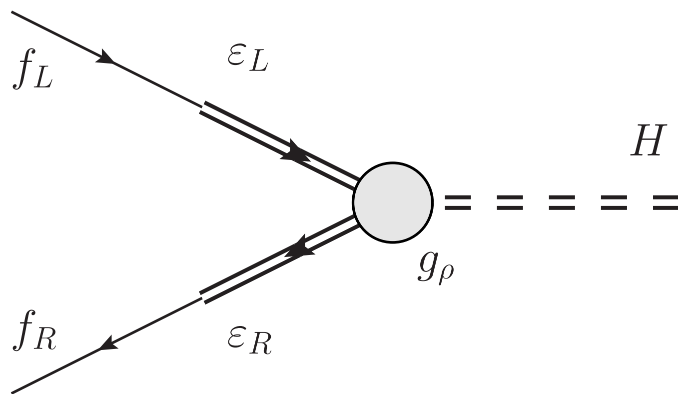

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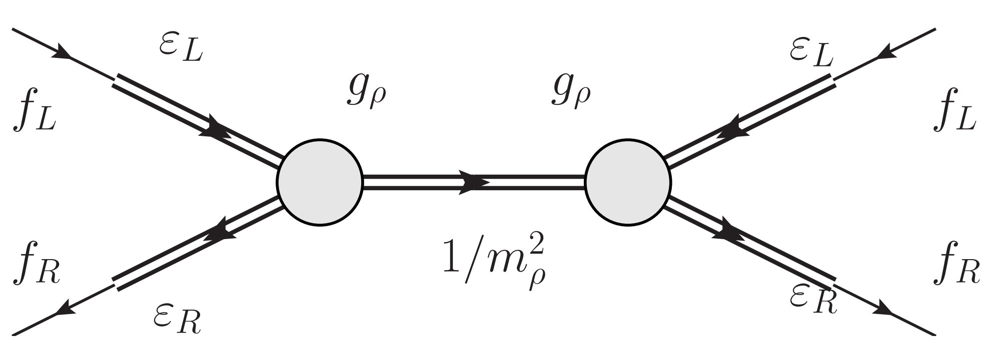

$$\sim \frac{g_\rho^2}{m_\rho^2} \epsilon_L^i \epsilon_R^i \epsilon_L^j \epsilon_R^j$$

FV related to the SM one but not in the Minimal FV way

Is it possible to generate CPV in the charm sector and be safe with respect to the other dangerous processes?

Yukawa (quark sector)

- Yukawas are given by

$$(Y_u)_{ij} \sim g_\rho \epsilon_i^q \epsilon_j^u \qquad\qquad (Y_d)_{ij} \sim g_\rho \epsilon_i^q \epsilon_j^d$$

- And diagonalized by

$$(L_u^\dagger Y_u R_u)_{ij} = g_\rho \epsilon_i^u \epsilon_i^q \delta_{ij} \equiv y_i^u \delta_{ij}\,, \qquad (L_d^\dagger Y_d R_d)_{ij} = g_\rho \epsilon_i^d \epsilon_i^q \delta_{ij} \equiv y_i^d \delta_{ij}\,,$$

$$(L_u)_{ij} \sim (L_d)_{ij} \sim \min\left(\frac{\epsilon_i^q}{\epsilon_j^q}, \frac{\epsilon_j^q}{\epsilon_i^q}\right)\,, \qquad (R_{u,d})_{ij} \sim \min\left(\frac{\epsilon_i^{u,d}}{\epsilon_j^{u,d}}, \frac{\epsilon_j^{u,d}}{\epsilon_i^{u,d}}\right)$$

- Link with the CKM $\quad V_{CKM} = L_d^\dagger L_u \sim L_{u,d}$

$$\frac{\epsilon_1^q}{\epsilon_2^q} \sim \lambda \qquad\qquad \frac{\epsilon_2^q}{\epsilon_3^q} \sim \lambda^2 \qquad\qquad \frac{\epsilon_1^q}{\epsilon_3^q} \sim \lambda^3$$

- Everything is fixed up to 2 parameters $\quad g_\rho, \epsilon_i^q, \epsilon_i^u, \epsilon_i^d \qquad 1+3+3+3=10$

$$m_i^u, m_i^d, V_{CKM} \qquad 3+3+2=8$$

(g_ρ, ϵ_3^u) or $(g_\rho, \frac{\epsilon_3^u}{\epsilon_3^q})$ in what follows

Effective Lagrangian

- Use Naive Dimensional Analysis to estimate the Wilson

$$\mathcal{L}_{\mathrm{NDA}} = \frac{m_\rho^4}{g_\rho^2}\left[\mathcal{L}^{(0)}\left(\frac{g_\rho \epsilon_i^a\, f_i^a}{m_\rho^{3/2}}, \frac{D_\mu}{m_\rho}, \frac{g_\rho H}{m_\rho}\right) + \frac{g_\rho^2}{16\pi^2}\,\mathcal{L}^{(1)}\left(\frac{g_\rho \epsilon_i^a\, f_i^a}{m_\rho^{3/2}}, \frac{D_\mu}{m_\rho}, \frac{g_\rho H}{m_\rho}\right) + \dots\right]$$

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$$\begin{aligned}
\mathcal{L}_{\Delta F=1} \quad &\sim \quad \epsilon_i^a \epsilon_j^b g_\rho \, \frac{v}{m_\rho^2} \frac{g_\rho^2}{(4\pi)^2} \, \overline{f}_i^a \sigma_{\mu\nu} g_{\rm SM} F_{\rm SM}^{\mu\nu} f_j^b \\
&+ \quad \epsilon_i^a \epsilon_j^b \, \frac{g_\rho^2}{m_\rho^2} \, \overline{f}_i^a \gamma^\mu f_j^b i H^\dagger \overleftrightarrow{D}_\mu H \\
\mathcal{L}_{\Delta F=2} \quad &\sim \quad \epsilon_i^a \epsilon_j^b \epsilon_k^c \epsilon_l^d \, \frac{g_\rho^2}{m_\rho^2} \, \overline{f}_i^a \gamma^\mu f_j^b \, \overline{f}_k^c \gamma_\mu f_l^d
\end{aligned}$$

- In tractable theories, dipole operators are generated at the 1-loop level
- Charm CPV asymmetry is induced by $\overline{u}_L \sigma^{\mu\nu} g_s G_{\mu\nu} c_R$
- Better to have large g_ρ
- Useful to define $\Lambda = \dfrac{4\pi}{g_\rho} m_\rho$

Effective Lagrangian

$$\begin{aligned}\mathcal{L}_{\Delta F=1} &= \epsilon_i^a \epsilon_j^b g_\rho v \frac{c^{ab}_{ij,g_{\rm SM}}}{\Lambda^2}\ \overline{f}^a_i \sigma_{\mu\nu} g_{\rm SM} F^{\mu\nu}_{\rm SM} f^b_j \\ &+ \epsilon_i^a \epsilon_j^b g_\rho^2 \frac{(4\pi)^2}{g_\rho^2}\ \frac{c^{ab}_{ij}}{\Lambda^2} \overline{f}^a_i \gamma^\mu f^b_j\ iH^\dagger \overleftrightarrow{D}_\mu H \\ \mathcal{L}_{\Delta F=2} &= \epsilon_i^a \epsilon_j^b \epsilon_k^c \epsilon_l^d g_\rho^2 \frac{(4\pi)^2}{g_\rho^2}\ \frac{c^{abcd}_{ijkl}}{\Lambda^2} \overline{f}^a_i \gamma^\mu f^b_j\, \overline{f}^c_k \gamma_\mu f^d_l .\end{aligned}$$

- The induced CVP asymmetry is given by:

$$\Delta a_{CP} \approx -(0.13\%)\mathrm{Im}(\Delta R^{SM}) - 0.65\% \left(\frac{10\ \mathrm{TeV}}{\Lambda}\right)^2 \left(\frac{\mathrm{Im}(c^{qu}_{12,g})}{0.8}\right) \frac{\mathrm{Im}(\Delta R^{NP})}{0.2}$$

- As a reference value we take

$$\Lambda = 10\ \mathrm{TeV}, \qquad\qquad \mathrm{Im}(c^{qu}_{12,g}) \sim 1$$

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Is this picture compatible with the other experimental data?

- c are O(1) in a natural theory
- Strategy: apply bounds on the coefficients c

Quark sector

$m_\rho = 10$ TeV $\quad g_\rho = 4\pi$

Operator $\Delta F = 2$	$\mathrm{Re}(c) \times (4\pi/g_\rho)^2$	$\mathrm{Im}(c) \times (4\pi/g_\rho)^2$	Observables
$(\bar{s}_L \gamma^\mu d_L)^2$	$6 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_K; ϵ_K [44][45]
$(\bar{s}_R d_L)^2$	500	2	"
$(\bar{s}_R\, d_L)(\bar{s}_L d_R)$	2×10^2	0.6	"
$(\bar{c}_L \gamma^\mu u_L)^2$	$4 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$70 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_D; $\lvert q/p\rvert, \phi_D$ [44][45]
$(\bar{c}_L\, u_R)^2$	30	6	"
$(\bar{c}_R\, u_L)(\bar{c}_L u_R)$	3×10^2	50	"
$(\bar{b}_L \gamma^\mu d_L)^2$	$5 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$ [44][45]
$(\bar{b}_R\, d_L)^2$	80	30	"
$(\bar{b}_R\, d_L)(\bar{b}_L d_R)$	3×10^2	80	"
$(\bar{b}_L \gamma^\mu s_L)^2$	$6 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$		Δm_{B_s} [44][45]
$(\bar{b}_R\, s_L)^2$	1×10^2		"
$(\bar{b}_R\, s_L)(\bar{b}_L s_R)$	3×10^2		"
Operator $\Delta F = 1$	**$\mathrm{Re}(c)$**	**$\mathrm{Im}(c)$**	**Observables**
$\overline{s_R} \sigma^{\mu\nu} e F_{\mu\nu} b_L$	1		$B \to X_s$ [46]
$\overline{s_L} \sigma^{\mu\nu} e F_{\mu\nu} b_R$	2	9	"
$\overline{s_R} \sigma^{\mu\nu} g_s G_{\mu\nu} d_L$	-	0.4	$K \to 2\pi$; ϵ'/ϵ [47]
$\overline{s_L} \sigma^{\mu\nu} g_s G_{\mu\nu} d_R$	-	0.4	"
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$30 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$B_s \to \mu^+\mu^-$ [48]
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$6 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$10 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$B \to X_s\, \ell^+\ell^-$ [46]
Operator $\Delta F = 0$	**$\mathrm{Re}(c)$**	**$\mathrm{Im}(c)$**	**Observables**
$\bar{d} \sigma^{\mu\nu} e F_{\mu\nu} d_{L,R}$	-	3×10^{-2}	neutron EDM [49][50]
$\bar{u} \sigma^{\mu\nu} e F_{\mu\nu} u_{L,R}$	-	0.3	"
$\bar{d} \sigma^{\mu\nu} g_s G_{\mu\nu} d_{L,R}$	-	4×10^{-2}	"
$\bar{u} \sigma^{\mu\nu} g_s G_{\mu\nu} u_{L,R}$	-	0.2	"
$\bar{b}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$5 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$Z \to b\bar{b}$ [51]

Quark sector

$m_\rho = 10$ TeV $\quad g_\rho = 4\pi$

Operator $\Delta F = 2$	$\mathrm{Re}(c) \times (4\pi/g_\rho)^2$	$\mathrm{Im}(c) \times (4\pi/g_\rho)^2$	Observables
$(\bar{s}_L\gamma^\mu d_L)^2$	$6 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_K; ϵ_K [44][45]
$(\bar{s}_R d_L)^2$	500	2	"
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	2×10^2	0.6	"
$(\bar{c}_L\gamma^\mu u_L)^2$	$4 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$70 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_D; $\lvert q/p\rvert, \phi_D$ [44][45]
$(\bar{c}_L u_R)^2$	30	6	"
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	3×10^2	50	"
$(\bar{b}_L\gamma^\mu d_L)^2$	$5 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$ [44][45]
$(\bar{b}_R d_L)^2$	80	30	"
$(\bar{b}_R d_L)(\bar{b}_L d_R)$	3×10^2	80	"
$(\bar{b}_L\gamma^\mu s_L)^2$	$6 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$		Δm_{B_s} [44][45]
$(\bar{b}_R s_L)^2$	1×10^2		"
$(\bar{b}_R s_L)(\bar{b}_L s_R)$	3×10^2		"

Operator $\Delta F = 1$	$\mathrm{Re}(c)$	$\mathrm{Im}(c)$	Observables
$\overline{s_R}\sigma^{\mu\nu} e F_{\mu\nu} b_L$	1		$B \to X_s$ [46]
$\overline{s_L}\sigma^{\mu\nu} e F_{\mu\nu} b_R$	2	9	"
$\overline{s_R}\sigma^{\mu\nu} g_s G_{\mu\nu} d_L$	-	0.4	$K \to 2\pi$; ϵ'/ϵ [47]
$\overline{s_L}\sigma^{\mu\nu} g_s G_{\mu\nu} d_R$	-	0.4	"
$\bar{s}_L\gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$30 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$B_s \to \mu^+\mu^-$ [48]
$\bar{s}_L\gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$6 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$10 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$B \to X_s \ell^+\ell^-$ [46]

Operator $\Delta F = 0$	$\mathrm{Re}(c)$	$\mathrm{Im}(c)$	Observables
$\bar{d}\sigma^{\mu\nu} e F_{\mu\nu} d_{L,R}$	-	3×10^{-2}	neutron EDM [49][50]
$\bar{u}\sigma^{\mu\nu} e F_{\mu\nu} u_{L,R}$	-	0.3	"
$\bar{d}\sigma^{\mu\nu} g_s G_{\mu\nu} d_{L,R}$	-	4×10^{-2}	"
$\bar{u}\sigma^{\mu\nu} g_s G_{\mu\nu} u_{L,R}$	-	0.2	"
$\bar{b}_L\gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$5 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$Z \to b\bar{b}$ [51]

Quark sector

$$m_\rho = 10\ \text{TeV} \qquad g_\rho = 4\pi$$

Operator $\Delta F = 2$	$\mathrm{Re}(c) \times (4\pi/g_\rho)^2$	$\mathrm{Im}(c) \times (4\pi/g_\rho)^2$	Observables
$(\bar{s}_L \gamma^\mu d_L)^2$	$6 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_K; ϵ_K [44][45]
$(\bar{s}_R d_L)^2$	500	2	"
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	2×10^2	0.6	"
$(\bar{c}_L \gamma^\mu u_L)^2$	$4 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$70 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_D; $\lvert q/p\rvert, \phi_D$ [44][45]
$(\bar{c}_L u_R)^2$	30	6	"
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	3×10^2	50	"
$(\bar{b}_L \gamma^\mu d_L)^2$	$5 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$ [44][45]
$(\bar{b}_R d_L)^2$	80	30	"
$(\bar{b}_R d_L)(\bar{b}_L d_R)$	3×10^2	80	"
$(\bar{b}_L \gamma^\mu s_L)^2$	$6 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$		Δm_{B_s} [44][45]
$(\bar{b}_R s_L)^2$	1×10^2		"
$(\bar{b}_R s_L)(\bar{b}_L s_R)$	3×10^2		"
Operator $\Delta F = 1$	**$\mathrm{Re}(c)$**	**$\mathrm{Im}(c)$**	**Observables**
$\overline{s_R} \sigma^{\mu\nu} e F_{\mu\nu} b_L$	1		$B \to X_s$ [46]
$\overline{s_L} \sigma^{\mu\nu} e F_{\mu\nu} b_R$	2	9	"
$\overline{s_R} \sigma^{\mu\nu} g_s G_{\mu\nu} d_L$	-	0.4	$K \to 2\pi$; ϵ'/ϵ [47]
$\overline{s_L} \sigma^{\mu\nu} g_s G_{\mu\nu} d_R$	-	0.4	"
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$30 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$B_s \to \mu^+\mu^-$ [48]
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$6 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$10 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$B \to X_s \ell^+\ell^-$ [46]
Operator $\Delta F = 0$	**$\mathrm{Re}(c)$**	**$\mathrm{Im}(c)$**	**Observables**
$\bar{d} \sigma^{\mu\nu} e F_{\mu\nu} d_{L,R}$	-	3×10^{-2}	neutron EDM [49][50]
$\bar{u} \sigma^{\mu\nu} e F_{\mu\nu} u_{L,R}$	-	0.3	"
$\bar{d} \sigma^{\mu\nu} g_s G_{\mu\nu} d_{L,R}$	-	4×10^{-2}	"
$\bar{u} \sigma^{\mu\nu} g_s G_{\mu\nu} u_{L,R}$	-	0.2	"
$\bar{b}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$5 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$Z \to b\bar{b}$ [51]

Quark sector

$m_\rho = 10$ TeV $\quad g_\rho = 4\pi$

Operator $\Delta F = 2$	$\mathrm{Re}(c) \times (4\pi/g_\rho)^2$	$\mathrm{Im}(c) \times (4\pi/g_\rho)^2$	Observables
$(\bar{s}_L \gamma^\mu d_L)^2$	$6 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$\Delta m_K;\ \epsilon_K$ [44][45]
$(\bar{s}_R d_L)^2$	500	2	"
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	2×10^2	0.6	"
$(\bar{c}_L \gamma^\mu u_L)^2$	$4 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$70 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$ [44][45]
$(\bar{c}_L u_R)^2$	30	6	"
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	3×10^2	50	"
$(\bar{b}_L \gamma^\mu d_L)^2$	$5 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$ [44][45]
$(\bar{b}_R d_L)^2$	80	30	"
$(\bar{b}_R d_L)(\bar{b}_L d_R)$	3×10^2	80	"
$(\bar{b}_L \gamma^\mu s_L)^2$	$6 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$		Δm_{B_s} [44][45]
$(\bar{b}_R s_L)^2$	1×10^2		"
$(\bar{b}_R s_L)(\bar{b}_L s_R)$	3×10^2		"

Operator $\Delta F = 1$	$\mathrm{Re}(c)$	$\mathrm{Im}(c)$	Observables
$\overline{s_R}\sigma^{\mu\nu} e F_{\mu\nu} b_L$	1		$B \to X_s$ [46]
$\overline{s_L}\sigma^{\mu\nu} e F_{\mu\nu} b_R$	2	9	"
$\overline{s_R}\sigma^{\mu\nu} g_s G_{\mu\nu} d_L$	-	0.4	$K \to 2\pi;\ \epsilon'/\epsilon$ [47]
$\overline{s_L}\sigma^{\mu\nu} g_s G_{\mu\nu} d_R$	-	0.4	"
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$30 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$B_s \to \mu^+\mu^-$ [48]
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$6 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$10 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$B \to X_s \ell^+\ell^-$ [46]

Operator $\Delta F = 0$	$\mathrm{Re}(c)$	$\mathrm{Im}(c)$	Observables
$\bar{d}\sigma^{\mu\nu} e F_{\mu\nu} d_{L,R}$	-	3×10^{-2}	neutron EDM [49][50]
$\bar{u}\sigma^{\mu\nu} e F_{\mu\nu} u_{L,R}$	-	0.3	"
$\bar{d}\sigma^{\mu\nu} g_s G_{\mu\nu} d_{L,R}$	-	4×10^{-2}	"
$\bar{u}\sigma^{\mu\nu} g_s G_{\mu\nu} u_{L,R}$	-	0.2	"
$\bar{b}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$5 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$Z \to b\bar{b}$ [51]

Quark sector

$$m_\rho = 10\ \text{TeV} \qquad g_\rho = 4\pi$$

Operator $\Delta F = 2$	$\text{Re}(c) \times (4\pi/g_\rho)^2$	$\text{Im}(c) \times (4\pi/g_\rho)^2$	Observables
$(\bar{s}_L \gamma^\mu d_L)^2$	$6 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_K; ϵ_K [44][45]
$(\bar{s}_R d_L)^2$	500	2	"
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	2×10^2	0.6	"
$(\bar{c}_L \gamma^\mu u_L)^2$	$4 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$70 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_D; $\|q/p\|, \phi_D$ [44][45]
$(\bar{c}_L u_R)^2$	30	6	"
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	3×10^2	50	"
$(\bar{b}_L \gamma^\mu d_L)^2$	$5 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$ [44][45]
$(\bar{b}_R d_L)^2$	80	30	"
$(\bar{b}_R d_L)(\bar{b}_L d_R)$	3×10^2	80	"
$(\bar{b}_L \gamma^\mu s_L)^2$	$6 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$		Δm_{B_s} [44][45]
$(\bar{b}_R s_L)^2$	1×10^2		"
$(\bar{b}_R s_L)(\bar{b}_L s_R)$	3×10^2		"
Operator $\Delta F = 1$	**$\text{Re}(c)$**	**$\text{Im}(c)$**	**Observables**
$\overline{s_R}\sigma^{\mu\nu} e F_{\mu\nu} b_L$	1		$B \to X_s$ [46]
$\overline{s_L}\sigma^{\mu\nu} e F_{\mu\nu} b_R$	2	9	"
$\overline{s_R}\sigma^{\mu\nu} g_s G_{\mu\nu} d_L$	-	0.4	$K \to 2\pi$; ϵ'/ϵ [47]
$\overline{s_L}\sigma^{\mu\nu} g_s G_{\mu\nu} d_R$	-	0.4	"
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$30 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$B_s \to \mu^+\mu^-$ [48]
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$6 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$10 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$B \to X_s \ell^+\ell^-$ [46]
Operator $\Delta F = 0$	**$\text{Re}(c)$**	**$\text{Im}(c)$**	**Observables**
$\bar{d}\sigma^{\mu\nu} e F_{\mu\nu} d_{L,R}$	-	3×10^{-2}	neutron EDM [49][50]
$\bar{u}\sigma^{\mu\nu} e F_{\mu\nu} u_{L,R}$	-	0.3	"
$\bar{d}\sigma^{\mu\nu} g_s G_{\mu\nu} d_{L,R}$	-	4×10^{-2}	"
$\bar{u}\sigma^{\mu\nu} g_s G_{\mu\nu} u_{L,R}$	-	0.2	"
$\bar{b}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$5 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$Z \to b\bar{b}$ [51]

- Close to the current sensitivity

Quark sector

Operator $\Delta F = 2$	$\text{Re}(c) \times (4\pi/g_\rho)^2$	$\text{Im}(c) \times (4\pi/g_\rho)^2$	Observables
$(\bar{s}_L \gamma^\mu d_L)^2$	$6 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_K; ϵ_K [44][45]
$(\bar{s}_R d_L)^2$	500	2	"
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	2×10^2	0.6	"
$(\bar{c}_L \gamma^\mu u_L)^2$	$4 \times 10^2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$70 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_D; $\lvert q/p\rvert, \phi_D$ [44][45]
$(\bar{c}_L u_R)^2$	30	6	"
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	3×10^2	50	"
$(\bar{b}_L \gamma^\mu d_L)^2$	$5 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$ [44][45]
$(\bar{b}_R d_L)^2$	80	30	"
$(\bar{b}_R d_L)(\bar{b}_L d_R)$	3×10^2	80	"
$(\bar{b}_L \gamma^\mu s_L)^2$	$6 \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$		Δm_{B_s} [44][45]
$(\bar{b}_R s_L)^2$	1×10^2		"
$(\bar{b}_R s_L)(\bar{b}_L s_R)$	3×10^2		"
Operator $\Delta F = 1$	**$\text{Re}(c)$**	**$\text{Im}(c)$**	**Observables**
$\overline{s_R} \sigma^{\mu\nu} e F_{\mu\nu} b_L$	1		$B \to X_s$ [46]
$\overline{s_L} \sigma^{\mu\nu} e F_{\mu\nu} b_R$	2	9	"
$\overline{s_R} \sigma^{\mu\nu} g_s G_{\mu\nu} d_L$	-	0.4	$K \to 2\pi$; ϵ'/ϵ [47]
$\overline{s_L} \sigma^{\mu\nu} g_s G_{\mu\nu} d_R$	-	0.4	"
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$30 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$B_s \to \mu^+\mu^-$ [48]
$\bar{s}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$6 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$10 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$B \to X_s \ell^+\ell^-$ [46]
Operator $\Delta F = 0$	**$\text{Re}(c)$**	**$\text{Im}(c)$**	**Observables**
$\bar{d} \sigma^{\mu\nu} e F_{\mu\nu} d_{L,R}$	-	3×10^{-2}	neutron EDM [49][50]
$\bar{u} \sigma^{\mu\nu} e F_{\mu\nu} u_{L,R}$	-	0.3	"
$\bar{d} \sigma^{\mu\nu} g_s G_{\mu\nu} d_{L,R}$	-	4×10^{-2}	"
$\bar{u} \sigma^{\mu\nu} g_s G_{\mu\nu} u_{L,R}$	-	0.2	"
$\bar{b}_L \gamma^\mu b_L\, H^\dagger i \overleftrightarrow{D}_\mu H$	$5 \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$Z \to b\bar{b}$ [51]

$$m_\rho = 10 \text{ TeV} \qquad g_\rho = 4\pi$$

- Close to the current sensitivity

Quark sector

$m_\rho = 10\ \mathrm{TeV} \qquad g_\rho = 4\pi$

Operator $\Delta F = 2$	$\mathrm{Re}(c) \times (4\pi/g_\rho)^2$	$\mathrm{Im}(c) \times (4\pi/g_\rho)^2$	Observables
$(\bar{s}_L\gamma^\mu d_L)^2$	$6\times 10^2\ \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2\ \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_K; ϵ_K [44][45]
$(\bar{s}_R d_L)^2$	500	2	"
$(\bar{s}_R\, d_L)(\bar{s}_L d_R)$	2×10^2	0.6	"
$(\bar{c}_L\gamma^\mu u_L)^2$	$4\times 10^2\ \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$70\ \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_D; $\lvert q/p\rvert, \phi_D$ [44][45]
$(\bar{c}_L\, u_R)^2$	30	6	"
$(\bar{c}_R\, u_L)(\bar{c}_L u_R)$	3×10^2	50	"
$(\bar{b}_L\gamma^\mu d_L)^2$	$5\ \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	$2\ \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$ [44][45]
$(\bar{b}_R\, d_L)^2$	80	30	"
$(\bar{b}_R\, d_L)(\bar{b}_L d_R)$	3×10^2	80	"
$(\bar{b}_L\gamma^\mu s_L)^2$	$6\ \left(\frac{\epsilon_3^u}{\epsilon_3^q}\right)^2$		Δm_{B_s} [44][45]
$(\bar{b}_R\, s_L)^2$	1×10^2		"
$(\bar{b}_R\, s_L)(\bar{b}_L s_R)$	3×10^2		"
Operator $\Delta F = 1$	**$\mathrm{Re}(c)$**	**$\mathrm{Im}(c)$**	**Observables**
$\overline{s_R}\sigma^{\mu\nu}eF_{\mu\nu}b_L$	1		$B\to X_s$ [46]
$\overline{s_L}\sigma^{\mu\nu}eF_{\mu\nu}b_R$	2	9	"
$\overline{s_R}\sigma^{\mu\nu}g_sG_{\mu\nu}d_L$	-	0.4	$K\to 2\pi$; ϵ'/ϵ [47]
$\overline{s_L}\sigma^{\mu\nu}g_sG_{\mu\nu}d_R$	-	0.4	"
$\bar{s}_L\gamma^\mu b_L\, H^\dagger i\overleftrightarrow{D}_\mu H$	$30\ \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$B_s\to\mu^+\mu^-$ [48]
$\bar{s}_L\gamma^\mu b_L\, H^\dagger i\overleftrightarrow{D}_\mu H$	$6\ \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$10\ \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$	$B\to X_s\,\ell^+\ell^-$ [46]
Operator $\Delta F = 0$	**$\mathrm{Re}(c)$**	**$\mathrm{Im}(c)$**	**Observables**
$\bar{d}\sigma^{\mu\nu}eF_{\mu\nu}d_{L,R}$	-	3×10^{-2}	neutron EDM [49][50]
$\bar{u}\sigma^{\mu\nu}eF_{\mu\nu}u_{L,R}$	-	0.3	"
$\bar{d}\sigma^{\mu\nu}g_sG_{\mu\nu}d_{L,R}$	-	4×10^{-2}	"
$\bar{u}\sigma^{\mu\nu}g_sG_{\mu\nu}u_{L,R}$	-	0.2	"
$\bar{b}_L\gamma^\mu b_L\, H^\dagger i\overleftrightarrow{D}_\mu H$	$5\ \left(\frac{g_\rho}{4\pi}\right)^2 (\epsilon_3^u)^2$		$Z\to b\bar{b}$ [51]

- Close to the current sensitivity
- Not excluded, given the uncertainties

SUSY

- As usual in SUSY case, it is possible to define the mass insertions

$$(\delta_{ij}^{u,d})_{LL} = (c_{ij}^{u,d})_{LL} \;\times\; \frac{\tilde{m}_0^2}{\tilde{m}^2}\;\epsilon_i^q \epsilon_j^q, \qquad (\delta_{ij}^{u,d})_{RR} = (c_{ij}^{u,d})_{RR} \;\times\; \frac{\tilde{m}_0^2}{\tilde{m}^2}\;\epsilon_i^{u,d} \epsilon_j^{u,d},$$

$$(\delta_{ij}^{u,d})_{LR} = (c_{ij}^{u,d})_{LR} \;\times\; g_\rho\, \epsilon_i^q \epsilon_j^{u,d}\, \frac{v_{u,d}\, A_0}{\tilde{m}^2}, \qquad (\delta_{ij}^{u,d})_{RL} = (c_{ij}^{u,d})_{RL} \;\times\; g_\rho\, \epsilon_i^{u,d} \epsilon_j^q\, \frac{v_{u,d}\, A_0}{\tilde{m}^2},$$

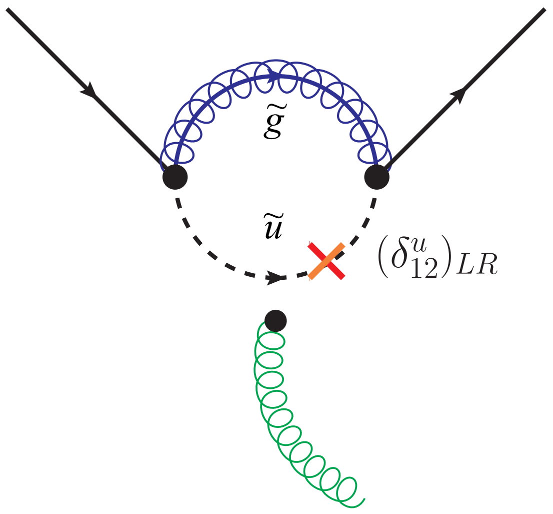
SUSY

- As usual in SUSY case, it is possible to define the mass insertions

$$(\delta_{ij}^{u,d})_{LL} = (c_{ij}^{u,d})_{LL} \times \frac{\tilde{m}_0^2}{\tilde{m}^2} \epsilon_i^q \epsilon_j^q, \qquad (\delta_{ij}^{u,d})_{RR} = (c_{ij}^{u,d})_{RR} \times \frac{\tilde{m}_0^2}{\tilde{m}^2} \epsilon_i^{u,d} \epsilon_j^{u,d},$$

$$(\delta_{ij}^{u,d})_{LR} = (c_{ij}^{u,d})_{LR} \times g_\rho \, \epsilon_i^q \epsilon_j^{u,d} \frac{v_{u,d} \, A_0}{\tilde{m}^2}, \qquad (\delta_{ij}^{u,d})_{RL} = (c_{ij}^{u,d})_{RL} \times g_\rho \, \epsilon_i^{u,d} \epsilon_j^q \frac{v_{u,d} \, A_0}{\tilde{m}^2},$$

- The asymmetry in the charm sector is given by



$$\Delta a_{CP} \approx -(0.13\%)\mathrm{Im}(\Delta R^{SM}) - 0.65\% \left(\frac{1 \text{ TeV}}{\tilde{m}}\right)^2 \left(\frac{A_0}{8\tilde{m}} \mathrm{Im}(c_{12}^u)_{LR}\right) \frac{\mathrm{Im}(\Delta R^{NP})}{0.2}.$$

$$\mathrm{Im}(c_{12}^u)_{LR} \times \frac{A_0}{\tilde{m}} \times \left(\frac{1 \text{ TeV}}{\tilde{m}}\right)^2 \sim 8,$$

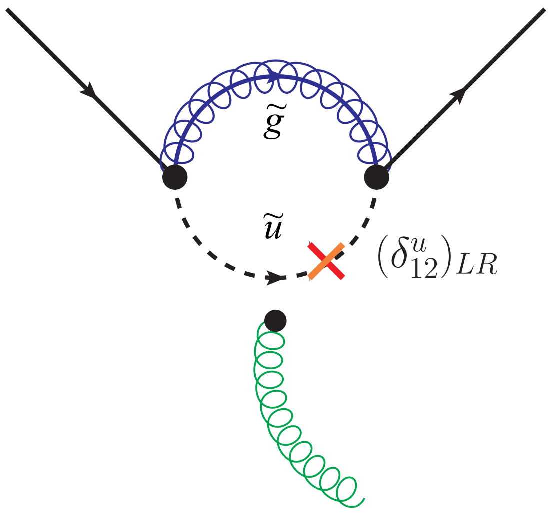
SUSY

- As usual in SUSY case, it is possible to define the mass insertions

$$(\delta^{u,d}_{ij})_{LL} = (c^{u,d}_{ij})_{LL} \times \frac{\tilde m_0^2}{\tilde m^2}\, \epsilon^q_i \epsilon^q_j, \qquad (\delta^{u,d}_{ij})_{RR} = (c^{u,d}_{ij})_{RR} \times \frac{\tilde m_0^2}{\tilde m^2}\, \epsilon^{u,d}_i \epsilon^{u,d}_j,$$

$$(\delta^{u,d}_{ij})_{LR} = (c^{u,d}_{ij})_{LR} \times g_\rho\, \epsilon^q_i \epsilon^{u,d}_j \frac{v_{u,d}\, A_0}{\tilde m^2}, \qquad (\delta^{u,d}_{ij})_{RL} = (c^{u,d}_{ij})_{RL} \times g_\rho\, \epsilon^{u,d}_i \epsilon^q_j \frac{v_{u,d}\, A_0}{\tilde m^2},$$

- The asymmetry in the charm sector is given by



$$\Delta a_{CP} \approx -(0.13\%)\mathrm{Im}(\Delta R^{SM}) - 0.65\% \left(\frac{1\ \mathrm{TeV}}{\tilde m}\right)^2 \left(\frac{A_0}{8\tilde m}\, \mathrm{Im}(c^u_{12})_{LR}\right) \frac{\mathrm{Im}(\Delta R^{NP})}{0.2}.$$

$$\mathrm{Im}(c^u_{12})_{LR} \times \frac{A_0}{\tilde m} \times \left(\frac{1\ \mathrm{TeV}}{\tilde m}\right)^2 \sim 8,$$

Is this picture compatible with the other experimental data?

- Strategy: apply bounds con the coefficients c
- We choose $\tilde m = \tilde m_0 = 1\ \mathrm{TeV}$ and $\frac{A_0}{\tilde m} = 2$

Bounds

Coefficient	Upper bound	Observables
$(c^u_{12})_{LL}$	$200\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LL}$	$60\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{LL}$	$20\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LL}$	$10\left(\frac{1}{\epsilon^q_3}\right)^2$	$B \to X_s\gamma$
$(c^u_{12})_{RR}$	$2\times10^3\left(\frac{1}{\epsilon^u_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{RR}$	$3\times10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{RR}$	$8\times10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{RR}$	$2\times10^4\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_{B_s}
$\sqrt{(c^u_{12})_{LL}(c^u_{12})_{RR}}$	$60\ g_\rho$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$\sqrt{(c^d_{12})_{LL}(c^d_{12})_{RR}}$	$30\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_K;\ \epsilon_K$
$\sqrt{(c^d_{13})_{LL}(c^d_{13})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_{B_d};\ S_{\psi K_S}$
$\sqrt{(c^d_{23})_{LL}(c^d_{23})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	Δm_{B_s}
$(c^u_{12})_{LR}$	90	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^u_{12})_{RL}$	2×10^3	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LR}$	2	ϵ'/ϵ
$(c^d_{12})_{RL}$	2	ϵ'/ϵ
$(c^d_{13})_{LR}$	2×10^3	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{13})_{RL}$	200	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LR}$	20	$B \to X_s\gamma$
$(c^d_{23})_{RL}$	8	$B \to X_s\gamma$
$(c^u_{11})_{LR}$	0.4	EDMs
$(c^d_{11})_{LR}$	0.09	EDMs
$(c^e_{12})_{RR}$	$4\times10^4\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LL}$	$4\times10^3\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LR,RL}$	0.6	$\mu \to e\gamma$
$(c^e_{11})_{LR}$	0.5	electron EDM

$$\tilde{m} = 1\ \text{TeV}$$

Bounds

$\tilde{m} = 1\ \mathrm{TeV}$

Coefficient	Upper bound	Observables
$(c^u_{12})_{LL}$	$200\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LL}$	$60\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{LL}$	$20\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LL}$	$10\left(\frac{1}{\epsilon^q_3}\right)^2$	$B \to X_s \gamma$
$(c^u_{12})_{RR}$	$2 \times 10^3\left(\frac{1}{\epsilon^u_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{RR}$	$3 \times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{RR}$	$8 \times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{RR}$	$2 \times 10^4\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_{B_s}
$\sqrt{(c^u_{12})_{LL}(c^u_{12})_{RR}}$	$60\ g_\rho$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$\sqrt{(c^d_{12})_{LL}(c^d_{12})_{RR}}$	$30\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_K;\ \epsilon_K$
$\sqrt{(c^d_{13})_{LL}(c^d_{13})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_{B_d};\ S_{\psi K_S}$
$\sqrt{(c^d_{23})_{LL}(c^d_{23})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	Δm_{B_s}
$(c^u_{12})_{LR}$	90	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^u_{12})_{RL}$	2×10^3	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LR}$	2	ϵ'/ϵ
$(c^d_{12})_{RL}$	2	ϵ'/ϵ
$(c^d_{13})_{LR}$	2×10^3	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{13})_{RL}$	200	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LR}$	20	$B \to X_s \gamma$
$(c^d_{23})_{RL}$	8	$B \to X_s \gamma$
$(c^u_{11})_{LR}$	0.4	EDMs
$(c^d_{11})_{LR}$	0.09	EDMs
$(c^e_{12})_{RR}$	$4 \times 10^4\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LL}$	$4 \times 10^3\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LR,RL}$	0.6	$\mu \to e\gamma$
$(c^e_{11})_{LR}$	0.5	electron EDM

Bounds

Coefficient	Upper bound	Observables
$(c^u_{12})_{LL}$	$200\ \left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LL}$	$60\ \left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{LL}$	$20\ \left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LL}$	$10\ \left(\frac{1}{\epsilon^q_3}\right)^2$	$B \to X_s\gamma$
$(c^u_{12})_{RR}$	$2\times 10^3\ \left(\frac{1}{\epsilon^u_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{RR}$	$3\times 10^3\ \left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{RR}$	$8\times 10^3\ \left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{RR}$	$2\times 10^4\ \left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_{B_s}
$\sqrt{(c^u_{12})_{LL}(c^u_{12})_{RR}}$	$60\ g_\rho$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$\sqrt{(c^d_{12})_{LL}(c^d_{12})_{RR}}$	$30\ \left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_K;\ \epsilon_K$
$\sqrt{(c^d_{13})_{LL}(c^d_{13})_{RR}}$	$100\ \left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_{B_d};\ S_{\psi K_S}$
$\sqrt{(c^d_{23})_{LL}(c^d_{23})_{RR}}$	$100\ \left(\frac{g_\rho}{t_\beta}\right)$	Δm_{B_s}
$(c^u_{12})_{LR}$	90	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^u_{12})_{RL}$	2×10^3	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LR}$	2	ϵ'/ϵ
$(c^d_{12})_{RL}$	2	ϵ'/ϵ
$(c^d_{13})_{LR}$	2×10^3	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{13})_{RL}$	200	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LR}$	20	$B \to X_s\gamma$
$(c^d_{23})_{RL}$	8	$B \to X_s\gamma$
$(c^u_{11})_{LR}$	0.4	EDMs
$(c^d_{11})_{LR}$	0.09	EDMs
$(c^e_{12})_{RR}$	$4\times 10^4\ \left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LL}$	$4\times 10^3\ \left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LR,RL}$	0.6	$\mu \to e\gamma$
$(c^e_{11})_{LR}$	0.5	electron EDM

$\tilde{m} = 1\ \mathrm{TeV}$

- As before, a bit better

Bounds

Coefficient	Upper bound	Observables
$(c^u_{12})_{LL}$	$200\left(\frac{1}{\epsilon^q_3}\right)^2$	Δm_D; $\lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LL}$	$60\left(\frac{1}{\epsilon^q_3}\right)^2$	Δm_K; ϵ_K
$(c^d_{13})_{LL}$	$20\left(\frac{1}{\epsilon^q_3}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$
$(c^d_{23})_{LL}$	$10\left(\frac{1}{\epsilon^q_3}\right)^2$	$B \to X_s\gamma$
$(c^u_{12})_{RR}$	$2\times 10^3\left(\frac{1}{\epsilon^u_3}\right)^2$	Δm_D; $\lvert q/p\rvert, \phi_D$
$(c^d_{12})_{RR}$	$3\times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_K; ϵ_K
$(c^d_{13})_{RR}$	$8\times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_{B_d}; $S_{\psi K_S}$
$(c^d_{23})_{RR}$	$2\times 10^4\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_{B_s}
$\sqrt{(c^u_{12})_{LL}(c^u_{12})_{RR}}$	$60\ g_\rho$	Δm_D; $\lvert q/p\rvert, \phi_D$
$\sqrt{(c^d_{12})_{LL}(c^d_{12})_{RR}}$	$30\left(\frac{g_\rho}{t_\beta}\right)$	Δm_K; ϵ_K
$\sqrt{(c^d_{13})_{LL}(c^d_{13})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	Δm_{B_d}; $S_{\psi K_S}$
$\sqrt{(c^d_{23})_{LL}(c^d_{23})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	Δm_{B_s}
$(c^u_{12})_{LR}$	90	Δm_D; $\lvert q/p\rvert, \phi_D$
$(c^u_{12})_{RL}$	2×10^3	Δm_D; $\lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LR}$	2	ϵ'/ϵ
$(c^d_{12})_{RL}$	2	ϵ'/ϵ
$(c^d_{13})_{LR}$	2×10^3	Δm_{B_d}; $S_{\psi K_S}$
$(c^d_{13})_{RL}$	200	Δm_{B_d}; $S_{\psi K_S}$
$(c^d_{23})_{LR}$	20	$B \to X_s\gamma$
$(c^d_{23})_{RL}$	8	$B \to X_s\gamma$
$(c^u_{11})_{LR}$	0.4	EDMs
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$(c^e_{12})_{RR}$	$4\times 10^4\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LL}$	$4\times 10^3\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LR,RL}$	0.6	$\mu \to e\gamma$
$(c^e_{11})_{LR}$	0.5	electron EDM

$\tilde{m} = 1\ \mathrm{TeV}$

- As before, a bit better

Bounds

Coefficient	Upper bound	Observables
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$(c^d_{13})_{LL}$	$20\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LL}$	$10\left(\frac{1}{\epsilon^q_3}\right)^2$	$B \to X_s\gamma$
$(c^u_{12})_{RR}$	$2\times 10^3\left(\frac{1}{\epsilon^u_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{RR}$	$3\times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{RR}$	$8\times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{RR}$	$2\times 10^4\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_{B_s}
$\sqrt{(c^u_{12})_{LL}(c^u_{12})_{RR}}$	$60\ g_\rho$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$\sqrt{(c^d_{12})_{LL}(c^d_{12})_{RR}}$	$30\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_K;\ \epsilon_K$
$\sqrt{(c^d_{13})_{LL}(c^d_{13})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_{B_d};\ S_{\psi K_S}$
$\sqrt{(c^d_{23})_{LL}(c^d_{23})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	Δm_{B_s}
$(c^u_{12})_{LR}$	90	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^u_{12})_{RL}$	2×10^3	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LR}$	2	ϵ'/ϵ
$(c^d_{12})_{RL}$	2	ϵ'/ϵ
$(c^d_{13})_{LR}$	2×10^3	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{13})_{RL}$	200	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LR}$	20	$B \to X_s\gamma$
$(c^d_{23})_{RL}$	8	$B \to X_s\gamma$
$(c^u_{11})_{LR}$	0.4	EDMs
$(c^d_{11})_{LR}$	0.09	EDMs
$(c^e_{12})_{RR}$	$4\times 10^4\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LL}$	$4\times 10^3\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LR,RL}$	0.6	$\mu \to e\gamma$
$(c^e_{11})_{LR}$	0.5	electron EDM

$$\tilde{m} = 1\ \text{TeV}$$

- As before, a bit better

- (Problem solved in the lepton sector!)

Bounds

Coefficient	Upper bound	Observables
$(c^u_{12})_{LL}$	$200\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LL}$	$60\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{LL}$	$20\left(\frac{1}{\epsilon^q_3}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LL}$	$10\left(\frac{1}{\epsilon^q_3}\right)^2$	$B \to X_s\gamma$
$(c^u_{12})_{RR}$	$2\times 10^3\left(\frac{1}{\epsilon^u_3}\right)^2$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{RR}$	$3\times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_K;\ \epsilon_K$
$(c^d_{13})_{RR}$	$8\times 10^3\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{RR}$	$2\times 10^4\left(\frac{1}{\epsilon^u_3 t_\beta}\right)^2$	Δm_{B_s}
$\sqrt{(c^u_{12})_{LL}(c^u_{12})_{RR}}$	$60\ g_\rho$	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$\sqrt{(c^d_{12})_{LL}(c^d_{12})_{RR}}$	$30\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_K;\ \epsilon_K$
$\sqrt{(c^d_{13})_{LL}(c^d_{13})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	$\Delta m_{B_d};\ S_{\psi K_S}$
$\sqrt{(c^d_{23})_{LL}(c^d_{23})_{RR}}$	$100\left(\frac{g_\rho}{t_\beta}\right)$	Δm_{B_s}
$(c^u_{12})_{LR}$	90	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^u_{12})_{RL}$	2×10^3	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
$(c^d_{12})_{LR}$	2	ϵ'/ϵ
$(c^d_{12})_{RL}$	2	ϵ'/ϵ
$(c^d_{13})_{LR}$	2×10^3	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{13})_{RL}$	200	$\Delta m_{B_d};\ S_{\psi K_S}$
$(c^d_{23})_{LR}$	20	$B \to X_s\gamma$
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$(c^u_{11})_{LR}$	0.4	EDMs
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$(c^e_{12})_{RR}$	$4\times 10^4\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LL}$	$4\times 10^3\left(\frac{g_\rho}{4\pi}\right)\left(\frac{\epsilon^e_3}{\epsilon^\ell_3 t_\beta}\right)$	$\mu \to e\gamma$
$(c^e_{12})_{LR,RL}$	0.6	$\mu \to e\gamma$
$(c^e_{11})_{LR}$	0.5	electron EDM

$\tilde{m} = 1$ TeV

- As before, a bit better

- (Problem solved in the lepton sector!)

CH: loop in the strong sector
SUSY: Bino vs Gluino loop

Conclusions

- Flavor and CP violation in the charm sector could represent the first hint of non minimal flavor violating New Physics. Unfortunately SM is not under control.

- Partial compositeness, could explain the “observed” CP asymmetry in the charm sector

- Other effects near the corner, in particular NP effects in the neutron EDM

- Composite Higgs case: resonances at 10 TeV

- SUSY case: CP asymmetry is reproduced with sparticles at 1 TeV

Backup

CP Asymmetry in D decays

- CPV in violation in the charm sector is very interesting:

1. Sensitive to NP in the up sector
2. In the SM, direct CPV violation enters (naively) at $\mathcal{O}\left(\frac{V_{cb}V_{ub}}{V_{cs}V_{us}}\frac{\alpha_s}{\pi}\right) \sim 10^{-4}$

Experimental results

FORSE TAGLIO

- Time-integrated CPV decay asymme tes:

$$a_f \equiv \quad \to f) \quad \to f)$$

$$\Delta a_{CP} = a_{K^+K^-} - a_{\pi^+\pi^-}$$

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SM cannot be excluded

Golden, Grinstein, Phys. Lett B. 222 (1989)
Brod, Kagan, Zupan, 1111.5000
Brod, Grossman, Kagan, Zupan, 1203.6659
Feldmann, Nandi & Soni 1202.3795
....

Could be non MFV new physics!

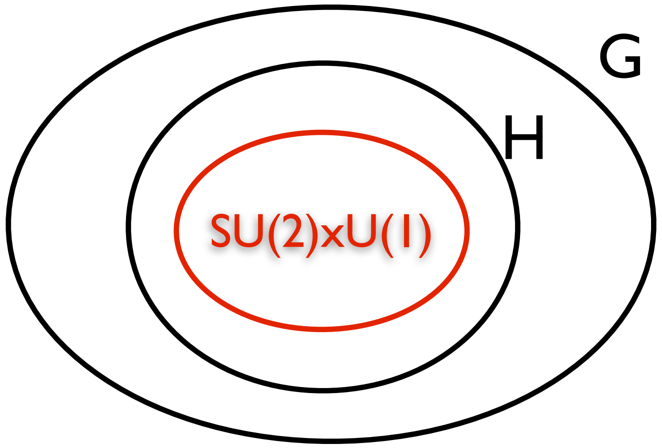
Grossman, Kagan, Nir hep-ph/069178
Isidori, Kamenik, Ligeti, Perez 1111.4987
Giudice, Isidori, Paradisi 1201.6204
Hiller, Hochberg, Nir 1204.1046
....

Composite Higgs

Georgi, Kaplan (1984)
Agashe, Contino, Pomarol hep-ph/0412089
Contino, 1005.4269

- The Higgs is a pseudo Goldstone boson

- Pattern of symmetry breaking:



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by strong interactions g_ρ, m_ρ

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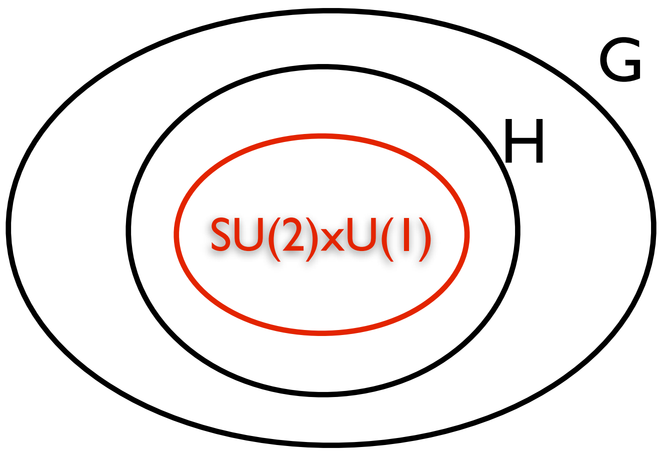

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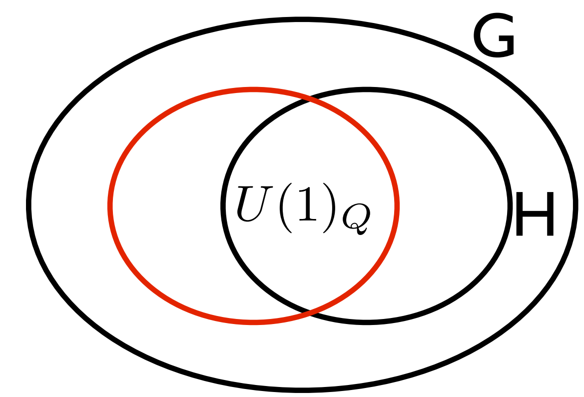

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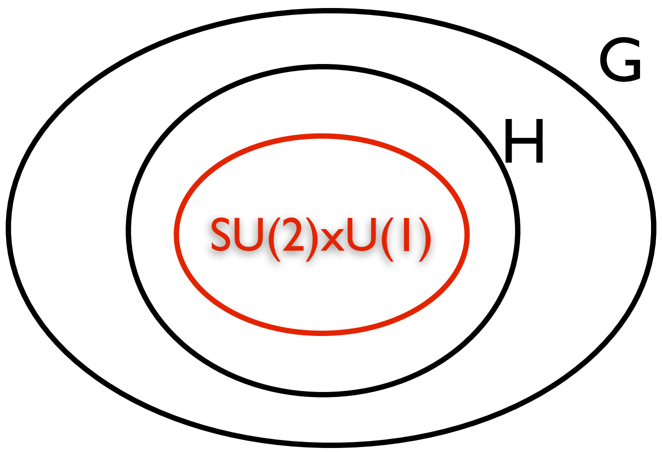

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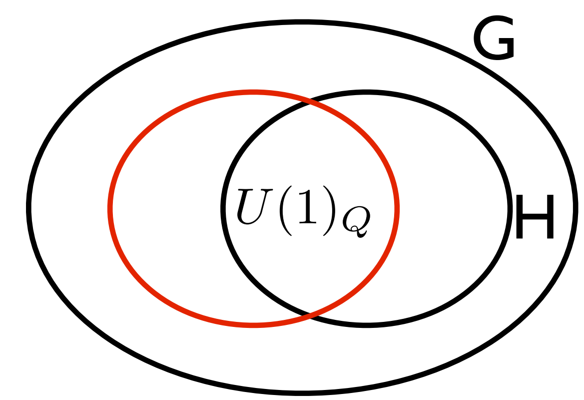

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    1. EW symmetry is broken
    2. Higgs mass is generated

$$V(H) \sim \frac{m_\rho^4}{g_\rho^2} \times \frac{y_{L,R}^2}{16\pi^2} \times \hat{V}(H/f)$$

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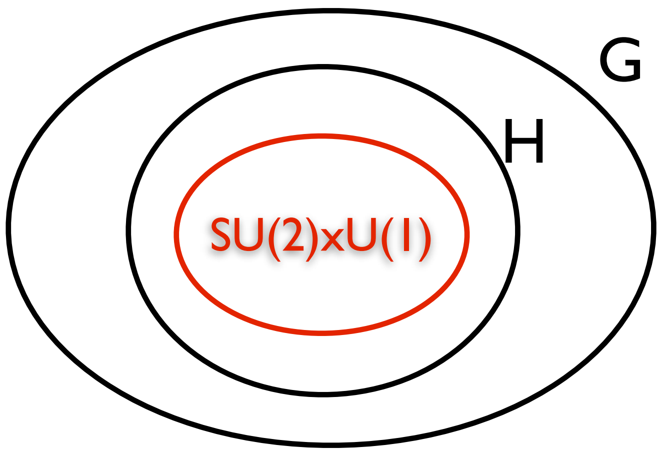

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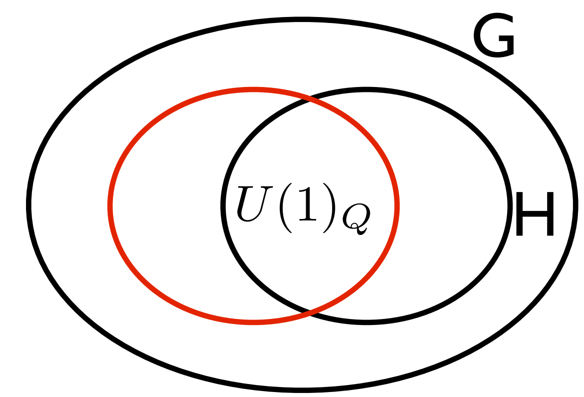

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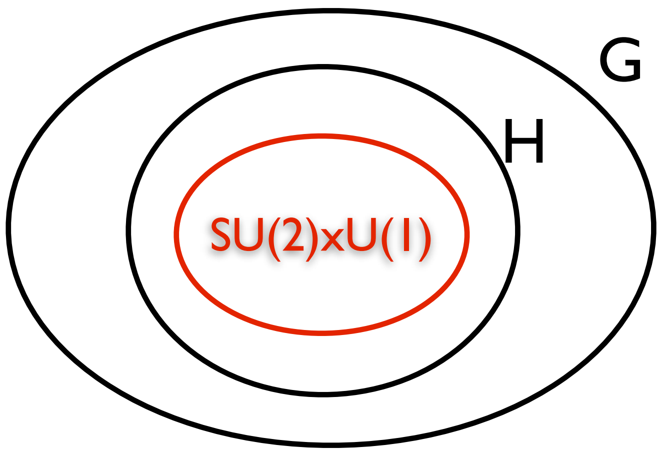

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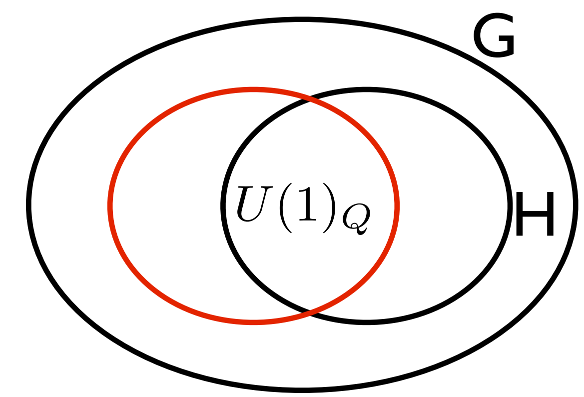

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- Minimal realization

  1. H contains EW group and the custodial symmetry $H = SO(4)$
  2. G/H contains only one Higgs doublet $G/H = SO(5)/SO(4)$

Lepton sector

- Yukawas for charged leptons $(Y_e)_{ij} \sim g_\rho \epsilon_i^\ell \epsilon_j^e,$

Taglia (?)

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- If neutrinos are Dirac particles $(Y_\nu)_{ij} \sim g_\rho \epsilon_i^\ell$ [illegible]

$$V_{PMNS} = L_e^\dagger L_\nu \longrightarrow \epsilon_i^\ell / \epsilon_j^\ell \text{ [illegible] } \sim m_i^e / m_j^e.$$

- If neutrinos are Majorana particles, other pa[illegible]ed

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- In any case the phenomenologically most favorable scenario is the LR symmetric case

$$\frac{\epsilon^\ell_i}{\epsilon^\ell_j} \sim \frac{\epsilon^e_i}{\epsilon^e_j} \sim \sqrt{\frac{m^e_i}{m^e_j}}.$$

Leptonic Operator	Re(c)	Im(c)	Observables
$\bar{e}\sigma^{\mu\nu} e F_{\mu\nu} e_{L,R}$	-	5×10^{-2}	electron EDM [52]
$\bar{\mu}\sigma^{\mu\nu} e F_{\mu\nu} e_{L,R}$	4×10^{-3}		$\mu \to e\gamma$ [53]
$\bar{e}\gamma^\mu \mu_{L,R} H^\dagger i \overleftrightarrow{D}_\mu H$	$1.5 \left(\frac{g_\rho}{4\pi}\right) \frac{\epsilon^e_3}{\epsilon^\ell_3}$		$\mu(Au) \to e(Au)$ [54]

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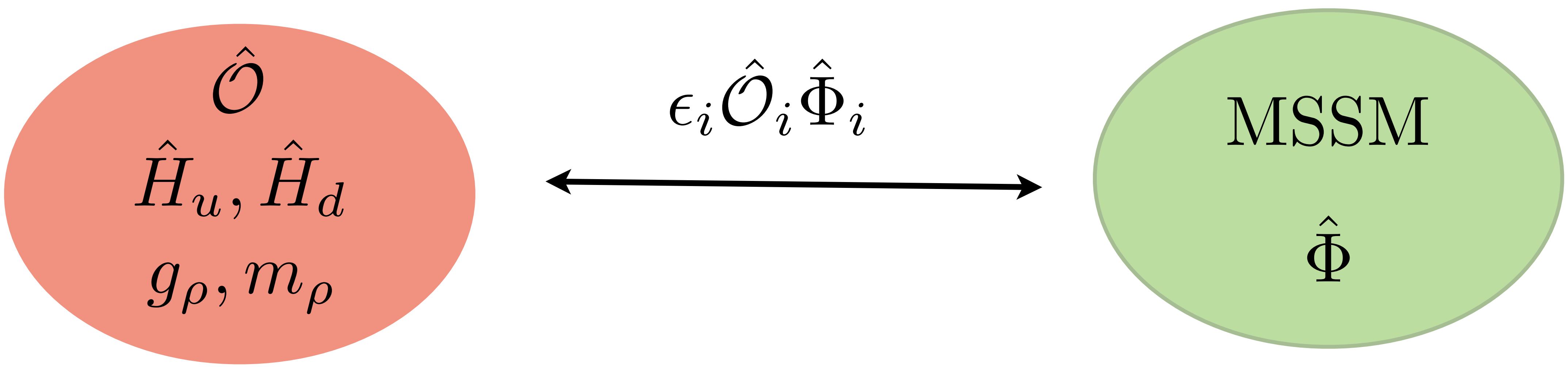
PC is ruled out or extra flavor protection in the strong sector is needed
(no hadronic uncertainties to blame!)

Summary CH models

- The New Physics scale required to saturate the CPV in D decays is too large for direct production
- Tuning of O(0.1-1%) why not?!
- The model is marginally consistent with all the bounds in the quark sector. Neutron EDM provides the most robust constraint (signature?!)
- Possible effects in $\epsilon_K, \epsilon'/\epsilon, B \to X_s\gamma$
- Lepton sector problematic, needs ad hoc symmetries

SUSY

(Nomura, Papucci, Stolarski 2008)



- Flavor is generated at a scale $\Lambda_F = m_\rho$
- Another scale associated to the mediation of SUSY breaking Λ_S

Low energy MSSM

- Low energy EFT can be derived from

$$\mathcal{L}_{\rm NDA}^{\rm SUSY} = \int d^2\theta \int d^2\overline{\theta}\, \frac{m_\rho^2}{g_\rho^2}\, \mathcal{K}\left(\frac{\epsilon_i^a g_\rho \Phi_i^a}{m_\rho}, X, \frac{g_\rho H_{u,d}}{m_\rho}\right) + \left[\int d^2\theta\, \frac{m_\rho^3}{g_\rho^2}\, \mathcal{W}\left(\frac{\epsilon_i^a g_\rho \Phi_i^a}{m_\rho}, X, \frac{g_\rho H_{u,d}}{m_\rho}\right) + \text{h.c.}\right]$$

- As before but with $f \longrightarrow \Phi$ and X keep track of SUSY breaking
- Respect to the non susy case $m_\rho \gg 10\ \text{TeV}$

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- Soft terms:

$$(m_Q^2)_{ij} = \tilde m_Q^2 \delta^{ij} + \tilde m_0^2 c_Q^{ij}\, \epsilon_Q^i \epsilon_Q^j \sim \delta^{ij} + \epsilon_Q^i \times \epsilon_Q^j$$
$$(m_U^2)_{ij} = \tilde m_U^2 \delta^{ij} + \tilde m_0^2 c_U^{ij}\, \epsilon_U^i \epsilon_U^j \sim \delta^{ij} + \epsilon_U^i \times \epsilon_U^j$$
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$$A_U^{ij} = \epsilon_Q^i \epsilon_U^j g_\rho\, a_U^{ij} \tilde m_0 \sim Y_U^{ij} \tilde m_0$$
$$A_D^{ij} = \epsilon_Q^i \epsilon_D^j g_\rho\, a_D^{ij} \tilde m_0 \sim Y_D^{ij} \tilde m_0$$

No exact proportionality.
This realize the “Disoriented A-terms” scenario
Giudice, Isidori, Paradisi (2012)

Flavorful Supersymmetry

- Flavor and SUSY breaking

Λ_F — • Generation of the flavor $\longrightarrow$ Y_u, Y_d, Y_e

Λ_S — • Mediation of SUSY breaking $\longrightarrow$ $\tilde{m}^2_{ij} = \tilde{m}^2_0\,\delta_{ij} \quad A = 0$

• RGE

m_{soft} — • Low energy MFV MSSM

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- Flavorful SUSY (Nomura, Papucci, Stolarski 2008)

Λ_S $\longrightarrow$ $\tilde{m}^2_{ij} = \tilde{m}^2_0\, \delta_{ij} \quad A = 0$

$$W_{\text{mix}} = \epsilon_i^Q\, \hat{Q}_i\, \mathcal{O}_{\hat{Q}_i} + \ldots$$

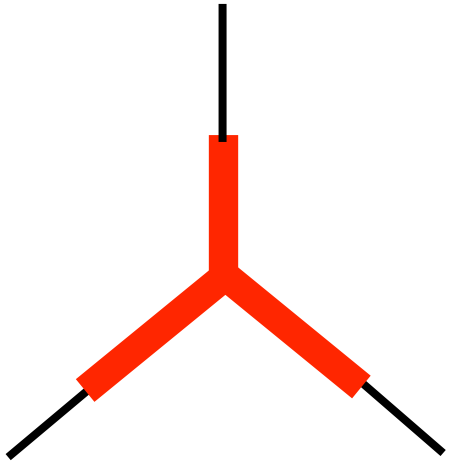
$\Lambda_F = m_\rho$ $\longrightarrow$

$$Y = g_\rho \epsilon_L \epsilon_R$$
$$\tilde{m}^2_{ij} = \tilde{m}^2_0\, \left(\delta_{ij} + c_{ij}\, \epsilon_i \epsilon_j\right)$$
$$A \sim Y A_0$$

m_{soft} • Low energy Flavorful MSSM

R Parity Violation and PC

- Without extra symmetries in the flavor sector we expect R parity violating couplings:



$$W_{\not B} = \frac{1}{2}\lambda''_{ijk} u_i d_j d_k, \qquad \lambda''_{ijk} \sim 2 g_{\not B} \epsilon^u_i \epsilon^d_j \epsilon^d_k$$

$$W_{\not L} = \frac{1}{2}\lambda_{ijk} L_i L_j e_k + \lambda'_{ijk} L_i Q_j d_k \qquad \lambda_{ijk} \sim 2 g_{\not L} \epsilon^\ell_i \epsilon^\ell_j \epsilon^e_k \qquad \lambda'_{ijk} \sim g_{\not L} \epsilon^\ell_i \epsilon^q_j \epsilon^d_k$$

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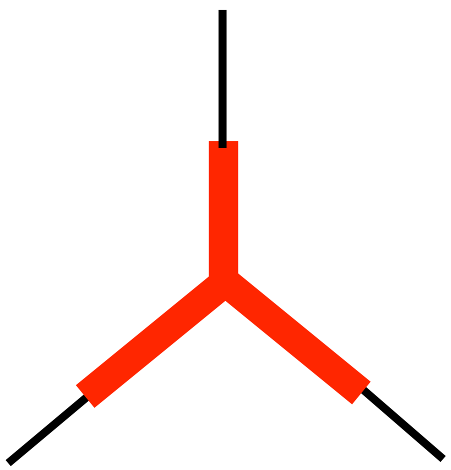

$$\begin{aligned} W_{\not B} &= \frac{1}{2}\lambda''_{ijk} u_i d_j d_k, \\ W_{\not L} &= \frac{1}{2}\lambda_{ijk} L_i L_j e_k + \lambda'_{ijk} L_i Q_j d_k \end{aligned}$$

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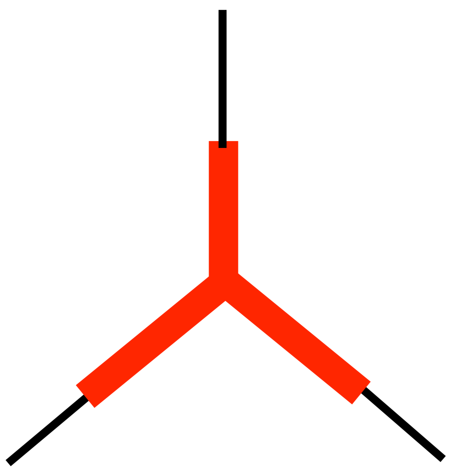

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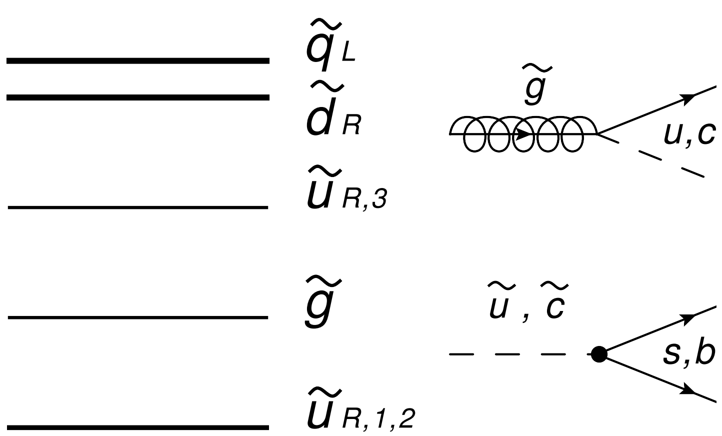
- Simultaneous baryon and lepton number violation generate a too fast proton decay
- Lepton number violation is severely constraints by neutrino masses
- Baryon number violation is very welcome to hide SUSY at colliders



Depending on the spectra, bounds on squark and gluino down to 400 GeV

Partial Compositeness in CH models

Λ^{cutoff} $\quad \mathcal{L} = \epsilon_i f_i \mathcal{O}_i + \ldots$ $\qquad \epsilon_i = \mathcal{O}(1)$

~ conformal

m_ρ $\quad \mathcal{L}_{\text{SM}} + \underbrace{\ldots}$

Higher Dim. Operators controlled by m_ρ
(here focus on Flavor Violation)

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$$\epsilon_1 \ll \epsilon_2 \ll \epsilon_3$$

natural explanation of flavor hierarchy!

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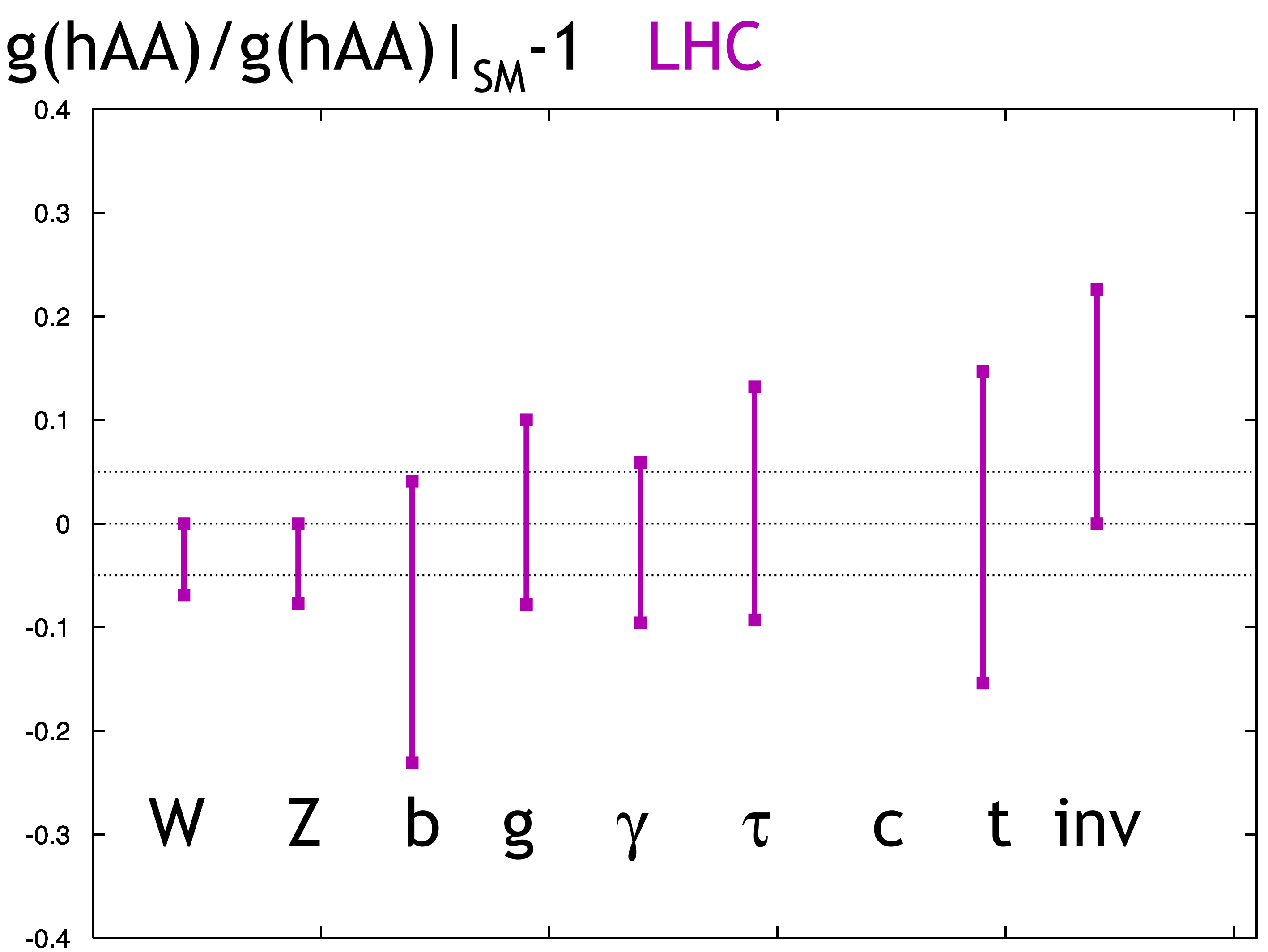
Higher Dim. Operators controlled by m_ρ
(here focus on Flavor Violation)

- Use Naive Dimensional Analysis to estimate the Wilson Coefficients:

$$\mathcal{L}_{\rm NDA} = \frac{m_\rho^4}{g_\rho^2}\left[\mathcal{L}^{(0)}\left(\frac{g_\rho \epsilon_i^a f_i^a}{m_\rho^{3/2}}, \frac{D_\mu}{m_\rho}, \frac{g_\rho H}{m_\rho}\right) + \frac{g_\rho^2}{16\pi^2}\,\mathcal{L}^{(1)}\left(\frac{g_\rho \epsilon_i^a f_i^a}{m_\rho^{3/2}}, \frac{D_\mu}{m_\rho}, \frac{g_\rho H}{m_\rho}\right) + \ldots\right]$$

Higgs: the future



$300\ \mathrm{fb}^{-1}$

$14\ \mathrm{TeV}$

$$g(f)/SM = 1 + (3-9)\% \cdot \left(\frac{1\ \mathrm{TeV}}{f}\right)^2$$

PC

$$g(\tau)/SM = 1 + 10\% \left(\frac{400\ \mathrm{GeV}}{m_A}\right)^2$$

SUSY

$$g(g)/SM = 1 + (5-9)\%$$
$$g(\gamma)/SM = 1 + (5-6)\%$$

Little Higgs