FCNC from Hierarchical Sfermions

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with A. Romanino

How to do it?

- Direct searches (produce new particles directly)
- Indirect searches

Let us consider the second option in more detail:

Road map

- 1) Select physical (measured) observables ($\rightarrow$ FCNC)

$$EXP = SM + NP$$
$$EXP \approx SM$$

- 2) Select your new physics model ($\rightarrow$ MSSM)

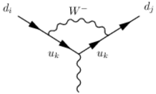
$$EXP = SM + NP(\{m\}, \{g\}, \{\theta\})$$

- 3) Give bounds to the NP parameters ($\rightarrow \delta_{ij}$)

FCNC in MSSM

Feynman diagrams for $s \longrightarrow d, b \longrightarrow s, b \longrightarrow d$ processes:

- W^- and up quarks



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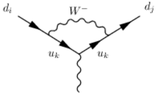

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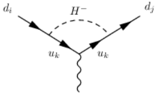

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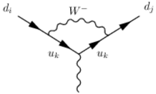

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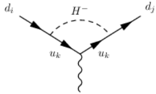
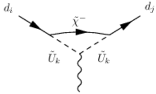


- $\tilde{\chi}^-$ and up squarks



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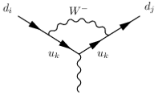

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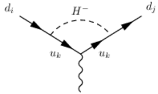

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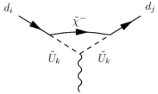
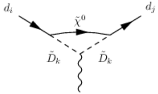


- $\tilde{\chi}^0$ and down squarks



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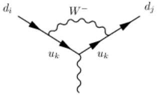

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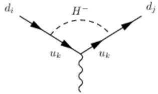

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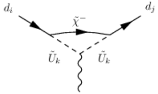

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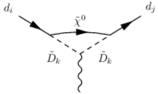
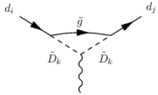
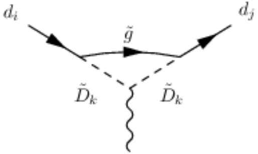


- $\tilde{g}$ and down squarks



Gluino Dominance in SUSY

Focusing on the gluino:



Motivations

- α_s enhanced vs. other diagrams
- $SU(3)_C$ is unbroken, easier to be studied

- Amplitude $\propto \alpha_s W_{d_i \tilde{D}_k} f(x_k) W^{\dagger}_{\tilde{D}_k d_j}$
- $x_k = \frac{m^2_{\tilde{D}_k}}{m^2_{\tilde{g}}}$
- W is the 6x6 matrix that diagonalizes the sfermion mass matrix

Mass Insertion Approximation

For phenomenological reasons, off diagonal terms in the sfermion mass matrices (Δ_{ij}) must be small with respect to the diagonal entries. This allows us the following approximation:

$$W_{d_i\tilde{D}_k} f(x_k) W^{\dagger}_{\tilde{D}_k d_j} \approx F(x_i, x_j)\frac{\Delta_{ij}}{m_{\tilde{g}}^2} = \frac{\tilde{m}^2}{m_{\tilde{g}}^2} F(x_i, x_j)\delta_{ij}$$

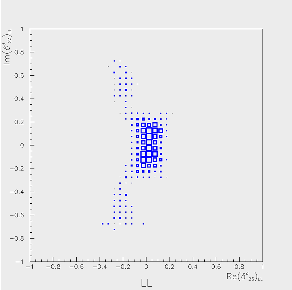
- $F(x_i, x_j) = \frac{f(x_i) - f(x_j)}{x_i - x_j}$
- $\delta_{ij} = \frac{\Delta_{ij}}{\tilde{m}^2}$
- $\tilde{m}$ is the average sfermion mass

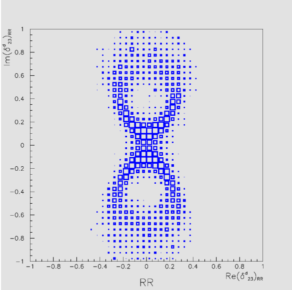
Degenerate Case

In order to reduce the number of SUSY parameters, it is widely assumed in letterature that all sfermion masses are equal. In this case we obtain:

$$W_{d_i \tilde{D}_k} f(x_k) W^\dagger_{\tilde{D}_k d_j} \approx x f^{(1)}(x) \delta_{ij} \qquad x = \frac{\tilde{m}^2}{m^2_{\tilde{g}}}$$

Using FCNC constraints it's possible to give bounds on the flavor violating parameters δ_{ij}:





Ciuchini, Silvestrini arXiv:hep-ph/0603114

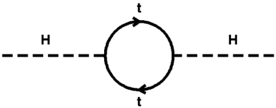
Hierachical Case

We want to study the case in which the third family is lighter than the first two

Motivations

- Radiative corrections drives the third family to be lighter (because of large Yukawa coupling)
- Correlations between the size of different observables may depend significantly on the degeneracy assumption

What about naturalness?



$$\delta M_H^2 = \sum_f \frac{3}{\sqrt{2}\pi^2} G_F m_f^2 \Lambda_f^2$$

$$\approx \sum_f \left(0.2 \frac{m_f}{m_t} \Lambda_f\right)^2$$

For lighter quarks we can encrease the scalar partner mass without spoiling naturalness

arXiv:hep-ph/9610252, Effective Supersymmetry

FCNC from Hierarchical Sfermions

Hierarchical case

- $\Delta F = 1 \qquad f(x)\hat{\delta}$
- $\Delta F = 2 \qquad g^{(1)}(x)\hat{\delta}^2$

Degenerate case

- $\Delta F = 1 \qquad x f^{(1)}(x)\delta$
- $\Delta F = 2 \qquad \frac{x^2}{3!} g^{(3)}(x)\delta^2$

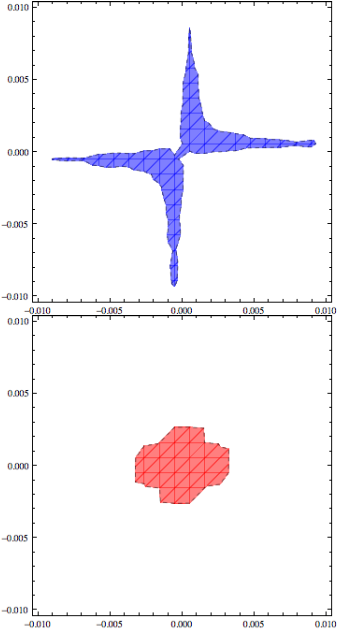
New insertions $\hat{\delta}$

The new insertions in the hierarchical limit are correlated and can be expressed in terms of $\hat{\delta}_{L_i L_3}$ and $\hat{\delta}_{R_i R_3}$:

- $\hat{\delta}_{Li,Lj} = \hat{\delta}_{Li,L3}\hat{\delta}_{L3,Lj}$
- $\hat{\delta}_{Li,Rj} = \frac{\Delta_{L3,R3}}{\tilde{m}_3^2}\hat{\delta}_{Li,L3}\hat{\delta}_{R3,Rj}$
- $\hat{\delta}_{Li,R3} = \frac{\Delta_{L3,R3}}{\tilde{m}_3^2}\hat{\delta}_{Li,L3}$

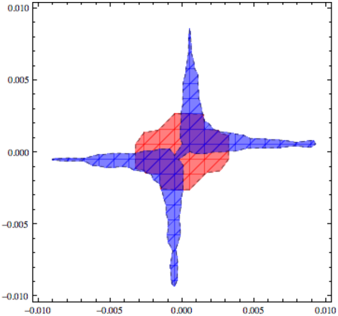
In the degenerate case all δ are independent

$\hat{\delta}$ Correlations



- Direct bound on $\hat{\delta}_{d_L s_L}$ using Δm_K
- Direct bound on $\hat{\delta}_{d_L b_L}$ using Δm_{B_d}
- Direct bound on $\hat{\delta}_{b_L s_L}$ using Δm_{B_s}
- Indirect bound on $\hat{\delta}_{d_L s_L} = \hat{\delta}_{d_L b_L} \hat{\delta}_{d_L b_L}$

$\hat{\delta}$ Correlations



Using both direct and indirect bound we can reduce the allowed region in the $\mathrm{Re}\,\hat{\delta} - \mathrm{Im}\,\hat{\delta}$ plane

Conclusions

- The degenerate and the hierarchical limit of the mass insertion approximation are quantitatively and qualitatively different
- The degenerate limit of the mass insertion approximation, the one widely used in the literature, does not really represent the general case. The latter can be better represented by the range between the two complementary extremes, the degenerate and the hierarchical ones