THE MSSM WITH NONMINIMAL FLAVOUR VIOLATION

Luca Silvestrini
INFN, Rome

- Introduction
- Constraints on the MSSM
- Summary

Based on:

M. Ciuchini, E. Franco, D. Guadagnoli, V. Lubicz, V. Porretti, L.S., hep-ph/0701xxx

For large tan β, see talk by Paride Paradisi

INTRODUCTION - I

- We know very well how to build a SUSY version of the MSSM:
  - Gauge interactions: fixed by SUSY
  - Yukawa interactions fixed by SUSY + R parity: 2HDM w. tan β & 5 physical Higgses
- We do not know how to break SUSY: soft SUSY breaking terms: sfermion bilinears & trilinears, gaugino masses. Can all violate flavour & CP.

INTRODUCTION - II

- Super-CKM basis: all gauge interactions governed by the CKM matrix. Additional sources of flavour violation in squark masses:

$$\mathcal{M}^2_{\tilde{U}} = \begin{pmatrix} (M^2_{\tilde{U}})_{LL} + m_u^2 - \frac{\cos 2\beta}{6}(M_Z^2 - 4M_W^2)\hat{1} & (M^2_{\tilde{U}})_{LR} - \cot\beta\mu m_u \\ (M^2_{\tilde{U}})^\dagger_{LR} - \cot\beta\mu^\star m_u & (M^2_{\tilde{U}})_{RR} + m_u^2 + \frac{2\cos 2\beta}{3}M_Z^2 \sin^2\theta_W \hat{1} \end{pmatrix}$$

$$\mathcal{M}^2_{\tilde{D}} = \begin{pmatrix} (M^2_{\tilde{D}})_{LL} + m_d^2 - \frac{\cos 2\beta}{6}(M_Z^2 + 2M_W^2)\hat{1} & (M^2_{\tilde{D}})_{LR} - \tan\beta\mu m_d \\ (M^2_{\tilde{D}})^\dagger_{LR} - \tan\beta\mu^\star m_d & (M^2_{\tilde{D}})_{RR} + m_d^2 - \frac{\cos 2\beta}{3}M_Z^2 \sin^2\theta_W \hat{1} \end{pmatrix};$$

INTRODUCTION - III

$$(M^2_{\tilde{D}})_{LL} = V^D_L M^2_Q V^{D\dagger}_L \qquad (M^2_{\tilde{D}})_{RR} = V^D_R M^{2T}_D V^{D\dagger}_R \qquad (M^2_{\tilde{D}})_{LR} = \frac{v\cos\beta}{\sqrt{2}} V^D_L A^\star_D V^{D\dagger}_R$$

M^2_Q, M^2_D, A_D soft SUSY breaking terms, $V^D_{L,R}$ quark mass rotation matrices. Squark masses not diagonal unless M^2_Q, M^2_D proportional to identity matrix or to quark mass squared, and A_D proportional to quark mass:

Universality/alignment of soft SUSY breaking

INTRODUCTION - IV

- Flavour changing Mass Insertions (MI):

$$(M^2_{\tilde{U}})_{LL} = \begin{pmatrix} (m^2_{U1})_{LL} & (\Delta^{12}_U)_{LL} & (\Delta^{13}_U)_{LL} \\ (\Delta^{21}_U)_{LL} & (m^2_{U2})_{LL} & (\Delta^{23}_U)_{LL} \\ (\Delta^{31}_U)_{LL} & (\Delta^{32}_U)_{LL} & (m^2_{U3})_{LL} \end{pmatrix}$$

$$(\delta^{IJ}_U)_{LR} = \frac{(\Delta^{IJ}_U)_{LR}}{(m_{UI})_{LL}\,(m_{UJ})_{RR}}$$

INTRODUCTION - V

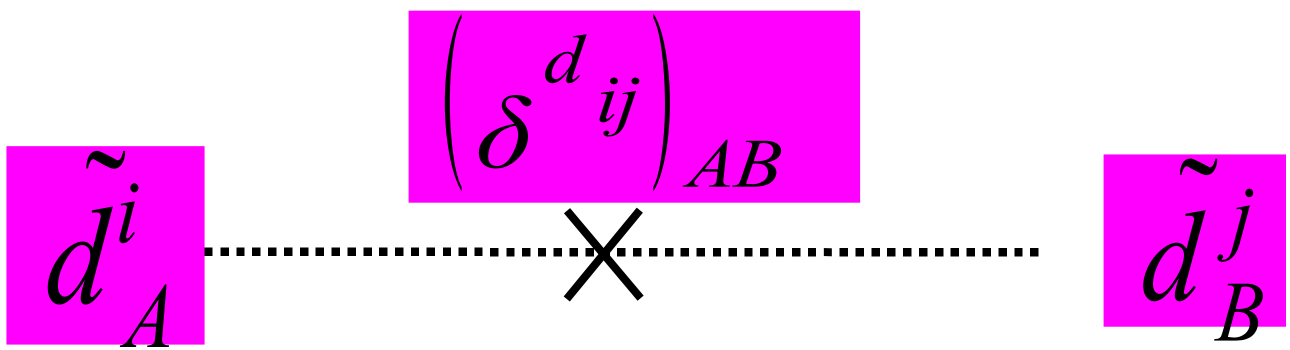
- In the MSSM, two classes of contributions to FCNC's:
  - Supersymmetrization of SM contributions ($W \to \tilde{w}$, $t \to \tilde{t}$) + $H^{\pm}$: also present with $\delta=0$
  - Pure SUSY contributions: $\tilde{g}$ - $\tilde{q}$: require $\delta\neq 0$

Hall, Kostelecky & Raby; Gabbiani et al.

CONSTRAINTS ON THE MSSM

Ciuchini et al., to appear, Preliminary

- We consider a MSSM with generic soft SUSY-breaking terms, but
  - dominant gluino contributions only
  - mass insertion approximation



four insertions AB=LL, LR, RL, RR

WHAT IS NEW SINCE GGMS '96

- Theory:
  - LO & NLO anomalous dimensions for $\Delta F=2$ (strong enhancement of NP operators)

    Bagger et al; Ciuchini et al; Buras et al
  - Lattice QCD B-parameters for $\Delta F=2$

    Donini et al; Becirevic et al; Babich et al; CP-PACS
  - SM NNLO $b \to s\gamma$, $b \to sll$

    Misiak et al; Ghinculov et al; ...
  - NLO matching for gluino $\Delta F=2$

    Ciuchini et al

WHAT IS NEW SINCE GGMS '96

- Experiment:
  - CP violation in B_d mixing and decay

    BaBar, Belle
  - B_s mixing and lifetime

    CDF, D0
  - $b \to s\gamma$, $b \to sll$ with CP asymmetries

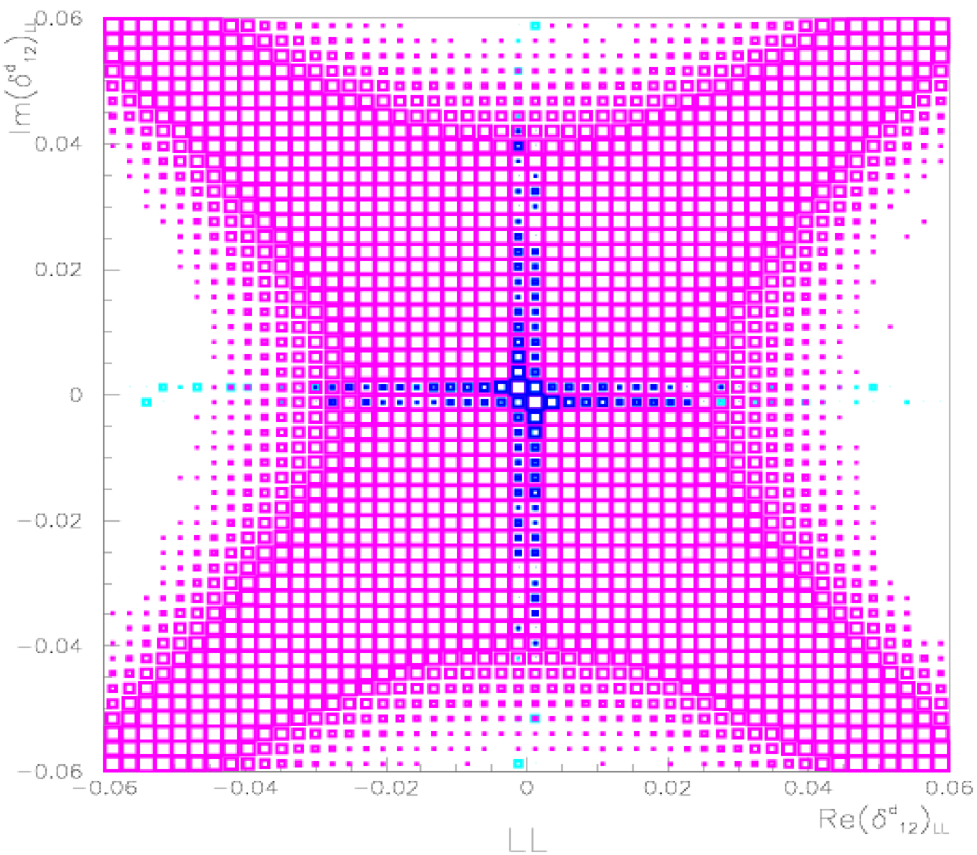
    BaBar, Belle
  - CKM determination in the presence of NP

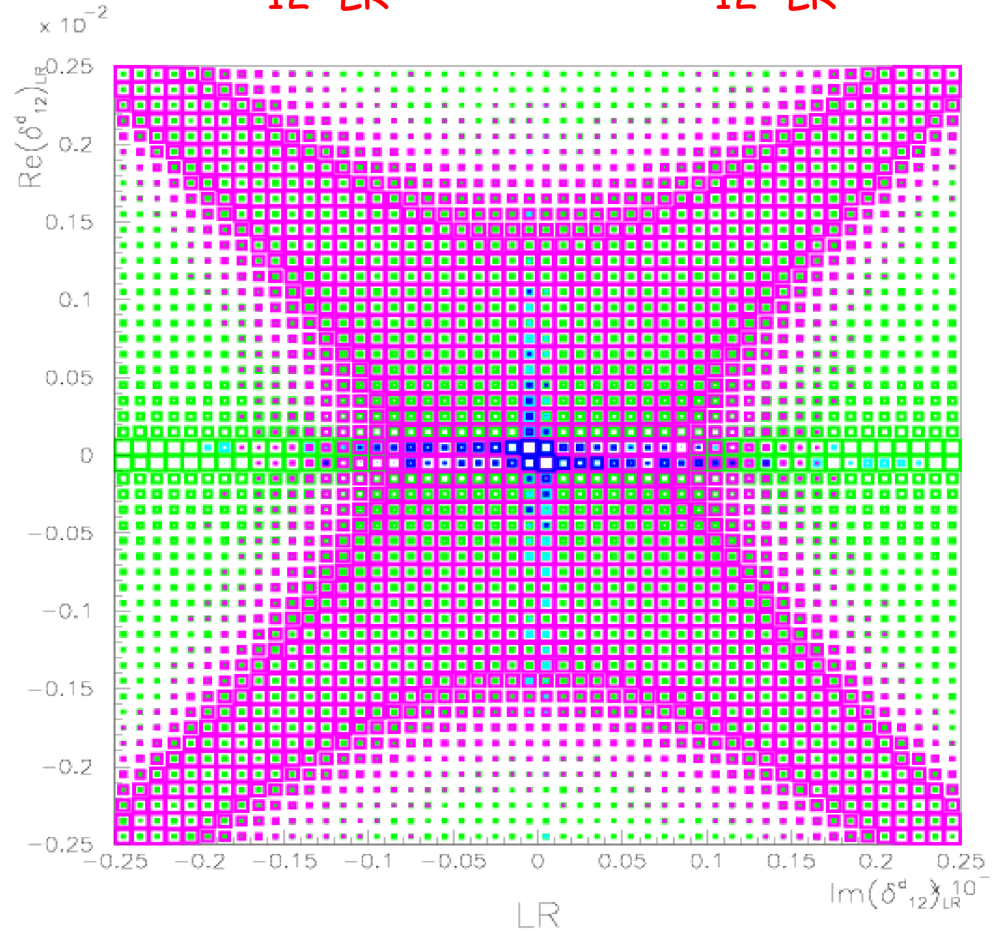
    UTfit coll.

CONSTRAINTS ON δ's

- $\left(\delta^{d}{}_{12}\right)_{AB}$ contribute to Kaon mixing: constraints from Δm_K, ε_K & ε'/ε
- $\left(\delta^{d}{}_{13}\right)_{AB}$ contribute to B mixing: constraints from Δm_B & CPV
- $\left(\delta^{d}{}_{23}\right)_{AB}$ contribute to Bs mixing and $b \to s$ decays: constraints from Δm_{Bs}, $\Delta\Gamma_s$, $b \to s\gamma$, $b \to s l^+ l^-$
- for reference, choose $m_{gl}=m_{sq}$=350 GeV

Re $(\delta^d_{12})_{LL,RR}$ vs Im $(\delta^d_{12})_{LL,RR}$ Re $(\delta^d_{12})_{LR}$ vs Im $(\delta^d_{12})_{LR}$



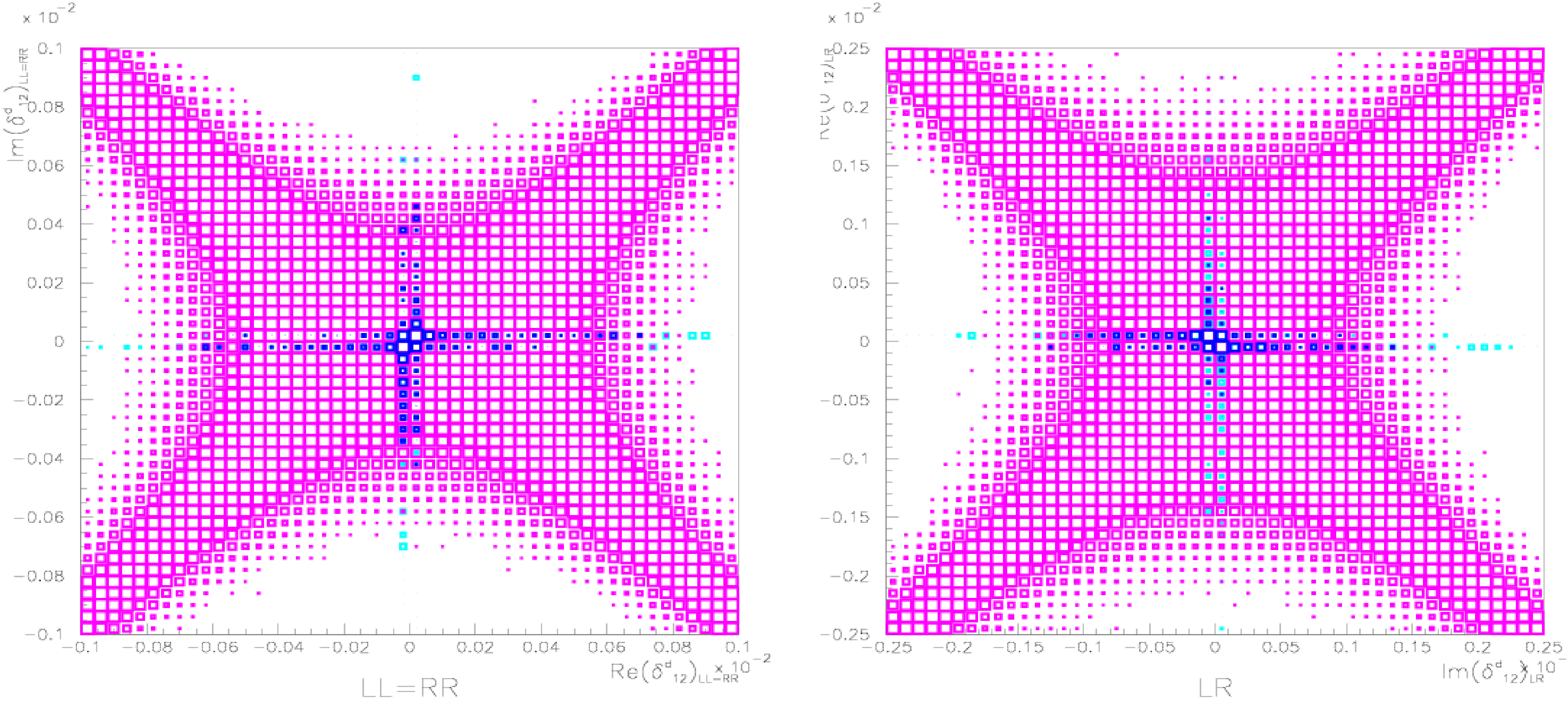


Δm_K only ε'/ε only

ε_K only

Δm_K and ε_K $m_{sq}=m_{gl}=350$ GeV

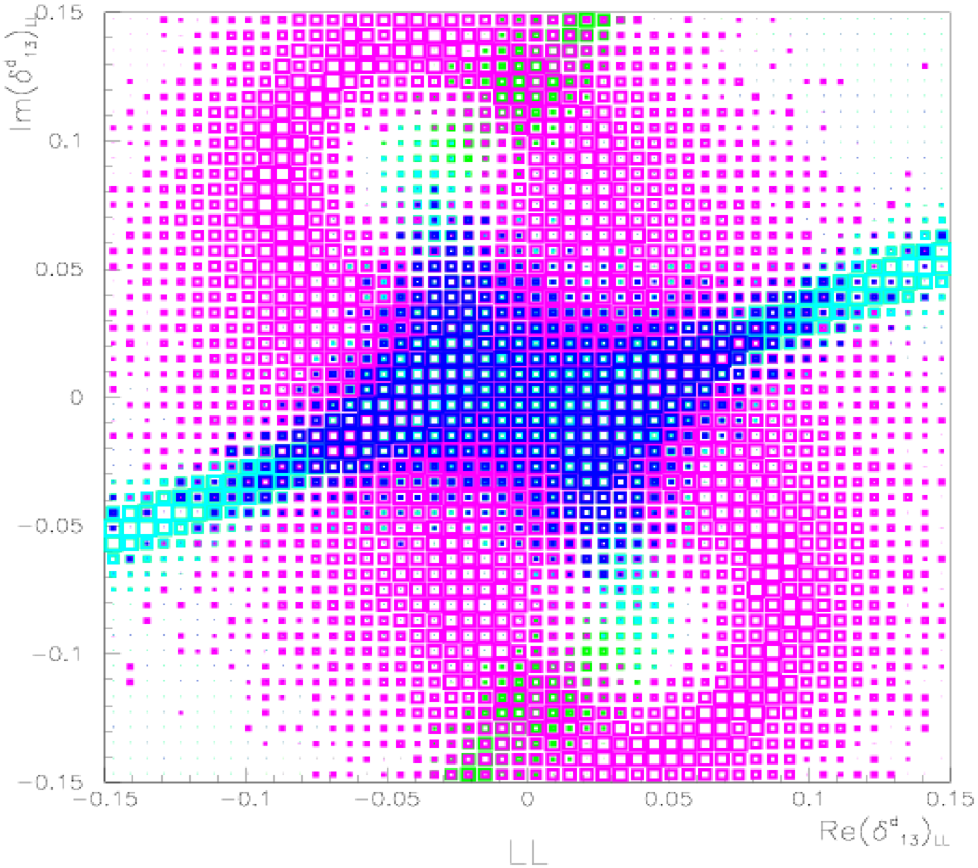
Re $(\delta^d_{12})_{LL=RR}$ vs Im $(\delta^d_{12})_{LL=RR}$ Re $(\delta^d_{12})_{RL}$ vs Im $(\delta^d_{12})_{RL}$

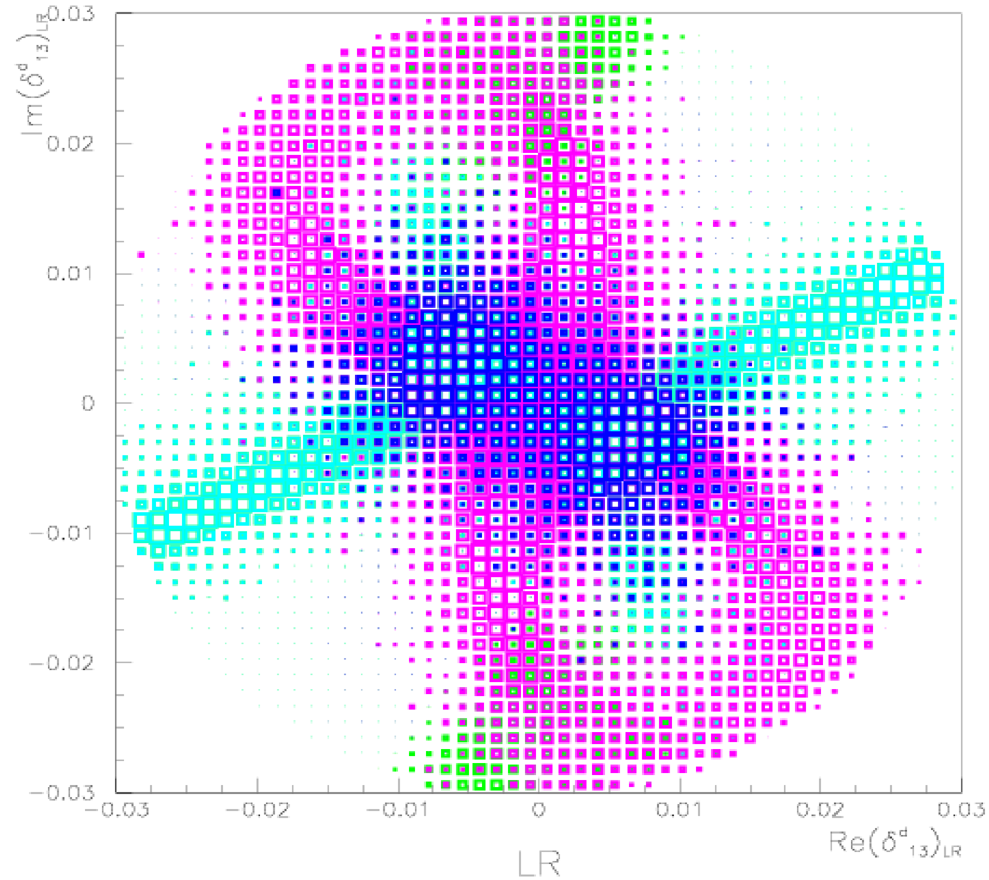


Δm_K only

ε_K only

Δm_K and ε_K $m_{sq}=m_{gl}=350$ GeV





Re $(\delta^d{}_{13})_{LL,RR}$ vs Im $(\delta^d{}_{13})_{LL,RR}$

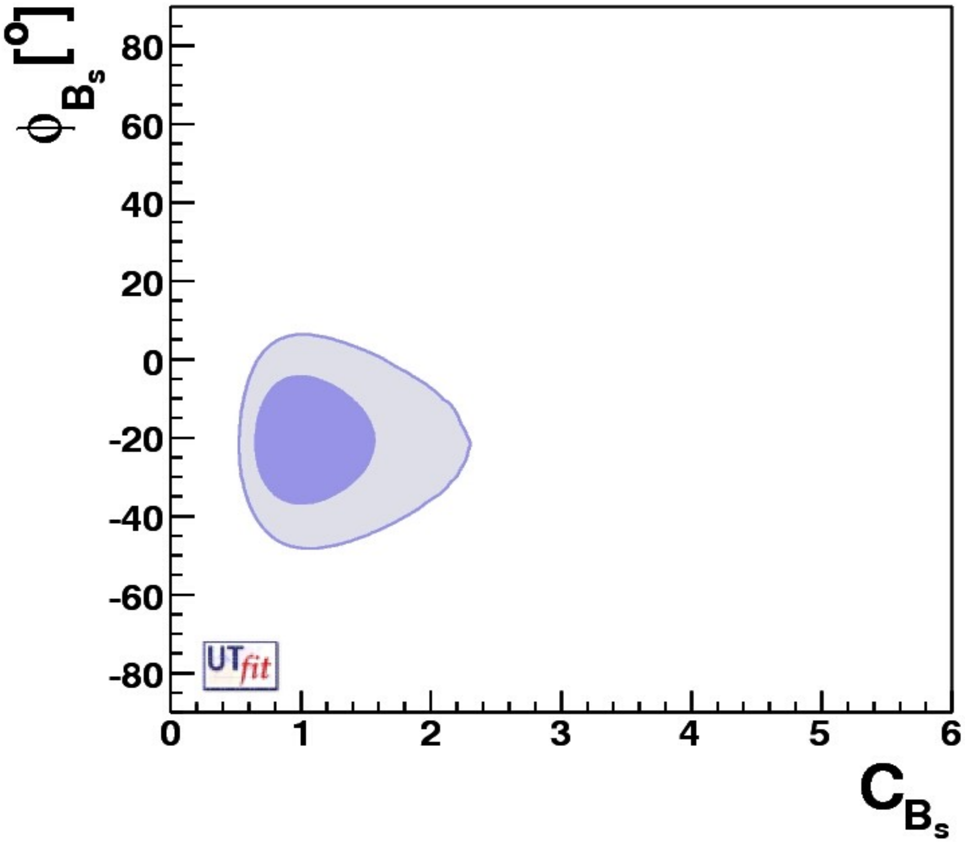
Re $(\delta^d{}_{13})_{LR,RL}$ vs Im $(\delta^d{}_{13})_{LR,RL}$

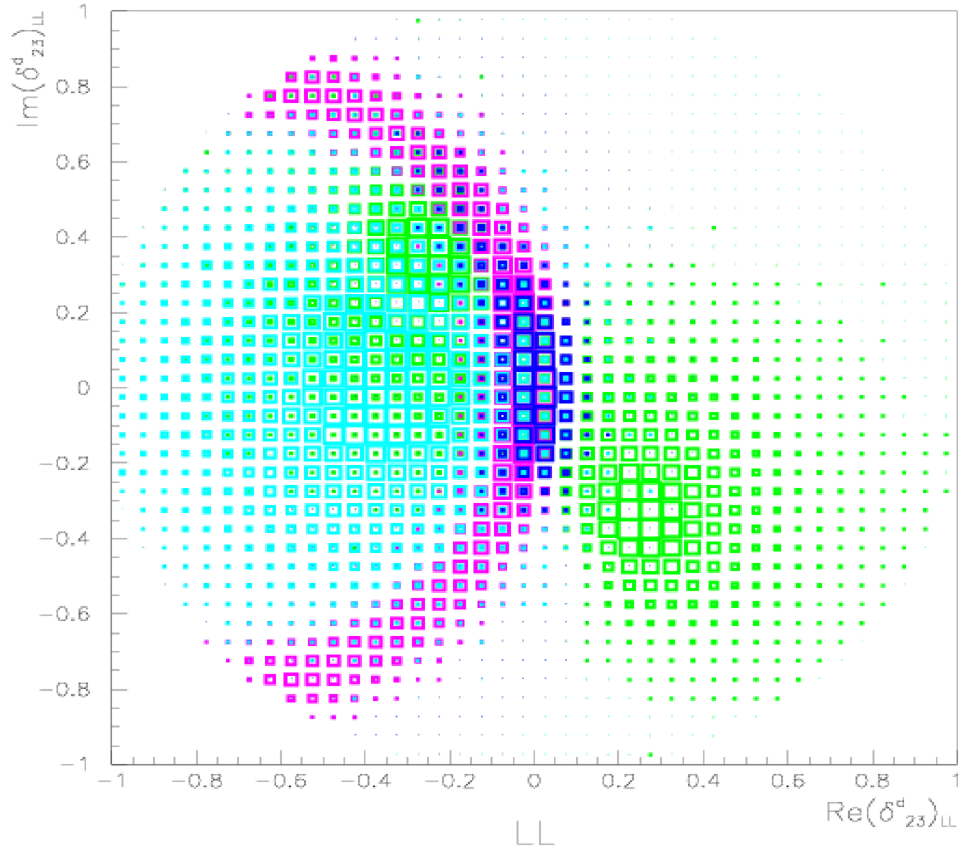
Δm_B only

sin 2β only

sin 2β and cos 2β

All constraints





UTfit coll., PRELIMINARY

Re $(\delta^d_{23})_{LL}$ vs Im $(\delta^d_{23})_{LL}$

tanβ=3

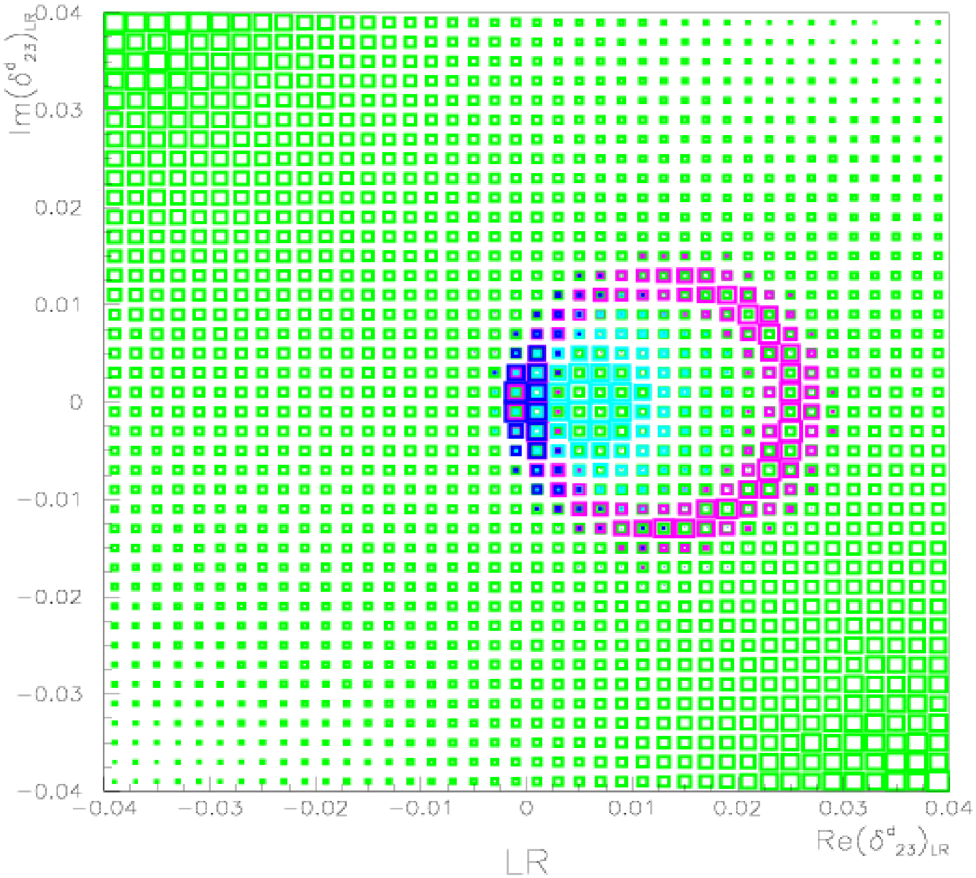
$$C_{B_s} e^{2i\phi_{B_s}} = \frac{A_{\rm mix}^{\rm SM+SUSY}}{A_{\rm mix}^{\rm SM}}$$

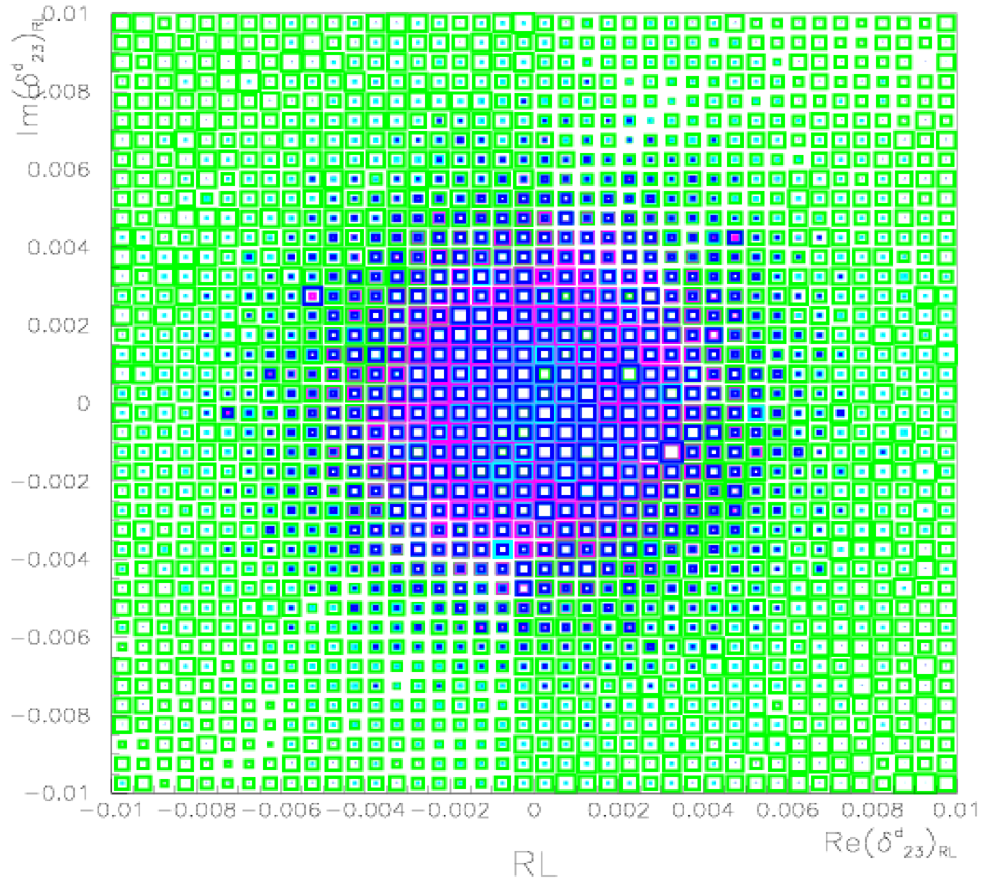
Constraint from b → s ll

Constraint from b → s γ

Constraint from C_{Bs}, ϕ_{Bs}

All constraints

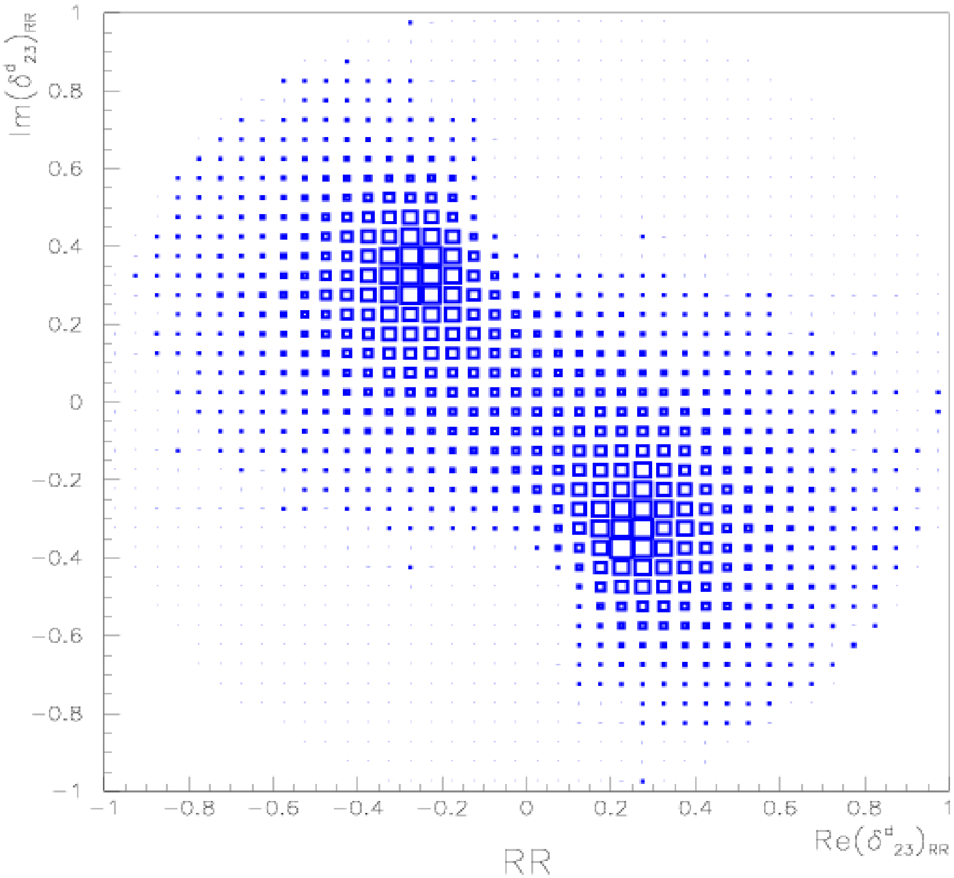


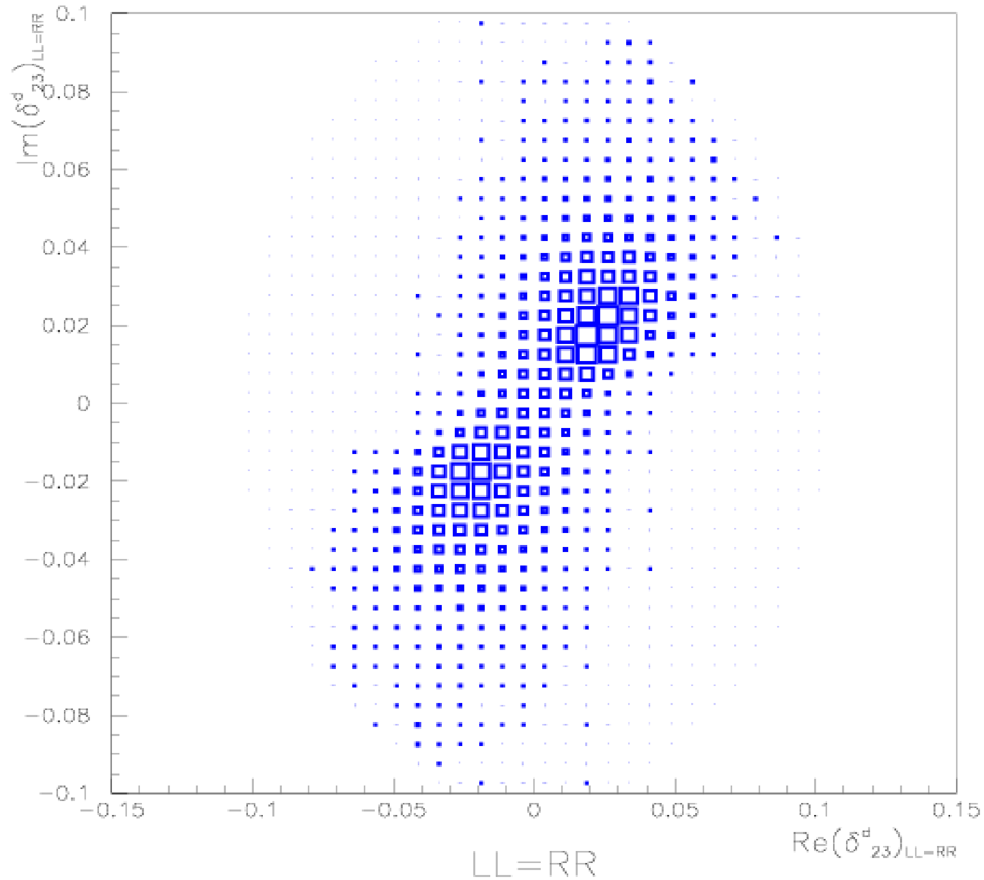


Re $(\delta^d_{23})_{LR}$ vs Im $(\delta^d_{23})_{LR}$ Re $(\delta^d_{23})_{RL}$ vs Im $(\delta^d_{23})_{RL}$

LR & RL dominated by BR($b \to s \gamma$) & BR($b \to s\, l^+ l^-$)

RL does not interfere with the SM





Re $(\delta^d_{23})_{RR}$ vs Im $(\delta^d_{23})_{RR}$ Re $(\delta^d_{23})_{LL=RR}$ vs Im $(\delta^d_{23})_{LL=RR}$

LL & LL=RR dominated by C_{Bs}, ϕ_{Bs}

Could easily explain a nonzero ϕ_{Bs}

SUMMARY

$\left\|\left(\delta^d_{12}\right)_{LL,RR}\right\|$	$\left\|\left(\delta^d_{12}\right)_{LL=RR}\right\|$	$\left\|\left(\delta^d_{12}\right)_{LR}\right\|$	$\left\|\left(\delta^d_{12}\right)_{RL}\right\|$
$1 \cdot 10^{-2}$	$2 \cdot 10^{-4}$	$5 \cdot 10^{-4}$	$5 \cdot 10^{-4}$
$\left\|\left(\delta^d_{13}\right)_{LL,RR}\right\|$	$\left\|\left(\delta^d_{13}\right)_{LL=RR}\right\|$	$\left\|\left(\delta^d_{13}\right)_{LR}\right\|$	$\left\|\left(\delta^d_{13}\right)_{RL}\right\|$
$7 \cdot 10^{-2}$	$5 \cdot 10^{-3}$	$1 \cdot 10^{-2}$	$1 \cdot 10^{-2}$
$\left\|\left(\delta^d_{23}\right)_{LL}\right\|$	$\left\|\left(\delta^d_{23}\right)_{RR}\right\|$	$\left\|\left(\delta^d_{23}\right)_{LL=RR}\right\|$	$\left\|\left(\delta^d_{23}\right)_{LR,RL}\right\|$
$2 \cdot 10^{-1}$	$6 \cdot 10^{-1}$	$5 \cdot 10^{-2}$	$5 \cdot 10^{-3}$

$m_{sq}=m_{gl}=-\mu=350$ GeV, $\tan\beta = 3$;

all bounds scale approx. as $m_{SUSY}/350$ GeV