B PHYSICS AND SUPERSYMMETRY

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INTRODUCTION

SUSY CAN MODIFY SM PREDICTIONS ON FLAVOUR PHYSICS IN THREE WAYS:

① WITH ADDITIONAL LOOP CONTRIBUTIONS GOVERNED BY THE CKM MATRIX
(PRESENT IN ALL SUSY MODELS)

② WITH ADDITIONAL LOOP CONTRIBUTIONS GOVERNED BY NEW SOURCES OF FV & CPV
(Ex. $\tilde{g}$-MEDIATED FCNC, PRESENT BEYOND MFV)

③ WITH ADDITIONAL TREE-LEVEL CONTRIBUTIONS GOVERNED BY NEW SOURCES OF FV & CPV
(ONLY PRESENT IN MODELS WITH $\cancel{R}_p$)

THE MSSM WITH MINIMAL FLAVOUR AND CP VIOLATION

Bertolini, Borzumati, Masiero & Ridolfi; Gabrielli & Giudice; Cho, Misiak & Wyler; Ali & London; Goto et al.; Misiak, Pokorski & Rosiek; Ciuchini, Degrassi, Gambino & Giudice; D'Ambrosio, Giudice, Isidori & Strumia; Buras et al

* ALL SFERMION MASSES FLAVOUR DIAGONAL AND REAL AT THE EW SCALE
* ALL GAUGINO AND HIGGS MASS PARAMETERS REAL

$\Rightarrow$ FLAVOUR & CP VIOLATION GOVERNED BY THE CKM MATRIX

* NOT TOO LARGE $\tan\beta$ ($\lesssim 10$)

$\Rightarrow$ NO NEW OPERATOR IN FCNC EFFECTIVE HAMILTONIAN

* ALL SQUARKS DEGENERATE BUT $\tilde{t}$; LR MIXING NEGLIGIBLE EXCEPT FOR $\tilde{t}_L - \tilde{t}_R$

$\Rightarrow$ SUSY ONLY MODIFIES "TOP CONTRIBUTION" IN THE EFFECTIVE HAMILTONIAN

INPUT PARAMETERS:

$m_{\tilde{t}_1}, m_{\tilde{t}_2}, \theta_{\tilde{t}}, m_{\chi_1^+}, \mu, \tan\beta, m_{H^+}$

THE MSSM WITH MFV COULD GIVE LARGE CONTRIBUTIONS TO $b \to s\gamma$ - ONCE THE $b \to s\gamma$, M_h AND DIRECT SEARCH BOUNDS HAVE BEEN APPLIED, UT FIT IS NOT DISTINGUISHABLE FROM THE SM. SMALL DEVIATIONS POSSIBLE IN RARE DECAYS.

Gabrielli & Giudice; Giudini, Degrassi, Gambino & Giudice; Buras, Gambino, Gorbahn, Jäger & LS

ALSO BEYOND SUSY, MFV MODELS GIVE UT FITS $\sim$ SM

Buras, Parodi, Stocchi; Parodi's Talk in CP session

$b \to s\gamma$ & $b \to s\, \ell^+\ell^-$ MOST SENSITIVE PROBES OF MFV IN NEAR FUTURE

D'Ambrosio, Giudice, Isidori & Strumia

HOWEVER, AT LARGE $\tan\beta$ BIG EFFECTS POSSIBLE IN $B_s \to \mu^+\mu^-$:

Babu & Kolda; Chankowski & Slawianowska; Bobeth et al; Huang et al; Isidori & Retico

$$BR(B_s \to \mu^+\mu^-)_{SM} \sim 4 \cdot 10^{-9}$$

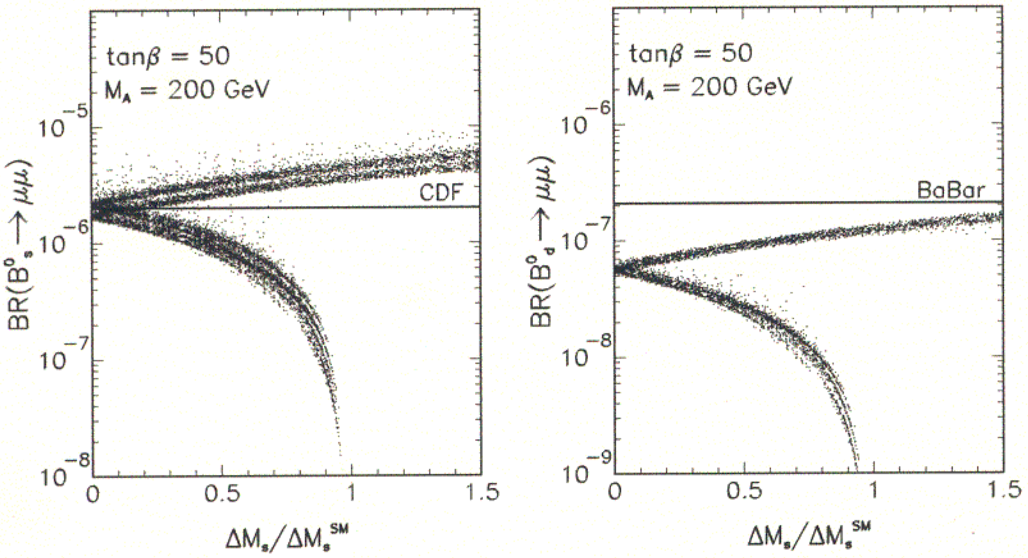
$$\downarrow$$

$$BR(B_s \to \mu^+\mu^-)_{SUSY} \sim 10^{-6}$$

BEHIND THE CORNER OF $BR(B_s \to \mu^+\mu^-)_{EXP} < 2 \cdot 10^{-6}$ Tevatron

INTERESTING CORRELATIONS:

① ΔM_{B_s} & $BR(B_{s,d} \to \mu^+\mu^-)$



FROM Buras, Chankowski, Rosiek & Slawianowska

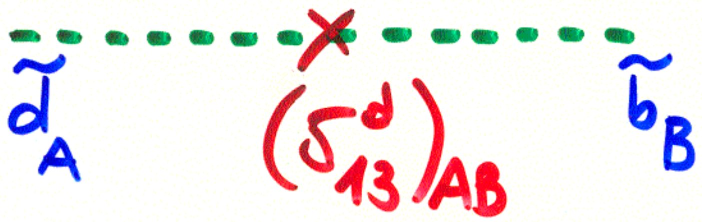
② $BR(B_s \to \mu^+\mu^-)$ & $(g-2)_\mu$

IN MSUGRA, ENHANCEMENTS OF $BR(B_s \to \mu^+\mu^-)$ OF A FACTOR 10-100 FOR PARAMETERS FAVOURED BY $(g-2)_\mu$

Dedes, Dreiner & Nierste

MODEL-INDEPENDENT CONSTRAINTS ON $(\delta^d_{13})_{AB}$ FROM ΔM_{B_d} AND $a_{B\to J/\psi K_S}$

Becirevic, Ciuchini, Franco, Gimenez, Martinelli, Masiero, Papinutto, Reyes, L.S., hep-ph/0112303



USING $(\Delta M_{B_d})_{EXP}$ AND $(a_{J/\psi K_S})_{EXP}$ DETERMINE ALLOWED REGIONS IN

$$\left(\mathrm{Re}(\delta^d_{13})_{AB},\ \mathrm{Im}(\delta^d_{13})_{AB}\right)$$

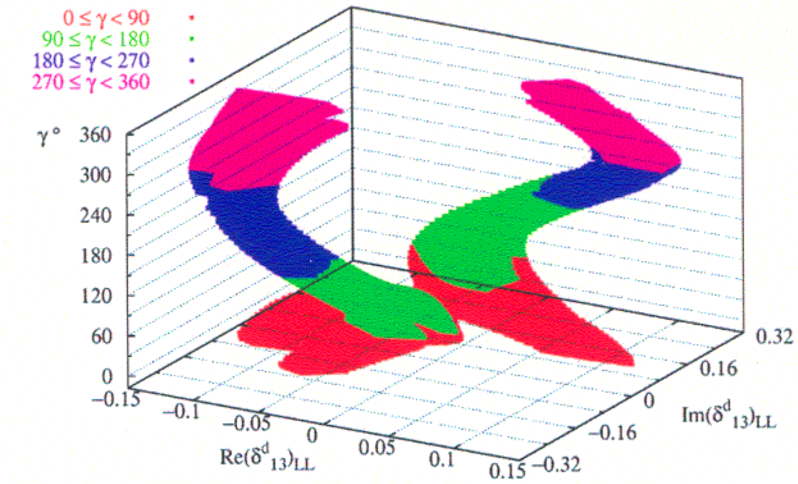
PLANE. INGREDIENTS:

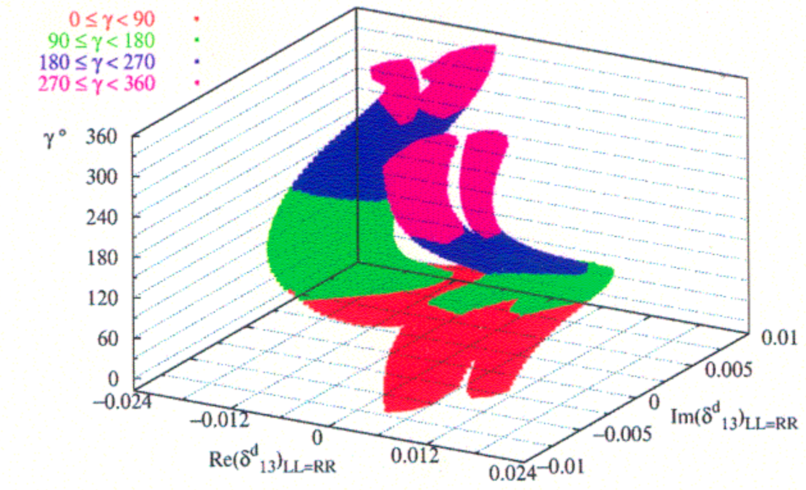
1. RECENTLY COMPUTED LATTICE MATRIX ELEMENTS FOR ALL $\Delta B=2$ OP.S — Becirevic et al, hep-lat
2. NLO QCD CORRECTIONS — Ciuchini et al; Buras et al
3. LO COEFFICIENT FUNCTIONS FOR GLUINO-MEDIATED CONTRIBUTIONS — Gabbiani et al

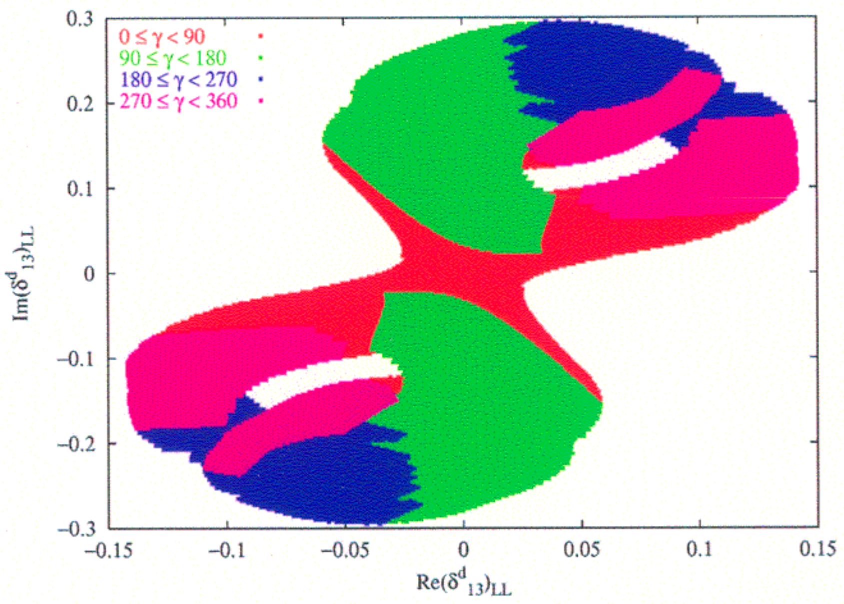
(CONSTRAINTS FROM $\chi^{\pm}$-EXCHANGE AT MOST COMPARABLE) Gabrielli & Khalil

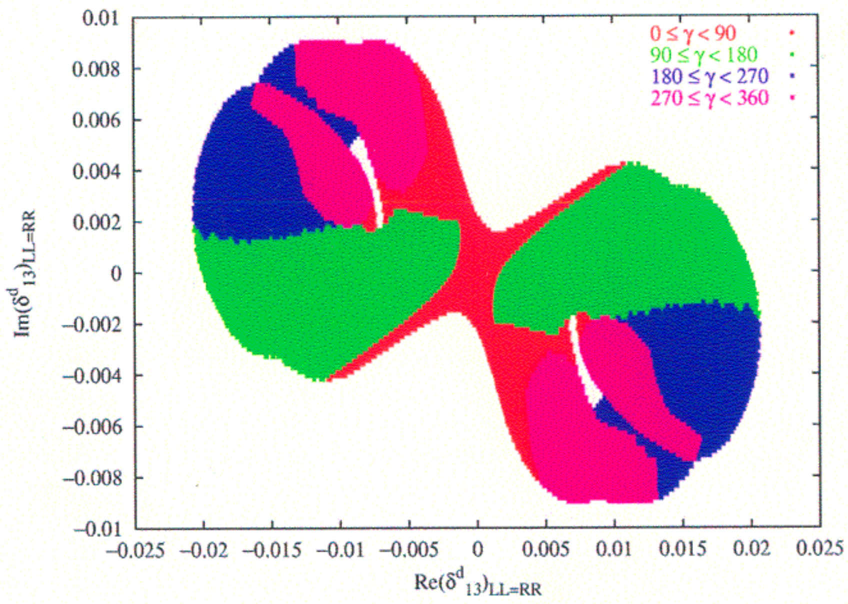
$m^2_{\tilde{q}} = m^2_{\tilde{g}} = 500$ GeV

Becirevic et al 01



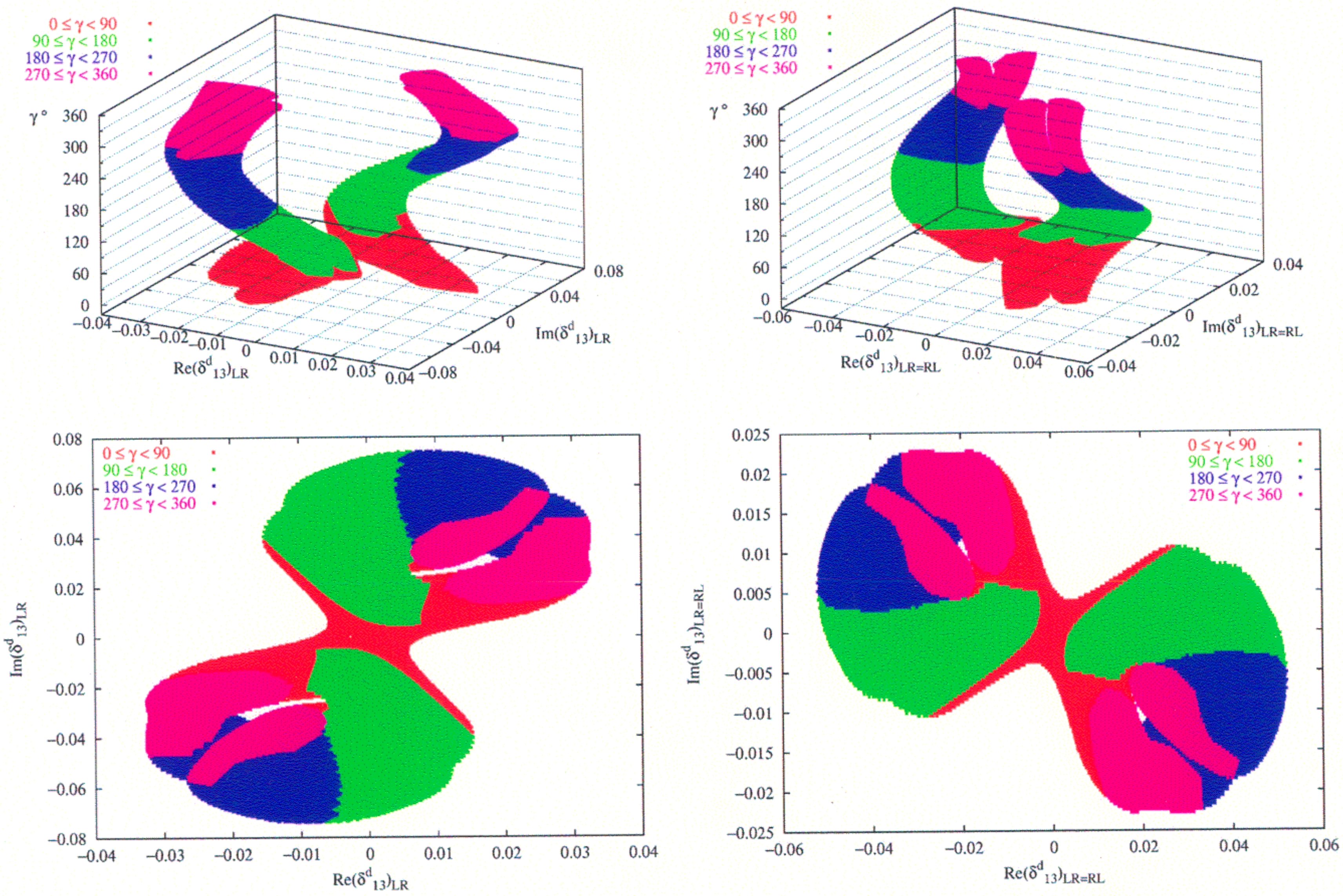




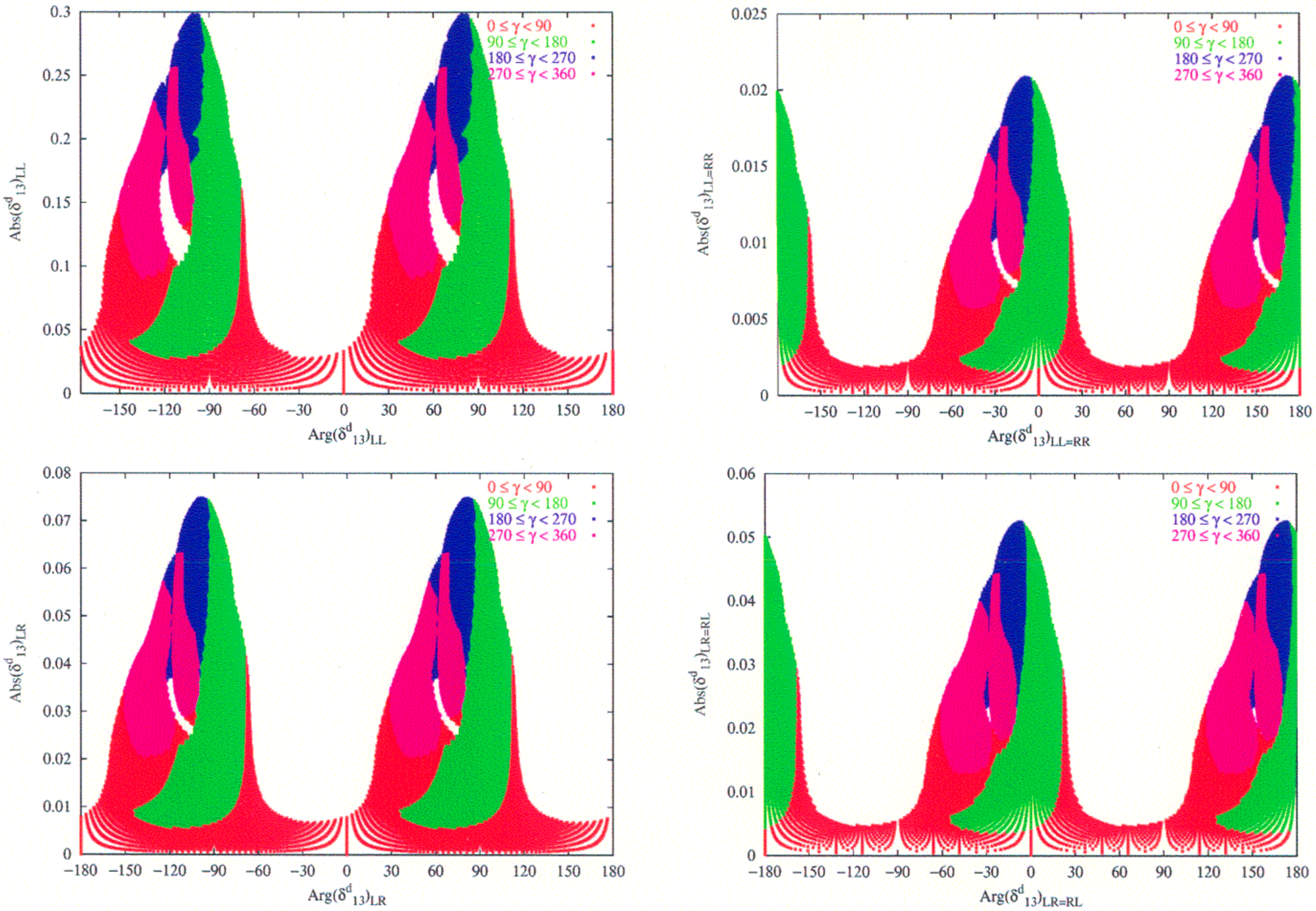


$m^2_{\tilde q} = m^2_{\tilde g} = 500$ keV

Becirevic et al 01



Bećirević et al 01



Becirevic et al

SUMMARIZING

$|\mathrm{Re}(\delta^d_{13})_{LL}| < 1.4 \cdot 10^{-1}$ $\quad ((\delta^d_{13})_{LL} \gg (\delta^d_{13})_{RR})$

$|\mathrm{Re}(\delta^d_{13})_{LL}| < 2.1 \cdot 10^{-2}$ $\quad ((\delta^d_{13})_{LL} = (\delta^d_{13})_{RR})$

$|\mathrm{Im}(\delta^d_{13})_{LL}| < 3 \cdot 10^{-1}$ $\quad ((\delta^d_{13})_{LL} \gg (\delta^d_{13})_{RR})$

$|\mathrm{Im}(\delta^d_{13})_{LL}| < 9 \cdot 10^{-3}$ $\quad ((\delta^d_{13})_{LL} = (\delta^d_{13})_{RR})$

$|\mathrm{Re}(\delta^d_{13})_{LR}| < 3.3\ 10^{-2}$ $\quad ((\delta^d_{13})_{LR} \gg (\delta^d_{13})_{RL})$

$|\mathrm{Re}(\delta^d_{13})_{LR}| < 5.2\ 10^{-2}$ $\quad ((\delta^d_{13})_{LR} = (\delta^d_{13})_{RL})$

$|\mathrm{Im}(\delta^d_{13})_{LR}| < 7.4\ 10^{-2}$ $\quad ((\delta^d_{13})_{LR} \gg (\delta^d_{13})_{RL})$

$|\mathrm{Im}(\delta^d_{13})_{LR}| < 2.3\ 10^{-2}$ $\quad ((\delta^d_{13})_{LR} = (\delta^d_{13})_{RL})$

FOR $m^2_{\tilde{q}} = m^2_{\tilde{g}} = 500$ GeV

COMPARE WITH

Ciuchini et al

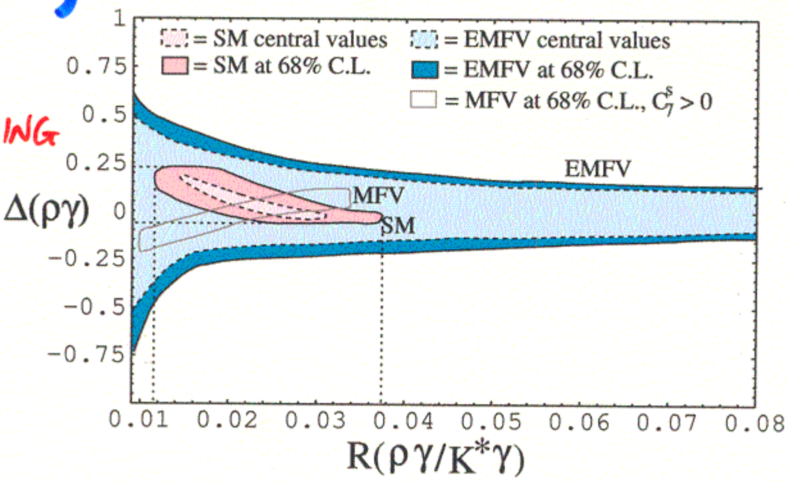
$\sqrt{|\mathrm{Re}(\delta^d_{12})^2_{LL}|} < 4.6\ 10^{-2}$ $\quad \sqrt{|\mathrm{Im}(\delta^d_{12})^2_{LL}|} < 6.1\ 10^{-3}$

$\sqrt{|\mathrm{Re}(\delta^d_{12})^2_{LR}|} < 2.8\ 10^{-3}$ $\quad \sqrt{|\mathrm{Im}(\delta^d_{12})^2_{LR}|} < 3.7\ 10^{-4}$

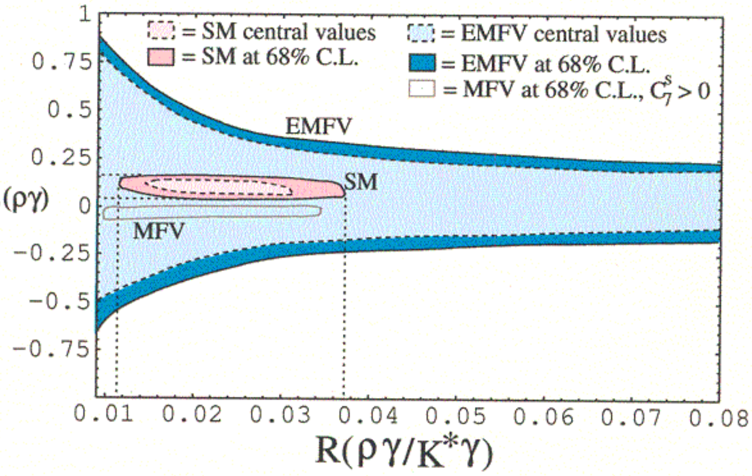
SUSY EFFECTS IN $b \to d$ CAN ALSO BE TESTED USING $B \to \rho\gamma$

Ali & Lunghi

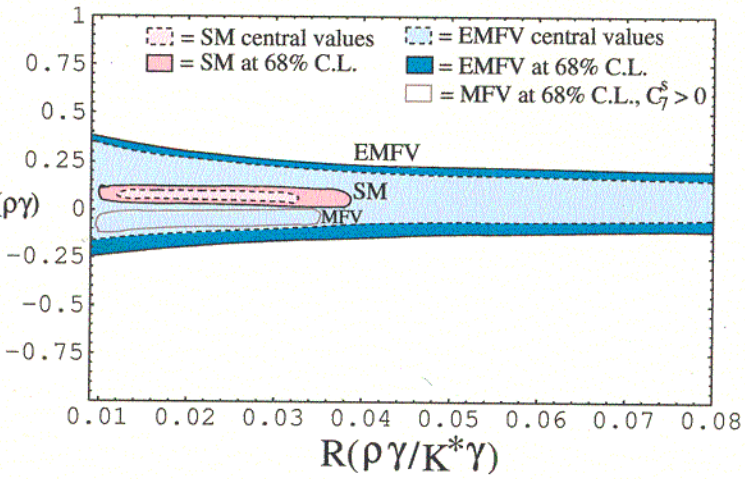
ISOSPIN BREAKING IN $B \to \rho\gamma$



$$\frac{B(B^- \to \rho^-\gamma) - B(B^+ \to \gamma\rho^+)}{B(B^- \to \rho^-\gamma) + B(B^+ \to \rho^+\gamma)} \equiv A_{CP}^{\pm}(\rho\gamma)$$



$$\frac{B(B^0 \to \rho^0\gamma) - B(\bar{B}^0 \to \rho^0\gamma)}{B(B^0 \to \rho^0\gamma) + B(\bar{B}^0 \to \rho^0\gamma)} \equiv A_{CP}^{0}(\rho\gamma)$$



$$R\left(\frac{\rho\gamma}{K^*\gamma}\right) = \frac{B(B \to \rho\gamma)}{B(B \to K^*\gamma)}$$

MODEL-INDEPENDENT CONSTRAINTS ON (δ^d_{23}) FROM ΔM_{B_s} & $B \to X_s \gamma$

PRESENTLY AVAILABLE:

$\Delta M_{B_s} > 14.9\ ps^{-1}$ @ 95% CL

$BR(B \to X_s \gamma) = (3.23 \pm 0.42)\ 10^{-4}$

TO BE COMPARED WITH

$(\Delta M_{B_s})_{SM} = 17.1^{+1.5}_{-1.9}$ Ciuchini et al.

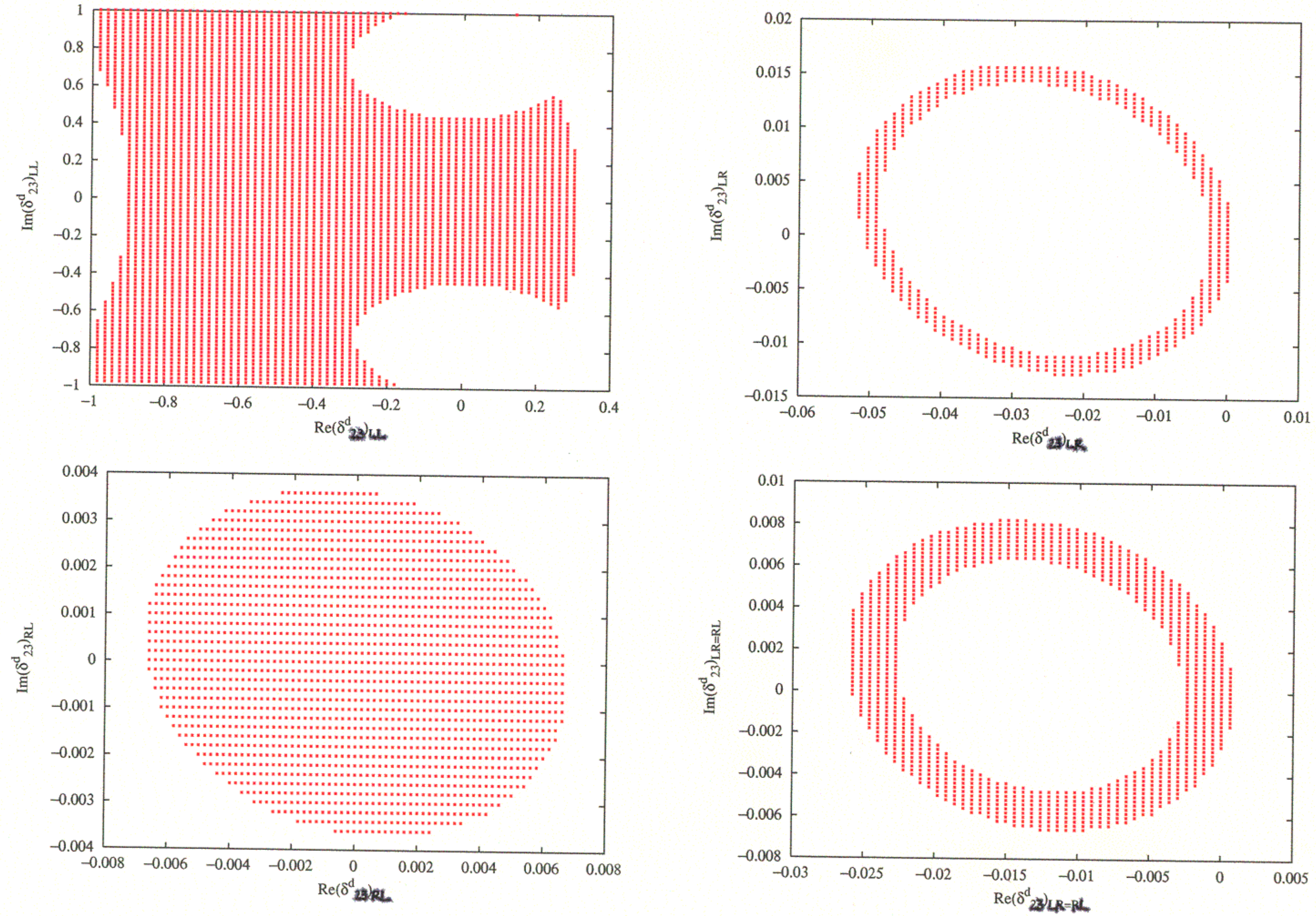
$BR(B \to X_s \gamma) = (3.73 \pm 0.30)\ 10^{-4}$ Gambino & Misiak

USE LATTICE MATRIX ELEMENTS, NLO QCD CORRECTIONS & LO WILSON COEFFICIENTS @ M_{SUSY}

TO DETERMINE ALLOWED REGIONS IN $Re(\delta^d_{23})$, $Im(\delta^d_{23})$ PLANE

PRELIMINARY - $B \to X_s \gamma$ & LOWER BOUND ON ΔM_{B_s}

$m^2_{\tilde{q}} = m^2_{\tilde{g}} = 500$ GeV



Ciuchini et al, in progress

$B \to X_s \gamma$

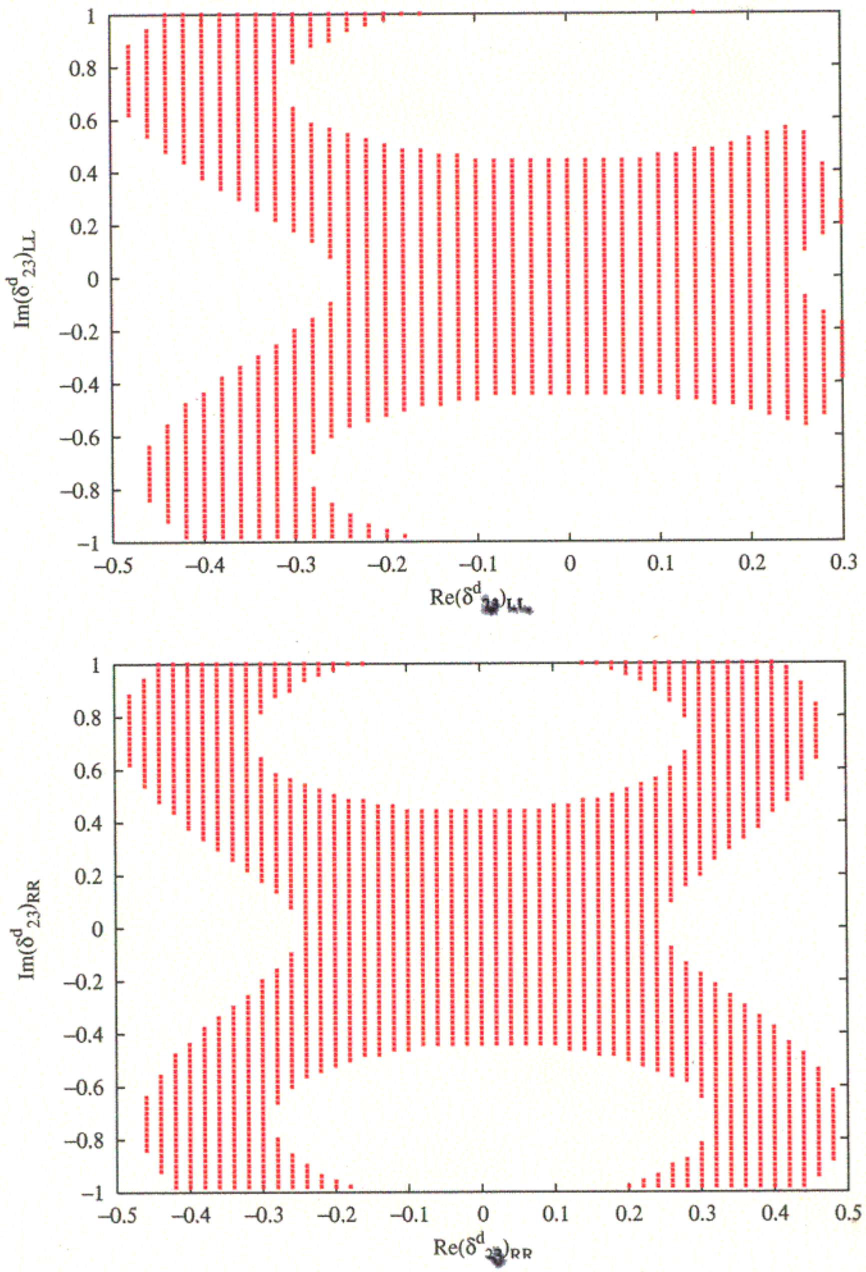
AND

$14/ps \leq \Delta M_{B_s} \leq 20/ps$

Ciuchini et al, in progress

PRELIMINARY

$m^2_{\tilde{q}} = m^2_{\tilde{g}} = 500\,GeV$



(A) $B^0 \to J/\psi K_S$ $(b \to c\bar{c}s)$

DOMINATED BY TREE LEVEL OPERATOR $(\bar{b}c)(\bar{c}s)$ WITH $\phi = 0$. SUBLEADING $b \to sq\bar{q}$ PENGUIN ALSO HAS $\phi = 0$.

SUSY $b \to sq\bar{q}$ PENGUIN $\ll$ SM TREE LEVEL

$\Rightarrow$ $B^0 \to J/\psi$ MEASURES ϕ^M ($= \beta$ IN SM) WITHIN A FEW %.

(B) $B^0 \to \phi K_S$ $(b \to s\bar{s}s)$

PURE PENGUIN PROCESS

SM: ONLY ONE AMPLITUDE WITH $\phi^{SM} = 0 + O(\lambda^2)$ $\Rightarrow$ $\boxed{a^{SM}_{\phi K_S}(t) = a^{SM}_{\psi K_S}(t)}$

SUSY: $b \to sq\bar{q}$ PENGUIN CAN BE LARGE $A^{SUSY} \sim A^{SM}$

$\Rightarrow$ CP ASYMMETRY CAN BE MODIFIED

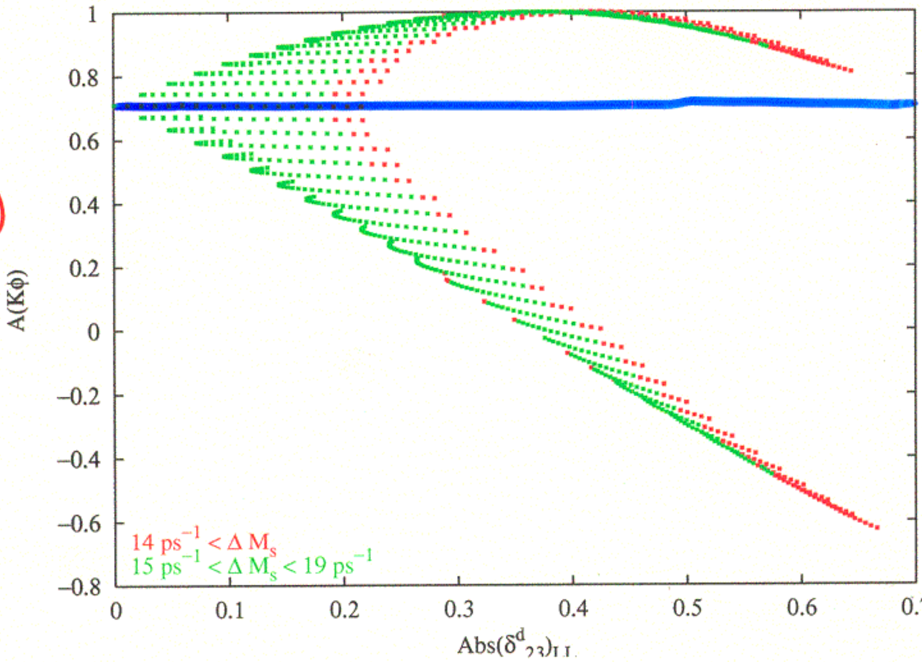
$$a^{SUSY}_{\phi K_S}(t) \neq a^{SUSY}_{J/\psi K_S}(t)$$

Grossman & Worah
Ciuchini et al
Barbieri & Strumia

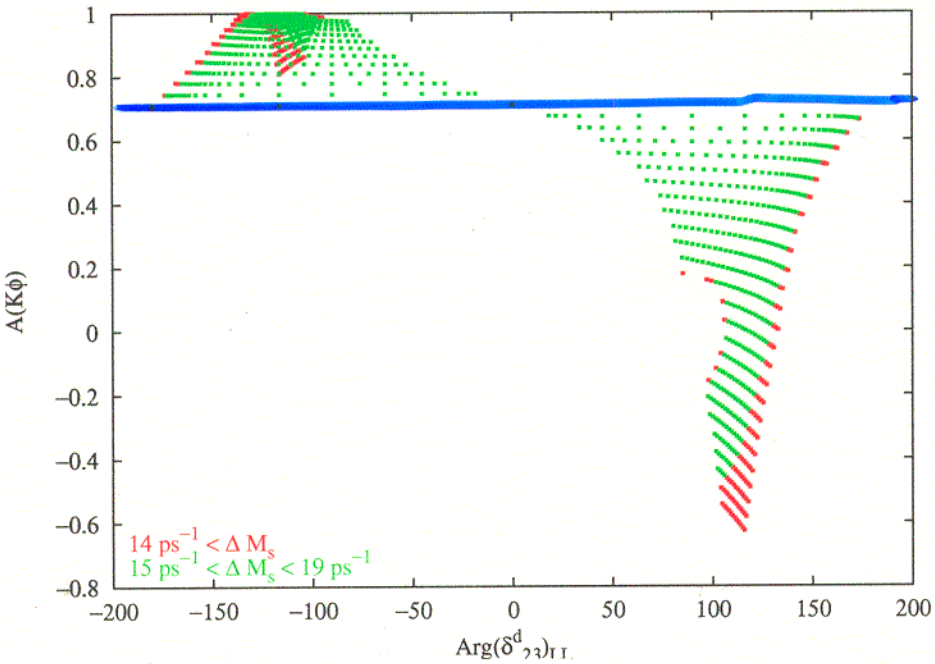
PRELIMINARY

Ciuchini et al., in progress

$\mathcal{A}_{CP}(B\to\phi K_S)$



$\mathcal{A}_{CP}(B\to\phi K_S)$



$15/ps < \Delta M_s < 19/ps$

$14/ps < \Delta M_s$

$m^2_{\tilde q} = m^2_{\tilde g} = 250\,\mathrm{GeV}$

FROM Gabrielli & Khalil

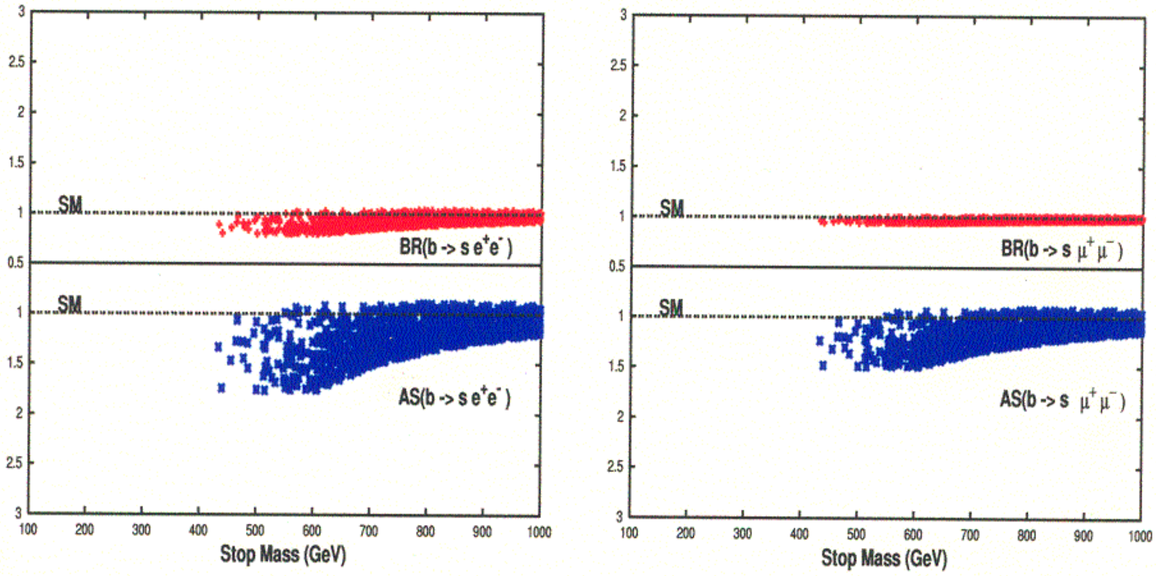


Figure 1: Branching ratio (BR) and energy asymmetry (AS) of $B \to X_s\, e^+e^-$ and $B \to X_s\, \mu^+\mu^-$ (normalized to the corresponding SM ones) versus the lightest stop mass in minimal SUGRA model.

BR(b→s $\ell^+\ell^-$) & A(b→s $\ell^+\ell^-$) SENSITIVE TO SUSY CONTRIBUTIONS

Bertolini et al; Cho, Misiak & Wyler; Goto et al; Gabrielli & Sarid; Lunghi et al; Ali et al; Kim et al

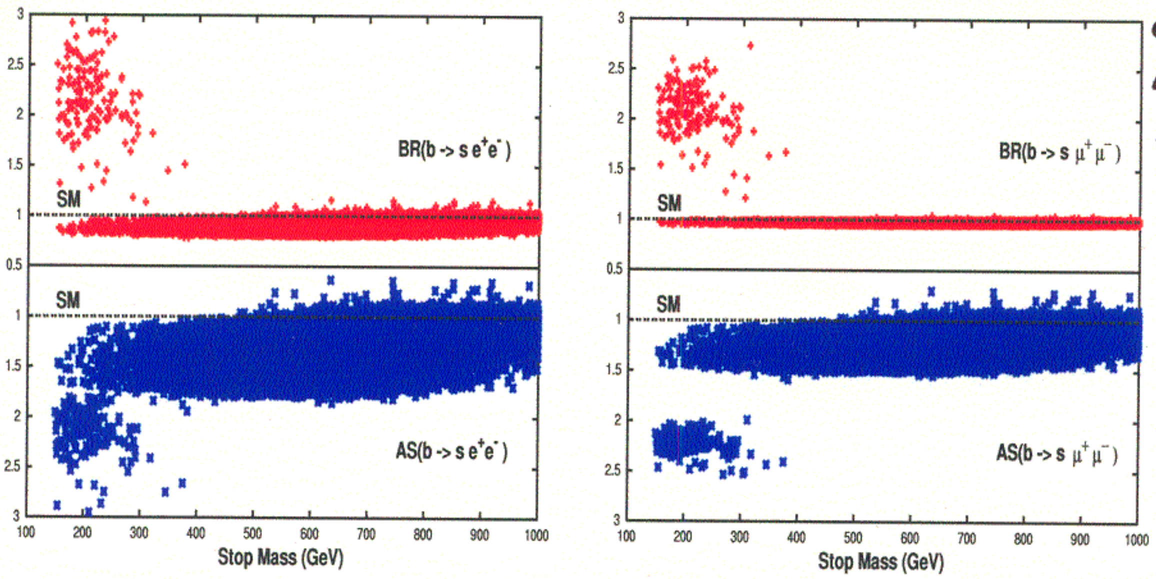


Figure 2: As in Fig. 1, but for SUSY model with non–universal soft breaking terms.

AN EXAMPLE OF EFFECTS OF $\not{R}_p$ COUPLINGS IN B PHYSICS

Bar-Shalom, Eilam & Yang

$$W_{\not{R}_p} = \varepsilon^{ab}\delta^{\alpha\beta}\lambda'_{ijk} L_{ia} Q_{jb\alpha} D^c_{k\beta} + \frac{1}{2}\varepsilon^{\alpha\beta\gamma}\lambda''_{i[jk]} U^c_{i\alpha} D^c_{j\beta} D^c_{k\gamma}$$

PROVIDES NEW CONTRIBUTIONS TO THE PENGUIN DECAY $b \to d\bar{s}s$

$\Rightarrow$ EFFECTS IN $B \to \phi\pi$, $B \to \phi\phi$

FROM $BR(B \to \phi\pi)_{Exp} < 1.6\ 10^{-6}$ BaBar

BEY OBTAIN

$$|\lambda''_{i23}\lambda''^{*}_{i21}| < 6.5 \cdot 10^{-5}\left(\frac{m_{\tilde{u}_{Ri}}}{100}\right)^2$$

$$|\lambda'_{i32}\lambda'^{*}_{i12}| < 4 \cdot 10^{-4}\left(\frac{m_{\tilde{\nu}_{Li}}}{100}\right)^2$$

$$|\lambda'_{i21}\lambda'^{*}_{i23}| < 4 \cdot 10^{-4}\left(\frac{m_{\tilde{\nu}_{Li}}}{100}\right)^2$$

RESPECTING THESE CONSTRAINTS, $BR(B^0 \to \phi\phi)$ COULD GO UP TO 10^{-7}

CONCLUSIONS & OUTLOOK

WHATEVER YOUR FAVOURITE SUSY MODEL, B PHYSICS IS THE PLACE TO LOOK FOR IT:

* IN MINIMAL FLAVOUR VIOLATION, $B_s \to \mu^+\mu^-$ COULD BE ROUND THE CORNER
* A LARGE $\tilde{b}-\tilde{s}$ MIXING IS PRESENT IN MANY FLAVOUR MODELS, AND CAN GENERATE LARGE EFFECTS IN $\mathcal{A}_{CP}(B \to \phi K_S)$, $b \to s e^+ e^-$, ...
* VERY LARGE EFFECTS IN B DECAYS ARE POSSIBLE IN MODELS WITH $\cancel{R}_p$
* FORTHCOMING DATA WILL EITHER (HOPEFULLY) SHOW SIGNALS OF SUSY OR STRONGLY CONSTRAIN SUSY MODEL BUILDING