LA THUILE 2002

RARE DECAYS AND CP≠ FROM SM TO NEW PHYSICS?

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- WHAT IS NEW IN FLAVOR PHYSICS AND HOW DOES IT AFFECT THE SM
- NEW CP≠ SOURCES IN SUSY EXTENSIONS OF THE SM
- LINK BETWEEN LFV and CP≠ IN B PHYSICS IN GUT's

NOVELTIES IN FLAVOR PHYSICS

in the last few years

- ν OSCILLATIONS
  (in particular, large ν mixing in atm. ν's)

- $\varepsilon' \neq 0$ ("large" ε'/ε)

- $\sin 2\beta \neq 0$ ($CP\!\!\!/$ in B physics)

IMPLICATIONS FOR NEW PHYSICS

ν OSC. $\Longrightarrow$ new physics originates ν masses and the large ν mixing in the 2-3 sector

"large" ε' $\Longrightarrow$ new physics can possibly account for the "large" ε' (but it is and, probably, it will be unclear whether the SM is not able to reproduce the exp. value of ε')

$\sin 2\beta$ $\Longrightarrow$ agreement of $\sin 2\beta$ as determined from $a_{J/\psi K_S}$ with the SM, but it is possible that new physics modifies other $CP\!\!\!/$ B decays (involved with β, γ)

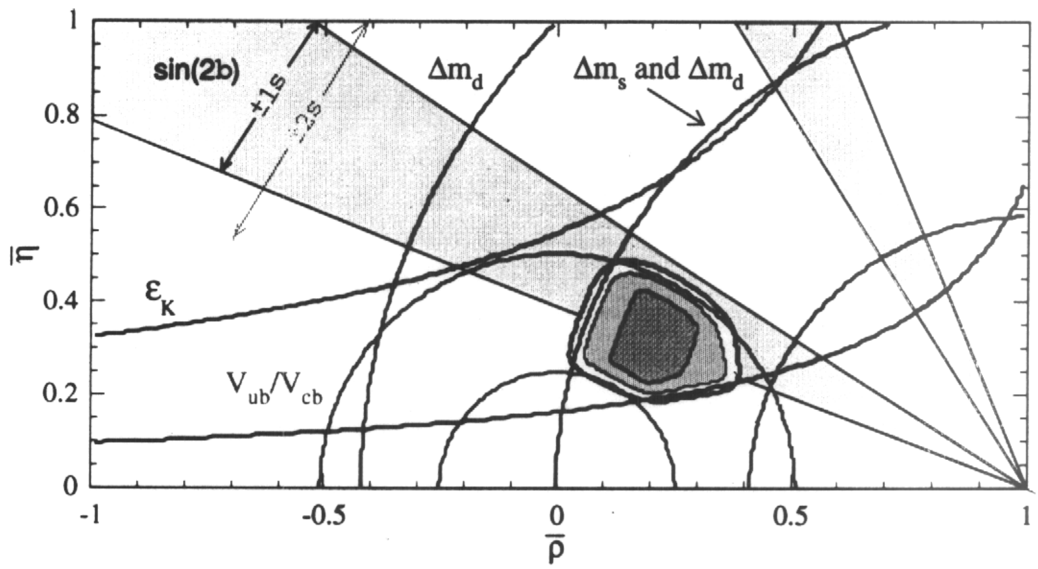


Figure 51. *Constraints from* $\sin 2\beta$ *measurement overlaid with other constraints (Hocker 2001). The inner band is at* 1σ *while the outer band, shown on one band only, is at* 2σ.

combined. Note, that the systematic errors are also difficult sometimes to quantify and are not necessarily Gaussian, but they judged to be sufficiently well known as to not cause a problem.

Hocker et al. (Höcker 2001) have decided to use a method which restricts the theoretical quantities to a 95% confidence interval where the parameter in question is just as likely to lie anywhere in the interval. They call this the "Rfit" method. Of course assigning the 95% confidence interval is a matter of judgment which they fully admit. Ciuchini et al. (Ciuchini 2001) treat the theoretical errors in the same manner as the experimental errors. They call theirs "the standard method" with just a bit of hubris. They argue that QCD is mature enough to trust its predictions, that they know the sign and rough magnitude of corrections and they can assign reasonable errors, so it would be wrong to throw away information.

Hocker et al. point out an extreme interesting but generally unknown danger with the Bayesian approach, which is that in multi-dimension problems the Bayesian treatment unfairly predicts a narrowing of possible results. The following discussion will demonstrate this.

Let x_i denote N theoretical parameters over the identical ranges $[-\Delta, +\Delta]$; then the theoretical prediction is

$$T_P^{(N)} = \prod_i^N x_i \quad . \tag{100}$$

In the 95% scan scheme $[T_P^{(N)}] = [-\Delta^N, +\Delta^N]$ while in the Bayesian approach the con-

MINIMAL LOW ENERGY SUSY

- minimal amount of superpart. needed to supersymmetrize the SM
- IMPOSING THE (ADDITIONAL) SYMM. R parity
  $\Rightarrow$ to eliminate $\not B$ and $\not L$ dangereous terms

$$\mathcal{L} = \mathcal{L}_{N=1\ \text{SUSY SM}} + \mathcal{L}_{\text{soft SUSY breaking}}$$

$\ldots h_{U_{ij}} Q_i H_U U_j + h_{D_{ij}} Q_i H_D D_j + h_{L_{ij}} L_i H_D E_j + \mu H_U H_D$

trilinear and bilinear scalar terms + gaugino masses

NEW FLAVOR STRUCTURES

$\underline{m^2_{ij}} \varphi_i \varphi_j^* \quad \mu B H_U H_D \quad \underline{A_{U_{ij}}} \tilde{Q}_i H_U \tilde{U}_j$

$\underline{A_{D_{ij}}} \tilde{Q}_i H_D \tilde{D}_j \quad \underline{A_{L_{ij}}} \tilde{L}_i H_D \tilde{E}_j \quad M_k \lambda_K \lambda_K$

$\hookrightarrow SU(3), SU(2), U(1)$

$\Longrightarrow$ 124 PARAM.

CMSSM or mSUGRA

↳ Constrained — $\underbrace{\text{mSUGRA}}_{\text{minimal SuperGravity}}$

or how to reduce the param. from 124 → 5

MSSM

\+

FLAVOR UNIVERSALITY

$$m^2_{ij} = \delta_{ij}\, m_0^2$$

m_0^2: common scalar mass term

$$A_{ij} \to A_0 \to$$ common scalar trilinear coeff. multiplying the Yukawa coupl.

(GRAND) UNIFICATION

$$M_1 = M_2 = M_3 \equiv M$$

M: common gaugino mass

m^2_{ij}, A_{ij}, M_i → "running" quantities : specify the energy scale where the above equalities hold

→ BOUNDARY CONDITIONS AT THE LARGE SCALE WHERE SUPERGRAVITY IS BROKEN M_X

at M_X : $\underset{\text{real}}{m_0^2}$, $\underset{\text{complex}}{\mu}$, $\underset{\text{complex}}{B_0}$, $\underset{\text{complex}}{A_0}$, $\underset{\text{complex}}{M}$

NEW CP$\neq$ in SUSY

unconstrained MSSM $\Rightarrow$ ~40 phases

mSUGRA $\Rightarrow$ μ M A B 4 phases
but only 2 combinations
are physical

Dugan, Grinstein, Hall;
Dimopoulos, Thomas

* THE PRESENCE OF LOW ENERGY SUSY
* ENTAILS THE PRESENCE OF (AT LEAST TWO)
* NEW CP$\neq$ PHASES IN ADDITION TO
* THE CKM PHASE

THE PRESENCE OF NEW SOURCES OF CP$\neq$ IS
NEEDED TO HAVE AN EFFICIENT BARYOGENESIS
(in SM no significant baryogenesis is possible;
in MSSM only a very limited area of the parameter space
is available for baryogenesis $\Rightarrow$ light $\tilde{t}$, $\tilde{\chi}^+$)

$\Downarrow$ testable at Tevatron

ORIGIN of FLAVOR

SUSY BREAKING

NO RELATION

SUSY BREAKING

is **FLAVOR BLIND**

(ex.: GMSB, AMSB,
pure dilaton breaking, ...)

- still NEW SOURCES OF $CP\!\!\!/$ (at least 2 $CP\!\!\!/$ phases - unrelated to the flavor structure)
- CKM + exchange of SUSY particles (light $\tilde{t} - \tilde{\chi}$)

LARGE RGE effects spoiling flavor universality (ex. SUSY GUTs)

SUSY BREAKIN

KNOWS FLAVOR

SUSY breaking term
introduce a NEW
FLAVOR STRUCTUR
in addition to the
Yukawa flavor structu
of the SM

$A \Rightarrow A_{ij} \not\propto h_{ij}$

$\tilde{m} \to \tilde{m}_{ij} \not\propto \delta_{ij}\tilde{m}$

Ex :

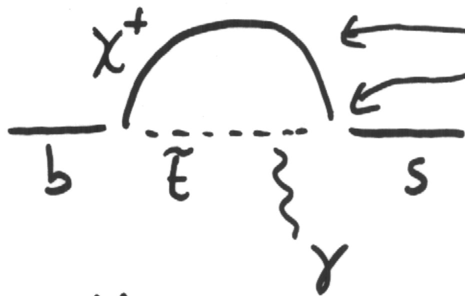
- $B_s - \overline{B}_{\bar{s}}$ mixing $\Delta m_{B_s} \simeq (28 \pm 5) \dfrac{\Delta m_{B_d}}{\underbrace{\left[(1-\rho)^2 + \eta^2\right]}}$

Branco, Cho, Kizukuri, Oshimo ;
Branco, Grimus, Lavoura ;
Brignole, Feruglio, Zwirner ;
Misiak, Pokorski, Rosiek ; Chankowski, Pokorski : can be smaller than in SM
new MSSM contributions to Δm_{B_d} and ε_K
Ali-London : effects up to 60% of the SM contribution

- $CP \neq$ in $B \to X_s + \gamma$

$A_{CP}^{b \to s\gamma}$ in SM is very small < 1 %
(because of a combination of CKM and GIM suppressions
Soares ; Kagan, Neubert ; Ali, Asatrian, Greub

in Constrained MSSM :
Kagan, Neubert



φ_A, φ_μ SUSY $CP\neq$ phases

if $\varphi_\mu = 0$ (to avoid severe problems with d_e^n)
$\Rightarrow$ $A_{CP}^{b \to s\gamma}$ can still grow up to few (4 or 5) %
Aoki, Cho, Oshimo

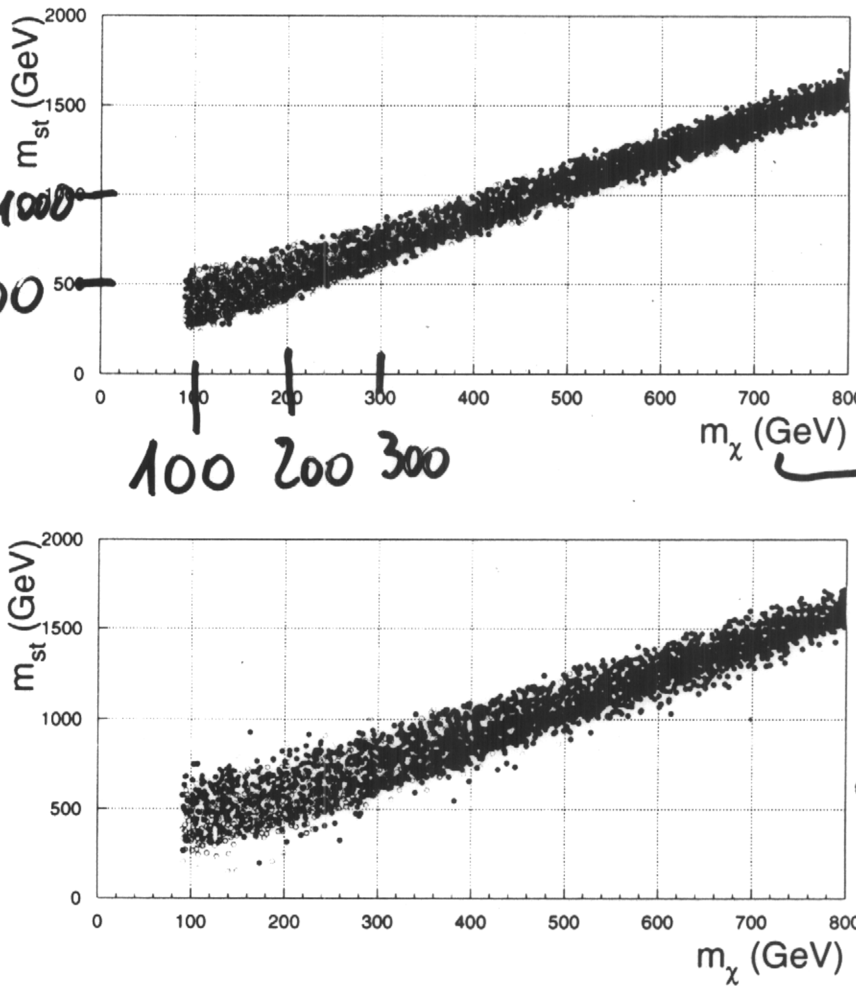
if both $\varphi_A, \varphi_\mu \neq 0$ $\Rightarrow$ $A_{CP}^{b \to s\gamma}$ can reach 10 %
Chua, He, Hou
Baek, Ko

Bartl, Gajdosik, Lunghi, A. M., Porod, Stockinger, Stremnitzer, Vives: mSUGRA and minimal SU(5) (with 2-loop RGE for running $M_{GUT} \to M_W$)

light $\tilde{t}$ mass

1000

500



100 200 300

in mSUGRA

chargino mass

in SUSY SU(5)

Figure 1: Chargino mass versus lightest stop mass as for the parameter space described in the text in the CMSSM and SU(5) cases.

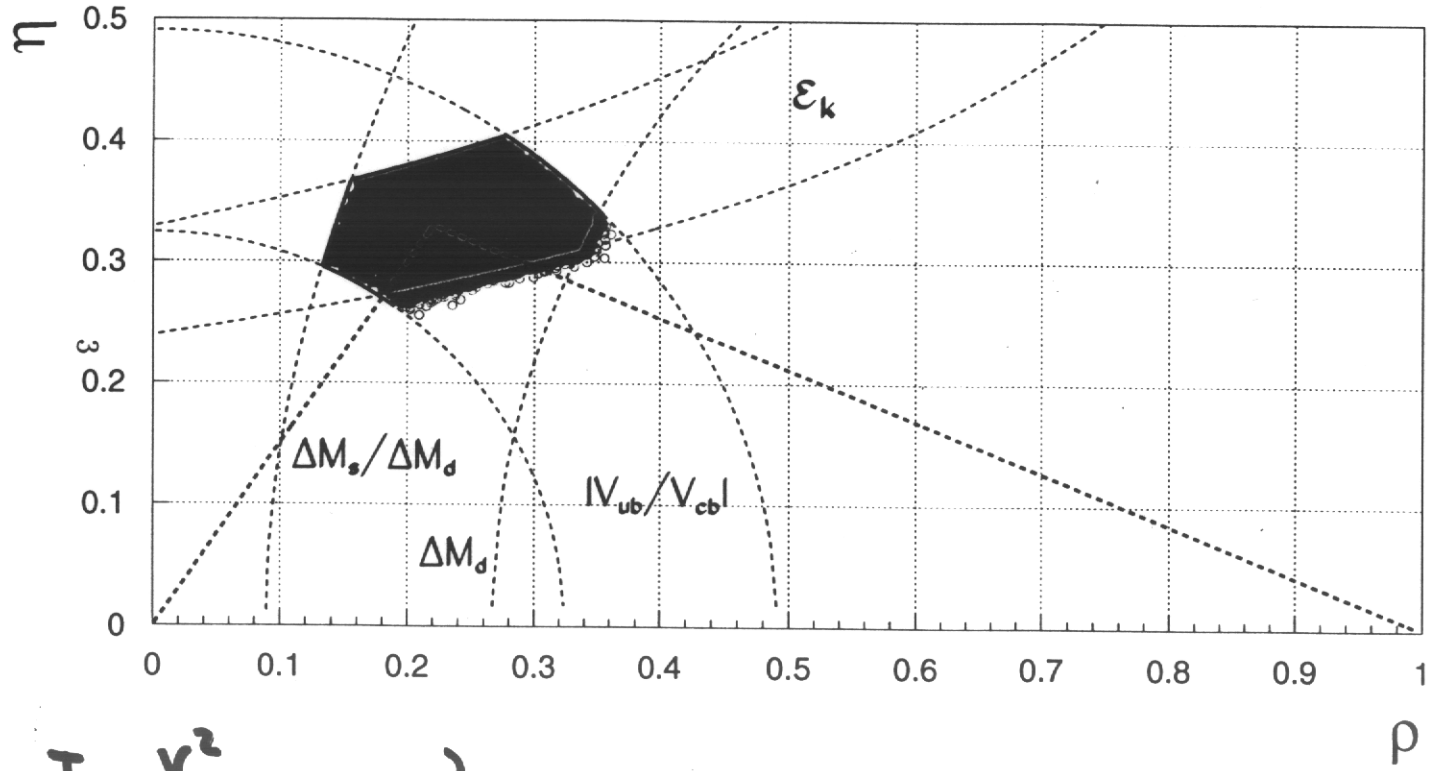
for $m_\chi = 100$ GeV $\Rightarrow$ 240 GeV $< m_{\tilde{t}_1} <$ 660 GeV

(in mSUGRA)

with 10^2 GeV $< m_0 < 1$ TeV

BARTL et al.

- red dots: departure from SM due to the exchange of mSUGRA particles



$$\left.\begin{array}{l} \varepsilon_K \rightarrow \mathrm{Im}\, V_{td}^2 \\ \Delta m_d \rightarrow \mathrm{Re}\, V_{td}^2 \\ a_{J/\psi K_S} \rightarrow \mathrm{Im}\, V_{td} \end{array}\right\} \Rightarrow V_{td} \qquad V_{ub}$$

MSSM without new flavor structure but with new, large CP $\neq$ phases

(d_n^e tamed by cancellations among different contributions)

Ibrahim, Nath; Brhlik, Good, Kane; Brhlik, Everett, Kane, Lykken; Accomando, Arnowitt, Dutta

$\Rightarrow$ GENERAL MSSM with $\delta_{CKM} = 0$

WITH ALL POSSIBLE PHASES IN THE SOFT BREAKING TERMS

$$\left(A_u e^{i\varphi_{A_u}},\ A_D e^{i\varphi_{A_D}},\ A_E e^{i\varphi_{A_E}},\ m_{\tilde{g}} e^{i\varphi_3},\ m_{\tilde{W}} e^{i\varphi_2},\ m_{\tilde{B}} e^{i\varphi_1},\ \mu = |\mu| e^{i\varphi_\mu} \right)$$

BUT **NO NEW FLAVOR STRUCTURE** in addition to the usual Yukawa matrices

DEMIR, A.M., VIVES

IT IS NOT POSSIBLE TO GIVE SIZABLE CONTRIBUTIONS TO ε, ε'/ε, HADRONIC B^0 CP ASYMMETRIES

(only $A_{CP}^{b\to s\gamma}$, isospin violation in $B \to \rho\gamma$ Ali, Handoko London

if some new flavor structure is present (even if phases flavor indep.)

$\Rightarrow$ possibly large effects Brhlik, Everett, Kane, King, Lebedev

SUSY WITH NEW FLAVOR STRUCTURE

- FCNC and CP $\not{}$ CONSTRAINTS ON SUSY ARE SEVERE (→ NEED FOR A "PROTECTING" FLAVOR SYMMETRY ?) AND "DECOUPLE" SLOWLY (still present even with $\tilde{q}$, $\tilde{g}$ masses up to the TeV region) ⇒ NEED OF A FLAVOR SYMMETRY ?

- CP $\not{}$ constraints are stronger than the FCNC CP conserving ones

- POSSIBLE TO OBTAIN SIZEABLE SUSY CONTRIBUTIONS TO BOTH ε and ε' IN MODELS WITH NON NEGLIGIBLE FLAVOR CHANGE IN $\tilde{Q}_L - \tilde{Q}_L$ and $\tilde{Q}_L - \tilde{Q}_R$ TRANSITIONS
  + possible enhancement for FCNC and CP $\not{}$ rare K decays

- LARGE CONTRIBUTIONS FROM SUSY (ex. $(\delta^d_{23})_{RR}$) to SOME CP $\not{}$ B DECAYS

GIVEN THE ABOVE CONSTRAINTS on the δ's

WHERE (in FCNC and $\not{CP}$) TO LOOK FOR SUSY SIGNALS ?

(maximally allowed FCNC and $\not{CP}$ SUSY contributions, not typical SUSY predictions)

KAON PHYSICS

ε_K , ε'/ε

↳ large SUSY contributions

enhancement of rare K decays

$K_L \to \pi^0 \nu\bar{\nu}$, $K^+ \to \pi^+ \nu\bar{\nu}$, $K_L \to \pi^0 e^+ e^-$, $K_L \to \mu^+\mu^-$

B PHYSICS

$b \to s \ell^+ \ell^-$

$b \to d\gamma$ $(B \to \rho\gamma)$

$\not{CP}$ B decays

LEPTON PHYSICS

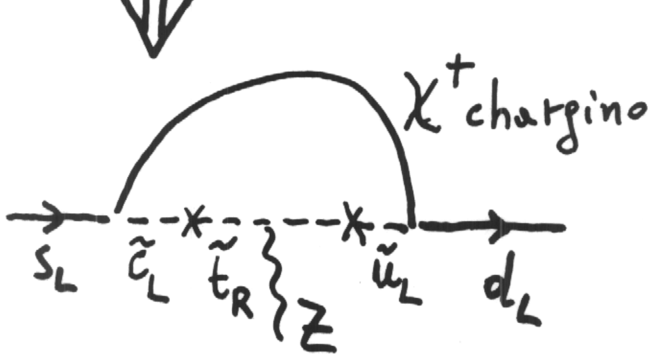
$\mu \to e\gamma$

$\mu \to e e \bar{e}$

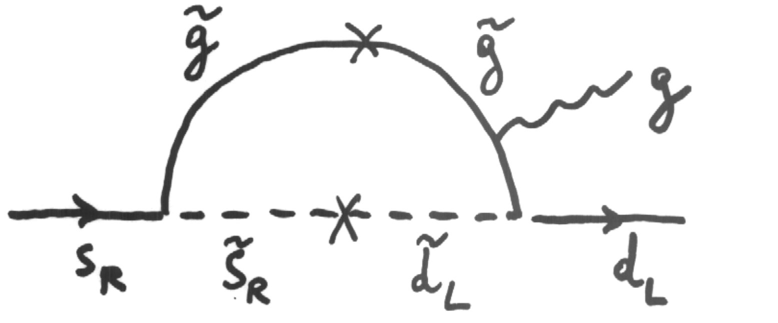
$\mu - e$ conversion in nuclei

ε'/ε and RARE K DECAYS

BURAS, COLANGELO, ISIDORI, ROMANINO, SILVESTRINI



s-d-Z



s-d-g

enhancement of $K_L \to \pi^0 e^+ e^-$, $K_L \to \pi^0 \nu\bar{\nu}$, $K^+ \to \pi^+ \nu\bar{\nu}$

assuming the usual determination of the CKM param.

+ no cancellations among different SUSY effects in ε'/ε

$\Downarrow$

		SM
$BR(K_L \to \pi^0 e^+ e^-)_{dir}$	$\lesssim 2 \cdot 10^{-11}$	$(7 \cdot 10^{-12})$
$BR(K_L \to \pi^0 \nu\bar{\nu})$	$\lesssim 1.2 \cdot 10^{-10}$	$(3 \cdot 10^{-11})$
$BR(K^+ \to \pi^+ \nu\bar{\nu})$	$\lesssim 1.7 \cdot 10^{-10}$	([illegible] $\cdot 10^{-10}$)

(larger values possible but rather unlikely)

correlation "sin 2β" from K and B decays NIR, WORAH

$b \to s\, l^+ l^-$

Lunghi, A.M., Scimemi,
Silvestrini

Cho - Misiak - Wyler
Goto - Okada - Shimizu - Tanaka
Ali - Giudice - Mannel
Gronau - London
ALI - LUNGHI -
GREUB - HILLER

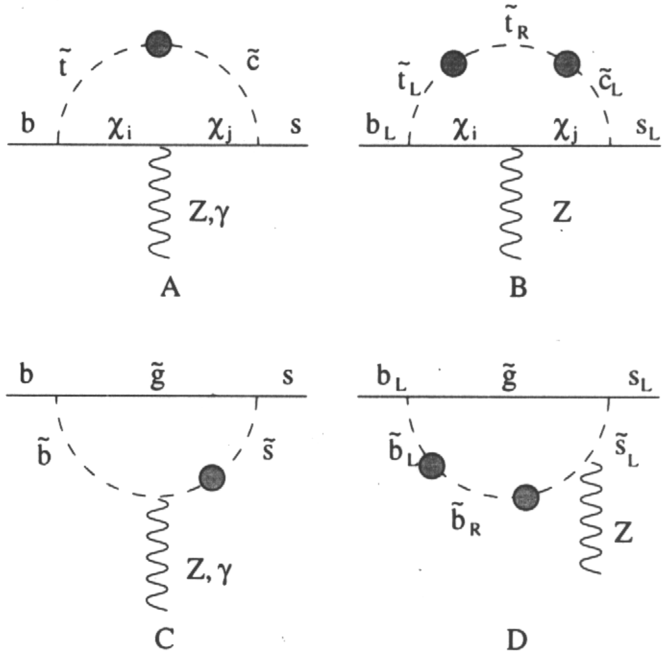


Figure 5: *Some of the relevant penguin diagrams for semileptonic B-decays. Bubbles indicate Mass Insertions. Diagrams A,B are based on chargino interaction. Diagrams C,D consider gluino interactions.*

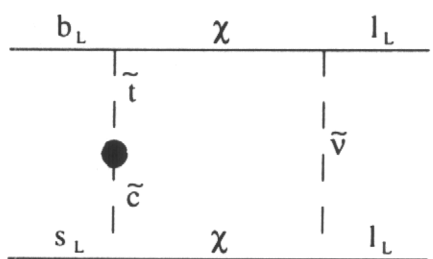


Figure 6: *Relevant box diagram for semileptonic B-decays. Bubble indicates Mass Insertion.*

DIFFERENTIAL BR $(B \to X_s \ell^+ \ell^-)$

——— SM

- - - - SUSY LARGEST ENHANCEMENT

-·-·-· SUSY LARGEST NEGATIVE INTERFERENCE

· · · · · SUSY LARGEST ENHANCEMENT with C_7 of the SAME SIGN AS IN SM

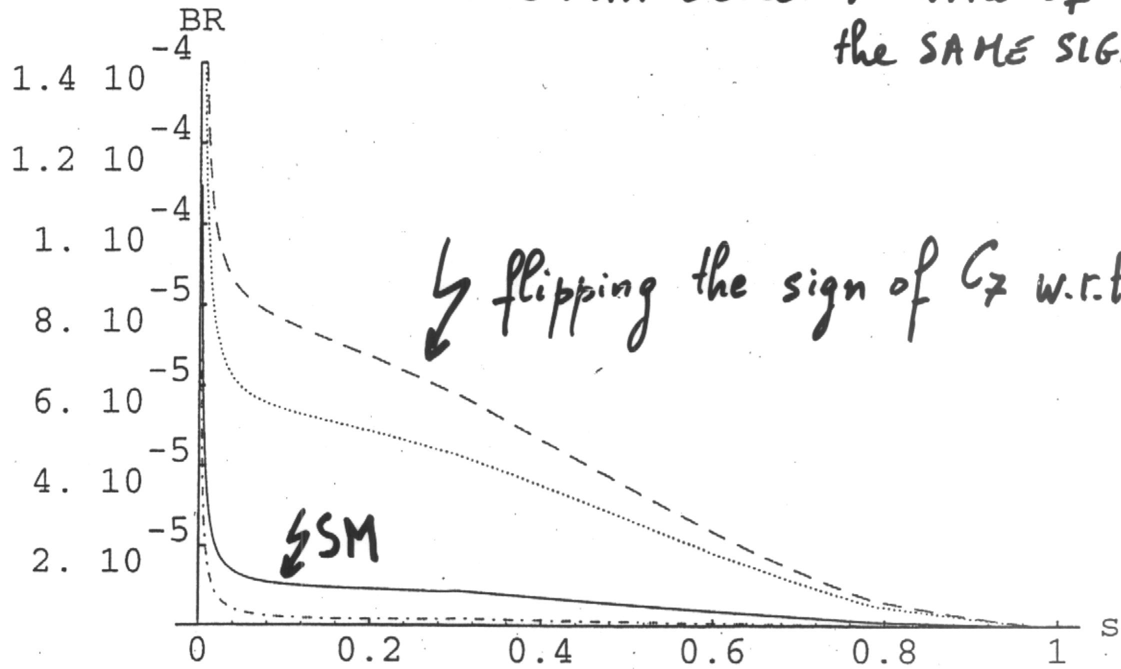


Figure 5: *Differential branching ratio for the decay $B \to X_s \ell^+ \ell^-$. The solid line corresponds to the SM expectation; the dashed and dotted–dashed lines correspond respectively to the SUSY best enhancement ($C_7^{eff} = 0.445, C_9^{MI} = 1.7, C_{10}^{MI} = -8.3$) and depression ($C_7^{eff} = -0.250, C_9^{MI} = -1.0, C_{10}^{MI} = 5.1$); the dotted line is the maximum enhancement obtained without changing the sign of C_7 ($C_7^{eff} = -0.445, C_9^{MI} = 1.25, C_{10}^{MI} = -7.6$).*

LUNGHI, A.M., SCIMEMI, SILVESTRINI

A_{FB} for $B \to X_s \ell^+ \ell^-$

LUNGHI, A.M., SCIMEMI, SILVESTRINI

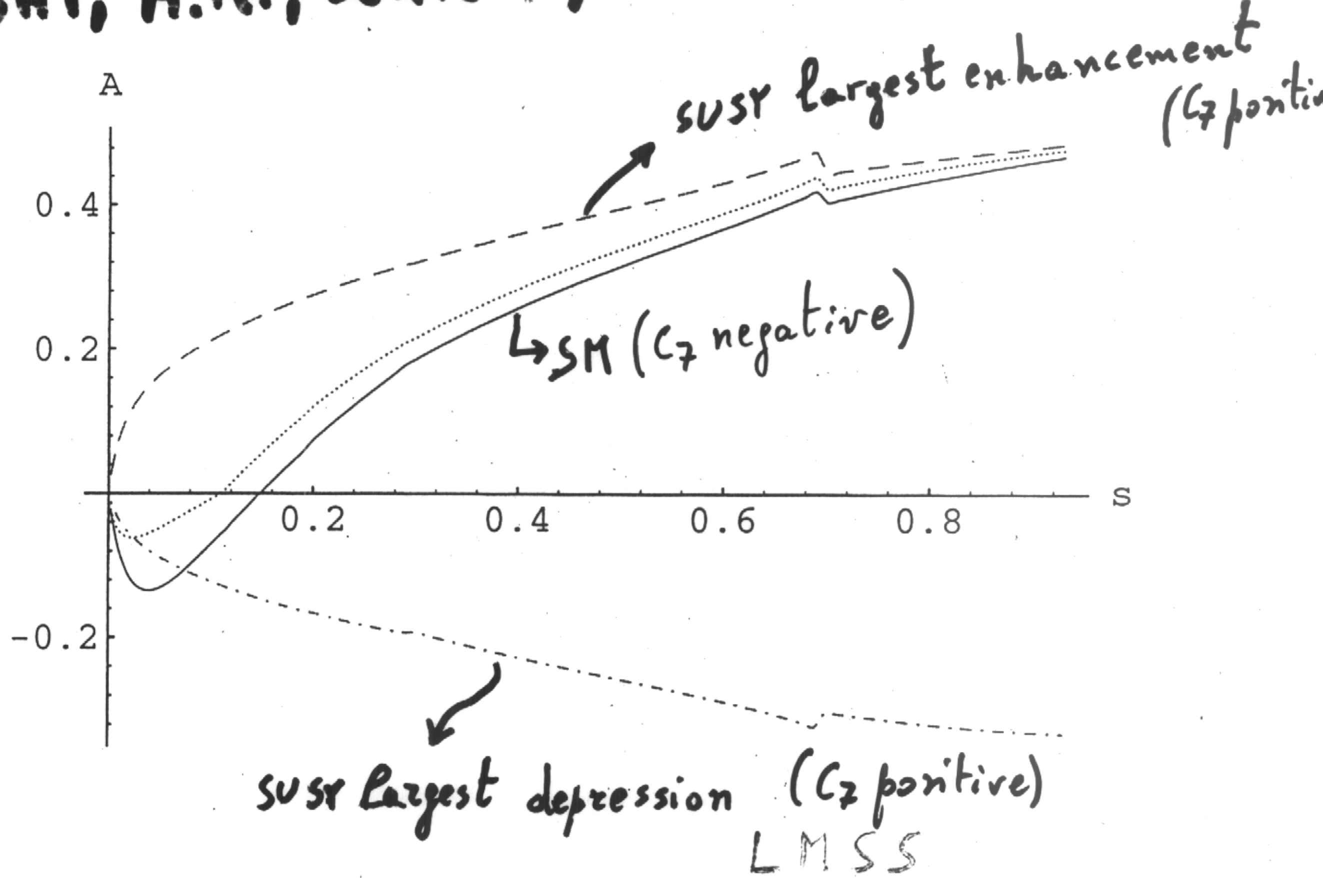
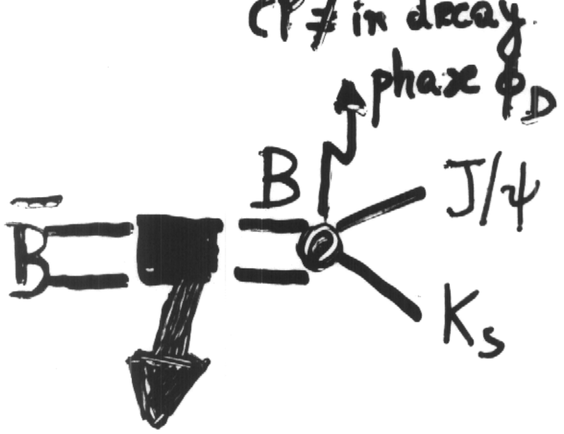


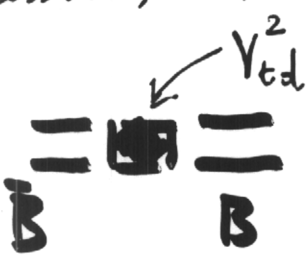
Figure 6: *Forward–Backward asymmetry (A_{FB}) for the decay $B \to X_s \ell^+ \ell^-$. The solid line corresponds to the SM expectation; the dashed and dotted-dashed line corresponds to the SUSY best enhancement ($C_7^{eff} = 0.445, C_9^{MI} = 1.2, C_{10}^{MI} = -2.1$) and depression ($C_7^{eff} = .250, C_9^{MI} = -0.5, C_{10}^{MI} = 6.6$); the dotted line is the maximum enhancement obtained without changing the sign of C_7 ($C_7^{eff} = -0.250, C_9^{MI} = 0.5, C_{10}^{MI} = 1.1$).*

WILL SUSY SHOW UP IN CP≠ B DECAYS ?



CP≠ in mixing → phase ϕ_M

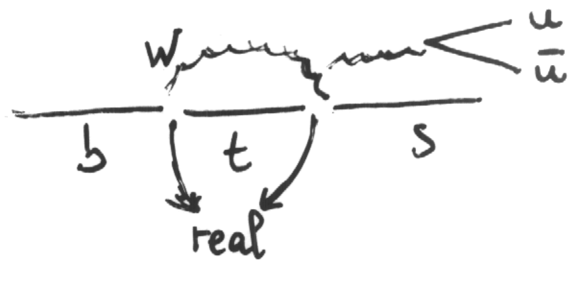
Nir, Quinn ;
Gronau, London ;
Grossman, Nir, Rattazzi



Ciuchini, Franco, Martinelli, A.M. and Silvestrini ;
Grossman and Worah ;
Barbieri and Strumia

if only one decay amplitude
⟹ CP≠ asymmetry depends on $\phi_M + \phi_D$

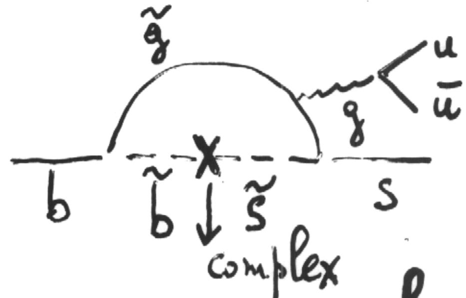
ex. : $B \to K_S \pi^0$



small

$$r_{SM} = \left(\frac{A_{subleading}}{A_{leading}} \right) < 8\%$$

SUSY :



$$r_{SUSY} = \left(\frac{A_{SUSY}}{A_{SM}} \right) \simeq 0.4 - 0.7$$

for SUSY masses ~ 250GeV and maximal SUSY phase

$B \to J/\psi\, K_S \qquad r_{SUSY} < 0.10 \qquad r_{SM} \sim 0$

$B \to \Phi\, K_S \qquad r_{SUSY} \sim 0.4 - 0.7 \qquad r_{SM} < 8\%$

$B \to D^0 \pi^0 \qquad r_{SUSY} \sim 0 \qquad r_{SM} < 4\%$

$\Rightarrow$ in SM all the above decays

$$\left.\begin{array}{l} B_d \to \pi^0 K_S \; ; \quad B_d \to \phi K_S \; ; \\ B_d \to J/\psi K_S \; ; \quad B_d \to D^0 \pi^0 \end{array}\right\rangle \sin 2\beta$$

measure the <u>MIXING</u> <u>PHASE</u> $\underline{\beta} \leftrightarrow V_{td}$

when SUSY is included some decays

$(B \to D^0 \pi^0)$ are not affected $(\phi = \phi_M \Rightarrow \beta)$

some may be significantly shifted $(B \to J/\psi K_S)$

$(\phi = \phi_M + \phi_D \to$ comes from r_{SUSY} up to $10\%)$

some may be completely different $(B \to \phi K_S, B \to \pi^0 K_S$

$(\phi = \phi_M + \phi_D \to$ from r_{SUSY} up to $70\%)$

LEPTON FLAVOR $\not=$

Yanagida; Gell-Mann, Ramond, Slanski; Mohapatra, Senjanovic

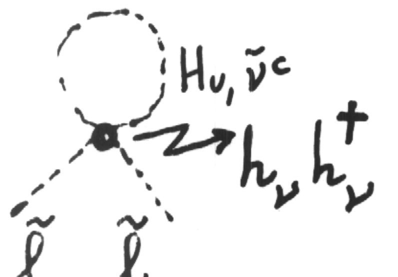
Ex: SUSY SEE-SAW MECHANISM

Borzumati, A.M.; Leontaris, Tamvakis, Vergados;

n SUSY SU(5) Barbieri, Hall; Barbieri, Hall, Strumia;

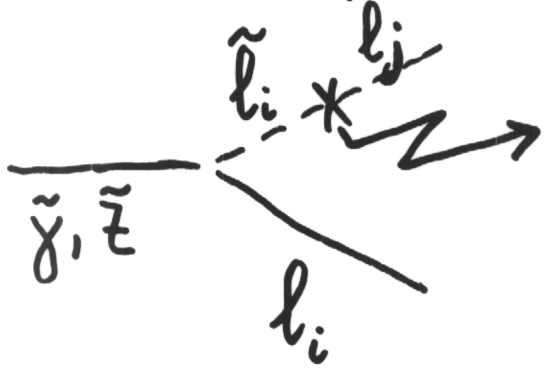
Hisano, Nomura, Yanagida; Hisano, Moroi, Tobe, Yamaguchi;
Moroi; Carvalho, Ellis, Gomez, Lola

$$W = h_L L H_d e^c + h_\nu L H_u \nu^c + M \nu^c \nu^c$$



$$\Longrightarrow M_{\tilde{\ell}_L \tilde{\ell}_L^+} = \tilde{m}^2 \mathbb{1} + m_\ell m_\ell^+ + c\, m_\nu^D m_\nu^{D+}$$

$$m_\nu^D = h_\nu \langle H_u \rangle$$



$$\Delta^\ell_{ij} = c \left(\underbrace{U}_{\text{diagonalizes } m_\ell m_\ell^+} m_\nu^D m_\nu^{D+} U^+ \right)_{ij}$$

for $m_\nu^D \sim 10-20$ GeV and $U \sim K_{CKM}$

$$BR(\mu \to e\gamma) \sim 10^{-12} \div 10^{-13}$$

and also μ-e conversion in nuclei close to the exp. bound

link between neutrino mass textures $\to \mu \to e\gamma$ in SUSY

CASAS et al.
Lavignac et al.

$$W = W_0 + \nu_R^{cT} Y_\nu L H^u - \frac{1}{2} \nu_R^{cT} \mathcal{M} \nu_R$$

$\mathcal{M} \rightarrow M \mathbb{1}$ (but in SO(10) $\mathcal{M}$ hierarch.)

$$W_{eff} = W_0 + \frac{1}{2} (Y_\nu L H^u) \mathcal{M}^{-1} (Y_\nu L H^u)$$

$$\delta \mathcal{L}_{\nu mass} = -\frac{1}{2} \nu^T \mathcal{M}_\nu \nu + h.c.$$

$$\mathcal{M}_\nu = Y_\nu^T \mathcal{M}^{-1} Y_\nu \langle H_0^u \rangle^2 \equiv m_D^T \mathcal{M}^{-1} m_D$$

$\langle H_0^u \rangle^2 \rightarrow v^2 \sin^2\beta \qquad v = 174 \text{ GeV}$

$$U^T \mathcal{M}_\nu U = \mathrm{diag}(m_{\nu_1} \; m_{\nu_2} \; m_{\nu_3})$$

take hierarchical m_ν :

$m_{\nu_1} \sim 0$

$m_{\nu_2} \sim \sqrt{\Delta m^2_{solar}}$

$m_{\nu_3} \sim \sqrt{\Delta m^2_{atm}}$

neglecting phases

$$U \sim \begin{pmatrix} 1 & 0 & 0 \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 0 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix}$$

single maximal mixing (in the ν_{atm} sector)

$$U \sim \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -\frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{2} & -\frac{1}{2} & \frac{1}{\sqrt{2}} \end{pmatrix}$$

bimaximal mixing (if also large mixing in ν_{solar} → now LMA in MSW is slightly favoured by the data)

CASAS, IBARRA
LAVIGNAC, MASINA, SAVOY; in SO(10) BUCHMULLER, WYLER
CARVALHO, ELLIS, GOMEZ, LOLÁ

$$\Rightarrow \left(Y_\nu^+ Y_\nu\right)_{ij} \simeq M\left[\frac{m_{\nu_2}}{v_u^2} U_{i2} U_{j2}^* + \frac{m_{\nu_3}}{v_u^2} U_{i3} U_{j3}^*\right]$$

$$\left|\left(Y_\nu^+ Y_\nu\right)_{23}\right| \sim \left|M \frac{m_{\nu_3}}{v_u^2} U_{23} U_{33}^*\right| \sim \frac{1}{2} |Y_0|^2$$

$|Y_0|^2 \to$ largest eigenvalue of $Y_\nu^+ Y_\nu$

$$\|Y_0(M_x)\| = \|Y_t(M_x)\|$$ unif. condition

$t-\nu_\tau$ unif. (in addition to $b-\tau$ unif.)

if $t-\nu_\tau$ unif. :

$$\left(Y_\nu^+ Y_\nu\right)_{23} \sim \frac{1}{2} Y_t^2$$

$$\left(\Delta^\ell_{23}\right)_{LL} \sim -\frac{1}{8\pi^2}\left(3m_0^2 + A_0^2\right)\left(Y_\nu^+ Y_\nu\right)_{23} \log \frac{M_{Pl}}{M_X}$$

$$\Longrightarrow \left(\delta^\ell_{23}\right)_{LL} \sim \frac{\left(\Delta^\ell_{23}\right)_{LL}}{\tilde{m}^2} \sim 0.2-0.3$$

(upper bound on $\left(Y_\nu^+ Y_\nu\right)_{\mu\tau} \log \frac{M_{Pl}}{M_X}$ for

$Br(\tau \to \mu\gamma) < 1.1 \times 10^{-6}$ Lavignac, Masina, Savoy

allowed to take $\left(Y_\nu^+ Y_\nu\right)_{\mu\tau} \sim h_t^2/2$)

$$\left(Y_\nu^+ Y_\nu\right)_{12} \sim M\left(\frac{m_{\nu_2}}{v_u^2} U_{12} U_{22} + \frac{m_{\nu_3}}{v_u^2} U_{13} U_{23}\right)$$

$$\sim M \frac{m_{\nu_2}}{v_u^2} U_{12} U_{22} \underset{\uparrow}{\sim} \frac{1}{2\sqrt{2}} \left(\frac{m_{\nu_2}}{m_{\nu_3}}\right) |Y_0|^2$$

if bimaximal (~0 if single maximal)

$\rightarrow$ respects $BR(\mu \to e\gamma) < 1.2 \times 10^{-11}$

So far :

$$\left.\begin{array}{l}\text{LARGE } \nu \text{ MIXING} \\ \quad + \\ \text{LARGE } Y_\nu\end{array}\right\} \Longrightarrow \begin{array}{l}\text{LARGE} \\ \Delta^\ell_{LL}\end{array}$$

significant effects in LFV physics

Now: add LEPTON-QUARK UNIFICATION

example: $SU(5)$ $d^c \leftrightarrow \nu$ MORO1 p0104263

$SO(10)$ $u \leftrightarrow \nu$ CHANG, A.M., MURAYAMA (in progress)

$\Longrightarrow$ LARGE Δ^ℓ TRANSLATE INTO

LARGE Δ^d

$\rightarrow$ large $(\delta^\ell_{LL})_{23}$ $\rightarrow$ large $(\delta^d_{RR})_{23}$

$\Rightarrow$ effects for B physics

IMPLICATIONS OF A LARGE $(\delta^d_{23})_{RR}$ (with possibly a large phase) Chang, A.M., Murayama

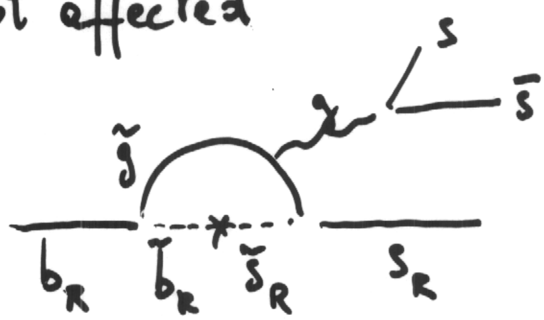
- ΔM_s : ΔM_s^{SUSY} becomes comparable to ΔM_s^{SM}

- $b \to s\gamma$: no sizeable effect

- effects on $\sin 2\beta$:

$B_d \to J/\psi K_s$ not affected

$B_d \to \phi K_s$



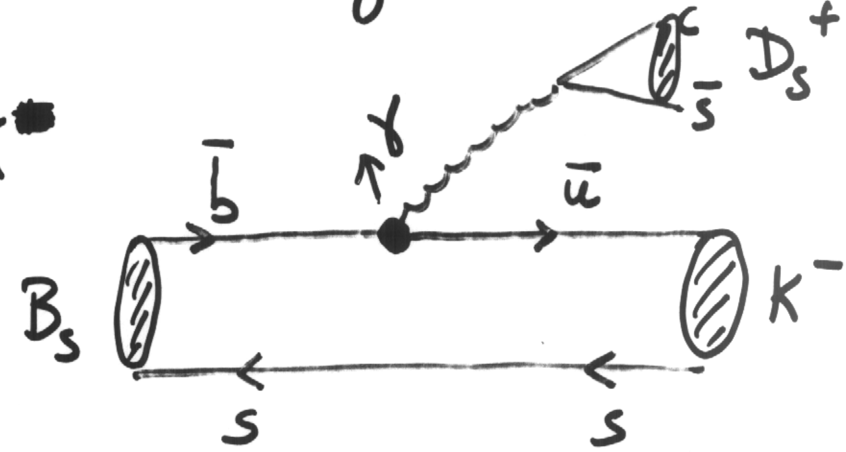
from Ciuchini et al. for $(\delta^d_{23})_{RR} \simeq 1$

$$\frac{A^{SUSY}_{B\to\phi K_s}}{A^{SM}_{B\to\phi K_s}} \begin{cases} 0.7 \text{ for } \tilde{m} \sim 800 \text{ GeV} \\ 0.2 \text{ for } \tilde{m} \sim 500 \text{ GeV} \end{cases}$$

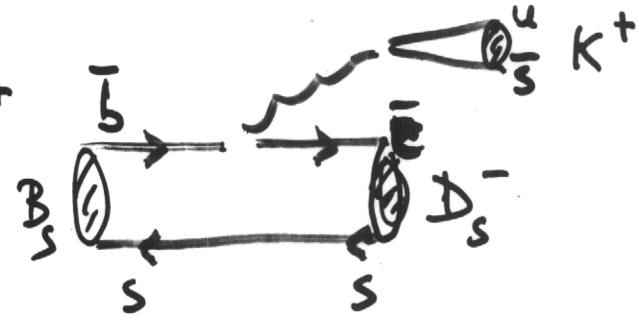
$\Rightarrow$ if $(\delta^d_{23})_{RR}$ has also a large phase: $\sin 2\beta$ measured from $B \to J/\psi K_s$ and $B \to \phi K_s$ could differ as much as 50% due to the new SUSY contributions

EFFECTS OF A LARGE $(\delta^d_{23})_{RR}$ on the DETERMINATION OF γ

1) $B_s \to D_s^+ K^-$



$B_s \to D_s^- K^+$



B_s can reach $D_s^+ K^-$ either through the $b\bar{u}$ vertex or first oscillating to $\bar{B}_s$ with $\bar{B}_s$ then decaying into $D_s^+ K^-$ via a normal $b\bar{c}$ vertex

γ

SM: $$\frac{A(B_s \to D_s^+ K^-)}{A(B_s - \bar{B}_s)\; A(\bar{B}_s \to D_s^+ K^-)} \Longrightarrow \gamma$$

no phase   no phase

SUSY + SM :

γ

$$\frac{A(B_s \to D_s^+ K^-)}{A(B_s-\bar{B}_s)\,A(\bar{B}_s \to D_s^+ K^-)}$$

$2\varphi_\delta$

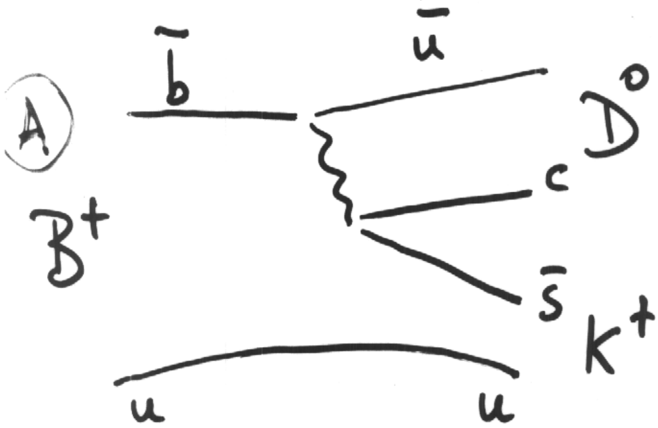
if $(\delta^d_{23})_{RR} = |(\delta^d_{23})_{RR}|\, e^{i\varphi_\delta}$

$$A(B_s-\bar{B}_s) = A^{SM}(B_s-\bar{B}_s)\left(1+\frac{b^{SUSY}_{box}}{b^{SM}_{box}}\, e^{2i\varphi_\delta}\right)$$

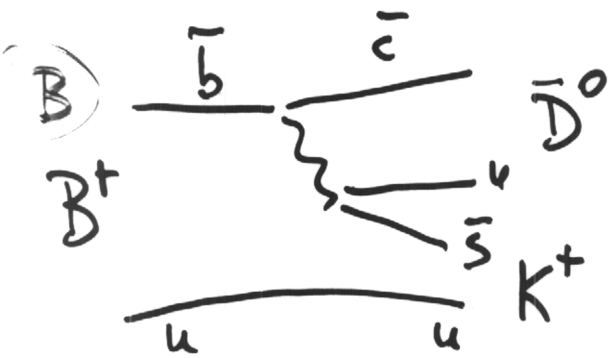
if $(\delta^d_{23})_{RR}$ large $b^{SUSY}_{box} \sim b^{SM}_{box}$

$\Rightarrow$ for large $|(\delta^d_{23})_{RR}|$ and large φ_δ the determination of "γ" from $B_s \to D_s^+ K^-$ can be strongly affected by $\mathrm{Im}(\delta^d_{23})_{RR}$

2) $B^\pm \to D^0 K^\pm$



expected BR $\sim 2 \cdot 10^{-6}$



$B^+ \to \bar{D}^0 K^+$

expected BR $\sim 2 \times 10^{-4}$

in $B^+ \to D_{CP} K^+$ interference of A and B

$\Rightarrow \gamma$

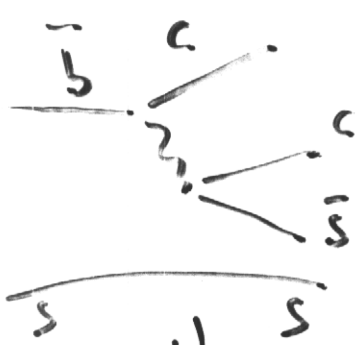
Here No SUSY contribution

"γ" as determined from $B^+ \to D^0 K^+$ and from $B_s \to D_s^+ K^-$ would be quite different for large $(\delta^d_{23})_{RR}$

STRIKING EFFECT OF A LARGE COMPLEX $(\delta^d_{23})_{RR}$

$CP\!\!\!/$ in some B decays which are expected to be essentially CP conserving in the SM

ex: $B_s \to J/\psi\,\phi$ (expected $BR \sim 10^{-3}$)



no phase

interference with

$B_s \to \bar{B}_s \to J/\psi\,\phi$

also here no phase in SM

but φ_d in SUSY

$\Rightarrow$ possible large CP asymmetry for large $(\delta^d_{23})_{RR}$ and large φ_d

CONCLUSIONS

1. THE UNITARITY TRIANGLE PROBE OF THE SM : YET ANOTHER SUCCESS FOR THE SM SO FAR, BUT STILL RELEVANT ROOM FOR NEW PHYSICS (ex., new sources of $CP\!\!\!/$ in $b \to s$ transitions)

2. FCNC and $CP\!\!\!/$ SUSY CONTRIBUTIONS
   → tight constraints on SUSY
   → existence of a FLAVOR SYMMETRY ?

SUSY SIGNALS IN RARE PROCESSES :

*** – EDM's (susy $CP\!\!\!/$ phases in 1-loop contributions to d_n^e, d_e^e, d_{Hg}^e)

*** – LFV ($\mu \to e\gamma$, μ-e conversion in nuclei, $\tau \to \mu\gamma$, ...)
   ↳ "natural" in SUSY SEE-SAW

** – $CP\!\!\!/$ in $b \to s$ ($B \to \phi K_S$, $B \to K\pi$, $a_{b\to s\gamma}$)

* – RARE K DECAYS