Complete One-Loop MSSM Predictions for $B^0 \to \ell^+\ell'^-$ at the Tevatron and LHC

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FLAVIANet, Kazimierz, 25 July 2009

based on work with A. Dedes and P. Tanedo

- Introduction - flavour violation in the MSSM
- Leptonic B decays
  - experimental perspectives
  - calculation of supersymmetric contributions
- Numerical analysis
- SusyFlavour public FORTRAN code
- Conclusions

1. Introduction

Flavour and CP violation in the SM:

- relatively simple - determined entirely by the 3 angles and phase of the CKM matrix (also QCD strong phase?)
- neutral currents flavour conserving at the tree level, CKM appears only in W couplings.

Enough to generate very rich phenomenology!

General MSSM much more complicated:

- SM flavour violating couplings replicated in new SUSY vertices
- numerous new sources in the SUSY soft breaking sector
- tree level FCNC present in the latter!

General MSSM: 105 free parameters, most of them connected with flavour and CP violation (much more if R-parity is not conserved or non-holomorphic soft terms present).

First problem: convenient classification of the MSSM flavour and CP breaking couplings.

- CKM parameters
- new "flavour-diagonal" CP breaking - complex phases in μ parameter, gaugino mass parameters, flavour-diagonal trilinear sfermion-Higgs couplings
- flavour off-diagonal entries in sfermion soft mass matrices and trilinear couplings.

CKM only or CKM and "diagonal" phases $\rightarrow$ Minimal Flavour Violation (MFV) models, SM type Wilson coefficients of various operators modified by SUSY, no new operators.

All terms present - "general" MSSM, new Wilson coefficients contribute significantly to amplitudes $\rightarrow$ considered in this talk.

Squark sector soft terms contributing to hadronic rare decays:

$$\begin{aligned} - &\; (M_Q^2)^{IJ} Q_{Li}^{I*} Q_{Li}^{J} - (M_D^2)^{IJ} D_R^{I*} D_R^{J} - (M_U^2)^{IJ} U_R^{I*} U_R^{J} \\ + &\; \epsilon_{ij} (A_d^{IJ} H_i^1 Q_j^I D^J + A_u^{IJ} H_i^2 Q_j^I U^J + \text{H.c.}) \end{aligned}$$

M_Q^2, M_U^2, M_D^2 are hermitian and A_d, A_u general complex 3×3 matrices.
Useful notation - "mass insertions". Example:

$$(M_{\tilde{U}}^2)_{LL} = \begin{pmatrix} (m_{U1}^2)_{LL} & (\Delta_U^{12})_{LL} & (\Delta_U^{13})_{LL} \\ (\Delta_U^{21})_{LL} & (m_{U2}^2)_{LL} & (\Delta_U^{23})_{LL} \\ (\Delta_U^{31})_{LL} & (\Delta_U^{32})_{LL} & (m_{U3}^2)_{LL} \end{pmatrix}$$

Dimensionless mass insertions are defined as:

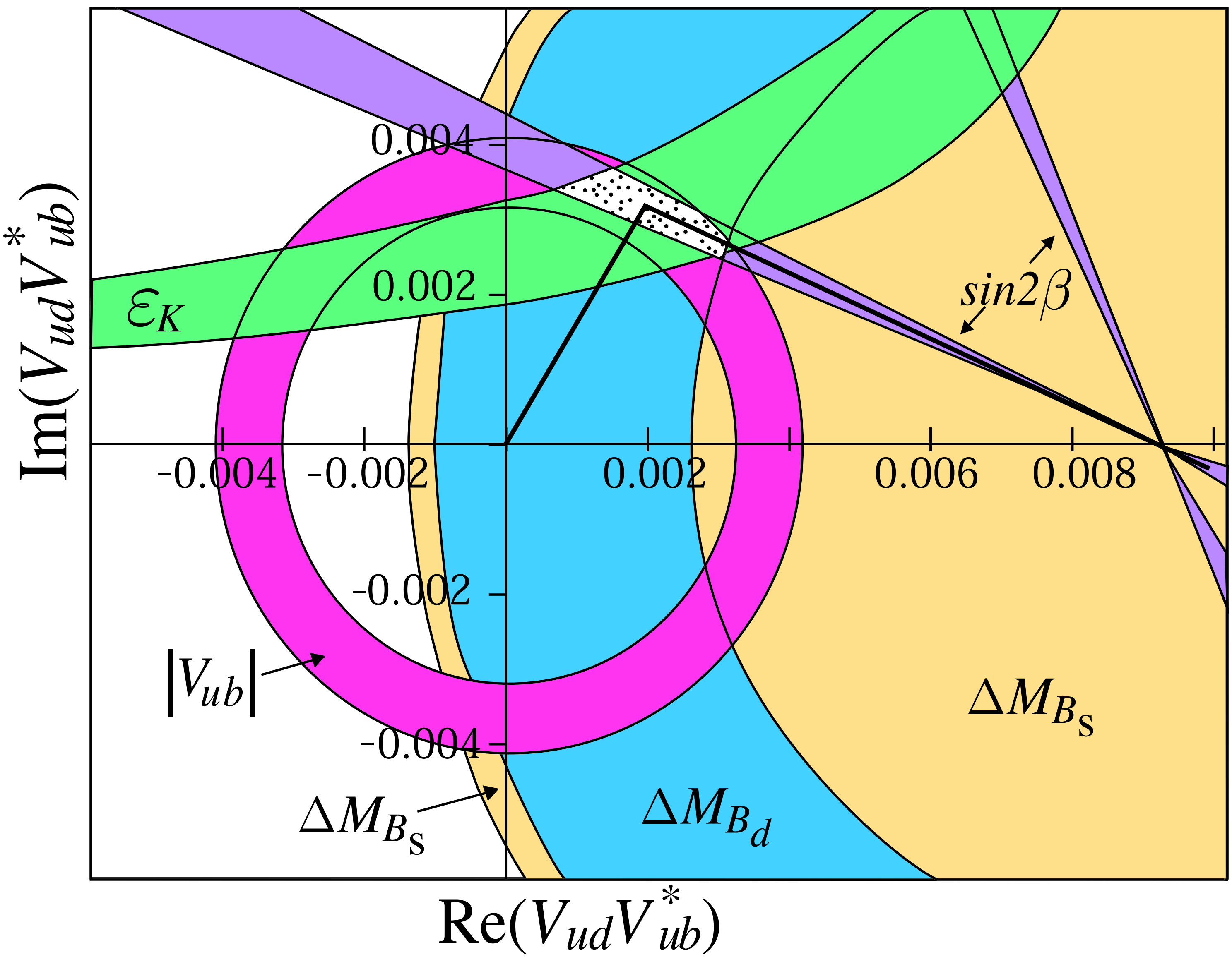
$$(\delta_U^{IJ})_{LR} = \frac{(\Delta_U^{IJ})_{LR}}{(m_{UI})_{LL}\,(m_{UJ})_{RR}}$$

and similarly for other soft terms. $(\delta_Q^{IJ})_{XY}$ measure the amount of flavour violation in sfermion mass matrices.

“General” MSSM: potentially very difficult technical problem - how to disentangle effects of interfering mass insertion in each process?

Experiment: SM flavour violation seem to explain current measurements within experimental bounds! Standard test: “unitarity triangle” - graphical representation of the unitarity relation $V_{ud}V_{ub}^{\star} + V_{cd}V_{cb}^{\star} + V_{td}V_{tb}^{\star} = 0$. Remarkable consistency (plot on next page from PDG review)

SUSY mass insertions must be small - expansion in MI to lowest order usually works. In effect, process involving transition between generations I and J sensitive mostly to few mass insertions with indices IJ, not all sfermion matrices simultaneously - makes the analysis more feasible.



0.004
0.002
-0.002
-0.004
-0.004
-0.002
0.002
0.006
0.008
$\mathrm{Im}(V_{ud}V_{ub}^*)$
$\mathrm{Re}(V_{ud}V_{ub}^*)$
ε_K
$sin2\beta$
$|V_{ub}|$
ΔM_{B_s}
ΔM_{B_s}
ΔM_{B_d}

2. Leptonic B decays

Recent years: lot of new data in rare decay physics, rare K decays, B factories (BaBar, BELLE) and Tevatron.

Near future: LHC as another giant B (and t-quark) factory - first chance to measure leptonic $B \to l^+ l^-$ decay, very rare in the SM (prediction first calculated by Buchalla and Buras). Winter 2008 experimental status :

Channel	Expt.	Bound (90% CL)	SM Prediction
$B_s^0 \to \mu^+\mu^-$	CDF II	$< 4.7 \times 10^{-8}$	$(4.8 \pm 1.3) \times 10^{-9}$
$B_d^0 \to \mu^+\mu^-$	CDF II	$< 1.5 \times 10^{-8}$	$(1.4 \pm 0.4) \times 10^{-10}$
$B_s^0 \to \mu^+ e^-$	CDF	$< 6.1 \times 10^{-6}$	≈ 0
$B_d^0 \to \mu^+ e^-$	BABAR	$< 9.2 \times 10^{-8}$	≈ 0

LHC: LHCb will be able to probe $B_s^0 \to \mu^+\mu^-$ down to the SM prediction at 3σ (5σ) significance with 2 fb^{-1} (6 fb^{-1}) of data, or after about 1 year (3 years).

ATLAS and CMS will be able to reconstruct the $B_s^0 \to \mu^+\mu^-$ signal with significance of 3σ after $\approx$ 30 fb^{-1}

Other decays:

– not clear whether LHC can reach the SM expectation for $B_d^0 \to \mu^+\mu^-$

– $B_s^0 \to \tau^+\tau^-$ or $B_s^0 \to \tau^+\mu^-$ cannot be observed accurately at the Tevatron or LHC

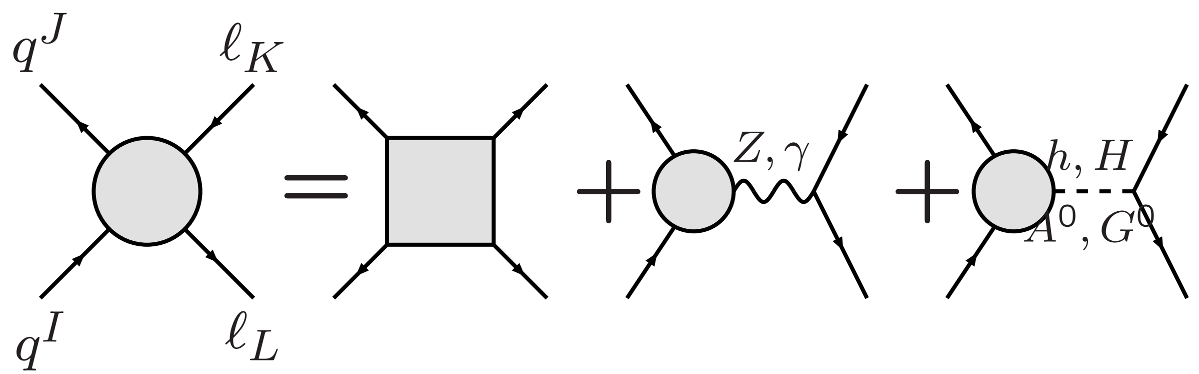
– lepton flavour violating B-decays like $B^0 \to \mu^\pm e^\mp$ typically very small, thus neglected in our calculations but not in numerical analysis (adding possible and straightforward)

Theoretical calculation of $Br(B^0_{s,d} \to \ell^+ \ell'^-)$ in MSSM

Large values of $\tan\beta$ - Higgs penguin dominates. In MFV scenario:

$$\mathcal{B}(B^0_s \to \mu^+\mu^-) \approx 5 \cdot 10^{-7} \left(\frac{\tan\beta}{50}\right)^6 \left(\frac{300\ \text{GeV}}{M_A}\right)^4 ,$$

High $\tan\beta$ already mostly excluded by current CDF bound - in low(er) $\tan\beta$ regime other corrections have to be included: gauge penguins and box diagrams with contributions from squark flavour violating terms.



10 effective operators can contribute to the effective Hamiltonian in the general MSSM (flavour and colour indices suppressed):

$$\mathcal{H} = \frac{1}{(4\pi)^2} \sum_{X,Y=L,R} (C_{VXY}\, \mathcal{O}_{VXY} + C_{SXY}\, \mathcal{O}_{SXY} + C_{TX}\, \mathcal{O}_{TX}) \, ,$$

The (V)ector, (S)calar and (T)ensor operators are given by

$$\begin{aligned}
\mathcal{O}^{IJKL}_{VXY} &= (\overline{q^J}\, \gamma^\mu\, P_X\, q^I)(\overline{\ell^L}\, \gamma_\mu\, P_Y\, \ell^K) \, , \\
\mathcal{O}^{IJKL}_{SXY} &= (\overline{q^J}\, P_X\, q^I)(\overline{\ell^L}\, P_Y\, \ell^K) \, , \\
\mathcal{O}^{IJKL}_{TX} &= (\overline{q^J} \sigma^{\mu\nu}\, P_X\, q^I)(\overline{\ell^L}\, \sigma_{\mu\nu}\, \ell^K) \, .
\end{aligned}$$

$q^J \equiv b$ and $q^I \equiv s$ or d for $B^0_{s,d} \to \ell^+ \ell'^-$ respectively.

Vector and scalar currents hadronize to B_s-mesons (B_d analogous) as

$$\langle 0|\bar{b}\gamma_\mu P_{L(R)} s|B_s(p)\rangle = -(+)\frac{i}{2} p_\mu f_{B_s} ,$$

$$\langle 0|\bar{b} P_{L(R)} s|B_s(p)\rangle = +(-)\frac{i}{2}\frac{M_{B_s}^2 f_{B_s}}{m_b + m_s} .$$

(we use $f_{B_s} = 230 \pm 30$ MeV , $f_{B_d} = 200 \pm 30$ MeV).

Simplifications:

• tensor operators vanish in $\langle 0|\bar{b}\,\sigma_{\mu\nu}\, s|B_s(p)\rangle$ - no way to make an antisymmetric tensor with the single momentum p_μ.

• also the photon penguin contribution vanishes in matrix element calculation

4 effective formfactors remain:

$$\mathcal{M} = F_S\,\bar{\ell}\ell + F_P\,\bar{\ell}\gamma_5\ell + F_V\, p^\mu\bar{\ell}\gamma_\mu\ell + F_A\, p^\mu\bar{\ell}\gamma_\mu\gamma_5\ell ,$$

The (S)calar, (P)seudoscalar, (V)ector and (A)xial formfactors in terms of Wilson coefficients:

$$
\begin{aligned}
F_S &= \frac{i}{4}\frac{M_{B_s}^2 f_{B_s}}{m_b+m_s}\left(C_{SLL}+C_{SLR}-C_{SRR}-C_{SRL}\right) , \\
F_P &= \frac{i}{4}\frac{M_{B_s}^2 f_{B_s}}{m_b+m_s}\left(-C_{SLL}+C_{SLR}-C_{SRR}+C_{SRL}\right) , \\
F_V &= -\frac{i}{4} f_{B_s}\left(C_{VLL}+C_{VLR}-C_{VRR}-C_{VRL}\right) , \\
F_A &= -\frac{i}{4} f_{B_s}\left(-C_{VLL}+C_{VLR}-C_{VRR}+C_{VRL}\right) .
\end{aligned}
$$

The explicit forms of Wilson coefficients C_{XYZ} at $Q = M_W$ (1-loop, no $\tan\beta$ resummation) - see Dedes, JR, Tanedo. We calculate them in mass eigenstate basis, no MIA expansion, no assumption of small flavour violation.

Formfactors F_X do not receive additional renormalisation due to QCD running:

– the conservation of axial-vector current: vanishing anomalous dimension associated with relevant operators $\mathcal{O}_{VXY}$

– the scalar operators ($\mathcal{O}_{SXY}$) renormalise like a quark mass parameter: the ratio $C_{SXY}(Q)/[m_b(Q) + m_s(Q)]$ is RG invariant

Running quark masses in $\bar{DR}$ scheme.

General form of branching ratio (no lepton flavour conservation):

$$\mathcal{B}(B_s^0 \to \ell_L^- \ell_K^+) = \frac{\tau_{B_s}}{16\pi} \frac{|\mathcal{M}|^2}{M_{B_s}} \sqrt{1 - (\frac{m_{\ell_K} + m_{\ell_L}}{M_{B_s}})^2} \sqrt{1 - (\frac{m_{\ell_K} - m_{\ell_L}}{M_{B_s}})^2}$$

where τ_{B_s} is the lifetime of B_s meson, and

$$\begin{aligned}
|\mathcal{M}|^2 &= 2|F_S|^2 \left[M_{B_s}^2 - (m_{\ell_L} + m_{\ell_K})^2\right] + 2|F_P|^2 \left[M_{B_s}^2 - (m_{\ell_L} - m_{\ell_K})^2\right] \\
&+ 2|F_V|^2 \left[M_{B_s}^2 (m_{\ell_K} - m_{\ell_L})^2 - (m_{\ell_K}^2 - m_{\ell_L}^2)^2\right] \\
&+ 2|F_A|^2 \left[M_{B_s}^2 (m_{\ell_K} + m_{\ell_L})^2 - (m_{\ell_K}^2 - m_{\ell_L}^2)^2\right] \\
&+ 4\,\mathrm{Re}(F_S F_V^*)(m_{\ell_L} - m_{\ell_K}) \left[M_{B_s}^2 + (m_{\ell_K} + m_{\ell_L})^2\right] \\
&+ 4\,\mathrm{Re}(F_P F_A^*)(m_{\ell_L} + m_{\ell_K}) \left[M_{B_s}^2 - (m_{\ell_L} - m_{\ell_K})^2\right] .
\end{aligned}$$

General formulae bit complicated - our general numerical code works for $K \neq L$, but in further analysis we assume lepton conserving case.

Contribution from the vector amplitude, F_V, vanishes in the lepton flavour conserving case, $L = K$.

For most interesting $B^0_{s,d} \to \mu^+\mu^-$ decays expressions simplify even more ($K = L = 2$ and $m_\mu/M_{B_q} \to 0$):

$$\mathcal{B}(B^0_q \to \mu^- \mu^+) \approx \frac{\tau_{B_q} M_{B_q}}{8\pi} \left(|F_S|^2 \; + \; |F_P + 2\, m_\mu\, F_A|^2\right)$$

3. Numerical analysis

Lets consider $B_s^0 \to \mu^+\mu^-$ decay first.

Two possible scenarios:

1. Higgs penguin domination or large $\tan\beta \gtrsim 10$. Thoroughly investigated in the literature, although mostly in the MFV limit. Barring accidental cancellations, one gets $|F_S| \approx |F_P| \gg 2m_\ell|F_A|$ due to $\tan^2\beta$ enhancement and full branching ratio also enhanced.
2. Comparable Box, Z-penguin and Higgs penguin contributions or low $\tan\beta \lesssim 10$. Higgs-mediated form factors $F_{S,P}$ comparable to or even smaller than F_A. Full 1-loop corrections to the amplitude are needed. Either an enhancement or a suppression of the branching ratios is possible depending on the particular choice of MSSM parameters.

Enhancement of BR can come from any of the contributions, box or penguin. If observed, gives information on MSSM parameters - lets wait for specific data, too many options for the moment.

Lets concentrate on less known option - suppression below the SM prediction also possible! A bit trickier - requires a cancellation between various terms. 2 cases:

$$F_P + 2\,m_\ell\, F_A \approx 0 \qquad \text{and} \qquad F_P \gg F_S\ ,$$

or

$$|F_S| \approx |F_P| \approx |F_A| \approx 0\ .$$

Both scenarios investigated in our numerical analysis - can be realised, although with a certain amount of fine tuning once constraints on squark mass insertions from other flavour-changing neutral current (FCNC) measurements are imposed.

First case require appropriate left- and right-handed squarks mixing between the strange and charm sectors.

Second case: possible for low $\tan\beta$ and large M_A (kills F_S, F_P) and when and F_A becomes small due to cancellations among the C_{VXY} Wilson coefficients

Numerical setup. We varied the following MSSM parameters:

Parameter	Symbol	Min	Max	Step
Ratio of Higgs vevs	$\tan\beta$	2	30	varied
CKM phase	γ	0	π	$\pi/25$
CP-odd Higgs mass	M_A	100	500	200
SUSY Higgs mixing	μ	-450	450	300
$SU(2)$ gaugino mass	M_2	100	500	200
Gluino mass	M_3	$3M_2$	$3M_2$	0
SUSY scale	M_{SUSY}	500	1000	500
Slepton Masses	$M_{\tilde{\ell}}$	$M_{\mathrm{SUSY}}/3$	$M_{\mathrm{SUSY}}/3$	0
Left top squark mass	$M_{\tilde{Q}_L}$	200	500	300
Right bottom squark mass	$M_{\tilde{b}_R}$	200	500	300
Right top squark mass	$M_{\tilde{t}_R}$	150	300	150
Mass insertion	δ^{13}_{dLL}, δ^{23}_{dLL}	-1	1	1/10
Mass insertion	δ^{13}_{dLR}, δ^{23}_{dLR}	-0.1	0.1	1/100

where:

– "SUSY scale" refers to the common mass parameter for the first two squark generations.

– $\tan\beta$ takes values within the set $(2, 4, 6, 8, 10, 13, 16, 19, 22, 25, 30)$.

– δ^{IJ}_{dLL}, δ^{IJ}_{dLR}, μ and M_2 parameters are chosen to be real.

– the trilinear soft SUSY breaking couplings are set to $A_t = A_b = M_{\tilde{Q}_L}$ and $A_{\tilde{\tau}} = M_{\tilde{\ell}}$.

Most relevant parameters chosen, other do not lead to significant variations of the BR.

Multi-dimensional scan - constraints from other processes necessary to get meaningful results. We use the set listed in the next slide (additionally LEP data are used for the Higgs mass bound, i.e. $m_h \geq 92.8 - 114$ GeV depending on the value of $\sin^2(\alpha - \beta)$).

Quantity	Current Measurement	Experimental Error
$m_{\chi_1^0}$	> 46 GeV	
$m_{\chi_1^\pm}$	> 94 GeV	
$m_{\tilde{b}}$	> 89 GeV	
$m_{\tilde{t}}$	> 95.7 GeV	
m_h	> 92.8 GeV	
$\lvert\epsilon_K\rvert$	$2.232 \cdot 10^{-3}$	$0.007 \cdot 10^{-3}$
$\lvert\Delta M_K\rvert$	$3.483 \cdot 10^{-15}$	$0.006 \cdot 10^{-15}$
$\lvert\Delta M_D\rvert$	$< 0.46 \cdot 10^{-13}$	
ΔM_{B_d}	$3.337 \cdot 10^{-13}$ GeV	$0.033 \cdot 10^{-13}$ GeV
ΔM_{B_s}	$116.96 \cdot 10^{-13}$ GeV	$0.79 \cdot 10^{-13}$ GeV
$\mathrm{Br}(B \to X_s \gamma)$	$3.34 \cdot 10^{-4}$	$0.38 \cdot 10^{-4}$
$\mathrm{Br}(K_L \to \pi^0 \nu\bar{\nu})$	$< 1.5 \cdot 10^{-10}$	
$\mathrm{Br}(K^+ \to \pi^+ \nu\bar{\nu})$	$1.5 \cdot 10^{-10}$	$1.3 \cdot 10^{-10}$
Electron EDM	$< 0.07 \cdot 10^{-26}$	
Neutron EDM	$< 0.63 \cdot 10^{-25}$	

For the quantities where the experimental result and its error are known, we require

$$|Q^{exp} - Q^{th}| \leq 3\Delta Q^{exp} + q|Q^{th}|.$$

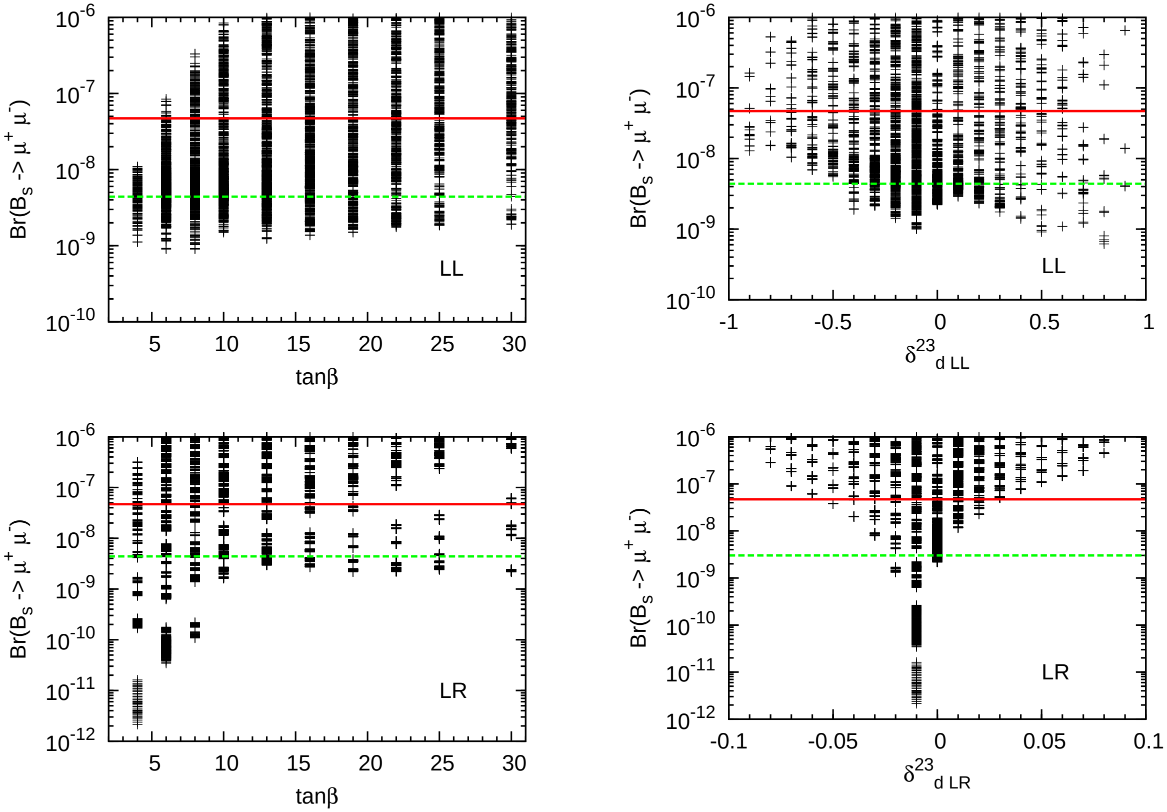
For the quantities for which only the upper bound is known, we require

$$(1+q)|Q^{th}| \leq Q^{exp}.$$

Term $q|Q^{th}|$ represent the "theoretical error". It may come both from uncertainties in the QCD evolution and hadronic matrix elements and the limited density of a numerical scan (11 variables).

We use generic wide error $q = 0.5$. q can be lowered with dense scan, but wide error should be sufficient to find generic MSSM parameters ranges fulfilling all constraints - smaller q may lead to picking strongly fine tuned parameter sets (see Buras, Ewerth, Jäger, JR for more detailed discussion).

Scan results (red line: CDF limit, green line: SM prediction):



Upper panel: $\mathcal{B}(B_s \to \mu^+\mu^-)$ versus $\tan\beta$ (left) and $\delta^{23}_{d\,LL}$ (right).
Lower panel: as the upper panel but with $\delta^{23}_{d\,LR}$ varied.
$\delta^{23}_{d\,LL}$ and $\delta^{23}_{d\,LR}$ varied one at a time while setting the other to zero, e.g. all $\delta^{ij}_{XY} = 0$ and only $\delta^{23}_{d\,LL} \neq 0$ in the upper panel.

Remarks:

1. The upper CDF bound can be attained with very low values of $\tan\beta$.

2. With $\delta^{23}_{d\,LL}$ varied in the range $[-1, 1]$, minimal $\mathcal{B}(B^0_s \to \mu^+\mu^-)_{min} \approx 10^{-9}$, almost independent of $\tan\beta$ but depending on the magnitude of the mass insertion.

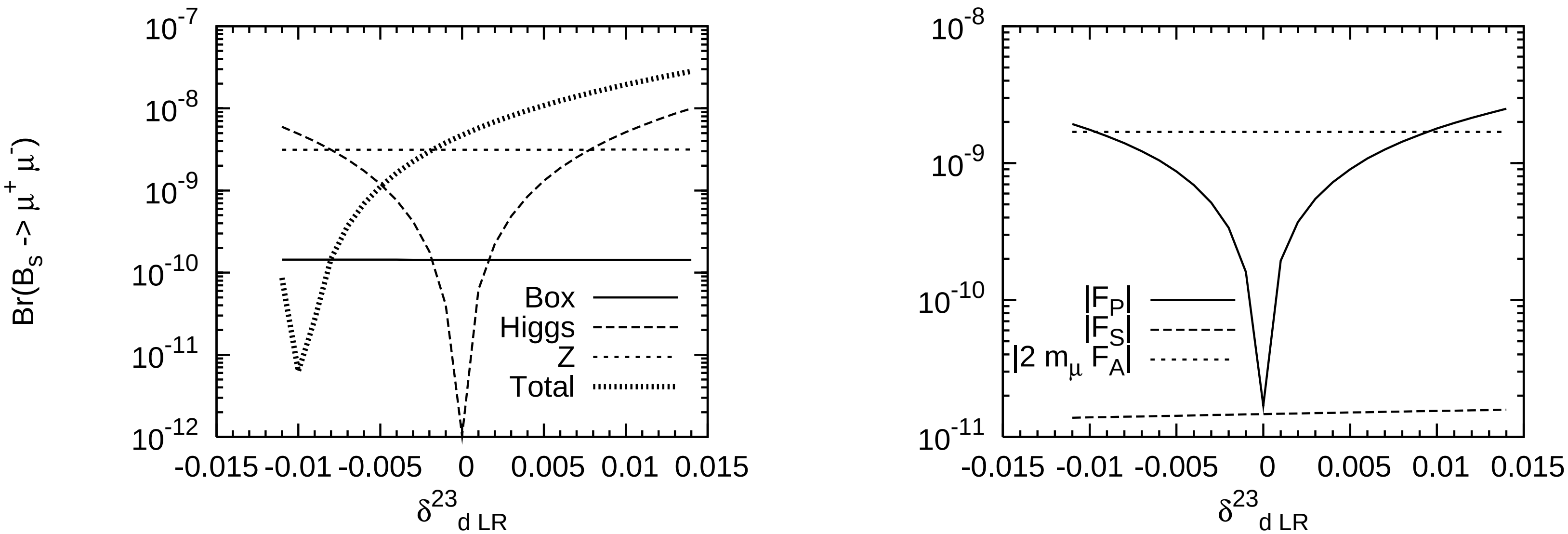
3. $|\delta^{23}_{d\,LL}|$ can reach ≈ 0.9 passing all applied constraints, though points beyond 0.3 are less dense. Correct LEP Higgs mass bound important - setting $m_h > 114$ GeV independently of the value of the ZZH coupling gives $|\delta^{23}_{d\,LL}| \lesssim 0.3$.

4. Results more sensitive to $\delta^{23}_{d\,LR}$ variation, $\delta^{23}_{d\,LR} \lesssim 0.08$ required by CDF bound.

5.Narrow cancellation region around $\delta^{23}_{d\,LR} \approx -0.01$ and $\tan\beta \lesssim 10$ where $\mathcal{B}(B^0_s \to \mu^+\mu^-)_{min} \approx 10^{-12}$, 3 orders below the SM prediction - effectively unobservable at the LHC!

Cancellation example for a very low branching ratio point.

$$\tan\beta = 4, \quad M_A = 300, \quad \mu = -450, \quad M_2 = 100, \quad M_3 = 300,$$
$$\text{SUSY scale} = 400, \quad M_{\tilde{t}_R} = 150, \quad A_{t,b} = M_{\tilde{t}_L} = M_{\tilde{b}_{(L,R)}} = 600$$



Left: The 'Box', 'Higgs' and 'Z' lines indicate the value of $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ given by only the listed contribution with all others set to zero. The total prediction for $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ is also indicated.
Right: Magnitude of the formfactors appearing in the expression for BR.

Cancellation region:

–box diagrams negligible, thus Z- versus Higgs-penguins must cancel

– at the minimum point of total BR $|F_S|$ is negligible and $|F_P| \approx |2m_\mu F_A|$

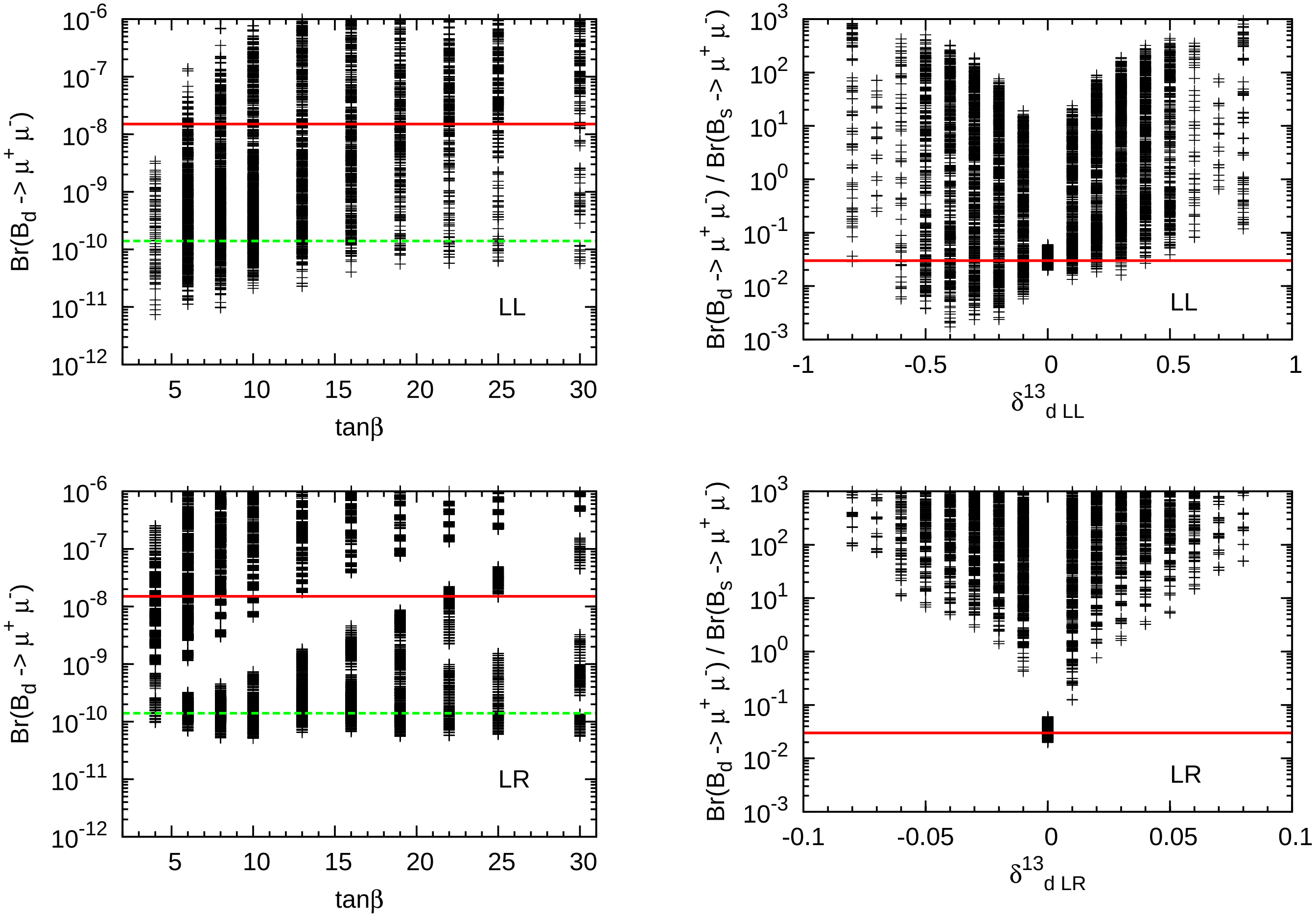
– for $\delta^{23}_{dLR} = \left(\delta^{32}_{dLR}\right)^\star$, as we set, C_{SLR} and C_{SRL} have similar sizes and interfere destructively/constructively in F_S/F_P

– for some given value of δ^{23}_{dLR} also $|F_P| \approx |2m_\mu F_A|$ - full cancellation!

General remark: bounds on the δ parameters have been presented in the literature using the MIA and under very specific assumptions - usually for single chosen point in MSSM parameters space. Our bounds are weaker but much more generic - extensive numerical scan over many parameters + many experimental bounds applied. Result: δ^{23}_{dLL} is still rather weakly constrained, whereas $\delta^{23}_{dLR} \lesssim 0.08$.

Other mass insertions not important here: varying δ^{13}_{dLL} or δ^{13}_{dLR} has almost no effect on $\mathcal{B}(B^0_s \to \mu^+\mu^-)$.

Another decay: $\mathcal{B}(B_d \to \mu^+\mu^-)$ versus $\tan\beta$ and for $\mathcal{B}(B_d \to \mu^+\mu^-)/\mathcal{B}(B_s \to \mu^+\mu^-)$ versus $\delta^{13}_{d\,LL(LR)}$ (red line: CDF bound, green: SM expectation)



Both enhancement and suppression comparing to SM possible.

$\mathcal{B}(B_d \to \mu^+\mu^-)$ can be reduced by an order of magnitude relative to the SM (more likely in 'LL' case).

MSSM can significantly enhance $\mathcal{B}(B_d \to \mu^+\mu^-)/\mathcal{B}(B_s \to \mu^+\mu^-)$ ratio comparing to SM (where it is fixed to ≈ 0.03) even for small values of $\delta^{13}_{d\,LL}$ or $\delta^{13}_{d\,LR}$.

Collider searches for $\mathcal{B}(B_d \to \mu^+\mu^-)$ are as important as those for $\mathcal{B}(B_s \to \mu^+\mu^-)$? See also Bobeth at al in MFV scenario.

Parallel project & advertisement: public SusyFlavour code!

Long history of working on the general MSSM flavour violation:

- Misiak, Pokorski, JR, *Adv.Ser.Direct.High Energy Phys 1998*
- JR, *Acta Phys.Polon.B 1999*
- Pokorski, JR, Savoy, *Nucl.Phys.B 2000*
- Buras, Chankowski, JR, Sławianowska, *Nucl.Phys.B 2001*
- Chankowski, JR, *Acta Phys.Polon.B 2002*
- Buras, Chankowski, JR, Sławianowska, *Phys.Lett.B 2002*
- Buras, Chankowski, JR, Sławianowska, *Nucl.Phys.B 2003*
- Buras, Ewerth, Jäger, JR, *Nucl.Phys.B 2005*
- Dedes, JR, Tanedo, *Phys.Rev.D 2009*

Many processes calculated in the same framework, consistent set of MSSM input parameters, Feynman rules, always in the mass eigenstates formalism, without MIA expansion.

Lot of work, could be useful for external users. Currently program description prepared for Computer Physics Communications. In the first version, following processes will be available:

- $\bar{K}^0 K^0$ mixing
- $\bar{D} D$ mixing
- $\bar{B}_d B_d$ and $\bar{B}_s B_s$ mixing
- $B \to X_s \gamma$ decay
- $B_{s,d} \to l^+ l^-$ decays
- $K_L^0 \to \pi^0 \bar{\nu}\nu$ and $K^+ \to \pi^+ \bar{\nu}\nu$ decays
- Electric Dipole Moment of electron and neutron

All considered processes are calculated at the 1-loop level (excluding some QCD corrections implemented to higher levels) using the exact mass eigenstate basis.

Available soon, hopefully! Future plans: add $g-2$, rare lepton decays, $B_{s,d} \to X l^+ l^-$, general large $\tan\beta$ resummation, ...

4. Conclusions

- $B^0_{s,d} \to \mu^+\mu^-$ soon to become important experimental test of the New Physics
- in the general unconstrained MSSM for not very high $\tan\beta$ both suppression and enhancement of both decays $B^0_{s,d} \to \mu^+\mu^-$ comparing to the SM prediction - thus also *not* finding at least $B^0_s \to \mu^+\mu^-$ at LHC would be an important discovery possibly pointing to SUSY effects
- both options would put strong bounds on the size of allowed flavour violation in the squark sector
- FORTRAN code calculating many important SUSY rare decays in the uniform setup available, will be published soon - multiparameter and multiprocess analyses can be performed