BSM Tools for B–Physics

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Flavour and LHC, 31st January 2005

Based on K. Okumura, L. Roszkowski (JHEP ’03, PRL ’04) and
JF, K. Okumura, L. Roszkowski (hep-ph/0410323, in preperation)

Outline

Supersymmetry

Beyond Leading Order Calculations

- $\tan\beta$ Enhanced Effects
- $\bar{B} \to X_s\gamma$
- $\bar{B}_s \to \mu^+\mu^-$ and $\bar{B}_s - B_s$ mixing

Constraining SUSY Flavour Violation Contributions

Supersymmetry

- Currently one of the best candidates for new physics at the LHC.
- How SUSY is broken, particularly the flavour structure, is currently not known
- FCNC processes ($\bar{B} \to X_s\gamma$, $\bar{B}_s \to \mu^+\mu^-$, $\bar{B}_s - B_s$ mixing) can provide a useful tool when probing the flavour structure of SUSY models.
- Usefulness of these limits dependent on the accuracy of the underlying calculation.

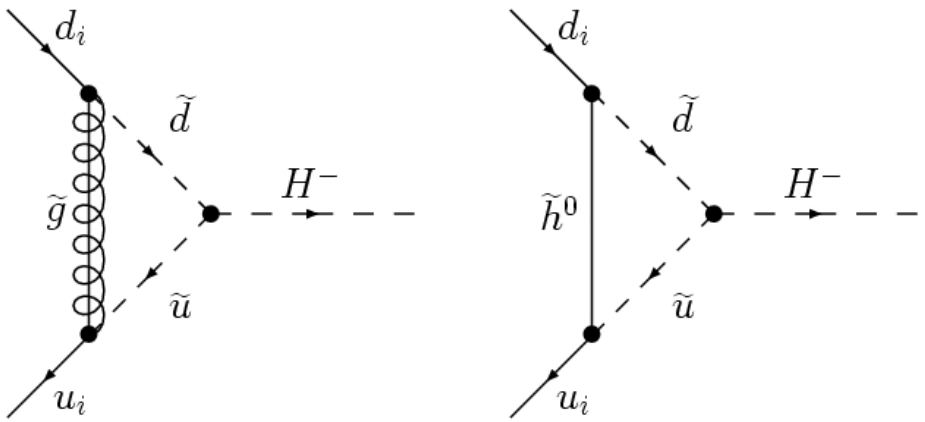
Beyond Leading Order Calculations

- Beyond Leading Order (BLO) calculations are the current state of the art of theoretical precision for both minimal flavour violation and general flavour mixing models.
- Assume the hierarchy ($m_{SUSY} > m_W, m_H > m_b$).
- Include resummation of $\alpha_s \tan\beta$, $\alpha_t \tan\beta$ enhanced terms, large logarithms.
- Large logs $\left(\log m^2_{SUSY}/m^2_W\right)$ induced by running from the SUSY to the electroweak scale.

tan β Enhanced Effects

Minimal Flavour Violation

- Originate from SUSY corrections to the down quark mass matrix and the charged and neutral Higgs vertices, *e.g.*

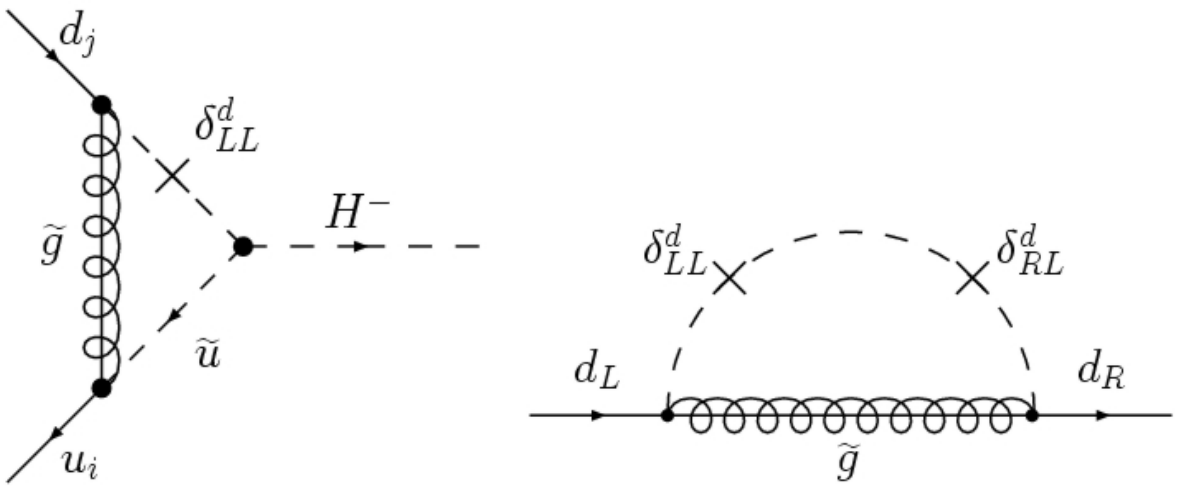


- Since the original papers, there have been many improvements and generalisations (EW corrections, $\boldsymbol{SU(2)_L \times U(1)_Y}$ breaking effects, CP violation, general flavour mixing).

tan β Enhanced Effects

General Flavour Mixing

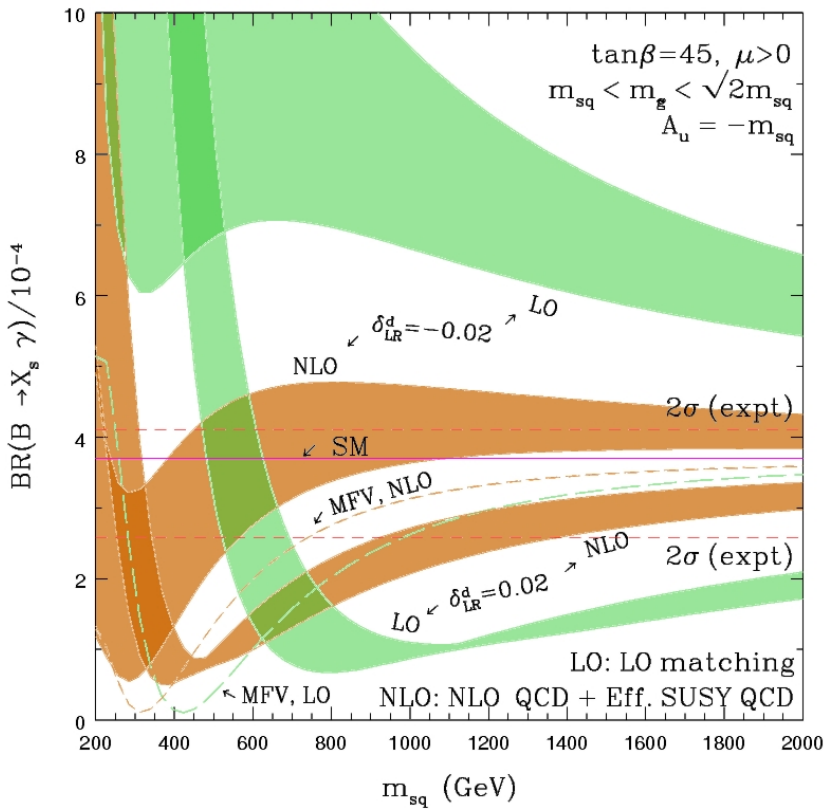
- GFM effects can further modify the structure of the corrected vertices and masses present in the theory.



- K. Okumura, L. Roszkowski (JHEP ’03, PRL ’04) and JF, K. Okumura, L. Roszkowski (in preperation).

Focussing Effect Beyond the Leading Order

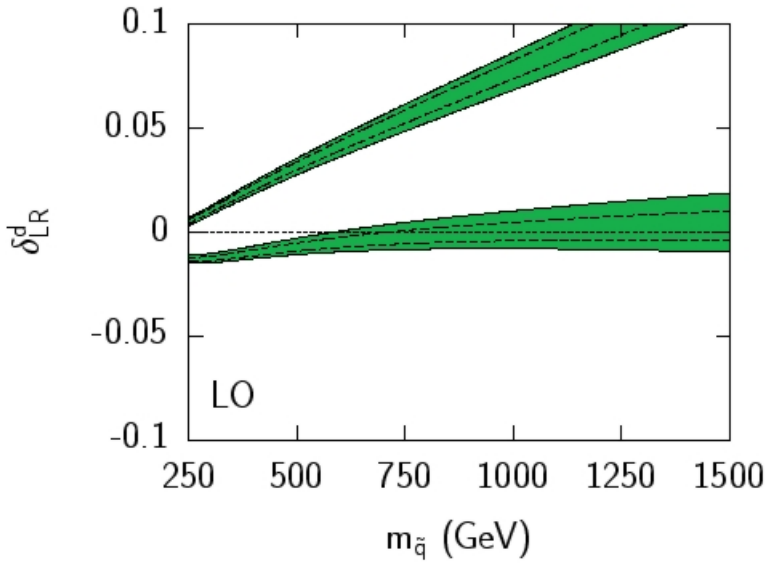
- BLO effects lead to a “focussing” towards the SM value.
- Can be more dramatic for GFM than MFV. (K. Okumura, L.Roszkowski, PRL ’04)

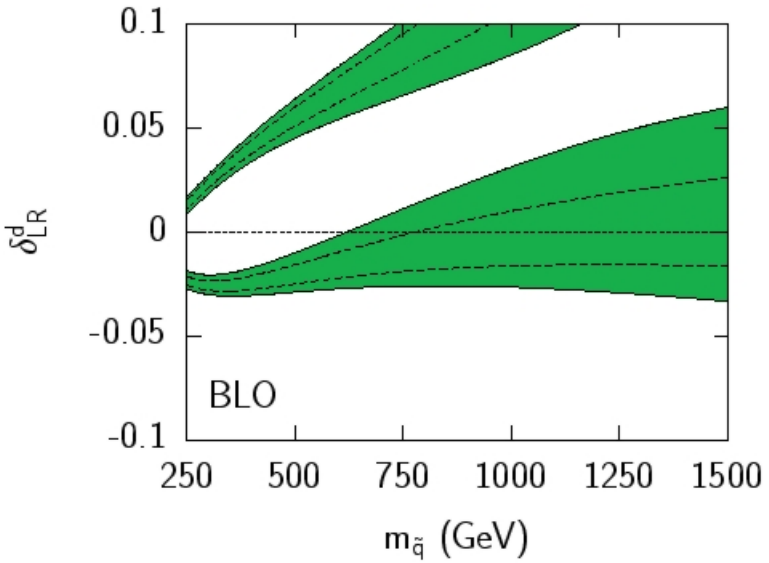


Focussing Effect Beyond the Leading Order

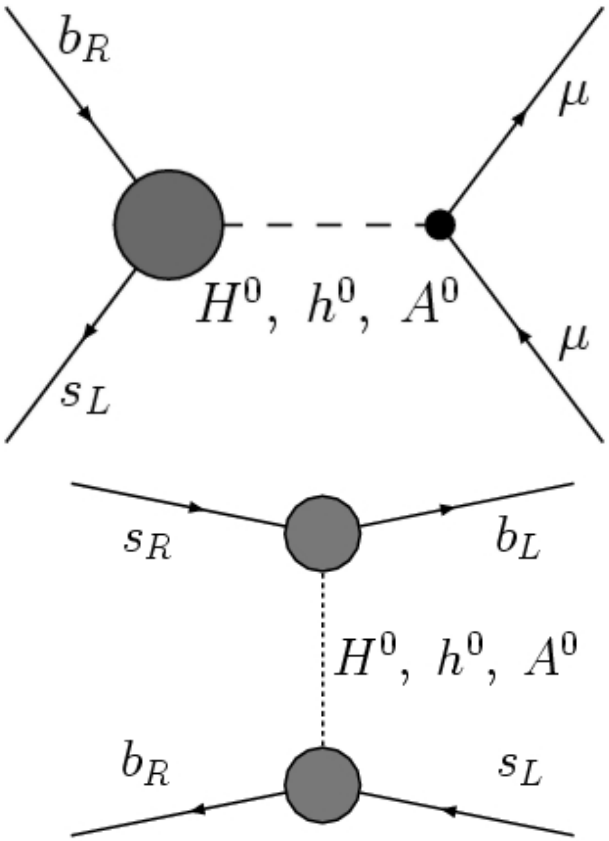
$\tan\beta = 40$, $\mu > 0$, $m_{\tilde{g}} = \sqrt{2} m_{\tilde{q}}$

- Inclusion of BLO effects can loosen the bounds placed on the mixing amoungst squarks (left–right mixings in particular). *e.g.*
- $\mathrm{BR}\left(\bar{B} \to X_s\gamma\right) = 3.52^{+0.30}_{-0.28} \times 10^{-4}$





$\bar{B}_s \to \mu^+\mu^-$ and $\bar{B}_s - B_s$ Mixing



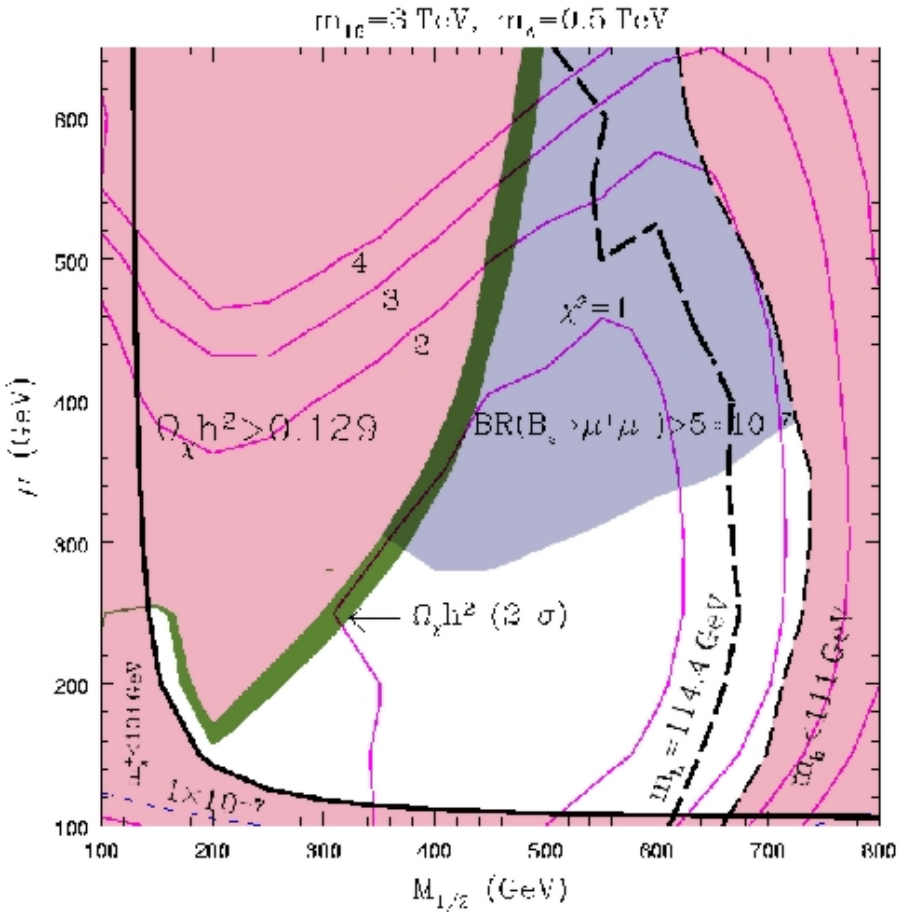
- The SUSY corrections to the corrected neutral Higgs vertex $\propto \mathbf{\tan^2}\,\beta$.
- Contributions due to this vertex to $\bar{B}_s \to \mu^+\mu^-$ can lead to BR$\propto \mathbf{\tan^6}\,\beta$.
- Contributions to $\bar{B}_s - B_s$ mixing $\propto \mathbf{\tan^4}\,\beta$.

Searches for $\bar{B}_s \to \mu^+\mu^-$ and ΔM_{B_s}

- GFM and MFV models with large **tan** β can lead to predictions for $\mathrm{BR}\left(\bar{B}_s \to \mu^+\mu^-\right)$ many orders of magnitude greater than the SM prediction $\mathrm{BR}\left(\bar{B}_s \to \mu^+\mu^-\right)_{SM} \sim 3 \times 10^{-9}$.
- Collider searches for the decay are already providing a useful constraint in the large **tan** β limit.
- ΔM_{B_s} has remained unobserved so far.
- MFV : small deviations from the SM prediction of $\mathbf{18 ps^{-1}}$.
- GFM : values far in excess of this value.

Searches for $\bar{B}_s \to \mu^+\mu^-$ and ΔM_{B_s}

- *e.g.* $SO(10)$ models (R. Dermisek, S. Raby, L. Roszkowski, R. Ruiz de Austri, hep-ph/0304101 and in prep.)



Constraining SUSY Flavour Violation

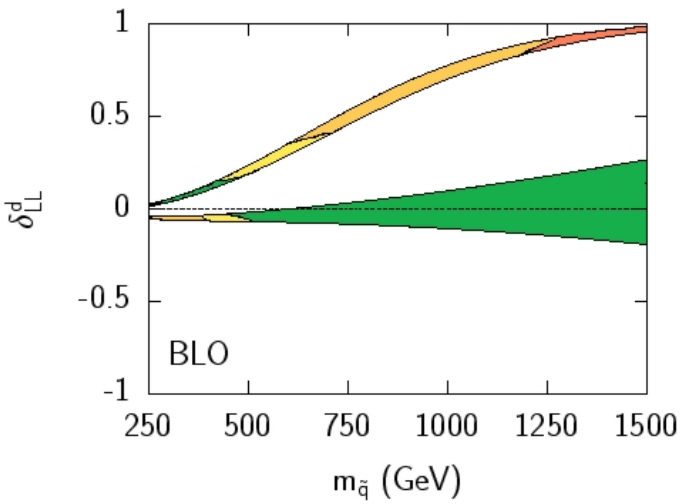
- Combining the constraints provided by all three decays can improve the limits placed on flavour violation.
- δ^d_{RL} and δ^d_{RR} in particular are left relatively unconstrained by $\bar{B} \to X_s\gamma$.
- The limits on ΔM_{B_s} and $\bar{B}_s \to \mu^+\mu^-$ can place stricter bounds on both sources of flavour violation (JF, K. Okumura and L. Roszkowski, hep-ph/0410323, PLB to appear).
- World average for $\Delta M_{B_s} > 14.5 ps^{-1}$ (95% C.L.).
- Current Tevatron (DØ) bound on $\bar{B}_s \to \mu^+\mu^-$ is BR($\bar{B}_s \to \mu^+\mu^-$)$< 5 \times 10^{-7}$ (95% C.L.).

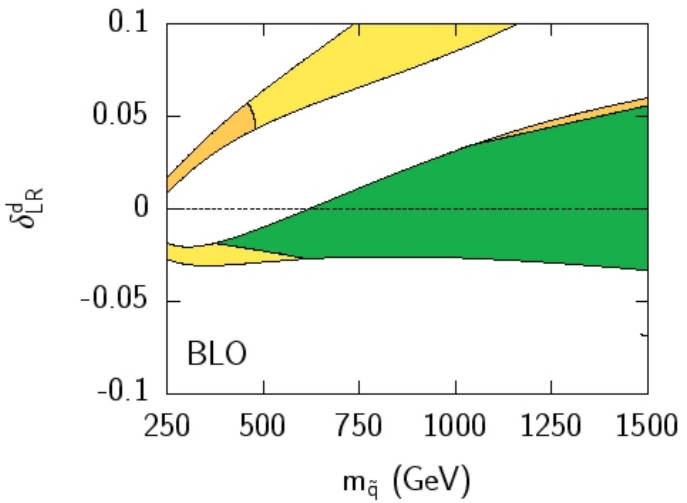
Limits on Flavour Violation – Present Day

$\tan\beta = 40$, $\mu > 0$, $m_{\tilde{g}} = \sqrt{2} m_{\tilde{q}}$

- Limits on δ^d_{LL} and δ^d_{LR} dominated by $\bar{B} \to X_s\gamma$.
- $\bar{B}_s \to \mu^+\mu^-$ and ΔM_{B_s} rule out only extreme scenarios.

Allowed by all
ΔM_{B_s} (Excl.)
$\bar{B}_s \to \mu^+\mu^-$ (Excl.)
$\bar{B}_s \to \mu^+\mu^- + \Delta M_{B_s}$ (Excl.)



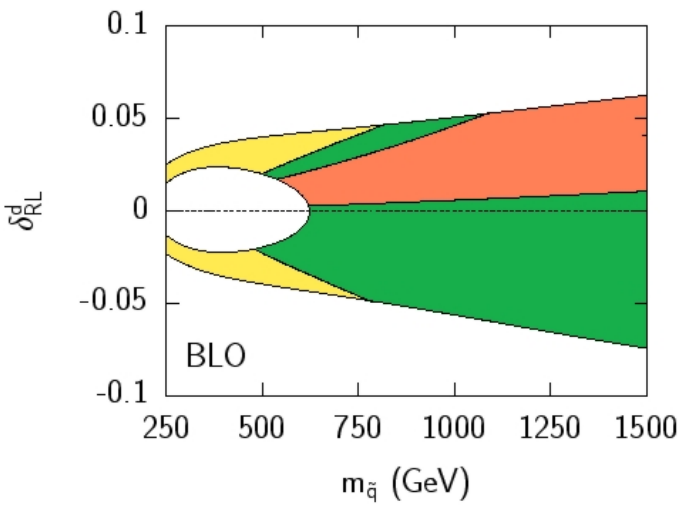


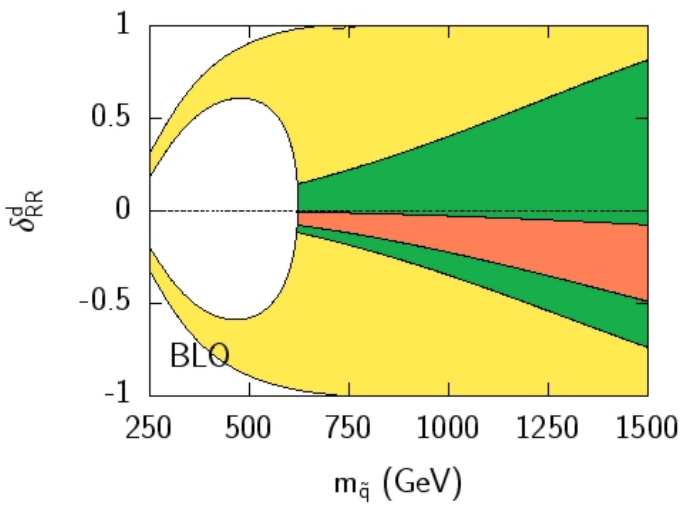
Limits on Flavour Violation – Present Day

$\tan\beta = 40$, $\mu > 0$, $m_{\tilde{g}} = \sqrt{2} m_{\tilde{q}}$

- $\bar{B} \to X_s\gamma$ limits far looser for δ^d_{RL} and δ^d_{RR}.
- $\bar{B}_s \to \mu^+\mu^-$ and ΔM_{B_s} already provide useful constraints.

Allowed by all
ΔM_{B_s} (Excl.)
$\bar{B}_s \to \mu^+\mu^-$ (Excl.)
$\bar{B}_s \to \mu^+\mu^- + \Delta M_{B_s}$ (Excl.)





Prospects for the LHC

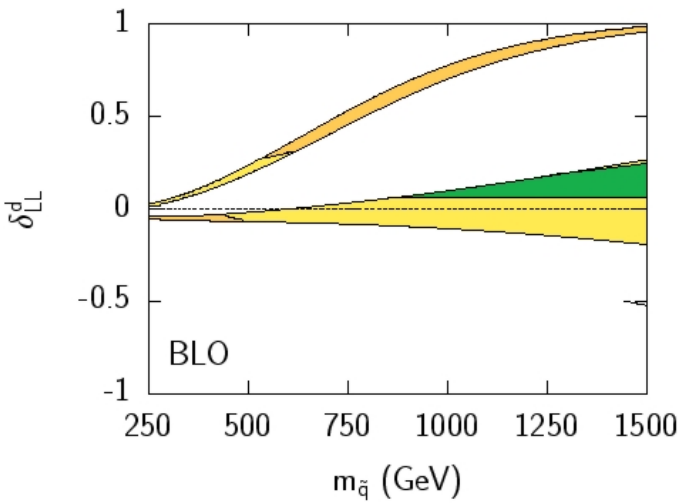
- CDF and DØ expect to set more stringent limits on $\mathrm{BR}\left(\bar{B}_s \to \mu^+\mu^-\right)$ and ΔM_{B_s}.
- A large region of parameter space is still available at the LHC, in particular for GFM models.
- All three LHC experiments will be able to detect $\bar{B}_s \to \mu^+\mu^-$ after $\sim$ three years running and limits of up to $\mathbf{40ps^{-1}}$ can be placed on ΔM_{B_s} putting the SM value easily within reach.
- Successful measurement of $\mathrm{BR}\left(\bar{B}_s \to \mu^+\mu^-\right)$ and ΔM_{B_s} will be able to place useful limits on SUSY flavour violation if $\mathbf{\tan}\,\beta$ is large.

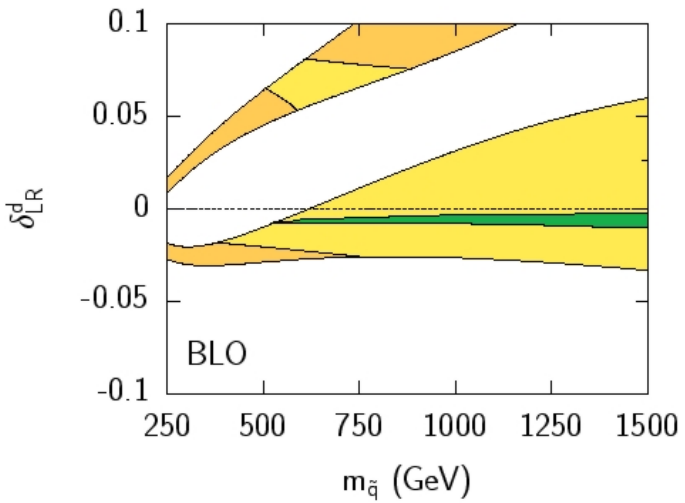
Worst Case Scenario

tan $\beta = 40$, $\mu > 0$, $m_{\tilde{g}} = \sqrt{2} m_{\tilde{q}}$

- If $\bar{B}_s \to \mu^+\mu^-$ and ΔM_{B_s} are observed at their SM values then large **tan** β will remain viable for small deviations from MFV.

Allowed by all
ΔM_{B_s} (Excl.)
$\bar{B}_s \to \mu^+\mu^-$ (Excl.)
$\bar{B}_s \to \mu^+\mu^- + \Delta M_{B_s}$ (Excl.)





Summary

- Rare B–decays provide an ideal probe of the flavour structure of soft SUSY breaking.
- Beyond Leading Order corrections play an important role in MFV and GFM frameworks.
- The B physics programs at the LHC will be able to probe a large range of allowed parameter space for GFM models with large **tan** β.