Updated flavour constraints on SUSY

Nazila Mahmoudi

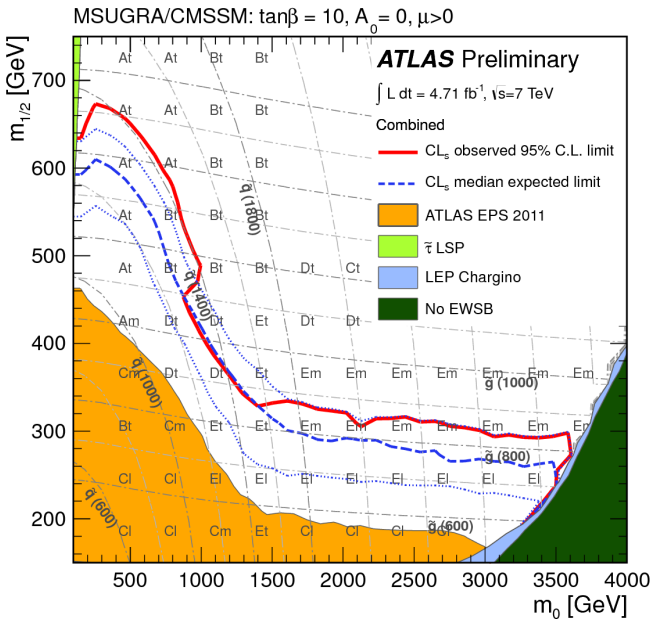
CERN TH & LPC Clermont-Ferrand

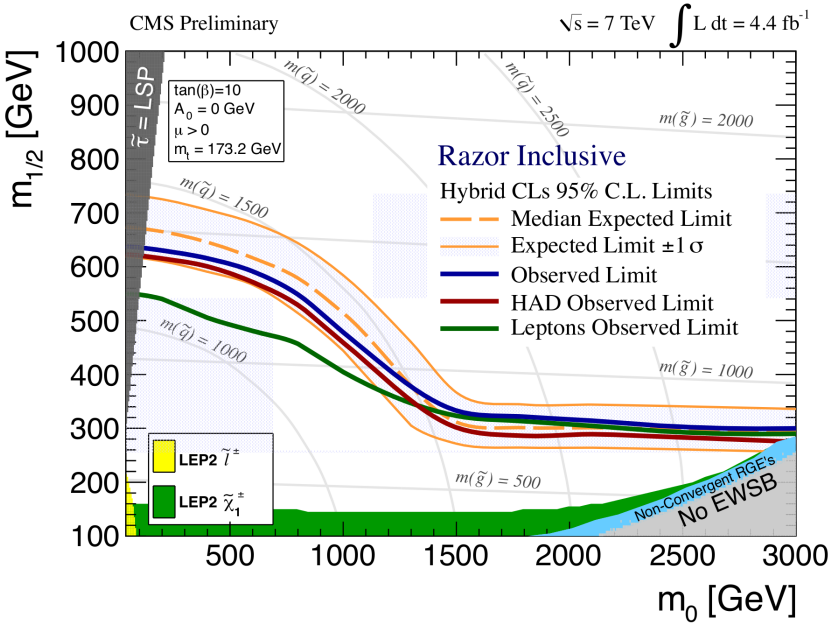
Work in collaboration with S. Neshatpour and J. Orloff
and with A. Arbey and M. Battaglia

Implications of LHC results for TeV-scale physics
CERN, March 26-30, 2012

- Direct searches

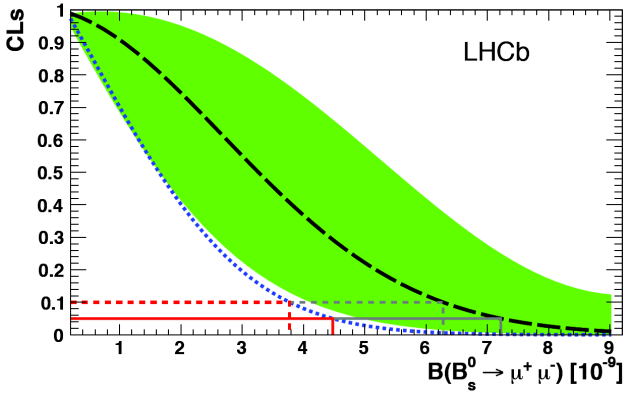
- Search for SUSY is the main focus of BSM searches in both **ATLAS** and **CMS**
- Strong limits in the constrained SUSY scenarios
- No signal so far...

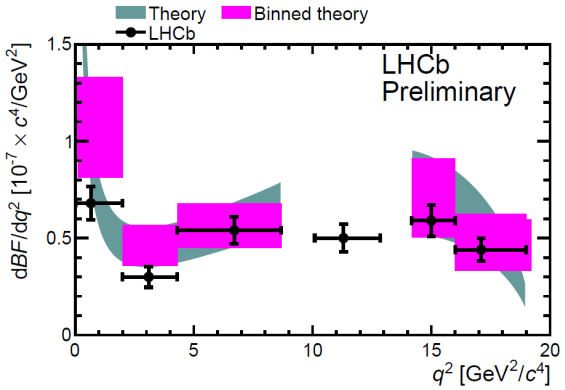


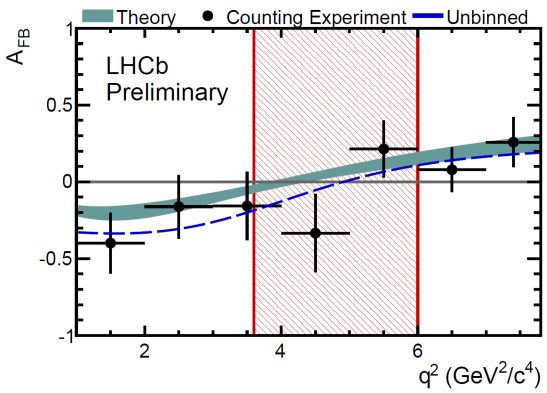


- Indirect searches (flavour)

- **LHCb** has also a rich BSM program through indirect searches!
- key processes: $B_s \to \mu^+\mu^-$, $B \to K^*\mu^+\mu^-$ and CP violation







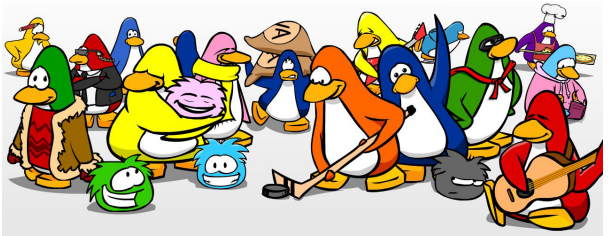
While direct searches are only pushing the limits higher, flavour physics can add to the picture substantially!

- Indirect searches (Dark matter, precision tests,...)

Not subject of this talk

Exciting time for flavour physics!

- Soon the discovery of $B_s \to \mu^+\mu^-$
- Many new observables are now in the game!



- However, a correct estimate of the theory predictions and uncertainties is crutial!

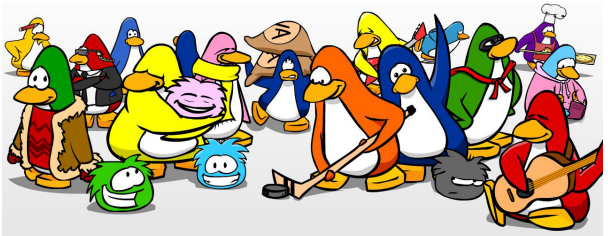
In this talk:

Consider the new rare decay limits/measurements of LHCb

- Theoretical framework
- SM predictions and errors
- Implications for SUSY

Exciting time for flavour physics!

- Soon the discovery of $B_s \to \mu^+\mu^-$
- Many new observables are now in the game!



- However, a correct estimate of the theory predictions and uncertainties is crutial!

In this talk:

Consider the new rare decay limits/measurements of LHCb

- Theoretical framework
- SM predictions and errors
- Implications for SUSY

A multi-scale problem

- new physics: $1/\Lambda_{\rm NP}$
- electroweak interactions: $1/M_W$
- hadronic effects: $1/m_b$
- QCD interactions: $1/\Lambda_{\rm QCD}$

$\Rightarrow$ Effective field theory approach:

separation between low and high energies using Operator Product Expansion

- short distance: Wilson coefficients, computed perturbatively
- long distance: local operators

$$\mathcal{H}_{\rm eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \Big(\sum_{i=1\cdots 10,S,P} \big(C_i(\mu)\mathcal{O}_i(\mu) + C_i'(\mu)\mathcal{O}_i'(\mu) \big) \Big)$$

New physics:

- Corrections to the Wilson coefficients: $C_i \to C_i + \Delta C_i^{NP}$
- Additional operators: $\sum_j C_j^{NP} \mathcal{O}_j^{NP}$

A multi-scale problem

- new physics: $1/\Lambda_{\rm NP}$
- electroweak interactions: $1/M_W$
- hadronic effects: $1/m_b$
- QCD interactions: $1/\Lambda_{\rm QCD}$

$\Rightarrow$ Effective field theory approach:

separation between low and high energies using Operator Product Expansion

- short distance: Wilson coefficients, computed perturbatively
- long distance: local operators

$$\mathcal{H}_{\rm eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \Big(\sum_{i=1\cdots 10,S,P} \big(C_i(\mu)\mathcal{O}_i(\mu) + C_i'(\mu)\mathcal{O}_i'(\mu) \big) \Big)$$

New physics:

- Corrections to the Wilson coefficients: $C_i \to C_i + \Delta C_i^{NP}$
- Additional operators: $\sum_j C_j^{NP} \mathcal{O}_j^{NP}$

A multi-scale problem

- new physics: $1/\Lambda_{\rm NP}$
- electroweak interactions: $1/M_W$
- hadronic effects: $1/m_b$
- QCD interactions: $1/\Lambda_{\rm QCD}$

$\Rightarrow$ Effective field theory approach:

separation between low and high energies using Operator Product Expansion

- short distance: Wilson coefficients, computed perturbatively
- long distance: local operators

$$\mathcal{H}_{\rm eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \Big(\sum_{i=1\cdots 10,S,P} \big(C_i(\mu)\mathcal{O}_i(\mu) + C_i'(\mu)\mathcal{O}_i'(\mu) \big) \Big)$$

New physics:

- Corrections to the Wilson coefficients: $C_i \to C_i + \Delta C_i^{NP}$
- Additional operators: $\sum_j C_j^{NP} \mathcal{O}_j^{NP}$

$\mathcal{O}$perators

$$\mathcal{O}_7 = \frac{e}{g^2} m_b (\bar{s}\sigma_{\mu\nu} P_R b) F^{\mu\nu} \qquad \mathcal{O}'_7 = \frac{e}{g^2} m_b (\bar{s}\sigma_{\mu\nu} P_L b) F^{\mu\nu}$$

$$\mathcal{O}_8 = \frac{1}{g} m_b (\bar{s}\sigma_{\mu\nu} T^a P_R b) G^{\mu\nu\, a} \qquad \mathcal{O}'_8 = \frac{1}{g} m_b (\bar{s}\sigma_{\mu\nu} T^a P_L b) G^{\mu\nu\, a}$$

$$\mathcal{O}_9 = \frac{e^2}{g^2} (\bar{s}\gamma_\mu P_L b)(\bar{\mu}\gamma^\mu \mu) \qquad \mathcal{O}'_9 = \frac{e^2}{g^2} (\bar{s}\gamma_\mu P_R b)(\bar{\mu}\gamma^\mu \mu)$$

$$\mathcal{O}_{10} = \frac{e^2}{g^2} (\bar{s}\gamma_\mu P_L b)(\bar{\mu}\gamma^\mu \gamma_5 \mu) \qquad \mathcal{O}'_{10} = \frac{e^2}{g^2} (\bar{s}\gamma_\mu P_R b)(\bar{\mu}\gamma^\mu \gamma_5 \mu)$$

$$\mathcal{O}_S = \frac{e^2}{16\pi^2} m_b (\bar{s} P_R b)(\bar{\mu}\mu) \qquad \mathcal{O}'_S = \frac{e^2}{16\pi^2} m_b (\bar{s} P_L b)(\bar{\mu}\mu)$$

$$\mathcal{O}_P = \frac{e^2}{16\pi^2} m_b (\bar{s} P_R b)(\bar{\mu}\gamma_5 \mu) \qquad \mathcal{O}'_P = \frac{e^2}{16\pi^2} m_b (\bar{s} P_L b)(\bar{\mu}\gamma_5 \mu)$$

Primed operators: opposite chirality to the unprimed ones,
vanish or highly suppressed in the SM

Wilson coefficients

Wilson coeff.	description	SM	enhancement in models
$C_{1,2}$	charged current	YES	
$C_{3,..,6}$	QCD penguins	YES	SUSY
$C_{7,8}$	γ, g-dipole	YES	SUSY, large $\tan\beta$
$C_{9,10}$	(axial-)vector	YES	SUSY
$C_{S,P}$	(pseudo-)scalar	$\sim m_l m_b / m_W^2$	SUSY, large $\tan\beta$, R-parity viol.
$C'_{S,P}$	(pseudo-)scalar flipped	$\sim m_l m_s / m_W^2$	SUSY, R-parity viol.
$C'_{3,..,6}$	QCD peng. flipped	$\sim m_s / m_b$	SUSY
$C'_{7,8}$	γ, g-dipole flipped	$\sim m_s / m_b$	SUSY, esp. large $\tan\beta$
$C'_{9,10}$	(axial-)vector flipped	$\sim m_s / m_b$	SUSY
$C_{T,T5}$	tensor	negligible	leptoquarks

G. Hiller, arXiv:0911.4054

$\rightarrow$ Need for many orthogonal observables!

Two main steps:

- Calculating $C_i^{eff}(\mu)$ at scale $\mu \sim M_W$ by requiring matching between the effective and full theories

$$C_i^{eff}(\mu) = C_i^{(0)eff}(\mu) + \frac{\alpha_s(\mu)}{4\pi} C_i^{(1)eff}(\mu) + \cdots$$

- Evolving the $C_i^{eff}(\mu)$ to scale $\mu \sim m_b$ using the RGE:

$$\mu \frac{d}{d\mu} C_i^{eff}(\mu) = C_j^{eff}(\mu) \gamma_{ji}^{eff}(\mu)$$

driven by the anomalous dimension matrix $\hat{\gamma}^{eff}(\mu)$:

$$\hat{\gamma}^{eff}(\mu) = \frac{\alpha_s(\mu)}{4\pi} \hat{\gamma}^{(0)eff} + \frac{\alpha_s^2(\mu)}{(4\pi)^2} \hat{\gamma}^{(1)eff} + \cdots$$

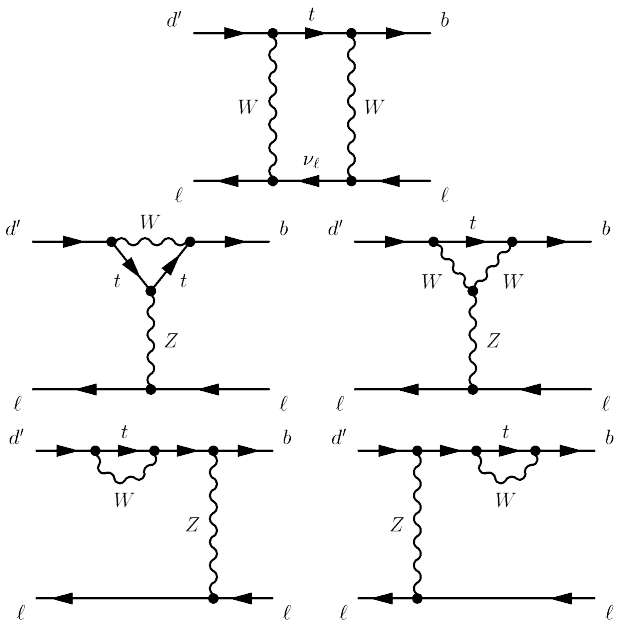
Knowing the Wilson coefficients we can go ahead and calculate the observables.

Important operators:

$$\mathcal{O}_{10} = \frac{e^2}{(4\pi)^2}(\bar{s}\gamma^\mu b_L)(\bar{\ell}\gamma_\mu\gamma_5\ell)$$

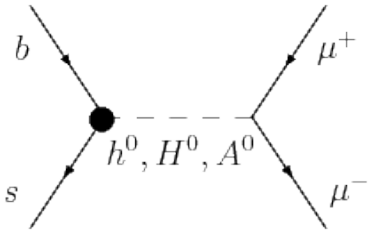
$$\mathcal{O}_S = \frac{e^2}{16\pi^2} m_b(\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\,\ell)$$

$$\mathcal{O}_P = \frac{e^2}{16\pi^2} m_b(\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\gamma_5\ell)$$



Very sensitive to new physics, especially for large $\tan\beta$:

SUSY contributions can lead to an O(100) enhancement over the SM!



$$\mathrm{BR}(B_s \to \mu^+\mu^-)_{MSSM} \sim \frac{m_b^2 m_\mu^2 \tan^6\beta}{M_A^4}$$

Experimental results:

LHCb: $\mathrm{BR}(B_s \to \mu^+\mu^-) < 4.5 \times 10^{-9}$ at 95% C.L. LHCb-TALK-2012-028

CMS: $\mathrm{BR}(B_s \to \mu^+\mu^-) < 7.7 \times 10^{-9}$ at 95% C.L. CMS BPH11020

→ Approaching dangerously the SM value!
→ Crucial to have a clear estimation of the SM prediction!

Most up-to-date key input parameters:

f_{B_s}	V_{ts}	V_{tb}	M_{B_s}	τ_{B_s}
234 MeV	-0.0403	0.999152	5.3663 GeV	1.472 ps

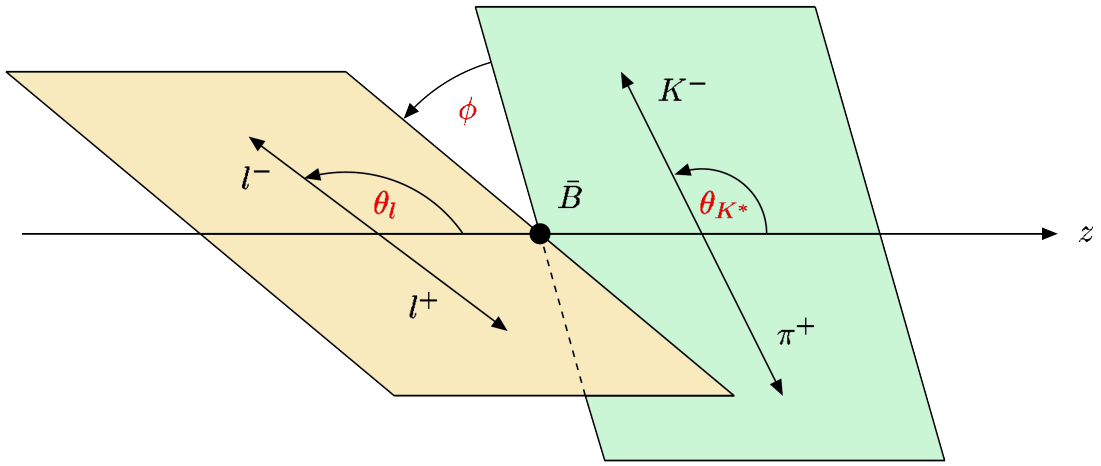
SM prediction: $\mathrm{BR}(B_s \to \mu^+\mu^-) = (3.58 \pm 0.36) \times 10^{-9}$

Most important sources of uncertainties:

8% from f_{B_s}
2% from EW corrections
1% from matching scale
2% from μ_b scale
2% from B_s lifetime
5% from V_{ts}
1.3% from top mass

Overall TH uncertainty: 10%.

Angular distributions

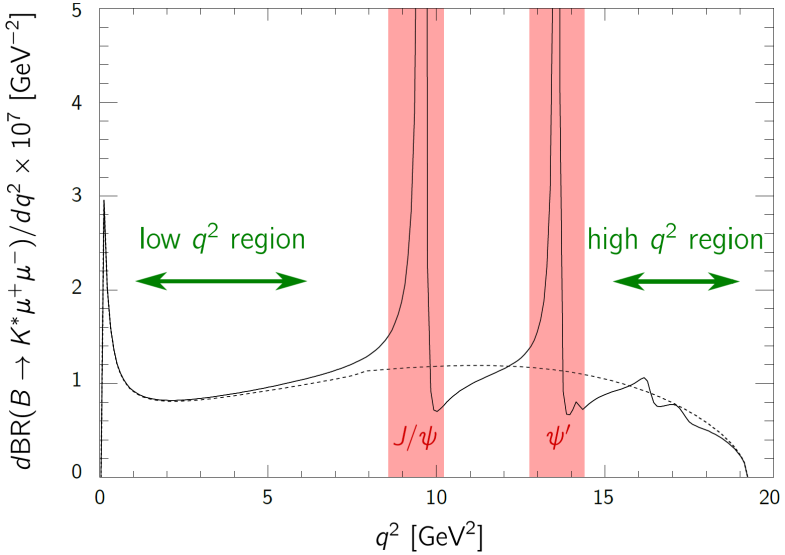


The full angular distribution of the decay $\bar{B}^0 \to \bar{K}^{*0} \ell^+ \ell^-$ with $\bar{K}^{*0} \to K^- \pi^+$ on the mass shell is completely described by four independent kinematic variables:

- q^2: dilepton invariant mass squared
- θ_ℓ: angle between ℓ^- and the $\bar{B}$ in the dilepton frame
- θ_{K^*}: angle between K^- and $\bar{B}$ in the $K^- \pi^+$ frame
- ϕ: angle between the normals of the $K^- \pi^+$ and the dilepton planes

$B \to K^* \mu^+ \mu^-$ – Low q^2 vs high q^2

- Low q^2
  - small $1/m_b$ corrections
  - sensitivity to the interference of C_7 and C_9
  - high rate
  - long-distance effects not fully under control
  - non-negligible scale and m_c dependence
- High q^2
  - negligible scale and m_c dependence due to the strong sensitivity to C_{10}
  - negligible long-distance effects of the type $B \to J/\Psi X_s \to X_s + X' \ell^+ \ell^-$
  - sizable $1/m_b$ corrections
  - low rate



Differential decay distribution:

$$\frac{d^4\Gamma}{dq^2\, d\cos\theta_\ell\, d\cos\theta_{K^*}\, d\phi} = \frac{9}{32\pi} J(q^2, \theta_\ell, \theta_{K^*}, \phi)$$

Kinematics: $4m_\ell^2 \leqslant q^2 \leqslant (M_B - m_{K^*})^2$, $-1 \leqslant \cos\theta_\ell \leqslant 1$, $-1 \leqslant \cos\theta_{K^*} \leqslant 1$, $0 \leqslant \phi \leqslant 2\pi$

$J(q^2, \theta_\ell, \theta_{K^*}, \phi)$ are written in function of the angular coefficients $J_{1-9}^{s,c}$

J_{1-9}: functions of the spin amplitudes A_0, $A_\parallel$, $A_\perp$, A_t, and A_S

Spin amplitudes: functions of Wilson coefficients and form factors

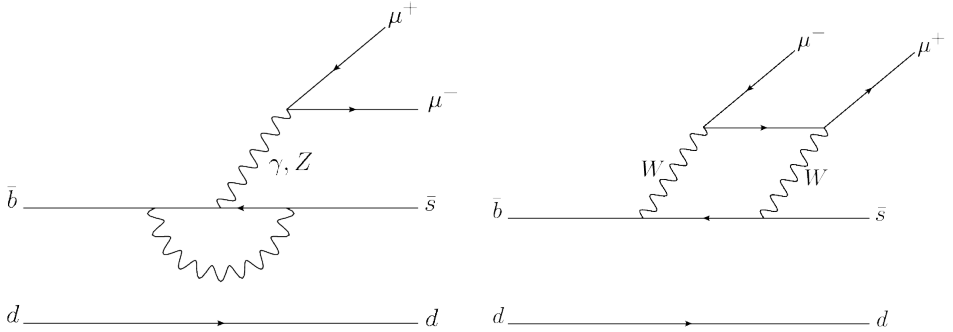
Main operators:

$$\mathcal{O}_9 = \frac{e^2}{(4\pi)^2}(\bar{s}\gamma^\mu b_L)(\bar{\ell}\gamma_\mu \ell)$$

$$\mathcal{O}_{10} = \frac{e^2}{(4\pi)^2}(\bar{s}\gamma^\mu b_L)(\bar{\ell}\gamma_\mu\gamma_5 \ell)$$

$$\mathcal{O}_S = \frac{e^2}{16\pi^2}(\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\,\ell)$$

$$\mathcal{O}_P = \frac{e^2}{16\pi^2}(\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\gamma_5 \ell)$$



Dilepton invariant mass spectrum

$$\frac{d\Gamma}{dq^2} = \frac{3}{4}\left(J_1 - \frac{J_2}{3}\right)$$

Forward backward asymmetry

Difference between the differential branching fractions in the forward and backward directions:

$$A_{\rm FB}(q^2) \equiv \left[\int_0^1 - \int_{-1}^0\right] d\cos\theta_l \, \frac{d^2\Gamma}{dq^2\, d\cos\theta_l} \Big/ \frac{d\Gamma}{dq^2} = \frac{3}{8} J_6 \Big/ \frac{d\Gamma}{dq^2}$$

$\to$ Reduced theoretical uncertainty

Forward backward asymmetry zero-crossing

$\to$ Reduced form factor uncertainties

$$q_0^2 \simeq -2 m_b m_B \frac{C_9^{\rm eff}(q_0^2)}{C_7} + O(\alpha_s, \Lambda/m_b)$$

$\to$ fix the sign of C_9/C_7

Polarization fractions:

$$F_L(q^2) = \frac{|A_0|^2}{|A_0|^2 + |A_\parallel|^2 + |A_\perp|^2}$$

$$F_T(q^2) = 1 - F_L(q^2) = \frac{|A_\perp|^2 + |A_\parallel|^2}{|A_0|^2 + |A_\parallel|^2 + |A_\perp|^2}$$

K^* **polarization parameter:**

$$\alpha_{K^*}(q^2) = \frac{2F_L}{F_T} - 1 = \frac{2|A_0|^2}{|A_\parallel|^2 + |A_\perp|^2} - 1$$

Transverse asymmetries:

$$A_T^{(1)}(q^2) = \frac{-2\Re(A_\parallel A_\perp^*)}{|A_\perp|^2 + |A_\parallel|^2} \qquad A_T^{(2)}(q^2) = \frac{|A_\perp|^2 - |A_\parallel|^2}{|A_\perp|^2 + |A_\parallel|^2}$$

$$A_T^{(3)}(q^2) = \frac{|A_{0L} A_{\parallel L}^* + A_{0R}^* A_{\parallel R}|}{\sqrt{|A_0|^2 |A_\perp|^2}} \qquad A_T^{(4)}(q^2) = \frac{|A_{0L} A_{\perp L}^* - A_{0R}^* A_{\perp R}|}{|A_{0L} A_{\parallel L}^* + A_{0R}^* A_{\parallel R}|}$$

$$A_{Im}(q^2) = -2\,\mathrm{Im}\left(\frac{A_\parallel A_\perp^*}{|A_\perp|^2 + |A_\parallel|^2}\right) \qquad S_3(q^2) = \frac{1}{2}(1 - F_L(q^2)) A_T^{(2)}(q^2)$$

Isospin asymmetry:

Non-factorizable graphs: annihilation or spectator-scattering diagrams

Isospin asymmetry arises when a photon is radiated from the spectator quark

$\to$ depends on the charge of the spectator quark

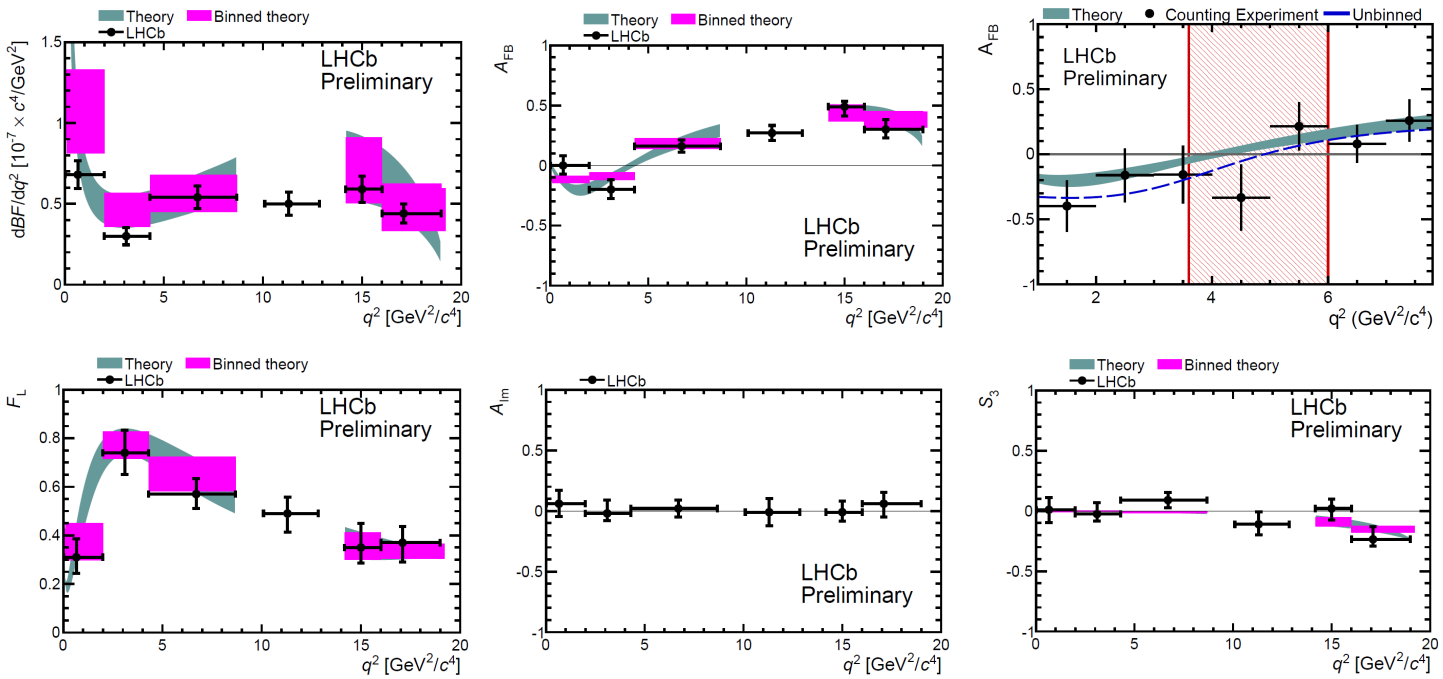
$\to$ different for charged and neutral B meson decays

$$\frac{dA_I}{dq^2} \equiv \frac{\frac{d\Gamma}{dq^2}(B^0 \to K^{*0}\ell^+\ell^-) - \frac{d\Gamma}{dq^2}(B^- \to K^{*-}\ell^+\ell^-)}{\frac{d\Gamma}{dq^2}(B^0 \to K^{*0}\ell^+\ell^-) + \frac{d\Gamma}{dq^2}(B^- \to K^{*-}\ell^+\ell^-)}$$

The SM is sensitive to C_5 and C_6 at small q^2, but to C_3 and C_4 at larger q^2

Need to calculate higher order effects!

$B \to K^* \mu^+ \mu^-$ – Experimental results from LHCb



q^2 range (GeV$^2/c^4$)	dBF/dq^2 ($\times 10^{-7}$ GeV$^{-2}c^4$)	$A_{\rm FB}$	$F_{\rm L}$	$A_{\rm Im}$	$2S_3$
$0.05 < q^2 < 2.00$	$0.68 \pm 0.07 \pm 0.05$	$0.00^{+0.08+0.01}_{-0.07-0.01}$	$0.31^{+0.07+0.03}_{-0.06-0.03}$	$0.06^{+0.11+0.00}_{-0.10-0.03}$	$0.02^{+0.20+0.00}_{-0.21-0.03}$
$2.00 < q^2 < 4.30$	$0.30 \pm 0.05 \pm 0.02$	$-0.20^{+0.08+0.01}_{-0.07-0.03}$	$0.74^{+0.09+0.02}_{-0.08-0.04}$	$-0.02^{+0.10+0.05}_{-0.06-0.01}$	$-0.05^{+0.18+0.05}_{-0.12-0.01}$
$4.30 < q^2 < 8.68$	$0.54 \pm 0.05 \pm 0.05$	$0.16^{+0.05+0.01}_{-0.05-0.01}$	$0.57^{+0.05+0.04}_{-0.05-0.03}$	$0.02^{+0.07+0.01}_{-0.07-0.01}$	$0.18^{+0.13+0.01}_{-0.13-0.01}$
$10.09 < q^2 < 12.89$	$0.50 \pm 0.06 \pm 0.04$	$0.27^{+0.06+0.02}_{-0.06-0.01}$	$0.49^{+0.06+0.03}_{-0.07-0.03}$	$-0.01^{+0.11+0.02}_{-0.11-0.03}$	$-0.22^{+0.20+0.02}_{-0.17-0.03}$
$14.18 < q^2 < 16.00$	$0.59 \pm 0.07 \pm 0.04$	$0.49^{+0.04+0.02}_{-0.06-0.05}$	$0.35^{+0.07+0.07}_{-0.06-0.02}$	$-0.01^{+0.08+0.04}_{-0.07-0.02}$	$0.04^{+0.15+0.04}_{-0.19-0.02}$
$16.00 < q^2 < 19.00$	$0.44 \pm 0.05 \pm 0.03$	$0.30^{+0.07+0.04}_{-0.07-0.01}$	$0.37^{+0.06+0.03}_{-0.07-0.04}$	$0.06^{+0.09+0.03}_{-0.10-0.05}$	$-0.47^{+0.21+0.03}_{-0.10-0.05}$
$1.00 < q^2 < 6.00$	$0.42 \pm 0.04 \pm 0.04$	$-0.18^{+0.06+0.01}_{-0.06-0.02}$	$0.66^{+0.06+0.04}_{-0.06-0.03}$	$0.07^{+0.07+0.02}_{-0.07-0.01}$	$0.10^{+0.15+0.02}_{-0.16-0.01}$

LHCb-CONF-2012-008

Integrated values for 1 GeV $< q^2 <$ 6 GeV

Using the full form factors:

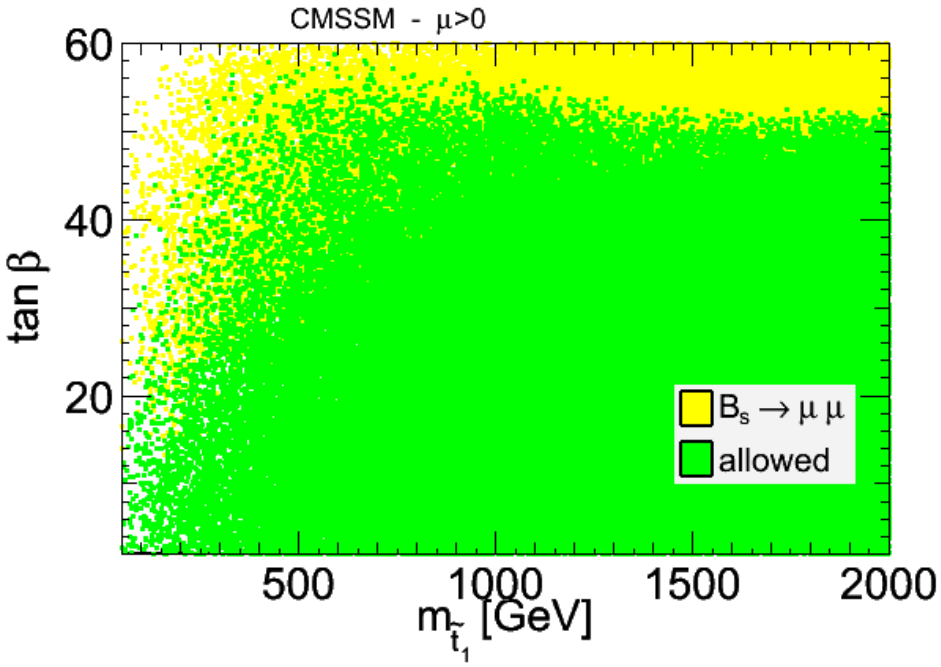
Observables	Central value	σ_{Λ/m_b}	σ_{FF}	σ_{m_t}	σ_{m_b}	σ_{m_c}	σ_{μ_b}	$\sigma_{V_{ts}}$
$d\mathrm{BF}/dq^2 \times 10^7$	2.34	0.17	1.34	0.04	0.01	0.01	0.06	0.05
A_{FB}	-0.06	0.01	0.04	0.01	0.03	0.03	0.03	0.05
$q^2(A_{\mathrm{FB}} = 0)$	4.26	0.10	0.30	0.01	0.03	0.03	0.03	0.05
F_L	0.71	0.02	0.13	0.01	0.03	0.03	0.03	0.05

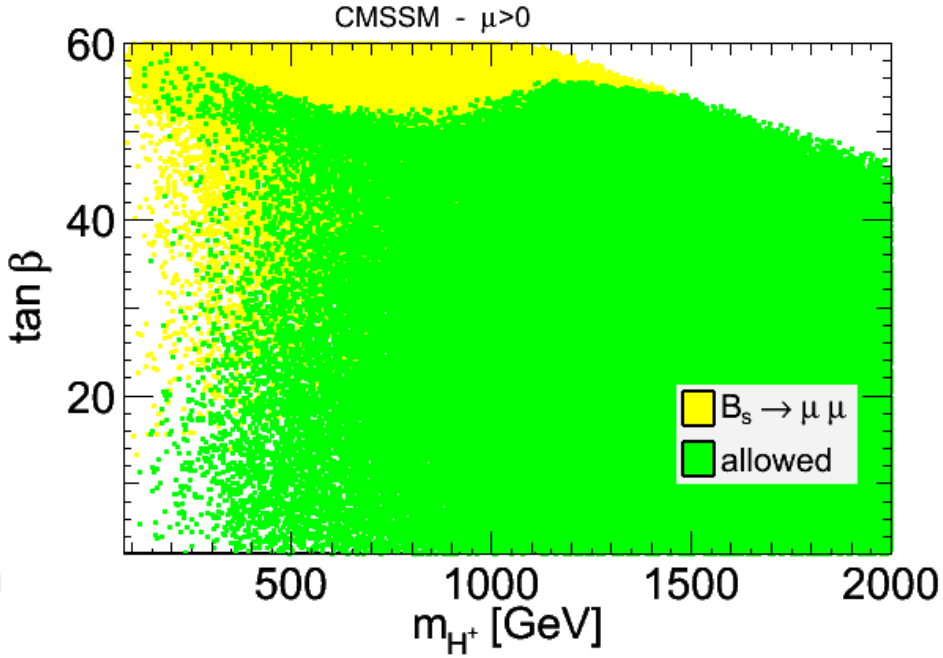
Using the soft form factors:

Observables	Value	σ_{Λ/m_b}	σ_{FF}	σ_{FF}^{soft}	σ_{m_t}	σ_{m_b}	σ_{m_c}	σ_{μ_b}	$\sigma_{V_{ts}}$
$d\mathrm{BF}/dq^2 \times 10^7$	2.38	0.36	1.25	0.49	0.04	0.01	0.01	0.06	0.05
A_{FB}	-0.06	0.02	0.03	0.01	0.01	0.03	0.03	0.03	0.05
$q^2(A_{\mathrm{FB}} = 0)$	4.18	0.20	0.02	0.02	0.01	0.03	0.03	0.03	0.05
F_L	0.71	0.04	0.13	0.06	0.01	0.03	0.03	0.03	0.05

Implications

Constraints in CMSSM (all parameters varied)

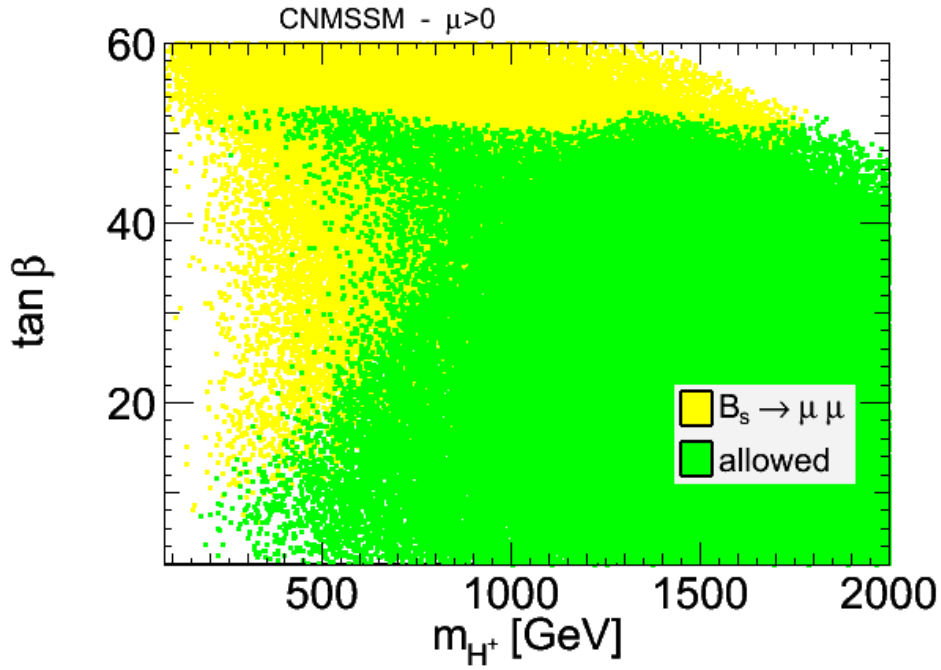


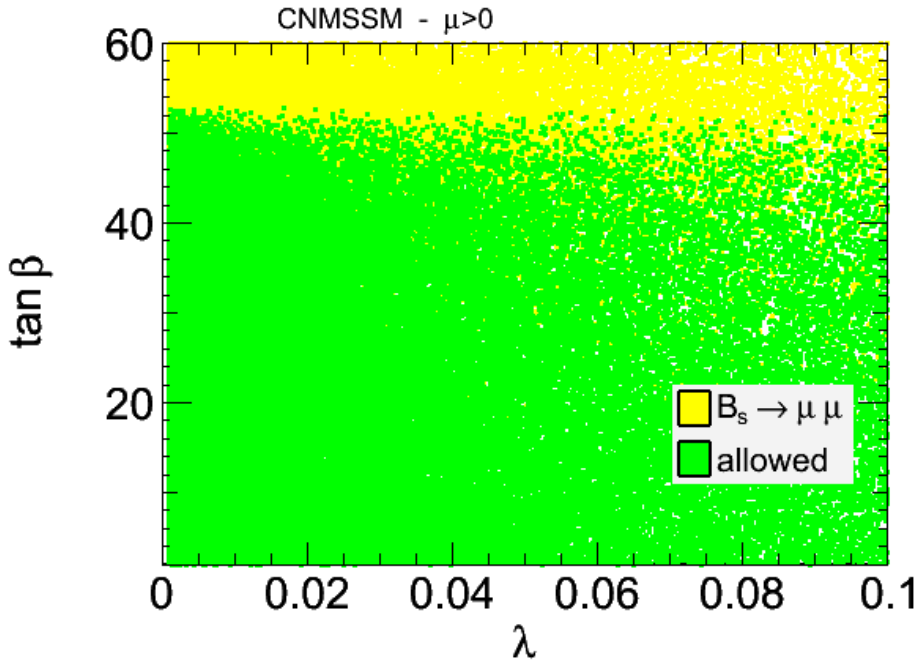


At 95% C.L., including th uncertainty: $\mathrm{BR}(B_s \to \mu^+\mu^-) < 5.0 \times 10^{-9}$

A.G. Akeroyd, F.M., D. Martinez Santos, JHEP 1112 (2011) 088
SuperIso v3.2

Constraints in CNMSSM (all parameters varied)

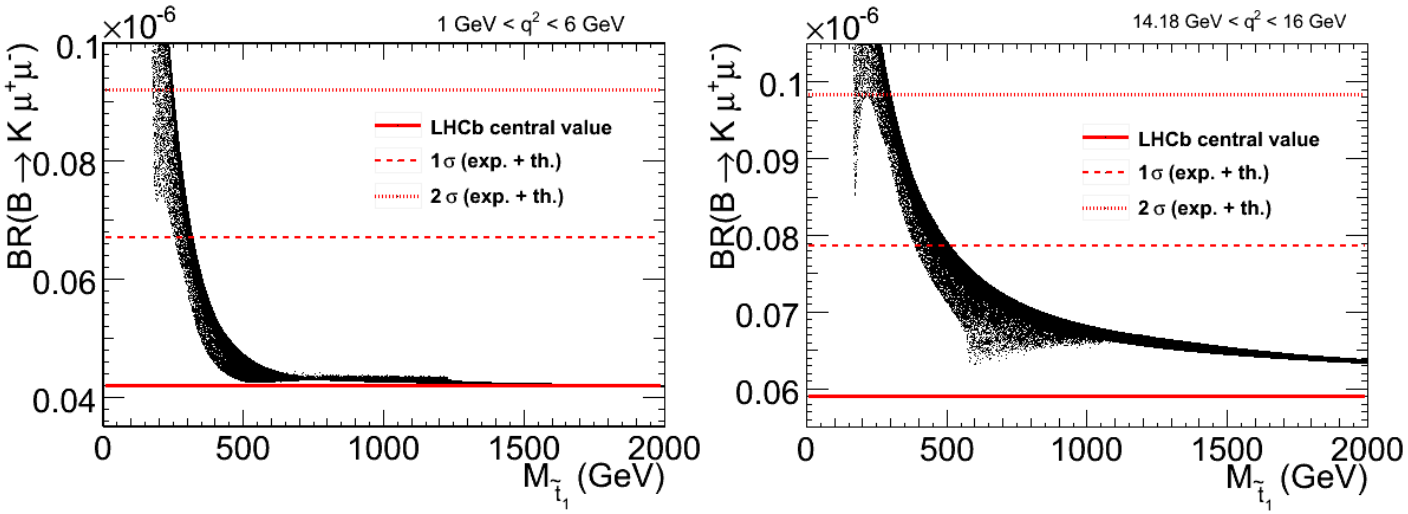




A.G. Akeroyd, F.M., D. Martinez Santos, JHEP 1112 (2011) 088
SuperIso v3.2

BR($B \to K^* \mu^+ \mu^-$) in the low and high q^2 regions:

CMSSM - $\tan\beta = 50$



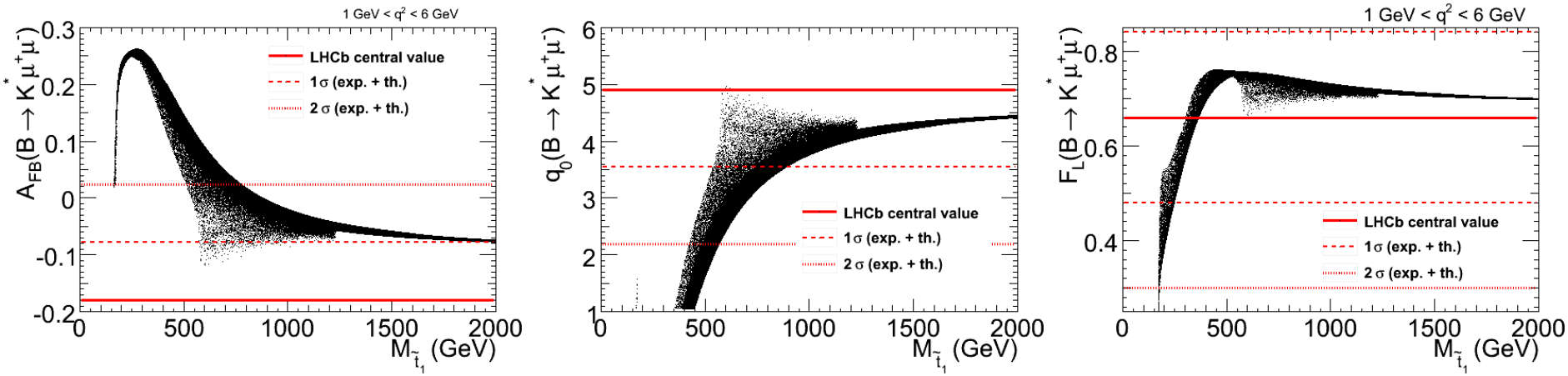
preliminary results, SuperIso v3.2+

For $m_{\tilde{t}_1} >\sim 400$ GeV, SUSY spread is within the th+exp error

→ Look at other observables (A_{FB}, F_L,...)

→ Reduce both theory and experimental errors.

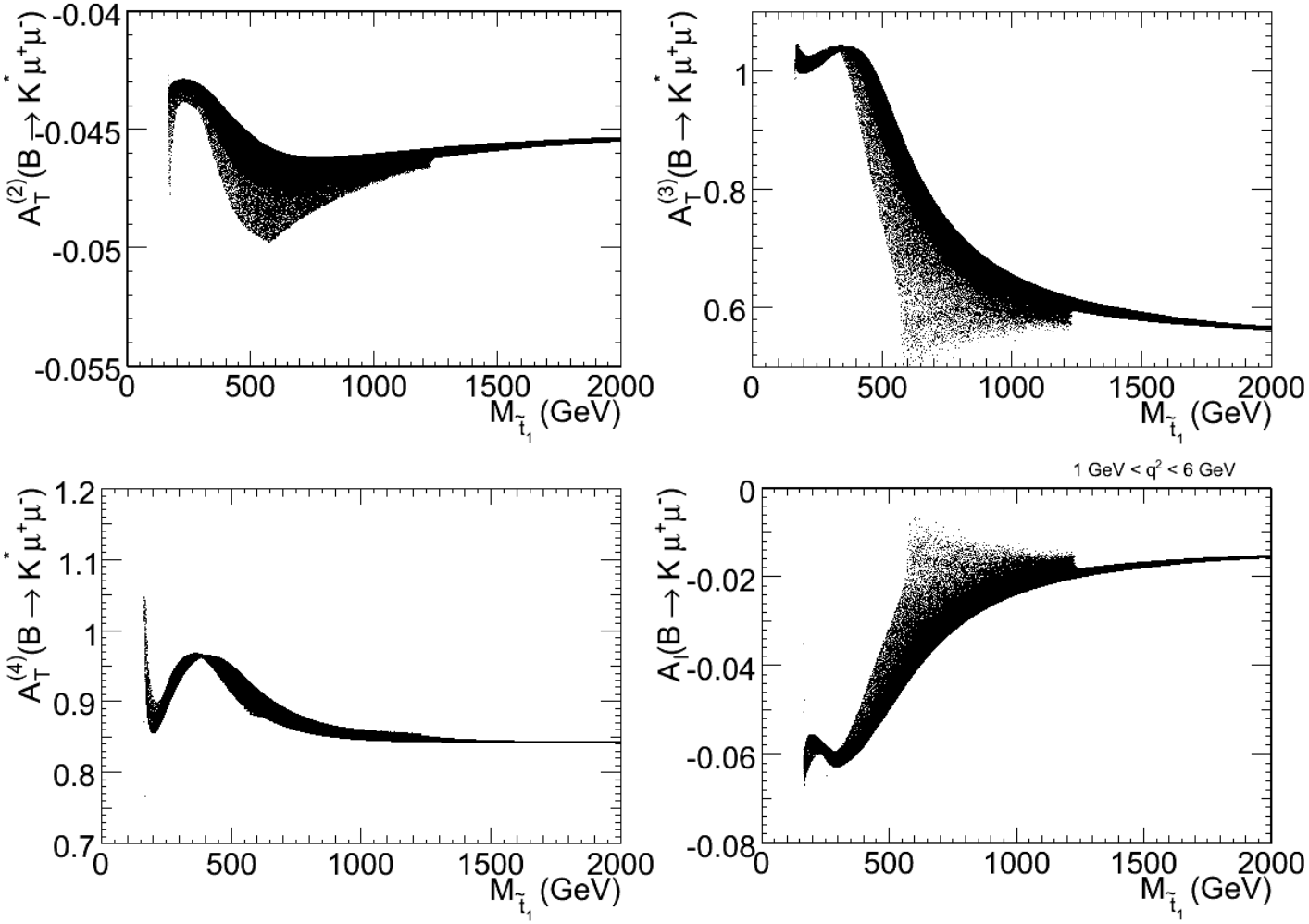
Other observables of interest:



preliminary results, SuperIso v3.2+

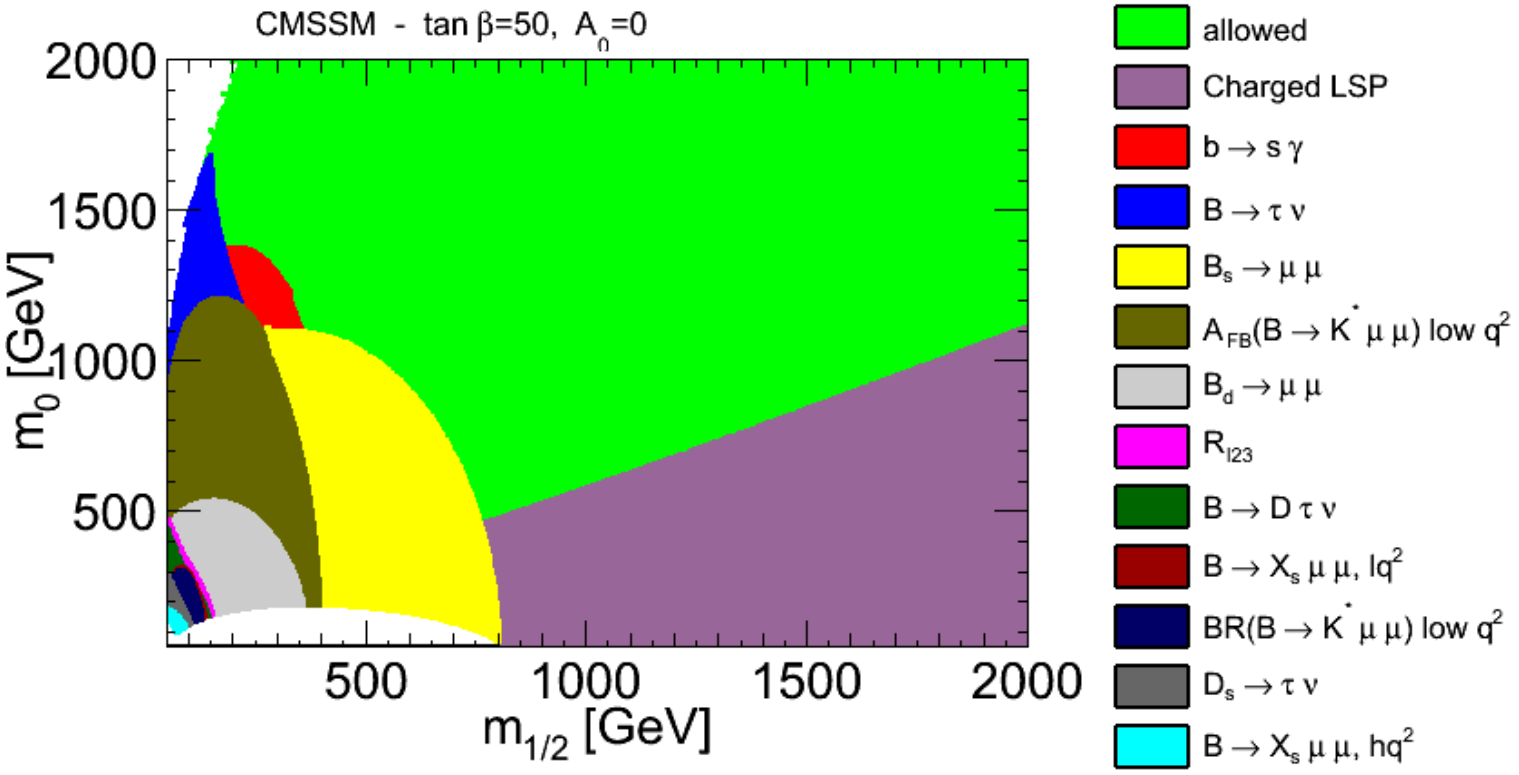
A_{FB} in the low q^2 region is especially interesting!

Other observables not yet observed:

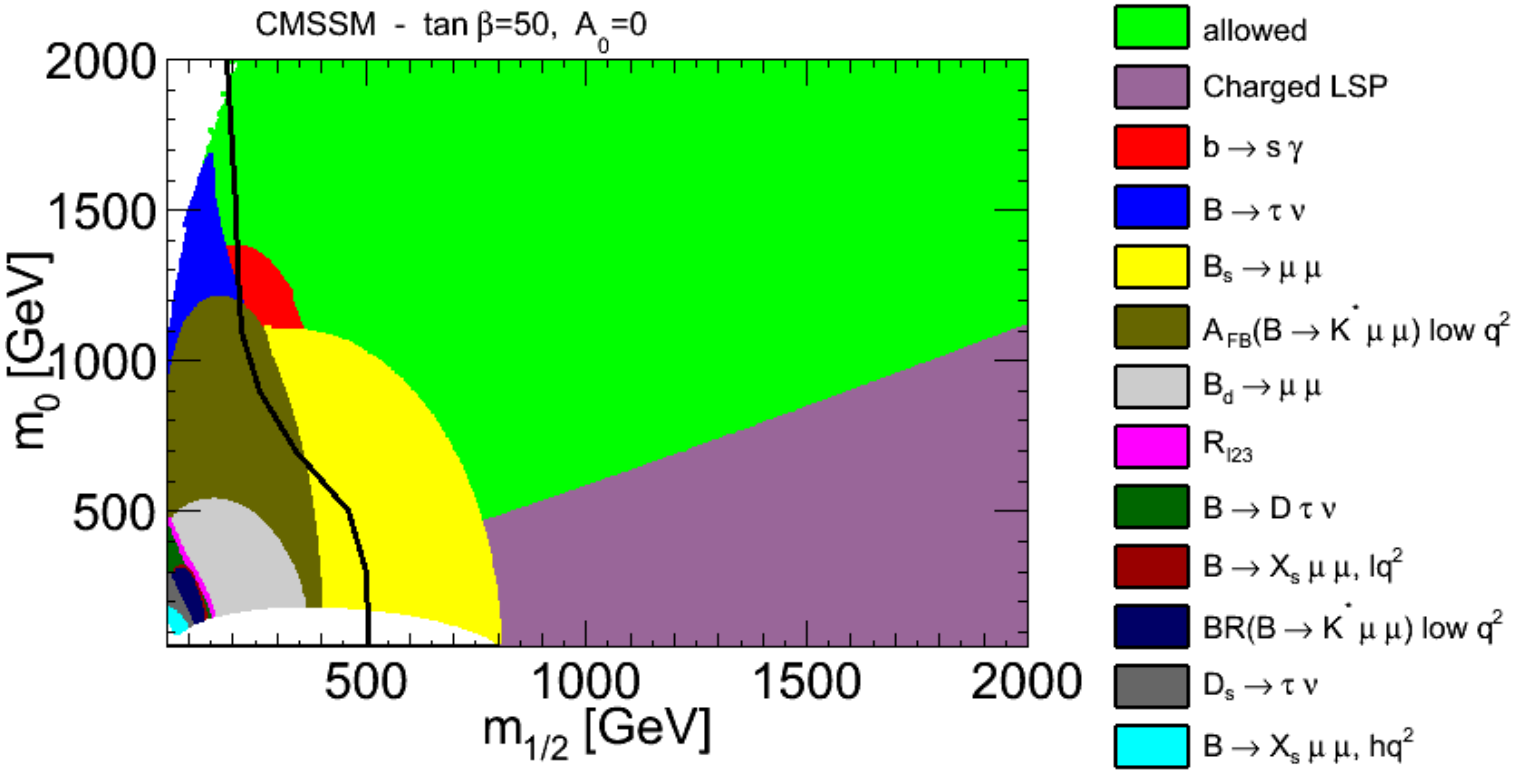


preliminary results, SuperIso v3.2+

Implications



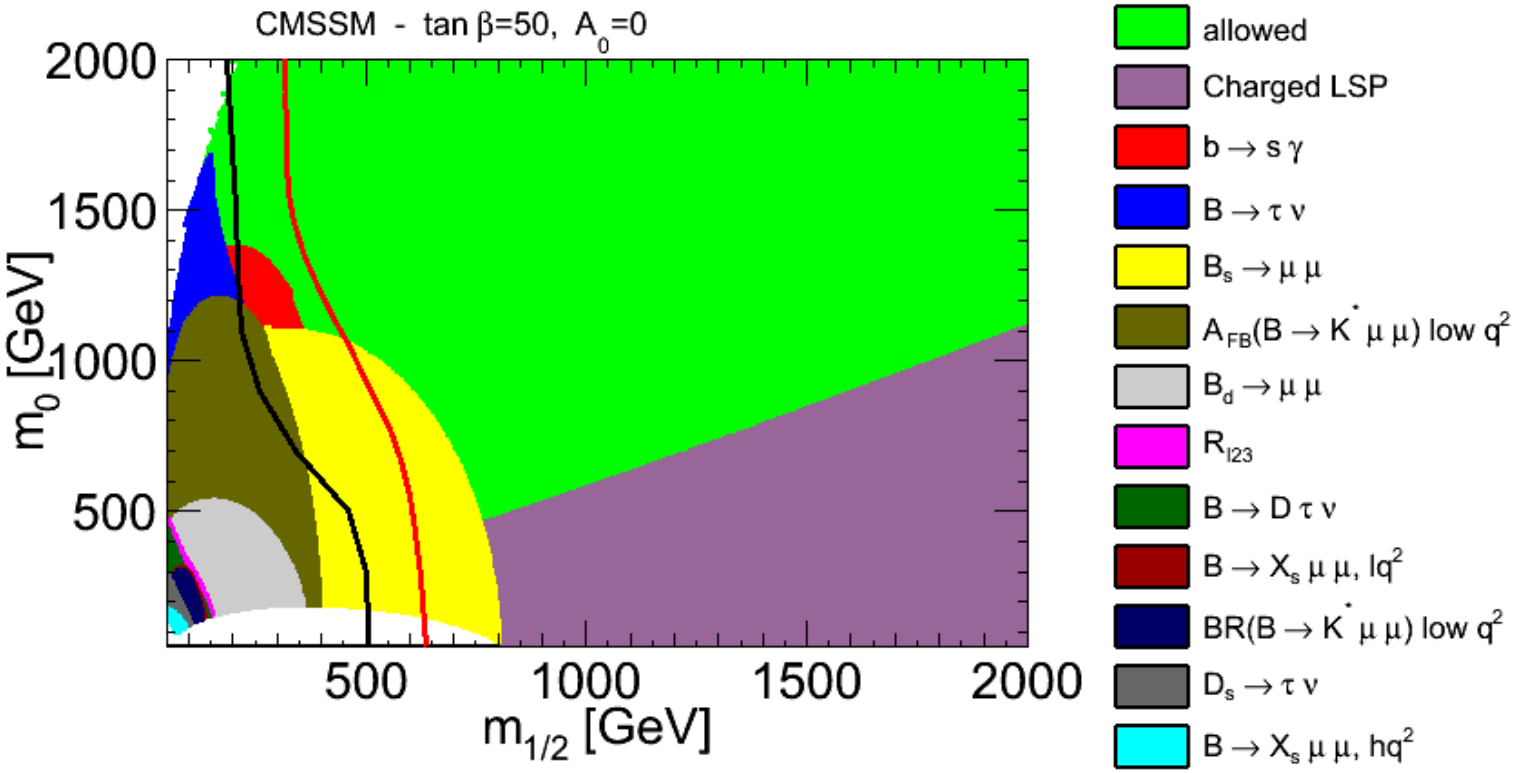
SuperIso v3.2+



Black line: CMS exclusion limit with 1.1 fb^{-1} data

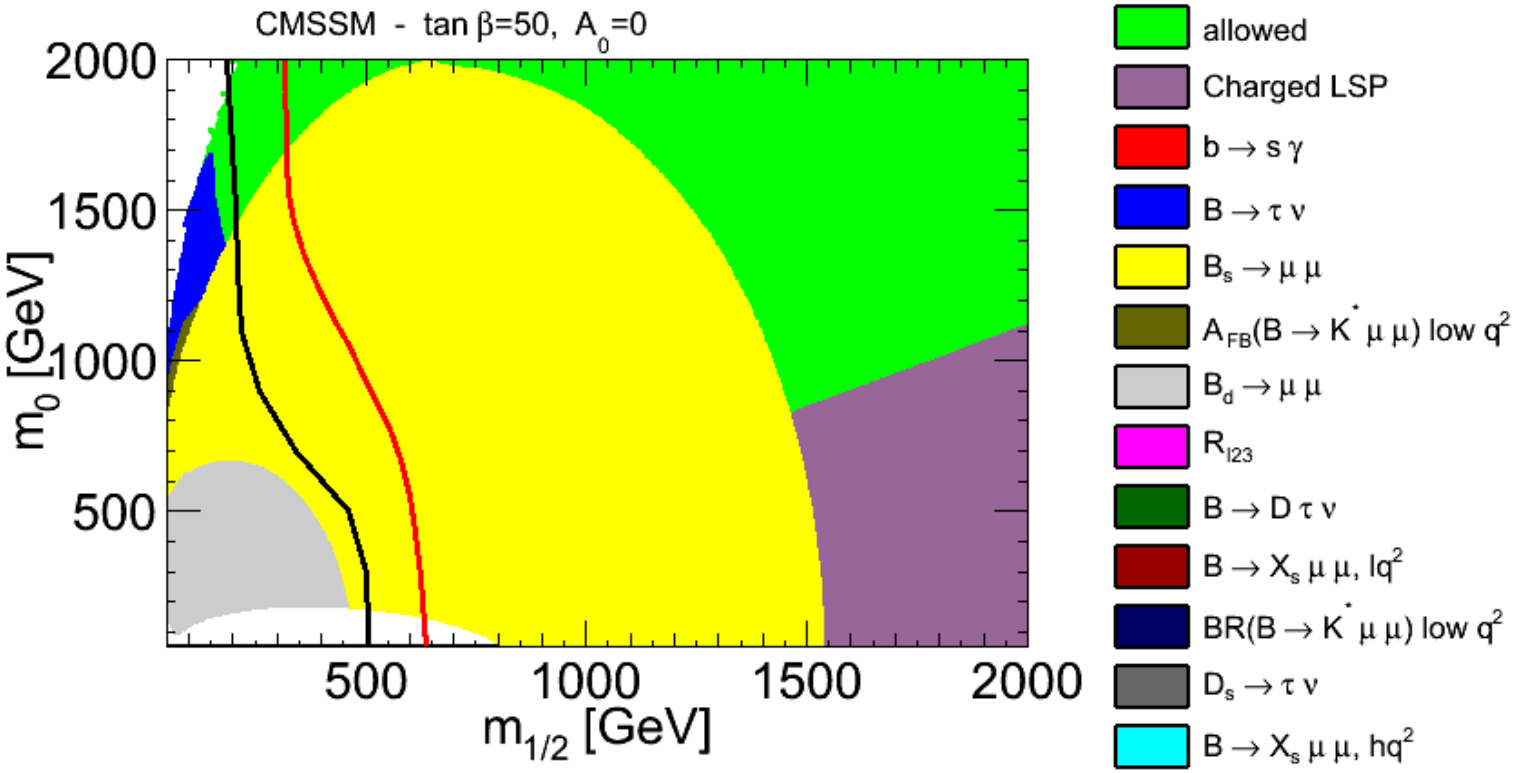
SuperIso v3.2+

Implications



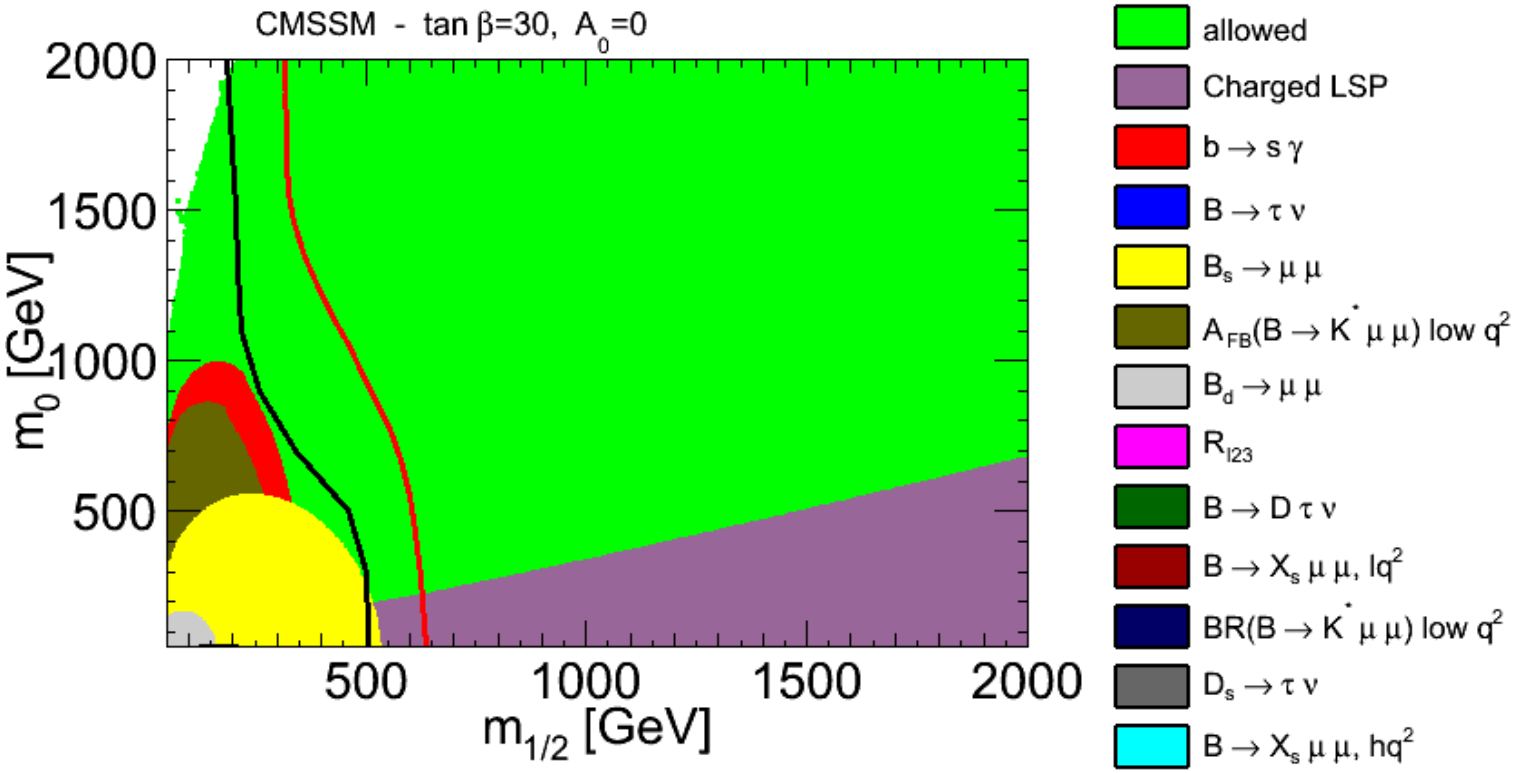
Black line: CMS exclusion limit with 1.1 fb^{-1} data
Red line: CMS exclusion limit with 4.4 fb^{-1} data

SuperIso v3.2+



Black line: CMS exclusion limit with 1.1 fb^{-1} data
Red line: CMS exclusion limit with 4.4 fb^{-1} data
New LHCb limits for BR($B_s \to \mu^+\mu^-$) and BR($B_d \to \mu^+\mu^-$)

SuperIso v3.2+



Black line: CMS exclusion limit with 1.1 fb^{-1} data
Red line: CMS exclusion limit with 4.4 fb^{-1} data
New LHCb limits for BR($B_s \to \mu^+\mu^-$) and BR($B_d \to \mu^+\mu^-$)

SuperIso v3.2+

Going beyond constrained scenarios

- CMSSM useful for benchmarking, model discrimination,...
- However the mass patterns could be more complicated

Phenomenological MSSM (pMSSM)

- Flat scans over the pMSSM 19 parameters

$\rightarrow$ **Interplay between low energy observables and high p_t results**

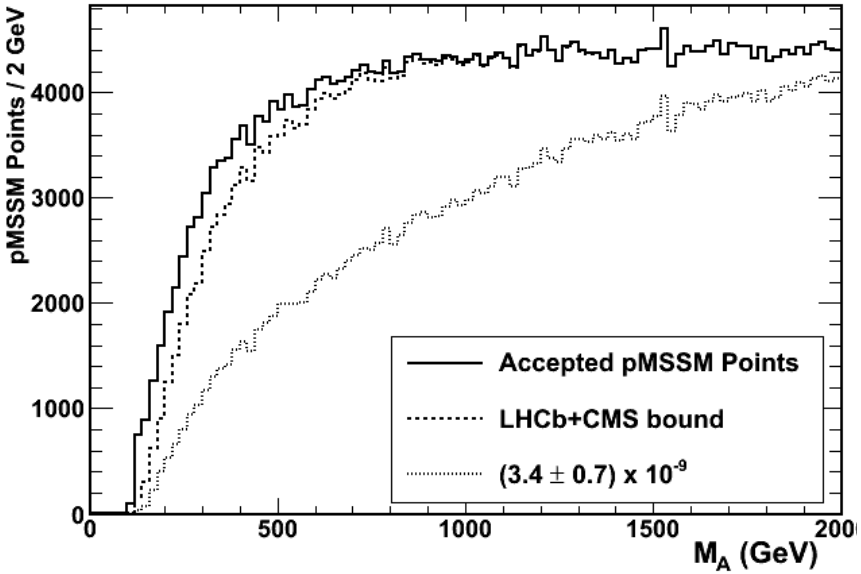
General MSSM – Sensitivity to M_A from BR($B_s \to \mu^+\mu^-$)

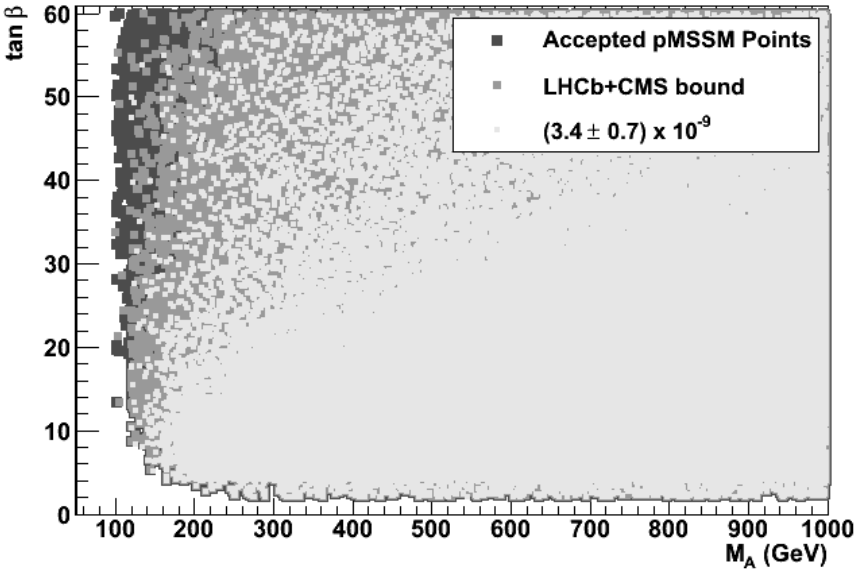
Considering 2 scenarios:

- 2011 bound from LHCb+CMS + estimated th syst:

$$\mathrm{BR}(B_s \to \mu^+\mu^-) < 1.26 \times 10^{-8}$$

- SM like branching ratio with estimated 20% total uncertainty





Light M_A strongly constrained!

A. Arbey, M. Battaglia, F.M., Eur.Phys.J. C72 (2012) 1847
A. Arbey, M. Battaglia, F.M., Eur.Phys.J. C72 (2012) 1906

SuperIso

- Public C program dedicated to the flavour physics observable calculations
- Various models implemented: General 2HDM, MSSM, NMSSM, BMSSM
- Many flavour observables: $B \to X_s\gamma$, $B_{s,d} \to \mu^+\mu^-$, $B \to \tau\nu$, $B \to D\tau\nu$, $B \to De\nu$, $D_s \to \tau\nu$, $D_s \to \mu\nu$, $K \to \mu\nu$, ... + $(g-2)_\mu$ + relic density + ...

http://superiso.in2p3.fr

Next release will include all the $B \to K^*\ell^+\ell^-$ and $B \to X_s\ell^+\ell^-$ observables

FM, Comput. Phys. Commun. 178 (2008) 745
FM, Comput. Phys. Commun. 180 (2009) 1579
FM, Comput. Phys. Commun. 180 (2009) 1718

Conclusion

- Interplay between direct and indirect searches is very important and will play a crucial role in the near future
- Many interesting flavour observables available
- The constrained SUSY scenarios are highly constrained
- General MSSM: A lot of viable model points survive, but flavour data can help squeezing the parameter space
- The study in SUSY is very illustrative, but can be repeated for other NP models.

We have learned a lot from flavour physics so far,
but what is still to be discovered is more!

Backup

Double ratios of leptonic decays

$$R = \left(\frac{\mathrm{BR}(B_s \to \mu^+\mu^-)}{\mathrm{BR}(B_u \to \tau\nu)}\right) \Big/ \left(\frac{\mathrm{BR}(D_s \to \tau\nu)}{\mathrm{BR}(D \to \mu\nu)}\right)$$

From the form factor and CKM matrix point of view:

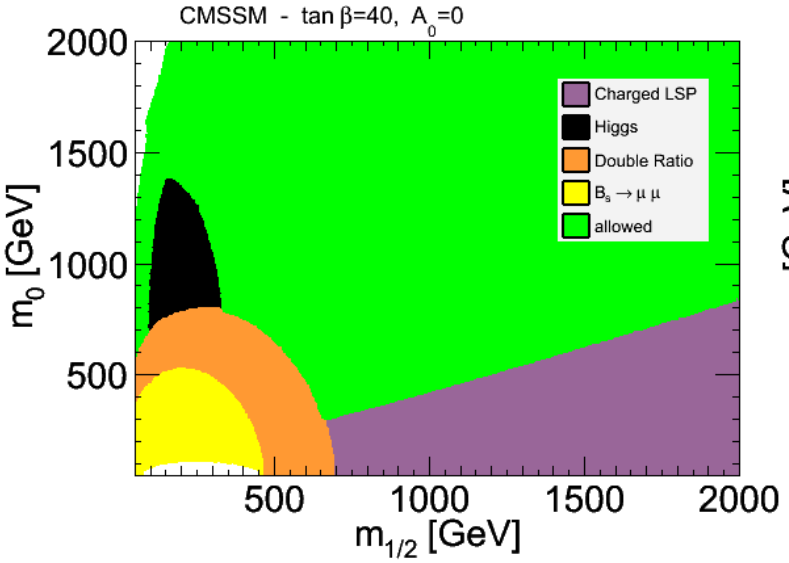
$$R \propto \frac{|V_{ts}V_{tb}|^2}{|V_{ub}|^2}\frac{(f_{B_s}/f_B)^2}{(f_{D_s}/f_D)^2} \qquad \text{with:} \qquad \frac{(f_{B_s}/f_B)}{(f_{D_s}/f_D)} \approx 1$$

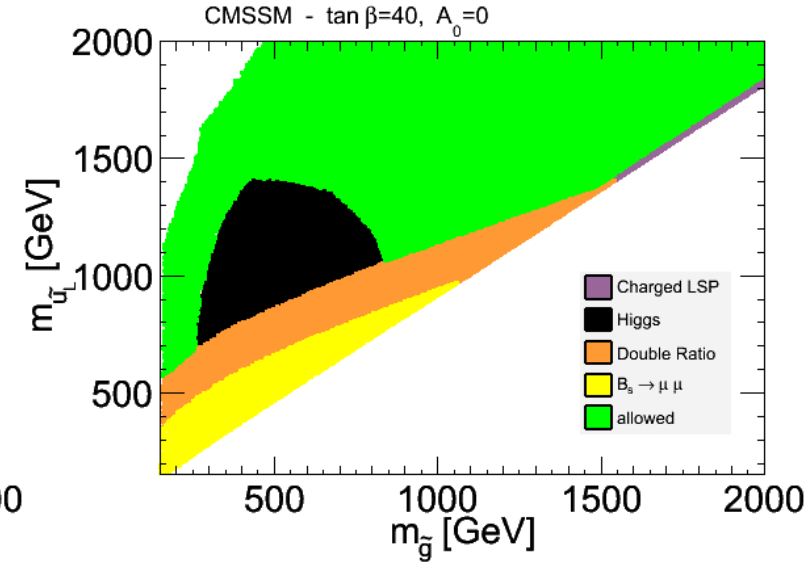
R has no dependence on the decay constants, contrary to each decay taken individually!

- No dependence on lattice quantities
- Interesting for V_{ub} determination
- Interesting for probing new physics
- Promising experimental situation

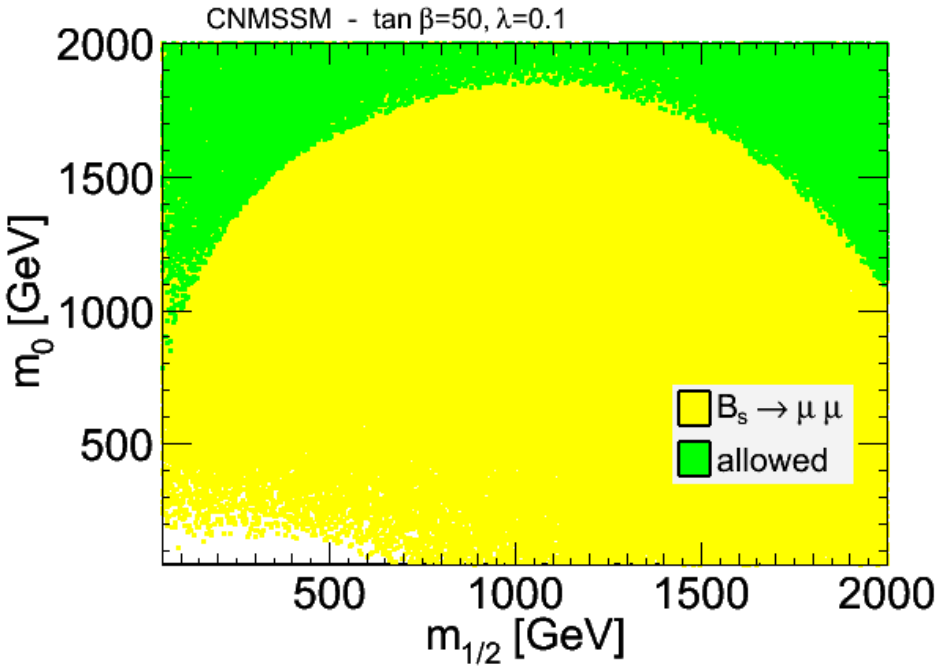
B. Grinstein, Phys. Rev. Lett. 71 (1993)
A.G. Akeroyd, FM, JHEP 1010 (2010)

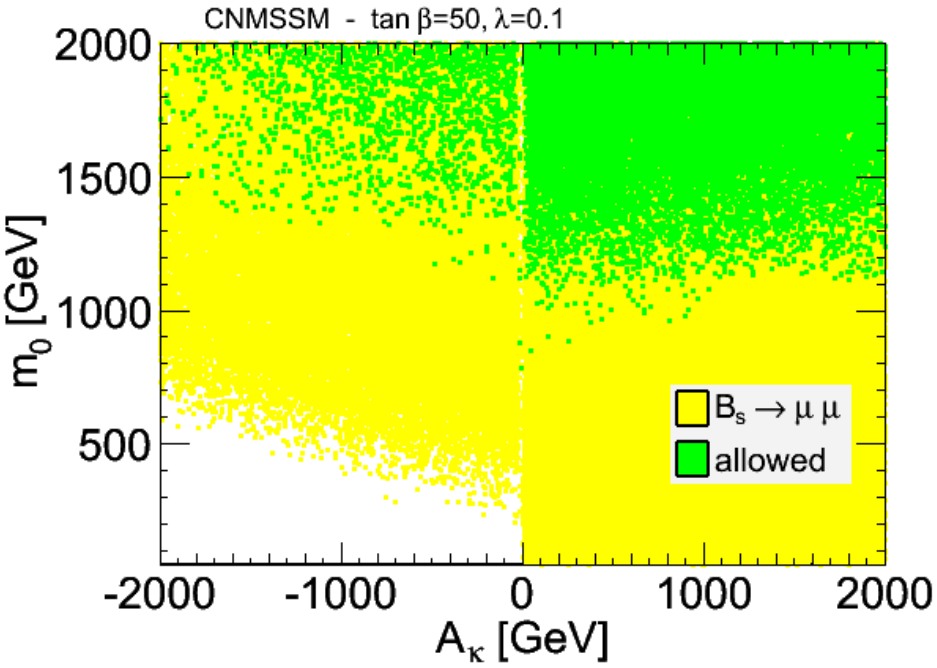
Constrained MSSM





Constraints in CNMSSM (all parameters varied)





A.G. Akeroyd, F.M., D. Martinez Santos, JHEP 1112 (2011) 088
SuperIso v3.2

Muon anomalous magnetic moment