$B_s \to \mu\mu$

theory perspective

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Grad Student Joint Meetings

PSB 470, 1:30-2pm Monday before the 'grown up' meeting
http://www.lepp.cornell.edu/~pt267/journal.html

Next joint hep-ex/ph student meeting

10 Oct, Nic Eggert, *Status of Higgs Searches* (TBC)

Next week: Bibhushan Shakya, *Deconstructing the* 5^{th} *Dimension*
All LEPP students are welcome, hep-ph students are implored to attend

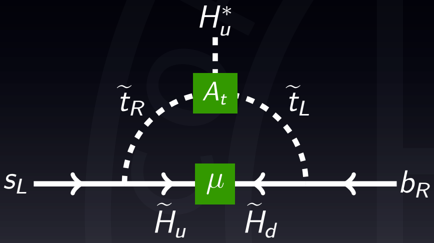
Implications of $B_s \to \mu\mu$

- Significance of large $\tan\beta$ in the MSSM
- Beyond MFV in the MSSM
- Relation to ΔM_s

Two Higgs Doublet Models

Type II 2HDM: (e.g. MSSM) avoid tree-level FCNC by having H_u only talk to u_R and H_d only talk to d_R and e_R.

But: violated at loop-level by ~~SUSY~~ terms.



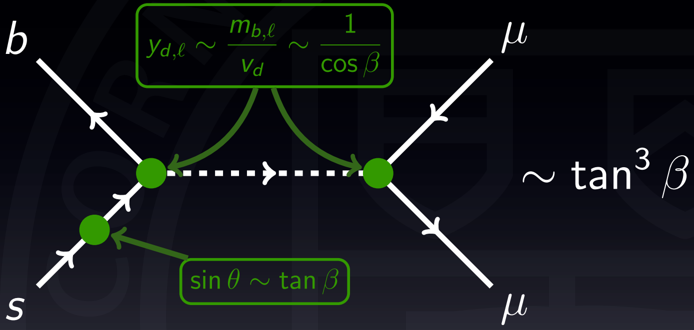
$$\begin{pmatrix} m_s & 0 \\ y_b \epsilon v_u & m_b \end{pmatrix}$$

$$\epsilon \sim y_t V_{ts}/(16\pi)^2$$

Loop-level s_L–b_L mixing:

$$\sin\theta \sim \frac{y_b \epsilon v_u}{m_b} \sim \epsilon \tan\beta$$

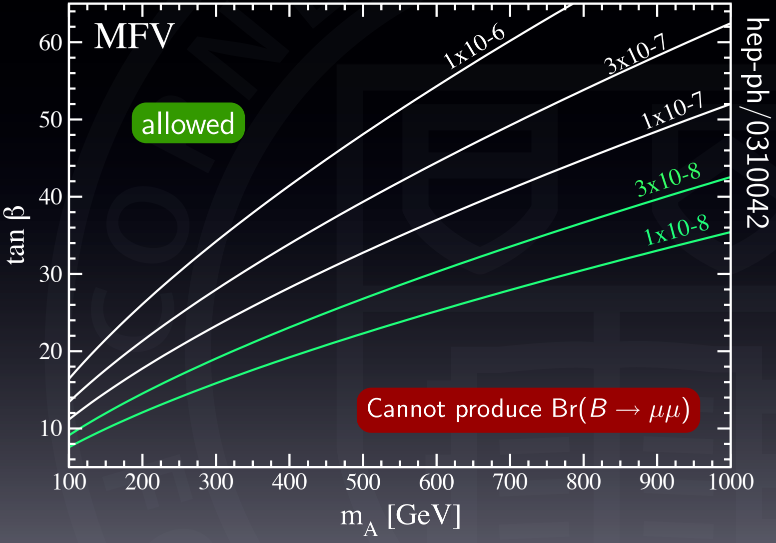
Enhancement by $\tan^6\beta$ in SUSY



Other SUSY diagrams are negligible in the large $\tan\beta$ limit.

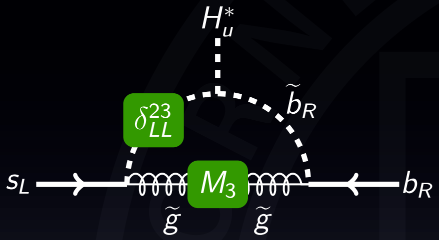
MFV bound

Contours of fixed $\mathrm{Br}(B_s \to \mu\mu)$, MFV



Beyond MFV in the MSSM

Parameterize new flavor structure with squark mass insertions



$$\delta_{LL}^{ij} = \frac{(\Delta m_{LL}^2)_{ij}}{m_{LL}^2}$$

Also $LL \to RR$

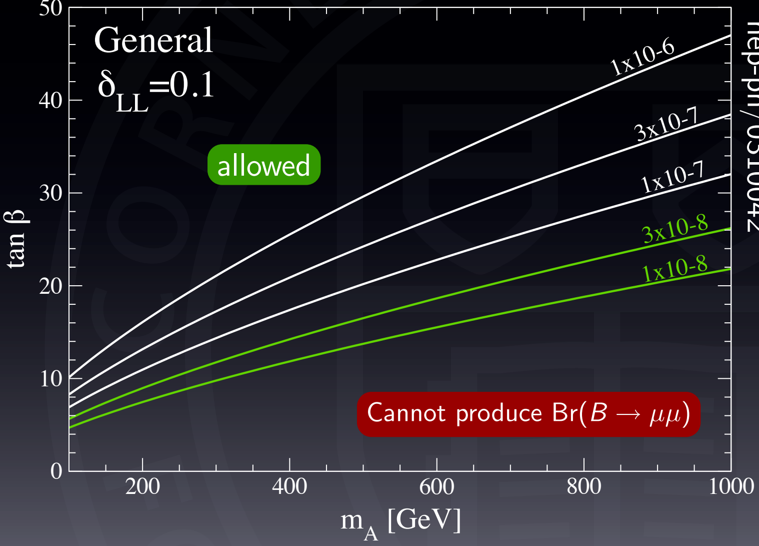
see, e.g. 0712.2074

Danger: constraints from $B \to K^*\gamma$ and $B \to \phi K_S$, but those carry additional powers of $(m_{LL})^{-2}$.

Remark: Renormalization generates $\delta_{LL}^{ij} \lesssim \mathcal{O}(V_{ts})$

Beyond MFV bound

Contours of fixed Br($B_s \to \mu\mu$), including δ_{LL}



hep-ph/0310042

Relation to ΔM_s MSSM

Another observable sensitive to δ^{23}_{LL} is ΔM_s in $\bar{B}_s$–B_s mixing

$$\Delta M_s \approx \left| (\Delta M_s)_{\text{SM}} + \left(\frac{3.5\ \text{TeV}}{\tilde{m}} \right)^2 \left(\delta^{23}_{LL}\right)^2 \right|$$

hep-ph/0112303, hep-ph/0206297

But: $\left|\Delta M_s^{(\text{new})} / \Delta M_s^{(\text{SM})}\right| \lesssim 20\% \Rightarrow$ large $\tilde{m}$ or small δ^{23}_{LL}.

Suppresses $B_s \to \mu\mu$ and tightens $\tan\beta$ bound for given $\text{Br}(B_s \to \mu\mu)$.

CP observables? $B_d \to \phi K_S$, $\Delta\Gamma_s$, $B_s \to J/\psi\,\phi$, ...

Relation to ΔM_s, MFV

Minimal Flavor Violation: NP (not necessarily SUSY) carries the same flavor structure as the SM: V_{CKM}.

hep-ph/0303060: Ratios can reduce uncertainties from $f_{B_{d,s}}$

See also 1004.3982 for an alternate approach

$$\frac{\text{Br}(B_s \to \mu\mu)}{\text{Br}(B_d \to \mu\mu)} = \frac{(\text{non-perturbative})_s}{(\text{non-perturbative})_d} \frac{\tau(B_s)}{\tau(B_d)} \frac{\Delta M_s}{\Delta M_d}$$

- (non-pert.) is independent of f_B and RG invariant
- UV model-dependence cancels in the ratio

Relation to ΔM_s, simple models

Alternate approach (0903.2830, 1102.0009)

$$\mathcal{H} \sim \sum_i g_i \bar{b}\gamma^\mu s V_\mu + g_i' \bar{\ell}\gamma^\mu \ell V_\mu + \cdots$$

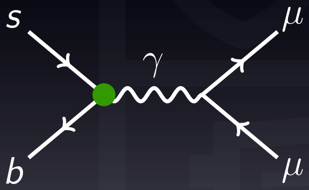
- ΔM_s operators expressed in terms of $g_i g_j$
- $B \to \mu\mu$ operators expressed in terms of $g_i g_j'$

Relations can reduce (sometimes eliminate) low-energy new physics parameters.

Comment: the ΔM_{B_s} bounds are much more stringent than ΔM_D, in which one could assume ΔM_D came entirely from NP and then predict $D \to \mu\mu$.

Remarks

- Photon penguin does not contribute (Ward identity)
- s-channel scalar does not contribute (0^-)



Relation to ΔM_s, simple models

Ex: **Flavor-changing** Z' (e.g. RS models)

$$\Delta M_s^{(Z')} = \frac{M_s f_{B_s}^2 B_{B_s} r_1(m_b, M_{Z'})}{3} \cdot \frac{g_{Z'sb}^2}{M_{Z'}^2}$$

$$\mathrm{Br}(B_s \to \mu\mu) = \frac{G_F f_{B_s}^2 m_\mu^2 M_{B_s}}{16\sqrt{2}\pi\Gamma_{B_s}} \sqrt{1 - \frac{4m_\mu^2}{M_{B_s}^2}} \cdot \frac{g_{Z'sb}^2}{M_{Z'}^2} \cdot \frac{M_Z^2}{M_{Z'}^2}$$

NP parameters completely fixed, end up with

$$\mathrm{Br}(B_s \to \mu\mu) \leq 0.25 \cdot 10^{-9} \left(\frac{1 \text{ TeV}}{M_{Z'}^2}\right)^2$$

Similar story for gauged family symmetry, $\mathrm{Br}(B_s \to \mu\mu) \lesssim 10^{-12}$

Relation to ΔM_s, simple models

Ex: R-parity violating MSSM

$$W_{\not R} = \lambda LLE^c + \lambda' LQD^c + \lambda'' U^c D^c D^c$$

Assume $\lambda'' = 0$ for B conservation, $\lambda, \lambda' \in \mathbb{R}$ for CP

Tree-level contributions from sneutrino exchange (dominated by $\tilde{\nu}_k$)

$$\Delta M_s^{(\not R)} \sim \sum_i \frac{\lambda'_{isd}\lambda'_{ids}}{M^2_{\tilde{\nu}_i}}$$

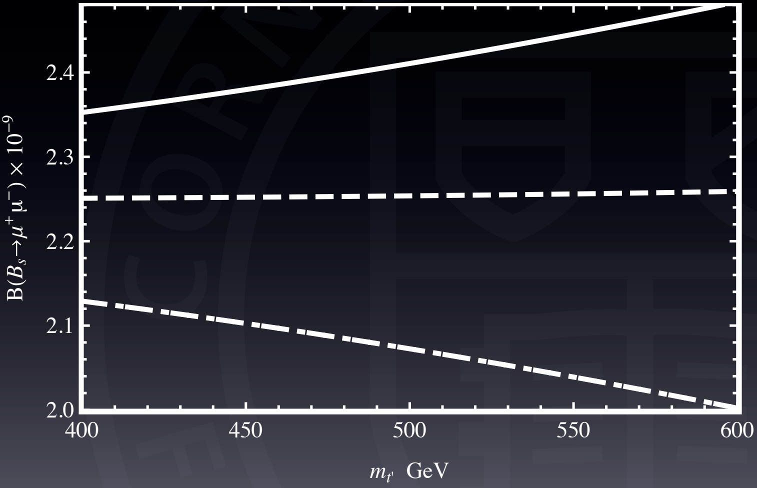
$$\text{Br}(B_s \to \mu\mu)^{(\not R)} \sim \left(\frac{\lambda_{k\mu\mu}\lambda'_{kbs}}{M^2_{\tilde{\nu}_k}}\right)$$

Sets upper bound on $\lambda_{i\mu\mu}\lambda'_{ibs}$ in terms of $M^2_{\tilde{\nu}_i}$. If $\lambda'_{ibs} = \lambda'_{isb}$, then

$$\text{Br}(B_s \to \mu\mu)^{(\not R)} \sim x_{B_s}^{(\not R)} \frac{\lambda^2_{k\mu\mu}}{M^2_{\tilde{\nu}_k}}$$

Relation to ΔM_s, simple models

Ex: Fourth generation 1002.0595, 1102.0009



Relation to ΔM_s, simple models

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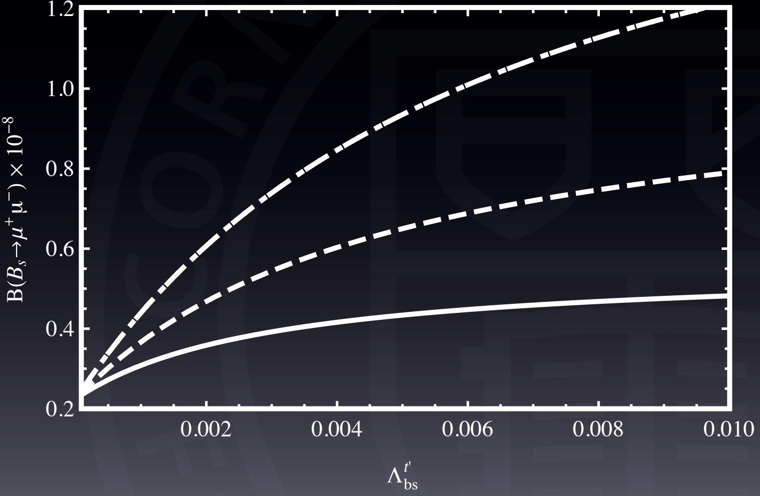

Thanks

That's all I've got. . . discuss!