Workshop on the Discovery Potential of an
Asymmetric B Factory at 10^{36} Luminosity
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Lepton Flavour Violation in B and τ-Decays

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1. Model : seesaw MSSM, (minimal SO(10) motivated)
2. Higgs mediated Lepton Flavour violating τ-decays
3. Higgs mediated Quark Flavour violating B-decays
4. Results

Introduction

• Neutrino masses

Neutrino masses arise in the SM or MSSM from a dimension 5 operator (Weinberg '79)

$$\Delta\mathcal{L} = -\frac{1}{4\Lambda}\mathbf{C}^{AB}\,(\epsilon_{ij}\,H_i\,l_j^A)\,(\epsilon_{lk}\,H_l\,l_k^B)\;+\;\mathrm{H.c}$$

$$\Downarrow$$

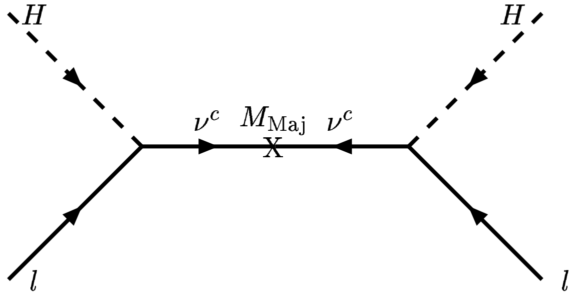
$$\mathcal{L}^{\nu}_{\mathrm{mass}} = -\frac{1}{2}\,(\frac{v^2}{4\Lambda})\,\mathbf{C}^{AB}\,\nu^A\nu^B\;+\;\mathrm{H.c}$$

• Seesaw mechanism

Add a $SU(2)_L \times U(1)_Y$ singlet leptonic field ν^c to the Lagrangian (Gell-Mann, Ramond, Slansky; Yanagida '79)

$$\Delta\mathcal{L} = -\epsilon_{ij}\,H_i\,\nu^{cA}\,\mathbf{Y}_{\nu}{}^{AB}\,l_j^B\;-\;\frac{1}{2}\,M^{AB}_{\mathrm{Maj}}\,\nu^{cA}\nu^{cB}\;+\;\mathrm{H.c}$$

$$\Downarrow$$



$$\Downarrow$$

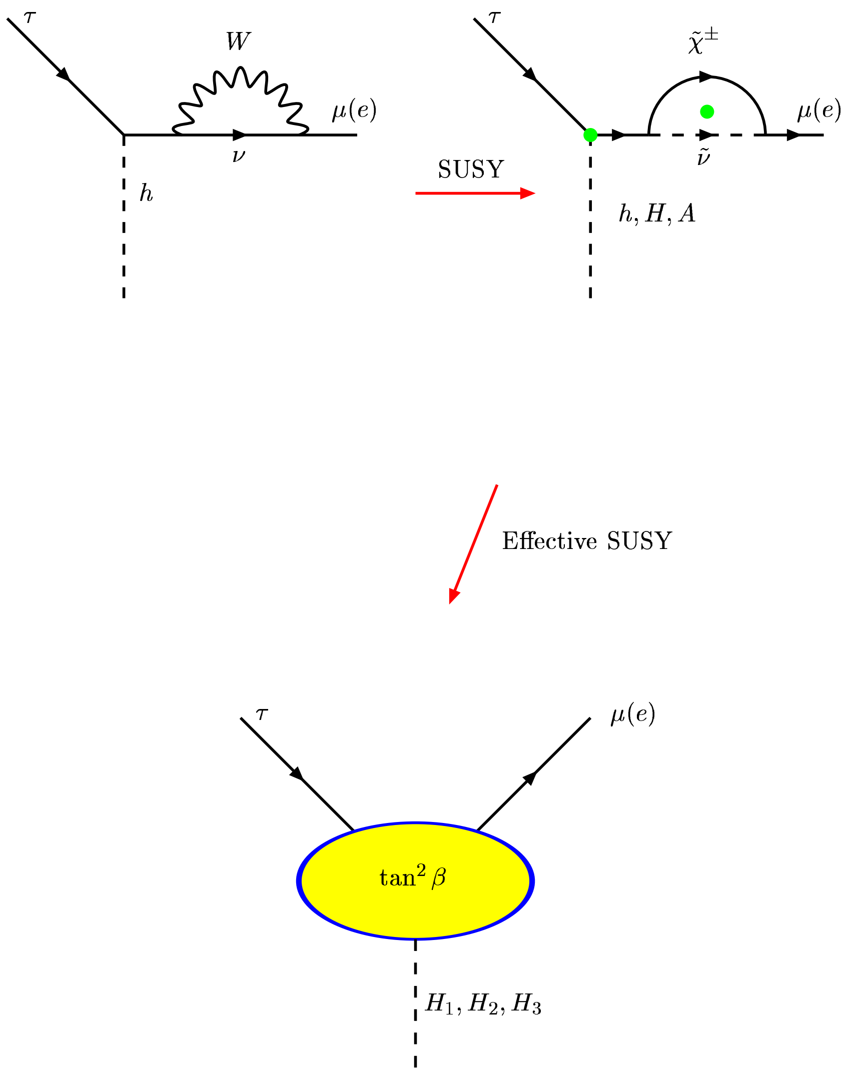
$$\Lambda^{-1}\mathbf{C} = \mathbf{Y}_{\nu}{}^{T}(\mathbf{M}_{\mathrm{Maj}})^{-1}\mathbf{Y}_{\nu}$$

• Slepton mixing

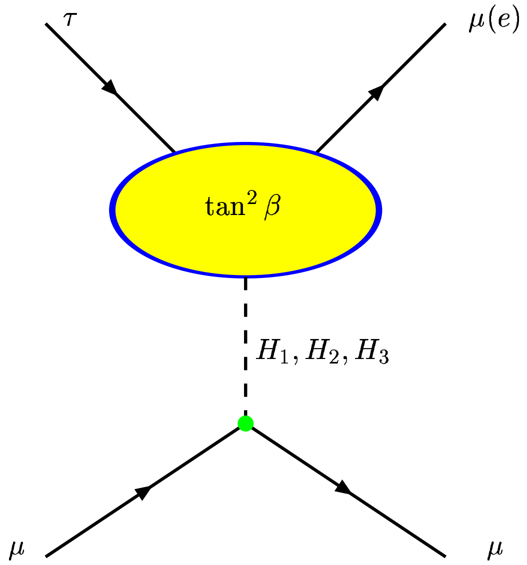
The influence of the renormalizable Yukawa coupling Y_ν in the RGE running from the Planck (or GUT) scale to the scale $\mathbf{M}_{\rm Maj}$ induces a mixing among sleptons at low energies

$$(\Delta m^2_{\tilde{L}})_{ij} \simeq -\frac{1}{8\pi^2}(3m_0^2 + A_0^2)(\mathbf{Y}_\nu{}^\dagger \ln \frac{M_{\rm GUT}}{\mathbf{M}_{\rm Maj}} \mathbf{Y}_\nu)$$

• Lepton Flavour Violating Higgs couplings



Application 1 : $\tau \to 3\mu, \tau \to e\mu\mu$



$$\mathcal{B}(\tau \to 3\mu)^{\rm Higgs} \simeq 1.6 \times 10^{-8} \left(\frac{\tan\beta}{60}\right)^6 \left(\frac{100 \text{ GeV}}{M_{H_3}}\right)^4$$

$$\mathcal{B}(\tau \to 3\mu)^{\gamma} \simeq 3.0 \times 10^{-6} \left(\frac{\tan\beta}{60}\right)^2 \left(\frac{100 \text{ GeV}}{M_{\rm SUSY}}\right)^4$$

If $M_H << M_{SUSY} \simeq 1$ TeV then the Higgs mediated diagram dominates

A. Dedes, J. R. Ellis and M. Raidal, Phys. Lett. B **549** (2002) 159 [arXiv:hep-ph/0209207].

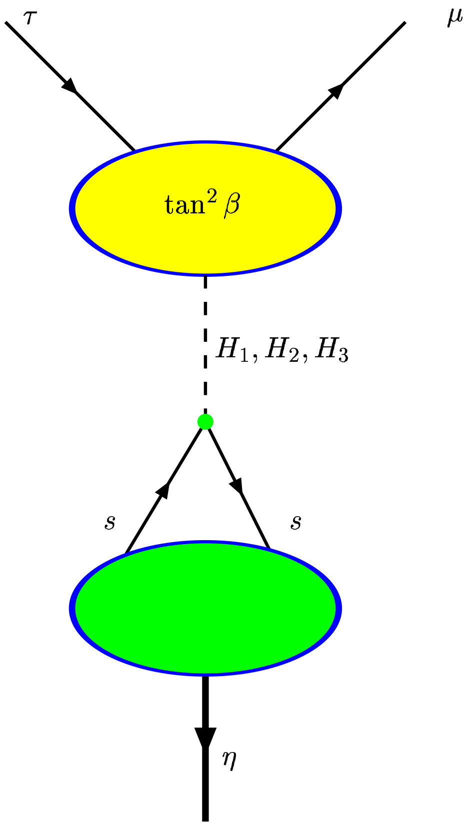
K. S. Babu and C. Kolda, Phys. Rev. Lett. **89** (2002) 241802 [arXiv:hep-ph/0206310].

A. Brignole and A. Rossi, arXiv:hep-ph/0304081.

- It should be also compared with

$$\mathcal{B}(\tau \to \mu\gamma) \simeq 1.3 \times 10^{-3} \left(\frac{\tan\beta}{60}\right)^2 \left(\frac{100 \text{ GeV}}{M_{\rm SUSY}}\right)^4$$

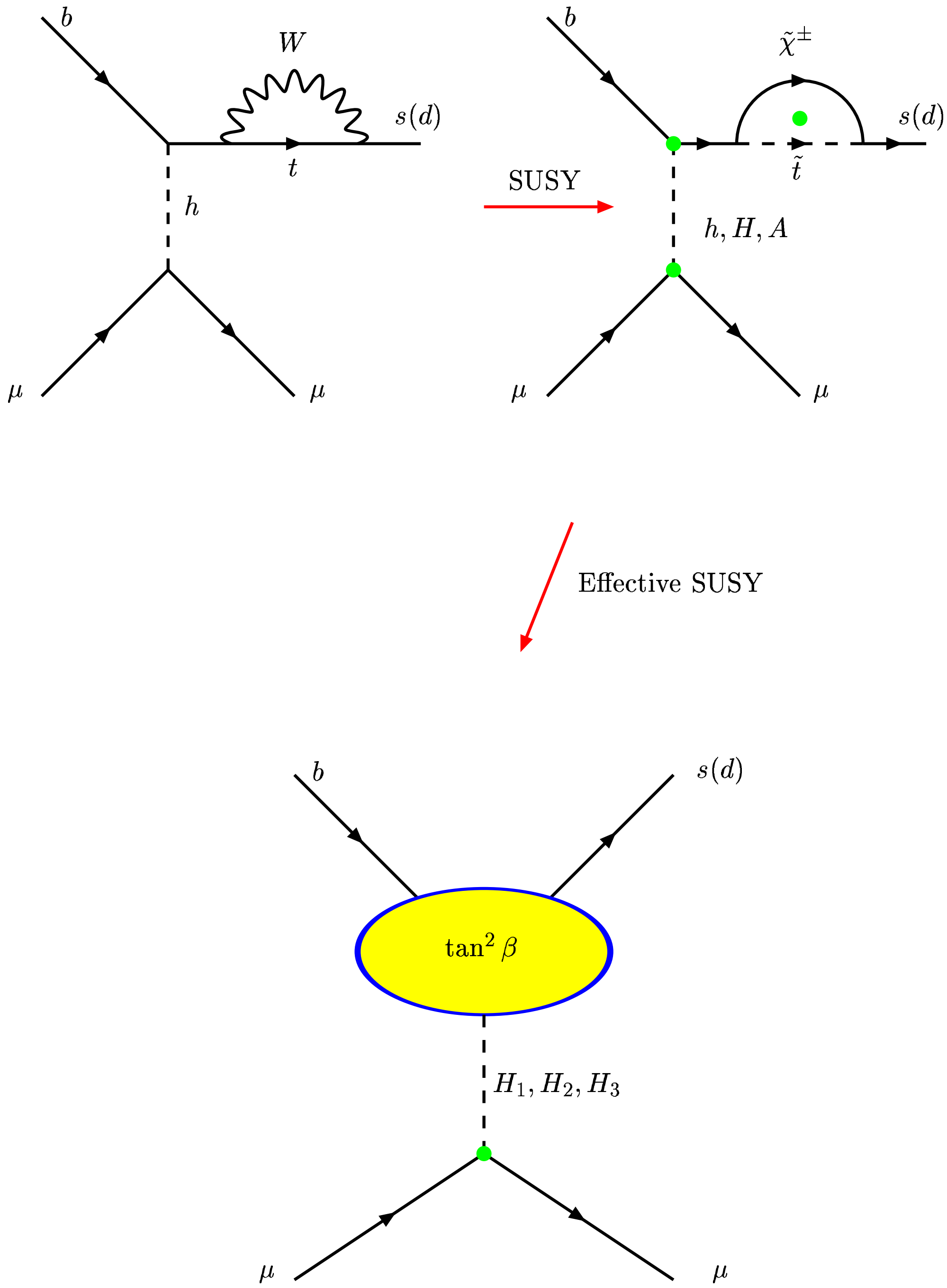
Application 2 : $\tau \to \mu\eta$



$$\mathcal{B}(\tau \to \mu\eta)^{\text{Higgs}} = 8.4 \times \mathcal{B}(\tau \to 3\mu)^{\text{Higgs}}$$

M. Sher, Phys. Rev. D **66** (2002) 057301 [arXiv:hep-ph/0207136].

Application 3 : $B_{s,d} \to \mu\mu$



$$\mathcal{B}(B_s \to \mu^+\mu^-) \simeq 1.0 \times 10^{-6} \left(\frac{\tan\beta}{60}\right)^6 \left(\frac{100\text{GeV}}{M_{H_3}}\right)^4$$

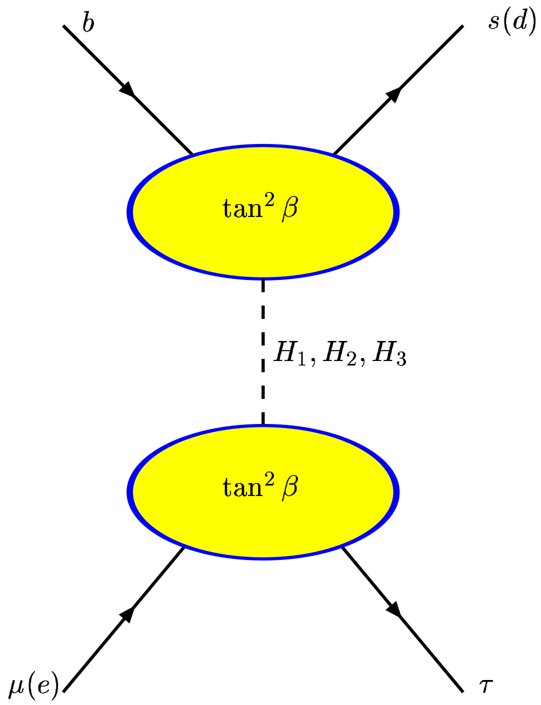
MSSM : K. S. Babu and C. Kolda, '99,
S.R. Choudhury and N. Gaur,'99
C. Hamzaoui, M. Pospelov and M. Toharia,'99
C. Huang, W. Liao and Q. Yan, '98,'99
P. H. Chankowski and L. Slawianowska, '01,
C. Bobeth, T. Ewerth, F. Krüger and J. Urban, '01, '02
G. Isidori, A. Retico, '01,'02
C. Bobeth, A. J. Buras, F. Krüger and J. Urban, '01,
G. D'Ambrosio, G. F. Giudice, G. Isidori and A. Strumia,'02
A. Dedes and A. Pilaftsis, '02
A. J. Buras, P. H. Chankowski, J. Rosiek and L. Slawianowska, "02
D. Demir, '03
Y. Wang and D. Atwood, '03

mSUGRA : A. Dedes, H. K. Dreiner and U. Nierste, '01
R. Arnowitt, B. Dutta, T. Kamon and M. Tanaka, '02
J. K. Mizukoshi, X. Tata and Y. Wang,'02
A. Dedes, H. K. Dreiner and U. Nierste, P. Richardson, '02
T. Ibrahim and P. Nath, '02

GMSB, AMSB : S. w. Baek, P. Ko and W. Y. Song, '02

Exp Review : T. Kamon [CDF Collaboration], arXiv:hep-ex/0301019.
Theory Review : A. Dedes , to appear.

Application 4 : $B_{s,d} \to \tau\mu, B_{s,d} \to \tau e$



$$\mathcal{B}(B_s \to \tau\mu) \simeq 3.6 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^8 \left(\frac{100\mathrm{GeV}}{M_{H_3}}\right)^4$$

$$\mathcal{B}(B_d \to \tau\mu) \simeq 1.8 \times 10^{-8} \left(\frac{\tan\beta}{60}\right)^8 \left(\frac{100\mathrm{GeV}}{M_{H_3}}\right)^4$$

A. Dedes, J. R. Ellis and M. Raidal, Phys. Lett. B **549** (2002) 159 [arXiv:hep-ph/0209207].

*** Before constraints!! ***

Experimental bounds and SM predictions

$\mathcal{B}$(Channel)	Expt.	Bound (90% CL)	SM prediction
$B_s \to e^+e^-$	L3	$< 5.4 \times 10^{-5}$	$(8.9 \pm 2.3) \times 10^{-14}$
$B_s \to \mu^+\mu^-$	CDF	$< 2.0 \times 10^{-6}$	$(3.8 \pm 1.0) \times 10^{-9}$
$B_s \to \tau^+\tau^-$	LEP	< 0.05	$(8.2 \pm 2.1) \times 10^{-7}$
$B_d \to e^+e^-$	BaBar	$< 3.3 \times 10^{-7}$	$(2.4 \pm 1.4) \times 10^{-15}$
$B_d \to \mu^+\mu^-$	BaBar	$< 2.0 \times 10^{-7}$	$(1.0 \pm 0.6) \times 10^{-10}$
$B_d \to \tau^+\tau^-$	LEP*	< 0.015	$(2.1 \pm 1.2) \times 10^{-8}$
$B_s \to e^+\mu^-$	CDF	$< 6.1 \times 10^{-6}$	~ 0
$B_s \to e^+\tau^-$	–	– –	~ 0
$B_s \to \mu^+\tau^-$	–	– –	~ 0
$B_d \to e^+\mu^-$	BaBar	$< 2.0 \times 10^{-7}$	~ 0
$B_d \to e^+\tau^-$	CLEO	$< 5.3 \times 10^{-4}$	~ 0
$B_d \to \mu^+\tau^-$	CLEO	$< 8.3 \times 10^{-4}$	~ 0
$\tau^- \to \mu^-\mu^+\mu^-$	Belle	$< 3.8 \times 10^{-7}$	~ 0
$\tau^- \to e^-\mu^+\mu^-$	Belle	$< 3.1 \times 10^{-7}$	~ 0
$\tau^- \to \mu^-\eta$	CLEO	$< 9.6 \times 10^{-6}$	~ 0
$\tau^- \to \mu^-\gamma$	CLEO	$< 1.1 \times 10^{-6}$	~ 0

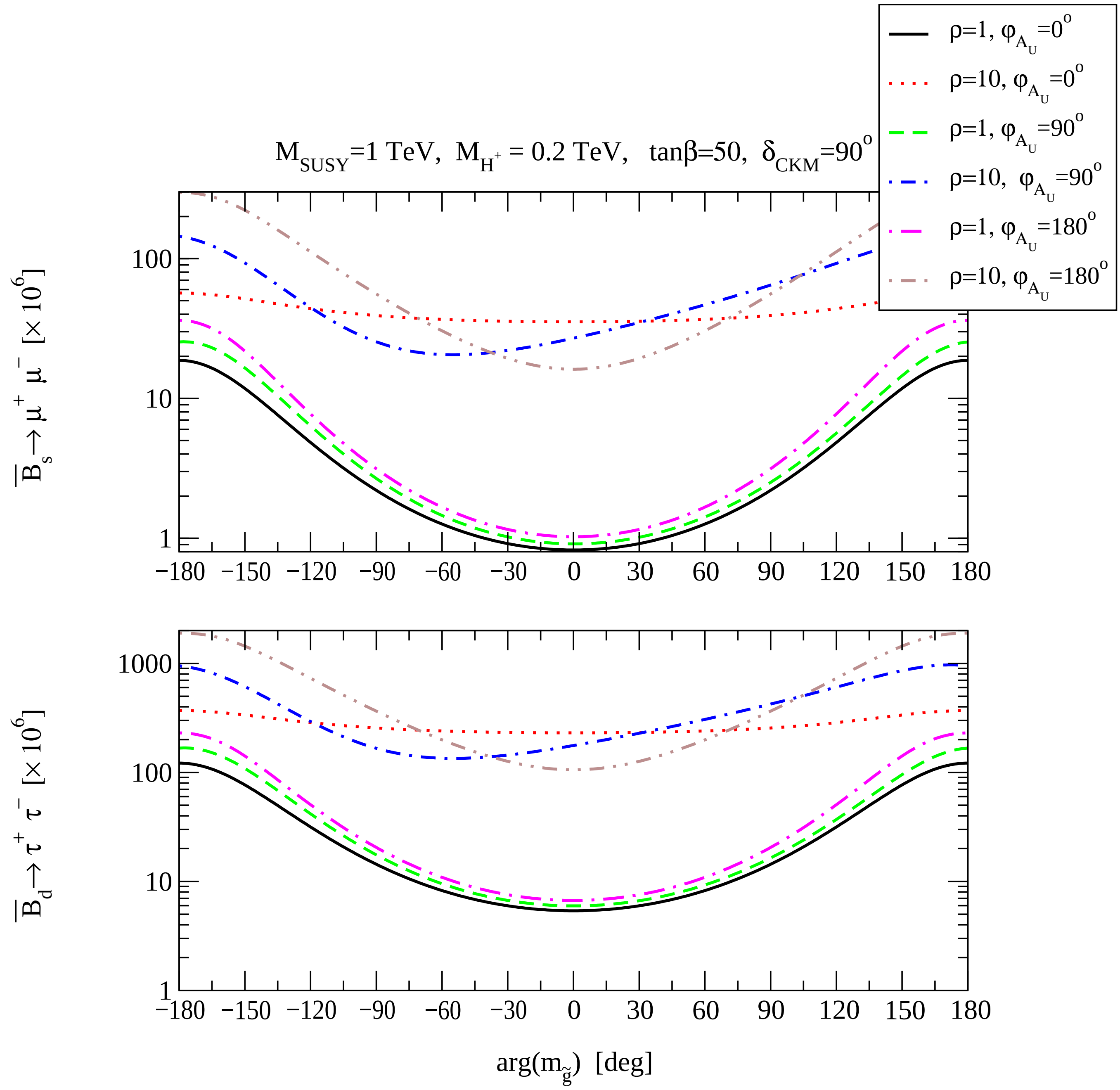
* from Y. Grossman, Z. Ligeti and E. Nardi, Phys. Rev. D **55** (1997) 2768 [arXiv:hep-ph/9607473].

LFV B-decays

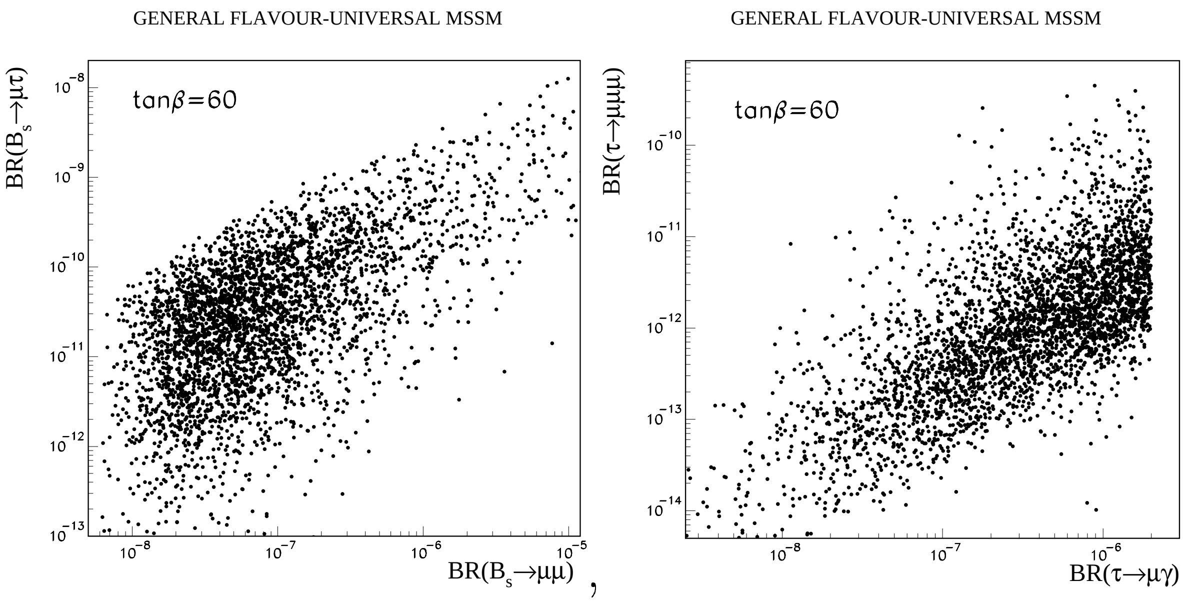
LFV τ-decays

Results

A. Dedes and A. Pilaftsis, Phys. Rev. D **67**, 015012 (2003) [arXiv:hep-ph/0209306].



$$\mathcal{B}(B_d \to \tau^+\tau^-)_{\rm Higgs} \simeq 7 \times \mathcal{B}(B_s \to \mu^+\mu^-)_{\rm Higgs}$$



After constraints :

$$\mathcal{B}(B_s \to \mu\tau,\ e\tau) \lesssim 4 \times 10^{-9}$$

$$\mathcal{B}(B_d \to \mu\tau,\ e\tau) \lesssim 2 \times 10^{-10}$$

$$\mathcal{B}(\tau \to 3\mu,\ e\mu\mu) \lesssim 4 \times 10^{-10}$$

$$\mathcal{B}(\tau \to \mu\eta) \lesssim 3 \times 10^{-9}$$

A. Dedes, J. Ellis, and M. Raidal, Phys. Lett. B **549** (2002) 159 [arXiv:hep-ph/0209207].

Higgs mediated (seesaw) MSSM predictions

$\mathcal{B}$(Channel)	Expt.	Bound (90% CL)	Higgs med. MSSM
$B_s \to e^+e^-$	L3	$< 5.4 \times 10^{-5}$	$\lesssim 4.5 \times 10^{-11}$
$B_s \to \mu^+\mu^-$	CDF	$< 2.0 \times 10^{-6}$	$< 2.0 \times 10^{-6}$
$B_s \to \tau^+\tau^-$	LEP	< 0.05	$\lesssim 3.4 \times 10^{-4}$
$B_d \to e^+e^-$	BaBar	$< 3.3 \times 10^{-7}$	$\lesssim 4.5 \times 10^{-12}$
$B_d \to \mu^+\mu^-$	BaBar	$< 2.0 \times 10^{-7}$	$< 2.0 \times 10^{-7}$
$B_d \to \tau^+\tau^-$	LEP	< 0.015	$\lesssim 3.3 \times 10^{-5}$
$B_s \to e^+\mu^-$	CDF	$< 6.1 \times 10^{-6}$	$\lesssim 10^{-11}$
$B_s \to e^+\tau^-$	–	– –	$\lesssim 4 \times 10^{-9}$
$B_s \to \mu^+\tau^-$	–	– –	$\lesssim 4 \times 10^{-9}$
$B_d \to e^+\mu^-$	BaBar	$< 2.0 \times 10^{-7}$	$\lesssim 6 \times 10^{-13}$
$B_d \to e^+\tau^-$	CLEO	$< 5.3 \times 10^{-4}$	$\lesssim 2 \times 10^{-10}$
$B_d \to \mu^+\tau^-$	CLEO	$< 8.3 \times 10^{-4}$	$\lesssim 2 \times 10^{-10}$
$\tau^- \to \mu^-\mu^+\mu^-$	Belle	$< 3.8 \times 10^{-7}$	$\lesssim 4 \times 10^{-10}$
$\tau^- \to e^-\mu^+\mu^-$	Belle	$< 3.1 \times 10^{-7}$	$\lesssim 4 \times 10^{-10}$
$\tau^- \to \mu^-\eta$	CLEO	$< 9.6 \times 10^{-6}$	$\lesssim 3 \times 10^{-9}$
$\tau^- \to \mu^-\gamma$	CLEO	$< 1.1 \times 10^{-6}$	$< 1.1 \times 10^{-6}$

* Results on $B \to l^+l^-$ are based on the analysis : A. Dedes and A. Pilaftsis, Phys. Rev. D **67**, 015012 (2003) [arXiv:hep-ph/0209306]

** Results on $B \to l^{+'}l^-$, $\tau^- \to l^-l^+l^-$ are based on the analysis : A. Dedes, J. R. Ellis and M. Raidal, Phys. Lett. B **549** (2002) 159 [arXiv:hep-ph/0209207].

*** For the $\tau \to \mu\eta$ I use the relation $\mathcal{B}(\tau \to \mu\eta)^{\rm Higgs} = 8.4 \times \mathcal{B}(\tau \to 3\mu)^{\rm Higgs}$ from M. Sher, Phys. Rev. D **66** (2002) 057301 [arXiv:hep-ph/0207136].

Conclusions

• Higgs boson mediated FCNC (LFV) processes are interesting in the MSSM (seesaw). They are enhanced by powers of $\tan\beta$ and are orders of magnitude larger than the Standard Model predictions .

• $\mathcal{B}(B_{s,d} \to \mu^+\mu^-)$ not rare in the MSSM. Accessible at Tevatron (even with 2 fb^{-2}), LHC, and B-factories (for B_d)

• $\mathcal{B}(B_d \to \tau^+\tau^-)$ is enhanced by orders of magnitude if the MSSM Higgs mediated phenomenon is correct. The current exp bound is poor, so before we speculate rates at SuperB, we encourage our colleagues at BaBar and Belle to look for it!!

• $\tau \to \mu\gamma$ is (at the moment) the only LFV decay which can saturate the exp bound. Searching this mode at an upgrade B-factory is compulsory.

• Other LFV modes like $B \to l'l, \tau \to l'll$, $\tau \to \mu\eta$, (relevant to B-factories) turn out to be small, with Br's at $10^{-9} - 10^{-10}$ if current exp constraints are imposed.

• Searching for LFV modes like $B \to l'l, \tau \to l'll$, $\tau \to \mu\eta$, could distinguish among various models for neutrino masses , for example : R-parity violating MSSM and seesaw MSSM.

- Results and the sensitivity of an Asymmetric B-factory

$\mathcal{B}$(Channel)	10^{36} B-factory sensitivity	Higgs med. MSSM
$B_d \to e^+e^-$	$\sim 5\times 10^{-9}$	$< 4.5\times 10^{-12}$
$B_d \to \mu^+\mu^-$	$\sim 5\times 10^{-9}$	$< 2.0\times 10^{-7}$
$B_d \to \tau^+\tau^-$	$\sim 2\times 10^{-6}$	$< 3.3\times 10^{-5}$
$B_d \to e^+\mu^-$	$\sim 5\times 10^{-9}$	$\lesssim 6\times 10^{-13}$
$B_d \to e^+\tau^-$	$\sim 5\times 10^{-7}$	$\lesssim 2\times 10^{-10}$
$B_d \to \mu^+\tau^-$	$\sim 5\times 10^{-7}$	$\lesssim 2\times 10^{-10}$
$\tau^- \to \mu^-\mu^+\mu^-$	?	$\lesssim 4\times 10^{-10}$
$\tau^- \to e^-\mu^+\mu^-$	?	$\lesssim 4\times 10^{-10}$
$\tau^- \to \mu^-\eta$	?	$\lesssim 3\times 10^{-9}$
$\tau^- \to \mu^-\gamma$	$\sim 10^{-8}$	$< 1.1\times 10^{-6}$