Patterns of flavor signals in supersymmetric models

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T. G., Y. Okada (KEK), T. Shindou (DESY) and M. Tanaka (Osaka),
arXiv:0711.2935 [hep-ph].

Introduction

Flavor physics: probe for new physics.

- Heavy particles and their interactions contribute in various ways.

$\Rightarrow$ Plays a complementary role with direct measurements (@LHC).

  - ▷ SM: $b \to s, d$ (flavor) $\oplus$ m_t (direct) $\Rightarrow$ V_{td}, V_{ts}.
  - ▷ Similar case will occur in the study of physics beyond the SM.
    - $*$ $b \to s, d \oplus m_{\widetilde{q}} \Rightarrow q_i - \widetilde{q}_j - \widetilde{g}$ coupling.

Experimental improvements expected.

- MEG (soon?): search for $\mu \to e\,\gamma$ with b.r. down to 10^{-13}.
  - ▷ current upper limit: $\mathrm{B}(\mu \to e\,\gamma) < 1.1 \times 10^{-11}$.
- LHCb (2008$\sim$): $S_{\mathrm{CP}}(B_s \to J/\psi\phi)$, $\cdots$.
- Super B factories (under discussion) with $\int \mathcal{L} = 50 - 75\mathrm{ab}^{-1}$:

$\Rightarrow$ uncertainties reduced by $\sim \frac{1}{7}$ ($\int \mathcal{L}(\mathrm{KEKB} + \mathrm{PEPII}) \approx 1.3\mathrm{ab}^{-1}$).

In this work, we study quark/lepton flavor signals:

- LFV ($\mu \to e\,\gamma$, $\tau \to \mu\,\gamma$, $\tau \to e\,\gamma$),
- CP Asymmetries in B decays,

in SUSY models with typical flavor structures:

- mSUGRA,
- MSSM with ν_R's,
- SU(5) SUSY GUT with ν_R's,
- U(2) Flavor Symmetry model.

We show the pattern of flavor signals varies depending on the model.

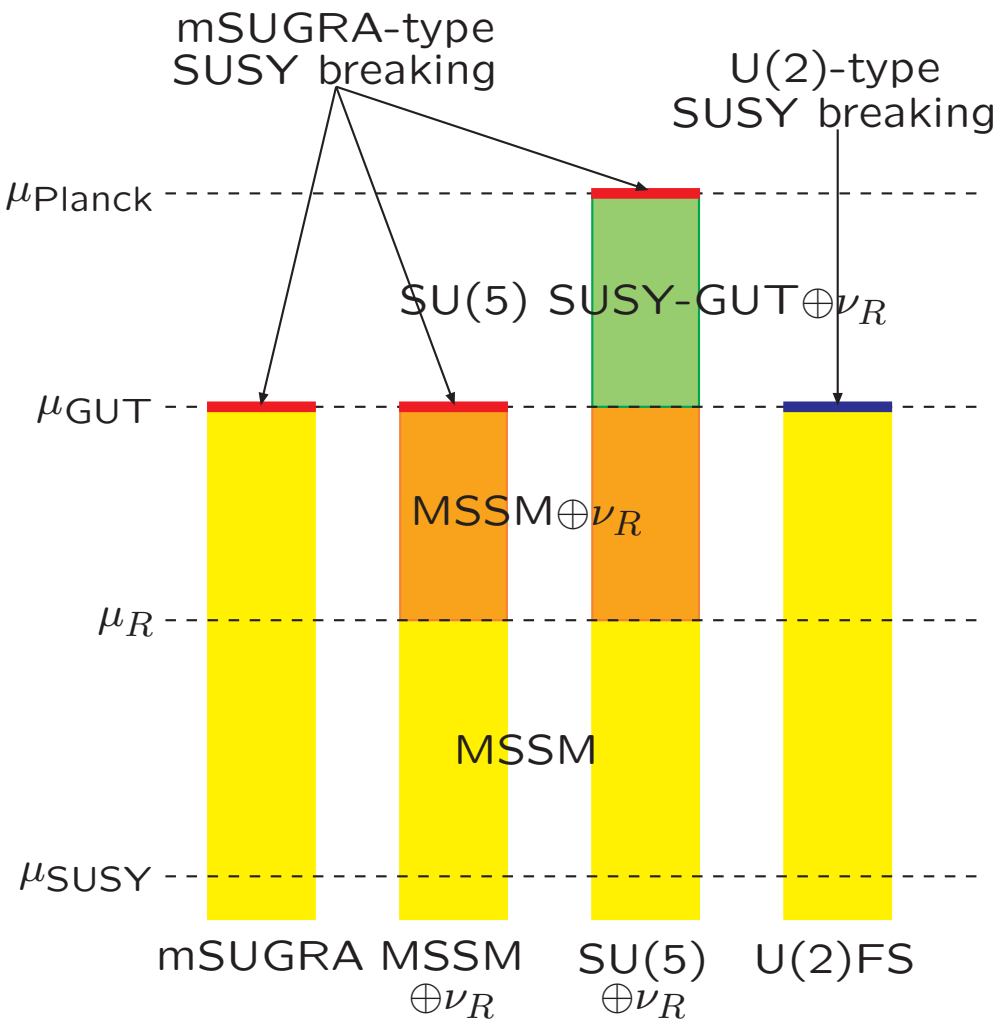
$\Rightarrow$ Flavor measurements are useful to distinguish models.

Contents:

- Models
- Numerical results
- Summary

Models: Minimal Supersymmetric Standard Model $+\alpha$

"$+\alpha$": mechanism which controls flavor mixing in SUSY breaking.



- mSUGRA: flavor-blind SUSY breaking.
  - ▷ $m_Q^2 = \cdots = m_0^2 1$.
  - ▷ $A_{U,D,\cdots} = A_0 Y_{U,D,\cdots}$.
  - ▷ $M_1 = M_2 = M_3 = m_{1/2}$.
- ν_R active above μ_R in models with ν_R's. $\rightarrow$ Y_ν affects running.
- U(2) flavor symmetry:
  - ▷ $Y_{U,D} \sim \begin{bmatrix} & \epsilon' & \\ \epsilon' & \epsilon & \epsilon \\ & \epsilon & 1 \end{bmatrix}$,
    $(\epsilon \sim V_{cb},\ \epsilon'/\epsilon \sim V_{us})$.
  - ▷ $m^2_{Q,U,D} \sim m_0^2 \begin{bmatrix} 1 & & \\ & 1 & \epsilon \\ & \epsilon & O(1) \end{bmatrix}$,

Flavor mixing/CPV source

- $V_{\rm CKM}$ (all cases) $\Longrightarrow$ $\tilde{q}_L$ mixing (running).
  - ▷ Significant in $B(b \to s\gamma)$; small in others.
  - ▷ GUT $\Longrightarrow$ $\tilde{\ell}_R$ mixing (Barbieri-Hall). $\quad \mathbf{10} = \{q_L, (u_R)^c, (e_R)^c\}$.
- Y_ν (cases with ν_R's) $\Longrightarrow$ $\tilde{\ell}_L$ mixing (running above μ_R).
  - ▷ GUT $\Longrightarrow$ $\tilde{d}_R$ mixing (Moroi) $\qquad \overline{\mathbf{5}} = \{(d_R)^c, \ell_L\}$.
- $m^2_{Q,U,D}(\mu_{\rm GUT})$ (U(2)FS).
  - ▷ U(2) structure neglected in (s)lepton sector.
- SUSY CPV phases (ϕ_A, ϕ_μ, $\cdots$).
  - ▷ Affect CP asymmetries in b decays, EDMs (e, n, Hg).

Structure of Y_ν

Y_ν, M_{ν_R} have more degrees of freedom than low-energy ν parameters
$(m_\nu = \langle h_2 \rangle^2 Y_\nu^T M_{\nu_R}^{-1} Y_\nu)$.

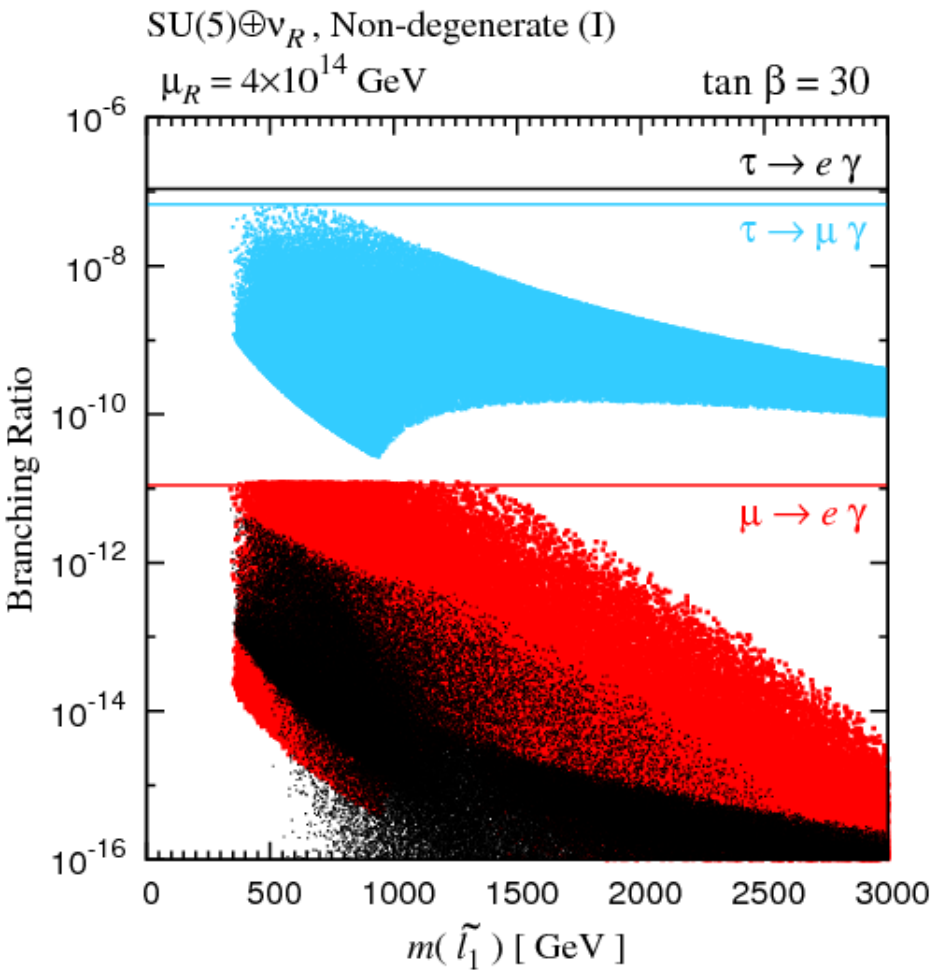
$\Longrightarrow$ Three patterns of Y_ν studied for a fixed set of m_ν and $U_{\rm MNS}$.

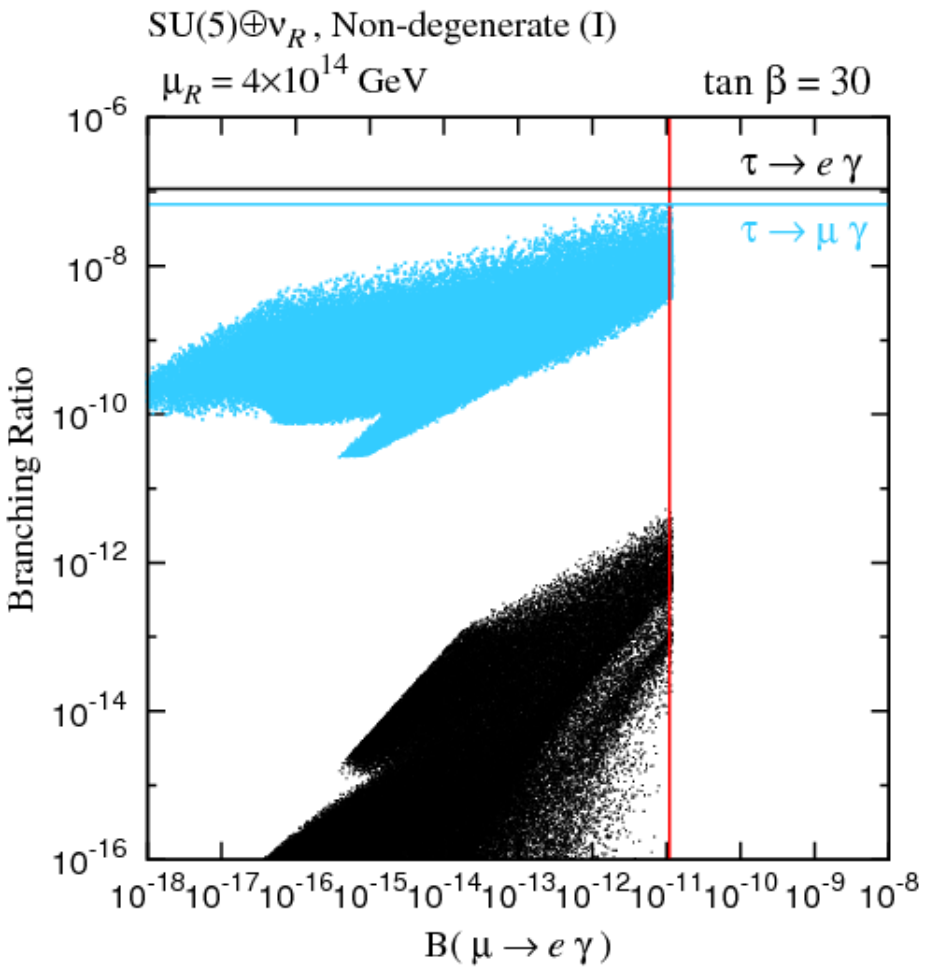
- Degenerate: $M_{\nu_R} \propto$ unit matrix.
  - ▷ $\nu_\odot$ mixing (1st–2nd) $\Longrightarrow$ $\mu \to e$, $\stackrel{\rm GUT}{\longrightarrow}$ $s \to d$.
  - ▷ $\nu_{\rm atm}$ mixing (2nd–3rd) $\Longrightarrow$ $\tau \to \mu$, $\stackrel{\rm GUT}{\longrightarrow}$ $b \to s$.
- Non-degenerate (I): $M_{\nu_R} \not\propto$ unit matrix.
  - ▷ $Y_\nu \sim \begin{bmatrix} * & & \\ & * & * \\ & * & * \end{bmatrix}$: $\mu \to e$, $\tau \to e$ suppressed; $\begin{matrix} \tau \to \mu \\ (b \to s) \end{matrix}$ unsuppressed.
- Non-degenerate (II): $M_{\nu_R} \not\propto$ unit matrix.
  - ▷ $Y_\nu \sim \begin{bmatrix} * & & * \\ & * & \\ * & & * \end{bmatrix}$: $\mu \to e$, $\tau \to \mu$ suppressed; $\begin{matrix} \tau \to e \\ (b \to d) \end{matrix}$ unsuppressed.

  (Ellis-Hisano-Raidal-Shimizu)

$M_{\nu_R} \sim \mu_R \sim 10^{14}$GeV $\Leftrightarrow$ $Y_\nu \sim 1$.

LFV: $\mu \to e\gamma$, $\tau \to \mu\gamma$, $\tau \to e\gamma$

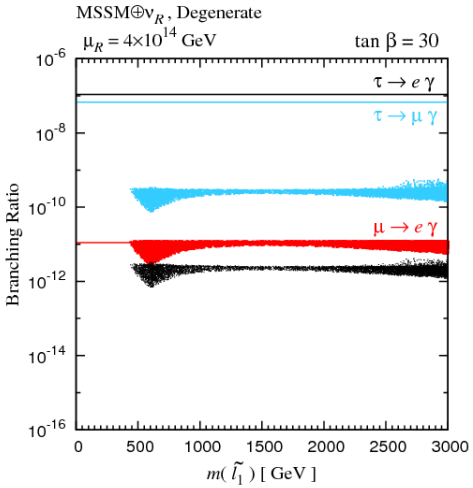


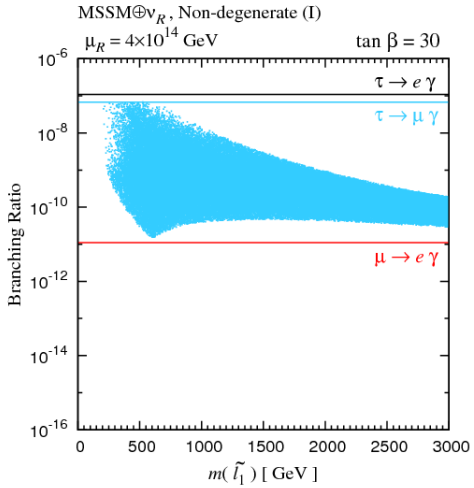


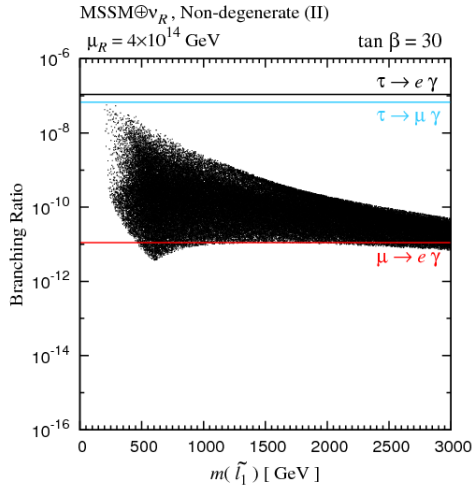
$m_{1/2}(\mu_G) \leq 1.5\text{TeV}$, $m_0(\mu_P) \leq 4\text{TeV}$ scanned.

LFV: $\mu \to e\gamma$, $\tau \to \mu\gamma$, $\tau \to e\gamma$

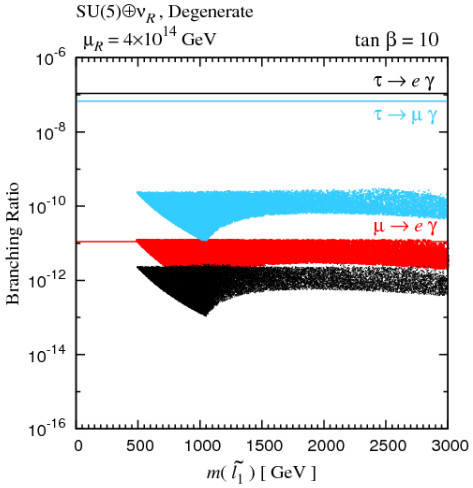
MSSM$\oplus\nu_R$ (LFV from Y_ν only)

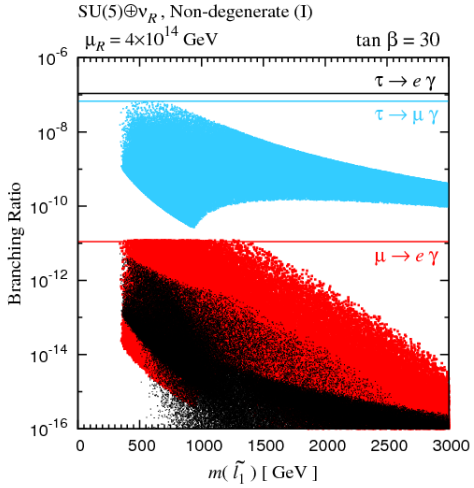


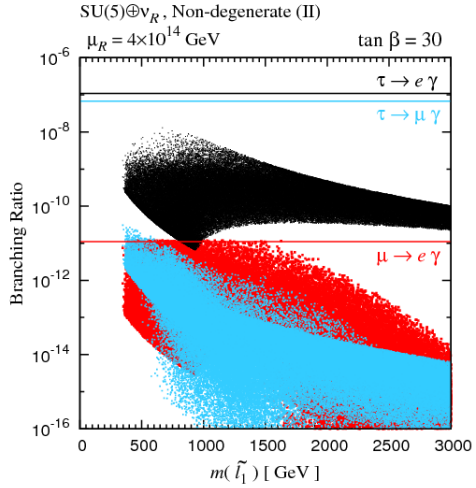




Degenerate Non-degen.(I) Non-degen.(II)







SU(5)$\oplus\nu_R$ (LFV from Y_ν and $\mu_P \leftrightarrow \mu_G$ running)

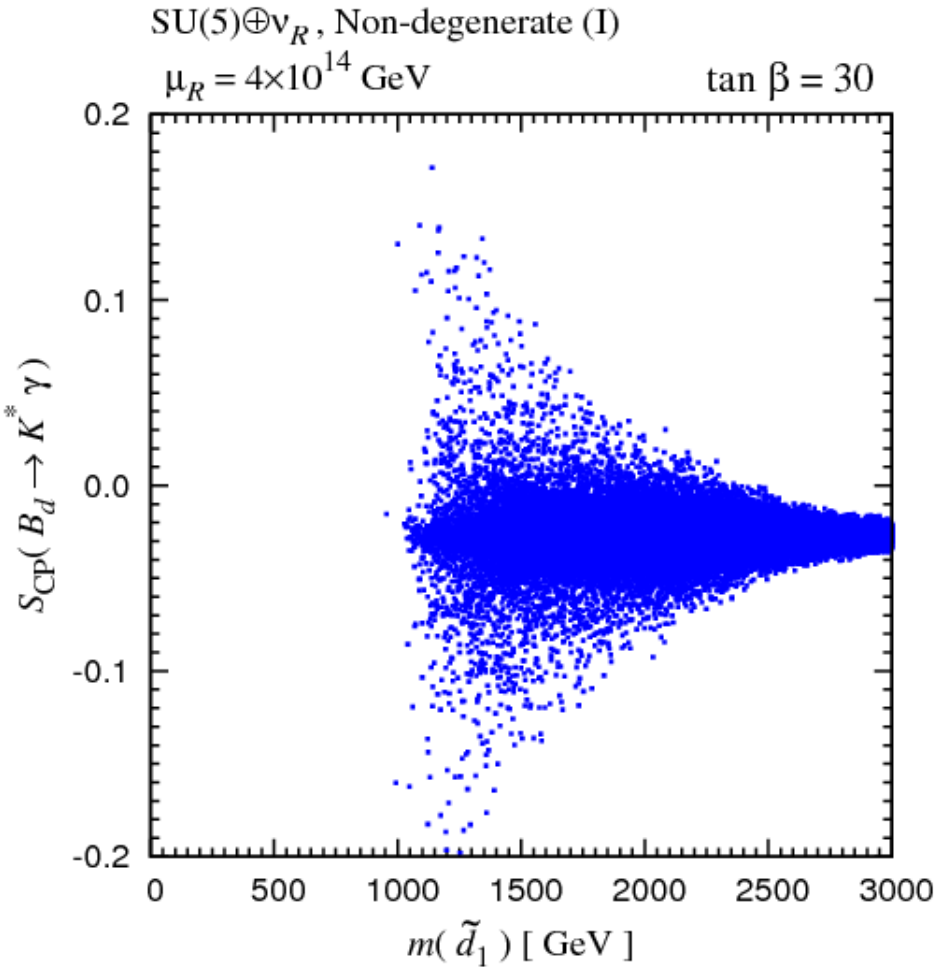
Time-dependent CP asymmetries in $b \to s/b \to d$ decays

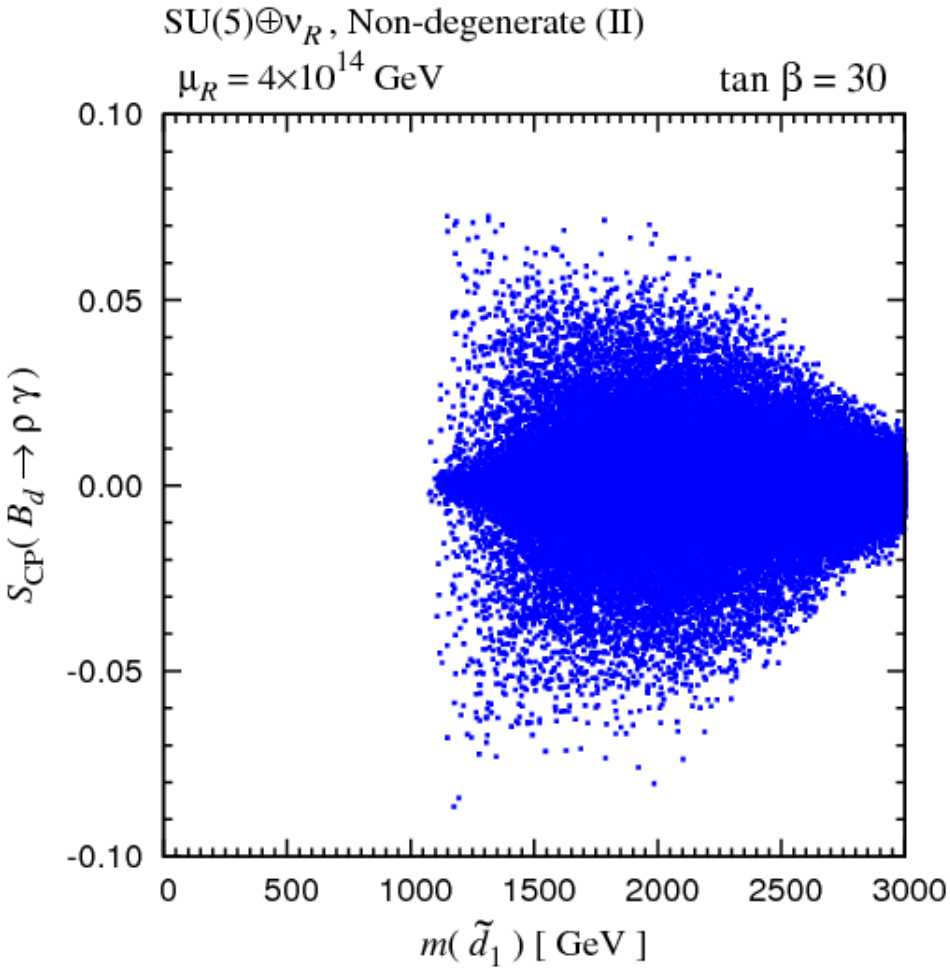
- $S_{\rm CP}(B_d \to K^* \gamma)$, $S_{\rm CP}(B_d \to \rho \gamma)$
  - ▷ $B_d - \overline{B}_d$ mixing $\otimes$ $b \to s(d) \gamma$ decay.
  - ▷ Interference between $b_R \to s(d)_L \gamma_L$ and $\overline{(b_L)} \to \overline{(s(d)_R)} \gamma_L$; suppressed by $m_{s,d}/m_b$ in SM (Atwood-Gronau-Soni).
- $S_{\rm CP}(B_d \to \phi K_S)$
  - ▷ $B_d - \overline{B}_d$ mixing $\otimes$ $b \to s\, s\, \bar{s}$ decay.
  - ▷ Differs from $S_{\rm CP}(B_d \to J/\psi K_S)$ if new phase exists in $b \to s$ penguin amplitude.
- $S_{\rm CP}(B_s \to J/\psi \phi)$
  - ▷ $B_s - \overline{B}_s$ mixing $\otimes$ $b \to s\, c\, \bar{c}$ decay.
  - ▷ Small in SM; enhanced if new phase exists in $B_s - \overline{B}_s$ mixing.

$\Longrightarrow$ $\tilde{d}_R$ mixing can contribute to all.

- Significant in SU(5) SUSY-GUT$\oplus \nu_R$ and U(2)FS.

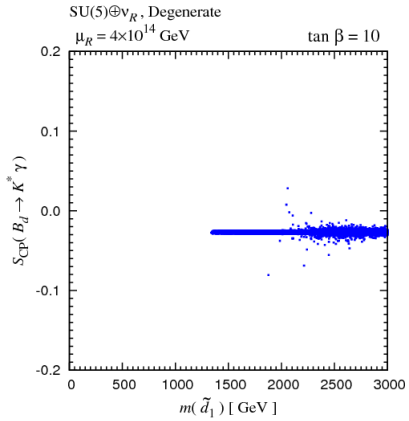
$S_{\rm CP}(B_d \to K^*\gamma)$ $[b \to s]$, $S_{\rm CP}(B_d \to \rho\gamma)$ $[b \to d]$

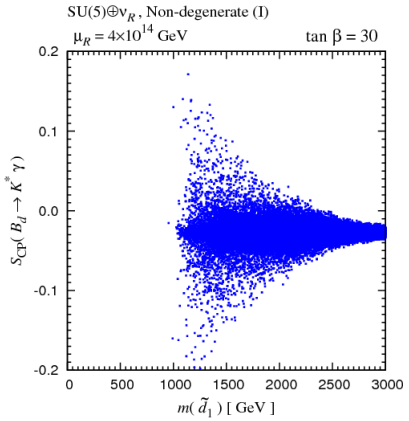


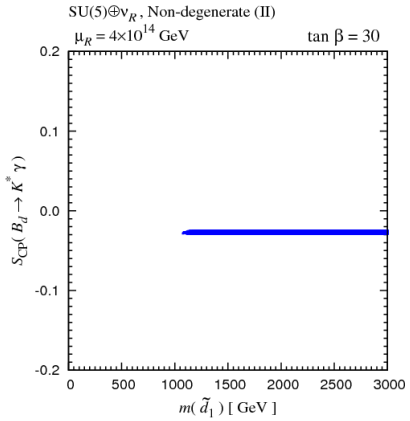


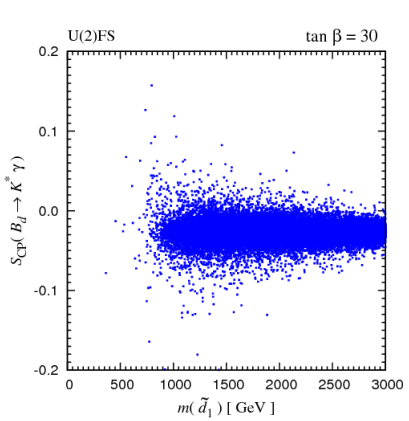
$S_{\rm CP}(B_d \to K^*\gamma)$ [$b \to s$], $S_{\rm CP}(B_d \to \rho\gamma)$ [$b \to d$]

$S_{\rm CP}(B_d \to K^*\gamma)$ vs. $m(\tilde{d}_1)$

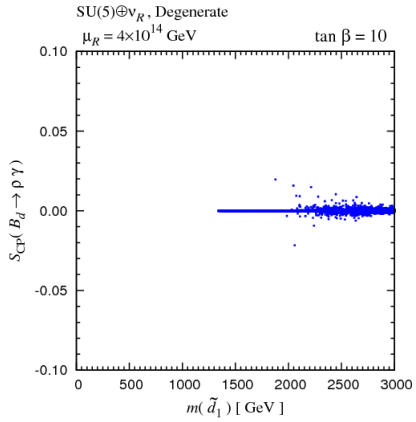


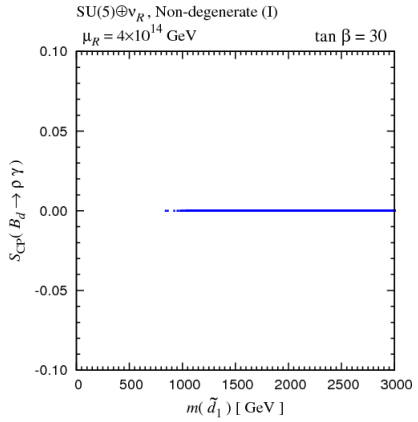


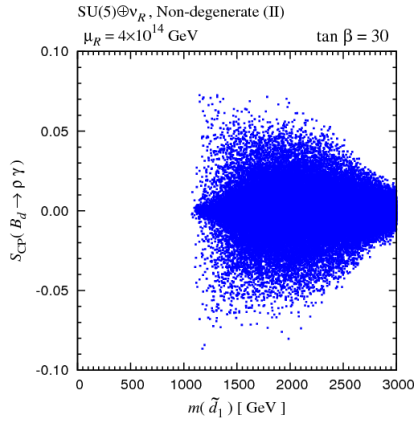


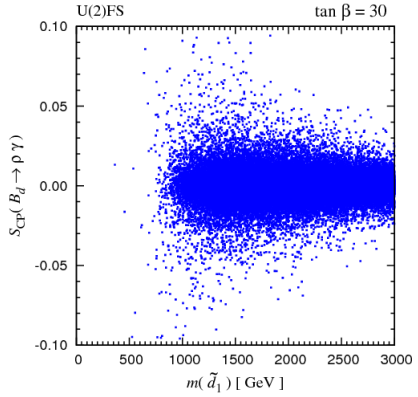


Degenerate | Non-degen.(I) | Non-degen.(II) | U(2)FS





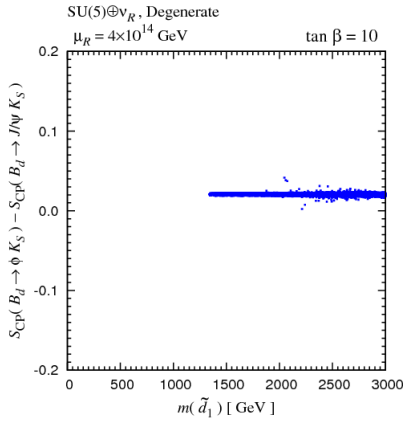


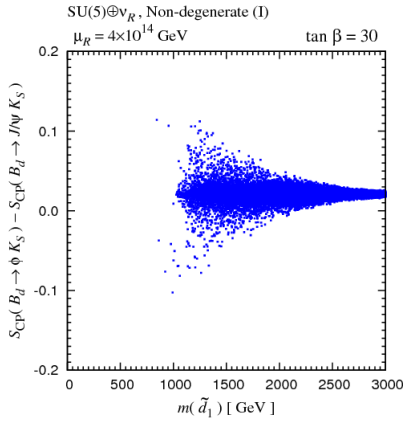


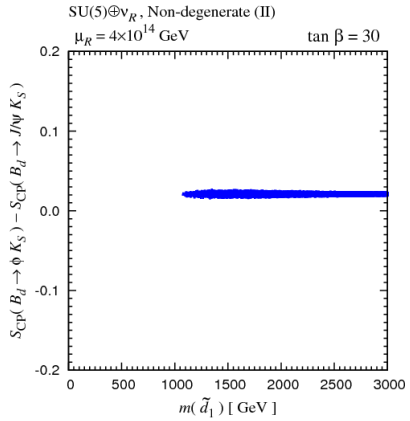
$S_{\rm CP}(B_d \to \rho\gamma)$ vs. $m(\tilde{d}_1)$

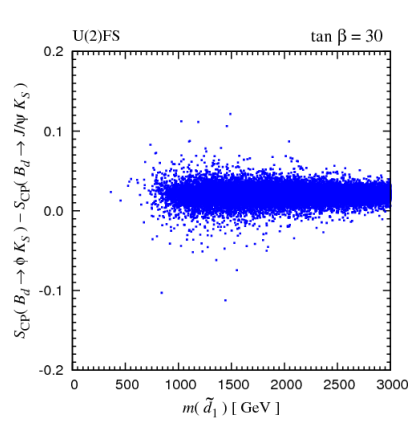
$S_{\rm CP}(B_d \to \phi K_S)$, $S_{\rm CP}(B_s \to J/\psi\phi)$ $[b \to s]$

$S_{\rm CP}(B_d \to \phi K_S) - S_{\rm CP}(B_d \to J/\psi K_S)$ vs. $m(\tilde{d}_1)$

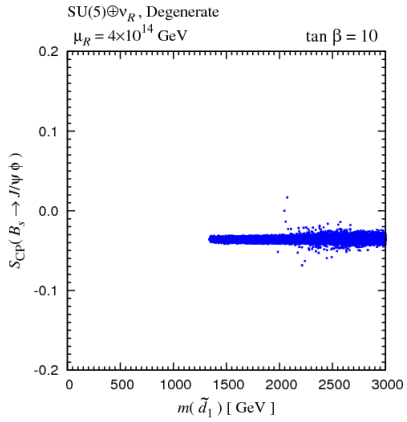


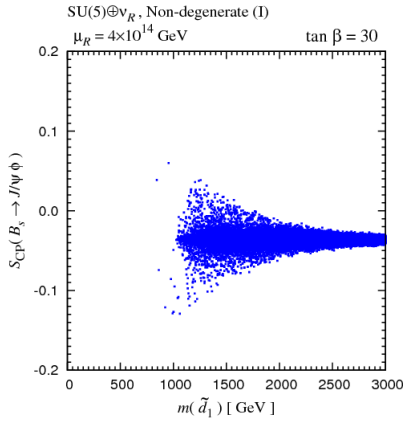


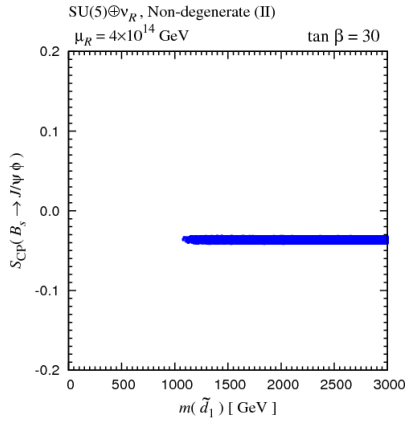


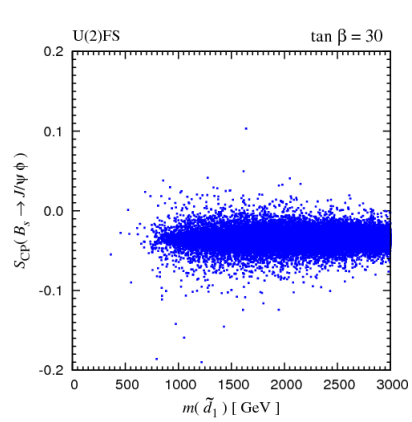


Degenerate Non-degen.(I) Non-degen.(II) U(2)FS









$S_{\rm CP}(B_s \to J/\psi\phi)$ vs. $m(\tilde{d}_1)$

Summary: LFV

	$\mu \to e\gamma$	$\tau \to \mu\gamma$	$\tau \to e\gamma$
MSSM$\oplus\nu_R$			
degenerate	$\surd$		
non-degen. (I)		$\surd$	
non-degen. (II)			$\surd$
SU(5)$\oplus\nu_R$			
degenerate	$\surd$		
non-degen. (I)	$\surd$	$\surd$	
non-degen. (II)	$\surd$		$\surd$
Exp. sensitivity	10^{-13}	$2-8\times10^{-9}$	
	MEG	SuperB@$50-75\text{ab}^{-1}$	

- $\surd$: $\sim 10^{-11}$ for $\mathrm{B}(\mu \to e\,\gamma)$, $\sim 10^{-8}$ for $\mathrm{B}(\tau \to \mu(e)\gamma)$ possible.

Summary: Time-dependent CPV in $b \to s(d)$

	$S_{CP}(K^*\gamma)$	$S_{CP}(\rho\gamma)$	$\Delta S_{CP}(\phi K_S)$	$S_{CP}(B_s \to J/\psi\phi)$
SU(5)+RN				
degenerate	~ 0.01	~ 0.01	~ 0.01	~ 0.01
non-degen. (I)	~ 0.2		~ 0.1	~ 0.1
non-degen. (II)		~ 0.1		
U(2)FS	~ 0.2	~ 0.1	~ 0.1	~ 0.1
Exp. precision	$0.02 - 0.03$	$0.08 - 0.12$	$0.02 - 0.03$	~ 0.01
	SuperB@50 $-$ 75ab^{-1}			LHCb@10fb^{-1}

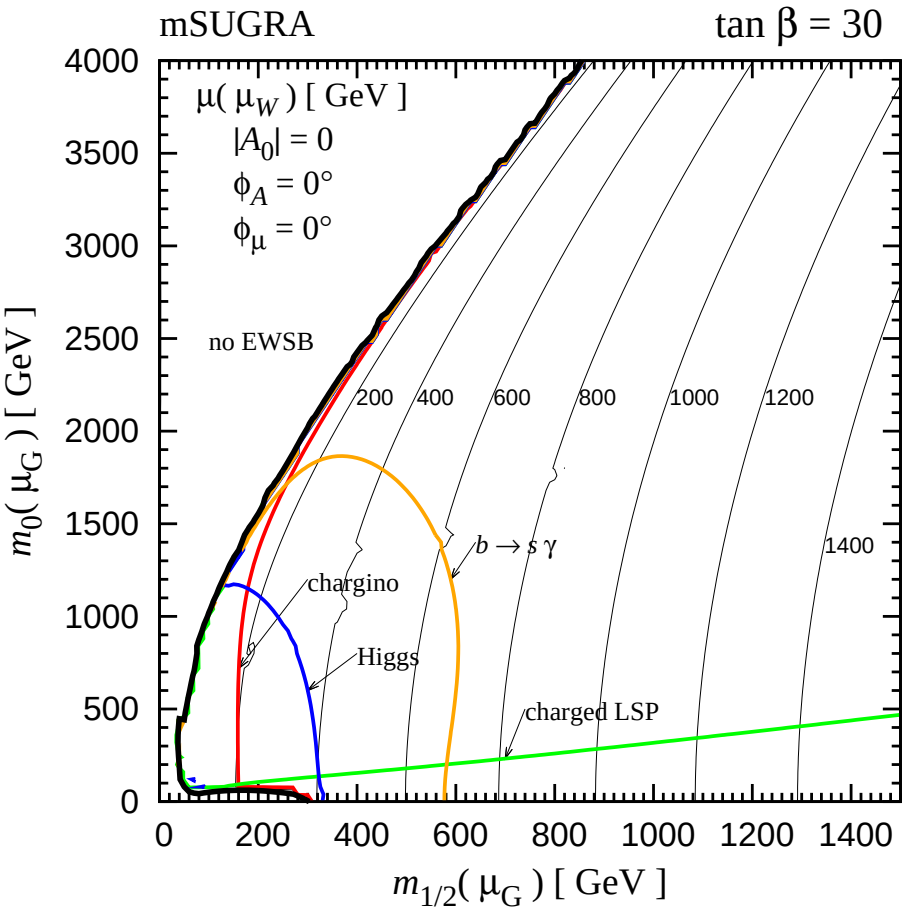
- Deviations are small in mSUGRA and MSSM$\oplus\nu_R$.
- Reducing theoretical (hadronic) uncertainties in SM predictions to $O(\%)$ level is important.

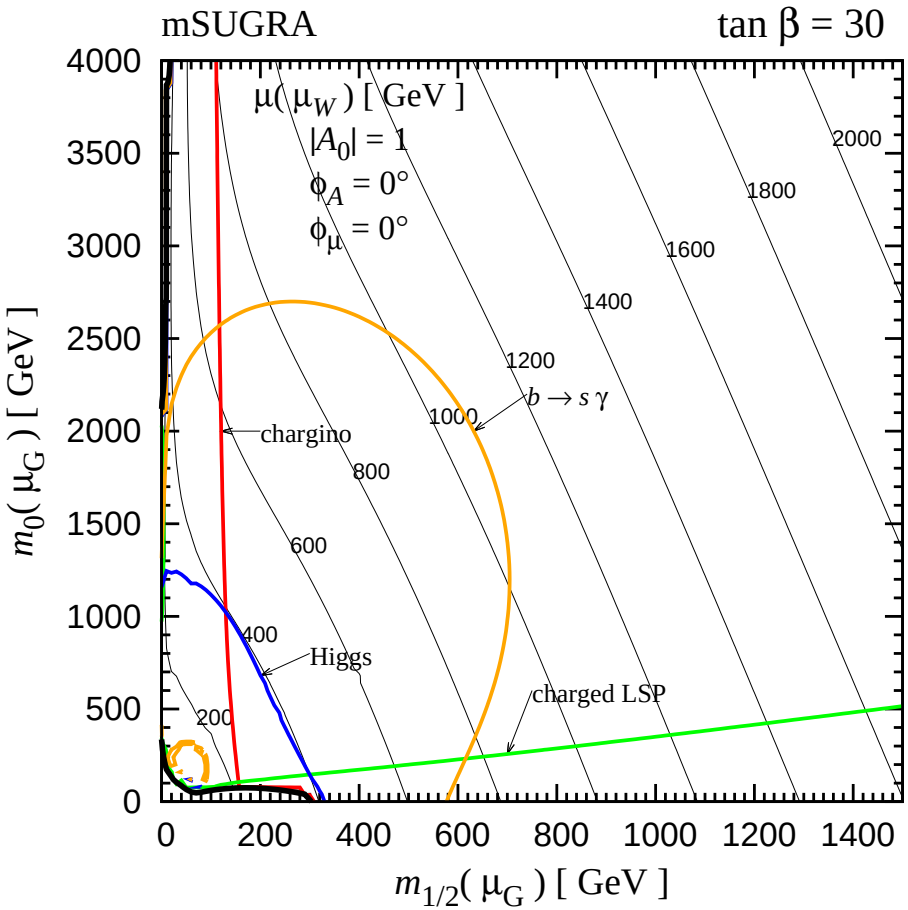
Conclusion

- Quark and lepton flavor signals are studied for SUSY models with various flavor structures.
- Each model gives different pattern of signals in $b \to s$, $b \to d$ and LFV processes.
- Measuring many processes is important to explore flavor structure of new physics beyond the SM.

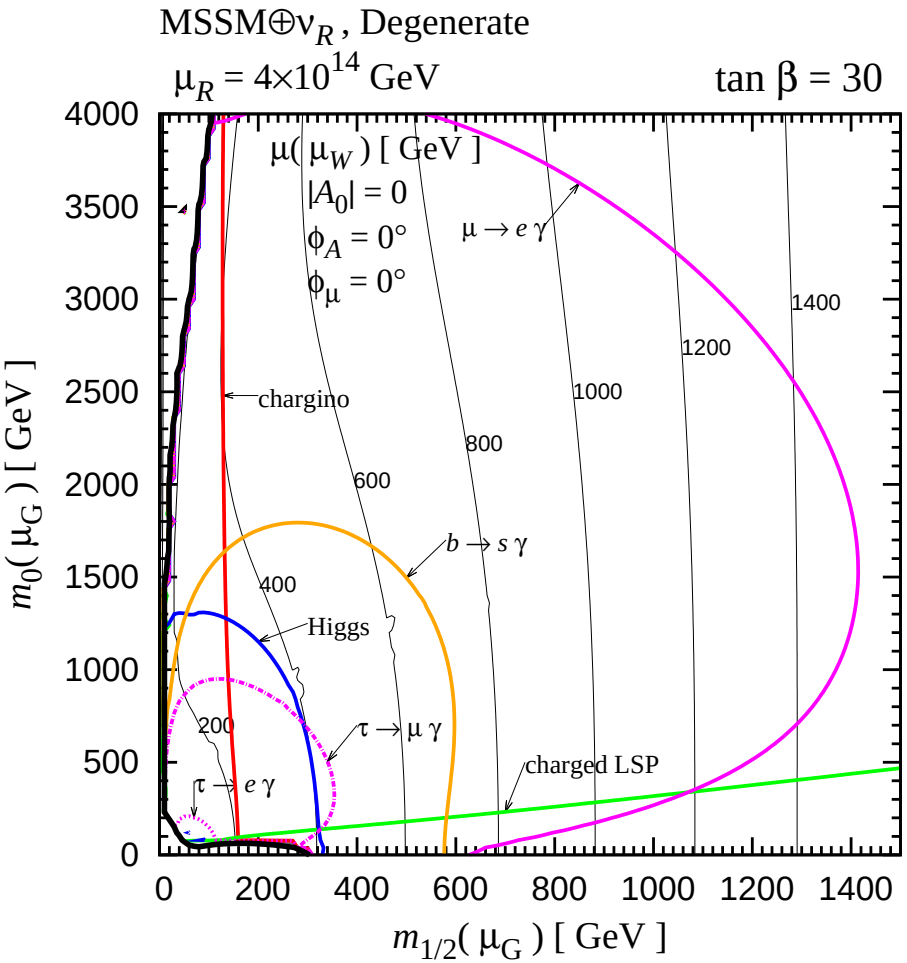
Backup Slides

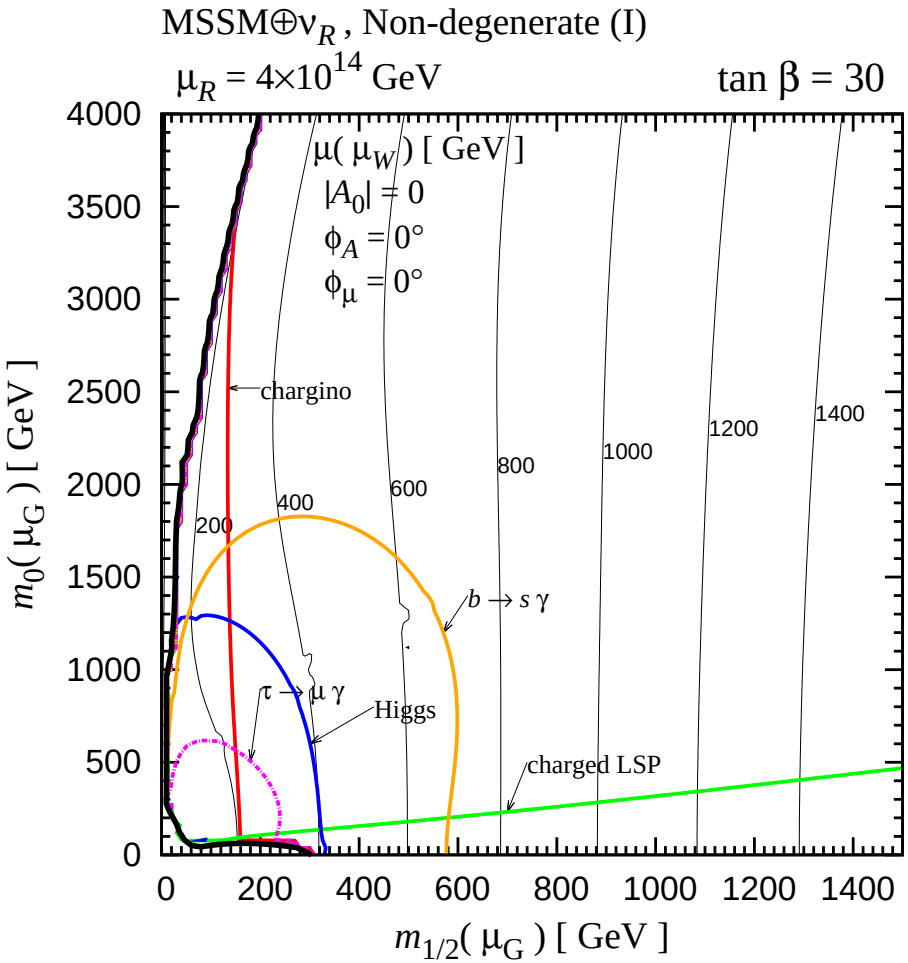
Allowed parameter space: mSUGRA



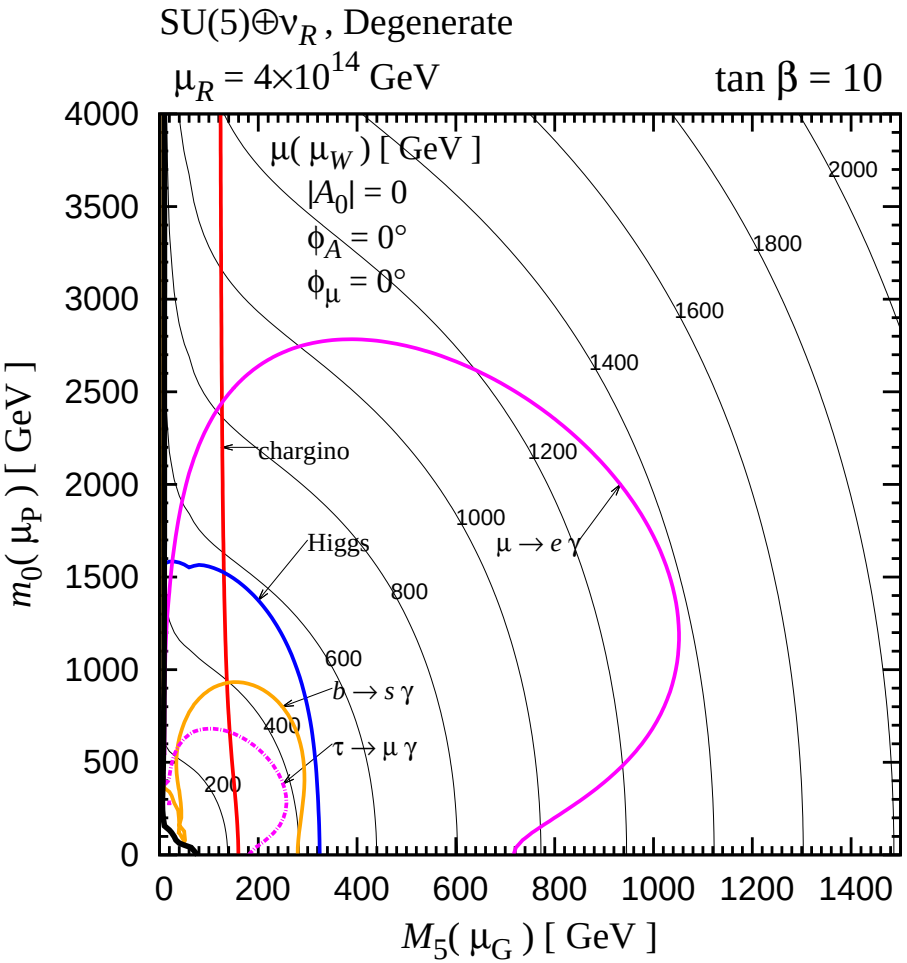


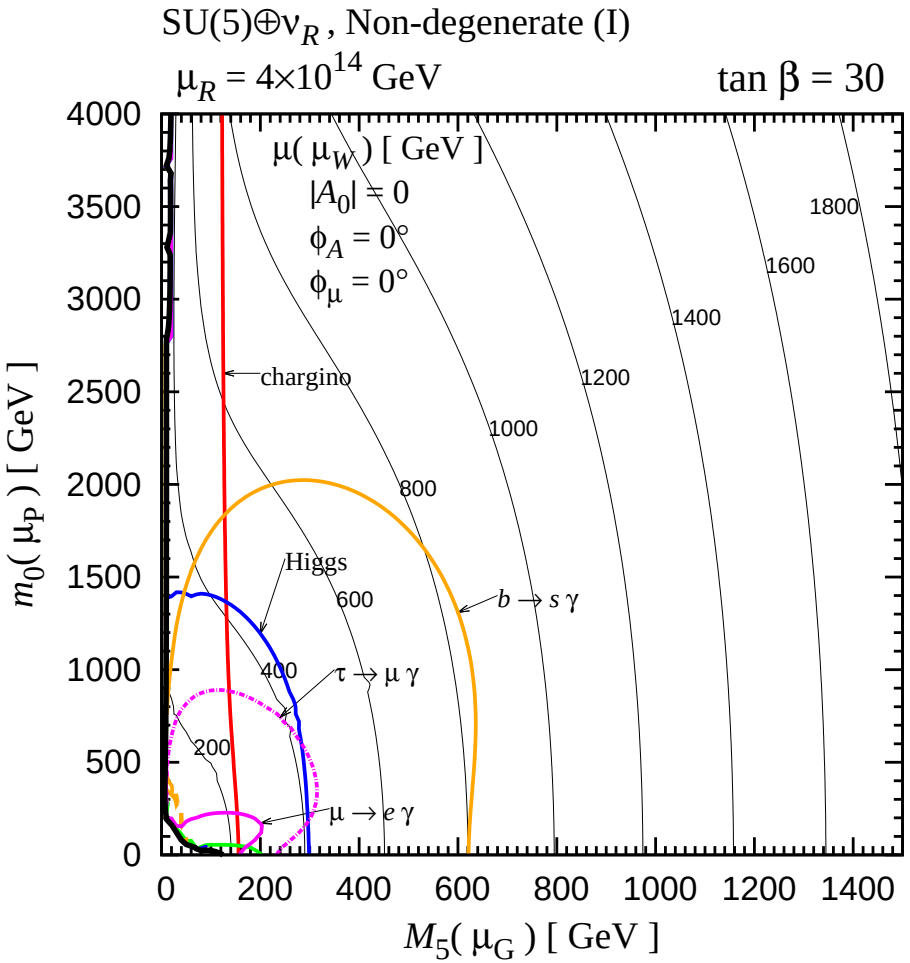
Allowed parameter space: MSSM$\otimes\nu_R$



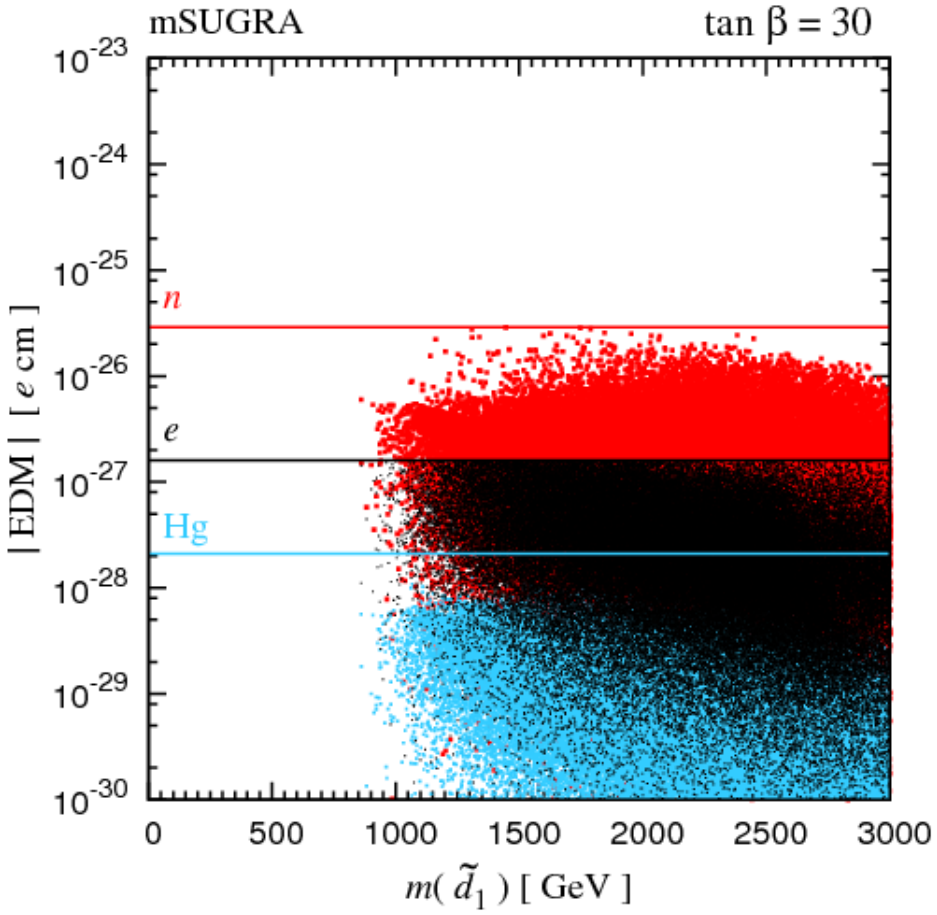


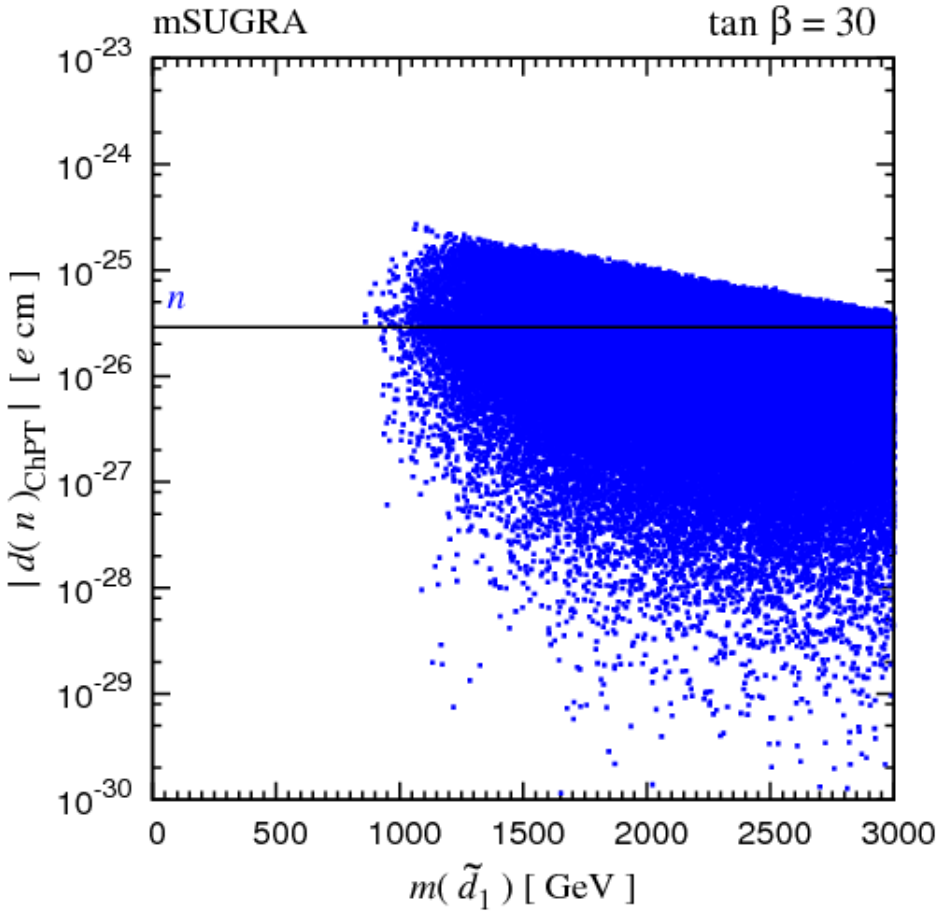
Allowed parameter space: SU(5)$\otimes\nu_R$





Neutron EDM: naive quark model vs. chiral perturbation theory





Source: ϕ_A.