
Unitarity triangle and rare decays in SUSY models

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2nd Workshop on the Discovery Potential
of an Asymmetric B Factory at 10^{36} Luminosity
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Contents

1. Unitarity triangle and rare decays in minimal Supergravity model with/without SU(5) GUT with right-handed neutrinos.
(Summary and updates of the analysis shown at the May workshop.)
2. Case for Snowmass points and slopes.

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Unitarity triangle and rare B decays in three SUSY models

- In order to illustrate how B physics is useful to explore the SUSY breaking sector, we consider four cases in three models.
 1. Minimal supergravity model
 2. SU(5) SUSY GUT with right-handed neutrino
 - 2-1. degenerate case
 - 2-2. non-degenerate case
 - (3. MSSM with U(2) flavor symmetry: shown in May)
- We study various flavor signals
 - CP violation in K-K mixing (ε).
 - Bd-Bd mixing, Bs-Bs mixing.
 - Mixing-induced CP violation in $B \rightarrow J/\psi K_s$, $B \rightarrow \phi K_s$, $B \rightarrow M_s \gamma$.
 - Direct CP violation in $b \rightarrow s \gamma$.

1. Minimal Supergravity model

Universal scalar masses at the Planck scale. The CKM matrix is the only source of the flavor mixing.

2. SU(5) SUSY GUT with right-handed neutrino (RHN)

The neutrino Yukawa coupling is another source of flavor mixing in quark sector.

Neutrino mass
$$m_\nu = y_\nu^T \frac{1}{M_R} y_\nu (v^2 \sin^2 \beta / 2)$$

Slepton mass
(Right-handed sdown mass)
$$(\delta m_L^2)^{ij} \cong -(y_\nu^\dagger y_\nu)^{ij} \cdot (3 + |A_0|^2) \ln(M_P / M_R) / 8\pi^2$$

2-1. Degenerate case

$$(M_R)_{ij} = M \delta_{ij}$$

Severe $\mu \rightarrow e\gamma$ constraint

2-2. Non-degenerate case

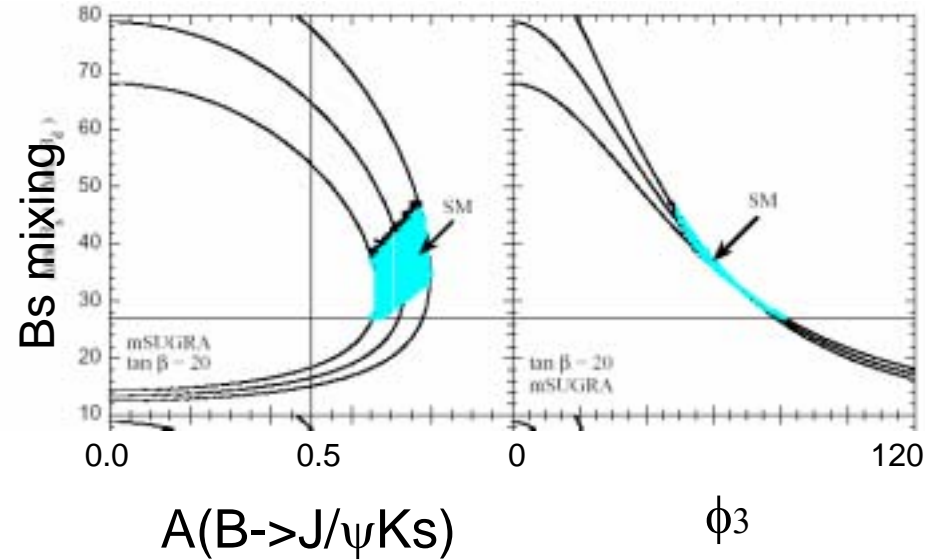
$$y_\nu^\dagger y_\nu = \begin{pmatrix} Y_{11} & 0 & 0 \\ 0 & Y_{22} & Y_{23} \\ 0 & Y_{23}^* & Y_{33} \end{pmatrix}$$

$\mu \rightarrow e\gamma$ suppressed

Unitarity triangle

mSUGRA : small deviation
 Degenerate : 1-2 mixing
 Non-degenerate : 2-3 mixing

mSUGRA

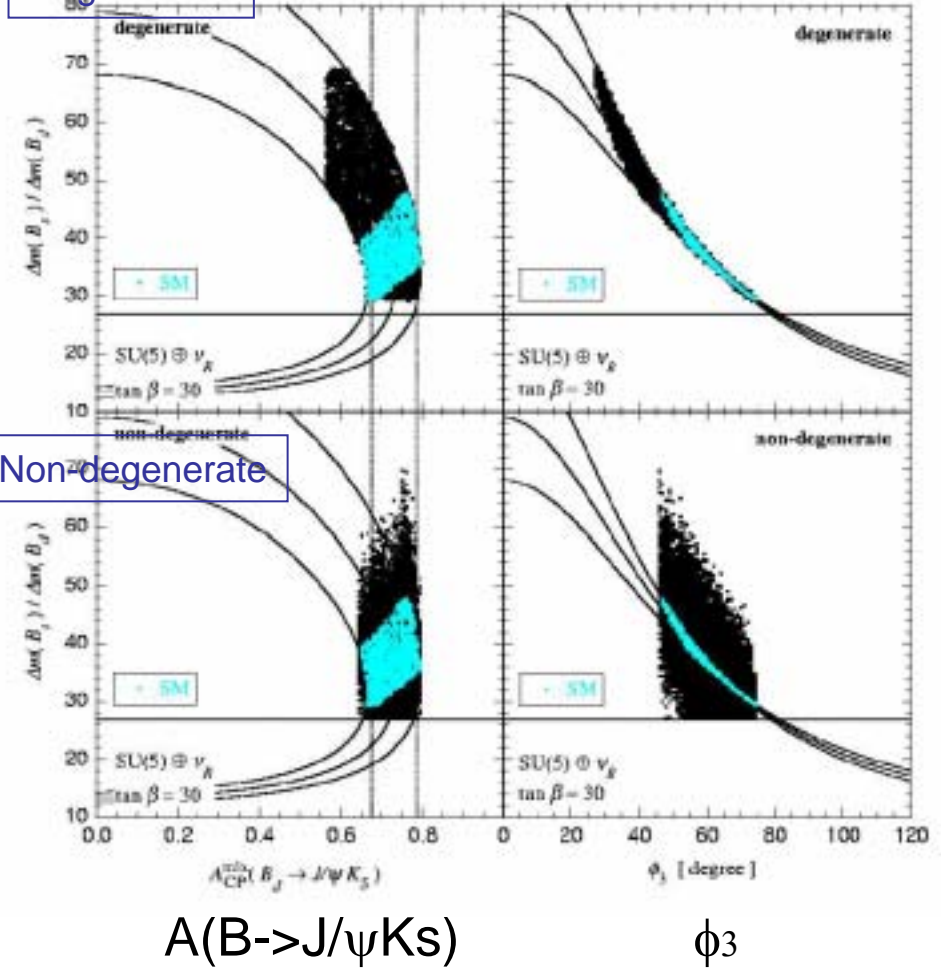


SU(5) SUSY GUT with RHN

Degenerate

B_s mixing

Non-degenerate



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Rare B decays

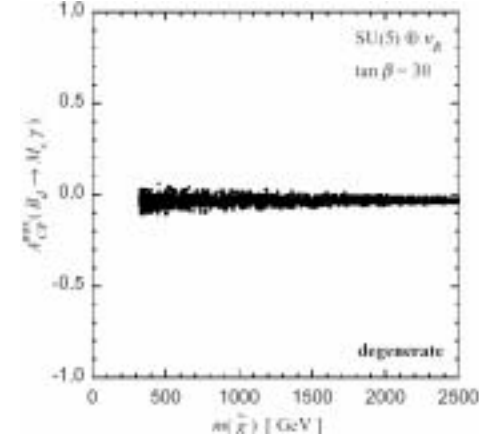
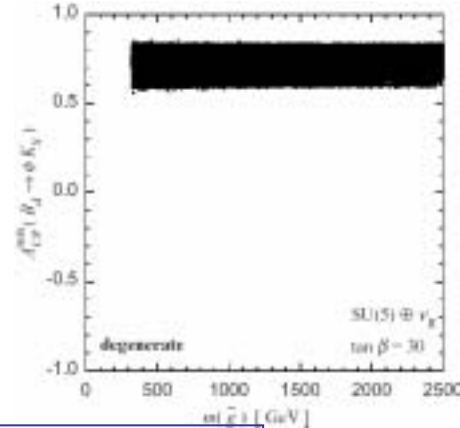
A correlation between $A(B \rightarrow \phi K_s)$ and the s-quark EDM is pointed out. A constraint from the Hg EDM is strong. (J.Hisano and Y.Shimizu, 2003)

SU(5) SUSY GUT with RHN

Degenerate

$A(B \rightarrow \phi K_s)$

$A(B \rightarrow M_s \gamma)$

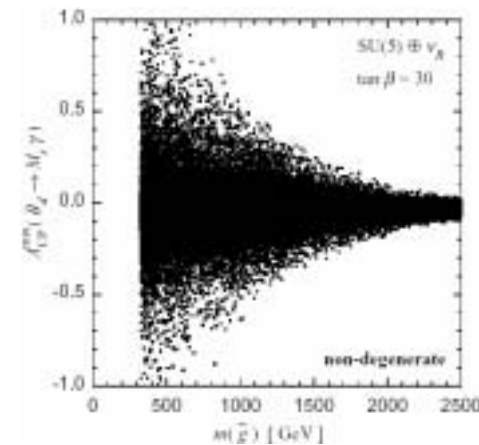
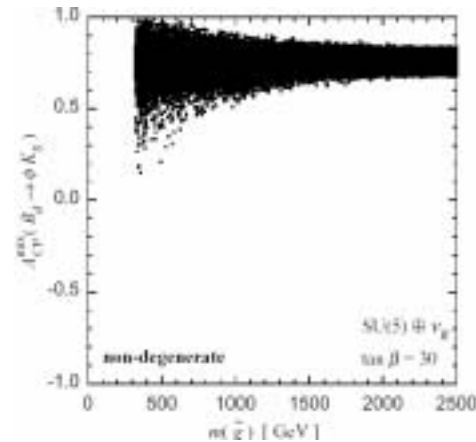
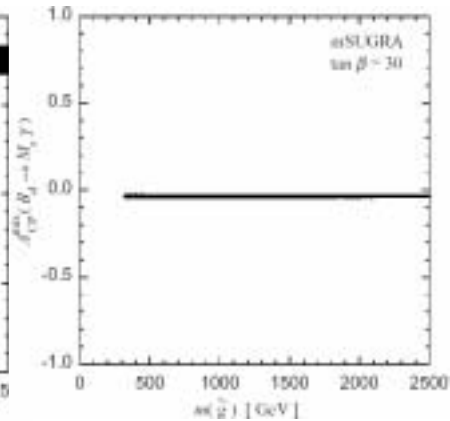
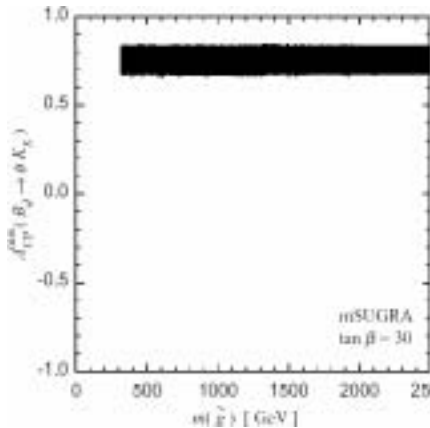


mSUGRA

$A(B \rightarrow \phi K_s)$

$A(B \rightarrow M_s \gamma)$

Non-degenerate



Hg EDM constraint included

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Pattern of the deviation from the SM in various SUSY models.

$\checkmark\checkmark$ large deviation
 \checkmark sizable deviation
 $—$ small deviation

	Bd-unitarity	ε	$\Delta m(B_s)$	$B \rightarrow \phi K_s$	$B \rightarrow M_s \gamma$ indirect CP	$b \rightarrow s \gamma$ direct CP
mSUGRA	closed	—	—	—	—	\checkmark
SU(5)SUSY GUT + ν_R (degenerate)	closed	$\checkmark\checkmark$	—	—	\checkmark	—
SU(5)SUSY GUT + ν_R (non-degenerate)	closed	—	$\checkmark\checkmark$	$\checkmark\checkmark$	$\checkmark\checkmark$	\checkmark
U(2) Flavor symmetry	$\checkmark\checkmark$	$\checkmark\checkmark$	$\checkmark\checkmark$	$\checkmark\checkmark$	$\checkmark\checkmark$	$\checkmark\checkmark$

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Snowmass Points and Slopes (SPS)

Benchmark points and model lines for SUSY studies mostly for LHC/LC.

B.Allanach et al, Eur. Phys. J. C25, 113 (2002)

We consider benchmark lines for the two cases of SU(5) GUT with RHN.

Can B physics distinguish different models, even if the SUSY spectrum is the same as (similar to) the mSUGRA case?

Diagonal term : Benchmark

Off-diagonal term : GUT interaction

$$(m_{\tilde{q}}^2)_{ij} = \begin{pmatrix} m_{11}^2 & m_{12}^2 & m_{13}^2 \\ m_{21}^2 & m_{22}^2 & m_{23}^2 \\ m_{31}^2 & m_{32}^2 & m_{33}^2 \end{pmatrix}$$

Complementarity of LHC and Super B factory

SPS is defined by mSUGRA inputs

$$m_0, m_{1/2}, A_0, \tan \beta, (\mu > 0)$$

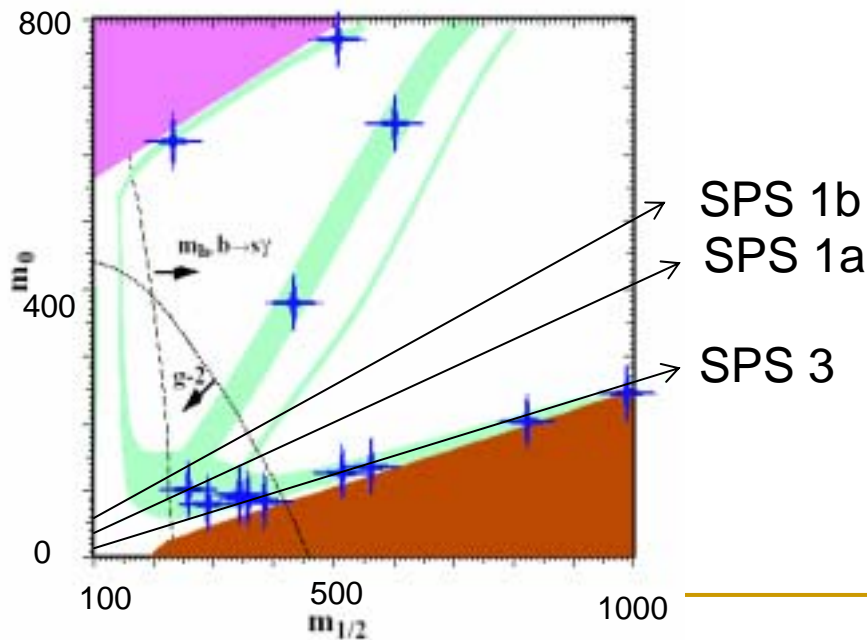
Typical points

SPS 1a $m_0 = -A_0 = 0.4m_{1/2}, \tan \beta = 10$

“**SPS 1b**” $m_0 = 0.5m_{1/2}, A_0 = 0, \tan \beta = 30$

Coannihilation region **SPS 3**

$$m_0 = 0.25m_{1/2} - 10\text{GeV}, A_0 = 0, \tan \beta = 10$$

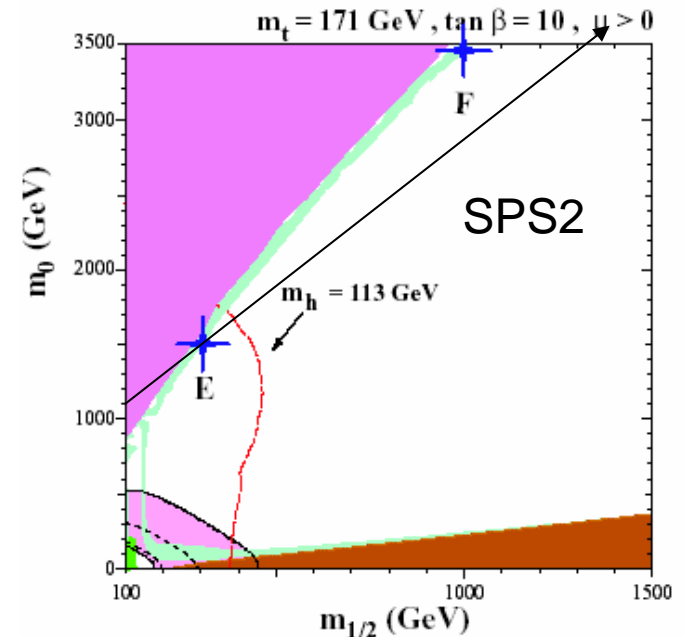


Focus point

SPS 2

$$m_0 = 2m_{1/2} + 850 \text{ GeV}$$

$$A_0 = 0, \tan \beta = 10$$



M.Battaglia, et al, 2001

ϵ_K and B_s mixing

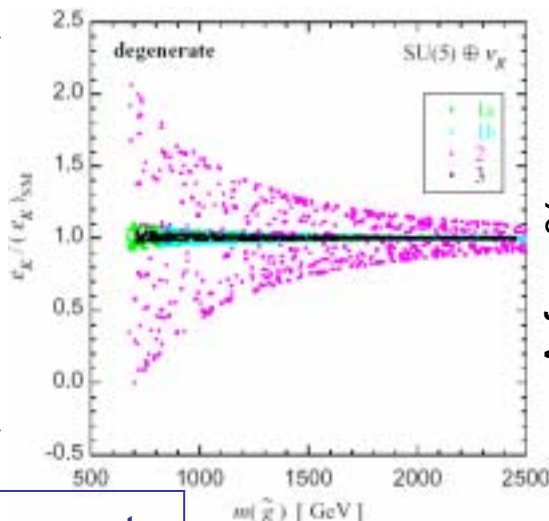
Degenerate

$$\epsilon_K / (\epsilon_K)_{SM}$$

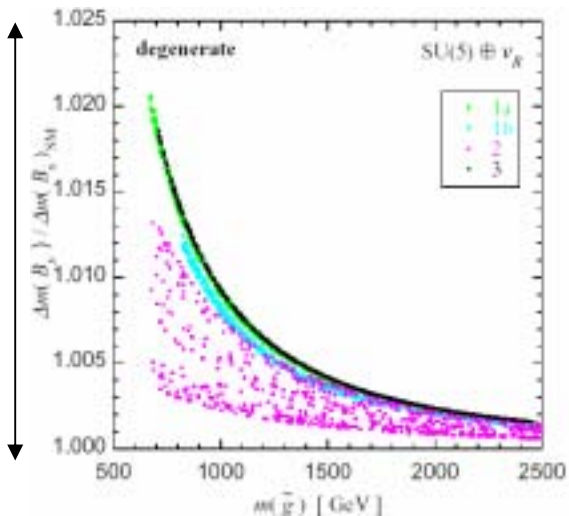
$$\Delta m_{B_s} / (\Delta m_{B_s})_{SM}$$

Input parameters.
 SUSY parameters : SPS
 Neutrino parameters: fixed
 (Hierarchical neutrino masses with
 $M_R \sim O(10^{14})$ GeV)
 GUT phases: varied

$O(1)$



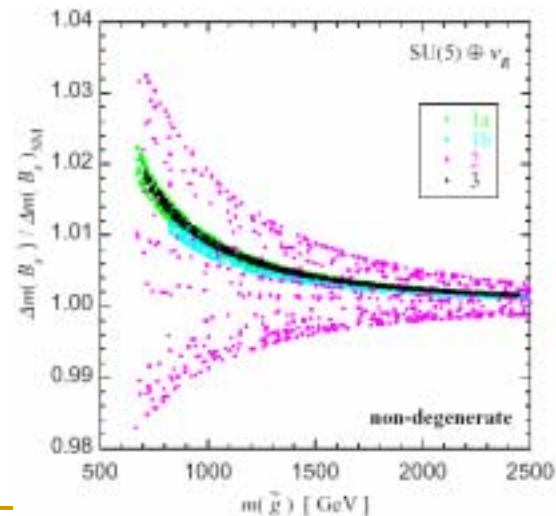
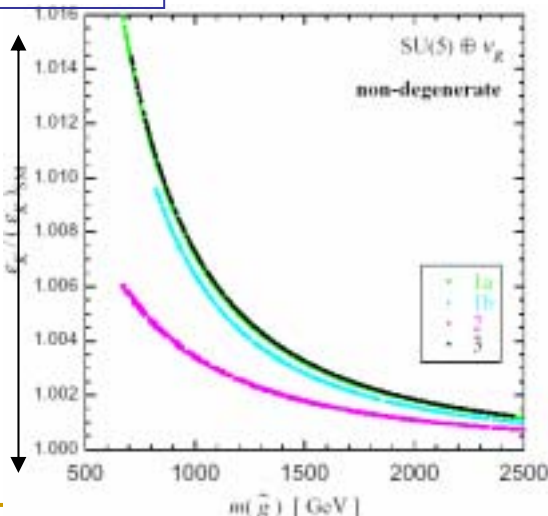
A few %



Non-degenerate

Deviation is small
 except for ϵ_K in the
 degenerate case
 of SPS2.

A few %

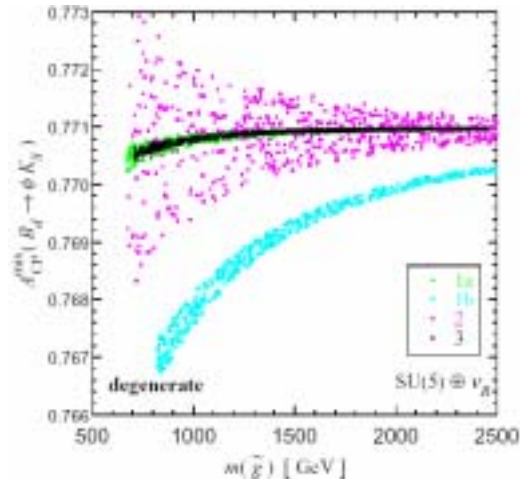


Rare decays with $b \rightarrow s$ transition

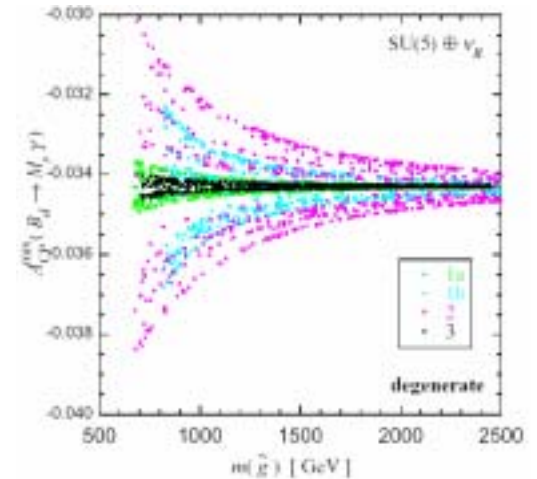
Degenerate

Less than 1%

$A(B \rightarrow \phi K_s)$

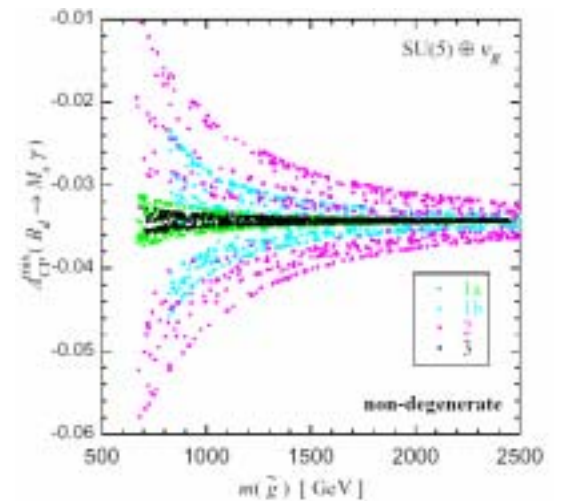
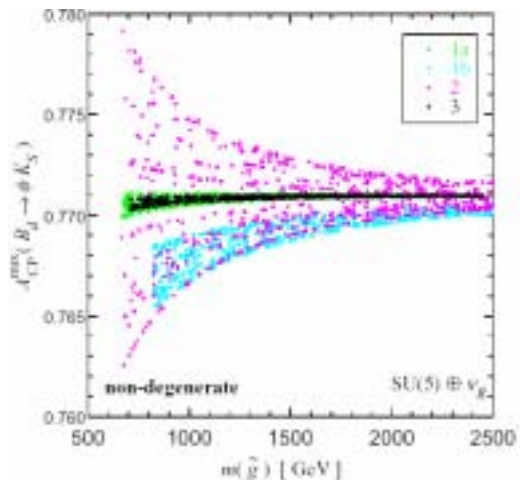


$A(B \rightarrow M_s \gamma)$



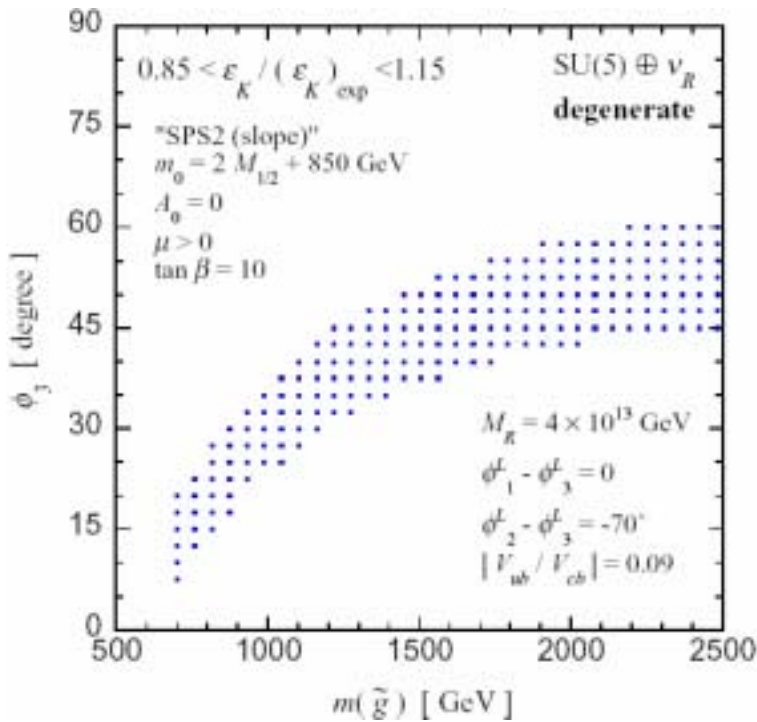
Non-degenerate

A few %

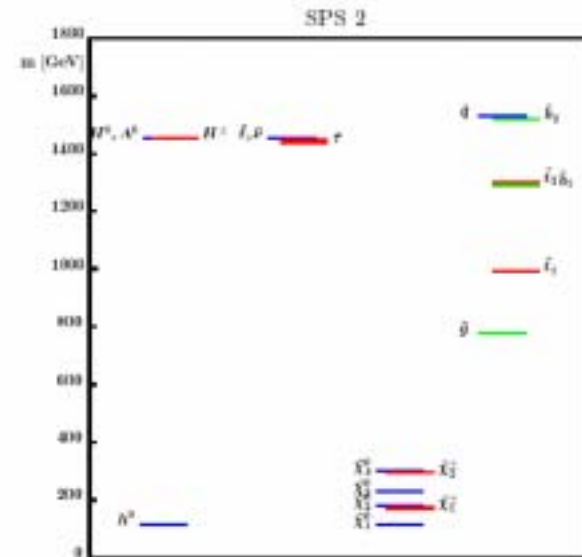
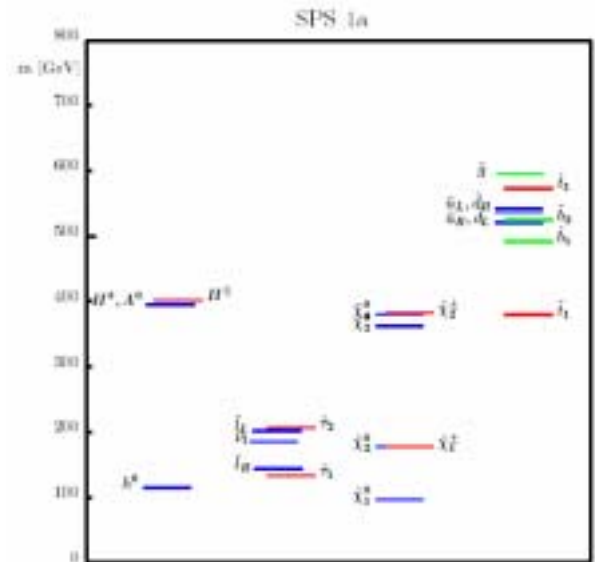


Deviation is not so large even for the non-degenerate case.

In SPS2 (Focus point), ϕ_3 can be different from the SM prediction.
 Inconsistency between the Bd unitarity and ϵ_K .



The squark mass splitting is larger for SPS 2.

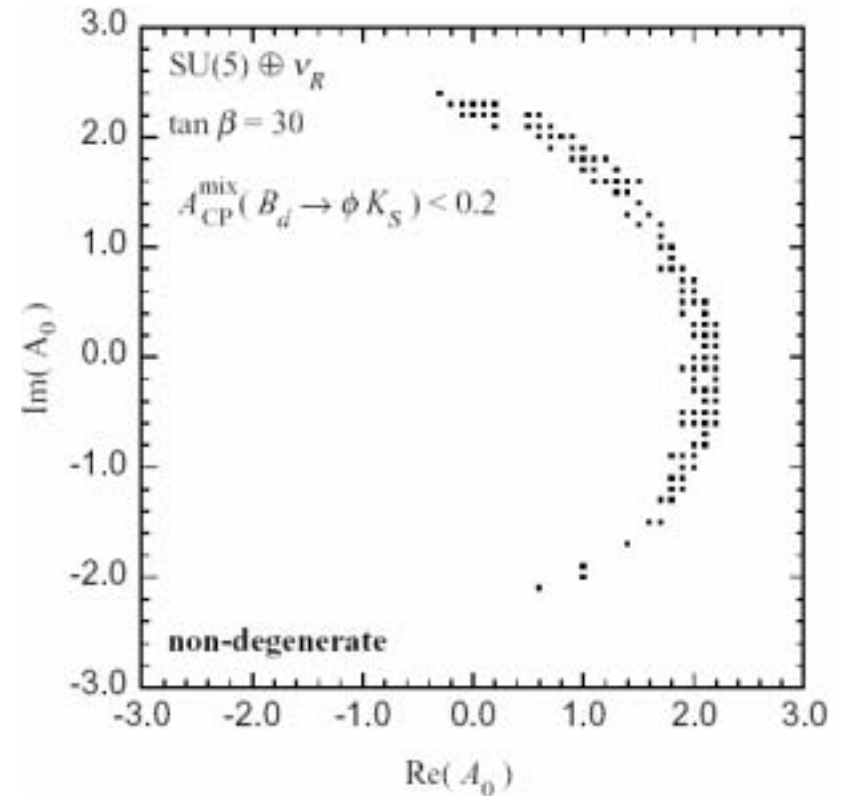


On the SPS lines, no large enhancement of the b-s transition is seen in $B \rightarrow \phi K_S$ and $b \rightarrow s \gamma$.

These lines do not seem to correspond to the parameter space of a large deviation.

The value of A_0 seems to be important to have a large deviation.

The range of A_0 for large deviations in the b-s transition.



Summary

- We studied the unitarity triangle and the b - s transition in rare B decays for two cases of $SU(5)$ SUSY GUT with right-handed neutrinos.
- A large deviation is possible in the 1-2 transition for the degenerate case, and in the 2-3 transition for the non-degenerate case.
- We also studied the parameter space based on Snowmass Points and Slopes (SPS).

The deviation due to ϵ_K be sizable for SPS 2 (focus points) in the degenerate case.