Searching for SUSY in B Decays

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New era of B physics

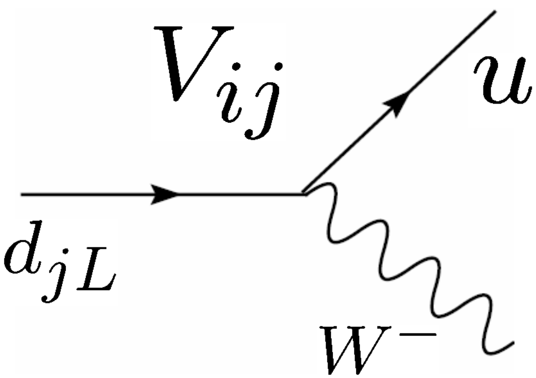
- Two B factory experiments Belle at KEKB and BABAR at PEPII are very successful.

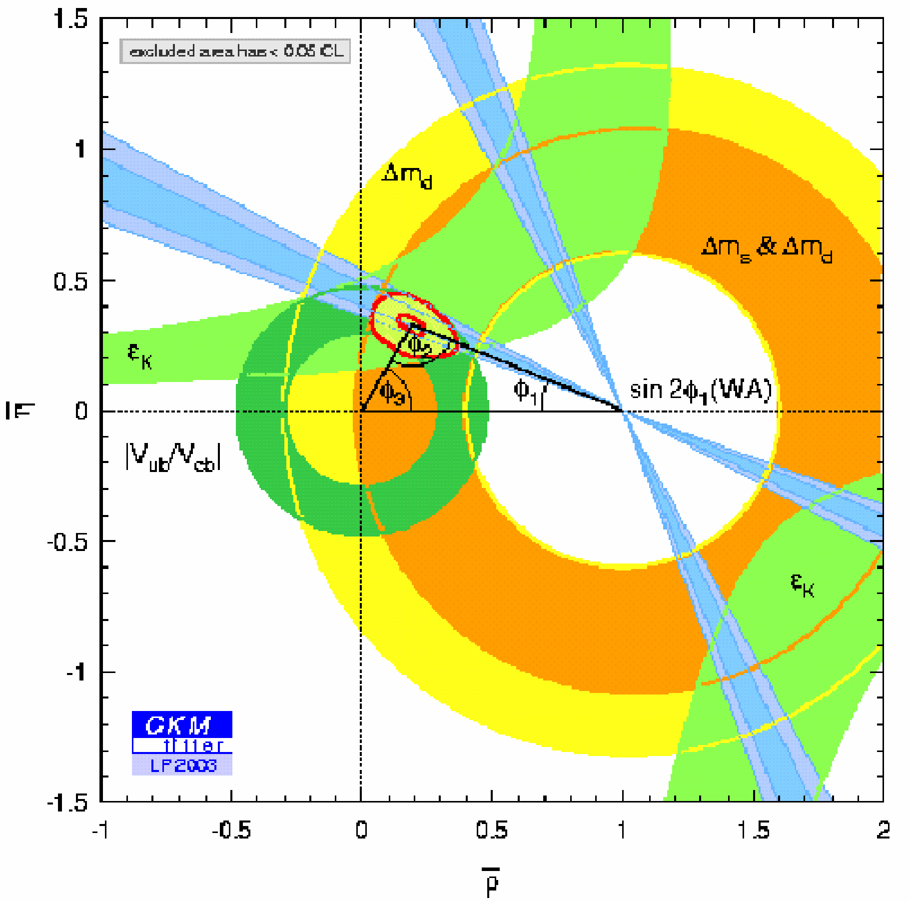
  (~290/fb at KEKB and ~250/fb at PEPII)
- The asymmetric B factories provides measurements of time-dependent CP violations in B decays.
- In future, more B physics will come at hadron machines (Tevatron, LHCb) and upgrade of the current B factories as well as Super B Factory

  (5-10/ab/year).

Achievement of current B factories

- Established the Kobayashi-Maskawa mechanism of CP violation in the quark sector.
- All quark flavor mixing and CP violation phenomena can be explained by the CKM matrix.





Goals of future B physics

- Main purpose of B physics from now on is to search for new physics effects in flavor-mixing and CP violation.
- There are several ways to look for new physics in CP violation and rare B decay processes.
- In order to identify a new physics model, we need to know pattern of the deviations from the SM predictions in various observables.

SUSY and Flavor Physics

- SUSY modes introduce SUSY partners.
- Squark mass matrixes are new sources of flavor mixing and CP violation.
- Squark masses depend on SUSY breaking terms as well as the Yukawa coupling constants.

quark (q)	squark $(\tilde{q})$
lepton (l)	slepton $(\tilde{l})$
gluon (g)	gluino $(\tilde{g})$
W,Z,γ,H	neutralino, chargino $(\tilde{\chi})$

Quark mass $$(m_q)_{ij} = Y_{ij} v$$

Squark mass $$(m^2_{\tilde{q}})_{ij} = (Y^\dagger Y)_{ij} v^2 + m^2_{ij}$$

SUSY breaking

- Squark mass matrixes carry information on the SUSY breaking mechanism and interactions at the GUT scale.

Origin of SUSY breaking
(mSUGRA, AMSB, GMSB, Flavor symmetry, etc.)

↓ ← Renormalization
(SUSY GUT, neutrino Yukawa couplings etc.)

SUSY breaking terms at the Mw scale
(squark, slepton, chargino, neutralino, gluino masses)

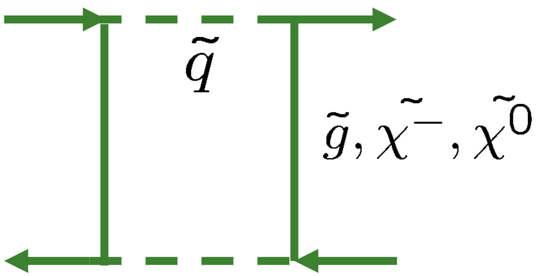
Diagonal : LHC/LC
Off-diagonal: Future Flavor exp.

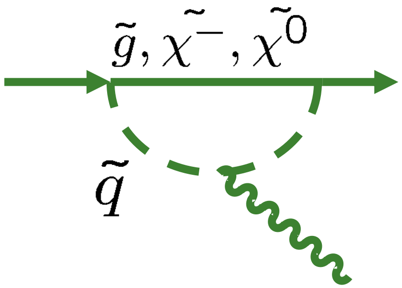
$$(m^2_{\tilde{q}})_{ij} = \begin{pmatrix} m^2_{11} & m^2_{12} & m^2_{13} \\ m^2_{21} & m^2_{22} & m^2_{23} \\ m^2_{31} & m^2_{32} & m^2_{33} \end{pmatrix}$$

↔ **Top quark: Tevatron**
KM phase: B factories

SUSY loop effects in B physics

SUSY particles contribute to various box and penguin amplitudes.



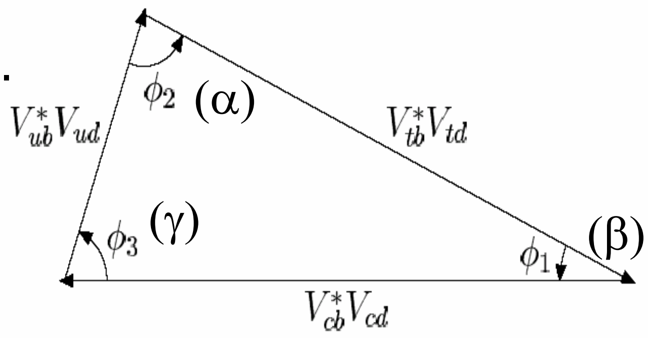


Different processes are sensitive to different aspects of loop amplitudes.

Various ways to search for new physics effects

1. **Bd-unitarity triangle**

   –> New contributions to the Bd mixing amplitude.

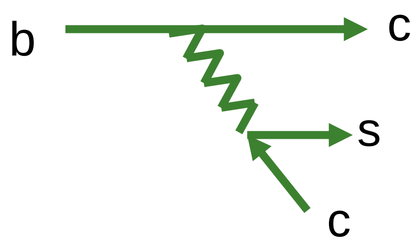


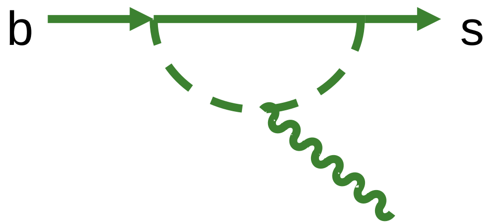
2. **Bs mixing and CP asymmetry in Bs –>J/ψ ϕ**

   –> The magnitude and the phase of the Bs mixing amplitude.

3. Comparison of CP asymmetries from B –>J/ψKs, B –>φKs, B –>η'Ks.

–> A new CP phase in the b-s-g amplitude. These should be the same in the SM.





4. Direct CP asymmetry in b –> s γ

–> A new CP phase in b-s-γ amplitude.
~0.4 % in the SM

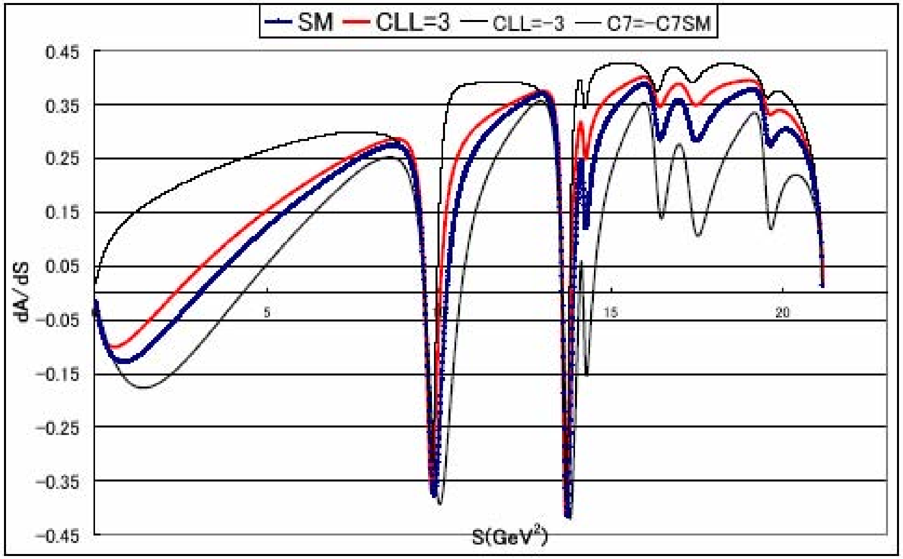
5. Time-dep CP asymmetry in B –>Ms γ (ex. K*γ)

–> Co-existence of b –> s γ_L and b –>s γ_R .
0(ms/mb) in the SM.

6. Branching ratio and lepton forward-backward asymmetry of b –>s ll.

–> Various tensor structures.

Forward-backward asymmetry in b->s ll in various cases..

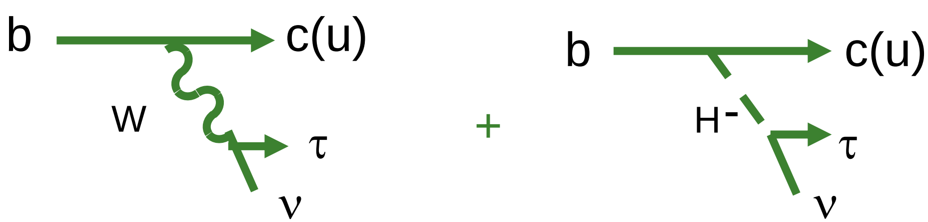


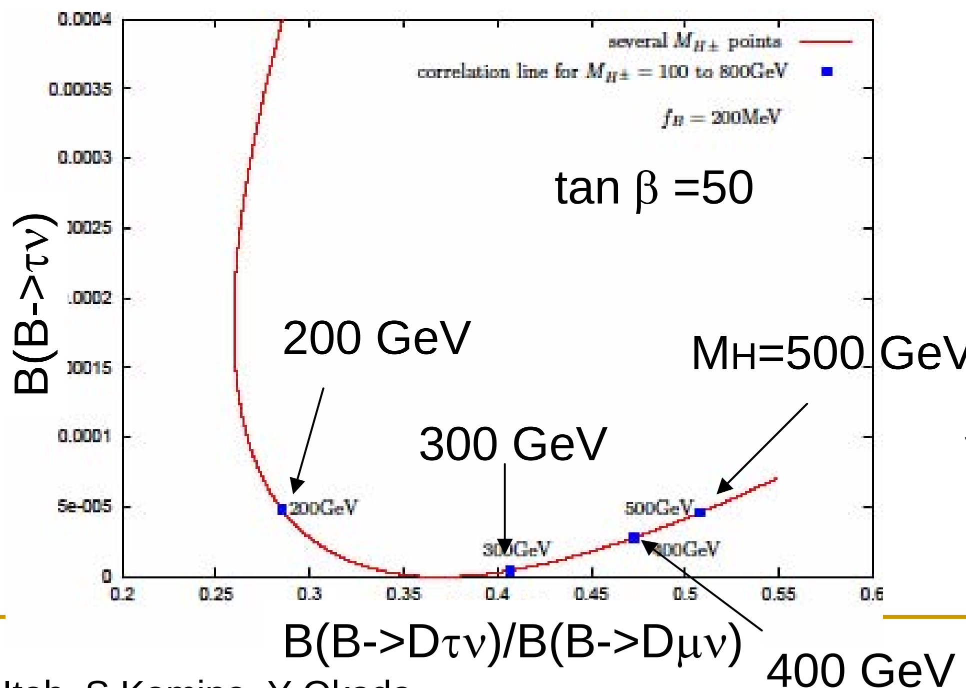
S.Fukae, C.S.Kim, T.Morozumi,T.Yoshikawa

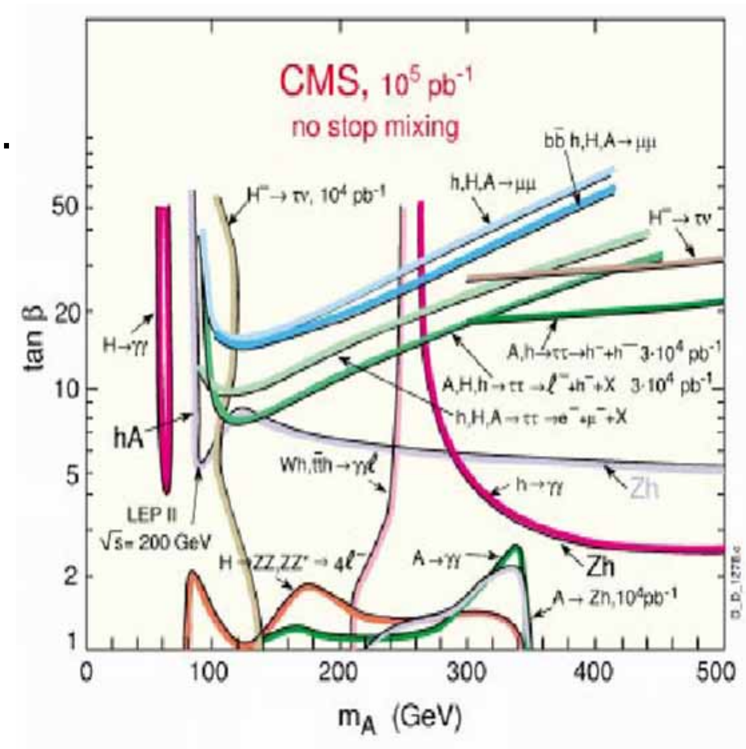
Tauonic B decay, B->D τν, B->τν

Charged Higgs boson exchange.

Cover the parameter space comparable to the LHC heavy Higgs boson search in MSSM.







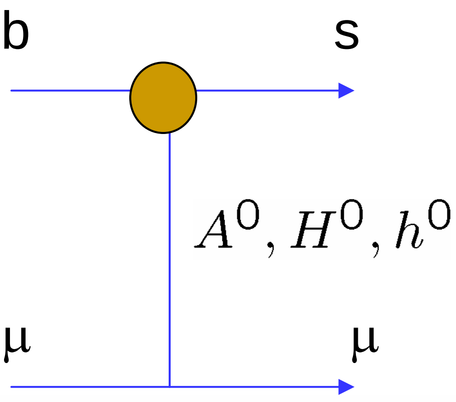
Super KEKB sensitivity form B->Dτν

$$M_H < M_W \tan\beta/11 \text{ @5/fb}$$

H.Itoh, S.Komine, Y.Okada

B(Bs->μμ)

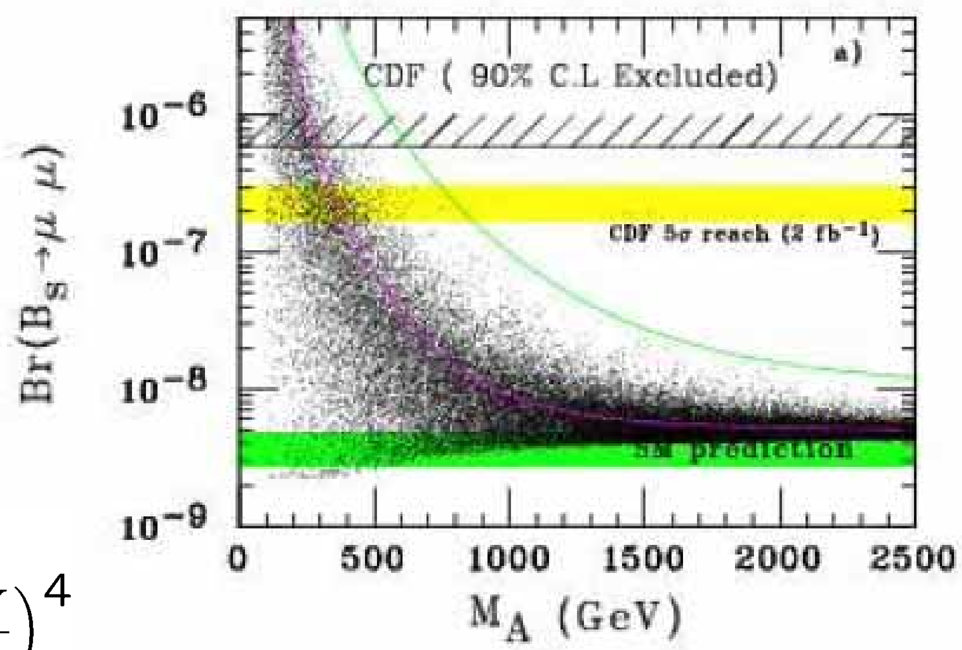
Loop-induced neutral Higgs exchange effects



- SUSY loop corrections can enhance B(Bs->μμ) by a few orders of magnitude from the SM prediction for large values of tan β.

  This is within the reach of Tevatron exp.

$$B(B_s \to \mu\mu) \sim 5 \times 10^{-7} \left(\frac{\tan\beta}{50}\right)^6 \left(\frac{300GeV}{M_A}\right)^4$$



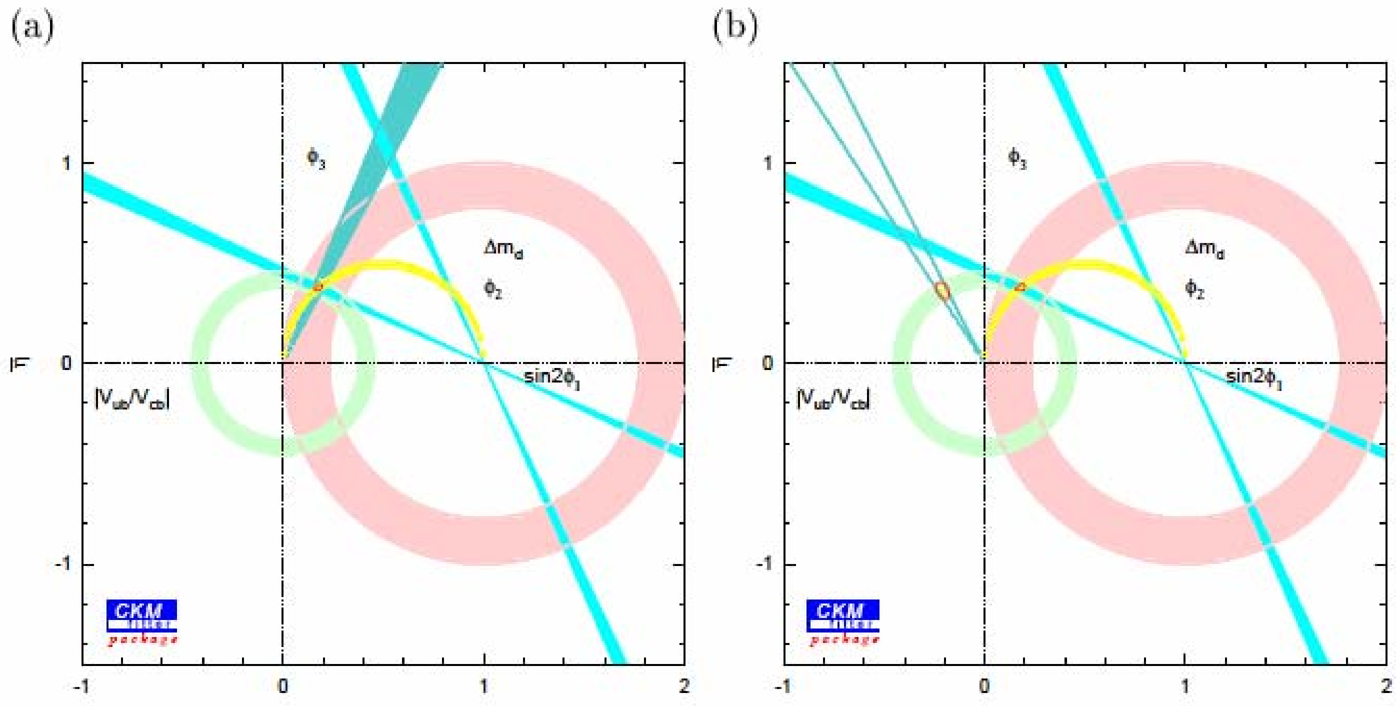
A.Dedes, B.T.Huffman

Sensitivity in future Super B Factory

Physics potential of Super B Factory at 5/ab and 50/ab has been studied.

Super KEKB LoI ,hep-ex/0406071

Expected improvement of the Bd triangle determination by $\phi 1$, $\phi 2$, $\phi 3$, |Vub| and Δm(Bd) at the Super B Factory (50/fb)

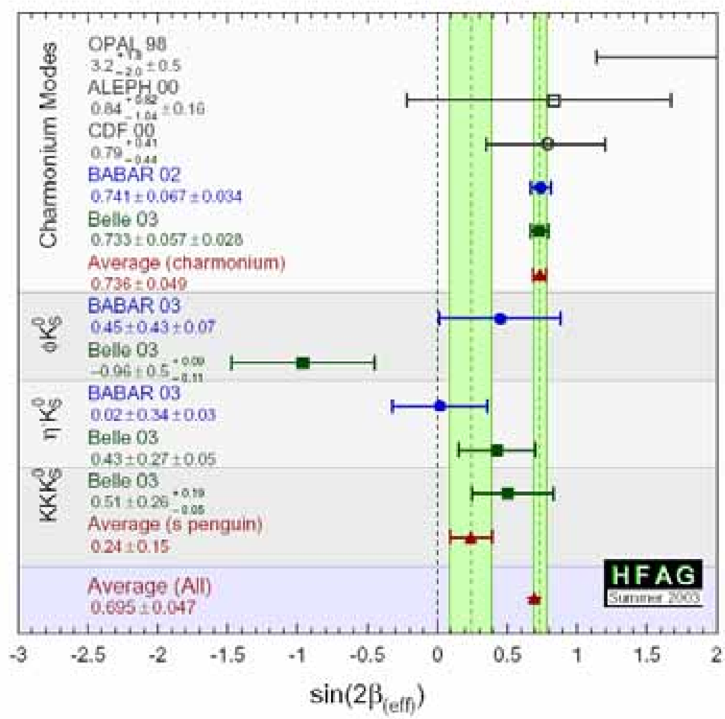


Consistent with the SM

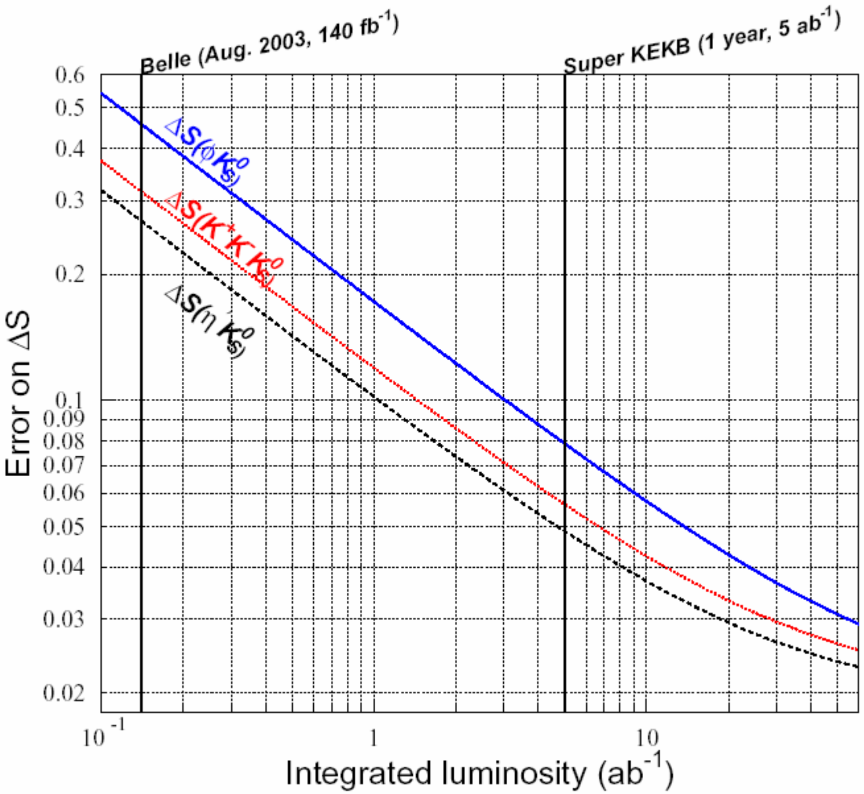
Deviation observed

Time dependent CP asymmetry in various modes

Current experimental results on time-dependent CP asymmetries



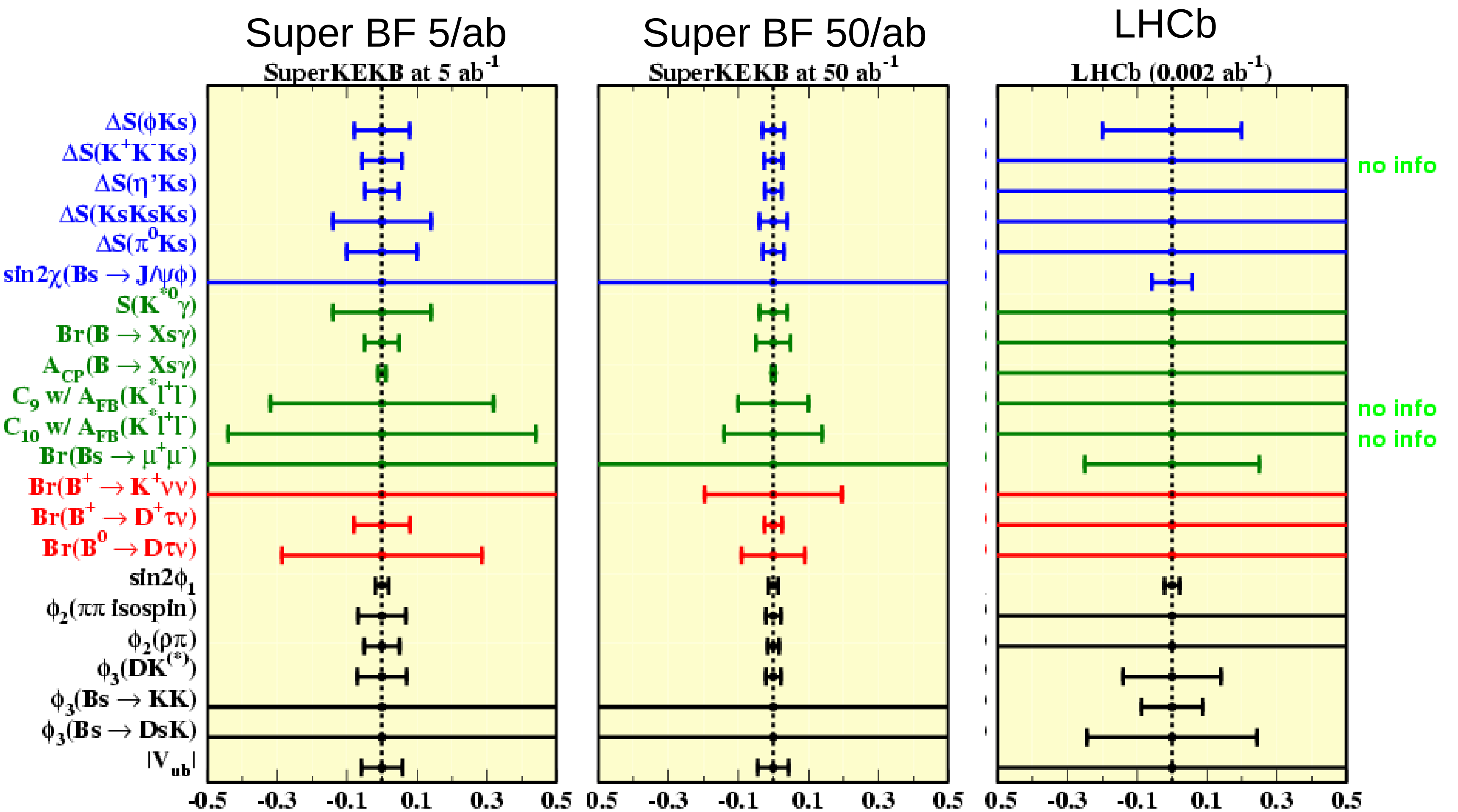
Future prospects



In order to confirm the anomaly of b-s transition, we need a large luminosity (>a few /ab)

Summary of physics reach

Super KEKB LoI



Complementarity between Super B Factory and hadron B programs

Distinguishing different SUSY models

T.Goto, Y.Okada, Y.Shimizu, T.Shindou, and M.Tanaka

- In order to illustrate the potential of B physics in exploring flavor structure of SUSY breaking, we calculate various observables in four cases of SUSY models.

Models

1. Minimal supergravity model
2. SU(5) SUSY GUT with right-handed neutrino

   2-1. degenerate RHN case

   2-2. non-degenerate RHN case
3. MSSM with U(2) flavor symmetry

Obserbavles

- Bd-Bd mixing, Bs-Bs mixing.
- CP violation in K-K mixing (ε).
- Time-dependent CP violation in B ->J/ψKs, B->ϕKs, B->K*γ .
- Direct CP violation in b->s γ.

Three SUSY Models

Origin of the squark mixing

$$(m^2_{\tilde{q}})_{ij} = (Y^\dagger Y)_{ij} v^2 + m^2_{ij}$$

1. Minimal supergravity model. Only the CKM matrix

Minimal Flavor Violation

2. SU(5) SUSY GUT with right-handed neutrino.
   The CKM matrix and the neutrino Yukawa coupling constants
   2-1. degenerate RHN case (μ -> e γ large)
   2-2. non-degenerate case (μ -> e γ suppressed)

Neutrino Flavor Mixing

$$m^2_{ij} \sim c(y^\dagger_\nu y_\nu)_{ij}$$

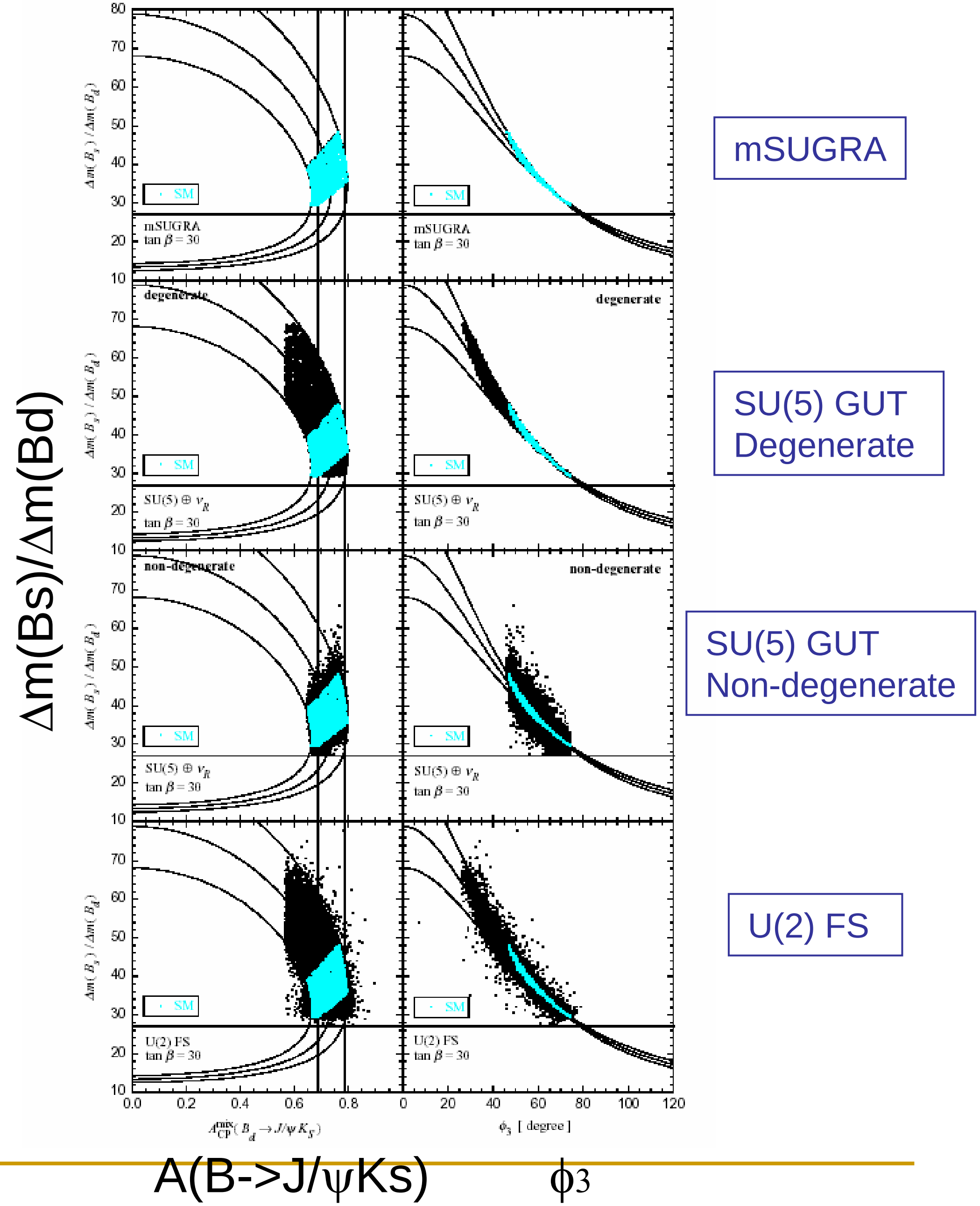
3. MSSM with U(2) flavor symmetry.
   Both Yukawa coupling constants and SUSY breaking terms
   have the (12)-3 structure.

$$(m^2_{\tilde{q}})_{ij} \simeq \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 + O(\epsilon^2) & O(\epsilon) \\ 0 & O(\epsilon) & O(1) \end{pmatrix}$$

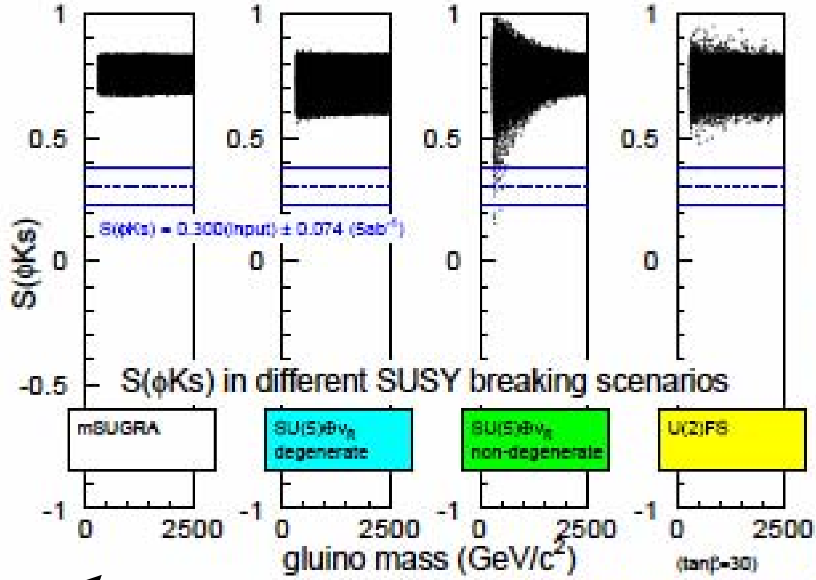
Approximate Flavor Symmetry

Unitarity triangle

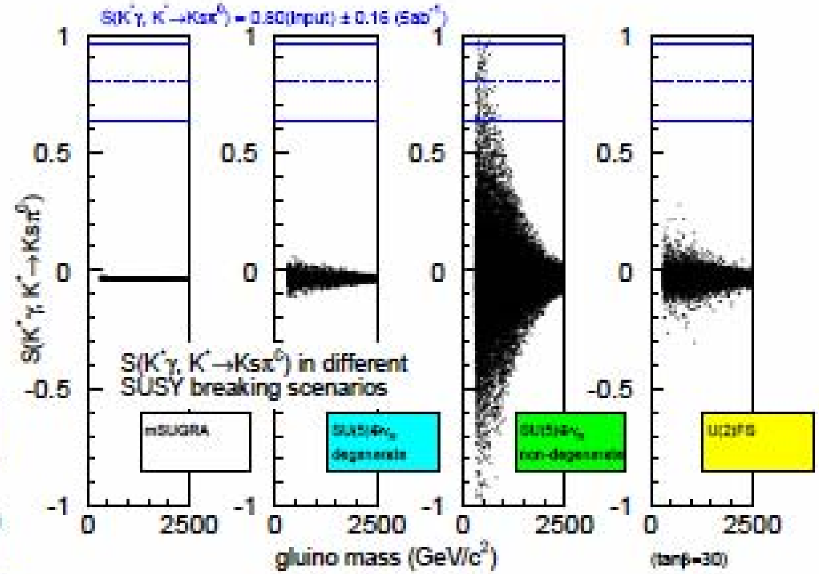
- Small deviationin mSUGRA.
- Bd unitarity triangle is closed, but epsilon_K has a large SUSY contribution in SU(5) GUT for the degenerate M_R case.
- Bs mixing receives SUSY effects for the non-degenerate case.
- Various SUSY conributions for the U(2)flavor symmetry model.



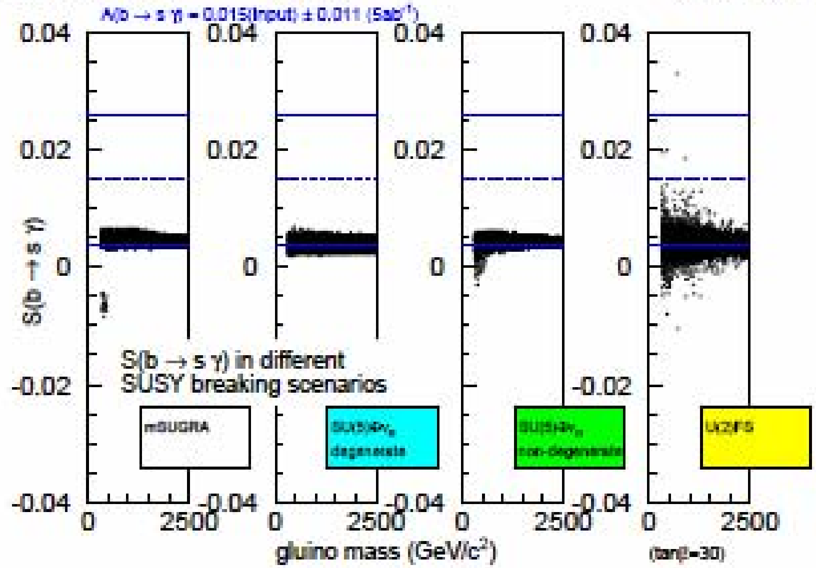
CP asymmetries in B –>ϕ Ks and b–> sγ



CP asymmetry in B –>ϕ Ks

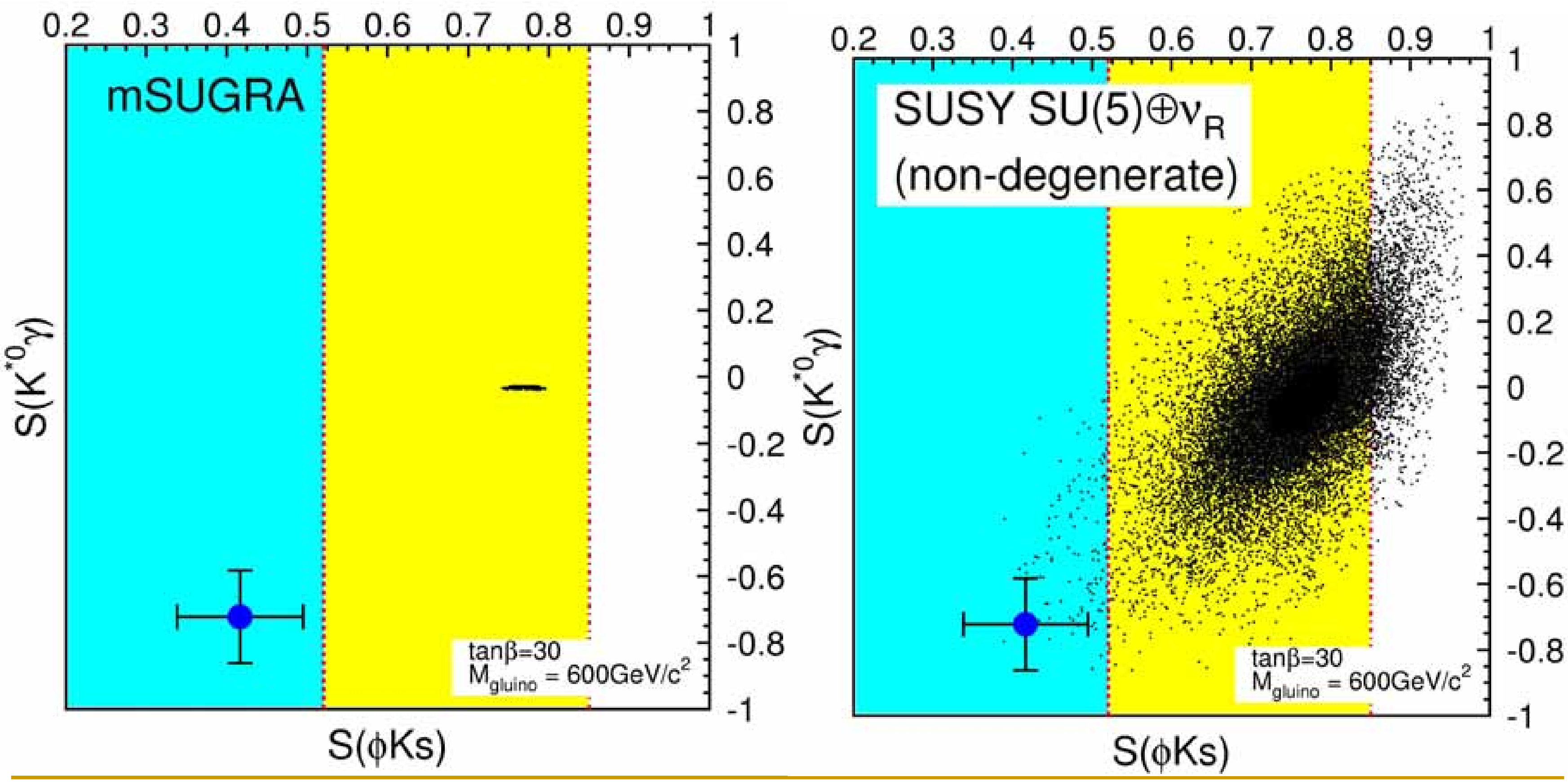


CP asymmetry in B –> K*γ



Direct asymmetry in b –> s γ

Correlation between time-dependent asymmetries of B->ϕKs and B->K*γ



Super KEKB LoI

Pattern of deviations from the SM prediction

	B_d unitarity			$A_{CP}^{\rm mix}$	$A_{CP}^{\rm mix}$	$A_{CP}^{\rm dir}$	$A_{CP}^{\rm mix}$
	closure	$+\epsilon_K$	$+\Delta m(B_s)$	$B \to \phi K_S$	$B \to K^* \gamma$	$B \to X_s \gamma$	$B_s \to J/\psi \phi$
mSUGRA	closed	-	-	-	-	-	-
SU(5) SUSY GUT (degenerate RHN)	closed	$\surd$	-	-	-	-	-
SU(5) SUSY GUT (non-deg. RHN)	closed	-	$\surd$	$\surd$	$\surd$	-	$\surd$
MSSM with U(2)	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$

mSUGRA: small deviation
SUSY SU(5) with degenerate RHN: singals in 1-2 mixing
SUSY SU(5) with non-degenerate RHN: singals in 2-3 mixing
MSSM with U(2) FS: various new phsycs signals

Summary

- If SUSY is realized in Nature, determination of the SUSY breaking mechanism has a fundamental importance. B physics is essential to determine the flavor structure of SUSY breaking terms.
- There are a variety of ways to look for SUSY effects in B decays.
- In order to distinguish different SUSY models, we need to see pattern of the deviations from the SM predictions in various processes. For this purpose, it is important to have both an asymmetric B factory and B experiments in hadron machines.