Physics opportunities at a Super Flavor Factory in The LHC era

Hassan Jawahery
University of Maryland

HEPAP meeting
May 21, 2009

Acknowledgment:

Discussions with D. MacFarlane, D. Leith, D. Roberts, G. Simi

A rich set of documents & talks on studies and discussions of flavor physics in the LHC era:

Super KEKB LOI

Super B LOI

D. Hitlin et al, Proceeding of Super B physics workshop hep-ph-0810.1312

Grossman, Ligeti & Nir hep-ph-09004.4262

Browder, Ciuchini, Gershon, Hazumi, Hurth, Okada & Stocchi, hep-ph-0710.3799

A. Hoecher et al hep-ph-0104062 /hep-ph-0406184 (CKMfitter collab.)

M. Bona et al (UTfit collaboration), hep-ph-0509219

Goto, Okada, Shindou,Tanaka hep-ph-0711.2935

LHCb physics reach: Talk by Ulrich Uwer, Moriond EW (2009)

Talks by Giorgi, Ciuchini, Stocchi, Hitlin, Yamauchi, Browder, Nir,, Ligeti, Silvestrini, Gershen, Hazumi

Why do flavor physics in the LHC era?

- Rare flavor processes are sensitive to physics at higher energies:

  a proven technique.. K^0 mixing->charm mass, B^0 mixing→top mass limit,...

- At the current precision of the data, it is shown that Flavor Physics is sensitive to TeV scale effects.

  - Together with direct observation of NP at LHC, flavor physics can help uncover its flavor structure.

  - Observed FCNC processes are very small & their properties are consistent with SM. Why is there no modification due to NP? This has very important implications for the flavor structure of NP & must be measured with much higher precision.

- Baryon asymmetry problem is still not solved:
  - CPV phases in the NP flavor sector could be responsible.

NP implications of the flavor physics agreement with SM

For example see Y. Nir et al hep-ph-07081872

M. Bona et al (UTfit) hep-ph-0509219)

Allow for tree level ΔF=2 (FCNC) $\frac{z_{bs}}{\Lambda_{NP}^2}(\bar{s}_L\gamma_\mu b_L)^2$ altering mixing rate, CPV,..

Comparison with data:

Y. Nir et al

For z_{ij}=O(1), Scale of NP>>TeV

$$\Lambda_{\rm NP} \gtrsim \begin{cases} \sqrt{\mathcal{I}m(z_{sd})}\; 2\times 10^4\; TeV & \epsilon_K \\ \sqrt{z_{sd}}\; 1\times 10^3\; TeV & \Delta m_K \\ \sqrt{z_{cu}}\; 9\times 10^2\; TeV & \Delta m_D \\ \sqrt{z_{bd}}\; 4\times 10^2\; TeV & \Delta m_B \\ \sqrt{z_{bs}}\; 7\times 10^1\; TeV & \Delta m_{B_s} \end{cases}$$

For NP at ~ TeV, suppressed FCNC

$$\begin{aligned} \mathcal{I}m(z_{sd}) &\lesssim 6\times 10^{-9}\;(\Lambda_{\rm NP}/TeV)^2, \\ z_{sd} &\lesssim 8\times 10^{-7}\;(\Lambda_{\rm NP}/TeV)^2, \\ z_{cu} &\lesssim 1\times 10^{-6}\;(\Lambda_{\rm NP}/TeV)^2, \\ z_{bd} &\lesssim 6\times 10^{-6}\;(\Lambda_{\rm NP}/TeV)^2, \\ z_{bs} &\lesssim 2\times 10^{-4}\;(\Lambda_{\rm NP}/TeV)^2. \end{aligned}$$

It is clear that Flavor Physics is already sensitive to NP at energy scales well above TeV & has as message on the NP flavor structure.

Flavor Physics program in the LHC era

- If New Physics is found at LHC, then its flavor structure must be discovered:
  - New CPV phases
  - Flavor interactions involving right-handed currents
  - FCNC processes could be present at the lowest level
  - Lepton Flavor Violation in charged leptons

- If no New Physics is found at the TeV energy regime:
  - Then, Flavor physics will serve as a powerful way of probing physics at much higher energies.

<u>The key experimental handles</u>:

- CKM parameters (aiming for O(1%) level)
- FCNC processes
- Lepton Flavor Violation

Next generation of Flavor Experiments

At LHC:

- LHCb:
  At $L \sim 2x10^{32}/cm^2/s$
  Expect ~10/fb in 5 yrs
  Incoming rate $\sim 10^{12}$ B's/Yr(2/fb)
  +trigger
  B_d, B_u, B_s, B_c, Λ_b,...

- ATLAS and CMS
  The main focus on
  $B_s \to \mu\mu$
  (SM $Br \sim 3x10^{-9}$)

- **In planning:**
- An asymmetric energy $e^+ + e^-$ collider to operate mainly at the $\Upsilon(4S)$ resonance:
  - Super KEKB in Japan
  - SuperB in Frascati, Italy
- At $L \sim 10^{36}$ /s/cm2
  Aiming for a data set of ~ 50 to 75/ab in 5 yrs.
  - $\sim 10^{11}$ B decays
  - $\sim 10^{11}$ tau decays
  - $\sim 10^{11}$ charm decays

  ➔BaBar+Belle (~1.4/ab) : $\sim 10^9$ B's

  ❖ polarized beam(s) are also considered.

10^{11}--

The 50/ab phase: Study the flavor structure of New Physics through precision measurements of CKM [O(1%) level], precision measurements of FCNC processes & Lepton Flavor Violation- a complementary program to the direct search for NP at LHC.

10^{10}--

10^{9}--

The 1/ab phase: D0 mixng, CPV in pure penguin processes, Leptonic $B \to \tau\nu$; Bs mixing at Tevatron & , limit on tau LFV< 10^{-7}; Hints of tension (~2σ) with SM: CKM fit, $K\pi$ puzzle, ϕs, polarization effects, ..

10^{8}--

Precision $\sin 2\beta$; α & γ measured; CKM over-constrained and established as the primary source of observed CPV effects. Observation of direct CPV in $B \to K\pi$.

#B's

2001- CPV in B decays observed. Sin2β consistent with SM

10^{7}--

1999- B Factories start operation.

10^{6}--

1993-CLEO observed loop level processes in B decays: $b \to s\gamma$; constraints on charged higgs mass & SUSY models

B factory projects launched.

10^{5}--

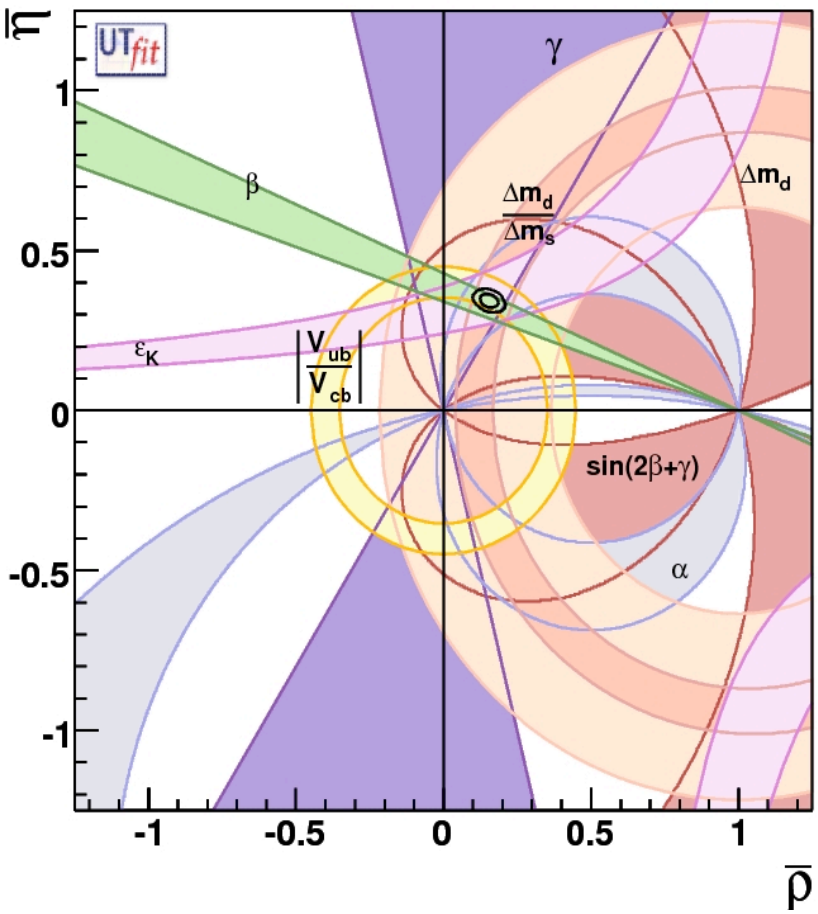
1987-B^0 mixing & V_{ub} measured; Lower bound on m(top)> 42 GeV; Well ahead of energy frontier of the time. With non-zero V_{ub}, CKM in the game as a source of CPV

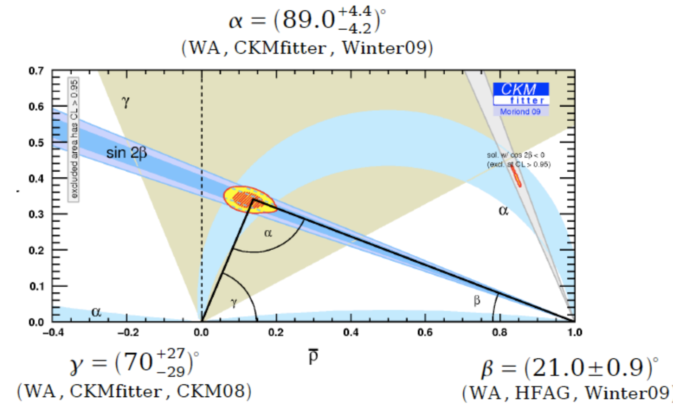
10^{4}--

1982-B meson observed

Precision measurement of CKM

Global CKM fit- current status





ρ = 0.163 ± 0.028
η = 0.344 ± 0.016

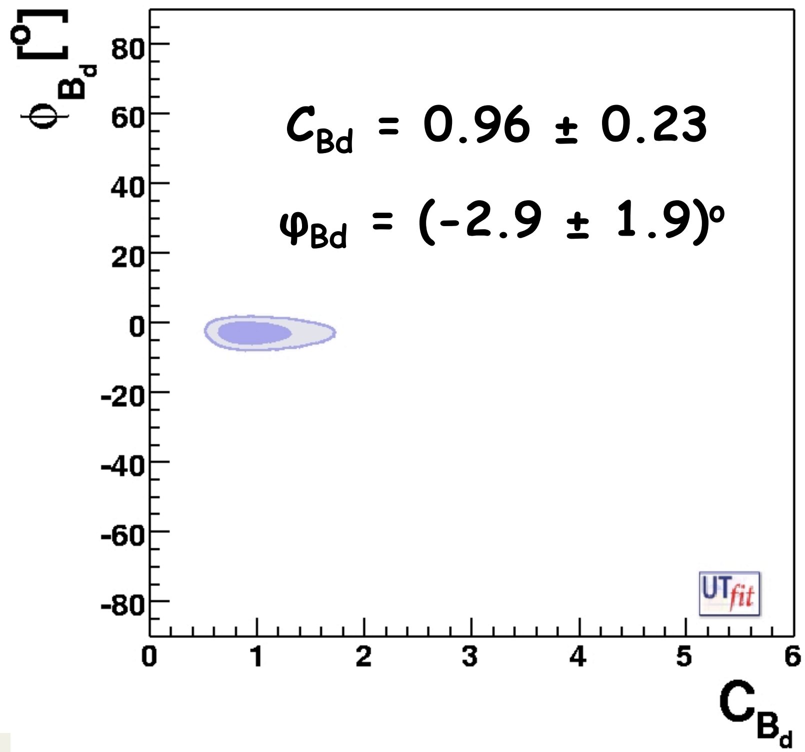
The Standard Model is remarkably accurate in describing flavor physics measurements. But there are a few areas of tensions with data.

Any room for NP in the CKM parameters?

The global fits (CKMfitter and UTfit) have tried model independent methods to determine the size & phase of non-SM component.

e.g. Utfit, allows for deviation from SM in mixing amplitude & phase::

$$C_{Bd} \; e^{2 i \varphi_{Bd}} = \frac{\langle B_d | H_{eff}^{full} | \overline{B}_d \rangle}{\langle B_d | H_{eff}^{SM} | \overline{B}_d \rangle}$$

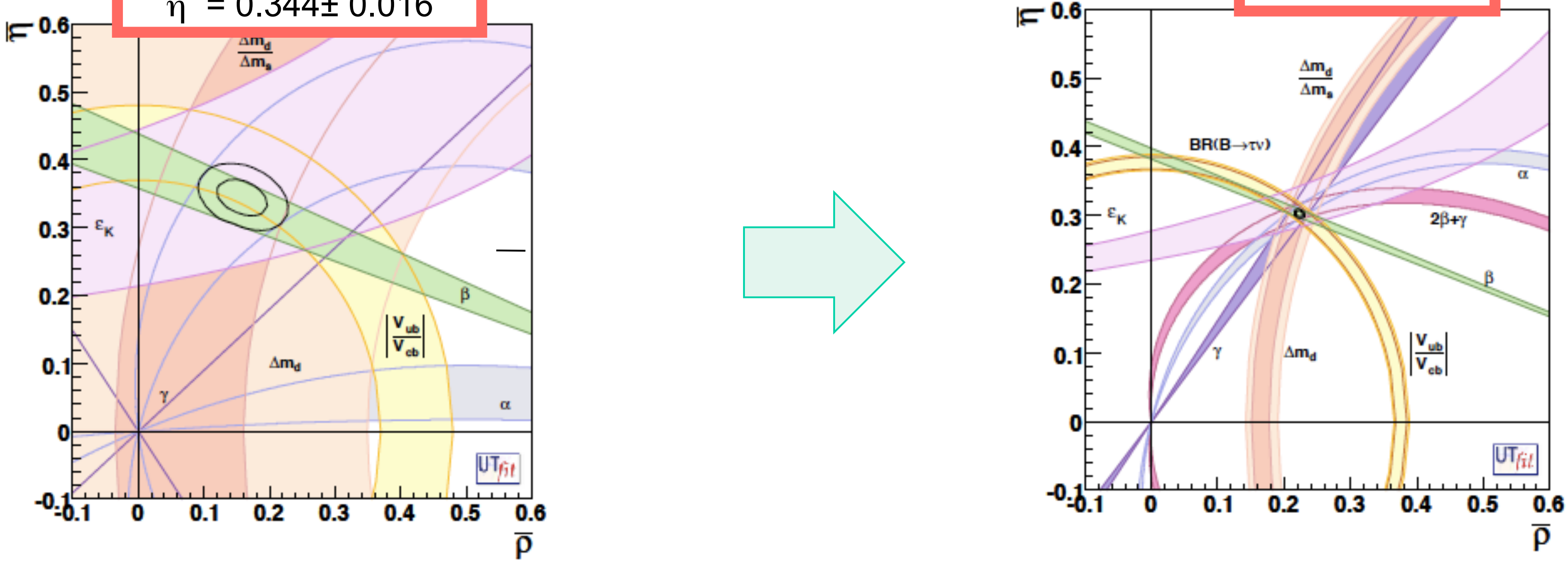


Consistent with zero (at ~1.5 sigma), but there is some room for NP

The Goal

$\rho = 0.163 \pm 0.028$
$\eta = 0.344 \pm 0.016$

$\rho = \quad \pm 0.0028$
$\eta = \quad \pm 0.0024$



•<u>This is an enormous undertaking for both experiment & theory:</u>

To reach this goal, accuracy of the theoretical inputs must match the experimental precision:

- Improved Lattice QCD calculations of decay constants & form factors are needed for B mixing parameters, leptonic decays, $|V_{ub}|$, $|V_{cb}|$,..

- The experience of B factories shows that: we need comprehensive measurements of all channels connected through known symmetries, e.g. Isospin, SU(3) etc. (The stories of α & γ – involving many channels- are good examples)

Expected experimental precision of CKM observables

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\, K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\, \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
α $(B \to \pi\pi)$	$\sim 16°$	3°
α $(B \to \rho\rho)$	$\sim 7°$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12°$	2°
α (combined)	$\sim 6°$	1–2° (∗)
γ $(B \to DK$, $D \to CP$ eigenstates)	$\sim 15°$	2.5°
γ $(B \to DK$, $D \to$ suppressed states)	$\sim 12°$	2.0°
γ $(B \to DK$, $D \to$ multibody states)	$\sim 9°$?	1.5°
γ $(B \to DK$, combined)	$\sim 6°$	1–2°
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)?	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)

Expected progress on theoretical inputs

percent level calculations are promised for Lattice QCD on the Super B time scale

From Christine Davis's talk
at Super B physics in Warwick workshop April 2009

Precision data at the same level of accuracy is needed to test LQCD calculations

What can we achieve in five years?

For calcs required to extract CKM, progress required is clear

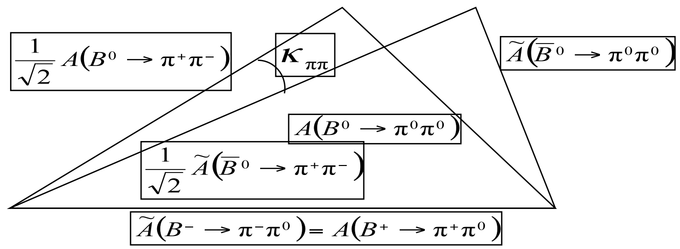
process/ latt. calc.	K mixing	$K \to \pi l \nu$ $f_+(0)$	$\frac{K \to l\nu}{\pi \to l\nu}$ (f_K/f_π)	$D, D_s \to l\nu$ $(f_{D_{(s)}})$	B, "B_s" $\to l\nu$ $(f_{B_{(s)}})$	$B \to D, \pi l \nu$ $f_+(q^2)$	B_s, B_d mixing	$\sqrt{ratio}$ (ξ)
current lattice error	7% disc.	0.5% chiral	0.6% volume	2% a	6% normln	4-10% stat. chiral normln	6% normln stat.	3% chiral stat.
current exptl error	0.5%	0.2%	0.2%	4%	30%	4%	1%	0.5%
future lattice error	2%	0.2%	0.3%	0.5%	2%	2-4%	3%	1%

+ penguins, further boxes and related calcs......

More on controlling theory input: an example

The story of α at the B factories

Br& CPV in $B \to \pi\pi$

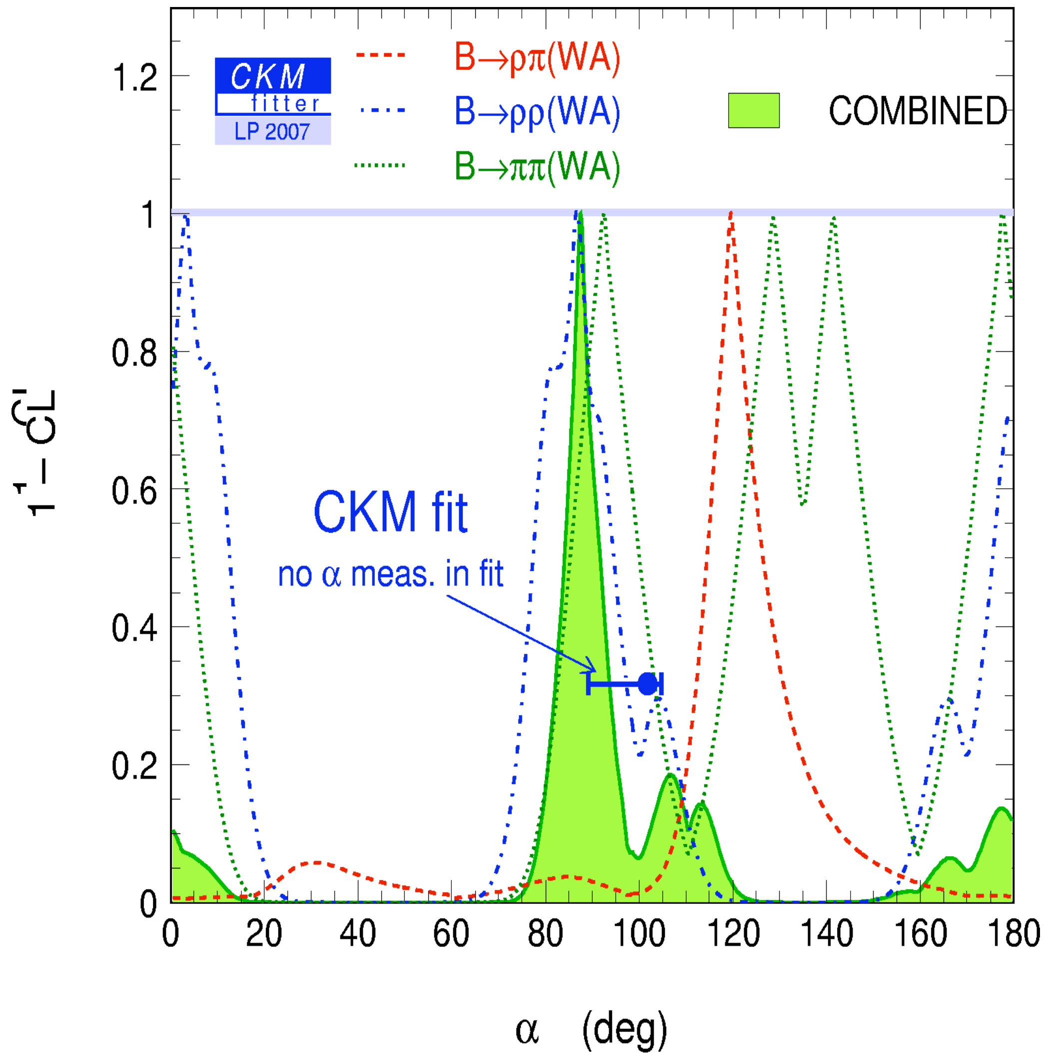


The full Time-dependent Dalitz Analysis of

$B \to \pi\pi\pi(\rho^+\pi^-, \rho^-\pi^+, \rho^0\pi^0, \pi^+\pi^-\pi^0)$

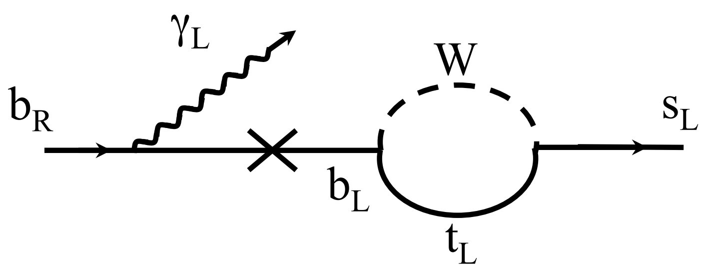
The entire $B \to \rho\rho$ components for isospin analysis & Time-dependent CPV

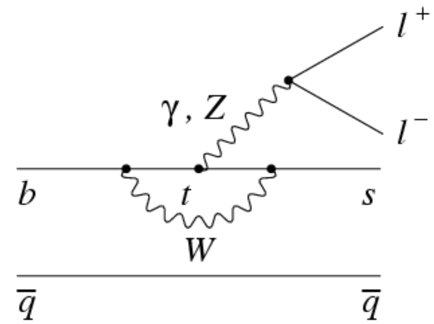
$B \to \pi\pi\pi(\rho^+\rho^-, \rho^+\rho^0, \rho^0\rho^0)$

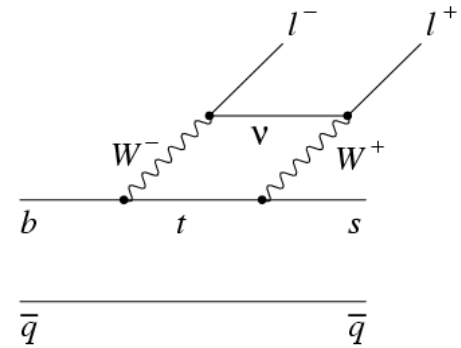


Searches for New Physics
via
FCNC processes

Searches for New Physics via FCNC decays of B

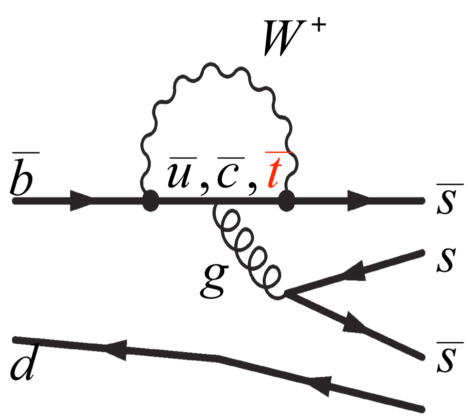




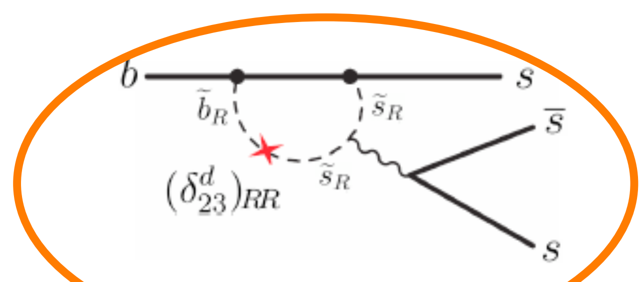


- Rates
- Photon helicity in b→$\gamma_L s$ (γ left-handed in SM)
- Direct CP violation – nearly zero in SM
- In B→Kll- q^2 dependence of the rate; FB asymmetry, CPV in FB asymmetry

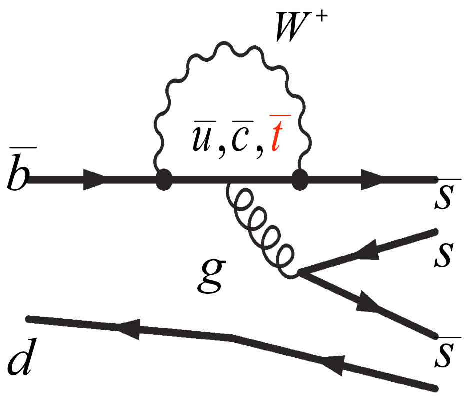
Search for modification of Wilson coefficients C7, C9, C10 & new operators



Observable: Rates, CPV, polarization,..

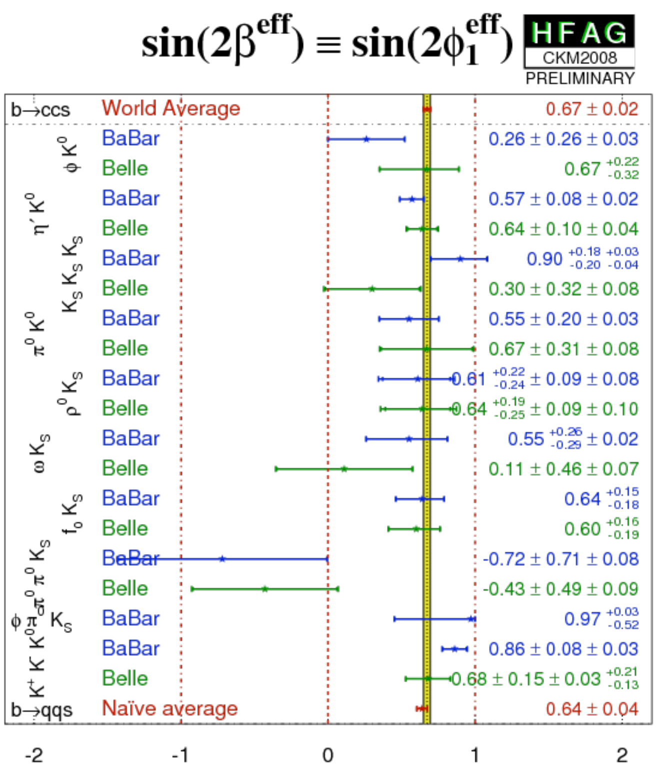


CP violation in Penguin dominated B Decays



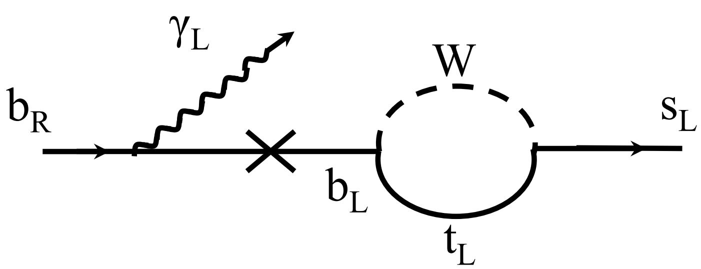
- In SM: Time-Dependent CP violation: S ~ sin2β
- Looking for a ΔS=S-sin2β, sensitive to new CPV phases.
- Must understand SM predictions for ΔS
  - QCD calculations
  - Comprehensive measurements of many channels and the use of symmetries to relate them.

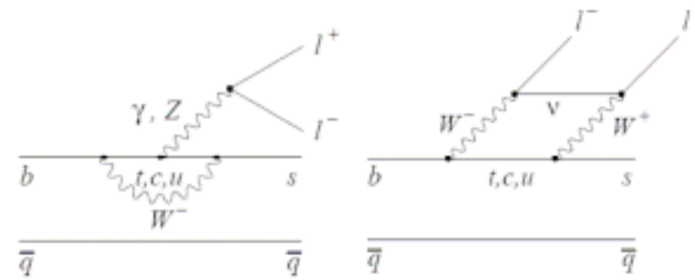
Current data is now consistent with SM- a small tension still present



Channel	2/ab	75/ab
$S(\phi K^0)$	0.13	0.02 (*)
$S(\eta' K^0)$	0.05	0.01 (*)
$S(K^0_S K^0_S$	0.15	0.02 (*)
$S(K^0_S \pi^0$	0.15	0.02 (*)
$S(\omega K^0_S)$	0.17	0.03 (*)
$S(f_0 K^0_S)$	0.12	0.02 (*)

B decays through radiative penguins





Measured rates consistent with SM

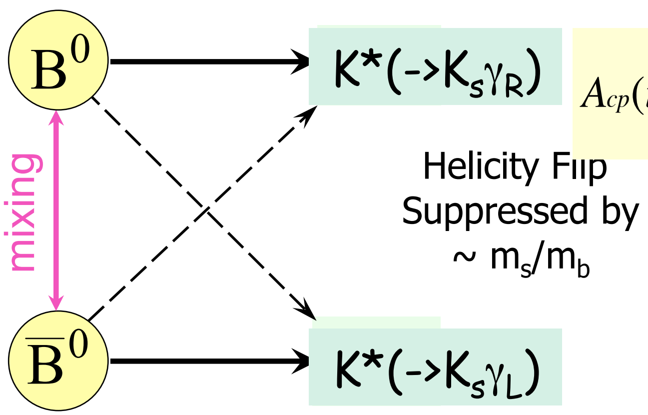
Key observables

- Rates
  - Sensitive to charged higgs & couplings
- Direct CP violation:
  - Very close to zero in SM
- Forward-Backward asymmetry $A_{FB}(q^2)$
  - CPV in AFB
- Photon helicity as a probe of right-handed currents
- Isospin asymmetry

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	∼ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K^0_S\pi^0\gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

Probing right-handed currents through radiative B penguins

For in $b \to \gamma_L s$ - employ time-dependent CP asymmetry to determine the helicity of photon: proposed by Atoowd, Gronau, & Soni (1997)



$$A_{cp}(t) = \frac{\Gamma(\bar{B}^0(t) \to f_{cp}\gamma) - \Gamma(B^0(t) \to f_{cp}\gamma)}{\Gamma(\bar{B}^0(t) \to f_{cp}\gamma) + \Gamma(B^0(t) \to f_{cp}\gamma)} = S_{fcp\gamma} \sin \Delta mt - C_{fcp\gamma} \cos \Delta mt$$

$$S_{K^*\gamma} \propto \eta_{cp} \frac{A[\bar{B}^0 \to K^{*0}(\to K_s^0 \pi)\gamma_R]}{A[\bar{B} \to K^{*0}(\to K_s^0 \pi)\gamma_L]} \sin 2\beta$$

In SM: $S_{K^*\gamma} \sim 0.04$

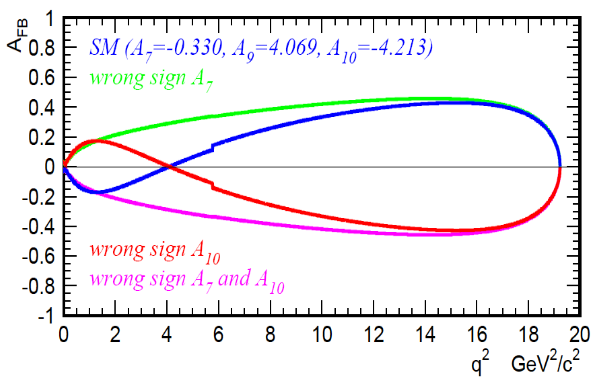
The value of $S_{K^*\gamma}$ is a measure of the magnitude of a right-handed current in the process- present in many NP models.

Current data: $S_{K^*\gamma} = -0.16 \pm 0.22$

With 50/ab, expect: $\sigma(S_{K^*\gamma}) \sim 0.02$

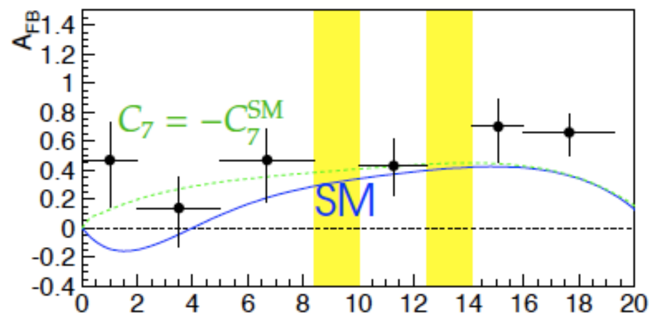
B decays through radiative penguins: $B \rightarrow K(^*)l^+l^-$

•Forward-Backward asymmetry $A_{FB}(q^2)$ in $B \rightarrow K(^*)l^+l^-$ is a powerful probe of NP



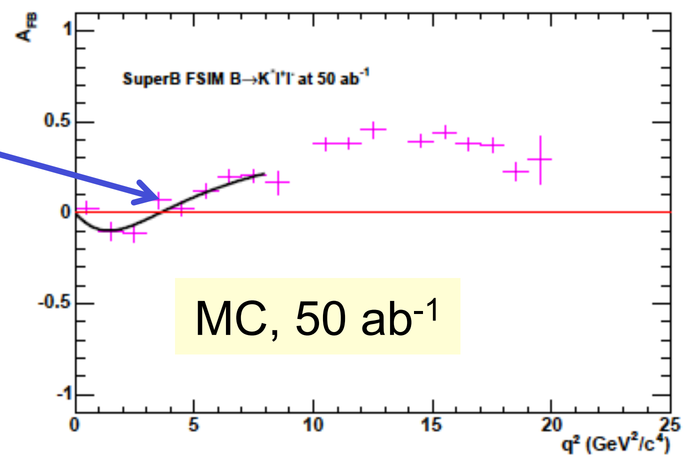
Belle

A_{FB} (Belle arXiv:0810.0335, 657M $B\bar{B}$)



Some tension with SM is already present

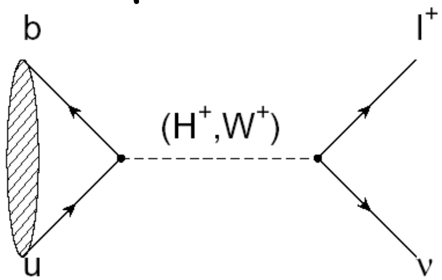
Sensitivity at Super KEKB



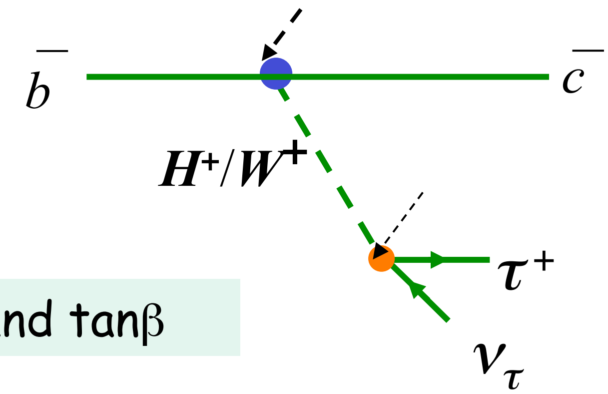
Error on zero-crossing point ~0.3 GeV

Rare Leptonic Decays

B→μν & B→τν

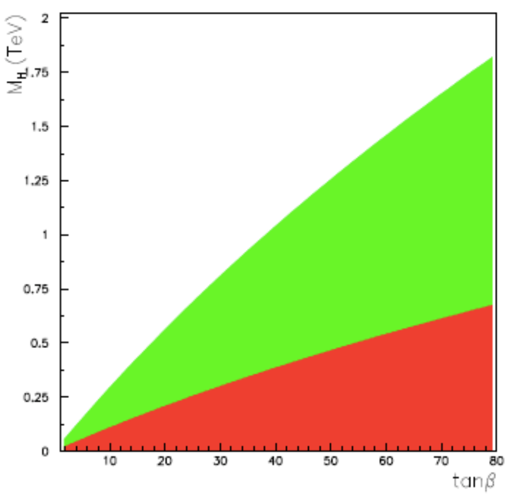


B→D(*)τν

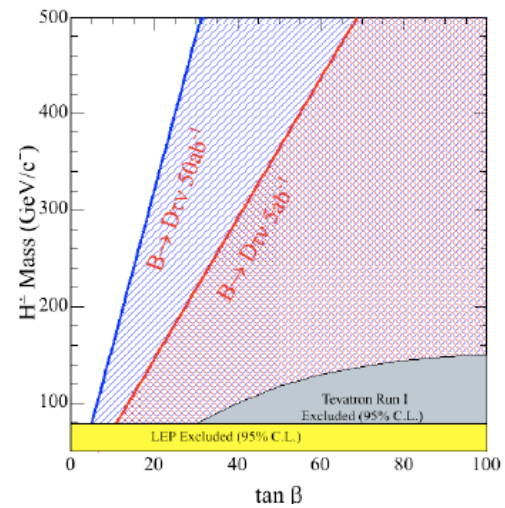


Sensitive to charged Higgs and tanβ

$$BR(B \to \tau\nu) = BR_{SM}(B \to \tau\nu)\left(1 - \frac{m_B^2}{M_H^2}\tan^2\beta\right)^2$$



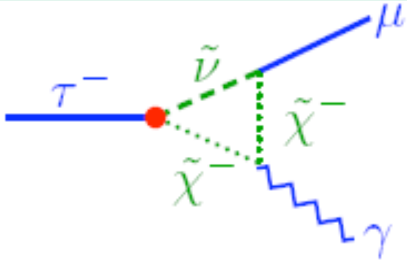
Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%

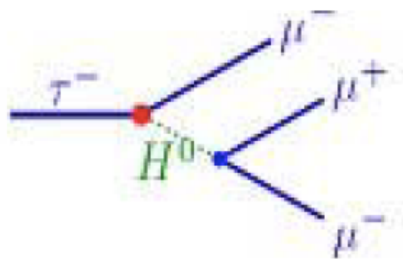


Lepton Flavor Violation

Within SM- LFV in charged leptons is extremely suppressed: Br~ 10^{-50}
Many NP models predict much larger rates

e.g. $\mu \to e\gamma$ & $\tau \to \mu\gamma$ & & $\tau \to \mu\mu\mu$



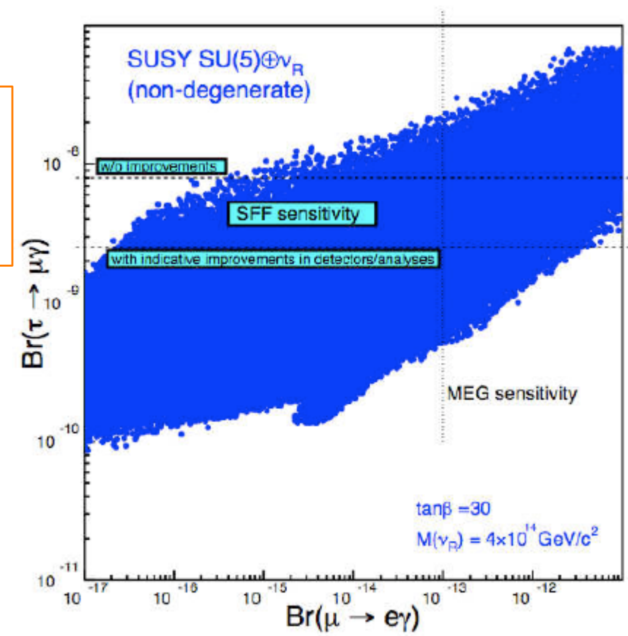


Current data:
$B(\tau \to \mu\gamma) < 4.5\times10^{-8}$ (Belle)
$< 6.8\times10^{-8}$ (BaBar)

Super B sensitivity

Process	Sensitivity
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K_S^0)$	2×10^{-10}

For comparison:
MEG sensitivity: $\mu \to e\gamma$ 10^{-13}
Comparable with SF $\tau \to \mu\gamma$



N

Other physics possibilities

- CP violation in charm decays and mixing
  - Highly suppressed in SM, thus a good place to look for deviation from SM

- Possibility of polarized beams enhances the physics reach of the LFV studies in τ decays:
  - It helps in background discrimination
  - If observed, it allows for exploring the chiral structure of the physics responsible for the process

- Quarkonium physics:
  - Search for light Higgs and dark matter candidates
  - Study QCD effects and new states- XYZ-like- yet to be understood

Super B & LHCb

- The two programs are largely complementary
  - LHCb will dominate the B_s measurements & some exclusive channels in B_d
  - Super B will have full coverage of B_d, (Bs coverage from 5S run), charm and tau decays.
    - Including inclusive channels and modes containing neutrals.

A lineup of key flavor measurements (M. Ciuchini)

$\Delta m_K \quad \epsilon_K \quad \epsilon'/\epsilon_K \quad B(K_L \to \pi^0 \nu \bar{\nu}) \quad B(K^+ \to \pi^+ \nu \bar{\nu}) \quad B(K^+ \to l^+ \nu)$

$\Delta m_d \quad A_{SL}(B_d) \quad S(B_d \to J/\psi K_S) \quad S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho) \quad \gamma(B \to DK) \quad CKM\ fits$

$\Delta m_s \quad A_{SL}(B_s) \quad S(B_s \to J/\psi \phi) \quad S(B_s \to \phi\phi)$

$B(b \to s\gamma) \quad A_{CP}(b \to s\gamma) \quad S(B^0 \to K_S \pi^0 \gamma) \quad S(B_s \to \phi\gamma)$

$B(b \to d\gamma) \quad A_{CP}(b \to d\gamma) \quad A_{CP}(b \to (d+s)\gamma) \quad S(B^0 \to \rho^0 \gamma)$

$B(b \to s l^+ l^-) \quad B(b \to d l^+ l^-) \quad A_{FB}(b \to s l^+ l^-) \quad B(b \to s \nu \bar{\nu})$

$B(B_s \to l^+ l^-) \quad B(B_d \to l^+ l^-) \quad B(B^+ \to l^+ \nu)$

$B(\mu \to e\gamma) \quad B(\mu \to e^+ e^- e^+) \quad (g-2)_\mu \quad \mu\ EDM$

$B(\tau \to \mu\gamma) \quad B(\tau \to e\gamma) \quad B(\tau^+ \to l^+ l^- l^+) \quad \tau\ CPV \quad \tau\ EDM$

$B(D^+_{(s)} \to l^+ \nu) \quad x_D \quad y_D \quad charm\ CPV$

Super B & LHCb-*comparisons in a few modes*

	LHCb(10/fb)	Super Flavor (75/ab)
$B_s \to \mu^+\mu^-$	SM seen at 5σ	---
Φ_s	0.01	---
γ (DK)	2-3°	1-2°
$\alpha(\pi\pi,\rho\pi,\rho\rho)$		1-2°
$S(J/\psi K_s)$	0.01	0.005
$S(\phi K_s)$	---	0.03
$S(\eta' K_s)$	---	0.02
$S(\pi^0 K_s)$	---	0.02
$S(K^*\gamma)$	---	0.03
$S(\phi\gamma)$	0.03	----
$A_{cp}(K^*\gamma)$	0.01	0.004
$A_{cp}(b \to s\gamma)$	---	0.005
$A_{FB}(K^*ll)$	36 K	15 K
q^2 zero-crossing	0.28 GeV	0.25 GeV
$B \to K^*\nu\nu$	---	20% meas. Of SM
$B \to \tau\nu$	---	4%
$\tau \to \mu\gamma$	----	2×10^{-9}

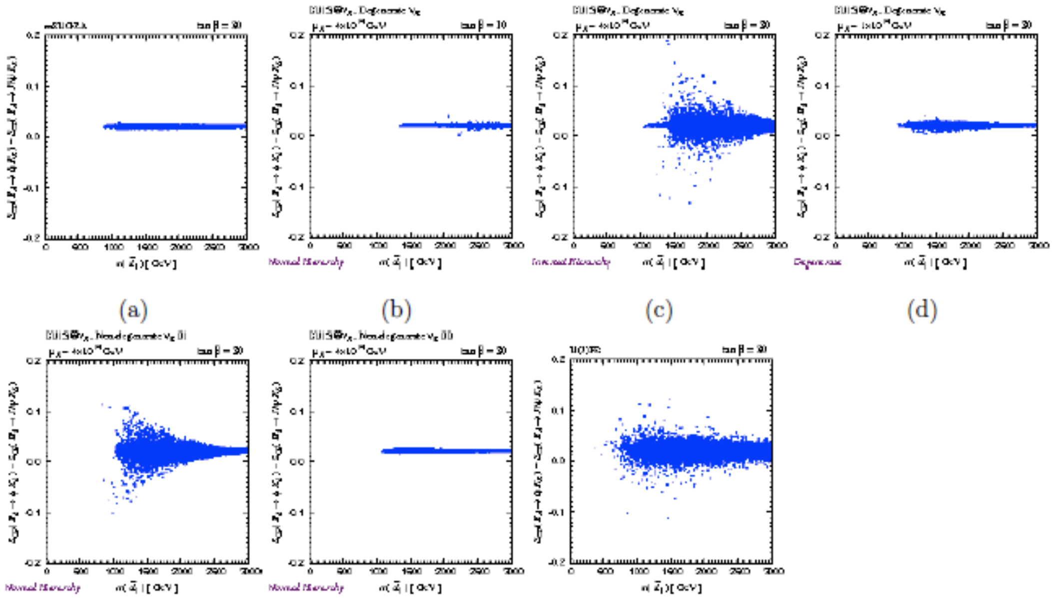
Is there a "Golden" mode/measurement?

- There is no obvious single "golden" measurement for testing NP effects
    - Sin2β was considered the "golden" measurement for testing the CKM
    - In reality, while sin2β helped establish CPV in B's- the CKM test required a great number of measurements.

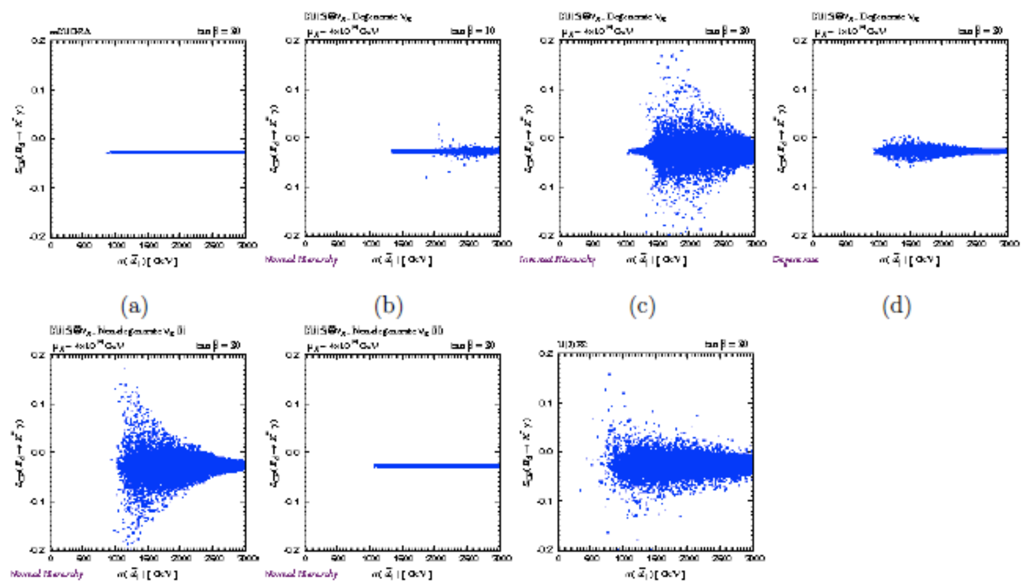
- For the Flavor Physics program in NP era: The "golden" signature is likely to be the emergence of a pattern of deviations from the SM in a key set of channels.

	H^+ high $\tan\beta$	Minimal FV	Non-Minimal FV (1-3)	Non-Minimal FV (2-3)	NP Z-penguins	Right-Handed currents
$\mathcal{B}(B \to X_s\gamma)$		X		O		O
$A_{CP}(B \to X_s\gamma)$				X		O
$\mathcal{B}(B \to \tau\nu)$	X-CKM					
$\mathcal{B}(B \to X_s l^+ l^-)$				O	O	O
$\mathcal{B}(B \to K\nu\overline{\nu})$				O	X	
$S(K_S\pi^0\gamma)$						X
β			X-CKM			O

T. Goto, Y. Okada. T. Shindou, M. Tanaka (hep-ph-0711.2935) on pattern of signals in flavor observables for various SUSY models.



S(ϕKs)−S(J/ψKs)

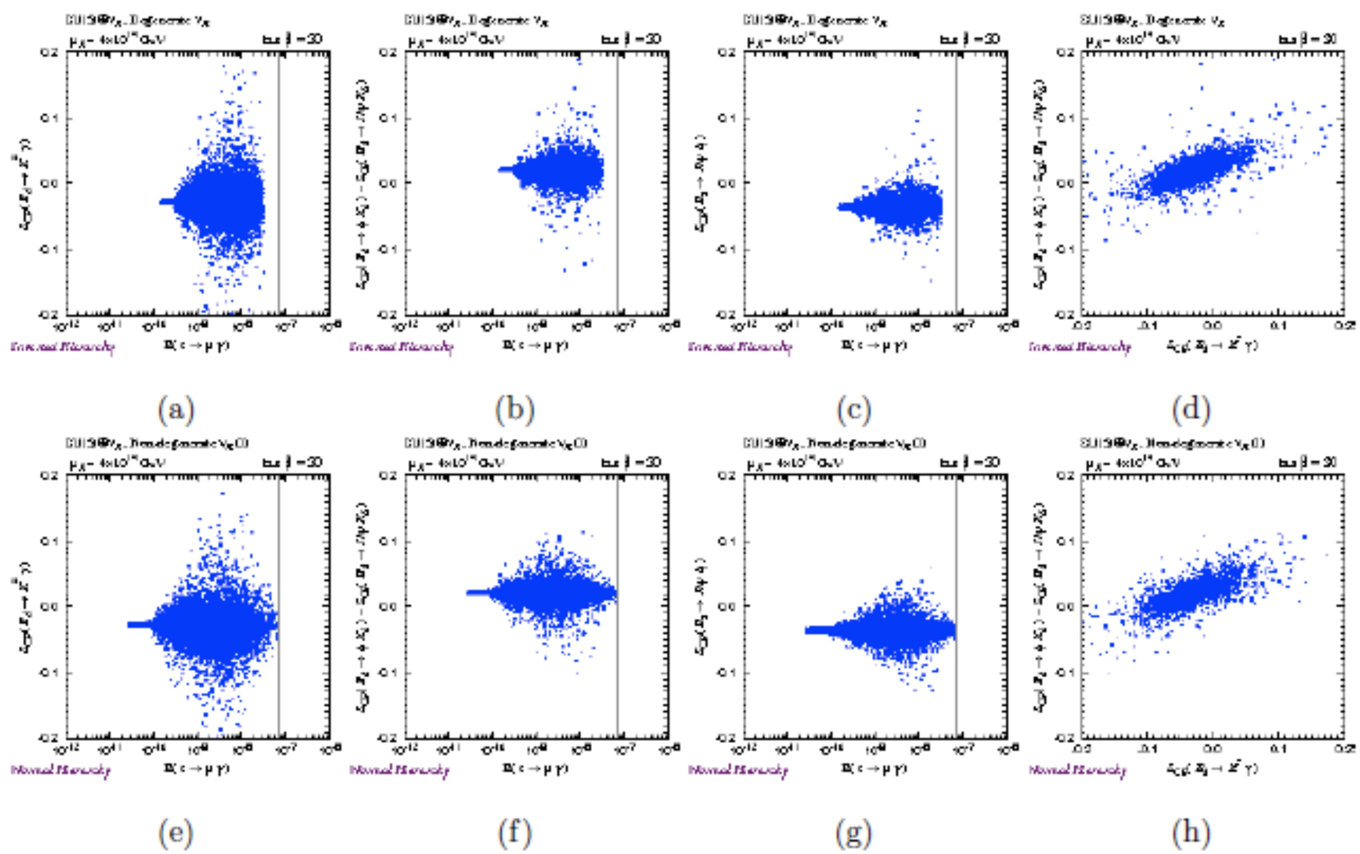


S($K_s\pi^0\gamma$)

More on pattern of signals from SUSY

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

Correlation between b→sγ & τ→$\mu\gamma$



Conclusions

- Experimental studies of flavor is a necessary and complementary program to the direct search for New Physics at LHC.
- A Super B factory at $L \sim 10^{36}$ /s/cm^2 allows for comprehensive studies of a broad set of rare decay processes in B, charm and tau decays with sensitivity to NP in the TeV scale.
- The overall pattern of deviations from SM will serve as a means for studying the flavor properties of NP.
- The physics reach of LHCb and Super B factories are complementary- allowing for a complete set of precision measurements including the B_s system.

**Experience of B factories has shown that the success in this already very mature field depends heavily on having a full set of measurements in all related channels: both to understand and control the theoretical inputs and to distinguish NP effects from SM background.

Back up slides

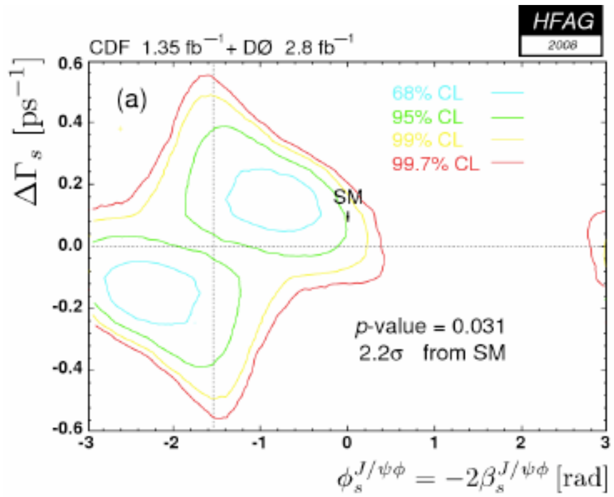
A few tensions with SM/(Indications for NP?)

- The Kπ puzzle: $A_{CP}(B^-(\bar{b}u) \to K^+\pi^0) - A_{CP}(B^0(\bar{b}d) \to K^+\pi^-) - = 0.148 \pm 0.028$

Possible NP contributions or an innocent SM effect?

Needs a complete analysis of the B→Kπ system ($K^+\pi^-$, $K^+\pi^0$, $K^0\pi^0$, $K^0\pi^+$) system to rule out the SM hypothesis – current data consistent with SM.

- Tevatron measurement of B_s mixing phase : $\varphi_s^{J/\psi}$ deviates from SM by ~2.2 sigma



In SM: $\varphi_s^{J/\psi}$~0.04

CDF and D0 have much more data to analysis

- The pattern of polarization measurements in B→VV channels do not follow SM expectation.