Highlights of Super-KEB Physics LoI

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2nd Super B Factory Workshop in Hawaii

In This Talk, …

Physics case with $5ab^{-1}$ → $50\ ab^{-1}$ data at Super-B based on

- Letter of Intent for KEK Super B Factory (KEK Report 2004-4)
- Physics at Super B Factory (hep-ex/0406071)

cf) SLAC-R-709
The Discovery Potential of a Super B Factory
Proceedings of the 2003 SLAC Workshops

Contents;

- Super-B Motivation
- Super-B Physics Reach
- Studies of NP Scenario
- Summary

Success of B Factories

First precise test of KM picture for CPV.

- $\sin 2\phi_1 = +0.726 \pm 0.037$ is now a precise measurement (~5%).
- The other angles are being measured more seriously.
  - ϕ_2 from $S\rho\rho$ and $\rho\pi$ Dalitz
  - $2\phi_1+\phi_3$ from $B \to D^{(*)}\pi$
  - $\phi 3$ from $B \to DK$ (w/ D Dalitz)

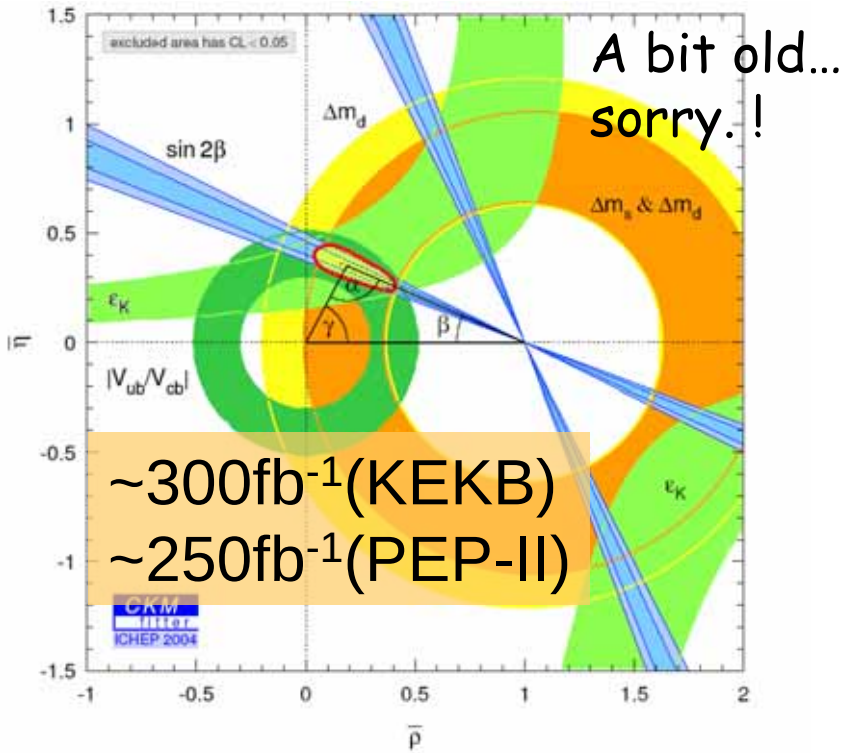
  + side measurements too.

    $|V_{cb}|$, $|V_{ub}|$. Δm_d

Paradigm change: look for Alternatives to CKM

⇩

Corrections by NP ?



Far Precise Test to Look for Correction by NP !

New Physics in b→s loop ?

- Present constraint mainly with transitions between
  - 3⇔1 generation
  - 2⇔1 generation

- CPV (b→sqq) Anomaly?

  ‹charmonium› =

  0.726 ± 0.037

  ‹b→s penguin› =

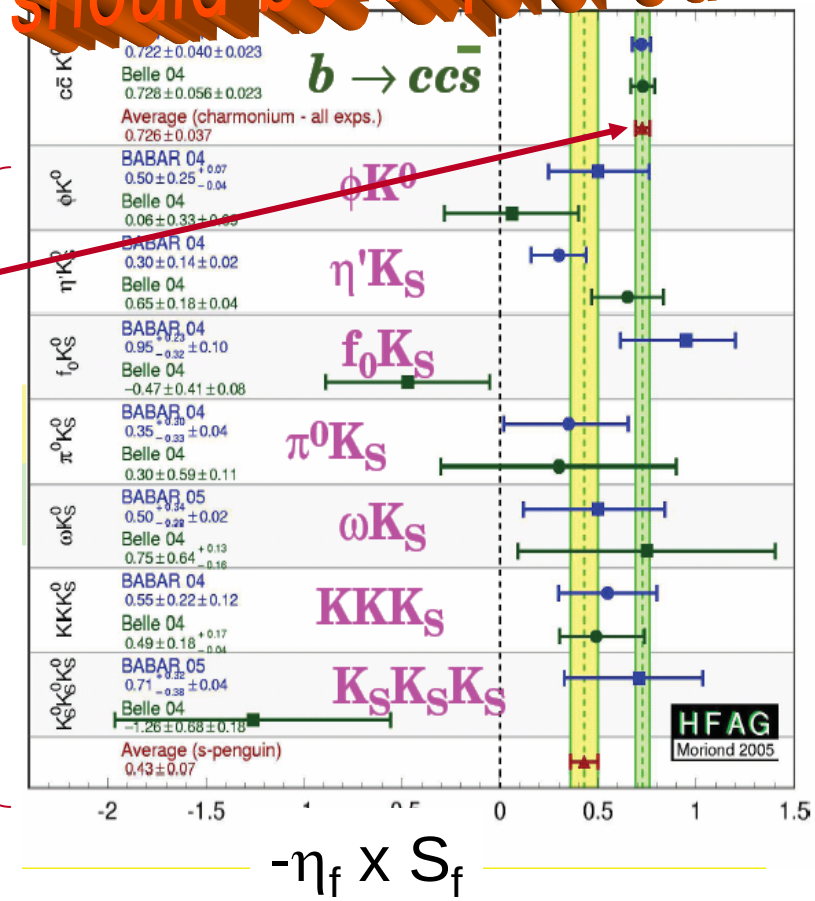
  0.43 ± 0.07 ('05 winter)

  0.39 ± 0.11 (Belle)

  0.45 ± 0.10 (*BABAR*)

3.7σ deviation !!

b⇔s (3rd⇔2nd) should be explored.



Search for New Origin of Flavor Mixing & CP Violation !

B Physics in LHC Era

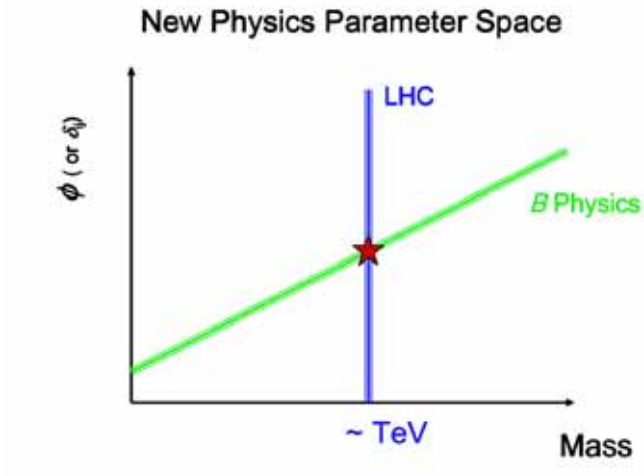
- Once NP found in B/LHC, the next question would be

  What is the NP scenario ?

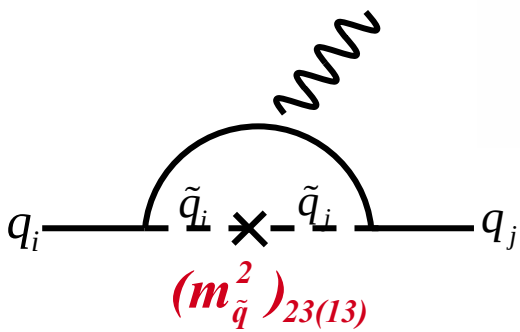
- Orthogonality of B physics to LHC

  The squark/slepton mass matrix

  Sensitive to SUSY breaking mechanism.



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



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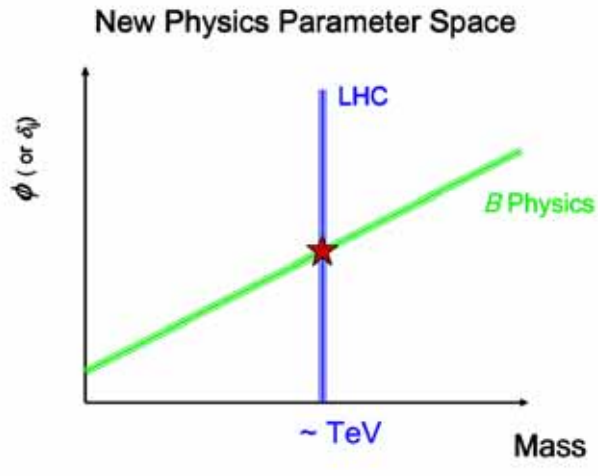


$$\left(m^2_{\tilde{q}}\right)_{ij} = \begin{pmatrix} m^2_{11} & m^2_{12} & m^2_{13} \\ m^2_{21} & m^2_{22} & m^2_{23} \\ m^2_{31} & m^2_{32} & m^2_{33} \end{pmatrix}$$

Off-diagonal terms
Flavor Physics
Luminosity frontier

q_i - l_j

Diagonal terms:
LHC/ILC
Energy frontier

cf) Top quark:
Mass/width by Tevatron
Mixing/phase by B factories

B and τ are in the 3rd generation ("hub" quark & lepton)
⇒ probe for both 3→2, 3→1 transitions.

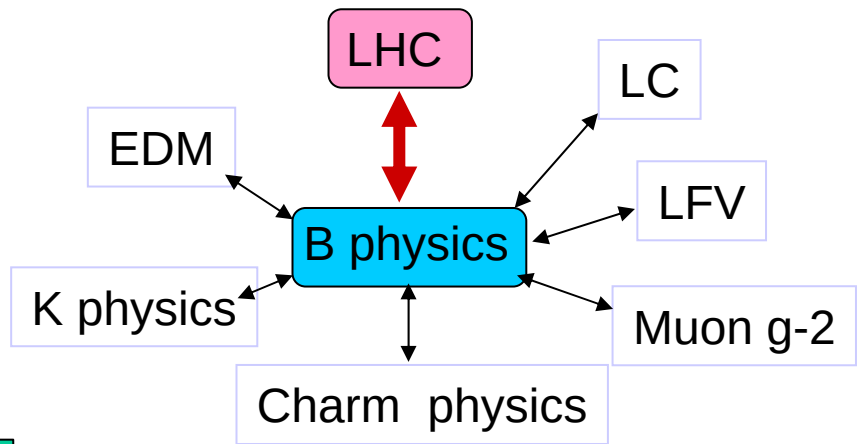
Cont'd

B & τ decays would be ideal probes for flavor structure of NP.

Super-B key measurements
- CPV in b→s
- FCNC (Kll, Kνν etc.)
- LFV (τ decays)
- Higgs mediation (B→Dτν etc.)
- CKM

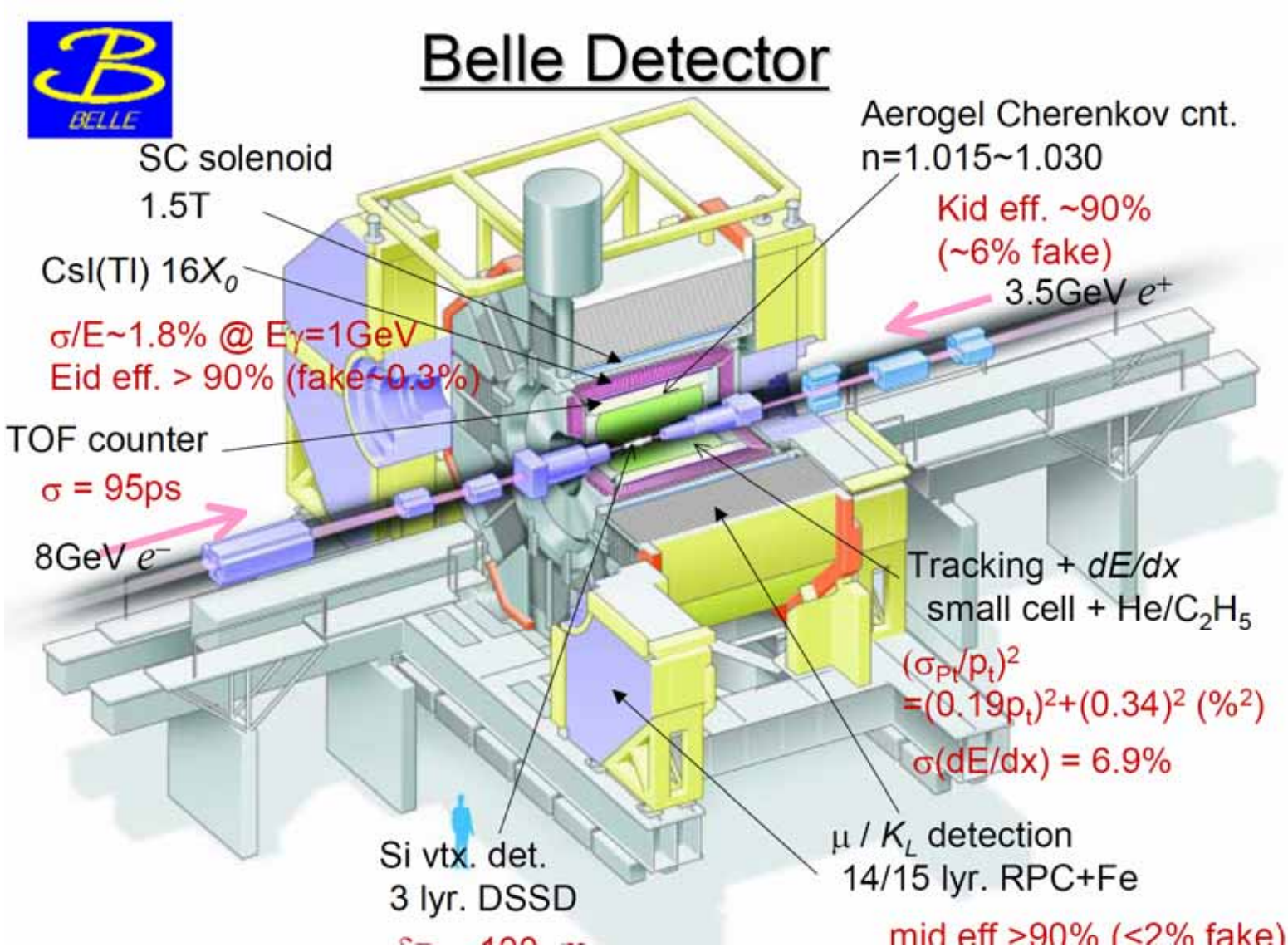
+ their correlation

+ Synergy to LHC and other flavor physics exp's.

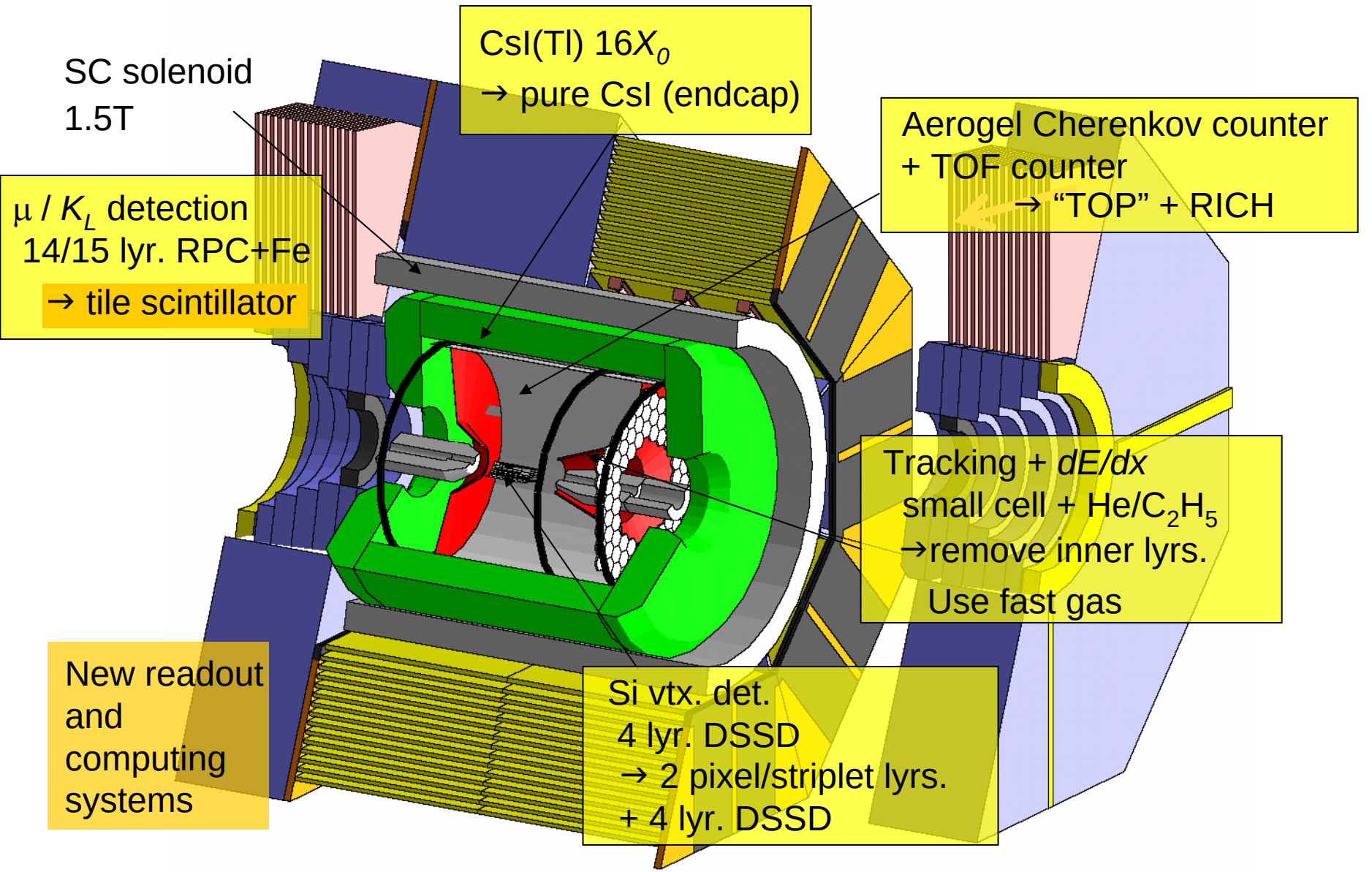


Elucidation of New Physics Scenario

Super Belle

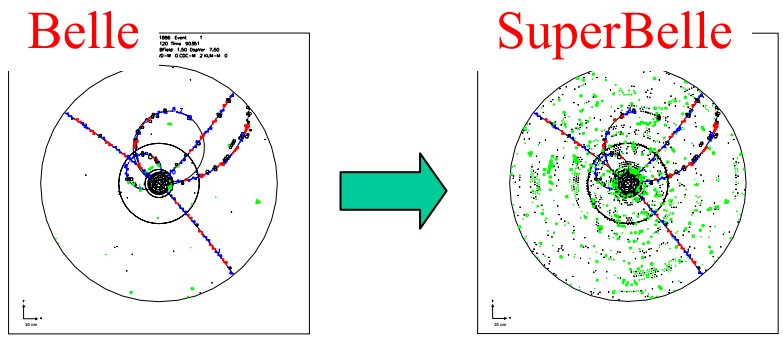

Belle Detector
SC solenoid
1.5T
CsI(Tl) 16X_0
σ/E~1.8% @ Eγ=1GeV
Eid eff. > 90% (fake~0.3%)
TOF counter
σ = 95ps
8GeV e^-
Aerogel Cherenkov cnt.
n=1.015~1.030
Kid eff. ~90%
(~6% fake)
3.5GeV e^+
Tracking + dE/dx
small cell + He/C_2H_5
$(\sigma_{Pt}/p_t)^2$
$=(0.19p_t)^2+(0.34)^2$ (%^{2})
σ(dE/dx) = 6.9%
μ / K_L detection
14/15 lyr. RPC+Fe
Si vtx. det.
3 lyr. DSSD

Super Belle


SC solenoid
1.5T
CsI(Tl) 16X_0
→ pure CsI (endcap)
Aerogel Cherenkov counter
+ TOF counter
→ "TOP" + RICH
μ / K_L detection
14/15 lyr. RPC+Fe
→ tile scintillator
Tracking + *dE/dx*
small cell + He/C_2H_5
→remove inner lyrs.
Use fast gas
New readout
and
computing
systems
Si vtx. det.
4 lyr. DSSD
→ 2 pixel/striplet lyrs.
+ 4 lyr. DSSD

Feature of Super-Belle Exp.

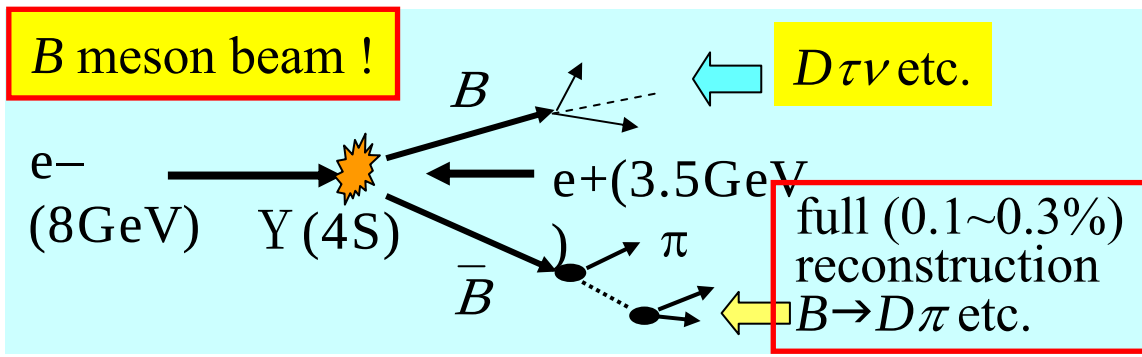
- Cleaner than hadron machines even after the upgrade
  - Many off-timing hits, but typical track eff. 91% → 89%



- *B* decays with neutrinos

  $B \to D\tau\nu$, $\tau\nu$, $u\,l\,\nu$ etc.

  Charged Higgs — Vub



- *B* decays with γ, π^0

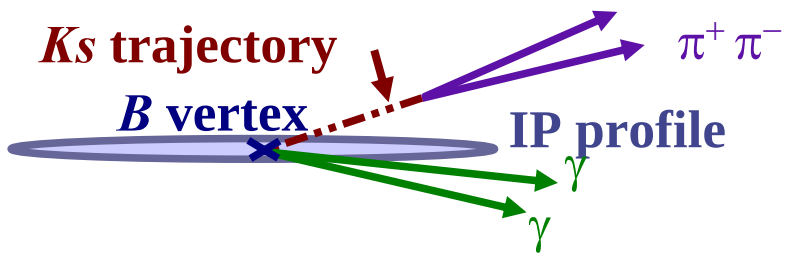
  $B \to Xs\gamma$, $\pi^0\pi^0$ etc.

  direct *CPV*

  $\phi_2(\alpha)$ isospin analysis

- *B* vertex reconstruction with *Ks* only !

  $B \to Ks\pi^0$, $Ks\pi^0\gamma$ etc.

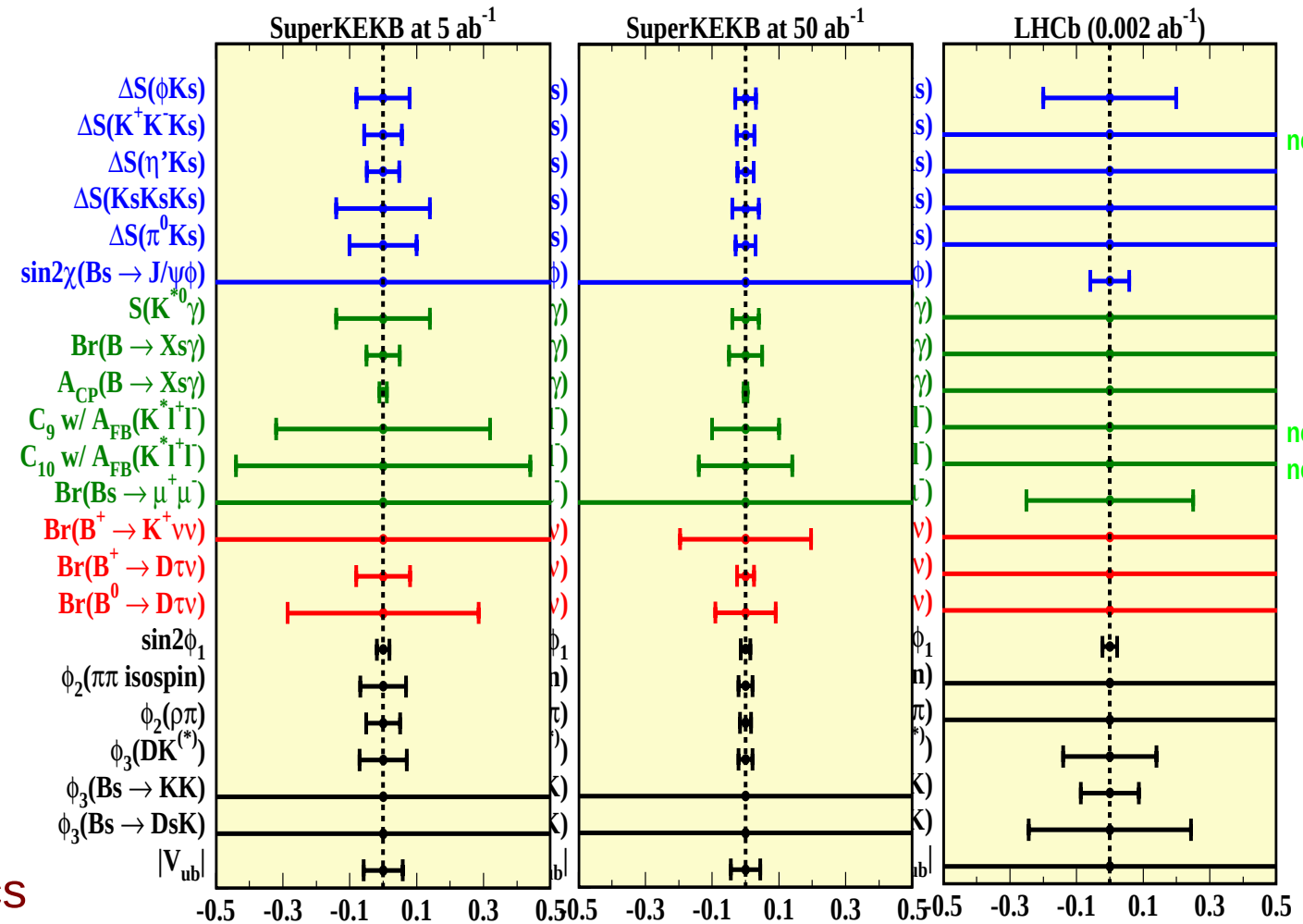


Physics Reach at Super-KEKB

		SuperKEKB ($5\ ab^{-1}$)	($50\ ab^{-1}$)
CPV ($b \to s$)	S	0.079	0.031
	S	0.056	0.026
	S	0.049	0.024
	S	0.14	0.04
	S	0.10	0.03
	A_{CP}	×	×
FCNC	S	0.14	0.04
	A_{CP}	5%	5%
	A_{CP}	0.011	5×10^{-3}
	A_{FB}	32%	10%
	A_{FB}	44%	14%
	A_{FB}	×	×
w/ ν	Br		5.1σ
	Br	8%	2.5%
	Br	3.5σ	9%
CKM	$\lvert V_{ub}\rvert$	0.019	0.014
	ϕ_1	3.9°	1.2°
	ϕ_2	2.9°	0.9°
	ϕ_2	4°	1.2°
	ϕ_3	×	×
	ϕ_3	×	×
	ϕ_3	5.8%	4.4%

and rich τ physics

SuperKEKB 5ab^{-1} 50ab^{-1} LHCb 2fb^{-1}

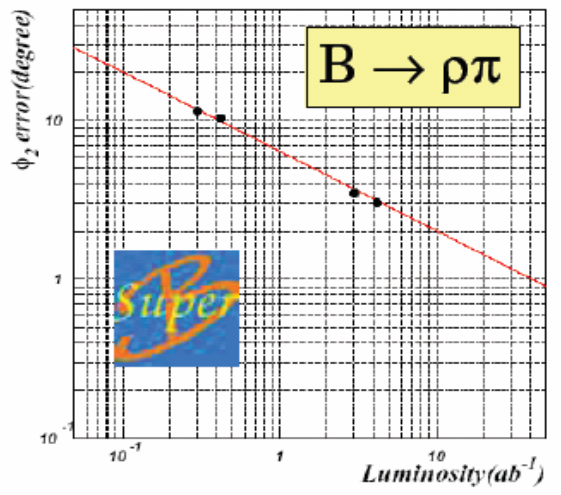


Measurement of ϕ_2 and ϕ_3

- ϕ_2 measurement
  - B→ππ (isospin analysis)

    $\Delta\phi_2$ = 3.9/1.2 deg. (5/50ab^{-1})
  - B→ρπ (Dalitz plot analysis)

    $\Delta\phi_2$ = 2.9/0.9 deg. (5/50ab^{-1})



- ϕ_3 measurement by B→DK
  - Dalitz analysis

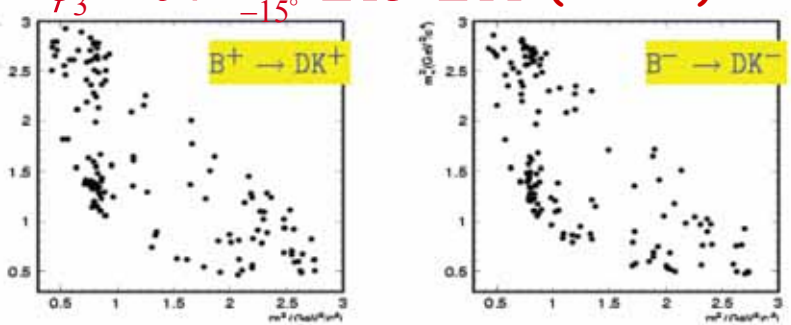
    $\Delta\phi_3$ = 4/1.2 deg. (5/50ab^{-1})

    Model error ?
  - ADS method

    $\Delta\phi_3$ = 16/ 5 deg. (5/50ab^{-1})

Belle @ present

$\phi_3 = 64^\circ\ ^{+14^\circ}_{-15^\circ} \pm 13^\circ \pm 11^\circ$ (model)



Limited by stat.

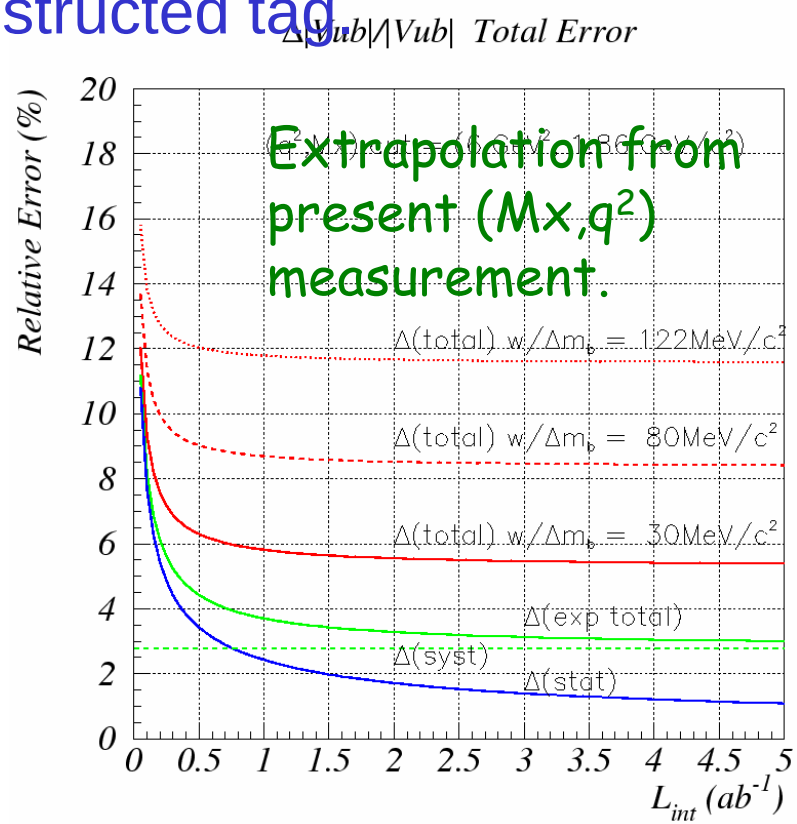
Measurement of $|V_{ub}|$

- Inclusive b→u l ν with fully reconstructed tag

  ➡ Mx, q^2, P_+

  – Good determination of m_b by b→c l ν / b→sγ is essential.

  δm_b ~ 70 MeV presently



- Exclusive B→π l ν with full recon or D* l ν tagging.
  – High quality data in high q^2
  – Form factor by unquenched lattice ⬅ D→π l ν @ CLEO-c

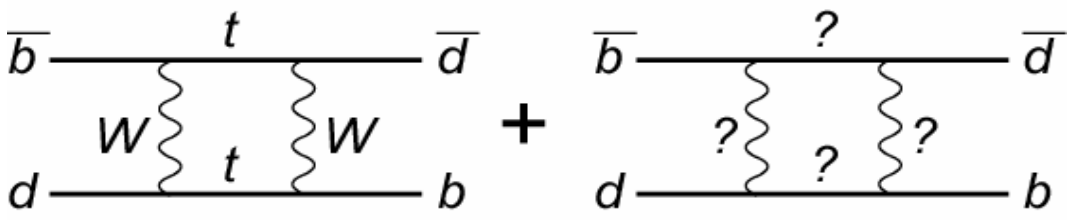
~5% determination is possible.

CKM at Super-B

50 ab^{-1}

CKM is only one part of Super-B physics programs, but still provides model indep. approach to constrain NP.

$M_{12}=M_{12}^{SM}+M_{12}^{NP}$

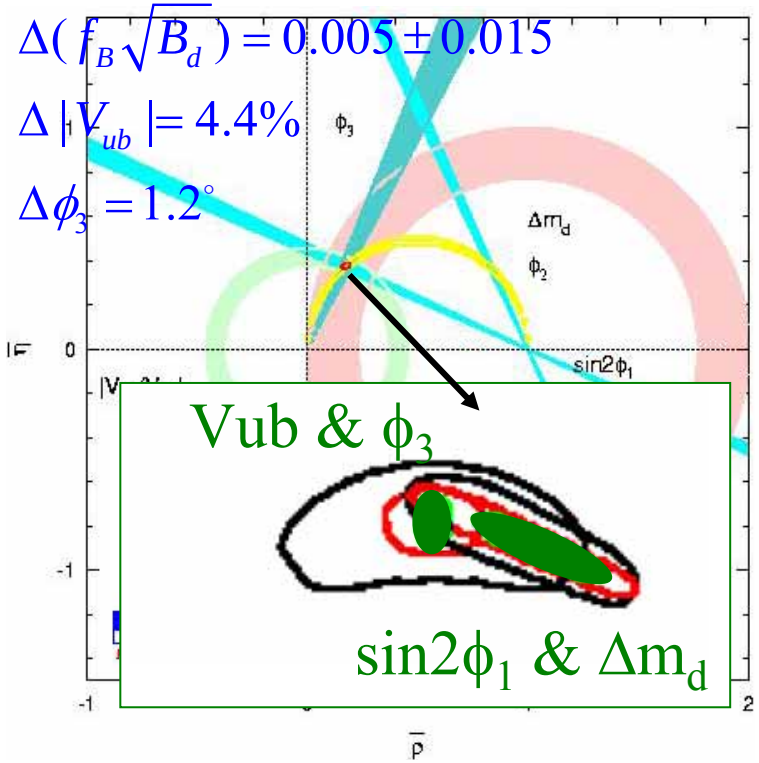


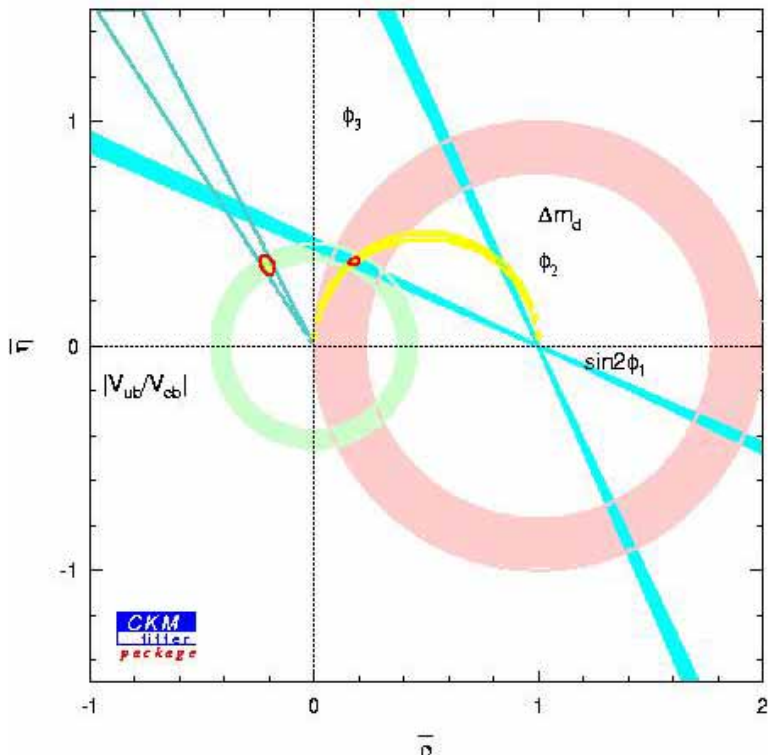
$\Delta \sin 2\phi_1 = 0.014$

$\Delta(f_B\sqrt{B_d}) = 0.005 \pm 0.015$

$\Delta|V_{ub}| = 4.4\%$

$\Delta\phi_3 = 1.2^\circ$



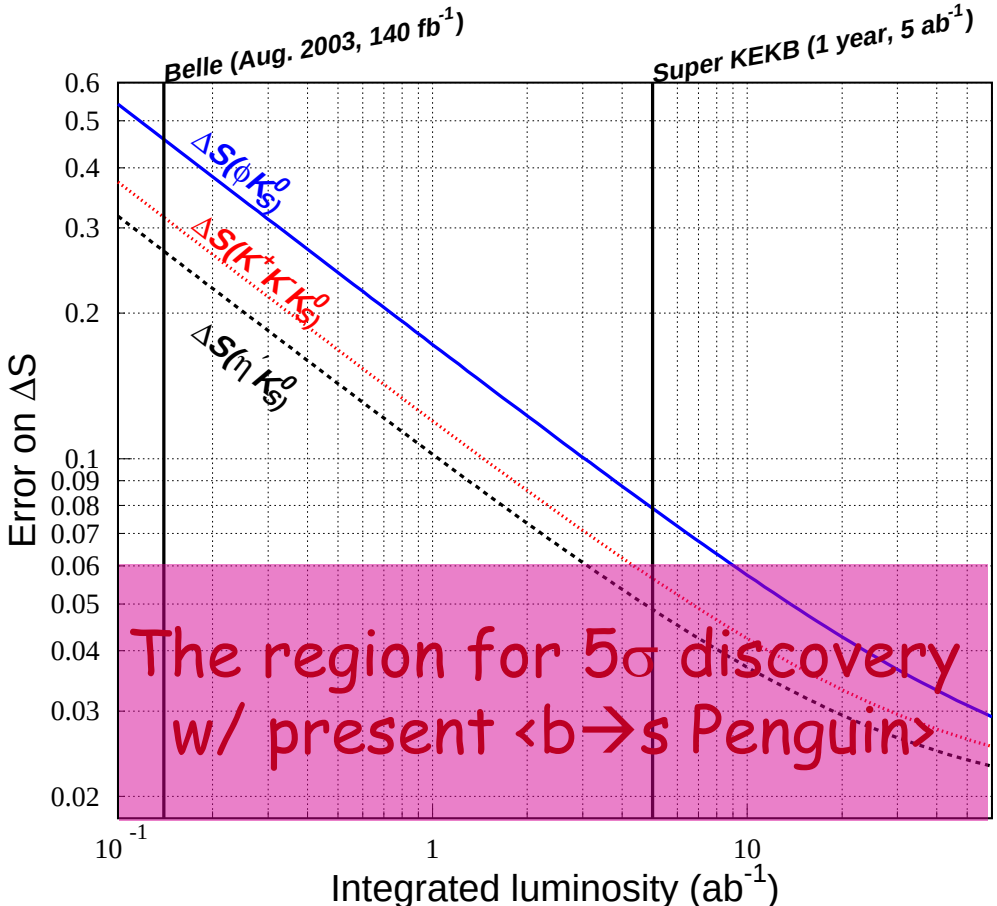


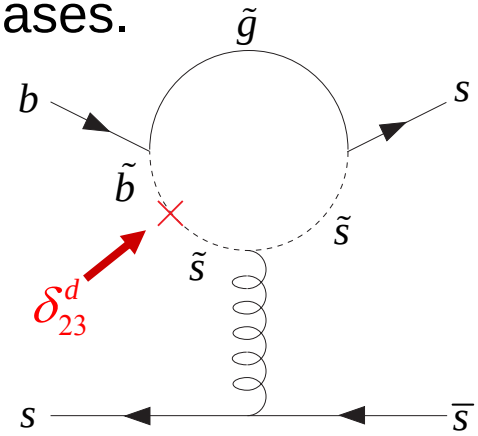
New CPV Phases in b→sq̄q

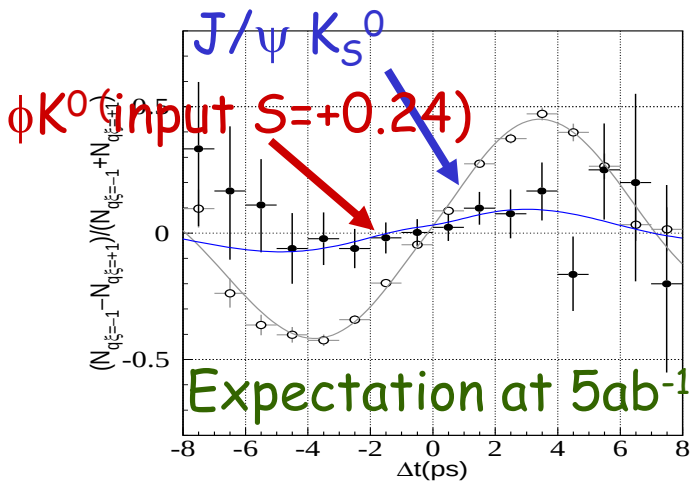
- b→s loop is the ideal place to look for new CPV phases.

$$B^0 \to \phi K^0, \eta' K^0, K^+K^-K^0, \ldots$$

$$A_{CP}(t) \propto \sin 2(\phi_1 + \phi_{NP}) \times \sin(\Delta m_d t)$$



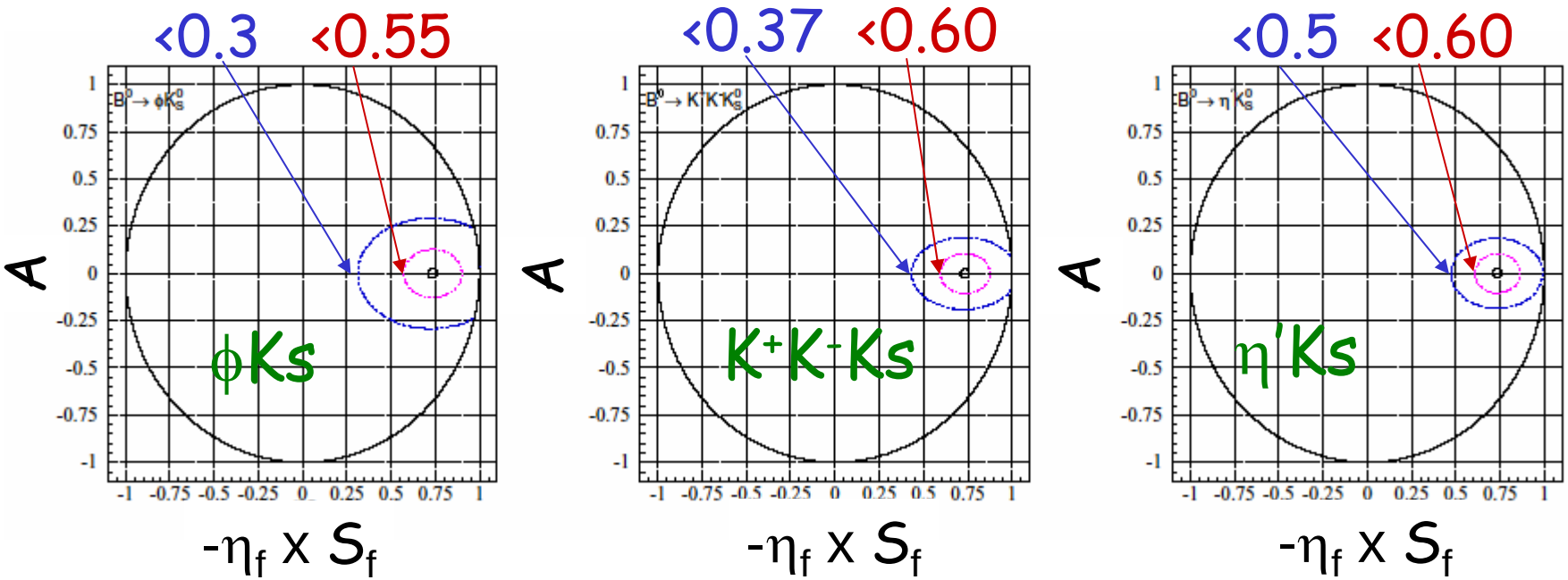




ΔS theory error
φK⁰: ~0.05
h'K⁰: ~0.10

Cont'd

- 5σ confidence region for A and S (5ab^{-1}/50ab^{-1})



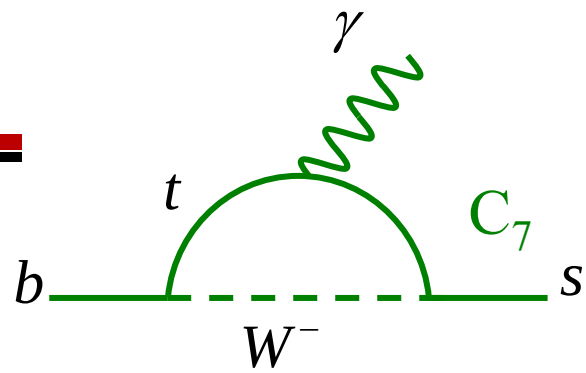
Sanda @ CKM2005.
The reason why present B is so successful.
"Luminosity requirement was set so that we can find CPV even if sin2ϕ_1 ~0.10, but it is turned out to be large (~0.72)"

Theoretical limitation

The region to cover

Luminosity goal

$B \to X_s \gamma$ CP Asymmetry

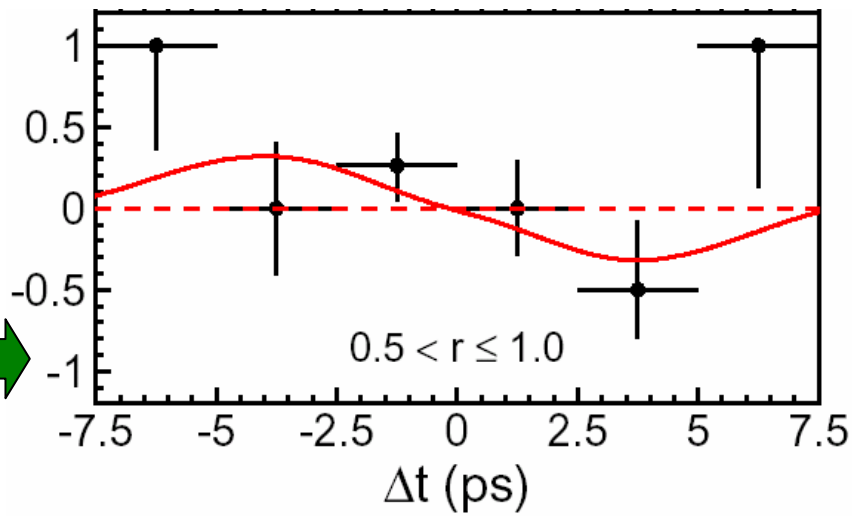


- Sensitive NP.
- Theoretically clean.
- Standard Model "~Zero".
  - Helicity flip of γ suppressed by $\sim m_s/m_b$

Present result

$S = -0.79\ ^{+0.63}_{-0.50} \pm 0.09$ (Belle)

$S = +0.25 \pm 0.63 \pm 0.14$ (BaBar)

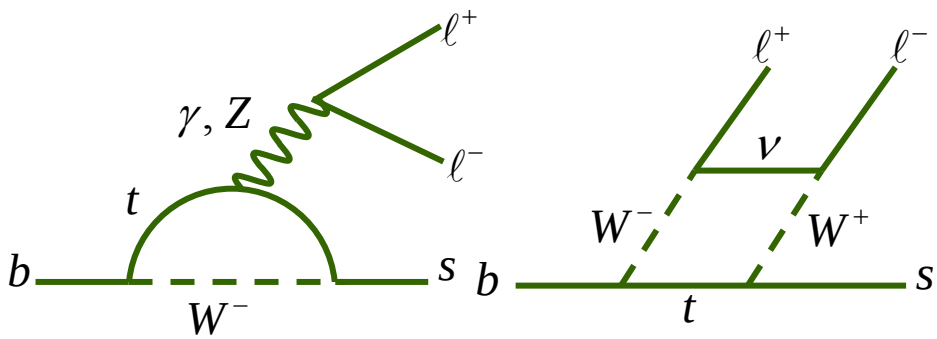


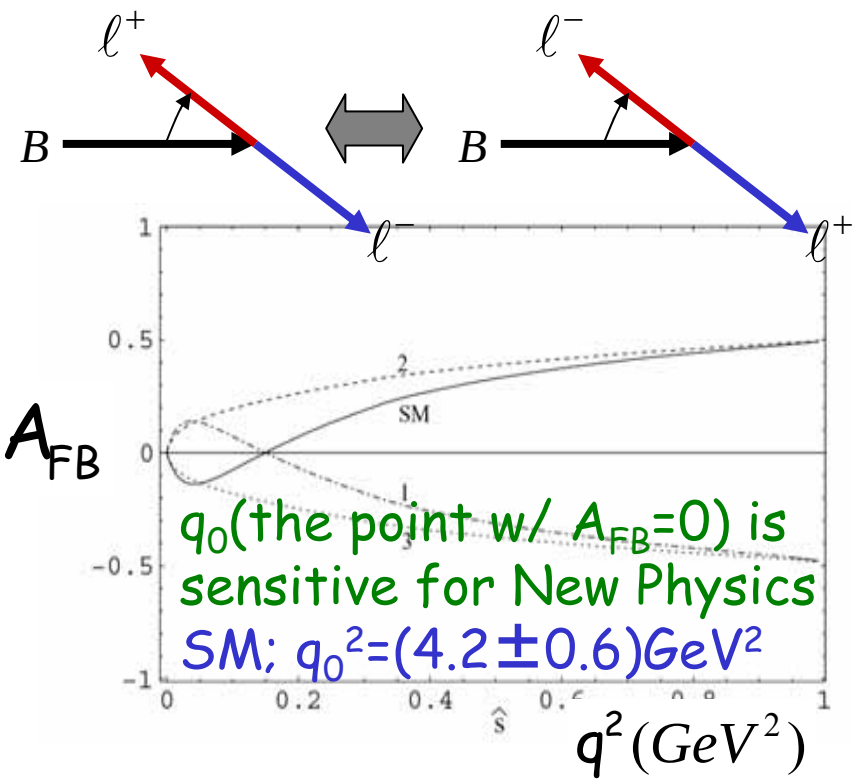
	Present Belle (stat./syst.)	5ab^{-1}	50ab^{-1}
$A_{cp}^{mix}(B \to K^*\gamma,\ K^* \to K_S\pi^0)$	0.56 / 0.09	0.14	0.04
$A_{cp}^{dir}(B \to X_s\gamma)$	0.051 / 0.038	0.011	0.005

$B \to X_s ll$ FB Asymmetry

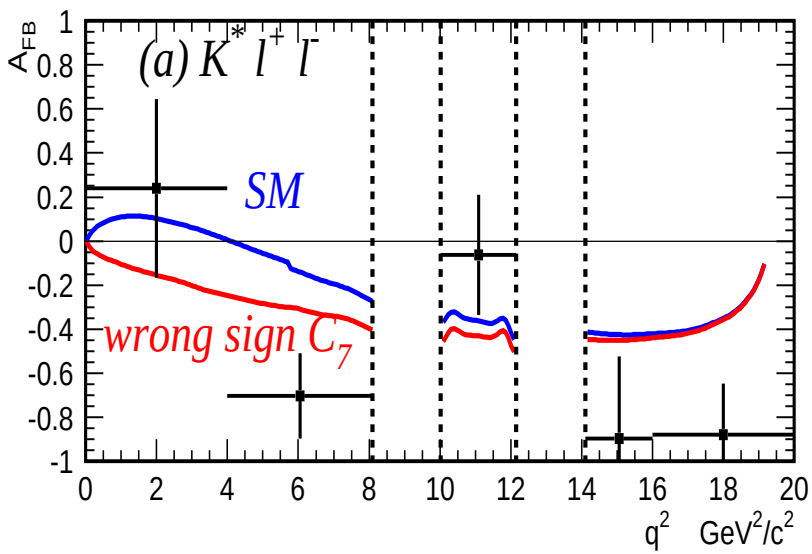
- Good electroweak probe for b→s loop.
- q^2 distribution has different pattern depending on sign(C_7).

$$A_{FB} \propto \Re\left[C_{10}^{*} \left(s C_9^{eff}(s) + r(s) C_7 \right) \right]$$





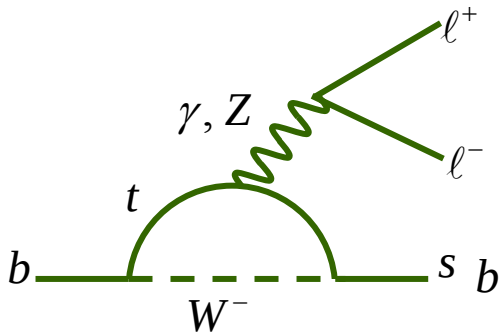
Belle at 250fb^{-1}

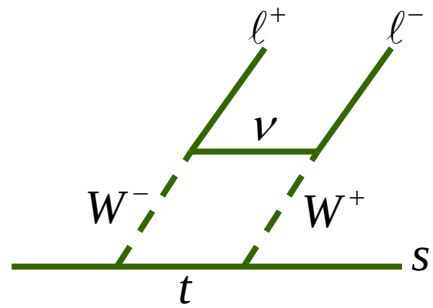


※ shown w/ reversed sign definition.

$B \to X_s \ell\ell$ FB Asymmetry

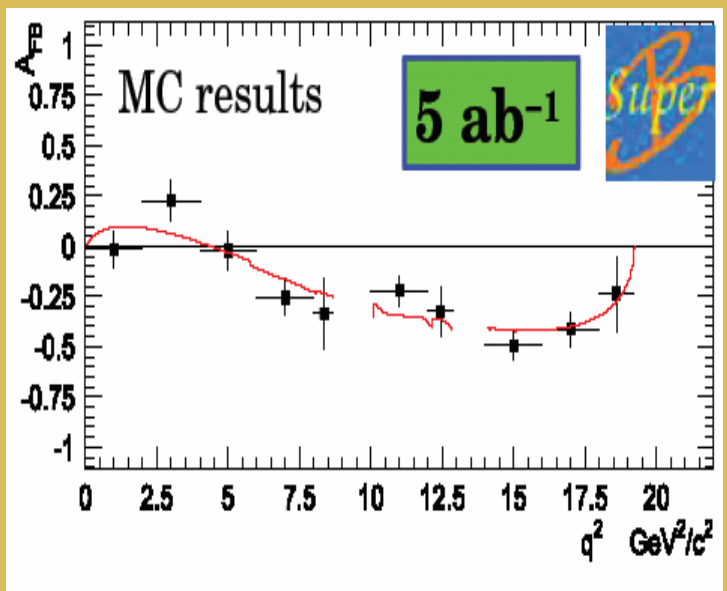
- Good electroweak probe for b→s loop.
- q^2 distribution has different pattern depending on sign(C_7).





$$A_{FB} \propto \Re\left[C_{10}^{*} \left(s C_9^{eff}(s) + r(s) C_7 \right) \right]$$

Update from a recent study

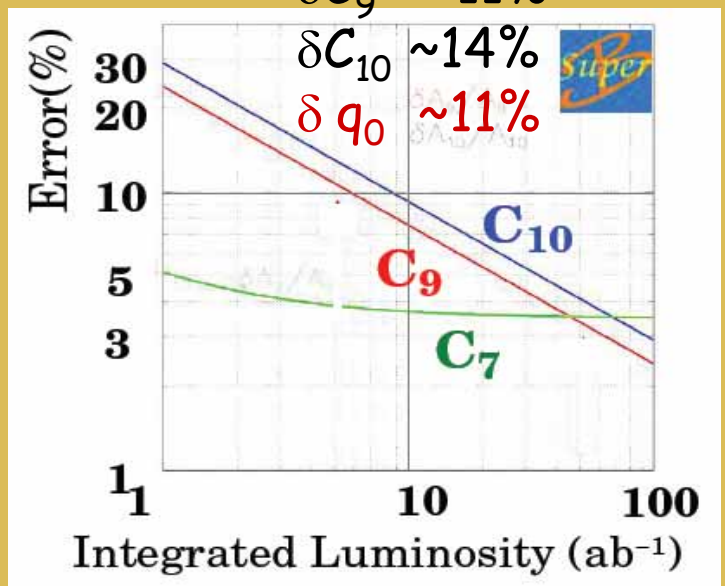


@ 5ab^{-1}

δC_9 ~ 11%

δC_{10} ~14%

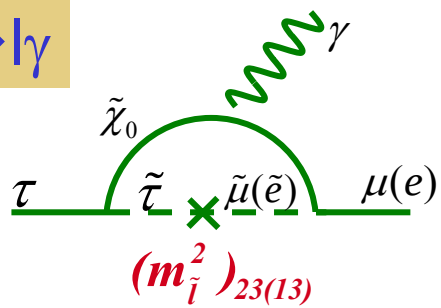
$\delta\, q_0$ ~11%



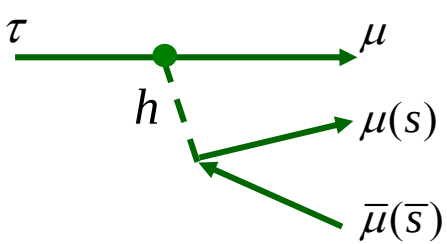
Lepton Flavor Violation

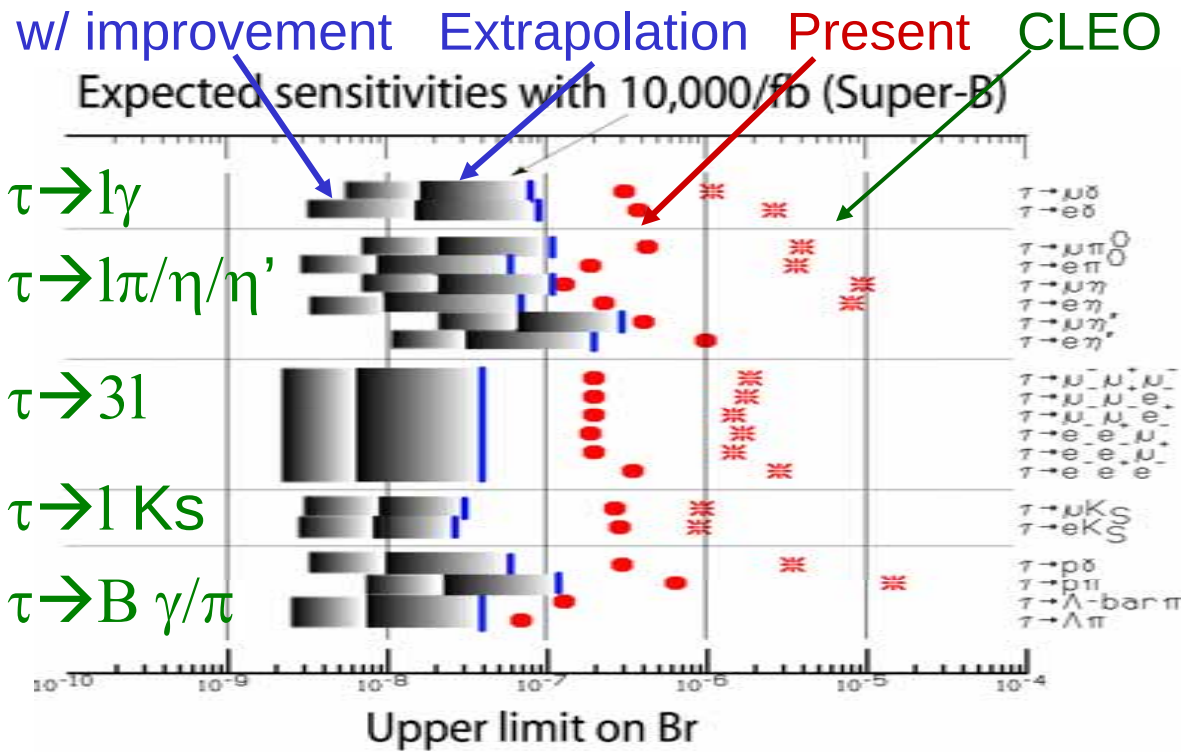
LFV in neutrino sector ⇒LFV in charged leptons ?
Search for “SM Zero”

τ→lγ



τ→3l, lη





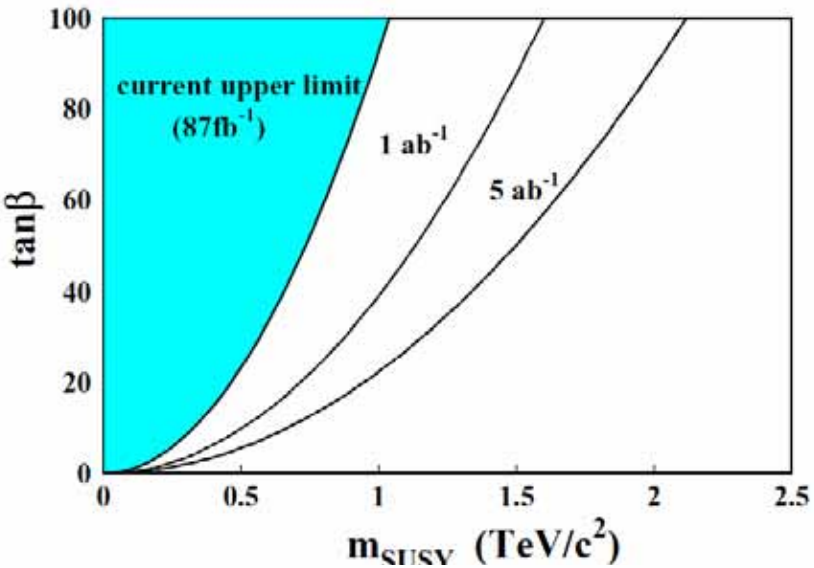
B-factory = “Tau-factory” ⟶ 10^{10} τ pairs at $10ab^{-1}$
Search region enters into $O(10^{-8}\rightarrow10^{-9})$

τ→lγ/3l,lη

τ→lγ

- SUSY + Seasaw
- Large LFV Br(τ→μγ)=O($10^{-7\sim9}$)

$$Br(\tau \to \mu\gamma) \sim 10^{-6} \times \left(\frac{\left(m_{\tilde{L}}^2\right)_{32}}{\bar{m}_{\tilde{L}}^2} \right) \left(\frac{1\,TeV}{m_{SUSY}} \right)^4 \tan^2\beta$$

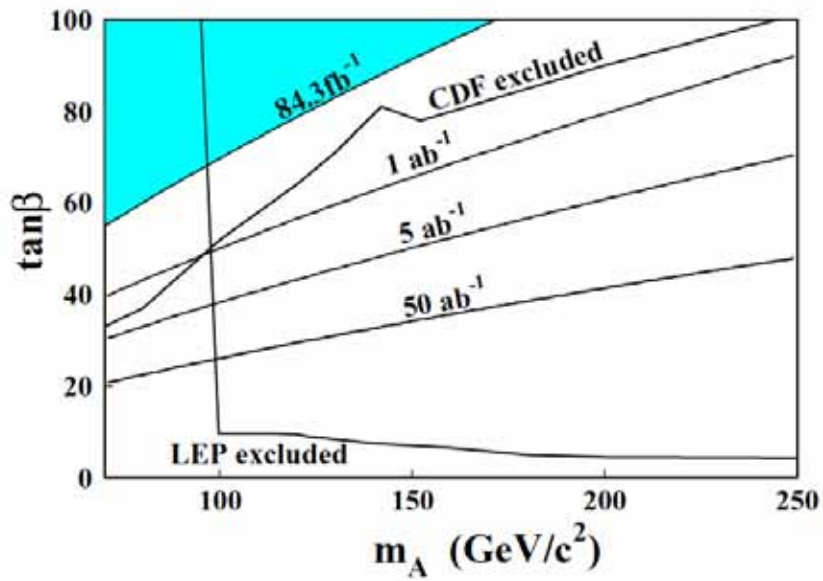


τ→3l,lη

- Neutral Higgs mediated decay.
- Important when MSUSY >> EW scale.

$$Br(\tau \to 3\mu) =$$

$$4\times10^{-7} \times \left(\frac{\left(m_{\tilde{L}}^2\right)_{32}}{\bar{m}_{\tilde{L}}^2} \right) \left(\frac{\tan\beta}{60} \right)^6 \left(\frac{100GeV}{m_A} \right)^4$$

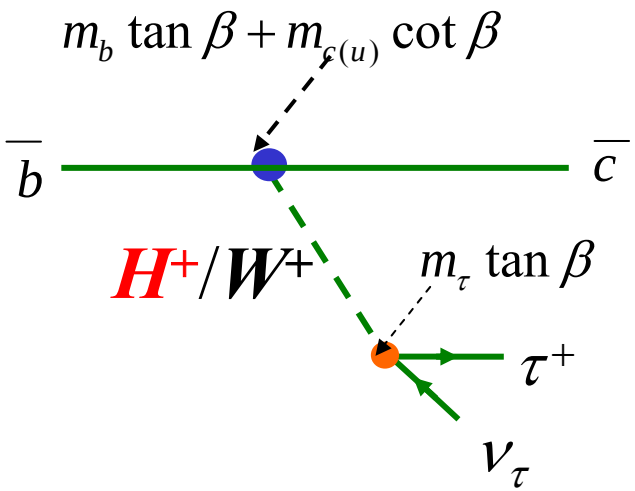


$$Br(\tau \to \mu\eta) : Br(\tau \to 3\mu) : Br(\tau \to \mu\gamma)$$

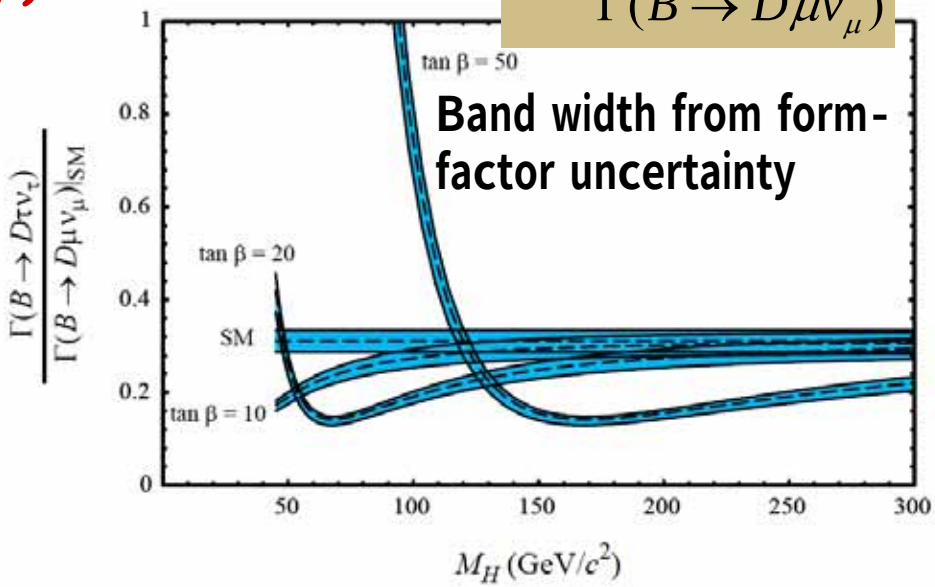
$$= 5 : 1 : 0.5$$

Search for Charged Higgs

- B→Dτν (semileptonic decay)

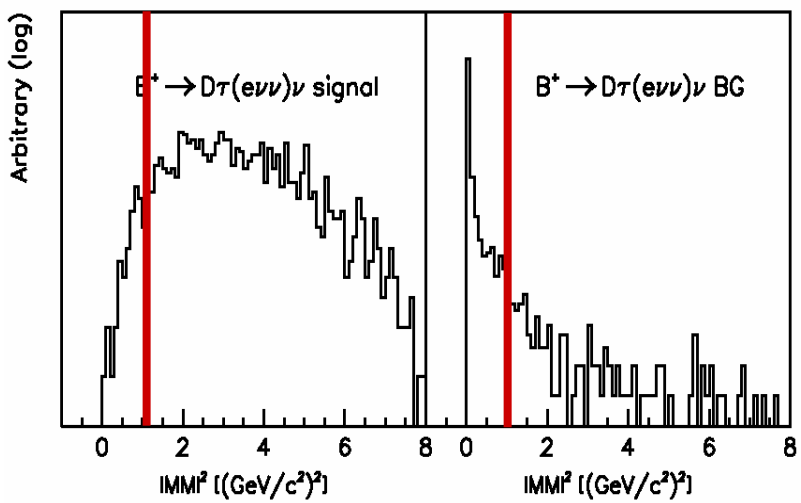


$$B = \frac{\Gamma(B \to \bar{D}\tau\nu_\tau)}{\Gamma(B \to \bar{D}\mu\nu_\mu)}$$

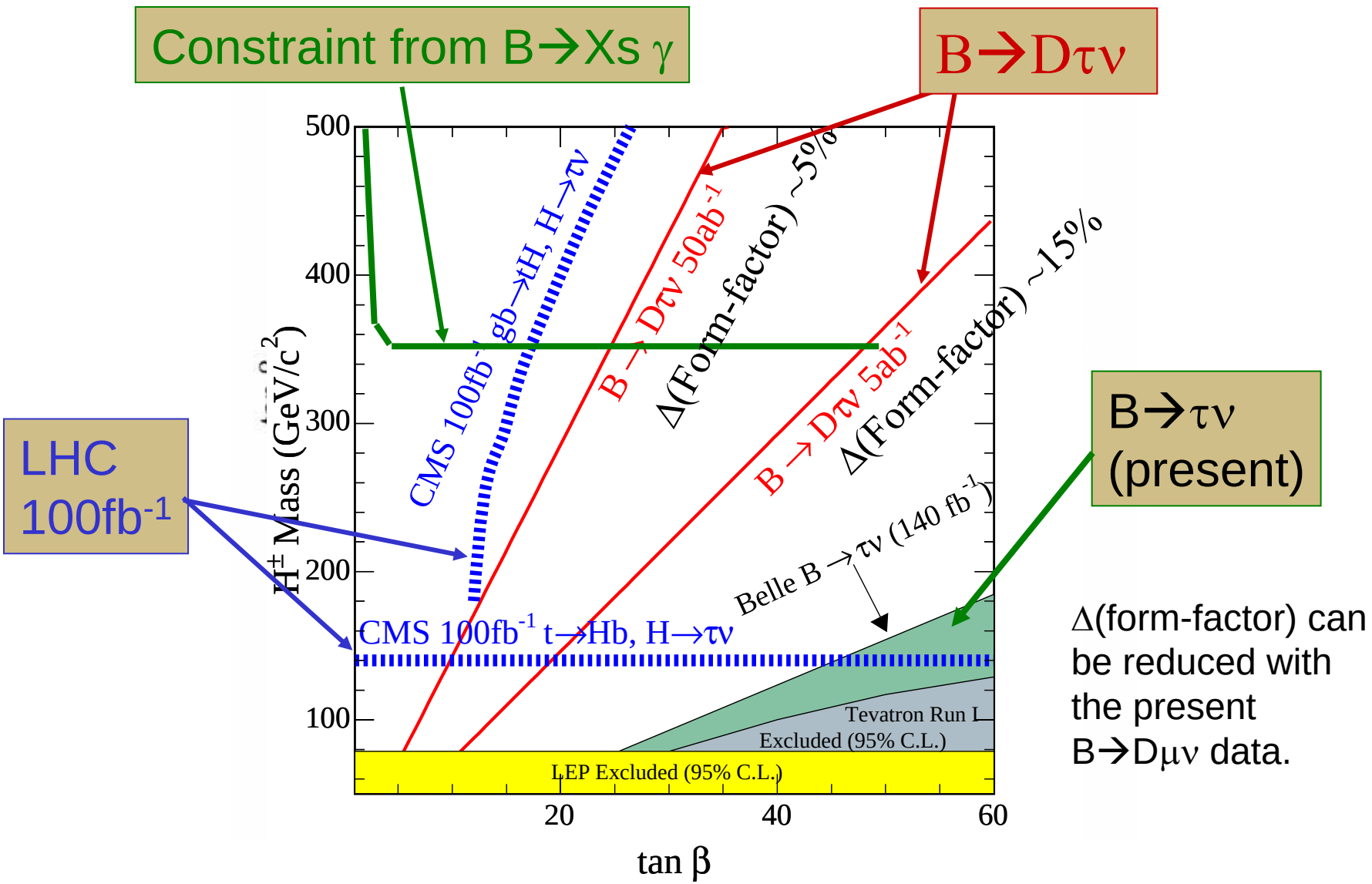


- Full reconstruction tag
- Signal → large missing mass
- Expected at 5ab^{-1}

Mode	Nsig	Nbkg	dB/B
$D^0\tau^+(\ell^+\bar{\nu}_\tau\nu_\ell)\nu_\tau$	280	550	7.9%
$D^0\tau^+(h^+\bar{\nu}_\tau)\nu_\tau$	620	3600	



Sensitivity for Charged Higgs



Δ(form-factor) can be reduced with the present B→Dμν data.

Elucidation of NP Scenario

- T. Goto, Y.Okada, Y.Shimizu,T.Shindou, M.Tanaka, hep-ph/0306093, also in SuperKEKB LoI

SUSY Models

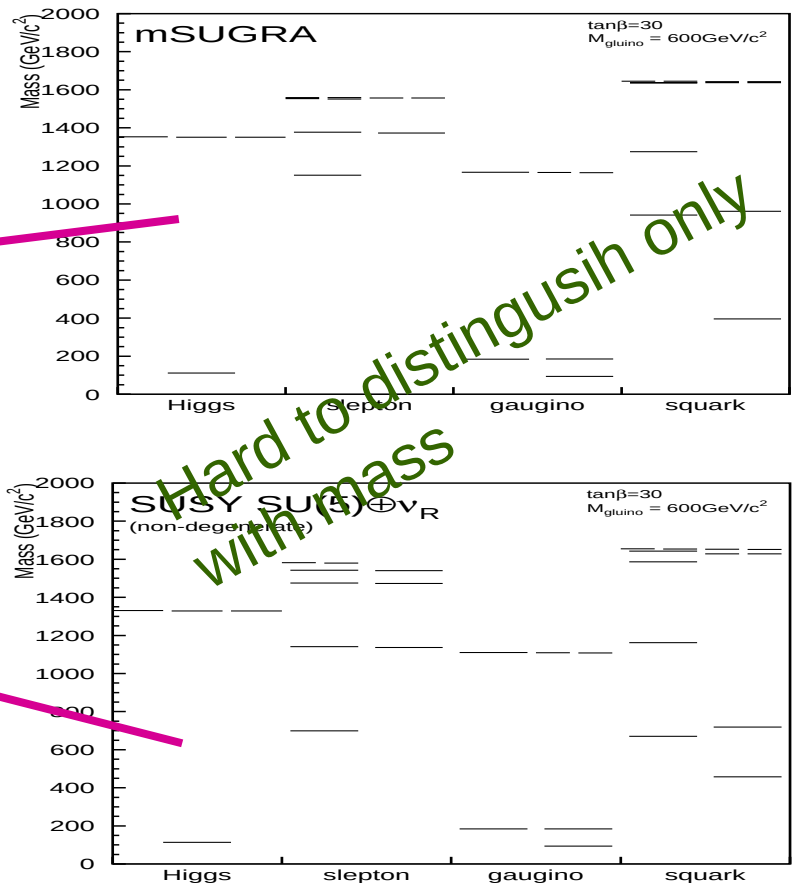
squark $\left(m^2_{\tilde{d}_R}\right)_{23}$ ⟺ slepton $\left(m^2_{\tilde{l}_L}\right)_{23}$

1
- **mSUGRA**
  - $\mathfrak{L}_{soft}$ is flavor blind
  - KM mixings → mixing in $\tilde{q}_L$

2
- **SUSY SU(5) w/ ν_R**
  - Large mixing in ν → mixing in $\tilde{d}_R, \tilde{l}_L$ New CP phase
  - KM mixings → mixing in $\tilde{q}_L$
  - Mass of ν_R
    - Degenerate
    - Non-degenerate

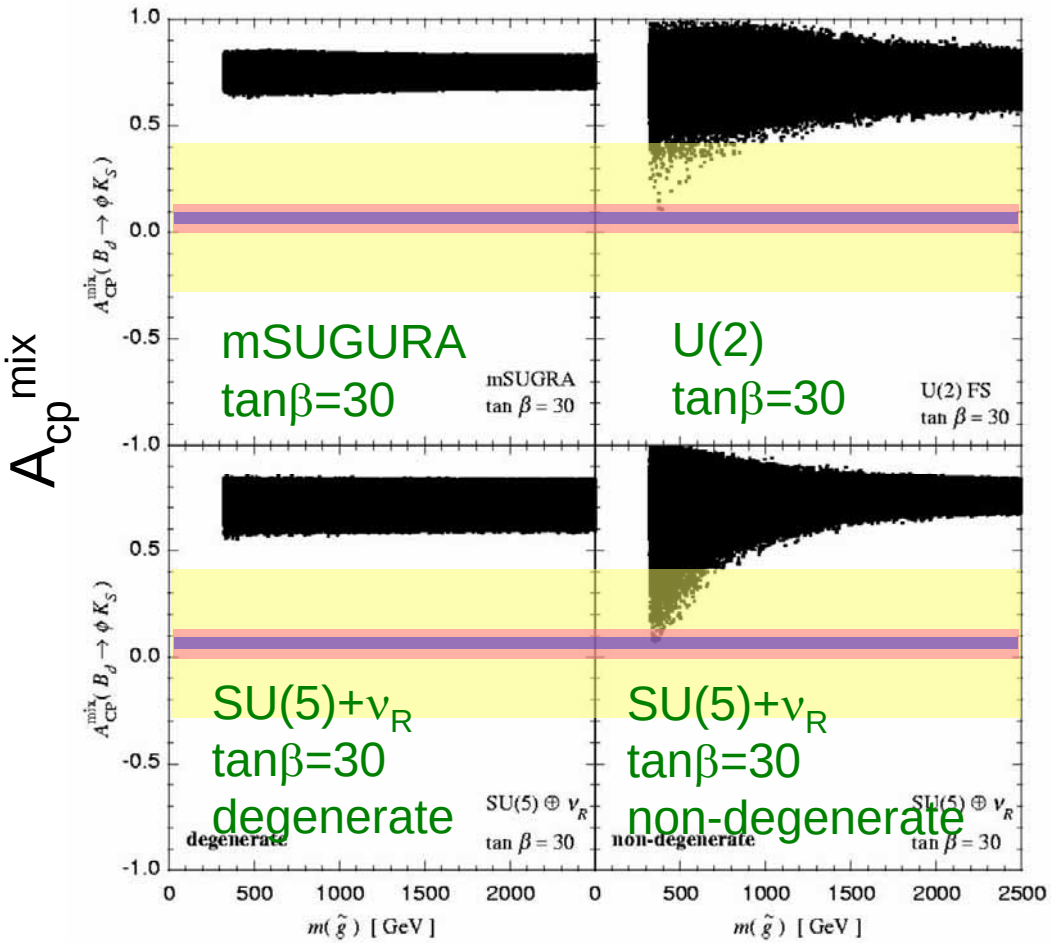
3
- small 2-3 mixing in $\tilde{d}_R$
- large 2-3 mixing in $\tilde{d}_R$

4
- **U(2) flavor symmetry**
  - 1,2 gen. (u,d,c,s,e,μ) U(2) doblet
  - 3rd gen. (t,b,τ) U(2) singlet → $O(\lambda^2)$ 2-3 mixing in $\tilde{q}_L$



Can we distinguish these 4 senarios at Super-KEKB?

$A_{cp}(B \to \phi Ks)$ vs SUSY Models



280fb^{-1}

5ab^{-1}

50ab^{-1}

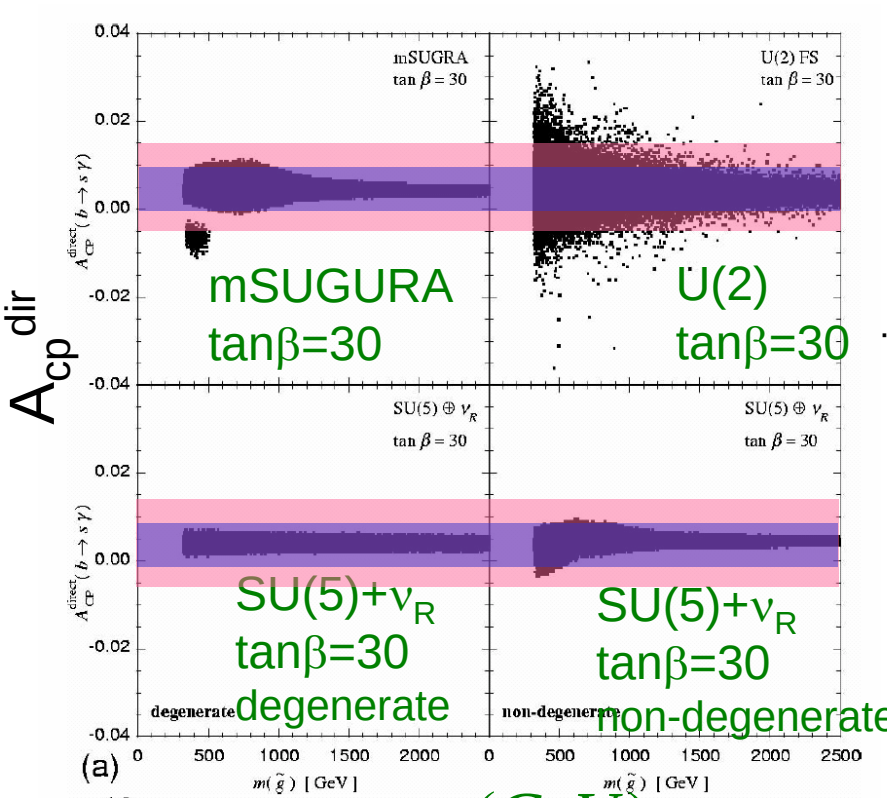
$m_{\tilde{g}}(GeV)$

If confirmed with the central value unchanged.
Large impact on LHC physics and cosmology if new CPV in b→s:
~~Eg. mSUGRA, Gauge mediated SUSY breaking~~

$A_{cp}(B \to X_s\gamma)$ vs SUSY models

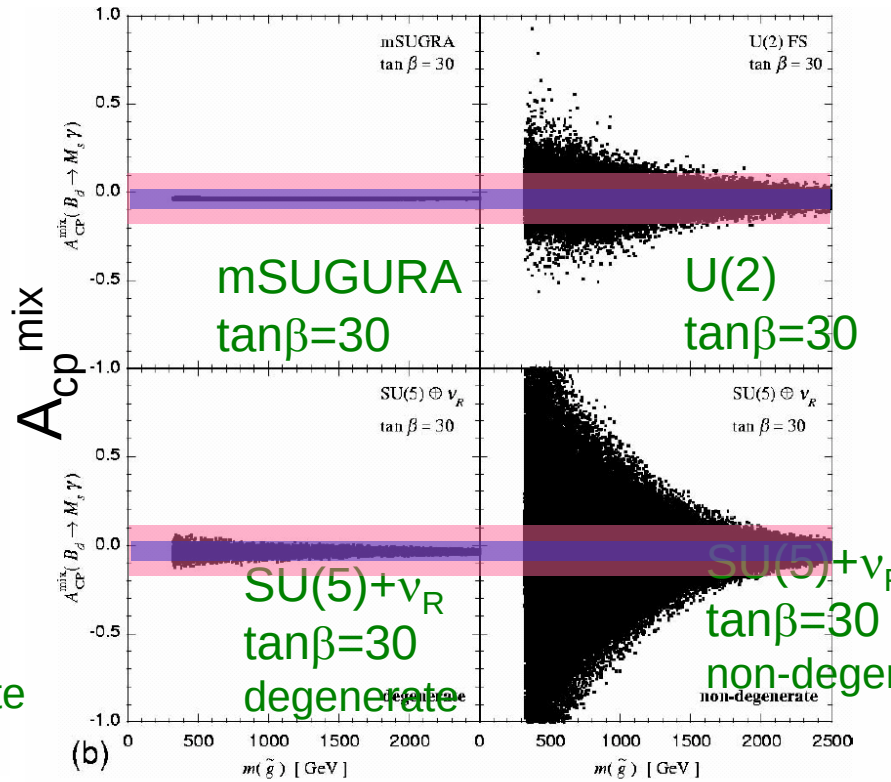
5ab^{-1} 50ab^{-1}

Direct CPV



$m_{\tilde{g}}\,(GeV)$

Mixing CPV



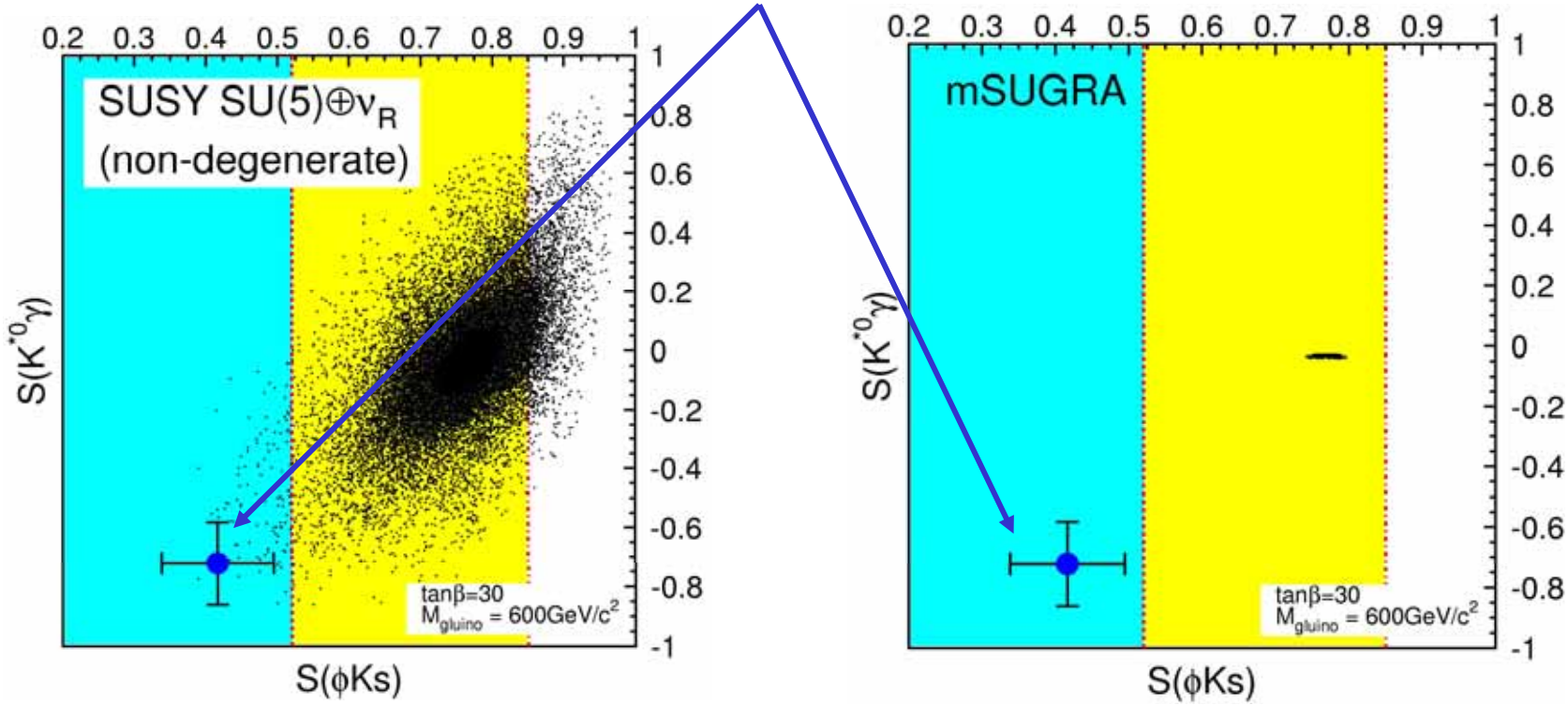
$m_{\tilde{g}}\,(GeV)$

$m_{\tilde{g}}$ up to 2TeV can be explored.

CPV in b→s and SUSY Scenario

- Different SUSY breaking scenario can be distinguished in $A_{cp}^{mix}(\phi Ks)$ - $A_{cp}^{mix}(K^{*0}\gamma)$ correlation.

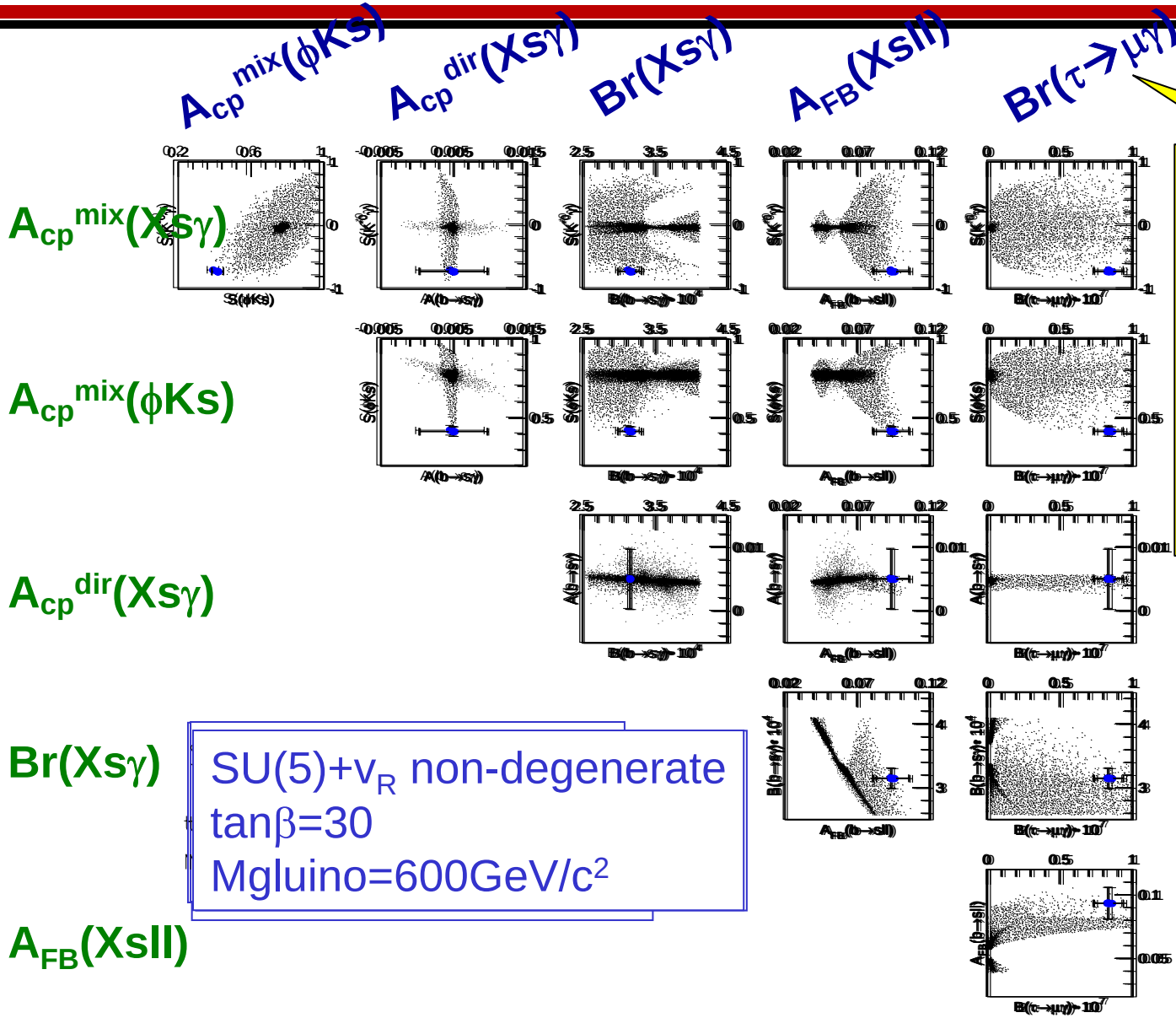
Expected precision at $5ab^{-1}$



Correlation of other ovservables are also useful.

$A_{cp}^{dir}(X_s\gamma)$, $A_{FB}(X_sll)$, $Br(\tau\rightarrow\mu\gamma)$, CKM

More Tests of SUSY Scenario



SUSY GUT relation

$$\left(m^2_{\tilde{d}_R}\right)_{23} \approx \left(m^2_{\tilde{l}_L}\right)_{23} e^{i(\varphi_2-\varphi_3)}$$

Correlation to b→s

SU(5)+v_R non-degenerate
tanβ=30
Mgluino=600GeV/c^2

Summary

Super-B is an unique facility to provide $O(10^{10})$ B and τ in clean environment ($5 \rightarrow 50 ab^{-1}$)

The Mission

Far Precise Test to Look for Correction by NP.

Search for New Origin of Flavor Mixing & CP Violation

Elucidation of New Physics Scenario

Summary

Super-B is an unique facility to provide O(10^{10})
B and τ in clean environment (5→50ab^{-1})

Theoretical limitation ?
Detector feasibility

The Mission

Far Precise Test to Look for Correction by NP.

Search for New Origin of Flavor Mixing & CP Violation

Elucidation of New Physics Scenario

Synergy to LHC (need more studies)

Particle Physics

Super-B has
Significant impact on particle physics in LHC era
Links to other fields

Particle Physics at Higher Energy
at TeV (Higgs, SUSY…), GUT

Physics at Super-KEKB/Belle
New Origin of Flavor Mixing and CPV
Elucidation of NP Scenario

Synergy with HE frontier and
other flavor physics exp's

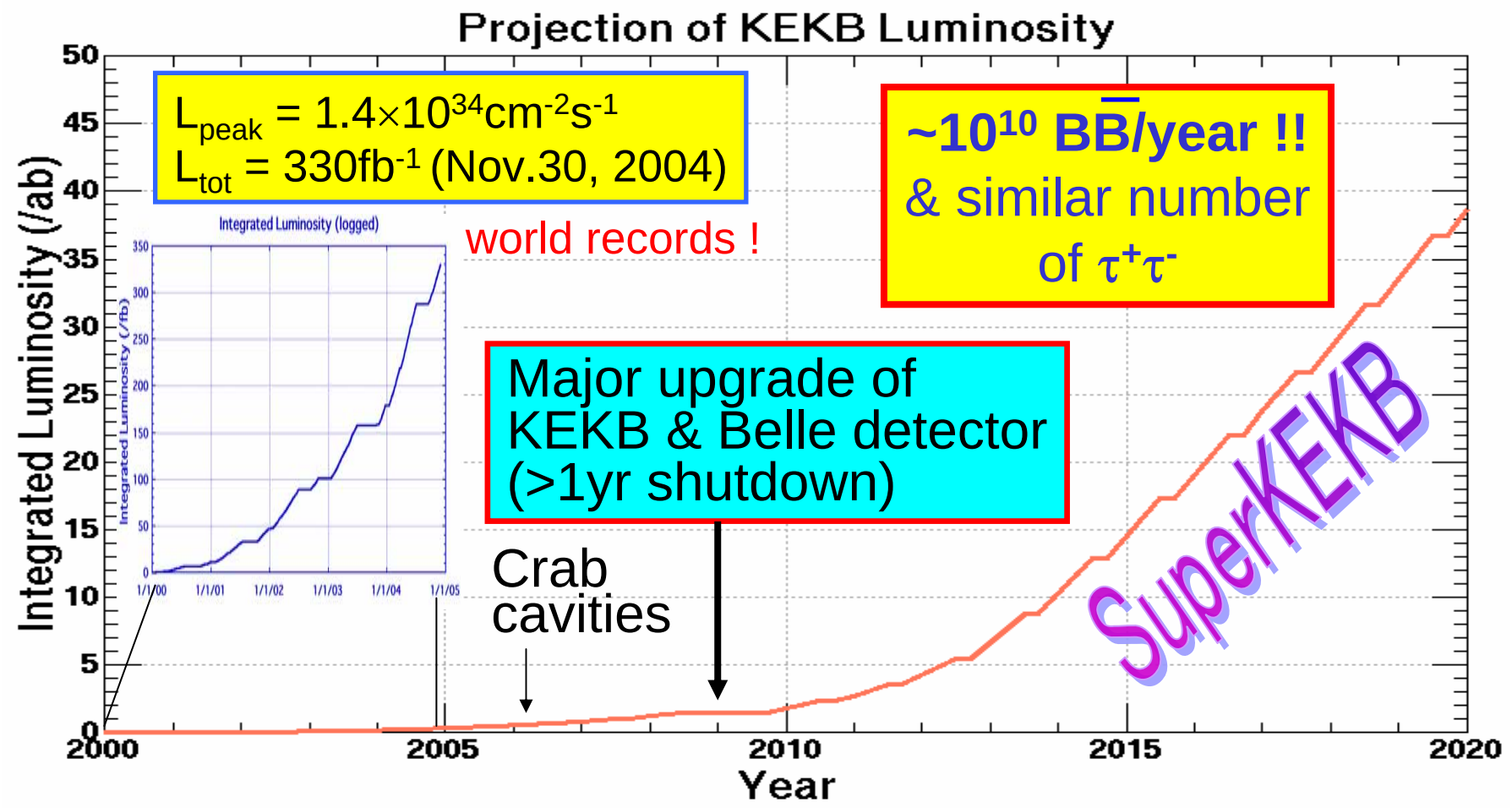
Cosmology
Baryogenesis

Hadron Physics
New states

We should convince community in and around
HEP the importance of Super-B.

Backup Slides

KEKB Upgrade Scenario



L_{peak} (cm^{-2}s^{-1})	1.4x10^{34}	5x10^{34}	5x10^{35}
L_{int}	330 fb^{-1}	~1 ab^{-1}	~10 ab^{-1}

Pattern of Deviation from SM

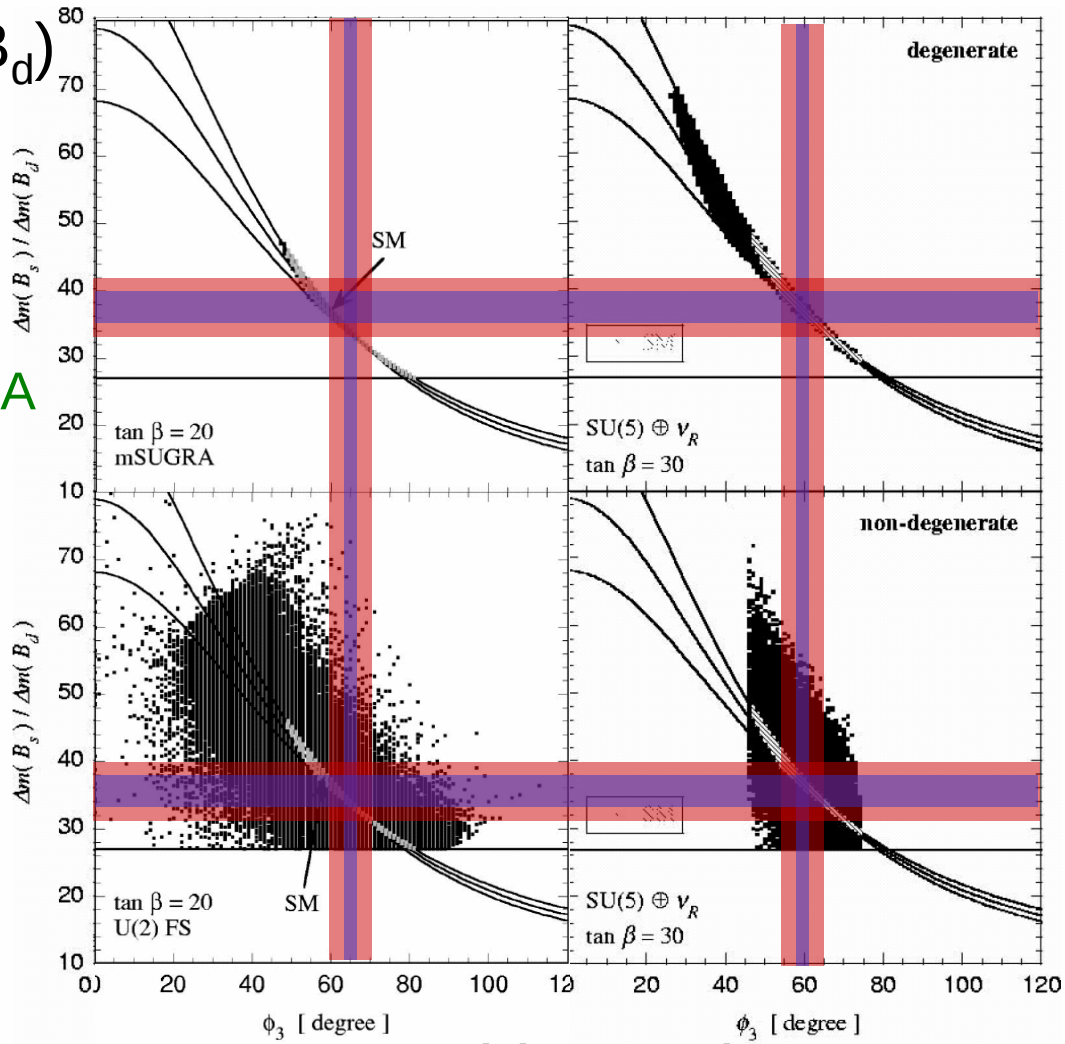
Unitarity triangle | Rare decay | Y.Okada

	Bd-unitarity	ε	Δ m(Bs)	B->ϕKs	B->Msγ indirect CP	b->sγ direct CP
mSUGRA	-	-	-	-	-	+
SU(5)SUSY GUT + ν_R (degenerate)	-	+	+	-	+	-
SU(5)SUSY GUT + ν_R (non-degenerate)	-	-	+	++	++	+
U(2) Flavor symmetry	+	+	+	++	++	++

++: Large, +: sizable, -: small

UT vs SUSY models

$\Delta m(B_s)/\Delta m(B_d)$



ϕ_3 (degree)

5ab^{-1}

50ab^{-1}

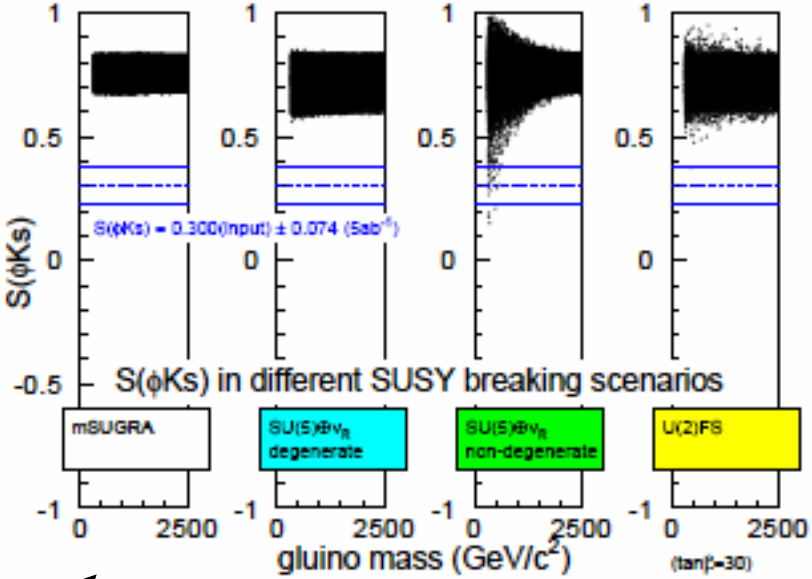
mSUGRA
tanβ=30

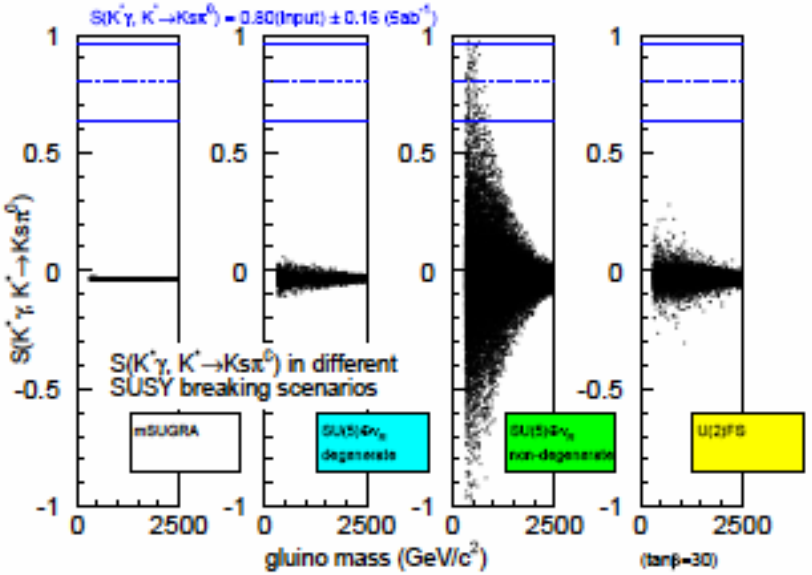
U(2)
tanβ=30

SU(5)+ν_R
tanβ=30
degenerate

SU(5)+ν_R
tanβ=30
non-degenerate

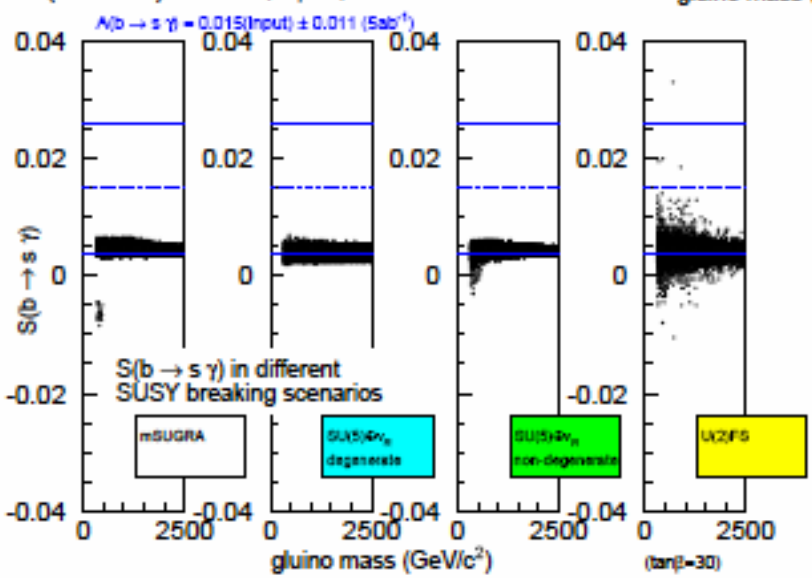
CP Asymmetries in B –>ϕ Ks and b–> sγ





CP asymmetry in B –>ϕ Ks

CP asymmetry in B –> K*γ



Direct asymmetry in b –> s γ

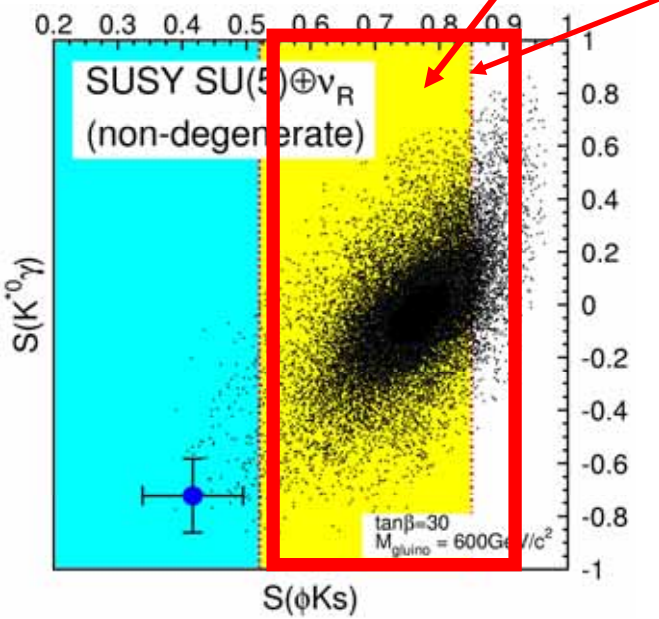
SUSY vs. Warped Extra Dimensions

Agashe,Perez,Soni, hep-ph/0406101(PRL); hep-ph/0408134

at LHCb

SuperKEKB

	Δm_{B_s}	$S_{B_s\to\psi\phi}$	$S_{B_d\to\phi K_s}$	$Br[b\to sl^+l^-]$	$S_{B_{d,s}\to K^*,\phi\gamma}$	$S_{B_{d,s}\to\rho,K^*\gamma}$
RS1	$\Delta m_{B_s}^{SM}[1+O(1)]$	$O(1)$	$\sin 2\beta \pm O(.2)$	$Br^{SM}[1+O(1)]$	$O(1)$	$O(1)$
SM	$\Delta m_{B_s}^{SM}$	λ_c^2	$\sin 2\beta$	Br^{SM}	$\frac{m_s}{m_b}\left(\sin 2\beta, \lambda_c^2\right)$	$\frac{m_d}{m_b}\left(\lambda_c^2, \sin 2\beta\right)$

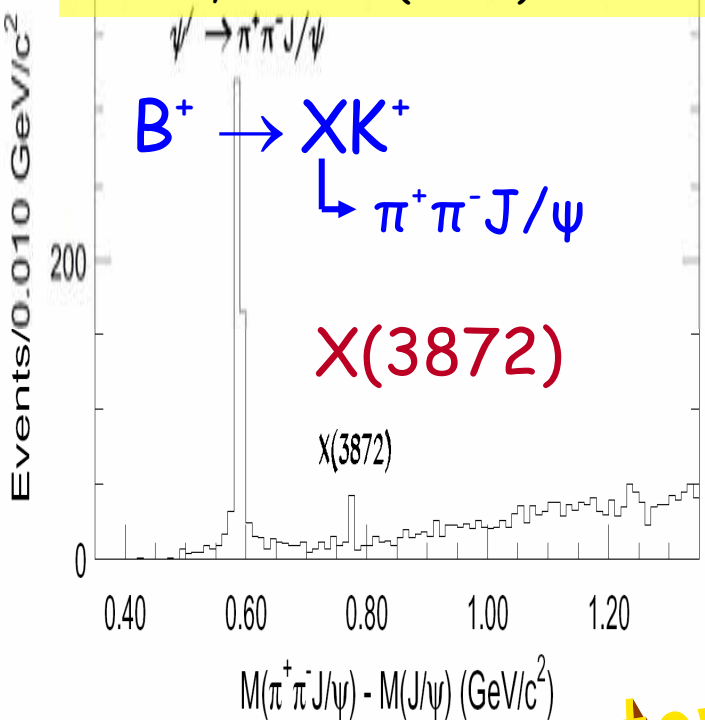


B(B → Xsl+l-) = (4.5±1.0) x 10^{-6} (present WA)
also constrains RR and LL mass insertions:
i.e. related to $S(\phi K_s)$

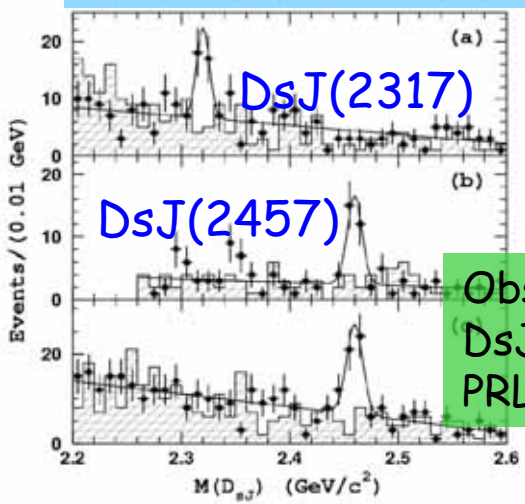
"DNA Identification" of
New Physics from Flavor Structure

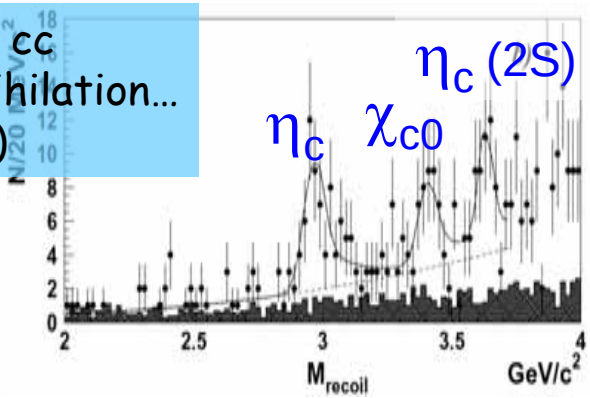
Search for New Hadrons

Observation of a New Narrow Charmonium State…
PRL 91, 262001 (2003)



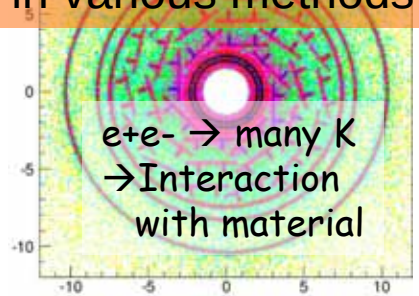
Observation of double cc production in e+e- annihilation…
PRL 89, 142001 (2002)

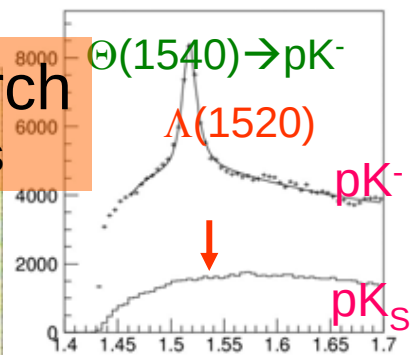




Observation of DsJ(2317) and DsJ(2457) in B decays
PRL 89, 142001 (2002)

Pentaquark search
in various methods





Charmed partner
$B \to \Theta_c^0 \bar{p}\pi^+$
$\hookrightarrow \bar{D}^- p$

B factory is a gateway to new hadrons.