Unique New Physics Search at BelleII

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arXiv: 1002.5012

Physics at Super B Factory

February 11, 2010

Possible updates of this document will be in the future available at
http://belle2.kek.jp/physics.html

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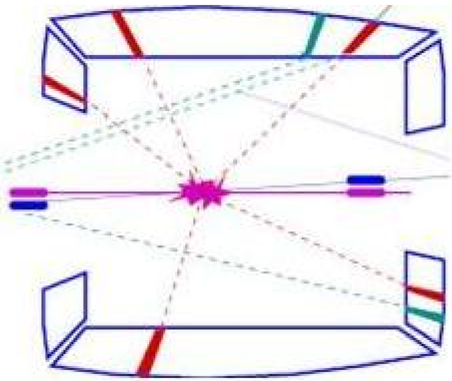
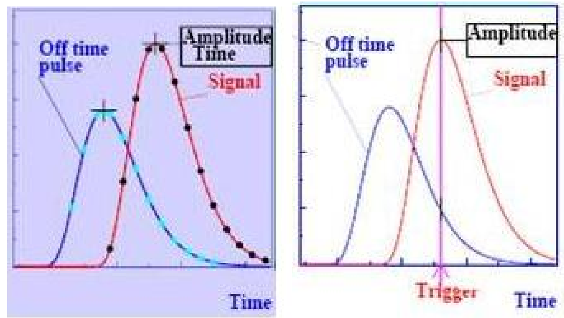
- Select a few channels that BelleII/SuperB can probe new physics better than LHC.
- Adrian will highlight the strength of SuperB
- New ideas, comments and suggestions are welcome.
- Slides are selected from the talk slides given by Bostjan Golob at BPAC meeting.

Charged Higgs on B $\rightarrow \tau\,\nu$

$B_{sig}B_{tag} \rightarrow (\tau\nu)(X\ell\nu)$

$\rightarrow (Y\nu\nu)(X\ell\nu)$



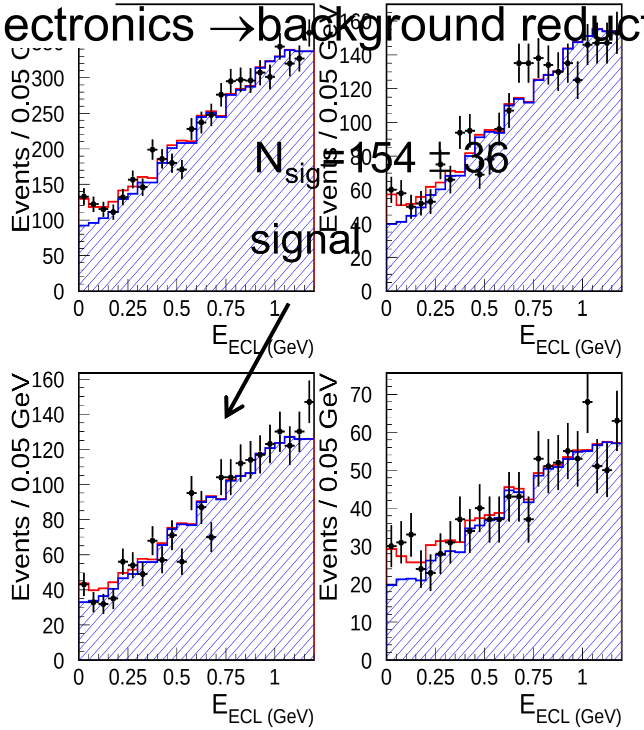


ECL: new electronics $\rightarrow$ background reduction

$$\Gamma(B^+ \rightarrow \tau^+\nu) =$$

$$= \Gamma^{SM}(B^+ \rightarrow \tau^+\nu)\cdot\left(1-\frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

$$Br(B^+ \rightarrow \tau\nu) = (1.65 \pm^{0.38}_{0.37} \pm^{0.35}_{0.37})\cdot 10^{-4}$$



$N_{sig} = 154 \pm 36$

signal

Belle 50 ab^{-1}: semil. + hadr. tag;

main syst. reducible:

bkg. ECL shape, ε B_{tag}

V_{ub} ±3%, f_B ±3%

$$\sigma(Br(B^+ \rightarrow \tau\nu) \approx 0.05\cdot 10^{-4}$$

$$\sigma(\Gamma/\Gamma^{SM}) \approx 0.08$$

Charged Higgs Search

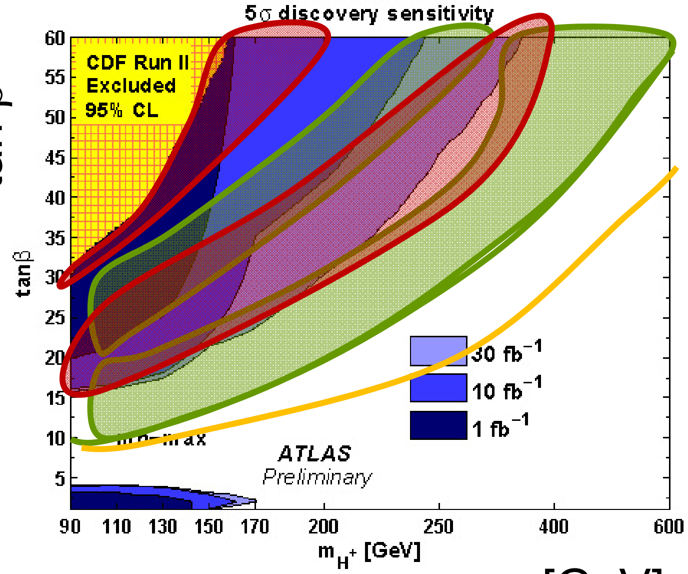
Atlas

Belle II, 5 ab^{-1}

Belle II, 50 ab^{-1}

5 σ discovery sensitivity

tan β



m_{H+} [GeV]

- excluded currently ($Br(B\to\tau\nu)$) @ 95.5%
- 5σ discovery, Belle II, 5 ab^{-1}
- 5σ discovery, Belle II, 50 ab^{-1}

Belle II $Br(B\to\tau\nu)$) sensitive to H^+ at large m_{H+} and tan β

at low tan β $B \to X_s \gamma$ constraints the parameters

Belle II reach @ $\mathcal{L}$ can be parametrized:

$\tan\beta \geq 5 \cdot \sqrt{(0.5\ ab^{-1}/\mathcal{L})} \cdot [1\cdot 10^{-4} GeV^{-2} \cdot (m - 90\ GeV)^2 + 12.2]$

- Similar study for $B\to D^{(*)}\tau\nu$
- $B \to \mu\nu$: 4.3 ab^{-1} for 5σ discovery (SM Br);

$$R_{\tau\mu} = \frac{Br(B^+ \to \tau\nu)}{Br(B^+ \to \mu\nu)} \sim \frac{m_\tau^2}{m_\mu^2}$$

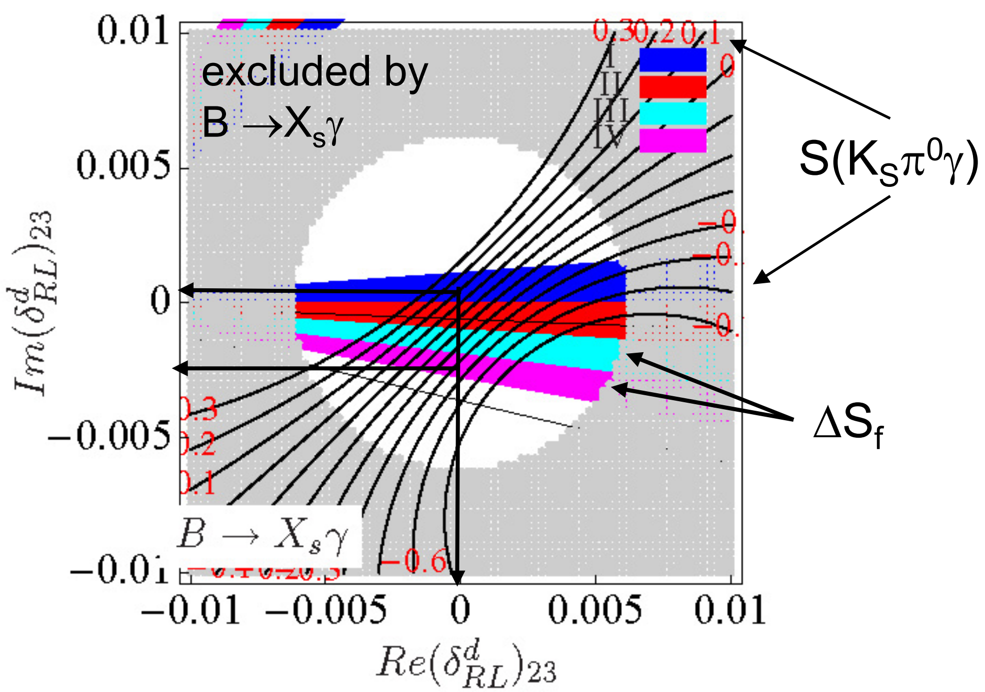
MSSM searches Belle II

A.G. Akeroyd et al., KEK Report 2009-12

mass insertion approximation,
example of flavor observables

$$m_{\tilde{q}} = m_{\tilde{g}} = 500\,GeV$$

low tanβ

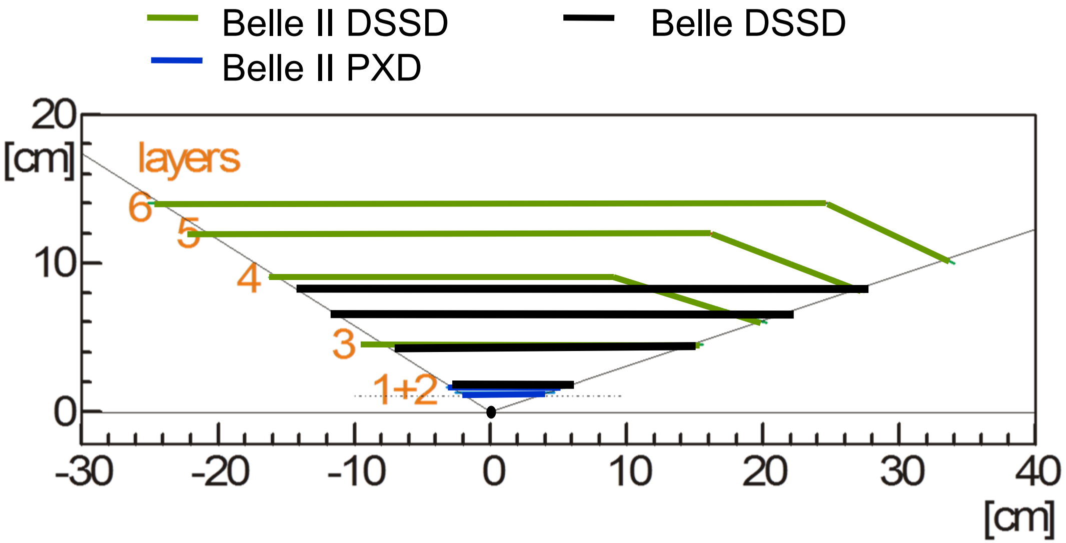


$\Delta S_f = \sin 2\phi_1(c\bar{c}s) - \sin 2\phi_1(s\bar{s}s)$

two points in (ΔS_f, $S(K_S\pi^0\gamma)$)

- ΔS_f= [-0.3,-0.2] $S(K_S\pi^0\gamma)$ ~ -0.4
- ΔS_f= [0,0.1] $S(K_S\pi^0\gamma)$ ~ 0.1

Search for Right-Handed Neutral Currents



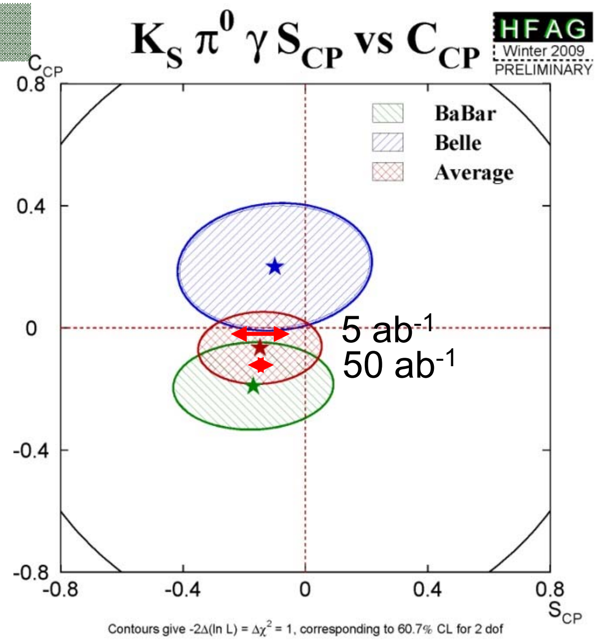
t-dependent CPV in $K_S\pi^0\gamma$ $(S(K_S\pi^0\gamma))$

B decay vtx from K_s and IP;
vertex detector: $\varepsilon(K_S \to \pi^+\pi^-)$, $\sigma(t)$

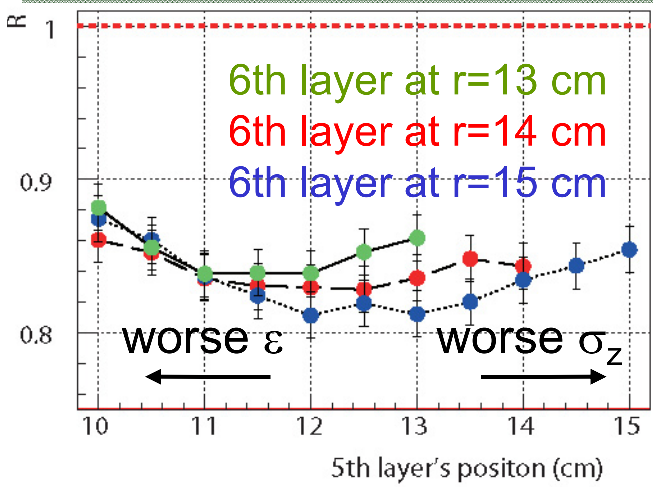
A.G. Akeroyd et al., KEK Report 2009-12

$\sigma(S_{CP}(K_s\pi^0\gamma))$=
0.09 @ 5 ab^{-1}
0.03 @ 50 ab^{-1}

$\sigma(\Delta S(K_s\phi))$=
0.10 @ 5 ab^{-1}
0.05 @ 50 ab^{-1}



sBelle Design Group, KEK Report 2008-7



MSSM searches Belle II

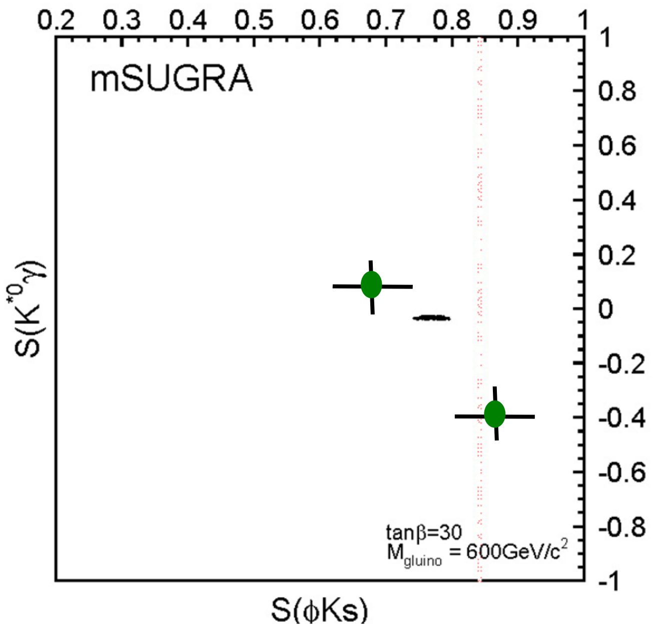
Example points:

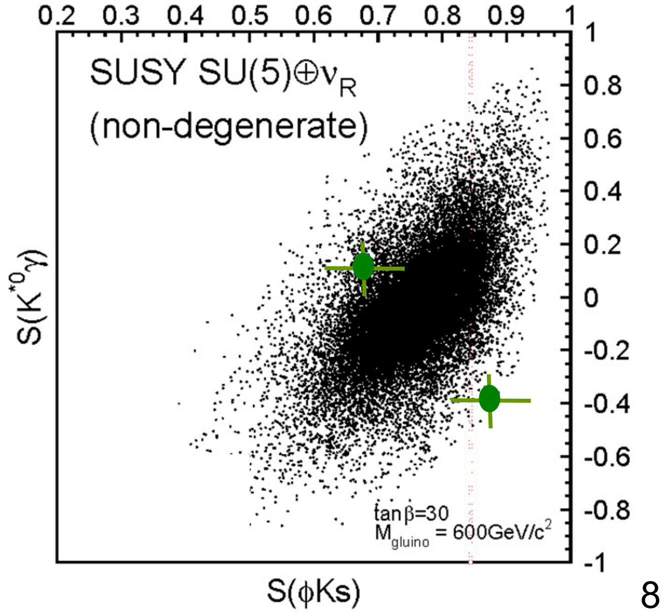
ΔS_f= [-0.3,-0.2] $S(K_S\pi^0\gamma)$ ~ -0.4
ΔS_f= [0,0.1] $S(K_S\pi^0\gamma)$ ~ 0.1

shown with expected accuracy @ 5 ab^{-1}

Belle II can distinguish various SUSY models

A.G. Akeroyd et al., KEK Report 2009-12





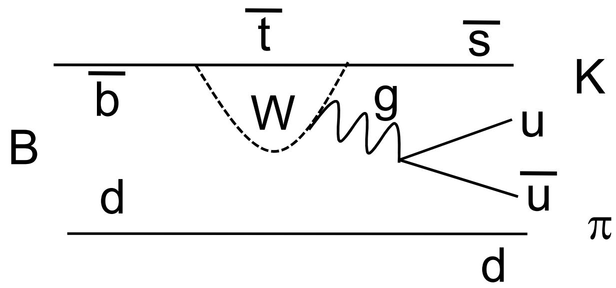
Search for New CP Phase

:

Tree+penguin processes, B $\rightarrow K\pi$

$\Delta A_{K\pi} = A(K^+\pi^-) - A(K^+\pi^0) = -0.147 \pm 0.028$

HFAG, LP'09



penguin dominated

model independent sum rule:

$$\mathcal{A}_f(K^+\pi^-) + \mathcal{A}_f(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)\tau_{B^0}}{\mathcal{B}(K^+\pi^-)\tau_{B^+}} =$$

$$\mathcal{A}_f(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)\tau_{B^0}}{\mathcal{B}(K^+\pi^-)\tau_{B^+}} + \mathcal{A}_f(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}.$$

M. Gronau, PLB627, 82 (2005);
D. Atwood, A. Soni, PRD58, 036005 (1998)

$A(K^0\pi^+) = 0.009 \pm 0.025$

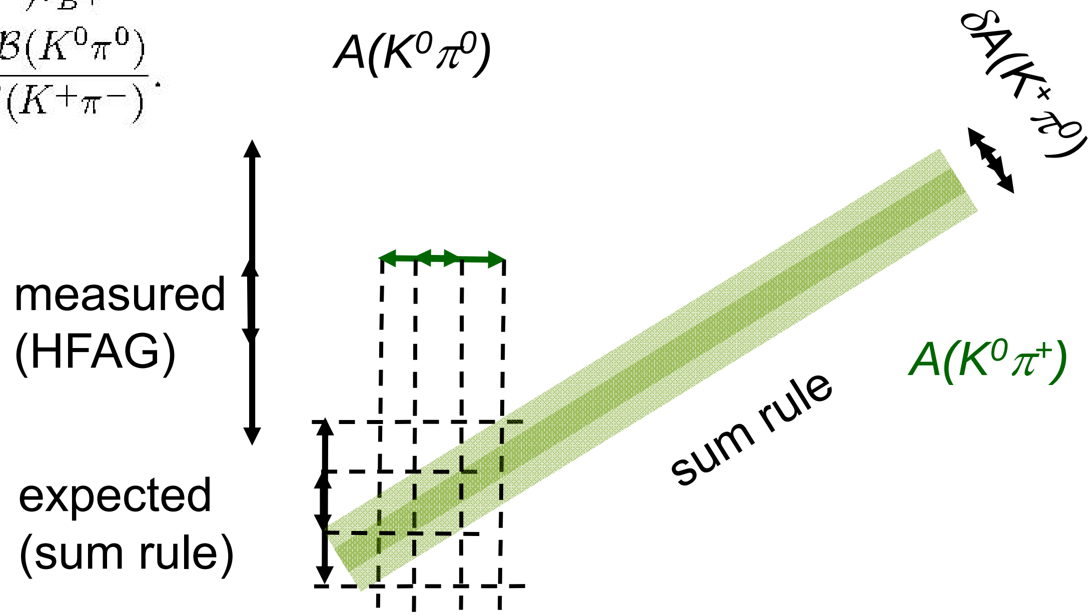
$A(K^+\pi^0) = 0.050 \pm 0.025$

$A(K^+\pi^-) = -0.098 \pm 0.012$

$A(K^0\pi^0) = -0.01 \pm 0.10$

Belle II 50 ab^{-1}

HFAG, LP'09



Tree+penguin processes, $B^0 \to K\pi\pi^0$

M. Gronau, D. Pirjol, J. Zupan, arXiv:1001.0702

$K^*\pi$, $K\rho$: $T+P_{EW}/P_{QCD}$ larger than in $K\pi$
similar as in $K\pi$: isospin sum rule

$$-A(K^{*+}\pi^-) = \lambda_t^{(s)}(P_{tc,P} + \frac{2}{3}P^C_{EW,P}) + \lambda_u^{(s)}(P_{uc,P} + T_P)$$

$$\sqrt{2}A(K^{*0}\pi^0) = \lambda_t^{(s)}(P_{tc,P} - P_{EW,V} - \frac{1}{3}P^C_{EW,P}) + \lambda_u^{(s)}(P_{uc,P} - C_V)$$

$$A(K^{*+}\pi^-) + \sqrt{2}A(K^{*0}\pi^0) = P_{EW} + T << P_{tc}$$

- $B^0 \to K\pi\pi^0$: $A(K^{*+}\pi^-)$ & $A(K^{*0}\pi^0)$ should destructively interfere.

- Large Acp on $B^0 \to K^{*+}\pi^-$, $\rho^- K^+$ and $B^0 \to K^{*+}\pi^0$, $\rho^0 K^+$
- Check three Acp sum rules: $K^*\pi$, ρK and $K\pi$

Search for LFV in τ decays

$\tau \to l\gamma$, $\tau \to l\,h$, $\tau \to l$

- $\tau \to l\gamma$: bkg from ee→ $\tau\tau\gamma$ (U.L. ∝ 1/√**L**)
- $\tau \to l\,h$, t→ lll : bgk free (U.L. ∝ 1/**L**)

example:

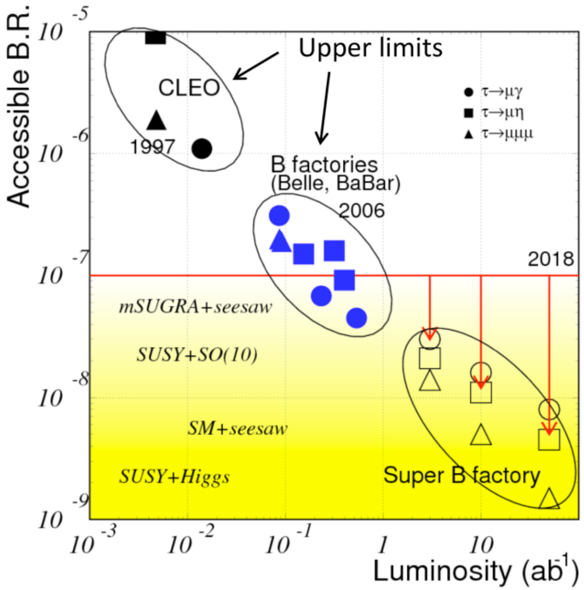
Higgs mediated LFV, $\tau \to \mu\eta$

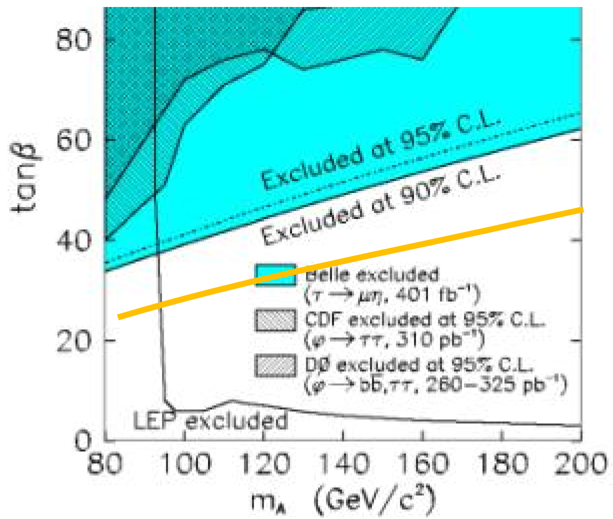
with 10 ab^{-1} constraints on tanβ improved by 30 - 40% for all m_A

identification of specific models

$$\frac{Br(\tau \to \mu ee)}{Br(\tau \to \mu\gamma)} = \begin{cases} 0.3-1.6 & \text{little Higgs T parity} \\ \sim 0.01 & \text{MSSM} \end{cases}$$

sensitivity ~10^{-9} and ~7×10^{-9} @ 50 ab^{-1}





Belle, 10 ab^{-1}

Other Topics and Summary

- B $\rightarrow$ K* $\nu\nu$, Charm mixing, $A_{FB}(ee\rightarrow\mu\mu)$ ...
  $\Rightarrow$ Adrian's talk
- Possible polarized beam and run at charm threshold for SuperB.
- NP search:
  B$\rightarrow\tau\nu$, right-handed neutral currents,
  Acp($K^{(*)}\pi$)/A(ρK) sum rule tests,
  LFV in τ decays

Physics on Super B Factory, 1

Observable	Belle 2006	SuperKEKB		†LHCb	
	($\sim$0.5 ab^{-1})	(5 ab^{-1})	(50 ab^{-1})	(2 fb^{-1})	(10 fb^{-1})
Hadronic $b \to s$ transitions					
$\Delta\mathcal{S}_{\phi K^0}$	0.22	0.073	0.029		0.14
$\Delta\mathcal{S}_{\eta' K^0}$	0.11	0.038	0.020		
$\Delta\mathcal{S}_{K_S^0 K_S^0 K_S^0}$	0.33	0.105	0.037	-	-
$\Delta\mathcal{A}_{\pi^0 K_S^0}$	0.15	0.072	0.042	-	-
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014		
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°		
Radiative/electroweak $b \to s$ transitions					
$\mathcal{S}_{K_S^0 \pi^0 \gamma}$	0.32	0.10	0.03	-	-
$\mathcal{B}(B \to X_s \gamma)$	13%	7%	6%	-	-
$A_{CP}(B \to X_s \gamma)$	0.058	0.01	0.005	-	-
C_9 from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-	11%	4%		
C_{10} from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-	13%	4%		
C_7/C_9 from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-		5%		7%
R_K		0.07	0.02		0.043
$\mathcal{B}(B^+ \to K^+ \nu\nu)$	†† $< 3\ \mathcal{B}_{\rm SM}$		30%	-	-
$\mathcal{B}(B^0 \to K^{*0} \nu\bar{\nu})$	†† $< 40\ \mathcal{B}_{\rm SM}$		35%	-	-
Radiative/electroweak $b \to d$ transitions					
$\mathcal{S}_{\rho\gamma}$	-	0.3	0.15		
$\mathcal{B}(B \to X_d \gamma)$	-	24% (syst.)		-	-

Physics at Super B Factory, 2

Leptonic/semileptonic B decays					
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%	-	-
$\mathcal{B}(B^+ \to \mu^+\nu)$	$^{\dagger\dagger} < 2.4\mathcal{B}_{\rm SM}$	4.3 $\rm ab^{-1}$ for 5σ discovery		-	-
$\mathcal{B}(B^+ \to D\tau\nu)$	-	8%	3%	-	-
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%	-	-
LFV in τ decays (U.L. at 90% C.L.)					
$\mathcal{B}(\tau \to \mu\gamma)$ $[10^{-9}]$	45	10	5	-	-
$\mathcal{B}(\tau \to \mu\eta)$ $[10^{-9}]$	65	5	2	-	-
$\mathcal{B}(\tau \to \mu\mu\mu)$ $[10^{-9}]$	21	3	1	-	-
Unitarity triangle parameters					
$\sin 2\phi_1$	0.026	0.016	0.012	$\sim$0.02	$\sim$0.01
ϕ_2 $(\pi\pi)$	11°	10°	3°	-	-
ϕ_2 $(\rho\pi)$	$68^\circ < \phi_2 < 95^\circ$	3°	1.5°	10°	4.5°
ϕ_2 $(\rho\rho)$	$62^\circ < \phi_2 < 107^\circ$	3°	1.5°	-	-
ϕ_2 (combined)		2°	$\lesssim 1^\circ$	10°	4.5°
ϕ_3 $(D^{(*)}K^{(*)})$ (Dalitz mod. ind.)	20°	7°	2°	8°	
ϕ_3 $(DK^{(*)})$ (ADS+GLW)	-	16°	5°	5-15°	
ϕ_3 $(D^{(*)}\pi)$	-	18°	6°		
ϕ_3 (combined)		6°	1.5°	4.2°	2.4°
$\|V_{ub}\|$ (inclusive)	6%	5%	3%	-	-
$\|V_{ub}\|$ (exclusive)	15%	12% (LQCD)	5% (LQCD)	-	-
$^{\dagger\dagger\dagger}\bar{\rho}$	20.0%		3.4%		
$^{\dagger\dagger\dagger}\bar{\eta}$	15.7%		1.7%		

Physics on Super B Factory, 3

Observable	Belle	Belle/SuperKEKB		LHCb†	
				($2\ fb^{-1}$)	($10\ fb^{-1}$)
B_s physics	($25\ fb^{-1}$)	(	$5\ ab^{-1}$)		
$\mathcal{B}(B_s \to \gamma\gamma)$	$< 8.7 \times 10^{-6}$	0.25×10^{-6}		-	-
$\Delta\Gamma_s^{CP}/\Gamma_s$ ($Br(B_s \to D_s^{(*)} D_s^{(*)})$)	3%	1% (model dependency)		-	-
$\Delta\Gamma_s/\Gamma_s$ ($B_s \to f_{CP}$ t-dependent)	-	1.2%		-	-
ϕ_s (with $B_s \to J/\psi\phi$ etc.)	-	-	-	0.02	0.01
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-			$6\ fb^{-1}$ for 5σ discovery	
ϕ_3 ($B_s \to KK$)	-			7-10°	
ϕ_3 ($B_s \to D_s K$)	-			13°	
Υ decays	($3\ fb^{-1}$)	($500\ fb^{-1}$)			
$\mathcal{B}(\Upsilon(1S) \to$ invisible)	$< 2.5 \times 10^{-3}$	$< 2 \times 10^{-4}$			
	($\sim 0.5\ ab^{-1}$)‡	($5\ ab^{-1}$)	($50\ ab^{-1}$)		
Charm physics					
D mixing parameters					
x	0.25%	0.12%	0.09%		0.25%††
y	0.16%	0.10%	0.05%		0.05%††
$\delta_{K\pi}$	10°	6°	4°		
$\lvert q/p \rvert$	0.16	0.1	0.05		
ϕ	0.13 rad	0.08 rad	0.05 rad		
A_D	2.4%	1%	0.3%		
New particles$^{\aleph}$					
$\gamma\gamma \to Z(3930) \to D\bar{D}^*$		$> 3\sigma$			
$B \to KX(3872)(\to D^0\bar{D}^{*0})$		400 events			
$B \to KX(3872)(\to J/\psi\pi^+\pi^-)$		1250 events			
$B \to KZ^+(4430)(\to \psi'\pi^+)$		1000 events			
$e^+e^- \to \gamma_{ISR} Y(4260)(\to J/\psi\pi^+\pi^-)$		3000 events			
Electroweak parameters		($\sim 10\ ab^{-1}$)			
$\sin^2\Theta_W$	-	3×10^{-4}			