Univerza v Ljubljani

Rare decays at B factories

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Fundamental Questions in Flavor Physics

Are there new sources of CP violation?

Experiments: $b \to s$ CPV, compare CPV angles from tree and loops

Are there new operators with quarks enhanced by New Physics ?

Experiments: $A_{FB}(B \to K^* l\, l)$, $B \to K\, \pi$ rates and asymmetries

Are there right-handed currents ?

Experiments: $b \to s\, \gamma$ CPV, $B \to V\, V$ triple-product asymmetries

Are there new flavor changing neutral currents ?

Experiments: $b \to s\ \nu\ \nu$ bar, D-Dbar mixing+CPV+rare, $\tau \to \mu\, \gamma$

Data sample of ~$50ab^{-1}$@Y(4S) needed to address these questions

Contents

FCNC $b \rightarrow s$ decays

- $b \rightarrow s\gamma$: inclusive rate, CP violation
- $b \rightarrow d$ penguins: $B \rightarrow \rho\gamma, \omega\gamma$ decays
- Measurement of A_{fb} vs q^2 in $B \rightarrow K^* l^+ l^-$ decays

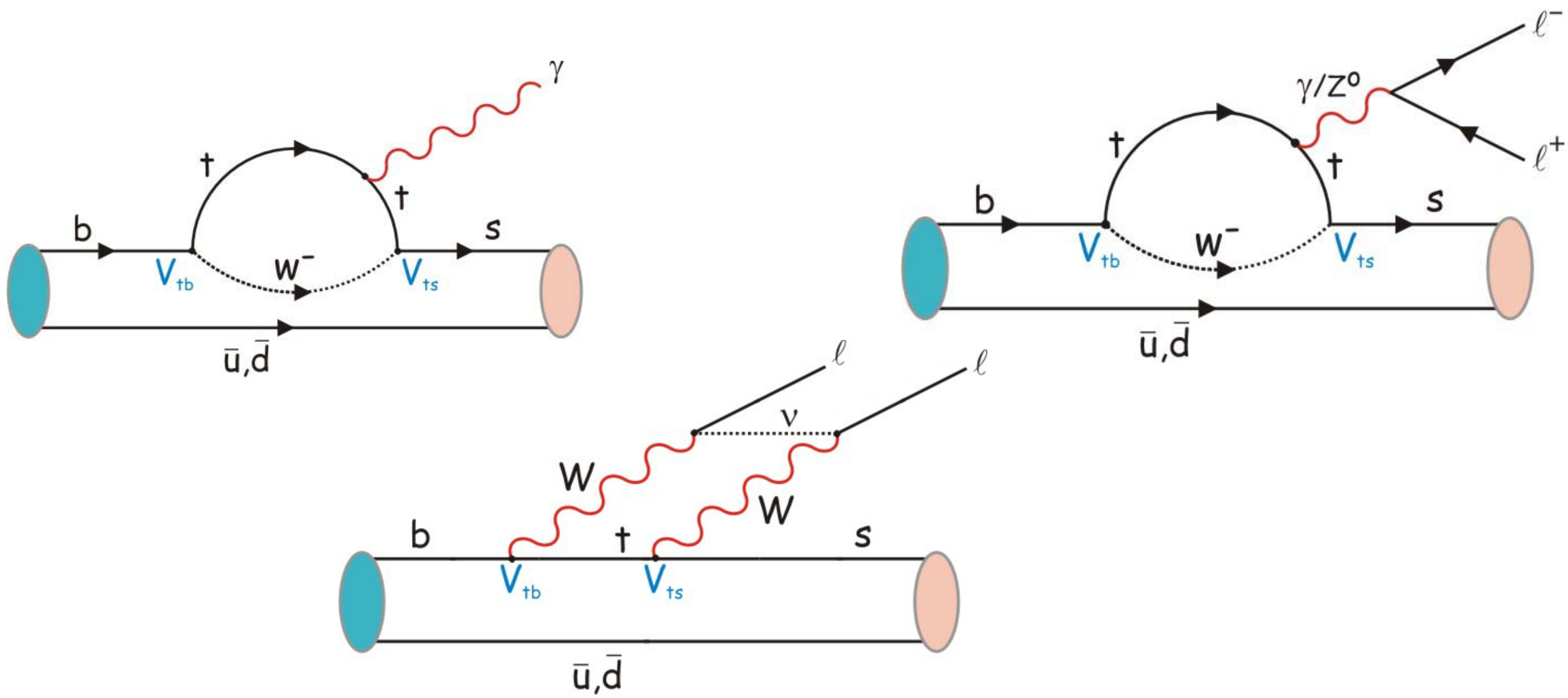
Decays with >1 neutrino

- Purely leptonic decays: $B^- \rightarrow \tau^- \nu_\tau$, $B^0 \rightarrow \tau^+ \tau^-$
- $B^- \rightarrow K^- \nu \nu$
- Semileptonic decay: $B^- \rightarrow D^{(*)} \tau^- \nu_\tau$

... Only a limited selection of topics.

Why FCNC decays?

Flavour changing neutral current (FCNC) processes (like b→s, b→d) are fobidden at the tree level in the Standard Model. Proceed only at low rate via higher-order loop diagrams. Ideal place to search for new physics.



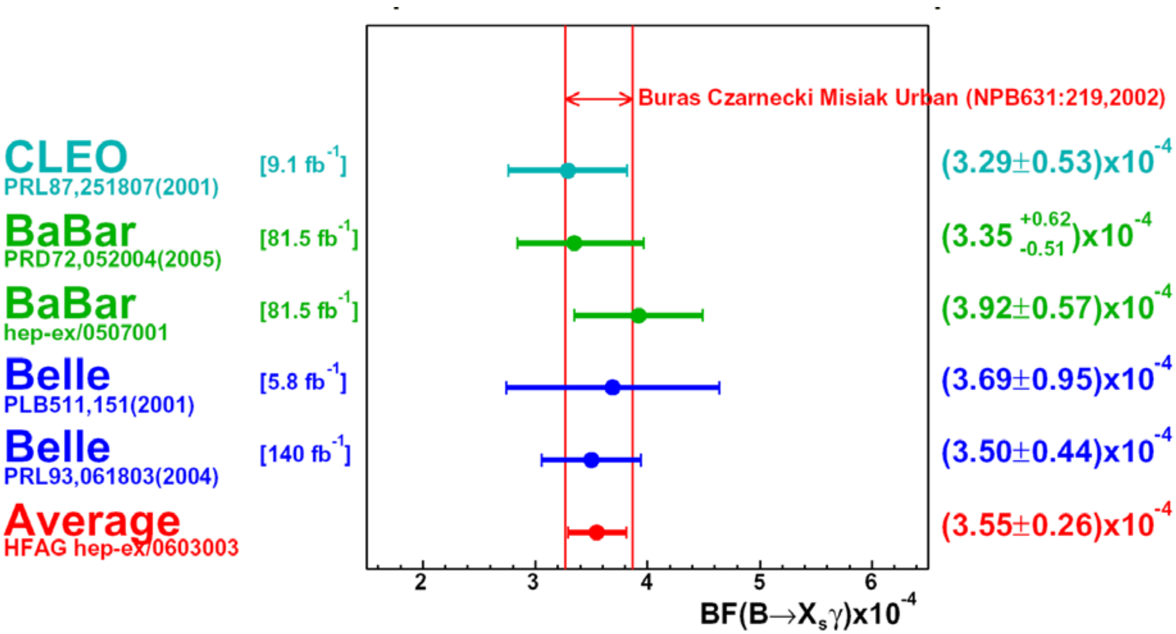
Radiative Decays

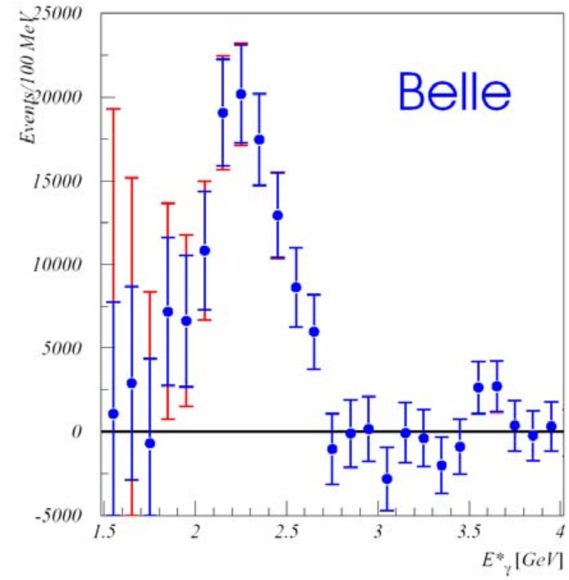
- Inclusive Br($b \rightarrow s\gamma$) — $|C_7|$, SF for $|V_{ub}|$
- $B \rightarrow K^*\gamma$ isospin asymmetry (Δ^{+-}) — sign of C_7
- Mixing induced CPV
- Direct CPV in $B \rightarrow X_s\gamma$
- $B \rightarrow X_d \gamma$

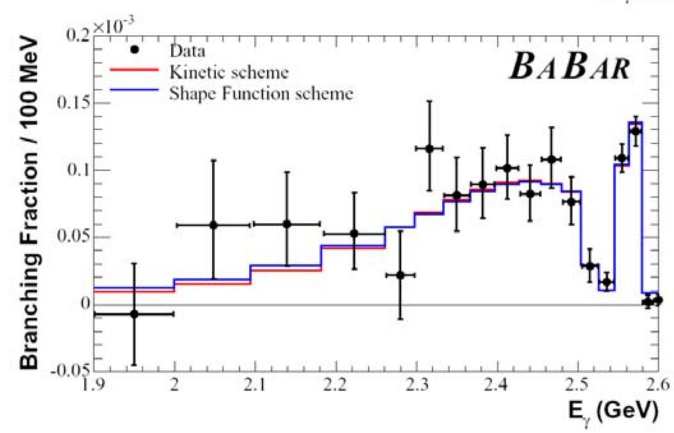
red: discussed in this talk

Inclusive Br(b→sγ)

Motivation: measure $|C_7|$ and shape function parameters (from E_γ spectrum for $|V_{ub}|$ extraction)







Inclusive and semi-inclusive →

38 modes, 55% rate

Inclusive Br($b \rightarrow s\gamma$)

$BF(B \rightarrow X_s \gamma, E_\gamma > 1.6\ GeV) = (3.55 \pm 0.24\ ^{+0.09}_{-0.10} \pm 0.03) \times 10^{-4}$

→ consistent with SM expectations $(3.57 \pm 0.30) \times 10^{-4}$

However: theory error is expected to get reduced (NNLL calculations are under way)

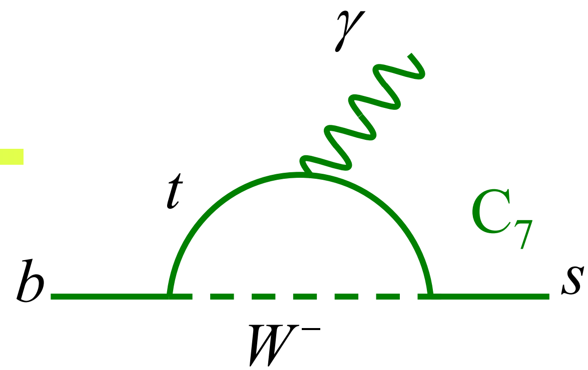
→interesting for charged Higgs mass limit

→need a better measurement of inclusive rate

Also: important to fix the value of Wilson coeff. C_7 and to determine the spectrum shape.

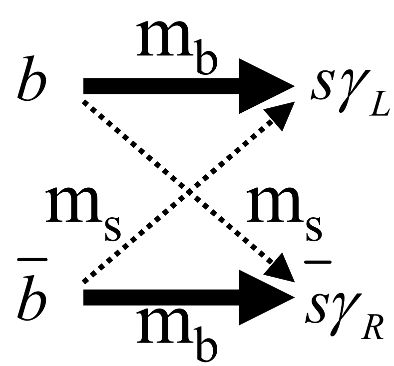
At 5 ab^{-1} : $E_\gamma$min down to 1.5 GeV and stat. error ~5%

$B \to X_s \gamma$ CP Asymmetry

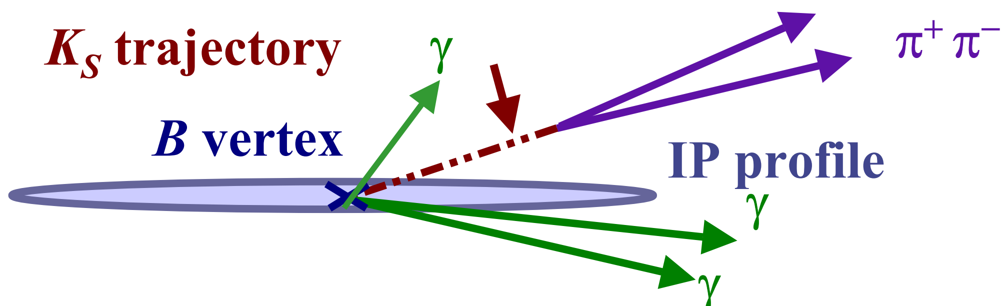


- Sensitive to NP – right handed currents
- Theoretically clean.
- Standard Model "~Zero".
  - γ is polarized, and the final state is almost flavor specific.
  - Helicity flip of γ suppressed by $\sim m_s/m_b \to S \sim 0.02$
  - QCD corrections → S<8%

  (Grinstein, Pirjol, hep-ex/0510105)



- Time dependent CPV requires vertex reconstruction with $K_S \to \pi^+\pi^-$



$\sigma_x = 100\mu m, \sigma_y = 5\mu m, \sigma_z = 3mm,$

Possible at e^+e^- B-factory

Vertex recon. eff. at Belle 51% (SVD2), 40% (SVD1)

$B^0 \rightarrow K_S \pi^0 \gamma$ time dependent CPV

Atwood, Gershon, Hazumi, Soni, PRD71, 076003 (2005)

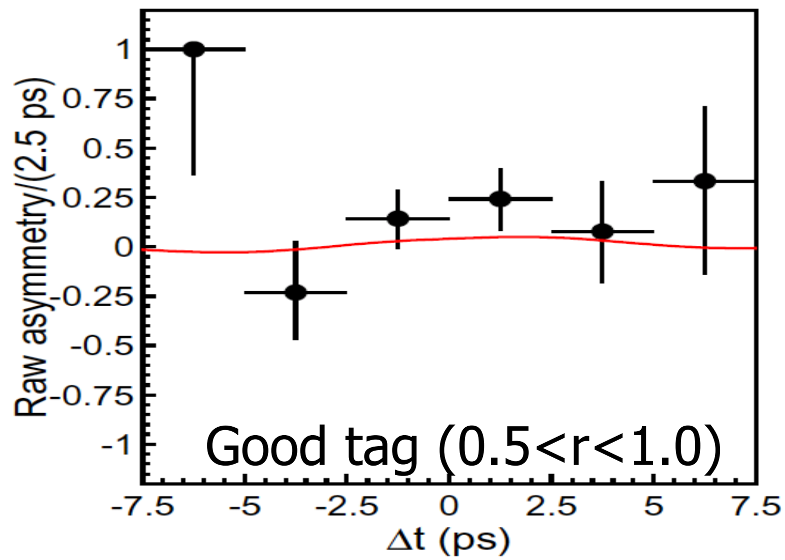
$M(K_S\pi^0) < 1.8 GeV/c^2$

– NP effect is independent of the resonance structure.

Example: Belle 386MBB

- Two $M(K_S\pi^0)$ regions(MR1:0.8-1.0GeV/c^2/MR2: <1.8GeV/c^2)
- 70+-11 (45+-11) events in MR1(2).

S= +0.08 $\pm$0.41 $\pm$0.10
A= +0.12$\pm$0.27$\pm$0.10



$B^0 \to K_S \pi^0 \gamma$ time dependent CPV

Results:

Belle hep-ex/0507059

$S(B \to K^*\gamma, K^* \to K_S \pi^0) = -0.01 \pm 0.52 \pm 0.11$

$S(B \to K_S \pi^0 \gamma) = 0.08 \pm 0.41 \pm 0.10$

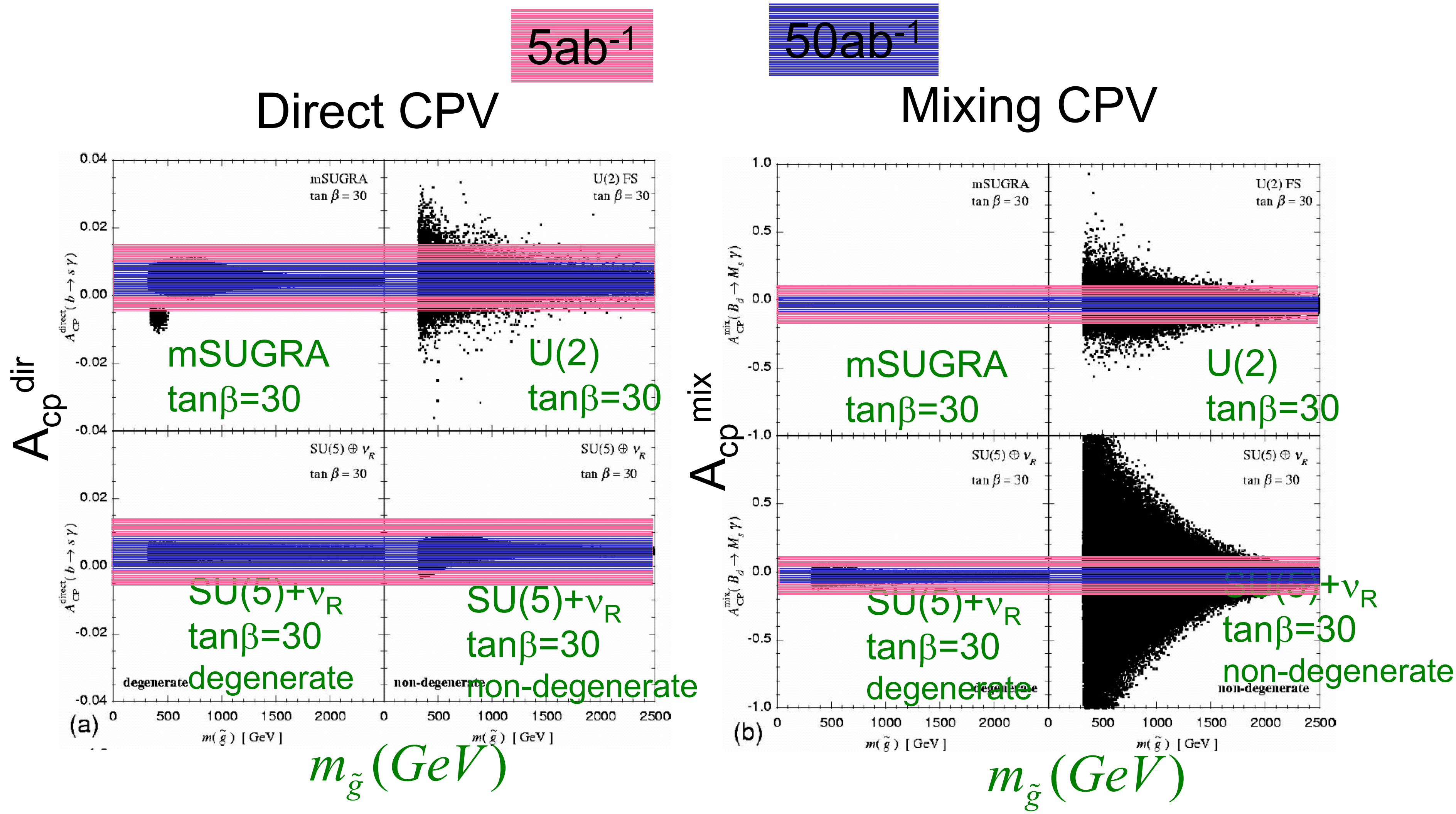
BaBar PRD 71 (2005) 0501103

$S(B \to K^*\gamma, K^* \to K_S \pi^0) = -0.21 \pm 0.40 \pm 0.05$

Prospects:	Present Belle (stat./syst.)	→ $5 ab^{-1}$	→ $50 ab^{-1}$
$A_{cp}^{mix}(B \to K^*\gamma, K^* \to K_S \pi^0)$	0.41 / 0.10	0.14	0.04
$A_{cp}^{dir}(B \to X_s \gamma)$	0.051 / 0.038	0.011	0.005

Add more modes: $B \to K_S \phi \gamma$ (with angular analyisis), higher K resonances, $B \to K_S \eta \gamma$ (recent observation by BaBar),...

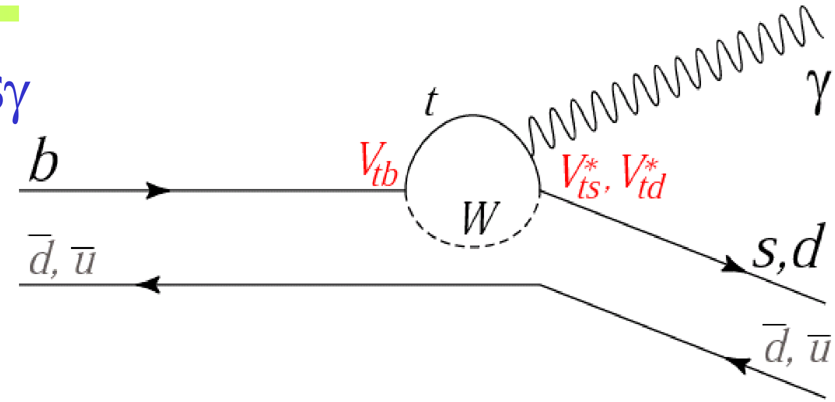
$A_{cp}(B \rightarrow X_s\gamma)$ vs SUSY models



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

b→d penguins

Supressed by $|V_{td}/V_{ts}|^2$ vs b → sγ



Interesting:

•Measurement of $|V_{td}/V_{ts}|$

Addresses the same physics issue as B_s- B_s mixing (from a different perspective: box vs loop)

$$\frac{\mathcal{B}(B \to (\rho,\omega)\gamma)}{\mathcal{B}(B \to K^*\gamma)} = S_\rho \left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2}\right)^3 \zeta^2 \left[1 + \Delta R\right]$$

Difference in dynamics

Form factor ratio

•CP violation could be sizeable in SM (order 10%)

•New physics could be quite different from b → sγ

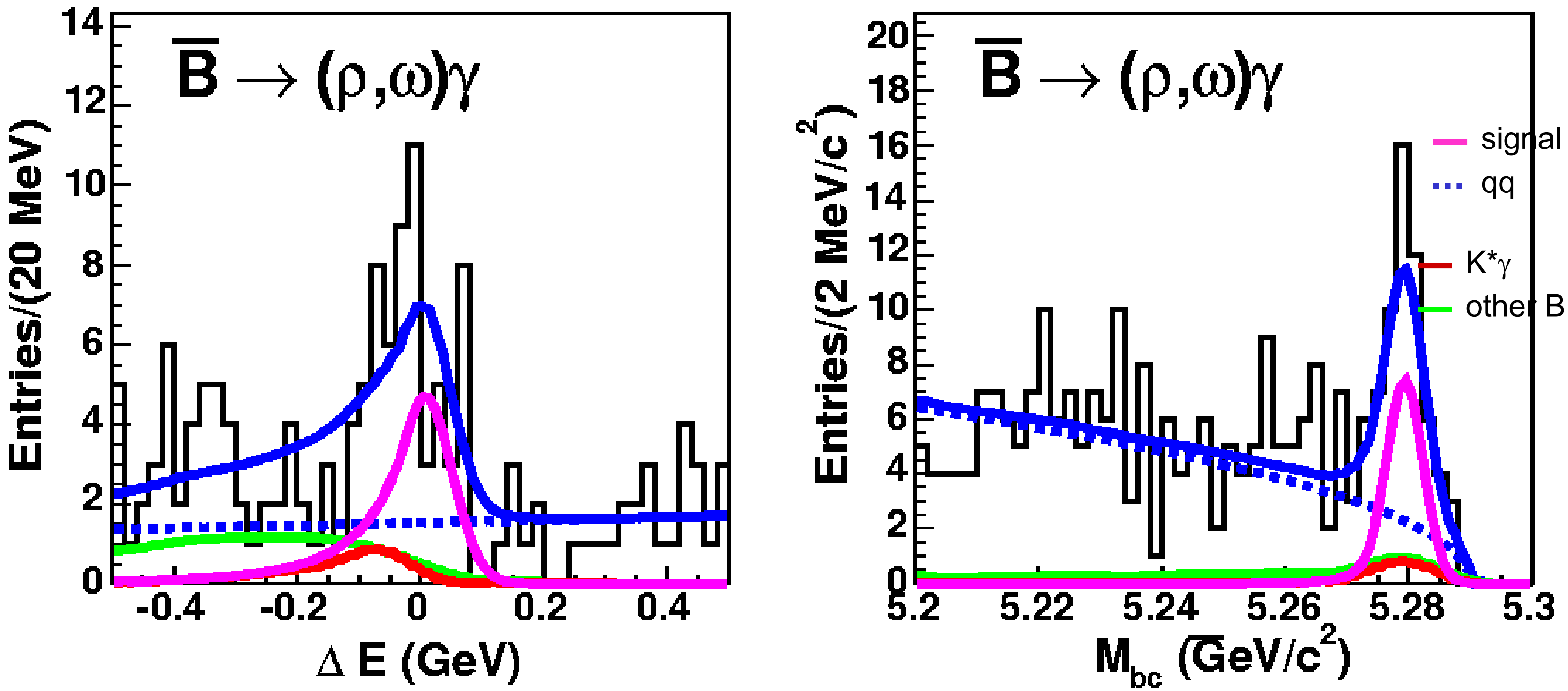
Belle: First observation of B → ργ, ωγ

Ref: PRL 96, 221601 (2006)

Reconstructing rare B meson decays at Υ(4s): use two variables, energy diference ΔE and beam constrained mass M_{bc}

$$\Delta E \equiv \sum E_i - E_{CM}/2$$

$$M_{bc} = \sqrt{(E_{CM}/2)^2 - (\sum \vec{p}_i)^2}$$



V_{td}/V_{ts} from B → ργ, ωγ

The measured branching fraction

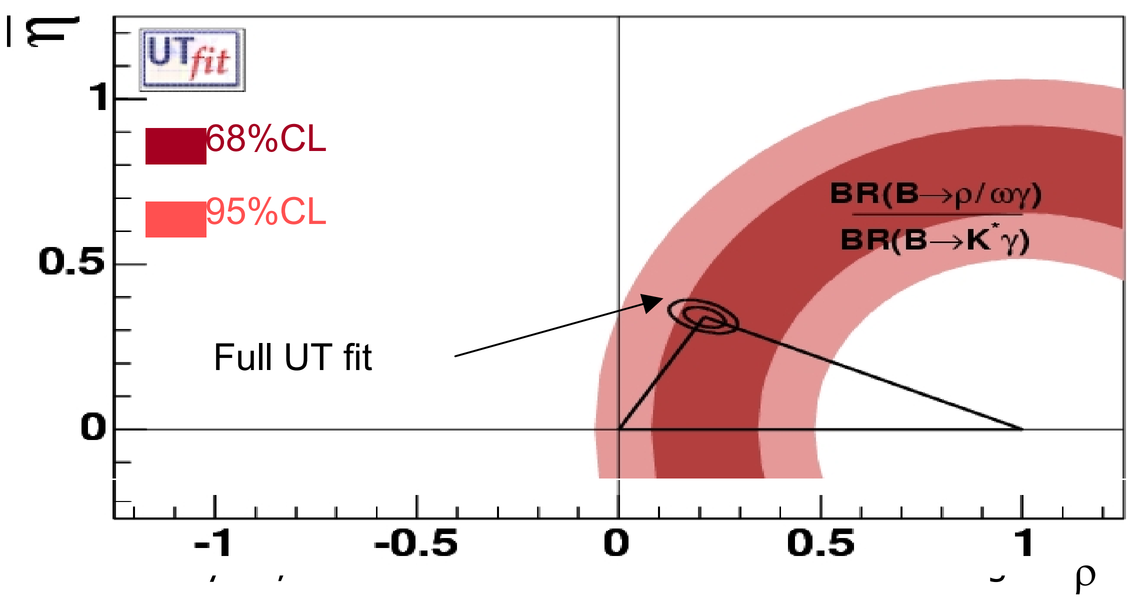
Ref: PRL 96, 221601 (2006)

$$BF(B \to \rho/\omega\gamma) = 1.32\ ^{+0.34}_{-0.31}\ (\text{exp.})\ ^{+0.10}_{-0.09}\ (\text{theo.})$$

Translates to

$$|V_{td}|/|V_{ts}| = 0.199\ ^{+0.026}_{-0.025}\ (\text{exp.})\ ^{+0.018}_{-0.015}\ (\text{theo.})$$

which is compatible with SM constraints based on fits of other CKM parameters.



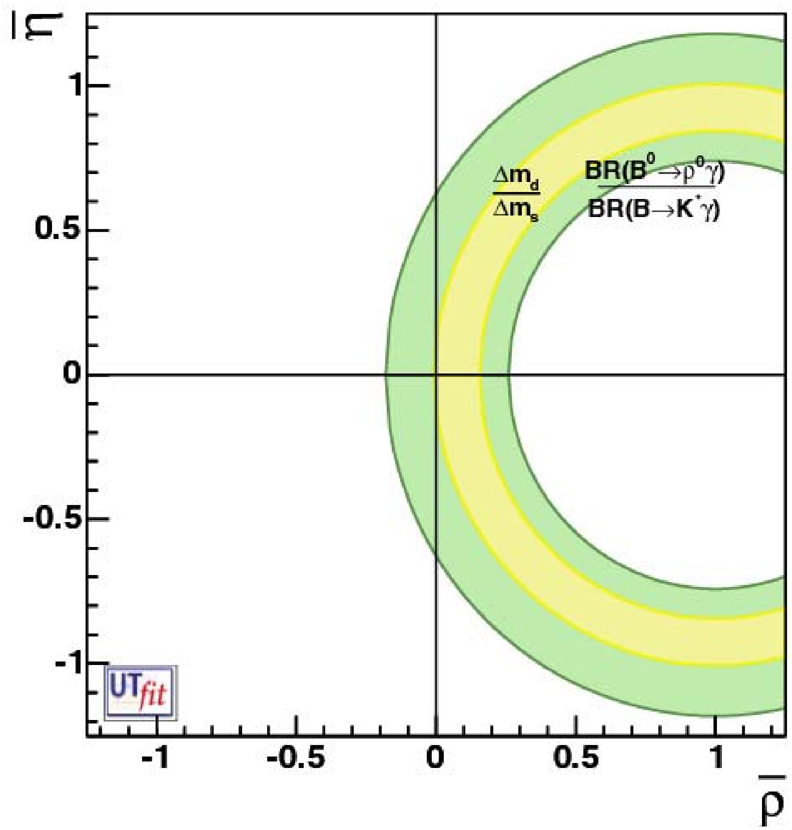
Together with the evidence of B→K^0 K decays modes, this demonstrates the existence of a new quark level transition: b→d

Implications of Belle's observation of b→d γ

Comparison with the recent observation of B_s mixing at Tevatron:

•green: Belle measurement of $|V_{td}/V_{ts}|$ in b→d γ

•yellow: CDF measurement of $|V_{td}/V_{ts}|$ from B_s mixing



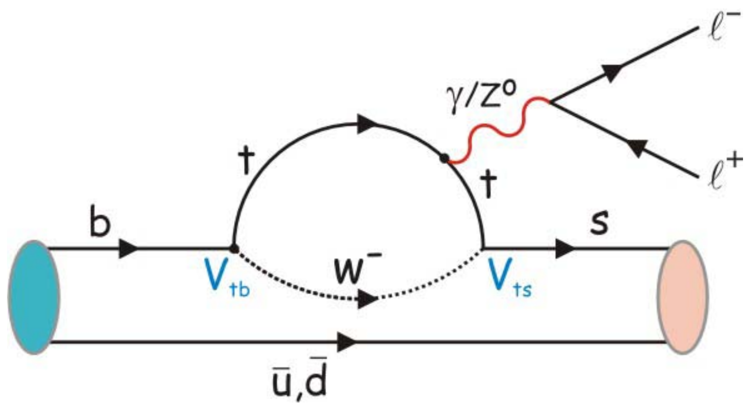
The width of the Bs mixing contour is limited by theory while B→d γ needs much more data.

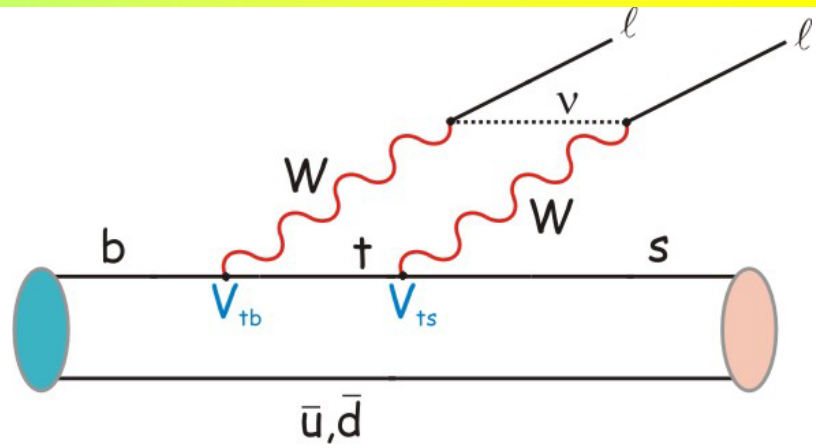
$b \to d\,\gamma$ future prospects

With 1-2 orders of magnitude more statistics (5 ab^{-1}, 50 ab^{-1}):

- Direct CP violation and time-dependent CPV with $B \to \rho^0\,\gamma$ and $B \to \omega\gamma$
- Measurements of inclusive $b \to d\,\gamma$

B → K* l+ l-





b → s l+l- was first measured in B → K l+l- by Belle (2001).

Important for further searches for the physics beyond SM

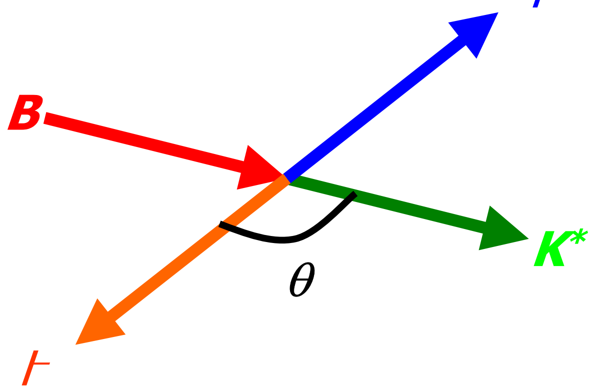
$$\frac{d\Gamma\left(b \to s\ell^+\ell^-\right)}{d\hat{s}} = \left(\frac{\alpha_{em}}{4\pi}\right)^2 \frac{G_F^2 m_b^5 \left|V_{ts}^* V_{tb}\right|^2}{48\pi^3}\left(1-\hat{s}\right)^2$$

$$\times\left[\left(1+2\hat{s}\right)\left(\left|C_9^{\text{eff}}\right|^2+\left|C_{10}^{\text{eff}}\right|^2\right)+4\left(1+\frac{2}{\hat{s}}\right)\left|C_7^{\text{eff}}\right|^2+12\,\text{Re}\left(C_7^{\text{eff}}C_9^{\text{eff}*}\right)\right]$$

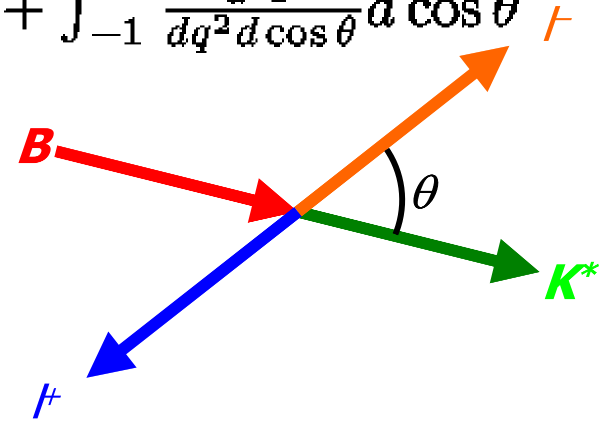
C_i: Wilson coefficients

Particularly sensitive: forward-backward asymmetry in K* l+l

$$A_{\mathrm{FB}}(q^2) = \frac{\int_0^1 \frac{d^2\Gamma}{dq^2\, d\cos\theta}\, d\cos\theta - \int_{-1}^0 \frac{d^2\Gamma}{dq^2\, d\cos\theta}\, d\cos\theta}{\int_0^1 \frac{d^2\Gamma}{dq^2\, d\cos\theta}\, d\cos\theta + \int_{-1}^0 \frac{d^2\Gamma}{dq^2\, d\cos\theta}\, d\cos\theta}.$$



Backward event



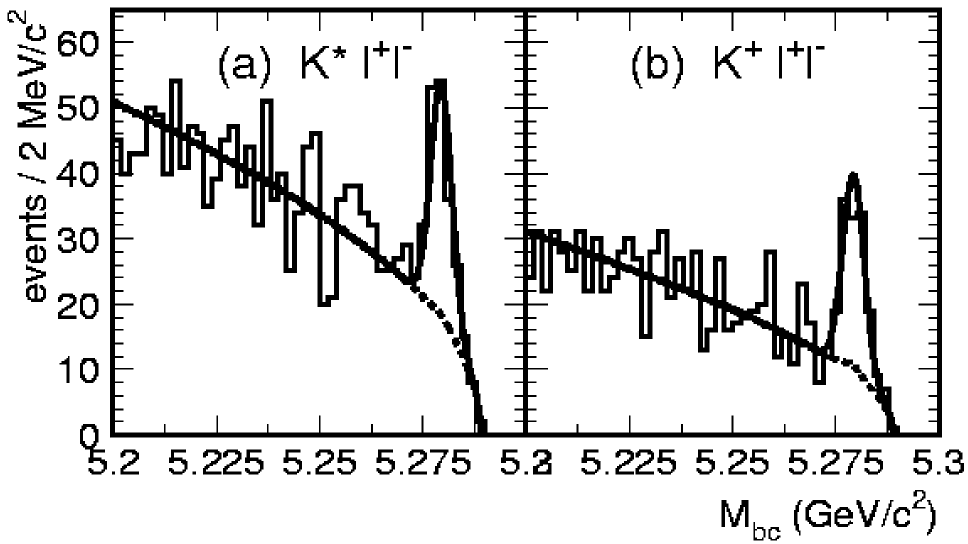
Forward event

[γ* and Z* contributions in B→K* l l interfere and give rise to forward-backward asymmetries c.f. $e^+e^- \rightarrow \mu^+ \mu^-$]

$$A_{FB}(K^* l^+ l^-) \propto C_{10}\, \xi(q^2) \left[\mathrm{Re}(C_9) F_1 + \frac{1}{q^2} C_7 F_2 \right]$$

Sample used for $A_{FB}(B \to K^* ll)(q^2)$

Ref: PRL 96, 251801 (2006)



$$\begin{aligned}
&P(q^2, \cos\theta; A_9/A_7, A_{10}/A_7) \\
&= f_{\rm sig}\epsilon_{\rm sig}(q^2,\cos\theta)\frac{d^2\Gamma}{dq^2 d\cos\theta}(q^2,\cos\theta)/N_{\rm sig} \\
&+ f_{\rm cfcf}\epsilon_{\rm cfcf}(q^2,\cos\theta)\frac{d^2\Gamma}{dq^2 d\cos\theta}(q^2,\cos\theta)/N_{\rm cfcf} \\
&+ f_{\rm ifcf}\epsilon_{\rm ifcf}(q^2,\cos\theta)\frac{d^2\Gamma}{dq^2 d\cos\theta}(q^2,-\cos\theta)/N_{\rm ifcf} \\
&+ f_{X_s\ell\ell}\mathcal{P}_{X_s\ell\ell}(q^2,\cos\theta) \\
&+ f_{\rm dilep}\Big\{(1-f_{K^*\ell h})\mathcal{P}_{\rm dilep}(q^2,\cos\theta) \\
&\quad +f_{K^*\ell h}\mathcal{P}_{K^*\ell h}(q^2,\cos\theta)\Big\} \\
&+ f_{K^*hh}\mathcal{P}_{K^*hh}(q^2,\cos\theta) + f_\psi\mathcal{P}_\psi(q^2,\cos\theta), \qquad (
\end{aligned}$$

Treat q^2, $\cos(\theta)$ dependence of bkgs.

Sample for $B \to K^*$ l l:
113±13 events

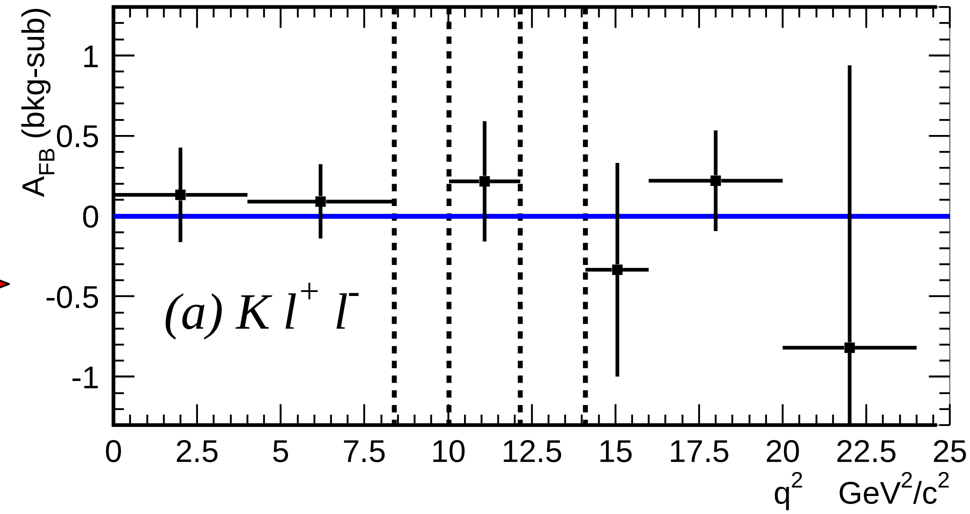
Unbinned fit to the variables q^2 (di-lepton invariant mass) and $\cos(\theta)$ for the $B \to K^*$ l l data.

Fit parameters A_9/A_7 and A_{10}/A_7 (A_i = leading term in C_i)

Control sample B→Kll

B→K l l control sample:
96±12 events

Consistent with flat

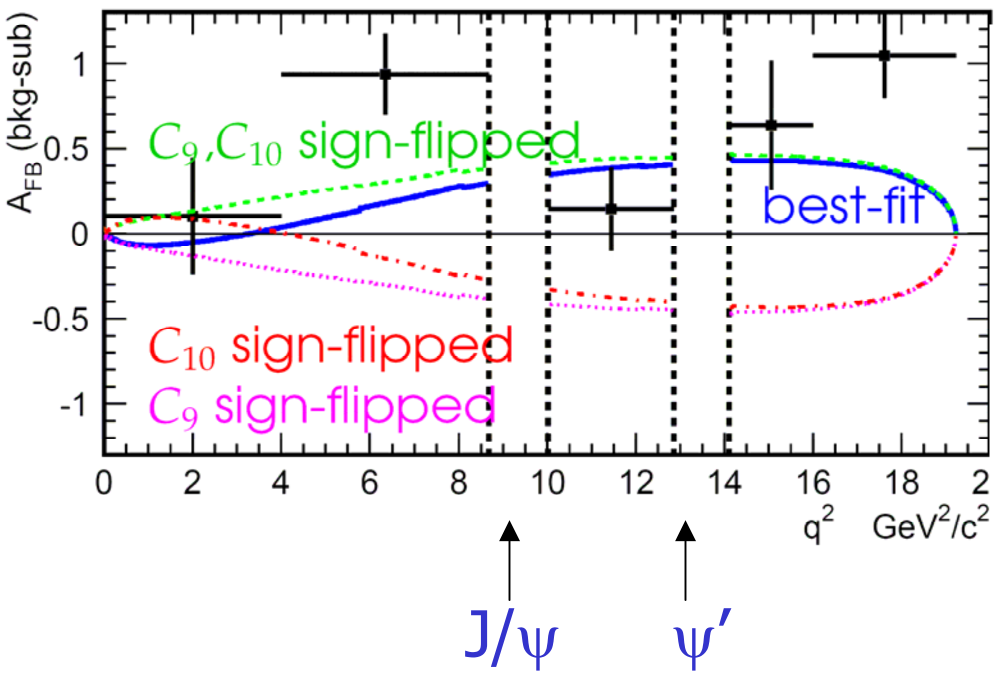


Integrated asymmetry:

$$A_{FB}(B \to K^+ l^- l^+) =$$
$$0.10 \pm 0.14 \pm 0.01$$

Constraints on Wilson coefficients from $A_{FB}(B \to K^* l\, l)(q^2)$

Projections of the full fit to q^2, cos(θ)



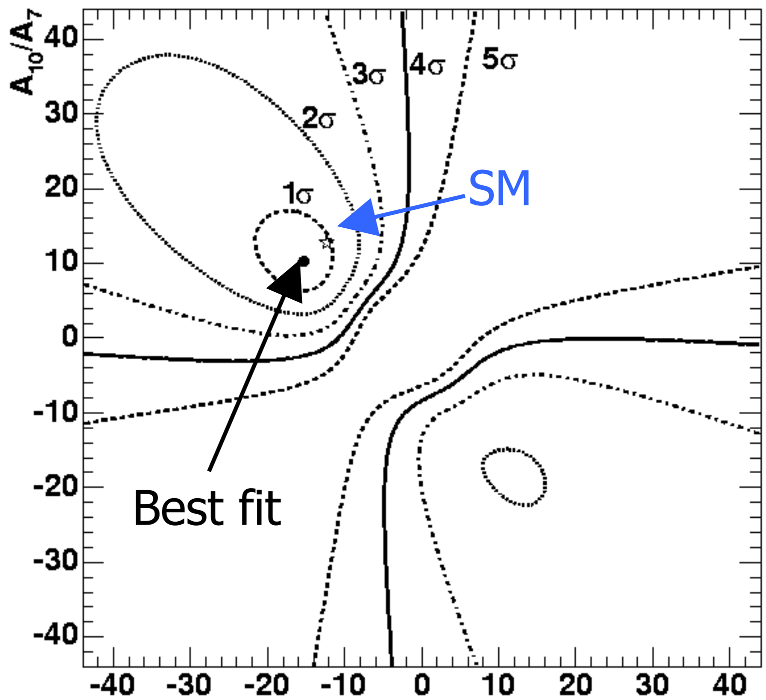
Integrated FB asymmetry

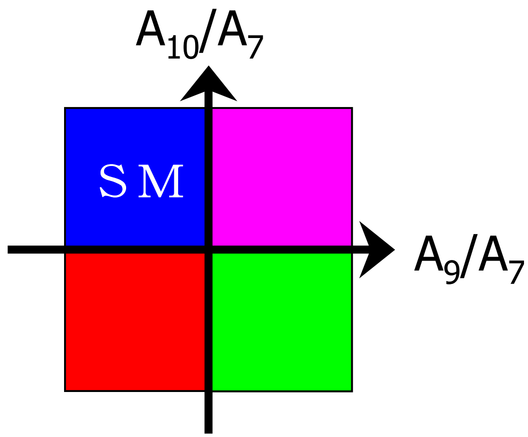
$$A_{FB}(B \to K^* l^- l^+) =$$
$$0.50 \pm 0.12 \pm 0.02; (3.4\sigma)$$

Observed integrated A_{FB} rules out some radical New Physics Models with incorrect signs/magnitudes of C_9 and C_{10} (red and pink curves)

Results of the unbinned fit to q^2 and cos(θ) distributions for ratios of Wilson coefficients.

A_{10}/A_7





$|A_7|$ constrained from $b \to s\gamma$ to be close to SM

A_9/A_7

Ref: PRL 96, 251801 (2006)

	negative A_7	positive A_7
A_9/A_7	$-15.3^{+3.4}_{-4.8} \pm 1.1$	$-16.3^{+3.7}_{-5.7} \pm 1.4$
A_{10}/A_7	$10.3^{+5.2}_{-3.5} \pm 1.8$	$11.1^{+6.0}_{-3.9} \pm 2.4$

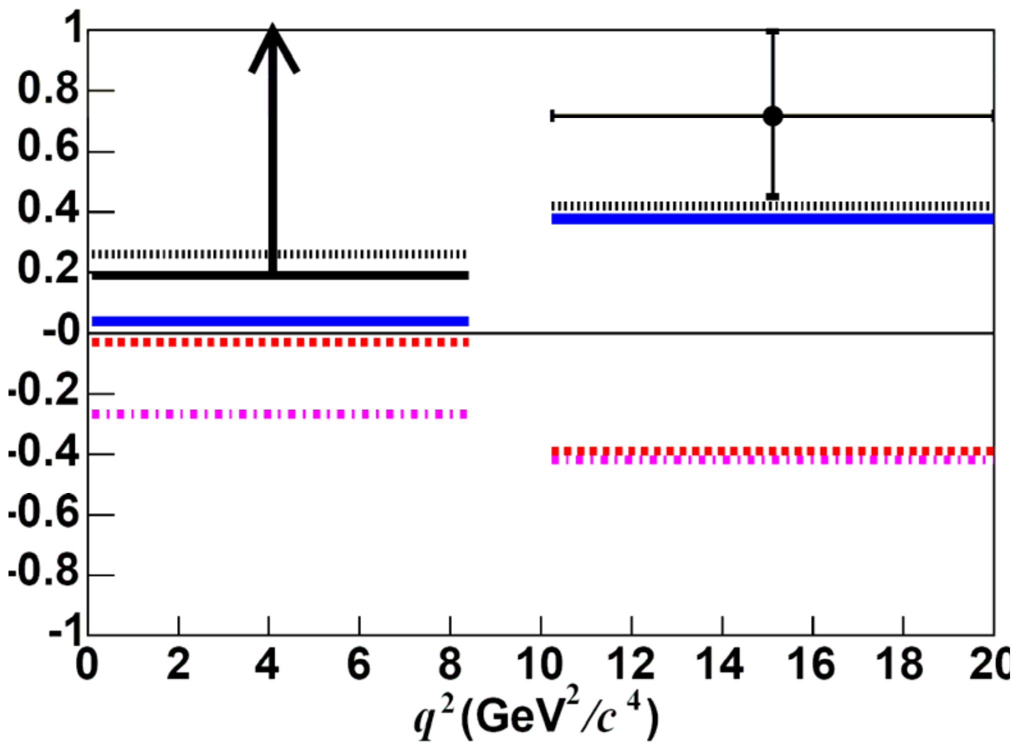
$$-1401 < A_9 A_{10}/A_7^2 < -26.4.$$

at 95% C.L.

$A_{FB}(B \rightarrow K^* l l)(q^2)$, BaBar

BaBar: 229 M BB

PRD 73 (2006) 092001

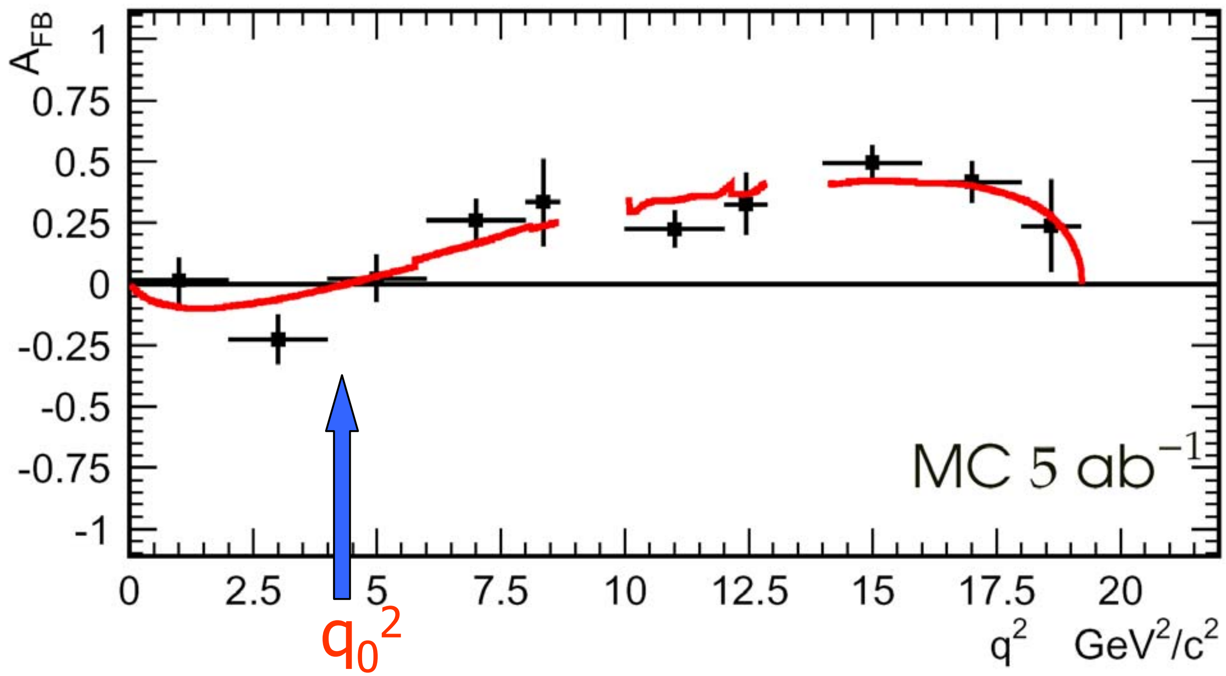


Integrated FB asymmetry

A_{FB} >0.55 (@ 95% CL)

First bin excludes SM (blue) at 2σ level?

$A_{FB}(B \rightarrow K^* l^+ l^-)[q^2]$ at Super B Factory



Precision with 5ab^{-1}

δC_9 ~ 11%

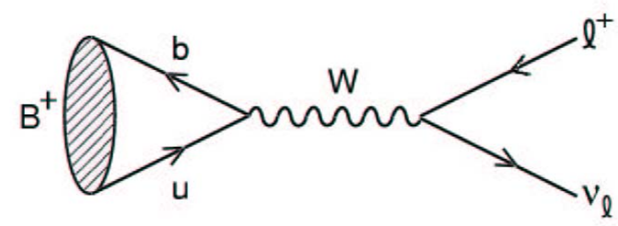
δC_{10} ~14%

$\delta\, q_0^2/q_0^2$ ~11%

- A_{FB} zero-crossing q_0^2 will be determined with 5% error with 50ab^{-1}

Purely leptonic decay $B \to \tau \nu$

- Proceed via W annihilation in the SM.



- Branching fraction

$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

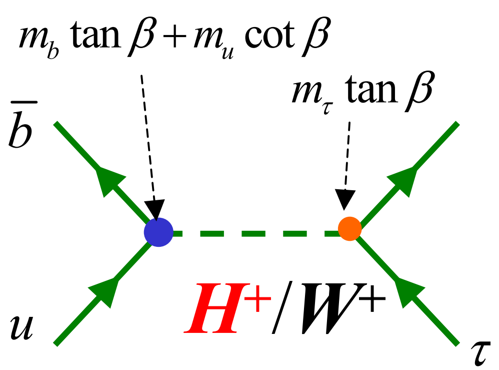
- Provide information of $f_B|V_{ub}|$
  - $|V_{ub}|$ from $B \to X_u l \nu$ ➡ f_B ⬄ cf) Lattice
  - $Br(B \to \tau\nu)/\Delta m_d$ ➡ $|V_{ub}| / |V_{td}|$

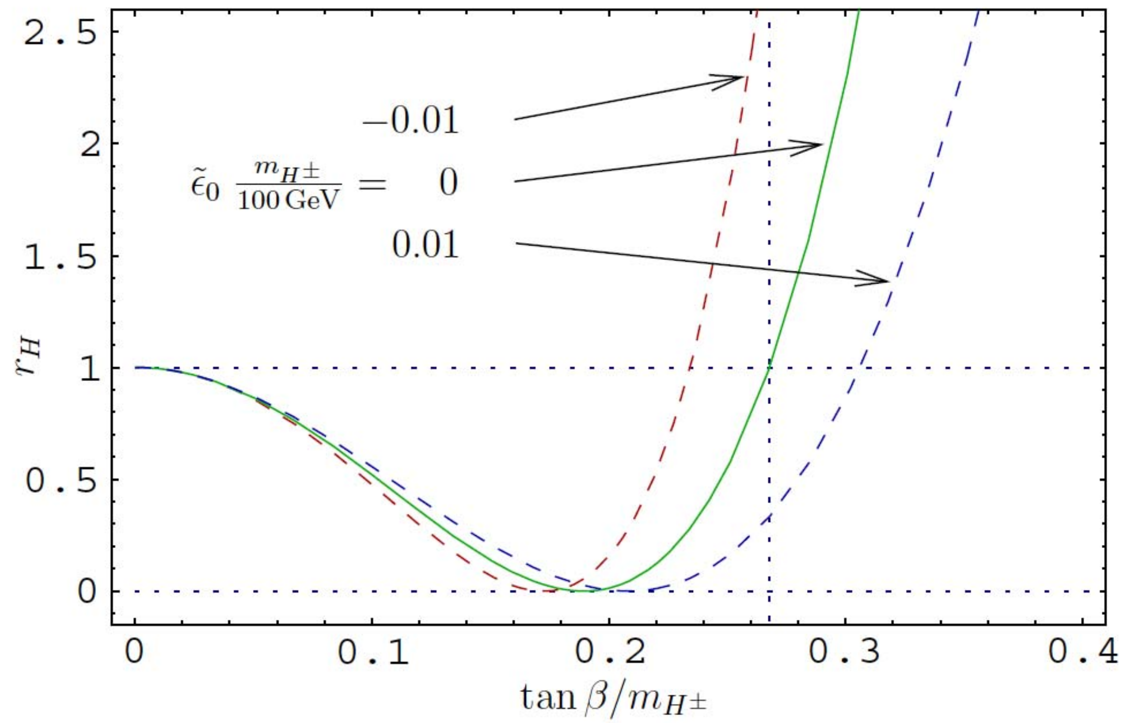
- Expected branching fraction

$|V_{ub}| = (4.39 \pm 0.33)\times 10^{-3}$ (HFAG)
$f_B = (216 \pm 22)$ MeV (lattice)

} $BF(B \to \tau \nu_\tau) = (1.59 \pm 0.40)\times 10^{-4}$

Charged Higgs contribution to B→τ ν





$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\rm SM} \times r_H,$$

$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

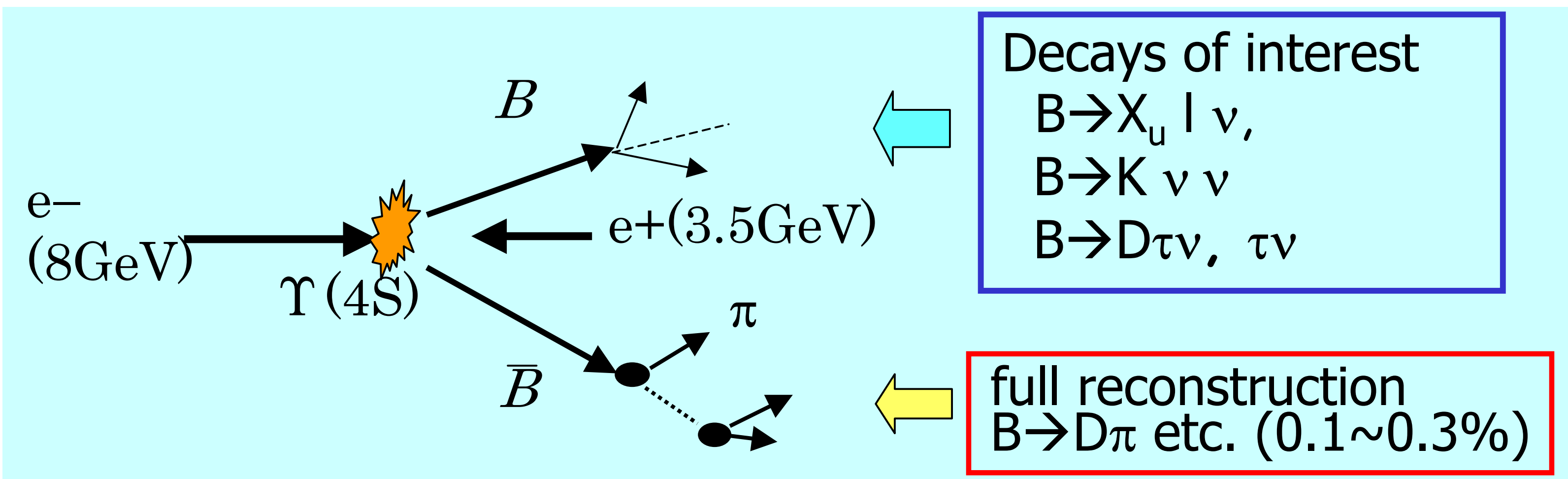
$\tilde{\varepsilon}_0$ = SUSY corrections to b Yukawa coupling

Br(SM) ~ 1.59 x 10^{-4}

Phys. Rev. D **48**, 2342 (1993)

Full Reconstruction Method

- Fully reconstruct one of the B's to
  - Tag B flavor/charge
  - Determine B momentum
  - Exclude decay products of one B from further analysis



Offline B meson beam!

Powerful tool for B decays with neutrinos

Fully reconstructed sample

Belle (447M $B\bar{B}$) → 4.12×10^5 $B^0\bar{B}^0$

+ 6.80×10^5 B^+B^-

Fully reconstructed sample

Clean environment but small sample: $\varepsilon_{reco} \approx 3\cdot10^{-3}$

Exclusive method: 180 decay channels

Reconstructed channels:

$B^0 \to D^{(*)-}\pi^+ \,/\, D^{(*)-}\rho^+ \,/\, D^{(*)-}a_1^+ \,/\, D^{(*)-}D_s^{(*)+}$

$B^+ \to D^{(*)0}\pi^+ \,/\, D^{(*)0}\rho^+ \,/\, D^{(*)0}a_1^+ \,/\, D^{(*)0}D_s^{(*)+}$

$D^{*0} \to D^0\pi^0$

$D^* \to D^0\pi \,/\, D\pi^0$

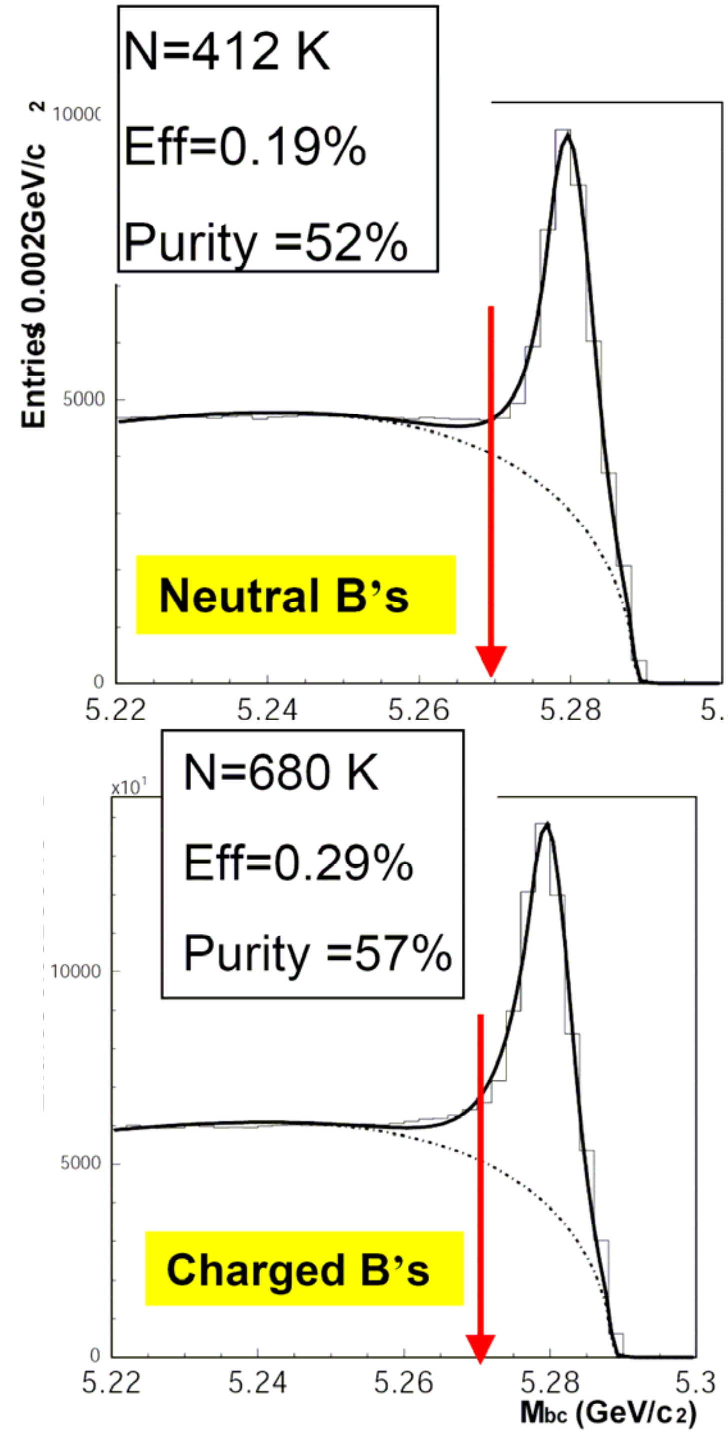
$D_s^* \to D_s\gamma$

$D^0 \to K\pi / K\pi\pi^0 / K\pi\pi\pi / K_s\pi^0 / K_s\pi\pi / K_s\pi\pi\pi^0 / KK$

$D \to K\pi\pi / K\pi\pi\pi^0 / K_s\pi / K_s\pi\pi^0 / K_s\pi\pi\pi / KK\pi$

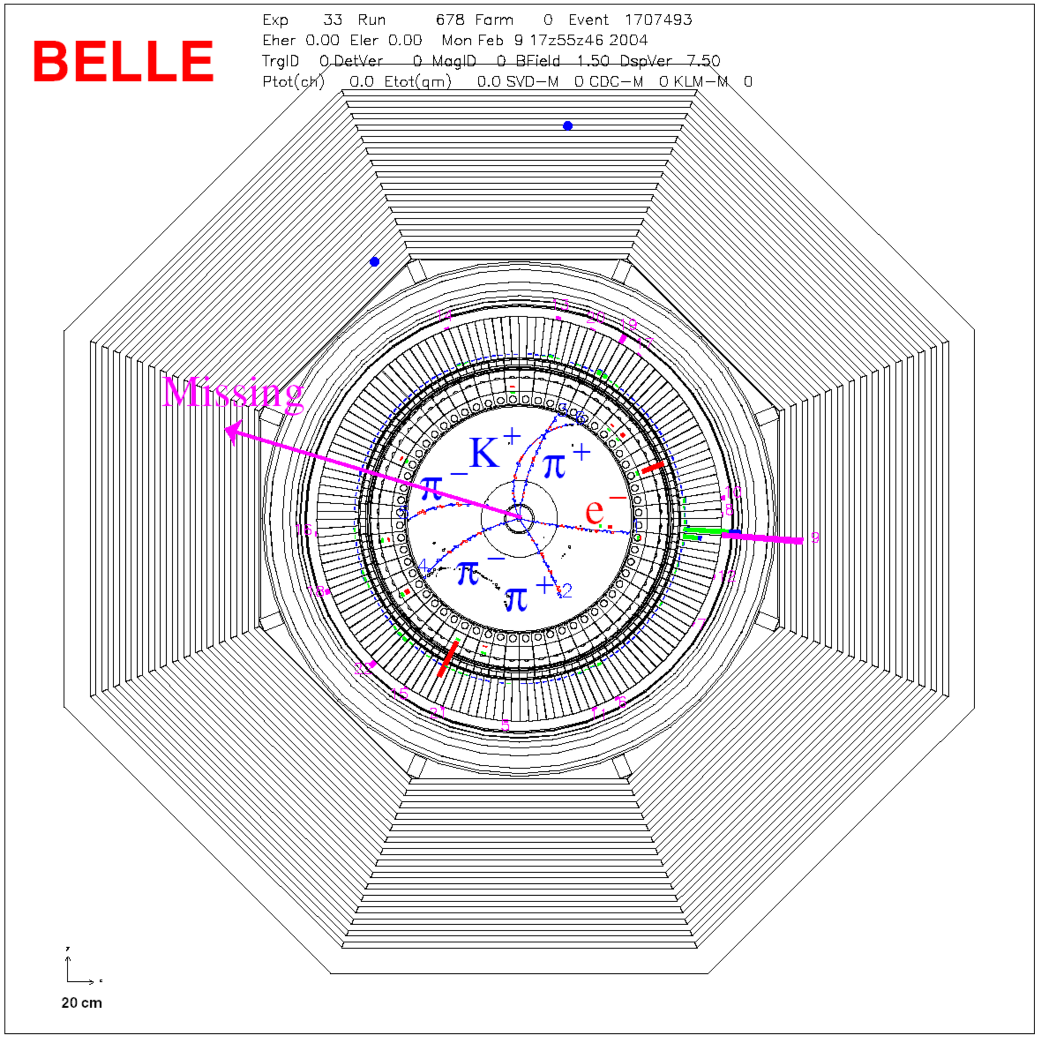
$D_s \to K_sK\pi / KK\pi$

Ilija Bizjak, Ljubljana @ CKM05, March 2005



Event candidate $B^- \rightarrow \tau^- \nu_\tau$

$$B^+ \to D^0\pi^+$$
$$(\to K\pi^-\pi^+\pi^-)$$
$$B^- \to \tau(\to e\nu\bar{\nu})\nu$$



B→τ ν (Belle)

- N_{BB} (produced) = 447M
- N_{B+B-} (full recon.) = 6.80 x 10^5 (purity 0.57)
- τ decay modes

$$\tau^- \to \mu^- \nu \bar{\nu}, e^- \nu \bar{\nu}$$
$$\tau^- \to \pi^- \nu, \pi^- \pi^0 \nu, \pi^- \pi^+ \pi^- \nu$$

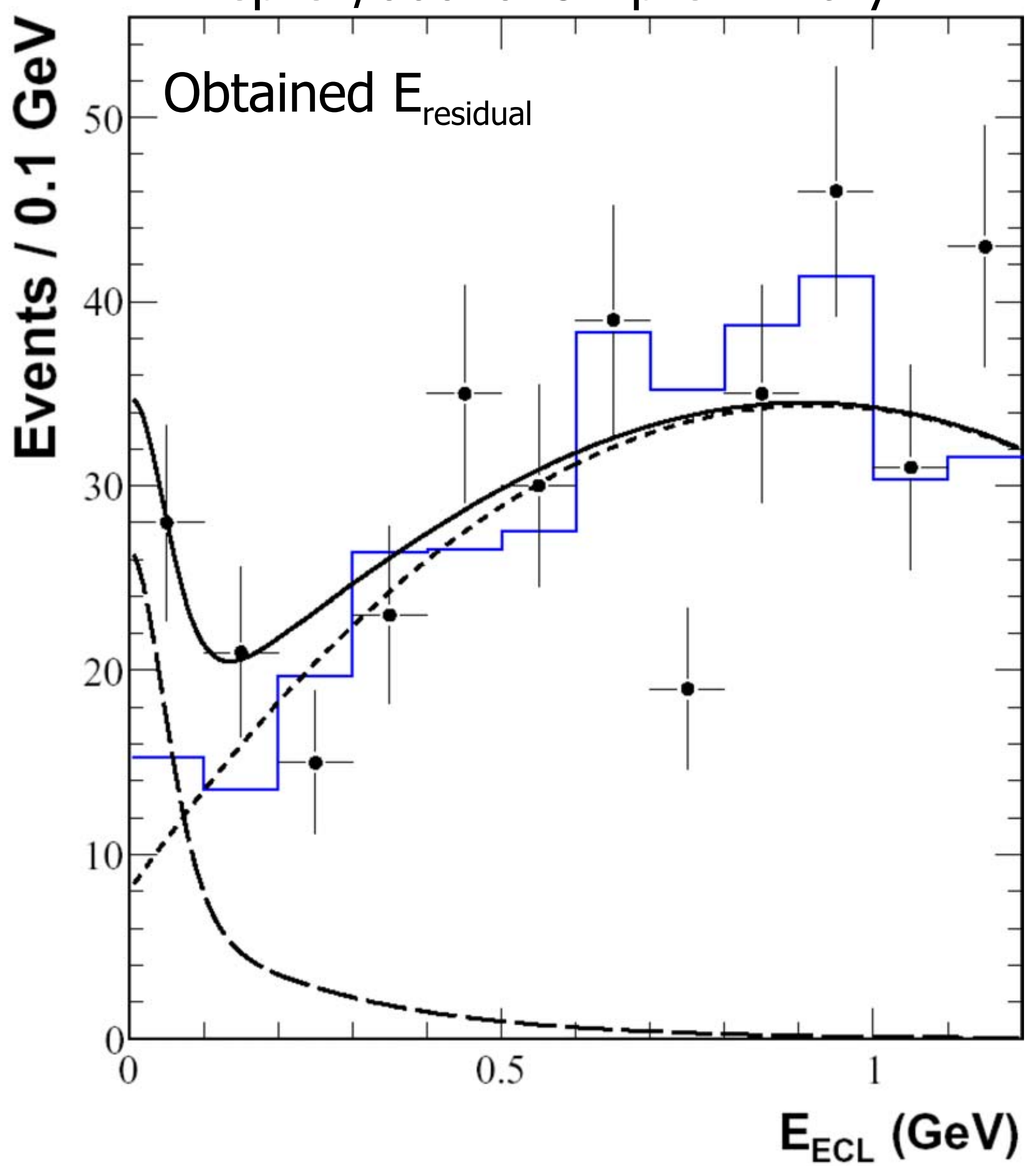
  - Cover 81% of τ decays

- Event selection
  - Main discriminant: residual ECL energy

Fit to $E_{residual}$ → $21.2^{+6.7}_{-5.7}$ signal events.

→4.2σ significance including systematics

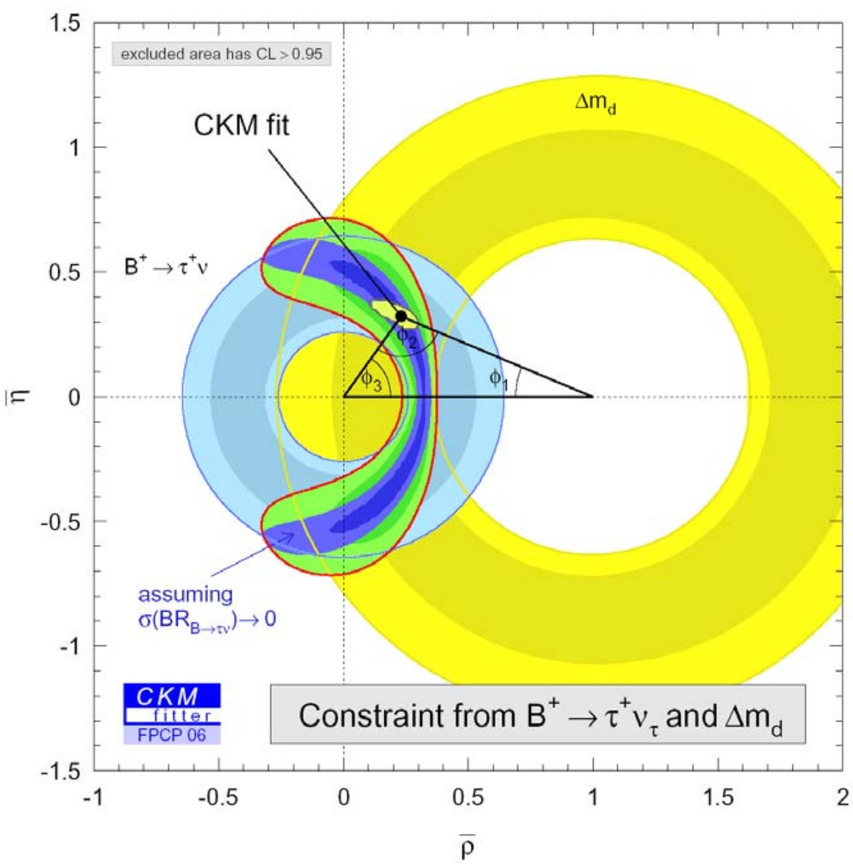
hep-ex/0604018 - preliminary



Impact of $B^- \rightarrow \tau^- \nu_\tau$

•From BF($B \rightarrow \tau \nu_\tau$) →Product of B meson decay constant f_B and CKM matrix element $|V_{ub}|$→use $|V_{ub}|$ from HFAG → f_B

•Use BF($B \rightarrow \tau \nu_\tau$) with Δm_d → constraint in the (ρ,η) plane

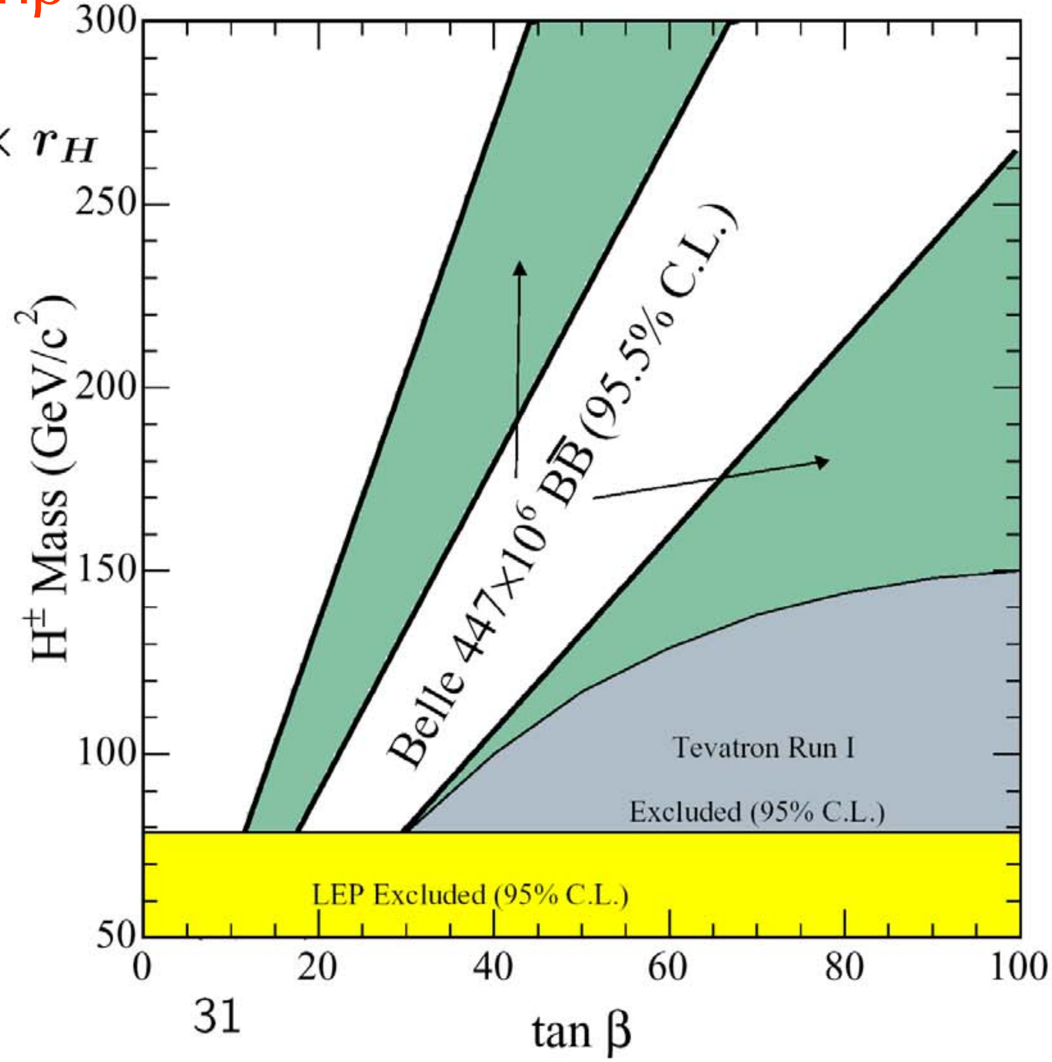


The common uncertainty from f_B cancels in this ratio.

Charged Higgs limits from $B^- \to \tau^- \nu_\tau$

If the theoretical prediction is taken for $\mathbf{f_B}$ → limit on charged Higgs mass vs. tanβ

$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\rm SM} \times r_H$$
$$r_H = 1 - \frac{m_B^2}{m_H^2} \tan\beta$$
$$\Rightarrow r_H = 0.67^{+0.29}_{-0.26}$$



B→τ ν prospects

- Expected precision at Super-B
  - 13% at 5 ab^{-1}
  - 7% at 50 ab^{-1}

- Search with $D^{(*)}$ l ν tag will help.

  → BaBar 232M BB PRD 73 (2006) 057101
  - Tag eff ~ 1.75×10^{-3}
  - Signal selection eff. ~31%
  - Similar S/N to Belle (full recon. sample)

$$\Rightarrow Br(B \to \tau\nu) < 2.8 \times 10^{-4} (90\% CL)$$

Future Prospects: $B \to \tau\nu$

95.5%C.L. exclusion boundaries

Δf_B(LQCD) = 5%

(for $BF_{obs} = BF_{SM}$)

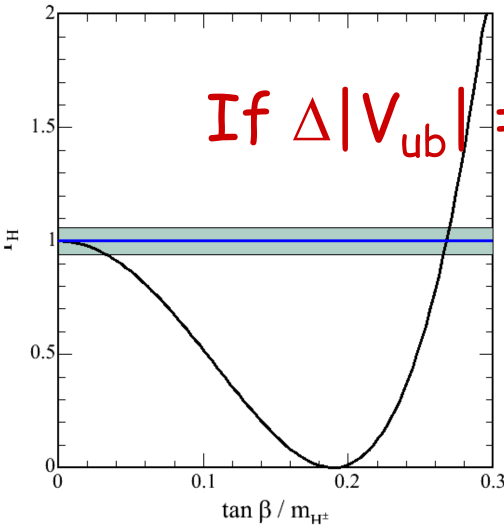
Extrapolations (T.Iijima)

Lum.	$\Delta B(B \to \tau\nu)_{exp}$	$\Delta\|V_{ub}\|$
414 fb^{-1}	36%	7.5%
5 ab^{-1}	10%	5.8%
50 ab^{-1}	3%	4.4%

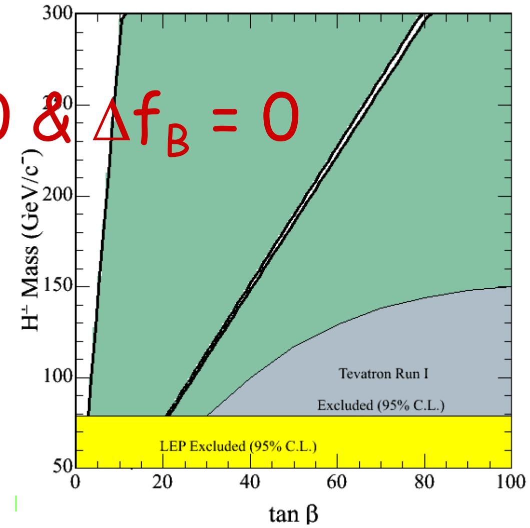
50ab $^{-1}$

If $\Delta|V_{ub}| = 0$ & $\Delta f_B = 0$

r_H



$\tan\beta / m_H$



$B \to \tau^+\tau^-$

BaBar (232M BB) PRL 96 (2006) 241802

Challenging measurement: 2-4 neutrinos per event!

•Fully reconstruct one B ($\to D^{(*)}X$, X=combination of up to 5 pions and kaons), 280k events

• τ decay modes: $l\nu\nu$, $\pi^-\nu$, $\rho^-\nu$ (51% of $\tau\tau$ decays)

•Reject events with K_L, K_S, $K^\pm$ and employ neural network (kinematics of charged track momenta and ECL residual energy)

$\to 263 \pm 19$ events (expect 281 ± 40 from sidebands, MC)

$BF(B \to \tau^+\tau^-) < 4.1 \times 10^{-3}$ (90%CL) SM prediction: 0.12×10^{-6}

$\to$ First ever limit on this channel

Constrains leptoquark couplings and $\tan\beta$ enhancements

$B^- \to K^- \nu \nu$

$B \to K(*)\nu\nu$ is a particularly interesting and challenging mode (with $B \to \tau\nu$ as a small background), theoretically clean

Experimental signature: $B \to K$ + nothing

The "nothing" can also be light dark matter with mass of order 1 GeV. Direct dark-matter searches cannot see the M<10 GeV region.

SM prediction: $(3.8^{+1.2}_{-0.6}) \times 10^{-6}$

$B \to \tau\nu$ analysis is a proof that such a one prong decay can be studied at a B factory

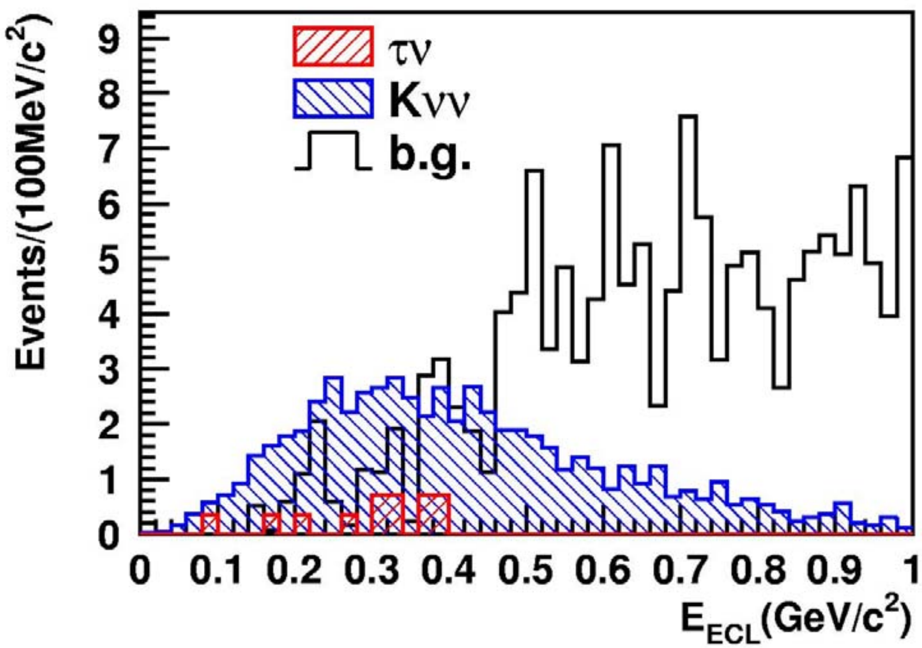
Present limits:

- BaBar (89M BB): $BF(B^+ \to K^+\nu\nu) < 52 \times 10^{-6}$ PRL 94 (2005)101801
- Belle (275M BB): $BF(B^+ \to K^+\nu\nu) < 36 \times 10^{-6}$ hep-ex/0507034

$B^- \to K^- \nu \nu$ prospects

MC extrapolation to 50 ab^{-1}

5σ Observation of $B^\pm \to K^\pm \nu \nu$



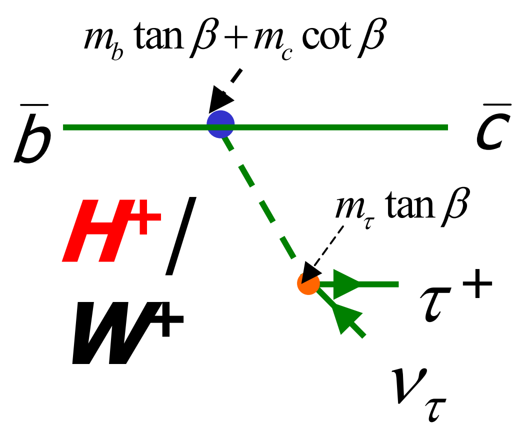
Extra EM calorimeter energy

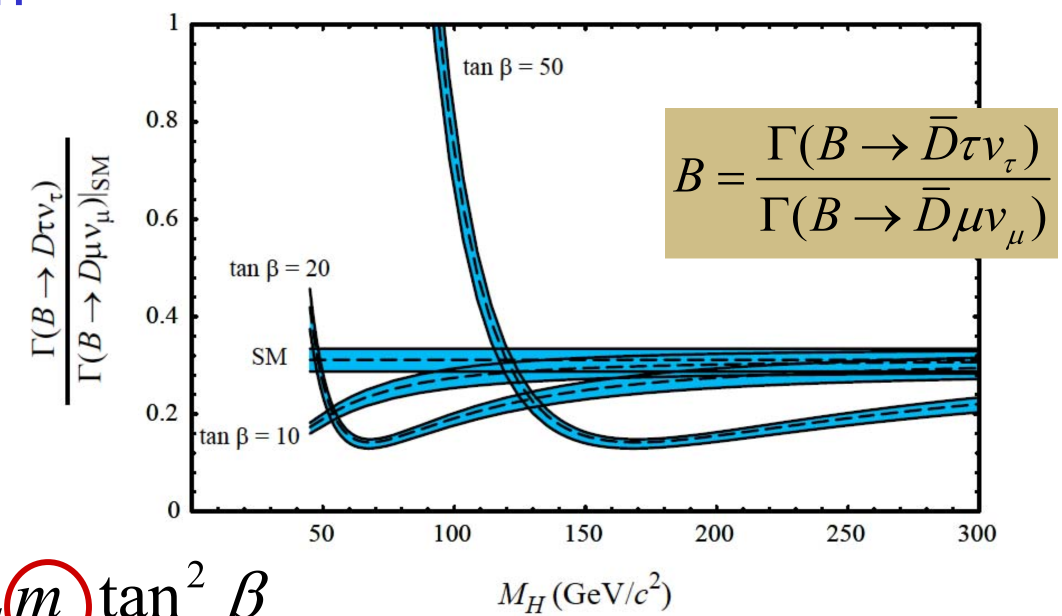
SM prediction:
G.Buchalla, G.Hiller, G.Isidori
(PRD 63 014015)

Fig. From SuperKEKB LoI

Charged Higgs search in B→D τ ν

Charged Higgs contribution





Decay amplitude $\propto m_b m_\tau \tan^2\beta$

Br(SM) ~ 8 x 10^{-3}

Tauonic decay is the most sensitive

- Analysis: reject events with p, K, reject $D^*\tau\nu$ contamination, no remaining charged or π^0 tracks, cut on the ECL residual energy, angle between two ν's and missing mass.

$B \to D\, \tau\, \nu$ (MC studies)

- Signal selection efficiency

$\bar{D}^0\tau^+(e^+\bar{\nu}_\tau\nu_e)\nu_\tau$	10.2%	$\bar{D}^0\tau^+(\pi^+\bar{\nu}_\tau)\nu_\tau$	26.1%
$\bar{D}^0\tau^+(\mu^+\bar{\nu}_\tau\nu_e)\nu_\tau$	2.6%	$\bar{D}^0\tau^+(\rho^+\bar{\nu}_\tau)\nu_\tau$	13.3%

- Expectation at 5 / 50 ab^{-1} for B^+ decay

	$5ab^{-1}$				$50ab^{-1}$			
Mode	Nsig	Nbkg	Σ	$\delta B/B$	Nsig	Nbkg	Σ	$\delta B/B$
$\bar{D}^0\tau^+(\ell^+\bar{\nu}_\tau\nu_\ell)\nu_\tau$	280	550	12.7	7.9%	2800	5500	40.3	2.5%
$\bar{D}^0\tau^+(h^+\bar{\nu}_\tau)\nu_\tau$	620	3600			6200	36000		

5σ observation possible at $1ab^{-1}$

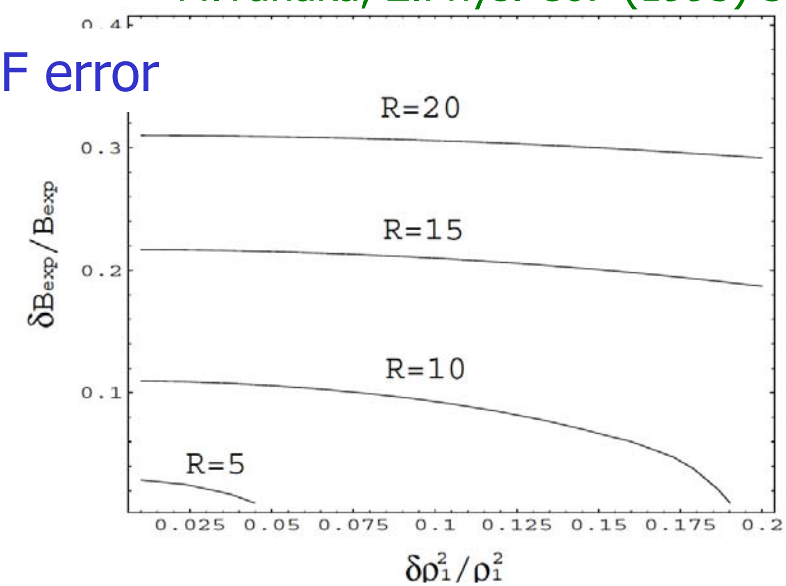
B→D τ ν constraint on charged Higgs

Once branching fraction is measured, we can determine R.

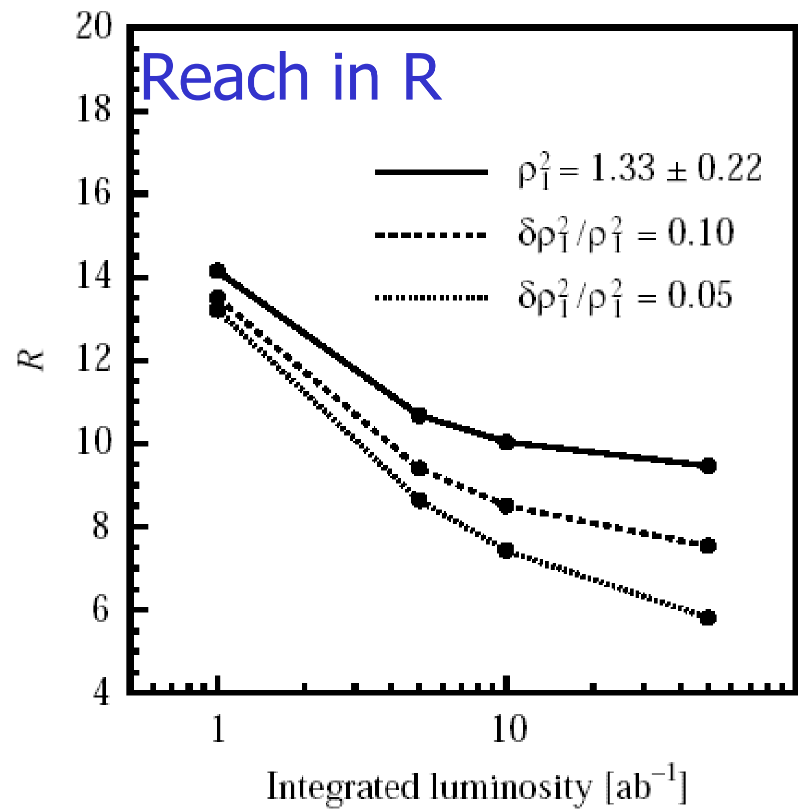
$$R \equiv \frac{M_W}{M_H} \tan\beta$$

M.Tanaka, Z.Phys. C67 (1995) 321

BF error



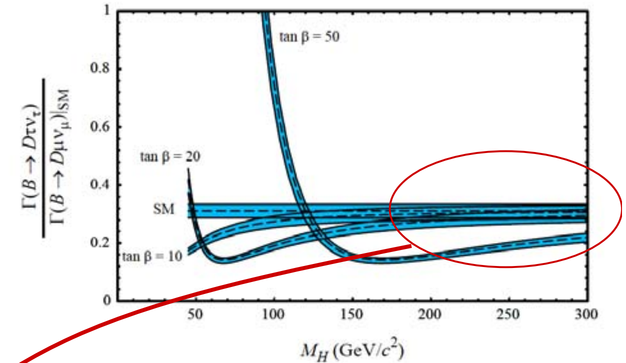
Form factor error



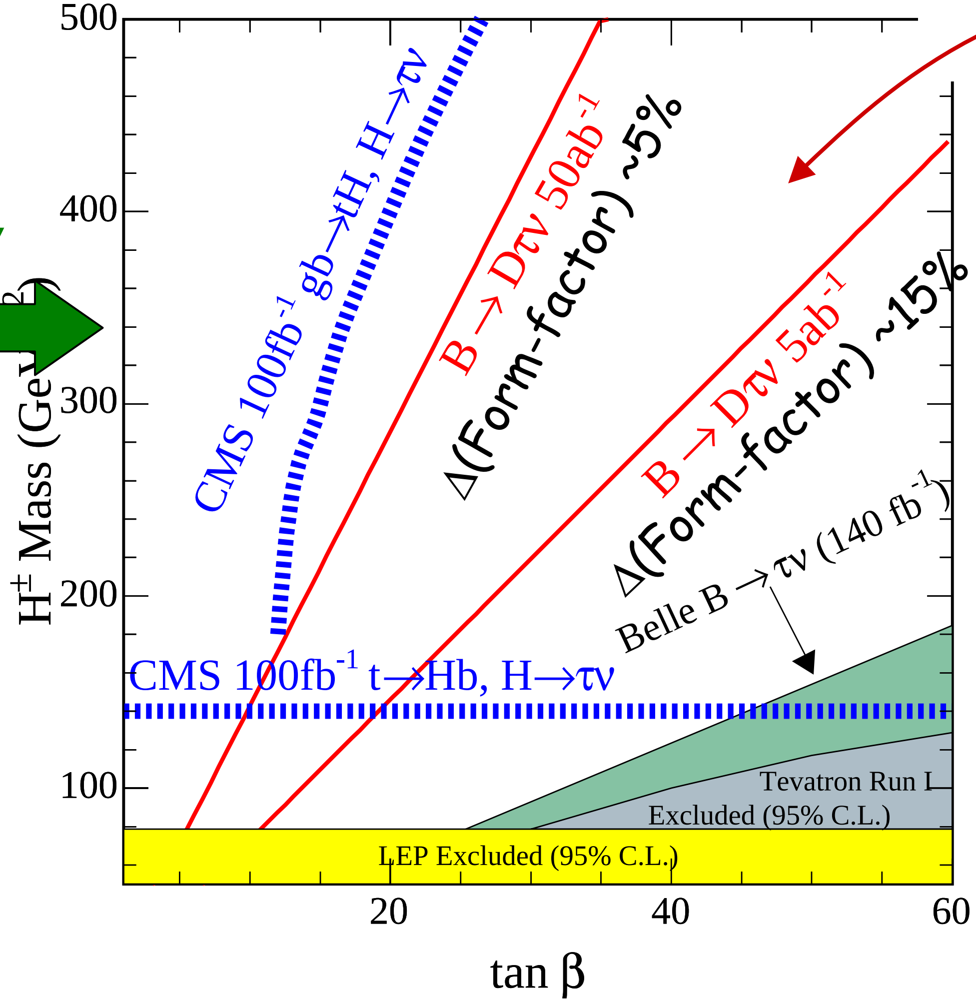
→Reach in R: 11 at 5ab^{-1}

→ This decay explores the region $M_H < \tan\beta\, M_W/11$

B→D τ ν → charged Higgs

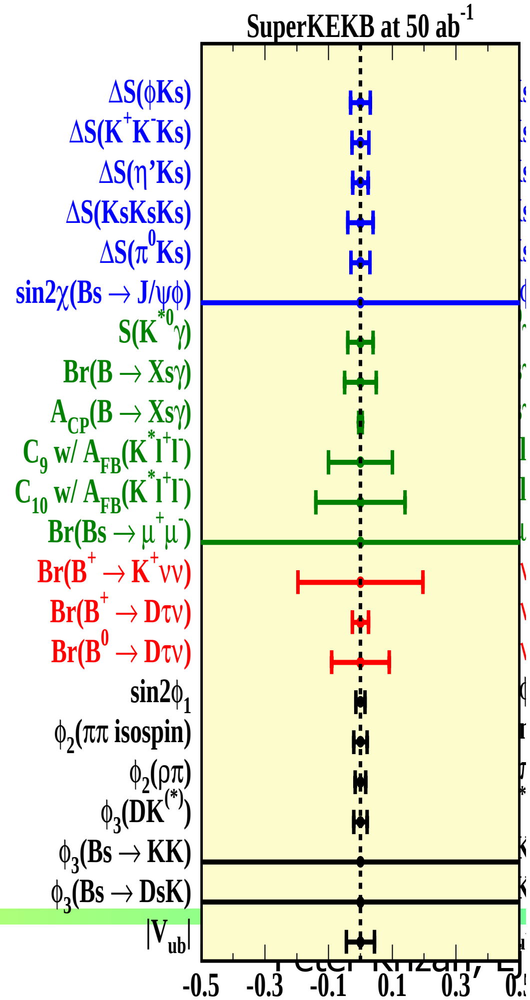


Constraint
From b→sγ



Super-B and LHCb: complementary

- Clean environment → measurements that no other experiment can perform. Examples: CPV in $B \to \phi K^0$, $B \to \eta' K^0$ for new phases, $B \to K_S \pi^0 \gamma$ for right-handed currents.
- "*B*-meson beam" technique → access to new decay modes; proof $B \to \tau\nu$ Example: discover $B \to K\nu\nu$.
- Measure new types of asymmetries. Example: forward-backward asymmetry in $b \to s\mu\mu$, *see*
- Rich, broad physics program including *B*, τ and charm physics. Examples: searches for $\tau \to \mu\gamma$ and *D-D* mixing with unprecedented sensitivity.



→LHCb

→LHCb

→LHCb

Summary

- Radiative, electroweak and tauonic B decays are of great importance to probe new physics.
- We are starting to measure $B \rightarrow \tau\nu$, $D\tau\nu$, $A_{FB}(K^*ll)$, $A_{CP}(K\pi^0\gamma)$ etc. at the current B factories.

  → Hot topics in the coming years !

  → Watch out for updates (including this week)...

- For precise measurements, we need a Super-B factory!

→ Observe $K^{(*)}\nu\nu$, zero crossing in A_{FB}, $D^{(*)}\tau\nu$

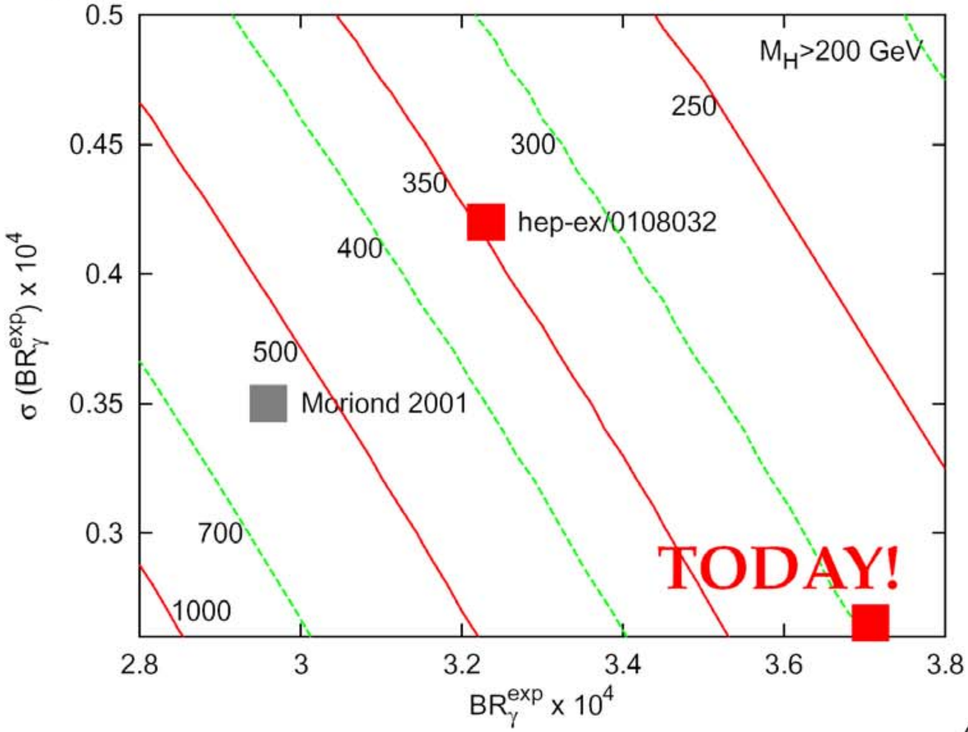
→ Expected precision ($5ab^{-1} \rightarrow 50ab^{-1}$);

  - $Br(\tau\nu)$: 13% → 7%
  - $Br(D^{(*)}\tau\nu)$: 7.9% → 2.5%
  - q_0^2 of $A_{FB}(K^*ll)$: 11% → 5%
  - $A_{CP}(K\pi^0\gamma)$ tCPV: 0.14 → 0.04

Additional slides

Charged Higgs from Br(b→sγ)

m_{H^+} bounds as a function of $\mathcal{B}$ and $\delta\mathcal{B}$ (5 year old plot)



- Lower limit on type-II charged Higgs mass for any $\tan\beta$
  $m_{H^+} \gtrsim 300$ GeV
  (if no other destructive SUSY amplitudes)
- Previous limit was higher since the measured rate was lower than prediction

(This plot is made for $\mathcal{B}_{th} = 3.73 \pm 0.31$)

Expected improvements:

- Measurements: more data
  (current results are based on ~1/4 of full dataset for both Belle/BaBar)
- Theory: NNLO calculations are coming

Radiative decays: prospects

	$0.5\ ab^{-1}$	$5\ ab^{-1}$	$50\ ab^{-1}$
Branching fraction			
$\mathcal{B}(B \to X_s\gamma)$	<10%	"5%"	still 5%
$\mathcal{B}(B \to X_d\gamma)$	—	—	possible?
Sign of C_7			
$\Delta_{0+}(B \to K^*\gamma)$	4%	2%	no better
$\Delta_{0+}(B \to \rho\gamma)$	possible?	reasonable	precise
Mixing CPV			
$S(K_S^0\pi^0\gamma)$	—	0.12	0.05
$S(K_S^0\phi\gamma)$	—	0.5	0.15
$S(K_1(1270)\gamma)$	—	difficult?	possible?
Direct CPV			
$A_{CP}(B \to X_s\gamma)$ inclusive	4.5%	1.4%	0.5%
$A_{CP}(B \to X_s\gamma)$ sum-of-excl.	3%	1%	0.5%
$A_{CP}(B \to K^*\gamma)$	1.8%	0.6%	0.2%

Summary by M. Nakao 1st Super-B workshop at Hawaii (2004)

$B^- \to e^- \nu_e, \mu^- \nu_\mu$

Helicity supressed with respect to $B \to \tau\nu$

$B^- \to \mu^-\nu_\mu$ SM prediction: 0.4×10^{-6}

(Possibly better for charged Higgs limits than $\tau\nu$ at high stat)

Present limits:

- Belle (152M BB): $BF(B^- \to \mu^-\nu_\mu) < 2 \times 10^{-6}$ hep-ex/0408132
- BaBar (89M BB): $BF(B^- \to \mu^-\nu_\mu) < 6.6 \times 10^{-6}$ PRL 92 (2005)221803

$B^- \to e^- \nu_e$ SM prediction: $\sim 0.00001 \times 10^{-6}$

Present limit:

- Belle (65M BB): $BF(B^- \to e^- \nu_e) < 5.4 \times 10^{-6}$ BELLE-CONF-0247

$B^- \to e^+e^-, \mu^+\mu^-$

No new results from B factories...

- BaBar (120M BB): $BF(B \to e^+e^-) < 0.083 \times 10^{-6}$
  $BF(B \to \mu^+\mu^-) < 0.061 \times 10^{-6}$ PRL94(2005)221803
- Belle (85M BB): $BF(B \to e^+e^-) < 0.19 \times 10^{-6}$
  $BF(B \to \mu^+\mu^-) < 0.16 \times 10^{-6}$ PRD 68 (2003)111101

.... With present statistics we could be competitive with Tevatron

Limits from Tevatron: hep-ex/0508058

$BF(B_d \to \mu^+\mu^-) < 0.032 \times 10^{-6}$ SM prediction: 0.0001×10^{-6}

$BF(B_s \to \mu^+\mu^-) < 0.12 \times 10^{-6}$ SM prediction: 0.0035×10^{-6}

B→D τ ν (MC studies)

- Use fully reconstructed samples.
- τ decay modes

$$\tau^- \rightarrow \mu^- \nu\bar{\nu}, e^- \nu\bar{\nu}, \pi^- \nu, \rho^- \nu$$

- Analysis cuts;
  - Reject events with *p, K$_L$*
  - Reject *D** τ ν contamination

$$|m_{D^{*0}} - m_{D^0} - 142| < 10\,\mathrm{MeV}/c^2$$

  - No remaining charged or π^0 tracks
  - ECL residual energy

$$E_{residual} < 100 MeV$$

  - Angle between two ν's

$$-1.0 \le \cos\theta_{\nu\nu} \le 0.8$$

  - Missing mass

$$|p_B - p_D - p_\ell|^2 > 1.2\,(GeV/c^2)^2$$