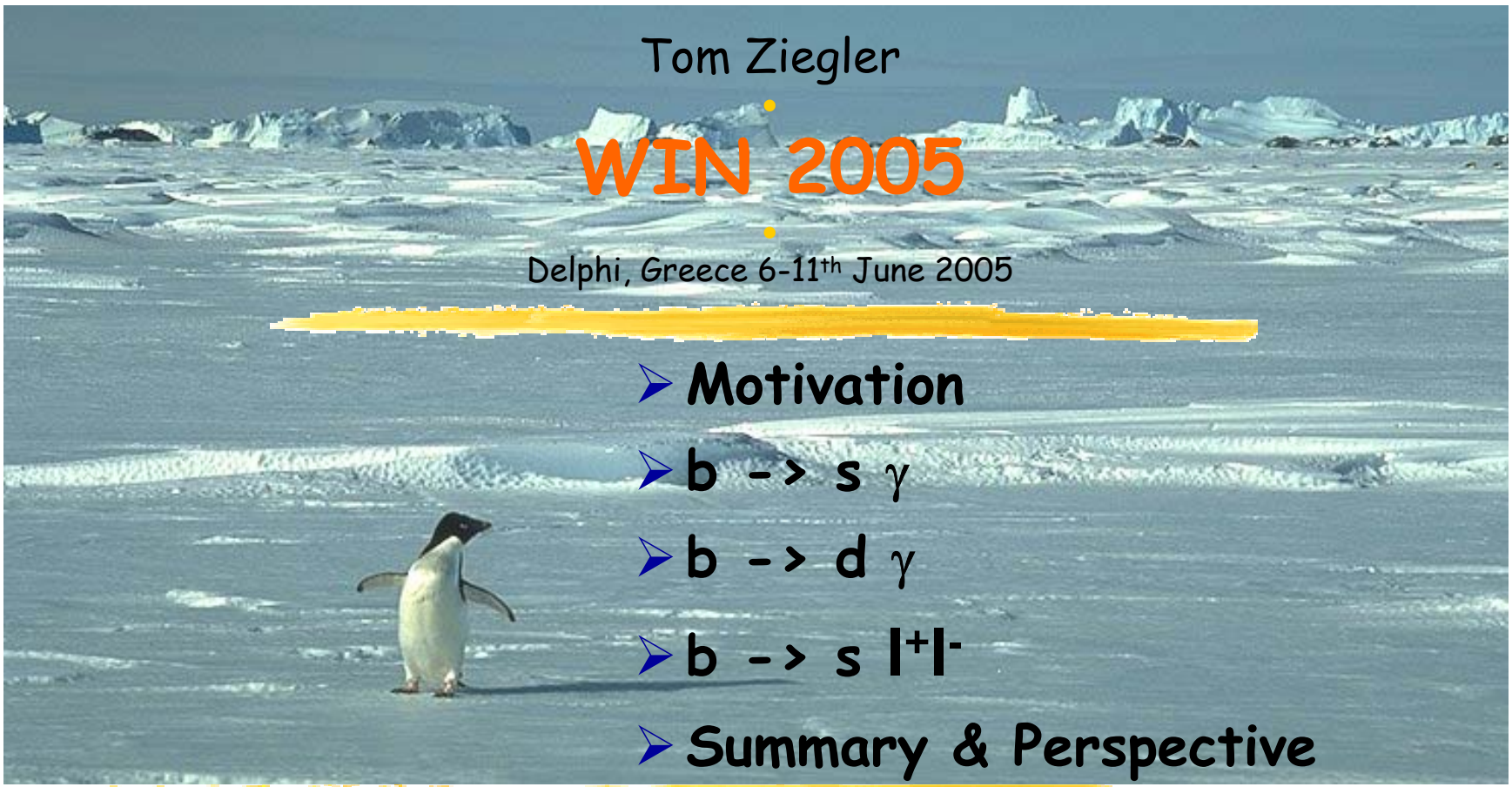
b -> s γ , b -> s l^+l^- and other rare B decays with the Belle Detector



Tom Ziegler

WIN 2005

Delphi, Greece 6-11th June 2005

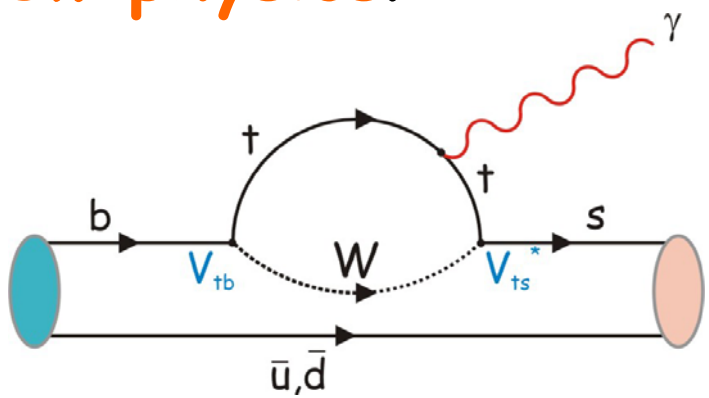
- Motivation
- b -> s γ
- b -> d γ
- b -> s l^+l^-
- Summary & Perspective

Flavor Changing Neutral Current

Decays in this talk proceed via
Flavour Changing Neutral Currents (FCNC)
=> penguin and box diagrams

=> Test SM and search for new physics!

- Branching fractions
- Direct CP violation
- CP violation phase
- CKM elements V_{td}, V_{ts}
- Wilson coefficients
- Energy/mass spectra, moments, ...

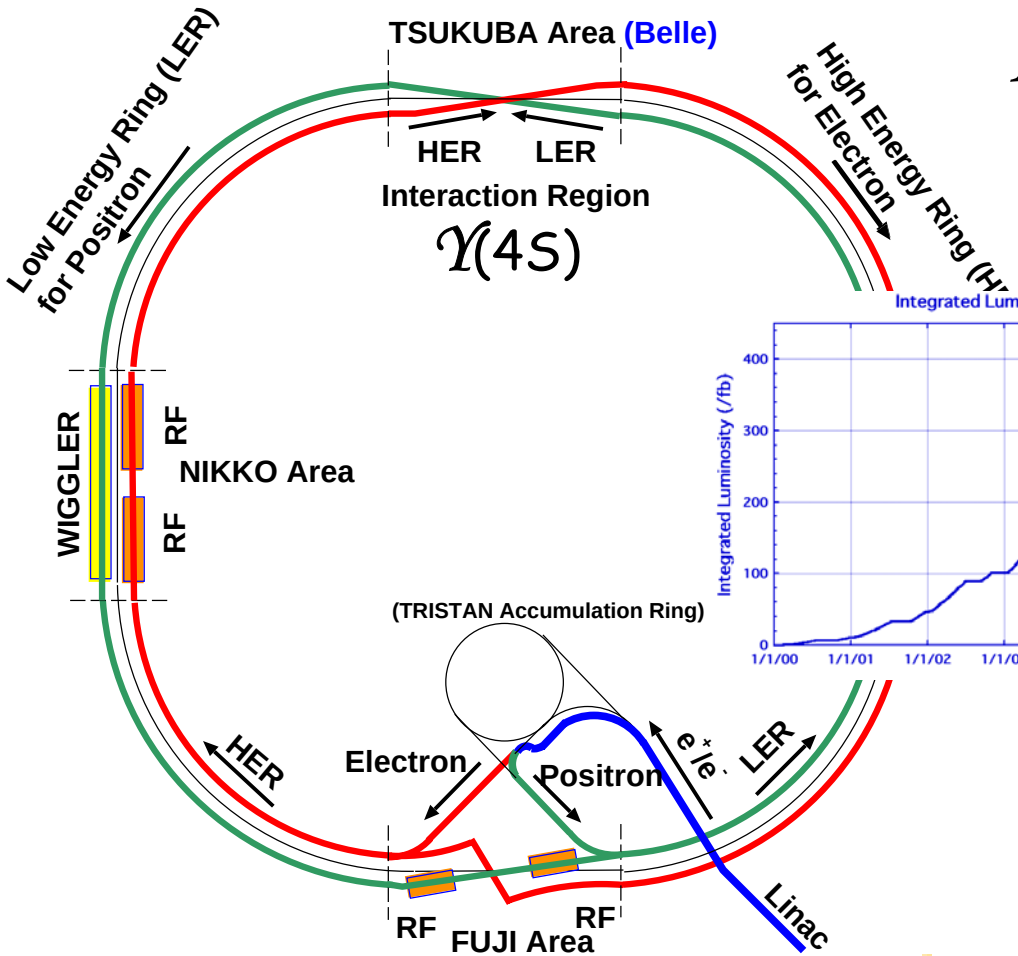


The KEK-B collider

3.5 GeV e^+ on 8 GeV e^- => Currents: 1.8 A x 1.3 A

$\mathcal{L} = (1.6 \times 10^{34})/cm^2/sec$

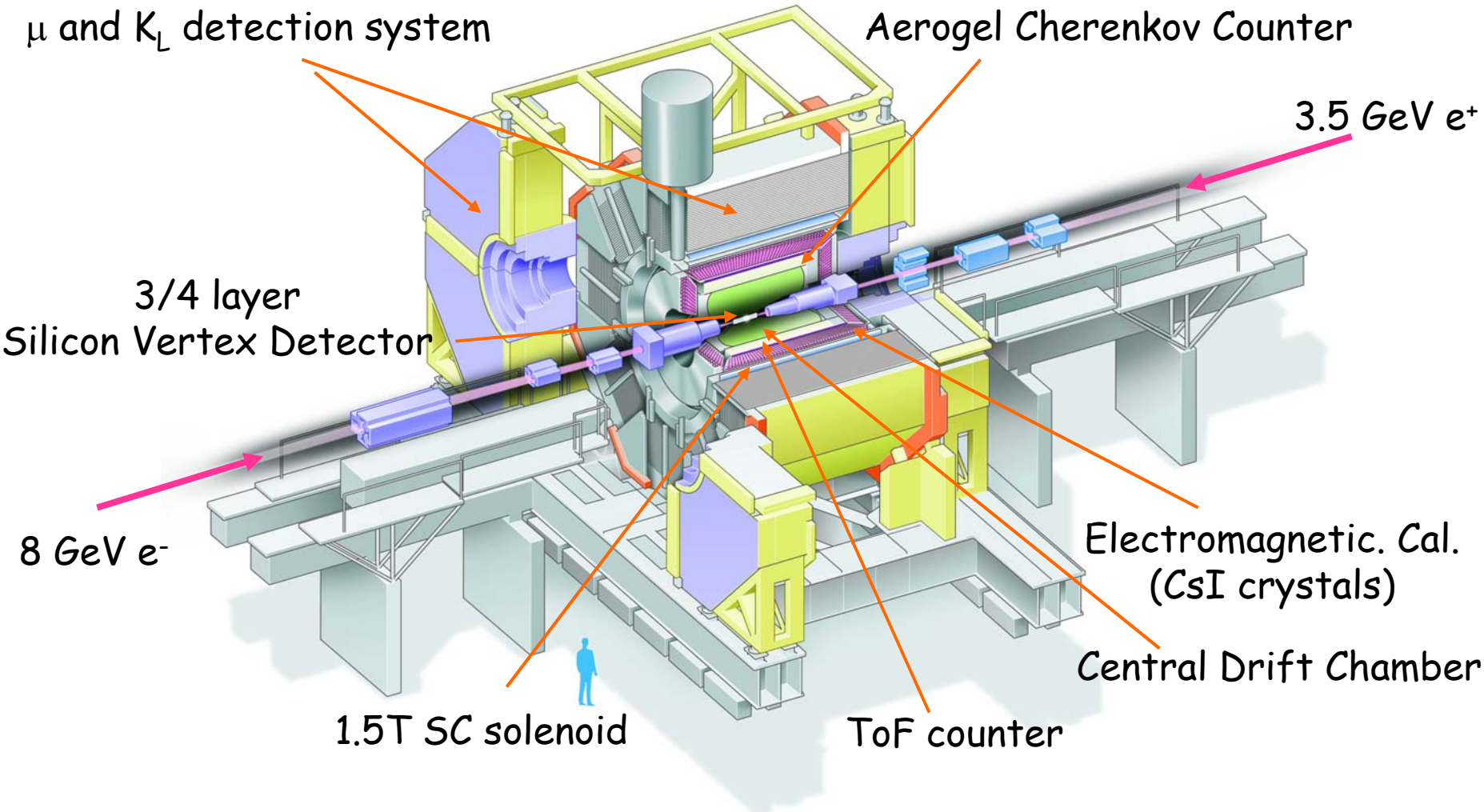
18-may-2005



$\int \mathcal{L}\, dt > 450\ fb^{-1}$

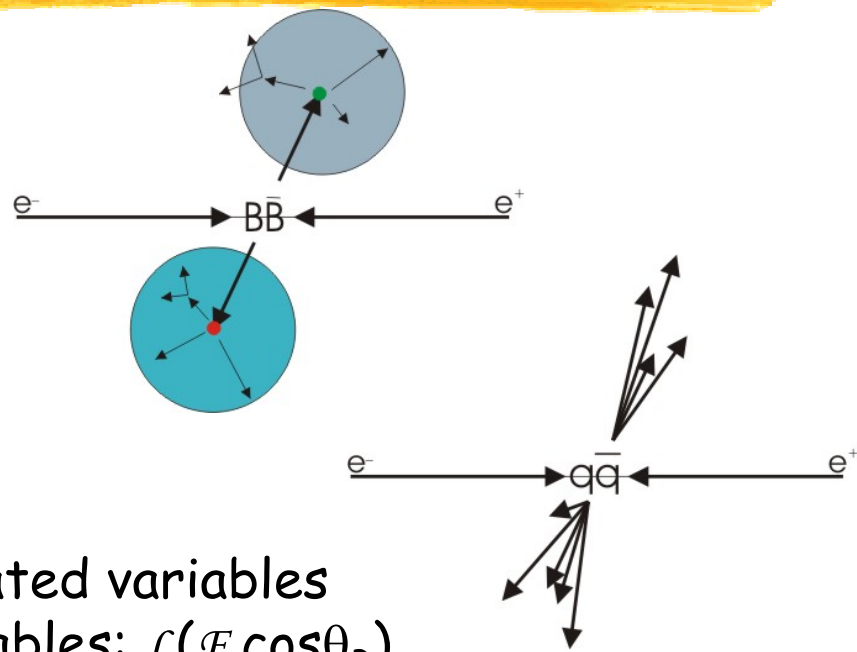
31-may-2005

The Belle Detector



Continuum suppression

$B\bar{B}$ and $q\bar{q}$ have different topologies!



Typical variables for Bkg suppression:
- Modified Fox Wolfram moments
- Sphericity $\cos(\theta_{sph})$
- Thrust, $\cos(\theta_{thr})$
- ...

=> Build Fisher discriminant $\mathcal{F}$ for correlated variables
=> Form Likelihood for uncorrelated variables: $\mathcal{L}(\mathcal{F},\cos\theta_B)$

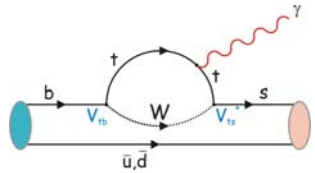
=> Build Likelihood ratio: LR = $\mathcal{L}_B$ / ($\mathcal{L}_B$+$\mathcal{L}_{qq}$)

Kinematic Variables:

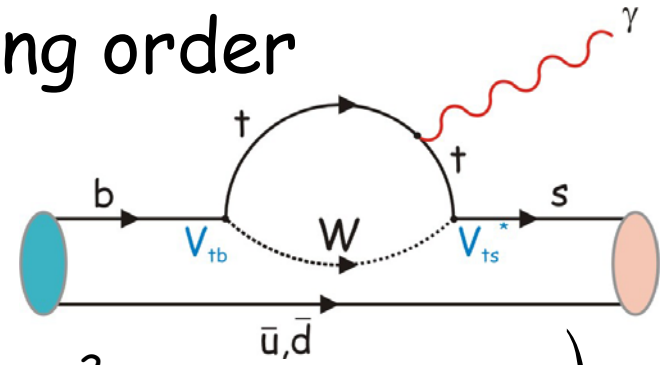
$$\Delta E = E_B^* - E_{beam}^*$$

$$M_{bc} = \sqrt{(E_{beam}^*)^2 - \left|p_B^*\right|^2}$$

b -> s γ



Pure penguin diagram in leading order



$BR(b \to s\gamma) \approx 3.5 \times 10^{-4}$

Not so rare actually…

$$\Gamma(b \to s\gamma) = \frac{G_F^2 \alpha_{em} m_b^5}{32\pi^4} \left|V_{ts}^* V_{tb}\right|^2 \left(\left|C_{eff}^7\right|^2 + \text{corr.}(1/m_b)\right)$$

Wilson coefficient

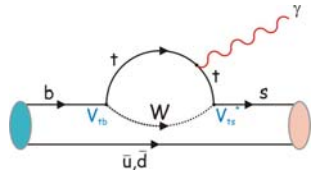
Investigate
- inclusive
- exclusive

decays => extract observables

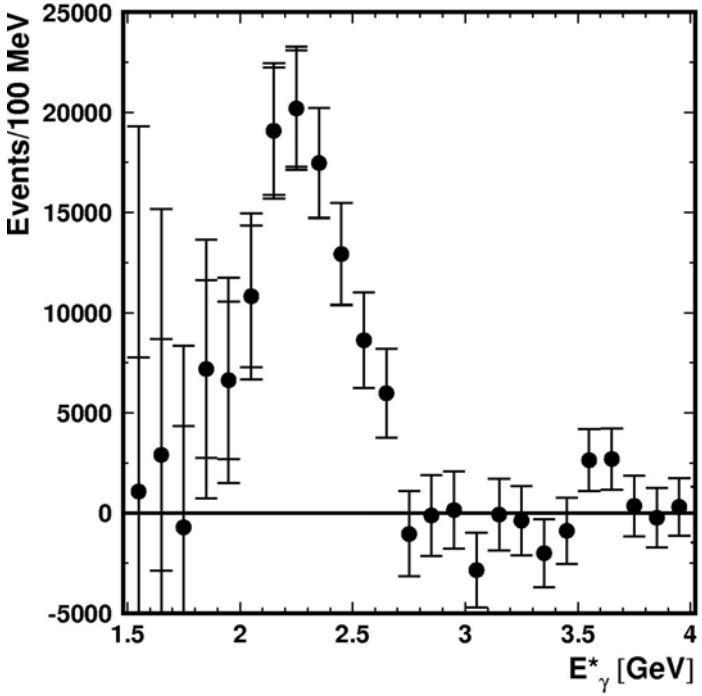
=> Test SM and search for new physics!

[B9]

Inclusive b -> X_s γ



- Select photons with $E^*_\gamma > 1.5$ GeV
  (analysis done with $E^*_\gamma > 1.8$ GeV)
- Veto photons from π^0 and η decays
- Subtract background



based on 140 fb^{-1}

$\langle E_\gamma \rangle = 2.289 \pm 0.026 \pm 0.034$ GeV

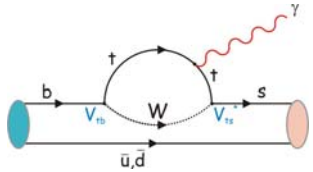
$\langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2 =$
$0.0311 \pm 0.0073 \pm 0.0063$ GeV^2

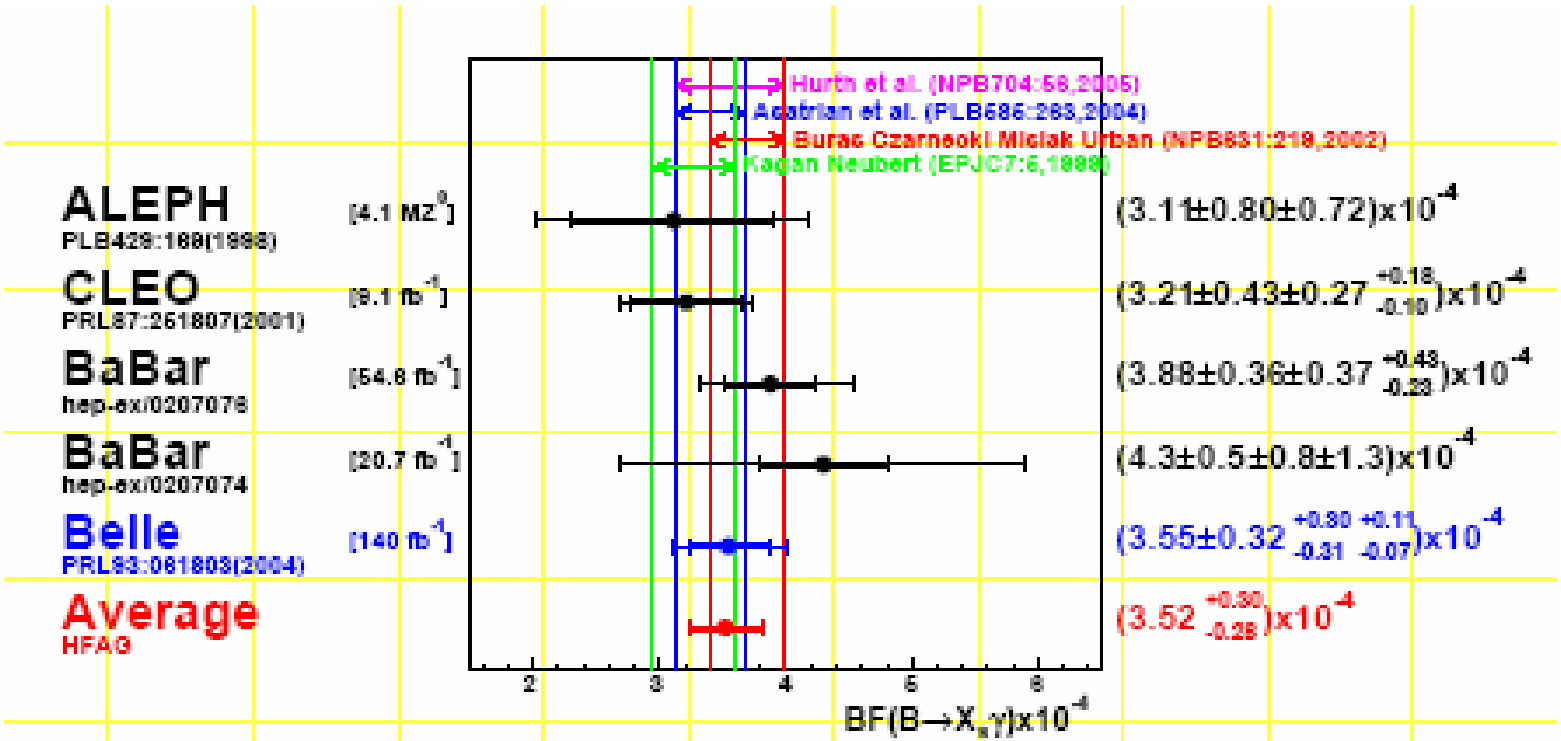
Smeared by motion of b quark inside the B meson and gluon emission => dynamics of B meson

⇒ important for V_{ub} measurement from inclusive charmless semileptonic decays [B18,B19]

[B9]

Extract BR(b -> X_s γ)

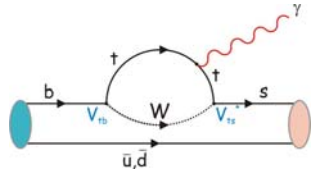




Measurements and SM calculations agree very well, theoretical uncertainties are already of same order than statistical errors of measurement!

[B8]

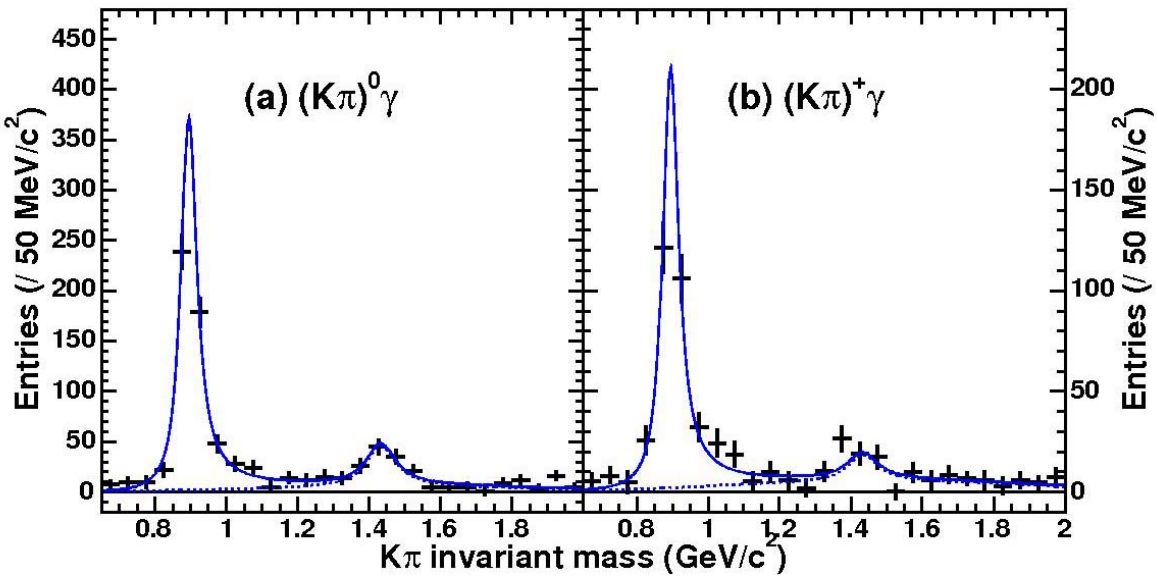
B -> K*γ

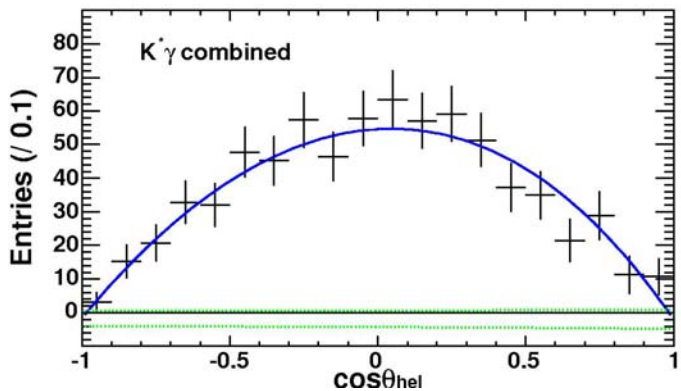


- K*(892) reconstructed in 4 final states:

  $K^+\pi^-$, $K^0_S\pi^0$, $K^+\pi^0$, $K^0_S\pi^+$ with

  $|M(K\pi) - M(K^*)_r| < 75\ MeV/c^2$

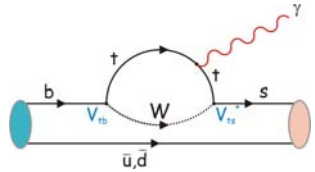




Based on 78 fb^{-1}

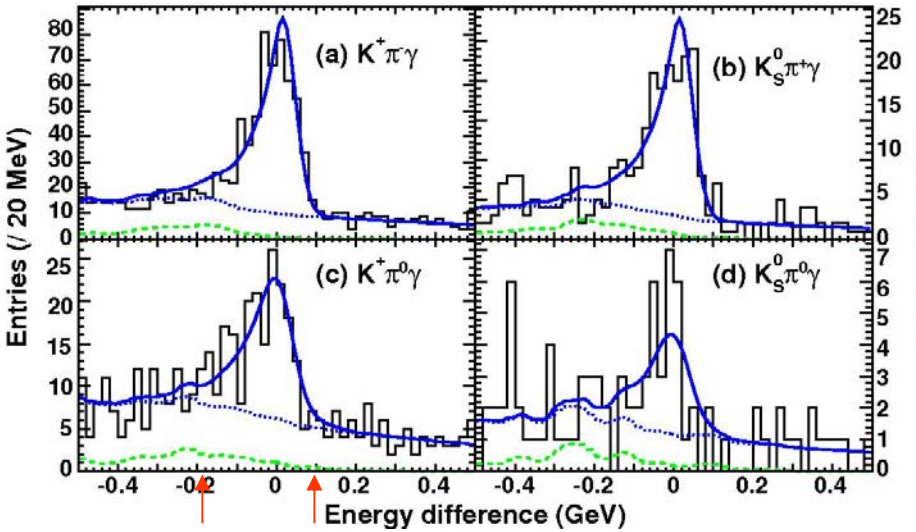
[B8]

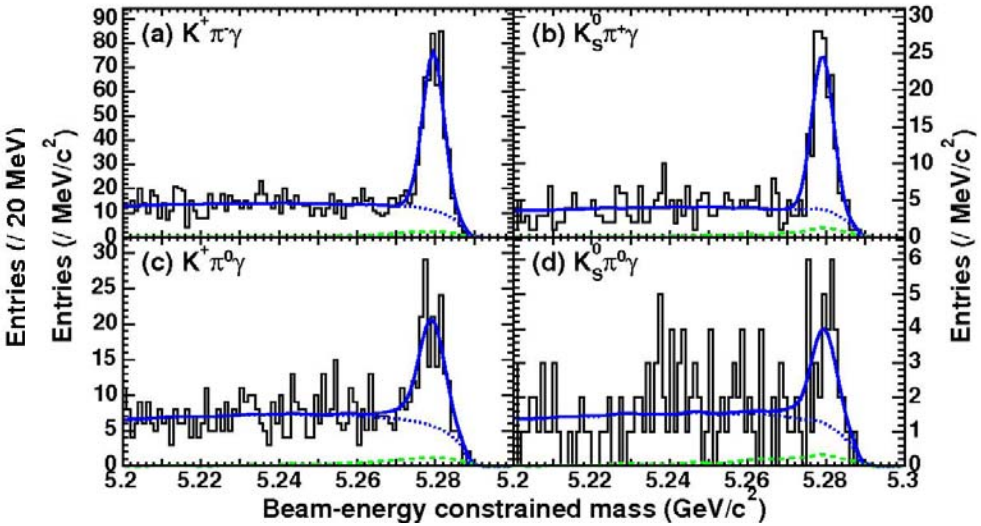
BR(B -> K*γ)



$$\Delta E = E_B^* - E_{beam}^*$$

$$M_{bc} = \sqrt{(E_{beam}^*)^2 - |p_B^*|^2}$$





$BR(B^0 \to K^{*0}\gamma) = (40.1 \pm 2.1 \pm 1.7) \cdot 10^{-6}$ NLO calc = $(71 \pm 23) \cdot 10^{-6}$

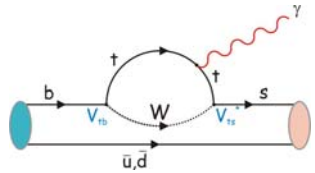
$BR(B^+ \to K^{*+}\gamma) = (42.5 \pm 3.1 \pm 2.4) \cdot 10^{-6}$ NLO calc = $(75 \pm 23) \cdot 10^{-6}$

Ali, Parkhomenko [T2]
Bosch,Buchalla [T3]

Based on 78 fb^{-1}

[B8]

$\Delta_{0+}(B \to K^*\gamma)$



BELLE

Investigate Isospin asymmetry between B^0 and B^+:

$$\Delta_{0+} = \frac{\tau_{B^+}/\tau_{B^0}\,\mathcal{BR}(B^0 \to K^{0*}\gamma) - \mathcal{BR}(B^+ \to K^{+*}\gamma)}{\tau_{B^+}/\tau_{B^0}\,\mathcal{BR}(B^0 \to K^{0*}\gamma) + \mathcal{BR}(B^+ \to K^{+*}\gamma)}$$

$\tau_{B^+}/\tau_{B^0} = 1.083 \pm 0.017$ [PDG2002]

SM predicts +(5-10)%!

Kagan, Neubert [T4]

Assumes $f_+/f_0 = 1$!

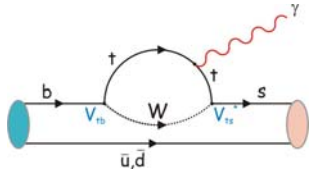
$f_+/f_0 = 1.072 \pm 0.057$ [PDG2002]

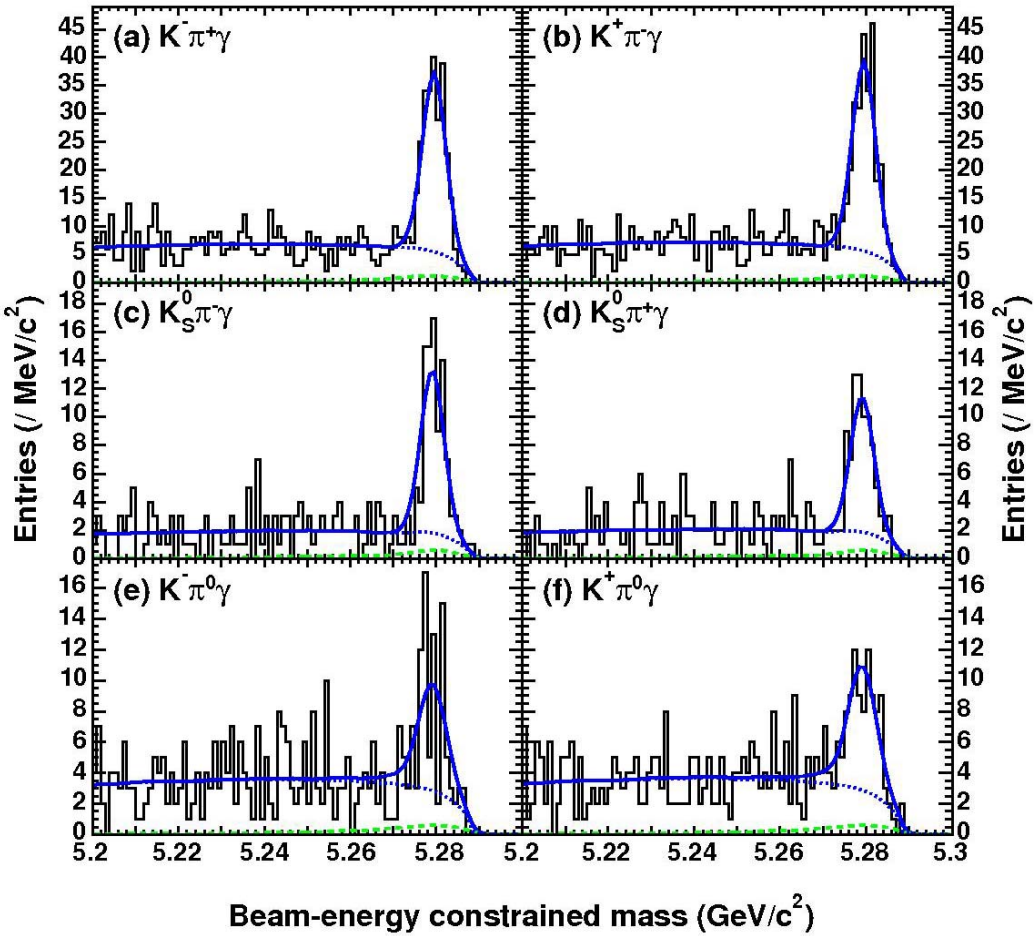
$$\Delta_{0+} = (+1.2 \pm 4.4 \pm 2.6)\%$$

Based on 78 fb^{-1}

[B8]

$A_{CP}(B \to K^*\gamma)$





$$M_{bc} = \sqrt{E^{*2}_{beam} - |p^*_B|^2}$$

Based on 78 fb^{-1}

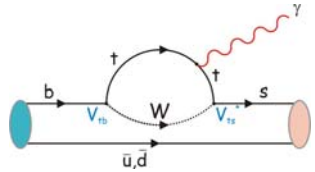
Bosch,Buchalla [T3]

In SM A_{CP} should be smaller than 1% !

$$A_{CP} = 1/(1-2w) \times \frac{N(\bar{B}\to\bar{K}^*\gamma) - N(B\to K^*\gamma)}{N(\bar{B}\to\bar{K}^*\gamma) + N(B\to K^*\gamma)}$$

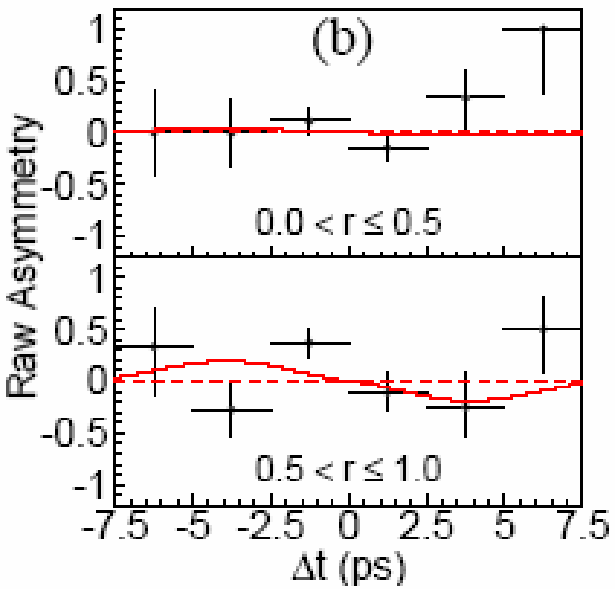
$$A_{CP} = (-1.5 \pm 4.4 \pm 1.2)\%$$

[B17] Time-dependent CPV



Use $K^0_S\pi^0\gamma$ final state for time-dependent CP analysis:

$$A_{CP} = \frac{\Gamma\left(B^0(t) \to K^0_S\pi_0\gamma\right) - \Gamma\left(\overline{B^0}(t) \to K^0_S\pi^0\gamma\right)}{\Gamma\left(B^0(t) \to K^0_S\pi_0\gamma\right) + \Gamma\left(\overline{B^0}(t) \to K^0_S\pi^0\gamma\right)} = S \cdot \sin\Delta m\Delta t + A \cdot \cos\Delta m\Delta t$$



SM <0.1

$$S(K^0_S\pi^0\gamma) = -0.58\,^{+0.46}_{-0.38} \pm 0.11$$

$$A(K^0_S\pi^0\gamma) = +0.03 \pm 0.34 \pm 0.11$$

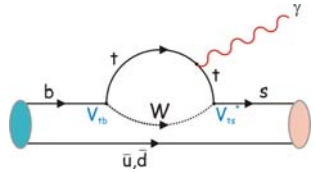
SM <0.01

Atwood et al [T5]
Gronau et al [T6]

Based on 253 fb^{-1}

[B11]

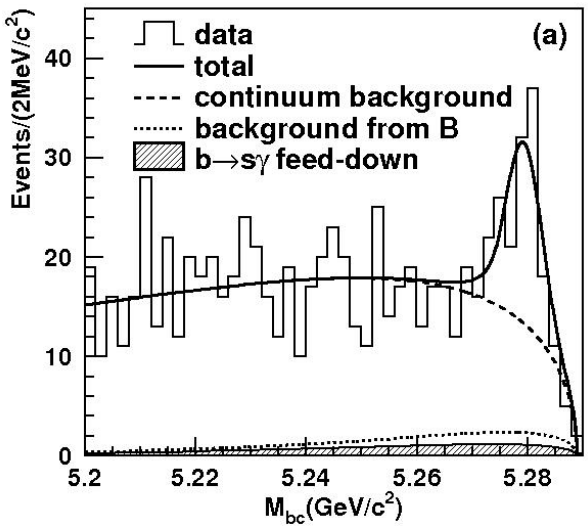
B -> K η γ



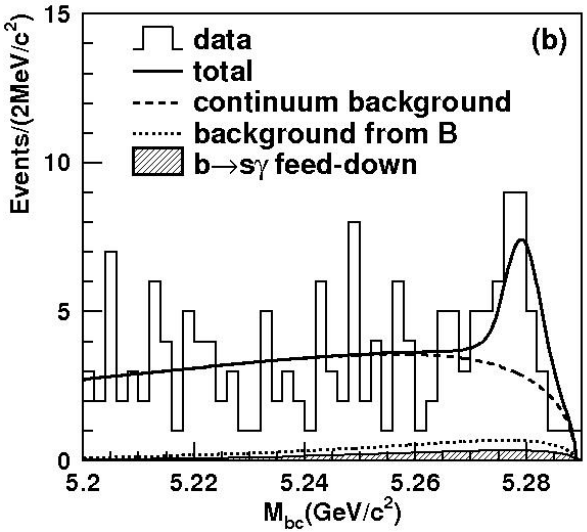
Based on 253 fb^{-1}

- Reconstruct η -> γγ and η -> $\pi^+ \pi^- \pi^0$
- K^0_S -> $\pi^+ \pi^-$
- $|M(K\eta)| < 2.4\ GeV/c^2$ ($E^B_\gamma > 2.1$ GeV, about 84% of b->sγ)

$B^+ \to K^+ \eta\gamma$



6.8σ



$B^0 \to K^0 \eta\gamma$

3.4σ

$$\mathcal{BR}(B^+ \to K^+\eta\gamma) = \left(8.4 \pm 1.5\,^{+1.2}_{-0.9}\right)\cdot 10^{-6}$$

$$\mathcal{BR}(B^0 \to K^0_S\eta\gamma) = \left(8.7\,^{+3.1\ +1.9}_{-2.7\ -1.6}\right)\cdot 10^{-6}$$

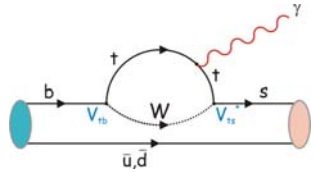
Good candidate for time-dependent CPV!

No hint for B -> $K^*_3(1780)$ γ

Atwood et al [T5]

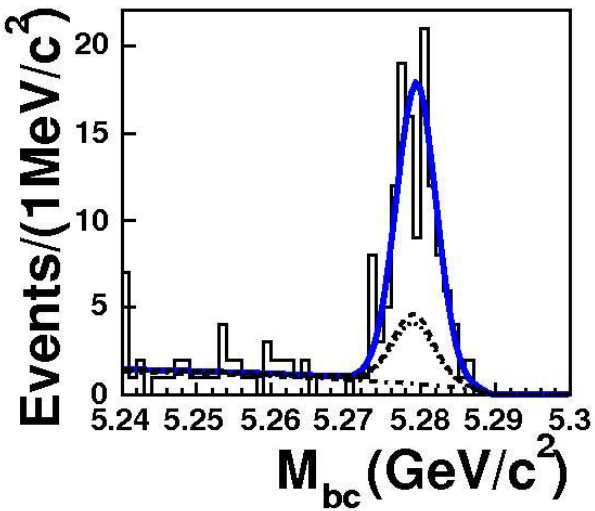
[B12]

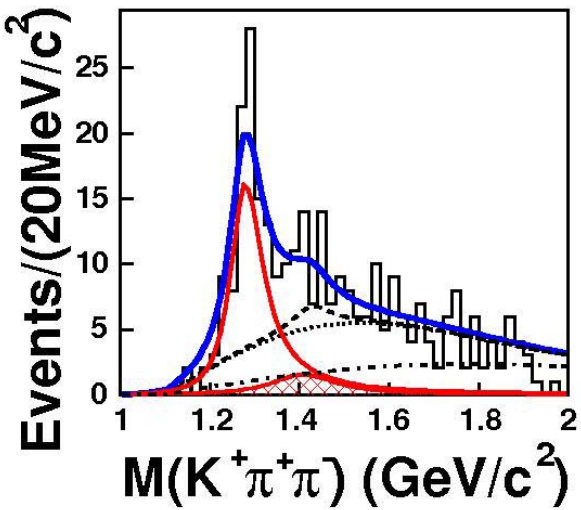
B -> $K_1(1270)\,\gamma$



- Reconstruct $K^+\pi^+\pi^-\,\gamma$ and $K^0\pi^+\pi^-\,\gamma$
- Search for resonant structure in $M(K\pi^+\pi^-)$

first observation! of axial-vector resonance radiative B-decay





Based on 140 fb^{-1}

$$\mathcal{BR}(B^+ \to K_1(1270)^+\gamma) = (4.3 \pm 0.9 \pm 0.9)\cdot 10^{-5} \quad (7.3\ \sigma)\ \text{(large!)}$$

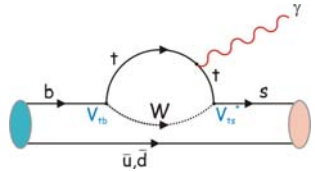
=> prediction: 0.5-2.0 · 10^{-5} [T8]

$$\mathcal{BR}(B^0 \to K_1(1270)^0\gamma) < 5.8\cdot 10^{-5} \qquad \mathcal{BR}(B^+ \to K(1400)^+\gamma) < 1.5\cdot 10^{-5} \quad @90\%\ CL$$

Interesting: time-dependent CPV, photon-helicity Atwood et al [T5]

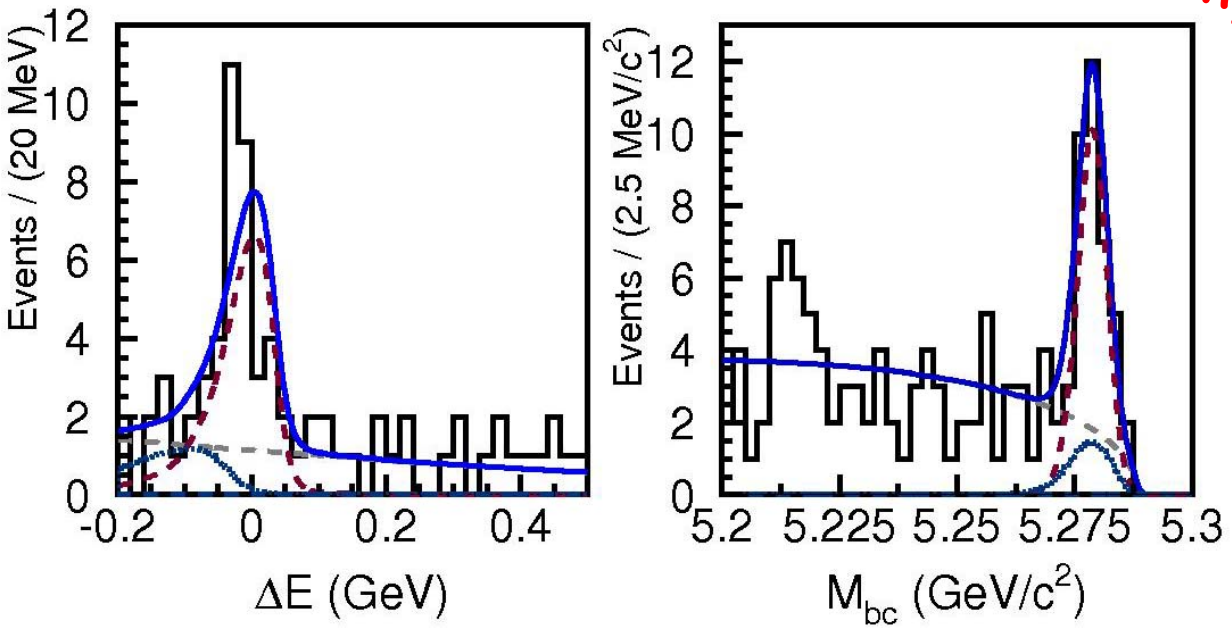
[B14]

$B^+ \to p \bar{\Lambda} \gamma$



- Reconstruct $\Lambda \to p + \pi$

first observation of hyperonic radiative decay!



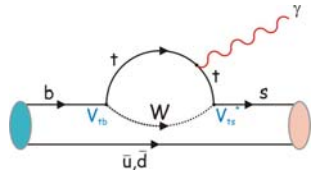
Based on 140 fb^{-1}

$$\mathcal{BR}(B^+ \to p\bar{\Lambda}\gamma) = \left(2.16\,^{+0.58}_{-0.53} \pm 0.20\right) \cdot 10^{-6} \qquad (8.6\ \sigma)$$

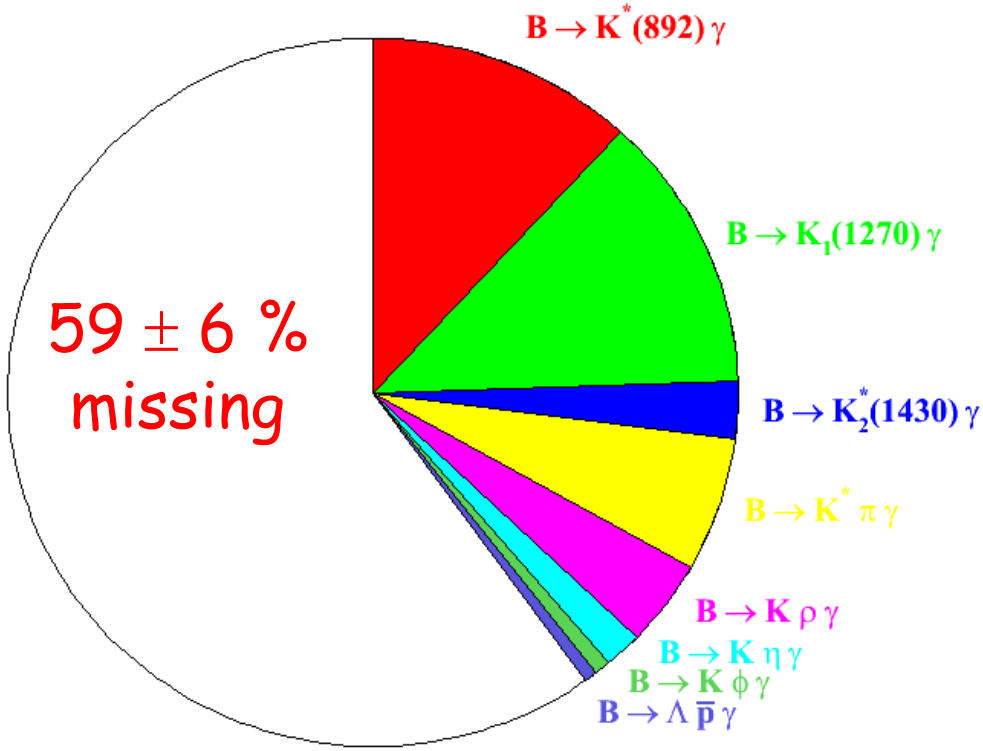
$$\mathcal{BR}(B^0 \to p\bar{\Sigma}^0\gamma) < 4.6 \cdot 10^{-6} \quad @90\%\ CL$$

SM expectation: $\approx 10^{-6}$ Cheng, Yang [T11] Geng, Hsiao [T12]

Summary of b -> s γ

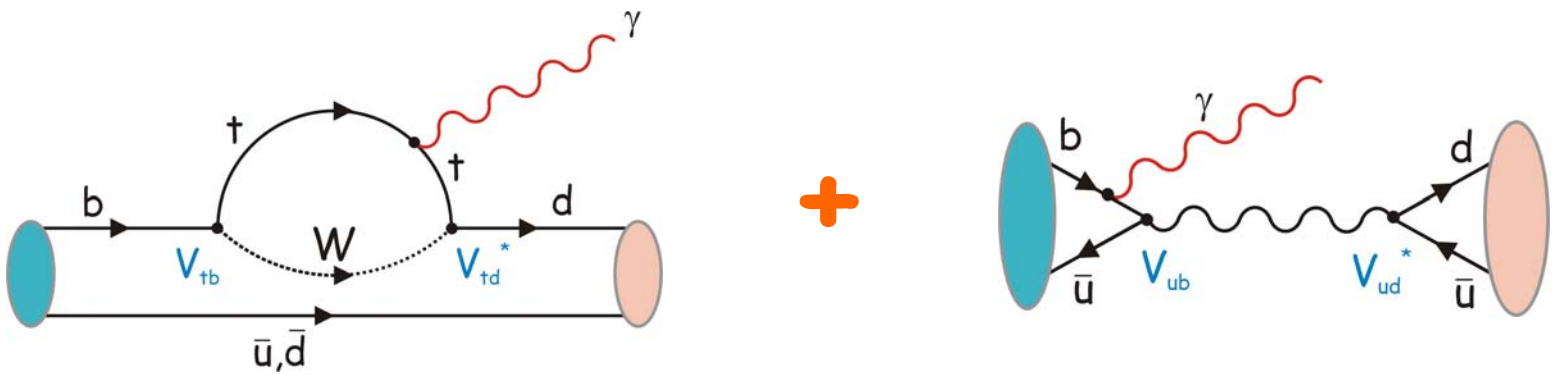


- Many neutral exclusive b -> s γ modes for time-dependent CPV!
- $K\pi\pi^0\gamma$ final state should help for photon polarization
- useful to reduce inclusive b -> s γ systematic errors
- isospin in B and $K^{(*)}$ decays is assumed



b -> d γ

The b -> dγ transition should be suppressed by $|V_{td}/V_{ts}|^2 \approx 0.04$ (large uncertainties on V_{td})
=> $\mathcal{BR} \approx 0.9\text{-}2.7 \cdot 10^{-6}$ expected



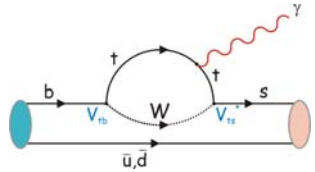
Look for the exclusive modes:

$B^- \to \rho^-\gamma$, $\bar{B}^0 \to \rho^0\gamma$, $\bar{B}^0 \to \omega\gamma$

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

[B15]

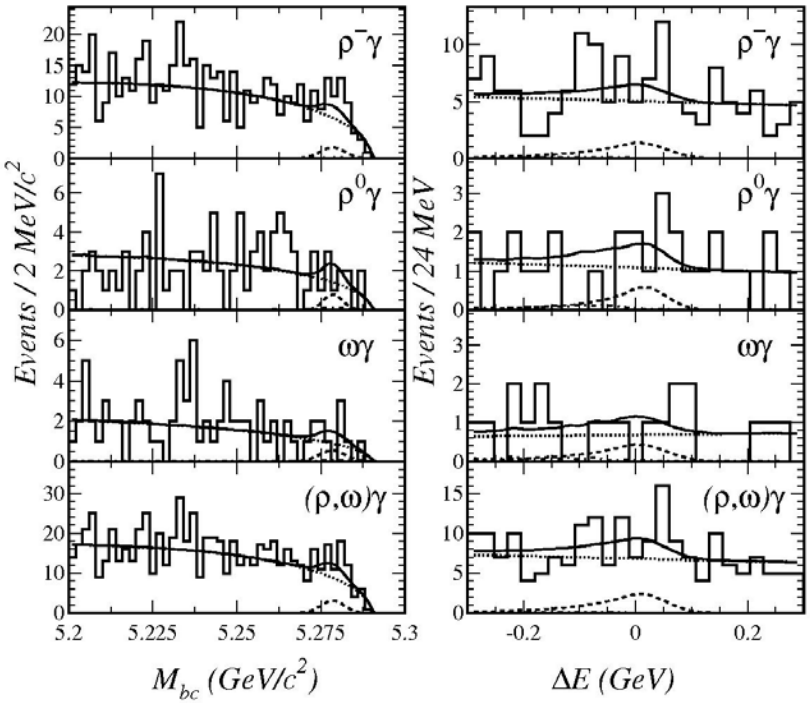
B -> ργ and B^0 -> ωγ



Simultaneous fit to B^+ -> $\rho^+\gamma$, B^0 -> $\rho^0\gamma$ and B^0 -> $\omega\gamma$
From isospin relations:

$\mathcal{BR}(B^+ \to \rho^+\gamma) = 2\,(\tau(B^+)/\tau(B^0)) \cdot \mathcal{BR}(B^0 \to \rho^0\gamma) = 2 \cdot (\tau(B^+)/\tau(B^0))\ \mathcal{BR}(B^0 \to \omega\gamma)$

$(\tau(B^+)/\tau(B^0) = 1.086 \pm 0.017)$

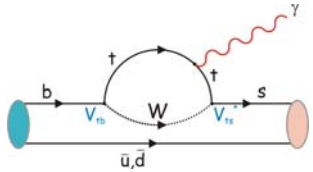


Limit:

$\mathcal{BR}((\rho,\omega)\gamma) < 1.4 \cdot 10^{-6}$ @ 90% CL

Based on 253 fb^{-1}

[B15] $|V_{td}/V_{ts}|$ from B -> $(\rho,\omega)\gamma$



$$\mathcal{BR}((\rho,\omega)\gamma) = (0.72\,^{+0.43}_{-0.39} \pm 0.28)\cdot 10^{-6}$$ Significance: 1.2σ

SM predictions:

Ali-Parkhomenko[T2]: $\mathcal{BR}(B^+ \to \rho^+\gamma) = (0.90 \pm 0.34)\cdot 10^{-6}$

Bosch-Buchalla[T3]: $\mathcal{BR}(B^+ \to \rho^+\gamma) = (1.50 \pm 0.50)\cdot 10^{-6}$

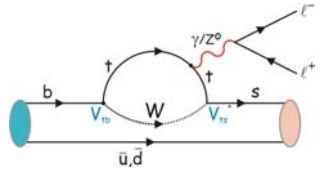
Constraint on V_{td}:

$$\frac{\mathcal{BR}(B \to (\rho,\omega)\gamma)}{\mathcal{BR}(B \to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{(1 - m^2_{(\rho,\omega)}/m_B^2)^3}{(1 - m^2_{K^2}/m_B^2)^3}\,\zeta^2(1+\Delta R)$$

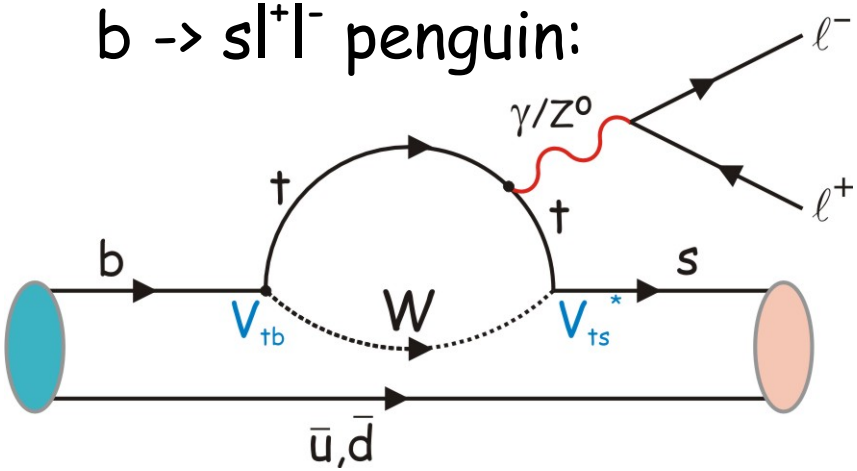
$$\left|\frac{V_{td}}{V_{ts}}\right| < 0.22 \quad @\ 90\%\ CL$$

Based on 253 fb^{-1}

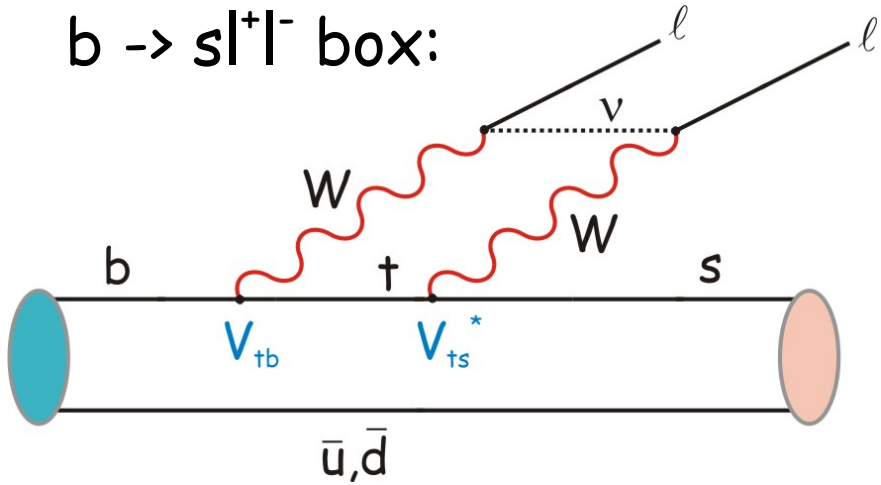
$B \to X_s l^+ l^-$



b -> sl^+l^- penguin:



b -> sl^+l^- box:



$$\mathcal{BR}(b \to s l^+ l^-) \sim \alpha_{em} \cdot \mathcal{BR}(b \to s\gamma) \approx 10^{-6} \text{ !!!}$$

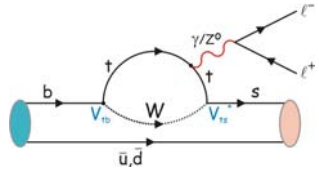
Again: New particles can/will contribute significantly to the decay rates and various asymmetries via the loops!
=> Testing ground for SM and extensions (2HDM, MSSM, GUT, ...?)

$$\hat{s} = (M_{\ell^+\ell^-}/m_b)^2$$

$$\frac{d\Gamma(b \to s\ell^+\ell^-)}{d\hat{s}} \sim \alpha_{em}^2 \left|V_{ts}^* V_{tb}\right|^2 \left(\left|C_{eff}^7\right|^2, \left|C_{eff}^9\right|^2, \left|C_{eff}^{10}\right|^2, \mathrm{Re}\left(C_{eff}^7 C_{eff}^9\right) \right) + \text{corr.}(1/m_b)$$

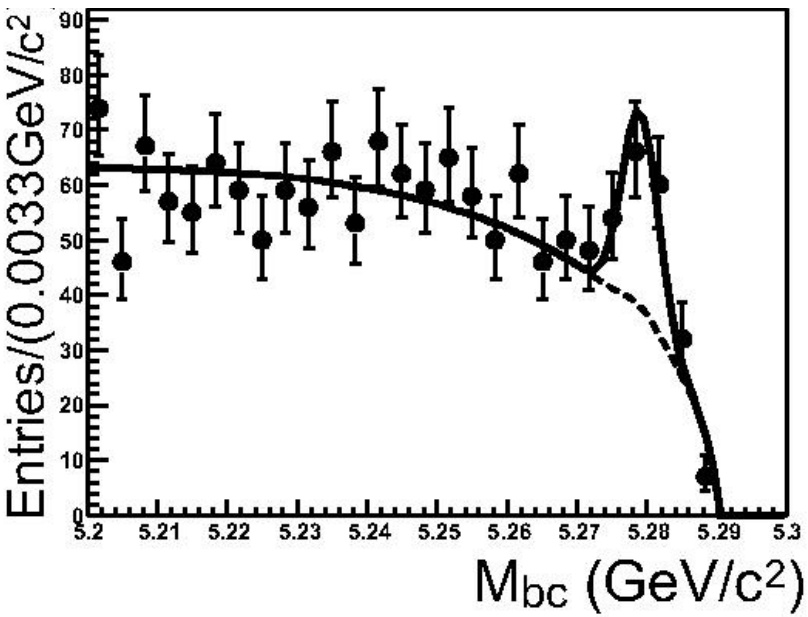
[B13]

Inclusive b -> s l^+l^-



- Select oppositely charged leptons ($e^{\pm}$,$\mu^{\pm}$)
- Reconstruct hadronic system semi-inclusively (K($n\pi$))
- M(l^+l^-) > 0.2 GeV/c2

$$\mathcal{BR}(B \to X_s \ell^+ \ell^-) = \left(4.11 \pm 0.83^{+0.85}_{-0.81}\right) \cdot 10^{-6}$$



$$\mathcal{BR}(B \to X_s \mu^+ \mu^-) = \left(4.13 \pm 1.05^{+0.85}_{-0.81}\right) \cdot 10^{-6}$$

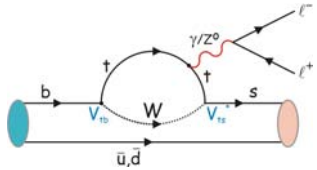
$$\mathcal{BR}(B \to X_s e^+ e^-) = \left(4.04 \pm 1.30^{+0.87}_{-0.83}\right) \cdot 10^{-6}$$

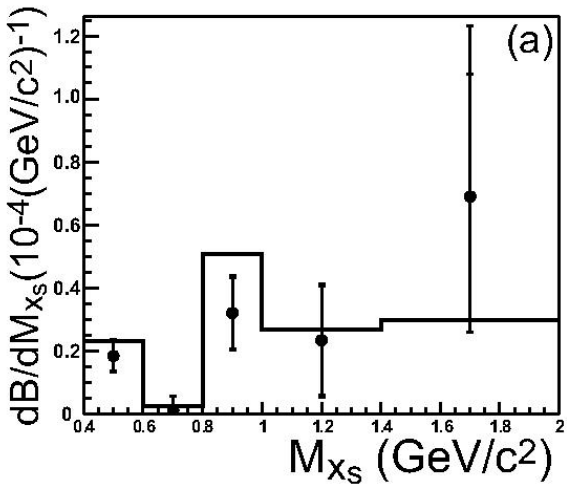
Ali et al [T13-T15]

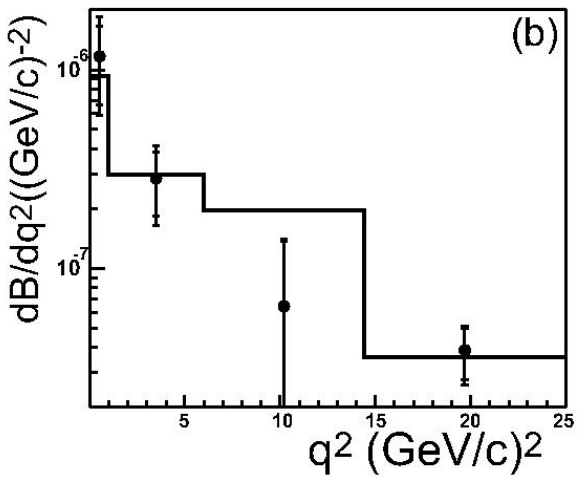
$$\mathcal{BR}(B \to X_s \ell^+ \ell^-) = (4.2 \pm 0.70) \cdot 10^{-6}$$

Based on 140 fb^{-1}

[B13] Dynamics of b->s l^+l^- transition







$M(X_s)$: test model fragmentation

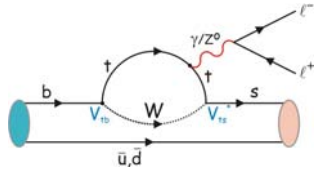
$q^2 = M^2(l^+l^-)$:
check for non-SM effects

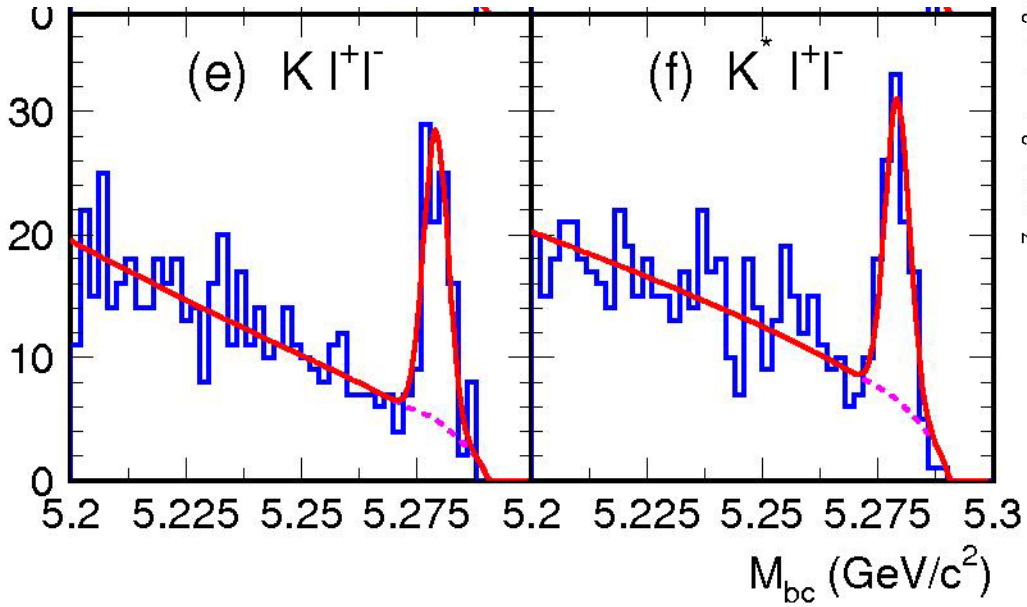
No surprises so far
with available statistics!

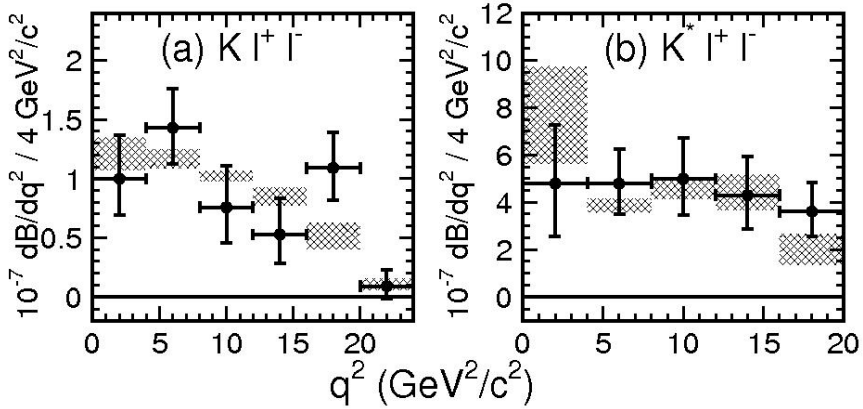
Based on 140 fb^{-1}

[B13]

exclusive B -> K(*) l+l-







q^2 distribution in comparison with SM pred.
[T13,T16,T17]

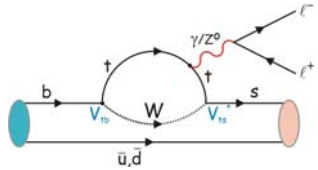
$$\mathcal{BR}(B \to K\ell^+\ell^-) = \left(5.50^{+0.75}_{-0.70} \pm 0.27 \pm 0.02\right) \cdot 10^{-7}$$

$$\mathcal{BR}(B \to K^*\ell^+\ell^-) = \left(16.5^{+2.3}_{-2.2} \pm 0.9 \pm 0.4\right) \cdot 10^{-7}$$

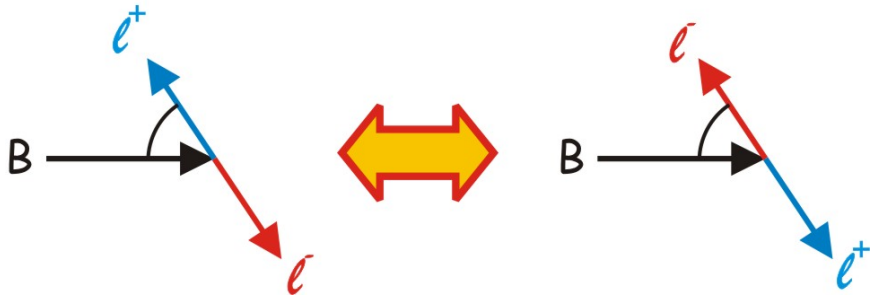
Based on 253 fb^{-1}

[B13]

A_{FB} in B -> K* l^+l^-



In $\ell^+\ell^-$ rest-frame



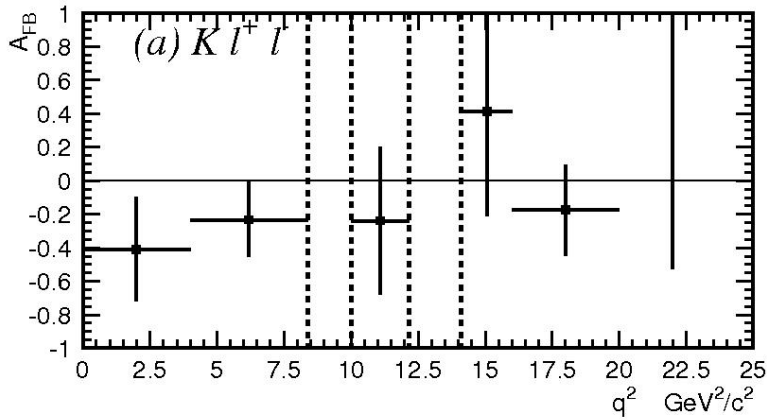
$$A_{FB} = \frac{\Gamma(\cos\theta_{B\ell^+} > 0) - \Gamma(\cos\theta_{B\ell^+} < 0)}{\Gamma(\cos\theta_{B\ell^+} > 0) + \Gamma(\cos\theta_{B\ell^+} < 0)}$$

A_{FB} in q^2 bins from M_{bc} fit

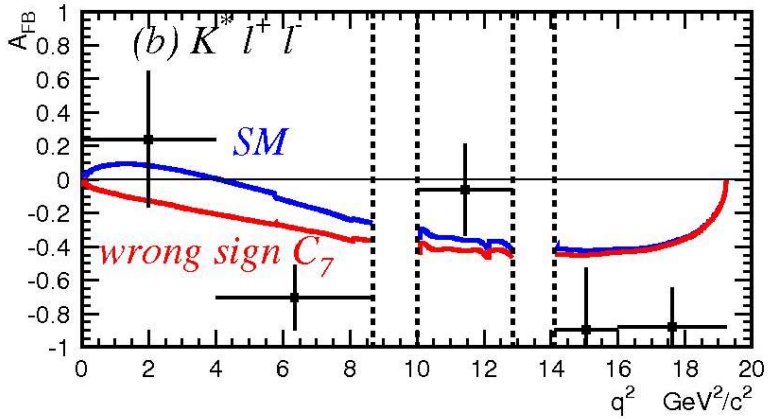
γ and Z interference in SM: sensitive to C7, C9 and C10

=> errors still too large!

$A_{FB}(K\ l^+l^-) = 0$ (control sample)

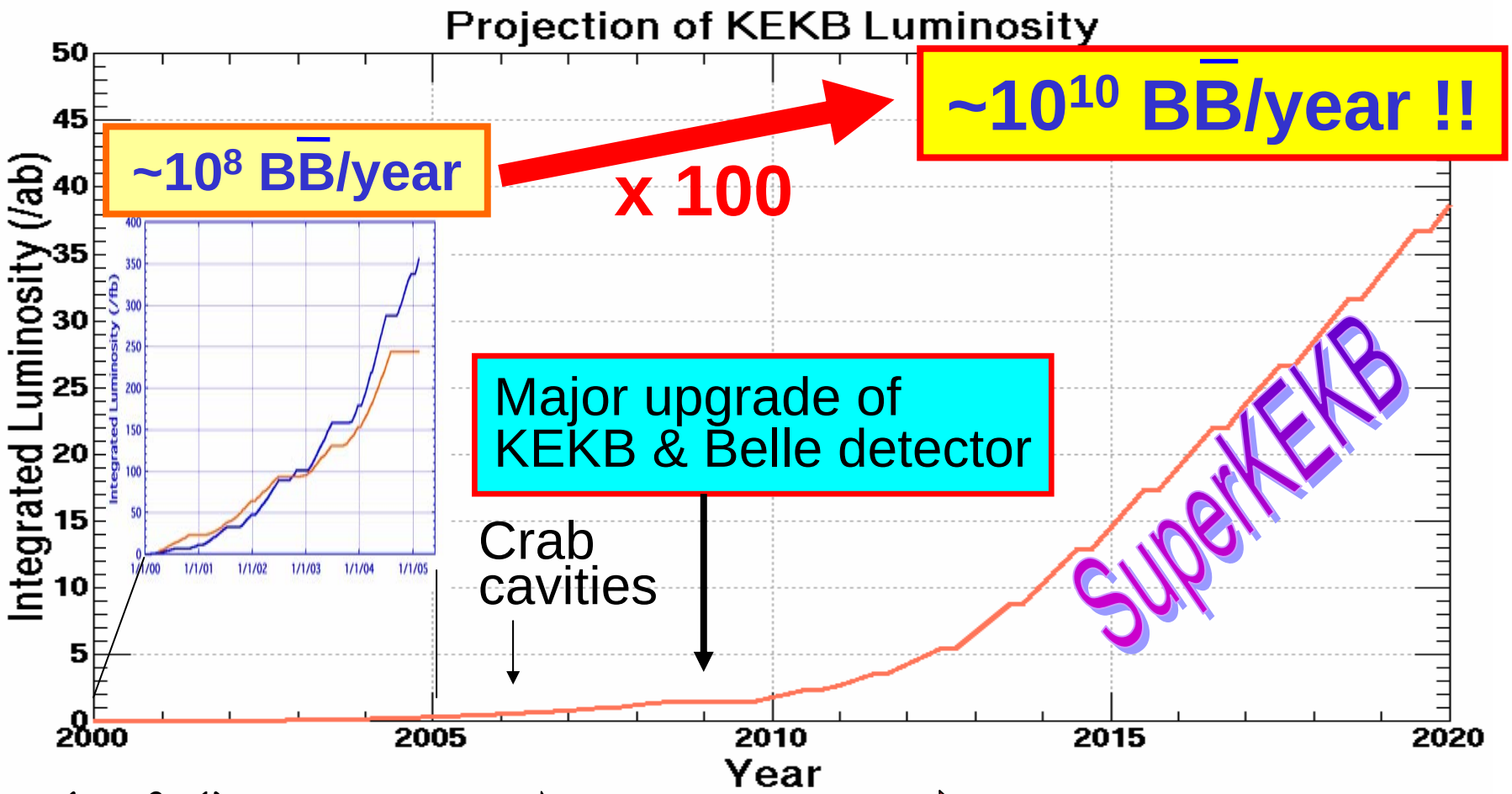


$A_{FB}(K^*\ l^+l^-)$



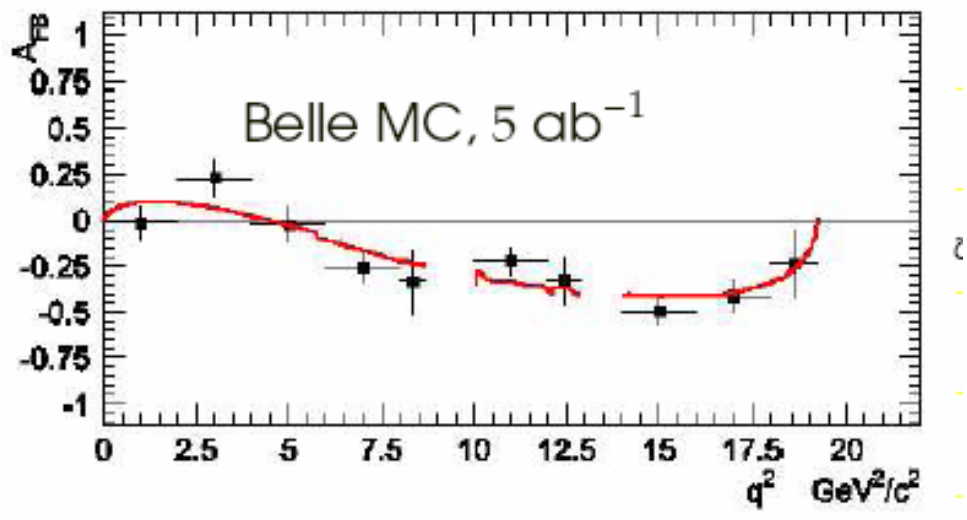
Based on 253 fb^{-1}

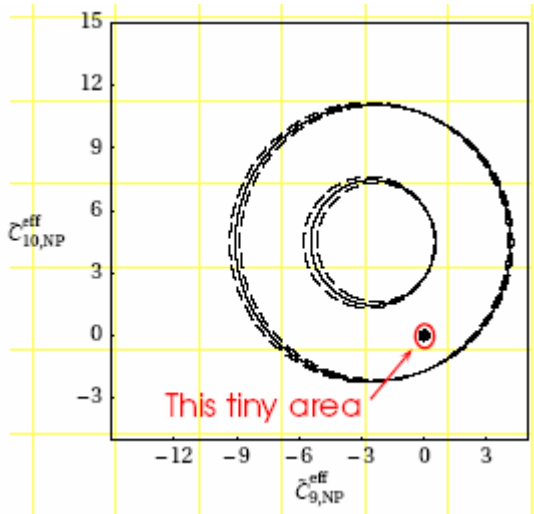
Super KEK-B



$\mathcal{L}_{peak}$ ($cm^{-2}s^{-1}$)	1.6×10^{34}	5×10^{34}	2.5×10^{35}
$\mathcal{L}_{int}$	450 fb^{-1}	~1 ab^{-1}	~10 ab^{-1}

AFB in B -> K* l^+l^-





Precise determination of C_9 and C_{10} is possible
=> $\Delta C_9/C_9$ 10%, $\Delta C_{10}/C_{10}$ 13% at 5 ab^{-1},
C_7 fixed from b -> sγ
Need fit to 2-dim q^2 vs. angular distribution
(systematic error neglected here)

What have we achieved?

What did we know before the B-factories?
Radiative B-Decays in PDG 2000:

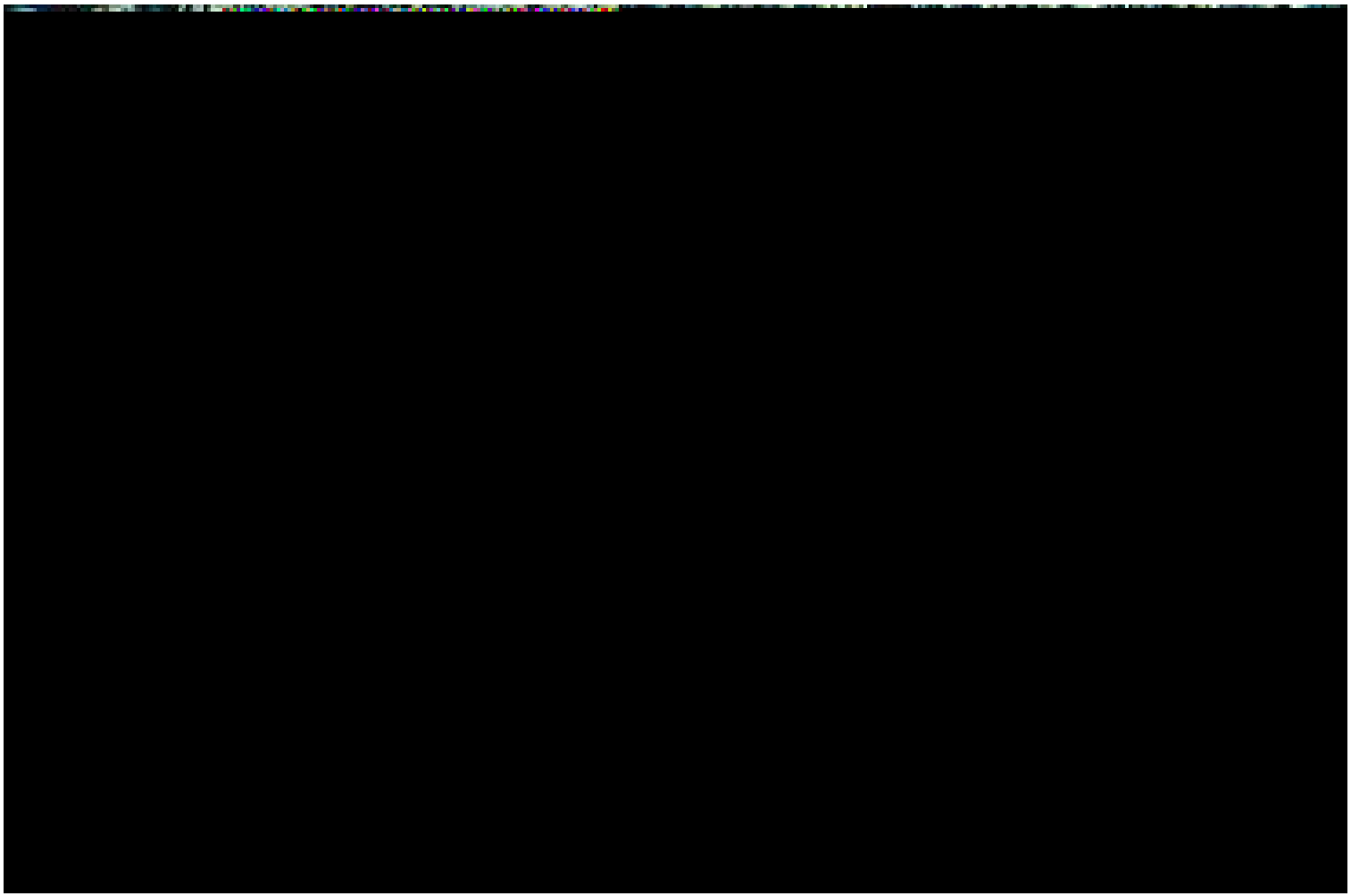
	charged modes	neutral modes	
$K^*(892)\,\gamma$	$(5.7\pm3.3)\cdot10^{-5}$	$(4.0\pm1.9)\cdot10^{-5}$	PDG 2000
$K_1(1270)\,\gamma$	$< 7.3\cdot10^{-3}$	$< 7.0\cdot10^{-3}$	PDG 2000
$K^*_2(1400)\,\gamma$	$< 2.2\cdot10^{-3}$	$< 4.3\cdot10^{-3}$	PDG 2000
$K^*_2(1430)\,\gamma$	$< 1.4\cdot10^{-3}$	$< 4.0\cdot10^{-4}$	PDG 2000
$K^*(1680)\,\gamma$	$< 1.9\cdot10^{-3}$	$< 2.0\cdot10^{-3}$	PDG 2000
$K^*_3(1780)\,\gamma$	$< 5.5\cdot10^{-3}$	$< 1.0\cdot10^{-2}$	PDG 2000
$K^*_4(2045)\,\gamma$	$< 9.9\cdot10^{-3}$	$< 4.3\cdot10^{-3}$	PDG 2000

Dramatic improvement of our knowledge of radiative B-decays!

Summary

- Radiative B decays are **rich field with interesting physics**
- Knowledge increased dramatically since start ofB-factories
- Measurements of BR have already very small errors
- **B -> s γ**
  many decay modes seen, time-dependent CPV,
  constraint on V_{ts}, a lot of useful observables for
  test of SM and its extensions
- **B -> d γ**
  not yet seen, but should be available soon,
  constraint on V_{td}
- **B -> s l^+l^-**
  established, important to pin down Wilson coefficients

... a lot of work lies still ahead!



References I, Belle

[B1] K. Abe, et al, A Measurement of the Branching Fraction for the Inclusive B -> $X_s \gamma$ Decays with Belle, PLB 511, 151 (2001), hep-ex/0103042

[B2] K. Abe, et al, Observation of the Decay B -> K l^+l^-, PRL 88, 021801 (2002), hep-ex/0109026

[B3] S. Nishida, et al, Radiative B Meson Decays into K π γ and K π π γ Final States, PRL 89, 231801 (2002), hep-ex/0205025

[B4] J. Kaneko, et al, Measurement of the Electroweak Penguin Process B-> X_s l^+l^-, PRL 90, 021801 (2003), hep-ex/0208029

[B5] A. Drutskoy, et al, Observation of radiative B -> φ K γ decays, PRL 92, 051801 (2004)

[B6] A. Ishikawa, et al, Observation of B -> K* l^+l^-, PRL 91, 261601 (2003), hep-ex/0308044

[B7] M.-C. Chang, et al, Search for B^0 -> l^+l^- at Belle, PRD 68, 111101 (2003), hep-ex/0309069

[B8] M. Nakao, et al, Measurement of the B -> K* γ Branching Fractions and Asymmetries, PRD 69, 112001 (2004), hep-ex/0402042

References II, Belle

[B9] P. Koppenburg, et al, An inclusive measurement of the photon energy spectrum in b -> s γ decays, PRL 93, 061803 (2004), hep-ex/0403004

[B10] S. Nishida, et al, Measurement of the CP Asymmetry in B -> X_s γ, PLB 93, 0218038 (2004), hep-ex/0308038

[B11] S. Nishida, et al, Observation of B^+ -> K^+ η γ, PLB 610, 23 (2005), hep-ex/0411065

[B12] H. Yang, et al, Observation of B^+ -> $K_1(1270)$ γ, PRL 94, 091601(2005), hep-ex/0412039

[B13] M. Iwasaki et al, Improved Measurement of the Electroweak Penguin Process B -> X_s ll, submitted to PRD, hep-ex/0503044

[B14] Y.-J. Lee, et al, Observation of B^+ -> p $\bar{\Lambda}$ γ, submitted to PRL, hep-ex/0503046

[B15] D. Mohapatra, et al, Search for the b -> d γ process, submitted to PRD, hep-ex/0505097

[B16] K. Abe, et al, Measurement of the Differential q^2 Spectrum and Forward-Backward Asymmetry for B -> $K^{(*)}$ l^+l^-, hep-ex/0410006

[B17] Y. Ushiroda, et al, New Measurement of Time-Dependent CP-Violating Asymmetry in B^0 -> K^0_S π^0 γ Decay, hep-ex/0503008

References III, Belle

[B18] I. Bizjak, et al, Measurement of the Inclusive Charmless Semileptonic Partial Branching Fraction of B Mesons and Determination of $|V_{ub}|$ using the Full Reconstruction Tag, hep-ex/0505088

[B19] A. Limosani, T. Nozaki, Extraction of the b quark shape function parameters using the Belle B -> $X_s \gamma$ photon energy spectrum, hep-ex/0407052

References I, Theory

[T1] A.L. Kagan, M. Neubert, QCD anatomy of B -> $X_s \gamma$ decays, EPJC 7, 5 (1999)

[T2] A. Ali, A.Y. Parkhomenko, Branching ratios for B -> $K^* \gamma$ and B -> $\rho \gamma$ decays in next-to-leading order in the Large Energy Effective Theory, EPJC 23, 89 (2002)

[T3] S.W. Bosch, G. Buchalla, The radiative decays B -> V γ at next-to-leading order in QCD, NPB 621, 459 (2002)

[T4] A.L. Kagan, M. Neubert, Isospin Breaking in B -> $K^* \gamma$ decays, PLB 539, 227 (2002)

[T5] D. Atwood, M. Gronau, A. Soni, Mixing-Induced CP-Asymmetries in Radiative B-Decays in and beyond the Standard Model, PRL 79, 185 (1997)\

[T6] B. Grinstein, et al, Photon polarization in B -> X γ in the standard model, PRD 71, 011504 (2005)

[T7] S. Veseli, M.G. Olsson, Radiative rare B decays revisited, PLB 367, 309 (1996)

[T8] D. Ebert, et al, Rare radiative B decays to orbitally excited K mesons, PRD 64, 054001 (2001)

[T9] A. Safir, The radiative rare decays B -> $K^{**} \gamma$ in the light cone QCD sum rule approach, EPJC 3, 15 (2001), hep-ex/0109232

[T10] H.Y. Cheng, C.K. Chua, Covariant light-front approach for B -> $K^* \gamma$, $K_1 \gamma$, $K^*_2 \gamma$ decays, PRD 69, 094007 (2004)

References II, Theory

[T11] H.-Y. Cheng, K.-C. Yang, Penguin-induced radiative baryonic B decays, PLB 533, 271 (2002)

[T12] C.Q. Geng, Y.K. Hsiao, Radiative baryonic B decays, PLB 610, 67 (2005)

[T13] A. Ali, et al, Improved model-independent analysis of semileptonic and radiative rare B decays, PRD 66, 034002 (2002)

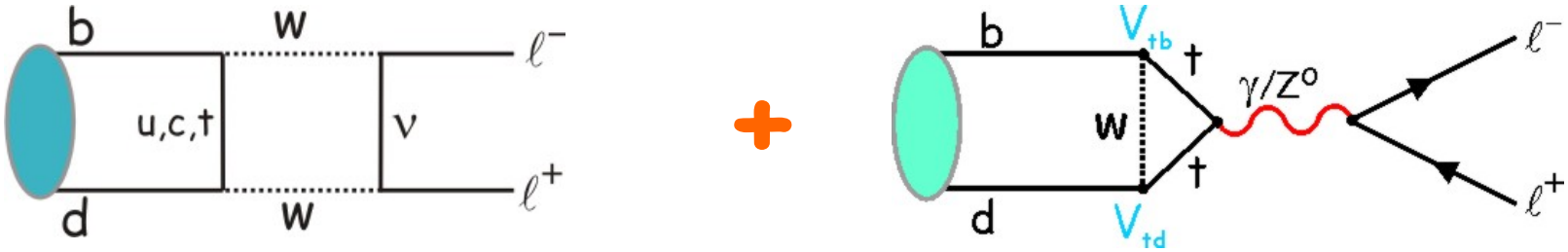
[T14] A. Ali, Next-to-leading Order Calculations of the Radiative and Semileptonic Rare B Decays in the Standard Model and Comparison with Data, hep-ex/0210183

[T15] A. Ghinculov, et al, The rare decay B -> X_s l^+l^- to NNLL precision for arbitrary dilepton invariant mass, NPB 685, 351 (2004)

[T16] D. Melikhov, N. Nikitin, S. Simula, PLB 410, 290 (1997)

[T17] P. Colangelo et al. PRD 53, 3672 (1998), Erratum-ibid.D 57, 3186 (1998)

$B^0 \rightarrow l^+l^-$



=> Helicity suppressed 2-body decay in SM

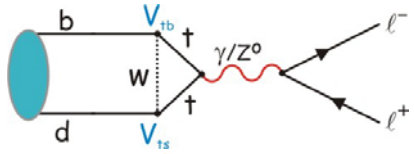
BR in SM: $B \rightarrow \mu\mu : (1.00 \pm 0.14) \cdot 10^{-10}$

$B \rightarrow ee : (2.34 \pm 0.33) \cdot 10^{-15}$

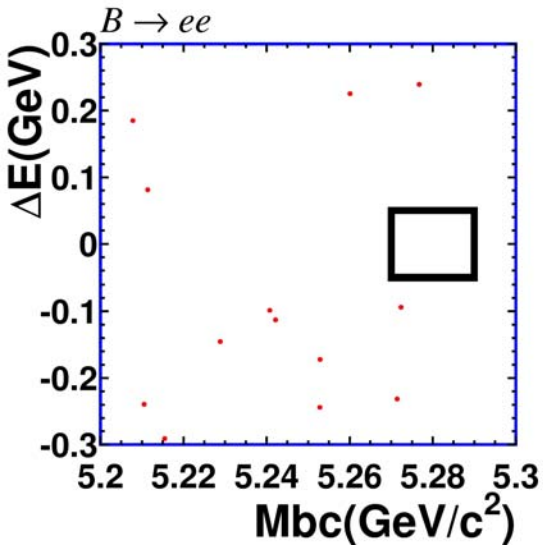
Not observable, but enhancement by 2-3 orders of magnitude in 2HDM or Z mediated FCNC models.

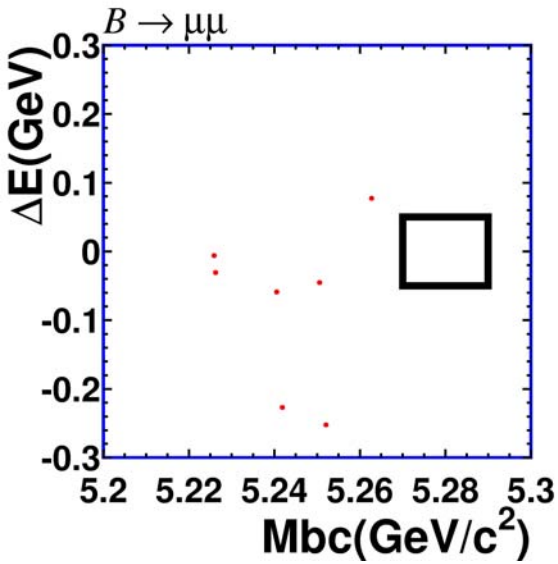
$B \rightarrow e\mu$ forbidden in SM, but possible in SUSY or Lepto-Quark models!

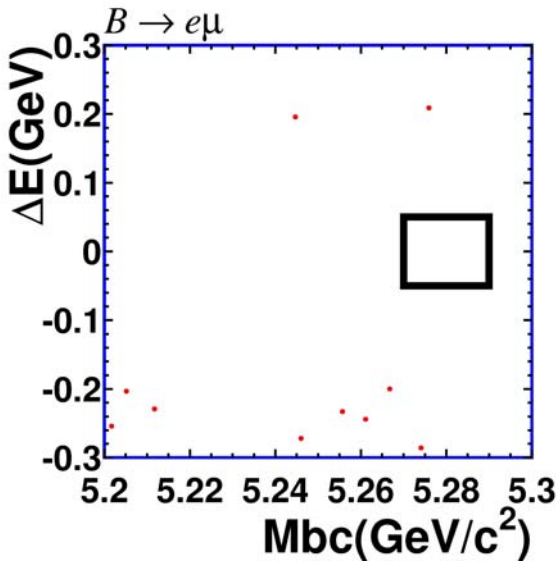
$B^0 \to l^+l^-$



- Tight cut on leptons (e/μ): $\mathcal{L} > 0.9$
- BKG suppression with LR($\mathcal{F}$,cos(θ^*_B))
- Signal box: $5.27 < M_{bc} < 5.29$ GeV/c^2, $|\Delta E| < 0.05$GeV





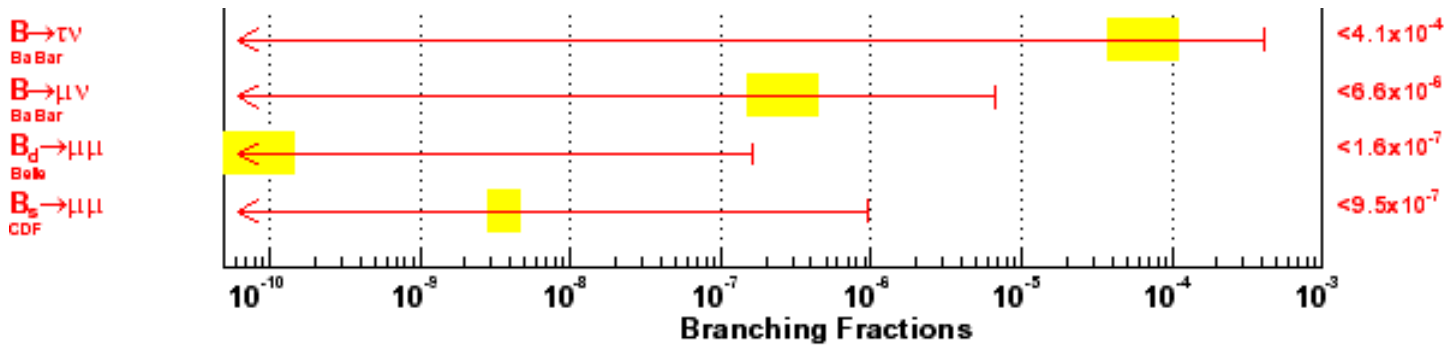


$\Delta E = E^*_B - E^*_{beam}$

$M_{bc} = \sqrt{E^{*2}_{beam} - |p^*_B|^2}$

Status of B → ll

Channel	BR (@90% C.L.)	∫Ldt	
B->ee	< $1.9 \cdot 10^{-7}$	78 fb^{-1}	Belle
B->μμ	< $1.6 \cdot 10^{-7}$	78 fb^{-1}	Belle
B->eμ	< $1.7 \cdot 10^{-7}$	78 fb^{-1}	Belle
B->μμ	< $2.5 \cdot 10^{-7}$	113 pb^{-1}	CDF
B_s->μμ	< $9.5 \cdot 10^{-7}$	113 pb^{-1}	CDF
B_s->μμ	< $16 \cdot 10^{-7}$	100 pb^{-1}	D0
B->eν	< $5.4 \cdot 10^{-6}$	60 fb^{-1}	Belle
B->μν	< $6.8 \cdot 10^{-6}$	60 fb^{-1}	Belle
B->μν	< $6.6 \cdot 10^{-6}$	81 fb^{-1}	Babar
B->τν	< $4.1 \cdot 10^{-4}$	81 fb^{-1}	Babar



Future? $B \to ll(\gamma)$

SM prediction for purely leptonic/radiative B-decays:

$B \to \tau\tau$	$: \approx 3 \cdot 10^{-8}$	$B \to \tau\tau\gamma$	$: > 3 \cdot 10^{-8}$
$B \to \mu\mu$	$: \approx 1 \cdot 10^{-10}$	$B \to \mu\mu\gamma$	$: \approx \text{few} \cdot 10^{-10}$
$B \to ee$	$: \approx 3 \cdot 10^{-15}$	$B \to ee\gamma$	$: \approx \text{few} \cdot 10^{-10}$
$B \to \tau\nu$	$: \approx 7 \cdot 10^{-5}$	$B \to \tau\nu\gamma$	$: > 7 \cdot 10^{-5}$
$B \to \mu\nu$	$: \approx 3 \cdot 10^{-7}$	$B \to \mu\nu\gamma$	$: \approx \text{few} \cdot 10^{-6}$
$B \to e\nu$	$: \approx 7 \cdot 10^{-12}$	$B \to e\nu\gamma$	$: \approx \text{few} \cdot 10^{-6}$

Any significant increase in these BR might give hint for new physics

Some of these modes should be accessible with the B-factories!

Low energy eff. Hamiltonian

$$\mathcal{H}_{eff} \sim \sum^{10}_{i=1} C_i(\mu) O_i(\mu)$$

$$\Gamma(b \to s\gamma) = 1/32\pi^4 \, G^2_F \, \alpha_{em} \, m^5_b \, |V^*_{ts} V_{tb}|^2 \, (|C_7^{eff}|^2 + O(1/m_b, 1/m_c)))$$

=> Access to $|C_7|$

Low energy eff. Hamiltonian

$$\mathcal{H}_{eff} \sim \sum^{10}_{i=1} C_i(\mu) O_i(\mu)$$

$$\Gamma(b \to s\gamma) \sim |V^*_{ts} V_{tb}|^2 \; |C_7^{eff}|^2$$

=> Access to $|C_7|$
Interesting observables: BR, A_{CP}, γ spectrum

$$\Gamma(b \to s\ell^+\ell^-)/ds \sim |V^*_{ts} V_{tb}|^2 \; O(s, \; |C_7^{eff}|^2, \; |C_9^{eff}|^2 \; , |C_{10}^{eff}|^2 \; , \; C_7^{eff} Re(C_9^{eff}))$$

$$s = q^2/m^2_b = (M(\ell^+\ell^-)/m_b)^2$$

=> Access to $|C_7|$, $|C_9|$, $|C_{10}|$, $sgn(C_7)$
Interesting observables: BR, A_{FB}, q^2 distribution

Particle ID & Kinematic Variables

K/π separation:
- dE/dx from CDC
- light yield from ACC
- t from ToF

e ID:
- dE/dx from CDC
- light yield from ACC
- t from ToF
- CsI (ECL)

μ ID:
- hits in KLM

γ ID:
- $16X_0$ CsI (ECL)

Kinematic Variables:

$$\Delta E = E^*_B - E^*_{beam}$$

$$M_{bc} = \sqrt{E^{*2}_{beam} - |p^*_B|^2}$$