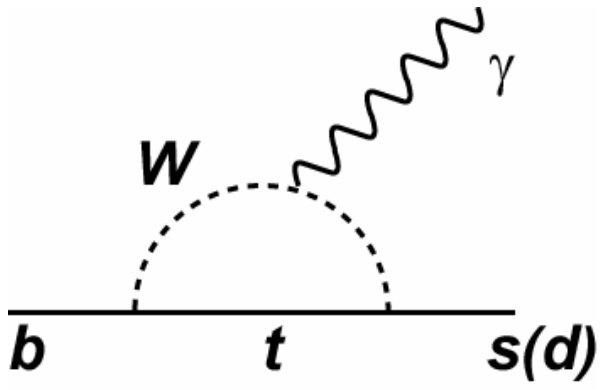
Recent results on B meson rare decays from Belle

M. Iwasaki
University of Tokyo
For the Belle Collaboration

特定領域「質量起源と超対称性物理の研究」

Introduction(I)



FCNC processes

In SM forbidden at tree level .. One loop or box

→ Sensitive to the New physics

Rare-decay … require very high statistics and superb background

B-Factory experiments

The best experiment to measure FCNC

High luminosity (Belle: >350 fb^{-1}!!)

e^+e^- collider → Clean environment

Introduction (II)

- Observables
  - → Branching fraction, A_{cp}
    Kinematical distributions q^2, A_{FB} , ...

- -

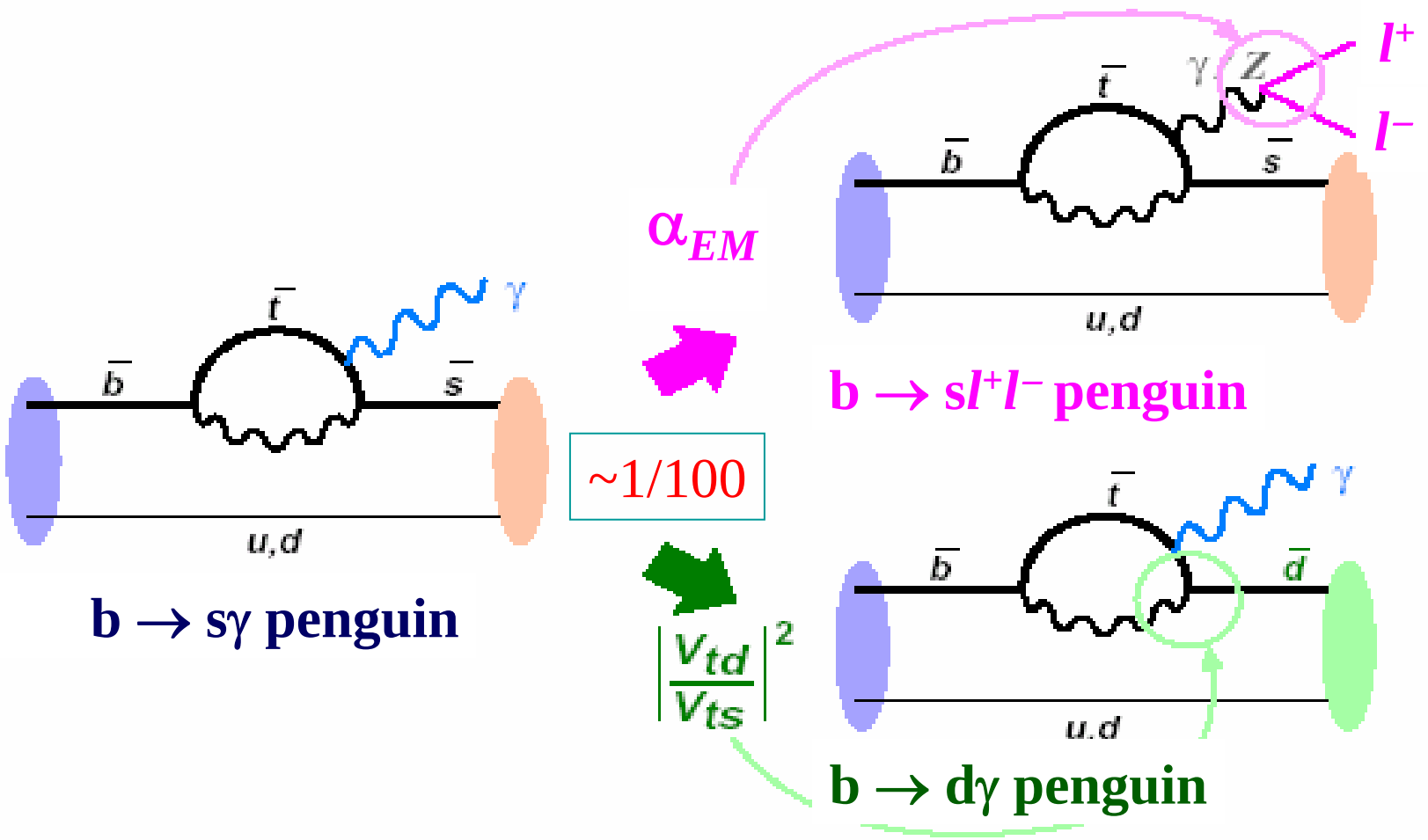
In this talk, we cover b→sll, b→dγ and b→sγ

1) **Semi-inclusive B→Xsl$^+$l$^-$** (Br, q^2 and M_{xs} spectrum)
2) **Exclusive B→K$^{(*)}$l$^+$l$^-$** (Br, q^2 spectrum, e/μ, A_{FB})
3) **Search for b→dγ** (Br)
4) **Exclusive b→sγ modes** (Br)
5) **Inclusive B→Xsγ** (Br, E_γ spectrum)

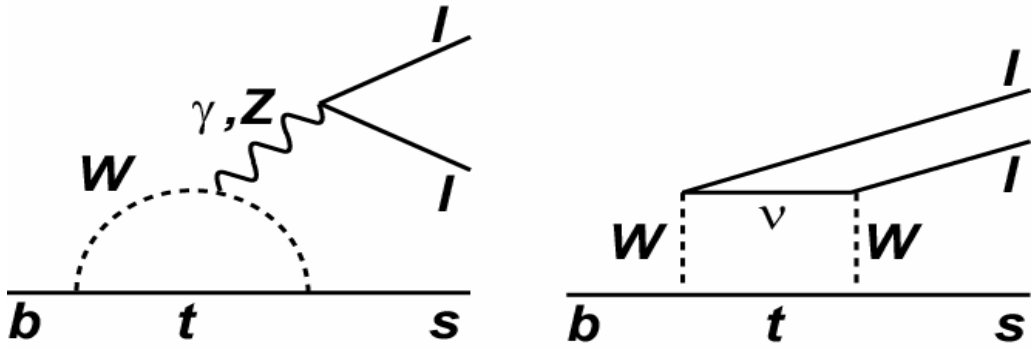
b→sll and b→ dγ

$b \to s l^+ l^-, d\gamma$ decays proceed via **FCNC** like b→sγ

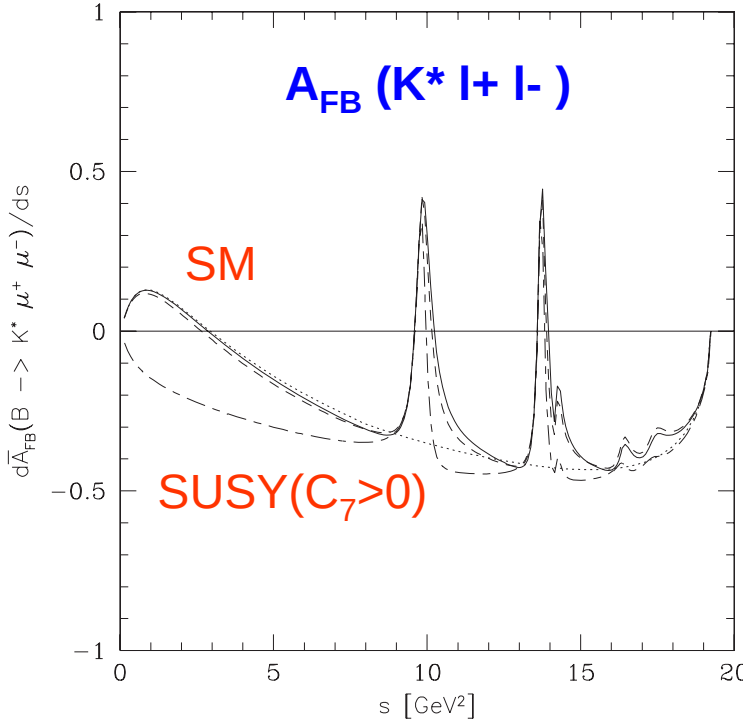
Br ratio … 1/100 of the b→sγ very rare decays



b→sll measurements



Br is low (b→sγ: 10^{-4} b→sll: 10^{-6})
Exists the contribution from Z^{0*}
Br, q^2 ($=m_{ll}^2$) distribution, $A_{FB}(q^2)$
.. Sensitive to the New Physics



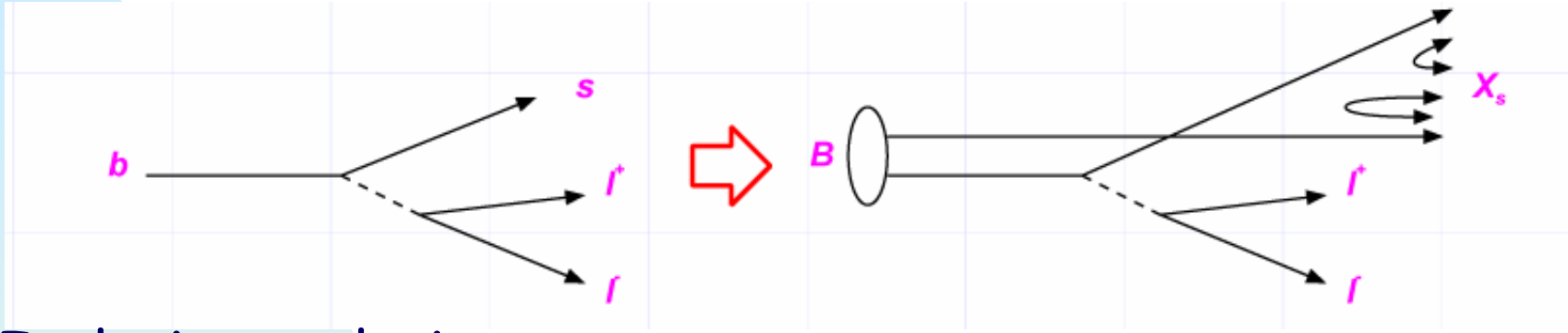
Ali et al. PRD61 (2000) 074024

Two analysis approaches:

- Semi-inclusive B→Xsll
- Exclusive B→K(*)ll

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

(Semi-)inclusive $B \to X_s l^+ l^-$ as a sum of exclusive modes



Inclusive analysis

→ theoretical uncertainty is smaller than exclusive analysis

- Reconstructed Xs system

  …1 (K^+ or K_s^0) + 0-4π (at most 1π^0)

- Backgrounds

  Dominant sources … 1) continuum 2) $B\bar{B} \to l^+\nu X + l^-\nu X$

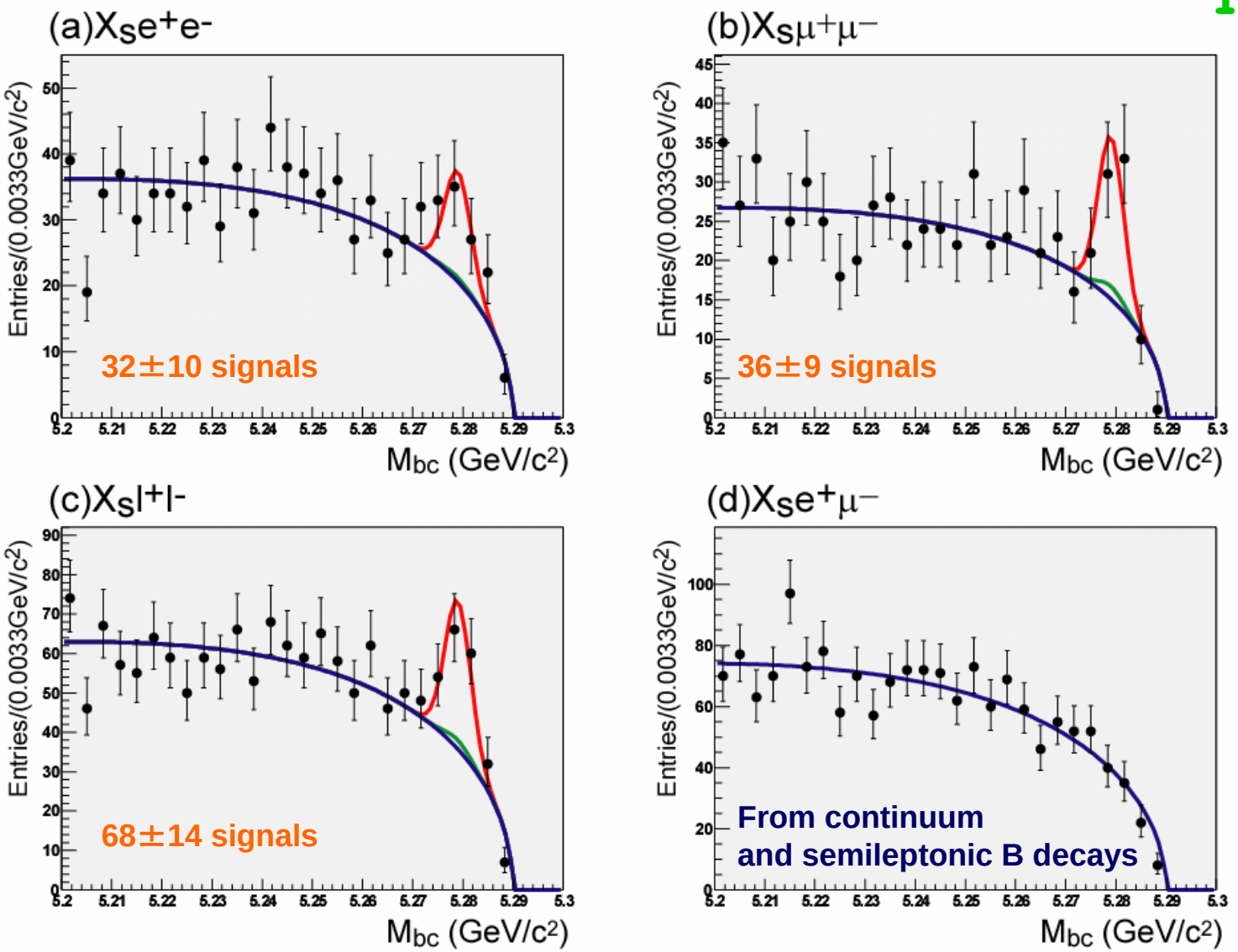
- Ali et al. SM prediction (M_{ll}>0.2GeV)

  $Br(B \to X_s ll) = (4.2 \pm 0.7) \times 10^{-6}$

Semi-inclusive B→Xsll

M_{bc} unbinned likelihood fits, after all cuts

140fb^{-1}



$X_s = K + (0 \ldots 4)\,\pi$, $X_s e\mu$ *to model background, extra small peaking background*

B→Xsll results

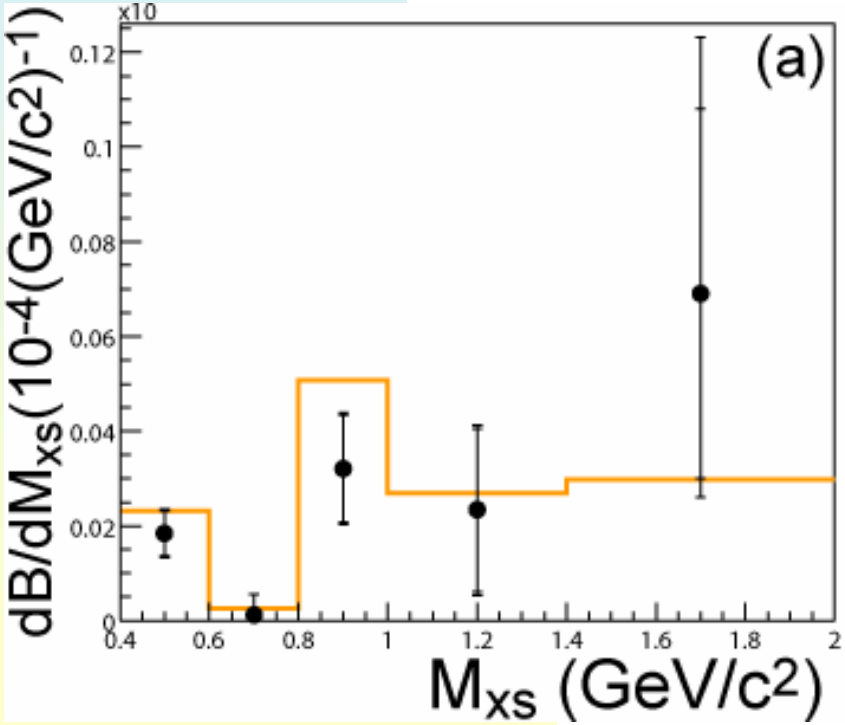
140fb^{-1}

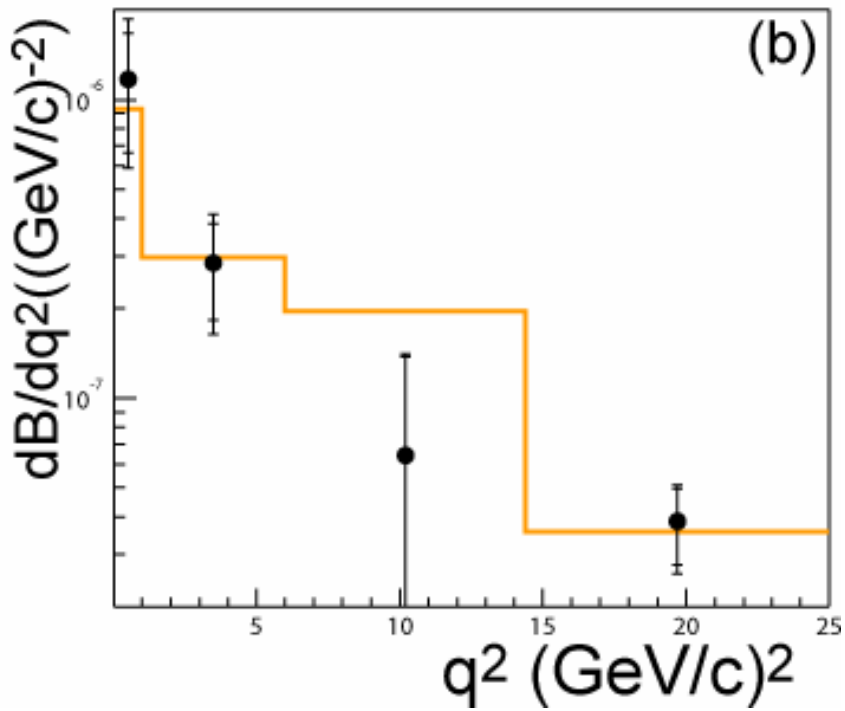
68 net signal, significance 5.4σ, Ave. of e^+e^-, $\mu^+\mu^-$

$$Br(B \to Xsll) = [4.11 \pm 0.83^{+0.85}_{-0.81}] \times 10^{-6}$$

for $M_{\ell^+\ell^-} > 0.2$ GeV

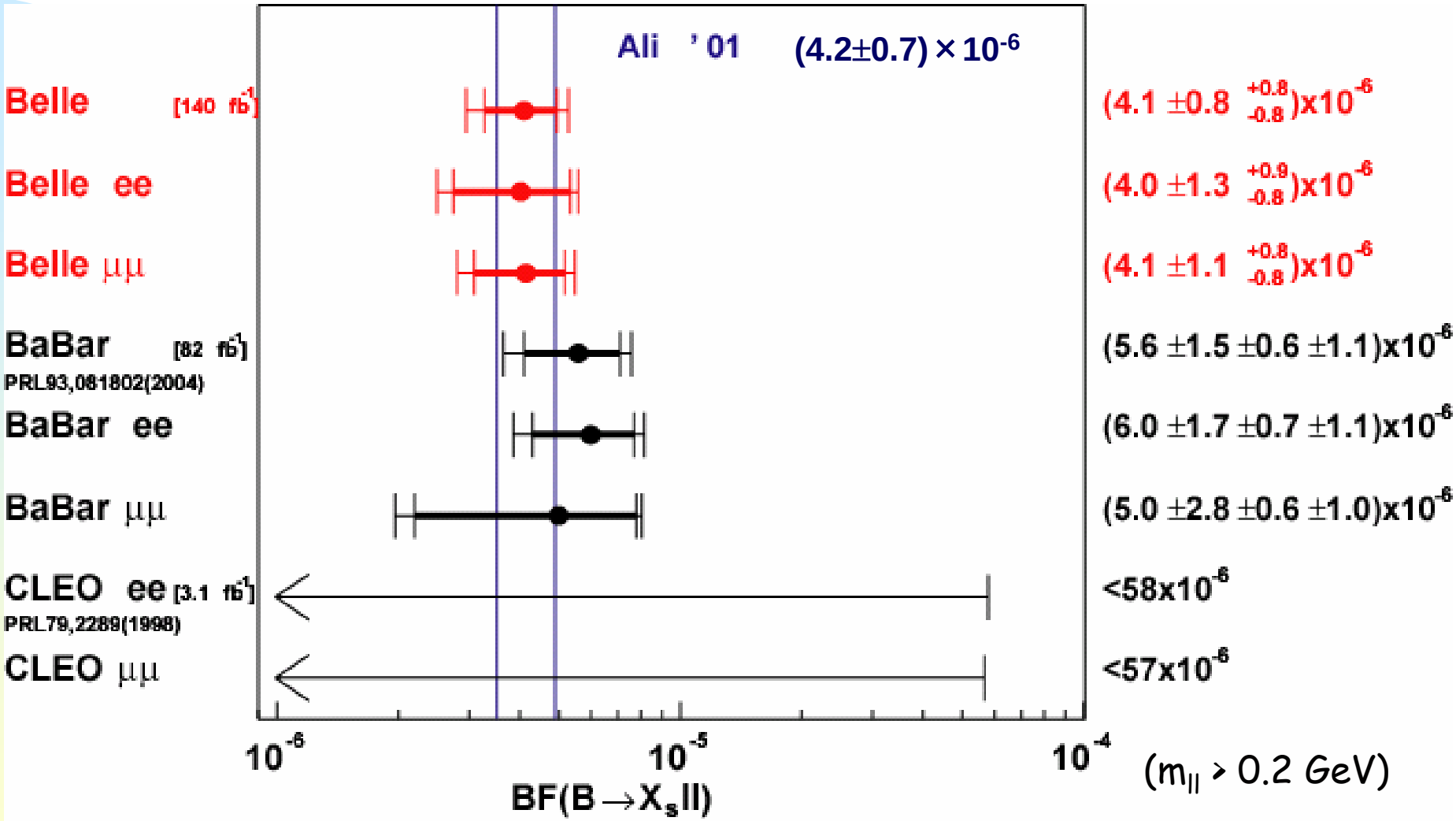
[cf. BaBar: $(5.6 \pm 1.5 \pm 0.6 \pm 1.1) \times 10^{-6}$, SM (Ali et al.): $(4.2 \pm 0.7) \times 10^{-6}$]





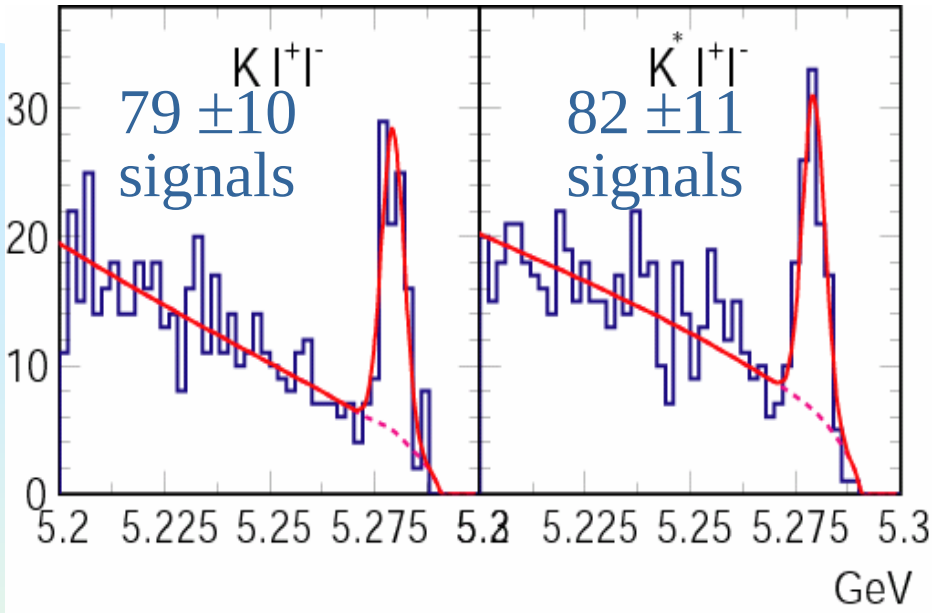
The result is in agreement with SM

B→Xsll results



Both Belle and BaBar results are consistent with SM

Exclusive B→ K(*)l+l-



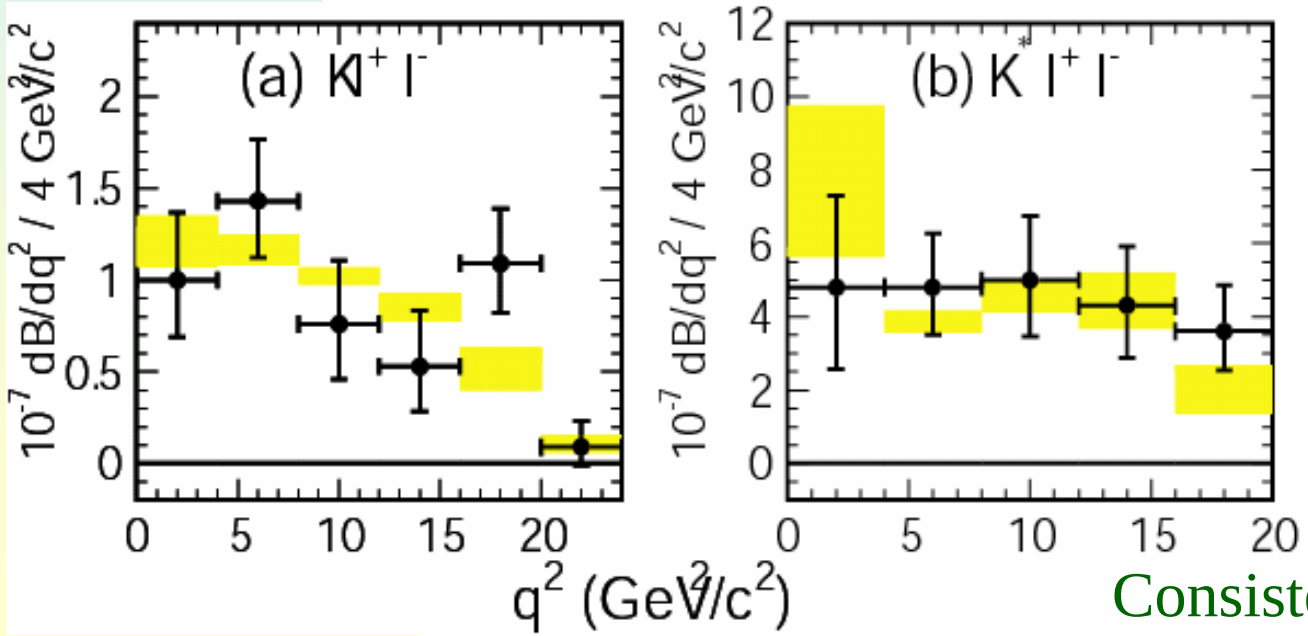
Updated with 253 fb^{-1} data

$\mathcal{B}$ (Kll)= $(5.50 \pm ^{0.75}_{0.70} \pm 0.27 \pm 0.02)$

$\mathcal{B}$ (K*ll)= $(16.5 \pm ^{2.3}_{2.2} \pm 0.9 \pm 0.4)$ x 10^{-7}

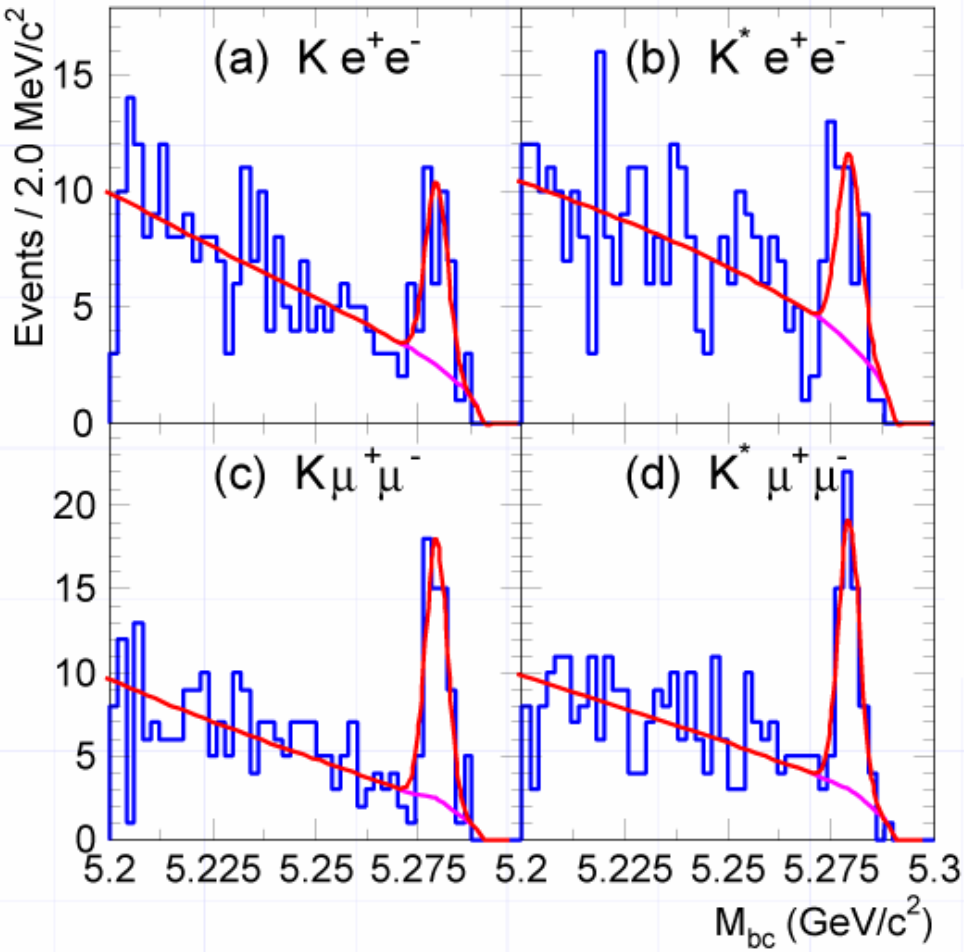
>10σ

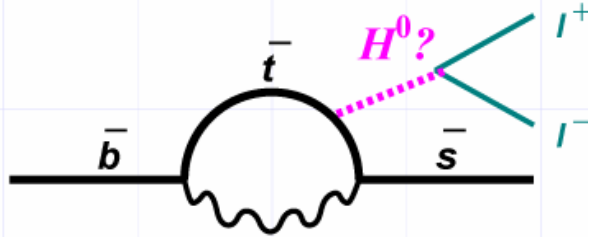
preliminary



Consistent with SM

B → K* l⁺l⁻ :electron/muon ratio





Ratio of $K^{(*)}\mu^+\mu^-$ to $K^{(*)}e^+e^-$ is sensitive to neutral SUSY Higgs if $\tan\beta$ is large

($O(1)$ enhancement if $\tan\beta \sim 30$)

preliminary 253 fb^{-1}

$$\mathcal{B}(B \to K\mu^+\mu^-)/\mathcal{B}(B \to Ke^+e^-) = 1.38\,^{+0.39\ +0.06}_{-0.41\ -0.07}$$ (1.00 in SM)

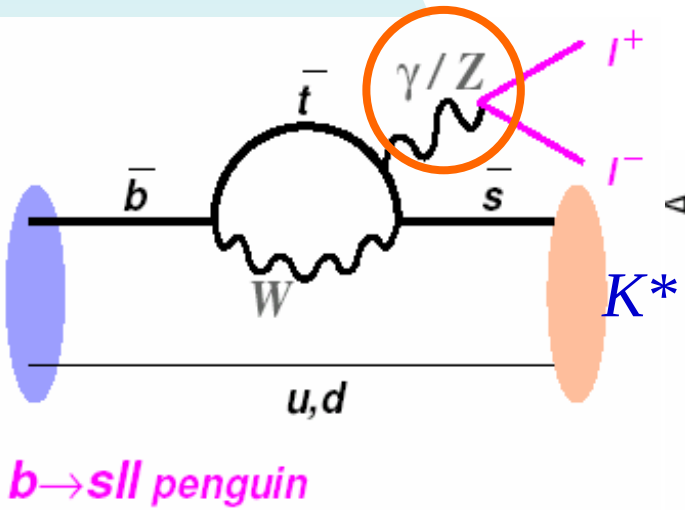
$$\mathcal{B}(B \to K^*\mu^+\mu^-)/\mathcal{B}(B \to K^*e^+e^-) = 0.98\,^{+0.30}_{-0.31} \pm 0.08$$ (~ 0.75 in SM)

B → K* l⁺l⁻ :FB Asymmetry

$A_{FB}(K^*ll)$: **very sensitive to new physics that may not be seen in $\mathcal{B}(b\to s\gamma)$**

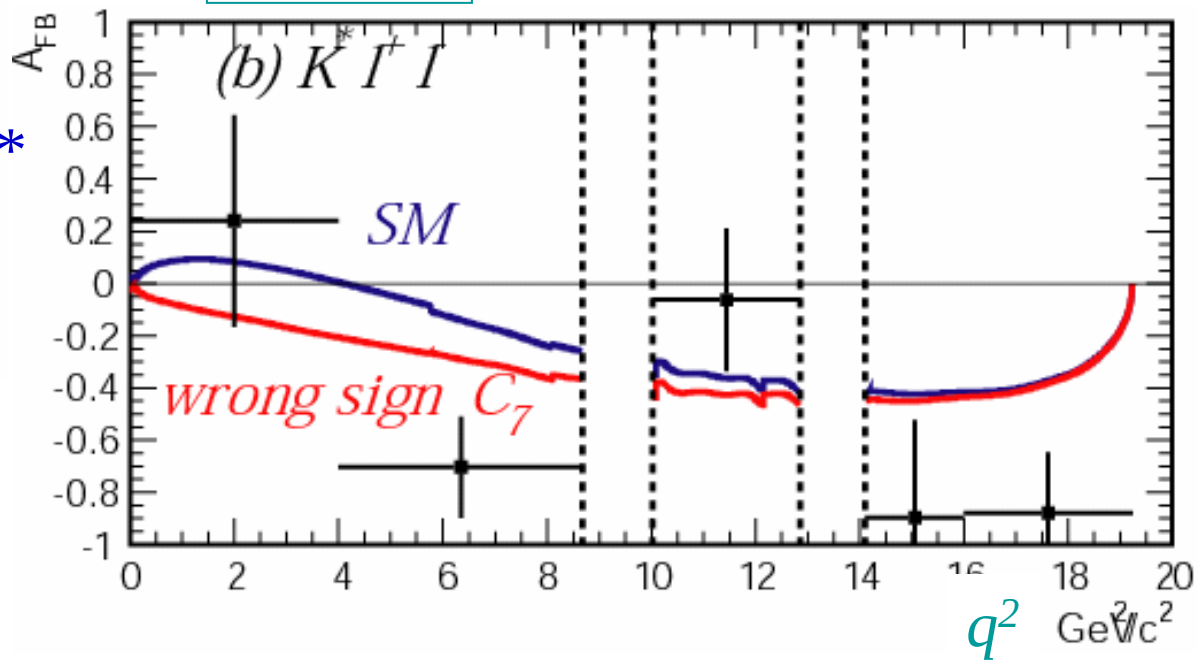
253 fb^{-1}

$$A_{FB} = \frac{\Gamma(\theta_{Bl^+} < \pi/2) - \Gamma(\theta_{Bl^+} > \pi/2)}{\Gamma(\theta_{Bl^+} < \pi/2) + \Gamma(\theta_{Bl^+} > \pi/2)}$$



b→sll penguin

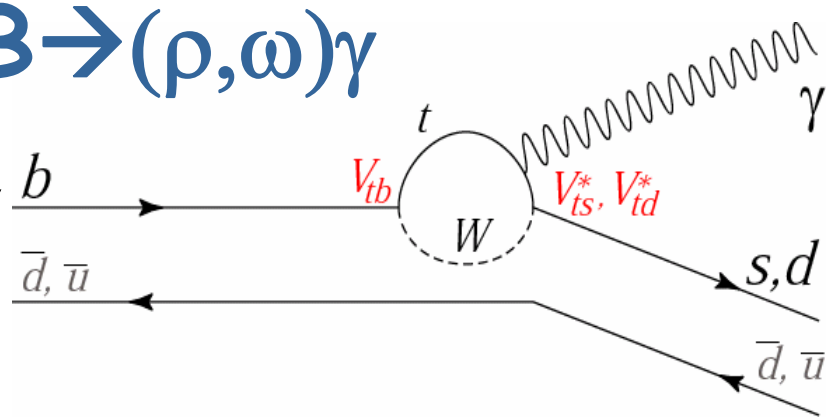
Raw A_{FB}



First Look !

b→dγ measurements : Exclusive B→(ρ,ω)γ

b→dγ: more suppressed than b→sγ



Measurements of b→sγ & b→dγ

→ Sensitive to V_{td}/V_{ts} … constraints the SM

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

Exclusive B→$\rho^0/\rho^+/\omega\gamma$ measurements($\rho^0 \to \pi^+\pi^-, \rho^+ \to \pi^0\pi^+, \omega \to \pi^+\pi^-\pi^0$)

Simultaneous fit to 3 signal + 2 K*γ assuming isospin:

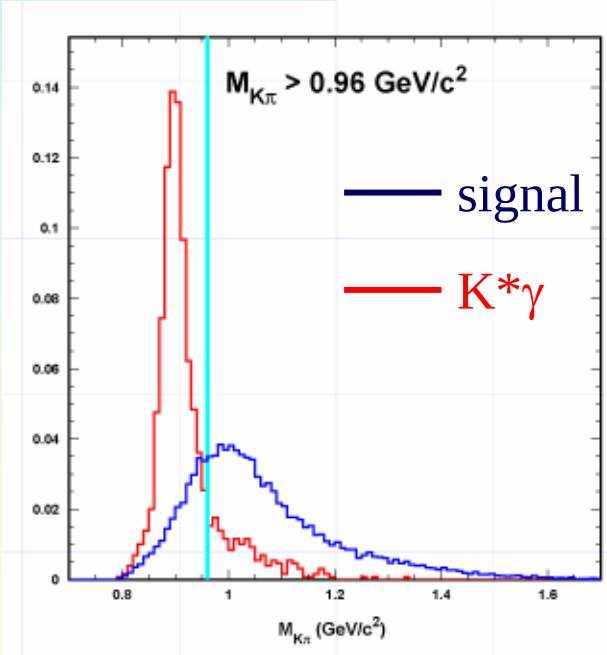
$$Br(B \to (\rho,\omega)\gamma) \equiv Br(B^+ \to \rho^+\gamma)$$
$$= 2(\tau(B^+)/\tau(B^0))Br(B^0 \to \rho^0\gamma)$$
$$= 2(\tau(B^+)/\tau(B^0))Br(B^0 \to \omega\gamma)$$

Exclusive B→ρ/ωγ : BG suppression

BG source of $B\to\rho^0/\rho^+/\omega\gamma$ ($\rho^0\to\pi^+\pi^-$, $\rho^+\to\pi^0\pi^+$, $\omega\to\pi^+\pi^-\pi^0$)

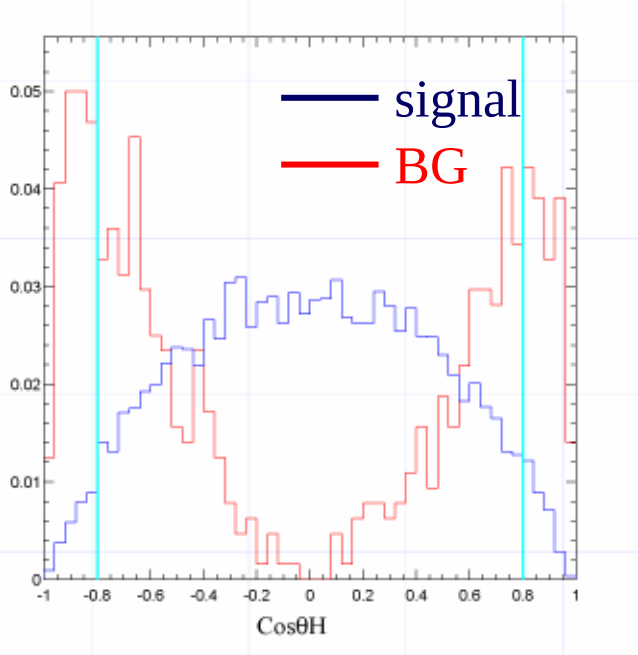
… $B\to K^*\gamma$ feed down, $B\to\rho/\omega\pi^0$, continuum

BG from $K^*\gamma$



Apply Mkπ cut

BG from $B\to\rho\pi^0$



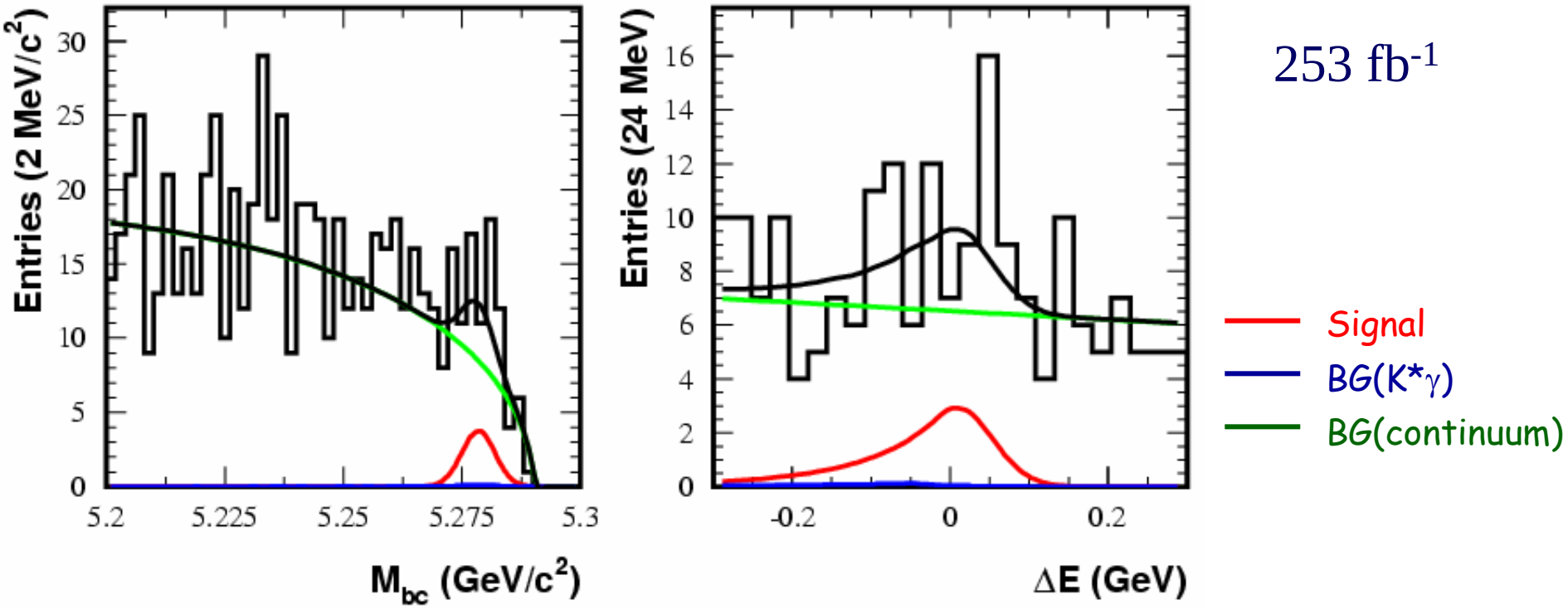
Apply helicity angle cut

continuum rejection : by Fisher, vertexing, flavor-tag

Exclusive B→ρ/ωγ : results

Projection of the Simultaneous fit in M_{bc} and ΔE

Simultaneous fit : $\Gamma(B\to(\rho,\omega)\gamma) = \Gamma(B^+\to\rho^+\gamma) = 2\Gamma(B^0\to\rho^0\gamma) = 2\Gamma(B^0\to\omega\gamma)$



Significance = 1.9σ (from simultaneous fit)

preliminary

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

$\mathcal{B}(B\to(\rho,\omega)\gamma) / B(B\to K^*\gamma) < 0.035 \ldots |V_{td}/V_{ts}| < 0.21$ @90%CL

$b \to s\gamma$ measurements

1) Exclusive $b \to s\gamma$ measurements

- $B \to K^*\gamma$
- $B \to K^*_2(1430)\gamma$
- $B \to K^* \pi\gamma$ and $K\rho\gamma$
- $B \to K\phi\gamma$
- $B \to K\eta\gamma$
- $B \to K\pi\pi\gamma$ and $K_1(1270)\gamma$
- $B \to \Lambda p\gamma$

New measurements

2) Inclusive $b \to s\gamma$ analysis

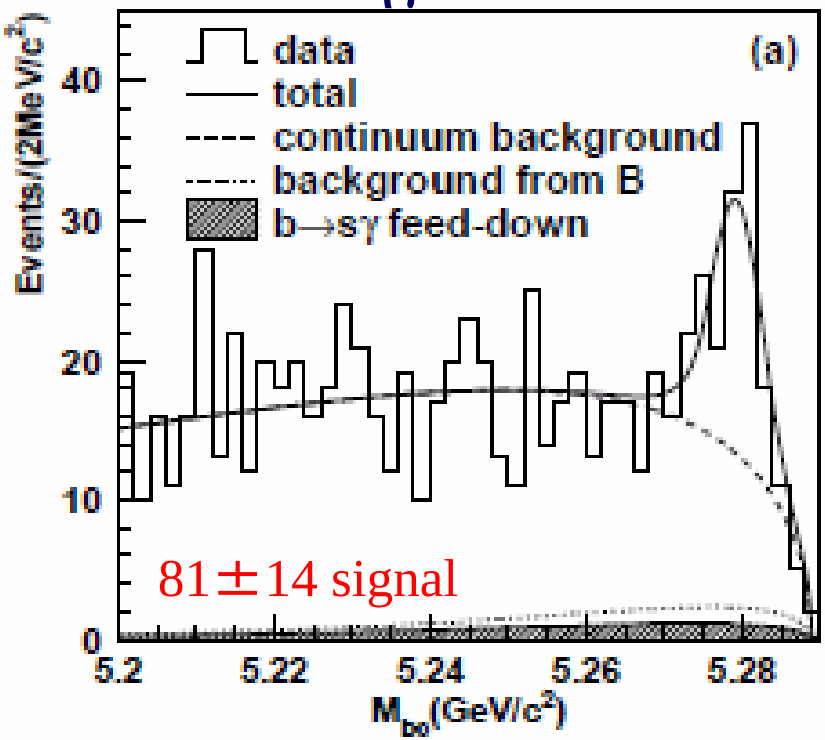
Measure the $E\gamma$ spectrum from 1.8GeV

$B \to K\eta\gamma$ ($K^+\eta\gamma$ and $K^0_s\eta\gamma$)

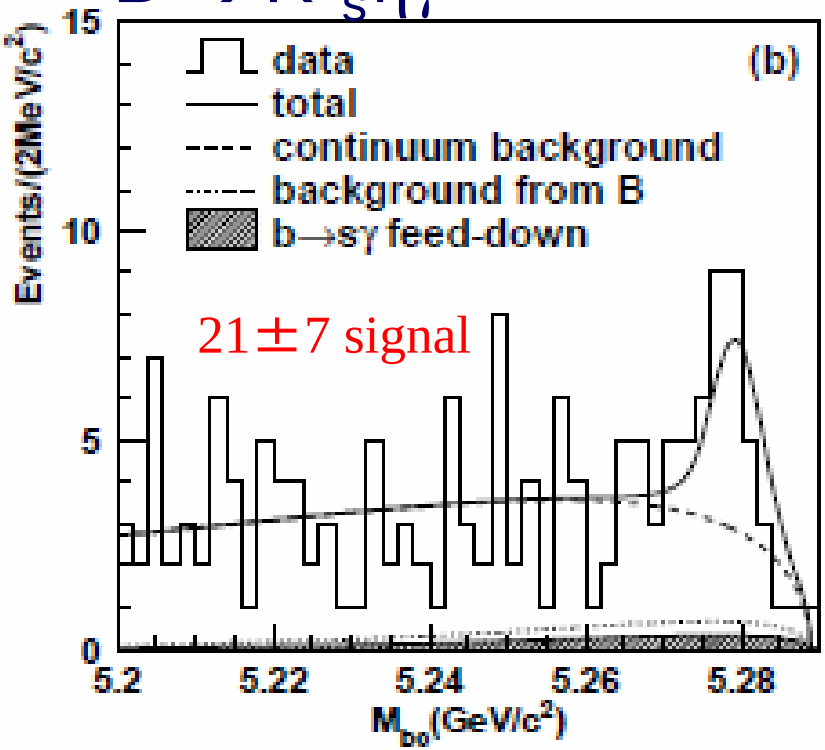
$B \to K\eta\gamma$, $\eta \to \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^0$, $M(k\eta) < 2.4GeV$

253 fb^{-1}

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



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



$$Br(B^+ \to K^+\eta\gamma) = [8.4 \pm 1.5^{+1.2}_{-0.9}] \times 10^{-6} \quad (6.8\sigma \text{ 1st observation})$$

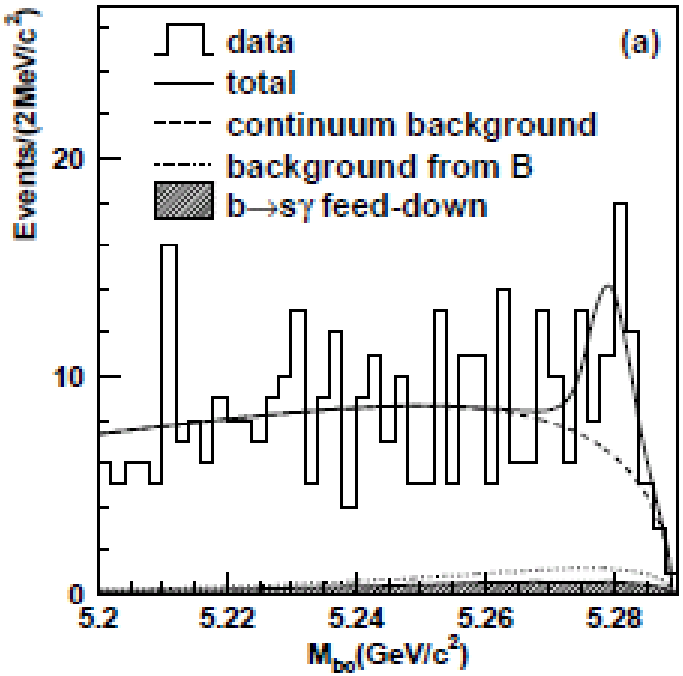
$$Br(B^0 \to K^0\eta\gamma) = [8.7^{+3.1+1.9}_{-2.7-1.6}] \times 10^{-6} \quad (3.4\sigma \text{ 1st evidence})$$

$B \to K^+ \eta\gamma$: A_{CP} measurement

$B \to K \eta\gamma$, $\eta \to \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^0$, $M(k\eta) < 2.4 GeV$

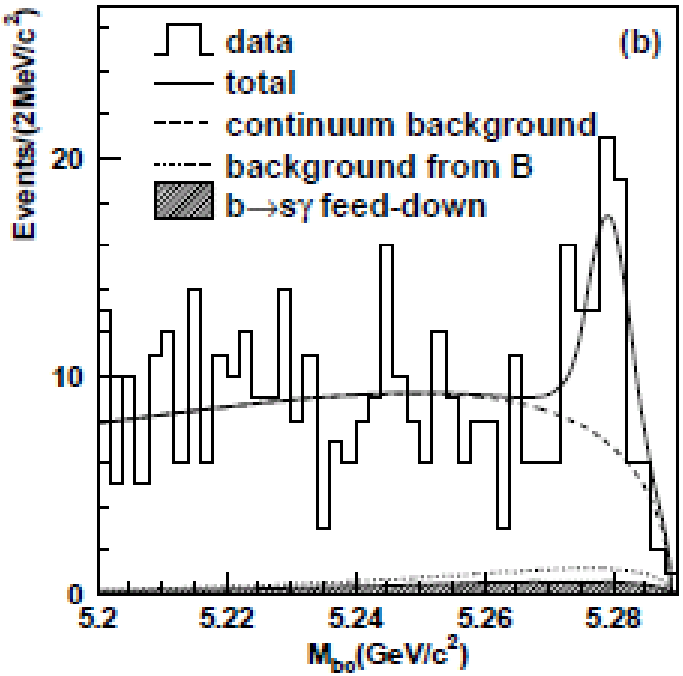
253 fb^{-1}

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



$$N_- = 34.0^{+9.8}_{-9.0}$$

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



$$N_+ = 46.7^{+10.5}_{-9.8}$$

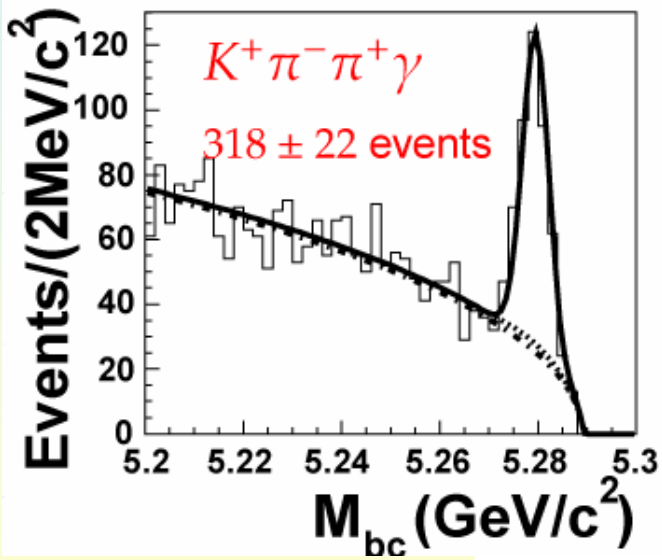
$$A_{cp} = -0.16 \pm 0.09 \pm 0.06$$

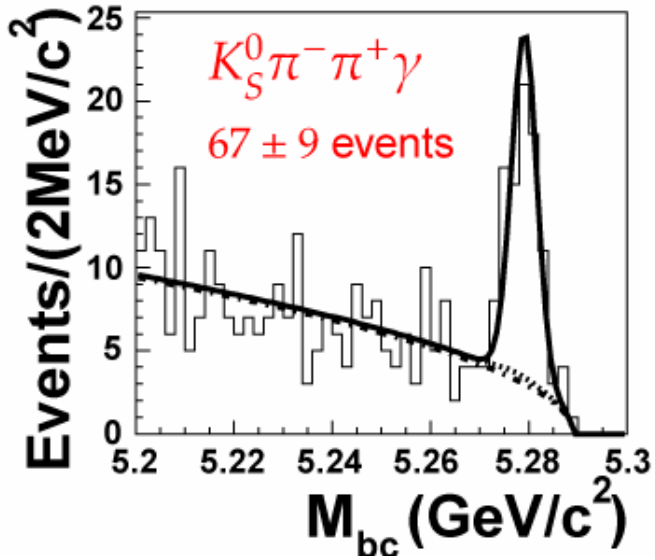
B→Kππγ

$K_1(1270)$ and $K_1(1400)$

$K_1(1270)\to K\rho\ (\rho\to\pi\pi)$	(42%)	$K_1(1400)\to K\rho\ (\rho\to\pi\pi)$	(3%)
$\to K^*\pi\ (K^*\to K\pi)$	(16%)	$\to K^*\pi\ (K^*\to K\pi)$	(94%)
$\to K_0^*\pi\ (K_0^*\to K\pi)$	(28%)	$\to K_0^*\pi\ (K_0^*\to K\pi)$	(0%)
$K_1(1270)\to K\pi\pi$ (inclusive)	(86%)	$K_1(1400)\to K\pi\pi$ (inclusive)	(97%)

Both K_1 dominantly decay into $K\pi\pi$ (and other high K resonances, too)





Belle 140fb^{-1}

$$\mathcal{B}(B^+\to K^+\pi^-\pi^+\gamma) = (2.50\pm0.18\pm0.22)\times10^{-5}\ (20.4\sigma)$$

$$\mathcal{B}(B^0\to K^0\pi^-\pi^+\gamma) = (2.43\pm0.36\pm0.34)\times10^{-5}\ (10.9\sigma)$$

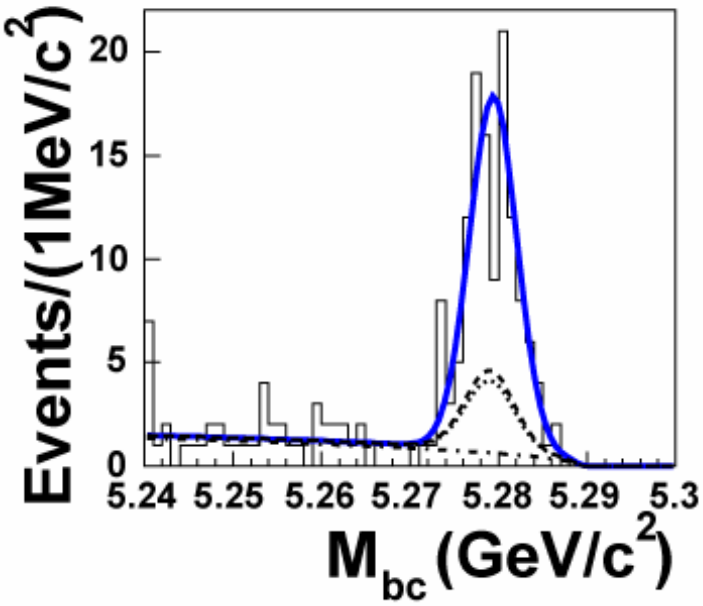
$B \to K_1\gamma$

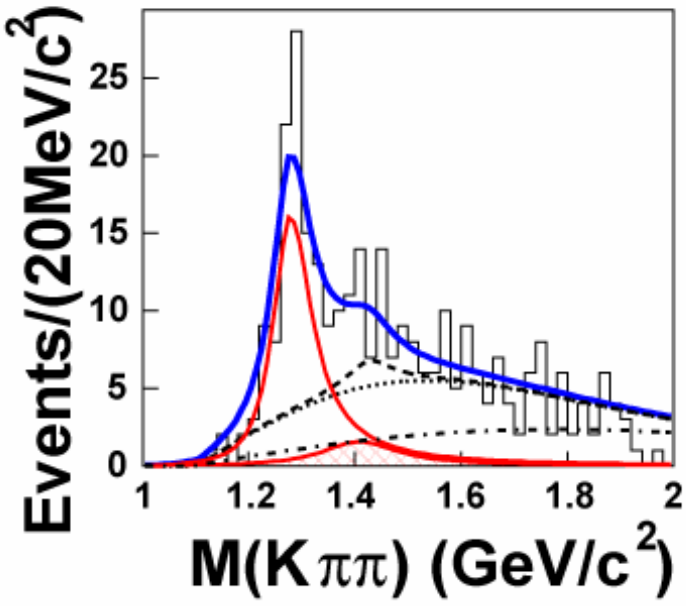
- Enhance $K_1(1270)$ by selecting $K\rho\gamma$ — $(0.6 < M(\pi\pi) < 0.8$ GeV)
- Enhance $K_1(1400)$ by selecting $K^*\pi\gamma$ — $(0.8 < M(K\pi) < 1.0$ GeV)

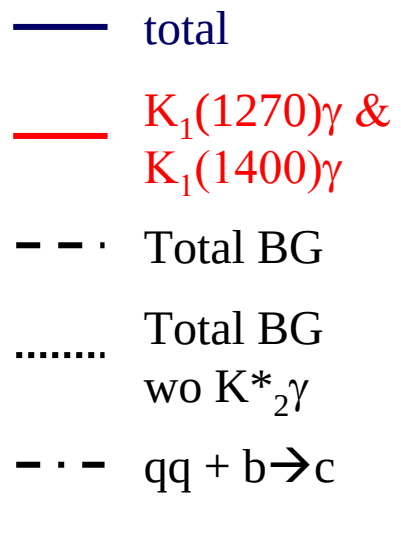
$K^*_2(1430) \to K\pi\pi$ BG is fixed

$K_1(1270)\gamma$ enhanced sample

$140fb^{-1}$





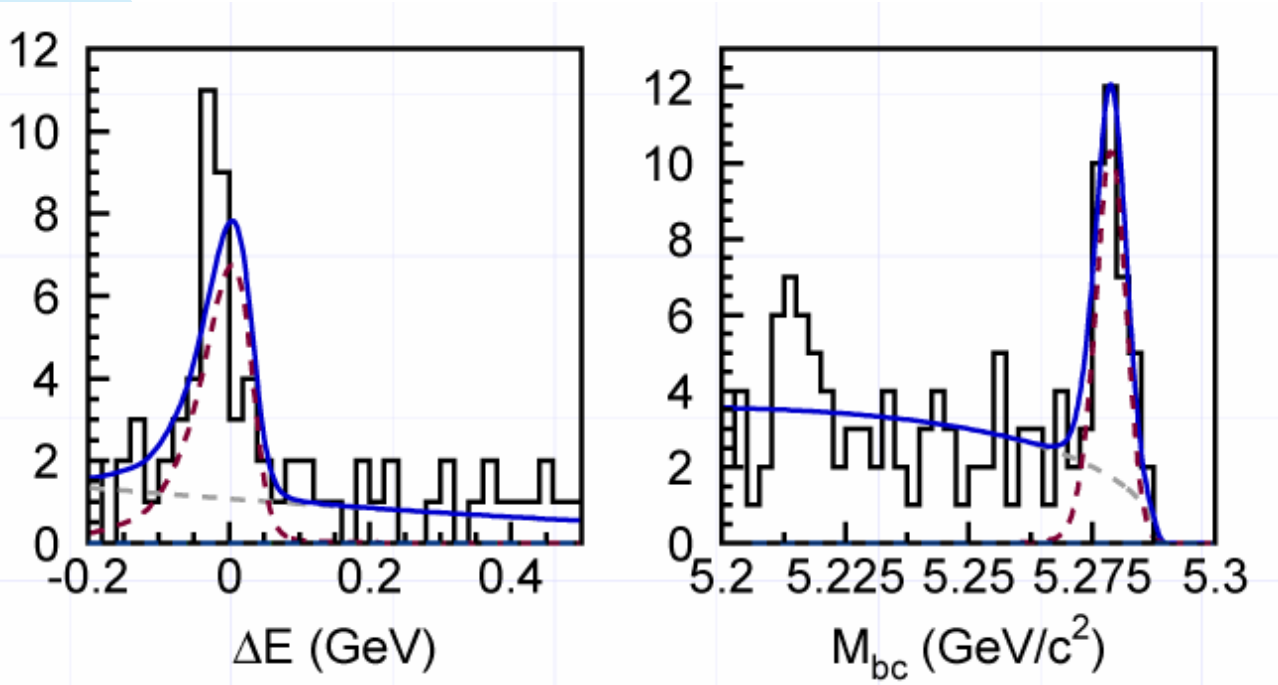


$$Br(B^+ \to K_1(1270)^+\gamma) = [4.28 \pm 0.94 \pm 0.86] \times 10^{-5} \quad (9.2\sigma)$$

$$Br(B^+ \to K_1(1400)^+\gamma) < 1.48 \times 10^{-5} \quad @90\%\text{C.L.} \quad (1.3\sigma)$$

B→Λpγ

- $B \to$ 3-body baryonic decays are now popular:
  $B \to p\bar{p}K,\ p\bar{p}\pi,\ \Lambda\bar{p}\pi,\ \Lambda\bar{\Lambda}K,\ \ldots$

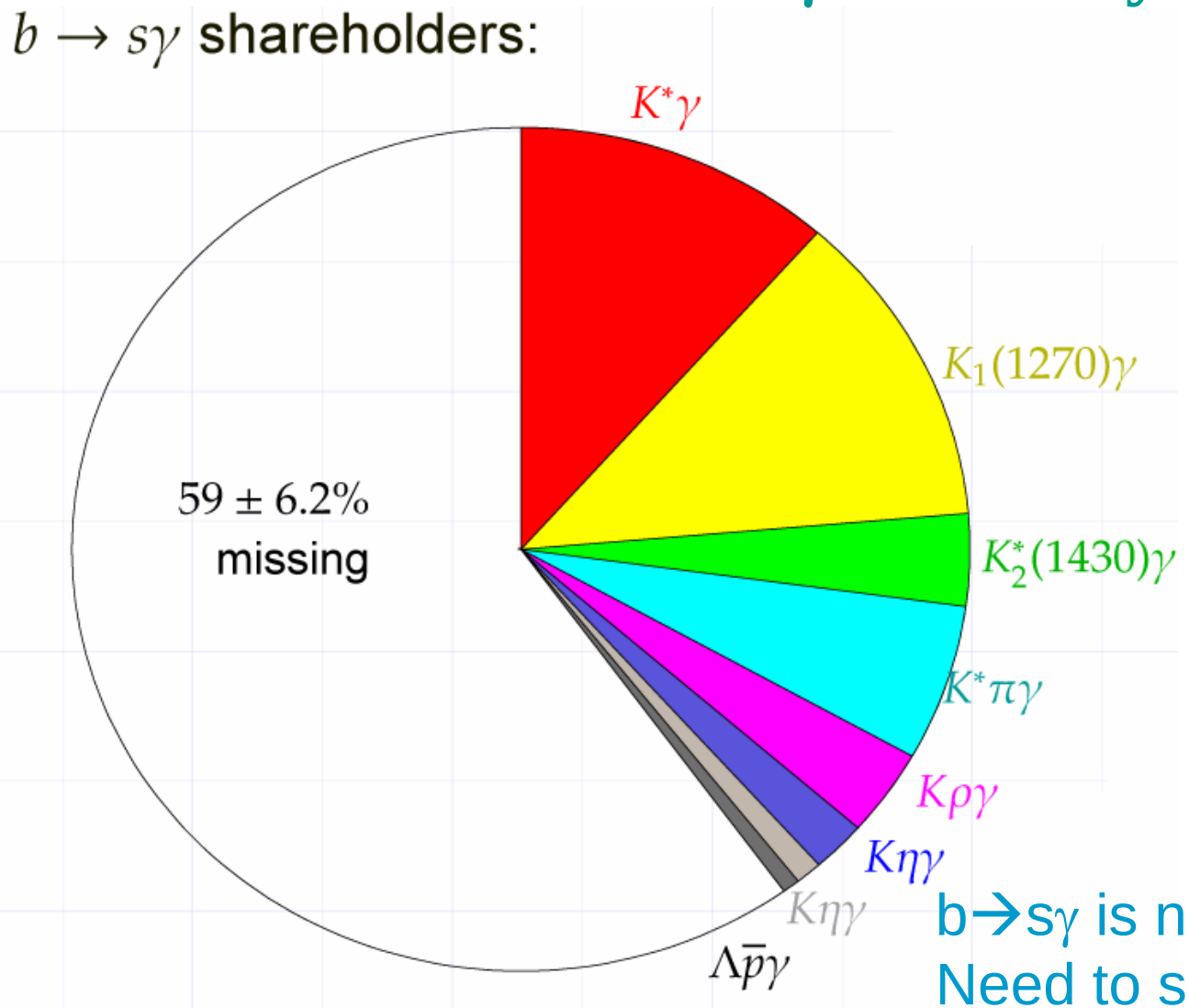


Belle 140fb^{-1}

$\mathcal{B}(B^- \to \Lambda\bar{p}\gamma) = (2.16\ ^{+0.58}_{-0.53} \pm 0.20) \times 10^{-6}\ (8.6\sigma)$

$\mathcal{B}(B^- \to \Sigma^0\bar{p}\gamma) < 0.8 \times 10^{-6}$ 90% CL $(M(p\Lambda) < 2.4$ GeV)

b→sγ summary



b→sγ is now precision physics
Need to seek for small
new physics signatures

6% less missing than the last year

Inclusive $B \rightarrow X_s\gamma$

Analysis of $B \rightarrow X_s\gamma$

- Fully inclusive reconstruction: see only the γ spectrum

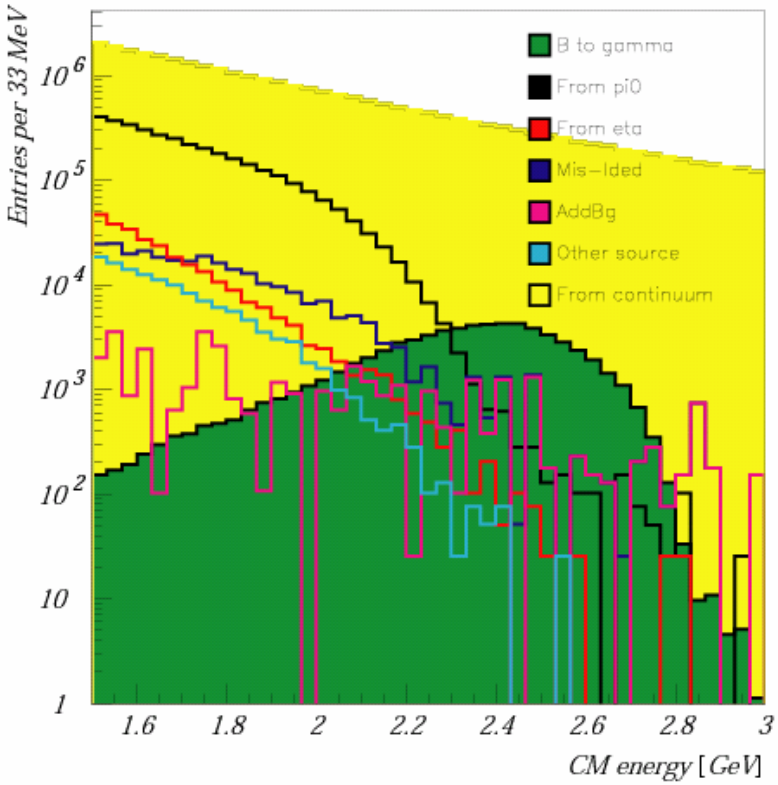
  Measure $E\gamma$ spectrum (single high-energy photon)
- Huge BG … Subtract BG $E\gamma$ spectrum

- $E\gamma >$ 1.8 GeV (CLEO… 2.0GeV BaBar … 2.1GeV)

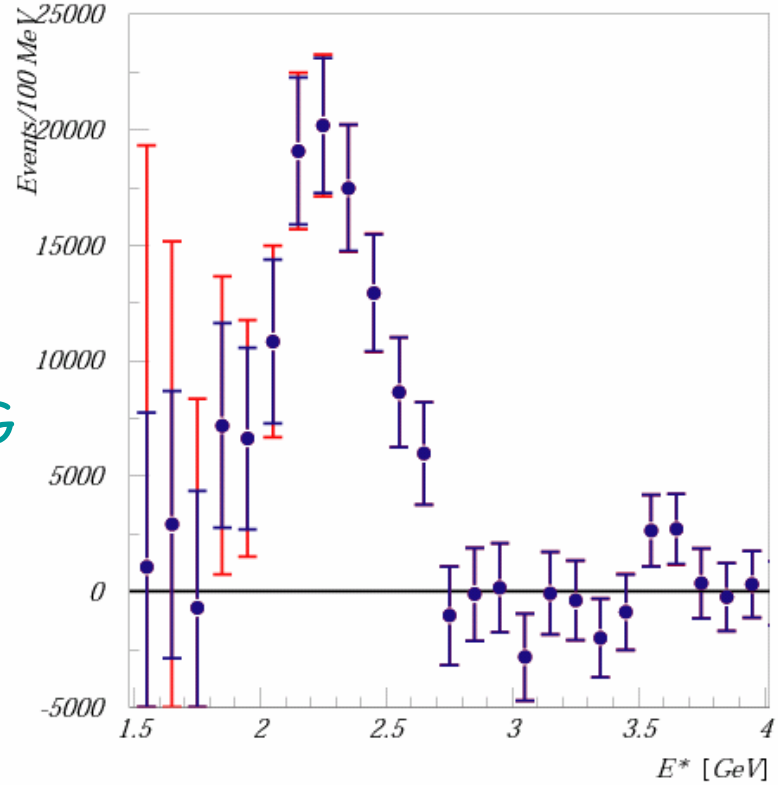
  → reduce theoretical model error

Inclusive B→Xsγ

Belle 140fb^{-1}



Subtract BG
ε correction



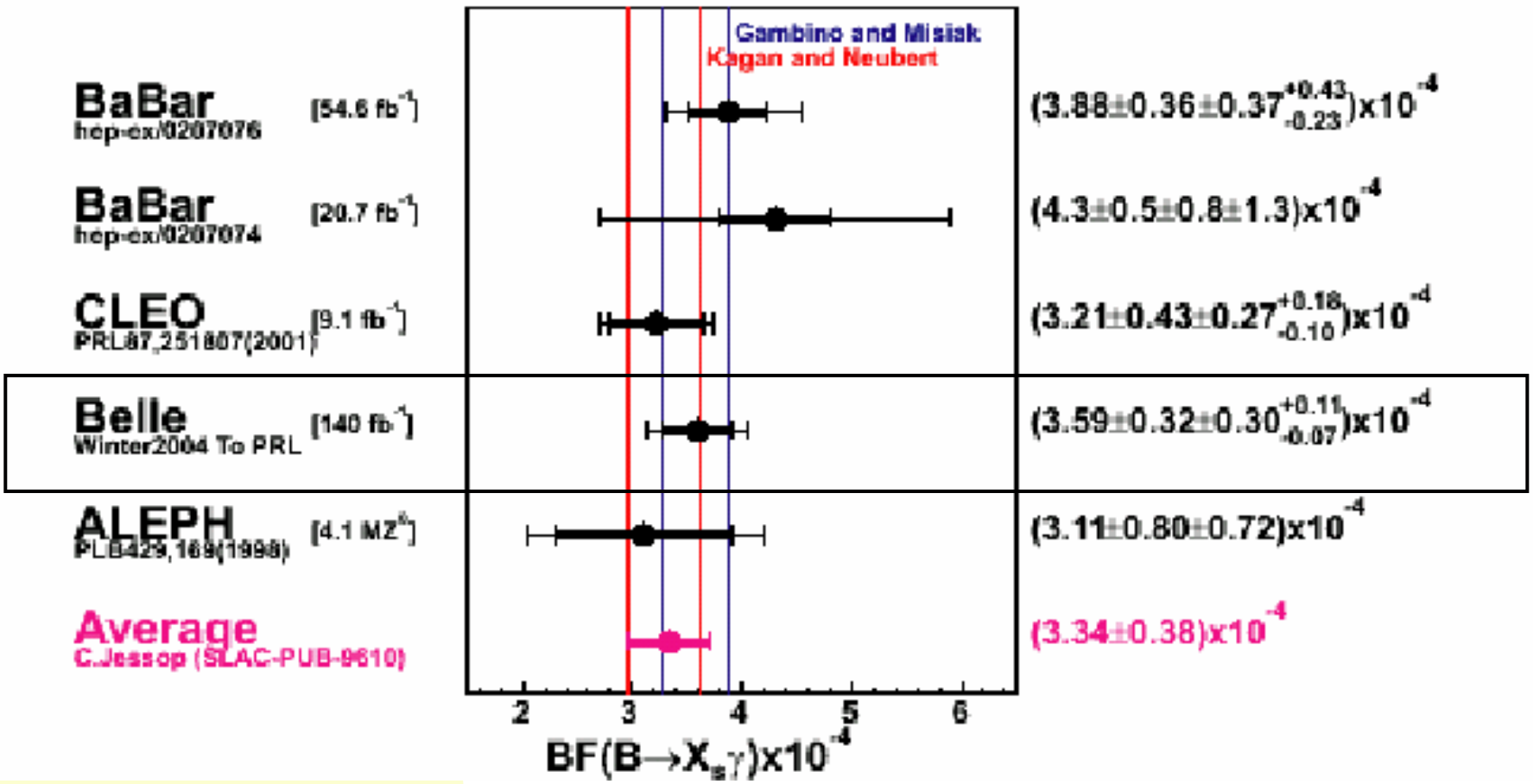
$$Br(b \to s\gamma) = (3.59 \pm 0.32^{+0.30}_{-0.31}{}^{+0.11}_{-0.07}) \times 10^{-4}$$

$$\langle E\gamma \rangle = 2.289 \pm 0.026 \pm 0.034 (GeV)$$

$$\langle E\gamma^2 \rangle - \langle E\gamma \rangle^2 = 0.0311 \pm 0.073 \pm 0.063 (GeV^2)$$

1.8<Eγ<2.8GeV

Inclusive $B \to X_s\gamma$ results



Summary

With the world highest luminosity provided by KEKB, Belle is continually updating the results.

- Can access very rare decays of $b \to s\ell\ell$ and $b \to d\gamma$
- $b \to K^*\ell\ell$: First measurement of A_{FB}
- Can measure the $b \to s\gamma$ process very precisely
- Exclusive $b \to s\gamma$: many new measurements