Observation of $B \to K^* ll$ and related modes

- Measurements of $b \to d,s\gamma$ and $b \to sll$ -

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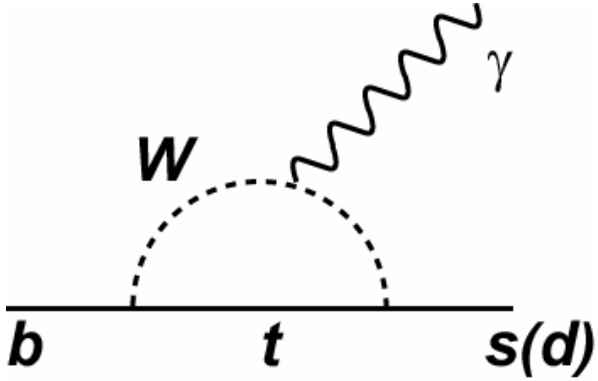
For the Belle Collaboration

Introduction



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: >200 fb^{-1}!!)

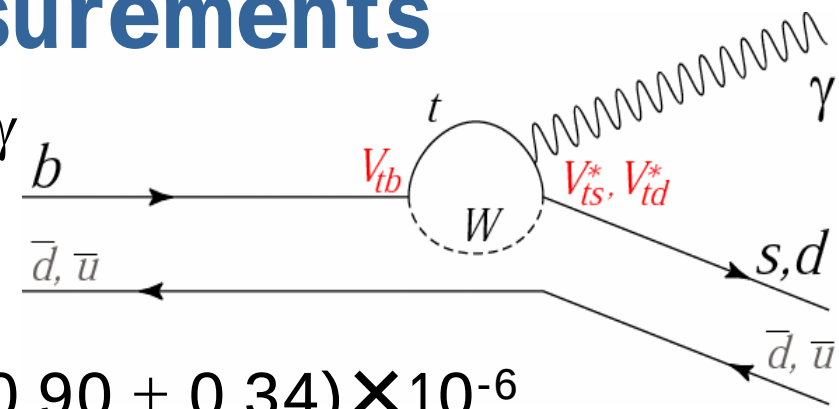
e^+e^- collider → Clean environment

In this talk, we cover

New New

$b \to d\gamma$ $b \to s\gamma$ and $b \to sll$ measurements

$b \to d\gamma$ measurements



$b \to d\gamma$: more suppressed than $b \to s\gamma$

Measurements of $b \to s\gamma$ & $b \to d\gamma$

→ V_{td}/V_{ts} … constraints the SM

SM Predictions: $B^+ \to \rho^+\gamma$ $(0.90 \pm 0.34) \times 10^{-6}$

$B^0 \to \rho^0\gamma, \omega\gamma$ $(0.49 \pm 0.18) \times 10^{-6}$

Ali et.al. hep-ph/0105302

$B^+ \to \rho^+\gamma$ $(1.58\ {}^{+0.53}_{-0.46}) \times 10^{-6}$

Bosch et.al. hep-ph/0106081

Experiments: So far only upper limits $(1\sim2) \times 10^{-6}$

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

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

cont. rejection … improved by <u>Fisher, vertexing, flavor-tag</u>

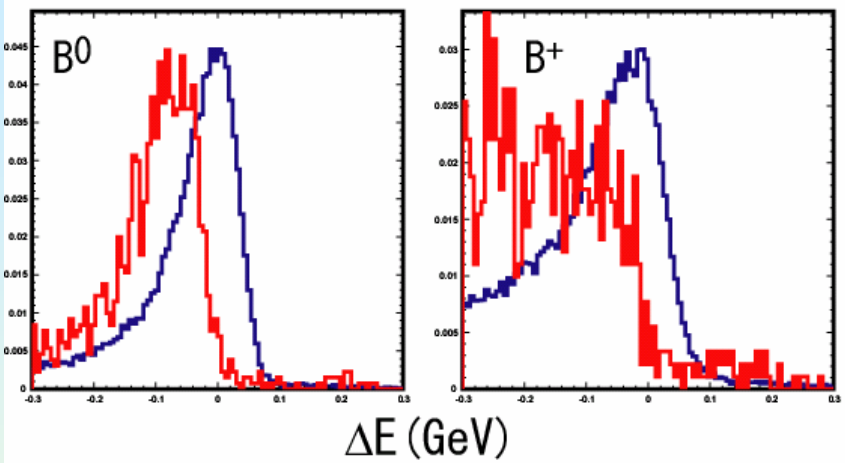
Signal yield: Use 2-D unbinned maximum likelihood fit

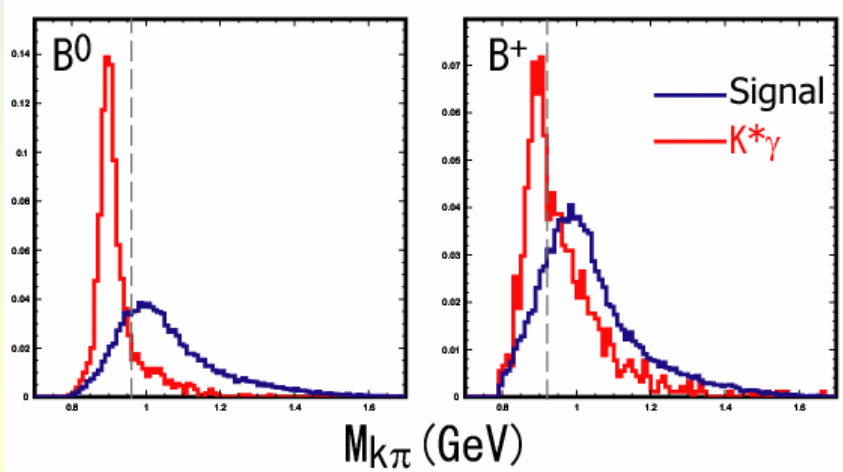
Simultaneous fit to 3 signal + 2 $K^*\gamma$ assuming isospin:

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

Exclusive B→ρ/ωγ : BG suppression

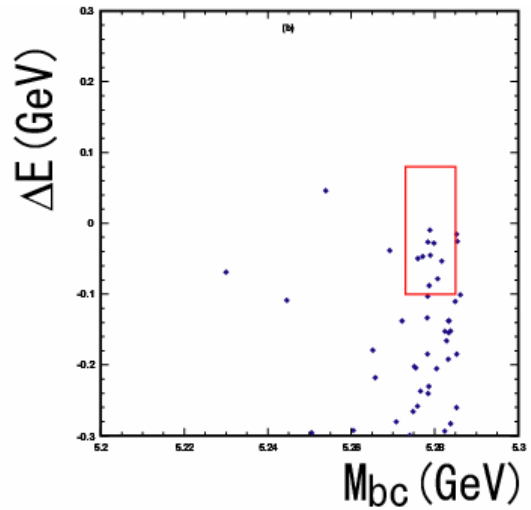
BG from K*γ

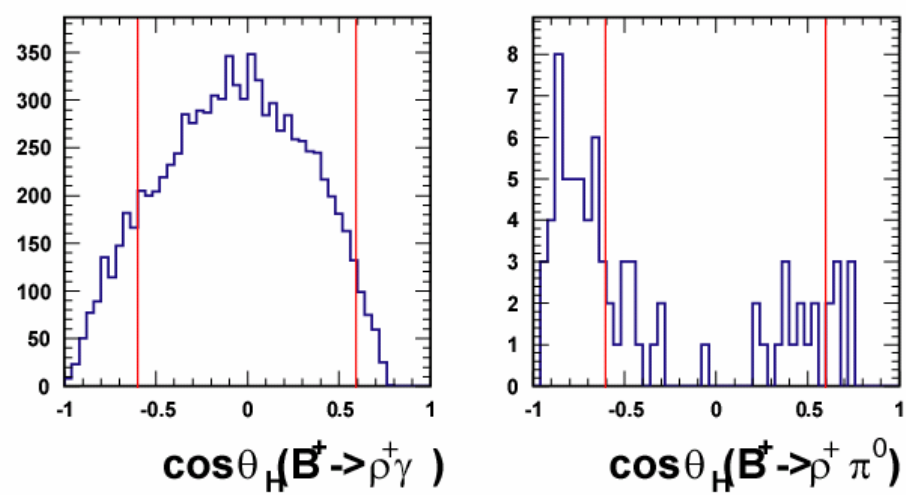




Apply Mkπ cut

BG from B→ρπ0





Apply helicity angle cut

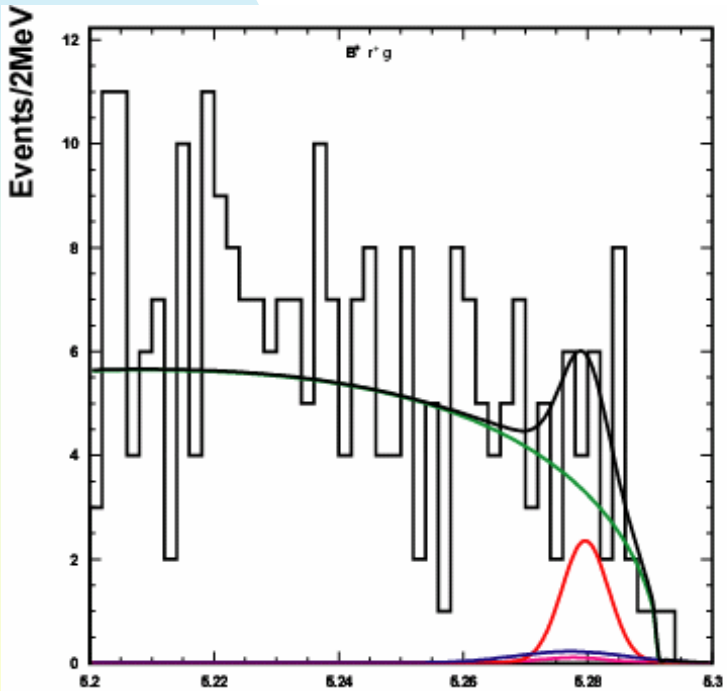
Exclusive $B \to \rho/\omega\gamma$

Belle 140fb^{-1}

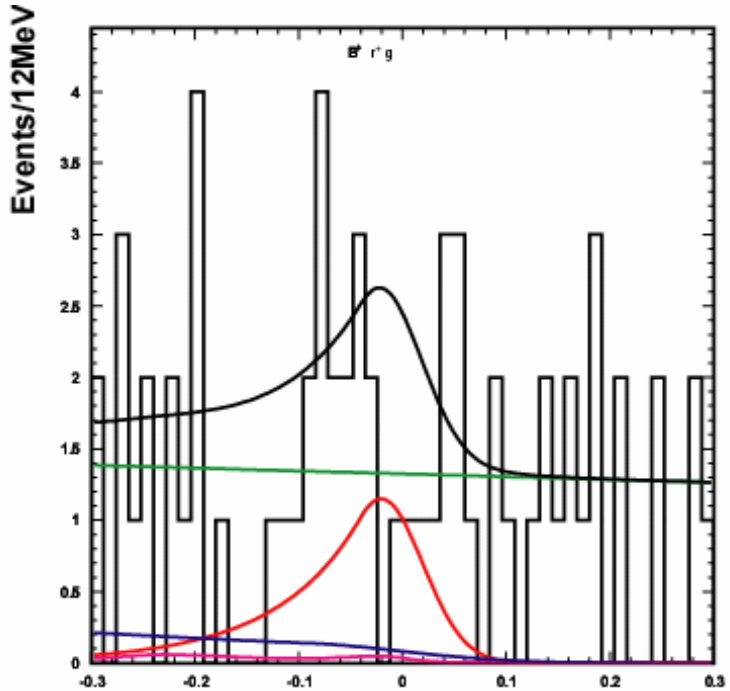
$B \to \rho^+\gamma$

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

$Br(B^+ \to \rho^+\gamma) = Br(B \to (\rho,\omega)\gamma)$



M_{bc}



ΔE

Signal

BG(K*γ)

BG(continuum)

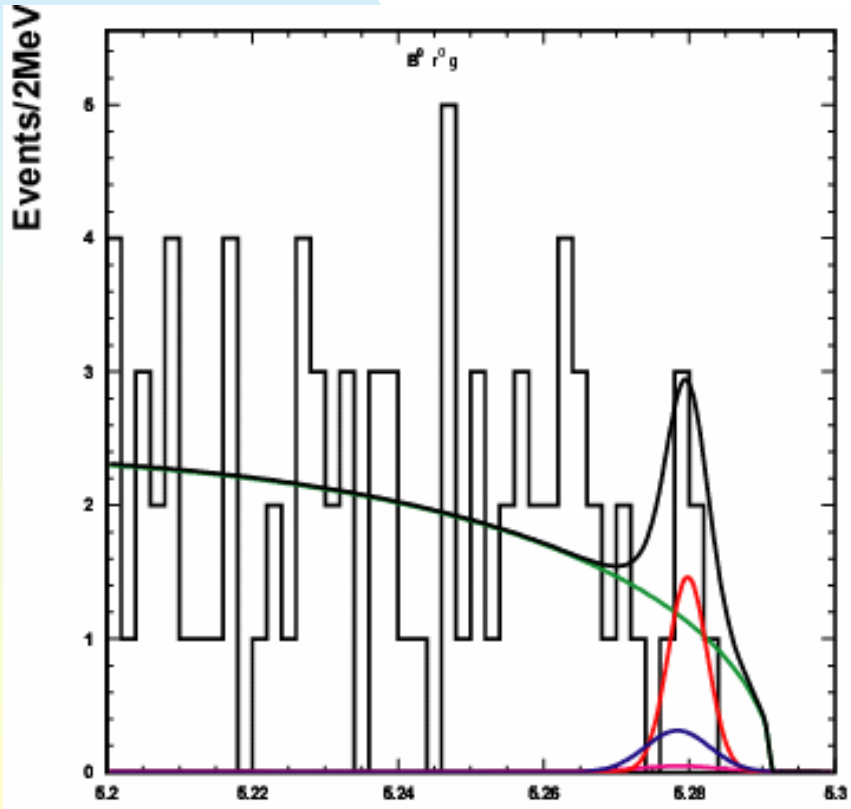
Exclusive $B \to \rho/\omega\gamma$

Belle 140fb^{-1}

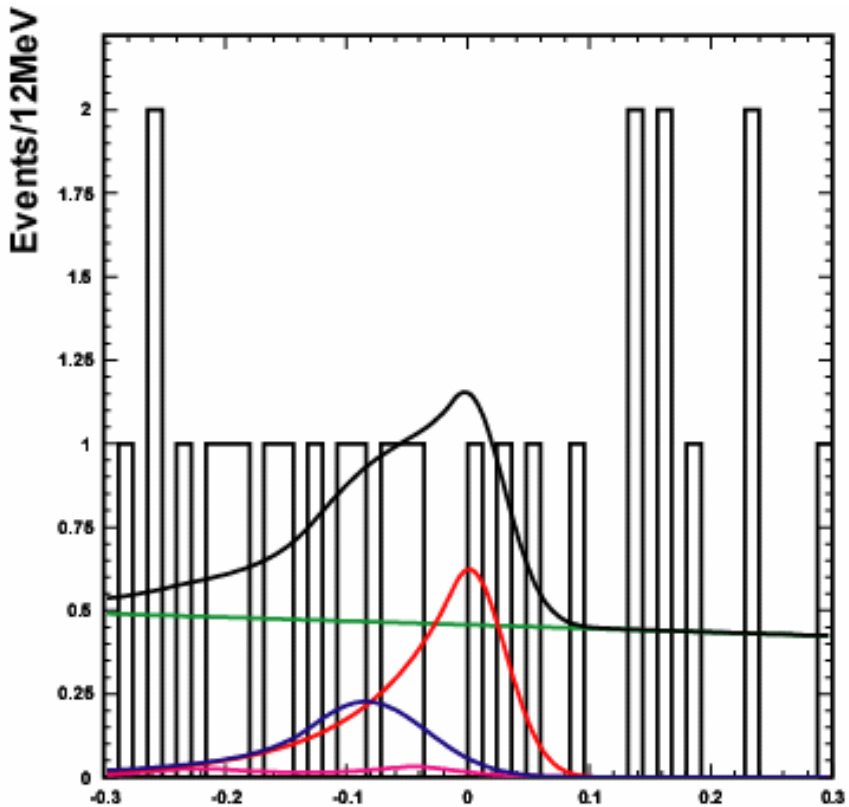
$B \to \rho^0\gamma$

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

$$Br(B^0 \to \rho^0\gamma) = \tfrac{1}{2}\,(\tau(B^0)/\tau(B^+))\; Br(B \to (\rho,\omega)\gamma)$$



M_{bc}



ΔE

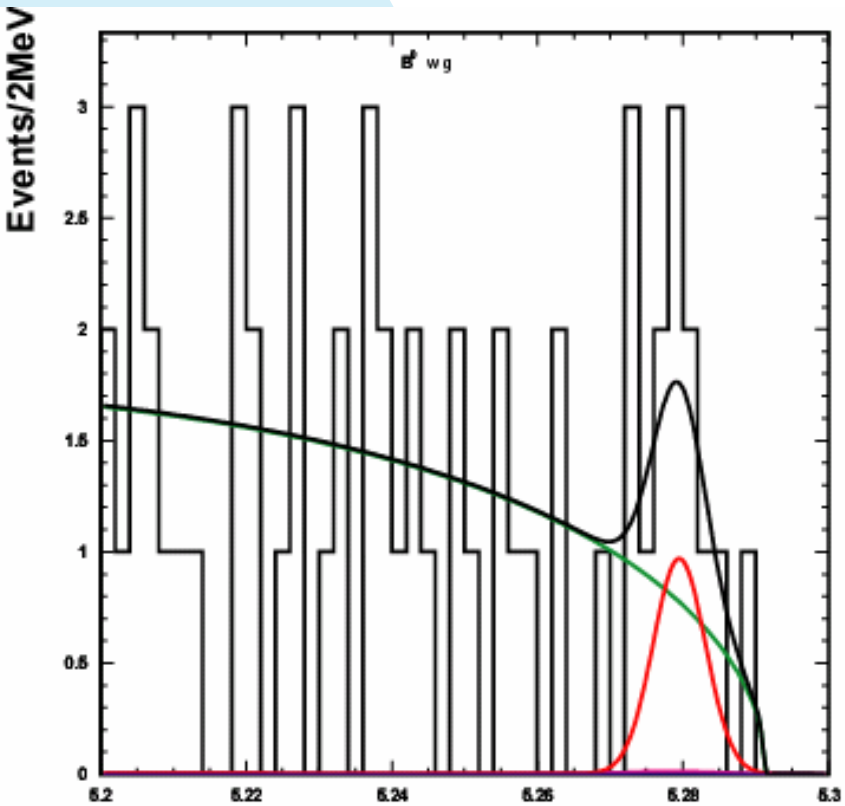
Exclusive $B \to \rho/\omega\gamma$

Belle 140fb^{-1}

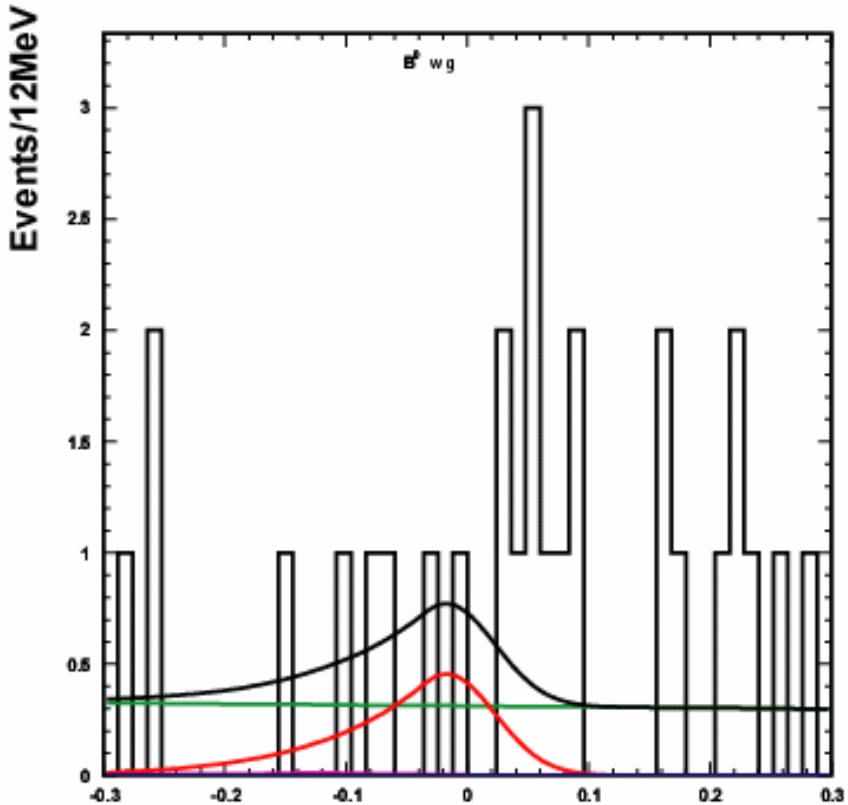
$B \to \omega\gamma$

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

$$Br(B^0 \to \omega\gamma) = \tfrac{1}{2}\,(\tau(B^0)/\tau(B^+))\; Br(B \to (\rho,\omega)\gamma)$$



M_{bc}



ΔE

Exclusive $B \to \rho/\omega\gamma$: results

Belle 140fb^{-1} preliminary

$B \to \rho/\omega\gamma$ 27.4 net signal (from the simultaneous fit)

significance 3.5 (include systematic error)

BF($B \to \rho/\omega\gamma$) $(1.8\ ^{+0.6}_{-0.5}\ \pm 0.1) \times 10^{-6}$

Result from the simultaneous Fit → *3.5 σ (incl sys)*

First evidence for the $b \to d\gamma$ process!!
In agreement with SM

SM Predictions ($B^+ \to \rho^+\gamma$)

$(0.90 \pm 0.34) \times 10^{-6}$ Ali et.al. hep-ph/0105302

$(1.58\ +0.53\ -0.46) \times 10^{-6}$ Bosch et.al. hep-ph/0106081

Inclusive $B \to X_s\gamma$

Analysis of $B \to X_s\gamma$

- Fully inclusive reconstruction: see only the γ spectrum
  1) Measure $E\gamma$ spectrum (single high-energy photon)
  2) Continuum suppression based on the event shape
  3) π^0/η veto

- Huge BG … Subtract BG $E\gamma$ spectrum

  γ from Continuum estimated by off-resonance data

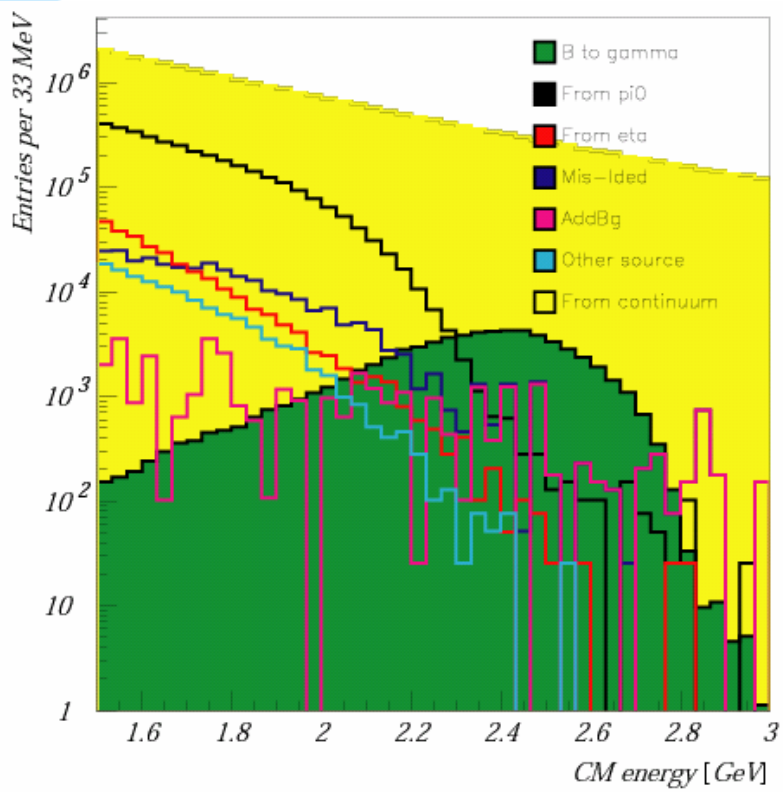
  γ from π^0/η in BB estimate the $E\gamma$ spectrum by on- and off-resonance data

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

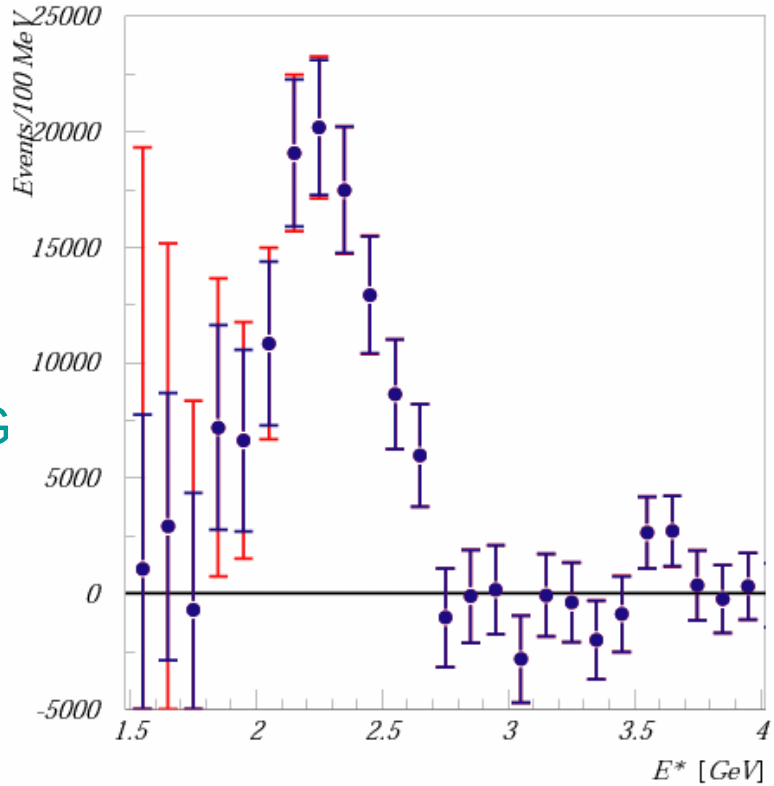
  → reduce theoretical model error

Inclusive B→Xsγ

Belle 140fb^{-1}



Subtract BG
ε correction



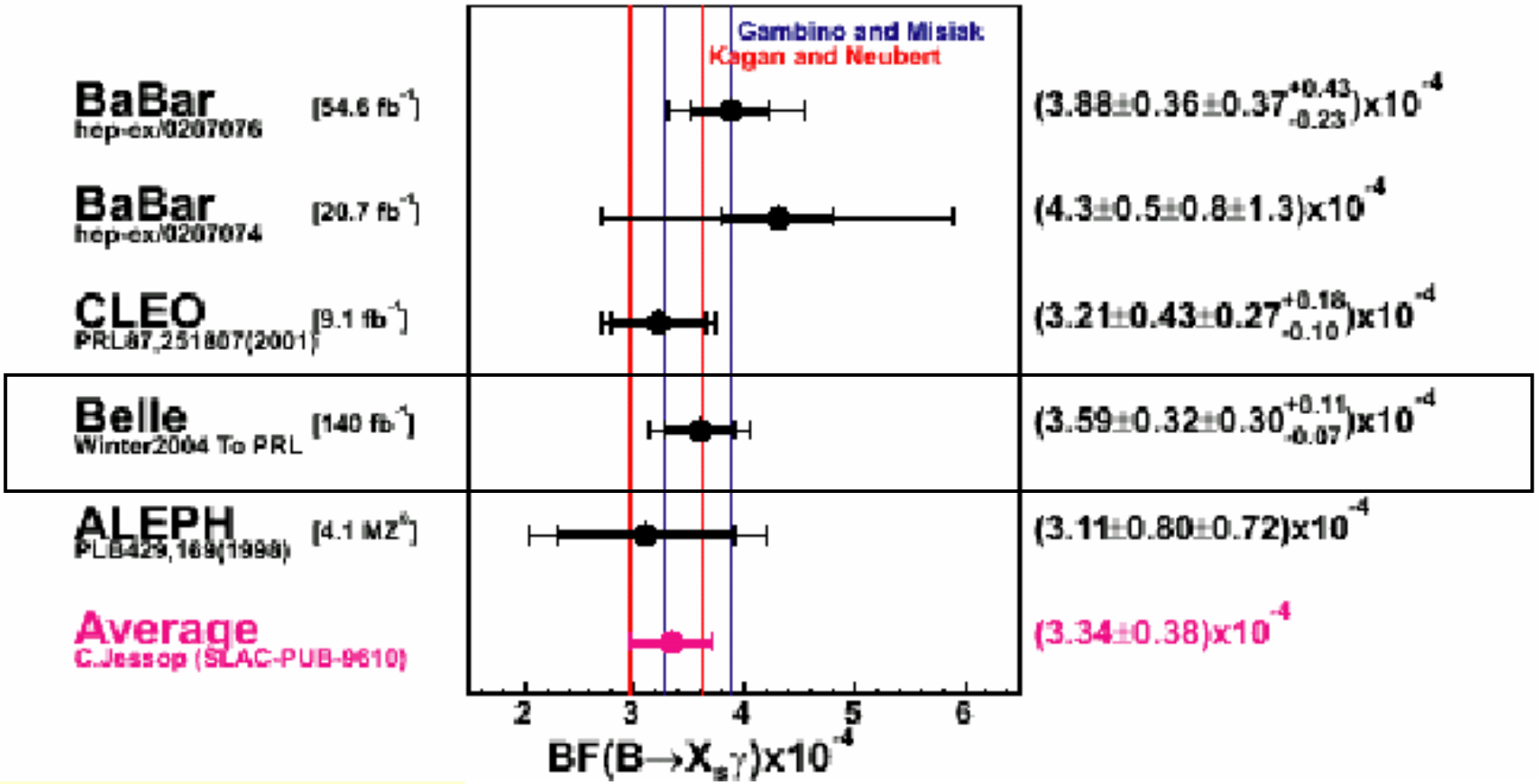
$$Br(b \to s\gamma) = (3.59 \pm 0.32^{+0.30}_{-0.31}{}^{+0.11}_{-0.07}) \times 10^{-4}$$

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

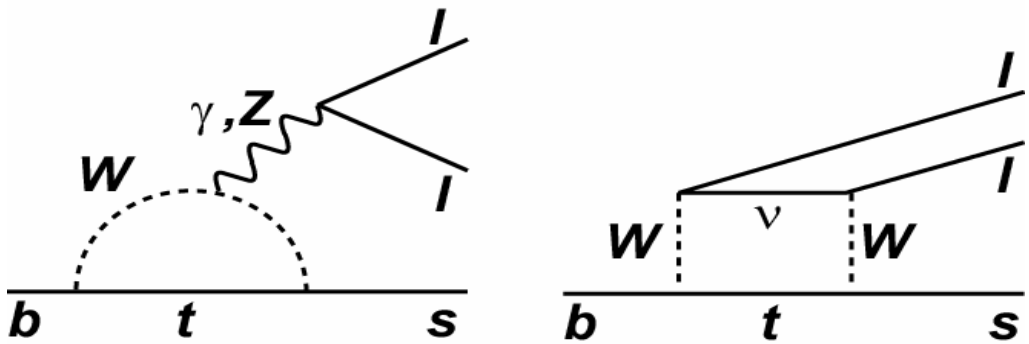
$$\langle E\gamma^2 \rangle - \langle E\gamma \rangle^2 = 0.0311 \pm 0.073 \pm 0.063 (GeV^2)$$

1.8<Eγ<2.8GeV

Inclusive B→Xsγ results



b→sll measurements

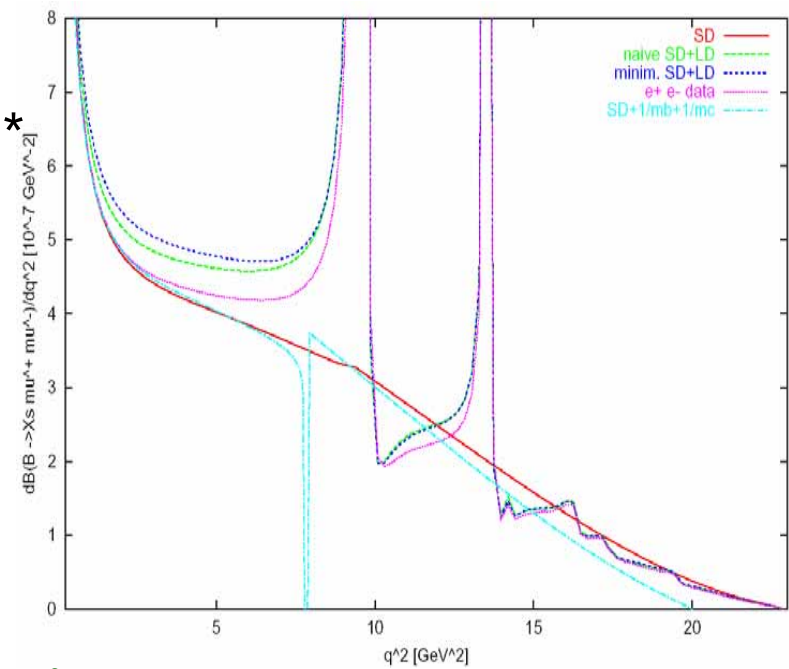


Br is low (b→sγ: 10^{-4} b→sll: 10^{-6})

Exists the contribution from Z^{0*}

Br, q^2 distribution, $A_{FB}(q^2)$

.. Sensitive to the New Physics



Two analysis approaches:

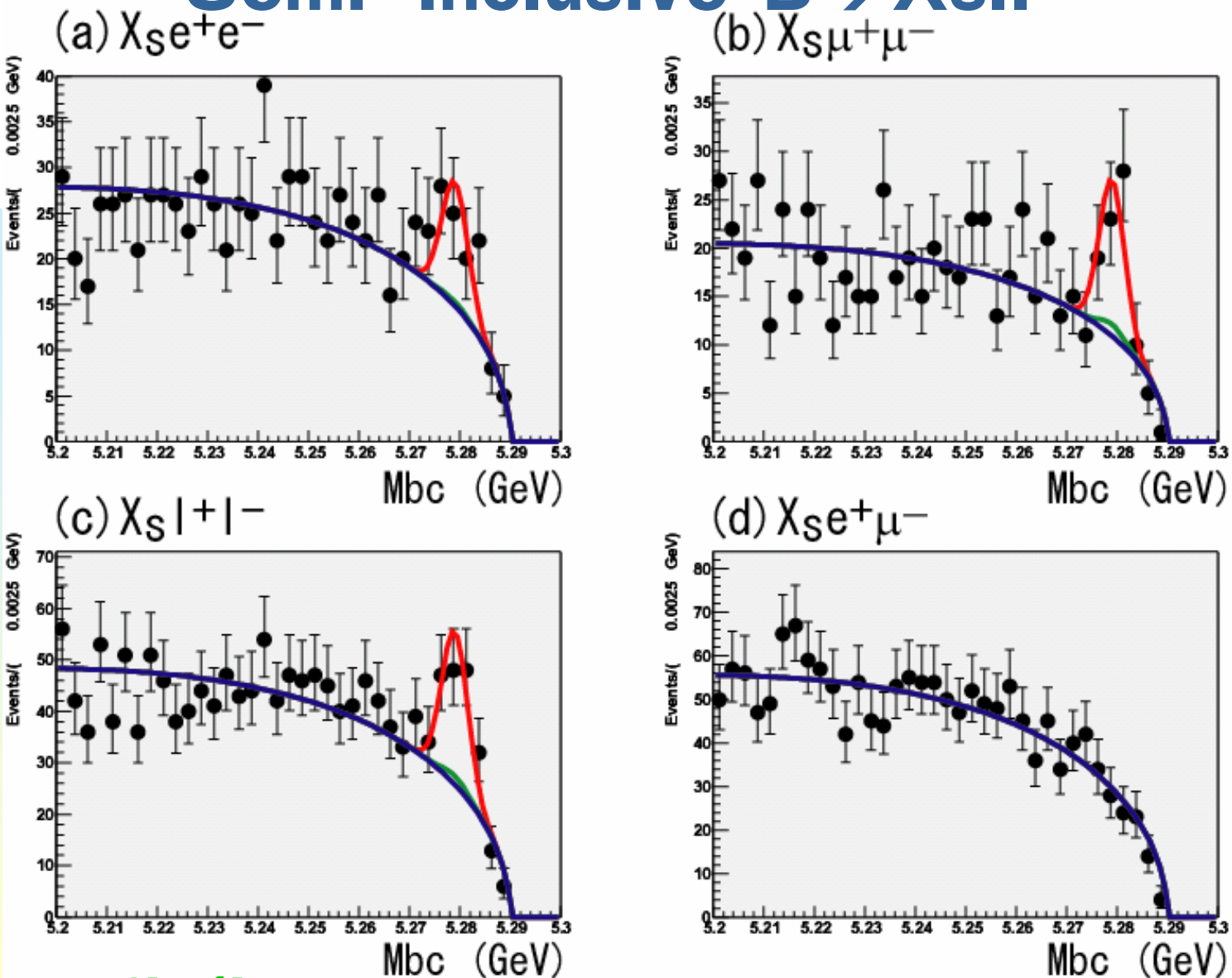
- Semi-inclusive B→Xsll

  reconstruct X_s with K or K^0_s+0-4π (#$\pi^0 \leq 1$)

  Just updated with 140 fb^{-1} data

- Exclusive B→$K^{(*)}$ll

Semi-inclusive B→Xsll



Belle (140 fb^{-1}) M_{bc} unbinned likelihood fits, after all cuts

72 net signal, significance 6.2σ, Ave. of e^+e^-, $\mu^+\mu^-$

Semi-inclusive B→Xsll

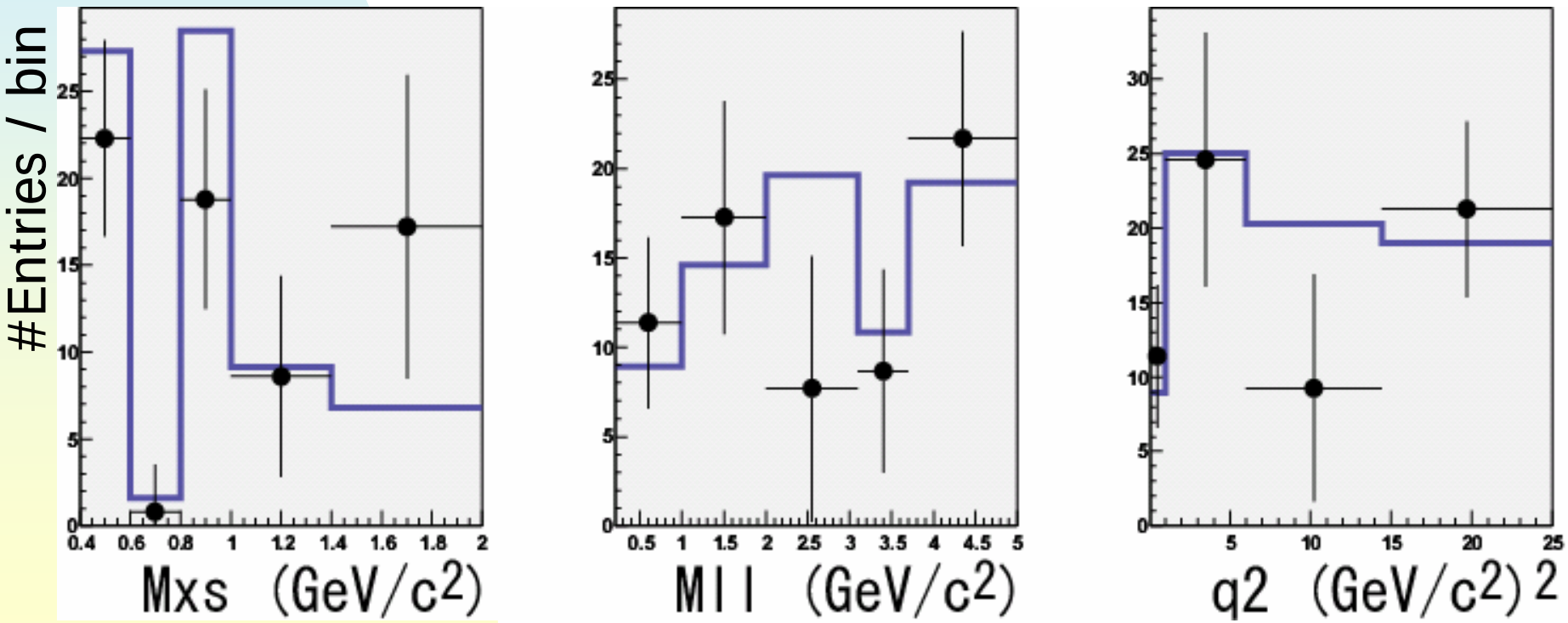
Belle 140fb^{-1} preliminary

$$Br(B \to Xsee) = [4.45 \pm 1.32^{+0.84}_{-0.79}] \times 10^{-6}$$

$$Br(B \to Xs\mu\mu) = [4.31 \pm 1.06^{+0.74}_{-0.70}] \times 10^{-6}$$

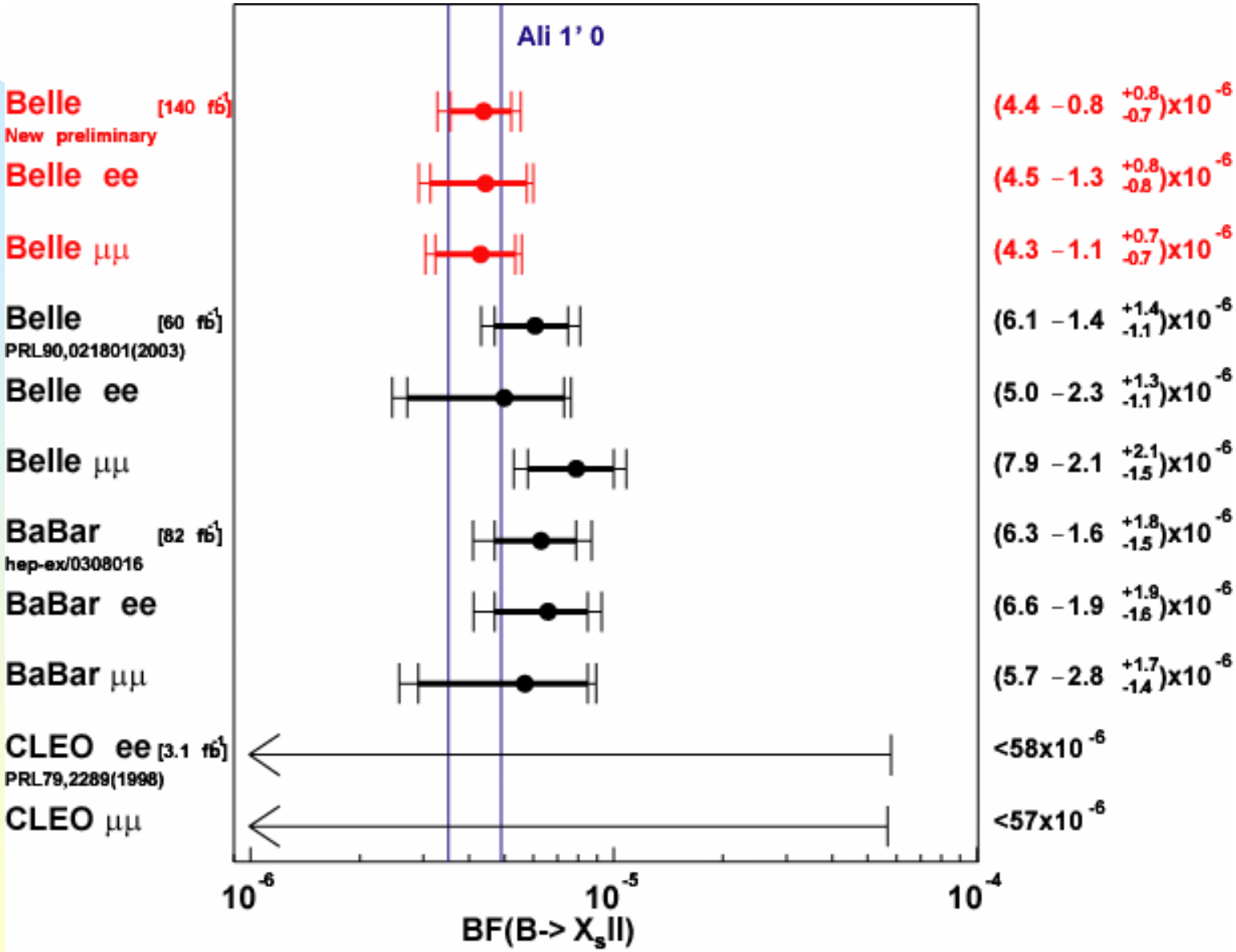
$$Br(B \to Xsll) = [4.39 \pm 0.84^{+0.78}_{-0.73}] \times 10^{-6}$$

(m_{ll} > 0.2 GeV)



The results are in agreement with SM

B→Xsll results (II)



Both Belle and BaBar results are consistent with SM

Summary

With the world's highest luminosity provided by KEKB, Belle continues to update the results.

Exclusive $B \rightarrow \rho,\omega\gamma$ ($140 fb^{-1}$)

preliminary

First evidence!!

In agreement with SM.

Inclusive $B \rightarrow X_s\gamma$ ($140 fb^{-1}$)

Fully inclusive method $E\gamma > 1.8 GeV$

Very precise measurement

Semi-inclusive $B \rightarrow X_s ll$ ($140 fb^{-1}$)

preliminary

Update the measurement

In agreement with SM.

Belle also measure Exclusive $B \rightarrow K^*\gamma$ $B \rightarrow K^{(*)}ll$

$K^*\gamma$: measure A_{cp}, Δ_{0+} K^*ll : First observation (PRL)