Karlsruhe Institute of Technology

KEKB uest for CPV kekb.jp

BELLE

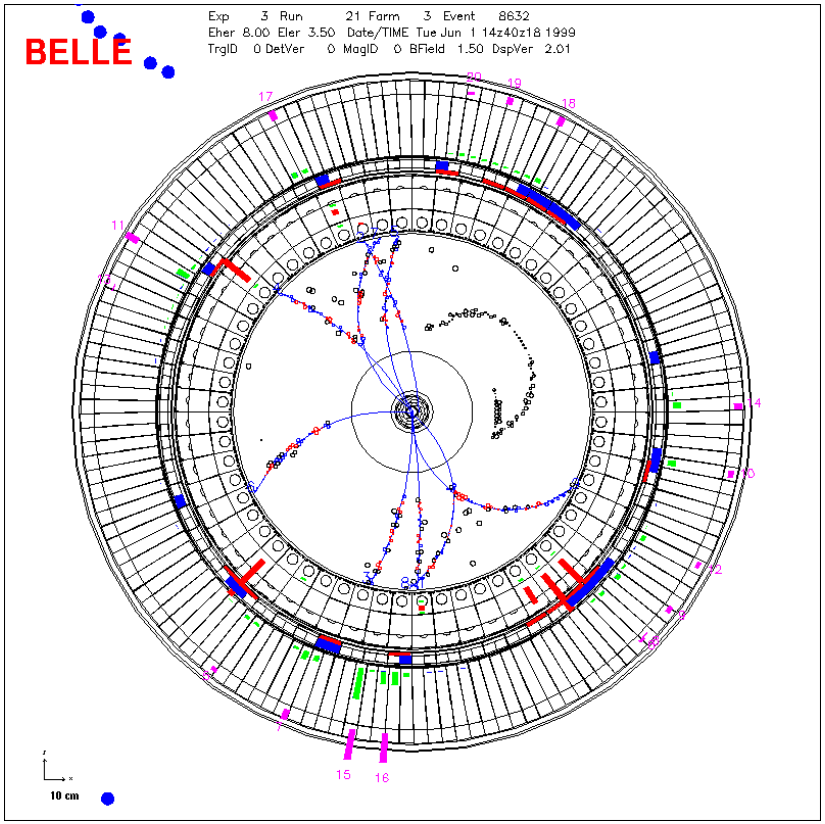
Study of B meson systems and searches for new physics at Belle

PANIC, Hamburg

Bastian Kronenbitter | 28.08.2014

INSTITUT FÜR EXPERIMENTELLE KERNPHYSIK (IEKP)

Typical Hadronic Event



- Few tracks and clusters
- Nothing produced additional to $\Upsilon(4S)$
- High reconstruction efficiency
- Very good particle identification

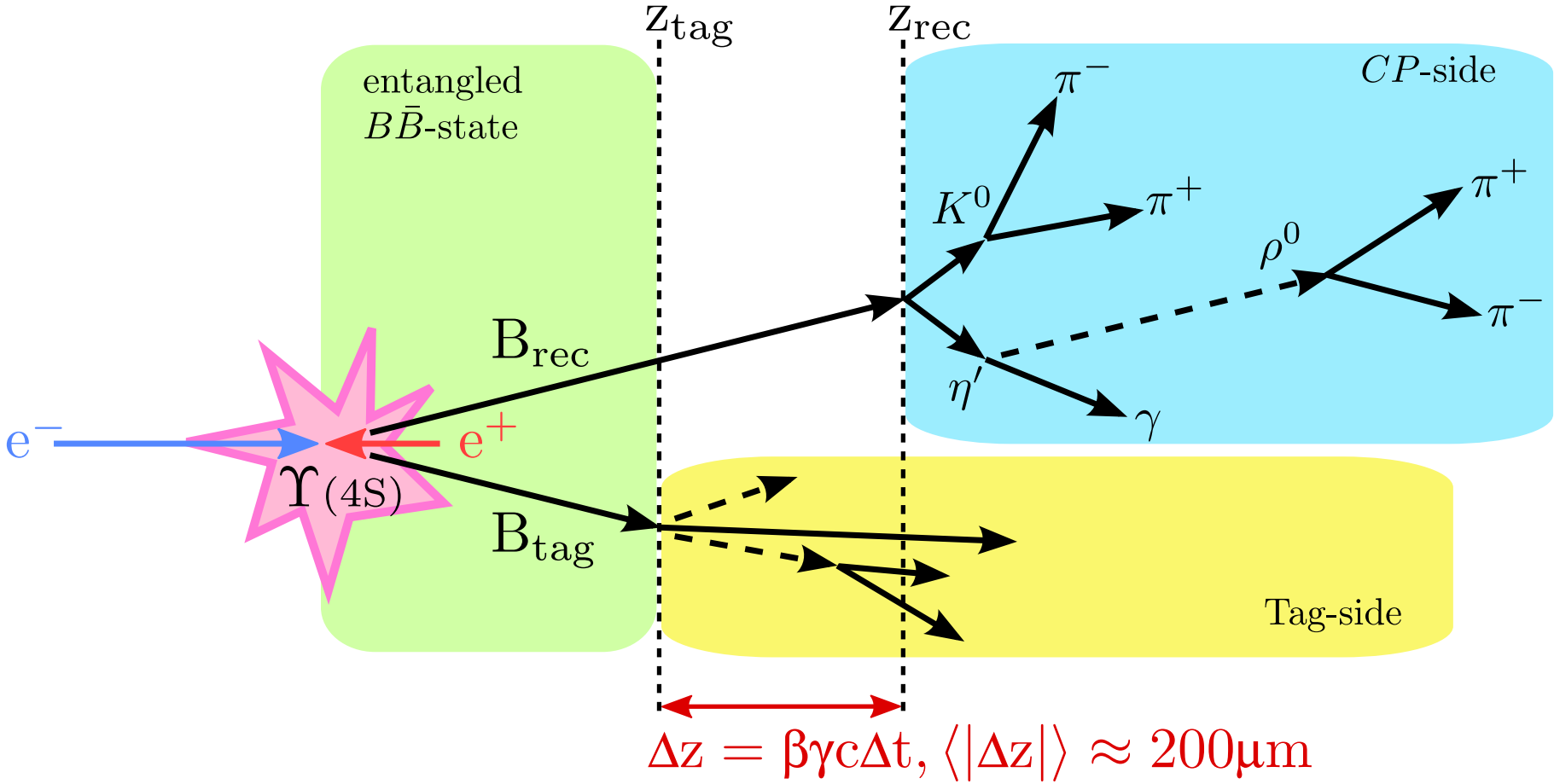
Final data sample

- $711\,\mathrm{fb}^{-1}$ recorded at the $\Upsilon(4S)$ resonance
- $79\,\mathrm{fb}^{-1}$ recorded below the $\Upsilon(4S)$ resonance
- about $200\,\mathrm{fb}^{-1}$ at other Υ resonances

Recent measurements

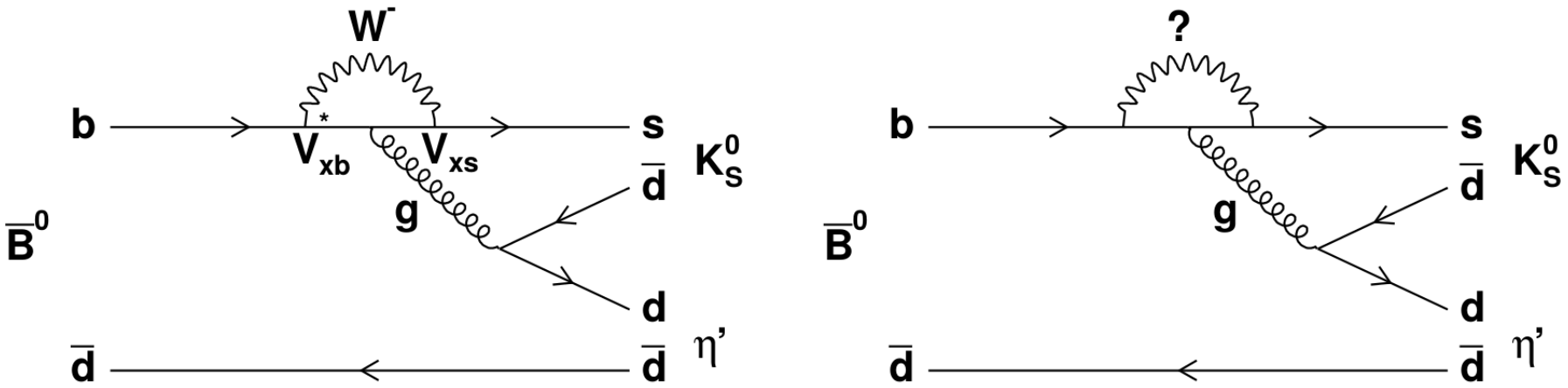
- **Time-dependent CP violation in $B^0 \to \eta' K^0$**
- **Search for $B^+ \to \mu^+ \nu_\mu$ and $B^+ \to e^+ \nu_e$**
- **Branching fraction of $\bar{B} \to X_s \gamma$**
- **Forward-backward asymmetry in $\bar{B} \to X_s \ell^+ \ell^-$**
- Branching fraction of $B \to D \ell \nu$
- Branching fraction of $B^0 \to \pi^0 \pi^0$
- Branching fraction of $B^0 \to D_s^- K_S^0 \pi^+$ and $B^+ \to D_s^- K^+ K^+$
- CP violation in $B^0 \to \eta' K^*(892)^0$
- Time-dependent CP violation in $B^0 \to \omega K^0$
- Branching fraction and longitudinal fraction of $B^+ \to \bar{K}^+(892)^0 K^*(892)^+$
- Branching fraction of $B^0 \to \eta' K^*(892)^0$

Measurement of time-dependent CP violation



$$\mathcal{P}(\Delta t, q) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}} \left(1 + \mathcal{S}\sin(\Delta m \Delta t) + \mathcal{A}\cos(\Delta m \Delta t)\right)$$

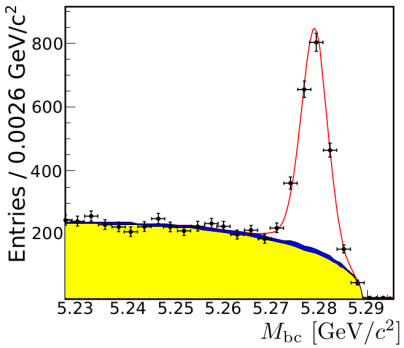
Time-dependent CP violation in $B^0 \to \eta' K^0$



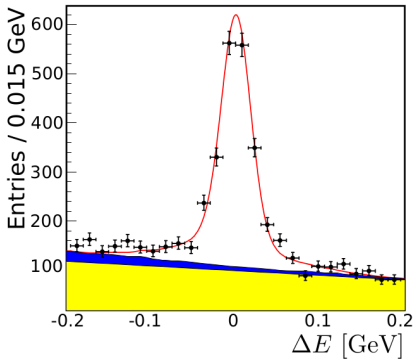
- Tree contribution suppressed
- In the Standard Model: $\mathcal{S}_{K^0\eta'} = f \sin 2\phi_1$
- Highly sensitive to new physics in the Penguin

Time-dependent CP violation in $B^0 \to \eta' K^0$

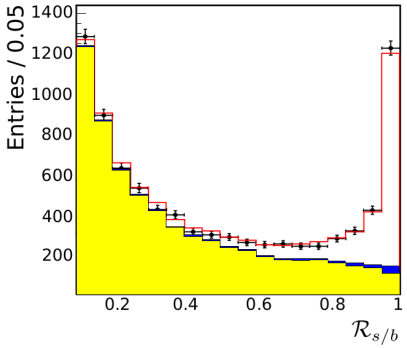
$B^0 \to \eta' K^0_S$



Beam constrained mass



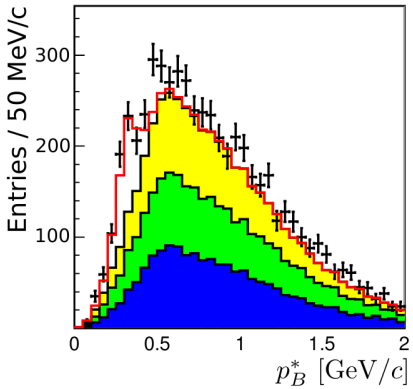
Energy difference



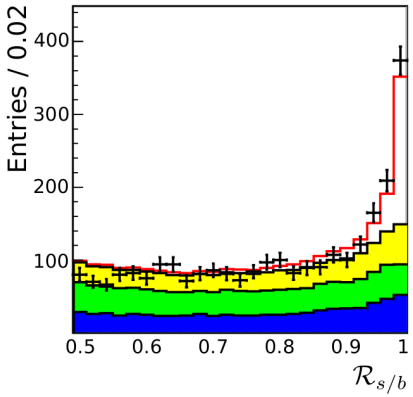
Continuum suppression

- $B\bar{B}$ BG
- $e^+e^- \to q\bar{q}$ BG

$B^0 \to \eta' K^0_L$



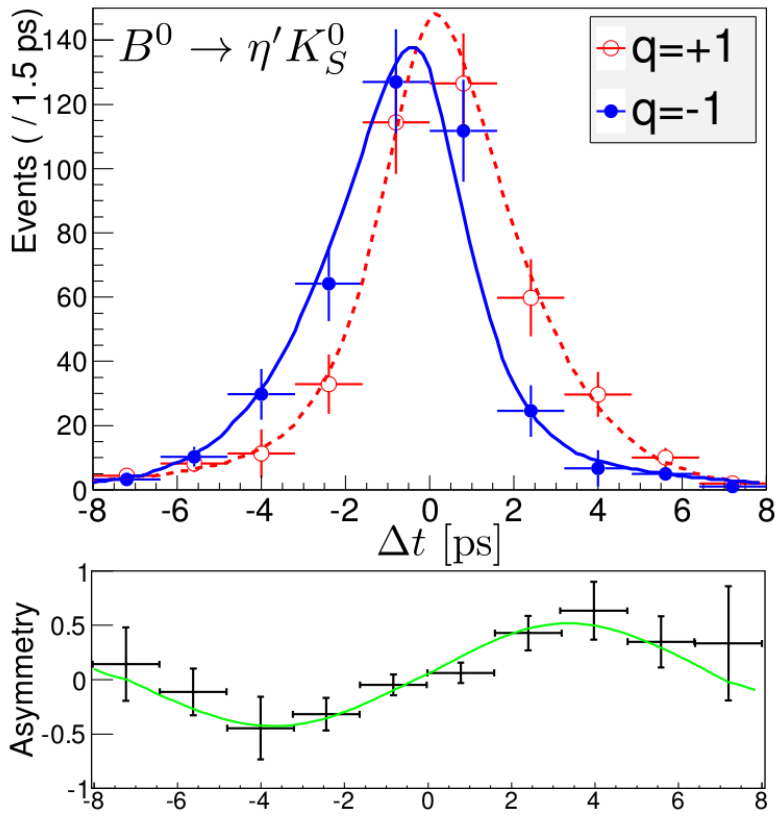
Momentum

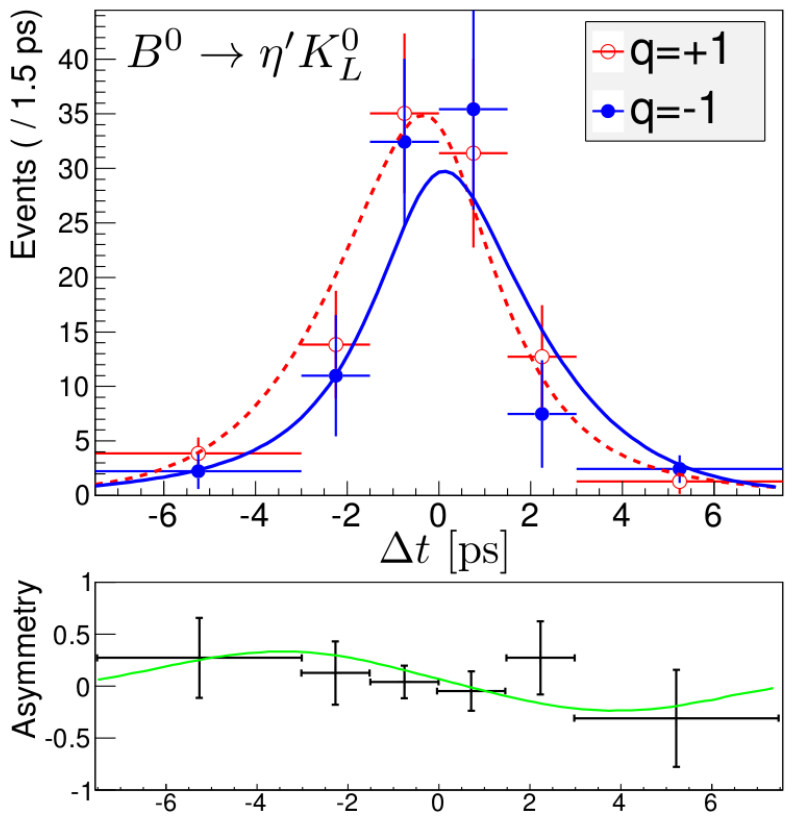


Continuum suppression

- fake η' BG
- real η', fake K_L BG
- real η', real K_L BG

Time-dependent CP violation in $B^0 \to \eta' K^0$

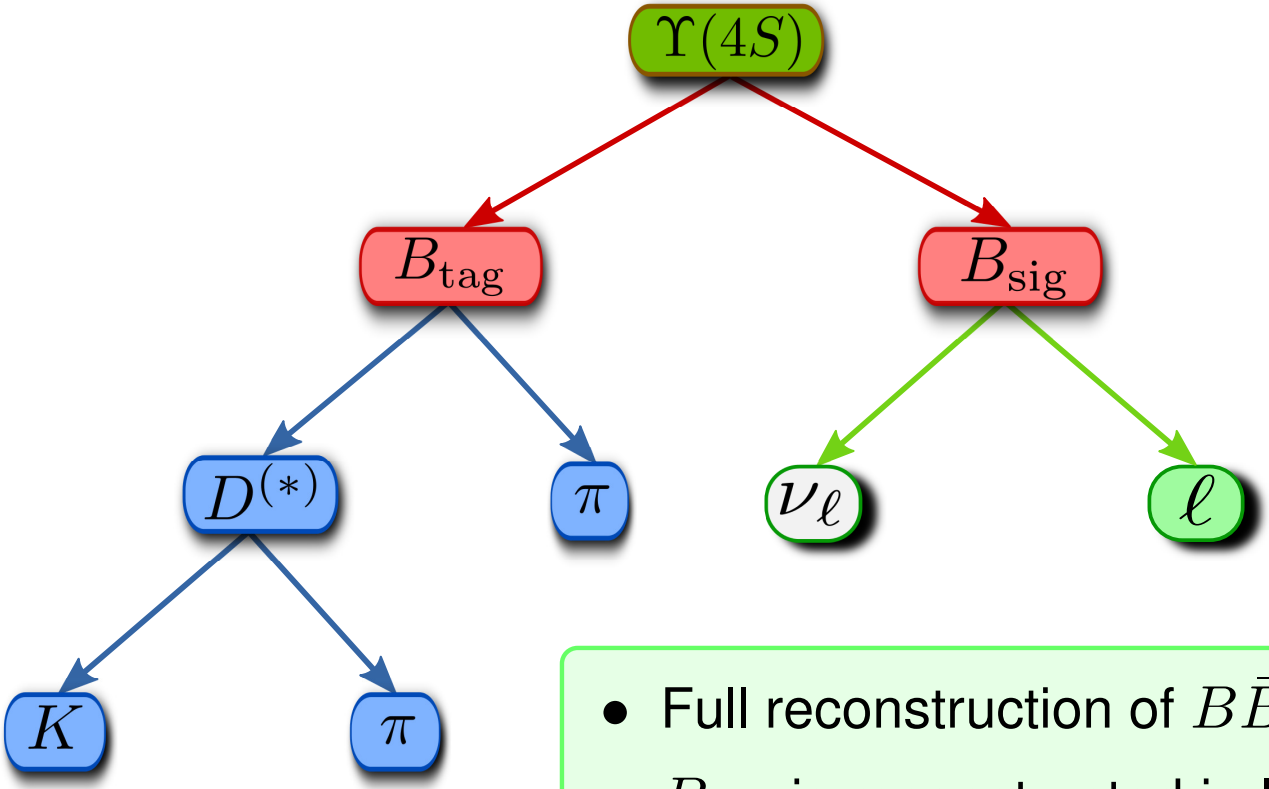




$$\mathcal{S}_{\eta' K^0} = 0.68 \pm 0.07 \pm 0.03 \qquad \mathcal{A}_{\eta' K^0} = 0.03 \pm 0.05 \pm 0.04$$

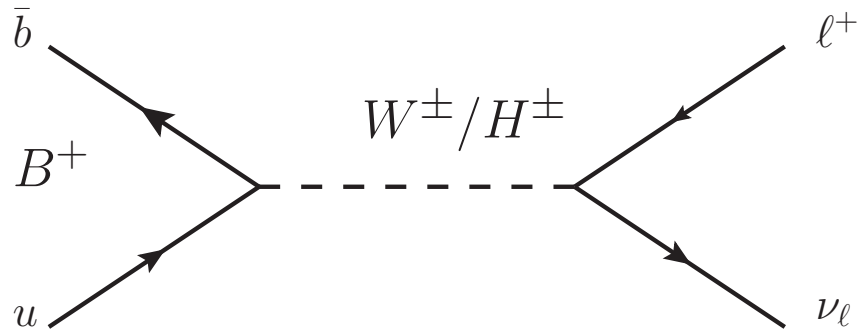
- Consistent with Standard Model expectation
- Most precise measurement

Full reconstruction



- Full reconstruction of $B\bar{B}$ events
- B_{tag} is reconstructed in large number of decay channels
- B_{tag} reconstruction efficiency of $\approx 0.3\%$
- Allows determination of charge and four-momentum of B_{sig}

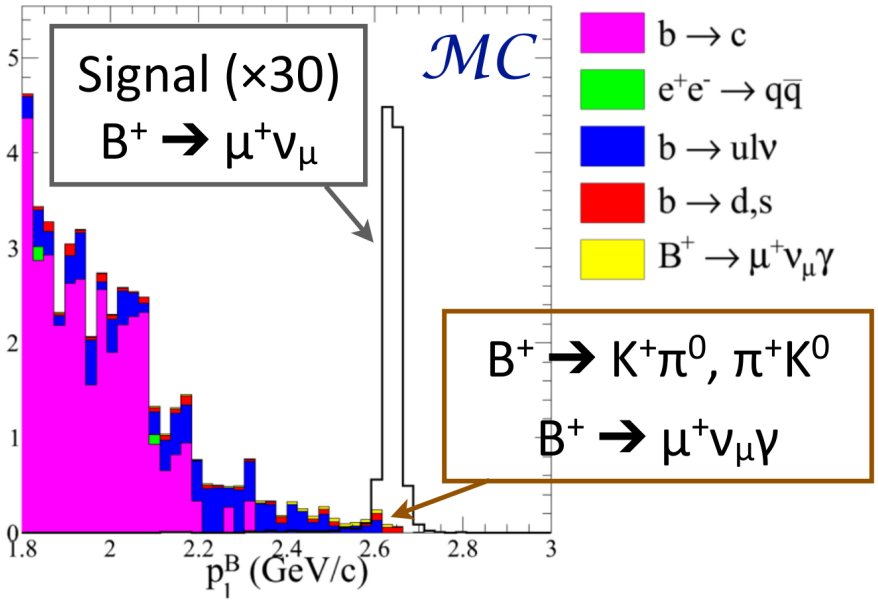
Search for $B^+ \to \mu^+\nu_\mu$ and $B^+ \to e^+\nu_e$



- $\mathcal{B}(B^+ \to \ell^+\nu_\ell)$ very sensitive to new charged particles.
  Can be lower or higher than Standard Model expectation.
- In the Standard Model:

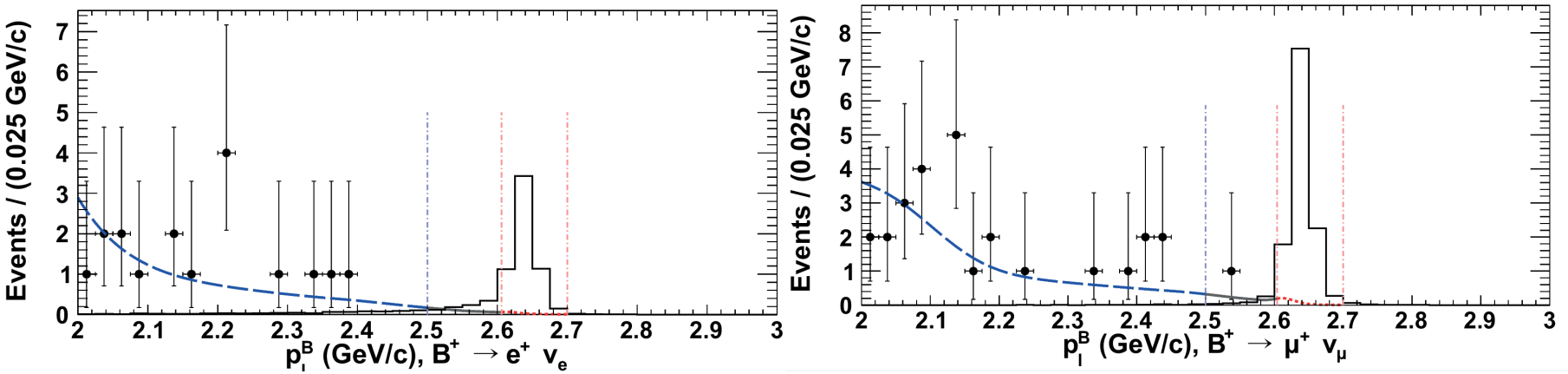
  $$\mathcal{B}(B^+ \to e^+\nu_e) = (7.9^{+0.8}_{-0.7}) \times 10^{-12}$$
  $$\mathcal{B}(B^+ \to \mu^+\nu_\mu) = (3.4 \pm 0.3) \times 10^{-7}$$
  $$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (7.5 \pm 0.7) \times 10^{-5}$$
  Measured: $\mathcal{B}(B^+ \to \tau^+\nu_\tau)_{\mathrm{WA}} = (10.5 \pm 2.5) \times 10^{-5}$
- $R^{\ell\ell'} = \mathcal{B}(B^+ \to \ell^+\nu_\ell)/\mathcal{B}(B^+ \to \ell'^+\nu_{\ell'})$
  also sensitive to certain types of new physics models.

Search for $B^+ \to \mu^+\nu_\mu$ and $B^+ \to e^+\nu_e$



- Momentum of B_{sig} is known
  $\Rightarrow$ Momentum of lepton in the rest frame of B_{sig} is known
- Two-body decay: Sharp peak at $p_\ell = 2.6$ GeV
- Background estimated from sideband and simulation

Search for $B^+ \to \mu^+\nu_\mu$ and $B^+ \to e^+\nu_e$



Signal scaled by 10^6 and 40 times SM expectation

No signal observed!

ℓ	$N_{\mathrm{bkg,exp}}$	N_{obs}	$\mathcal{B}$	$\mathcal{B}_{\mathrm{SM}}$
e	0.10 ± 0.04	0	$< 3.4 \times 10^{-6}$	$(7.9^{+0.8}_{-0.7}) \times 10^{-12}$
μ	$0.26^{+0.09}_{-0.08}$	0	$< 2.7 \times 10^{-6}$	$(3.4 \pm 0.3) \times 10^{-7}$

Branching fraction of $\bar{B} \to X_s\gamma$

Inclusive $\xrightarrow[\text{Theoretical accessibility}]{\text{Experimental accessibility}}$ **Exclusive**

Sum-of-exclusive approach is used.

X_s reconstructed in 38 decay channels

- $K\pi$
- $K\pi\pi$
- $K\pi\pi\pi$
- $K\pi\pi\pi\pi$
- $K\eta$
- KKK

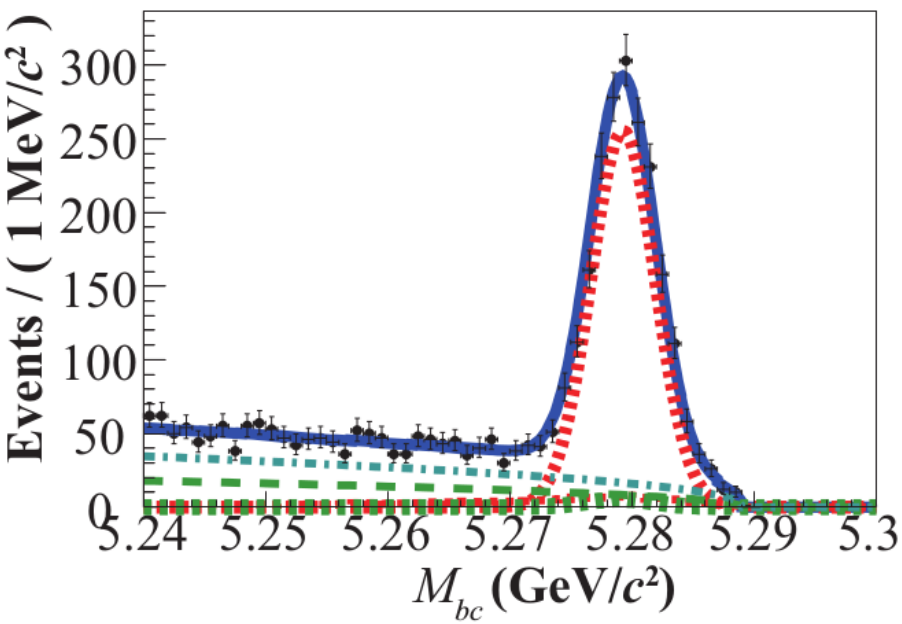
Reconstruct about 70% of X_s

Unmeasured modes are covered by fragmentation model

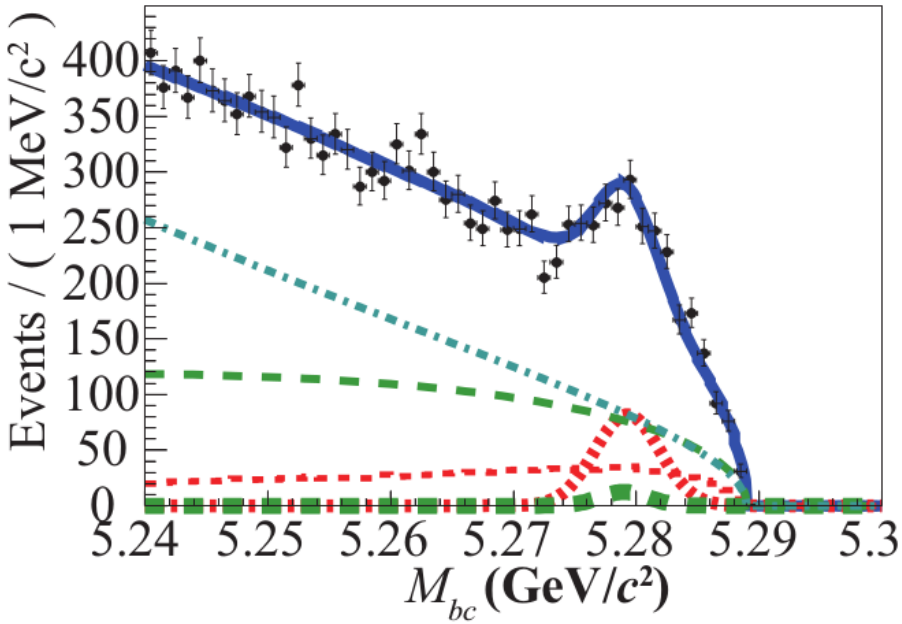
Calibration performed on part of the data sample

Branching fraction of $\bar{B} \to X_s\gamma$

Signal extraction is performed in bins of M_{X_s}

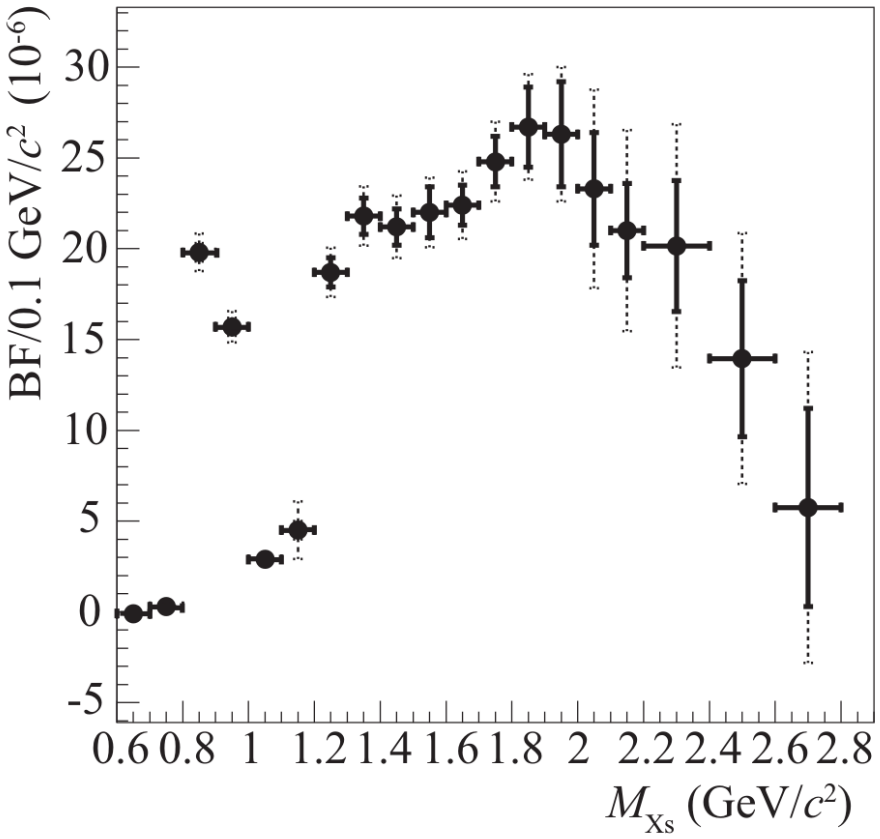


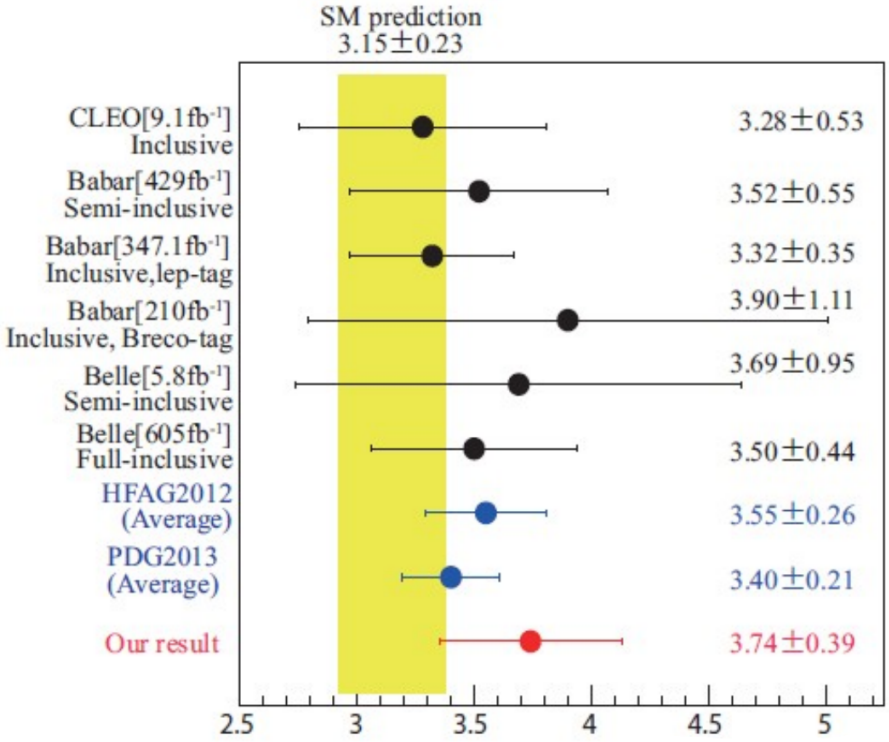
$0.9 < M_{X_s} < 1.0$ GeV



$1.9 < M_{X_s} < 2.0$ GeV

Branching fraction of $\bar{B} \to X_s\gamma$



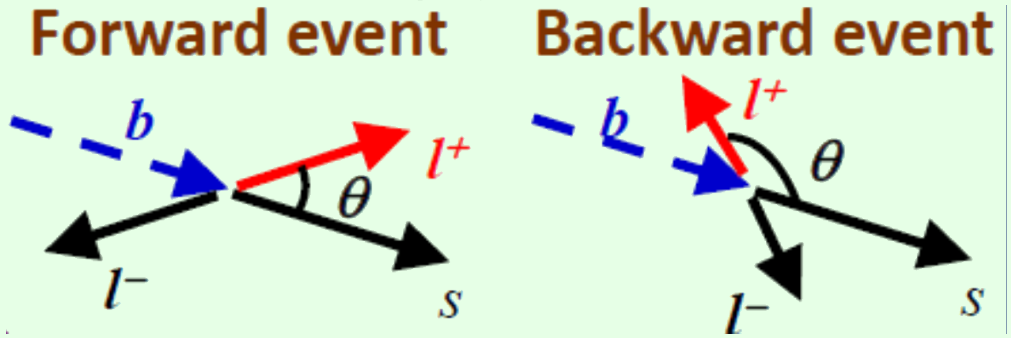


Result:

$$\mathcal{B}(\bar{B} \to X_s\gamma) = (3.51 \pm 0.17 \pm 0.33) \times 10^{-4}$$

Forward-backward asymmetry in $\bar{B} \to X_s \ell^+ \ell^-$

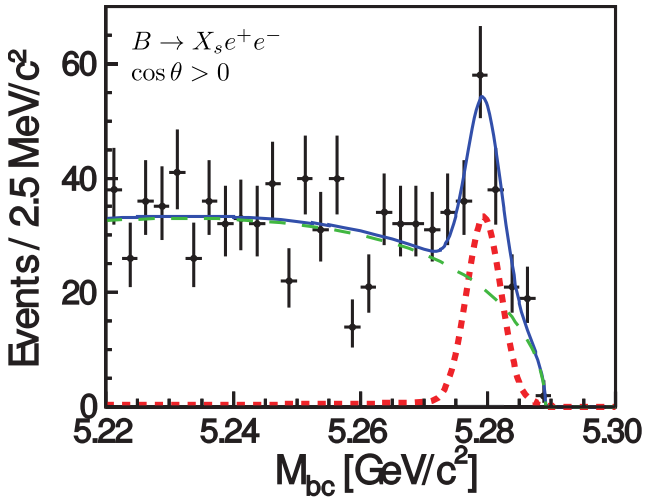
$\mathcal{A}_{\mathrm{FB}}$
Can be more sensitive to new physics



- $\mathcal{A}_{\mathrm{FB}}$ in $B \to K^* \ell^+ \ell^-$ has been measured by many experiments.
- Here: **sum-of-exclusive** method.
  X_s reconstructed in 20 decay channels.
- Measured in bins of $q^2 = M_{\ell^+ \ell^-}$

Forward-backward asymmetry in $\bar{B} \to X_s \ell^+ \ell^-$

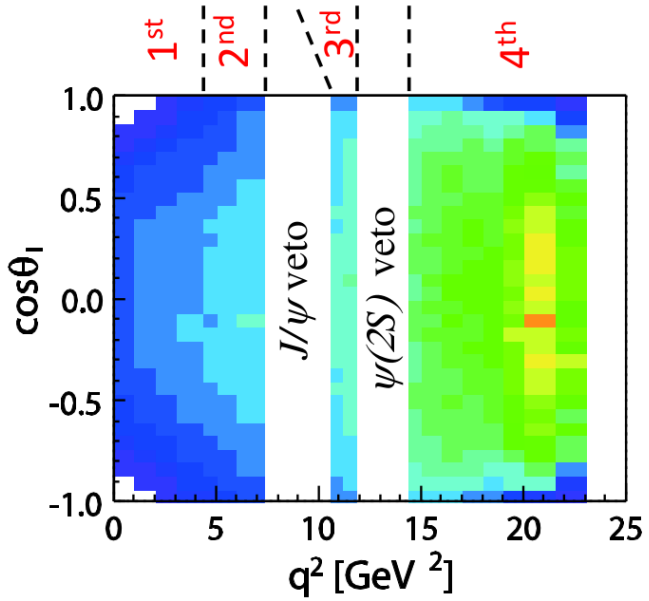
Number of signal extracted with fit on $M_{\rm bc}$:



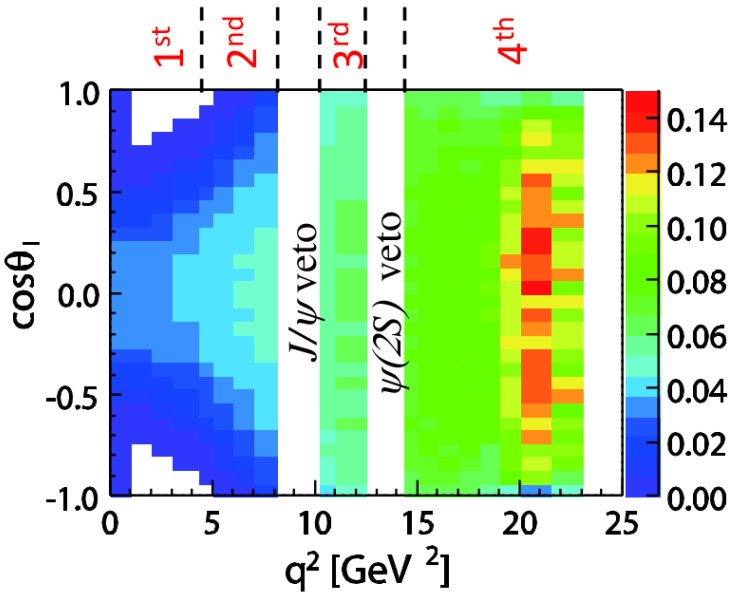
$$\mathcal{A}_{\rm FB}^{\rm raw} = \frac{N(\cos\theta>0) - N(\cos\theta<0)}{N(\cos\theta>0) + N(\cos\theta<0)}$$

$$\mathcal{A}_{\rm FB} = \alpha^{ee/\mu\mu} \mathcal{A}_{\rm FB}^{\rm raw}$$

$\alpha^{ee/\mu\mu}$: Scale factor for efficiency



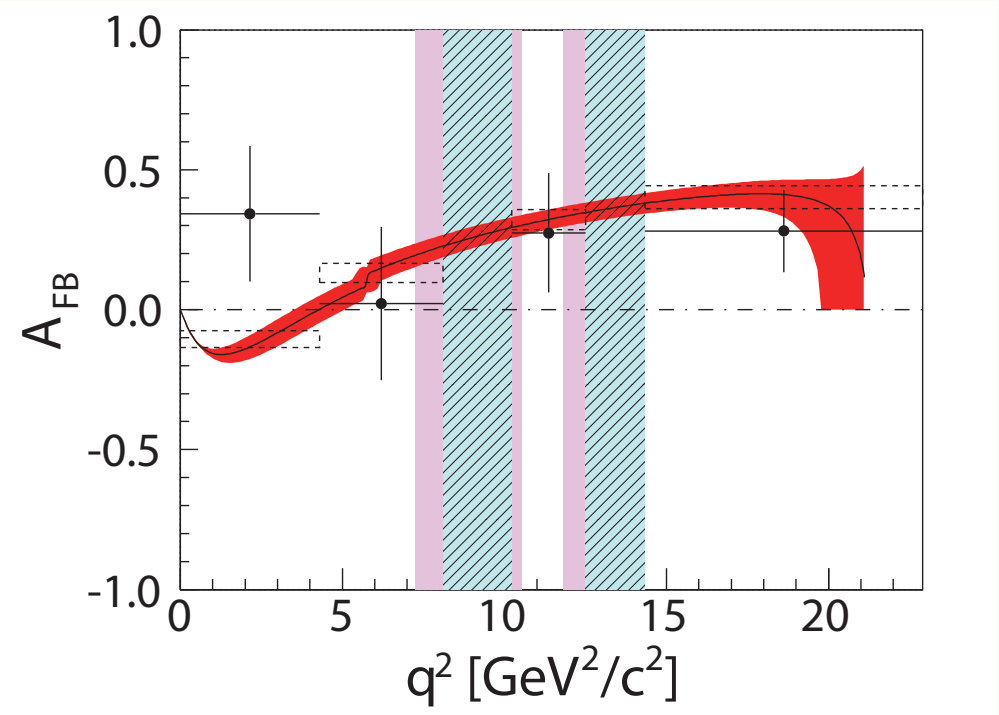
$\epsilon(X_s e^+ e^-)$



$\epsilon(X_s \mu^+ \mu^-)$

Forward-backward asymmetry in $\bar{B} \to X_s \ell^+ \ell^-$

Results



bin	$\mathcal{A}_{\mathrm{FB}}$
1	$0.34 \pm 0.24 \pm 0.02$
2	$0.04 \pm 0.31 \pm 0.05$
3	$0.28 \pm 0.21 \pm 0.01$
4	$0.28 \pm 0.15 \pm 0.01$

- Result consistent with the Standard Model
- Can be used to constrain various extensions of the Standard Model

Conclusion

- The Belle collaboration has a wide physics program
- Four results have been presented,
  all of them performed with the full Belle data sample
- A lot more were presented recently
  and are published or will be published soon
- No sign of new physics (yet)