$B^{\pm} \to \omega K^{\pm}/\pi^{\pm}$ and Time-dependent CPV in $B \to \eta' Ks$ at Belle

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The Belle Collaboration

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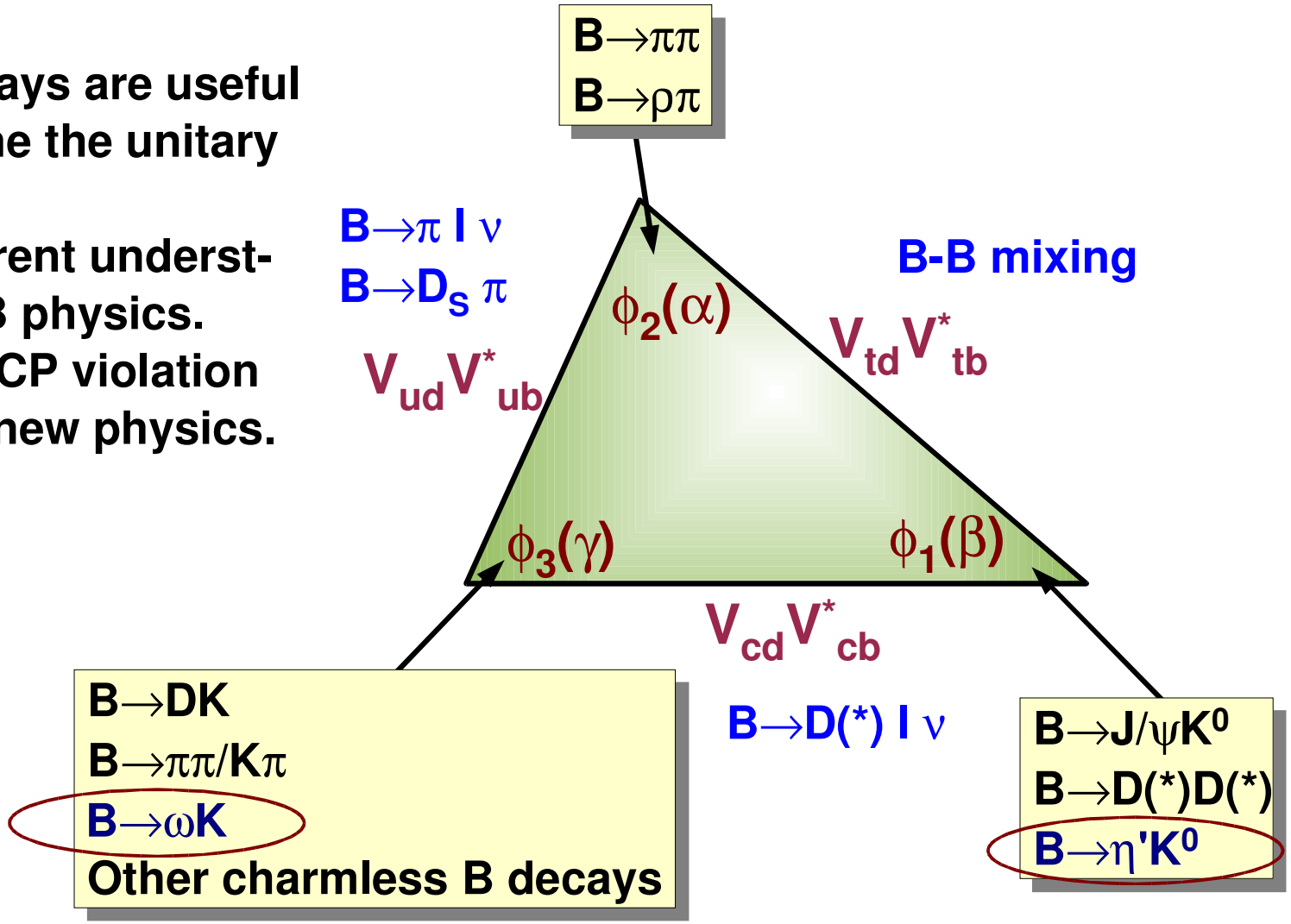
Outline

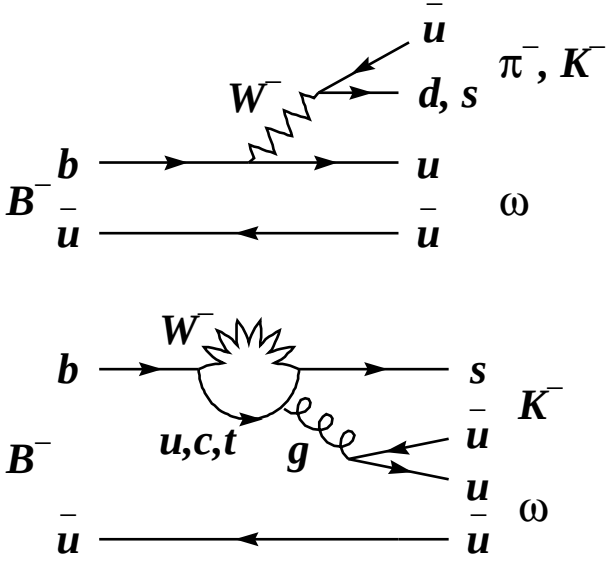
- **Introduction**
- **$B^{\pm} \to \omega K^{\pm}$**
- **CP in $B \to \eta' Ks$**
- **Summary**

Intoduction

- Rare B decays are useful to determine the unitary triangle.
- Test of current understanding of B physics.
- Search for CP violation and probe new physics.



$B^{\pm}\to\omega h^{\pm}$ Introduction

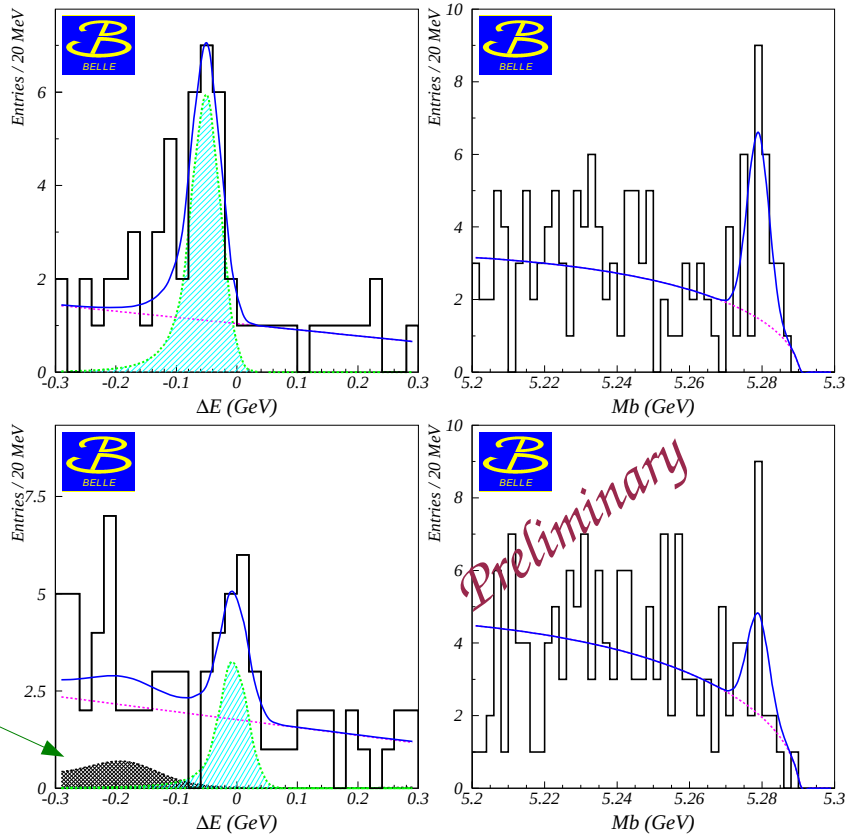


- **$B^{\pm}\to\omega h^{\pm}$ can test B decay models.**
- **Useful to search for direct CP violation.**
- **Brief History:**
  - **CLEO first reported the $B^{\pm}\to\omega K^{\pm}$ decay branching fractions in 1998.** [PRL **81**, 272(1998)]
  - **$B^{\pm}\to\omega\pi^{\pm}$ is found to be larger than $\omega K^{\pm}$ with new data set.** [PRL **85**, 2881(2000)]
  - **BaBar confirms $B^{\pm}\to\omega\pi^{\pm}$>$\omega K^{\pm}$.** [PRL **87**, 221802(2001)]

	$\mathcal{B}(B\to\omega\pi)\times10^{-6}$	$\mathcal{B}(B\to\omega K)\times10^{-6}$
CLEO(1998)	<2.3	$15^{+7}_{-6}\pm2$
CLEO(2000)	$11.3^{+3.3}_{-2.9}\pm1.5$	<8 $[3.2^{+2.4}_{-1.9}\pm0.8]$
BaBar(2001)	$6.6^{+2.1}_{-1.8}\pm0.7$	<4 $[1.4^{+1.3}_{-1.0}\pm0.3]$

$B^{\pm} \to \omega h^{\pm}$ Results

- **Results from 31.9M $B\bar{B}$ pairs.**
- **Yields are extracted by a 2-dimensional unbinned likelihood method.**



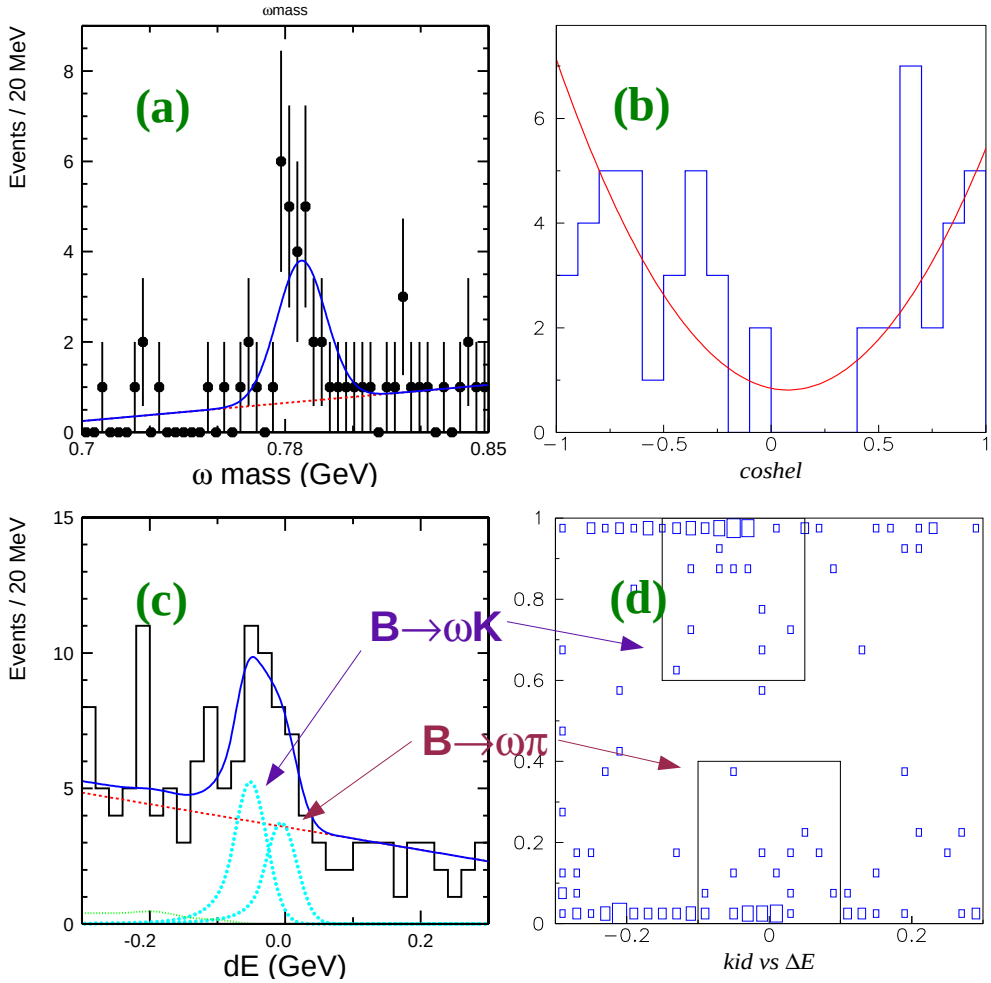
$B^{\pm} \to \omega K^{\pm}$

$B^{\pm} \to \omega \pi^{\pm}$

Background from B decays

	Yield	Σ	ε	$\mathcal{B}(\times 10^{-6})$	U.L
$B \to \omega\pi$	$\mathbf{10.6^{+4.8+0.4}_{-4.5-0.6}}$	3.3σ	7.7%	$\mathbf{4.3^{+2.0}_{-1.8} \pm 0.5}$	<8.2
$B \to \omega K$	$\mathbf{19.7^{+5.4+0.7}_{-4.8-0.5}}$	6.4σ	6.3%	$\mathbf{9.9^{+2.7}_{-2.4} \pm 1.0}$	-

Consistency Checks



(a) A clear ω peak shown in $\pi^+\pi^-\pi^0$ spectrum with B candidate.

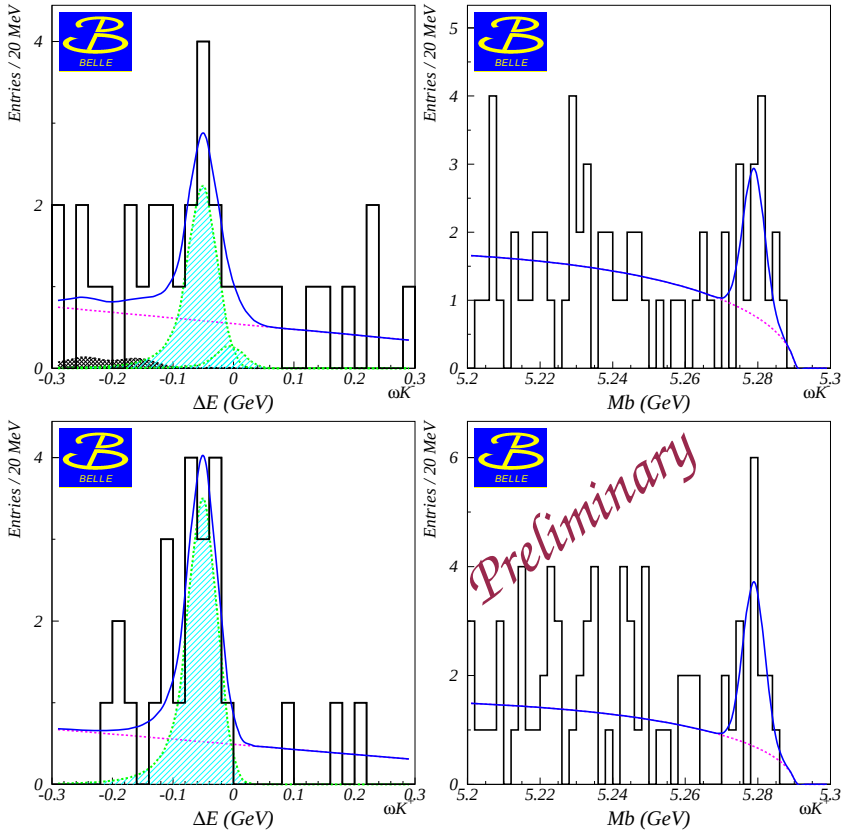
(b) The ω helicity angle distribution matches **P→VP** decay.

(c),(d) By removing the KID requirement, the ΔE distribution is consistent with **ωK** and **ωπ** yields.

Direct CPV in $B^{\pm} \to \omega K^{\pm}$

- **Search for Acp in $B^{\pm} \to \omega K^{\pm}$ mode.**
- **Acp(= $\frac{\omega K^- - \omega K^+}{\omega K^- + \omega K^+}$) = -0.22±0.27±0.04**

  (-0.70<Acp<0.26 @ 90% C.L.)



$B \to \omega K^-$
7.4±3.5 events

$B \to \omega K^+$
11.6±3.7 events

Summary of $B^{\pm} \to \omega h^{\pm}$

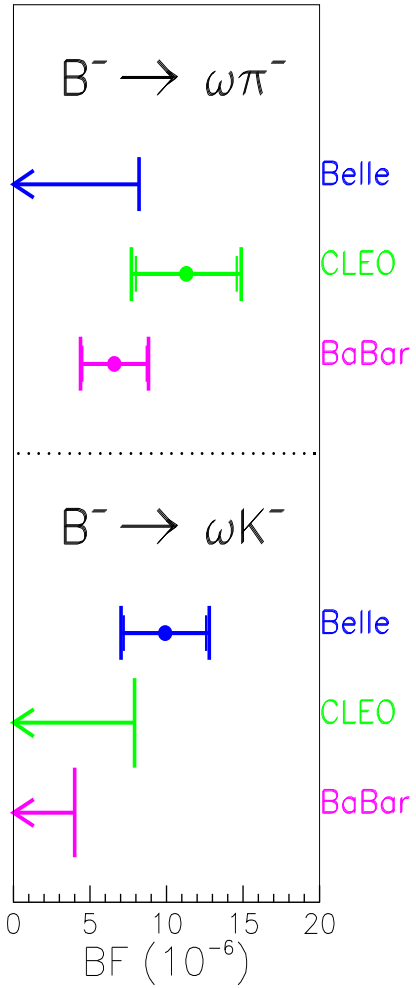
- **We have observed $B^{\pm} \to \omega K^{\pm}$, and evidence for $B^{\pm} \to \omega \pi^{\pm}$.**

$$\mathcal{B}(\omega K^{\pm}) = (9.9^{+2.7}_{-2.4} \pm 1.0) \times 10^{-6}\ (6.4\sigma)$$

$$\mathcal{B}(\omega \pi^{\pm}) = (4.3^{+2.0}_{-1.8} \pm 0.5) \times 10^{-6}\ (3.3\sigma) < 8.2 \times 10^{-6}$$

- **Compare results with other experiments:**

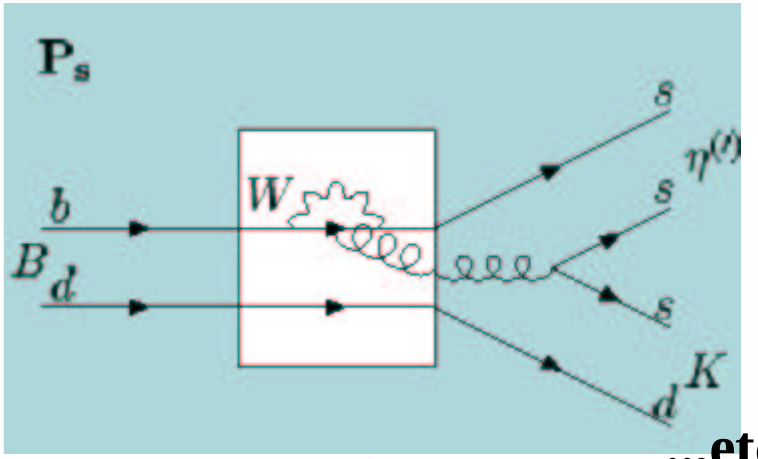
	$\mathcal{B}(B \to \omega\pi) \times 10^{-6}$	$\mathcal{B}(B \to \omega K) \times 10^{-6}$
Belle(2002)	$<8.2\ [4.3^{+2.0}_{-1.8} \pm 0.5]$	$9.9^{+2.7}_{-2.4} \pm 1.0$
BaBar(2001)	$6.6^{+2.1}_{-1.8} \pm 0.7$	$<4\ [1.4^{+1.3}_{-1.0} \pm 0.3]$
CLEO(2000)	$11.3^{+3.3}_{-2.9} \pm 1.5$	$<8\ [3.2^{+2.4}_{-1.9} \pm 0.8]$



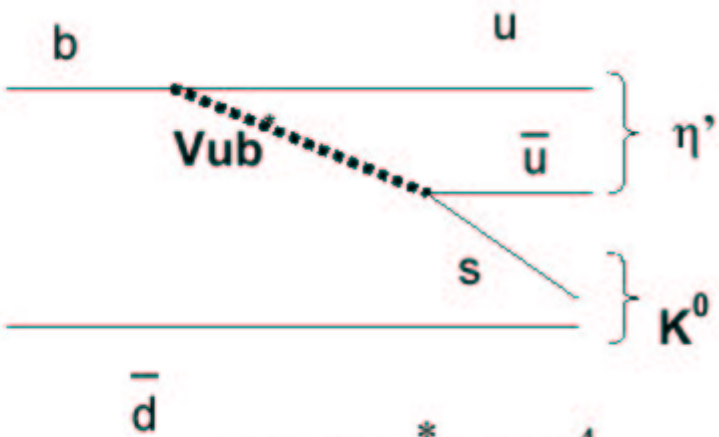
- **Acp($\omega K^{\pm}$) = -0.22±0.27±0.04**
  (-0.70<Acp<0.26 @ 90% C.L.)

CPV in B→η'K

- **Within the SM, B→η'K consists of penguin process and contribution from tree diagrams.**



..,etc.



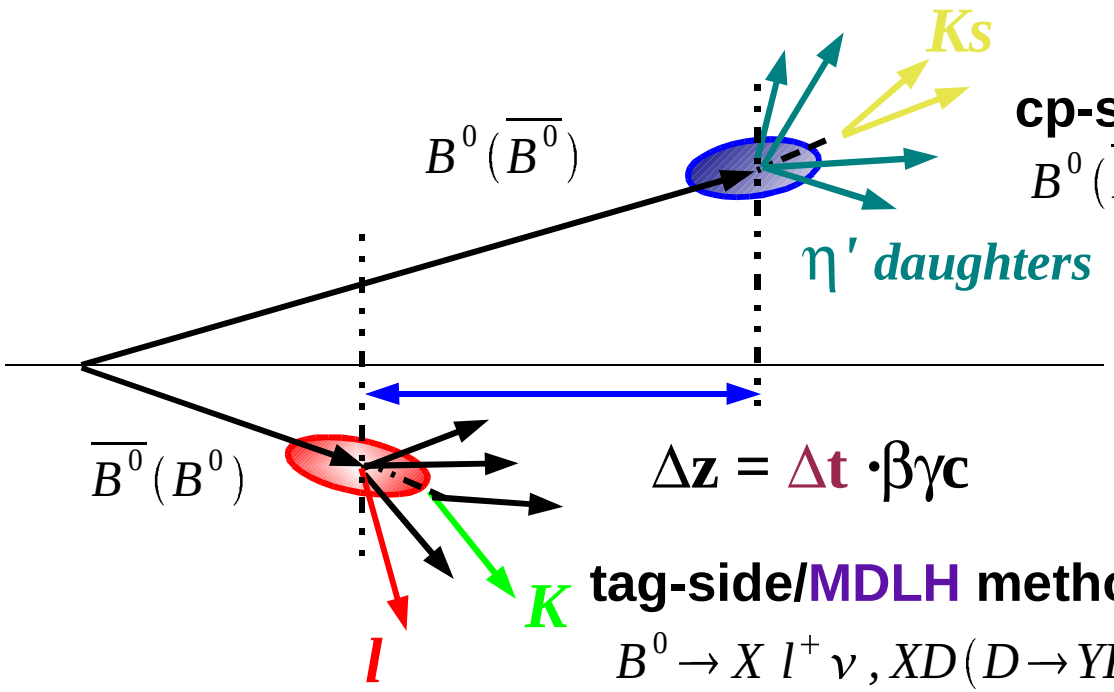
$$V_{tb}V_{ts}^{*} \propto \lambda^{2} \qquad V_{ub}V_{us}^{*} \propto \lambda^{4}$$

- **The time-dependent CP asymmetry can be expressed as:**

$$A_{CP}(\Delta t)=\frac{\Gamma(\overline{B^0}(t)\to\eta' K_S)-\Gamma(B^0(t)\to\eta' K_S)}{\Gamma(\overline{B^0}(t)\to\eta' K_S)+\Gamma(B^0(t)\to\eta' K_S)}=A_{\eta' K_S}\cos\Delta m\Delta t+S_{\eta' K_S}\sin\Delta m\Delta t$$

$$\approx S_{\eta' K_S}\sin\Delta m\Delta t=sin2(\phi_1+\phi_{NP})\sin\Delta m\Delta t \quad (\text{If } A_{\eta' K_S}=0)$$

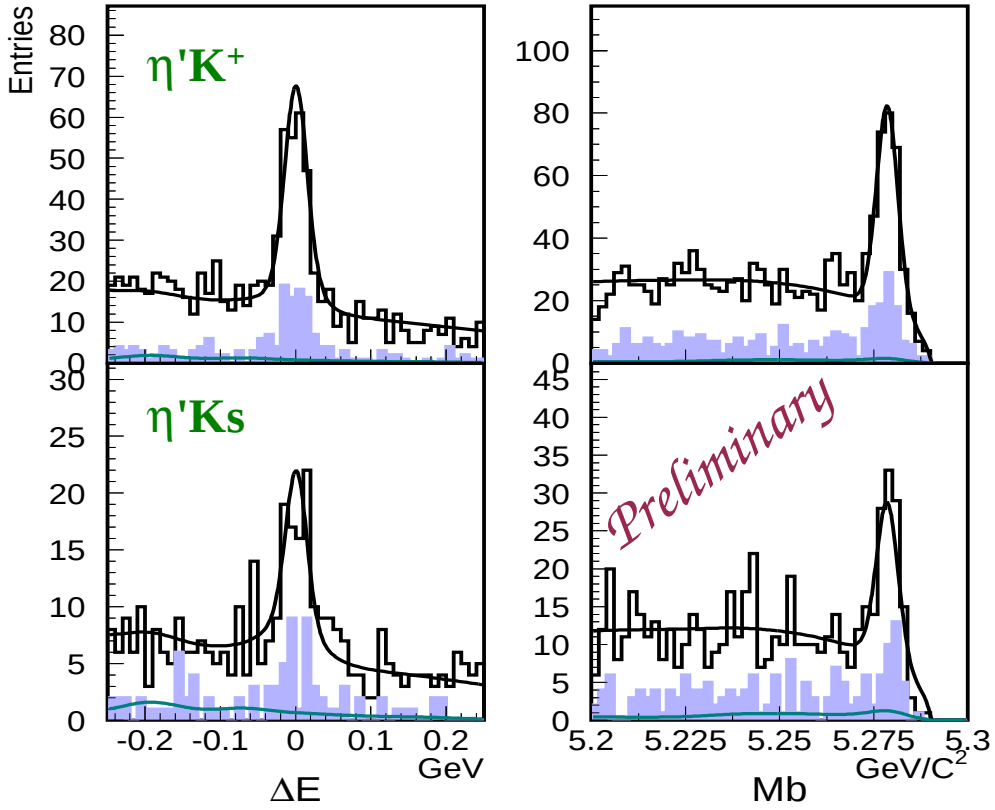
Time-dependent Measurement



- **Fully reconstruct B→η'Ks as cp-side.(η'K± as control sample)**
- **The b-flavor is determined by the accompanying B meson(Btag) by a multi-dimensional likelihood method(MDLH).**
- **Determine the CP parameters from the Δt distribution by an unbinned likelihood fit.**

B→η'K Reconstruction

- **Data set for this analysis is 42fb^{-1}.**
- **Two sub decay modes of η' are reconstructed:**
  η'→ηππ and η'→ργ .
- **A unbinned 2-dimensional likelihood fit is performed.**



η'→ηππ
Combined
expected BB̄ background

$N(\eta\pi\pi\ K^+) = 78.5^{+9.6}_{-9.1}$

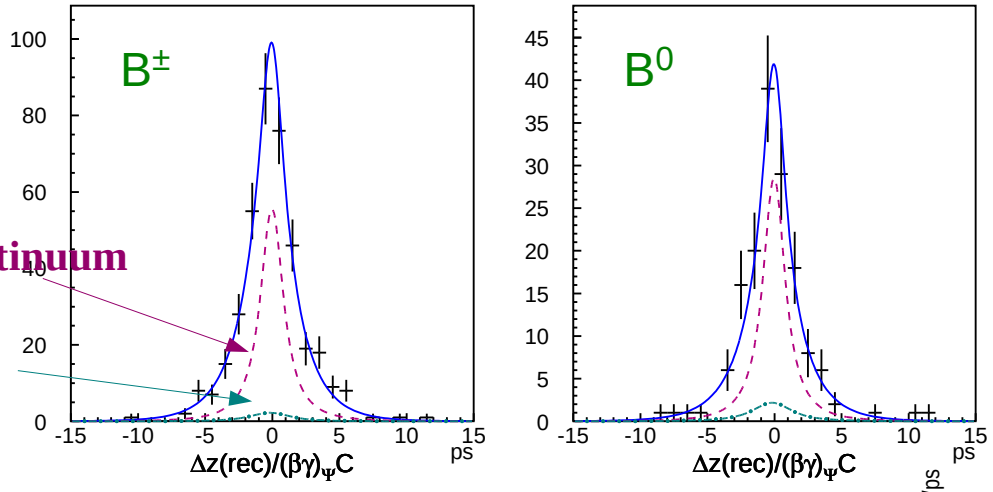
$N(\rho\gamma\ K^+) = 150 \pm 14$

$N(\eta\pi\pi\ Ks) = 27.4^{+6.2}_{-5.6}$

$N(\rho\gamma\ Ks) = 45.7^{+8.6}_{-7.9}$

Consistency Checks

- **Checks by B-lifetime fit with 229 $\eta'K^{\pm}$ and 73 $\eta'K_S$ events:**



$\tau(B^{\pm}) = 1.54^{+0.14}_{-0.13}$ ps

(PDG: 1.653±0.028 ps)

$\tau(B^{0}) = 1.58^{+0.31}_{-0.26}$ ps

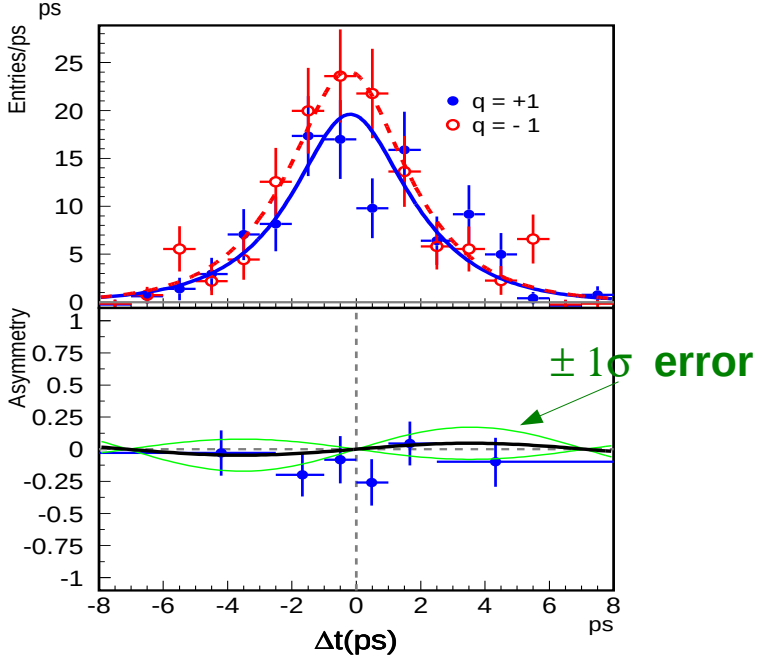
(PDG: 1.548±0.032 ps)

- **CP-fit with non-asymmetric sample: $\eta'K^{\pm}$**

" $\sin2(\phi_1+\phi_{NP})$" = $0.11^{+0.29}_{-0.30}$

" $S(\eta'K^{\pm})$" = 0.11±0.29

" $A(\eta'K^{\pm})$" = -0.27±0.17



Time-dependent Acp

- **CP-fit is performed with 73 η'Ks signal candidates.**

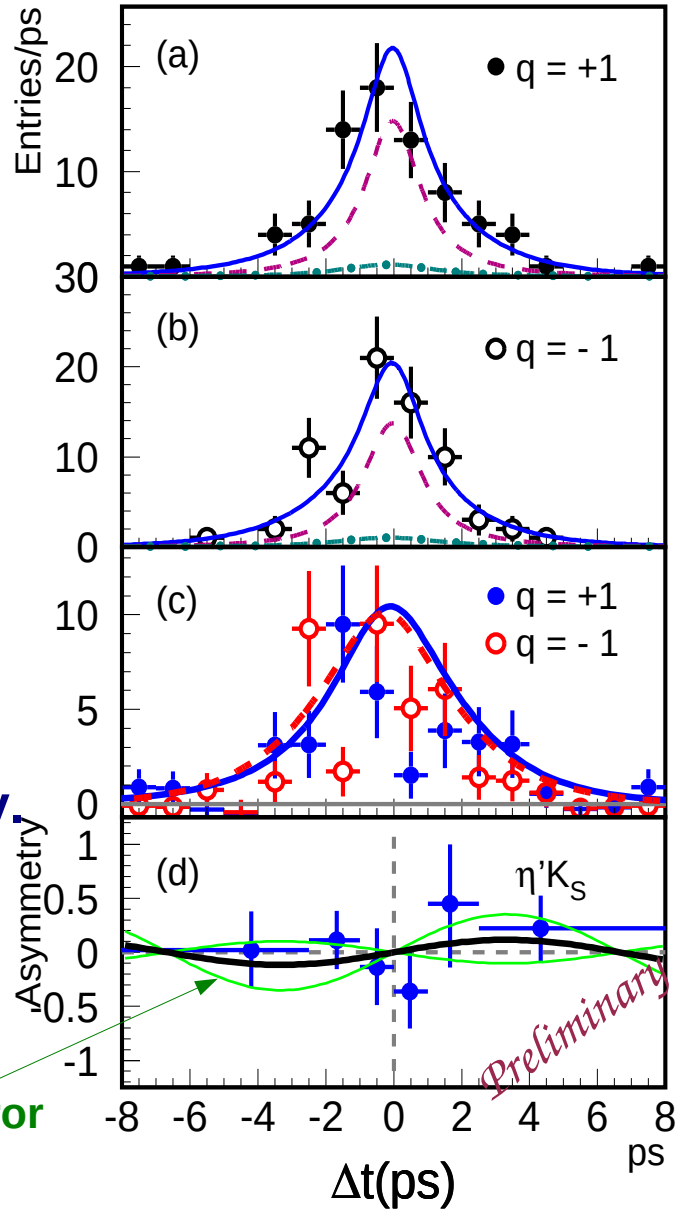
$$S(\eta'Ks) = 0.27^{+0.54}_{-0.55}$$

$$A(\eta'Ks) = 0.12 \pm 0.32$$

If A(η'Ks) is set to be zero:

$$\sin 2(\phi_1+\phi_{NP}) = 0.29^{+0.53}_{-0.54}$$

- **First measurement of time-dependent CPV in B→η'Ks decay.**
- **Probe phases from New Physics.**



Systematic Uncertainties

- **Systematic uncertainties are determined by repeating fit on data with ±1σ to each parameters.**
- **Systematic uncertainties include**

	S(η'Ks)	A(η'Ks)	sin2(φ1+ϕ_{NP})
Vertexing/track selection	+0.02/-0.03	+0.03/-0.03	+0.02/-0.02
Physics parameters	+0.03/-0.03	+0.01/-0.00	+0.02/-0.03
Wtag fractions	+0.03/-0.03	+0.01/-0.01	+0.03/-0.02
Resolution function	+0.04/-0.03	+0.01/-0.01	+0.04/-0.03
PDF functions	+0.03/-0.03	+0.06/-0.05	+0.04/-0.04
Event fractions	+0.02/-0.02	+0.01/-0.01	+0.02/-0.02
BB background	+0.02/-0.02	+0.00/-0.01	+0.02/-0.01
Sum	+0.07/-0.07	+0.07/-0.07	+0.07/-0.07

Preliminary

Summary of CPV in η'K

- **First measurement of time-dependent CPV parameters in B→η'Ks decay**
- **Probe for phases from New Physics.**

$$S(\eta' K_S) = 0.27^{+0.54}_{-0.55}\,(\text{stat.}) \pm 0.07(\text{syst.})$$

$$A(\eta' K_S) = 0.12 \pm 0.32(\text{stat.}) \pm 0.07(\text{syst.})$$

If A(η'Ks) set to be zero:

$$\sin 2(\phi_1+\phi_{NP}) = 0.29^{+0.53}_{-0.54}\,(\text{stat.}) \pm 0.07(\text{syst.})$$

Preliminary

Belle

$$\sin 2(\phi_1) = 0.82 \pm 0.12(\text{stat.}) \pm 0.05(\text{syst.})$$

Conclusion

$B^{\pm} \to \omega h^{\pm}$

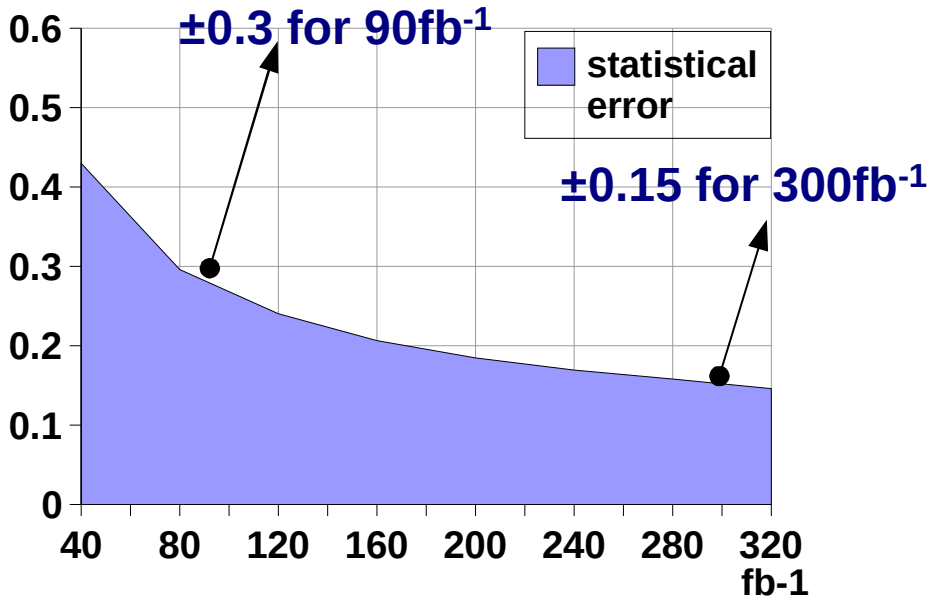
- We have observed $B \to \omega K^{\pm}$
- Evidence for $B \to \omega \pi^{\pm}$.
- First look at direct CPV in $B \to \omega K^{\pm}$.

CP in $B \to \eta' K$

- First measurement of time-dependent CPV in $B \to \eta' K_S$ decay.

Perspectives

- More data are coming soon
  - 8 fb^{-1} per month.
  - 90fb^{-1} for summer.



Statistical Error VS. Luminosity