Measurement of the Angle $\phi_1(\beta)$ and $B\bar{B}$ Mixing

(Recent results from BaBar and Belle)

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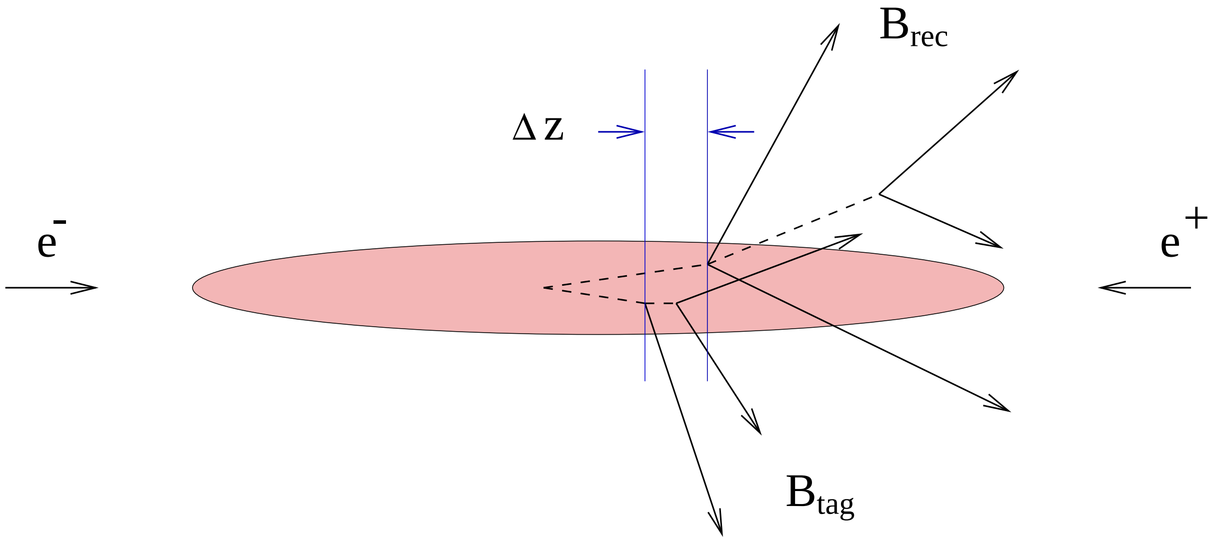
$e^+e^- \to \Upsilon(4S) \to B\bar{B}$

Charge-conjugation is conserved in $\Upsilon(4S) \to B^0\bar{B}^0$ decay. $(C = -1)$
Time structure stays $\psi(t) = |B^0 > |\bar{B}^0 > -|\bar{B}^0 > |B^0 >$ at any t



BaBar: $9\ \mathrm{GeV} \times 3.1\ \mathrm{GeV} \to \Delta z \simeq 260\mu\mathrm{m}$
Belle: $8.5\ \mathrm{GeV} \times 3\ \mathrm{GeV} \to \Delta z \simeq 200\mu\mathrm{m}$
$\Delta t = \Delta z/\gamma\beta c$

Interaction region (KEKB):
$2.3\mu\mathrm{m(y)} \times 100\mu\mathrm{m(x)} \times 7\mathrm{mm(z)}$
much larger than Δz

Time-reference is given by the decay point of other B (Δt measurement).

Flavor of B_{rec} is opposite of B_{tag} at $\Delta z = 0$ (Flavor-tagging).

$B\bar{B}$ Mixing

- Mass and flavor eigenstates:

$$| B_1 >= p \mid B^0 > +q \mid \overline{B^0} >$$
$$| B_2 >= p \mid B^0 > -q \mid \overline{B^0} >$$

- Well-defined time dependence of $(B_1,\ B_2)$
  Flavor-specific decays of $(B^0,\ \bar{B}^0)$ $\Big\}$ lead to $B^0\bar{B}^0$ oscillation

$$P^{\rm OF} \propto \frac{e^{-|\Delta t/\tau_{B^0}|}}{4\tau_{B^0}}\left[1+\cos(\Delta m_d \Delta t)\right], \quad P^{\rm SF} \propto \frac{e^{-|\Delta t/\tau_{B^0}|}}{4\tau_{B^0}}\left[1-\cos(\Delta m_d \Delta t)\right]$$

Lifetime distributions with $1 \pm \cos(\Delta m_d \Delta t)$ modulation.

- $B_{\rm rec}$: $D^{(*)}\pi$, $D^{(*)}\rho$, $D^{(*)}l\nu$, $\cdots$ (flavor-specific states)

  dilepton: $B_{\rm rec} = B_{\rm tag}$=lepton only(special case)

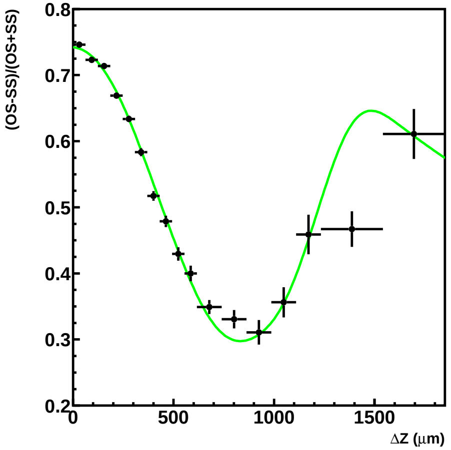
- $B_{\rm rec}$ for CP analysis: $J/\psi K_S, J/\psi K_L, \cdots$ (CP-eigenstates)

  Lifetime distributions with $1 \pm \sin 2\phi_1 \sin(\Delta m_d \Delta t)$ modulation.

(OF-SF)/(OF+SF) Asymmetries

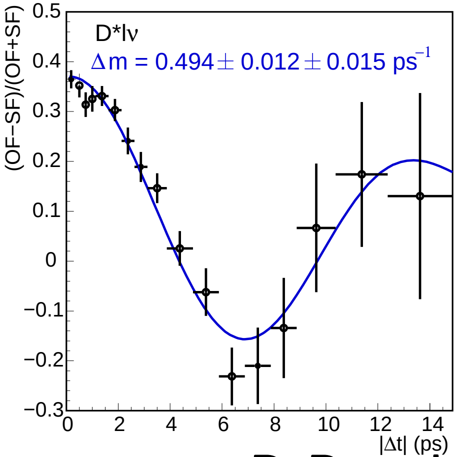
Belle dilepton

(32M $B\bar{B}$)



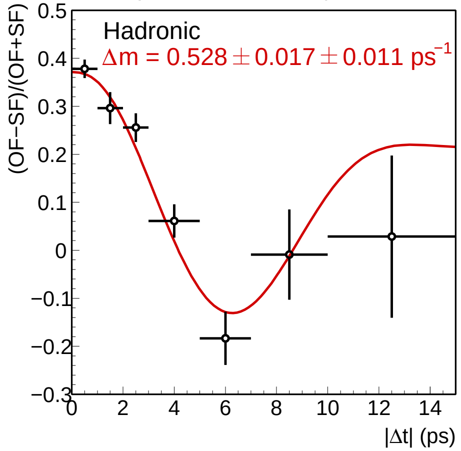
Belle s.l.

(32M $B\bar{B}$)



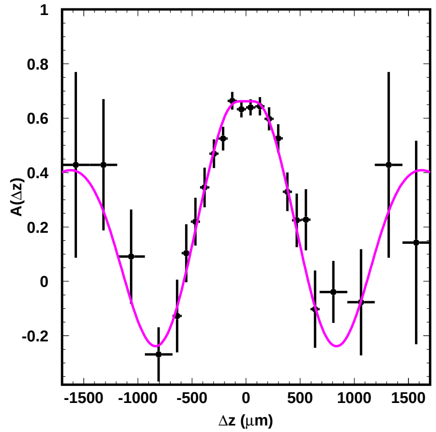
Belle hadronic

(32M $B\bar{B}$)



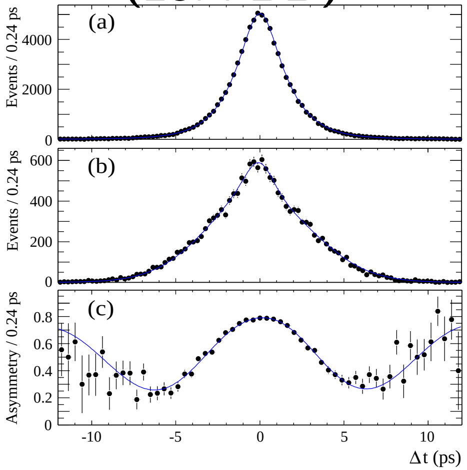
Belle $D^*\pi$ partial

(32M $B\bar{B}$)



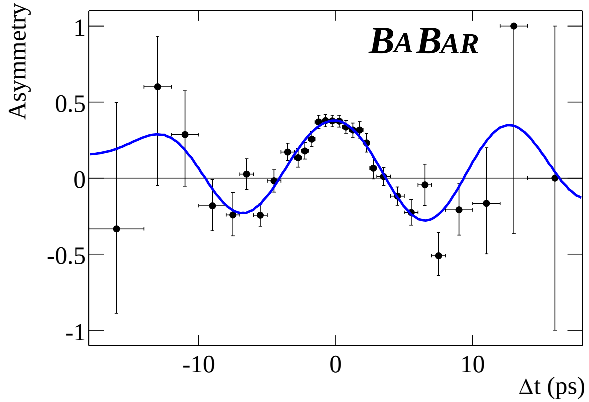
BaBar dilepton

(23M $B\bar{B}$)



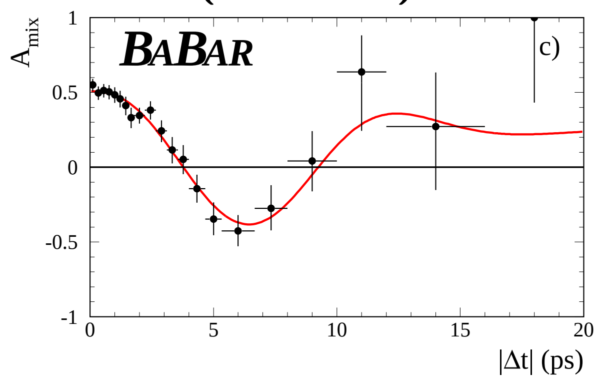
BaBar s.l.

(23M $B\bar{B}$)



BaBar hadronic

(32M $B\bar{B}$)



Δm_d Results

- BaBar+Belle:

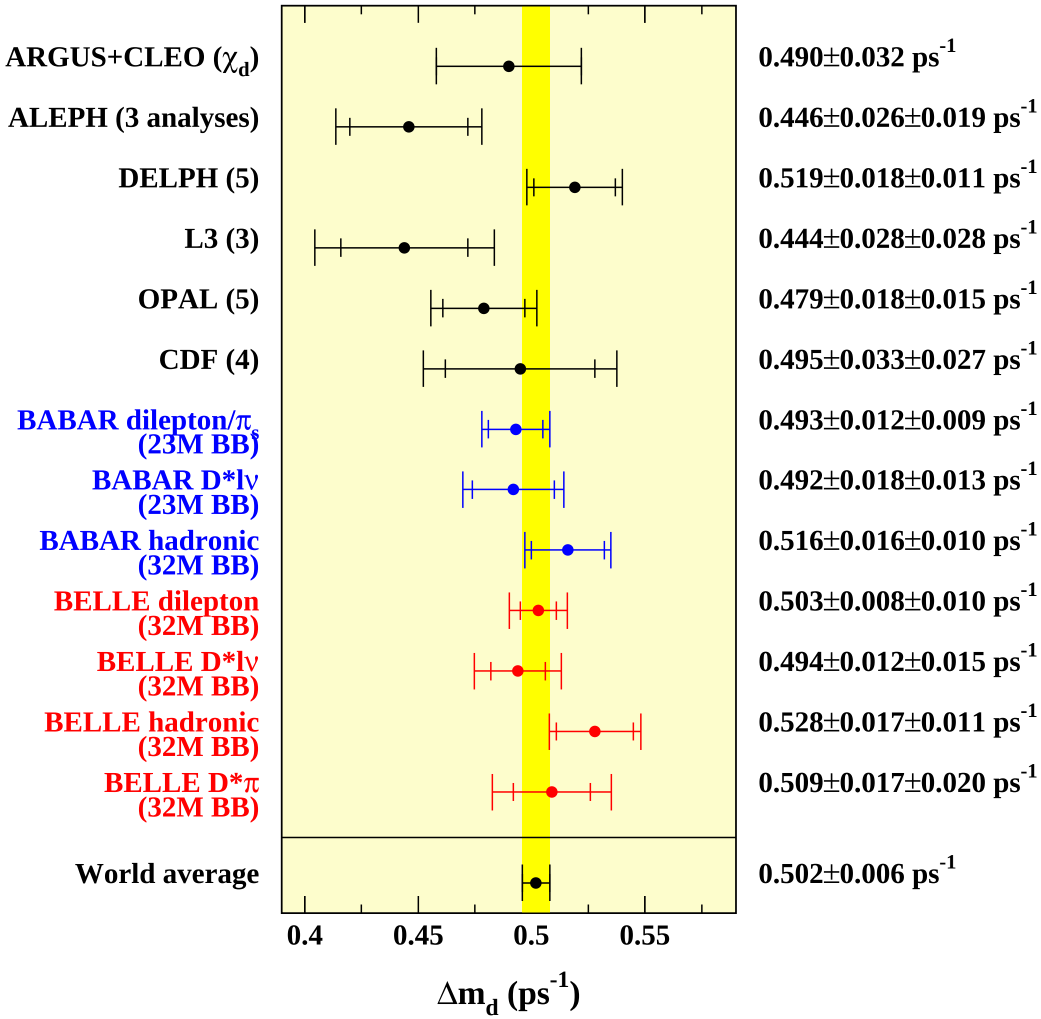
  $\Delta m_d = 0.504 \pm 0.007\ \text{ps}^{-1}$

- World average:

  $\Delta m_d = 0.502 \pm 0.006\ \text{ps}^{-1}$

- 1.2% accuracy

  What is this good for?



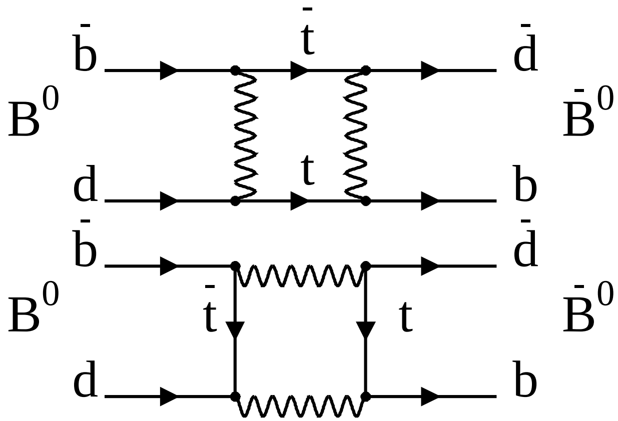
$B\bar{B}$ Mixing in Standard Model

- Box-diagram is responsible for $B\bar{B}$ mixing.

$$\Delta m_d = m_{\rm H} - m_{\rm L} = 2|M_{12}|$$

(redefine $B_1,\ B_2$ with $B_{\rm H},\ B_{\rm L}$)

$$M_{12} = -\frac{G_F^2 m_W^2 \eta_B m_B B_B f_B^2}{12\pi^2} S_0(m_t^2/m_W^2)(V_{td}^* V_{tb})^2$$



- $|V_{td}|$ extraction is dominated by $f_{B_d}\sqrt{B_{B_d}} = 230 \pm 40$MeV. Precise Δm_d does not help. (Lattice QCD approach, Δm_s measurement)

- Mixing also has absorptive part: $\Delta\Gamma = \Gamma_{\rm L} - \Gamma_{\rm H} = 2|\Gamma_{12}|$

- $\Delta\Gamma$ is tiny: $\left|\frac{\Gamma_{12}}{M_{12}}\right| \sim \frac{\Delta\Gamma}{\Gamma} \simeq \frac{3\pi}{2}\frac{m_b^2}{m_W^2}\frac{1}{S_0(m_t^2/m_W^2)} \sim 5 \times 10^{-3}(\pm 30\%)$

  Any deviation will be difficult to explain in SM. Interesting

$\Delta\Gamma$ Measurement

- Time-dependent decay rates must include non-zero $\Delta\Gamma$.
- Flavor-specific state ($B \to f(\bar{f})$):

$$[1 \pm \cos(\Delta m_d \Delta t)] \to \left[\cosh \frac{\Delta\Gamma_d \Delta t}{2} \pm \cos(\Delta m \Delta t)\right]$$

- CP eigenstate ($B^0 \to f_{CP}$, CP-even (CP-odd)):

$$[1 \pm \sin 2\phi_1 \sin(\Delta m_d \Delta t)]$$

$$\to \left[\cosh \frac{\Delta\Gamma_d \Delta t}{2} \mp \cos 2\phi_1 \sinh \frac{\Delta\Gamma_d \Delta t}{2} \pm \sin 2\phi_1 \sin(\Delta m \Delta t)\right]$$

CP Violation in $B\bar{B}$ Mixing

CP violation leads to $\rightarrow |q/p| \neq 1$

- $1 - |\frac{q}{p}|^2 \simeq Im\left(\frac{\Gamma_{12}}{M_{12}}\right) < 10^{-3}$

  $\left(|\Gamma_{12}/M_{12}| \sim 5 \times 10^{-3}, \quad \phi_{M_{12}} - \phi_{\Gamma_{12}} = \pi + O(m_c^2/m_b^2)\right)$

- $P_{++}^{\mathrm{SF}} = |\frac{p}{q}|^2 \cdot P^{\mathrm{SF}} \qquad P_{--}^{\mathrm{SF}} = |\frac{q}{p}|^2 \cdot P^{\mathrm{SF}}$

  P_{++}^{SF} and P_{--}^{SF} can be fifferent $\rightarrow$ charge asymmetry in SF events

- Possible new physics through $\phi_{M_{12}} - \phi_{\Gamma_{12}}$ at $O(10^{-3})$ level. Interesting

CPT Violation in $B\bar{B}$ Mixing

CPT violation leads to $p \neq p'$ and/or $q \neq q'$

- $\mid B_H >= p \mid B^0 > +q \mid \overline{B^0} >, \quad \mid B_L >= p' \mid B^0 > -q' \mid \overline{B^0} >$

  $\frac{q}{p} = \tan(\frac{\theta}{2})e^{i\phi}, \quad \frac{q'}{p'} = \cot(\frac{\theta}{2})e^{i\phi}$ (θ can deviate from $90°$)

- Time dependence of OF decay is modified:

  $1 + \cos(\Delta m_d \Delta t) \rightarrow$

  $$[1 + |\cos\theta|^2 + (1 - |\cos\theta|^2)\cos(\Delta m_d \Delta t) - 2Im(\cos\theta)\sin(\Delta m_d \Delta t)]$$

- P^{OF}_{+-} and P^{OF}_{-+} can be different $\rightarrow$ time-dependent asymmetry in OF events

- Quantum Mechanics test, exotics. Something to continue looking for

$\Delta\Gamma/\Gamma$, $|q/p|$, $\cos\theta(z)$ Results

BaBar: Fully reconstructed hadronic events (88M $B\bar{B}$)

$$\begin{aligned}
\text{sgn}(\text{Re}\lambda_{CP})\Delta\Gamma/\Gamma &= -0.008 \pm 0.037 \pm 0.018 \;\; (\text{sgn}(\text{Re}\lambda_{CP}) = +1 \text{ in SM}) \\
|q/p| &= 1.029 \pm 0.013 \pm 0.011 \\
\text{Re}\lambda_{CP}/|\lambda_{CP}|\text{Re}z &= 0.014 \pm 0.035 \pm 0.034 \;\; (\text{Re}\lambda_{CP}/|\lambda_{CP}| \simeq 0.672 \pm 0.068) \\
\text{Im}z &= 0.038 \pm 0.029 \pm 0.025
\end{aligned}$$

BaBar: dilepton events (23M $B\bar{B}$)

$$|q/p| = 0.998 \pm 0.005 \pm 0.007$$

Belle: dilepton events (32M $B\bar{B}$)

$$\begin{aligned}
\text{Im}(\cos\theta) &= 0.03 \pm 0.01 \pm 0.03 \\
\text{Re}(\cos\theta) &= 0.00 \pm 0.12 \pm 0.01
\end{aligned}$$

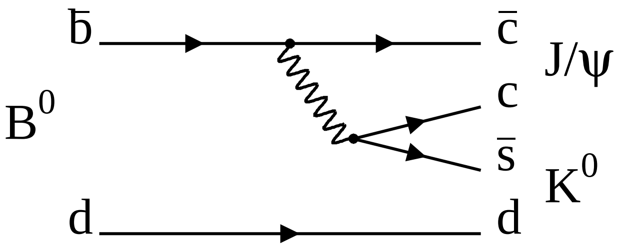
- $\delta(\Delta\Gamma/\Gamma) \sim 0.05$ (10^{-2} in SM),
  $\delta(|q/p|) \sim 0.01$ ($\sim 10^{-3}$ in SM),
  $\delta(Im(\cos\theta)) \sim 0.03$, $\delta(Re(\cos\theta)) \sim 0.07$.

$\sin 2\phi_1$ from $J/\psi K_S$ and other $b \to c\bar{c}s$ decays

Asymmetry between ($B^0 \to f$) and ($\bar{B}^0 \to \bar{f}$) for final state $f = \bar{f} = f_{CP}$:

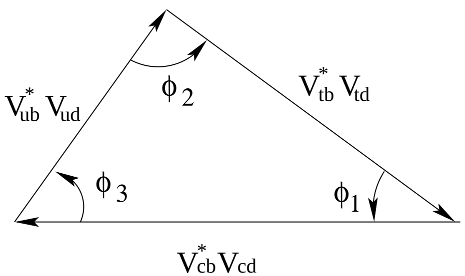
$$a_f(t) = \frac{\Gamma(\bar{B}^0(t) \to f) - \Gamma(B^0(t) \to f)}{\Gamma(\bar{B}^0(t) \to f) + \Gamma(B^0(t) \to f)} = \frac{2Im\lambda_f}{|\lambda_f|^2 + 1}\sin(\Delta m t) + \frac{|\lambda_f|^2 - 1}{|\lambda_f|^2 + 1}\cos(\Delta m t)$$

$Im\lambda_f \neq 0 \to$ Mixing-assisted CP violation, $|\lambda_f| \neq 1 \to$ Direct CP violation



$$\lambda_f = \frac{q}{p}\frac{< f|H|\bar{B}^0 >}{< f|H|B^0 >}$$

$$\frac{q}{p} = \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \to e^{-2i\phi_1} \text{ (Standard Model)}$$



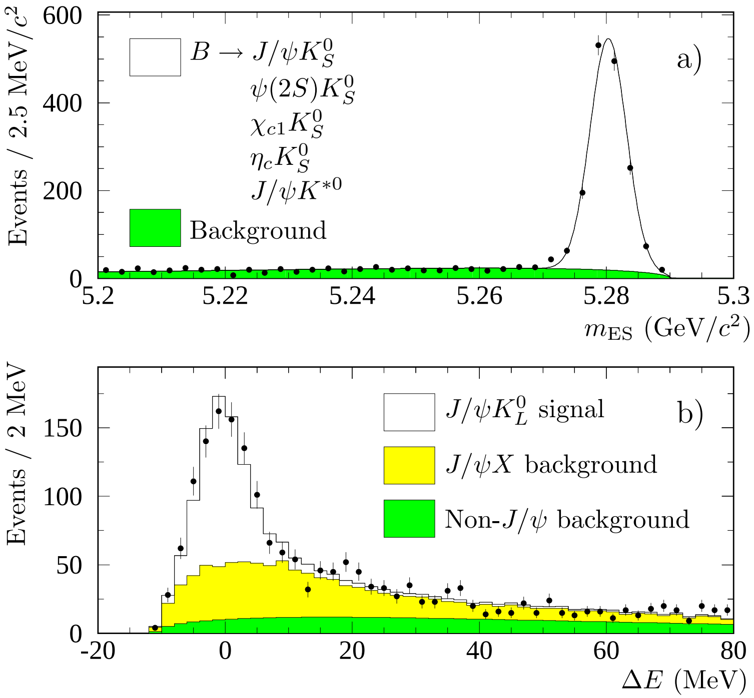
$$\lambda(J/\psi K_S) = \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \cdot \eta_{J\psi K_S} \cdot \left(\frac{V_{cb} V_{cs}^*}{V_{cb}^* V_{cs}}\right) \cdot \left(\frac{V_{cd}^* V_{cs}}{V_{cs}^* V_{cd}}\right)$$

$$\to Im\lambda(J/\psi K_S) = \sin 2\phi_1 \quad (-\sin 2\phi_1 \text{ for } J/\psi K_L)$$

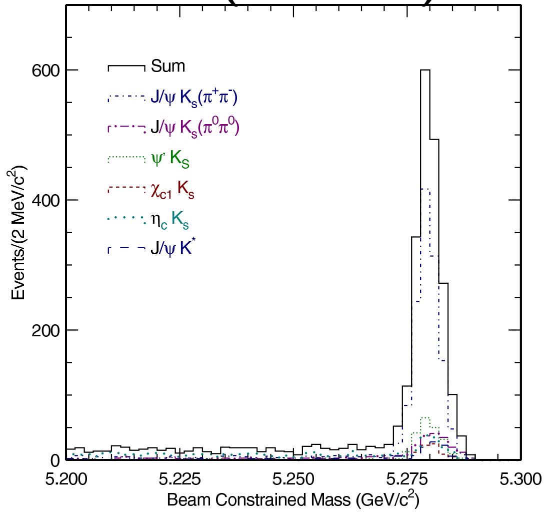
(sign of $\sin 2\phi_1$ depends on CP of final state η_f)

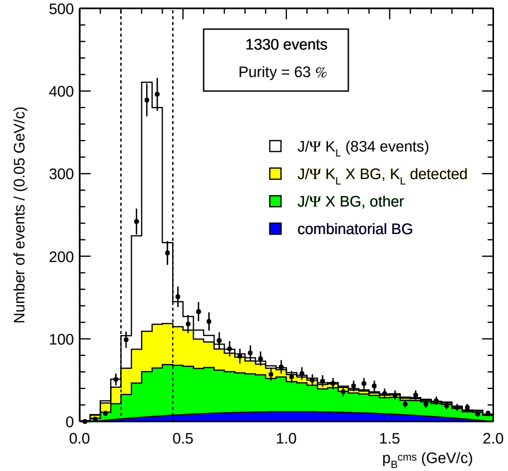
Selection of $J/\psi K_S$ and other $b \to c\bar{c}s$ Events

BaBar (88M $B\bar{B}$)



Belle (85M $B\bar{B}$)





- **Signal peaks at M_B in beam-energy constrained B mass distributions.**

- **No K_L energy measurement. Calculated $\Delta E = E_{J/\psi K_L} - E_{\text{beam}}$ (peaks at 0 MeV) or p_B^* (peaks at 340 MeV/c).**

Extraction of $\sin 2\phi_1$

- **Tag the flavor** of each candidate event. Categorize according to the quality of tagging.
- Determine mistag fraction from the data (assuming Δm_d is known).
  $(N_{OF} - N_{SF})/(N_{OF} + N_{SF}) = (1 - 2w)\cos(\Delta m_d \Delta t)$

BaBar

category	$\epsilon(\%)$	$w(\%)$	$\Delta w(\%)$	$\epsilon_{\rm eff}(\%)$
lepton	$9.1 \pm .2$	$3.3 \pm .6$	-1.5 ± 1.1	$7.9 \pm .3$
kaon I	$16.7 \pm .2$	$10.0 \pm .7$	-1.3 ± 1.1	$10.7 \pm .4$
kaon II	$19.8 \pm .3$	$20.9 \pm .8$	-4.4 ± 1.2	$6.7 \pm .4$
inclusive	$20.0 \pm .3$	$31.5 \pm .9$	-2.4 ± 1.3	$2.7 \pm .3$
all	$65.6 \pm .5$			$28.1 \pm .7$

$(\Delta w = w(B^0) - w(\bar{B}^0),\ \epsilon_{\rm eff} = \epsilon(1-2w)^2)$

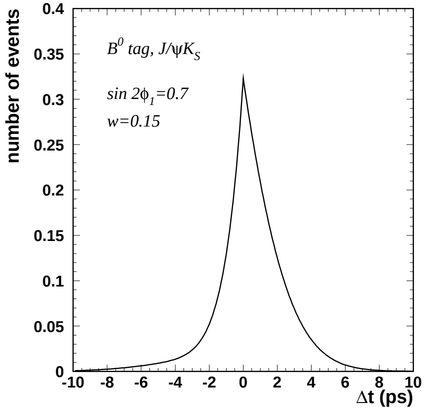
Belle

cat.	$\epsilon(\%)$	$w(\%)$	$\epsilon_{\rm eff}(\%)$
1	39.8	$45.8 \pm .6$	$0.3 \pm .1$
2	14.6	$33.6 \pm .9$	$1.6 \pm .2$
3	10.4	$22.8 \pm 1.$	$3.1 \pm .2$
4	12.2	$16.0 \pm .9$	$5.6 \pm .3$
5	9.4	$11.2 \pm .9$	$5.6 \pm .3$
6	13.6	$2.0 \pm .6$	$12.6 \pm .4$
all	100.0		$28.8 \pm .6$

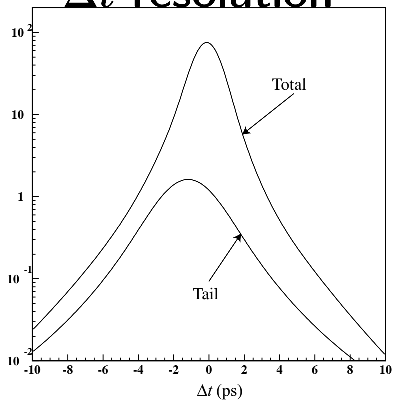
- **Fit Δt distribution.** Maximize $L = \prod_i P_i$ (i $\cdots$each candidate event)

$$P_i = \int [f_{\rm sig} P_{\rm sig}(\Delta t') R_{\rm sig}(\Delta t - \Delta t') + (1 - f_{\rm sig}) P_{\rm bkg}(\Delta t') R_{\rm bkg}(\Delta t - \Delta t')]\, d\Delta t'$$

Signal PDF



Δt resolution



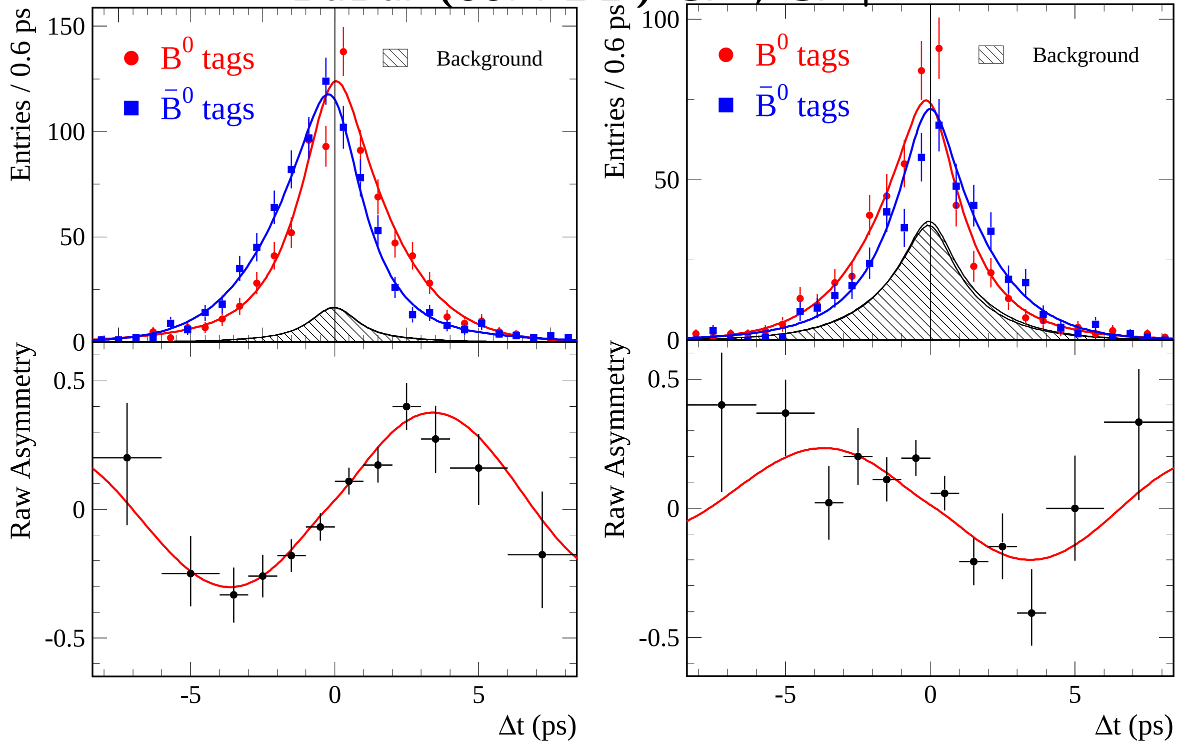
$f_{\rm sig}$: signal fraction of candidate event

$P_{\rm sig}$, $P_{\rm bkg}$:t probability density function

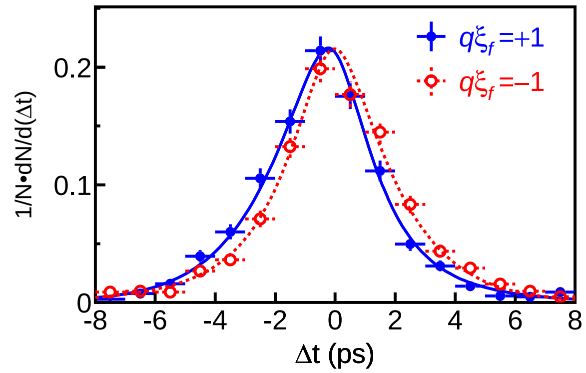
$R_{\rm sig}$, $R_{\rm bkg}$: Δt resolution

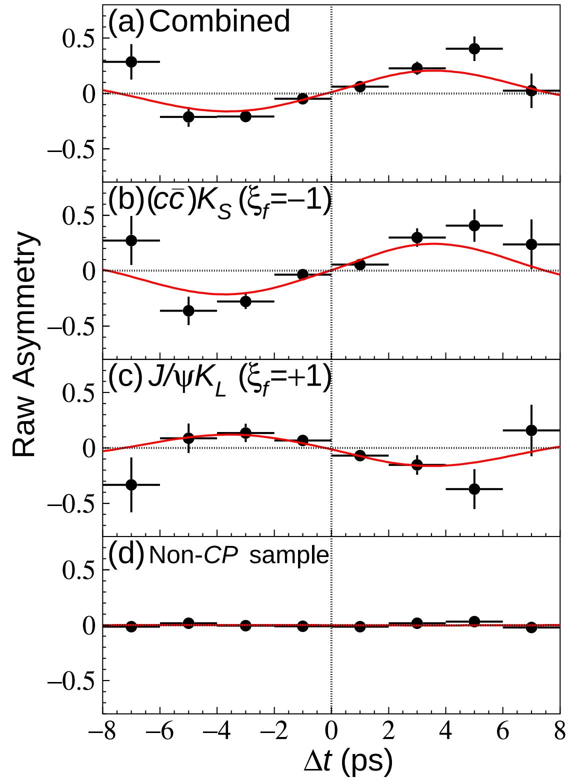
Δt Distributions

BaBar (88M $B\bar{B}$) CP-, CP+



Belle (85M $B\bar{B}$) Combined





$\sin 2\phi_1$ Results: $J/\psi K_S$ and other $b \to c\bar{c}s$ decays

BaBar (88M $B\bar{B}$)

$$\sin 2\beta = 0.741 \pm 0.067 \pm 0.034$$

$$|\lambda| = 0.948 \pm 0.051 \pm 0.030$$

Belle (85M $B\bar{B}$)

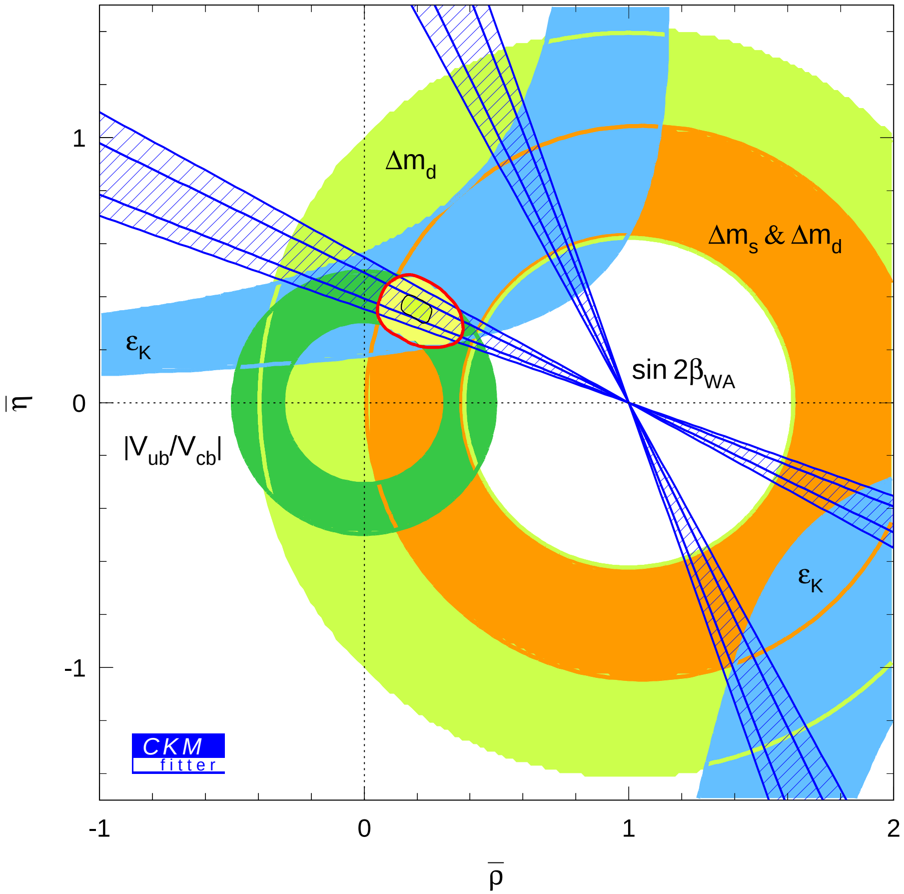
$$\sin 2\phi_1 = 0.719 \pm 0.074 \pm 0.035$$

$$|\lambda| = 0.950 \pm 0.049 \pm 0.025$$

BaBar and Belle combined

$$\sin 2\phi_1 = 0.734 \pm 0.055$$

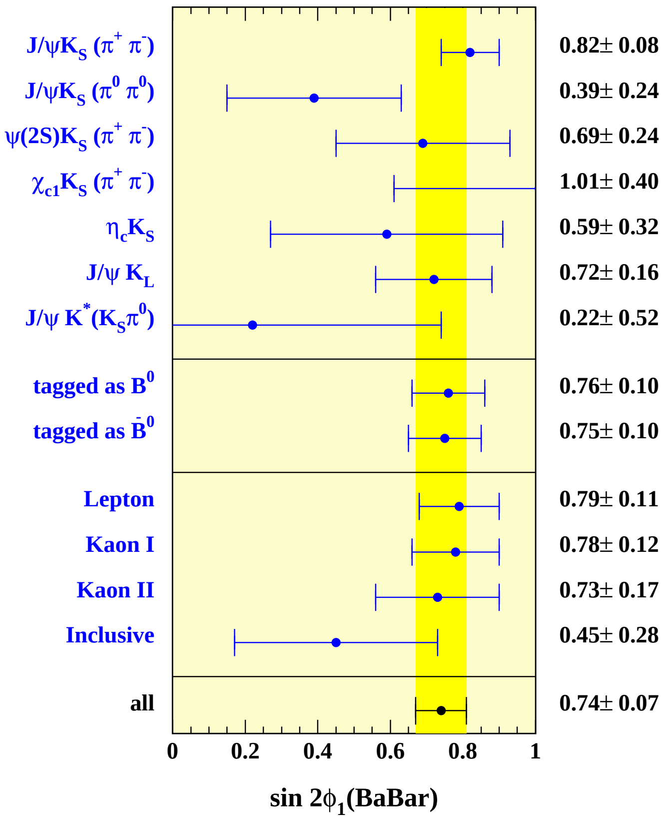
Good agreement with CKM fit.

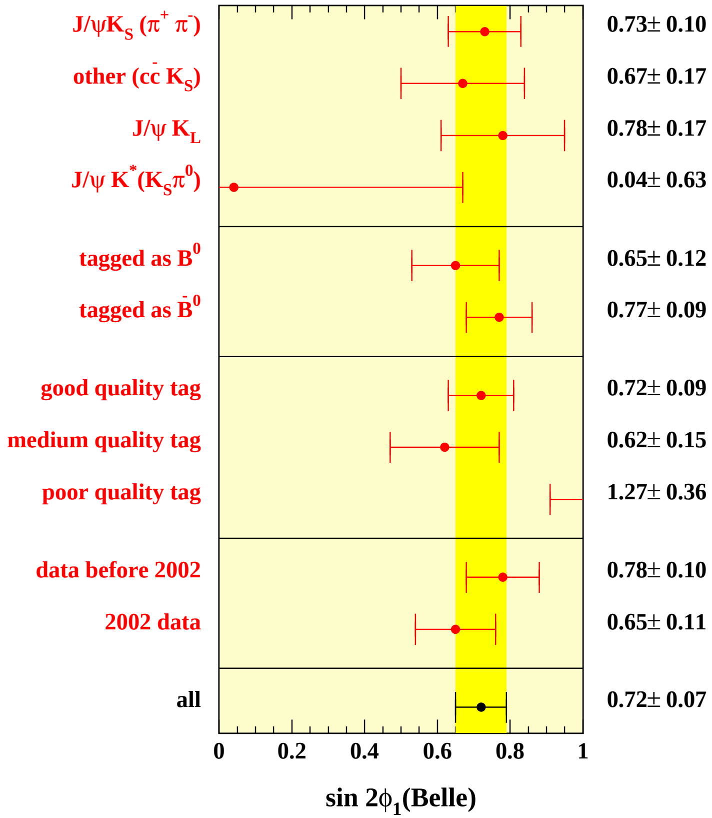


Red (black): 90% (5%) CL contour without $\sin 2\phi_1$

Shaded: 1σ, 2σ regions for $\sin 2\phi_1$

Consistency among Subsamples

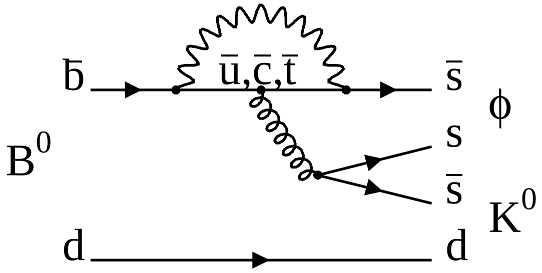




All $b \to c\bar{c}s$ modes point to the same $\sin 2\phi_1$ within the present precision. How about the modes from other diagrams ?

$\sin 2\phi_1$ from ϕK_S

Only $b \to s s \bar{s}$ penguin contribution in SM.



Leading term: $V_{cb}V_{cs}^*(P_c - P_t) = A\lambda^2(P_c - P_t)$
Next term: $V_{ub}V_{us}^*(P_u - P_t) = A\lambda^4(\rho - i\eta)(P_u - P_t)$
(penguin amplitudes: $P_t \gg P_c \gg P_u$)

- Leading term has the same CKM factor as $b \to c\bar{c}s$.
  Next term has a different phase, but suppressed by $\lambda^2 \simeq 5\%$.
- $\eta_{\phi K_s} = -1 \to Im\lambda \simeq \sin 2\phi_1$ in SM.
- Allow room for new physics. Parameterize Δt distributions by

  $a_f(\Delta t) = S_f \sin(\Delta m_d \Delta t) + A_f \cos(\Delta m_d \Delta t)$

  $S_f = \frac{2Im\lambda_f}{|\lambda_f|^2+1} \simeq -\eta_f \sin 2\phi_1$ in SM $\quad A_f = -C_f = \frac{|\lambda_f|^2-1}{|\lambda_f|^2+1} \simeq 0$ in SM.

- Deviation is an indication of new physics in penguin loop (not in mixing).

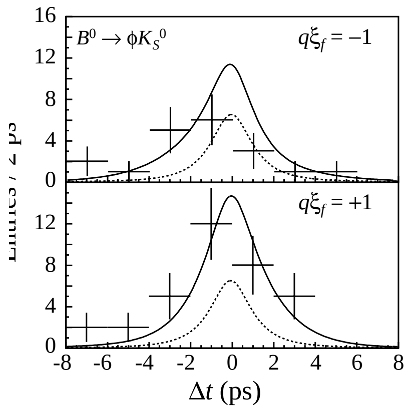
$\sin 2\phi_1$ from ϕK_S: Results

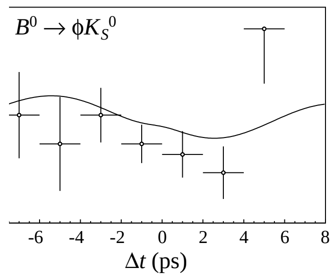
BaBar (84M $B\bar{B}$)

$$S_{\phi K_s} = -0.18 \pm 0.51 \pm 0.07$$

$$A_{\phi K_s} = +0.80 \pm 0.38 \pm 0.12$$

Belle (85M $B\bar{B}$)



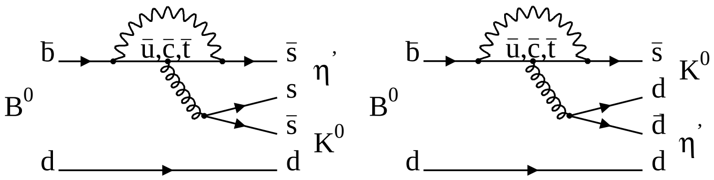


$$S_{\phi K_s} = -0.73 \pm 0.64 \pm 0.22$$

$$A_{\phi K_s} = -0.56 \pm 0.41 \pm 0.16$$

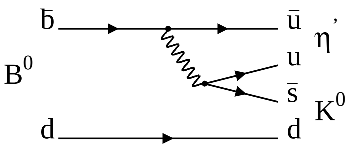
$\sin 2\phi_1$ from $\eta' K_S$

Additional $b \to sd\bar{d}$ penguin and $b \to u$ tree



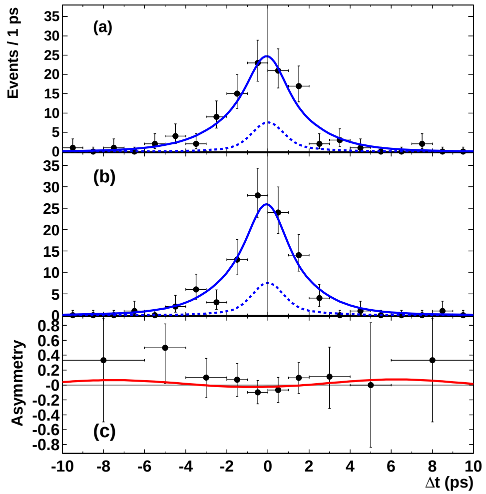
$$V_{cb}V_{cs}^*(P_c - P_t) = A\lambda^2(P_c - P_t)$$

$$V_{ub}V_{us}^*(P_u - P_t) = A\lambda^4(\rho - i\eta)(P_u - P_t)$$



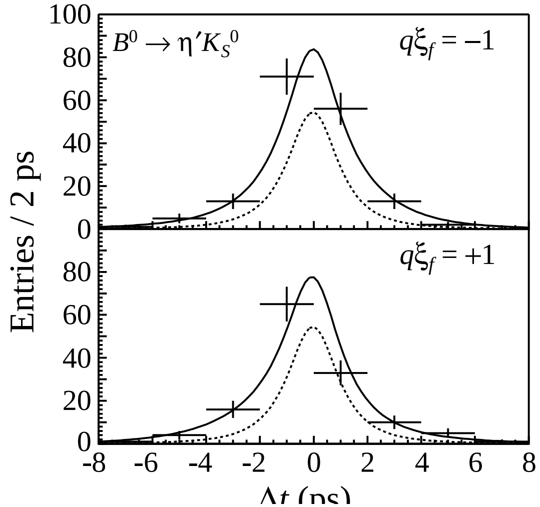
$$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$$

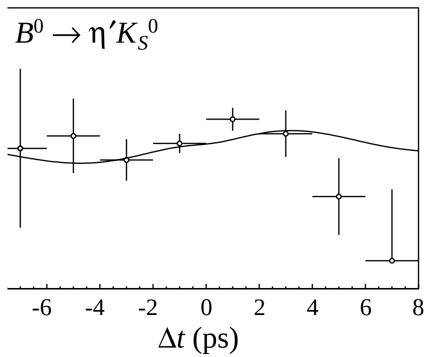
BaBar (88.9M $B\bar{B}$)



$$S_{\eta' K_S} = +0.02 \pm 0.34 \pm 0.03$$
$$A_{\eta' K_S} = -0.10 \pm 0.23 \pm 0.03$$

Belle (85M $B\bar{B}$)



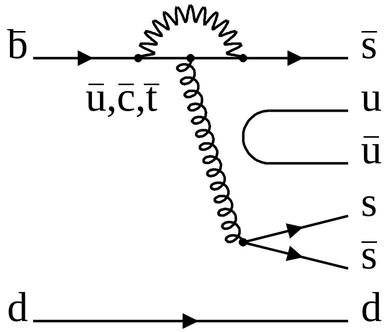


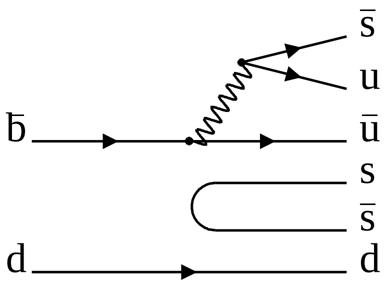
$$S_{\eta' K_S} = +0.71 \pm 0.37^{+0.05}_{0.06}$$
$$A_{\eta' K_S} = +0.26 \pm 0.22 \pm 0.03$$

Additional 5% $b \to u$ tree effect compared with ϕK_S.

$\eta_{\eta' K_S} = -1 \to S_f \simeq \sin 2\phi_1$.

$\sin 2\phi_1$ from $K^+K^-K_S$





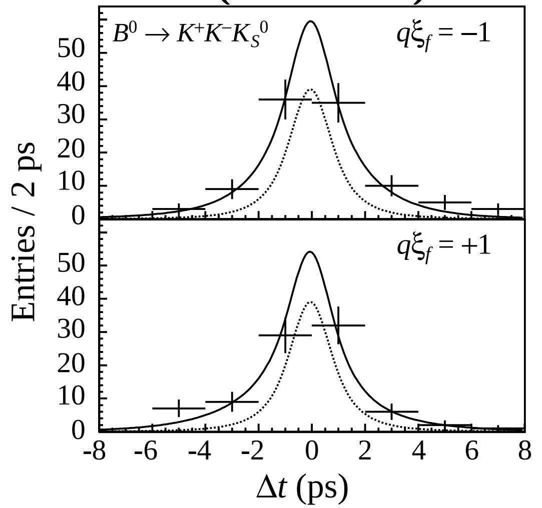
- $b \to s s \bar{s}$ penguin and $b \to u$ tree can contribute.

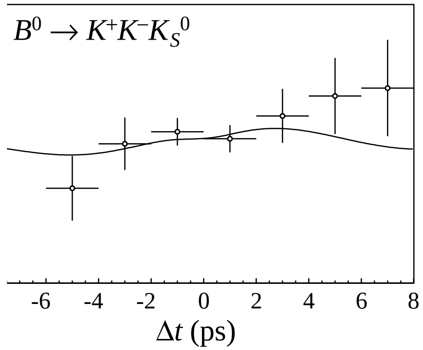
- Three body final state: mixture of CP+ and CP-.

  Belle analyses show $b \to u$ tree is negligible and $\eta_{K^+K^-K_s} \simeq +1$.

  $S_f \simeq -\sin 2\phi_1$.

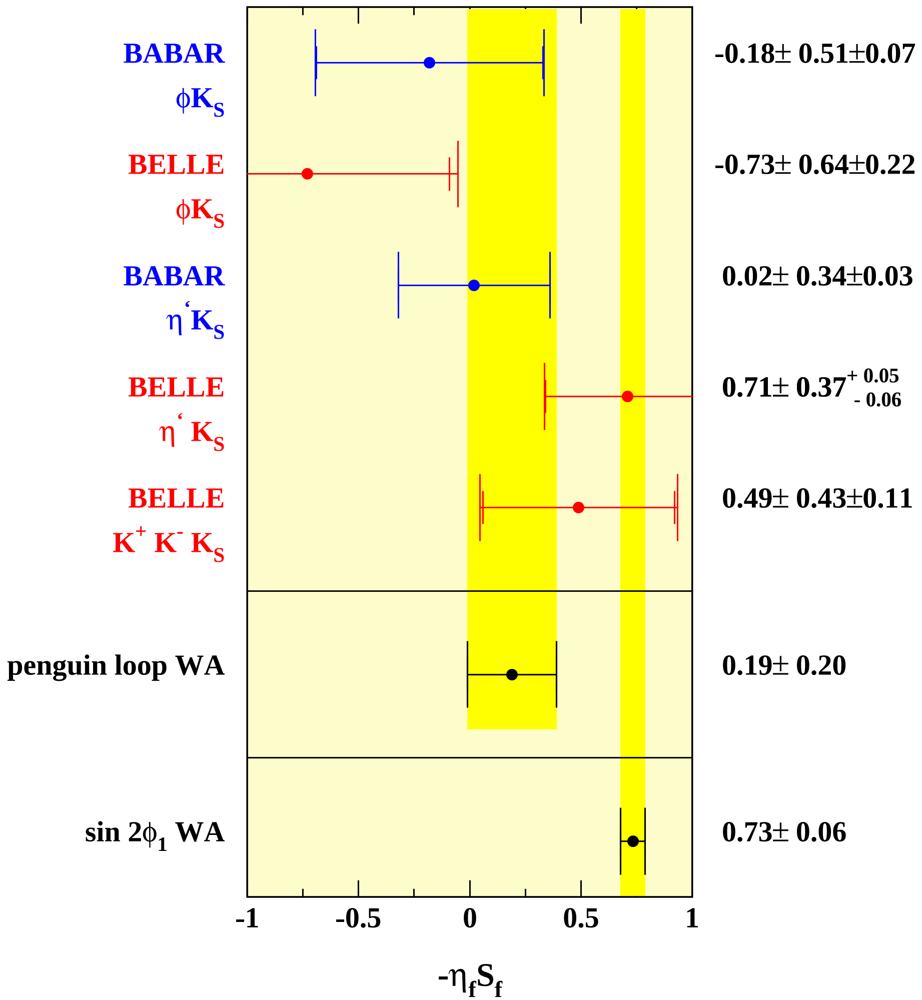
Belle (85M $B\bar{B}$)





$$S_{K^+K^-K_S} = -0.49 \pm 0.43 \pm 0.11$$
$$A_{K^+K^-K_S} = -0.40 \pm 0.33 \pm 0.10$$

$-\eta_f S_f$ for Penguin Loops ($= \sin 2\phi_1$ in SM)

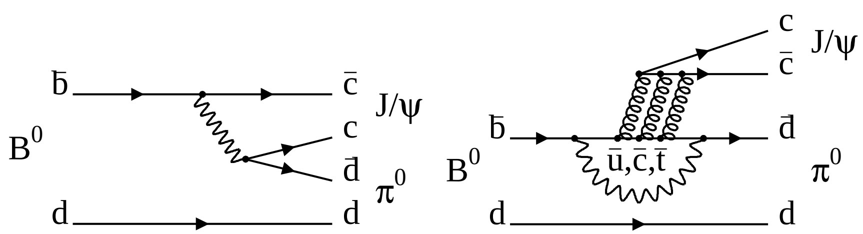


Hint of anomaly?

New physics search in B meson decays is now a reality.

$\sin 2\phi_1$ from $J/\psi\pi^0$?

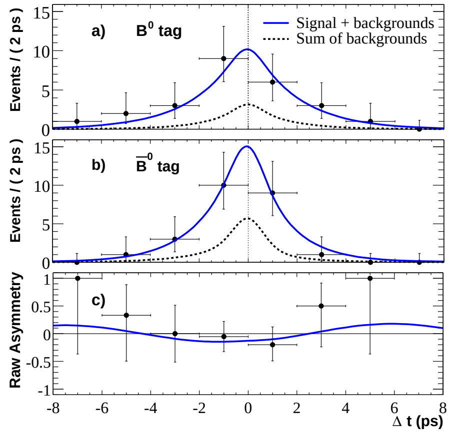
Tree and penguin are comparable



$$V_{cb}V_{cd}^* = -A\lambda^3$$
$$V_{cb}V_{cd}^*(P_c - P_t) = -A\lambda^3(P_c - P_t)$$
$$V_{ub}V_{ud}^*(P_u - P_t) = A\lambda^3(\rho - i\eta)(P_u - P_t)$$

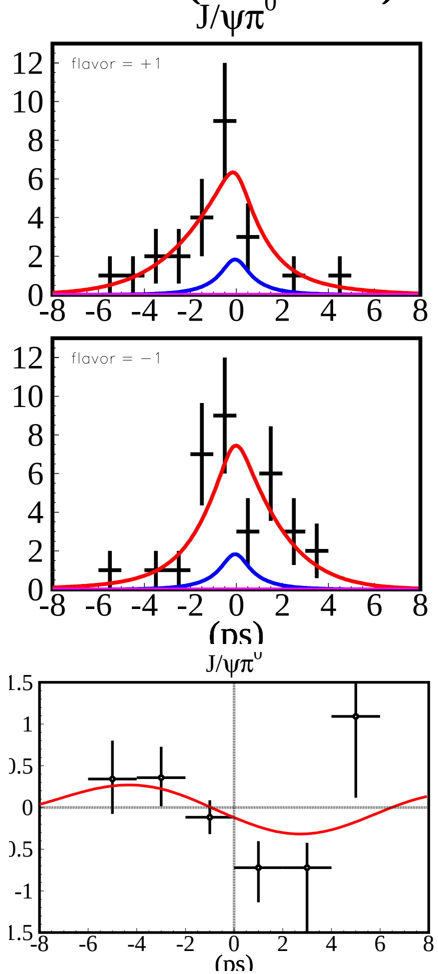
- **CKM factor of tree same as** $J/\psi K^0$ $(K^0 \to K_S)$.
- $\eta_{J/\psi\pi^0} = +1 \to S_f \simeq -\sin 2\phi_1$ **(If no penguin)**
- **If a deviation is seen, penguin should be the first suspect.**

BaBar (88M $B\bar{B}$)



$S_{J/\psi\pi^0} =$
$+0.05 \pm 0.49 \pm 0.16$
$A_{J/\psi\pi^0} =$
$-0.38 \pm 0.41 \pm 0.09$

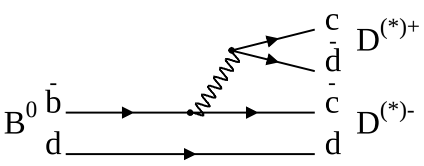
Belle (85M $B\bar{B}$)

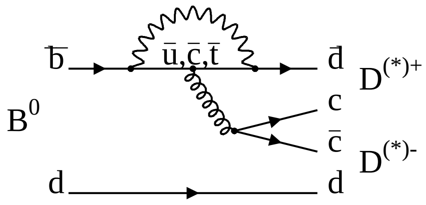


$S_{J/\psi\pi^0} =$
$-0.93 \pm 0.49 \pm 0.08$
$A_{J/\psi\pi^0} =$
$-0.25 \pm 0.39 \pm 0.06$

$\sin 2\phi_1$ from $D^{*+}D^{*-}$ and $D^{*+}D^{-}$?

Similar "penguin pollution" as $J/\psi\pi^0$





$$V_{cb}V_{cd}^* = -A\lambda^3$$
$$V_{cb}V_{cd}^*(P_c - P_u) = -A\lambda^3(P_c - P_u)$$
$$V_{tb}V_{td}^*(P_t - P_u) = A\lambda^3(1 - \rho + i\eta)(P_t - P_u)$$

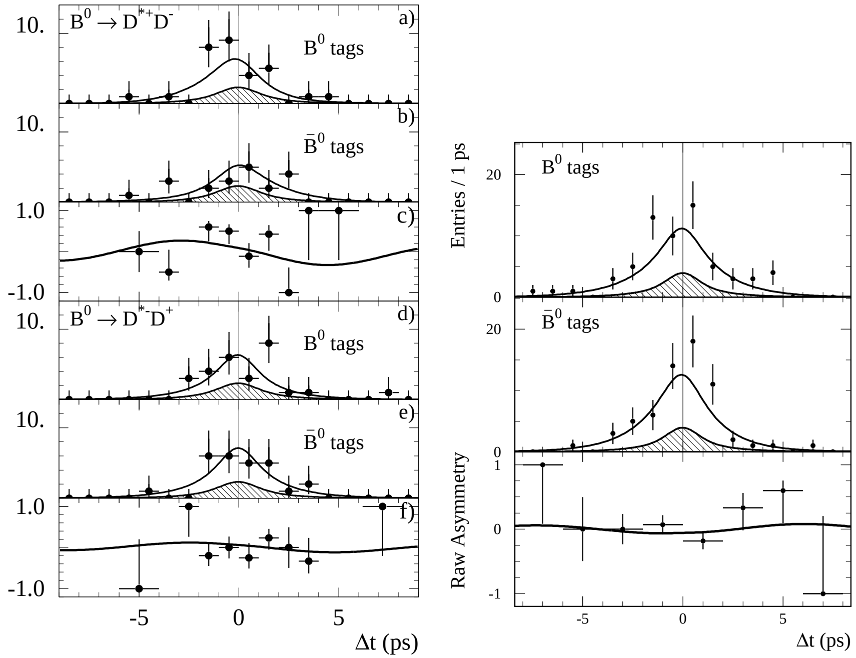
- $D^{*+}D^{*-}$: mix of CP+ and CP-

  BaBar angular analysis
  $\eta_{D^{*+}D^{*-}} \simeq +1$
  $S_f \simeq -\sin 2\phi_1$ (if no penguin)

- $D^{*+}D^{-}$: Mixing-induced CPV measurement using non-CP final states.

  $S_f \simeq -\sin 2\phi_1$ (if no penguin)

BaBar (88M $B\bar{B}$), D^*D and D^*D^* (right)



$$S_{D^*D}^{\pm} = -0.24 \pm 0.69 \pm 0.12$$
$$S_{D^*D}^{\mp} = -0.82 \pm 0.75 \pm 0.14$$
$$A_{D^*D}^{\pm} = +0.22 \pm 0.37 \pm 0.10$$
$$A_{D^*D}^{\mp} = +0.47 \pm 0.40 \pm 0.12$$

For CP+ component:
$$Im\lambda_{f+}(D^*D^*) = 0.05 \pm 0.29 \pm 0.10$$
$$|\lambda_{f+}(D^*D^*)| = 0.75 \pm 0.19 \pm 0.02$$

Summary

- Precision of Δm_d reached 1.2%.
  - New physics effects in $B\bar{B}$ mixing vigorously explored.

    $\delta(\Delta\Gamma/\Gamma) \sim 0.05$ ($< 10^{-2}$ in SM), $\delta(|q/p|) \sim 0.01$ (10^{-3} in SM), $Re(\cos\theta) \sim 0.07$, $Im(\cos\theta) \sim 0.03$.
  - Important test ground for Δt measurement and flavor tagging.
- Precision of $\sin 2\phi_1$ reached 8%. Good agreement between BaBar and Belle.
  - Statistical error still dominates.
  - Good agreement with global CKM fit (without $\sin 2\phi_1$).
  - $|\lambda|$ is consistent with 1 in $b \to c\bar{c}s$ decays as expected in SM.
- New physics search by "$\sin 2\phi_1$" measurements in penguin loops is well under way.
  - $\delta S_{\phi K_s} \sim \pm 0.6$, $\delta S_{\eta' K_s} \sim \pm 0.4$, $\delta S_(K^+K^-K_S) \sim \pm 0.4$.
  - "$\sin 2\phi_1$" (penguin) $= 0.19 \pm 0.20$ ($\sin 2\phi_1 = 0.734 \pm 0.055$). Very exciting.
- "$\sin 2\phi_1$" measurements in "penguin polluted" decays were also pushed to find useful information.

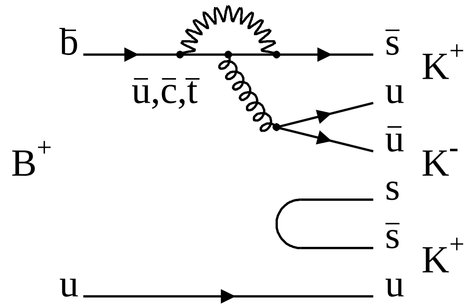
Backup: References

		BaBar	Belle
Δm_d	dilepton	PRL 88, 221803 (2002)	PRD 67, 052004 (2003)
	hadronic	PRL 88, 221802 (2002)	PL B542, 207 (2002)
	semileptonic	hep-ex/0212017	PRL 89, 251803 (2002)
	$D^*\pi$ partial r		PRD 67, 092004 (2003)
$\Delta\Gamma/\Gamma$		hep-ex/0303043	
CPV		hep-ex/0303043	
		PRL 88, 231801 (2002)	
$CPTV$		hep-ex/0303043	PRD 67, 052004 (2003)
$\sin 2\phi_1$		PRL 89, 201802 (2002)	PRD 66, 071102 (2002)
$S_{\phi K_S}$		Moriond (March 2003)	PRD 67, 031102(R) (2003)
$S_{\eta' K_S}$		hep-ex/0303046	above
$S_{K^+K^-K_S}$			above
$S_{J/\psi\pi^0}$		hep-ex/0303018	Belle-CONF-0201
S_{D^*D}		hep-ex/0303004	
$S_{D^*D^*}$		FPCP (June 2003)	

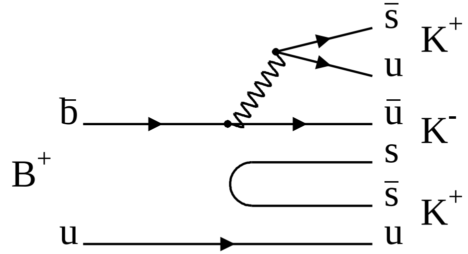
Backup: Parameters of CP Fit

Parameterization	**BaBar**	**Belle**
Signal PDF	$\sin 2\beta$ (1)	$\sin 2\phi_1$ (1)
Signal mistag frac.	w, Δw for 4 cat. (8)	w for 6 cat. (6)
Background mistag frac.	w, Δw for 4 cat. (8)	(0)
Signal Δt resolution	(9)	(13)
Background Δt resolution	(9)	(11)
Fitting method	Use B_{CP} and B_{flav} events Miximize $L_{CP} + L_{\text{mix}}$ Fit with 35 parameters	Use B_{CP} events only Maximize L_{CP} Fit with $\sin 2\phi_1$ only Others from data and MC

Backup slide: $b \to u$ tree contribution to KKK final state



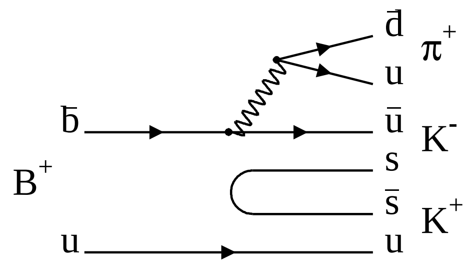
- KKK is dominated by $b \to s$ penguin.



- $KK\pi$ is dominated by $b \to u$ tree.

- $b \to u$ tree contribution to KKK :

- $F = \left|\frac{A^{KKK}_{b\to u}}{A^{KKK}_{\text{total}}}\right| = \frac{B(B^+ \to K^+K^-\pi^+)}{B(B^+ \to K^+K^+K^-)} \times \left(\frac{f_K}{f_\pi}\right) \times \tan^2\theta_C$



- Belle results:

  $F = 0.022 \pm 0.005\ (B^+)$
  $F = 0.023 \pm 0.013\ (B^0)$

- $b \to u$ tree constribution is 10 - 15% in amplitude.

Backup slide: CP content in $K_S^0 K^+ K^-$ state

- Isospin symmetry:

- $B(B^0 \to K^0 K^+ K^-) = B(B^+ \to K^+ K^0 \bar{K}^0) \times \frac{\tau_{B^0}}{B_{\tau_{B^+}}}$

- $K^0 \bar{K}^0$ must be symmetric (Bose statistics):

- $|K^+ K^0 \bar{K}^0 >= \alpha \frac{|K^+ K_S K_S> + |K^+ K_L K_L>}{\sqrt{2}} + \beta |K^+ K_S K_L >$
  (α, $\beta \cdot \cdot$relative orbital angular momentum even, odd)

- $\alpha^2 = 2 \frac{B(B^+ \to K^+ K_S K_S)}{B(B^0 \to K^0 K^+ K^-)} \times \frac{\tau_{B^0}}{\tau_{B^+}}$

  α gives CP even component of $K_S K^+ K^-$.

- Belle result (after removing ϕK_S events):

  $\alpha^2 = 1.04 \pm 0.19 \pm 0.06$

Backup slide: Contributing terms for CP mode decays

mode	leading termr	next term
$J/\psi K_S$	$V_{cb}V_{cs}^* = A\lambda^2$	$V_{ub}V_{us}^*(P_u - P_t) = A\lambda^4(\rho - i\eta)(P_u - P_t)$
	$V_{cb}V_{cs}^*(P_c - P_t) = A\lambda^2(P_c - P_t)$	
ϕK_S	$V_{cb}V_{cs}^*(P_c - P_t) = A\lambda^2(P_c - P_t)$	$V_{ub}V_{us}^*(P_u - P_t) = A\lambda^4(\rho - i\eta)(P_u - P_t)$
$\eta' K_S$	$V_{cb}V_{cs}^*(P_c - P_t) = A\lambda^2(P_c - P_t)$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$
$J/\psi\pi^0$	$V_{cb}V_{cd}^* = -A\lambda^3$	
	$V_{cb}V_{cd}^*(P_c - P_u) = -A\lambda^3(P_c - P_u)$	
	$V_{tb}V_{td}^*(P_t - P_u) = A\lambda^3(1 - \rho + i\eta)(P_t - P_u)$