Time-dependent CPV and mixing at B-factories

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KM unitarity triangle and CPV parameter convention

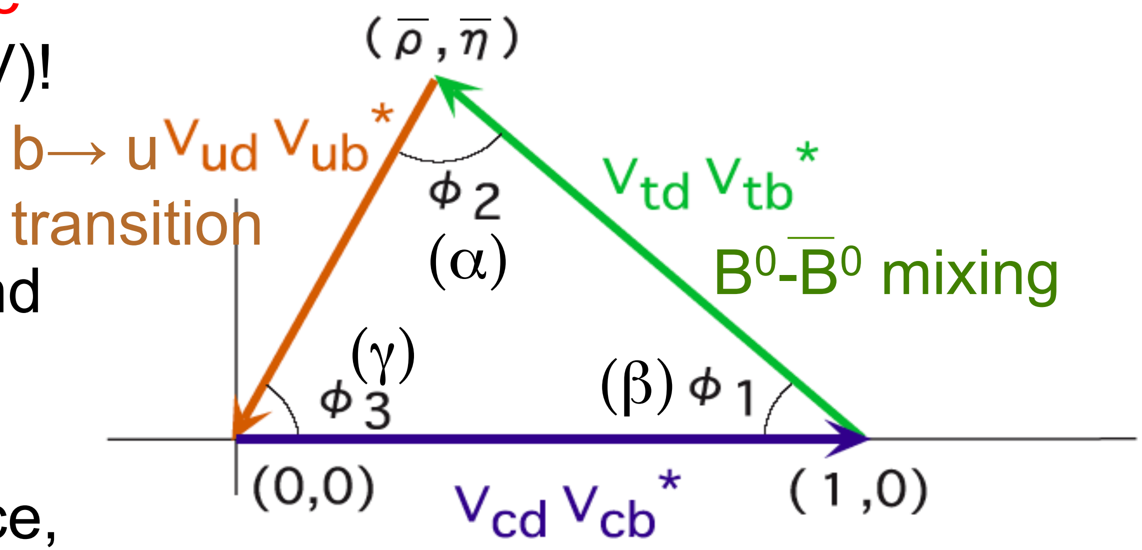
$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

by Wolfenstein parametrization

Irreducible complex phase causes CP Violation (CPV)!

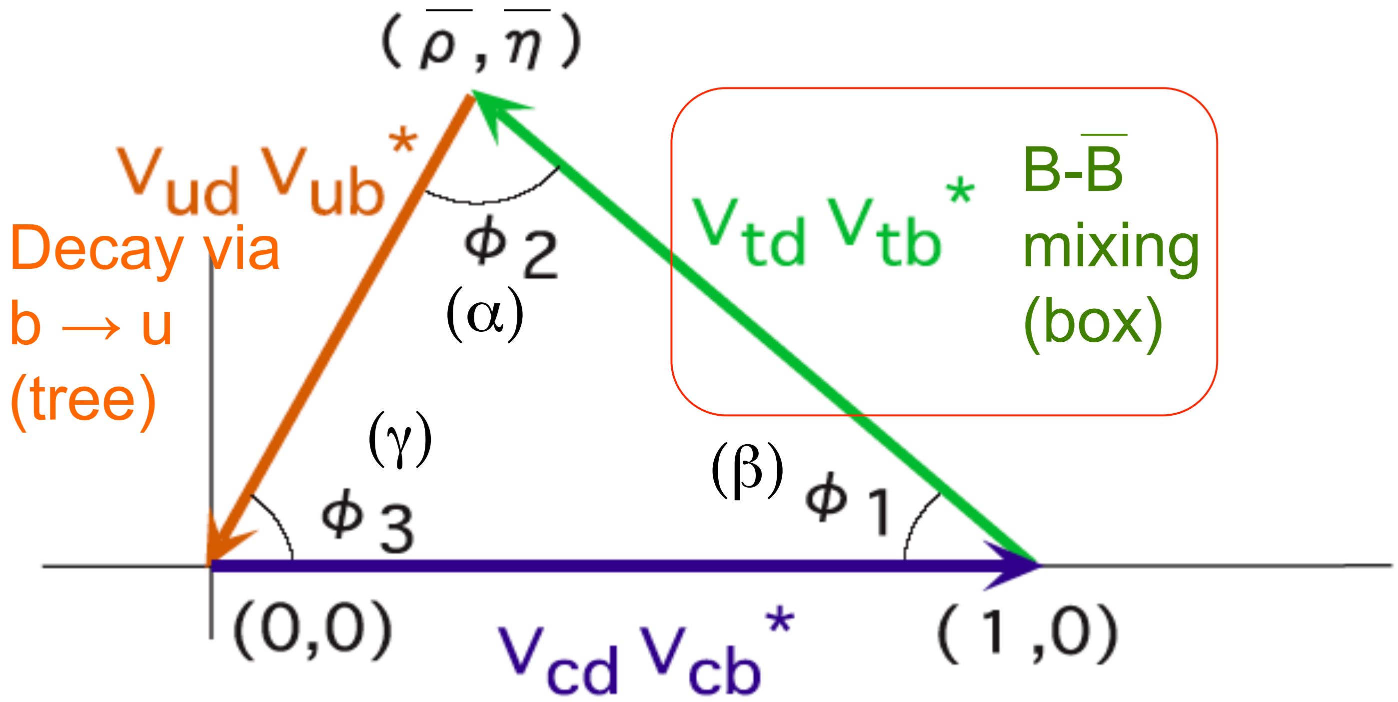
Comprehensive test; measure all the angles and sides.

B system : very good place, all the angles are $O(0.1)$!



$$V_{td} V_{tb}^* + V_{cd} V_{cb}^* + V_{ud} V_{ub}^* = 0$$

Angle measurements and mixing



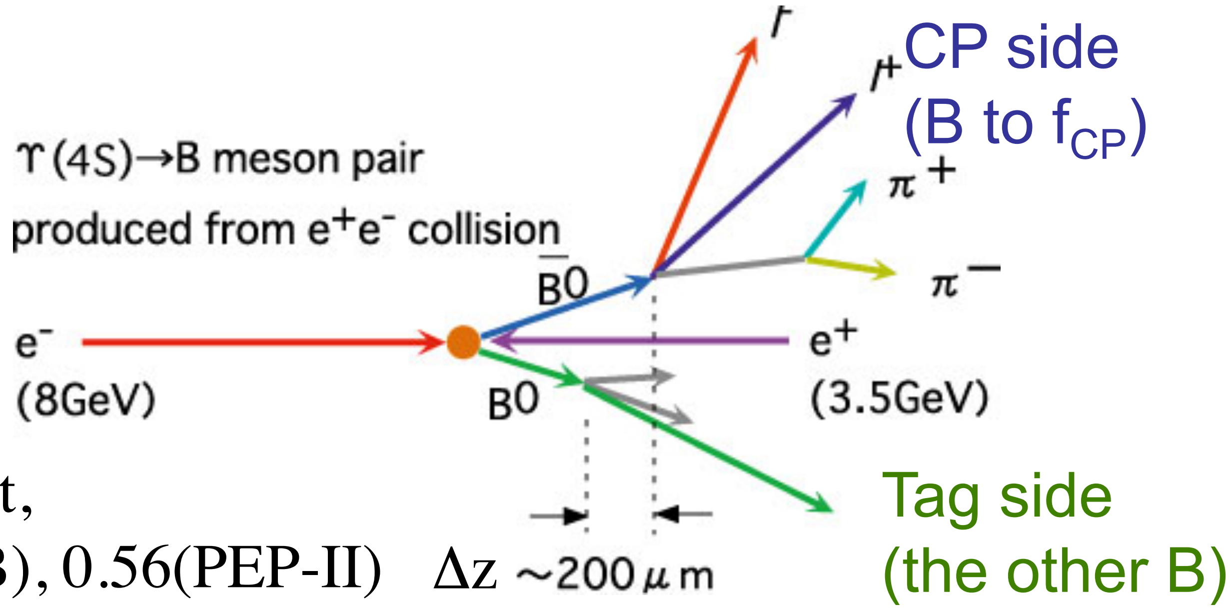
Decay via b → c (tree)

How about b → s (penguin)??

b → d (penguin) is also participating in some cases → direct CPV.

Time-dependent CPV

In order to see CPV by interference between decay and mixing.



$\Delta z = \beta\gamma c \Delta t$,

$\beta\gamma = 0.425$(KEKB), 0.56(PEP-II)

$$A_{CP}(\Delta t) = \frac{\Gamma(\bar{B}^0(\Delta t)\to f_{CP}) - \Gamma(B^0(\Delta t)\to f_{CP})}{\Gamma(\bar{B}^0(\Delta t)\to f_{CP}) + \Gamma(B^0(\Delta t)\to f_{CP})} = S_{f_{CP}}\sin(\Delta m \Delta t) + A_{f_{CP}}\cos(\Delta m \Delta t)$$

$$S_{f_{CP}} = \frac{2\,Im(\lambda)}{|\lambda|^2+1} \qquad A_{f_{CP}} = \frac{|\lambda|^2-1}{|\lambda|^2+1} \qquad \lambda = \frac{q}{p}\frac{\bar{A}(f_{CP})}{A(f_{CP})}$$

$$-C_{f_{CP}} = A_{f_{CP}} \qquad |\lambda| = 1 \text{ if no DCPV}$$

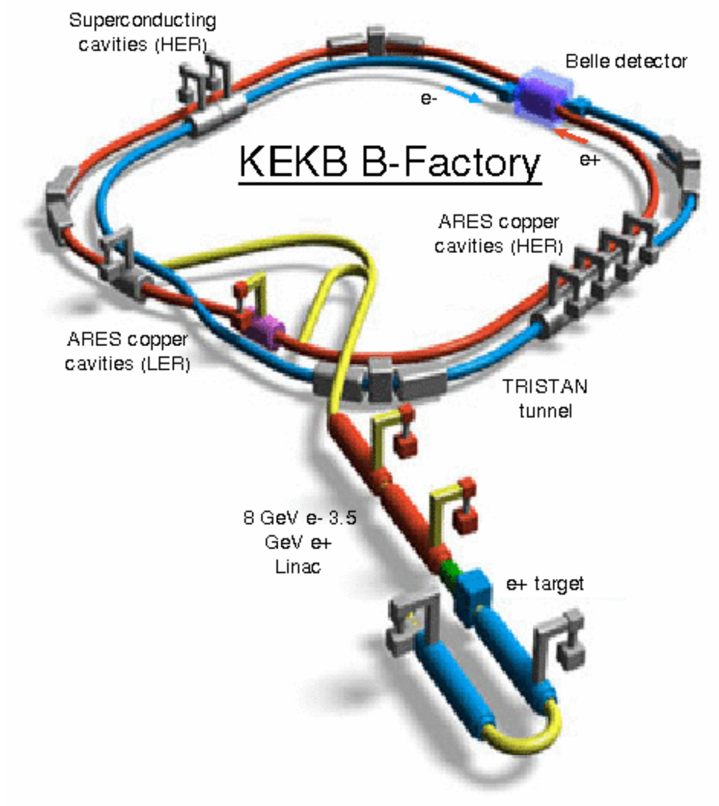
In order to perform such studies

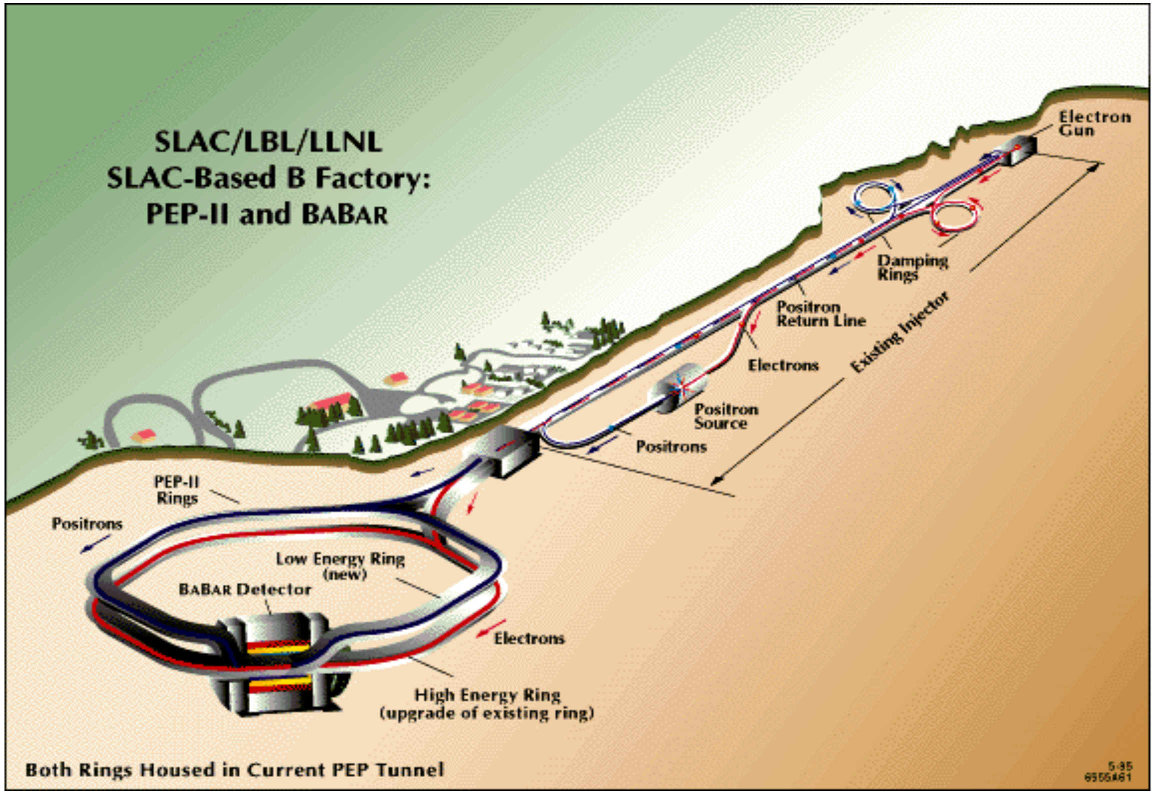
PDG2011 **Charmonium modes**

Γ_{156}	$\eta_c K^0$	$(8.9 \pm 1.6) \times 10^{-4}$		
Γ_{157}	$\eta_c K^*(892)^0$	$(6.1 \pm 1.0) \times 10^{-4}$		
Γ_{158}	$\eta_c(2S) K^{*0}$	$< 3.9 \times 10^{-4}$		CL=90%
Γ_{159}	$h_c(1P) K^{*0}$	$< 4 \times 10^{-4}$		CL=90%
Γ_{160}	$J/\psi(1S) K^0$	$(8.71 \pm 0.32) \times 10^{-4}$		
Γ_{161}	$J/\psi(1S) K^+ \pi^-$	$(1.2 \pm 0.6) \times 10^{-3}$		
Γ_{162}	$J/\psi(1S) K^*(892)^0$	$(1.33 \pm 0.06) \times 10^{-3}$		
Γ_{163}	$J/\psi(1S) \eta K^0_S$	$(8 \pm 4) \times 10^{-5}$		
Γ_{164}	$J/\psi(1S) \eta' K^0_S$	$< 2.5 \times 10^{-5}$		CL=90%

B meson is so heavy that many decay modes are available.
Branching fraction to the modes usable for CPV is limited.
→ Huge ($O(10^8)$) amount of B mesons is necessary.
→ Measurement of time evolution of B meson pair is required.

Two B-factories at KEK and SLAC

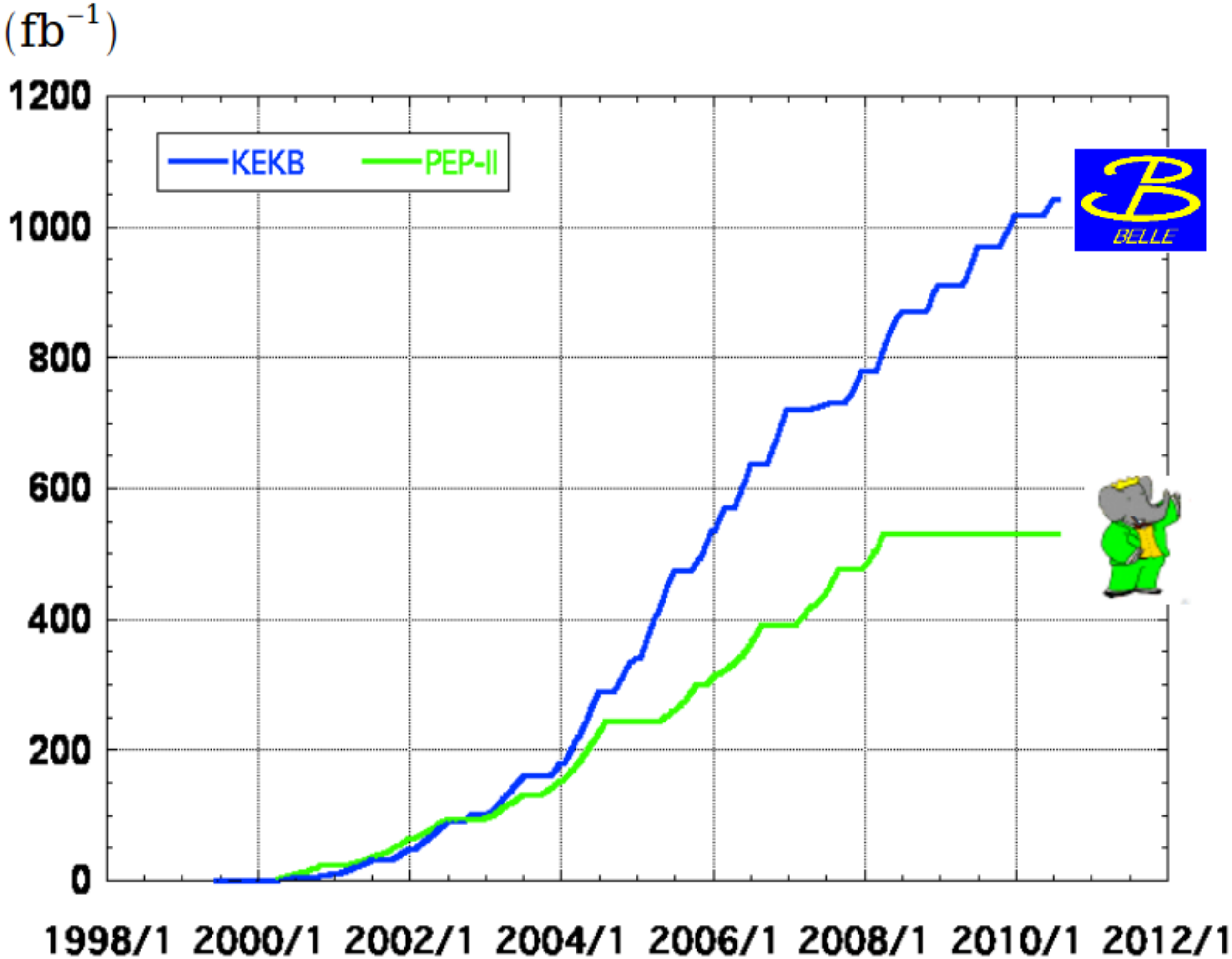




8GeV(e^-)X3.5GeV(e^+), $L_{max} = 2.1\times10^{34}cm^{-2}s^{-1}$

9GeV(e^-)X3.1GeV(e^+), $L_{max} = 1.2\times10^{34}cm^{-2}s^{-1}$

Integrated luminosity of B factories



$> 1\ ab^{-1}$

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1} 772M $B\overline{B}$

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 25 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan:

$\sim 100\ fb^{-1}$

$\sim 550\ fb^{-1}$

On resonance:

$\Upsilon(4S)$: 433 fb^{-1} 470M $B\overline{B}$

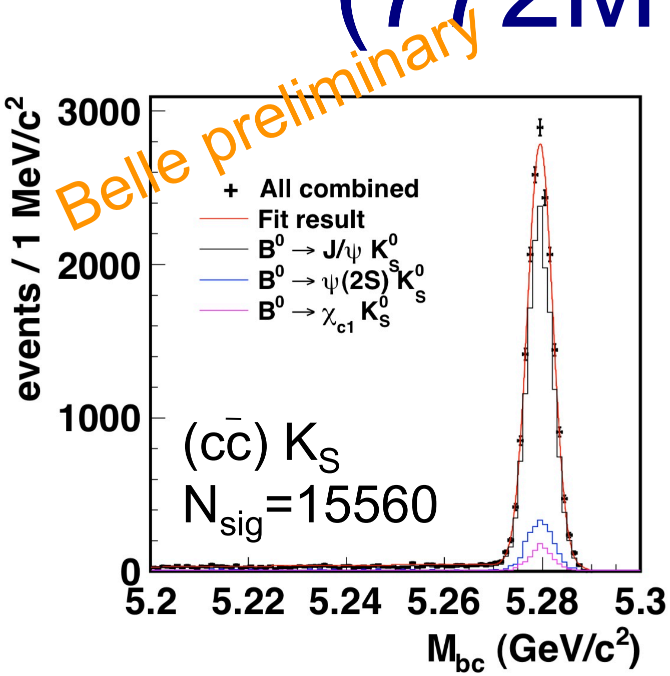
$\Upsilon(3S)$: 30 fb^{-1}

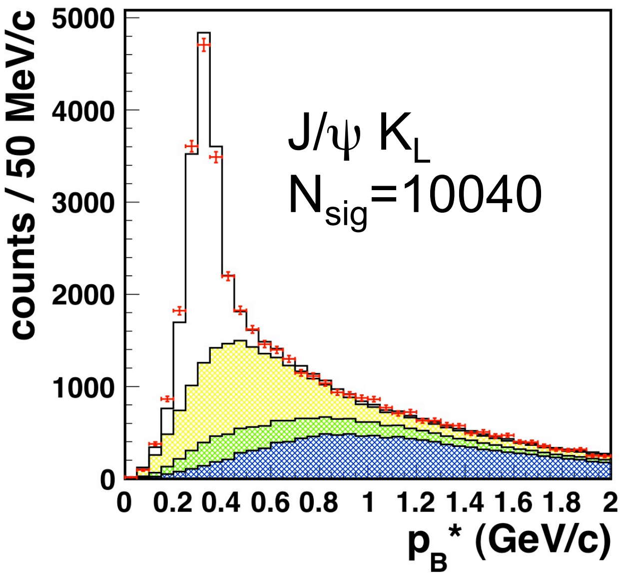
$\Upsilon(2S)$: 14 fb^{-1}

Off resonance:

$\sim 54\ fb^{-1}$

$\sin2\phi_1$ at Belle (772M $B\bar{B}$, final sample)

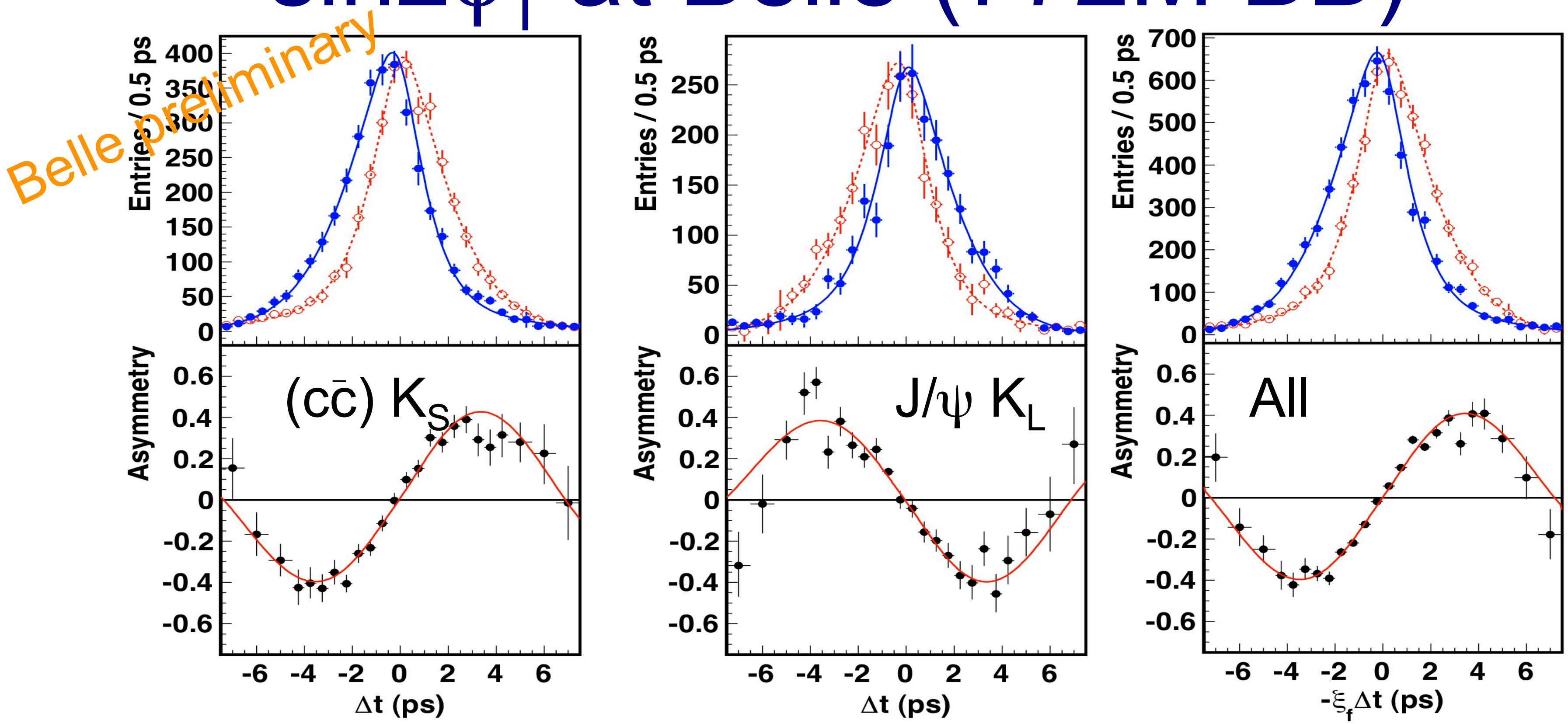




Signal yield increased more than $N_{B\bar{B}}$ compared to the previous publication (PRL98,031802), thanks to the data reprocessing with improved tracking.

	$J/\psi\ K_S$	$J/\psi\ K_L$	ψ (2S) K_S	$\chi_{c1}\ K_S$	N_{BB}
N_{sig}	12727±115	10087±154	1981±46	943±33	772 M
Purity(%)	97	63	93	89	
N_{sig}(prev.)	7484±87	6512±123	N/A	N/A	535 M
Purity(%) (prev.)	97	59			

$\sin 2\phi_1$ at Belle (772M $B\bar{B}$)

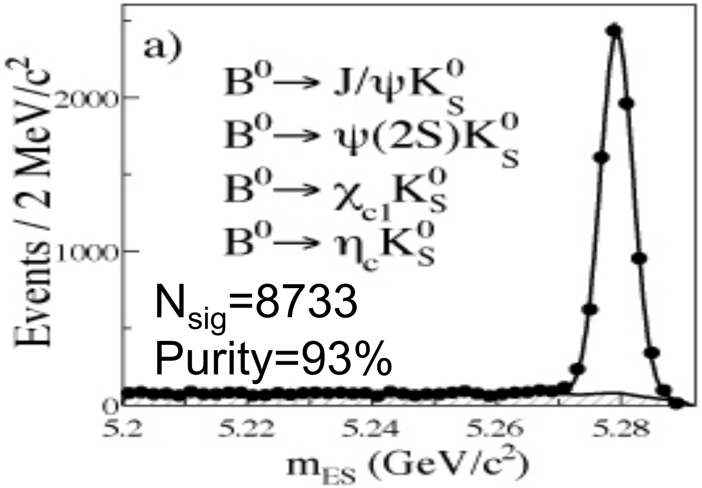


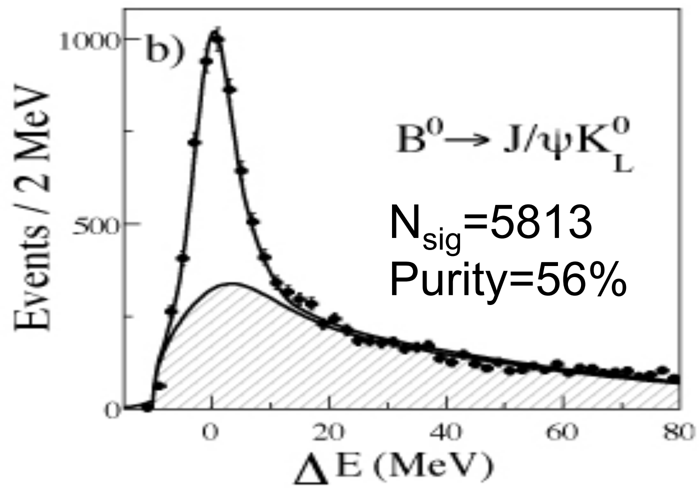
B decay mode	$\mathcal{S}_f$	$\mathcal{A}_f$
$J/\psi K_S^0$	0.671 ± 0.029	-0.014 ± 0.021
$\psi(2S) K_S^0$	0.739 ± 0.079	0.103 ± 0.055
$\chi_{c1} K_S^0$	0.636 ± 0.117	-0.023 ± 0.083
$J/\psi K_L^0$	-0.641 ± 0.047	0.019 ± 0.026

$\sin 2\phi_1 = 0.668 \pm 0.023 \pm 0.013$

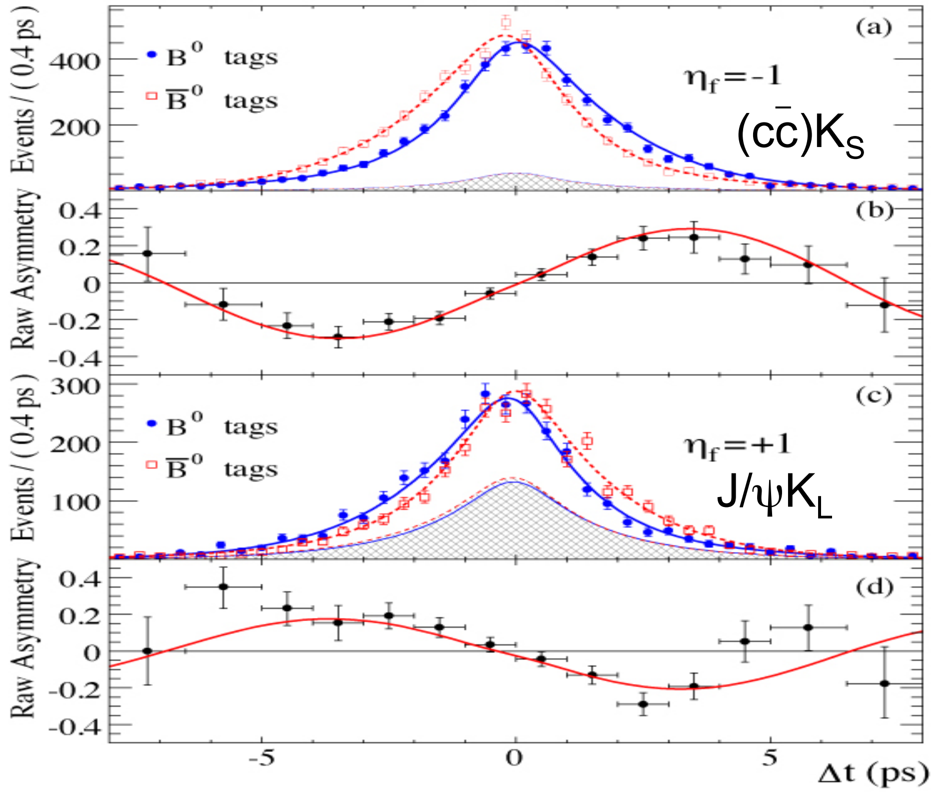
$A_{fCP} = 0.007 \pm 0.016 \pm 0.013$

$\sin 2\phi_1 (=\sin 2\beta)$ at BaBar (465M $B\bar{B}$)





$E_B - E_{CM}/2$

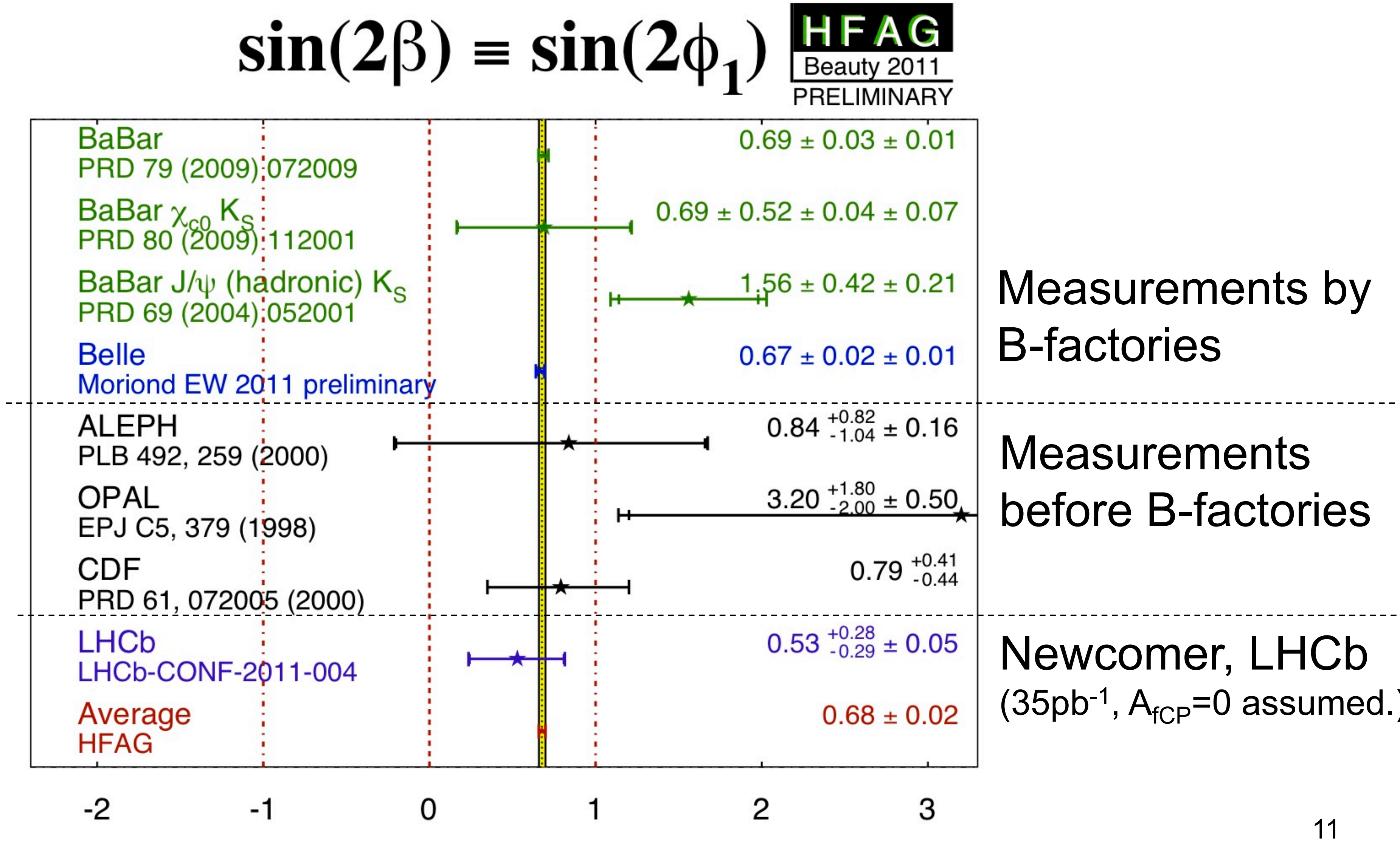


$\sin 2\phi_1 = 0.687 \pm 0.028 \pm 0.012$

$A_{fCP} = -0.024 \pm 0.020 \pm 0.016$

PRD79,072009(2009)

Now it is a firm SM reference!



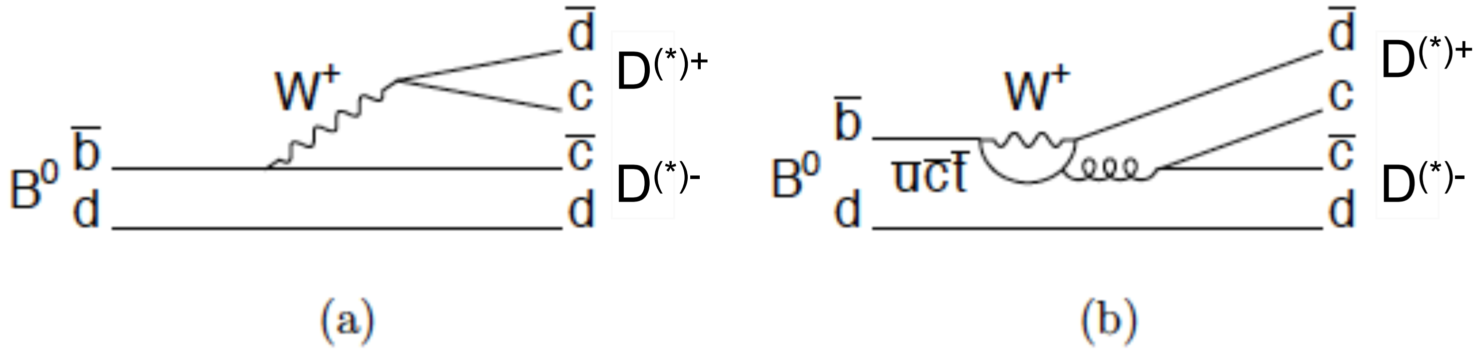
Measurements by B-factories

Measurements before B-factories

Newcomer, LHCb

($35pb^{-1}$, $A_{fCP}=0$ assumed.)

b→c$\bar{c}$d process is pursuit of

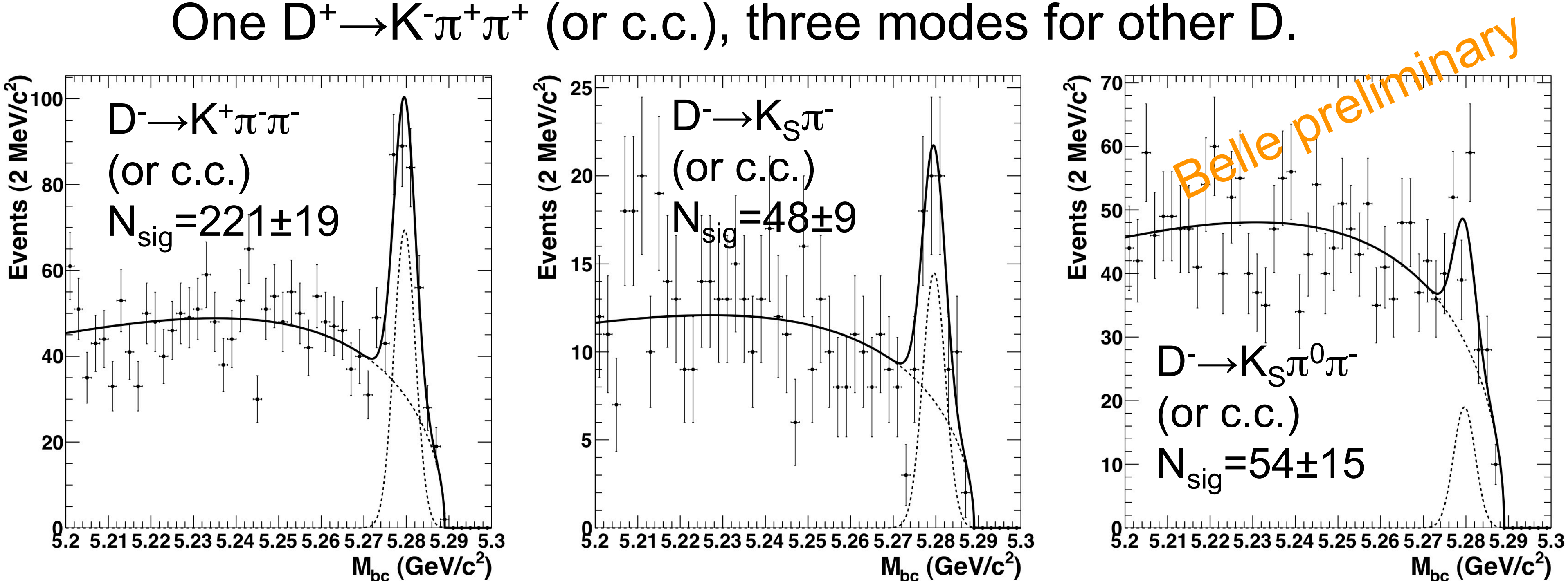


In $B^0 \to D^+D^-$ case,
If tree (a) dominant, $S_{fCP} \to -\sin 2\phi_1$, $A_{fCP} \to 0$,
while if penguin (b) is substantial, complex phase due to V_{td} may cause Direct CPV.

Since $B^0 \to D^{*+}D^{*-}$ is a B→VV mode, the admixture of CP even/odd eigenstates must be determined before measuring CP violation.

$B^0 \to D^+D^-$ reconstruction

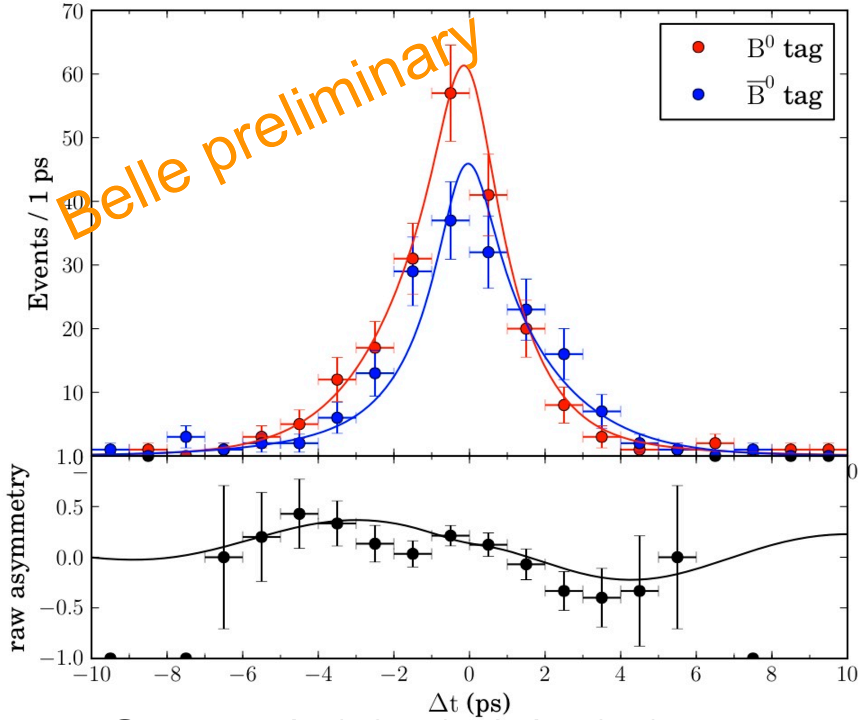
One $D^+ \to K^-\pi^+\pi^+$ (or c.c.), three modes for other D.

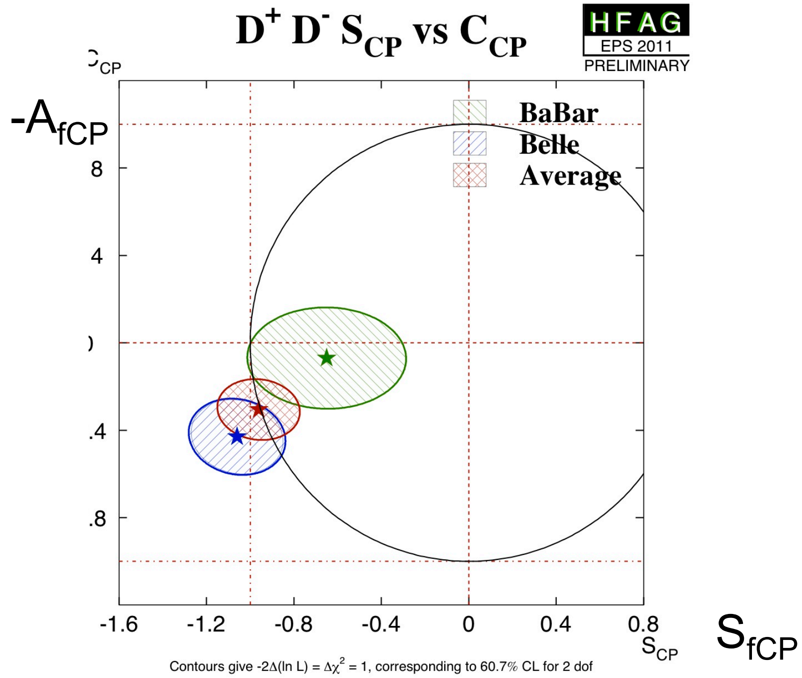


$Br(B^0 \to D^+D^-) = (2.09 \pm 0.15 \pm 0.18) \times 10^{-4}$

cf. Previous result (PRL98,221802) based on 535M $B\overline{B}$, N_{sig}=150±15 ($D^- \to K_S\pi^0\pi^-$ not used), improvement in N_{sig} by data reprocessing is more significant than $(c\overline{c})$ K^0 because of the larger track multiplicity.

$B^0 \to D^+D^-$ CP violation



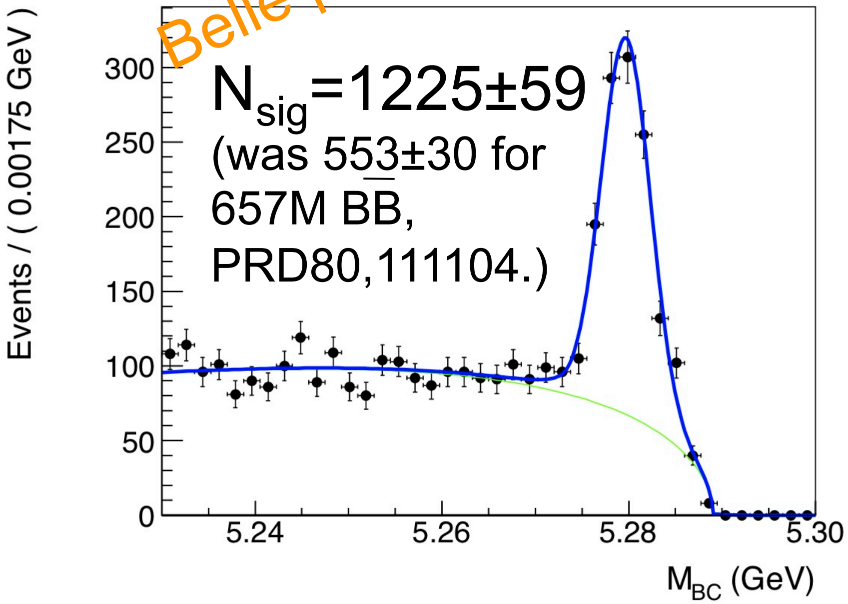


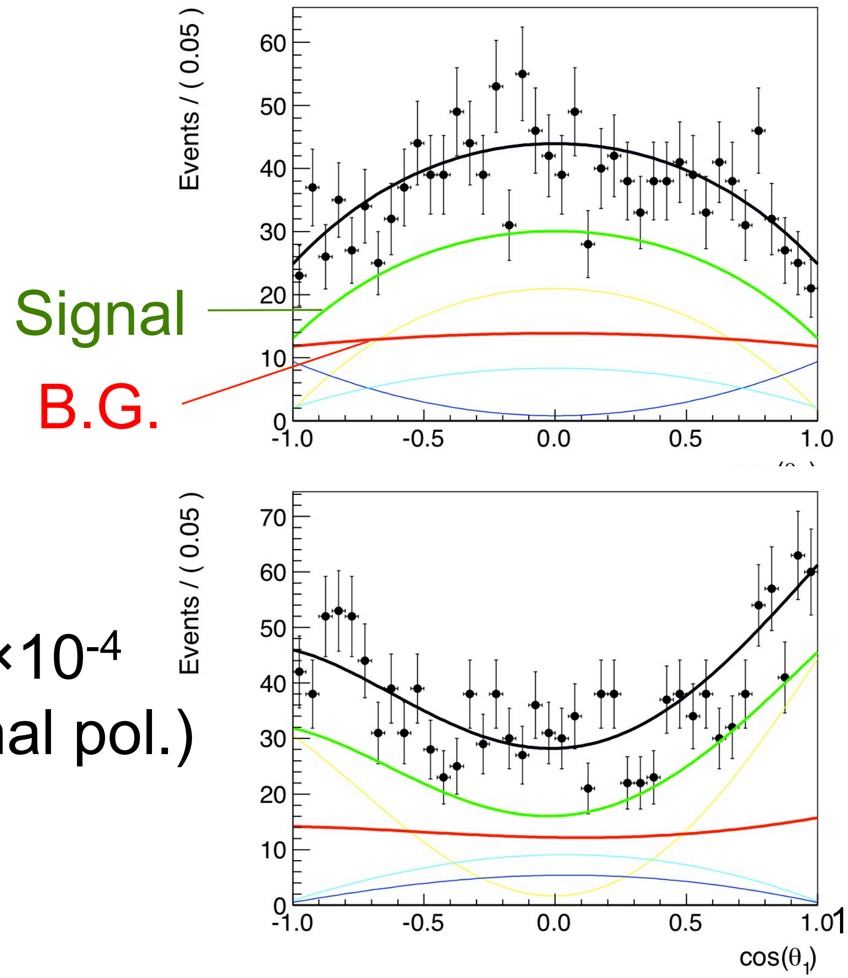
$S_{fCP}=-1.06\pm0.21\pm0.07$

$A_{fCP}=+0.43\pm0.17\pm0.04$ ($D^- \to K_S\pi^0\pi^-$ not used because of background forming a peak at same position as signal.)

S_{fCP} is similar. However A_{fCP} has decreased compared to previous publication with 535M $B\overline{B}$ (PRL98,221802).
($S_{fCP}=-1.13\pm0.37\pm0.09$, $A_{fCP}=+0.91\pm0.23\pm0.06$)

$B^0 \to D^{*+}D^{*-}$ branching and polarization



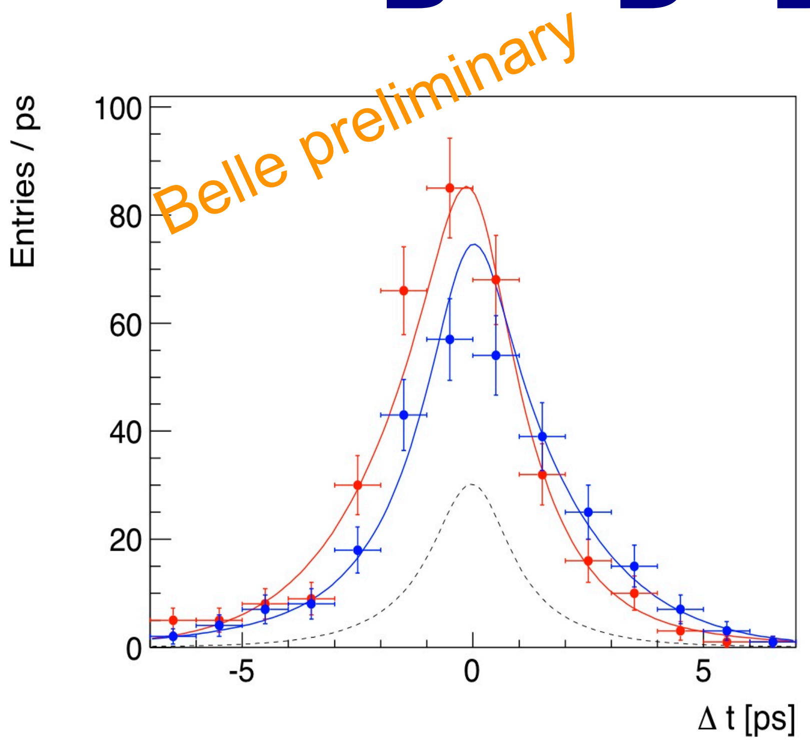


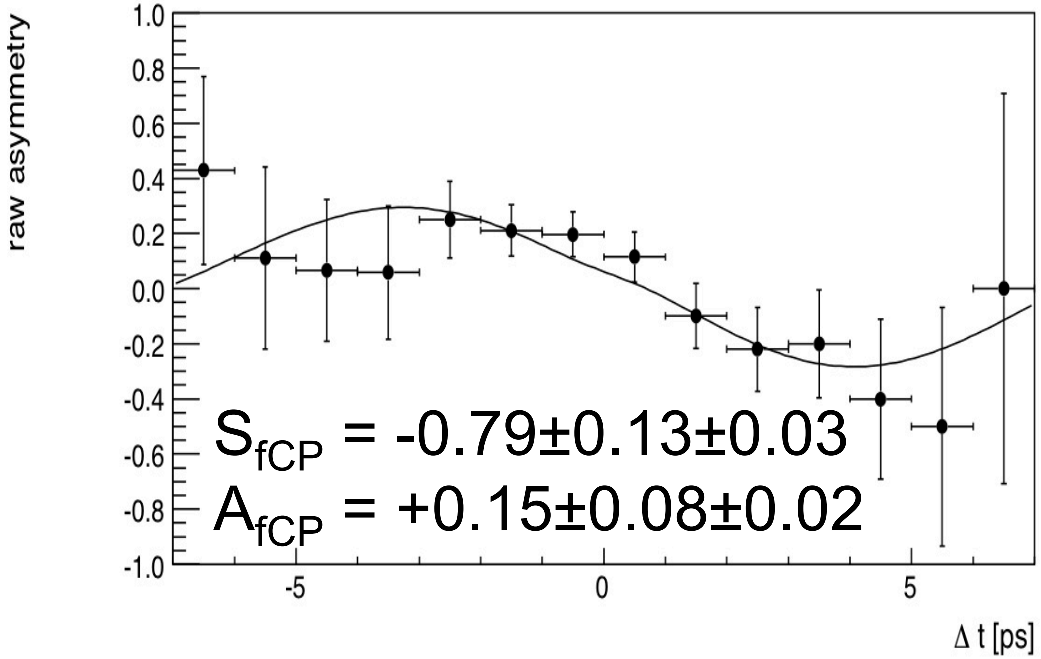
$Br(B^0 \to D^{*+}D^{*-}) = (7.82 \pm 0.38 \pm 0.60) \times 10^{-4}$

R_0 = 0.62±0.03±0.01 (longitudinal pol.)

R_{perp} = 0.14±0.02±0.01 (CP-odd)

$B^0 \to D^{*+}D^{*-}$ CP violation

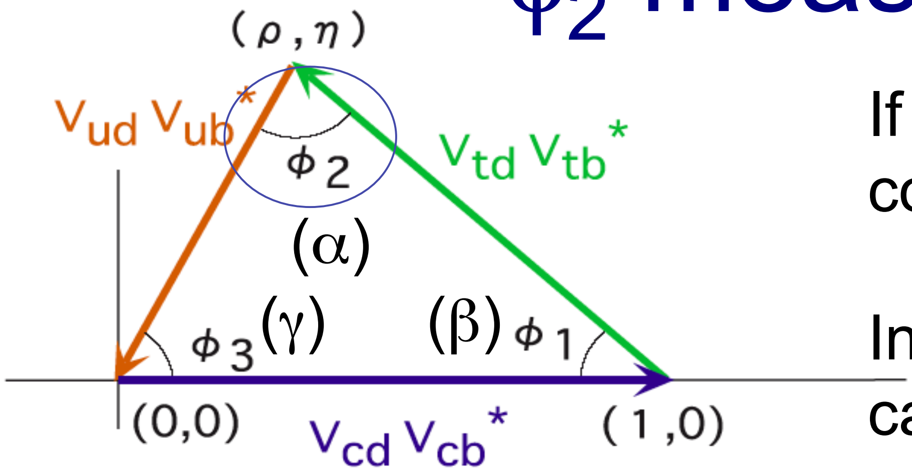




As a result of data reprocessing, signal yield from 772M $B\bar{B}$ pairs is ×2.2 larger than the yield with the 657M $B\bar{B}$ sample used for the previous result (PRD80,111104).

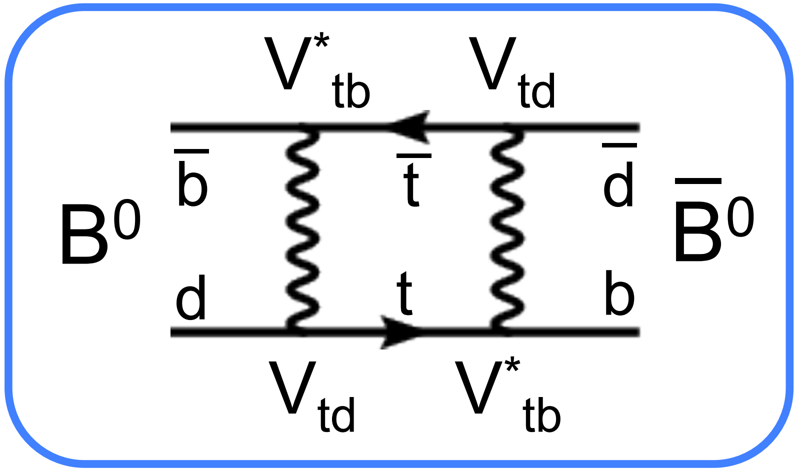
→significant improvement (S_{fCP} and A_{fCP} errors down to 60%)!

ϕ_2 measurement

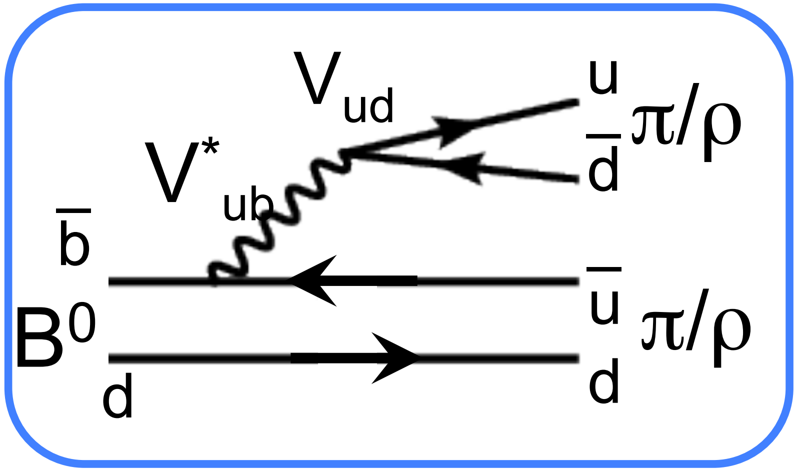


If tree only, S_f is directly connected to $\sin 2\phi_2$ and A_f=0.

Interference with b→ d penguin can be solved by isospin analysis.



Mixing diagram

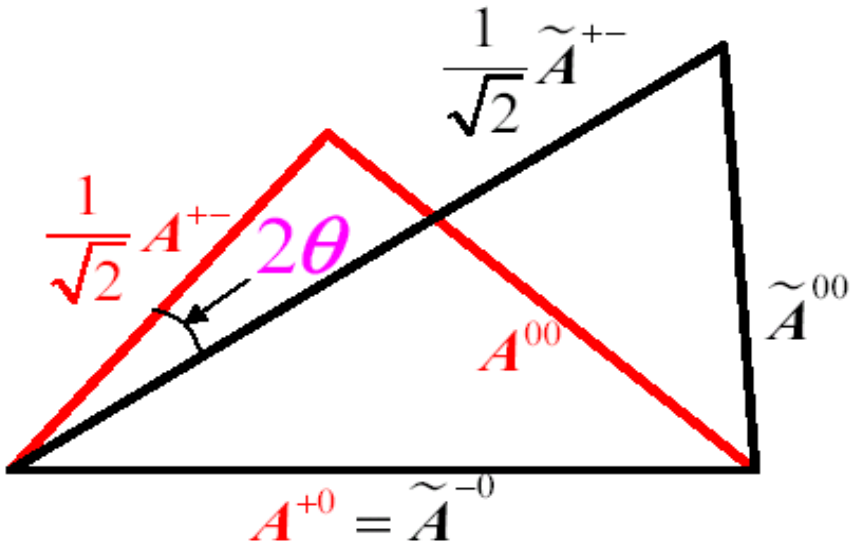


Decay diagram (tree)

There are 3 modes; ππ, ρρ, ρπ. In addition $a_1\pi$.

Extract ϕ_2; isospin analysis

M. Gronau and D. London, PRL 65, 3381 (1990)



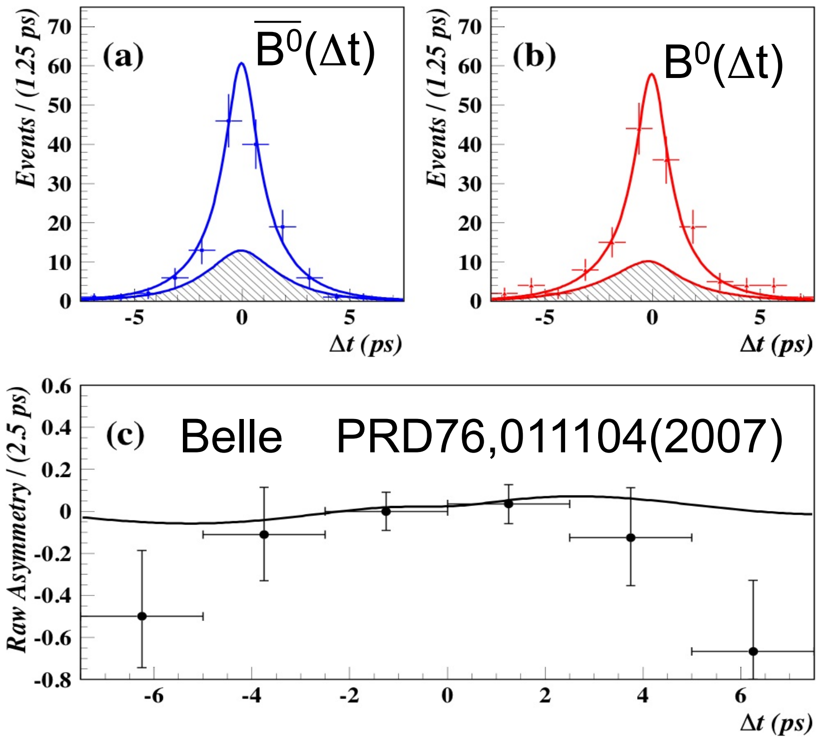
	Amplitude for
$A^{+-}(\bar{A}^{+-})$	$B^0(\bar{B}^0) \to \pi^+\pi^-$
$A^{00}(\bar{A}^{00})$	$B^0(\bar{B}^0) \to \pi^0\pi^0$
$A^{+0}(\bar{A}^{-0})$	$B^+(B^-) \to \pi^+\pi^0(\pi^-\pi^0)$

$$\tilde{A}^{ij} = e^{2\phi_3}\bar{A}^{ij}$$

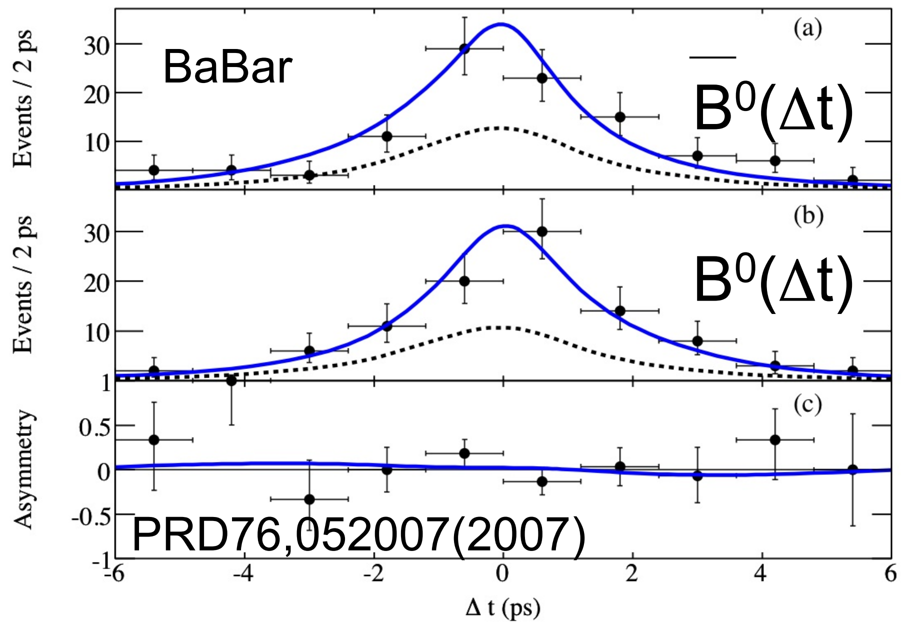
$B^0 \to \pi^+\pi^-$, $\pi^0\pi^0$, $B^\pm \to \pi^\pm\pi^0$ branching fractions,
and $B^0 \to \pi^0\pi^0$ Direct CPV are used as inputs to solve this relation.
The correction from SU(2) breaking effect is still much smaller than measurements' errors.

$B^0 \to \rho^+ \rho^-$

B→ VV, almost purely longitudinally polarized=CP eigenstate.
Small Br($B^0 \to \rho^0\rho^0$), i.e. small penguin pollution.

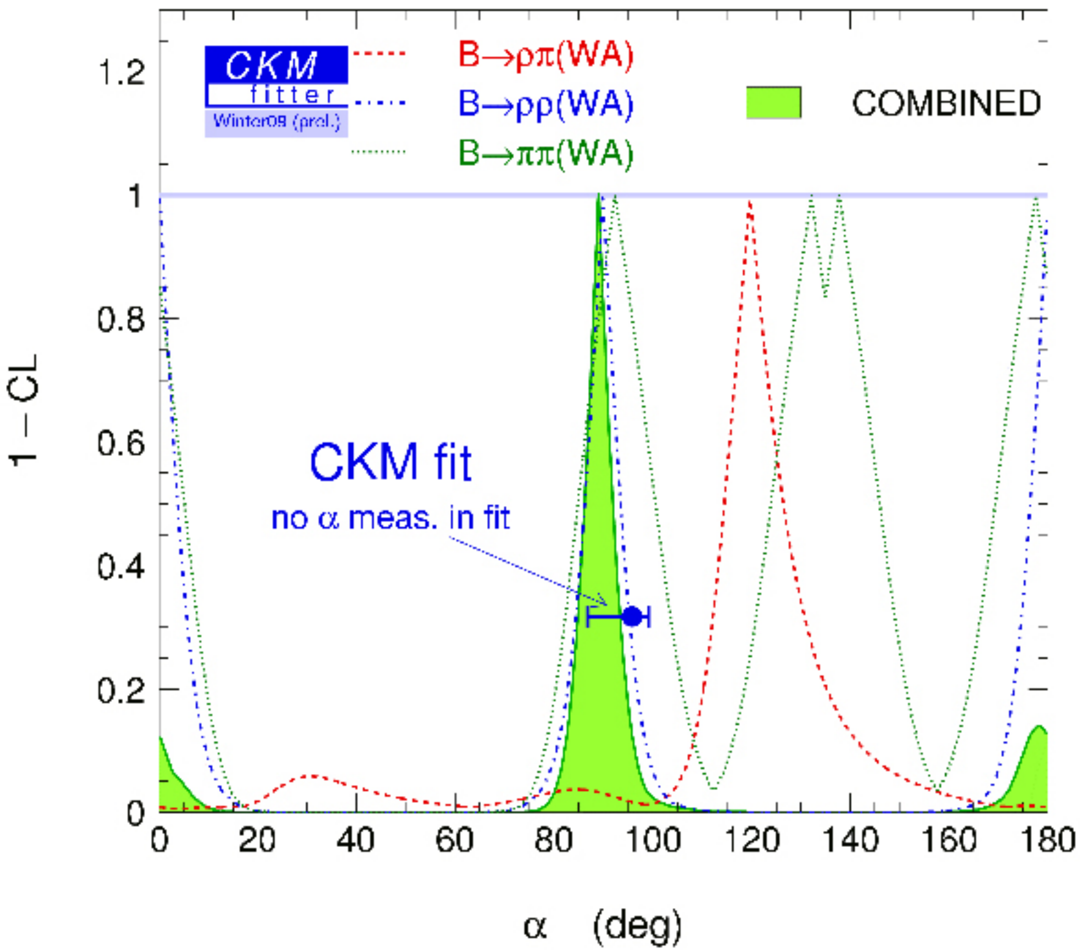


f_L=0.941+0.034/-0.040±0.030
S_f=0.19±0.30±0.07
A_f=0.16±0.21±0.07



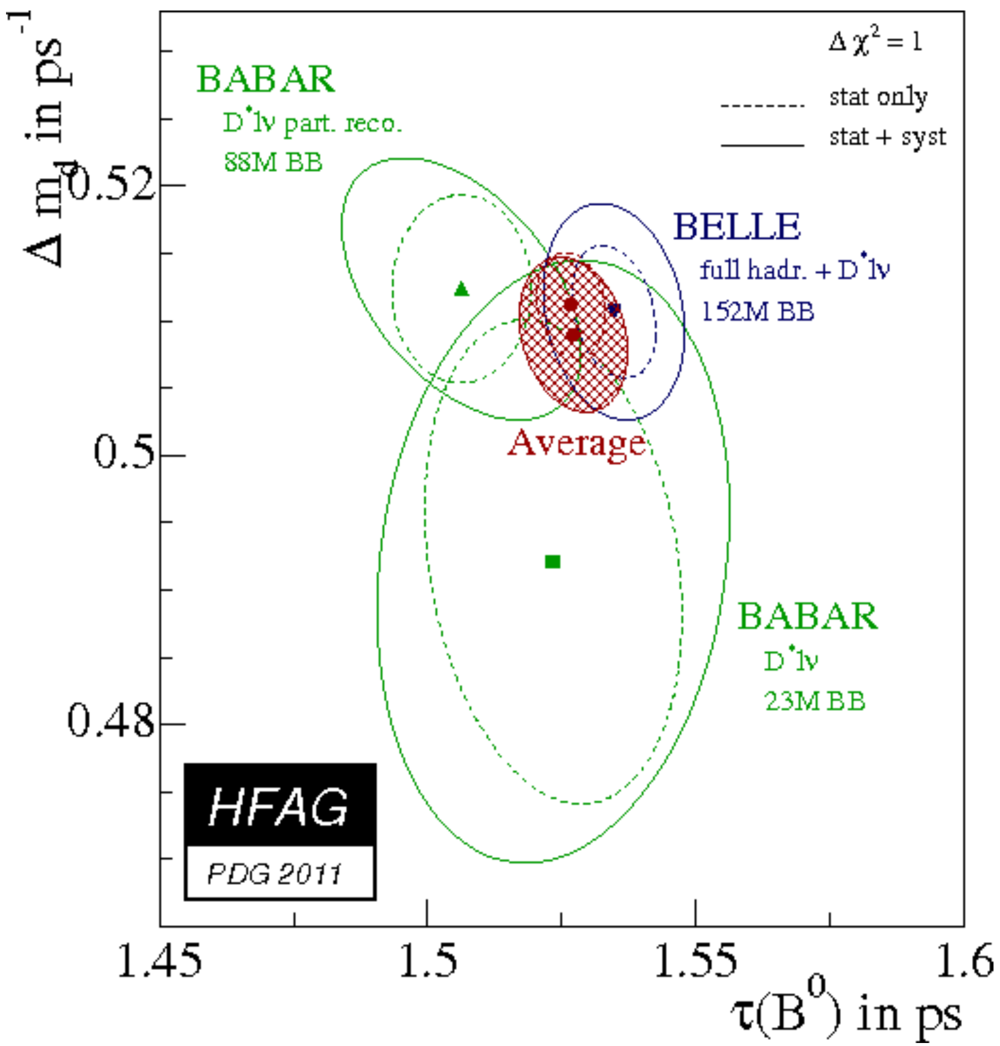
f_L=0.992±0.024+0.026/-0.013
S_f=0.19±0.30±0.07
A_f=0.16±0.21±0.07

Constraint on ϕ_2



ϕ_2=89.0+4.4/-4.2 deg.

As for Δm_d measurement

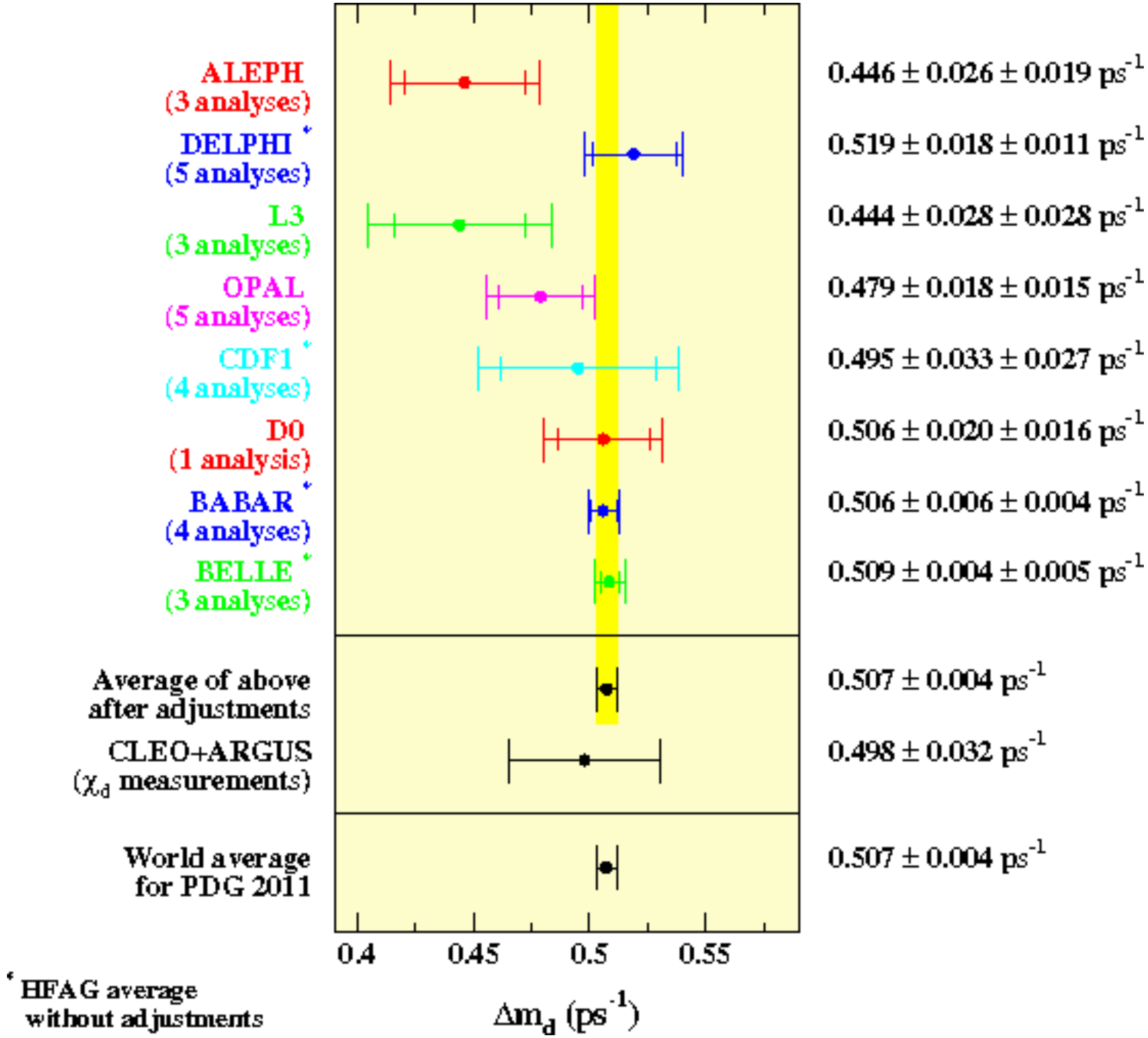


BaBar: $D^* l\nu$ partial recon., opposite side B is tagged by high momentum lepton.

Belle: $D^* l\nu$ and $D^{(*)}X$ hadronic modes full recon., opposite side B tagging is the one for time-dependent CPV.

Δm_d and B lifetime are obtained simultaneously. With ~20% of entire $\Upsilon(4S)$ data, but systematic dominant.

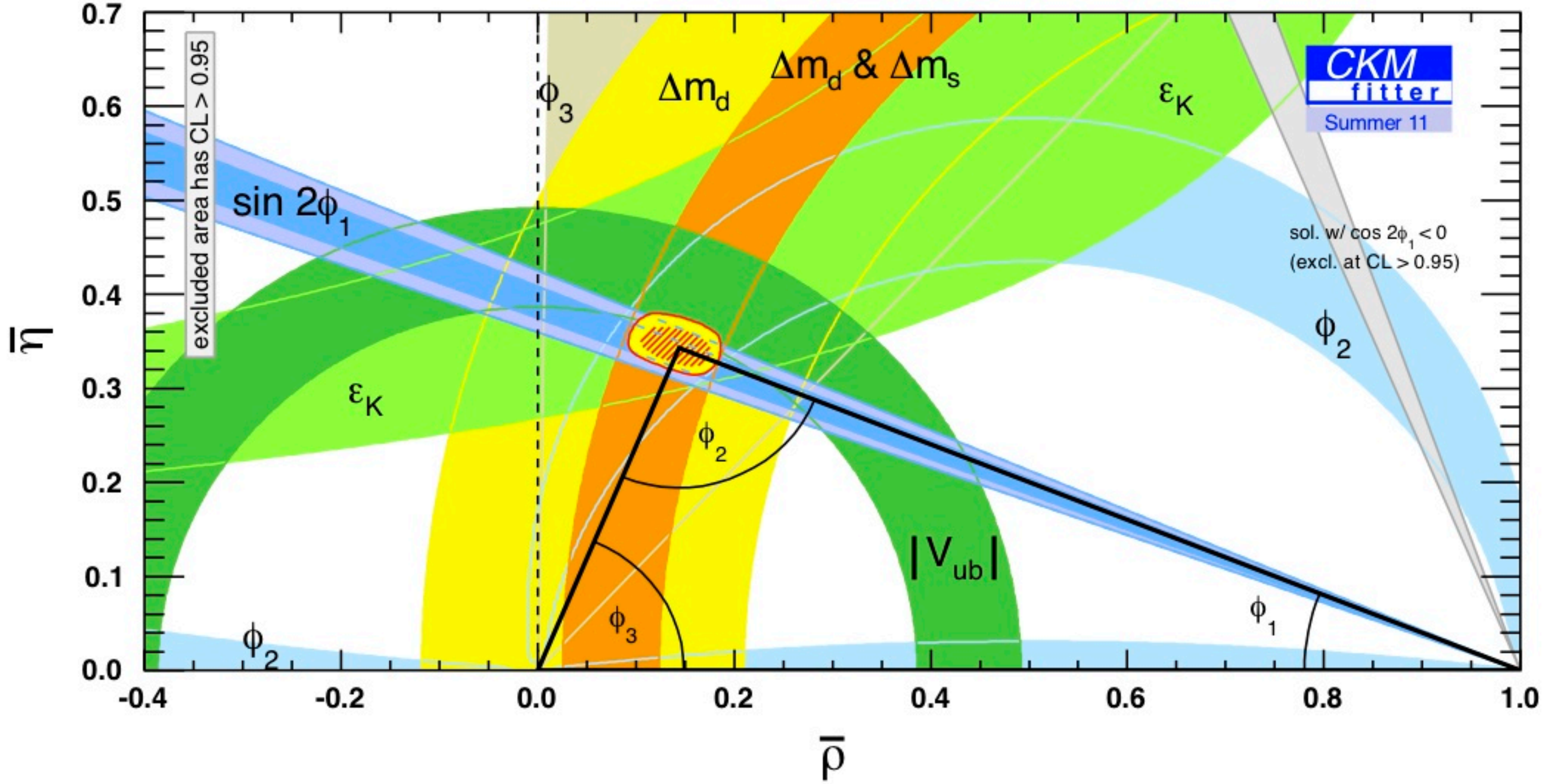
Δm_d without/with B-factories



BaBar and Belle results 4-5 times more precise than LEP and Tevatron experiments.

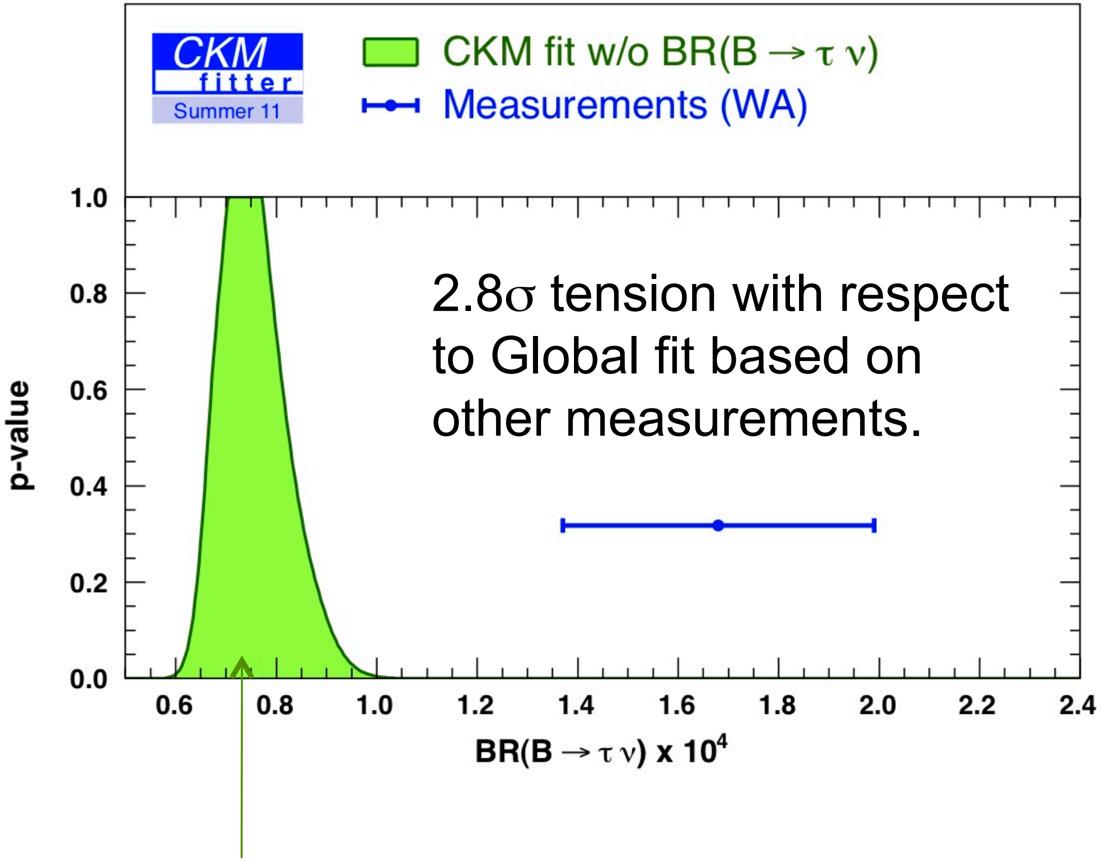
Now 1% precision has been achieved. This gives another reference point to constrain unitarity triangle, i.e. $|V_{td}|$ in the SM framework.

KM scheme has been tested.



ϕ_3 precision improved, $\sigma(\phi_3)$~10° (See Y.Horii's talk).
Is the unitarity triangle a right triangle?

However, tension with Br($B^+ \to \tau^+ \nu$)



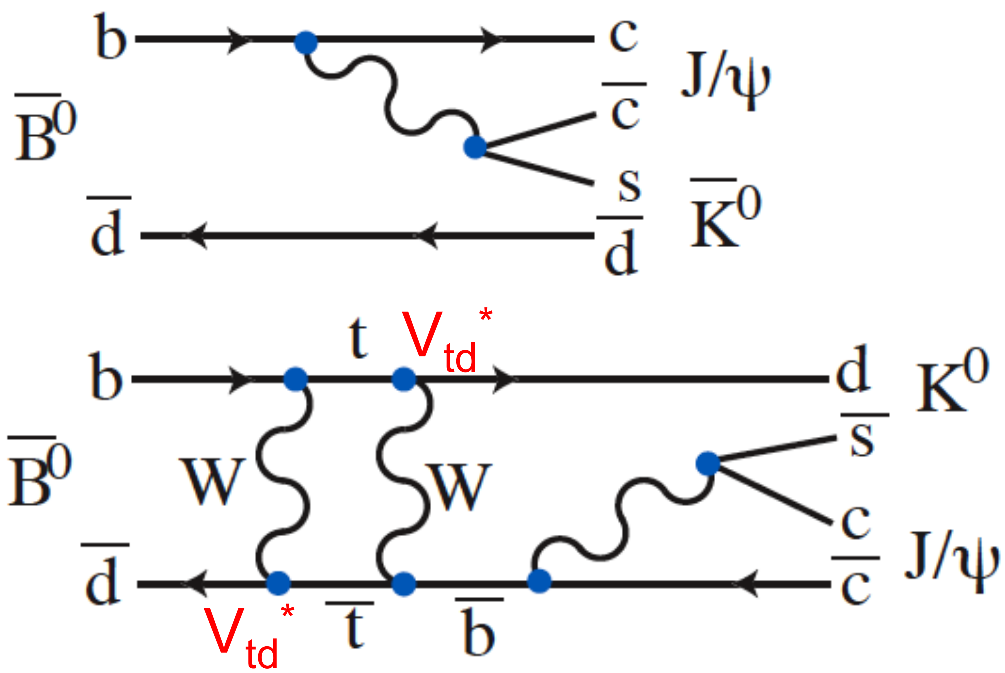
Of course, new physics (NP) could be present in $B^+ \to \tau^+ \nu$. We need an update of this measurement.
But no other place?

$\sin 2\phi_1$ measurement gives a stringent constraint.

S_{fCP} and $\sin 2\phi_1$ SM relation

(1) Decay

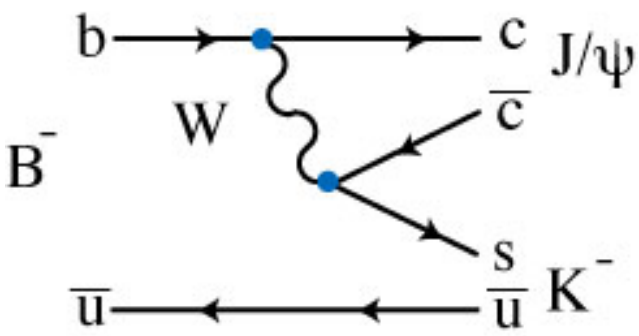
(2) Decay with mixing



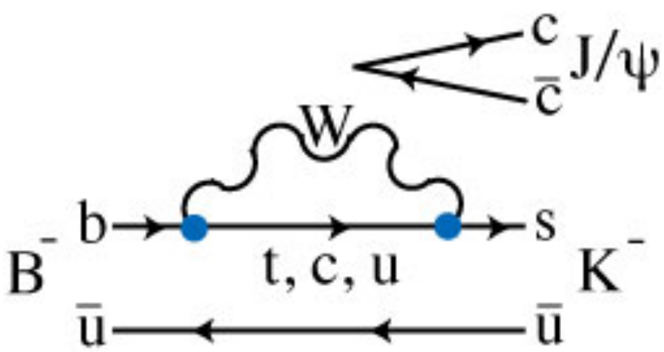
Interference between (1) and (2) results in CP violation.

$S_{fCP} = -\xi_{CP} \sin 2\phi_1$, ξ_{CP} =-1 (CP-odd), +1 (CP-even), $A_{fCP}=0$.
Is there room to accommodate new physics (NP)?

NP room is unlikely in $b \to c\bar{c}s$ decays

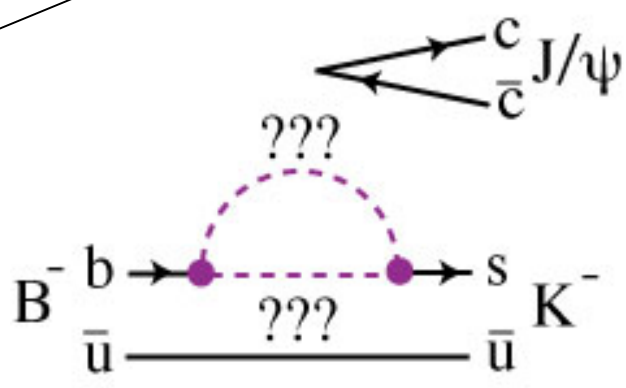


SM tree



SM penguin

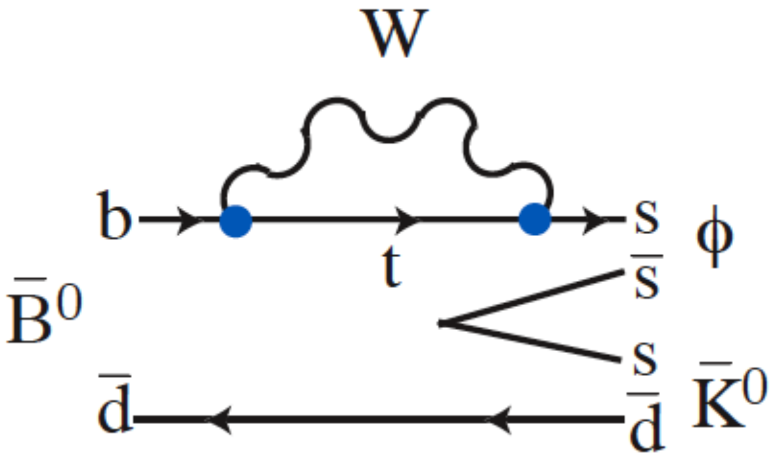
Same weak phase



NP penguin

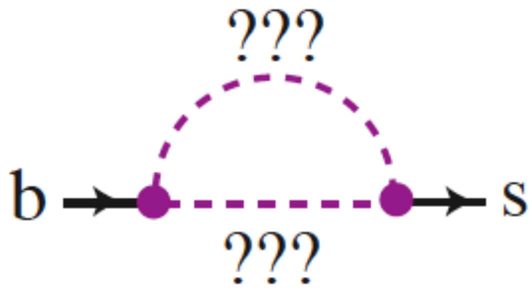
If NP penguin is substantial and has different phase, it causes Direct CPV in $B^{\pm} \to J/\psi\ K^{\pm}$.
No direct CP violation has been observed so far.
-0.76±0.50±0.22% at Belle (PRD82,091104),
$(1\pm7)\times10^{-3}$ in PDG2011.
However, there is room for NP in B-$\bar{B}$ mixing.

Effective ϕ_1 in penguin decays



SM penguin;
No complex phase in decay.

as well as

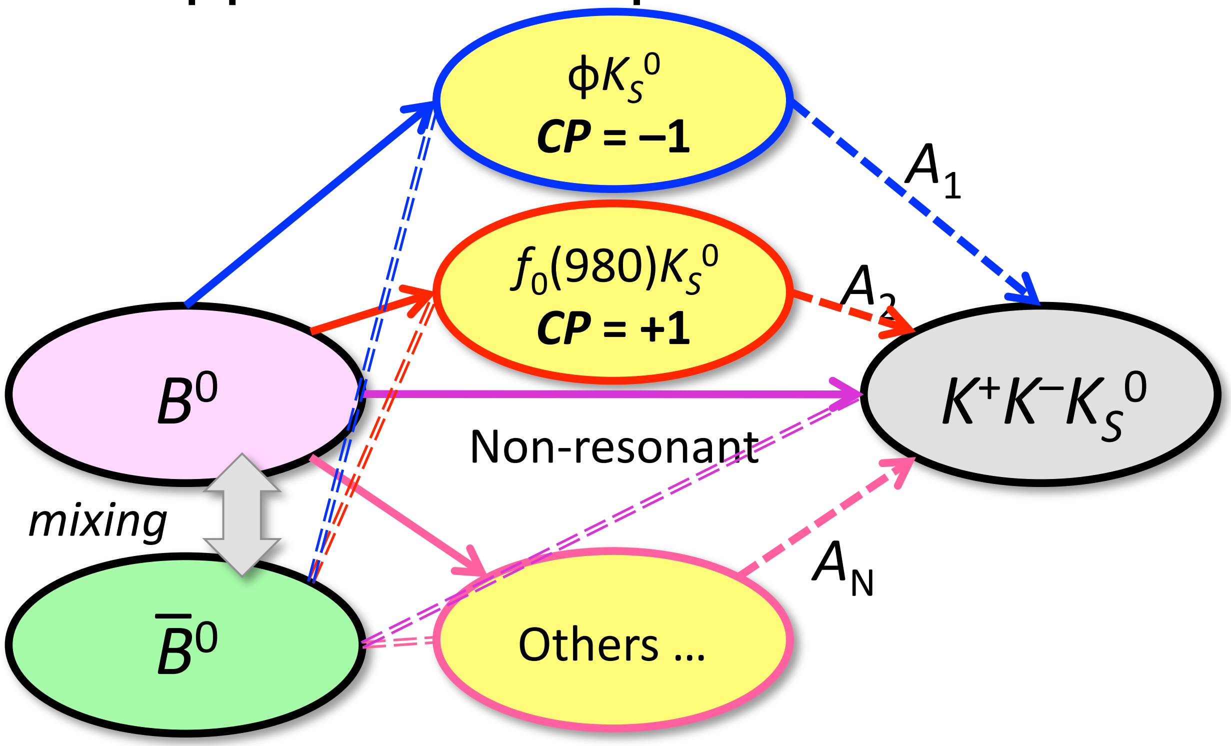


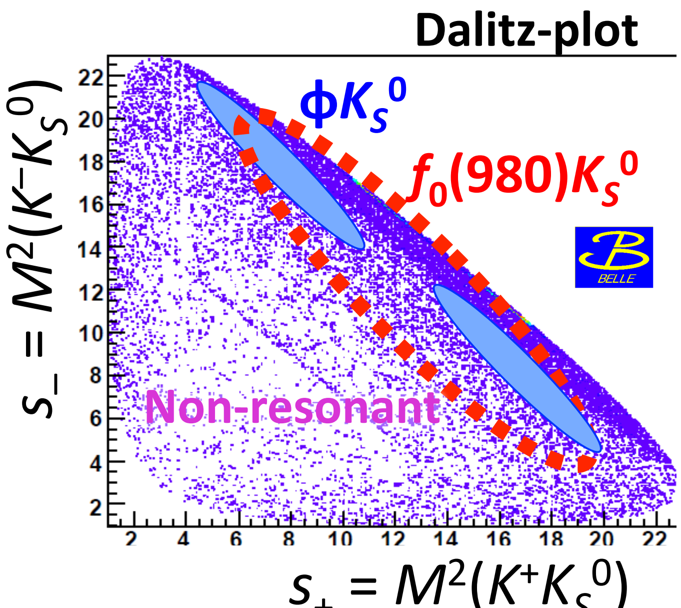
New Physics in the loop;
may have a different weak phase.
CPV deviation from $J/\psi\ K^0$?

Many two-body and quasi-two body analyses have been done. Since $\phi \to K^+K^-$, $f_0 \to K^+K^-$ and non-resonant contributions overlap in invariant mass (as do $\rho^0 \to \pi^+\pi^-$ and $f_0 \to \pi^+\pi^-$), recently time-dependent Dalitz analyses have been performed in three-body decays such as $B^0 \to (K^+K^-)K_S$ and $B^0 \to (\pi^+\pi^-)K_S$.

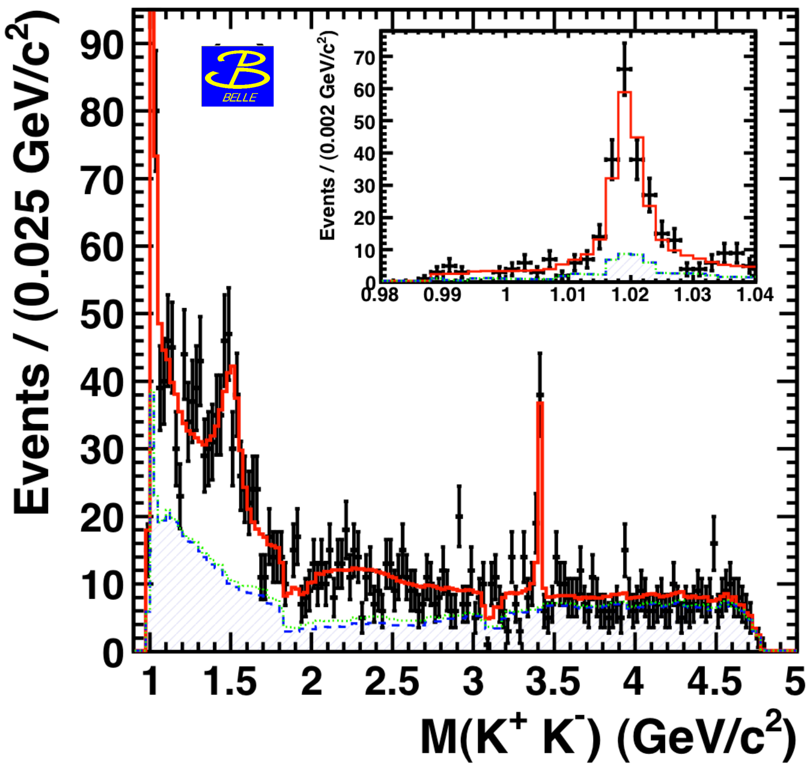
Several contributions are overlapping

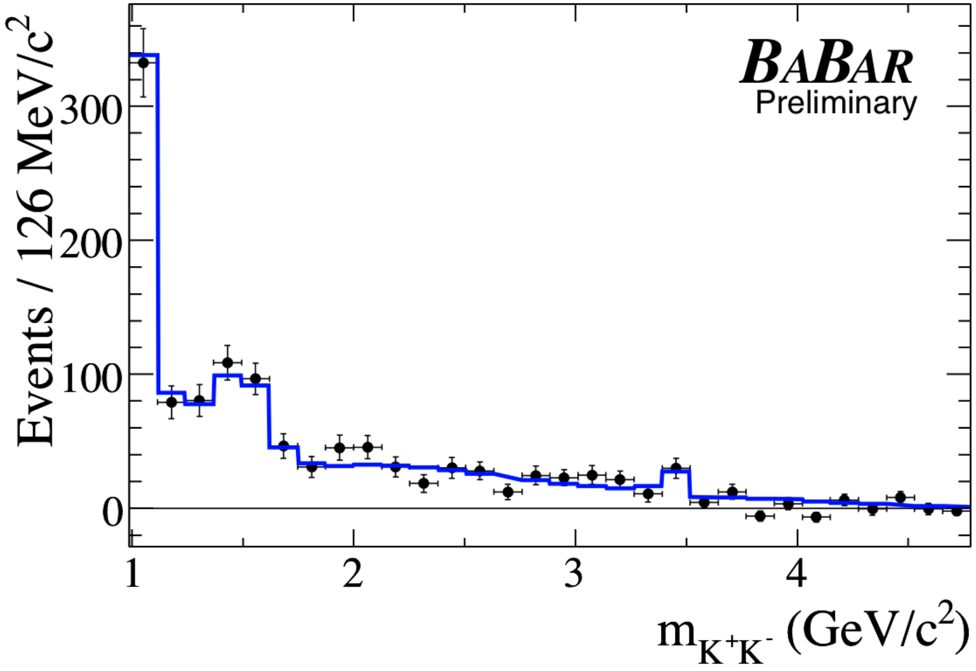
- For example, $B^0 \rightarrow K^+K^-K_S$ final state has several different paths.
- Resolve them by fitting the Dalitz distribution. Same approach is required for $B^0 \rightarrow \pi^+\pi^-K_S$.





Projections of Dalitz distribution (M_{K+K-})

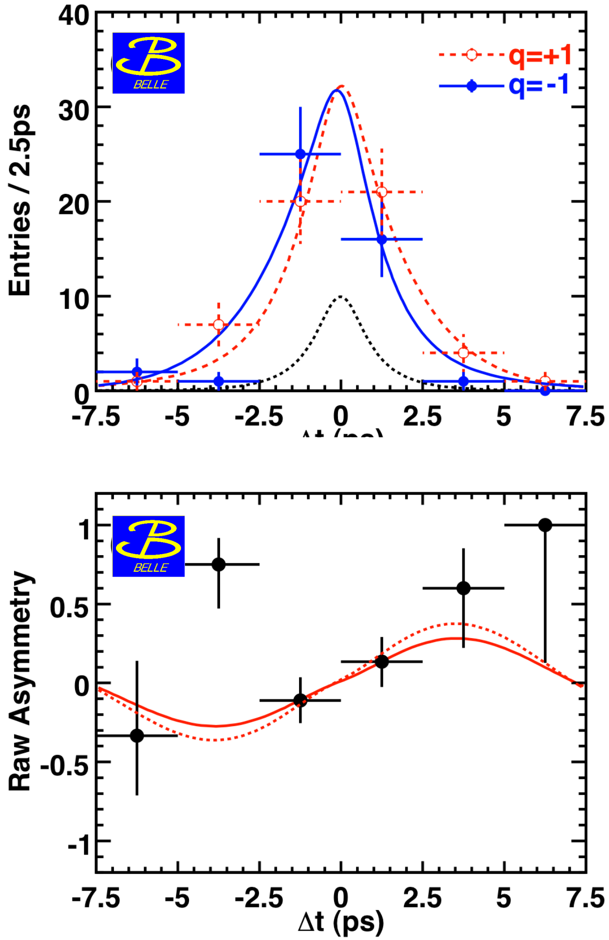




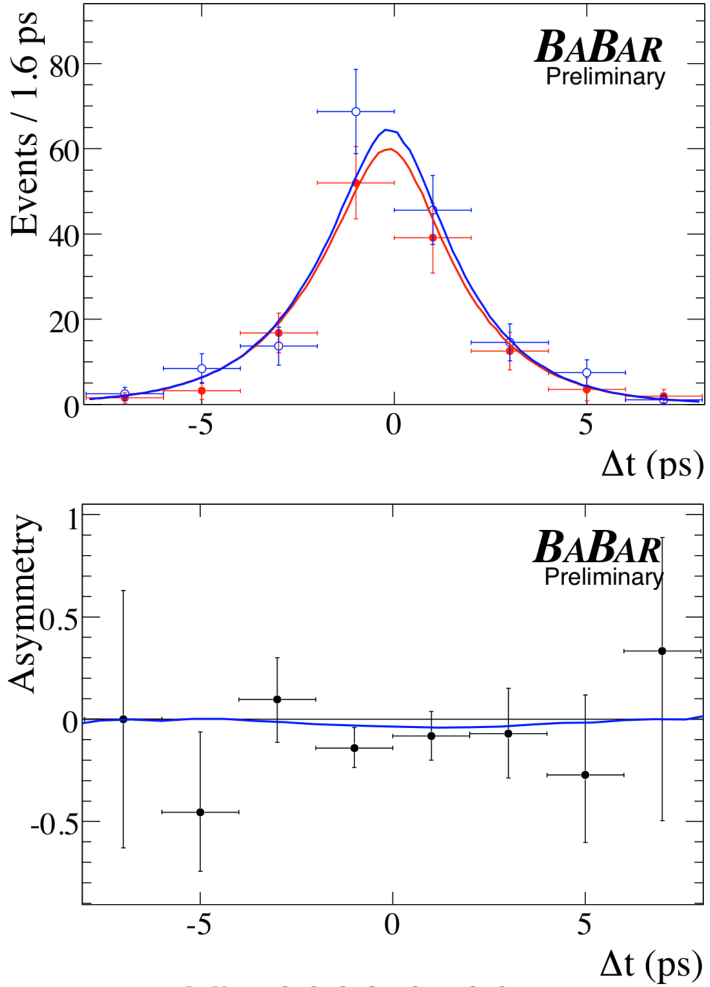
Peak around 1GeV/c^2 : ϕ(1020) and f_0(980), at 1.5GeV/c^2 : fX, at 3.4GeV/c^2 : χ_{c0}

There are multiple solutions (Belle found 4, BaBar found 2).

Δt distribution in φ mass region

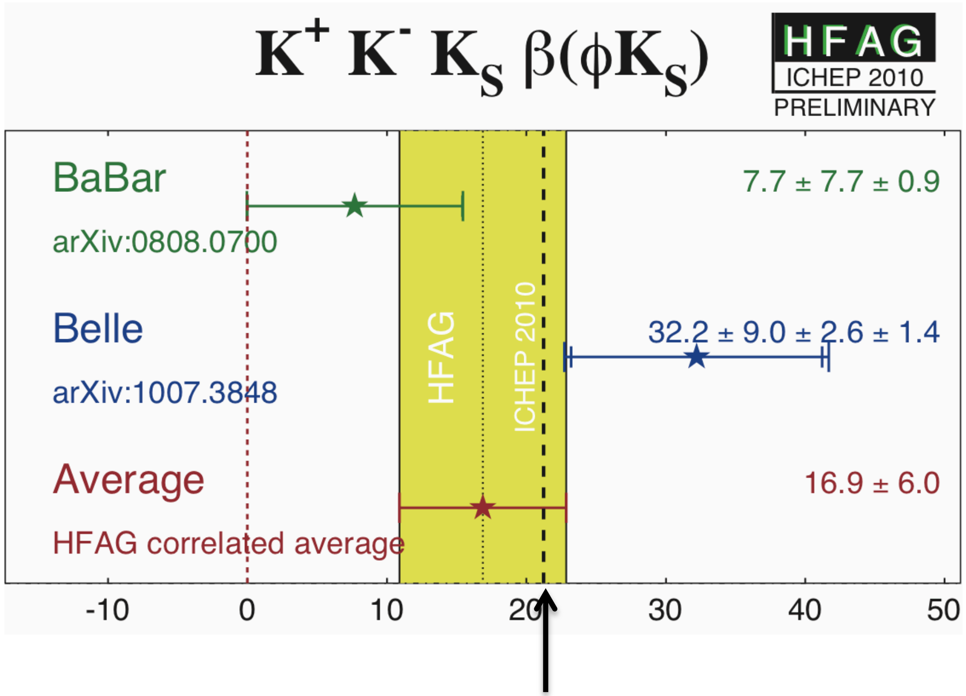


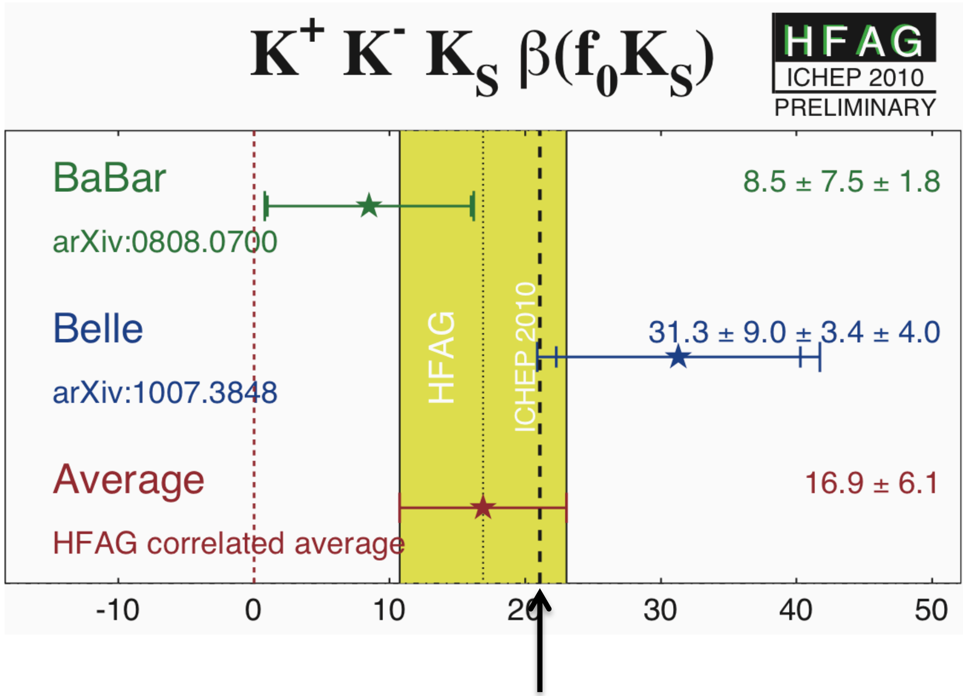
PRD82,073011(2010)



arXiv:0808.0700

Effective ϕ_1 of "solution 1"

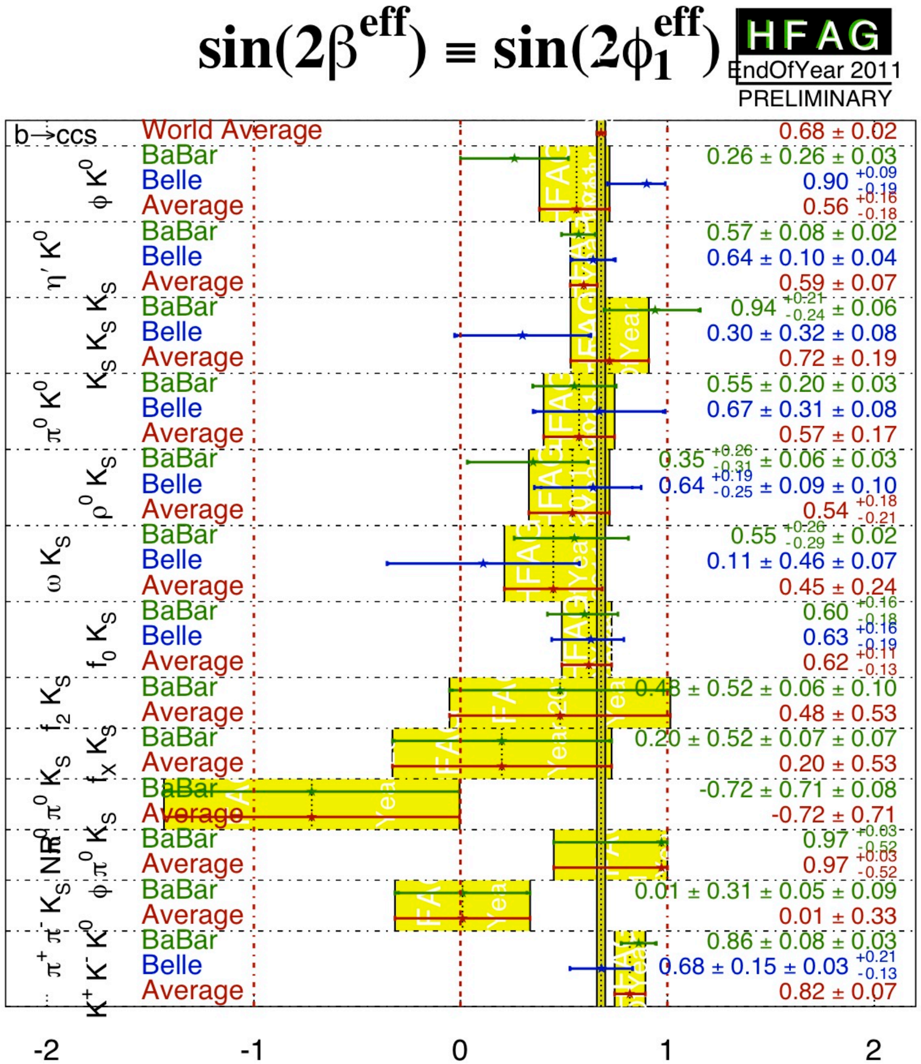




ϕ_1 by $(c\bar{c})K^0$ $\qquad$ ϕ_1 by $(c\bar{c})K^0$

With current statistics, we could not distinguish multiple solutions by the likelihood alone. The preferred solution is shown.
No significant deviation from measurements with $B^0 \to (c\bar{c})\, K^0$.

Compilation of effective sin2ϕ_1

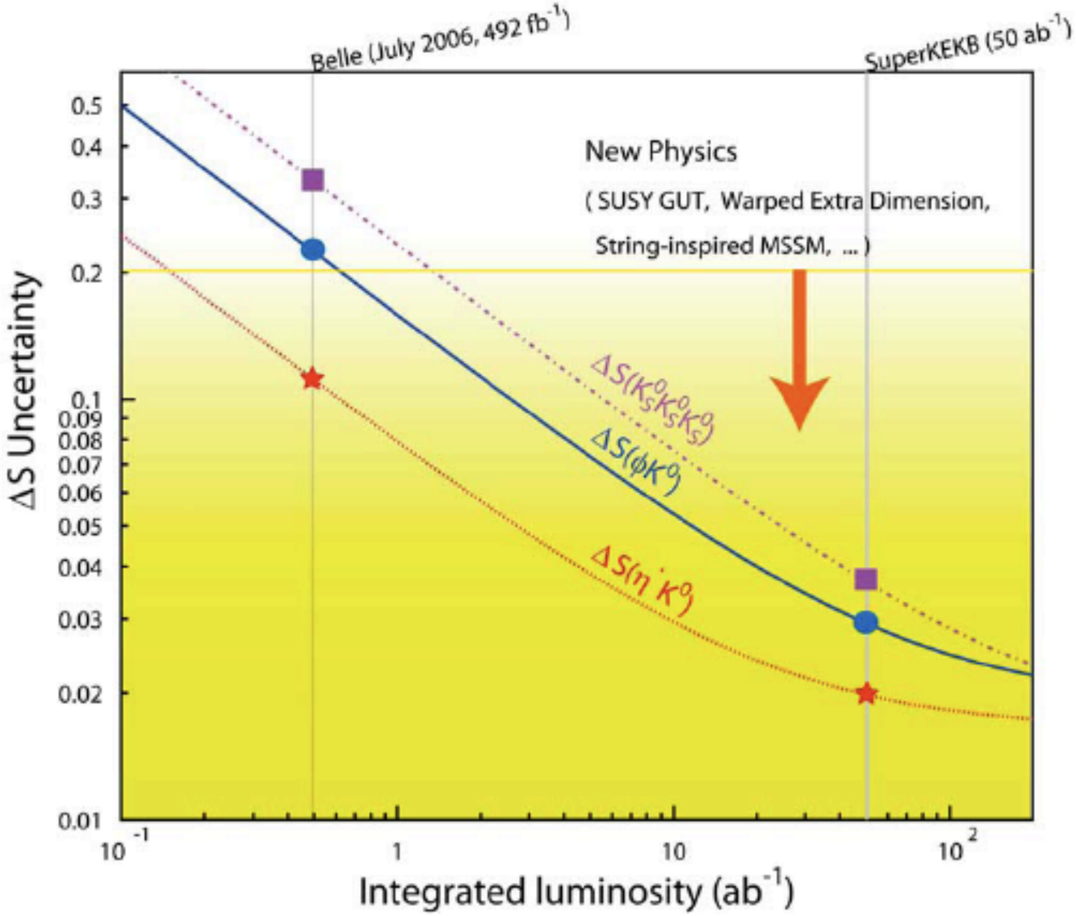


Still precision is statistically dominated.

↓

To obtain sensitivity in effective sin2ϕ_1 of $O(10^{-2})$, we need $O(10\,ab^{-1})$ integrated luminosity.

Future sensitivity



Error of effective $\sin 2\phi_1$ would be 0.03($\eta' K^0$)-0.1($K_S K_S K_S$).

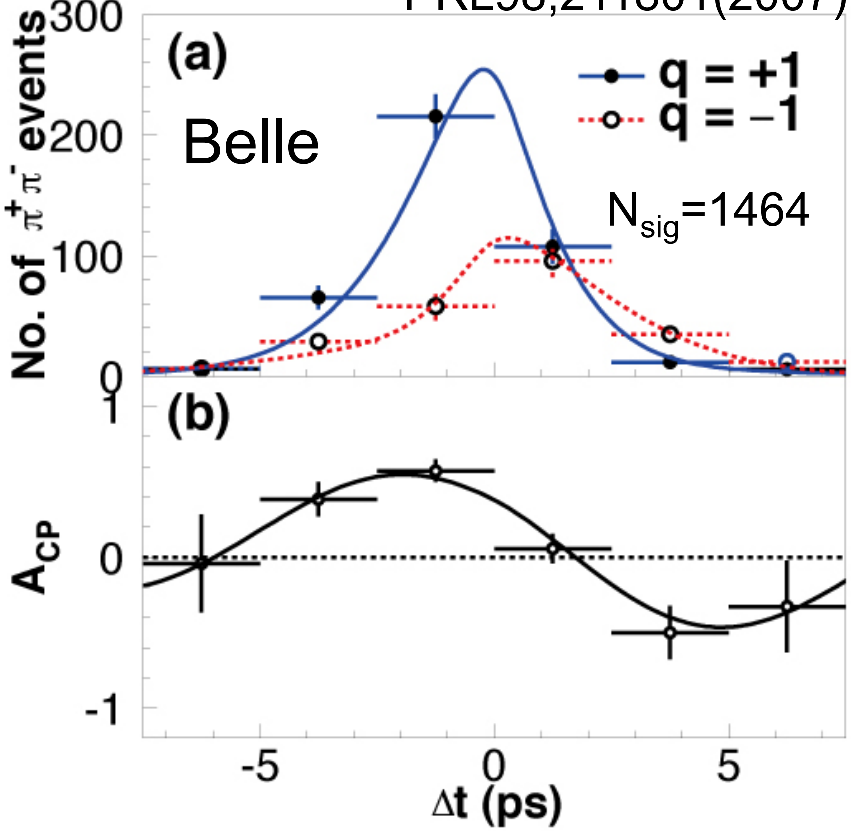
Summary

- $\sin 2\phi_1$=0.68±0.02 in World Average
  - It is a firm SM reference point.
- Constraint on ϕ_2 : 89.0 +4.4/-4.2 deg.
  - The unitarity triangle appears to be a right triangle.
- Δm_d is precisely determined by B-factories.
  - Now 1% precision has been achieved, giving a firm reference.
- Tension around Br($B^+ \to \tau^+ \nu$)
  - Need an update of measurement.
  - Comparing to $\sin 2\phi_1$ measurement, expect mixing has room for NP.
- CPV in $b \to s$ penguin modes
  - Reach $O(10^{-2})$ sensitivity with Super B-factories.

Backup slides

$B^0 \to \pi^+\pi^-$

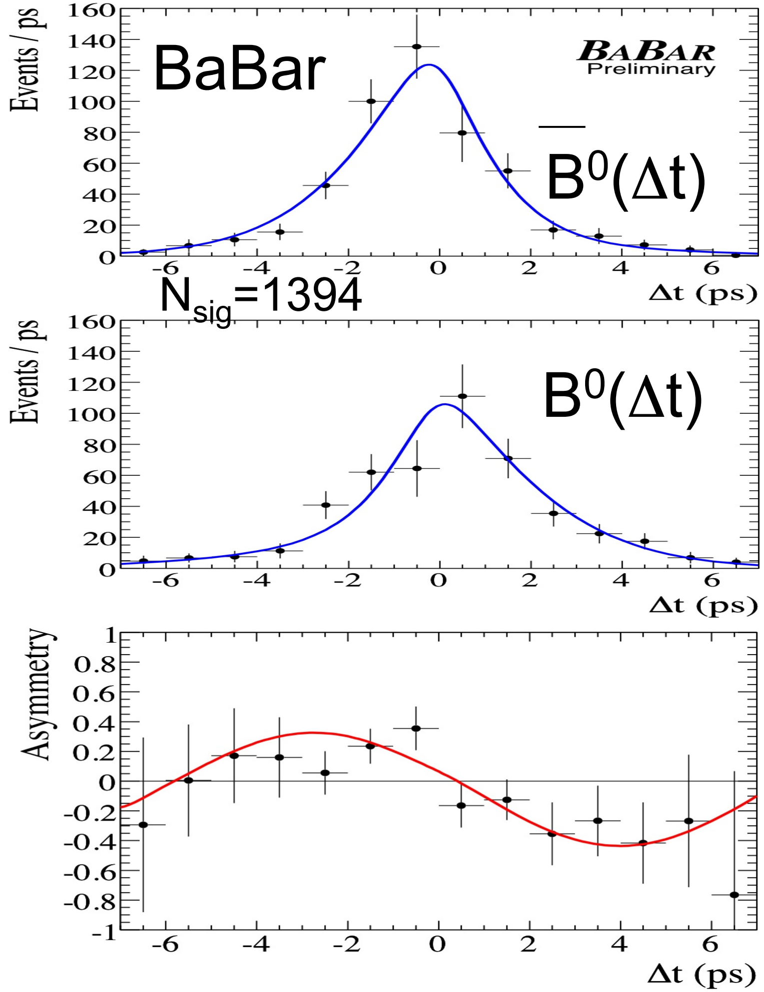
PRL98,211801(2007)



S_f=-0.61±0.10±0.04

A_f=0.55±0.08±0.05

arXiv:0807.4226

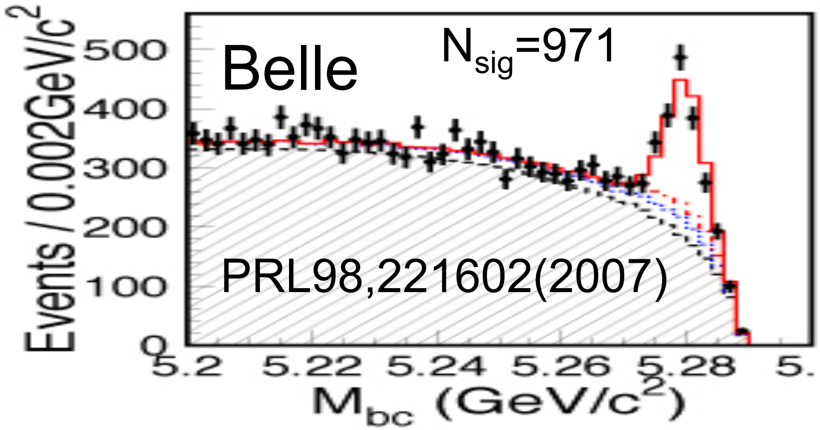


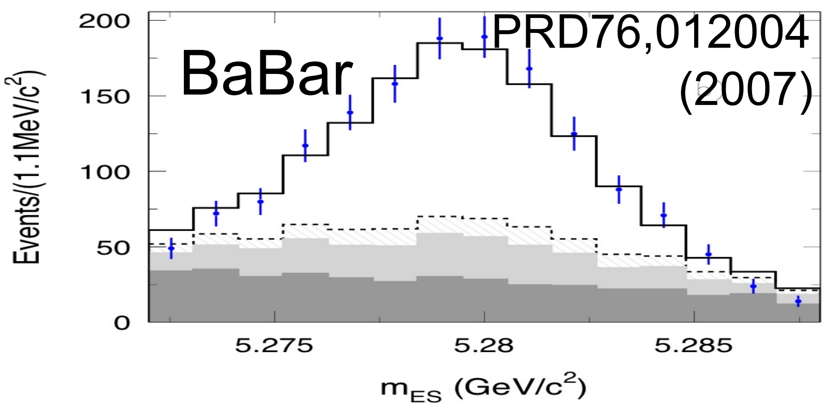
S_f=-0.68±0.10±0.03

A_f=0.25±0.08±0.02

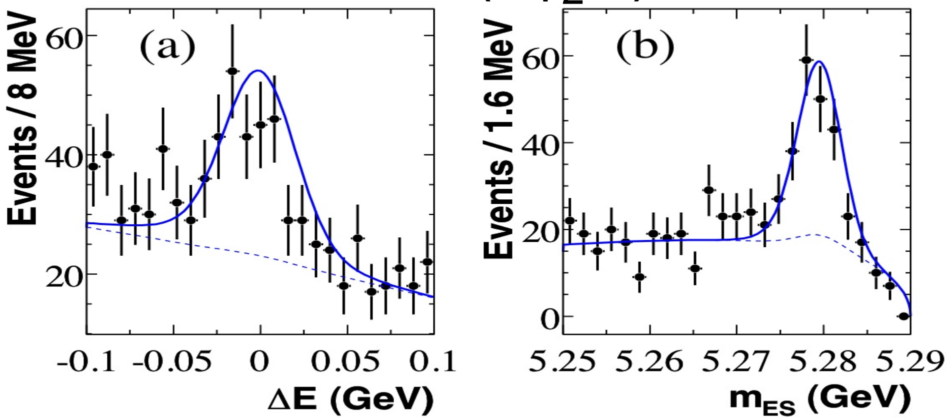
$B^0 \to (\rho\pi)^0$, $B^0 \to a_1^{\pm}\pi^{\mp}$

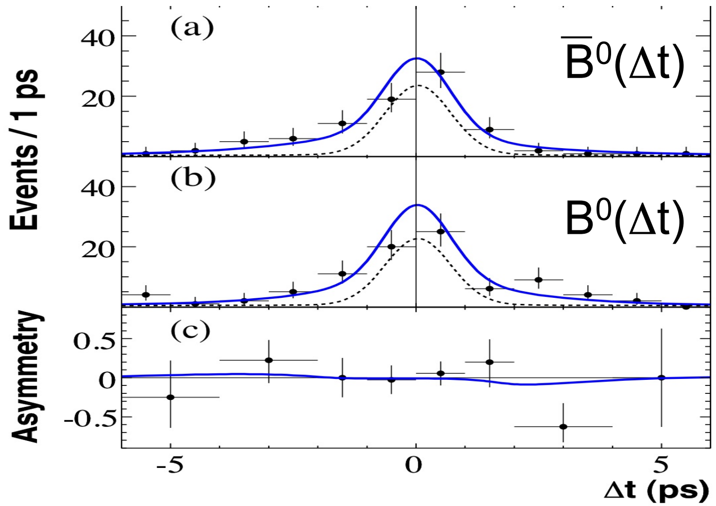
$B^0 \to \rho^+\pi^-$, $\rho^-\pi^+$, $\rho^0\pi^0$ interfere
$\to$ time-dep. Dalitz analysis





BaBar (384M BB) $a_1^{\pm}\pi^{\mp}$;
obtained α^{eff}(=ϕ_2^{eff})





PRL98,
181803(2007)

Coefficients of Dalitz plot functions are interrupted to CPV parameters of quasi-2-body decays, $B\to\rho^+\pi^-$ and $B\to\rho^0\pi^0$

$$\mathcal{C}^+ = \frac{U_+^-}{U_+^+},\quad \mathcal{C}^- = \frac{U_-^-}{U_-^+},\quad \mathcal{S}^+ = \frac{2I_+}{U_+^+},\quad \mathcal{S}^- = \frac{2I_-}{U_-^+},\quad \mathcal{A}_{\rho\pi}^{CP} = \frac{U_+^+ - U_-^+}{U_+^+ + U_-^+}$$

$$\mathcal{C} \equiv \frac{\mathcal{C}^+ + \mathcal{C}^-}{2},\quad \Delta\mathcal{C} \equiv \frac{\mathcal{C}^+ - \mathcal{C}^-}{2},\quad \mathcal{S} \equiv \frac{\mathcal{S}^+ + \mathcal{S}^-}{2},\quad \Delta\mathcal{S} \equiv \frac{\mathcal{S}^+ - \mathcal{S}^-}{2}$$

$$\mathcal{A}_{\rho^0\pi^0} = -\frac{U_0^-}{U_0^+},\quad \text{and}\quad \mathcal{S}_{\rho^0\pi^0} = \frac{2I_0}{U_0^+}$$

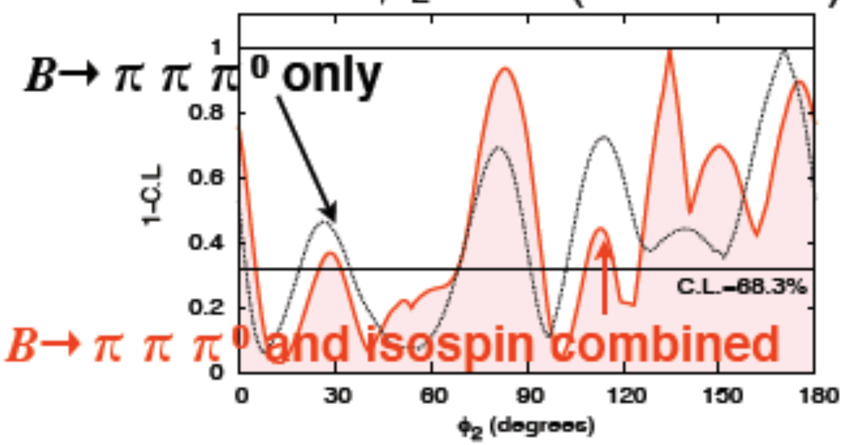
Belle 449M $B\overline{B}$ (PRL98 221602)

$$\begin{aligned}
\mathcal{A}_{\rho\pi}^{CP} &= -0.12 \pm 0.05 \pm 0.04\\
\mathcal{C} &= -0.13 \pm 0.09 \pm 0.05\\
\Delta\mathcal{C} &= +0.36 \pm 0.10 \pm 0.05\\
\mathcal{S} &= +0.06 \pm 0.13 \pm 0.05\\
\Delta\mathcal{S} &= -0.08 \pm 0.13 \pm 0.05\\
\mathcal{A}_{\rho^0\pi^0} &= -0.49 \pm 0.36 \pm 0.28\\
\mathcal{S}_{\rho^0\pi^0} &= +0.17 \pm 0.57 \pm 0.35
\end{aligned}$$

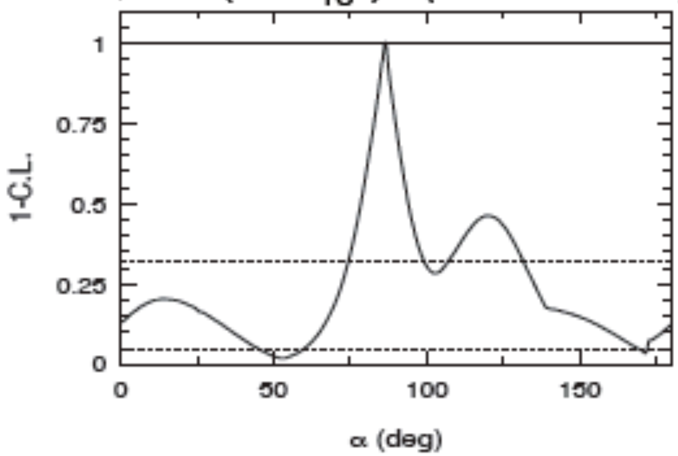
BABAR 375M $B\overline{B}$ (PRD76 012004)

$$\begin{aligned}
\mathcal{A}_{\rho\pi} &= -0.14 \pm 0.05 \pm 0.02\\
C &= 0.15 \pm 0.09 \pm 0.05\\
S &= -0.03 \pm 0.11 \pm 0.04\\
\Delta C &= 0.39 \pm 0.09 \pm 0.09\\
\Delta S &= -0.01 \pm 0.14 \pm 0.06\\
C_{00} = \frac{U_0^-}{U_0^+} &= -0.10 \pm 0.40 \pm 0.53\\
S_{00} = \frac{2\,I_0}{U_0^+} &= 0.04 \pm 0.44 \pm 0.18
\end{aligned}$$

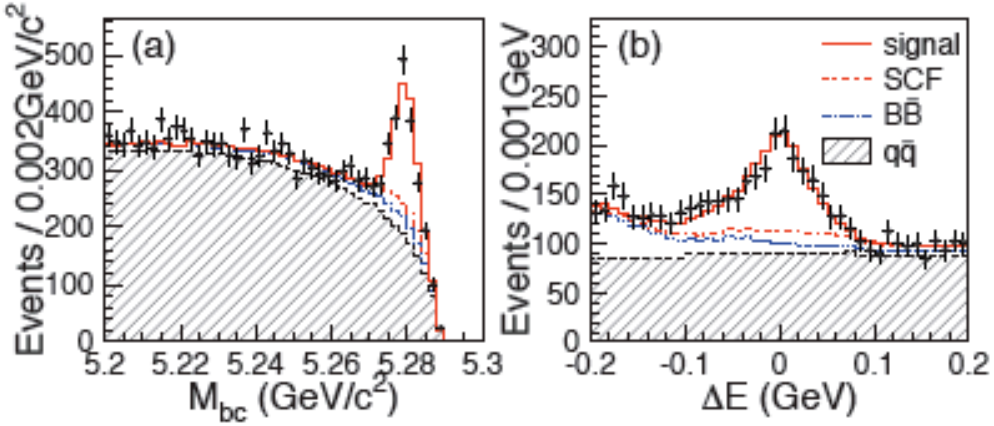
$68° < \phi_2 < 95°$ (68.3% C.L.)



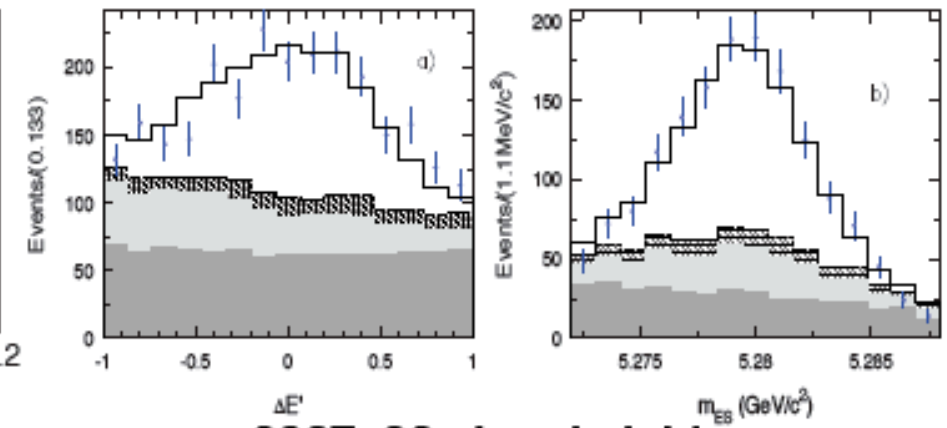
$\phi_2 = (87^{+45}_{-13})°$ (68.3% C.L.)



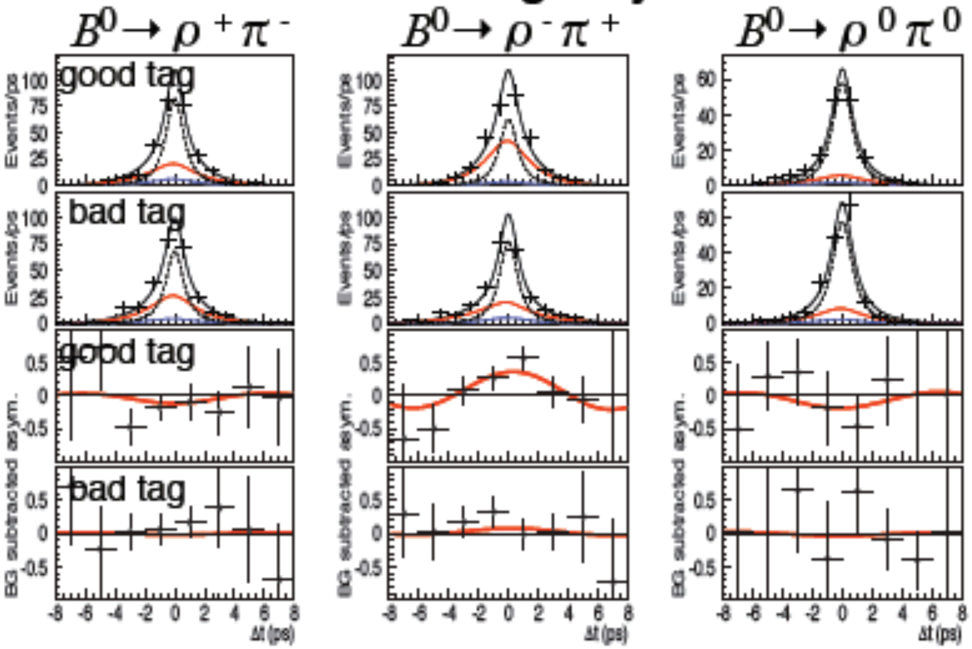
Belle 449M $B\bar{B}$ (PRL98 221602)



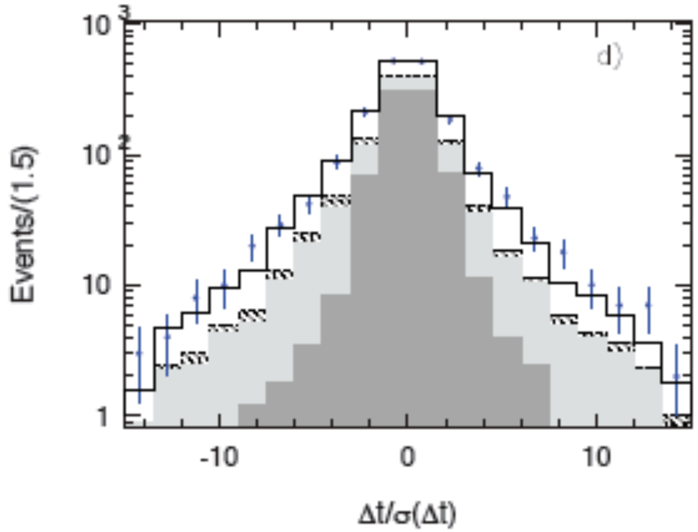
BABAR 375M $B\bar{B}$ (PRD76 012004)



971±41 signal yields



2067±86 signal yields



Multiple solutions

Belle found 4 solutions

	Solution 1	Solution 2	Solution 3	Solution 4
$\mathcal{A}_{CP}(f_0(980)K_S^0)$	$-0.30 \pm 0.29 \pm 0.11 \pm 0.09$	$-0.20 \pm 0.15 \pm 0.08 \pm 0.05$	$+0.02 \pm 0.21 \pm 0.09 \pm 0.09$	$-0.18 \pm 0.14 \pm 0.08 \pm 0.06$
$\phi_1^{\rm eff}(f_0(980)K_S^0)$	$(31.3 \pm 9.0 \pm 3.4 \pm 4.0)^\circ$	$(26.1 \pm 7.0 \pm 2.4 \pm 2.5)^\circ$	$(25.6 \pm 7.6 \pm 2.9 \pm 0.8)^\circ$	$(26.3 \pm 5.7 \pm 2.4 \pm 5.8)^\circ$
$\mathcal{A}_{CP}(\phi(1020)K_S^0)$	$+0.04 \pm 0.20 \pm 0.10 \pm 0.02$	$+0.08 \pm 0.18 \pm 0.10 \pm 0.03$	$-0.01 \pm 0.20 \pm 0.11 \pm 0.02$	$+0.21 \pm 0.18 \pm 0.11 \pm 0.05$
$\phi_1^{\rm eff}(\phi(1020)K_S^0)$	$(32.2 \pm 9.0 \pm 2.6 \pm 1.4)^\circ$	$(26.2 \pm 8.8 \pm 2.7 \pm 1.2)^\circ$	$(27.3 \pm 8.6 \pm 2.8 \pm 1.3)^\circ$	$(24.3 \pm 8.0 \pm 2.9 \pm 5.2)^\circ$
$\mathcal{A}_{CP}$(others)	$-0.14 \pm 0.11 \pm 0.08 \pm 0.03$	$-0.06 \pm 0.15 \pm 0.08 \pm 0.04$	$-0.03 \pm 0.09 \pm 0.08 \pm 0.03$	$+0.04 \pm 0.11 \pm 0.08 \pm 0.02$
$\phi_1^{\rm eff}$(others)	$(24.9 \pm 6.4 \pm 2.1 \pm 2.5)^\circ$	$(29.8 \pm 6.6 \pm 2.1 \pm 1.1)^\circ$	$(26.2 \pm 5.9 \pm 2.3 \pm 1.5)^\circ$	$(23.8 \pm 5.5 \pm 1.9 \pm 6.4)^\circ$

The preferred solution can not be selected by the fit likelihood value alone. With external information, solution 1 is preferred.

BaBar found 2 solutions in low-mass fit, (1) is chosen as nominal.

Name	Solution (1)	Solution (2)	Correlation			
			1	2	3	4
1 $A_{CP}(\phi K_S^0)$	$0.14 \pm 0.19 \pm 0.02$	0.13 ± 0.18	1.0	-0.09	-0.28	0.09
2 $\beta_{\it eff}(\phi K_S^0)$	$0.13 \pm 0.13 \pm 0.02$	0.14 ± 0.14		1.0	0.54	0.65
3 $A_{CP}(f_0 K_S^0)$	$0.01 \pm 0.26 \pm 0.07$	-0.49 ± 0.25			1.0	0.25
4 $\beta_{\it eff}(f_0 K_S^0)$	$0.15 \pm 0.13 \pm 0.03$	3.44 ± 0.19				1.0

Again multiple solutions

Belle found 4 solutions. After ensemble test checks and by using external information, two of them are chosen as possible physical solutions. Solution 1 is preferred ($K^{*+}_0(1430)\pi$ fraction and $K_S\pi$ mass spectrum). (PRD79,072004(2009))

Parameter	Solution 1 (-2ln$L$=18472.5)	Solution 2 (-2ln$L$=18465.5)
$A(f_0K_S)$	0.08±0.19±0.03±0.04	0.23±0.19±0.03±0.04
$\beta(f_0K_S)=\phi_1(f_0K_S)$	(36.0±9.8±2.1±2.1)°	(56.2±10.4±2.1±2.1)°
$A(\rho^0K_S)$	-0.05±0.26±0.10±0.03	-0.14±0.26±0.10±0.03
$\beta(\rho^0K_S)=\phi_1(\rho^0K_S)$	(10.2±8.9±3.0±1.9)°	(33.4±10.4±3.0±1.9)°

Again multiple solutions

Parameter	Solution 1	Solution 2
$C(f_0K_S)=-A(f_0K_S)$	0.08±0.19±0.03±0.04	0.23±0.19±0.03±0.04
$\beta(f_0K_S)=\phi_1(f_0K_S)$	(36.0±9.8±2.1±2.1)°	(56.2±10.4±2.1±2.1)°
$C(\rho^0K_S)=-A(\rho^0K_S)$	-0.05±0.26±0.10±0.03	-0.14±0.26±0.10±0.03
$\beta(\rho^0K_S)=\phi_1(\rho^0K_S)$	(10.2±8.9±3.0±1.9)°	(33.4±10.4±3.0±1.9)°

BaBar found 2 solutions.
(PRD80,112001(2009))