Recent results on CP violation in B decays

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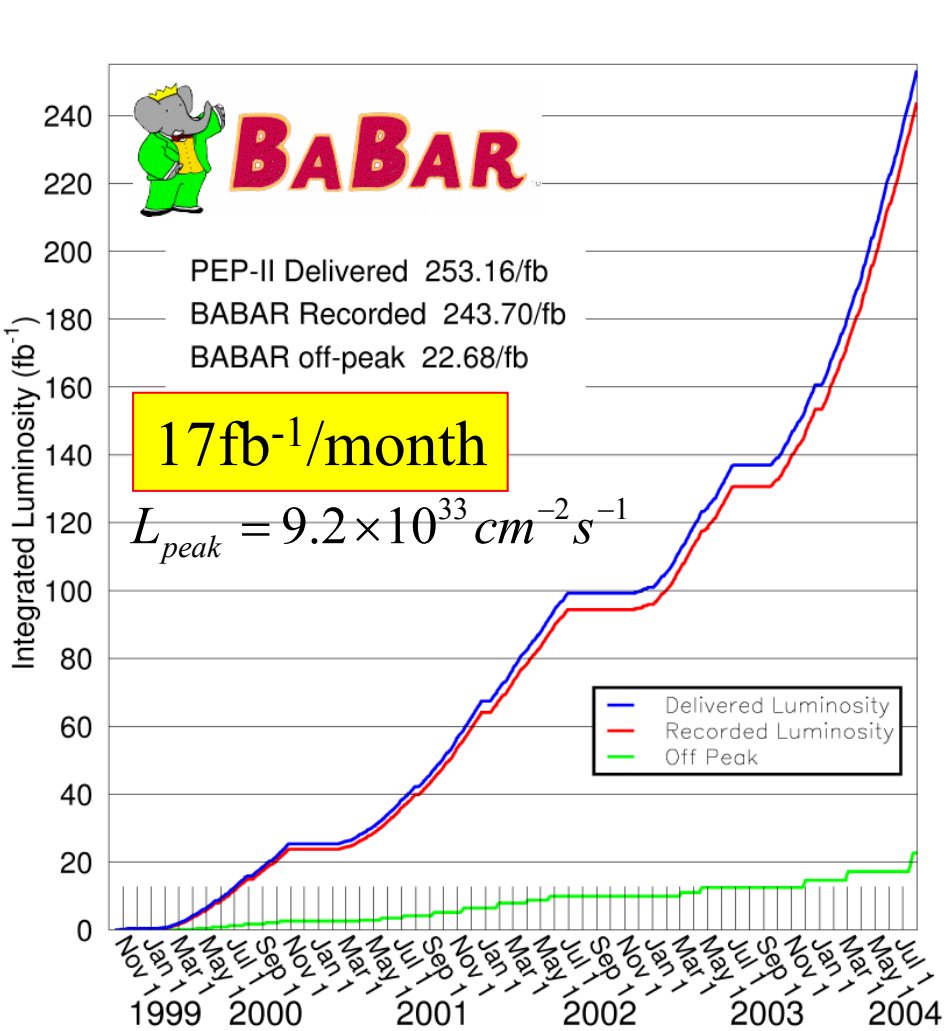
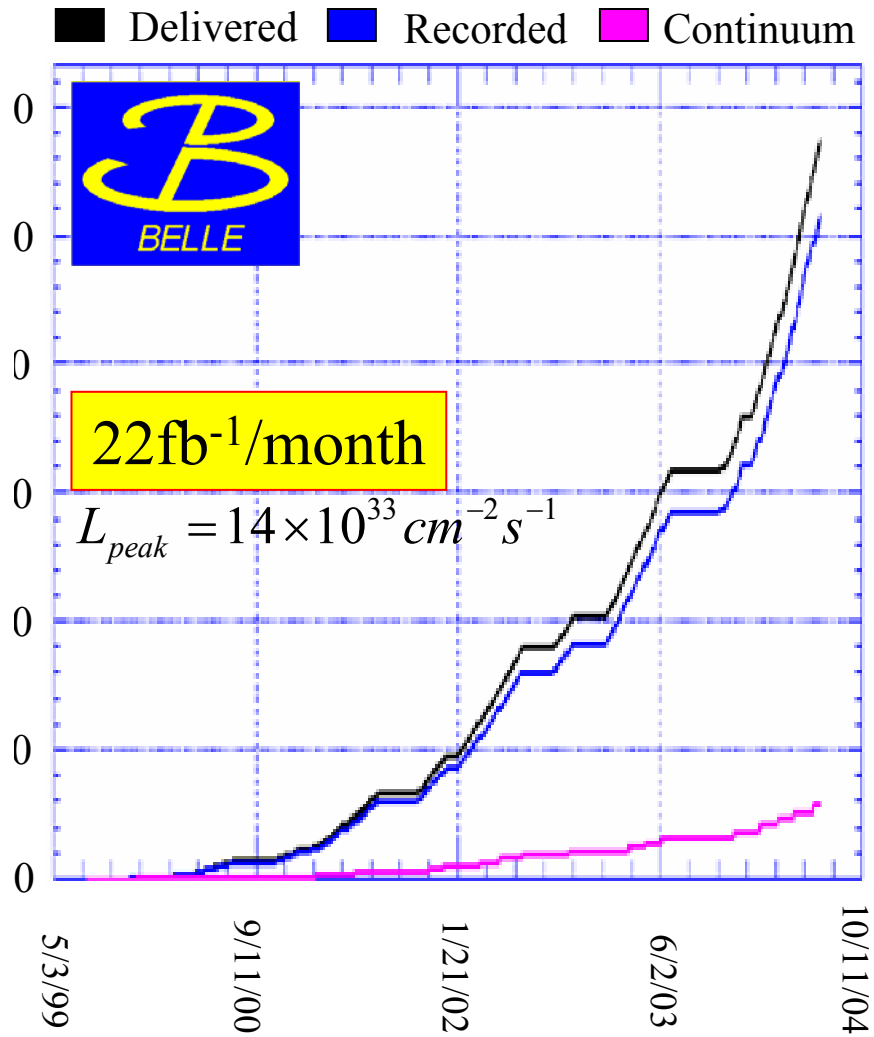
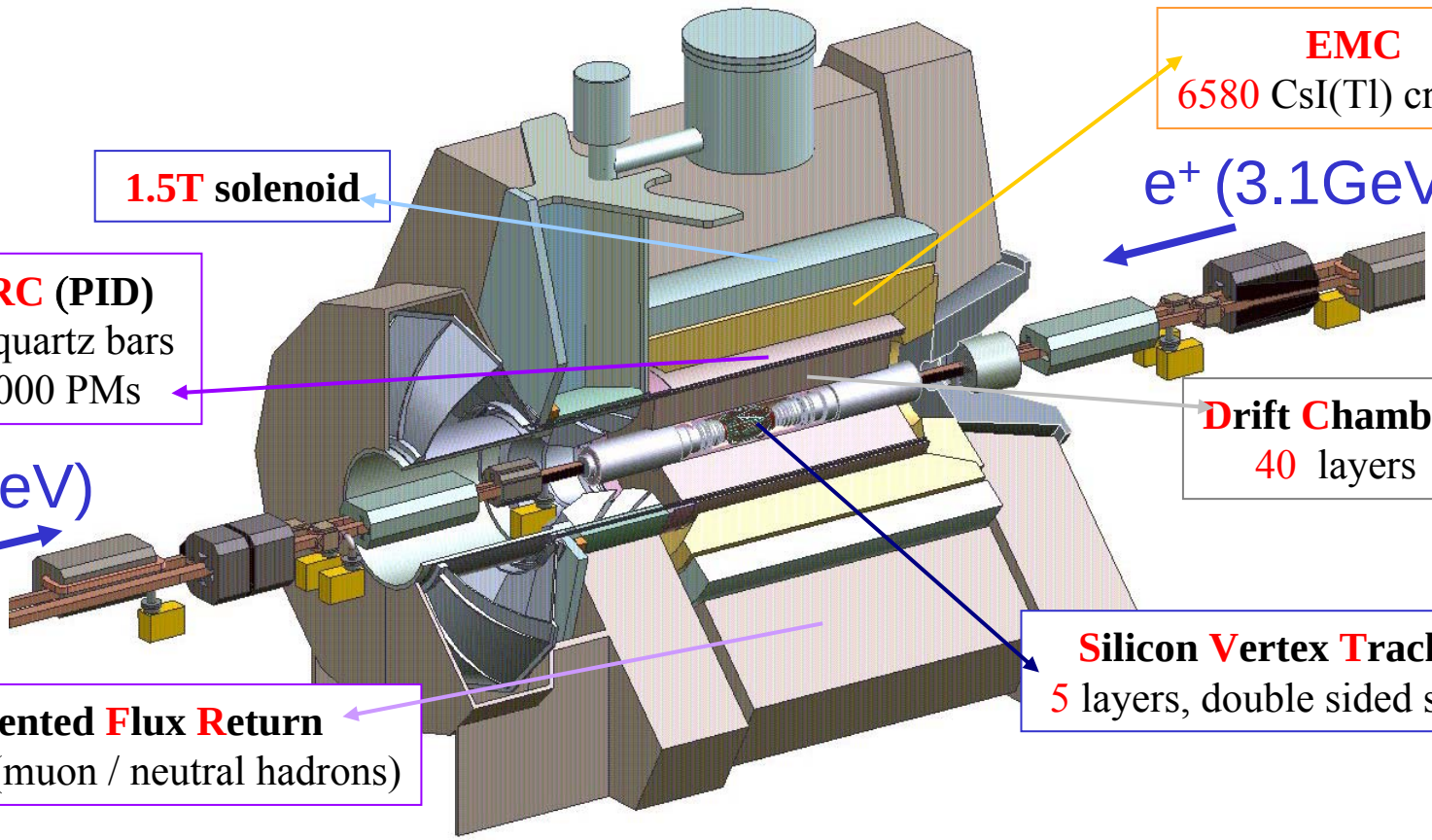
Current luminosities and data samples

Total 244 + 286 fb^{-1} = 0.530 ab^{-1}!!

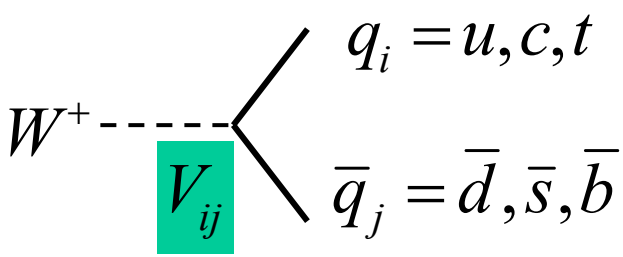




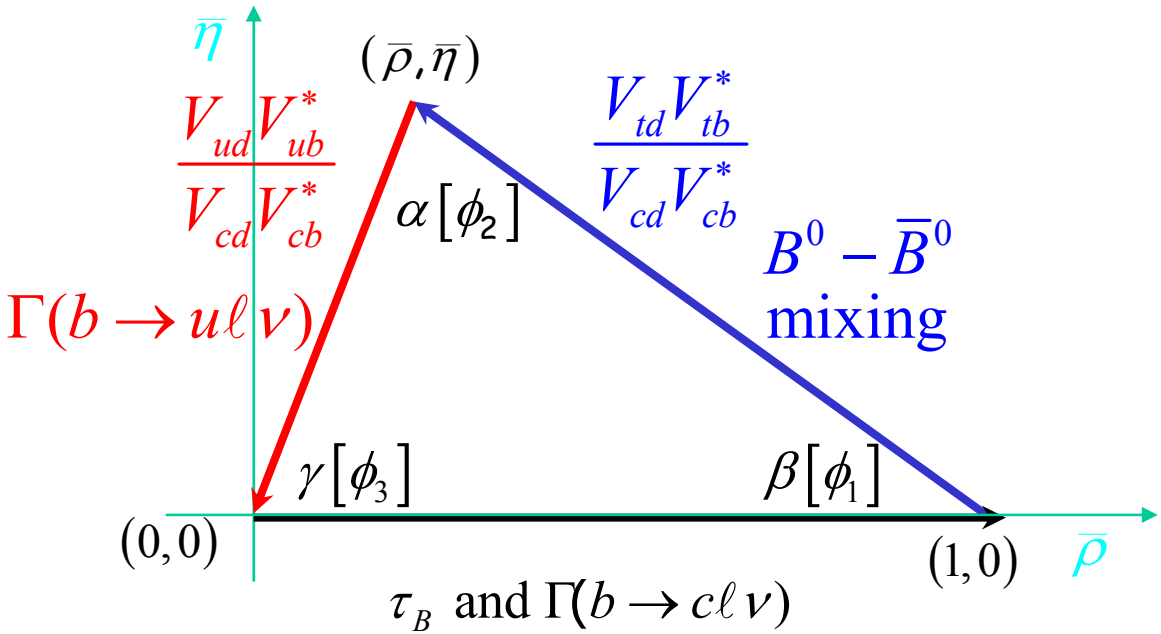
BABAR Detector



CKM and unitarity conditions

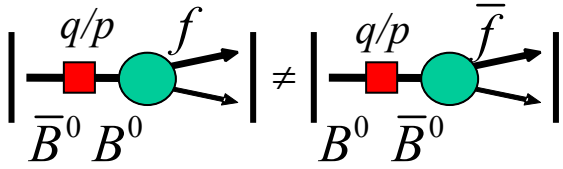


$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



3 ways for CP violation

1. CP violation in mixing



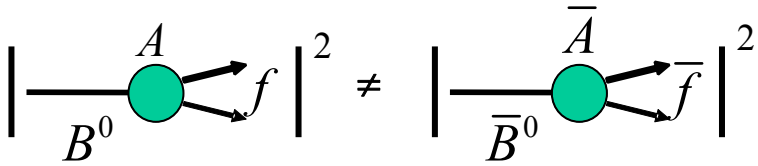
First mechanism observed historically in kaon decays

$$\left|\frac{q}{p}\right| = \sqrt{\frac{(M_{12}^* - i\frac{\Gamma_{12}^*}{2})}{(M_{12} - i\frac{\Gamma_{12}}{2})}} \neq 1$$

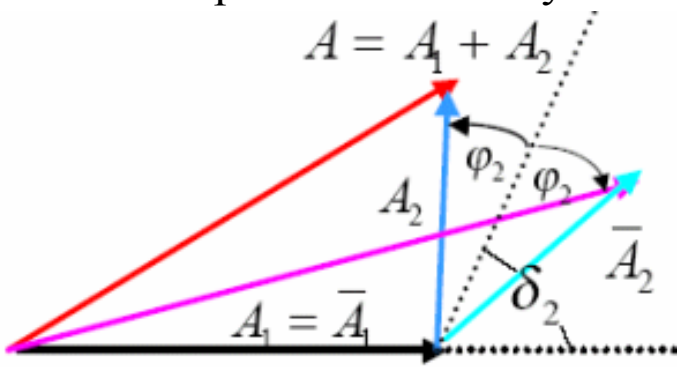
SM predicts:

$$\left|\frac{q}{p}\right| - 1 \approx 4\pi \frac{m_c^2}{m_t^2} \sin\beta \approx 5\times 10^{-4}$$

2. Direct CP violation in the decay



Occurs when $\left|\bar{A}/A\right| \neq 1$ where A is the amplitude for B decays into a final state f and $\bar{A}$ is the amplitude of $\bar{B}$ decays into the CP conjugate state $\bar{f}$.



Two amplitudes A_1 and A_2 with a relative CP violating phase ϕ_2 and a CP conserving phase δ :
CP violation and $|A| \neq |\bar{A}|$

First observation of Direct CPV in B decays

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

BABAR *hep-ex/0408057, submitted to PRL*

$A_{CP} = -0.133 \pm 0.030 \pm 0.009$

4.2σ

Belle **Confirmation at ICHEP04**

Signal ($274M$ $B\bar{B}$ pairs): 2140 ± 53

$A_{CP} = -0.101 \pm 0.025 \pm 0.005$

3.9σ

Average $A_{CP} = -0.114 \pm 0.020$

3.6σ

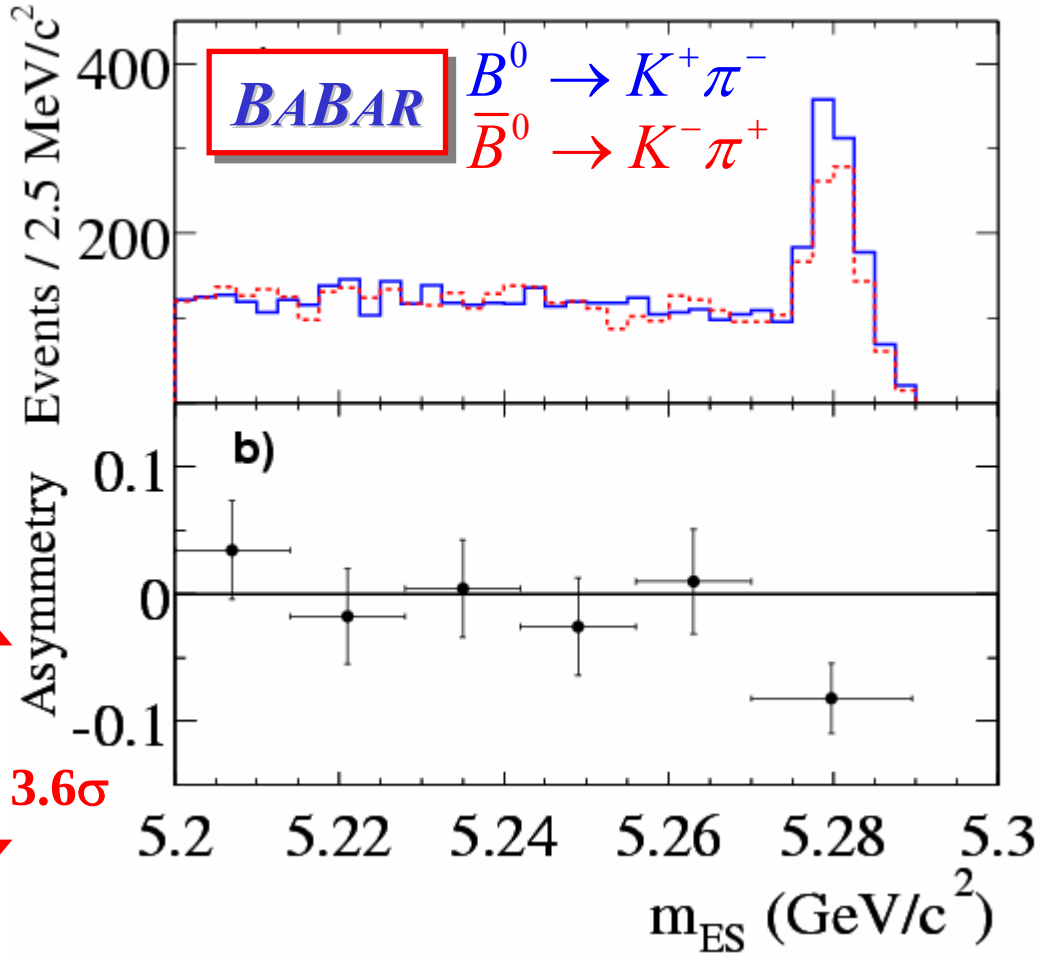
$B^+ \to K^+\pi^0$

$A_{CP} = +0.06 \pm 0.06 \pm 0.01$ *BABAR*

$A_{CP} = +0.04 \pm 0.05 \pm 0.02$ Belle

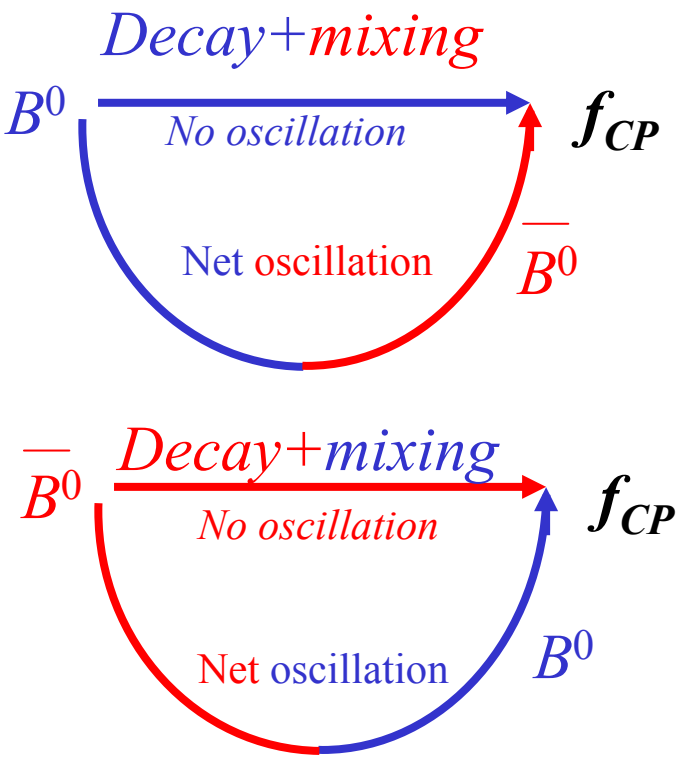
Average $A_{CP} = +0.049 \pm 0.040$

Signal ($227M$ $B\bar{B}$ pairs): 1606 ± 51



3 ways for CP violation

3.Time dependent



$$\Gamma\left(B^0_{phys}(t)\to f_{CP}\right)$$
$$\neq$$
$$\Gamma\left(\overline{B}^0_{phys}(t)\to f_{CP}\right)$$

Define CP Asymmetry as:

$$A_{f_{CP}}(t)=\frac{\Gamma\left(\overline{B}^0_{phys}(t)\to f_{CP}\right)-\Gamma\left(B^0_{phys}(t)\to f_{CP}\right)}{\Gamma\left(B^0_{phys}(t)\to f_{CP}\right)+\Gamma\left(\overline{B}^0_{phys}(t)\to f_{CP}\right)}$$

$$A_{f_{CP}}=-C_{f_{CP}}\cos(\Delta mt)+S_{f_{CP}}\sin(\Delta mt)$$

$$\lambda_{f_{CP}}=\frac{q}{p}\frac{\overline{A}_{\overline{f}_{CP}}}{A_{f_{CP}}}\approx e^{-2i\beta}$$

Amplitude ratio

CP parameter

$$C_{f_{CP}}=\frac{1-|\lambda_{f_{CP}}|^2}{1+|\lambda_{f_{CP}}|^2}$$

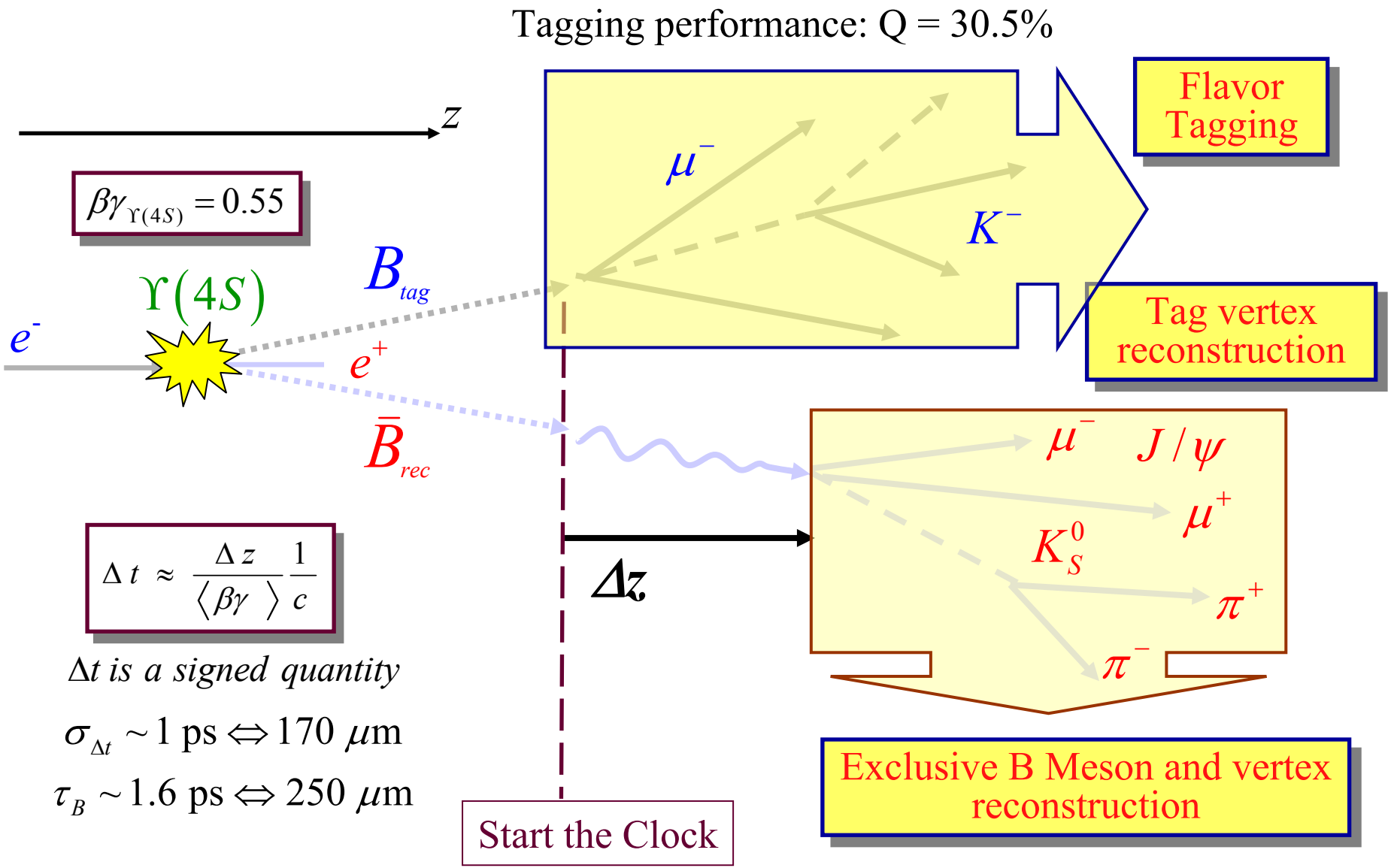
For single amplitude $= 0$

$$S_{f_{CP}}=\frac{-2\,\mathrm{Im}\,\lambda_{f_{CP}}}{1+|\lambda_{f_{CP}}|^2}$$

$= -\mathrm{Im}\,\lambda_{f_{CP}}$

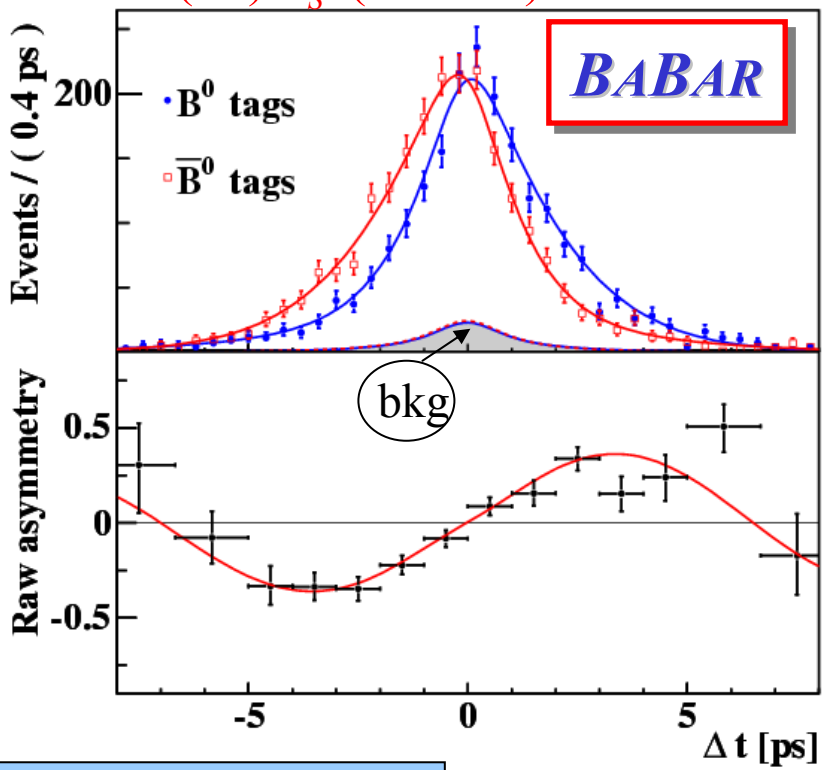
$C_{f_{CP}}\neq 0$ implies Direct *CP* Violation

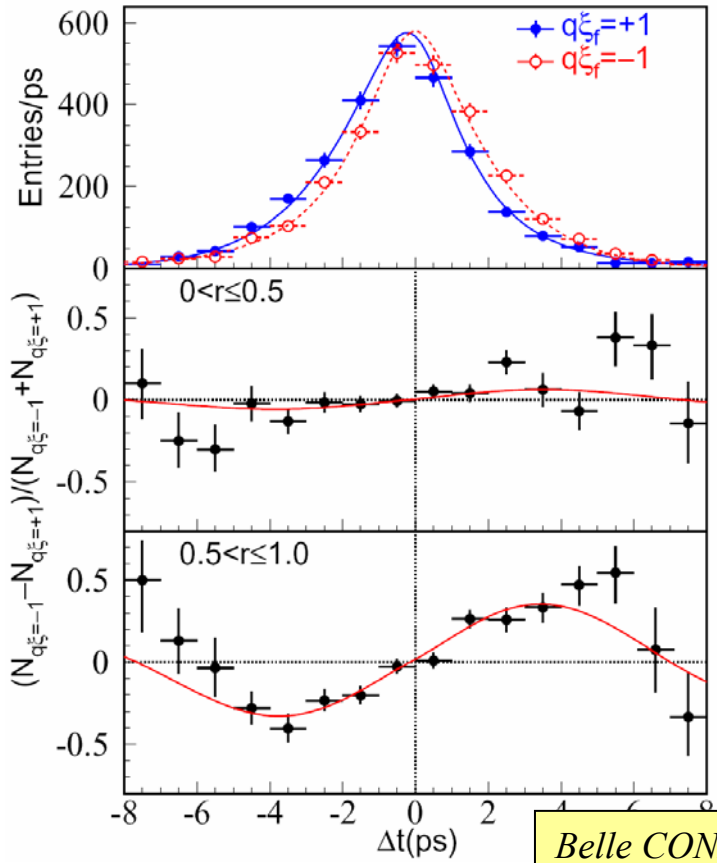
Measuring time-dependent CP asymmetries



sin2β results from charmonium modes

$(c\bar{c})K^0_S$ (CP odd) modes





Update for ICHEP04

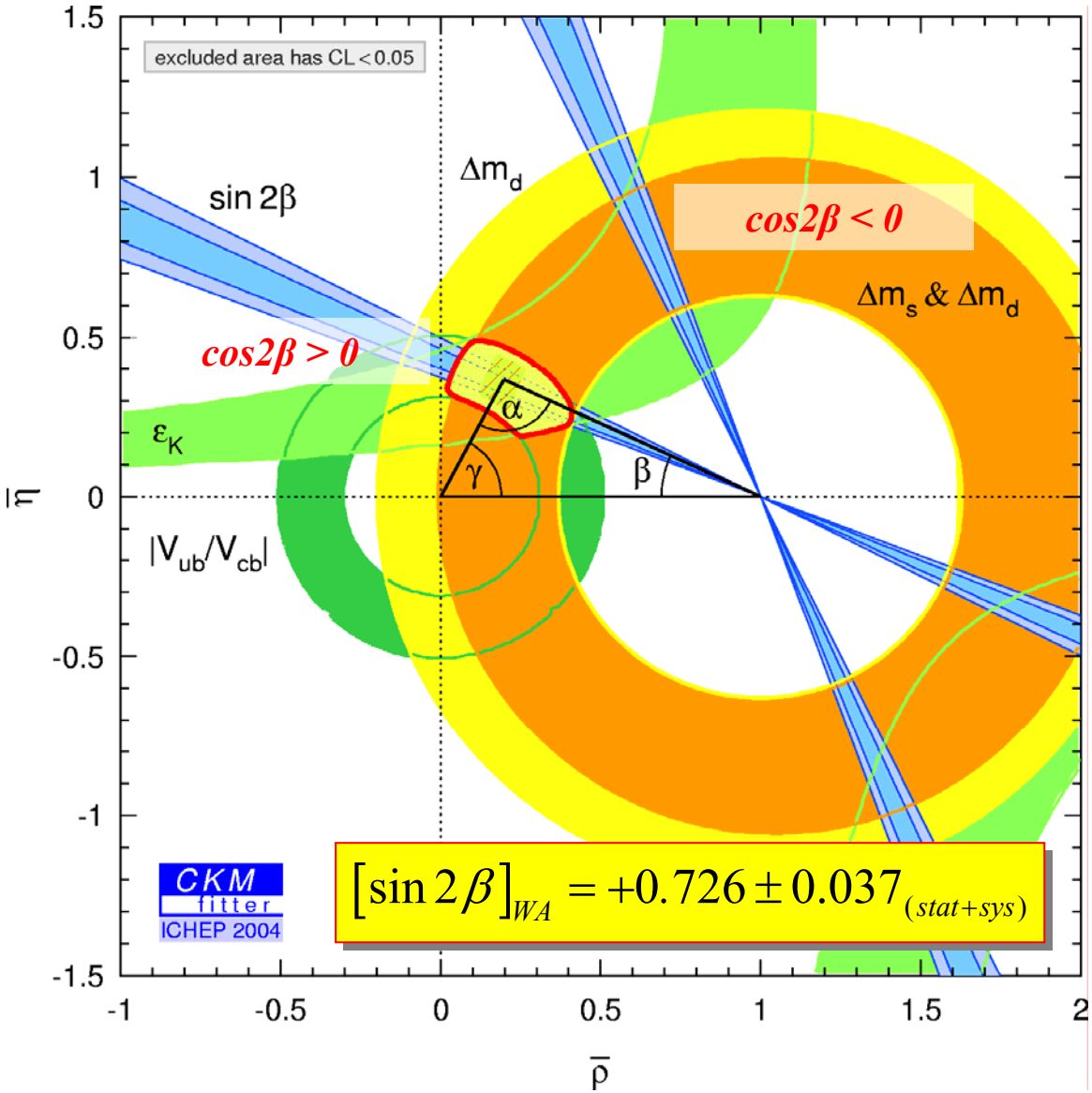
BABAR PUB-04/038

Belle CONF-0436

$(c\bar{c})K^0_S$+ $(c\bar{c})K^0_L$

$\sin 2\beta = +0.722 \pm 0.040 \pm 0.023$	$\sin 2\beta = +0.728 \pm 0.056 \pm 0.023$
$\lvert\lambda\rvert = \lvert\bar{A}/A\rvert = 0.950 \pm 0.031 \pm 0.013$	$\lvert\lambda\rvert = \lvert\bar{A}/A\rvert = 1.007 \pm 0.041 \pm 0.033$
Limit on direct CPV	
$205\,fb^{-1}$ on peak or $227M$ $B\bar{B}$ pairs	$140\,fb^{-1}$ on peak or $152M$ $B\bar{B}$ pairs
7730 CP events (tagged signal)	4347 CP events (tagged signal)

sin2β, cos2β and CKM constraints



BABAR

cos2β < 0 ruled out at 87% CL by s- and p-wave interference in angular analysis of $B\ J/\psi K^{*0}$ ($K_S\pi^0$)

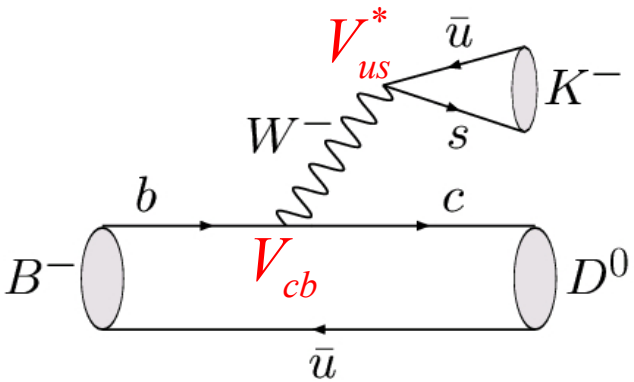
M.Bruinsma, CP-3

CKM fit to indirect constraints overlaid with sin2β_{WA} measurement

Methods for extraction of γ

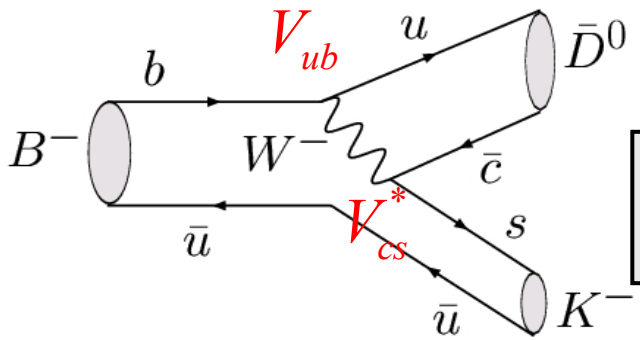
γ is phase between $b \to u$ $(\propto V_{ub})$ and $b \to c$ $(\propto V_{cb})$ amplitudes

Basic Idea Use interference between $B^- \to D^0 K^-$ and $B^- \to \bar{D}^0 K^-$ decays where the $D^0 (\bar{D}^0)$ decay to a common final state f



$A \propto V_{cb} V_{us}^*$ $\propto \lambda^3$

$A \propto V_{ub} V_{cs}^*$ $\propto \lambda^3 \sqrt{\rho^2 + \eta^2}\, e^{i\gamma}$



Color suppressed

GLW *Gronau-London-Wyler, 1991*
Use $B^- \to D^0_{CP\pm} K^-$ decays

ADS *Atwood-Dunietz-Soni, 2001*
Use $B^- \to D^{(*)0} \left[K^+ \pi^- \right] K^-$ decays

D⁰ Dalitz plot Use $B^- \to D^{(*)0} \left[K^0_S \pi^+ \pi^- \right] K^-$ decays

Size of CP asymmetry depends on

$$r_B^{(*)} \equiv \frac{|A(B^- \to \bar{D}^{(*)0} K^-)|}{|A(B^- \to D^{(*)0} K^-)|} \sim 0.1 - 0.3$$

$B^- \to D^{(*)0}[K^+\pi^-]K^-$ decays: ADS method

favored $B^- \to D^0 K^-$, **suppressed** $D^0 \to K^+\pi^-$

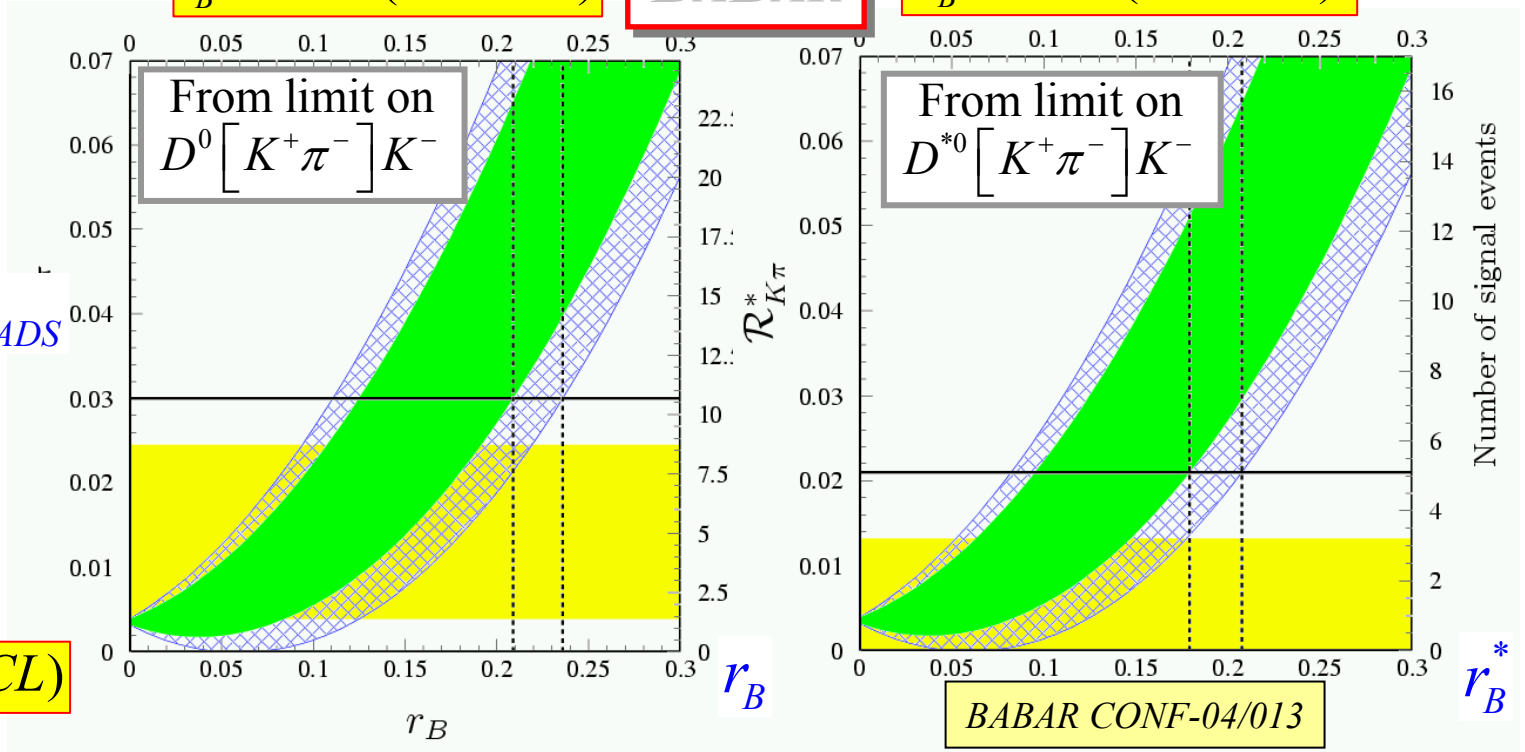
suppressed $B^- \to \overline{D}^0 K^-$, **favored** $\overline{D}^0 \to K^+\pi^-$

$$R_{ADS} = \frac{BF([K^+\pi^-]K^-) + BF([K^-\pi^+]K^+)}{BF([K^-\pi^+]K^-) + BF([K^+\pi^-]K^+)} \sim r_B^2$$

$[K^+\pi^-]_D K^-$

Update for ICHEP04

$r_B < 0.23$ (90% CL) **BABAR** $r_B^* < 0.21$ (90% CL)



Belle

$r_B < 0.28$ (90% CL)

First look at $B^- \to D^{(*)0}[K_S\pi^+\pi^-]K^-$ sample by Belle

New: Winter 04

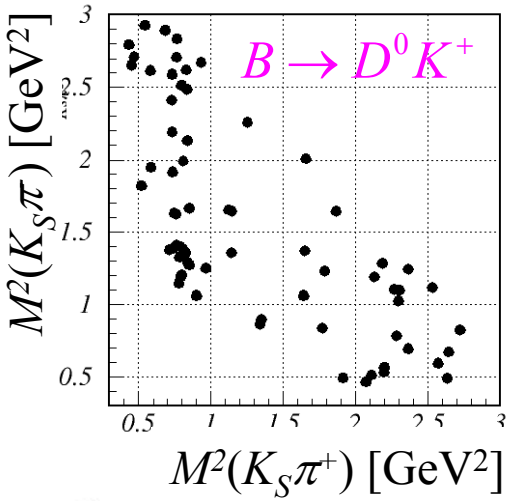
Belle
140 fb^{-1}

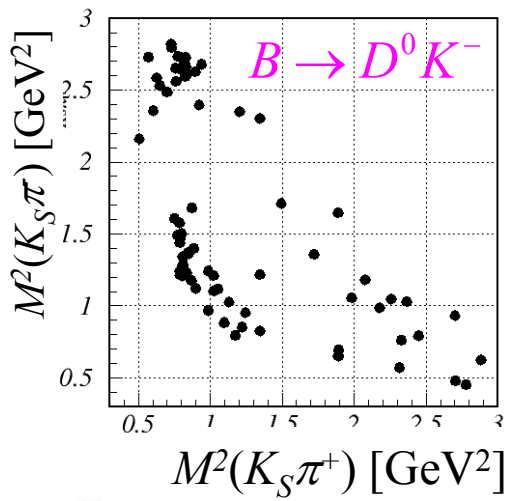
Visible asymmetry in Dalitz plots

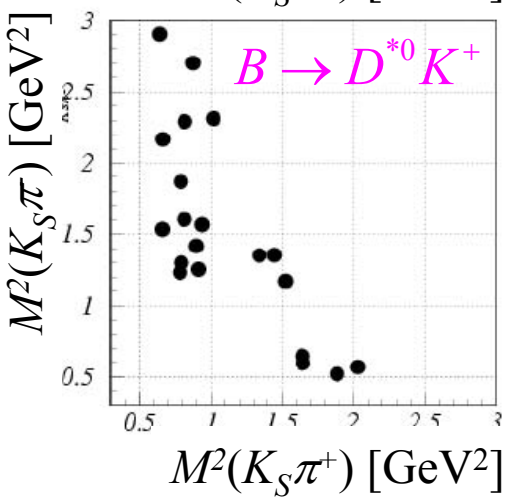
Parameters:
$\gamma, r_D, r_{D^*}, \delta_D, \delta_{D^*}$

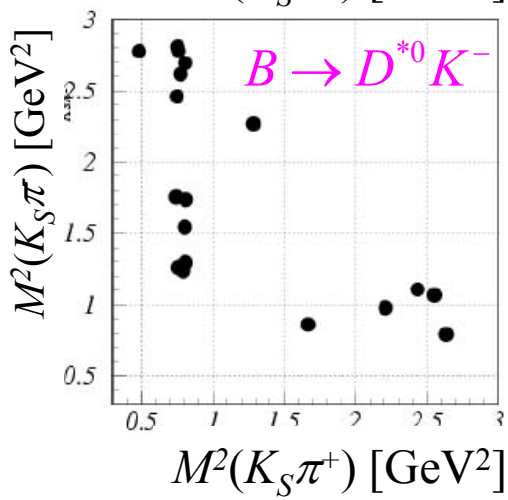
$$\gamma = 77^\circ \,^{+17}_{-19} \pm 13 \pm 11_{(model)}$$
$$26 < \gamma < 126^\circ \ [95\%\ \mathrm{CL}]$$

$$r_B = 0.26 \,^{+0.10}_{-0.14} \pm 0.03 \pm 0.04$$
$$r_B^* = 0.20 \,^{+0.19}_{-0.17} \pm 0.02 \pm 0.04$$



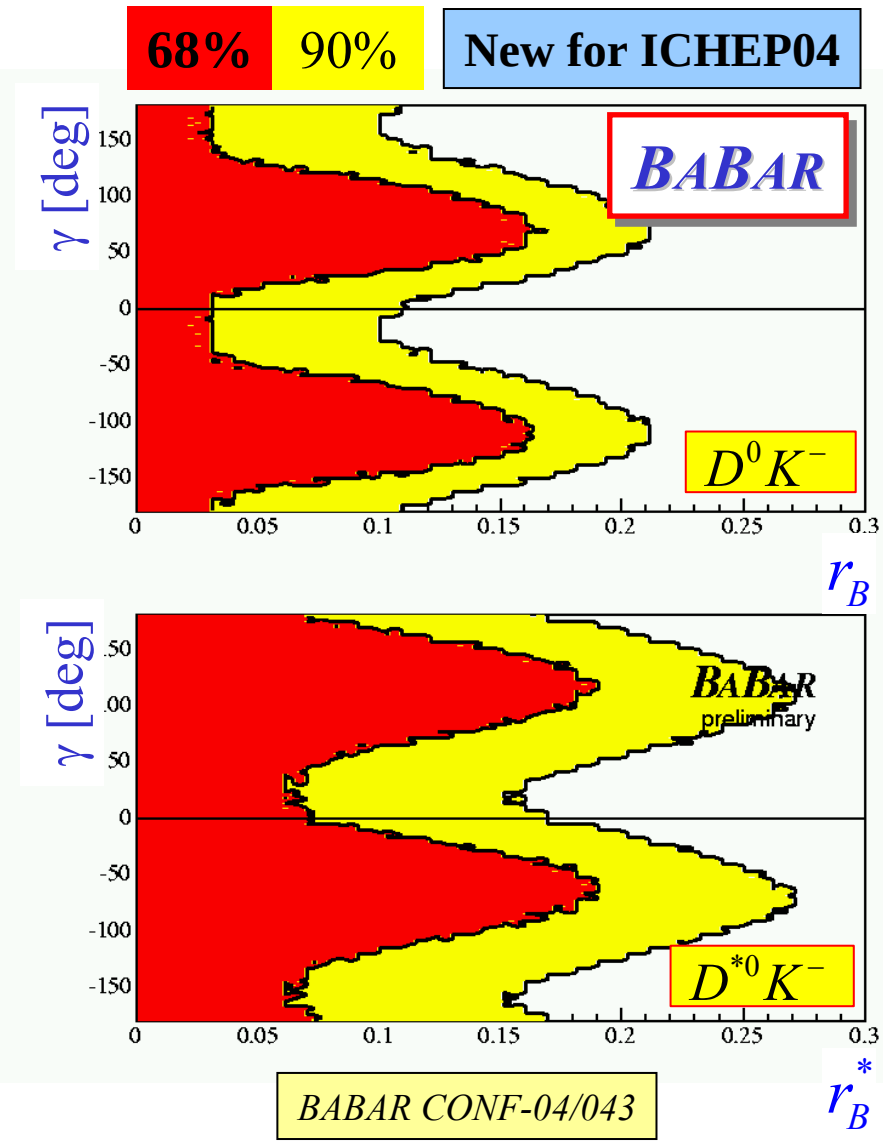


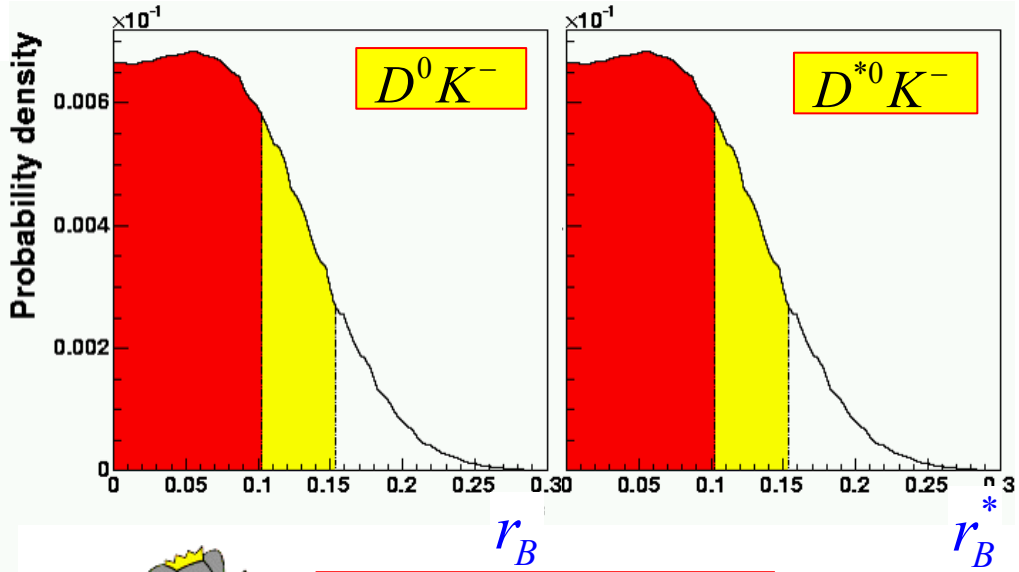




hep-ex/0406067

BABAR analysis of $B^- \to D^{(*)0}[K_S\pi^+\pi^-]K^-$





$r_B < 0.17$ (90% CL)

$r_B^* < 0.23$ (90% CL)

[No sensitivity to $r_B < 0.1$]

$$\delta_B = (130 \pm 45 \pm 8 \pm 10_{(model)})^o$$
$$\delta_B^* = (311 \pm 52 \pm 23 \pm 10_{(model)})^o$$
$$\gamma = (88 \pm 41 \pm 19 \pm 10_{(model)})^o$$

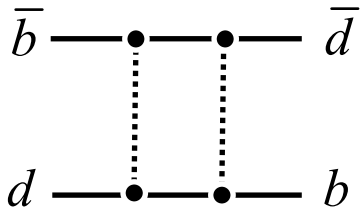
Poor constraints on γ as yet

$\sin 2\alpha$ from $B \to \pi\pi, \rho\pi, \rho\rho$

Interference of suppressed
b → u "tree" decay with mixing

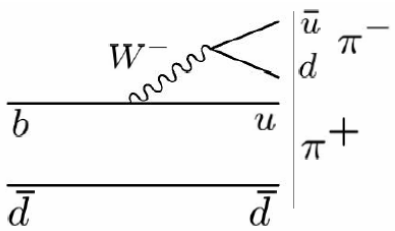
but: "penguin"
is sizeable!

B^0 mixing



$\oplus$

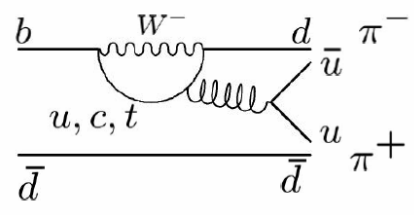
B^0 decay: tree



$q/p \propto V_{tb}^* V_{td} / V_{tb} V_{td}^*$ $\quad A \propto V_{ub}^* V_{ud}$ $\quad \propto \lambda^3$

$\oplus$

B^0 decay: penguin



$A \propto V_{td}^* V_{tb}$ $\quad \propto \lambda^3$

$$\lambda_{\pi\pi} = \frac{q}{p}\frac{\bar{A}_{\pi\pi}}{A_{\pi\pi}} = e^{-i2\beta} e^{-i2\gamma} = e^{i2\alpha}$$

$$\lambda_{\pi\pi} = e^{i2\alpha} \frac{T + Pe^{+i\gamma} e^{i\delta}}{T + Pe^{-i\gamma} e^{i\delta}}$$

Coefficients of time-dependent CP Asymmetry

With no penguins

$$S_{\pi\pi} = \sin 2\alpha$$
$$C_{\pi\pi} = 0$$

With large penguins
and |P/T| ~ 0.3

$$S_{\pi\pi} = \sqrt{1 - C_{\pi\pi}^2}\, \sin 2\alpha_{eff}$$
$$C_{\pi\pi} \propto \sin\delta$$

Results for $\sin 2\alpha_{eff}$ from $B \to \pi\pi$ decays

BABAR: Updated for ICHEP04

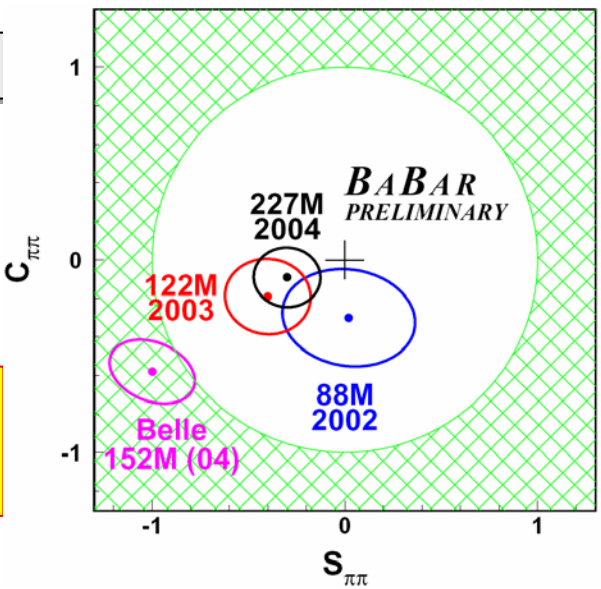
$B^0 \to \pi^+\pi^-$ (227*M* pairs)

$$S_{\pi\pi} = -0.30 \pm 0.17 \pm 0.03$$
$$C_{\pi\pi} = -0.09 \pm 0.15 \pm 0.04$$

Belle: PRL 93 (2004) 021601

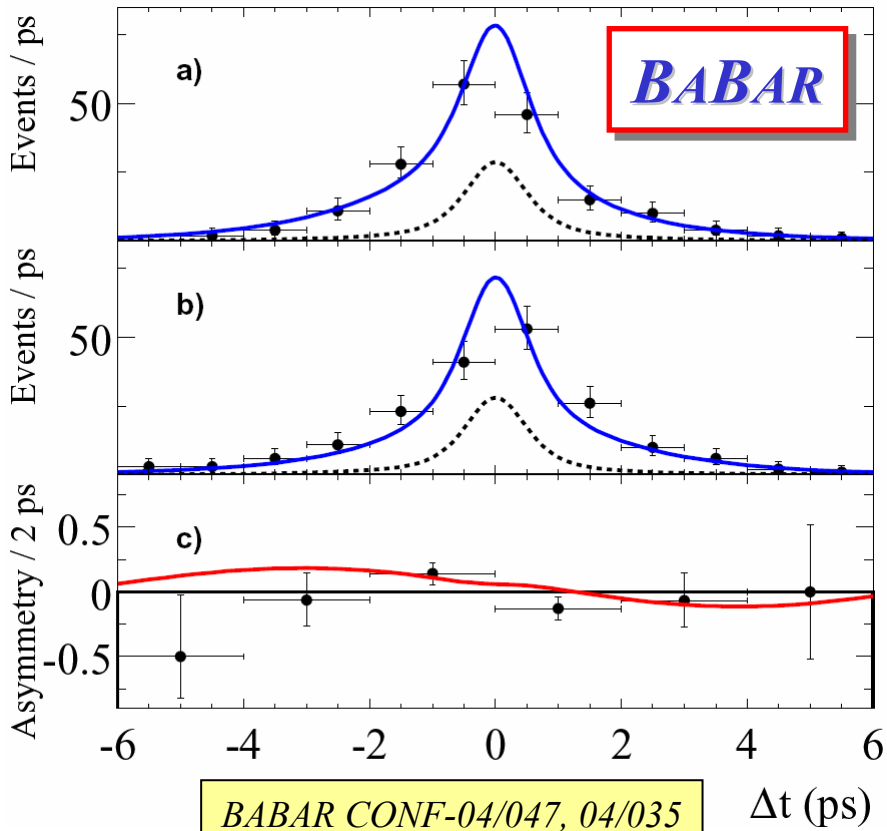
$$S_{\pi\pi} = -1.00 \pm 0.21 \pm 0.07$$
$$C_{\pi\pi} = -0.58 \pm 0.15 \pm 0.07$$

152*M* pairs



Comparison

Caution averaging!



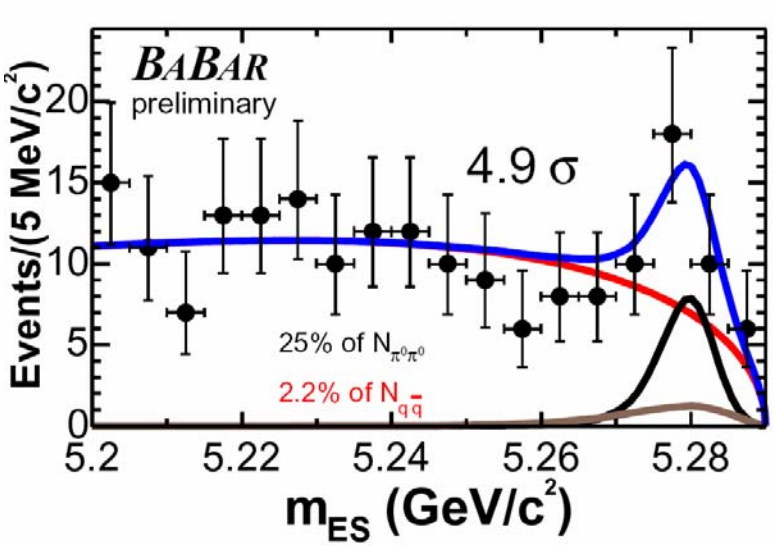
BABAR CONF-04/047, 04/035

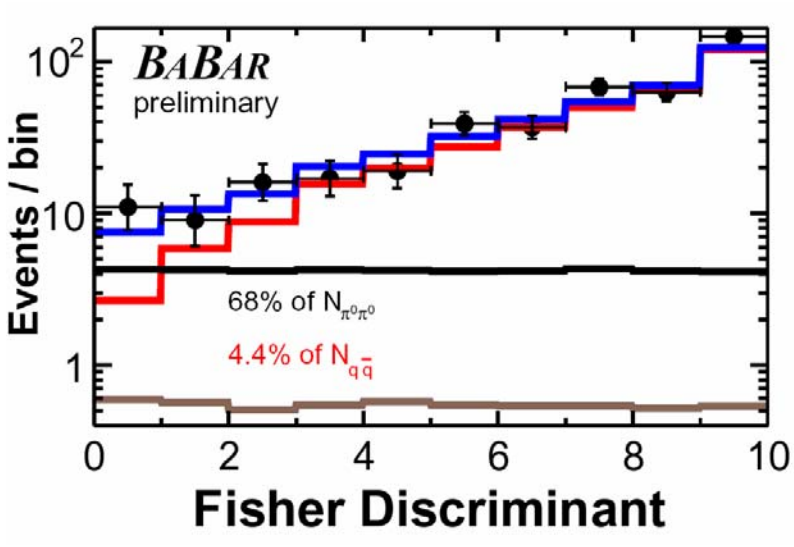
$B^\pm \to \pi^\pm\pi^0$ (227*M* pairs)

$$A_{\pi^\pm\pi^0} = -0.01 \pm 0.10 \pm 0.02$$
$$BF_{\pi^\pm\pi^0} = (5.8 \pm 0.6 \pm 0.4) \times 10^{-6}$$

Updated for ICHEP04

Result for $B \to \pi^0\pi^0$





Fit = $q\bar{q}$ bkgd + $B^0 \to \rho^{\pm}\pi^0$ + signal

BABAR CONF-04/035

Improved understanding of π^0 efficiency:

$\varepsilon_{data} / \varepsilon_{MC} = 0.99 \pm 0.03$ vs 0.88 ± 0.08

BABAR	$B\bar{B}$ pairs	$N(\pi^0\pi^0)$
Run 1-3	122*M*	44±13
Run 4	105*M*	17±11
Run 1-4	227*M*	61±17

Consistent at 1.3σ level

$BF_{\pi^0\pi^0} = (1.17 \pm 0.32 \pm 0.10) \times 10^{-6}$ 4.9σ

$C_{\pi^0\pi^0} = -0.12 \pm 0.56 \pm 0.06$ First measurements

$\alpha - \alpha_{eff} \leq 35^\circ$ at 90% CL

BELLE

$BF_{\pi^0\pi^0} = (2.32^{+0.41+0.22}_{-0.48-0.18}) \times 10^{-6}$ 6.0σ

$C_{\pi^0\pi^0} = -0.43 \pm 0.51^{+0.16}_{-0.17}$ First measurements

Results for $\sin 2\alpha_{eff}$ from $B \to \rho\rho$ decays

Extraction of α similar to ππ, but with advantage of smaller Penguin pollution:

$\frac{|A^{00}|}{|A^{+0}|}, \frac{|A^{00}|}{|A^{+-}|}$ much smaller: $\alpha - \alpha_{eff}$ smaller

Potentially $\rho^+\rho^-$ could be mixed CP, but is observed to be almost pure CP = +1

Moriond QCD04

$B^0 \to \rho^+\rho^-$ (122M $B\bar{B}$ pairs)

Signal: 314 ± 34 events

$f_{long} = 1.00 \pm 0.02$

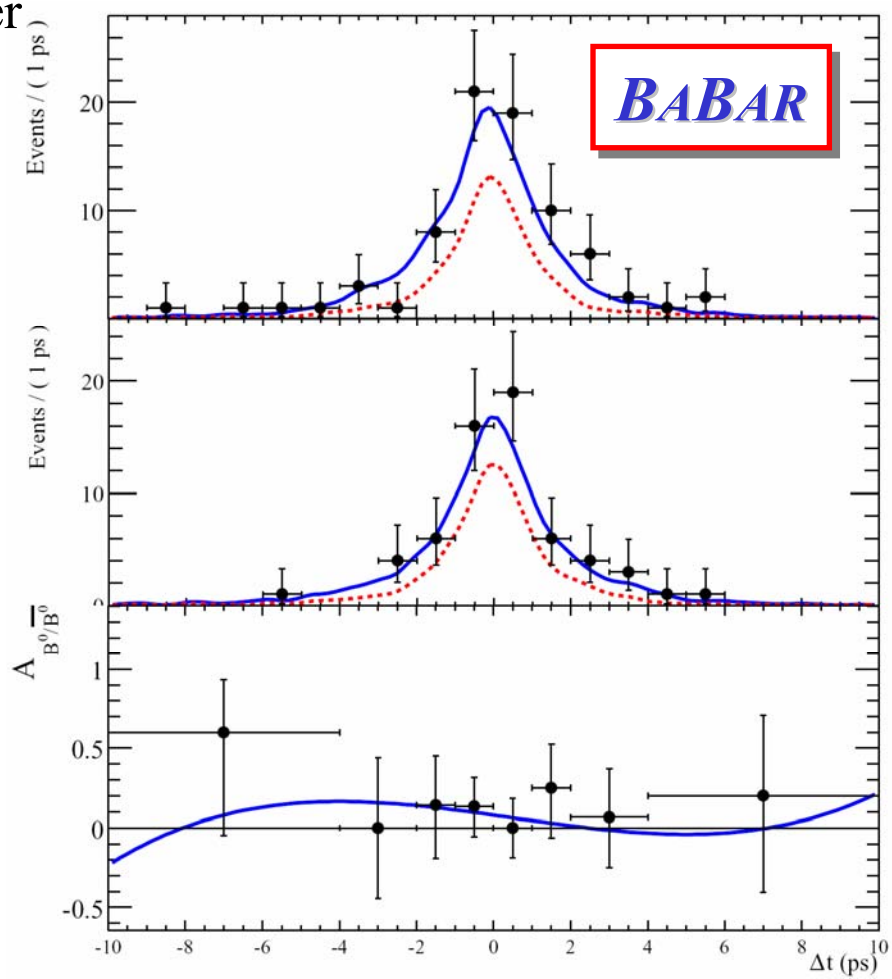
$S_{long} = -0.19 \pm 0.33 \pm 0.11$

$C_{long} = -0.23 \pm 0.24 \pm 0.14$

hep-ex/0404029 *to PRL* (89M $B\bar{B}$ pairs)

$S_{long} = -0.42 \pm 0.42 \pm 0.14$

$C_{long} = -0.17 \pm 0.27 \pm 0.14$



Isospin Corrections for α

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

PRL 91 (2003) 171802

First result from Run 1-2 ($89M$ $B\bar{B}$ pairs)

$$BF(B^+ \to \rho^+\rho^0) = (22.5^{+5.7}_{-5.4} \pm 5.8)\times 10^{-6}$$

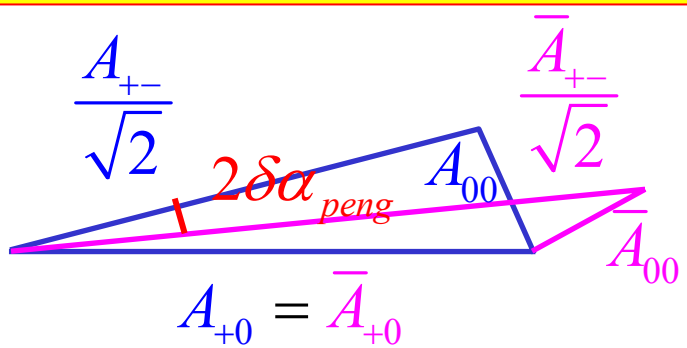
$B^0 \to \rho^0\rho^0$

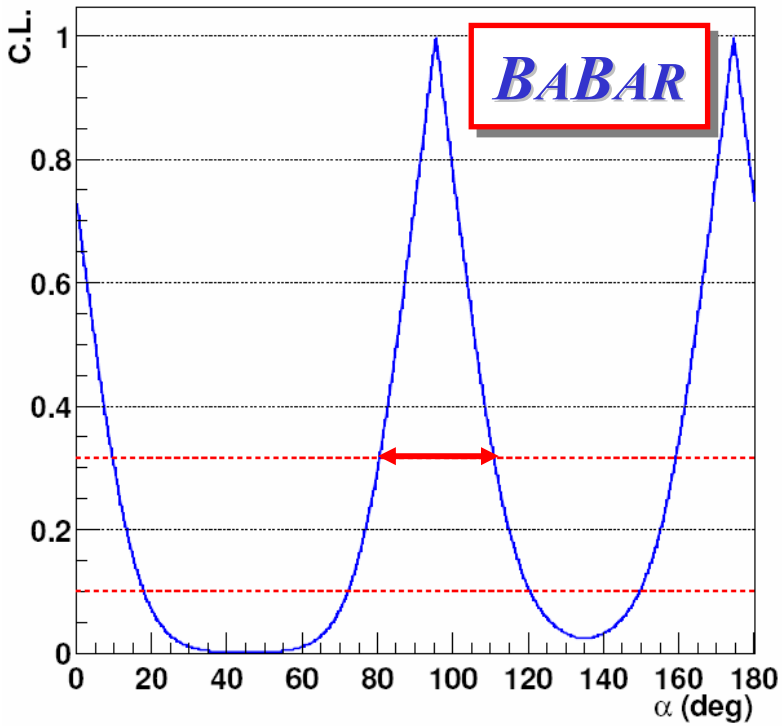
Updated for ICHEP04

BABAR CONF-04/037

Updated result from Run 1-4 ($227M$ $B\bar{B}$ pairs)

$$BF(B^0 \to \rho^0\rho^0) < 1.1\times 10^{-6} \ (90\%\ \mathrm{CL})$$





$$\alpha = \left[96 \pm 10_{(stat)} \pm 4_{(sys)} \pm 11_{(peng)}\right]^{o}$$

Geometric limit on $2\delta\alpha_{peng}$: Grossman-Quinn bound

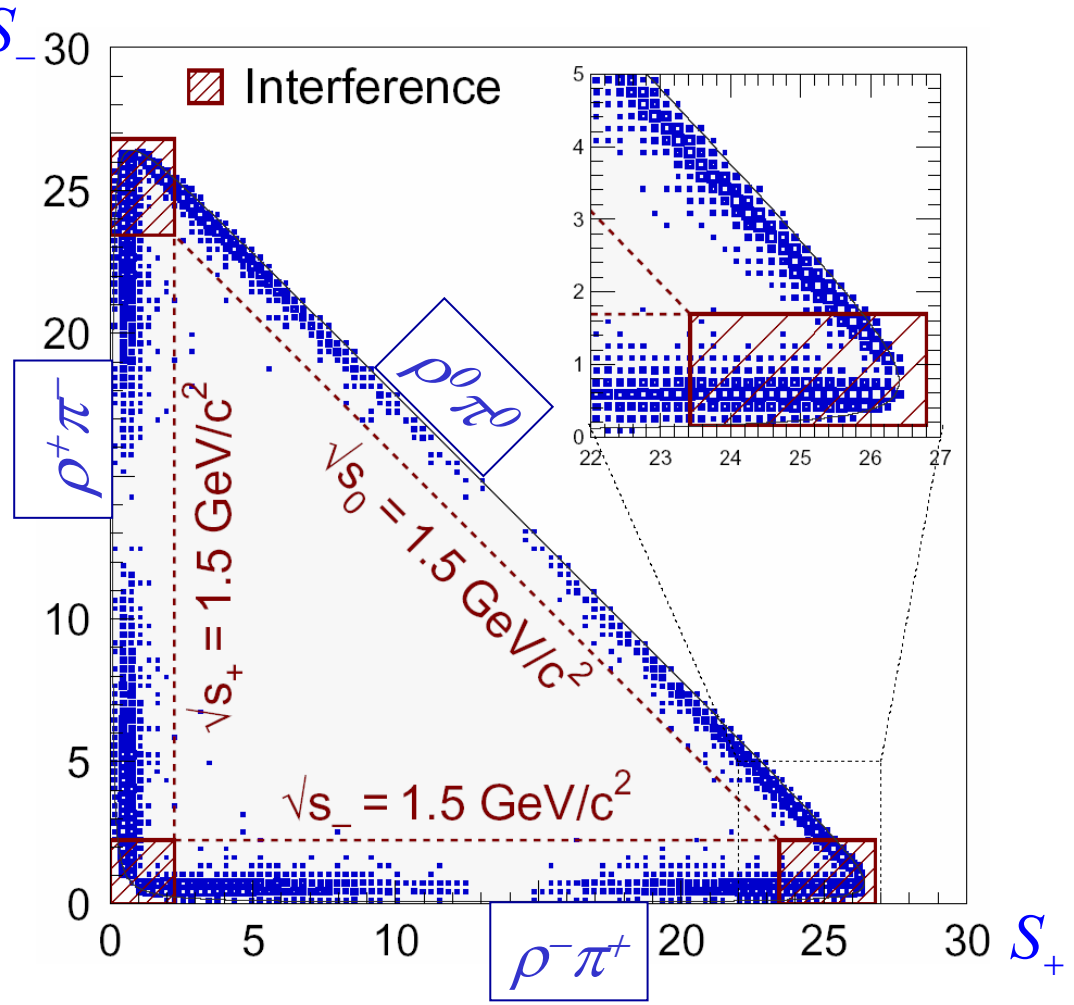
Compare with 35° for $\pi\pi$

Basis for Dalitz plot analysis of $B^0 \to (\rho\pi)^0$

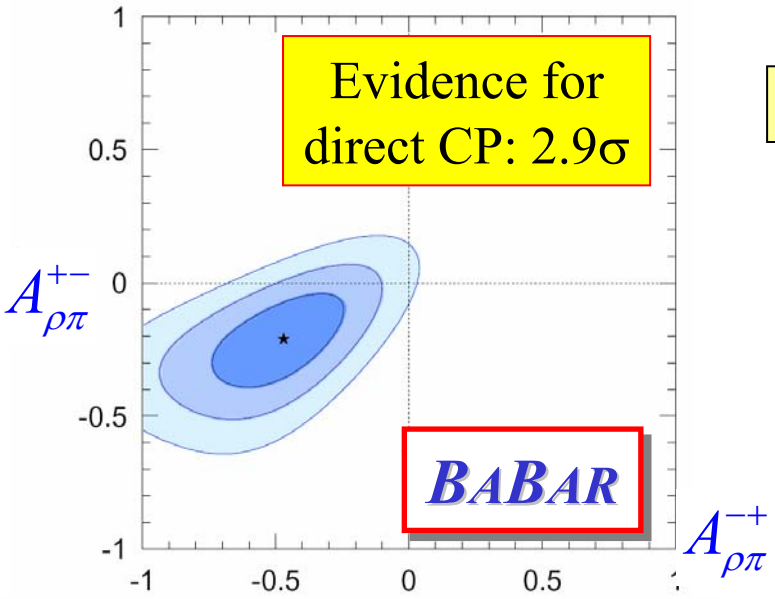
Quasi-two-body approach to Snyder-Quinn method

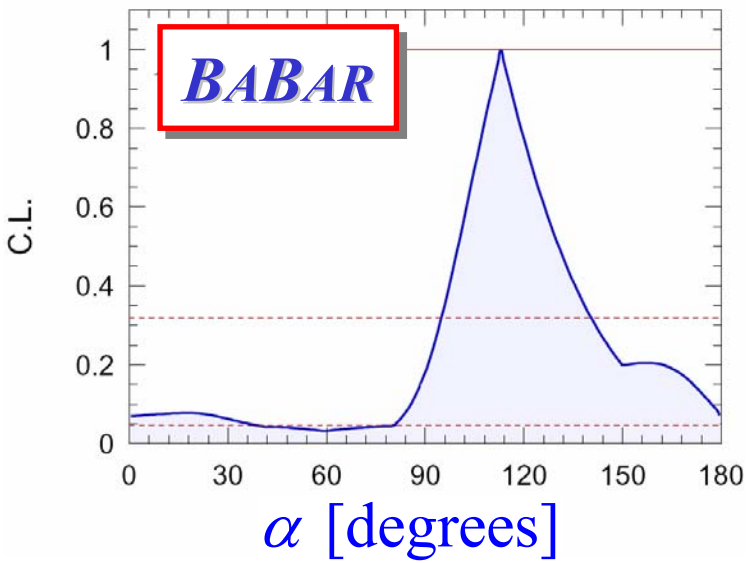
Phys.Rev. D 48, 2139 (1993)

- Extract α and strong phases using interference between amplitudes
- Amplitude $A_{3\pi}$ dominated by $\rho^+\pi^-$, $\rho^-\pi^+$, $\rho^0\pi^0$ and radial excitations
- Form time-dependent decay rate coefficients of $\cos(\Delta m_d \Delta t)$ and $\sin(\Delta m_d \Delta t)$ on this basis



Results from Dalitz analysis of $B^0 \to (\rho\pi)^0$





	Belle [152M]	*BABAR* [213M]
$A_{CP}^{\rho\pi}$	$-0.16^{+0.09}_{-0.10}$	$-0.088 \pm 0.049 \pm 0.013$
S	$-0.28 \pm 0.23^{+0.10}_{-0.08}$	$-0.10 \pm 0.14 \pm 0.04$
C	$0.25 \pm 0.17^{+0.02}_{-0.06}$	$0.34 \pm 0.11 \pm 0.05$
A^{+-}	$-0.02 \pm 0.16^{+0.05}_{-0.02}$	$-0.21 \pm 0.11 \pm 0.04$
A^{-+}	$-0.53 \pm 0.29^{+0.09}_{-0.04}$	$-0.47 \pm 0.15 \pm 0.06$

combined 3.6σ

$\alpha = (102 \pm 11 \pm 15)^\circ$

[Based on factorization & SU(3); Gronau & Zupan]

hep-ex/0408003

$\alpha = (113^{+27}_{-17} \pm 6)^\circ$

BABAR CONF-04/038

Summary of constraints on α

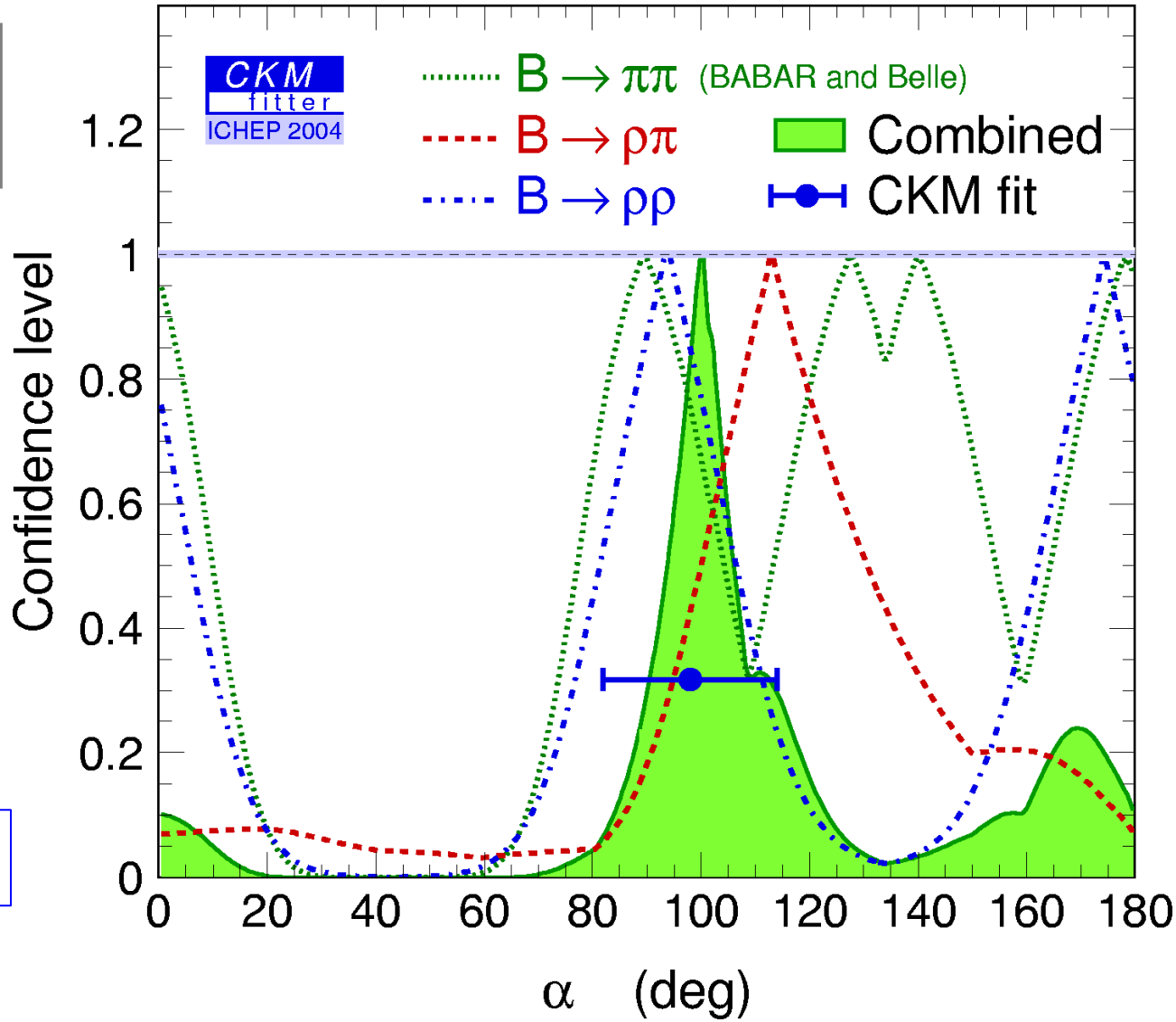
BABAR & Belle combined

Mirror solutions disfavored

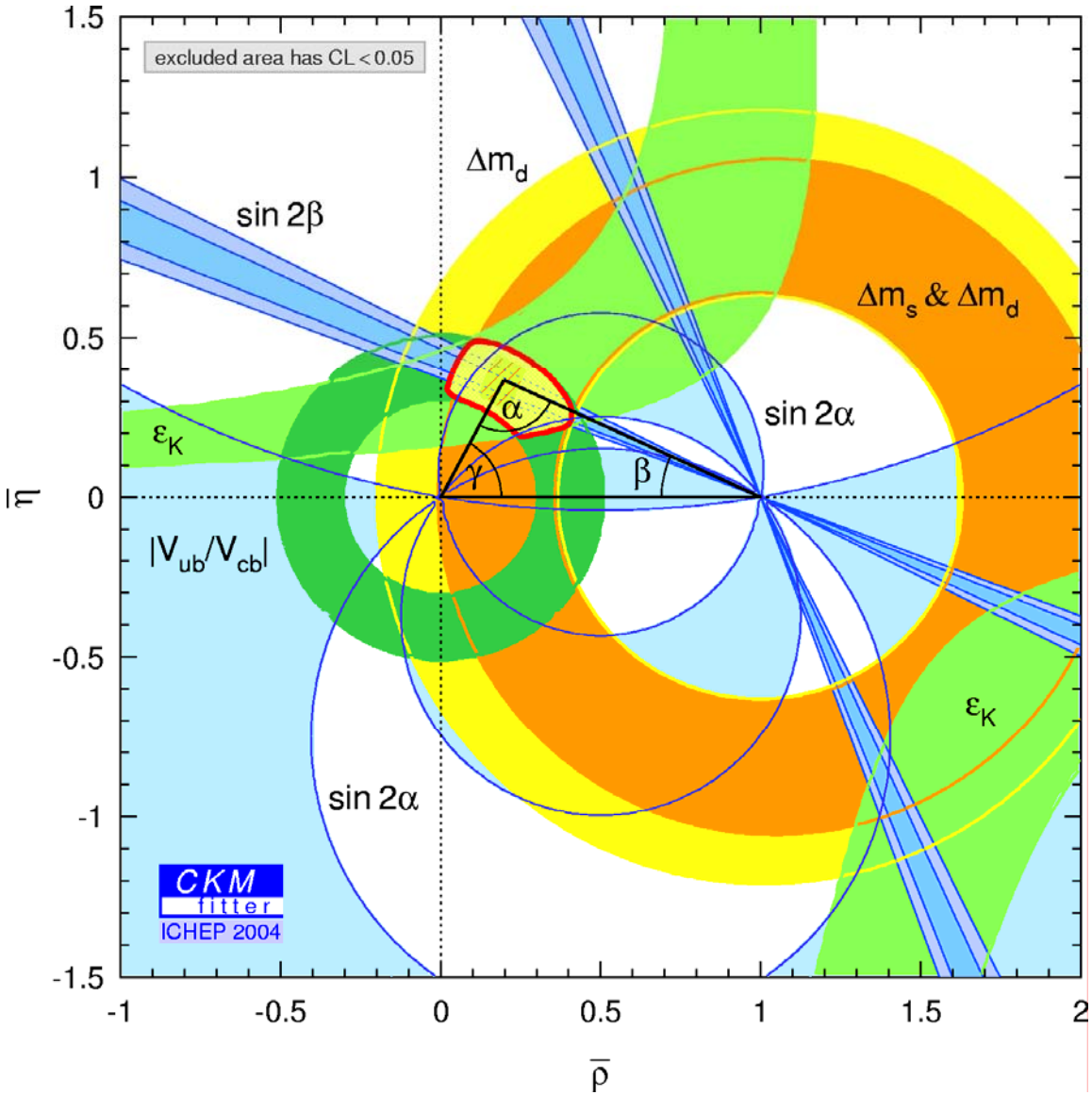
From combined $\pi\pi, \rho\pi, \rho\rho$ results:

$$\alpha = \left[100^{+12}_{-11}\right]^{\circ}$$

CKM indirect constraint fit:
$\alpha = 98 \pm 16^{\circ}$



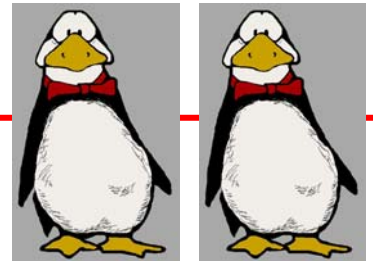
CKM constraints and sin2β and α measurements



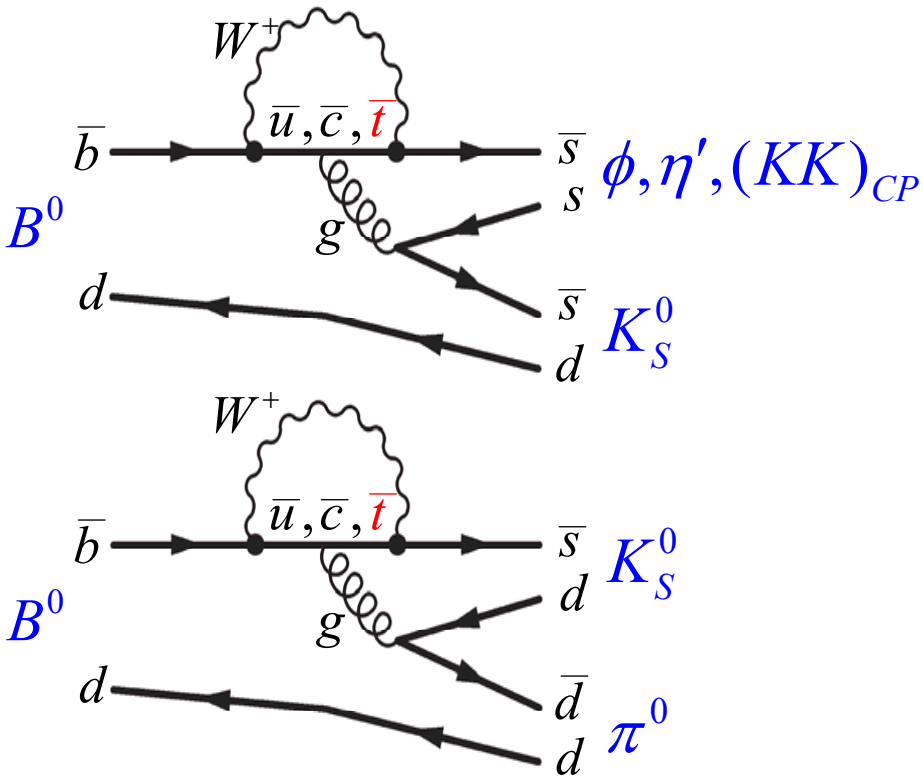
CKM fit to indirect constraints overlaid with sin2β_{WA} and α measurements

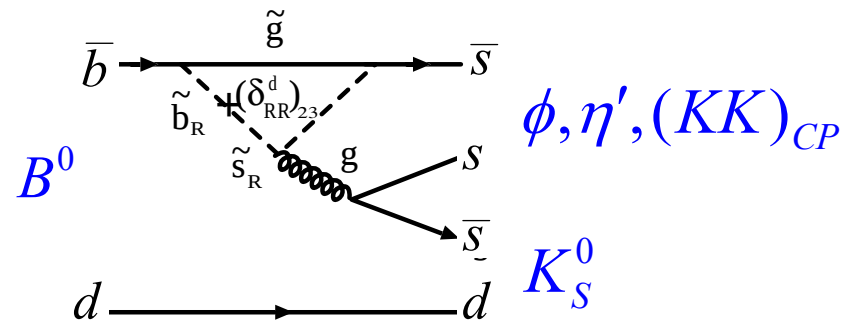
Beyond the Standard Model?

Do  and  yield the same sin2β ?

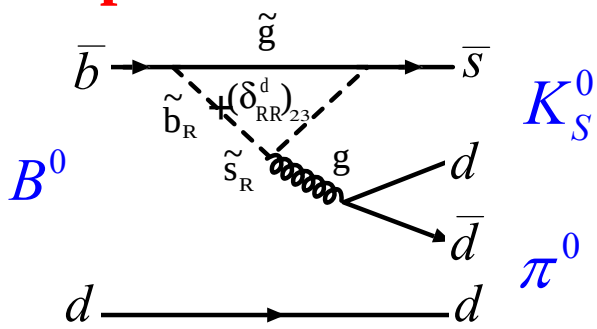
$\sin 2\beta$ and...  and.... 

In SM interference between B mixing, K mixing and Penguin $b\to s\bar{s}s$ or $b\to s\bar{d}d$ gives the same $e^{-2i\beta}$ as in tree process $b\to c\bar{c}s$. However loops can also be sensitive to New Physics!



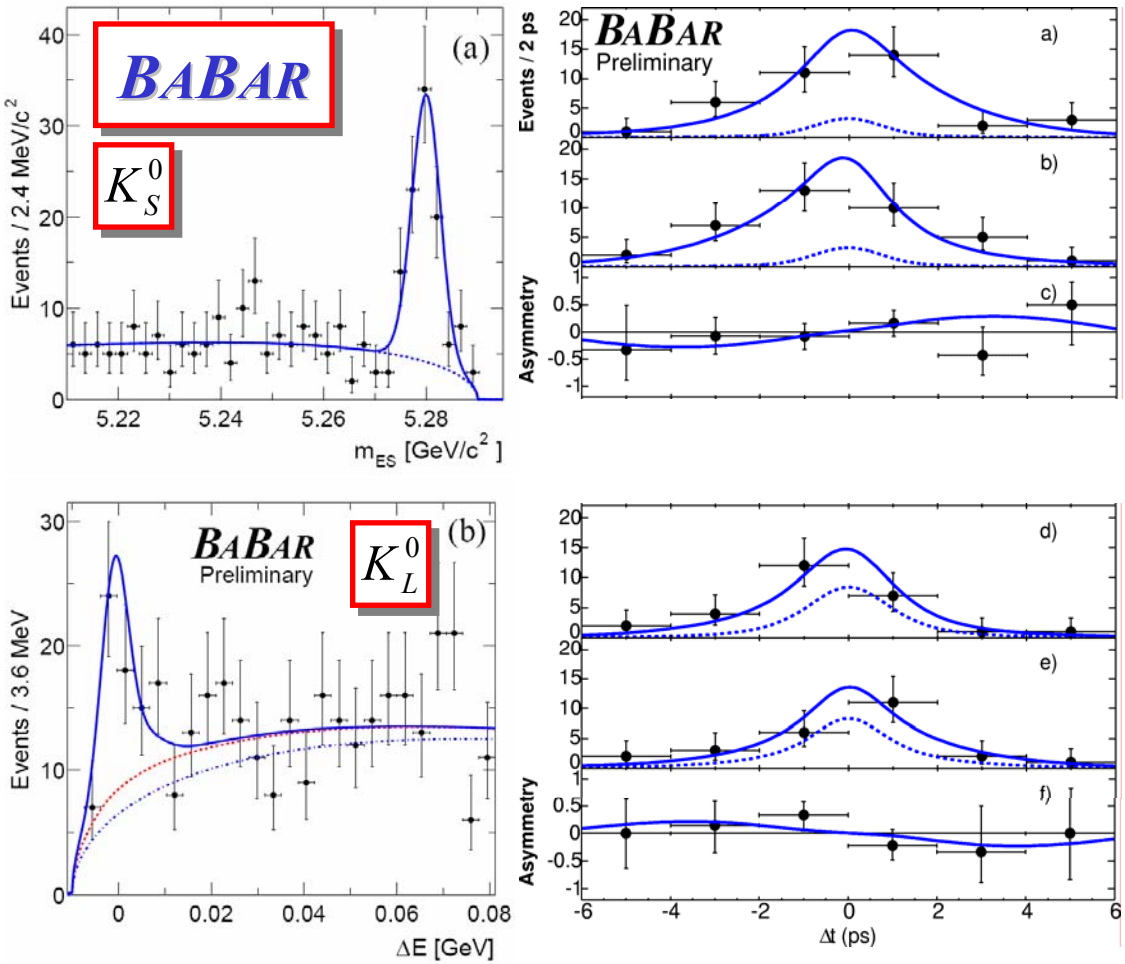


New phases from SUSY?



BABAR results for $B^0 \to \phi K^0$

2004 = 227*M BB* pairs (2003 = 120M pairs)



2003 result

$$-\eta_{CP} \cdot S_{\phi K^0} = +0.47 \pm 0.34 \,^{+0.08}_{-0.06}$$
$$C_{\phi K^0} = +0.10 \pm 0.33 \pm 0.10$$

Update for ICHEP04

$B^0 \to \phi K^0_S$ 114 ± 12 events

$$S_{\phi K^0_S} = +0.29 \pm 0.31$$

$B^0 \to \phi K^0_L$ 98 ± 18 events

$$S_{\phi K^0_L} = -1.05 \pm 0.51$$

$$-\eta_{CP} \cdot S_{\phi K^0} = +0.50 \pm 0.25 \,^{+0.07}_{-0.04}$$
$$C_{\phi K^0} = +0.00 \pm 0.23 \pm 0.05$$

BABAR-CONF 04/033

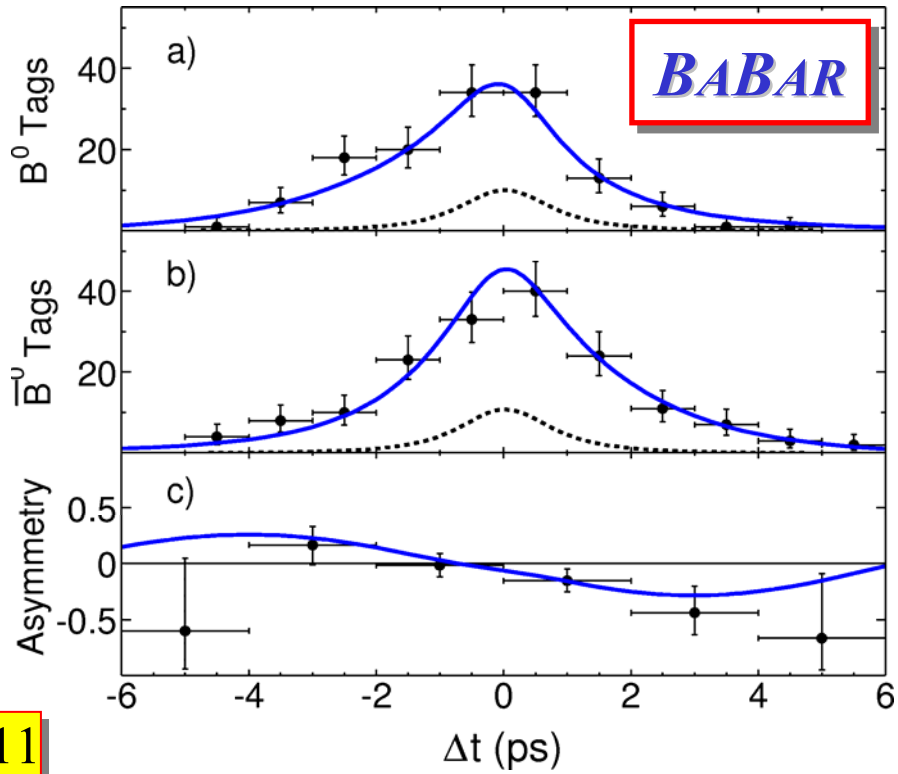
More BABAR results from b → s$\bar{s}$s penguins

Update for ICHEP04

BABAR CONF-04/025

$B^0 \to (K^+K^-)_{CP} K_S^0$ (208M pairs)

- Independent sample with (K^+K^-) mass outside ϕ region
- CP content can be determined experimentally with an angular moment analysis through the helicity angle distribution



Signal: 481 ± 29 events

$$f_{even} = 0.89 \pm 0.08 \pm 0.04$$

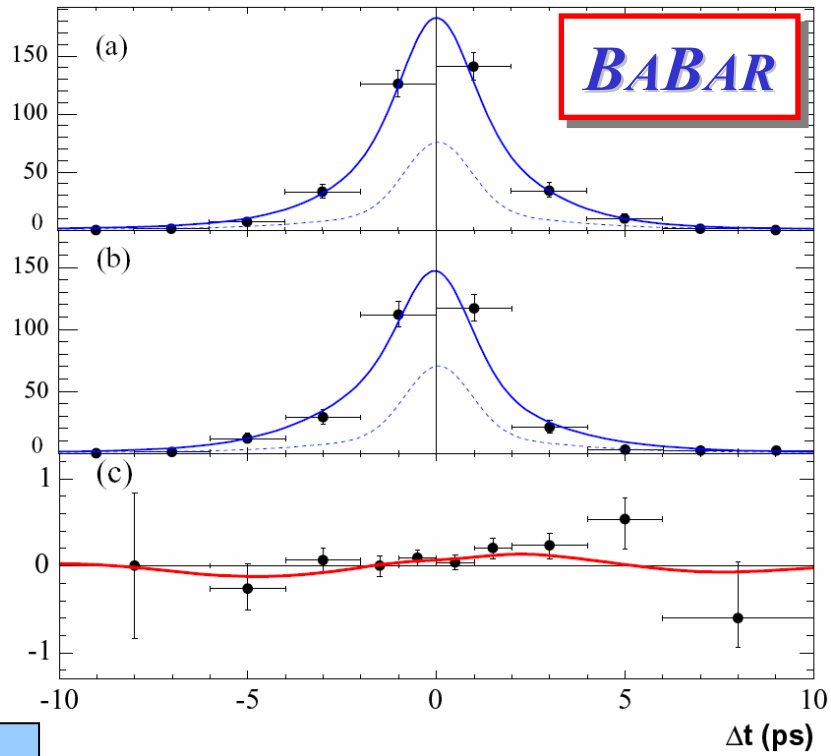
$$S_{KKK_S^0} = -0.42 \pm 0.17 \pm 0.04$$

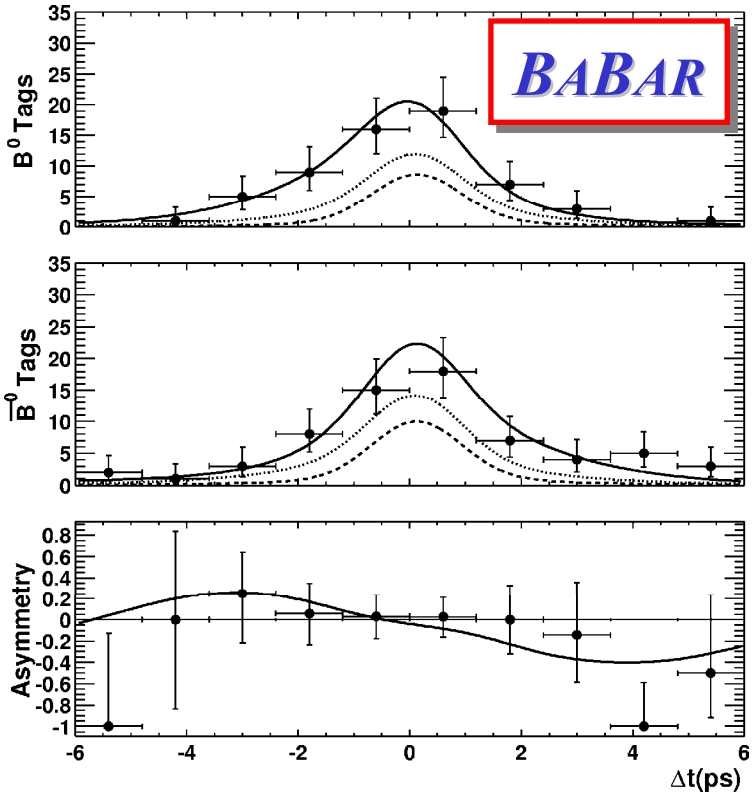
$$-(2 f_{even} - 1) \cdot S_{KKK_S^0} = +0.55 \pm 0.22 \pm 0.04 \pm 0.11$$

$$C_{KKK_S^0} = +0.10 \pm 0.14 \pm 0.06$$

More BABAR results from $b \to s\bar{s}s$ penguins

CONF 04/040
CONF 04/019





Updates for ICHEP04

$208M\ B\bar{B}$ pairs

$\eta' \to \rho^0\gamma, \eta\pi^+\pi^-$
$\eta \to \gamma\gamma, \pi^+\pi^-\pi^0$
$K_S^0 \to \pi^+\pi^-, \pi^0\pi^0$

$B^0 \to \eta' K_S^0$ Signal: 819 ± 38

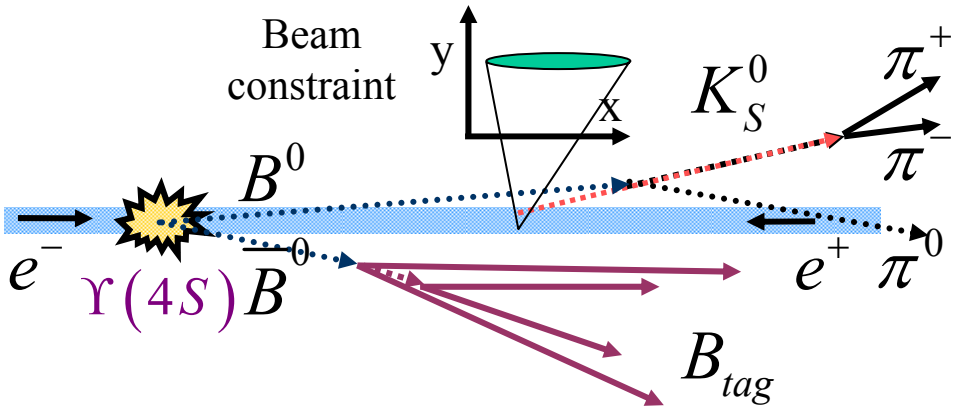
$\neq \sin 2\beta[c\bar{c}]@3.0\sigma$

$$-\eta_{CP} \cdot S_{\eta' K_S^0} = +0.27 \pm 0.14 \pm 0.03$$
$$C_{\eta' K_S^0} = -0.21 \pm 0.10 \pm 0.03$$

$B^0 \to f_0 K_S^0$ Signal: 152 ± 19

$$-\eta_{CP} \cdot S_{f_0 K_S^0} = +0.95\ ^{+0.32}_{-0.23} \pm 0.10$$
$$C_{f_0 K_S^0} = -0.24 \pm 0.31 \pm 0.15$$

Still another penguin mode: $B^0 \to \pi^0 K_S$



BABAR technique from 2003

Updated for ICHEP04

BABAR

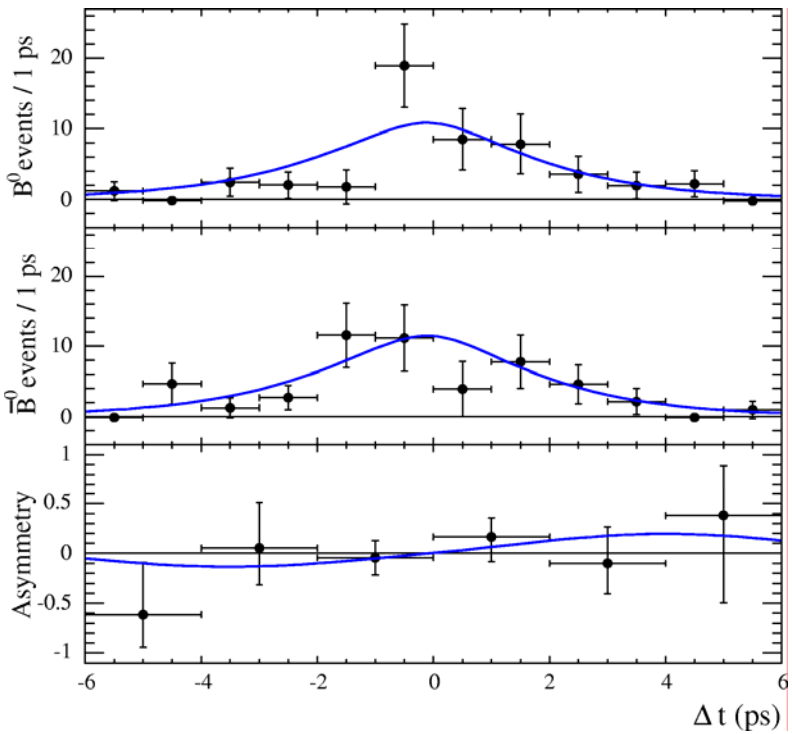
BABAR CONF-04/030

$227M\ B\bar{B}$ pairs

Signal: 192 w/vertex, 108 w/o

$$-\eta_{CP} \cdot S_{\pi^0 K_S^0} = +0.35\,^{+0.30}_{-0.33} \pm 0.04$$
$$C_{\pi^0 K_S^0} = +0.06 \pm 0.18 \pm 0.06$$

[sPlots: Pivk, Le Diberder, physics/0402083]



BABAR

Belle

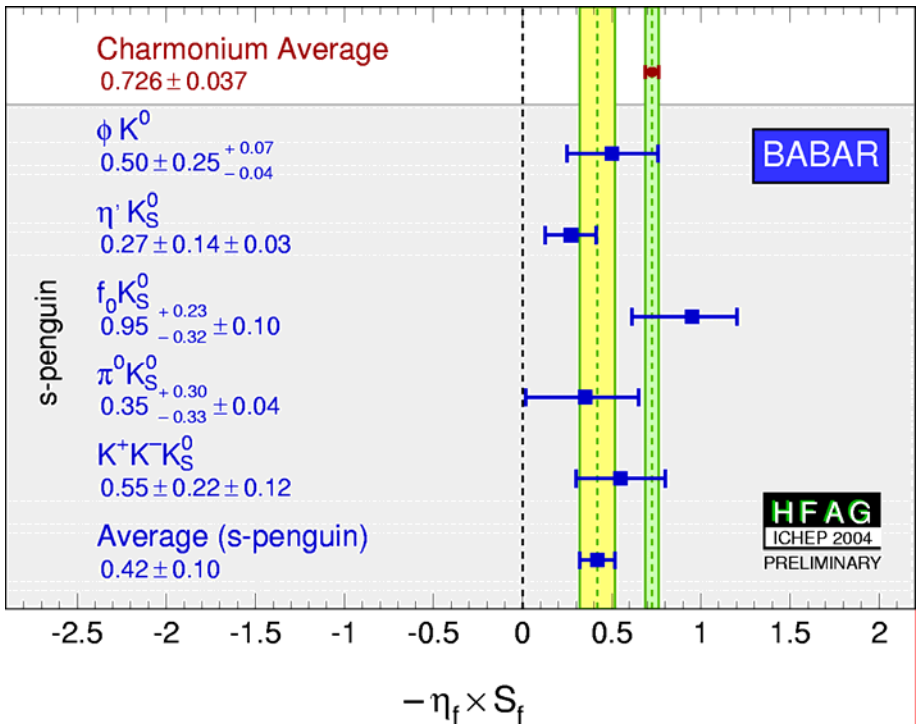
$274M\ B\bar{B}$ pairs

Signal: 77 w/vertex, 173 w/o

$$-\eta_{CP} \cdot S_{\pi^0 K_S^0} = +0.30 \pm 0.59 \pm 0.11$$
$$C_{\pi^0 K_S^0} = -0.12 \pm 0.20 \pm 0.07$$

Results on sin2β from s-penguin modes

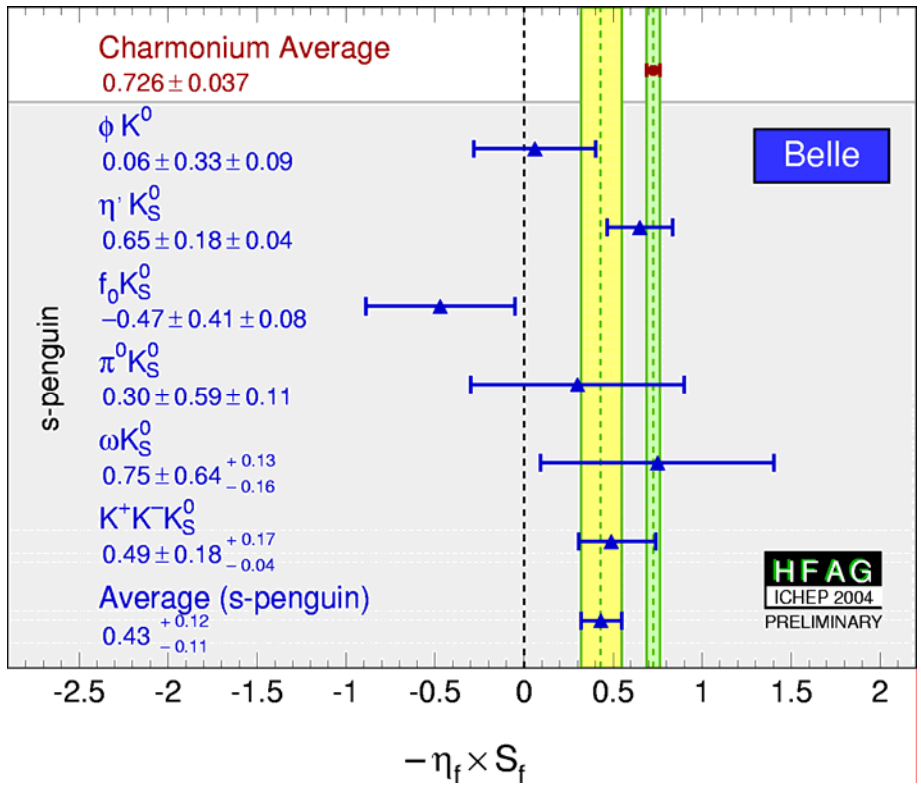
All new!



2.7σ from s-penguin to sin2β ($c\bar{c}$)

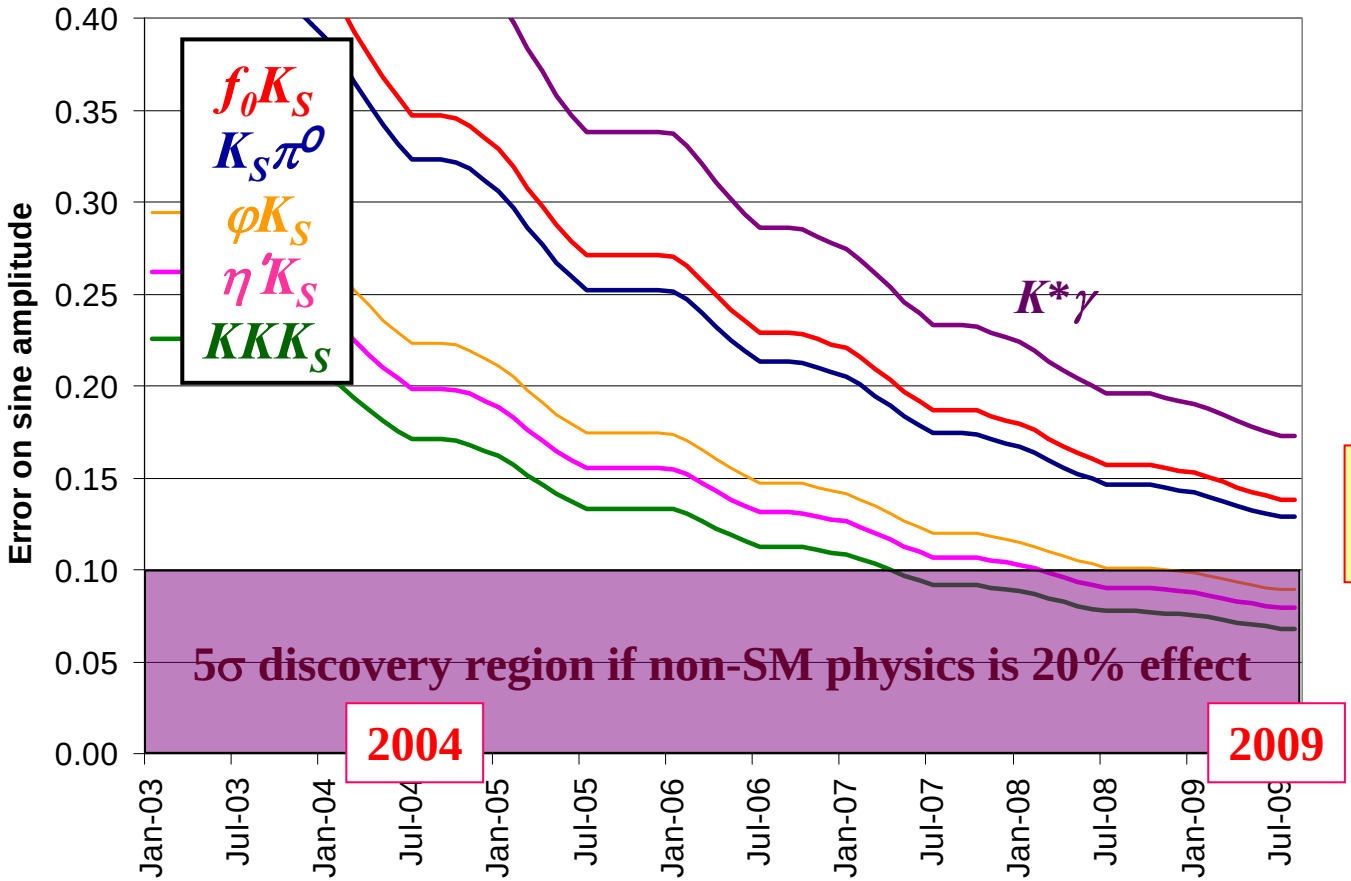
BELLE

All new!



2.4σ from s-penguin to sin2β ($c\bar{c}$)

Projections for Penguin Modes



Luminosity expectations:

2004=240 fb^{-1}
2009=1.5 ab^{-1}

Similar projections for Belle as well

Projections are statistical errors only;
but systematic errors at few percent level

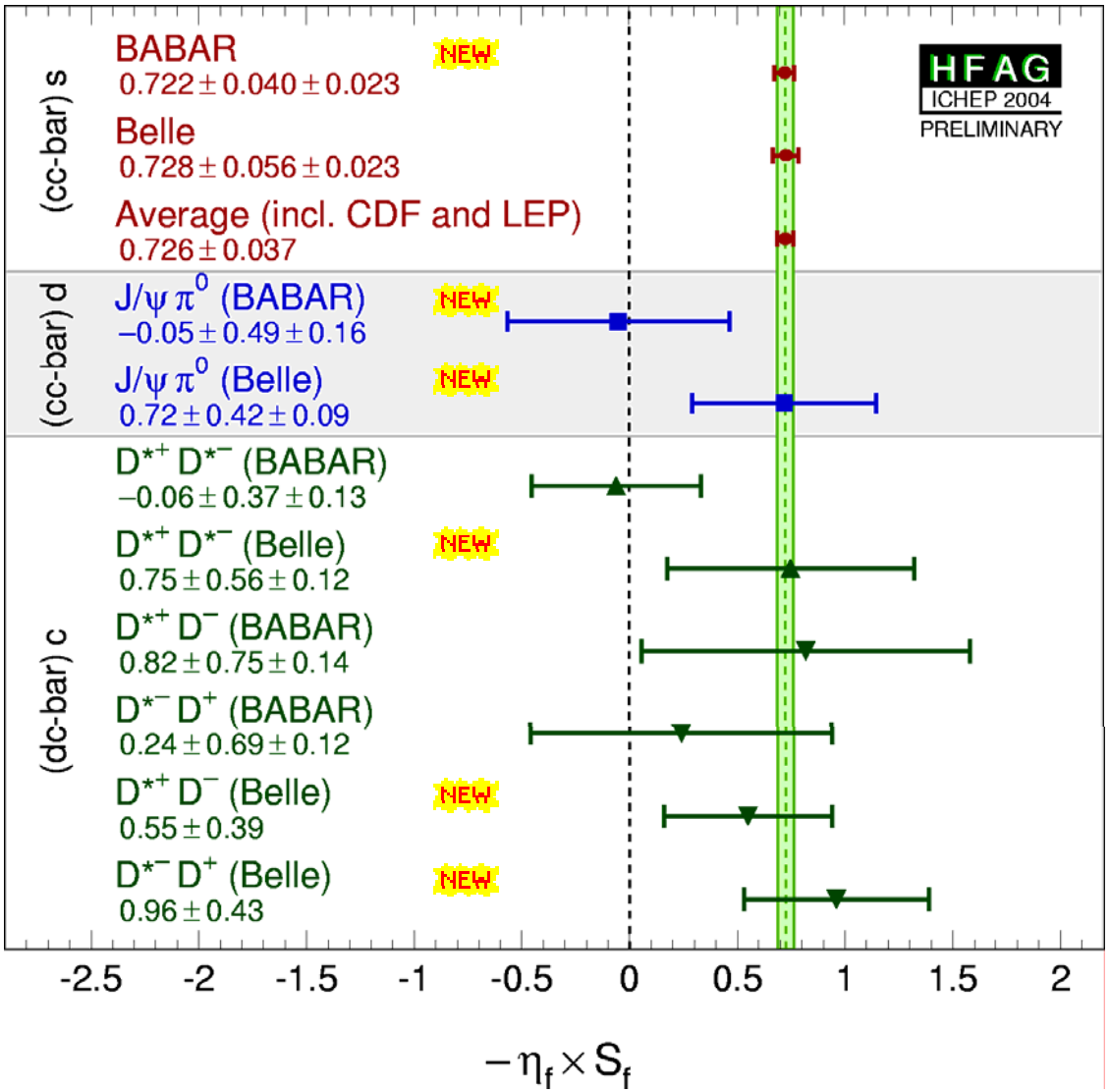
Conclusions and outlook

- Success of *B* Factory experiments BaBar and Belle of $b \to c\bar{c}s$ (new $\sin 2\beta$ value from charmonium 0.726 ± 037)
- Good agreement between BaBar and Belle results on $b \to s\bar{s}s$ penguin, but both experiments still show discrepancies (2.7 and 2.4σ) with charmonium!!
- Observation by BaBar of direct CP violation in charmless *B* decays confirmed by Belle (average value $A_{CP} = -0.114 \pm 0.020$)
- Quantitative measurements of $\alpha\,(\phi_2)$ are emerging (new value $\alpha = \left[106\,^{+8}_{-11}\right]^{\circ}$)
- Constraints on $\gamma\,(\phi_3)$ are still poor with present statistics (low values for r_B).

- A statistical increase on these modes in the next few years could well provide initial evidence for new physics in the unitarity triangle beyond the SM.
- Modes dominated by penguin amplitudes as $B^0 \to \phi K^0$ seem to be promising benchmarks for New Physics at a mass scale < 1 TeV. However unravelling the full flavour impact of this new physics will require a very high luminosity *B* Factory – a Super-*B* Factory – *(luminosity higher by a factor 50-100 than in the present machines).*

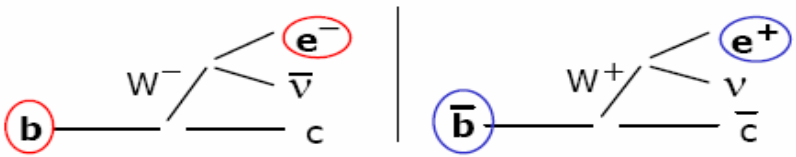
Backup Slides

Results on sin2β from $c\bar{c}s$, $d\bar{c}c$ modes

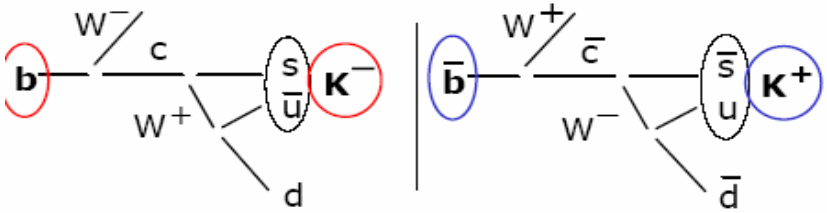


B flavor tagging and Δt measurement

Leptons : Cleanest tag. Correct >95%



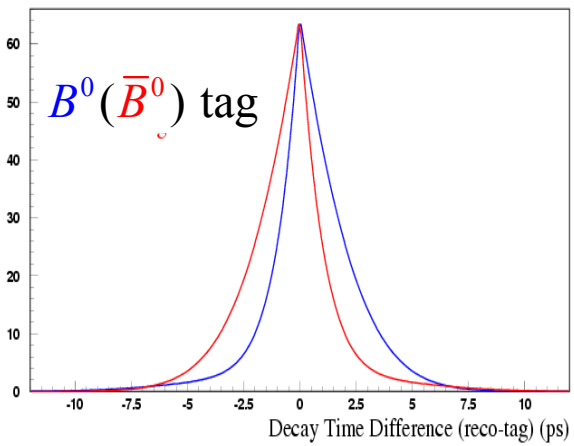
Kaons : Second best. Correct 80-90%



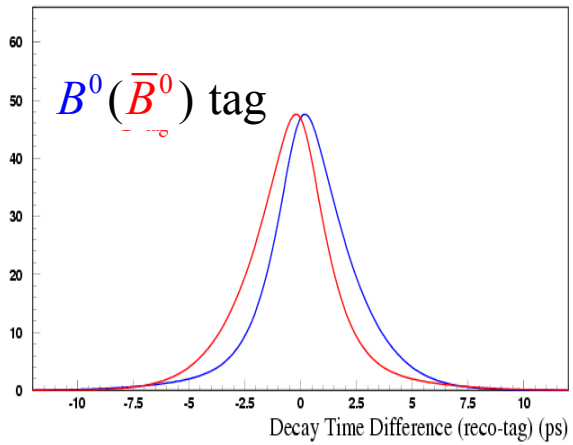
$$Q_T = \sum_i \varepsilon_i (1-2\omega_i)^2 \qquad \sigma(S_{f_{CP}}) \propto \frac{1}{\sqrt{N \times Q_T}}$$

Tagging performance
Q_T=30.5% (6 categories) from full Neural Network including these & other physics processes to identify b quark state

perfect resolution



smeared resolution



Δt resolution dominated by tag side:
σ(Δt) ~ 1 ps ⇔ 170 μm

τ_B ~ 1.6 ps ⇔ 250 μm

CP asymmetry

cos2β from $B^0 \to J/\psi K^{*0}(K_S\pi^0)$

- $J/\psi K^{*0}$ ($K_S\pi^0$) final state can be $\eta_F = +1$ or $\eta_F = -1$, depending on L = 0, 1, 2
- Full angular analysis allows for the separation of CP even ($A_{\|} = |A_{\|}| e^{i\delta\|}$, $A_0 = |A_0| e^{i\delta 0}$) and CP odd ($A_{\perp} = |A_{\perp}| e^{i\delta\perp}$)
- Many terms in time-dependent decay rate, but two are proportional to cos2β

$$\cos 2\beta = \pm 2.72 \pm {}^{+0.50}_{-0.79} \pm 0.027$$

(with sin(2β) fixed to 0.731)

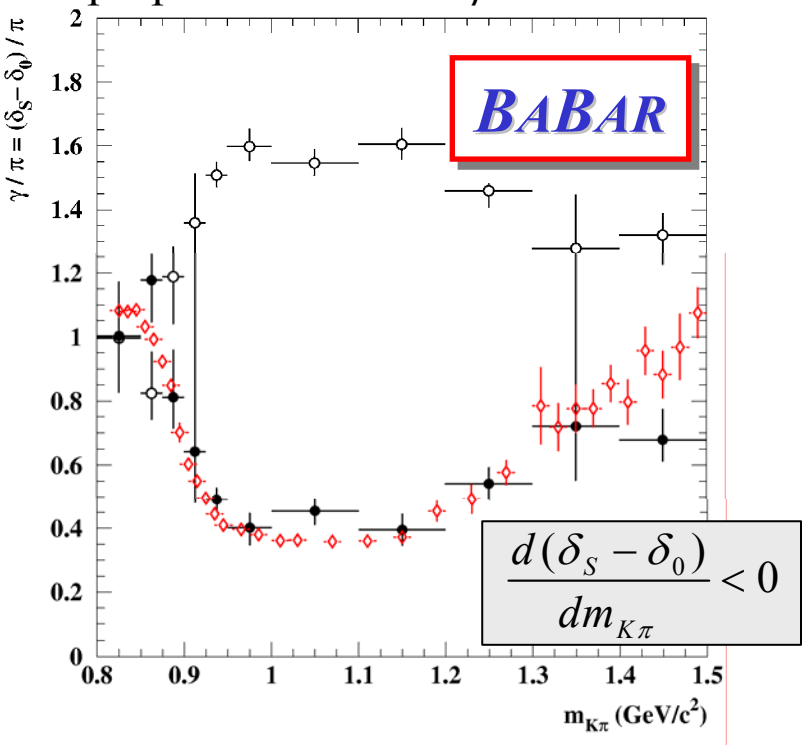
Sign ambiguity is related to the sign of strong phase difference

- Use interference of s-wave and p-wave contributions to Kπ final state to resolve sign ambiguity for strong phases

Assuming:

$$\cos 2\beta = \pm\sqrt{1 - \sin^2 2\beta}$$

$\cos 2\beta = -0.68$ excluded at 86% CL



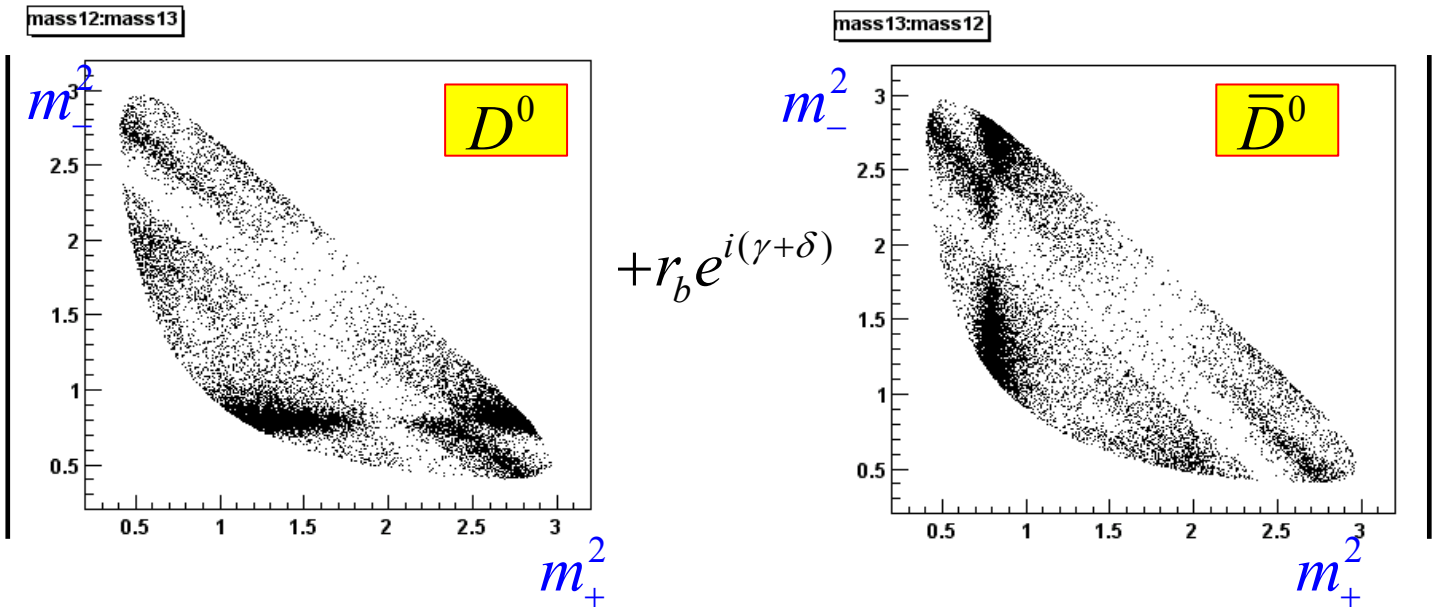
○ *solution 1: unphysical solution*
● *solution 2: physical solution*
○ *LASS data*

Dalitz analysis of $B^- \to D^{(*)0}[K_S\pi^+\pi^-]K^-$

For B^-: $|A_-|^2 = |f(m_-^2, m_+^2) + r_b e^{i(\delta-\gamma)} f(m_+^2, m_-^2)|^2$

$m_-^2 = M(K_S^0\pi^-)^2$
$m_+^2 = M(K_S^0\pi^+)^2$

$|A_-|^2 =$



Schematic view of the interference

For B^-: $|A_-|^2 = |f(m_-^2, m_+^2) + r_b e^{i(\delta+\gamma)} f(m_+^2, m_-^2)|^2$

Two-fold ambiguity remains in extraction of γ $(\gamma \to \gamma + \pi)$