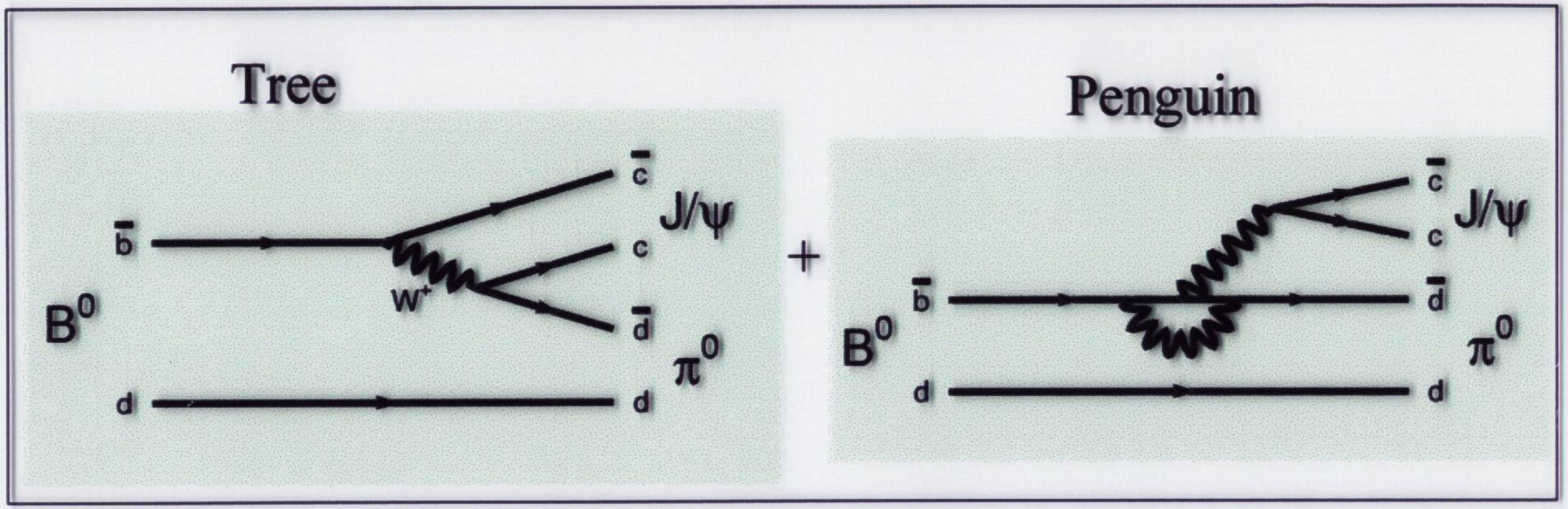
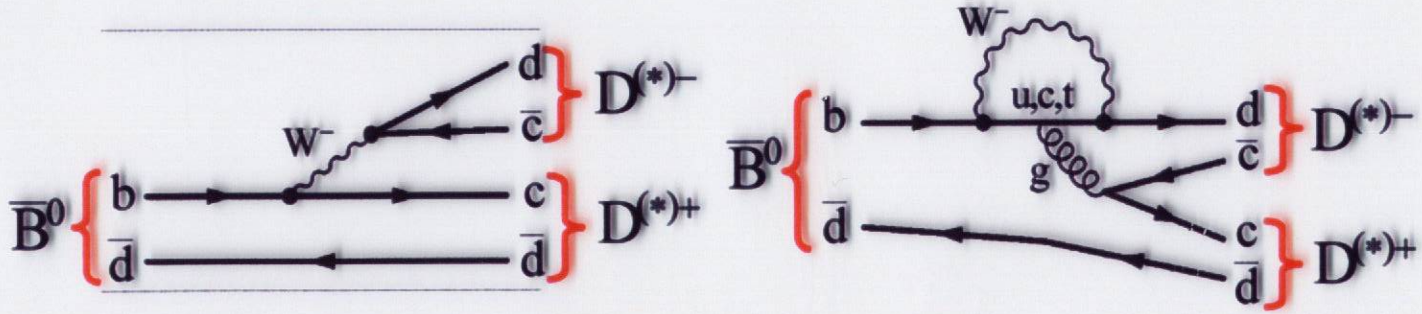
CPV in $b \rightarrow (c\,\bar{c}\,d)$ decays

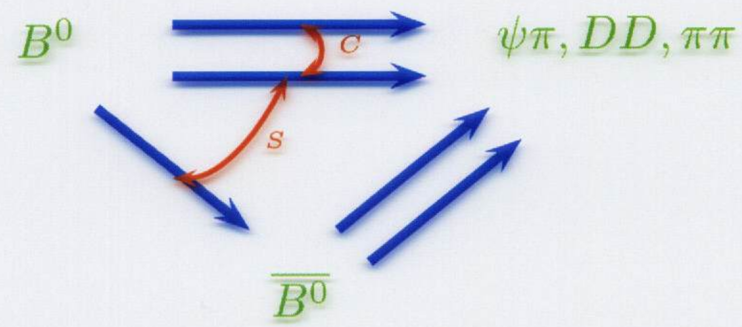




The same CPV phase as in $B \rightarrow J/\psi\, K_S$ but may have penguin pollution.

(Browder)

Tree/Penguin dominated decays $(b \to c\bar{c}d)$ & $(b \to u\bar{u}d)$



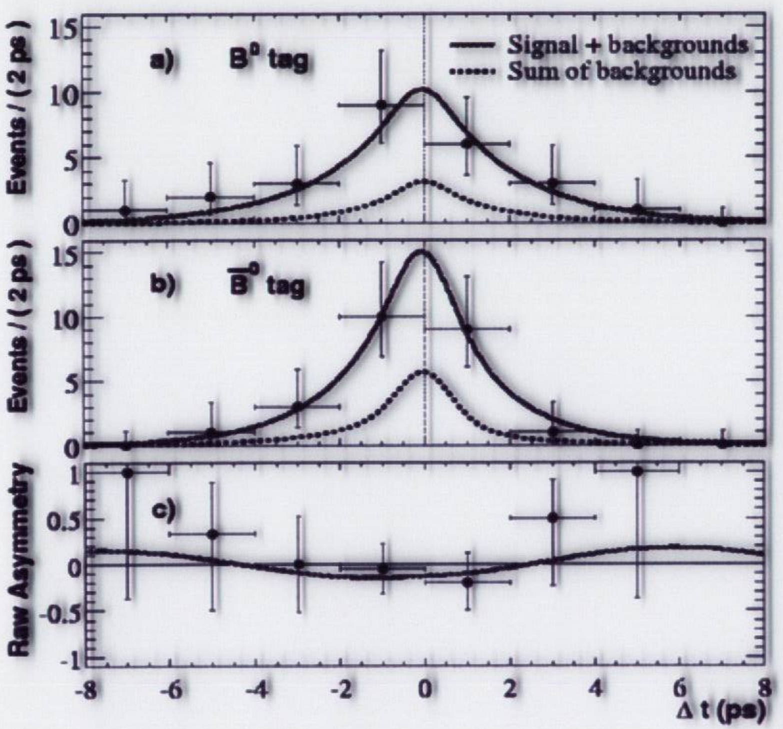
Source: HFAG (Summer 2003 Updates)

$S_{J/\psi\pi} = -0.40 \pm 0.33$ [BA, BE]	$C_{J/\psi\pi} = 0.13 \pm 0.24$
$S_{D^*\overline{D^*}} = 0.06 \pm 0.37 \pm 0.13$ [BA]	$C_{D^*\overline{D^*}} = 0.28 \pm 0.23 \pm 0.02$
$S_{+-}(D^{*+}D^-) = -0.82 \pm 0.75 \pm 0.14$ [BA]	$C_{+-}(D^{*+}D^-) = -0.47 \pm 0.40$
$S_{-+}(D^{*-}D^+) = -0.24 \pm 0.69 \pm 0.12$ [BA]	$C_{-+}(D^{*-}D^+) = -0.22 \pm 0.37$
$S_{\pi\pi} = -0.58 \pm 0.20$ [BA, BE]	$C_{\pi\pi} = -0.38 \pm 0.16$

- $B \to D^*\overline{D^*}$ dominated by CP $= +$ State
- $-$ for $S_{D^*\overline{D^*}}(\mathrm{CP} = +)$; $S_{J/\psi\pi}$; $S_{\pi\pi}$
- Violation of $-S_{J/\psi\pi} = S_{J/\psi K_s}$ or $-S_{D^*\overline{D^*}}(+) = S_{J/\psi K_s}$ or $-S_{\pi\pi} = S_{J/\psi K_s}$ signal direct CP violation; no evidence so far
- A model-independent determination of α from $S_{\pi\pi}$ requires isospin analysis [Gronau, London] or determination of $P_{\pi\pi}/T_{\pi\pi}$ [Gronau, Rosner], or use of $B_s \to K^+K^-$ & U-spin symmetry [Fleischer]

CPV in $b \rightarrow (c \bar{c} d)$ decays: $B \rightarrow \psi \pi^0$

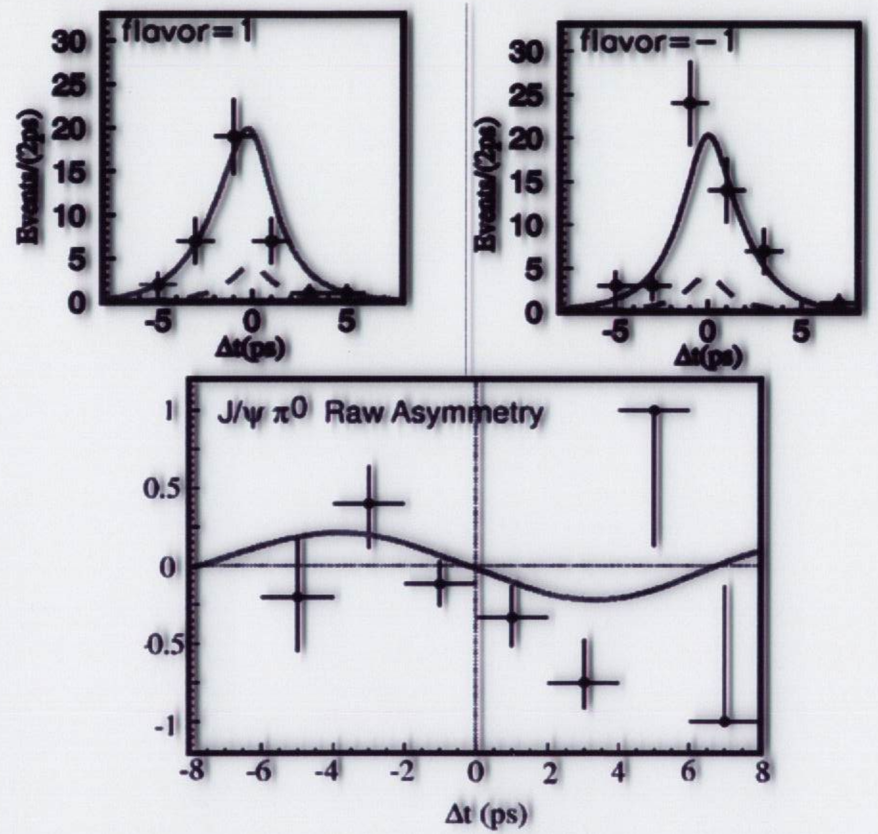
BaBar 2003



$\sin(2\varphi_{1eff}) = 0.05 \pm 0.49 \pm 0.16$

hep-ex/0303018

Belle 2003



$\sin(2\varphi_{1eff}) = 0.72^{+0.37}_{-0.42} \pm 0.08$

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Present Status of $\gamma(\phi_3)$

- $\gamma(\phi_3)$ from $B^\pm \to DK^\pm$ [Gronau, London, Wyler,..]
- $b \to u\bar{c}s$: $A(B^- \to \overline{D^0}K^-) = |A_1|\mathrm{e}^{i\delta_1}\mathrm{e}^{i\gamma}$
- $b \to c\bar{u}s$: $A(B^- \to D^0K^-) = |A_2|\mathrm{e}^{i\delta_2}$

- In the decays $B^\pm \to D^0_{\mathrm{CP}=\pm}K^\pm$, these two amplitudes interfere $\Longrightarrow$ sensitivity to γ

$$D^0_{\mathrm{CP}=\pm} = \frac{1}{\sqrt{2}}(D^0 \pm \overline{D^0})$$

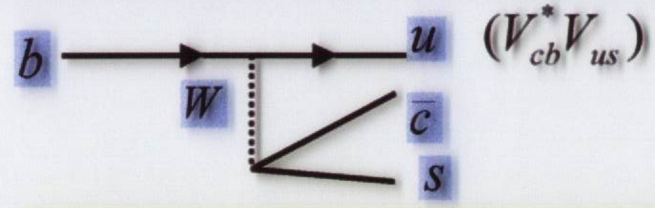
$$D^0_{\mathrm{CP}=+} \to K^+K^-;\;\; D^0_{\mathrm{CP}=-} \to K_s\pi^0;\;\; D^0 \to K^-\pi^+$$

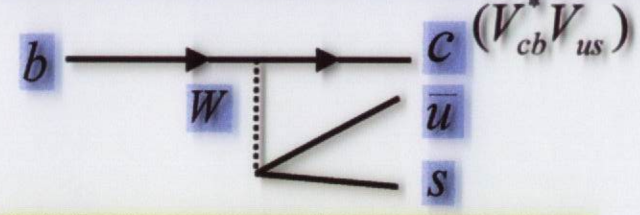
$$A(B^- \to D^0_\pm K^-) = \frac{1}{\sqrt{2}}[A(B^- \to D^0K^-) \pm A(B^- \to \overline{D^0}K^-)]$$

- Observables: $R_{\mathrm{CP}=\pm}$ and $A_{\mathrm{CP}=\pm}$

- Unknowns: $r = |A_2|/|A_1|$; $\delta = (\delta_2 - \delta_1)$; γ

B→DK Modes- No penguins





$A(B^- -> \overline{D}^0 K^-) = |A_1| e^{i\delta_2} e^{i\gamma}$

$A(B^- -> D^0 K^-) = |A_2| e^{i\delta_1}$

In $B^- \rightarrow D_{CP}K^-$, the diagrams interfere & provide the sensitivity to γ :

$[D_{CP} = (1/\sqrt{2})(D^0 \pm D^0)]$ $D_{CP\ even} = \pi^+\pi^-, K^+K^-$ $D_{CP\ odd} = K_s\pi^0, K_s\phi, ..$

DK triangle

Observables

$$R_{cp} = \frac{B(B^- \rightarrow D_{cp}^0 K^-) + B(B^+ \rightarrow \overline{D}_{cp}^0 K+)}{B(B^+ \rightarrow D^0 K^-) + B(B^+ \rightarrow \overline{D}^0 K+)} = 1 + r_{DK}^2 \pm 2r_{DK} \cos\delta_{DK} \cos\gamma$$

$$A_{cp} = \frac{B(B \rightarrow D_{cp}^0 K^-) - B(B \rightarrow \overline{D}_{cp}^0 K+)}{B(B \rightarrow D_{cp}^0 K^-) + B(B \rightarrow \overline{D}_{cp}^0 K+)} = \frac{\pm 2r_{DK} \sin\delta_{DK} \sin\gamma}{1 + r_{DK}^2 \pm 2r_{DK} \cos\delta_{DK} \cos\gamma}$$

Also unknown
r_{DK} (~0.1 –0.2) & δ_{DK}

Experimenters are very active in constructing the DK puzzle

Current Experimental Situation

$$R(K/\pi) \equiv \frac{\mathcal{B}(B^- \to D^0 K^-)}{\mathcal{B}(B^- \to D^0 \pi^-)}; \quad R(K/\pi)_\pm \equiv \frac{\mathcal{B}(B^\pm \to D^0_{\mathrm{CP}=\pm} K^\pm)}{\mathcal{B}(B^\pm \to D^0_{\mathrm{CP}=\pm} \pi^\pm)}$$

- All three quantities measured $\Longrightarrow R_\pm = \frac{R(K/\pi)_\pm}{R(K/\pi)}$

$$R_+ = 1.09 \pm 0.16 \quad A_+ = 0.07 \pm 0.13 \ (\mathrm{BELLE, BABAR})$$

$$R_- = 1.30 \pm 0.25 \quad A_- = -0.19 \pm 0.18 \ (\mathrm{BELLE})$$

$$\Longrightarrow \ r = 0.44^{+0.14}_{-0.24}; \qquad A_{\mathrm{av}} = 0.11 \pm 0.11$$

- Need more precise measurements of $R_\pm$ to constrain γ