Experimental review of ADS and GLW methods

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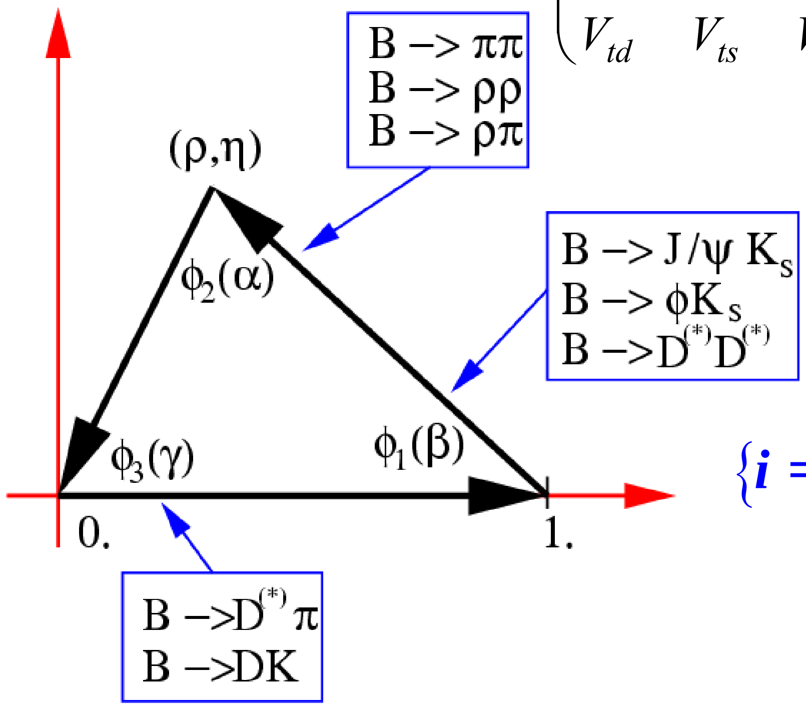
- Summary

Unitarity triangle

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



Using unitarity requirement:

$$\{i=1, k=3\} : V_{ub}^{*}V_{ud} + V_{cb}^{*}V_{cd} + V_{tb}^{*}V_{td} = 0$$

$$\Rightarrow \frac{V_{ub}^{*}V_{ud}}{V_{cb}^{*}V_{cd}} + 1 + \frac{V_{tb}^{*}V_{td}}{V_{cb}^{*}V_{cd}} = 0$$

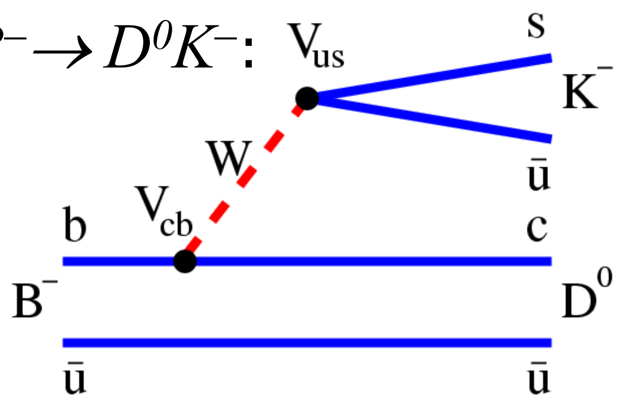
$\sin 2\varphi_1(\beta)$ is measured with a good accuracy at B-factories.

Measurement of all the angles needed to test SM.

$B^+ \to D^0 K^+$ decay

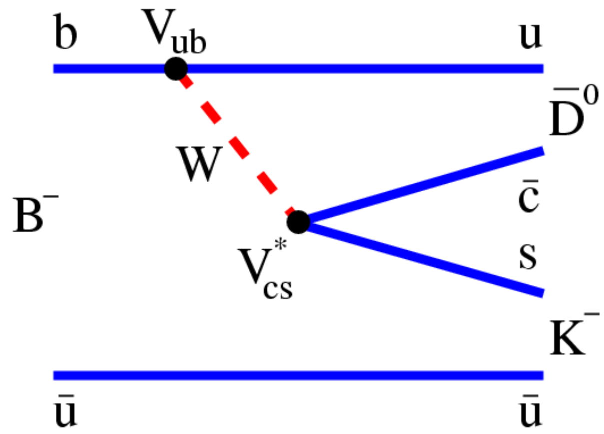
Need to use the decay where V_{ub} contribution interferes with another weak vertex.

$B^- \to D^0 K^-$:



$$\mathbf{A}_1 \sim V_{cb} V_{us}^* \sim A\lambda^3$$

$B^- \to \bar{D}^0 K^-$:



$$\mathbf{A}_2 \sim V_{ub} V_{cs}^* \sim A\lambda^3(\rho - i\eta) \sim e^{-i\gamma}$$

If D^0 and $\bar{D}^0$ decay into the same final state, $\left|\tilde{D}^0\right\rangle = \left|D^0\right\rangle + re^{i\theta}\left|\bar{D}^0\right\rangle$

Relative phase: $\theta = -\gamma + \delta \;\; (B^- \to DK^-)$, $\theta = +\gamma + \delta \;\; (B^+ \to DK^+)$

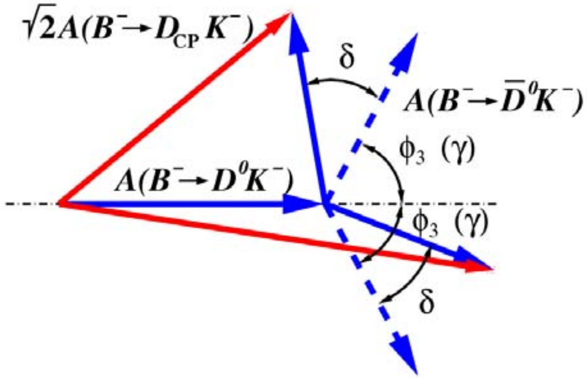
includes weak (γ/φ_3) and strong (δ) phase.

Amplitude ratio:

$$r_B = \left| \mathbf{A}(B^- \to \bar{D}^0 K^-) / \mathbf{A}(B^- \to D^0 K^-) \right| \approx \frac{\left|V_{ub}^* V_{cs}\right|}{\left|V_{cb}^* V_{us}\right|} \times [\text{color supp}] \approx 0.1 \div 0.2$$

Gronau-London-Wyler method

[Phys. Lett. B 253 (1991) 483]
[Phys. Lett. B 265 (1991) 172]



CP eigenstate of D-meson is used ($D_{\rm CP}$).
CP-even : $D_1 \to K^+K^-, \pi^+\pi^-$
CP-odd : $D_2 \to K_S\pi^0, K_S\omega, K_S\varphi, K_S\eta ...$

CP-asymmetry:

$$\mathcal{A}_{1,2} = \frac{Br(B^- \to D_{1,2}K^-) - Br(B^+ \to D_{1,2}K^+)}{Br(B^- \to D_{1,2}K^-) + Br(B^+ \to D_{1,2}K^+)} = \frac{2r_B \sin\delta' \sin\gamma}{1 + r_B^2 + 2r_B \cos\delta' \cos\gamma}$$

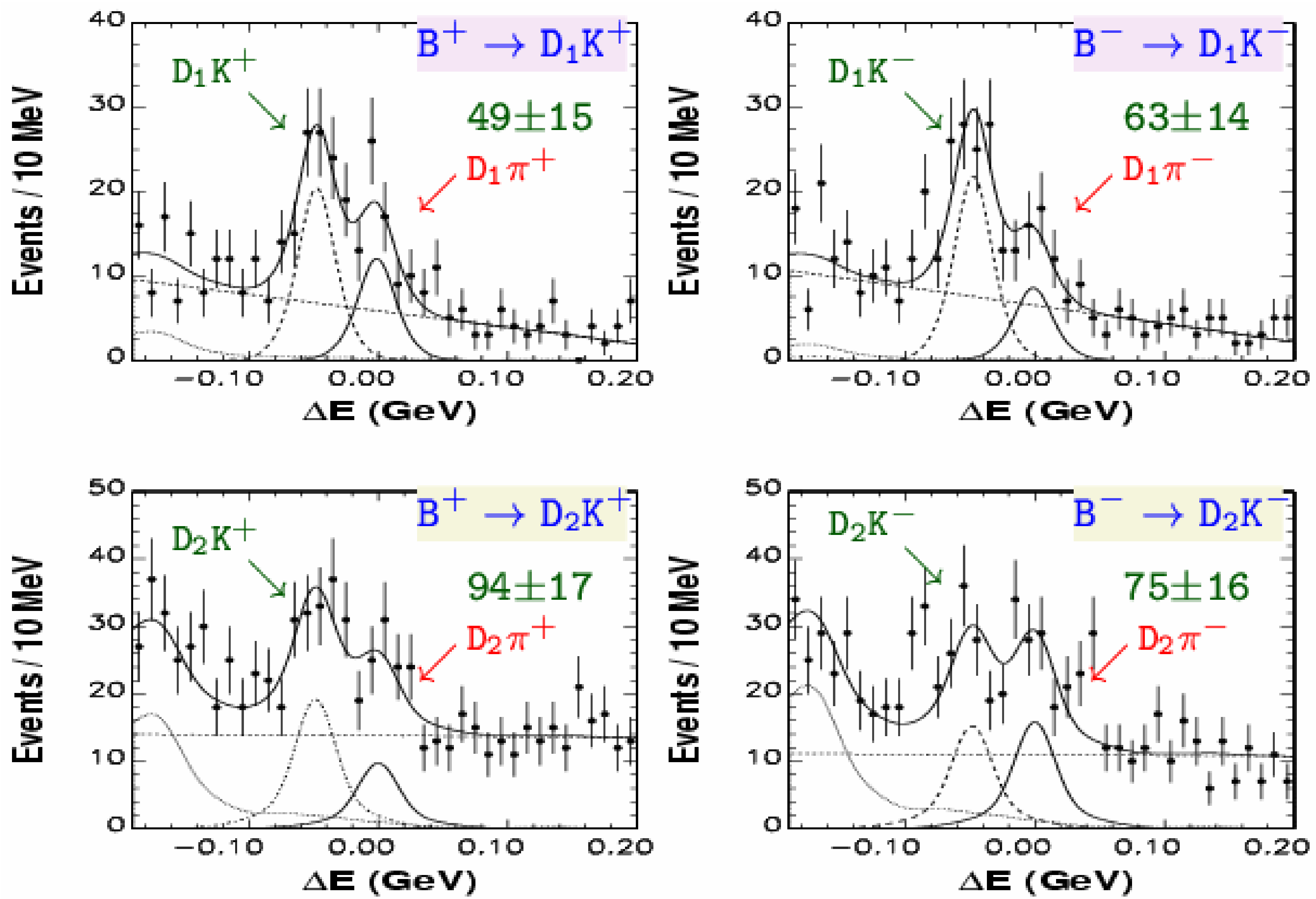
$$\delta' = \begin{cases} \delta & \text{for } D_1 \\ \delta + \pi & \text{for } D_2 \end{cases} \quad \Rightarrow \quad \mathcal{A}_{1,2} \text{ of different signs}$$

Additional constraint:

$$\mathcal{R}_{1,2} = \frac{Br(B \to D_{1,2}K)/Br(B \to D_{1,2}\pi)}{Br(B \to D^0K)/Br(B \to D^0\pi)} = 1 + r_B^2 + 2r_B \cos\delta' \cos\gamma$$

4 equations (3 independent: $\mathcal{A}_1\mathcal{R}_1 = -\mathcal{A}_2\mathcal{R}_2$), 3 unknowns (r_B, δ, γ)

GLW method (Belle)



GLW method (Belle)

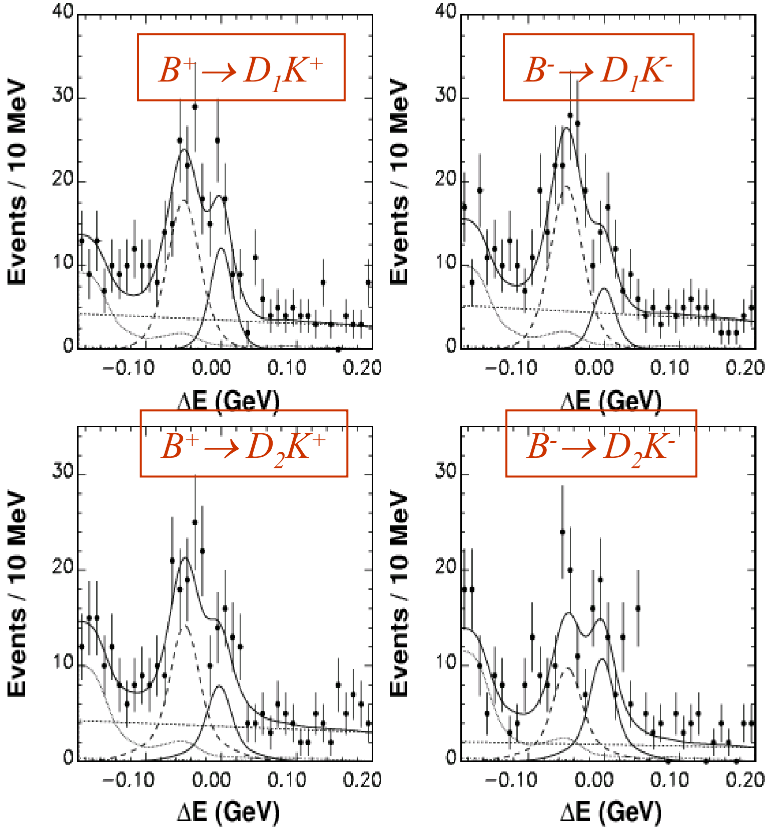
$B^{\pm} \to DK^{\pm}$ decay:

	$\mathcal{R}$	$\mathcal{A}$
$B \to D_1 K$	1.13 ±0.16±0.05	0.06±0.14±0.05
$B \to D_2 K$	1.17±0.14±0.14	-0.12±0.14±0.05

$B^{\pm} \to D^{*}K^{\pm}$, $D^{*} \to D\pi^0$ decay:

	$\mathcal{R}$	$\mathcal{A}$
$B \to D^{*}_1 K$	1.41±0.25±0.06	-0.20±0.22±0.04
$B \to D^{*}_2 K$	1.15±0.31±0.12	0.13±0.30±0.08

Belle results (253 fb^{-1})
hep-ex/0601032



GLW analyses alone do not constrain γ/φ_3 significantly yet, but can be combined with other measurements and provide information on r_B

GLW method (BaBar)

$B^{\pm}\rightarrow DK^{\pm}$ decay:

	$\mathcal{R}$	$\mathcal{A}$
$B\rightarrow D_{CP+}K$	0.90±0.12±0.04	0.35±0.13±0.04
$B\rightarrow D_{CP-}K$	0.86±0.10±0.05	-0.06±0.13±0.03

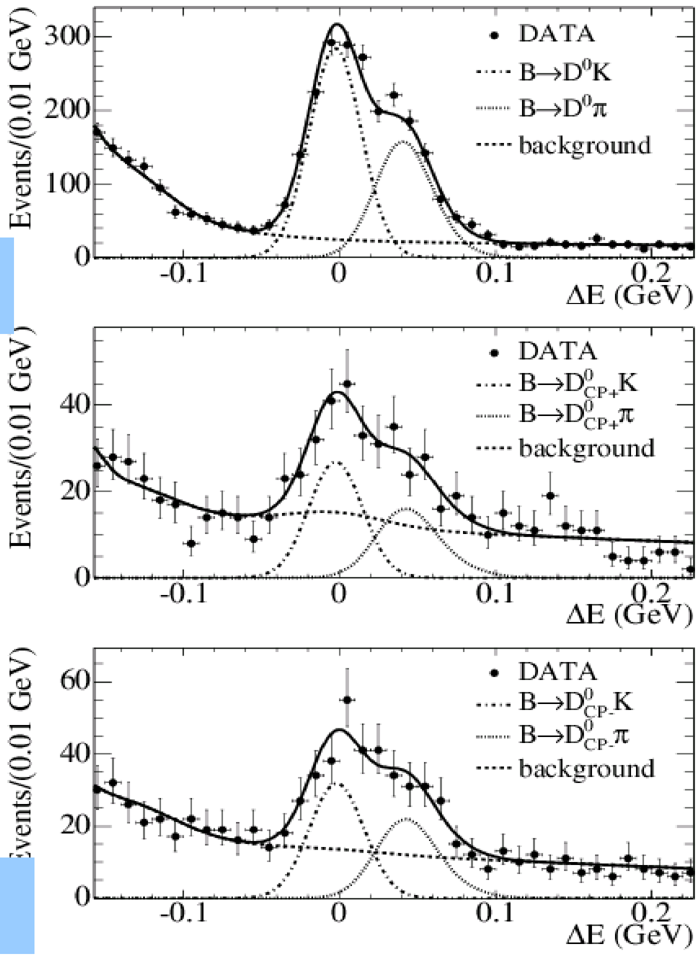
r_B^2=-0.12±0.08(stat)±0.03(syst)

$B^{\pm}\rightarrow DK^{*\pm}$, $K^{*\pm}\rightarrow K_S\pi^{\pm}$ decay:

	$\mathcal{R}$	$\mathcal{A}$
$B\rightarrow D_{CP+}K^*$	1.96±0.40±0.11	-0.08±0.19±0.08
$B\rightarrow D_{CP-}K^*$	0.65±0.26±0.08	-0.26±0.40±0.12

r_B^2=0.30±0.25

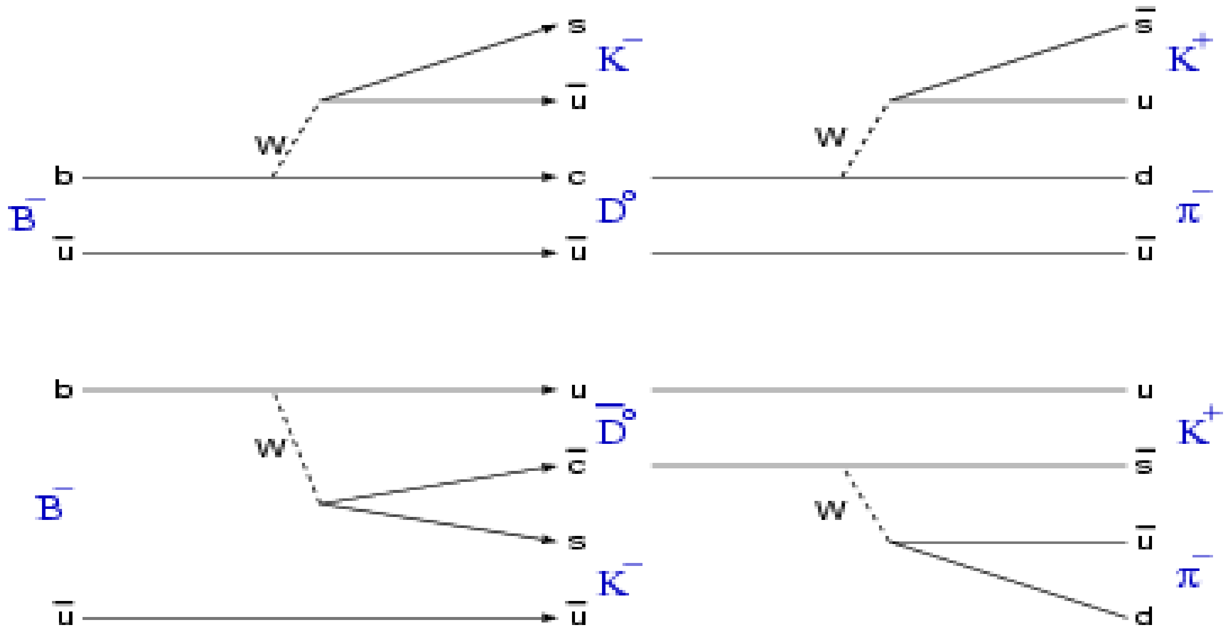
BaBar results (211 fb^{-1})
Phys.Rev. D73, 051105 ,
Phys.Rev. D72, 071103



Atwood-Dunietz-Soni method

D. Atwood, I. Dunietz and A. Soni, PRL **78**, 3357 (1997);
PRD **63**, 036005 (2001)

Enhancement of CP-violation due to use of Cabibbo-suppressed D decays



$B^- \to D^0 K^-$ - color allowed

$D^0 \to K^+\pi^-$ - doubly Cabibbo-suppressed

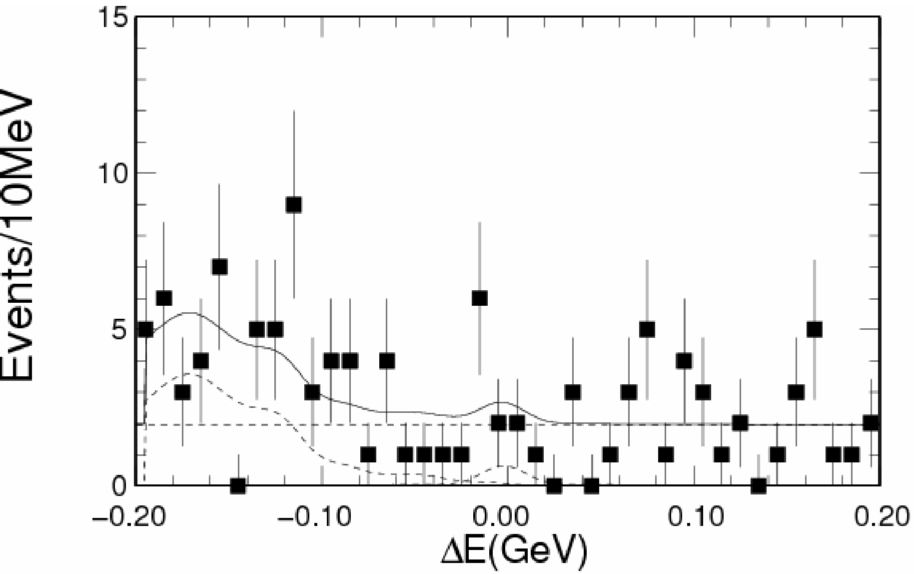
$B^- \to \bar{D}^0 K^-$ - color suppressed

$\bar{D}^0 \to K^+\pi^-$ - Cabibbo-allowed

$\Longrightarrow$ Interfering amplitudes are comparable

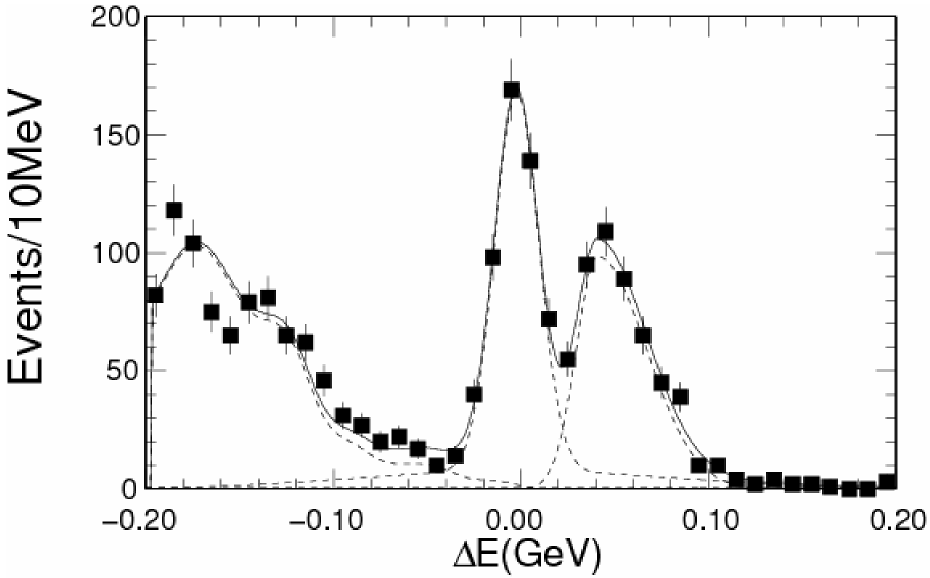
ADS method (Belle)

$B^+ \to D^0[K^+ \pi^-] \pi^+$



$2.4^{+4.9}_{-4.4}$ *events*

$B^+ \to \bar{D}^0[K^- \pi^+] \pi^+$



634^{+59}_{-99} *events*

Peaking background from $B^+ \to K^+ \pi^- \pi^+$ decay.

Using D sidebands to subtract it. After subtraction the signal yield is $0.0^{+5.3}_{-5.0}$ events

ADS method (Belle)

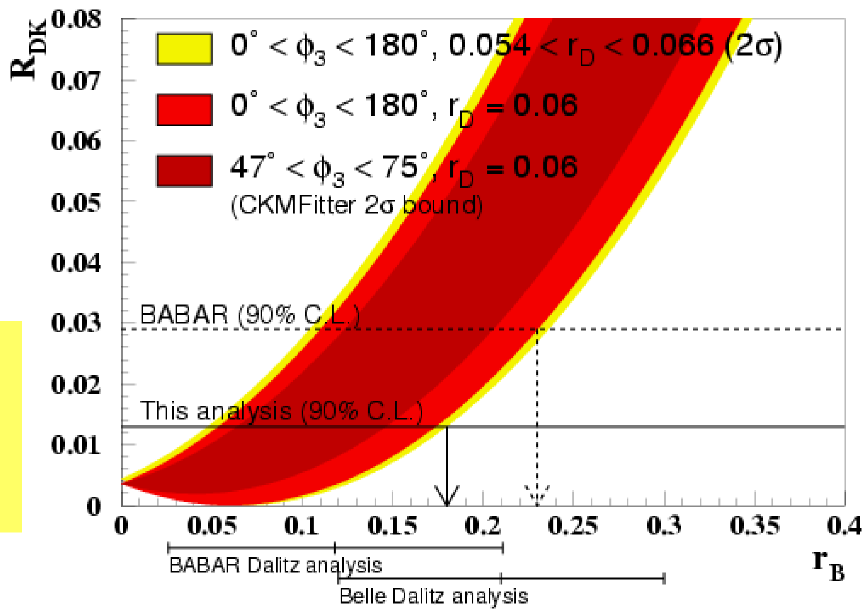
Belle results (357 fb^{-1}) hep-ex/0508048

$$\mathcal{R}_{DK} = \frac{Br(B \to D_{\text{supp}}K)}{Br(B \to D_{\text{fav}}K)} = r_B^2 + r_D^2 + 2 r_B r_D \cos\varphi_3 \cos\delta$$

$$r_D = \left| \mathbf{A}(D^0 \to K^+\pi^-) / \mathbf{A}(D^0 \to K^-\pi^+) \right|$$

Suppressed channel not visible yet:

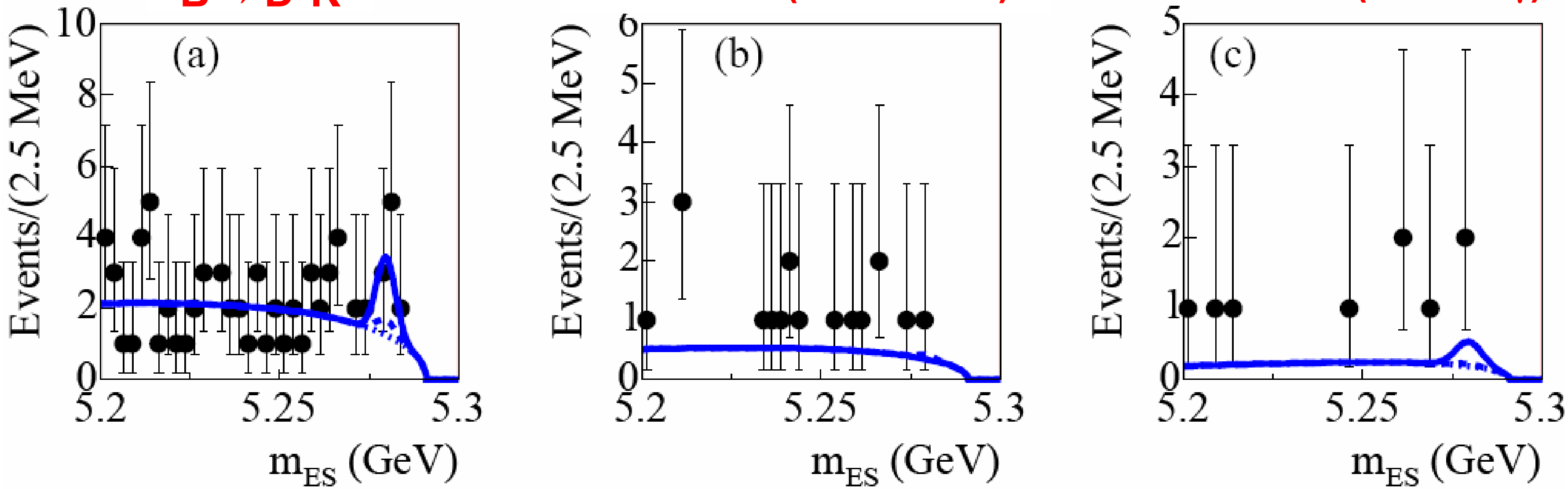
$$\mathcal{R}_{DK} = (0.0^{+8.4}_{-7.9} \pm 1.0) \times 10^{-3}$$



Using r_D=0.060±0.003,
for maximum mixing (φ_3=0, δ=180°):
r_B<0.18 (90% CL)

ADS method (BaBar)

$B \to D^0 K$ | $B \to D^{*0} K$ ($D^{*0} \to D^0 \pi^0$) | $B \to D^{*0} K$ ($D^{*0} \to D^0 \gamma$)



PRD 72 (2005) 071104

Suppressed channel not visible

$$\mathcal{R}_{DK} = 13^{+11}_{-9} \times 10^{-3}$$

$$\mathcal{R}_{D^*[D\pi^0]K} = -2^{+10}_{-6} \times 10^{-3}$$

$$\mathcal{R}_{D^*[D\gamma]K} = 11^{+18}_{-13} \times 10^{-3}$$

Bondar & Gershon *PRD70,091503(2004)*

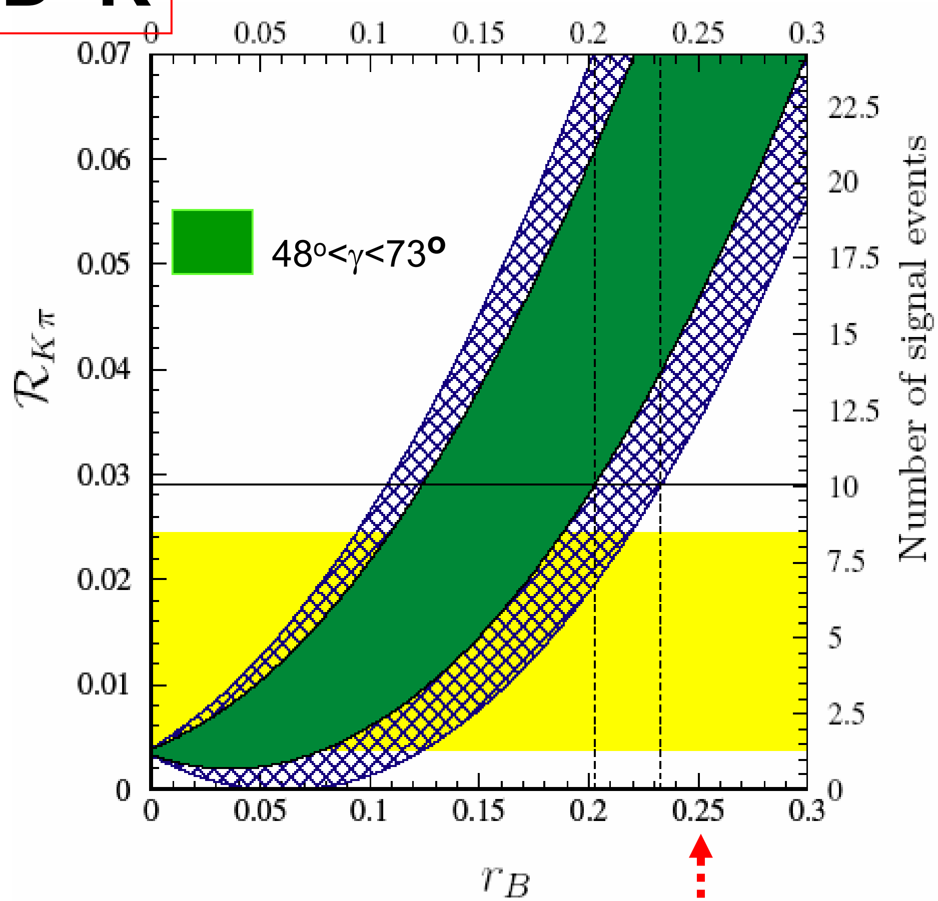
$$\mathcal{R}_{D^*[D\gamma]K} + \mathcal{R}_{D^*[D\pi^0]K} = 2(r_B^2 + r_D^2)$$

r_B<0.23 (90% CL) for $B \to DK$

r_B<0.16 for $B \to D^*K$

Constraints on r_B (BaBar)

D^0 K



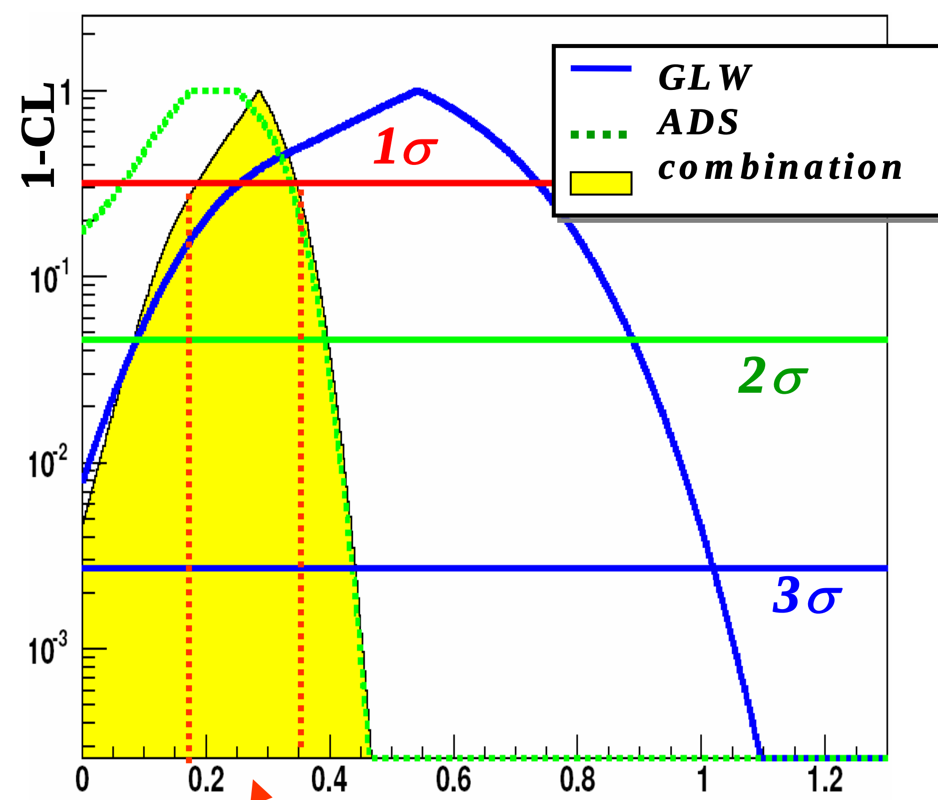
For maximum mixing (γ/φ_3=0, δ=180°):

r_B<0.23 @ 90% C.L.

D^0K^{*+}

DK*, GLW+ADS

$\gamma \in [0,\pi]$ & $(\delta_D+\delta_B)\in[0,2\pi]$

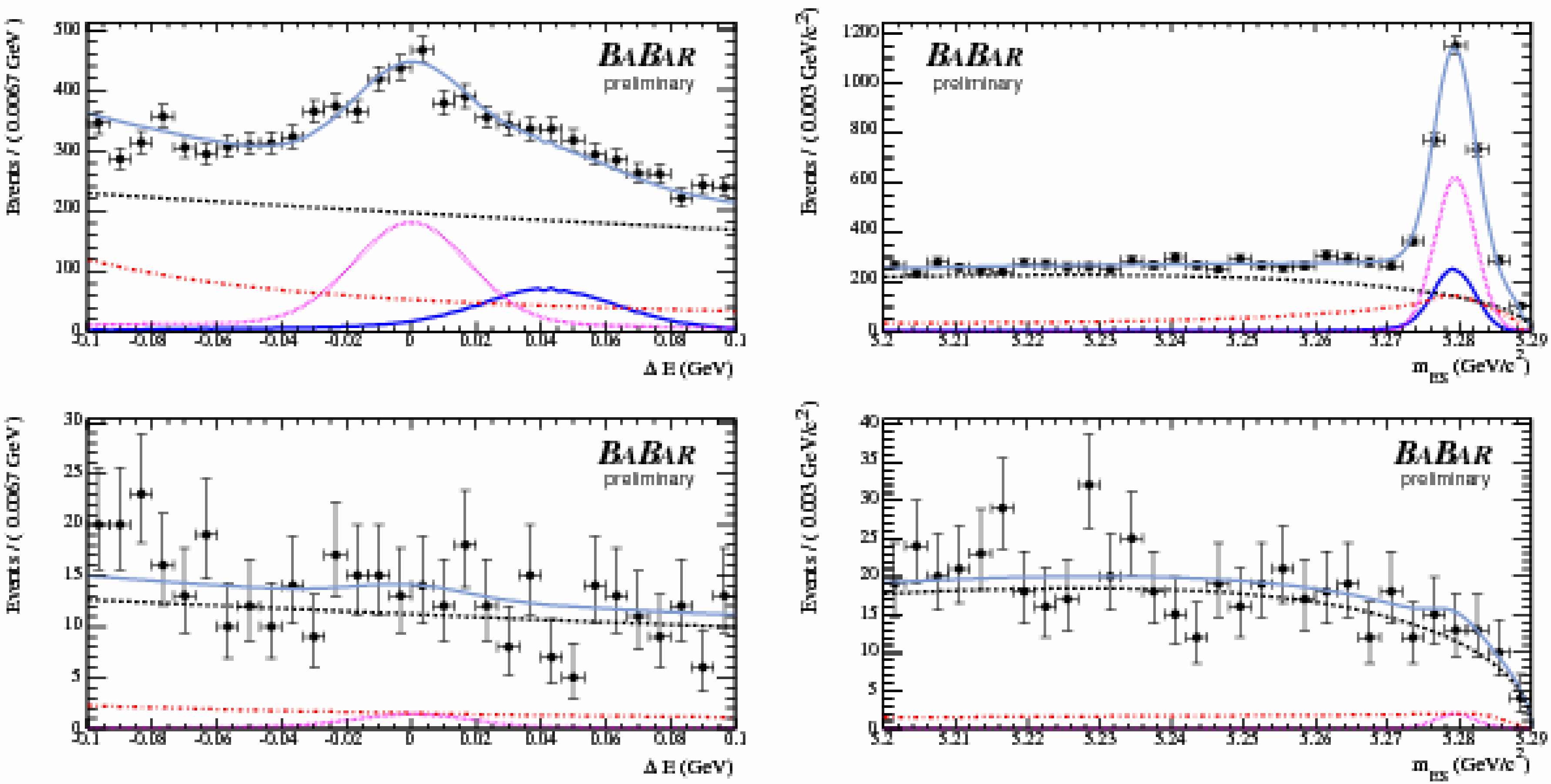


$r_B = 0.28^{+0.06}_{-0.10}$

ADS method (BaBar)

B->D[K$^+\pi^-\pi^0$] K

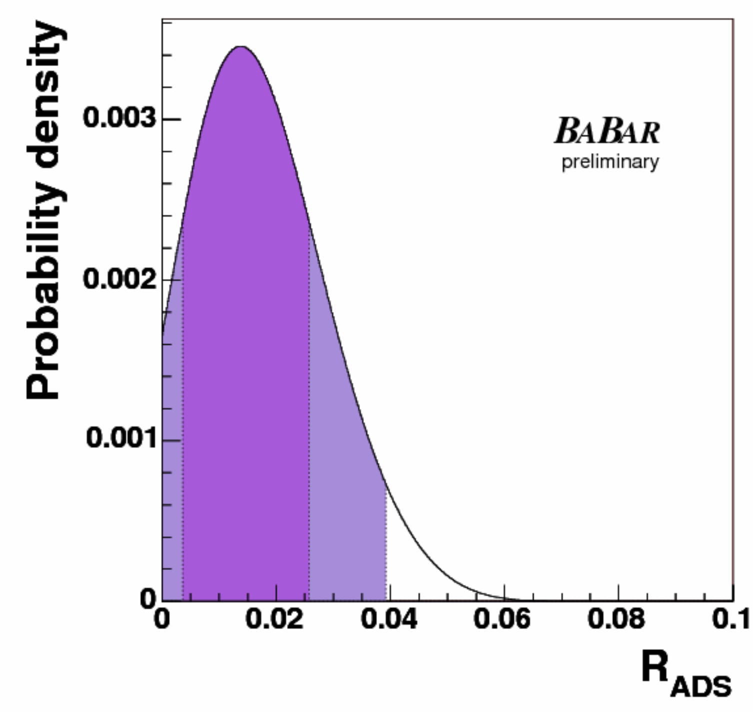
hep-ex/0607065 (ICHEP 06)

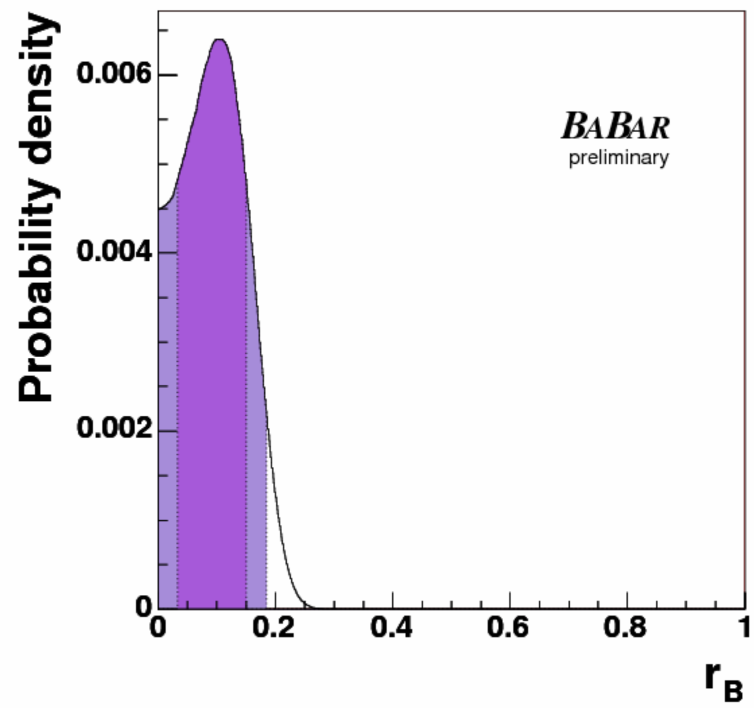


ADS method (BaBar)

$B \to D[K^+\pi^-\pi^0]$ K

hep-ex/0607065 (ICHEP 06)





$$\mathcal{R}_{DK} = 12^{+12+10}_{-10-7} \times 10^{-3}$$

$$\mathcal{R}_{B} = 91 \pm 59 \times 10^{-3}$$

$r_{DK}<0.039$ (95% CL)

$r_B<0.185$ (95% CL)

Summary

- The statistics is not enough for measure the φ_3/γ using ADS and GLW methods

- However these approaches can provide constrain for r_B and can be used combined with Dalitz analysis method

- There are perspectives for improving the result with larger data set