Measurement of the angle γ (ϕ_3) at the e^+e^- B-factories

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Flavor Physics & CP Violation 2013
May 20-24 2013, Buzios (Rio de Janeiro) Brazil

The angle γ

- CKM is 3x3 unitary matrix ➔ 4 parameters (after ad hoc choice of quark field phases): 3 real and 1 CP violating phase

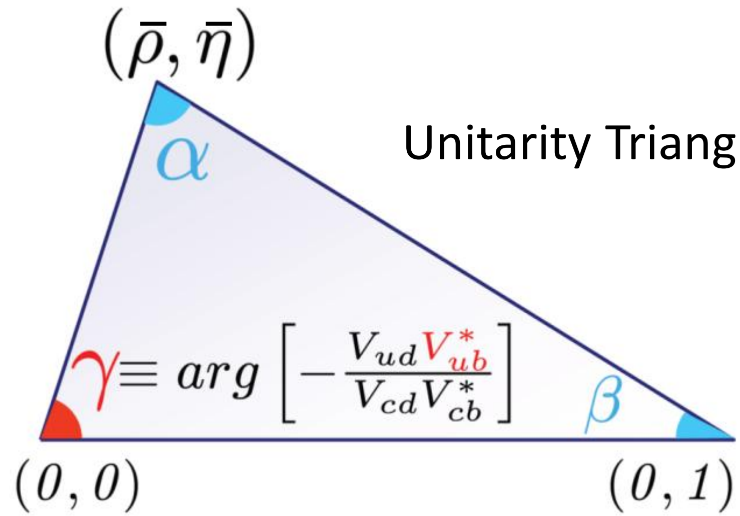
[Wolfenstein parametrization]

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

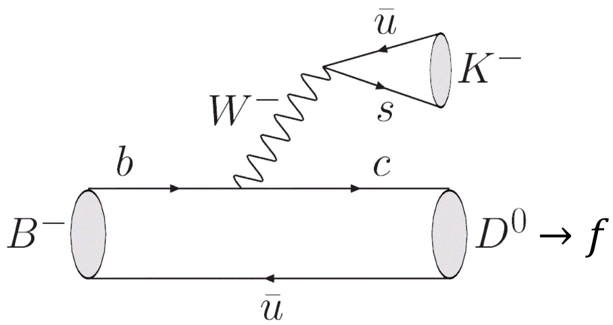
$A\lambda^3(\rho - i\eta) \rightarrow |V_{ub}|e^{-i\gamma}$

- From the unitarity of V:

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

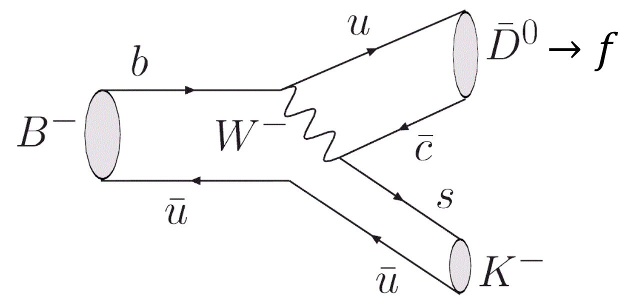


Measurement of γ with B→DK



color allowed

$A_1 \propto V_{cb}V_{us}^* \sim A\lambda^3$



color suppressed

$A_2 \propto V_{ub}V_{cs}^* \sim A\lambda^3(\rho + i\eta)$

- γ is measured in the interference of the two amplitudes

$$r_b \equiv \left|\frac{A(B^+ \to D^0 K^+)}{A(B^+ \to \overline{D^0} K^+)}\right| \sim 0.1$$

$$|A_{tot}|^2 = |A_1 + A_2|^2 = |A_1|^2 + |A_2|^2 + 2|A_1||A_2|\cos\phi$$

$$\phi = -\gamma + \delta$$

- unknowns: γ, r_b, δ_b + δ_D

B hadronic parameters extracted with γ

measured at charm factories

$\delta_b + \delta_D$= strong phase from B and D decay

- theoretically clean
- most sensitive method to constrain γ at present
- similar principle applies to several other processes: $B^0 \to D^{(*)+}\pi^-$, $B^0 \to D^0 K^{(*)0}$, $B_s \to D_s K$, …

Extraction of γ using B→DK decays

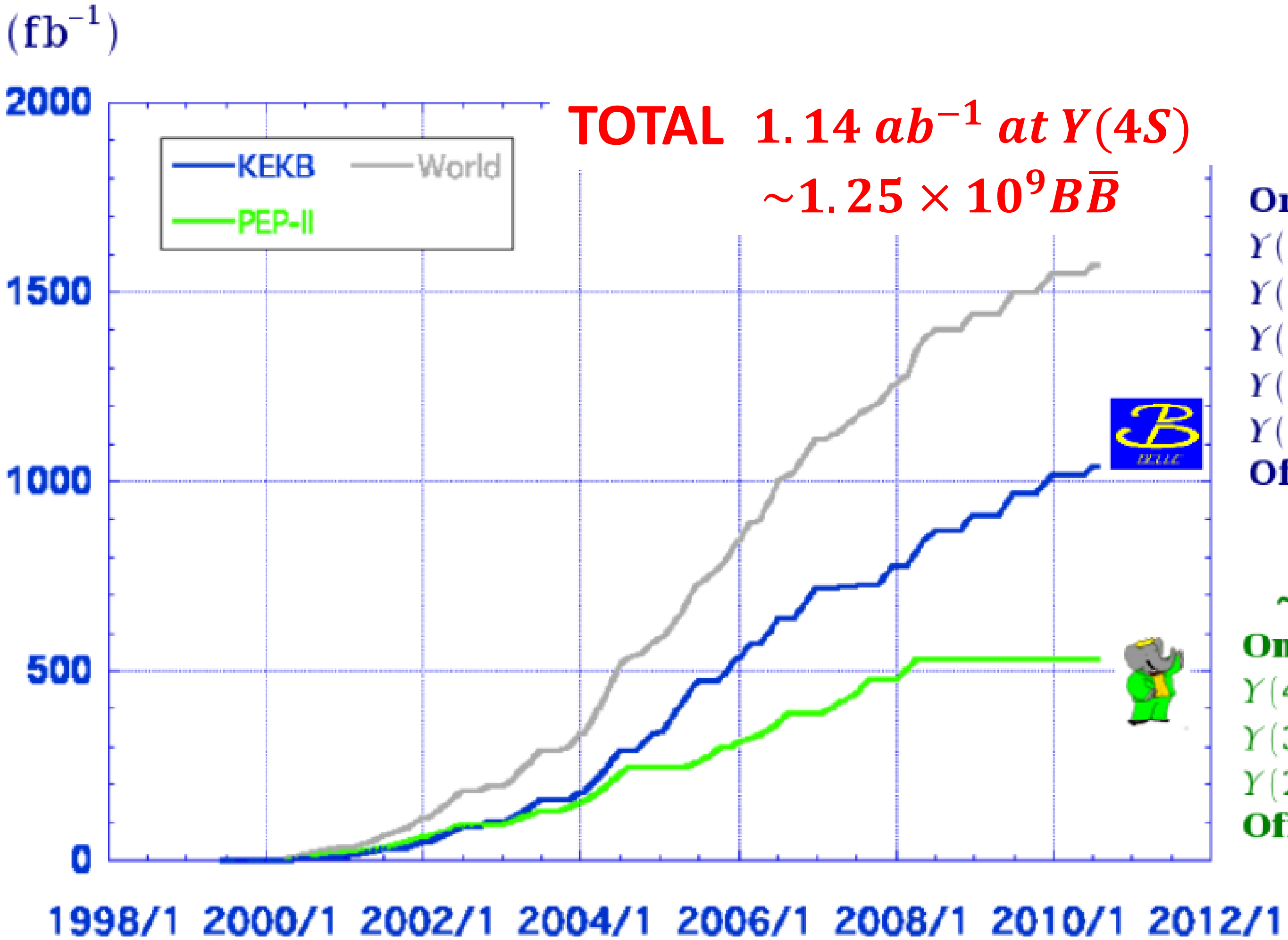
Different methods depending on D final state:

- GLW [M. Gronau, D. London, D. Wyler, PLB253,483 (1991); PLB 265, 172 (1991)]
  - D^0 to two-body CP eigenstates K^+K^-, $\pi^+\pi^-$ (even), $K_s\pi^0$, $K_s\omega$ (odd)
- ADS [D. Atwood, I. Dunietz, A. Soni, PRL 78, 3357 (1997)]
  - D^0 to doubly Cabibbo suppressed decays $K^+\pi^-$, $K^+\pi^-\pi^0$, …
- GGSZ (Dalitz) [D. Atwood et al., PRL78, 3257 (1997); A. Giri et al., PRD68, 054018 (2003)]
  - D^0 to 3-body decays $K_s\pi^+\pi^-$, $K_sK^+K^-$, $\pi^+\pi^-\pi^0$, etc.
    - Dalitz plot fitted to determine how the strong phase of D^0 decay amplitude varies over the Dalitz plane
    - model independent analysis

most powerful method nowadays

- Different B decays $D^0K^\pm$, $D^{*0}K^\pm$, $D^0K^{*\pm}$ and flavour-tagged D^0K^{*0}. They depend on mode-dependent hadronic factors (r_b, δ_b)
- Strategy: combine as many channels as possible to improve the overall sensitivity

The B-factories dataset

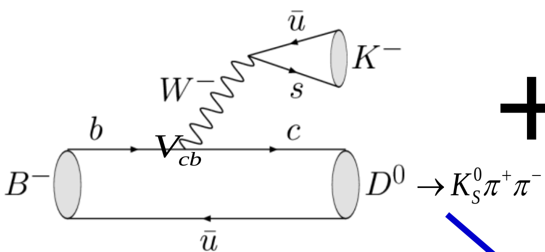


> 1 ab^{-1}
On resonance:
$\Upsilon(5S)$: 121 fb^{-1}
$\Upsilon(4S)$: 711 fb^{-1}
$\Upsilon(3S)$: 3 fb^{-1}
$\Upsilon(2S)$: 24 fb^{-1}
$\Upsilon(1S)$: 6 fb^{-1}
Off reson./scan:
~ 100 fb^{-1}

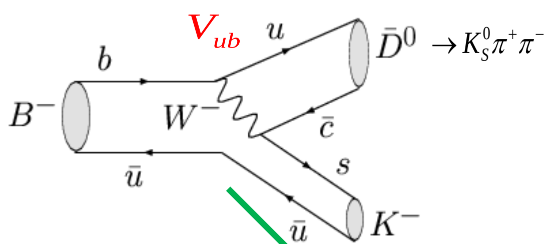
~ 550 fb^{-1}
On resonance:
$\Upsilon(4S)$: 433 fb^{-1}
$\Upsilon(3S)$: 30 fb^{-1}
$\Upsilon(2S)$: 14 fb^{-1}
Off resonance:
~ 54 fb^{-1}

The GGSZ method

- The interference varies as function of the position in the D^0 Dalitz plot



+

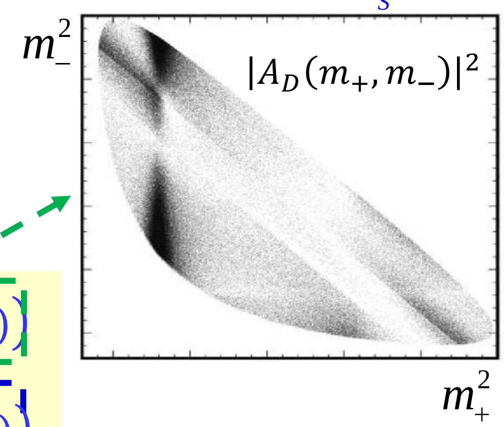


$$A_-(m_-^2, m_+^2) = |A(B^- \to D^0 K^-)(A_D(m_-^2, m_+^2) + r_b e^{i(\delta_b - \gamma)} A_D(m_+^2, m_-^2))$$

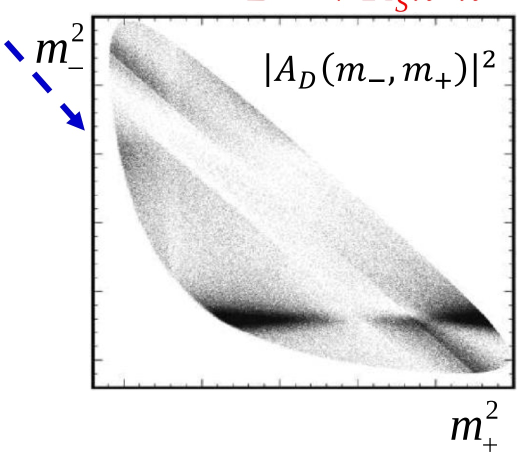
$$A_+(m_-^2, m_+^2) = |A(B^+ \to \overline{D^0} K^+)(A_D(m_+^2, m_-^2) + r_b e^{i(\delta_b + \gamma)} A_D(m_-^2, m_+^2))$$

$$m_\pm^2 \equiv m^2(K_S^0\pi^\pm)^2$$

$\overline{D}^0 \to K_S^0\pi^+\pi^-$



$D^0 \to K_S^0\pi^+\pi^-$



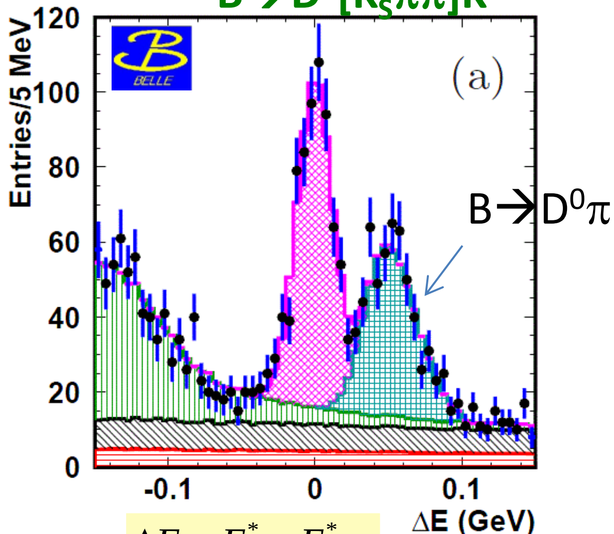
- $A_D(m_-^2, m_+^2)$ is measured with a Dalitz plot analysis of high statistics samples of flavour-tagged D^0 and $\bar{D}^0$
- The B^+ and B^- yields are measured as a function of the position in the D^0 Dalitz plot (ML fit)
- Unknowns: γ, rb and δ_b

Reconstructed decay modes

Decays	D^0K^+	$D^{*0}[D^0\pi^0]K^+$	$D^{*0}[D^0\gamma]K^+$	$D^0K^{*+}[K_S\pi]$
$D^0 \to K_S\pi\pi$	468M 657M	468M 657M	468M 657M	468M 386M
$D^0 \to K_SKK$	468M	468M	468M	468M

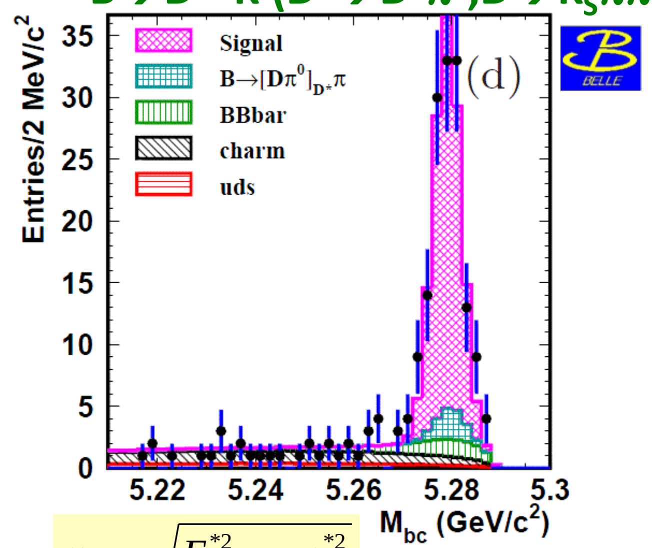
Signal region defined by ΔE and M_{bc}

$B \to D^0[K_S\pi\pi]K$



$$\Delta E = E_B^* - E_{beam}^*$$

$B \to D^{*0}K$ ($D^0 \to D^0\pi^0$, $D \to K_S\pi\pi$)



$$m_{bc} = \sqrt{E_{beam}^{*2} - p_B^{*2}}$$

both BaBar and Belle fit signal vs Dalitz plot position using likelihood(ΔE, M_{bc} ,event shape vars)

Measurement of $x_\pm, y_\pm$

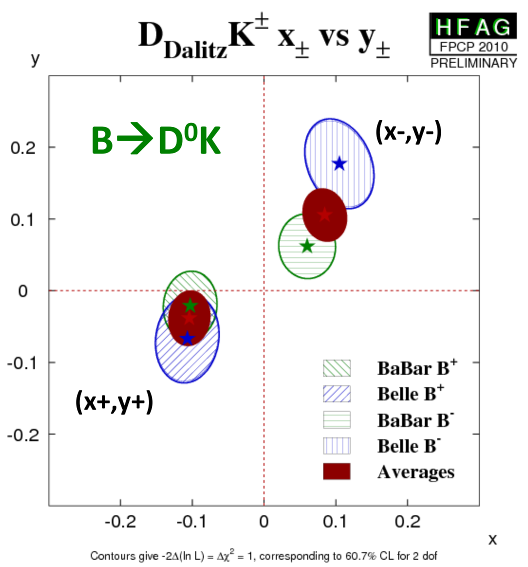
- Extract the *cartesian coordinates* instead of γ, r_b, δ_b (likelihood unbiased and Gaussian-shaped using x,y)

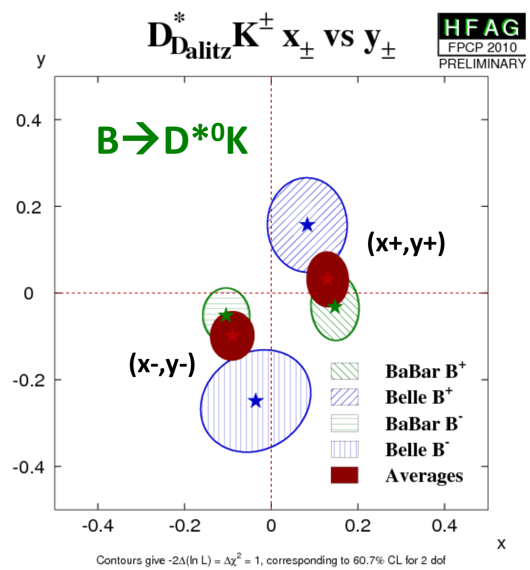
$$x_\mp = r_b \cos(\delta_b \mp \gamma)$$
$$y_\mp = r_b \sin(\delta_b \mp \gamma)$$

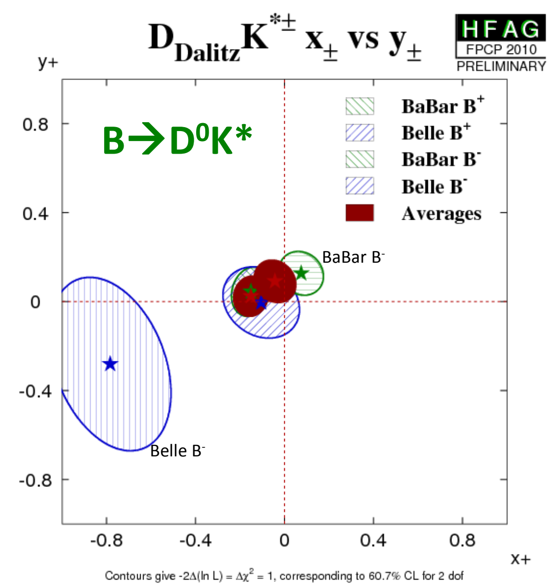
$$\begin{cases} \Gamma(B^+) \propto |f_+|^2 + (x_+^2 + y_+^2)|f_-|^2 + 2x_+ \,\mathrm{Re}(f_+ f_-^*) + 2y_+ \,\mathrm{Im}(f_+ f_-^*) \\ \Gamma(B^-) \propto |f_-|^2 + (x_-^2 + y_-^2)|f_+|^2 + 2x_- \,\mathrm{Re}(f_- f_+^*) + 2y_- \,\mathrm{Im}(f_- f_+^*) \end{cases}$$

$$f_\mp \equiv A_D(m_\mp^2, m_\pm^2)$$

$(x_\pm, y_\pm)$ 4 variables, 3 indep.
$x_+^2+y_+^2=x_-^2+y_-^2$





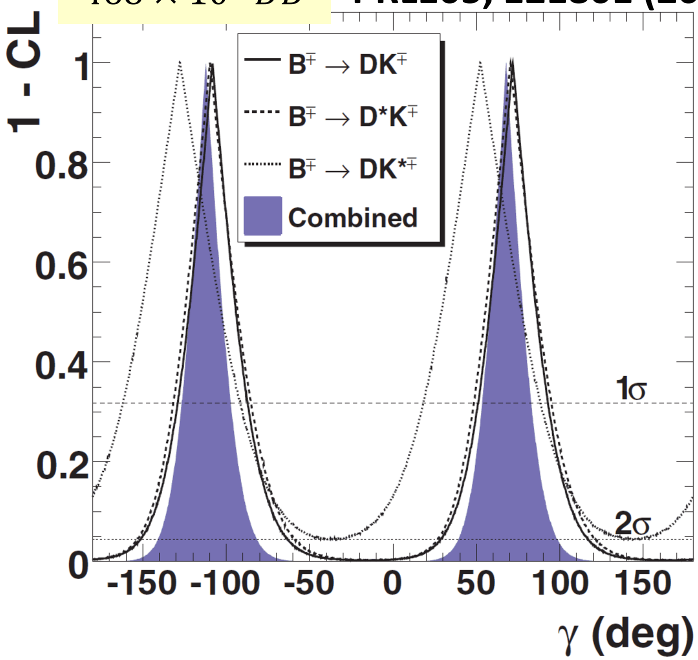


the contours do not include the Dalitz model errors

From $x_\pm, y_\pm$ to γ: BaBar

- Combine $B \to DK$, $B \to D^*K$, $B \to DK^*$ with $D \to K_S \pi^+ \pi^-$ and $D \to K_S K^+ K^-$
- Use frequentist method to derive the physical parameters γ, r_b, δ_b from $(x_\pm, y_\pm)$

$468 \times 10^6\ B\bar{B}$ **PRL105, 121801 (2010)**



3.5σ stat significance of CPV

total error — exp. sys. — Dalitz model sys.

Parameter	68.3% C.L.	95.4% C.L.
γ (°)	68^{+15}_{-14} {4, 3}	[39, 98]
r_B (%)	9.6 ± 2.9 {0.5, 0.4}	[3.7, 15.5]
$r^* B$ (%)	$13.3^{+4.2}_{-3.9}$ {1.3, 0.3}	[4.9, 21.5]
κr_s (%)	$14.9^{+6.6}_{-6.2}$ {2.6, 0.6}	<28.0
δ_B (°)	119^{+19}_{-20} {3, 3}	[75, 157]
δ^*_B (°)	-82 ± 21 {5, 3}	[−124, −38]
δ_s (°)	111 ± 32 {11, 3}	[42, 178]

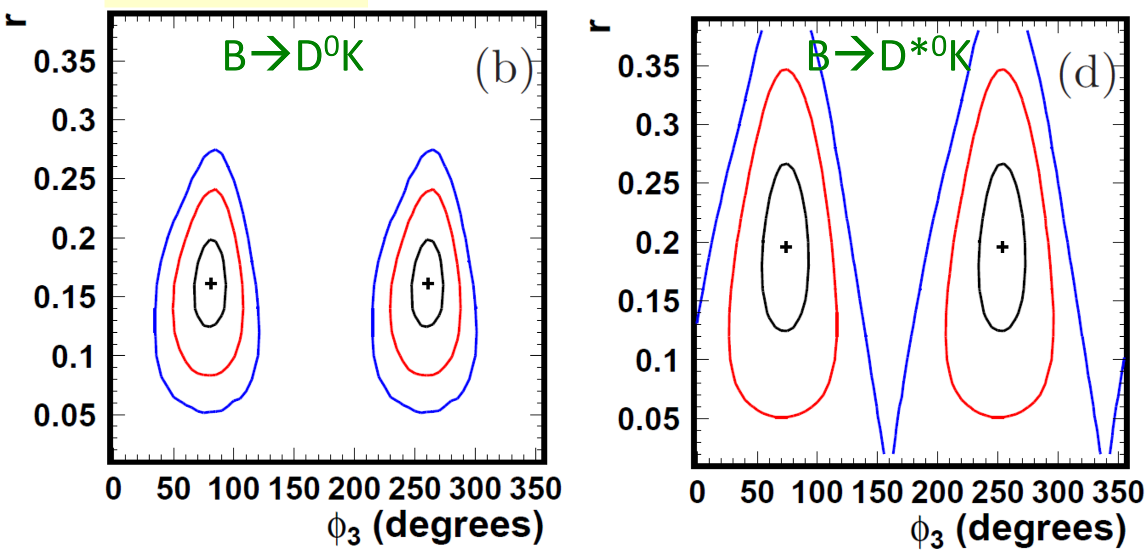
$$\gamma = (68 \pm 14 \pm 4 \pm 3)° \quad \text{(mod 180°)}$$

stat syst model

From $x_\pm, y_\pm$ to γ: Belle

- Combine $B \to D^0K$ and $B \to D^{*0}K$ with $D \to K_S\pi^+\pi^-$
- Use frequentist method to derive the physical parameters γ, r_b, δ_b from $(x_\pm, y_\pm)$

$657 \times 10^6\ B\bar{B}$ **PRD81, 112002 (2010)**



	$B^+ \to DK^+$ mode
γ	$(80.8^{+13.1}_{-14.8} \pm 5.0 \pm 8.9)^\circ$
r_b	$0.161^{+0.040}_{-0.038} \pm 0.011^{+0.050}_{-0.010}$
δ_b	$(137.4^{+13.0}_{-15.7} \pm 4.0 \pm 22.9)^\circ$

	$B^+ \to D^*K^+$ mode
γ	$(73.9^{+18.9}_{-20.2} \pm 4.2 \pm 8.9)^\circ$
r_b^*	$0.196^{+0.073}_{-0.072} \pm 0.013^{+0.062}_{-0.012}$
δ_b^*	$(341.7^{+18.6}_{-20.9} \pm 3.2 \pm 22.9)^\circ$

combined 3.5σ stat significance of CPV

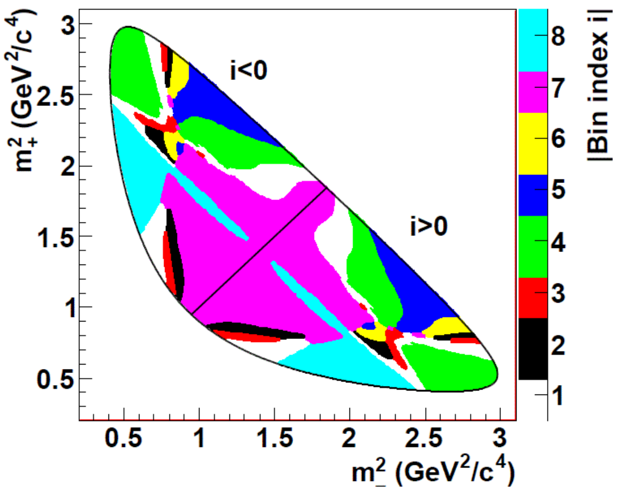
$$\gamma = (78.4^{+10.8}_{-11.6} \pm 3.6 \pm 8.9)^\circ \quad \text{(mod } 180^\circ)$$

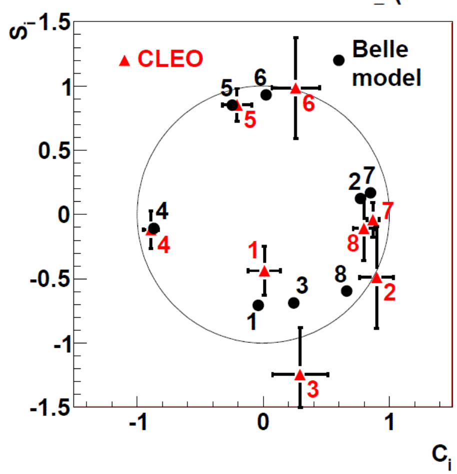
stat syst model

Model independent analysis

Model-independent measurement of γ.

Proposed by A. Giri et al. [Phys Rev. D68 054018 (2003)]. Pioneered by Belle.





- divide the D→$K_S\pi\pi$ Dalitz plot in 2k bins (symmetric w.r.t. the m_+^2 vs m_-^2 axis)
- express the $B^\pm \to DK^\pm$ yields in each bin *i* in terms of $x_\pm, y_\pm$ and 2 parameters c_i, s_i
- c_i, s_i are measured by CLEO exploiting the quantum coherence in $\psi(3770) \to \bar{D}^0 D^0$
- extract $x_\pm, y_\pm$ from ML fit to $B^\pm \to DK^\pm$ yields in all bins

$B^\pm \to DK^\pm$ yields

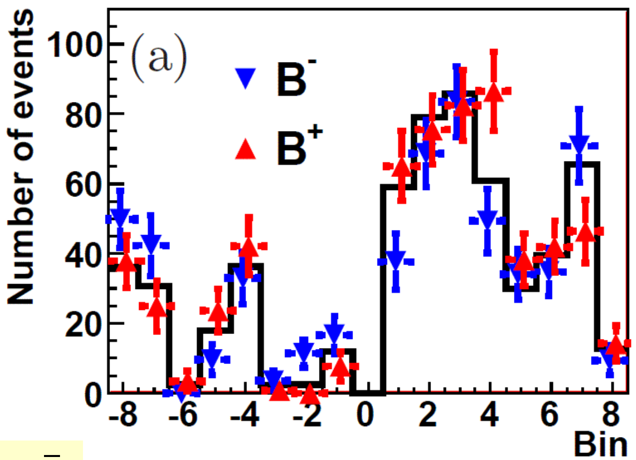
from flav.-tagged D→$K_S\pi\pi$

extracted from fit to the $B^\pm$ yields

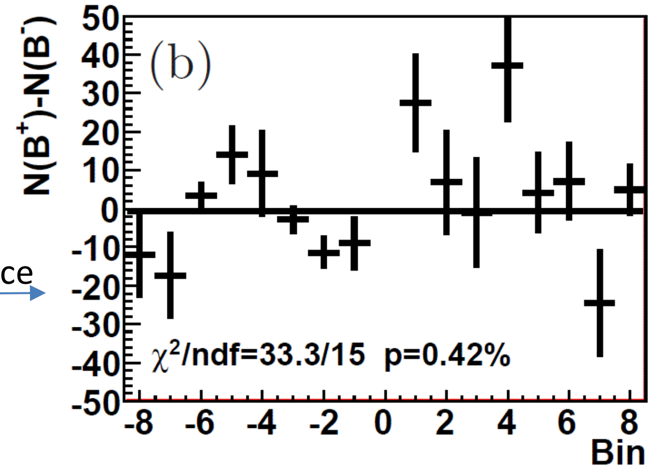
measured by CLEO [PRD82, 112006 (2010)]

$$N_i^\pm = h_B\left[K_{\pm i} + r_b^2 K_{\mp i} + 2\sqrt{K_i K_{-i}}\,(x_\pm c_i \pm y_\pm s_i)\right]$$

Model independent measurement

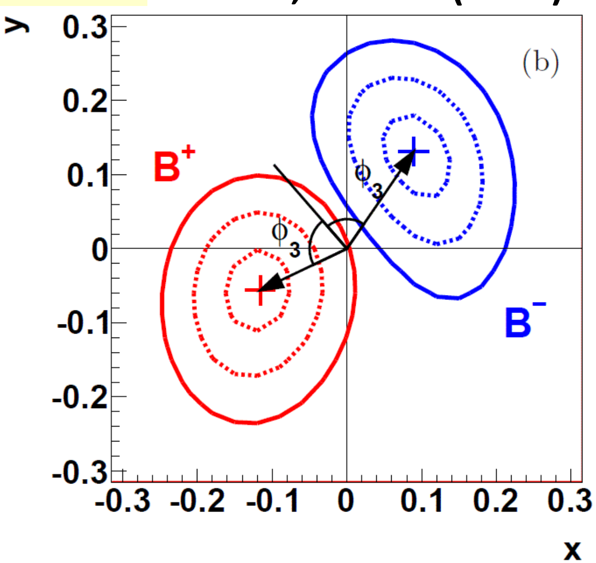


difference



$772 \times 10^6 \, B\bar{B}$

PRD85, 112014 (2012)



$$\gamma = (77.3^{+15.1}_{-14.9} \pm 4.1 \pm 4.3)^\circ \quad \text{(mod } 180^\circ)$$

stat exp sys c_i,s_i errors

$$r_b = 0.145 \pm 0.030 \pm 0.010 \pm 0.011$$

$$\delta_b = (129.9 \pm 15.0 \pm 3.8 \pm 4.7)^\circ$$

uncertainty in c_i, s_i can be reduced at BESIII and possible next generation charm-tau factories

GLW method

- D^0 to K^+K^-, $\pi^+\pi^-$ (CP+) and $K_S\pi^0$, $K_S\omega$, $K_S\phi$ (CP-)
- measure B^+ and B^- yields to determine the GLW observables:

$$R_{CP\pm} \equiv \frac{\Gamma(B^- \to D^0_{CP\pm}K^-) + \Gamma(B^+ \to D^0_{CP\pm}K^+)}{2\Gamma(B^- \to D^0 K^-)} = 1 \pm 2r_b \cos\gamma \cos\delta_b + r_b^2$$

$$A_{CP\pm} \equiv \frac{\Gamma(B^- \to D^0_{CP\pm}K^-) - \Gamma(B^+ \to D^0_{CP\pm}K^+)}{\Gamma(B^- \to D^0_{CP\pm}K^-) + \Gamma(B^+ \to D^0_{CP\pm}K^+)} = \pm 2r_b \sin\gamma \sin\delta_b / R_{CP\pm}$$

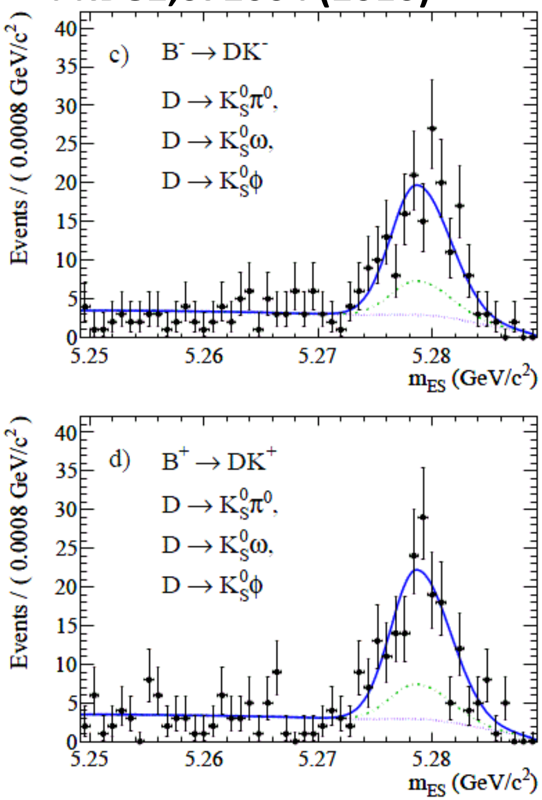
- 4 observables, 3 independent unknowns: γ, δ_b, r_b

GLW reconstructed decay modes

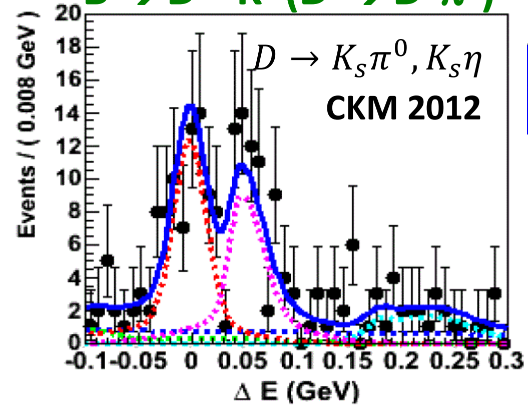
- $B \rightarrow D^0K$, $B \rightarrow D^{*0}K$ ($D^{*0} \rightarrow D^0\pi^0$ and $D^{*0} \rightarrow D^0\gamma$), $B \rightarrow D^0K^*$
- $D^0 \rightarrow K^+K^-$, $\pi^+\pi^-$ (CP+), $D^0 \rightarrow K_s\pi^0$, $K_s\omega$, $K_s\phi$, $K_s\eta$ (CP-)

very challenging at hadronic colliders

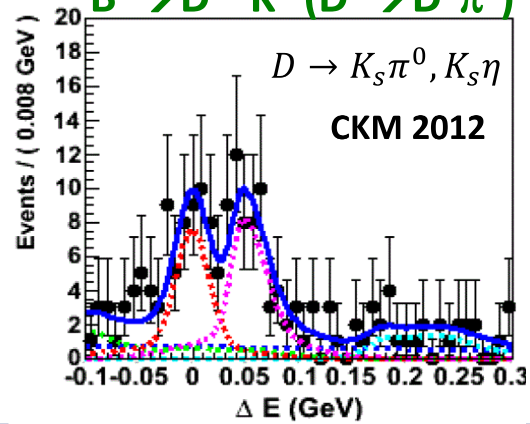
PRD82,072004 (2010)



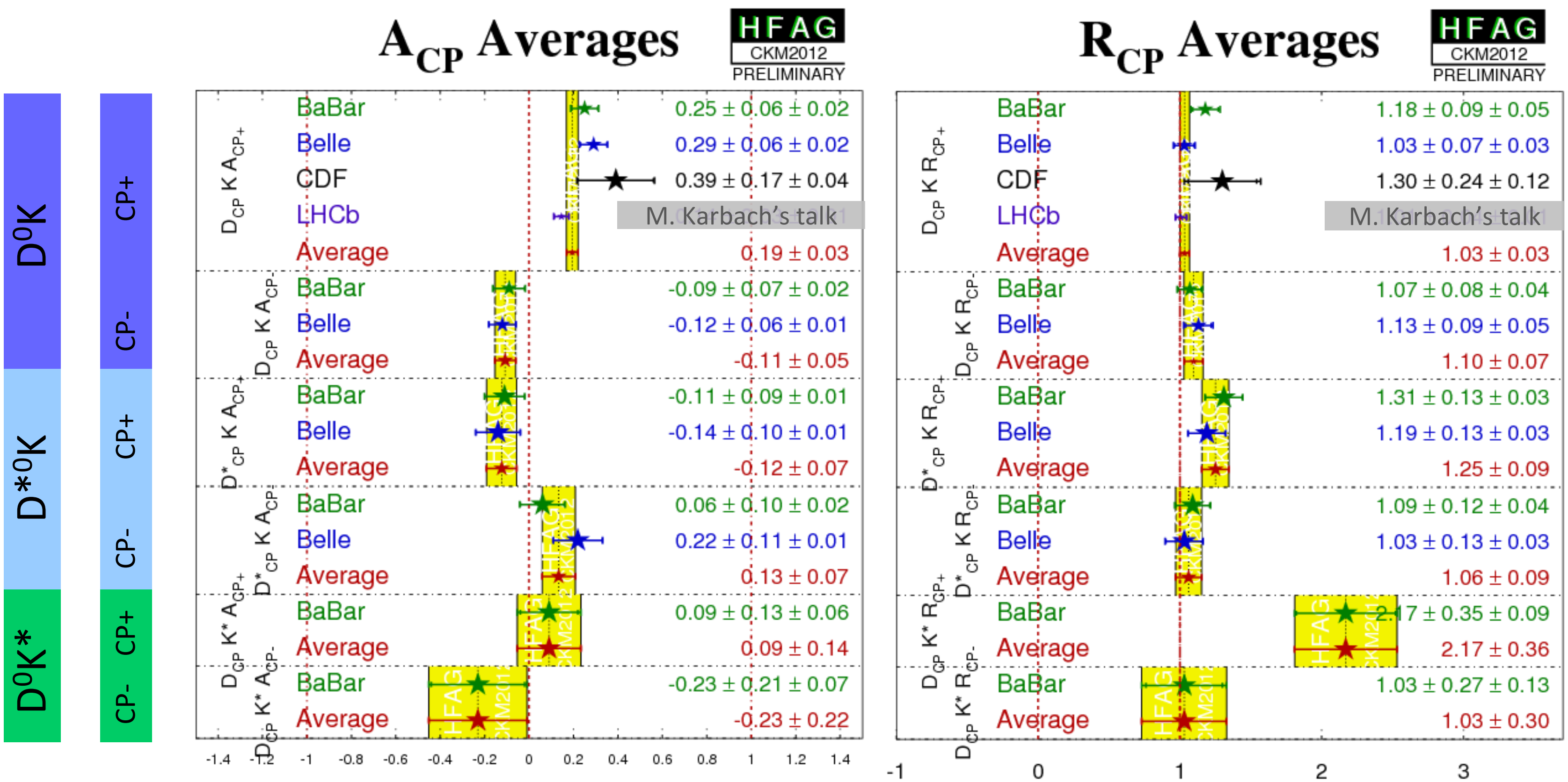
$B^- \rightarrow D^{*0}K^-$ ($D^0 \rightarrow D^0\pi^0$)



$B^+ \rightarrow D^{*0}K^+$ ($D^0 \rightarrow D^0\pi^0$)



GLW results


D^0K
$D^{*0}K$
D^0K^*
CP+
CP-
CP+
CP-
CP+
CP-
A_{CP} Averages
HFAG
CKM2012
PRELIMINARY
BaBar 0.25 ± 0.06 ± 0.02
Belle 0.29 ± 0.06 ± 0.02
CDF 0.39 ± 0.17 ± 0.04
LHCb
M. Karbach's talk
Average 0.19 ± 0.03
BaBar -0.09 ± 0.07 ± 0.02
Belle -0.12 ± 0.06 ± 0.01
Average -0.11 ± 0.05
BaBar -0.11 ± 0.09 ± 0.01
Belle -0.14 ± 0.10 ± 0.01
Average -0.12 ± 0.07
BaBar 0.06 ± 0.10 ± 0.02
Belle 0.22 ± 0.11 ± 0.01
Average 0.13 ± 0.07
BaBar 0.09 ± 0.13 ± 0.06
Average 0.09 ± 0.14
BaBar -0.23 ± 0.21 ± 0.07
Average -0.23 ± 0.22
-1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4
R_{CP} Averages
HFAG
CKM2012
PRELIMINARY
BaBar 1.18 ± 0.09 ± 0.05
Belle 1.03 ± 0.07 ± 0.03
CDF 1.30 ± 0.24 ± 0.12
LHCb
M. Karbach's talk
Average 1.03 ± 0.03
BaBar 1.07 ± 0.08 ± 0.04
Belle 1.13 ± 0.09 ± 0.05
Average 1.10 ± 0.07
BaBar 1.31 ± 0.13 ± 0.03
Belle 1.19 ± 0.13 ± 0.03
Average 1.25 ± 0.09
BaBar 1.09 ± 0.12 ± 0.04
Belle 1.03 ± 0.13 ± 0.03
Average 1.06 ± 0.09
BaBar 2.17 ± 0.35 ± 0.09
Average 2.17 ± 0.36
BaBar 1.03 ± 0.27 ± 0.13
Average 1.03 ± 0.30
-1 0 1 2 3

Why "not" γ from GLW alone

- The GLW observables can be expressed in terms of the cartesian coordinates $x_\pm, y_\pm$:

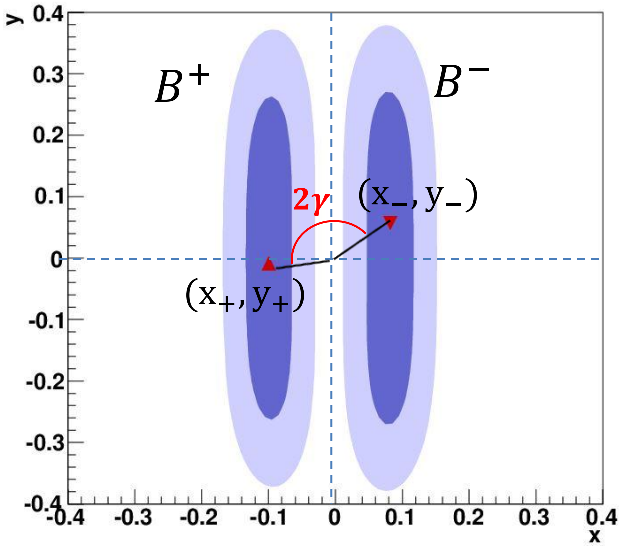
$$x_\pm = (\, R_{CP+}(1 \mp A_{CP+}) - R_{CP-}(1 \mp A_{CP-})\,)/4$$

good constraint on $x_\pm$ (comparable to GGSZ method when in same size dataset)

$$\mathrm{r_b^2} = x_\pm^2 + y_\pm^2 = (R_{CP+} + R_{CP-})/2$$

very loose constraint on $y_\pm$

arxiv:1001.2842



ADS method

- D^0 to $K^+\pi^-$, $K^+\pi^-\pi^0$, $K^+\pi^+\pi^+\pi^-$, … (doubly-Cabibbo-supp.)

suppressed $\qquad\qquad$ favored

$$B^+ \to D^{(*)0} K^{(*)+} \quad + \quad D^0 \to f$$

favored $\qquad\qquad$ suppressed

$$B^+ \to \overline{D}^{(*)0} K^{(*)+} \quad + \quad \overline{D}^0 \to f$$

same final state
large interference ~O(1)

- Measures B^+ and B^- yields to determine the ADS observables:

$$R_{ADS} \equiv \frac{\Gamma(B^- \to D[\to f]K^-) + \Gamma(B^+ \to D[\to \overline{f}]K^+)}{\Gamma(B^- \to D[\to \overline{f}]K^-) + \Gamma(B^+ \to D[\to f]K^+)} = r_b^2 + r_D^2 + 2 r_b r_D \cos(\delta_b + \delta_D)\cos\gamma$$

$$A_{ADS} \equiv \frac{\Gamma(B^- \to D[\to f]K^-) - \Gamma(B^+ \to D[\to \overline{f}]K^+)}{\Gamma(B^- \to D[\to f]K^-) + \Gamma(B^+ \to D[\to \overline{f}]K^+)} = 2 r_b r_D \sin(\delta_b + \delta_D)\sin\gamma / R_{ADS}$$

$$r_D = \left| \frac{A(\overline{D}^0 \to f)}{A(D^0 \to f)} \right|$$

($r_D(K^+\pi^-)=0.06$)

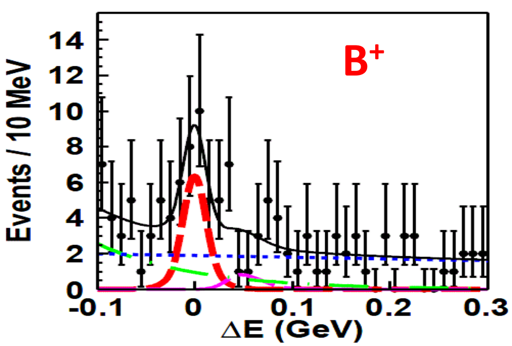
measured at CLEOc/BESIII ← $\delta_D = \arg\left[\frac{A(\overline{D}^0 \to f)}{A(D^0 \to f)} \right]$

ADS reconstructed decay modes

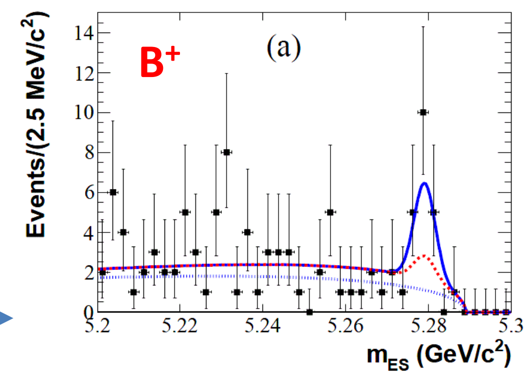
h=K,π

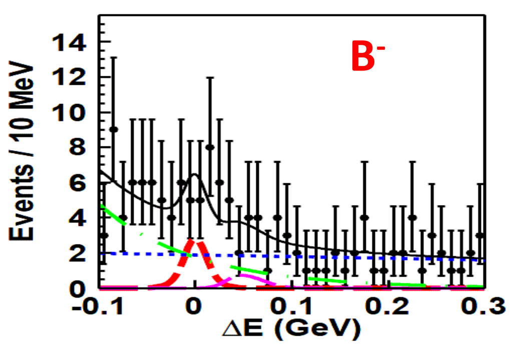
Decays	D^0h^+	$D^{*0}[D^0\pi^0]h^+$	$D^{*0}[D^0\gamma]h^+$	$D^0K^{*+}[K_s\pi]$
$D^0 \rightarrow K^+\pi^-$	467M 772M	467M 772M	467M 772M	379M ---
$D^0 \rightarrow K^+\pi^-\pi^0$	474M	---	---	---

example: $B \rightarrow D^0K$, $D^0 \rightarrow K^+\pi^-$

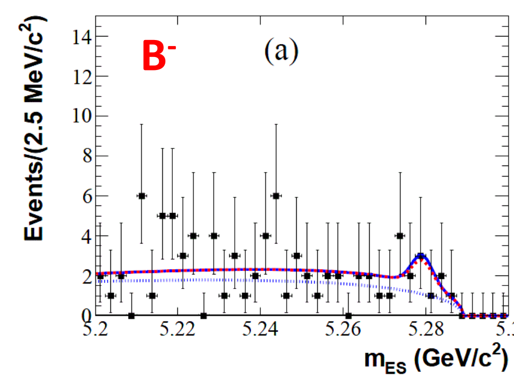


$$A_{ADS} = -0.82 \pm 0.46^{+0.12}_{-0.16}$$

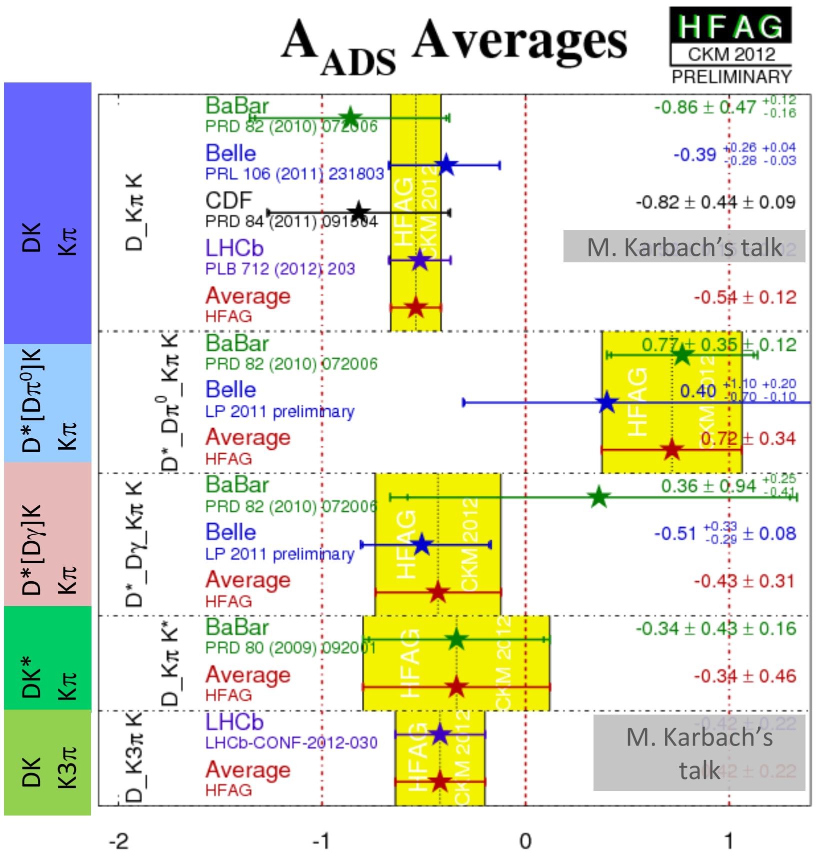


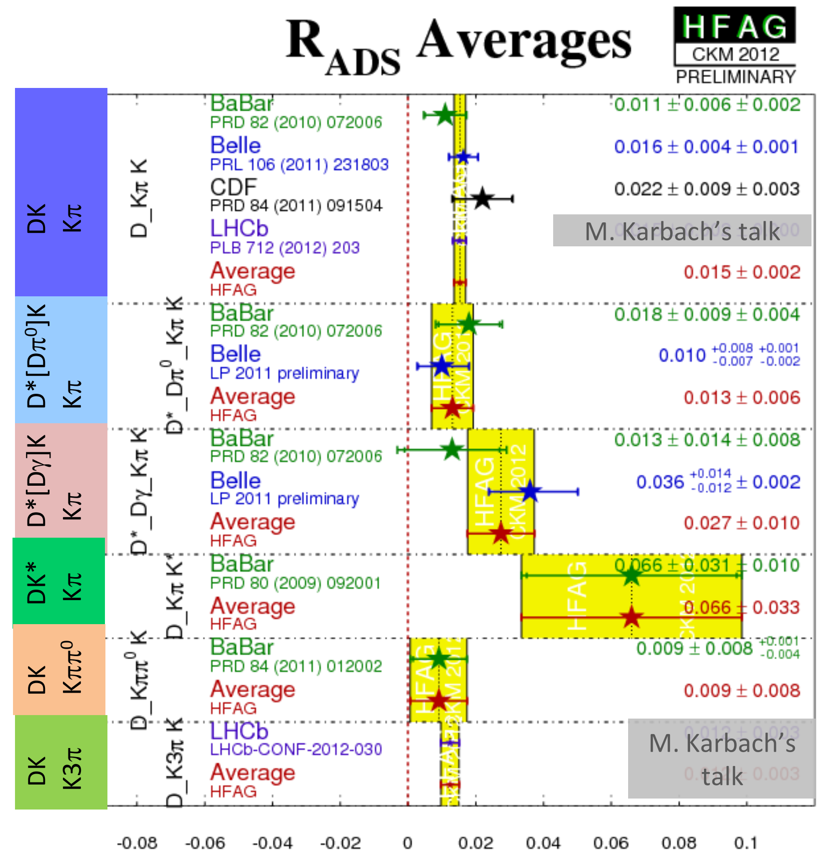


$$A_{ADS} = -0.39^{+0.26}_{-0.28}{}^{+0.04}_{-0.03}$$



ADS B→D$^{(*)}$K$^{(*)}$ results





* D$^{(*)}$π results available in backup slide

LHCb dominates the B→DK, D→Kπ mode.

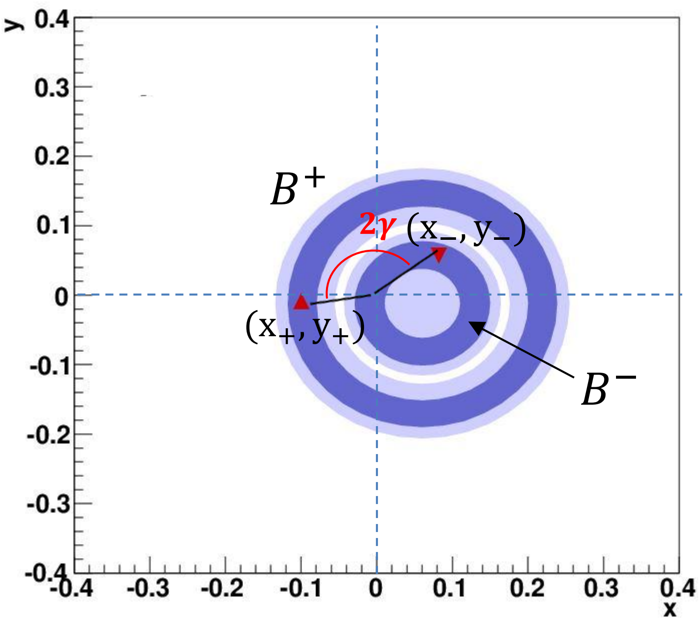
Final states with neutrals difficult in hadronic environment

Why "not" γ from ADS alone

- The ADS observables can be expressed in terms of the cartesian coordinates $x_\pm, y_\pm$:

$$(x_\mp + r_D \cos\delta_D)^2 + (y_\mp - r_D \sin\delta_D)^2 = \frac{\Gamma(B^\mp \to [K^\pm \pi^\mp]_D K^\mp)}{\Gamma(B^\mp \to [K^\mp \pi^\pm]_D K^\mp)}$$

arxiv:1001.2842



$x_\pm, y_\pm$ are delocalized over two circles

Note: for B→D^{*0}K the circles associated to $D^{*0}\to D^0\pi^0$ and $D^{*0}\to D^0\gamma$ are centered at opposite points $(\mp r_D \cos\delta_D, \pm r_D \sin\delta_D)$ and γ can be extracted in principle up to discrete ambiguities.

GLW + ADS can constrain γ

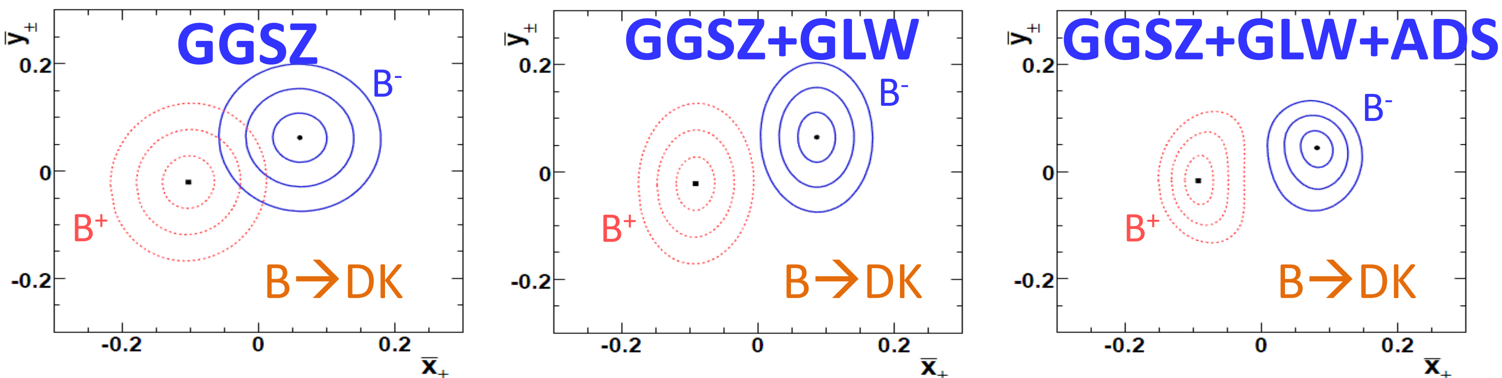
Note: uncertainty on the values of r_D and δ_D are neglected

BaBar GLW+ADS+GGSZ combination

Combination of GGSZ+GLW+ADS in two stages

I. combine the GGSZ, GLW and ADS $B^{\pm}\rightarrow D^{(*)}K^{(*)\pm}$ observables (34 in total) to extract the combined $x_{\pm}, y_{\pm}$ (4 for each B mode)
II. transform the combined $x_{\pm}, y_{\pm}$ into the physically relevant quantities γ, $\{r_b, \delta_b\}_{D(*)K(*)}$

stage I



contours for B→D*K and B→DK* in PRD87, 052015 (2013)

results:

$\bar{z} \equiv x + iy$

		Real part (%)	Imaginary part (%)
DK	$\bar{z}_-$	$8.1 \pm 2.3 \pm 0.7$	$4.4 \pm 3.4 \pm 0.5$
DK	$\bar{z}_+$	$-9.3 \pm 2.2 \pm 0.3$	$-1.7 \pm 4.6 \pm 0.4$
D*K	$\bar{z}^*_-$	$-7.0 \pm 3.6 \pm 1.1$	$-10.6 \pm 5.4 \pm 2.0$
D*K	$\bar{z}^*_+$	$10.3 \pm 2.9 \pm 0.8$	$-1.4 \pm 8.3 \pm 2.5$
DK*	$\bar{z}_{s-}$	$13.3 \pm 8.1 \pm 2.6$	$13.9 \pm 8.8 \pm 3.6$
DK*	$\bar{z}_{s+}$	$-9.8 \pm 6.9 \pm 1.2$	$11.0 \pm 11.0 \pm 6.1$

external input required for the D hadronic parameters $r_{K\pi}, \delta_{K\pi}$, $r_{K\pi\pi0}, \delta_{K\pi\pi0}$, $k_{K\pi\pi0}$

BaBar GLW+ADS+GGSZ combination

stage II

- $(x_{\pm},y_{\pm})_{D(*)K(*)} \rightarrow \gamma, \{r_b, \delta_b\}_{D(*)K(*)}$ with frequentist stat procedure

$\gamma = (69^{+17}_{-16})^{\circ}$ (modulo $180°$)

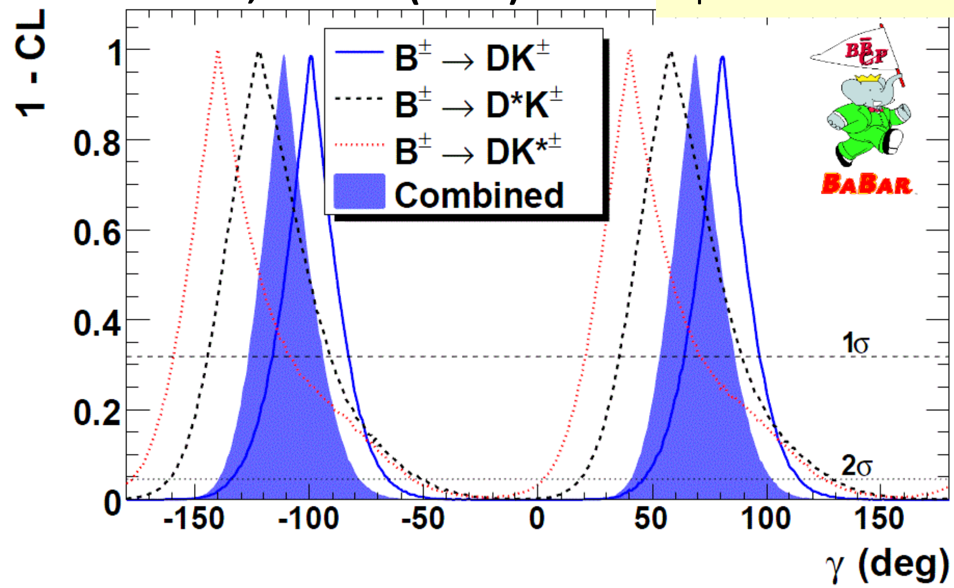
exp+DP model sys = $\pm 4°$

CPV significance: 5.9σ

(GGSZ alone 4.0σ. GGSZ+GLW 5.4σ)

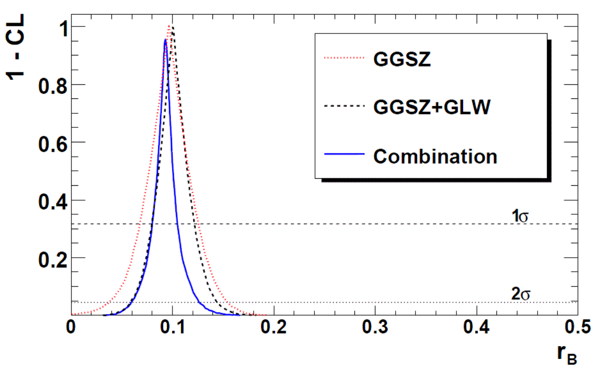
PRD87, 052015 (2013)

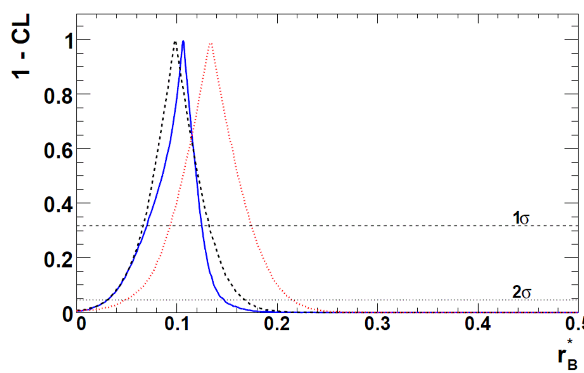
up to $474 \times 10^6\ B\bar{B}$

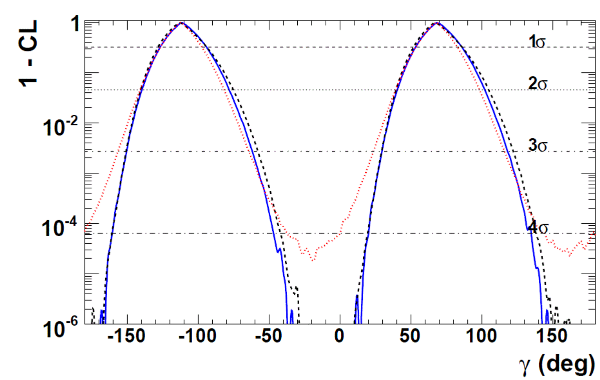


$r_b(\%) = 9.2^{+1.3}_{-1.2}$

$r_b^*(\%) = 10.6^{+1.9}_{-3.6}$





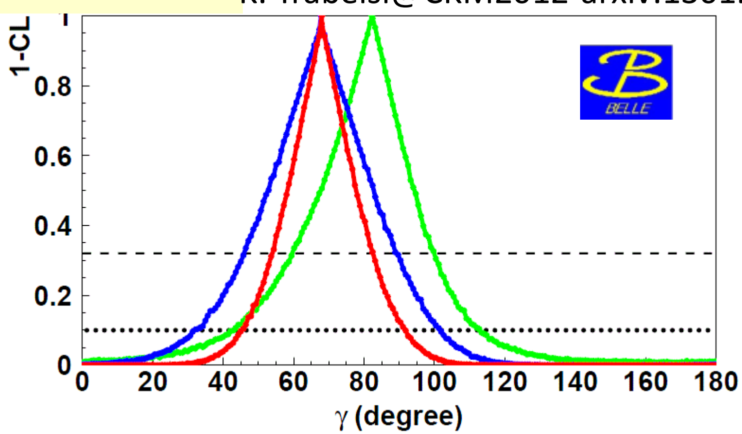


Belle GLW+ADS+GGSZ combination

Combination of GGSZ (mod. dep.)+GLW+ADS $B \to D^0K + B \to D^{*0}K$ (8+8+6 observables)

- frequentist stat procedure

up to $772 \times 10^6\ B\bar{B}$ K. Trabelsi@CKM2012 arxiv:1301.2033

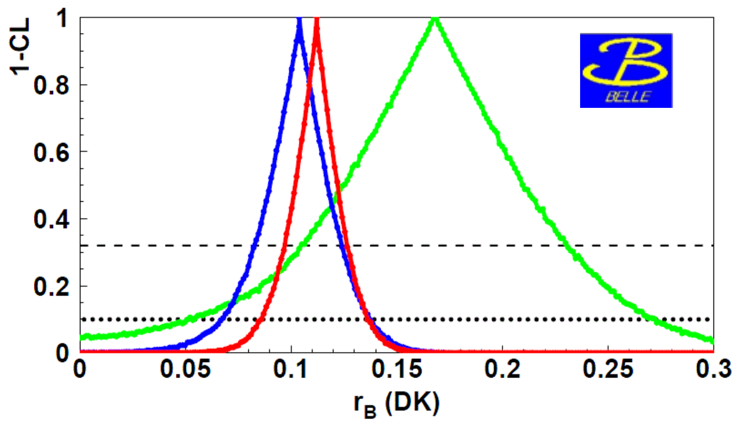


GGSZ: $\gamma = (82^{+18}_{-23})°$

GGSZ + ADS : $\gamma = (68 \pm 22)°$

GGSZ + ADS + GLW:

$\boldsymbol{\gamma = (68^{+15}_{-14})°}$



$B \to D^0K$:

$r_b = 0.168^{+0.063}_{-0.064}$

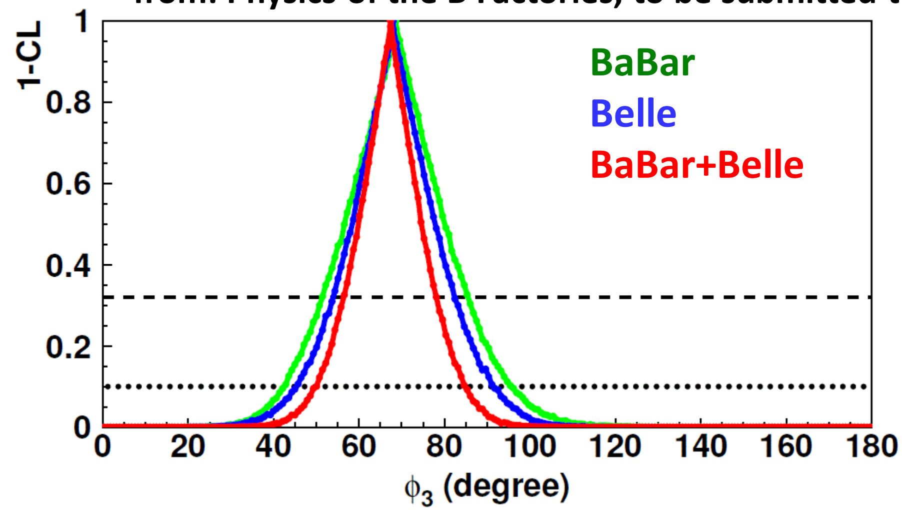
$r_b = 0.104^{+0.020}_{-0.021}$

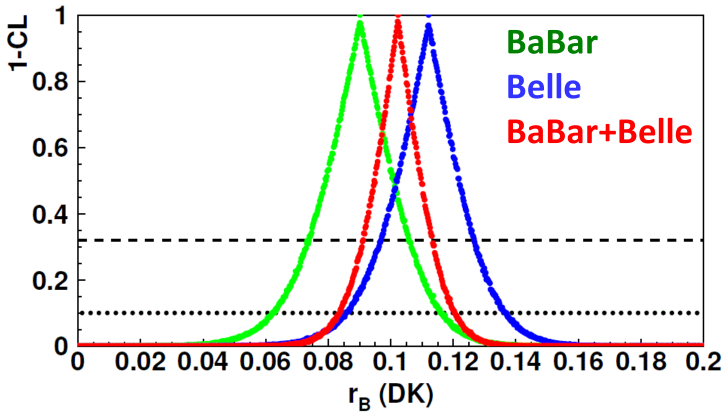
$r_b = 0.112^{+0.014}_{-0.015}$

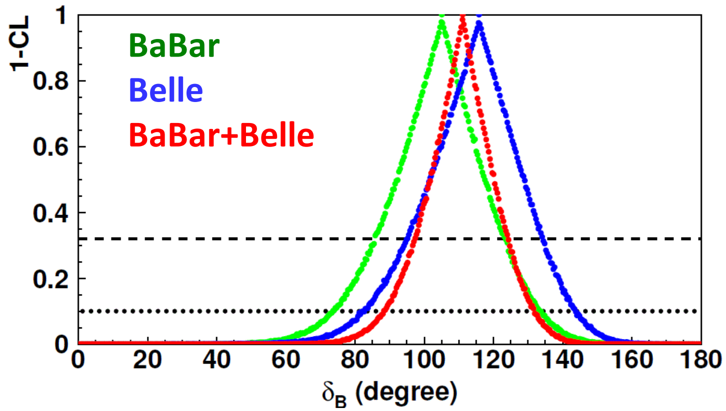
Belle and BaBar combination

Combination of BaBar and Belle: GGSZ mod. dep.+GLW+ADS with $B \rightarrow D^0K$, $B \rightarrow D^{*0}K$ and $B \rightarrow D^0K^*$(BaBar only). Frequentist stat procedure. BaBar and Belle model errors assumed uncorrelated.

from: Physics of the B Factories, to be submitted to EPJC.







BaBar + Belle:

$$\boldsymbol{\gamma = (67 \pm 11)^\circ}$$ (mod 180°)

$$r_b(DK) = 0.102 \pm 0.011$$

$$\delta_b(DK) = (111^{+13}_{-14})^\circ$$ (mod 180°)

D mixing and CPV in B→DK (and B→Dπ)

Several interesting studies on the effect of D mixing and CPV in the extraction of γ with $B \to D^{(*)}K^{(*)}$ (and $B \to D^{(*)}\pi$)

- Effect of D mixing
  - Y. Grossman, Z. Ligeti, A. Soffer, PRD67, 071301 (2003); PRD72, 031501 (2005)
  - A. Bondar, A. Poluektov, V. Vorobiev, PRD82, 034033 (2010) (Dalitz mod ind)
- Effect of CPV in D decays
  - W. Wang, PRL110, 061802 (2013) (GLW)
  - M. Martone and J. Zupan, arXiv:1212.0165 (GLW)
  - B. Bhattacharya, D. London, M. Gronau, J. L. Rosner, arXiv:1301.5631 (GLW)
  - A. Bondar, A. Dolgov, A. Poluektov, V. Vorobiev arxiv:1303.6305 (Dalitz)

Corrections for D mixing and CPV not considered in BaBar and Belle $B \to D^{(*)}K^{(*)}$ combinations

- effects expected to be small at present B-factories (although some may not be completely negligible)
- effects more and more important at LHCb and at Belle2

Summary

- Sensitivity to γ (ϕ_3) dominated by the $B^{\pm} \rightarrow D^{(*)0}K^{(*)\pm}$ decays so far
- BaBar and Belle have reconstructed all the most sensitive decay modes using all or almost all their final datasets
- BaBar GLW+ADS+GGSZ combination:

  $\boldsymbol{\gamma = \left(69^{+17}_{-16}\right)^{\circ}}$ (mod 180°)

  exp+DP model sys = $\pm 4°$

- Belle GLW+ADS+GGSZ combination:

  $\boldsymbol{\gamma = \left(68^{+15}_{-14}\right)^{\circ}}$ (mod 180°)

- B-factories average:

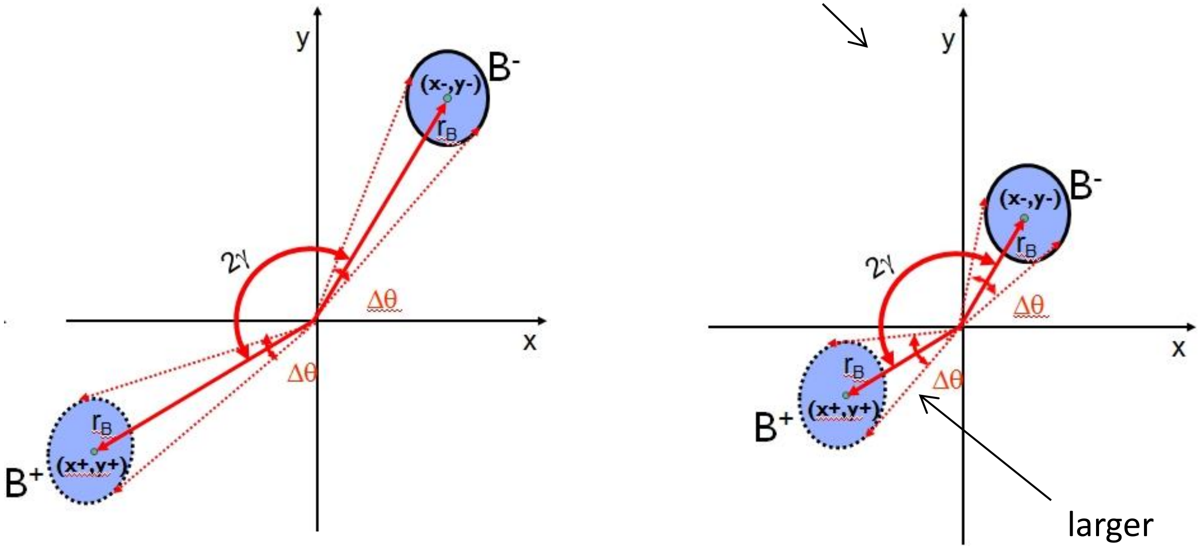
  $\boldsymbol{\gamma = (67 \pm 11)^{\circ}}$ (mod 180°)

BACKUP

Dependence of $\sigma(\gamma)$ on r_b

- the error on γ (at fixed x,y uncertainty) scales roughly as $1/r_b$

same x,y errors
but smaller r_b



larger
uncertainty on γ

$B \rightarrow D^{(*)}\pi$ ADS measurements