CPV involving b→u transitions from BaBar and Belle

Full title and outline:

- CPV in B→ππ
- measurements of ϕ_3/γ
- and $\sin(2\phi_1+\phi_3)/(2\beta+\gamma)$

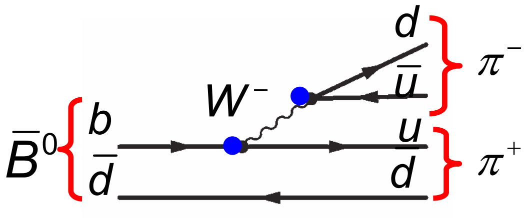
227M $\bar{B}B$

275M $\bar{B}B$

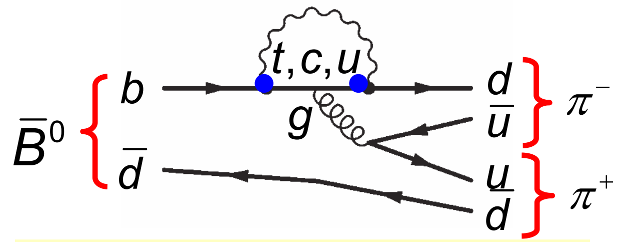
for most of the results

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

$b \to u\bar{u}d$

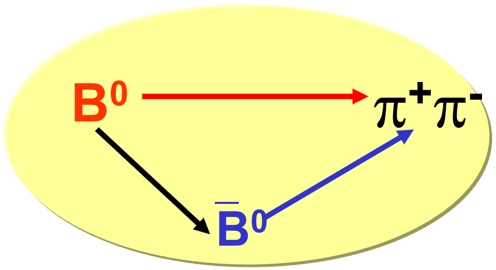


tree: $\propto V_{ub}V^*_{ud} \propto \lambda^3$



penguin: $\propto V_{tb}V^*_{td} \propto \lambda^3$

$$\lambda \equiv \frac{q}{p}\frac{\bar{A}_f}{A_f} = e^{-i\phi_M}\frac{\bar{A}_f}{A_f}$$



Mixing ind. CPV

$$\frac{2\,\mathrm{Im}\,\lambda}{1+|\lambda|^2}$$

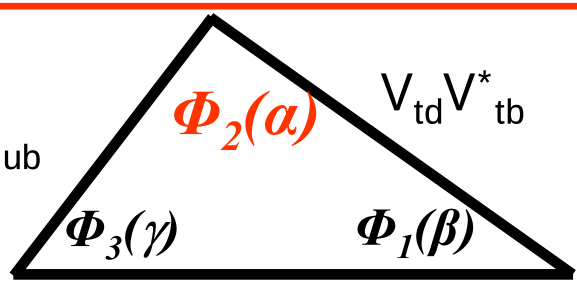
Direct CPV

$$-\frac{1-|\lambda|^2}{1+|\lambda|^2}$$

$$A_{CP} = \frac{\Gamma(\overline{B^0}(\Delta t)\to\pi^+\pi^-)-\Gamma(B^0(\Delta t)\to\pi^+\pi^-)}{\Gamma(\overline{B^0}(\Delta t)\to\pi^+\pi^-)+\Gamma(B^0(\Delta t)\to\pi^+\pi^-)} = S_{\pi\pi}\sin(\Delta m_d \Delta t) + A_{\pi\pi}\cos(\Delta m_d \Delta t)$$

$V_{ud}V^*_{ub}$

$V_{td}V^*_{tb}$



$V_{cd}V^*_{cb}$

$\Phi_2(\alpha) \equiv \arg(-V_{ud}V^*_{ub}/V_{td}V^*_{tb})$

$$S_{\pi\pi} = \sin 2\alpha \Rightarrow \sqrt{1-A^2_{\pi\pi}}\,\sin 2(\underbrace{\alpha+\theta_{peng}}_{\alpha_{eff}})$$

$A_f \equiv -C_f$

Methodology

Event selection

Include all $B \to h^+h^-$ (h=π/K)

$5.29 > M_{ES} > 5.2$ GeV, $|\Delta E| < 150$ MeV

$B \to h+h-$ (h – identified as π)

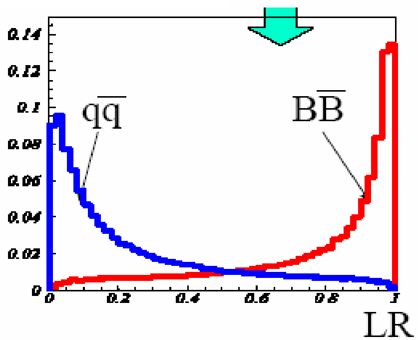
$5.287 > M_{bc} > 5.271$ GeV, $|\Delta E| < 64$ MeV

Background treatment

$|\cos(\theta_S)| < 0.8$

Simultaneuos fit to the signal and background components using discriminating variables: θ_c, ΔE, M_{ES}, **Fisher discr**. based on momentum flow relative to the h^+h^- thrust axis

cut on $$LR = \frac{\mathcal{L}_{B\bar{B}}}{\mathcal{L}_{B\bar{B}} + \mathcal{L}_{q\bar{q}}}$$



event shape &

B flight direction

Flavour tagging

Use charged particles that are not associated with the recontsructed B

Tagging efficiency ~30%

$$M_{ES} = \sqrt{(s/2 + \vec{p}_i \vec{p}_B)^2 / E_i^2 - p_B^2} \qquad \Delta E = E_B^* - E_{bean}^* \qquad M_{bc} = \sqrt{(E_{beam}^*)^2 - (p_B^*)^2}$$

Event yields

Unbinned maximum likelihood fit

$$L_k = \exp(-\sum_i n_i \varepsilon_{i,k}) \prod_j [\sum_i n_i \varepsilon_{i,k} P_{i,k}(\vec{x}_j, \vec{\alpha}_i)]$$

k: four flavor tagging categories
i: 8 signal and backgr.hypotheses
$\pi^+\pi^-$, $K^+\pi^-$, $K^-\pi^+$, K^+K^- ,bkgr.
n_i: event yield of type i
$\varepsilon_{i,k}$: tagging efficiency
x_j: m_{ES}, ΔE, F, θ+, θ−, Δt
α_i: PDF parameters

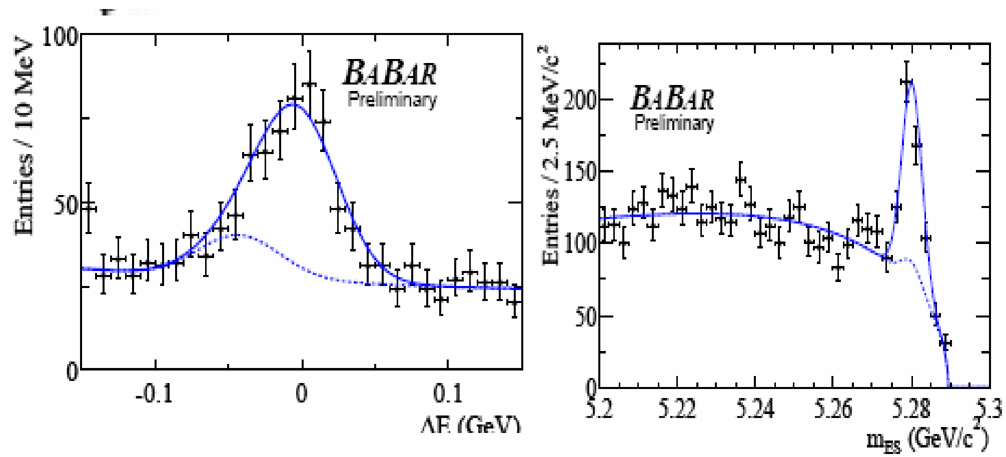
- **First stept**.

⇒ signal and background yields,
Kπ charge asymmetries

♦ <u>no flavor-tagging nor Δt in the fit</u>

68030 candidate events
467±33 signal events
1606±51 Kπ events

Signal enhanced ΔE and M_{ES} distributions

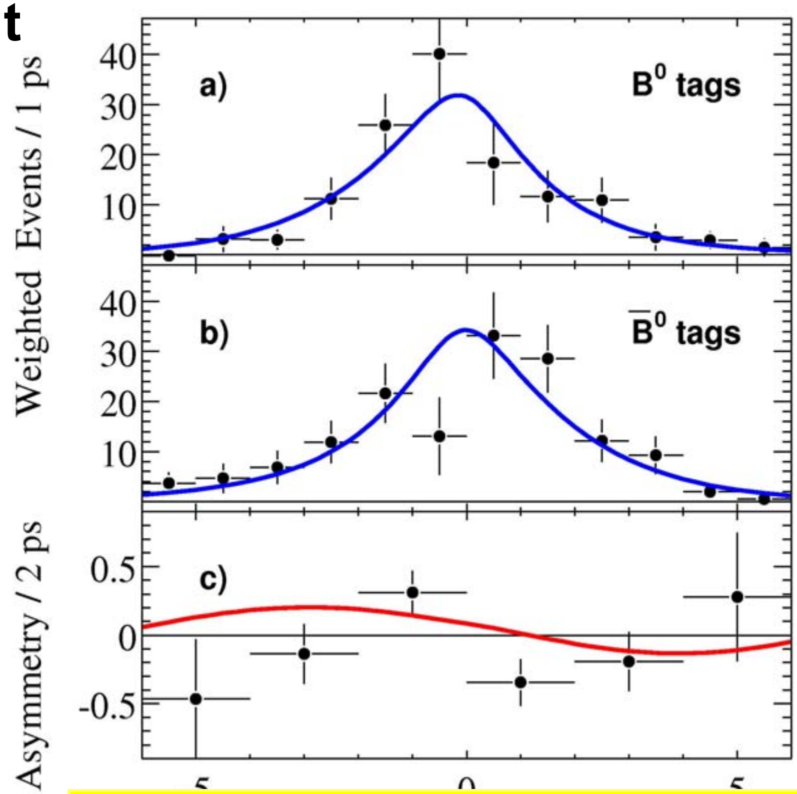


CP fit results

2nd step
– unbinned maximum likelihood fit with 46 parameters

- $S_{\pi\pi}$, $C_{\pi\pi}$
- 12 for background PDF of m_{ES}, ΔE and F
- 8 for background Δt PDF
- 12 for background flavor-tagging efficiency
- 12 for background flavor-tagging efficiency asymmetries.

Data ponits: event weighting techn.



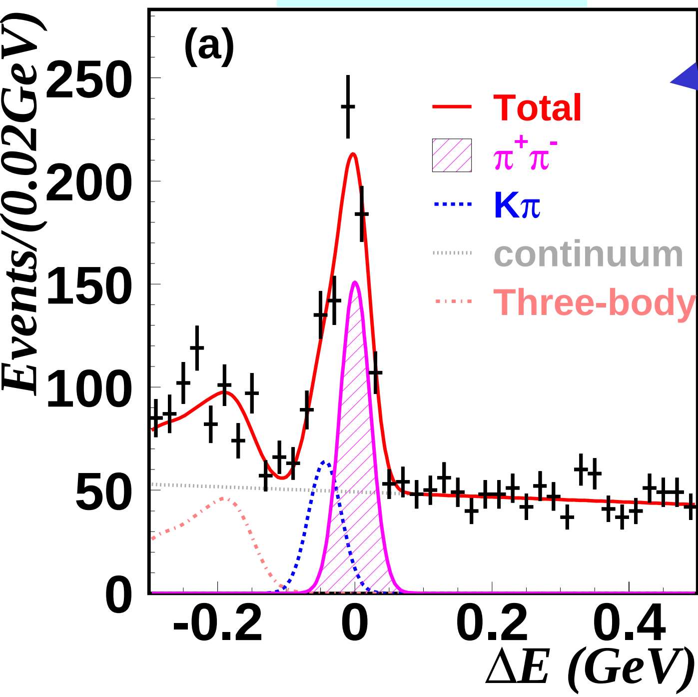
$C_{\pi\pi}$=-0.09±0.15(stat)±0.04(sys)

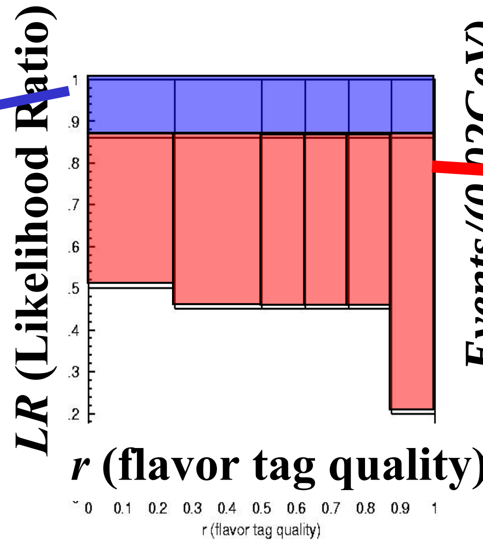
$S_{\pi\pi}$=-0.30±0.17(stat)±0.03(sys)

Signal yields

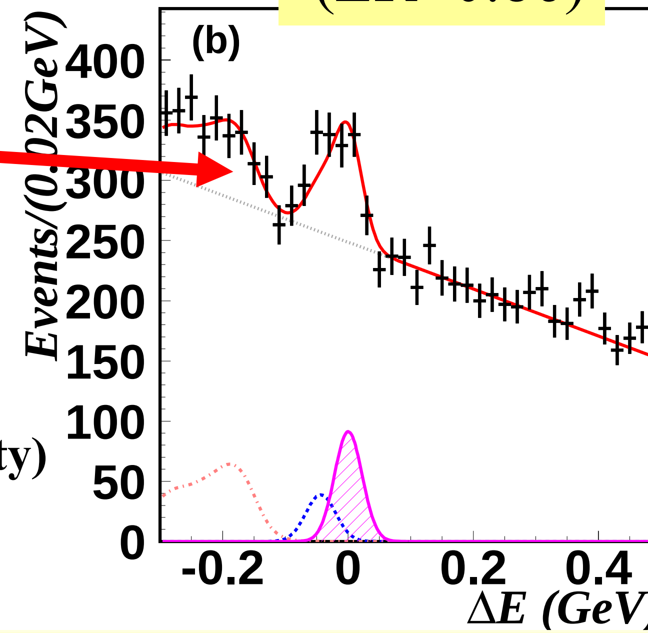
Unbinned 2-dim maximum likelihood fit to ΔE-M_{bc}

(LR>0.86)





(LR<0.86)



M_{bc}>5.2, -.3<ΔE<0.5 GeV

Signal ⊕ $K\pi$ ⊕ 3-body B decays ⊕ $\bar{q}q$ bgr.

total number of events

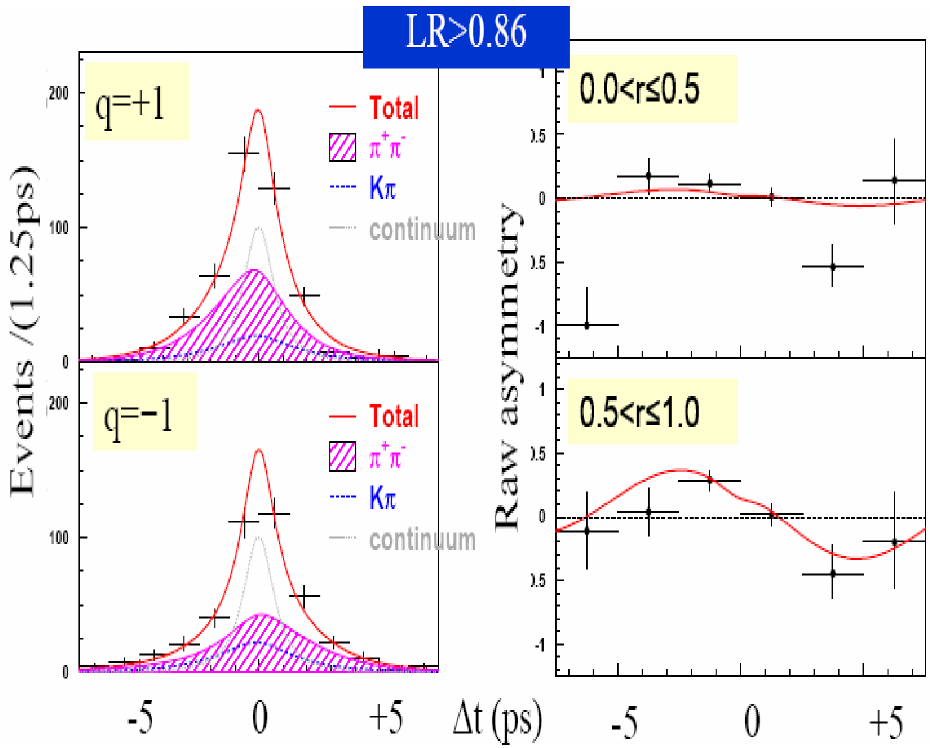
2820 candidate events

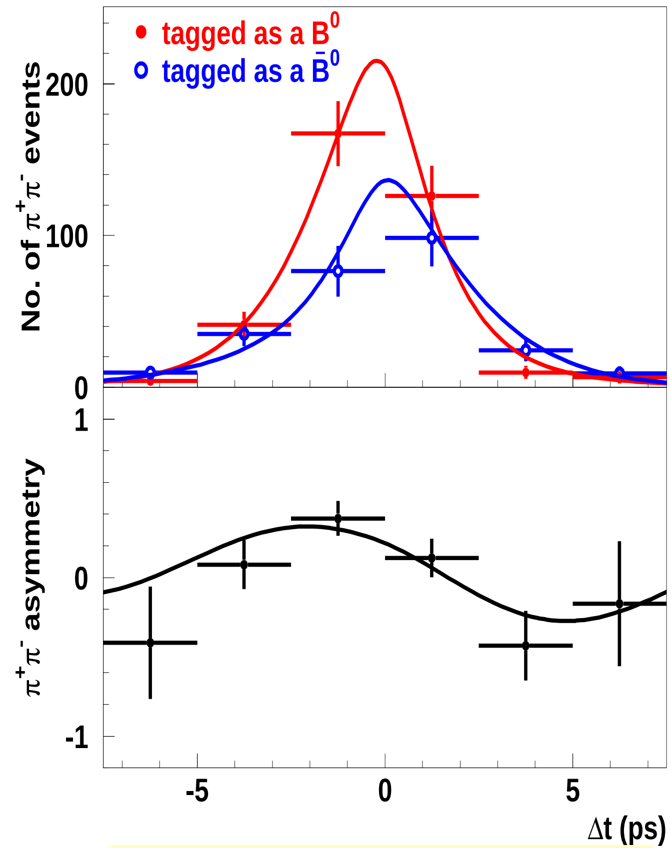
666±43 signal events

247±31 $K\pi$ events

CP FIT RESULTS

Unbinned maximum likelihood fit with 2 parameters: $A_{\pi\pi}$, $S_{\pi\pi}$



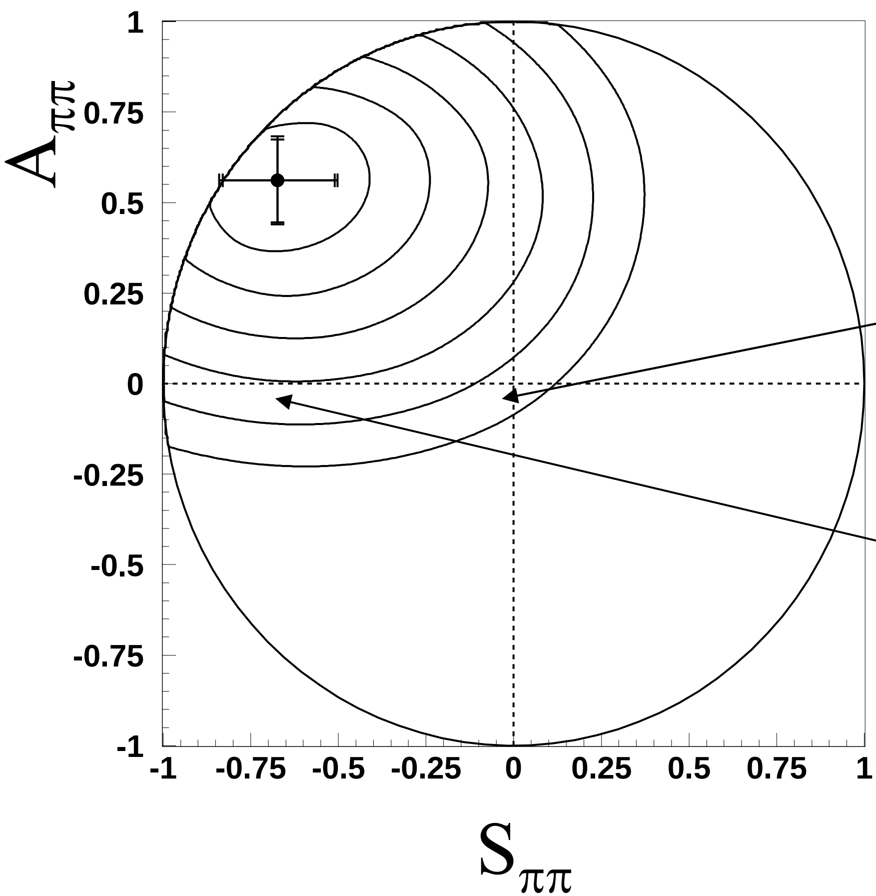


$A_{\pi\pi}$=+0.56±0.12(stat)±0.06(sys)

$S_{\pi\pi}$=-0.67±0.16(stat)±0.06(sys)

bckground subtracted
fit projection for all

Significance from Feldman-Cousin method



Large CP Violation,

(A,S)=(0,0)

1-C.L.=5.62x10^{-8}, 5.4σ

(A,S)=(0,−0.62)

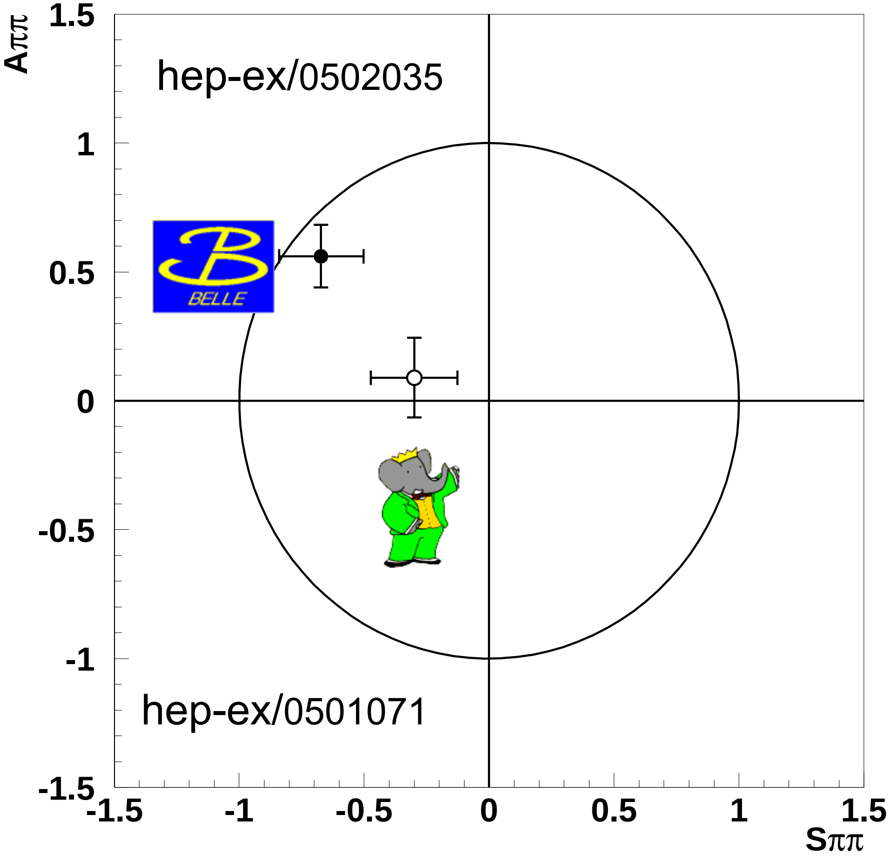
1-C.L.=5.13x10^{-5}, 4.0σ

Large Direct CP violation, confirmation of the previous Belle results

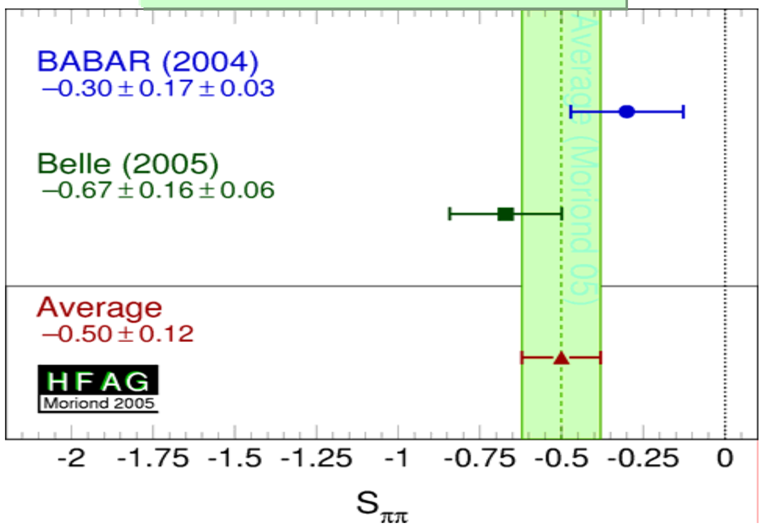
both statistical and systematic errors are taken into account.

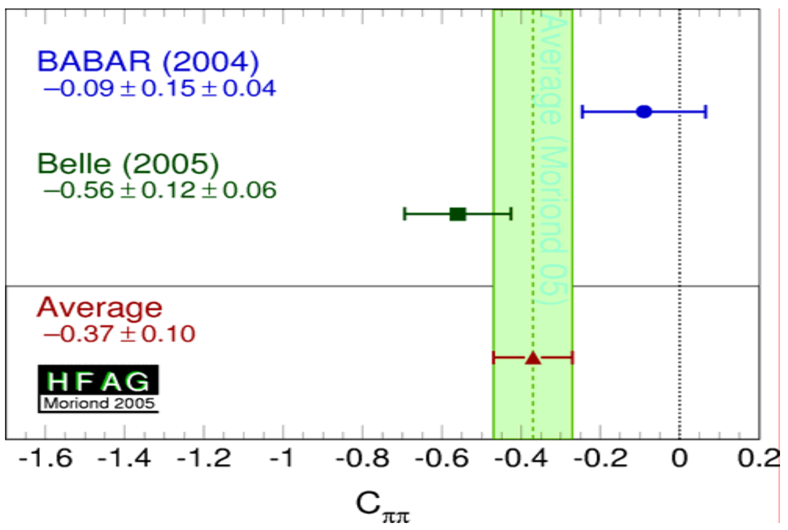
C.L. = Confidence Level

CPV parameters in $B^0 \to \pi^+\pi^-$



HFAG Moriond 2005

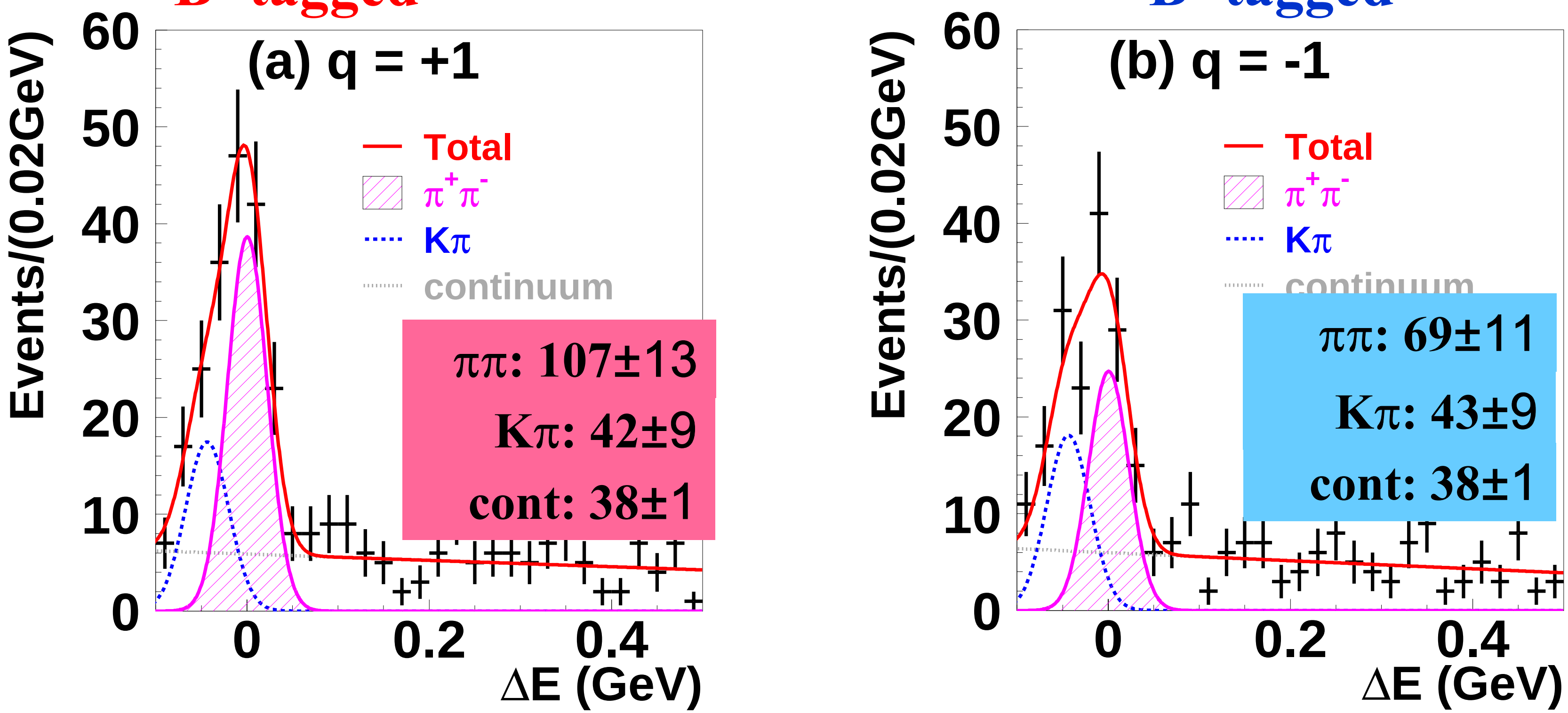




~2.3σ difference between
Belle & BaBar

Time-integrated asymmetry

B^0 tagged LR>0.86 & 0.5<r≤1.0 $\overline{B^0}$ tagged



$$A_{\pi\pi} = +0.52 \pm 0.14$$

consistent with time-dependent fit

$$SU(3): A_{CP}(K^+\pi^-) \sim -\frac{1}{3} A_{CP}(\pi^+\pi^-)$$

$$-\frac{1}{3} A_{CP}(\pi^+\pi^-) = -0.19 \pm 0.04$$

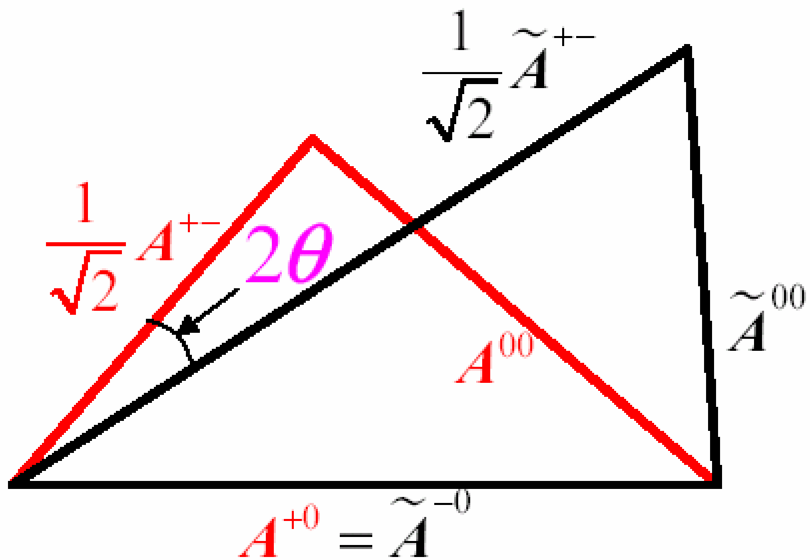
M. Gronau, J.L. Rosner, PLB 595, 339 (2004)

$$A_{CP}(K^+\pi^-) = -0.109 \pm 0.019$$

Isospin analysis

$$S_{\pi\pi} = \sqrt{1 - A_{\pi\pi}^2}\,\sin(2\phi_2 + 2\theta)$$

The cleanest method to extract ϕ_2



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

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

$\tilde{A}^{ij} = e^{2\phi_3}\bar{A}^{ij}$ $\equiv$ both real and positive

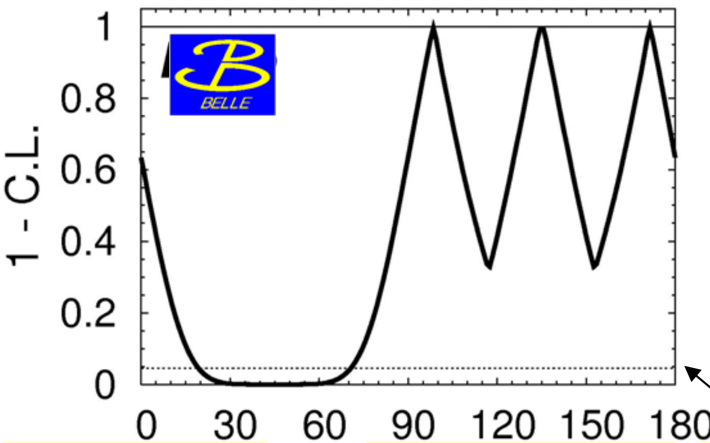
$$Br(\pi^0\pi^0) = (2.3^{+0.4+0.2}_{-0.5-0.3}) \times 10^{-6}$$
$$A_{CP}(\pi^0\pi^0) = +0.44^{+0.53}_{-0.52} \pm 0.17$$

$$Br(\pi^0\pi^0) = (1.17 \pm 0.32 \pm 0.10) \times 10^{-6}$$
$$A_{CP}(\pi^0\pi^0) = +0.12 \pm 0.56 \pm 0.06$$

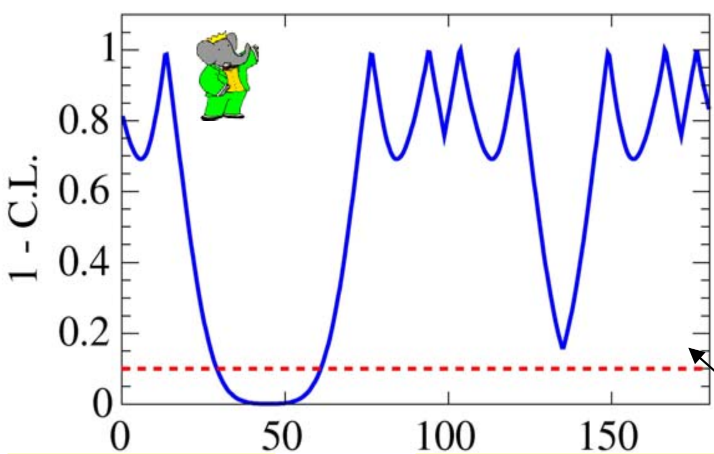
HFAG summer 2004 values for the branching ratios of $B^0 \to \pi^+\pi^-$, $\pi^0\pi^0$, $B^+ \to \pi^+\pi^0$ and A_{CP} ($B^0 \to \pi^0\pi^0$.)

statistical treatment:
J. Charles *et al*., hep-ph/0406184

Constraints on $\phi_2(\alpha)$ from isospin analysis

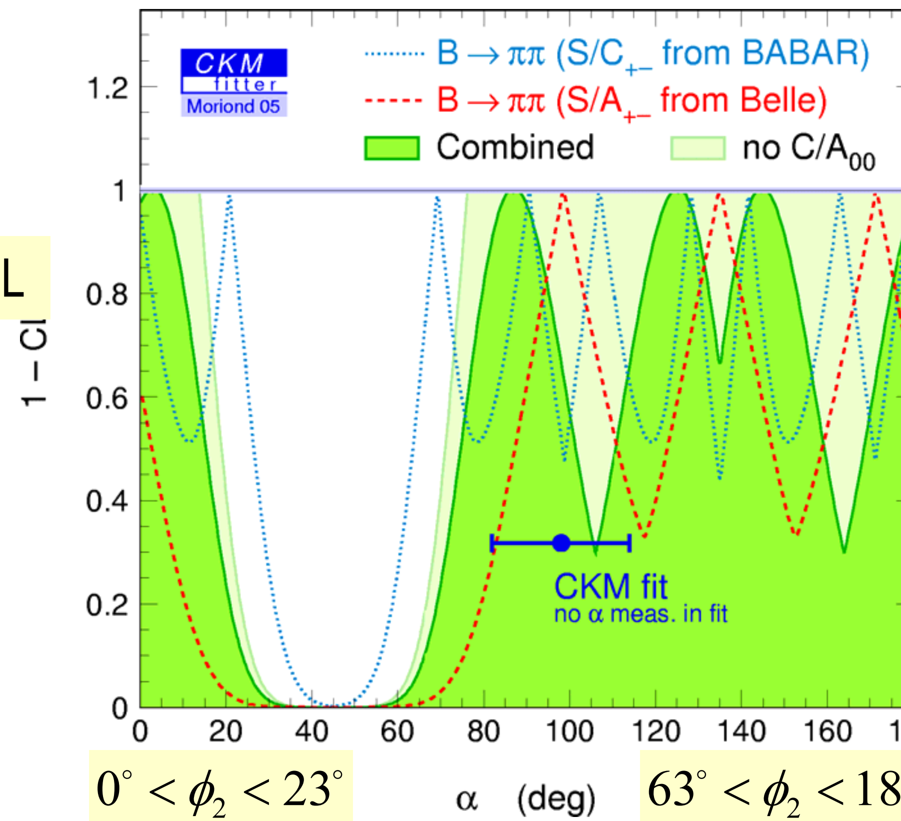


$0^\circ < \phi_2 < 19^\circ$ $\quad$ $71^\circ < \phi_2 < 180^\circ$ $\quad$ 95.4% CL



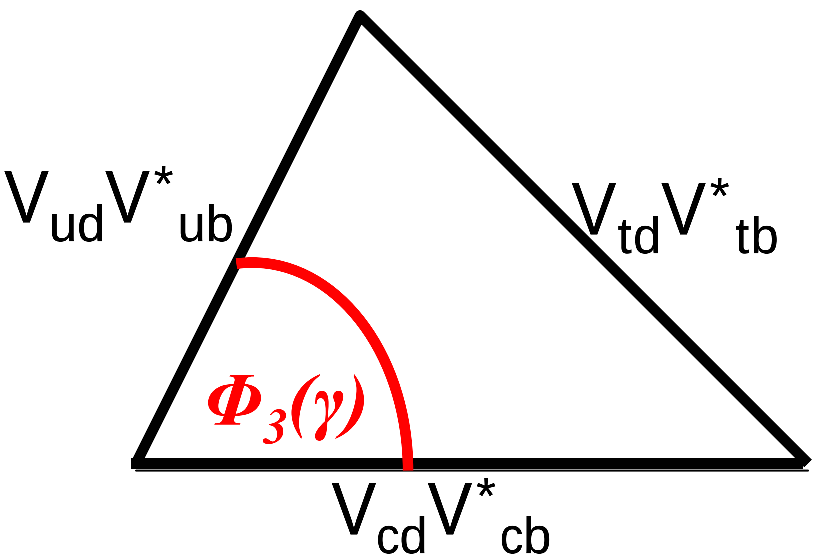
$0^\circ < \phi_2 < 29^\circ$ $\quad$ $61^\circ < \phi_2 < 180^\circ$ $\quad$ 90% CL

CKM fitter Moriond'05



$0^\circ < \phi_2 < 23^\circ$ $\quad$ $63^\circ < \phi_2 < 180^\circ$

Maesurements of Φ_3/γ



$\Phi_3/\gamma \equiv \arg(-V_{ud}V^*_{ub}/\ V_{cd}V^*_{cb})$

phase of V_{ub}

DCPV in $B \to K^+\pi^-$

$A^{CP}_{K\pi} = -0.133 \pm 0.030 \pm 0.009$

$A^{CP}_{K\pi} = -0.101 \pm 0.025 \pm 0.005$

AVERAGE $A^{CP}_{K\pi} = -0.109 \pm 0.019$

$>5\sigma$

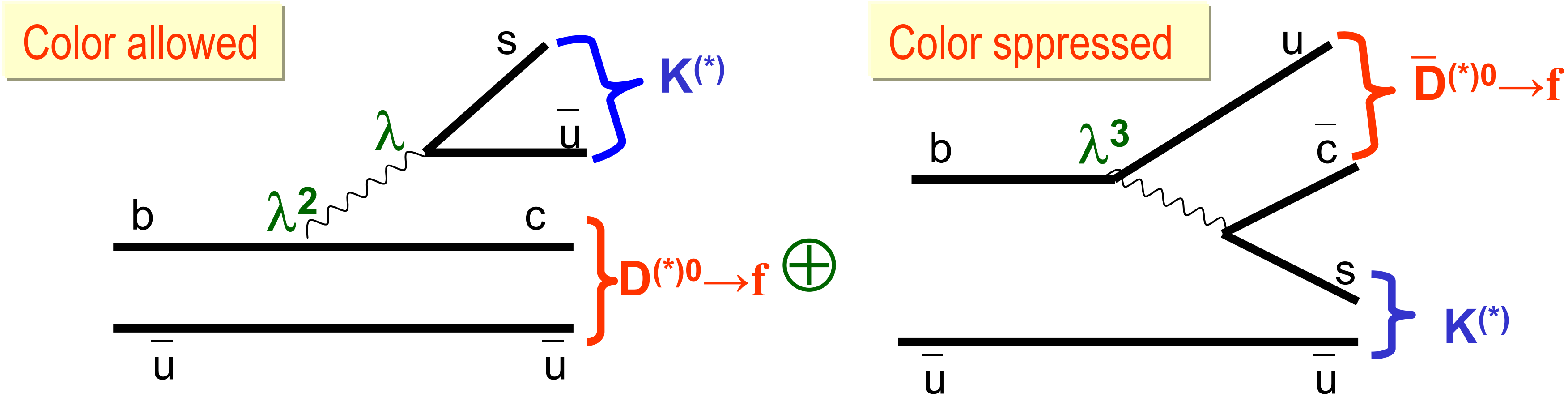
$\Phi_3 \neq 0$

$\bar{b} \to \bar{u}\, u\, s$ (tree) $\oplus$ $\bar{b} \to \bar{s}\, u\, \bar{u}$ (penguin)

Hard to extract ϕ_3/γ

Ways to measure Φ_3 in $B \to DX_s$

DCPV in interference between b→u & b→c



$\bar{D}^{(*)}$ & $D^{(*)}$ decay to the same final state f (f = $\pi\pi$, KK, Kπ…)

theoretically clean: only tree diagrams

$A_{CP} \equiv (\Gamma_{B+} - \Gamma_{B-})/(\Gamma_{B+} + \Gamma_{B-}) \propto r_B \sin(\gamma) \sin(\delta)$

- δ = the strong phase between A(b→u) & A(b→c)
- $r_B \equiv$ A(b→u)/ A(b→c)

experimentally challenging !!!

many methods with:
various f
various X_s
various observables
statistics required:
> 0.5 ab^{-1}

The Gronau-Wyler-London Method (GLW)

$B^{\pm} \to D_{CP} K^{(*)\pm}$, D_{CP} is CP-eigenstate

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

CP+ : $D^0 \to \pi^+\pi^-$, K^+K^- CP- : $D^0 \to K_S\pi^0, K_S\eta, K_S\omega, K_S\varphi$,…

4 observables (3 independent)

3 unknowns

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

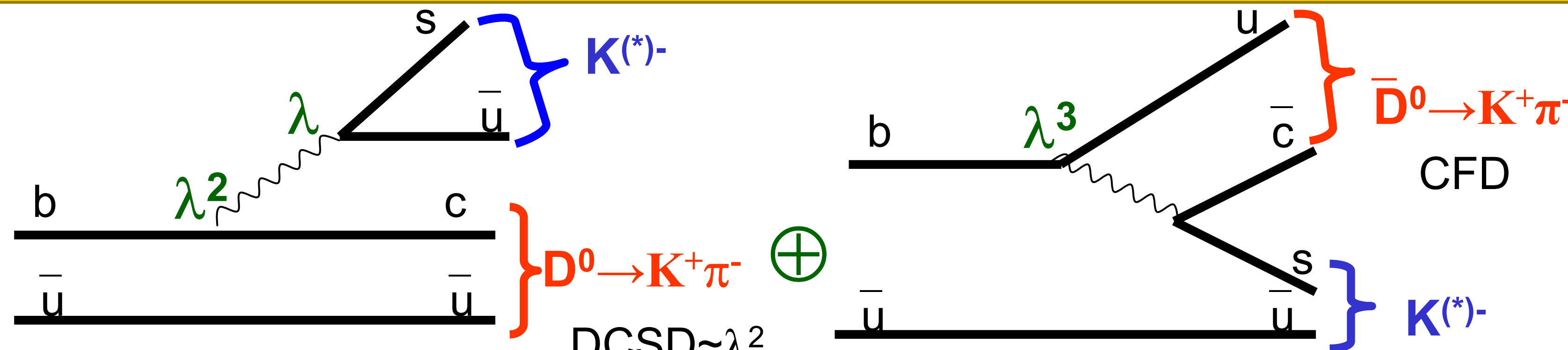
$$R_{CP\pm} \equiv \frac{\Gamma(B^- \to D^0_{CP\pm}K^-) + \Gamma(B^+ \to D^0_{CP\pm}K^+)}{2\Gamma(B^- \to D^0 K^-)} = 1 \pm 2 r_B \cos\gamma \ \cos\ \delta_B + r_B^2$$

$Br(B \to DK) \sim 10^{-4} \otimes Br(D \to f_{CP}) \sim 10^{-2}$

$r_B \sim 0.1$

} statisticaly limited

The Atwood-Dunietz-Soni Method (ADS)



$A(B^- \to D^0 K^-)$ $\quad$ $A(B^- \to \overline{D}{}^0 K^-) = r_B e^{-i\gamma} e^{i\delta} \,|\, A(B^- \to D^0 K^-) \,|$

both amplitudes of comparable size ⇒ big CPV, small effective Br

count B candidates with K^+K^- pairs

$$r_D = \frac{|A(D^0 \to K^+\pi^-)|}{|A(D^0 \to K^-\pi^+)|} = 0.060 \pm 0.003$$

Phys.Rev.Lett.91:171801,2003

$$A_{ADS} \equiv \frac{\Gamma(B^- \to [K^+\pi^-]K^-) - \Gamma(B^+ \to [K^-\pi^+]K^+)}{\Gamma(B^- \to [K^+\pi^-]K^-) + \Gamma(B^+ \to [K^-\pi^+]K^+)} = 2r_B r_D \sin\gamma \, \sin(\delta_B + \delta_D)/R_{ADS}$$

$$R_{ADS} \equiv \frac{\Gamma(B^- \to [K^+\pi^-]K^-) + \Gamma(B^+ \to [K^-\pi^+]K^+)}{\Gamma(B^- \to [K^-\pi^+]K^-) + \Gamma(B^+ \to [K^+\pi^-]K^+)} = 2r_B r_D \cos\gamma \, \cos(\delta_B + \delta_D) + r_B^2 + r_D^2$$

δ_D –D decay strong phase, unknown

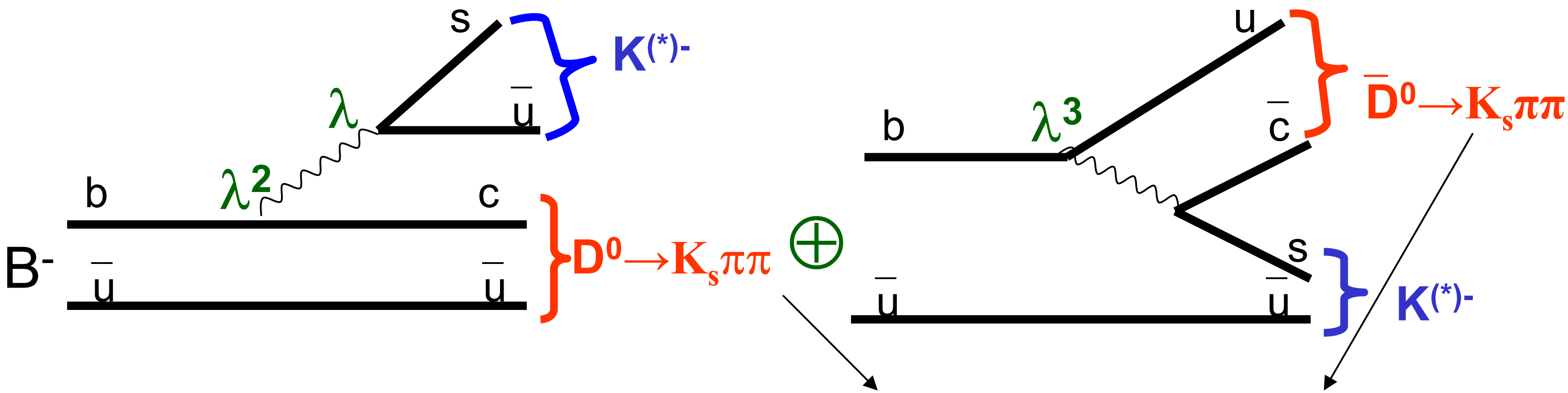
Bondar & Gershon
hep-ph/0409281

δ_D –differs by π for $D^* \to D\gamma$ & $D^* \to D\pi^0$

$R_{ADS}(D\pi) + R_{ADS}(D\gamma) = 2(r_B^2 + r_D^2)$

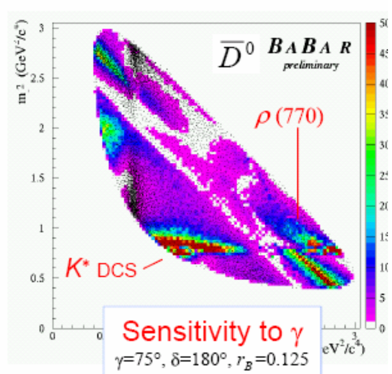
Dalitz analysis of $B^{\pm}\to D^{(*)0}K^{(*)\pm}$, $D^0\to K_S\pi^+\pi^-$

Giri, Grossman, Sofer & Zupan [Phys. Rev. D 68 (2003) 054018]

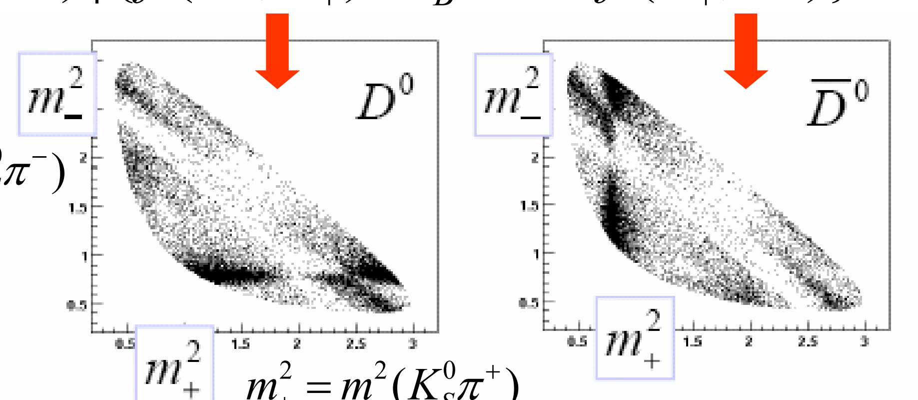


$$M_-(m_-^2,m_+^2)=|A(B^-\to D^0K^-)|\{f(m_-^2,m_+^2)+r_Be^{-i\gamma}e^{i\delta}f(m_+^2,m_-^2)\}$$

CP



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



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

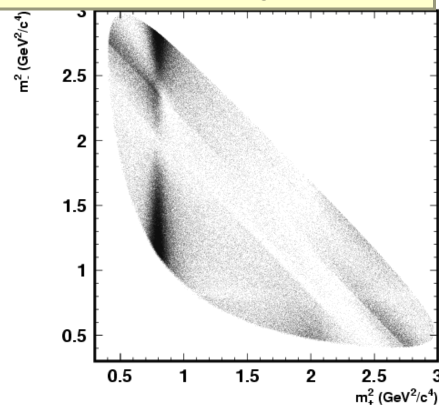
$$M_+(m_-^2,m_+^2)=|A(B^+\to \overline{D}^0K^+)|\{f(m_+^2,m_-^2)+r_Be^{i\gamma}e^{i\delta}f(m_-^2,m_+^2)\}$$

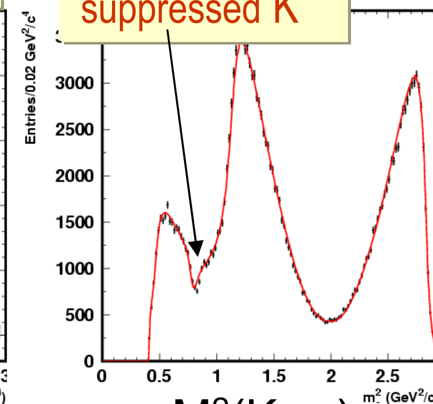
$D^0 \to K_S\pi^+\pi^-$ decay model

187k $D^{*-} \to D^0\pi^-$, $D^0 \to K_s\pi^+\pi^-$

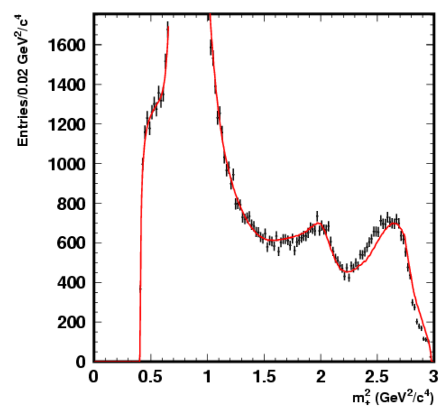
Intermediate state	Amplitude	Phase (°)	Fit fraction
$K_S\sigma_1$	1.57 ± 0.10	214 ± 4	9.8%
$K_S\rho^0$	1.0 (fixed)	0 (fixed)	21.6%
$K_S\omega$	0.0310 ± 0.0010	113.4 ± 1.9	0.4%
$K_S f_0(980)$	0.394 ± 0.006	207 ± 3	4.9%
$K_S\sigma_2$	0.23 ± 0.03	210 ± 13	0.6%
$K_S f_2(1270)$	1.32 ± 0.04	348 ± 2	1.5%
$K_S f_0(1370)$	1.25 ± 0.10	69 ± 8	1.1%
$K_S\rho^0(1450)$	0.89 ± 0.07	1 ± 6	0.4%
$K^*(892)^+\pi^-$	1.621 ± 0.010	131.7 ± 0.5	61.2%
$K^*(892)^-\pi^+$	0.154 ± 0.005	317.7 ± 1.6	0.55%
$K^*(1410)^+\pi^-$	0.22 ± 0.04	120 ± 14	0.05%
$K^*(1410)^-\pi^+$	0.35 ± 0.04	253 ± 6	0.14%
$K_0^*(1430)^+\pi^-$	2.15 ± 0.04	348.7 ± 1.1	7.4%
$K_0^*(1430)^-\pi^+$	0.52 ± 0.04	89 ± 4	0.43%
$K_2^*(1430)^+\pi^-$	1.11 ± 0.03	320.5 ± 1.8	2.2%
$K_2^*(1430)^-\pi^+$	0.23 ± 0.02	263 ± 7	0.09%
$K^*(1680)^+\pi^-$	2.34 ± 0.26	110 ± 5	0.36%
$K^*(1680)^-\pi^+$	1.3 ± 0.2	87 ± 11	0.11%
non-resonant	3.8 ± 0.3	157 ± 4	9.7%

13 distinct resonances + NR

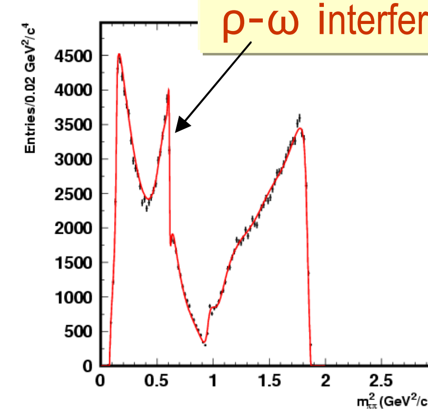




$M^2(K_S\pi^-)$



$M^2(K_S\pi^+)$



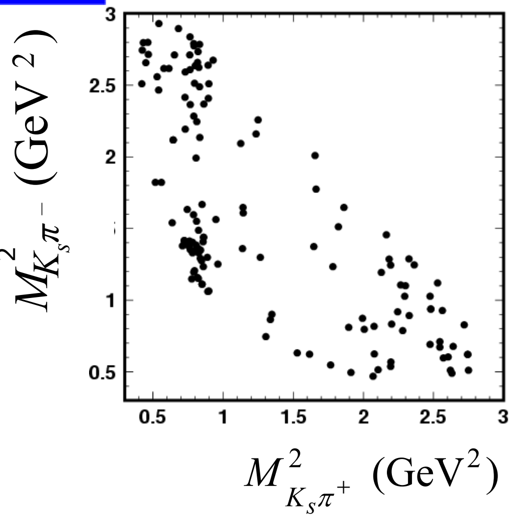
$M^2(\pi^-\pi^+)$

Isobar model (CLEO):

$$f(m_-^2, m_+^2) = \sum_r a_r e^{i\delta_r} A_r(m_-^2, m_+^2) + a_{nr} e^{i\delta_{nr}}$$

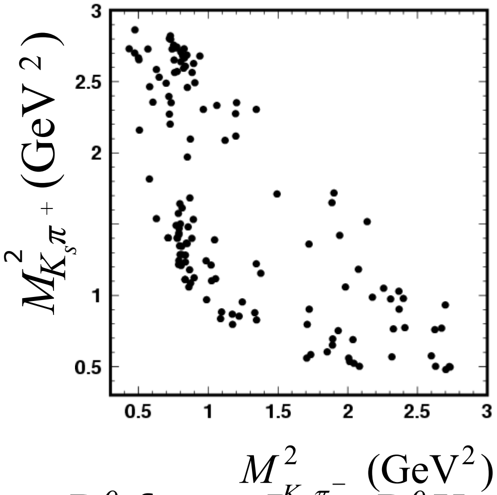
$B^{\pm} \to DK^{\pm}$, $D \to K_S \pi^+ \pi^-$ Dalitz plots

139 events



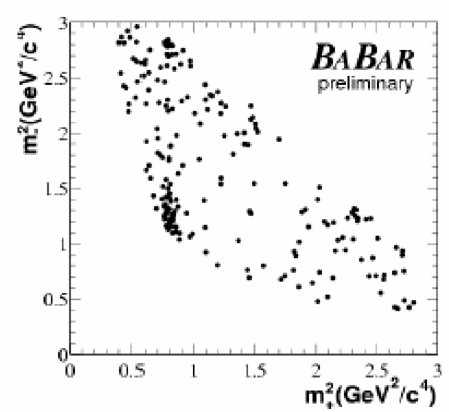
D^0 from $B^+ \to D^0 K^+$

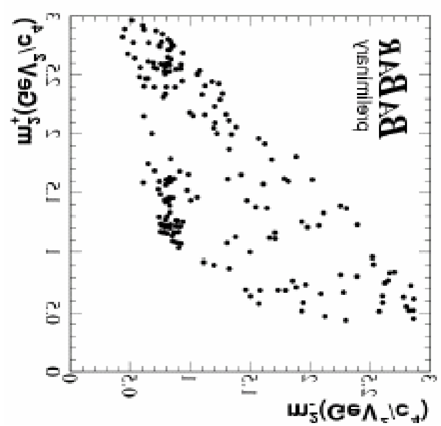
137 events



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

(π^+ and π^- interchanged)





Fit these D^0 Dalitz plots using unbinned maximum likelihood

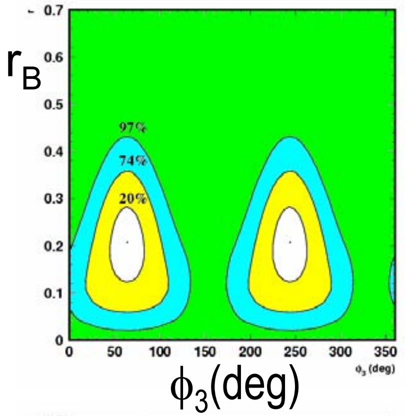
Free parameters: r_B, ϕ_3, δ

2-fold ambiguity:

ϕ_3, δ, $\cup$ $\phi_3+180°$, $\delta+180°$

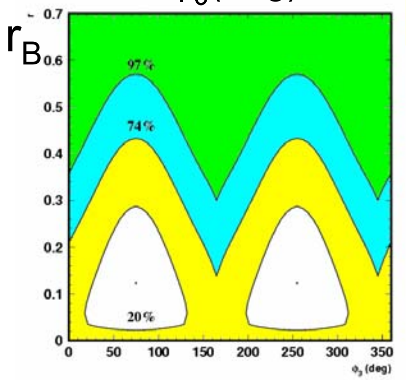
$B^{\pm} \rightarrow D^{(*)0}K^{(*)\pm}$ fit results (frequentist errors)

hep-ex/0411049



D^0K | **CPV signif. 94%**

$$\varphi_3 = [64 \pm 19 \pm 13(sys) \pm 11(model)]^{\circ}$$
$$r_B = 0.21 \pm 0.08 \pm 0.03(sys) \pm 0.04(model)$$
$$\delta_B = [157 \pm 19 \pm 11(sys) \pm 21(model)]^{\circ}$$



$D^{*0}K$ | **CPV signif. 38%**

$$\varphi_3 = [75 \pm 57 \pm 12(sys) \pm 11(model)]^{\circ}$$
$$r_B = 0.12^{+0.16}_{-0.11} \pm 0.02(sys) \pm 0.04(model)$$
$$\delta_B = [321 \pm 57 \pm 11(sys) \pm 21(model)]^{\circ}$$

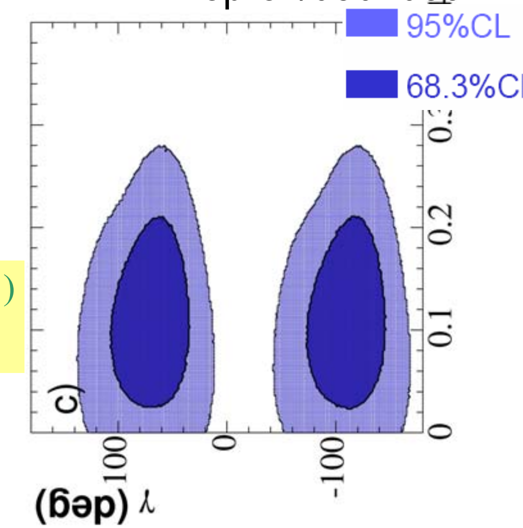
hep-ex/0504013

D^0K^* | **CPV signif. 63%**

$$\varphi_3 = [112 \pm 35 \pm 8(sys) \pm 21(model) \pm 8(nr)]^{\circ}$$
$$r_B = 025^{+0.17}_{-0.18} \pm 0.09(sys) \pm 0.04(model) \pm 0.08(nr)$$
$$\delta_B = [353 \pm 35 \pm 8(sys) \pm 21(model) \pm 49(nr)]^{\circ}$$

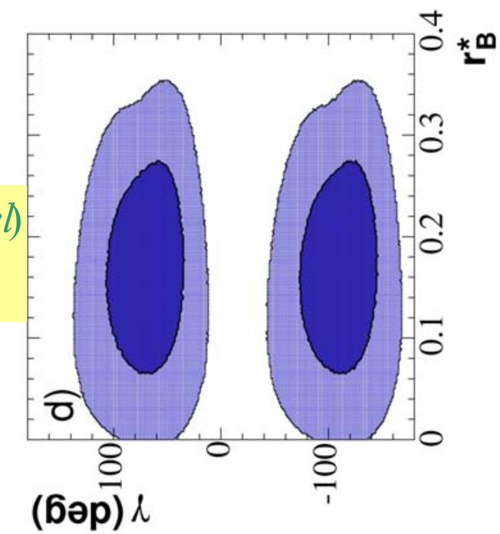
hep-ex/0504039

D^0K



$$r_B = 0.118 \pm 0.079 \pm 0.034(sys)^{+0.036}_{-.034}(model)$$
$$\delta_B = [104 \pm 45^{+17}_{-21}(sys)^{+16}_{-24}(model)]^{\circ}$$

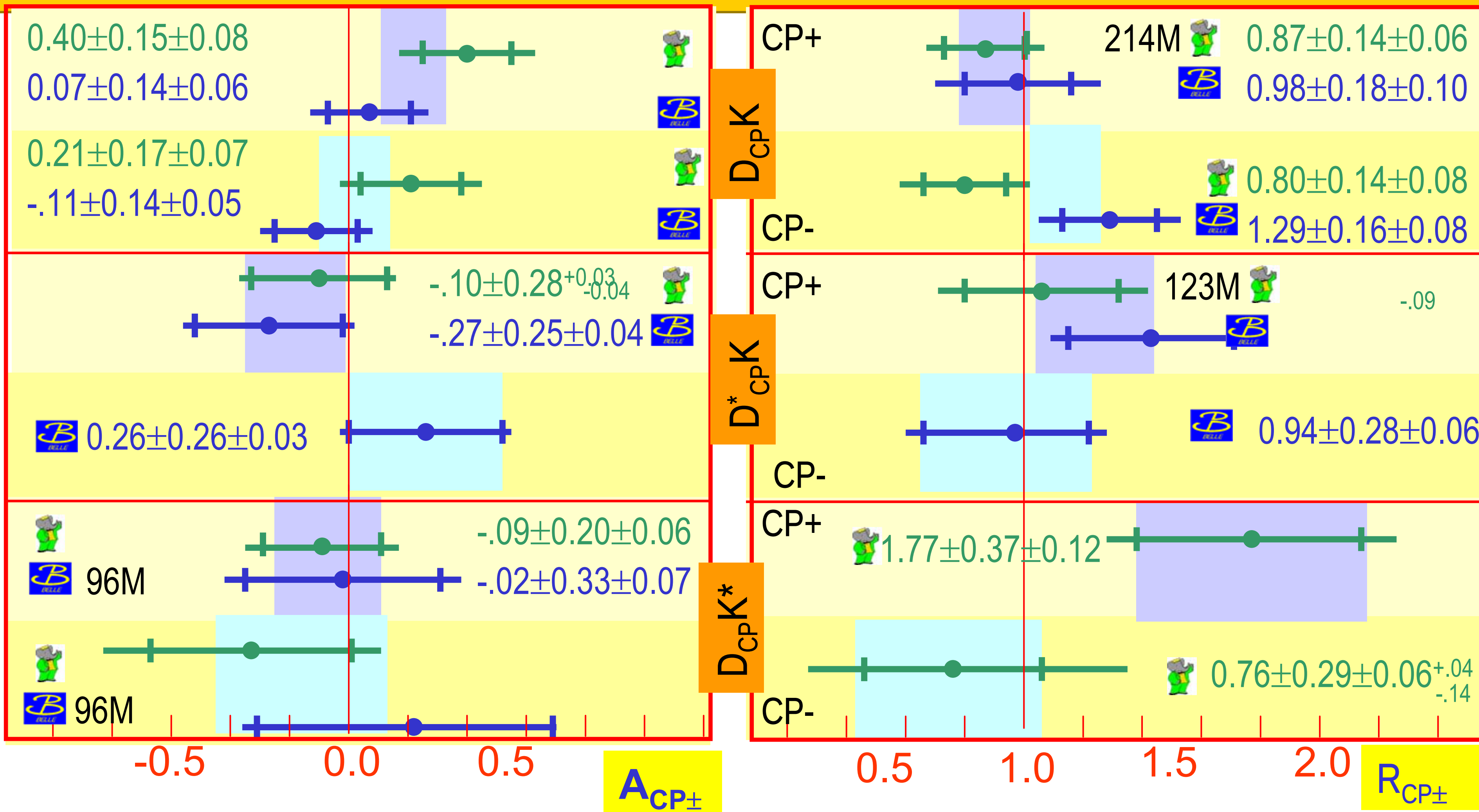
$D^{*0}K$



$$r^*_B = 0.169 \pm 0.096^{+0.030}_{-0.026}(sys)^{+0.029}_{-.026}(model)$$
$$\delta^*_B = [296 \pm 41^{+14}_{-12}(sys) \pm 15(model)]^{\circ}$$

$$\gamma = [70 \pm 31^{+12}_{-10}(sys)^{+14}_{-11}(model)]^{\circ}[12^{\circ}, 137^{\circ}]$$

GLW-results



$\sin^2(\Phi_3) \leq R_{CP\pm}$

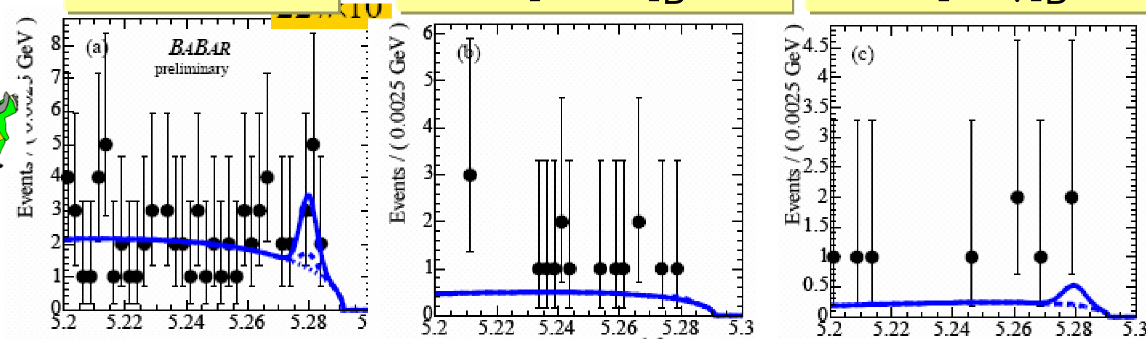
$0.5*(R_{CP+} + R_{CP-}) = 1 + r_B^2$

Loose bounds on r_B

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

$B^+ \to D^0 K^+$ | $B^+ \to [D^0\pi^0]_{D^*} K^+$ | $B^+ \to [D^0\gamma]_{D^*} K^+$

hep-ex/0408028



$N = 4.7^{+4.0}_{-3.2}$ $\quad R_{ADS} = 0.013^{+0.011}_{-0.009}$

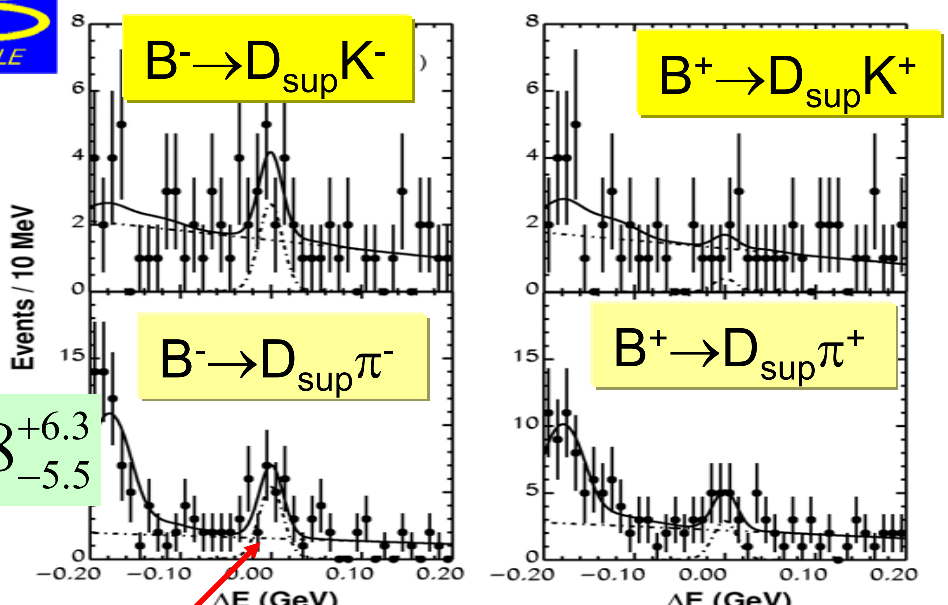
$N = -0.2^{+1.3}_{-0.8}$ $\quad R_{ADS} = -0.001^{+0.010}_{-0.006}$

$N = 1.2^{+2.1}_{-1.4}$ $\quad R_{ADS} = 0.011^{+0.019}_{-0.013}$

$r_B < 0.23$ DK (90%CL)

$r_B < 0.16$ D*K

hep-ex/0412025



$18.8^{+6.3}_{-5.5}$

First observation

$$R_{DK} = 2.3^{+1.6}_{-1.4} \pm 0.1(sys) \times 10^{-2}$$

$$A_{DK} = .88\ ^{+0.77}_{-0.62} \pm 0.1(sys)$$

$$R_{D\pi} = 3.5^{+1.0}_{-0.9} \pm 0.2(sys) \times 10^{-3}$$

$$A_{D\pi} = .30\ ^{+0.29}_{-0.25} \pm 0.06(sys)$$

$r_B < 0.27$ (90%CL)

Constraints on $\phi_3(\gamma)$ from $B \to DK$

BELLE

Dalitz analysis

$$\phi_3 = [68^{+14}_{-15} \pm 13(sys) \pm 11(model)]^\circ$$

$$[22^\circ, 113^\circ]$$

$$r_B(D^0K) = 0.21 \pm 0.08 \pm 0.03 \pm 0.04$$

$$r_B(D^{*0}K) = 0.12^{+0.16}_{-0.11} \pm 0.02 \pm 0.04$$

$$r_B(D^0K^*) = 0.24^{+0.17}_{-0.18} \pm 0.09 \pm 0.04 \pm 0.08$$

Dalitz analysis

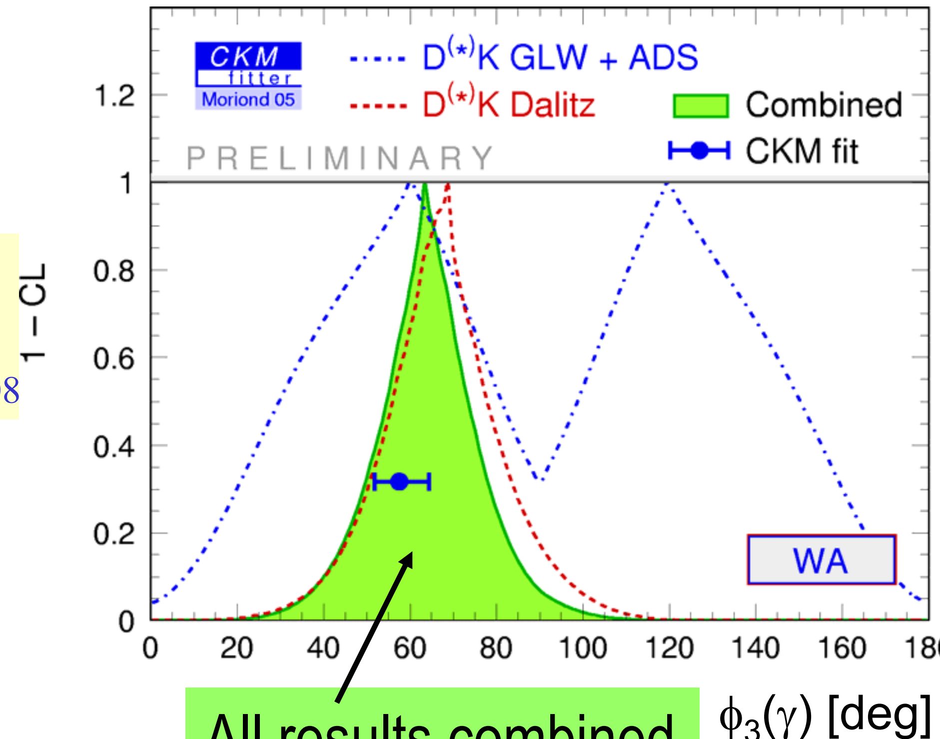
$$\gamma = [70 \pm 31^{+12}_{-10}(sys)^{+14}_{-11}(model)]^\circ$$

$$[12^\circ, 137^\circ]$$

$$r_B(D^0K) = 0.118^{+0.079}_{-0.096} \pm 0.034^{+0.036}_{-0.034}$$

$$r_B(D^{*0}K) = 0.169 \pm 0.096^{+0.03}_{-0.028}{}^{-0.029}_{-0.026}$$

CKM fitter Moriond'05



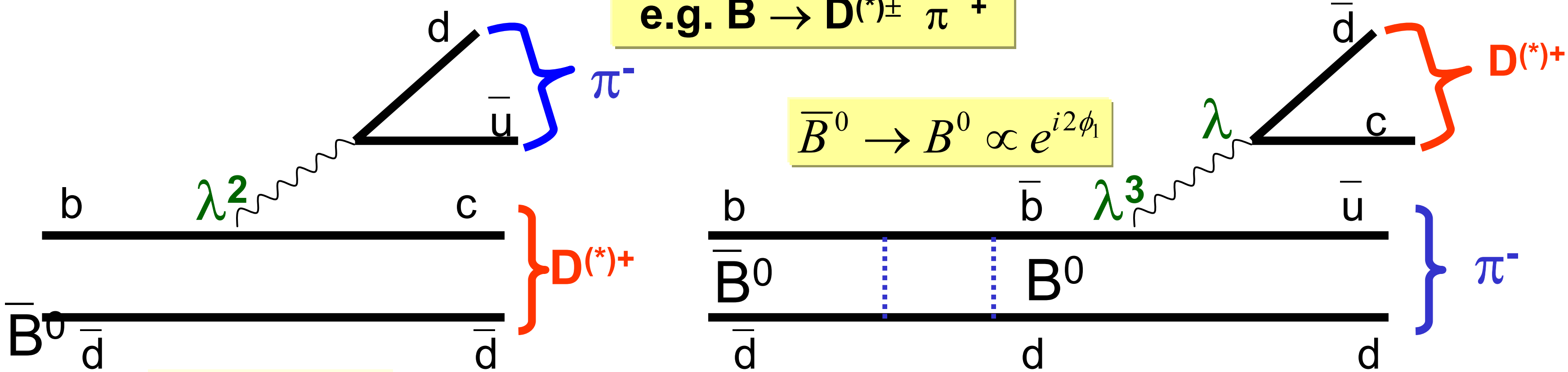
All results combined

Measurements of sin(2β+γ)/(2ϕ_1+ϕ_3)

I. Dunietz, Phys.Lett. B 427, 179(1998)

Use *interference* $b \to c\,\bar{u}\,d \oplus b \to u\,\bar{c}\,d$ instead of $b \to c\,\bar{u}\,s \oplus b \to u\,\bar{c}\,s$

e.g. $B \to D^{(*)\pm}\pi^{\mp}$



CFD~λ²

DCSD~λ⁴

$$P(B^0 \to D^{*\mp}\pi^{\pm}, \Delta t) \propto 1 \pm C\cos(\Delta m \Delta t) - S^{\mp}\sin(\Delta m \Delta t)$$

$$P(\bar{B}^0 \to D^{*\mp}\pi^{\pm}, \Delta t) \propto 1 \mp C\cos(\Delta m \Delta t) + S^{\mp}\sin(\Delta m \Delta t)$$

$$C = (1 - R^2_{D^*\pi})/(1 + R^2_{D^*\pi}) \approx 1$$

$$S^{\pm} = -2R_{D^*\pi}\sin(2\phi_1 + \phi_3 \pm \delta_{D^*\pi})$$

$$R_{D^*\pi} = \frac{|suppressed|}{|favoured|} \approx 0.02$$

$$a^*_{\pi} \equiv -\frac{S^+ + S^-}{2} \cong 2R_{D^*\pi}\sin(2\phi_1 + \phi_3)\cos\delta$$

$$c^*_{\pi} \equiv -\frac{S^+ - S^-}{2} \cong 2R_{D^*\pi}\cos(2\phi_1 + \phi_3)\sin\delta$$

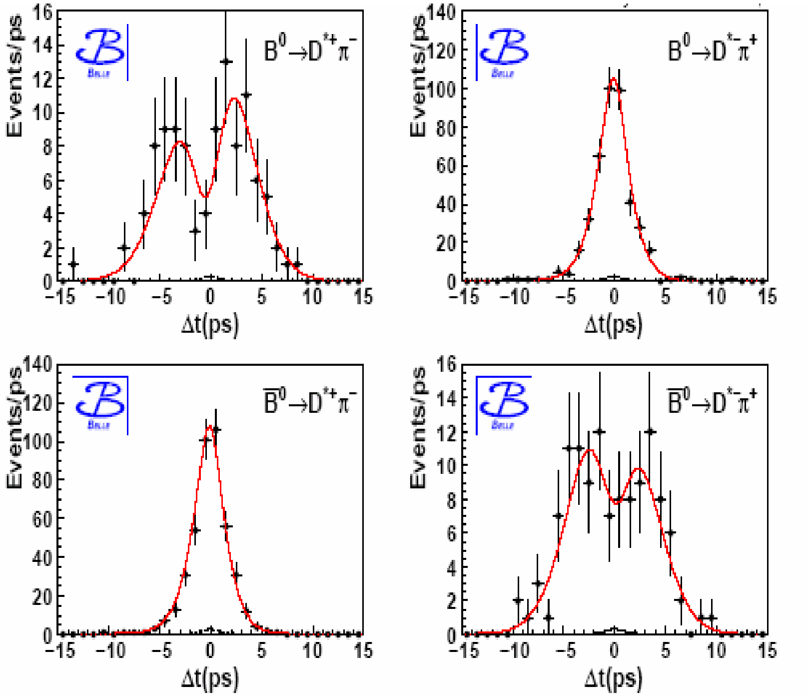
Very small asymmetry offset by copious statistics

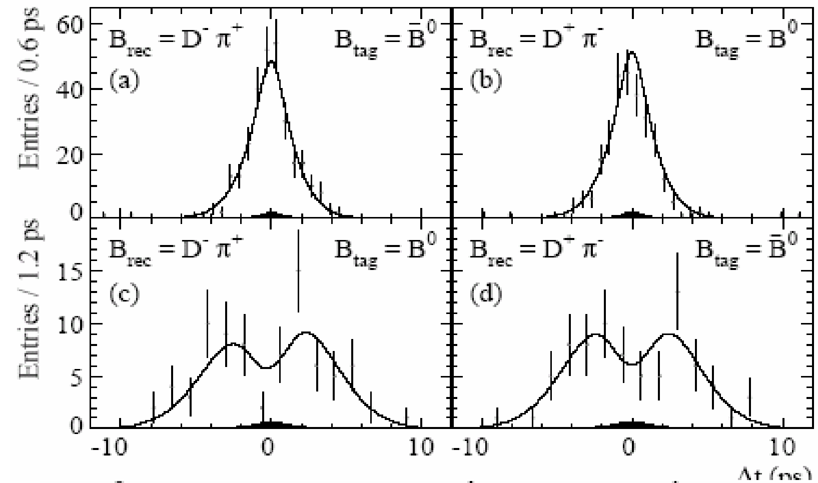
$B^0 \to D^{(*)-} \pi^+$ time dependent decay rates

152M $\bar{B}B$
hep-ex/0308048

exclusive reconstruction

110M $\bar{B}B$
hep-ex/0408059





$D^\pm \pi^\mp$ (all tag)	7611 ± 97	91%
$D^{*\pm} \pi^\mp$ (all tag)	7068 ± 89	95%
$D^\pm \rho^\mp$ (all tag)	4400 ± 79	88%

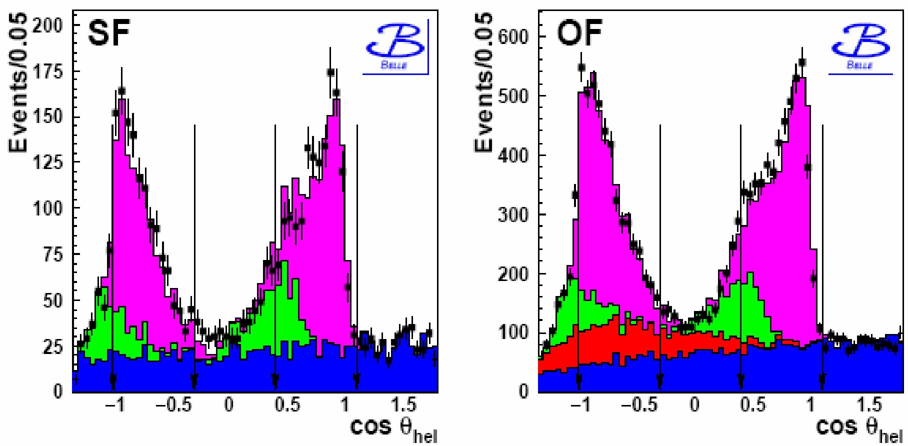
$D^*\pi$ 7763 events, purity 96%

$D\pi$ 9351 events, purity 91%

$B^0 \to D^{*-} \pi^+$ partial reconstruction

$B^+ \to D^{*-}\pi^+$ partial reconstruction :

- The decay products of the ***D*** are not reconstructed, but the topology of the prompt ("fast") pion and that from ***$D^{*+} \to D^- \pi^+$*** decay ("slow") and 2-body kinematics allow to separate signal from background.
- The presence of a high momentum lepton in the event suppress continuum background.



Mode	Data	Signal	$D^*\rho$	Corr. bkg	Uncorr. bkg	S/N
SF ($\pi_f^\pm \ell_{tag}^\pm$)	2823	1908	311	—	637	67%
OF ($\pi_f^\pm \ell_{tag}^\mp$)	10078	6414	777	928	1836	64%

Increase efficiency ,

worse purity

helicity angle calculated with π_{slow}

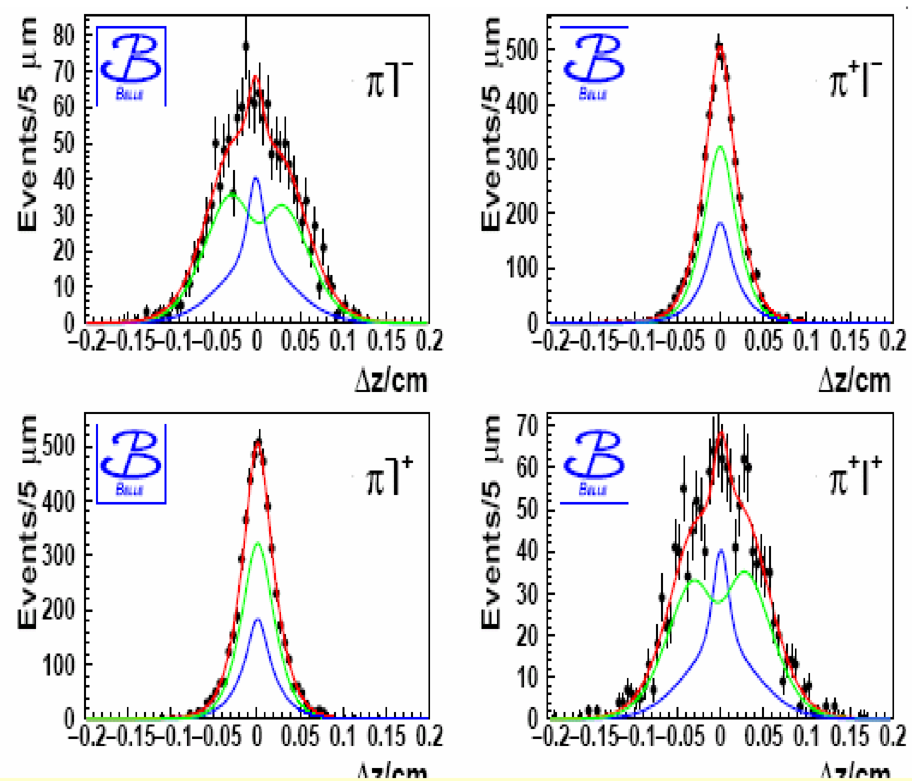
Belle $B^0 \to D^{(*)-} \pi^+$ results

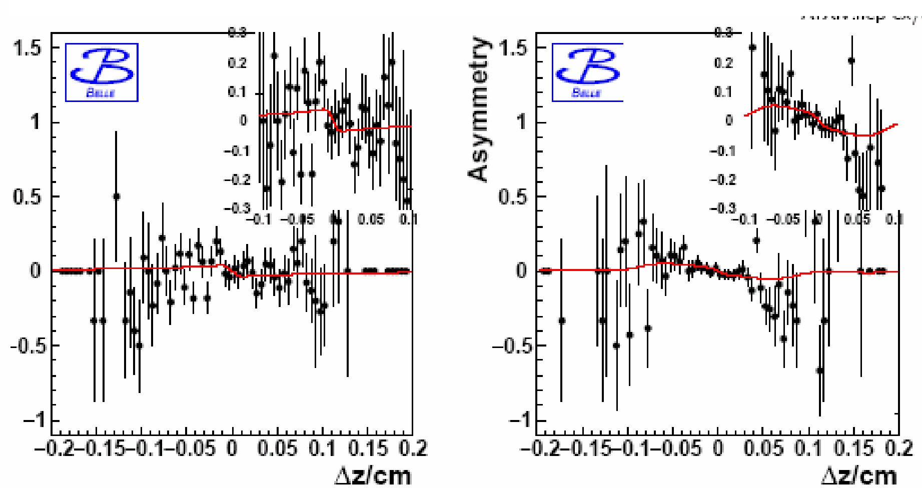
hep-ex/0408106

152M $\bar{B}B$

partial reconstruction

Lepton tag





$$\mathcal{A}^{SF} = \frac{N_{\pi^- \ell^-} - N_{\pi^+ \ell^+}}{N_{\pi^- \ell^-} + N_{\pi^+ \ell^+}} \qquad \mathcal{A}^{OF} = \frac{N_{\pi^+ \ell^-} - N_{\pi^- \ell^+}}{N_{\pi^+ \ell^-} + N_{\pi^- \ell^+}}$$

2823 (67%) Same Flavour (mixed)

10078 (64%) Opposite Flavour (unmixed)

$S^+ = +0.035 \pm 0.041 \pm 0.018$

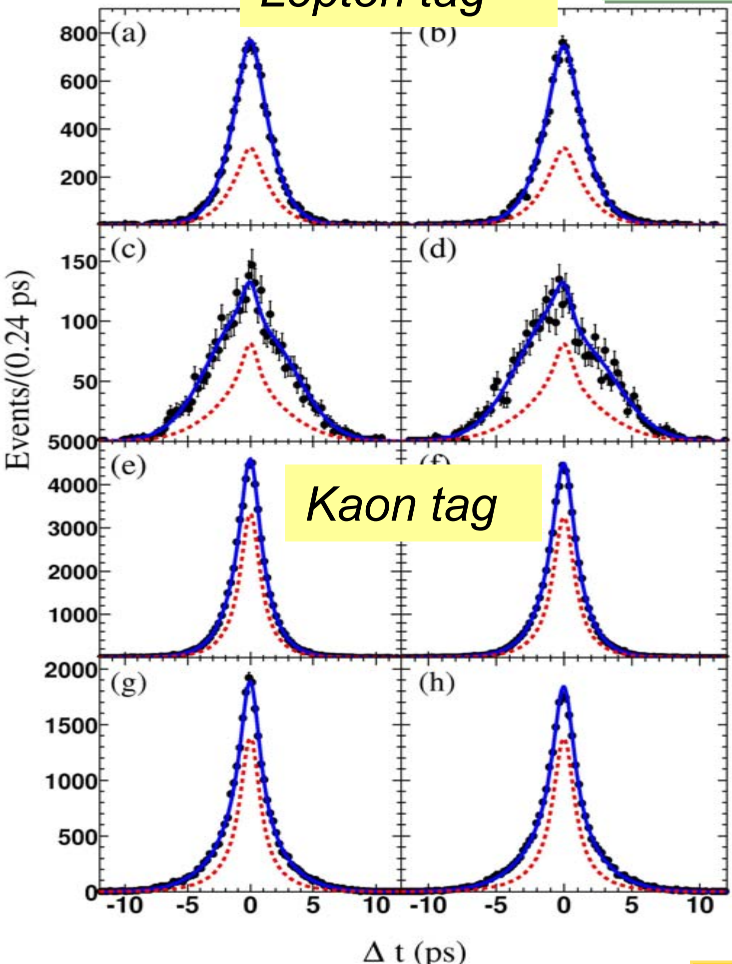
$S^- = +0.025 \pm 0.041 \pm 0.018$

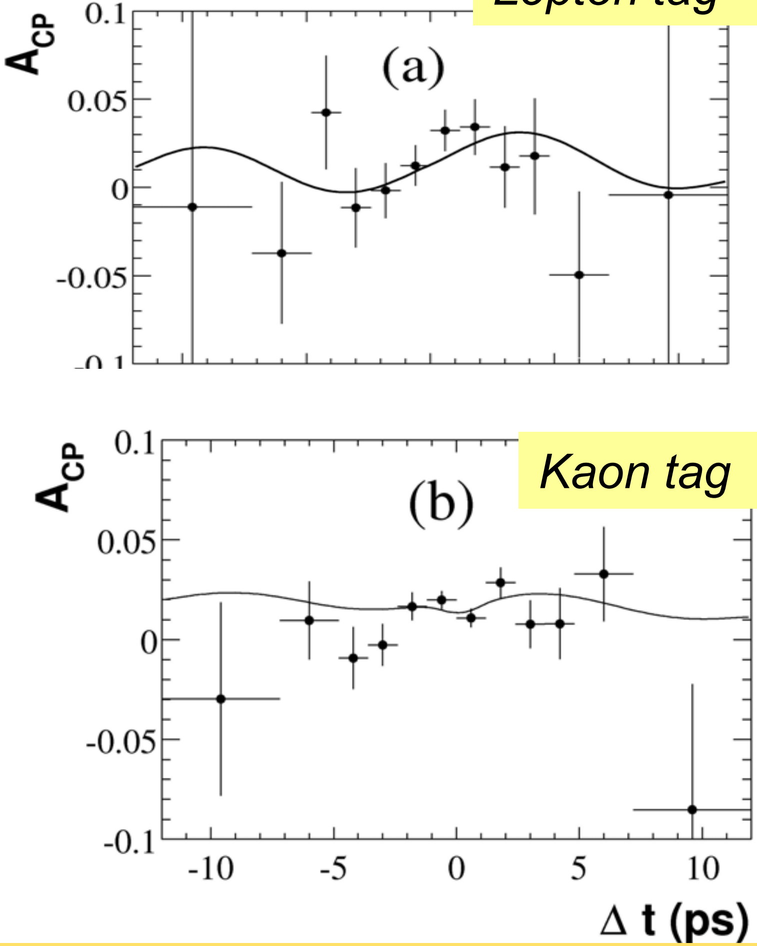
$B^0 \to D^{(*)-} \pi^+$

hep-ex/0504035

232M $\bar{B}B$

partial reconstruction



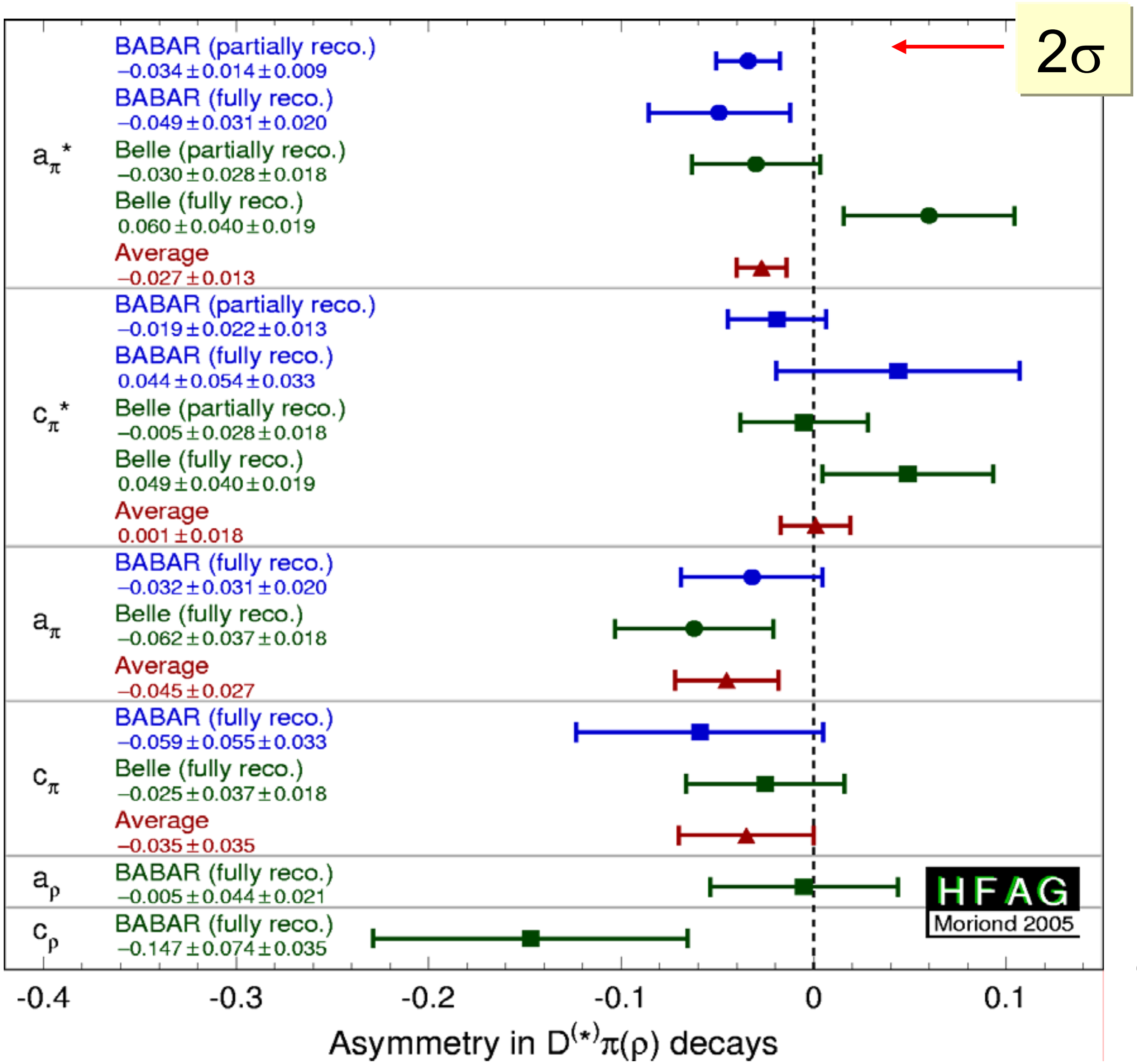


18705 (54%) , lepton tag

70584 (31%), Kaon tag

$$2r\sin(2\beta+\gamma)\cos\delta = -0.034 \pm 0.014 \pm 0.009$$

Asymmetry parameters in $B \to D^{(*)}\pi(\rho)$



Other modes can be used, e.g.: $B^0 \to D^{*\mp} a_1^\pm$

$B^0 \to D^{**\mp}\pi^\pm$

Summary and outlook

- **Summary:** direct measurements of the 3 angles

  of the Unitarity Triangle from B-factories;

  ϕ_2/α and ϕ_3/γ consistent with the CKM fits

- **Outlook:**
  - Other relevant decay modes for ϕ_3/γ and $2\phi_1+\phi_3/2\beta+\gamma$ have been observed
  - More data

Good prospects for Super B-factory …

Backup slides

outlook

➢ Outlook:

- Other relevant decay modes for ϕ_3/γ and $2\phi_1+\phi_3/2\beta+\gamma$ e.g.:

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

both amplitudes are color suppressed, expect r ~ 0.4

$$Br(B^0 \to \overline{D}^0 K^{*0}) = (3.08 \pm 0.56 \pm 0.31(sys)) \times 10^{-5}$$
$$Br(B^0 \to \overline{D}^0 K^0) = (3.72 \pm 0.65 \pm 0.37(sys)) \times 10^{-5}$$

Consistent with old results:
PRL 90, 141802 (2003)

$B^0 \to D^{(*)\pm} K^0 \pi^{\mp}$

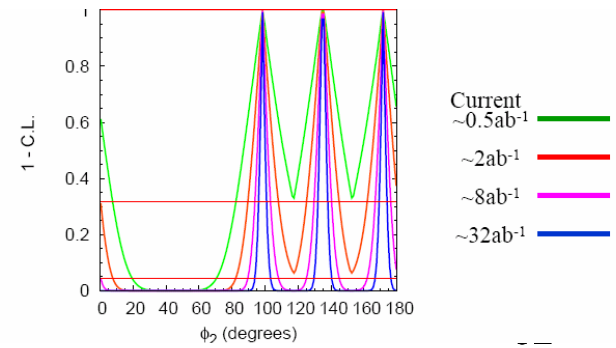
both amplitudes are color allowed

Time dep.Dalitz plot analysis

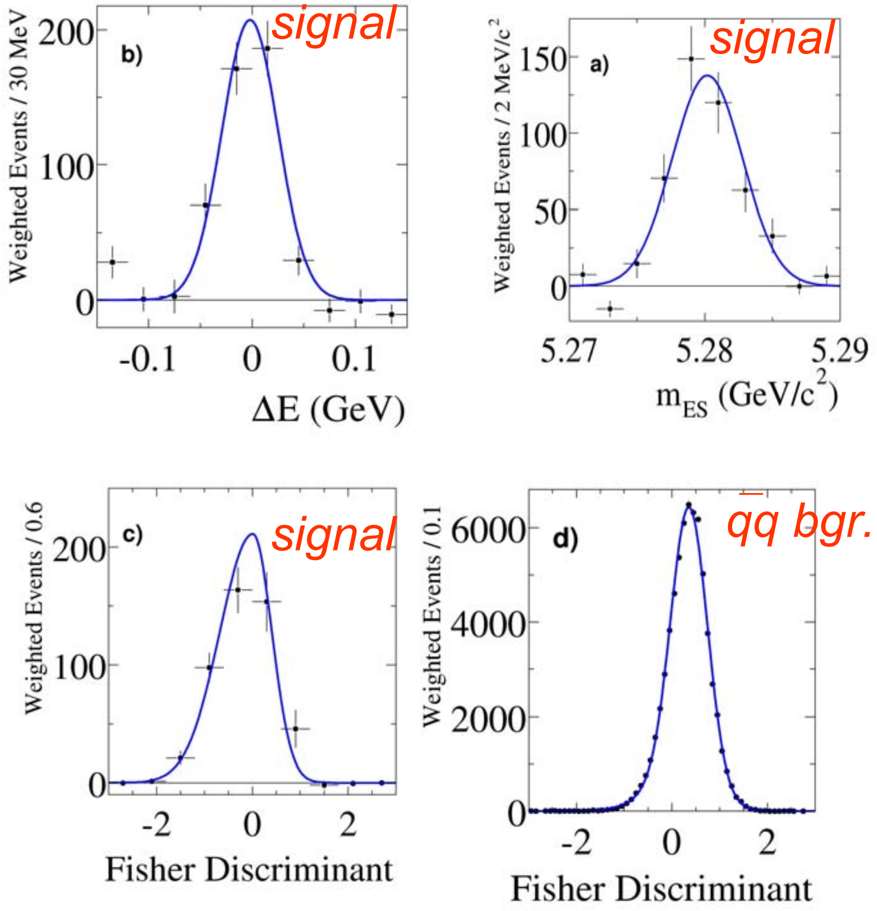
$$\mathcal{B}(B^0 \to D^{\mp} K^0 \pi^{\pm}) = (4.9 \pm 0.7_{\rm stat} \pm 0.5_{\rm syst}) \times 10^{-4}$$
$$\mathcal{B}(B^0 \to D^{*\mp} K^0 \pi^{\pm}) = (3.0 \pm 0.7_{\rm stat} \pm 0.3_{\rm syst}) \times 10^{-4}$$

- M

Extrapolation for ϕ_2/α



Event weighted distributions



CP FIT

$$L_i = (1-f_{ol})\int d\Delta t' \{(f_{\pi\pi}P_{\pi\pi} + f_{K\pi}P_{K\pi})R_{sig}(\Delta t - \Delta t') + f_{\bar{q}q}P_{\bar{q}q}R_{\bar{q}q}(\Delta t - \Delta t')\} + f_{ol}P_{ol}(\Delta t)$$

Unbinned maximum likelihood fit

$$L_{tot} = \Pi L_i(\Delta t, q)$$

$\pi\pi$

$$P_{\pi\pi}(\Delta t, q; A_{\pi\pi}, S_{\pi\pi}) = \frac{\exp(-|\Delta t|/\tau_{B^0})}{4\tau_{B^0}}\{1 - q\Delta w + q(1-2w)[A_{\pi\pi}\cos\Delta m\Delta t + S_{\pi\pi}\sin\Delta m\Delta t]\}$$

from data

2 fit parameters

$K\pi$

$P_{K\pi}(\Delta t, q)$:

$$S_{K\pi} = 0, A_{K\pi} = A_{K\pi}^{eff} = \frac{A_{K\pi}^{CP} + A_\varepsilon}{1 + A_{K\pi}^{CP}A_\varepsilon},$$

$$A_\varepsilon = \frac{p(K^-\to\pi^-)\varepsilon_{\pi^+} - p(K^+\to\pi^+)\varepsilon_{\pi^-}}{p(K^-\to\pi^-)\varepsilon_{\pi^+} + p(K^+\to\pi^+)\varepsilon_{\pi^-}}$$

HFAG'04

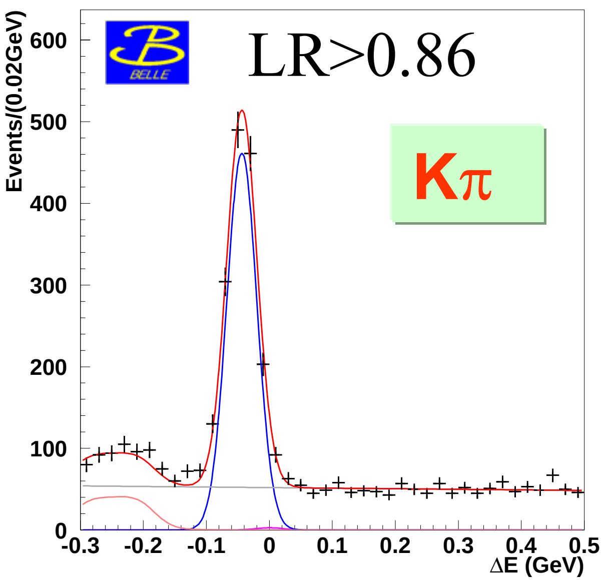
$$A_{K\pi}^{CP} = -0.109 \pm 0.019$$

$\bar{q}q$

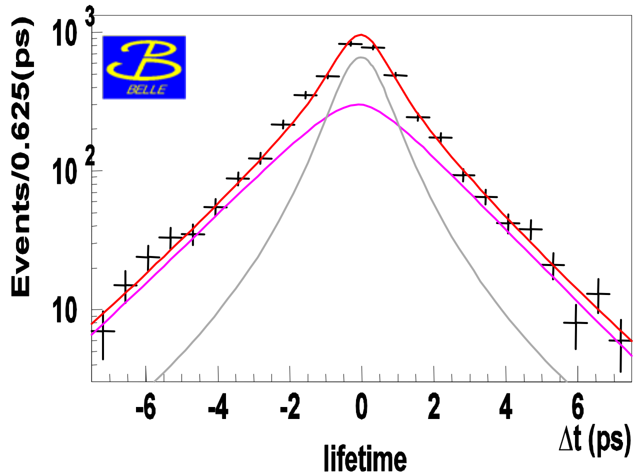
$P_{\bar{q}q}(\Delta t, q)$:

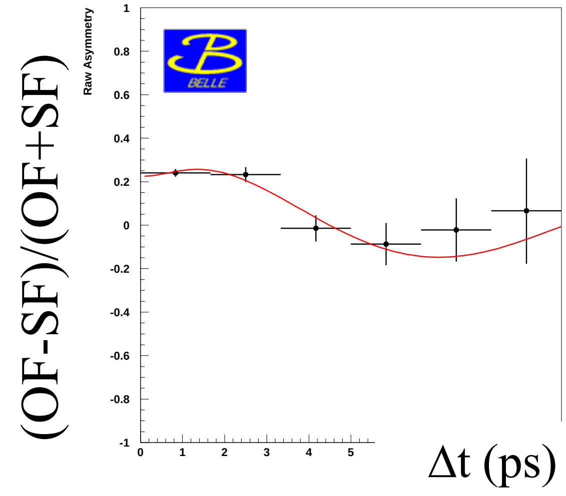
from sideband

Validity checks



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





$\tau_{B^0} = 1.52 \pm 0.04\, ps$ $\Delta m = 0.46 \pm 0.03\, ps^{-1}$

$\tau_{B^0} = 1.50 \pm 0.07\, ps$ ππ *sample*

$\tau_{B^0} = 1.60 \pm 0.04\, ps, \Delta m_d = 0.523 \pm 0.028\, ps^{-1}$

WA $\tau_{B^0} = 1.536 \pm 0.014\, ps, \Delta m_d = 0.502 \pm 0.007\, ps^{-1}$

.... many other checks

SYSTEMATICS

	$S_{\pi\pi}$	$C_{\pi\pi}$
B-flavor identification	±0.005	±0.015
τ_{B0} and Δm_d	±0.001	±0.004
PDF parameters	±0.017	±0.018
Potential bias	±0.013	±0.007
SVT alignment	±0.010	±0.002
Beam spot	±0.010	±0.010
Tag-side interference	±0.008	±0.023
total	±0.027	±0.035

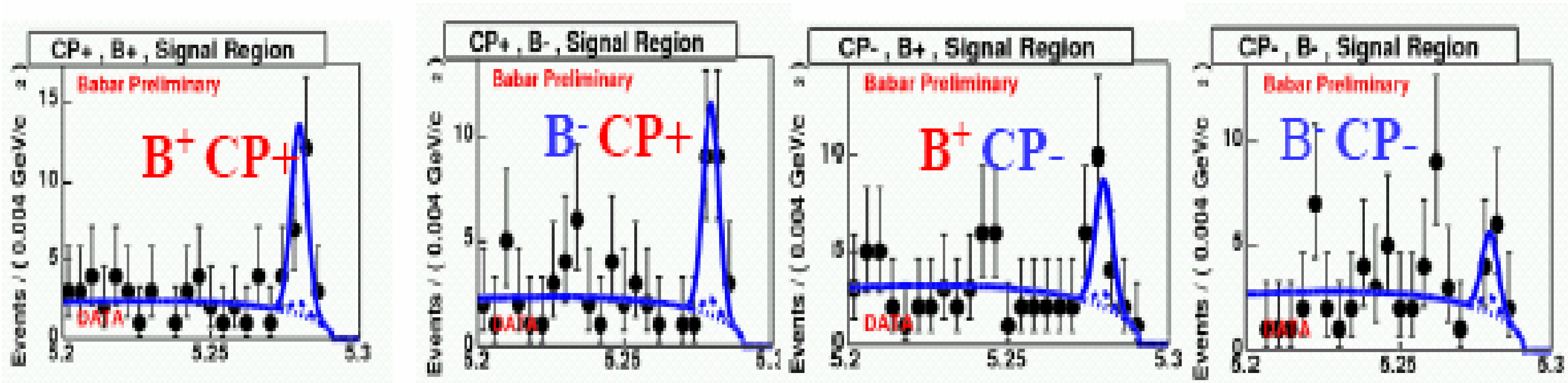
	$S_{\pi\pi}$	$A_{\pi\pi}$
wrong tag	±0.01	±0.01
physics param.	<0.01	±0.01
resolution func	±0.04	±0.01
bkg Dt shape	<0.01	<0.01
event fraction	±0.02	±0.04
fit bias	±0.01	±0.01
vertexing	±0.04	$^{+0.03}_{-0.01}$
tag side interfere	±0.01	$^{+0.02}_{-0.04}$
total	±0.06	±0.06

GLW: $B^{\pm} \to D_{CP} K^{(*)\pm}$

hep-ex/0408069

$D^0_{CP} K^{*-} (K^{*-} \to K_S \pi^-)$

$K_S \varphi$, $K_S \omega$, $K_S \pi^0$



CP+ 34.4±6.9

$N_{BB}=227\ 10^6$

CP− 15.1±5.8

$B^{\pm} \to D_{CP} K^{*\pm}$

R_{CP+} = 1.73±0.36(*stat.*) ±0.12(*syst.*) R_{CP-} = 0.76±0.29(*stat.*) ±0.06(*syst.*)$^{+0.04}_{-0.14}$

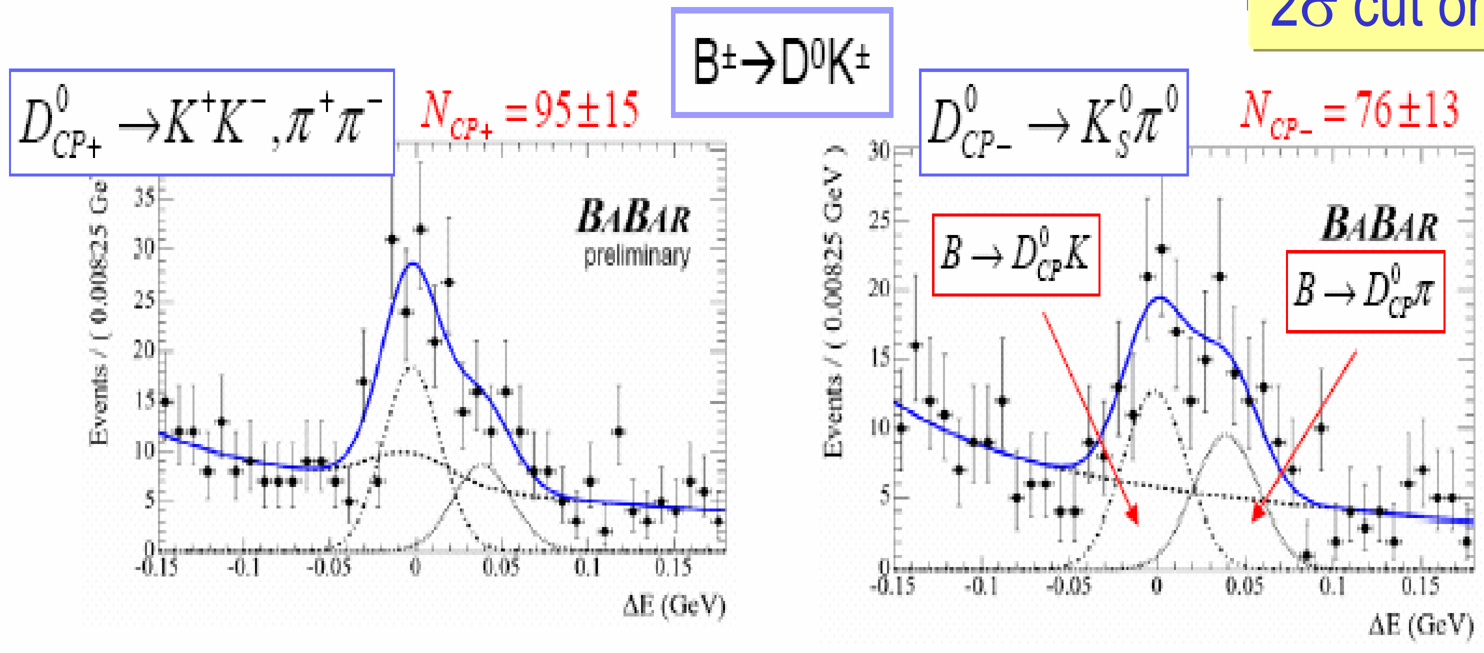
A_{CP+} = -.09±0.20(*stat.*) ±0.06(*syst.*) A_{CP-} = -.33±0.34(*stat.*) ±0.10(*syst.*)

$(+.15\pm0.1)(A_{CP-}-A_{CP+})$

GLW: $B^{\pm} \to D_{CP} K^{(*)\pm}$

hep-ex/0408082

2σ cut on θ_c



$B^{\pm} \to D_{CP} K^{\pm}$
214M

R_{CP+} = 0.87±0.14(*stat.*) ±0.06(*syst.*) R_{CP-}= 0.80±0.14(*stat.*) ±0.08(*syst.*)

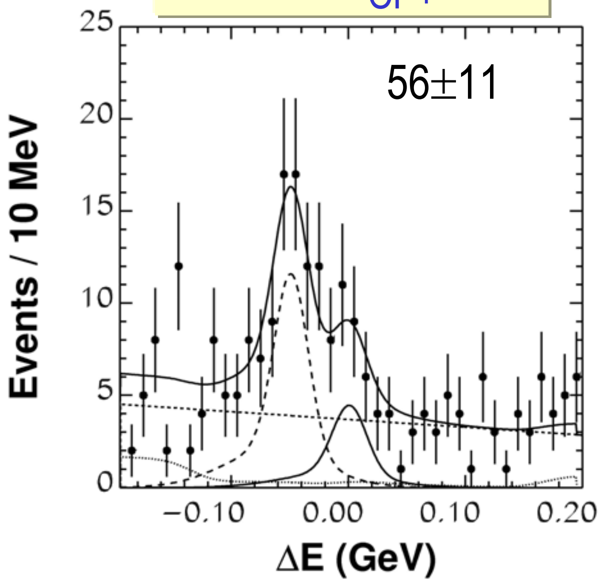
A_{CP+} = 0.40±0.15(*stat.*) ±0.08(*syst.*) A_{CP-}= 0.21±0.17(*stat.*) ±0.07(*syst.*)

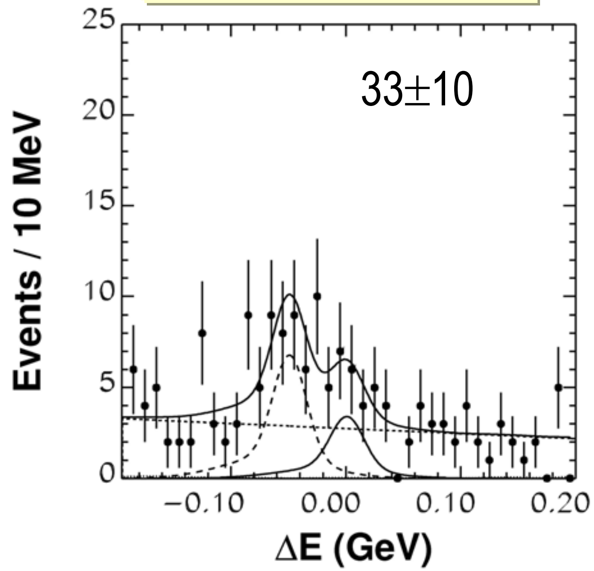
GLW: $B^{\pm} \rightarrow D^{*}_{CP} K^{\pm}$

Belle-CONF-0443

$B^{\pm} \rightarrow D^{*0}_{CP+} K^{\pm}$

$B^{\pm} \rightarrow D^{*0}_{CP-} K^{\pm}$ — $K_S\varphi$, $K_S\omega$, $K_S\pi^0$, $K_S\eta$





5.6σ   4.5σ

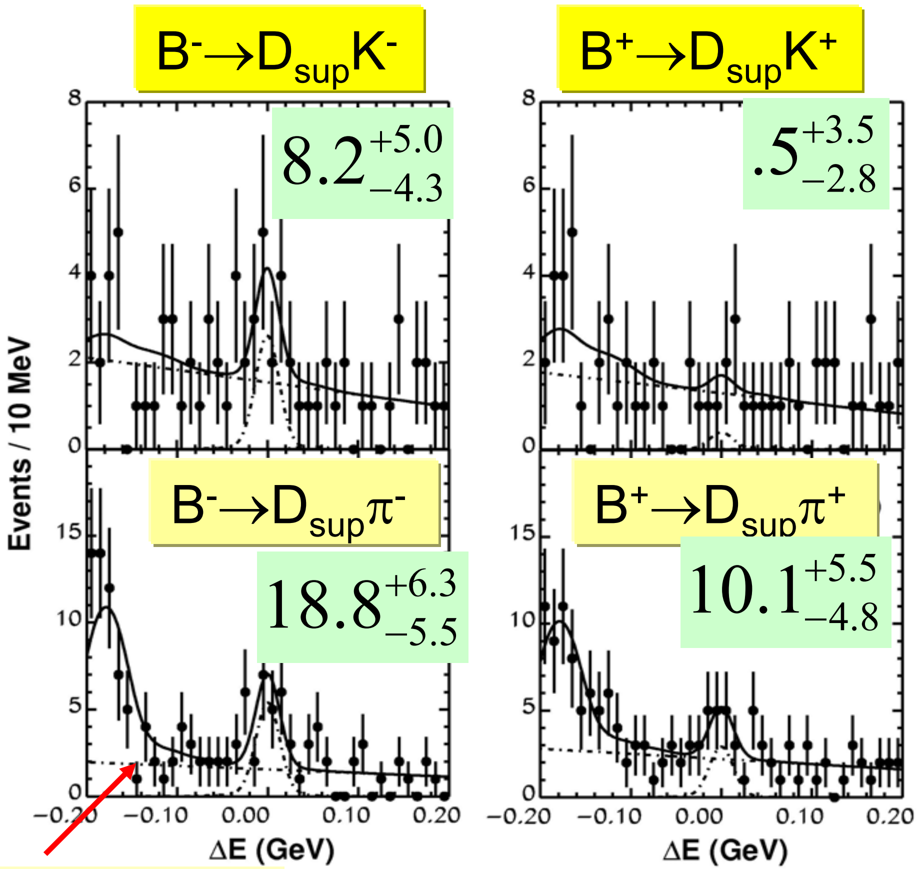
$B^{\pm} \rightarrow D^{*0}_{CP} K^{\pm}$

$D^{*0} \rightarrow D_{CP} \pi^0$

R_{CP+} = 1.43±0.28(*stat.*) ±0.06(*syst.*) R_{CP-} = 0.94±0.28(*stat.*) ±0.06(*syst.*)

A_{CP+} = -.27±0.25(*stat.*) ±0.04(*syst.*) A_{CP-} = 0.26±0.26(*stat.*) ±0.03(*syst.*)

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



First observation

$$A_{DK} = .88^{+0.77}_{-0.62} \pm 0.1(sys)$$

$$R_{DK} = 2.3^{+1.6}_{-1.4} \pm 0.1(sys) \times 10^{-2}$$

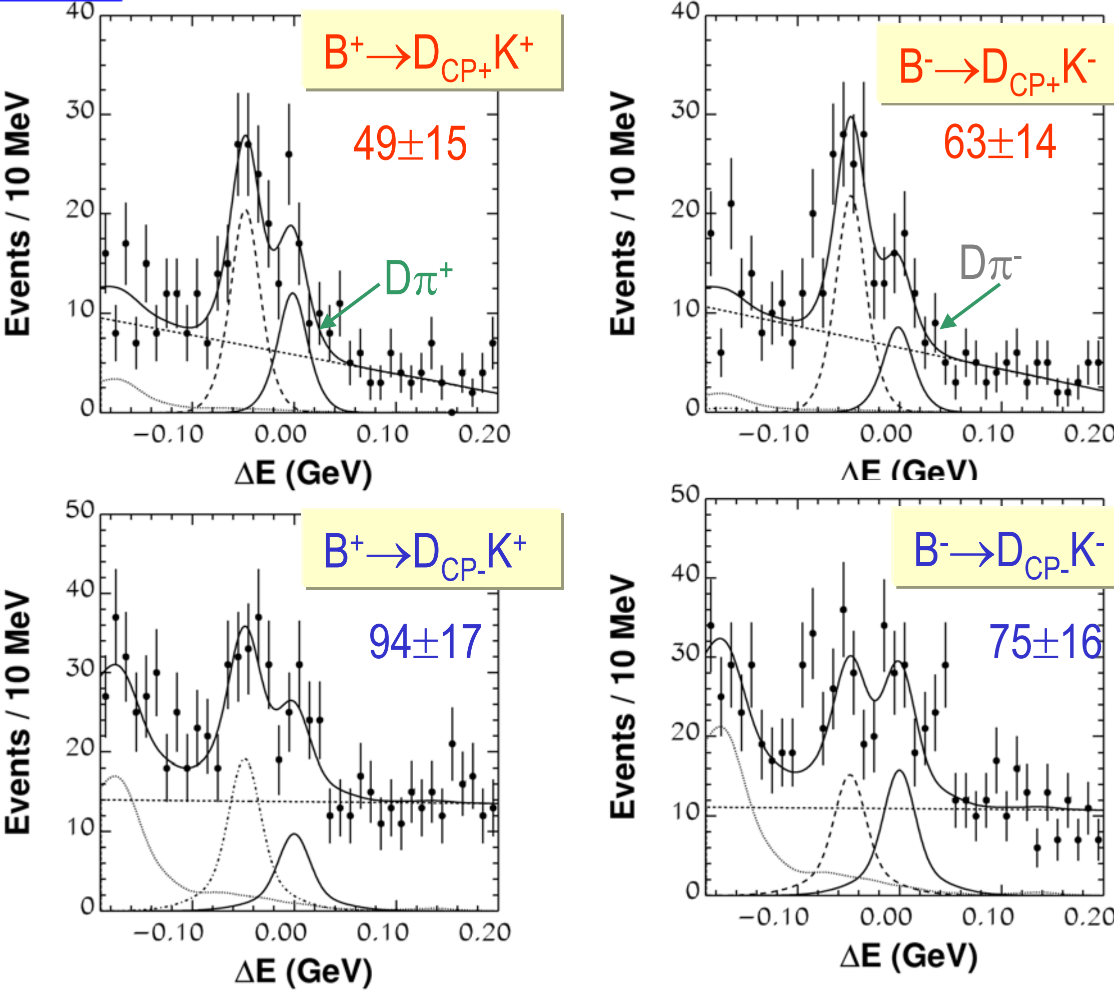
$$A_{D\pi} = .30^{+0.29}_{-0.25} \pm 0.06(sys)$$

$$R_{D\pi} = 3.5^{+1.0}_{-0.9} \pm 0.2(sys) \times 10^{-3}$$

$r_B < 0.27$ (90%CL)

GLW: $B^{\pm}\rightarrow D_{CP}K^{\pm}$

Belle-CONF-0443



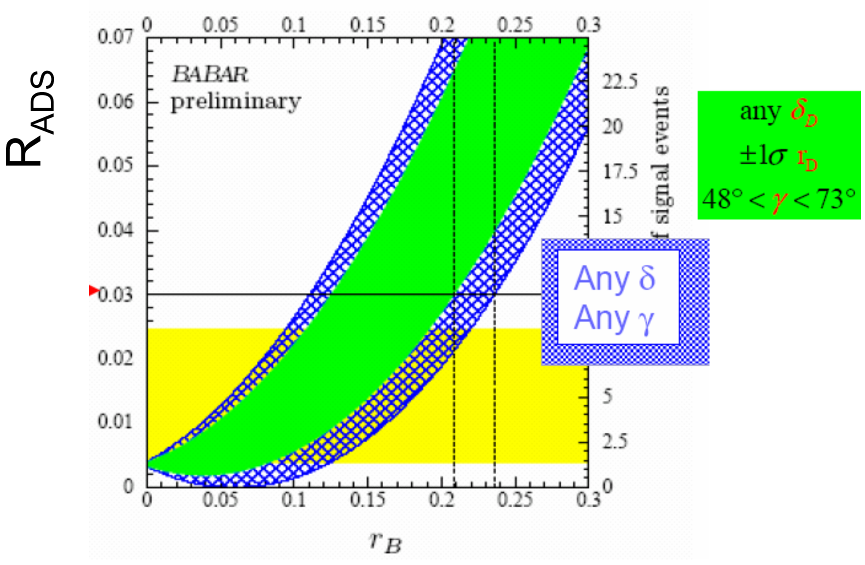
$B^{\pm}\rightarrow D_{CP}K^{\pm}$

R_{CP+} = 0.98±0.18(*stat.*) ±0.10(*syst.*)

A_{CP+} = 0.07±0.14(*stat.*) ±0.06(*syst.*)

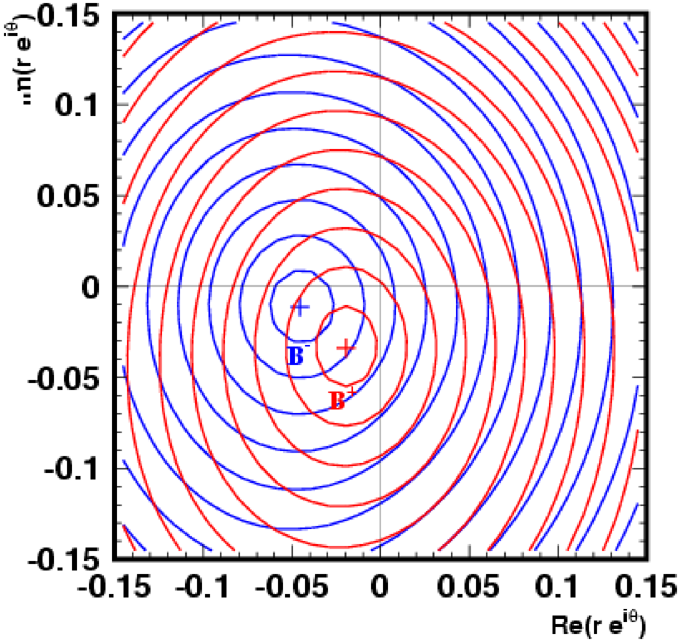
R_{CP-}= 1.29±0.16(*stat.*) ±0.08(*syst.*)

A_{CP-}= -0..11±0.14(*stat.*) ±0.05(*syst.*)

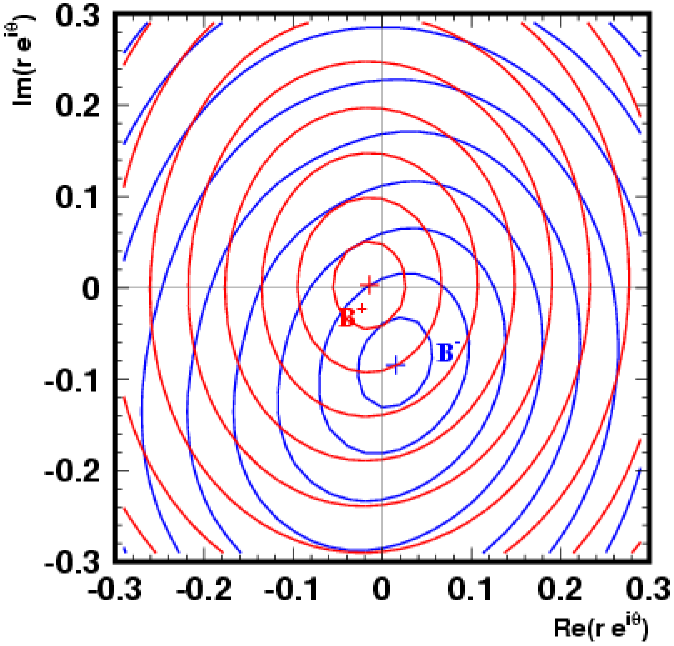

R_ADS
BABAR
preliminary
r_B
0 0.05 0.1 0.15 0.2 0.25 0.3
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07
signal events
0 2.5 5 15 17.5 20 22.5
any δ_D
$\pm 1\sigma$ r_D
$48° < \gamma < 73°$
Any δ
Any γ

Test sample fit

$B^+ \to D^0\pi^+$ (3425 events)



$B^+ \to D^{*0}\pi^+$ (642 events)



r_+=0.039±0.021, θ_+=240±28°

r_-=0.047±0.018, θ_-=193±24°

r_+=0.015±0.042, θ_+=169±186°

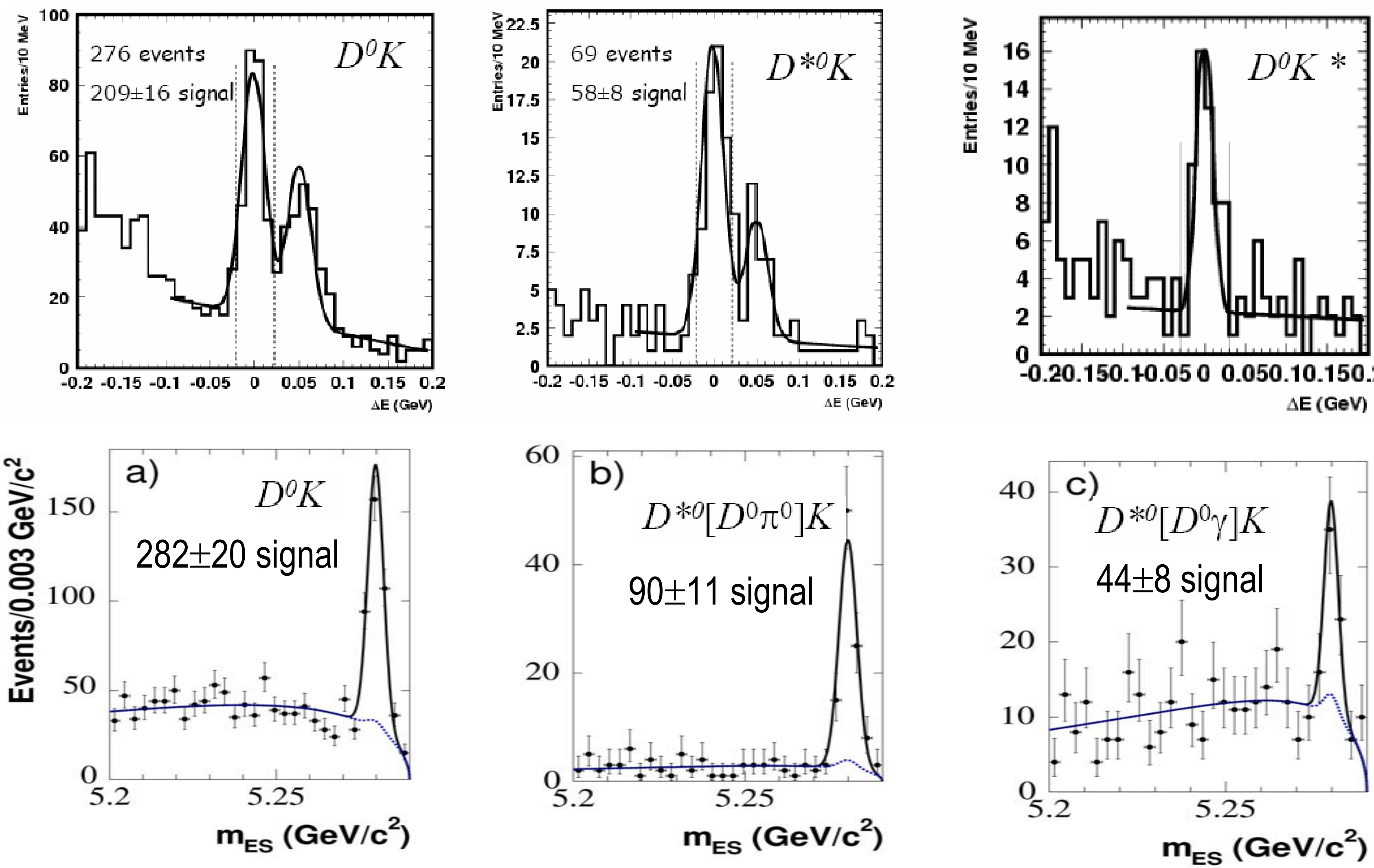
r_-=0.086±0.049, θ_-= 280±30°

Expect r~0.01-0.02

$x_+ = r_B\cos(\delta+\gamma)$ $\quad$ $x_- = r_B\cos(\delta-\gamma)$

$y_+ = r_B\sin(\delta+\gamma)$ $\quad$ $y_- = r_B\sin(\delta-\gamma)$

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

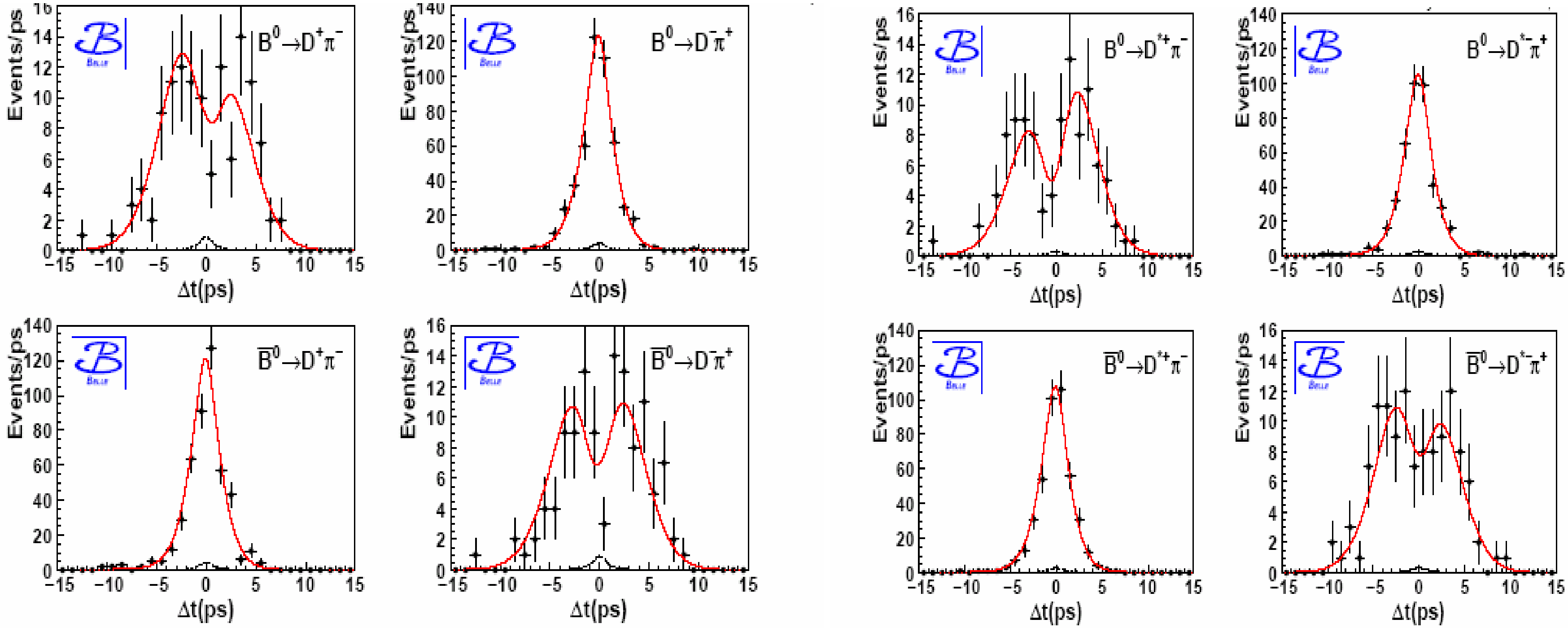


Belle $B^0 \to D^{(*)-} \pi^+$ results

Hep-ex/0308048

152M $\bar{B}B$

$D\pi$ *exclusive reconstruction* **$D^*\pi$**



$S^+ = +0.087 \pm 0.054 \pm 0.018$ $S^- = +0.037 \pm 0.052 \pm 0.018$ $S^+ = -0.109 \pm 0.057 \pm 0.019$ $S^- = -0.011 \pm 0.057 \pm 0.019$

9351 events, purity 91%

$D^+ \to K^-\pi^+\pi^+$

7763 events, purity 96%

$D^{*+} \to D^0\pi_s^+$

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

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

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

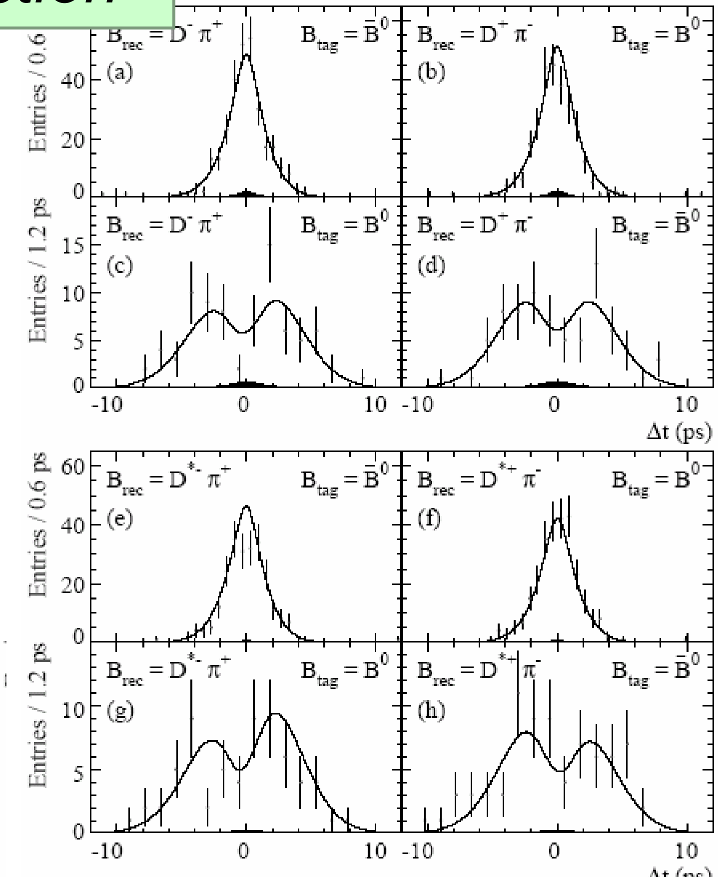
Babar $B^0 \to D^{(*)-}\pi^+/\rho^+$ results   hep-ex/0408059

110M $\bar{B}B$

exclusive reconstruction

abc parametrization

$$a = 2r\sin(2\beta+\gamma)\cos\delta$$
$$b = 2r'\sin(2\beta+\gamma)\cos\delta'$$
$$c = 2\cos(2\beta+\gamma)(r\sin\delta - r'\sin\delta')$$



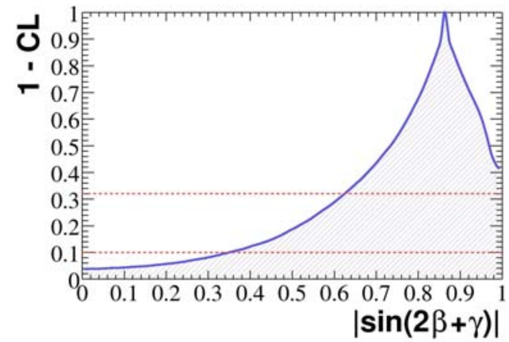
$D^\pm\pi^\mp$	(all tag)	7611 ± 97	91%
$D^{*\pm}\pi^\mp$	(all tag)	7068 ± 89	95%
$D^\pm\rho^\mp$	(all tag)	4400 ± 79	88%

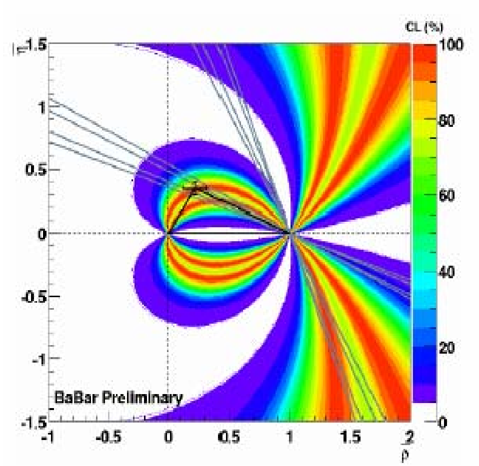
Simultaneous fit to all decay modes and tagging categories

$$2r^{D\pi}\sin(2\beta+\gamma)\cos\delta^{D\pi} = -0.032 \pm 0.031 \pm 0.020$$
$$2r^{D\pi}\cos(2\beta+\gamma)\sin\delta^{D\pi} = -0.059 \pm 0.055 \pm 0.033$$
$$2r^{D^*\pi}\sin(2\beta+\gamma)\cos\delta^{D^*\pi} = -0.049 \pm 0.031 \pm 0.020$$
$$2r^{D^*\pi}\cos(2\beta+\gamma)\sin\delta^{D^*\pi} = +0.044 \pm 0.054 \pm 0.033$$
$$2r^{D\rho}\sin(2\beta+\gamma)\cos\delta^{D\rho} = -0.005 \pm 0.044 \pm 0.021$$
$$2r^{D\rho}\cos(2\beta+\gamma)\sin\delta^{D\rho} = -0.147 \pm 0.074 \pm 0.035$$

SU(3) flavor symmetry:

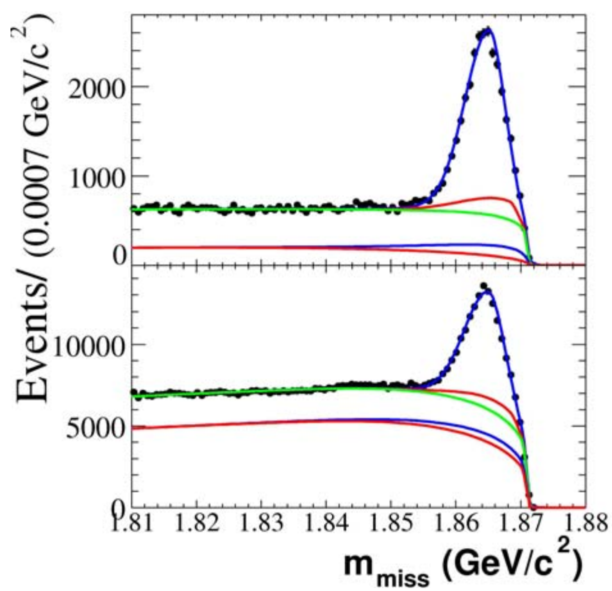
$$r_{D^*\pi} = \sqrt{\frac{Br(B^0 \to D_s^{*+}\pi^-)}{Br(B^0 \to D^{*-}\pi^+)}} \frac{f_{D^*}}{f_{D_s^*}} \tan\theta_C = 0.015^{+.004}_{-.006}$$





Lepton tag

Kaon tag



Continuum
peaking BB
Combinatoric BB
$D^*\rho$