γ/ϕ_3 @ ee colliders

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Tohoku University

On behalf of Belle

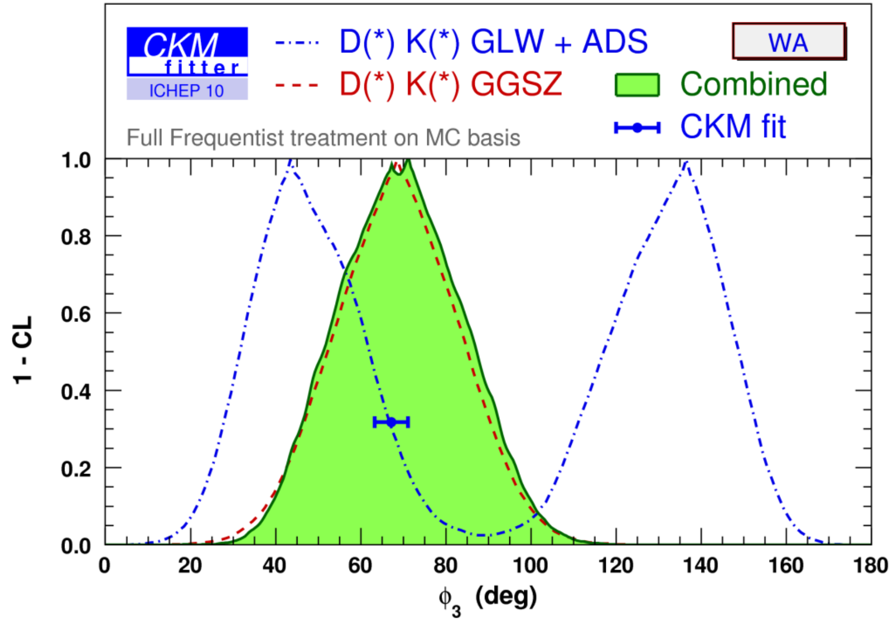
Flavor Physics and CP Violation 2011, 21 May 2011, Israel

On Earthquake

As is now well known, Japan suffered a terrible earthquake and tsunami on March 11, which has caused tremendous damage, especially in the Tohoku area. Fortunately, all KEK personnel and users are safe and accounted for. The injection linac did suffer significant but manageable damage, and repairs are underway. The damage to the KEKB main rings appears to be less serious, though non-negligible. No serious damage has been reported so far at Belle. Further investigation is necessary. We would like to convey our deep appreciation to everyone for your generous expressions of concern and encouragement.

Outline

- Introduction
- γ/ϕ_3 measurements
- Experimental apparatus
- GGSZ results
- ADS results
- GLW results
- Summary



Introduction

N. Cabibbo, PRL.10, 531 (1963);M. Kobayashi and T. Maskawa, Prog. Theor. Phys. 49, 652 (1973).
I. I. Bigi and A. I. Sanda, Phys. Lett. B 211, 213 (1988).

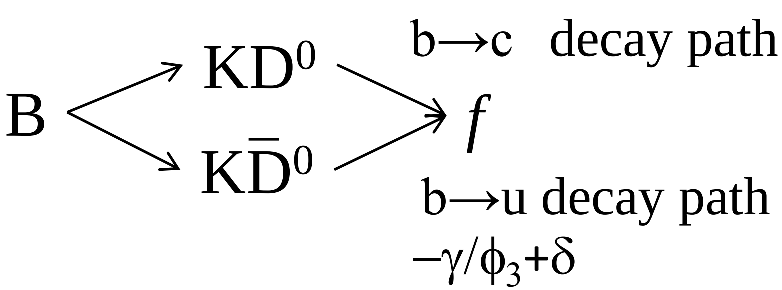
In the Standard Model, irreducible complex phase in Cabibbo-Kobayashi-Maskawa (CKM) matrix cause the *CP* violation.

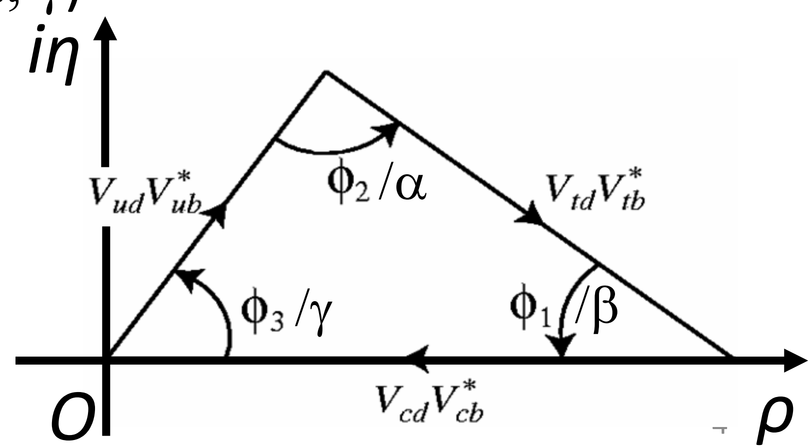
$$V_{n=3} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \simeq \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

One of the unitarity condition of CKM:

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

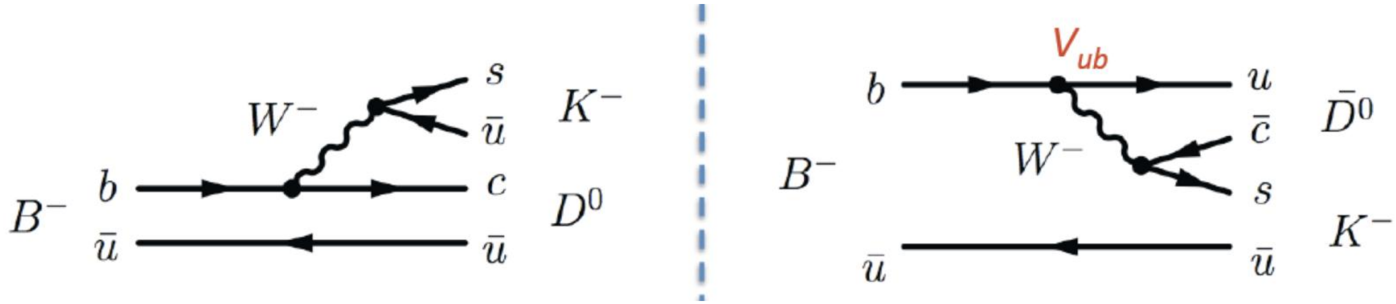
$(\phi_1, \phi_2, \phi_3) = (\beta, \alpha, \gamma)$





γ/ϕ_3 measurements

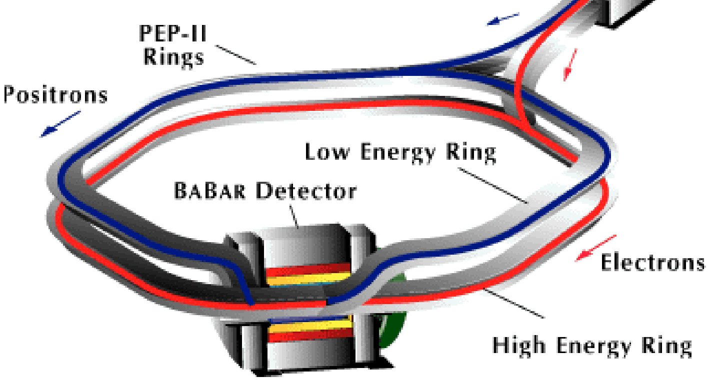
Interference between tree diagram $b \to c$ and $b \to u$($V_{ub} \propto e^{-i\phi_3}$)
in charged $B \to D^{(*)0}K^{(*)}$ or self-tagging neutral $B^0 \to D^{(*)0}K^{*0}$ ($K^{*0} \to K^+\pi^-$)

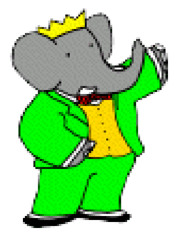


- GGSZ: Cabibbo favored multibody decays with Dalitz plane
- ADS: doubly Cabibbo suppressed
- GLW: CP eigenstates (Cabibbo suppressed)

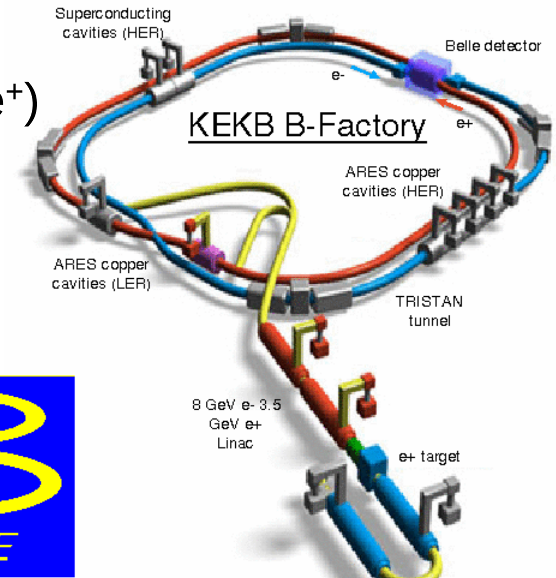
ee collider B-factories

PEP-II
9GeV(e^-),3.1GeV(e^+) $\beta\gamma$=0.56
1.2 $\times 10^{34}$cm^{-1}s^{-1}

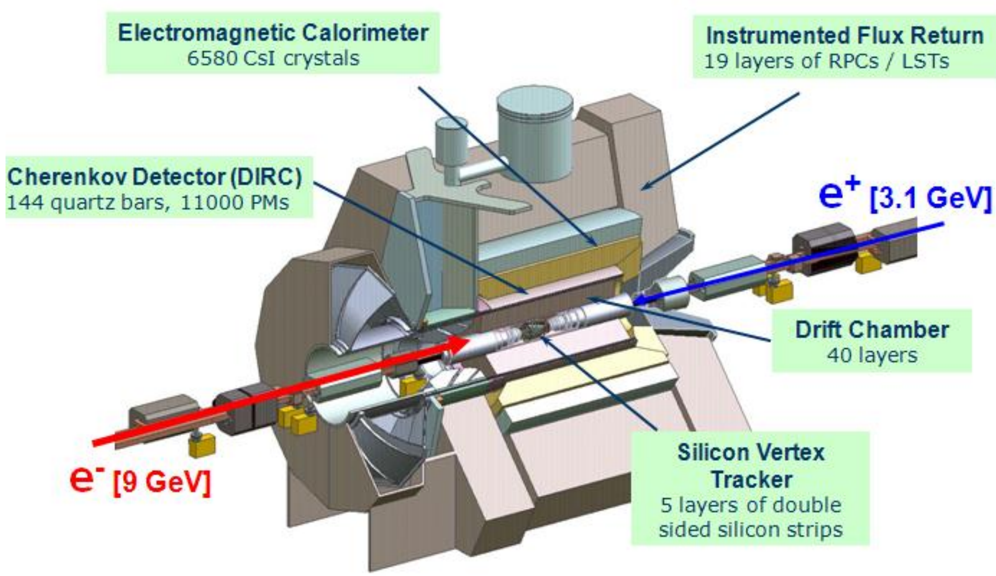




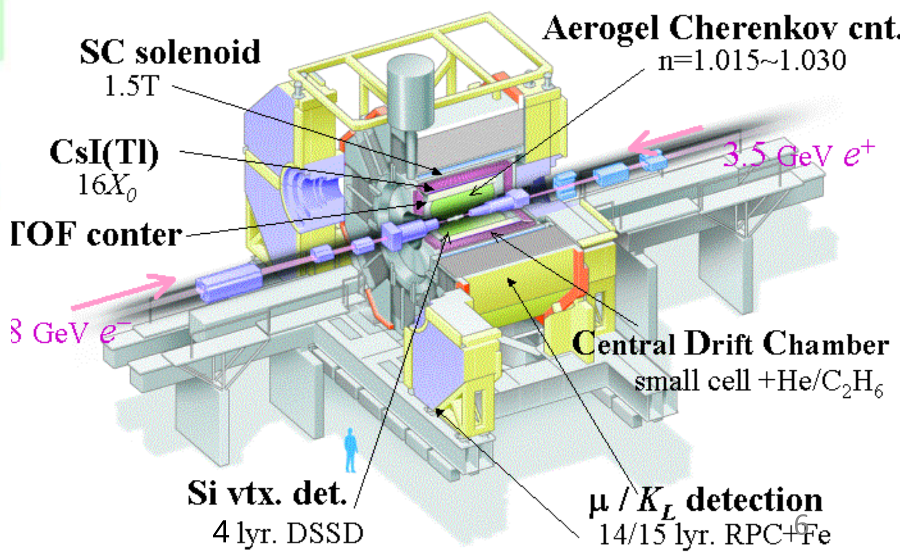
KEKB
8GeV(e^-)$\times$3.5GeV(e^+)
$\beta\gamma$=0.425
2.1$\times 10^{34}$cm^{-2}s^{-1}



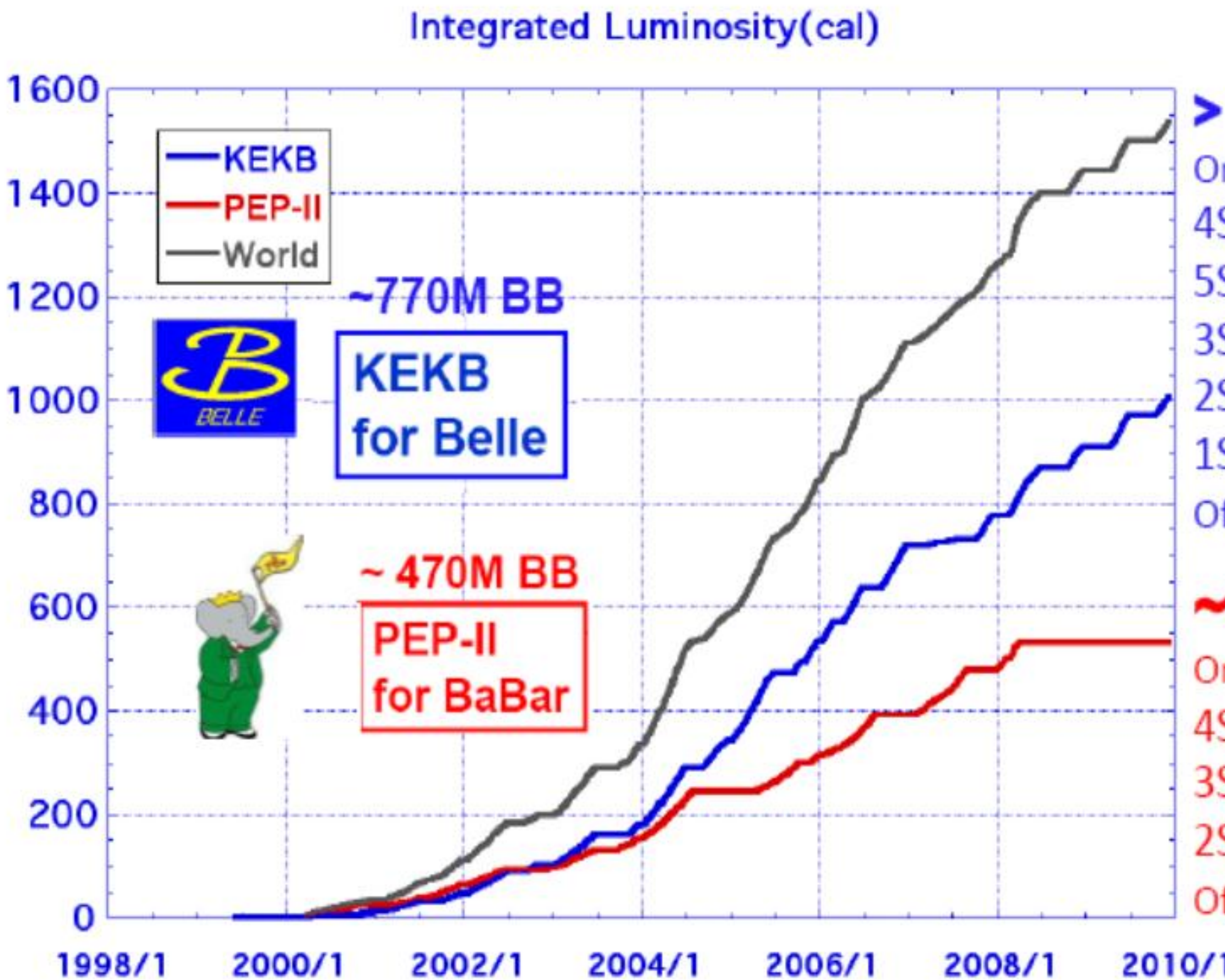
BaBar Detector



Belle Detector



Integrated Luminosity at B-factories



> 1.0 ab^{-1}

On-resonance samples:

4S: 711 fb^{-1}

5S: 121 fb^{-1}

3S: 3.0 fb^{-1}

2S: 24 fb^{-1}

1S: 5.7 fb^{-1}

Off-resonance: 87 fb^{-1}

~553 fb^{-1}

On-resonance samples:

4S: 433 fb^{-1}

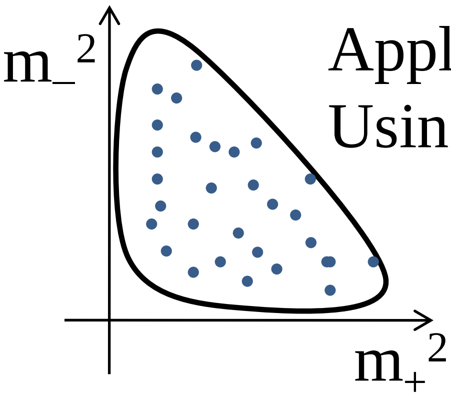
3S: 30 fb^{-1}

2S: 14 fb^{-1}

Off-resonance: 54 fb^{-1}

Dalitz Plot(DP) Analysis of $B^- \to D^{(*)}K^{(*)-}$ $D \to K_S h^+ h^-$

A. Bondar, Belle Dalitz analysis meeting, 24-26 Sep. 2002
A. Giri, Yu. Grossman, A. Soffer, J. Zupan, PRD 68, 054018 (2003)

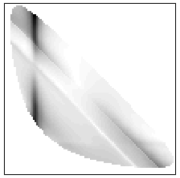
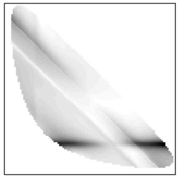


Application of $B^\pm \to DK^\pm$
Using D meson decay into CP eigenstate 3-body $D \to K_S h^+ h^-$

$$m_+ \equiv M_{Ksh+}, \quad m_- \equiv M_{Ksh-}$$

Dalitz plot amp. $M_\pm(m_+, m_-)$:

$$M_\pm(m_+^2, m_-^2) = f(m_+^2, m_-^2) + r_B e^{\pm i\phi 3 + i\delta_B} f(m_-^2, m_+^2)$$

$=$  $+ r_B e^{\pm i\phi 3 + i\delta_B}$ 

$f(m_+^2, m_-^2)$ …consists of summing over the intermediate resonance amplitudes of $K_S h^+ (K_S h^-)$ at each fraction.

r_B…is ratio of interfering amplitudes of $A(B \to DK)$ and $A(B \to \bar{D}K)$
$\sim |V_{ub}{}^* V_{cs}| / |V_{cb}{}^* V_{us}| \times$ color suppression~0.1-0.2

Model-dependent DP analysis

657M

A.Poluektov *et al.*,
PRD 81,112002(2010)

468M

P. del Amo Sanchez *et al.*
PRL 105, 121801(2010)

Belle: $D \to K_S \pi\pi$ produced in the $B^- \to D^{(*)}K^-$ where $D^* \to D\pi^0$ and $D\gamma$

BaBar: $D \to K_S \pi\pi$ and $D \to K_S KK$ produced in the $B^- \to D^{(*)}K^-$ and $B^- \to DK^{(*)-}$ where $D^* \to D\pi^0$ and $D\gamma$, $K^* \to K_S\pi$

Unbinned model-dependent DP analysis with isobar model

$D^0 \to K_S\pi\pi$ (Belle):

$\pi\pi$	σ_1^0
$\pi\pi$	$\rho(770)^0$
$\pi\pi$	$\omega(782)^0$
$\pi\pi$	$f0(980)^0$
$\pi\pi$	σ_2^0
$\pi\pi$	$f_2(1270)^0$
$\pi\pi$	$f_0(1370)^0$
$\pi\pi$	$\rho(1450)^0$
$K_S\pi$	$K^*(892)$
$K_S\pi$	$K^*(1410)$
$K_S\pi$	$K_2^*(1430)$
$K_S\pi$	$K^*(1680)$

$D^0 \to K_S\pi\pi$ (BaBar):

$\pi\pi$	$\omega(782)^0$
$\pi\pi$	$\rho(770)^0$
$K_S\pi$	$K^*(892)$
$K_S\pi$	$K^*(1680)^-$
$\pi\pi$	$f_2(1270)^0$
$K_S\pi$	$K_0^*(1430), K_2^*(1430)$
$\pi\pi$	S-wave K-matrix
$K_S\pi$	S-wave K-matrix

$D^0 \to K_SKK$:

KK_S	$a_0(980)$
KK_S	$a_0(1450)$
KK	$a_0(980)^0$
KK	$a_0(1450)^0$
KK	$f_0(1370)^0$
KK	$\phi(1020)^0$
KK	$f_2(1270)^0$

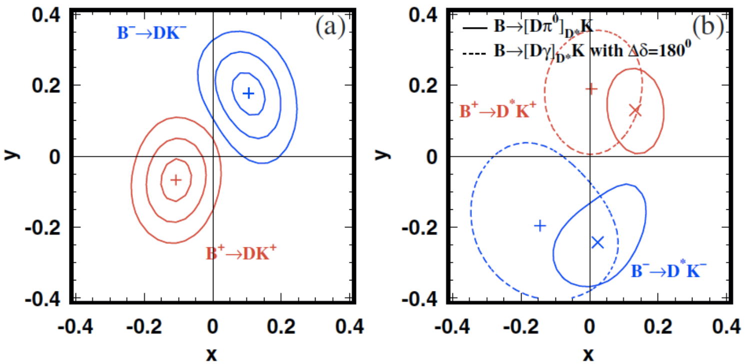
Model-dependent DP analysis results

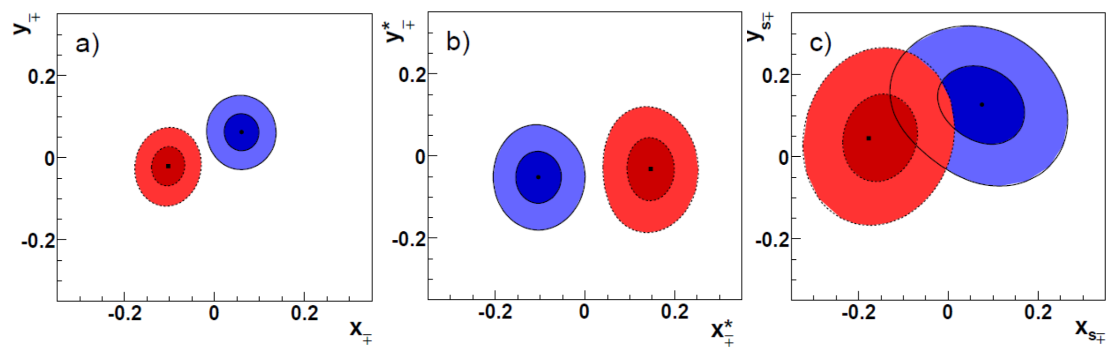
657M

A.Poluektov *et al.*,
PRD 81,112002(2010)

468M

P. del Amo Sanchez *et al.*
PRL 105, 121801(2010)





Combining the results for B→D$^{(*)}$K

ϕ_3=$(78.4^{+10.8}_{-11.6} \pm 3.6 \pm 8.9(\text{model}))^\circ$

$$r_{DK} = 0.160^{+0.040}_{-0.038} \pm 0.011^{+0.050}_{-0.010}$$
$$r_{D^*K} = 0.196^{+0.072}_{-0.069} \pm 0.012^{+0.062}_{-0.012}$$
$$\delta_{DK} = 136.7^\circ\ {}^{+13.0^\circ}_{-15.8^\circ} \pm 4.0^\circ \pm 22.9^\circ$$
$$\delta_{D^*K} = 341.9^\circ\ {}^{+18.0^\circ}_{-19.6^\circ} \pm 3.0^\circ \pm 22.9^\circ$$

Combining the results for B→D$^{(*)}$K$^{(*)}$

ϕ_3=$(68 \pm 14 \pm 4 \pm 3(\text{model}))^\circ$

$$r_B = 9.6 \pm 2.9\ \{0.5, 0.4\}$$
$$r^*B = 13.3^{+4.2}_{-3.9}\ \{1.3, 0.3\}$$
$$\kappa r_s = 14.9^{+6.6}_{-6.2}\ \{2.6, 0.6\}$$
$$\delta_B = 119^{+19}_{-20}\ \{3, 3\}$$
$$\delta^*_B = -82 \pm 21\ \{5, 3\}$$
$$\delta_s = 111 \pm 32\ \{11, 3\}$$

Where { , } is {experimental, model} systematic uncertainties.

Model-independent binned DP analysis

new

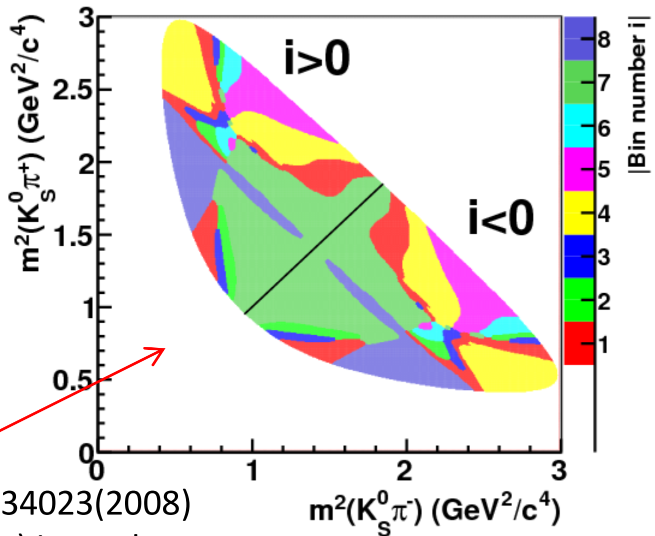
772M

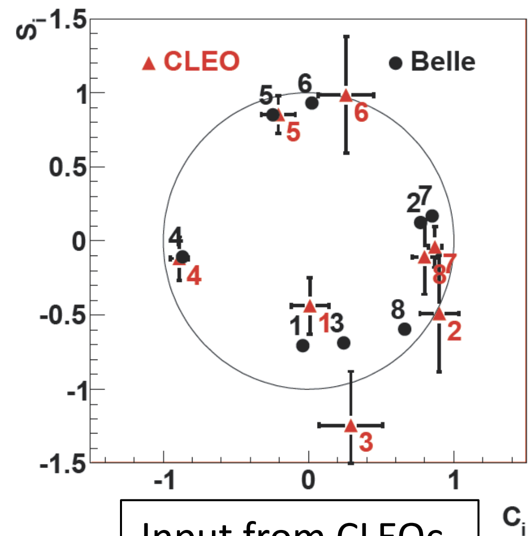
Belle Preliminary

Model-independent optimal binned DP analysis

A. Giri, Yu. Grossman, A. Soer, J. Zupan,PRD 68, 054018 (2003)
A. Bondar, A.Poluektov, EPJ C 47, 347 (2006);EPJ C 55, 51 (2008)

Binning is chosen to minimize the strong phase difference $\Delta\delta_D$ between $D^0 \to K_S\pi\pi$ and $\bar{D}^0 \to K_S\pi\pi$ from the isobar model.





Isobar model(PRD 78, 034023(2008) previous meas. by BaBar) is used for only binning

Input from CLEOc

$$M_i^{\pm} = h\{K_i + r_B^2 K_{-i} + 2\sqrt{K_i K_{-i}}(x_{\pm} c_i + y_{\pm} s_i)\}$$

where

- $M_i^{\pm}$: numbers of events in $D \to K_S^0\pi^+\pi^-$ bins from $B^{\pm} \to DK^{\pm}$
- $x_{\pm} = r_B \cos(\delta_B \pm \phi_3)$ $\quad y_{\pm} = r_B \sin(\delta_B \pm \phi_3)$
- $c_i = \langle \cos\Delta\delta_D \rangle, s_i = \langle \sin\Delta\delta_D \rangle$
- K_i: numbers of events in bins of flavor $\overline{D}^0 \to K_S^0\pi^+\pi^-$ from $D^* \to D\pi$.

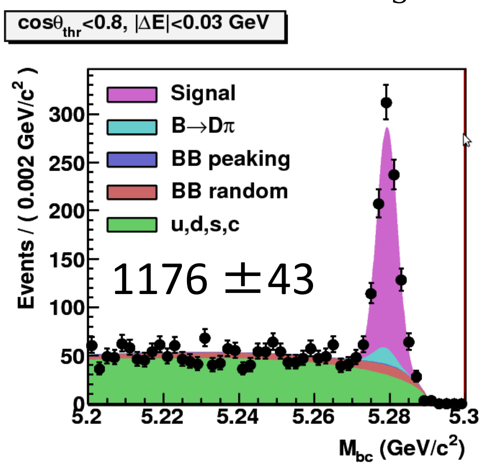
Model-independent Binned DP yield and plot

new

772M

Belle Preliminary

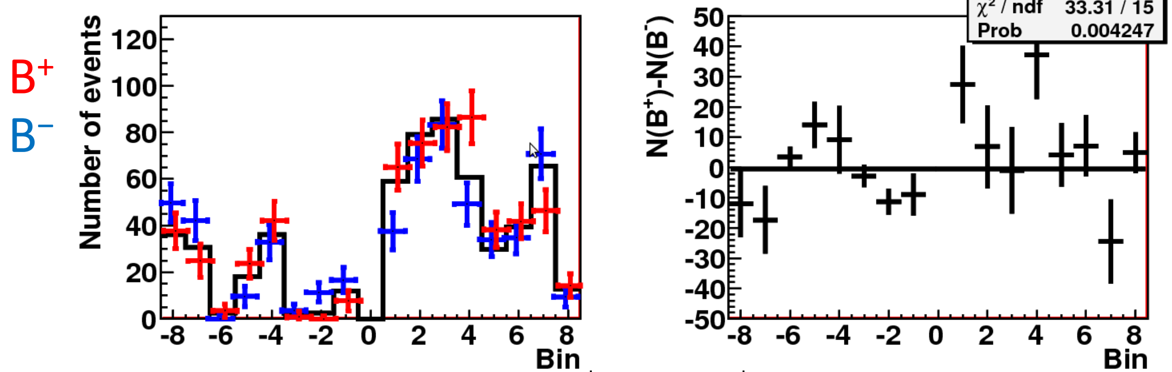
$B^{\mp} \to D^0 K^{\mp}$, $D^0 \to K_S \pi\pi$



- Using reprocessed data.
- Signal selection optimization

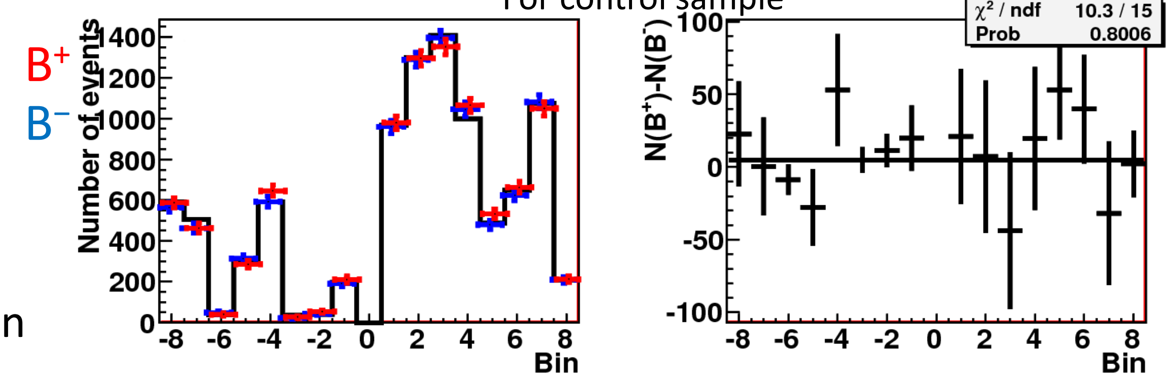
→Eff. increased ~55%

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



$B^{\pm} \to D\pi^{\pm}$

For control sample



$$M_i^{\pm} = h\{K_i + r_B^2 K_{-i} + 2\sqrt{K_i K_{-i}}(x_{\pm} c_i + y_{\pm} s_i)\}$$

where

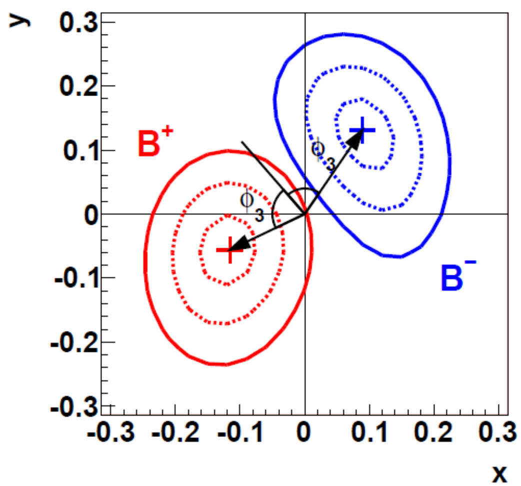
- $M_i^{\pm}$: numbers of events in $D \to K_S^0 \pi^+ \pi^-$ bins from $B^{\pm} \to DK^{\pm}$
- $x_{\pm} = r_B \cos(\delta_B \pm \phi_3) \quad y_{\pm} = r_B \sin(\delta_B \pm \phi_3)$
- $c_i = \langle \cos\Delta\delta_D \rangle$, $s_i = \langle \sin\Delta\delta_D \rangle$
- K_i: numbers of events in bins of flavor $\overline{D}^0 \to K_S^0 \pi^+ \pi^-$ from $D^* \to D\pi$.

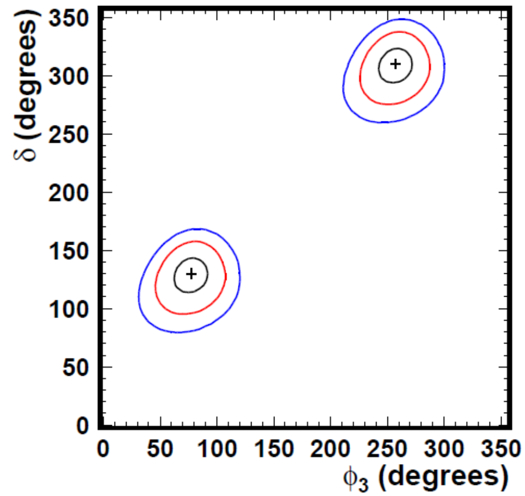
Dalitz analysis results of $B^- \to D^{(*)}K^{(*)-}, D \to K_S h^+ h^-$

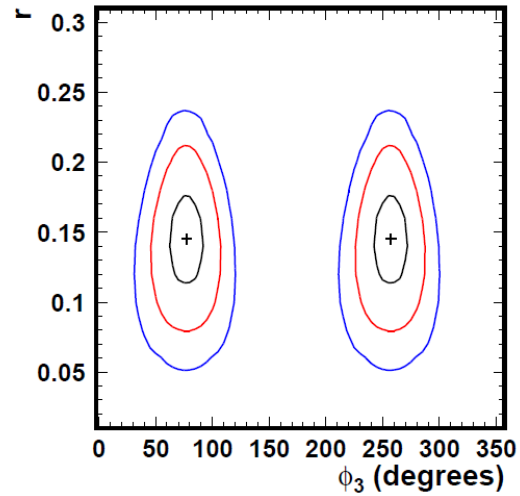
new

772M

Belle Preliminary





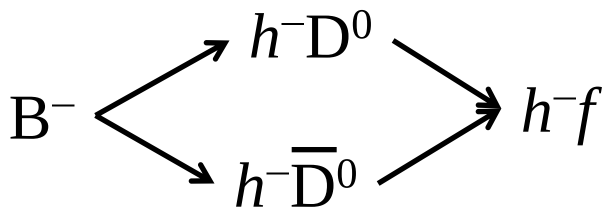


$$x_- = +0.095 \pm 0.045 \pm 0.014 \pm 0.017$$
$$y_- = +0.137\,^{+0.053}_{-0.057} \pm 0.019 \pm 0.029$$
$$x_+ = -0.110 \pm 0.043 \pm 0.014 \pm 0.016$$
$$y_+ = -0.050\,^{+0.052}_{-0.055} \pm 0.011 \pm 0.021$$

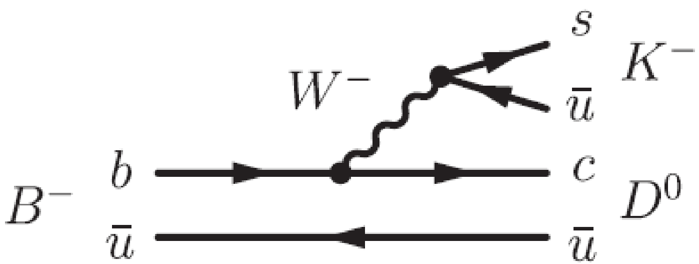
$$\phi_3 = (77.3\,^{+15.1}_{-14.9} \pm 4.2 \pm 4.3(c_i, s_i))^\circ$$
$$r_B = 0.145 \pm 0.030 \pm 0.011 \pm 0.011$$
$$\delta_B = (129.9 \pm 15.0 \pm 3.9 \pm 4.7)^\circ$$

ADS Analyses of $B^- \to D^{(*)}K^{(*)-}$

D. Atwood, I. Dunietz, and A. Soni, PRL. 78,3257 (1997); PRD 63, 036005 (2001).

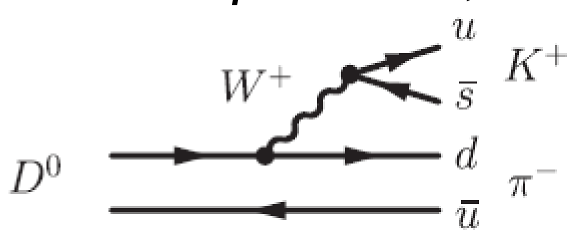


where $f = K^+\pi^-, K^+\pi^-\pi^0, K^+\pi^-\pi^+\pi^-, \ldots$

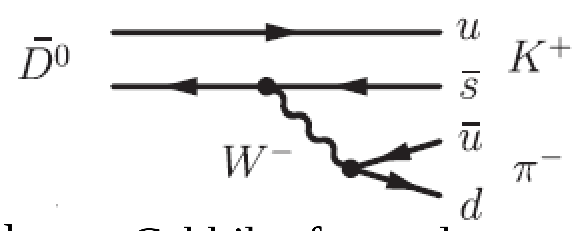


Color favored

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



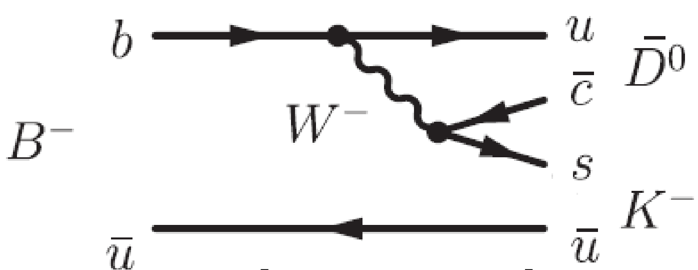
Doubly Cabbibo suppressed



Cabbibo favored

Choosing both contributing decay amplitudes are of comparable size.

$$R_{ADS} \equiv \frac{B(B^- \to D_{sup}h^-)}{B(B^- \to D_{fav}h^-)} = r_B^2 + r_D^2 + 2r_B r_D \cos\delta \cos\phi_3$$



Color suppressed

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

$$\text{where } r_B \equiv \frac{A(B^- \to \bar{D}^0K^-)}{A(B^- \to D^0K^-)}$$

$$r_D \equiv \frac{A(D^0 \to K^+\pi^-)}{A(D^0 \to K^-\pi^+)} = 0.0578 \pm 0.0008$$

$\delta_{B,D}$: Strong phase difference

ADS measurements at Belle

772M

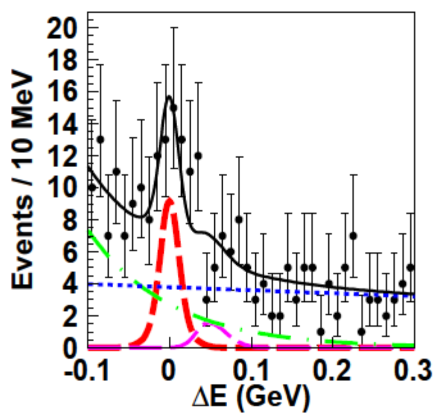
new

Y.Horii et al.,
arXiv:1103.5951v1
to appear in PRL

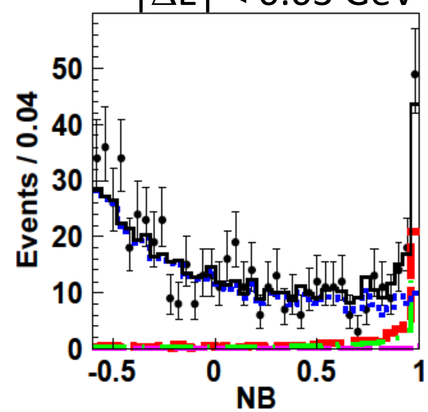
$B^- \to DK^-$, $D \to K^-\pi^+$
(favored mode)

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

NB > 0.9



|ΔE| < 0.03 GeV



NB: neural-network output for discriminating continuum background.

$$\mathcal{R}_{DK} = [1.63^{+0.44}_{-0.41}{}^{+0.07}_{-0.13}] \times 10^{-2}, \qquad \mathcal{A}_{DK} = -0.39^{+0.26}_{-0.28}{}^{+0.04}_{-0.03}$$

$$\mathcal{R}_{D\pi} = [3.28^{+0.38}_{-0.36}{}^{+0.12}_{-0.18}] \times 10^{-3}, \qquad \mathcal{A}_{D\pi} = -0.04 \pm 0.11^{+0.02}_{-0.01}$$

Belle reports the first evidence for $B^+ \to DK^+$, $D^0 \to K^+\pi^-$ with a significance of 4.1σ

ADS measurements at BaBar

467M

new

P. del Amo Sanchez et al., PRD82,072006(2010)

$B^- \to DK^-$, $D \to K^-\pi^+$
(favored mode)

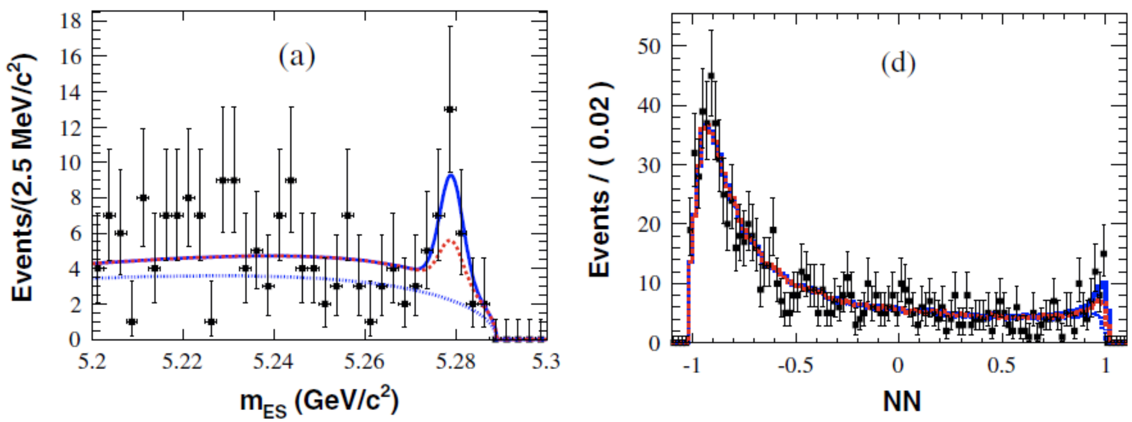
$B^- \to D^*K^-$,
$D^* \to D\pi^0$
$D \to K^-\pi^+$
(favored mode)

$B^- \to D^*K^-$
$D^* \to D\gamma$
$D \to K^-\pi^+$
(favored mode)

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

NN > 0.94

$5.2725 < m_{ES} < 5.2875$ GeV/c^2



$$\mathcal{R}_{DK} = (1.1 \pm 0.6 \pm 0.2) \times 10^{-2}.$$
$$\mathcal{R}^*_{(D\gamma)K} = (1.3 \pm 1.4 \pm 0.8) \times 10^{-2}.$$
$$\mathcal{R}^*_{(D\pi^0)K} = (1.8 \pm 0.9 \pm 0.4) \times 10^{-2}.$$

$$\mathcal{A}_{DK} = -0.86 \pm 0.47^{+0.12}_{-0.16}.$$
$$\mathcal{A}^*_{(D\pi^0)K} = +0.77 \pm 0.35 \pm 0.12.$$
$$\mathcal{A}^*_{(D\gamma)K} = +0.36 \pm 0.94^{+0.25}_{-0.41}.$$

BaBar reports $B^- \to D^{(*)}K^-$ followed by $D^* \to D\gamma, D\pi^0$ and $D \to K^-\pi^+$

ADS Results of $B^- \to D^{(*)}K^{(*)-}$ and $B^- \to D^{(*)}\pi^-$

new

474M

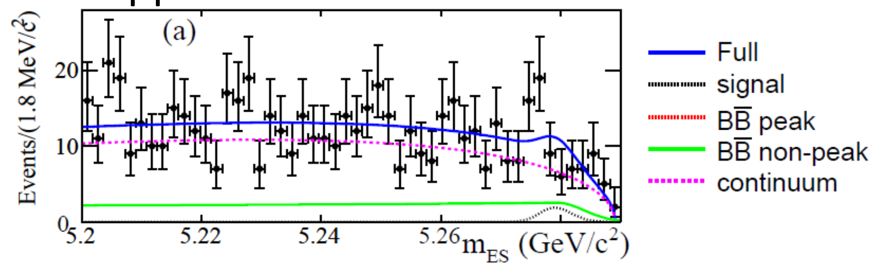
J. P. Lees et al., arXiv:1104.4472

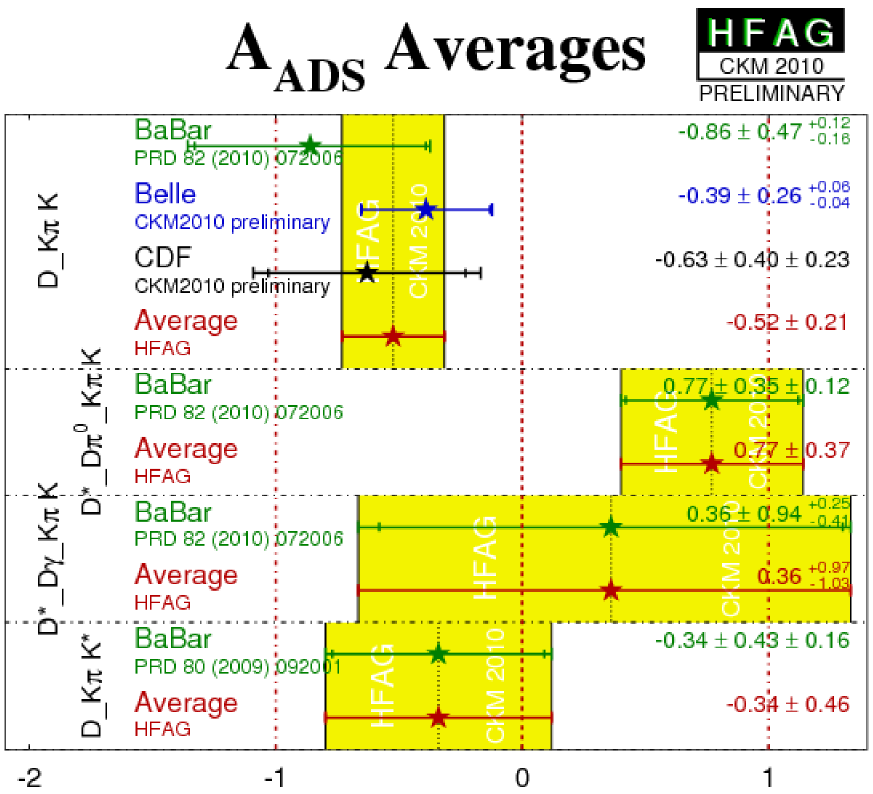
R_{ADS} with $B^+ \to DK^+$, $D \to K^-\pi^+\pi^0$ (favored mode)

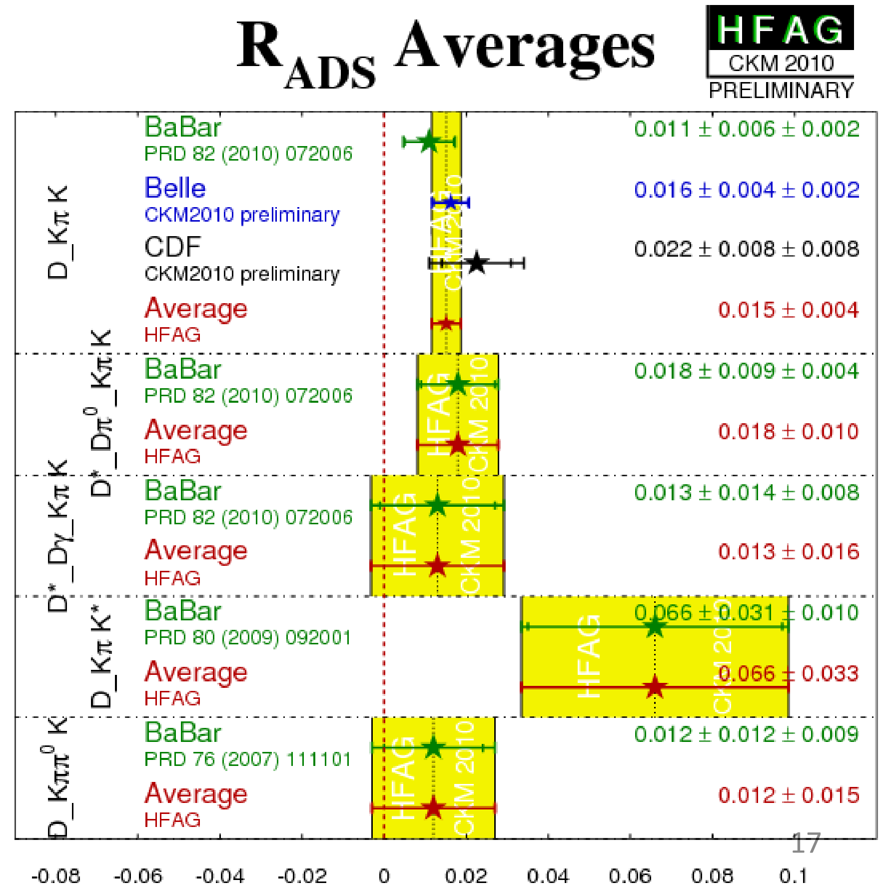
$R_{ADS} = (\, 9.1 \; ^{+8.2}_{-7.6} \; ^{+1.4}_{-3.7} \,) \times 10^{-3}$

$R_{ADS} < 21 \times 10^{-3}$ at 90% probability.

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







GLW Analyses of $B^- \to D^{(*)}K^{(*)-}$

M. Gronau and D. London, Phys. Lett. B **253**, 483 (1991);
M. Gronau and D. Wyler, Phys. Lett. B **265**, 172 (1991).

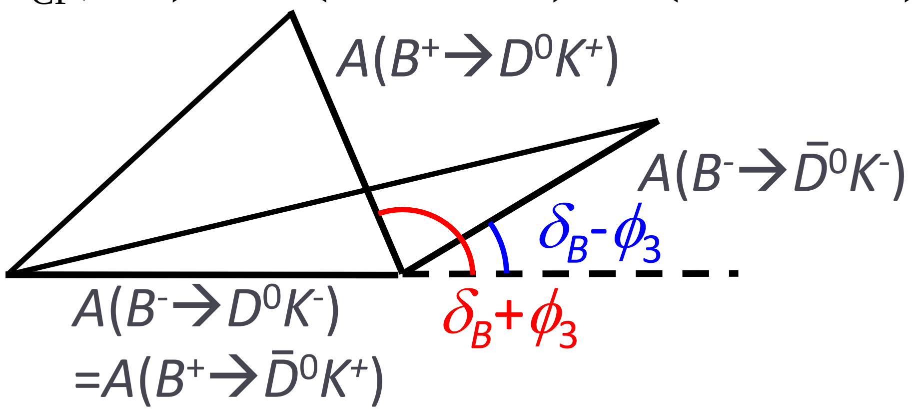
Defining the two CP eigenstates

$$|D_{CP\pm}^0\rangle = \frac{1}{\sqrt{2}}(|D^0\rangle \pm |\overline{D}^0\rangle)$$

where D_{CP+}:
KK, $\pi\pi$,...(CP even)
where D_{CP-}:
$K_S\pi^0$, $K_S\omega$, $K_S\phi$,..(CP odd)

one can write $B \to D_{CP+}$ decays as

$$\begin{cases} \sqrt{2}A(B^+\to D_{CP+}^0K^+) = A(B^+\to D^0K^+) + A(B^+\to \overline{D}^0K^+) \\ \sqrt{2}A(B^-\to D_{CP+}^0K^-) = A(B^-\to D^0K^-) + A(B^-\to \overline{D}^0K^-) \end{cases}$$



Observable

$$A_{CP\pm} \equiv \frac{B(B^-\to D_{CP\pm}^0K^-) - B(B^+\to D_{CP\pm}^0K^+)}{B(B^-\to D_{CP\pm}^0K^-) + B(B^+\to D_{CP\pm}^0K^+)} = \frac{2r_B \sin\delta_B \sin\phi_3}{1+r_B^2+2r_B\cos\delta_B\cos\phi_3}$$

Observable

$$R_{CP\pm} \equiv \frac{B(B^-\to D_{CP\pm}^0K^-) + B(B^+\to D_{CP\pm}^0K^+)}{B(B^-\to D^0K^-) + B(B^+\to \overline{D}^0K^+)} = 1+r_B^2+2r_B\cos\delta_B\cos\phi_3$$

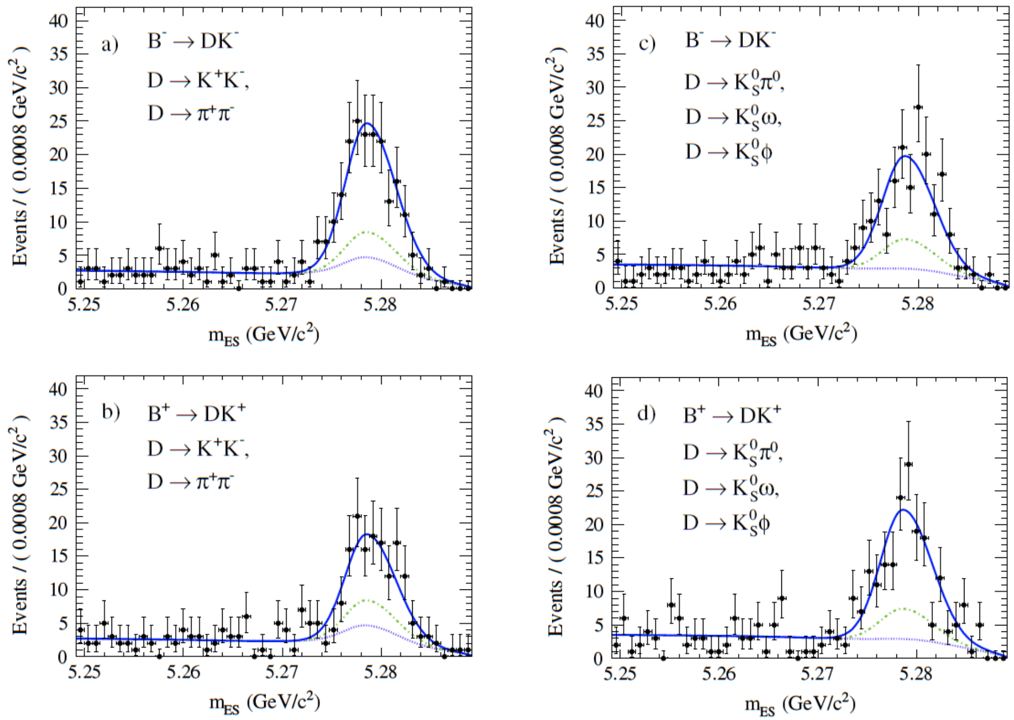
where $r_B \equiv \dfrac{A(B^-\to \overline{D}^0K^-)}{A(B^-\to D^0K^-)}$, δ_B: strong phase difference

GLW measurements

CP even | CP odd

Charge B^-

Charge B^+



new

467M

P. del Amo Sanchez *et al.*
PRD 82, 072004(2010)

$$A_{CP+} = 0.25 \pm 0.06(\text{stat}) \pm 0.02(\text{syst}), \quad A_{CP-} = -0.09 \pm 0.07(\text{stat}) \pm 0.02(\text{syst}),$$

$$R_{CP+} = 1.18 \pm 0.09(\text{stat}) \pm 0.05(\text{syst}), \quad R_{CP-} = 1.07 \pm 0.08(\text{stat}) \pm 0.04(\text{syst}).$$

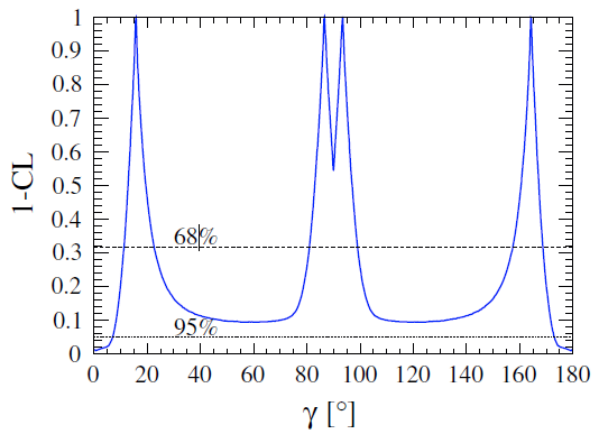
Direct CPV A_{CP+} 3.6σ away from 0

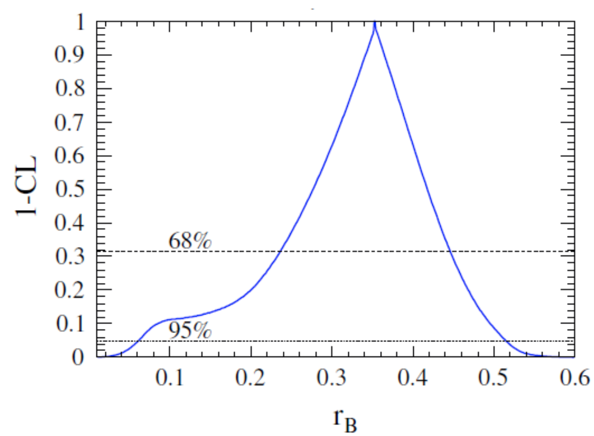
Translations to γ, r_B, δ_B

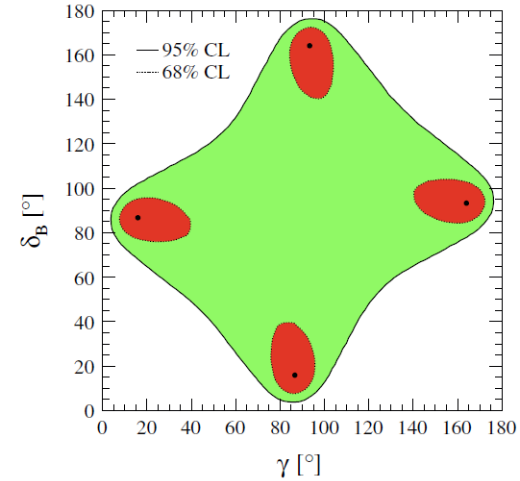
$$\mathcal{L}(\gamma,\delta_B,r_B)=\frac{1}{N}\exp\left(-\frac{1}{2}(\vec{y}-\vec{y}_t)^T V_{\rm cov}^{-1}(\vec{y}-\vec{y}_t)\right)$$

$$\chi^2(\gamma,\delta_B,r_B)=-2\ln\mathcal{L}(\gamma,\delta_B,r_B).$$

frequentist approach







68% CL [11.3, 22.7], [80.8, 99.2] ,[157.3, 168.7] [0.24, 0.45] [353.0, 360]

Also, exclude $D\to K_S\phi$, $\phi\to K^+K^-$ events and applied event selection Kh^+h^-

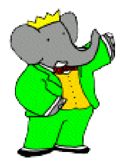
$$\begin{cases} A_{CP-} = -0.08 \pm 0.07(\text{stat}) \pm 0.02(\text{syst}), \\ R_{CP-} = 1.03 \pm 0.09(\text{stat}) \pm 0.04(\text{syst}). \end{cases}$$

$x_\pm = r_B\cos(\delta_B \pm \gamma)$

$$\begin{cases} x_+ = -0.057 \pm 0.039(\text{stat}) \pm 0.015(\text{syst}), \\ x_- = 0.132 \pm 0.042(\text{stat}) \pm 0.018(\text{syst}), \end{cases}$$

new

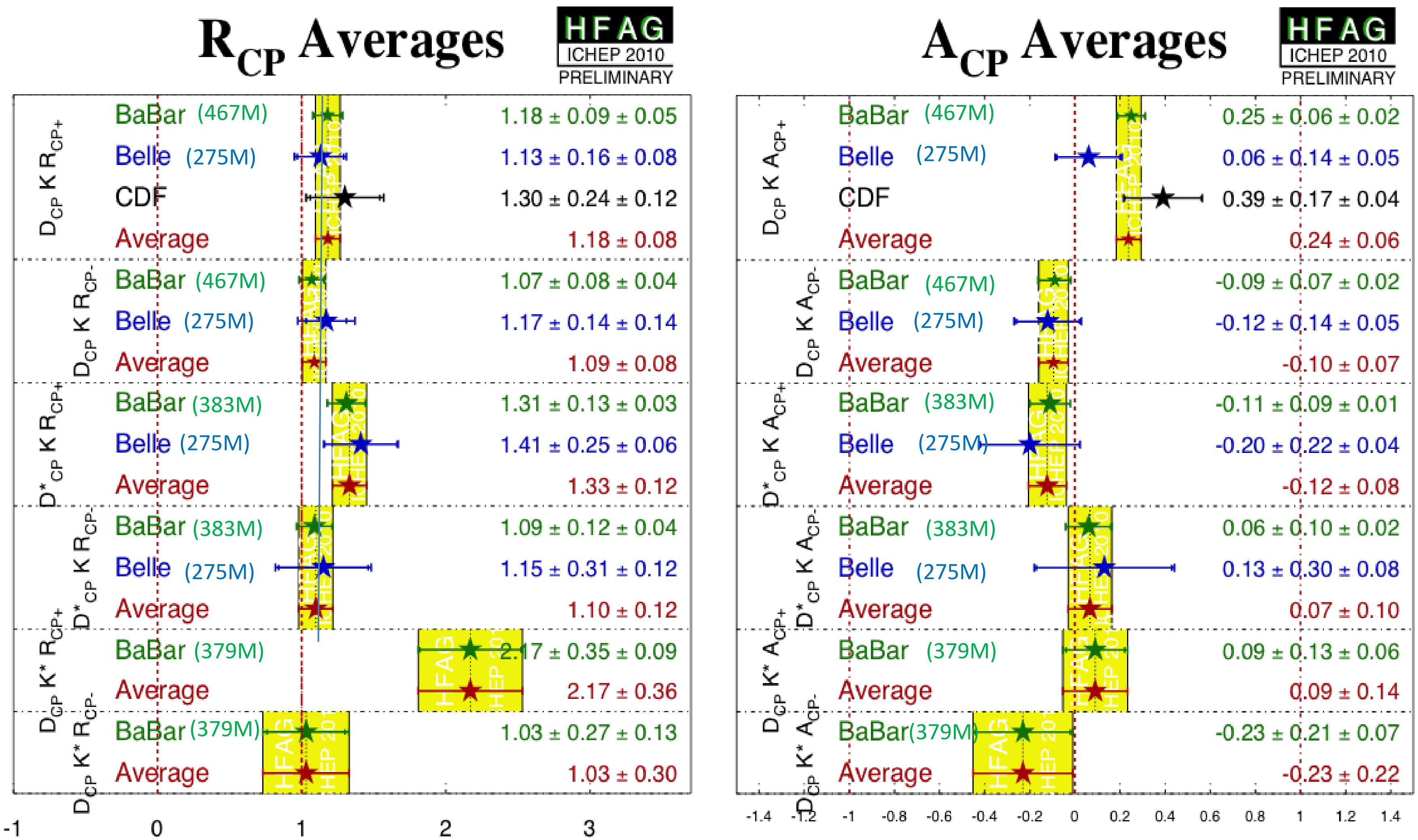
467M



P. del Amo Sanchez *et al.*
PRD 82, 072004(2010)

Agreement with the current Dalitz analysis.

GLW Results of $B^- \to D^{(*)}K^{(*)-}$



Currently, BaBar measurements are dominant in precision.
With the full data sample and improved tracking,
final Belle measurements will have comparable or better errors.

Summary

- Model-dependent unbinned Dalitz plot analysis of $B \to D^{(*)}K$, $D \to K_S\pi\pi$ in Belle.

  $\phi_3 = (78.4^{+10.8}_{-11.6} \pm 3.6 \pm 8.9(\text{model}))^\circ$

  A.Poluektov *et al.,* PRD 81,112002(2010)

- Model-dependent unbinned Dalitz plot analysis of $B \to D^{(*)}K^{(*)}$, $D \to K_S\pi\pi$ and K_SKK in BaBar.

  $\phi_3 = (68 \pm 14 \pm 4 \pm 3(\text{model}))^\circ$

  P. del Amo Sanchez *et al.* PRL 105, 121801(2010)

- First model-independent unbinned Dalitz plot analysis of $B \to DK$, $D \to K_S\pi\pi$ in Belle.

  $\phi_3 = (77.3^{+15.1}_{-14.9} \pm 4.2 \pm 4.3(c_i, s_i))^\circ$ Belle Preliminary

- First evidence of ADS R_{DK} with $B^- \to DK^-$, $D \to K^-\pi^+$ at 4.1σ in Belle.

  $\mathcal{R}_{DK} = [1.63^{+0.44}_{-0.41}(\,^{+0.07}_{-0.13}(\text{syst})] \times 10^{-2},$

  Y.Horii *et al.,* arXiv:1103.5951v1 accepted to PRL

- Direct CPV GLW A_{CP+} in $B \to DK$, $D \to KK$ and $\pi\pi$ at 3.6σ in BaBar.

  $A_{CP+} = 0.25 \pm 0.06(\text{stat}) \pm 0.02(\text{syst}),$

  P. del Amo Sanchez *et al.* PRD 82, 072004(2010)

- New ϕ_3/γ results from e^+e^- colliders are coming soon.

Backup slides

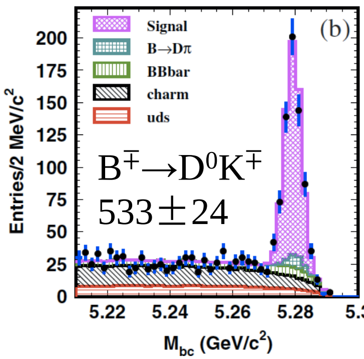
Yields of $B^- \to D^{(*)} K^{(*)-}$ with $D \to K_S h^+ h^-$

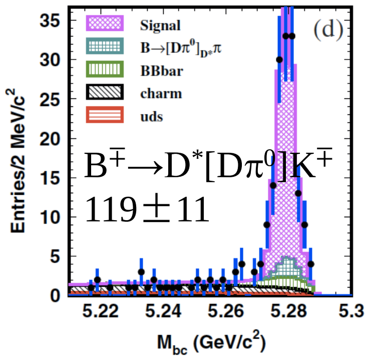
657M

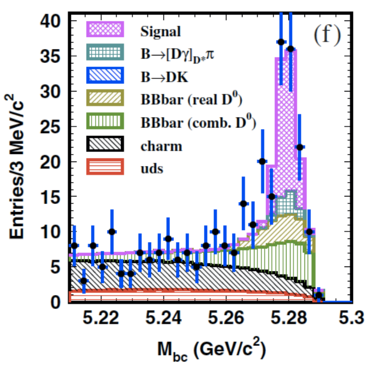
A.Poluektov *et al.*,
PRD 81,112002(2010)

468M

P. del Amo Sanchez *et al.*
PRL 105, 121801(2010)

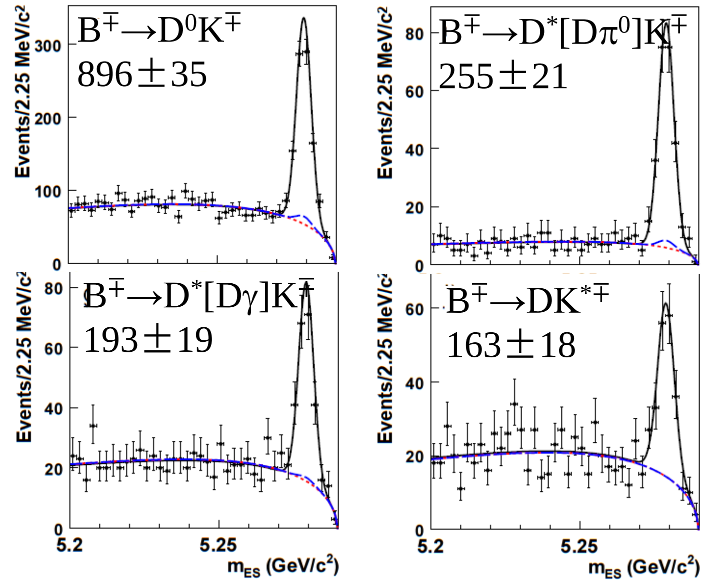




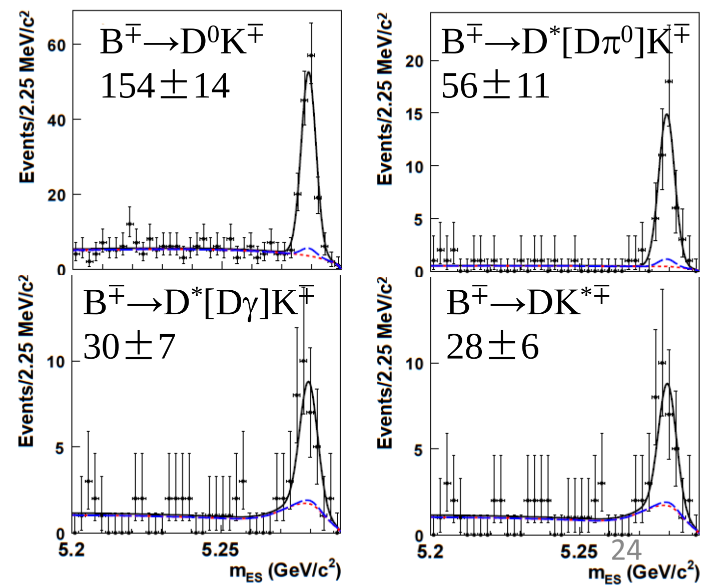


$B^\mp \to D^*[D\gamma]K^\mp$
58±8

1507 $D^0 \to K_S\pi\pi$



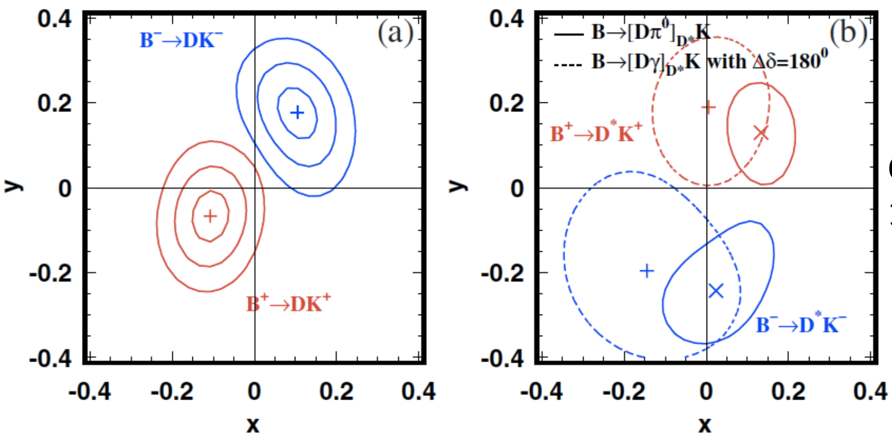
268 $D^0 \to K_S KK$



Previous results of Dalitz plot analysis

A.Poluektov *et al.*,
PRD 81,112002(2010)
$B^{\pm}\to D^{(*)}K^{\pm}, D\to K_S\pi^+\pi^-$

657M



Contours at 1,2,3σ

$\phi_3=(76\ ^{+12}_{-13}\ \pm 4\ \pm 9(\text{model}))^{\circ}$

$r_{DK}= 0.160\ ^{+0.040}_{-0.038}\ \pm 0.011\ ^{+0.050}_{-0.010}$

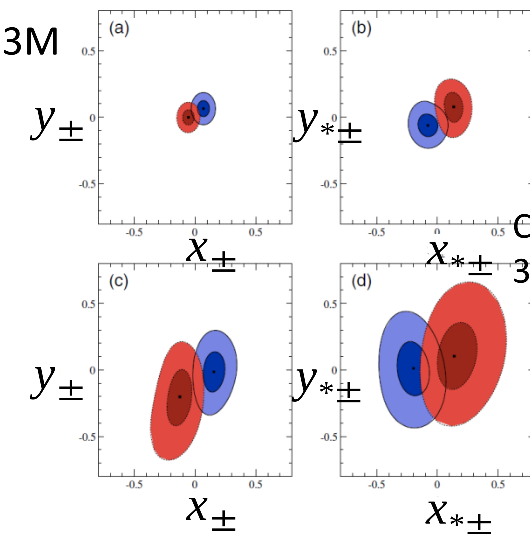
$r_{D*K}= 0.196\ ^{+0.072}_{-0.069}\ \pm 0.012\ ^{+0.062}_{-0.012}$

$\delta_{DK}=(136.7\ ^{+13.0}_{-15.8}\ \pm 4.0\ \pm 22.9\ )^{\circ}$

$\delta_{D*K}=(341.9\ ^{+18.0}_{-19.6}\ \pm 3.0\ \pm 22.9\ )^{\circ}$

AUBERT *et al.*,
PRD 78,054023(2008)
$B^{\pm}\to D^{(*)}K^{\pm}, D\to K_S\pi^+\pi^-, K_SK^+K^-$

383M



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

$D\to K_SK^+K^-$

Contours at 39.3%, 86.5% C.L.

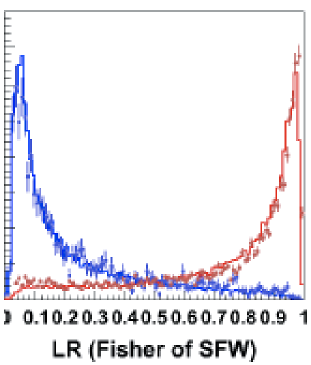
$\phi_3=(72\pm 22\pm 5\pm 5(\text{model}))^{\circ}$

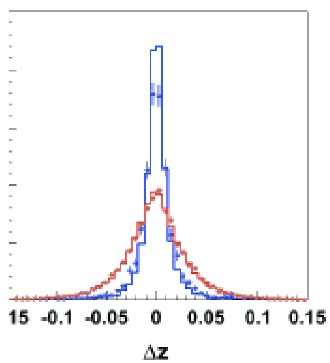
Both the measurements are adopted model-dependent Dalitz analysis.

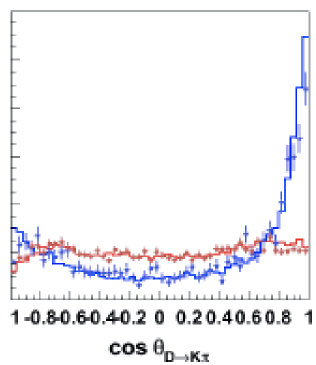
Continuum Suppression

- Main background is $e^+e^- \rightarrow q\bar{q}$ (q=u, d, s, c) continuum process.
- To discriminate this background,
  new technique employs NeuroBayes (NB) neural network.

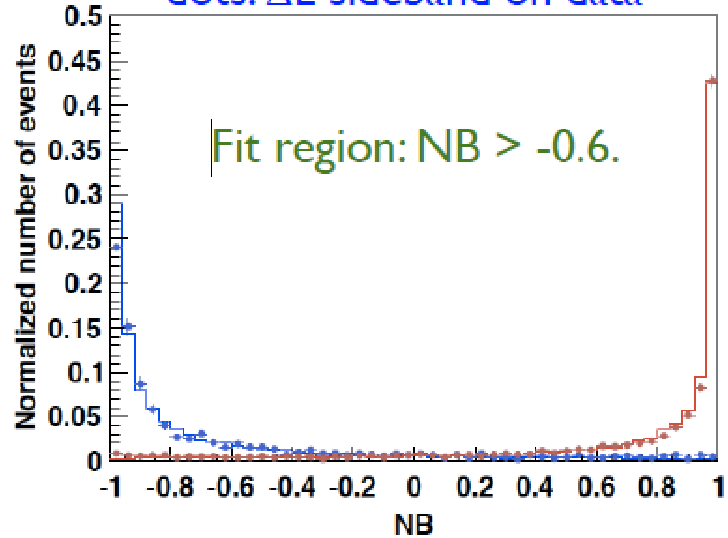
NB inputs (10 in total):
- LR for Fisher of SFW moments
- Vertex separation between reconstructed B and the other B (Δz)
- Decay angle for $D \rightarrow K\pi$
- ...







histogram: signal on MC
dots: Calib. mode ($D\pi$) on data
histogram: qq on MC
dots: ΔE sideband on data



Y. Horii @CKM2011

Belle model-dep. DP syst.

Source of uncertainty	Δx_-	Δy_-	Δx_+	Δy_+
Dalitz plot efficiency	± 3.0	± 1.9	± 3.2	± 1.6
Crossfeed between bins	$+0.4$	$+3.0$	-0.7	-0.9
Signal shape				
Parametrization				
$(M_{\rm bc}, \Delta E)$	-0.2	$+0.5$	$+0.2$	-4.8
$(\cos\theta_{\rm thr}, \mathcal{F})$	-0.5	-1.5	-0.8	-1.3
Correlation btw. $(M_{\rm bc}, \Delta E)$ and $(\cos\theta_{\rm thr}, \mathcal{F})$	$+0.2$	$+0.5$	$+0.0$	-0.2
MC uncertainty in $(\cos\theta_{\rm thr}, \mathcal{F})$	-0.5	-1.0	-0.5	-0.7
Correlation with Dalitz plot	$+0.5$	-0.1	-0.6	$+0.1$
u, d, s, c continuum shape				
Off-resonance data uncertainty in $(M_{\rm bc}, \Delta E)$	-0.2	$+0.2$	-0.1	-0.2
Parametrization				
$(M_{\rm bc}, \Delta E)$	$+0.3$	$+0.7$	$+0.2$	-0.6
$(\cos\theta_{\rm thr}, \mathcal{F})$	$+0.2$	$+1.1$	-0.1	$+0.5$
Correlation btw. $(M_{\rm bc}, \Delta E)$ and $(\cos\theta_{\rm thr}, \mathcal{F})$	$+0.8$	$+0.6$	$+0.8$	$+1.0$
Random $B\overline{B}$ shape				
Parametrization				
$(M_{\rm bc}, \Delta E)$	$+0.2$	$+0.3$	$+0.2$	$+0.2$
$(\cos\theta_{\rm thr}, \mathcal{F})$	$+0.3$	$+0.7$	$+0.4$	$+0.3$
Correlation btw. $(M_{\rm bc}, \Delta E)$ and $(\cos\theta_{\rm thr}, \mathcal{F})$	-0.2	-0.6	-0.2	-0.3
Dalitz distribution	$+3.2$	-0.7	$+4.5$	-0.6
MC uncertainty				
$(M_{\rm bc}, \Delta E)$	-0.5	-1.1	-0.4	-0.7
$(\cos\theta_{\rm thr}, \mathcal{F})$	$+0.0$	$+0.1$	-0.1	$+0.3$
Peaking $B\overline{B}$ shape				
Parametrization	< 0.1	< 0.1	< 0.1	< 0.1
MC uncertainty	< 0.1	< 0.1	< 0.1	< 0.1
c_i, s_i precision	± 2.6	± 6.5	± 2.6	± 6.5
Flavor-tagged statistics	± 1.7	± 2.0	± 1.6	± 2.0
Fit bias	± 0.4	± 0.5	± 0.4	± 0.5
Total without c_i,s_i precision	± 5.0	± 5.0	± 6.0	± 6.0
Total	± 5.6	± 8.2	± 6.5	± 8.8

BaBar model-dep. Prev. DP syst.

TABLE V. Summary of the main contributions to the Dalitz model systematic error on the *CP* parameters.

Source	x_-	y_-	x_+	y_+	x_-^*	y_-^*	x_+^*	y_+^*	x_{s-}	y_{s-}	x_{s+}	y_{s+}
Mass and width of Breit-Wigner's	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.003	0.003	0.001	0.002	0.002
$\pi\pi$ S-wave K-matrix solutions	0.003	0.012	0.003	0.001	0.003	0.007	0.002	0.009	0.001	0.001	0.013	0.003
$K\pi$ S-wave parametrization	0.001	0.001	0.002	0.004	0.001	0.003	0.001	0.003	0.005	0.001	0.004	0.002
Angular dependence	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.003	0.001	0.003	0.001
Blatt-Weisskopf radius	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.003
Add/remove resonances	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.002
Dalitz plot efficiency	0.006	0.004	0.008	0.001	0.002	0.004	0.002	0.003	0.008	0.001	0.008	0.004
Background Dalitz plot shape	0.003	0.002	0.004	0.001	0.001	0.001	0.001	0.001	0.004	0.001	0.004	0.002
Normalization and binning	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.003	0.001
Mistag rate	0.008	0.006	0.006	0.005	0.002	0.001	0.002	0.003	0.008	0.010	0.004	0.007
Dalitz plot complex amplitudes	0.002	0.002	0.003	0.004	0.001	0.001	0.002	0.006	0.003	0.003	0.004	0.002
Total Dalitz model	0.011	0.015	0.011	0.008	0.004	0.010	0.005	0.012	0.014	0.011	0.018	0.010

Belle ADS syst.

Source	R_{DK}	$R_{D\pi}$	$\mathcal{A}_{DK}$	$\mathcal{A}_{D\pi}$
Fit	$\pm 26\%$	$\pm 3.1\%$	± 0.40	± 0.04
Peaking backgrounds	$^{+2}_{-25}\%$	$^{+2.2}_{-5.3}\%$	…	…
Efficiency	$\pm 2.7\%$	$\pm 2.5\%$	…	…
Detector asymmetry	…	…	± 0.01	± 0.01

BaBar ADS syst.

TABLE V. Summary of systematic uncertainties on $\mathcal{R}$ for $D^{(*)}\pi$, in units of 10^{-3}.

Source	$\Delta\mathcal{R}(10^{-3})$ $D\pi$	$\Delta\mathcal{R}(10^{-3})$ $D^*_{D\pi^0}\pi$	$\Delta\mathcal{R}(10^{-3})$ $D^*_{D\gamma}\pi$
Signal NN	± 0.1	± 0.1	± 0.1
$B\bar{B}$ background NN	± 0.1	± 0.1	± 0.9
$udsc$ background NN	± 0.1	± 0.1	± 0.3
$B\bar{B}$ combinatorial background shape (m_{ES})	± 0.2	± 0.1	± 0.2
Peaking background WS	± 0.2	± 0.8	± 2.0
Peaking background RS	± 0.0	± 0.1	± 0.1
$B\bar{B}$ combinatorial background	-	± 0.0	± 0.4
Combined	± 0.4	± 0.8	± 2.2

Belle model-indep. DP syst.

ϕ_3: Systematic errors

Systematic errors in units 10^{-3}.

Source of uncertainty	Δx_-	Δy_-	Δx_+	Δy_+
Dalitz plot efficiency	4.8	2.0	5.6	2.1
Crossfeed between bins	0.4	9.0	0.6	3.0
Signal shape	7.3	7.4	7.3	5.1
u, d, s, c continuum background	6.7	5.6	6.6	3.2
$B\overline{B}$ background	7.8	12.2	7.2	6.1
$B^\pm \to D\pi^\pm$ background	1.2	4.2	1.9	1.9
Flavor-tagged statistics	1.5	2.7	1.7	1.9
Fit bias	3.2	5.8	3.2	5.8
c_i, s_i precision	10.1	22.5	7.2	17.4
Total without c_i, s_i precision	± 14.0	± 19.4	± 14.0	± 11.3
Total	± 17.3	± 29.7	± 15.7	± 20.7

CLEO ci,si result

TABLE IX. Fit results for c_i and s_i. The first error is statistical, the second error is the systematic uncertainty (excluding Δc_i, Δs_i), and the third error is the systematic uncertainty due to Δc_i and Δs_i that relate the $K_S^0\pi^+\pi^-$ and $K_L^0\pi^+\pi^-$ Dalitz-plot models.

i	c_i	s_i
1	$0.743 \pm 0.037 \pm 0.022 \pm 0.013$	$0.014 \pm 0.160 \pm 0.077 \pm 0.045$
2	$0.611 \pm 0.071 \pm 0.037 \pm 0.009$	$0.014 \pm 0.215 \pm 0.055 \pm 0.017$
3	$0.059 \pm 0.063 \pm 0.031 \pm 0.057$	$0.609 \pm 0.190 \pm 0.076 \pm 0.037$
4	$-0.495 \pm 0.101 \pm 0.052 \pm 0.045$	$0.151 \pm 0.217 \pm 0.069 \pm 0.048$
5	$-0.911 \pm 0.049 \pm 0.032 \pm 0.021$	$-0.050 \pm 0.183 \pm 0.045 \pm 0.036$
6	$-0.736 \pm 0.066 \pm 0.030 \pm 0.018$	$-0.340 \pm 0.187 \pm 0.052 \pm 0.047$
7	$0.157 \pm 0.074 \pm 0.042 \pm 0.051$	$-0.827 \pm 0.185 \pm 0.060 \pm 0.036$
8	$0.403 \pm 0.046 \pm 0.021 \pm 0.002$	$-0.409 \pm 0.158 \pm 0.050 \pm 0.002$

TABLE X. Fit results for c'_i and s'_i. The first error is statistical, the second error is the systematic uncertainty (excluding Δc_i, Δs_i), and the third error is the systematic uncertainty due to Δc_i and Δs_i.

i	c'_i	s'_i
1	$0.840 \pm 0.037 \pm 0.023 \pm 0.014$	$-0.021 \pm 0.160 \pm 0.080 \pm 0.036$
2	$0.779 \pm 0.071 \pm 0.039 \pm 0.008$	$-0.069 \pm 0.215 \pm 0.060 \pm 0.047$
3	$0.250 \pm 0.063 \pm 0.029 \pm 0.102$	$0.587 \pm 0.190 \pm 0.072 \pm 0.006$
4	$-0.349 \pm 0.101 \pm 0.057 \pm 0.092$	$0.275 \pm 0.217 \pm 0.067 \pm 0.058$
5	$-0.793 \pm 0.049 \pm 0.029 \pm 0.036$	$-0.016 \pm 0.183 \pm 0.046 \pm 0.042$
6	$-0.546 \pm 0.066 \pm 0.028 \pm 0.038$	$-0.388 \pm 0.187 \pm 0.056 \pm 0.072$
7	$0.475 \pm 0.074 \pm 0.036 \pm 0.081$	$-0.725 \pm 0.185 \pm 0.065 \pm 0.058$
8	$0.591 \pm 0.046 \pm 0.021 \pm 0.011$	$-0.374 \pm 0.158 \pm 0.059 \pm 0.054$

CLEO ci, si systematics

TABLE V. Systematic uncertainties for c_i.

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
$K_i^{(\prime)}$ statistics error	0.010	0.015	0.016	0.019	0.009	0.015	0.018	0.008
Momentum resolution	0.008	0.015	0.012	0.019	0.011	0.012	0.017	0.009
Efficiency variation	0.004	0.007	0.011	0.008	0.005	0.008	0.010	0.006
Single-tag yields	0.006	0.007	0.013	0.011	0.005	0.008	0.015	0.008
Tag side background	0.007	0.007	0.014	0.013	0.006	0.008	0.014	0.011
$K_S^0\pi^+\pi^-$ background	0.001	0.002	0.009	0.027	0.012	0.006	0.003	0.002
$K_L^0\pi^+\pi^-$ background	0.006	0.018	0.004	0.024	0.017	0.012	0.020	0.006
Multi-candidate selection	0.002	0.003	0.003	0.008	0.004	0.006	0.003	0.002
Non-$D/\bar{D}$	0.010	0.016	0.004	0.007	0.004	0.005	0.006	0.005
DCSD	0.009	0.012	0.005	0.013	0.014	0.010	0.013	0.006
Sum	0.022	0.037	0.031	0.052	0.032	0.030	0.042	0.021

TABLE VI. Systematic uncertainties for s_i.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8
$K_i^{(\prime)}$ statistics error	0.031	0.027	0.039	0.030	0.023	0.023	0.033	0.026
Momentum resolution	0.018	0.035	0.023	0.033	0.023	0.022	0.022	0.018
Efficiency variation	0.018	0.012	0.019	0.010	0.013	0.018	0.013	0.012
Single-tag yields	0.005	0.001	0.005	0.004	0.003	0.003	0.005	0.003
Tag side background	0.004	0.001	0.001	0.003	0.001	0.004	0.002	0.001
$K_S^0\pi^+\pi^-$ background	0.005	0.008	0.030	0.023	0.005	0.003	0.016	0.014
$K_L^0\pi^+\pi^-$ background	0.050	0.022	0.018	0.035	0.006	0.024	0.005	0.025
Multi-candidate selection	0.036	0.018	0.033	0.012	0.022	0.026	0.028	0.011
Non-$D/\bar{D}$	0.005	0.003	0.004	0.005	0.005	0.005	0.003	0.002
DCSD	0.023	0.004	0.030	0.019	0.015	0.006	0.027	0.020
Sum	0.077	0.055	0.076	0.069	0.045	0.052	0.060	0.050