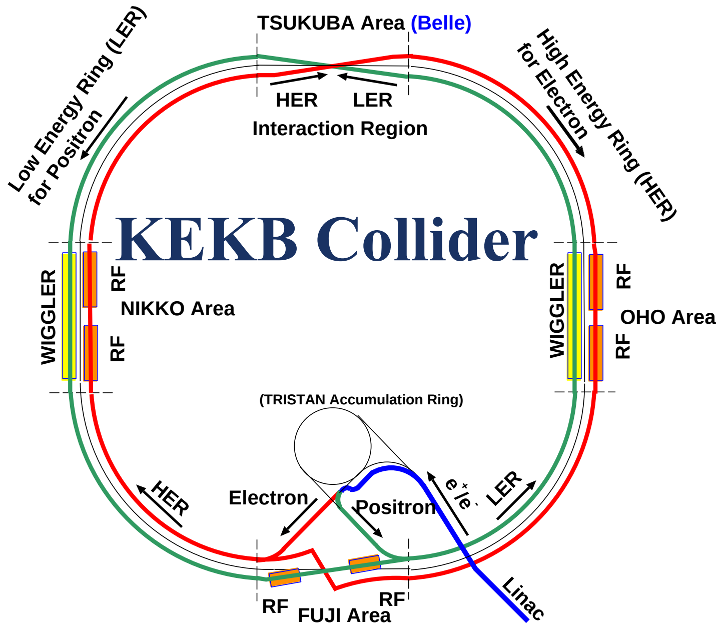
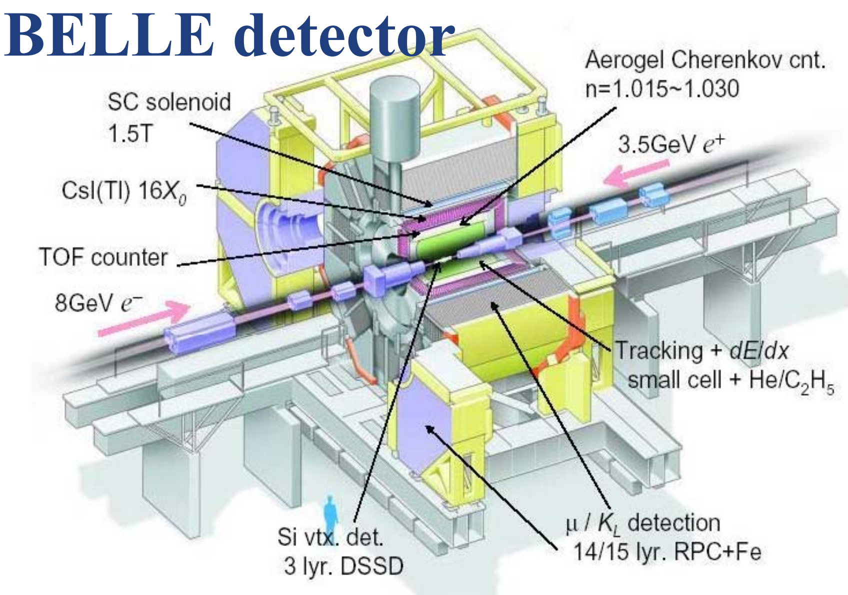
How charm data may help for φ_3 measurement at B-factories

Alex Bondar (BINP, Novosibirsk)
BELLE collaboration

1. Short description of the method
2. First results from Belle
3. Model uncertainties of the method
4. Model-independent approach using CP-tagged data from Charm Factories
5. Conclusion

KEKB & BELLE



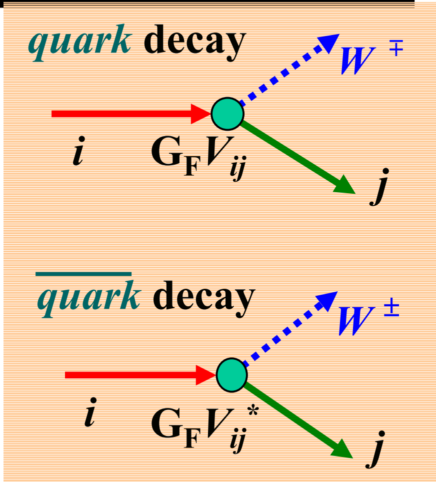


- 3.5GeV e^+ & 8GeV e^- **Asymmetric** Collider
- 3km circumference, 11*mrad* crossing angle
- L = 1.06 x 10^{34} $cm^{-2}s^{-1}$ (*world record*)
- $\int$ Ldt = 158 fb^{-1} @{Υ(4S)+off(~10%)}
  - ($140fb^{-1}$: 1.52 x 10^8 $B\bar{B}$ pairs)

~350 scientists, 55 institutions

The Weak Decays of Quarks

- **Coupling strength at decay vertex : $G_F V_{ij}$**
  - **universal Fermi weak coupling : G_F**
  - **V_{ij} : quark-mixing matrix elements**
- **CKM matrix :**
  - **unitarity : $V_{ji}^* V_{jk} = \delta_{ik}$**
  - **explicit parametrization (Wolfenstein)**
  - **complex phase leads to different $b \to u$ and $t \to d$ amplitudes for quarks and anti-quarks.**



$$V = \begin{pmatrix} Vud & Vus & Vub \\ Vcd & Vcs & Vcb \\ Vtd & Vts & Vtb \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & \lambda^3 A(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & \lambda^2 A \\ \lambda^3 A(1-\rho-i\eta) & -\lambda^2 A & 1 \end{pmatrix} + o(\lambda^4)$$

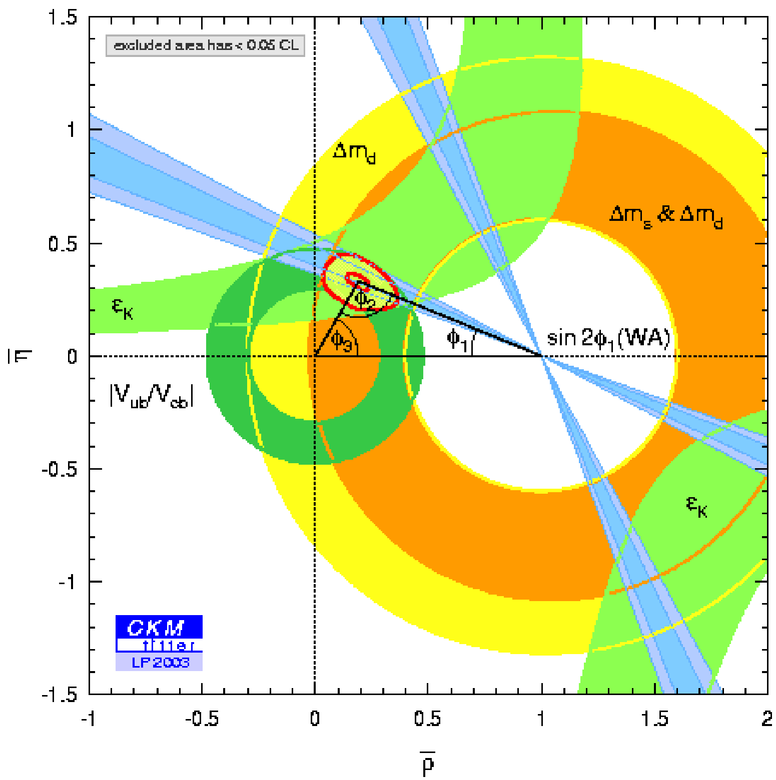
~~CP~~

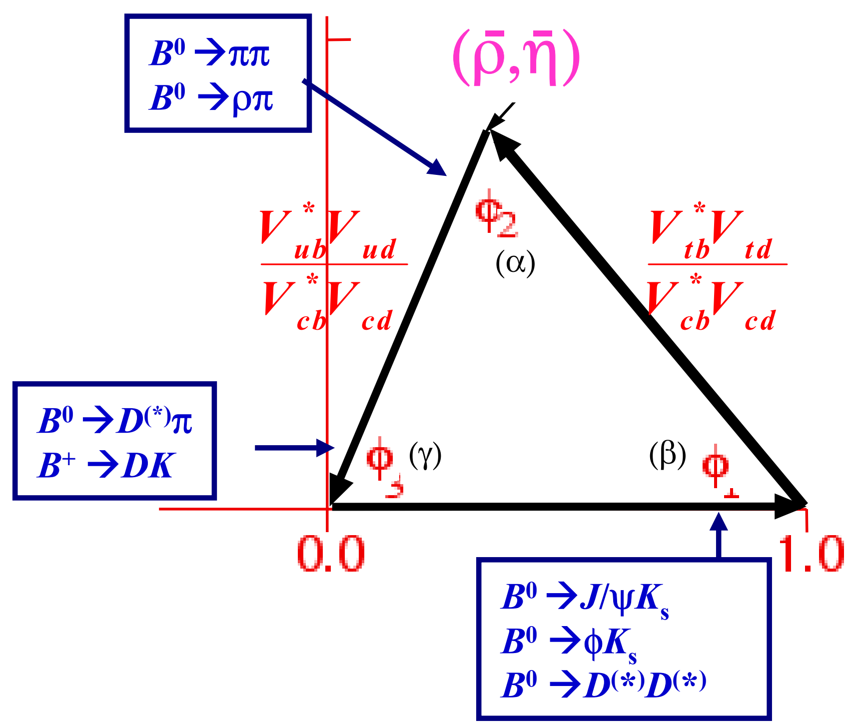
$\lambda = 0.2235 \pm 0.0033$ $A = 0.81 \pm 0.08$ $|\rho - i\eta| = 0.36 \pm 0.09$
$|1-\rho-i\eta| = 0.79 \pm 0.19$

The B Unitarity Triangle

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

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

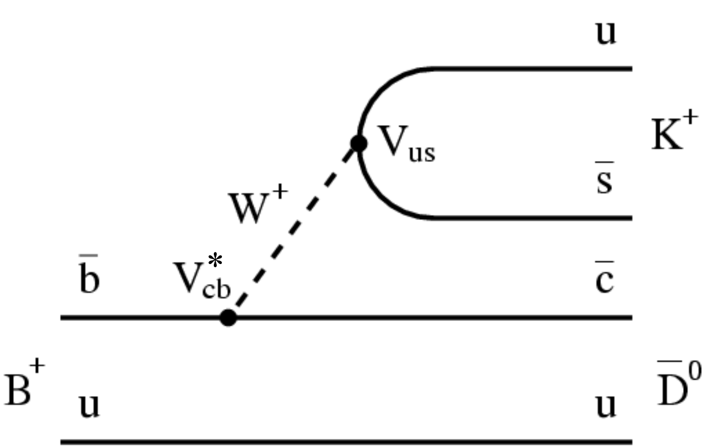


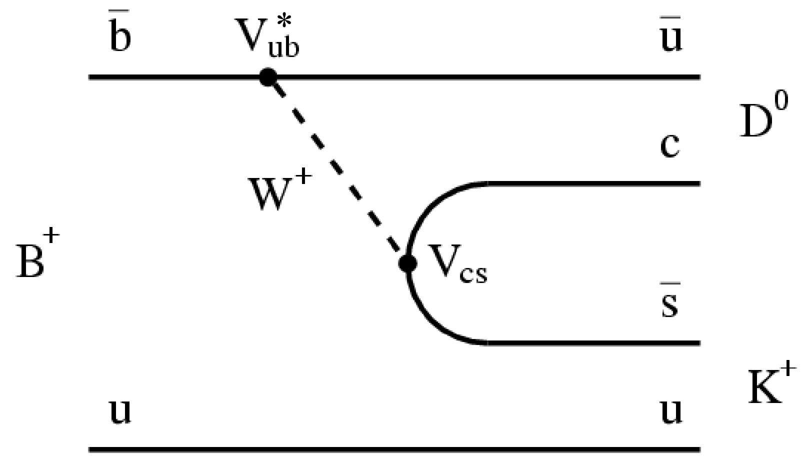


ϕ_3 measurements

- $b \to u(\bar{c}s)$ & $b \to c(\bar{u}s)$ **interference : $B^- \to DK^-$ decays**
  - **GLW method : use CP eigenstates of D^0 meson (D_{CP})**
  - **ADS method : use $K^+\pi^-$ mode as common final states of D^0 and $\bar{D}^0$**
- $b \to u(\bar{c}d)$ & $b \to c(\bar{u}d)$ **interference (& $B^0 - \bar{B}^0$ Mixing)**
  - **$\sin(2\phi_1+\phi_3)$ measurement via $B^0 \to D^{(*)+}\pi^-$**
- **Dalitz analysis of $B^- \to DK^-$ ($D \to K_S \pi^- \pi^+$) decays to get ϕ_3 directly. (A.Giri, et. Al hep-ph/0303187) Independently by Belle (unpublished)** **http://belle.kek.jp/secured/dcpvrare/meetings/binp/020926/bondar.pdf** **First Belle measurement hep-ex/0308043**

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





$$M_1 \sim V_{cb}^* V_{us} \sim A\lambda^3 \qquad M_2 \sim V_{ub}^* V_{cs} \sim A\lambda^3(\rho + i\eta) \sim e^{i\phi_3}$$

If both D^0 and $\overline{D}^0$ decay into the same final states

$B^+ \to D^0 K^+$ and $B^+ \to \overline{D}^0 K^+$ amplitudes interfere.

Mixed state is produced: $\left|\tilde{D}^0\right\rangle = \left|\overline{D}^0\right\rangle + ae^{i\theta}\left|D^0\right\rangle$

Total phase $\theta = \phi_3 + \delta$

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

$$\left| \widetilde{D}^0 \right\rangle = \left| \overline{D}^0 \right\rangle + a e^{i\theta} \left| D^0 \right\rangle$$

$$a = \frac{\left| V_{ub} V_{cs}^* \right|}{\left| V_{cb} V_{us}^* \right|} \times \frac{a_2}{a_1} \approx 0.09/0.22 \times 0.35 \approx 1/8 \qquad \theta = \delta + \varphi_3$$

$$a = \sqrt{\frac{Br(B^+ \to D^0 K^+)}{Br(B^+ \to \overline{D}^0 K^+)}}$$ in the case of no interference between D^0 and $\overline{D}^0$

Color suppression factor a_2/a_1=0.35 is estimated from the ratio of $B^0 \to D^0 K^0$ and $B^+ \to D^0 K^+$ branching fractions (measured by Belle)

Use 3 body D^0 decay, analyze Dalitz plot (fit relative amplitude a and phase θ)

$\theta = \delta + \varphi_3$ for B^+
$\theta = \delta - \varphi_3$ for B^-
} can obtain both φ_3 and δ separately

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

- **Use D^0 3-body final state : $B^+ \to D^0(\bar{D}^0)K^+ \to K_S\pi^+\pi^- K^+$**
- **3-body decay is parameterized by 2-variables: $m_+^2(K_s\pi^+)$ & $m_-^2(K_s\pi^-)$**

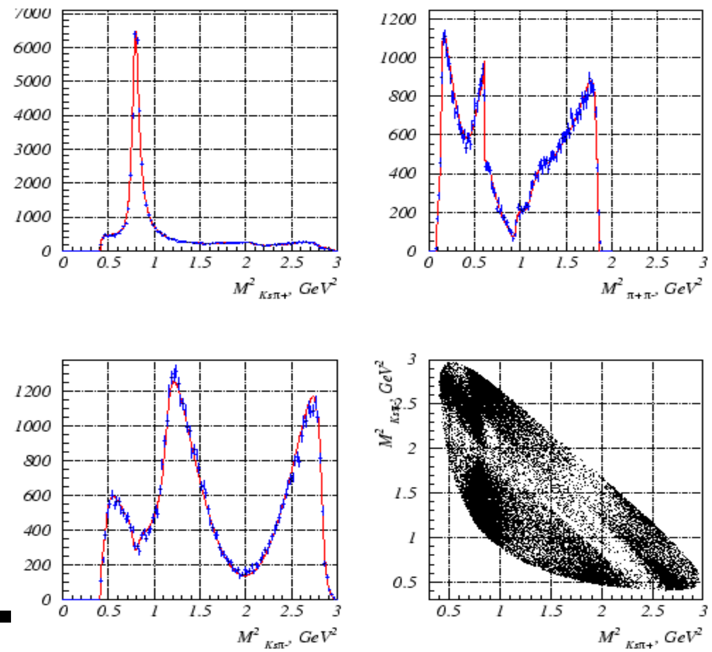
$$M_+(B^+ \to DK^+) = f(m_+^2, m_-^2) + ae^{i\theta_+} f(m_-^2, m_+^2) \qquad f(m_\pm^2, m_\mp^2): \bar{D}^0(D^0)\ decay\ amplitudes$$

$$M_-(B^- \to DK^-) = f(m_-^2, m_+^2) + ae^{i\theta_-} f(m_+^2, m_-^2) \qquad \theta_\pm = \delta \pm \phi_3$$

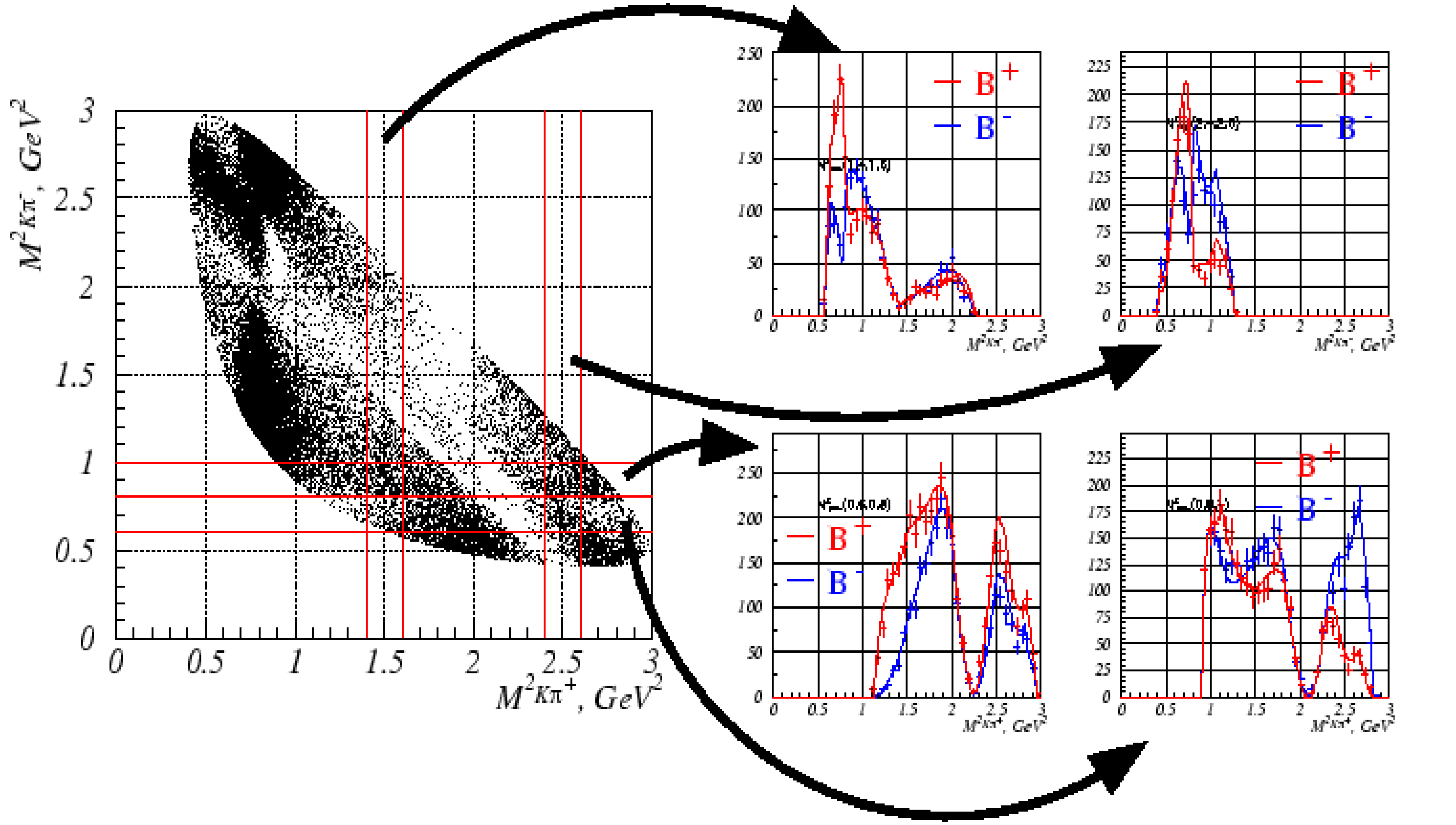
- **Determine each D^0 decay amplitudes by fitting relative amplitudes and relative phases.**

$D(2010)^{*+} \to D^0\pi^+ : 57800\ events\ @\ 78\ fb^{-1}$

Resonance	Amplitude	Phase, (deg)
$K^*(892)^-\pi^+$	1.706 ± 0.015	138.0 ± 0.9
$K_s\rho^0$	1.0 (fixed)	0 (fixed)
$K^*(892)^+\pi^-$	$(13.6 \pm 0.8) \times 10^{-2}$	330 ± 3
$K_s\omega$	$(32.8 \pm 1.8) \times 10^{-3}$	114 ± 3
$K_s f_0(980)$	0.385 ± 0.011	214.2 ± 2.3
$K_s f_0(1370)$	0.49 ± 0.04	311 ± 6
$K_s f_2(1270)$	1.66 ± 0.05	341.3 ± 2.3
$K_0^*(1430)^-\pi^+$	2.09 ± 0.05	353.6 ± 1.8
$K_2^*(1430)^-\pi^+$	1.20 ± 0.05	316.9 ± 2.1
$K^*(1680)^-\pi^+$	1.62 ± 0.24	84 ± 10
$K_s\sigma_1$ ($M_{\sigma_1} = 535 \pm 6$ MeV, $\Gamma_{\sigma_1} = 460 \pm 15$ MeV)	1.66 ± 0.09	217.3 ± 1.4
$K_s\sigma_2$ ($M_{\sigma_2} = 1063 \pm 7$ MeV, $\Gamma_{\sigma_2} = 101 \pm 12$ MeV)	0.31 ± 0.04	257 ± 11
non-resonant	6.51 ± 0.22	149.0 ± 1.6



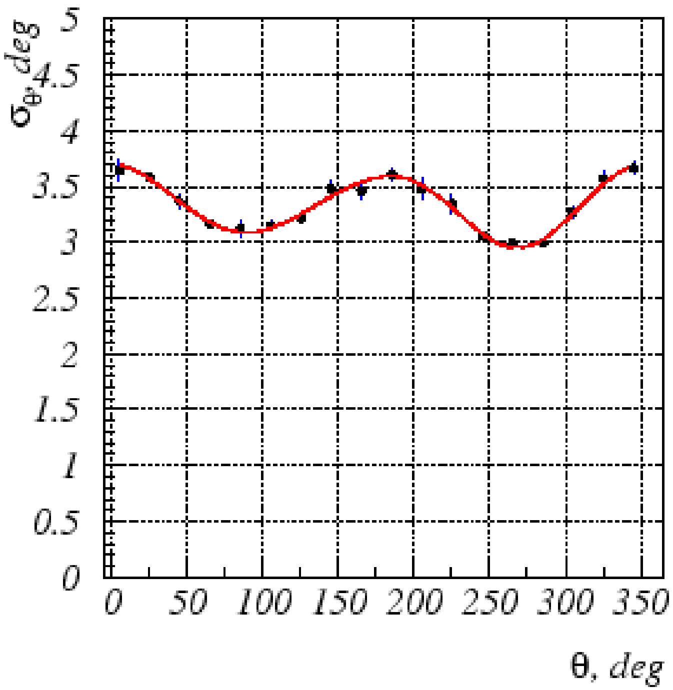
Effect of D^0-$\overline{D}^0$ interference



Most sensitive regions on the Dalitz plot ($\delta = 0^o$, $\phi_3 = 70^o$) $a = 0.125$.
5×10^4 detected events (equiv. $\int L \sim 50\ \mathrm{ab}^{-1}$).

Statistical accuracy (MC study)

Accuracy depends on the value of a. Use pessimistic value $a = 0.125$.



Statistical error of phase θ for 10^4 detected decays.

Generate $\tilde{D}^0$ Dalitz plot for $0^0 < \theta < 360^0$.

Fit Dalitz plot with free a and θ, extract σ_θ.

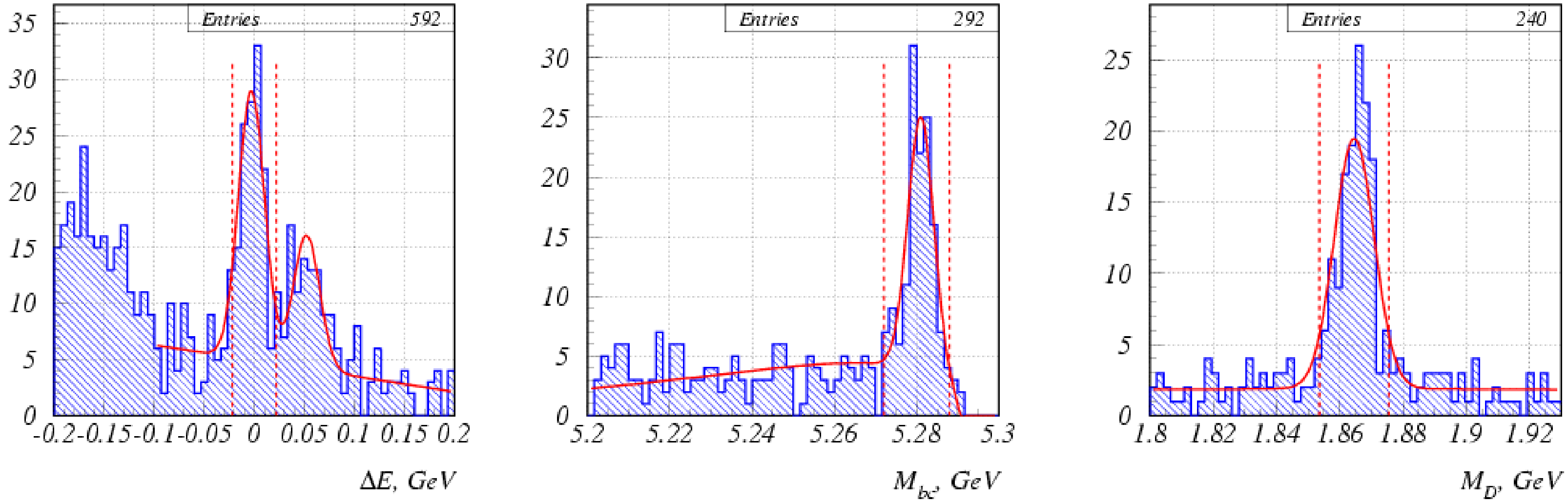
$$\phi_3 = \frac{\theta^+ - \theta^-}{2}$$

If $\sigma_\theta = Const$

$$\sigma_{\phi_3} = \sqrt{2} \cdot \frac{\sigma_\theta}{\sqrt{2}} = \sigma_\theta$$

$3.0^o < \sigma_{\phi_3} < 3.7^o$ for 10^4 *detected* $B^\pm$ decays

$B^+ \to D^0 K^+$ signal with 142 fb^{-1}



138 events

107±12 signal

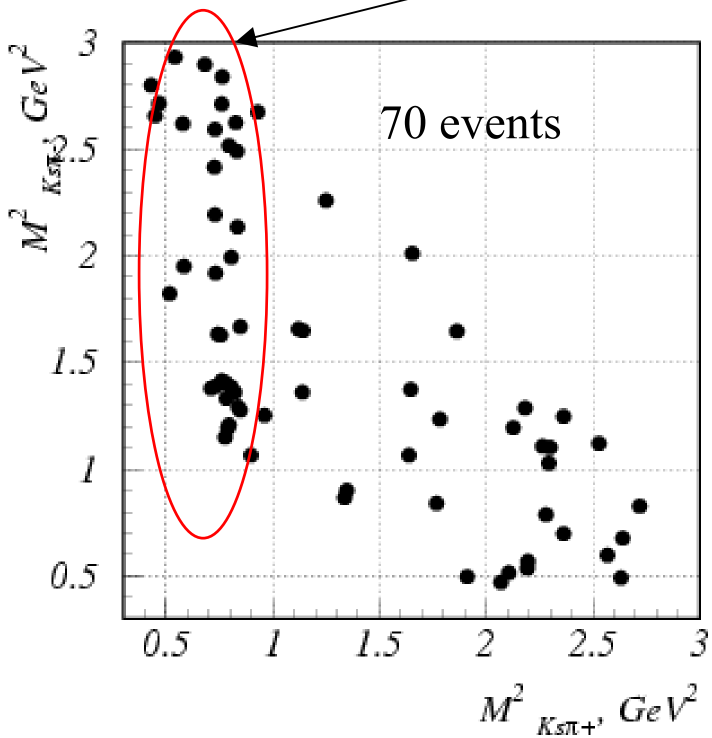
32±3 background

Signal selection cuts:

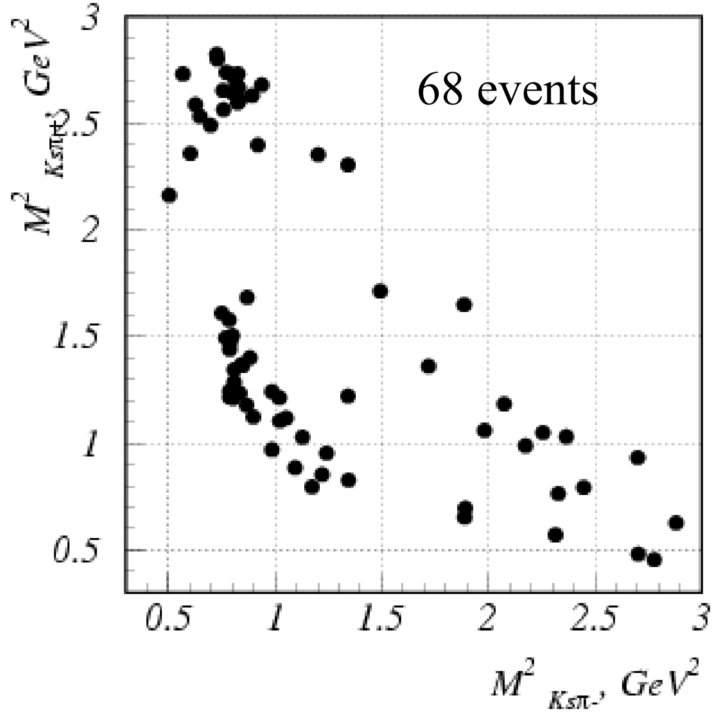
- $|\Delta E|<22$ MeV
- $5.272<M_{bc}<5.288$ GeV
- $|M_D-1.86\text{ GeV}|<11$ MeV
- $|\cos\Theta_{thr}|<0.8$
- Fisher discriminant $\mathcal{F}>-0.7$
- PID(K/π)>0.7

$B^+ \to D^0 K^+$, $D^0 \to K_s \pi^+ \pi^-$ Dalitz plot

K*(892) bands



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



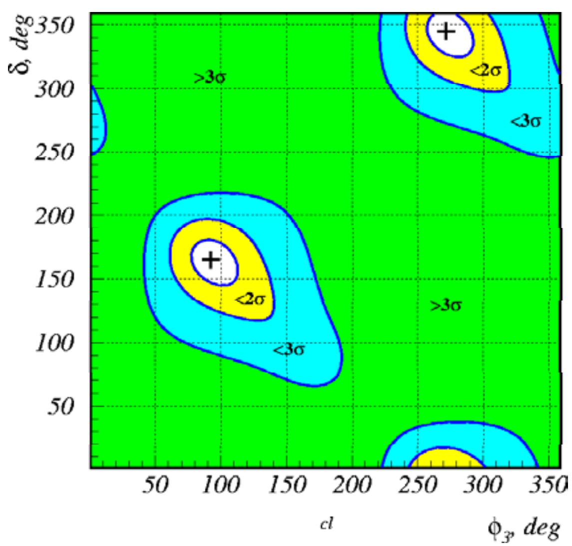
D^0 from $B^- \to D^0 K^-$
(π^+ and π^- interchanged)

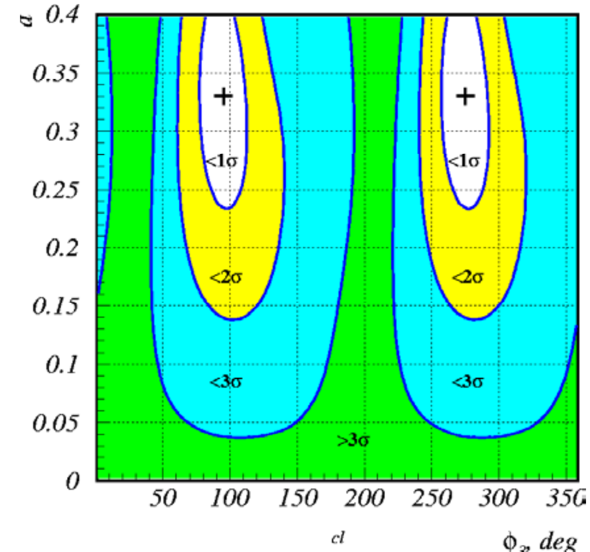
Backgrounds

- $q\bar{q}$ combinatorics (14%)
  - Fraction (together with D^0): from ΔE distribution
  - Dalitz plot: from continuum data (off-Υ(4S) or on-resonance)
- D^0 from $q\bar{q}$ (3%)
  - Fraction (relative to combinatorial): from $q\bar{q}$ M_D distribution
  - Dalitz plot: equal mixture of D^0 and $\bar{D}^0$
- B decays (2% neutral, 4% charged)
  - Fraction and Dalitz plot: from generic MC
- "Wrong" particles in D^0 decay (0.5%)
  - Fraction and Dalitz plot: from $B \to D^0 K$ MC
- $B \to D^0 \pi$ with K/π misidentification (0.5%)
  - Fraction: from signal ΔE distribution
  - Dalitz plot: D^0
- Flavour tagging K from combinatorics (<0.4% at 95 C.L. from MC)

Extracting ϕ_3

- **Fit D^0 Dalitz plots from $B^+ \to D^0 K^+$ and $B^- \to D^0 K^-$ processes simultaneously with three (a, ϕ_3 and δ) free parameters.**





- ***Weak phase*** $\phi_3 = 95^\circ\,^{+25^\circ}_{-20^\circ} \pm 13^\circ \pm 10^\circ$
- ***Strong phase*** $\delta = 162^\circ\,^{+20^\circ}_{-25^\circ} \pm 12^\circ \pm 24^\circ$
- ***Relative amplitude a*** $= 0.33 \pm 0.10 \pm 0.03 \pm 0.03$

@ 90% C.L.

$61^\circ < \phi_3 < 142^\circ$

$104^\circ < \delta < 214^\circ$

$0.15 < a < 0.50$

Model uncertainty (MC study)

Generate $\tilde{D}^0$ Dalitz plot for $0^0 < \theta < 360^0$.

Fit Dalitz plot with different model (free a and θ), $\Delta\theta = \theta_{fit} - \theta$.

Fit model	$(\Delta\phi_3)_{max}, deg$
$K^*(892)$, ρ, nonres	29.3
$K^*(892)$, ρ, DCS $K^*(892)$, $f^0(980)$, nonres	9.9
Meson formfactors $F_r = F_D = 1$	3.1
Width dependence $\Gamma(q^2) = Const$	4.7

Our estimation of model uncertainty is 10° (all wide resonances approximated by the flat term).

Source of model uncertainty

Complex D^0 decay amplitude f consists of absolute value $|f|$ and phase ϕ.

$$f = |f(m_+, m_-)|e^{i\phi(m_+,m_-)}$$

For $D^0 - \bar{D}^0$ interference from $B \to D^0 K$ decay:

$$\begin{aligned} A &= |f(m_+, m_-)|e^{-i\phi(m_+,m_-)} + ae^{i\theta}|f(m_-, m_+)|e^{-i\phi(m_-,m_+)} \\ &= |f(m_+, m_-)| + ae^{i\theta}|f(m_-, m_+)|e^{-i(\phi(m_-,m_+)-\phi(m_+,m_-))}. \end{aligned}$$

$|f|$ is directly measured in the experiment.

Phase difference $\phi(m_-, m_+) - \phi(m_+, m_-)$ is model-dependent.

Model-independent approach

Amplitude of D^0_{CP} decay:

$$A_{CP} = \frac{f(m_+, m_-) \pm f(m_-, m_+)}{\sqrt{2}} = \frac{|f(m_+, m_-)| \pm |f(m_-, m_+)| e^{i(\phi(m_+, m_-) - \phi(m_-, m_+))}}{\sqrt{2}}.$$

Phase difference can be obtained without model assumptions using D^0 and D_{CP}.

CP eigenstate of D^0 can be produced by $c\tau$-factory in decay $\psi'' \to D^0 \bar{D}^0$.
CP tag is provided by another D^0 decaying to CP eigenstate (like K^+K^-).

Preliminary

D^0	D_{CPeven}	D_{CPodd}	$(\Delta\phi_3)_{max}$
1000	100	100	15.2 ± 5.4
5000	500	500	7.0 ± 2.5
20000	2000	2000	1.6 ± 0.6

CP-tagged events at Charm Factories

CP properties of the D states produced in the Ψ(3700) are anticorrelated. If one D decaying as CP=+1 other state is "CP-tagged" as CP=-1

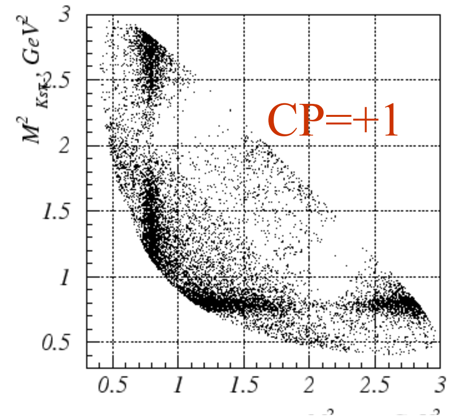
32,000 CP-tagged $K^+\pi^-$ decays are expected for one year run at CLEO-c (G.Burdman, I.Shipsey hep-ph/0310076)

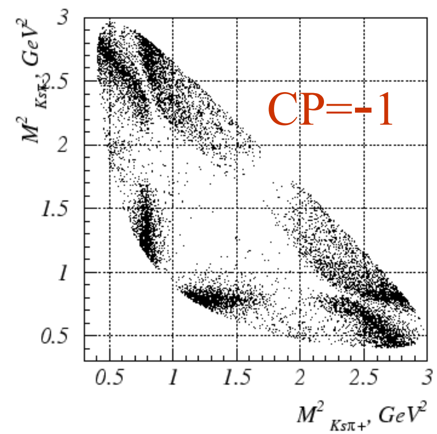
Based on this number we can estimate:

8,000 $K_S\pi^+\pi^-$

6,000 $\pi^+\pi^-\pi^0$

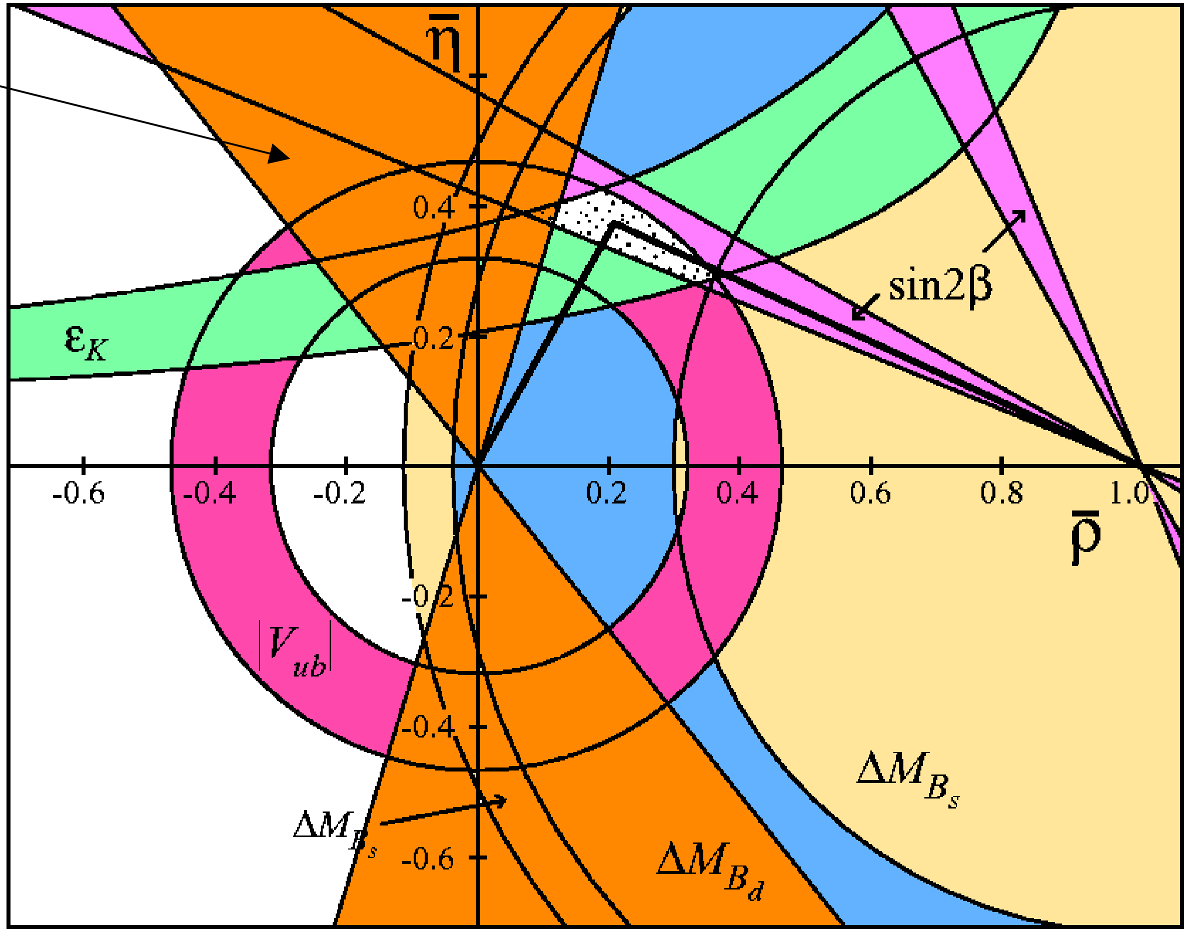
1,500 $K_SK^+K^-$





Comparison with indirect measurements

Our result (68% CL)



Conclusion

- ϕ_3 can be measured in $B \to D^0 K$, $D^0 \to K_s \pi^+ \pi^-$ decay. The advantages are:
  - Do not need absulute values of branchings.
  - Sensitive to ϕ_3 itself, no discrete ambiguities for $0 < \phi_3 < \pi$.
  - Model uncertainty is $\sim 10^\circ$
  - Model-independent approach exists Data from Charm Factory are necessary!
  - Sensitivity can be increased by using other decay modes:
    $B \to D^{*0} K$ with $D^{*0} \to D^0 \pi^0$;
    $D^0 \to K_s K^+ K^-$, $\pi^0 \pi^+ \pi^-$, 4-body decays.
- Expected sensitivity with 3 ab^{-1} and 10% detection efficiency:
  - $\sim 5 - 7^\circ$ for $a = 0.125$
  - $\sim 3 - 5^\circ$ for $a = 0.2$

CLEO $D^0 \to K_s\pi^+\pi^-$ Dalitz plot analysis

CLEO collected 5300 $D^0 \to K_s\pi^+\pi^-$ decays with 9 fb^{-1}. [PRL **89**,251802 (2002)]

D^0 amplitude is represented by a sum of 2-body decay amplitudes:

$$f = a_{K^*} e^{i\phi_{K^{*-}}} [F_D F_{K^*} M^J BW(m^2_{K_s\pi^-})] + a_\rho e^{i\phi_\rho} [F_D F_\rho M^J BW(m^2_{\pi^+\pi^-})] + \ldots$$

19 resonant components considered:

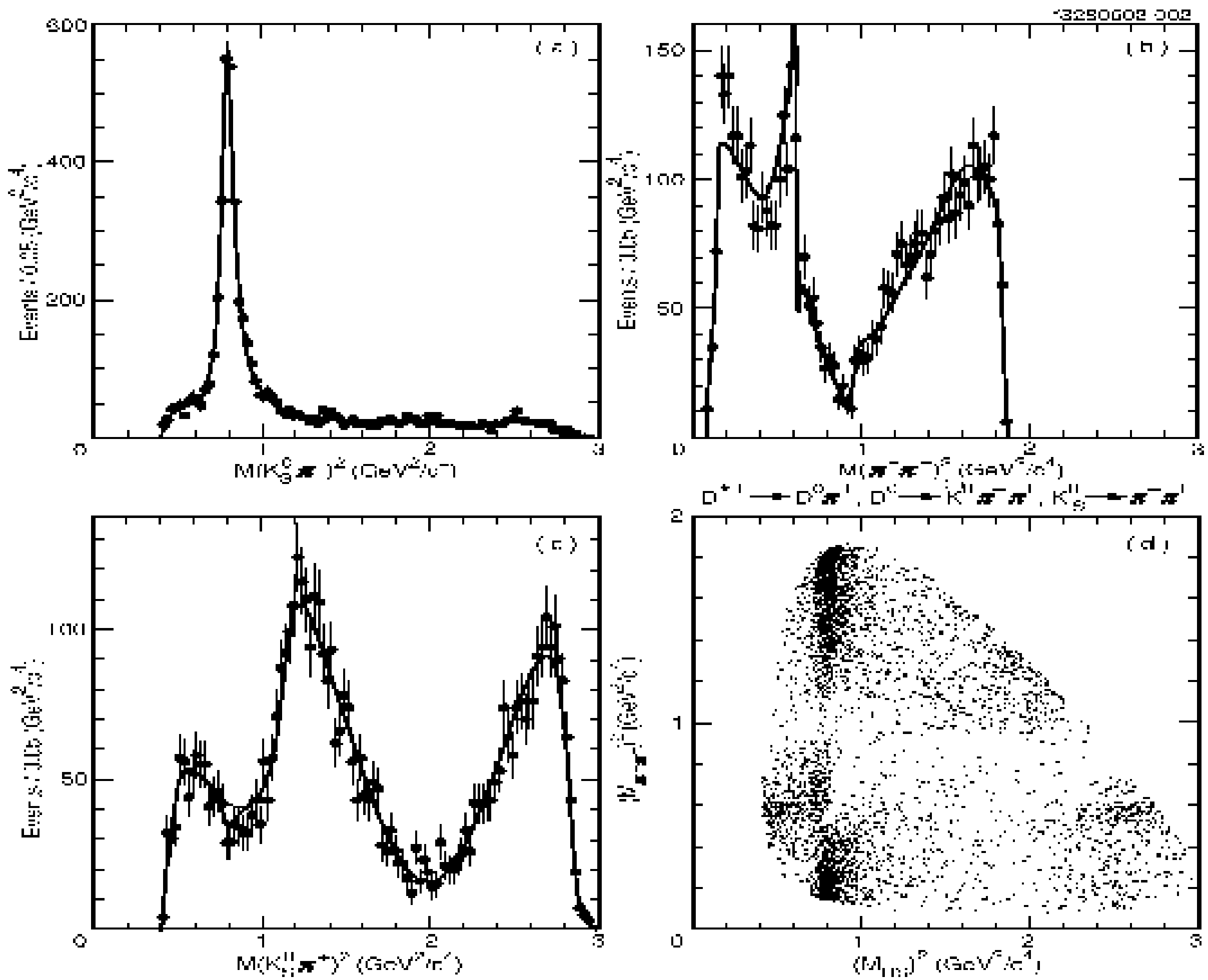
$K^{*-}\pi^+$, $\kappa(800)^-\pi^+$, $K^*(1410)^-\pi^+$, $K_0^*(1430)^-\pi^+$, $K_2^*(1430)^-\pi^+$, $K^*(1680)^-\pi^+$, $K_3^*(1780)^-\pi^+$, $K_s\rho$, $K_s\omega$, $K_s\rho(1450)$, $K_s\rho(1700)$, $K_s\sigma(500)$, $K_s f_0(980)$, $K_s f_2(1270)$, $K_s f_0(1370)$, $K_s f_0(1500)$, $K_s f_0(1710)$
Doubly Cabbibo-suppressed: $K^{*+}\pi^-$, $K_0^*(1430)^+\pi^-$

10 components found (red) + non-resonant.

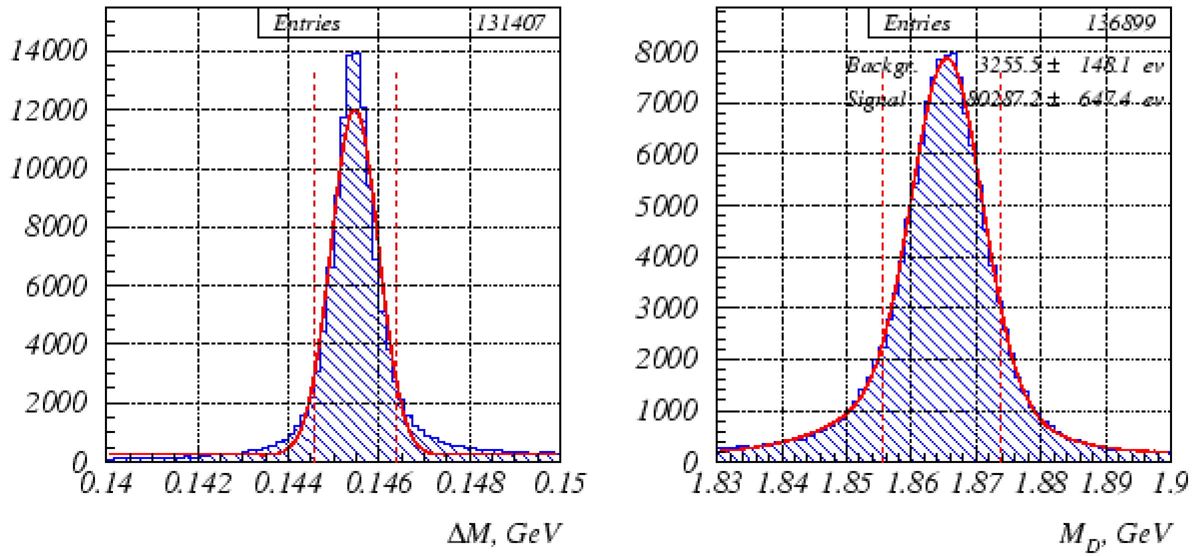
Doubly Cabibbo suppressed amplitude $K^{*+}\pi^-$ observed with 5.5σ significance.

No CPV observed. Mixing not studied.

CLEO $D^0 \to K_s \pi^+ \pi^-$ data and fit



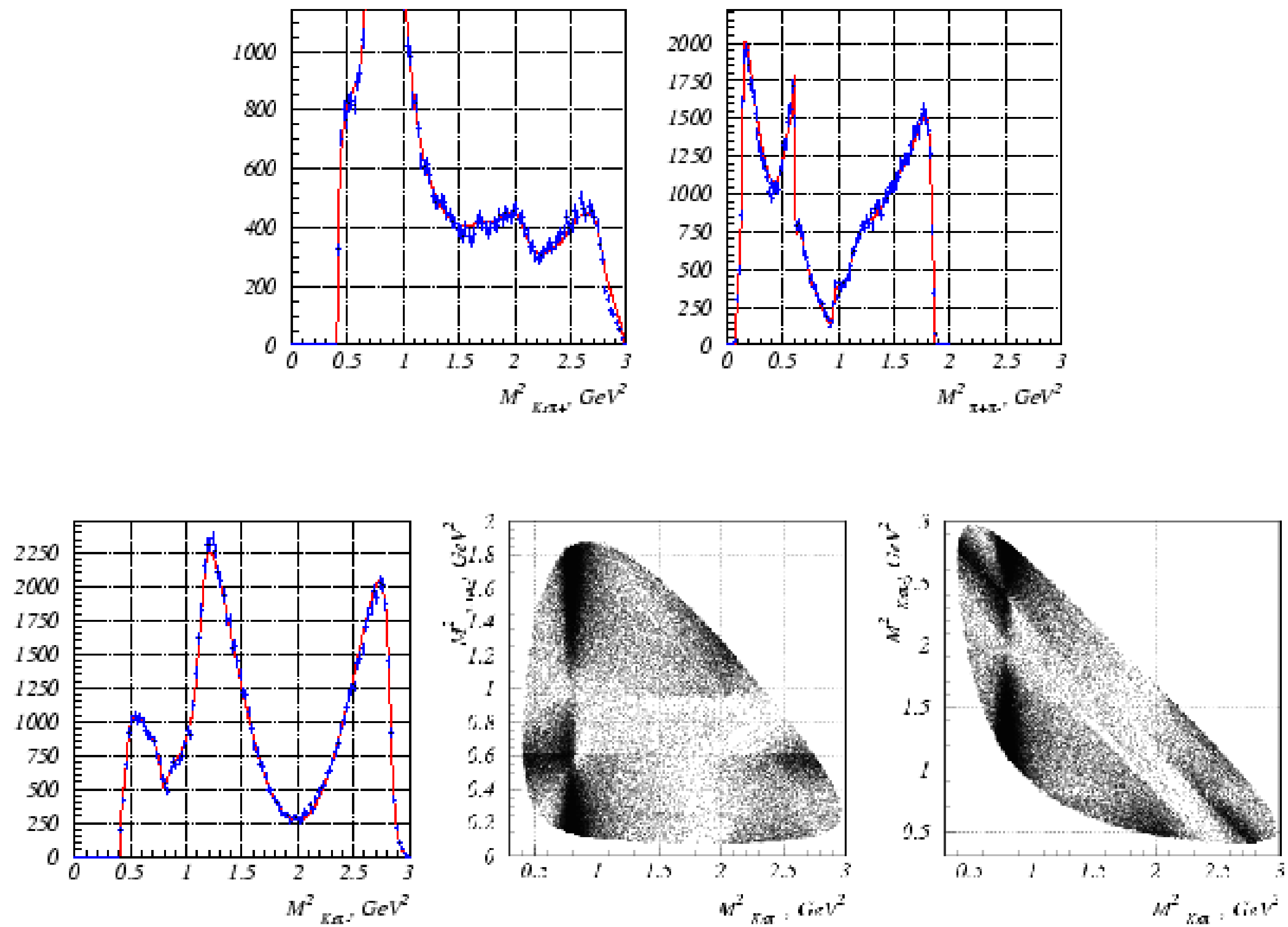
Event selection $D^{*+} \to D^0 \pi^+, D^0 \to K_s \pi^+ \pi^-$



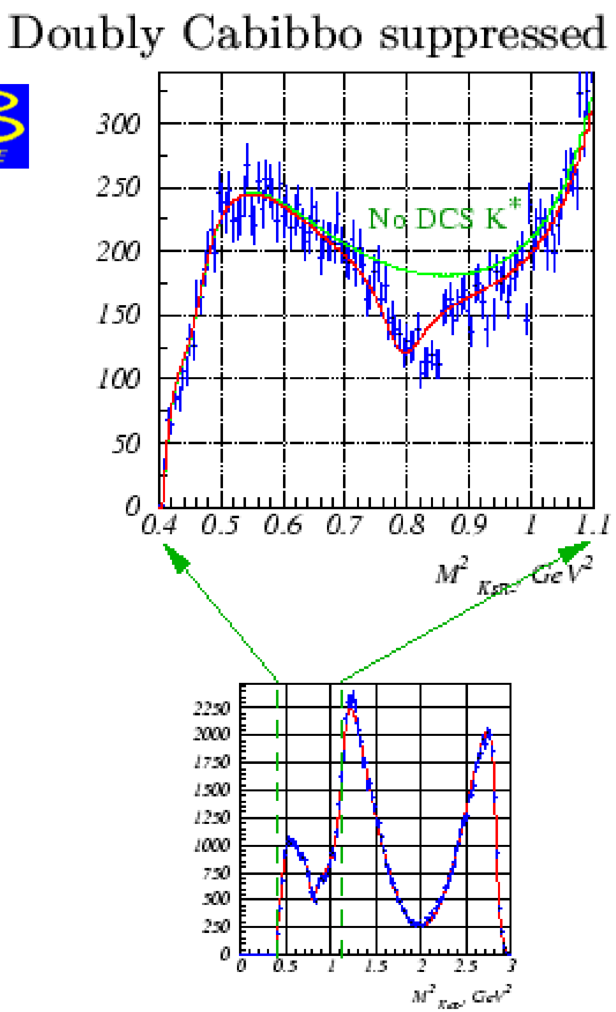
140 fb^{-1} sample
101000 events selected
5.6% background
$\sigma_{\Delta M} = 0.5$ MeV
$\sigma_{M_D} = 5.5$ MeV

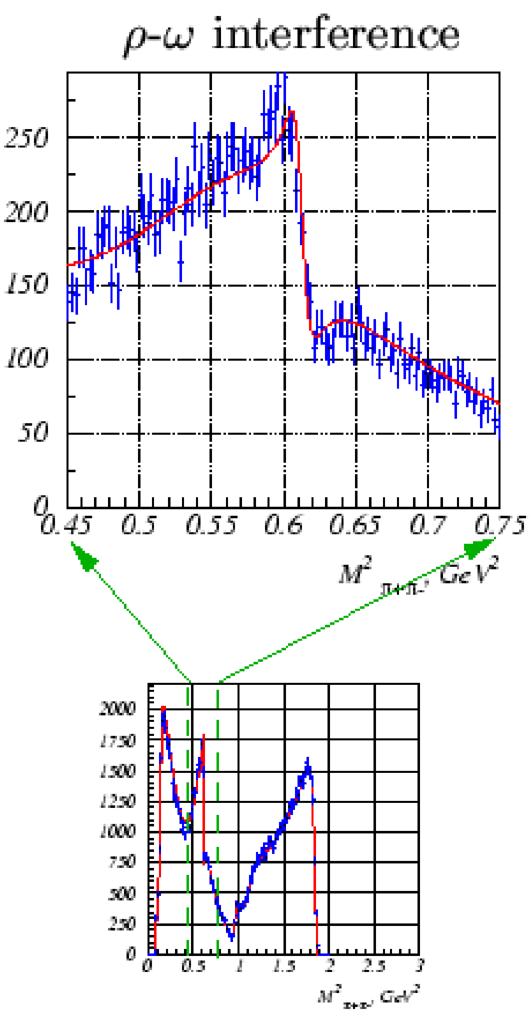
$4.39 < \Delta M = M_{D\pi} - M_D - m_\pi < 6.19$ MeV,
$|M_{K_s\pi\pi} - M_D| < 9$ MeV,
$|p_{D^0\pi}| > 2.7$ GeV,
K_s vertex dist. from I. P. >2 mm.

Belle $D^0 \to K_s \pi^+ \pi^-$ data and fit



Close look to $D^0 \rightarrow K_s \pi^+ \pi^-$ plot projections





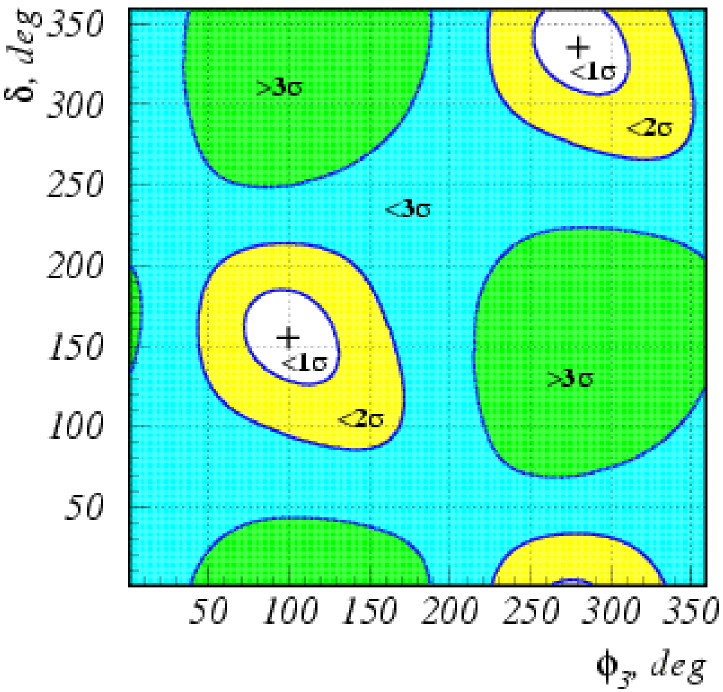
CLEO/Belle fit results

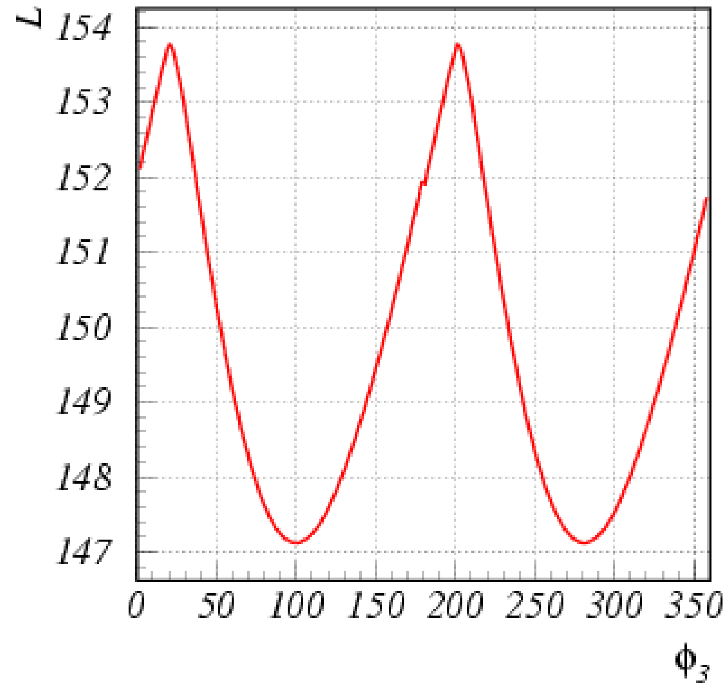
Preliminary

Resonance	CLEO fit			Our fit	
	Amplitude	Phase, deg	Br, %	Amplitude	Phase, deg
$K^*(892)^-\pi^+$	$1.56\pm0.03\pm0.02^{+0.15}_{-0.03}$	$150\pm2\pm2^{+2}_{-5}$	65.7 ± 1.3	1.64 ± 0.012	137.7 ± 0.7
$K^*(892)^+\pi^-$	$(11\pm2\,^{+4}_{-1}\,^{+4}_{-1})\times10^{-2}$	$321\pm10\pm3\,^{+15}_{-5}$	0.34 ± 0.13	$(14.6\pm0.7)\times10^{-2}$	324.2 ± 2.3
$K_0^*(1430)^-\pi^+$	$2.0\pm0.1\,^{+0.1}_{-0.2}\,^{+0.5}_{-0.1}$	$3\pm4\pm4\,^{+7}_{-24}$	7.3 ± 0.7	1.85 ± 0.04	354.5 ± 1.6
$K_0^*(1430)^+\pi^-$	-	-	-	0.33 ± 0.05	124 ± 8
$K_2^*(1430)^-\pi^+$	$1.0\pm0.1\pm0.1\,^{+0.3}_{-0.1}$	$335\pm7\,^{+1}_{-4}\,^{+7}_{-24}$	1.1 ± 0.2	1.23 ± 0.03	311.8 ± 1.9
$K_2^*(1430)^+\pi^-$	-	-	-	0.19 ± 0.03	277 ± 10
$K^*(1680)^-\pi^+$	$5.6\pm0.3\,^{+0.5}_{-0.2}\pm4.0$	$174\pm6\,^{+10}_{-3}\,^{+13}_{-19}$	2.2 ± 0.4	2.12 ± 0.23	72 ± 7
$K^*(1680)^+\pi^-$	-	-	-	1.25 ± 0.2	112 ± 9
$K_s\rho^0$	1.0 (fixed)	0 (fixed)	26.4 ± 0.9	1.0 (fixed)	0 (fixed)
$K_s\omega$	$(37\pm5\pm1\,^{+3}_{-8})\times10^{-3}$	$114\pm7\,^{+6}_{-4}\,^{+2}_{-5}$	0.72 ± 0.18	$(33.2\pm1.4)\times10^{-3}$	113.6 ± 2.4
$K_sf_0(980)$	$0.34\pm0.02\,^{+0.04}_{-0.03}\,^{+0.04}_{-0.02}$	$188\pm4\,^{+5}_{-3}\,^{+8}_{-6}$	4.3 ± 0.5	0.385 ± 0.008	209.3 ± 1.8
$K_sf_0(1370)$	$1.8\pm0.1\,^{+0.2}_{-0.1}\,^{+0.2}_{-0.6}$	$85\pm4\,^{+4}_{-1}\,^{+34}_{-13}$	9.9 ± 1.1	0.75 ± 0.06	320 ± 9
$K_sf_2(1270)$	$0.7\pm0.2\,^{+0.3}_{-0.1}\pm0.4$	$308\pm12\,^{+15}_{-25}\,^{+66}_{-6}$	0.27 ± 0.15	1.30 ± 0.06	353 ± 3
$K_s\sigma_1$	-	-	-	1.45 ± 0.09	211.6 ± 3.6
$K_s\sigma_2$	-	-	-	0.25 ± 0.04	253 ± 3
non-resonant	$1.1\pm0.3\,^{+0.5}_{-0.2}\,^{+0.9}_{-0.7}$	$340\pm11\,^{+30}_{-18}\,^{+55}_{-52}$	0.9 ± 0.4	5.46 ± 0.29	144.5 ± 2.4

$M_{\sigma_1}=525\pm9$ MeV, $\Gamma_{\sigma_1}=432\pm16$ MeV. $M_{\sigma_2}=1060\pm3$ MeV, $\Gamma_{\sigma_2}=99\pm10$ MeV.

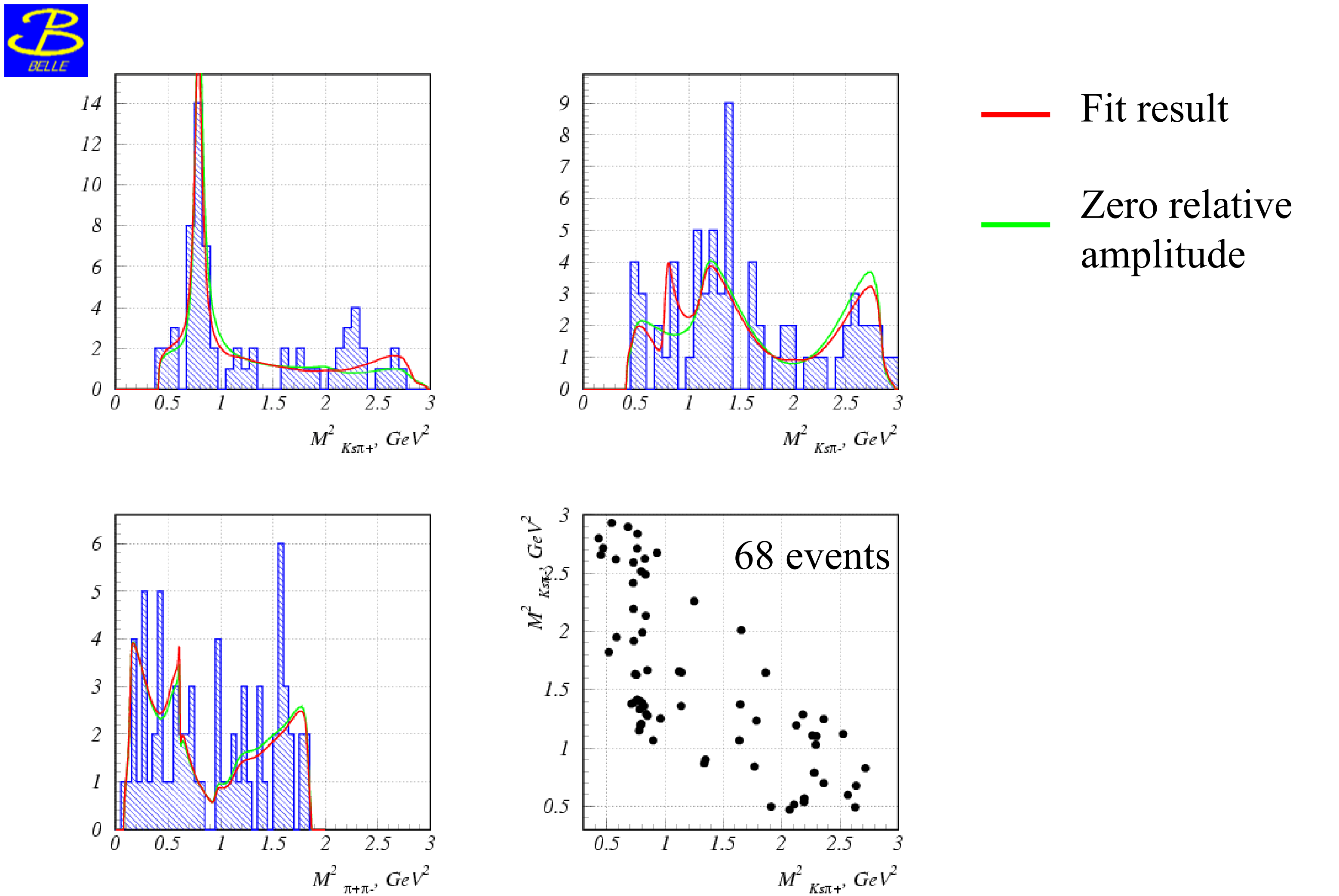
$B^+ \rightarrow D^0 K^+$ Dalitz plot fit results (fixed a)



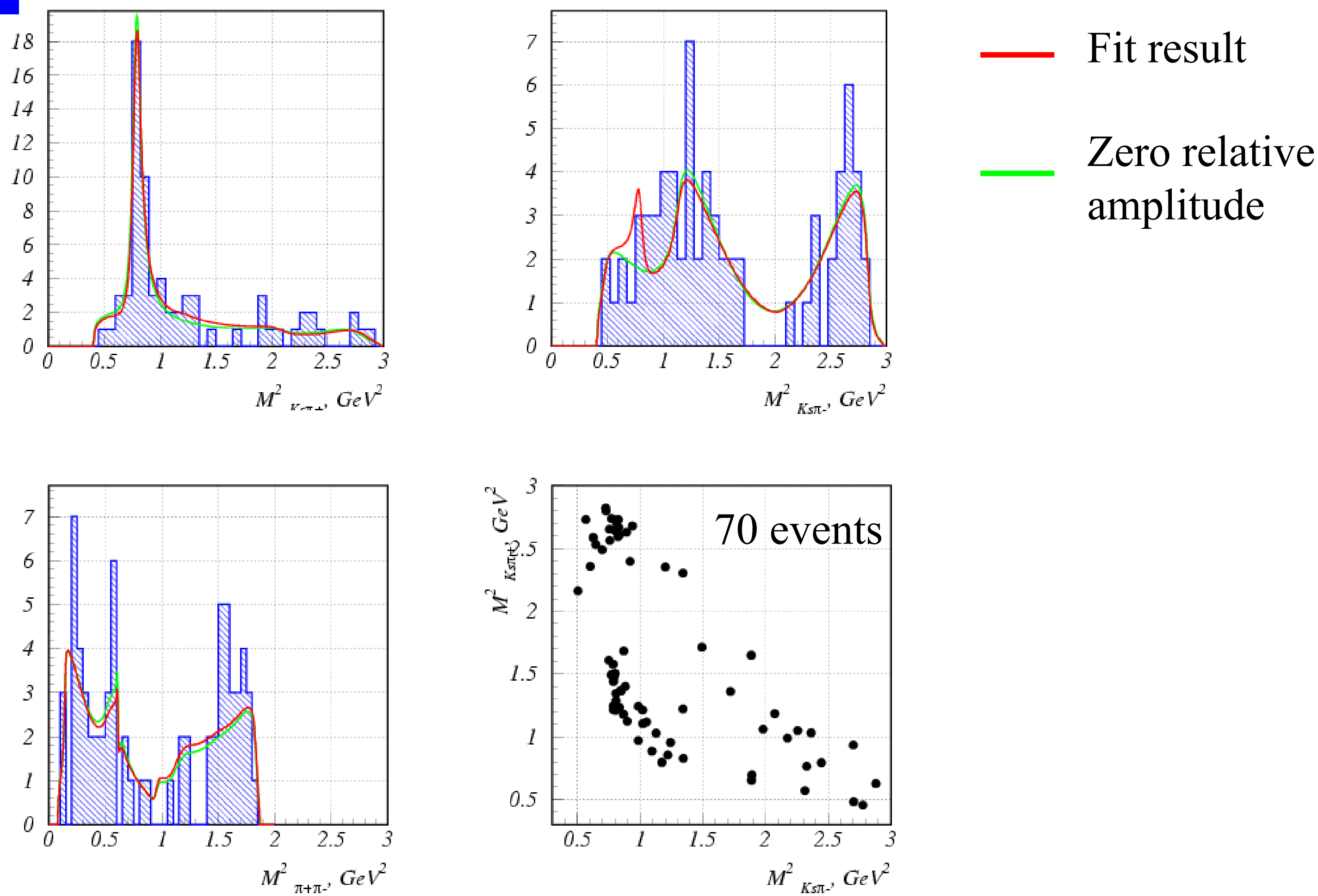


For fixed a=0.125: $\varphi_3 = 99^{+30}_{-26}$ $\delta = 155 \pm 30$

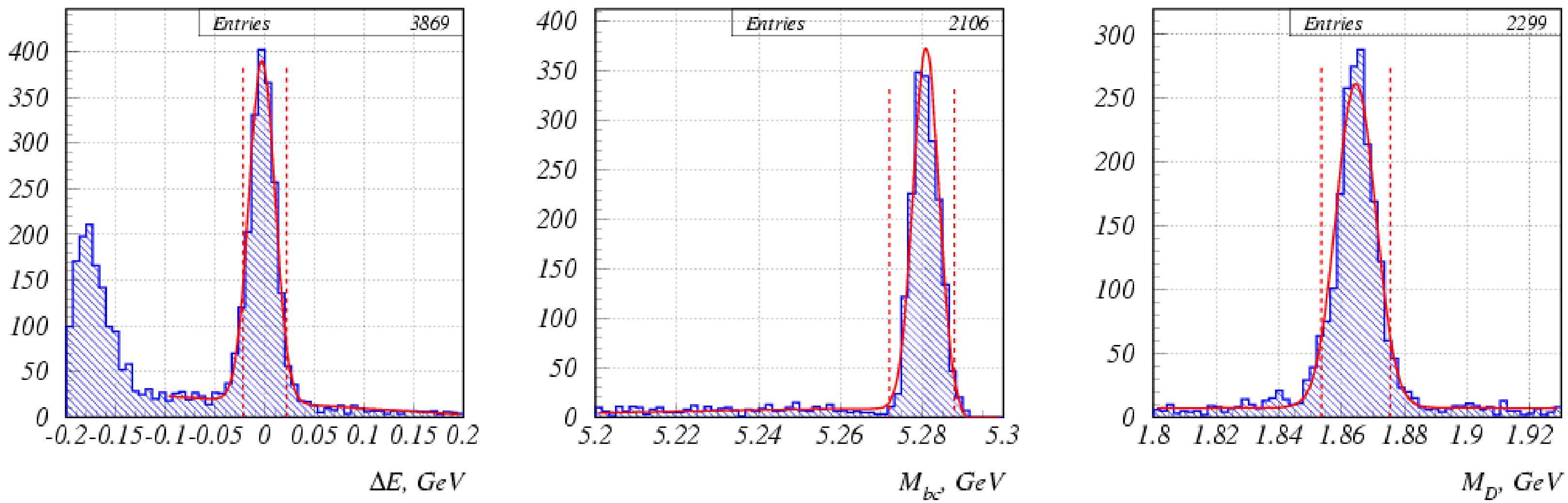
$B^+ \to D^0 K^+$ Dalitz plot and projections



$B^- \to D^0 K^-$ Dalitz plot and projections



$B^+ \to D^0\pi^+$ signal with 142 fb^{-1}



1752 events

1655±52 signal

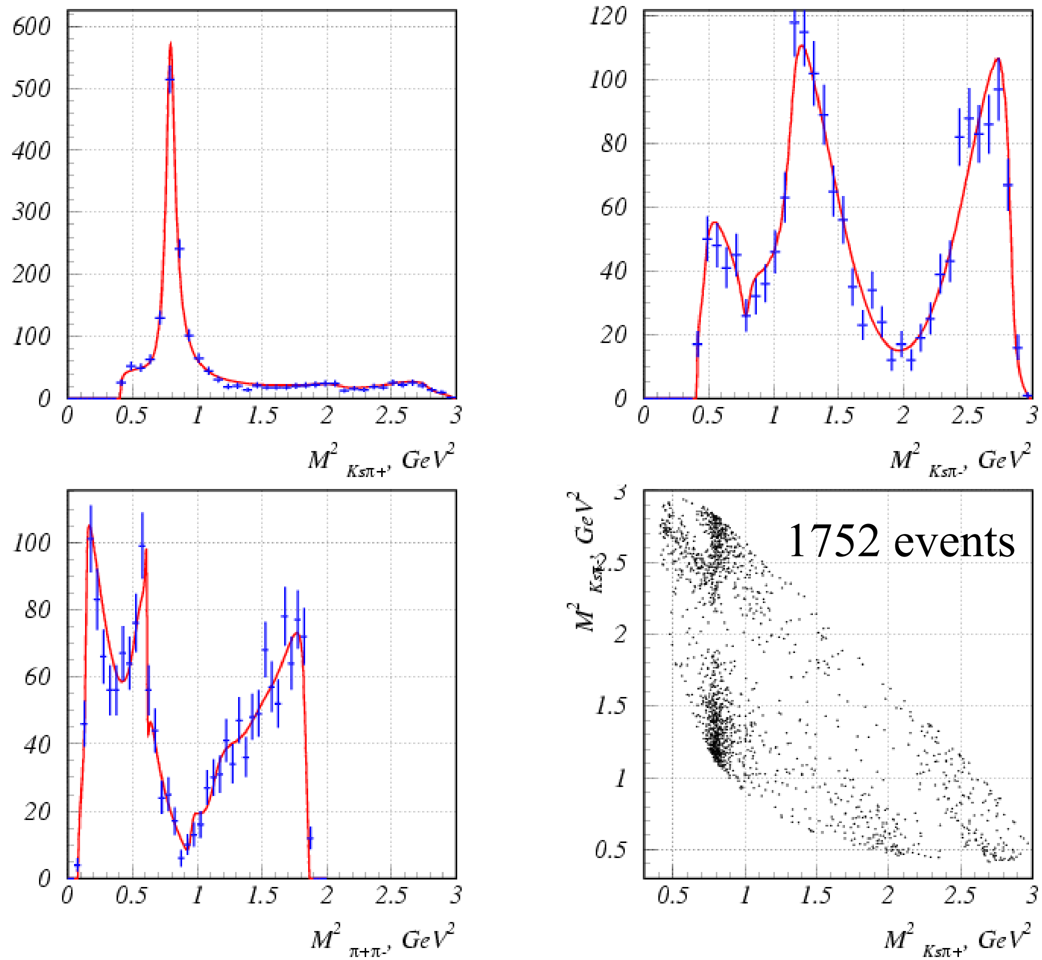
108±5 background

Used as a test sample for Dalitz plot fit

Signal selection cuts:

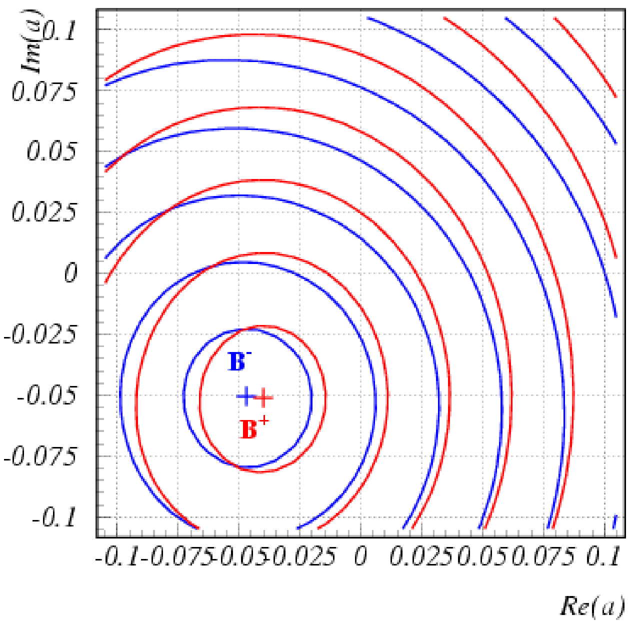
- $|\Delta E|<22$ MeV
- $5.272<M_{bc}<5.288$ GeV
- $|M_D-1.86\ \text{GeV}|<11$ MeV
- $|\cos\Theta_{thr}|<0.8$
- Fisher discriminant $\mathcal{F}>-0.7$
- PID(π/K)>0.5

$B^+ \to D^0\pi^+$, $D^0 \to K_s\pi^+\pi^-$ Dalitz plot

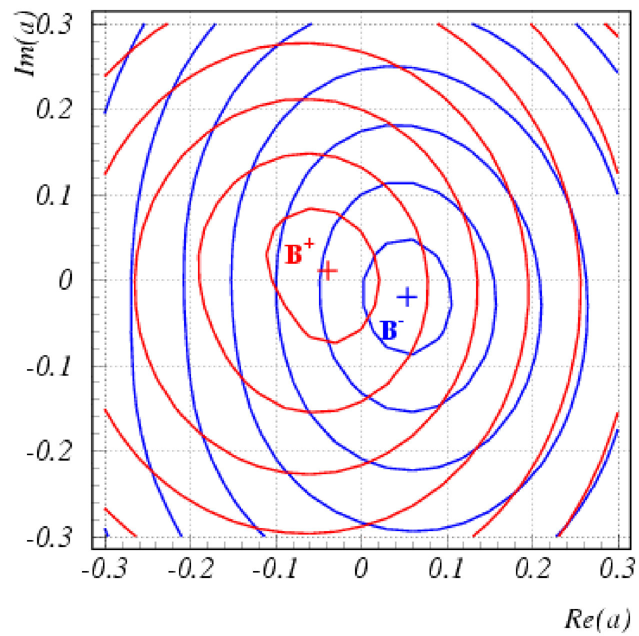


Test sample fits

Fit complex relative amplitude $ae^{i\theta}$ Expect $a\sim 0$



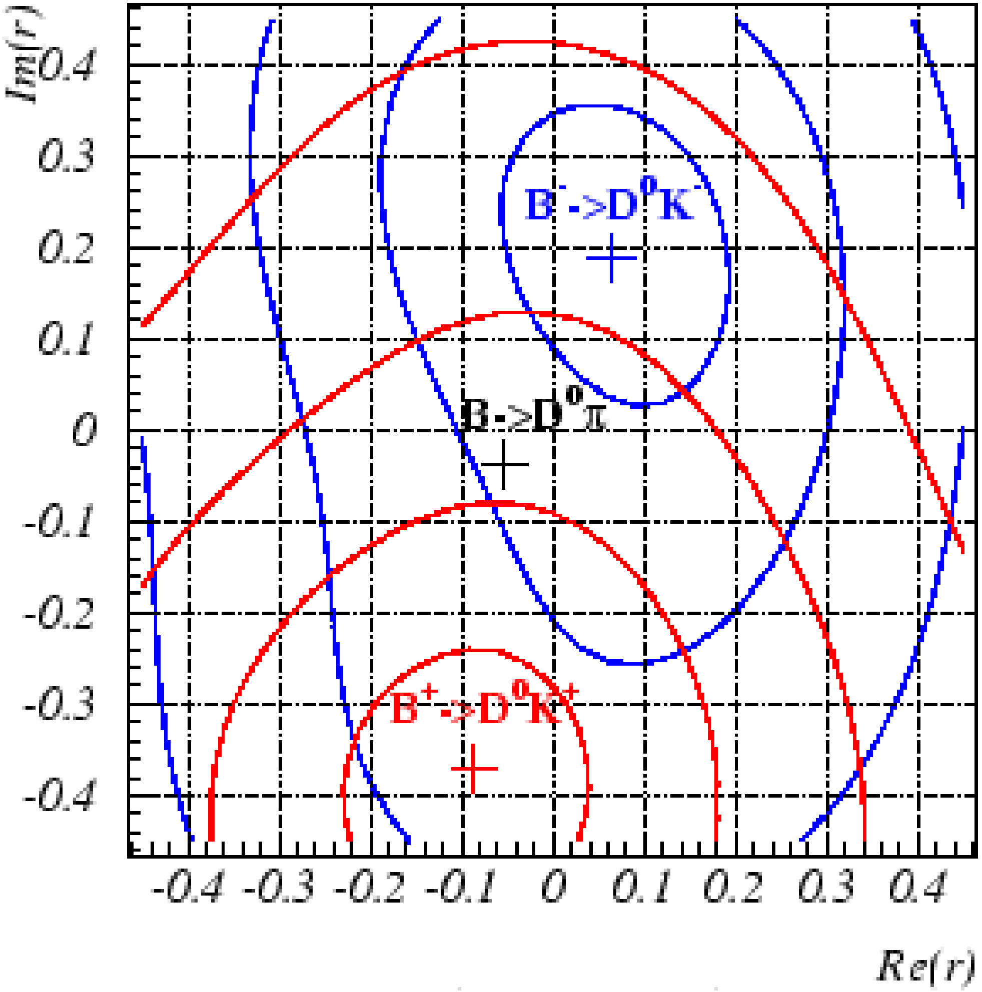
$B^+ \to D^0\pi^+$ (1750 events)



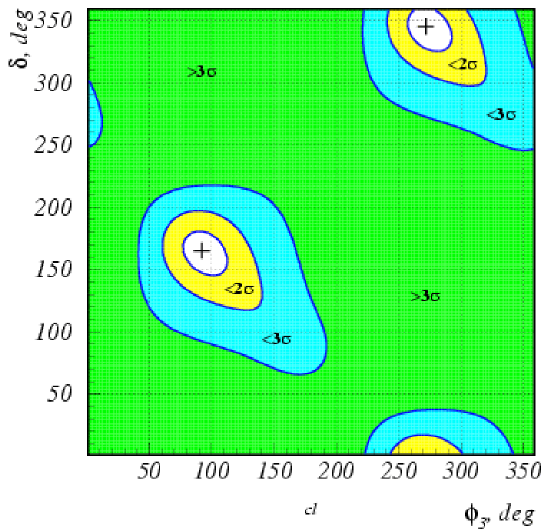
$B^+ \to D^{*0}\pi^+$ (350 events)

a=0.065±0.020 (~1-2% probability for $a=0$), however no CP asymmetry
Need further investigation. Stat. fluctuation can not be excluded

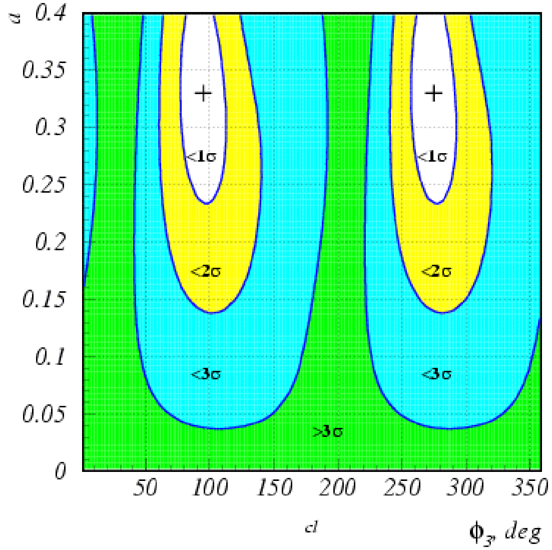
Constraints on complex D^0-$\bar{D}^0$ amplitude



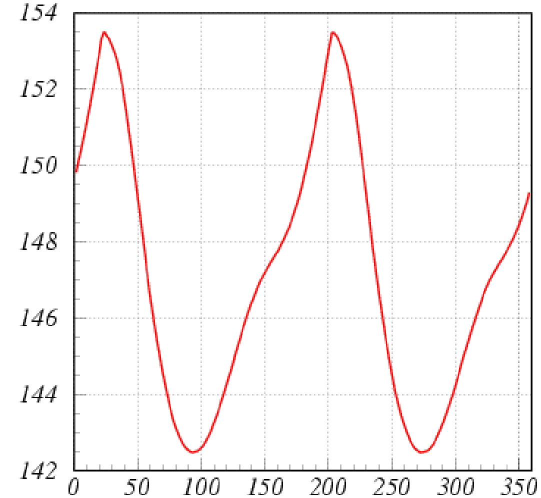
$B^+ \to D^0 K^+$ Dalitz plot fit results



CL vs. (δ, φ_3)



CL vs. (a, φ_3)



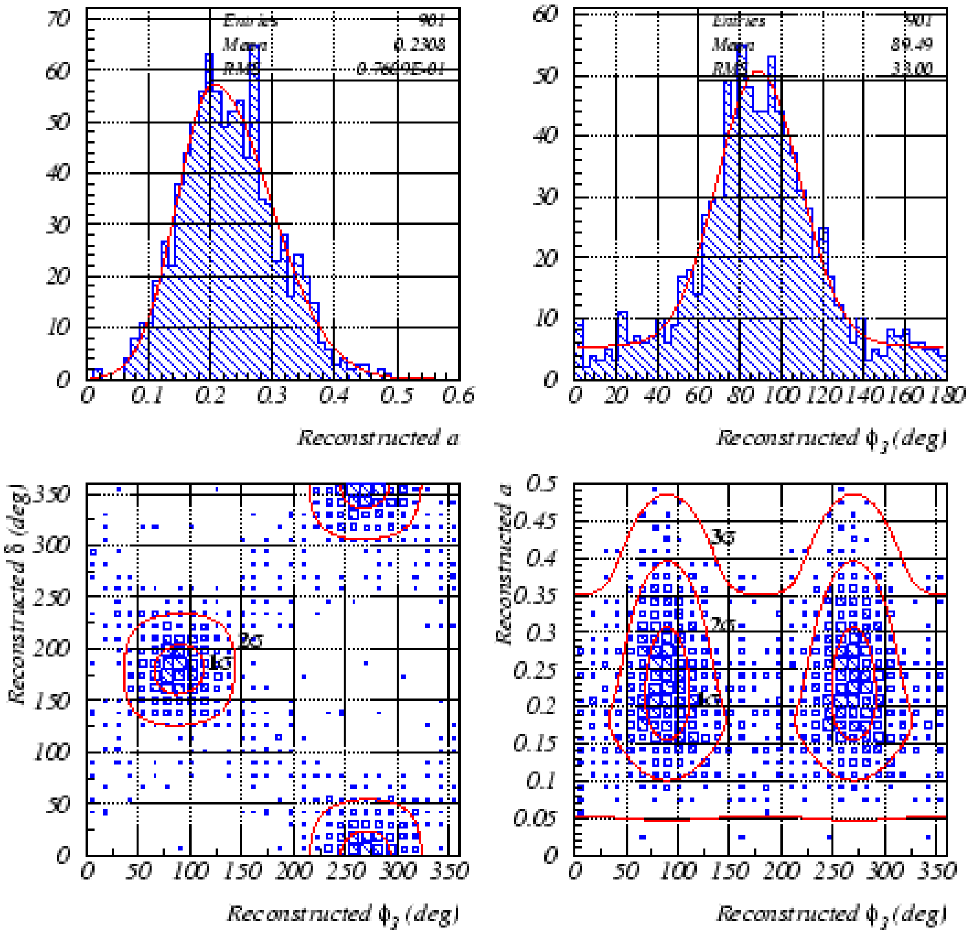
-2 log L vs. φ_3

For a, φ_3 and δ as free parameters:

$$a = 0.33 \pm 0.10 \quad \varphi_3 = 92^{+19}_{-17} \quad \delta = 165^{+17}_{-19}$$

Two solutions:
(φ_3, δ) and ($\varphi_3+\pi$, $\delta+\pi$)

Toy MC study



$a = 0.2$

$\phi_3 = 90°$ 2

$\delta = 180°$

70 events of each sign

Core ϕ_3 resolution:

$\sigma_{\phi_3} = 20°$

Gaussian core fraction: 85%

a bias:

$\Delta a = +0.03$

Strong phase value

Strong phase is 162° for $B \to D^0 K$

Does it agree with expectation based on factorization approach? Yes.

Hamiltonians:

$$\mathcal{H}(B^- \to D^0 K^-) = \frac{G_F}{\sqrt{2}} V_{us}^* V_{cb} [\bar{\mathcal{O}}_1 C_1(\mu) + \bar{\mathcal{O}}_2 C_2(\mu)]$$

$$\mathcal{H}(B^- \to \bar{D}^0 K^-) = \frac{G_F}{\sqrt{2}} V_{cs}^* V_{ub} [\mathcal{O}_1 C_1(\mu) + \mathcal{O}_2 C_2(\mu)]$$

Current-current operators:

$$\bar{\mathcal{O}}_1 = (\bar{s}_\alpha u_\beta)_{V-A} (\bar{c}_\beta b_\alpha)_{V-A};\ \bar{\mathcal{O}}_2 = (\bar{s}_\alpha u_\alpha)_{V-A} (\bar{c}_\beta b_\beta)_{V-A}$$

$$\mathcal{O}_1 = (\bar{s}_\alpha c_\beta)_{V-A} (\bar{u}_\beta b_\alpha)_{V-A};\ \mathcal{O}_2 = (\bar{s}_\alpha c_\alpha)_{V-A} (\bar{u}_\beta b_\beta)_{V-A}$$

$$A(B^- \to D^0 K^-) = < D^0 K^- | \mathcal{H}(B^- \to D^0 K^-) | B^- > = \frac{G_F}{\sqrt{2}} V_{us}^* V_{cb} \bar{M}$$

$$A(B^- \to \bar{D}^0 K^-) = < \bar{D}^0 K^- | \mathcal{H}(B^- \to \bar{D}^0 K^-) | B^- > = \frac{G_F}{\sqrt{2}} V_{cs}^* V_{ub} M$$

$$\bar{M} = < K^- D^0 | \bar{\mathcal{O}}_1 C_1(\mu) + \bar{\mathcal{O}}_2 C_2(\mu) | B^- >$$

$$M = < K^- \bar{D}^0 | \mathcal{O}_1 C_1(\mu) + \mathcal{O}_2 C_2(\mu) | B^- >$$

Strong phase value

$$A(B^- \to [K_s\pi^+\pi^-]_{\bar{D}^0}K^-) = A(B^- \to D^0K^-)A(D^0 \to K_s\pi\pi) + A(B^- \to \bar{D}^0K^-)A(\bar{D}^0 \to K_s\pi\pi) =$$
$$= \frac{G_F}{\sqrt{2}}V_{cb}V_{us}^*\bar{M}A(D^0 \to K_s\pi\pi)\left[1 + \frac{V_{ub}V_{cs}^*}{V_{cb}V_{us}^*}\frac{M}{\bar{M}}\frac{A(\bar{D}^0 \to K_s\pi\pi)}{A(D^0 \to K_s\pi\pi)}\right] =$$
$$= \frac{G_F}{\sqrt{2}}V_{cb}V_{us}^*\bar{M}A(D^0 \to K_s\pi\pi)\left[1 + \frac{V_{ub}V_{cs}^*}{V_{cb}V_{us}^*}ae^{i\delta}\right]$$

$$ae^{i\delta} = \Big/A(\bar{D}^0 \to K_s\pi\pi) = e^{-i\phi_{CP}(D)}A(D^0 \to K_s\pi\pi)\Big/ = e^{-i\phi_{CP}(D)}\frac{M}{\bar{M}} = /\text{factorization}/ =$$
$$= e^{-i\phi_{CP}(D)}\frac{a_2 < \bar{D}^0|(\bar{c}_\beta u_\beta)_{V-A}|0 >< K^-|(\bar{s}_\alpha b_\alpha)_{V-A}|B^- >}{a_2 < D^0|(\bar{u}_\beta c_\beta)_{V-A}|0 >< K^-|(\bar{s}_\alpha b_\alpha)_{V-A}|B^- > + a_1 < K^-|(\bar{s}_\beta u_\beta)_{V-A}|0 >< D^0|(\bar{c}_\alpha b_\alpha)_{V-A}|B^- >}.$$

For pseudoscalar D^0:

$$< \bar{D}^0|(\bar{c}_\beta u_\beta)_{V-A}|0 > = < \bar{D}^0|(\mathcal{CP})^\dagger(\mathcal{CP})(\bar{c}_\beta u_\beta)_{V-A}(\mathcal{CP})^\dagger(\mathcal{CP})|0 >= -e^{i\phi_{CP}(D)} < D^0|(\bar{u}_\beta c_\beta)_{V-A}|0 >$$
$$\Rightarrow ae^{i\delta} = -a_2/(fa_1 + a_2)$$

For vector D^{*0}:

$$< \bar{D}^0|(\bar{c}_\beta u_\beta)_{V-A}|0 > = < \bar{D}^0|(\mathcal{CP})^\dagger(\mathcal{CP})(\bar{c}_\beta u_\beta)_{V-A}(\mathcal{CP})^\dagger(\mathcal{CP})|0 >= +e^{i\phi_{CP}(D)} < D^0|(\bar{u}_\beta c_\beta)_{V-A}|0 >$$
$$\Rightarrow ae^{i\delta} = +a_2/(fa_1 + a_2)$$

where

$$f = \frac{< K^-|(\bar{s}_\beta u_\beta)_{V-A}|0 >< D^0|(\bar{c}_\alpha b_\alpha)_{V-A}|B^- >}{< D^0|(\bar{u}_\beta c_\beta)_{V-A}|0 >< K^-|(\bar{s}_\alpha b_\alpha)_{V-A}|B^- >}$$

is real and positive in factorization.

Strong phase $\delta = \pi$ for $B \to D^0K$ and $\delta = 0$ for $B \to D^{*0}K$ in factorization approach. [R. Fleisher, hep-ph/0301256, hep-ph/0304027].