Measuring Angle ϕ_3/γ

Hitoshi Yamamoto

University of Hawaii

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1. CP Violation and Unitarity of CKM Matrix (what is the angle ϕ_3/γ?)
2. Decay modes for the angle ϕ_3/γ

General left-handed quark-W Interaction

$$L_{\text{int}}(t) = \int d^3x \big(\mathcal{L}_{qW}(x) + \mathcal{L}^{\dagger}_{qW}(x)\big)$$

$$\mathcal{L}_{qW}(x) = \frac{g}{\sqrt{8}} \sum_{i,j=1,3} V_{i\,j}\, \bar{U}_i\, \gamma_\mu (1-\gamma_5) D_j\, W^\mu$$

$$U_i(x) \equiv \begin{pmatrix} u(x) \\ c(x) \\ t(x) \end{pmatrix}, \qquad D_j(x) \equiv \begin{pmatrix} d(x) \\ s(x) \\ b(x) \end{pmatrix}$$

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \quad \text{(CKM matrix)}$$

Experimentally, V has a hierarchical structure. Approximately,

$$|V_{i\,j}| \sim \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}$$

$$\lambda \sim 0.22$$

Transformation of L_{int} under CP

$$CP: \quad \begin{array}{l} \text{exchanges particle } (n) \leftrightarrow \text{antiparticle } (\bar{n}) \\ \text{flips momentum sign } (\vec{p} \leftrightarrow -\vec{p}) \\ \text{keeps the spin } z\text{-component } (\sigma) \text{ the same} \end{array} \qquad \text{(a)}$$

Such CP operator in Hilbert space is not unique:

$$\mathcal{CP} a^\dagger_{n,\vec{p},\sigma} \mathcal{P}^\dagger \mathcal{C}^\dagger = \eta_n a^\dagger_{\bar{n},-\vec{p},\sigma}$$

η_n: 'CP phase': arbitrary, depends on n
(for antiparticle: $\eta_{\bar{n}} = (-)^{2J} \eta_n^*$)

The choice of η_n amounts to choosing a specific operator in Hilbert space among those satisfying (a).

Then, a pure algebra leads to

$$\begin{aligned} &\mathcal{CP}\ \bar{u}(x)\gamma_\mu(1-\gamma_5)d(x)W^\mu(x)\ \mathcal{P}^\dagger\mathcal{C}^\dagger \\ &\qquad = \eta_u \eta_d^* \eta_W^* \left(\bar{u}(x')\gamma^\mu(1-\gamma_5)d(x')W_\mu(x')\right)^\dagger \end{aligned}$$

$$x' \equiv (t, -\vec{x})$$

$\mathcal{L}_{qW}$ transforms as (taking $\eta_W = 1$)

$$\mathcal{CP}\ \mathcal{L}_{qW}(x)\ \mathcal{P}^\dagger\mathcal{C}^\dagger = \frac{g}{\sqrt{8}} \sum_{i,\,j=1,3} \eta_{U_i}\eta^*_{D_j} V_{i\,j} \left(\bar{U}_i(x')\ \gamma^\mu(1-\gamma_5) D_j(x') W_\mu(x')\right)^\dagger$$

IF $\eta_{U_i}\eta^*_{D_j}$ can be chosen s.t.

$$\eta_{U_i}\eta^*_{D_j} V_{i\,j} = V^*_{i\,j} \quad (2)\,,$$

then, $L_{\text{int}}(t)$ becomes invariant under CP:

$$\mathcal{CP}\ \mathcal{L}_{qW}(x)\ \mathcal{P}^\dagger\mathcal{C}^\dagger = \mathcal{L}^\dagger_{qW}(x') \quad (x' = (t, -\vec{x}))$$

$$\begin{aligned} \rightarrow \mathcal{CP}\ L_{\text{int}}(t)\ \mathcal{P}^\dagger\mathcal{C}^\dagger & \\ &= \int d^3x\ \mathcal{CP}\left[\mathcal{L}_{qW}(x) + \mathcal{L}^\dagger_{qW}(x)\right]\mathcal{P}^\dagger\mathcal{C}^\dagger \\ &= \int d^3x\ \left[\mathcal{L}^\dagger_{qW}(x') + \mathcal{L}_{qW}(x')\right] \\ &= L_{\text{int}}(t) \end{aligned}$$

$\rightarrow S$ operator is invariant under CP
(through Dyson series)

Condition for CP Invariance

Rewrite the condition (2):

$$\frac{\eta_{D_j}}{\eta_{U_i}} = 2 \arg V_{i,j}$$

Thus, for a given (arbitrary) matrix $V_{i,j}$, if the CP phases η's can be chosen so that the phase difference between η_{D_j} and η_{U_i} is twice the arbitrary phase of $V_{i,j}$, then the physics is invariant under CP.

This is equivalent to rotate the quark phases to make $V_{i,j}$ all real.

In general, there are 5 phase differences for 6 quarks $\rightarrow$ 5 elements of V can be set to real always.

For example.,

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$V_{i,j}$: real
$V_{i,j}$: complex

(No unitarity condition imposed)

Any of the four red elements is not real
$\rightarrow$ CP violation

V_{CKM} **Phase Conventions**

(without unitarity constraint)

One can do

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \quad \begin{array}{l} V_{i,j}\text{ : real} \\ V_{i,j}\text{ : complex} \end{array}$$

Our standard phase convention

(Also force, $V_{ud}, V_{us}, -V_{cd}, V_{cb}, -V_{ts} > 0$)

or,

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \quad \begin{array}{l} V_{i,j}\text{ : real} \\ V_{i,j}\text{ : complex} \end{array}$$

etc. . . .

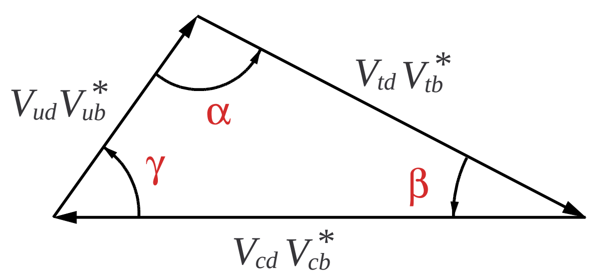
But one cannot do,

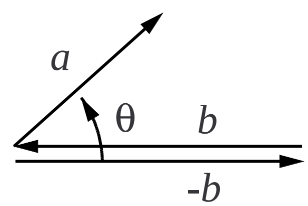
$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \quad \begin{array}{l} V_{i,j}\text{ : real} \\ V_{i,j}\text{ : complex} \end{array}$$

A Main Question of the CPV Study in B: ‘Is V unitary?’

e.g: orthogonality of d-column and b-column:

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





$$\theta = \text{arg}\,\frac{a}{-b}$$

$$\alpha \equiv \text{arg}\left(\frac{V_{td}V_{tb}^*}{-V_{ud}V_{ub}^*}\right),\ \beta \equiv \text{arg}\left(\frac{V_{cd}V_{cb}^*}{-V_{td}V_{tb}^*}\right),\ \gamma \equiv \text{arg}\left(\frac{V_{ud}V_{ub}^*}{-V_{cd}V_{cb}^*}\right) \tag{3}$$

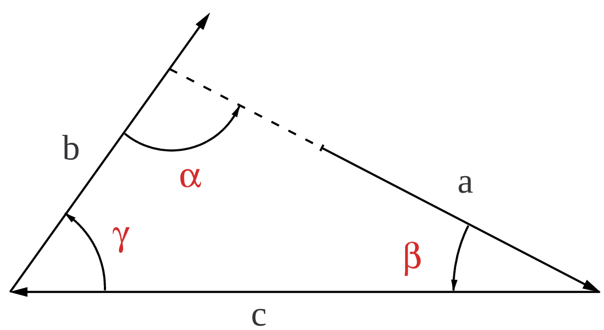
With our phase convention:

$$\alpha \equiv \text{arg}\left(\frac{V_{td}V_{tb}^*}{-V_{ub}^*}\right),\ \beta \equiv \text{arg}\left(V_{td}^*V_{tb}\right),\ \gamma \equiv \text{arg}\left(V_{ub}^*\right)$$

For **any** complex numbers a, b, c, trivially

$$\alpha + \beta + \gamma = \pi \quad (\text{mod } 2\pi)$$

$$\alpha \equiv \arg\left(\frac{a}{-b}\right), \quad \beta \equiv \arg\left(\frac{b}{-c}\right), \quad \gamma \equiv \arg\left(\frac{c}{-a}\right).$$



$\rightarrow$ The condition $\alpha + \beta + \gamma = \pi$ (mod2π) holds even if the triangle does not close.
It does **not** test the unitarity of V_{CKM}.

It simply tests if the angles measured are as defined in (3) in terms of V_{CKM}.

$\rightarrow$ It is critical to measure the length of the sides.

With Unitarity Constraint

Use our standard phase convention,
and the hierarchy of the sizes of the elements:

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \overset{\text{abs}}{\sim} \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}$$

Assume $\mathrm{Im}V_{ub}, \mathrm{Im}V_{td} \sim \lambda^3$
(i.e., the phase angles are of order unity), then

$$\sum_i V_{ui} V_{ci}^* = 0 \quad \rightarrow \quad \mathrm{Im}V_{cs} \sim \lambda^4$$

$$\sum_i V_{ci} V_{ti}^* = 0 \quad \rightarrow \quad \mathrm{Im}V_{tb} \sim \lambda^2$$

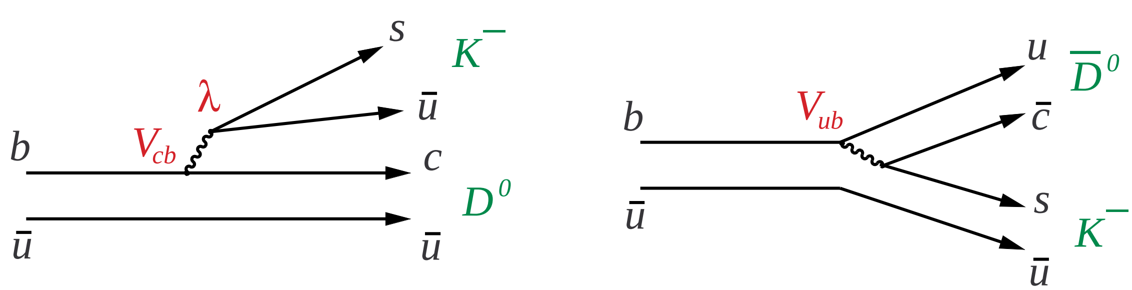
Under unitarity condition, V_{cs} is nearly real.
Assume it for now.

Gronau-London-Wyler (GLW) method to extract γ

$$B^- \to D^0_{CP} K^-$$

D^0_{CP} : CP eigenstate. e.g. $K_S\pi^0, K^+K^- \cdots$

Both D^0 and $\bar{D}^0$ decay to a CP eigenstate.
$\to$ 2 diagrams

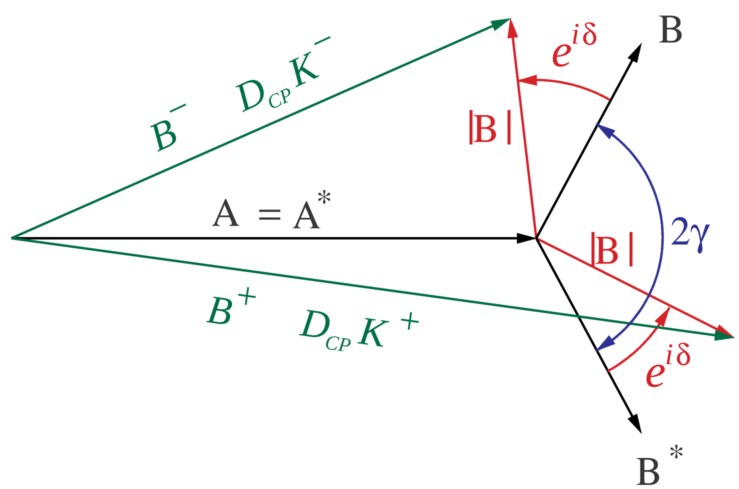


$A \equiv Amp(B^- \to D^0 K^-)$	$B \equiv Amp(B^- \to \bar{D}^0 K^-)$
λV_{cb}	$V_{ub} \sim 0.4\lambda V_{cb}$
Color-favored	Color-suppressed
$(a_1 + a_2 \sim 1.24)$	$(a_2 \sim 0.24)$
$\bar{A} \equiv Amp(B^+ \to \bar{D}^0 K^+)$	$\bar{B} \equiv Amp(B^+ \to D^0 K^+)$
$\bar{A} = A^*$	$\bar{B} = B^*$

($\lambda \sim 0.22$: Cabbibo factor)

Strong final-state-interaction phase:
B relative to A : $e^{i\delta}$ (δ could be complex)

Phase convention: $A = A^*$



$\gamma \equiv \arg B^* = \arg V_{ub}^*$

Measure 4 lengths:

$Amp(B^- \to D^0_{CP}K^-)$

$Amp(B^+ \to D^0_{CP}K^+)$

$|A|$ by $B^- \to D^0 K^-,\ D^0 \to K^-\pi^+$

$|B|$ by $B^- \to \bar{D}^0 K^-,\ \bar{D}^0 \to K^+\pi^-$

Reconstruct two triangles $\to \gamma$

CP asymmetry expected:

$$a_{cp} \equiv \frac{\Gamma[B^- \to (K_S\pi^0)K^-] - \Gamma[B^+ \to (K_S\pi^0)K^+]}{\Gamma[B^- \to (K_S\pi^0)K^-] + \Gamma[B^+ \to (K_S\pi^0)K^+]}$$

$$\frac{|B|}{|A|} \sim \underbrace{(\text{color factor})}_{\frac{a_2}{a_1+a_2} \sim 0.2}\underbrace{(\text{CKM factor})}_{\frac{V_{ub}}{\lambda V_{cb}} \sim 0.4} \sim 0.08$$

$\to a_{cp}$ is of order 10%.

(γ can be measured even if $a_{cp} = 0$)

Relevant D^0 decay modes:

CP eigenstates	$K_S\,\pi^0$	$1.06 \pm 0.11\%$	$CP-$
	$K_S\,\rho^0$	$0.60 \pm 0.09\%$	$CP-$
	$K_S\,\phi$	$0.84 \pm 0.10\%$	$CP-$
	K^+K^-	$0.43 \pm 0.03\%$	$CP+$
	$\pi^+\pi^-$	$0.15 \pm 0.01\%$	$CP+$
calibration	$K^-\pi^+$	$3.83 \pm 0.12\%$	

D^0 decay FSI phase does not contribute.
$\to$ can be combined.

Once $B^- \to (K^-\pi^+)K^-$ is observed, CP asymmetry in CP eigenstates is not far away.
(apart from extracting γ)

Problem with the GLW method and Solution
[Atwood, Dunietz, Soni (ADS)]

How to measure $B = Amp(B^- \to \bar{D}^0 K^-)$?

$$B^- \xrightarrow{B} \bar{D}^0 K^- \hookrightarrow K^+\pi^- \quad \text{but also} \quad B^- \xrightarrow{A} D^0 K^- \hookrightarrow K^+\pi^- \ (DCSD)$$

The ratio of the two amplitudes (R_{DCSD}):

$$R_{DCSD} = \underbrace{\frac{A}{B}}_{\sim \frac{1}{0.08}} \ \underbrace{\frac{Amp(D^0 \to K^+\pi^-)}{Amp(D^0 \to K^-\pi^+)}}_{\substack{0.088 \pm 0.020 \\ \text{(CLEO 94)}}} \sim 1$$

Phase of R_{DCSD} not known $\to$ cannot measure $|B|$.
(Difficult to detect $D^0 \to X_s^- \ell^+ \bar{\nu}$)

But: This interference causes CP asymmetry of **order unity** in the wrong-sign $K\pi$ modes:

$$\Gamma[B^- \to (K^+\pi^-)K^-] \quad \text{vs} \quad \Gamma[B^+ \to (K^-\pi^+)K^+]$$

To see this, in the GLW method simply replace

$$|B| \to \left| B \frac{Amp(D^0 \to K^-\pi^+)}{Amp(D^0 \to K^+\pi^-)} \right| \ (\sim |A|)$$

$\delta \to \delta_f$:combined FSI phases of B/D decays

ADS method to extract γ

Measure $B^- \to DK^-$ in two decay modes of D:
wrong-sign flavor-specific modes or CP eigenstates,
say $K^+\pi^-$ and $K_S\,\pi^0$ (and their conjugate modes).

$$\Gamma[B^- \to (K^+\pi^-)K^-] \quad \Gamma[B^+ \to (K^-\pi^+)K^+]$$
$$\Gamma[B^- \to (K_S\,\pi^0)K^-] \quad \Gamma[B^+ \to (K_S\,\pi^0)K^+]$$

Assume we know $|A|$ and D branching fractions
$\to$ 4 unknowns:

$$\gamma\,, \quad \delta_{K^-\pi^+}\,, \quad \delta_{K_S\pi^0}\,, \quad \frac{|B|}{|A|}$$

$\to$ can be solved.

Statistics: Possible at B-factories
(300 fb^{-1} needed)

Avoid using wrong-sign $B^+ \to D^0 K^+$

External input (experiment, theory):

$$r = \left|\frac{B}{A}\right| = \left|\frac{\bar{B}}{\bar{A}}\right| \sim 0.08$$

Measure

$$\begin{aligned}
\Gamma(B^- \to D_1 K^-) &= 1 + r^2 + 2r\cos(\gamma + \delta) \\
\Gamma(B^- \to D_2 K^-) &= 1 + r^2 - 2r\cos(\gamma + \delta) \\
\Gamma(B^+ \to D_1 K^+) &= 1 + r^2 + 2r\cos(\gamma - \delta) \\
\Gamma(B^+ \to D_2 K^+) &= 1 + r^2 - 2r\cos(\gamma - \delta)
\end{aligned}$$

in unit of $\Gamma(B^- \to D^0 K^-)$.

$\to$ fit for γ and δ.

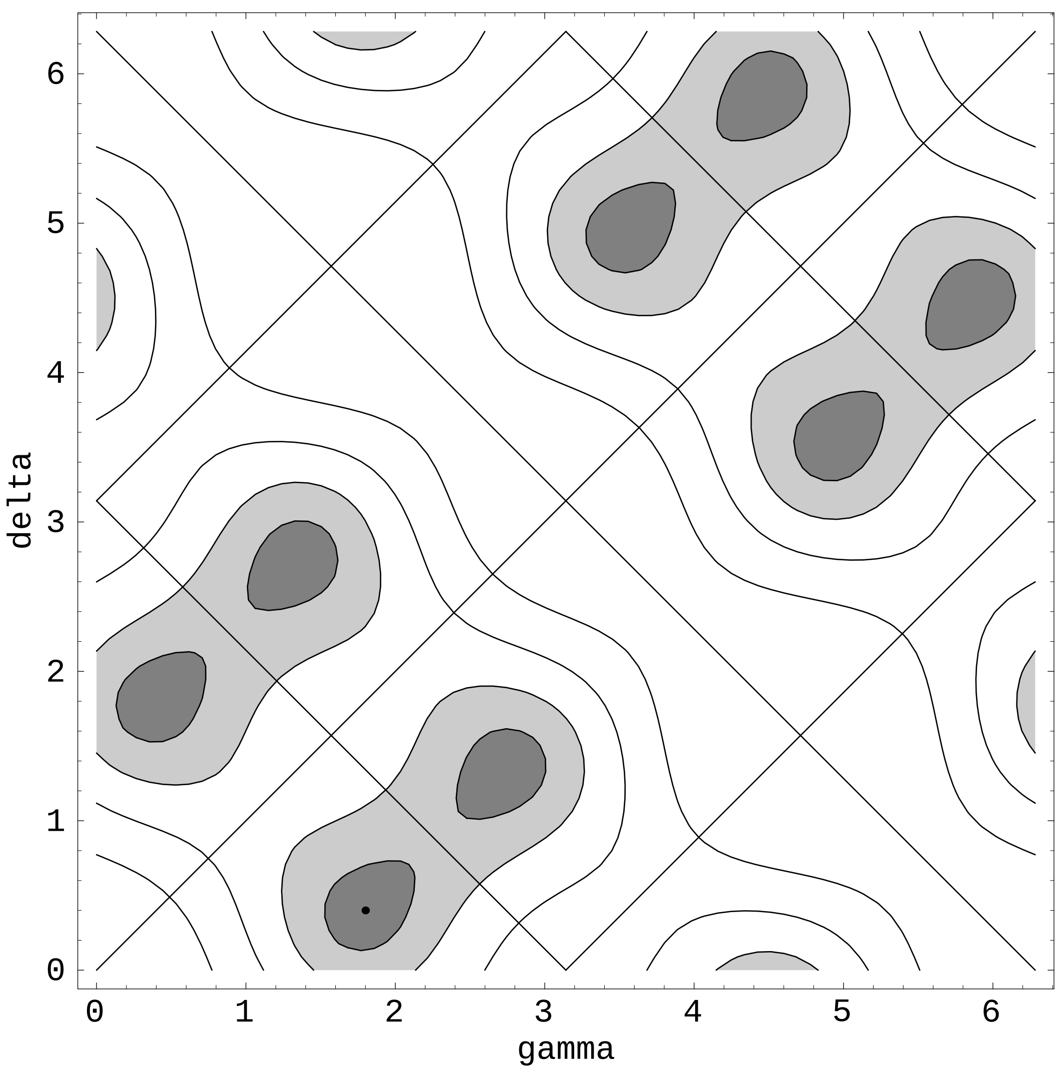
Ambiguity: the equations are symmetric under

$$\begin{aligned} \gamma &\to \quad n\pi \pm \delta \\ \delta &\to \mp n\pi \pm \gamma \end{aligned} \qquad (n : \text{integer})$$

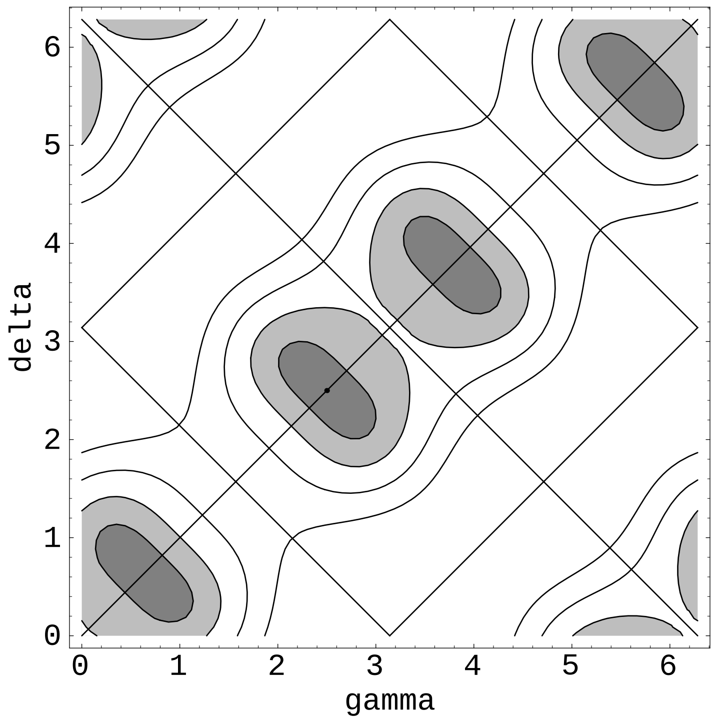
Fit result for γ and δ

Input:

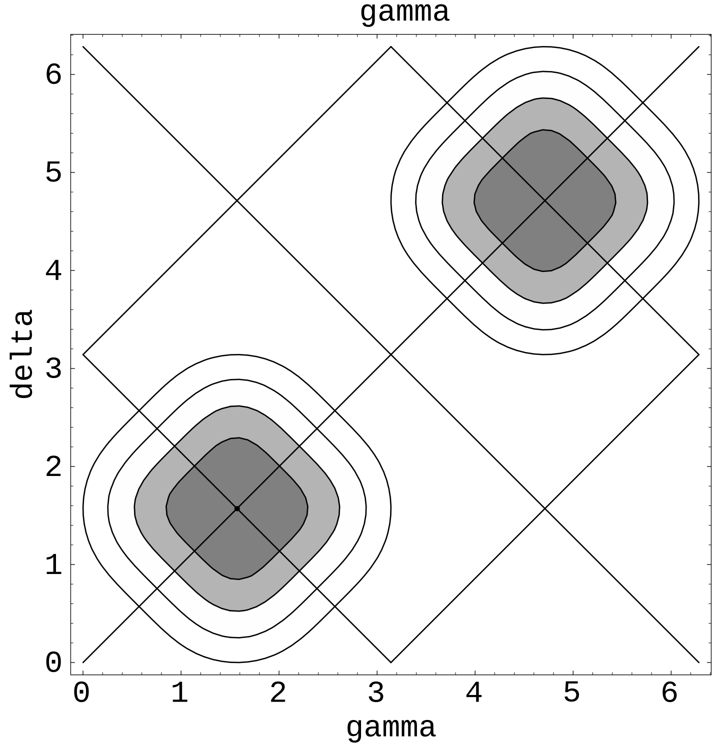
$\gamma = 1.8\,, \delta = 0.4$
$\sigma(\Gamma's) = 10\%$ (100 events each)
(300fb^{-1})



Fit result for γ and δ



$\gamma = 2.5$
$\delta = 2.5$



$\gamma = 1.57$
$\delta = 1.57$

Statistics Estimate

1. Relative yields (compare to $D^0 \to K^-\pi^+$)

   - $K^-\pi^+$(3.9%)
   - D_1: K^+K^-(0.43%) $+$ $\pi^+\pi^-$(0.15%) $=$ 0.58%.
   - D_2: $K_s\pi^0$(1.05%)$\times$2/3(K_sBr) $\times$ 1/2(π^0) $=$ 0.35%.

2. Yield of $B \to D^0K^-$, $D^0 \to K^-\pi^+$ at 3.1 fb^{-1}

   - CLEO: $N(D^0\pi^-) = 239$ at 3.1 fb^{-1}
   - Then, $N(D^0K^-) = 17.5$ at 3.1 fb^{-1}

3. Yields at 300 fb^{-1}

   - $N(D^0(K^-\pi^+)K^-) = 1694$
   - $N(D_1K^-) = 252$ (126 each for $B^{\pm}$)
   - $N(D_2K^-) = 152$ (76 each for $B^{\pm}$)

Background? Needs a good vertexing to reject continuum background.

Measurement of $B^- \to D^0 K^-$

Expect

$$\frac{Br(B^- \to D^0 K^-)}{Br(B^- \to D^0 \pi^-)} \sim \lambda^2 \left(\frac{f_K}{f_\pi}\right)^2 \sim 0.07$$

D^0 channels used:

$$\begin{aligned} D^0 \to K^-\pi^+ &\qquad (3.83\%) \\ K^-\pi^+\pi^0 &\qquad (13.9\%) \\ K^-\pi^+\pi^-\pi^+ &\quad (7.5\%) \end{aligned}$$

On $\Upsilon 4S$, the B mesons are generated with a known E_B and $|\vec{P}_B|$.

$$B \to f_1 + \cdots + f_n$$

$$\begin{aligned} E_{\rm tot} &\equiv \textstyle\sum_i E_i = E_B \\ P_{\rm tot} &\equiv |\textstyle\sum_i \vec{p}_i| = |\vec{P}_B| \end{aligned}$$

or euivqlently, plot:

$$\begin{aligned} \Delta E &\equiv E_{\rm tot} - E_B \\ M_B &\equiv \sqrt{E_B^2 - P_{\rm tot}^2} \quad \text{(beam-constrained mass)} \end{aligned}$$

$\sigma_{M_B} \sim 2.5$ MeV.
$\sim \times 10$ better than $M = \sqrt{E_{\rm tot}^2 - P_{\rm tot}^2}$.

Two major backgrounds and rejection parameters:

1. $B^- \to D^0\pi^-$
   ΔE, $dE/dx(K)$

2. continuum ($e^+e^- \to$ 2jets)
   θ_s: angle between the sphericity axis of the B candidate and that of the rest of the event.
   θ_B: B momentum polar angle in lab.
   F: Fischer discriminant

Fischer discriminant of variables $\vec{x} = (x_1 \dots x_n)$:

$$F \equiv \vec{\lambda} \cdot \vec{x}$$

$\vec{\lambda}$: constants to be chosen to maximize separation S between signal and background:

$$S \equiv \frac{(\langle F \rangle_s - \langle F \rangle_b)^2}{\sigma_F^2} = \frac{(\vec{\lambda} \cdot (\langle \vec{x} \rangle_s - \langle \vec{x} \rangle_b))^2}{\vec{\lambda}^T V \vec{\lambda}}$$

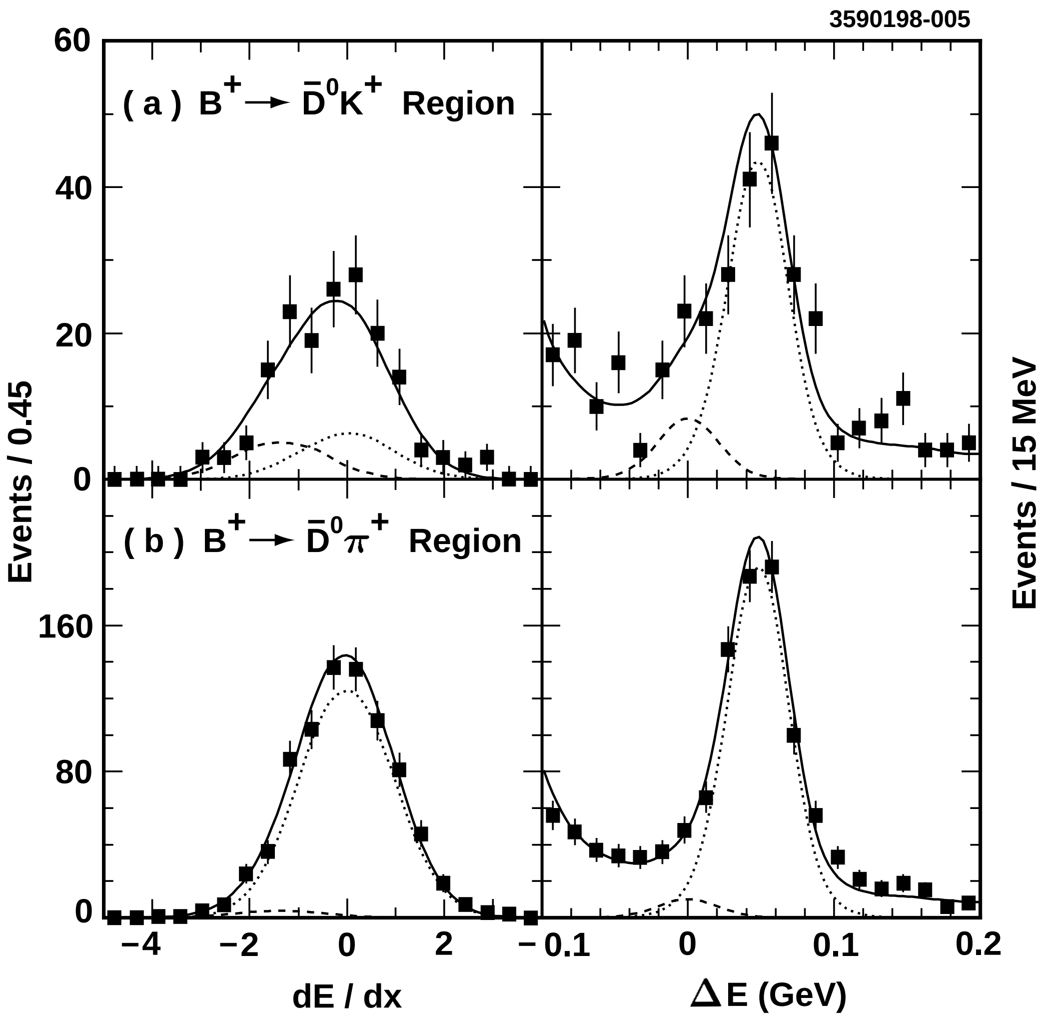
$$s : \text{signal}\,, \quad b : \text{bkg}\,, \quad V : \text{covariant matrix of } \vec{x}$$

$$\frac{\partial S}{\partial \lambda_i} = 0 \quad \to \quad \vec{\lambda} = V^{-1}(\langle \vec{x} \rangle_s - \langle \vec{x} \rangle_b)$$

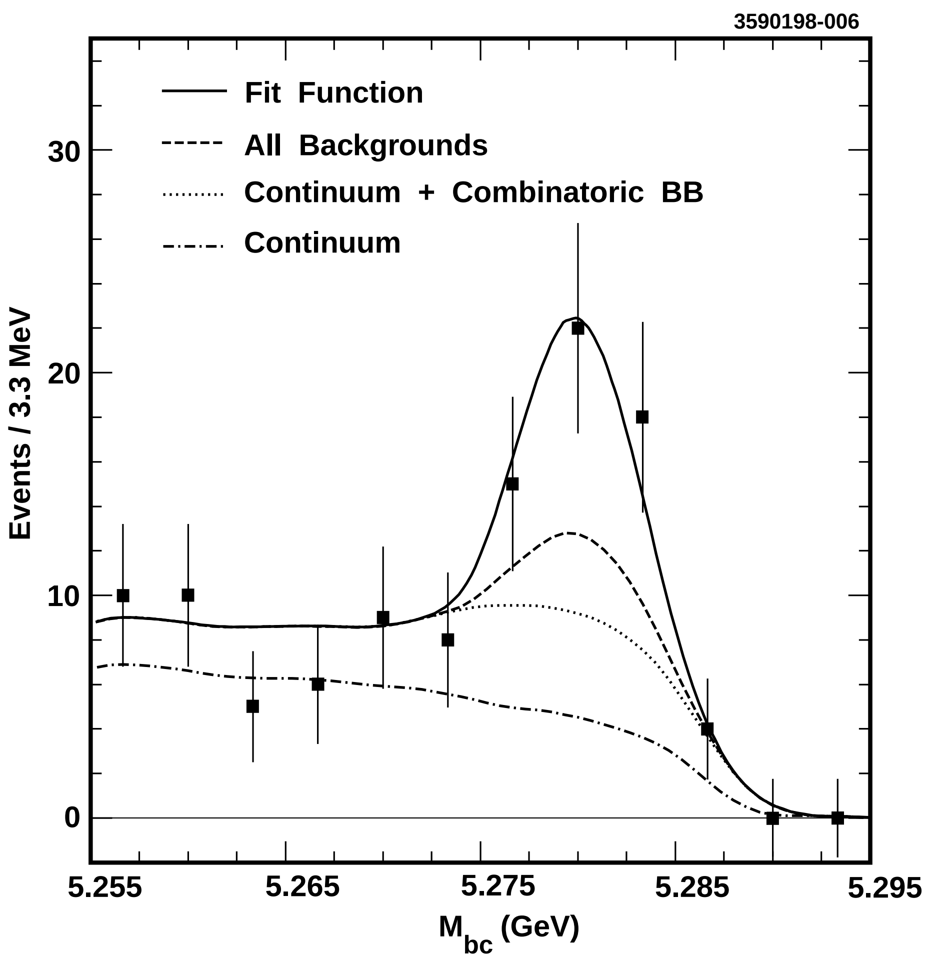
For $\vec{x}$, use the energy flows in 9 cones around the event axis, an event shape variable (Fox-Wolfram), and the polar angle in lab of B candidate event axis.

Maximum likelihood fit for the signal and background yields in the space of

$$M_B\,, \quad \Delta E\,, \quad dE/dx(K)\,, \quad M_D\,, \quad \cos\theta_B\,, \quad F$$



$dE/dx < -0.75$ and $-50 < \Delta E < 10$ MeV
(D^0K^- 'signal region')

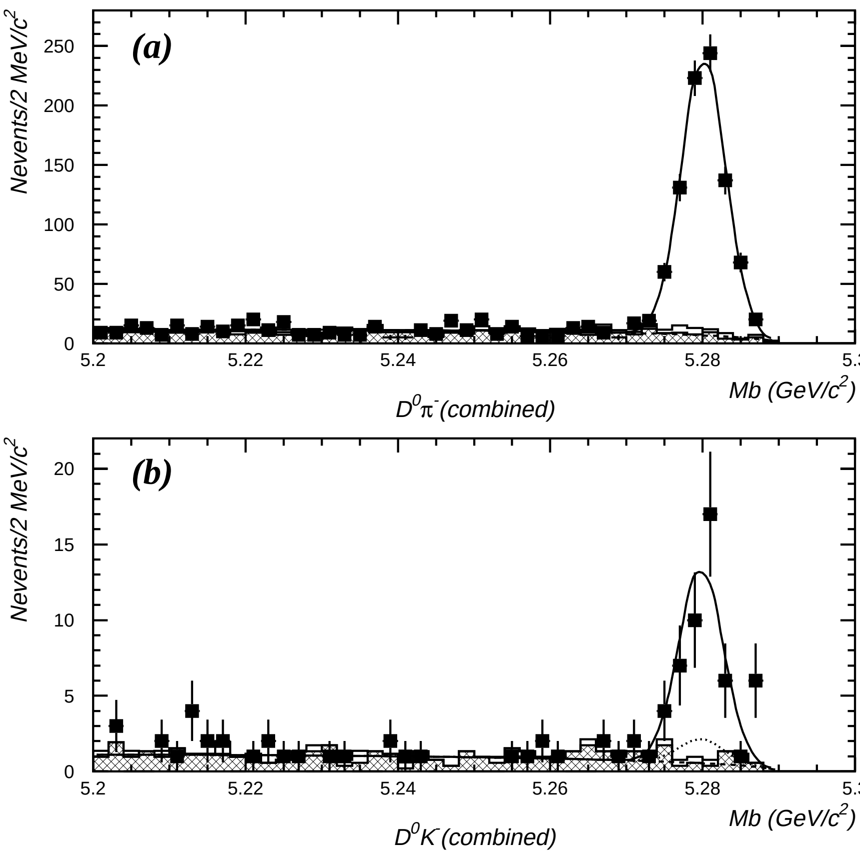


$$\frac{Br(D^0K^-)}{Br(D^0\pi^-)} = 0.055 \pm 0.014 \pm 0.005\,.$$

$B \to D^0 K^-$ (Belle)

π/K separation by Aerogel Cerenkov Counter.
(with dEdx, TOF)

Allows simple cuts/fits (e.g. ΔE plot; no Fischer)



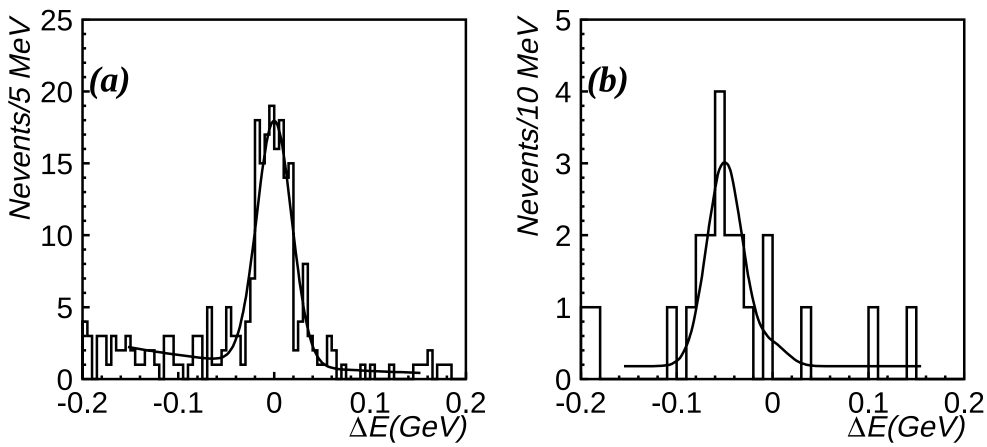
$$\frac{Br(D^0 K^-)}{Br(D^0 \pi^-)} = 0.081 \pm 0.014 \pm 0.011$$

$\bar{B}^0 \to D^{*+} K^-$ (Belle)

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

Reconstruct $\bar{B}^0 \to D^{*+} h^-$ $(h = K, \pi)$.

Assign pion mass always in calculating ΔE
$\Delta E \equiv E_{\text{tot}} - E_B$ (in $\Upsilon 4S$ c.m.)
(ΔE for $D^{*+} K^- \sim -0.05$ GeV)



$D^{*+} \pi^-$ sample $\qquad$ $D^{*+} K^-$ enriched

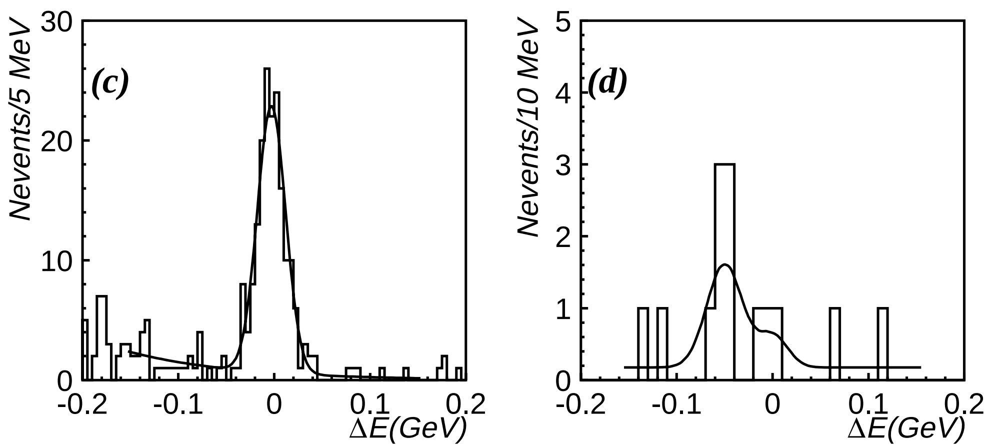
$$\frac{Br(D^{*+}K^-)}{Br(D^{*+}\pi^-)} = 0.134^{+0.045}_{-0.038} \pm 0.015$$

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

$D^{*0} \to D^0\pi^0$

Reconstruct $B^- \to D^{*+}h^-$ ($h = K, \pi$).

Pion mass is always assigned to h^-



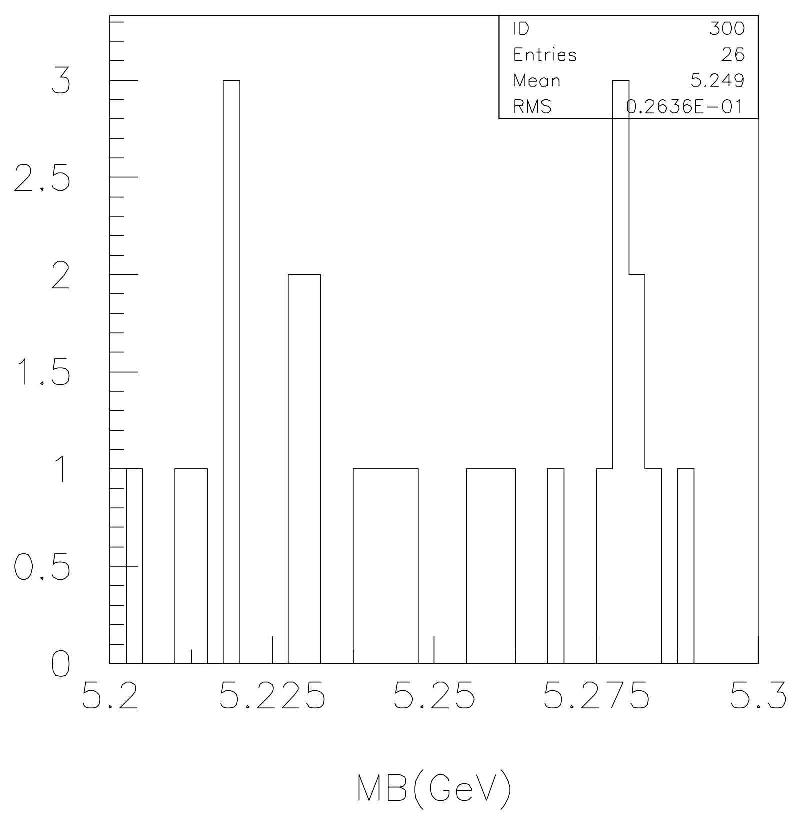
$D^{*0}\pi^-$ sample $\qquad$ $D^{*0}K^-$ enriched

$$\frac{Br(D^{*0}K^-)}{Br(D^{*0}\pi^-)} = 0.062^{+0.030}_{-0.024} \pm 0.013$$

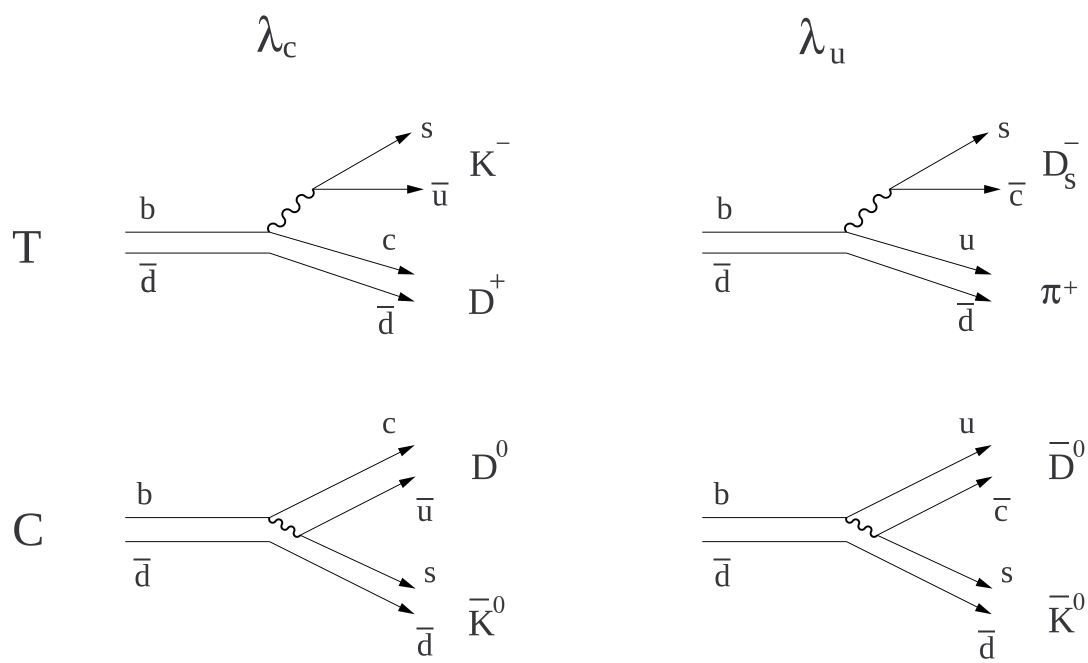
$B^- \to D^0 K^{*-}$ **(**$K^{*-} \to K_S \pi^-$**)**

CLEO, Very Preliminary

$K_s \to \pi^+\pi^-$ vertex: no need for π^+/K^+ separation.
(No contamination from $B \to D^0\rho^0$)



Classification of $\bar{B}^0 \to DK$

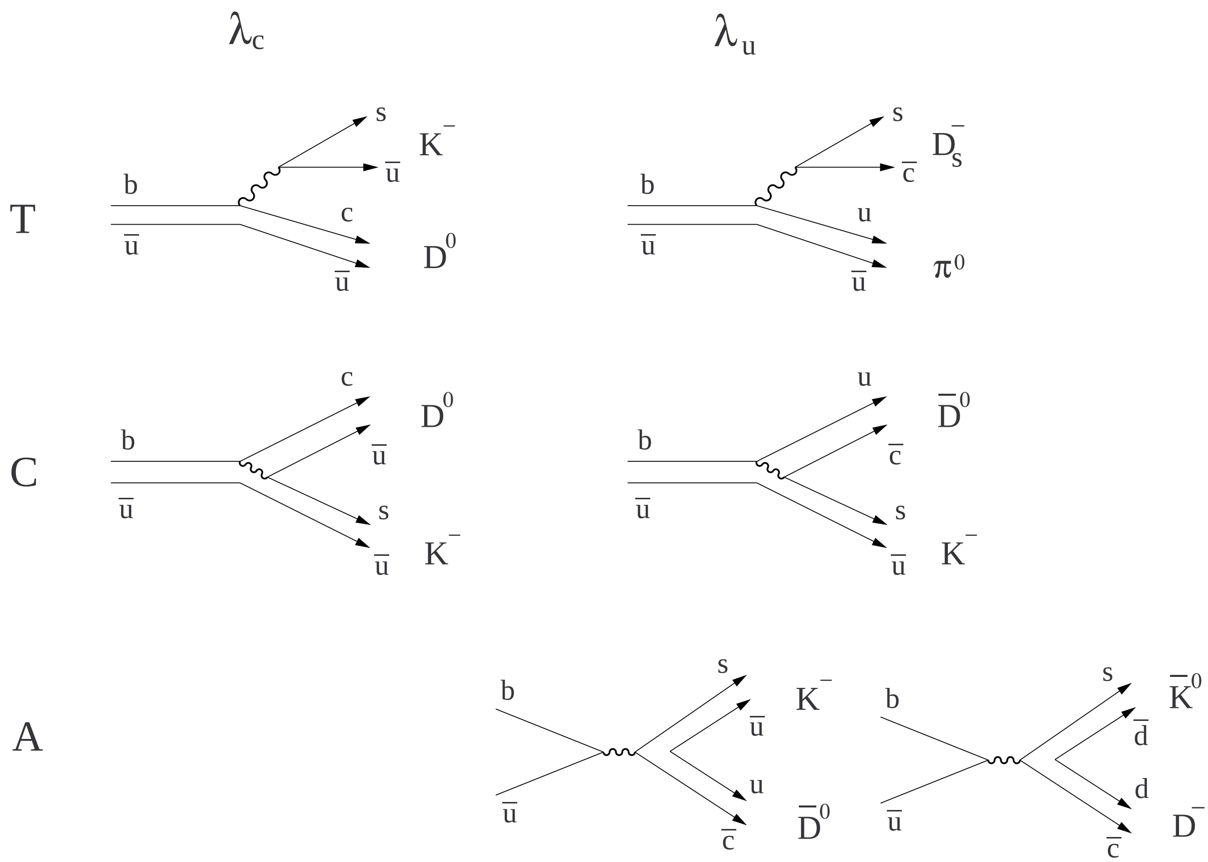


T: tree, C: color-suppressed, A: annihilation
(T, C: depends on $b \to c$ or $b \to u$)

$$\lambda_c = V_{cb} V_{cs}^*\,, \qquad \lambda_u = V_{ub} V_{us}^*\,.$$

$$\begin{aligned}
Amp(\bar{B}^0 \to D^+ K^-) &= \lambda_c T_c \\
Amp(\bar{B}^0 \to D^0 \bar{K}^0) &= \lambda_c C_c \\
Amp(\bar{B}^0 \to \bar{D}^0 \bar{K}^0) &= \lambda_u C_u \\
Amp(\bar{B}^0 \to D_s^- \pi^+) &= \lambda_u T_u
\end{aligned} \qquad (4)$$

Classification of $B^- \to DK$



$$Amp(B^- \to D^0 K^-) = \lambda_c T_c + \lambda_c C_c \qquad (5a)$$

$$Amp(B^- \to \bar{D}^0 K^-) = \lambda_u C_u + \lambda_u A \qquad (5b)$$

$$Amp(B^- \to D^- \bar{K}^0) = \lambda_u A \qquad (5c)$$

$$Amp(B^- \to D_s^- \pi^0) = \frac{1}{\sqrt{2}} \lambda_u T_u \qquad (5d)$$

Final-state Rescatterings

Final-state rescattering can occur:

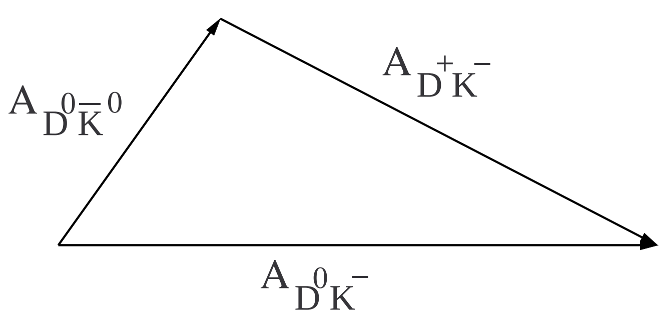
$$\bar{B}^0 \to D^+K^-(T_c) \to D^0\bar{K}^0(C_c)$$
$$\bar{B}^0 \to D_s^-\pi^+(T_u) \to \bar{D}^0\bar{K}^0(C_u)$$

We **define** T_c, C_c, T_u, C_u by (4) including rescattering effects.

Then, is (5a) still true?

$$Amp(B^- \to D^0K^-) = \lambda_c T_c + \lambda_c C_c$$
$$= Amp(\bar{B}^0 \to D^+K^-) + Amp(\bar{B}^0 \to D^0\bar{K}^0)$$

which is nothing but the isospin relation for $H_{\rm eff}$ having $|1/2, -1/2\rangle$ structure: (good to all orders as long as $m_u = m_d$)

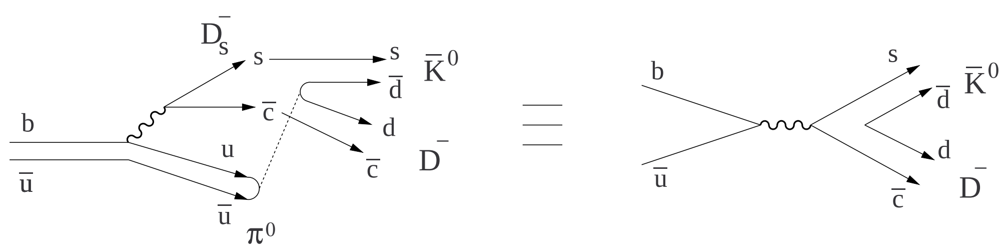


Final-state Rescatterings - annihilation

Final-state $D^-\bar{K}^0$ can be reached by

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

This is a 'long-distance' annihilation:

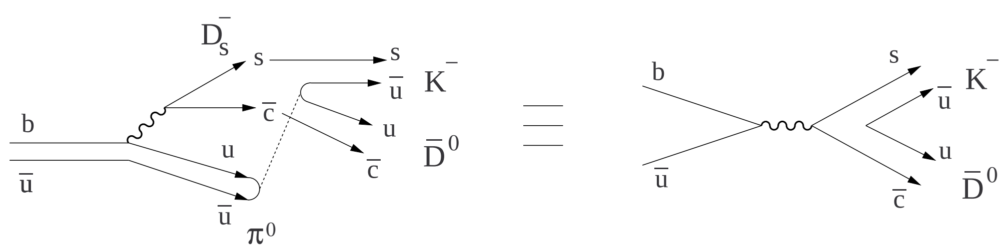


We thus **define** A by

$$Amp(B^- \to D^-\bar{K}^0) = \lambda_u A \quad (5c)$$

including the rescattering effect.

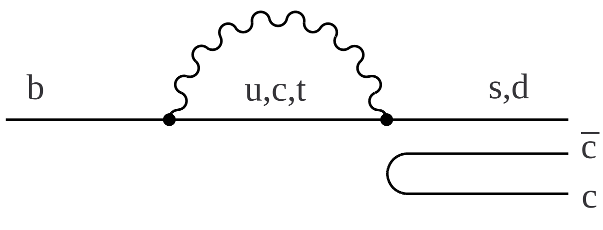
Then, the annihilation in $B^- \to \bar{D}^0 K^-$ (5b) has exactly the same rescattering contribution:



$B \to DK$ **Modes**

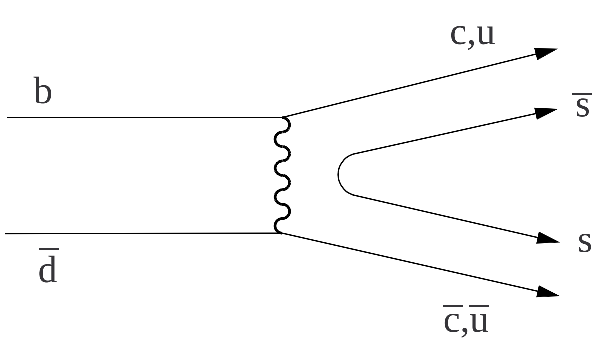
Final state: one charm, one strange.

- **No penguine contaminations**



Penguine should have even number of charms.
(True for charged and neutral B)

- **Neutral B has no annihilations**



Annihilations should have even number of stranges.

GLW, its variant, ADS methods:

Still work after including rescattering and annihilation effects:

$$A \equiv \lambda_c(T_c + C_c)$$
$$B \equiv \lambda_u(C_u + A)$$

where T_c, C_c, C_u, and A as redefined above.

Then, in particular,

$$r = \frac{\lambda_u}{\lambda_c}\frac{T_c + C_c}{C_u + A}\,.$$

A scenario:

Non observation of $D^- K_s \rightarrow$ smallness of A

$D^0\pi^0$, ΨK^-, $D_s^-\pi^0 \rightarrow r$

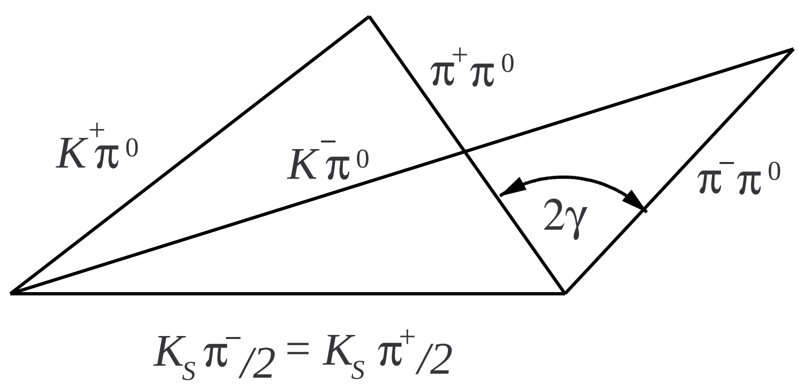
Using $B \to K\pi, \pi\pi$ for γ/ϕ_3

Tree-penguin interference
$\to$ large direct CP asymmetries expected.

Each CP asymmetry requires and depends on FSI phases (difficult to calculate).

But: Amplitude relations $\to$ α, γ, FSI phases.

For example:



Note:

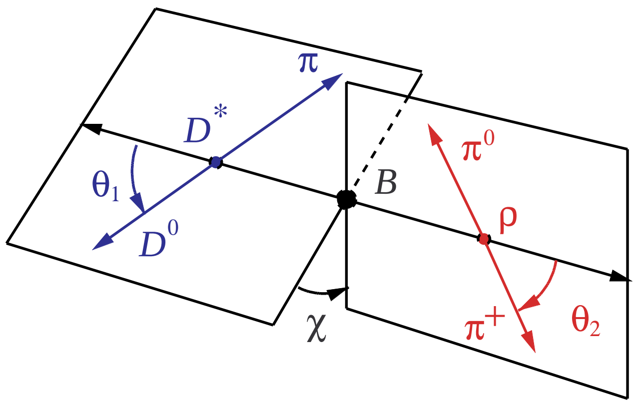
- All charged B modes $\to$ self-tagging.
- SU(3) breaking effect are reasonably under control. Complication by EW penguins which breaks the isospin.

$K\pi$ modes summary

	N(signal)	signif.	$Br(10^{-5})$
$\pi^+\pi^-$	9.9	2.2σ	< 1.5
$\pi^+\pi^0$	11.3	2.8σ	< 2.0
$\pi^0\pi^0$	2.7	2.4σ	< 0.93
$K^+\pi^-$	21.6	5.6σ	$1.5^{+0.5}_{-0.4} \pm 0.1 \pm 0.1$
$K^+\pi^0$	8.7	2.7σ	< 1.6
$K^0\pi^+$	9.2	3.2σ	$2.3^{+1.1}_{-1.0} \pm 0.3 \pm 0.2$
$K^0\pi^0$	4.1	2.2σ	< 4.1
K^+K^-	0.0	0.0σ	< 0.43
K^+K^0	0.6	0.2σ	< 2.1
K^0K^0	0	$-$	< 1.7
$h^+\pi^0$	20.0	5.5σ	$1.6^{+0.6}_{-0.5} \pm 0.3 \pm 0.2$

blue: the SU(3) triangle modes.

Angular correlation in $B \to D^* \rho$



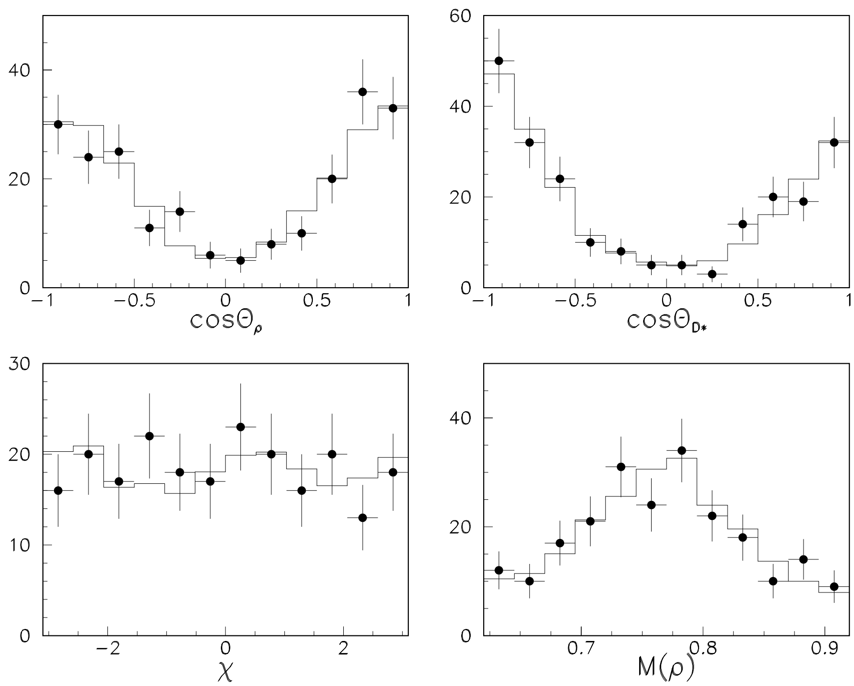
$$\frac{1}{\Gamma}\frac{d^3\Gamma}{dc_{\theta_1}dc_{\theta_2}d\chi} =$$

$$\frac{9}{32\pi}\Big\{4|H_0|^2 c_{\theta_1}^2 c_{\theta_2}^2 + (|H_+|^2 + |H_-|^2) s_{\theta_1}^2 s_{\theta_2}^2$$

$$+[\Re(H_- H_+^*) c_{2\chi} + \Im(H_- H_+^*) s_{2\chi}] 2 s_{\theta_1}^2 s_{\theta_2}^2$$

$$+[\Re(H_- H_0^* - H_+ H_0^*) c_\chi + \Im(H_- H_0^* - H_+ H_0^*) c_\chi] s_{2\theta_1} s_{2\theta_2}\Big\}$$

Preliminary



$$|H_0|^2 + |H_+|^2 + |H_-|^2 = 1\,, \qquad H_0 = \text{real}$$

$\bar{B}^0 \to D^{*+}\rho^-$

	$\lvert H \rvert$	$\arg H(rad)$
H_+	$0.153 \pm 0.052 \pm 0.013$	$1.36 \pm 0.36 \pm 0.32$
H_-	$0.311 \pm 0.048 \pm 0.036$	$0.19 \pm 0.23 \pm 0.13$

$B^- \to D^{*0}\rho^-$

	$\lvert H \rvert$	$\arg H(rad)$
H_+	$0.221 \pm 0.064 \pm 0.035$	$0.98 \pm 0.30 \pm 0.08$
H_-	$0.290 \pm 0.066 \pm 0.038$	$1.12 \pm 0.26 \pm 0.09$