CPV in DK decays of B-mesons

~ Observation of the Decay $B^- \rightarrow D_{CP}K^-$ ~

XIV th RECONTRES DE BLOIS

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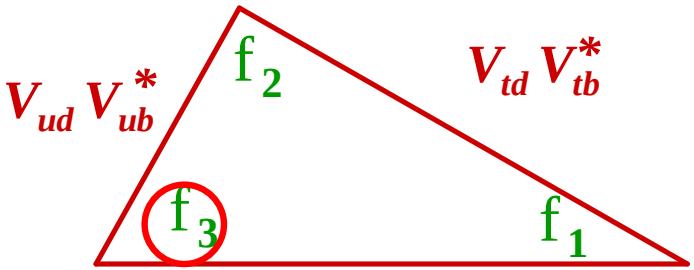
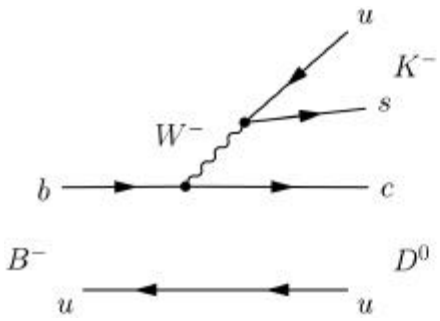
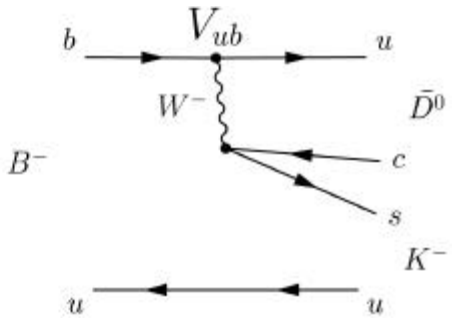
For Belle Collaboration

Introduction

- Goal of B-factory project
  - Understanding of CP violation.
  - Measurement of UT is essential.
    - accurately, many aspects…
- $B^- \rightarrow DK^-$
  - Sensitive to $\phi_3(\gamma)$
    - Theoretically clean method.
  - Use direct CP asymmetry
    - $B^- \rightarrow D_{CP}K^-$
      - Target NOW!
    - $B^- \rightarrow D^0(\rightarrow K^+\pi^-)K^-$ (DCSD)
      - Large CPV(?)
        but Br ~ $O(10^{-7})$.







$\arg(V_{ub}^*) \sim \phi_3$

Experimental challenges

- $B^- \rightarrow DK^-/D\pi^-$ separation
  - Large backgrounds from Cabibbo-favored decay, $B^- \rightarrow D\pi^-$

$$R = Br(B^- \rightarrow D^0K^-)/Br(B^- \rightarrow D^0\pi^-) = 0.079 \pm 0.009 \pm 0.006$$

[Belle, PRL87, 111801(2001)]

c.f. Naïve expectation : $R \sim (f_K/f_\pi)^2 \ \tan\theta_C^2 \sim 0.074$

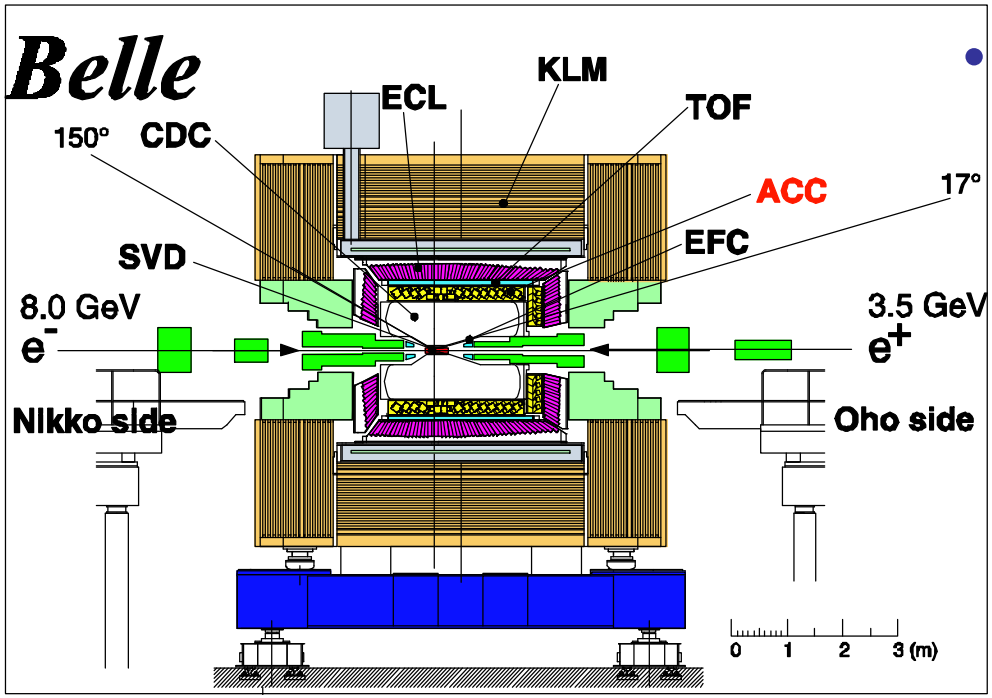
(f_K, f_π : form factor, θ_C : Cabibbo angle)

  - Due to similar topology, K/π separation at high momentum range (1.5 < P < 3.5 GeV/c) is very important.

- Small decay rate
  - $B^- \rightarrow D^0K^-$: Cabibbo-suppressed mode (Br ~ 4×10^{-4}).
  - D_{CP} decay rate is small (Br <~ 1%).

→ High B statistics is required.

Experimental apparatus



- Belle detector

  >2.5 σ K/π separation
  up to 3.5 GeV/c

ACC	Silica Aerogel Cerenkov Counters n=1.01~1.03
TOF	Time of flight, σ_t ~ 95 ps
dE/dx	Energy loss in CDC, σ(dE/dx) ~ 6.9%

- KEKB accelerator
  - >80fb^{-1} data with the world record luminosity, 7.2x10^{33}cm^{-2}s^{-1}
  - This analysis uses 29.1 fb^{-1} data (31.3 million $B\overline{B}$)

Analysis

- Reconstructed Modes : $B^- \rightarrow DK^-/D\pi^-$ (+ c.c. modes)

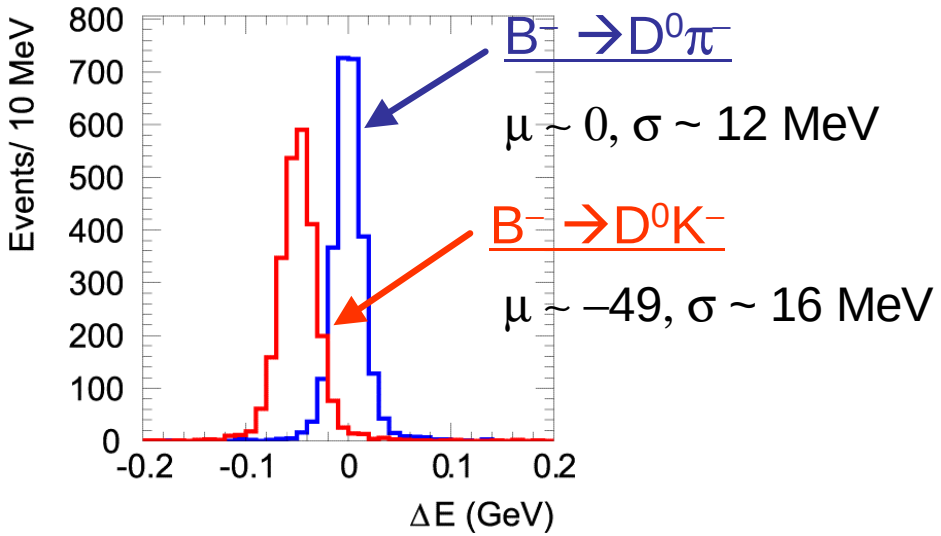
Flavor specific	$D_f \rightarrow K^-\pi^+$
CP= 1	$D_1 \rightarrow K^-K^+, \pi^-\pi^+$
CP= –1	$D_2 \rightarrow K_S\pi^0, K_S\omega, K_S\phi, K_S\eta, K_S\eta'$

- B reconstruction

Use ΔE after cutting on M_{bc}

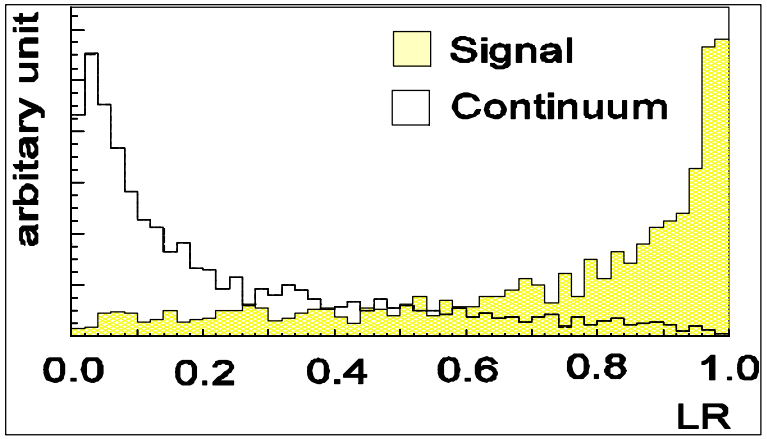
– $M_{bc} = \sqrt{(E^{lab}_B)^2 - (P^{lab}_B)^2}$
  - $\sigma \sim 2.8$ MeV/c^2
  - $5.27 < M_{bc} < 5.29$ GeV/c^2

– $\Delta E = E^{cm}_D + E^{cm}_h - E^{cm}_{beam}$
  - h : *pion assumption*



Background suppression

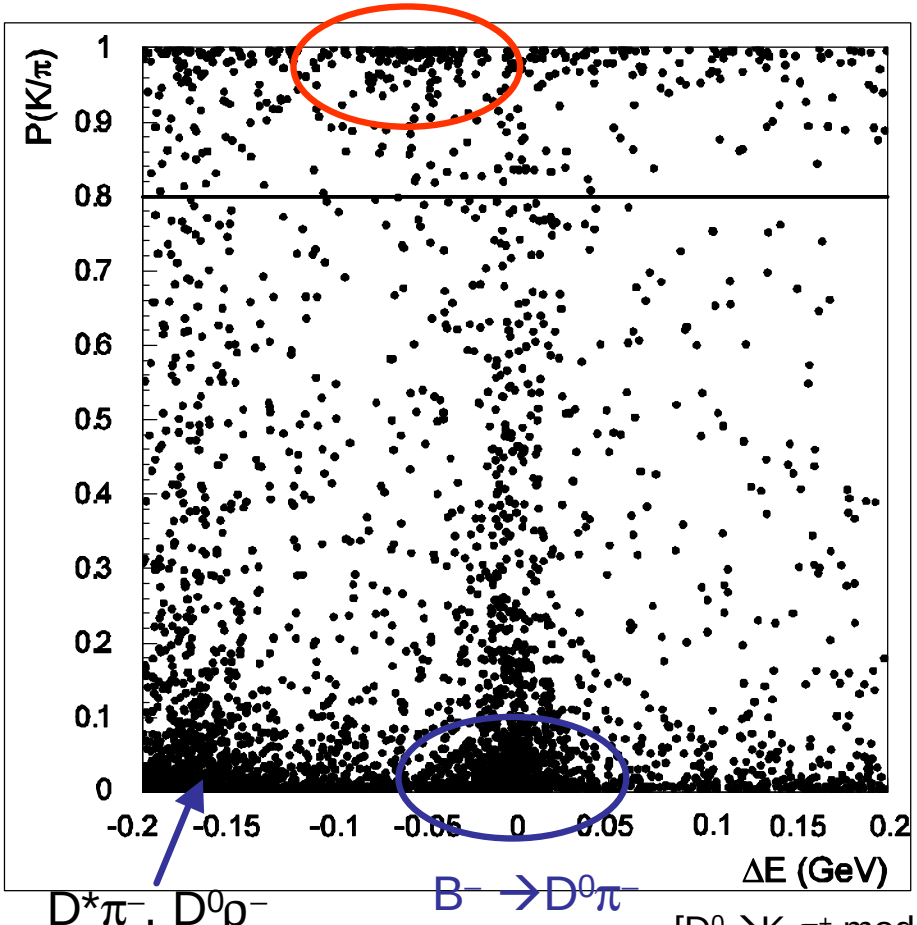
- Continuum suppression ($\sigma(q\bar{q})/\sigma(B\bar{B})\sim 3$)
  - $LR(F,\cos\theta_B) = L_{sig}/(L_{sig}+L_{cont})$
    - F: Fisher discriminant with SFW
      - SFW: use jet topology
    - $\cos\theta_B$: B flight direction



ex) LR>0.4 : ε(sig) = 87.1%, ε(cont) = 26.4%

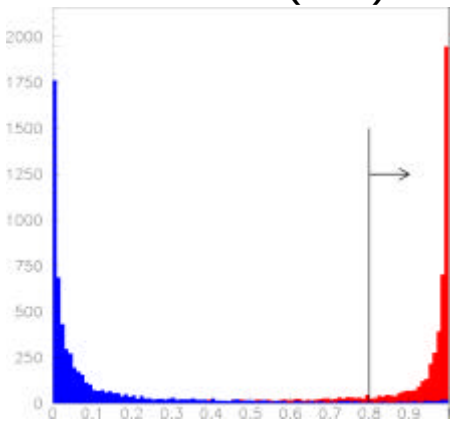
- Veto for B decays
  - $B^- \rightarrow D^0\pi^-$, $J/\Psi K^-$
    - For $B^- \rightarrow D_1(\rightarrow\pi^+\pi^-)h^-$, veto $M(h^-\pi^+)$ around $M(D^0)$, $M(J/\Psi)$
  - Non D_{CP} component
    - $D\rightarrow VP$ mode : veto on helicity angle, $|\cos\theta_{hel}|>0.4$
    - $D\rightarrow K_S\omega$: veto $M(K^{*-}(\rightarrow K_S\pi^-))$ to reduce $D^0\rightarrow K^{*-}\rho^+$

$B^- \to DK^-/D\pi^-$ separation



Clear separation!

- $P(K/\pi) = L(K)/(L(K)+L(\pi))$
  - use ACC and dE/dx
  - K : $P(K/\pi) \sim 1$, π : $P(K/\pi) \sim 0$



$P(K/\pi)>0.8$

- $\varepsilon(K) = 77.7\%$
- $\varepsilon(\pi) = 2.4\%$

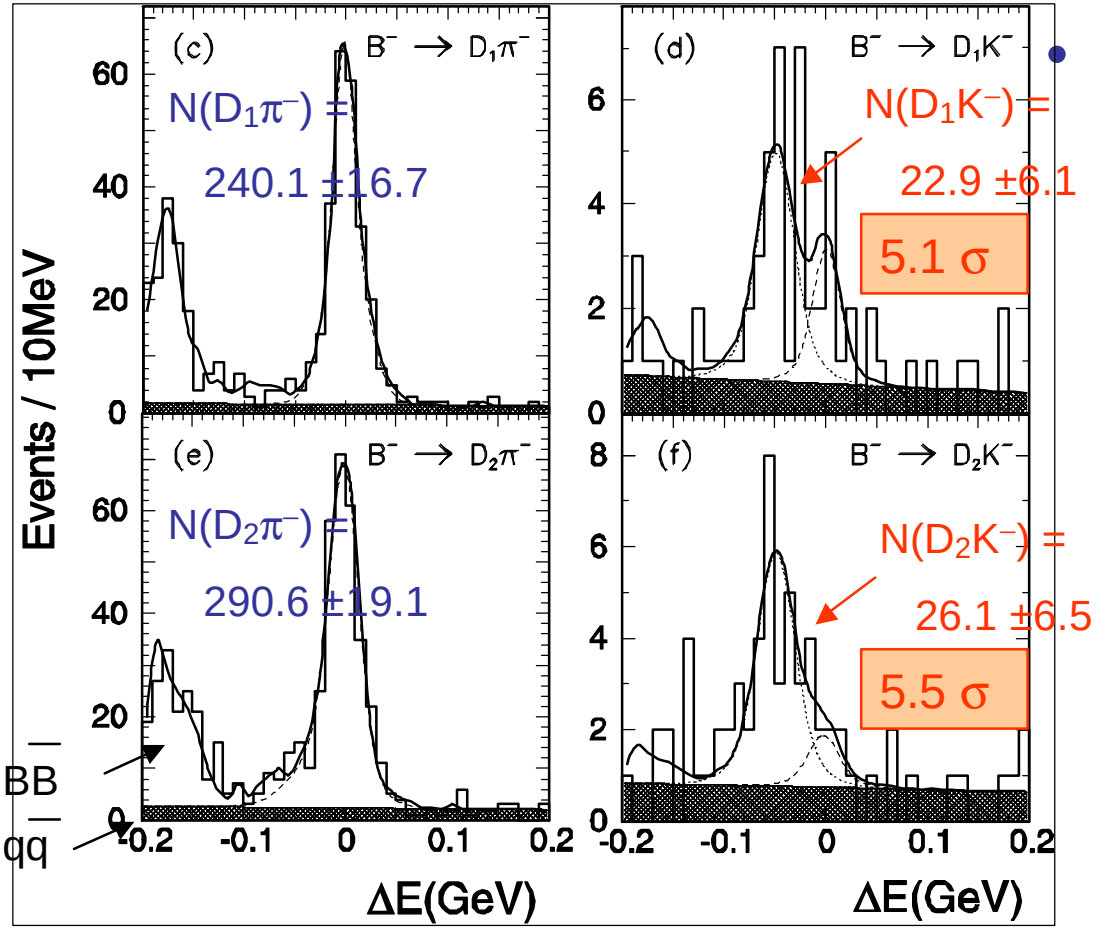
$P(K/\pi)$ in $D^{*+} \to D^0(\to K^-\pi^+)\pi^+$

($2.1<P^{cm}(h)<2.5$ GeV/c)

[$D^0 \to K^-\pi^+$ mode]

$B^- \rightarrow D_{CP}K^-$ results

$B^- \rightarrow D\pi^-$ [P(K/π) < 0.8] $B^- \rightarrow DK^-$ [P(K/π) > 0.8]



- Yield extraction
  - → ΔE, binned likelihood fit
  - $B^- \rightarrow D\pi^-$
    - $N(D\pi^-)$, $N(B\bar{B})$, $N(q\bar{q})$
      - $D\pi^-$ shape floated
  - $B^- \rightarrow DK^-$
    - $N(DK^-)$, $N(D\pi^-)$, $N(q\bar{q})$
      - N(BB) is fixed from measured fake rate

First observations!

$B^- \to DK^-/D\pi^-$ Ratio

- $R = Br(B^- \to DK^-)/Br(B^- \to D\pi^-)$
  $= N(DK^-)/N(D\pi^-) \times \eta(D\pi^-)/\eta(DK^-) \times \varepsilon(\pi)/\varepsilon(K)$

PID eff. [$\varepsilon(\pi) = 0.972$, $\varepsilon(K) = 0.778$]

Detection eff. [~1.05 due to Kaon decay in flight]

Consistent with previous value,
$R = 0.079 \pm 0.009 \pm 0.006$

	$N(DK^-)$	$N(D\pi^-)$	R
$B^- \to D_f h^-$	161.7±14.5	2245.1±51.0	0.094±0.009±0.007
$B^- \to D_1 h^-$	22.9±6.1	240.1±16.7	0.125±0.036±0.010
$B^- \to D_2 h^-$	26.1±6.5	290.6±19.1	0.119± 0.028±0.006

Preliminary

– Ratios for D_{CP} agree well with flavor specific's one.

Direct CPV

- $A_{CP} = \dfrac{Br(B^- \rightarrow DK^-) - Br(B^+ \rightarrow DK^+)}{Br(B^- \rightarrow DK^-) + Br(B^+ \rightarrow DK^+)}$
  - Obtained from ΔE fit for B^-/B^+ samples

Preliminary

	$N(B^-)$	$N(B^+)$	A_{CP}	90% C.L.
$B^\pm \rightarrow D_1 K^\pm$	14.7 ±4.6	8.1 ± 3.9	0.29 ± 0.26 ± 0.05	$-0.14 < A_1 < 0.73$
$B^\pm \rightarrow D_2 K^\pm$	10.6±4.2	16.4 ±4.2	–0.22 ± 0.24 ± 0.04	$-0.62 < A_2 < 0.18$

  - Consistent with zero asymmetry.

    c.f. Calibration mode : $A_{CP}(B^\pm \rightarrow D_f \pi^\pm) = -0.036 \pm 0.021$

Systematic errors

- Sources for systematic errors :
  - R : Most uncertainties cancel in the ratio
    - signal, background shape : 5.1– 7.9%
    - K/π ID eff. : 1.2%

    Total 5.2 – 8.0%
  - A_{CP}
    - background shape : 1.5 – 3.9%
    - Intrinsic asymmetry (from $A_{CP}(B^{\pm} \rightarrow D_f\pi^{\pm})$) : 3.6%
    - K ID eff. : 1.0%
    - Non D_{CP} component : ~ 0.1%

    Total 4.0 – 5.4%
- Statistical error still dominates

Toward ϕ_3

- CPV, CP av. Br in $B^- \rightarrow D_{CP}K^- \rightarrow$ constrain ϕ_3

$$A_{1,2} = 2r \sin\delta' \sin\phi_3 / (1 + r^2 + 2r \cos\delta' \cos\phi_3)$$
$$R_{1,2} = R(D_{1,2}) / R(D_f) = 1 + r^2 + 2r \cos\delta' \cos\phi_3$$

$r = |A(B^- \rightarrow \overline{D}^0 K^-)/A(B^- \rightarrow D^0 K^-)| \sim 0.1$ (naïve expectation)

δ' = δ (CP=1), $\delta + \pi$ (CP= –1)

  - assuming No D^0-$\overline{D}^0$ mixing, No CPV in $B^- \rightarrow D\pi^-$

- Current results → Consistent with no interference (i.e. $A_i = 0$, $R_i = 1$)

$A_1 = 0.29 \pm 0.26 \pm 0.05$	$A_2 = -0.22 \pm 0.24 \pm 0.04$
$R_1 = 1.33 \pm 0.37 \pm 0.12$	$R_2 = 1.27 \pm 0.29 \pm 0.09$

Preliminary

  - 300fb^{-1} data : $\delta(A_i, R_i) <\sim 0.1 \rightarrow$ Interesting results will be extracted!

(will be available before 2005)

Summary

- First observations of $B^- \rightarrow D_{CP}K^-$, will be used to measure ϕ_3 in unitarity triangle.
- First measurement of CPV in $B^- \rightarrow D_{CP}K^-$.
  We started to constrain these variables.

$A_1 =$	$0.29 \pm 0.26 \pm 0.05$	$-0.14 < A_1 < 0.73$
$A_2 =$	$-0.22 \pm 0.24 \pm 0.04$	$-0.62 < A_2 < 0.18$
$R_1 =$	$1.33 \pm 0.37 \pm 0.12$	
$R_2 =$	$1.27 \pm 0.29 \pm 0.09$	

90% C.L.

Preliminary

- Improved measurement will be expected with more recorded data.

  ~300 fb^{-1} data : $\delta(A_i, R_i) < \sim 0.1$