① Tree contributions are almost equal
in the three different approaches.

⇒ almost same Branching ratio.

However the penguin contribution are larger
in PQCD due to the dynamical enhancement!

$$\mu_{Fact.} : \quad m_b \text{ or } m_{b/2} \longrightarrow \sqrt{\bar{\Lambda} \, m_b} \sim 1.5 \, GeV$$

② Factorizable tree and Penguin contributions
  - PQCD : real
  - FA. BBNS : complex (BSS and FSI)

③ Important annihilation contribution!
  → Same order as the Factorized Penguin
  → large imaginary part.
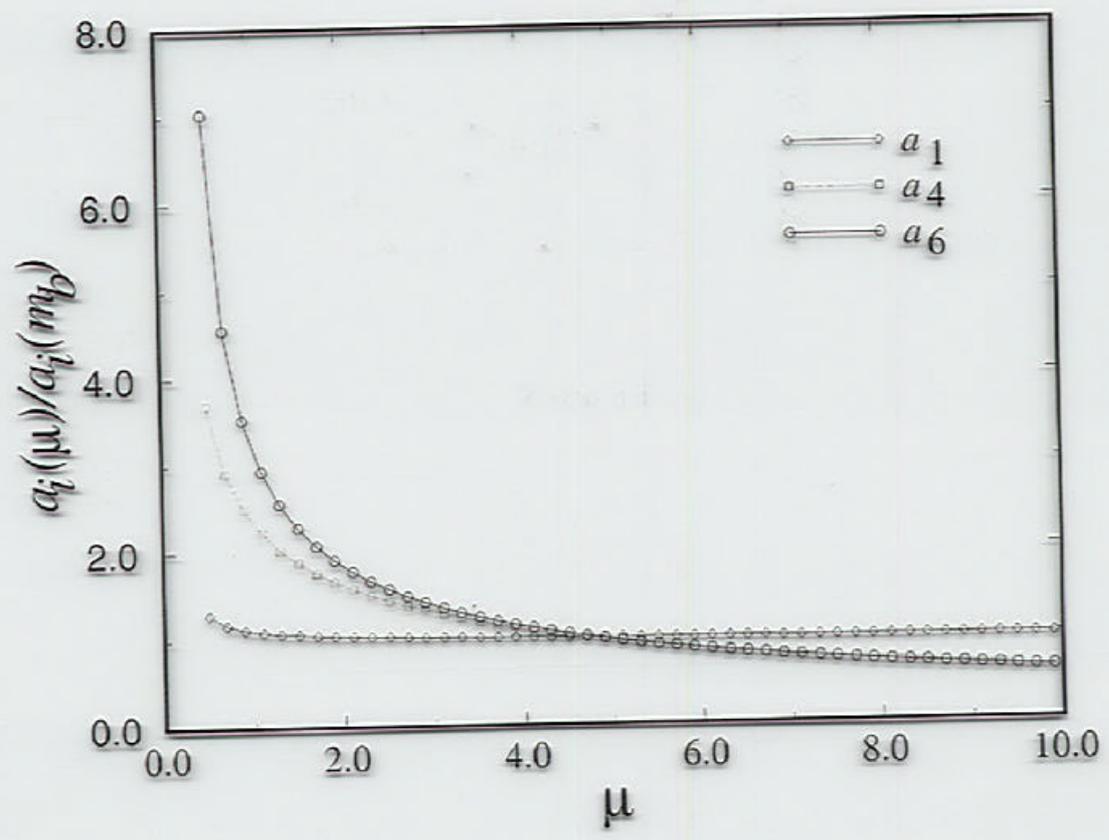 → the main source of strong phase!

Figure 9

④ Nonfactorizable contributions : M^P, M^T

- PQCD : complex
- BBNS : real
- FA : included in the wilson Coeff.

⑤ T and P ? (unit : 10^{-3})

$$T_{PQCD} = 83.40 + i\, 1.60 \; ; \; P_{PQCD} = -6.34 + i\, 3.89$$

$$T_{BBNS} = 74.93 + i\, 1.13 \; ; \; P_{BBNS} = 1.13 - i\, 1.27$$

$$T_{FA} = 75.70 + i\, 1.13 \; ; \; P_{FA} = -3.04 - i\, 1.27$$

$$\rightarrow \; |P_{PQCD}| \sim 4.4\, |P_{BBNS}| \sim 2.3\, |P_{FA}|$$

⑥ Large strong phase of $B^0 \rightarrow \pi^+\pi^-$;

$$A = V_t^* \, |P| \, e^{i\delta} - V_u^* \, |T|$$

- $\delta_{PQCD} = 147° \; ; \; \left|\dfrac{P}{T}\right| = 27\%$
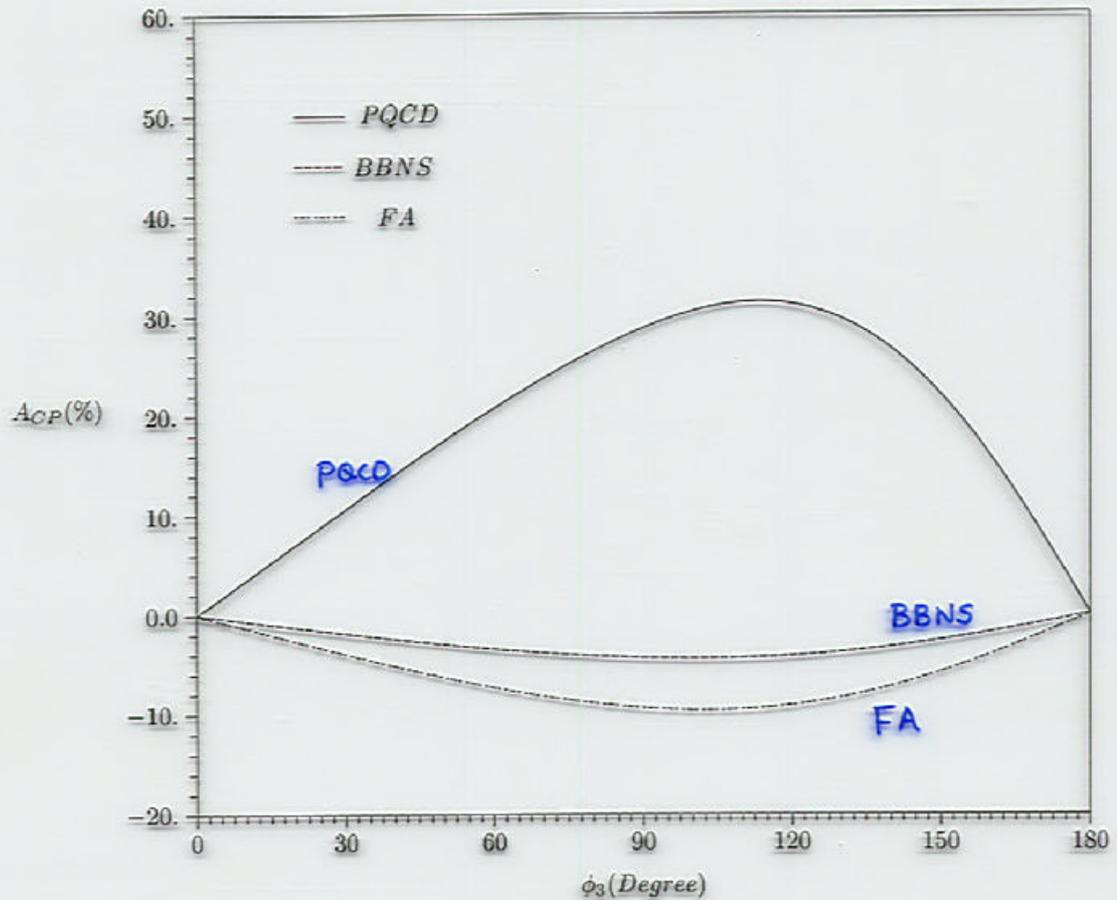- $\delta_{BBNS} = -50°$
- $\delta_{FA} = -113°$

⑦ Large $\cancel{CP}$:

$$|A_{CP}| < 30\% \; : \; PQCD$$

$$|A_{CP}| < 4\% \; : \; BBNS$$

$$|A_{CP}| < 10\% \; : \; FA$$

CP asymmetry in $B^0 \to \pi^+\pi^-$.

By measuring ✓ <u>Direct</u> CP asymmetry of $\pi^+\pi^-$,
We can distinguish PQCD method from others!

B) B → Kπ decays:

TABLES

Amplitude	Real part	Imaginary part
F_e	103.69	0
F_e^P	-8.17	0
F_a^P	-0.23	3.75

TABLE I. Amplitudes for the $\bar{B}^0 \to K^-\pi^+$ decay in units of 10^{-2} with $F_e^P = F_{e4}^P + F_{e6}^P$ and $F_a^P = F_{a4}^P + F_{a6}^P$.

$$\phi_3 = 80°$$

Branching ratio	PQCD prediction (10^{-6})		CLEO data (average) (10^{-6})
Br($B^\pm \to K^0\pi^+$)	$17.51^{+3.3}_{-2.8}$	$16.99^{+3.3}_{-2.7}$	$18.2^{+4.6}_{-4.0} \pm 1.6$
Br($B^- \to \bar{K}^0\pi^-$)	$16.48^{+3.2}_{-2.7}$	$A_{cp} = (3.0^{+0.2}_{-0.1})$ %	$18.2^{+4.6}_{-4.0} \pm 1.6$
Br($B^0 \to K^+\pi^-$)	$18.85^{+3.4}_{-2.7}$	$16.49^{+3.2}_{-2.5}$	$17.2^{+2.5}_{-2.4} \pm 1.2$
Br($\bar{B}^0 \to K^-\pi^+$)	$14.13^{+3.0}_{-2.3}$	$A_{cp} = (-14.3^{+1.1}_{-1.0})$ %	$17.2^{+2.5}_{-2.4} \pm 1.2$
Br($B^\pm \to K^+\pi^0$)	$10.08^{+2.0}_{-1.6}$	$9.04^{+1.9}_{-1.5}$	$11.6^{+3.0+1.4}_{-2.7-1.3}$
Br($B^- \to K^-\pi^0$)	$8.07^{+1.7}_{-1.4}$	$A_{cp} = (-11.5^{+0.9}_{-0.9})$ %	$11.6^{+3.0+1.4}_{-2.7-1.3}$
Br($B^0 \to K^0\pi^0$)	$10.2^{+0.3}_{-0.3}$	$10.6^{+0.3}_{-0.3}$	$14.6^{+5.9+2.4}_{-5.1-3.3}$
Br($\bar{B}^0 \to \bar{K}^0\pi^0$)	$10.9^{+0.3}_{-0.2}$	$A_{cp} = (3.4^{+0.4}_{-0.3})$ %	$14.6^{+5.9+2.4}_{-5.1-3.3}$

TABLE II. PQCD predictions of branching ratios for a representative parameters set.

$$\cdot \left| \frac{P}{T} \right| = \left| \frac{V_{ts}^* V_{tb}}{V_{us}^* V_{ub}} \right| \frac{(F_e^P + M_e^P + F_a^P + M_a^P)}{(F_e + M_e^T)}$$

$$\sim 6.0$$

- Ratios of CP-averaged rates :

	PQCD	BBNS	CLEO

- $\dfrac{Br(\pi^+\pi^-)}{Br(\pi^\pm K^\mp)} = 0.45 \sim 0.80 \qquad 0.5 \sim 1.9 \quad [0.25 \pm 0.10]$

- $\dfrac{Br(\pi^\mp K^\pm)}{2\,Br(\pi^0 K^0)} = 0.68 \sim 0.9 \qquad 0.9 \sim 1.4 \quad [0.59 \pm 0.27]$

- $\dfrac{2\,Br(\pi^0 K^\pm)}{Br(\pi^\pm K^0)} = 1.06 \sim 1.08 \qquad 0.9 \sim 1.3 \quad [1.27 \pm 0.47]$

- $\dfrac{\tau_{B^+}}{\tau_{B^0}} \cdot \dfrac{Br(\pi^\mp K^\pm)}{Br(\pi^\pm K^0)} = 1.03 \sim 1.10 \qquad 0.6 \sim 1.0 \quad [1.00 \pm 0.30]$

- $Br(B \to \pi^0 K^0) = (10.6 \pm 0.3) \cdot 10^{-6} :$ PQCD

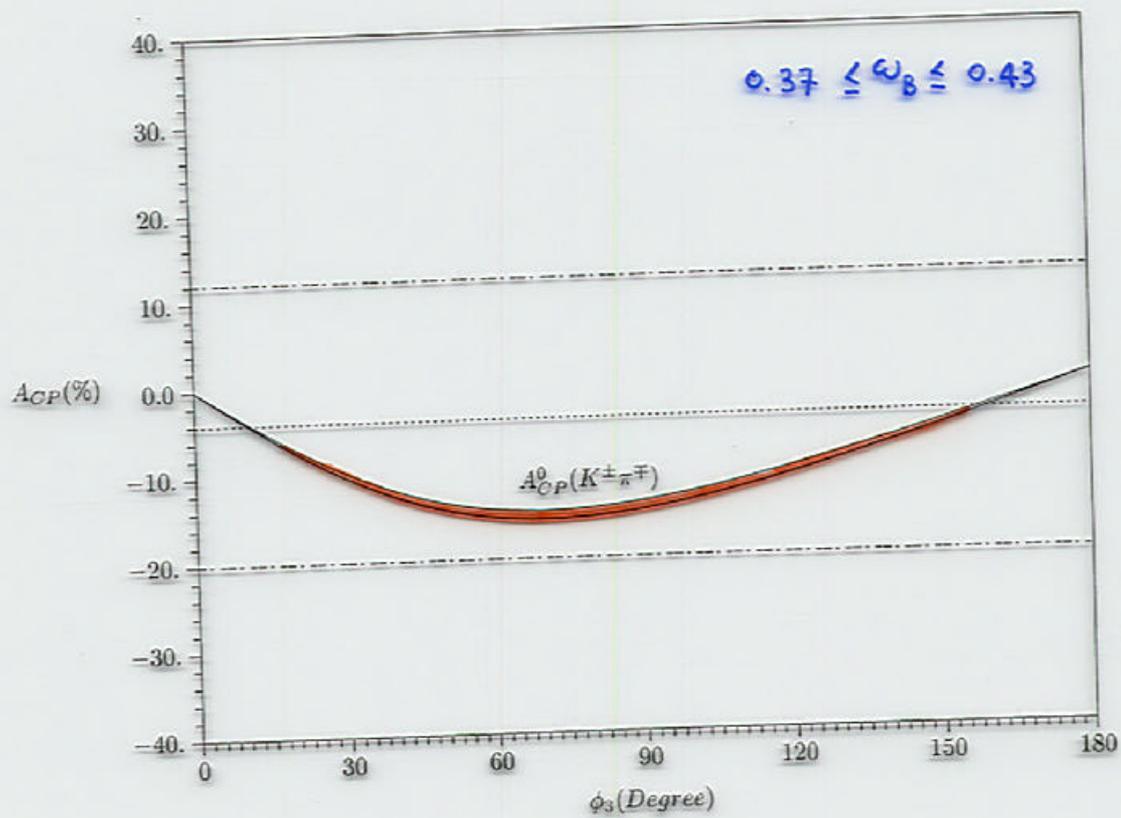 $\qquad\qquad\qquad = (4.5 \pm 2.5) \cdot 10^{-6} :$ BBNS
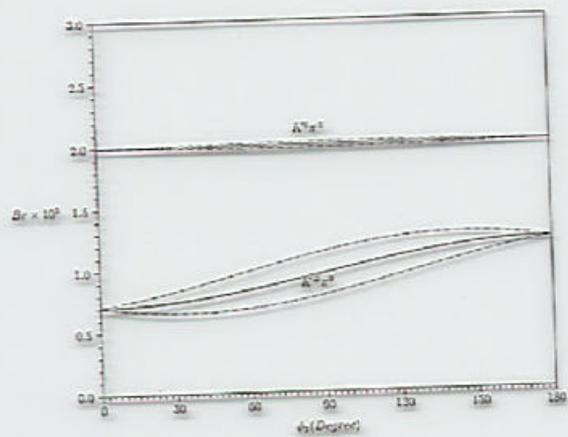
Two-times larger !!

CP Asymmetry of $B^0 \to K^{\pm}\pi^{\mp}$

Figure 7

Figure 5(a)

Figure 5(b)

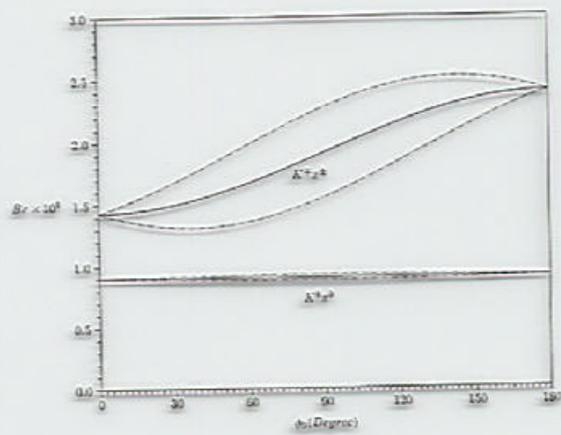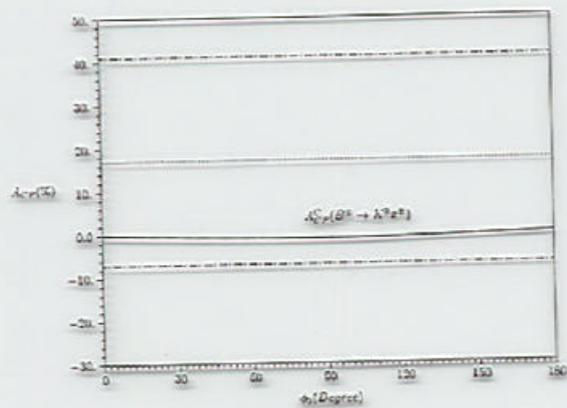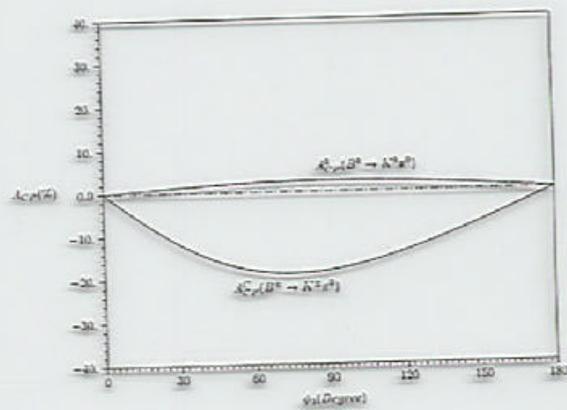Figure 7(a)

Figure 7(c)

c) B → φK decay

- B → VP mode.
- Pure Penguin process.

- $B^{\pm} \to \phi K^{\pm}$:

$$Av \, Br(B^{\pm} \to \phi K^{\pm}) = (12.1 \, {}^{+2.6}_{-1.9}) \cdot 10^{-6}$$

$$A_{cp} = 0.0\%$$

- $B^{0} \to \phi \bar{K}^{0}$:

$$Av \, Br(B^{0} \to \phi \bar{K}^{0}) = (9.0 \, {}^{+2.5}_{-1.8}) \times 10^{-6}$$

$$A_{cp} = -(1.7 \, {}^{+0.2}_{-0.1})\%$$

Summary :

With PQCD approach including $k_\perp$,

1. We can calculate Form Factors $\left(\begin{array}{c}\text{Spacelike}\\\text{timelike}\end{array}\right)$

- Sizable $k_\perp$ contributions
- Threshold Resummation

2. We have

Large Branching ratios in charmless B decays except $B \to \eta' K$ $\Leftarrow$ Dynamical Penguin Enhancement at $\mu \sim 1.5$ GeV

Large direct CP asym. for $B \to \pi^+\pi^-, K^+\pi^-, K^+\pi^0$ $\Leftarrow$ Large strong phase from the factorized Annihilation diagram

BRs in units of 10^{-6}

Decay	CLEO	BELLE	BABAR
$K^{\pm}\pi^{\mp}$	$17.2^{+2.5}_{-2.4}\pm1.2$	$17.4^{+5.1}_{-4.6}\pm3.4$	$12.5^{+3.0+1.3}_{-2.6-1.7}$
$K^{0}\pi^{\pm}$	$18.2^{+4.6}_{-4.0}\pm1.6$	$16.6^{+9.8+2.2}_{-7.8-2.4}$	
$K^{\pm}\pi^{0}$	$11.6^{+3.0+1.4}_{-2.7-1.3}$	$18.8^{+5.5}_{-4.9}\pm2.3$	
$K^{0}\pi^{0}$	$14.6^{+5.9+2.4}_{-5.1-3.3}$	$21.0^{+9.3+2.5}_{-7.8-2.3}$	
$\pi^{\pm}\pi^{\mp}$	$4.3^{+1.6}_{-1.4}\pm0.5$	$6.3^{+3.9}_{-3.5}\pm1.6$	$9.3^{+2.6+1.2}_{-2.3-1.4}$
$\pi^{\pm}\pi^{0}$	<12.7	<10.1	
$\pi^{0}\pi^{0}$	<5.7		
$K^{\pm}\eta'$	$80^{+10}_{-9}\pm7$		$62\pm18\pm8$
$K^{0}\eta'$	$89^{+18}_{-16}\pm9$		
$^{*}\rho^{\pm}\pi^{\mp}$	$27.6^{+8.4}_{-7.4}\pm4.2$		$49\pm13^{+6}_{-5}$
$\rho^{0}\pi^{\pm}$	$10.4^{+3.3}_{-3.4}\pm2.1$		
$\omega\pi^{\pm}$	$11.3^{+3.3}_{-2.9}\pm1.4$		
$K^{*\pm}\pi^{\mp}$	22^{+8+4}_{-6-5}		
$K^{*0}\eta$	$13.8^{+5.5}_{-4.6}\pm1.6$		
$K^{*\pm}\eta$	$26.4^{+9.6}_{-8.2}\pm3.3$		
$\phi K^{\pm}$	$6.4^{+2.5+0.5}_{-2.1-2.0}$	$17.2^{+6.7+1.8}_{-5.4-1.8}$	

PQCD

$16.5^{+3.2}_{-2.5}$

$17.0^{+3.3}_{-2.7}$

$9.1^{+1.9}_{-1.5}$

10.6 ± 0.3

$8.2^{+2.0}_{-1.5}$

~ 3.7 *

~ 0.2 *

~ 18.4 *

~ 34.0 *

~ 8.0 *

$12.1^{+2.6}_{-1.9}$

$9.0^{+2.5}_{-1.8}$

ϕK^0

* K. Ukai   * C.D. Lü, M. Yang
* E. Kou

3 Our results is well agreed with experimental data for Nonleptonic charmless B-meson decays.

→ See Table !

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To PQCD Group members,

Thanks for your collaboration and contributions !

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