Testing Uncertainty of

γ/ϕ_3 from Charmless B_s Decays

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Thanks A.Ali, G.Kramer and Li, Wang...

Outline

- Test of SU(3) breaking by charmless B^0 and B_s decays by pQCD approach
- BRs and Direct CP asymmetry
- Uncertainty of γ/ϕ_3 in Charmless B_s Decays
- Summary

pQCD approach based on k_T factorization

- All diagrams using the same wave functions
- (same order in α_s expansion)
- All channels use the same wave functions
- Number of parameters reduced

Do not need form factor inputs

CP Violation in $B \to \pi \pi (K)$ (real prediction before exp.)

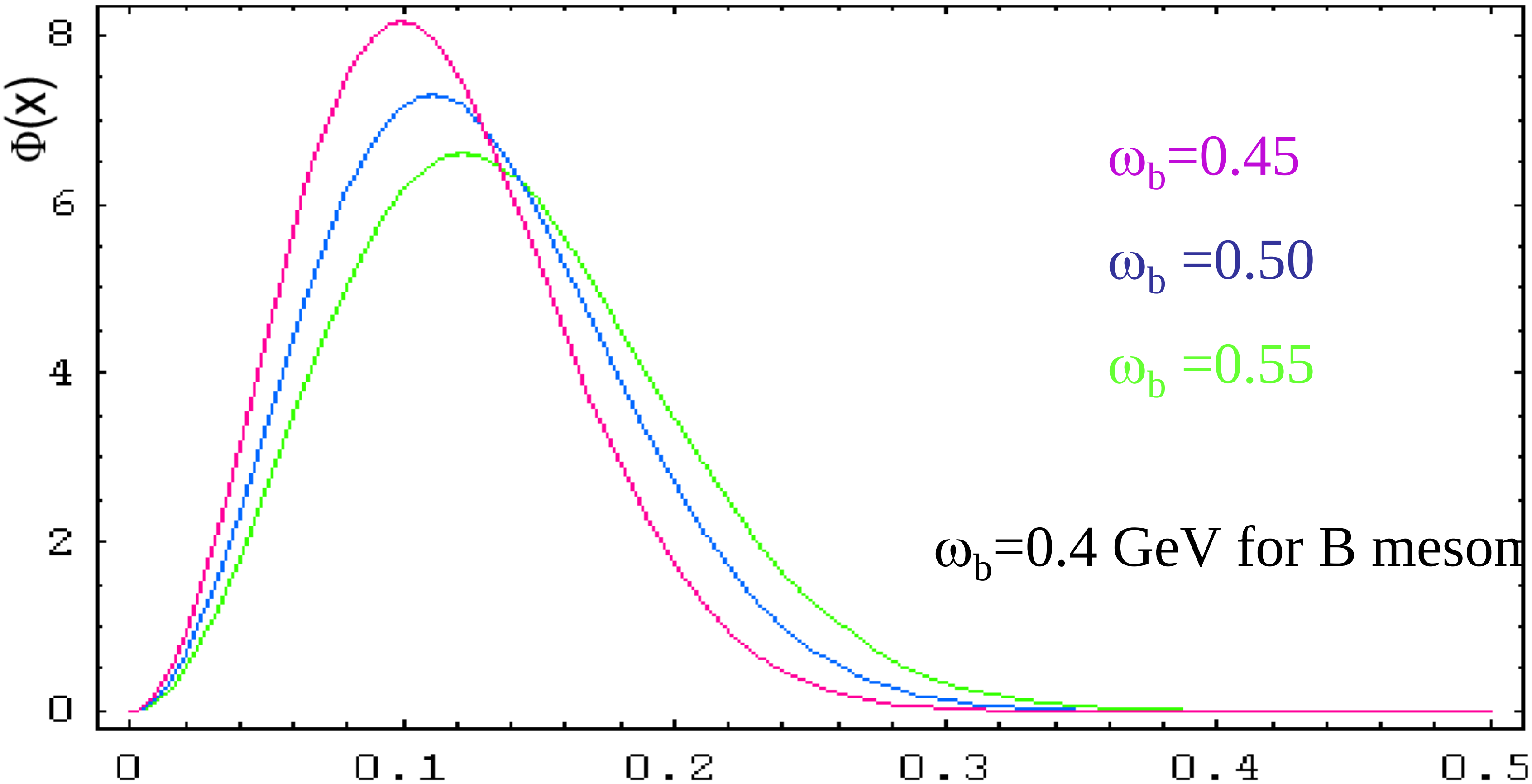
CP(%)	FA	BBNS	PQCD (2001)	Exp
$\pi^+ K^-$	$+9 \pm 3$	$+5 \pm 9$	-17 ± 5	-11.5 ± 1.8
$\pi^+ K^0$	1.7 ± 0.1	1 ± 1	-1.0 ± 0.5	-2 ± 4
$\pi^0 K^+$	$+8 \pm 2$	7 ± 9	-13 ± 4	$+4 \pm 4$
$\pi^+ \pi^-$	-5 ± 3	-6 ± 12	$+30 \pm 10$	$+37 \pm 10$

pQCD approach in B decays

- pQCD approach successfully describe the B^0 and B^+ decays
- Most of the branching ratios agree well with experiments
- The right direct CP asymmetry sign with the experiment

Using the constrained parameters determined here to predict B_s decays

B_s distribution amplitude



x = momentum fraction

Form factors derived from light cone wave functions

$$F_0^{B\to\pi} = 0.25, \quad F_0^{B\to K} = 0.31, \quad F_0^{B\to\eta_n} = 0.24$$

$$F_0^{B_s\to K} = 0.25, \quad F_0^{B_s\to\eta_s} = 0.37$$

Larger f_{Bs}, but smaller inverse moment of B_s meson distribution amplitude

QCDF:

$F_0^{B\to\pi}$	$F_0^{B\to K}$	$F_0^{B_s\to \bar{K}}$
0.28 ± 0.05	0.34 ± 0.05	0.31 ± 0.05

BR (x 10^{-6})

Modes	Class	QCDF	SCET	pQCD
$\overline{B}_s^0 \to K^+\pi^-$	T	$10.2^{+4.5+3.8+0.7+0.8}_{-3.9-3.2-1.2-0.7}$	$4.9 \pm 1.2 \pm 1.3 \pm 0.3$	$11.0^{+5.4+0.9+1.7}_{-4.6-0.8-1.4}$
$\overline{B}_s^0 \to K^0\pi^0$	C	$0.49^{+0.28+0.22+0.40+0.33}_{-0.24-0.14-0.14-0.17}$	$0.76 \pm 0.26 \pm 0.27 \pm 0.17$	$0.16^{+0.06+0.11+0.02}_{-0.06-0.06-0.03}$
$\overline{B}_s^0 \to K^+K^-$	P	$22.7^{+3.5+12.7+2.0+24.1}_{-3.2-8.4-2.0-9.1}$	$18.2 \pm 6.7 \pm 1.1 \pm 0.5$	$13.2^{+5.0+6.8+1.3}_{-4.8-3.8-0.9}$
$\overline{B}_s^0 \to K^0\overline{K}^0$	P	$24.7^{+2.5+13.7+2.6+25.6}_{-2.4-9.2-2.9-9.8}$	$17.7 \pm 6.6 \pm 0.5 \pm 0.6$	$15.1^{+5.9+7.9+0.0}_{-5.6-4.2-0.0}$
$\overline{B}_s^0 \to \pi^0\eta$	P_{EW}	$0.075^{+0.013+0.030+0.008+0.010}_{-0.012-0.025-0.010-0.007}$	$0.014 \pm 0.004 \pm 0.005 \pm 0.004$	$0.08^{+0.04+0.01+0.0}_{-0.03-0.01-0.0}$
$\overline{B}_s^0 \to \pi^0\eta'$	P_{EW}	$0.11^{+0.02+0.04+0.01+0.01}_{-0.02-0.04-0.01-0.01}$	$0.006 \pm 0.003 \pm 0.002^{+0.064}_{-0.006}$	$0.17^{+0.08+0.03+0.01}_{-0.07-0.01-0.01}$
$\overline{B}_s^0 \to K^0\eta$	C	$0.34^{+0.19+0.64+0.21+0.16}_{-0.16-0.27-0.07-0.08}$	$0.80 \pm 0.48 \pm 0.29 \pm 0.18$	$0.16^{+0.09+0.10+0.05}_{-0.07-0.05-0.02}$
$\overline{B}_s^0 \to K^0\eta'$	C	$2.0^{+0.3+1.5+0.6+1.5}_{-0.3-1.1-0.3-0.6}$	$4.5 \pm 1.5 \pm 0.4 \pm 0.5$	$0.71^{+0.26+0.30+0.16}_{-0.26-0.19-0.14}$
$\overline{B}_s^0 \to \eta\eta$	P	$15.6^{+1.6+9.9+2.2+13.5}_{-1.5-6.8-2.5-5.5}$	$7.1 \pm 6.4 \pm 0.2 \pm 0.8$	$11.2^{+3.9+6.9+0.0}_{-3.9-4.2-0.0}$
$\overline{B}_s^0 \to \eta\eta'$	P	$54.0^{+5.5+32.4+8.3+40.5}_{-5.2-22.4-6.4-16.7}$	$24.0 \pm 13.6 \pm 1.4 \pm 2.7$	$29.9^{+9.7+15.8+0.0}_{-10.1-10.0-0.0}$
$\overline{B}_s^0 \to \eta'\eta'$	P	$41.7^{+4.2+26.3+15.2+36.6}_{-4.0-17.2-8.5-15.4}$	$44.3 \pm 19.7 \pm 2.3 \pm 17.1$	$22.8^{+6.5+10.8+0.1}_{-7.4-6.9-0.0}$
$\overline{B}_s^0 \to \pi^+\pi^-$	ann	$0.024^{+0.003+0.025+0.000+0.163}_{-0.003-0.012-0.000-0.021}$	—	$0.73^{+0.26+0.06+0.02}_{-0.27-0.11-0.01}$
$\overline{B}_s^0 \to \pi^0\pi^0$	ann	$0.012^{+0.001+0.013+0.000+0.082}_{-0.001-0.006-0.000-0.011}$	—	$0.37^{+0.13+0.03+0.01}_{-0.13-0.06-0.01}$

preliminary

Three measurements of BRs in B_s

	SCET	QCDF	PQCD	EXP CDF
$B_s \to K^- pi^+$	4.9±1.8	10±6	11 ±6	5.0±1.3
$B_s \to K^- K^+$	18±7	23±27	13 ±9	24 ± 5
$B_s \to$ phi phi			33 ±13	14 ± 8

$|Vub|\ (10^{-3}) = 3.69 \to 4.31$

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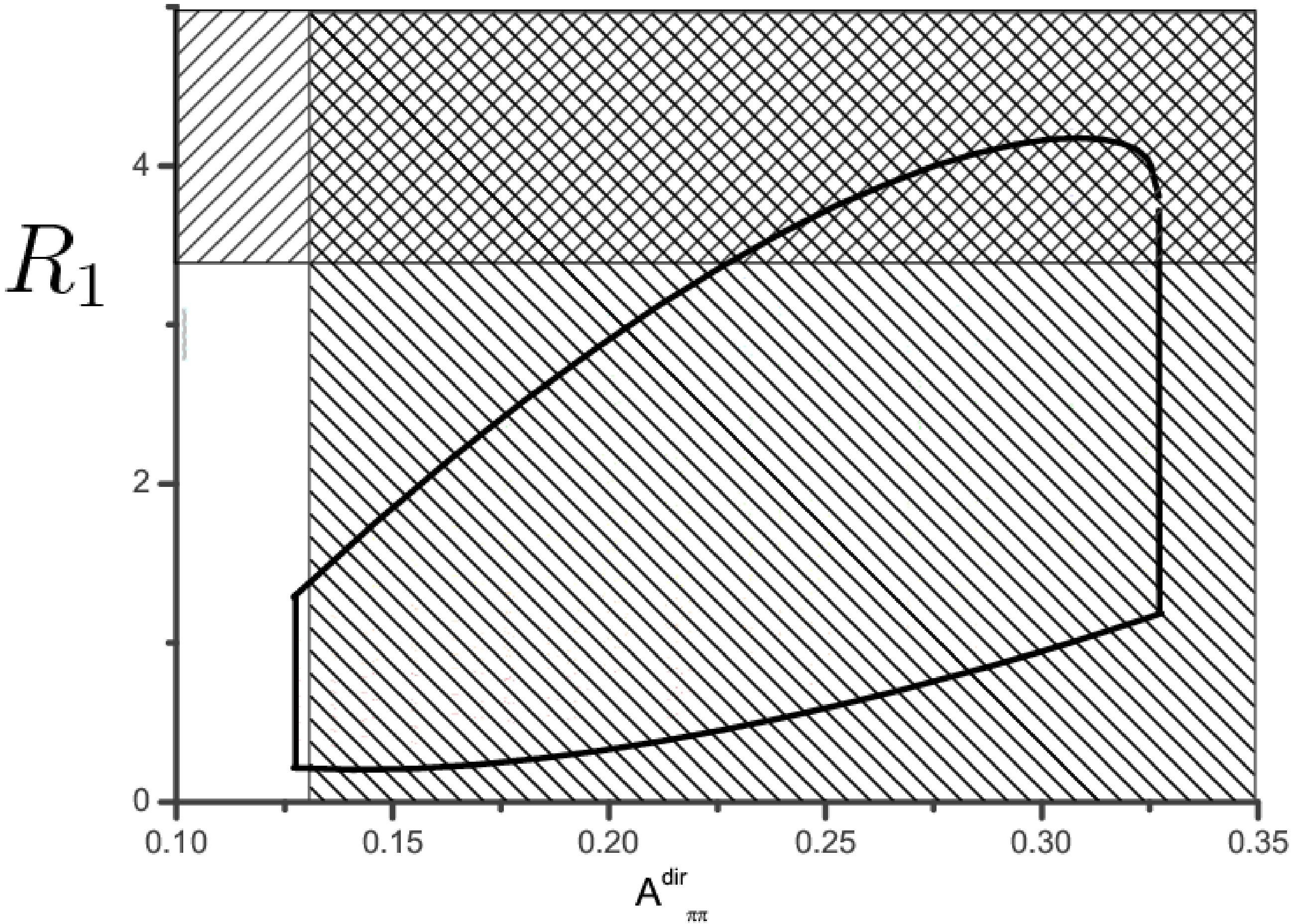
First measurement of CP in B_s

$B_s \rightarrow K^- pi^+$

SCET	QCDF	PQCD	EXP
20 ± 26	–6.7 ± 16	24 ± 6	39 ± 15 ± 8

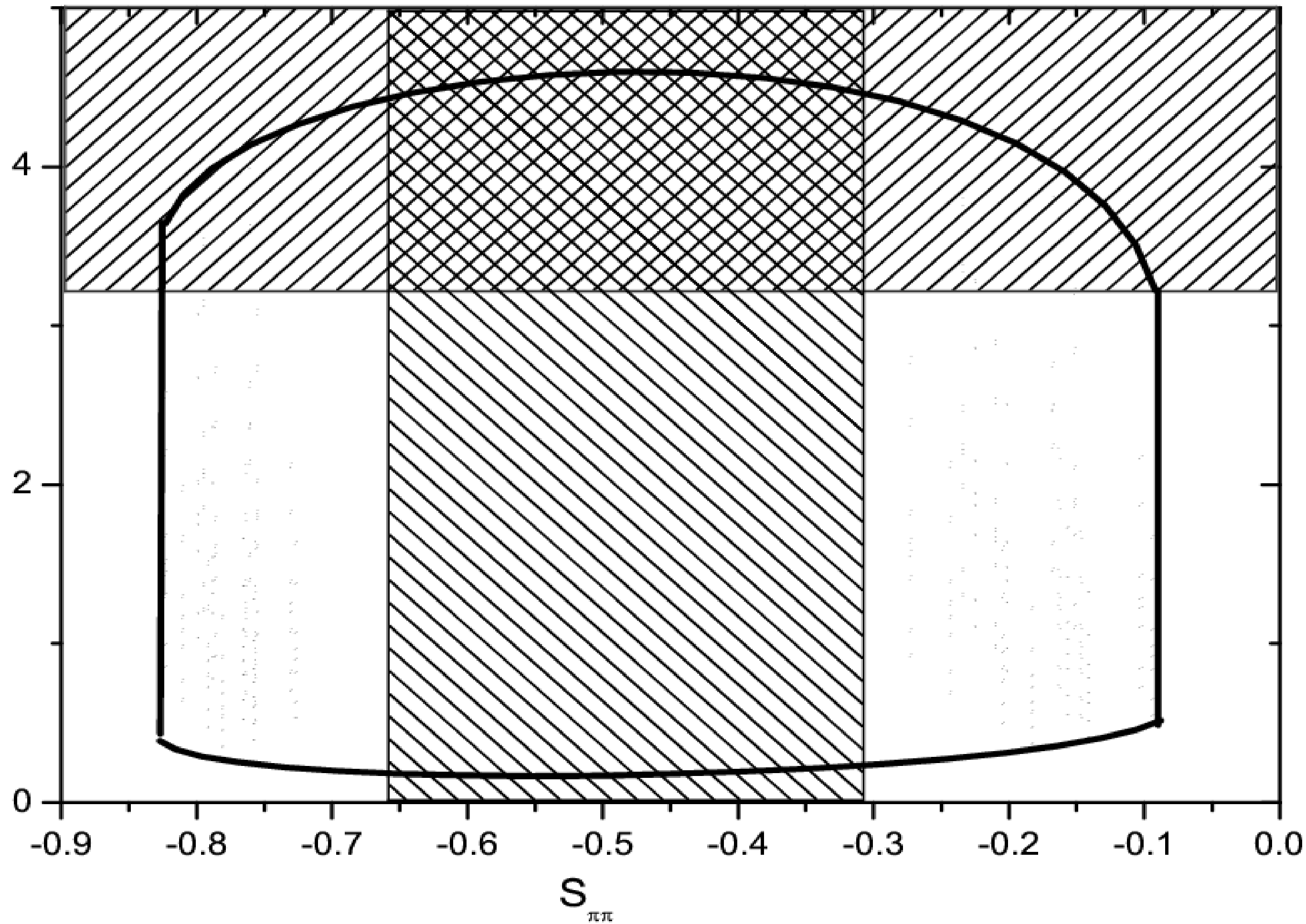
pQCD agree with EXP in CP

$R_1 = \frac{BR(B_s \to K^+K^-)}{BR(B^0 \to \pi^+\pi^-)}$ vs $A_{\pi\pi}$



$$R_1 = \frac{BR(B_s \to K^+ K^-)}{BR(B^0 \to \pi^+ \pi^-)}$$ vs $S_{\pi\pi}$

R_1



U-spin symmetry (Gronau,Rosner,Lipkin)

$$R_3 = \frac{|A(B_s \to \pi^+ K^-)|^2 - |A(\bar{B}_s \to \pi^- K^+)|^2}{|A(B_d \to \pi^- K^+)|^2 - |A(\bar{B}_d \to \pi^+ K^-)|^2} = -1$$

$$\Delta = \frac{A_{CP}^{dir}(\bar{B}_d \to \pi^+ K^-)}{A_{CP}^{dir}(\bar{B}_s \to \pi^+ K^-)} + \frac{BR(B_s \to \pi^+ K^-)}{BR(\bar{B}_d \to \pi^+ K^-)} \cdot \frac{\tau(B_d)}{\tau(B_s)} = 0$$

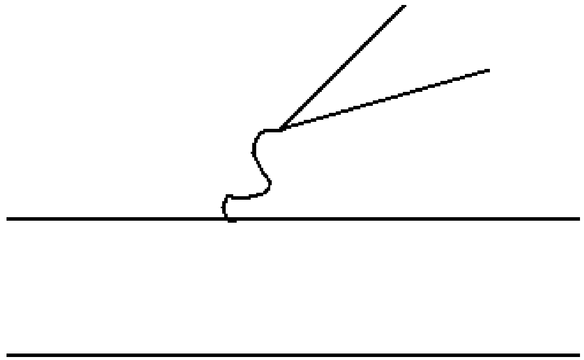
- Results from pQCD

$$R_3 = -0.72^{+0.26+0.19+0.11}_{-0.35-0.19-0.14}, \quad \Delta = -0.24^{+0.39+0.28+0.20}_{-0.29-0.24-0.20}$$

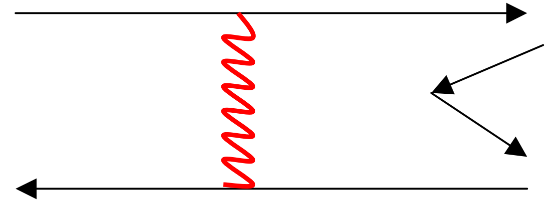
- Experimental data

$$R_3 = -0.84 \pm 0.42 \pm 0.15 \qquad \Delta = 0.04 \pm 0.11 \pm 0.08$$

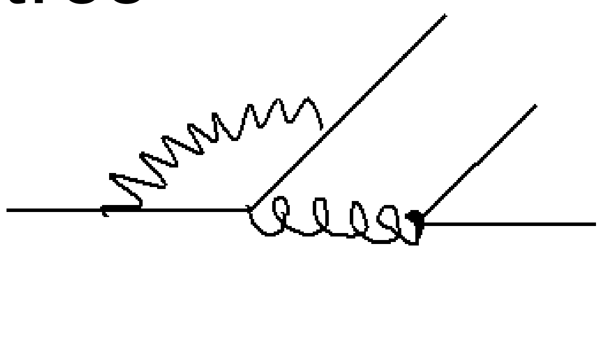
Topology diagrams



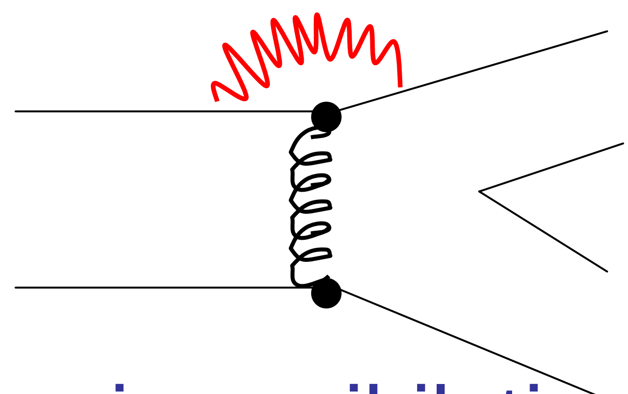
tree



W exchange



penguin



Penguin annihilation

U-spin, SU(3)

$$A(B_d^0 \to \pi^+\pi^-) \;=\; -T - P - E - PA - \frac{2}{3}P_{EW}^C$$

$$A(B_d^0 \to K^+\pi^-) \;=\; -T' - P' - \frac{2}{3}P_{EW}^{\prime C} \;.$$

$$A(B_s^0 \to K^+K^-) = -T' - P' - E' - PA' - \frac{2}{3}P_{EW}^{\prime C}$$

- T = tree
- P = QCD penguin
- E = W exchange

PA = penguin annihilation

P_{EW}= electroweak penguin

color suppressed

SU(3) breaking and relative size of different contributions

mode (GeV^2)	$\lvert\mathcal{T}\rvert^2$	$\lvert\mathcal{P}\rvert^2$	$\lvert\mathcal{E}\rvert^2$	$\lvert\mathcal{P_A}\rvert^2$	$\lvert\mathcal{P_{EW}}\rvert^2$
$B_d \to \pi^+\pi^-$	1.14	7.2×10^{-3}	5.0×10^{-3}	5.9×10^{-3}	2.1×10^{-6}
$B_s \to \pi^+K^-$	1.06	5.8×10^{-3}	0	5.5×10^{-3}	4.2×10^{-6}
$B_d \to K^+\pi^-$	1.76	14.7×10^{-3}	0	3.7×10^{-3}	5.8×10^{-6}
$B_s \to K^+K^-$	1.60	11.5×10^{-3}	3.6×10^{-3}	7.7×10^{-3}	2.4×10^{-6}

- CKM matrix elements already factored out
- SU(3) breaking is not negligible

$Bs \rightarrow \rho^0 K_S$

- Color suppressed tree is comparable with QCD penguin contribution
- Direct CP large

QCDF PQCD

25 ± 60 % 97 ± 30 %

Not good for gamma measurement

$B_s \to \pi^0 \phi$ (Fleischer 1994)

- I = 0 → I = 1
- Δ I = 1
- Both tree and electroweak penguin can give Δ I = 1 (QCD penguin Δ I =0)
- Like $B^+ \to pi^+pi^0$, only Δ I =3/2
- There should be only one strong phase, then no relative strong phase between amplitudes

$B_s \to \pi^0 \phi$

- Color suppressed tree is comparable with electroweak penguin contribution
- Direct CP small

	QCDF	PQCD
	27±40 %	9 ± 2 %

good for γ/ϕ_3 measurement

	QCDF	PQCD
BR(10^{-7})	1.2	2.0

Polarizations

Channel	$\vert A_0\vert^2(\%)$	$\vert A_\parallel\vert^2(\%)$	$\vert A_\perp\vert^2(\%)$	$\phi_\parallel(rad)$	$\phi_\perp(rad)$
$\bar{B}_s \to \rho^0 K^{*0}$	$47.8^{+0.9+5.7+2.0}_{-0.6-4.2-2.2}$	$26.3^{+0.3+2.0+1.1}_{-0.4-2.7-0.9}$	$25.9^{+0.2+2.2+1.1}_{-0.4-3.0-1.0}$	$3.2^{+0.1+0.1+0.5}_{-0.2-0.1-0.2}$	$3.3^{+0.1+0.1+0.5}_{-0.1-0.1-0.3}$
$\bar{B}_s \to \omega K^{*0}$	$57.2^{+1.4+3.2+3.5}_{-1.0-3.5-4.2}$	$21.6^{+0.5+1.6+2.0}_{-0.9-0.5-1.7}$	$21.2^{+0.5+1.9+2.2}_{-0.5-1.6-1.8}$	$1.7^{+0.1+0.1+0.0}_{-0.2-0.2-0.1}$	$1.7^{+0.1+0.1+0.0}_{-0.2-0.2-0.1}$
$\bar{B}_s \to \rho^- K^{*+}$	$94.2^{+0.1+0.1+0.1}_{-0.1-0.3-0.2}$	$3.1^{+0.1+0.2+0.2}_{-0.0-0.1-0.0}$	$2.7^{+0.0+0.1+0.1}_{-0.1-0.1-0.0}$	$3.2^{+0.0+0.0+0.1}_{-0.0-0.1-0.1}$	$3.2^{+0.0+0.0+0.1}_{-0.0-0.1-0.1}$
$\bar{B}_s \to K^{*-} \bar{K}^{*+}$	$53.1^{+5.7+1.6+4.3}_{-3.0-1.6-4.1}$	$25.1^{+2.7+0.8+2.2}_{-3.0-0.9-2.3}$	$21.8^{+2.3+0.9+1.9}_{-2.7-0.8-2.1}$	$1.9^{+0.1+0.1+0.0}_{-0.2-0.2-0.2}$	$1.9^{+0.1+0.1+0.0}_{-0.2-0.2-0.2}$
$\bar{B}_s \to K^{*0} \bar{K}^{*0}$	$58.6^{+5.8+1.5}_{-5.4-2.4}$	$22.1^{+2.8+1.2}_{-2.1-0.8}$	$19.4^{+2.5+1.0}_{-2.8-0.7}$	$1.5^{+0.1+0.0}_{-0.2-0.1}$	$1.4^{+0.2+0.1}_{-0.1-0.0}$
$\bar{B}_s \to \phi K^{*0}$	$75.1^{+3.4+3.8}_{-3.4-2.6}$	$13.4^{+1.8+1.4}_{-1.8-1.0}$	$11.5^{+1.6+1.2}_{-1.6-0.8}$	$1.5^{+0.1+0.0}_{-0.2-0.1}$	$1.5^{+0.1+0.1}_{-0.2-0.0}$
$\bar{B}_s \to \phi\phi$	$68.0^{+4.2+1.7}_{-4.0-2.2}$	$17.4^{+2.2+1.2}_{-2.3-1.0}$	$14.6^{+1.9+0.7}_{-1.9-0.9}$	$1.5^{+0.2+0.1}_{-0.1-0.1}$	$1.5^{+0.2+0.1}_{-0.1-0.1}$
$\bar{B}_s \to \rho^+\rho^-$	~ 100	~ 0	~ 0	$4.3^{+0.0+0.1+0.0}_{-0.0-0.1-0.0}$	$5.1^{+0.0+0.2+0.1}_{-0.0-0.4-0.1}$
$\bar{B}_s \to \rho^0\rho^0$	~ 100	~ 0	~ 0	$4.3^{+0.0+0.1+0.0}_{-0.0-0.1-0.0}$	$5.1^{+0.0+0.2+0.1}_{-0.0-0.4-0.1}$
$\bar{B}_s \to \rho^0\omega$	~ 100	~ 0	~ 0	$4.5^{+0.0+0.0+0.0}_{-0.1-1.0-1.6}$	$3.2^{+0.0+0.9+1.3}_{-0.1-0.2-0.2}$
$\bar{B}_s \to \omega\omega$	~ 100	~ 0	~ 0	$4.3^{+0.0+0.0+0.0}_{-0.1-0.1-0.0}$	$5.1^{+0.0+0.2+0.1}_{-0.1-0.4-0.1}$
$\bar{B}_s \to \phi\rho^0$	$87.8^{+0.4+0.6+1.0}_{-0.2-0.5-0.7}$	$6.3^{+0.2+0.3+0.4}_{-0.1-0.3-0.5}$	$5.8^{+0.2+0.3+0.4}_{-0.1-0.3-0.4}$	$3.5^{+0.1+0.1+0.2}_{-0.0-0.0-0.0}$	$3.6^{+0.0+0.0+0.1}_{-0.0-0.1-0.1}$
$\bar{B}_s \to \phi\omega$	$58.6^{+0.2+3.0+1.0}_{-3.0-3.5-0.7}$	$21.2^{+1.4+2.3+0.3}_{-0.1-1.5-0.5}$	$20.3^{+1.5+2.4+0.3}_{-0.2-2.6-0.5}$	$3.3^{+0.0+0.1+0.0}_{-0.1-0.2-0.1}$	$3.3^{+0.0+0.1+0.0}_{-0.1-0.2-0.1}$

Summary

- PQCD can give the right sign for CP asymmetry→ the strong phase from PQCD should be the dominant one.
- The SU(3) breaking effects are not very small as expected

Still much effort needed for the CKM angle hunting

Thank you!

Modes	Class	QCDF	This work
$\overline{B}_s^0 \to \pi^- K^{*+}$	T	$8.7^{+4.6+3.5+0.7+0.8}_{-3.7-2.9-1.0-0.7}$	$14.5^{+6.6+0.9+2.0}_{-6.0-0.7-1.9}$
$\overline{B}_s^0 \to \rho^- K^+$	T	$24.5^{+11.9+9.2+1.8+1.6}_{-\ 9.7-7.83.0-1.6}$	$27.0^{+13.2+1.7+3.9}_{-11.4-2.0-3.5}$
$\overline{B}_s^0 \to \pi^0 K^{*0}$	C	$0.25^{+0.08+0.10+0.32+0.30}_{-0.08-0.06-0.14-0.14}$	$0.10^{+0.04+0.07+0.01}_{-0.04-0.04-0.02}$
$\overline{B}_s^0 \to \rho^0 K^0$	C	$0.61^{+0.33+0.21+1.06+0.56}_{-0.26-0.15-0.38-0.36}$	$0.08^{+0.05+0.10+0.01}_{-0.03-0.03-0.01}$
$\overline{B}_s^0 \to K^{*0}\eta$	C	$0.26^{+0.15+0.49+0.15+0.57}_{-0.13-0.22-0.05-0.15}$	$0.16^{+0.07+0.11+0.03}_{-0.06-0.06-0.02}$
$\overline{B}_s^0 \to K^{*0}\eta'$	C	$0.28^{+0.04+0.46+0.23+0.29}_{-0.04-0.24-0.10-0.15}$	$0.09^{+0.03+0.04+0.01}_{-0.04-0.02-0.01}$
$\overline{B}_s^0 \to K^0\omega$	C	$0.51^{+0.20+0.15+0.68+0.40}_{-0.18-0.11-0.23-0.25}$	$0.12^{+0.04+0.08+0.02}_{-0.03-0.03-0.02}$
$\overline{B}_s^0 \to K^+ K^{*-}$	P	$4.1^{+1.7+1.5+1.0+9.2}_{-1.5-1.3-0.9-2.3}$	$6.0^{+2.2+1.5+1.4}_{-2.2-1.1-1.0}$
$\overline{B}_s^0 \to K^{*+} K^-$	P	$5.5^{+1.3+5.0+0.8+14.2}_{-1.4-2.6-0.7-\ 3.6}$	$5.3^{+1.6+2.6+0.1}_{-1.8-1.4-0.4}$
$\overline{B}_s^0 \to K^0 \overline{K}^{*0}$	P	$3.9^{+0.4+1.5+1.3+10.4}_{-0.4-1.4-1.4-\ 2.8}$	$7.0^{+2.9+2.0+0.0}_{-2.6-1.2-0.0}$
$\overline{B}_s^0 \to K^{*0} \overline{K}^0$	P	$4.2^{+0.4+4.6+1.1+13.2}_{-0.4-2.2-0.9-\ 3.2}$	$4.5^{+1.3+2.2+0.0}_{-1.5-1.3-0.0}$

$\overline{B}_s^0 \to \pi^0\phi$	P_{EW}	$0.12^{+0.03+0.04+0.01+0.02}_{-0.02-0.04-0.01-0.01}$	$0.20^{+0.10+0.03+0.01}_{-0.08-0.02-0.01}$
$\overline{B}_s^0 \to \rho^0\eta$	P_{EW}	$0.17^{+0.03+0.07+0.02+0.02}_{-0.03-0.06-0.02-0.01}$	$0.12^{+0.05+0.01+0.00}_{-0.06-0.02-0.01}$
$\overline{B}_s^0 \to \rho^0\eta'$	P_{EW}	$0.25^{+0.06+0.10+0.02+0.02}_{-0.05-0.08-0.02-0.02}$	$0.23^{+0.11+0.04+0.02}_{-0.10-0.05-0.02}$
$\overline{B}_s^0 \to \omega\eta$	P, C	$0.012^{+0.005+0.010+0.028+0.025}_{-0.004-0.003-0.006-0.006}$	$0.08^{+0.02+0.02+0.00}_{-0.03-0.01-0.00}$
$\overline{B}_s^0 \to \omega\eta'$	P, C	$0.024^{+0.011+0.028+0.077+0.042}_{-0.009-0.006-0.010-0.015}$	$0.52^{+0.21+0.17+0.03}_{-0.20-0.16-0.04}$
$\overline{B}_s^0 \to \phi\eta$	P	$0.12^{+0.02+0.95+0.54+0.32}_{-0.02-0.14-0.12-0.13}$	$1.4^{+0.5+0.0+0.0}_{-0.5-0.3-0.1}$
$\overline{B}_s^0 \to \phi\eta'$	P	$0.05^{+0.01+1.10+0.18+0.40}_{-0.01-0.17-0.08-0.04}$	$2.8^{+1.1+0.2+0.0}_{-1.0-0.3-0.0}$
$\overline{B}_s^0 \to K^0\phi$	P	$0.27^{+0.09+0.28+0.09+0.67}_{-0.08-0.14-0.06-0.18}$	$0.09^{+0.0+0.05+0.02}_{-0.03-0.02-0.02}$
$\overline{B}_s^0 \to \pi^0\omega$	ann	≈ 0.0005	$0.004^{+0.001+0.000+0.001}_{-0.001-0.000-0.000}$
$\overline{B}_s^0 \to \rho^+\pi^-$	ann	≈ 0.003	$0.42^{+0.13+0.06+0.01}_{-0.15-0.09-0.02}$
$\overline{B}_s^0 \to \pi^+\rho^-$	ann	≈ 0.003	$0.42^{+0.13+0.06+0.01}_{-0.15-0.08-0.02}$
$\overline{B}_s^0 \to \pi^0\rho^0$	ann	≈ 0.003	$0.41^{+0.13+0.08+0.01}_{-0.15-0.08-0.01}$