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Flavor and Top Physics @ 100 TeV Workshop

Updates and News on $B \to PP$ and VP Decays

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Based upon:
HY Cheng, CWC, AL Kuo, Phys.Rev. D91 (2015) 1, 014011

Motivations

- Two important goals of the heavy flavor physics program are (a) to verify the KM picture of CP violation and (b) to understand better strong interactions at low energies.
- Precision of many branching fractions of PP and VP decays currently reaches 5–10% level.
- 6 CPA's exceed 5σ (all but $S(\phi K_S)$ from PP), and
  7 CPA's at 3–5σ level.
  ➠ useful in fixing strong phases
- Examine what existing data tell us, check the consistency, and make predictions for yet unmeasured observables.
- Check whether flavor SU(3) symmetry is a good working principle.

Plan of Talk

Flavor Diagram Approach

PP Decays

VP Decays

Summary

FLAVOR DIAGRAM APPROACH

Advantages of This Approach

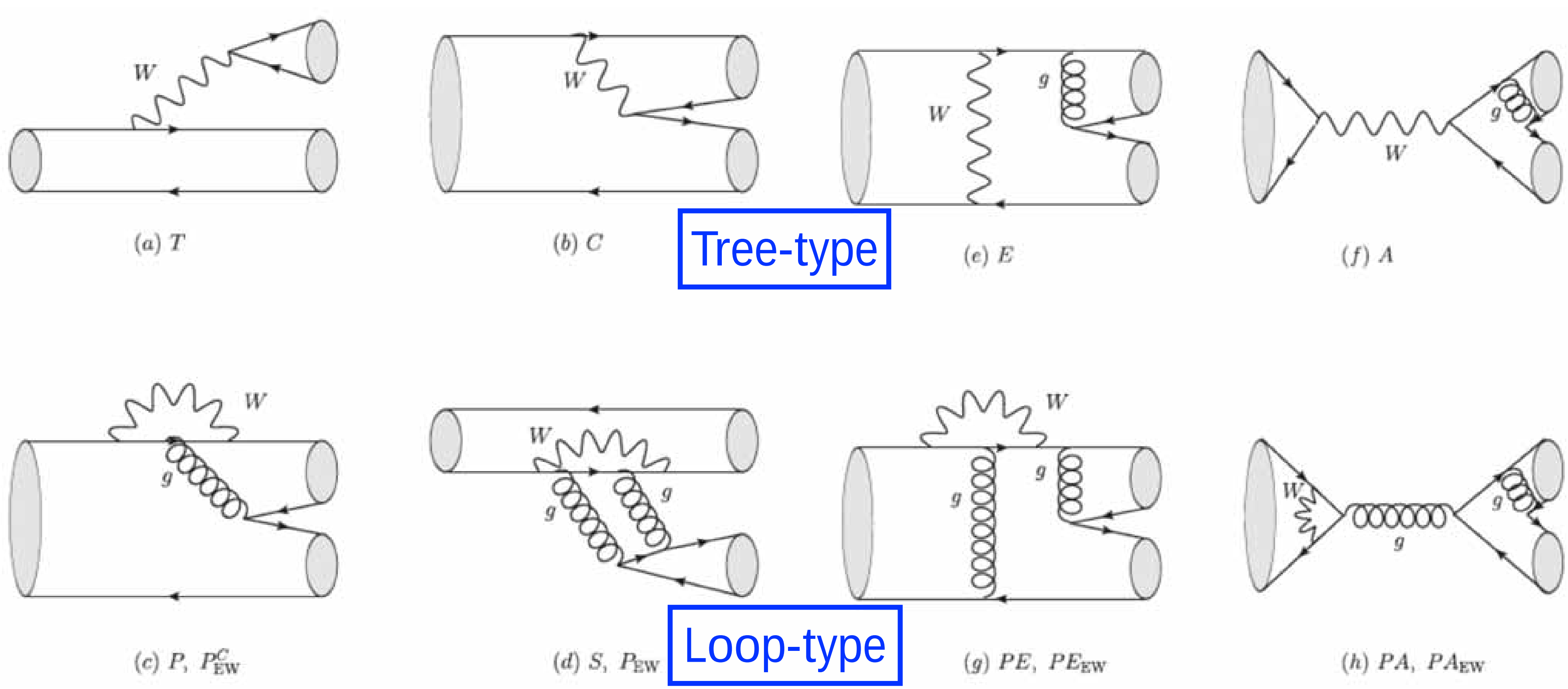
- Classify decay amplitudes according to the topology of flavor flows and relate decay diagrams, both sizes and strong phases, using flavor SU(3) symmetry.

- Model-independent.
- Encoded with all strong interaction and rescattering effects (not Feynman diagrams, thus non-perturbative *per se*).
- Clear weak interaction structure and thus weak phases.
- Good guide for perturbative approach based on EFT's.
- Indispensable for D systems.
- Predictive as other approaches.

FLAVOR DIAGRAMS

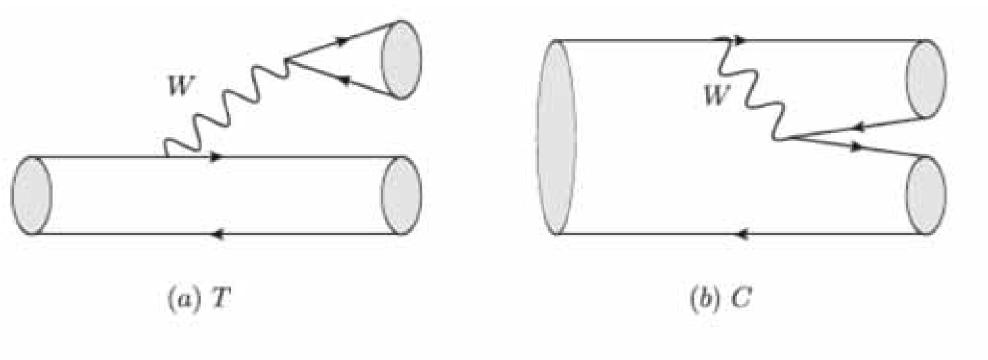
- Diagrams for two-body hadronic B decays can be classified according to flavor topology into the tree- and loop-types:

Zeppenfeld 1981
Chau and Cheng 1986, 1987, 1991
Savage and Wise 1989
Grinstein and Lebed 1996
Gronau et. al. 1994, 1995, 1995



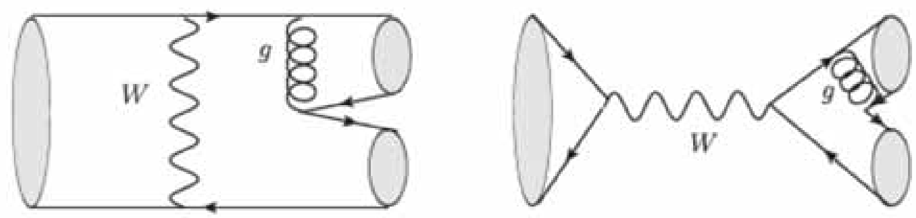
Flavor Diagrams

- T and C are expected to be the most dominant amplitudes, with C being naively smaller than T by a color factor of 3.



Flavor Diagrams

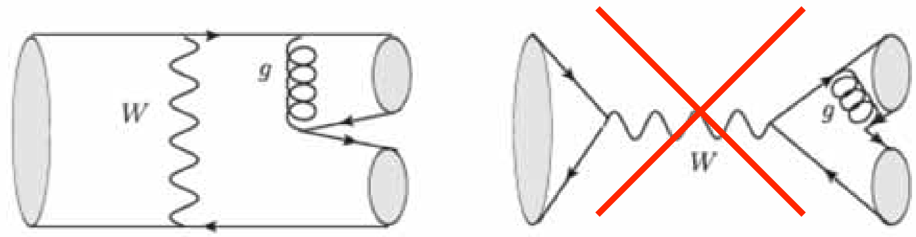
- E and A are suppressed by Λ/m_B due to the helicity and/or hadronic form factors.



(e) E (f) A

Flavor Diagrams

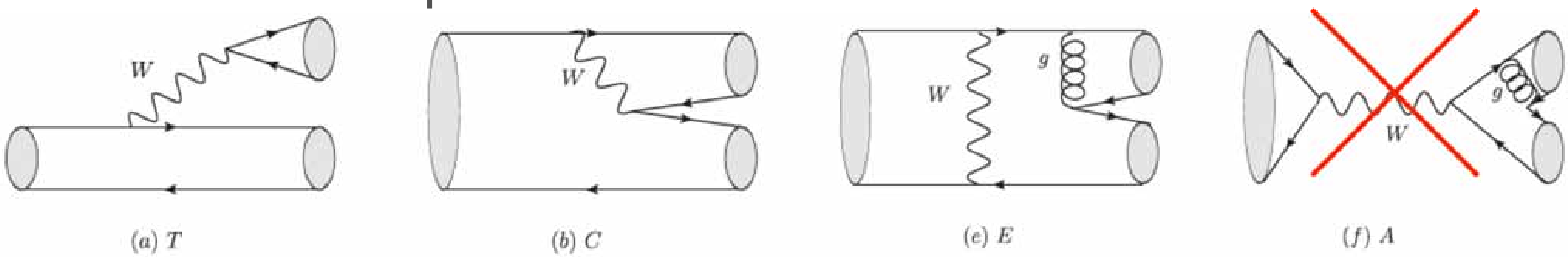
- E and A are suppressed by Λ/m_B due to the helicity and/or hadronic form factors.
- A is not called for by current data, thus ignored.



(e) E (f) A

Flavor Diagrams

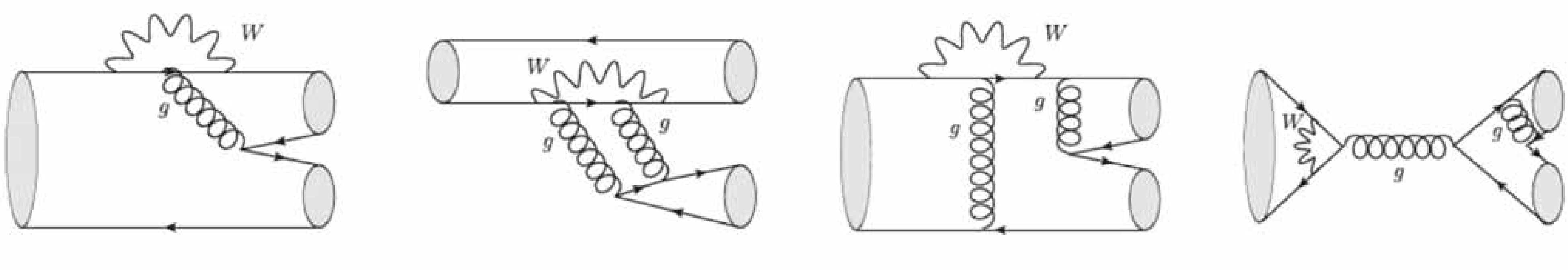
- E and A are suppressed by Λ/m_B due to the helicity and/or hadronic form factors.
- A is not called for by current data, thus ignored.
- 3 tree-level amplitudes left.



Flavor Diagrams

- These diagrams are suppressed by loop factors.
- Moreover, the EW penguin diagram is one order higher in weak interactions and thus even smaller in strength.

for EW penguins, one gluon line is replaced by a Z or γ line

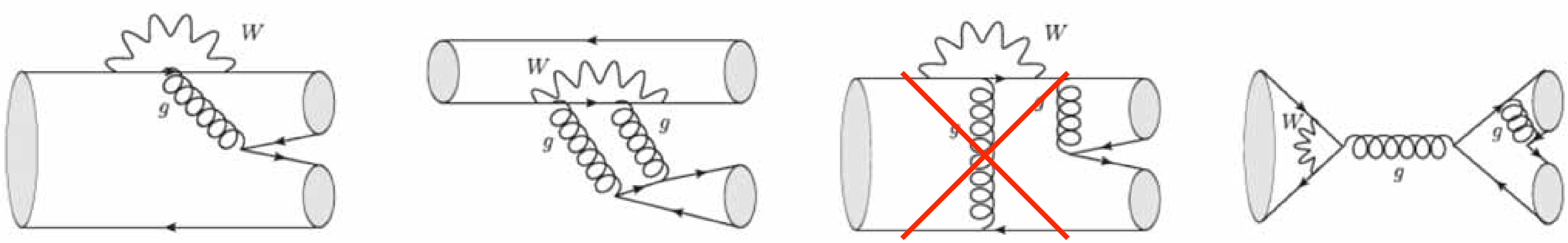


(c) P, $P_{\rm EW}^C$ (d) S, $P_{\rm EW}$ (g) PE, $PE_{\rm EW}$ (h) PA, $PA_{\rm EW}$

Flavor Diagrams

- These diagrams are suppressed by loop factors.
- Moreover, the EW penguin diagram is one order higher in weak interactions and thus even smaller in strength.
- P_{EW}^C, PE, PE_{EW}, and PA_{EW} are ignored.
- 4 loop-level amplitudes considered.

for EW penguins, one gluon line is replaced by a Z or γ line



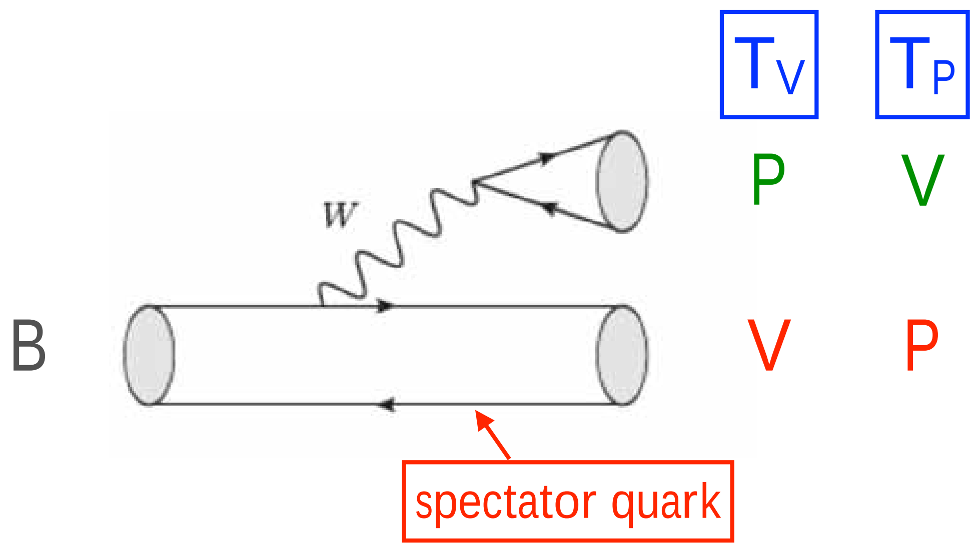
(c) P, P_{EW}^C (d) S, P_{EW} (g) PE, PE_{EW} (h) PA, PA_{EW}

Flavor Diagrams

- We are left with T, C, P, S, P_{EW}, E, and PA, listed roughly in the naive order of their magnitudes.
- However, the above hierarchy is not supported by data.
  ➠ hint of nonperturbative strong dynamics at play
- They are sufficient for the observed PP modes.

Flavor Diagrams

- In the case of VP modes, both E and PA are not required by data at current precision level, but the number of diagrams are otherwise doubled.



- The two sets of amplitudes are different *a priori*.
- They can be related under the assumption of factorization and with a specific model for form factors.

Flavor Diagrams

- By convention, we fix T (for PP) and T_P (for VP) to be real, and all the other strong phases, denoted by δ_X for amplitude X, are relative to these amplitudes; i.e.,

$$X = |X| e^{i\delta_X}$$

Flavor Diagrams

- In physical processes, the above-mentioned flavor amplitudes always appear in certain combinations, multiplied by appropriate CKM factors:

strangeness-conserving (ΔS = 0)	strangeness-changing (|ΔS| = 1)
$t = Y_{db}^u T - (Y_{db}^u + Y_{db}^c) P_{EW}^C$	$t' = Y_{sb}^u \xi_t T - (Y_{sb}^u + Y_{sb}^c) P_{EW}^C$
$c = Y_{db}^u C - (Y_{db}^u + Y_{db}^c) P_{EW}$	$c' = Y_{sb}^u \xi_c C - (Y_{sb}^u + Y_{sb}^c) P_{EW}$
$e = Y_{db}^u E$	$e' = Y_{sb}^u E$
$p = -(Y_{db}^u + Y_{db}^c)(P - \frac{1}{3} P_{EW}^C)$	$p' = -(Y_{sb}^u + Y_{sb}^c)(\xi_p P - \frac{1}{3} P_{EW}^C)$
$s = -(Y_{db}^u + Y_{db}^c)(S - \frac{1}{3} P_{EW})$	$s' = -(Y_{sb}^u + Y_{sb}^c)(\xi_s S - \frac{1}{3} P_{EW})$
$pa = -(Y_{db}^u + Y_{db}^c) PA$	$pa' = -(Y_{sb}^u + Y_{sb}^c) PA$

$$Y_{qb}^{q'} \equiv V_{q'q} V_{q'b}^* \text{ with } q = d, s \text{ and } q' = u, c$$

Flavor Diagrams

- ξ's are introduced to account for SU(3) breaking in amplitude magnitudes. ➠ preferred to be ~1 by data
- Strong phases are assumed to be the same.

strangeness-conserving (ΔS = 0)	strangeness-changing (|ΔS| = 1)
$t = Y_{db}^u T - (Y_{db}^u + Y_{db}^c) P_{EW}^C$	$t' = Y_{sb}^u \xi_t T - (Y_{sb}^u + Y_{sb}^c) P_{EW}^C$
$c = Y_{db}^u C - (Y_{db}^u + Y_{db}^c) P_{EW}$	$c' = Y_{sb}^u \xi_c C - (Y_{sb}^u + Y_{sb}^c) P_{EW}$
$e = Y_{db}^u E$	$e' = Y_{sb}^u E$
$p = -(Y_{db}^u + Y_{db}^c)(P - \frac{1}{3} P_{EW}^C)$	$p' = -(Y_{sb}^u + Y_{sb}^c)(\xi_p P - \frac{1}{3} P_{EW}^C)$
$s = -(Y_{db}^u + Y_{db}^c)(S - \frac{1}{3} P_{EW})$	$s' = -(Y_{sb}^u + Y_{sb}^c)(\xi_s S - \frac{1}{3} P_{EW})$
$pa = -(Y_{db}^u + Y_{db}^c) PA$	$pa' = -(Y_{sb}^u + Y_{sb}^c) PA$

$$Y_{qb}^{q'} \equiv V_{q'q} V_{q'b}^* \text{ with } q = d, s \text{ and } q' = u, c$$

Flavor Diagrams

- The CKM factors are evaluated using

$$A = 0.813^{+0.015}_{-0.027} \qquad \lambda = 0.22551^{+0.00068}_{-0.00035}$$

$$\bar{\rho} = 0.1489^{+0.0158}_{-0.0084} \qquad \bar{\eta} = 0.342^{+0.013}_{-0.011}$$

CKMfitter 2014

strangeness-conserving ($\Delta S = 0$)	strangeness-changing ($\lvert\Delta S\rvert = 1$)
$t = Y^u_{db} T - (Y^u_{db} + Y^c_{db}) P^C_{EW}$	$t' = Y^u_{sb} \xi_t T - (Y^u_{sb} + Y^c_{sb}) P^C_{EW}$
$c = Y^u_{db} C - (Y^u_{db} + Y^c_{db}) P_{EW}$	$c' = Y^u_{sb} \xi_c C - (Y^u_{sb} + Y^c_{sb}) P_{EW}$
$e = Y^u_{db} E$	$e' = Y^u_{sb} E$
$p = -(Y^u_{db} + Y^c_{db})(P - \frac{1}{3} P^C_{EW})$	$p' = -(Y^u_{sb} + Y^c_{sb})(\xi_p P - \frac{1}{3} P^C_{EW})$
$s = -(Y^u_{db} + Y^c_{db})(S - \frac{1}{3} P_{EW})$	$s' = -(Y^u_{sb} + Y^c_{sb})(\xi_s S - \frac{1}{3} P_{EW})$
$pa = -(Y^u_{db} + Y^c_{db}) PA$	$pa' = -(Y^u_{sb} + Y^c_{sb}) PA$

$$Y^{q'}_{qb} \equiv V_{q'q} V^*_{q'b} \text{ with } q = d, s \text{ and } q' = u, c$$

Amplitude Decomposition

- A few examples of flavor amplitude decomposition and observed data:

scale factor

	Mode	Flavor Amplitude	BF $(\times 10^{-6})$	A_{CP}
$B^+ \to$	$\pi^+\pi^0$	$-\frac{1}{\sqrt{2}}(t+c)$	$5.48^{+0.35}_{-0.34}$	0.026 ± 0.039
	$K^+\overline{K}^0$	p	1.19 ± 0.18 (1.02)	-0.086 ± 0.100
	$\eta\pi^+$	$\frac{c_\phi}{\sqrt{2}}[t+c+2p+(2-\sqrt{2}t_\phi)s]$	4.02 ± 0.27	-0.14 ± 0.05 (1.42)
	$\eta'\pi^+$	$\frac{s_\phi}{\sqrt{2}}[t+c+2p+(2+\frac{\sqrt{2}}{t_\phi})s]$	$2.7^{+0.5*}_{-0.4}$ (1.36)	$0.06 \pm 0.15^*$
$B^0 \to$	K^+K^-	$-(e+2pa)$	0.12 ± 0.05	-
	$K^0\overline{K}^0$	$p+2pa$	1.21 ± 0.16	0.06 ± 0.26 (1.38)
				-1.08 ± 0.49

$$\begin{pmatrix} \eta \\ \eta' \end{pmatrix} = \begin{pmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{pmatrix} \begin{pmatrix} \eta_q \\ \eta_s \end{pmatrix}$$

$$\eta_q = \frac{1}{\sqrt{2}}(u\bar{u}+d\bar{d})\ , \quad \eta_s = s\bar{s}\ , \quad \phi = 46^\circ$$

data too poor to include in fits

direct / indirect CPA's

Michael, Ottnad, Urbach 2012

Remarks

- Fit to observed $B_{u,d}$ decays and make predictions for as yet unmeasured quantities, particularly those for the B_s decays.
- Due to the hierarchy in CKM factors,
  - T and C: mainly determined by $\Delta S=0$ processes;
  - P, S, and P_{EW}: mainly determined by $|\Delta S|=1$ processes;
  - E and PA: only present in and determined by $\Delta S=0$ processes.

PP SECTOR

Results for PP Sector

limited fits (no S) — Schemes A, B; global fits — Schemes C, D

13 theory parameters

Parameter	Scheme A	Scheme B	Scheme C	Scheme D
$\|T\|$	$0.625^{+0.013}_{-0.014}$	$0.692^{+0.054}_{-0.085}$	$0.627^{+0.013}_{-0.014}$	$0.690^{+0.049}_{-0.062}$
$\|C\|$	0.500 ± 0.049	$0.480^{+0.087}_{-0.084}$	$0.607^{+0.036}_{-0.037}$	0.608 ± 0.054
δ_C	-60^{+9}_{-8}	-68 ± 9	-77 ± 5	-83^{+6}_{-5}
$\|P\|$	0.123 ± 0.001	0.124 ± 0.001	0.124 ± 0.001	0.124 ± 0.001
δ_P	-24 ± 2	-22^{+2}_{-4}	-24 ± 2	-22^{+2}_{-3}
$\|P_{EW}\|$	$0.012^{+0.005}_{-0.002}$	$0.011^{+0.004}_{-0.002}$	$0.018^{+0.006}_{-0.005}$	0.020 ± 0.006
$\delta_{P_{EW}}$	-6^{+29}_{-42}	-23^{+40}_{-39}	-77^{+20}_{-11}	-81^{+16}_{-9}
$\|E\|$	-	$0.098^{+0.022}_{-0.024}$	-	$0.101^{+0.020}_{-0.022}$
δ_E	-	-135^{+52}_{-44}	-	-129^{+36}_{-32}
$\|PA\|$	-	$0.011^{+0.004}_{-0.006}$	-	0.012 ± 0.004
δ_{PA}	-	-123^{+27}_{-25}	-	-130^{+23}_{-21}
$\|S\|$	-	-	0.080 ± 0.007	0.079 ± 0.006
δ_S	-	-	-101 ± 6	-98 ± 6
χ^2_{min}/dof	23.41/14	19.48/11	45.80/23	37.08/20
Fit quality	5.40%	5.30%	0.32%	1.14%
δ_{EW}				$.029 \pm 0.009$
$\|C/T\|$				0.89 ± 0.11

Magnitudes of the amplitudes are quoted in units of 10^4 eV, and the strong phases in units of degree.

Results for PP Sector

limited fits (no S) — global fits

13 theory parameters

Parameter	Scheme A	Scheme B	Scheme C	Scheme D
$\|T\|$	$0.625^{+0.013}_{-0.014}$	$0.692^{+0.054}_{-0.085}$	$0.627^{+0.013}_{-0.014}$	$0.690^{+0.049}_{-0.062}$
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$\|PA\|$	-	$0.011^{+0.004}_{-0.006}$	-	0.012 ± 0.004
δ_{PA}	-	-123^{+27}_{-25}	-	-130^{+23}_{-21}
$\|S\|$			$0.080 \pm$ [illegible]	[illegible] ± 0.006
δ_S			-10[illegible]	[illegible] ± 6
χ^2_{min}/dof	$23.41/14$	$19.48/11$	$45.80/23$	$37.08/20$
Fit quality	5.40%	5.30%	0.32%	1.14%
δ_{EW}	0.019 ± 0.006	0.016 ± 0.004	0.029 ± 0.009	0.029 ± 0.009
$\|C/T\|$	0.80 ± 0.08	0.69 ± 0.14	0.97 ± 0.06	0.89 ± 0.11

not much difference

>3 times better

Results for PP Sector

	limited fits (no S)		global fits	
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$\lvert T\rvert$	$0.625^{+0.013}_{-0.014}$	$0.692^{+0.054}_{-0.085}$	$0.627^{+0.013}_{-0.014}$	$0.690^{+0.049}_{-0.062}$
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$\lvert PA\rvert$	-	$0.011^{+0.004}_{-0.006}$	-	0.012 ± 0.004
δ_{PA}	-	-123^{+27}_{-25}	-	-130^{+23}_{-21}
$\lvert S\rvert$				0.079 ± 0.006
δ_S				-98 ± 6
χ^2_{min}/dof				$37.08/20$
Fit quality				1.14%
δ_{EW}				0.029 ± 0.009
$\lvert C/T\rvert$				0.89 ± 0.11

13 theory parameters

The amplitudes satisfy the hierarchy:

$$|T| \gtrsim |C| > |P|, |E| > |S| > |P_{EW}| \sim |PA|$$

- ➠ |E| is comparable to |P|
- ➠ |S| is larger than $|P_{EW}|$, required by BF(η'K)

Results for PP Sector

limited fits (no S) ↔ global fits

13 theory parameters

Parameter	Scheme A	Scheme B	Scheme C	Scheme D
$\|T\|$	$0.625^{+0.013}_{-0.014}$	$0.692^{+0.054}_{-0.085}$	$0.627^{+0.013}_{-0.014}$	$0.690^{+0.049}_{-0.062}$
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δ_E	-	-135^{+52}_{-44}	-	-129^{+36}_{-32}
$\|PA\|$	[illegible]	[illegible]	[illegible]	0.012 ± 0.004
δ_{PA}	[illegible]	[illegible]	[illegible]	-130^{+23}_{-21}
$\|S\|$	[illegible]	[illegible]	7	0.079 ± 0.006
δ_S	[illegible]	[illegible]	[illegible]	-98 ± 6
χ^2_{min}/dof	[illegible]	[illegible]	[illegible]	$37.08/20$
Fit quality	[illegible]	[illegible]	[illegible]	1.14%
δ_{EW}	0	[illegible]	9	0.029 ± 0.009
$\|C/T\|$	[illegible]	[illegible]	[illegible]	0.89 ± 0.11

Most parameters are stable across the fits, except for C and P_{EW}. This is because S also contains P_{EW}:

$$c = Y^u_{db} C - (Y^u_{db} + Y^c_{db}) P_{EW}$$

$$s = -(Y^u_{db} + Y^c_{db})(S - \frac{1}{3} P_{EW})$$

Results for PP Sector

limited fits (no S) — Scheme A, Scheme B; global fits — Scheme C, Scheme D

13 theory parameters

Parameter	Scheme A	Scheme B	Scheme C	Scheme D
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$\lvert C\rvert$	0.500 ± 0.049	$0.480^{+0.087}_{-0.084}$	$0.607^{+0.036}_{-0.037}$	0.608 ± 0.054
δ_C	-60^{+9}_{-8}	-68 ± 9	-77 ± 5	-83^{+6}_{-5}
$\lvert P\rvert$	0.123 ± 0.001	0.124 ± 0.001	0.124 ± 0.001	0.124 ± 0.001
δ_P	-24 ± 2	-22^{+2}_{-4}	-24 ± 2	-22^{+2}_{-3}
$\lvert P_{EW}\rvert$	$0.012^{+0.005}_{-0.002}$	$0.011^{+0.004}_{-0.002}$	$0.018^{+0.006}_{-0.005}$	0.020 ± 0.006
$\delta_{P_{EW}}$	-6^{+29}_{-42}	-23^{+40}_{-39}	-77^{+20}_{-11}	-81^{+16}_{-9}
$\lvert E\rvert$	-	$0.098^{+0.022}_{-0.024}$	-	$0.101^{+0.020}_{-0.022}$
δ_E	-	-135^{+52}_{-44}	-	-129^{+36}_{-32}
$\lvert PA\rvert$	-	$0.011^{+0.004}_{-0.006}$	-	0.012 ± 0.004
δ_{PA}	-	-123^{+27}_{-25}	-	-130^{+23}_{-21}
$\lvert S\rvert$	[illegible]	[illegible]	[illegible]	[illegible]9 ± 0.006
δ_S	[illegible]	[illegible]	[illegible]	[illegible]98 ± 6
χ^2_{min}/d[illegible]	[illegible]	[illegible]	[illegible]	[illegible]$.08/20$
Fit qua[illegible]	[illegible]	[illegible]	[illegible]	[illegible]$.14\%$
δ_{EW}	[illegible]	[illegible]	[illegible]	[illegible]9 ± 0.009
$\lvert C/T\rvert$	0.80 ± 0.08	0.69 ± 0.14	0.97 ± 0.06	0.89 ± 0.11

Large |C/T|, as partially required to explain the Kπ puzzle (but also modes involving singlet amplitudes).

➠ *cf.* hadronic D decays

Typical perturbative calculations give ~0.2−0.3

Results for PP Sector

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$\|C\|$	0.500 ± 0.049	$0.480^{+0.087}_{-0.084}$	$0.607^{+0.036}_{-0.037}$	0.608 ± 0.054
δ_C	-60^{+9}_{-8}	-68 ± 9	-77 ± 5	-83^{+6}_{-5}
$\|P\|$	0.123 ± 0.001	0.124 ± 0.001	0.124 ± 0.001	0.124 ± 0.001
δ_P	-24 ± 2	-22^{+2}_{-4}	-24 ± 2	-22^{+2}_{-3}
$\|P_{EW}\|$	$0.012^{+0.005}_{-0.002}$	$0.011^{+0.004}_{-0.002}$	$0.018^{+0.006}_{-0.005}$	0.020 ± 0.006
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$\|PA\|$	-	$0.011^{+0.004}_{-0.006}$	-	0.012 ± 0.004
δ_{PA}	-	-123^{+27}_{-25}	-	-130^{+23}_{-21}
$\|S\|$	-	-	0.080 ± 0.007	0.079 ± 0.006
δ_S	-	-	-101 ± 6	-98 ± 6
χ^2_{min}/dof	[illegible]	[illegible]	[illegible]	$37.08/20$
Fit quality	[illegible]	[illegible]	[illegible]	1.14%
δ_{EW}	0.019 ± 0.006	0.016 ± 0.004	0.029 ± 0.009	0.029 ± 0.009
$\|C/T\|$	0.80 ± 0.08	0.69 ± 0.14	0.97 ± 0.06	0.89 ± 0.11

Make preferred predictions based on Scheme D.

Remarks

- We have tried to include the SU(3) breaking factor f_K/f_π for factorizable T and C amplitudes, but found no significant change in fit quality.
  ➠ flavor SU(3) symmetry is a sufficiently good working principle
- Our predictions generally agree well with measured observables.
- In the following, we highlight some observables that have disagreements among data and theories.

PREDICTIONS - BF'S

due to constructive interference between S and other amplitudes

due to large |C|; smaller predictions in perturbative calculations

due to constructive interference between P and S amplitudes

Observable	$BF(B^+ \to \eta'\pi^+)$	$BF(B^0 \to \pi^0\pi^0)$	$BF(B^0 \to \eta'\pi^0)$
Data	$2.7^{+0.5}_{-0.4}$ (1.36)	1.17 ± 0.13	1.2 ± 0.4
This Work	5.59 ± 0.54	1.88 ± 0.42	1.21 ± 0.16
QCDF	$3.8^{+1.3+0.9}_{-0.6-0.6}$	$1.1^{+1.0+0.7}_{-0.4-0.3}$	$0.42^{+0.21+0.18}_{-0.09-0.12}$
pQCD	$2.4^{+0.8}_{-0.5} \pm 0.2 \pm 0.3$	~ 1.2	$0.19 \pm 0.02 \pm 0.03^{+0.04}_{-0.05}$
SCET	$2.4 \pm 1.2 \pm 0.2 \pm 0.4$	$0.84 \pm 0.29 \pm 0.30 \pm 0.19$	$2.3 \pm 0.8 \pm 0.3 \pm 2.7$

QCDF: Beneke, Buchalla, Neubert, Sachrajda 2001
Beneke, Neubert 2003
pQCD: Keum, Li, Sanda 2001
SCET: Bauer, Fleming, Pirjol, Stewart 2001
Bauer, Pirjol, Stewart 2001

Predictions - ACP's

diverse predictions;
all far from data;
pQCD gets wrong sign

agreeing with data;
others smaller by at least 30%

data recently updated;
scale factor = 1.94;
opposite sign in SCET

Observable	$A_{CP}(B^+ \to \eta'\pi^+)$	$A_{CP}(B^0 \to \pi^+\pi^-)$	$A_{CP}(B^0 \to \pi^0\pi^0)$
Data	0.06 ± 0.15	0.31 ± 0.05 >6σ	0.03 ± 0.17 (1.94)
This Work	0.374 ± 0.087	0.326 ± 0.081	0.611 ± 0.113
QCDF	$0.016^{+0.050+0.094}_{-0.082-0.111}$	$0.170^{+0.013+0.043}_{-0.012-0.087}$	$0.572^{+0.148+0.303}_{-0.208-0.346}$
pQCD	$-0.33^{+0.07}_{-0.08}$	~ 0.17	~ 0.36
SCET	$0.21 \pm 0.12 \pm 0.10 \pm 0.14$	$0.20 \pm 0.17 \pm 0.19 \pm 0.05$	$-0.58 \pm 0.39 \pm 0.39 \pm 0.13$

Predictions - ACP's

agreeing with data;
others off central value;
SCET gets wrong sign

diverse predictions; awaiting better data;
some wrong signs

Observable	$A_{CP}(B^+ \to \eta K^+)$	$A_{CP}(B^+ \to \eta' K^+)$	$\mathcal{S}(B^0 \to \eta' \pi^0)$
Data	-0.37 ± 0.08 ~4.6σ	0.013 ± 0.017	—
This Work	-0.426 ± 0.043	-0.027 ± 0.008	0.385 ± 0.114
QCDF	$-0.145^{+0.103+0.155}_{-0.260-0.107}$	$0.0045^{+0.0069+0.0120}_{-0.0055-0.0098}$	$-0.073^{+0.010+0.176}_{-0.018-0.140}$
pQCD	$-0.117^{+0.068+0.039+0.029}_{-0.096-0.042-0.056}$	$-0.062^{+0.012+0.013+0.013}_{-0.011-0.010-0.010}$	$-0.36^{+0.11}_{-0.10}$
SCET	$0.33 \pm 0.30 \pm 0.07 \pm 0.03$	$-0.010 \pm 0.006 \pm 0.007 \pm 0.005$	$-0.24 \pm 0.10 \pm 0.19 \pm 0.24$

Predictions - B_s Decays

agreeing with data; pQCD larger in central value

diverse predictions; awaiting better data

dominated by PA; agreeing well with data; BF($\pi^0\pi^0$) predicted to be half of this value

Observable	$BF(\pi^+K^-)$	$BF(K^+K^-)$	$BF(\pi^+\pi^-)$
Data	5.4 ± 0.6	24.5 ± 1.8	0.73 ± 0.14
This Work	5.86 ± 0.78	17.90 ± 2.98	0.80 ± 0.55
QCDF	$5.3^{+0.4+0.4}_{-0.8-0.5}$	$25.2^{+12.7+12.5}_{-7.2-9.1}$	$0.26 \pm 0.00^{+0.10}_{-0.09}$
pQCD	$7.6^{+3.2}_{-2.3} \pm 0.7 \pm 0.5$	$13.6^{+4.2+7.5+0.7}_{-3.2-4.1-0.2}$	$0.57^{+0.16+0.09+0.01}_{-0.13-0.10-0.00}$
SCET	$4.9 \pm 1.2 \pm 1.3 \pm 0.3$	$18.2 \pm 6.7 \pm 1.1 \pm 0.5$	—

Predictions – B_s Decays

agreeing with data; pQCD larger in central value

diverse predictions; awaiting better data

dominated by PA; agreeing well with data; $BF(\pi^0\pi^0)$ predicted to be half of this value

Observable	$BF(\pi^+K^-)$	$BF(K^+K^-)$	$BF(\pi^+\pi^-)$
Data	5.4 ± 0.6	24.5 ± 1.8	0.73 ± 0.14
This Work	5.86 ± 0.78	17.90 ± 2.98	0.80 ± 0.55
QCDF	$5.3^{+0.4+0.4}_{-0.8-0.5}$	$25.2^{+12.7+12.5}_{-7.2-9.1}$	$0.26 \pm 0.00^{+0.10}_{-0.09}$
pQCD	$7.6^{+3.2}_{-2.3} \pm 0.7 \pm 0.5$	$13.6^{+4.2+7.5+0.7}_{-3.2-4.1-0.2}$	$0.57^{+0.16+0.09+0.01}_{-0.13-0.10-0.00}$
SCET	4.9	[illegible]	—

It is claimed that large flavor symmetry breaking effects between the PA amplitudes of B_s and $B_{u,d}$ decays are needed in order to explain data of $B_s \to \pi^+\pi^-$ and $B_d \to K^+K^-$. This is not the case as we find.

Zhu 2011
Wang, Zhu 2013

Predictions - B_s Decays

agreeing better with data than others

awaiting better data since this decay has a large BF

Observable	$A_{CP}(\pi^+K^-)$	$\mathcal{A}(K^+K^-)$	$\mathcal{S}(K^+K^-)$
Data	0.26 ± 0.04 >6σ	-0.14 ± 0.11	0.30 ± 0.13
This Work	0.266 ± 0.033	-0.090 ± 0.021	0.140 ± 0.030
QCDF	$0.207^{+0.050+0.039}_{-0.030-0.088}$	$-0.077^{+0.016+0.040}_{-0.012-0.051}$	$0.22^{+0.04+0.05}_{-0.05-0.03}$
pQCD	$0.241^{+0.039+0.033+0.023}_{-0.036-0.030-0.012}$	$-0.233^{+0.009+0.049+0.008}_{-0.002-0.044-0.011}$	$0.28 \pm 0.03 \pm 0.04^{+0.02}_{-0.01}$
SCET	$0.20 \pm 0.17 \pm 0.19 \pm 0.05$	$-0.06 \pm 0.05 \pm 0.06 \pm 0.02$	$0.19 \pm 0.04 \pm 0.04 \pm 0.01$

VP SECTOR

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\|T_P\|$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\|T_V\|$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
δ_{T_V}	3 ± 4	1 ± 4	-6^{+28}_{-39}
$\|C_P\|$	$0.341^{+0.135}_{-0.130}$	$0.284^{+0.092}_{-0.081}$	$0.524^{+0.294}_{-0.301}$
δ_{C_P}	-24^{+41}_{-32}	-36^{+29}_{-23}	-54^{+32}_{-44}
$\|C_V\|$	$0.668^{+0.325}_{-0.276}$	$0.735^{+0.164}_{-0.161}$	$1.120^{+0.416}_{-0.339}$
δ_{C_V}	-89^{+27}_{-16}	-91^{+13}_{-10}	-93^{+15}_{-17}
$\|P_P\|$	0.083 ± 0.003	0.083 ± 0.002	0.083 ± 0.003
δ_{P_P}	-25 ± 6	-21 ± 5	-37^{+17}_{-39}
$\|P_V\|$	0.066 ± 0.005	0.069 ± 0.004	0.070 ± 0.004
δ_{P_V}	165 ± 9	159^{+7}_{-8}	142^{+17}_{-35}
$\|P_{EW,P}\|$	$0.035^{+0.010}_{-0.011}$	0.031 ± 0.010	$0.030^{+0.009}_{-0.010}$
$\delta_{PEW,P}$	51^{+12}_{-16}	44^{+11}_{-15}	25^{+20}_{-35}
$\|P_{EW,V}\|$	$0.061^{+0.029}_{-0.024}$	$0.058^{+0.017}_{-0.015}$	$0.064^{+0.020}_{-0.018}$
$\delta_{PEW,V}$	-100^{+35}_{-23}	-83^{+22}_{-15}	-105^{+26}_{-34}

Parameter	Scheme A	Scheme B	Scheme C
$\|S_P\|$	-	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
δ_{S_P}	-	-142^{+13}_{-21}	-154^{+21}_{-38}
$\|S_V\|$	-	0.033 ± 0.004	$0.035^{+0.005}_{-0.004}$
δ_{S_V}	-	-73 ± 24	-89^{+24}_{-27}
$\|E_P\|$	-	-	$0.266^{+0.829}_{-0.266}$
δ_{E_P}	-	-	120 ± 180
$\|E_V\|$	-	-	$0.467^{+0.526}_{-0.375}$
δ_{E_V}	-	-	-65^{+27}_{-86}
χ^2_{min}/dof	15.53/12	40.22/32	37.57/28
Fit quality	12.36 %	15.08%	10.67%

Magnitudes of the amplitudes are quoted in units of 10^4 eV, and the strong phases in units of degree.

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\|T_P\|$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\|T_V\|$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
δ_{T_V}	3 ± 4	1 ± 4	-6^{+28}_{-39}
$\|C_P\|$	$0.341^{+0.135}_{-0.130}$	$0.284^{+0.092}_{-0.081}$	$0.524^{+0.294}_{-0.301}$
δ_{C_P}	-24^{+41}_{-32}	-36^{+29}_{-23}	-54^{+32}_{-44}
$\|C_V\|$	$0.668^{+0.325}_{-0.276}$	$0.735^{+0.164}_{-0.161}$	$1.120^{+0.416}_{-0.339}$
δ_{C_V}	-89^{+27}_{-16}	-91^{+13}_{-10}	-93^{+15}_{-17}
$\|P_P\|$	0.083 ± 0.003	0.083 ± 0.002	0.083 ± 0.003
δ_{P_P}	-25 ± 6	-21 ± 5	-37^{+17}_{-39}
$\|P_V\|$	0.066 ± 0.005	0.069 ± 0.004	0.070 ± 0.004
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$\|P_{EW,V}\|$	$0.061^{+0.029}_{-0.024}$	$0.058^{+0.017}_{-0.015}$	$0.064^{+0.020}_{-0.018}$
$\delta_{PEW,V}$	-100^{+35}_{-23}	-83^{+22}_{-15}	-105^{+26}_{-34}

Parameter	Scheme A	Scheme B	Scheme C
$\|S_P\|$	-	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
δ_{S_P}	-	-142^{+13}_{-21}	-154^{+21}_{-38}
$\|S_V\|$	-	0.033 ± 0.004	$0.035^{+0.005}_{-0.004}$
δ_{S_V}	-	-73 ± 24	-89^{+24}_{-27}
$\|E_P\|$	-	-	$0.266^{+0.829}_{-0.266}$
δ_{E_P}	-	-	120 ± 180
$\|E_V\|$	-	-	$0.467^{+0.526}_{-0.375}$
δ_{E_V}	-	-	-65^{+27}_{-86}
χ^2_{min}/dof	15.53/12	40.22/32	37.57/28
Fit quality	12.36 %	15.08%	10.67%

some difference in fit quality

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

Parameter	Scheme A	Scheme B	Scheme C
$\|T_P\|$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\|T_V\|$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
δ_{T_V}	3 ± 4	1 ± 4	-6^{+28}_{-39}
$\|C_P\|$	$0.341^{+0.135}_{-0.130}$	$0.284^{+0.092}_{-0.081}$	$0.524^{+0.294}_{-0.301}$
δ_{C_P}	-24^{+41}_{-32}	-36^{+29}_{-23}	-54^{+32}_{-44}
$\|C_V\|$	$0.668^{+0.325}_{-0.276}$	$0.735^{+0.164}_{-0.161}$	$1.120^{+0.416}_{-0.339}$
δ_{C_V}	-89^{+27}_{-16}	-91^{+13}_{-10}	-93^{+15}_{-17}
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δ_{P_P}	-25 ± 6	-21 ± 5	-37^{+17}_{-39}
$\|P_V\|$	0.066 ± 0.005	0.069 ± 0.004	0.070 ± 0.004
δ_{P_V}	165 ± 9	159	
$\|P_{EW,P}\|$	$0.035^{+0.010}_{-0.011}$	0.031 ±	
$\delta_{P_{EW,P}}$	51^{+12}_{-16}	44	
$\|P_{EW,V}\|$	$0.061^{+0.029}_{-0.024}$	0.058	
$\delta_{P_{EW,V}}$	-100^{+35}_{-23}	−83	

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\|S_P\|$	-	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
δ_{S_P}	-	-142^{+13}_{-21}	-154^{+21}_{-38}
$\|S_V\|$	-	0.033 ± 0.004	$0.035^{+0.005}_{-0.004}$
δ_{S_V}	-	-73 ± 24	-89^{+24}_{-27}
$\|E_P\|$	-	-	$0.266^{+0.829}_{-0.266}$
δ_{E_P}	-	-	120 ± 180
$\|E_V\|$	-	-	$0.467^{+0.526}_{-0.375}$
	-	-	-65^{+27}_{-86}
	53/12	40.22/32	37.57/28
	36 %	15.08%	10.67%

large errors on E amplitudes
➠ not called for by data
also resulting in large errors
on other amplitudes
➠ prefer Scheme B

Cheng-Wei Chiang @ IHEP, 2015

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\vert T_P\vert$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\vert T_V\vert$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
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$\vert C_V\vert$	$0.668^{+0.325}_{-0.276}$	$0.735^{+0.164}_{-0.161}$	$1.120^{+0.416}_{-0.339}$
δ_{C_V}	-89^{+27}_{-16}	-91^{+13}_{-10}	-93^{+15}_{-17}
$\vert P_P\vert$	0.083 ± 0.003	0.083 ± 0.002	0.083 ± 0.003
δ_{P_P}	-25 ± 6	-21 ± 5	-37^{+17}_{-39}
$\vert P_V\vert$	0.066 ± 0.005	0.069 ± 0.004	0.070 ± 0.004
δ_{P_V}	165 ± 9	159^{+7}_{-8}	142^{+17}_{-35}
$\vert P_{EW,P}\vert$	0		
$\delta_{P_{EW,P}}$			
$\vert P_{EW,V}\vert$	0		
$\delta_{P_{EW,V}}$			

Parameter	Scheme A	Scheme B	Scheme C
$\vert S_P\vert$	-	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
δ_{S_P}	-	-142^{+13}_{-21}	-154^{+21}_{-38}
$\vert S_V\vert$	-	0.033 ± 0.004	$0.035^{+0.005}_{-0.004}$
δ_{S_V}	-	-73 ± 24	-89^{+24}_{-27}
$\vert E_P\vert$	-	-	$0.266^{+0.829}_{-0.266}$
δ_{E_P}	-	-	120 ± 180
$\vert E_V\vert$	-	-	$0.467^{+0.526}_{-0.375}$
δ_{E_V}	-	-	-65^{+27}_{-86}
			37.57/28
			10.67%

The amplitudes satisfy the hierarchy:

$$|T_{P,V}| > |C_{P,V}| > |P_{P,V}| \sim |P_{EW,V}| > |P_{EW,P}| \ , \ |S_{P,V}|$$

➠ unlike PP sector, $|S_{PV}|$ is smaller than $|P_{EW,PV}|$

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\|T_P\|$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\|T_V\|$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
δ_{T_V}	3 ± 4	1 ± 4	-6^{+28}_{-39}
$\|C_P\|$	$0.341^{+0.135}_{-0.130}$	$0.284^{+0.092}_{-0.081}$	$0.524^{+0.294}_{-0.301}$
δ_{C_P}	-24^{+41} [illegible]	-36^{+29} [illegible]	-54^{+32} [illegible]
$\|C_V\|$	0 [illegible]	[illegible]	[illegible]
δ_{C_V}	-89^{+27}_{-16}	-91^{+13}_{-10}	-93^{+15}_{-17}
$\|P_P\|$	0.083 ± 0.003	0.083 ± 0.002	0.083 ± 0.003
δ_{P_P}	-25 ± 6	-21 ± 5	-37^{+17}_{-39}
$\|P_V\|$	0.066 ± 0.005	0.069 ± 0.004	0.070 ± 0.004
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$\|P_{EW,P}\|$	$0.035^{+0.010}_{-0.011}$	0.031 ± 0.010	$0.030^{+0.009}_{-0.010}$
$\delta_{P_{EW,P}}$	51^{+12}_{-16}	44^{+11}_{-15}	25^{+20}_{-35}
$\|P_{EW,V}\|$	$0.061^{+0.029}_{-0.024}$	$0.058^{+0.017}_{-0.015}$	$0.064^{+0.020}_{-0.018}$
$\delta_{P_{EW,V}}$	-100^{+35}_{-23}	-83^{+22}_{-15}	-105^{+26}_{-34}

The relative phase between T_V and T_P is consistent with 0.

Parameter	Scheme A	Scheme B	Scheme C
$\|S_P\|$	-	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
δ_{S_P}	-	-142^{+13}_{-21}	-154^{+21}_{-38}
[illegible]	[illegible]	[illegible]04	$0.035^{+0.005}_{-0.004}$
δ_{S_V}	-	-75 ± 24	-89^{+24}_{-27}
$\|E_P\|$	-	-	$0.266^{+0.829}_{-0.266}$
δ_{E_P}	-	-	120 ± 180
$\|E_V\|$	-	-	$0.467^{+0.526}_{-0.375}$
δ_{E_V}	-	-	-65^{+27}_{-86}
χ^2_{min}/dof	15.53/12	40.22/32	37.57/28
Fit quality	12.36 %	15.08%	10.67%

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\|T_P\|$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\|T_V\|$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
δ_{T_V}	3 ± 4	[illegible]	[illegible]
$\|C_P\|$	$0.341^{+0.135}_{-0.130}$	[illegible]	[illegible]
δ_{C_P}	-24^{+41}_{-32}	[illegible]	[illegible]
$\|C_V\|$	$0.668^{+0.325}_{-0.276}$	[illegible]	[illegible]
δ_{C_V}	-89^{+27}_{-16}	[illegible]	[illegible]
$\|P_P\|$	0.083 ± 0.005	0.083 ± 0.002	0.083 ± 0.005
δ_{P_P}	-25 ± 6	-21 ± 5	-37^{+17}_{-39}
$\|P_V\|$	0.066 ± 0.005	0.069 ± 0.004	0.070 ± 0.004
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$\|P_{EW,V}\|$	$0.061^{+0.029}_{-0.024}$	$0.058^{+0.017}_{-0.015}$	$0.064^{+0.020}_{-0.018}$
$\delta_{PEW,V}$	-100^{+35}_{-23}	-83^{+22}_{-15}	-105^{+26}_{-34}

Parameter	Scheme A	Scheme B	Scheme C
	[illegible]	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
	[illegible]	-142^{+13}_{-21}	-154^{+21}_{-38}
	[illegible]	$.033 \pm 0.004$	$0.035^{+0.005}_{-0.004}$
	[illegible]	-73 ± 24	-89^{+24}_{-27}
	[illegible]	-	$0.266^{+0.829}_{-0.266}$
	[illegible]	[illegible]	120 ± 180
	[illegible]	[illegible]	$0.467^{+0.526}_{-0.375}$
δ_{E_V}	-	-	-65^{+27}_{-86}
χ^2_{min}/dof	15.53/12	40.22/32	37.57/28
Fit quality	12.36 %	15.08%	10.67%

P_V and P_P essentially opposite in strong phase
➠ consistent with the assumption made in early analyses based on G-parity argument
➠ interfering constructively and destructively in the ηK^* and $\eta' K^*$, respectively

Lipkin 1981, 1991, 1997, 1998
CWC, Gronau, Luo, Rosner, Suprun 2004

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

Parameter	Scheme A	Scheme B	Scheme C
$\lvert T_P\rvert$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\lvert T_V\rvert$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
δ_{T_V}	3 ± 4	1 ± 4	-6^{+28}_{-39}
$\lvert C_P\rvert$	$0.341^{+0.135}_{-0.130}$	$0.284^{+0.092}_{-0.081}$	$0.524^{+0.294}_{-0.301}$
δ_{C_P}	-24^{+41}_{-32}	-36^{+29}_{-23}	-54^{+32}_{-44}
$\lvert C_V\rvert$	$0.668^{+0.325}_{-0.276}$	$0.735^{+0.164}_{-0.161}$	$1.120^{+0.416}_{-0.339}$
δ_{C_V}	-89^{+27}_{-16}	-91^{+13}_{-10}	-93^{+15}_{-17}
$\lvert P_P\rvert$	0.083 ± 0.003	0.083 ± 0.002	0.083 ± 0.003
δ_{P_P}	-25 ± 6		
$\lvert P_V\rvert$	0.066 ± 0.005		
δ_{P_V}	165 ± 9	159^{+7}_{-8}	142^{+17}_{-35}
$\lvert P_{EW,P}\rvert$	$0.035^{+0.010}_{-0.011}$	0.031 ± 0.010	$0.030^{+0.009}_{-0.010}$
$\delta_{PEW,P}$	51^{+12}_{-16}	44^{+11}_{-15}	25^{+20}_{-35}
$\lvert P_{EW,V}\rvert$	$0.061^{+0.029}_{-0.024}$	$0.058^{+0.017}_{-0.015}$	$0.064^{+0.020}_{-0.018}$
$\delta_{PEW,V}$	-100^{+35}_{-23}	-83^{+22}_{-15}	-105^{+26}_{-34}

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\lvert S_P\rvert$	-	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
δ_{S_P}	-	-142^{+13}_{-21}	-154^{+21}_{-38}
$\lvert S_V\rvert$	-	0.033 ± 0.004	$0.035^{+0.005}_{-0.004}$
δ_{S_V}	-	-73 ± 24	-89^{+24}_{-27}
$\lvert E_P\rvert$	-	-	$0.266^{+0.829}_{-0.266}$
[illegible]	[illegible]	-	120 ± 180
[illegible]	[illegible]	-	$0.467^{+0.526}_{-0.375}$
δ_{E_V}	[illegible]	-	-65^{+27}_{-86}
χ^2_{min}/dof	$15.53/12$	$40.22/32$	$37.57/28$
Fit quality	12.36 %	15.08%	10.67%

$|C_V / C_P| \sim 2$ while $|T_P| > |T_V|$
correspondingly $|P_{EW,V} / P_{EW,P}|$, $|S_V / S_P| \sim 2$

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\|T_P\|$	$1.173^{+0.063}_{-0.066}$		
$\|T_V\|$	$0.880^{+0.058}_{-0.063}$		
δ_{T_V}	3 ± 4		
$\|C_P\|$	$0.341^{+0.135}_{-0.130}$		
δ_{C_P}	-24^{+41}_{-32}		
$\|C_V\|$	$0.668^{+0.325}_{-0.276}$		
δ_{C_V}	-89^{+27}_{-16}		
$\|P_P\|$	0.083 ± 0.003		
δ_{P_P}	-25 ± 6	-21 ± 5	-37^{+17}_{-39}
$\|P_V\|$	0.066 ± 0.005	0.069 ± 0.004	0.070 ± 0.004
δ_{P_V}	165 ± 9	159^{+7}_{-8}	142^{+17}_{-35}
$\|P_{EW,P}\|$	$0.035^{+0.010}_{-0.011}$	0.031 ± 0.010	$0.030^{+0.009}_{-0.010}$
$\delta_{PEW,P}$	51^{+12}_{-16}	44^{+11}_{-15}	25^{+20}_{-35}
$\|P_{EW,V}\|$	$0.061^{+0.029}_{-0.024}$	$0.058^{+0.017}_{-0.015}$	$0.064^{+0.020}_{-0.018}$
$\delta_{PEW,V}$	-100^{+35}_{-23}	-83^{+22}_{-15}	-105^{+26}_{-34}

		Scheme B	Scheme C
		$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
		-142^{+13}_{-21}	-154^{+21}_{-38}
		0.033 ± 0.004	$0.035^{+0.005}_{-0.004}$
		-73 ± 24	-89^{+24}_{-27}
		-	$0.266^{+0.829}_{-0.266}$
		-	120 ± 180
$\|E_V\|$	-	-	$0.467^{+0.526}_{-0.375}$
δ_{E_V}	-	-	-65^{+27}_{-86}
χ^2_{min}/dof	15.53/12	40.22/32	37.57/28
Fit quality	12.36 %	15.08%	10.67%

$|P_{EW,V}|$ is comparable to $|P_V|$!

➠ playing a crucial role so that CPA's of $K^{*+}\pi^0$ and $K^{*+}\pi^-$ have same sign, in contrast to the PP sector where CPA's of $K^+\pi^0$ and $K^+\pi^-$ have opposite signs

$$c'_V = Y^u_{sb} C_V - (Y^u_{sb} + Y^c_{sb}) P_{EW,V}$$

Results for VP Sector

limited fit (no S, E) | global fit (no E) | global fit

Parameter	Scheme A	Scheme B	Scheme C
$\|T_P\|$	$1.173^{+0.063}_{-0.066}$	$1.193^{+0.060}_{-0.063}$	$0.909^{+0.499}_{-0.331}$
$\|T_V\|$	$0.880^{+0.058}_{-0.063}$	$0.883^{+0.057}_{-0.060}$	$0.704^{+0.294}_{-0.275}$
δ_{T_V}	3 ± 4	1 ± 4	-6^{+28}_{-39}
$\|C_P\|$	$0.341^{+0.135}_{-0.130}$	$0.284^{+0.092}_{-0.081}$	$0.524^{+0.294}_{-0.301}$
δ_{C_P}	-24^{+41}_{-32}	-36^{+29}_{-23}	-54^{+32}_{-44}
$\|C_V\|$	$0.668^{+0.325}_{-0.276}$	$0.735^{+0.164}_{-0.161}$	$1.120^{+0.416}_{-0.339}$
δ_{C_V}	-89^{+27}_{-16}	-91^{+13}_{-10}	-93^{+15}_{-17}
$\|P_P\|$	0.083 ± 0.003	0.083 ± 0.002	0.083 ± 0.003
δ_{P_P}	-25 ± 6		
$\|P_V\|$	0.066 ± 0.00		
δ_{P_V}	165 ± 9		
$\|P_{EW,P}\|$	$0.035^{+0.010}_{-0.011}$		
$\delta_{PEW,P}$	51^{+12}_{-16}		
$\|P_{EW,V}\|$	$0.061^{+0.029}_{-0.024}$		
$\delta_{PEW,V}$	-100^{+35}_{-23}		

23 theory parameters

Parameter	Scheme A	Scheme B	Scheme C
$\|S_P\|$	-	$0.015^{+0.006}_{-0.005}$	0.014 ± 0.006
δ_{S_P}	-	-142^{+13}_{-21}	-154^{+21}_{-38}
$\|S_V\|$	-	0.033 ± 0.004	$0.035^{+0.005}_{-0.004}$
δ_{S_V}	-	-73 ± 24	-89^{+24}_{-27}
$\|E_P\|$	-	-	$0.266^{+0.829}_{-0.266}$
		-	120 ± 180
		-	$0.467^{+0.526}_{-0.375}$
		-	-65^{+27}_{-86}
		$40.22/32$	$37.57/28$
		15.08%	10.67%

$|C_V/T_P|$ and $|C_P/T_V|$ ratios:

	Scheme A	Scheme B
$\|C_V/T_P\|$	0.57 ± 0.26	0.62 ± 0.14
$\|C_P/T_V\|$	0.39 ± 0.15	0.32 ± 0.10

Predictions - BF's

most theories predict smaller rate for former due to π^0 wavefunction
our results has a sizeable c'_V amplitude which contributes constructively to $B^+ \to K^{*+}\pi^0$

Observable	$BF(B^+ \to K^{*+}\pi^0)$	$BF(B^0 \to K^{*+}\pi^-)$	$BF(B^0 \to \rho^0\pi^0)$
Data	9.2 ± 1.5	8.5 ± 0.7	2.0 ± 0.5
This Work	9.79 ± 2.95	8.35 ± 0.50	2.24 ± 0.93
QCDF	$6.7 \pm 0.7^{+2.4}_{-2.2}$	$9.2 \pm 1.0^{+3.7}_{-3.3}$	$1.3^{+1.7+1.2}_{-0.6-0.6}$
pQCD	$4.3^{+5.0}_{-2.2}$	$6.0^{+6.8}_{-2.6}$	~ 1.1
SCET	$6.5^{+1.9}_{-1.7} \pm 0.7$	$9.5^{+3.2+1.2}_{-2.8-1.1}$	$1.5 \pm 0.1 \pm 0.1$

wrong relative sizes?

due to constructive interference between C_P and C_V amplitudes

Predictions - CPA's

all theories have wrong sign in central values

diverse predictions that are far off from current data

Observable	$A_{CP}(B^+ \to \rho^0\pi^+)$	$A_{CP}(B^+ \to K^{*+}\pi^0)$	$A_{CP}(B^0 \to \rho^+\eta)$
Data	$0.18^{+0.09}_{-0.17}$ only by BaBar	-0.52 ± 0.15 only by BaBar	0.11 ± 0.11
This Work	-0.239 ± 0.084	-0.116 ± 0.092	0.162 ± 0.072
QCDF	$-0.098^{+0.034+0.114}_{-0.026-0.102}$	$0.016^{+0.031+0.111}_{-0.017-0.144}$	$-0.085 \pm 0.004^{+0.065}_{-0.053}$
pQCD	~ -0.31	$-0.32^{+0.21}_{-0.28}$	$0.019^{+0.001+0.002+0.001+0.006}_{-0.000-0.003-0.000-0.005}$
SCET	$-0.192^{+0.155+0.017}_{-0.134-0.019}$	$-0.129^{+0.120}_{-0.122} \pm 0.008$	$-0.091^{+0.167+0.009}_{-0.158-0.008}$

Predictions - B_s Decays

all theories consistent with one another, but more than twice larger than the central value of current data

larger than others due to our large $P_{EW,V}$; signal of new physics?

Hofer, Scherer, Vernazza 2011

Observable	$BF(K^{*-}\pi^+)$	$BF(\phi\pi^0)$
Data	3.3 ± 1.2	—
This Work	7.92 ± 1.02	1.94 ± 1.14
QCDF	$7.8^{+0.4+0.5}_{-0.7-0.7}$	$0.12^{+0.02+0.04}_{-0.01-0.02}$
pQCD	$7.6^{+2.9+0.4+0.5}_{-2.2-0.5-0.3}$	$0.16^{+0.06}_{-0.05} \pm 0.02 \pm 0.00$
SCET	$6.6^{+0.2}_{-0.1} \pm 0.7$	$0.09 \pm 0.00 \pm 0.01$

more on next page

PREDICTIONS – B_s DECAYS

- When $E_{P,V}$ amplitudes are ignored, we have the following predictions relating B_s and B^0 decays

$$BF(B_s \to K^{*-}\pi^+) \simeq BF(B^0 \to \rho^-\pi^+) \simeq 8 \times 10^{-6} \ ,$$
$$A_{CP}(B_s \to K^{*-}\pi^+) \simeq \mathcal{A}(B^0 \to \rho^-\pi^+) \simeq 0.14$$
$$BF(B_s \to \rho^+ K^-) \simeq BF(B^0 \to \rho^+\pi^-) \simeq 15 \times 10^{-6} \ ,$$
$$A_{CP}(B_s \to \rho^+ K^-) \simeq \mathcal{A}(B^0 \to \rho^+\pi^-) \simeq 0.12$$

largest in B_s decays

where the numbers are given by current data.

Summary

- Latest $B \to PP, VP$ modes are analyzed in flavor SU(3) framework.
- Fit to $B_{u,d}$ decay data and predict all observables, particularly for B_s.
- C is larger than previously known ($|C/T| \gtrsim 0.7$), and has a strong phase of $\sim -70^o$ –– partially due to $A_{CP}(K\pi)$ data
- S is essential for explaining BF($\eta' K$), and has a strong phase $\sim -100^o$.
- We have extracted for the first time the E and PA amplitudes in PP.
- C_V has a large size and a strong phase of $\sim -90^o$; $P_{EW,V}$ also has a similar strong phase and a magnitude comparable to P_V.
- $E_{P,V}$ are not called for under current data precision.
- A detailed comparison of our predictions with data and perturbative calculations is made.

THANK YOU

BACKUP SLIDES

$B \to PP,\ \Delta S = 0$

Mode		Flavor amplitude	BF	A_{CP}
$B^+ \to$	$\pi^+\pi^0$	$-\frac{1}{\sqrt{2}}(t+c)$	$5.48^{+0.35}_{-0.34}$	0.026 ± 0.039
	$K^+\bar{K}^0$	p	1.19 ± 0.18 (1.02)	-0.086 ± 0.100 [16]
	$\eta\pi^+$	$\frac{c_\phi}{\sqrt{2}}[t+c+2p+(2-\sqrt{2}t_\phi)s]$	4.02 ± 0.27	-0.14 ± 0.05 (1.42)
	$\eta'\pi^+$	$\frac{s_\phi}{\sqrt{2}}[t+c+2p+(2+\frac{\sqrt{2}}{t_\phi})s]$	$2.7^{+0.5*}_{-0.4}$ (1.36)	$0.06 \pm 0.15^*$
$B^0 \to$	K^+K^-	$-(e+2pa)$	0.12 ± 0.05	$\cdots$
	$K^0\bar{K}^0$	$p+2pa$	1.21 ± 0.16	0.06 ± 0.26 (1.38) -1.08 ± 0.49
	$\pi^+\pi^-$	$-(t+p+e+2pa)$	5.10 ± 0.19	0.31 ± 0.05 [17] -0.66 ± 0.06 [17]
	$\pi^0\pi^0$	$\frac{1}{\sqrt{2}}(-c+p+e+2pa)$	1.17 ± 0.13 (3.18) [21]	0.03 ± 0.17 (1.94) [21]
	$\eta\pi^0$	$\frac{c_\phi}{2}[2p+(2-\sqrt{2}t_\phi)s-2e]$	< 1.5	$\cdots$
	$\eta'\pi^0$	$s_\phi[p+(1+\frac{1}{\sqrt{2}t_\phi})s-e]$	1.2 ± 0.4 (1.46)	$\cdots$
	$\eta\eta$	$\frac{c_\phi^2}{\sqrt{2}}[c+p+(2-\sqrt{2}t_\phi)s+e+\frac{2}{c_\phi^2}pa]$	< 1.0	$\cdots$
	$\eta'\eta$	$\frac{c_\phi s_\phi}{2}[2c+2p+(4-\sqrt{2}t_\phi+\frac{\sqrt{2}}{t_\phi})s+2e]$	< 1.2	$\cdots$
	$\eta'\eta'$	$\frac{s_\phi^2}{\sqrt{2}}[c+p+(2+\frac{\sqrt{2}}{t_\phi})s+e+\frac{2}{s_\phi^2}pa]$	< 1.7	$\cdots$
$B_s \to$	π^+K^-	$-(t+p)$	$5.4 \pm 0.6^*$	$0.26 \pm 0.04^*$
	$\pi^0\bar{K}^0$	$\frac{1}{\sqrt{2}}(-c+p)$	$\cdots$	$\cdots$
	$\eta\bar{K}^0$	$\frac{c_\phi}{\sqrt{2}}[c+(1-\sqrt{2}t_\phi)p+(2-\sqrt{2}t_\phi)s]$	$\cdots$	$\cdots$
	$\eta'\bar{K}^0$	$\frac{s_\phi}{\sqrt{2}}[c+(1+\frac{\sqrt{2}}{t_\phi})p+(2+\frac{\sqrt{2}}{t_\phi})s]$	$\cdots$	$\cdots$

$B \to PP$, $|\Delta S| = 1$

Mode		Flavor amplitude	BF	A_{CP}
$B^+ \to$	$K^0\pi^+$	p'	23.79 ± 0.75	-0.017 ± 0.016 [16]
	$K^+\pi^0$	$-\frac{1}{\sqrt{2}}(p' + t' + c')$	$12.94^{+0.52}_{-0.51}$	0.040 ± 0.021
	ηK^+	$\frac{c_\phi}{\sqrt{2}}[t' + c' + (1 - \sqrt{2}t_\phi)p' + (2 - \sqrt{2}t_\phi)s']$	$2.36^{+0.22}_{-0.21}$ (1.18)	-0.37 ± 0.08
	$\eta' K^+$	$\frac{s_\phi}{\sqrt{2}}[t' + c' + (\frac{\sqrt{2}}{t_\phi} + 1)p' + (2 + \frac{\sqrt{2}}{t_\phi})s']$	71.1 ± 2.6	0.013 ± 0.017
$B^0 \to$	$K^+\pi^-$	$-(p' + t')$	$19.57^{+0.53}_{-0.52}$	-0.082 ± 0.006
	$K^0\pi^0$	$\frac{1}{\sqrt{2}}(p' - c')$	9.93 ± 0.49	-0.01 ± 0.10 (1.38) 0.57 ± 0.17
	ηK^0	$\frac{c_\phi}{\sqrt{2}}[c' + (1 - \sqrt{2}t_\phi)p' + (2 - \sqrt{2}t_\phi)s']$	$1.23^{+0.27}_{-0.24}$	$\cdots$
	$\eta' K^0$	$\frac{s_\phi}{\sqrt{2}}[c' + (\frac{\sqrt{2}}{t_\phi} + 1)p' + (2 + \frac{\sqrt{2}}{t_\phi})s']$	66.1 ± 3.1 (1.32)	0.05 ± 0.04 [22] 0.63 ± 0.06 [22]
$B_s \to$	K^+K^-	$-(p' + t' + e' + 2pa')$	$24.5 \pm 1.8^*$	$-0.14 \pm 0.11^*$ [17] $0.30 \pm 0.13^*$ [17]
	$K^0\bar{K}^0$	$p' + 2pa'$	$< 66^*$	$\cdots$
	$\pi^+\pi^-$	$-(e' + 2pa')$	$0.73 \pm 0.14^*$ (1.30)	$\cdots$
	$\pi^0\pi^0$	$\frac{1}{\sqrt{2}}(e' + 2pa')$	$\cdots$	$\cdots$
	$\eta\pi^0$	$-\frac{c_\phi}{2}[-\sqrt{2}t_\phi c' + 2e']$	$\cdots$	$\cdots$
	$\eta'\pi^0$	$-\frac{s_\phi}{2}[\frac{\sqrt{2}}{t_\phi}c' + 2e']$	$\cdots$	$\cdots$
	$\eta\eta$	$s_\phi c_\phi[-c' + \sqrt{2}t_\phi p' + (\sqrt{2}t_\phi - 2)s' + \frac{e'}{\sqrt{2}t_\phi} + \frac{\sqrt{2}}{c_\phi s_\phi}pa']$	$\cdots$	$\cdots$
	$\eta\eta'$	$-c_\phi s_\phi[(\frac{t_\phi}{\sqrt{2}} - \frac{1}{\sqrt{2}t_\phi})c' + 2p' + (\sqrt{2}t_\phi - \frac{\sqrt{2}}{t_\phi} + 2)s' - e']$	$\cdots$	$\cdots$
	$\eta'\eta'$	$c_\phi s_\phi[c' + \frac{\sqrt{2}}{t_\phi}p' + (2 + \frac{\sqrt{2}}{t_\phi})s' + \frac{t_\phi}{\sqrt{2}}e' + \frac{\sqrt{2}}{c_\phi s_\phi}pa']$	$\cdots$	$\cdots$

B→PP, Predictions

TABLE VI. Predicted branching fractions in units of 10^{-6} for the $B^{0,+}$ decays based on scheme D. Unless otherwise noted, QCDF predictions are taken from Refs. [24,25], and SCET predictions are taken from Ref. [26]. The pQCD predictions taken from Ref. [27] are for $S_e = -\pi/2$ with S_e being a strong phase induced by Glauber gluons.

Observable	Data	This work	QCDF	pQCD	SCET
$BF(\pi^+\pi^0)$	$5.48^{+0.35}_{-0.34}$	5.40 ± 0.79	$5.9^{+2.2+1.4}_{-1.1-1.1}$	~6.6 [27]	$5.2 \pm 1.6 \pm 2.1 \pm 0.6$
$BF(K^+\bar{K}^0)$	1.19 ± 0.18	1.03 ± 0.02	$1.8^{+0.9+0.7}_{-0.5-0.5}$	1.66 [28]	$1.1 \pm 0.4 \pm 1.4 \pm 0.03$
$BF(\eta\pi^+)$	4.02 ± 0.27	3.88 ± 0.39	$5.0^{+1.2+0.9}_{-0.6-0.7}$	$4.1^{+1.5}_{-1.1}$ [29]	$4.9 \pm 1.7 \pm 1.0 \pm 0.5$
$BF(\eta'\pi^+)$	$2.7^{+0.5}_{-0.4}$	5.59 ± 0.54	$3.8^{+1.3+0.9}_{-0.6-0.6}$	$2.4^{+0.8}_{-0.5} \pm 0.2 \pm 0.3$ [29]	$2.4 \pm 1.2 \pm 0.2 \pm 0.4$
$BF(K^+K^-)$	0.12 ± 0.05	0.15 ± 0.05	$0.10^{+0.03}_{-0.02} \pm 0.03$	0.046 [28]	
$BF(K^0\bar{K}^0)$	1.21 ± 0.16	0.89 ± 0.11	$2.1^{+1.0+0.8}_{-0.6-0.6}$	1.75 [28]	$1.0 \pm 0.4 \pm 1.4 \pm 0.03$
$BF(\pi^+\pi^-)$	5.10 ± 0.19	5.17 ± 1.03	$7.0^{+0.4}_{-0.7} \pm 0.7$	~6.4 [27]	$5.4 \pm 1.3 \pm 1.4 \pm 0.4$
$BF(\pi^0\pi^0)$	1.17 ± 0.13	1.88 ± 0.42	$1.1^{+1.0+0.7}_{-0.4-0.3}$	~1.2 [27]	$0.84 \pm 0.29 \pm 0.30 \pm 0.19$
$BF(\eta\pi^0)$	< 1.5	0.56 ± 0.03	$0.36^{+0.03+0.13}_{-0.02-0.10}$	0.23 ± 0.08 [29]	$0.88 \pm 0.54 \pm 0.06 \pm 0.42$
$BF(\eta'\pi^0)$	1.2 ± 0.4	1.21 ± 0.16	$0.42^{+0.21+0.18}_{-0.09-0.12}$	$0.19 \pm 0.02 \pm 0.03^{+0.04}_{-0.05}$ [29]	$2.3 \pm 0.8 \pm 0.3 \pm 2.7$
$BF(\eta\eta)$	< 1.0	0.77 ± 0.12	$0.32^{+0.13+0.07}_{-0.05-0.06}$	$0.067^{+0.032}_{-0.025}$ [30]	$0.69 \pm 0.38 \pm 0.13 \pm 0.58$
$BF(\eta'\eta)$	< 1.2	1.99 ± 0.26	$0.36^{+0.24+0.12}_{-0.10-0.08}$	0.018 ± 0.011 [30]	$1.0 \pm 0.5 \pm 0.1 \pm 1.5$
$BF(\eta'\eta')$	< 1.7	1.60 ± 0.20	$0.22^{+0.14+0.08}_{-0.06-0.06}$	$0.011^{+0.012}_{-0.009}$ [30]	$0.57 \pm 0.23 \pm 0.03 \pm 0.69$
$BF(K^0\pi^+)$	23.79 ± 0.75	23.53 ± 0.42	$21.7^{+9.2+9.0}_{-6.0-6.9}$	~21.1 [27]	$20.8 \pm 7.9 \pm 0.6 \pm 0.7$
$BF(K^+\pi^0)$	$12.94^{+0.52}_{-0.51}$	12.71 ± 1.05	$12.5^{+4.7+4.9}_{-3.0-3.8}$	~12.9 [27]	$11.3 \pm 4.1 \pm 1.0 \pm 0.3$
$BF(\eta K^+)$	$2.36^{+0.22}_{-0.21}$	1.93 ± 0.31	$2.2^{+1.7+1.1}_{-1.0-0.9}$ [24]	$3.2^{+3.2}_{-1.8}$ [31]	$2.7 \pm 4.8 \pm 0.4 \pm 0.3$
$BF(\eta' K^+)$	71.1 ± 2.6	70.92 ± 8.54	$74.5^{+57.9+25.6}_{-25.3-19.0}$ [24]	$51.0^{+18.0}_{-10.9}$ [31]	$69.5 \pm 27.0 \pm 4.3 \pm 7.7$
$BF(K^+\pi^-)$	$19.57^{+0.53}_{-0.52}$	20.18 ± 0.39	$19.3^{+7.9+8.2}_{-4.8-6.2}$	~17.7 [27]	$20.1 \pm 7.4 \pm 1.3 \pm 0.6$
$BF(K^0\pi^0)$	9.93 ± 0.49	9.73 ± 0.82	$8.6^{+3.8+3.8}_{-2.2-2.9}$	~7.2 [27]	$9.4 \pm 3.6 \pm 0.2 \pm 0.3$
$BF(\eta K^0)$	$1.23^{+0.27}_{-0.24}$	1.49 ± 0.27	$1.5^{+1.4+0.9}_{-0.8-0.7}$ [24]	$2.1^{+2.6}_{-1.5}$ [31]	$2.4 \pm 4.4 \pm 0.2 \pm 0.3$
$BF(\eta' K^0)$	66.1 ± 3.1	66.51 ± 7.97	$70.9^{+54.1+24.2}_{-23.8-18.0}$ [24]	$50.3^{+16.8}_{-10.6}$ [31]	$63.2 \pm 24.7 \pm 4.2 \pm 8.1$

TABLE VII. Same as Table VI but for CP asymmetries.

Observable	Data	This work	QCDF	pQCD	SCET
$A_{CP}(\pi^+\pi^0)$	0.026 ± 0.039	0.069 ± 0.027	$-0.0011\pm0.0001^{+0.0006}_{-0.0003}$	~-0.012 [27]	<0.04
$A_{CP}(K^+K_S)$	-0.086 ± 0.100	0	$-0.064^{+0.008}_{-0.006}\pm0.018$	0.11 [28]	⋯
$A_{CP}(\eta\pi^+)$	-0.14 ± 0.05	-0.081 ± 0.074	$-0.050^{+0.024+0.084}_{-0.034-0.103}$	$-0.37^{+0.09}_{-0.07}$ [29]	$0.05\pm0.19\pm0.21\pm0.05$
$A_{CP}(\eta'\pi^+)$	0.06 ± 0.15	0.374 ± 0.087	$0.016^{+0.050+0.094}_{-0.082-0.111}$	$-0.33^{+0.07}_{-0.08}$ [29]	$0.21\pm0.12\pm0.10\pm0.14$
$A_{CP}(K^+K^-)$	⋯	0.004 ± 0.612	0	0.29 [28]	⋯
$\mathcal{A}(K^0\bar{K}^0)$	0.06 ± 0.26	0.017 ± 0.041	$-0.100\pm0.007^{+0.010}_{-0.019}$	0 [28]	⋯
$\mathcal{A}(\pi^+\pi^-)$	0.31 ± 0.05	0.326 ± 0.081	$0.170^{+0.013+0.043}_{-0.012-0.087}$	~0.17 [27]	$0.20\pm0.17\pm0.19\pm0.05$
$\mathcal{A}(\pi^0\pi^0)$	0.03 ± 0.17	0.611 ± 0.113	$0.572^{+0.148+0.303}_{-0.208-0.346}$	~0.36 [27]	$-0.58\pm0.39\pm0.39\pm0.13$
$\mathcal{A}(\eta\pi^0)$	⋯	0.566 ± 0.114	$-0.052^{+0.028+0.246}_{-0.030-0.156}$	$-0.42^{+0.10}_{-0.13}$ [29]	$0.03\pm0.10\pm0.12\pm0.05$
$\mathcal{A}(\eta'\pi^0)$	⋯	0.385 ± 0.114	$-0.073^{+0.010+0.176}_{-0.018-0.140}$	$-0.36^{+0.11}_{-0.10}$ [29]	$-0.24\pm0.10\pm0.19\pm0.24$
$\mathcal{A}(\eta\eta)$	⋯	-0.405 ± 0.129	$-0.635^{+0.104+0.098}_{-0.064-0.124}$	$-0.33^{+0.026+0.041+0.035}_{-0.028-0.038-0.000}$ [30]	$-0.09\pm0.24\pm0.21\pm0.04$
$\mathcal{A}(\eta\eta')$	⋯	-0.394 ± 0.117	$-0.592^{+0.072+0.038}_{-0.068-0.048}$	$0.774^{+0.000+0.069+0.080}_{-0.056-0.112-0.090}$ [30]	⋯
$\mathcal{A}(\eta'\eta')$	⋯	-0.122 ± 0.136	$-0.449\pm0.031^{+0.085}_{-0.092}$	$0.237^{+0.100+0.105+0.060}_{-0.069-0.169-0.085}$ [30]	⋯
$A_{CP}(K_S\pi^+)$	-0.017 ± 0.016	0	$0.0028\pm0.0003^{+0.0009}_{-0.0010}$	~0.001 [27]	<0.05
$A_{CP}(K^+\pi^0)$	0.040 ± 0.021	0.047 ± 0.025	$0.049^{+0.039+0.044}_{-0.021-0.054}$	~0.10 [27]	$-0.11\pm0.09\pm0.11\pm0.02$
$A_{CP}(\eta K^+)$	-0.37 ± 0.08	-0.426 ± 0.043	$-0.145^{+0.103+0.155}_{-0.260-0.107}$ [24]	$-0.117^{+0.068+0.039+0.029}_{-0.096-0.042-0.056}$ [31]	$0.33\pm0.30\pm0.07\pm0.03$
$A_{CP}(\eta' K^+)$	0.013 ± 0.017	-0.027 ± 0.008	$0.0045^{+0.0069+0.0120}_{-0.0055-0.0098}$ [24]	$-0.062^{+0.012+0.013+0.013}_{-0.011-0.010-0.010}$ [31]	$-0.010\pm0.006\pm0.007\pm0.005$
$A_{CP}(K^+\pi^-)$	-0.082 ± 0.006	-0.080 ± 0.011	$-0.074^{+0.017+0.043}_{-0.015-0.048}$	~-0.11 [27]	$-0.06\pm0.05\pm0.06\pm0.02$
$\mathcal{A}(K_S\pi^0)$	-0.01 ± 0.10	-0.173 ± 0.019	$-0.106^{+0.027+0.056}_{-0.038-0.043}$	~-0.21 [27]	$0.05\pm0.04\pm0.04\pm0.01$
$\mathcal{A}(\eta K_S)$	⋯	-0.301 ± 0.041	$-0.236^{+0.098+0.126}_{-0.262-0.125}$ [24]	$-0.127\pm0.041^{+0.032+0.032}_{-0.015-0.067}$ [31]	$0.21\pm0.20\pm0.04\pm0.03$
$\mathcal{A}(\eta' K_S)$	0.05 ± 0.04	0.022 ± 0.006	$0.030^{+0.006}_{-0.005}\pm0.008$ [24]	$0.023^{+0.005+0.003+0.002}_{-0.004-0.006-0.001}$ [31]	$0.011\pm0.006\pm0.012\pm0.002$
$\mathcal{S}(K^0\overline{K^0})$	-1.08 ± 0.49	0	⋯	⋯	⋯
$\mathcal{S}(\pi^+\pi^-)$	-0.66 ± 0.06	-0.717 ± 0.061	$-0.69^{+0.08+0.19}_{-0.10-0.09}$	~-0.43 [27]	$-0.86\pm0.07\pm0.07\pm0.02$
$\mathcal{S}(\pi^0\pi^0)$	⋯	0.454 ± 0.112	⋯	~0.63 [27]	$0.71\pm0.34\pm0.33\pm0.10$
$\mathcal{S}(\eta\pi^0)$	⋯	-0.098 ± 0.338	$0.08^{+0.06+0.19}_{-0.12-0.23}$	$0.67^{+0.05}_{-0.11}$ [29]	$-0.90\pm0.08\pm0.03\pm0.22$
$\mathcal{S}(\eta'\pi^0)$	⋯	0.142 ± 0.234	$0.16^{+0.05+0.11}_{-0.07-0.14}$	$0.67^{+0.05}_{-0.11}$ [29]	$-0.96\pm0.03\pm0.05\pm0.11$
$\mathcal{S}(\eta\eta)$	⋯	-0.796 ± 0.077	$-0.77^{+0.07+0.12}_{-0.05-0.06}$	$0.535^{+0.000+0.031+0.021}_{-0.034-0.027-0.001}$ [30]	$-0.98\pm0.06\pm0.03\pm0.09$
$\mathcal{S}(\eta'\eta)$	⋯	-0.903 ± 0.049	$-0.76^{+0.07+0.06}_{-0.05-0.03}$	$-0.131^{+0.547+0.090+0.100}_{-0.488-0.099-0.062}$ [30]	$-0.82\pm0.02\pm0.04\pm0.77$
$\mathcal{S}(\eta'\eta')$	⋯	-0.964 ± 0.037	$-0.85^{+0.03+0.07}_{-0.02-0.06}$	$0.932^{+0.049+0.052+0.022}_{-0.024-0.111-0.021}$ [30]	$-0.59\pm0.05\pm0.08\pm1.10$
$\mathcal{S}(K_S\pi^0)$	0.57 ± 0.17	0.754 ± 0.014	$0.79^{+0.06}_{-0.04}\pm0.04$	~0.69 [27]	$0.80\pm0.02\pm0.02\pm0.01$
$\mathcal{S}(\eta K_S)$	⋯	0.592 ± 0.035	$0.79^{+0.04+0.08}_{-0.06-0.06}$	$0.619^{+0.358+0.353}_{-0.650-0.643}$ [31]	$0.69\pm0.15\pm0.05\pm0.01$
$\mathcal{S}(\eta' K_S)$	0.63 ± 0.06	0.685 ± 0.004	$0.67\pm0.01\pm0.01$	$0.627^{+0.355+0.354}_{-0.650-0.647}$ [31]	$0.706\pm0.005\pm0.006\pm0.003$

TABLE VIII. Predicted results for the B_s decays based on scheme D. QCDF predictions are taken from Ref. [32], pQCD predictions are taken from Ref. [33], and SCET predictions are taken from Ref. [26]. Branching fractions are quoted in units of 10^{-6}.

Observable	Data	This work	QCDF	pQCD	SCET
$BF(\pi^+K^-)$	5.4 ± 0.6	5.86 ± 0.78	$5.3^{+0.4+0.4}_{-0.8-0.5}$	$7.6^{+3.2}_{-2.3}\pm0.7\pm0.5$	$4.9\pm1.2\pm1.3\pm0.3$
$BF(\pi^0\bar{K}^0)$	···	2.25 ± 0.33	$1.7^{+2.5+1.2}_{-0.8-0.5}$	$0.16^{+0.05+0.10+0.02}_{-0.04-0.05-0.01}$	$0.76\pm0.26\pm0.27\pm0.17$
$BF(\eta\bar{K}^0)$	···	0.97 ± 0.16	$0.75^{+1.10+0.51}_{-0.35-0.22}$	$0.11^{+0.05+0.06}_{-0.03-0.03}\pm0.01$	$0.80\pm0.48\pm0.29\pm0.18$
$BF(\eta'\bar{K}^0)$	···	3.94 ± 0.39	$2.8^{+2.5+1.1}_{-1.0-0.8}$	$0.72^{+0.20+0.28+0.11}_{-0.16-0.17-0.05}$	$4.5\pm1.5\pm0.4\pm0.5$
$BF(K^+K^-)$	24.5 ± 1.8	17.90 ± 2.98	$25.2^{+12.7+12.5}_{-7.2-9.1}$	$13.6^{+4.2+7.5+0.7}_{-3.2-4.1-0.2}$	$18.2\pm6.7\pm1.1\pm0.5$
$BF(K^0\bar{K}^0)$	<66	17.48 ± 2.36	$26.1^{+13.5+12.9}_{-8.1-9.4}$	$15.6^{+5.0+8.3+0.0}_{-3.8-4.7-0.0}$	$17.7\pm6.6\pm0.5\pm0.6$
$BF(\pi^+\pi^-)$	0.73 ± 0.14	0.80 ± 0.55	$0.26\pm0.00^{+0.10}_{-0.09}$	$0.57^{+0.16+0.09+0.01}_{-0.13-0.10-0.00}$	···
$BF(\pi^0\pi^0)$	···	0.40 ± 0.27	$0.13\pm0.0\pm0.05$	$0.28^{+0.08+0.04+0.01}_{-0.07-0.05-0.00}$	···
$BF(\eta\pi^0)$	···	0.12 ± 0.07	$0.05^{+0.03+0.02}_{-0.01-0.01}$	$0.05\pm0.02\pm0.01\pm0.00$	$0.014\pm0.004\pm0.005\pm0.004$
$BF(\eta'\pi^0)$	···	0.12 ± 0.06	$0.04^{+0.01+0.01}_{-0.00-0.00}$	$0.11^{+0.05+0.02}_{-0.03-0.01}\pm0.00$	$0.006\pm0.003\pm0.002^{+0.064}_{-0.006}$
$BF(\eta\eta)$	···	8.24 ± 1.53	$10.9^{+6.3+5.7}_{-4.0-4.2}$	$8.0^{+2.6+4.7}_{-1.9-2.5}\pm0.0$	$7.1\pm6.4\pm0.2\pm0.8$
$BF(\eta\eta')$	···	33.47 ± 3.64	$41.2^{+27.3+17.8}_{-12.9-13.1}$	$21.0^{+6.0+10.0}_{-4.6-5.6}\pm0.0$	$24.0\pm13.6\pm1.4\pm2.7$
$BF(\eta'\eta')$	···	41.48 ± 6.25	$47.9^{+41.6+20.9}_{-17.1-15.3}$	$14.0^{+3.2+6.2}_{-2.7-3.9}\pm0.0$	$44.3\pm19.7\pm2.3\pm17.1$
$A_{CP}(\pi^+K^-)$	0.26 ± 0.04	0.266 ± 0.033	$0.207^{+0.050+0.039}_{-0.030-0.088}$	$0.241^{+0.039+0.033+0.023}_{-0.036-0.030-0.012}$	$0.20\pm0.17\pm0.19\pm0.05$
$\mathcal{A}(\pi^0K_S)$	···	0.724 ± 0.054	$0.363^{+0.174+0.266}_{-0.182-0.243}$	$0.594^{+0.018+0.074+0.022}_{-0.040-0.113-0.035}$	$-0.58\pm0.39\pm0.39\pm0.13$
$\mathcal{A}(\eta K_S)$	···	0.452 ± 0.057	$0.334^{+0.228+0.297}_{-0.238-0.216}$	$0.564^{+0.029+0.068+0.031}_{-0.034-0.080-0.034}$	$-0.56\pm0.46\pm0.14\pm0.06$
$\mathcal{A}(\eta' K_S)$	···	-0.367 ± 0.089	$-0.493^{+0.062+0.160}_{-0.090-0.130}$	$-0.199^{+0.016+0.051+0.014}_{-0.014-0.050-0.009}$	$-0.14\pm0.07\pm0.16\pm0.02$
$\mathcal{A}(K^+K^-)$	-0.14 ± 0.11	-0.090 ± 0.021	$-0.077^{+0.016+0.040}_{-0.012-0.051}$	$-0.233^{+0.009+0.049+0.008}_{-0.002-0.044-0.011}$	$-0.06\pm0.05\pm0.06\pm0.02$
$\mathcal{A}(K^0\bar{K}^0)$	···	-0.075 ± 0.035	$0.0040\pm0.0004^{+0.0010}_{-0.0004}$	0	<0.1
$\mathcal{A}(\pi^+\pi^-)$	···	-0.001 ± 0.110	0	$-0.012^{+0.001}_{-0.004}\pm0.012\pm0.001$	···
$\mathcal{A}(\pi^0\pi^0)$	···	-0.001 ± 0.110	0	$-0.012^{+0.001}_{-0.004}\pm0.012\pm0.001$	···
$\mathcal{A}(\eta\pi^0)$	···	-0.165 ± 0.292	$0.961^{+0.016+0.018}_{-0.143-0.771}$	$-0.004^{+0.006}_{-0.007}\pm0.022\pm0.000$	···
$\mathcal{A}(\eta'\pi^0)$	···	0.259 ± 0.335	$0.429^{+0.023+0.310}_{-0.081-0.409}$	$0.206^{+0.000+0.020+0.028}_{-0.007-0.025-0.012}$	···
$\mathcal{A}(\eta\eta)$	···	-0.116 ± 0.018	$-0.050^{+0.015+0.038}_{-0.025-0.028}$	$-0.006\pm0.002^{+0.006+0.000}_{-0.005-0.001}$	$0.079\pm0.049\pm0.027\pm0.015$
$\mathcal{A}(\eta\eta')$	···	-0.009 ± 0.003	$-0.006^{+0.003+0.005}_{-0.004-0.005}$	$-0.013\pm0.000^{+0.001}_{-0.002}\pm0.001$	$0.0004\pm0.0014\pm0.0039\pm0.0043$
$\mathcal{A}(\eta'\eta')$	···	0.016 ± 0.009	$0.032^{+0.008+0.010}_{-0.006-0.012}$	$0.019\pm0.002^{+0.003+0.002}_{-0.004-0.001}$	$0.009\pm0.004\pm0.006\pm0.019$
$\mathcal{S}(\pi^0K_S)$	···	0.302 ± 0.080	$0.08^{+0.29+0.23}_{-0.27-0.26}$	$-0.61^{+0.08+0.23+0.01}_{-0.06-0.19-0.03}$	$-0.16\pm0.41\pm0.33\pm0.17$
$\mathcal{S}(\eta K_S)$	···	0.787 ± 0.042	$0.26^{+0.33+0.21}_{-0.44-0.30}$	$-0.43^{+0.05+0.22+0.02}_{-0.04-0.21-0.03}$	$0.82\pm0.32\pm0.11\pm0.04$
$\mathcal{S}(\eta' K_S)$	···	0.191 ± 0.090	$0.08^{+0.21+0.20}_{-0.17-0.16}$	$-0.68^{+0.01+0.06}_{-0.02-0.05}\pm0.00$	$0.38\pm0.08\pm0.10\pm0.04$
$\mathcal{S}(K^+K^-)$	0.30 ± 0.13	0.140 ± 0.030	$0.22^{+0.04+0.05}_{-0.05-0.05}$	$0.28\pm0.03\pm0.04^{+0.02}_{-0.01}$	$0.19\pm0.04\pm0.04\pm0.01$
$\mathcal{S}(K^0\bar{K}^0)$	···	-0.039 ± 0.001	$0.004\pm0.0^{+0.002}_{-0.001}$	0.04	···
$\mathcal{S}(\pi^+\pi^-)$	···	0.114 ± 0.061	$0.15\pm0.00\pm0$	$0.14^{+0.02+0.08+0.09}_{-0.00-0.02-0.05}$	···
$\mathcal{S}(\pi^0\pi^0)$	···	0.114 ± 0.061	$0.15\pm0.00\pm0$	$0.14^{+0.02+0.08+0.09}_{-0.00-0.02-0.05}$	···
$\mathcal{S}(\eta\pi^0)$	···	0.836 ± 0.198	$0.26^{+0.06+0.46}_{-0.23-0.47}$	$0.17\pm0.04^{+0.10}_{-0.12}\pm0.01$	$0.45\pm0.14\pm0.42\pm0.30$
$\mathcal{S}(\eta'\pi^0)$	···	0.953 ± 0.116	$0.88^{+0.03+0.04}_{-0.15-0.29}$	$-0.17^{+0.00+0.07+0.05}_{-0.01-0.08-0.05}$	···
$\mathcal{S}(\eta\eta)$	···	-0.095 ± 0.020	$-0.07^{+0.03+0.04}_{-0.06-0.05}$	$0.03\pm0.00\pm0.01\pm0.00$	$-0.026\pm0.040\pm0.030\pm0.014$
$\mathcal{S}(\eta\eta')$	···	-0.036 ± 0.007	$-0.01^{+0.00}_{-0.01}\pm0.00$	$0.04\pm0.00\pm0.00\pm0.00$	$0.041\pm0.004\pm0.002\pm0.051$
$\mathcal{S}(\eta'\eta')$	···	0.028 ± 0.009	$0.04\pm0.01\pm0.01$	$0.04\pm0.00\pm0.01\pm0.00$	$0.049\pm0.005\pm0.005\pm0.031$

$B \to VP, \Delta S = 0$

TABLE IX. Same as Table I but for strangeness-conserving $B \to VP$ decays.

Mode		Flavor amplitude	BF	A_{CP}
$B^+ \to$	$\bar{K}^{*0}K^+$	p_P	< 1.1	$\cdots$
	$K^{*+}\bar{K}^0$	p_V	$\cdots$	$\cdots$
	$\rho^0\pi^+$	$-\frac{1}{\sqrt{2}}(t_V + c_P + p_V - p_P)$	$8.3^{+1.2}_{-1.3}$	$0.18^{+0.09*}_{-0.17}$
	$\rho^+\pi^0$	$-\frac{1}{\sqrt{2}}(t_P + c_V + p_P - p_V)$	$10.9^{+1.4}_{-1.5}$	0.02 ± 0.11
	$\rho^+\eta$	$\frac{c_\phi}{\sqrt{2}}[t_P + c_V + p_P + p_V + (-\sqrt{2}t_\phi + 2)s_V]$	6.9 ± 1.0 (2.06)	0.11 ± 0.11
	$\rho^+\eta'$	$\frac{s_\phi}{\sqrt{2}}[t_P + c_V + p_P + p_V + (\frac{\sqrt{2}}{t_\phi} + 2)s_V]$	$9.8^{+2.1}_{-2.0}$	0.26 ± 0.17
	$\omega\pi^+$	$\frac{1}{\sqrt{2}}(t_V + c_P + p_P + p_V + 2s_P)$	6.9 ± 0.5	-0.02 ± 0.06
	$\phi\pi^+$	s_P	< 0.15 [18]	$\cdots$
$B^0 \to$	$\bar{K}^{*0}K^0$	p_P	$\cdots$	$\cdots$
	$K^{*0}\bar{K}^0$	p_V	< 1.9	$\cdots$
	$\rho^-\pi^+$	$-(t_V + p_V + e_P)$	8.4 ± 1.1	-0.07 ± 0.09 0.05 ± 0.08
	$\rho^+\pi^-$	$-(t_P + p_P + e_V)$	14.6 ± 1.6	0.13 ± 0.06 0.07 ± 0.14
	$\rho^0\pi^0$	$-\frac{1}{2}(c_P + c_V - p_P - p_V - e_P - e_V)$	2.0 ± 0.5 (1.05)	-0.27 ± 0.24 -0.23 ± 0.34
	$\rho^0\eta$	$-\frac{c_\phi}{2}[c_P - c_V - p_P - p_V + (\sqrt{2}t_\phi - 2)s_V + e_P + e_V]$	< 1.5	$\cdots$
	$\rho^0\eta'$	$-\frac{s_\phi}{2}[c_P - c_V - p_P - p_V + (-\frac{\sqrt{2}}{t_\phi} - 2)s_V + e_P + e_V]$	< 1.3	$\cdots$
	$\omega\pi^0$	$\frac{1}{2}(c_P - c_V + p_P + p_V + 2s_P - e_P - e_V)$	< 0.5	$\cdots$
	$\omega\eta$	$\frac{c_\phi}{2}[c_P + c_V + p_P + p_V + 2s_P + (-\sqrt{2}t_\phi + 2)s_V + e_P + e_V]$	< 1.4	$\cdots$
	$\omega\eta'$	$\frac{s_\phi}{2}[c_P + c_V + p_P + p_V + 2s_P + (\frac{\sqrt{2}}{t_\phi} + 2)s_V + e_P + e_V]$	< 1.8	$\cdots$
	$\phi\pi^0$	$\frac{1}{\sqrt{2}}s_P$	< 0.15	$\cdots$
	$\phi\eta$	$\frac{c_\phi}{\sqrt{2}}s_P$	< 0.5	$\cdots$
	$\phi\eta'$	$\frac{s_\phi}{\sqrt{2}}s_P$	< 0.5	$\cdots$
	$K^{*-}K^+$	$-e_P$	$\cdots$	$\cdots$
	$K^{*+}K^-$	$-e_V$	$\cdots$	$\cdots$
	$K^{*\pm}K^\mp$		< 0.4 [19]	$\cdots$
$B_s^0 \to$	$\bar{K}^{*0}\pi^0$	$-\frac{1}{\sqrt{2}}(c_V - p_V)$	$\cdots$	$\cdots$
	$K^{*-}\pi^+$	$-(t_V + p_V)$	$3.3 \pm 1.2^*$ [19]	$\cdots$
	ρ^+K^-	$-(t_P + p_P)$	$\cdots$	$\cdots$
	$\rho^0\bar{K}^0$	$-\frac{1}{\sqrt{2}}(c_P - p_P)$	$\cdots$	$\cdots$
	$\bar{K}^{*0}\eta$	$\frac{c_\phi}{\sqrt{2}}[c_V - \sqrt{2}t_\phi p_P + p_V + (-\sqrt{2}t_\phi + 2)s_V]$	$\cdots$	$\cdots$
	$\bar{K}^{*0}\eta'$	$\frac{s_\phi}{\sqrt{2}}[c_V + \frac{\sqrt{2}}{t_\phi}p_P + p_V + (\frac{\sqrt{2}}{t_\phi} + 2)s_V]$	$\cdots$	$\cdots$
	$\omega\bar{K}^0$	$\frac{1}{\sqrt{2}}(c_P + p_P + 2s_P)$	$\cdots$	$\cdots$
	$\phi\bar{K}^0$	$p_V + s_P$	$\cdots$	$\cdots$

$B \to VP, |\Delta S| = 1$

TABLE X. Same as Table I but for strangeness-changing $B \to VP$ decays.

Mode		Flavor amplitude	BF	A_{CP}
$B^+ \to$	$K^{*0}\pi^+$	p'_P	10.1 ± 0.9 (1.28) [22]	-0.15 ± 0.07 [22]
	$K^{*+}\pi^0$	$-\frac{1}{\sqrt{2}}(t'_P + c'_V + p'_P)$	9.2 ± 1.5 [22]	-0.52 ± 0.15 [22]
	$\rho^0 K^+$	$-\frac{1}{\sqrt{2}}(t'_V + c'_P + P'_V)$	$3.81^{+0.48}_{-0.46}$	0.37 ± 0.11
	$\rho^+ K^0$	p'_V	9.4 ± 3.2 [22]	0.21 ± 0.36 [22]
	$K^{*+}\eta$	$\frac{c_\phi}{\sqrt{2}}[t'_P + c'_V + p'_P - \sqrt{2}t_\phi p'_V + (-\sqrt{2}t_\phi + 2)s'_V]$	19.3 ± 1.6	0.02 ± 0.06
	$K^{*+}\eta'$	$\frac{s_\phi}{\sqrt{2}}[t'_P + c'_V + p'_P + \frac{\sqrt{2}}{t_\phi}p'_V + (\frac{\sqrt{2}}{t_\phi} + 2)s'_V]$	$5.0^{+1.8}_{-1.6}$	-0.26 ± 0.27
	ωK^+	$\frac{1}{\sqrt{2}}(t'_V + c'_P + p'_V + 2s'_P)$	6.5 ± 0.4 (1.11) [20]	-0.02 ± 0.04 [20]
	ϕK^+	$p'_P + s'_P$	8.8 ± 0.5 (1.15)	0.04 ± 0.02 (1.26) [18]
$B^0 \to$	$K^{*+}\pi^-$	$-(t'_P + p'_P)$	8.5 ± 0.7	-0.23 ± 0.06
	$K^{*0}\pi^0$	$\frac{1}{\sqrt{2}}(c'_V - p'_P)$	$2.5 \pm 0.6^*$ (2.52)	$-0.15 \pm 0.13^*$
	$\rho^- K^+$	$-(t'_V + p'_V)$	7.2 ± 0.9 (1.63)	0.20 ± 0.11
	$\rho^0 K^0$	$-\frac{1}{\sqrt{2}}(c'_P - p'_V)$	4.7 ± 0.7	0.06 ± 0.20
				$0.54^{+0.18}_{-0.21}$
	$K^{*0}\eta$	$\frac{c_\phi}{\sqrt{2}}[c'_V + p'_P - \sqrt{2}t_\phi p'_V + (-\sqrt{2}t_\phi + 2)s'_V]$	15.9 ± 1.0	0.19 ± 0.05
	$K^{*0}\eta'$	$\frac{s_\phi}{\sqrt{2}}[c'_V + p'_P + \frac{\sqrt{2}}{t_\phi}p'_V + (\frac{\sqrt{2}}{t_\phi} + 2)s'_V]$	2.8 ± 0.6 [21]	-0.07 ± 0.18 [21]
	ωK^0	$\frac{1}{\sqrt{2}}(c'_P + p'_V + 2s'_P)$	4.8 ± 0.4 [20]	0.04 ± 0.14 (3.04)
				0.71 ± 0.21
	ϕK^0	$p'_P + s'_P$	$7.3^{+0.7}_{-0.6}$	-0.01 ± 0.14
				$0.74^{+0.11}_{-0.13}$ (1.04)
$B^0_s \to$	$K^{*+}K^-$	$-(t'_P + p'_P + e'_V)$		⋯
	$K^{*-}K^+$	$-(t'_V + p'_V + e'_P)$		⋯
	$K^{*\pm}K^\mp$		$12.7 \pm 2.7^*$ [19]	⋯
	$K^{*0}\bar{K}^0$	p'_P	⋯	⋯
	$\bar{K}^{*0}K^0$	p'_V	⋯	⋯
	$\rho^0\eta$	$\frac{s_\phi}{\sqrt{2}}c'_P - \frac{c_\phi}{2}(e'_P + e'_V)$	⋯	⋯
	$\rho^0\eta'$	$-\frac{c_\phi}{\sqrt{2}}c'_P - \frac{s_\phi}{2}(e'_P + e'_V)$	⋯	⋯
	$\omega\eta$	$-\frac{s_\phi}{\sqrt{2}}(c'_P + 2s'_P) + \frac{c_\phi}{2}(e'_P + e'_V)$	⋯	⋯
	$\omega\eta'$	$\frac{c_\phi}{\sqrt{2}}(c'_P + 2s'_P) + \frac{s_\phi}{2}(e'_P + e'_V)$	⋯	⋯
	$\phi\pi^0$	$-\frac{1}{\sqrt{2}}c'_V$	⋯	⋯
	$\phi\eta$	$-\frac{c_\phi}{\sqrt{2}}[-c'_V + \sqrt{2}t_\phi p'_P + \sqrt{2}t_\phi p'_V + \sqrt{2}t_\phi s'_P + (\sqrt{2}t_\phi - 2)s'_V]$	⋯	⋯
	$\phi\eta'$	$\frac{s_\phi}{\sqrt{2}}[c'_V + \frac{\sqrt{2}}{t_\phi}p'_P + \frac{\sqrt{2}}{t_\phi}p'_V + \frac{\sqrt{2}}{t_\phi}s'_P + (\frac{\sqrt{2}}{t_\phi} + 2)s'_V]$	⋯	⋯
	$\rho^+\pi^-$	$-e'_V$	⋯	⋯
	$\rho^-\pi^+$	$-e'_V$	⋯	⋯
	$\rho^0\pi^0$	$\frac{1}{2}(e'_P + e'_V)$	⋯	⋯
	$\omega\pi^0$	$-\frac{1}{2}(e'_P + e'_V)$	⋯	⋯

TABLE XIV. Predicted branching fractions (in units of 10^{-6}) of all the $B^{+,0}$ decays using the fit results of scheme B. All the predictions made by QCDF and SCET are taken from Ref. [25] and work 2 of Ref. [39], respectively. The pQCD predictions taken from Ref. [27] are for $S_e = -\pi/2$, with S_e being a strong phase induced by Glauber gluons. We have followed the prescription outlined in Sec. V to convert the $B^0 \to \rho^\pm \pi^\mp$ observables in Ref. [27] into the ones for $B^0 \to \rho^+\pi^-$ and $B^0 \to \rho^-\pi^+$.

Mode		Data	This work	QCDF	pQCD	SCET
$B^{+,0} \to$	$\bar{K}^{*0}K^+$	<1.1	0.46 ± 0.03	$0.80^{+0.20+0.31}_{-0.17-0.28}$	$0.32^{+0.12}_{-0.08}$ [40]	$0.51^{+0.18+0.07}_{-0.16-0.06}$
	$K^{*+}\bar{K}^0$	$\cdots$	0.31 ± 0.03	$0.46^{+0.37+0.42}_{-0.17-0.26}$	$0.21^{+0.14}_{-0.12}$ [40]	$0.51^{+0.21+0.08}_{-0.17-0.07}$
	$\rho^0\pi^+$	$8.3^{+1.2}_{-1.3}$	7.59 ± 1.41	$8.7^{+2.7+1.7}_{-1.3-1.4}$	~ 9.3 [27]	$7.9^{+0.2}_{-0.1} \pm 0.8$
	$\rho^+\pi^0$	$10.9^{+1.4}_{-1.5}$	12.15 ± 2.52	$11.8^{+1.8}_{-1.1} \pm 1.4$	~ 7.2 [27]	$11.4 \pm 0.6^{+1.1}_{-0.9}$
	$\rho^+\eta$	6.9 ± 1.0	5.26 ± 1.19	$8.3^{+1.0}_{-0.6} \pm 0.9$	$6.7^{+2.6}_{-1.9}$ [41]	$3.3^{+1.9}_{-1.6} \pm 0.3$
	$\rho^+\eta'$	$9.8^{+2.1}_{-2.0}$	5.66 ± 1.25	$5.6^{+0.9+0.8}_{-0.5-0.7}$	$4.6^{+1.6}_{-1.4}$ [41]	$0.44^{+3.18+0.06}_{-0.20-0.05}$
	$\omega\pi^+$	6.9 ± 0.5	7.03 ± 1.42	$6.7^{+2.1+1.3}_{-1.0-1.1}$	~ 6.1 [27]	$8.5 \pm 0.3 \pm 0.8$
	$\phi\pi^+$	<0.15	0.04 ± 0.02	≈ 0.043	$0.032^{+0.008-0.012}_{-0.007+0.018}$ [42]	≈ 0.003
	$\bar{K}^{*0}K^0$	$\cdots$	0.43 ± 0.02	$0.70^{+0.18+0.28}_{-0.15-0.25}$	$0.24 \pm 0.02^{+0.00+0.03+0.06}_{-0.01-0.04-0.04}$ [40]	$0.47^{+0.17+0.06}_{-0.14-0.05}$
	$K^{*0}\bar{K}^0$	<1.9	0.29 ± 0.03	$0.47^{+0.36+0.43}_{-0.17-0.27}$	$0.49^{+0.12+0.08+0.05+0.03}_{-0.08-0.02-0.04-0.01}$ [40]	$0.48^{+0.20+0.07}_{-0.16-0.06}$
	$\rho^-\pi^+$	8.4 ± 1.1	8.22 ± 1.06	$9.2^{+0.4+0.5}_{-0.7-0.7}$	~ 10.7 [27]	$6.6^{+0.2}_{-0.1} \pm 0.7$
	$\rho^+\pi^-$	14.6 ± 1.6	15.20 ± 1.52	$15.9^{+1.1+0.9}_{-1.5-1.1}$	~ 20.1 [27]	$10.2^{+0.4}_{-0.5} \pm 0.9$
	$\rho^0\pi^0$	2.0 ± 0.5	2.24 ± 0.93	$1.3^{+1.7+1.2}_{-0.6-0.6}$	~ 1.1 [27]	$1.5 \pm 0.1 \pm 0.1$
	$\rho^0\eta$	<1.5	0.54 ± 0.32	$0.10^{+0.02+0.04}_{-0.01-0.03}$	$0.13^{+0.13}_{-0.06}$ [41]	$0.14^{+0.33}_{-0.13} \pm 0.01$
	$\rho^0\eta'$	<1.3	0.63 ± 0.33	$0.09^{+0.10+0.07}_{-0.04-0.05}$	0.10 ± 0.05 [41]	$1.0^{+3.5}_{-0.9} \pm 0.1$
	$\omega\pi^0$	<0.5	1.02 ± 0.66	$0.01^{+0.02+0.04}_{-0.00-0.01}$	~ 0.85 [27]	$0.015^{+0.034}_{-0.000} \pm 0.002$
	$\omega\eta$	<1.4	1.12 ± 0.44	$0.85^{+0.65+0.40}_{-0.26-0.24}$	$0.71^{+0.37}_{-0.28}$ [41]	$1.4^{+0.8}_{-0.6} \pm 0.1$
	$\omega\eta'$	<1.8	1.24 ± 0.47	$0.59^{+0.50+0.33}_{-0.20-0.18}$	$0.55^{+0.31}_{-0.26}$ [41]	$3.1^{+4.9}_{-2.6} \pm 0.3$
	$\phi\pi^0$	<0.15	0.02 ± 0.01	$0.01^{+0.03+0.02}_{-0.01-0.01}$	$0.0068 \pm 0.0003^{-0.0007}_{+0.0010}$ [42]	≈ 0.001
	$\phi\eta$	<0.5	0.01 ± 0.01	≈ 0.005	$0.011^{+0.062}_{-0.009}$ [41]	≈ 0.0008
	$\phi\eta'$	<0.5	0.01 ± 0.01	≈ 0.004	$0.017^{+0.161}_{-0.010}$ [41]	≈ 0.0007
	$K^{*0}\pi^+$	10.1 ± 0.9	10.47 ± 0.60	$10.4^{+1.3+4.3}_{-1.5-3.9}$	$6.0^{+2.8}_{-1.5}$ [43]	$9.9^{+3.5+1.3}_{-3.0-1.1}$
	$K^{*+}\pi^0$	9.2 ± 1.5	9.79 ± 2.95	$6.7 \pm 0.7^{+2.4}_{-2.2}$	$4.3^{+5.0}_{-2.2}$ [43]	$6.5^{+1.9}_{-1.7} \pm 0.7$
	ρ^0K^+	$3.81^{+0.48}_{-0.46}$	3.97 ± 0.90	$3.5^{+2.9+2.9}_{-1.2-1.8}$	$5.1^{+4.1}_{-2.8}$ [43]	$4.6^{+1.8+0.7}_{-1.5-0.6}$
	ρ^+K^0	9.4 ± 3.2	7.09 ± 0.77	$7.8^{+6.3+7.3}_{-2.9-4.4}$	$8.7^{+6.8}_{-4.4}$ [43]	$10.1^{+4.0+1.5}_{-3.3-1.3}$
	$K^{*+}\eta$	19.3 ± 1.6	16.57 ± 2.58	$15.8^{+8.2+9.6}_{-4.2-7.3}$ [24]	$22.13^{+0.26}_{-0.27}$ [44]	$18.6^{+4.5+2.5}_{-4.8-2.2}$
	$K^{*+}\eta'$	$5.0^{+1.8}_{-1.6}$	3.43 ± 1.43	$1.6^{+2.1+3.7}_{-0.3-1.6}$ [24]	6.38 ± 0.26 [44]	$4.8^{+5.3+0.8}_{-3.7-0.6}$
	ωK^+	6.5 ± 0.4	6.43 ± 1.49	$4.8^{+4.4+3.5}_{-1.9-2.3}$	$10.6^{+10.4}_{-5.8}$ [43]	$5.9^{+2.1+0.8}_{-1.7-0.7}$
	ϕK^+	8.8 ± 0.5	8.34 ± 1.31	$8.8^{+2.8+4.7}_{-2.7-3.6}$	$7.8^{+5.9}_{-1.8}$ [43]	$8.6^{+3.2+1.2}_{-2.7-1.0}$
	$K^{*+}\pi^-$	8.5 ± 0.7	8.35 ± 0.50	$9.2 \pm 1.0^{+3.7}_{-3.3}$	$6.0^{+6.8}_{-2.6}$ [43]	$9.5^{+3.2+1.2}_{-2.8-1.1}$
	$K^{*0}\pi^0$	2.5 ± 0.6	3.89 ± 1.98	$3.5 \pm 0.4^{+1.6}_{-1.4}$	$2.0^{+1.2}_{-0.6}$ [43]	$3.7^{+1.4}_{-1.2} \pm 0.5$
	ρ^-K^+	7.2 ± 0.9	8.28 ± 0.80	$8.6^{+5.7+7.4}_{-2.8-4.5}$	$8.8^{+6.8}_{-4.5}$ [43]	$10.2^{+3.8+1.5}_{-3.2-1.2}$
	ρ^0K^0	4.7 ± 0.7	4.97 ± 1.14	$5.4^{+3.4+4.3}_{-1.7-2.8}$	$4.8^{+4.3}_{-2.3}$ [43]	$5.8^{+2.1+0.8}_{-1.8-0.7}$
	$K^{*0}\eta$	15.9 ± 1.0	16.34 ± 2.48	$15.7^{+7.7+9.6}_{-4.0-7.3}$ [24]	$22.31^{+0.28}_{-0.29}$ [44]	$16.5^{+4.1+2.3}_{-4.3-2.0}$
	$K^{*0}\eta'$	2.8 ± 0.6	3.14 ± 1.24	$1.5^{+1.8+3.5}_{-0.3-1.6}$ [24]	$3.35^{+0.29}_{-0.27}$ [44]	$4.0^{+4.7+0.7}_{-3.4-0.6}$
	ωK^0	4.8 ± 0.4	4.82 ± 1.26	$4.1^{+4.2+3.3}_{-1.7-2.2}$	$9.8^{+8.6}_{-4.9}$ [43]	$4.9^{+1.9+0.7}_{-1.6-0.6}$
	ϕK^0	$7.3^{+0.7}_{-0.6}$	7.72 ± 1.21	$8.1^{+2.6+4.4}_{-2.5-3.3}$	$7.3^{+5.4}_{-1.6}$ [43]	$8.0^{+3.0+1.1}_{-2.5-1.0}$

TABLE XV. Same as Table XIV but for CP asymmetries.

Mode	Data	This work	QCDF	pQCD	SCET
$B^{+,0} \to \bar{K}^{*0}K^+$	$\cdots$	0	$-0.089 \pm 0.011^{+0.028}_{-0.024}$	$-0.069^{+0.115}_{-0.103}$ [40]	$-0.044 \pm 0.041 \pm 0.002$
$K^{*+}\bar{K}^0$	$\cdots$	0	$-0.078^{+0.059+0.041}_{-0.041-0.100}$	$0.065^{+0.123}_{-0.114}$ [40]	$-0.012 \pm 0.017 \pm 0.001$
$\rho^0\pi^+$	$0.18^{+0.09}_{-0.17}$	-0.239 ± 0.084	$-0.098^{+0.034+0.114}_{-0.026-0.102}$	~ -0.31 [27]	$-0.192^{+0.155+0.017}_{-0.134-0.019}$
$\rho^+\pi^0$	0.02 ± 0.11	0.053 ± 0.094	$0.097^{+0.021+0.080}_{-0.031-0.103}$	~ 0.13 [27]	$0.123^{+0.094+0.009}_{-0.100-0.011}$
$\rho^+\eta$	0.11 ± 0.11	0.162 ± 0.072	$-0.085 \pm 0.004^{+0.065}_{-0.053}$	$0.019^{+0.001+0.002+0.001+0.006}_{-0.000-0.003-0.000-0.005}$ [41]	$-0.091^{+0.167+0.009}_{-0.158-0.008}$
$\rho^+\eta'$	0.26 ± 0.17	0.223 ± 0.137	$0.014^{+0.008+0.140}_{-0.022-0.117}$	$-0.250^{+0.004+0.041+0.008+0.021}_{-0.003-0.016-0.007-0.018}$ [41]	$-0.217^{+1.359+0.021}_{-0.343-0.017}$
$\omega\pi^+$	-0.02 ± 0.06	0.075 ± 0.067	$-0.132^{+0.032+0.120}_{-0.021-0.107}$	~ -0.18 [27]	$0.023^{+0.134}_{-0.132} \pm 0.002$
$\phi\pi^+$	$\cdots$	0	0	$-0.080^{+0.009+0.015}_{-0.010-0.001}$ [42]	
$\bar{K}^{*0}K^0$	$\cdots$	0	$-0.135^{+0.016+0.014}_{-0.017-0.023}$		$-0.044 \pm 0.041 \pm 0.002$
$K^{*0}\bar{K}^0$	$\cdots$	0	$-0.035^{+0.013+0.007}_{-0.017-0.020}$		$-0.012 \pm 0.017 \pm 0.001$
$\rho^-\pi^+$	-0.07 ± 0.09	-0.136 ± 0.053	$-0.227^{+0.009+0.082}_{-0.011-0.044}$	~ -0.27 [27]	$-0.124^{+0.176+0.011}_{-0.153-0.012}$
$\rho^+\pi^-$	0.13 ± 0.06	0.120 ± 0.027	$0.044 \pm 0.003^{+0.058}_{-0.068}$	~ 0.05 [27]	$0.108^{+0.094+0.009}_{-0.102-0.010}$
$\rho^0\pi^0$	-0.27 ± 0.24	-0.043 ± 0.121	$0.110^{+0.050+0.235}_{-0.057-0.288}$	~ 0.18 [27]	$-0.035^{+0.214}_{-0.203} \pm 0.003$
$\rho^0\eta$	$\cdots$	-0.264 ± 0.215	$0.862^{+0.037+0.104}_{-0.058-0.214}$	$-0.896^{+0.019+0.137+0.007+0.046}_{-0.009-0.039-0.001-0.090}$ [41]	$0.333^{+0.649+0.031}_{-0.634-0.028}$
$\rho^0\eta'$	$\cdots$	-0.440 ± 0.317	$0.535^{+0.045+0.395}_{-0.079-0.576}$	$-0.757^{+0.056+0.131+0.063+0.129}_{-0.048-0.070-0.040-0.099}$ [41]	$0.522^{+0.199+0.044}_{-0.806-0.041}$
$\omega\pi^0$	$\cdots$	-0.188 ± 0.185	$-0.170^{+0.554+0.986}_{-0.228-0.823}$	~ -0.12 [27]	$0.395^{+0.791+0.034}_{-1.855-0.031}$
$\omega\eta$	$\cdots$	0.054 ± 0.137	$-0.447^{+0.131+0.177}_{-0.099-0.116}$	$0.335^{+0.010+0.008+0.059+0.039}_{-0.014-0.046-0.068-0.044}$ [41]	$-0.096^{+0.178}_{-0.168} \pm 0.009$
$\omega\eta'$	$\cdots$	-0.005 ± 0.259	$-0.414^{+0.025+0.195}_{-0.024-0.144}$	$0.160^{+0.001+0.033+0.022+0.017}_{-0.009-0.039-0.032-0.020}$ [41]	$-0.272^{+0.181+0.024}_{-0.297-0.022}$
$\phi\pi^0$	$\cdots$	0	0	$-0.063^{-0.005}_{+0.007} \pm 0.025$ [42]	
$\phi\eta$	$\cdots$	0	0	0 [41]	
$\phi\eta'$	$\cdots$	0	0	0 [41]	
$K^{*0}\pi^+$	-0.15 ± 0.07	0	$0.004^{+0.013+0.043}_{-0.016-0.039}$	$-0.01^{+0.01}_{-0.00}$ [43]	0
$K^{*+}\pi^0$	-0.52 ± 0.15	-0.116 ± 0.092	$0.016^{+0.031+0.111}_{-0.017-0.144}$	$-0.32^{+0.21}_{-0.28}$ [43]	$-0.129^{+0.120}_{-0.122} \pm 0.008$
ρ^0K^+	0.37 ± 0.11	0.306 ± 0.100	$0.454^{+0.178+0.314}_{-0.194-0.232}$	$0.71^{+0.25}_{-0.35}$ [43]	$0.160^{+0.205+0.013}_{-0.224-0.016}$
ρ^+K^0	0.21 ± 0.36	0	$0.003^{+0.003+0.005}_{-0.003-0.002}$	0.01 ± 0.01 [43]	0
$K^{*+}\eta$	0.02 ± 0.06	-0.016 ± 0.037	$-0.101^{+0.039+0.065}_{-0.037-0.078}$ [24]	$-0.2457^{+0.0072}_{-0.0027}$ [44]	$-0.019^{+0.034}_{-0.036} \pm 0.001$
$K^{*+}\eta'$	-0.26 ± 0.27	-0.391 ± 0.162	$0.697^{+0.065+0.279}_{-0.386-0.485}$ [24]	$0.0460^{+0.0116}_{-0.0132}$ [44]	$0.026^{+0.267}_{-0.329} \pm 0.002$
ωK^+	-0.02 ± 0.04	0.010 ± 0.080	$0.221^{+0.137+0.140}_{-0.128-0.130}$	$0.32^{+0.15}_{-0.17}$ [43]	$0.123^{+0.166+0.008}_{-0.173-0.011}$
ϕK^+	0.04 ± 0.02	0	$0.006 \pm 0.001 \pm 0.001$	$0.01^{+0.00}_{-0.01}$ [43]	0
$K^{*+}\pi^-$	-0.23 ± 0.06	-0.217 ± 0.048	$-0.121 \pm 0.005^{+0.126}_{-0.160}$	$-0.60^{+0.32}_{-0.19}$ [43]	$-0.122^{+0.114}_{-0.113} \pm 0.008$
$K^{*0}\pi^0$	-0.15 ± 0.13	-0.332 ± 0.114	$-0.108^{+0.018+0.091}_{-0.028-0.063}$	$-0.11^{+0.07}_{-0.05}$ [43]	$0.054^{+0.048+0.004}_{-0.051-0.005}$
ρ^-K^+	0.20 ± 0.11	0.134 ± 0.053	$0.319^{+0.115+0.196}_{-0.110-0.127}$	$0.64^{+0.34}_{-0.30}$ [43]	$0.096^{+0.130+0.007}_{-0.135-0.009}$
ρ^0K^0	0.06 ± 0.20	0.069 ± 0.053	$0.087 \pm 0.012^{+0.087}_{-0.068}$	$0.07^{+0.08}_{-0.05}$ [43]	$-0.035 \pm 0.048^{+0.003}_{-0.002}$
$K^{*0}\eta$	0.19 ± 0.05	0.099 ± 0.028	$0.034 \pm 0.004^{+0.027}_{-0.024}$ [24]	0.00570 ± 0.00011 [44]	$-0.007^{+0.012+0.001}_{-0.013-0.000}$
$K^{*0}\eta'$	-0.07 ± 0.18	0.069 ± 0.152	$0.088^{+0.088+0.308}_{-0.107-0.341}$ [24]	-0.0130 ± 0.0008 [44]	$0.099^{+0.062}_{-0.043} \pm 0.009$
ωK^0	0.04 ± 0.14	-0.053 ± 0.055	$-0.047^{+0.018+0.055}_{-0.016-0.058}$	$-0.03^{+0.02}_{-0.04}$ [43]	$0.038^{+0.052}_{-0.054} \pm 0.003$
ϕK^0	-0.01 ± 0.14	0	$0.009^{+0.002+0.002}_{-0.001-0.001}$	$0.03^{+0.01}_{-0.02}$ [43]	0

B→VP, Predictions

TABLE XVI. Same as Table XIV but for the time-dependent *CP* asymmetry $\mathcal{S}$.

Mode		Data	This work	QCDF	pQCD	SCET
$B^{+,0} \to$	$\rho^-\pi^+$	0.05 ± 0.08	-0.024 ± 0.065		~ 0.06 [27]	
	$\rho^+\pi^-$	0.07 ± 0.14	-0.049 ± 0.074		~ -0.22 [27]	
	$\rho^0\pi^0$	-0.23 ± 0.34	-0.229 ± 0.112	$-0.24^{+0.15+0.20}_{-0.14-0.22}$	~ -0.30 [27]	$-0.19 \pm 0.14^{+0.10}_{-0.15}$
	$\rho^0\eta$	$\cdots$	-0.628 ± 0.196	$0.51^{+0.08+0.19}_{-0.07-0.32}$	$0.227 \pm 0.061^{+0.139+0.096+0.236}_{-0.218-0.125-0.265}$ [41]	$0.29^{+0.36+0.09}_{-0.44-0.15}$
	$\rho^0\eta'$	$\cdots$	-0.714 ± 0.252	$0.80^{+0.04+0.24}_{-0.09-0.43}$	$-0.490^{+0.019+0.160+0.018+0.186}_{-0.008-0.081-0.042-0.178}$ [41]	$0.38^{+0.22+0.09}_{-1.24-0.14}$
	$\omega\pi^0$	$\cdots$	-0.315 ± 0.195	$0.78^{+0.14+0.20}_{-0.20-1.39}$	~ -0.26 [27]	$0.72^{+0.36+0.07}_{-1.54-0.11}$
	$\omega\eta$	$\cdots$	-0.461 ± 0.113	$-0.16 \pm 0.13^{+0.17}_{-0.16}$	$0.390^{+0.003+0.506+0.059+0.029}_{-0.002-0.662-0.033-0.019}$ [41]	$-0.16^{+0.14+0.10}_{-0.15-0.15}$
	$\omega\eta'$	$\cdots$	-0.624 ± 0.120	$-0.28^{+0.14+0.16}_{-0.13-0.13}$	$0.770^{+0.004+0.220+0.009+0.003}_{-0.001-0.529-0.001-0.000}$ [41]	$-0.27^{+0.17+0.09}_{-0.33-0.14}$
	$\phi\pi^0$	$\cdots$	0			
	$\phi\eta$	$\cdots$	0			
	$\phi\eta'$	$\cdots$	0			
	ρ^0K^0	$0.54^{+0.18}_{-0.21}$	0.643 ± 0.036	$0.50^{+0.07+0.06}_{-0.14-0.12}$	$0.50^{+0.10}_{-0.06}$ [43]	$0.56^{+0.02}_{-0.03} \pm 0.01$
	ωK^0	0.71 ± 0.21	0.789 ± 0.028	$0.84 \pm 0.05^{+0.04}_{-0.06}$	$0.84^{+0.03}_{-0.07}$ [43]	$0.80 \pm 0.02 \pm 0.01$
	ϕK^0	$0.74^{+0.11}_{-0.13}$	0.718 ± 0.000	$0.692^{+0.003}_{-0.000} \pm 0.002$	0.71 ± 0.01 [43]	0.69

B→VP, Predictions

TABLE XVII. Predicted branching fractions in units of 10^{-6} for all the B_s decays using the fit results of scheme B. Predictions made by QCDF, pQCD, and SCET are obtained from Refs. [32,33], and [39] (work 2), respectively.

Mode		This work	QCD	pQCD	SCET
$B_s \to$	$\bar{K}^{*0}\pi^0$	3.07 ± 1.20	$0.89^{+0.80+0.84}_{-0.34-0.35}$	$0.07^{+0.02+0.04}_{-0.01-0.02} \pm 0.01$	$1.07^{+0.16+0.10}_{-0.15-0.09}$
	$K^{*-}\pi^+$	7.92 ± 1.02	$7.8^{+0.4+0.5}_{-0.7-0.7}$	$7.6^{+2.9+0.4+0.5}_{-2.2-0.5-0.3}$	$6.6^{+0.2}_{-0.1} \pm 0.7$
	ρ^+K^-	14.63 ± 1.46	$14.7^{+1.4+0.9}_{-1.9-1.3}$	$17.8^{+7.7+1.3+1.1}_{-5.6-1.6-0.9}$	$10.2^{+0.4}_{-0.5} \pm 0.9$
	$\rho^0\bar{K}^0$	0.56 ± 0.24	$1.9^{+2.9+1.4}_{-0.9-0.6}$	$0.08 \pm 0.02^{+0.07+0.01}_{-0.03-0.00}$	$0.81^{+0.05+0.08}_{-0.02-0.09}$
	$\bar{K}^{*0}\eta$	1.44 ± 0.54	$0.56^{+0.33+0.35}_{-0.14-0.17}$	$0.17 \pm 0.04^{+0.10+0.03}_{-0.06-0.01}$	$0.62 \pm 0.14^{+0.07}_{-0.08}$
	$\bar{K}^{*0}\eta'$	1.65 ± 0.60	$0.90^{+0.69+0.72}_{-0.30-0.41}$	$0.09 \pm 0.02^{+0.03}_{-0.02} \pm 0.01$	$0.87^{+0.35+0.10}_{-0.32-0.08}$
	$\omega\bar{K}^0$	0.58 ± 0.25	$1.6^{+2.2+1.0}_{-0.7-0.5}$	$0.15^{+0.05+0.07+0.02}_{-0.04-0.03-0.01}$	$1.3 \pm 0.1 \pm 0.1$
	$\phi\bar{K}^0$	0.41 ± 0.07	$0.6^{+0.5+0.4}_{-0.2-0.3}$	$0.16^{+0.04+0.09+0.02}_{-0.03-0.04-0.01}$	$0.54^{+0.21+0.08}_{-0.17-0.07}$
	$K^{*+}K^-$	8.03 ± 0.48	$10.3^{+3.0+4.8}_{-2.2-4.2}$	$6.0^{+1.7+1.7+0.7}_{-1.5-1.2-0.3}$	$9.5^{+3.2+1.2}_{-2.8-1.1}$
	$K^{*-}K^+$	7.98 ± 0.77	$11.3^{+7.0+8.1}_{-3.5-5.1}$	$4.7^{+1.1+2.5}_{-0.8-1.4} \pm 0.0$	$10.2^{+3.8+1.5}_{-3.2-1.2}$
	$K^{*0}\bar{K}^0$	9.33 ± 0.54	$10.5^{+3.4+5.1}_{-2.8-4.5}$	$7.3^{+2.5+2.1}_{-1.7-1.3} \pm 0.0$	$9.3^{+3.2+1.2}_{-2.8-1.0}$
	$\bar{K}^{*0}K^0$	6.32 ± 0.68	$10.1^{+7.5+7.7}_{-3.6-4.8}$	$4.3 \pm 0.7^{+2.2}_{-1.4} \pm 0.0$	$9.4^{+3.7+1.4}_{-3.1-1.2}$
	$\rho^0\eta$	0.34 ± 0.21	$0.10^{+0.02+0.02}_{-0.01-0.01}$	$0.06^{+0.03}_{-0.02} \pm 0.01 \pm 0.00$	$0.06^{+0.03}_{-0.02} \pm 0.00$
	$\rho^0\eta'$	0.31 ± 0.19	$0.16^{+0.06}_{-0.02} \pm 0.03$	$0.13^{+0.06}_{-0.04} \pm 0.02^{+0.00}_{-0.01}$	$0.14^{+0.24}_{-0.11} \pm 0.01$
	$\omega\eta$	0.15 ± 0.16	$0.03^{+0.12+0.06}_{-0.02-0.01}$	$0.04^{+0.03+0.05}_{-0.01-0.02} \pm 0.00$	$0.007^{+0.011}_{-0.002} \pm 0.001$
	$\omega\eta'$	0.14 ± 0.14	$0.15^{+0.27+0.15}_{-0.08-0.06}$	$0.44^{+0.18+0.15+0.00}_{-0.13-0.14-0.01}$	$0.20^{+0.34}_{-0.17} \pm 0.02$
	$\phi\pi^0$	1.94 ± 1.14	$0.12^{+0.02+0.04}_{-0.01-0.02}$	$0.16^{+0.06}_{-0.05} \pm 0.02 \pm 0.00$	$0.09 \pm 0.00 \pm 0.01$
	$\phi\eta$	0.39 ± 0.39	$1.0^{+1.3+3.0}_{-0.1-1.2}$	$3.6^{+1.5+0.8}_{-1.0-0.6} \pm 0.0$	$0.94^{+1.89+0.16}_{-0.97-0.13}$
	$\phi\eta'$	5.48 ± 1.84	$2.2^{+4.5+8.3}_{-1.9-2.5}$	$0.19^{+0.06+0.19}_{-0.01-0.13} \pm 0.00$	$4.3^{+5.2+0.7}_{-3.6-0.6}$

TABLE XVIII. Same as Table XVII but for CP asymmetries. Whenever there exists more than one line, the upper line is $\mathcal{A}$, while the second line is $\mathcal{S}$.

Mode		This work	QCDF	pQCD	SCET
$B_s \to$	$\bar{K}^{*0}\pi^0$	-0.423 ± 0.158	$-0.263^{+0.108+0.422}_{-0.109-0.367}$	$-0.471^{+0.074+0.355+0.029}_{-0.087-0.298-0.070}$	$0.134^{+0.186+0.008}_{-0.188-0.012}$
	$K^{*-}\pi^+$	-0.136 ± 0.053	$-0.240^{+0.012+0.077}_{-0.015-0.039}$	$-0.190^{+0.025+0.027+0.009}_{-0.026-0.034-0.014}$	$-0.124^{+0.175+0.011}_{-0.153-0.012}$
	ρ^+K^-	0.120 ± 0.027	$0.117^{+0.035+0.101}_{-0.021-0.116}$	$0.142^{+0.024+0.023+0.012}_{-0.022-0.016-0.007}$	$0.108^{+0.094+0.009}_{-0.102-0.010}$
	$\rho^0\bar{K}^0$	-0.124 ± 0.453	$0.289^{+0.146+0.250}_{-0.145-0.237}$	$0.734^{+0.064+0.162+0.022}_{-0.117-0.478-0.039}$	$-0.325^{+0.307+0.027}_{-0.234-0.029}$
		-0.348 ± 0.285	$0.29^{+0.23+0.16}_{-0.24-0.21}$	$-0.57^{+0.22+0.51+0.02}_{-0.17-0.39-0.05}$	$-0.03^{+0.22+0.17}_{-0.17-0.12}$
	$\bar{K}^{*0}\eta$	0.828 ± 0.123	$0.400^{+0.111+0.531}_{-0.192-0.645}$	$0.512^{+0.062+0.141+0.020}_{-0.064-0.124-0.033}$	$-0.627^{+0.281+0.026}_{-0.225-0.039}$
	$\bar{K}^{*0}\eta'$	-0.408 ± 0.273	$-0.625^{+0.060+0.247}_{-0.055-0.202}$	$-0.511^{+0.046+0.150+0.032}_{-0.066-0.182-0.041}$	$-0.321^{+0.228+0.026}_{-0.232-0.017}$
	$\omega\bar{K}^0$	-0.029 ± 0.436	$-0.320^{+0.189+0.236}_{-0.175-0.262}$	$-0.521^{+0.032+0.227+0.032}_{-0.000-0.151-0.020}$	$0.182^{+0.164+0.012}_{-0.170-0.017}$
		0.928 ± 0.110	$0.92^{+0.03+0.08}_{-0.07-0.15}$	$-0.63 \pm 0.09^{+0.28+0.01}_{-0.11-0.02}$	$0.98^{+0.02+0.00}_{-0.04-0.01}$
	$\phi\bar{K}^0$	0	$-0.032^{+0.012+0.006}_{-0.014-0.013}$	0	$-0.022^{+0.030}_{-0.029} \pm 0.001$
		-0.692 ± 0.000	$-0.69 \pm 0.01 \pm 0.01$	-0.72	$-0.13 \pm 0.02 \pm 0.01$
	$K^{*+}K^-$	-0.217 ± 0.048	$-0.110^{+0.005+0.140}_{-0.004-0.188}$	$-0.366 \pm 0.023^{+0.028+0.013}_{-0.035-0.012}$	$-0.123^{+0.114}_{-0.113} \pm 0.008$
	$K^{*-}K^+$	0.134 ± 0.053	$0.255^{+0.092+0.163}_{-0.088-0.113}$	$0.553^{+0.044+0.085+0.051}_{-0.049-0.098-0.025}$	$0.096^{+0.130+0.007}_{-0.135-0.009}$
	$K^{*0}\bar{K}^0$	0	$0.0049^{+0.0008+0.0009}_{-0.0007-0.0012}$	0	0
	$\bar{K}^{*0}K^0$	0	$0.0010^{+0.0008+0.0005}_{-0.0007-0.0002}$	0	0
	$\rho^0\eta$	0.323 ± 0.136	$0.757^{+0.153+0.133}_{-0.176-0.375}$	$-0.092^{+0.010+0.028+0.004}_{-0.004-0.027-0.007}$	0
		-0.002 ± 0.168	$0.35^{+0.09+0.22}_{-0.16-0.40}$	$0.15 \pm 0.06^{+0.14}_{-0.16} \pm 0.01$	$0.60^{+0.30}_{-0.53} \pm 0.03$
	$\rho^0\eta'$	0.323 ± 0.136	$0.874^{+0.034+0.057}_{-0.106-0.303}$	$0.258^{+0.013+0.028+0.034}_{-0.020-0.036-0.015}$	0
		-0.002 ± 0.168	$0.45^{+0.05+0.30}_{-0.13-0.35}$	$-0.16 \pm 0.00^{+0.10+0.04}_{-0.12-0.05}$	$-0.41 \pm 0.75^{+0.10}_{-0.15}$
	$\omega\eta$	-0.432 ± 0.271	$-0.648^{+0.244+0.440}_{-0.034-0.316}$	$-0.167^{+0.058+0.154+0.008}_{-0.032-0.191-0.017}$	0
		-0.238 ± 0.296	$-0.76^{+0.16+0.52}_{-0.03-0.22}$	$-0.02^{+0.01+0.02}_{-0.03-0.08} \pm 0.00$	$0.93^{+0.04+0.03}_{-0.98-0.04}$
	$\omega\eta'$	-0.432 ± 0.271	$-0.394^{+0.044+0.104}_{-0.030-0.117}$	$0.077^{+0.004+0.045+0.094}_{-0.001-0.042-0.004}$	0
		-0.238 ± 0.296	$-0.84^{+0.06+0.04}_{-0.05-0.03}$	$-0.11^{+0.01}_{-0.00} \pm 0.04^{+0.02}_{-0.03}$	$-1.00^{+0.04+0.01}_{-0.00-0.00}$
	$\phi\pi^0$	0.073 ± 0.201	$0.822^{+0.109+0.090}_{-0.140-0.553}$	$0.133^{+0.003+0.021+0.015}_{-0.004-0.017-0.007}$	0
		0.439 ± 0.171	$0.40^{+0.04+0.32}_{-0.10-0.53}$	$-0.07 \pm 0.01^{+0.08+0.02}_{-0.09-0.03}$	$0.90 \pm 0.00^{+0.02}_{-0.03}$
	$\phi\eta$	0.428 ± 0.504	$-0.124^{+0.141+0.649}_{-0.057-0.398}$	$-0.018^{+0.000}_{-0.001} \pm 0.006^{+0.001}_{-0.002}$	$0.169^{+0.138}_{-0.183} \pm 0.016$
		0.534 ± 0.400	$0.21^{+0.08+0.61}_{-0.11-0.25}$	$-0.03^{+0.02+0.07+0.01}_{-0.01-0.20-0.02}$	$0.23^{+0.35}_{-0.16} \pm 0.02$
	$\phi\eta'$	0.043 ± 0.090	$0.139^{+0.154+0.285}_{-0.042-0.897}$	$0.078^{+0.015+0.012+0.001}_{-0.005-0.086-0.004}$	$0.078^{+0.050}_{-0.049} \pm 0.008$
		0.166 ± 0.057	$0.08^{+0.05+0.48}_{-0.06-0.81}$	$0.00 \pm 0.00 \pm 0.02 \pm 0.00$	$0.10^{+0.07}_{-0.05} \pm 0.01$