Analysis of charmless B decays in Factorization Assisted Topological Amplitude Approach

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Outline

- **Introduction/Motivation**
- **Factorization assisted topological diagram approach**
- Numerical results for charmless **hadronic B decays** and discussions
- **Summary**

Rich physics in hadronic B decays

- In principle, all hadronic physics should be calculated by QCD, provided you can renormalize the infinities and do all order calculations.
- Ultraviolet divergences → renormalization
- Infrared divergences? Infrared divergence in virtual corrections should be canceled by real emission
- In exclusive QCD processes → factorization

Factorization can only be proved in power expansion by operator product expansion. To achieve that, we need a hard scale Q

- In the certain order of 1/Q expansion, the hard dynamics characterized by Q factorize from the soft dynamics
- Hard dynamics is process-dependent, but calculable
- Soft dynamics are universal (process-independent) ⇨ predictive power of factorization theorem
- Factorization theorem holds up to all orders in α_s, but to certain power in 1/Q
- In B decays the hard scale Q is just the b quark mass

QCD-methods based on factorization work well for the leading power of $1/m_b$ expansion

Perturbative QCD approach based on k_T factorization
[Keum, Li, Sanda, 00' ; Lu, Ukai, Yang, 00']

collinear QCD Factorization approach
[Beneke, Buchalla, Neubert, Sachrajda, 99']

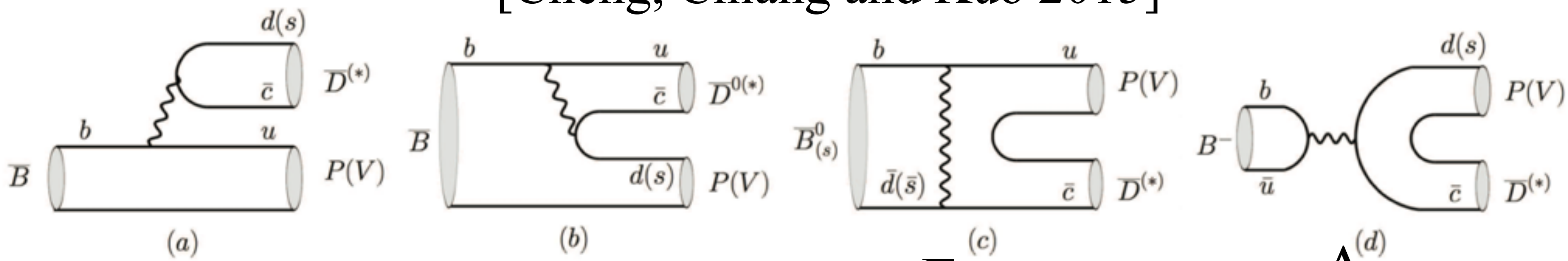
Soft-Collinear Effective Theory
[Bauer, Pirjol, Stewart, 01']

Unavailable for $1/m_b$ power corrections

- Work well for most of charmless B decays, except for ππ, πK puzzle etc.

Topological diagrammatic approach

[Cheng, Chiang and Kuo 2015]



T C E A

- Distinct by weak interaction and flavor flows with all strong interaction encoded, including non-perturbative ones. Model-independent
- Based on flavor SU(3) symmetry. Amplitudes with strong phases extracted from data. SU(3) breaking was lost.
- *PP*, *VP* and *PV* fitted separately, 13+19 = 32 parameters. Less predictive. Improved by FAT

Factorization assisted topological diagram approach first applied in hadronic D decays

[arXiv:1203.3120, PRD86 (2012) 036012]

Predictions of Direct CP asymmetries

Modes	A_{CP}(FSI)	A_{CP}(diagram)	$A_{CP}^{\rm tree}$	$A_{CP}^{\rm tot}$
$D^0 \to \pi^+\pi^-$	0.02 ± 0.01	0.86	0	0.58 ⬅
$D^0 \to K^+K^-$	0.13 ± 0.8	-0.48	0	-0.42 ⬅
$D^0 \to$				0.05
$D^0 \to$				1.38
$D^0 \to$				0.29
$D^0 \to$				1.53
$D^0 \to$				0.18
$D^0 \to$				0.94

First evidence of CP violation in charmed meson decays by LHCb, with 3.5 σ [arXiv:1112.0938]

$$\Delta A_{CP} \equiv A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$$
$$= [-0.82 \pm 0.21(\text{stat}) \pm 0.11(\text{syst})]\%,$$

Δ_{CP} = -1×10^{-3}

LHCb-PAPER-2013-003

LHCb-CONF-2013-003

LHCb combination

Semileptonic: $\Delta A_{CP} = (+0.49 \pm 0.30(stat.) \pm 0.14(syst.))\ \%$

Prompt: (preliminary) $\Delta A_{CP} = (-0.34 \pm 0.15(stat.) \pm 0.10(syst.))\ \%$

- The two measurement are compatible at the 3 % level

NEW *LHCb-PAPER-2015-055* *to be submitted to PRL*

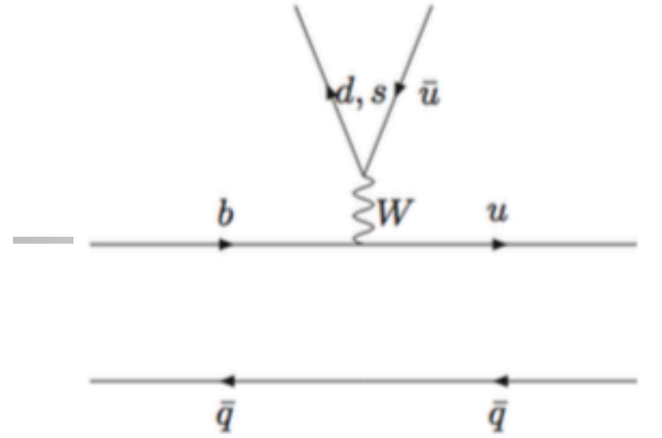
$\Delta A_{CP\ prompt} = (-0.10 \pm 0.08(stat) \pm 0.03(syst))\%$

compatible with the muon-tagged result
$\Delta A_{CP\ sec} = (+0.14 \pm 0.16(stat) \pm 0.08(syst))\%$ JHEP 07 (2014) 041

Both results are statistically and systematically uncorrelated

Tree topology diagram contributing to Charmless B decays

For the color favored diagram (T), it is proved factorization to all order of α_s expansion in soft-collinear effective theory,



(a) T

The decay amplitudes is just the decay constants and form factors times Wilson coeficients of four quark operators. The SU(3) breaking effect is automatically kept

$$T^{P_1P_2} = i\frac{G_F}{\sqrt{2}}V_{ub}V_{uq'}a_1(\mu)f_{p_2}(m_B^2 - m_{p_1}^2)F_0^{BP_1}(m_{p_2}^2),$$

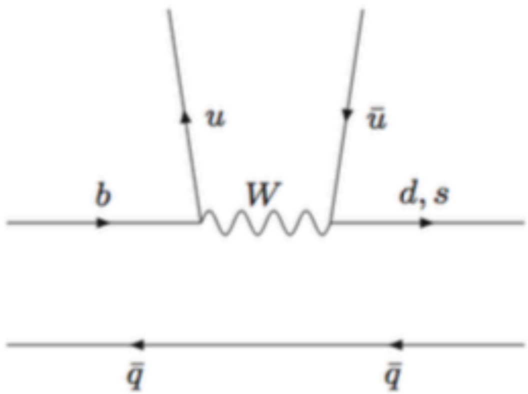
No free parameter

$$T^{PV} = \sqrt{2}G_F V_{ub}V_{uq'}a_1(\mu)f_V m_V F_1^{B-P}(m_V^2)(\varepsilon_V^* \cdot p_B),$$

$$T^{VP} = \sqrt{2}G_F V_{ub}V_{uq'}a_1(\mu)f_P m_V A_0^{B-V}(m_P^2)(\varepsilon_V^* \cdot p_B),$$

For other diagrams, we extract the amplitude and strong phase from experimental data by χ^2 fit

We factorize out the decay constants and form factor to keep the SU(3) breaking effect



(b) C

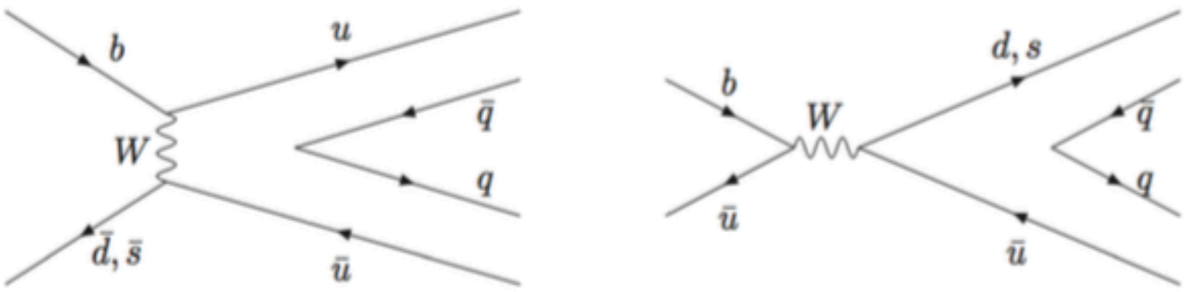
For the color suppressed tree diagram (C), we have two kinds of contributions

$$C^{P_1P_2} = i\frac{G_F}{\sqrt{2}} V_{ub} V_{uq'} \chi^{C} e^{i\phi^{C}} f_{P_2} (m_B^2 - m_{P_1}^2) F_0^{BP_1}(m_{P_2}^2),$$

$$C^{PV} = \sqrt{2} G_F V_{ub} V_{uq'} \chi^{C'} e^{i\phi^{C'}} f_V m_V F_1^{B-P}(m_V^2)(\varepsilon_V^* \cdot p_B),$$

$$C^{VP} = \sqrt{2} G_F V_{ub} V_{uq'} \chi^{C} e^{i\phi^{C}} f_P m_V A_0^{B-V}(m_P^2)(\varepsilon_V^* \cdot p_B),$$

For the annihilation type diagrams, we have one amplitude from W-exchange diagrams fitted from experimental data by χ^2 fit



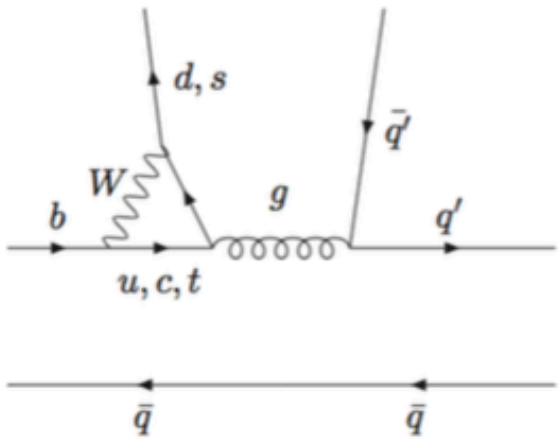
(c) E (d) A

$$E^{P_1P_2} = i\frac{G_F}{\sqrt{2}} V_{ub}V_{uq'}\chi^E \mathrm{e}^{i\phi^E} f_B m_B^2 (\frac{f_{p_1} f_{p_2}}{f_\pi^2}),$$

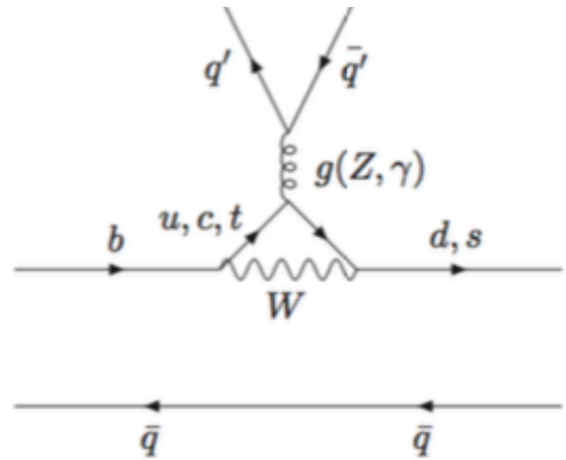
$$E^{PV,VP} = \sqrt{2} G_F V_{ub}V_{uq'}\chi^E \mathrm{e}^{i\phi^E}(\mu) f_B m_V (\frac{f_P f_V}{f_\pi^2})(\varepsilon_V^* \cdot p_B),$$

As discussed in conventional topological diagram approach, W-annihilation diagram contribution is negligible.

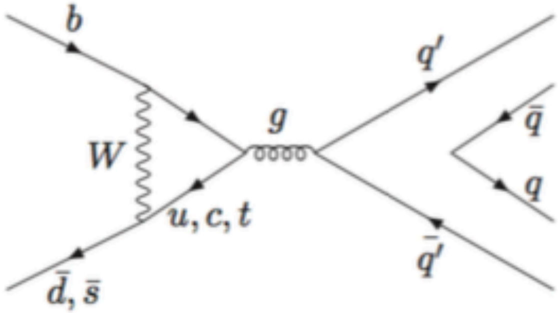
We also have four penguin type diagrams



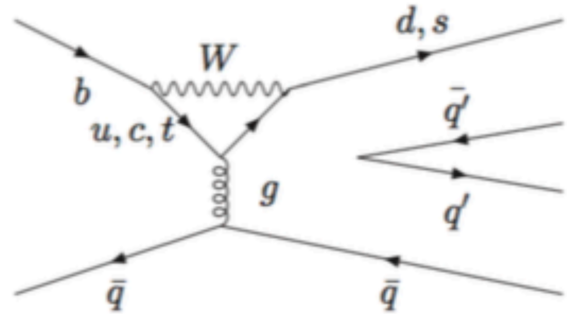
(a) P



(b) $P_C(P_{EW})$

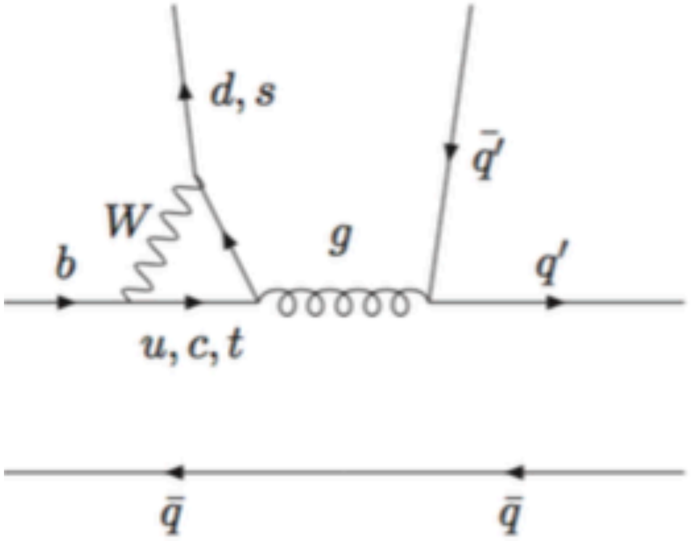


(c) P_E



(d) P_A

The penguin emission diagram(P) is the dominant diagram comparable with color favored tree (T).



(a) P

It is **approved factorization** in SCET, we can calculate without ambiguity. The additional **chiral enhanced** penguin of this diagram need to be fitted

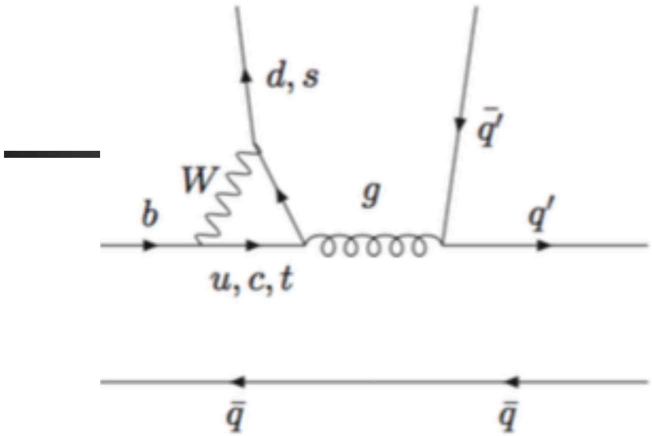
$$P^{PP} = -i\frac{G_F}{\sqrt{2}}V_{tb}V^*_{tq'}[a_4(\mu) + \chi^P e^{i\phi^P} r_\chi] f_{p_2}(m_B^2 - m_{p_1}^2)F_0^{BP_1}(m_{p_2}^2),$$

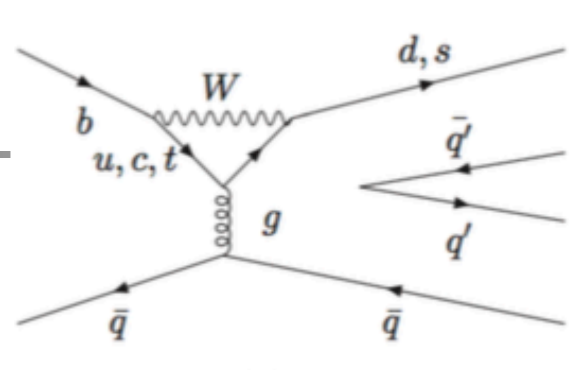
$$P^{PV} = -\sqrt{2}G_F V_{tb}V^*_{tq'} a_4(\mu) f_V m_V F_1^{B-P} m_V^2(\varepsilon_V^* \cdot p_B),$$

$$P^{VP} = -\sqrt{2}G_F V_{tb}V^*_{tq'}[a_4(\mu) - \chi^P e^{i\phi^P} r_\chi] f_P m_V A_0^{B-V}(m_P^2)(\varepsilon_V^* \cdot p_B).$$

However, this P is similar with penguin annihilation diagram P_A.

The difference is only at QCD not EW





(d) P_A

$$P^{PP} = -i\frac{G_F}{\sqrt{2}} V_{tb}V^*_{tq'}[a_4(\mu) + \chi^P e^{i\phi^P} r_\chi] f_{p_2}(m_B^2 - m_{p_1}^2) F_0^{BP_1}(m_{p_2}^2),$$

$$P^{PV} = -\sqrt{2} G_F V_{tb} V^*_{tq'} a_4(\mu) f_V m_V F_1^{B-P} m_V^2 (\varepsilon_V^* \cdot p_B),$$

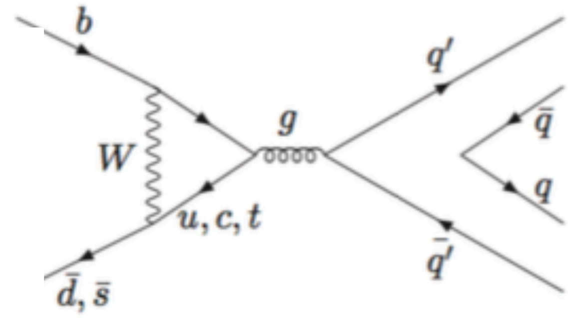
$$P^{VP} = -\sqrt{2} G_F V_{tb} V^*_{tq'} [a_4(\mu) - \chi^P e^{i\phi^P} r_\chi] f_P m_V A_0^{B-V}(m_P^2)(\varepsilon_V^* \cdot p_B).$$

The contribution of P_A can be included in χ^P, except for B→ PV decays, where we need two more parameters

$$P_A^{PV} = -\sqrt{2} G_F V_{tb} V^*_{tq'} \chi^{P_A} e^{i\phi^{P_A}} f_B m_V \left(\frac{f_P f_V}{f_\pi^2}\right)(\varepsilon_V^* \cdot p_B).$$

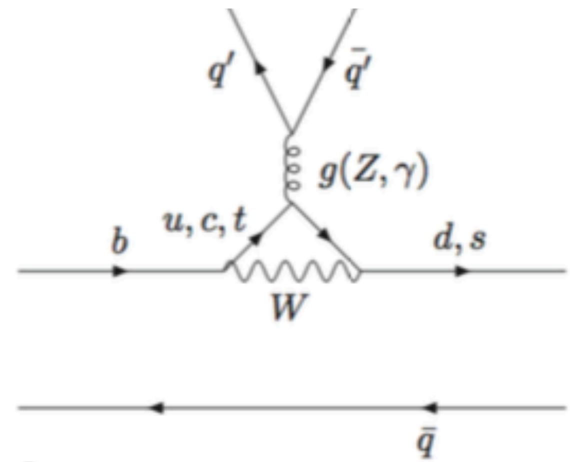
The contribution from P_E diagram is argued smaller than P_A diagram, which can be ignored reliably in decay modes not dominated by it, except $Bs \to \pi^+\pi^-$ decay

$$Br(B_s \to \pi^+\pi^-) = (0.76 \pm 0.19) \times 10^{-6}.$$



(c) P_E

The flavor-singlet QCD penguin diagram P_C only contribute to the isospin singlet mesons η, η′, ω and φ.



(b) $P_C(P_{EW})$

$$P_C^{PP} = -i\frac{G_F}{\sqrt{2}} V_{tb} V_{tq'}^* \chi^{PC} e^{i\phi^{PC}} f_{p_2}(m_B^2 - m_{p_1}^2) F_0^{BP_1}(m_{p_2}^2),$$

$$P_C^{PV} = -\sqrt{2} G_F V_{tb} V_{tq}^* \chi^{PC'} e^{i\phi^{PC'}} f_V m_V F_1^{B-P}(m_V^2)(\varepsilon_V^* \cdot p_B),$$

$$P_C^{VP} = -\sqrt{2} G_F V_{tb} V_{tq'}^* \chi^{PC} e^{i\phi^{PC}} f_P m_V A_0^{B-V}(m_P^2)(\varepsilon_V^* \cdot p_B),$$

All together we have 14 parameters to be fitted for all B→PP, PV, VP decays

Recent update for B→PP channels with η–η' mixing by Hsiao, Chang & He, PRD93, 114002 (2016), have 12 parameters

In put parameters

$$\lambda = 0.22537 \pm 0.00061, \quad A = 0.814^{+0.023}_{0.024}$$

$$\bar{\rho} = 0.117 \pm 0.021, \quad \bar{\eta} = 0.353 \pm 0.013.$$

Decay constants (MeV) (Uncertainty 5 %)

f_π	f_K	f_B	f_{B_s}	f_ρ	f_{K^*}	f_ω	f_ϕ
130	156	190	225	213	220	192	225

form factors (Uncertainty 10%)

	$F_0^{B\to\pi}$	$F_0^{B\to K}$	$F_0^{B_s\to K}$	$F_0^{B\to\eta_q}$	$F_0^{B_s\to\eta_s}$
$F(0)$	0.27	0.29	0.25	0.21	0.30
α_1	0.50	0.53	0.54	0.52	0.53
α_2	-0.13	-0.13	-0.15	0	0
	$F_1^{B\to\pi}$	$F_1^{B\to K}$	$F_1^{B_s\to K}$	$F_1^{B\to\eta_q}$	$F_1^{B_s\to\eta_s}$
$F(0)$	0.27	0.29	0.25	0.21	0.30
α_1	0.52	0.54	0.57	1.43	1.48
α_2	0.45	0.50	0.50	0.41	0.46
	$A_0^{B\to\rho}$	$A_0^{B\to\omega}$	$A_0^{B\to K^*}$	$A_0^{B_s\to K^*}$	$A_0^{B_s\to\phi}$
$A(0)$	0.29	0.25	0.36	0.27	0.30
α_1	0.50	0.53	0.54	0.52	0.53
α_2	-0.13	-0.13	-0.15	0	0

Global Fit for all B→PP, VP and PV decays

35 branching Ratios and 11 CP violation observations data are used for the fit

$$\chi^C = 0.48 \pm 0.06, \quad \phi^C = -1.58 \pm 0.08,$$
$$\chi^{C'} = 0.42 \pm 0.16, \quad \phi^{C'} = 1.59 \pm 0.17,$$
$$\chi^E = 0.057 \pm 0.005, \quad \phi^E = 2.71 \pm 0.13,$$
$$\chi^P = 0.10 \pm 0.02, \quad \phi^P = -0.61 \pm 0.02.$$
$$\chi^{P_C} = 0.048 \pm 0.003, \quad \phi^{P_C} = 1.56 \pm 0.08,$$
$$\chi^{P'_C} = 0.039 \pm 0.003, \quad \phi^{P'_C} = 0.68 \pm 0.08,$$
$$\chi^{P_A} = 0.0059 \pm 0.0008, \quad \phi^{P_A} = 1.51 \pm 0.09,$$

$$\chi^2 = \sum_{i=1}^{n} \left(\frac{x_i^{\rm th} - x_i}{\Delta x_i} \right)^2 .$$

Large strong phase

Global Fit for all B→PP, VP and PV decays

with $\chi^2/\text{d.o.f} = 45.2/34 = 1.3.$

χ^2 is smaller than previous topology diagram approach. Number of free parameters is much reduced.

Nonperturbative parameters $\chi^C, \phi^C, \chi^E, \phi^E$ **are universal** for all the PP, VP and PV modes

$$T^{\pi\pi} : C^{\pi\pi} : E^{\pi\pi} : P^{\pi\pi} = 1 : 0.51 : 0.26 : 0.36$$

$$T^{\rho\pi} : C'^{\pi\rho} : P^{\rho\pi} : P_{EW}^{\pi\rho} = 1 : 1.03 : 0.31 : 0.053$$

$$T^{\pi\rho} : C^{\rho\pi} : P^{\rho\pi} : P_{EW}^{\rho\pi} = 1 : 0.32 : 0.19 : 0.021.$$

In these tree dominant decays, the relative importance of topological diagrams is easy to be reached:

$$T > C > E \sim P > P_{EW}.$$

$$T^{\pi K} : C^{\pi K} : P^{\pi K} : P_{EW}^{\pi K} = 1 : 0.47 : 6.18 : 0.59$$

$$T^{\pi K^*} : C^{K^*\pi} : P^{\pi K^*} : PA^{\pi K^*} : P_{EW}^{K^*\pi} = 1 : 0.39 : 3.17 : 1.69 : 0.50.$$

In these penguin dominant decays, the relative importance of topological diagrams is also reached as:

$$P > PA > T > C \sim P_{EW}.$$

For B → ρK decays, we have

$$T^{\rho K} : C'^{K\rho} : P^{\rho K} : P_{EW}^{K\rho} = 1 : 0.94 : 3.4 : 0.95.$$

$$P > T \sim C' \sim P_{EW}.$$

B→PP branching ratios ΔS=0

Mode	Amplitudes	Exp	This work	Flavor diagram
$\pi^-\pi^0$	T, C, P_{EW}	$\star 5.5 \pm 0.4$	$5.08 \pm 0.39 \pm 1.02 \pm 0.02$	5.40 ± 0.79
$\pi^-\eta$	T, C, P, P_C, P_{EW}	$\star 4.02 \pm 0.27$	$4.13 \pm 0.25 \pm 0.64 \pm 0.01$	3.88 ± 0.39
$\pi^-\eta'$	T, C, P, P_C, P_{EW}	$\star 2.7 \pm 0.9$	$3.37 \pm 0.21 \pm 0.49 \pm 0.01$	5.59 ± 0.54
$\pi^+\pi^-$	$T, E, (P_E), P$	$\star 5.12 \pm 0.19$	$5.15 \pm 0.36 \pm 1.31 \pm 0.14$	5.17 ± 1.03
$\pi^0\pi^0$	$C, E, P, (P_E), P_{EW}$	$\star 1.91 \pm 0.22$	$1.94 \pm 0.30 \pm 0.28 \pm 0.05$	1.88 ± 0.42
$\pi^0\eta$	$C, E, P_C, (P_E), P_{EW}$	< 1.5	$0.86 \pm 0.08 \pm 0.08 \pm 0.04$	0.56 ± 0.03
$\pi^0\eta'$	$C, E, P_C, (P_E), P_{EW}$	1.2 ± 0.6	$0.87 \pm 0.08 \pm 0.10 \pm 0.03$	1.21 ± 0.16
$\eta\eta$	$C, E, P_C, (P_E), P_{EW}$	< 1.0	$0.44 \pm 0.09 \pm 0.08 \pm 0.005$	0.77 ± 0.12
$\eta\eta'$	$C, E, P_C, (P_E), P_{EW}$	< 1.2	$0.77 \pm 0.13 \pm 0.14 \pm 0.008$	1.99 ± 0.26
$\eta'\eta'$	$C, E, P_C, (P_E), P_{EW}$	< 1.7	$0.38 \pm 0.05 \pm 0.07 \pm 0.003$	1.60 ± 0.20
K^-K^0	P	$\star 1.31 \pm 0.17$	$1.32 \pm 0.04 \pm 0.26 \pm 0.01$	1.03 ± 0.02
$K^0\bar{K}^0$	P	$\star 1.21 \pm 0.16$	$1.23 \pm 0.03 \pm 0.25 \pm 0.01$	0.89 ± 0.11

$B \to PP$ branching ratios $\Delta S=1$

Mode	Amplitudes	Exp	This work	Flavor diagram
$\pi^- \bar{K}^0$	P	$\star 23.7 \pm 0.8$	$23.2 \pm 0.6 \pm 4.6 \pm 0.2$	23.53 ± 0.42
$\pi^0 K^-$	T, C, P, P_{EW}	$\star 12.9 \pm 0.5$	$12.8 \pm 0.32 \pm 2.35 \pm 0.10$	12.71 ± 1.05
ηK^-	T, C, P, P_C, P_{EW}	$\star 2.4 \pm 0.4$	$2.0 \pm 0.13 \pm 1.19 \pm 0.03$	1.93 ± 0.31
$\eta' K^-$	T, C, P, P_C, P_{EW}	$\star 70.6 \pm 2.5$	$70.1 \pm 4.7 \pm 11.3 \pm 0.22$	70.92 ± 8.54
$\pi^+ K^-$	T, P	$\star 19.6 \pm 0.5$	$19.8 \pm 0.54 \pm 4.0 \pm 0.2$	20.2 ± 0.39
$\pi^0 \bar{K}^0$	C, P, P_{EW}	$\star 9.9 \pm 0.5$	$8.96 \pm 0.26 \pm 1.96 \pm 0.09$	9.73 ± 0.82
$\eta \bar{K}^0$	C, P, P_C, P_{EW}	$\star 1.23 \pm 0.27$	$1.35 \pm 0.10 \pm 1.02 \pm 0.03$	1.49 ± 0.27
$\eta' \bar{K}^0$	C, P, P_C, P_{EW}	$\star 66 \pm 4$	$66.4 \pm 4.5 \pm 10.6 \pm 0.21$	66.51 ± 7.97

The direct CP asymmetries (A) and mixing-induced CP asymmetries (S)

Mode	$\mathcal{A}_{\exp}$	$\mathcal{A}_{this\ work}$	$\mathcal{A}_{Flavor\ diagram}$	$\mathcal{S}_{\exp}$	$\mathcal{S}_{this\ work}$	$\mathcal{S}_{Flavor\ diagram}$
$\pi^+\pi^-$	$\star 0.31 \pm 0.05$	0.31 ± 0.04	0.326 ± 0.081	$\star - 0.67 \pm 0.06$	-0.60 ± 0.03	-0.717 ± 0.061
$\pi^0\pi^0$	0.43 ± 0.24	0.57 ± 0.06	0.611 ± 0.113		0.58 ± 0.06	0.454 ± 0.112
$\pi^0\eta$		-0.16 ± 0.16	0.566 ± 0.114		-0.98 ± 0.04	-0.098 ± 0.338
$\pi^0\eta'$		0.39 ± 0.14	0.385 ± 0.114		-0.90 ± 0.07	0.142 ± 0.234
$\eta\eta$		-0.85 ± 0.06	-0.405 ± 0.129		0.33 ± 0.12	-0.796 ± 0.077
$\eta\eta'$		-0.97 ± 0.04	-0.394 ± 0.117		-0.20 ± 0.15	-0.903 ± 0.049
$\eta'\eta'$		-0.87 ± 0.07	-0.122 ± 0.136		-0.46 ± 0.14	-0.964 ± 0.037
$\pi^0 K_s$	0.00 ± 0.13	-0.14 ± 0.03	-0.173 ± 0.019	$\star 0.58 \pm 0.17$	0.73 ± 0.01	0.754 ± 0.014
ηK_s		-0.30 ± 0.10	-0.301 ± 0.041		0.68 ± 0.04	0.592 ± 0.035
$\eta' K_s$	0.06 ± 0.04	0.030 ± 0.004	0.022 ± 0.006	$\star 0.63 \pm 0.06$	0.69 ± 0.00	0.685 ± 0.004
$K^0\bar{K}^0$		-0.057 ± 0.002	0.017 ± 0.041	0.8 ± 0.5	0.099 ± 0.002	0

The direct CP asymmetries (A) of B→PP

The pi K puzzle

Mode	$\mathcal{A}_{exp}$	$\mathcal{A}_{this\ work}$	$\mathcal{A}_{Flavor\ diagram}$
$\pi^-\pi^0$	0.03 ± 0.04	-0.026 ± 0.003	0.069 ± 0.027
$\pi^-\eta$	-0.14 ± 0.07	-0.14 ± 0.07	-0.081 ± 0.074
$\pi^-\eta'$	0.06 ± 0.16	0.37 ± 0.07	0.374 ± 0.087
$\pi^-\bar{K}^0$	-0.017 ± 0.016	0.0027 ± 0.0001	0
$\pi^0 K^-$	0.037 ± 0.021	0.065 ± 0.024	0.047 ± 0.025
ηK^-	$\star - 0.37 \pm 0.08$	-0.22 ± 0.08	-0.426 ± 0.043
$\eta' K^-$	0.013 ± 0.017	-0.021 ± 0.007	-0.027 ± 0.008
K^-K^0	-0.21 ± 0.14	-0.057 ± 0.002	0
π^+K^-	$\star - 0.082 \pm 0.006$	-0.081 ± 0.005	-0.080 ± 0.011

The direct CP asymmetries (A) of B→PV

Mode	$\mathcal{A}_{exp}$	$\mathcal{A}_{this\ work}$	$\mathcal{A}_{Flavor\ diagram}$
$\pi^-\rho^0$	$0.18^{+0.09}_{-0.17}$	-0.45 ± 0.04	-0.239 ± 0.084
$\pi^-\omega$	-0.04 ± 0.06	0.054 ± 0.052	0.075 ± 0.067
$\pi^0\rho^-$	0.02 ± 0.11	0.16 ± 0.02	0.053 ± 0.094
$\eta\rho^-$	0.11 ± 0.11	-0.11 ± 0.02	0.162 ± 0.072
$\eta'\rho^-$	0.26 ± 0.17	0.45 ± 0.05	0.223 ± 0.137
$\pi^-\bar{K}^{*0}$	-0.04 ± 0.09	0.005 ± 0.001	0
$\pi^0 K^{*-}$	-0.06 ± 0.24	0.088 ± 0.040	-0.116 ± 0.092
ηK^{*-}	0.02 ± 0.06	-0.17 ± 0.02	-0.016 ± 0.037
$\eta' K^{*-}$	-0.26 ± 0.27	-0.45 ± 0.09	-0.391 ± 0.162
$K^-\rho^0$	$\star 0.37 \pm 0.10$	0.59 ± 0.06	0.306 ± 0.100
$K^-\omega$	0.02 ± 0.05	0.19 ± 0.09	0.010 ± 0.080
$K^-\phi$	0.04 ± 0.04	-0.006 ± 0.001	0
$K^- K^{*0}$		-0.10 ± 0.02	0
$K^0 K^{*-}$		-0.18 ± 0.01	0
$\bar{K}^0\rho^-$	-0.12 ± 0.17	0.009 ± 0.000	0
$\pi^+ K^{*-}$	$\star -0.22 \pm 0.06$	-0.20 ± 0.04	-0.217 ± 0.048
$\pi^0 \bar{K}^{*0}$	-0.15 ± 0.13	-0.27 ± 0.05	-0.332 ± 0.114
$\eta \bar{K}^{*0}$	$\star 0.19 \pm 0.05$	0.065 ± 0.011	0.099 ± 0.028
$\eta' \bar{K}^{*0}$	-0.07 ± 0.18	0.059 ± 0.049	0.069 ± 0.152
$K^-\rho^+$	0.21 ± 0.11	0.59 ± 0.01	0.134 ± 0.053

The direct CP asymmetries (A) and mixing-induced CP asymmetries (S) of Bs

Mode	$\mathcal{A}_{this\ work}$	$\mathcal{A}_{Flavor\ diagram}$	$\mathcal{S}_{this\ work}$	$\mathcal{S}_{Flavor\ diagram}$
$\pi^0\phi$	0.89 ± 0.04	0.073 ± 0.201	-0.25 ± 0.07	0.439 ± 0.171
$\eta\rho^0$	-0.46 ± 0.38	0.323 ± 0.136	0.88 ± 0.19	-0.002 ± 0.168
$\eta\omega$	-0.086 ± 0.071	-0.432 ± 0.271	-0.31 ± 0.06	-0.238 ± 0.296
$\eta\phi$	0.083 ± 0.113	0.428 ± 0.504	0.39 ± 0.15	0.534 ± 0.400
$\eta'\rho^0$	-0.67 ± 0.10	0.323 ± 0.136	-0.72 ± 0.07	-0.002 ± 0.168
$\eta'\omega$	0.33 ± 0.06	-0.432 ± 0.271	-0.14 ± 0.07	-0.238 ± 0.296
$\eta'\phi$	-0.010 ± 0.017	0.043 ± 0.090	0.047 ± 0.015	0.166 ± 0.057
K^+K^{*-}	-0.30 ± 0.04	-0.217 ± 0.048	-0.78 ± 0.06	0
K^-K^{*+}	0.39 ± 0.04	0.134 ± 0.053	0.67 ± 0.05	0
$K_s\rho^0$	-0.42 ± 0.15	-0.124 ± 0.453	0.78 ± 0.08	-0.348 ± 0.285
$K_s\omega$	-0.010 ± 0.151	-0.029 ± 0.436	-0.32 ± 0.30	0.928 ± 0.110
$K_s\phi$	-0.003 ± 0.033	0	-0.85 ± 0.01	-0.692 ± 0.000
$K^0\bar{K}^{*0}$	0.002 ± 0.001	0	-0.74 ± 0.05	0
$\bar{K}^0K^{*0}$	0.009 ± 0.000	0	0.83 ± 0.04	0

SU(3) breaking effects in amplitudes to be **10~20%**

$$\left|\frac{T(B^- \to \pi^0\pi^-)}{V_{ub}V_{ud}^*}\right| : \left|\frac{T(B^- \to \pi^0 K^-)}{V_{ub}V_{us}^*}\right| = 1 : 0.83$$

$$\left|\frac{C(B^- \to \pi^0\pi^-)}{V_{ub}V_{ud}^*}\right| : \left|\frac{C(B^- \to \pi^0 K^-)}{V_{ub}V_{us}^*}\right| = 1 : 0.92$$

$$\left|\frac{P(B^0 \to \pi^+\pi^-)}{V_{ub}V_{ud}^*}\right| : \left|\frac{P(B^0 \to \pi^+ K^-)}{V_{ub}V_{us}^*}\right| = 1 : 0.95$$

$$\left|\frac{PC(B^- \to \eta\pi^-)}{V_{ub}V_{ud}^*}\right| : \left|\frac{PC(B^- \to \eta K^-)}{V_{ub}V_{us}^*}\right| = 1 : 0.91$$

SU(3) breaking

$$|\frac{T(B^- \to \pi^0 \rho^-)}{V_{ub}V_{ud}^*}| : |\frac{T(B^- \to \pi^0 K^{*-})}{V_{ub}V_{us}^*}| = 1 : 0.83$$

$$|\frac{C(B^- \to \rho^- \pi^0)}{V_{ub}V_{ud}^*}| : |\frac{C(B^- \to K^{*-} \pi^0)}{V_{ub}V_{us}^*}| = 1 : 0.68$$

$$|\frac{P(B^0 \to \pi^+ \rho^-)}{V_{ub}V_{ud}^*}| : |\frac{P(B^0 \to \pi^+ K^{*-})}{V_{ub}V_{us}^*}| = 1 : 0.73$$

$$|\frac{PC(B^- \to \eta \rho^-)}{V_{ub}V_{ud}^*}| : |\frac{PC(B^- \to \eta K^{*-})}{V_{ub}V_{us}^*}| = 1 : 0.68$$

$$|\frac{PA(B^0 \to \pi^+ \rho^-)}{V_{ub}V_{ud}^*}| : |\frac{PA(B^0 \to \pi^+ K^{*-})}{V_{ub}V_{us}^*}| = 1 : 0.84$$

SU(3) breaking effects can be described by decay constants

Summary

- charmless **hadronic** ***B*** **decays are studied in the factorization -assisted topological-amplitude approach**
- **Only 14 universal non-perturbative parameters to be fitted from all** ***B→PP, VP*** **and** ***PV decay channels*****, more predictive power than ever**
- **Results are consistent with data. SU(3) breakings are studied.**
- **Predictions for more than 100 channels to be tested by future exp. Power corrections are needed**

Thank you!