Analysis of charmless B decays in Factorization Assisted Topological Amplitude Approach

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Based on work collaborated with

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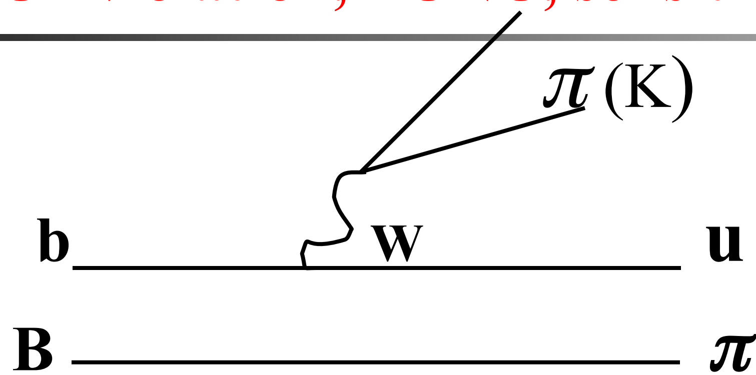
Outline

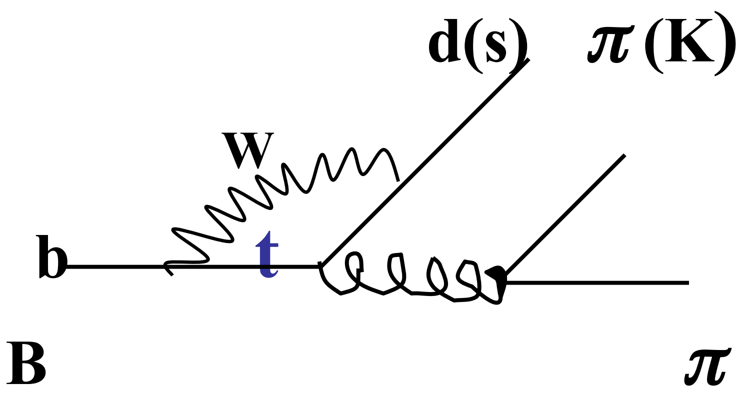
- **Introduction/Motivation**
- **Factorization assisted topological diagram approach**
- Numerical results for charmless **hadronic B decays** and discussions
- **Summary**

Rich physics in hadronic B decays

CP violation, FCNC, sensitive to new physics contribution…



The standard model describes interactions amongst quarks and leptons



In experiments, we can only observe hadrons

How can we test the standard model without solving QCD?

Perturbative calculations

- 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']

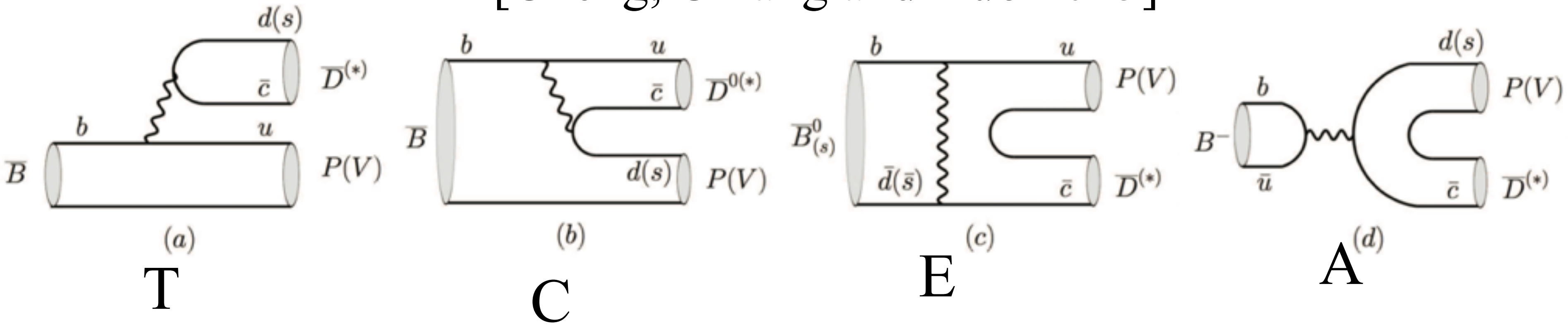
Soft-Collinear Effective Theory
[Bauer, Pirjol, Stewart, 01']

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]



- 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

We first apply our **factorization assisted topological diagram** approach in hadronic D decays

[arXiv:1203.3120, PRD86 (2012) 036012]

Predictions of Direct CP asymmetries

Modes	$A_{CP}(\text{FSI})$	$A_{CP}(\text{diagram})$	A_{CP}^{tree}	A_{CP}^{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

Δ_{CP} = -1 x10^{-3}

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

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

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

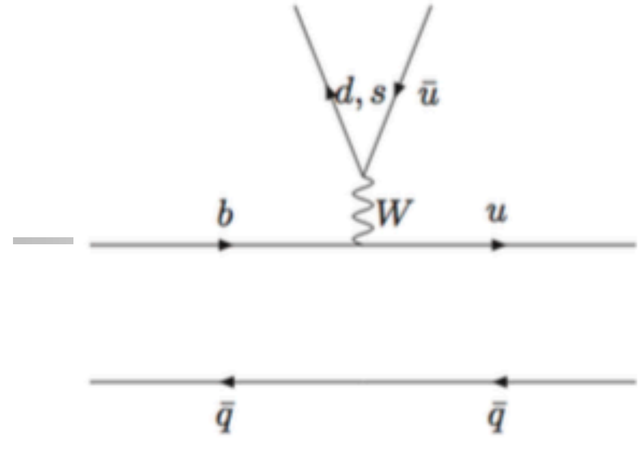
$\Delta A_{CP\ prompt} = (-0.10 \pm 0.08(stat) \pm 0.03(syst))\%$

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

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

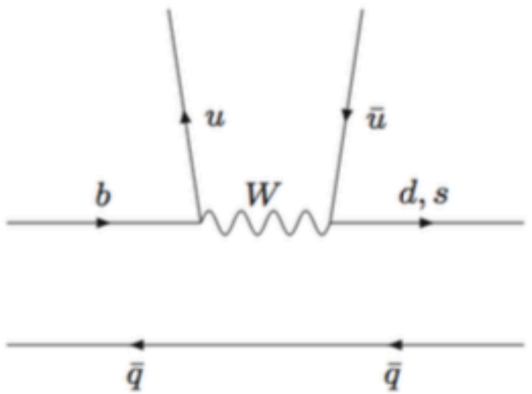
$$T^{PV} = \sqrt{2}G_F V_{ub}V_{uq'}a_1(\mu)f_V m_V F_1^{B-P}(m_V^2)(\varepsilon_V^* \cdot p_B),$$

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

No free parameter

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

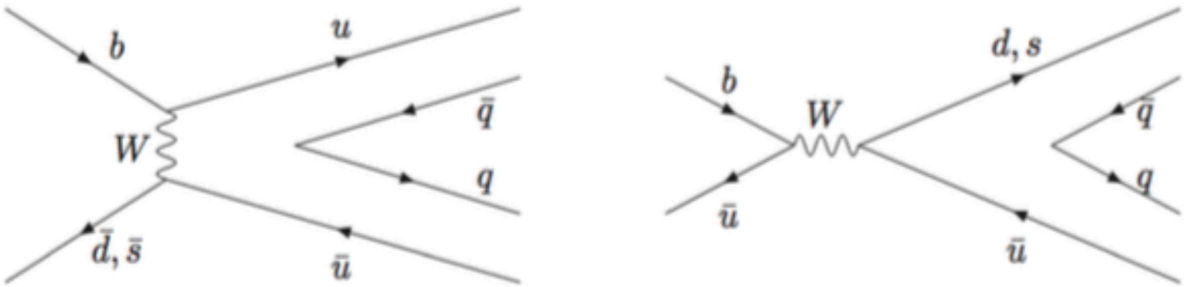
For the color suppressed tree diagram (C), we have two kinds of contributions

$$C^{P_1P_2} = i\frac{G_F}{\sqrt{2}}V_{ub}V_{uq'}\chi^C e^{i\phi^C} f_{p_2}(m_B^2 - m_{p_1}^2)F_0^{BP_1}(m_{p_2}^2),$$

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

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

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



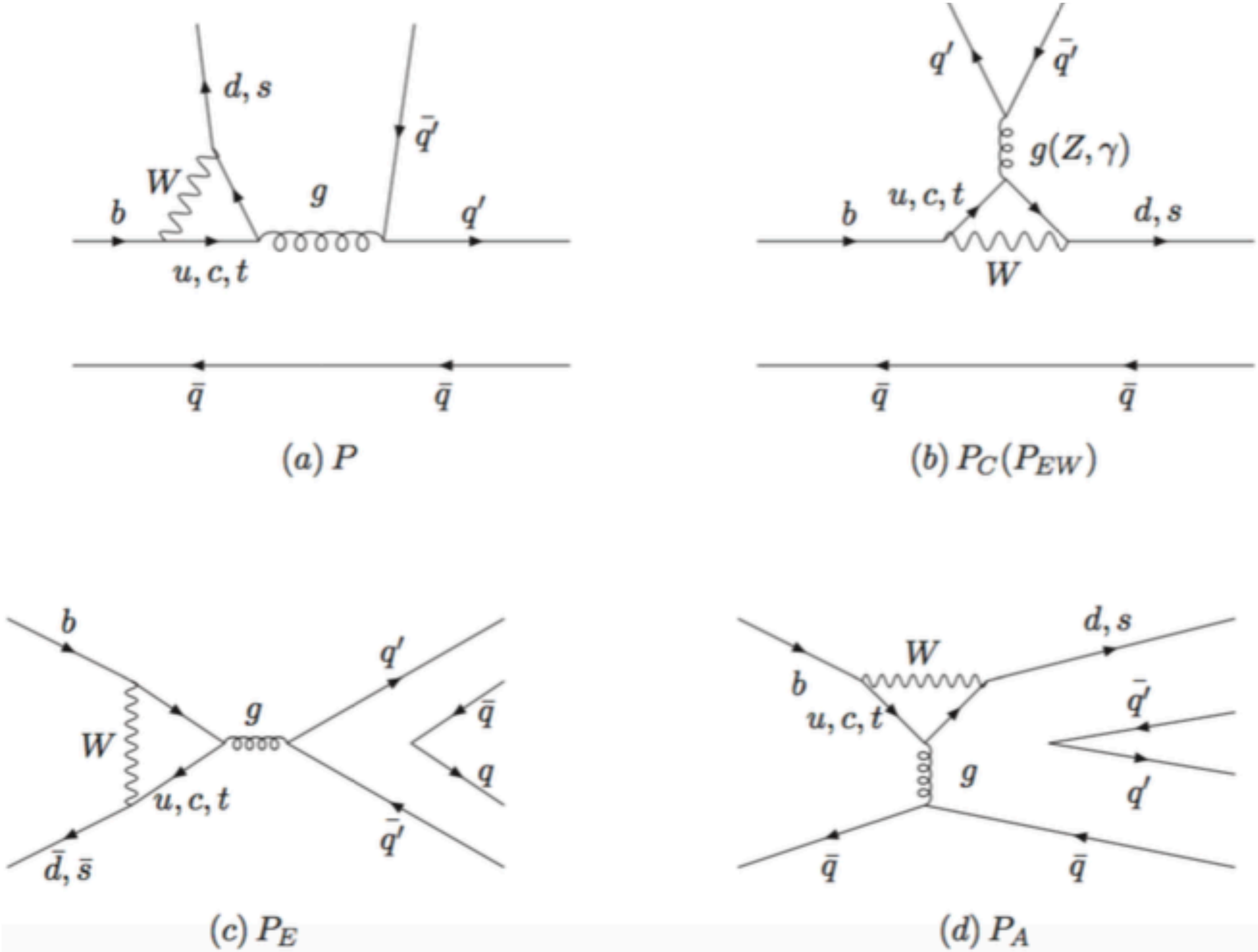
(c) E (d) A

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

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

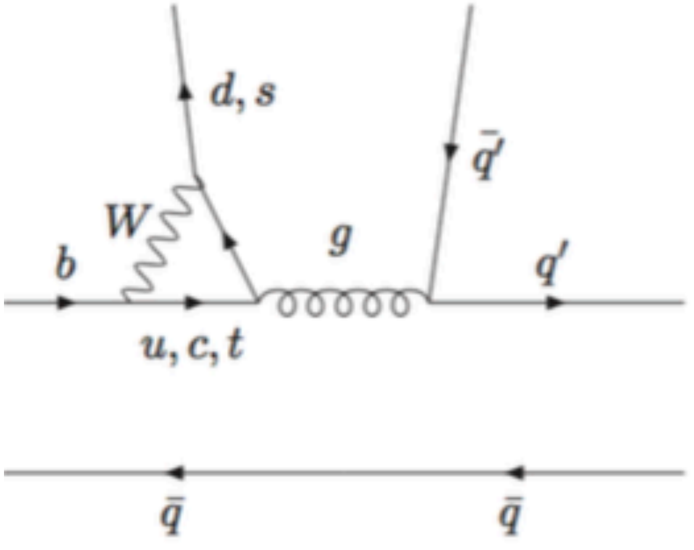
As discussed in conventional topological diagram approach, W-annihilation diagram contribution is negligible.

We also have four penguin type diagrams



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

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



(a) P

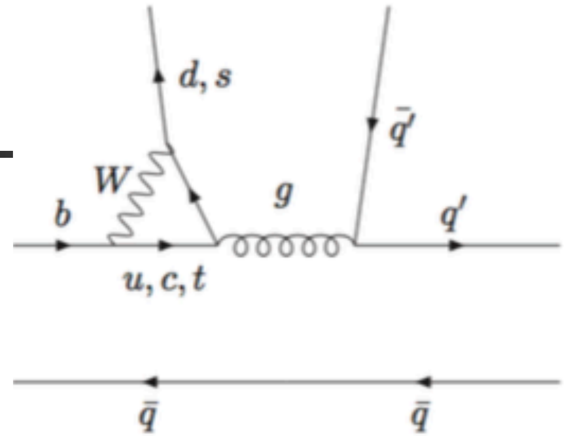
$$P^{PP} = -i\frac{G_F}{\sqrt{2}}V_{tb}V^*_{tq'}[a_4(\mu) + \chi^P e^{i\phi^P} r_\chi] f_{p_2}(m_B^2 - m_{p_1}^2)F_0^{BP_1}(m_{p_2}^2),$$

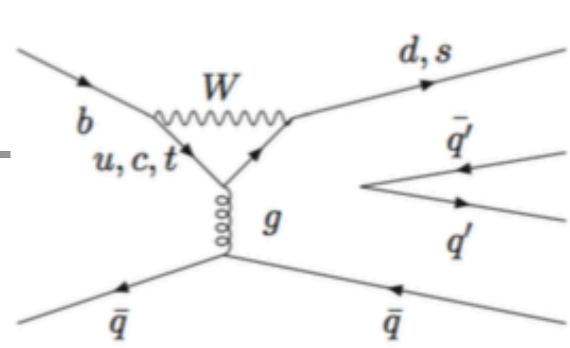
$$P^{PV} = -\sqrt{2}G_F V_{tb}V^*_{tq'}a_4(\mu) f_V m_V F_1^{B-P} m_V^2(\varepsilon_V^* \cdot p_B),$$

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

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

The difference is only at QCD not EW





(d) P_A

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

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

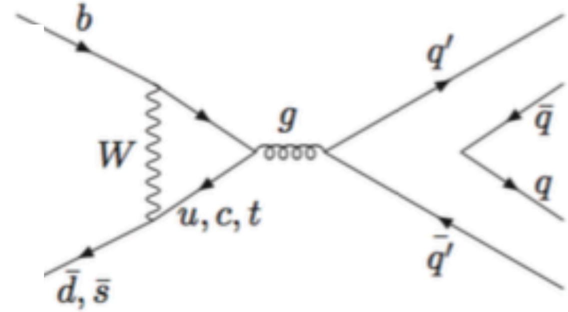
$$P^{VP} = -\sqrt{2}G_F V_{tb}V^*_{tq'}[a_4(\mu) - \chi^P \mathrm{e}^{i\phi^P} r_\chi] f_P m_V A_0^{B-V}(m_P^2)(\varepsilon_V^* \cdot p_B).$$

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

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

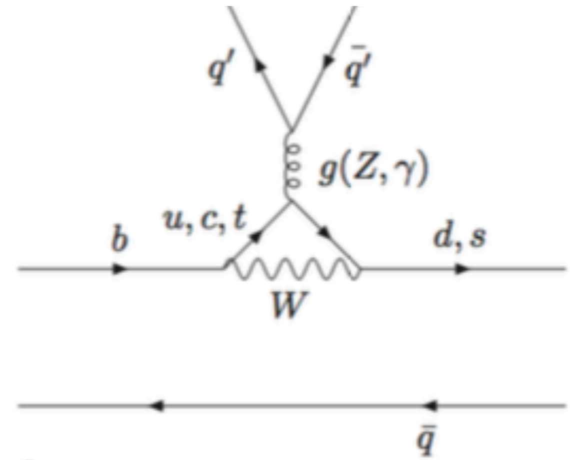
The contribution from P_E diagram is argued smaller than P_A diagram, which can be ignored reliably in decay modes not dominated by it, except $B_s \to \pi^+\pi^-$ decay

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



(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

$$\chi^C = 0.54 \pm 0.06, \quad \phi^C = -1.55 \pm 0.088,$$

$$\chi^{C'} = 0.67 \pm 0.11, \quad \phi^{C'} = 1.58 \pm 0.15,$$

$$\chi^E = 0.051 \pm 0.004, \quad \phi^E = 2.96 \pm 0.19,$$

$$\chi^P = 0.11 \pm 0.01, \quad \phi^P = -3.85 \pm 0.02.$$

$$\chi^{PC} = 0.054 \pm 0.005, \quad \phi^{PC} = 1.52 \pm 0.09,$$

$$\chi^{PC'} = 0.044 \pm 0.002, \quad \phi^{PC'} = 0.66 \pm 0.07,$$

$$\chi^{PA} = -0.0068 \pm 0.0008, \quad \phi^{PA} = -1.73 \pm 0.07,$$

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

Large strong phase

Global Fit for all B→DP, D*P and DV decays

$$\chi^2/\text{d.o.f} = 30.47/32 = 0.95.$$

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

Nonperturbative parameters χ^C, ϕ^C, χ^E, ϕ^E are universal for all the PP, VP and PV modes

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

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

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

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

Meson	Mode	Amplitudes	$\mathcal{B}_{\rm exp}(\times 10^{-6})$	$\mathcal{B}_{\rm th}(\times 10^{-6})$
	$\Delta S = 0$	$V_{u(-t)b}V^*_{u(t)d}$		
$B^-, \overline{B}^0$	$\pi^-\pi^0$	T, C, P_{EW}	5.5 ± 0.4	$5.19 \pm 0.43 \pm 1.04 \pm 0.02$
	$\pi^-\eta$	T, C, P, PC, P_{EW}	4.02 ± 0.27	$4.17 \pm 0.31 \pm 0.63 \pm 0.01$
	$\pi^-\eta'$	T, C, P, PC, P_{EW}	2.7 ± 0.9	$3.54 \pm 0.28 \pm 0.51 \pm 0.01$
	$\pi^+\pi^-$	T, E, P	5.12 ± 0.19	$5.05 \pm 0.29 \pm 1.29 \pm 0.14$
	$\pi^0\pi^0$	C, E, P, P_{EW}	1.91 ± 0.22	$1.84 \pm 0.33 \pm 0.30 \pm 0.04$
	$\pi^0\eta$	C, E, PC, P_{EW}	< 1.5	$0.83 \pm 0.09 \pm 0.07 \pm 0.04$
	$\pi^0\eta'$	C, E, PC, P_{EW}	1.2 ± 0.6	$0.91 \pm 0.11 \pm 0.11 \pm 0.03$
	$\eta\eta$	C, E, PC, P_{EW}	< 1.0	$0.54 \pm 0.11 \pm 0.09 \pm 0.01$
	$\eta\eta'$	C, E, PC, P_{EW}	< 1.2	$0.92 \pm 0.16 \pm 0.16 \pm 0.01$
	$\eta'\eta'$	C, E, PC, P_{EW}	< 1.7	$0.45 \pm 0.07 \pm 0.08 \pm 0$
	K^-K^0	P	1.31 ± 0.17	$1.32 \pm 0.19 \pm 0.26 \pm 0.01$
	K^+K^-	E	0.13 ± 0.05	$1.06 \pm 0.16 \pm 0 \pm 0.10$
	$K^0\bar{K}^0$	P	1.21 ± 0.16	$1.22 \pm 0.17 \pm 0.24 \pm 0.01$

B→PP branching ratios

Mode	Amplitudes	$\mathcal{B}_{\rm exp}(\times 10^{-6})$	$\mathcal{B}_{\rm th}(\times 10^{-6})$
$\Delta S = 1$	$V_{u(-t)b}V^*_{u(t)s}$		
$\pi^- \bar{K}^0$	P	23.7 ± 0.8	$23.5 \pm 3.3 \pm 4.7 \pm 0.2$
$\pi^0 K^-$	T, C, P, P_{EW}	12.9 ± 0.5	$12.9 \pm 1.7 \pm 2.4 \pm 0.1$
ηK^-	T, C, P, PC, P_{EW}	2.4 ± 0.4	$1.96 \pm 0.30 \pm 1.15 \pm 0.03$
$\eta' K^-$	T, C, P, PC, P_{EW}	70.6 ± 2.5	$69.8 \pm 10.8 \pm 11.3 \pm 0.2$
$\pi^+ K^-$	T, P	19.6 ± 0.5	$20.2 \pm 2.9 \pm 4.0 \pm 0.2$
$\pi^0 \bar{K}^0$	C, P, P_{EW}	9.9 ± 0.5	$9.22 \pm 1.45 \pm 2.00 \pm 0.09$
$\eta \bar{K}^0$	C, P, PC, P_{EW}	1.23 ± 0.27	$1.34 \pm 0.25 \pm 0.99 \pm 0.03$
$\eta' \bar{K}^0$	C, P, PC, P_{EW}	66 ± 4	$66.0 \pm 10.1 \pm 10.6 \pm 0.2$

B→PV branching ratios ΔS=0

	Mode	Amplitudes	$\mathcal{B}_{\rm exp}(\times 10^{-6})$	$\mathcal{B}_{\rm th}(\times 10^{-6})$
$B^-, \overline{B}^0$	$\pi^-\rho^0$	T, C', P, PA, P_{EW}	8.3 ± 1.2	$8.98 \pm 1.98 \pm 1.26 \pm 0.05$
	$\pi^-\omega$	$T, C', P, PC', PA, P_{EW}$	6.9 ± 0.5	$6.91 \pm 1.60 \pm 0.97 \pm 0.04$
	$\pi^-\phi$	PC', P_{EW}	< 0.15	$0.32 \pm 0 \pm 0.06 \pm 0$
	$\pi^0\rho^-$	T, C, P, PA, P_{EW}	10.9 ± 1.4	$12.53 \pm 0.65 \pm 2.24 \pm 0.11$
	$\eta\rho^-$	T, C, P, PC, PA, P_{EW}	7.0 ± 2.9	$7.38 \pm 0.41 \pm 1.30 \pm 0.06$
	$\eta'\rho^-$	T, C, P, PC, PA, P_{EW}	9.7 ± 2.2	$5.35 \pm 0.29 \pm 0.87 \pm 0.05$
	$\pi^+\rho^-$	T, E, P		$11.8 \pm 0.3 \pm 3.1 \pm 0.4$
	$\pi^-\rho^+$	T, E, P		$3.27 \pm 0.21 \pm 1.033 \pm 0.19$
	$\pi^0\rho^0$	C, C', E, P, PA, P_{EW}	2 ± 0.5	$1.57 \pm 0.67 \pm 0.19 \pm 0.11$
	$\pi^0\omega$	C, C', E, P, PA, P_{EW}	< 0.5	$4.02 \pm 1.15 \pm 0.49 \pm 0.08$
	$\pi^0\phi$	PC', P_{EW}	< 0.15	$0.15 \pm 0 \pm 0.03 \pm 0$
	$\eta\rho^0$	$C, C', E, P, PC, PC', PA, P_{EW}$	< 1.5	$4.46 \pm 0.98 \pm 0.49 \pm 0.12$
	$\eta\omega$	$C, C', E, P, PC, PC', PA, P_{EW}$	$0.94^{+0.40}_{-0.31}$	$0.96 \pm 0.34 \pm 0.13 \pm 0.08$
	$\eta\phi$	PC', P_{EW}	< 0.5	$0.08 \pm 0 \pm 0.02 \pm 0$
	$\eta'\rho^0$	$C, C', E, P, PC, PC', P_{EW}$	< 1.3	$3.16 \pm 0.66 \pm 0.34 \pm 0.09$
	$\eta'\omega$	$C, C', E, P, PC, PC', P_{EW}$	$1.0^{+0.5}_{-0.4}$	$0.94 \pm 0.23 \pm 0.09 \pm 0.06$
	$\eta'\phi$	PC', P_{EW}	< 0.5	$0.056 \pm 0.001 \pm 0.011 \pm 0.001$
	K^-K^{*0}	P, PA	< 1.1	$0.58 \pm 0.05 \pm 0.10 \pm 0.01$
	K^0K^{*-}	P		$0.57 \pm 0.10 \pm 0.12 \pm 0.01$
	K^+K^{*-}	E		$1.91 \pm 0.03 \pm 0.00 \pm 0.19$
	K^-K^{*+}	E		$1.91 \pm 0.03 \pm 0.00 \pm 0.19$
	$K^0\bar{K}^{*0}$	P		$0.53 \pm 0.10 \pm 0.11 \pm 0.01$
	$\bar{K}^0K^{*0}$	P, PA		$0.54 \pm 0.05 \pm 0.10 \pm 0.01$

B→PV branching ratios ΔS=1

Mode	Amplitudes	$\mathcal{B}_{\rm exp}(\times 10^{-6})$	$\mathcal{B}_{\rm th}(\times 10^{-6})$
$\pi^- \bar{K}^{*0}$	P, PA	10.1 ± 0.9	$10.1 \pm 0.8 \pm 1.9 \pm 0.1$
$\pi^0 K^{*-}$	T, C, P, PA, P_{EW}	8.2 ± 1.9	$6.14 \pm 0.42 \pm 1.02 \pm 0.06$
ηK^{*-}	$T, C, P, PC, , PA, P_{EW}$	19.3 ± 1.6	$17.5 \pm 3.0 \pm 2.6 \pm 0.4$
$\eta' K^{*-}$	T, C, P, PC, PA, P_{EW}	$4.8^{+1.8}_{-1.6}$	$3.25 \pm 1.54 \pm 0.32 \pm 0.13$
$K^- \rho^0$	T, C', P, P_{EW}	3.7 ± 0.5	$3.75 \pm 0.49 \pm 0.72 \pm 0.03$
$K^- \omega$	T, C', P, PC', P_{EW}	6.5 ± 0.4	$6.41 \pm 0.98 \pm 1.31 \pm 0.07$
$K^- \phi$	P, PC', PA, P_{EW}	8.8 ± 0.7	$8.37 \pm 1.17 \pm 0.56 \pm 0.57$
$\bar{K}^0 \rho^-$	P	8 ± 1.5	$7.41 \pm 1.35 \pm 1.48 \pm 0.07$
$\pi^+ K^{*-}$	T, P, PA	8.4 ± 0.8	$8.42 \pm 0.66 \pm 1.54 \pm 0.11$
$\pi^0 \bar{K}^{*0}$	C, P, PA, P_{EW}	3.3 ± 0.6	$3.46 \pm 0.32 \pm 0.69 \pm 0.07$
$\eta \bar{K}^{*0}$	C, P, PC, PA, P_{EW}	15.9 ± 1	$16.6 \pm 2.9 \pm 2.4 \pm 0.3$
$\eta' \bar{K}^{*0}$	$C, P, PC, PC', PA, P_{EW}$	2.8 ± 0.6	$3.02 \pm 1.57 \pm 0.29 \pm 0.12$
$K^- \rho^+$	T, P	7 ± 0.9	$7.44 \pm 1.39 \pm 1.49 \pm 0.07$
$\bar{K}^0 \rho^0$	C', P, P_{EW}	4.7 ± 0.4	$4.54 \pm 0.90 \pm 0.76 \pm 0.03$
$\bar{K}^0 \omega$	C', P, PC', P_{EW}	4.8 ± 0.6	$5.02 \pm 0.83 \pm 1.15 \pm 0.06$
$\bar{K}^0 \phi$	P, PC', PA, P_{EW}	7.3 ± 0.7	$7.76 \pm 1.08 \pm 0.52 \pm 0.52$

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

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

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

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

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

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

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

Summary

- charmless **hadronic** ***B*** **decays are studied in the factorization -assisted topological-amplitude approach**
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Thank you!