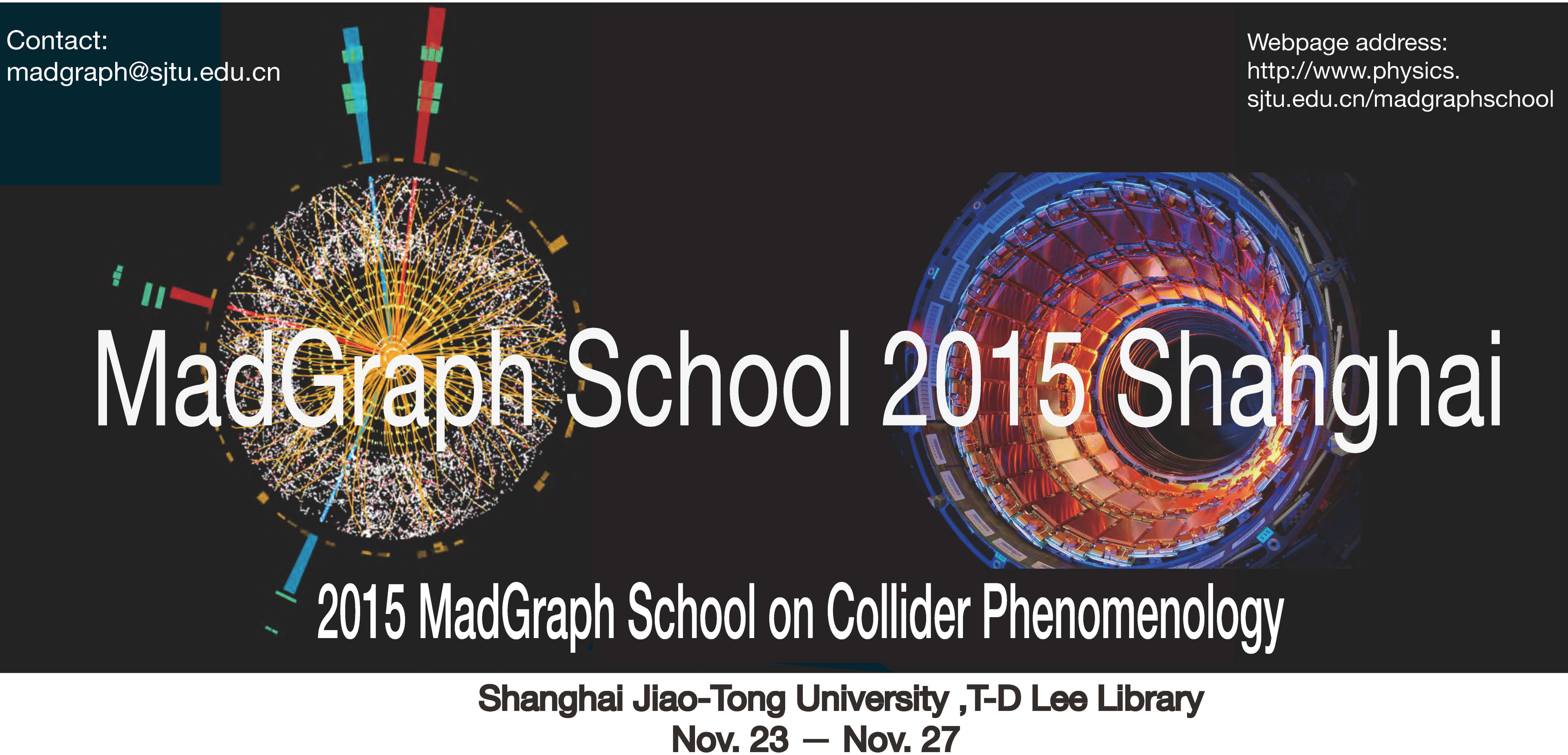


November 23 – 27, 2015

http://www.physics.sjtu.edu.cn/madgraphschool

Ab.	Contents	h	Suggested Lecturer
CP	Collider Phenomenology: basics	2h	Fabio Maltoni
MCS	Shower MC's and merging	2h	Stefan Prestel&Andreas Papaefstathiou
NLO	NLO and matching to PS	2h	Stefano Frixione
FR	Introduction to FeynRules	1h	Claude Duhr
MG	Introduction to MadGraph5_aMC@NLO	1h	Olivier Mattaelaer
JET	Jets/Jetsubstructure/pileup/Boosted	2h	Matteo Cacciari
BSM	New Physics simulations (LO and NLO) & Recasting	3h	Benjamin Fuks & Hua-Sheng Shao
NI	Search for New Interactions (EFT)	1h	Cen Zhang
DM	Dark Matter search at the LHC	1h	Mihailo Backovic
FDS	Fast Detector Simulation	1h	Michele Selvaggi
FHC	Physics at future hadron colliders	2h	Michelangelo Mangano
FEC	Physics (and sims) at future e+e- colliders	2h	Keisuke Fujii
L2E	From Lagrangian to events (tutorials)		Kentarou Mawatari (coordinator)

Verification of SM Predictions for CP Violating Relations in Charmless Two body b-Hadron Decays

Xiao-Gang He
SJTU/NTU

1. Introduction: b-mesons and b-baryons
2. CPV relations with flavor SU(3) for b-mesons
3. CPV relations with flavor SU(3) for b-baryons
4. A comment on Diquark Model for pentaquark

HFCPV-2015, Lanzhou, July, 2015

Introduction

Ground states of b-Mesons and b-Baryons

b-Mesons:

$B_u = B^+ : (u\bar{b}),\ B_d = B^0 : (d\bar{b}),\ B_s = B_s^0 : (s\bar{b})$

These states have been measured with $5.30 \sim 5.37$GeV for their masses.

The $(u,\ d,\ s)$ are light compared with QCD scale of about 1 GeV.
The QCD Lagrangain is approximately flavor $SU(3)$ symmetric
with $(u,\ d,\ s)$ as a fundamental representation 3, flavor $SU(3)$ symmetry.

b quark is much heavier, is a siglet under the flavor $SU(3)$ symmetry,
So, $(B_u,\ B_d,\ B_s)$ transform as a $SU(3)$ fundamental representation 3, too.

b-Baryons:

$\frac{1}{2}^+$ ground state formed by a b quark and two light quarks.

Two light quarks can form $1 \times (3 \times 3) = \bar{3} + 6$ flavor $SU(3)$ representations.

The anti-triplet $\mathcal{B}_{\bar{3}}$:

$$(\mathcal{B}_{\bar{3}})_{ij} = \begin{pmatrix} 0 & \Lambda_b^0 & \Xi_b^0 \\ -\Lambda_b^0 & 0 & \Xi_b^- \\ -\Xi_b^0 & -\Xi_b^- & 0 \end{pmatrix}$$

$$\Lambda_b^0 = \frac{1}{\sqrt{2}}(ud - du)b; \ \Xi_b^0 = \frac{1}{\sqrt{2}}(su - us)b; \ \Xi_b^- = \frac{1}{\sqrt{2}}(ds - sd)b \ .$$

The sextet $\mathcal{B}_6$:

$$(\mathcal{B}_6)_{ij} = \begin{pmatrix} \Sigma_b^+ & \frac{\Sigma_b^0}{\sqrt{2}} & \frac{\Xi_b^{\prime 0}}{\sqrt{2}} \\ \frac{\Sigma_b^0}{\sqrt{2}} & \Sigma_b^- & \frac{\Xi_b^{\prime -}}{\sqrt{2}} \\ \frac{\Xi_b^{\prime 0}}{\sqrt{2}} & \frac{\Xi_b^{\prime -}}{\sqrt{2}} & \Omega_b^- \end{pmatrix}$$

with

$$\Sigma_b^+ = uub \ , \ \ \Sigma_b^0 = \frac{1}{\sqrt{2}}(ud + du)b \ , \ \ \Sigma_b^- = ddb;$$

$$\Xi_b^{\prime 0} = \frac{1}{\sqrt{2}}(us + su)b \ , \ \ \Xi_b^{\prime -} = \frac{1}{\sqrt{2}}(ds + sd)b \ , \ \ \Omega_b^- = ssb \ .$$

These states have been observed also with mass in the range of $5.62 \sim 6.05$ GeV.

This talk

Focuses on CP violation in charmless two body decays of b-mesons and b-baryons:

B mesons decay into two light pesudoscalar mesons MM in octet $\mathcal{M}$: $B \to MM$,

$\mathcal{B}$ baryons decay into a M and a light baryon F in the octet $\mathcal{F}$: $\mathcal{B} \to MF$.

Here M and F are members in $\mathcal{M}$ and $\mathcal{F}$ given by

$$\mathcal{M} = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\frac{2\eta_8}{\sqrt{6}} \end{pmatrix}, \quad \mathcal{F} = \begin{pmatrix} \frac{\Sigma^0}{\sqrt{2}} + \frac{\Lambda^0}{\sqrt{6}} & \Sigma^+ & p \\ \Sigma^- & -\frac{\Sigma^0}{\sqrt{2}} + \frac{\Lambda^0}{\sqrt{6}} & n \\ \Xi^- & \Xi^0 & -\frac{2\Lambda^0}{\sqrt{6}} \end{pmatrix}.$$

Why these processes are interesting for CP violation ?

Both tree and penguin amplitudes contribute to the decays offering the possibility of large CP violation: in B -> MM CP asymmetry can be as large as about 10%! Several of them measured.

Expecting similar size of CPV in b-baryon charmless two body decays!

Some predictions for CPV relations for B -> MM to better than 10% level.

Universal or accidental?

Similar things will happen in $\mathcal{B}$ -> M $\mathcal{F}$? Provide further tests

Well tested SM prediction: B -> MM relations

CPV relation between $B_s \rightarrow K^- \pi^+$ and $B_d \rightarrow K^+ \pi^-$

LHCb collaboration, arXiv:1304.6173

First observation of CP violation in the decays of B_s^0 mesons

Using pp collision data, corresponding to an integrated luminosity of 1.0 fb^{-1}, collected by LHCb in 2011 at a center-of-mass energy of 7 TeV, we report the measurement of direct CP violation in $B_s^0 \to K^-\pi^+$ decays, $A_{CP}(B_s^0 \to K^-\pi^+) = 0.27 \pm 0.04\,(\mathrm{stat}) \pm 0.01\,(\mathrm{syst})$, with significance exceeding five standard deviations. This is the first observation of CP violation in the decays of B_s^0 mesons. Furthermore, we provide an improved determination of direct CP violation in $B^0 \to K^+\pi^-$ decays, $A_{CP}(B^0 \to K^+\pi^-) = -0.080 \pm 0.007\,(\mathrm{stat}) \pm 0.003\,(\mathrm{syst})$, which is the most precise measurement of this quantity to date.

$$\mathcal{E} = \frac{A_{CP}(B^0 \to K^+\pi^-)}{A_{CP}(B_s^0 \to K^-\pi^+)} + \frac{Br(B_s^0 \to K^-\pi^+)\tau_d}{Br(B_0 \to K^+\pi^-)\tau_s} = 0\,, \qquad \mathcal{E} = -0.02 \pm 0.05 \pm 0.04\,.$$

Relation derived from SU(3) flavor symmetry.

Confirm SU(3) prediction!?

World Average (HFAG)

B_d

Mode	PDG2014 Avg.	BABAR	Belle	CDF	LHCb	New Avg.
$K^+\pi^-$	-0.082 ± 0.006 [1]	$-0.107 \pm 0.016^{+0.006}_{-0.004}$	$-0.069 \pm 0.014 \pm 0.007$	$-0.083 \pm 0.013 \pm 0.004$	$-0.080 \pm 0.007 \pm 0.003$	-0.082 ± 0.006

B_s

Mode	PDG2014 Avg.	Belle	CDF	LHCb	New Avg.
π^+K^-	0.28 ± 0.04		$0.22 \pm 0.07 \pm 0.02$	$0.27 \pm 0.04 \pm 0.01$	0.26 ± 0.04

To gauge the level of the relation hold, define

$$\delta = \frac{A_{CP}(\bar{B}^0_s \to K^+\pi^-)}{A_{CP}(\bar{B}^0 \to K^-\pi^+)} \Big/ \frac{Br(\bar{B}^0 \to K^-\pi^+)\tau_{\bar{B}^0_s}}{Br(\bar{B}^0_s \to K^+\pi^-)\tau_{\bar{B}^0}} + 1 \; .$$

Combining all data show that the above is at about 5% away from central value at 1-sigma level hold.

Relation holds well. Consistent with SU(3) prediction
What will happen for b-baryon decay? What are the corresponding decays? Can use them to test similar relations.

Related relation, first Considered in 1995 by Deshpande and He

Phys. Rev. Lett. 75, 1703–1706 (1995)

CP Asymmetry Relations between $\bar{B}^0 \to \pi\pi$ and $\bar{B}^0 \to \pi K$ Rates

N. G. Deshpande and Xiao-Gang He
Institute of Theoretical Science, University of Oregon, Eugene, Oregon 97403-5203

Received 30 December 1994; published in the issue dated 28 August 1995

We prove that the *CP* violating rate difference $\Delta(\pi^+\pi^-) = \gamma(\bar{B}^0 \to \pi^+\pi^-) - \gamma(B^0 \to \pi^-\pi^+)$ is related to $\Delta(\pi^+K^-) = \gamma(\pi^+K^-) - \gamma(B^0 \to \pi^-K^+)$ in the three generation standard model. Neglecting small annihilation diagrams, and in the SU(3) symmetry limit, we show that $\Delta(\pi^+\pi^-) = -\Delta(\pi^+K^-)$. The SU(3) breaking effects are estimated using the factorization approximation, and yield $\Delta(\pi^+\pi^-) \approx -(f_\pi/f_K)^2 \Delta(\pi^+K^-)$. The usefulness of this relation for determining phases in the CKM unitarity triangle is discussed.

Related between $B_s \to K^-\pi^+$, $B \to K^+\pi^-$ and more, first Considered in 1998 by X-G. He

SU(3) analysis of annihilation contributions and CP violating relations in B ---> P P decays
Xiao-Gang He (Taiwan, Natl. Taiwan U.). Oct 1998. 16 pp.
Published in **Eur.Phys.J. C9 (1999) 443-448**
DOI: 10.1007/s100529900064
e-Print: **hep-ph/9810397** | **PDF**

In the SU(3) limit we find the following equalities:

$$
\begin{aligned}
(1)\quad & \Delta(B^- \to K^- K^0) = -\Delta(B^- \to \pi^- \bar{K}^0),\\
(2)\quad & \Delta(\bar{B}^0 \to \pi^-\pi^+) = -\Delta(B_s \to K^- K^+),\\
(3)\quad & \Delta(\bar{B}^0 \to K^- K^+) = -\Delta(B_s \to \pi^-\pi^+)\\
& = -2\Delta(B_s \to \pi^0\pi^0),\\
(4)\quad & \Delta(\bar{B}^0 \to \bar{K}^0 K^0) = -\Delta(B_s \to K^0 \bar{K}^0),\\
(5)\quad & \Delta(\bar{B}^0 \to \pi^+ K^-) = -\Delta(B_s \to K^+\pi^-),\\
(6)\quad & \Delta(\bar{B}^0 \to \pi^0 \bar{K}^0) = -\Delta(B_s \to K^0\pi^0)\\
& = 3\Delta(\bar{B}^0 \to \eta_8 \bar{K}^0) = -3\Delta(B_s \to K^0 \eta_8). \quad (16)
\end{aligned}
$$

Later studied by

The Role of $B_s \to K\pi$ in determining the weak phase γ
Michael Gronau (Technion), Jonathan L. Rosner (Chicago U., EFI & Chicago U.). Mar 2000. 8 pp.
Published in **Phys.Lett. B482 (2000) 71-76**
TECHNION-PH-00-25, EFI-2000-8
DOI: 10.1016/S0370-2693(00)00508-6
e-Print: **hep-ph/0003119** | PDF

Is observed direct CP violation in B(d) ---> K+ pi- due to new physics? Check standard model prediction of equal violation in B(s) ---> K- pi+
Harry J. Lipkin (Weizmann Inst. & Tel Aviv U. & Argonne). Mar 2005. 9 pp.
Published in **Phys.Lett. B621 (2005) 126-132**
TAUP-2798-05, ANL-HEP-PR-05-11, WIS-06-05-FEB-DPP
DOI: 10.1016/j.physletb.2005.06.023
e-Print: **hep-ph/0503022** | **PDF**

2. CPV relations with flavor SU(3) for b-mesons

SU(3) Symmetry Derivation CPV relations
(Nation change: In the following P=M discussions)

$$\Delta(B \to PP) = \Gamma(\bar{B} \to \bar{P}\,\bar{P}) - \Gamma(B \to P\,P)$$

$$A_{CP}(B \to PP) = \frac{\Gamma(\bar{B} \to \bar{P}\,\bar{P}) - \Gamma(B \to P\,P)}{\Gamma(\bar{B} \to \bar{P}\,\bar{P}) + \Gamma(B \to P\,P)}$$

If: $\Delta(B^0 \to K^+\pi^-) = -\Delta(B_s^0 \to K^-\pi^+)$

Replacing "-" to "+" will also work for this purpose, but "-" is predicted by SU(3) flavory symmetry.

Then: $$\frac{A_{CP}(B^0 \to K^+\pi^-)}{A_{CP}(B_s^0 \to K^-\pi^+)} + \frac{Br(B_s^0 \to K^-\pi^+)\tau_{B^0}}{Br(B^0 \to K^+\pi^-)\tau_{B_s^0}} = 0$$

How to get: $\Delta(B^0 \to K^+\pi^-) = -\Delta(B_s^0 \to K^-\pi^+)$?

In the SM with flavor SU(3), one has

$$A(\bar{B}^0 \to K^-\pi^+) = V_{ub}V_{us}^*T + V_{tb}V_{ts}^*P\ , \quad A(B^0 \to K^+\pi^-) = V_{ub}^*V_{us}T + V_{tb}^*V_{ts}P$$

$$A(\bar{B}_s^0 \to K^+\pi^-) = V_{ub}V_{ud}^*T + V_{tb}V_{td}^*P\ , \quad A(B_s^0 \to K^-\pi^+) = V_{ub}^*V_{ud}T + V_{tb}^*V_{td}P$$

$$T = C_{\bar{3}}^T + C_6^T - A_{\overline{15}}^T + 3C_{\overline{15}}^T\ , \quad P = C_{\bar{3}}^P + C_6^P - A_{\overline{15}}^P + 3C_{\overline{15}}^P.$$

$$\Delta(B \to PP) = \Gamma(\bar{B} \to \bar{P}\,\bar{P}) - \Gamma(B \to P\,P)$$

$$= \frac{\lambda_{ab}}{8\pi m_B}(|A(\bar{B} \to \bar{P}\,\bar{P})|^2 - |A(B \to P\,P)|^2)\ ,$$

$$Im(V_{ub}V_{ud}^*V_{tb}^*V_{td}) = -Im(V_{ub}V_{us}^*V_{tb}^*V_{ts}),$$

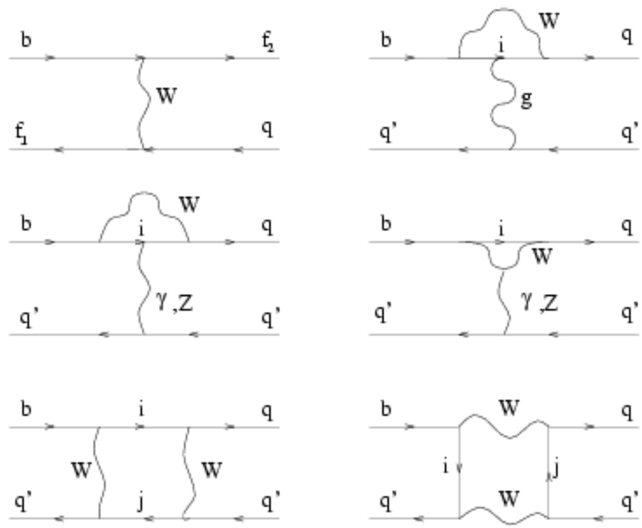
$$\Delta(B^0 \to K^+\pi^-) = -\Delta(B_s^0 \to K^-\pi^+)$$

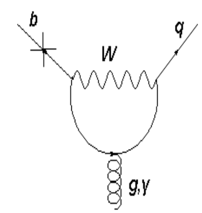
$$\frac{A_{CP}(B^0 \to K^+\pi^-)}{A_{CP}(B_s^0 \to K^-\pi^+)} + \frac{Br(B_s^0 \to K^-\pi^+)\tau_{B^0}}{Br(B^0 \to K^+\pi^-)\tau_{B_s^0}} = 0$$

Test for SU(3) flavor symmetry, and also SM with 3 generations!

Effective Hamiltonian

$$H^q_{eff} = \frac{4G_F}{\sqrt{2}}[V_{ub}V^*_{uq}(c_1O_1 + c_2O_2) - \sum_{i=3}^{12}(V_{ub}V^*_{uq}c_i^{uc} + V_{tb}V^*_{tq}c_i^{tc})O_i],$$



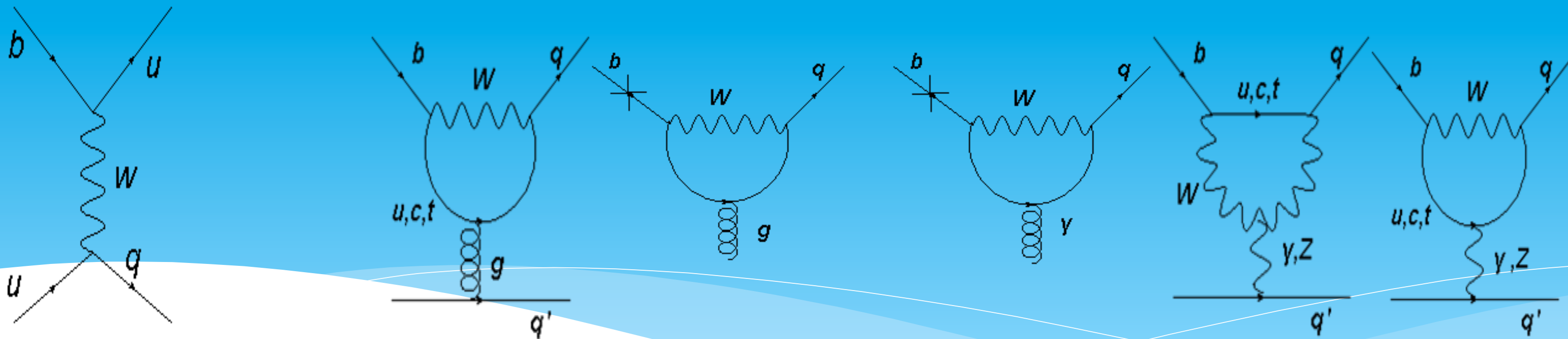


$$O_1 = (\bar{q}_i u_j)_{V-A}(\bar{u}_i b_j)_{V-A} \,, \qquad O_2 = (\bar{q}u)_{V-A}(\bar{u}b)_{V-A} \,,$$

$$O_{3,5} = (\bar{q}b)_{V-A}\sum\nolimits_{q'}(\bar{q}'q')_{V\mp A} \,, \qquad O_{4,6} = (\bar{q}_i b_j)_{V-A}\sum\nolimits_{q'}(\bar{q}'_j q'_i)_{V\mp A} \,,$$

$$O_{7,9} = \tfrac{3}{2}(\bar{q}b)_{V-A}\sum\nolimits_{q'} e_{q'}(\bar{q}'q')_{V\pm A} \,, \qquad O_{8,10} = \tfrac{3}{2}(\bar{q}_i b_j)_{V-A}\sum\nolimits_{q'} e_{q'}(\bar{q}'_j q'_i)_V$$

$$O_{11} = \frac{g_s}{16\pi^2}\bar{q}\sigma_{\mu\nu}G^{\mu\nu}(1+\gamma_5)b \,, \qquad O_{12} = \frac{Q_b e}{16\pi^2}\bar{q}\sigma_{\mu\nu}F^{\mu\nu}(1+\gamma_5)b.$$



$3 \times 3 \times \bar{3} = \overline{15} + 6 + \bar{3} + \bar{3}$ $\bar{3} \times 1 = \bar{3}$ $3 \times 8 = \overline{15} + 6 + \bar{3}$

The $SU(3)$ flavor symmetry transformation properties for operators $O_{1,2}$, $O_{3-6,11,12}$, and O_{7-10} are: $\bar{3}_a + \bar{3}_b + 6 + \overline{15}$, $\bar{3}$, and $\bar{3}_a + \bar{3}_b + 6 + \overline{15}$, respectively. We indicate these representations by matrices in $SU(3)$ flavor space by $H(\bar{3})$, $H(6)$ and $H(\overline{15})$. For $q = d$, the non-zero entries of the matrices $H(i)$ are given by [12, 13]

$$\begin{aligned} H(\bar{3})^2 &= 1\,, \quad H(6)^{12}_1 = H(6)^{23}_3 = 1\,, \quad H(6)^{21}_1 = H(6)^{32}_3 = -1\,, \\ H(\overline{15})^{12}_1 &= H(\overline{15})^{21}_1 = 3\,,\; H(\overline{15})^{22}_2 = -2\,,\; H(\overline{15})^{32}_3 = H(\overline{15})^{23}_3 = -1\,. \end{aligned} \tag{2.4}$$

And for $q = s$, the non-zero entries are

$$H(\bar{3})^3 = 1\,, \quad H(6)^{13}_1 = H(6)^{32}_2 = 1\,, \quad H(6)^{31}_1 = H(6)^{23}_2 = -1\,,$$

$$A = < final\ state|H^q_{eff}|\bar{B}> = V_{ub}V^*_{uq}T(q) + V_{tb}V^*_{tq}P(q)$$ .5)

$$A = < final\ state | H^q_{eff} | \bar{B} > = V_{ub} V^*_{uq} T(q) + V_{tb} V^*_{tq} P(q)$$

$$\begin{aligned} T(q) &= A^T_{\bar{3}} \bar{B}_i H(\bar{3})^i (M^k_l M^l_k) + C^T_{\bar{3}} \bar{B}_i M^i_k M^k_j H(\bar{3})^j \\ &+ A^T_6 \bar{B}_i H(6)^{ij}_k M^l_j M^k_l + C^T_6 \bar{B}_i M^i_j H(6)^{jk}_l M^l_k \\ &+ A^T_{\overline{15}} \bar{B}_i H(\overline{15})^{ij}_k M^l_j M^k_l + C^T_{\overline{15}} \bar{B}_i M^i_j H(\overline{15})^{jk}_l M^l_k \end{aligned}$$

$B_i = (B^+, B^0, B^0_s)$ is an $SU(3)$ triplet,

M^j_i is the $SU(3)$ pseudoscalar octet,

A_i-annihilation amplitude, small.
C_6-A_6 appear together, just use C_6.
Smilar structure for penguin amplitude,
indicate the corresponding amplitudes by A^P_i and C^P_i.

Other Similar Tests

SU(3) decay amplitudes for B → PP

$\Delta S = 0$

$$T^{B_u}_{\pi^-\pi^0}(d) = \frac{8}{\sqrt{2}} C^T_{\overline{15}},$$
$$T^{B_u}_{\pi^-\eta_8}(d) = \frac{2}{\sqrt{6}}(C^T_{\bar 3} - C^T_6 + 3A^T_{\overline{15}} + 3C_{\overline{15}}),$$
$$T^{B_u}_{K^-K^0}(d) = C^T_{\bar 3} - C^T_6 + 3A^T_{\overline{15}} - C^T_{\overline{15}},$$
$$T^{B_d}_{\pi^+\pi^-}(d) = 2A^T_{\bar 3} + C^T_{\bar 3} + C^T_6 + A^T_{\overline{15}} + 3C^T_{\overline{15}},$$
$$T^{B_d}_{\pi^0\pi^0}(d) = \frac{1}{\sqrt{2}}(2A^T_{\bar 3} + C^T_{\bar 3} + C^T_6 + A^T_{\overline{15}} - 5C^T_{\overline{15}}),$$
$$T^{B_d}_{K^-K^+}(d) = 2(A^T_{\bar 3} + A^T_{\overline{15}}),$$
$$T^{B_d}_{\bar K^0 K^0}(d) = 2A_{\bar 3} + C^T_{\bar 3} - C^T_6 - 3A^T_{\overline{15}} - C_{\overline{15}},$$
$$T^{B_d}_{\pi^0\eta_8}(d) = \frac{1}{\sqrt{3}}(-C^T_{\bar 3} + C^T_6 + 5A^T_{\overline{15}} + C_{\overline{15}}),$$
$$T^{B_d}_{\eta_8\eta_8}(d) = \frac{1}{\sqrt{2}}(2A_{\bar 3} + \frac{1}{3}C^T_{\bar 3} - C^T_6 - A^T_{\overline{15}} + C_{\overline{15}}),$$
$$T^{B_s}_{K^+\pi^-}(d) = C^T_{\bar 3} + C^T_6 - A^T_{\overline{15}} + 3C_{\overline{15}},$$
$$T^{B_s}_{K^0\pi^0}(d) = -\frac{1}{\sqrt{2}}(C^T_{\bar 3} + C^T_6 - A^T_{\overline{15}} - 5C_{\overline{15}}),$$
$$T^{B_s}_{K^0\eta_8}(d) = -\frac{1}{\sqrt{6}}(C^T_{\bar 3} + C^T_6 - A^T_{\overline{15}} - 5C_{\overline{15}}),$$

$\Delta S = -1$

$$T^{B_u}_{\pi^-\bar K^0}(s) = C^T_{\bar 3} - C^T_6 + 3A^T_{\overline{15}} - C^T_{\overline{15}},$$
$$T^{B_u}_{\pi^0 K^-}(s) = \frac{1}{\sqrt{2}}(C^T_{\bar 3} - C^T_6 + 3A^T_{\overline{15}} + 7C^T_{\overline{15}}),$$
$$T^{B_u}_{\eta_8 K^-}(s) = \frac{1}{\sqrt{6}}(-C^T_{\bar 3} + C^T_6 - 3A^T_{\overline{15}} + 9C^T_{\overline{15}}),$$
$$T^{B_d}_{\pi^+K^-}(s) = C^T_{\bar 3} + C^T_6 - A^T_{\overline{15}} + 3C^T_{\overline{15}},$$
$$T^{B_d}_{\pi^0\bar K^0}(s) = -\frac{1}{\sqrt{2}}(C^T_{\bar 3} + C^T_6 - A^T_{\overline{15}} - 5C^T_{\overline{15}}),$$
$$T^{B_d}_{\eta_8\bar K^0}(s) = -\frac{1}{\sqrt{6}}(C^T_{\bar 3} + C^T_6 - A^T_{\overline{15}} - 5C^T_{\overline{15}}),$$
$$T^{B_s}_{\pi^+\pi^-}(s) = 2(A^T_{\bar 3} + A^T_{\overline{15}}),$$
$$T^{B_s}_{\pi^0\pi^0}(s) = \sqrt{2}(A^T_{\bar 3} + A^T_{\overline{15}}),$$
$$T^{B_s}_{K^+K^-}(s) = 2A^T_{\bar 3} + C^T_{\bar 3} + C^T_6 + A^T_{\overline{15}} + 3C^T_{\overline{15}},$$
$$T^{B_s}_{K^0\bar K^0}(s) = 2A^T_{\bar 3} + C^T_{\bar 3} - C^T_6 - 3A^T_{\overline{15}} - C^T_{\overline{15}},$$
$$T^{B_s}_{\pi^0\eta_8}(s) = \frac{2}{\sqrt{3}}(C^T_6 + 2A^T_{\overline{15}} - 2C^T_{\overline{15}}),$$
$$T^{B_s}_{\eta_8\eta_8}(s) = \sqrt{2}(A^T_{\bar 3} + \frac{2}{3}C^T_{\bar 3} - A^T_{\overline{15}} - 2C^T_{\overline{15}}).$$

The amplitudes Ai is called the annihilation amplitudes which are small!

Several other SU(3) predictions

$$P1)\quad \Delta(B^+ \to K^+\bar{K}^0) = -\Delta(B^+ \to K^0\pi^+)\ ,$$
$$P2)\quad \Delta(B^0 \to \pi^+\pi^-) = -\Delta(B_s^0 \to K^-K^+)\ ,$$
$$P3)\quad \Delta(B^0 \to K^+K^-) = -\Delta(B_s^0 \to \pi^+\pi^-) = -2\Delta(B_s^0 \to \pi^0\pi^0)\ ,$$
$$P4)\quad \Delta(B^0 \to \bar{K}^0K^0) = -\Delta(B_s^0 \to K^0\bar{K}^0)\ ,$$
$$P5)\quad \Delta(B_s^0 \to K^-\pi^+) = -\Delta(B^0 \to K^+\pi^-),$$
$$P6)\quad \Delta(B_s^0 \to \bar{K}^0\pi^0) = -\Delta(B^0 \to K^0\pi^0).$$

Neglect annihilation contributions, neglecting A_i

$$P1) \approx P4)\ , \quad P2) \approx P5)\ , \quad P6) \approx \Delta(B^0 \to \pi^0\pi^0)\ .$$

Example:

$$A = V_{ub}V_{uq}^* T + V_{tb}V_{tq}^* P\ ,$$

$$T(\bar{B}^0 \to K^-\pi^+; \bar{B}_s^0 \to K^+\pi^-) = C_{\bar{3}}^T + C_6^T - A_{\overline{15}}^T + 3C_{\overline{15}}^T\ ,$$
$$P(\bar{B}^0 \to K^-\pi^+; \bar{B}_s^0 \to K^+\pi^-) = C_{\bar{3}}^P + C_6^P - A_{\overline{15}}^P + 3C_{\overline{15}}^P\ ,$$

$$T(\bar{B}^0 \to \pi^-\pi^+) = 2A_{\bar{3}}^T + C_{\bar{3}}^T + C_6^T + A_{\overline{15}}^T + 3C_{\overline{15}}^T\ ,$$
$$P(\bar{B}^0 \to \pi^-\pi^+) = 2A_{\bar{3}}^P + C_{\bar{3}}^P + C_6^P - A_{\overline{15}}^P + 3C_{\overline{15}}^P\ .$$

neglecting annihilation contributions:

setting $A_i = 0$

$$T(\bar{B}^0 \to K^-\pi^+; \bar{B}_s^0 \to K^+\pi^-) = T(\bar{B}^0 \to \pi^-\pi^+)\ ,$$
$$P(\bar{B}^0 \to K^-\pi^+; \bar{B}_s^0 \to K^+\pi^-) = P(\bar{B}^0 \to \pi^-\pi^+)\ .$$

$$\frac{A_{CP}(\bar{B}^0 \to \pi^-\pi^+)}{A_{CP}(\bar{B}^0 \to K^-\pi^+)} \approx -\frac{Br(\bar{B}^0 \to K^-\pi^+)}{Br(\bar{B}^0 \to \pi^-\pi^+)}$$

Data left: -3.78+-0.67 right: -3.72+-0.17

Agree very well. Neglecting annihilation may be a good approximation!

SU(3) breaking effects

Naïve factorization: Deshpand and He, 1995, He 1998

$$A(B^0 \to K^+\pi^-) \sim (m_B^2 - m_\pi^2) f_K F_0^{B\to\pi}(m_K^2)$$
$$A(B_s^0 \to K^-\pi^+) \sim (m_{B_s}^2 - m_K^2) f_\pi F_0^{B\to K}(m_\pi^2)$$

$$r_c \approx \frac{\lambda_{K\pi}^B/m_B}{\lambda_{K\pi}^{B_s}/m_{B_s}} \left(\frac{(m_B^2 - m_\pi^2) f_K F_0^{B\to\pi}(m_K^2)}{(m_{B_s}^2 - m_K^2) f_\pi F_0^{B_s\to K}(m_\pi^2)} \right)^2$$

QCD factorization: other SU(3) breaking effect. Deshpande, et al, 2003
Example: K, pi wave function amplitudes Beneke, 2003
Wang and Zhu, 2013

$$\Phi_M(x) = 6x(1-x)[1 + \alpha_1 C_1^{(3/2)}(2x-1) + \alpha_2 C_2^{3/2}(2x-1) + \ldots],$$

$$r_c \approx \frac{\lambda_{K\pi}^B/m_B}{\lambda_{K\pi}^{B_s}/m_{B_s}} \left(\frac{(m_B^2 - m_\pi^2) f_K F_0^{B\to\pi}(m_K^2)}{(m_{B_s}^2 - m_K^2) f_\pi F_0^{B_s\to K}(m_\pi^2)} \right)^2 \times \left[\frac{1 - 0.748\alpha_1^K - 0.109\alpha_2^K - 0.017 H_{K\pi}^B}{1 - 0.748\alpha_1^\pi - 0.109\alpha_2^\pi - 0.017 H_{\pi K}^{B_s}} \right].$$

rc range: 0.86 – 1.67,
central value: 1.15

pQCD estimate: rc range: 0.90 – 1.10, central value: 1.0.
C. D Lu et al. 2007

Data consistent with SU(3) prediction.
Not conclusive whether SU(3) breaking effects showed up.

3. CPV relations with flavor SU(3) for b-baryons

X-G He, G -N Li arXiv:1501.00846, and M He, -G He, -N Li in preparation

Experimental observables

$\mathcal{B} \to \mathcal{M} + \mathcal{F}$ decay amplitude $\mathcal{A}$ induced by weak interaction in the SM can have both parity conserving A_c and violating A_v amplitudes

$$\mathcal{A} = \mathcal{M}\bar{\mathcal{F}}(A_v + iA_c\gamma_5)\mathcal{B} = S + P\sigma \cdot \vec{p}_c\ , \quad \Gamma = 2|p_c|(|\mathcal{S}|^2 + |\mathcal{P}|^2)\ ,$$

$|p_c| = \sqrt{E_{\mathcal{F}}^2 - m_{\mathcal{F}}^2}$ is the final baryon $\mathcal{F}$ momentum.

$\mathcal{S}$ and $\mathcal{P}$ are referred as S- and P- wave amplitudes with

$$\mathcal{S} = A_v\sqrt{\frac{(m_{\mathcal{B}} + m_{\mathcal{F}})^2 - m_{\mathcal{M}}^2}{16\pi m_{\mathcal{B}}^2}}\ , \quad \mathcal{P} = A_c\sqrt{\frac{(m_{\mathcal{B}} - m_{\mathcal{F}})^2 - m_{\mathcal{M}}^2}{16\pi m_{\mathcal{B}}^2}}\ .$$

More observables in the decay angular distribution. In the rest frame of the initial b-baryon,

$$\frac{4\pi}{\Gamma}\frac{d\Gamma}{d\Omega} = 1 + \alpha\vec{s}_{\mathcal{B}}\cdot\vec{n} + \vec{s}_{\mathcal{F}}\cdot\left[(\alpha + \vec{s}_{\mathcal{B}}\cdot\vec{n})\vec{n} + \beta\vec{s}_{\mathcal{B}}\times\vec{n} + \gamma(\vec{n}\times(\vec{s}_{\mathcal{B}}\times\vec{n}))\right]\ ,$$

$\vec{s}_{\mathcal{B}}, \vec{s}_{\mathcal{F}}$ are the spins of initial b-baryon and final octet baryon,
$\vec{n} = \vec{p_c}/|p_c|$ is the direction of the final baryon $\mathcal{F}$.

$$\alpha = \frac{2Re(\mathcal{S}^*\mathcal{P})}{|\mathcal{S}|^2 + |\mathcal{P}|^2},\ \beta = \frac{2Im(\mathcal{S}^*\mathcal{P})}{|\mathcal{S}|^2 + |\mathcal{P}|^2},\ \gamma = \frac{|\mathcal{S}|^2 - |\mathcal{P}|^2}{|\mathcal{S}|^2 + |\mathcal{P}|^2}\ .$$

only two of them are independent with $\alpha^2 + \beta^2 + \gamma^2 = 1$.

CP violating observables

$$A_{CP} = \frac{\Gamma - \bar{\Gamma}}{\Gamma + \bar{\Gamma}}\ , \quad A_{\alpha} = \frac{\Gamma\alpha + \bar{\Gamma}\bar{\alpha}}{\Gamma + \bar{\Gamma}}\ .$$

In the SM there are tree and penguin contributions to $\mathcal{S}$ and $\mathcal{P}$ amplitudes can be written as:

$$\mathcal{S}(q) = V_{ub}V_{uq}^{*}T(q)_0 + V_{tb}V_{tq}^{*}P(q)_0,\ \mathcal{P}(q) = V_{ub}V_{uq}^{*}T(q)_1 + V_{tb}V_{tq}^{*}P(q)_1,$$

$$\bar{\mathcal{S}}(q) = -[V_{ub}^{*}V_{uq}T(q)_0 + V_{tb}^{*}VtqP(q)_0],\ \bar{\mathcal{P}}(q) = V_{ub}^{*}V_{uq}T(q)_1 + V_{tb}^{*}VtqP(q)_1\ ,$$

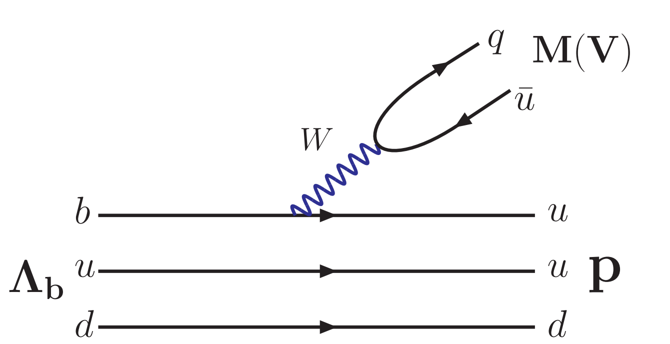
Then

$$\Delta(q) = \Gamma(q) - \bar{\Gamma}(q) = -8|p_c|Im(V_{ub}V_{uq}^{*}V_{tb}^{*}V_{tq})Im[T(q)_0P(q)_0^{*} + T(q)_1P(q)_1^{*}]\ ,$$

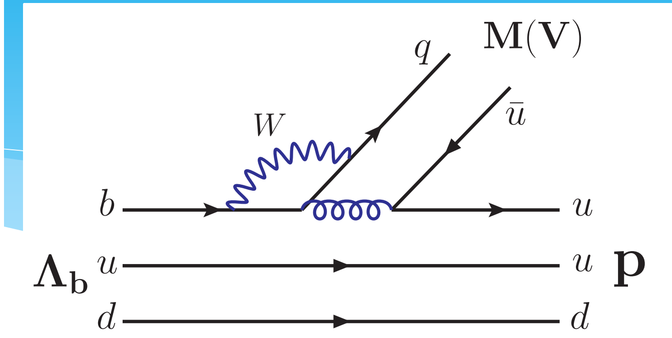
$$\Gamma\alpha + \bar{\Gamma}\bar{\alpha} = Re(\mathcal{S}^{*}\mathcal{P}) + Re(\bar{\mathcal{S}}^{*}\bar{\mathcal{P}}) = 2Im(V_{ub}V_{uq}^{*}V_{tb}^{*}V_{tq})[Im(T(q)_0^{*}P(q)_1) - Im(P(q)_0^{*}T(q)_1)],$$

A_{CP} and A_{α} probe different combinations of CPV amplitudes.

Model calculations



(a)



(b)

C.-D. Lv et al, PRD80, 034011 (2009)

	pQCD (conventional)	pQCD (hybrid scheme)
$\mathcal{B}(\Lambda_b \to p\pi)$	$4.66^{+2.08+0.70+0.35}_{-1.74-0.35-0.35} \times 10^{-6}$	$5.21^{+2.42+0.30+0.42}_{-1.89-0.10-0.37} \times 10^{-6}$
$\mathcal{B}(\Lambda_b \to pK)$	$1.82^{+0.74+0.62+0.07}_{-0.71-0.80-0.05} \times 10^{-6}$	$2.02^{+0.78+0.55+0.10}_{-0.86-0.90-0.05} \times 10^{-6}$
$A_{\rm CP}(\Lambda_b \to p\pi)$	$-0.32^{+0.27+0.41+0.01}_{-0.00-0.00-0.01}$	$-0.31^{+0.28+0.32+0.01}_{-0.00-0.00-0.01}$
$A_{\rm CP}(\Lambda_b \to pK)$	$-0.03^{+0.21+0.13+0.00}_{-0.00-0.04-0.00}$	$-0.05^{+0.26+0.03+0.01}_{-0.00-0.05-0.00}$
$\alpha(\Lambda_b \to p\pi)$	$-0.83^{+0.03+0.03+0.01}_{-0.01-0.07-0.01}$	$-0.84^{+0.03+0.00+0.01}_{-0.00-0.00-0.01}$
$\alpha(\Lambda_b \to pK)$	$0.03^{+0.00+0.00+0.03}_{-0.36-0.07-0.05}$	$0.08^{+0.00+0.05+0.04}_{-0.38-0.42-0.04}$

Direct CP violation in Λ_b decays

Y.K. Hsiao[1,2] and C.Q. Geng[1,2,3]

[1] *Physics Division, National Center for Theoretical Sciences, Hsinchu, Taiwan 300*

[2] *Department of Physics, National Tsing Hua University, Hsinchu, Taiwan 300*

[3] *Chongqing University of Posts & Telecommunications, Chongqing, 400065, China*

arXiv: 1412.1899

(Dated: December 8, 2014)

	our result	pQCD [5]	data
$10^6\mathcal{B}(\Lambda_b \to pK^-)$	$4.8 \pm 0.7 \pm 0.1 \pm 0.3$	$2.0^{+1.0}_{-1.3}$	4.9 ± 0.9 [4]
$10^6\mathcal{B}(\Lambda_b \to p\pi^-)$	$4.2 \pm 0.6 \pm 0.4 \pm 0.2$	$5.2^{+2.5}_{-1.9}$	4.1 ± 0.8 [4]
$10^6\mathcal{B}(\Lambda_b \to pK^{*-})$	$2.5 \pm 0.3 \pm 0.2 \pm 0.3$	—	—
$10^6\mathcal{B}(\Lambda_b \to p\rho^-)$	$11.4 \pm 1.6 \pm 1.2 \pm 0.6$	—	—
$10^2\mathcal{A}_{CP}(\Lambda_b \to pK^-)$	$5.8 \pm 0.2 \pm 0.1$	$-5^{+26}_{-\ 5}$	$-10 \pm 8 \pm 4$ [8]
$10^2\mathcal{A}_{CP}(\Lambda_b \to p\pi^-)$	$-3.9 \pm 0.2 \pm 0.0$	$-31^{+43}_{-\ 1}$	$6 \pm 7 \pm 3$ [8]
$10^2\mathcal{A}_{CP}(\Lambda_b \to pK^{*-})$	$19.6 \pm 1.3 \pm 1.0$	—	—
$10^2\mathcal{A}_{CP}(\Lambda_b \to p\rho^-)$	$-3.7 \pm 0.3 \pm 0.0$	—	—

Construction of SU(3) decay amplitudes

Example: the $T(q)$ amplitude for antitriplet is gievn by

$$
\begin{aligned}
T_{tri}(q) \;=\;& a(\overline{3})\langle \mathcal{F}^k_l \mathcal{M}^l_k | H(\overline{3})^i | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} + b(\overline{3})_1 \langle \mathcal{F}^k_j \mathcal{M}^i_k | H(\overline{3})^j | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} \\
+\;& b(\overline{3})_2 \langle \mathcal{F}^i_k \mathcal{M}^k_j | H(\overline{3})^j | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} + a(6)_1 \langle \mathcal{F}^k_l \mathcal{M}^l_j | H(6)^{ij}_k | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} \\
+\;& a(6)_2 \langle \mathcal{F}^l_j \mathcal{M}^k_l | H(6)^{ij}_k | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} + b(6)_1 \langle \mathcal{F}^l_k \mathcal{M}^i_j | H(6)^{jk}_l | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} \\
+\;& b(6)_2 \langle \mathcal{F}^i_j \mathcal{M}^l_k | H(6)^{jk}_l | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} + a(\overline{15})_1 \langle \mathcal{F}^k_l \mathcal{M}^l_j | H(\overline{15})^{ij}_k | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} \\
+\;& a(\overline{15})_2 \langle \mathcal{F}^l_j \mathcal{M}^k_l | H(\overline{15})^{ij}_k | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} + b(\overline{15})_1 \langle \mathcal{F}^l_k \mathcal{M}^i_j | H(\overline{15})^{jk}_l | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} \\
+\;& b(\overline{15})_2 \langle \mathcal{F}^i_j \mathcal{M}^l_k | H(\overline{15})^{jk}_l | \mathcal{B}_{i'i''}\rangle \epsilon^{ii'i''} \\
+\;& c(\overline{3}) \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{3})^{i''} | \mathcal{B}_{jj'}\rangle \epsilon_{ii'i''} + d(\overline{3})_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{3})^j | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} \\
+\;& d(\overline{3})_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(\overline{3})^j | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} + e(\overline{3})_1 \langle \mathcal{M}^i_{j'} \mathcal{F}^{i'}_j | H(\overline{3})^j | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} \\
+\;& e(\overline{3})_2 \langle \mathcal{F}^i_{j'} \mathcal{M}^{i'}_j | H(\overline{3})^j | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} + c(6) \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(6)^{jj'}_k | \mathcal{B}_{i''k}\rangle \epsilon_{ii'i''} \\
+\;& d(6)_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(6)^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} + d(6)_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(6)^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} \\
+\;& e(6)_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(6)^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''} + e(6)_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(6)^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''} \\
+\;& f(6) \langle \mathcal{M}^i_j \mathcal{F}^k_{j'} | H(6)^{i'i''}_k | \mathcal{B}_{jj'}\rangle \epsilon_{ii'i''} + g(6) \langle \mathcal{M}^k_j \mathcal{F}^i_{j'} | H(6)^{i'i''}_k | \mathcal{B}_{jj'}\rangle \epsilon_{ii'i''} \\
+\;& m(6) \langle \mathcal{M}^k_j \mathcal{F}^j_k | H(6)^{ii'}_l | \mathcal{B}_{i''l}\rangle \epsilon_{ii'i''} + n(6)_1 \langle \mathcal{M}^k_j \mathcal{F}^j_l | H(6)^{ii'}_k | \mathcal{B}_{i''l}\rangle \epsilon_{ii'i''} \\
+\;& n(6)_2 \langle \mathcal{F}^k_j \mathcal{M}^j_l | H(6)^{ii'}_k | \mathcal{B}_{i''l}\rangle \epsilon_{ii'i''} + c(\overline{15}) \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{15})^{jj'}_k | \mathcal{B}_{i''k}\rangle \epsilon_{ii'i''} \\
+\;& d(\overline{15})_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{15})^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} + d(\overline{15})_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(\overline{15})^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} \\
+\;& e(\overline{15})_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{15})^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''} + e(\overline{15})_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(\overline{15})^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''}
\end{aligned}
$$

Similar for penguin amplitudes, and also for S-wave and P-wave amplidues $\mathcal{S}$ and $\mathcal{P}$.

For the sextet baryons, the $SU(3)$ invariant amplitude can be expressed by

$$
\begin{aligned}
T_{sex}(q) \;=\;& a(\overline{3})\langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{3})^{i''} | \mathcal{B}_{jj'}\rangle \epsilon_{ii'i''} + b(\overline{3})_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{3})^{j} | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} \\
+\;& b(\overline{3})_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(\overline{3})^{j} | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} + c(\overline{3})_1 \langle \mathcal{M}^i_{j'} \mathcal{F}^{i'}_{j} | H(\overline{3})^{j} | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} \\
+\;& c(\overline{3})_2 \langle \mathcal{F}^i_{j'} \mathcal{M}^{i'}_{j} | H(\overline{3})^{j} | \mathcal{B}_{i''j'}\rangle \epsilon_{ii'i''} + a(6) \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(6)^{jj'}_k | \mathcal{B}_{i''k}\rangle \epsilon_{ii'i''} \\
+\;& b(6)_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(6)^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} + b(6)_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(6)^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} \\
+\;& c(6)_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(6)^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''} + c(6)_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(6)^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''} \\
+\;& d(6) \langle \mathcal{M}^i_j \mathcal{F}^{k}_{j'} | H(6)^{i'i''}_k | \mathcal{B}_{jj'}\rangle \epsilon_{ii'i''} + e(6) \langle \mathcal{M}^k_j \mathcal{F}^{i}_{j'} | H(6)^{i'i''}_k | \mathcal{B}_{jj'}\rangle \epsilon_{ii'i''} \\
+\;& f(6) \langle \mathcal{M}^k_j \mathcal{F}^{j}_{k} | H(6)^{ii'}_l | \mathcal{B}_{i''l}\rangle \epsilon_{ii'i''} + g(6)_1 \langle \mathcal{M}^k_j \mathcal{F}^{j}_{l} | H(6)^{ii'}_k | \mathcal{B}_{i''l}\rangle \epsilon_{ii'i''} \\
+\;& g(6)_2 \langle \mathcal{F}^k_j \mathcal{M}^{j}_{l} | H(6)^{ii'}_k | \mathcal{B}_{i''l}\rangle \epsilon_{ii'i''} + a(\overline{15}) \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{15})^{jj'}_k | \mathcal{B}_{i''k}\rangle \epsilon_{ii'i''} \\
+\;& b(\overline{15})_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{15})^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} + b(\overline{15})_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(\overline{15})^{i''j}_k | \mathcal{B}_{j'k}\rangle \epsilon_{ii'i''} \\
+\;& c(\overline{15})_1 \langle \mathcal{M}^i_j \mathcal{F}^{i'}_{j'} | H(\overline{15})^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''} + c(\overline{15})_2 \langle \mathcal{F}^i_j \mathcal{M}^{i'}_{j'} | H(\overline{15})^{i''j'}_k | \mathcal{B}_{jk}\rangle \epsilon_{ii'i''} \;,
\end{aligned}
$$

$\mathcal{B}^{ij}$ with (i,j) is symmetric, and due to the nature of matrix H^{ij}_k,
(i,j) is antisymmetric for (6), while symmetric for $(\overline{15})$,
so $a(\overline{3}), a(6), d(6), e(6), f(6), a(\overline{15})$ have no new contribution with the exchange of $\mathcal{F}$ and $\mathcal{M}$.
for $(\overline{15})$, it do not have d, e, f, g terms like (6) for the symmetric nature of (i,j) of $H^{ij}_k(\overline{15})$.

Expanding previous relations, one obtains the decay amplitudes for all decay processes. One finds the following relations for anti-triplet decays:

$$
\begin{aligned}
&T(\Xi_b^- \to K^- n) = T(\Xi_b^- \to \pi^- \Xi^0)\ , && T(\Xi_b^0 \to \bar{K}^0 n) = T(\Lambda_b^0 \to K^0 \Xi^0)\ ,\\
&T(\Xi_b^- \to K^0 \Xi^-) = T(\Xi_b^- \to \bar{K}^0 \Sigma^-)\ , && T(\Xi_b^0 \to K^0 \Xi^0) = T(\Lambda_b^0 \to \bar{K}^0 n)\ ,\\
&T(\Xi_b^0 \to \pi^- \Sigma^+) = T(\Lambda_b^0 \to K^- p)\ , && T(\Lambda_b^0 \to \pi^- p) = T(\Xi_b^0 \to K^- \Sigma^+);\\
&T(\Xi_b^0 \to \pi^+ \Sigma^-) = T(\Lambda_b^0 \to K^+ \Xi^-)\ , && T(\Lambda_b^0 \to K^+ \Sigma^-) = T(\Xi_b^0 \to \pi^+ \Xi^-)\ ,\\
&T(\Xi_b^- \to \eta_1 \Sigma^-) = T(\Xi_b^- \to \eta_1 \Xi^-)\ , && T(\Lambda_b^0 \to \eta_1 n) = T(\Xi_b^0 \to \eta_1 \Xi^0)\ ,\\
&T(\Xi_b^0 \to K^- p) = T(\Lambda_b^0 \to \pi^- \Sigma^+)\ , && T(\Xi_b^0 \to K^+ \Xi^-) = T(\Lambda_b^0 \to \pi^+ \Sigma^-)\ .
\end{aligned}
$$

These relations are due to U-spin symmetry: d and s exchange ($\Delta S = 0$ and $\Delta S = -1$) .

$$T(\Sigma_b^+ \to n\pi^+) = -T(\Sigma_b^+ \to \Xi^0 K^+) \,, \quad T(\Sigma_b^+ \to \Sigma^+ K^0) = -T(\Sigma_b^+ \to p\bar{K}^0) \,,$$

$$T(\Sigma_b^- \to n\pi^-) = -T(\Omega_b^- \to \Xi^0 K^-) \,, \quad T(\Sigma_b^- \to \Sigma^- K^0) = -T(\Omega_b^- \to \Xi^- \bar{K}^0) \,,$$

$$T(\Omega_b^- \to \Xi^0\pi^-) = -T(\Sigma_b^- \to nK^-) \,, \quad T(\Omega_b^- \to \Sigma^- \bar{K}^0) = -T(\Sigma_b^- \to \Xi^- K^0) \,,$$

$$T(\Sigma_b^0 \to \Sigma^- K^+) = -T(\Xi_b'^0 \to \Xi^-\pi^+) \,, \quad T(\Sigma_b^0 \to p\pi^-) = -T(\Xi_b'^0 \to \Sigma^+ K^-);$$

$$T(\Xi_b'^0 \to \Xi^- K^+) = -T(\Sigma_b^0 \to \Sigma^-\pi^+) \,, \quad T(\Xi_b'^0 \to \Sigma^-\pi^+) = -T(\Sigma_b^0 \to \Xi^- K^+) \,,$$

$$T(\Xi_b'^0 \to pK^-) = -T(\Sigma_b^0 \to \Sigma^+\pi^-) \,, \quad T(\Xi_b'^0 \to \Sigma^+\pi^-) = -T(\Sigma_b^0 \to pK^-) \,,$$

$$T(\Xi_b'^0 \to \Xi^0 K^0) = -T(\Sigma_b^0 \to n\bar{K}^0) \,, \quad T(\Xi_b'^0 \to n\bar{K}^0) = -T(\Sigma_b^0 \to \Xi^0 K^0) \,,$$

$$T(\Xi_b'^- \to nK^-) = -T(\Xi_b'^- \to \Xi^0\pi^+) \,, \quad T(\Xi_b'^- \to \Xi^- K^0) = -T(\Xi_b'^- \to \Sigma^- \bar{K}^0) \,.$$

In addition to U-spin amplitude relations, there are also some isospin relations

$$T(\Omega_b^- \to \pi^-\Xi^0) = \frac{1}{\sqrt{2}} T(\Omega_b^- \to \pi^0\Xi^-); \; T(\Omega_b^- \to K^-\Sigma^0) = \frac{1}{\sqrt{2}} T(\Omega_b^- \to \bar{K}^0\Sigma^-);$$

Using

$$\mathcal{S}(q) = V_{ub}V_{uq}^{*}T(q)_0 + V_{tb}V_{tq}^{*}P(q)_0,\ \mathcal{P}(q) = V_{ub}V_{uq}^{*}T(q)_1 + V_{tb}V_{tq}^{*}P(q)_1,$$

$$\bar{\mathcal{S}}(q) = -[V_{ub}^{*}V_{uq}T(q)_0 + V_{tb}^{*}VtqP(q)_0],\ \bar{\mathcal{P}}(q) = V_{ub}^{*}V_{uq}T(q)_1 + V_{tb}^{*}VtqP(q)_1\ ,$$

$$\Delta(q) = \Gamma(q) - \bar{\Gamma}(q) = -8|p_c|Im(V_{ub}V_{uq}^{*}V_{tb}^{*}V_{tq})Im[T(q)_0P(q)_0^{*} + T(q)_1P(q)_1^{*}]\ ,$$

The U-spin related pairs would have

$$\Delta(d) = -\Delta(s)\ ,\quad \frac{A_{CP}(\mathcal{B}_a \to \mathcal{MF})_{\Delta S=0}}{A_{CP}(\mathcal{B}_b \to \mathcal{MF})_{\Delta S=-1}} = -\frac{Br(\mathcal{B}_b \to \mathcal{MF})_{\Delta S=-1}}{Br(\mathcal{B}_a \to \mathcal{MF})_{\Delta S=0}} \cdot \frac{\tau_{\mathcal{B}_a}}{\tau_{\mathcal{B}_b}}\ .$$

Comparison of relations for $B \to MM$ and $\mathcal{B} \to MF$.

Well tested relation in $B \to MM$

$$\frac{A_{CP}(\bar{B}_s^0 \to K^+\pi^-)}{A_{CP}(\bar{B}^0 \to K^-\pi^+)} = -\frac{Br(\bar{B}^0 \to K^-\pi^+)\tau_{\bar{B}_s^0}}{Br(\bar{B}_s^0 \to K^+\pi^-)\tau_{\bar{B}^0}} .$$

The present data give: left 3.41 ± 0.55 and right 3.56 ± 0.40.

These two values agree with the prediction very well.

Corresponding to the above relation, there are two relations for b-baryon decays.

$$\frac{\mathcal{A}_\alpha(\mathcal{B}_a \to \mathcal{M}\mathcal{F})_{\Delta S=0}}{\mathcal{A}_\alpha(\mathcal{B}_b \to \mathcal{M}\mathcal{F})_{\Delta S=-1}} = -\frac{Br(\mathcal{B}_b \to \mathcal{M}\mathcal{F})_{\Delta S=-1}}{Br(\mathcal{B}_a \to \mathcal{M}\mathcal{F})_{\Delta S=0}} \cdot \frac{\tau_{\mathcal{B}_a}}{\tau_{\mathcal{B}_b}} ,$$

$$\frac{A_{CP}(\mathcal{B}_a \to \mathcal{M}\mathcal{F})_{\Delta S=0}}{A_{CP}(\mathcal{B}_b \to \mathcal{M}\mathcal{F})_{\Delta S=-1}} = -\frac{Br(\mathcal{B}_b \to \mathcal{M}\mathcal{F})_{\Delta S=-1}}{Br(\mathcal{B}_a \to \mathcal{M}\mathcal{F})_{\Delta S=0}} \cdot \frac{\tau_{\mathcal{B}_a}}{\tau_{\mathcal{B}_b}} ,$$

These relations will hold at the same level as their $B \to MM$ counter parts.

Anti-triplet
Practical test for A_{CP} relations

$$(\Xi_b^- \to K^0\Xi^-,\ \ \Xi_b^- \to \bar{K}^0\Sigma^-)\ ,$$
$$(\Xi_b^0 \to \pi^-\Sigma^+,\ \ \Lambda_b^0 \to K^-p)\ , \qquad (\Lambda_b^0 \to \pi^-p,\ \ \Xi_b^0 \to K^-\Sigma^+)\ ,$$
$$(\Xi_b^0 \to \pi^+\Sigma^-,\ \ \Lambda_b^0 \to K^+\Xi^-)\ , \qquad (\Lambda_b^0 \to K^+\Sigma^-,\ \ \Xi_b^0 \to \pi^+\Xi^-)\ ,$$
$$(\Xi_b^0 \to K^-p,\ \ \Lambda_b^0 \to \pi^-\Sigma^+)\ , \qquad (\Xi_b^0 \to K^+\Xi^-,\ \ \Lambda_b^0 \to \pi^+\Sigma^-)\ .$$

Practical test for A_a relations

$$(\Xi_b^- \to K^0\Xi^-,\ \ \Xi_b^- \to \bar{K}^0\Sigma^-)\ ,\ \ (\Xi_b^0 \to \pi^+\Sigma^-,\ \ \Lambda_b^0 \to K^+\Xi^-)\ ,$$
$$(\Lambda_b^0 \to K^+\Sigma^-,\ \ \Xi_b^0 \to \pi^+\Xi^-)\ ,\ \ (\Xi_b^0 \to K^+\Xi^-,\ \ \Lambda_b^0 \to \pi^+\Sigma^-)\ .$$

Sextet
Practical test for A_{CP} relations

$$
\begin{aligned}
&(\Sigma_b^+ \to \Sigma^+ K^0\ ,\ \ \Sigma_b^+ \to p\bar{K}^0)\ ,\ \ (\Sigma_b^- \to \Sigma^- K^0\ ,\ \ \Omega_b^- \to \Xi^- \bar{K}^0)\ ,\\
&(\Omega_b^- \to \Sigma^- \bar{K}^0\ ,\ \ \Sigma_b^- \to \Xi^- K^0)\ ,\ \ (\Sigma_b^0 \to \Sigma^- K^+\ ,\ \ \Xi_b'^0 \to \Xi^- \pi^+)\ ,\\
&(\Sigma_b^0 \to p\pi^-\ ,\ \ \Xi_b'^0 \to \Sigma^+ K^-)\ ,\ \ (\Xi_b'^0 \to \Xi^- K^+\ ,\ \ \Sigma_b^0 \to \Sigma^- \pi^+)\ ,\\
&(\Xi_b'^0 \to \Sigma^- \pi^+\ ,\ \ \Sigma_b^0 \to \Xi^- K^+)\ ,\ \ (\Xi_b'^0 \to pK^-\ ,\ \ \Sigma_b^0 \to \Sigma^+ \pi^-)\ ,\\
&(\Xi_b'^0 \to \Sigma^+ \pi^-\ ,\ \ \Sigma_b^0 \to pK^-)\ ,\ \ (\Xi_b'^- \to \Xi^- K^0\ ,\ \ \Xi_b'^- \to \Sigma^- \bar{K}^0).
\end{aligned}
$$

Practical test for A_a relations

$$
\begin{aligned}
&(\Sigma_b^- \to \Sigma^- K^0\ ,\ \ \Omega_b^- \to \Xi^- \bar{K}^0)\ ,\ \ (\Omega_b^- \to \Sigma^- \bar{K}^0\ ,\ \ \Sigma_b^- \to \Xi^- K^0)\ ,\\
&(\Sigma_b^0 \to \Sigma^- K^+\ ,\ \ \Xi_b'^0 \to \Xi^- \pi^+)\ ,\ \ (\Xi_b'^0 \to \Xi^- K^+\ ,\ \ \Sigma_b^0 \to \Sigma^- \pi^+)\ ,\\
&(\Xi_b'^0 \to \Sigma^- \pi^+\ ,\ \ \Sigma_b^0 \to \Xi^- K^+)\ ,\ \ (\Xi_b'^- \to \Xi^- K^0\ ,\ \ \Xi_b'^- \to \Sigma^- \bar{K}^0).
\end{aligned}
$$

4. A comment on Diquark Model for pentaquark

* L. Maiani et al., arxiv:1507.0489

The LHCb collaboration has reported observation of two new resonances in the Λ_b decay [1],

$$\Lambda_b(bud) \to \mathbb{P}^+ K^- \quad (1)$$

each decaying according to

$$\mathbb{P}^+ \to J/\Psi + p \quad (2)$$

Thus the new particles carry a unit of baryonic number and feature the valence quark composition

$$\mathbb{P}^+ = \bar{c}cuud \quad (3)$$

whence the name pentaquarks.

The best fit quantum numbers and masses are [1]

$$\begin{aligned} J^P &= 3/2^-, M \simeq 3380 \text{ GeV}, \text{ fract.} \simeq 8.4 \% \\ J^P &= 5/2^+, M \simeq 4450 \text{ GeV}, \text{ fract.} \simeq 4.1 \% \quad (4) \end{aligned}$$

$$\mathbb{P}(3/2^-) = \{\bar{c}\,[cq]_{s=1}[q'q'']_{s=1}, L=0\}$$
$$\mathbb{P}(5/2^+) = \{\bar{c}\,[cq]_{s=1}[q'q'']_{s=0}, L=1\}$$

In the particular case of the newly discovered pentaquarks, we are led to identify the basic (color $\bar{\mathbf{3}}$) units as: the charm antiquark $\bar{c}$, one heavy-light diquark, $[cq]$, and one light-light diquark, $[q'q'']$ (q, q', q'' denote light quarks, which we restric at first to be the u, d quarks, extending later to the flavor SU(3) triplet, u, d, s).

$$\mathbb{P}_A = \epsilon^{\alpha\beta\gamma}\,\{\bar{c}_\alpha\,[cq]_{\beta,s=0,1}\,[q'q'']_{\gamma,s=0}, L\} = \\ = \mathbf{3}\otimes\bar{\mathbf{3}} = \mathbf{1}\oplus\mathbf{8} \quad (8)$$

$$\mathbb{P}_S = \epsilon^{\alpha\beta\gamma}\,\{\bar{c}_\alpha\,[cq]_{\beta,s=0,1}\,[q'q'']_{\gamma,s=1}, L\} = \\ = \mathbf{3}\otimes\mathbf{6} = \mathbf{8}\oplus\mathbf{10} \quad (9)$$

$$(\mathcal{P}_i^j) = \begin{pmatrix} \frac{\Sigma_p^0}{\sqrt{2}} + \frac{\Lambda_p^0}{\sqrt{6}} & \Sigma_p^+ & p_p \\ \Sigma_p^- & -\frac{\Sigma_p^0}{\sqrt{2}} + \frac{\Lambda_p^0}{\sqrt{6}} & n_p \\ \Xi_p^- & \Xi_p^0 & -\frac{2\Lambda_p^0}{\sqrt{6}} \end{pmatrix}$$

For S-waves, the first and the second series give the angular momenta

$$\mathbb{P}_A(L=0):\ J = 1/2\ (2), 3/2\ (1) \quad (10)$$

$$\mathbb{P}_S(L=0):\ J = 1/2\ (3), 3/2\ (3), 5/2\ (1) \quad (11)$$

(in parenthesis the multiplicity of each spin value). In consideration of (5), we propose to assign the $3/2^-$ and the $5/2^+$ states to the symmetric and antisymmetric serieses, respectively.

$$\mathcal{P}_{111} = \Xi_{10}^{++}\,,\qquad \mathcal{P}_{112} = \Xi_{10}^{+}/\sqrt{3}\,,$$
$$\mathcal{P}_{122} = \Xi_{10}^{0}/\sqrt{3}\,,\qquad \mathcal{P}_{222} = \Xi_{10}^{-}\,,$$
$$\mathcal{P}_{113} = \Sigma_{10}^{+}/\sqrt{3}\,,\qquad \mathcal{P}_{123} = \Sigma_{10}^{+}/\sqrt{6}\,,$$
$$\mathcal{P}_{223} = \Sigma_{10}^{-}/\sqrt{3}\,,\qquad \mathcal{P}_{133} = N_{10}^{0}/\sqrt{3}\,,$$
$$\mathcal{P}_{223} = N_{10}^{+}/\sqrt{3}\,,\qquad \mathcal{P}_{333} = \Omega_{10}^{-}\,.$$

For Pentaquark in 8 (the two new ones), same treatment as what we did for $\mathcal{B}$ to $\mathcal{F}$ $\mathcal{M}$ for as anti-triplet b-baryons. $\mathcal{F}$ *is* now can in pentaquark $\mathcal{P}$ (octet)
$\mathcal{P}$ can also be a decuplet.

$$H_{eff}(q) = \frac{4G_F}{\sqrt{2}}[V_{cb}V_{cq}^*(c_1O_1 + c_2O_2), \quad \begin{array}{ll} H(\bar{3})^2 = 1\,, & \text{for } \Delta S = 0\,, \\ H(\bar{3})^3 = 1\,, & \text{for } \Delta S = -1\,. \end{array}$$

Consider $\mathcal{B}_3$ to M $\mathcal{P}_8$

$$
\begin{aligned}
&T_t(\Xi_b^- \to K^- n_p) = T_t(\Xi_b^- \to \pi^- \Xi_p^0)\ , \quad T_t(\Xi_b^0 \to \bar{K}^0 n_p) = T_t(\Lambda_b^0 \to K^0 \Xi_p^0)\ ,\\
&T_t(\Xi_b^- \to K^0 \Xi_p^-) = T_t(\Xi_b^- \to \bar{K}^0 \Sigma_p^-)\ , \quad T_t(\Xi_b^0 \to K^0 \Xi_p^0) = T_t(\Lambda_b^0 \to \bar{K}^0 n_p)\ ,\\
&T_t(\Xi_b^0 \to \pi^- \Sigma_p^+) = T_t(\Lambda_b^0 \to K^- p_p)\ , \quad T_t(\Lambda_b^0 \to \pi^- p_p) = T_t(\Xi_b^0 \to K^- \Sigma_p^+)\ ,\\
&T_t(\Xi_b^0 \to \pi^+ \Sigma_p^-) = T_t(\Lambda_b^0 \to K^+ \Xi_p^-)\ , \quad T_t(\Lambda_b^0 \to K^+ \Sigma_p^-) = T_t(\Xi_b^0 \to \pi^+ \Xi_p^-)\ ,\\
&T_t(\Xi_b^0 \to K^- p_p) = T(\Lambda_b^0 \to \pi^- \Sigma_p^+)\ , \quad T_t(\Xi_b^0 \to K^+ \Xi_p^-) = T_t(\Lambda_b^0 \to \pi^+ \Sigma_p^-)\ .
\end{aligned}
$$

$$
A(\mathcal{B} \to M\mathcal{P}, \Delta S = 0) \quad = V_{cb} V_{cd}^* T\ , \quad A(\mathcal{B} \to M\mathcal{P}, \Delta S = -1) = V_{cb} V_{cs}^*) T\ ,
$$

$$
\frac{\Gamma(\mathcal{B} \to M\mathcal{P}, \Delta S = 0)}{\Gamma(\mathcal{B} \to M\mathcal{P}, \Delta S = -1)} = \frac{|V_{cd}|^2}{|V_{cs}|^2}\ .
$$

$$
\begin{aligned}
T(\Lambda_b^0 \to \pi^+\Xi_{10}^-) &= \frac{1}{\sqrt{3}} T(\Lambda_b^0 \to K^+\Sigma_{10}^-) = \frac{1}{\sqrt{6}} T(\Lambda_{10}^0 \to \pi^0\Xi_{10}^0) \\
&= -\frac{1}{\sqrt{3}} T(\Lambda_b^0 \to \pi^-\Xi_{10}^+) = -\frac{1}{\sqrt{6}} T(\Lambda_b^0 \to K^0\Sigma_{10}^0) \\
&= \frac{1}{\sqrt{3}} T(\Lambda_b^0 \to \pi^0\Sigma_{10}^0) = \frac{\sqrt{2}}{3} T(\Lambda_b^0 \to \eta_8\Sigma_{10}^0) = \frac{1}{\sqrt{3}} T(\Lambda_{10}^0 \to \pi^+\Sigma_{10}^-) \\
&= \frac{1}{\sqrt{3}} T(\Lambda_b^0 \to K^+N_{10}^-) = -\frac{1}{\sqrt{3}} T(\Lambda_b^0 \to K^-\Xi_{10}^+) \\
&= -\frac{1}{\sqrt{3}} T(\Lambda_b^0 \to \bar{K}^0\Xi_{10}^0) \; .
\end{aligned}
$$

Can be tested at the LHCb!

Several other SU(3) predictions

$$P1) \quad \Delta(B^+ \to K^+\bar{K}^0) = -\Delta(B^+ \to K^0\pi^+) ,$$
$$P2) \quad \Delta(B^0 \to \pi^+\pi^-) = -\Delta(B_s^0 \to K^-K^+) ,$$
$$P3) \quad \Delta(B^0 \to K^+K^-) = -\Delta(B_s^0 \to \pi^+\pi^-) = -2\Delta(B_s^0 \to \pi^0\pi^0) ,$$
$$P4) \quad \Delta(B^0 \to \bar{K}^0K^0) = -\Delta(B_s^0 \to K^0\bar{K}^0) ,$$
$$P5) \quad \Delta(B_s^0 \to K^-\pi^+) = -\Delta(B^0 \to K^+\pi^-),$$
$$P6) \quad \Delta(B_s^0 \to \bar{K}^0\pi^0) = -\Delta(B^0 \to K^0\pi^0).$$

Neglect annihilation contributions

$$P1) \approx P4) , \quad P2) \approx P5) , \quad P6) \approx \Delta(B^0 \to \pi^0\pi^0) .$$

$$\frac{A_{CP}(\bar{B}^0 \to \pi^-\pi^+)}{A_{CP}(\bar{B}^0 \to K^-\pi^+)} \approx -\frac{Br(\bar{B}^0 \to K^-\pi^+)}{Br(\bar{B}^0 \to \pi^-\pi^+)}$$

Data left: -3.78+-0.67 right: -3.72+-0.17

Agree very well. Neglecting annihilation is a good approximation!

CP asymmetry relation for B → PV

Deshpande, He and Shi, 2000

$$
\begin{aligned}
&V1) \quad \Delta(B^+ \to K^+ \bar{K}^{*0}) = -\Delta(B^+ \to K^{*0}\pi^+)\ ,\\
&V2) \quad \Delta(B^0 \to K^0 \bar{K}^{*0}) = -\Delta(B_s^0 \to \bar{K}^0 K^{*0})\ ,\\
&V3) \quad \Delta(B^+ \to \bar{K}^0 K^{*+}) = -\Delta(B^+ \to K^0 \rho^+)\ ,\\
&V4) \quad \Delta(B^0 \to \bar{K}^0 K^{*0}) = -\Delta(B_s^0 \to K^0 \bar{K}^{*0})\ ,\\
&V5) \quad \Delta(B^0 \to \pi^+ \rho^-) = -\Delta(B_s^0 \to K^+ K^{*-})\ ,\\
&V6) \quad \Delta(B_s^0 \to \pi^+ K^{*-}) = -\Delta(B^0 \to K^+ \rho^-)\ ,\\
&V7) \quad \Delta(B^0 \to \pi^- \rho^+) = -\Delta(B_s^0 \to K^- K^{*+})\ ,\\
&V8) \quad \Delta(B_s^0 \to K^- \rho^+) = -\Delta(B^0 \to \pi^- K^{*+})\ ,\\
&V9) \quad \Delta(B^0 \to K^+ K^{*-}) = -\Delta(B_s^0 \to \pi^+ \rho^-)\ ,\\
&V10) \quad \Delta(B^0 \to K^- K^{*+}) = -\Delta(B_s^0 \to \pi^- \rho^+).
\end{aligned}
$$

Neglect annihilation contributions

$$V1) \approx V2)\ , \quad V3) \approx V4)\ , \quad V5) \approx V6)\ , \quad V7) \approx V8).$$

B ➔ PP data
Branching ratios (HFAG averages)

P1)	$B^+ \to K^+ \overline{K}^0$	1.19 ± 0.18	$B^+ \to K^0 \pi^+$	23.80 ± 0.74
P2)	$B^0 \to \pi^+ \pi^-$	5.10 ± 0.19	$B_s^0 \to K^- K^+$	24.5 ± 1.8
P3)	$B^0 \to K^+ K^-$	0.12 ± 0.06	$B_s^0 \to \pi^+ \pi^-$	0.73 ± 0.14
			$B_s^0 \to \pi^0 \pi^0$	$--$
P4)	$B^0 \to \overline{K}^0 K^0$	1.21 ± 0.16	$B_s^0 \to K^0 \overline{K}^0$	< 66
P5)	$B_s^0 \to K^- \pi^+$	5.4 ± 0.6	$B^0 \to K^+ \pi^-$	$19.55^{+0.54}_{-0.53}$
P6)	$B_s^0 \to \overline{K}^0 \pi^0$	$--$	$B^0 \to K^0 \pi^0$	$9.92^{+0.49}_{-0.48}$
			$B^0 \to \pi^0 \pi^0$	$1.91^{+0.22}_{-0.23}$

CP asymmetries and predictions for B → PP

	$A_{CP}^{Exp.}(\Delta S=0)$	$A_{CP}^{Pred.}(\Delta S=-1)$	$A_{CP}^{Exp.}(\Delta S=-1)$	$A_{CP}^{Pred.}(\Delta S=0)$
P1)	$B^+ \to K^+\overline{K}^0$ 0.041 ± 0.141	$B^+ \to K^0\pi^+$ -0.0021 ± 0.0071	$B^+ \to K^0\pi^+$ -0.015 ± 0.012	$B^+ \to K^+\overline{K}^0$ 0.300 ± 0.244
P2)	$B^0 \to \pi^+\pi^-$ 0.29 ± 0.05	$B_s^0 \to K^-K^+$ -0.060 ± 0.011	$B_s^0 \to K^-K^+$ $0.02 \pm 0.18 \pm 0.04$	$B^0 \to \pi^+\pi^-$ -0.097 ± 0.892
P3)	$B^0 \to K^+K^-$ $--$	$B_s^0 \to \pi^+\pi^-$ $B_s^0 \to \pi^0\pi^0$	$B_s^0 \to \pi^+\pi^-$ $--$ $B_s^0 \to \pi^0\pi^0$ $--$	$B^0 \to K^+K^-$ $B^0 \to K^+K^-$
P4)	$B^0 \to \overline{K}^0K^0$ $--$	$B_s^0 \to K^0\overline{K}^0$	$B_s^0 \to K^0\overline{K}^0$ $--$	$B^0 \to \overline{K}^0K^0$
P5)	$B_s^0 \to K^-\pi^+$ 0.26 ± 0.04	$B^0 \to K^+\pi^-$ -0.073 ± 0.010	$B^0 \to K^+\pi^-$ -0.085 ± 0.006	$B_s^0 \to K^-\pi^+$ 0.304 ± 0.040
P6)	$B_s^0 \to \overline{K}^0\pi^0$ $--$ $B^0 \to \pi^0\pi^0$ 0.43 ± 0.24	$B^0 \to K^0\pi^0$ $B^0 \to K^0\pi^0$ -0.083 ± 0.047	$B^0 \to K^0\pi^0$ -0.01 ± 0.10	$B_s^0 \to \overline{K}^0\pi^0$ $B^0 \to \pi^0\pi^0$ 0.052 ± 0.519

New from LHCb: arXiv:1308.1428.

$A_{CP}(\pi^+\pi^-)$ = 0.38+- 0.15+- 0.02, $A_{CP}(K^+K^-)$ = -0.14+-0.11+-0.30

With in error bar with theory prediction!

Data for B ➔ PV

Branching ratios

	$\Delta S = 0$ *Process*	$Br^{HFAG}(10^{-6})$	$\Delta S = -1$ *Process*	$Br^{HFAG}(10^{-6})$
V1)	$B^+ \to K^+ \bar{K}^{*0}$	$--$	$B^+ \to K^{*0}\pi^+$	$9.9^{+0.8}_{-0.9}$
V2)	$B^0 \to K^0 \bar{K}^{*0}$	$--$	$B_s^0 \to \bar{K}^0 K^{*0}$	$--$
V3)	$B^+ \to \bar{K}^0 K^{*+}$	$--$	$B^+ \to K^0 \rho^+$	$8.0^{+1.5}_{-1.4}$
V4)	$B^0 \to \bar{K}^0 K^{*0}$	< 1.9	$B_s^0 \to K^0 \bar{K}^{*0}$	$--$
V5)	$B^0 \to \pi^+ \rho^-$	23 ± 2.3	$B_s^0 \to K^+ K^{*-}$	$--$
V6)	$B_s^0 \to \pi^+ K^{*-}$	$--$	$B^0 \to K^+ \rho^-$	7.2 ± 0.9
V7)	$B^0 \to \pi^- \rho^+$	23 ± 2.3	$B_s^0 \to K^- K^{*+}$	$--$
V8)	$B_s^0 \to K^- \rho^+$	$--$	$B^0 \to \pi^- K^{*+}$	8.5 ± 0.7
V9)	$B^0 \to K^+ K^{*-}$	$--$	$B_s^0 \to \pi^+ \rho^-$	$--$
V10)	$B^0 \to K^- K^{*+}$	$--$	$B_s^0 \to \pi^- \rho^+$	$--$

CP asymmetries and predictions for B → PV

	$A_{CP}^{Exp.}(\Delta S=0)$	$A_{CP}^{Pred.}(\Delta S=-1)$	$A_{CP}^{Exp.}(\Delta S=-1)$	$A_{CP}^{Pred.}(\Delta S=0)$
V1)	$B^+ \to K^+\bar{K}^{*0}$ $--$	$B^+ \to K^{*0}\pi^+$	$B^+ \to K^{*0}\pi^+$ -0.038 ± 0.042	$B^+ \to K^+\bar{K}^{*0}$
V2)	$B^0 \to K^0\bar{K}^{*0}$ $--$	$B_s^0 \to \bar{K}^0 K^{*0}$	$B_s^0 \to \bar{K}^0 K^{*0}$ $--$	$B^0 \to K^0\bar{K}^{*0}$
V3)	$B^+ \to \bar{K}^0 K^{*+}$ $--$	$B^+ \to \bar{K}^0 K^{*+}$	$B^+ \to K^0\rho^+$ -0.12 ± 0.17	$B^+ \to \bar{K}^0 K^{*+}$
V4)	$B^0 \to \bar{K}^0 K^{*0}$ $--$	$B_s^0 \to K^0\bar{K}^{*0}$	$B_s^0 \to K^0\bar{K}^{*0}$ $--$	$B^0 \to \bar{K}^0 K^{*0}$
V5)	$B^0 \to \pi^+\rho^-$ -0.13 ± 0.04	$B_s^0 \to K^+K^{*-}$ $B^0 \to K^+\rho^-$ 0.415 ± 0.144	$B_s^0 \to K^+K^{*-}$ $--$	$B^0 \to \pi^+\rho^-$
V6)	$B_s^0 \to \pi^+K^{*-}$ $--$	$B^0 \to K^+\rho^-$	$B^0 \to K^+\rho^-$ 0.20 ± 0.11	$B_s^0 \to \pi^+K^{*-}$ $B^0 \to \pi^+\rho^-$ -0.063 ± 0.036
V7)	$B^0 \to \pi^-\rho^+$ -0.13 ± 0.04	$B_s^0 \to K^-K^{*+}$ $B^0 \to \pi^-K^{*+}$ 0.352 ± 0.117	$B_s^0 \to K^-K^{*+}$ $--$	$B^0 \to \pi^-\rho^+$
V8)	$B_s^0 \to K^-\rho^+$ $--$	$B^0 \to \pi^-K^{*+}$	$B^0 \to \pi^-K^{*+}$ -0.23 ± 0.06	$B_s^0 \to K^-\rho^+$ $B^0 \to \pi^-\rho^+$ 0.085 ± 0.025