Right-handed charged current of b->u transition

Tetsuya Enomoto (Osaka university)

In collaboration with Minoru Tanaka(Osaka university)
and Ryoutaro Watanabe(KEK)

Right-handed charged current

A. Crivellin, Phys. Rev. D 81,031301(2010).

Now new physics we consider is right-handed charged current in b->u transition.
So we need the following dimension-six operator

$$\mathcal{L}_6 = \frac{C}{\Lambda^2}\bar{u}\gamma^\mu P_R b\tilde{\Phi}^\dagger iD_\mu\Phi + \text{h.c.}$$

$$\Lambda : \text{New Physics Scale} \qquad \Phi : \text{Higgs}$$

Then lagrangian of b->u transition

$$\mathcal{L}_{CC}^{\text{eff}} = \frac{g}{\sqrt{2}}W_\mu^+\bar{u}\gamma_\mu(V_{ub}^L P_L + V_{ub}^R P_R)b + \text{h.c.}$$

is found by combining the usual SM interaction with the extra contributions. RH Vub is induced by dim 6 operator and estimated by

TeV scale

$$V_{ub}^R = \frac{C}{2\sqrt{2}G_f\Lambda^2} \simeq 0.003\left(\frac{C}{1}\right)\left(\frac{3\text{TeV}}{\Lambda}\right)^2 \quad (|V_{ub}^L| = 0.00389)$$

Even if Λ=3TeV, b->u RHCC is sensitive.

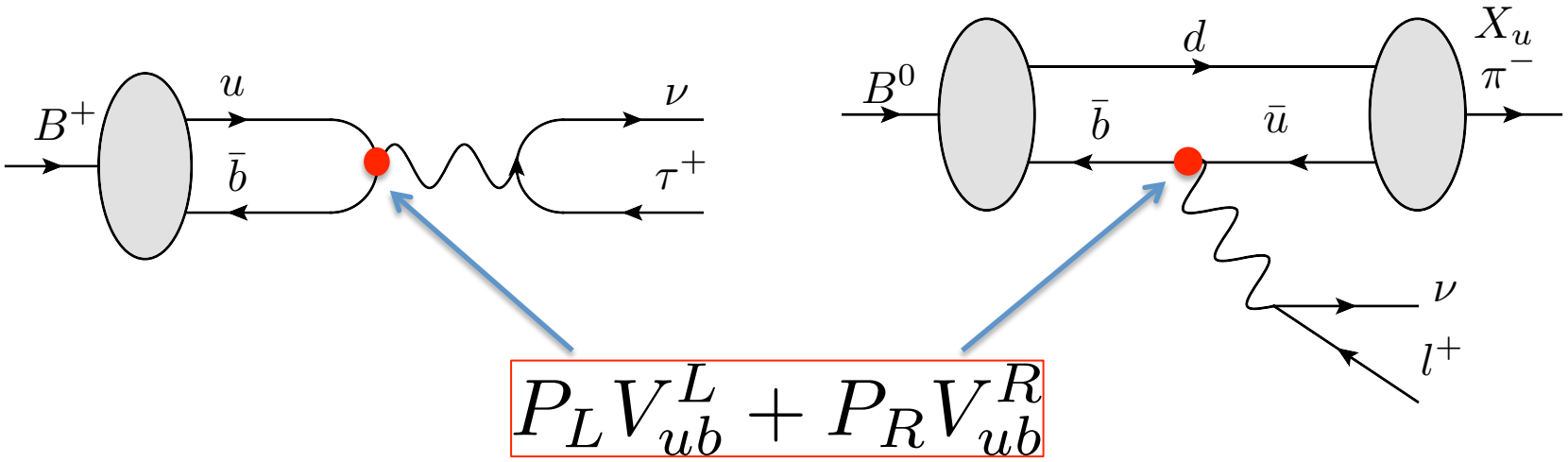
contents

- Constraint from
  - measurement of |Vub|
  - measurement of CP violation in B->ππ
  - measurement of CP violation in B->DK

- Right-handed charged current in MSSM

Constraint from measurement of |Vub|

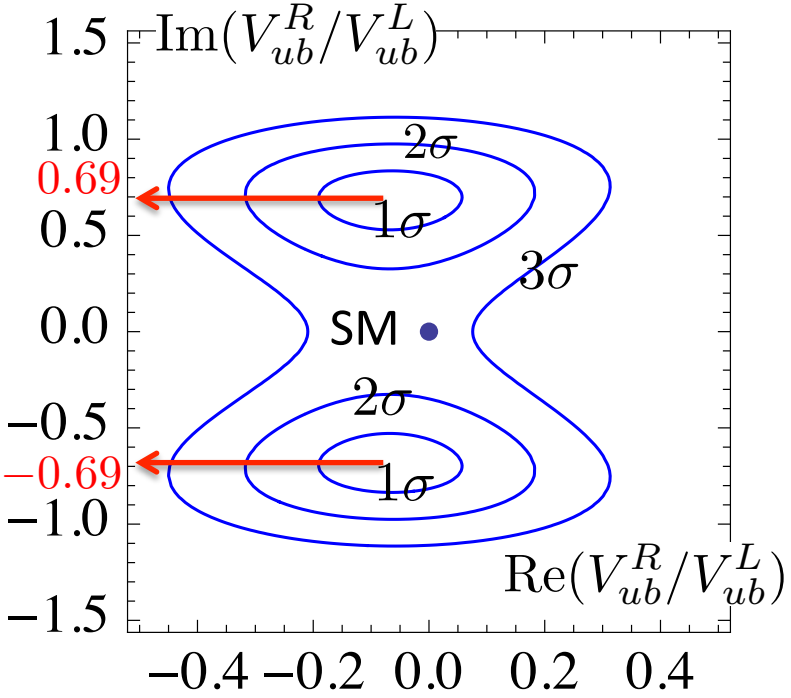
Effect from RHCC



Decay Rate		In SM	With RHCC
$\Gamma(B \to \tau\nu)$	$\propto$	$\lvert V_{ub}^L \rvert^2$	$\lvert V_{ub}^L - V_{ub}^R \rvert^2$
$\Gamma(B \to \pi l\nu)$	$\propto$	$\lvert V_{ub}^L \rvert^2$	$\lvert V_{ub}^L + V_{ub}^R \rvert^2$
$\Gamma(B \to X_u l\nu)$	$\propto$	$\lvert V_{ub}^L \rvert^2$	$\lvert V_{ub}^L \rvert^2 + \lvert V_{ub}^R \rvert^2$
Indirect measurement		$\lvert V_{ub}^L \rvert^2$	$\lvert V_{ub}^L \rvert^2$

We can constrain RH Vub.

Constraint of RHCC



	In SM	With RHCC
$\chi^2/d.o.f$	3.26	2.06

RHCC is better.

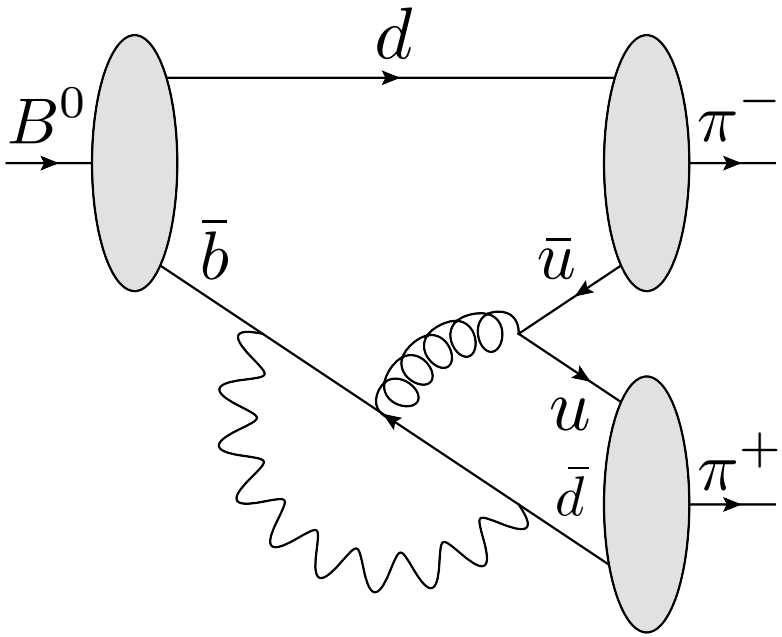
Best fit is $V_{ub}^R/V_{ub}^L = -0.067 \pm 0.69i$.

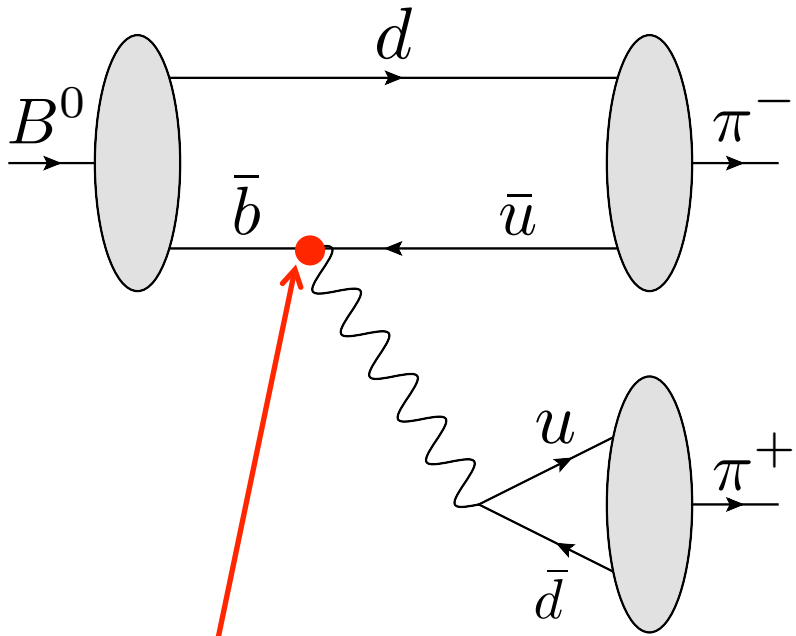
Large Imaginary part is preferred.

If this is true, b->u RHCC can affect CP violation.

Constraint from measurement of CP violation in B->ππ

Diagram of B->ππ





$$P_L V_{ub}^L + P_R V_{ub}^R$$

Effect of RHCC on CP violation in B->ππ

2 CP violating measurements

Direct CP Asymmetry $A_{\pi\pi} = \dfrac{\Gamma(B^+ \to \pi^+\pi^0) - \Gamma(B^- \to \pi^-\pi^0)}{\Gamma(B^+ \to \pi^+\pi^0) + \Gamma(B^- \to \pi^-\pi^0)}$

$\delta\phi_2 =$ (Phase measured by B->ππ and isospin analysis) – (Angle of Unitary Triangle)

Analysis and experiment

	$\sin\delta\phi_2$	$A_{\pi\pi}$
In SM	0	0
With RHCC	$\dfrac{\mathrm{Im}[R_{\pi\pi}]}{\lvert R_{\pi\pi}\rvert}$	$\dfrac{1-\lvert R_{\pi\pi}\rvert^2}{1+\lvert R_{\pi\pi}\rvert^2}$
Experiment	0.017±0.226	0.026±0.039

We can constrain $R_{\pi\pi}$.

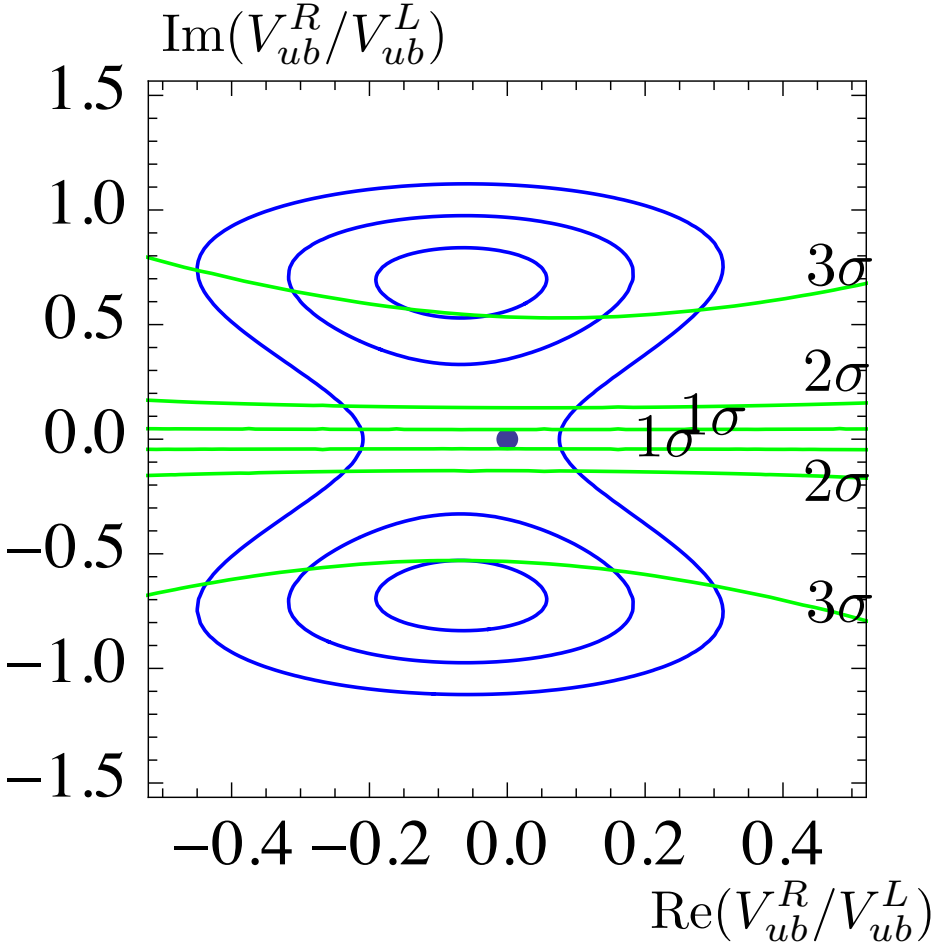
$$R_{\pi\pi} = \frac{1 + (V_{ub}^R/V_{ub}^L)c_\pi}{1 + (V_{ub}^R/V_{ub}^L)^* c_\pi}$$

c_π:complex constant

We can constrain V_{ub}^R/V_{ub}^L.

(factorization approximation)

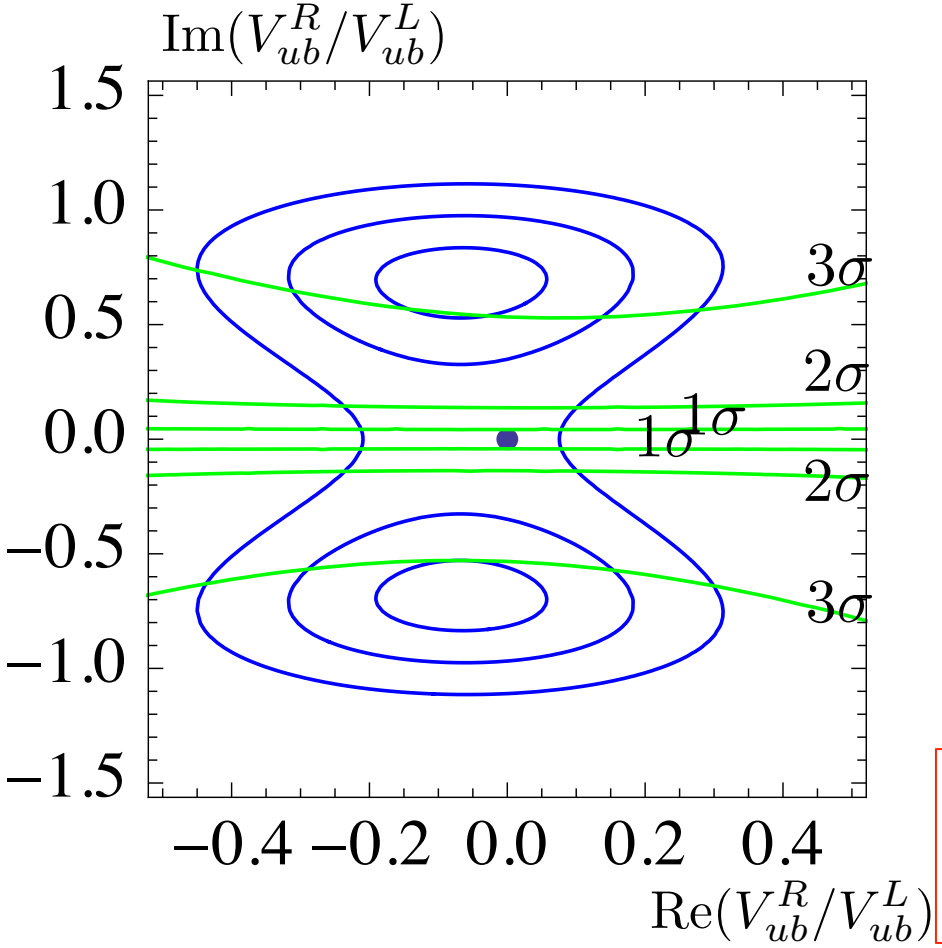
Constraint from CP violation of B→ππ



Green line: Constraint from B->ππ
Blue line: Constraint from |Vub|
black point: Standard Model

Measurements of |Vub| imply a large $|\mathrm{Im}(V_{ub}^R/V_{ub}^L)|$.
But measurement of B->ππ exclude the large one.

Constraint from CP violation of B→ππ



Green line: Constraint from B->ππ
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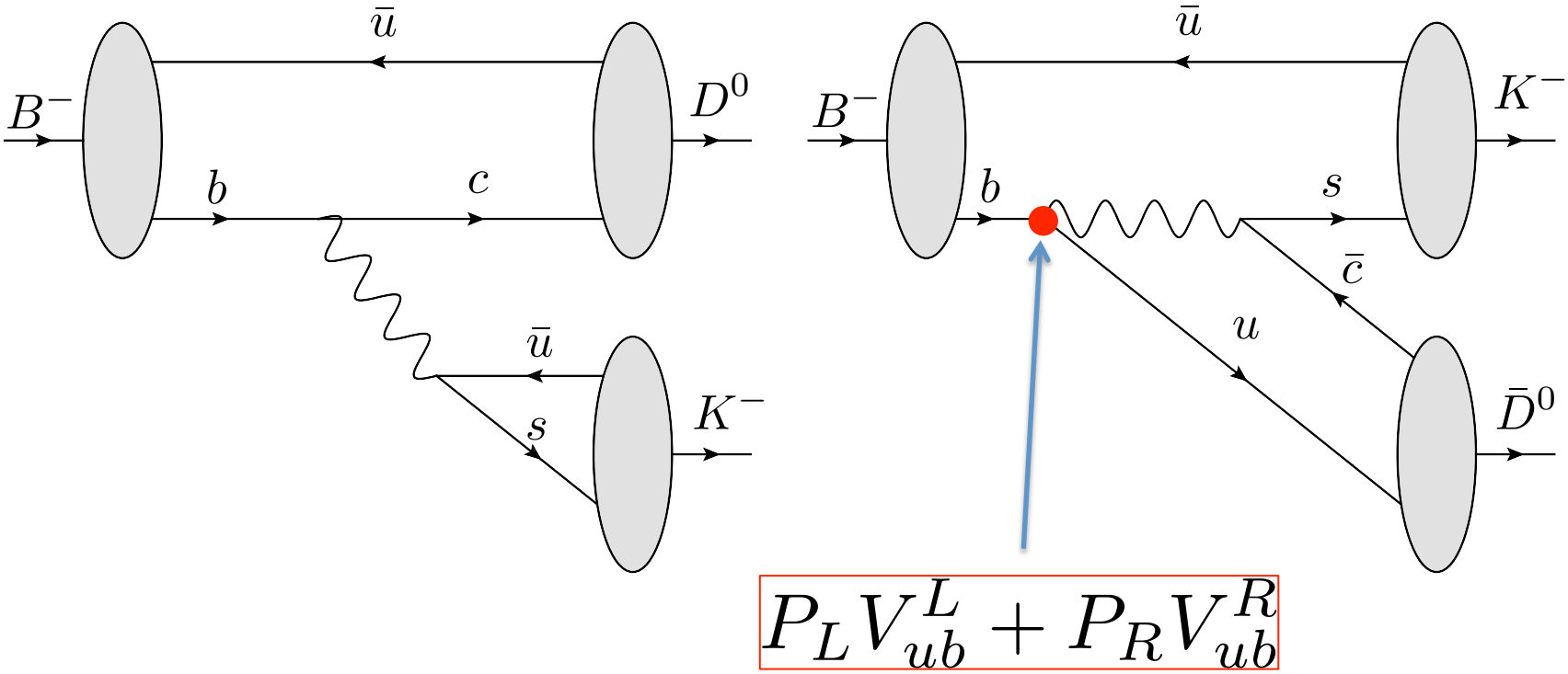
Measurements of |Vub| imply a large $|\mathrm{Im}(V_{ub}^R/V_{ub}^L)|$.
But measurement of B->ππ exclude the large one.

Discrepancy?
or
Effect of Factorization approximation?

I should analyze another decay mode.
=B->DK

Constraint from measurement of CP violation in B->DK

Diagram of B->DK



Effect of RHCC on CP violation in B->DK

2 CP violating measurement

Direct CP Asymmetry $A_{DK} = \dfrac{\Gamma(B^- \to \bar{D}^0 K^-) - \Gamma(B^+ \to D^0 K^+)}{\Gamma(B^- \to \bar{D}^0 K^-) + \Gamma(B^+ \to D^0 K^+)}$

$\delta\phi_3 =$ (Phase measured by B->DK and Dalitz Plot analysis) – (Angle of Unitary Triangle)

Analysis and experiment

	$\sin\delta\phi_3$	A_{DK}
In SM	0	0
With RHCC	$\dfrac{\mathrm{Im}[R_{DK}]}{\lvert R_{DK}\rvert}$	$\dfrac{1-\lvert R_{DK}\rvert^2}{1+\lvert R_{DK}\rvert^2}$
Experiment	0.08±0.25	0.27±0.40

My calculation from dalitz plot analysis

(phys. rev. D85, 112014)

We can constrain R_{DK} .

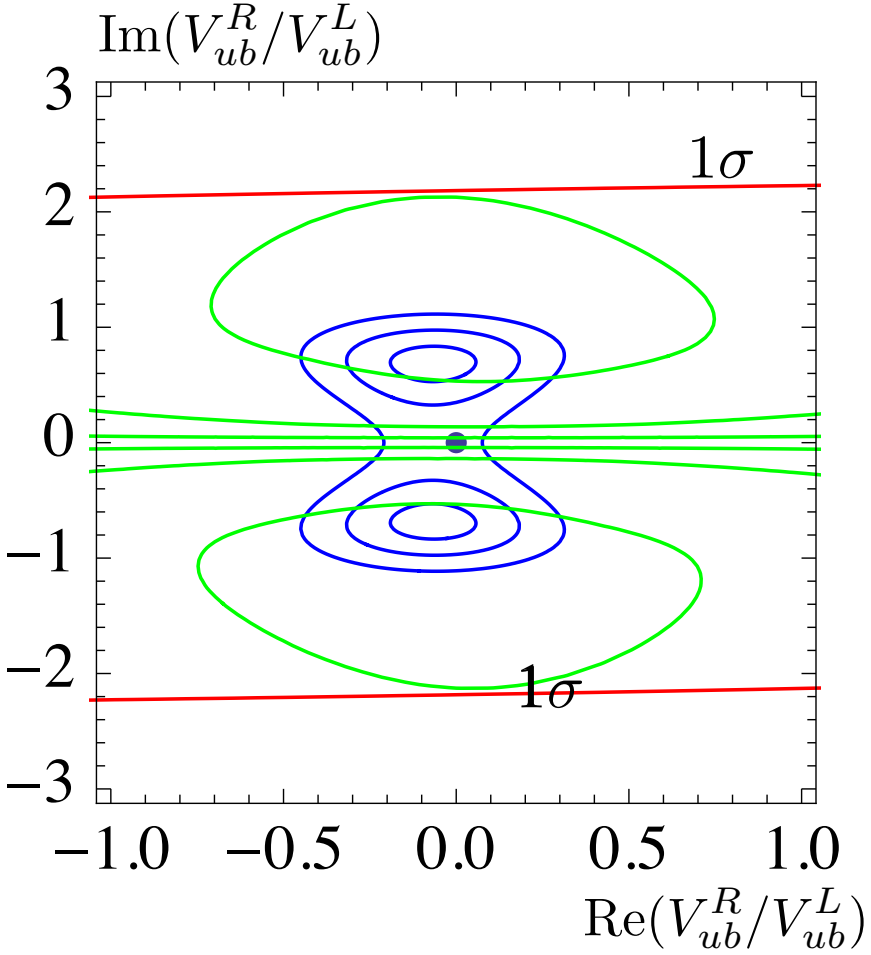
$$R_{DK} = \frac{1 + (V_{ub}^R/V_{ub}^L)c_{DK}}{1 + (V_{ub}^R/V_{ub}^L)^* c_{DK}}$$

c_{DK}: complex constant

We can constrain V_{ub}^R/V_{ub}^L .

(Factorization approximation)

Constraint from CP violation of B→DK



Red line: Constraint from B->DK
Green line: Constraint from B->ππ
Blue line: Constraint from |Vub|
black point: Standard Model

Constraint from B->DK is very weak.
But SuperBFactory will make it strong.

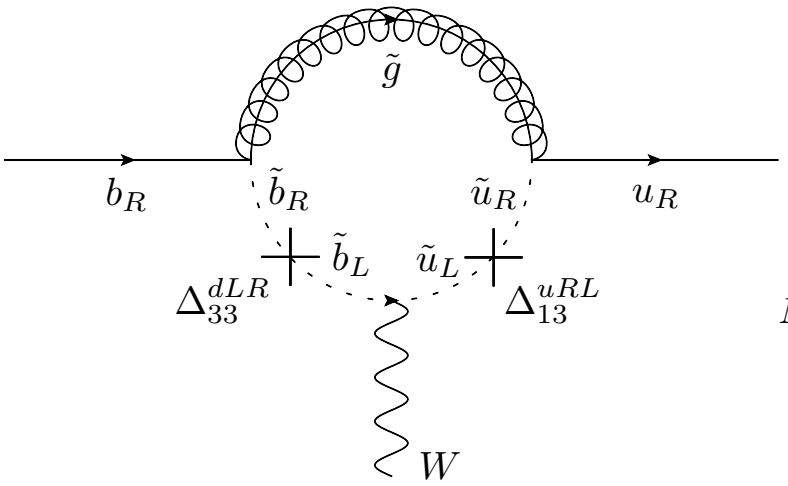
RHCC in MSSM

RHCC in MSSM

Reference

A. Crivellin, Phys. Rev. D 81,031301(2010).

A. Crivellin and U. Nierste, Phys. Rev. D 79, 035018(2009).



Mass matrix of down type squark.

(up type one is down type one that replace d into u.

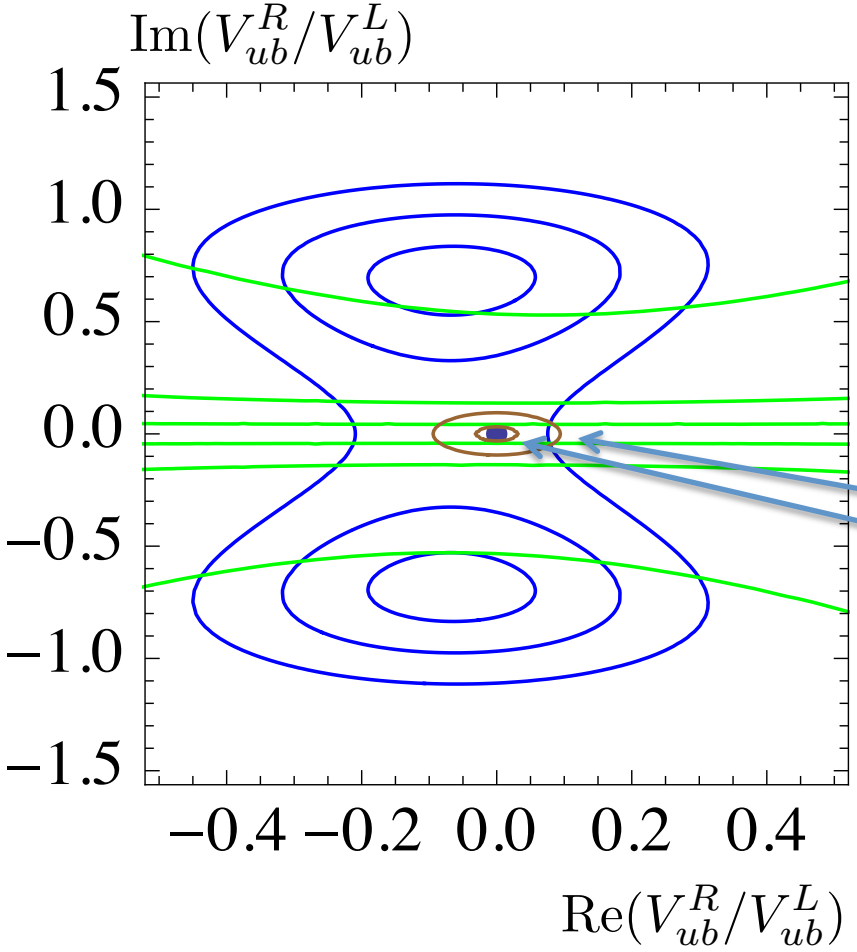
$$M_{\tilde{d}}^2 = \begin{pmatrix} (M_{1L}^{\tilde{d}})^2 & \Delta_{12}^{\tilde{d}LL} & \Delta_{13}^{\tilde{d}LL} & \Delta_{11}^{\tilde{d}LR} & \Delta_{12}^{\tilde{d}LR} & \Delta_{13}^{\tilde{d}LR} \\ \Delta_{21}^{\tilde{d}LL} & (M_{2L}^{\tilde{d}})^2 & \Delta_{23}^{\tilde{d}LL} & \Delta_{21}^{\tilde{d}LR} & \Delta_{22}^{\tilde{d}LR} & \Delta_{23}^{\tilde{d}LR} \\ \Delta_{31}^{\tilde{d}LL} & \Delta_{32}^{\tilde{d}LL} & (M_{3L}^{\tilde{d}})^2 & \Delta_{31}^{\tilde{d}LR} & \Delta_{32}^{\tilde{d}LR} & \Delta_{33}^{\tilde{d}LR} \\ \Delta_{11}^{\tilde{d}RL} & \Delta_{12}^{\tilde{d}RL} & \Delta_{13}^{\tilde{d}RL} & (M_{1R}^{\tilde{d}})^2 & \Delta_{12}^{\tilde{d}RR} & \Delta_{13}^{\tilde{d}RR} \\ \Delta_{21}^{\tilde{d}RL} & \Delta_{22}^{\tilde{d}RL} & \Delta_{23}^{\tilde{d}RL} & \Delta_{21}^{\tilde{d}RR} & (M_{2R}^{\tilde{d}})^2 & \Delta_{23}^{\tilde{d}RR} \\ \Delta_{31}^{\tilde{d}RL} & \Delta_{32}^{\tilde{d}RL} & \Delta_{33}^{\tilde{d}RL} & \Delta_{31}^{\tilde{d}RR} & \Delta_{32}^{\tilde{d}RR} & (M_{3R}^{\tilde{d}})^2 \end{pmatrix}$$

I assume SUSY particle mass is same. Then we can calculate

$$V_{ub}^R = \frac{\alpha_s}{36\pi}\delta_{13}^{uRL}\delta_{33}^{dLR}$$

※ $$\delta_{ij}^{qXY} = \frac{\Delta_{ij}^{\tilde{q}XY}}{\Sigma_s [M_{\tilde{q}}^2]_{ss}/6}$$

RHCC in MSSM



Brown: RH charged current by MSSM.
Green line: Constraint from B->ππ
Blue line: Constraint from |Vub|
black point: Standard Model

$|\delta_{13}^{uRL}\delta_{33}^{dLR}| = 0.3$
$|\delta_{13}^{uRL}\delta_{33}^{dLR}| = 0.1$

Mass insertion of MSSM can NOT explain the measurement of |Vub|.
But the RHCC in MSSM may affect B->ππ.

SUMMARY

Large $\mathrm{Im}(V_{ub}^R/V_{ub}^L)$ is needed for explanation of |Vub| determination.

Measurement of CP violation in B->ππ may exclude large $\mathrm{Im}(V_{ub}^R/V_{ub}^L)$.

Constraint from B->DK is very weak now.

RHCC in MSSM may be measured in B->ππ.

Thank you for your attention.

Why right-handed charged current?

Right-handed charged current of b->u transition

Why b->u transition?

Tetsuya Enomoto (Osaka university)

In collaboration with Minoru Tanaka and Ryoutaro Watanabe

Charged current in SM

$$\mathcal{L}_{CC} = \frac{g}{\sqrt{2}} W_\mu^+ \bar{u}_L \gamma^\mu V_{CKM} d_L + \text{h.c.}$$

$$|V_{CKM}| = \begin{pmatrix} 0.97425(22) & 0.2252(9) & 0.00389(44) \\ 0.230(11) & 1.023(36) & 0.0406(13) \\ 0.0084(6) & 0.0387(21) & 0.88(7) \end{pmatrix}$$

Because |Vub| is the smallest, Vub component could easily be affected by new physics compared to other component.

We consider charged current in b -> u transition.

Charged current in SM

$$\mathcal{L}_{CC} = \frac{g}{\sqrt{2}} W_\mu^+ \bar{u}_L \gamma^\mu V_{CKM} d_L + \text{h.c.}$$

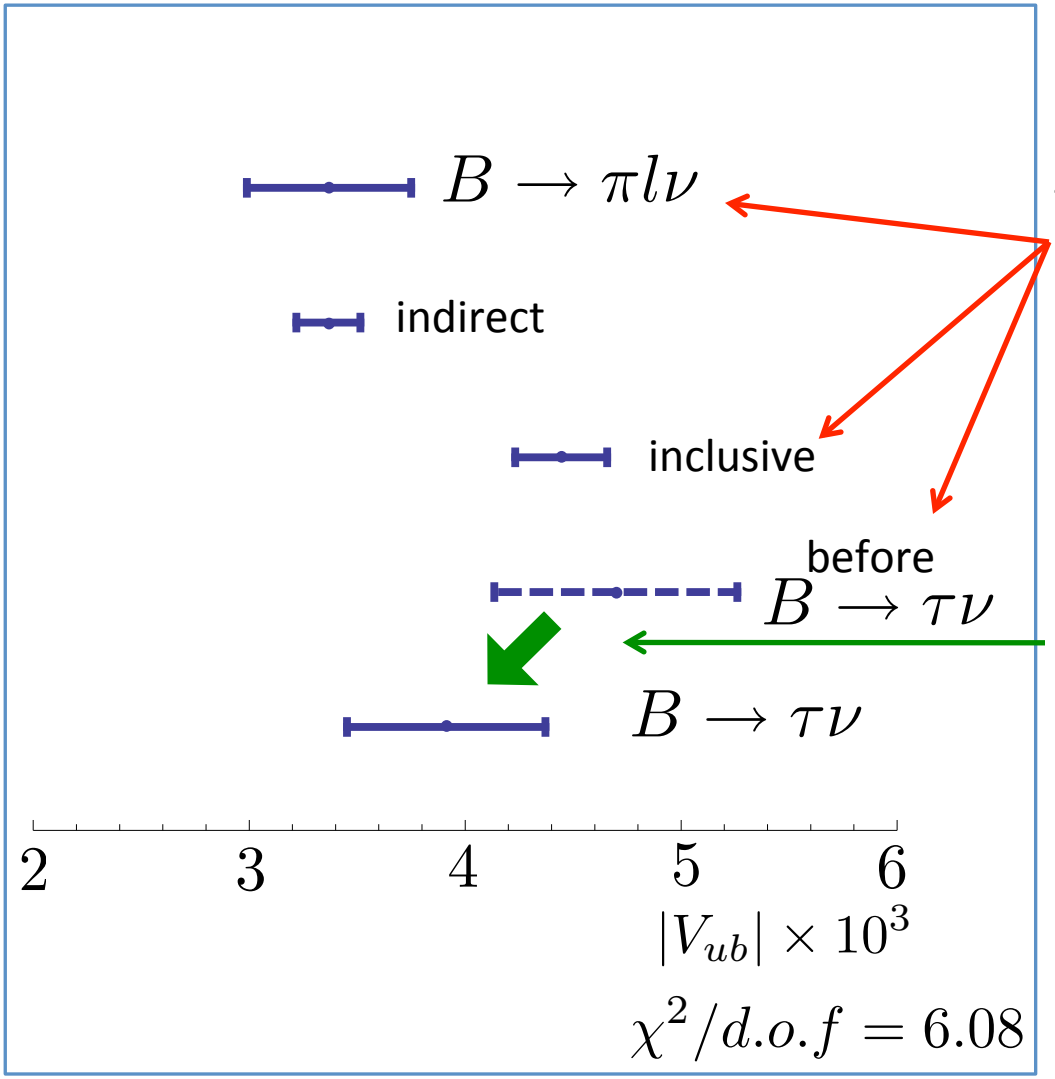
$$|V_{CKM}| = \begin{pmatrix} 0.97425(22) & 0.2252(9) & 0.00389(44) \\ 0.230(11) & 1.023(36) & 0.0406(13) \\ 0.0084(6) & 0.0387(21) & 0.88(7) \end{pmatrix}$$

Charged current in SM is Left-handed.

We consider charged current in b -> u transition.

right-handed charged current.

measurement of $|V_{ub}|$



RH charged current can remove the discrepancies between the determinations

A. Crivellin, Phys. Rev. D 81,031301(2010).

BUT

New Result

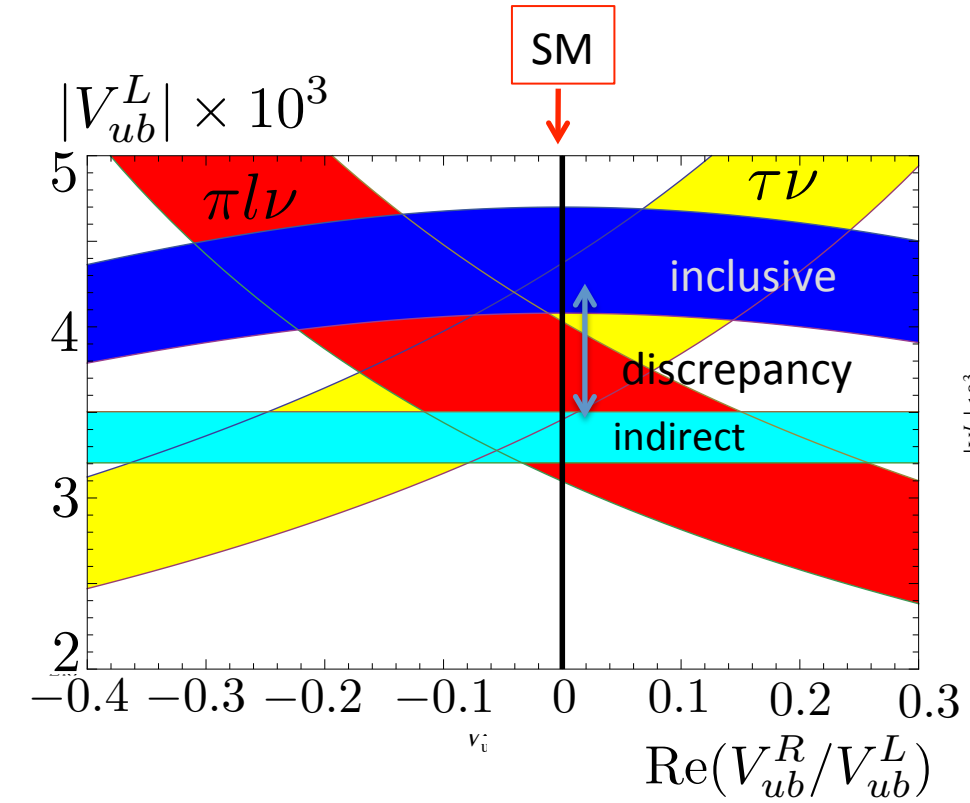
We need a check that RH charged current is utility.

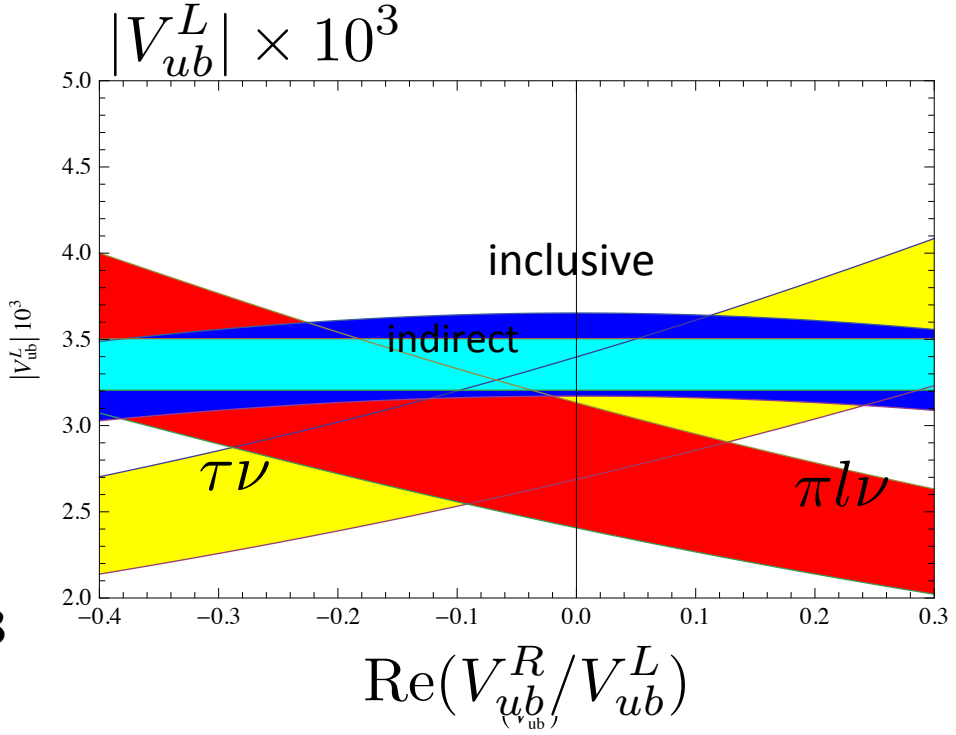
Constraint of RHCC

$$\mathrm{Im}(V_{ub}^R/V_{ub}^L) = 0$$

$$|\mathrm{Im}(V_{ub}^R/V_{ub}^L)|$$

=0.69(best fit)





Isospin Analysis

Isospin Analysis can remove the effect of Penguin diagram from the measurement of $\phi_2 = \alpha$

$$A(B^0 \to \pi^+\pi^-) = \frac{1}{\sqrt{6}}\mathcal{A}_2 + \frac{1}{\sqrt{3}}\mathcal{A}_0$$

$$A(B^0 \to \pi^0\pi^0) = \sqrt{\frac{2}{3}}\mathcal{A}_2 - \frac{1}{\sqrt{3}}\mathcal{A}_0$$

$$A(B^+ \to \pi^+\pi^0) = \sqrt{\frac{3}{2}}\mathcal{A}_2$$

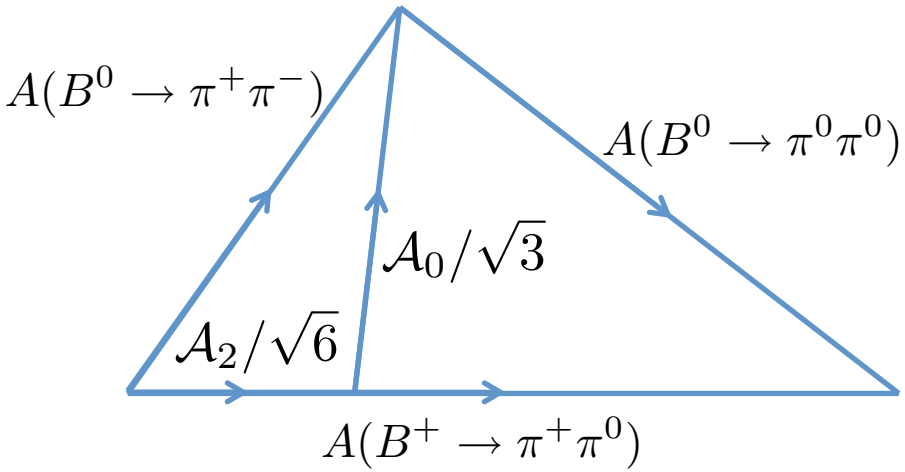
$\mathcal{A}_I, \bar{\mathcal{A}}_I$:Amplitude to Isospin I state

Diagrams contribute Isospin state or not.

	Tree diagram	Penguin diagram
$\mathcal{A}_2$	contribute	NOT contribute
$\mathcal{A}_0$	contribute	contribute

If we trace right side triangle, we can know

$$z = \sqrt{2}\frac{\mathcal{A}_0}{\mathcal{A}_2}$$



Isospin Analysis

Time dependent CP asymmetry

$$S_{\pi\pi} = \frac{2\mathrm{Im}\frac{q}{p}\bar{\rho}}{1+|\bar{\rho}|^2} \qquad \bar{\rho} = \frac{A(\bar{B}^0 \to \pi^+\pi^-)}{A(B^0 \to \pi^+\pi^-)}$$

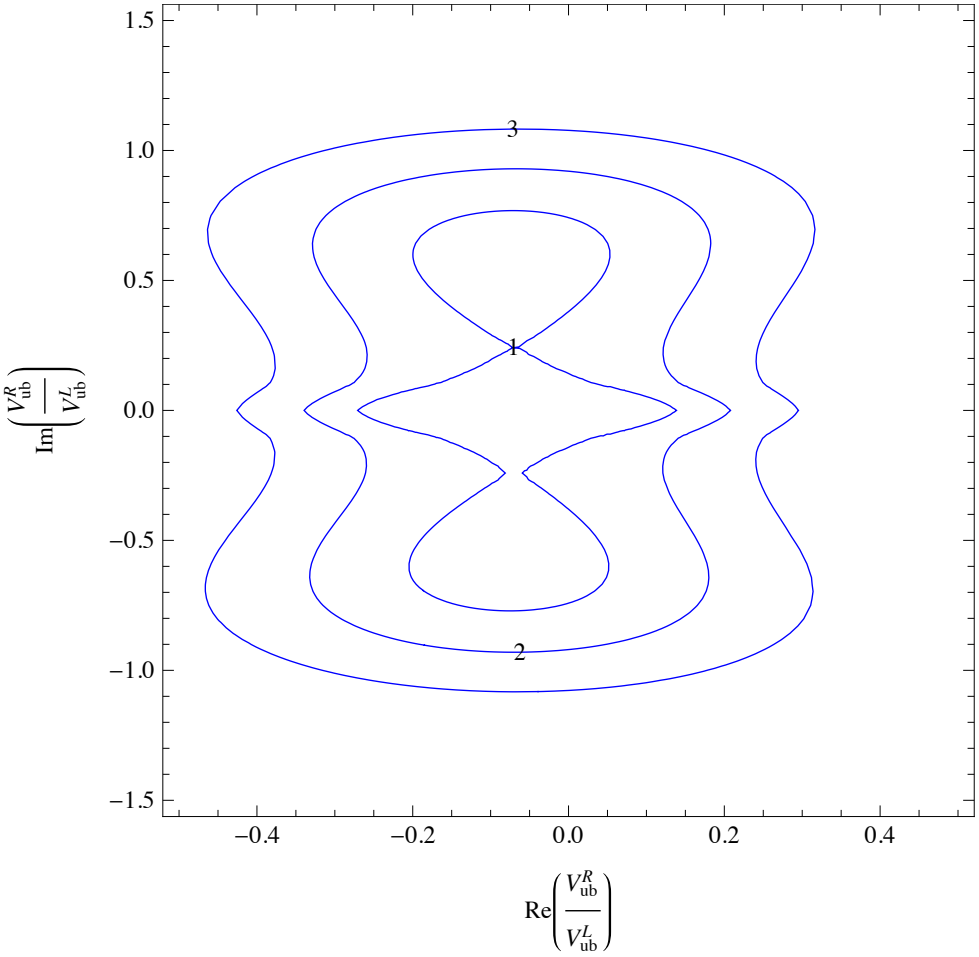
Penguin diagram contribute only $\mathcal{A}_0$, and we know z.
So we can extraction only A2 from $\bar{\rho}$.

$$\frac{q}{p}\bar{\rho} = \frac{q}{p}\frac{\bar{\mathcal{A}}_2}{\mathcal{A}_2}\left(\frac{1+\bar{z}}{1+z}\right) \qquad z = \sqrt{2}\frac{\mathcal{A}_0}{\mathcal{A}_2}$$

$$\overset{\text{(SM)}}{=} e^{2i\phi_2}\left(\frac{1+\bar{z}}{1+z}\right)$$

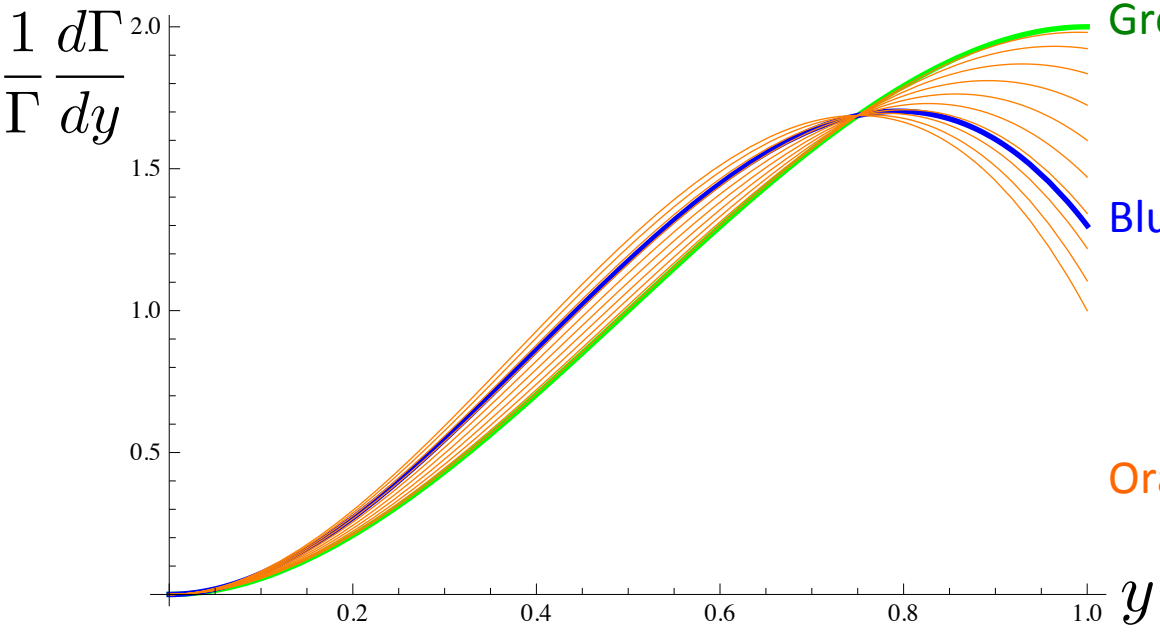
So we can measure ϕ_2 from observable $S_{\pi\pi}$.

Combine B→ππ and |Vub|



Inclusive decayのlepton energy分布

Γ: Decay rate of B->Xu l ν $\quad y = \dfrac{P_B \cdot P_l}{2m_b^2}$



Green: SM

Blue: best fit

Orange: $\left|\dfrac{V_{ub}^R}{V_{ub}^L}\right| = \left\{ 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1 \right.$

There is difference RHCC from SMCC.

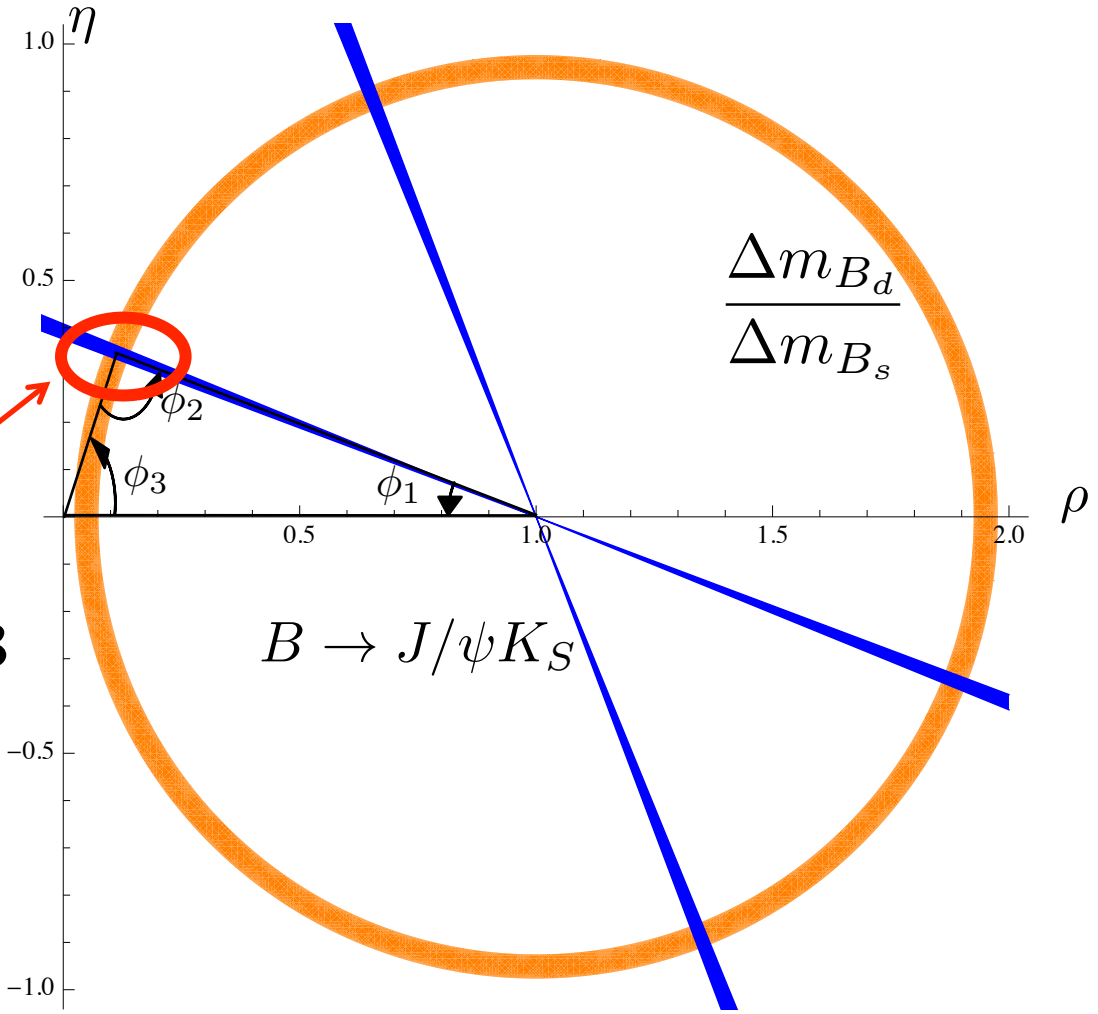
Indirect measurement of Vub

assumption

V_{ub}^L is unitary.

Theory is SM + b->u RHCC.

$$|V_{ub}^L| \simeq 3.4 \times 10^{-3}$$
$$\arg\left(V_{ub}^{L*}\right) \simeq 72^\circ$$



Effect of RHCC

Measurement of B->τν

Axial Vector current

$$|V_{ub}^{\tau}|^2 = |V_{ub}^{L} - V_{ub}^{R}|^2 = |V_{ub}^{L}|^2 \left(1 + \left|\frac{V_{ub}^{R}}{V_{ub}^{L}}\right|^2 - 2\mathrm{Re}\left(\frac{V_{ub}^{R}}{V_{ub}^{L}}\right)\right)$$

Measurement of B->πlν

Vector current

$$|V_{ub}^{\pi}|^2 = |V_{ub}^{L} + V_{ub}^{R}|^2 = |V_{ub}^{L}|^2 \left(1 + \left|\frac{V_{ub}^{R}}{V_{ub}^{L}}\right|^2 + 2\mathrm{Re}\left(\frac{V_{ub}^{R}}{V_{ub}^{L}}\right)\right)$$

Measurement of B->Xulν

Interferrnce term is propotional to m_u/m_b .

$$|V_{ub}^{\mathrm{inc}}|^2 = |V_{ub}^{L}|^2 + |V_{ub}^{R}|^2 = |V_{ub}^{L}|^2 \left(1 + \left|\frac{V_{ub}^{R}}{V_{ub}^{L}}\right|^2\right)$$