Effect of High Mass *t′* on sin $2\Phi_{Bs}$

George Wei-Shu Hou (侯維恕) and Chien-Yi Ma (馬鑑一)
National Taiwan University, Taipei, Taiwan

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Introduction

Recent measurements $2\Phi_{Bs}$ (also called $-2\beta_s$ or ϕ_s)

$2\Phi_{Bs}$ (CDF) $\in -[0.32, 2.82]$ (68% C.L.)

$2\Phi_{Bs}$ (DØ) $= -\ 0.57 \pm^{0.24}_{0.30}$ (stat) $\pm^{0.07}_{0.02}$ (syst)

However, $2\Phi^{SM}_{Bs} \sim -0.04$

4th generation (SM4) introduces another heavy quark t' to interfere with t in the B_s-B_s mixing box diagrams

Large sin $2\Phi_{Bs}$

SM4 makes SM triangle into quadrangle

$$V^*_{us}V_{ub} + V^*_{cs}V_{cb} + V^*_{ts}V_{tb} + V^*_{t's}V_{t'b} = 0$$

Define

$$V^*_{t's}V_{t'b} \equiv r_{sb}\exp(i\phi_{sb})$$

Combine Δm_{Bs} [box diagram] and

$\mathcal{B}(b \to s\ell\ell)$ [Z penguin diagram]

to determine r_{sb} and ϕ_{sb}

Use parametrization matrix
[Hou, Soni and Steger PLB **192** (1987)]

$$
V^4_{CKM} = \begin{pmatrix}
\begin{array}{l} c_{12}\,c_{13}\,c_{14} \\ -c_{13}\,s_{12}\,s_{14}\,s_{24}\,\exp\left[-i(\phi_{db}-\phi_{sb})\right] \\ -c_{24}\,s_{13}\,s_{14}\,s_{34}\,\exp\left[-i(\phi_{db}+\phi_{ub})\right] \end{array} &
\begin{array}{l} c_{13}\,c_{24}\,s_{12} \\ -s_{13}\,s_{24}\,s_{34}\,\exp\left[-i(\phi_{sb}+\phi_{ub})\right] \end{array} &
c_{34}\,s_{13}\,\exp\left[-i\phi_{ub}\right] &
\begin{array}{l} c_{12}\,c_{13}\,s_{14}\,\exp\left[i\phi_{db}\right] \\ +c_{13}\,c_{14}\,s_{12}\,s_{24}\,\exp\left[i\phi_{sb}\right] \\ +c_{14}\,c_{24}\,s_{13}\,s_{34}\,\exp\left[-i\phi_{ub}\right] \end{array} \\[2ex]
\begin{array}{l} -c_{14}\,c_{23}\,s_{12} \\ -c_{12}\,c_{14}\,s_{13}\,s_{23}\,\exp\left[i\phi_{ub}\right] \\ -c_{12}\,c_{23}\,s_{14}\,s_{24}\,\exp\left[-i(\phi_{db}-\phi_{sb})\right] \\ +s_{12}\,s_{13}\,s_{14}\,s_{23}\,s_{24}\,\exp\left[-i(\phi_{db}-\phi_{sb}-i\phi_{ub})\right] \\ -c_{13}\,c_{24}\,s_{14}\,s_{23}\,s_{34}\,\exp\left[-i\phi_{db}\right] \end{array} &
\begin{array}{l} c_{12}\,c_{23}\,c_{24} \\ -c_{24}\,s_{12}\,s_{13}\,s_{23}\,\exp\left[i\phi_{ub}\right] \\ -c_{13}\,s_{23}\,s_{24}\,s_{34}\,\exp\left[-i\phi_{sb}\right] \end{array} &
c_{13}\,c_{34}\,s_{23} &
\begin{array}{l} -c_{23}\,s_{12}\,s_{14}\,\exp\left[i\phi_{db}\right] \\ -c_{12}\,s_{13}\,s_{14}\,s_{23}\,\exp\left[i(\phi_{db}+\phi_{ub})\right] \\ +c_{12}\,c_{14}\,c_{23}\,s_{24}\,\exp\left[i\phi_{sb}\right] \\ -c_{14}\,s_{12}\,s_{13}\,s_{23}\,s_{24}\,\exp\left[i(\phi_{sb}+\phi_{ub})\right] \\ +c_{13}\,c_{14}\,c_{24}\,s_{23}\,s_{34} \end{array} \\[2ex]
\begin{array}{l} -c_{12}\,c_{14}\,c_{23}\,s_{13}\,\exp\left[i\phi_{ub}\right] \\ +c_{14}\,s_{12}\,s_{23} \\ +c_{23}\,s_{12}\,s_{13}\,s_{14}\,s_{24}\,\exp\left[-i(\phi_{db}-\phi_{sb}-i\phi_{ub})\right] \\ +c_{12}\,s_{14}\,s_{23}\,s_{24}\,\exp\left[-i(\phi_{db}-\phi_{sb})\right] \\ -c_{13}\,c_{23}\,c_{24}\,s_{14}\,s_{34}\,\exp\left[-i\phi_{db}\right] \end{array} &
\begin{array}{l} -c_{23}\,c_{24}\,s_{12}\,s_{13}\,\exp\left[i\phi_{ub}\right] \\ -c_{12}\,c_{24}\,s_{23} \\ -c_{13}\,c_{23}\,s_{24}\,s_{34}\,\exp\left[i\phi_{sb}\right] \end{array} &
c_{13}\,c_{23}\,c_{34} &
\begin{array}{l} -c_{12}\,c_{23}\,s_{13}\,s_{14}\,\exp\left[i(\phi_{db}+\phi_{ub})\right] \\ +s_{12}\,s_{14}\,s_{23}\,\exp\left[i\phi_{db}\right] \\ -c_{14}\,c_{23}\,s_{12}\,s_{13}\,s_{24}\,\exp\left[i(\phi_{sb}+\phi_{ub})\right] \\ -c_{12}\,c_{14}\,s_{23}\,s_{24}\,\exp\left[i\phi_{sb}\right] \\ +c_{13}\,c_{14}\,c_{23}\,c_{24}\,s_{34} \end{array} \\[2ex]
-c_{24}\,c_{34}\,s_{14}\,\exp\left[-i\phi_{db}\right] & -c_{34}\,s_{24}\,\exp\left[-i\phi_{sb}\right] & -s_{34} & c_{14}\,c_{24}\,c_{34}
\end{pmatrix}
$$

Use parametrization matrix [Hou, Soni and Steger PLB **192** (1987)]

$$V_{ud} = -c_{13}\, s_{14}\, s_{12}\, s_{24}\, e^{i\,\Phi_{sb} - i\,\Phi_d} - s_{13}\, c_{24}\, s_{14}\, s_{34}\, e^{-i\,\Phi_d - i\,\phi_3} + c_{14}\, c_{13}\, c_{12}$$

$$V_{us} = c_{13}\, c_{24}\, s_{12} - s_{13}\, s_{34}\, s_{24}\, e^{-i\,\Phi_{sb} - i\,\phi_3}$$

$$V_{ub} = s_{13}\, c_{34}\, e^{-i\,\phi_3}$$

$$\boxed{V_{ub'} = c_{14}\, c_{13}\, s_{12}\, s_{24}\, e^{i\,\Phi_{sb}} + c_{13}\, c_{12}\, s_{14}\, e^{i\,\Phi_d} + s_{13}\, c_{14}\, c_{24}\, e^{-i\,\phi_3}\, s_{34}}$$

$$\boxed{\begin{aligned} V_{t'd} &= -c_{34}\, c_{24}\, s_{14}\, e^{-i\,\Phi_d} \\ V_{t's} &= -c_{34}\, s_{24}\, e^{-i\,\Phi_{sb}} \\ V_{t'b} &= -s_{34} \\ V_{t'b'} &= c_{14}\, c_{34}\, c_{24} \end{aligned}}$$

$$V_{cd} = s_{14}\, s_{13}\, s_{12}\, s_{24}\, s_{23}\, e^{i\,\Phi_{sb} - i\,\Phi_d + i\,\phi_3} - c_{12}\, c_{23}\, s_{14}\, s_{24}\, e^{i\,\Phi_{sb} - i\,\Phi_d} - c_{13}\, c_{24}\, s_{14}\, s_{34}\, s_{23}\, e^{-i\,\Phi_d} - c_{14}\, c_{12}\, e^{i\,\phi_3}\, s_{13}\, s_{23} - c_{14}\, c_{23}\, s_{12}$$

$$V_{cs} = -c_{13}\, s_{34}\, s_{24}\, s_{23}\, e^{-i\,\Phi_{sb}} - c_{24}\, e^{i\,\phi_3}\, s_{13}\, s_{12}\, s_{23} + c_{12}\, c_{24}\, c_{23}$$

$$V_{cb} = c_{13}\, c_{34}\, s_{23}$$

$$\boxed{V_{cb'} = -c_{14}\, s_{13}\, s_{12}\, s_{24}\, s_{23}\, e^{i\,\Phi_{sb} + i\,\phi_3} + c_{14}\, c_{12}\, c_{23}\, s_{24}\, e^{i\,\Phi_{sb}} - c_{12}\, s_{14}\, s_{13}\, s_{23}\, e^{i\,\Phi_d + i\,\phi_3} - c_{23}\, s_{14}\, s_{12}\, e^{i\,\Phi_d} + c_{14}\, c_{13}\, c_{24}\, s_{34}\, s_{23}}$$

$$V_{td} = c_{23}\, s_{14}\, s_{13}\, s_{12}\, s_{24}\, e^{i\,\Phi_{sb} - i\,\Phi_d + i\,\phi_3} + c_{12}\, s_{14}\, s_{24}\, s_{23}\, e^{i\,\Phi_{sb} - i\,\Phi_d} - c_{13}\, c_{24}\, c_{23}\, s_{14}\, s_{34}\, e^{-i\,\Phi_d} + c_{14}\, s_{12}\, s_{23} - c_{14}\, c_{12}\, c_{23}\, e^{i\,\phi_3}\, s_{13}$$

$$V_{ts} = -c_{13}\, c_{23}\, s_{34}\, s_{24}\, e^{-i\,\Phi_{sb}} - c_{12}\, c_{24}\, s_{23} - c_{24}\, c_{23}\, e^{i\,\phi_3}\, s_{13}\, s_{12}$$

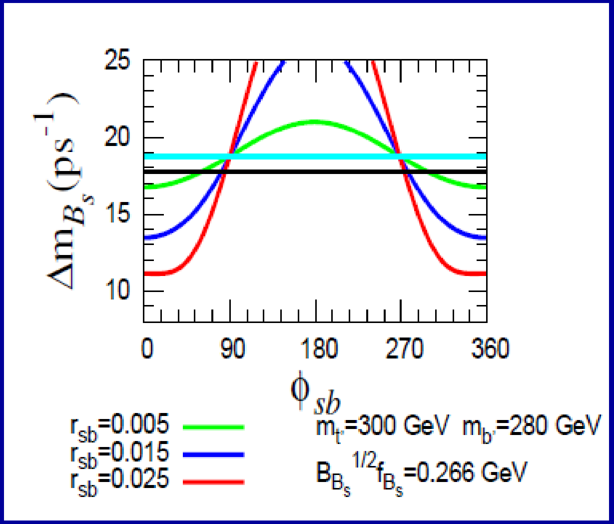
$$V_{tb} = c_{13}\, c_{34}\, c_{23}$$

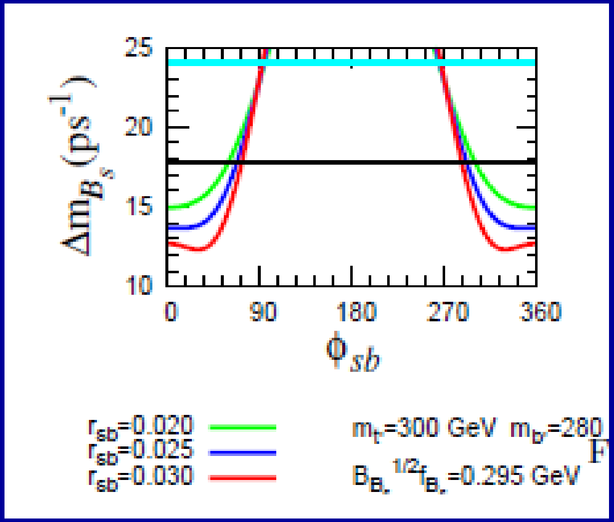
$$V_{tb'} = -c_{14}\, c_{23}\, s_{13}\, s_{12}\, s_{24}\, e^{i\,\Phi_{sb} + i\,\phi_3} - c_{14}\, c_{12}\, s_{24}\, s_{23}\, e^{i\,\Phi_{sb}} - c_{12}\, c_{23}\, s_{14}\, s_{13}\, e^{i\,\Phi_d + i\,\phi_3} + s_{14}\, s_{12}\, s_{23}\, e^{i\,\Phi_d} + c_{14}\, c_{13}\, c_{24}\, c_{23}\, s_{34}$$

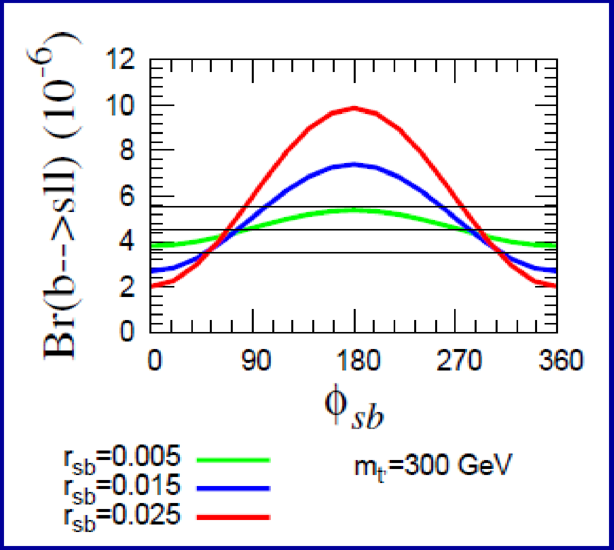
Hou, Nagashima and Soddu
[PRD**72**(2005),PRD**76**(2007)]
explored the $m_{t'} = 300$ GEV case for
$f_{Bs}\sqrt{B_{Bs}} = 295$ MEV

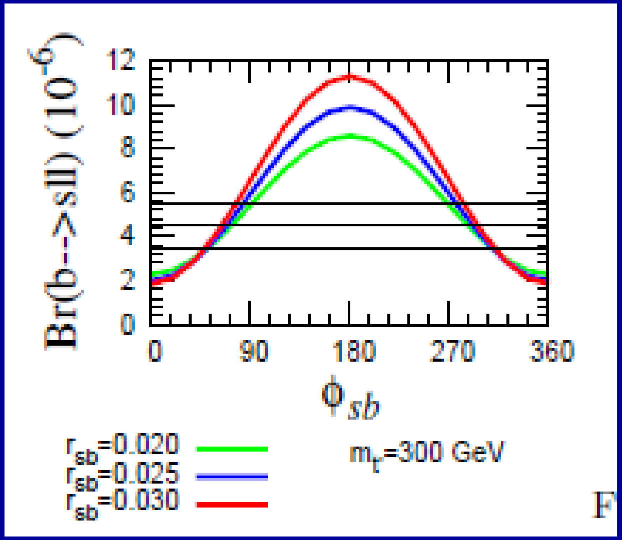
Revisit $m_{t'} = 300$ GEV with $f_{Bs}\sqrt{B_{Bs}} = 266(18)$ MEV
[HPQCD Collabor. arXiv:0902.1815]

$f_{Bs}\sqrt{B_{Bs}}$ = 266 MEV $\quad V^*_{t's}V_{t'b} \equiv r_{sb}\exp(i\phi_{sb})$ $\quad f_{Bs}\sqrt{B_{Bs}}$ = 295 MEV

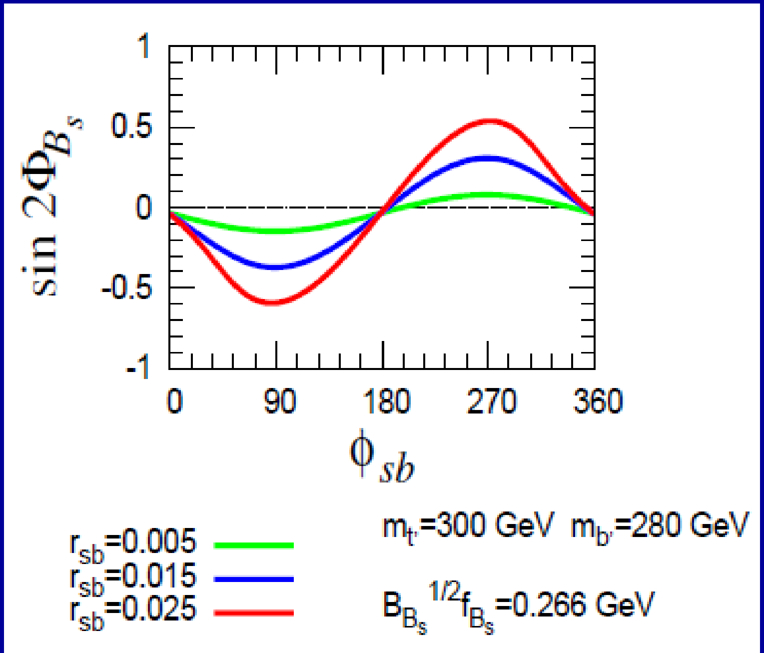


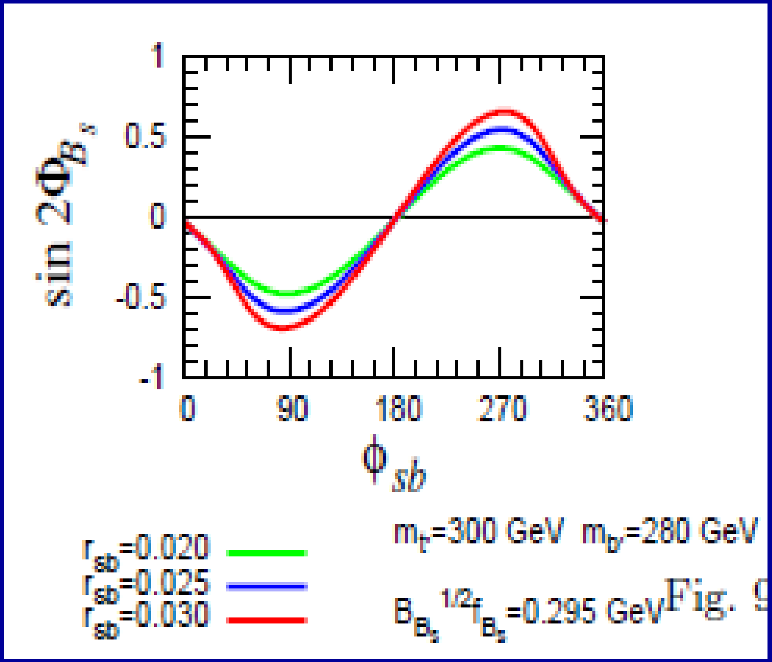






$f_{Bs}\sqrt{B}_{Bs}$ = 266 MEV $\quad V^*_{t's}V_{t'b} \equiv r_{sb}\exp(i\phi_{sb})$ $\quad f_{Bs}\sqrt{B}_{Bs}$ = 295 MEV





r_{sb} = 0.005 ~ 0.025,

$\phi_{sb} = 60^\circ \sim 85^\circ$,

$\sin 2\Phi_{Bs} = -0.13 \sim -0.59$

r_{sb} = 0.020 ~ 0.030,

$\phi_{sb} = 60^\circ \sim 80^\circ$,

$\sin 2\Phi_{Bs} = -0.5 \sim -0.7$

$f_{Bs}\sqrt{B_{Bs}} = 266$ MEV

$V^*_{t's} V_{t'b} \equiv r_{sb} \exp(i\phi_{sb})$

$f_{Bs}\sqrt{B_{Bs}} = 295$ MEV

Blue curve (central value)

$|V^*_{t's} V_{t'b}| = r_{sb} = 0.015$,

$\phi_{sb} = 81^\circ$,

$\sin 2\Phi_{Bs} = -0.37$

Blue curve (central value)

$|V^*_{t's} V_{t'b}| = r_{sb} = 0.025$,

$\phi_{sb} = 70^\circ$,

$\sin 2\Phi_{Bs} = -0.6$

What is the range of $V_{t'b}$?

Upper Bound of $|V_{t'b}|$

$V_{t'b} = -s_{34}$

[Yanir JHEP06 (2002)]

$$\Gamma(Z \to q\bar{q}) = \frac{\bar{\alpha}}{16\hat{s}_W^2\hat{c}_W^2} m_Z(|a_q|^2 + |v_q|^2)(1+\delta_q^{(0)})(1+\delta_{QED}^q) \times \\ \times (1+\delta_{QCD}^q)(1+\delta_\mu^q)(1+\delta_{tQCD}^q)(1+\delta_b)$$

$$\delta_b \approx 10^{-2}\left[\left(-\frac{m_t^2}{2m_Z^2}+0.2\right)|V_{tb}|^2 + \left(-\frac{m_{t'}^2}{2m_Z^2}+0.2\right)|V_{t'b}|^2\right]$$

$m_{t'} = 300$ GeV	$\lvert V_{tb}\rvert^2 + 3.4\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.24$
$m_{t'} = 350$ GeV	$\lvert V_{tb}\rvert^2 + 4.7\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.20$
$m_{t'} = 400$ GeV	$\lvert V_{tb}\rvert^2 + 6.1\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.17$
$m_{t'} = 450$ GeV	$\lvert V_{tb}\rvert^2 + 7.8\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.14$
$m_{t'} = 500$ GeV	$\lvert V_{tb}\rvert^2 + 9.6\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.13$

$|V_{t'b}| = 0.24$ Upper Bound

Hou, Nagashima and Soddu
Use

$m_{t'} = 300$ GeV	$\lvert V_{tb}\rvert^2 + 3.4\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.24$

$|V_{t'b}| = 0.22$ [PRD**72**(2005),PRD**76**(2007)]

"wanted larger $V_{t'b}$"

What is a Lower Bound of $|V_{t'b}|$?

It can be obtained from $\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu})$ and x_D

Lower Bound of $|V_{t'b}|$

$V_{t'b} = -s_{34}$

$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) = (1.47^{+1.30}_{-0.89}) \times 10^{-10}$

[Anisimovsky *et al*. PRL **93** (2004)]

$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) = (1.73 \pm {}^{1.15}_{1.05}) \times 10^{-10}$

[Artamonov *et al*. PRL **101** (2008)]

$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) < 3.6 \times 10^{-10}$ (90% C.L.)

$$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) \;=\; \kappa_+ \left| \frac{\lambda_c^{ds}}{|V_{us}|} P_c + \frac{\lambda_t^{ds}}{|V_{us}|^5} \eta_t X_0(x_t) \; + \frac{\lambda_{t'}^{ds}}{|V_{us}|^5} \eta_{t'} X_0(x_{t'}) \right|^2$$

Lower Bound of $|V_{t'b}|$

$V_{t'b} = -s_{34}$

$x_D^{\exp} = (9.1 \pm ^{2.5}_{2.6}) \times 10^{-3}$

Barberio *et al*. [HFAG] arXiv:0808.1297

$$M_{12}^{D^0} \propto \lambda_s^2 S_0(x_s) + 2\lambda_s\lambda_b S(x_s, x_b) + \lambda_b^2 S_0(x_b) + LD$$
$$+2\lambda_s\lambda_{b'} S(x_s, x_{b'}) + 2\lambda_b\lambda_{b'} S(x_b, x_{b'}) + LD$$
$$+\lambda_{b'}^2 S_0(x_{b'}), \qquad \boxed{\lambda_x^{D^0} = V_{cx}V_{ux}^*}$$

Neglect all terms in M^{D0}_{12}, except $M^{D0}_{12,b'}$ and equate this with $x_D^{\exp}$ and enhance the possible space by a factor of 3 [Golowich *et al*. PRD76(2007), Bobrowski *et al*. arXiv:0902.4893]

$m_{b'} = 280$ GeV	$\lvert V_{ub'} V_{cb'} \rvert < 0.0033$
$m_{b'} = 330$ GeV	$\lvert V_{ub'} V_{cb'} \rvert < 0.0029$
$m_{b'} = 380$ GeV	$\lvert V_{ub'} V_{cb'} \rvert < 0.0026$
$m_{b'} = 430$ GeV	$\lvert V_{ub'} V_{cb'} \rvert < 0.0023$
$m_{b'} = 480$ GeV	$\lvert V_{ub'} V_{cb'} \rvert < 0.0021$

$$\boxed{\lambda_x^{D^0} = V_{cx} V_{ux}^*}$$

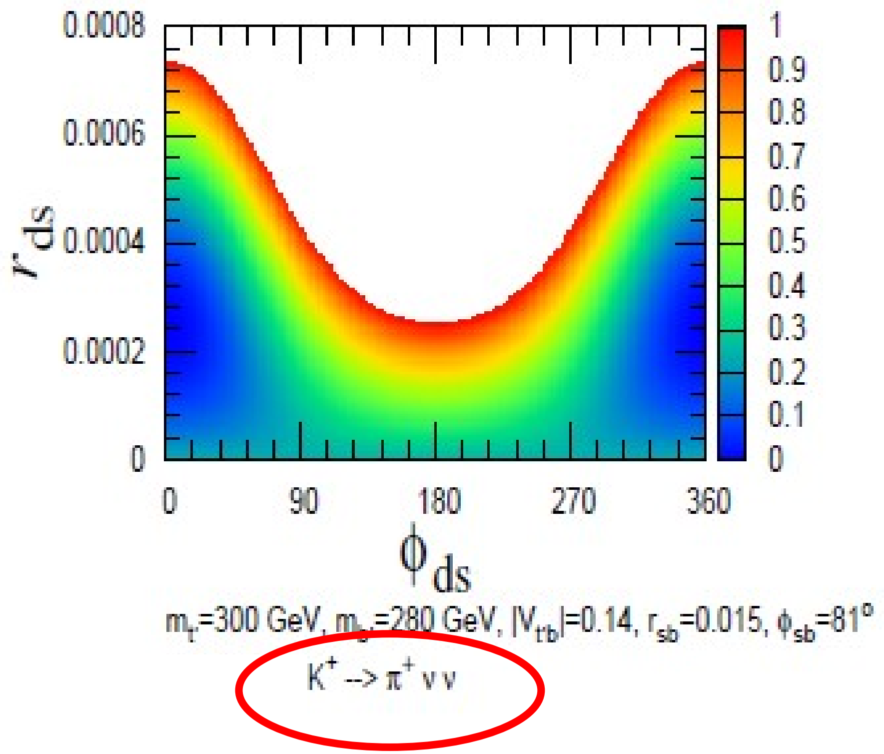
$$V_{ub'} = c_{14}\, c_{13}\, s_{12}\, s_{24}\, e^{i\,\Phi_{sb}} + c_{13}\, c_{12}\, s_{14}\, e^{i\,\Phi_d} + s_{13}\, c_{14}\, c_{24}\, e^{-i\,\phi_3}\, s_{34}$$

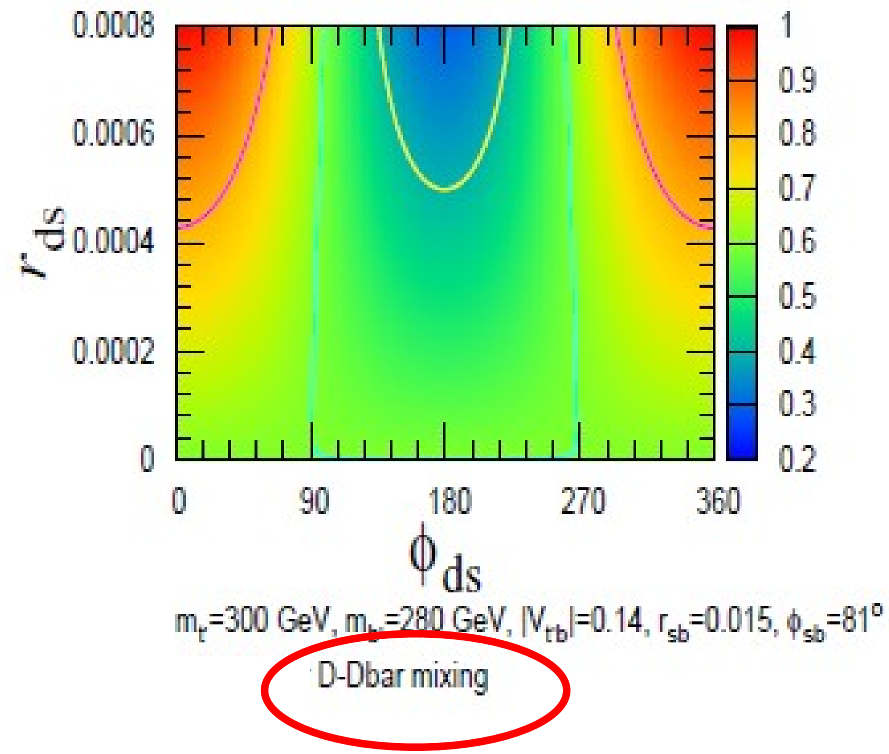
$$V_{t'd} = -c_{34}\, c_{24}\, s_{14}\, e^{-i\,\Phi_d}$$

Vanishing $|V_{t'd}|$ DOES NOT lead to vanishing $|V_{ub'}|$

UPDATE OF $m_{t'}$ = 300 GEV ($f_{Bs}\sqrt{B_{Bs}}$ = 266 MEV)

For $|V^*_{t's}V_{t'b}|$ = 0.015 fixed, ϕ_{sb} = 81°, $V^*_{t'd}V_{t's} \equiv r_{ds}\exp(i\phi_{ds})$

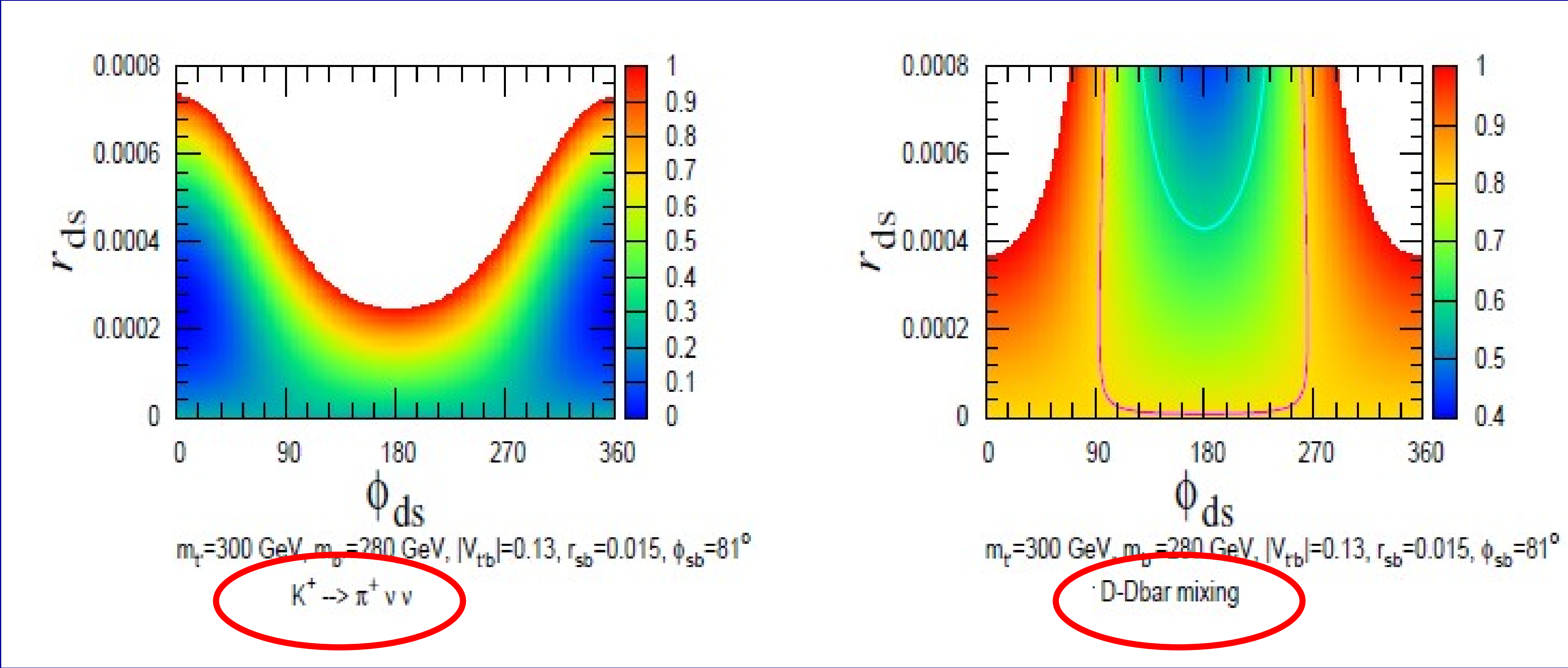




$|V_{t'b}|$ = 0.14

UPDATE OF $m_{t'}$ = 300 GEV ($f_{Bs}\sqrt{\hat{B}_{Bs}}$ = 266 MEV)

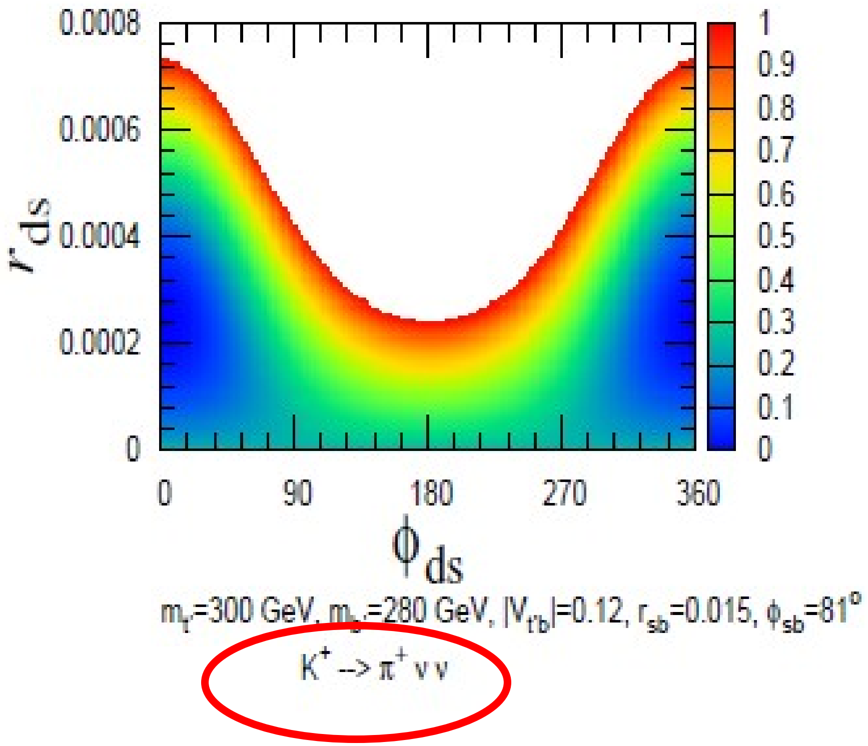
For $|V^*_{t's}V_{t'b}|$ = 0.015 fixed, ϕ_{sb} = 81°, $V^*_{t'd}V_{t's} \equiv r_{ds}\exp(i\phi_{ds})$

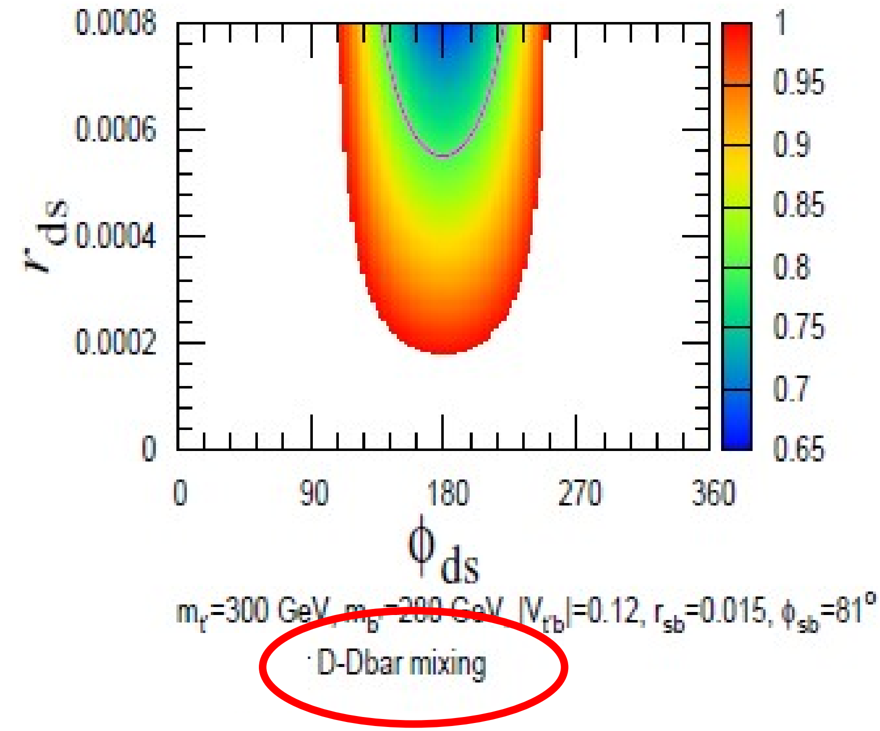


$|V_{t'b}|$ = 0.13

UPDATE OF $m_{t'}$ = 300 GEV ($f_{B_s}\sqrt{B_{B_s}}$ = 266 MEV)

For $|V^*_{t's}V_{t'b}| = 0.015$ fixed, $\phi_{sb} = 81^\circ$, $V^*_{t'd}V_{t's} \equiv r_{ds}\exp(i\phi_{ds})$





$|V_{t'b}| = 0.12$

Lower Bound

Calculate Re(ε'/ε) ?

$$\mathrm{Re}\,\frac{\varepsilon'}{\varepsilon} = \mathrm{Im}\,(\lambda_c^{ds})P_0 + \mathrm{Im}\,(\lambda_t^{ds})F(x_t) + \mathrm{Im}\,(\lambda_{t'}^{ds})F(x_{t'}),$$

$$F(x) = P_X X_0(x) + P_Y Y_0(x) + P_Z Z_0(x) + P_E E_0(x).$$

$$P_i = r_i^{(0)} + r_i^{(6)} R_6 + r_i^{(8)} R_8,$$

[Buras *et al*. JHEP01 (2004)]

What R_6, R_8 really are ?

Try $\mathcal{B}(K_L \to \pi^0 \nu\bar{\nu})$

Status of $\mathcal{B}(K_L \to \pi^0 \nu\bar{\nu})$

E391a has recently released the results from the second run,

$$\mathcal{B}^{\mathrm{exp}}(K_L \to \pi^0 \nu\bar{\nu}) < 6.7 \times 10^{-8}$$

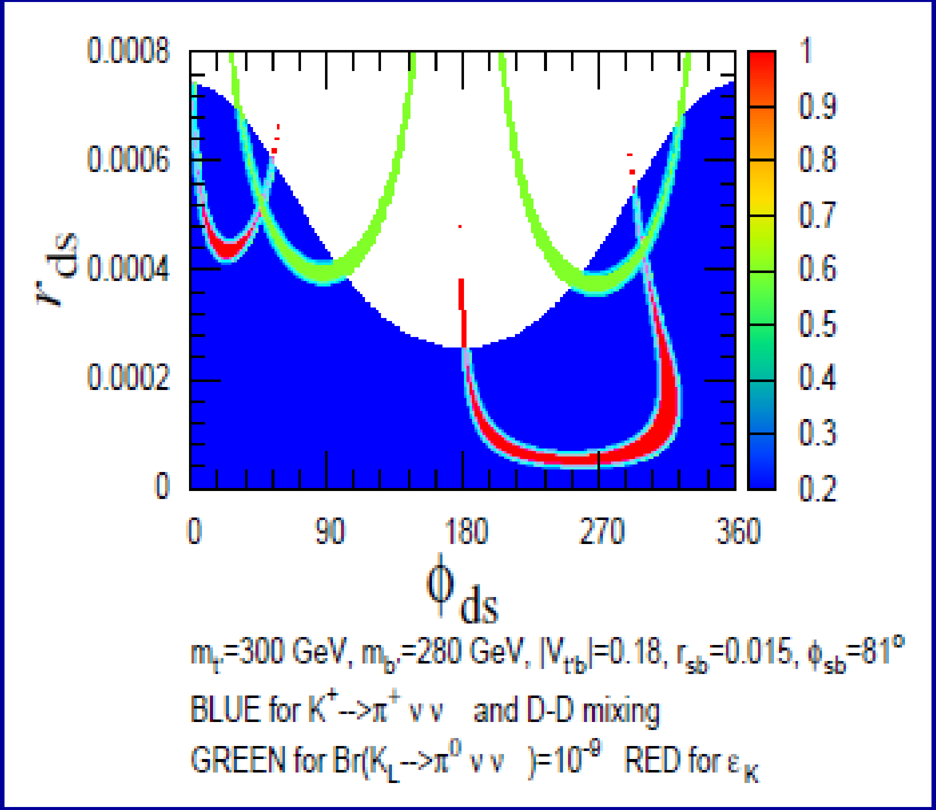
[E391a Collab. PRL **100** (2008)]

E14 will have a three-year physics run beginning in 2011.

$0.12 < |V_{t'b}| < 0.24$

Take $|V_{t'b}| = 0.18$ & $\mathcal{B}(K_L \to \pi^0 \nu\bar{\nu}) = 10^{-9}$

$\mathcal{B}^{exp}(K_L \to \pi^0 \nu\bar{\nu}) < 6.7 \times 10^{-8}$



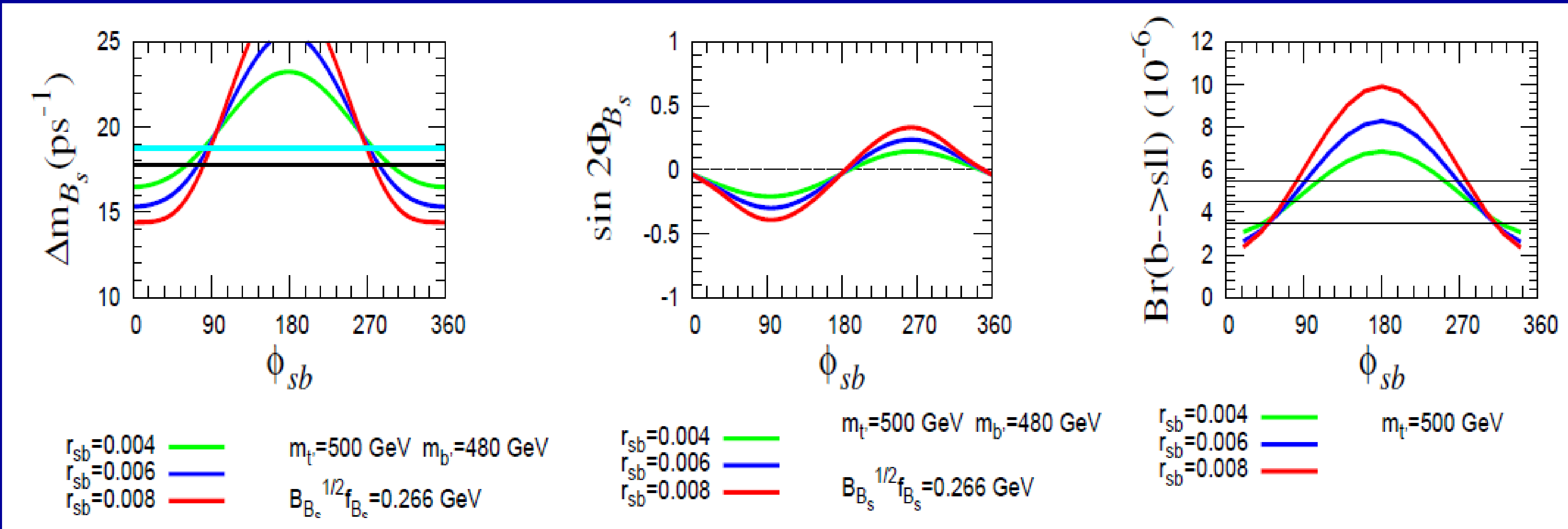
RED *for* ε_K

GREEN *for* $\mathcal{B}(K_L \to \pi^0 \nu\bar{\nu})$

$V^*_{t'd} V_{t's} \equiv r_{ds} \exp(i\phi_{ds})$

$m_{t'}$ = 500 GEV

$f_{Bs}\sqrt{B_{Bs}}$ = 266 MEV



Take central value (blue curve) r_{sb} = 0.006, ϕ_{sb} = 75°,

sin $2\Phi_{Bs}$ = – 0.33

$m_{t'} = 500$ GEV

$\Gamma(Z \to b\bar{b})$

$m_{t'} = 300$ GeV	$\lvert V_{tb}\rvert^2 + 3.4\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.24$
$m_{t'} = 350$ GeV	$\lvert V_{tb}\rvert^2 + 4.7\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.20$
$m_{t'} = 400$ GeV	$\lvert V_{tb}\rvert^2 + 6.1\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.17$
$m_{t'} = 450$ GeV	$\lvert V_{tb}\rvert^2 + 7.8\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.14$
$m_{t'} = 500$ GeV	$\lvert V_{tb}\rvert^2 + 9.6\lvert V_{t'b}\rvert^2 < 1.14$	$\lvert V_{t'b}\rvert < 0.13$

$\lvert V_{t'b}\rvert = 0.13$ Upper Bound

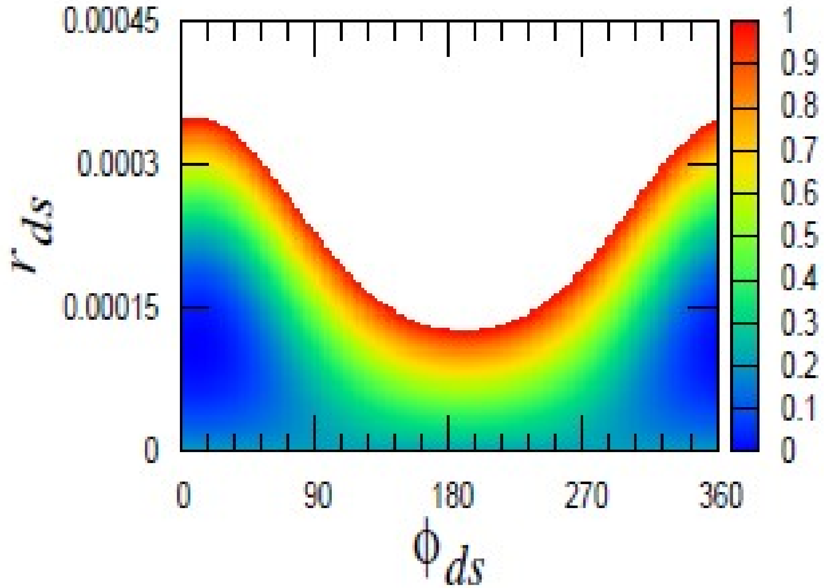
$m_{t'}$ = 500 GEV

Take $m_{b'}$ = 480 GEV

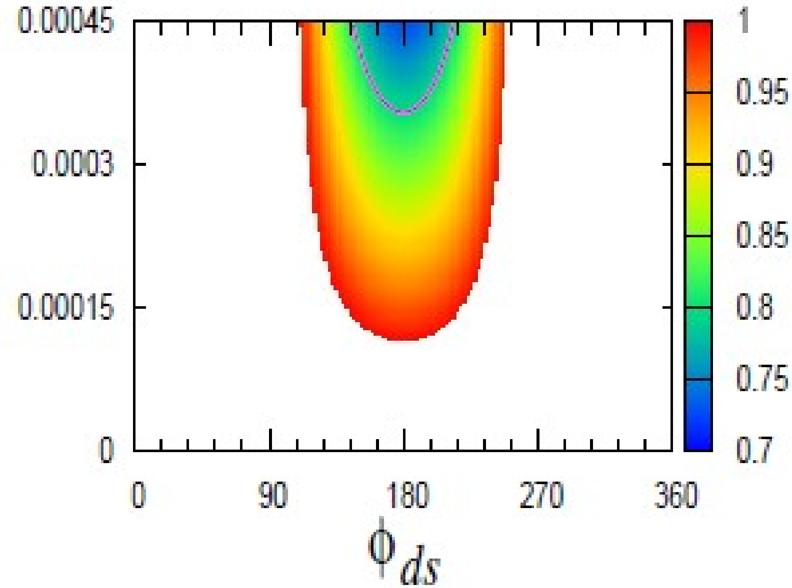
$m_{b'} = 480\ \text{GeV} \quad |V_{ub'}V_{cb'}| < 0.0021$

$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) < 3.6 \times 10^{-10}$

$|V^*_{ub'} V_{cb'}| < 0.0021$



$m_{t'}$=500 GeV, $|V_{t'b}|$=0.06, r_{sb}=0.006, ϕ_{sb}=75°
COLOR for $K^+ \to \pi^+ \nu \nu$



$m_{b'}$=480 GeV, $|V_{t'b}|$=0.06, r_{sb}=0.006, ϕ_{sb}=75°
COLOR for D-D mixing

$|V_{t'b}| = 0.06$

Lower Bound

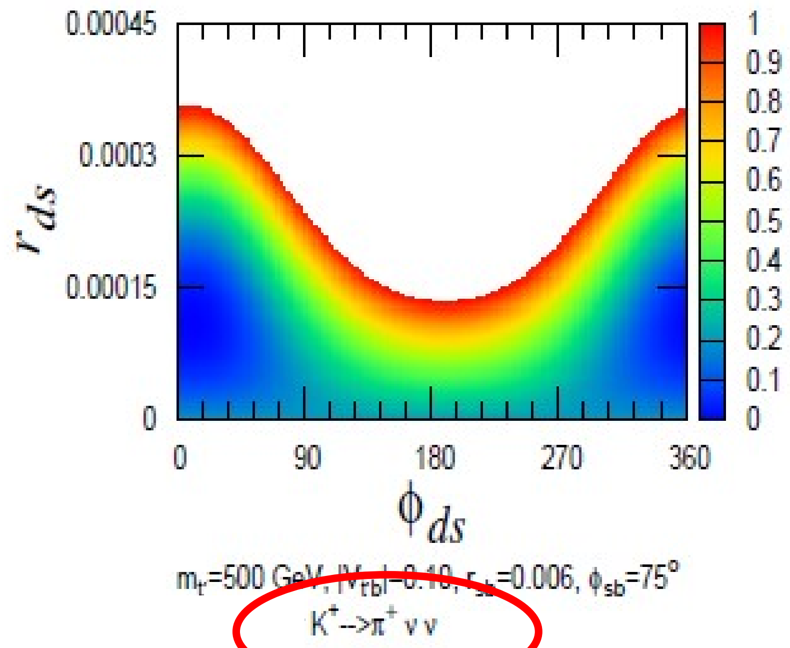
$m_{t'} = 500$ GEV, $m_{b'} = 480$ GEV

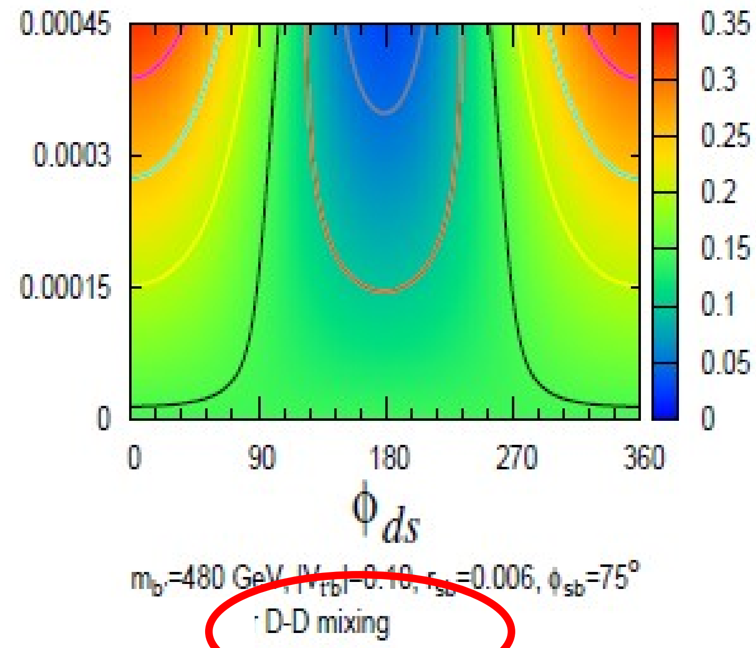
0.06 $< |V_{t'b}| <$ **0.13**

Take $|V_{t'b}| = 0.100$

$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) < 3.6 \times 10^{-10}$

$|V^*_{ub'} V_{cb'}| < 0.0021$

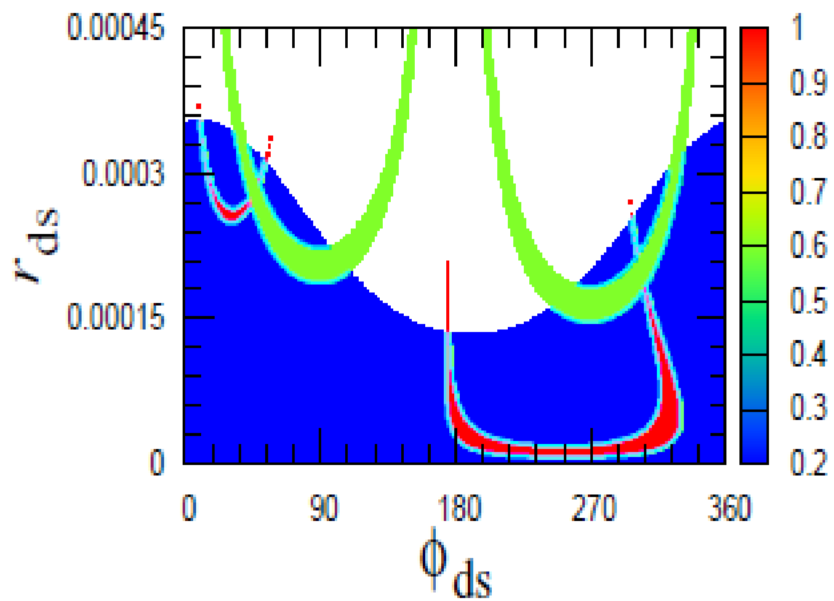




$m_{t'}$ = 500 GEV, $m_{b'}$ = 480 GEV

0.06 < $|V_{t'b}|$ < 0.13

Take $|V_{t'b}| = 0.10$ & $\mathcal{B}(K_L \to \pi^0 \nu\bar{\nu}) = 10^{-9}$



$m_{t'}$=500 GeV, $m_{b'}$=480 GeV, $|V_{t'b}|$=0.10, r_{sb}=0.006, ϕ_{sb}=75°
BLUE for $K^+ \to \pi^+ \nu\nu$ and D-D mixing
GREEN for $Br(K_L \to \pi^0 \nu\nu) = 10^{-9}$ RED for ε_K

$\mathcal{B}^{exp}(K_L \to \pi^0 \nu\bar{\nu}) < 6.7 \times 10^{-8}$

RED for ε_K

GREEN for $\mathcal{B}(K_L \to \pi^0 \nu\bar{\nu})$

$V^*_{t'd} V_{t's} \equiv r_{ds} \exp(i\phi_{ds})$

Conclusion

I. For $f_{Bs}\sqrt{B_{Bs}} = 266$ MEV, the central value of

$\sin 2\Phi_{Bs} \sim -0.35$, insensitive of $m_{t'}$

(if $f_{Bs}\sqrt{B_{Bs}}$ higher, central $\sin 2\Phi_{Bs}$ decrease for heavier $m_{t'}$)

II. Upper bound of $|V_{t'b}|$ can be obtained from $\Gamma(Z \to b\bar{b})$

III. For fixed $|V^*_{t's}V_{t'b}|$, lower bound of $|V_{t'b}|$ can be obtained from $\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu})$ and $D - \bar{D}$ mixing

IV. measurement $\mathcal{B}(K_L \to \pi^0\nu\bar{\nu})$ determines $V^*_{t'd}V_{t's}$