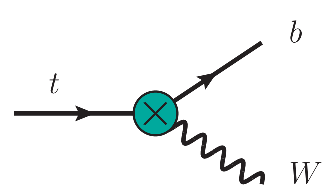
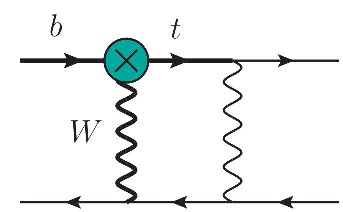
Anomalous tWb couplings

Interplay of top and bottom physics





Jure Drobnak

Institut
"Jožef Stefan"
Ljubljana, Slovenija

12. 4. 2011, Portorož

The role of heavy fermions in fundamental physics

Outline of the talk

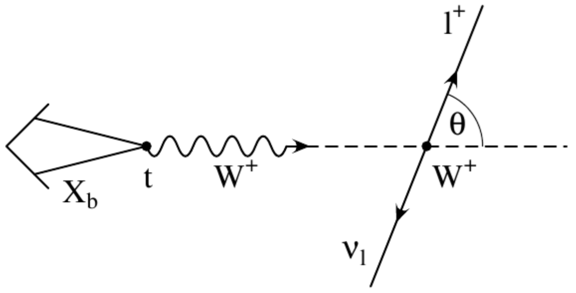
- Anomalous tWb couplings and top quark decays.
  - Effects on helicity fractions of W boson.
  - Analysis at NLO in QCD.
  - Direct constraints.
- Anomalous tWb couplings and $B_{d,s} - \bar{B}_{d,s}$ mixing.
  - Effects on the the mixing amplitude M_{12}.
  - Can these effects complie with the favored non-SM M_{12} values from recent fits?
  - If so, what kind of helicity fractions do they predict? $\leftarrow$ interplay
- Conclusions.

Helicity fractions of W boson in $t \to bW$

- We can split the decay width $\Gamma(t \to Wb)$ with respect to the polarization of the W boson.

$$\Gamma_{t\to bW} \quad = \quad \Gamma_L + \Gamma_- + \Gamma_+ \,, \qquad \mathcal{F}_i = \Gamma_i/\Gamma \,.$$

- Helicity fractions $\mathcal{F}_i$ are accessable through angular distribution of final state leptons M. Fischer et al. hep-ph/0011075 .



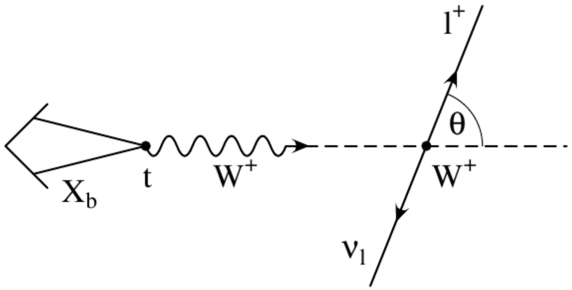
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta} = \frac{3}{8}(1+\cos\theta)^2\mathcal{F}_+ + \frac{3}{8}(1-\cos\theta)^2\mathcal{F}_- + \frac{3}{4}\sin^2\theta\mathcal{F}_L$$

Helicity fractions of W boson in $t \to bW$

- We can split the decay width $\Gamma(t \to Wb)$ with respect to the polarization of the W boson.

$$\Gamma_{t\to bW} \quad = \quad \Gamma_L + \Gamma_- + \Gamma_+ \,, \qquad \mathcal{F}_i = \Gamma_i/\Gamma \,.$$

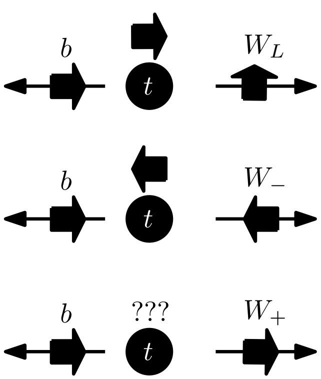
- Helicity fractions $\mathcal{F}_i$ are accessable through angular distribution of final state leptons **M. Fischer et al.** hep-ph/0011075 .



$$\frac{1}{\Gamma}\frac{\mathrm{d}\Gamma}{\mathrm{d}\cos\theta} = \frac{3}{8}(1+\cos\theta)^2\mathcal{F}_+ + \frac{3}{8}(1-\cos\theta)^2\mathcal{F}_- + \frac{3}{4}\sin^2\theta\mathcal{F}_L$$

Theory side

- The “transverse plus” component is highly surpressed!
- Non-zero $\mathcal{F}_+$ in SM comes from QCD and EW corrections, $m_b \neq 0$.



$$\mathcal{F}_L^{\rm SM} = 0.687(5) \qquad \mathcal{F}_+^{\rm SM} = 0.0017(1)$$

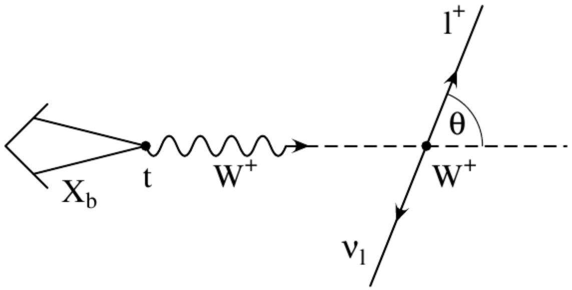
A. Czarnecki et al. 1005.2625 **H. S. Do et al.** hep-ph/0209185 **M. Fischer et al.** hep-ph/0101322

- Measured $\mathcal{F}_+ > 0.2\%$ would indicate new physics effect!

Helicity fractions of W boson in $t \to bW$

- We can split the decay width $\Gamma(t \to Wb)$ with respect to the polarization of the W boson.

$$\Gamma_{t\to bW} \quad = \quad \Gamma_L + \Gamma_- + \Gamma_+ \,, \qquad \mathcal{F}_i = \Gamma_i / \Gamma \,.$$



- Helicity fractions $\mathcal{F}_i$ are accessable through angular distribution of final state leptons M. Fischer et al. hep-ph/0011075 .

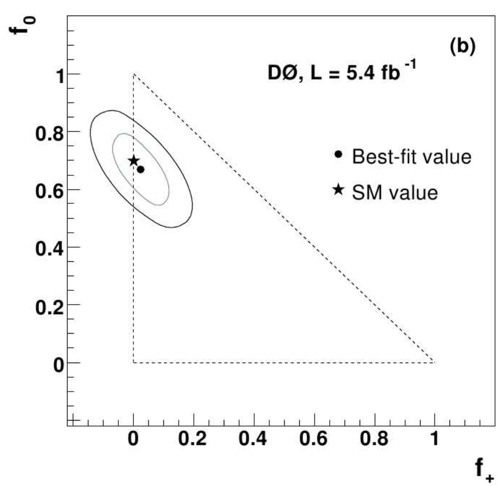
$$\frac{1}{\Gamma}\frac{\mathrm{d}\Gamma}{\mathrm{d}\cos\theta} = \frac{3}{8}(1+\cos\theta)^2\mathcal{F}_+ + \frac{3}{8}(1-\cos\theta)^2\mathcal{F}_- + \frac{3}{4}\sin^2\theta\mathcal{F}_L$$

Experiment side

- Most recent measurements from Tevatron

$$\mathcal{F}_L = 0.88(13) \qquad \mathcal{F}_+ = -0.15(9)$$ CDF 1003.0224

$$\mathcal{F}_L = 0.67(10) \qquad \mathcal{F}_+ = 0.023(53)$$ D0 1011.6549

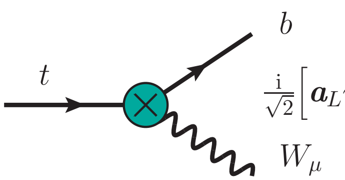


- Projected sensitivity for LHC

$$\sigma(\mathcal{F}_+) = \pm 0.002 \qquad \sigma(\mathcal{F}_L) = \pm 0.02$$ J. A. Aguilar-Saavedra 0705.3041

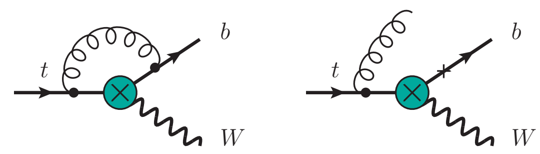
NP in tWb: effects on $\mathcal{F}_i$

- Most general parameterization of tWb vertex. **J. A. Aguilar-Saavedra** 0811.3842



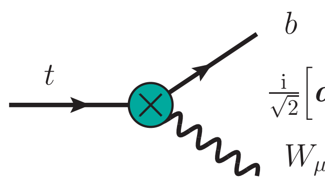
$$\frac{\mathrm{i}}{\sqrt{2}}\Big[\boldsymbol{a}_L\gamma^\mu P_L - \boldsymbol{b}_{LR}\frac{2\mathrm{i}\sigma^{\mu\nu}}{m_t}q_\nu P_R + (L\leftrightarrow R)\Big]W_\mu$$

- Helicity surpression present also in anomalous contributions.
- This mandates analysis at NLO in QCD. **J. Drobnak, J. F. Kamenik, S. Fajfer** 1010.2402



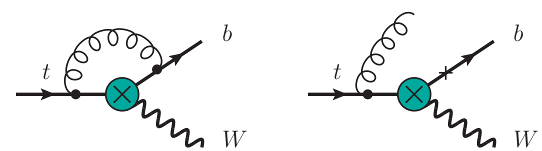
NP in tWb: effects on $\mathcal{F}_i$

- Most general parameterization of tWb vertex. **J. A. Aguilar-Saavedra** 0811.3842



$$\frac{\mathrm{i}}{\sqrt{2}}\Big[\boldsymbol{a}_L\gamma^\mu P_L - \boldsymbol{b}_{LR}\frac{2\mathrm{i}\sigma^{\mu\nu}}{m_t}q_\nu P_R + (L\leftrightarrow R)\Big]W_\mu$$

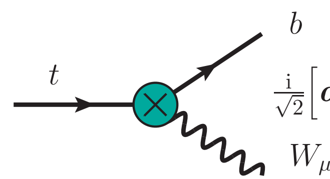
- Helicity suppression present also in anomalous contributions.
- This mandates analysis at NLO in QCD. **J. Drobnak, J. F. Kamenik, S. Fajfer** 1010.2402



- Indirect $b \to s\gamma$ constrains on $a_{L,R}$, $b_{LR,RL}$ stronger than present or projected precision of direct $\mathcal{F}_i$ measurements. **B. Grzadkowski, M. Misiak** 0802.1413
- **One exception:** b_{LR}

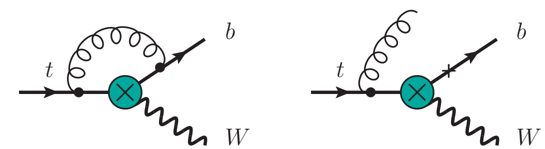
NP in tWb: effects on $\mathcal{F}_i$

- Most general parameterization of tWb vertex. **J. A. Aguilar-Saavedra** 0811.3842



$$\frac{\mathrm{i}}{\sqrt{2}}\Big[\boldsymbol{a}_L\gamma^\mu P_L - \boldsymbol{b}_{LR}\frac{2\mathrm{i}\sigma^{\mu\nu}}{m_t}q_\nu P_R + (L \leftrightarrow R)\Big]W_\mu$$

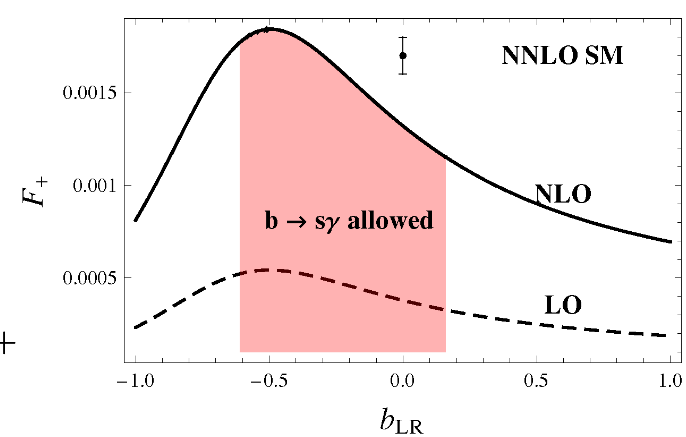
- Helicity suppression present also in anomalous contributions.
- This mandates analysis at NLO in QCD. **J. Drobnak, J. F. Kamenik, S. Fajfer** 1010.2402



- Indirect $b \to s\gamma$ constrains on $a_{L,R}$, $b_{LR,RL}$ stronger than present or projected precision of direct $\mathcal{F}_i$ measurements. **B. Grzadkowski, M. Misiak** 0802.1413
- **One exception:** b_{LR}

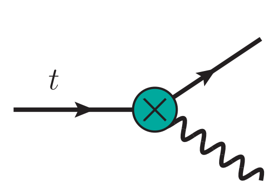
	SM (δa_L)	a_R	b_{RL}
$\mathcal{F}_+^{\mathrm{NLO}}/10^{-3}$	1.32	1.34	1.34

  - Presence of NP can not significantly affect $\mathcal{F}_+$ value!



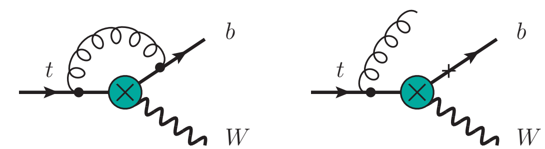
NP in tWb: effects on $\mathcal{F}_i$

- Most general parameterization of tWb vertex. J. A. Aguilar-Saavedra 0811.3842



$$\frac{\mathrm{i}}{\sqrt{2}}\Big[\boldsymbol{a}_L\gamma^\mu P_L - \boldsymbol{b}_{LR}\frac{2\mathrm{i}\sigma^{\mu\nu}}{m_t}q_\nu P_R + (L\leftrightarrow R)\Big]W_\mu$$

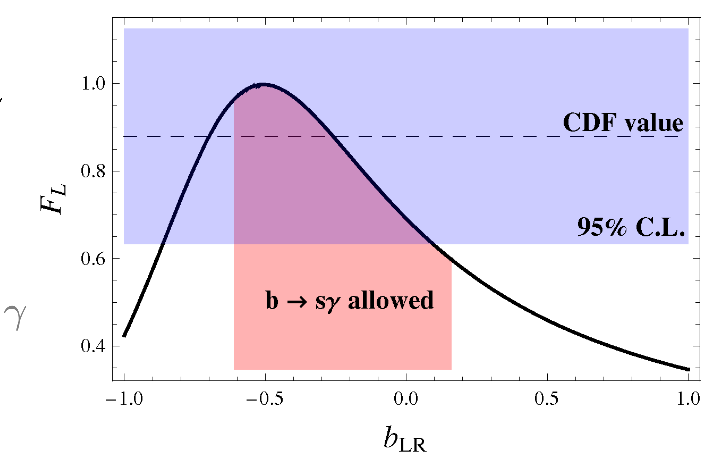
- Helicity suppression present also in anomalous contributions.
- This mandates analysis at NLO in QCD. J. Drobnak, J. F. Kamenik, S. Fajfer 1010.2402



- Indirect $b \to s\gamma$ constrains on $a_{L,R}$, $b_{LR,RL}$ stronger than present or projected precision of direct $\mathcal{F}_i$ measurements. B. Grzadkowski, M. Misiak 0802.1413

- **One exception:** b_{LR}
  - CDF measurement of $\mathcal{F}_L$ puts bounds on b_{LR} that are *competitive* with indirect $b \to s\gamma$ constraints.

$$b_{LR} < 0.09\,,\ 95\%\ \text{C.L. from } \mathcal{F}_+$$
$$b_{LR} < 0.16\,,\ 95\%\ \text{C.L. from } b\to s\gamma$$



$B_{d,s} - \bar{B}_{d,s}$ *mixing*

- Tevatron experiments quantifying B_s sector.

Some indications of NP

$B_{d,s} - \bar{B}_{d,s}$ mixing

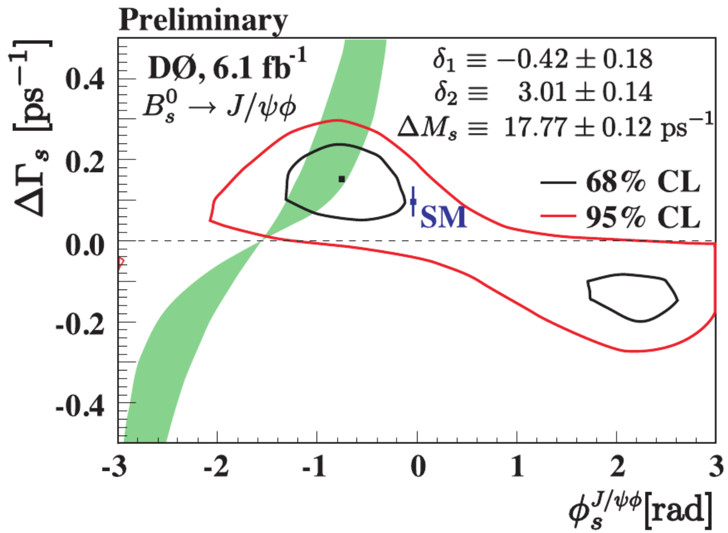
- Tevatron experiments quantifying B_s sector.

Some indications of NP

- $\Delta\Gamma_s$ vs. $\phi_s^{J/\psi\phi}$.

D0 Note 6093-CONF

CDF Public Note 10206



$B_{d,s} - \bar{B}_{d,s}$ *mixing*

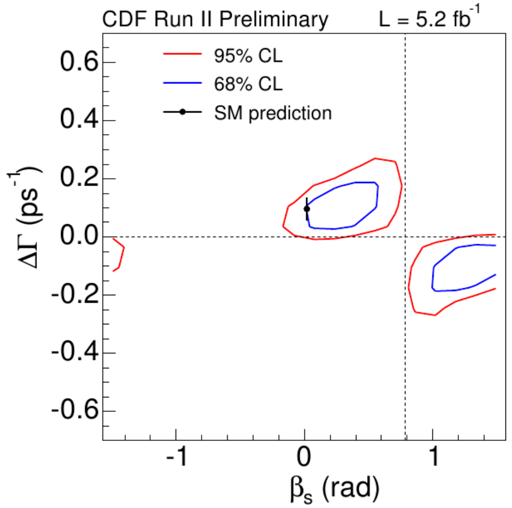
- Tevatron experiments quantifying B_s sector.

Some indications of NP

- $\Delta\Gamma_s$ vs. $\phi_s^{J/\psi\phi}$.

D0
Note 6093-CONF

CDF
Public Note 10206



$B_{d,s} - \bar{B}_{d,s}$ **mixing**

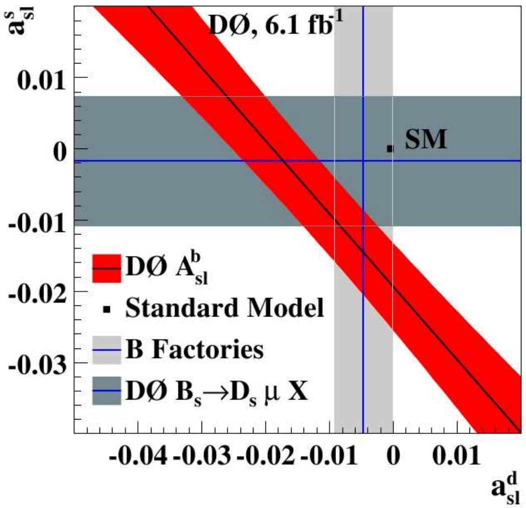
- Tevatron experiments quantifying B_s sector.

Some indications of NP

- $\Delta\Gamma_s$ vs. $\phi_s^{J/\psi\phi}$.

  D0 Note 6093-CONF **CDF** Public Note 10206

- Dimuon charge asymmetry. **D0** 1007.0395



$B_{d,s} - \bar{B}_{d,s}$ mixing

- Tevatron experiments quantifying B_s sector.

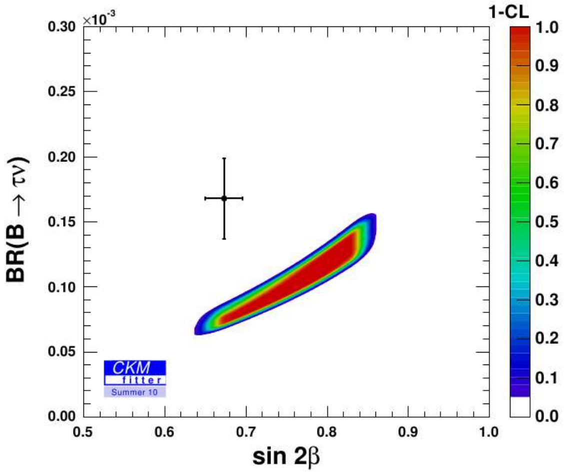
Some indications of NP

- $\Delta\Gamma_s$ vs. $\phi_s^{J/\psi\phi}$.

  D0 Note 6093-CONF **CDF** Public Note 10206

- Dimuon charge asymmetry. **D0** 1007.0395

- Tension between $\sin 2\beta$ and $\mathrm{Br}(B \to \tau\nu_\tau)$. **A. Lenz, U. Nierste and CKMfitter group** 1008.1593



$B_{d,s} - \bar{B}_{d,s}$ *mixing*

- Tevatron experiments quantifying B_s sector.

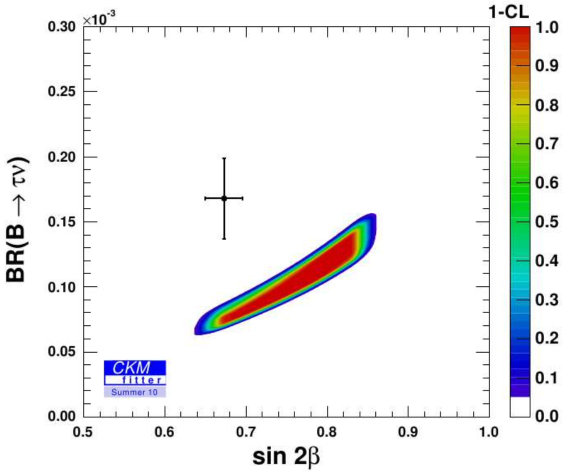
Some indications of NP

- $\Delta\Gamma_s$ vs. $\phi_s^{J/\psi\phi}$.

  D0 Note 6093-CONF   **CDF** Public Note 10206

- Dimuon charge asymmetry. **D0** 1007.0395

- Tension between $\sin 2\beta$ and $\mathrm{Br}(B \to \tau\nu_\tau)$. **A. Lenz, U. Nierste and CKMfitter group** 1008.1593



- Could NP be hiding in $B_{d,s} - \bar{B}_{d,s}$ mixing?

$$\boxed{M_{12}^{(d,s)} = M_{12}^{(d,s)\mathrm{SM}}\,\Delta_{d,s}}$$

- Analyzed and found consistancy with present data. $\Delta_{d,s} = 1$ disfavored!

  Z. Ligeti, M. Papucci, G. Perez, J. Zupan 1006.0432   **A. Lenz, U. Nierste and CKMfitter group** 1008.1593

NP in tWb: $B_{d,s} - \bar{B}_{d,s}$ mixing

- Anomalous tWb can cause $\Delta_{d,s} \neq 1$!
- Effective vertex notation sufficient for setting direct constraints from $t \to Wb$ decays.
- For indirect constraints we take a step further: effective theory, described by the Lagrangian

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda^2} \sum_i C_i \mathcal{Q}_i + \text{h.c.} + \mathcal{O}(1/\Lambda^3)\,.$$

NP in tWb***:*** $B_{d,s} - \bar{B}_{d,s}$ ***mixing***

- Anomalous tWb can cause $\Delta_{d,s} \neq 1$!
- Effective vertex notation sufficient for setting direct constraints from $t \to Wb$ decays.
- For indirect constraints we take a step further: effective theory, described by the Lagrangian

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda^2} \sum_i C_i \mathcal{Q}_i + {\rm h.c.} + \mathcal{O}(1/\Lambda^3)\,.$$

- Restrictions:
  - Dim. 6 operators, invariant under SM gauge group, involving charged quark currents with W.
  - Minimal Flavor Violation.
  - Rid tree level FCNCs and flavor universal interactions affecting G_F.

NP in tWb: $B_{d,s} - \bar{B}_{d,s}$ mixing

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda^2}\sum_i C_i \mathcal{Q}_i + \text{h.c.} + \mathcal{O}(1/\Lambda^3)$$

Simplest linear MFV

$$\begin{aligned}
\mathcal{Q}_{RR} &= V_{tb}[\bar{t}_R\gamma^\mu b_R]\big(\phi_u^\dagger \mathrm{i}D_\mu\phi_d\big)\,,\\
\mathcal{Q}_{LL} &= [\bar{Q}'_3\tau^a\gamma^\mu Q'_3]\big(\phi_d^\dagger\tau^a \mathrm{i}D_\mu\phi_d\big)\\
&- [\bar{Q}'_3\gamma^\mu Q'_3]\big(\phi_d^\dagger \mathrm{i}D_\mu\phi_d\big),\\
\mathcal{Q}_{LRt} &= [\bar{Q}'_3\sigma^{\mu\nu}\tau^a t_R]\phi_u W^a_{\mu\nu}\,,\\
\mathcal{Q}_{LRb} &= [\bar{Q}_3\sigma^{\mu\nu}\tau^a b_R]\phi_d W^a_{\mu\nu}\,.
\end{aligned}$$

Same operator bases used in $b \to s\gamma$ decays

B. Grzadkowski, M. Misiak

0802.1413

Non-linear MFV

Large bottom Yukawa effects **A. L. Kagan et al.** 0903.1794

$$\begin{aligned}
\mathcal{Q}'_{LL} &= [\bar{Q}_3\tau^a\gamma^\mu Q_3]\big(\phi_d^\dagger\tau^a \mathrm{i}D_\mu\phi_d\big)\\
&- [\bar{Q}_3\gamma^\mu Q_3]\big(\phi_d^\dagger \mathrm{i}D_\mu\phi_d\big),\\
\mathcal{Q}''_{LL} &= [\bar{Q}'_3\tau^a\gamma^\mu Q_3]\big(\phi_d^\dagger\tau^a \mathrm{i}D_\mu\phi_d\big)\\
&- [\bar{Q}'_3\gamma^\mu Q_3]\big(\phi_d^\dagger \mathrm{i}D_\mu\phi_d\big),\\
\mathcal{Q}'_{LRt} &= [\bar{Q}_3\sigma^{\mu\nu}\tau^a t_R]\phi_u W^a_{\mu\nu}\,.
\end{aligned}$$

- Rotation to mass eigen-basis: $Q_i = (V^*_{ki}u_{Lk}, b_{Li})$, $\bar{Q}'_3 = \bar{Q}_i V^*_{ti}$.

NP in tWb: $B_{d,s} - \bar{B}_{d,s}$ mixing

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda^2}\sum_i C_i \mathcal{Q}_i + {\rm h.c.} + \mathcal{O}(1/\Lambda^3)$$

Simplest linear MFV

$$\begin{aligned}
\mathcal{Q}_{RR} &= V_{tb}[\bar{t}_R\gamma^\mu b_R](\phi_u^\dagger {\rm i}D_\mu \phi_d)\,,\\
\mathcal{Q}_{LL} &= [\bar{Q}'_3\tau^a\gamma^\mu Q'_3](\phi_d^\dagger\tau^a {\rm i}D_\mu\phi_d)\\
&- [\bar{Q}'_3\gamma^\mu Q'_3](\phi_d^\dagger {\rm i}D_\mu\phi_d)\,,\\
\mathcal{Q}_{LRt} &= [\bar{Q}'_3\sigma^{\mu\nu}\tau^a t_R]\phi_u W^a_{\mu\nu}\,,\\
\mathcal{Q}_{LRb} &= [\bar{Q}_3\sigma^{\mu\nu}\tau^a b_R]\phi_d W^a_{\mu\nu}\,.
\end{aligned}$$

Same operator bases used in $b \to s\gamma$ decays
B. Grzadkowski, M. Misiak
0802.1413

Non-linear MFV

Large bottom Yukawa effects — **A. L. Kagan et al.** 0903.1794

$$\begin{aligned}
\mathcal{Q}'_{LL} &= [\bar{Q}_3\tau^a\gamma^\mu Q_3](\phi_d^\dagger\tau^a {\rm i}D_\mu\phi_d)\\
&- [\bar{Q}_3\gamma^\mu Q_3](\phi_d^\dagger {\rm i}D_\mu\phi_d)\,,\\
\mathcal{Q}''_{LL} &= [\bar{Q}'_3\tau^a\gamma^\mu Q_3](\phi_d^\dagger\tau^a {\rm i}D_\mu\phi_d)\\
&- [\bar{Q}'_3\gamma^\mu Q_3](\phi_d^\dagger {\rm i}D_\mu\phi_d)\,,\\
\mathcal{Q}'_{LRt} &= [\bar{Q}_3\sigma^{\mu\nu}\tau^a t_R]\phi_u W^a_{\mu\nu}\,.
\end{aligned}$$

- Rotation to mass eigen-basis: $Q_i = (V^*_{ki}u_{Lk}, b_{Li})$, $\bar{Q}'_3 = \bar{Q}_i V^*_{ti}$.
- $\mathcal{Q}_{LL}$ and $\mathcal{Q}_{LRt}$ modify also tWd and tWs couplings

NP in tWb: $B_{d,s} - \bar{B}_{d,s}$ mixing

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda^2}\sum_i C_i \mathcal{Q}_i + \text{h.c.} + \mathcal{O}(1/\Lambda^3)$$

Simplest linear MFV

$$\begin{aligned}
\mathcal{Q}_{RR} &= V_{tb}[\bar{t}_R\gamma^\mu b_R]\big(\phi_u^\dagger \mathrm{i}D_\mu\phi_d\big)\,,\\
\mathcal{Q}_{LL} &= [\bar{Q}'_3\tau^a\gamma^\mu Q'_3]\big(\phi_d^\dagger\tau^a \mathrm{i}D_\mu\phi_d\big)\\
&- [\bar{Q}'_3\gamma^\mu Q'_3]\big(\phi_d^\dagger \mathrm{i}D_\mu\phi_d\big),\\
\mathcal{Q}_{LRt} &= [\bar{Q}'_3\sigma^{\mu\nu}\tau^a t_R]\phi_u W^a_{\mu\nu}\,,\\
\mathcal{Q}_{LRb} &= [\bar{Q}_3\sigma^{\mu\nu}\tau^a b_R]\phi_d W^a_{\mu\nu}\,.
\end{aligned}$$

Same operator bases used in $b \to s\gamma$ decays
B. Grzadkowski, M. Misiak
0802.1413

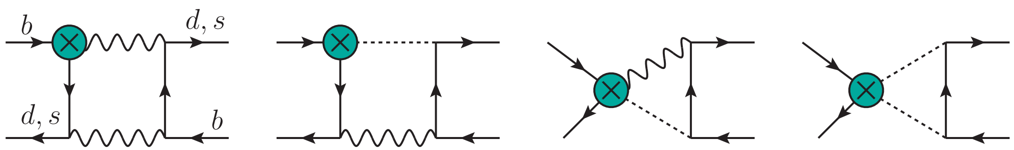
Non-linear MFV

Large bottom Yukawa effects **A. L. Kagan et al.** 0903.1794

$$\begin{aligned}
\mathcal{Q}'_{LL} &= [\bar{Q}_3\tau^a\gamma^\mu Q_3]\big(\phi_d^\dagger\tau^a \mathrm{i}D_\mu\phi_d\big)\\
&- [\bar{Q}_3\gamma^\mu Q_3]\big(\phi_d^\dagger \mathrm{i}D_\mu\phi_d\big),\\
\mathcal{Q}''_{LL} &= [\bar{Q}'_3\tau^a\gamma^\mu Q_3]\big(\phi_d^\dagger\tau^a \mathrm{i}D_\mu\phi_d\big)\\
&- [\bar{Q}'_3\gamma^\mu Q_3]\big(\phi_d^\dagger \mathrm{i}D_\mu\phi_d\big),\\
\mathcal{Q}'_{LRt} &= [\bar{Q}_3\sigma^{\mu\nu}\tau^a t_R]\phi_u W^a_{\mu\nu}\,.
\end{aligned}$$

- Rotation to mass eigen-basis: $Q_i = (V^*_{ki}u_{Lk}, b_{Li})$, $\bar{Q}'_3 = \bar{Q}_i V^*_{ti}$.
- $\mathcal{Q}_{LL}$ and $\mathcal{Q}_{LRt}$ modify also tWd and tWs couplings
- $\mathcal{Q}'_{LL}$ and $\mathcal{Q}_{LRb}$ modify also uWb and cWb couplings

Anomalous tWb couplings and M_{12}



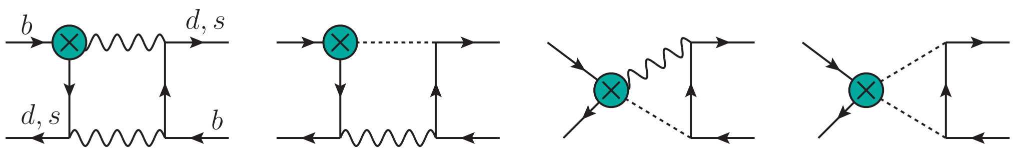
- The set of our seven dim-six operators contribute to $\Delta_{d,s}$

J. Drobnak, J. F. Kamenik, S. Fajfer
1102.4347

$$\begin{aligned}\Delta_{d,s} &= 1 - 2.57\,\kappa_{LL} + 2.00\,\kappa'_{LL} - 1.29\,\kappa''_{LL} - 1.54\,\kappa_{LRt} \\ &- 0.77\,\kappa'_{LRt} + \{4.48_d, 4.46_s\}\kappa^2_{RR} + \{4.15_d, 4.13_s\}\kappa^2_{LRb}\,,\end{aligned}$$

- Analyze one operator at the time

Anomalous tWb couplings and M_{12}



- The set of our seven dim-six operators contribute to $\Delta_{d,s}$

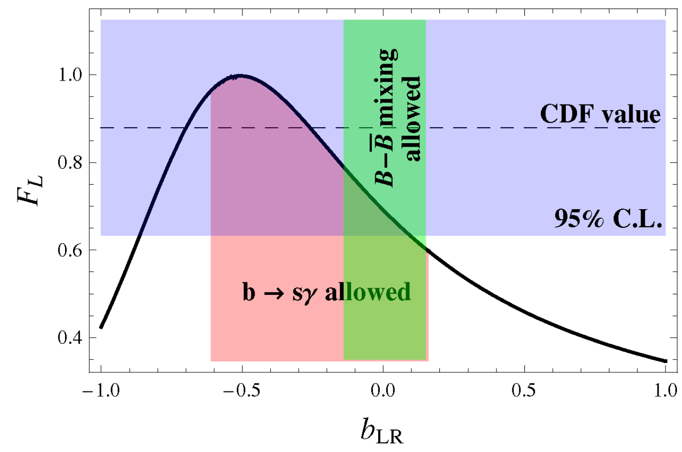
J. Drobnak, J. F. Kamenik, S. Fajfer
1102.4347

$$\Delta_{d,s} = 1 - 2.57\,\kappa_{LL} + 2.00\,\kappa'_{LL} - 1.29\,\kappa''_{LL} - 1.54\,\kappa_{LRt} - 0.77\,\kappa'_{LRt} + \{4.48_d, 4.46_s\}\kappa^2_{RR} + \{4.15_d, 4.13_s\}\kappa^2_{LRb}\,,$$

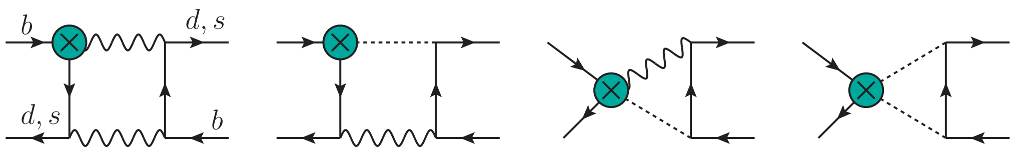
- Analyze one operator at the time

1) $\kappa_{LL} = \frac{\mathrm{Re}[C_{LL}]}{\Lambda^2\sqrt{2}G_F}$ and $\kappa_{LRt} = \frac{\mathrm{Re}[C_{LRt}]}{\Lambda^2 G_F}$ can not contribute new CPV phases.
New bounds obtained

$$-0.082 < \kappa_{LL} < 0.078\,, \quad \text{at 95\% C.L.}\,,$$
$$-0.14 < \kappa_{LRt} < 0.13\,, \quad \text{at 95\% C.L.}\,.$$



Anomalous tWb couplings and M_{12}



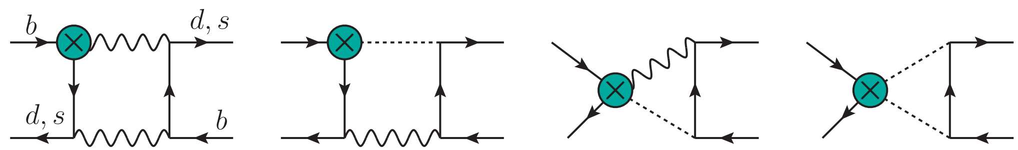
- The set of our seven dim-six operators contribute to $\Delta_{d,s}$ J. Drobnak, J. F. Kamenik, S. Fajfer 1102.4347

$$\begin{aligned}\Delta_{d,s} &= 1 - 2.57\,\kappa_{LL} + 2.00\,\kappa'_{LL} - 1.29\,\kappa''_{LL} - 1.54\,\kappa_{LRt} \\ &- 0.77\,\kappa'_{LRt} + \{4.48_d, 4.46_s\}\kappa^2_{RR} + \{4.15_d, 4.13_s\}\kappa^2_{LRb}\,,\end{aligned}$$

- Analyze one operator at the time

2) $\kappa_{RR} = \frac{C_{RR}}{\Lambda^2 2\sqrt{2}G_F}$ and $\kappa_{LRb} = \frac{C_{LRb}}{\Lambda^2 G_F}$ severely constrained by $b \to s\gamma$. Contribute to mixing only upon two insertions. No considerable effect on $\Delta_{d,s}$.

Anomalous tWb couplings and M_{12}



- The set of our seven dim-six operators contribute to $\Delta_{d,s}$

J. Drobnak, J. F. Kamenik, S. Fajfer
1102.4347

$$\begin{aligned}\Delta_{d,s} &= 1 - 2.57\,\kappa_{LL} + 2.00\,\kappa'_{LL} - 1.29\,\kappa''_{LL} - 1.54\,\kappa_{LRt} \\ &- 0.77\,\kappa'_{LRt} + \{4.48_d, 4.46_s\}\kappa^2_{RR} + \{4.15_d, 4.13_s\}\kappa^2_{LRb}\,,\end{aligned}$$

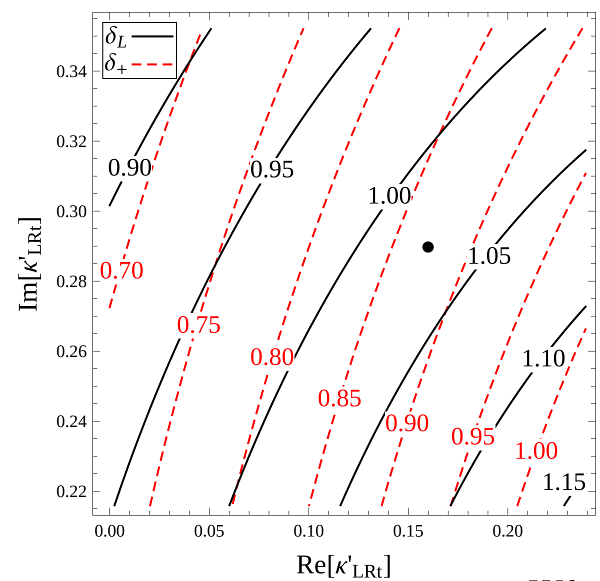
- Analyze one operator at the time

3) $\kappa'^{(\prime\prime)}_{LL} = \frac{C'^{(\prime\prime)}_{LL}}{\Lambda^2\sqrt{2}G_F}$ and $\kappa'_{LRt} = \frac{C'_{LRt}}{\Lambda^2 G_F}$ not overly constrained by $b \to s\gamma$.

	Re	Im
κ'_{LL}	$-0.062^{+0.063}_{-0.030}$	$-0.110^{+0.029}_{-0.024}$
κ''_{LL}	$0.097^{+0.048}_{-0.098}$	$0.180^{+0.037}_{-0.044}$
κ'_{LRt}	$0.160^{+0.079}_{-0.160}$	$0.290^{+0.062}_{-0.074}$

Central fitted values and 1σ intervals

- Up to 30% change in $\mathcal{F}_+$
- Up to 15% change in $\mathcal{F}_L$



Conclusions

- Helicity fractions can give information about tWb coupling
  - Possible measured $\mathcal{F}_+ \gg 0.1\%$ can not be explained by a simple effective vertex.
  - Latest measurements of $\mathcal{F}_L$ give direct bounds on anomalous dipole couplings competitive with indirect bounds from $b \to s\gamma$ (MFV).

Conclusions

- Helicity fractions can give information about tWb coupling
  - Possible measured $\mathcal{F}_+ \gg 0.1\%$ can not be explained by a simple effective vertex.
  - Latest measurements of $\mathcal{F}_L$ give direct bounds on anomalous dipole couplings competitive with indirect bounds from $b \to s\gamma$ (MFV).
- Anomalous top coupling affect $B - \bar{B}$ mixing.
  - For MFV models with small bottom Yukawa effects, the bounds are competitive (in some cases improved) compared to $b \to s\gamma$.
  - MVF models with large bottom Yukawa effects could accommodate the latest global fits (Complex Wilson coefficients).

Conclusions

- Helicity fractions can give information about tWb coupling
  - Possible measured $\mathcal{F}_+ \gg 0.1\%$ can not be explained by a simple effective vertex.
  - Latest measurements of $\mathcal{F}_L$ give direct bounds on anomalous dipole couplings competitive with indirect bounds from $b \to s\gamma$ (MFV).
- Anomalous top coupling affect $B - \bar{B}$ mixing.
  - For MFV models with small bottom Yukawa effects, the bounds are competitive (in some cases improved) compared to $b \to s\gamma$.
  - MVF models with large bottom Yukawa effects could accommodate the latest global fits (Complex Wilson coefficients).
  - Favored non-zero dipole Wilson coefficient affects the helicity fractions!
  - In addition other observables "beyond helicity fractions" might be affected

J. A. Aguilar-Saavedra, J. Bernabeu
1005.5382

Extra slides: MFV framework

- Lagrangian formally invariant under the SM flavor group $\mathcal{G}^{\rm SM} = U(3)_Q \times U(3)_u \times U(3)_d$
- Only $\mathcal{G}^{\rm SM}$ symmetry breaking spurionic fields in the theory are the up and down quark Yukawa matrices $Y_{u,d}$, formally transforming as $(3, \bar{3}, 1)$ and $(3, 1, \bar{3})$ respectively.
- Most general $\mathcal{G}^{\rm SM}$ invariant quark bilinear flavor structures

$$\bar{u} Y_u^\dagger \mathcal{A}_{ud} Y_d d\,, \quad \bar{Q} \mathcal{A}_{QQ} Q\,, \quad \bar{Q} \mathcal{A}_{Qu} Y_u u\,, \quad \bar{Q} \mathcal{A}_{Qd} Y_d d\,,$$

  where $\mathcal{A}_{xy}$ are arbitrary polynomials of $Y_u Y_u^\dagger$ and/or $Y_d Y_d^\dagger$,
- $\langle Y_d \rangle = {\rm diag}(m_d, m_s, m_b)/v_d$ and $\langle Y_u \rangle = V^\dagger {\rm diag}(m_u, m_c, m_t)/v_u$

Extra slides: MFV framework

Linear MFV

- Simplest case of linear MFV where within $\langle \mathcal{A}_{xy} \rangle$ higher powers of $\langle Y_d Y_d^\dagger \rangle \simeq \mathrm{diag}(0, 0, m_b^2/v_d^2)$ can be neglected. Neglecting also contributions suppressed by first and second generation quark masses, the only relevant flavor contributions of the arbitrary $\mathcal{A}_{xy}$ structures

$$\bar{t}_R V_{tb} b_R \, , \qquad \bar{Q}_i Q_i \, , \qquad \bar{Q}_i V_{ti}^* V_{tj} Q_j \, ,$$
$$\bar{Q}_i V_{ti}^* t_R \, , \qquad \bar{Q}_3 b_R \, , \qquad \bar{Q}_i V_{ti}^* V_{tb} b_R \, ,$$

Extra slides: MFV framework

Non-Linear MFV

- Generalization to MFV scenarios where large bottom Yukawa effects can be important.
- Higher powers of $\langle Y_d Y_d^\dagger \rangle$ within $\mathcal{A}_{xy}$ effectively project to the third generation in the down sector yielding the following additional flavor structures

$$\bar{Q}_3 Q_3 \,, \qquad \bar{Q}_3 V_{tb}^* V_{tj} Q_j \,, \qquad \bar{Q}_3 V_{tb}^* t_R \,.$$