Comparison of direct and indirect constraints on anomalous tWb couplings

Anastasiia Kozachuk, Dmitri Melikhov

Skobeltsyn Institute of Nuclear Physics
Lomonosov Moscow State University

EPS-HEP conference
Ghent, Belgium

11 June 2019

Introduction

- The top quark is the heaviest of all known elementary particles and is expected to have large couplings with non-SM physics
- One of the possibilities is to study the possible anomalous interactions of the Wtb vertex

The most general, lowest-dimension, CP-conserving Lagrangian for the Wtb vertex has the following form:

$$\mathcal{L} = \frac{g}{\sqrt{2}}\bar{\mathrm{b}}\gamma^{\mu}\left(f_{\mathrm{V}}^{\mathrm{L}}P_{\mathrm{L}} + f_{\mathrm{V}}^{\mathrm{R}}P_{\mathrm{R}}\right)\mathrm{t}\mathrm{W}_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{\mathrm{b}}\frac{\sigma^{\mu\nu}\partial_{\nu}\mathrm{W}_{\mu}^{-}}{M_{\mathrm{W}}}\left(f_{\mathrm{T}}^{\mathrm{L}}P_{\mathrm{L}} + f_{\mathrm{T}}^{\mathrm{R}}P_{\mathrm{R}}\right)\mathrm{t} + \mathrm{h.c.},$$

where $P_{\mathrm{L,R}} = (1 \mp \gamma_5)/2$, $\sigma_{\mu\nu} = i(\gamma_\mu\gamma_\nu - \gamma_\nu\gamma_\mu)/2$, g is the coupling constant of the weak interaction, the form factor $f_{\mathrm{V}}^{\mathrm{L}}$ ($f_{\mathrm{V}}^{\mathrm{R}}$) represents the left-handed (right-handed) vector coupling, and $f_{\mathrm{T}}^{\mathrm{L}}$ ($f_{\mathrm{T}}^{\mathrm{R}}$) represents the left-handed (right-handed) tensor coupling.

The SM has the following set of coupling values:
$f_{\mathrm{V}}^{\mathrm{L}} = V_{\mathrm{tb}}, f_{\mathrm{V}}^{\mathrm{R}} = f_{\mathrm{T}}^{\mathrm{L}} = f_{\mathrm{T}}^{\mathrm{R}} = 0.$

Experimental Data

Experimental data on anomalous Wtb couplings can be divided into two types:

- direct constraints (e.g. from single top quark production)
- indirect constraints from B-physics

In B-physics the following three channels give the most stringent constraints:

- Data on $B_{d,s} - \bar{B}_{d,s}$ oscillations
- The branching ratio of the $\bar{B} \to X_s \gamma$ decay
- The branching ratio of the $\bar{B} \to X_s \mu^+ \mu^-$ decay

Scenarios

We considered the following scenarios when two or three couplings can have non-SM values:

$(f_V^L; f_V^R)$
$(f_V^L; f_T^L)$
$(f_V^L; f_T^R)$
$(f_V^L; f_T^L; f_T^R)$

With these scenarios we compared the results from indirect constraints obtained from B-physics and direct constraints obtained from single top quark production [1]

[1] V. Khachatryan *et al.* [CMS Collaboration], JHEP **1702**, 028 (2017)

Theoretical framework for B-physics

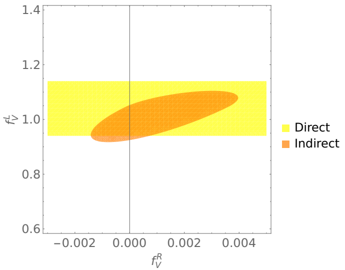
In case of B-physics the constraints on anomalous couplings can be obtained through the corresponding constraints on the non-SM additions to the Wilson coefficients. We used the scheme proposed in Drobnak et al. 10.1016/j.nuclphysb.2011.10.004, where in the Lagrangian at the scale $\mu \sim \mathrm{m_b}$ of the B-meson decays the Wilson coefficients have the form $C_i = C_i^{SM} + \delta C_i$:

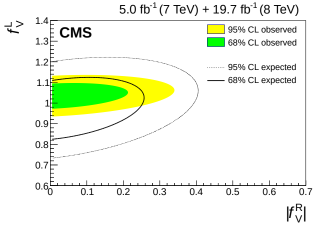
$$\begin{aligned}\mathcal{L} = \mathcal{L}_{QCD\times QED} \quad &+ \quad \frac{4G_F}{\sqrt{2}}\left[\sum_{i=1}^{2} C_i\left(V_{ub}V_{us}^{*}\mathcal{O}_i^{(u)} + V_{cb}V_{cs}^{*}\mathcal{O}_i^{(c)}\right)\right] + \\ &+ \quad \frac{4G_F}{\sqrt{2}} V_{tb}V_{ts}^{*}\sum_{i=3}^{10} C_i\mathcal{O}_i,\end{aligned}$$

where the first term consists of the kinetic terms of the light SM particles and their QCD and QED interactions

Results: constraints on anomalous tWb couplings

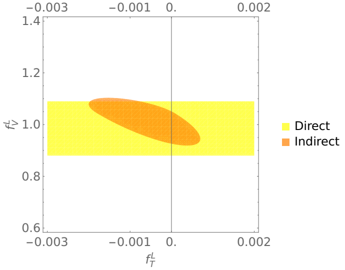
$$f_V^L - f_V^R$$

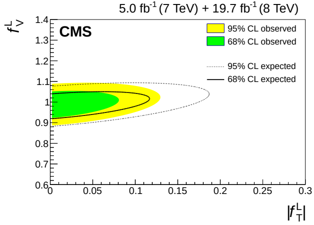




Results: constraints on anomalous tWb couplings

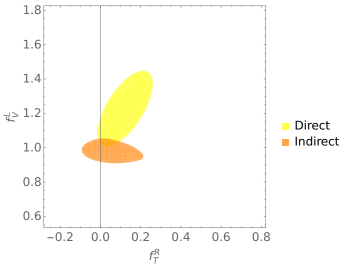
$$f_V^L - f_T^L$$

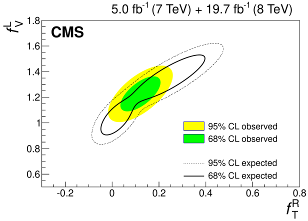




Results: constraints on anomalous tWb couplings

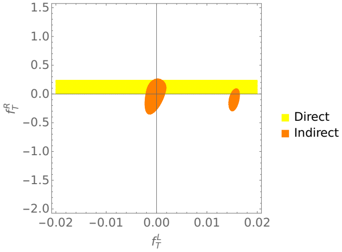
$$f_V^L - f_T^R$$

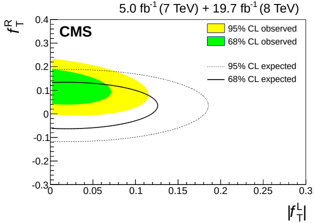




Results: constraints on anomalous tWb couplings

$$f_V^L - f_T^R - f_T^L$$





Conclusions

- Indirect constraints from B-physics in most scenarios are more rigid than direct constraints from single top quark production
- So far no deviations from the Standard Model have been observed