

SM test in $\mathcal{R}(D^{(*)})$ anomaly

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Motivation

Definition

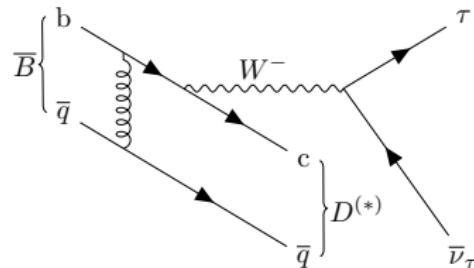
$$\mathcal{R}(D^{(*)}) = \frac{\mathcal{B}(\bar{B} \rightarrow D^{(*)}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \rightarrow D^{(*)}\ell^-\bar{\nu}_\ell)} \quad (\ell = e, \mu)$$

	SM prediction	Experimental results(HFAG Moriond 2017) [3]		
$\mathcal{R}(D)$	$0.300 \pm 0.008[1]$	$0.403 \pm 0.040 \pm 0.024$	$\sim 2.2\sigma$	
$\mathcal{R}(D^*)$	$0.252 \pm 0.003[2]$	$0.310 \pm 0.015 \pm 0.008$	$\sim 3.4\sigma$	3.9σ

→ Hint for lepton non universality → new physics in $b \rightarrow c\tau^-\bar{\nu}_\tau$

$\overline{B} \rightarrow D\tau^-\bar{\nu}_\tau$ standard model

SM process:



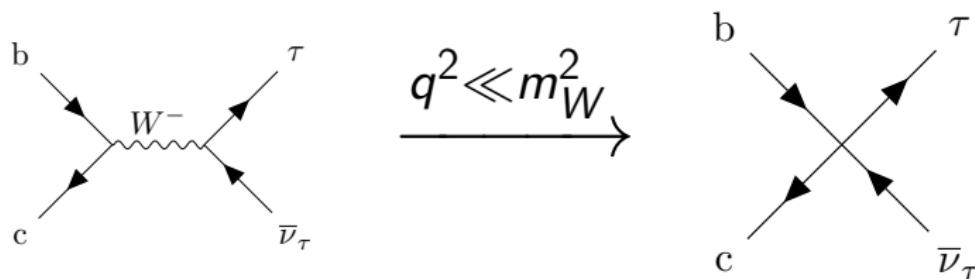
→ Amplitude $\mathcal{M} \propto G_F V_{cb} \underbrace{\langle D(p_D) | \bar{c} \gamma^\mu b | \overline{B}(p_B) \rangle}_{\text{non perturbative}}$ for $\overline{B} \rightarrow D\tau^-\bar{\nu}_\tau$

Need form factors:

$$\begin{aligned} \langle D(p_D) | \bar{c} \gamma^\mu b | \overline{B}(p_B) \rangle &= \left((p_B + p_D)^\mu - q^\mu \frac{m_B^2 - m_D^2}{q^2} \right) F_1(q^2) \\ &\quad + q^\mu \frac{m_B^2 - m_D^2}{q^2} F_0(q^2), \quad q^2 = (p_B - p_D)^2 \end{aligned}$$

$\overline{B} \rightarrow D\tau^-\bar{\nu}_\tau$ standard model

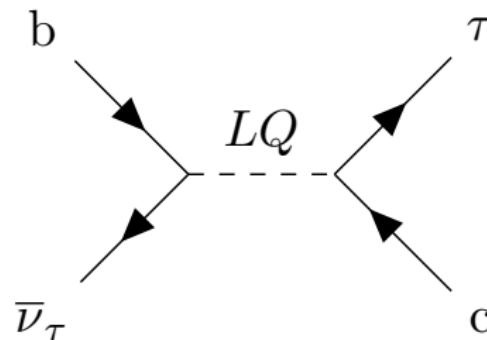
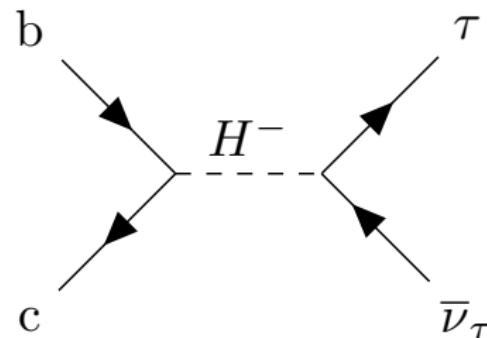
Effective Field Theory(EFT):



$$\rightarrow \mathcal{H}_{\text{eff}}^{\text{SM}} = \frac{4G_F}{\sqrt{2}} V_{cb} [\bar{c}_L \gamma^\mu b_L] [\bar{\ell}_L \gamma_\mu \nu_{\ell L}] =: \frac{4G_F}{\sqrt{2}} V_{cb} \mathcal{O}_{V1} \text{ with } G_F = \frac{\sqrt{2}}{8} \frac{g^2}{M_W^2}$$

$\bar{B} \rightarrow D\tau^-\bar{\nu}_\tau$ beyond standard model

For example:



For new particles → effective vertices → contributions $\propto C_X \cdot \mathcal{O}_X$

\mathcal{O}_X : **model independent** Operators

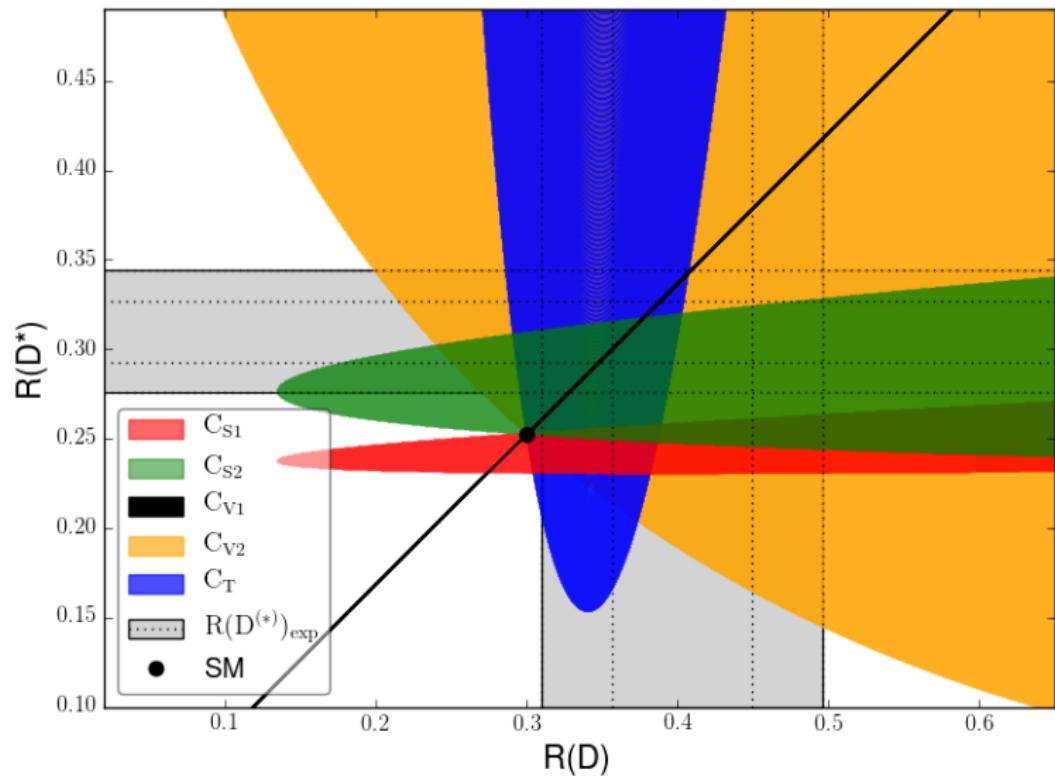
C_X : model dependent Wilson coefficients

Beyond standard model five (dimension six) operators are possible:

$$\begin{aligned}\mathcal{O}_{V1(2)} &= [\bar{c}_{L(R)} \gamma^\mu b_{L(R)}] [\bar{\ell}_L \gamma_\mu \nu_{\ell L}], \quad \mathcal{O}_{S1(2)} = [\bar{c}_{L(R)} b_{R(L)}] [\bar{\ell}_R \nu_{\ell L}] \\ \mathcal{O}_T &= [\bar{c}_R \sigma^{\mu\nu} b_L] [\bar{\ell}_R \sigma_{\mu\nu} \nu_{\ell L}]\end{aligned}$$

$$\mathcal{H}_{\text{eff}}^{\text{NP}} = \frac{4G_F}{\sqrt{2}} V_{cb} [(\underbrace{1}_{\text{SM}} + C_V) \mathcal{O}_{V1} + C_{V2} \mathcal{O}_{V2} + C_{S1} \mathcal{O}_{S1} + C_{S2} \mathcal{O}_{S2} + C_T \mathcal{O}_T]$$

Correlation between $R(D)$ and $R(D^*)$



Thank you for your attention!

References

- [1]: H. Na et al., Phys.Rev.D 92, 054410 (2015)
- [2]: S.Fajfer, J.F.Kamenik, and I.Nisandzic, Phys.Rev.D85(2012) 094025
- [3]: HFAG, <http://www.slac.stanford.edu/xorg/hfag/semi/moriond17/RDRDs.html>