Matching of gauge invariant dimension-six operators for $b \to s$ and $b \to c$ transitions

Jason Aebischer

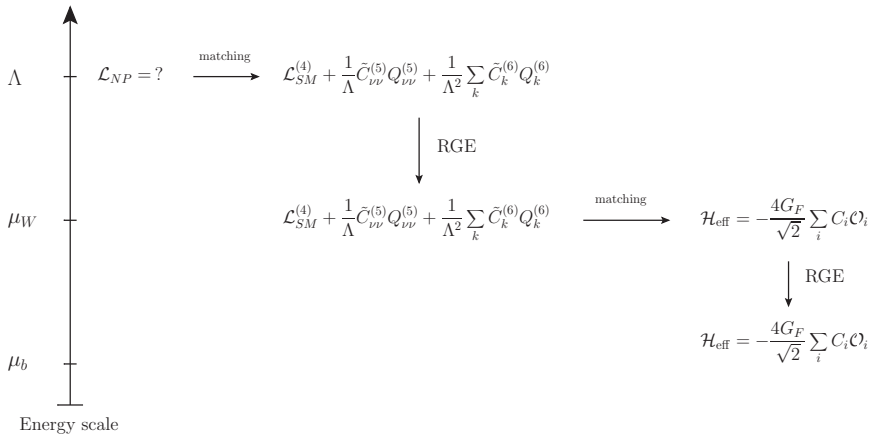In collaboration with M. Fael, A. Crivellin and C. Greub
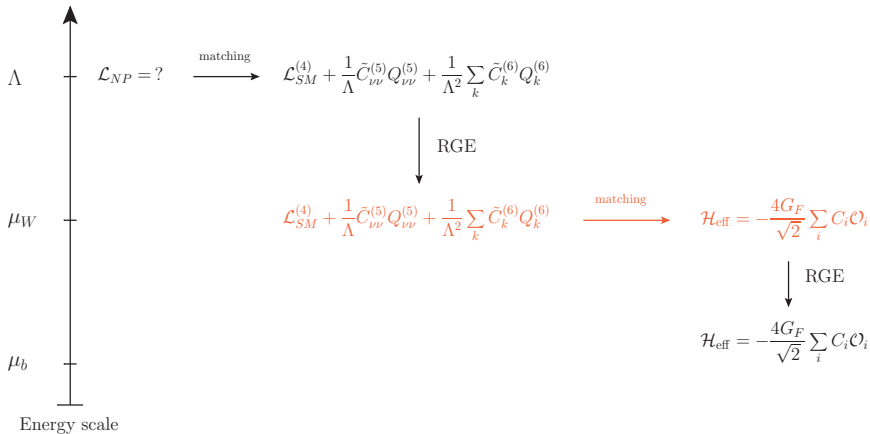
arXiv:1512:02830

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$$\mathcal{L}_{\text{SM}} = \mathcal{L}_{\text{SM}}^{(4)} + \frac{1}{\Lambda} C_{\nu\nu}^{(5)} Q_{\nu\nu}^{(5)} + \frac{1}{\Lambda^2} \sum_k C_k^{(6)} Q_k^{(6)}$$

$$\Lambda \quad\quad \mathcal{L}_{NP} = ? \quad \xrightarrow{\text{matching}} \quad \mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\tilde{C}_{\nu\nu}^{(5)}Q_{\nu\nu}^{(5)} + \frac{1}{\Lambda^2}\sum_k \tilde{C}_k^{(6)}Q_k^{(6)}$$

RGE

$$\mu_W \quad\quad \mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\tilde{C}_{\nu\nu}^{(5)}Q_{\nu\nu}^{(5)} + \frac{1}{\Lambda^2}\sum_k \tilde{C}_k^{(6)}Q_k^{(6)} \quad \xrightarrow{\text{matching}} \quad \mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}}\sum_i C_i\mathcal{O}_i$$

RGE

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}}\sum_i C_i\mathcal{O}_i$$

$$\mu_b$$

Energy scale

Λ — $\mathcal{L}_{NP} = ?$ $\xrightarrow{\text{matching}}$ $\mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\tilde{C}_{\nu\nu}^{(5)}Q_{\nu\nu}^{(5)} + \frac{1}{\Lambda^2}\sum_k \tilde{C}_k^{(6)}Q_k^{(6)}$

$\downarrow$ RGE

μ_W — $\mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\tilde{C}_{\nu\nu}^{(5)}Q_{\nu\nu}^{(5)} + \frac{1}{\Lambda^2}\sum_k \tilde{C}_k^{(6)}Q_k^{(6)}$ $\xrightarrow{\text{matching}}$ $\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}}\sum_i C_i\mathcal{O}_i$

$\downarrow$ RGE

$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}}\sum_i C_i\mathcal{O}_i$

μ_b —

Energy scale

EW scale matching

Integrating out top, W, Z and the Higgs

EW scale matching

Integrating out top, W, Z and the Higgs

Tree level

Complete tree-level matching coefficients for $b \to s$ and $b \to c$ transitions (including lepton flavor violating operators)

EW scale matching
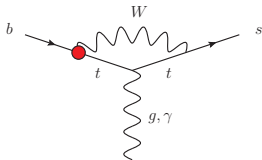Integrating out top, W, Z and the Higgs

Tree level
Complete tree-level matching coefficients for $b \to s$ and $b \to c$ transitions (including lepton flavor violating operators)

1-loop
1-loop matching contributions, in cases where operators do not give a matching contribution at tree level

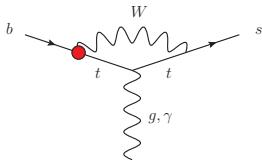$$Q_{\varphi ud}^{33} = (\widetilde{\varphi}^{\dagger}\, iD_{\mu}\varphi)(\bar{t}\gamma^{\mu}b)$$

$$Q^{33}_{\varphi ud} = (\widetilde{\varphi}^{\dagger} \, iD_{\mu}\varphi)(\bar{t}\gamma^{\mu}b)$$

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$$C_7 = \frac{m_t}{m_b}\frac{v^2}{\Lambda^2} E_{\varphi ud}^7(x_t)\, \widetilde{C}_{\varphi ud}^{33}\, V_{ts}^*$$

$$C_8 = \frac{m_t}{m_b}\frac{v^2}{\Lambda^2} E_{\varphi ud}^8(x_t)\, \widetilde{C}_{\varphi ud}^{33}\, V_{ts}^*$$

$$\mathcal{B}^{\mathrm{th}}(\overline{B} \to X_s \gamma) \times 10^4 = (3.36 \pm 0.23) - \frac{8.22 \, \Delta C_7 + 1.99 \, \Delta C_8}{V_{tb} V_{ts}^*}$$

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Constraint:

$$-3.3 \times 10^{-3} \leq \widetilde{C}_{\varphi ud}^{33}\,[\mu_W = 160\,\text{GeV}]\,\frac{v^2}{\Lambda^2} \leq 2.7 \times 10^{-3}$$

Tree level

Complete tree-level matching coefficients for $b \to s$ and $b \to c$

1-loop matching

In cases where tree level contribution is zero

Future

Constraining wilson coefficients