

EXERCISES ON SMEFT IN TOP PHYSICS

ELENI VRYONIDOU

Conventions: We will follow arXiv:1802.07237 for conventions. Please keep that note at hand when trying these questions!

(1) **Question 1:** Operators and EOMs

Show that the two operators in:

$$(1) \quad \mathcal{O}_{gt} = \bar{t} T_A \gamma^\mu D^\nu t G_{\mu\nu}^A,$$

$$(2) \quad \mathcal{O}_{gQ} = \bar{Q} T_A \gamma^\mu D^\nu Q G_{\mu\nu}^A,$$

can be written as a sum of four fermion operators

(2) **Question 2:** EFT and anomalous couplings

Write down the Feynman rules for the ttZ vertex including the impact of 2-fermion operators $\mathcal{O}_{tZ}, \mathcal{O}_{\phi t}, \mathcal{O}_{\phi Q}^3, \mathcal{O}_{\phi Q}^-$ e.t.c. and compare with the typical anomalous coupling parametrisation of the ttZ vertex.

$$\mathcal{L}_{ttZ} = e \bar{u}(p_t) \left[\gamma^\mu (C_{1,V}^Z + \gamma_5 C_{1,A}^Z) + \frac{i\sigma^{\mu\nu} q_\nu}{m_Z} (C_{2,V}^Z + i\gamma_5 C_{2,A}^Z) \right] v(p_{\bar{t}}) Z_\mu$$

What are the expressions for: $C_{1,V}^Z, C_{1,A}^Z, C_{2,V}^Z$ and $C_{2,A}^Z$ in terms of the dim-6 Wilson coefficients?

(3) **Question 3** Extract the map between Warsaw to dim6top (arXiv:1802.07237) operator coefficients for the subset of 4-heavy operators: $c_{QQ}^1, c_{QQ}^8, c_{Qt}^1, c_{Qt}^8, c_{Qb}^1, c_{Qb}^8, c_{tb}^1, c_{tb}^8, c_{tt}^1$.

(4) **Question 4:** Top Spin analysing power

The top decay width given by:

$$\frac{1}{\Gamma} \frac{d\Gamma_t}{d\cos\theta_X} = \frac{1 + \alpha_X \cos\theta}{2},$$

where α_X is a parameter known as *spin analyzing power* of particle X , and θ_X is the angle between the original top spin and the direction of the emitted X in the top rest frame. Show that

$$\alpha_b(c_{tW}) = \alpha_b(\text{SM}) + \Re(c_{tW}) \frac{8\sqrt{2}v^2 m_t m_W (m_t^2 - m_W^2)}{\Lambda^2 (m_t^2 + 2m_W^2)^2} + \mathcal{O}\left(\frac{c_{tW}^2 v^4}{\Lambda^4}\right)$$

and find the impact on α_ℓ

(5) **Question 5:** Dimension-6 operators in top pair production

Compute the matrix element squared for top pair production in gluon fusion and quark anti-quark annihilation for the chromomagnetic dipole moment of the top. Extract an expression for $\frac{d\sigma}{d\cos\theta}$ where θ is the scattering angle in the centre of mass frame. Include the linear and quadratic contributions.

(6) **Question 6 (Optional):** Helicity amplitudes and Energy growth

Compute the helicity amplitudes for $bW \rightarrow tH$ in the presence of the dimension-6 operators $\mathcal{O}_{tW}, \mathcal{O}_{\phi Q3}$ and examine what happens at high energy for different helicity configurations.