

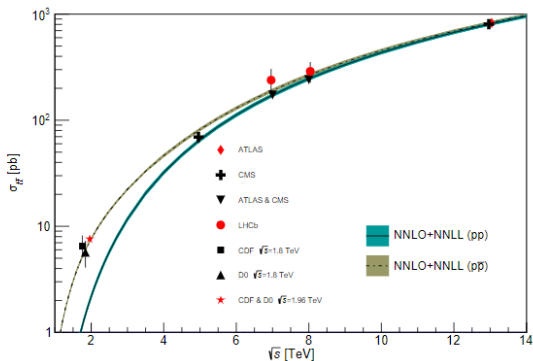


AG Buchalla

Gluon fusion top-pair production in SMEFT
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Why is gluon fusion top-pair production interesting?

- Top-quark potentially sensitive to new physics
- Most important parton-level process for $pp \rightarrow \bar{t}t$ at LHC



Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01

Standard Model Effective Field Theory (SMEFT)

- High energy physics unknown
- Need model independent method to parameterize new effects

Bottom-up EFT:

→ Degrees of freedom

→ Symmetries

→ Powercounting

Canonical dimension not sufficient

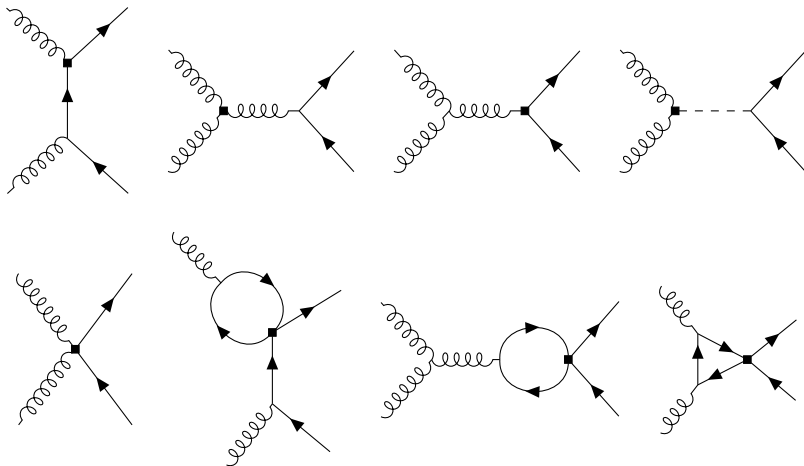
The diagram illustrates the decomposition of a gluon fusion top-pair production process. On the left, a gluon (wavy line) splits into two top quarks (solid lines with arrows), which then meet at a vertex. A dashed line indicates a loop structure. This process is shown to be equivalent to the sum of two diagrams: a loop diagram with a gluon entering from the left and two top quarks exiting to the right, and a contact diagram where a gluon enters from the left and two top quarks meet at a single vertex on the right.

$$\frac{1}{16\pi^2} \frac{1}{\Lambda^2} \longrightarrow \frac{1}{16\pi^2} \frac{C_1}{\Lambda^2} + \frac{C_2}{\Lambda^2}$$

- Arzt et al. Nucl.Phys.B 433 (1995)
- Buchalla et al. Phys.Lett.B 731 (2014)

SMEFT calculation

- Zhang et al. Phys.Rev.D 83 (2011): tree-level, analytical
- Degrande et al. Phys.Rev.D 103 (2021): one-loop, numerical



Relevant operators

Grzadkowski et al. JHEP 10 (2010) 085: Warsaw basis

$$Q_{(G)} = f^{ABC} G_{\mu}^{A\nu} G_{\nu}^{B\rho} G_{\rho}^{C\mu}$$

$$Q_{(\varphi G)} = \varphi^{\dagger} \varphi G_{\mu\nu}^A G^{A\mu\nu}$$

$$Q_{(uG)} = (\bar{q}\sigma_{\mu\nu} T^A t) \tilde{\varphi} G^{A\mu\nu}$$

$$Q_{(qd)}^{(1)} = (\bar{q}\gamma_{\mu} q)(\bar{b}\gamma^{\mu} b)$$

$$Q_{(qd)}^{(8)} = (\bar{q}\gamma_{\mu} T^A q)(\bar{b}\gamma^{\mu} T^A b)$$

$$Q_{(ud)}^{(1)} = (\bar{t}\gamma_{\mu} t)(\bar{b}\gamma^{\mu} b)$$

$$Q_{(ud)}^{(8)} = (\bar{t}\gamma_{\mu} T^A t)(\bar{b}\gamma^{\mu} T^A b)$$

$$Q_{(qu)}^{(1)} = (\bar{q}\gamma_{\mu} q)(\bar{t}\gamma^{\mu} t)$$

$$Q_{(qu)}^{(8)} = (\bar{q}\gamma_{\mu} T^A q)(\bar{t}\gamma^{\mu} T^A t)$$

$$Q_{(qq)}^{(1)} = (\bar{q}\gamma_{\mu} q)(\bar{q}\gamma^{\mu} q)$$

$$Q_{(qq)}^{(3)} = (\bar{q}\gamma_{\mu} \tau^I q)(\bar{q}\gamma^{\mu} \tau^I q)$$

$$Q_{(uu)} = (\bar{t}\gamma_{\mu} t)(\bar{t}\gamma^{\mu} t)$$

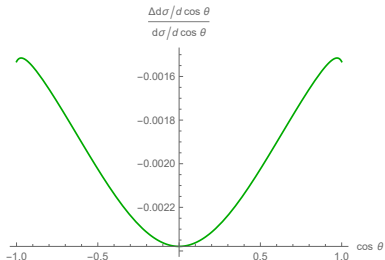
$$Q_{(quqd)}^{(1)} = (\bar{q}^j t) \epsilon_{jk} (\bar{q}^k b)$$

$$Q_{(quqd)}^{(8)} = (\bar{q}^j T^A t) \epsilon_{jk} (\bar{q}^k T^A b)$$

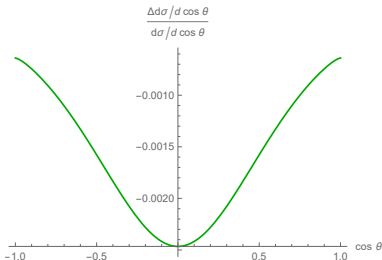
Corrections to the SM cross section for $\Lambda = 1$ TeV

$$\frac{\Delta d\sigma}{d \cos \theta} = -\frac{C_{(uG)}}{\Lambda^2} \frac{\alpha_s^{3/2} \sqrt{\pi} v m_t \beta}{12\sqrt{2}s} \frac{7m_t^4 - 7m_t^2(t+u) + 4t^2 - tu + 4u^2}{(m_t^2 - t)(m_t^2 - u)} +$$

$$+\frac{C_{(uu)}}{\Lambda^2} \frac{\alpha_s^2 m_t^2 \beta}{768\pi s} \frac{13s^2 S_1(s, m_t) - 3(t-u)^2 S_2(s, m_t)}{(m_t^2 - t)(m_t^2 - u)} + \dots$$



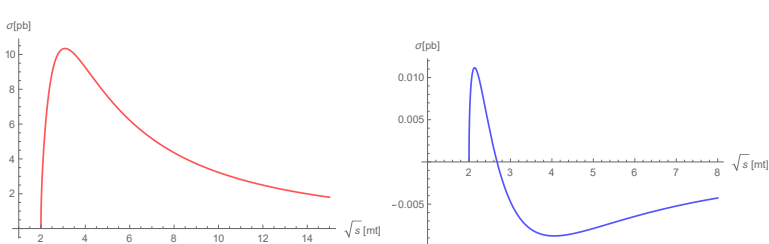
$$C_{(uG)} = 1/16\pi^2$$



$$C_{(uu)} = 1$$

Physical implications

- Change of sign shortly after threshold for $Q_{(uu)}$:



- Scenarios with strong dynamics of electroweak symmetry breaking enhance $Q_{(\varphi G)}$ \rightarrow match to Higgs-Electroweak Chiral Lagrangian:

$$\frac{C_{(\varphi G)}}{\Lambda^2} = \frac{\alpha_s}{8\pi v^2} c_g$$

Summary and Outlook

- Quite general assumptions on high energy theory imply $C_{(uG)} = \mathcal{O}(1/16\pi^2)$
- SMEFT corrections to $gg \rightarrow \bar{t}t$ are rather small
- Need very high experimental precision or customized high energy scenario

Thanks for your attention!