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Gluon fusion top-pair production in SMEFT

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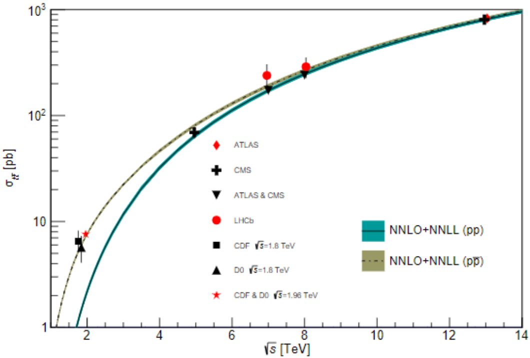
Why is gluon fusion top-pair production interesting?

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

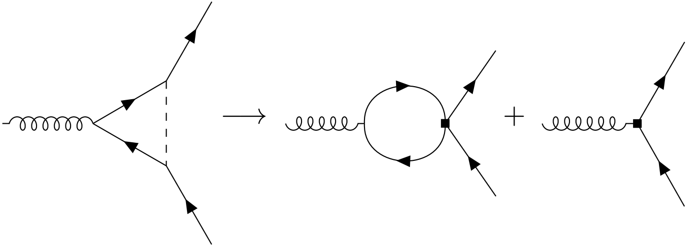
Bottom-up EFT:

$\longrightarrow$ Degrees of freedom

$\longrightarrow$ Symmetries

$\longrightarrow$ Powercounting

Canonical dimension not sufficient

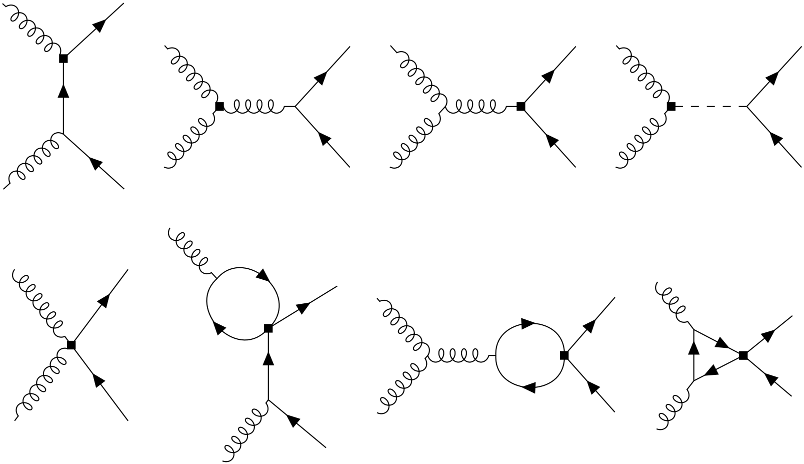


$$\frac{1}{16\pi^2}\frac{1}{\Lambda^2} \longrightarrow \frac{1}{16\pi^2}\frac{C_1}{\Lambda^2} + \frac{C_2}{\Lambda^2}$$

- 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

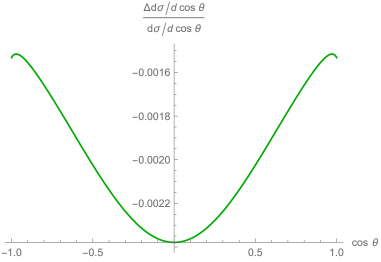
$$
\begin{aligned}
Q_{(G)} &= f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu} \\
Q_{(\varphi G)} &= \varphi^\dagger \varphi G^A_{\mu\nu} G^{A\mu\nu} \\
Q_{(uG)} &= (\bar{q}\sigma_{\mu\nu} T^A t)\tilde{\varphi} G^{A\mu\nu}
\end{aligned}
$$

$$
\begin{aligned}
Q^{(1)}_{(qd)} &= (\bar{q}\gamma_\mu q)(\bar{b}\gamma^\mu b) & Q^{(8)}_{(qd)} &= (\bar{q}\gamma_\mu T^A q)(\bar{b}\gamma^\mu T^A b) \\
Q^{(1)}_{(ud)} &= (\bar{t}\gamma_\mu t)(\bar{b}\gamma^\mu b) & Q^{(8)}_{(ud)} &= (\bar{t}\gamma_\mu T^A t)(\bar{b}\gamma^\mu T^A b) \\
Q^{(1)}_{(qu)} &= (\bar{q}\gamma_\mu q)(\bar{t}\gamma^\mu t) & Q^{(8)}_{(qu)} &= (\bar{q}\gamma_\mu T^A q)(\bar{t}\gamma^\mu T^A t) \\
Q^{(1)}_{(qq)} &= (\bar{q}\gamma_\mu q)(\bar{q}\gamma^\mu q) & Q^{(3)}_{(qq)} &= (\bar{q}\gamma_\mu \tau^I q)(\bar{q}\gamma^\mu \tau^I q) \\
Q_{(uu)} &= (\bar{t}\gamma_\mu t)(\bar{t}\gamma^\mu t) & Q^{(1)}_{(quqd)} &= (\bar{q}^j t)\epsilon_{jk}(\bar{q}^k b) \\
Q^{(8)}_{(quqd)} &= (\bar{q}^j T^A t)\epsilon_{jk}(\bar{q}^k T^A b) & &
\end{aligned}
$$

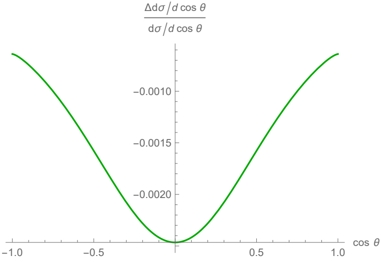
Corrections to the SM cross section for $\Lambda = 1$ TeV

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

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



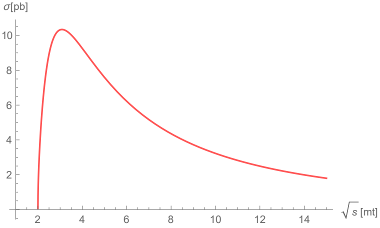
$C_{(uG)} = 1/16\pi^2$

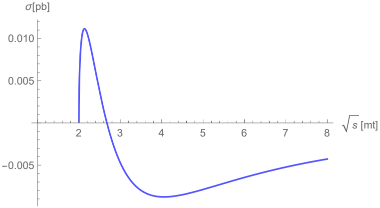


$C_{(uu)} = 1$

Physical implications

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





- Scenarios with strong dynamics of electroweak symmetry breaking enhance $Q_{(\varphi G)}$ $\longrightarrow$ 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 $gg \to \bar{t}t$ are rather small
- Need very high experimental precision or customized high energy scenario

Thanks for your attention!