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Non-factorisable two-loop contribution to t-channel single-top production

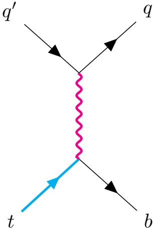
Based on arXiv:2108.09222 with Kirill Melnikov, Jérémie Quarroz & Chen-Yu Wang

Christian Brønnum-Hansen | 15 Sep 2021 | TOP2021

Non-factorisable contribution to t-channel single-top production

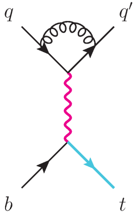
- Process interesting for studies of for example tbW vertex, V_{tb} constraints, Γ_t and m_t. *See Monday's talks by Victor Rodriguez Bouza and John Campbell*

Tree level



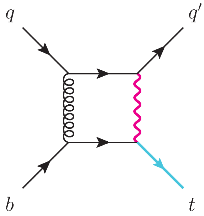
$\delta_{ij}\delta_{kl}$

Factorisable



$\mathrm{tr}\,(t^a t^a)\,\delta_{kk} = \frac{1}{2}(N_c^2 - 1)$

Non-factorisable



$\mathrm{tr}\,(t^a)\,\mathrm{tr}\,(t^a) = 0$

- Cross section at NLO known since a while *Harris et al. 2002; Campbell, Ellis, et al. 2004; Sullivan 2004; Cao and Yuan 2005; Sullivan 2005; Schwienhorst et al. 2011*
- No non-factorisable contribution to $\mathcal{A}_{\mathrm{LO}} \otimes \mathcal{A}_{\mathrm{NLO}}$

Non-factorisable contribution to t-channel single-top production

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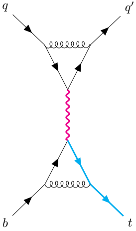
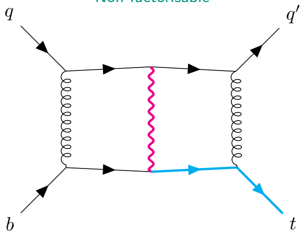
- For the NNLO correction to the cross section, we consider the interferences $\mathcal{A}_{\mathrm{LO}} \otimes \mathcal{A}_{\mathrm{NNLO}}$ and $\mathcal{A}_{\mathrm{NLO}} \otimes \mathcal{A}_{\mathrm{NLO}}$.
- Non-factorisable diagrams are colour-suppressed:

Factorisable



$$\mathrm{tr}\,(t^a t^a)\,\mathrm{tr}\left(t^b t^b\right) = \frac{1}{4}(N_c^2 - 1)^2$$

Non-factorisable



$$\mathrm{tr}\left(t^a t^b\right)\mathrm{tr}\left(t^a t^b\right) = \frac{1}{4}(N_c^2 - 1)$$

- Calculations of the factorisable contribution at NNLO exists. *Brucherseifer et al. 2014; Berger et al. 2016; Campbell, Neumann, et al. 2021*
- Non-factorisable contribution demonstrated to be enhanced for VBF Higgs production. *Liu, Melnikov, et al. 2019*

Non-factorisable diagrams at two loops

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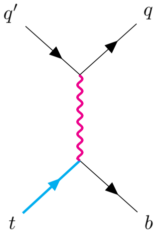
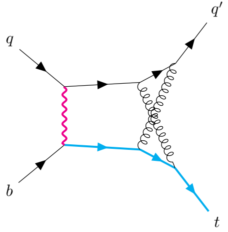
- For the NNLO correction to the cross section, we consider the interferences $\mathcal{A}_{\text{LO}} \otimes \mathcal{A}_{\text{NNLO}}$ and $\mathcal{A}_{\text{NLO}} \otimes \mathcal{A}_{\text{NLO}}$.



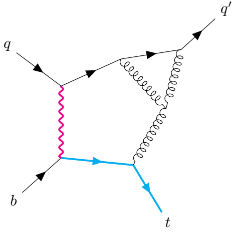
$\delta_{ij}\delta_{kl}$

Abelian



$(t^a t^b)_{ij}(t^b t^a)_{kl}$

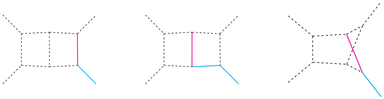
Non-Abelian



$f^{abc}(t^a t^b)_{ij}(t^c)_{kl}$

- Only **18 non-vanishing diagrams**, generated in `QGRAF` *Nogueira 1993* and processed in `FORM` *Vermaseren 2000; Kuipers et al. 2015; Ruijl et al. 2017.*
- Integral reduction performed **analytically** with `KIRA` 2.0 *Klappert, Lange, et al. 2020* and `FireFly` *Klappert and Lange 2020; Klappert, Klein, et al. 2021*
- We find **428** masters in 18 different families

Master integral evaluation



- Based on the **auxiliary mass flow method** *Liu, Ma, and Wang 2018; Liu, Ma, Tao, et al. 2020; Liu and Ma 2021*

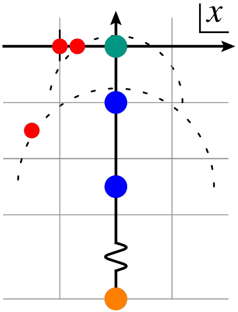
$$m_W^2 \to m_W^2 - i\eta.$$

- Solve differential equations at each kinematic point

$$\partial_x \boldsymbol{I} = \boldsymbol{M}\boldsymbol{I}, \quad x \propto -i\eta.$$

with boundary condition $x \to -i\infty$.

$$\boldsymbol{I} = \sum_j^M \epsilon^j \sum_k^N \sum_l \boldsymbol{c}_{jkl} x^k \ln^l x + \dots$$



Stepping from the boundary at $x \to -i\infty$, via regular points, to the physical mass. Step size is limited by singularities of the equation.

Results

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- All **428** master integrals evaluated in $\sim$ 30 minutes on a single core
- Comparison of poles at a typical phase space point

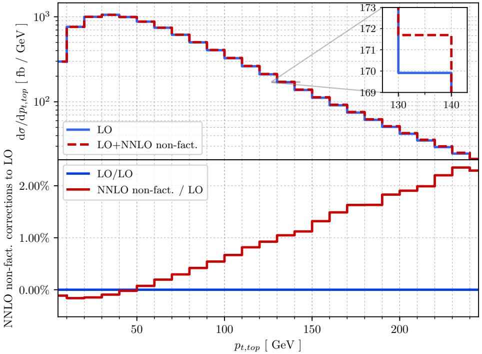
	ϵ^{-2}	ϵ^{-1}
$\langle \mathcal{A}^{(0)} \vert \mathcal{A}^{(2)}_{\mathrm{nf}} \rangle$	$-229.0940408654660 - 8.978163333241640i$	$-301.1802988944764 - 264.1773596529505i$
IR poles	$-229.0940408654665 - 8.978163333241973i$	$-301.1802988944791 - 264.1773596529535i$

- Double-virtual cross-section calculation from fixed grid of 100k points

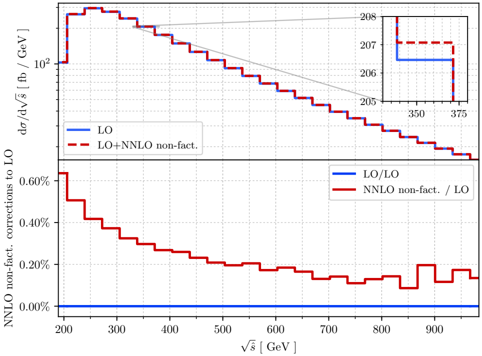
$$\sigma^{ub}_{pp\to dt} = \left(90.3 + 0.3\left(\frac{\alpha_s(\mu_{\mathrm{nf}})}{0.108}\right)^2\right)\ \mathrm{pb}$$

- Correction of about 0.3% for $\mu_{\mathrm{nf}} = 173$ GeV
- Real corrections are to be included and good choice of μ_{nf} is unclear

Results



(a) The top quark transverse momentum distribution.



(b) Differential cross section with respect to the partonic centre-of-mass energy $\sqrt{\hat{s}}$.

- Constant relative importance between factorisable and non-factorisable contributions throughout phase space