NLO QCD corrections to off-shell $t\bar{t}W^+$ production at the LHC

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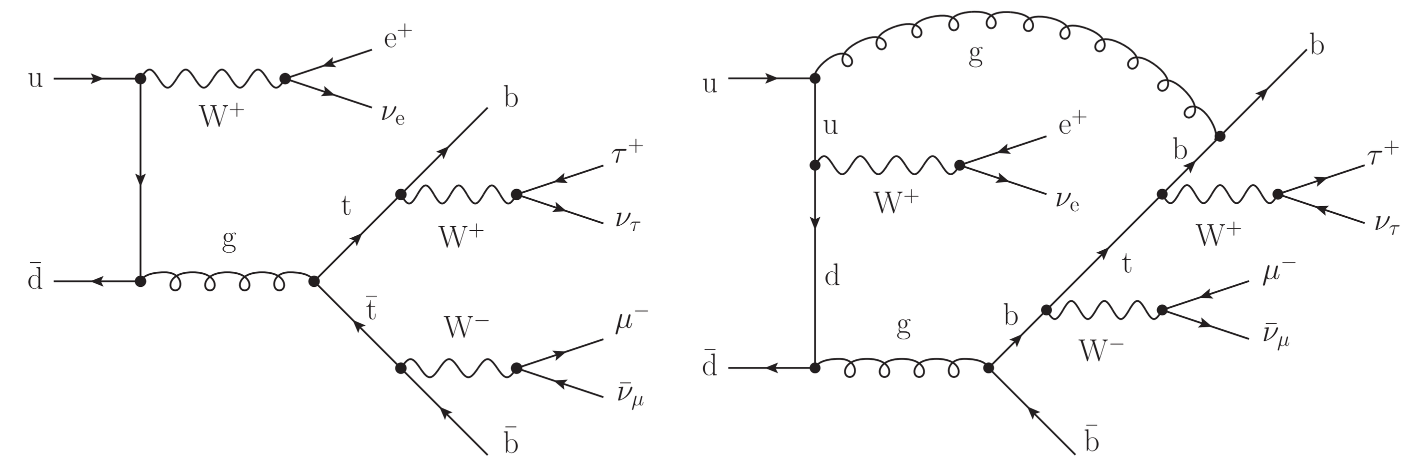
Motivations

- One of the heaviest signatures at LHC (SM/BSM).
- Relevant background for $t\bar{t}H$ production at the LHC.
- Improved theory modeling needed to compare with data.
- So far on-shell calculations, only recently a first off-shell one appeared [Bevilacqua et al. 2005.09427].

We present an independent computation of the **complete NLO QCD corrections to off-shell $t\bar{t}W^+$** in the channel $pp \to e^+\nu_e\,\mu^-\bar{\nu}_\mu\,\tau^+\nu_\tau\,b\,\bar{b}$, including full off-shell effects, spin-correlations, interferences [Denner, Pellicciol 2007.12089].

Details of the calculation



At **LO** ($\alpha_s^2\alpha^6$) only $q\bar{q}$ channel, dominated by $t\bar{t}$ resonances. At **NLO** ($\alpha_s^3\alpha^6$) integration of real corrections challenging (large multiplicity, 2→9), virtual corrections feature up to 7-point one-loop amplitudes.

Setup of the simulations

- Full tree-level ($g_s^2 g^6$, $g_s^3 g^6$) and one-loop ($g_s^4 g^6$) amplitudes with RECOLA [Actis et al. 1605.01090]
- Integration with MoCaNLO in-house Monte Carlo
- Dipole subtraction scheme [Catani, Seymour 9605323]
- Complex-mass scheme [Denner et al. 9904472]
- NNPDF3.1 (N)LO PDFs [Ball et al. 1706.00428], $N_F = 5$
- Selections: 2 b-jets (anti-k_t, $R = 0.4, p_{T,b} > 25$ GeV, $|\eta_b| < 2.5$), 3 ch. leptons ($p_{T,\ell} > 27$ GeV, $|\eta_\ell| < 2.5, \Delta R_{\ell b} > 0.4$).

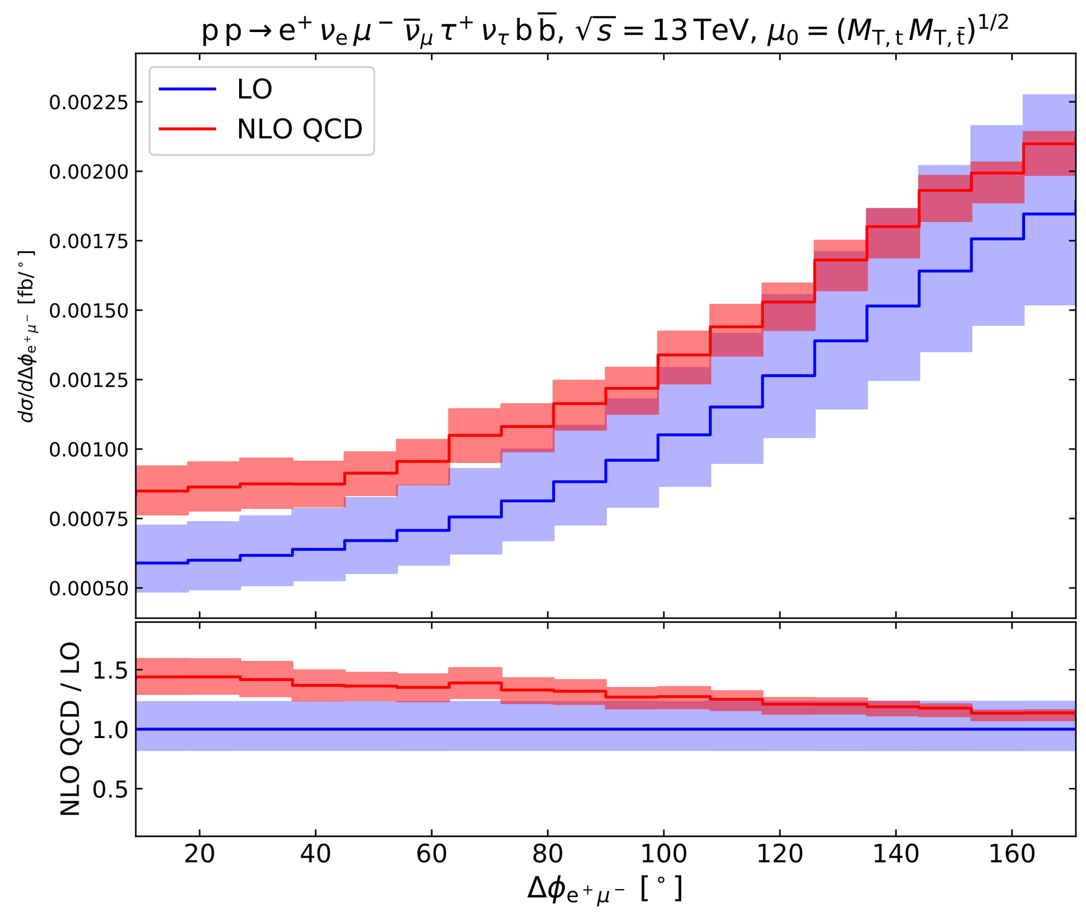
Integrated cross-sections

Different scale choices (fixed, dynamical) give **between +7% and +25% corrections** to the total cross-section. **Scale uncertainties significantly reduced** at NLO.

central scale	LO	NLO QCD	K-factor
$\mu_0^{(a)} = M_t + M_W/2$	$0.2042(1)^{+23.8\%}_{-18.0\%}$	$0.2452(7)^{+4.5\%}_{-6.8\%}$	1.20
$\mu_0^{(b)} = H_T/2$	$0.1931(1)^{+23.0\%}_{-17.5\%}$	$0.2330(9)^{+4.2\%}_{-6.5\%}$	1.21
$\mu_0^{(c)} = H_T/3$	$0.2175(1)^{+24.2\%}_{-18.2\%}$	$0.2462(8)^{+2.8\%}_{-5.8\%}$	1.13
$\mu_0^{(d)} = (M_{T,t}M_{T,\bar{t}})^{1/2}$	$0.1920(1)^{+23.0\%}_{-17.5\%}$	$0.2394(6)^{+5.4\%}_{-7.2\%}$	1.25
$\mu_0^{(e)} = (M_{T,t}M_{T,\bar{t}})^{1/2}/2$	$0.2360(1)^{+24.9\%}_{-18.7\%}$	$0.2535(8)^{+3.4\%}_{-5.2\%}$	1.07

Differential results

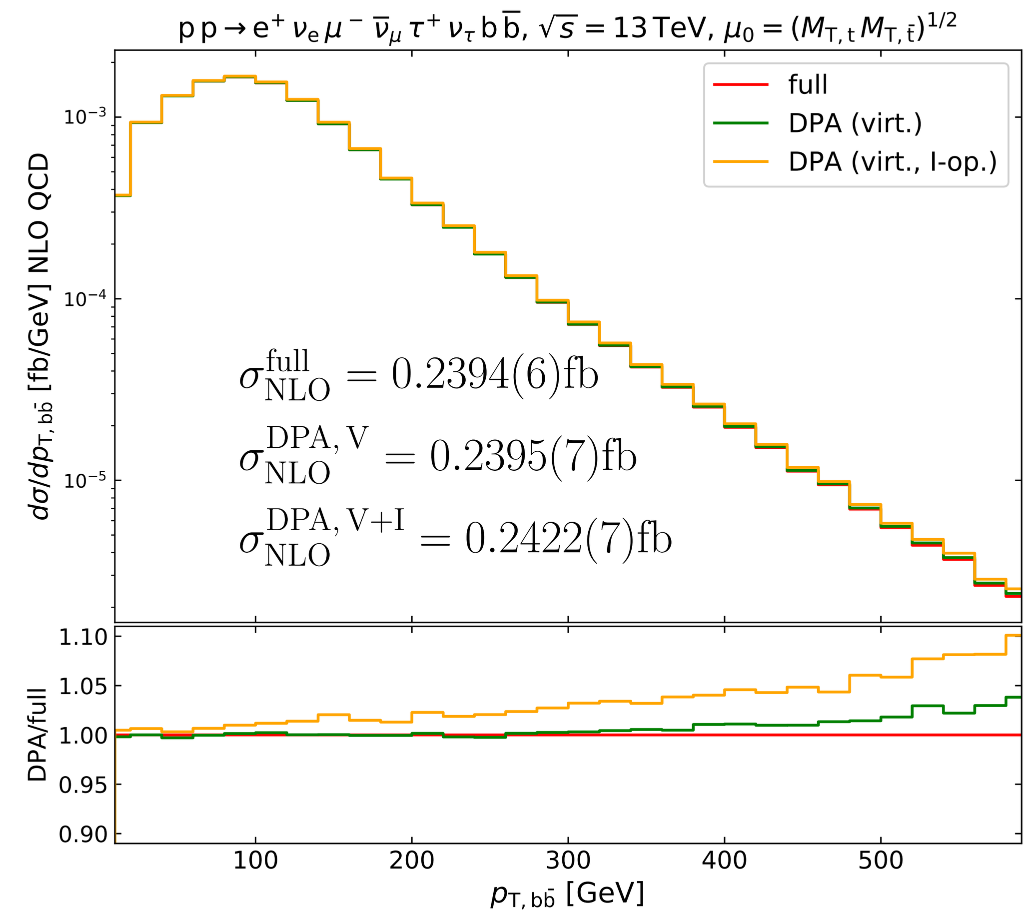
Flatter corrections for dynamical scale choices. Fig.: azimuthal separation between positron and muon.



Moderate shape distortion due to NLO corrections. **Large K-factor in some distribution tails**, *e.g.* large $p_{T,bb}$.

Double-pole approximation

Two different **calculations**: applied DPA($t\bar{t}$) only to virtual corrections or also to integrated dipoles I-operators.



Impressive agreement for DPA virtual only (small virt. corrections). Larger discrepancies in off-shell regions if DPA applied to I-operators.

Conclusion

NLO QCD corrections (about 20% at integrated level) reduce scale uncertainties. Some distributions: much **larger K-factors in suppressed phase-space regions**. **Double-pole approx.** leads to a few % agreement with full calculation (integrated level). The **discrepancy reaches 10% and more in regions not dominated by resonant $t\bar{t}$**.

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