NLO QCD corrections for off-shell $t\bar{t}b\bar{b}$

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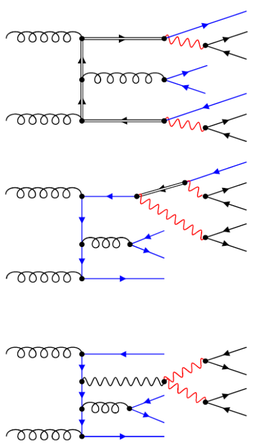
Introduction



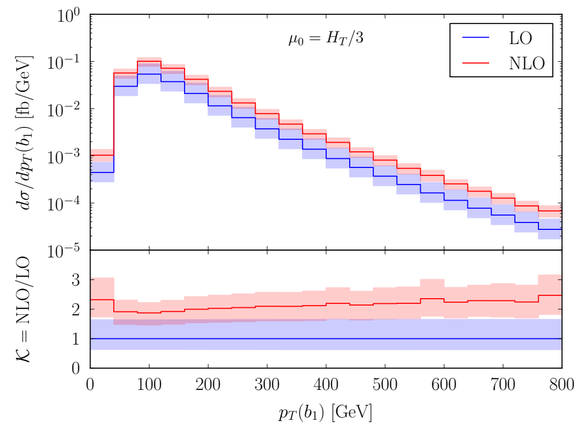
We present an independent computation of the complete NLO QCD corrections to the off-shell production of $t\bar{t}b\bar{b}$ in the di-lepton top-quark decay channel ($\boldsymbol{pp \to e^+\nu_e\mu^-\bar{\nu}_\mu b\bar{b}b\bar{b}}$) for LHC $\sqrt{s} = 13$ TeV, obtained using the **HELAC-NLO** Monte-Carlo framework. The motivations behind this study are manifold:

- Irreducible background to $pp \to t\bar{t}H \to t\bar{t}b\bar{b}$ (prime ingredient to extract information on the top-Yukawa coupling).
- multi-scale process
- first full off-shell NLO QCD calculation only last year [Denner, Lang, Pellen '20]

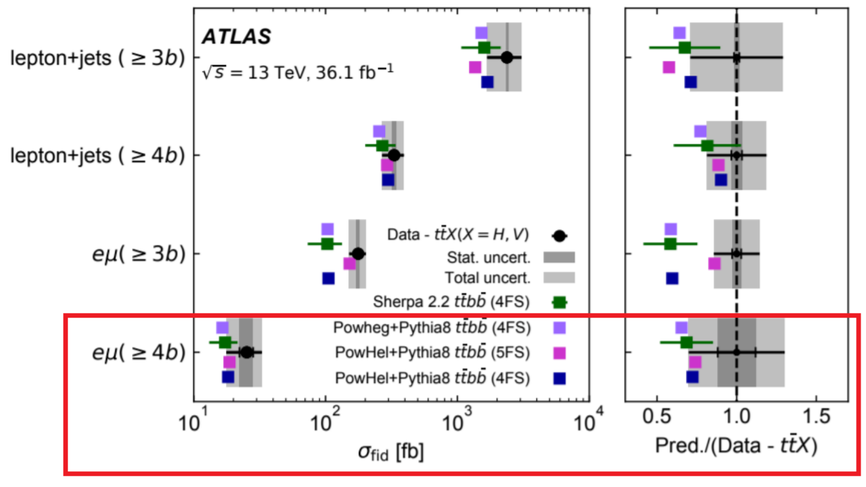
Results

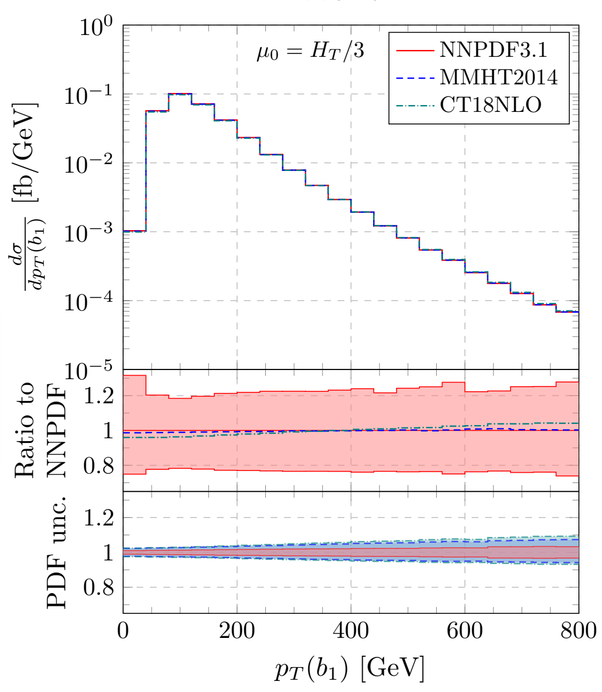
The results in the table refer to the default PDF choice NNPDF3.1 ($N_F = 5$) and the default cuts $p_T(\ell) > 20$ GeV, $|y(\ell)| < 2.5$, $p_T(b) > 25$ GeV, $|y(b)| < 2.5$, $\Delta R(bb) > 0.4$:

$\mu_R = \mu_F = \mu_0$	$\sigma^{\rm LO}$ [fb]	$\delta_{\rm scale}$	$\sigma^{\rm NLO}$ [fb]	$\delta_{\rm scale}$	$\delta_{\rm PDF}$	$\mathcal{K} = \sigma^{\rm NLO}/\sigma^{\rm LO}$
m_t	6.998	$^{+4.525\ (65\%)}_{-2.569\ (37\%)}$	13.24	$^{+2.33\ (18\%)}_{-2.89\ (22\%)}$	$^{+0.19\ (1\%)}_{-0.19\ (1\%)}$	1.89
$H_T/3$	6.813	$^{+4.338\ (64\%)}_{-2.481\ (36\%)}$	13.22	$^{+2.66\ (20\%)}_{-2.95\ (22\%)}$	$^{+0.19\ (1\%)}_{-0.19\ (1\%)}$	1.94



Theoretical predictions	$\sigma_{e\mu+4b}$ [fb]
Sherpa+OpenLoops (4FS)	17.2 ± 4.2
Powheg-Box+Pythia 8 (4FS)	16.5
PowHel+Pythia 8 (5FS)	18.7
PowHel+Pythia 8 (4FS)	18.2
Helac-Nlo (5FS)	20.0 ± 4.3
Experimental result (Atlas)	25 ± 6.5





[Atlas collaboration '18, Bevilacqua et al. '21]

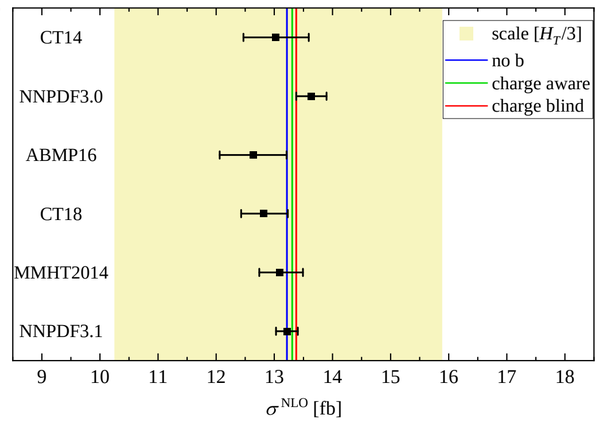
Atlas cuts: $p_T(\ell) > 25$ GeV, $|y(\ell)| < 2.5$, $p_T(b) > 25$ GeV, $|y(b)| < 2.5$, $\Delta R(bb) > 0.4$, $\Delta R(\ell b) > 0.4$

b-quark initial states and b-jet tagging

We investigated the contribution of the b-quark initial states. We defined two b-jet tagging schemes:

- **Charge aware tagging scheme** ($b\bar{b} \to g$, $bb \to b$, $\bar{b}\bar{b} \to \bar{b}$, $bg \to b\ \bar{b}g \to \bar{b}$)
- **Charge blind tagging scheme** ($b\bar{b} \to g$, $bb \to g$, $\bar{b}\bar{b} \to g$, $bg \to b\ \bar{b}g \to \bar{b}$)

b-jet tagging	$\sigma^{\rm LO}$ [fb]	$\frac{\sigma_i}{\sigma_{\text{no } b}} - 1$ [%]	$\sigma^{\rm NLO}$ [fb]	$\frac{\sigma_i}{\sigma_{\text{no } b}} - 1$ [%]
no b	6.813(3)	-	13.22(3)	-
aware	6.822(3)	0.1	13.31(3)	0.7
blind	6.828(3)	0.2	13.38(3)	1.2



Conclusion

This process is affected by **large NLO QCD corrections (89%)**. **Theoretical uncertainties** drop to **20% at NLO**. We provided two different b**-jet tagging schemes**. The contribution of the **initial state** b**-quarks is negligible**.