13th International Workshop on Top-Quark Physics

Poster session - 16th September 2020

$t\bar{t}W$ PRODUCTION: A VERY COMPLEX PROCESS

MC: Monte Carlo
ME: Matrix Element
PS: Parton Shower
QCD: Quantum Chromodynamics
EW: Electroweak

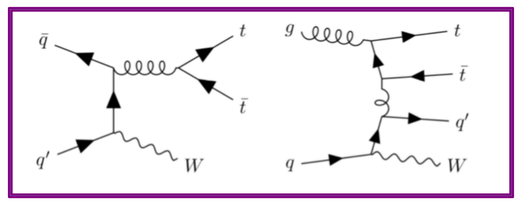
INTRODUCTION

- $t\bar{t}W$ process: rates measured at the LHC with larger yields than reference Standard Model (SM) predictions (CERN YR4); background for BSM searches and rare SM processes (such as $t\bar{t}H$ and $t\bar{t}t\bar{t}$); these motivate further study of this process.
- Event selection: $t\bar{t}$ semileptonic decay and a W boson leptonic decay, being both charged leptons of the same sign. Selection cuts to particle level jets: $p_T(j) > 25$ GeV and $|\eta| < 2.5$ except when forward jets are defined $(2.5 < |\eta| < 4.5)$.

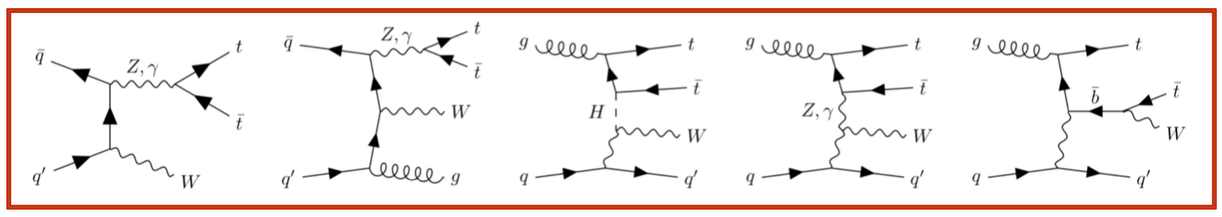
DISENTANGLEMENT OF HIGHER ORDER EFFECTS

- Higher order effects (in QCD strong coupling constant α_S and EW coupling constant α) are very important for $t\bar{t}W$ production and can significantly modify leading order predictions.
- For MadGraph5_aMC@NLO MC generator: scale variations of μ_R and μ_F scales in the ME (comparisons with of three different functional forms); multileg setups $t\bar{t}W + 0{,}1j\text{NLO} + 2j\text{LO}$ (with FxFx algorithm); and systematic parameter variations have been studied.

QCD Production



"tree-level EW" Production



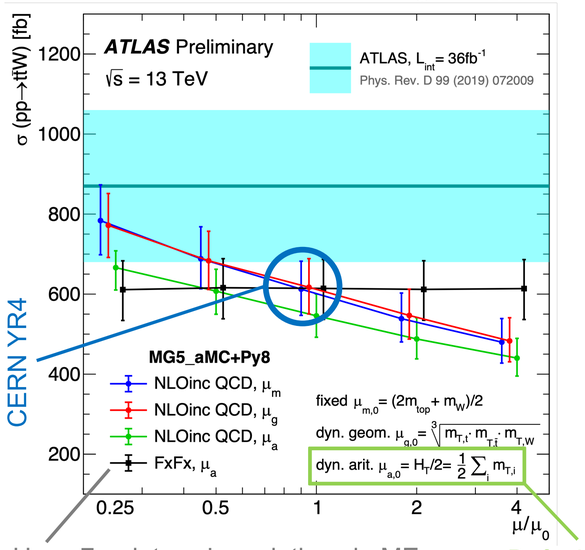
$$\sigma^{NLO}_{QCD+EW} = \mathcal{O}(\alpha_S^2\alpha) + \mathcal{O}(\alpha_S^3\alpha) + \mathcal{O}(\alpha^3) + \mathcal{O}(\alpha_S\alpha^3) + \underbrace{\mathcal{O}(\alpha_S^2\alpha)}_{\text{NLO EW}} + \underbrace{\mathcal{O}(\alpha^4)}_{\text{negligible}}$$

Feynman Diagrams and orders in α_S and α included in this poster's MC simulations

QCD PRODUCTION WITH NLO INCLUSIVE AND MULTILEG MERGED SETUPS

Cross-section dependence with three functional forms of the μ_R and μ_F scales

- Big effect on NLOinc samples: $\sigma(\mu_0/4)/\sigma(\mu_0) \sim 1.4$
- Small effect for FxFx multileg samples

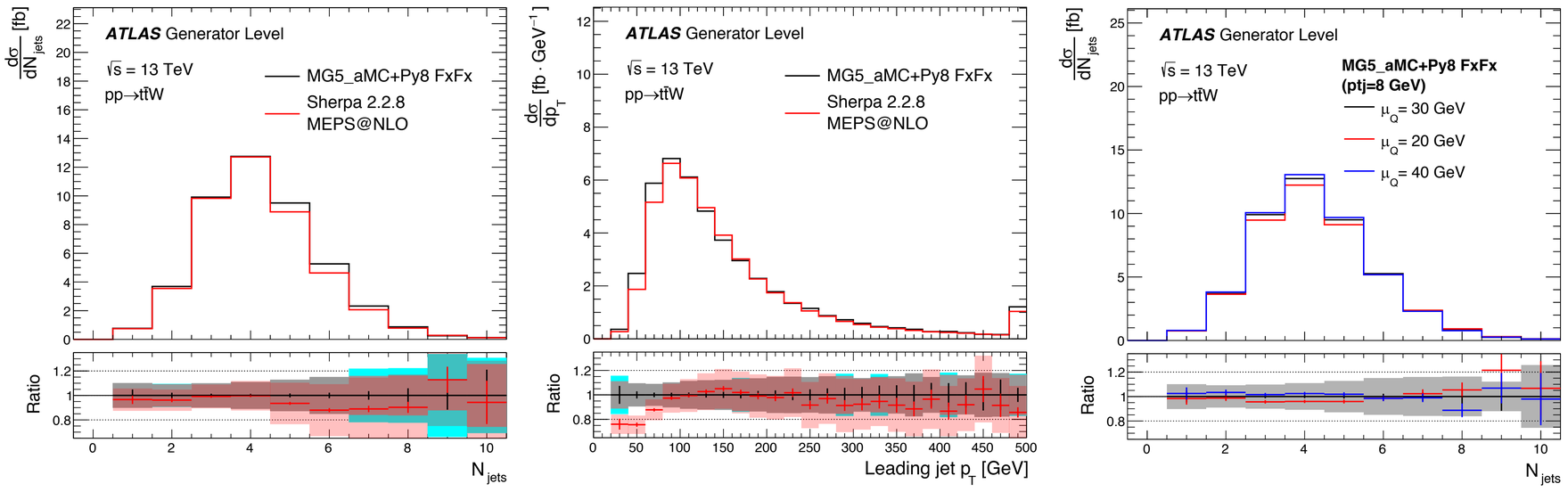


Unc.: 7-point scale variations in ME

Default scale in MG5_aMC@NLO

Comparisons between the MG5_aMC@NLO and Sherpa MC generators

- Good agreement between both generators inside unc. bands:
  - Grey: MG5_aMC@NLO 7-point scale variations in ME
  - Cyan: same scale variations propagated in a correlated way to the PS
  - Red: Sherpa scale variations in both the ME and PS



Vertical error lines show statistical uncertainty, shaded error bands as described above

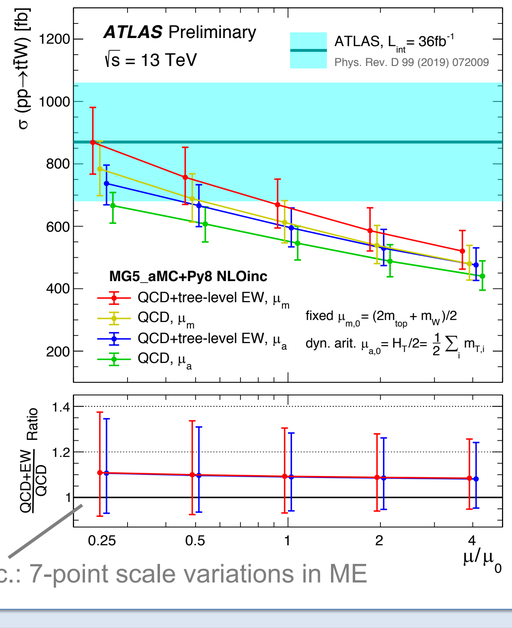
MG5_aMC@NLO FxFx samples

- Nominal: $\mu_Q = 30$ GeV, ptj = 8 GeV
- Merging scale (μ_Q) variations:
  - No significant shape effects
  - Cross-section difference of ~2%
- No effect for min. jet p_T (ptj) variations

"tree-level EW" PRODUCTION

Cross-section dependence with two functional forms of the μ_R and μ_F scales

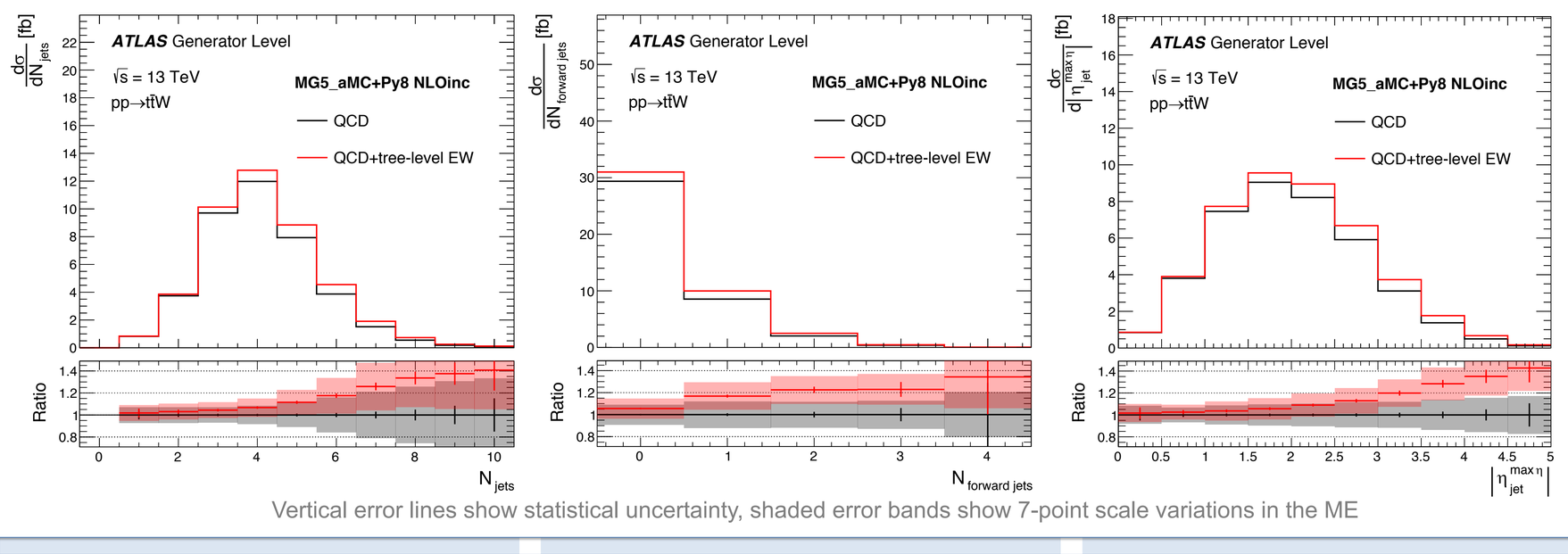
- Low values of these scales + EW contribution give better cross-section agreement with data



Unc.: 7-point scale variations in ME

Effect of the "tree-level EW" contribution for MG5_aMC@NLO for some kinematic variable distributions

- ~20% effect for events in high central and forward jet multiplicity and in high pseudo rapidity region $(2.5 < |\eta| < 4.5)$ where the extra jet in $tW \to tW$ scattering is expected
- MG5_aMC@NLO predicts a ~10% cross-section increase while Sherpa predicts a ~5%



Vertical error lines show statistical uncertainty, shaded error bands show 7-point scale variations in the ME

CONCLUSIONS

- ~11% increase in cross-section using NLO multileg compared to NLO inclusive
- Good agreement among multileg setups and small syst. parameter effects
- EW corrections boost $t\bar{t}W$ cross-section by ~10% and have significant effects in some kinematic distributions

This project is funded by LCF/BQ/PI19/11690014

Marcos Miralles López,
María Moreno Llácer,
on behalf of ATLAS Collaboration

1. ATLAS Collaboration, *Modelling of rare top quark processes at $\sqrt{s} = 13$ TeV in ATLAS*, tech. rep. ATL- PHYS-PUB-2020-024, CERN, 2020
2. J. Alwall et al., *The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations*, JHEP **07** (2014) 079, arXiv: 1405.0301 [hep-ph]
3. E. Bothmann et al., *Event Generation with Sherpa 2.2*, SciPost Phys. **7** (2019) 034, arXiv: 1905. 09127 [hep-ph]
4. C. Gütschow, J. M. Lindert and M. Schönherr, *Multi-jet merged top-pair production including electroweak corrections*, Eur. Phys. J. C **78** (2018) 317, arXiv: 1803.00950 [hep-ph]
5. R. Frederix, D. Pagani and M. Zaro, *Large NLO corrections in $t\bar{t}W^{\pm}$ and $t\bar{t}t\bar{t}$ hadroproduction from supposedly subleading EW contributions*, JHEP **02** (2018) 031, arXiv: 1711.02116 [hep-ph]