ATLAS PUB Note
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Studies of matrix element correction in $t\bar{t}$ events using MG5_aMC@NLO+Pythia8

The ATLAS Collaboration

We discuss the effect of matrix element corrections (MEC) to parton showers for $t\bar{t}$ events using the MadGraph5_aMC@NLO +Pythia 8 event generators. The studies are done for inclusive $t\bar{t}$ production as well as for a setup using the FxFx procedure with up to 2 additional jets in the matrix element. The predictions are additionally compared to the ATLAS default sample produced with the Powheg Box and showered with Pythia 8.

1 Overview

This is a collection of plots comparing Monte Carlo simulation of $t\bar{t}$ events produced with the MadGraph5_aMC@NLO 3.5.1 [1] generator and with the Powheg Box v2 [2–4]. In both cases the events are showered using Pythia 8.3 [5]. The plots shown here focus on comparing the impact of the new recommendation of using matrix element corrections (MEC) in the decay based on Ref. [6]. In case of MadGraph5_aMC@NLO two setups for $t\bar{t}$ production at NLO in QCD are considered:

- Inclusive $t\bar{t}$ production, where the renormalisation and factorisation scales were set dynamically on an event-by-event basis, namely to $\mu_r = \mu_f = \sqrt{m^2_{top} + p^2_{T,top}}$.
- Merging all of the underlying matrix elements with up to two partons at the Born level using the FxFx prescription [7] and a merging scale $\mu_Q = 70\,\text{GeV}$ and $\mu_r = \mu_f = H_T/2$. Here H_T is the sum of the transverse masses of the matrix element partons, defined as $\sum_i \sqrt{m_i^2 + p_T^2}$.

Samples are generated in a 5-flavour scheme and using the NNPDF3.0NLO PDF [8] set with $\alpha_s = 0.118$. The top quark mass value m_{top} is set to 172.5 GeV. The parton showers, hadronisation and the underlying event were modelled using Pythia 8.3 with the A14 set of tuned parameters [9] and the NNPDF2.3lo PDF set [10]. The A14 tune is modified according to the authors recommendations for the MC@NLO method and further optimised for the FxFx setup. All modified parameters are listed in Table 1, in addition an overview of the relevant settings for the different MEC settings is given in Table 2.

Table 1: Summary of the modifications on top of the A14 tune together with the default A14 values.

Settings	Value	Default / A14
SpaceShower:pTmaxMatch	1	0
TimeShower:globalRecoil	on	off
TimeShower:limitPTmaxGlobal	on	off
TimeShower:nMaxGlobalRecoil	1	2
TimeShower:globalRecoilMode	2	2
TimeShower:nMaxGlobalBranch	1	-1
TimeShower:weightGluonToQuark	1	4
Additionally for FxFx		
SpaceShower:rapidityOrder	off	on
SpaceShower:alphaSorder	2	1
SpaceShower:alphaSuseCMW	on	off
SpaceShower:alphaSvalue	0.118	0.127
TimeShower:alphaSorder	2	1
TimeShower:alphaSuseCMW	on	off
TimeShower:alphaSvalue	0.118	0.127

The observables considered are obtained from the differential cross-section measurement performed on 36.1 fb^{-1} of data collected by the ATLAS experiment and targets $t\bar{t}$ events with one leptonically decaying and one hadronically decaying top quark [11]. The measurement is performed at stable particle-level (mean lifetime > 30 ps). The fiducial phase-space is defined in the lepton+jets channel by requiring the presence of a single e or μ with $p_T > 27\,\text{GeV}$ and $|\eta| < 2.5$ and at least 4 jets with $p_T > 25\,\text{GeV}$ and

Table 2: Settings concerning the matrix element corrections for PYTHIA 8.

Settings	No MEC	MEC in decay
`SpaceShower:MEcorrections`	off	off
`TimeShower:MEcorrections`	off	on
`TimeShower:MEextended`	—	off

$|\eta| < 2.5$. At least two jets are required to be ghost-matched with b hadrons. The $t\bar{t}$ system is reconstructed by combining jets, leptons and $E_{\mathrm{T}}^{\mathrm{miss}}$ according to the the pseudo-top algorithm [12], where the W mass is employed as constraint to reconstruct the component of the neutrino momenta along the beam axis. The distributions of the simulations and data with respect to several kinematic variables are compared in Figures 1–3. The following observables are shown:

- the number of jets in the event not used to reconstruct the $t\bar{t}$ system ($N^{\mathrm{extra-jets}}$),
- the invariant mass of the $t\bar{t}$ system ($m^{t\bar{t}}$),
- the transverse momentum of the leading top-quark ($p_{\mathrm{T}}^{t,1}$).

The impact of the MEC corrections on the number of additional jets is only evident in the first bin in case of the inclusive production. Conversely, with the FxFx setup, differences are visible across the entire distribution. Significant differences in the low $m^{t\bar{t}}$ persist for both setups in a similar manner, whereas the variations in $p_{\mathrm{T}}^{t,1}$ are again different. The inclusive setup shows deviations for $p_{\mathrm{T}}^{t,1} > 200\,\mathrm{GeV}$, while the FxFx sample shows differences for $p_{\mathrm{T}}^{t,1} < 200\,\mathrm{GeV}$.

2 Plots

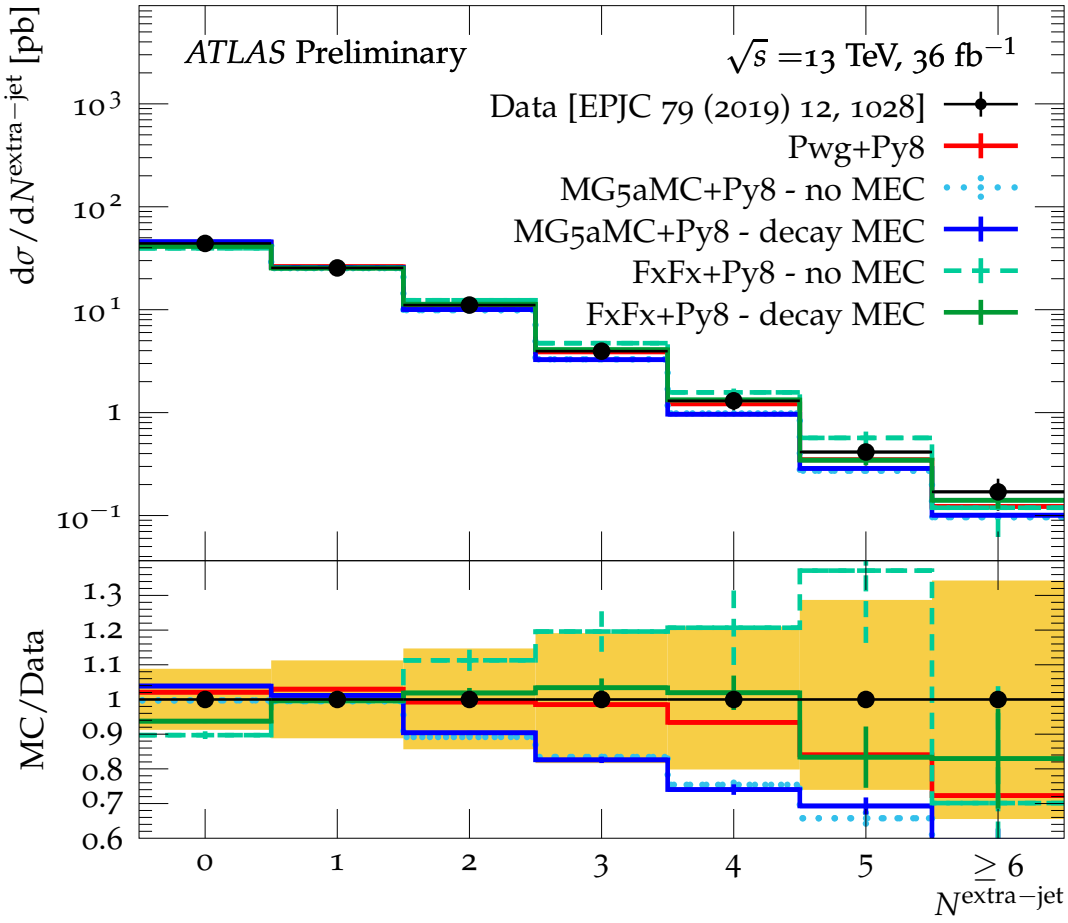

Figure 1: Comparison of the number of additional jets between the nominal ATLAS POWHEG +PYTHIA 8 MC sample and the inclusive $t\bar{t}$ production using MADGRAPH5_AMC@NLO +PYTHIA 8 and $t\bar{t}$ production with up to 2 additional jets using the FxFx approach. For the latter two samples settings with matrix element corrections in the decay switched on and off are compared as well. The data are taken from a differential cross-section measurement in the single lepton channel using ATLAS data at 13 TeV [11], and the same event selection and reconstruction is applied to each of the Monte Carlo predictions. The orange band in the ratio panel shows the statistical+systematic uncertainty on the data.

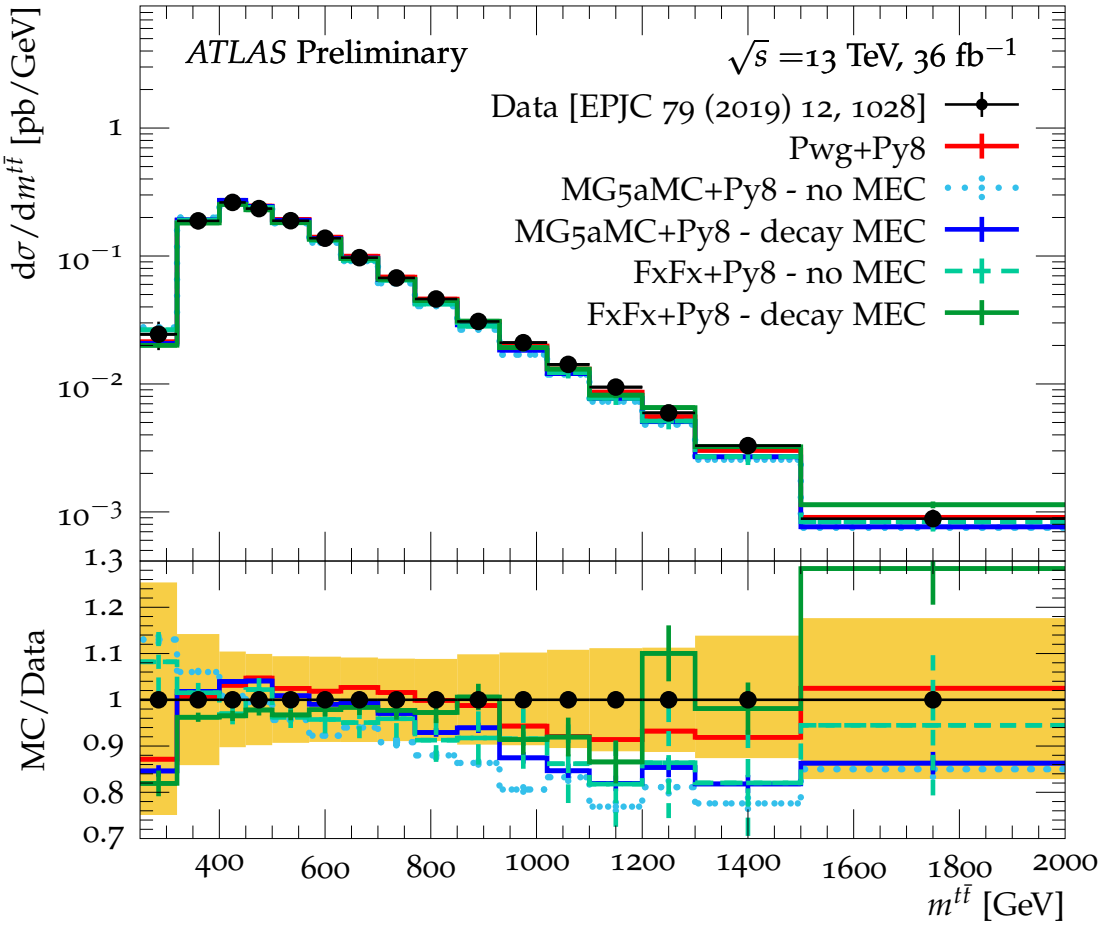

Figure 2: Comparison of $m_{t\bar{t}}$ between the nominal ATLAS Powheg +Pythia 8 MC sample and the inclusive $t\bar{t}$ production using MadGraph5_aMC@NLO +Pythia 8 and $t\bar{t}$ production with up to 2 additional jets using the FxFx approach. For the latter two samples settings with matrix element corrections in the decay switched on and off are compared as well. The data are taken from a differential cross-section measurement in the single lepton channel using ATLAS data at 13 TeV [11], and the same event selection and reconstruction is applied to each of the Monte Carlo predictions. The orange band in the ratio panel shows the statistical+systematic uncertainty on the data.

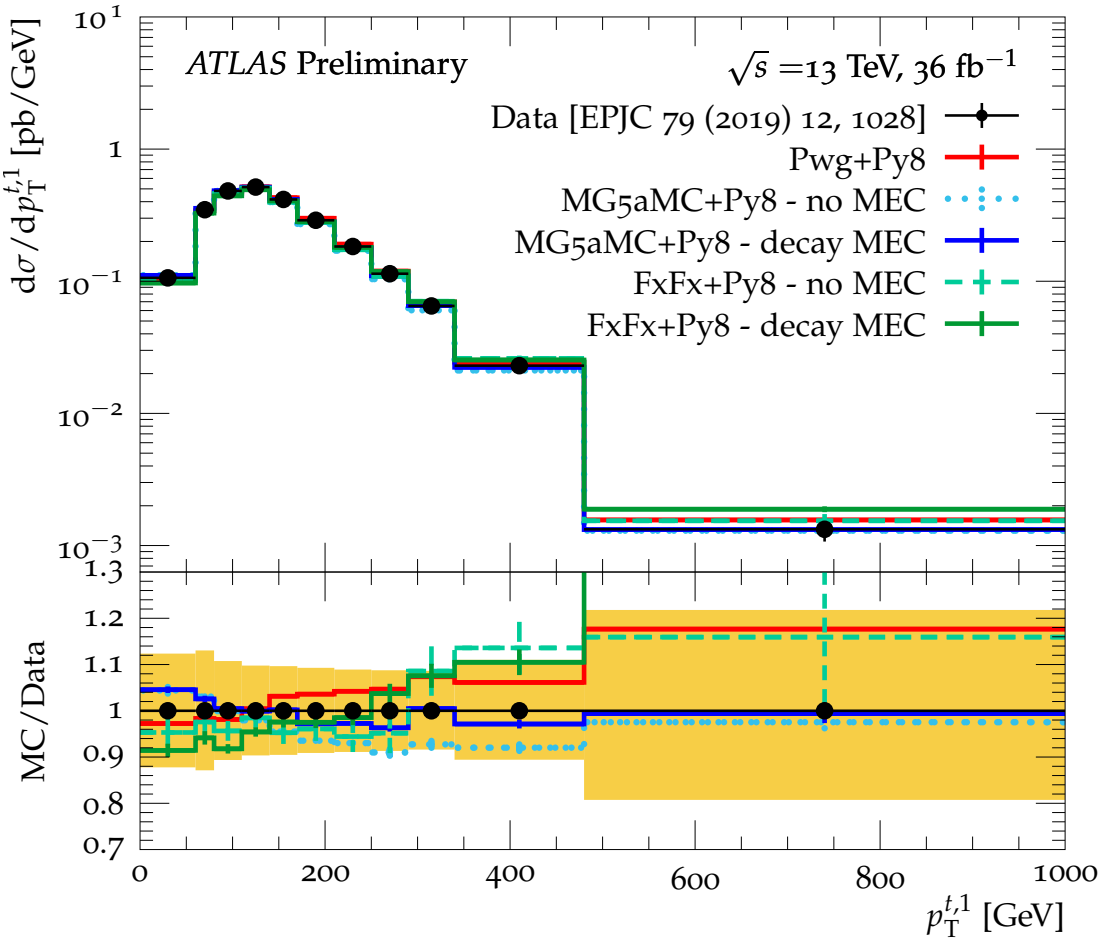

Figure 3: Comparison of the leading top-quark p_T between the nominal ATLAS POWHEG +PYTHIA 8 MC sample and the inclusive $t\bar{t}$ production using MADGRAPH5_AMC@NLO +PYTHIA 8 and $t\bar{t}$ production with up to 2 additional jets using the FxFx approach. For the latter two samples settings with matrix element corrections in the decay switched on and off are compared as well. The data are taken from a differential cross-section measurement in the single lepton channel using ATLAS data at 13 TeV [11], and the same event selection and reconstruction is applied to each of the Monte Carlo predictions. The orange band in the ratio panel shows the statistical+systematic uncertainty on the data.

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