Measurement of the jet multiplicity in dileptonic top-quark pair events at $\sqrt{s} = 8$ TeV

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Jet multiplicity distributions in top pair events are measured in pp collisions at $\sqrt{s}$ =8 TeV with the CMS detector using a dataset corresponding to 19.6 fb^{-1}. The normalized differential top-antitop quark cross section is measured in the dileptonic $t\bar{t}$ decay channels as a function of the jet multiplicity for different jet transverse momentum (p_T) thresholds. Furthermore, the distribution of the fraction of events without additional jets above a threshold is measured as functions of the additional jets p_T and of the scalar sum of the transverse momenta of all additional jets. The data are compared to several predictions from perturbative QCD calculations.

1 Introduction

A high fraction of processes that occur in pp collisions at the Large Hadron Collider involve large hadronic activity and hence high jet multiplicities. The fraction of $t\bar{t}$ events with additional jets in the final state contributes to about half of the total number of $t\bar{t}$ events. These events with high jet multiplicities provide a handle to constrain initial and final state radiation, test perturbative QCD, and to tune parton shower models. Furthermore, these events are dominant background for associated Higgs + $t\bar{t}$ production and for several searches for physics beyond the Standard Model. The measurement [1] of jet production in association with top pairs is performed using dileptonic decays of top quarks in proton-proton collisions at $\sqrt{s} = 8$ TeV using data collected with the CMS detector [2] corresponding to a luminosity of 19.6 fb^{-1}.

2 Event selection

The dileptonic decays of the top-quark pair are characterized by a subsequent decay of both W-bosons to a lepton and a neutrino. The final states containing e^+e^-, $\mu^+\mu^-$, and $e^\pm\mu^\mp$ are subject of the presented analysis. Therefore, events are selected with at least two oppositely charged isolated leptons ($p_T > 20$ GeV, $|\eta| < 2.4$) and two jets ($p_T > 30$ GeV, $|\eta| < 2.4$) of which at least one is identified as a b-jet to reduce background from Drell-Yan processes. Heavy-flavor resonance decays are suppressed by removing events with a dilepton invariant mass $M_{ll} < 20$ GeV in all channels. Contributions from Z production in the ee and $\mu\mu$ channels are further reduced by requiring M_{ll} to be outside of (91 ± 15) GeV and $\not{E}_T > 40$ GeV. A kinematic reconstruction is performed to distinguish between the two b-jets originating from the $t\bar{t}$ decay and additional jets.

3 Differential cross section as a function of jet multiplicity

The differential cross section as a function of jet multiplicity is defined as

$$\frac{d\sigma_{t\bar{t}}}{dN_j^i} = \frac{N_{data}^i - N_{bkg}^i}{\Delta_x^i \epsilon^i \mathcal{L}} \tag{1}$$

where N_j^i is the jet multiplicity, N_{data}^i is the number of selected events in jet multiplicity bin i, N_{bkg}^i is the number of estimated background events, $\mathcal{L}$ the integrated luminosity, Δ_x^i is the bin width, and ϵ^i the selection efficiency including acceptance effects. Detector effects are corrected using a regularized single-value-decomposition unfolding technique. The differential cross section is normalized to the total cross section measured in the same analysis and the results of all studied top-decay channels are combined. Systematic uncertainties are estimated for each jet multiplicity individually. The dominant contributions arise from the jet energy scale and variations of model parameters. The measurement is restricted to the visible phase space defined in the simulation: all decay products of the top-quark pair (except for the neutrinos) and all additional jets are required to fulfill the acceptance criteria $|\eta^l| < 2.4$, $p_T^l > 20$ GeV (leptons) and $|\eta^j| < 2.4$, $p_T^j > 30$ GeV (jets). A jet is rejected if it contains a leading lepton in a cone of $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$ =0.4.

In Figure 1 the normalized differential cross section for two different jet p_T thresholds is shown. The data are compared to MadGraph and POWHEG, both interfaced to PYTHIA, and MC@NLO interfaced to HERWIG. In all simulations, the top-quark mass is set to 172.5 GeV. Missing higher order QCD contributions to the matrix element calculations are estimated by variations of renormalization (μ_R) and factorization scale (μ_F). The scale ($Q^2 = \mu_R^2 = \mu_F^2$) in MADGRAPH is set to the squared sum of top mass and the p_T of all visible decay products. It is varied by a factor of four up and down. A preference of the data to higher Q^2 in MADGRAPH is observed.

4 Additional jet gap fraction

The gap fraction is defined as the fraction of events that do not contain additional jets above a certain p_T threshold. This observable provides insight into jet activity arising from gluon radiation. Additional generated jets are defined in the visible phase space except for the two highest p_T jets originating from B-hadrons.

In Figure 2 the gap fraction for different pseudorapidity ranges is shown. The predictions from MADGRAPH+PYTHIA and POWHEG+PYTHIA are similar and slightly below the measured values. MC@NLO+HERWIG predicts a higher gap fraction for central η, but agrees well with data for larger pseudorapidities.

The veto on additional jets can be applied to the scalar sum of all additional jet transverse momenta (H_T). The resulting gap fraction for the full pseudorapidity range is presented in Figure 3. The values obtained with MADGRAPH+PYTHIA and POWHEG+PYTHIA are slightly below the measurements, whereas MC@NLO+HERWIG predicts a slightly higher gap fraction. Predictions using MADGRAPH+PYTHIA with the nominal and a higher choice of Q^2 describe the data better than the ones with lower scale choice.

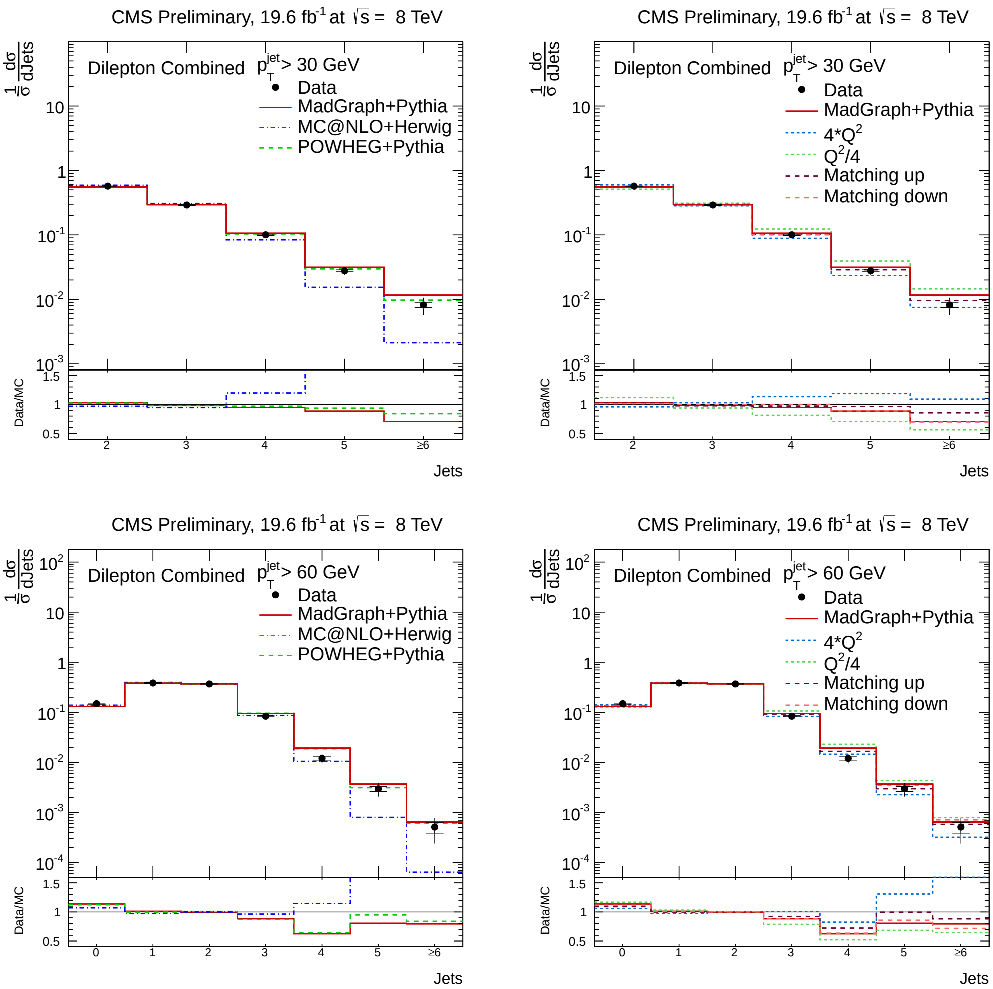

Figure 1: Measurements of the normalized differential cross section shown as a function of jet multiplicity for jet $p_T > 30$ GeV (top) and jet $p_T > 60$ GeV (bottom). The inner (outer) error bars represent statistical (total) experimental uncertainties. Left: the measurements (closed symbols) are compared to predictions using MADGRAPH+PYTHIA (solid line), POWHEG+PYTHIA (dashed line) and MC@NLO+HERWIG (dash-dotted line). Right: The measurements are compared to MADGRAPH predictions with different choices of the scale in the matrix element (Q^2) and for the parton-shower matching.

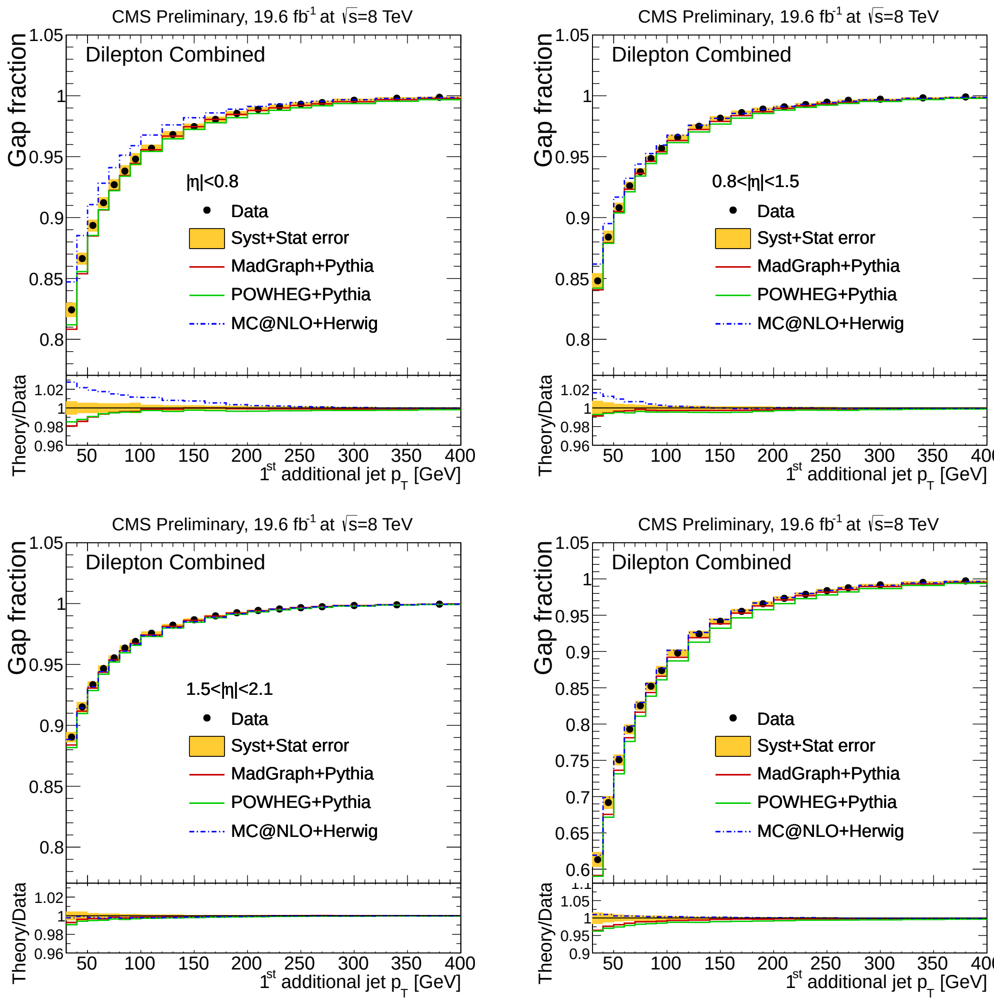

Figure 2: Gap fraction as a function of leading additional jet p_T for different η regions. The measurements (closed symbols) are presented with statistical uncertainties (vertical error bars, covered by the size of the symbols) and total uncertainties, represented by a shaded band. For comparison, predictions from MADGRAPH+PYTHIA (dark solid line), POWHEG+PYTHIA (light solid line) and MC@NLO+HERWIG (dashed line) are shown.

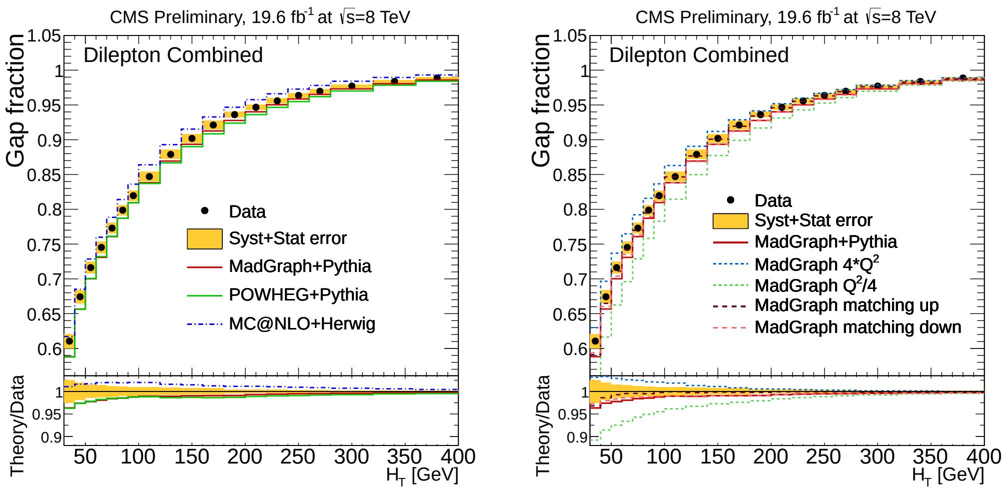

Figure 3: Gap fraction as a function of H_T. The measurements (closed symbols) are presented with statistical uncertainties (vertical error bars, covered by the size of the symbols) and total uncertainties, represented by a shaded band. For comparison, predictions from MADGRAPH+PYTHIA (dark solid line), POWHEG+PYTHIA (light solid line) and MC@NLO+HERWIG (dashed line) are shown on the left. On the right side, the measurements are compared to MADGRAPH predictions with different choices of the scale in the matrix element (Q^2) and for the parton-shower matching.

5 Summary

The normalized top-pair production cross section in pp collisions at $\sqrt{s}$ =8 TeV is measured at the CMS experiment using data based on an integrated luminosity of 19.6 fb^{-1}. The cross section is measured in the dileptonic decay channels and presented as a function of the number of jets in the event. The gap fraction is studied as a function of leading-jet transverse momentum and as a function of the scalar sum of all additional jets. The measurements are compared to QCD predictions obtained using MADGRAPH and POWHEG, interfaced to PYTHIA, and MC@NLO interfaced to HERWIG. Different scale choices for the hard scattering and the parton shower matching are studied.

References

[1] CMS Collaboration, CMS-PAS-TOP-12-041.

[2] S. Chatrchyan *et al.* [CMS Collaboration], JINST **3** (2008) S08004.