

Latest results on differential $t\bar{t}$ cross sections and analyses availability in RIVET



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On behalf of the **ATLAS** and **CMS** collaborations

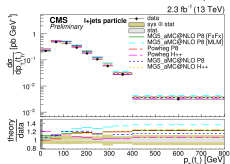
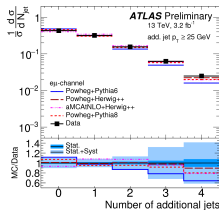
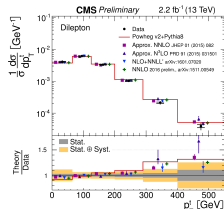


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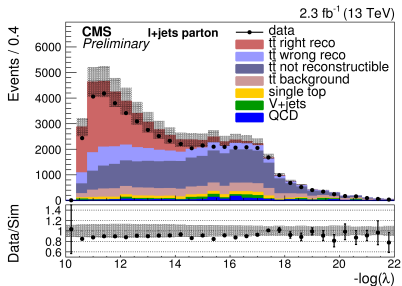
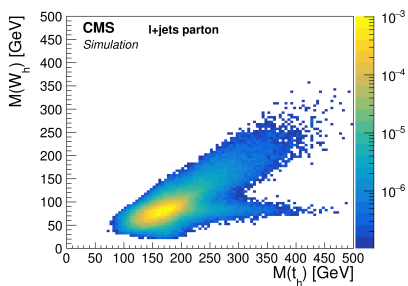
- Parton level cross sections at 13 TeV
- Reminder particle level definitions
 - ATLAS: jet multiplicities in $t\bar{t}$ events
 - CMS: differential cross sections of pseudo top quarks
- Status of rivetized top analyses in ATLAS and CMS
 - RIVET example



CMS: TOP-16-008, 2.3 fb^{-1} , 13 TeV

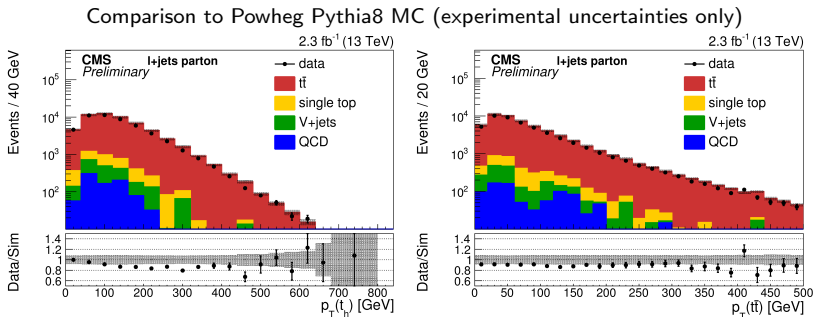
Parton level measurements of $t\bar{t}$ variables in $l+jets$ channel (e/μ).

- 1 lepton with $p_T > 30 \text{ GeV}$, $|\eta| < 2.1$.
- at least 4 jets with $p_T > 30 \text{ GeV}$, $|\eta| < 2.4$. 2 b-tagged.
- use mass constraints of M_t , M_W on leptonic side to obtain neutrino momentum (Nucl.Instrum.Meth 736 (2014), 169), and correct b-jet.
- calculate likelihood λ according to 2D mass distributions of M_t , M_W on hadronic side and compatibility of b-jet on leptonic side.
- select permutation of jets with highest $t\bar{t}$ compatibility.



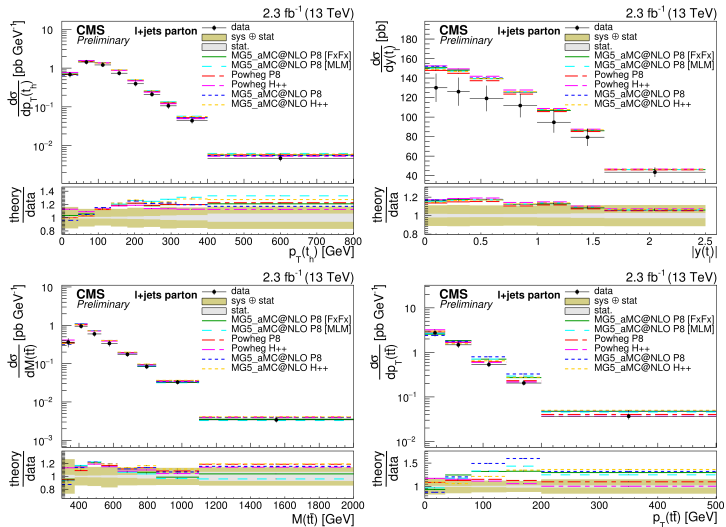
Parton matched to jet with highest p_T in $\Delta R < 0.4$

Parton level measurements of $t\bar{t}$ variables in $l+\text{jets}$ channel (e/μ).



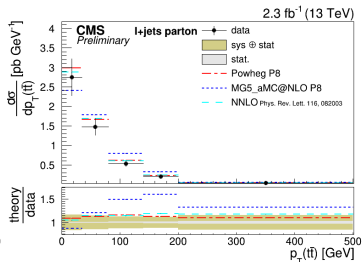
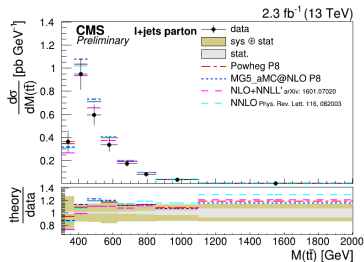
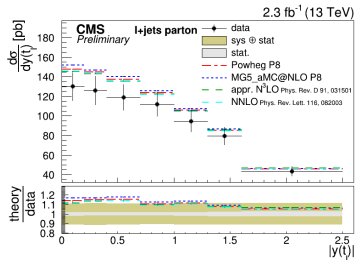
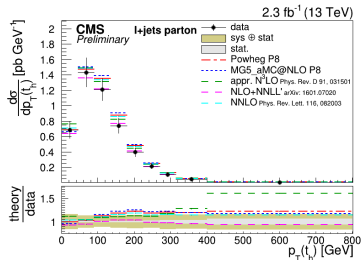
- observed number of events slightly lower than expected, but compatible within uncertainty.
- background estimations: W/DY/QCD estimated from inverted b-tagging sideband, single top from theory prediction.

Parton level measurements of $t\bar{t}$ variables in $l+j$ jets channel (e/μ).



- results unfolded to parton level full phase space.
- parton level is last copy of top quarks in MC record, i.e., NLO calculation combined with initial state radiation from parton shower.

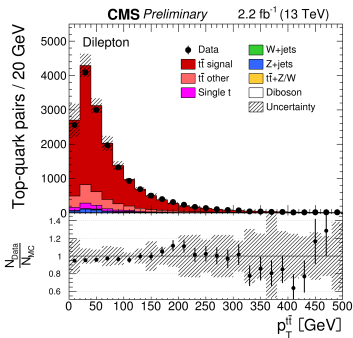
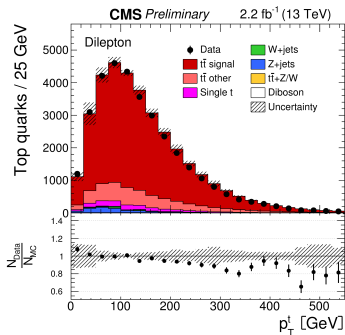
Parton level measurements of $t\bar{t}$ variables in $l+\text{jets}$ channel (e/μ).



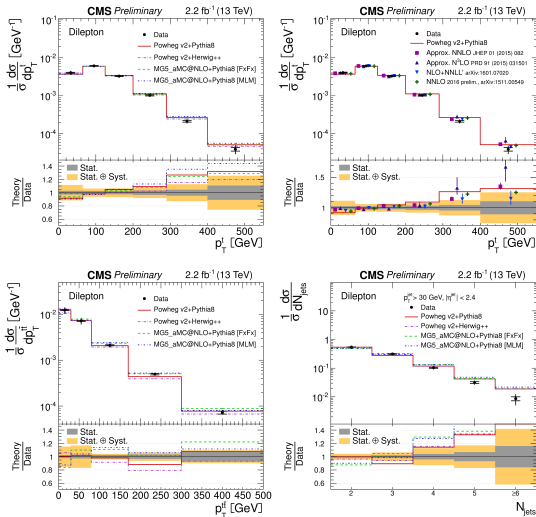
- results compared to various parton level $t\bar{t}$ theory predictions

Parton level measurements of $t\bar{t}$ variables in dilepton channel ($ee, \mu\mu, e\mu$).

- 2 oppositely charged leptons with $p_{\text{T}} > 20 \text{ GeV}$, $|\eta| < 2.4$.
- exclude $|M_{\text{ll}} - M_{\text{Z}}| < 15 \text{ GeV}$ mass window in ee and $\mu\mu$ channels (used for DY normalization).
- at least 2 jets with $p_{\text{T}} > 30 \text{ GeV}$, $|\eta| < 2.4$. 2 b-tagged.
- use constrains of M_{t} , M_{W} on both sides to obtain solution for p_z of neutrinos.
- select solution with minimum $M(t\bar{t})$.
- smear jets and leptons within their resolutions (100 times) and sum results weighted according to the expected $M(\text{lb})$.



Parton level measurements of $t\bar{t}$ variables in dilepton channel ($e\bar{e}, \mu\mu, e\mu$).



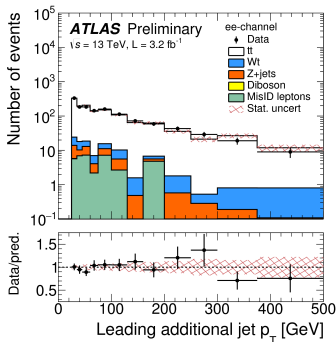
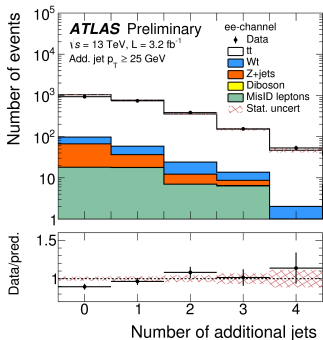
- jet multiplicities lower than expected for all MCs. Parton shower tunes Pythia8: CUETP8M1, Herwig++: EE5C.

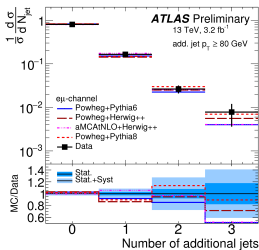
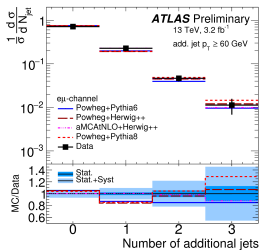
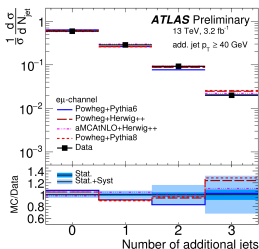
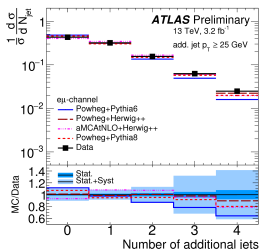
Based on long-living particles at generator level define:

- **electrons** and **muons** that do not have their origin in a decay of a hadron are selected and corrected for final state radiation. The anti-kt jet algorithm with a size parameter of 0.1 is used to cluster photons around the leptons as radiative corrections.
- all **neutrinos** that do not have their origin in a decay of a hadron are selected.
- **jets** are clustered by the anti-kt jet algorithm with a size parameter of 0.4. All stable particles excluding selected neutrinos and selected leptons together with their radiative correction are considered.
- **b jets** selected by matching jets to b hadrons, whose momenta are scaled down to a negligible value for jet clustering (ghost matching).

Parton level measurements of jet multiplicities in dilepton channel ($ee, \mu\mu, e\mu$).

- 2 oppositely charged leptons with $p_T > 25 \text{ GeV}$, $|\eta| < 2.5$.
- exclude $|M_{ll} - M_Z| < 10 \text{ GeV}$ mass window in ee and $\mu\mu$ channels (used for DY background normalization).
- jets with $p_T > 25 \text{ GeV}$, $|\eta| < 2.5$. 2 b-tagged jets.
- assign 2 b jets with highest p_T to $t\bar{t}$ system and look at additional jets.





- results unfolded to fiducial phase space.
- Pythia8 tune A14, Pythia6 tune Perugia2012, good data to MC agreement.

Particle level measurements of $t\bar{t}$ variables in $l+jets$ channel (e/μ).

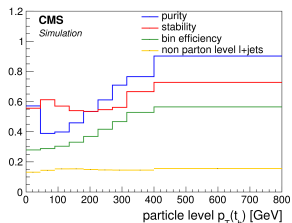
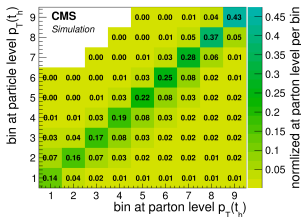
Construction of top quark proxies ($l+jets$)

Events with exactly one electron or muon with $p_T > 30 \text{ GeV}$ and $|\eta| < 2.5$ are selected

Sum momenta of all selected neutrinos p_N and find the permutation of jets that minimizes:

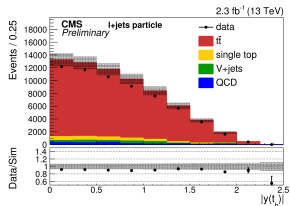
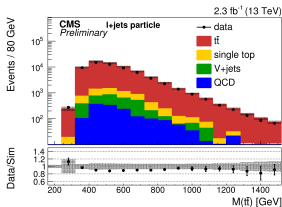
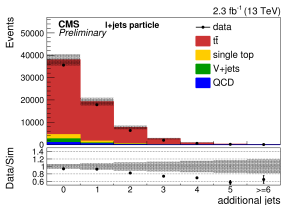
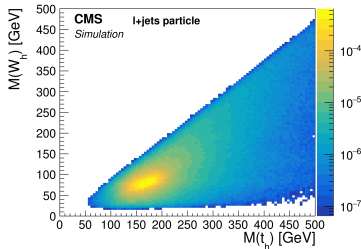
$$K^2 = (M(p_N + p_\ell + p_{b_1}) - m_t)^2 + (M(p_{j_1} + p_{j_2}) - m_W)^2 + (M(p_{j_1} + p_{j_2} + p_{b_2}) - m_t)^2$$

All jets with $p_T > 25 \text{ GeV}$ and $|\eta| < 2.5$ are considered. At least two b jets and a total number of at least four jets are required. If there are more than 2 b jets, we allow b jets as decay product of the W boson.

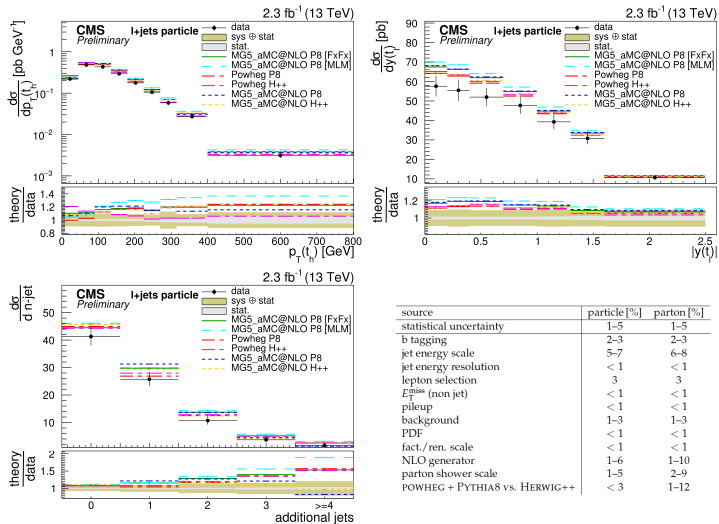


purity: fraction of diagonal element in particle level bin (row), stability: diagonal element in parton level bin (column).

- object and event selection as same as for parton level measurement.
- reconstruction based on new probability distributions of M_t , M_W



Particle level measurements of $t\bar{t}$ variables in $l+\text{jets}$ channel (e/μ).



- reduced systematic uncertainties from theory based extrapolations: parton shower (scale variation) and Herwig++/Pythia8 comparison.
- overall data-MC agreement is reasonable. Jet multiplicity not well modeled.

ATLAS

- Measurement of $t\bar{t}$ production with a veto on additional central jet activity in pp collisions at 7 TeV using the ATLAS detector, Eur.Phys.J. C72 (2012), 2043
- Measurement of jet shapes in $t\bar{t}$ events at 7 TeV using the ATLAS detector, Eur.Phys.J. C73 (2013) no.12, 2676
- Measurement of the top-anti-top production cross-section as a function of jet multiplicity and jet transverse momentum produced in 7 TeV proton-proton collisions with the ATLAS detector, JHEP01(2015)020
- Differential top-antitop cross-section measurements as a function of observables constructed from final-state particles using pp collisions 7 TeV in the ATLAS detector, JHEP 06 (2015), 100
- Measurement of colour flow with the jet pull angle in $t\bar{t}$ events using the ATLAS detector at 8 TeV, Phys. Let. B(2015), 475
- Measurement of the differential cross-section of highly boosted top quarks as a function of their transverse momentum in 8 TeV proton-proton collisions using the ATLAS detector, Phys. Rev. D93 (2016), 032009
- **Measurements of fiducial cross-sections for $t\bar{t}$ production with one or two additional b-jets in pp collisions at 8 TeV using the ATLAS detector, Eur. Phys. J. C (2016), 76:11**

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopRivetAnalyses>

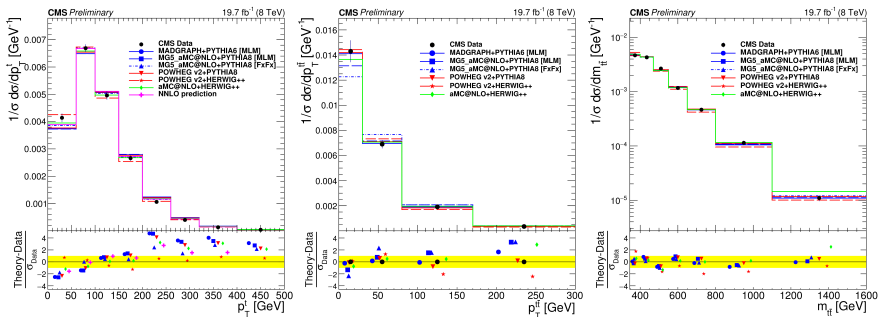
CMS

- Measurement of the differential cross section for top quark pair production in pp collisions at 8 TeV, Eur. Phys. J. C75 (2015), 542
- Measurement of $t\bar{t}$ production with additional jet activity, including b quark jets, in the dilepton decay channel using pp collisions at \sqrt{s} 8 TeV, arXiv:1510.03072 accepted by EPJC
- **Measurement of the integrated and differential $t\bar{t}$ production cross sections for high- p_T top quarks in pp collisions at 8 TeV, arXiv:1605.00116 submitted to Phys. Rev. D.**

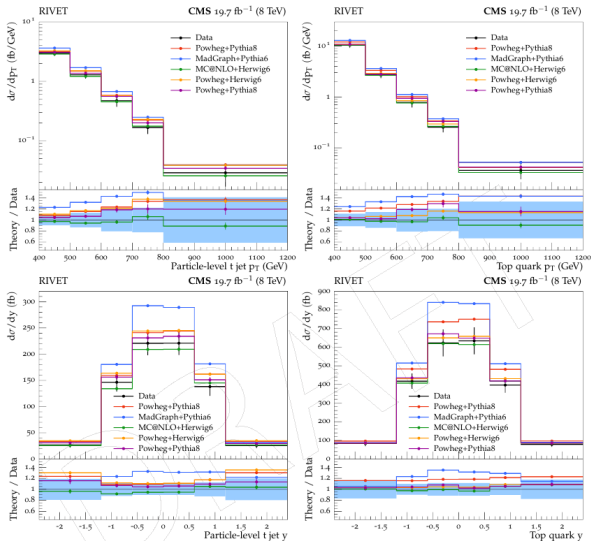
CMS: TOP-15-011, 19.7 fb^{-1} , 8 TeV

Comparison of 8 TeV differential measurements to new NLO MCs.

- Since TOP-12-028 was published as parton level result, corrections to particle level using the original MC are provided.
- Now every full event simulation can be compared to the data.



Measurement of differential $t\bar{t}$ cross sections for high- p_T top quarks



Differential cross sections

- measurements of differential cross sections at 13 TeV are available with full 2015 dataset.
- results are presented at parton and particle level.
- reasonable agreements with theory calculations in all distributions.
- jet multiplicities better described in ATLAS measurement (effect of different MC tunes?)

RIVET

- more analyses available in RIVET.
- has proven to be very useful to test new MC predictions.
- is also used for MC tuning (see talk on MC modeling by Javier)

Backup