

Run 2 Top Results



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On behalf of the ATLAS and CMS collaborations

University of Rochester

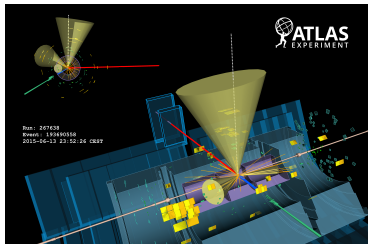
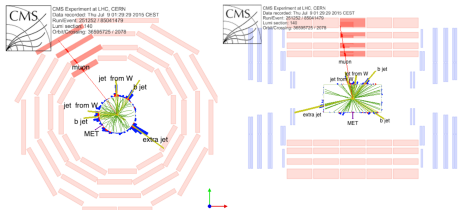


LHC TOP WG meeting
CERN

18.11.2015

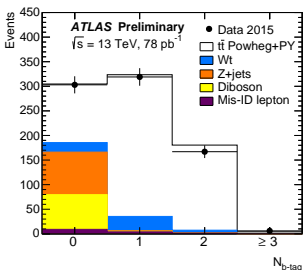
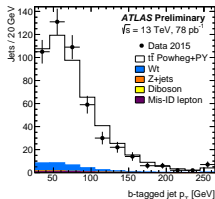
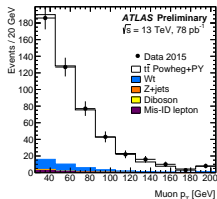
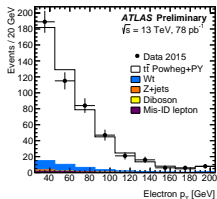
ATLAS and CMS presented first 13 TeV results with luminosities of 40-80 pb⁻¹:

- good measurements of inclusive $t\bar{t}$ cross section in various channels.
- first look at differential distributions.
- looking for single top (t-channel).



ATLAS: ATLAS-CONF-2015-033, 78 pb⁻¹, 13 TeV

Using $e\mu$ events with b-tagged jets: $\sigma_{t\bar{t}} = 829 \pm 50 \pm 56 \pm 83$ pb
 -select events with oppositely charged $e\mu$ pair.



- Define two categories: 1 and 2 b-tagged jets

$$N_1 = L\sigma_{t\bar{t}}\epsilon_{e\mu}2\epsilon_b(1 - C_b\epsilon_b) + N_1^{\text{bkg}}$$

$$N_2 = L\sigma_{t\bar{t}}\epsilon_{e\mu}C_b\epsilon_b^2 + N_2^{\text{bkg}}$$

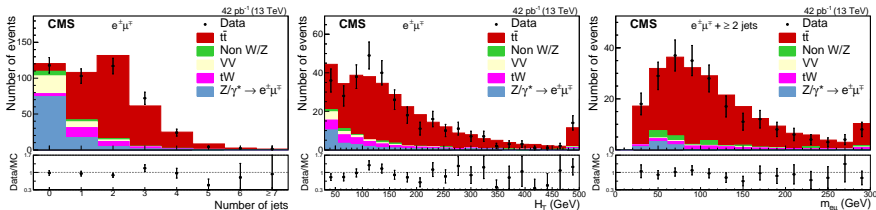
Solve for ϵ_b and $\sigma_{t\bar{t}}$.

- $\epsilon_{e\mu}$ and $C_b = 1.005$ (correlation) from simulation.
- single top, Z+jet, diboson bkg from simulation
- mis-identified leptons estimated using same sign events.

Main uncertainties: hadronization 4.5%, electron identification 4.0%.

Using $e\mu$ events: $\sigma_{t\bar{t}} = 769 \pm 60 \pm 55 \pm 92 \text{ pb}$

- select events with oppositely charged $e\mu$ pair $p_T > 20 \text{ GeV}$, $m_{e\mu} > 20 \text{ GeV}$.
- at least 2 jets $p_T > 30 \text{ GeV}$ (no b-tagging required).



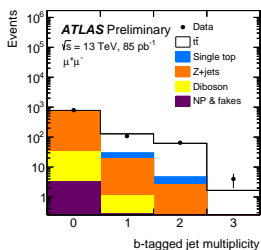
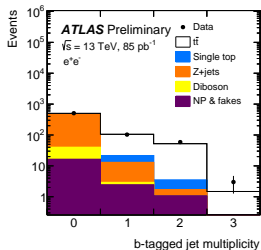
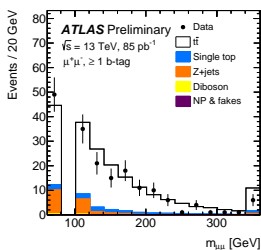
Background estimation:

- DY normalized to e^+e^- and $\mu^+\mu^-$ yield at Z-peak.
- non-prompt/fakes: same sign selection extrapolated using simulation.

Main uncertainties: trigger efficiency 4.4%, lepton efficiency 3.4%, (hadronization 1.8%).

ATLAS: ATLAS-CONF-2015-049, 85 pb⁻¹, 13 TeV

Using $\mu^+\mu^-$ and e^+e^- events with b-tagged jets: $\sigma_{t\bar{t}} = 749 \pm 57 \pm 79 \pm 74$ pb
 -leptons: $p_T > 30$ GeV, $60 < m_{ll} < 81$ GeV or $m_{ll} > 101$ GeV



- Define two categories: 1 and 2 b-tagged jets

$$N_1 = L\sigma_{t\bar{t}}\epsilon_{ll}2\epsilon_b^{ll}(1 - C_b^{ll}\epsilon_b) + N_1^{\text{bkg},ll}$$

$$N_2 = L\sigma_{t\bar{t}}\epsilon_{ll}C_b^{ll}\epsilon_b^{ll2} + N_2^{\text{bkg},ll}$$

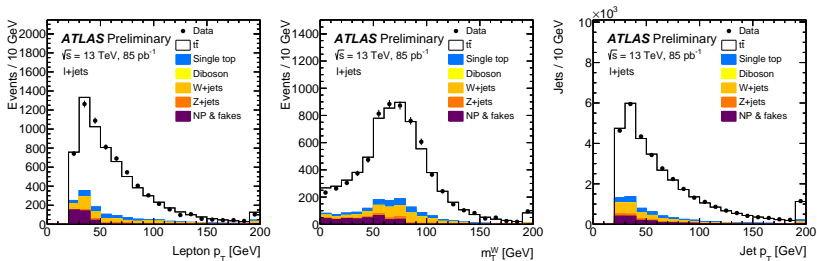
Solve for ϵ_b and $\sigma_{t\bar{t}}$, ll: $\mu\mu$ or ee , ϵ_{ll} and C_b^{ll} from simulation.

- single top, diboson bkg from simulation
- Z+jet normalized using event yield in veto region (after small background subtraction).
- mis-identified leptons estimated using same sign events.

Main uncertainties: hadronization 7.5%, PDF 3.7%, electron identification 3.6%.

Using $\mu + jet$ and $e + jet$ events with b-tagged jets: $\sigma_{t\bar{t}} = 817 \pm 13 \pm 103 \pm 88$ pb

- exactly 1 lepton: $p_T > 30$ GeV
- at least 4 jets, at least 1 b-tagged
- muon channel: $E_T^{\text{miss}} + m_T^W > 60$ GeV, electron channel: $E_T^{\text{miss}} > 40$ GeV or $m_T^W > 50$ GeV



W+jets: background estimation:

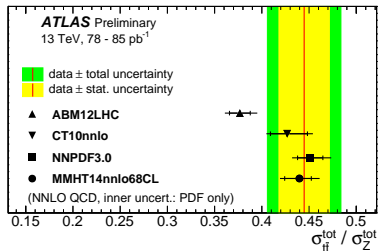
- use W charge asymmetry: $N_{>1b} = n_{>1b} \frac{(N_{0b}^+ - \text{bkg}_{0b}^+) - (N_{0b}^- - \text{bkg}_{0b}^-)}{n_{0b}^+ - n_{0b}^-}$
- Data: N, MC: n, bkg

Main uncertainties: jet energy scale 9%, b-tagging 4.2%, hadronization 4.1%.

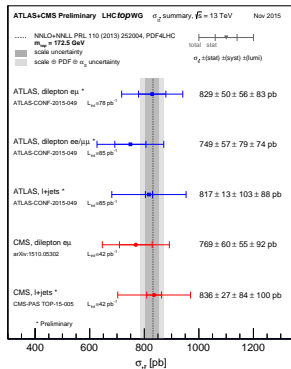
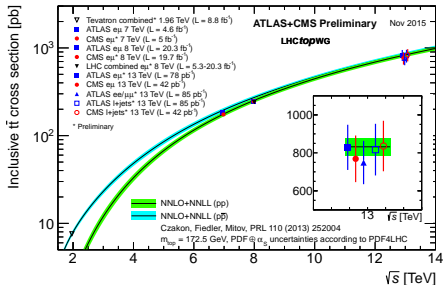
Ratio of $t\bar{t}$ and Z cross sections

- use $e\mu$ channel $t\bar{t}$ measurement.
- $Z \rightarrow e^+e^-$ and $Z \rightarrow \mu^+\mu^-$, $66 < m_{ll} < 116$ GeV
- same selection of leptons in both analyses.

$$R_{t\bar{t}/Z} = 0.445 \pm 0.027 \text{ (stat)} \pm 0.028 \text{ (syst)}$$



- uncertainty in luminosity (9%) cancels.
- uncertainties in lepton efficiencies partially cancel (due to different kinematics).
- measurement constrains ratio of gluon and sea-quarks PDFs.



CMS:

channel: $\sigma_{t\bar{t}} \pm (\text{stat}) \pm (\text{syst}) \pm (\text{lumi})$
 $e\mu$: $769 \pm 60 \pm 55 \pm 92 \text{ pb}$
 $e/\mu + jets^*$: $836 \pm 27 \pm 88 \pm 100 \text{ pb}$

ATLAS:

channel: $\sigma_{t\bar{t}} \pm (\text{stat}) \pm (\text{syst}) \pm (\text{lumi})$
 $e\mu$: $829 \pm 50 \pm 56 \pm 83 \text{ pb}$
 $ee/\mu\mu$: $749 \pm 57 \pm 79 \pm 74 \text{ pb}$
 $e/\mu + jets$: $817 \pm 13 \pm 103 \pm 88 \text{ pb}$

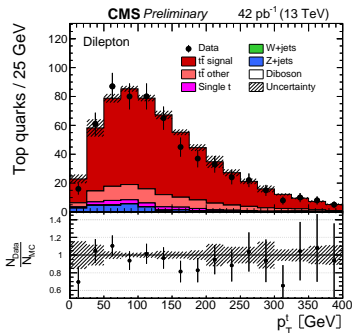
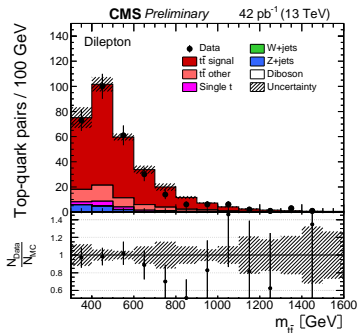
SM expectation: $\sigma_{t\bar{t}}^{\text{NNLO+NNLL}} = 832_{-29}^{+20} (\text{scale})_{-35}^{+35} (\text{PDF}/\alpha_s) \text{ pb}$

*analysis shown later

CMS: CMS-PAS-TOP-15-010, 42 pb^{-1} , 13 TeV

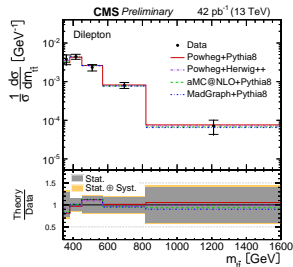
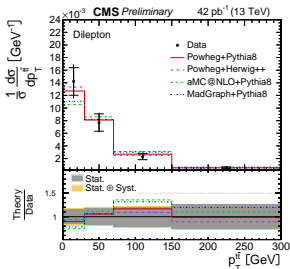
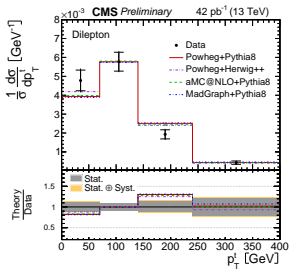
Parton level measurements of $t\bar{t}$ variables in dilepton channels ($ee, e\mu, \mu\mu$).

- two leptons with $p_T > 20 \text{ GeV}$, $|\eta| < 2.4$. Drell-Yan mass window excluded.
- at least two jets $p_T > 30 \text{ GeV}$, $|\eta| < 2.4$. At least 1 b-tagged.
- algebraic reconstruction with smearing using p_T balance, top and W mass constraints.
- about 300 observed events; 80% signal.



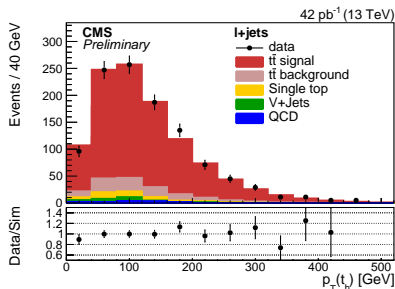
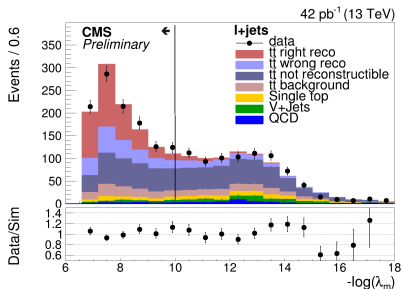
Parton level measurements of $t\bar{t}$ variables in dilepton channels ($ee, e\mu, \mu\mu$).

- unfolded and extrapolated to full phase space.
- uncertainty dominated by statistics.
- new MC setup: MG5_aMC@NLO (+0,1,2 jets at NLO matched to PS), parton shower with Pythia8 or Herwig++, NNPDF 3.0 NLO.



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

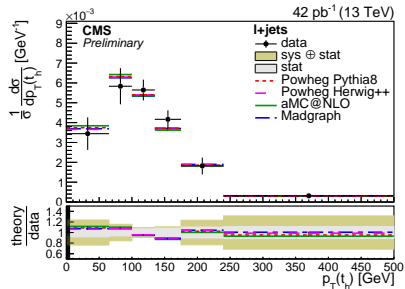
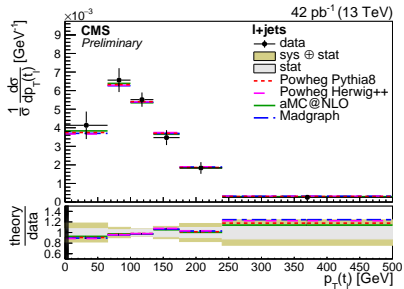
- 1 lepton with $p_T > 30$ GeV, $|\eta| < 2.1$.
- at least 4 jets with $p_T > 25$ GeV, $|\eta| < 2.4$. At least 1 b-tagged.
- use mass constraints of M_t , M_W on leptonic side to obtain neutrino momentum (Nucl.Instrum.Meth 736 (2014), 169), and correct b-jet.
- calculate probability λ_m according to 2D mass distributions of M_t , M_W on hadronic side to obtain best permutation of jets.
- cut $-\log(\lambda_m) < 10$: 1100 event 83% signal.



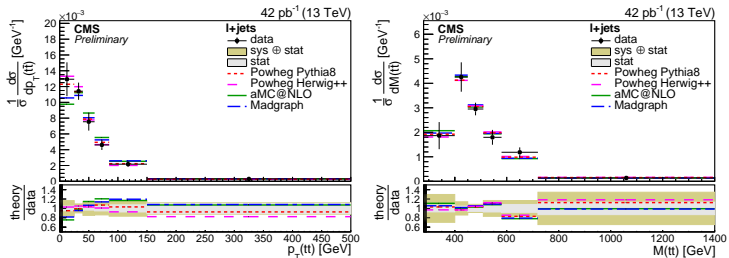
Parton matched to jet with highest p_T in $\Delta R < 0.4$

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

- unfolded and extrapolated to full phase space.
- uncertainty dominated by statistics and parton shower/hadronization (Pythia8 vs. Herwig++).
- not yet able to test $p_T(t)$ modelling with NLO+PS and Run 2 data.



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



- $p_T(t\bar{t})$ better described by Powheg than by MG5_aMC@NLO or Madgraph (+ 0,1,2,3 jets LO).

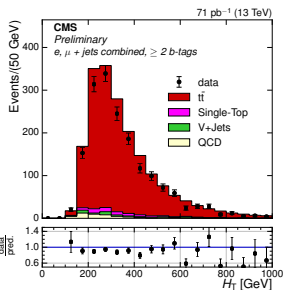
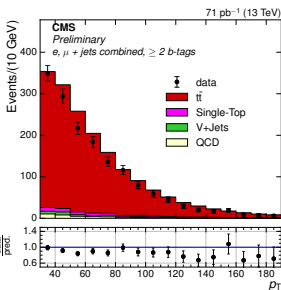
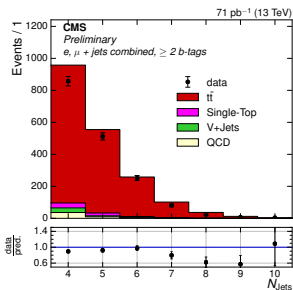
Inclusive cross section

Use this selection for inclusive cross section measurement.

- single top, DY, W, QCD background are about 7%. Subtracted according to MC prediction with 50% uncertainty each.
- uncertainty dominated by b-tagging 5.1%, theory (PDF 4.7%, hadronization 3.4%...), and jet energy scale/resolution 3.5%.

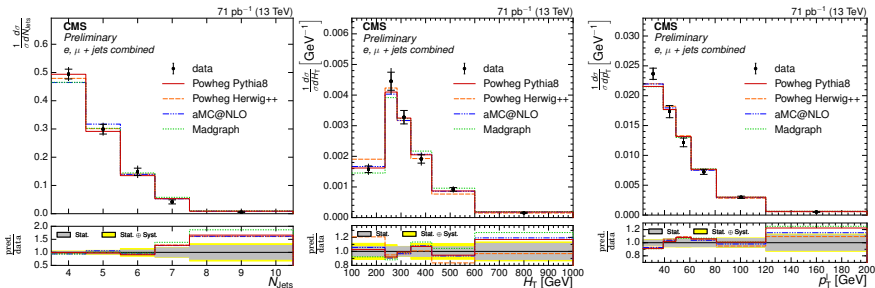
Event variables in fiducial phase space, l+jets channel (e/μ).

- exactly 1 lepton $|\eta| < 2.1$ $p_T(e) > 30$ GeV $p_T(\mu) > 23$ GeV.
- at least 4 jets with $p_T > 25$ GeV, $|\eta| < 2.4$
- at least 2 b-tagged.
- 1700 events 84% signal.



Fiducial phase space at particle level:

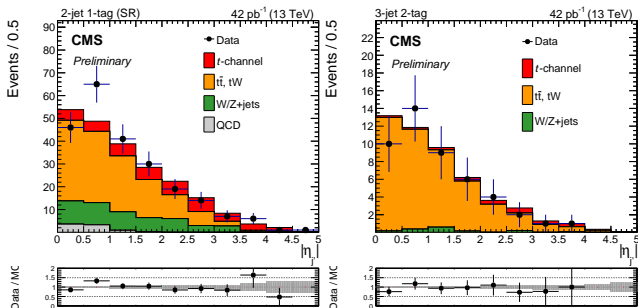
- exactly 1 lepton $|\eta| < 2.1$, $p_T > 23$ GeV (including radiation in 0.1 cone).
- at least 4 jets with $p_T > 25$ GeV, $|\eta| < 2.4$
- at least 2 b-jets (with b-hadron, ghost-matching).
- $E_T^{\text{miss}} > 23$ GeV, $m_T^W > 30$ GeV



CMS: CMS-PAS-TOP-15-004, 42 pb^{-1} , 13 TeV

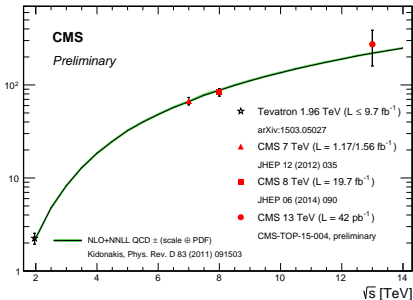
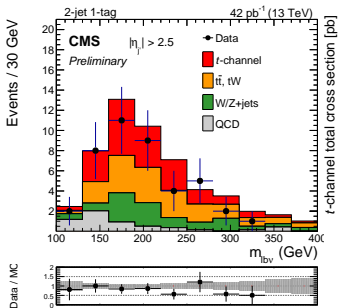
t-channel single top with one μ final-state

- exactly one μ $p_T > 22 \text{ GeV}$, $|\eta| < 2.1$.
- two jets $p_T > 40 \text{ GeV}$, $|\eta| < 4.7$. 1 b-tagged.
- $m_T(\nu l) > 50 \text{ GeV}$
- $130 < m_{l\nu b} < 225 \text{ GeV}$



Signal yield extracted by simultaneous fit on 2j1b and 3j2b categories:

- template: single top from MC, norm: free
- template: W/Z+jets MC (varied in $m_{l\nu b}$ sideband), norm: MC 30%
- template: $t\bar{t}$ /tW from MC, norm: MC 20%
- template: QCD shape from μ isolation sideband, norm: fit on $m_T(\nu l)$ full range.

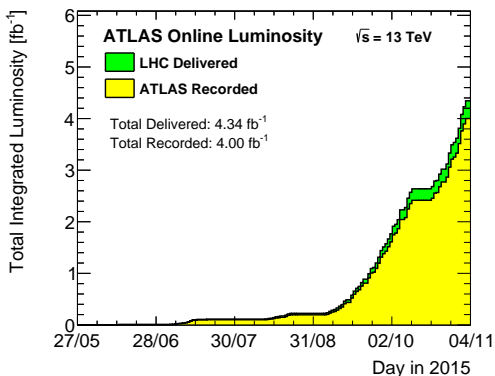


$$\sigma_{t\text{-ch}} = 274 \pm 98 \text{ (stat)} \pm 53 \text{ (syst)} \pm 98 \text{ (lumi)} \text{ pb}$$

significance of 3.5 standard deviations (2.5 expected).

SM prediction: $\sigma_{\text{NLO}} = 217_{-5}^{+7}$ (scale) ± 6 (pdf) pb

Impressive work and nice results with first $< 0.08 \text{ fb}^{-1}$ of data at 13 TeV,



but this is only the beginning ...

Backup