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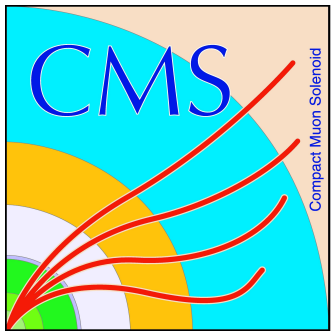

Measurements of the inclusive top quark pair production cross section in pp collisions at 7 and 8 TeV with CMS

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On behalf of the CMS Collaboration

Interuniversity Institute for High Energies - Vrije Universiteit Brussel

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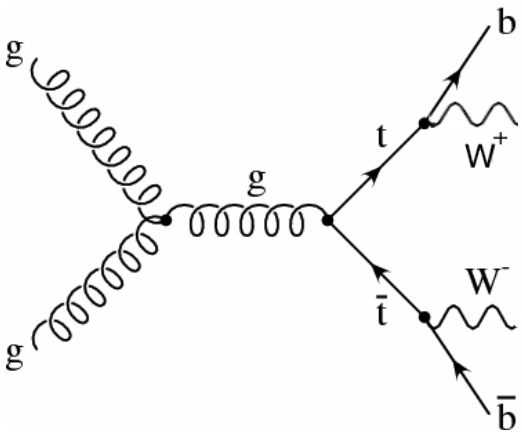
Introduction

- Top quark is the heaviest particle in the Standard Model
- The question is: does it behave like the SM predicts?
- $\sigma_{t\bar{t}}$ is a test of the Standard Model
  - Test of perturbative QCD
- Important for BSM searches
  - $t\bar{t}$ is a background to many BSM models e.g SUSY
- This presentation will show the latest results from CMS on the inclusive top quark cross section.

Top quark pair production at the LHC



Production

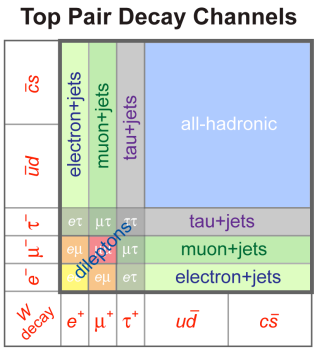
- At the LHC dominant $t\bar{t}$ production mode is through gluon fusion
- $|V_{tb}| \approx 1$
- Cross section calculations now reach NNLO+NNLL precision (Czakon et. al. arxiv:1303.6254)

$$\sigma_{t\bar{t}}^{7TeV} = 172.0pb \; {}^{+2.6}_{-3.4}(scale) \pm 2.7(PDF) \pm 1.7(\alpha_s)\%$$

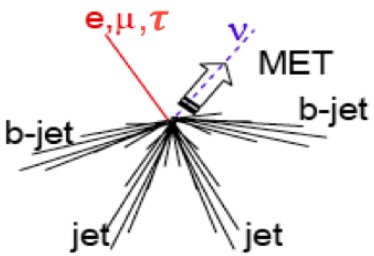
$$\sigma_{t\bar{t}}^{8TeV} = 245.8pb \; {}^{+2.5}_{-3.4}(scale) \pm 2.5(PDF) \pm 1.6(\alpha_s)\%$$

- Results on single top production: see A. Iorio's talk

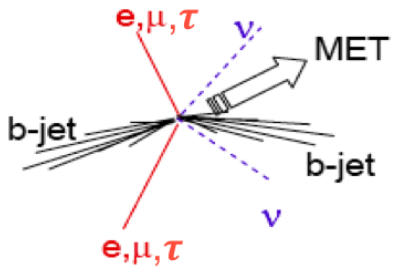
Decay



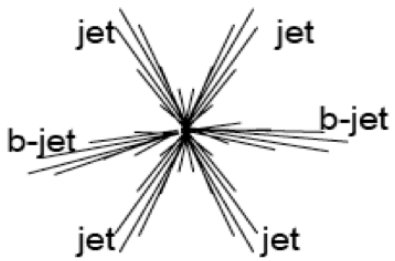
semi-leptonic



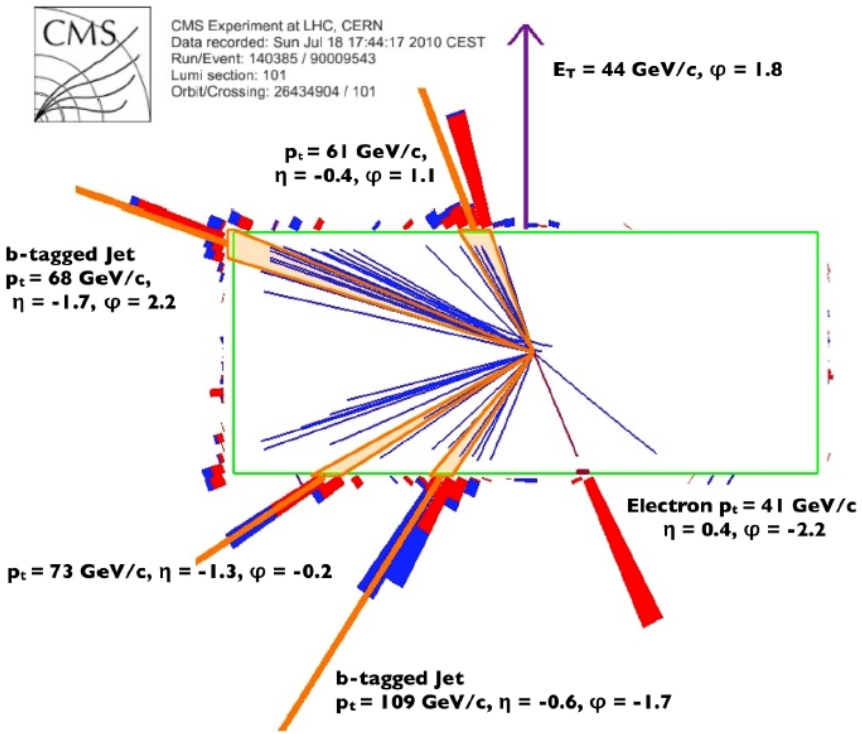
di-leptonic



hadronic



Object reconstruction

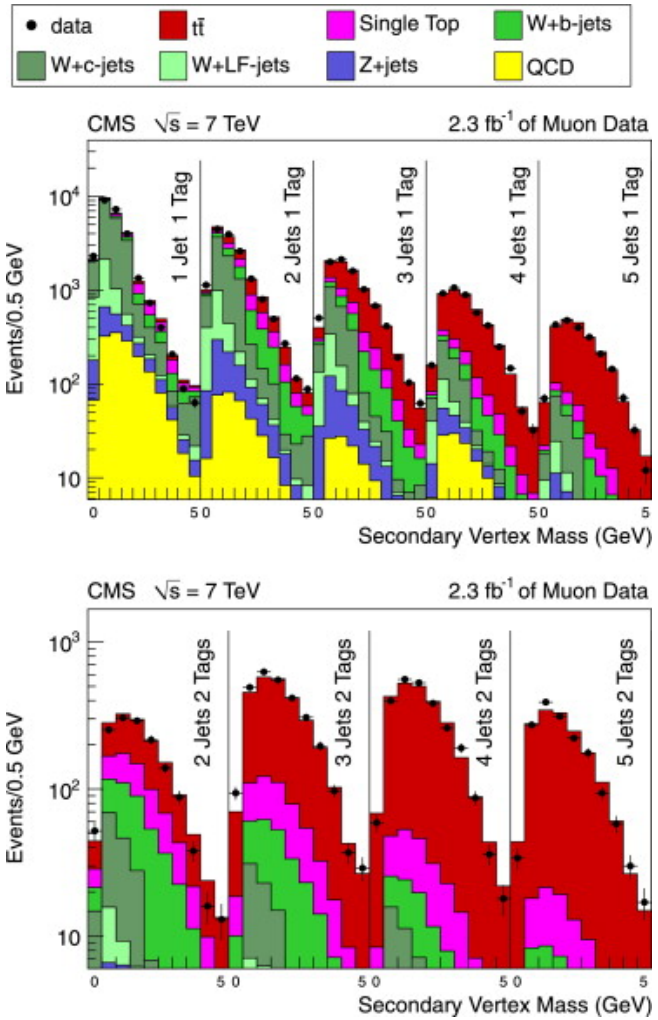


- Event is reconstructed using the ParticleFlow reconstruction
- Jets are clustered using the ak5 algorithm
- Jet energy scale corrections are applied
- $\not\!\!E_T$ is calibrated for JES
- Leptons are reconstructed using ParticleFlow and have a particle based isolation definition

Cross section in e/μ+jets channel (arXiv:1212.6682)

$$\mathcal{L} = 2.3\ (\mu)\ 2.2\ (\mathrm{e})\ fb^{-1}$$

$$\sigma_{t\bar{t}} = 158.1 \pm 2.1(stat.) \pm 10.2(syst.) \pm 3.5(lum.)pb \sim 6.9\%$$



Event selection

- Single lepton trigger (μ, e$\rightarrow\mathcal{L} \leq 0.9fb^{-1}$)
  Eletron+multijet trigger (e$\rightarrow\mathcal{L} > 0.9fb^{-1}$)
- 1 isolated lepton $p_T > 35GeV$ $|\eta|$ <2.1(2.5) for μ(e)
- $\geq$ 4 jets with $p_T > 35GeV$ $|\eta|$ <2.4, $\geq$ 1 b-tagged jet
- $\not{E}_T$ >20 GeV

Method

- Profile likelihood fit on #jets (1-4,$\geq$5), #b-tags (1,2) and secondary vertex mass
- Nuisance parameters: Jet Energy Scale (2.4%), b-tagging (2.1%) and W+Jets Q^2-scale (1.6%)
- Data-driven multijet background

Cross section in τ+jets channel (arXiv:1301.5755)

$\mathcal{L} = 3.9\ fb^{-1}$

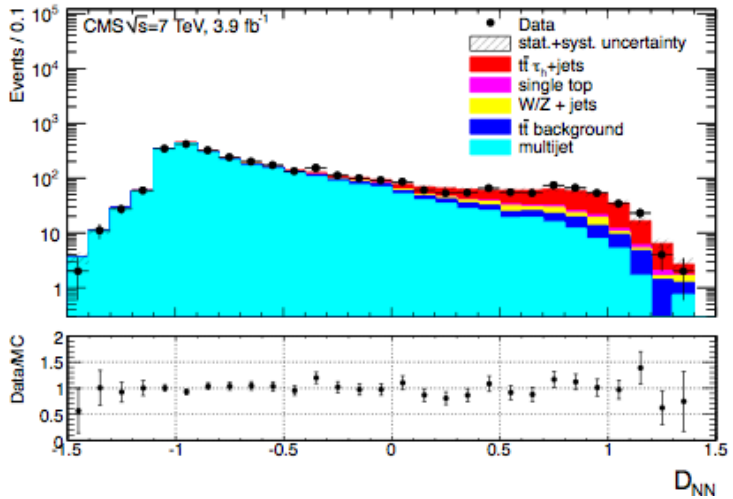
$\sigma_{t\bar{t}} = 152.0 \pm 12.0(stat.) \pm 32.0(syst.) \pm 3.0(lum.)pb \sim 22.6\%$

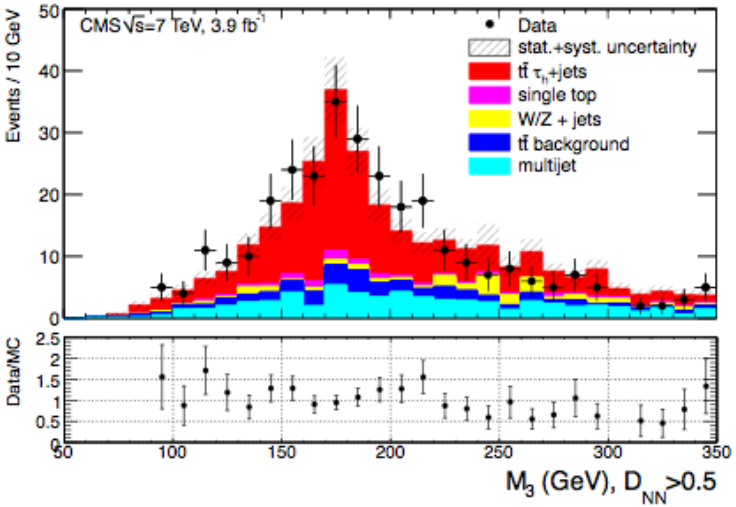
Event selection

- τ+multijets trigger, 1 isolated hadronic τ $p_T > 45GeV$ $|\eta| < 2.3$, $\not{E}_T$ >20 GeV
- $\geq$ 3 jets with $p_T > 45GeV$ $|\eta|$ <2.3, 4th jet $p_T > 20GeV$, $\geq$ 1 b-tagged jet (medium WP)

Method

- Neural network to discriminate signal from background
- $\sigma_{t\bar{t}} \rightarrow$ template fit on D_{NN}
- Data-driven Multijet background (90% of total bkg)
- Main systematics: JES (11%), trigger (7%), τ ID (9%), $\not{E}_T$ (7%)





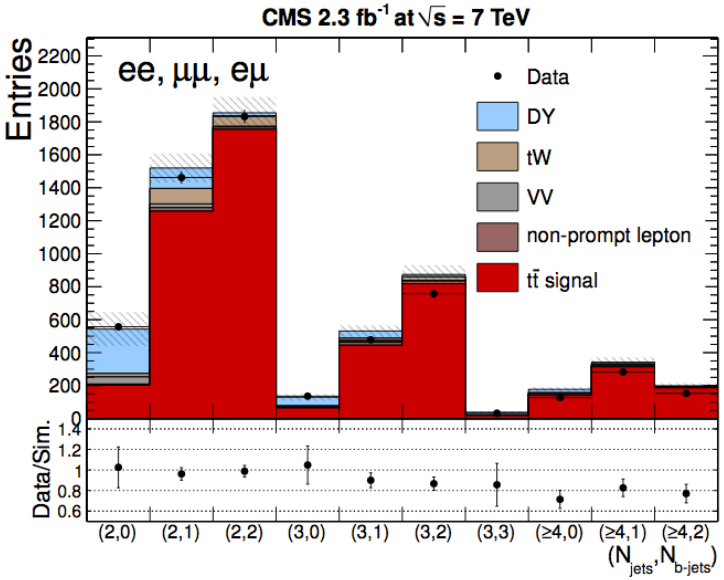
Cross section in the dilepton channel (arXiv:1208.2671)

$\mathcal{L} = 2.3\ fb^{-1}$

$\sigma_{t\bar{t}} = 161.9 \pm 2.5(stat.)^{+5.1}_{-5.0}(syst.) \pm 3.6(lum.)pb \sim ^{+4.2}_{-4.1}\%$

Event selection

- dilepton trigger, 2 isolated leptons $p_T > 20GeV$ $|\eta| < 2.1(2.5)$ for muons (electrons)
- $\not{E}_T$ >40 GeV ($\mu^+\mu^-/e^+e^-$)
- Reject $76 < M_{ll} < 106$ for $\mu^+\mu^-/e^+e^-$
- $\geq$ 2 jets with $p_T > 30GeV$ $|\eta|$ <2.5



Background estimation

- Very small background levels → **Most precise $\sigma_{t\bar{t}}$ result at $\sqrt{s}$=7TeV**
- Profile Likelihood Ratio fit on (N_{jets}, N_{bjets}) with nuisance parameters
- Data-driven estimation of DY+jets background
- Data-driven estimation from non-prompt leptons background
- Main systematics: JES (1.8%), Lepton eff (1.7%), W branching fraction (1.7%)

Cross section in dilepton decays with τ (arXiv:1203.6810)

$$\mathcal{L} = 2.0\ (\mu)\ 2.2\ (\mathrm{e})\ fb^{-1}$$

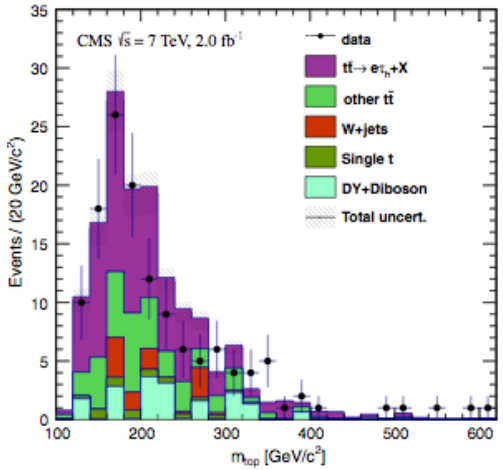
$$\sigma_{t\bar{t}} = 143.0 \pm 14.0(stat.) \pm 22(syst.) \pm 3.0(lum.)pb \sim 18.4\%$$

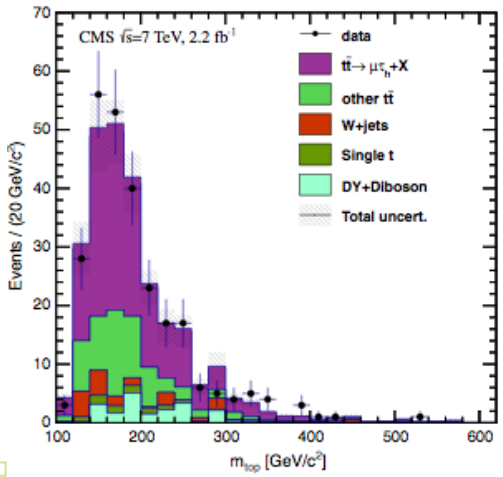
$t\bar{t} \rightarrow W^+bW^-\bar{b} \rightarrow (l\nu_l)(\tau_h\nu_\tau)b\bar{b}$ $(l = e, \mu)$

- Single muon trigger OR Electron+dijet+H_T^{miss} trigger
- 1 isolated lepton $p_T > 35(30)GeV$ $|\eta| < 2.5(2.1)$ for e(μ)
- 1 isolated τ_h $p_T > 20GeV$ $|\eta| < 2.4$
- $l^{\pm}\tau^{\mp} \rightarrow$ opposite charge sign
- $\not{E}_T$ >45(40) GeV e(μ)
- $\geq$ 2 jets with p_T >35(30) GeV e(μ), 1 jet p_T >20 GeV
- $\geq$ 1 b-tagged jet

Method

- Template fit on m_{top} (extracted with KinB method)
- Data-driven τ-fake background estimation
- Main systematics: Background estimation(10.8%), τ ID (6.3%), b-tagging (5.3%), JES (5.8%)





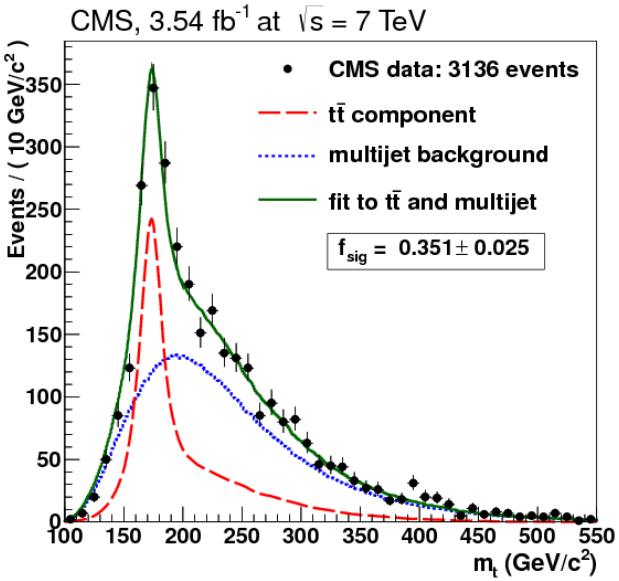
Cross section in the hadronic channel (arXiv:1302.0508)

$\mathcal{L} = 3.54\ fb^{-1}$

$\sigma_{t\bar{t}} = 139.0 \pm 10.0(stat.) \pm 26.0(syst.) \pm 3.0(lum.)pb \sim 20.2\%$

Event selection

- multijet trigger, $\geq$ 6 jets $p_T > 60/60/60/60/50/40$ GeV
- $\geq$ 2 tight b-tagged jets



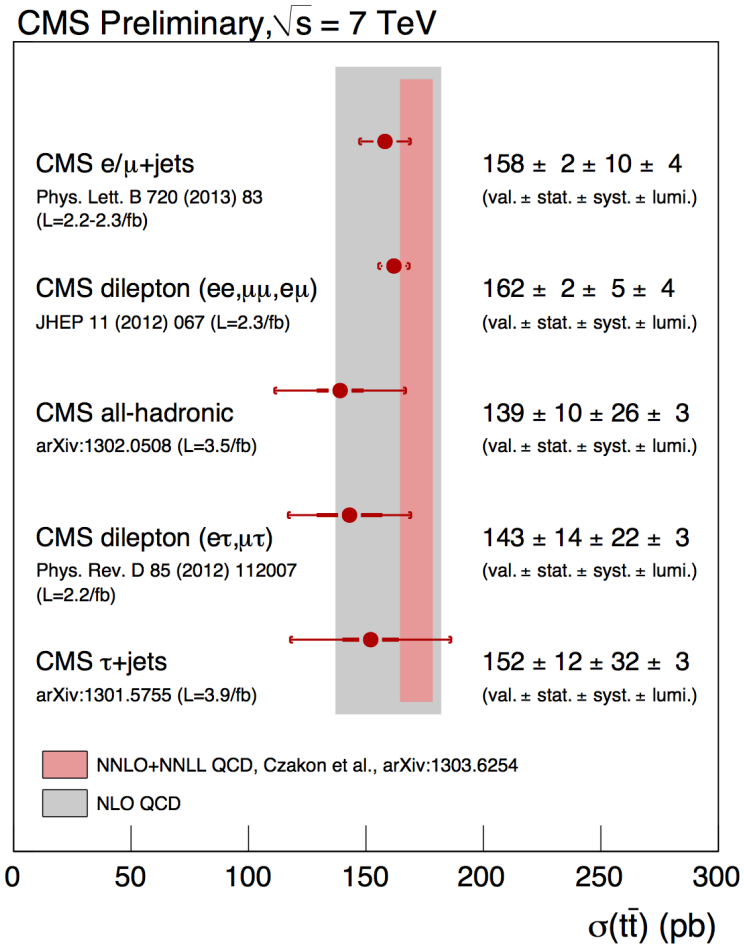
Jet combination

- Kinematic fit to all jet combinations
- $m_W = 80.4GeV$, $m_t == m_{\bar{t}}$
- b-tagged jets taken as b-jet candidates

Method

- Unbinned maximum likelihood fit to m_{top}
- Data-driven estimate of dominant multijet background

Cross section measurements at $\sqrt{s} = 7$TeV

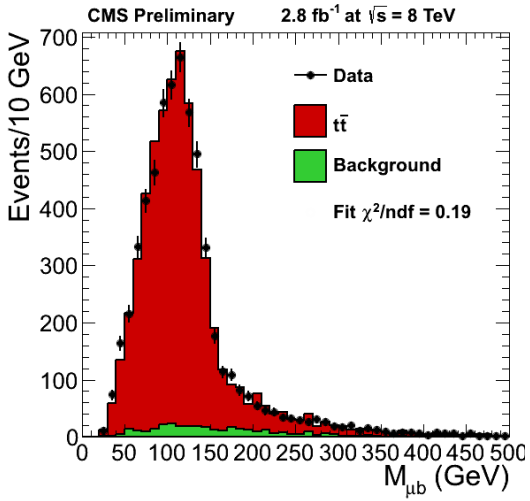


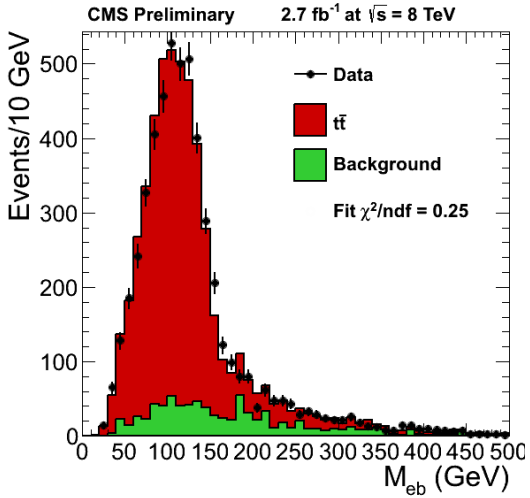
- Most $t\bar{t}$ decay modes have been used to measure the cross section
- Highest precision reached in the di-lepton channel
- All results are consistent
- Results are in agreement with NNLO+NNLL predictions

Cross section in the e/μ+jets channel (PAS-TOP-12-006)

$$\mathcal{L} = 2.8\ (2.7)\ fb^{-1}\ \mu(\mathrm{e})$$

$$\sigma_{t\bar{t}} = 228.4 \pm 9.0(stat.)^{+29.0}_{-26.0}(syst.) \pm 10.0(lum.)pb \sim^{+13.9}_{-12.8}\ \%$$





Event selection

- lepton+multijet trigger
- 1 isolated lepton $p_T > 26(30)GeV$ $|\eta| < 2.1(2.5)$ for muons (electrons)
- $\geq$ 4 jets with $p_T > 45/45/35/35GeV$ $|\eta|$ <2.5
- b-jet candidate from the leptonic decay leg is required to be b-tagged

Method

- Binned maximum likelihood fit on M_{lb}
- Signal and background templates taken from simulation
- Simultaneous measurement of ϵ_b
- Main systematics: JES (5%), b-tagging (8%), $t\bar{t}$ modelling (2-6%)

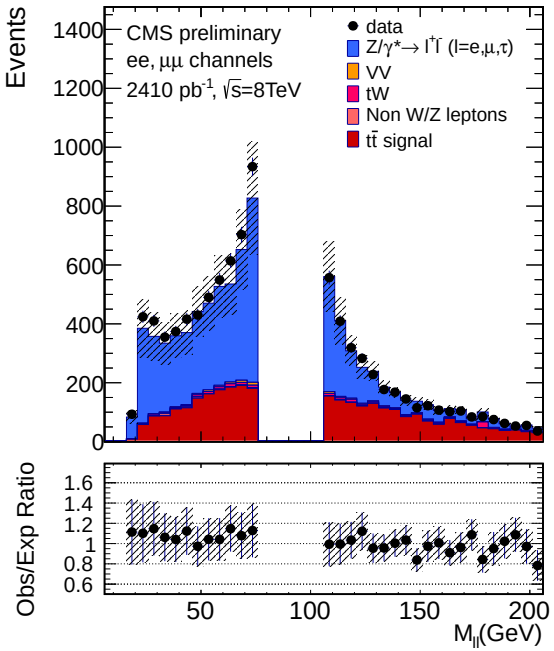
Cross section in the dilepton channel (PAS-TOP-12-007)

$\mathcal{L} = 2.4\ fb^{-1}$

$\sigma_{t\bar{t}} = 227.0 \pm 3.0(stat.) \pm 11.0(syst.) \pm 10.0(lum.)pb \sim 6.7\%$

Event selection

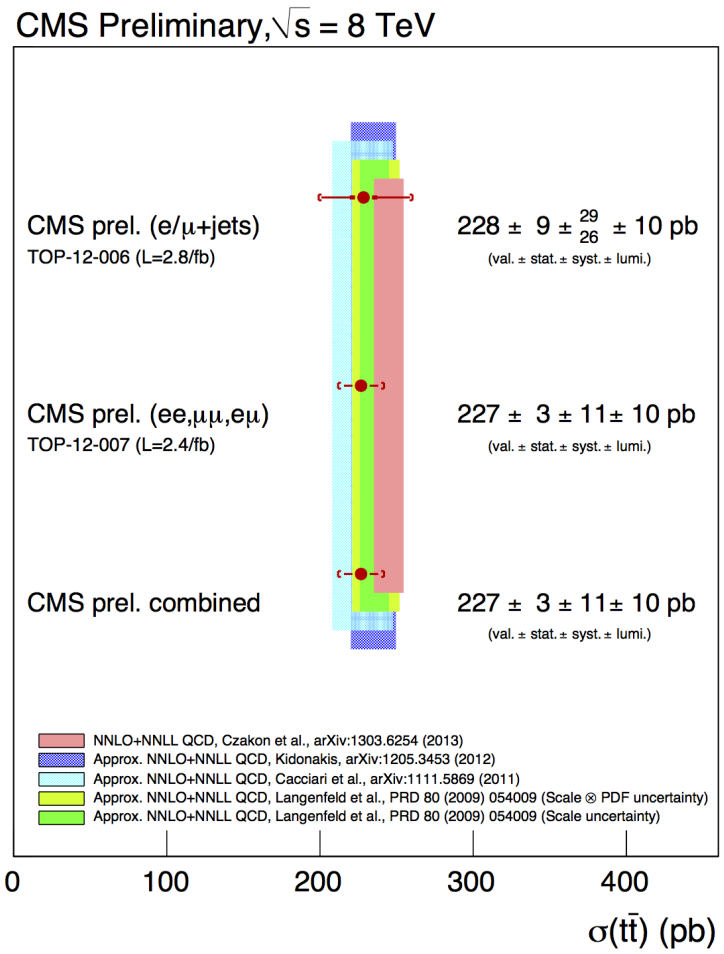
- dilepton trigger, 2 isolated leptons $p_T > 20GeV$ $|\eta| < 2.4(2.5)$ for muons (electrons)
- $\not{E}_T$ >40 GeV ($\mu^+\mu^-/e^+e^-$)
- Reject $76 < M_{ll} < 106$ for $\mu^+\mu^-/e^+e^-$, $M_{ll} > 20GeV$
- $\geq$ 2 jets with $p_T > 30GeV$ $|\eta|$ <2.5, $\geq$ 1 b-tagged jet



Method

- Counting analysis
- Data-driven estimation of DY+jets
- Data-driven backgrounds from non-prompt leptons extrapolated from 7TeV
- Main systematics: JES $\mathcal{O}(3\%)$, Trigger/Lepton effs $\mathcal{O}(2\%)$

Cross section measurements at $\sqrt{s} = 8$TeV



- Most $t\bar{t}$ decay modes have been used to measure the cross section
- Highest precision reached in the di-lepton channel
- All results are consistent
- Results are in agreement with NNLO+NNLL predictions

Conclusion

- The $\mathrm{t\bar{t}}$ cross section has been measured at $\sqrt{s} = 7$ and 8TeV
- Good agreement has been found with NNLO+NNLL predictions
- At $\sqrt{s} = 7$TeV most decay modes have been studies yield consistent results
- Preliminary results have been obtained at 8TeV in l+jets and di-lepton
- Large 8TeV dataset provides the possibility to do high-precision cross section measurements
- Publication of 8TeV cross section results in the pipeline