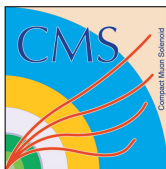


Top quark pair production cross section at CMS

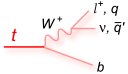
A.Y. Rodríguez-Marrero on behalf of the CMS Collaboration

Instituto de Física de Cantabria (CSIC-UC)

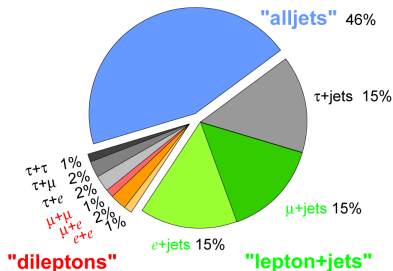
36th International Conference on High Energy Physics,
4 – 11 July 2012



Top Pair Production and Decay at the LHC

- Top pair production happens via gluon fusion (mainly), and $q\bar{q}$ annihilation
 - approx. NNLO: $\sigma_{t\bar{t}}(\text{LHC@7TeV}) = 163 \text{ pb}$, $\sigma_{t\bar{t}}(\text{LHC@8TeV}) = 225 \text{ pb}$
- Top quark decays almost exclusively via the W decay
 
- Measurements done according to the decay channel

Top Pair Branching Fractions

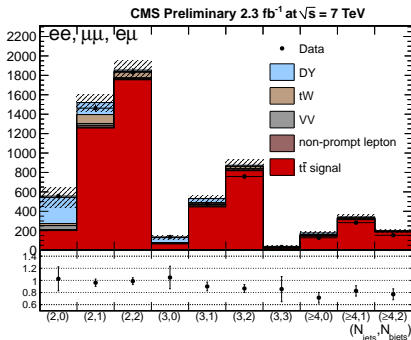


Decay channel	$\int dt \mathcal{L} \text{ (fb}^{-1}\text{)}$
dilepton (e, μ) @ 7 TeV	2.3
dilepton ($\tau, e/\mu$) @ 7 TeV	2.0-2.2
lepton (e/μ) + jets @ 7 TeV	0.8-1.1
τ + jets @ 7 TeV	3.9
all hadronic @ 7 TeV	1.1
dilepton (e, μ) @ 8 TeV	2.4
lepton (e/μ) + jets @ 8 TeV	2.7-2.8

To be submitted to JHEP (update of CMS-TOP-11-005)

- Require 2 OS isolated and high-pT leptons, veto Z-mass region for ee & $\mu\mu$, ≥ 2 jets, minimum E_T^{miss}
- DY and non-W/Z lepton backgrounds estimated from data
- Profile likelihood fit of a 2-dimensional space of the jet multiplicity, and the multiplicity of b-tagged jets
- Cross-check: cut-based analysis performed after requiring ≥ 1 b-tagged jet in three categories ee , $e\mu$, $\mu\mu$; combined using BLUE^a

^aL. Lyons et al., Nucl. Instrum. Meth. A 270 (1988) 110



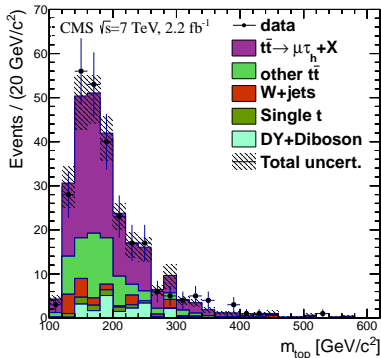
$$\sigma_{t\bar{t}} = 161.9 \pm 2.5(\text{stat.})_{-5.0}^{+5.1}(\text{syst.}) \pm 3.6(\text{lumi}) \text{ pb}, \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 4.2\%$$

Main systematics: lepton efficiencies $\sim 2\%$, jet energy scale $\sim 2\%$

First measurement in dilepton final states containing a τ !

arXiv:1203.6810, submitted to Phys.Rev.D

- Require 1 isolated and high-pT lepton, ≥ 2 jets, minimum E_T^{miss} , 1 hadronically decaying τ lepton, and ≥ 1 b-tagged jet
- Hadronic tau decays reconstructed with the HPS algorithm
- Tau-misidentified leptons determined from data using QCD events
- The reconstructed top mass indicates the consistency of the selected samples in data with the sum of signal and background
- Measurement performed in two categories $e\tau, \mu\tau$; combined using BLUE

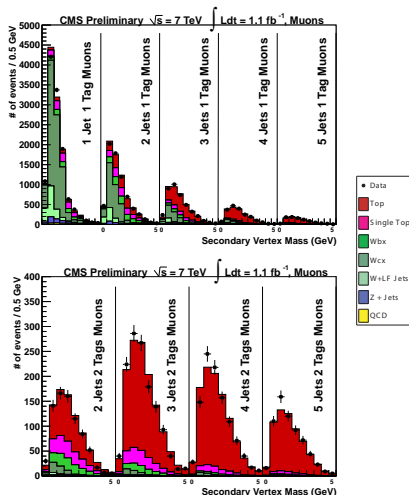


$$\sigma_{t\bar{t}} = 143 \pm 14(\text{stat.}) \pm 22(\text{syst.}) \pm 3(\text{lumi.}) \text{ pb}, \quad \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 18\%$$

Main systematics: τ identification $\sim 6\%$, jet energy scale $\sim 6\%$

CMS-PAS-TOP-11-003

- Require 1 isolated high-pT μ/e , veto on additional leptons, ≥ 4 jets, minimum E_T^{miss} , and ≥ 1 b-tagged jet
- QCD multijet background shape from MC, normalization from data
- Profile likelihood fit from secondary vertex mass, number of jets and number of b-tagged jets
- Treat some systematic uncertainties as nuisance parameters in the fit

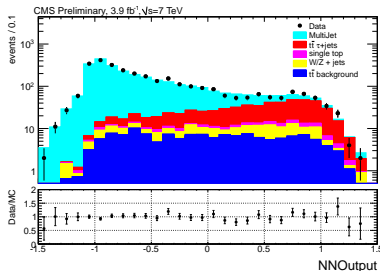


$$\sigma_{t\bar{t}} = 164.4 \pm 2.8(\text{stat.}) \pm 11.9(\text{syst.}) \pm 7.4(\text{lumi.}) \text{ pb}, \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 8.7\%$$

Main systematics: lepton efficiencies $\sim 3\%$, jet energy scale $\sim 3\%$

CMS-PAS-TOP-11-004

- Require ≥ 4 jets: ≥ 1 b-tag and 1 hadronically decaying τ lepton, minimum E_T^{miss}
- Hadronic tau decays reconstructed with the HPS algorithm
- QCD background extracted from untagged data
- Cross section extracted from a likelihood fit of a NN output

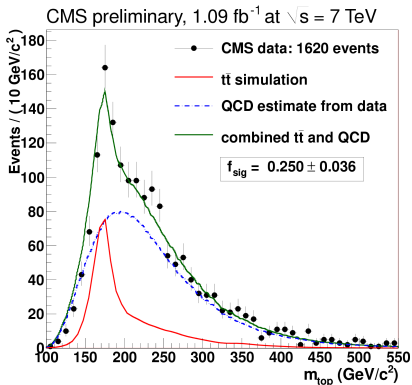


$$\sigma_{t\bar{t}, m_{t\bar{t}}=172.5\text{GeV}} = 156 \pm 12(\text{stat.}) \pm 33(\text{syst.}) \pm 3(\text{lumi.}) \text{ pb}, \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 23\%$$

Main systematics: τ identification $\sim 9\%$, jet energy scale $\sim 11\%$

CMS-PAS-TOP-11-007

- Require ≥ 6 jets with different high- p_T thresholds, ≥ 2 b-tag
- Channel fully dominated by QCD, b-tagging is essential
- Tag rate function $R(p_T, \eta)$ used as a weight on the untagged data sample
- Cross section extracted from an unbinned likelihood fit to the top quark mass



$$\sigma_{t\bar{t}} = 136 \pm 20(\text{stat.}) \pm 40(\text{syst.}) \pm 8(\text{lumi.}) \text{ pb}, \quad \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 33\%$$

Main systematics: b-tagging efficiencies $\sim 16\%$, jet energy scale $\sim 14\%$

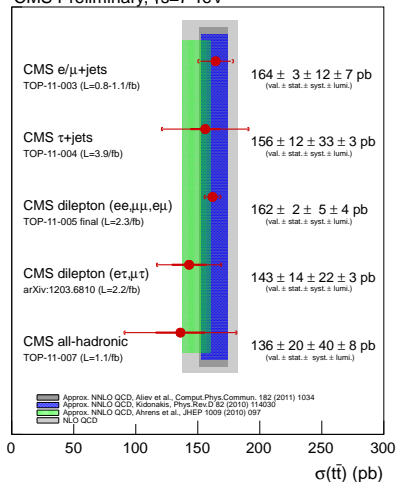
CMS-PAS-TOP-11-024

- Combination done using a binned maximum likelihood fit
- Includes measurements with 0.8 and 1.1 fb⁻¹
- $165.8 \pm 2.2 \pm 10.6 \pm 7.8$ pb

Today's results

- Measured cross sections in agreement with each other and with approx NNLO predictions
- All measurements are now systematics limited
- Experimental uncertainty is now lower than theoretical uncertainties

CMS Preliminary, $\sqrt{s}=7$ TeV

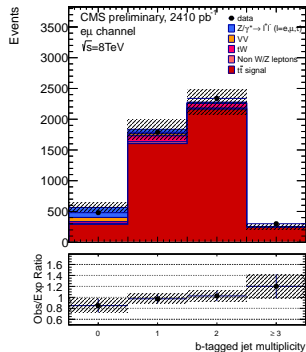




First measurement in the dilepton channel at 8 TeV!

CMS-PAS-TOP-12-007

- Require 2 OS isolated and high- p_T leptons, veto Z-mass region for ee & $\mu\mu$, ≥ 2 jets, minimum E_T^{miss} , ≥ 1 b-tagged jet
- DY and non-W/Z lepton backgrounds estimated from data
- Cut-based analysis performed in three categories ee , $e\mu$, $\mu\mu$; combined using BLUE
- Very clean sample after the different selection steps



$$\frac{\sigma_{t\bar{t}}(@8\text{TeV})}{\sigma_{t\bar{t}}(@7\text{TeV})} = 1.41 \pm 0.11$$

$$\sigma_{t\bar{t}} = 226.8 \pm 3.1(\text{stat.}) \pm 10.7(\text{syst.}) \pm 10.0(\text{lumi.}) \text{ pb}, \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 6.6\%$$

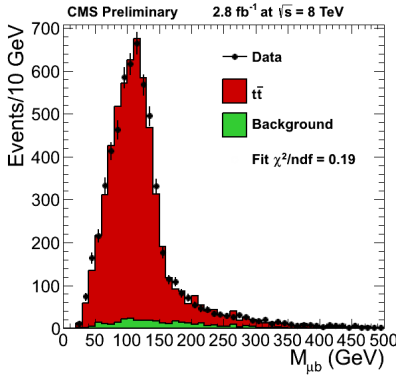
Main systematics: lepton efficiencies $\sim 2\%$, jet energy scale $\sim 3\%$



First measurement in the lepton + jets channel at 8 TeV!

CMS-PAS-TOP-12-006

- Require 1 isolated high- p_T μ/e , veto on additional leptons, ≥ 4 jets, and ≥ 1 b-tagged jet
- QCD multijet background shape and normalization from data
- Binned likelihood fit of the invariant mass of the b-jet and the lepton (M_{lb})
- Cross-check: uses the mass of the three-jet combination with the highest p_T



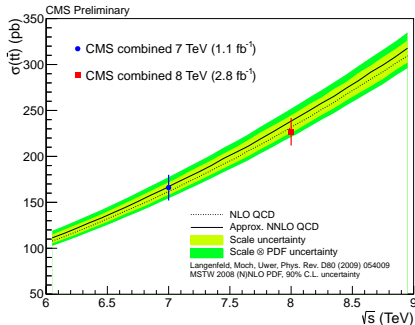
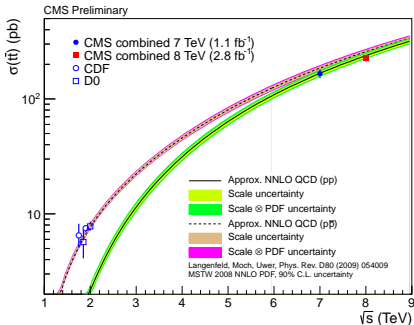
$\sigma_{t\bar{t}} = 228.4 \pm 9.0(\text{stat.}) \pm_{26.0}^{29.0}(\text{syst.}) \pm 10.0(\text{lumi.}) \text{ pb}, \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 14\%$

Main systematics: b-tagging efficiencies $\sim 8\%$, jet energy scale $\sim 5\%$

CMS Preliminary, combination @ 8 TeV

- dilepton (CMS-PAS-TOP-12-007), and lepton + jets (CMS-PAS-TOP-12-006)
- Combined using BLUE

$$\sigma_{t\bar{t}} = 227 \pm 3(\text{stat.}) \pm 11(\text{syst.}) \pm 10(\text{lumi.}) \text{ pb}, \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 7\%$$



- The LHC is a top factory
- CMS has a huge physics program for top quark physics
 - follow other presentations in parallel talks at TR4
- $\sigma_{t\bar{t}}$ measurements at (almost) all the different experimental signatures @ 7 TeV
- First cross section measurements at 8 TeV:
 - first data arrived only three months ago!
- Good agreement with SM predictions at both 7 and 8 TeV
 - Starting to challenge theory predictions
- Stay tuned!
 - <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP>

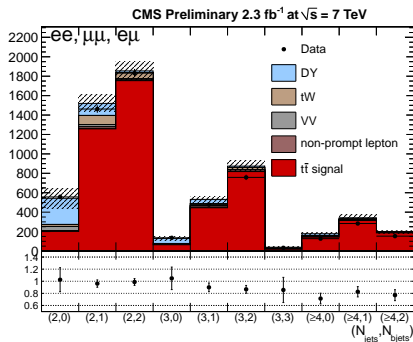


Thank you

Back-up

To be submitted to JHEP

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$$\sigma_{t\bar{t}} = 161.9 \pm 2.5(\text{stat.})_{-5.0}^{+5.1}(\text{syst.}) \pm 3.6(\text{lumi}) \text{ pb}, \delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 4.2\%$$

$$\sigma_{t\bar{t}, m_t} = \sigma_{t\bar{t}} - 1.29 \cdot (m_t - 172.5) - 0.02 \cdot (m_t - 172.5)^2$$