Inclusive top-quark pair production cross section in the CMS detector with the *Cut and Count* method

Juan Rodrigo González Fernández on behalf of the CMS collaboration

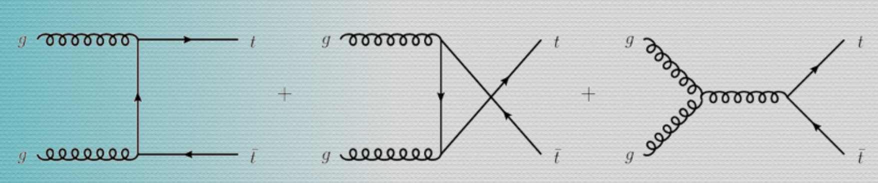
7 & 8 TeV (5 & 20 fb^{-1})	13 TeV (2.2 fb^{-1})
arXiv:1603.02303 [hep-ex]	CMS-PAS-TOP-16-005

1. Introduction and motivation

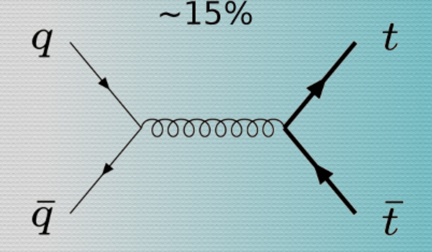
- Important test for the Standard Model
- Main source of background in many searches for physics beyond the SM
- This measurement can provide constraints on the top mass, proton PDFs, α_s and new physics scenarios

Production processes and decay

~85%



~15%



- The top-quark decays into W bosons and b-quarks (BR>99%)
- In this analysis leptonic decays of W bosons are considered

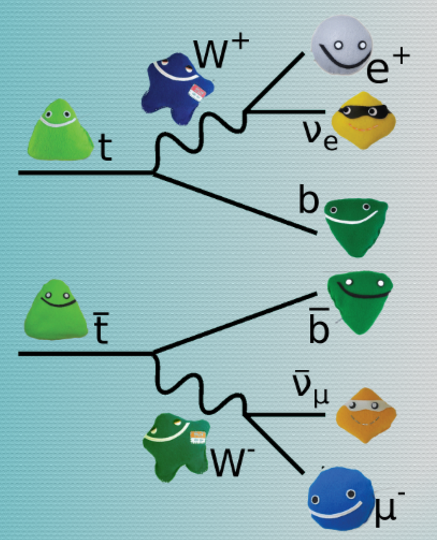
The ***Cut and Count*** method

- Count the number of events in data after a final selection, substract the background expectations and extrapolate the production cross section:

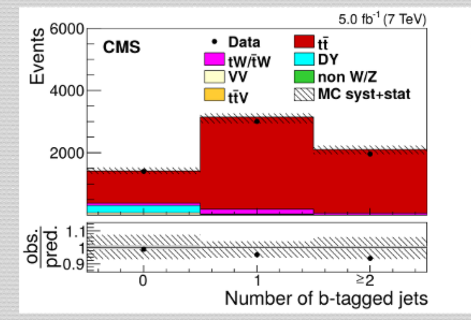
$$\sigma_{t\bar{t}} = \frac{N - N_{bkg}}{\epsilon \cdot \mathcal{L}}$$

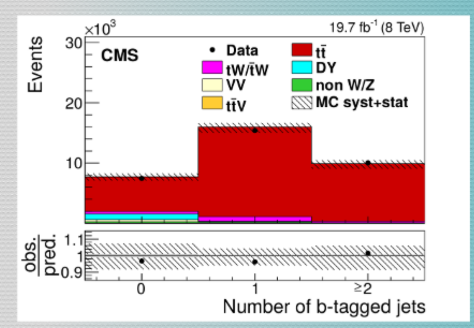
2. Event selection

- Electron-muon pair with opposite charge
- At least 2 jets
- At least *1 b-tagged jet*

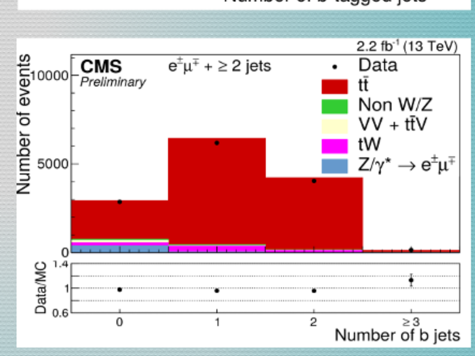


- The b-tagging working point provides an ID eff. of 70% and mistagging eff. of 1%



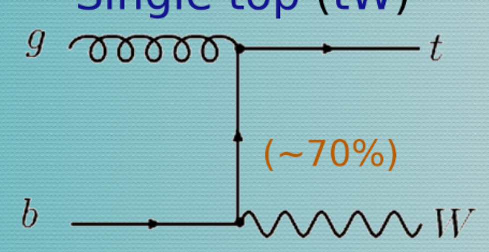


The signature of $t\bar{t}$ process has two b-jets. With the exception of tW, the background sources rarely produce b-jets.



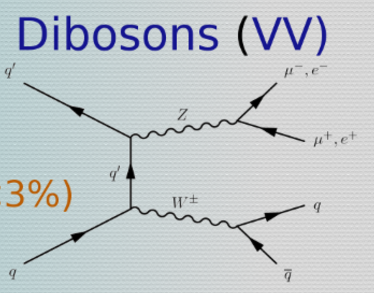
3. Background estimation

· Single top (tW)



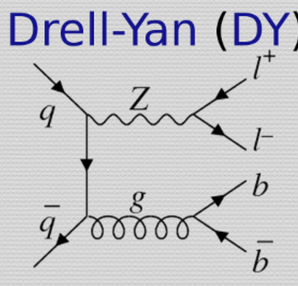
(~70%)

· Dibosons (VV)



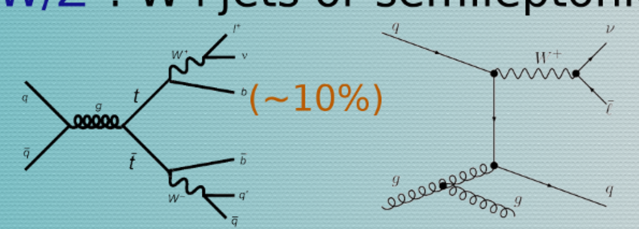
(<3%)

· Drell-Yan (DY)



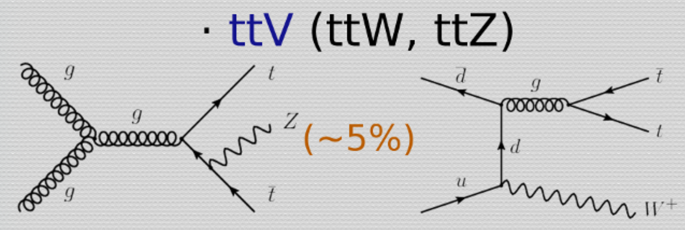
(~10%)

· "Non-W/Z": W+jets or semileptonic $t\bar{t}$



(~10%)

· ttV (ttW, ttZ)



(~5%)

Data driven techniques used to estimate DY and Non-W/Z, MC used for others

Source	Number of eμ events 7 TeV	8 TeV
DY	$22 \pm 3 \pm 3$	$173 \pm 25 \pm 26$
Non W/Z	$51 \pm 5 \pm 15$	$146 \pm 10 \pm 44$
Single top quark (tW)	$204 \pm 3 \pm 61$	$1034 \pm 3 \pm 314$
VV	$7 \pm 1 \pm 2$	$35 \pm 2 \pm 11$
$t\bar{t}$V	$12 \pm 1 \pm 3$	$84 \pm 1 \pm 26$
Total background	$296 \pm 6 \pm 63$	$1472 \pm 27 \pm 319$
$t\bar{t}$ dilepton signal	$5008 \pm 15 \pm 188$	$24440 \pm 44 \pm 956$
Data	4970	25441

Source (13 TeV)	Number of $e^{\pm}\mu^{\mp}$ events
Drell–Yan	$24 \pm 9 \pm 4$
Non-W/Z leptons	$109 \pm 50 \pm 33$
Single top quark	$463 \pm 6 \pm 145$
VV	$15 \pm 2 \pm 5$
$t\bar{t}$ V	$31 \pm 1 \pm 10$
Total background	$642 \pm 52 \pm 149$
$t\bar{t}$ dilepton signal	$10199 \pm 14 \pm 462$
Data	10368

DY estimation: $R_{in/out}$

Shapes are taken from MC, data used to normalize:

$$DY = R_{in/out} \cdot (N_{in}^{ll} - 0.5 N_{in}^{e\mu} \cdot k)$$

$R_{in/out}$: ratio between #events inside and outside the Z peak taken from MC

N_{in}^{ll}: #events in the Z peak taken from data in ll channel

k: factor to take into account the difference in efficiencies between e and μ

Estimation of non-W/Z

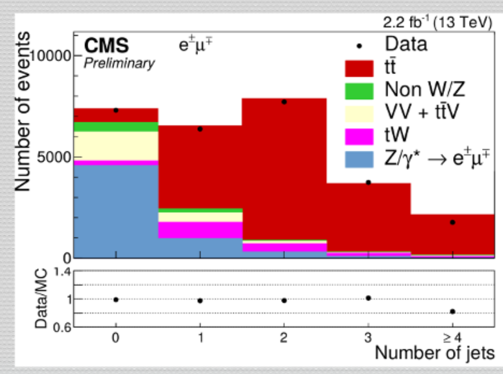
A control region with the same selection but same-sign (SS) leptons is used:

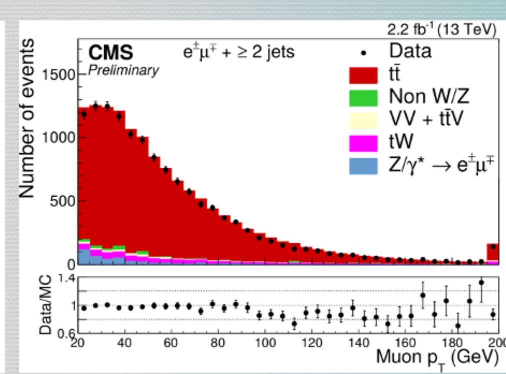
$$N_{data}^{OS\,fake} = (N_{data}^{SS} - N_{p,MC}^{SS}) \cdot N_{MC}^{OS\,fake} / N_{MC}^{SS\,fake}$$

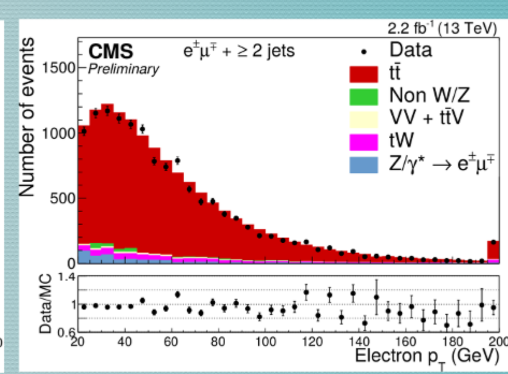
N_{data}^{SS}: number of SS events in data in the region of interest

$N_{p,MC}^{SS}$: number of SS events with prompt leptons taken from MC

$N_{MC}^{OS\,fake}/N_{MC}^{SS\,fake}$: ratio of events with fake leptons taken from semilep ttbar and W+Jets MC







4. Systematic uncertainties

Most important uncertainties

- ***Trigger*** and ***lepton efficiencies:*** estimated by varying data-to-MC scale factors (SFs) by their uncertainties (1-2%)
- ***Jet energy scale*** *and* ***b-tagging efficiency:*** determined by varying the jet energy and b-tagging SFs according to its p_T and η-dependent uncertainties
- ***Generators:*** calculated by comparing different MC simulations, Powheg/aMC@NLO (13 TeV) and MadGraph/Powheg (7 and 8 TeV)
- ***Hadronization***: estimated by comparing MC simulations of Pythia/Herwig
- ***Single top normalization***: a conservative 30% is assumed

Source	$\Delta\sigma_{t\bar{t}}$ (pb)	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)
Data statistics	8.3	1.0
Trigger efficiencies	9.7	1.2
Lepton efficiencies	18.4	2.3
Lepton energy scale	0.3	0.04
Jet energy scale	17.0	2.2
Jet energy resolution	0.8	0.1
b tagging	11.0	1.4
Mistagging	0.5	0.06
Pileup	1.5	0.2
Single top quark	11.8	1.5
VV	0.4	0.06
Drell–Yan	0.3	0.04
Non-W/Z leptons	2.7	0.3
$t\bar{t}$ V	0.8	0.1
PDF	4.8	0.6
Scale (μ_F and μ_R)	0.8	0.1
Parton shower scale	6.4	0.8
$t\bar{t}$ NLO generator	16.8	2.1
$t\bar{t}$ hadronization	10.2	1.3
Total systematic (no integrated luminosity)	38.0	4.8
Integrated luminosity	21.4	2.7
Total	44.4	5.6

Systematic uncertainties for the measurement at 13 TeV

5. Results

The **predicted** cross sections are:

$\sigma_{t\bar{t}}(7\ TeV) = 177.3 \pm 6.0\ (scale) \pm 9.0\ (PDF+\alpha_s)$ pb

$\sigma_{t\bar{t}}(8\ TeV) = 252.9 \pm 8.6\ (scale) \pm 11.7 (PDF+\alpha_s)$ pb

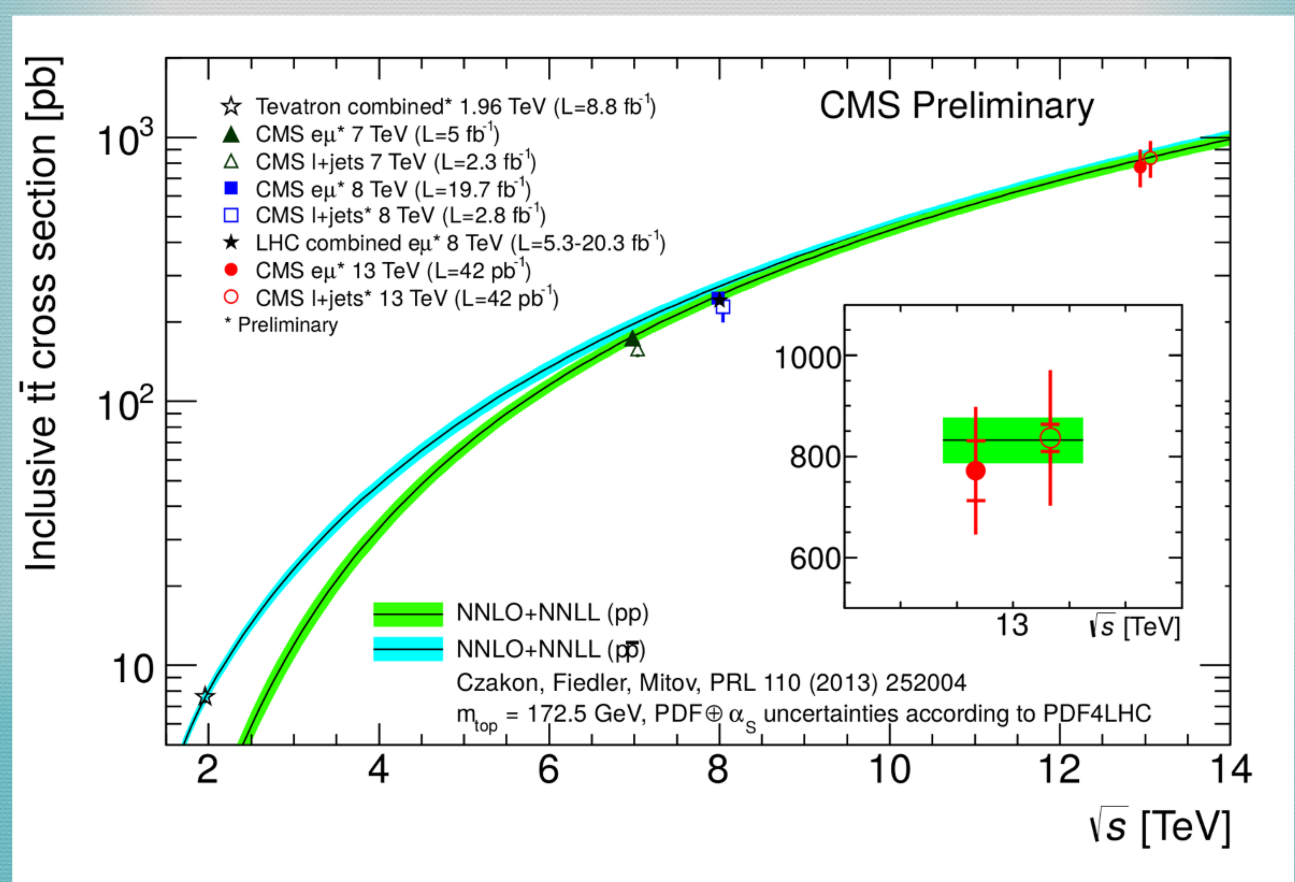
$\sigma_{t\bar{t}}(13\ TeV) = 831.8 \pm 29.2 (scale) \pm 35.1 (PDF+\alpha_s)$ pb

And the **measured** cross sections are:

$\sigma_{t\bar{t}}(7\ TeV) = 174.5 \pm 2.1 (stat) \pm 4.5\ (syst) \pm 3.8 (lumi)$ pb

$\sigma_{t\bar{t}}(8\ TeV) = 245.6 \pm 1.3 (stat) \pm 6.65 (syst) \pm 6.5 (lumi)$ pb

$\sigma_{t\bar{t}}(13\ TeV) = 793 \pm 8\ (stat) \pm 38\ (syst) \pm 21\ (lumi)$ pb



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