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Measurement of the inclusive top-antitop pair production cross section in pp collisions at 5.02 TeV

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Introduction

➔ A **measurement** of the **production cross section of top-antitop pair** production at **5.02 TeV** in pp collisions, recorded by the **CMS experiment**, is presented CMS-PAS-TOP-20-004.

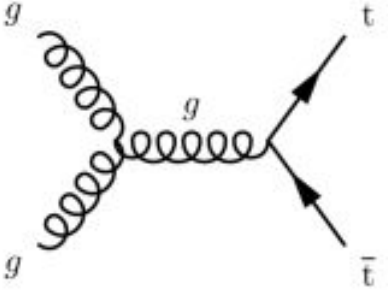
➔ The study of the production and properties of the **top quark** is one of the **core** elements of the LHC physics programme.

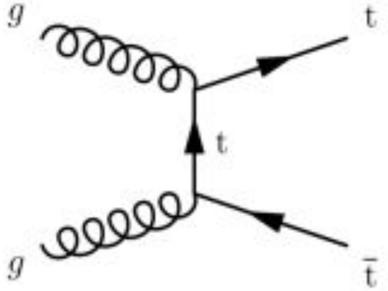
➔ The main production mechanism of top quarks at the LHC is through **top-antitop annihilation**.

➔ The analysis is performed using data from the low pileup run of 2017 → **Statistically limited measurement** (L=304 1/pb and ~2 pileup interactions per bunch crossing).

➔ Focus in **dileptonic final states**

➔ The result is combined with the measured cross section from the l+jets 10.1007/JHEP03(2018)115





Analysis strategy

➔ **Monte Carlo** simulated event samples are used to define the analysis strategy

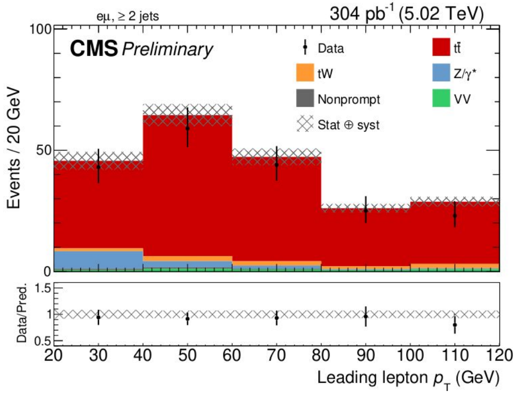
- To estimate the **background contribution** in the final state
- Evaluation of **efficiencies** and **uncertainties**.

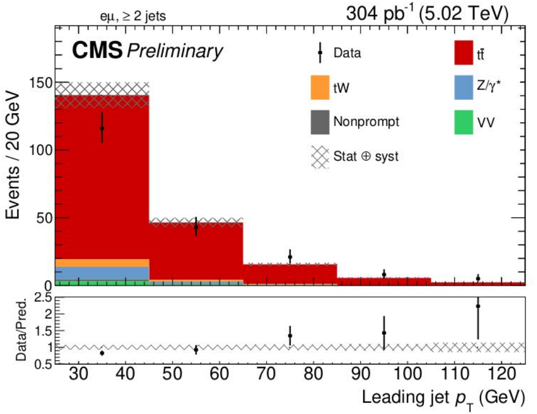
Process	Generator + parton shower
$t\bar{t}$	POWHEG (v2)+PYTHIA 8
tW	POWHEG (v2)+PYTHIA 8
W+jets	MADGRAPH5_aMC@NLO +PYTHIA 8
DY	MADGRAPH5_aMC@NLO +PYTHIA 8
VV	POWHEG (v2)+PYTHIA 8

Main background contributions

Semileptonic tt and **W+jets** backgrounds are grouped in the non-prompt category.

Estimated from data using the **Rout/in method**





Analysis strategy

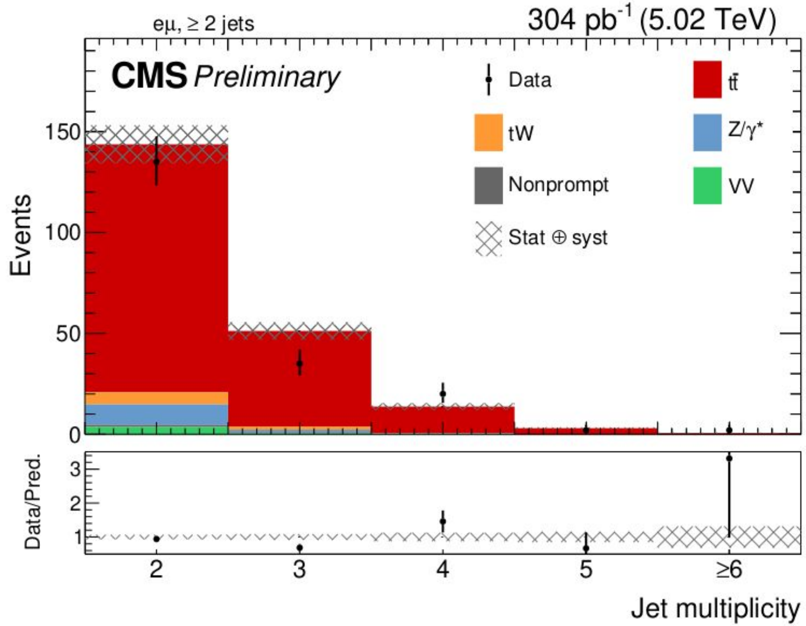
➔ Particle candidates are reconstructed using the **Particle Flow** algorithm

electrons	$\lvert\eta\rvert < 2.5,\ p_T > 10$ GeV
Muons	$\lvert\eta\rvert < 2.4,\ p_T > 10$ GeV
Jets	$\lvert\eta\rvert < 2.4,\ p_T > 25$ GeV

➔ **Baseline selection:** 2 leptons (**eμ**) with opposite sign + 2 jets.

➔ Further **kinematic requirements** are applied to define the full phase space

- Leading lepton is required to have p_T>20 GeV.
- Dilepton invariant mass above 20 GeV



Results

2017: dilepton channel only

- The tt production cross section is extracted by performing a counting experiment

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

- The measurement of the cross section is affected by sources of systematic uncertainty that originate from detector effects or theoretical assumptions

$$\sigma_{t\bar{t}} = 60.3 \pm 5.0\ (\text{stat}) \pm 2.8\ (\text{syst}) \pm 0.9\ (\text{lumi})\ \text{pb}$$

Source	$\Delta\sigma_{t\bar{t}} / \sigma_{t\bar{t}}$ (%)
tW	1.0
Nonprompt leptons	0.4
Drell–Yan	1.8
VV	0.8
Trigger efficiency	1.3
L1 prefiring	1.4
Electron efficiency	1.6
Muon efficiency	0.6
JES	2.2
JER	1.2
μ_R, μ_F scales	0.2
PDF$\oplus\alpha_S(m_Z)$	0.3
Final state radiation	1.1
Initial state radiation	< 0.1
h_{damp}	1.0
Underlying event tune	0.7
Total systematic	4.3
Integrated luminosity	1.5
Statistical uncertainty	8.2

2017+2015: (dilepton channel) ⊕ (lepton + jets)

- To reduce the statistical limitation of the presented measurement, the result is combined with that obtained in the l + jets decay channel (L=27.4 1/pb)
- The combination is performed using the **Best Linear Unbiased Estimator.**

$$\sigma_{t\bar{t}} = 62.6 \pm 4.1\ (\text{stat}) \pm 3.0\ (\text{syst+lumi})\ \text{pb}$$

Summary and conclusions

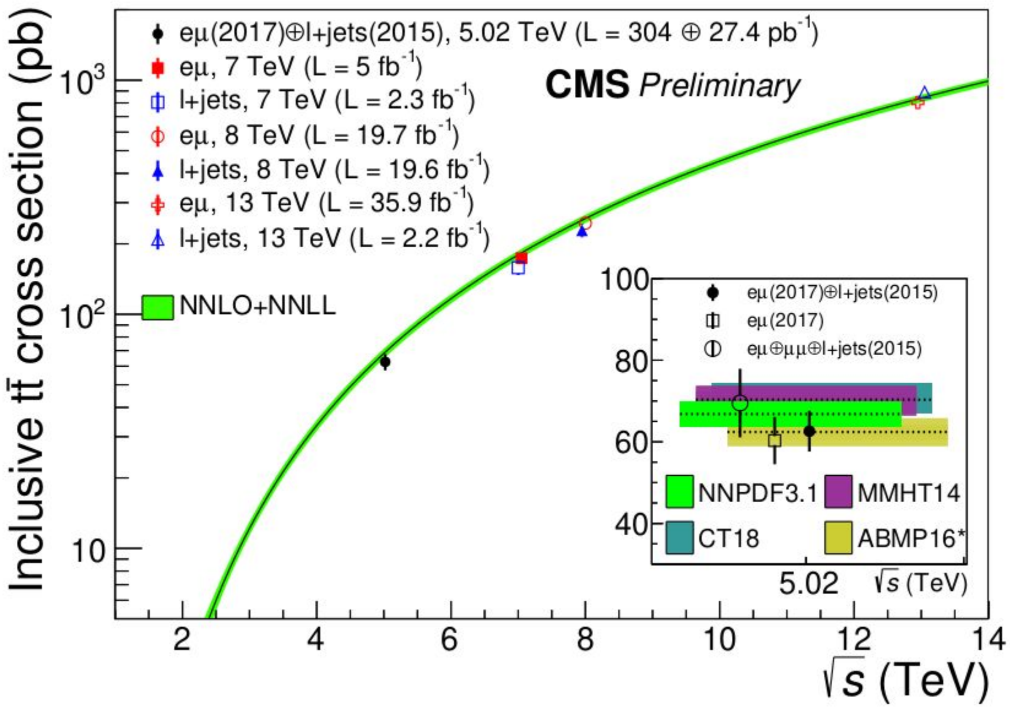
➔ This analysis has achieved an **improvement** of 5.1% (from **13% in 2015** to **7.9% in 2017+2015**) in the total uncertainty.

Predicted value:

$$\sigma_{t\bar{t}}^{SM} = 66.8 \pm^{1.9}_{2.3} \text{ (scale)} \pm 1.7\text{(PDF)} \pm^{1.4}_{1.3} \; (\alpha_S(m_Z)) \text{ pb.}$$

Measured value:

$$\sigma_{t\bar{t}} = 62.6 \pm 4.1 \text{ (stat)} \pm 3.0 \text{ (syst+lumi) pb}$$



➔ Summary plot of CMS measurements in pp collisions at different center-of-mass energies.

Thank you very much for your attention

Backup slides

Monte Carlo simulations

➔ **Simulated tt** events are generated at next-to-leading order (NLO) using POWHEG (v2) [m_{top} = 172.5 GeV]
➔ Events are interfaced with PYTHIA 8 (v230), using the CP5 tune for PS, hadronization and UE
➔ Nominal PDFs are simulated using NNPDF3.1 at next-to-next-to-leading order

Process	Generator + parton shower	Cross section order
$t\bar{t}$	POWHEG (v2)+PYTHIA 8	(NNLO+NNLL) [25, 26]
tW	POWHEG (v2)+PYTHIA 8	(approximate NNLO) [27]
W+jets	MADGRAPH5_aMC@NLO +PYTHIA 8	(NNLO[QCD]+NLO[EWK]) [28]
DY	MADGRAPH5_aMC@NLO +PYTHIA 8	(NNLO[QCD]+NLO[EWK]) [28]
VV	POWHEG (v2)+PYTHIA 8	(NLO)

$R_{out/min}$ method

- ➔ **Events** with **same-flavored leptons** are **used to normalize** the yield of **different-flavored pairs** from DY production of τ lepton pairs
- ➔ A **data-to-simulation normalization factor is estimated** from the number of events in data within a 15 GeV window around the Z boson mass
- ➔ The **norm. factor is extrapolated to the number of events outside the Z mass window** with corrections applied using control regions enriched in DY events in data
- ➔ This factor is measured to be **0.91 ± 0.01**
- ➔ The **stability of the method** against a potential mismodeling of the jet multiplicity was **checked** and found to be within 30%
- ➔ **Considered as an extra systematic** uncertainty to this background estimation.

Object and event selection

- **Events of interest** are selected online using a two-tiered trigger system: **L1 & HLT**
- **Only** events that fired at least one of the **single-lepton** triggers with transverse momentum (p_T) thresholds greater than 12 (17) GeV in the case of muons (electrons) are considered.

- **Particle candidates** are reconstructed using the **Particle Flow** algorithm

Electrons

- $|\eta| < 2.5$
- pT > 10 GeV
- **MVA score**
- Conversions veto

Muons

- $|\eta| < 2.4$
- pT > 10 GeV
- **Geometrical criteria**
- Conversions veto

Jets

- AK4 jets
- pT > 25 GeV
- **b-tags: DEEPJET**
- loose working point

Nonprompt lepton identification

➔ **Nonprompt** (not coming from W/Z) leptons are **identified** using a MVA based on a **boosted decission tree**

b-tagging score
$\frac{p_T^\ell}{p_T^j}$
p_T^j (transverse to the lepton's direction)
p_T^ℓ
η^ℓ
I_{rel}
longitudinal impact parameter (IP)
transverse IP

Some of the **input variables** used for training the **BDT**

➔ **To further suppress nonprompt leptons** originating from b quark decays, **leptons associated with a jet** satisfying the **loose working** point of the **DEEPCSV b tagging** algorithm **are rejected.**

Yields at the final state

Process	Event yield		
tW	8	± 0.1	± 2
Nonprompt leptons	1.7	± 0.1	± 0.9
DY	10	± 0.1	± 3
VV	4	± 0.1	± 1
Total background	24	± 0.2	± 4
$t\bar{t}$	187	± 1	± 8
Data	194		