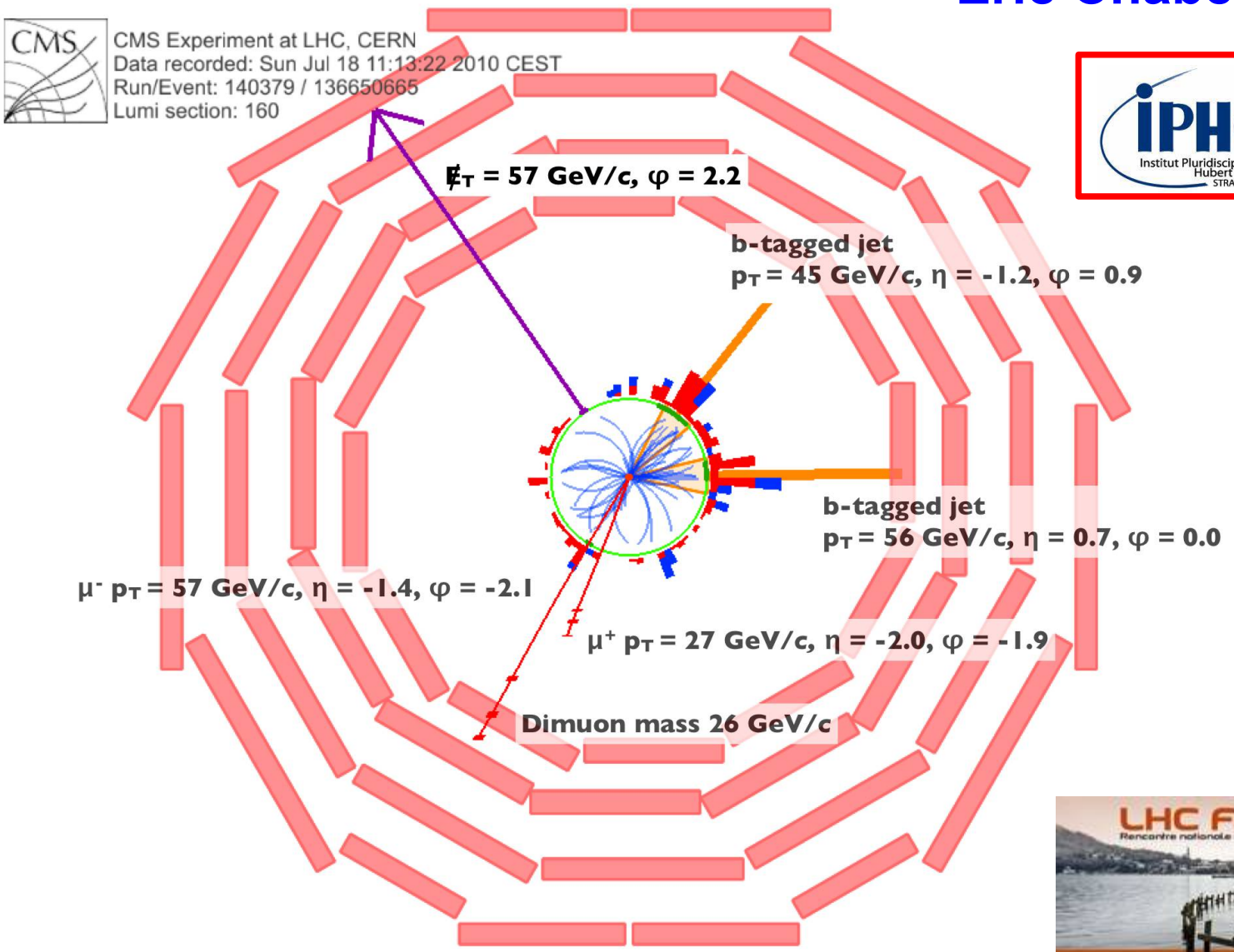
Top pair cross-section in dilepton channel with CMS

Eric Chabert, *IPHC Strasbourg*



Outline

7 TeV Analysis

- ee-eμ-μμ channels @ 2.3 fb^{-1}
- μτ channel @ 1.1 fb^{-1}
- μτ-eτ channels @ 2.2 fb^{-1}
- CMS combination @ 0.8-1.1 fb^{-1}
- LHC combination @ 0.7-1.1 fb^{-1}

8 TeV Analysis

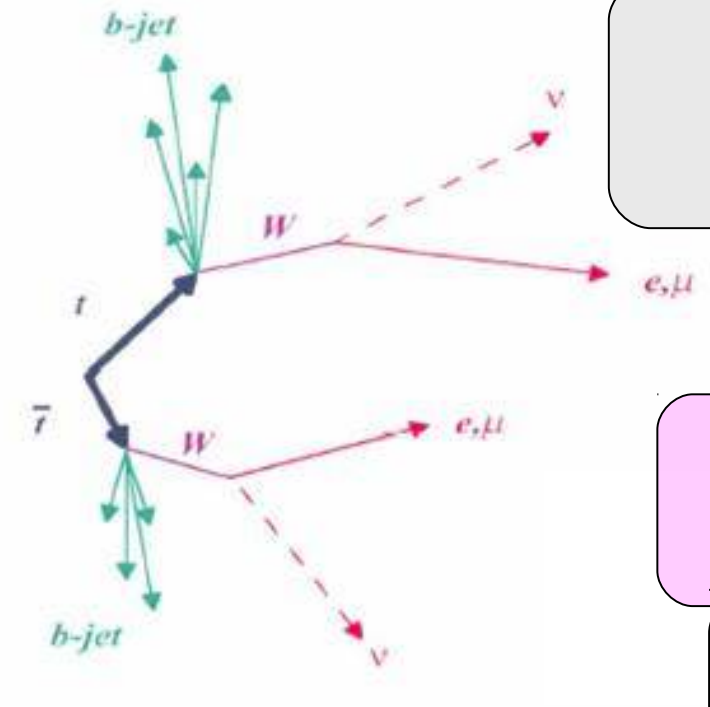
- ee-eμ-μμ channels @ 2.3 fb^{-1}
- CMS combination @ 2.3 fb^{-1}

dilepton channels : e/μ

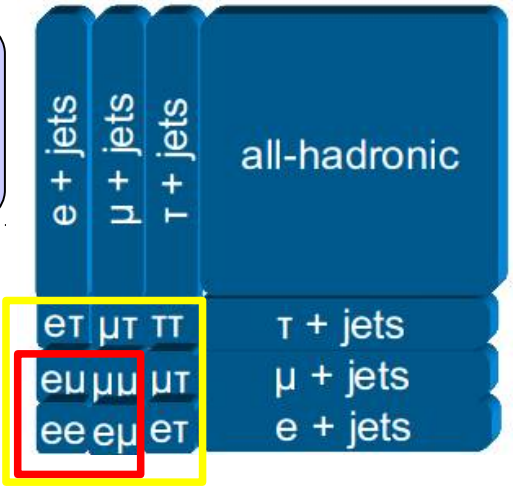
Event Selection

Jets :
Anti-K_T - R=0.5 - **Particle Flow**
≥2 jets with p_T>30 GeV and |η|<2.5.

B-tagging:
Algo: **Combined Secondary Vertex**
≥1b-tagged jets



MET:
JEC applied
MET > 40 GeV (ee, μμ)



Channels	B.R.	$+\tau_l$
ee	1.23 %	1.66 %
μμ	1.23 %	1.66 %
eμ	2.46 %	3.32 %

Total BR ~6.6 %

Muon:
Global muon isolated
p_T>20 GeV and |η|<2.5

Dilepton :
2 opposite sign leptons
m_{ll}>20 GeV
$|m_{ll}-m_Z|$> 15 GeV (ee, μμ)

Electron :
GsfElectron isolated
p_T>20 GeV and |η|<2.5

Dilepton Trigger :
E_T(electrons) > 8-17 GeV
p_T(muons) > 7-17 GeV

σ(tt) in dilepton channel (e/μ) @ 7 TeV

Event yields and data/MC comparison

Many measurements since the begining of data-taking :

Luminosity = 36 pb^{-1} $168 \pm 18(\text{stat}) \pm 14(\text{syst}) \pm 7(\text{lum})$ pb — 14.2 % — TOP-10-005

Luminosity = 1.1 fb^{-1} $169.9 \pm 3.9\ (\text{stat.}) \pm 16.3\ (\text{syst.}) \pm 7.6\ (\text{lumi.})$pb — 10.8 % — TOP-11-005

→ Used for the combinations

Luminosity = 2.3 fb^{-1}

JHEP 11 (2012) 065
(arXiv:1208.2671)

<= Focus on the latest result

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Luminosity = 2.3 fb^{-1}

Used for the combinations

JHEP 11 (2012) 065
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<= Focus on the latest result

Dilepton is a very clean channel

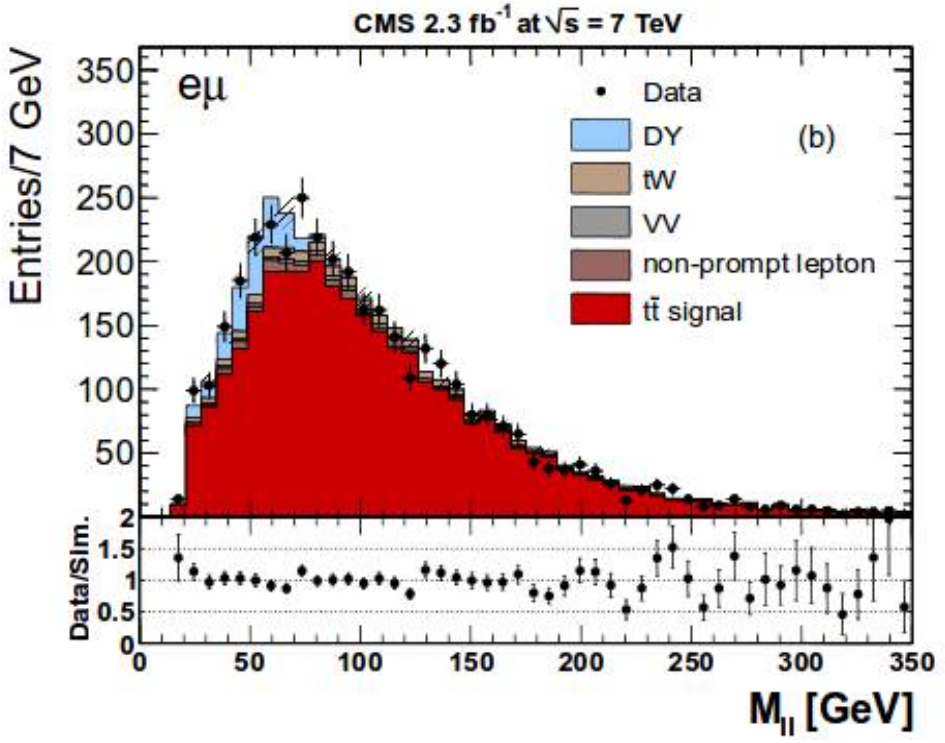
Good modelisation of the signal

(b) ≥ 1b-tagged jet

Source	$\mu^+\mu^-$	e^+e^-	$e^\pm\mu^\mp$
Drell-Yan	62±16	82±21	89±19
Nonprompt leptons	2.4±4.8	10.0±5.5	50±15
Diboson	5.7±1.4	6.1±1.5	22.3±5.3
Single top	37.5±7.8	47.0±9.8	140±29
Total background	108±18	145±24	301±38
$t\bar{t}$ signal	759±33	991±42	3082±122
Total predicted	867±38	1136±48	3383±128
Data	875	1074	3339

(c) $t\bar{t}$ acceptance × eff.× B (%)

b-tagging selection	e^+e^-	$\mu^+\mu^-$	$e^\pm\mu^\mp$
No selection	0.22±0.01	0.28±0.01	0.87±0.04
≥ 1b-tagged jet	0.20±0.01	0.27±0.01	0.83±0.04



eμ channel :eff = 33 % - purity = 91 % !

σ(tt) in dilepton channel (e/μ) @ 7 TeV

The data driven ingredients ...

Drell-Yan estimation

ee μμ channels : Z^{peak} : R^{in}/R^{out}
Ratio taken from simulation but corrected using control region in data
eμ channel : template fit

Fake lepton background estimation
(tt→l+jets,W+jets,QCD)

estimation using a « **Matrix Method** »

MET cut eff.

Estimation from eμ channel

$$\sigma_{t\bar{t}} = \frac{N - N^{bkg}}{A \times \epsilon \times L}$$

Lepton efficiencies

Tag & probe on (Z→ll)+jets events

Determine p_T,η dependance
Rescale to ttbar MC accordingly

Trigger efficiencies

Use of an independent MET trigger

σ(tt) in dilepton channel (e/μ) @ 7 TeV

Study of the systematic uncertainties

Cut & count method (eμ)

Source	Uncertainty on $\sigma_{t\bar{t}}$(pb)
Diboson	0.4
Single top	2.3
Drell-Yan	1.0
Non-W/Z leptons	0.6
Lepton efficiencies	1.7
Lepton energy scale	0.5
Jet energy scale	2.8
Jet energy resolution	0.5
$\not{E}_T$ efficiency	1.9
b-tagging	1.1
Pileup	0.7
Scale of QCD (μ)	1.0
Matching partons to showers	1.0
W branching fraction	2.7
Total systematic	5.6
Integrated luminosity	3.6
Statistical	2.6

TDR expectations (14 TeV,10fb^{-1})

6.1

5.8

11.7

4.8

Conservative **data-driven uncertainties** are translated in reasonnable σ(tt) uncertainties (thanks to the purity)

σ(tt) in dilepton channel (e/μ) @ 7 TeV

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Since 2011, the total uncert. Is dominated by **systematic** uncert.

σ(tt) in dilepton channel (e/μ) @ 7 TeV

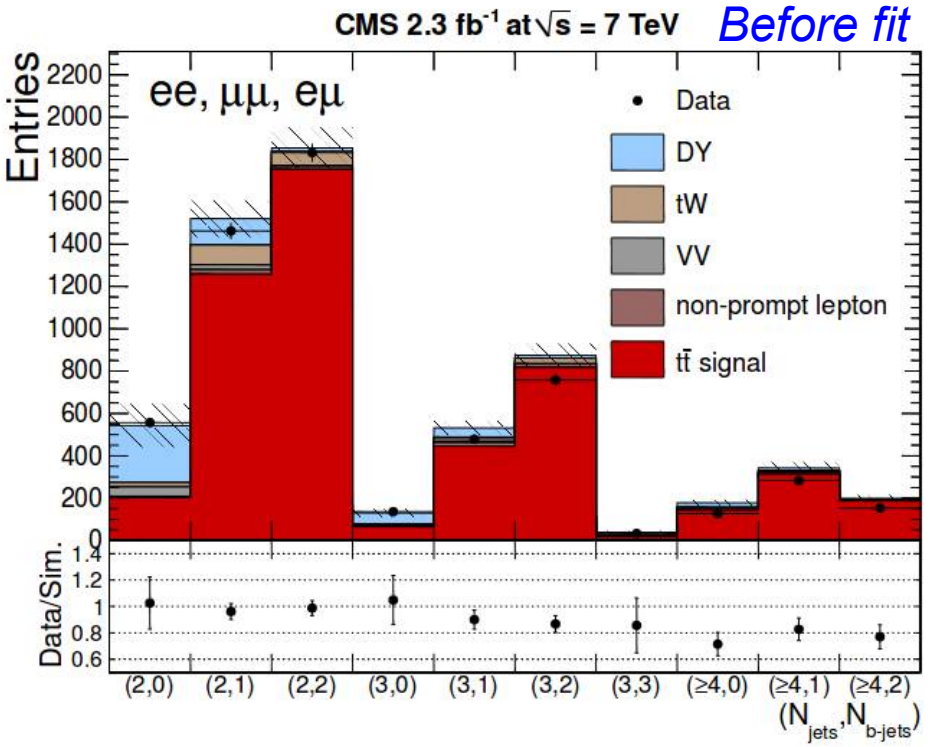
Into the precision area : 4.2 % uncertainty

Cross section is measured from a **profile likelihood ratio** using the N_{jets} vs N_{bjets} distribution

2 extraction methods :

- Cut & Count *(cross-check)*
  - Combination with a BLUE method
- **Profile Likelihood Ratio method**

- Combination with a treatment of nuisance parameters correlation btw channels
- gain with PLR : 12 % on systematics
- gain with comb. (rel. eμ) : 19 % on statistics
- Combination driven by the eμ channel (less backgrounds, no MET selection)



Channel	PLR method	Counting analysis
ee	$168.0 \pm 6.6^{+7.6}_{-7.0} \pm 3.7$	$165.9 \pm 6.4 \pm 7.0 \pm 3.6$
$\mu\mu$	$156.3 \pm 5.6^{+7.7}_{-6.6} \pm 3.5$	$153.8 \pm 5.4 \pm 6.6 \pm 3.4$
$e\mu$	$161.9 \pm 3.1^{+5.8}_{-5.4} \pm 3.6$	$161.6 \pm 3.1 \pm 5.6 \pm 3.6$
Combined	$161.9 \pm 2.5^{+5.1}_{-5.0} \pm 3.6$	$161.0 \pm 2.6 \pm 5.6 \pm 3.6$

4.2 %

good agreement btw. the 2 methods

σ(tt) in dilepton channel (e/μ) @ 7 TeV

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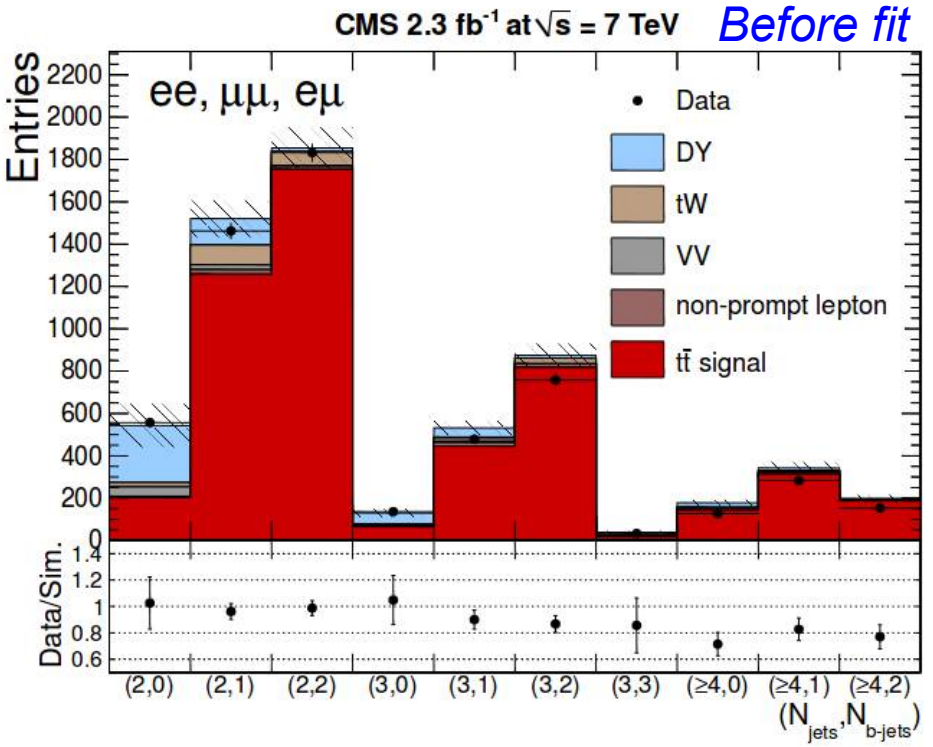

Channel	PLR method	Counting analysis
ee	$168.0 \pm 6.6^{+7.6}_{-7.0} \pm 3.7$	$165.9 \pm 6.4 \pm 7.0 \pm 3.6$
μμ	$156.3 \pm 5.6^{+7.7}_{-6.6} \pm 3.5$	$153.8 \pm 5.4 \pm 6.6 \pm 3.4$
eμ	$161.9 \pm 3.1^{+5.8}_{-5.4} \pm 3.6$	$161.6 \pm 3.1 \pm 5.6 \pm 3.6$
Combined	$161.9 \pm 2.5^{+5.1}_{-5.0} \pm 3.6$	$161.0 \pm 2.6 \pm 5.6 \pm 3.6$

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good agreement btw. the 2 methods

Top mass dependance :

$$\sigma_{t\bar{t}}/\sigma_{t\bar{t}}(m_t = 172.5) = 1.00 - 0.008 \times (m_t - 172.5) - 0.000137 \times (m_t - 172.5)^2.$$

Top mass uncertainty at WA : 1.4 pb (0.9%)

σ(tt) in dilepton channel (μτ$_h$) @ 7 TeV

Looking for an hadronically decaying τ

TOP-11-006

Luminosity = 1.09 fb^{-1}

Event Selection

- Single-muon trigger
- 1 isolated muon p_T > 20 GeV
- 1 tau with p_T > 20 GeV
- Opposite sign requirement
- ≥2 jets with p_T > 20 GeV
- ≥1 b-tagged jet
- MET > 40 GeV

Data Driven estimation :

Measurement of jets faking τ probability w(η, p_T) using with high-p_T jet trigger

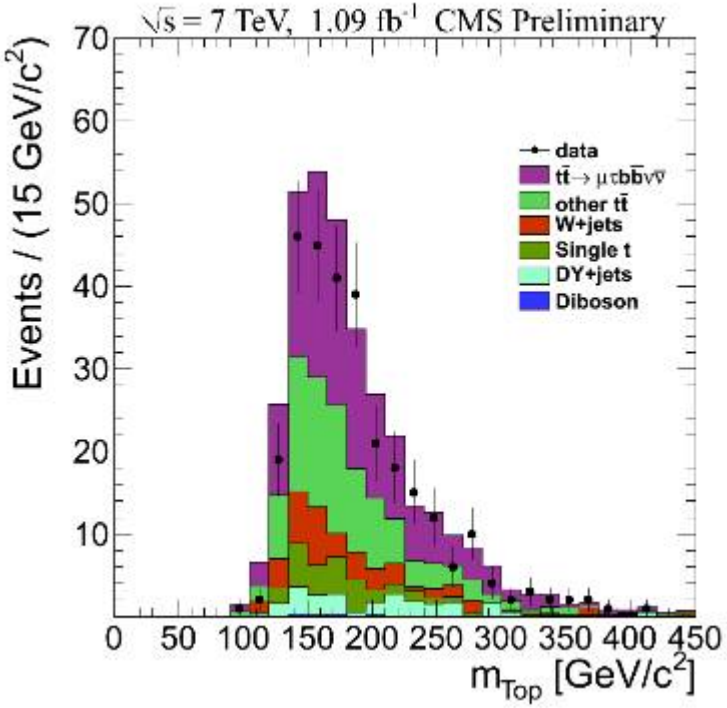
Statistical procedure : cut & count

Measurement :

$$\sigma_{t\bar{t}} = 148.7 \pm 23.6(\text{stat.}) \pm 26.0(\text{syst.}) \pm 8.9(\text{lumi.})\ \text{pb}$$

25.3 %

	Uncertainties [%]
τ fake background	13.0
τ jet identification	7.3
b-jet tagging & jet→b mis-id	5.5
jet energy scale, jet energy resolution, E_T^{miss}	4.4
theoretical uncertainty on signal efficiency	4.0
pileup modeling	3.1
lepton selection	2.1
cross-section of MC backgrounds	1.6
luminosity	6.0



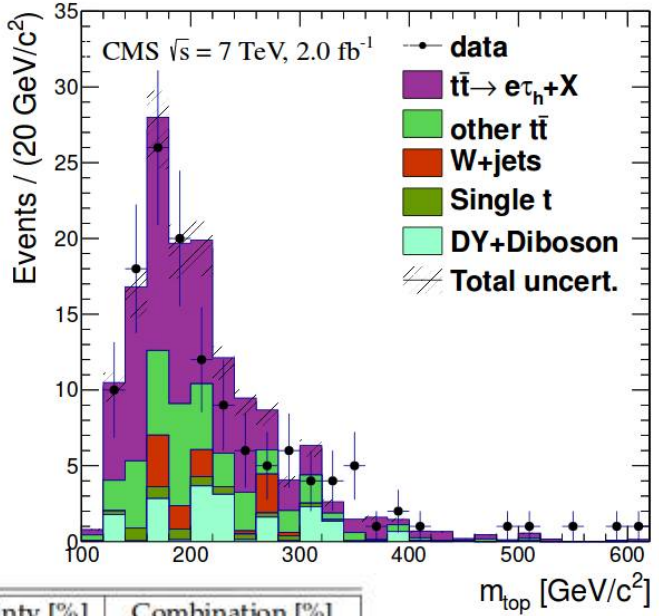
reconstructed top quark mass with a kinematic fit

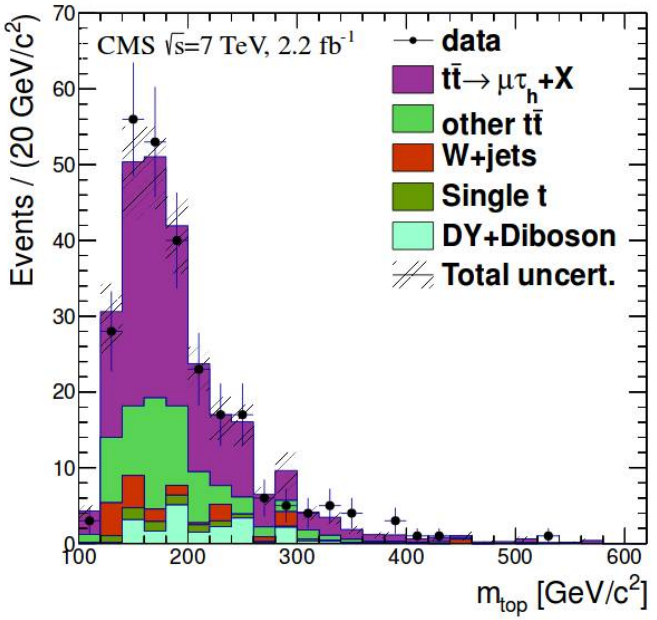
σ(tt) in dilepton channel (e/μ,τ) @ 7 TeV

Update with eτ channel and higher luminosity

Luminosity = 2.2 fb^{-1}

arXiv:1203.6810



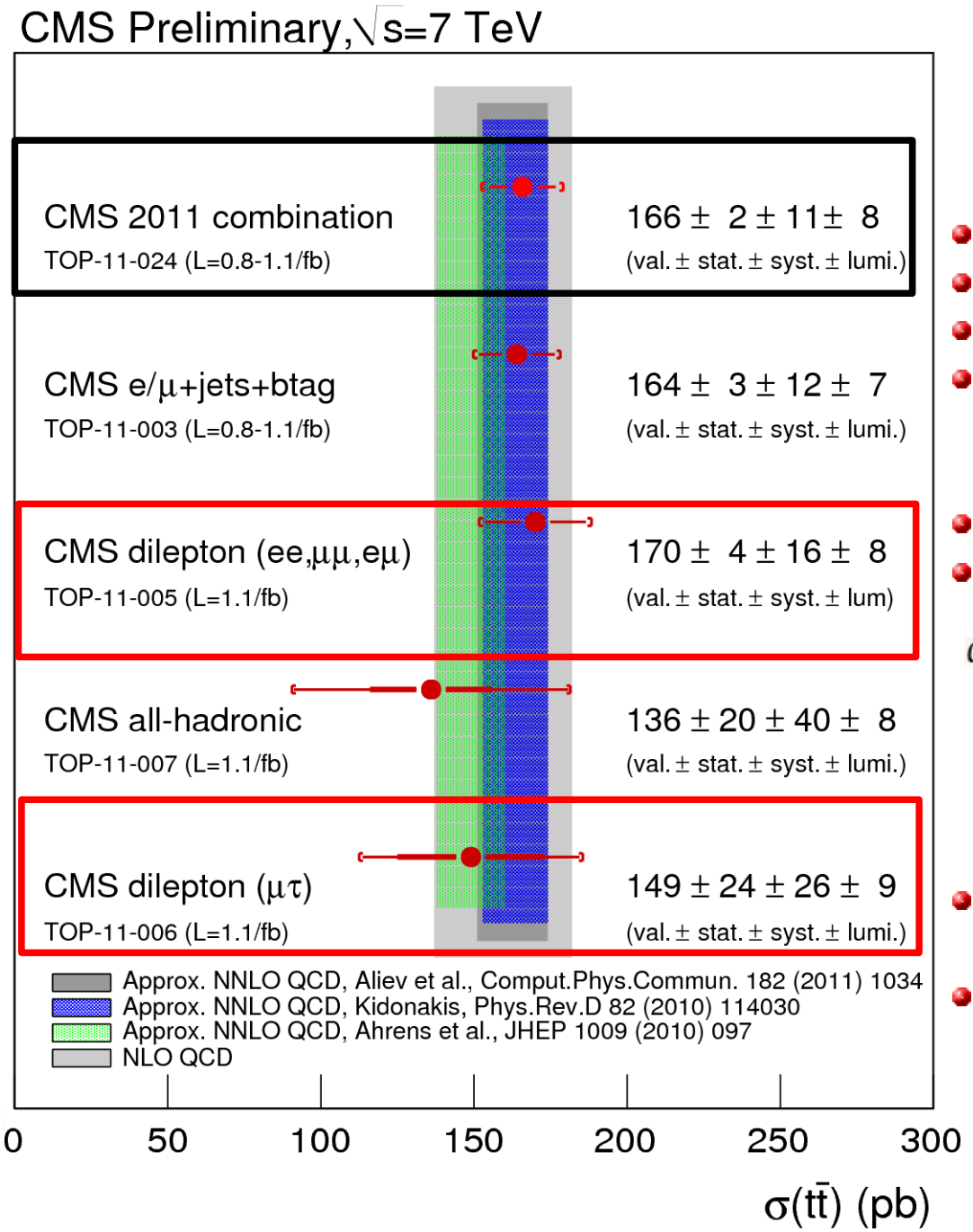


Source	Uncertainty [%]		Combination [%]
	$e\tau_h$	$\mu\tau_h$	
τ misidentification background	12.6	9.8	10.8
τ jet identification	6.4	6.3	6.3
b-jet tagging, misidentification	5.3	5.3	5.3
jet energy scale, jet energy resolution, E_T^{miss}	5.1	6.2	5.8
theoretical uncertainty on signal efficiency	4.0	4.0	4.0
pile-up modelling	2.3	2.3	2.3
electron selection	3.1	0	1.1
muon selection	0	2.0	1.3
cross section of MC backgrounds	1.6	1.4	1.5
luminosity	2.2	2.2	2.2
weight	0.38	0.62	$\chi^2/N_{dof} = 2.381/1$ (p-value = 0.198)

18.4 %

$$\sigma_{t\bar{t}} = 143 \pm 14(\text{stat.}) \pm 22(\text{syst.}) \pm 3(\text{lumi.})\ \text{pb}$$

CMS combination @ 7 TeV



TOP-11-024

- Combination using with L=0.8-1.1fb^{-1}
- Use of a binned maximum likelihood
- Gain 7 % of stat. and 7 % of syst. uncert.
- Cross check with a BLUE method

- l-jets channels gave the best precision
- Dilepton analysis has then been updated

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

=> more precise than the previous combination

- Experimental measurements compatible with the prediction(s)
- Experimental precision is comparable to the theoritical uncertainties

LHC combination @ 7 TeV

LHC combination from TOPLHCWG

Inputs : ATLAS (ATLAS-CONF-2012-00) and CMS (CMS PAS TOP-12-003) combinations

Assumption of the correlation tested

Luminosity partially correlated

	ATLAS	CMS	Correlation	LHC combination
Cross-section	177.0	165.8		173.2
Uncertainty				
Statistical	3.7	2.2	0	2.6
JES	2.7	3.5	0	2.1
Detector model	5.3	8.8	0	4.6
Signal model				
Monte-Carlo	4.2	1.1	1	3.1
Parton shower	1.3	2.2	1	1.6
Radiation	0.8	4.1	1	1.9
PDF	1.9	4.1	1	2.6
Background from data	1.5	3.4	0	1.6
Background from MC	1.6	1.6	1	1.6
Method	2.4	n/e	1	1.6
W leptonic branching	1.0	1.0	1	1.0
Luminosity				
Bunch current	5.3	4.3	1	5.3
Detector effects	5.1	5.9	0	3.4
Total systematic	10.8	14.2		9.8
Total	11.4	14.4		10.2

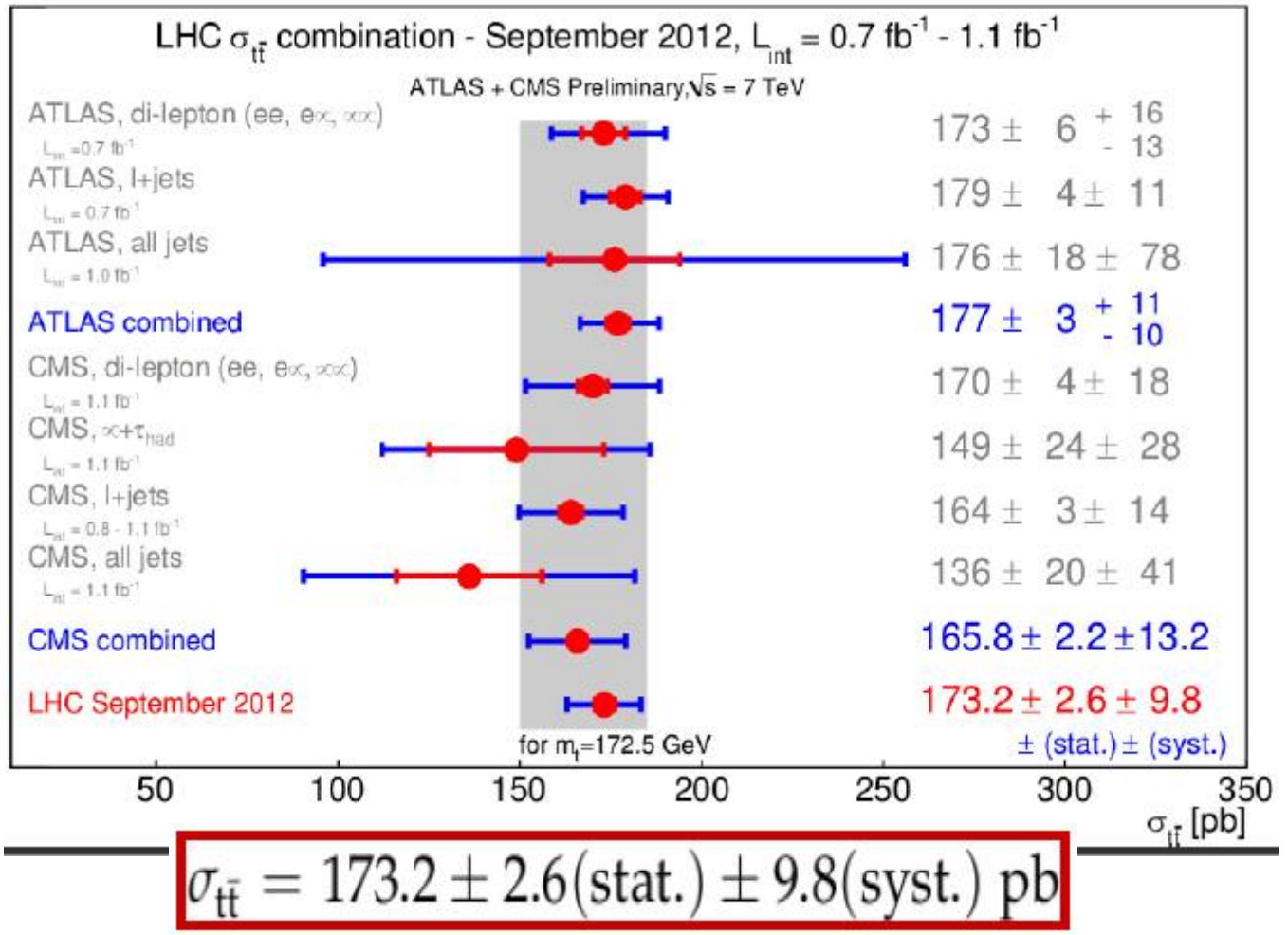
Treatment of the different uncertainties with their correlation

Total correlations between the measurements : 29%.

LHC combination @ 7 TeV

LHC combination from TOPLHCWG

Combined ttbar cross section uncertainty becomes 5.8% (around 10 pb)
=> gain about 10%.



$$\sigma_{t\bar{t}} = 173.2 \pm 2.6(\text{stat.}) \pm 9.8(\text{syst.})\ \text{pb}$$

Better results are expected with new measurements :
more statistics, better lumi. systematic,...

σ(tt) in dilepton channel (e/μ) @ 8 TeV

Luminosity = 2.4 fb^{-1}

Event Selection :

- Similar to 7 TeV analysis
- Changes to be robust againts PU :
  - Change lepton isolation definition
  - Change energy correction of jets (MET)

Data driven estimations :

- Similar to 7 TeV analysis

Statistical procedure :

- Cut & count

Measurement :

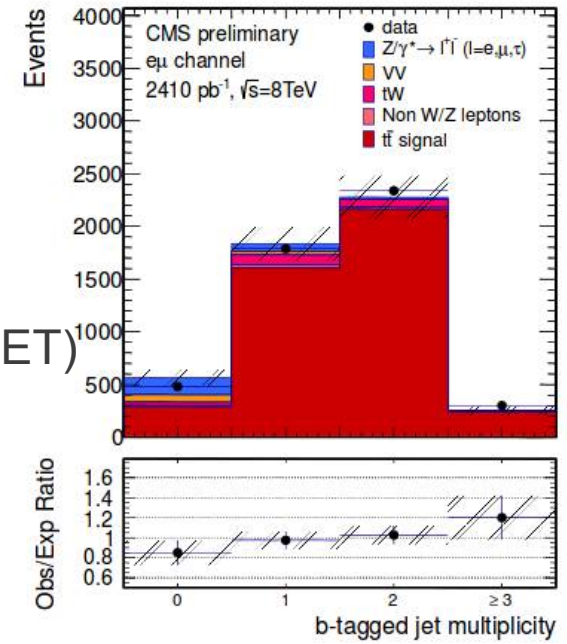
6.7 %

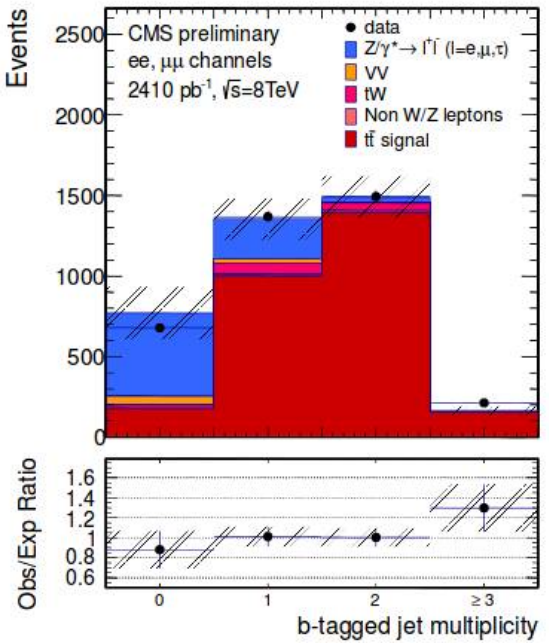
$$\sigma_{t\bar{t}} = 227 \pm 3\ (\text{stat.}) \pm 11\ (\text{syst.}) \pm 10\ (\text{lumi})\ \text{pb}$$

Systematic uncertainties :

- Dector related uncertainties increased
- Pileup uncertainty increased
- It still reach a **6.7 %** of total precision

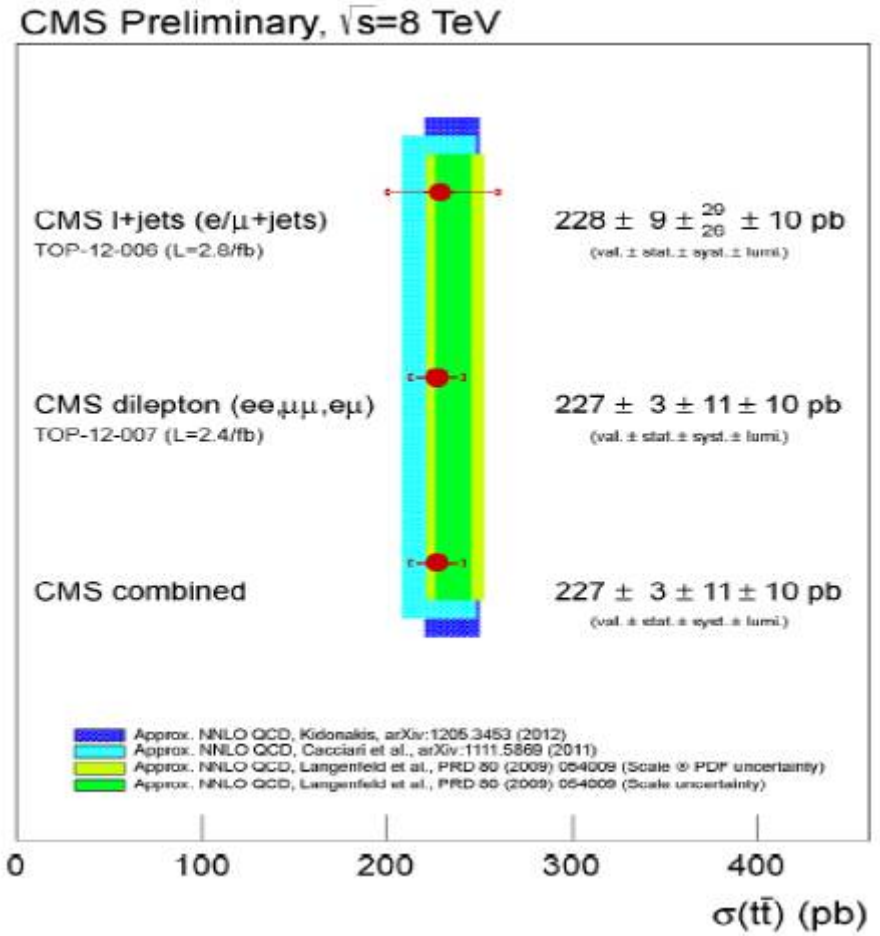
TOP-12-007





Source	Cont. to the $\sigma_{t\bar{t}}$(pb)	Cont. to the $\sigma_{t\bar{t}}$(%)
VV	0.3	0.1
Single top - tW	2.2	1.0
Non W/Z leptons	3.2	1.4
Drell-Yan	1.6	0.7
Lepton efficiencies	4.0	1.8
LES	0.7	0.3
JES	5.7	2.5
JER	3.8	1.7
B-tagging	2.0	0.9
pileup	3.3	1.5
Branching ratio	3.9	1.7
Event Q^2 scale	1.6	0.7
Matching	1.6	0.7
Total Systematic	10.7	4.7
Luminosity	10.0	4.4
Statistics	3.1	1.4

CMS combination @ 8 TeV

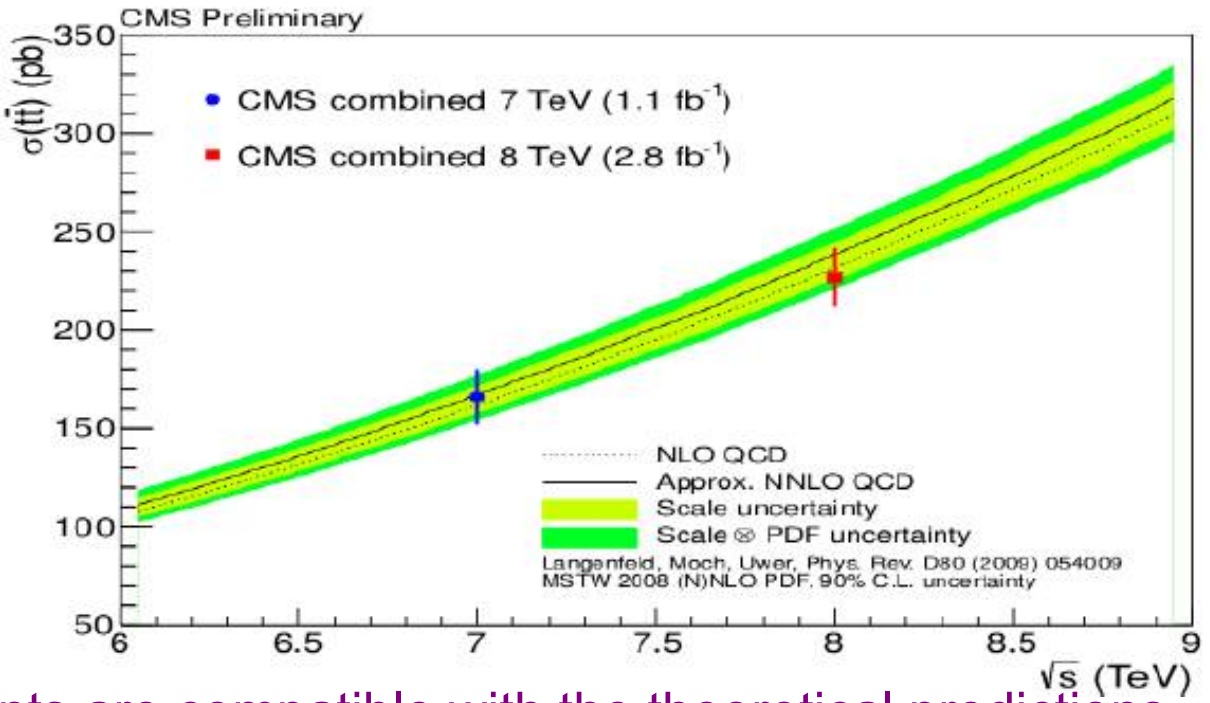


- Combination of the CMS 8 TeV measurements using a BLUE method
- Combination dominated by the dilepton channel
- Combined cross section measurement :

6.7 %

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

CMS combination @ 7 & 8TeV



- Measurements are compatible with the theoretical predictions
- Ratio of the 8TeV (combination) and 7TeV cross sections (dilepton at 2.3 pb^{-1})
  - Lot of systematic uncertainties cancel out
  - Ratio is found to be 1.41±0.10

- Dilepton channel is very pure (>90%) and allows high precision measurements
- The CMS dilepton analysis @ 7 TeV reached a very high precision: 7 pb (4.2%) => most precise top pair cross section measurement
- Despite the high multiplicity of pileup events, the CMS dilepton analysis @ 8 TeV reached a good precision: 15 pb (6.7%)