Measurement of production cross section of top quark at LHC

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PARIS

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ATLAS EXPERIMENT

CMS Compact Muon Solenoid

Outline

Motivation for the measurement of production cross section

Introduction: top production at the LHC

Selection of recent results:
- top pair:
  - inclusive and differential cross sections in dilepton and lepton + jets
  - inclusive cross section in full hadronic at 7 TeV
  - τ_h + jets at 7 TeV
  - ATLAS and CMS combination at 7 TeV
- single top
  - Wt channel at 7 TeV
  - t-channel at 8 TeV
  - R_t ratio of top and antitop in t-channel

Conclusion

Why measuring production cross section of the top quark?

The LHC gives an unprecedented sample of top quark to study.

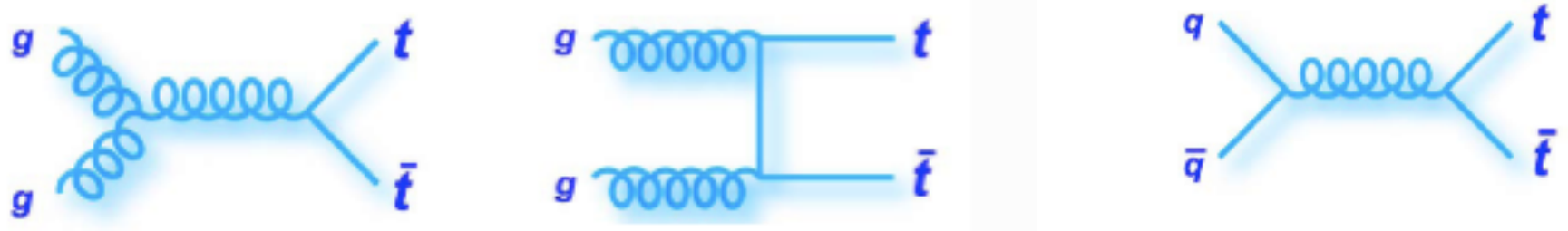
5 fb^{-1} at 7 TeV and 20 fb^{-1} at 8 TeV per experiment which correspond to 5 600 000 top pairs and 2 700 000 single top events.

This large dataset allows differential measurements, observation for difficult decay channels, associated production, besides requirements of 2 or more b tagged jets for a pure sample.

These data are analyzed for Standard Model tests, perturbative QCD measurements, new physics searches, understanding backgrounds for Higgs boson and new physics searches.
Single top production is proportional to $|V_{tb}|^2$ and is sensitive to any effect that can modify the top quark weak coupling.

Top pair production at LHC

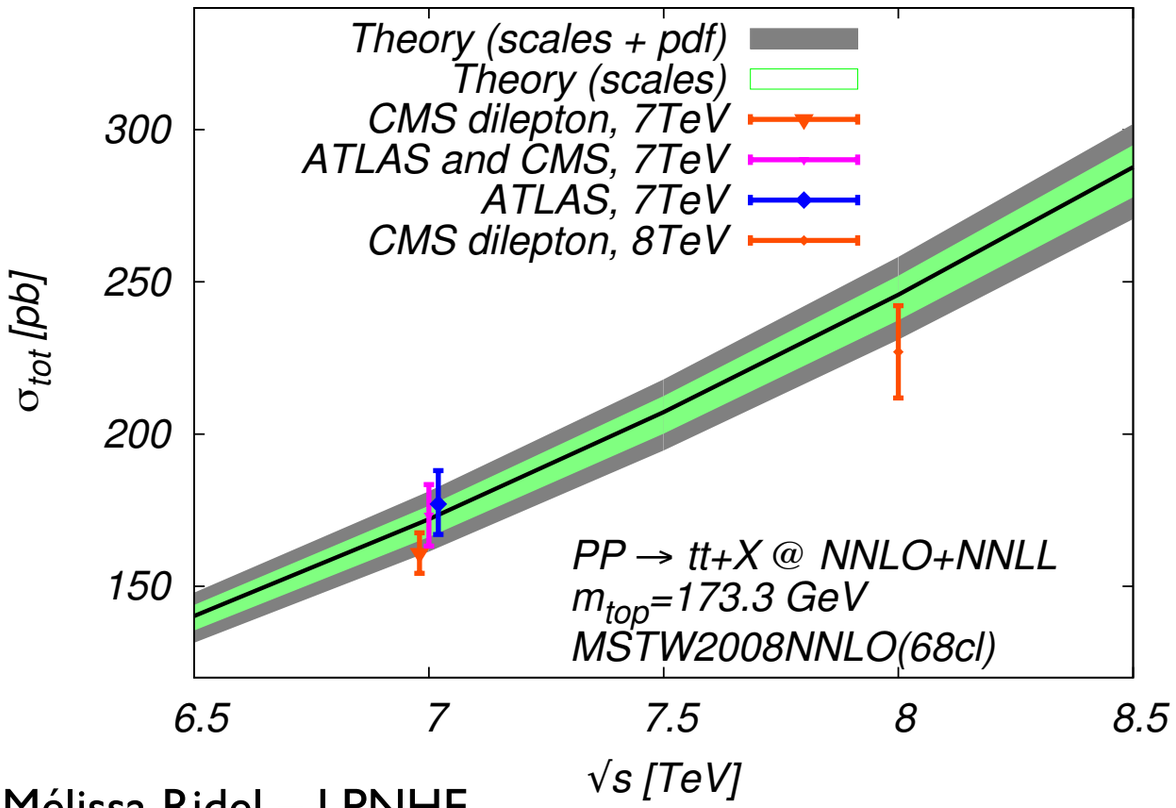
ttbar production dominated
by gluon fusion at LHC
at 7 TeV and at 8 TeV (85%)



Results presented in this talk
are compared to NNLO computation
(arXiv:1208.5578)

	LHC 7 TeV	LHC 8 TeV
$\sigma(t\bar{t})$ [pb]	$163^{+7}_{-5} \pm 9$	$234^{+10}_{-7} \pm 12$

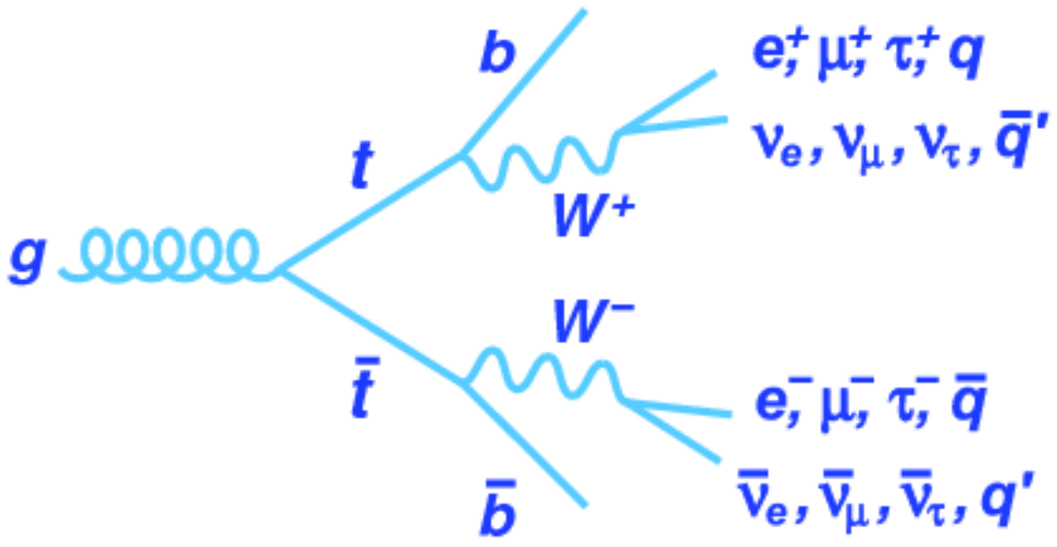
Full NNLO+NNLL are now available including NNLO correction for gg→ttbar(arXiv:1303.6254)

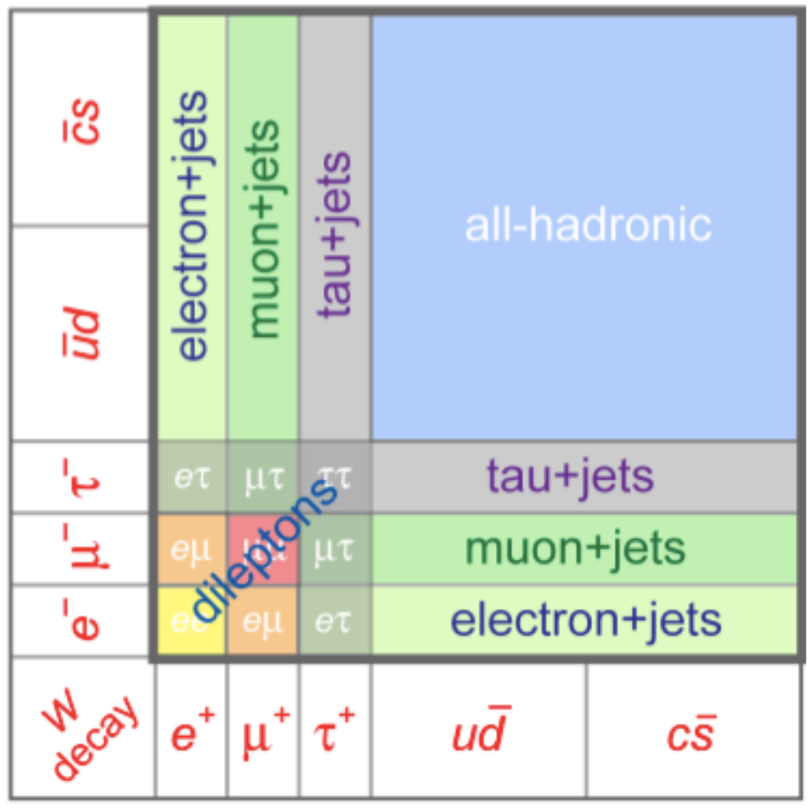


Collider	$\sigma_{\rm tot}$ [pb]	scales [pb]	pdf [pb]
Tevatron	7.164	$^{+0.110(1.5\%)}_{-0.200(2.8\%)}$	$^{+0.169(2.4\%)}_{-0.122(1.7\%)}$
LHC 7 TeV	172.0	$^{+4.4(2.6\%)}_{-5.8(3.4\%)}$	$^{+4.7(2.7\%)}_{-4.8(2.8\%)}$
LHC 8 TeV	245.8	$^{+6.2(2.5\%)}_{-8.4(3.4\%)}$	$^{+6.2(2.5\%)}_{-6.4(2.6\%)}$
LHC 14 TeV	953.6	$^{+22.7(2.4\%)}_{-33.9(3.6\%)}$	$^{+16.2(1.7\%)}_{-17.8(1.9\%)}$

Top pair channels

top pairs are identified through top decay: t→Wb at 100% in the standard model





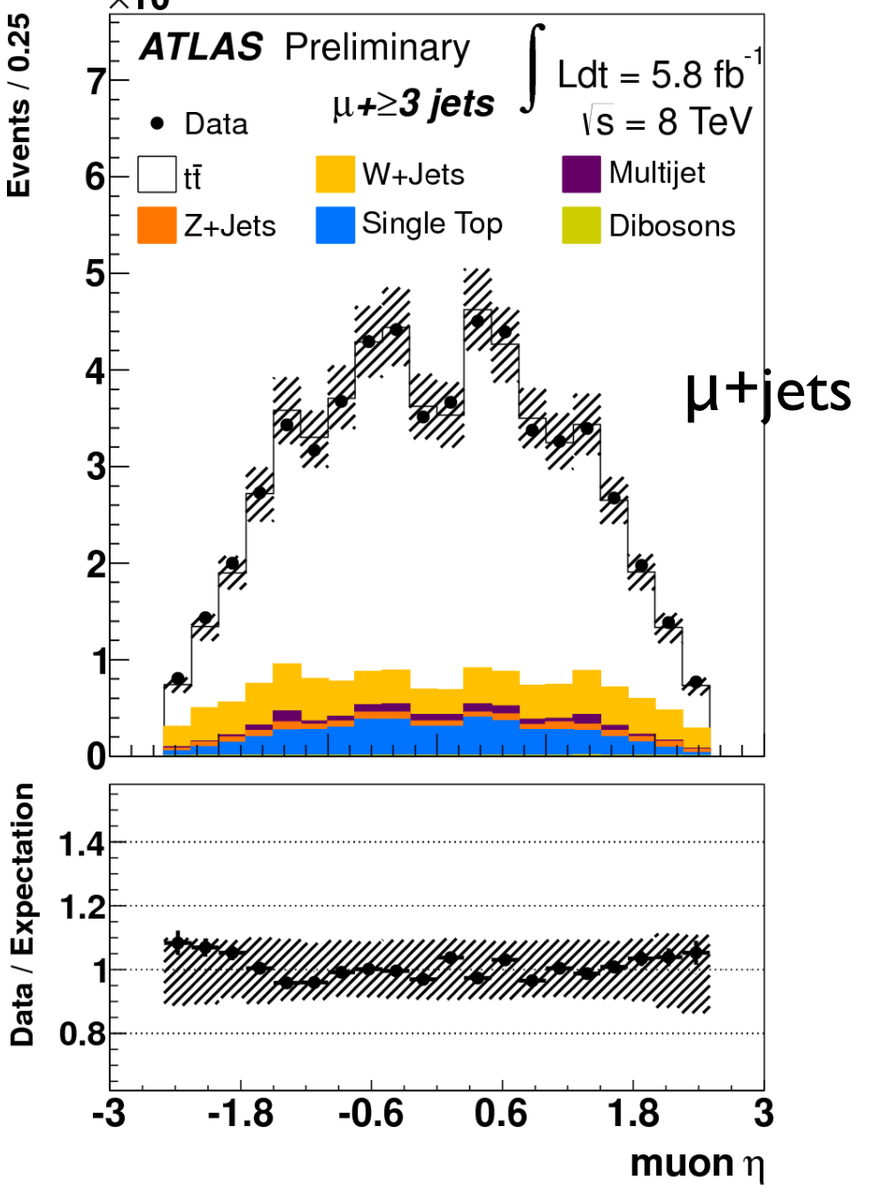
Single lepton (e/μ) + jets = 34.3%
Dilepton (ee / eμ / μμ) = 6.4%
All-hadronic light jets = 45.7%
τ + jets (hadronic τ + light jets) = 9.8%
τ + lepton (hadronic τ + (e/μ)) = 3.7%

ATLAS and CMS have measured the ttbar cross section in all final states except hadronic τ + hadronic τ + jets

Inclusive σ(ttbar) measurements at LHC at 8 TeV in lepton + jets channel

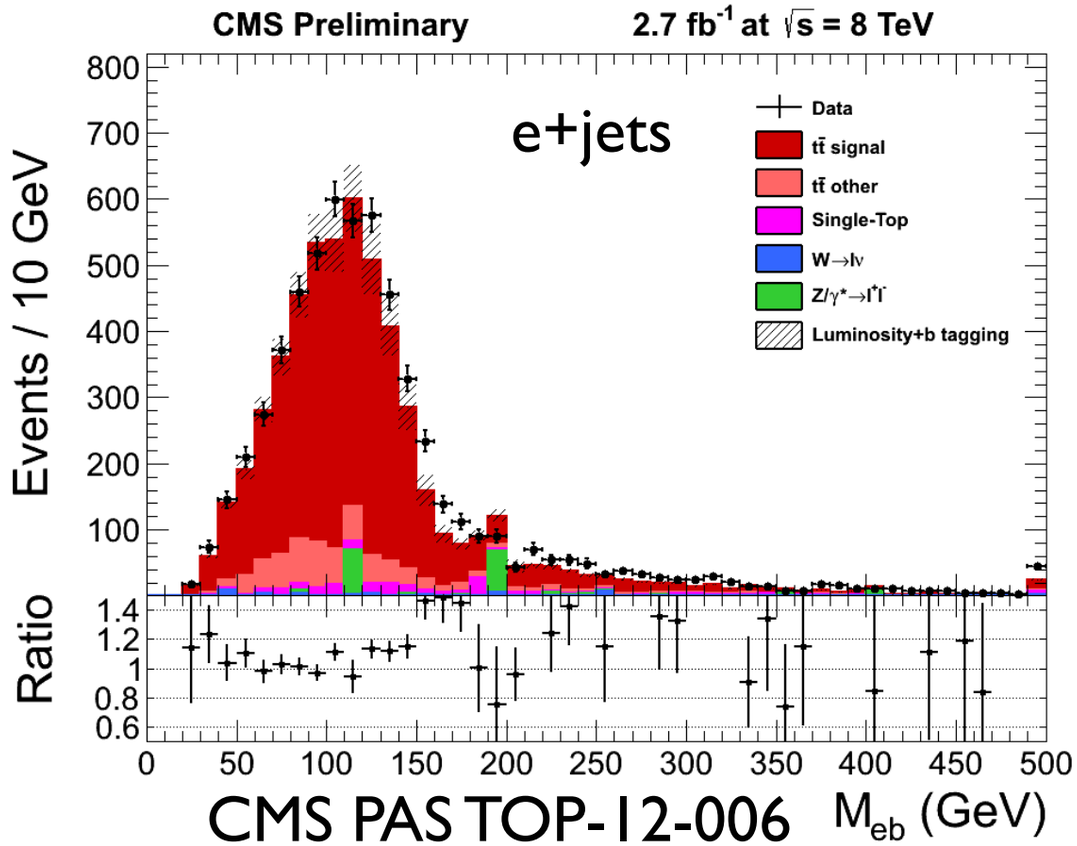
Very generic selection: one isolated lepton, 4 jets, 1 b-jet and missing E_T

ATLAS-CONF-2012-149



μ+jets

σ(ttbar) = 241±2(stat)±31(syst)±9(lumi)pb



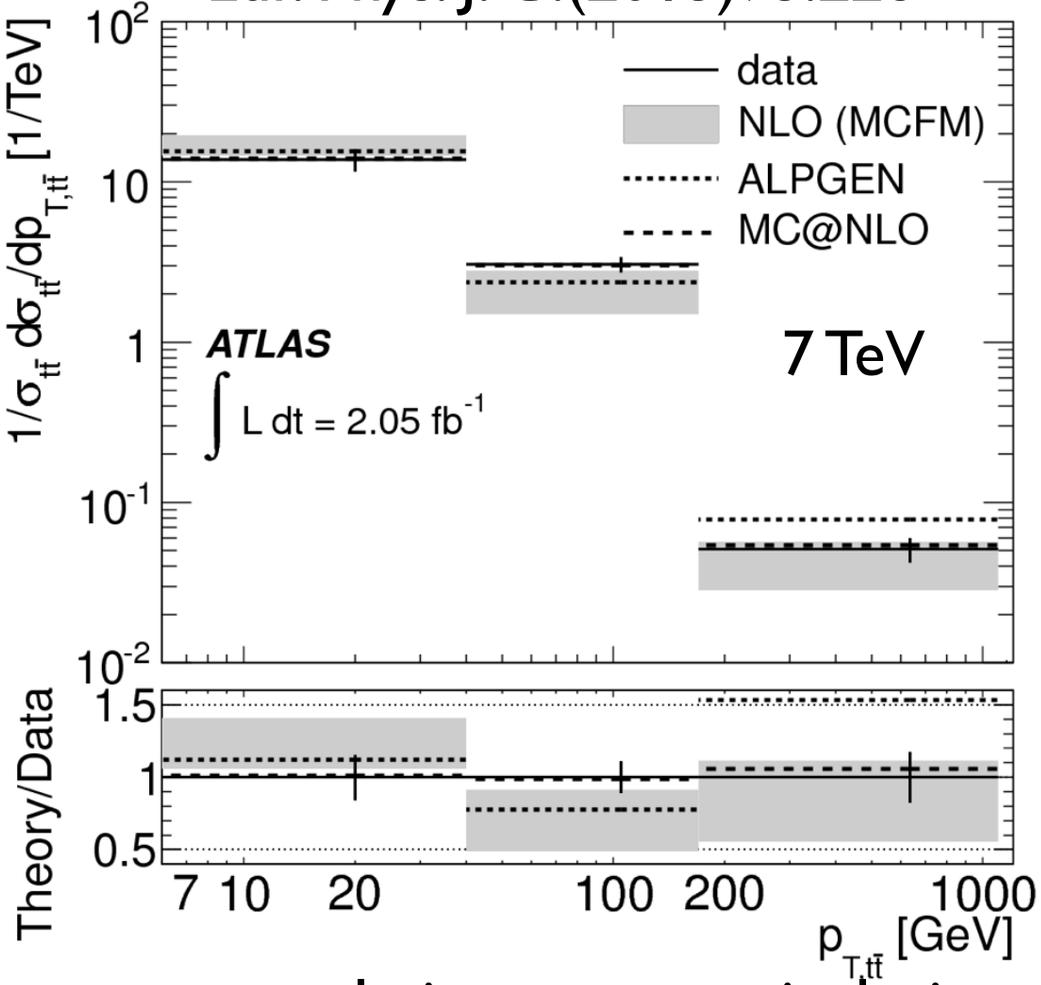
CMS PAS TOP-12-006

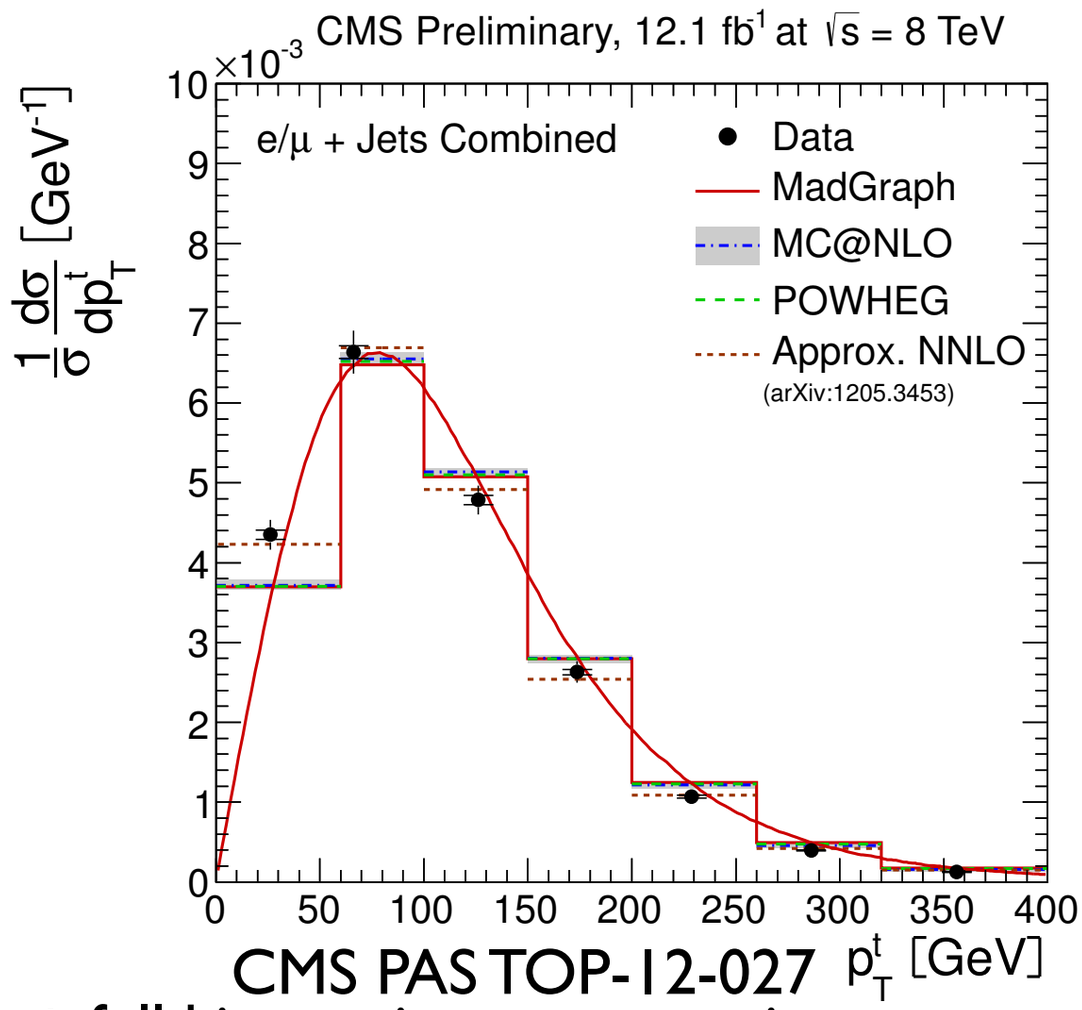
$\sigma(\text{ttbar}) = 228.4 \pm 9(\text{stat})^{+29}_{-26}(\text{syst}) \pm 10(\text{lumi})\text{pb}$

both analysis have 13% errors
ATLAS main systematics: MC modeling, JES
CMS main systematics: JES, b tagging efficiency
excellent data/MC agreement

Differential σ(ttbar) measurements at LHC in lepton + jets channel

Eur. Phys. J. C.(2013)73:226





same analysis strategy as inclusive measurements + full kinematic reconstruction

differential distribution unfolded for detector effects

ATLAS systematic uncertainty 10-20% dominated by jets and missing E_T reconstruction

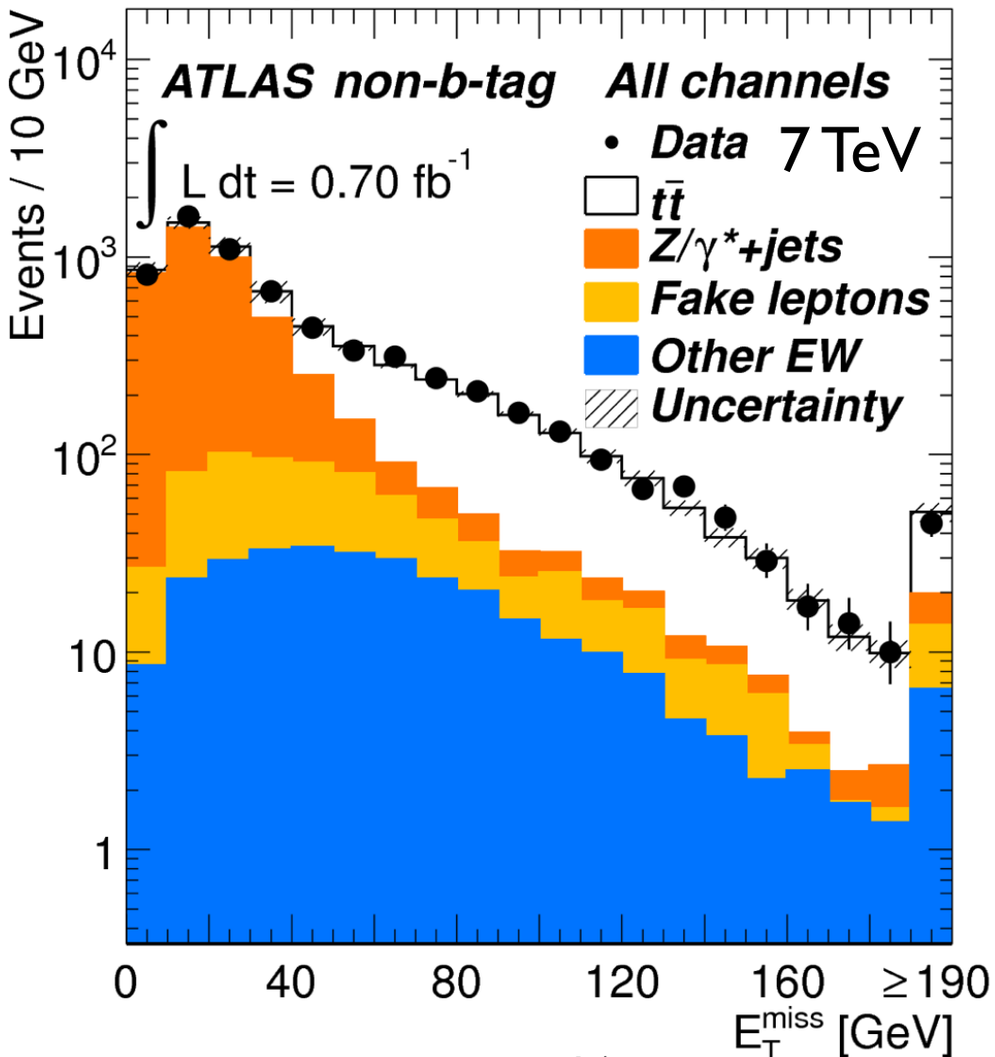
CMS systematic uncertainty 5.4% (half experimental and half modeling)

no deviation from the standard model

good agreement with generators

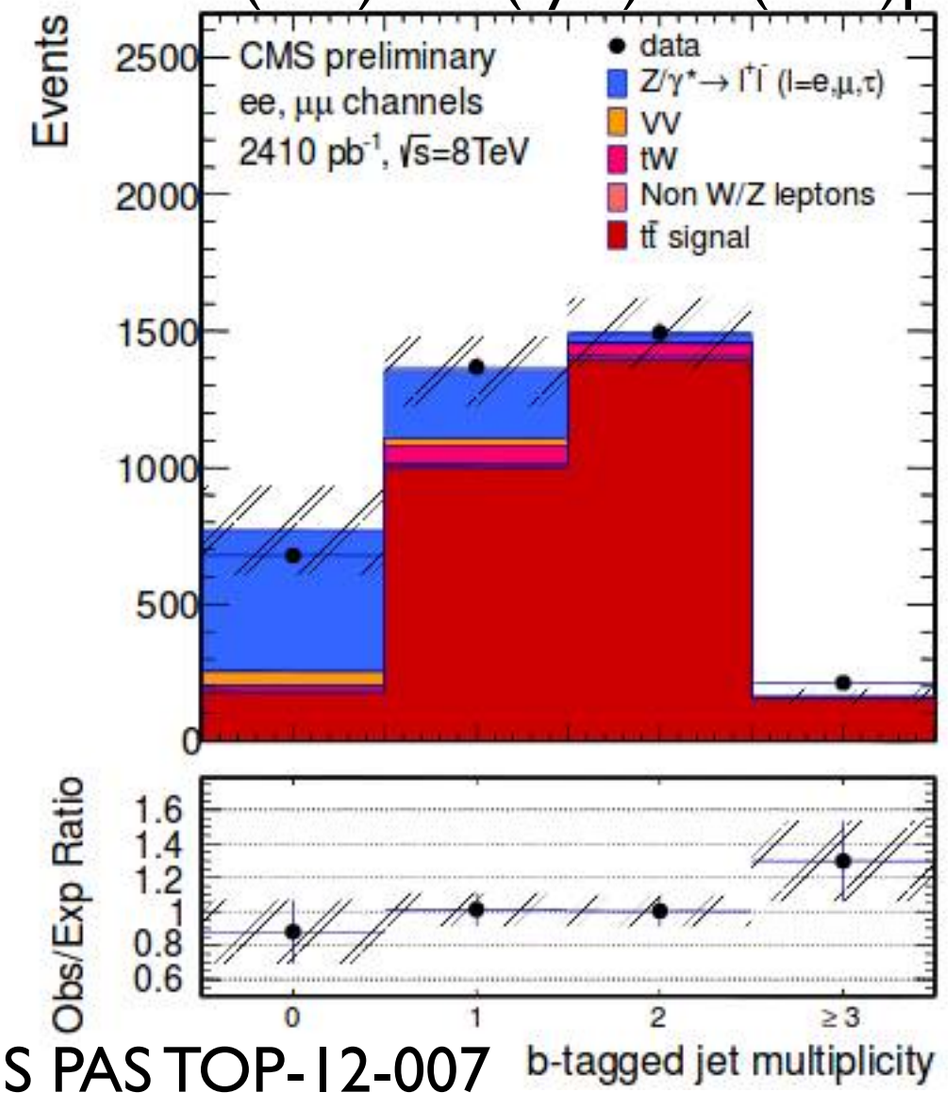
Inclusive σ(ttbar) measurements at LHC in dilepton channel

JHEP1205(2012)059



σ(ttbar) = 176±5(stat)$^{+14}_{-11}$(syst)±8(lumi)pb

σ(ttbar) = 227±3(stat) ±11(syst)±10(lumi)pb

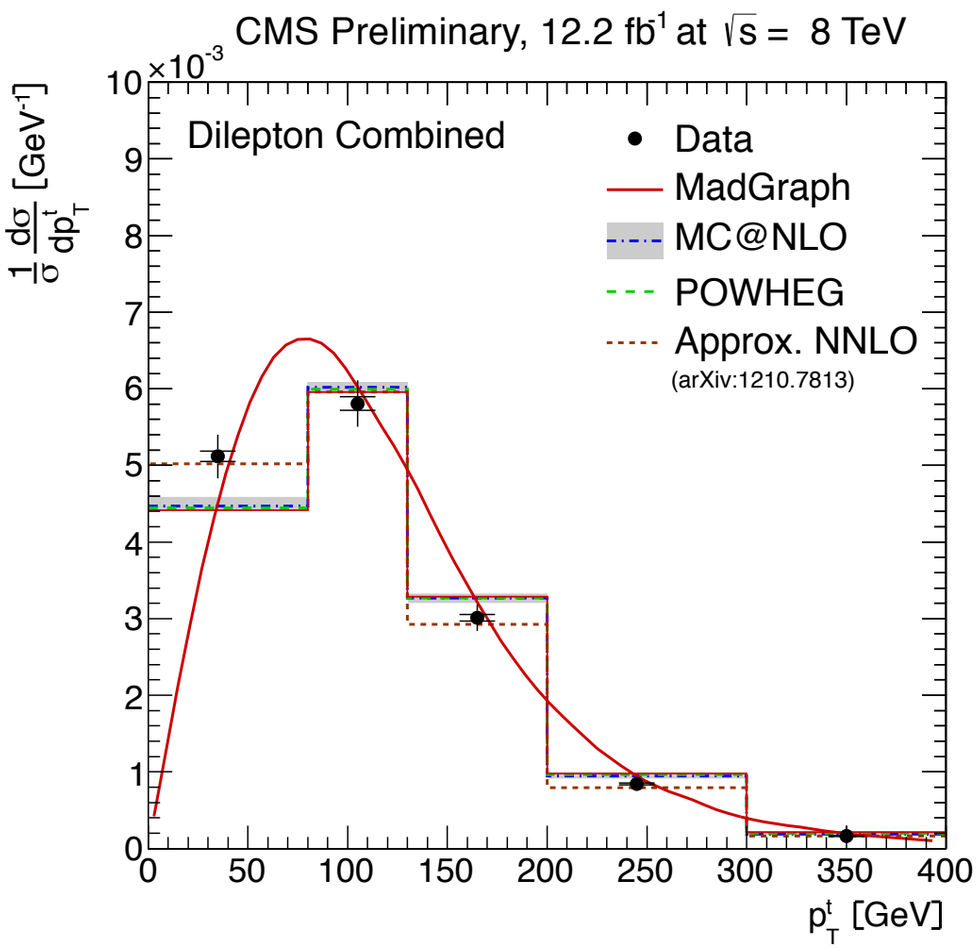


CMS PAS TOP-12-007

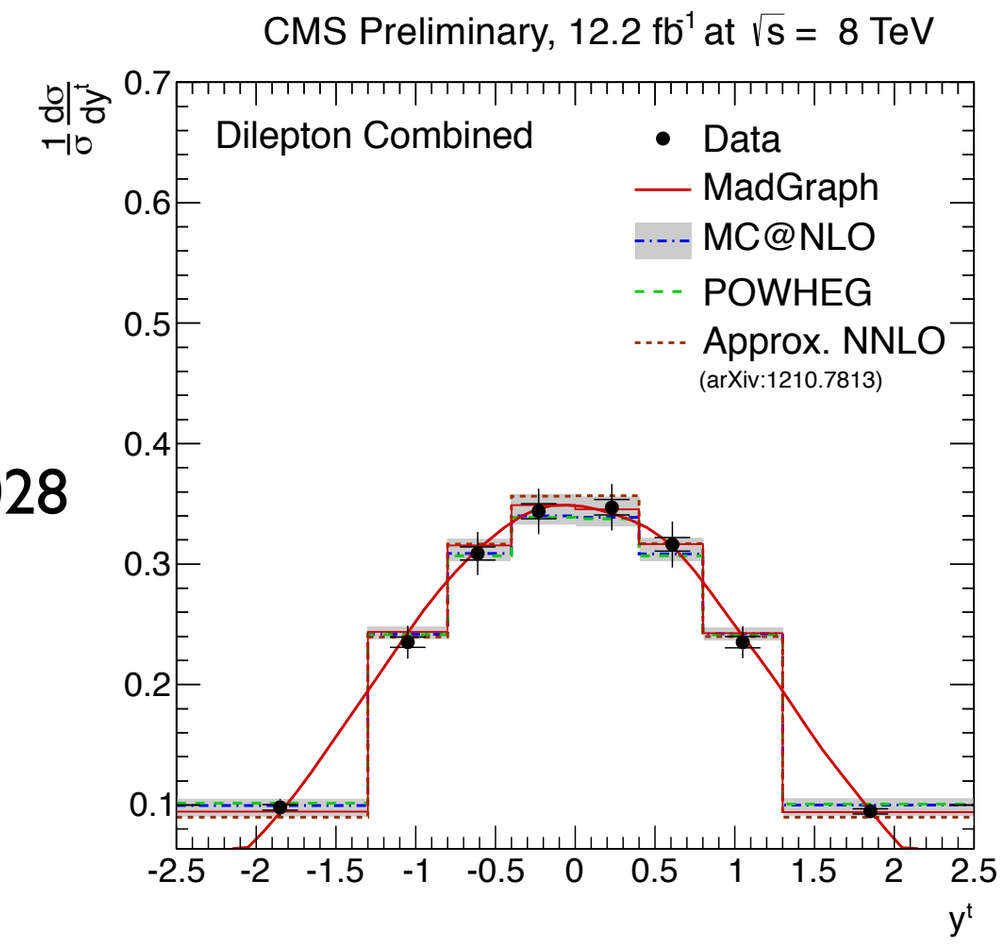
CMS at 7 TeV:
σ(ttbar) = 161.9±2.5(stat) ±5.1(syst)±3.6(lumi)pb

2 isolated leptons, 2 jets with one b-tag jet and missing E_T
overall precision 9% for ATLAS and 6.7% for CMS
ATLAS main systematics: 4% from jets/missing E_T, 5% from generator
CMS detector and pileup related uncertainties increased compared to 7 TeV

Differential σ(ttbar) measurements at CMS at 8 TeV in dilepton channel



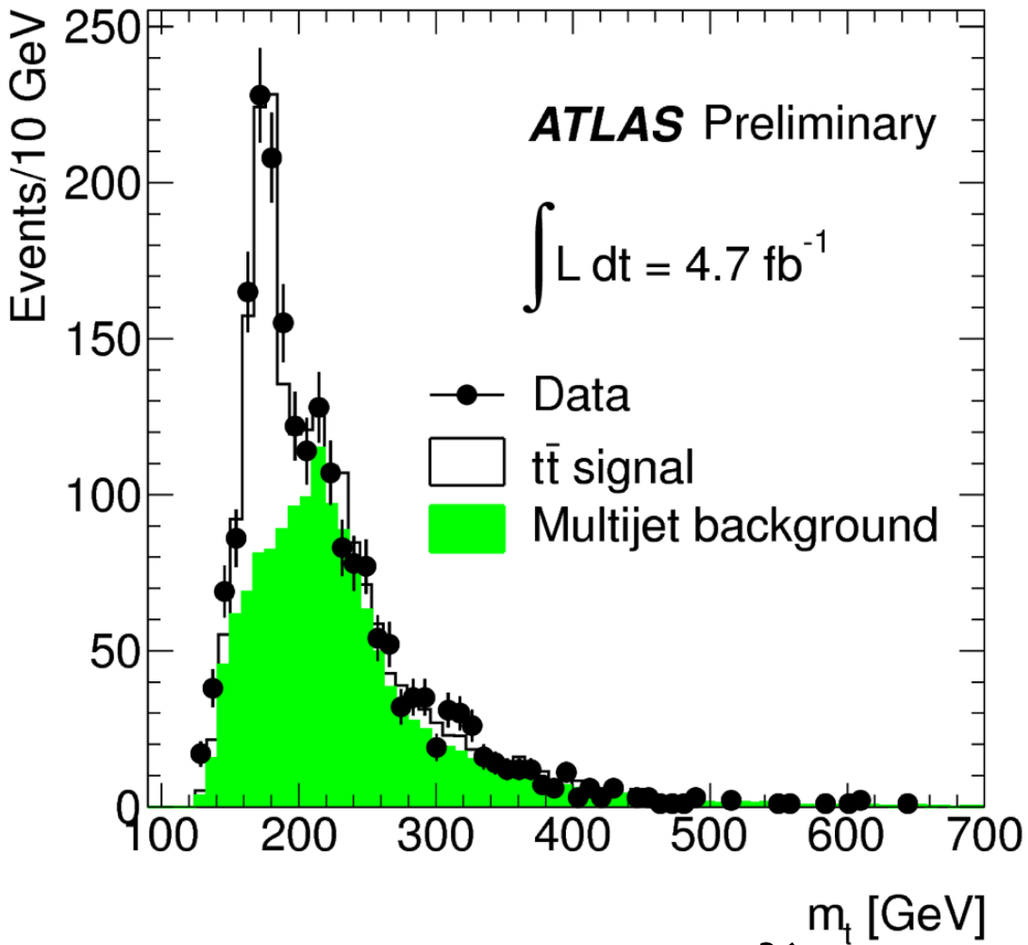
CMS PAS TOP-12-028



2 leptons, at least 2 jets and at least 1 b tag jet
an alternative kinematic reconstruction method is used for the ttbar reconstruction with a wider top mass assumption
typical systematic uncertainties 3.9% (half experimental and half modeling)

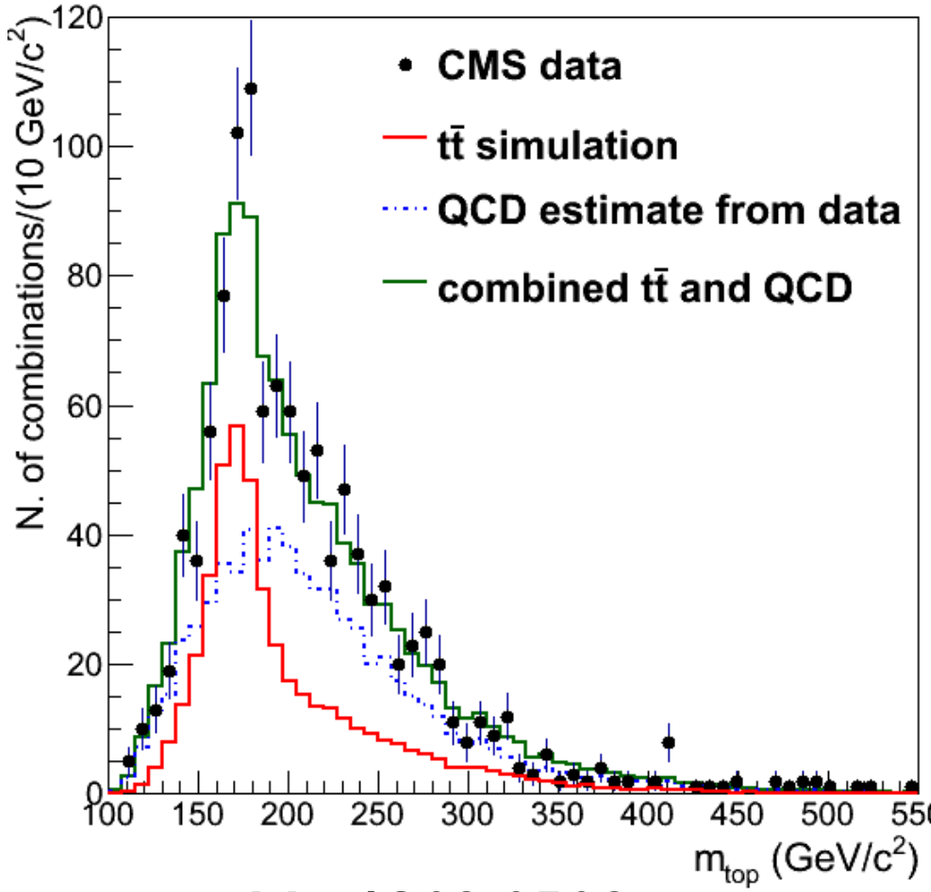
Inclusive σ(ttbar) measurements at LHC in full hadronic channel at 7 TeV

ATLAS-CONF-2012-031



$\sigma(ttbar) = 168 \pm 12(stat)^{+36}_{-34}(syst)pb$

CMS preliminary, 1.09 fb^{-1} at $\sqrt{s}$ = 7 TeV



arXiv:1302.0508

$\sigma(ttbar) = 139 \pm 10(stat) \pm 26(syst)pb$

Busy final state: 4 light jets and 2 b jets
5 jets and 2 b tag jets, different working point (60% for ATLAS and 47% for CMS)
kinematic fit
main systematics: JES, b tagging and ISR/FSR for both experiments
with differences in analysis strategies

τ_h + jets at 7 TeV

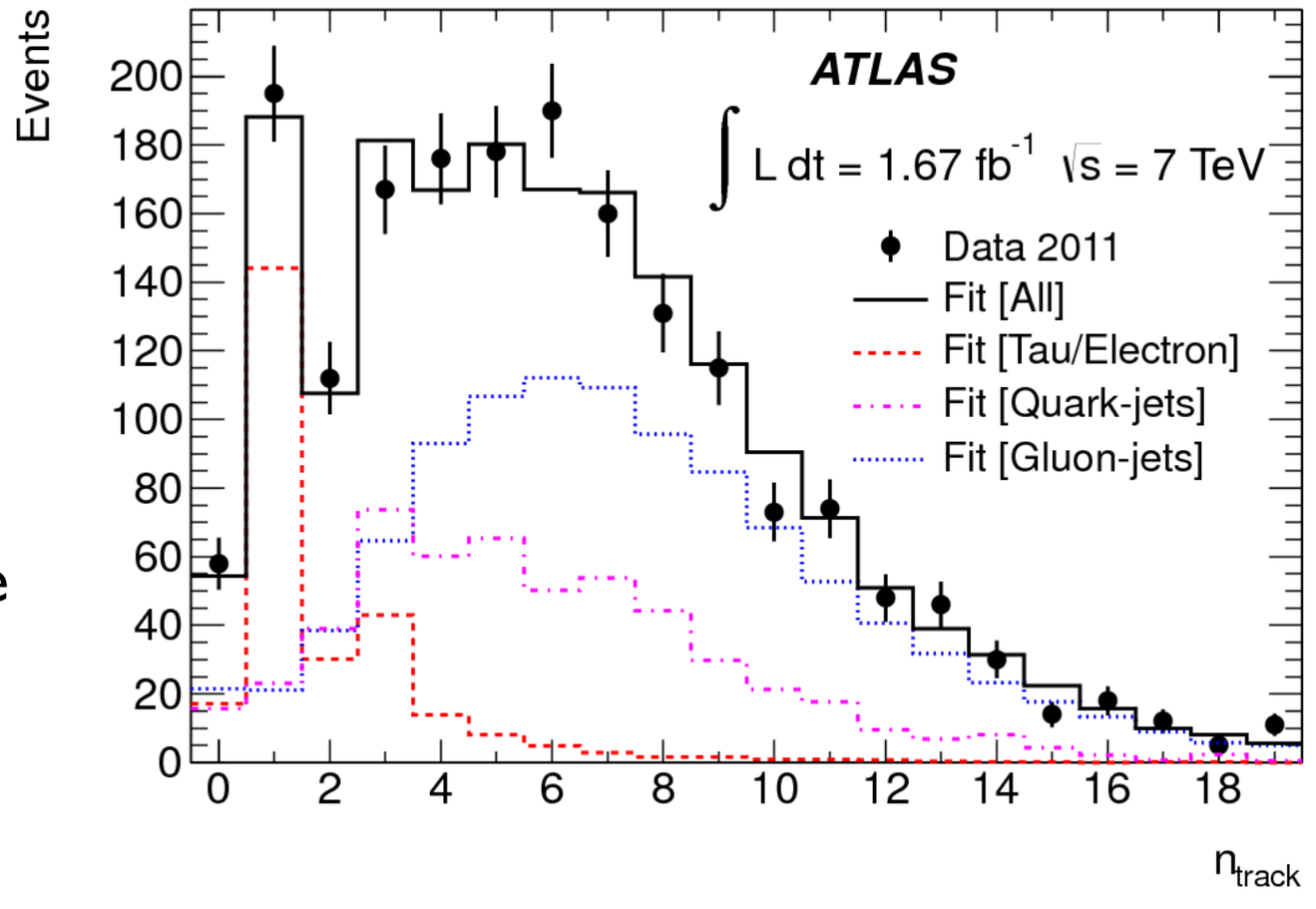
Cross section in di-lepton final states including a τ lepton already measured at the LHC:

CMS: σ(ttbar) = 143±14(stat)±22(syst)±3(lumi)pb (precision 18%)
Phys ReV D85(2012)112007
ATLAS: σ(ttbar) = 186±13(stat)±20(syst)±7(lumi)pb (precision 13%)
Phys Lett B717(2012)89-108

Largest contribution including a τ in the final state

- ATLAS analysis strategy:
trigger of at least 4 jets with 2 b jets
5 jets selection:
2 b jets, 2 jets associated with a W
and remaining jet as τ candidate
missing E_T
lepton veto

- signal extracted using a template fit to the number of tracks associated to the τ candidate (relaxed cut on the number of tracks to identify the τ (1 or 3) in this plot)

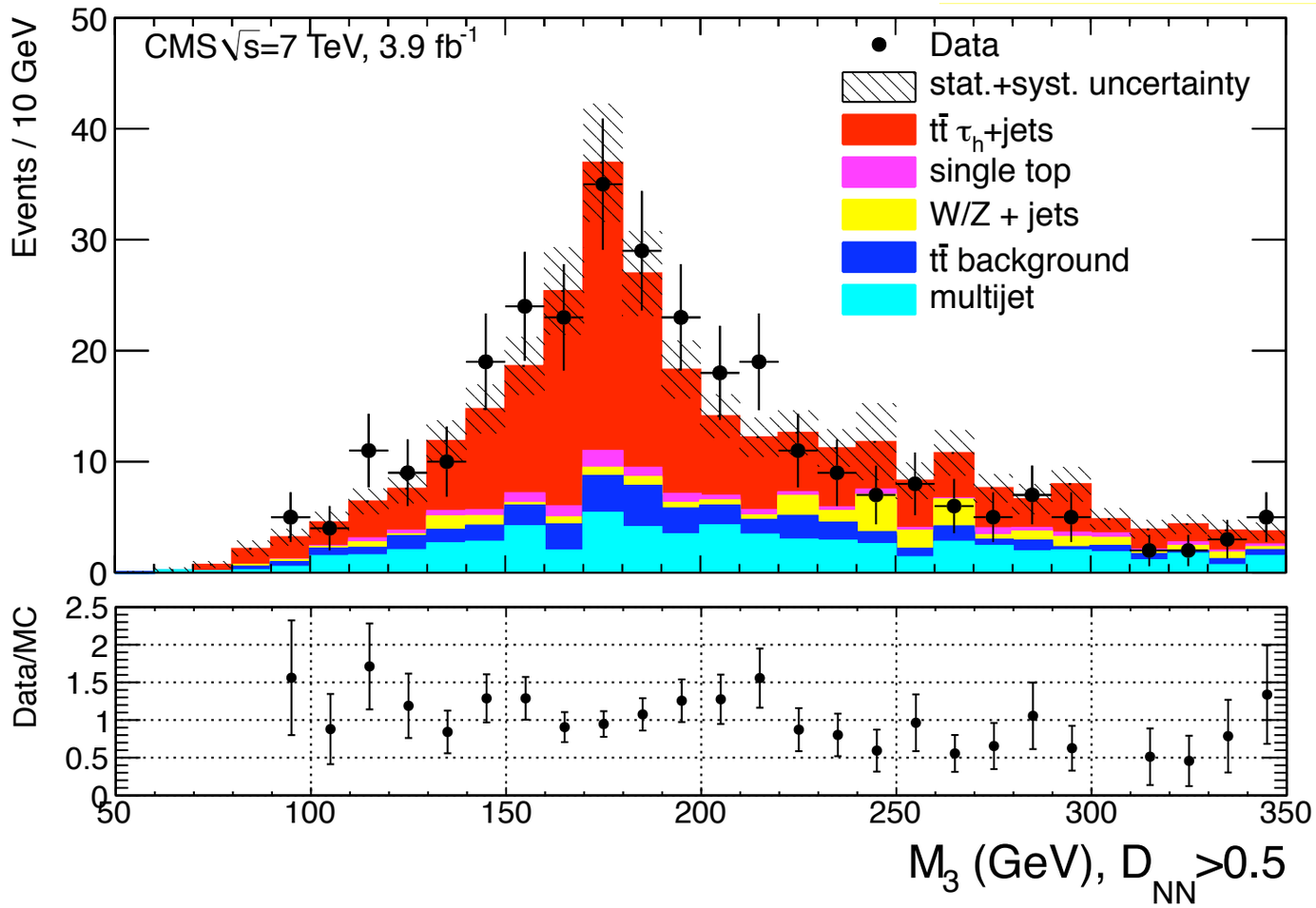


τ_h + jets at 7 TeV (2/2)

- CMS analysis strategy
dedicated tau trigger
4 jets with at least one b jet
1 τ candidate
missing E_T
lepton veto

- signal extracted from a template fit to a NN output distribution

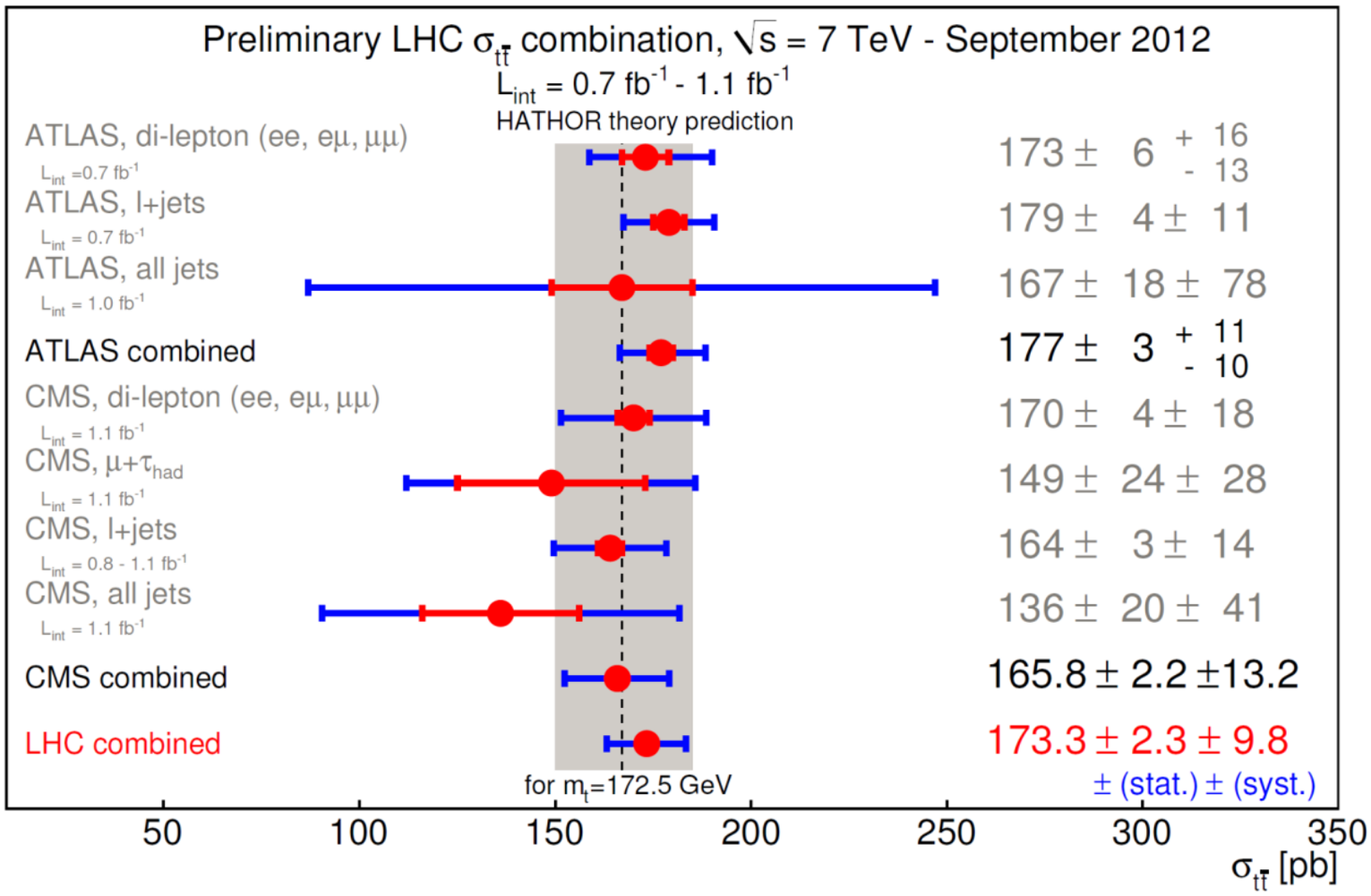
- largest uncertainties from JES, τ identification and energy scale and trigger efficiency

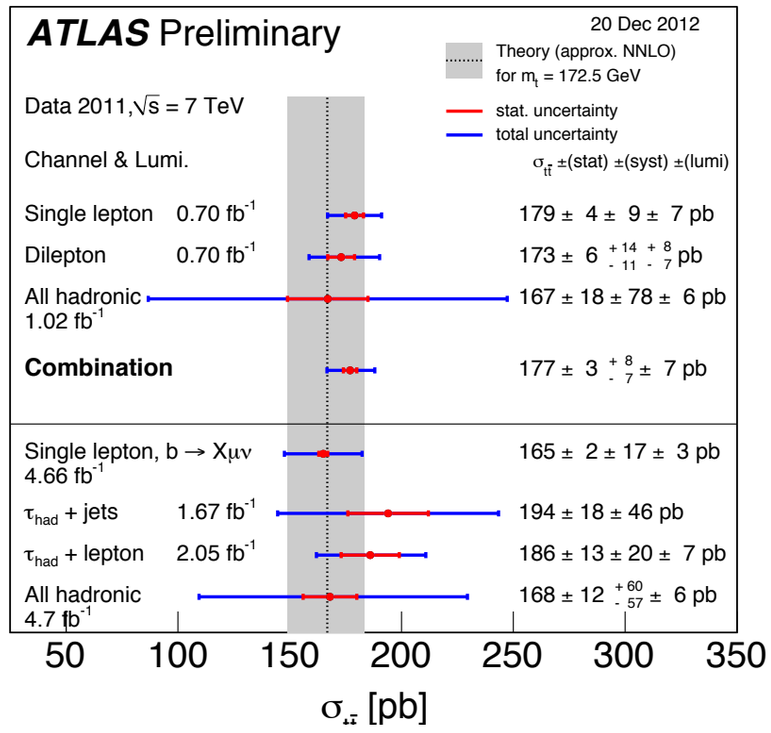


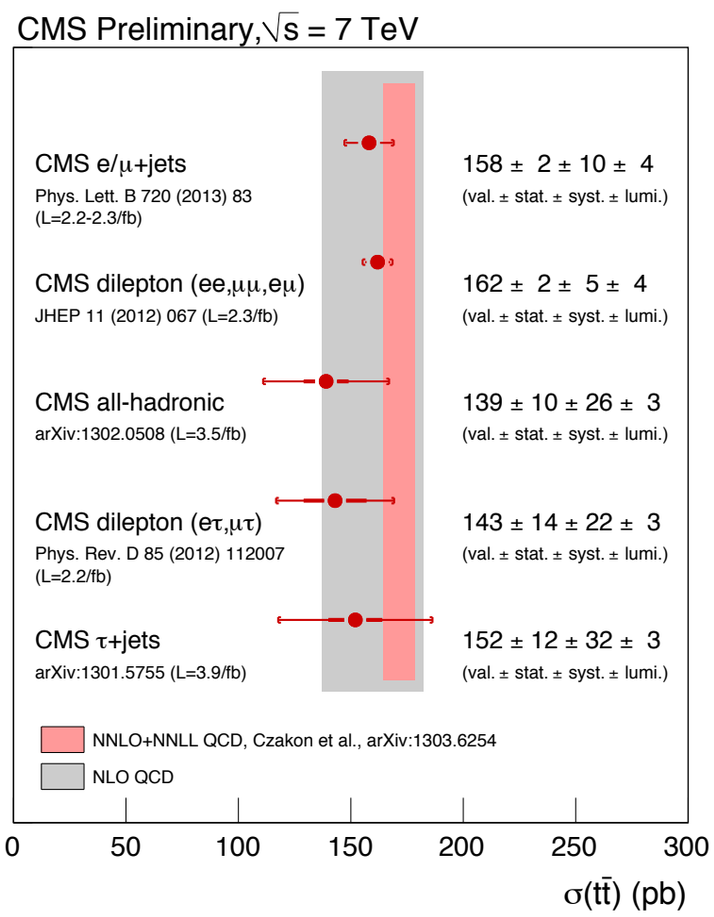
Results:
ATLAS: σ(ttbar) = 194±18(stat)±46(syst)pb (precision 25%)
EPJC 73 3(2013)2328

CMS: σ(ttbar) = 152±12(stat)±32(syst)±3(lumi)pb (precision 22%)
arXiv:1201.5755

Inclusive σ(ttbar) measurements at LHC at 7 TeV







σ_{ttbar} at 7 TeV: ATLAS and CMS combination

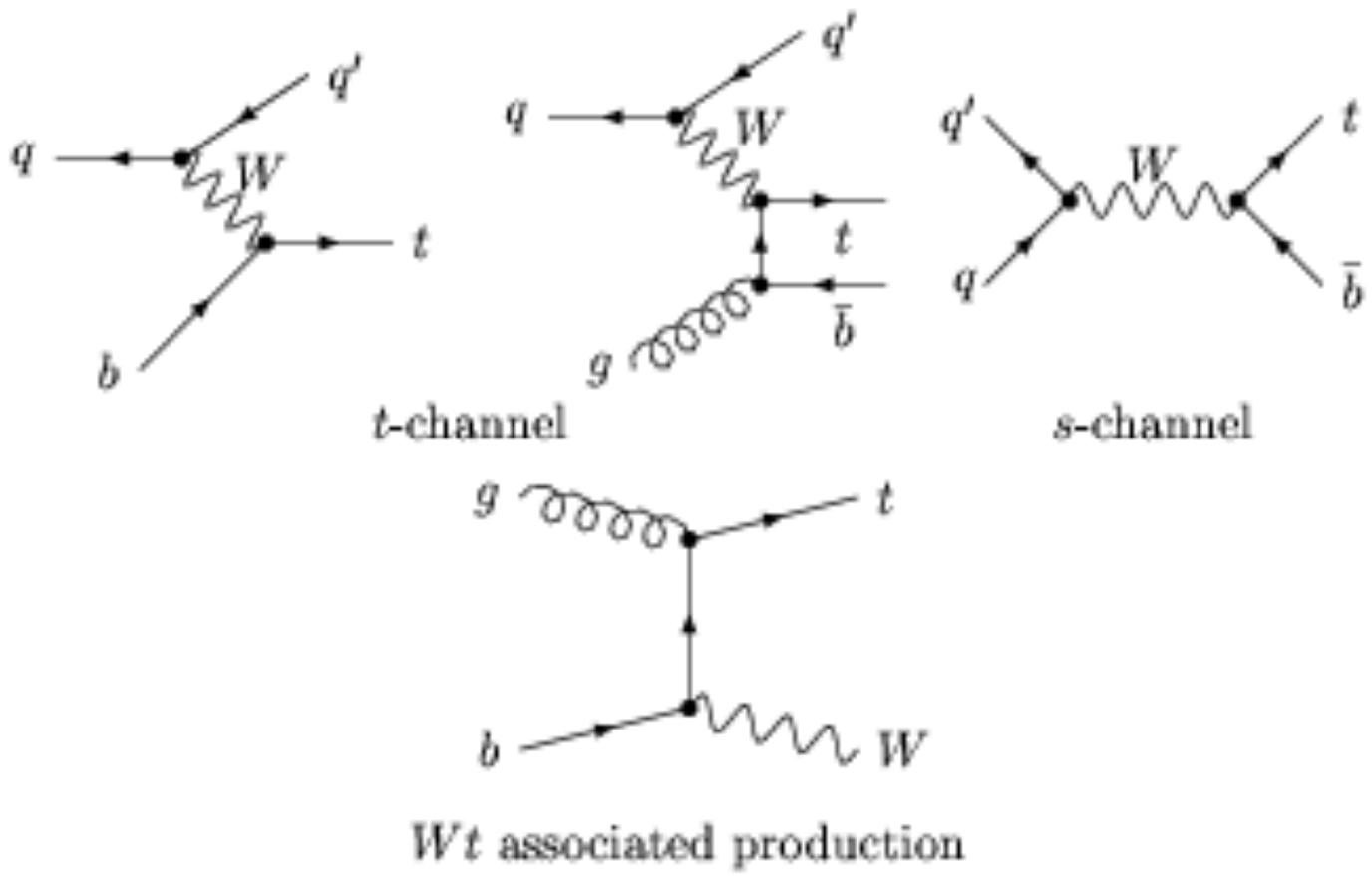
➠ total uncertainty of 5.8%

ATLAS-CONF-2012-134

and CMS PAS TOP-12-003

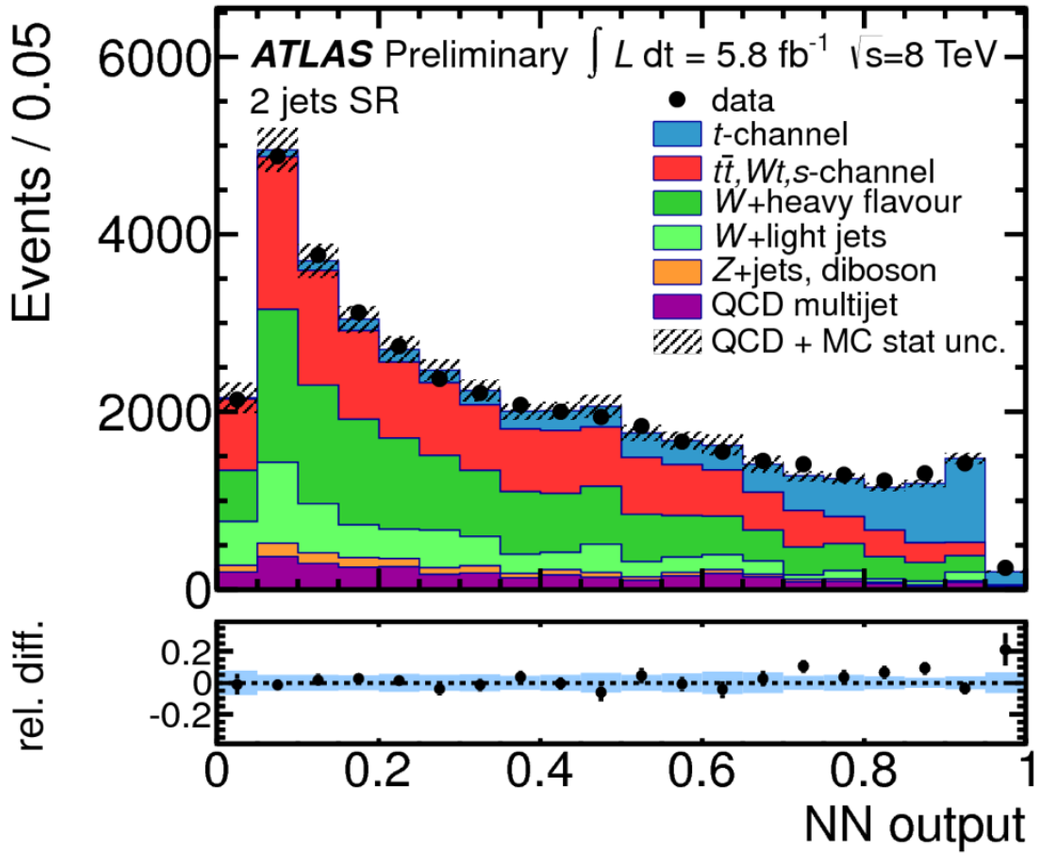
Single top production at LHC

Electroweak production of the quark top

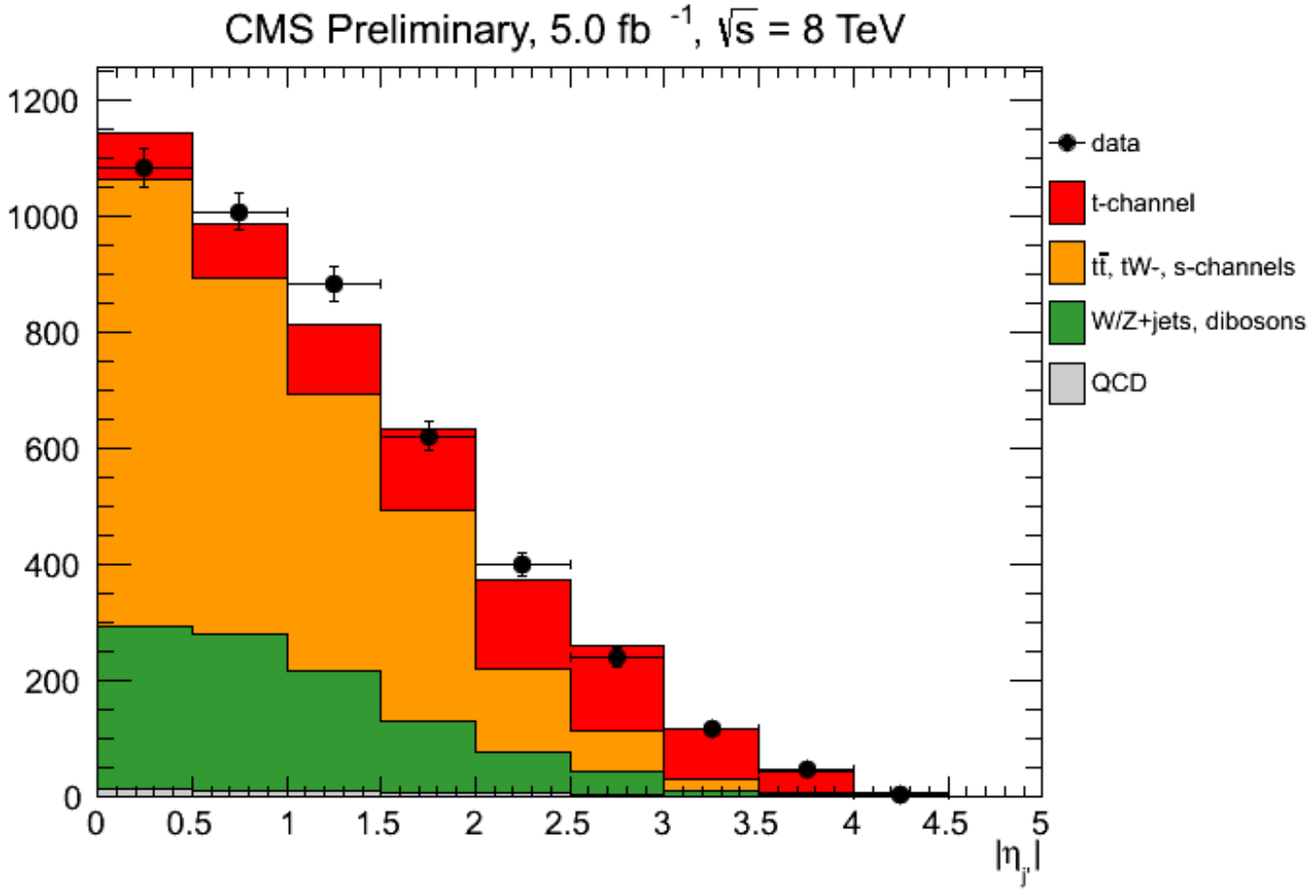


- The dominant process (t-channel) is equivalent to 1/3 of the ttbar production
σ_t = 88 pb at 8 TeV
it has been observed in 2009 at the TeVatron and in 2011 at the LHC
- Evidence of Wt at ATLAS and CMS
- The s-channel has the smallest cross section (1/15 of t-channel)
a limit is given by ATLAS
Note: the number of top and of anti-top produced is different (see slide 18)

t-channel at 8 TeV



ATLAS-CONF-2012-132



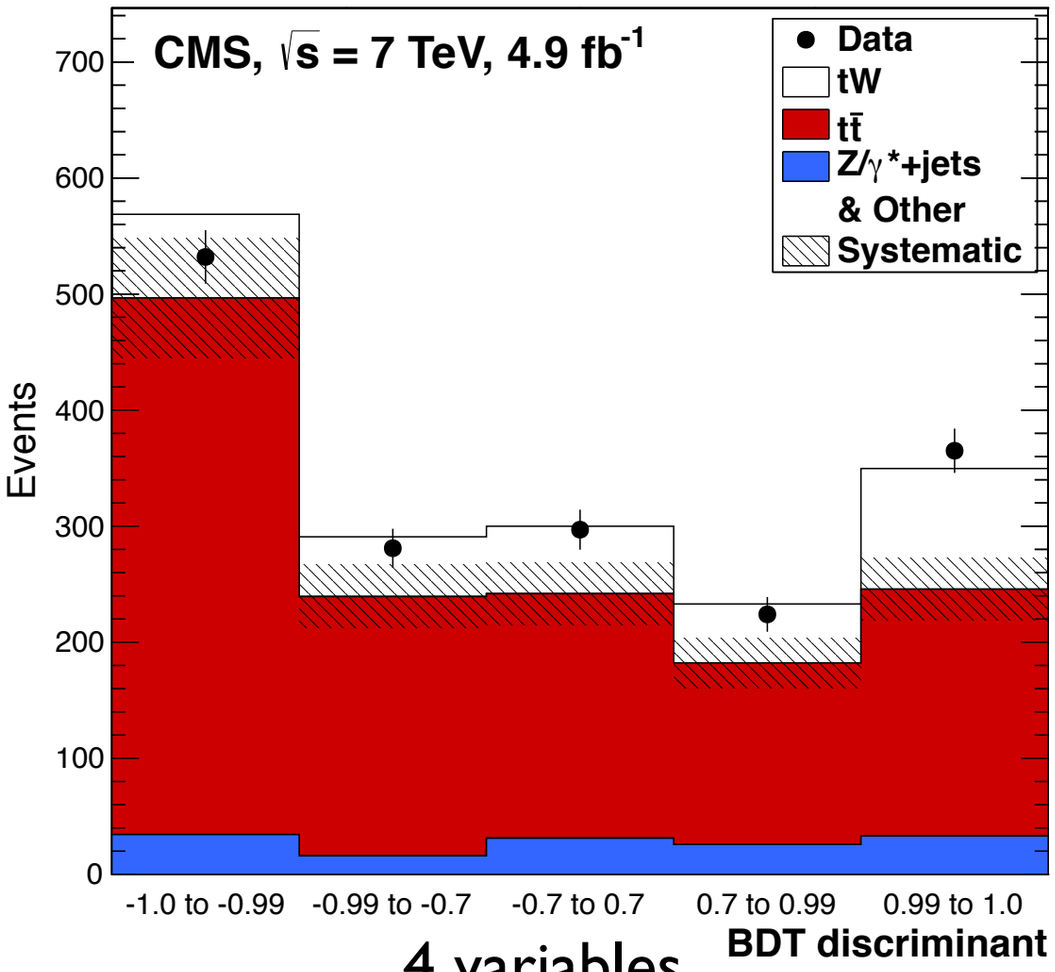
CMS PAS TOP-12-011

Selection: one lepton, missing E_T, one b jet, one recoil jet
Analysis strategies: signal extracted from a fit on a NN discriminant for ATLAS and on η distribution of the recoil jet for CMS

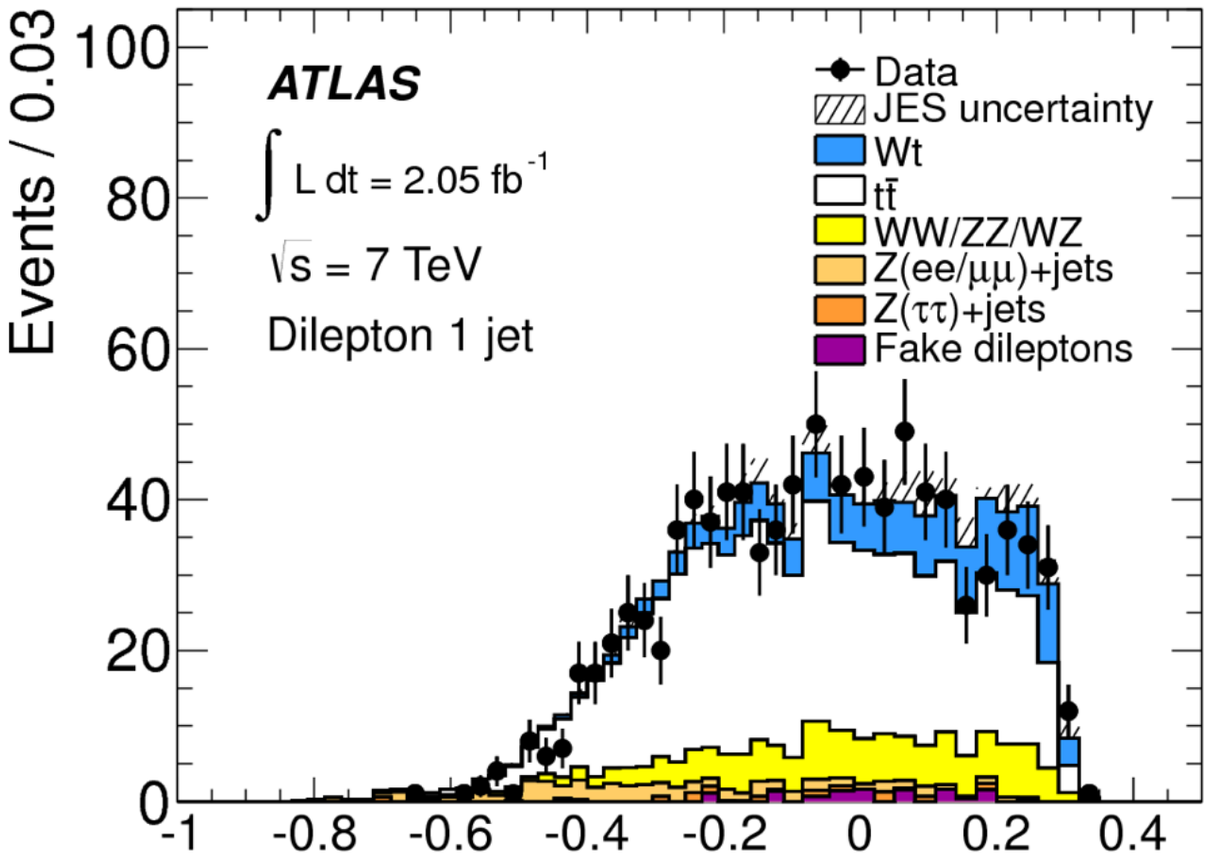
σ(t) = 95.1±2.4(stat)±18(syst)pb
19% precision
(9% IFR/FSR, 9% b-tag, 8% JES, 7% generators)

σ(t) = 80.1±5.7(stat)±11(syst)±4(lumi)pb
16% precision
(8% JES, 6% generators, 5% muon, 5% b-tag, 5% PDF)

Wt channel at 7 TeV



4 variables



22 variables

CMS: Phys Rev Lett 110(2013)022003

ATLAS: Phys Lett B716(2012)142-159

Selection: 2 leptons, missing E_T, 1 b jet

Signal extraction: simultaneous fits of BDT outputs in different jet-bin regions

First evidence from ATLAS with 2 fb^{-1} and confirmation from CMS with more statistics

ATLAS:

$\sigma(t) = 16.8 \pm 2.9(stat) \pm 4.9(syst)pb$ (precision 34%)

measurement signifiance: 3

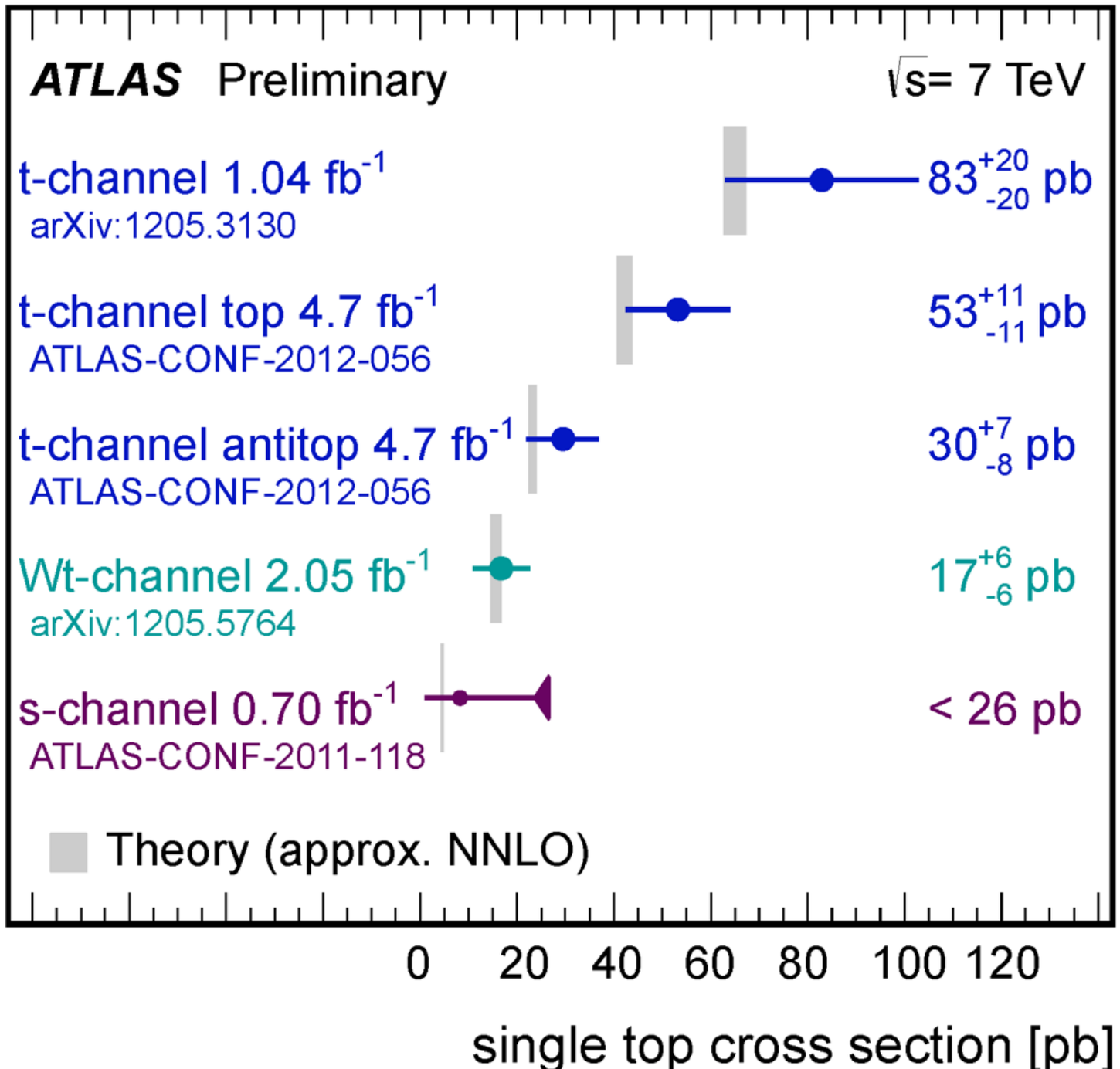
CMS:

$\sigma(t) = 16^{+5}_{-4}pb$ (precision 31%)

4 σ

main systematics from JES and parton shower

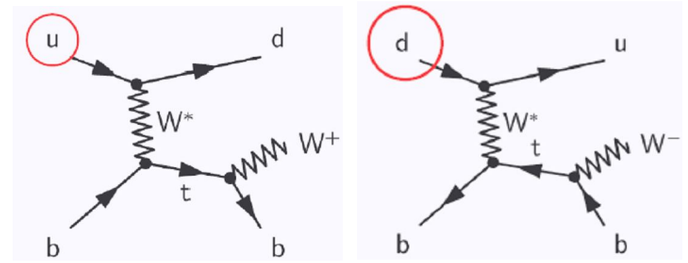
Single top cross section measurements with ATLAS

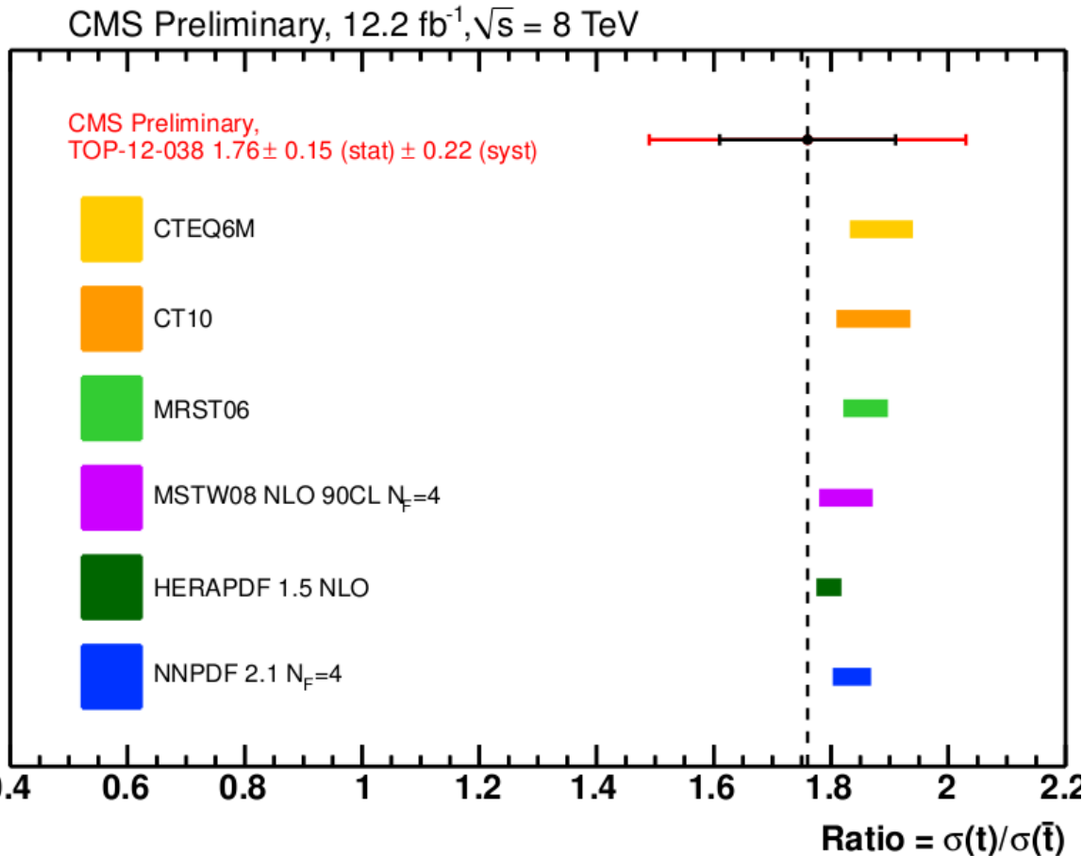


Comparison of the different ATLAS measurements in single top production with the theoretical prediction

R_t ratio of top and antitop in t-channel

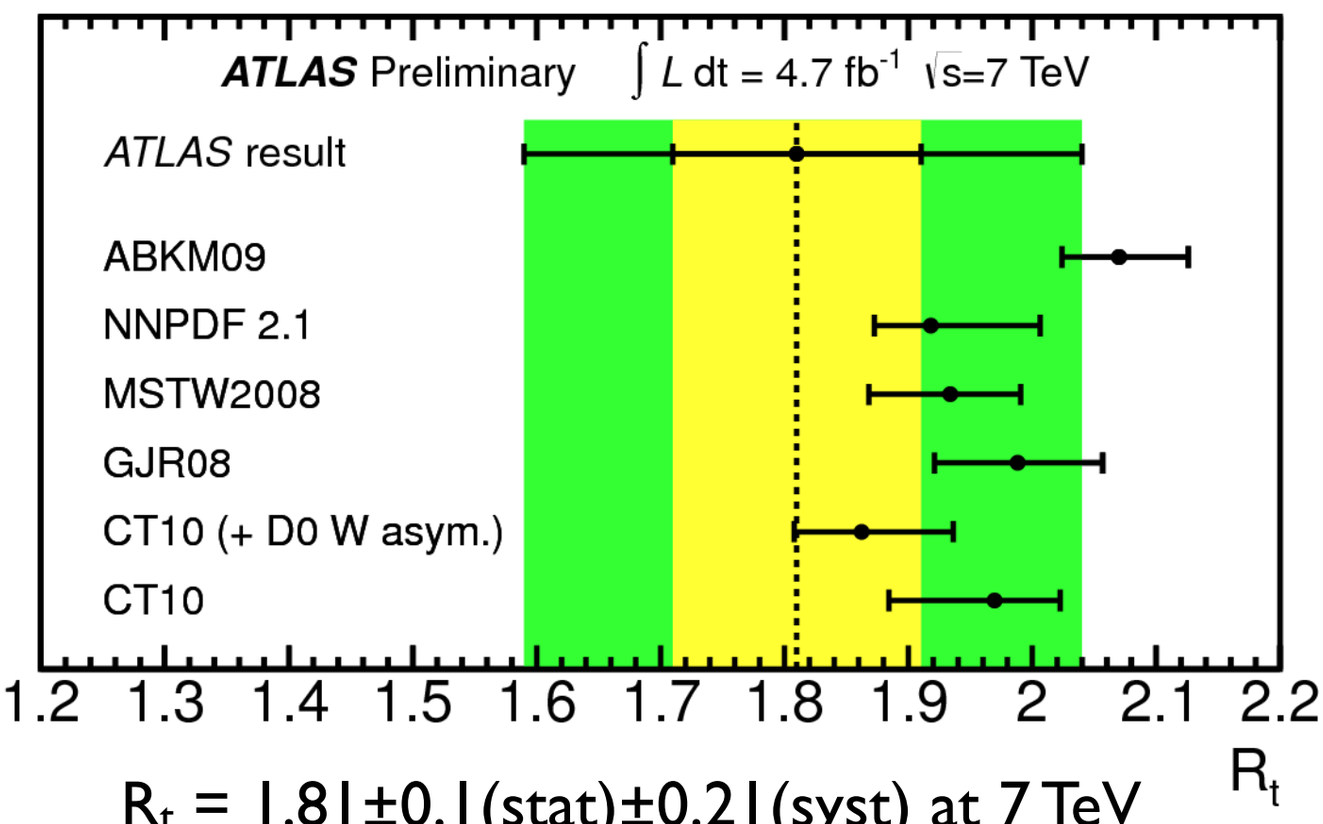
R_t is sensitive to u/d PDF





R_t = 1.76±0.14(stat)±0.21(syst) at 8 TeV

CMS PAS TOP-12-038



R_t = 1.81±0.1(stat)±0.21(syst) at 7 TeV

ATLAS-CONF-2012-056

Analysis strategies:
fit to NN outputs for l^+ and l^- for ATLAS and fit to η of the recoil jets for l^+ and l^- for CMS
both results agree with standard model prediction

Conclusions

Many top measurements from 7 TeV 5 fb^{-1} of data, and further statistics of 8 TeV data
- first LHC σ(ttbar) combination and ongoing work to uniformize the systematics estimates.
- improved σ(ttbar) and σ(t) measurements

ATLAS and CMS have measured the top pair cross sections in many channels.

Large statistics of the LHC sample allows to perform more detailed top measurements (differential cross sections or R_t measurement in t-channel single top for example).

Excellent agreement data/MC and cross section measurements in very good agreement with approx. NNLO calculations.

Better understanding of QCD in ttbar final states through differential measurements.

Only a subset of ATLAS and CMS results have been shown here, please have a look at the experiment public pages for a full list of the top quark publications.

More detailed and interesting top results to come.