$t\bar{t}$ cross section measurements at LHC

(lepton+jets/all jets)

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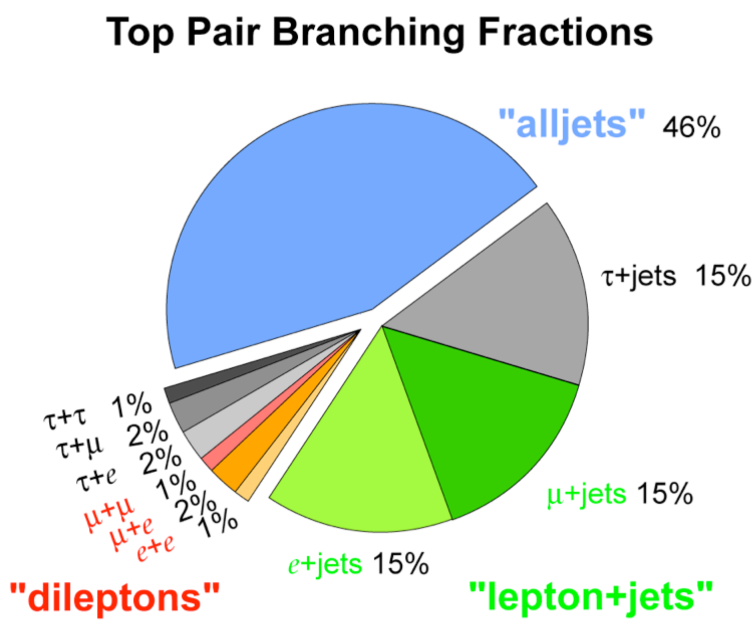
Outline

- Importance of measuring top quark cross-section.
- Cross section measurements:
  - Lepton + Jets without using b-tagging cross-section measurements.
  - Lepton + Jets using b-tagging cross-section measurements.
  - Fully Hadronic cross-section measurements.
- Summary and Conclusions.

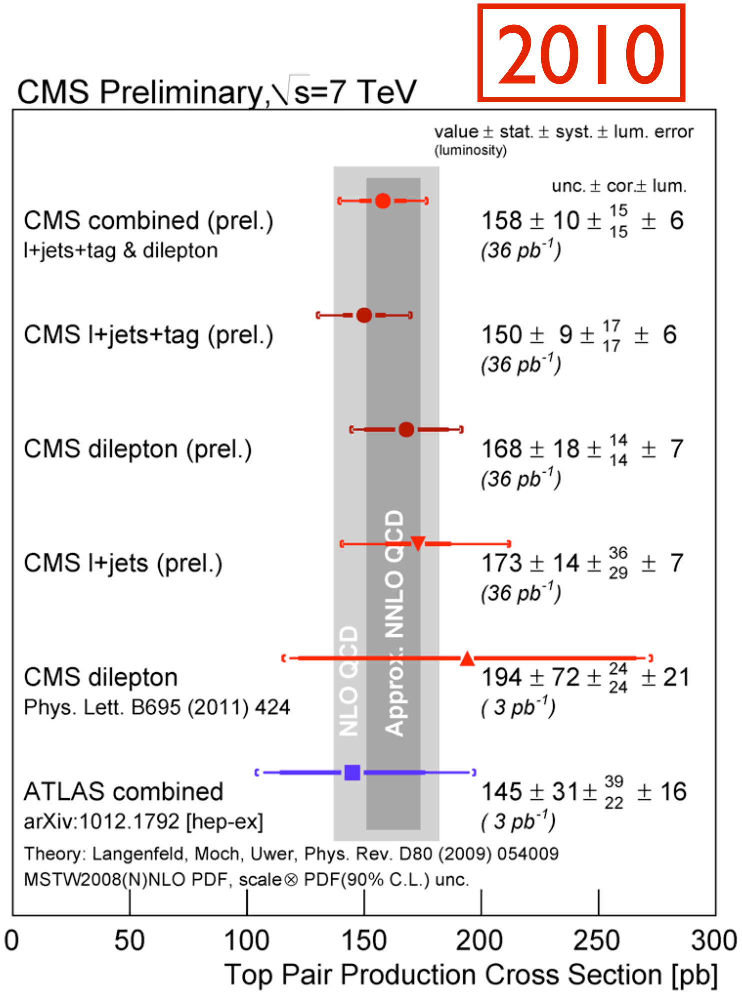


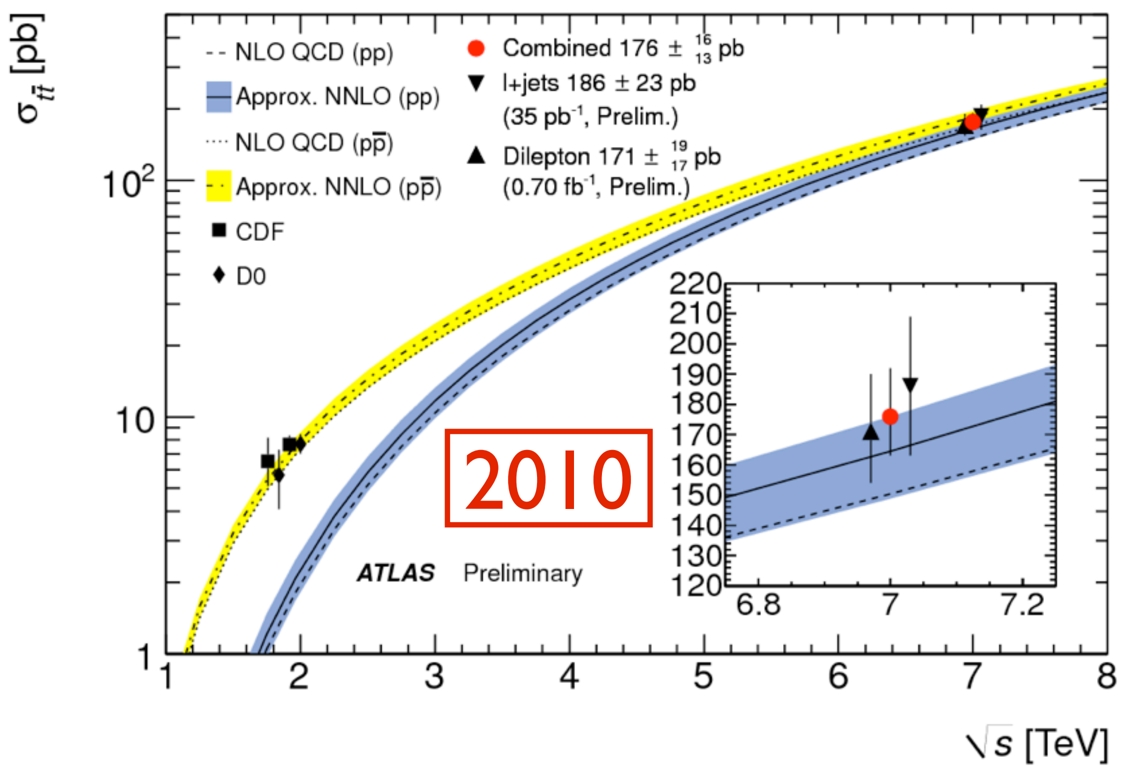
Importance of measuring top quark pair cross-section

Cross-section measurements represent a unique test of perturbative QCD predictions.

Comparing cross-section measurements in all different channels can give constraints on physics beyond the SM.

Ttbar is a dominant background for several new physics searches such as SUSY.





Lepton plus jets *final state*

Event selection

ATLAS	Electron	Muon
Trigger	$p_T > 20$ GeV	$p_T > 18$ GeV
Jets	Anti-Kt 0.4, $p_T > 20$ GeV, $\|\eta\| < 2.5$, ΔR(jet, electron) < 0.2	
Electron	$E_T > 25$ GeV, $\|\eta\| < 2.5$, E_T (cone 0.2) < 3.5 GeV	
Muon	$p_T > 20$ GeV, $\|\eta\|<2.1$, E_T (cone 0.3) < 4 GeV & P_T (cone 0.3) < 4 GeV, ΔR(muon,jet (p_T>20 GeV)) < 0.4	
Missing E_T	> 35 GeV	> 25 GeV
$m_T(W_{lep})$	> 25 GeV	$E_T + m_T(W_{lep})$> 60 GeV

CMS	Electron	Muon
Trigger	$p_T > 22$ GeV	$p_T > 15$ GeV
Jets	Anti-Kt 0.5, $p_T > 30$ GeV, $\|\eta\| < 2.4$ ΔR(jet, muon || electron) < 0.3	
Electron	$E_T > 30$ GeV, $\|\eta\| < 2.5$ I_{rel}(cone 0.3) < 0.1	
Muon	$p_T > 20$ GeV, $\|\eta\|<2.1$, I_{rel} (cone 0.3) < 0.05	
Missing E_T	no cut on missing E_T as is used in the likelihood	

$$m_T(W) = \sqrt{2p_T^l p_T^\nu (1 - \cos(\phi^l - \phi\nu))}$$

$$I_{rel} = (I_{charged} + I_{neutral} + I_{photon})/p_T$$

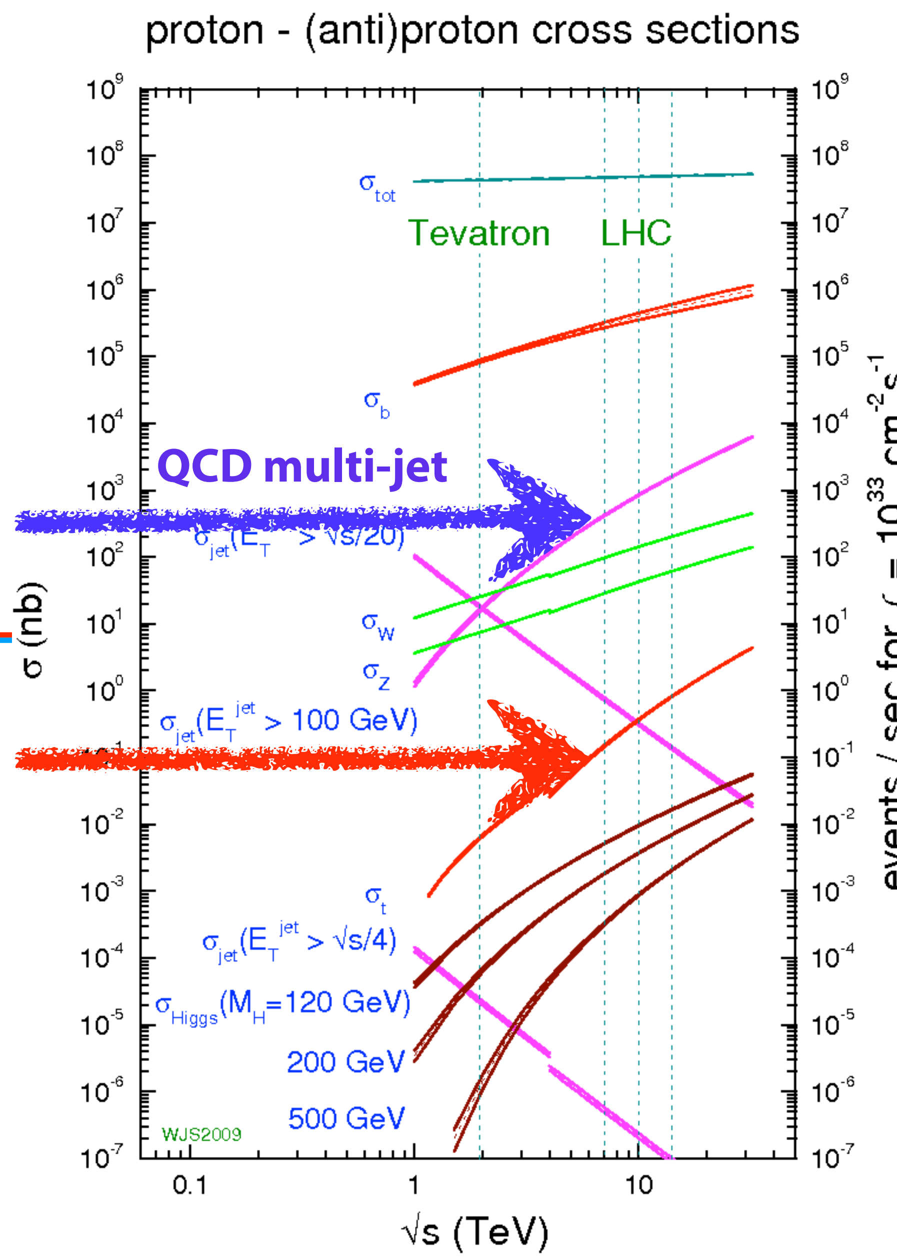
ATLAS

QCD multi-jet background is derived from data:

Electron: Fitting method (failing ID cuts).

Muon: Matrix method technique.

(See Jörgen talk's)



CMS

QCD multi-jet background is derived from data:

Electron (failing at least two of three requirements): Relative isolation, transverse impact parameter (< 0.02 cm) or standard electron identification criteria.

Muon softening isolation requirements: Relative isolation between 0.2 and 0.5.

Profile likelihood

- Most of the measurements presented are dominated by systematic uncertainties that need a more complex treatment than a *simple likelihood fit.*
- Profile likelihood has the advantage that many systematic uncertainties are measured *in situ* and scale inversely with the integrated luminosity.
- Data can potentially constrain the magnitude of the systematic and reduce their impact on the overall precision of the measurement.

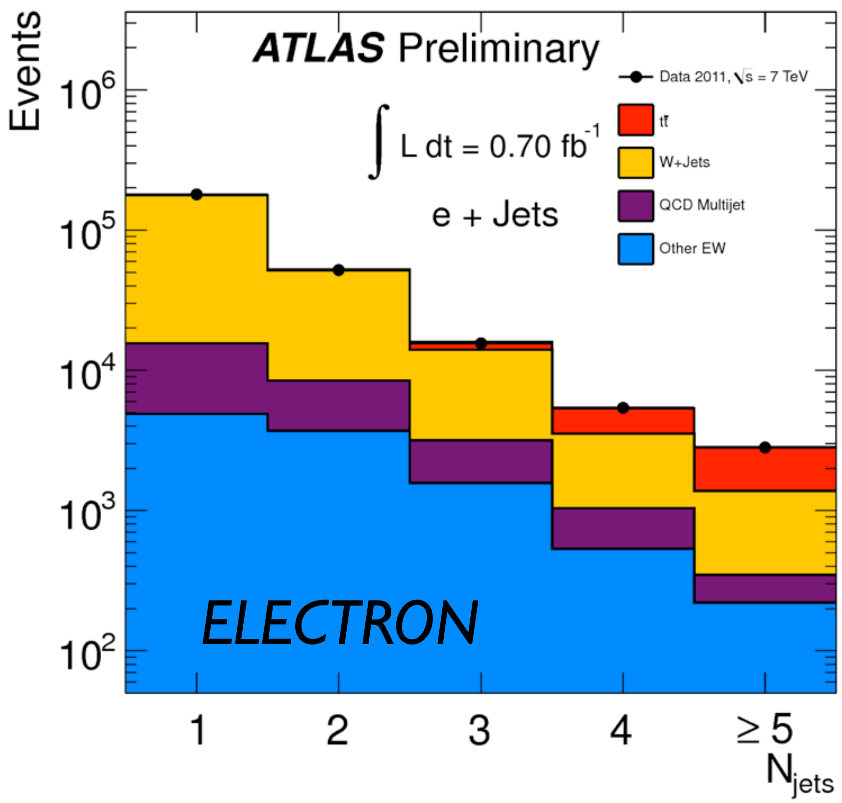
$$-2\ln L(k_{t\bar{t}}, k_{W+jets}, \vec{\alpha}) \propto -2\sum_{i=1}^{N_{bins}} n_i \ln \mu_i - \mu_i + \sum_{j=1}^{N_{Syst}} \alpha^2$$

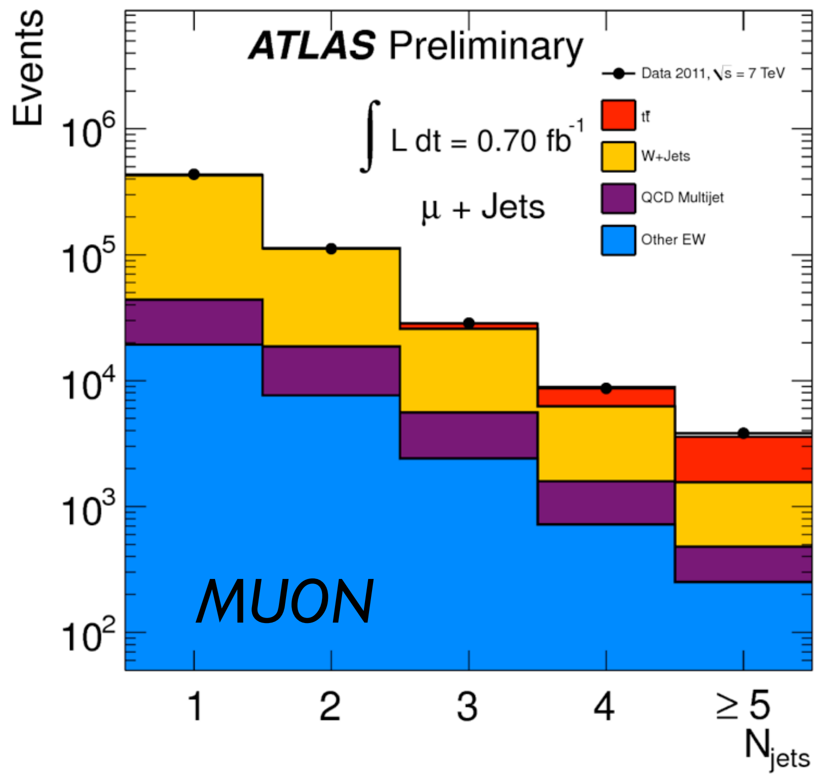
$$\mu_i = \mu_i(k_{t\bar{t}}, k_{W+jets}, \vec{\alpha})$$

Measurement of the ttbar production cross-section in the ***lepton plus jets untagged*** *final state*

Untagged analyses avoid large sources of systematic uncertainties (b-jet tagging and HF fractions) but have worse S/B.

Using the ATLAS common selection (p. 5) :





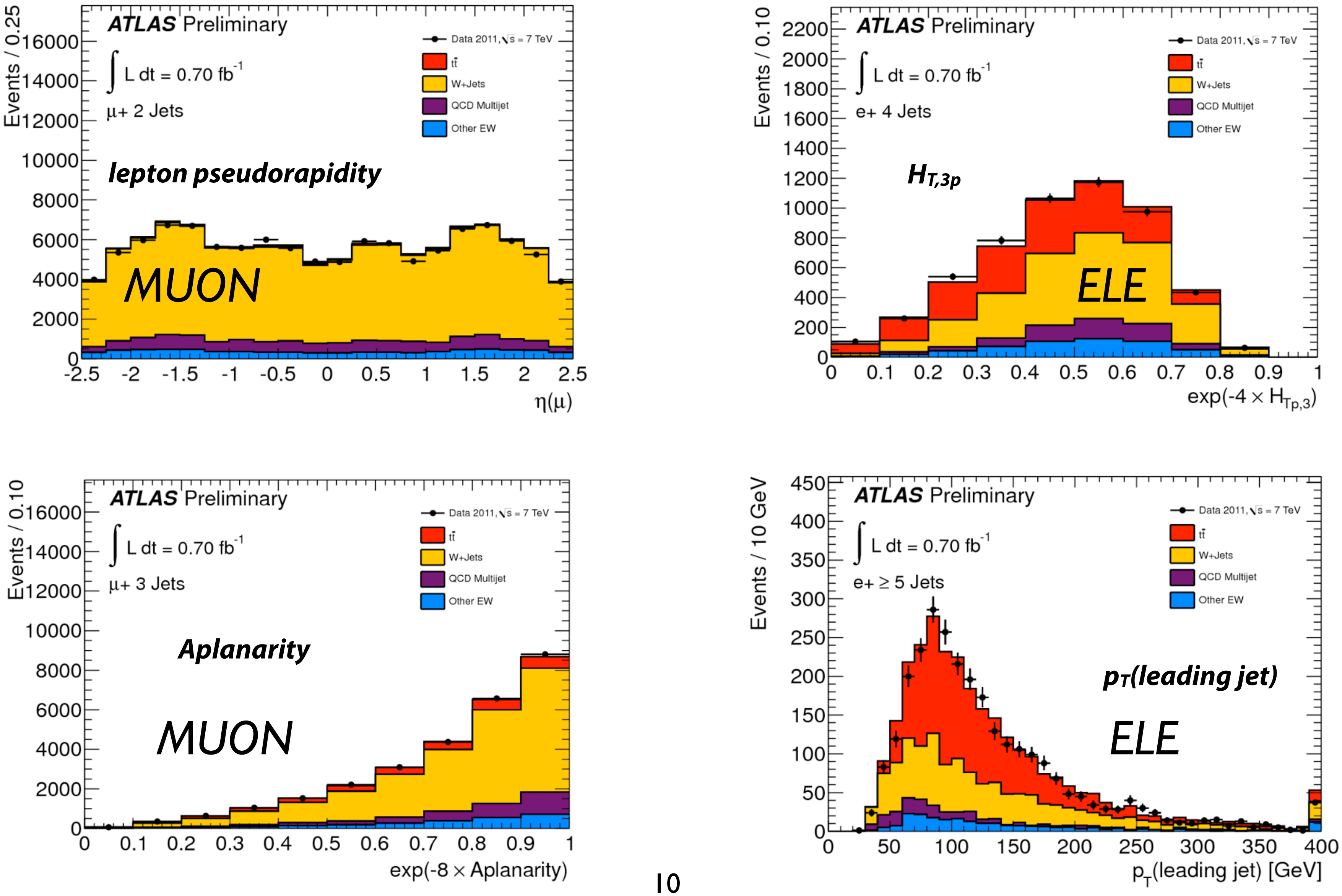
Good agreement between data/mc is achieved.

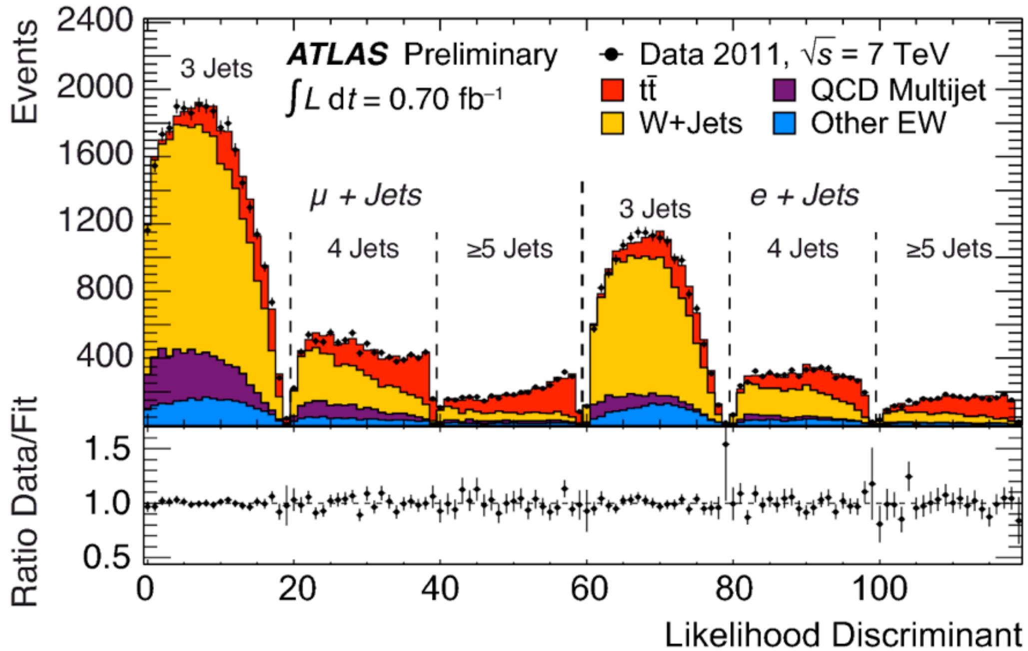
Single Lepton Untagged

$$H_{T,3p} = \frac{\sum_{i=3}^{N_{jets}} |p_{T,i}|}{\sum_{j=1}^{N_{jets}} |p_{z,j}|}$$

ATLAS **0.7 fb^{-1}**

Maximum likelihood to discriminant variable built from kinematical variables in the (discriminant from 4 variables)x(= 3, = 4, ≥ 5 jets multiplicity bins)x(ele,muon)





Uncertainty	up (pb)	down (pb)	up (%)	down (%)
Statistical	3.9	−3.9	2.2	−2.2
Detector simulation				
Jets	3.2	−4.3	1.8	−2.4
Muon	4.1	−4.1	2.3	−2.3
Electron	2.7	−3.0	1.5	−1.7
E_T^{miss}	2.0	−1.6	1.1	−0.9
Signal model				
Generator*)	5.4	−5.4	3.0	−3.0
Hadronization*)	0.9	−0.9	0.5	−0.5
ISR/FSR	3.0	−2.3	1.7	−1.3
PDF*)	1.8	−1.8	1.0	−1.0
Background model				
QCD shape*)	0.7	−0.7	0.4	−0.4
W shape*)	0.9	−0.9	0.5	−0.5
Monte Carlo statistics*)	3.2	−3.2	1.8	−1.8
Systematic	9.0	−9.0	5.0	−5.0
Stat. & Syst.	9.8	−9.8	5.4	−5.4
Luminosity	6.6	−6.6	3.7	−3.7
Total	11.8	−11.8	6.6	−6.6

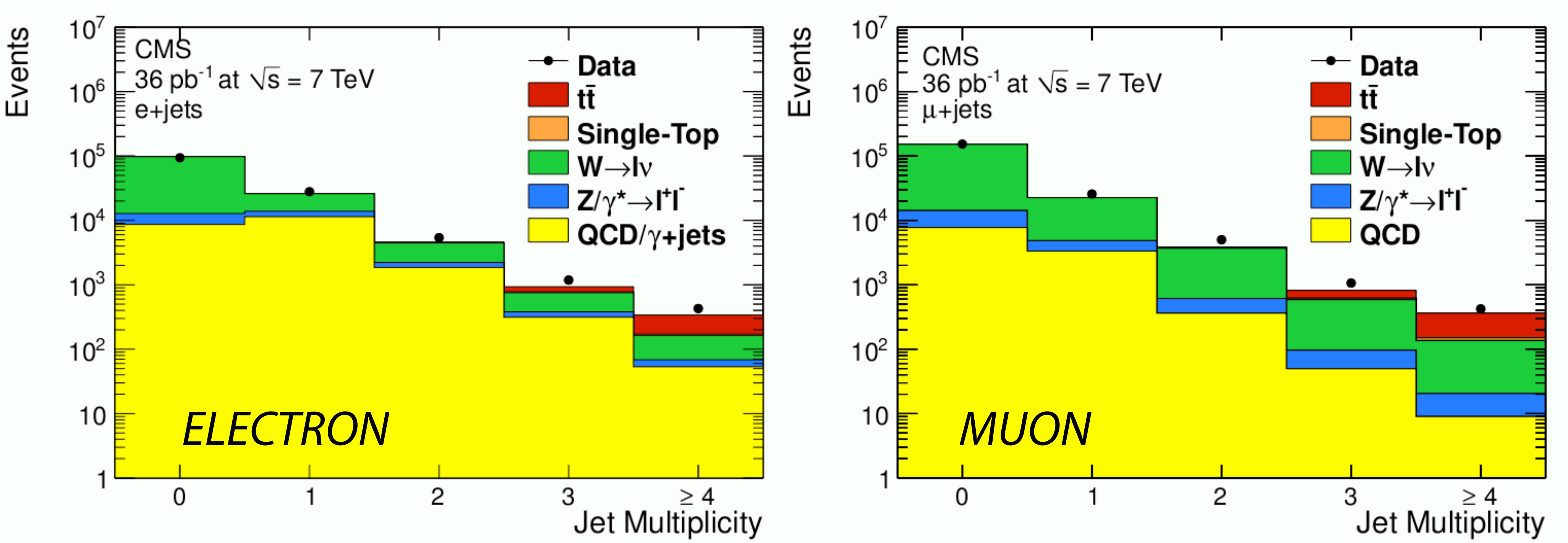
This is the most precise top pair cross-section measurement so far:

$$\sigma_{t\bar{t}} = 179.0^{+7.0}_{-6.0}(stat + syst) \pm 6.6(lumi)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 6.6\%$$

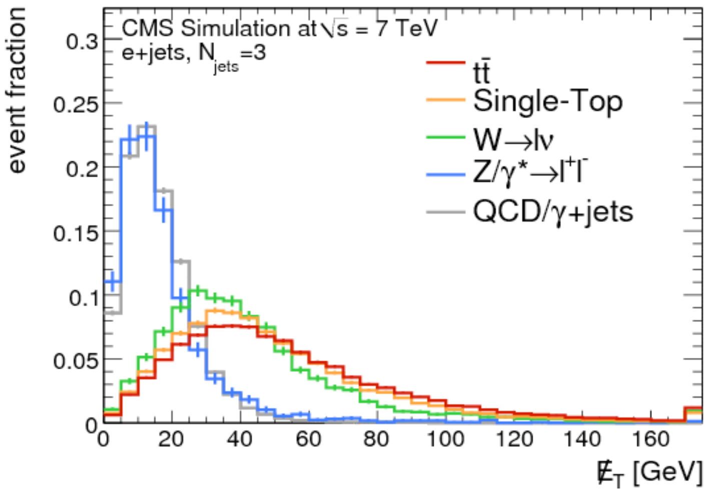
Already challenging for theoretical uncertainties!

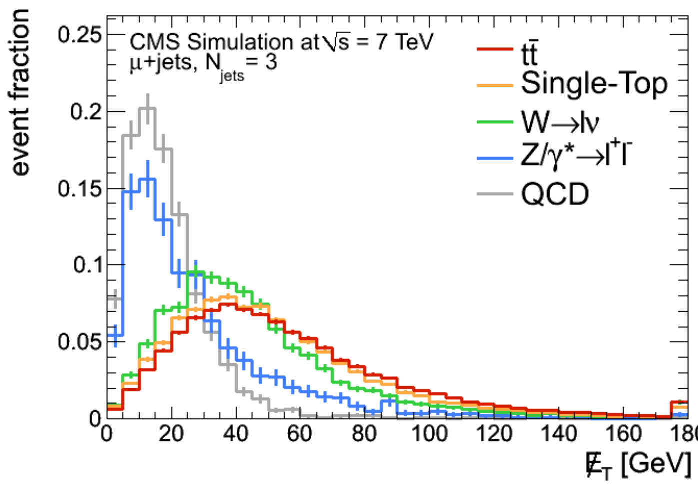
Using the CMS common selection (p. 5) :



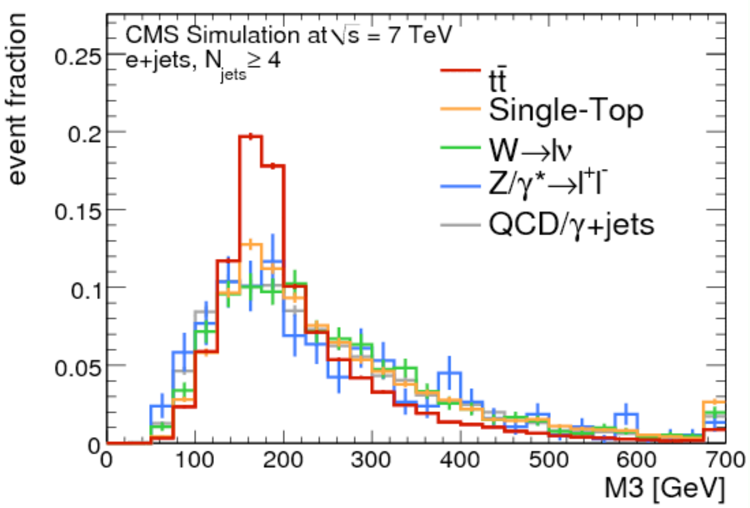
Good agreement between data/mc is achieved.

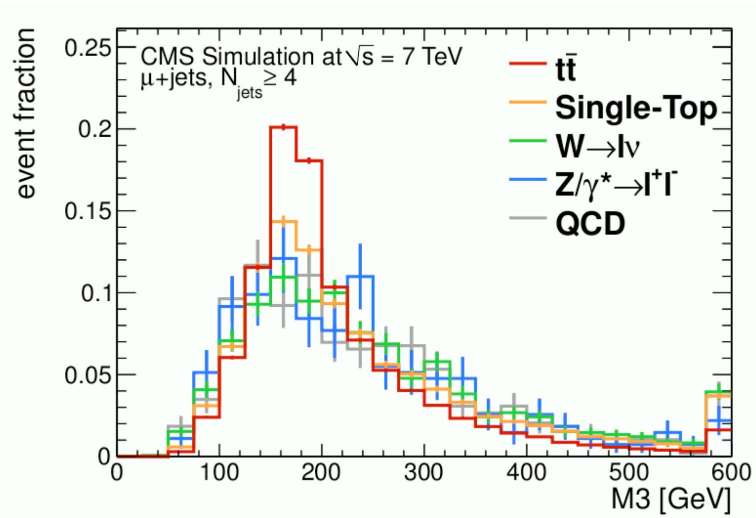
(Binned likelihood) Fit simultaneously to M3 and MET:





MET in $N_{jets} = 3$:
Separates QCD/Z+jets from W+jets and Top.



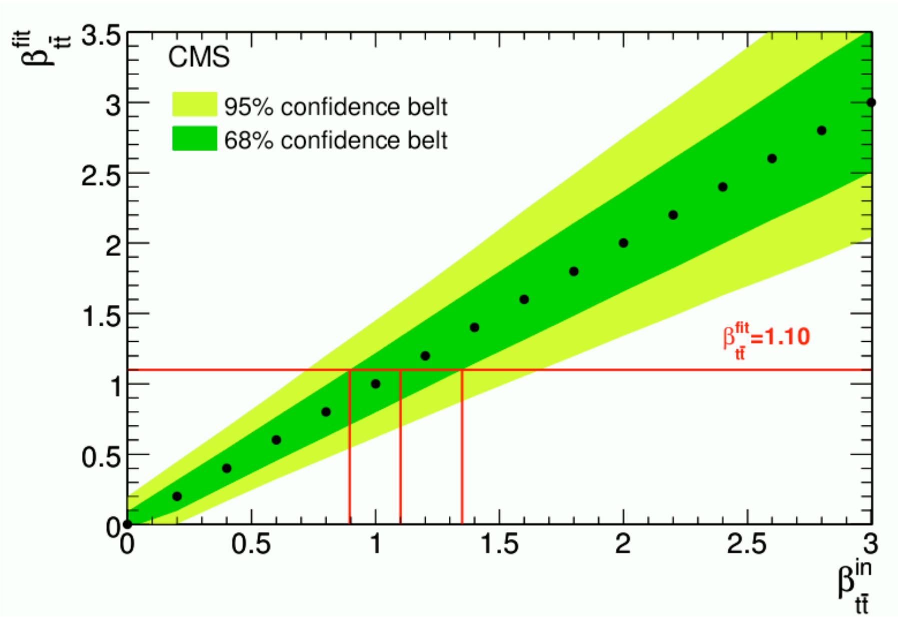


M3 in $N_{jets} \geq 4$:
Separates Top signal from other backgrounds.

M3: invariant mass of the combination of the three jets with the largest vectorially summed transverse momentum.

	$\beta_{t\bar{t}}$	$N_{t\bar{t}}$	$N_{single\text{-}top}$	N_{W+jets}	N_{Z+jets}	N_{QCD} e+jets	N_{QCD} μ+jets
predicted	1.00	733 ± 116	72 ± 4	1069 ± 77	138 ± 10	367 ± 27	58 ± 4
fitted	$1.10^{+0.25}_{-0.21}$	806^{+183}_{-154}	76 ± 22	1475 ± 86	184 ± 51	440 ± 44	113 ± 31

	stat.+syst. uncertainty	
Stat.+bkg. uncertainty	−8.4%	+8.7%
JES	−17.6%	+20.3%
JER	−8.4%	+8.8%
ISR/FSR variation	−8.6%	+9.0%
Factorization scale	−10.6%	+11.2%
Matching threshold	−9.8%	+10.5%
Branching ratio	−8.6%	+8.9%
Efficiencies (from T&P)	−8.7%	+9.2%
QCD rate & shape	−8.9%	+9.1%
Lepton scale	−8.4%	+8.7%
PDF uncertainty	−8.5%	+8.7%
Pile-up	−9.3%	+9.3%
Total	−19.3%	+23.5%



$$\sigma_{t\bar{t}} = 173^{+39}_{-32}(stats. + syst.) \pm 7(lumi)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 23\%$$

Single Lepton Untagged

ATLAS

Luminosity = **0.7 fb^{-1}**
Variables: $H_{T,3p}$, p_T(leading jet), aplanarity, lepton pseudo-rapidity
Jet multiplicity: = 3, 4 & ≥ 5 jets
Main systematics : signal MC generator, JES calibration and the modeling of ISR/FSR
Stat. error : 2.2 % (3.9 pb)

$$\sigma_{t\bar{t}} = 179.0^{+7.0}_{-6.0}(stat + syst) \pm 6.6(lumi)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 6.6\%$$

CMS

Luminosity = **36 pb^{-1}**
Variables: M3 & MET
Jet multiplicity: = 3 & ≥ 4 jets
Main systematics : JES Calibration, Factorization scale & Matching threshold
Stat. error : 8.1 % (14 pb)

$$\sigma_{t\bar{t}} = 173^{+39}_{-32}(stats. + syst.) \pm 7(lumi)pb$$

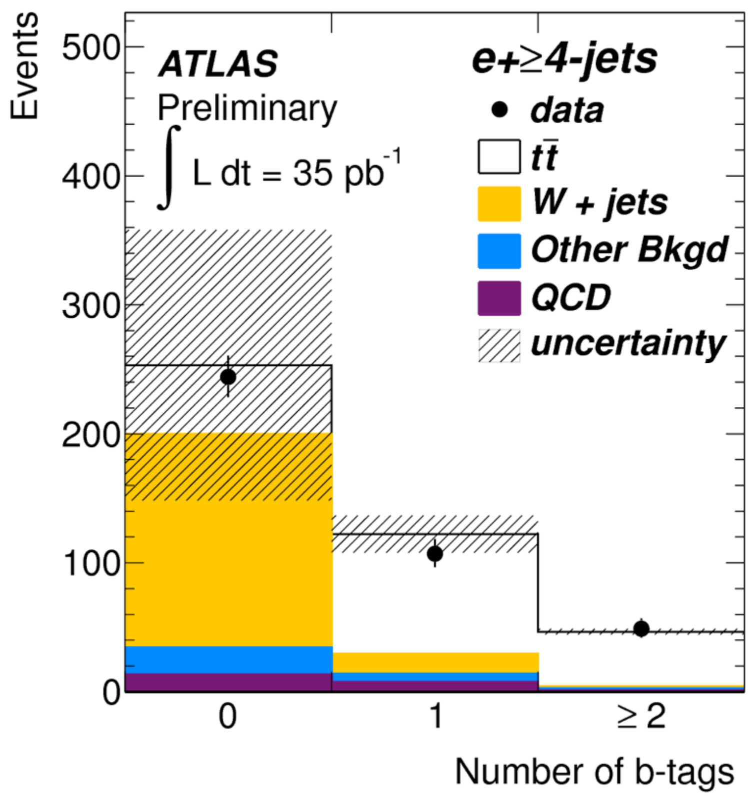
$$\frac{\delta\sigma}{\sigma} \sim 23\%$$

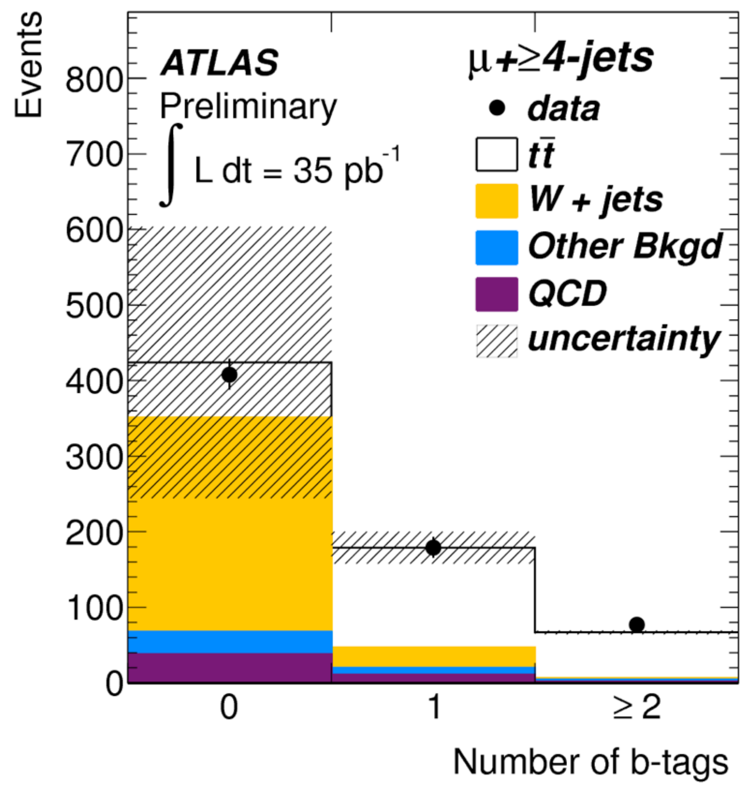
Measurement of the ttbar production cross-section in the
***lepton plus jets tagged** final state*

Using the ATLAS common selection (p. 5) except for:

Electrons: $p_T > 20$ GeV, $|\eta| < 2.5$, E_T (cone 0.2) < 4 GeV.

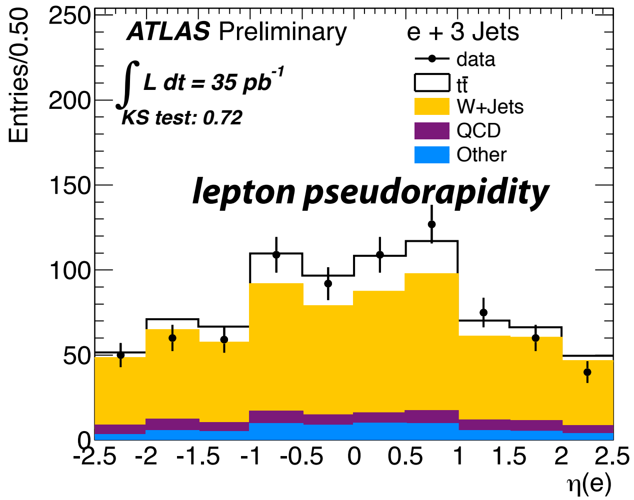
Muons: Missing-E_T > 20 GeV.

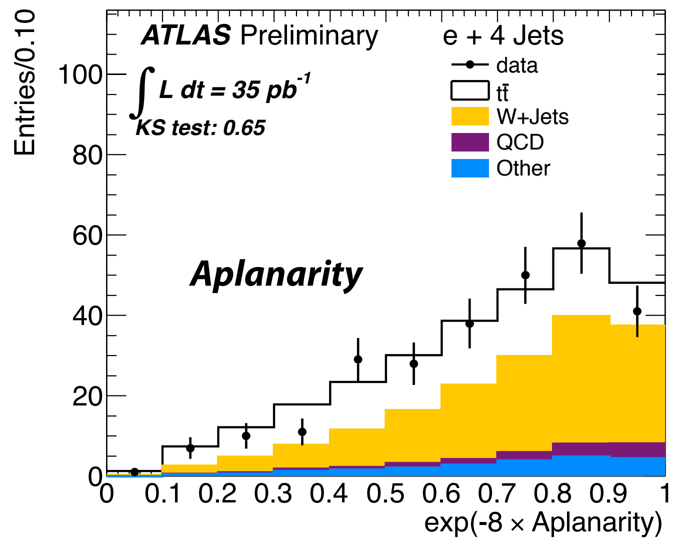


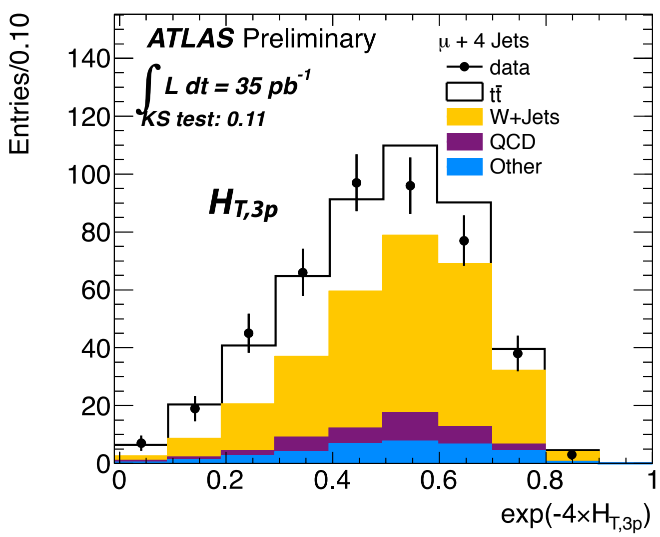


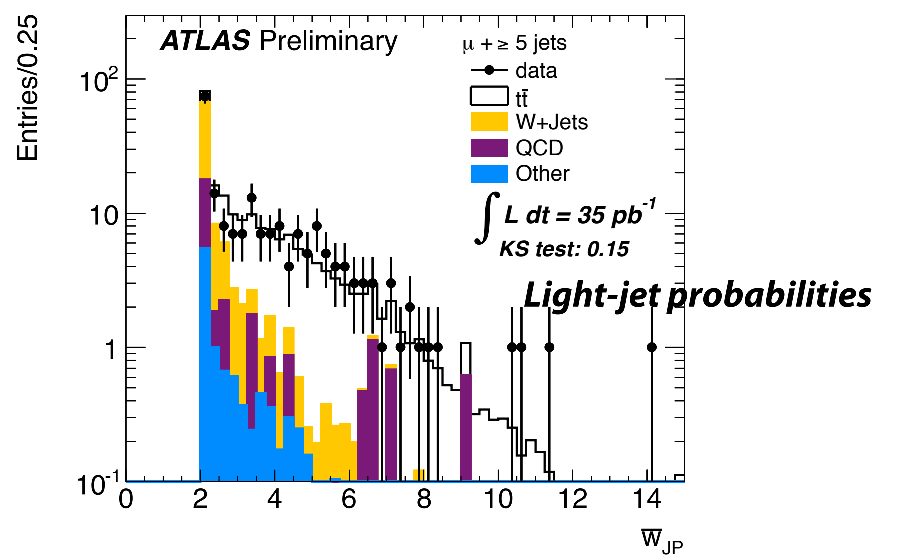
Single Lepton tagged ATLAS 35 pb^{-1}

Multivariate likelihood discriminant constructed from the following variables fitting simultaneously = 3 , = 4 & ≥ 5 jets :

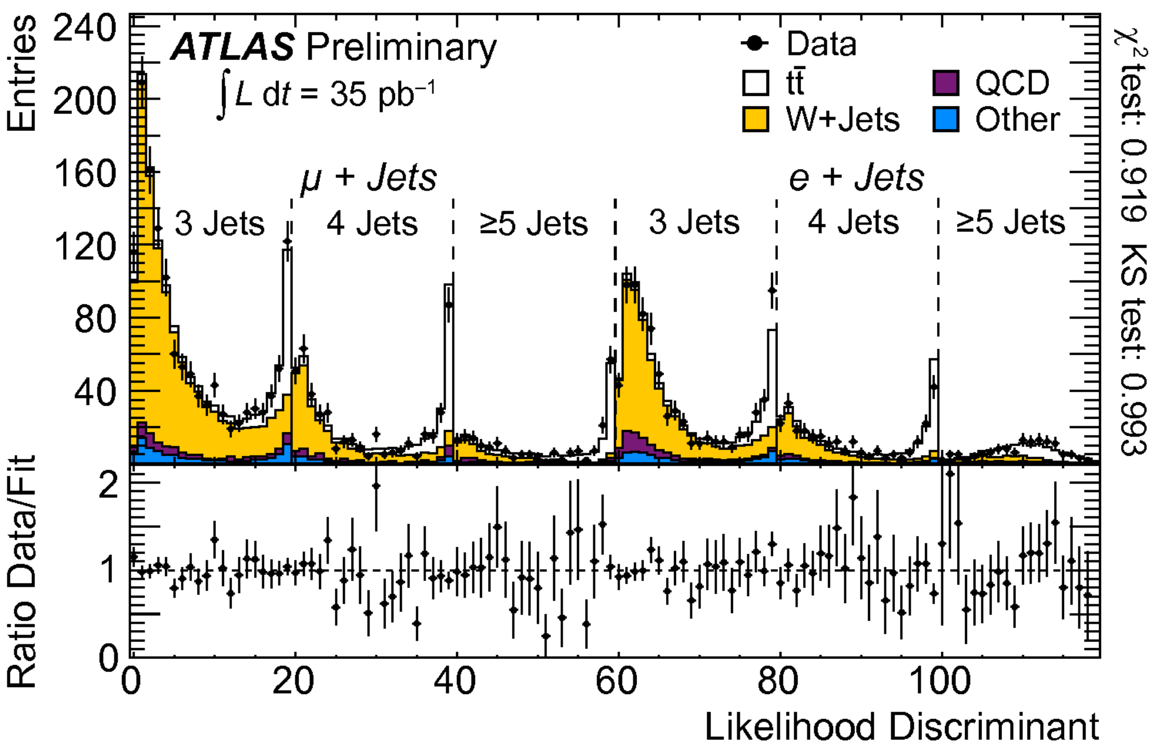








The average of the two lowest light-jet probabilities (P_l) in the event. These are the jets which have the most significant *b*-tags. The weight returned by the tagger is transformed to $W_{JP} = -\log_{10} P_l$.



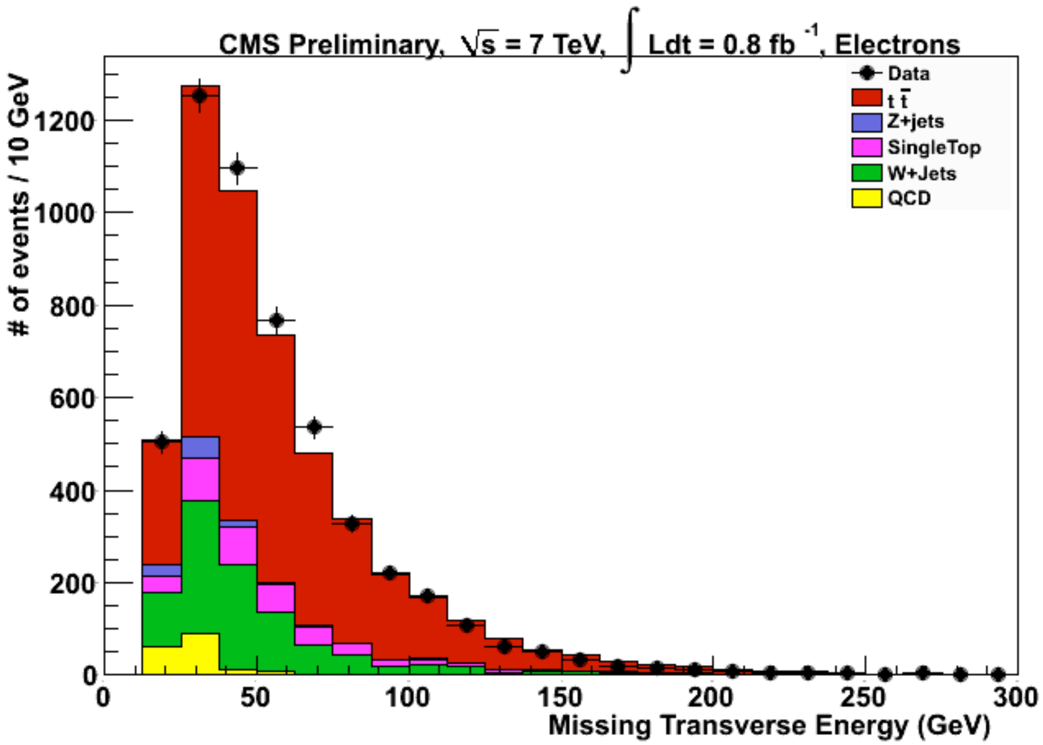
Statistical Error (%)	**+5.3**	**-5.2**
Object selection (%)		
Jet energy scale	+3.8	-2.8
Jet reconstruction efficiency	+4.2	-4.2
Jet energy resolution	+0.8	-0.2
Electron scale factor	+1.2	-0.8
Muon scale factor	+0.5	-0.6
Electron smearing	+0.3	-0.2
Muon smearing	+0.6	-0.4
Background modeling (%)		
Wjets HF content	+7.2	-6.3
Wjets shape	+1.5	-1.5
QCD shape	+1.0	-1.0
$t\bar{t}$ signal modeling (%)		
ISR/FSR	+4.0	-4.0
NLO generator	+0.5	-0.7
Hadronisation	+0.0	-0.6
PDF	+1.7	-1.7
Others (%)		
b-tagging calibration	+7.5	-6.3
Simulation of pile-up	+1.5	-0.6
Templates statistics	+1.6	-1.5
Total Systematic (%)	**+11.5**	**-10.5**

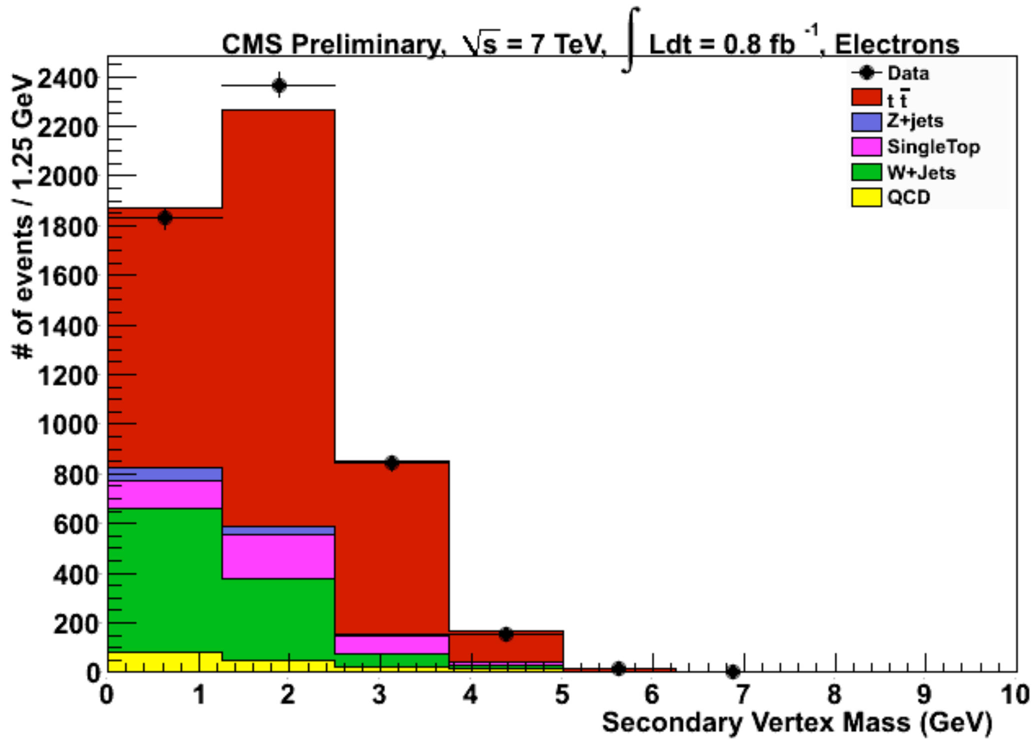
$$\sigma_{t\bar{t}} = 186 \pm 10(stat.)^{+21}_{-20}(syst.) \pm 6(lumi.)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 13\%$$

Using the CMS common selection (p. 6) except for:

- Lepton p_T: Electron $p_T > 45$ GeV, Muons $p_T > 35$ GeV.
- Missing E_T: Electrons $\not{E}_T > 30$ GeV, Muons $\not{E}_T > 20$ GeV.
- At least one selected jet is b tagged.



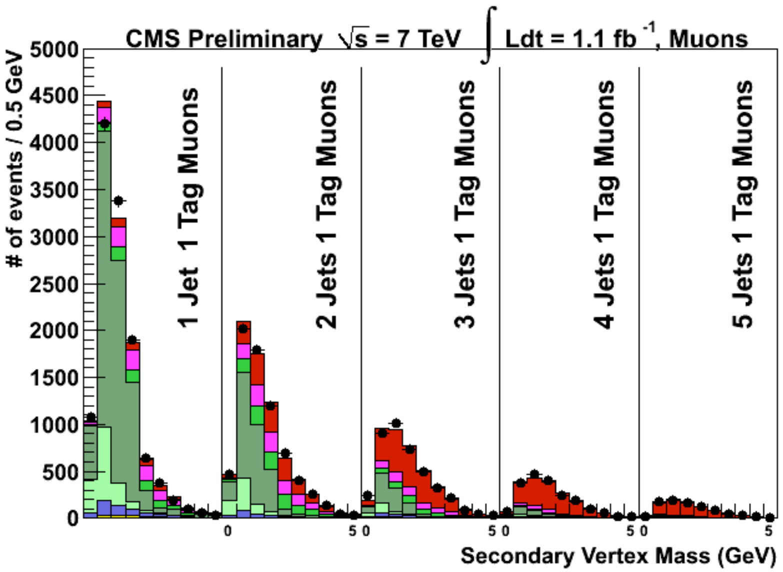


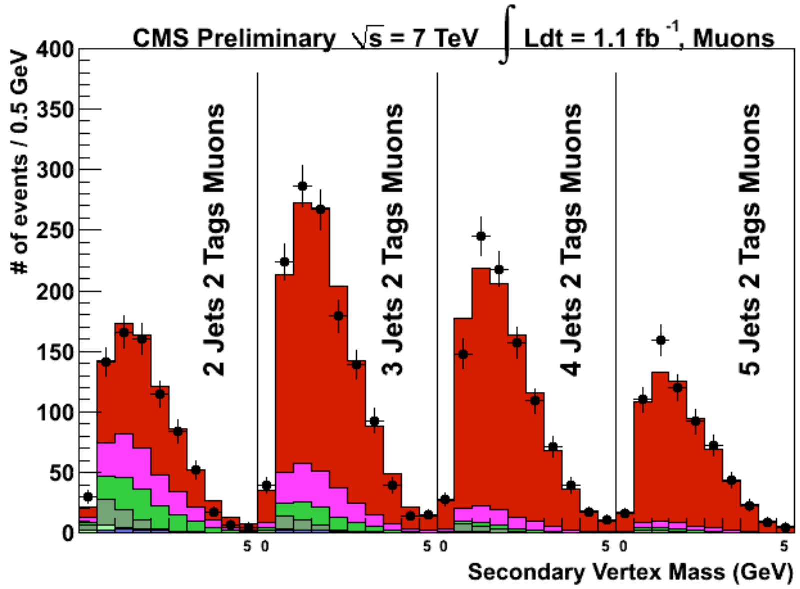
Single Lepton tagged

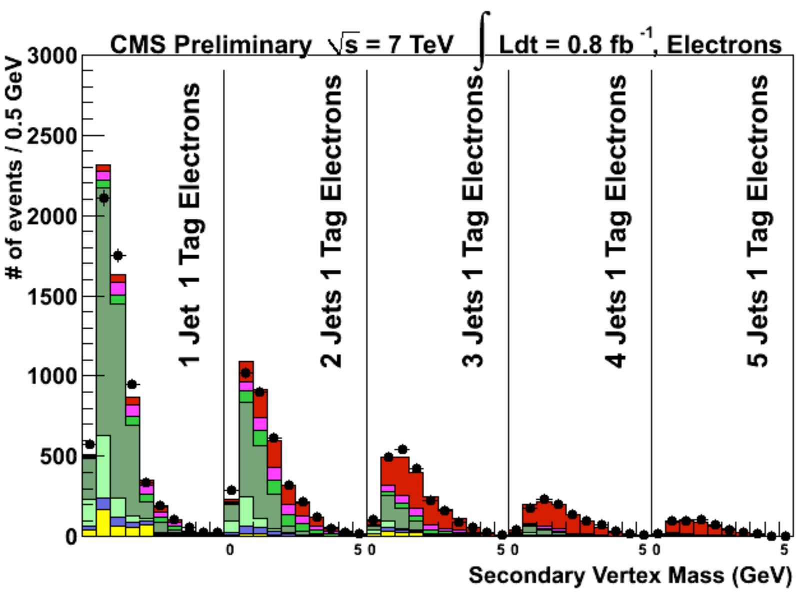
CMS

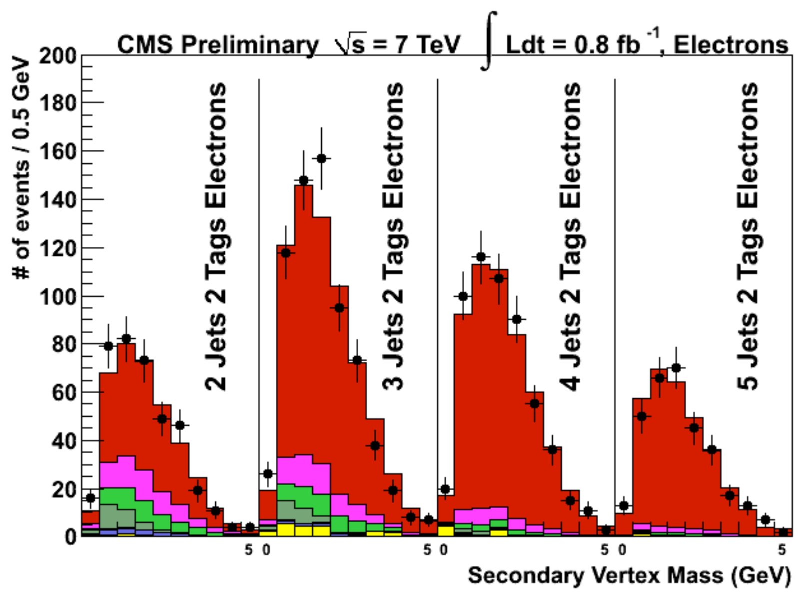
Electrons 0.8 fb^{-1}
Muons 1.1 fb^{-1}

Maximum likelihood fit to the number of reconstructed jets (j = 1-4, ≥ 5), number of b-tagged jets (b-jet = 1, ≥2) and secondary vertex mass distribution.









Source	Muon Analysis	Electron Analysis	Combined Analysis
Quantity	Uncertainty (%)		
Lepton ID/reco/trigger	3.4	3	3.4
$\not\!\!E_T$ resolution due to unclustered energy	< 1	< 1	< 1
$t\bar{t}$+jets Q^2 scale	2	2	2
ISR/FSR	2	2	2
ME to PS matching	2	2	2
Pile-up	2.5	2.6	2.6
PDF	3.4	3.4	3.4
Profile Likelihood Parameter	Uncertainty (%)		
Jet energy scale and resolution	4.2	4.2	3.1
b-tag efficiency	3.3	3.4	2.4
W+jets Q^2 scale	0.9	0.8	0.7
Combined	7.8	7.8	7.3

Combined Result

$$\sigma_{t\bar{t}} = 164.4 \pm 2.8(stat.) \pm 11.9(syst.) \pm 7.4(lum.)pb \qquad \frac{\delta\sigma}{\sigma} \sim 8{,}7\,\%$$

Electron

$$\sigma_{t\bar{t}} = 163.0 \pm 4.4(stat.) \pm 12.7(syst.) \pm 7.3(lum.)pb \qquad \frac{\delta\sigma}{\sigma} \sim 9{,}4\,\%$$

Muon

$$\sigma_{t\bar{t}} = 163.2 \pm 3.4(stat.) \pm 12.7(syst.) \pm 7.3(lum.)pb \qquad \frac{\delta\sigma}{\sigma} \sim 9{,}2\,\%$$

ATLAS

Luminosity = **35 pb^{-1}**
Variables: $H_{T,3p}$, light-jet probability, aplanarity & lepton pseudorapidity
Jet multiplicity: = 3, 4 & ≥ 5 jets
Main systematics : b-tagging, HF fractions & jet reconstruction efficiency.

$$\sigma_{t\bar{t}} = 186 \pm 10(stat.)^{+21}_{-20}(syst.) \pm 6(lumi.)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 13\%$$

CMS

Luminosity = **0.8/1.1 pb^{-1}**
Variables: num. of jets, num. of b-tagged jets & secondary mass distribution.
Jet multiplicity: = 3 & ≥ 4 jets
Main systematics : JES & JER, b-tagging eff & W+jets Q^2-scale

$$\sigma_{t\bar{t}} = 164.4 \pm 2.8(stat.) \pm 11.9(syst.) \pm 7.4(lum.)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 8.7\%$$

Measurement of the ttbar production cross-section in the
***fully hadronic** final state*

Event selection:

Anti-Kt jet using $\Delta R = 0.4$.

At least 5 jets with $p_T > 55$ GeV, 6th with $p_T > 30$ GeV and additional jets only if $p_T > 20$ GeV

All jets within $|\eta| < 4.5$

At least two b-tagged jets ($p_T > 20$ GeV) are required.

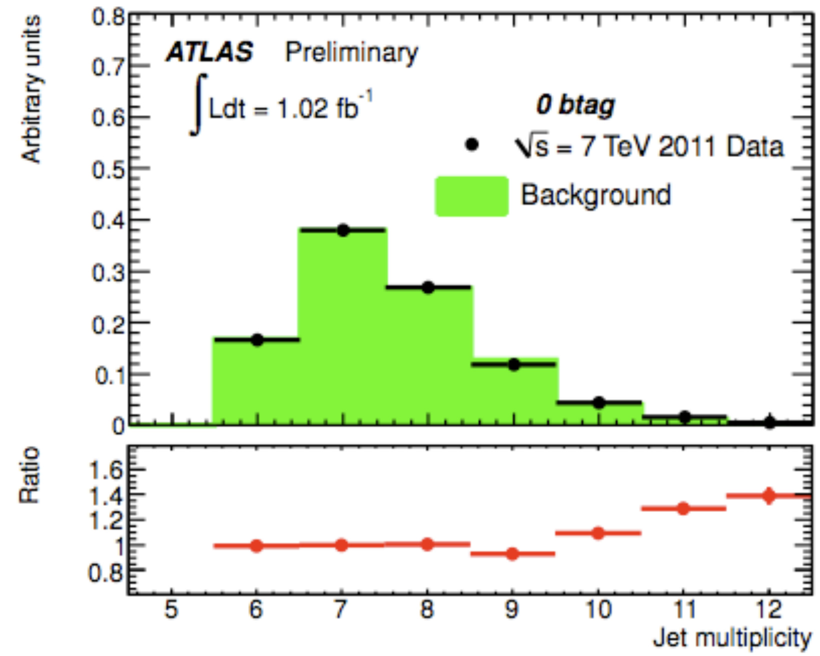
Missing E_T significance $\frac{E_T}{\sqrt{H_T}} < 3$, H_T is the scalar sum of the transverse momentum of all jets in the event.

$\Delta R(b,B) > 1.2$

Background modeling:

Event Mixing technique uses a sample with a lower number of jets (exclusive) to model a sample with a large multiplicity: the target multiplicity is made up by adding jets to the initial sample.

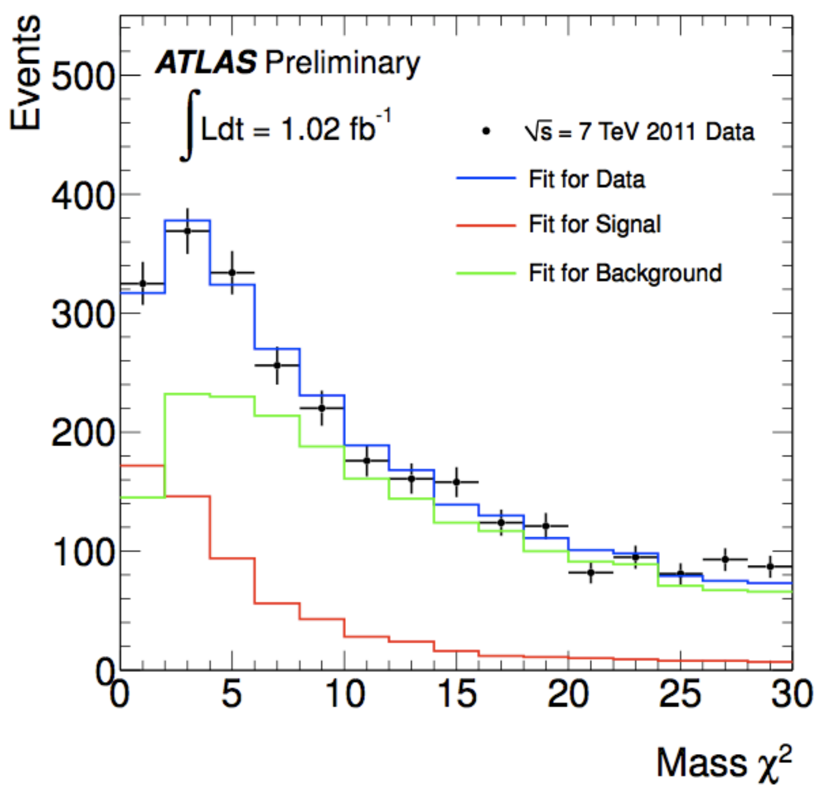
The technique is used to model events with at least six jets from events with a jet-multiplicity equal to exactly four or five .



A chisquare based discriminant observable is implemented to extract the ttbar signal from the mutlijet background:

$$\chi^2 = \frac{(M_{j_1,j_2} - M_w)^2}{\sigma_w^2} + \frac{(M_{j_1,j_2,b_1} - M_t)^2}{\sigma_t^2} + \frac{(M_{j_3,j_4} - M_w)^2}{\sigma_w^2} + \frac{(M_{j_3,j_4,b_2} - M_t)^2}{\sigma_t^2}$$

Ttbar signal fraction are extracted from a likelihood fit to the data mass chisquare distribution:



Source of uncertainty	Event Mixing (%)	ABCD (%)
Jet energy scale	24.2	13.7
Jet reconstruction efficiency	0.1	0.3
Jet energy resolution	13.5	6.8
Multi-jet trigger	10.0	10.0
LAr readout problem	0.6	0.3
b-tagging	23.0	30.0
Generator (PS., Hadronisation)	5.4	13.0
ISR, FSR	23.4	10.0
PDF	8.6	8.6
Luminosity	3.7	3.7
Multi-jet modelling	12.1	30.0
Total	46.7	49.9

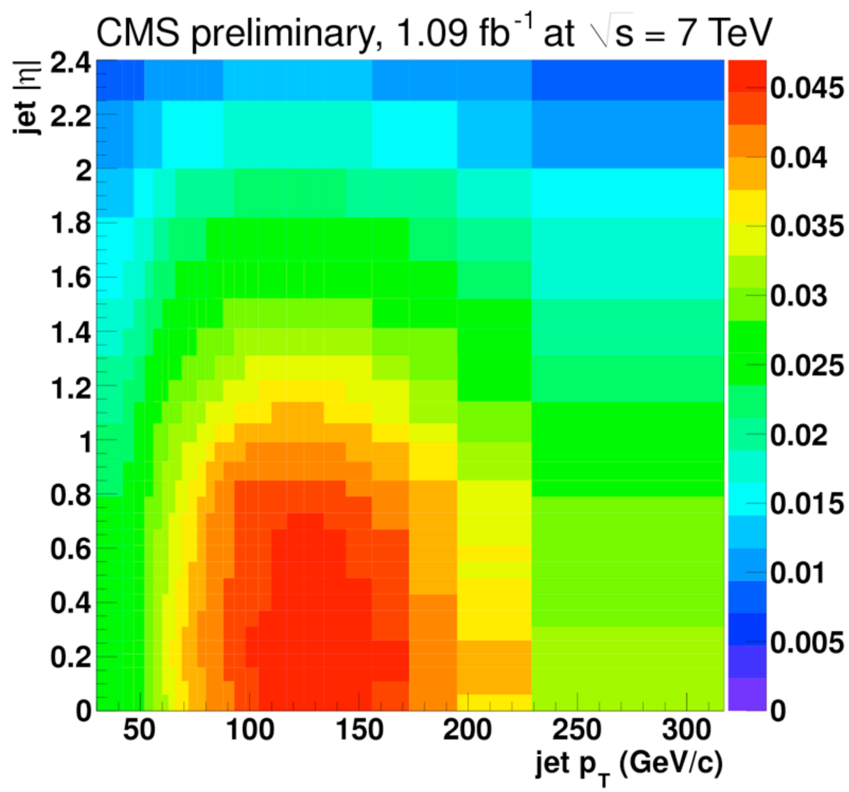
$$\sigma_{t\bar{t}} = 167 \pm 18(stats.) \pm 78(syst.) \pm 6(lumi) pb \qquad \frac{\delta\sigma}{\sigma} \sim 48\,\%$$

Event selection:

- Anti-Kt jet using ΔR = 0.5.
- At least 4 jets with $p_T > 60$ GeV, a 5th jet with $p_T > 50$ GeV & 6th $p_T > 40$ GeV (additional jets only if $p_T > 30$ GeV).
- All jets within $|\eta| < 2.4$
- At least two b-tagged jet are required.

Probability for b-tagging a jet as a function of its transverse momentum p_T and $|\eta|$.

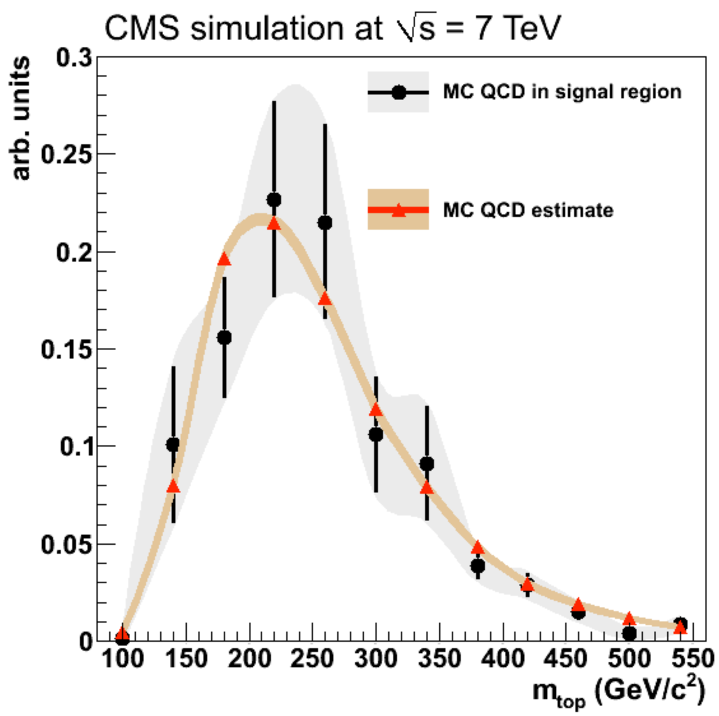
$$R(p_T, |\eta|) = \frac{N(p_T, |\eta|, d_B > 2.0)}{N(p_T, |\eta|, d_B < 2.0)}$$

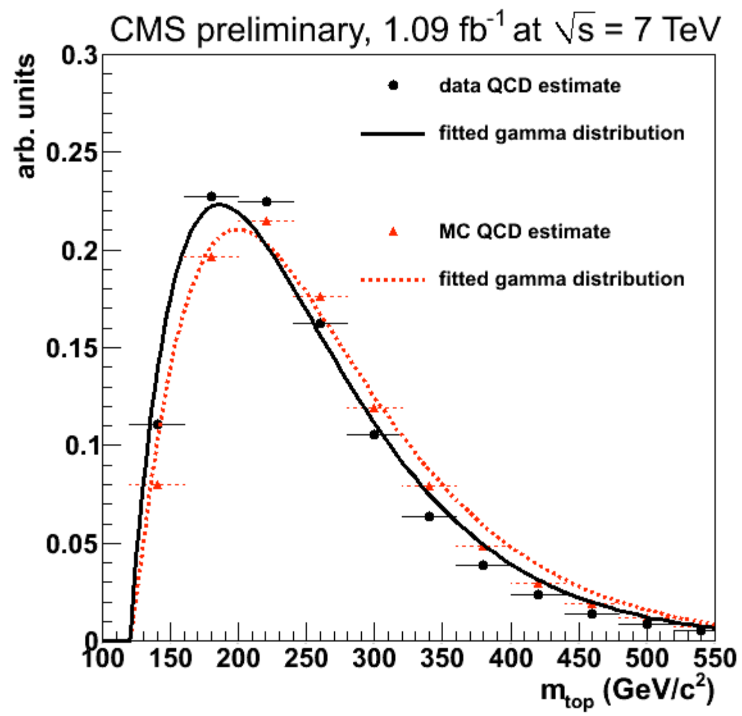


QCD is estimated from the weight ω and from events with ≥ 6 jets with exactly zero tagged:

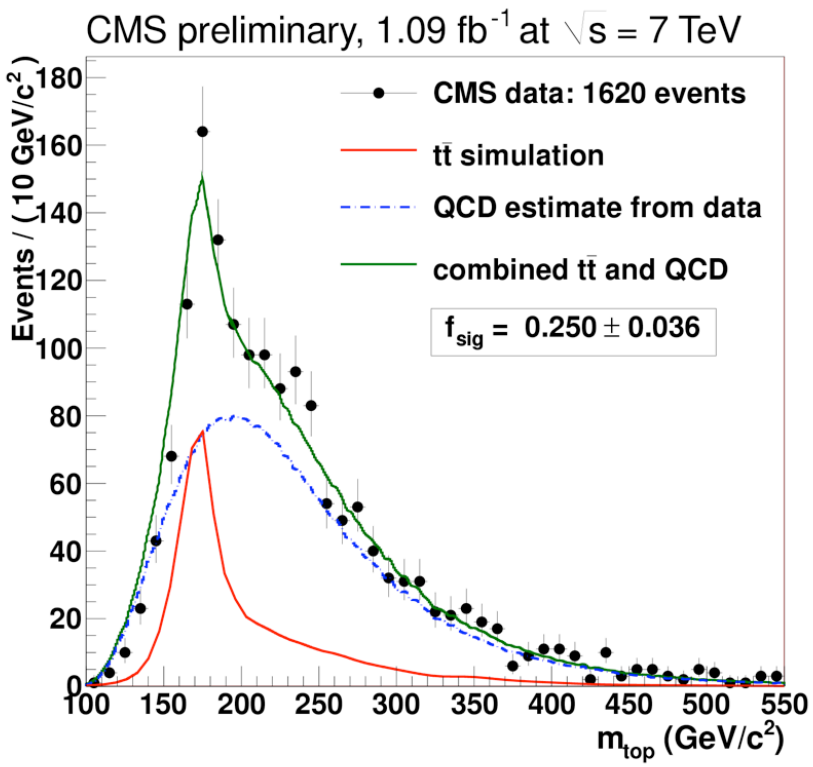
$$\omega = R(p_T^b, |\eta|^b) \times R(p_T^{\bar{b}}, |\eta|^{\bar{b}})$$

The contribution of bottom quark in the control region for the background estimation is about 1-2%.





The cross section is determined from an unbinned maximum likelihood fit to the reconstructed top quark mass.



Source	Relative Uncertainty (%)
B-Tagging	15.7
Jet Energy Scale	13.5
Background	12.2
Q^2 Scale	8.7
Tune	8.1
ISR/FSR	5.6
Top Quark Mass	5.3
Parton Shower Matching	5.2
Jet Energy Resolution	4.8
Trigger	4.5
Pile-Up	0.6
Systematic	29.1
Statistical	14.3
Luminosity	6.0
Total Uncertainty	33.0

$$\sigma_{t\bar{t}} = \frac{f_{sig} \cdot N}{\epsilon \cdot L_{int}}$$

$$\sigma_{t\bar{t}} = 136 \pm 20\,(\text{stat.}) \pm 40\,(\text{sys.}) \pm 8\,(\text{lumi.})\ \text{pb}$$

$$\frac{\delta\sigma}{\sigma} \sim 33\%$$

Fully hadronic

ATLAS

Luminosity = **1.02 fb^{-1}**
Variables: mass X^2
Jet multiplicity: ≥ 5 jets
Main systematics : b-tagging, JES and the modeling of ISR/FSR

$$\boxed{\sigma_{t\bar{t}} = 167 \pm 18(stats.) \pm 78(syst.) \pm 6(lumi)pb} \qquad \frac{\delta\sigma}{\sigma} \sim 48\,\%$$

CMS

Luminosity = **1.09 fb^{-1}**
Variables: mass M3
Jet multiplicity: ≥ 4 jets
Main systematics : b-tagging, JES.

$$\boxed{\sigma_{\mathrm{t\bar{t}}} = 136 \pm 20\ (\mathrm{stat.}) \pm 40\ (\mathrm{sys.}) \pm 8\ (\mathrm{lumi.})\ \mathrm{pb}} \qquad \frac{\delta\sigma}{\sigma} \sim 33\%$$

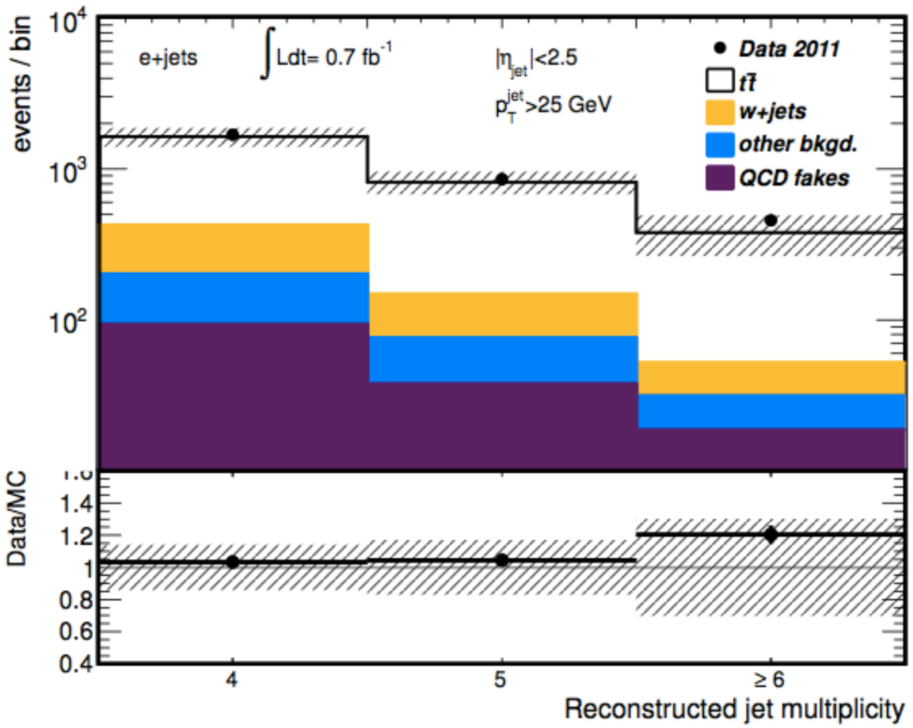
ttbar +jets

The measurement of associated jet production rates has the potential to reduce the Initial State Radiation (ISR) and Final State Radiation (FSR) modeling uncertainty.

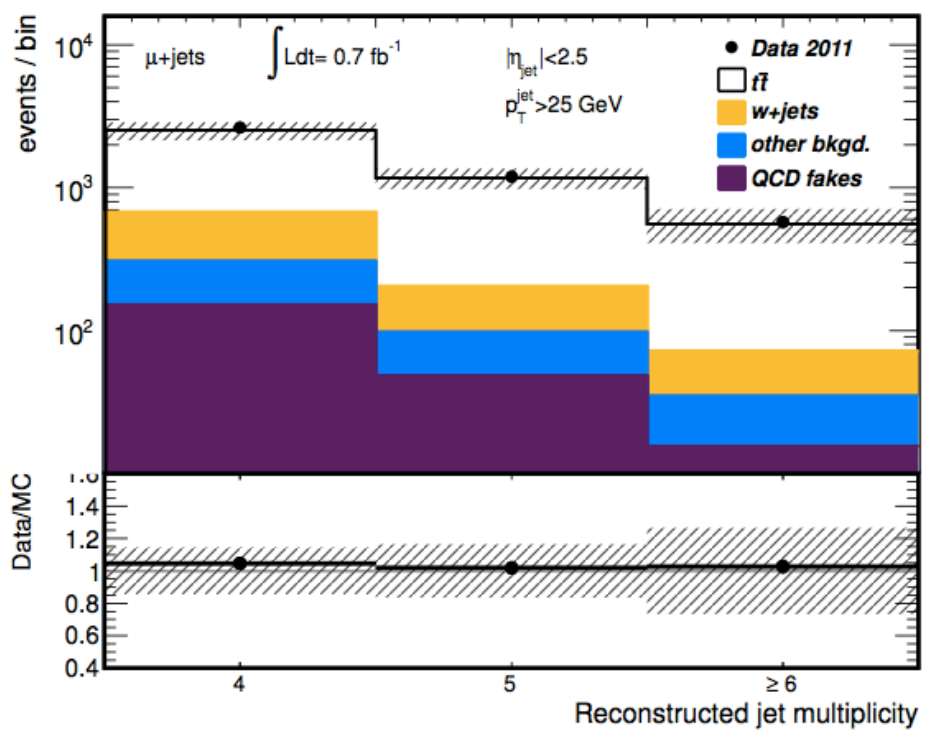
This would enable a reduction of this important source of systematic uncertainty for all top measurements, including the top mass measurement and the *tt* production cross section measurement.

Standard l+jets event selection plus:

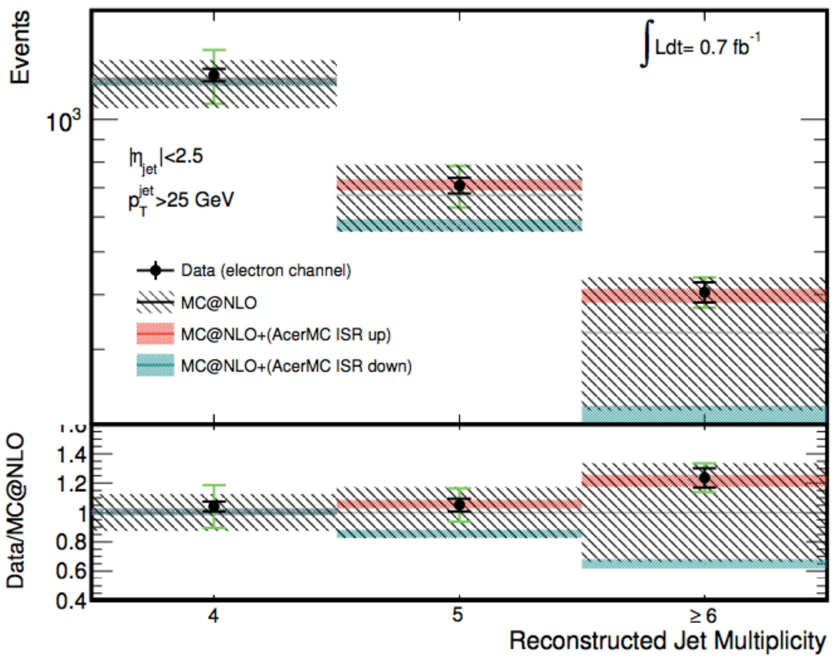
- Require at least one jet to pass a b-tag with SV0 > 5.85



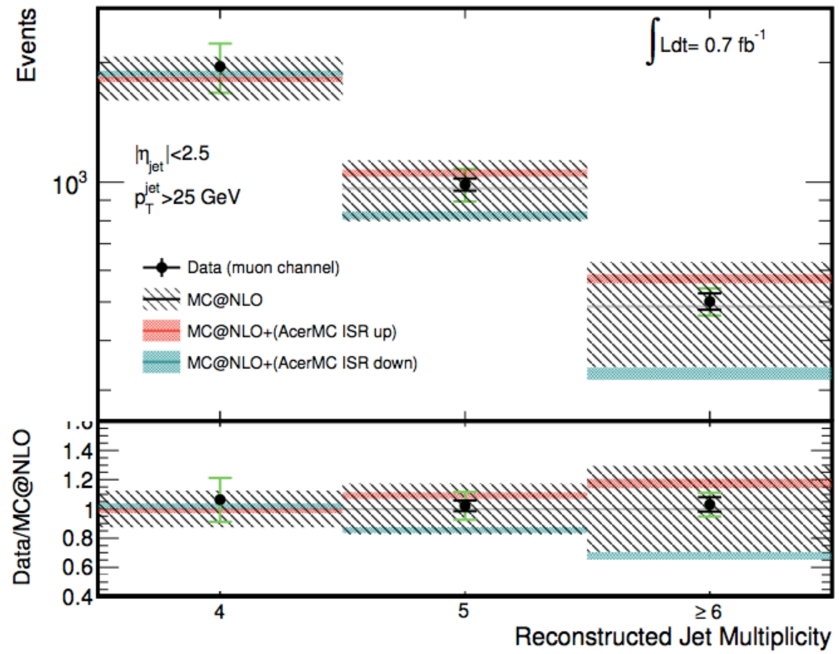
ELECTRON



MUON



ELECTRON



MUON

Within the uncertainties (dominated by the Jet Energy Scale) no distinction between the models can be made. The analysis would benefit from more data; this will allow the ISR contribution to be cleanly probed by providing more high- *pT* jet events.

Summary of ttbar cross-section measurements in ATLAS

Lepton + Jets untagged in 0.7 fb^{-1}

$$\sigma_{t\bar{t}} = 179 \pm 3.9(stat.) \pm 9.0(syst.) \pm 6.6(lumi.)pb \qquad \frac{\delta\sigma}{\sigma} \sim 6.6\%$$

Lepton + Jets with b-tag in 35 pb^{-1}

$$\sigma_{t\bar{t}} = 189 \pm 11(stat.)^{+15}_{-14}(syst.) \pm 6(lumi.)pb \qquad \frac{\delta\sigma}{\sigma} \sim 10.3\%$$

All Hadronic channel in 1.02 fb^{-1}

$$\sigma_{t\bar{t}} = 167 \pm 18(stat.) \pm 75(syst.) \pm 6(lumi.)pb \qquad \frac{\delta\sigma}{\sigma} \sim 46\%$$

Summary of ttbar cross-section measurements in CMS

Lepton + Jets untagged in 0.7 fb^{-1}

$$\sigma_{t\bar{t}} = 173^{+39}_{-32}(stats. + syst.) \pm 7(lumi)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 23\%$$

Lepton + Jets with b-tag in 35 pb^{-1}

$$\sigma_{t\bar{t}} = 164.4 \pm 2.8(stat.) \pm 11.9(syst.) \pm 7.4(lum.)pb$$

$$\frac{\delta\sigma}{\sigma} \sim 9\%$$

All Hadronic channel in 1.02 fb^{-1}

$$\sigma_{t\bar{t}} = 136 \pm 20\ (\mathrm{stat.}) \pm 40\ (\mathrm{sys.}) \pm 8\ (\mathrm{lumi.})\ \mathrm{pb}$$

$$\frac{\delta\sigma}{\sigma} \sim 33\%$$

Conclusions

Thanks to the great performance of the detector and accelerator a full suite of analyses have been accomplished.

L+jets, full hadronic and ttbar +jets analyses have been presented.

Need still a better understanding of some systematics: Jet energy scale, b-tagging, theory uncertainties are some of the main contributions for all the analyses. Reduction on the luminosity error would be also interesting.

Results are consistent with theoretical QCD predictions, no significant deviations from expectations of the SM.

New analyses are coming along: hadronic tau channel, differential cross-section, etc.

Back-up

Overview of the Matrix Method

For the matrix method we define two sets of events, **loose** and **tight**, the tight being a subset of the loose one.

Both selections have the same kinematic cuts but differ on the lepton quality requirements.

The tight selection has typically the final selection cuts of the analysis.

$$N_{loose} = N_{loose}^{fake} + N_{loose}^{real}$$
$$N_{tight} = \epsilon_{fake} \cdot N_{loose}^{fake} + \epsilon_{real} \cdot N_{loose}^{real}$$

$$N_{fake}^{tight} = \frac{\epsilon_{fake}}{\epsilon_{real} - \epsilon_{fake}} (N_{loose}\epsilon_{real} - N_{tight})$$

These two efficiencies are required to be as different as possible to improve the statistical precision on N_{tight}^{fake}

Where to measure these efficiencies:

ϵ^{real} will be measured in data control samples, such as Z+jets (inclusive) events.

ϵ^{fake} will be measured in data enriched in QCD multi-jets like events with low E_T.

$$m_T(W) = \sqrt{2p_T^l p_T^\nu(1-\cos(\phi^l - \phi\nu))}$$

Single lepton triggers.

Exactly one isolated lepton:

Electron: $E_T > 25$ GeV, $|\eta| < 2.5$ - crack, E_T (cone 0.2) < 3.5 GeV.

Muon: $p_T > 20$ GeV, $|\eta|<2.1$, E_T (cone 0.3) < 4 GeV & P_T (cone 0.3) < 4 GeV,

ΔR(muon,jet (p_T>20 GeV)) < 0.4.

Jets: Anti-Kt 0.4, $p_T > 25$ GeV, $|\eta| < 2.5$, ΔR(jet, electron) < 0.2.

Missing E_T: Electrons $\not{E}_T > 35$ GeV, Muons $\not{E}_T > 25$ GeV.

W transverse mass : Electrons $m_T(W) > 25$ GeV, Muons $\not{E}_T + m_T(W) > 60$ GeV.

QCD multi-jets background is extracted using a data driven technique called matrix method [1]

[1]- Phys.Rev. **D76** 092007 (2007)

Event selection

CMS

$$I_{rel} = (I_{charged} + I_{neutral} + I_{photon})/p_T$$

Single lepton triggers.

Exactly one isolated lepton:

- Electron: $E_T > 30$ GeV, $|\eta| < 2.5$ - crack, relative isolation(cone 0.3) < 0.1
- Muon: $p_T > 20$ GeV, $|\eta|<2.1$,relative isolation (cone 0.3) < 0.05

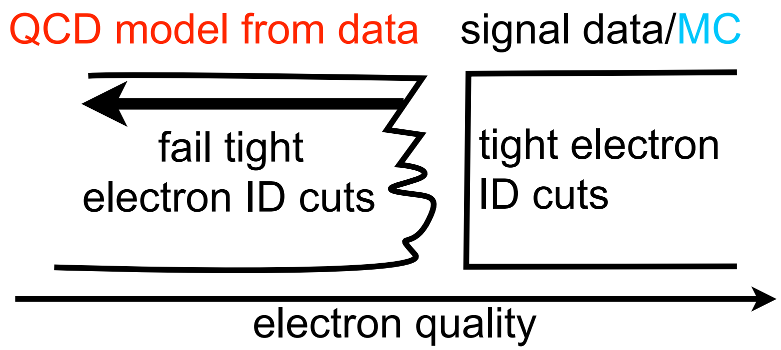
Jets: Anti-Kt 0.5, $p_T > 30$ GeV, $|\eta| < 2.4$

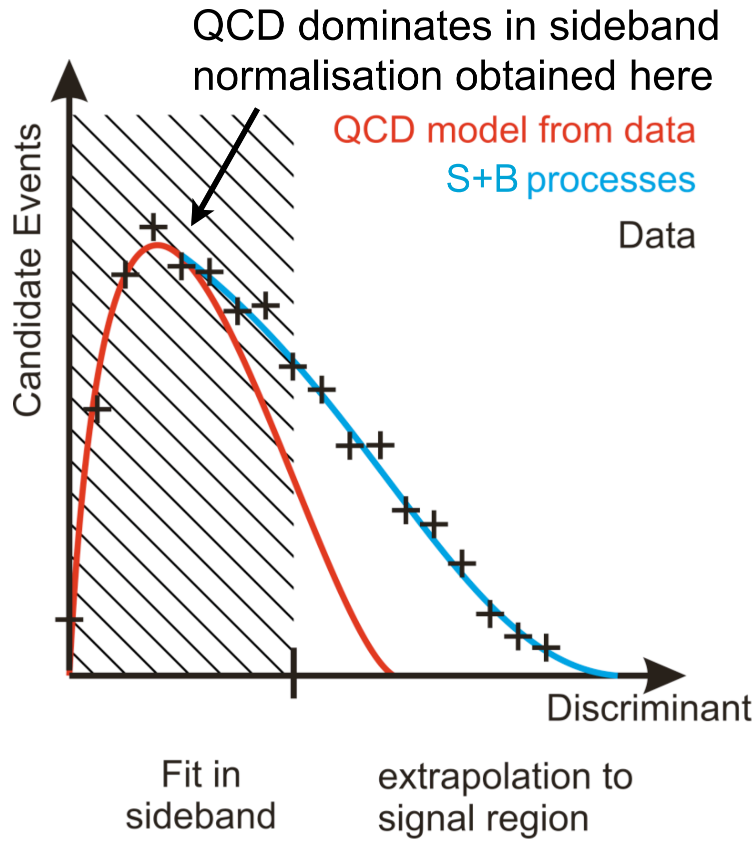
QCD multi-jet background is derived from data:

- Electron (failing at least two of three requirements): Relative isolation, transverse impact parameter (< 0.02 cm) or standard electron identification criteria.
- Muon softening isolation requirements: Relative isolation between 0.2 and 0.5.

brief reminder of the method

- need to find region where QCD dominates while staying as close as possible to signal selection
- select sample orthogonal to standard top selection by inverting cut on electron particle ID selection → **anti-electron sample - provides full QCD model**
- find distribution that is sensitive to lepton fakes → **missing transverse energy** (QCD here mostly instrumental background)
- shape of QCD background taken from data, but model provides no cross-section → **determine amount of QCD background from fit in sideband (0-35 GeV)**
- see **Note V** and **Note M4 for more**





An advantage of this approach is that many systematics uncertainties are measured in situ and inversely scale with the integrated luminosity.

Data can potentially constrain the magnitude of the systematic and reduce their impact on the overall precision of the measurement.

$$-2\ln L(k_{t\bar{t}}, k_{W+jets}, \vec{\alpha}) \propto -2\sum_{i=1}^{N_{bins}} n_i \ln \mu_i - \mu_i + \sum_{j=1}^{N_{Syst}} \alpha^2$$

$$\mu_i = \mu_i(k_{t\bar{t}}, k_{W+jets}, \vec{\alpha})$$

The nuisance parameters are subject to a Gaussian penalty term that constrain each of them to their a-priori uncertainties.

The fitted value for a nuisance parameter has the meaning of number of standard deviations form nominal preferred by data, while its uncertainty is measured in units of the a-priori standard deviation for such uncertainty source.

A fitted nuisance parameter of

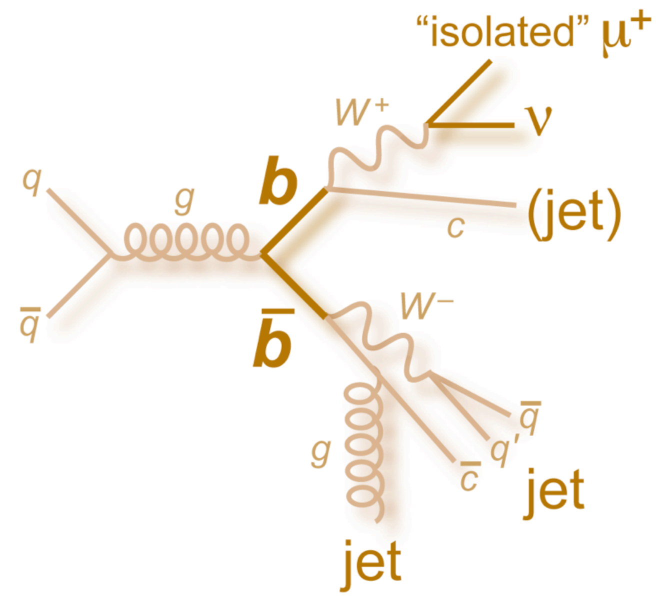
$$\alpha_j = -0.5 \pm 0.1$$

should be interpreted as the data preferring a shift in the model corresponding to -0.5·σ of the a-priori systematic uncertainty, and a reduction of the systematic uncertainty down to 10% of its original magnitude.

Signal and background modeling

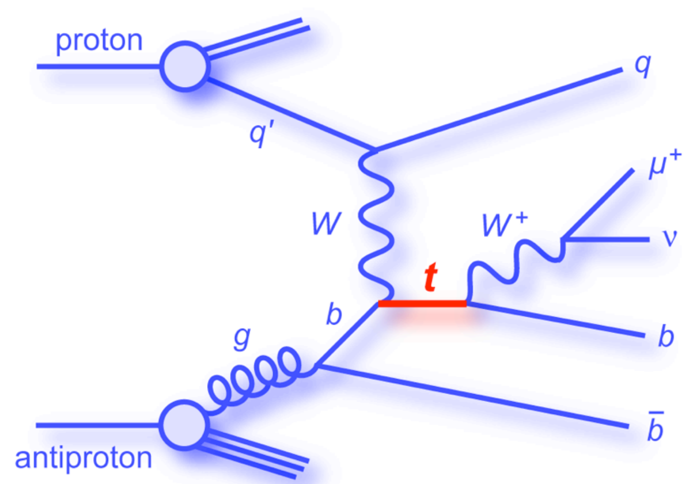
ATLAS

ttbar MC@NLO
W+jets / Z+jets ALPGEN
Diboson Herwig
Single top MC@NLO



CMS

ttbar MADGRAPH
W+jets / Z+jets MADGRAPH
Single top MCFM



Selection efficiency

Single Lepton Untagged **ATLAS**

Electrons	3 ex (%)	4 ex (%)	5 in (%)
Selection efficiency	3.10	3.00	2.40

Muons	3 ex (%)	4 ex (%)	5 in (%)
Selection efficiency	4.40	4.40	3.30