Top 2013

Top-Quark Mass at the LHC

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On behalf of the ATLAS and CMS Collaborations

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GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

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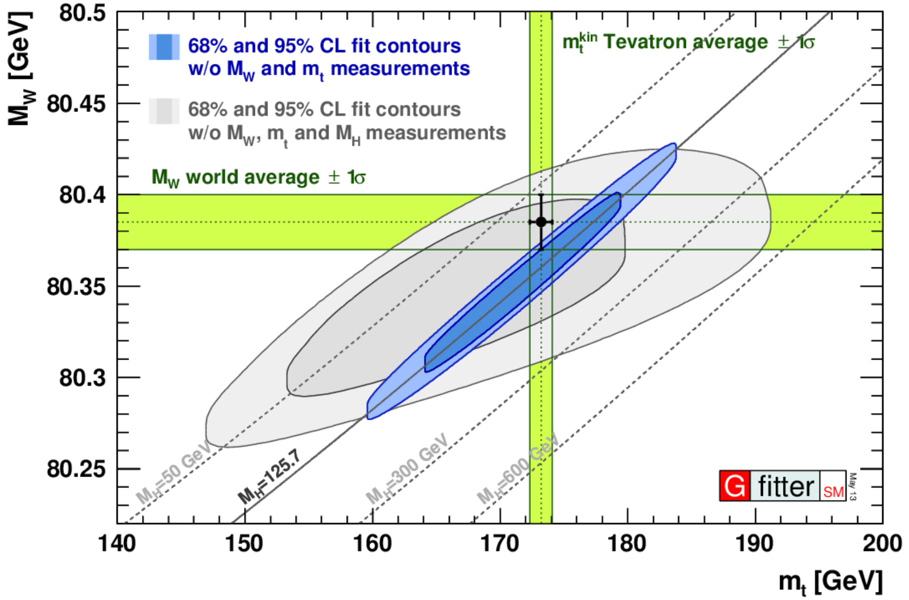
Why more accurate top-quark mass measurements?

- Fundamental parameter of the Standard Model
- Important for many radiative corrections
- Now that we know the Higgs-boson mass, is the Standard Model still internally consistent?
- Vacuum stability?



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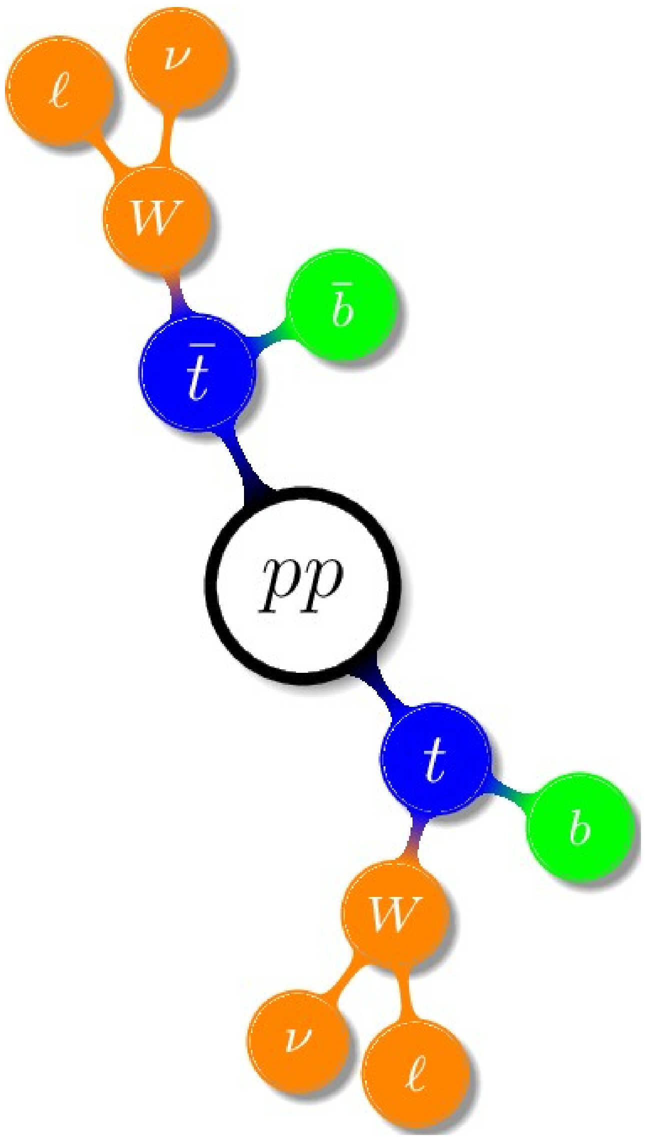
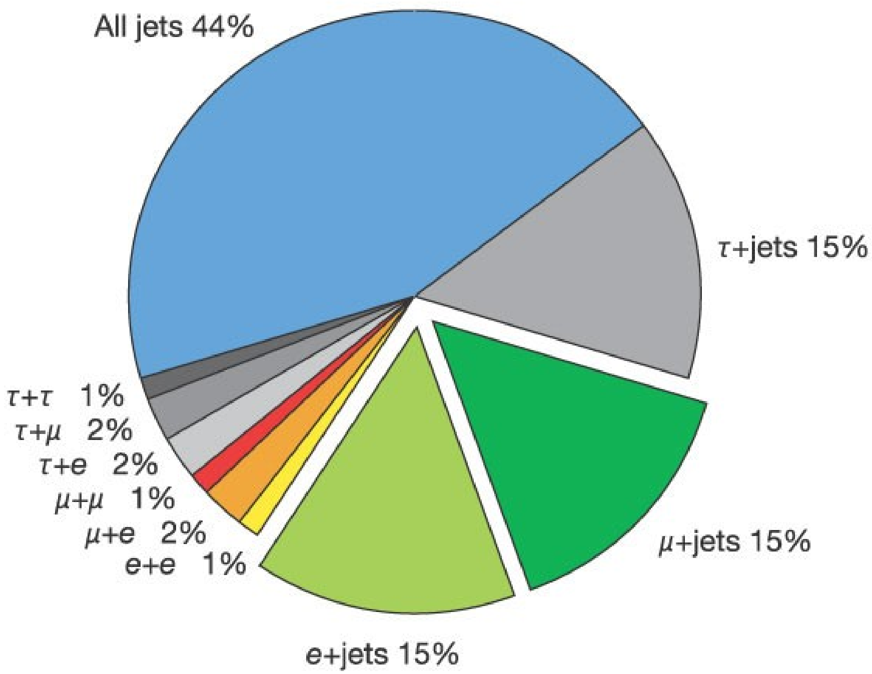
Top quarks at the LHC





3 topologies used for top-quark mass measurements:

- Dilepton (both W decay leptonically)

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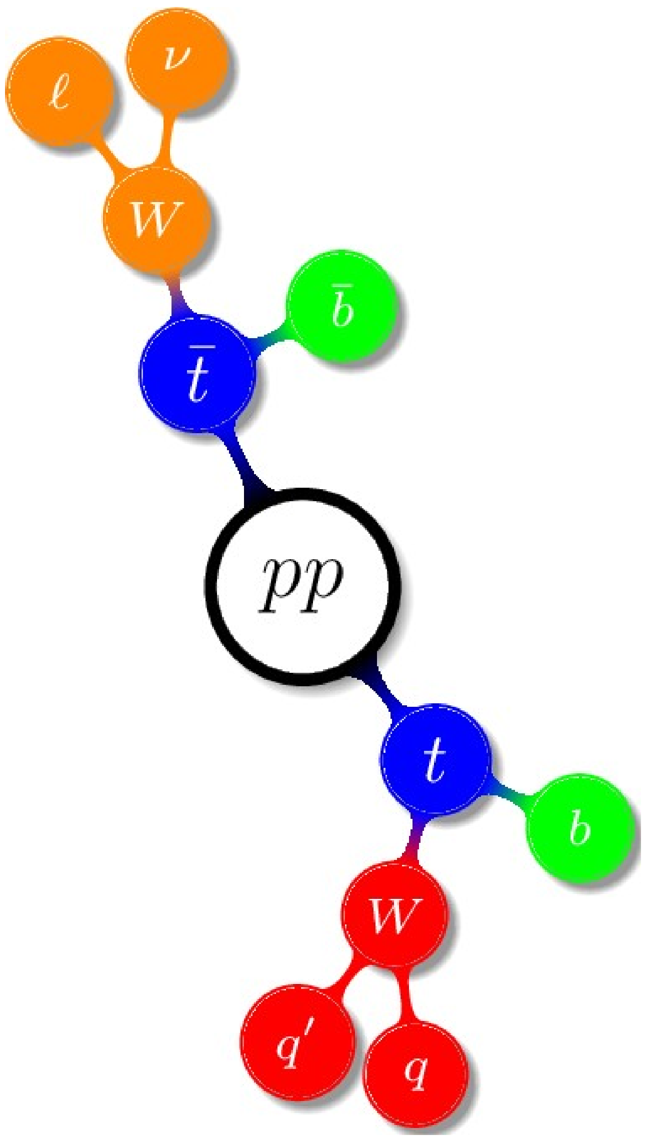
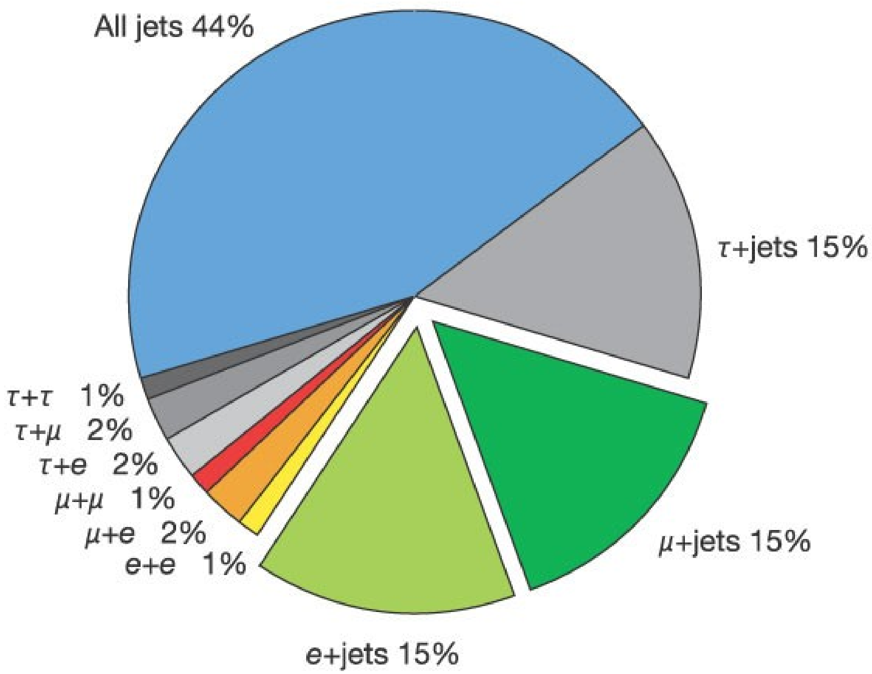
Top quarks at the LHC





3 topologies used for top-quark mass measurements:

- Dilepton (both W decay leptonically)
- Lepton + jets (1 W decays leptonically)

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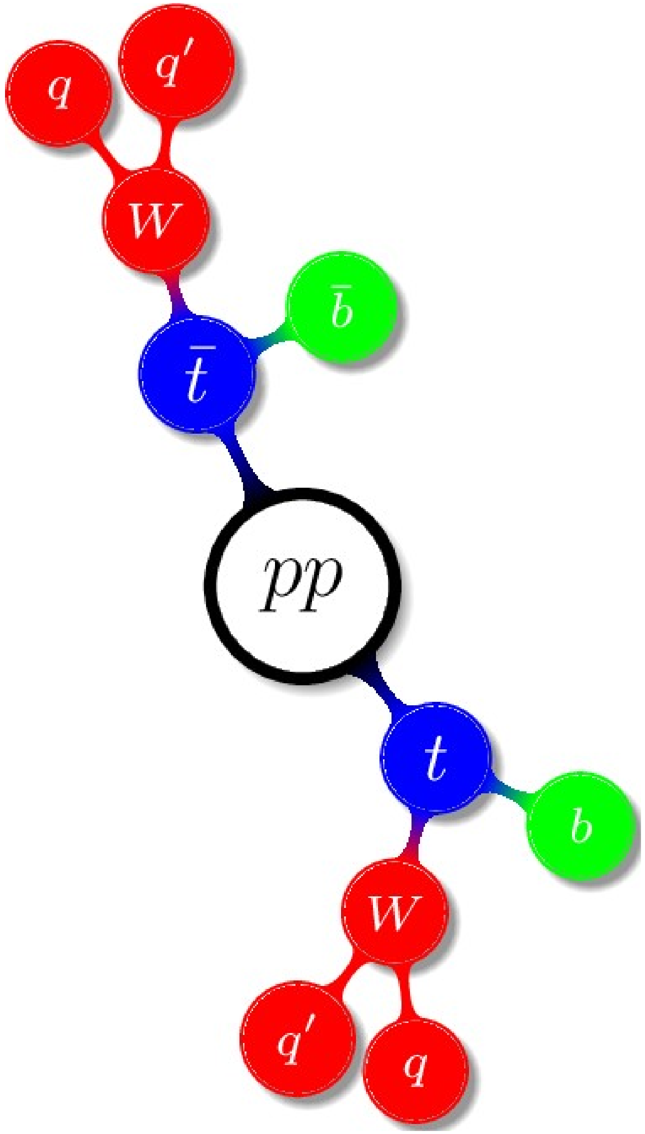
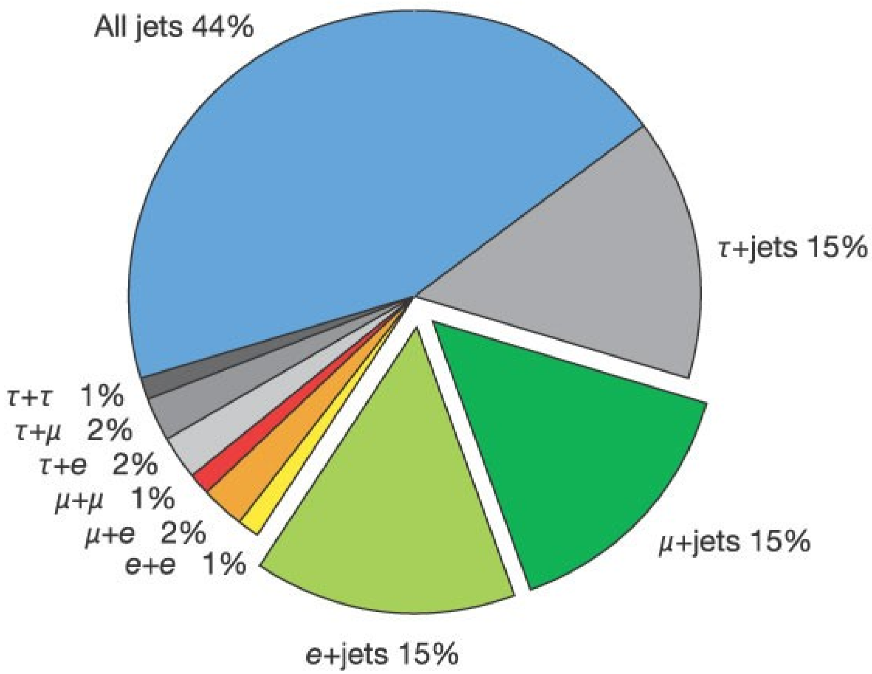
Top quarks at the LHC





3 topologies used for top-quark mass measurements:

- Dilepton (both W decay leptonically)
- Lepton + jets (1 W decays leptonically)
- All-hadronic (both W decay hadronically

Datasets

- Most analyses based on 4.7-5.0 fb^{-1} data from 2011 at $\sqrt{s}$ = 7 TeV
- Plenty of statistics:
  - 800k $t\bar{t}$ events produced per experiment (2011 data)
- Reducing and controlling systematic uncertainties is the key
- Getting improved measurements with high pile-up 2012 data will take a while
  - CMS has an updated Δm_t measurement

Measurements

- ATLAS m_t
  - Dilepton
    - Template method
  - Lepton+jets
    - 3D template method
  - All-hadronic
    - 1D template method
- ATLAS Δm_t

- CMS m_t
  - Dilepton
    - Matrix weighting
  - Lepton+jets
    - 2D ideogram method
  - All-hadronic
    - 1D and 2D ideogram method
- CMS Δm_t

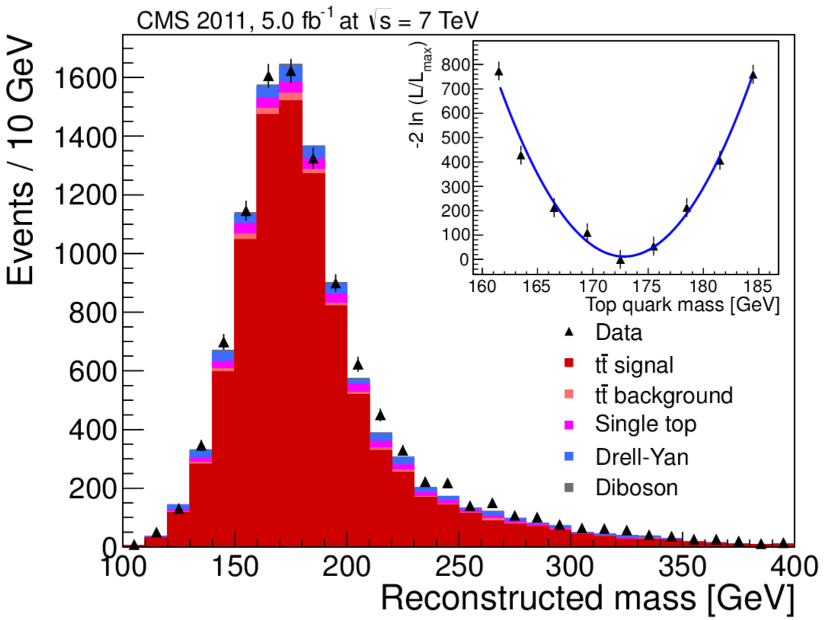
CMS dileptons

- 5.0 fb^{-1} 7 TeV data
- Events
  - 2 charged leptons
  - ≥ 2 jets
  - ≥ 1 *b*-tagged jet
  - E_T^{miss}
- Use analytical matrix weighting technique (AMWT) + likelihood

- AMWT
  - Scan different m_t hypotheses
    - Solve kinematic equations of $t\bar{t}$ system
    - Repeat with smeared jets and assign weight
    - Sum weights for each mass hypothesis
  - Reconstructed mass from hypothesis with highest weight

EPJ C 72 (2012) 2202

CMS dileptons



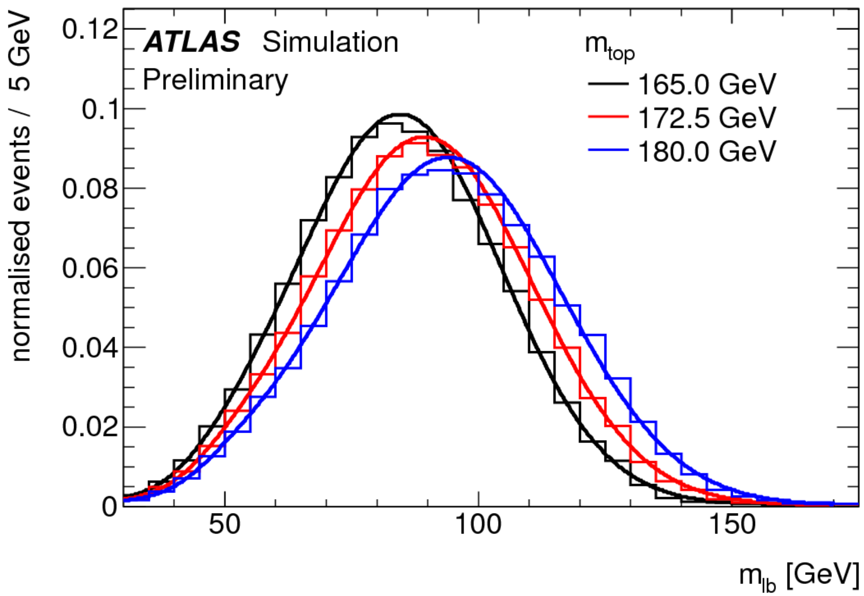
Main uncertainties

Description	Value [GeV]
Statistics	0.4
Jet energy scale	+0.90/-0.97
b-jet energy scale	+0.76/-0.66
μ_R and μ_F scales	0.55
Underlying event	0.26
Total	**1.48**

m_t = 172.5 ±0.4 (stat) ±1.5 (syst) GeV.

ATLAS dileptons

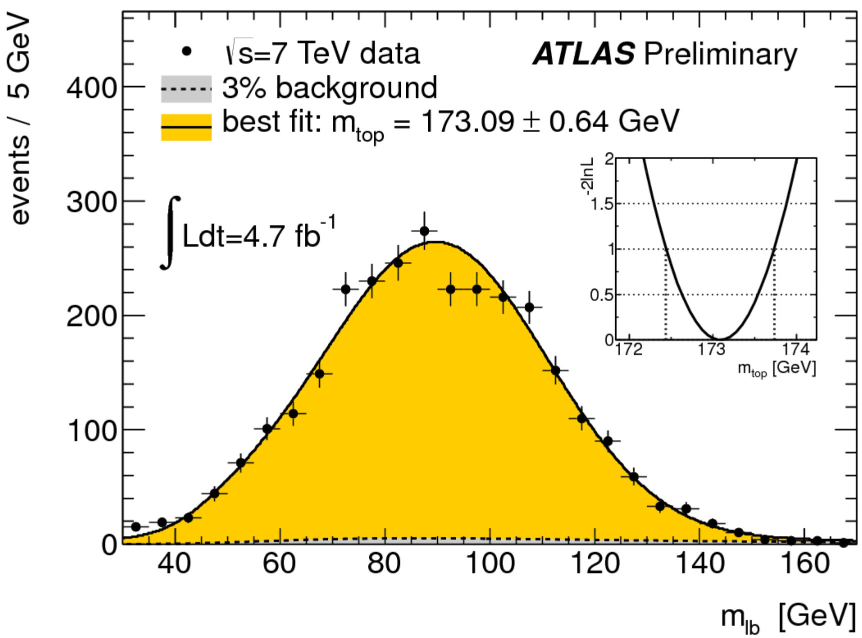
- 4.7 fb^{-1} 7 TeV data
- Events
  - 2 charged leptons
  - 2 *b*-tagged jets
  - E_T^{miss} (ee/μμ) or H_T (eμ) cut
- 1D template method
  - m_{lb} as estimator for m_t
  - Lower m_{lb} average value used



ATLAS-CONF-2013-077

ATLAS dileptons

Almost background free sample (< 3% single top)



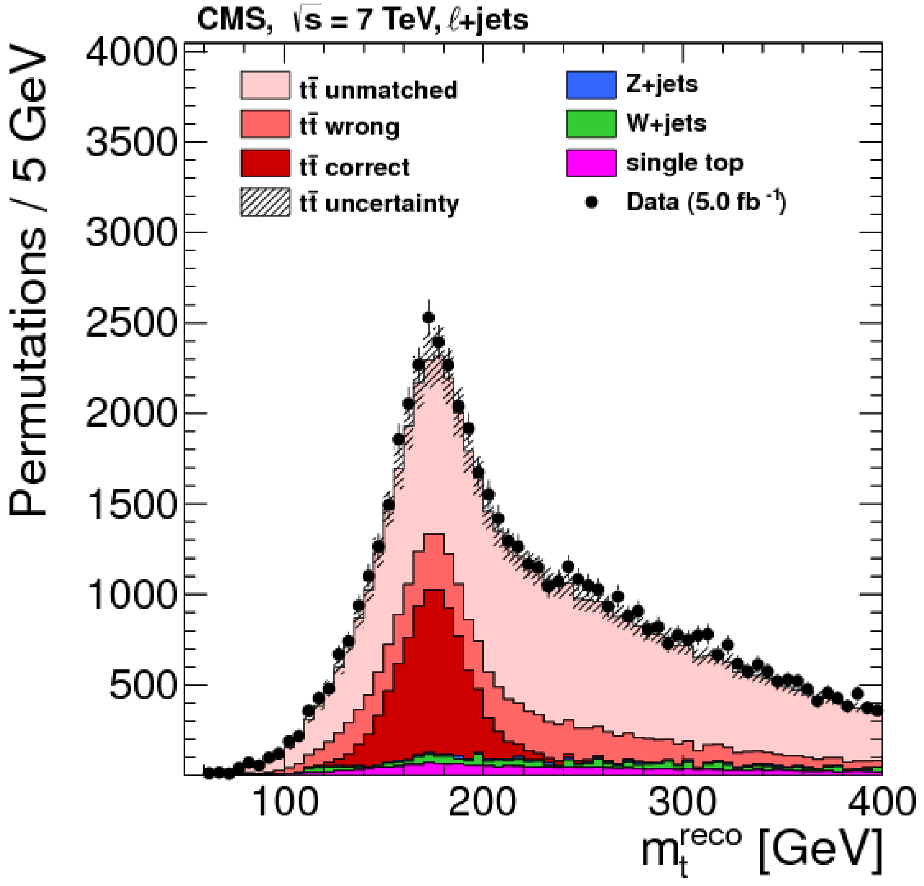
Main uncertainties

Description	Value [GeV]
Statistics	0.64
Hadronisation	0.44
Underlying event	0.42
ISR/FSR	0.37
Jet energy scale	0.89
b-jet energy scale	0.71
b-tagging	0.46
Total	**1.50**

m_t = 173.09 ±0.64 (stat) ±1.50 (syst) GeV

CMS lepton+jets

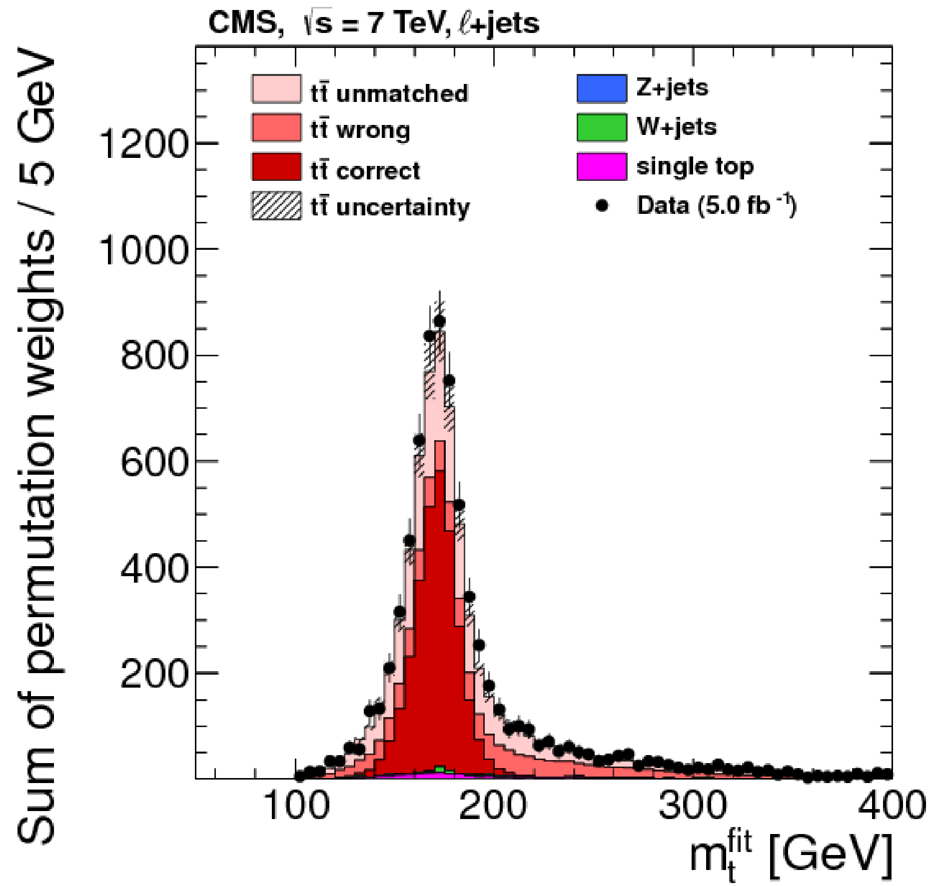
- 5 fb^{-1} 7 TeV data
- Events
  - 1 charged lepton
  - ≥ 4 jets
  - ≥ 2 b-tagged jets



JHEP 12 (2012) 105

CMS lepton+jets

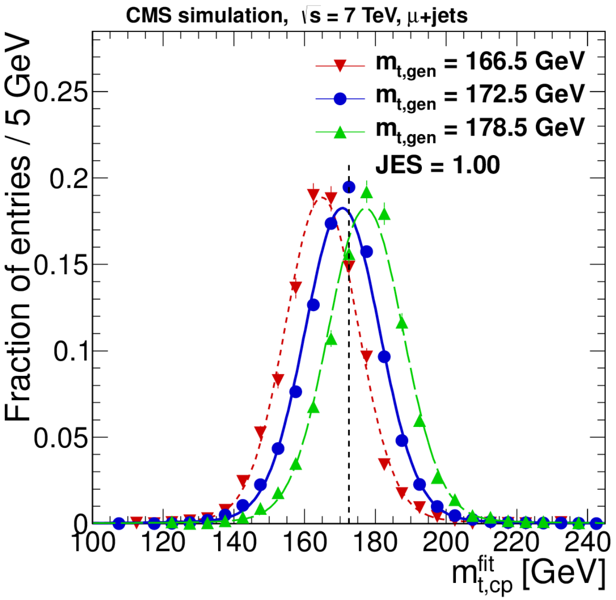
- 5 fb^{-1} 7 TeV data
- Events
  - 1 charged lepton
  - ≥ 4 jets
  - ≥ 2 b-tagged jets
- Improve reconstruction purity with kinematic fit
  - Cut on goodness-of-fit and use it as a weight
  - Correct permutation fraction went from 13% to 44%

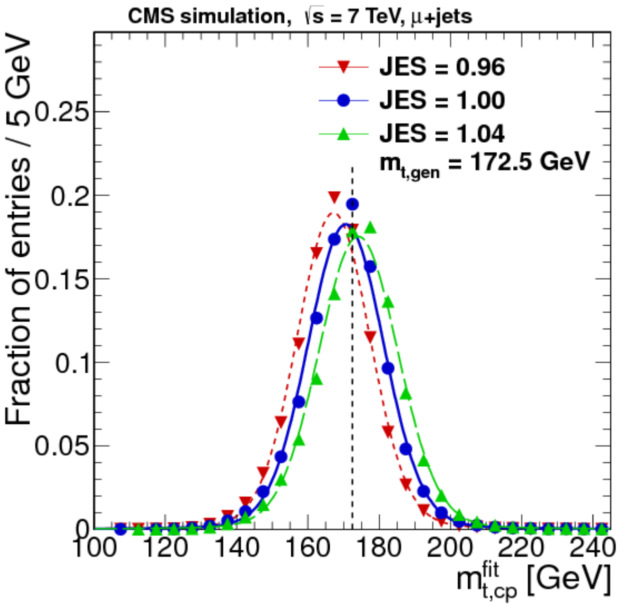


JHEP 12 (2012) 105

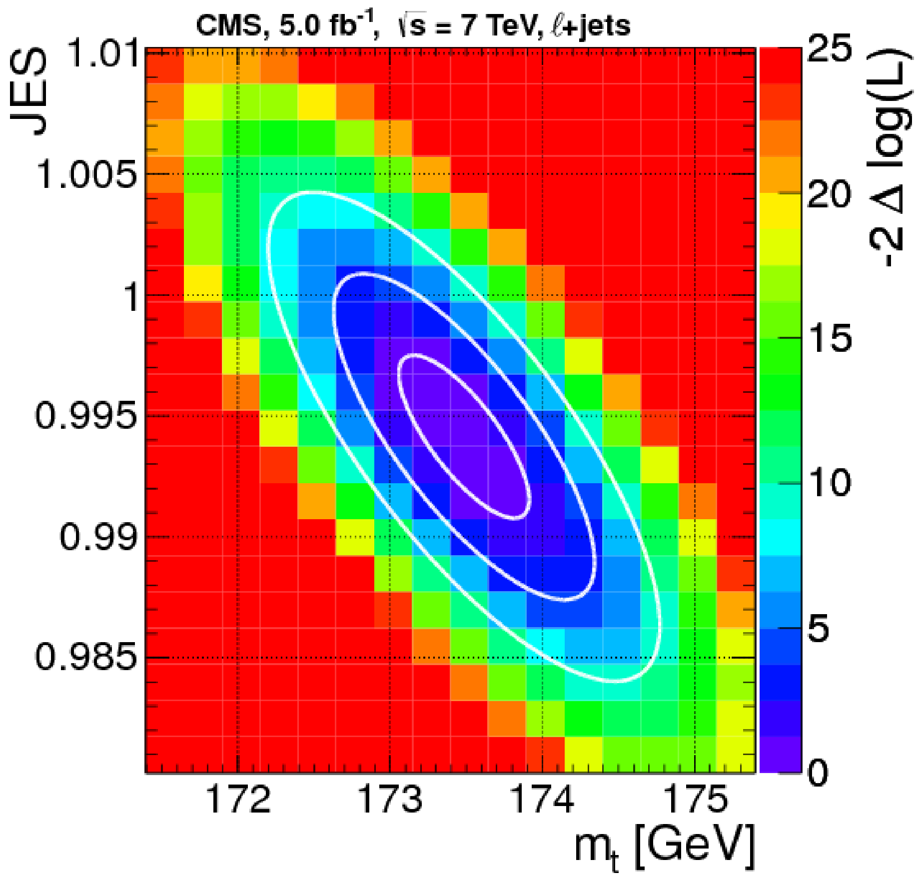
CMS lepton+jets

- Measure top-quark mass and JES simultaneously
- Ideogram:
  - Go from $P(\text{event}|m_t, \text{JES})$ to $P(m_t, \text{JES}|\text{sample})$
  - Weight with quality of event reconstruction
- Use all allowed permutations per event





CMS lepton+jets



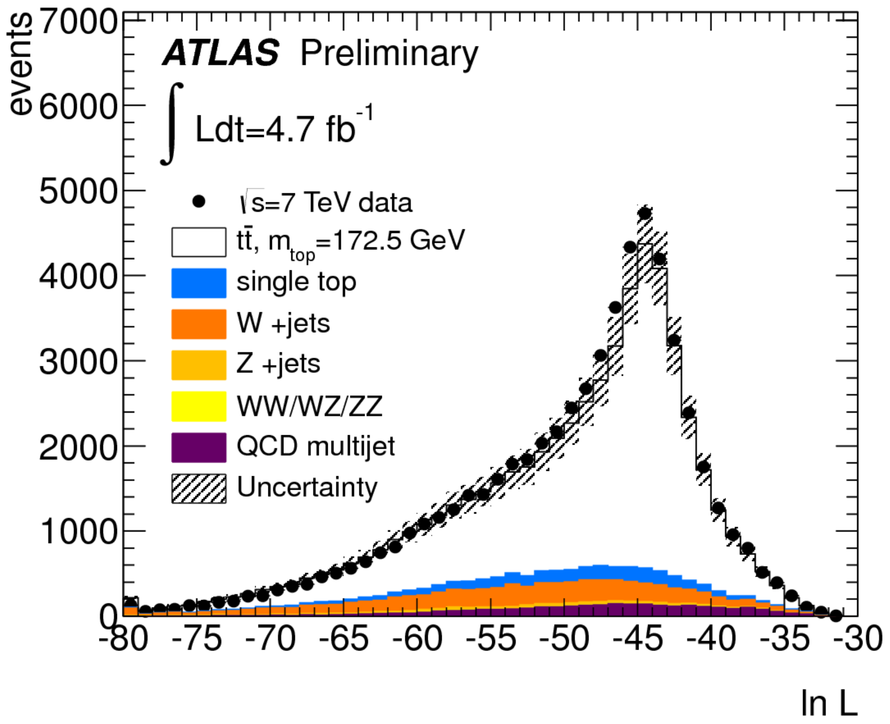
Main uncertainties

Description	Value [GeV]
Statistics	0.43
Jet energy scale	0.28
b-JES	0.61
Jet energy resolution	0.23
μ_R and μ_F scales	0.24
Colour reconnection	0.54
ME-PS matching	0.18
Total systematic	**0.98**

$$m_t = 173.49 \pm 0.43(\text{stat} + \text{JES}) \pm 0.98(\text{syst})\,\text{GeV}$$
$$\text{JES} = 0.994 \pm 0.003(\text{stat}) \pm 0.008(\text{syst})$$

ATLAS lepton+jets

- 4.7 fb^{-1} 7 TeV data
- Events
  - 1 charged lepton
  - ≥ 4 jets
  - 1 or 2 *b*-tagged jets
- Use a kinematic fitter to reconstruct event
  - Correct assignment of jets to partons > 70%



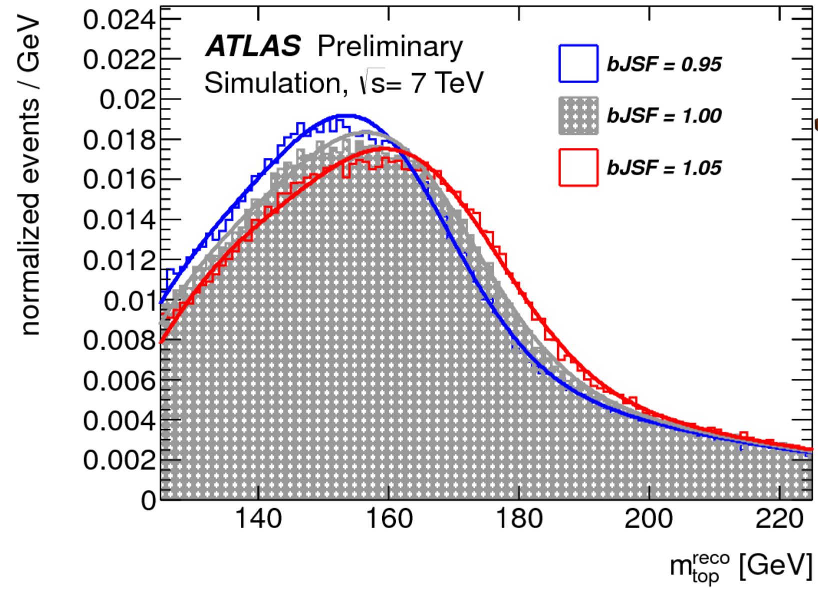
ATLAS-CONF-2013-046

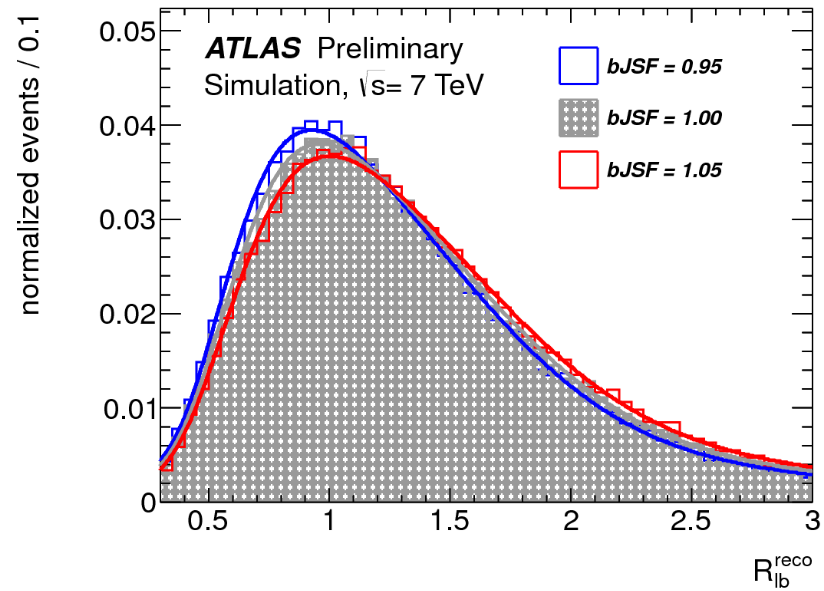
ATLAS lepton+jets

- Use *W* mass to constrain overall jet energy scale (JSF)
- Use (for 1 *b*-tag)

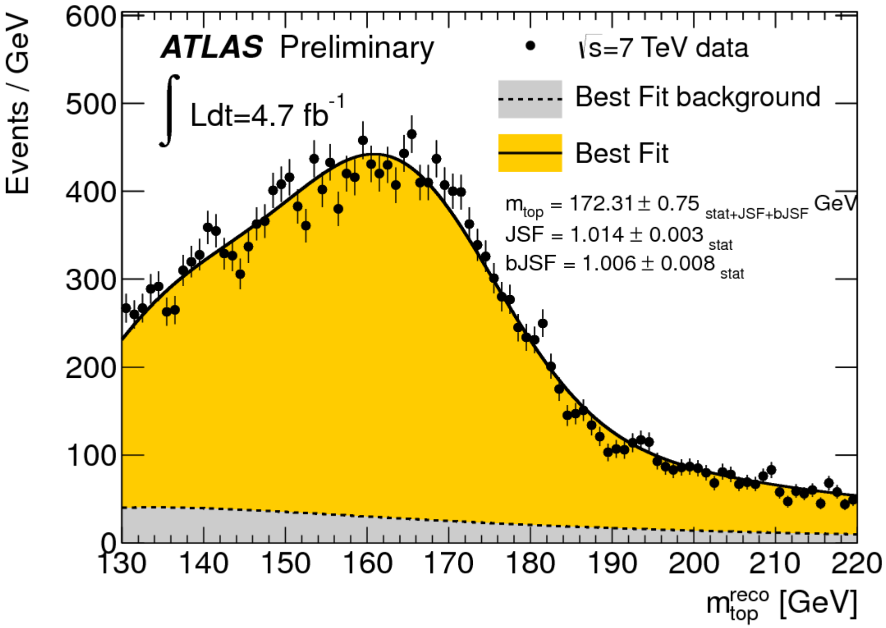
$$R_{lb}^{\mathrm{reco}} = \frac{2p_{\mathrm{T}}^{b\text{-tag}}}{p_{\mathrm{T}}^{\mathrm{light},1} + p_{\mathrm{T}}^{\mathrm{light},2}}$$

  to constrain overall ratio of *b* to light-parton jet energy scale (bJSF)
  - not correlated with JSF

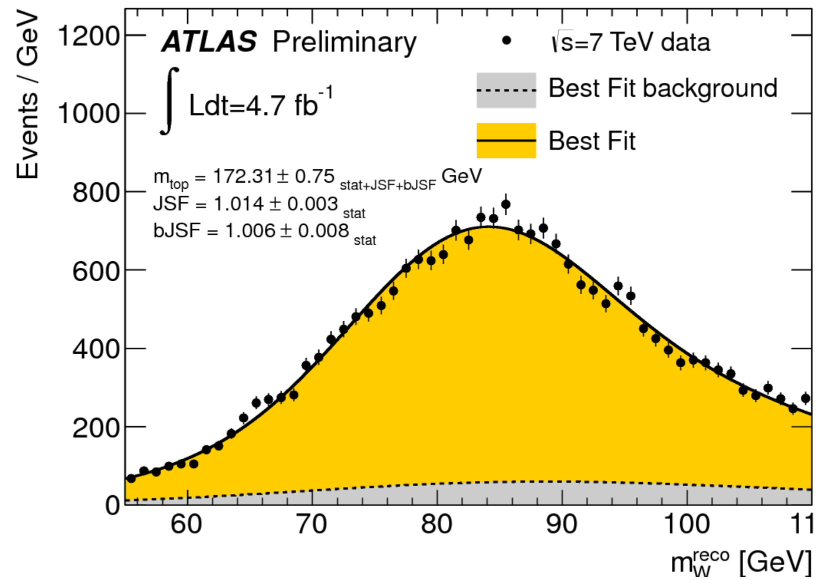


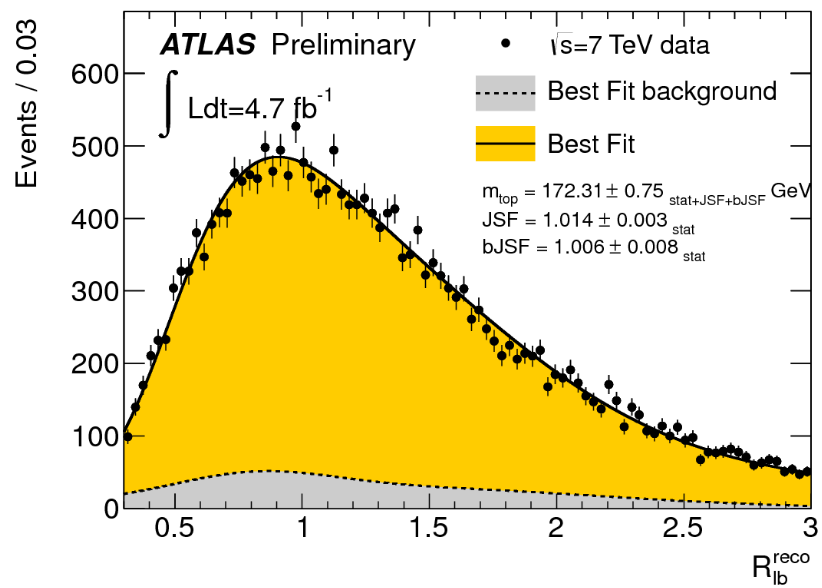


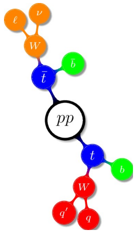
ATLAS lepton+jets



- Parametrise shapes as a function of m_t and perform unbinned likelihood fit







ATLAS lepton+jets

- *b*-jet energy scale uncertainty down to 0.08 GeV!
- Modelling uncertainties from hadronisation and ISR/FSR substantially decreased
- Jets still largest source of uncertainty
- Modelling uncertainties are also significant
- Work ongoing to reduce b-tagging uncertainty

Main uncertainties

Description	Value [GeV]
Statistics	0.23
JSF (stat)	0.27
bJSF (stat)	0.67
Hadronisation	0.27
Colour reconnection	0.32
ISR/FSR	0.45
Jet energy scale	0.79
b-tagging	0.81
Total systematic	**1.35**

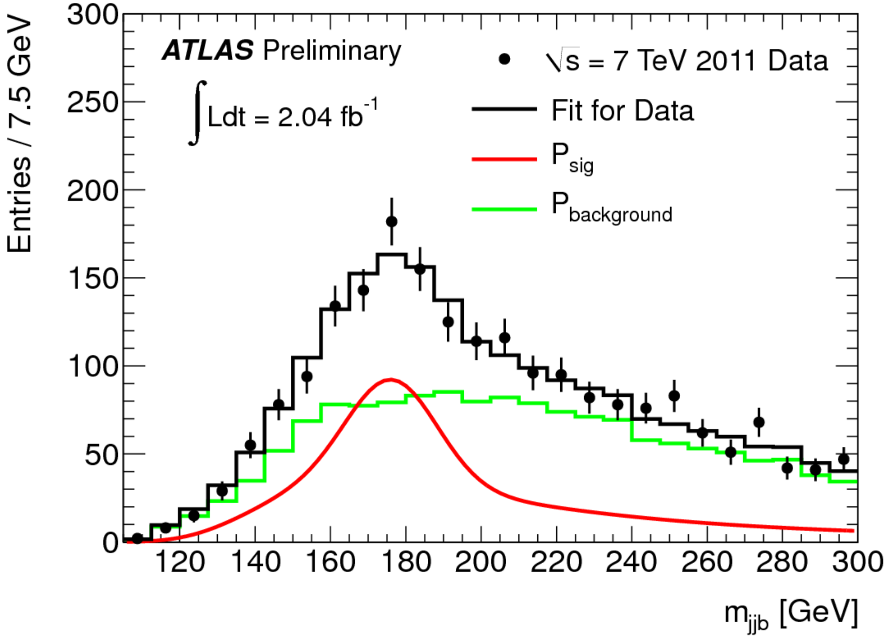
$$m_t = 172.31 \pm 0.75(\text{stat} + \text{JSF} + \text{bJSF}) \pm 1.35(\text{syst})\,\text{GeV}$$

$$\text{JSF} = 1.014 \pm 0.003(\text{stat}) \pm 0.021(\text{syst})$$

$$\text{bJSF} = 1.006 \pm 0.008(\text{stat}) \pm 0.020(\text{syst})$$

ATLAS all-hadronic

- 2.04 fb^{-1} 2011 data
- Events
  - ≥ 6 jets
  - 2 *b*-tagged jets
- χ^2 fit for jet to parton assignment
- Use event mixing to estimate multijet background
- 1D template fit m_{jjb}

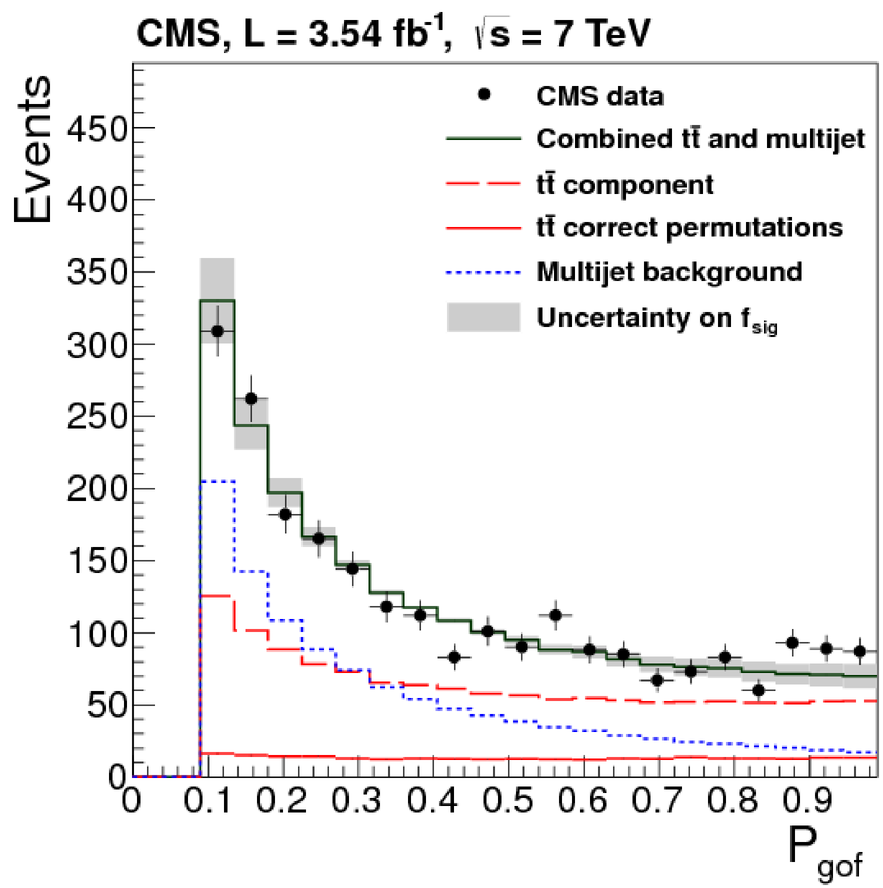


m_t = 174.9 ± 2.1(stat) ± 3.8(syst) GeV

ATLAS-CONF-2012-030

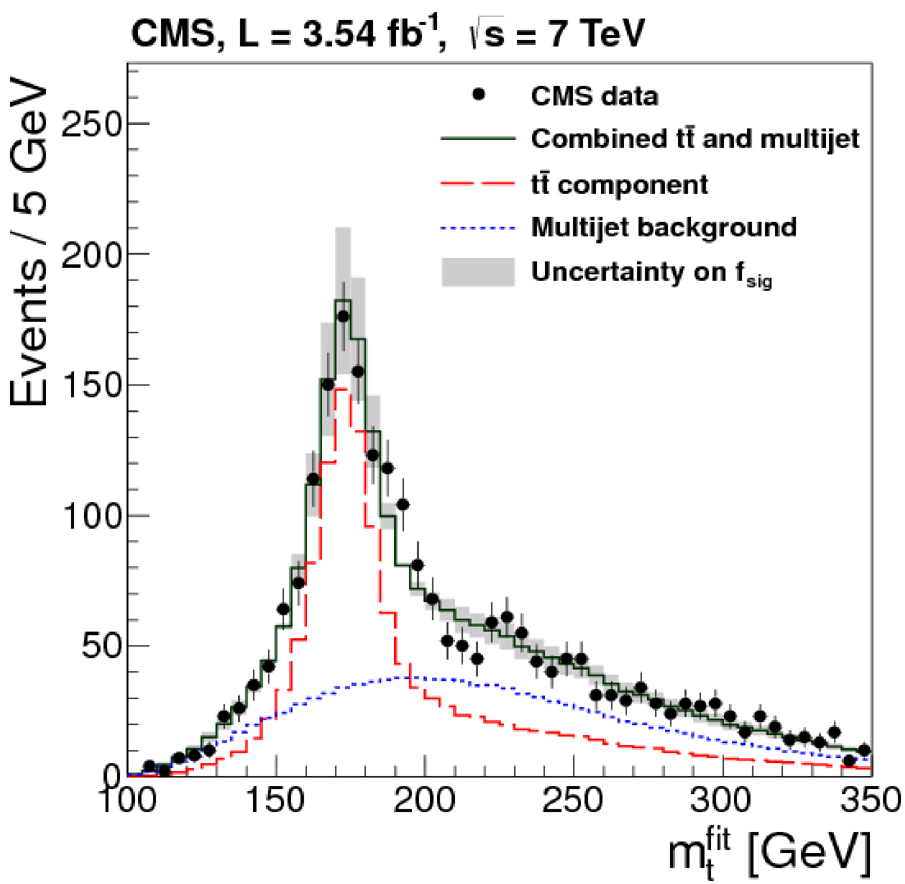
CMS all-hadronic

- 3.54 fb^{-1} 7 TeV data
- Events:
  - ≥ 6 jets
  - ≥ 2 *b*-tagged jets
- Use event mixing to estimate multijet background
- Improve reconstruction purity with kinematic fit
  - Cut on goodness-of-fit and use it as a weight
  - Signal fraction 51%



CMS-TOP-11-017
arXiv:1307.4617

CMS all-hadronic



Main uncertainties (1D)

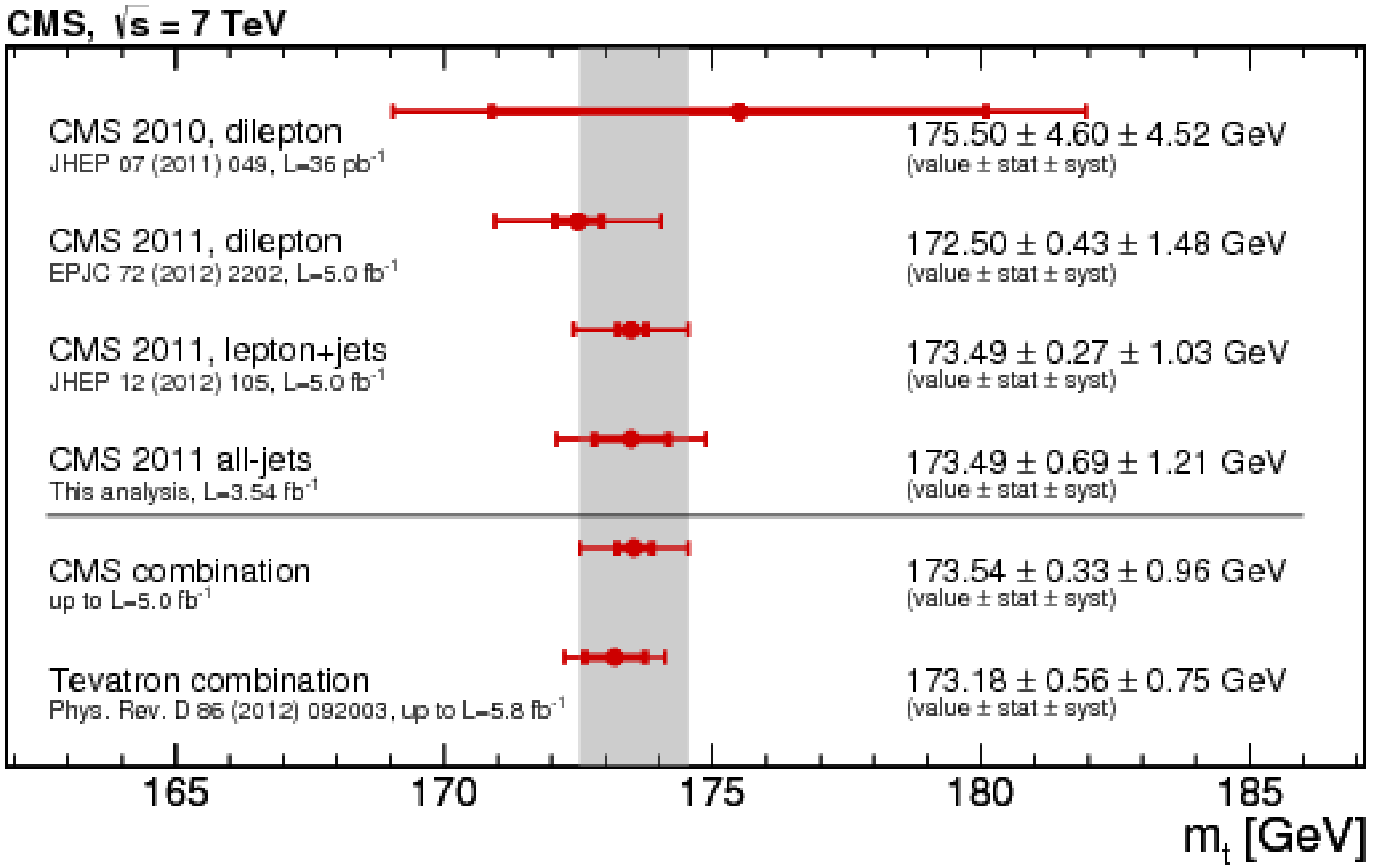
Description	Value [GeV]
Statistics	0.69
Jet energy scale	0.97
b-JES	0.49
Trigger	0.24
μ_R and μ_F scales	0.22
Colour reconnection	0.15
ME-PS matching	0.24
Underlying event	0.20
Total systematic	**1.21**

$$m_t = 173.49 \pm 0.69(\mathrm{stat}) \pm 1.21(\mathrm{syst})\mathrm{GeV}\ \ 1\mathrm{D}$$

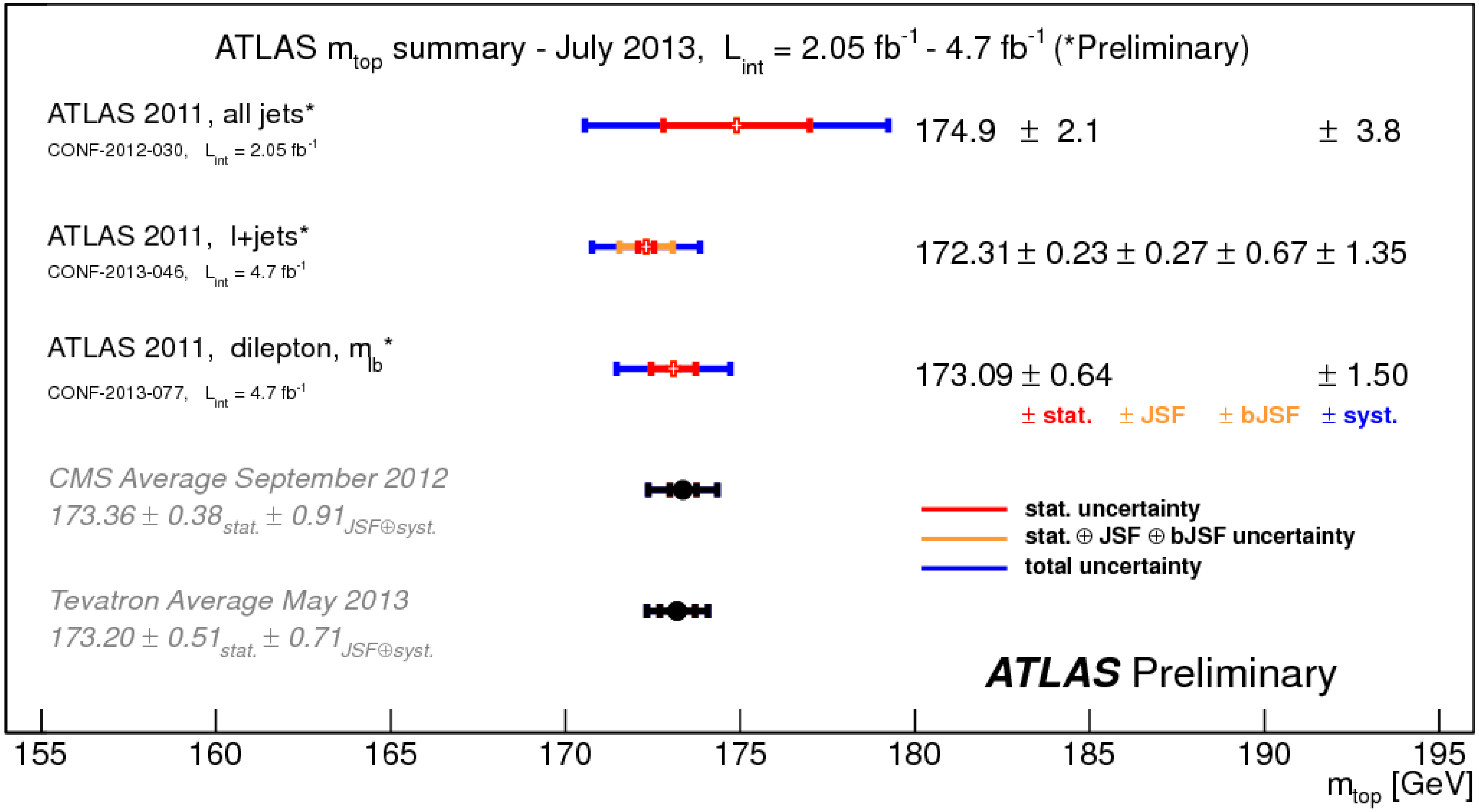
$$m_t = 174.28 \pm 1.00(\mathrm{stat}\ +\ \mathrm{JES}) \pm 1.23(\mathrm{syst})\mathrm{GeV}\ \ 2\mathrm{D}$$

$$\mathrm{JES} = 0.991 \pm 0.008(\mathrm{stat}) \pm 0.013(\mathrm{syst})$$

CMS combination



ATLAS summary



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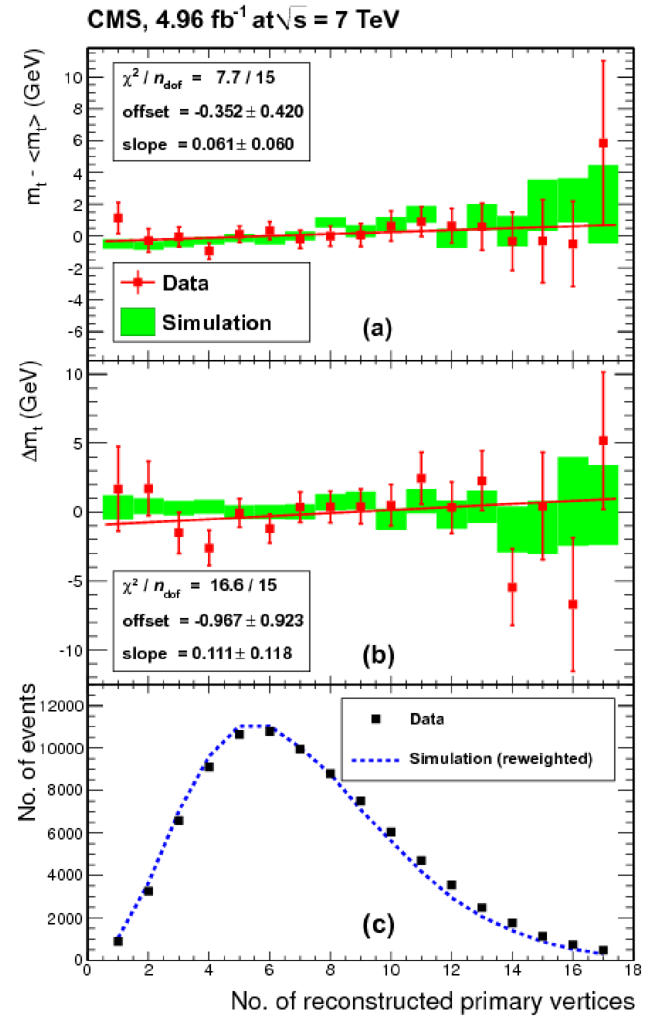
Δm_t from CMS

- 5.0 fb^{-1} 7 TeV data
  18.9 fb^{-1} 8 TeV data
- Events:
  - 1 charged lepton
  - ≥ 4 jets
- Ideogram method to measure m_t and $m_{\bar{t}}$ using ℓ^++jets and ℓ^-+jets events
- Calibrate using pseudo-experiments



$$\Delta m_t = -0.44 \pm 0.46(\text{stat}) \pm 0.27(\text{syst})\,\text{GeV} \quad (2011)$$

$$\Delta m_t = -0.27 \pm 0.20(\text{stat}) \pm 0.12(\text{syst})\,\text{GeV} \quad (2012)$$

JHEP 06 (2012) 109

CMS-PAS-TOP-12-031

Δm_t from ATLAS

- 4.7 fb^{-1} 7 TeV data
- Events:
  - 1 charged lepton
  - ≥ 4 jets
  - ≥ 2 *b*-tagged jets
  - E_T^{miss}
- PYTHIA MC samples with $\Delta m_t \neq 0$
- Checks and pseudo-experiments use MC@NLO
- PYTHIA vs. EVTGEN for $b/\bar{b}$ decay uncertainties

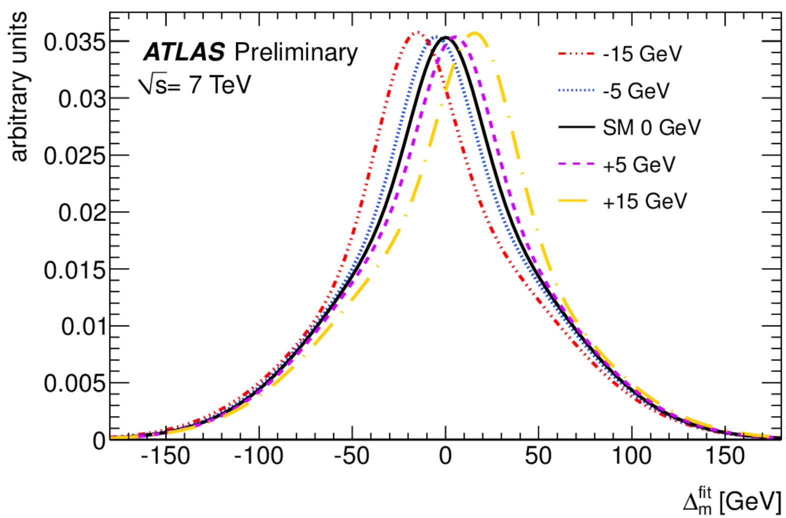
- Kinematic χ^2 fitter used to determine t and $\bar{t}$ masses from leptons, jets and E_T^{miss}
- Average m_t fixed, Δm_t can vary
- $\Delta m^{fit} = q_\ell \, (m_{b\ell\nu} - m_{bjj})^{fit}$
- $\chi^2 < 10$ to select good combinations and reduce background

NEW

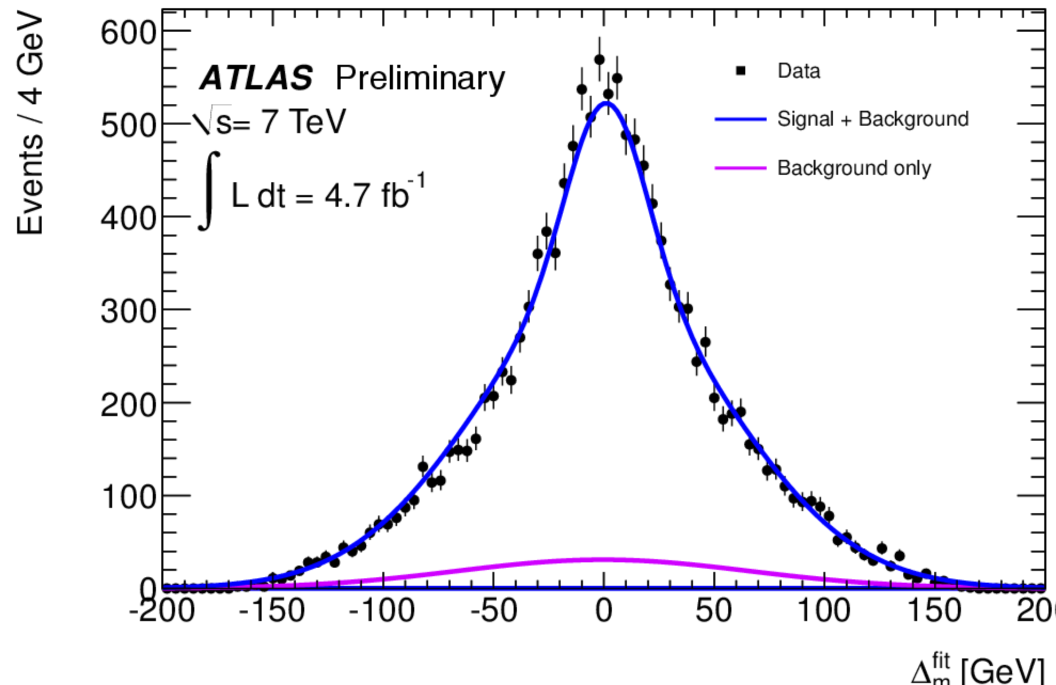
ATLAS-CONF-2012-006

Δm_t from ATLAS

Templates



Fit to data



Main uncertainties

Description	Value [GeV]
Statistics	0.61
Parton shower	0.08
MC generator	0.08
ISR/FSR	0.07
b tagging	0.08
b/b decay uncertainties	0.35
K in *b* jets	0.08
Residual b/b diffs.	0.08
Total systematic	**0.41**

PYTHIA vs. EVTGEN

$$\Delta m_t = +0.67 \pm 0.61(\text{stat}) \pm 0.41(\text{syst})\text{GeV}$$

Conclusions

- Steady progress in precision of m_t measurements at the LHC
- Statistics no longer a problem
- Modelling systematics are hard to quantify and differ somewhat between experiments
- Uncertainty now at 1 GeV level
  - Improving further is hard work, but ongoing!
- Combinations are subject of next talk
- No difference seen between m_t and $m_{\bar{t}}$

Backup

ATLAS dilepton
ATLAS-CONF-2013-077
http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2013-077/

Event selection

- Electron:
  - E_T > 25 GeV
  - $|\eta| < 2.47$
  - Isolation (E_T and p_T)
- Muon
  - p_T > 20 GeV
  - $|\eta| < 2.5$
  - Isolation (E and p_T)
- Jets
  - Anti-k_T, R=0.4
  - p_T > 25 GeV
  - $|\eta| < 2.5$, |JVF| > 0.75
- Good primary vertex
- 2 OS leptons
  - E_T^{miss} > 60 GeV (ee, μμ)
  - H_T > 130 GeV (eμ)
  - $m_{ee,\mu\mu}$ > 15 GeV
  - $|m - 91|$ > 10 GeV
- ≥ 2 jets
- 2 b-tagged jets (70% tagging eff)

Systematics

Description	Value [GeV]
Measured value	173.09
Statistical uncertainty	0.64
Method calibration	0.07
Signal MC generator	0.20
Hadronisation	0.44
Underlying event	0.42
Colour reconnection	0.29
ISR/FSR	0.37
Proton PDF	0.12
Background	0.14
Jet energy scale	0.89
b-jet energy scale	0.71
b-tagging efficiency and mistag rate	0.46
Jet energy resolution	0.21
Missing transverse momentum	0.05
Pile-up	0.01
Electron uncertainties	0.11
Muon uncertainties	0.05
Total systematic uncertainty	1.50
Total uncertainty	1.63

Table 2: The measured value of m_{top} and the contributions of the various sources detailed in the text to the total systematic uncertainty.

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CMS dilepton
Eur. Phys. J. C72 (2012) 2202
http://inspirehep.net/record/1185104

Event selection

- Electron + muon:
  - $p_T > 20$ GeV
  - $|\eta| < 2.4$
  - Isolation (relative p_T of particles)
- Jets
  - Anti-k_T, R=0.5
  - $p_T > 30$ GeV
  - $|\eta| < 2.4$
- Good primary vertex
- 2 OS leptons
  - $E_T^{miss} > 40$ GeV (ee, μμ)
  - $m_{ee,\mu\mu} > 20$ GeV
  - $|m - 91| > 15$ GeV
- ≥ 2 jets
- ≥ 1 b-tagged jet

Systematics

Table 2: List of systematic uncertainties with their contributions to the top-quark mass measurement.

Source	Δm_t (GeV)
Jet energy scale	$^{+0.90}_{-0.97}$
b-jet energy scale	$^{+0.76}_{-0.66}$
Jet energy resolution	± 0.14
Lepton energy scale	± 0.14
Unclustered E_T^{miss}	± 0.12
b-tagging efficiency	± 0.05
Mistag rate	± 0.08
Fit calibration	± 0.40
Background normalization	± 0.05
Matching scale	± 0.19
Renormalisation and factorisation scale	± 0.55
Pileup	± 0.11
PDFs	± 0.09
Underlying event	± 0.26
Colour reconnection	± 0.13
Monte Carlo generator	± 0.04
Total	± 1.48

KINb method

- See JHEP 1107 (2011) 049, arXiV:1105.5661
- p_T(jet) > 35 GeV
- E_T^{miss} ($e\mu$) > 30 GeV

m_t = 171.8 ±0.6 (stat) ±2.2 (syst) GeV

- No improvement by combining AMWT and KINb methods

ATLAS lepton+jets
ATLAS-CONF-2013-046
http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2013-046/

Systematics

	2d-analysis		3d-analysis		
	m_{top} [GeV]	JSF	m_{top} [GeV]	JSF	bJSF
Measured value	172.80	1.014	172.31	1.014	1.006
Data statistics	0.23	0.003	0.23	0.003	0.008
Jet energy scale factor (stat. comp.)	0.27	n/a	0.27	n/a	n/a
bJet energy scale factor (stat. comp.)	n/a	n/a	0.67	n/a	n/a
Method calibration	0.13	0.002	0.13	0.002	0.003
Signal MC generator	0.36	0.005	0.19	0.005	0.002
Hadronisation	1.30	0.008	0.27	0.008	0.013
Underlying event	0.02	0.001	0.12	0.001	0.002
Colour reconnection	0.03	0.001	0.32	0.001	0.004
ISR and FSR (signal only)	0.96	0.017	0.45	0.017	0.006
Proton PDF	0.09	0.000	0.17	0.000	0.001
single top normalisation	0.00	0.000	0.00	0.000	0.000
W+jets background	0.02	0.000	0.03	0.000	0.000
QCD multijet background	0.04	0.000	0.10	0.000	0.001
Jet energy scale	0.60	0.005	0.79	0.004	0.007
b-jet energy scale	0.92	0.000	0.08	0.000	0.002
Jet energy resolution	0.22	0.006	0.22	0.006	0.000
Jet reconstruction efficiency	0.03	0.000	0.05	0.000	0.000
b-tagging efficiency and mistag rate	0.17	0.001	0.81	0.001	0.011
Lepton energy scale	0.03	0.000	0.04	0.000	0.000
Missing transverse momentum	0.01	0.000	0.03	0.000	0.000
Pile-up	0.03	0.000	0.03	0.000	0.001
Total systematic uncertainty	2.02	0.021	1.35	0.021	0.020
Total uncertainty	2.05	0.021	1.55	0.021	0.022

Table 2: The measured values of m_{top} and the contributions of various sources to the uncertainty of the 2d-analysis and 3d-analysis.The corresponding uncertainties on the measured values of the JSF and for the 3d-analysis also the bJSF are also shown. The *Signal MC generator* systematic uncertainty is obtained from pairs of independent Monte Carlo samples. The statistical precision on m_{top} of all Monte Carlo samples in the 3d-analysis (2d-analysis) is about 0.15 GeV (0.07 GeV). The corresponding values for the JSF and bJSF are 0.0017 and 0.0006, respectively. Consequently, for the uncertainty source *Signal MC generator* the statistical uncertainty of the evaluation of the systematic uncertainty on m_{top} is 0.21 GeV for the 3d-analysis and 0.10 GeV for the 2d-analysis. For the sources *Hadronisation*, *Underlying event*, *Colour reconnection*, *ISR and FSR* the same hard scattering events before hadronisation are used, albeit with respective different further processing for the source under study. For these sources the samples are not independent, and the statistical uncertainty of the evaluation of the systematic uncertainty is correspondingly smaller.

CMS lepton+jets
JHEP 1212 (2012) 105
http://inspirehep.net/record/1185101

Event selection

- Electron + muon:
  - p_T > 30 GeV
  - $|\eta|$ < 2.1
  - Isolation (relative p_T of particles)
- Jets
  - Anti-k_T, R=0.5
  - p_T > 30 GeV
  - $|\eta|$ < 2.4
- Good primary vertex
- 2 OS leptons
  - E_T^{miss} > 40 GeV (ee, μμ)
  - $m_{ee,\mu\mu}$ > 20 GeV
  - $|m - 91|$ > 15 GeV
- ≥ 4 jets
- ≥ 2 b-tagged jets

Systematics

Table 1: List of systematic uncertainties for the muon+jets and electron+jets final states, and for the combined fit to the entire data set

	μ+jets		e+jets		ℓ+jets	
	$\delta^{\mu}_{m_t}$ (GeV)	$\delta^{\mu}_{\mathrm{JES}}$	$\delta^{\mathrm{e}}_{m_t}$ (GeV)	$\delta^{\mathrm{e}}_{\mathrm{JES}}$	$\delta^{\ell}_{m_t}$ (GeV)	$\delta^{\ell}_{\mathrm{JES}}$
Fit calibration	0.08	0.001	0.09	0.001	0.06	0.001
b-JES	0.60	0.000	0.62	0.000	0.61	0.000
p_T- and η-dependent JES	0.30	0.001	0.28	0.001	0.28	0.001
Lepton energy scale	0.03	0.000	0.04	0.000	0.02	0.000
Missing transverse momentum	0.05	0.000	0.07	0.000	0.06	0.000
Jet energy resolution	0.22	0.004	0.24	0.004	0.23	0.004
b tagging	0.11	0.001	0.15	0.001	0.12	0.001
Pileup	0.07	0.002	0.08	0.001	0.07	0.001
Non-$t\bar{t}$ background	0.10	0.001	0.16	0.000	0.13	0.001
Parton distribution functions	0.07	0.001	0.07	0.001	0.07	0.001
Renormalization and factorization scales	0.23	0.004	0.41	0.005	0.24	0.004
ME-PS matching threshold	0.17	0.000	0.15	0.001	0.18	0.001
Underlying event	0.26	0.002	0.24	0.001	0.15	0.002
Color reconnection effects	0.66	0.004	0.39	0.003	0.54	0.004
Total	1.06	0.008	1.00	0.007	0.98	0.008

ATLAS all-hadronic
ATLAS-CONF-2012-030
http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-030/

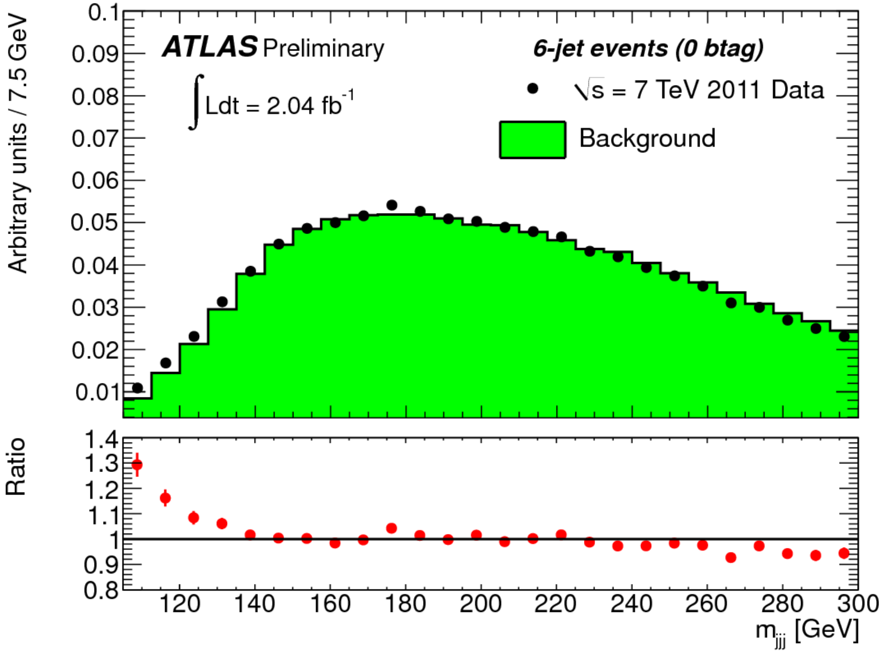
Event selection

- Trigger
  - $\geq$ 5 jets p_T > 30 GeV (analysis sample)
  - $\geq$ 4 jets p_T > 45 GeV (control sample)
- Jets
  - Anti-k_T, R=0.4
  - $|\eta| < 4.5$
- Note:
  - MC@NLO used as signal MC for this analysis

- Good primary vertex
- $\geq$ 5 jets p_T > 55 GeV
- 6^{th} jet p_T > 30 GeV
- $\Delta R > 0.6$ jet separation
- 2 b-tagged jets
  - $\Delta R > 1.2$
- $E_T^{miss} / (\sqrt{H_T}\ \mathrm{GeV}^{1/2}) < 3$
- $50 < m_W < 110$ GeV
- Mass $\chi^2 < 8$
- Rescale light-quark jet energies to m_W

Event mixing

- Use 5 jet events
  - Add jets with $p_T < 5^{th}$ highest p_T jet from ≥6 jet events
- Control QCD background with 4/5 jet events
  - Add in 2/1 jets from events with ≥6 jets
- Check with *b*-tagged and *b*-anti-tagged samples



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Systematics

Source	Uncertainty [GeV]
Method	0.4
Template statistics	0.9
MC generator	0.5
ISR/FSR	1.7
PDF	0.6
Background modelling	1.9
Jet energy scale	2.1
b-jet energy scale	1.4
b-tag efficiency scale factors	0.3
Jet energy resolution	0.3
Jet reconstruction efficiency	0.2
Total systematic uncertainty	3.8

Table 1: Compilation of systematic uncertainty contributions on the measurement of m_t.

CMS all-hadronic
JHEP 1212 (2012) 105
http://inspirehep.net/record/1185101

Event selection

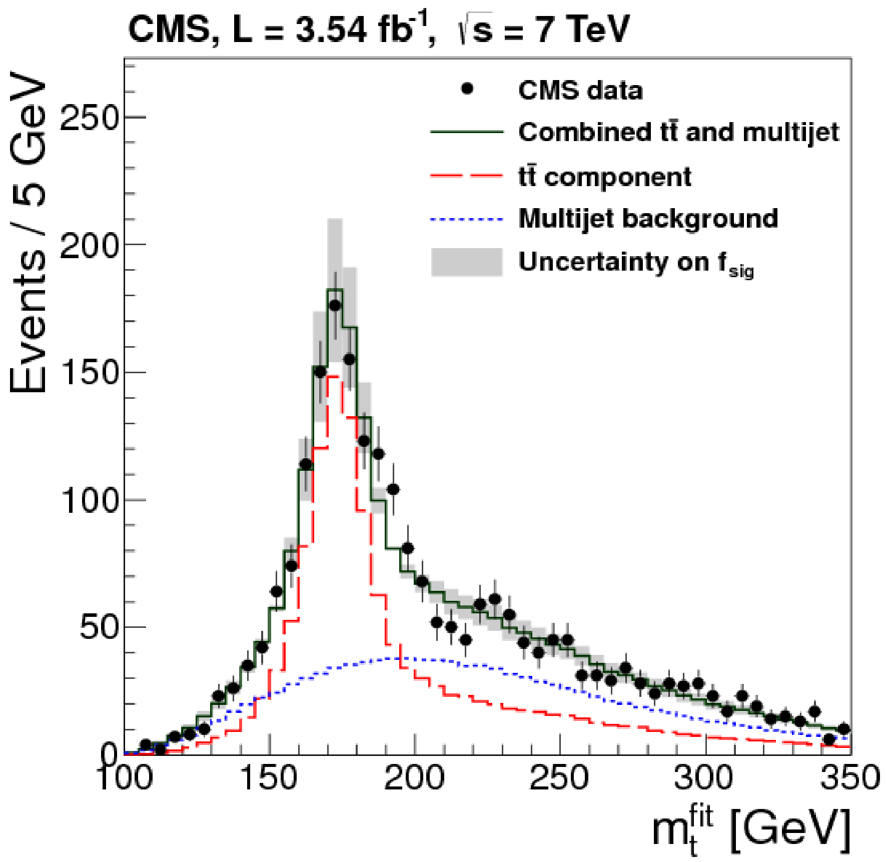
- Trigger
  - $\geq$ 4 jets p_T > 50 GeV
  - 5^{th} jet p_T > 40 GeV
  - 6^{th} jet p_T > 30 GeV

  for 3.19 fb^{-1}
- Jets
  - Anti-k_T, R=0.5
  - $|\eta| < 2.4$
- Note:
  - MC@NLO used as signal MC for this analysis

- Good primary vertex
- $\geq$ 4 jets p_T > 60 GeV
- 5^{th} jet p_T > 50 GeV
- 6^{th} jet p_T > 40 GeV
- $\geq$ 2 *b*-tagged jets
  - ε = 60%
  - $\Delta R_{bb} > 1.5$

Event mixing

- Use all events after *b*-tagging
- Mix jets from different events
- Require at least 2 *b*-tagged jets in each event
- Apply standard cuts on P_{gof} and ΔR_{bb}
- Signal fraction from simulation
  - varied by ±5%



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Systematics

Table 2: Overview of systematic uncertainties. The total is defined by adding in quadrature the contributions from all sources, by choosing for each the larger of the estimated shift or its statistical uncertainty, as indicated by the bold script.

	1D analysis	2D analysis	
	δ_{m_t} (GeV)	δ_{m_t} (GeV)	δ_{JES}
Fit calibration	**0.13**	**0.14**	**0.001**
Jet energy scale	**0.97** ± 0.06	0.09 ± **0.10**	**0.002** ± 0.001
b-JES	**0.49** ± 0.06	**0.52** ± 0.10	**0.001** ± 0.001
Jet energy resolution	**0.15** ± 0.06	**0.13** ± 0.10	**0.003** ± 0.001
b tagging	0.05 ± **0.06**	0.04 ± **0.10**	**0.001** ± 0.001
Trigger	**0.24** ± 0.06	**0.26** ± 0.10	**0.006** ± 0.001
Pileup	0.05 ± **0.06**	0.09 ± **0.10**	**0.001** ± 0.001
Parton distribution functions	0.03 ± **0.06**	0.07 ± **0.10**	**0.001** ± 0.001
Renormalization and factorization scale	0.08 ± **0.22**	0.31 ± **0.34**	**0.005** ± 0.003
ME-PS matching threshold	**0.24** ± 0.22	0.29 ± **0.34**	0.001 ± **0.003**
Underlying event	**0.20** ± 0.12	**0.42** ± 0.20	**0.004** ± 0.002
Color reconnection effects	0.04 ± **0.15**	**0.58** ± 0.25	**0.006** ± 0.002
Multijet background	**0.13** ± 0.06	**0.60** ± 0.10	**0.006** ± 0.001
Total	1.21	1.23	0.013

ATLAS Δm_t
ATLAS-CONF-2012-006

Systematics

Systematic Uncertainty	Δm [GeV]
$b/\bar{b}$ decay uncertainties	0.35
Kaons inside b-jets	0.08
Residual b vs $\bar{b}$ differences	0.08
b-tagging	0.08
Mis-tagging as a b-quark jet	0.05
Jet energy scale	0.04
b-jet energy scale	0.05
Jet energy resolution	0.03
Parton shower	0.08
MC generator	0.08
ISR/FSR	0.07
Calibration method	0.05
Non-$t\bar{t}$ normalization	0.04
Non-$t\bar{t}$ shape	0.04
Parton distribution function	0.02
Asymmetry in lepton energy scale	< 0.01
Electron reconstruction & identification	0.02
Muon reconstruction & identification	0.04
Top mass input	0.04
Total	0.41

Table 2: Systematic uncertainties.

CMS Δm_t

JHEP 1206 (2012) 109

http://inspirehep.net/record/1110691

CMS-PAS-TOP-12-031

http://cds.cern.ch/record/1528156

Event selection (2012)

- Electron:
  - $p_T > 32$ GeV
  - $|\eta| < 2.5$
  - Isolation
- Muon:
  - $p_T > 25$ GeV
  - $|\eta| < 2.1$
  - Isolation
- Jets
  - Anti-k_T, R=0.5
  - $p_T > 30$ GeV
  - $|\eta| < 2.5$

- Good primary vertex
- 1 charged lepton
- $E_T^{miss} > 40$ GeV
- ≥ 4 jets
- ≥ 1 *b*-tagged jets
  (ε = 65.6%)

Systematics (2012)

Table 2: Overview of systematic uncertainties on Δm_t. For each contribution the larger of the estimated shift or its statistical uncertainty is taken, as indicated by the bold script.

Source	Estimated effect (MeV)
Jet energy scale	$\mathbf{17} \pm 15$
Jet energy resolution	$8 \pm \mathbf{11}$
b vs. $\bar{\text{b}}$ jet response	$\mathbf{64} \pm 7$
Signal fraction	$\mathbf{45} \pm 2$
Background charge asymmetry	$\mathbf{12.43} \pm 0.03$
Background composition	$\mathbf{50} \pm 1$
Pileup	$\mathbf{17.4} \pm 0.4$
b-tagging efficiency	$\mathbf{20} \pm 8$
b vs. $\bar{\text{b}}$ tagging efficiency	$\mathbf{43} \pm 6$
Method calibration	$15 \pm \mathbf{54}$
Parton distribution functions	$\mathbf{12} \pm 3$
Total	122

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