Top Quark Mass Measurements in ATLAS + CMS

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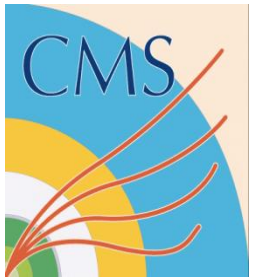
On behalf of the ATLAS and CMS Collaborations



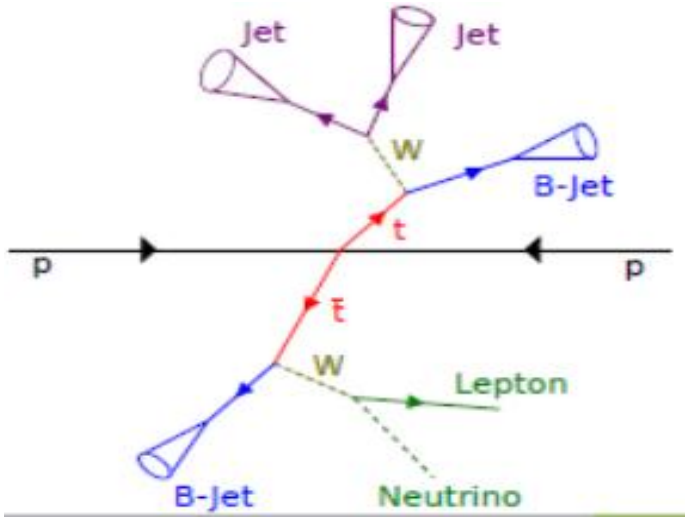
LHC France 2013

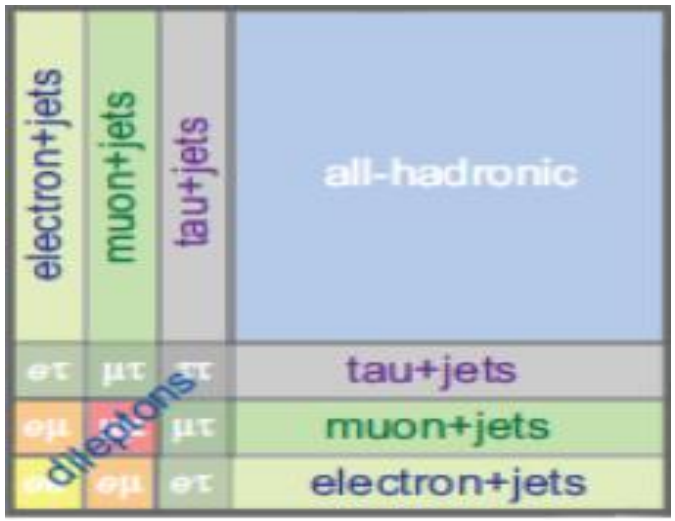
4 April, Annecy

Introduction

- **Top quark mass measurements are done in $t\bar{t}$ pairs production;**
- **Final state determined by W decays:**

di-lepton : extremely pure, low rate, no fully reconstructed top
lepton+jets : compromise: good purity, one fully reconstructed top
all-jet : large background, two fully reconstructed tops





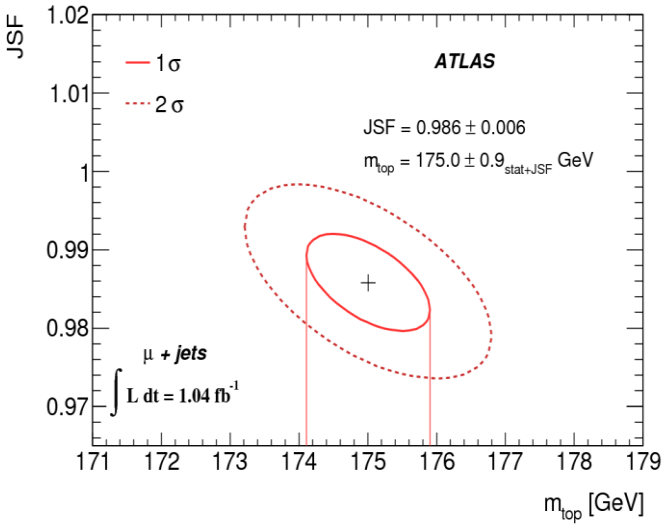
Top quark mass has been measured at all those channels by LHC France

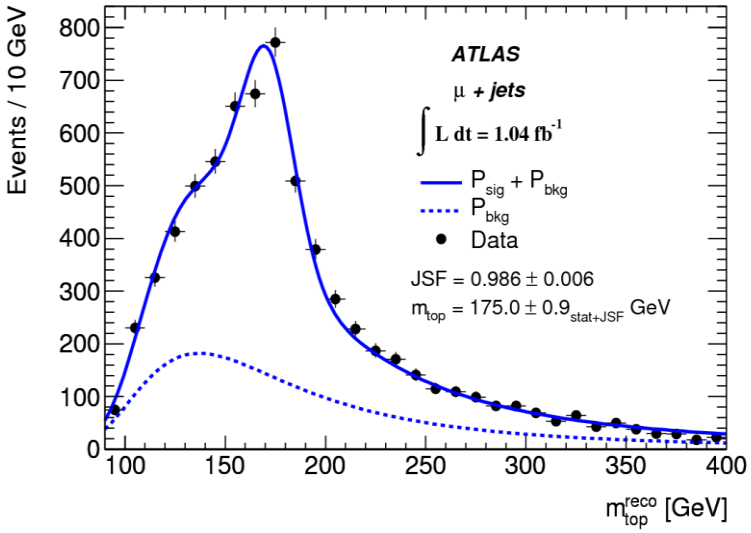
lepton + jets (ATLAS 1.04 fb^{-1} @7 TeV)

contributions from IRFU

- **Event Selection**
  - Exactly1 isolated muon (P_T >20 GeV) or electron (E_T > 25 GeV);
  - E_T^{miss} > 20/25 GeV (u/e) and E_T^{miss} + M_T (W) > 60GeV / M_T (W) > 25GeV (u/e);
  - >= 4 jets with P_T > 25 GeV, >= 1bjet
- **Top reconstruction : Kinematic fit + highest P_T**

➢ **2D template method** : m_{top} and Jet Energy Scale Factor (JSF) simultaneously fitted





m_{top} = 174.5 ± 0.6 (stat) ± 2.3 (syst) GeV

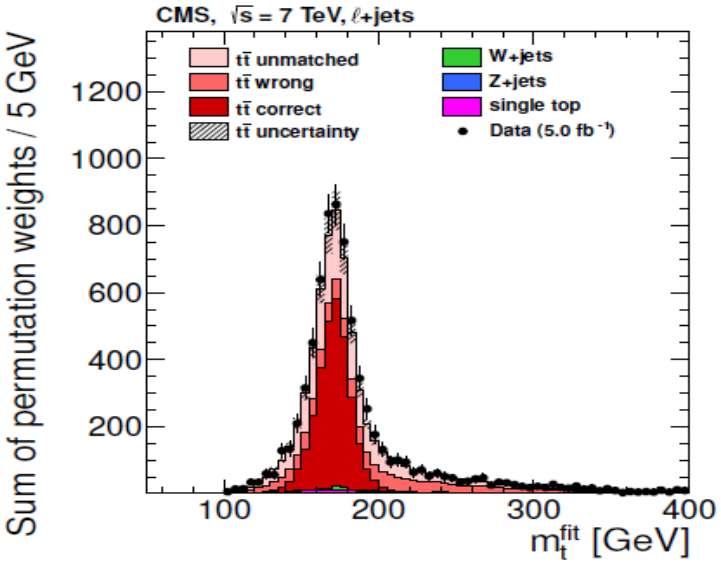
Eur. Phys. J. C72 (2012) 2046

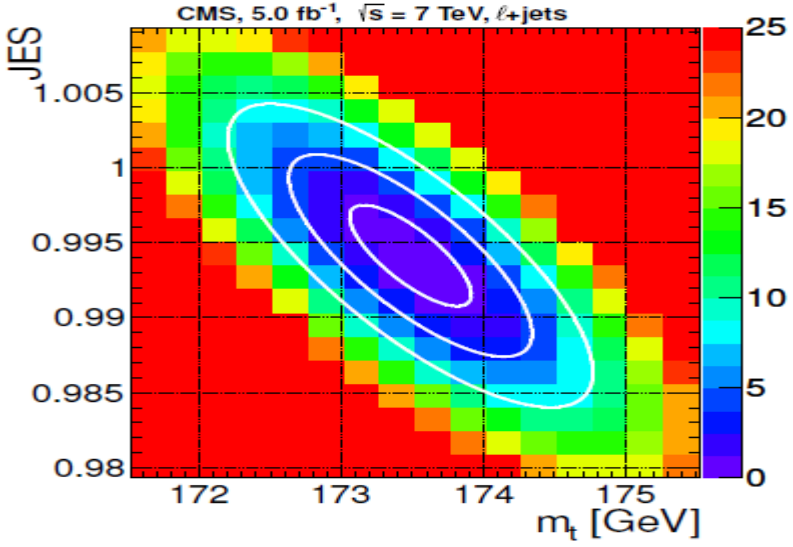
Systematic uncertainties :
bJES (1.58), JES (0.66),
ISR/FSR (1.01)

lepton + jets (CMS 5.0 fb^{-1} @7 TeV)

- **Event Selection**
  - Exactly1 isolated muon / electron (P_T > 30 GeV);
  - >= 4 jets with P_T > 30 GeV, >= 2 bjets
- **Top reconstruction : Kinematic fit**

➢ **2D Ideogram method** : m_{top} and JES simultaneously fitted





m_{top} = 173.5 ± 0.4 (stat+JES) ± 1.0 (syst) GeV

JHEP 12 (2012) 105

Systematic uncertainties : bJES (0.61) and Color reconnections (0.54)

Di-lepton (CMS 5.0 fb^{-1} @7 TeV)

contributions from IPHC

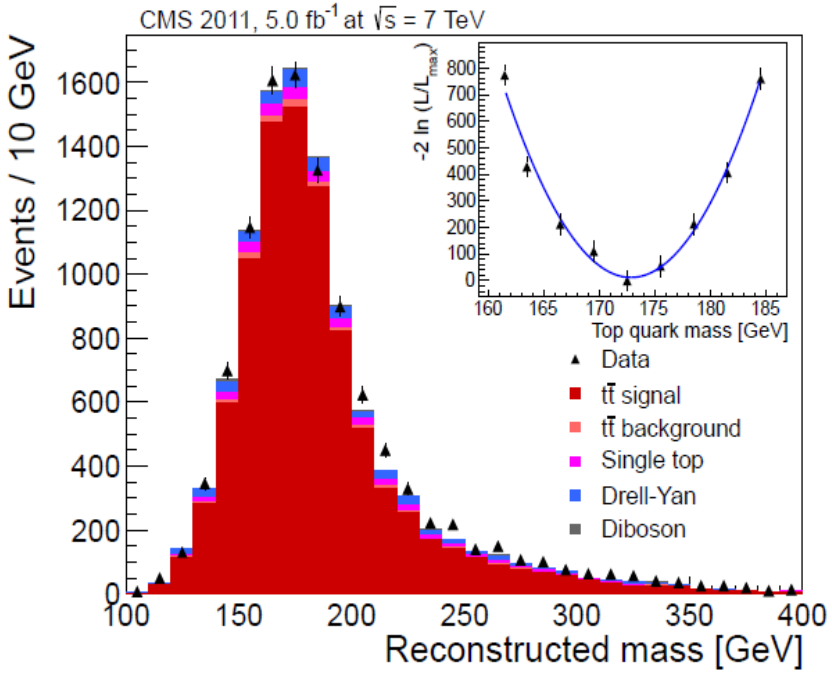
AMWT method : Analytical Matrix Weighting Technique.

Kinematic of ttbar events are reconstructed assuming a top mass.

The best solution is determined through the calculation of a weight.

The kinematics is solved scanning on the top mass.

The most probable top mass is measured using a likelihood profile technique (top mass distribution).



$$m_t = 172.5 \pm 0.4\,(\text{stat.}) \pm 1.5\,(\text{syst.})\ \text{GeV}$$

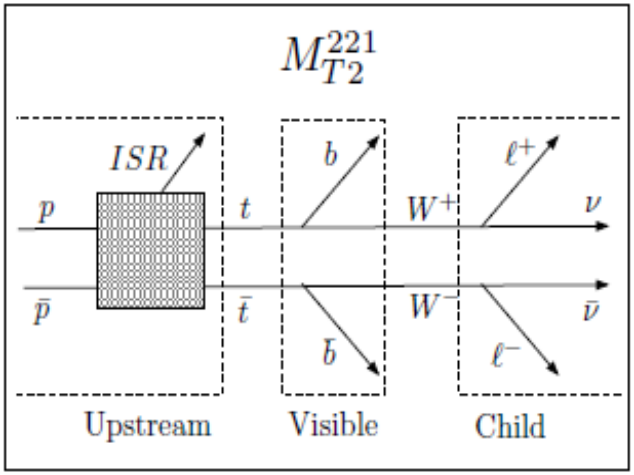
Systematic uncertainties :

bJES (0.71), JES (0.94)

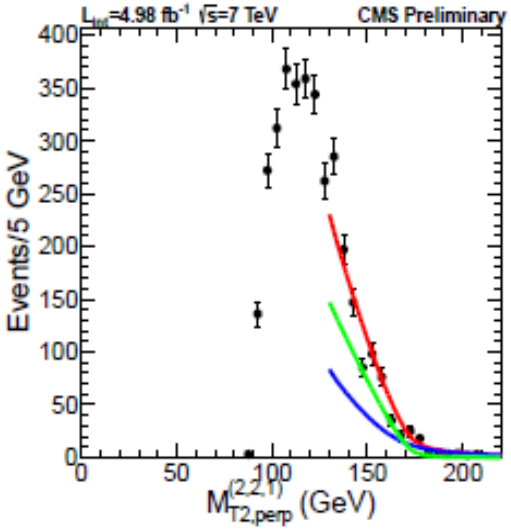
Eur. Phys. J. C72 (2012) 2202

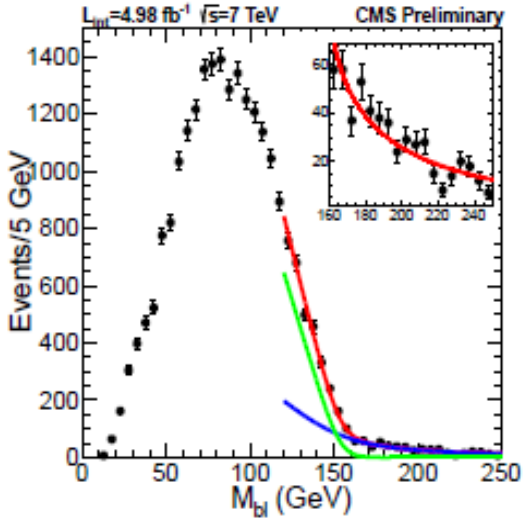
Di-lepton (CMS 5.0 fb^{-1} @7 TeV)

The top mass is measured using the Endpoint method.



- $m_{T2\perp}^{221}$ lower bound of m_t for known m_W
- Also use $m_{b\ell}^{\max} = \sqrt{\left(m_t^2 - m_W^2\right)\left(m_W^2 - m_\nu^2\right)}/m_W$
- Fit both endpoints





Systematic uncertainties :

JES (+0.5/-1.4), colour reconnnection(0.6)

CMS PAS-TOP-11-027

m_{top} = 173.9± 0.9 (stat) $^{+\ 1.2}_{-\ 1.8}$(syst) GeV

Di-lepton (ATLAS 4.7 fb^{-1} @7 TeV)

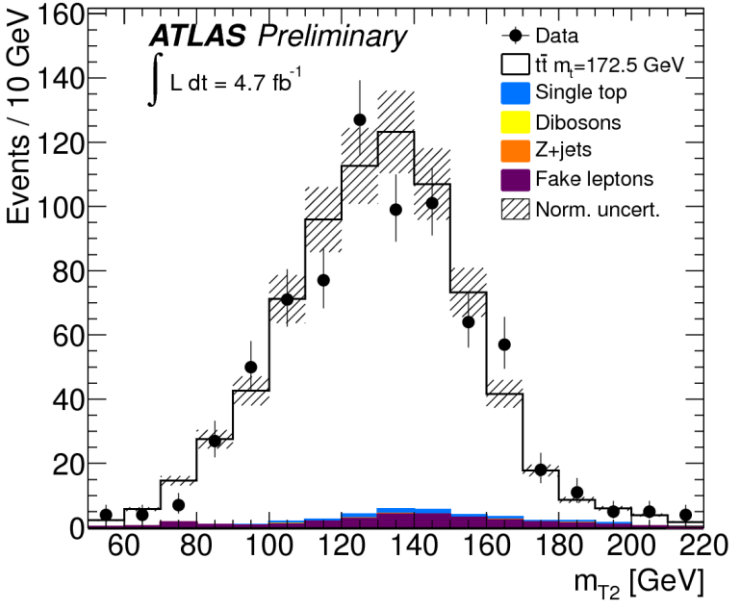
contributions from IRFU

Neutrino method

- calculate probability for each neutrino pair possibility and use templates from MC;
- to handle the two neutrinos, define M_{T2} (Stransverse mass, a lower bound of the parent particle mass);
- calibration curve to map mean value of M_{T2} distribution to m_{top} using simulation samples with varied input top mass.

$$m_{top} = (175.2 \pm 1.6_{stat} {}^{+3.1}_{-2.8}{}_{syst})\text{GeV}$$

Systematic uncertainties :
generator model (1.3), colour reconnection (1.2), bJES (1.4) and JES (1.5)



ATLAS-CONF-2012-082

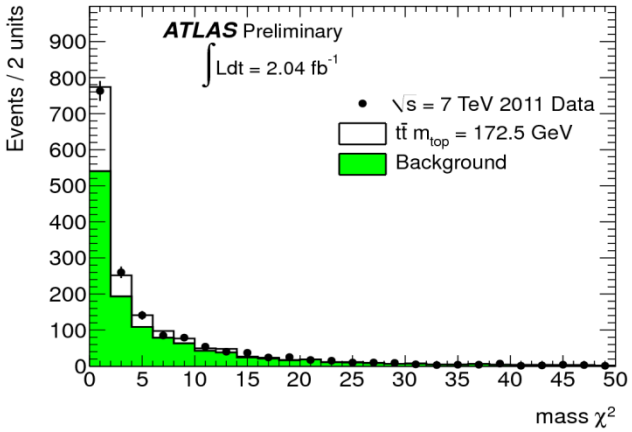
All jets (ATLAS 2.04 fb^{-1} @7 TeV)

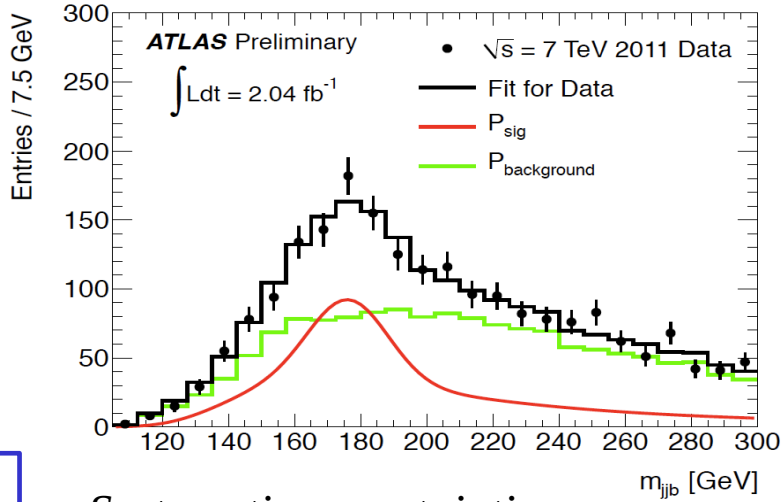
contributions from LPC

- **Event Selection**
  - ≥ 5 jets with p_T>55 GeV, ≥ 2 b-jets with ΔR_{bb}>1.2, 6th jet with p_T>30 GeV, jets well separated
  - $E_T^{miss}/sqrt(H_T) < 3$, no isolated lepton with p_T>20 GeV
- **Reconstruction**
  - ✓ minimize global χ^2 to associate light (j) and b jets to hadronic top

➢ **m_{top} extracted with a template method**

➢ **Multi-jet sample, estimated by event mixing data-driven method**





m_{top}= (174.9 ± 2.1$_{stat}$ ± 3.8$_{syst}$)GeV

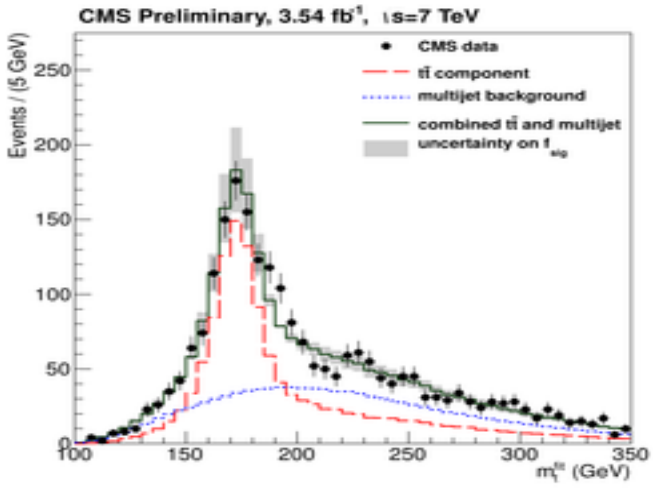
ATLAS-CONF-2012-030

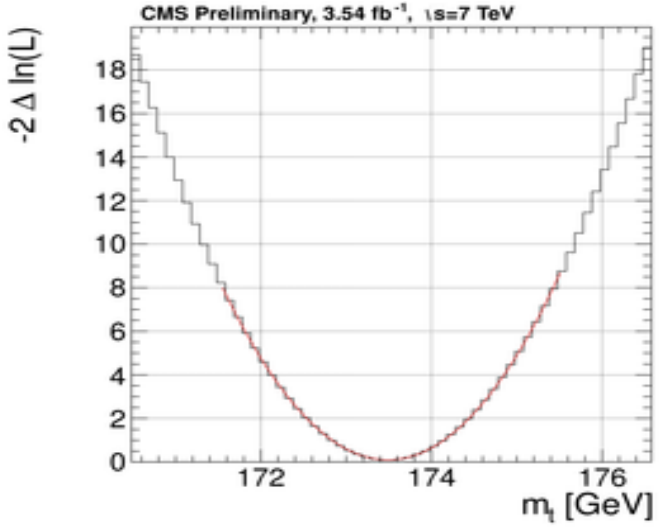
Systematic uncertainties :
JES (2.1), background modelling (1.9), ISR/FSR (1.7)

All jets (CMS 3.54 fb^{-1} @7 TeV)

- **Event Selection**
  - ≥ 4 jets with p_T > 60 GeV, ≥ 5 jets with p_T>50 GeV, ≥ 6 jets with p_T>40 GeV
  - ≥ 2 b-jets with p_T> 30 GeV, and ΔR_{bb}>1.5
- **Reconstruction : kinematic fit**

- **m_{top} extracted with ideogram method**
- **Multi-jet sample, estimated by event mixing data-driven method**





m_{top}= (173.5 ± 0.7$_{stat}$ ± 1.3$_{syst}$)GeV

CMS PAS-TOP-11-017

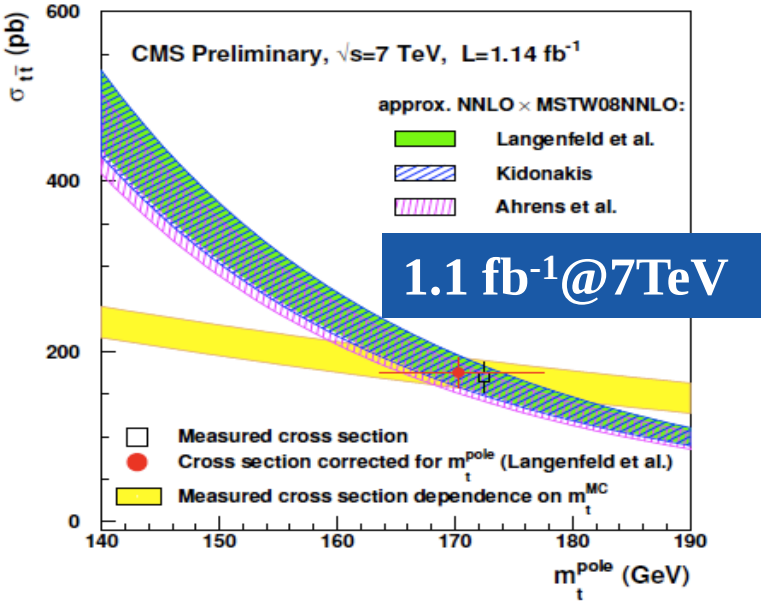
Systematic uncertainties :
JES (0.97),bJES (0.49)

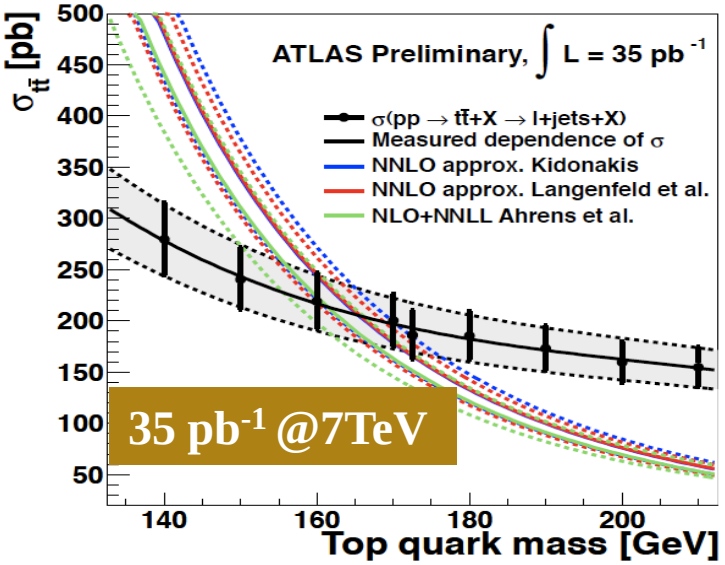
Top Quark Mass from Cross Section

- Parametrize measured and predicted cross-section in dependency of top mass
- Extract top mass using joint-likelihood approach

$$L(m_t) = \int f_{\mathrm{exp}}(\sigma_{t\bar{t}}|m_t) f_{\mathrm{th}}(\sigma_{t\bar{t}}|m_t) d\sigma_{t\bar{t}}.$$

contributions from IRFU





$m_{top}^{pole} = 170.3\ ^{+7.3}_{-7.6}$ GeV *NNLO-Langenfeld*

$m_{top}^{pole} = 170.0\ ^{+7.6}_{-7.1}$ GeV *NNLO-Kidonakis*

$m_{top}^{pole} = 167.6\ ^{+7.6}_{-7.1}$ GeV *NNLL-Ahrens*

CMS PAS-TOP-11-008

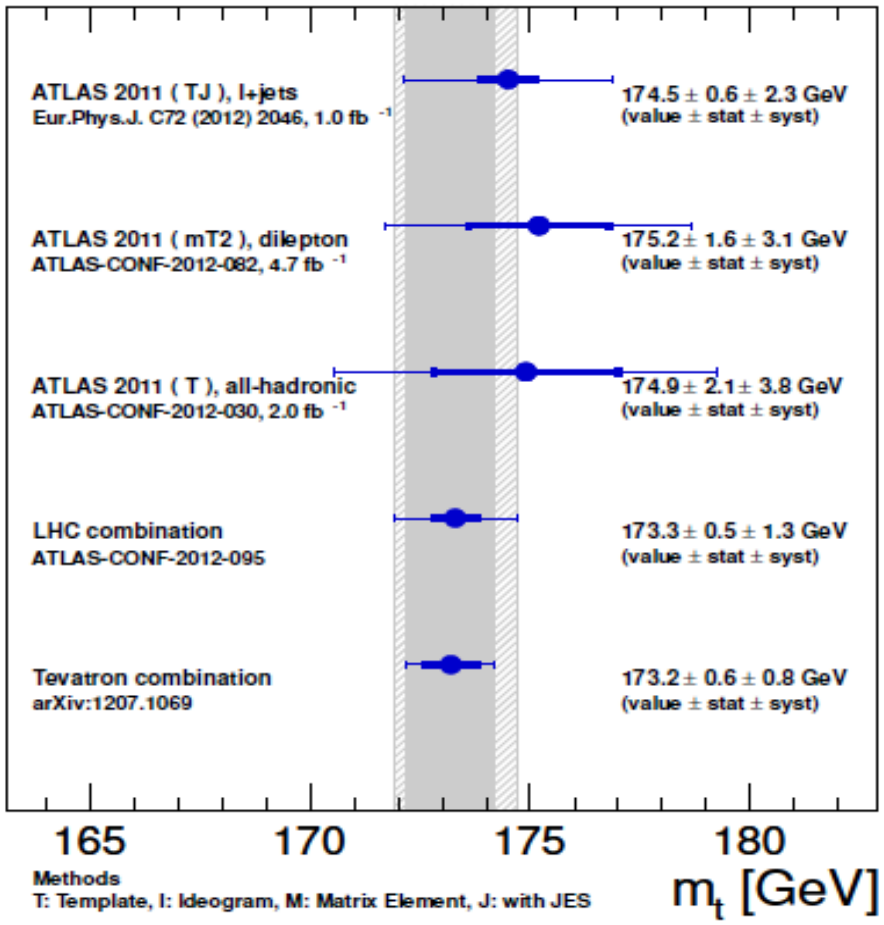
$m_{top}^{pole} = 166.4\ ^{+7.8}_{-7.3}$ GeV *NNLO-Langenfeld*

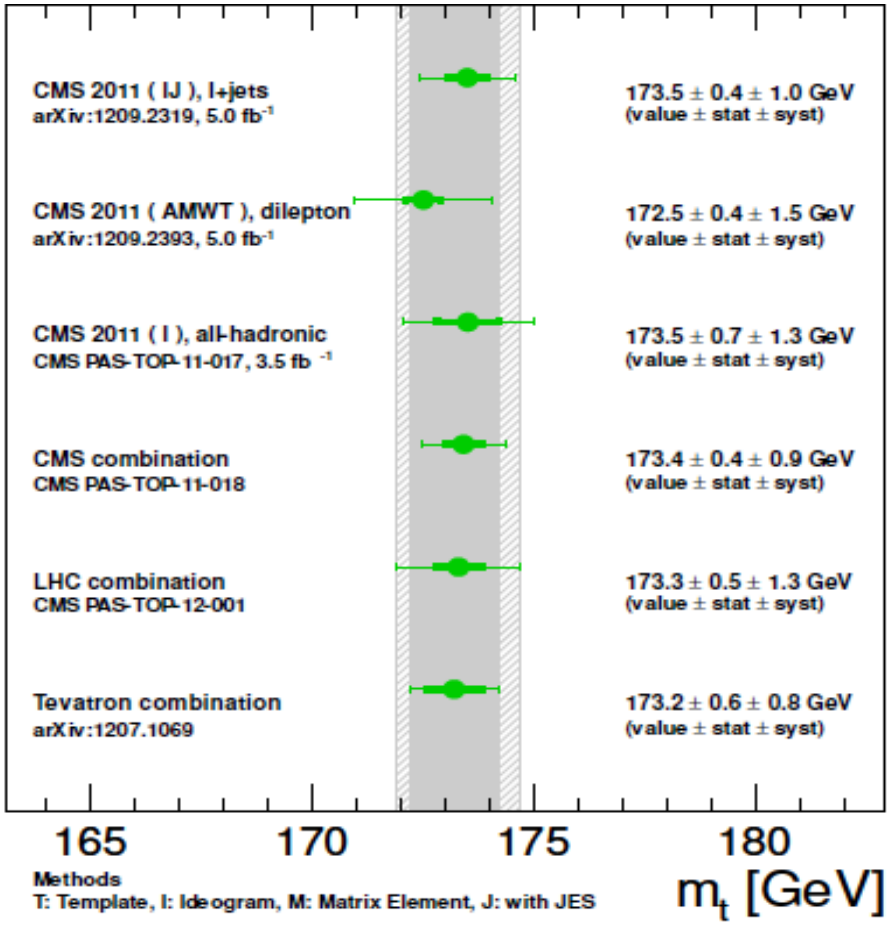
$m_{top}^{pole} = 166.2\ ^{+7.8}_{-7.4}$ GeV *NNLO-Kidonakis*

$m_{top}^{pole} = 162.2\ ^{+8}_{-7}$ GeV *NNLL-Ahrens*

ATLAS-CONF-2011-054

Most Precise Direct Measurements and Combinations





LHC France measurements have significant contribution to LHC top mass combination

Summary

- **Systematic uncertainties dominant the top mass measurement;**

- **LHC are catching up with the Tevatron precision of top quark mass measurement;**

- **LHC France has significant contribution to LHC top quark mass measurements;**

- **More new measurements are coming soon.**

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP

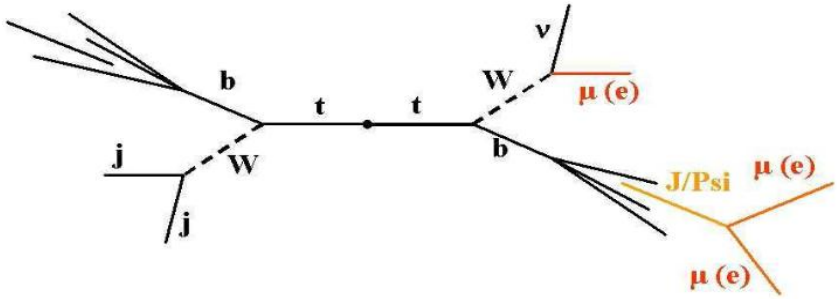
backup

Top mass using J/psi

IPNL

E. Bouvier, R.Chierici, V. Sordini, P. Verdier

Top mass measurement using lepton+jets events with a b-jets containing a J/Psi.



Signature : 1 isolated lepton, 4 jets, and two opposite-sign electrons or muons compatible with J/Psi candidates.

Main advantages :

- Invariant mass of the 3 leptons correlated with the top mass,
- Almost not affected by systematics on JES and b-tagging .

But low statistic.

Plan : Prepare the analysis for the re-start of data taking (13 TeV?) with high luminosity, when this analysis may become competitive with the direct reconstruction ones.

Matrix Element Method

- calculate probability event by event
  - use full event kinematic information
  - likelihood function of m_{top} for a given set of observables + calibration curve

LPNHE developped on MC at 14 and 10 TeV, results expected on data soon