Top quark properties

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LIP Lisbon

- Differential distributions
- Spin correlation
- Charge asymmetry
- Mass
- Taus

Contents

will use c=1

- Introduction (discovery, object ID)
- Top pair production at the Tevatron
- Top pair production at LHC

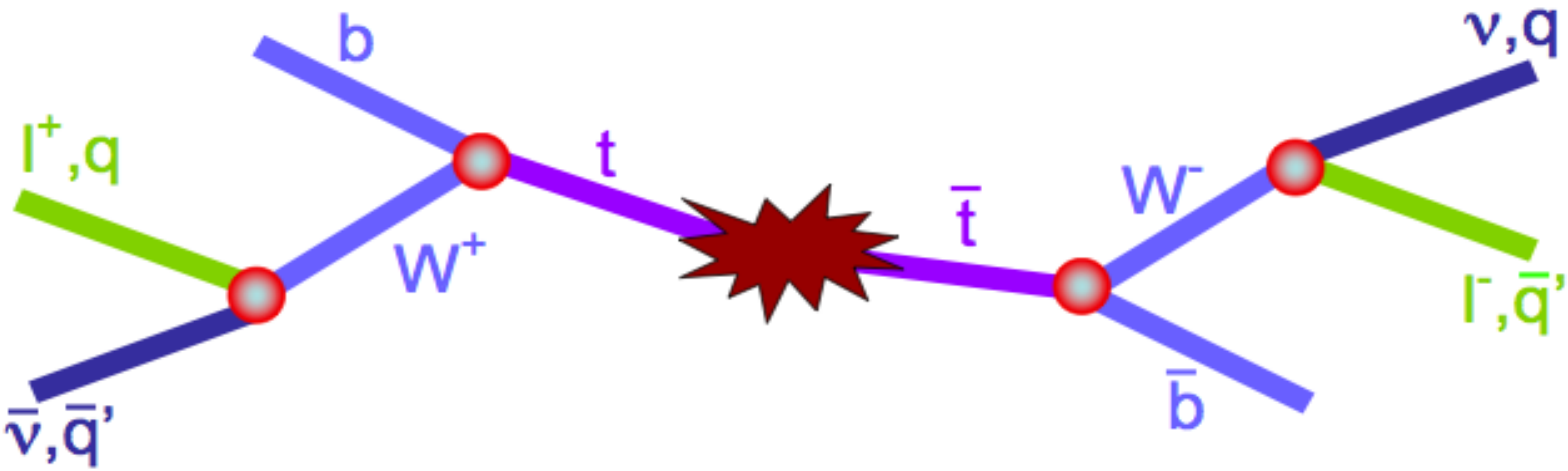
- Properties: differential cross section
- Spin correlation, charge asymmetry
- Mass, taus

today

- Single top production
- Flavor Changing Neutral Currents (FCNC)

- Search for top partners and 4th generation quarks
- Search for ttbar resonances

Interesting physics with Top quark



PRODUCTION
Cross section
Resonances X→tt
Fourth generation t'
Spin-correlations
New physics (SUSY)
Flavour physics (FCNC)
...

PROPERTIES
Mass
Kinematics
Charge
Lifetime and width
W helicity
Spin
...

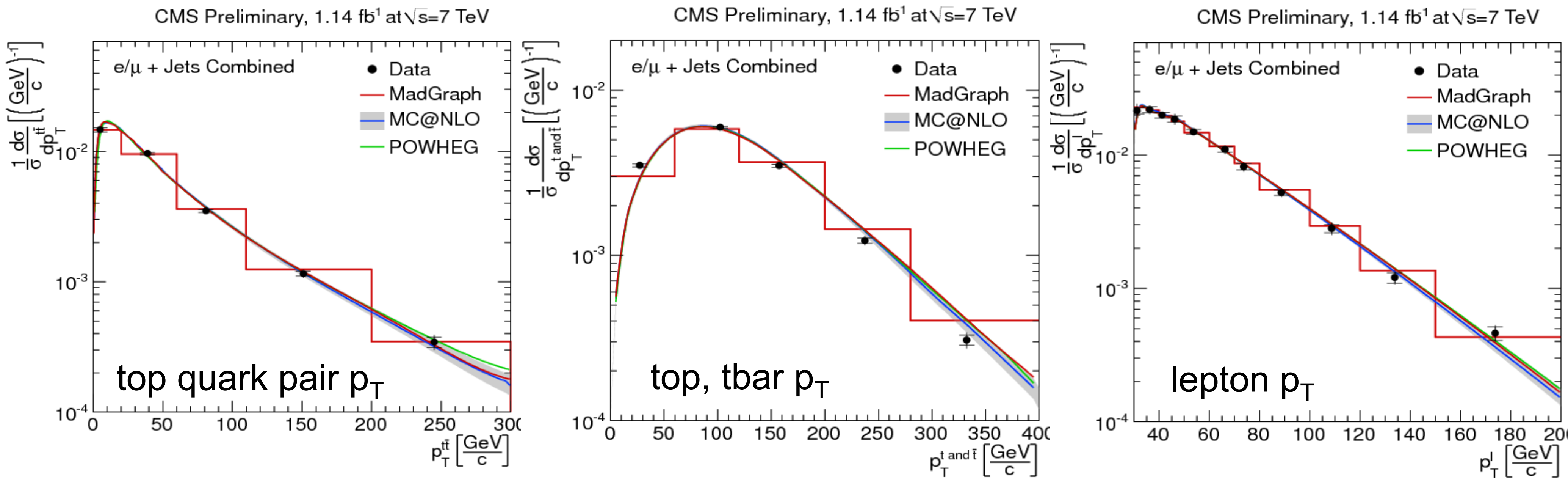
DECAY
Branching ratios
Charged Higgs (non-SM)
Anomalous couplings
Rare decays
CKM matrix elements
Calibration sample @LHC
...

Differential cross section

- Measure differential cross section
  - Test perturbative QCD
  - Test BSM scenarios (Z' decays, etc) with narrow resonance
- Reconstruct event kinematic properties
- Cross sections measured as a function of p_T, η, invariant mass of the final state leptons, the top quarks, and the tt system
- Good agreement found in dilepton and lepton+jet channels

$$\frac{1}{\sigma_{t\bar{t}}} \frac{d\sigma_{t\bar{t}}}{dX}$$

CMS-TOP-11-013



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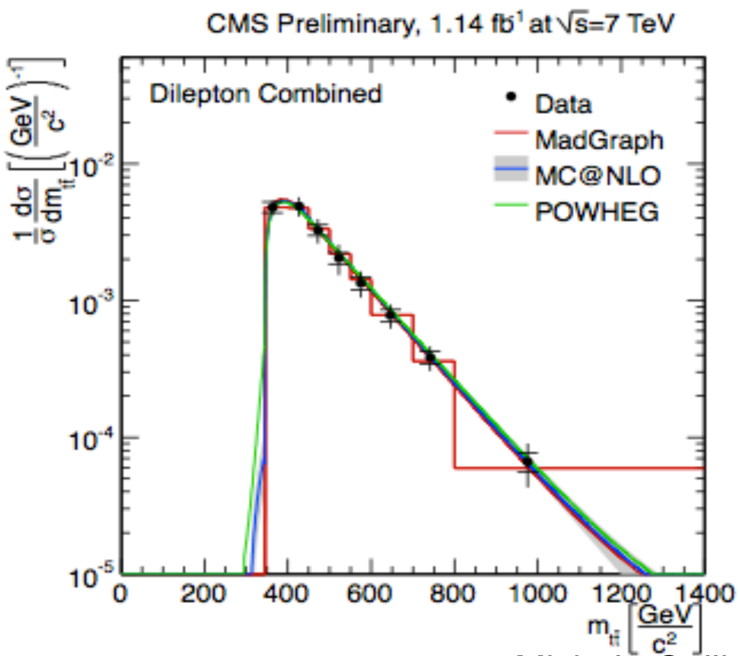
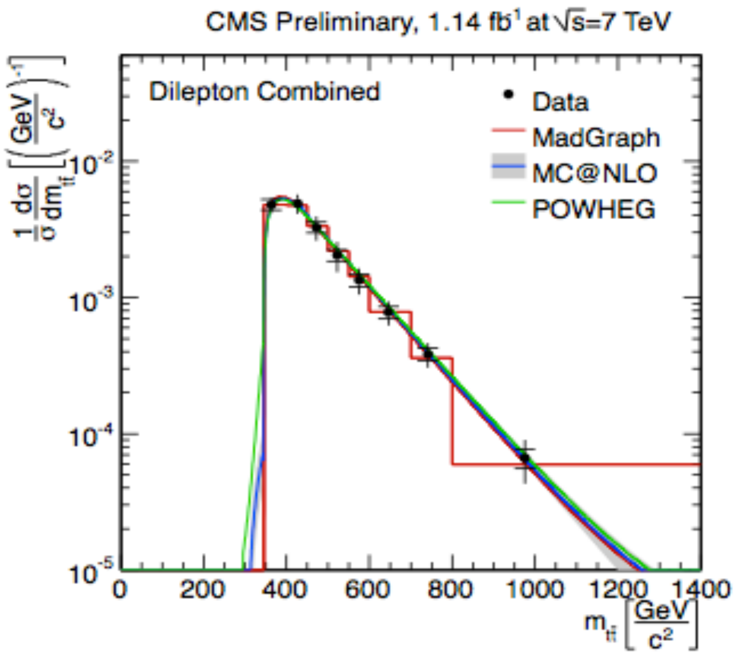


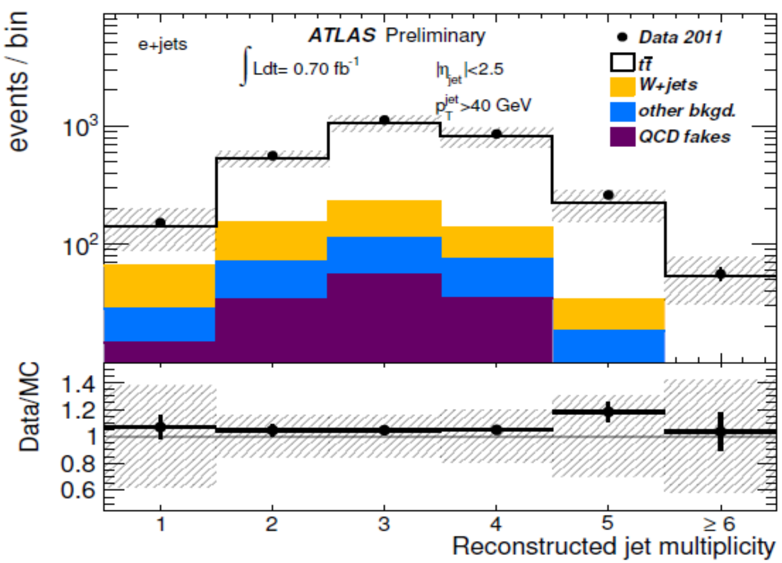
top quark pair invariant mass



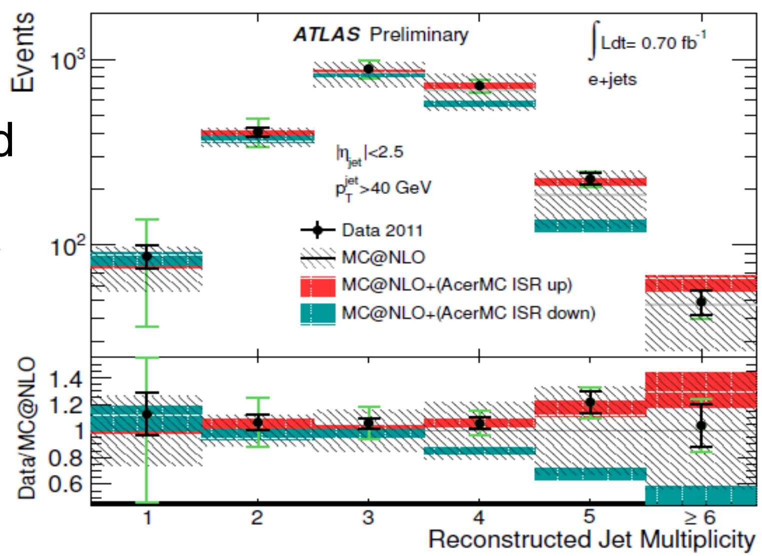
Jet multiplicities: test of pQCD

- Jet scaling tests QCD: PDF evolution and running α_s
  - useful to constrain initial state radiation (ISR) at the scale of the top quark mass
  - provides a test of perturbative QCD in a new energy regime
- Study multiplicity distribution of reconstructed jets
  - Analysis performed in the single lepton channel
- data in agreement with signal ttbar MC distributions
- Comparison with different ISR MC samples
- Uncertainties dominated by JES

ATLAS-CONF-2011-142



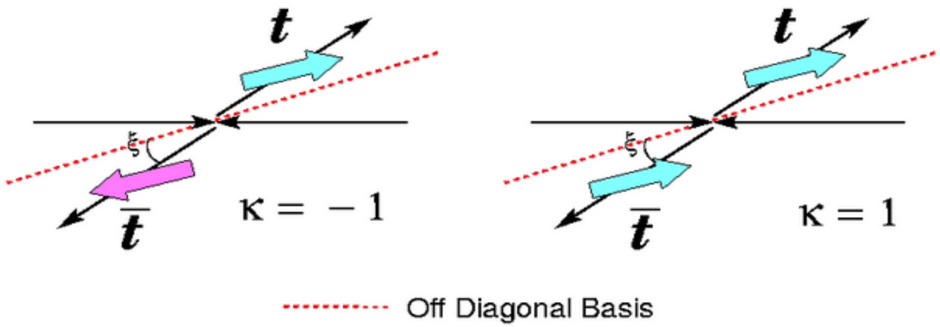
After background subtraction



Spin correlation

- Important tool for precise studies of top quark interactions
- Top quark produced are not polarized
  - …but spins between quark and anti-quark are correlated
- Top quark decays before spins decorrelate
  - Top quark decays before hadronization ($\tau \sim 10^{-25}$ sec) ⇒ spin information transmitted to the decay products (W boson, b quark)
- Spin correlation depends on the production mode

$$\kappa = \frac{n_{\pm\pm} - n_{\pm\mp}}{n_{\pm\pm} + n_{\pm\mp}}$$



$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_1 d\cos\theta_2} = \frac{1}{4}\left(1 + \kappa \cos\theta_1 \cos\theta_2\right)$$

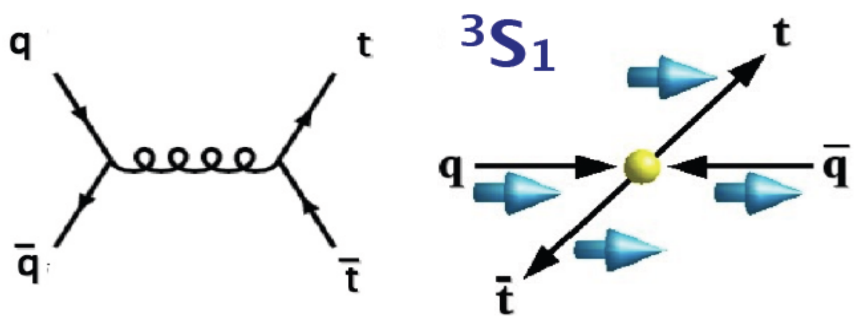
- Analyze spin using angular distributions of decay products
  - θ_1 and θ_2 are the angles of decay products wrt a “quantization axis”
  - value of κ depends on spin basis (for example, off-diagonal vs maximal)

Spin correlation

- Spin correlation may differ from that expected in the SM
  - top quark decays into a charged Higgs boson and a b quark ($t \rightarrow H^{+}b$)
  - Other BSM scenarios

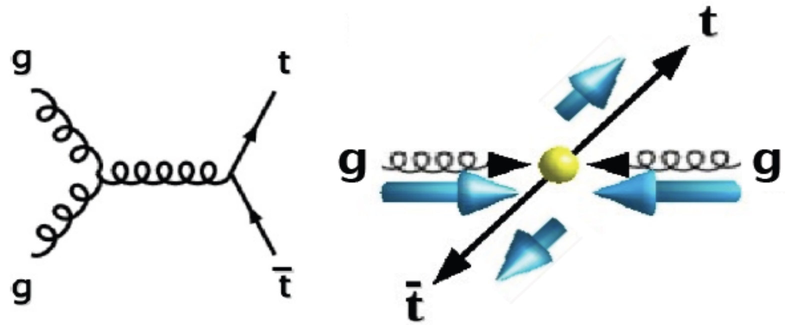
Spin correlation: Tevatron vs LHC

$$A = \frac{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} - N_{\uparrow\downarrow} - N_{\downarrow\uparrow}}{N_{\uparrow\uparrow} + N_{\downarrow\downarrow} + N_{\uparrow\downarrow} + N_{\downarrow\uparrow}}$$



Tevatron

- dominated by $q\bar{q}$ annihilation
- $t\bar{t}$ pairs close to the threshold
- beam axis as spin quantisation axis
  NLO QCD: A = 0.78
- optimised "off-diagonal" basis



LHC

- dominated by gg fusion
- $t\bar{t}$ pairs far off the threshold
- helicity basis as spin quantisation axis
  NLO QCD: A = 0.32
- maximal basis

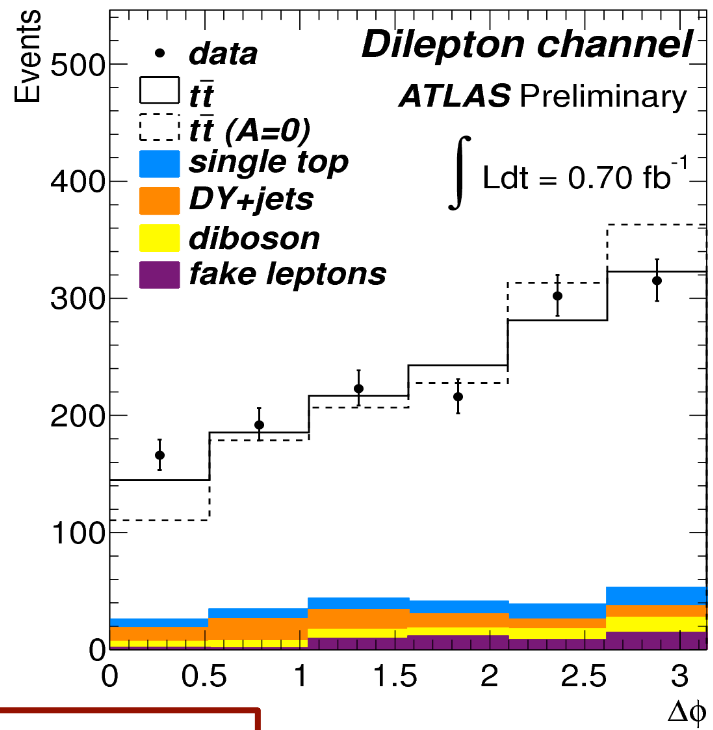
Bernreuther, Brandenburg, Si, Uwer, Nucl. Phys. B690, 81 (2004)

complementary between Tevatron and LHC

Spin correlation

- Access spin information via the angular distributions of its decay products
- Most sensitive probes are leptons and d-type quarks
- Strategy: fit Δφ dilepton distribution with binned SM distribution and in the case with uncorrelated spin distribution
- Translate result to maximal/helicity basis
- Main systematics: ISR/FSR and signal modelling
- Results in agreement with SM:

$$A = \frac{N_{like} - N_{unlike}}{N_{like} + N_{unlike}}$$



$$A_{\text{helicity}} = 0.34 \pm 0.07_{\text{stat}} \ {}^{+0.13}_{-0.09} \ \text{syst} \qquad A^{\text{SM}}_{\text{helicity}} = 0.32$$

$$A_{\text{maximal}} = 0.47 \pm 0.09_{\text{stat}} \ {}^{+0.18}_{-0.12} \ \text{syst} \qquad A^{\text{SM}}_{\text{maximal}} = 0.44$$

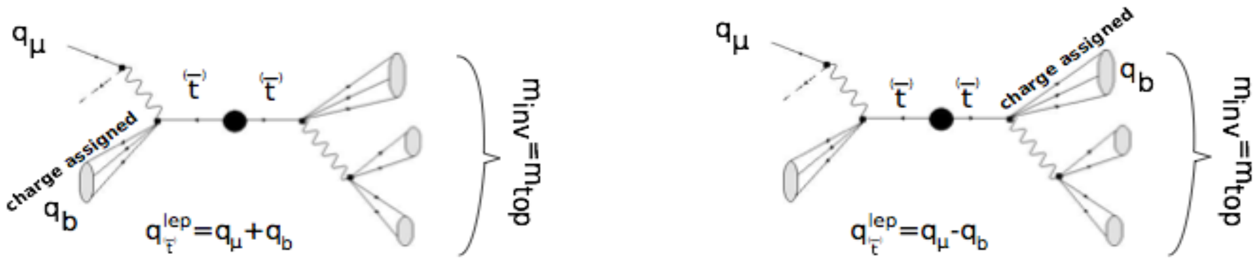
ATLAS-CONF-2011-117

Top quark charge

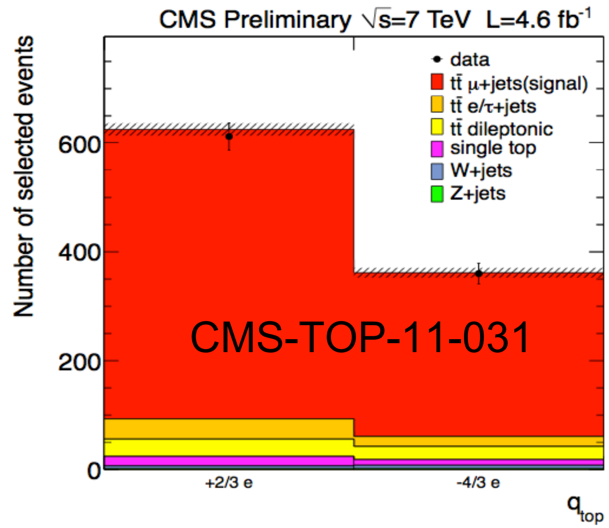
- top quark is the electroweak isospin partner of the bottom quark and is expected to have a charge of +2/3 e
- Use lepton+jets final state
- Measure charges of W and b quark
  - assign charge from semi-leptonic b-decays
  - Establish correlation between charge of the b-quark and a weighted sum of the electric charges of the particles belonging to the b-jet
  - Dilution: B-oscillations and presence of semi-leptonic c-quark decays

$$Q_{b\,jet} = \frac{\sum_i q_i |\vec{j}\cdot\vec{p}_i|^\kappa}{\sum_i |\vec{j}\cdot\vec{p}_i|^\kappa}$$

- Define two categories: +2/3e and -4/3e
- Pair b-jet to top quark charge



(a) (b)



Top quark charge

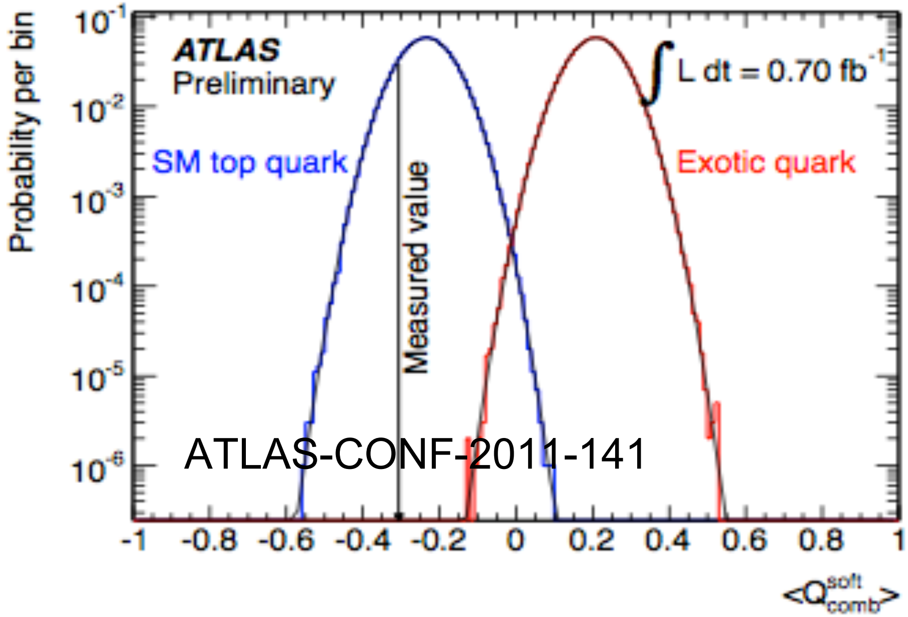
- Scenario with exotic top of charge −4/3 e would correspond to an asymmetry between the two categories of $A = -1$

$$A = \frac{1}{D_S} \frac{N_{SM} - N_{XM} - < N_{BG} > D_B}{N_{SM} + N_{XM} - < N_{BG} >}$$

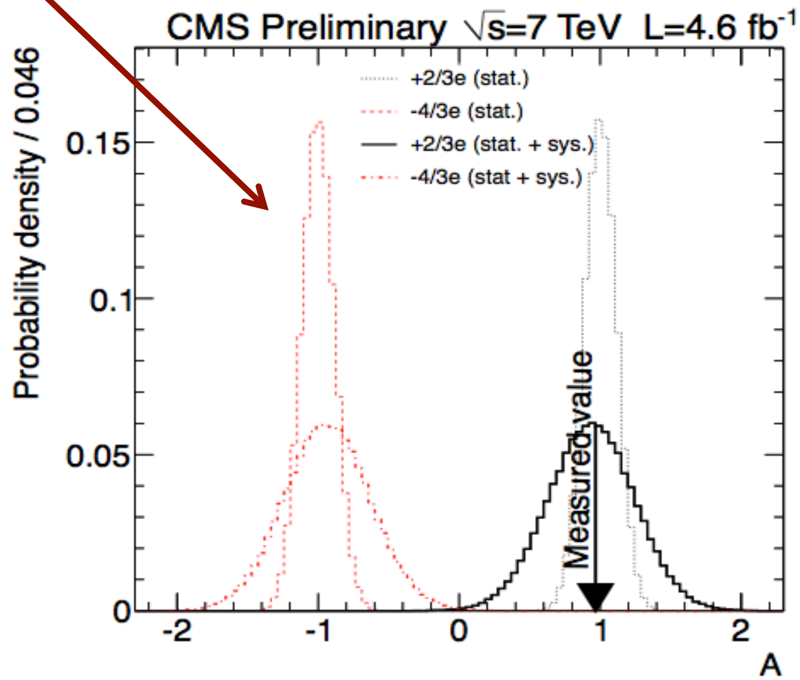
- Measure:

$$A_{meas} = 0.97 \pm 0.12(\text{stat.}) \pm 0.31(\text{sys.})$$

- Exclude exotic quark with charge -4/3 e



CMS-TOP-11-031



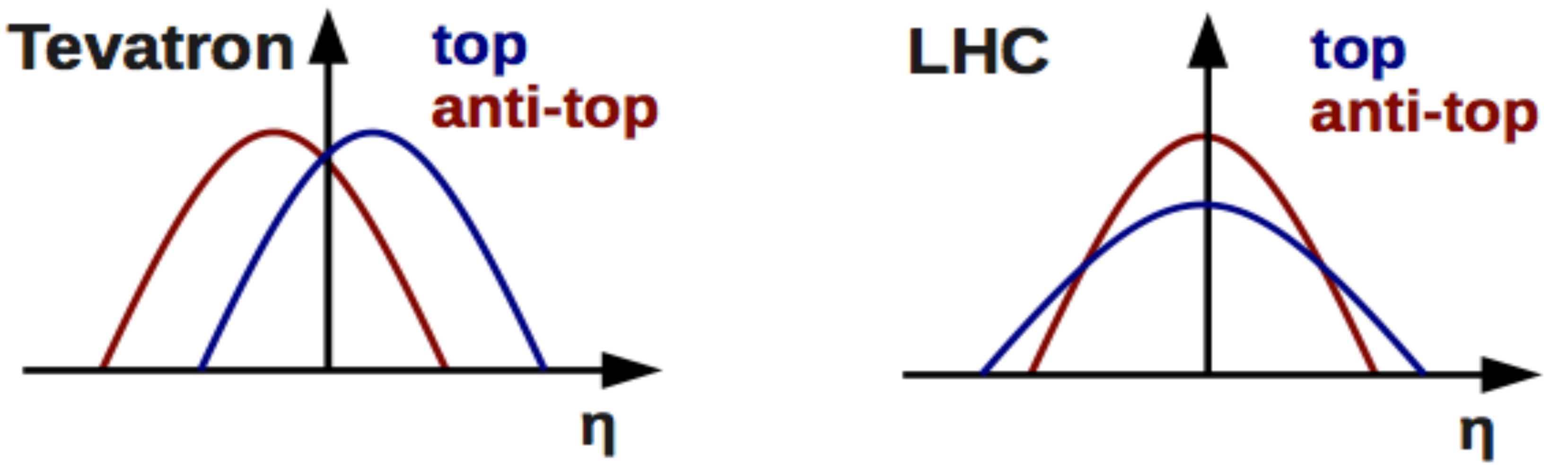
⇒Both experiments exclude exotic scenario at >5σ

Charge asymmetry

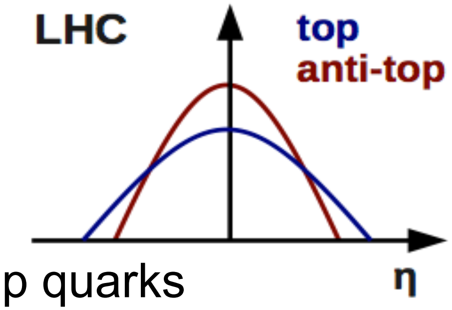
- In qqbar→ttbar (Tevatron): top quarks are emitted in the direction of the incoming quark, anti-top quarks in the direction of the incoming anti-quark
- No asymmetry in gg→ttbar (LHC)

SM: Only small asymmetry due to ISR/FSR

New physics: production mechanisms with new exchange bosons could enhance the charge asymmetry



Charge asymmetry



- Quarks have larger momentum than anti-quarks
- Anti-quarks from sea tend to have lower x
  - larger average momentum fraction of quarks leads to an excess of top quarks produced in the forward directions
- Charge asymmetry transfers boost difference to ttbar final state
- Effects at LHC are smaller due to larger gg→ttbar contribution
- Variables sensitive to the asymmetry are:

$$\Delta|\eta| = |\eta_t| - |\eta_{\bar{t}}| \qquad \Delta|y| = |y_t| - |y_{\bar{t}}| \qquad \Delta y^2 = y_t^2 - y_{\bar{t}}^2$$

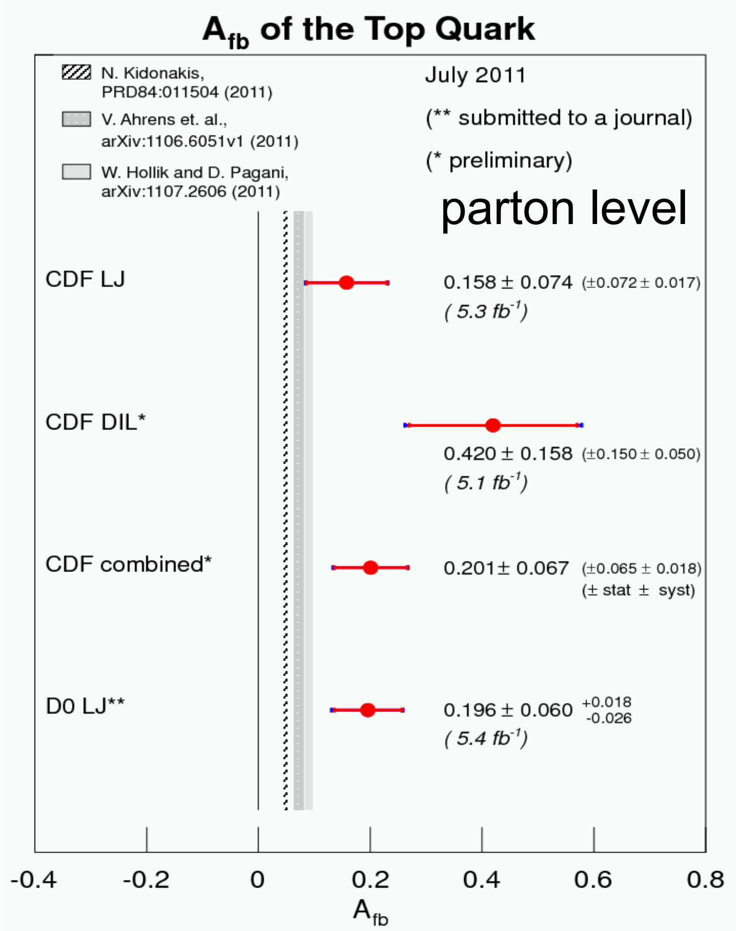
- At LHC, asymmetry defined as:

$$A_C = \frac{N^+ - N^-}{N^+ + N^-}$$

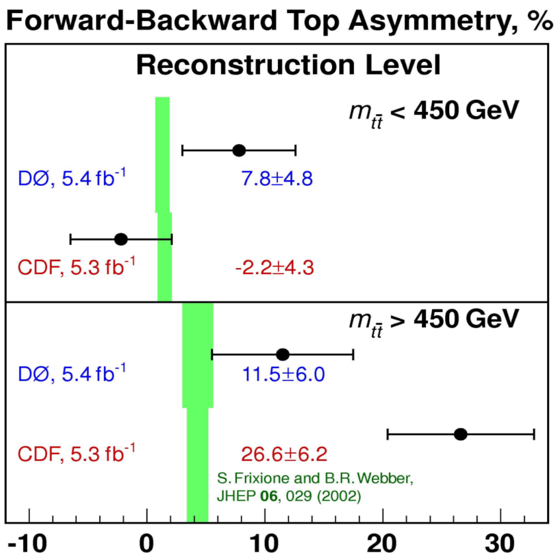
$N^+(N^-)$: number of events with positive and negative values in the sensitive variable

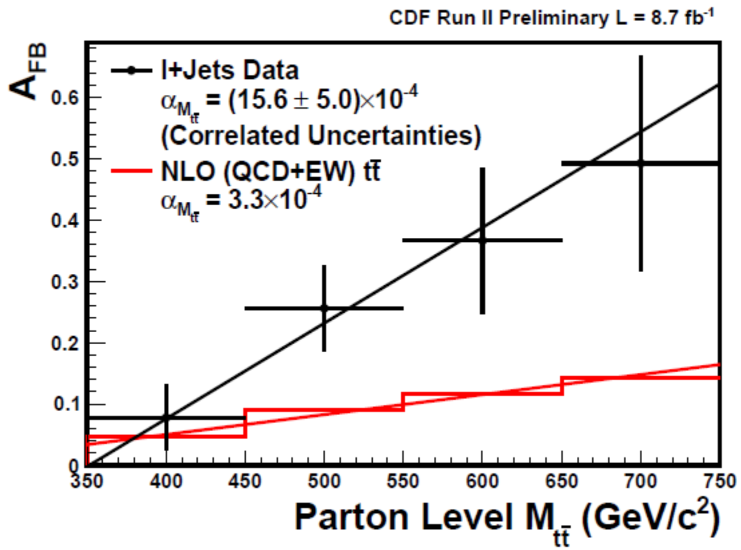
Charge asymmetry anomaly

- Tevatron experiments observe a differential dependency on charge asymmetry
  - Sign of new physics?



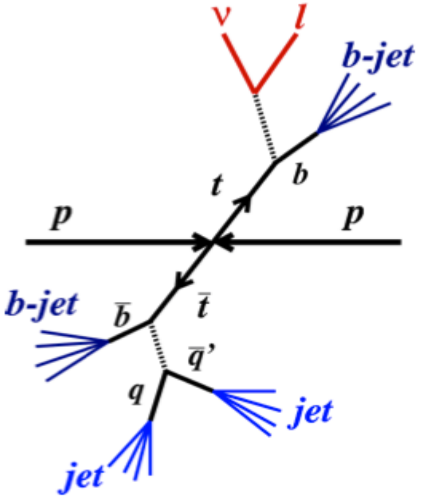
- At high mass, a 3σ discrepancy
- Study asymmetry vs mass of ttbar system

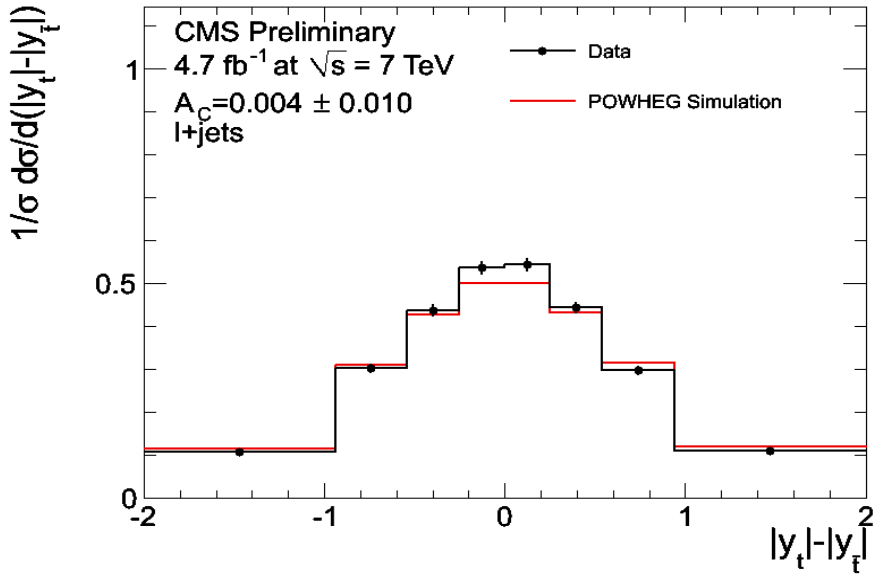


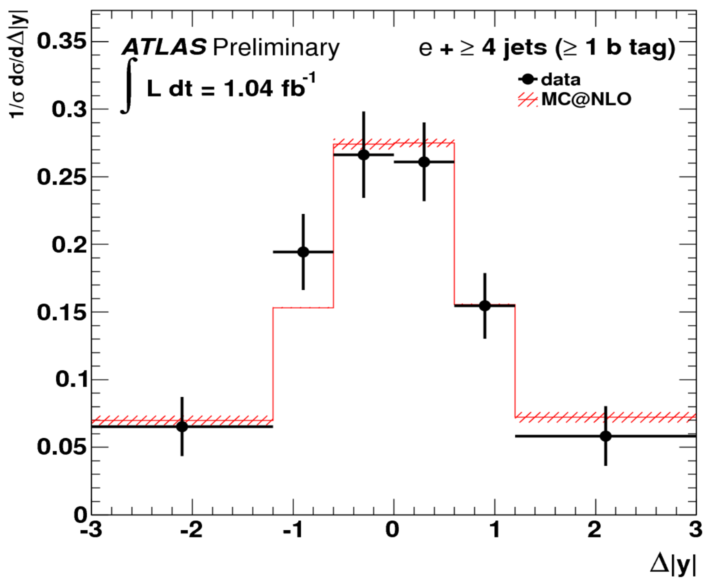


Charge asymmetry

- Use lepton+jet final state
- Measurement is based on the fully reconstructed 4 momenta of top and anti-top in each event





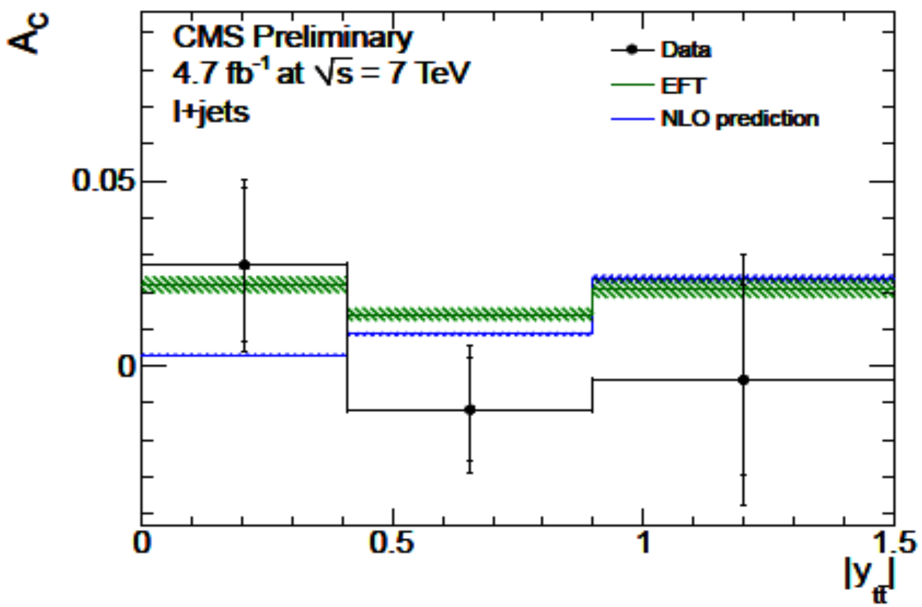


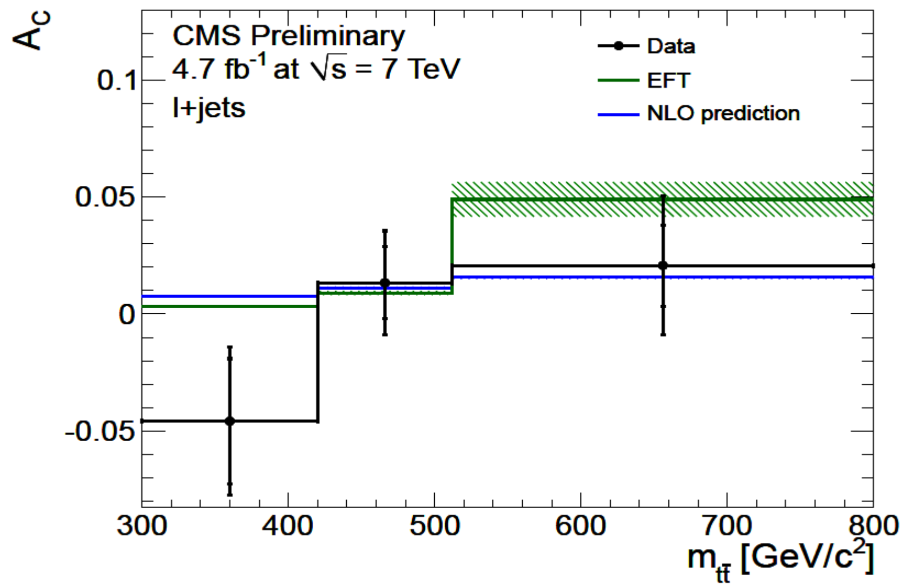
ATLAS-CONF-2011-106	-0.024 ± 0.016 (stat) ± 0.023 (syst)
CMS PAS-11-030	0.004 ± 0.010 (stat.) ± 0.012 (syst.)
Theory prediction (SM)	0.0115 ± 0.0006

Differential charge asymmetry

CMS PAS-11-030

- Asymmetry measured in p_T, y or invariant mass of the top pair system
- Good agreement found between data and SM expectations within uncertainties



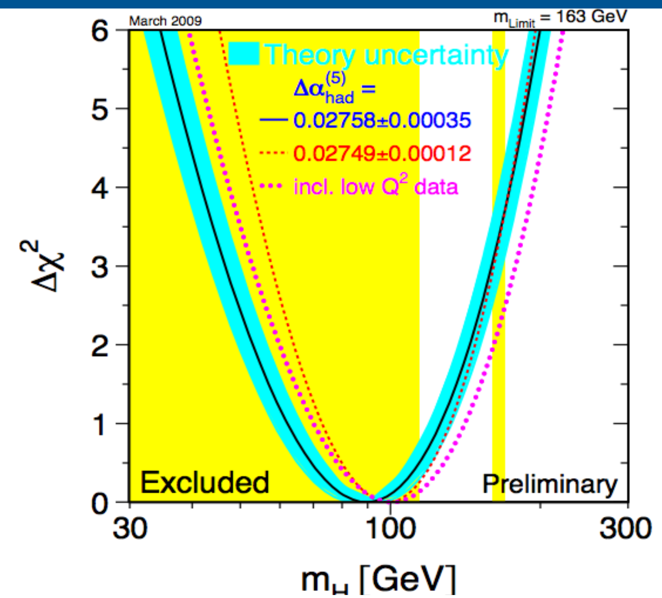


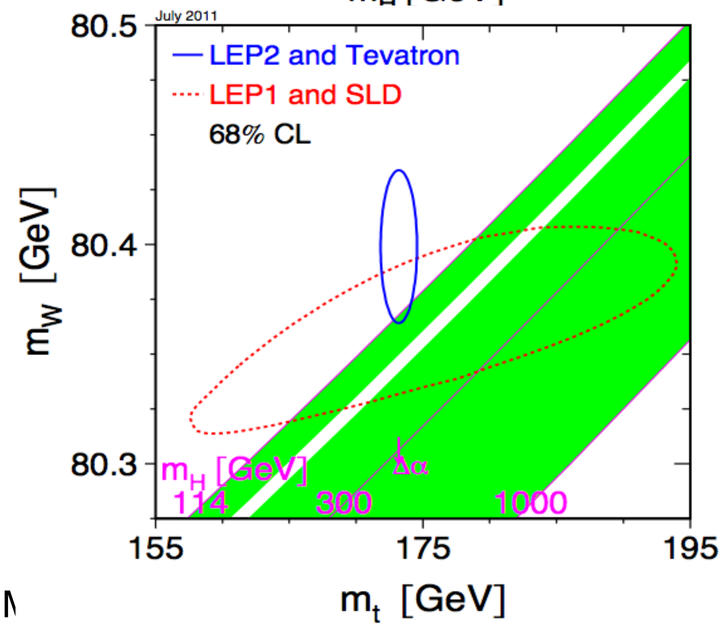
Top quark mass and constraints

- Top quark mass is a fundamental parameter of the SM
  - Known with good accuracy from the Tevatron: 173.2±0.9 GeV (arXiv:1107.5255)
  - Indirect constraint on the Higgs boson mass via EW corrections
  - $\Rightarrow m_H = 92^{+34}_{-26}$ GeV or <161 GeV

$\delta m_W \propto m_t^2$ $\delta m_W \propto \log m_h$

- Top is the only fermion with the mass of the order of EWSB scale
- Measuring precisely m_W and m_{top}
  - Test consistency of SM
  - Search for new Physics





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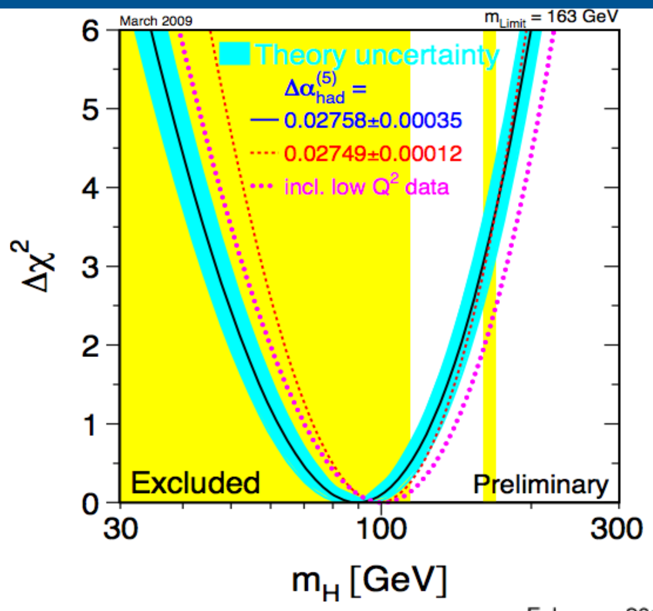

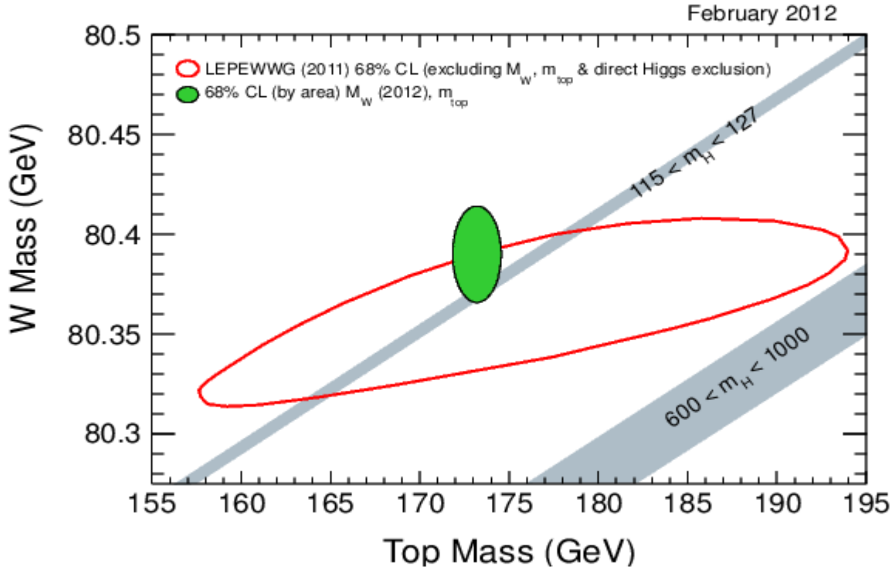

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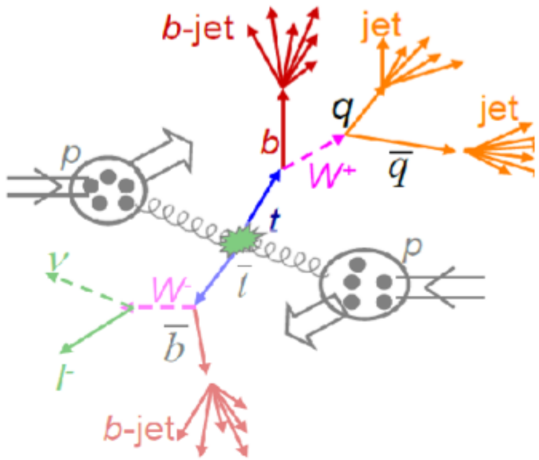
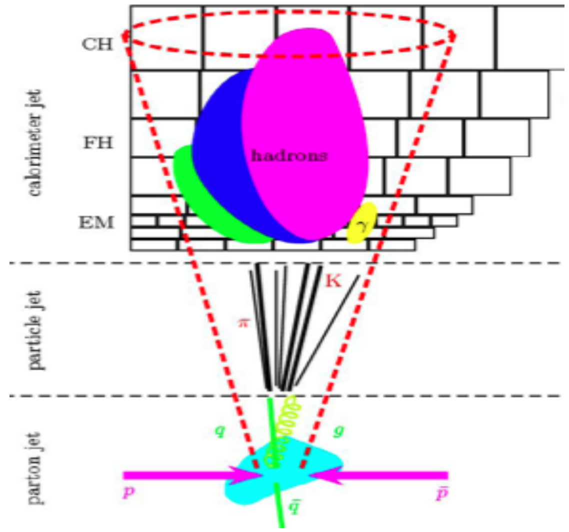
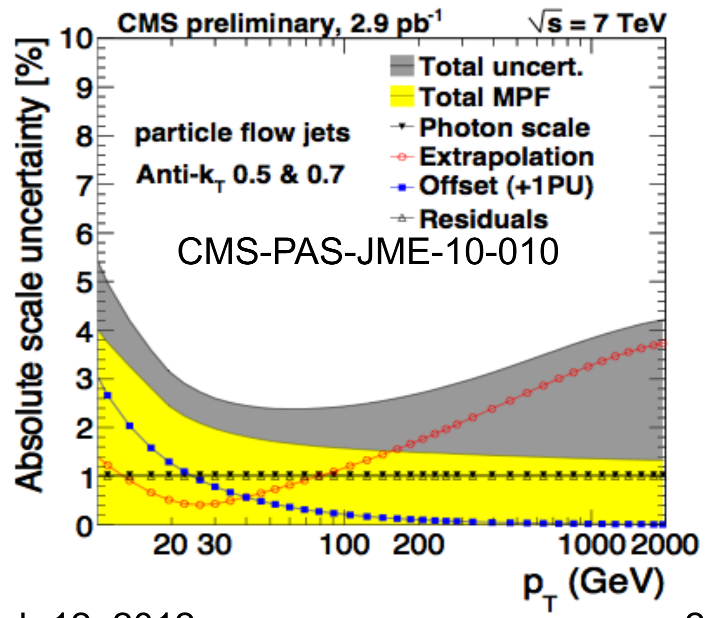
Jet reconstruction in Top events

- Top mass measurement needs parton information, but we measure jets
- Use calorimeter information to correct jets to particle level



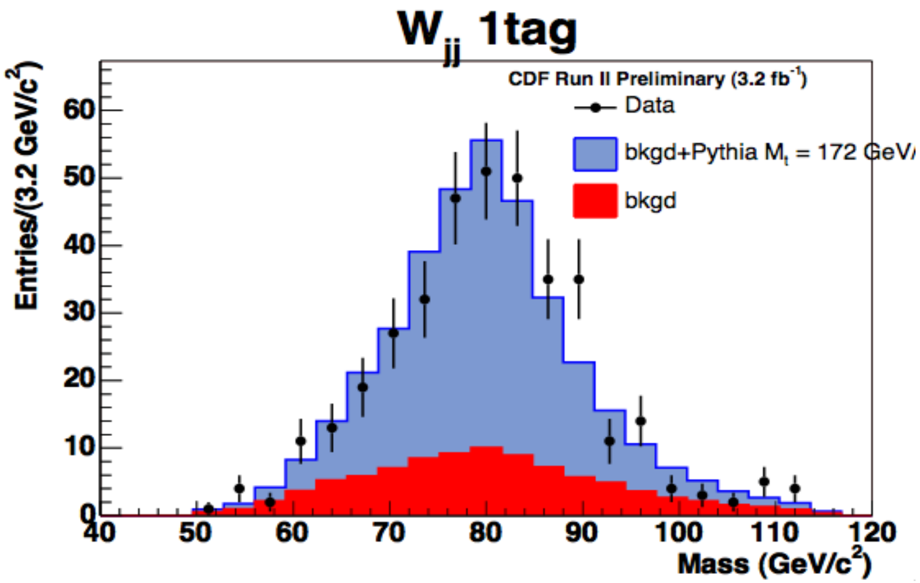


- Jet energy scale (JES) is the main source of uncertainty
  – Look at quantities insensitive to JES (e.g. lepton p_T)
  – "b-jet" tag helps reducing number of permutations
- JES "in-situ" calibration in ttbar events
  – Use W→jj constraint to measured W mass
  – Can be used in lepton+jets (and all-hadronic) channel



Top as a calibration tool

- Top quarks can be used as calibration tool
  – Top mass, W mass, b/q jets
- can determine:
  – b-tagging efficiency
  – jet energy scale



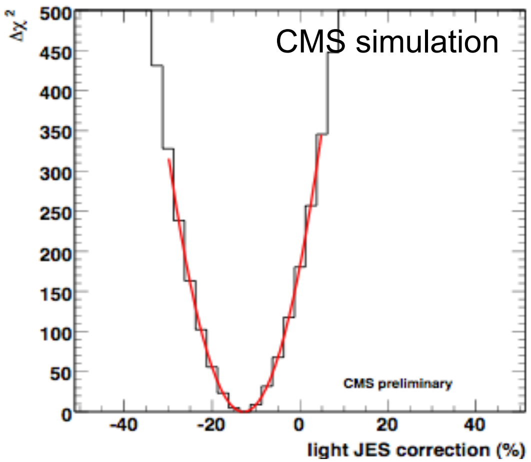
…or alternatively…

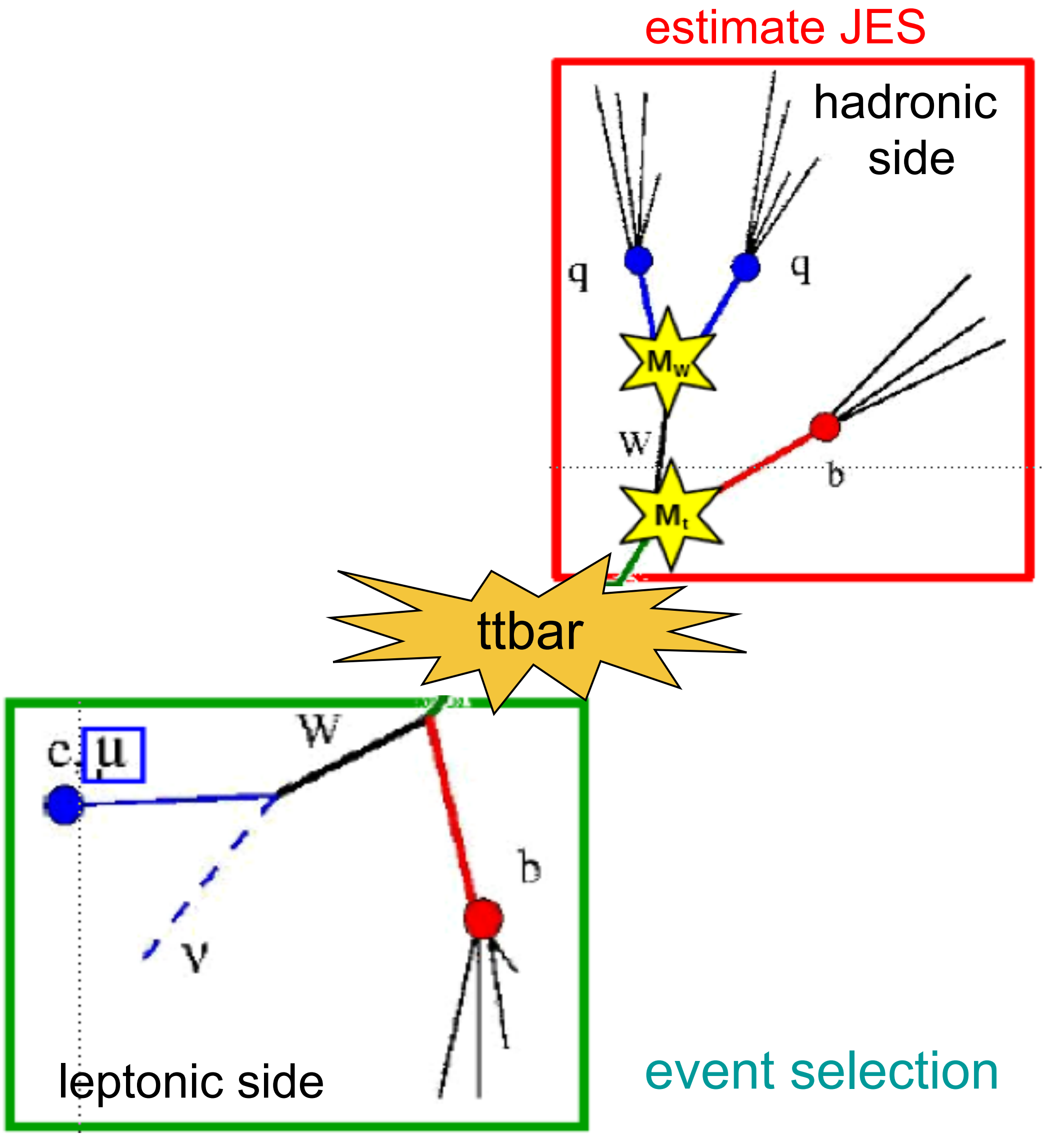
- use b-tag as a probe
  – compare rates in different b-tag multiplicity bins
  – is the signal, ttbar or not?
- BSM may appear in the sample and "distort" the distribution

Jet energy correction from Top

- Use semi-leptonic events
  - –1 isol μ (p_T>30 GeV)+≥4 jets (40 GeV)
- Estimate jet energy corrections by applying event-by-event kinematical fit to W and Top masses
- Likelihood is used to assign jets
- Kinematical fit returns $P(\chi^2)$
- Find best JES by minimizing χ^2

⇨with 200/pb can reach 1% on JEC





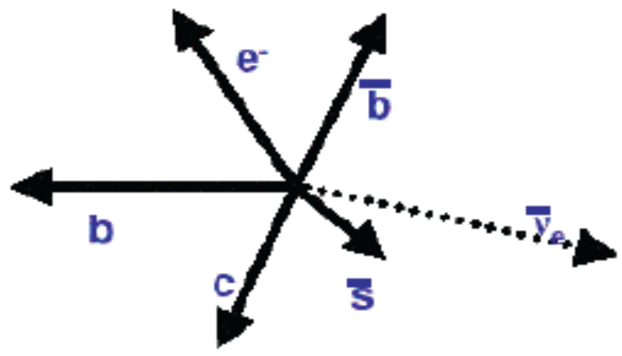
Measuring the top mass

Challenging:

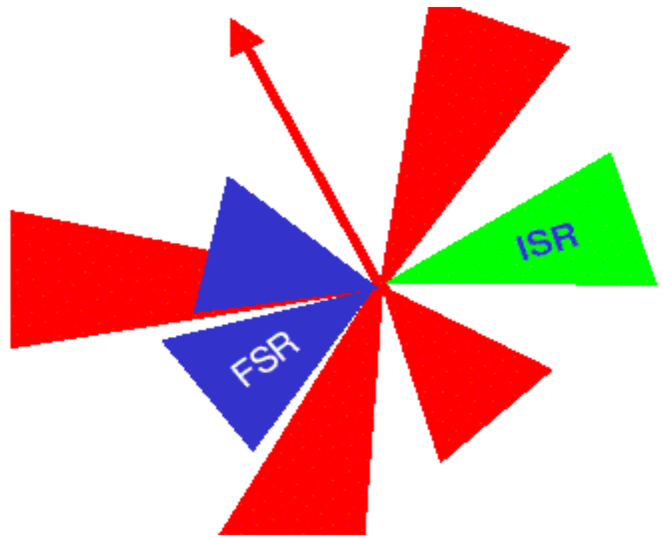
➢ **Lepton+jets**
- undetected neutrino
  - P_x and P_y from E_T conservation
  - 2 solutions for P_z from $M_W = M_{l\nu}$
- leading 4-jet combinatorics
  - 12 possible jet-parton assignments
  - 6 with 1 b-tag
  - 2 with 2 b-tags
- ISR + FSR

➢ **Dileptons**
- (less statistics)
- two undetected neutrinos
- less combinatorics: 2 jets

LO final state:

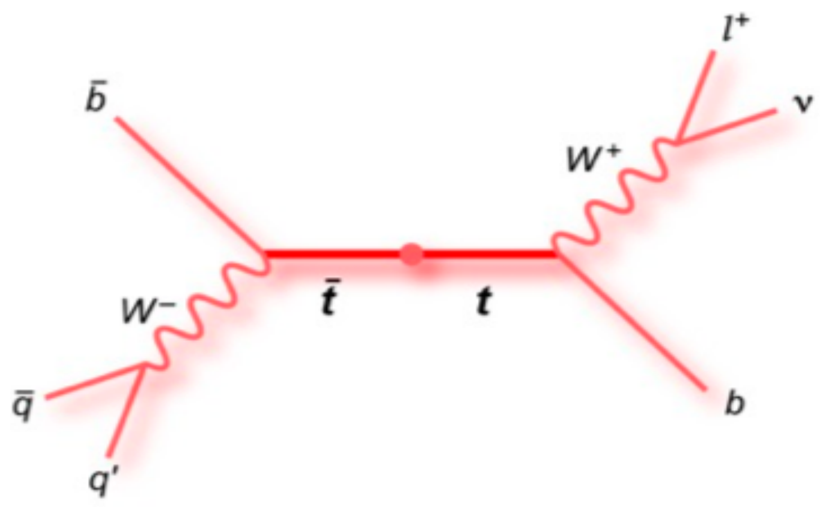


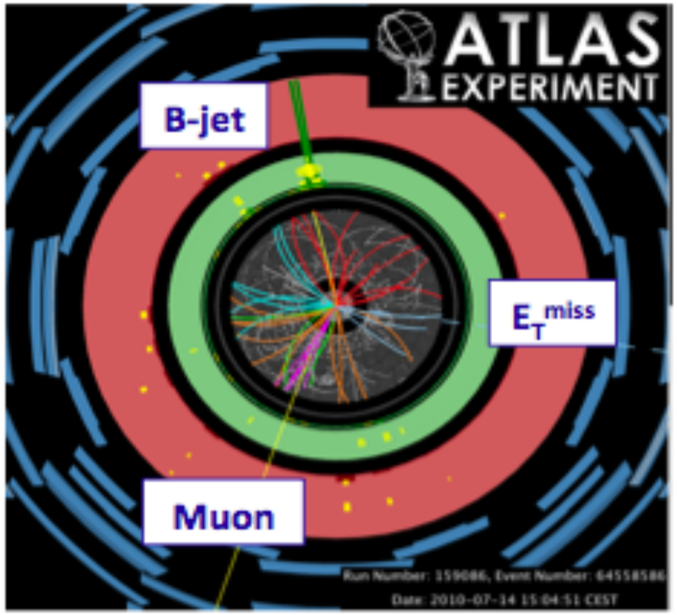
experiment sees:



Lepton+jet channel

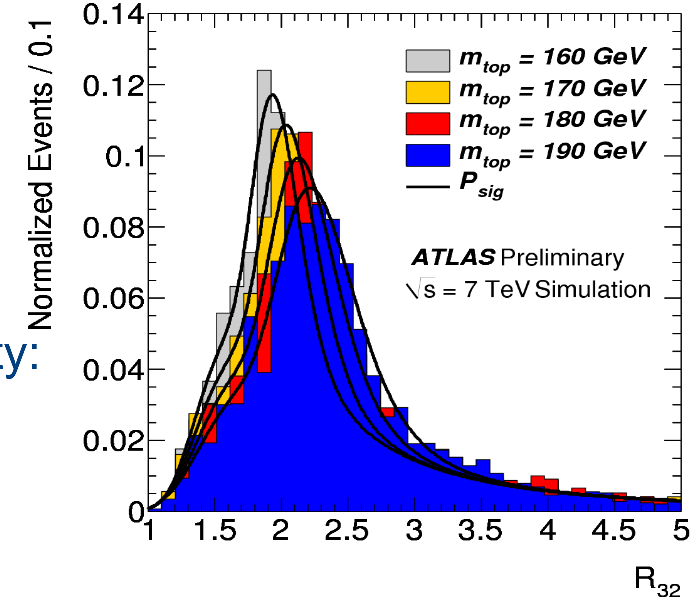
- Best channel (for now) to measure top quark mass
- Compromise between large branching ratio (BR=30%) and a good background rejection
- Well defined final state (1 lepton, one neutrino, 2 b-jets, W→qq')

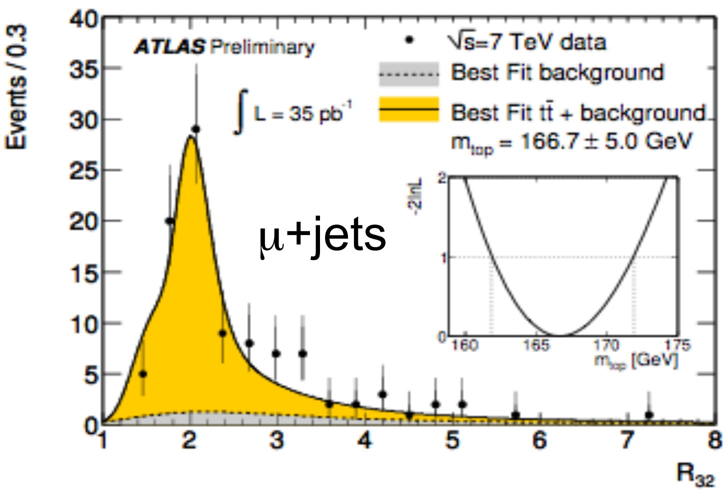




Template method

- Choose a variable sensitive to top mass
- Predict the distribution with MC templates vs top mass
- Evaluate likelihood for each top mass
- Maximize likelihood
- JES is dominant source of uncertainty
- Complementary methods developed to reduce JES uncertainty:
  - 1D template analysis is based on the ratio R_{32}=M(jjb)/M(jj)
  - Template fit to m_{top} from kinematic reconstruction
  - 2D JSF template analysis: simultaneous fit to m_{top} and JES

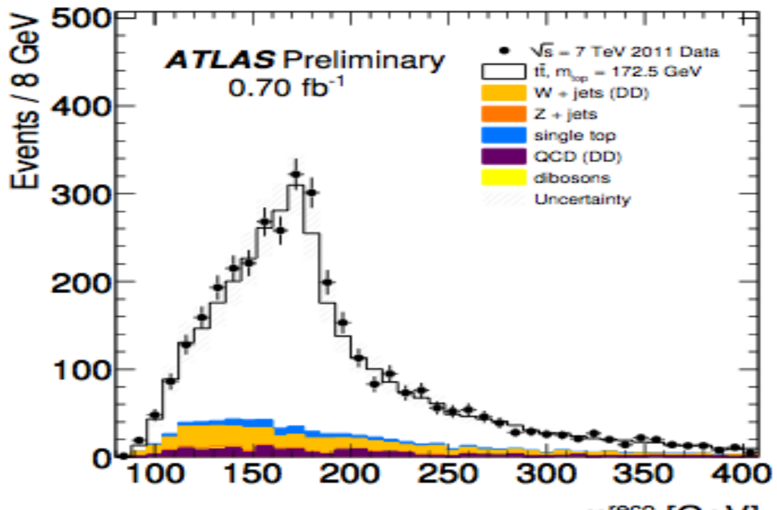




simple reconstruction method:
m_{top}^{reco} = jet triplet that maximizes p_T
m_W^{reco} = untagged jet-pair, or jet pair with DR_{min} in the top rest frame

Template analysis

- 2-d template analysis: m_{top} and Jet energy Scale Factor (JSF) determined simultaneously from distributions of reconstructed m_{top} and m_W
- Take information from hadronically decaying W mass to constrain JES
  - in-situ jet energy rescaling, determine m_{top}
- How is the association done?
  - Each light jet pair with $50<m_W<100$ GeV is combined with b-tagged jet
  - Triplet with maximum p_T is chosen as top candidate
  - Measure mass of hadronic top: $t \rightarrow W(qq')b$
  - 2-jet inv. mass constrained to m_W (Γ_w=2.2 GeV)
- Signal template: for m_{top} and m_W
- Background template: includes single top, mass-dep.
- Fit data (i.e. m_{top}^{reco}) to sum of signal and background PDF (probability density function)



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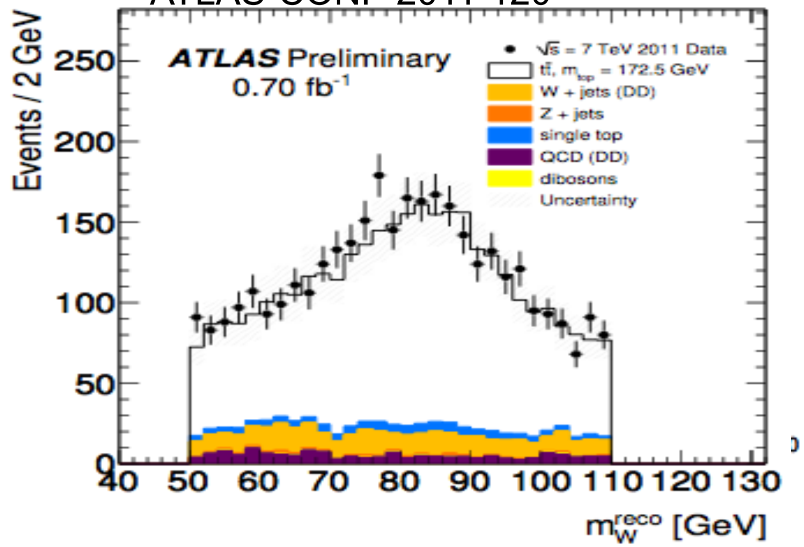
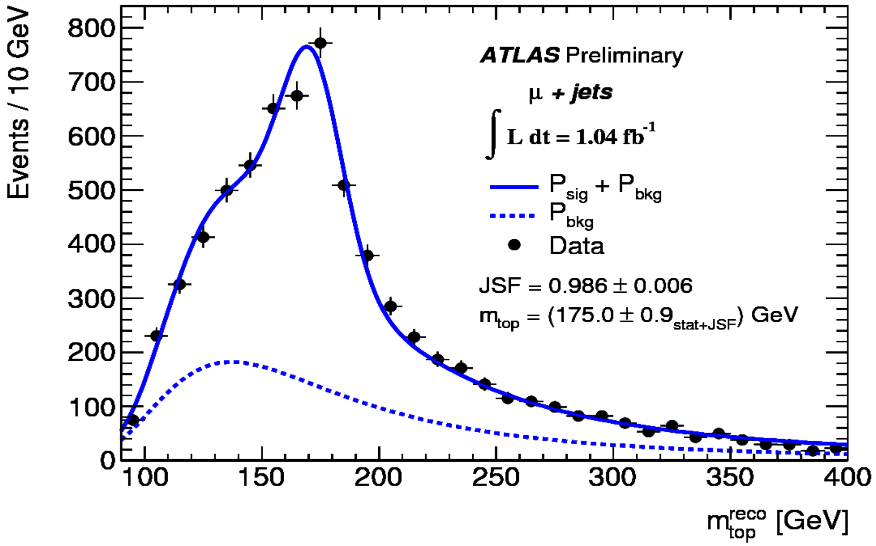


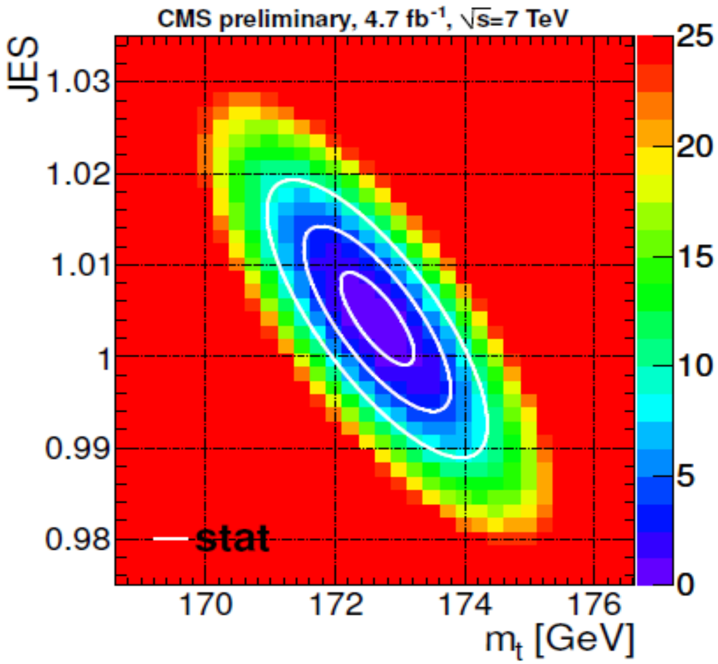
Lepton+jet channel

- in-situ calibration of the light quark JES from W→ qq'

ATLAS: template fit as function of JES and top quark mass



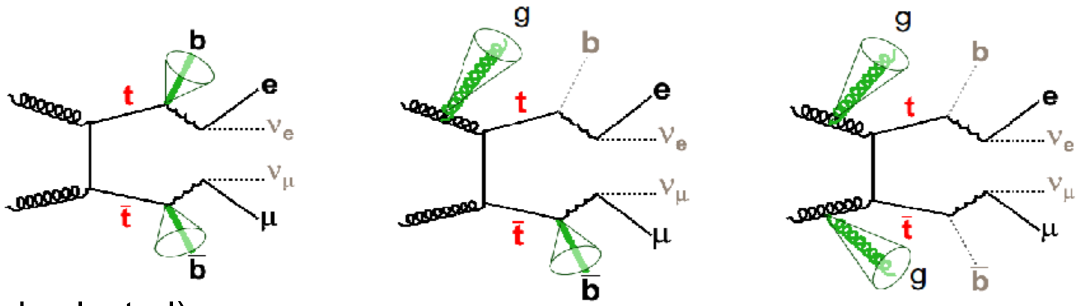
CMS: kinematic fit + "ideogram" method combine event-per-event likelihood



⇨ m_{top}=174.4 ± 0.6 (stat) ± 2.3 (syst) GeV — ATLAS CONF-2011-120

172.6 ± 0.6 (stat) ± 1.2 (syst) GeV — CMS PAS-11-015

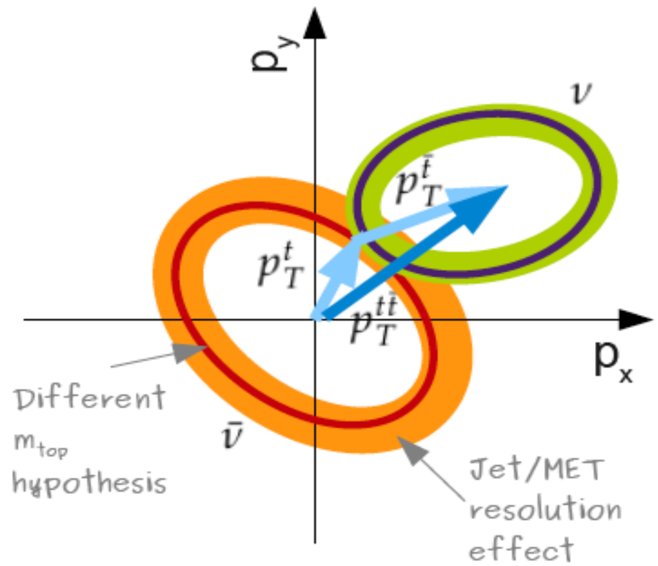
Dilepton channel: challenges



- Combinatorics
  - Identify top quark decay products
  - Ambiguity
  - ISR/FSR introduces further complexity for selection

  (~70% of the events have both b-jets reconstructed and selected)

- Missing transverse energy
  - Constrains the contribution from undetected particles
  - In the dilepton channel: 2 neutrinos ⇒ $\vec{E}_T^{miss} = \vec{p}_T^{\nu} + \vec{p}_T^{\bar{\nu}}$

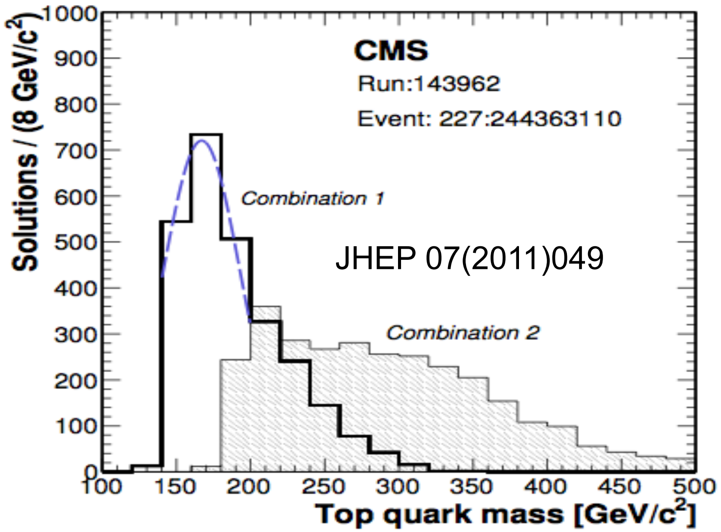


- Jet energy scale
  - m_{top} reconstruction requires measuring the parton energy
  - parton→jet affected by resolution and absolute energy scale
- Pile-up
  - Jet energy scale, MET measurement, extra jets/leptons
  - N_{pileup}≈ 2.1 (6) for most of data collected in 2010 (2011)

KINb and AWMT methods

KINb

- Full Kinematic Analysis
- Equations solved for each lepton-jet combination
- p_z distribution is assumed
- Accept solutions if two decay legs agree within Δm_{top}<3 GeV



AWMT

- Analytical Matrix Weighting Technique
- Iterate over values of m_{top} hypothesis from 100 to 700 GeV
  - solve kinematic equations for fixed values of m_{top}
  - Assign weights to each solution based on pdf and kinematic quantities

$$w = \{\sum F(x_1)F(\bar{x}_2)\}\, p(E^*_{\ell^+}|m_t)p(E^*_{\ell^-}|m_t)$$

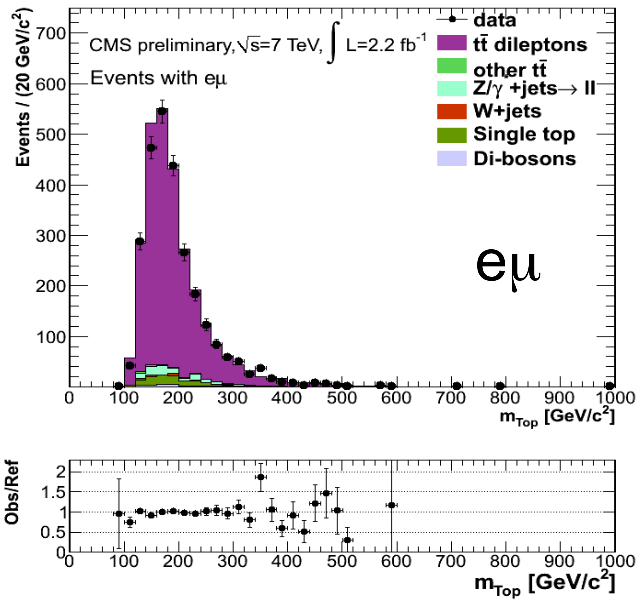
- From inclusive weight distribution estimate top mass
- For each event, take value of top mass with highest sum of weights (m_{peak})

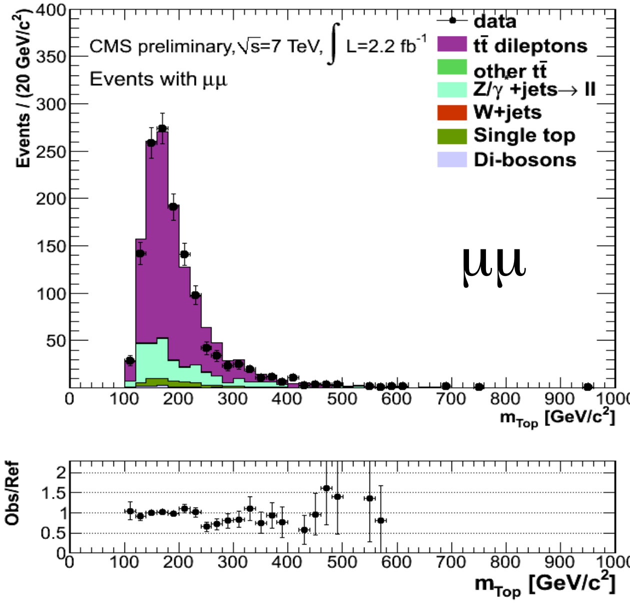
Reconstructed mass

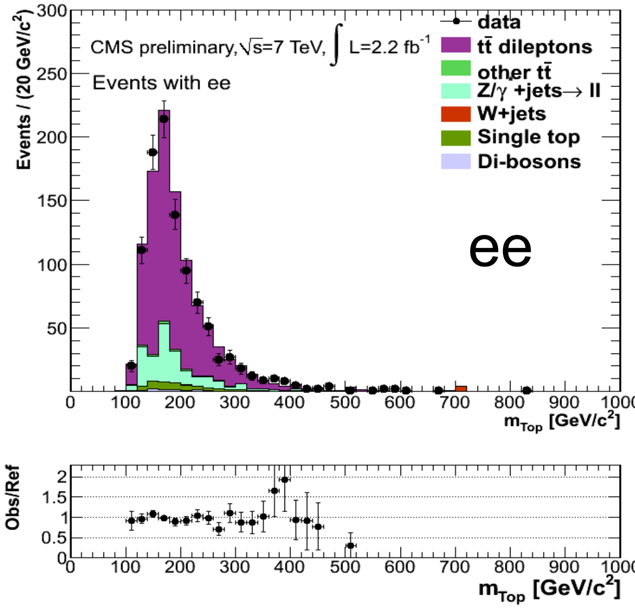
CMS-PAS-TOP-11-016

- Select events
- Reconstruct mass

Process	Pre-selection	KINb	=1 b-tag	$\geq$ 2 b-tags
Di-bosons	73 ± 14	55 ± 10	18 ± 4	4 ± 1
Single top	247 ± 92	182 ± 68	88 ± 33	76 ± 29
W+jets	22 ± 10	16 ± 8	8 ± 6	-
$Z/\gamma^* \to \ell\ell$	1091 ± 97	756 ± 71	238 ± 29	47 ± 11
other $t\bar{t}$	32 ± 4	28 ± 3	11 ± 2	14 ± 2
$t\bar{t}$ dileptons	5057 ± 463	4209 ± 385	1379 ± 127	2623 ± 240
total expected	6522 ± 482	5246 ± 398	1742 ± 134	2765 ± 242
data	6358	5047	1692	2620



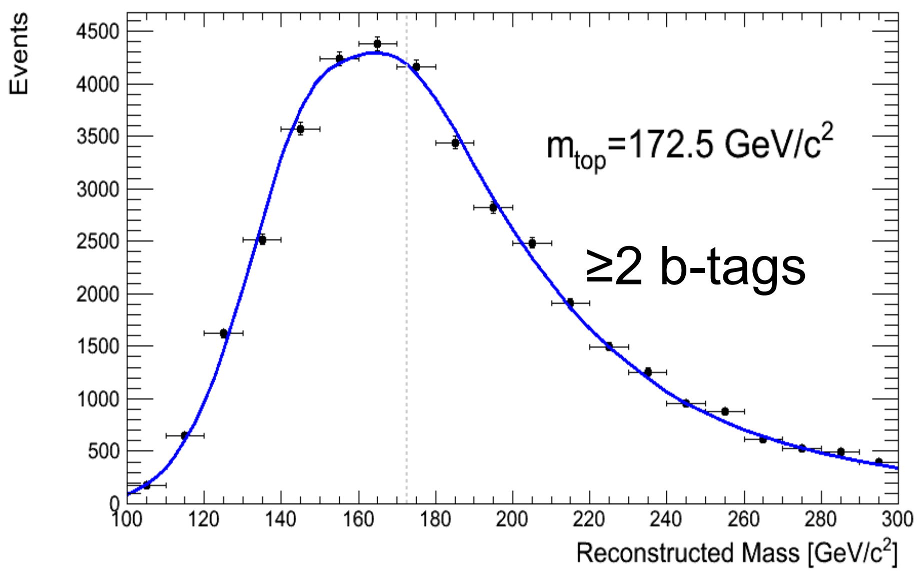


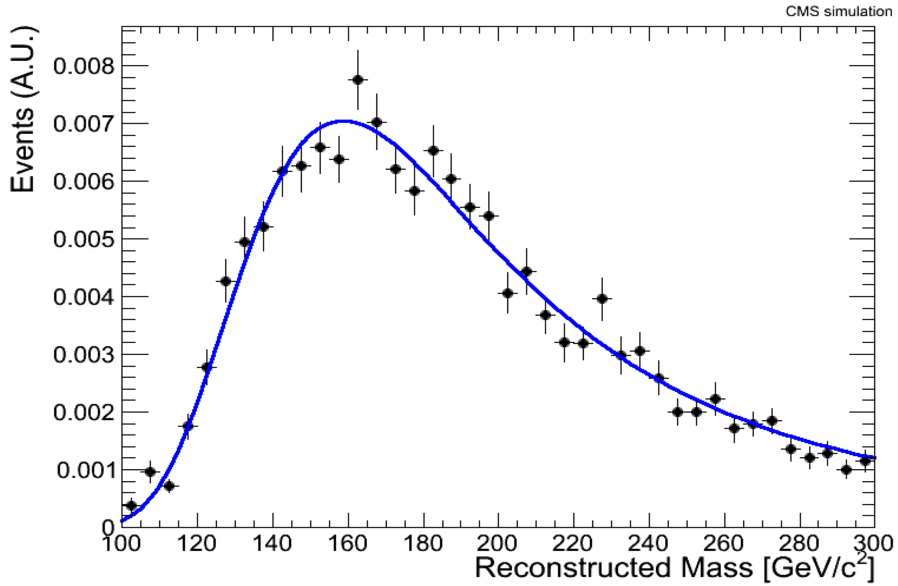


Signal and background

- Signal component in the mass spectrum modelled: simulation
- Fit: Landau+Gaussian
- Categories: =1 and ≥2 b-tags

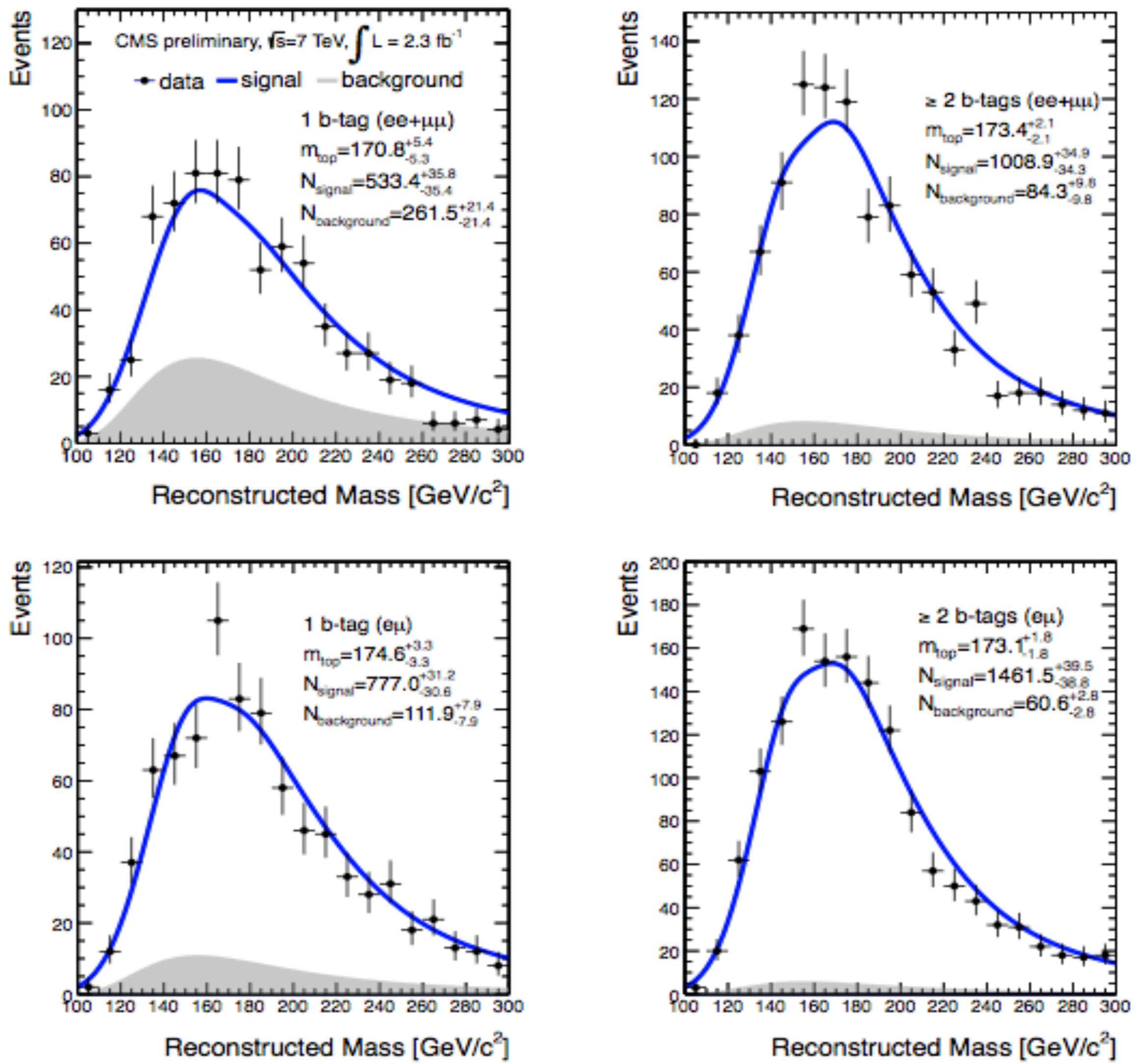
- Background component in the mass spectrum modelled with data +simulation
- Fit: Landau





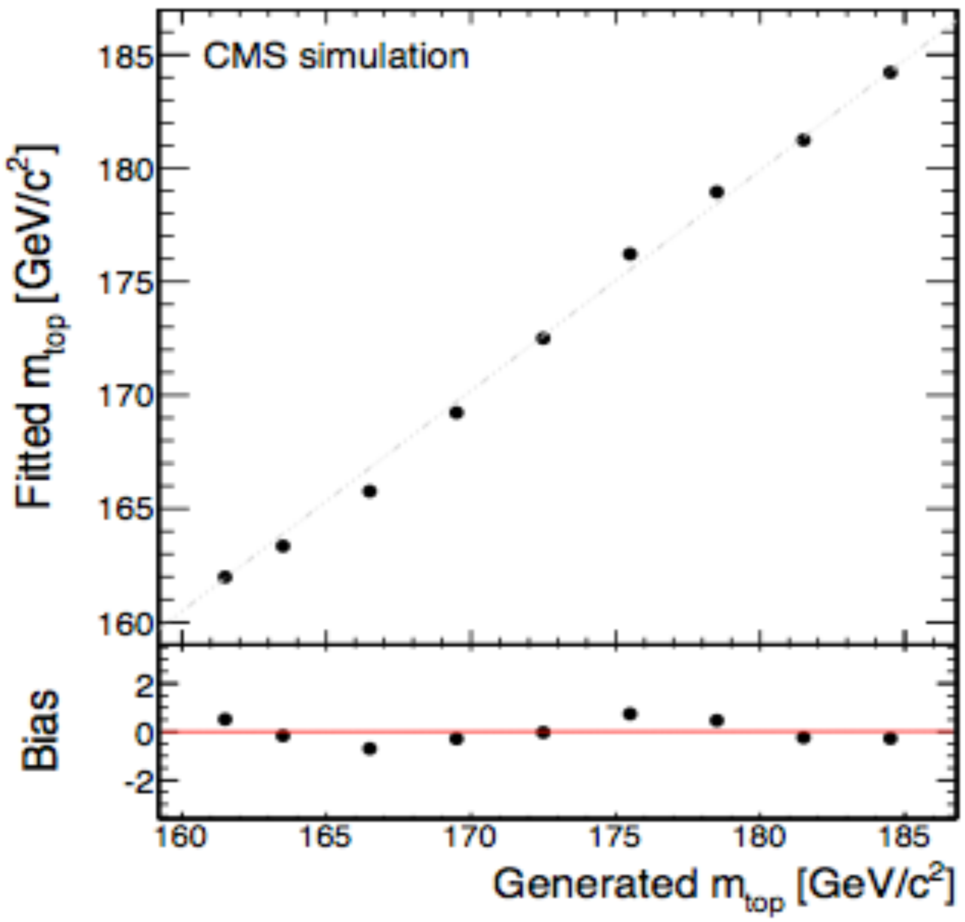
Reconstructed mass

- Top quark mass is reconstructed in different categories
- Signal and background shapes



Correct for the bias

- Check and correct for the bias in the measurement

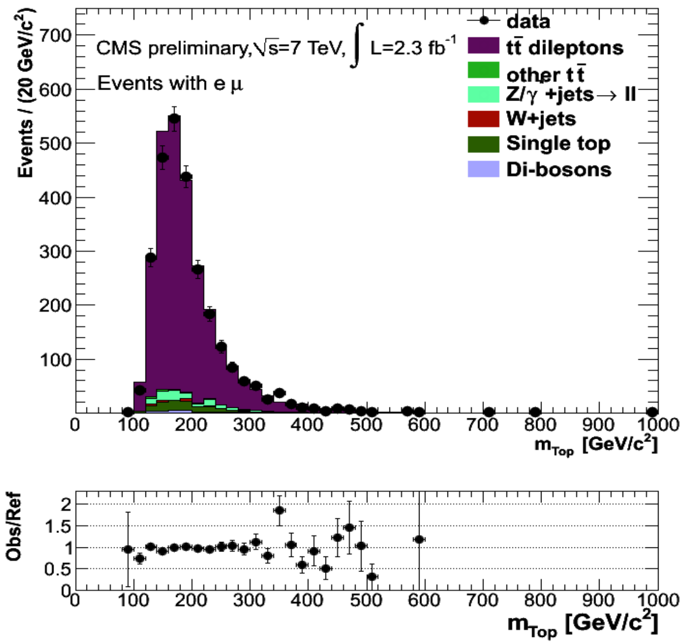


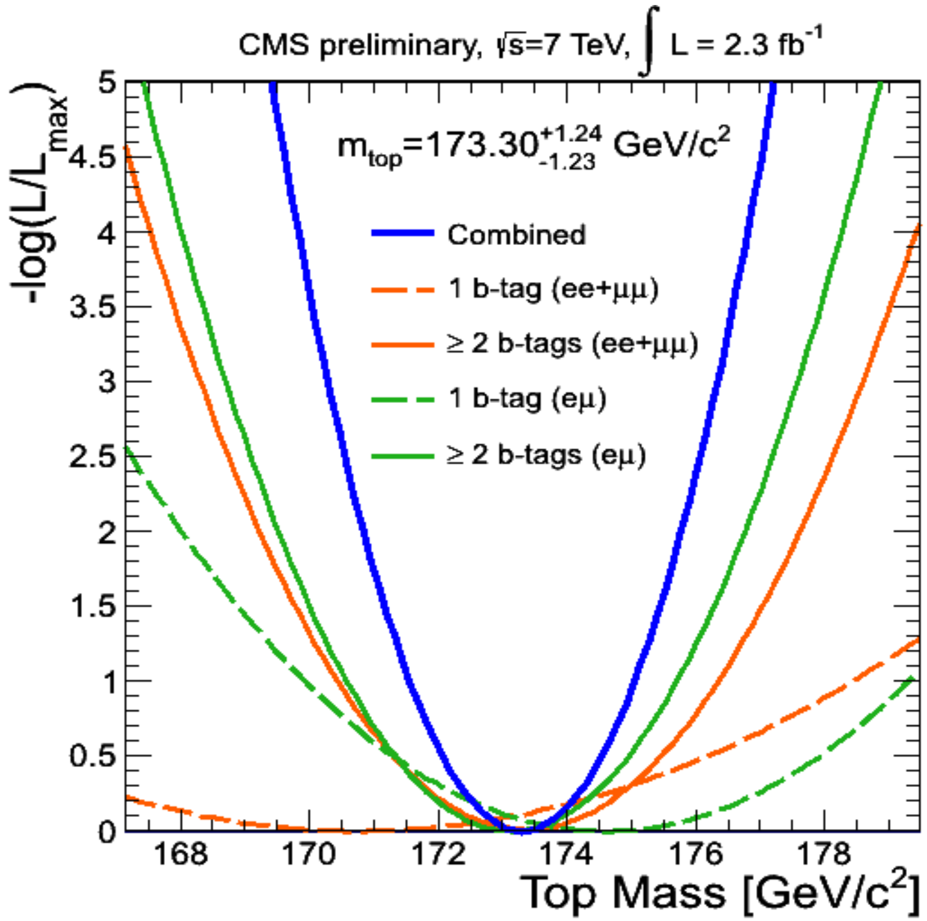
Do not forget the systematics

- Jet energy scale (JES) is the largest unc.
  - JES is varied up and down and difference in m_{top} is accounted for as systematics
  - Flavor (b) specific uncertainty added in quadrature
- Other systematics:
  - Difference with respect to reference sample used for signal
  - MC: compare Alpgen and Powheg with Madgraph
  - Vary factorization/matching scale, ISR/FSR

Source	Δm_{top} (GeV/c^2)
JES	$^{+1.90}_{-2.00}$
flavor-JES	$^{+1.08}_{-1.13}$
JER	$\pm$ 0.30
LES	$^{+0.12}_{-0.18}$
Unclustered $E_{\text{T}}^{\text{miss}}$	$\pm$ 0.43
Fit calibration	$\pm$ 0.40
DY normalization	$\pm$ 0.40
Factorization scale	$\pm$ 0.41
Jet parton matching scale	$\pm$ 0.65
Pile-up	$\pm$ 0.19
b-tagging uncertainty	$\pm$ 0.30
mis-tagging uncertainty	$\pm$ 0.43
MC generator	$\pm$ 0.14
PDF uncertainty	$\pm$ 0.39
Total	$^{+2.52}_{-2.63}$

Final fit

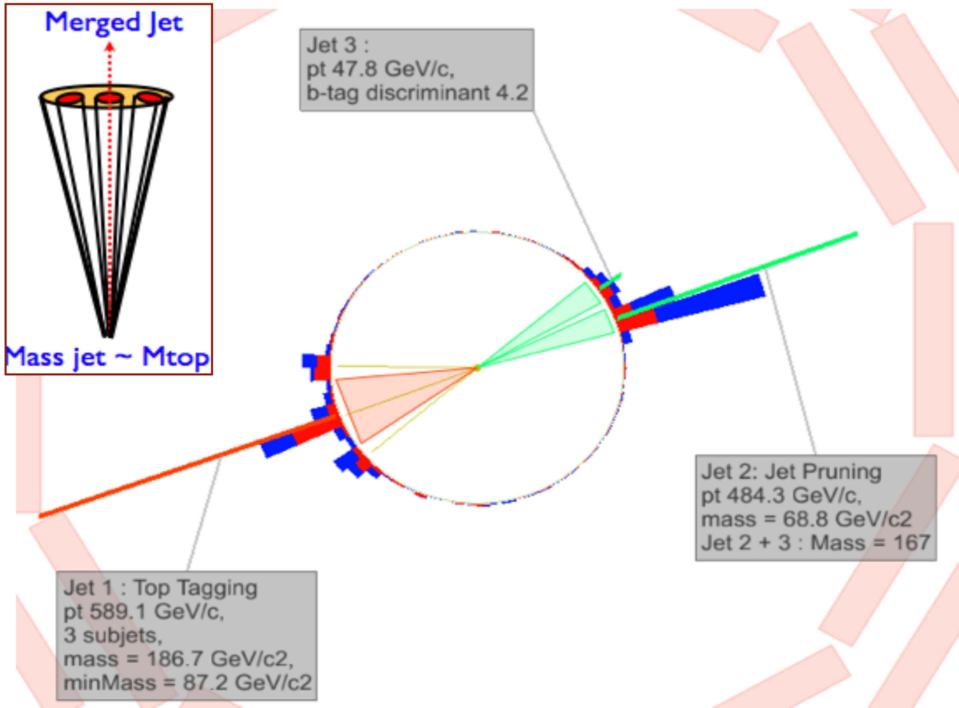


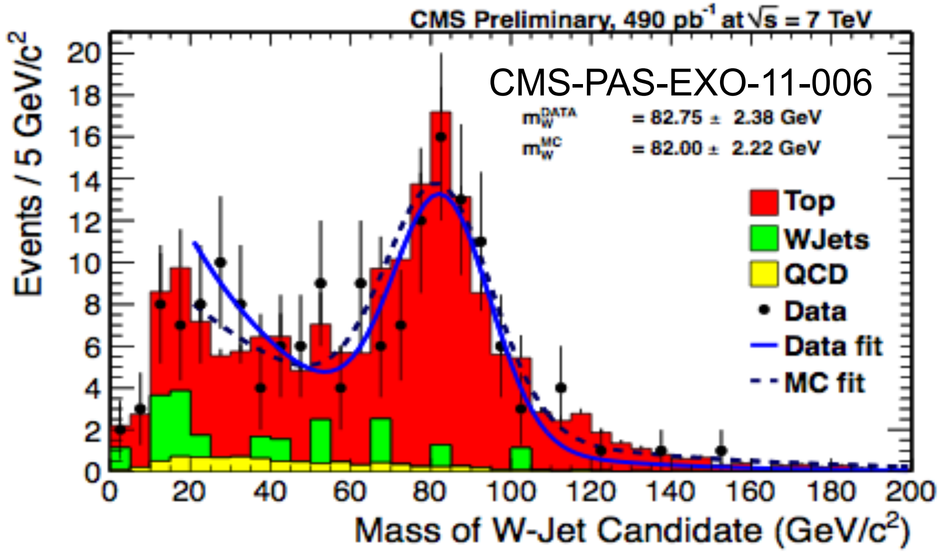


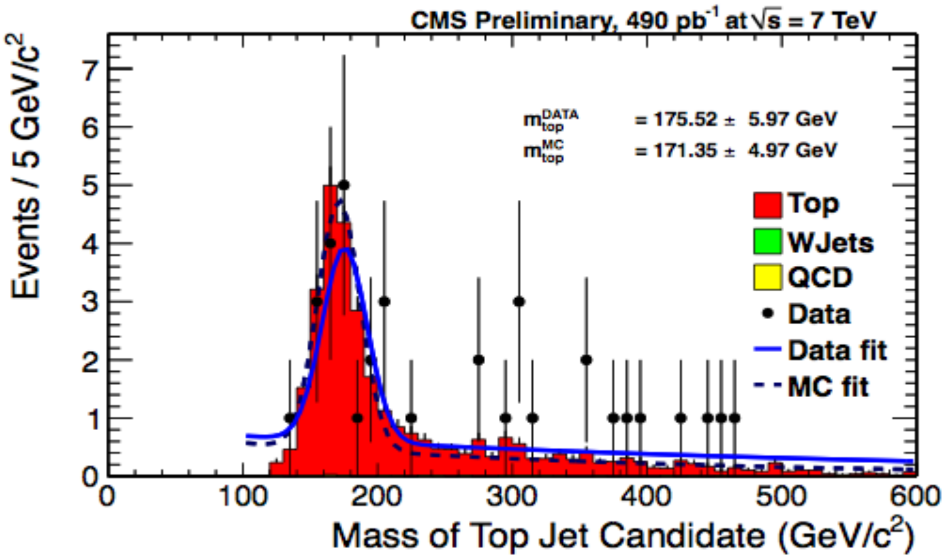
$$m_{\text{top}} = 173.3 \pm 1.2(\text{stat.})^{+2.5}_{-2.6}(\text{syst.})\ \text{GeV}/c^2$$

CMS PAS-11-016

Boosted jet topology







- Using top-tagging
- Still statistically limited
- Could provide precise measurement
- Need to understand biases

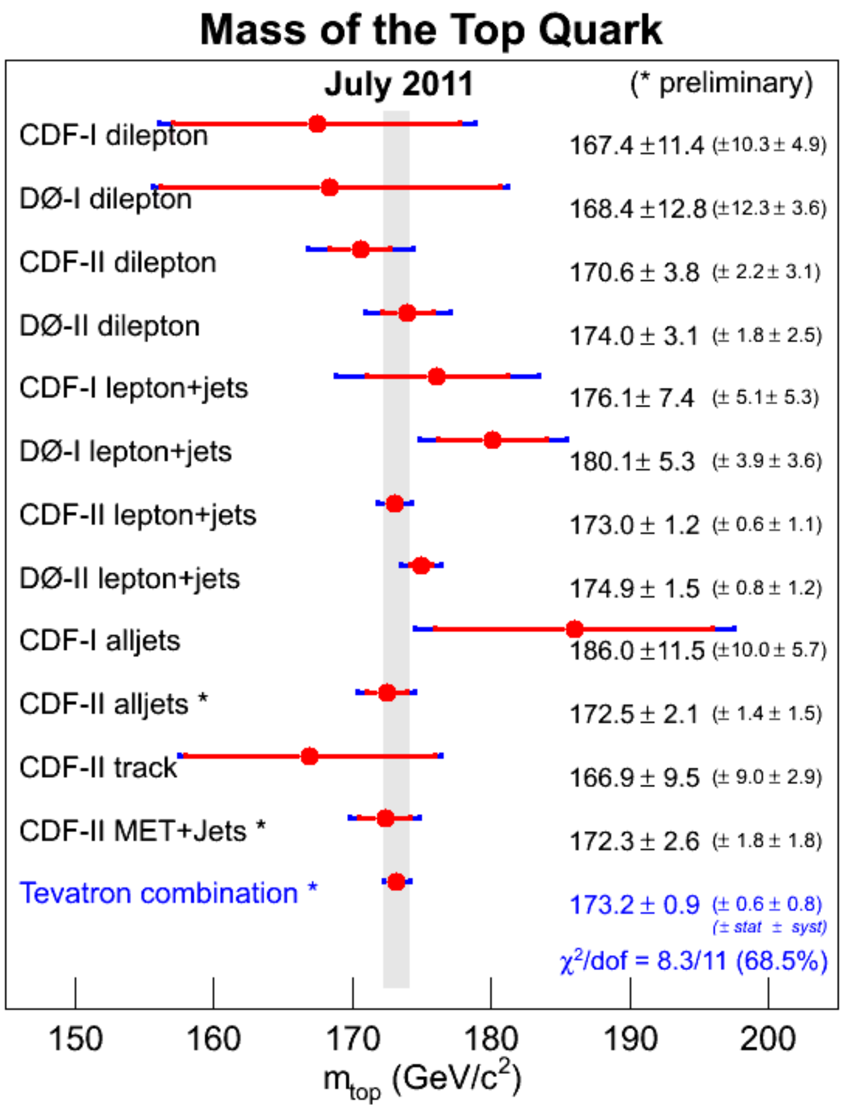
Tevatron measurement

m_{top} = 173.2 ± 0.9 GeV/c^2 (0.5%)

Global EWK fit:

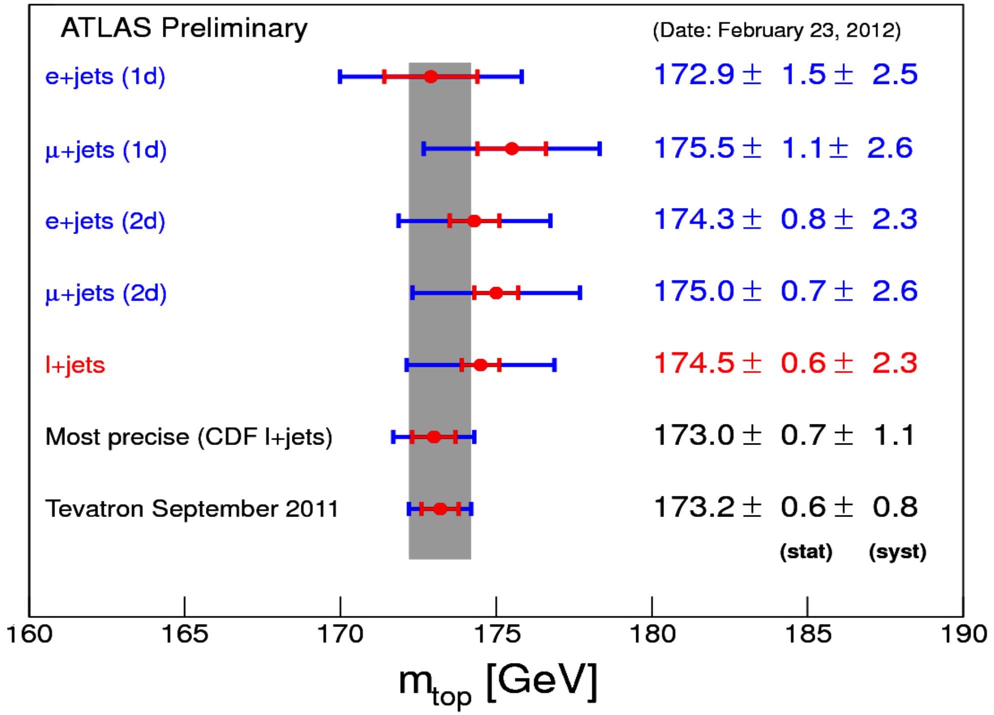
- $M_H = 92^{+34}_{-26}$GeV, or M_H<161GeV
- direct searches: M_H>115.5 GeV, M_H<127 GeV

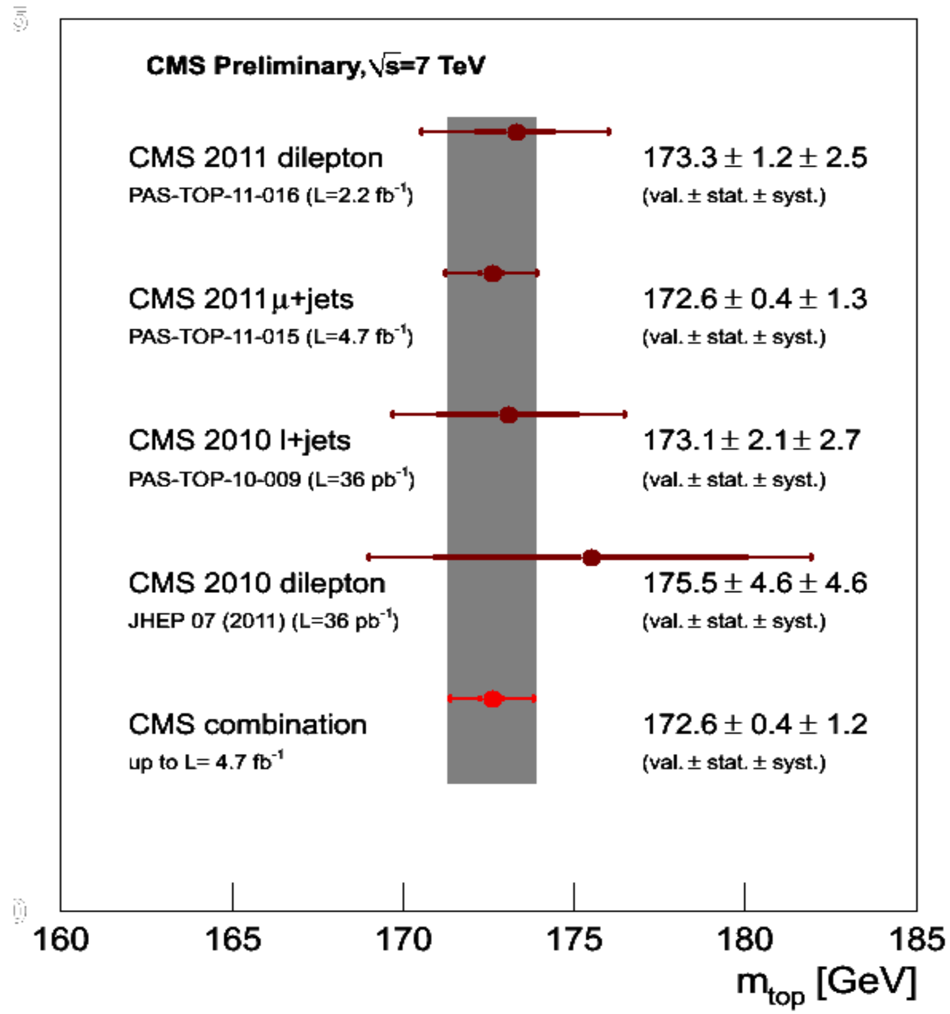
⇨ fit suggests SM Higgs is light



Top quark mass at the LHC

- Measurement of the top quark mass tests the understanding of the detector calibration
- Measurements at the LHC will improve the world's average



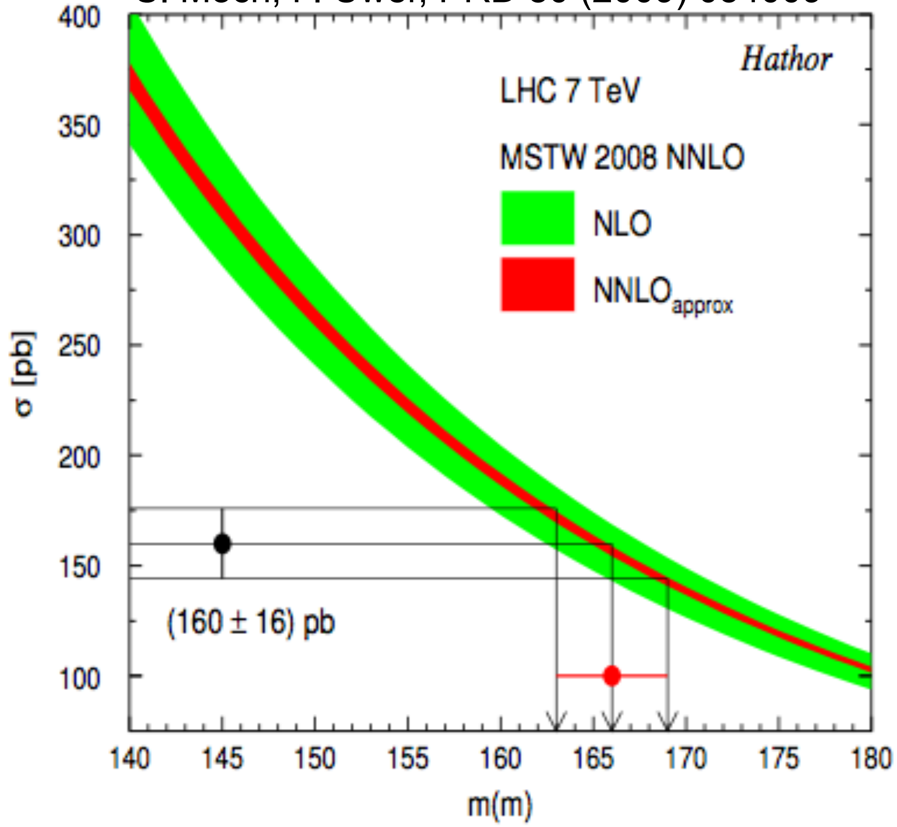


Top mass from cross section

- Direct m_{top} measurements rely on details of kinematics, reconstruction, calibration
- Experimental measurement has small uncertainty: ~0.5%
- What mass is measured?
  - Could be interpreted as pole mass

- Compare theory prediction (measured) cross section vs pole mass (=m_{top})
- Exploit relation of cross section and mass:
  - $\Delta\sigma/\sigma = -A \cdot \Delta m/m$ (A=4-5)

S. Moch, P. Uwer, PRD 80 (2009) 054009



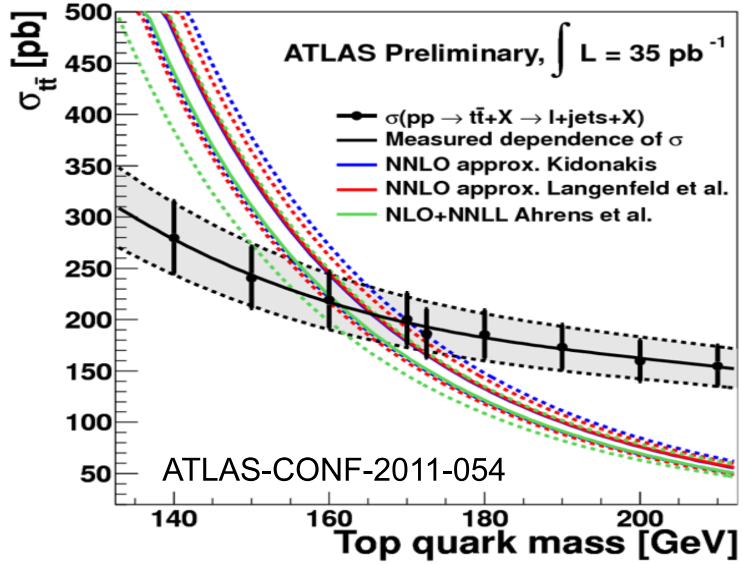
Top mass from cross section

- determine top quark pole mass using the experimental ttbar production cross section
  - from lepton+jets channel (ATLAS) with 35/pb

$$m_{\text{top}}^{\text{pole}} = (166.4\,^{+7.8}_{-7.3})\ \text{GeV}$$

  - from dilepton cross section (CMS) with 1.1/fb

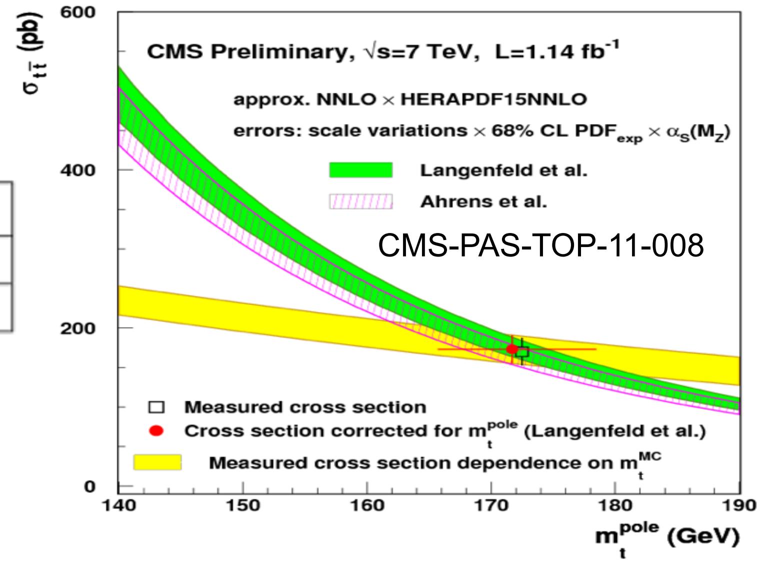
$$m_t^{pole} = 170.3^{+7.3}_{-6.7}\,\text{GeV}$$



Also determine m(MSbar):

Approx. NNLO × HERAPDF15NNLO	m_t^{pole} / GeV	$m_t^{\overline{\text{MS}}}$ / GeV
Langenfeld et al. [7]	$171.7^{+6.8}_{-6.0}$	$164.3^{+6.5}_{-5.7}$
Ahrens et al. [9]	$169.1^{+6.7}_{-5.9}$	$161.0^{+6.8}_{-6.1}$

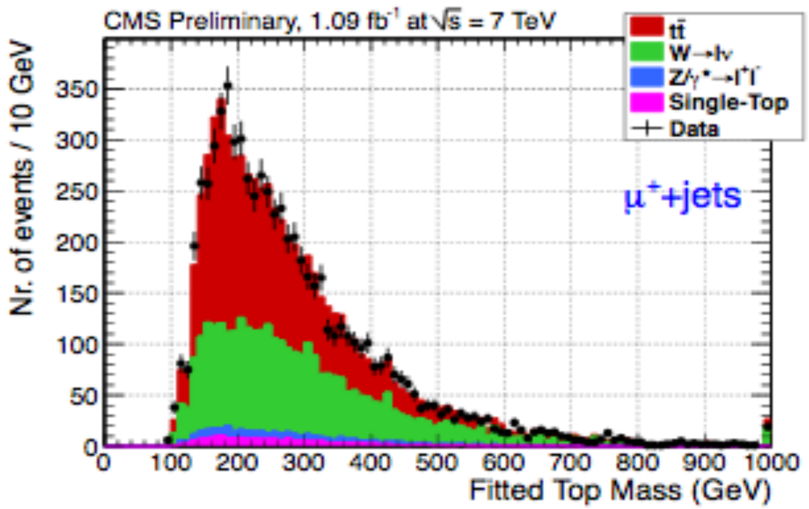
CMS-PAS-TOP-11-008

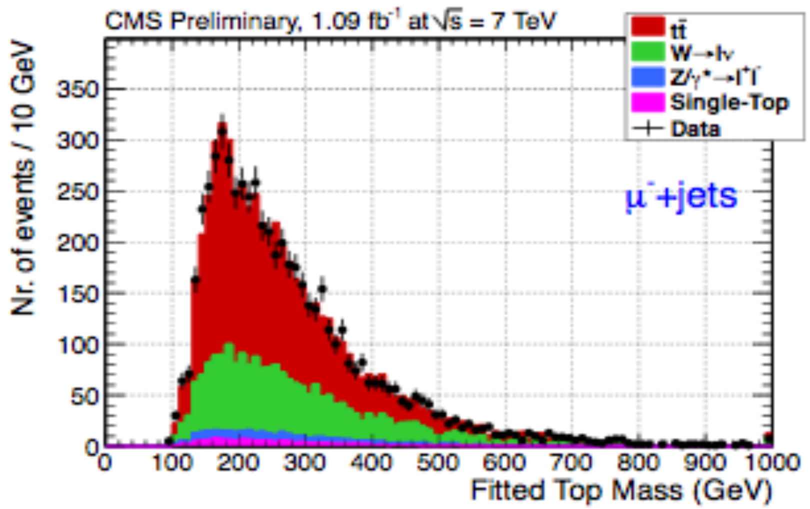


Top-antiTop mass difference

- Test of CPT invariance: particle and anti-particle have same mass
  - If masses are different →CPT violation
  - Top quark is unique because it decays before hadronizing
- use μ+jet ttbar events: positive/negative muons (L=1.1/fb)
  - Compare mass measured from μ^+/μ^- +jets
  - Use hadronic side
- Measure mass in both samples (ideogram method)

CMS-PAS-TOP-11-019





$$\Delta m_t^{\mathrm{measured}} = -1.20 \pm 1.21\ (\mathrm{stat}) \pm 0.47\ (\mathrm{syst})\ \mathrm{GeV}$$

Most precise top quark mass difference (statistically limited)

Top quark decays and taus

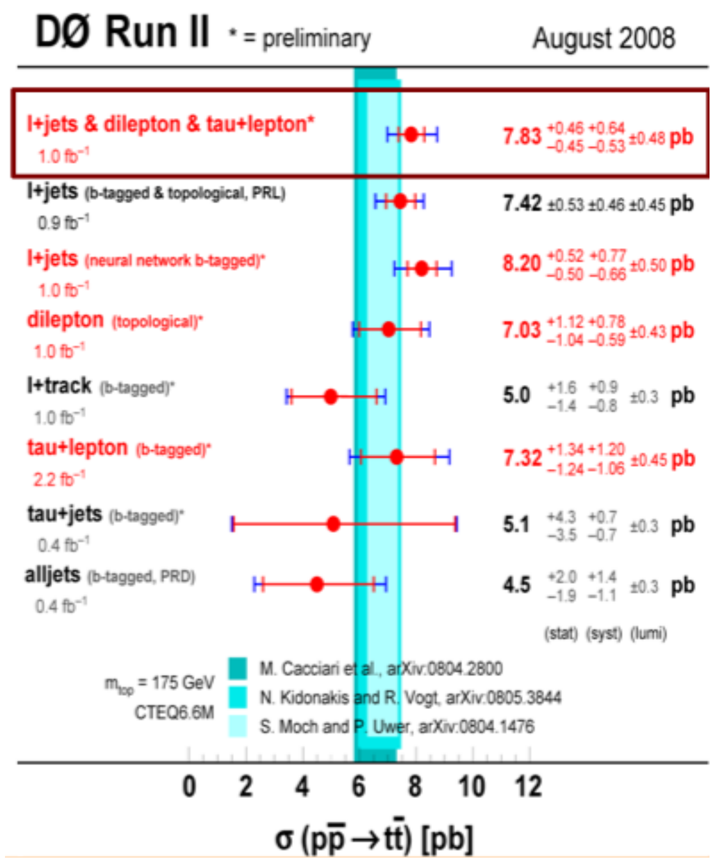
Taus in top quark decays

- Measurement of ttbar cross section with tau leptons in final state is important:
  - channel not well explored
  - Cross-check to other channels
  - increase acceptance of ttbar events
  - involves only 3rd generation leptons/quarks
  - probe non-standard physics ($t \to H^{\pm}b$, …)

Channel	Signature	BR
Dilepton(e/μ)	*ee*,μμ,*e*μ + 2*b*-jets	4/81
Single lepton	*e*,μ + jets + 2*b*-jets	24/81
All-hadronic	jets + 2*b*-jets	36/81
Tau dilepton	*e*τ, μτ +2 *b*-jets	4/81
Tau+jets	τ + jets + 2*b*-jets	12/81

Taus in top quark decays

- Measure: R= $\dfrac{BR(tt\rightarrow l\tau\nu\nu jj)}{BR(tt\rightarrow ll\nu\nu jj)}$ (l=e,μ)

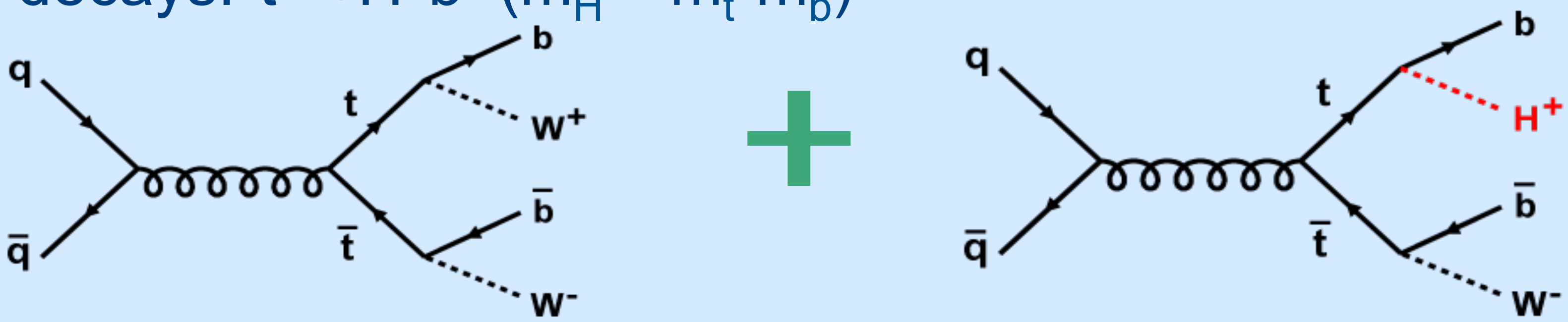


- Advantages:
  - increase statistics
  - cross-check to other BRs
- Disadvantages:
  - small statistics/larger background
  - Tau ID is not easy

Charged Higgs

- Tau dilepton channel is of particular interest as existence of charged Higgs can give rise to **anomalous** tau lepton production

If top decays: $t \rightarrow H^{+}b$ $(m_H < m_t - m_b)$



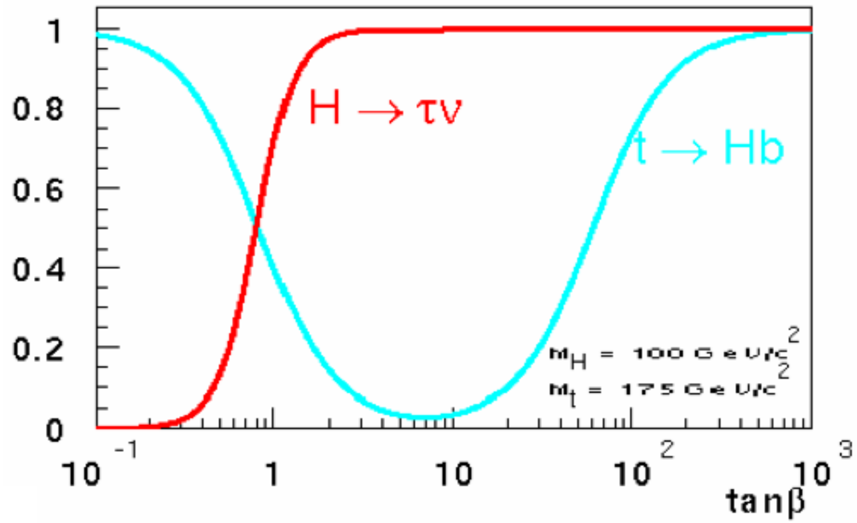
⇨directly observable in this channel

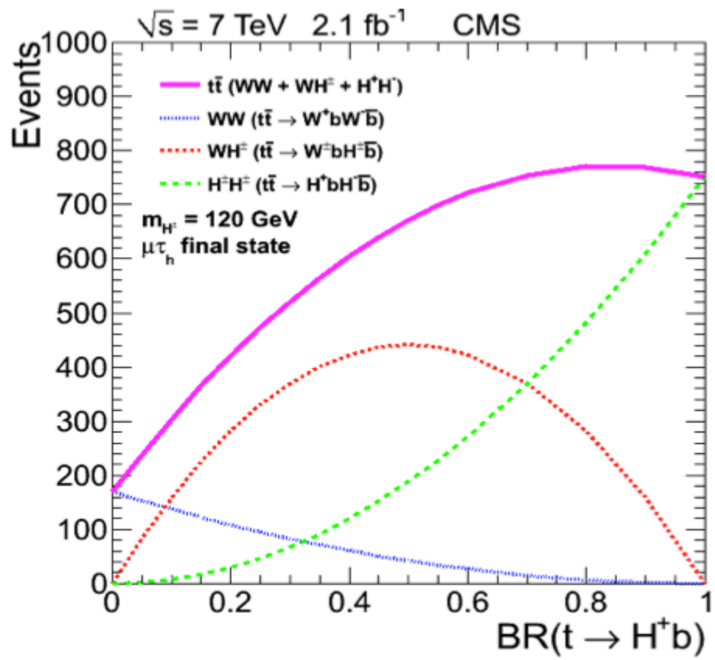
Charged Higgs

- BR($t \to H^+ b$) could be large
- $H^+ \to t^+ \nu_\tau$ enhanced if tanβ large

⇨observe more taus

(tanβ: ratio of vacuum expectation values)





⇨number of tau dilepton events can be large

Measuring ratios

- Except for the case of a very large signal significance (i.e. resonance), signal will be marginal
- Need to reduce uncertainties
- Discovery will go through systematic uncertainties
  - Always unexpected problems, unknowns
- Goal is to minimize the source of syst uncertainties and increase robustness of result
- Using ratios, or shapes, moving cuts, compare to similar analyses
- In the ratio, systematics are due to shapes, p_T dependence and not to overall scale

Measuring ratios

- Tau dilepton analysis is useful check on tau efficiency and can be sensitive to non-SM physics

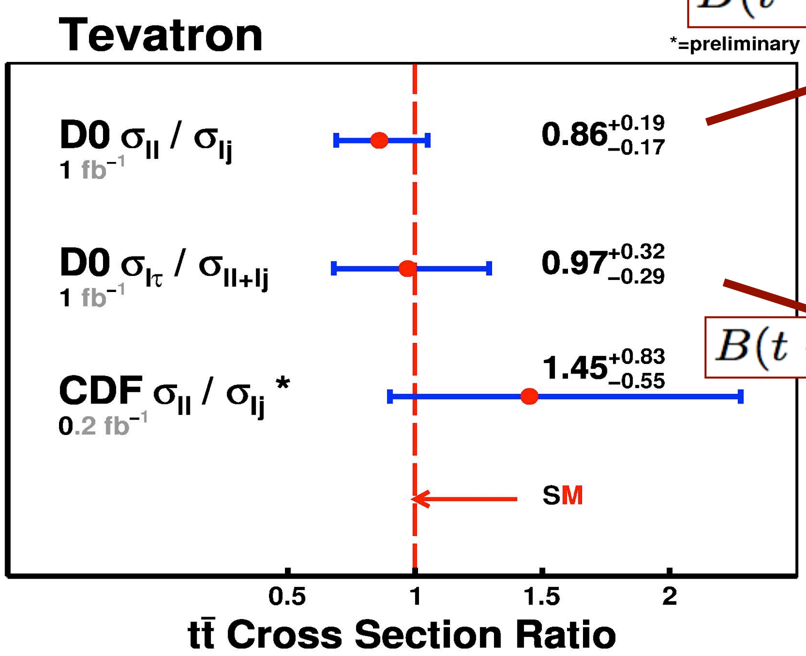
- Key is to understand relative efficiency of l/τ
- All other systematic cancel out (i.e. ISR/FSR, lumi, etc.)
- If discrepancy is found, case is more convincing

Cross section ratios

arXiv:0903.5525

Many systematic unc. cancel in the ratio
Study of cross section ratios
⇨sensitive to BSM

1. BR(l+jets)/BR(ll)
2. BR(l+tau)/BR(ll)

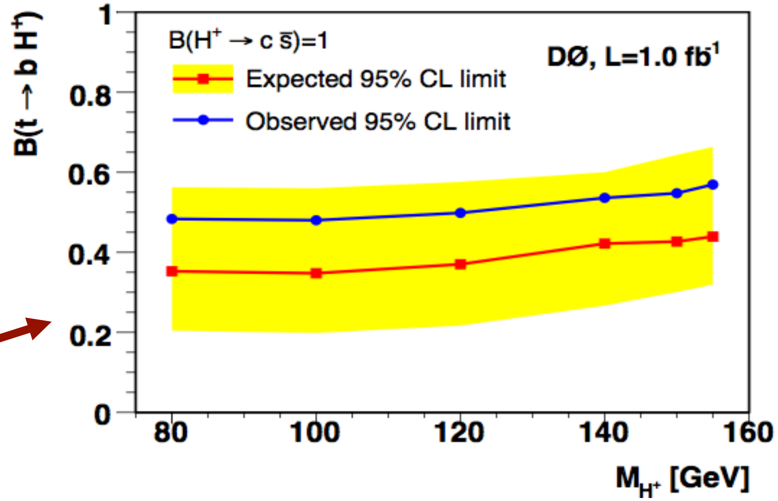


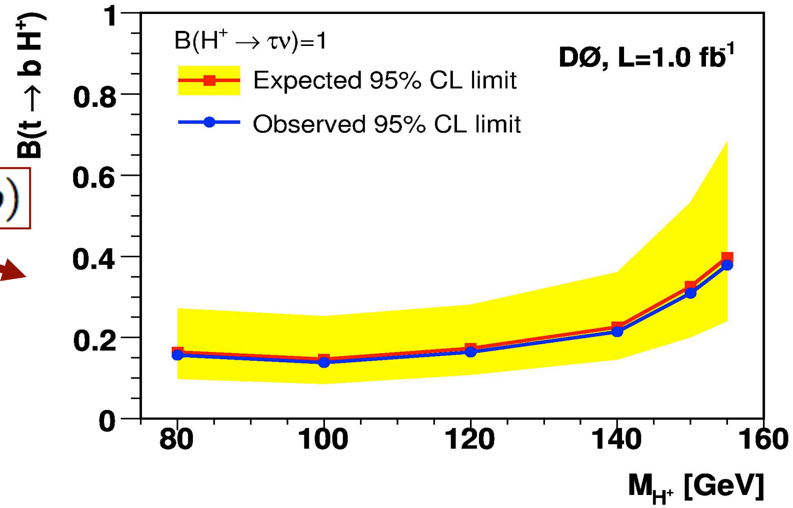
$B(t \to H^+ b \to c\bar{s}b)$

lept.+jets

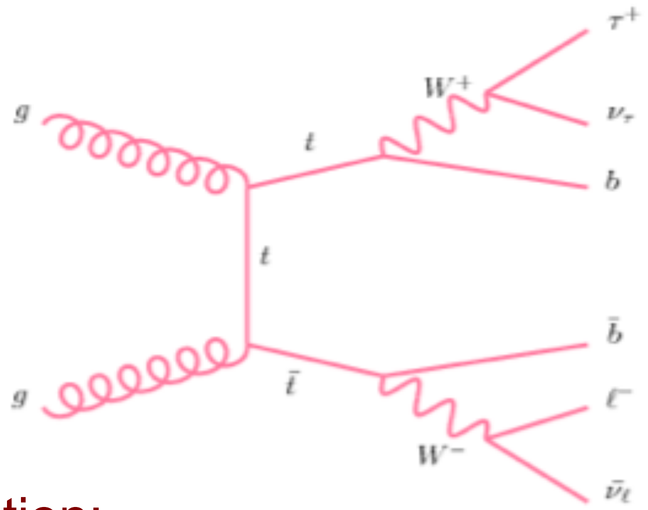
$B(t \to H^+ b \to \tau^+ \nu b)$

tau leptons

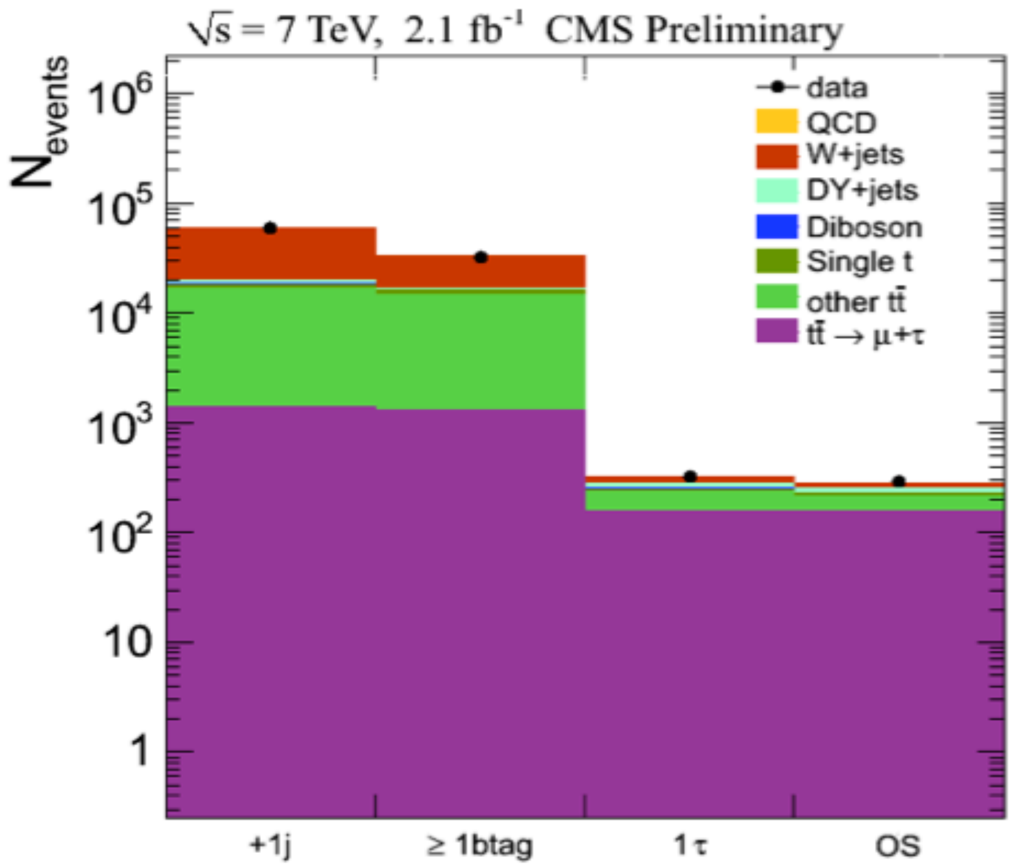




Taus in top quark decays



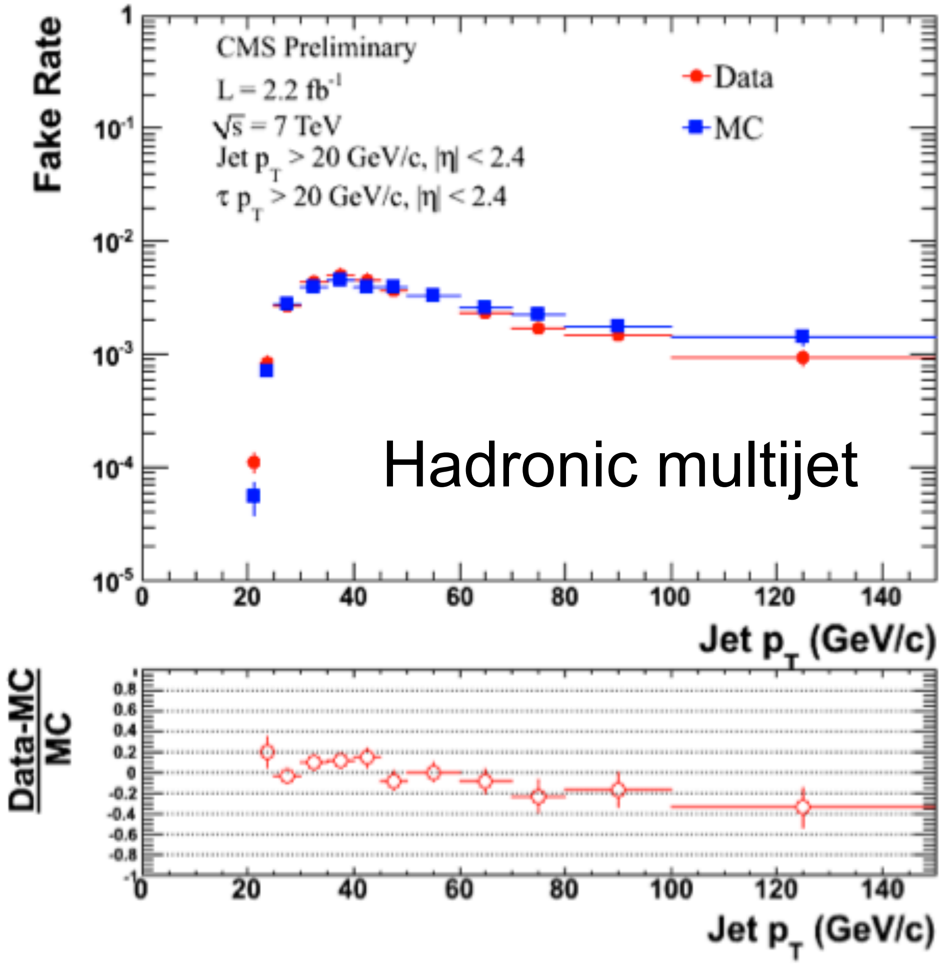
- Selection:
  - one isolated lepton (e/μ)
  - OS tau
  - at least two jets (one b-tagged)
  - MET>30 (45) GeV
- Determine τ fakes from data
  - Expected to be dominated by quark/gluon jets
  - Conservative approach: average W+jets and QCD



Tau fake rate

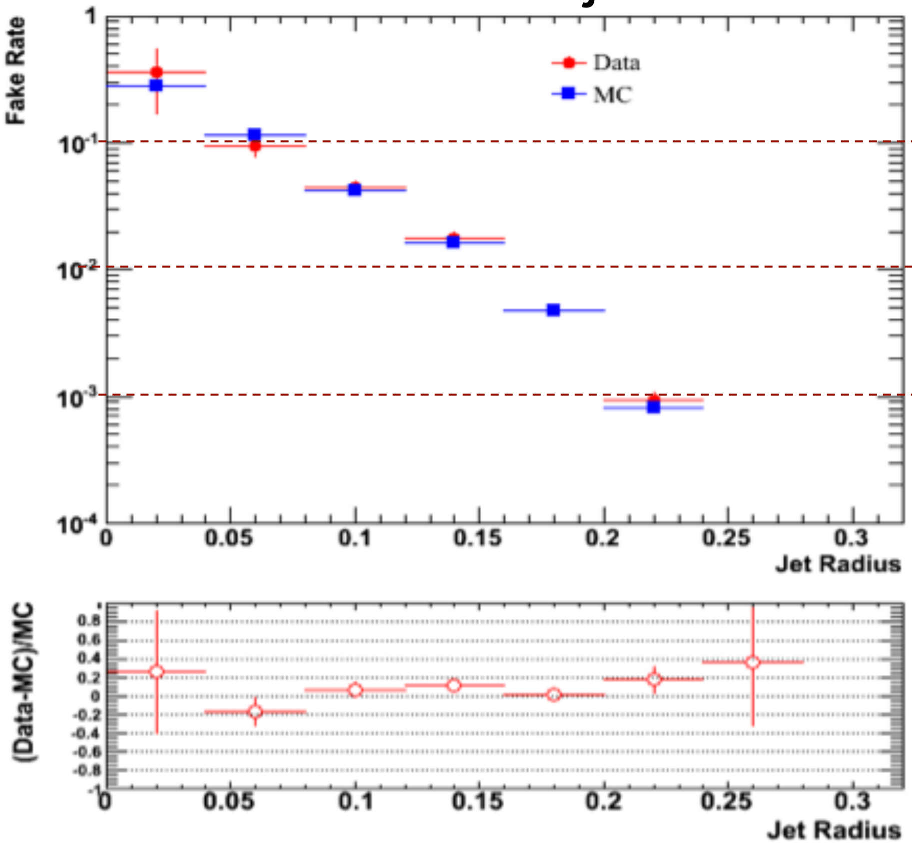
- Main background from "fake" tau jets
- Background estimated from data:
  - Select jets in events with:

    1 lepton+MET+≥3 jets (one jet is b-tagged)
  - Apply to every jet the "jet→tau probability (p_T, η, jet witdth)"
  - tau fake probability evaluated from data
- Estimate "fake" rate in different samples and take average

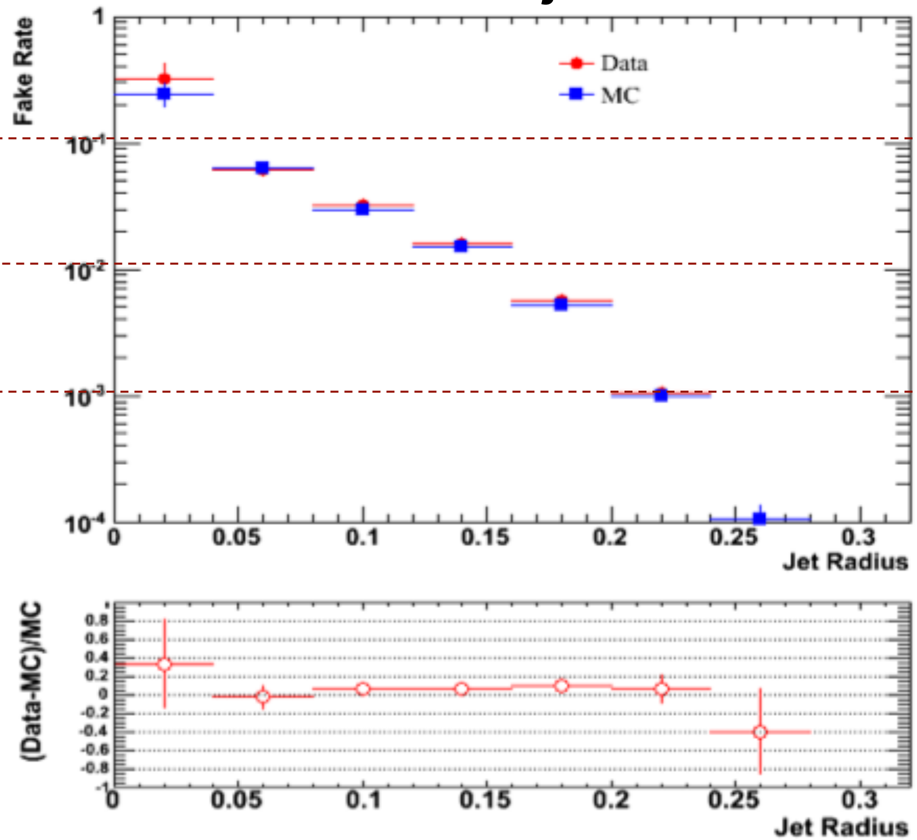


Fake rate vs jet width

QCD multijets



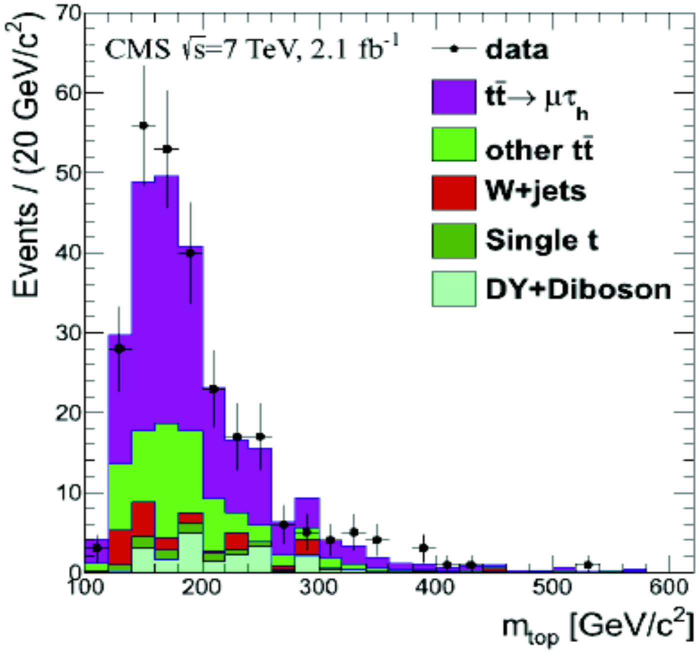
W+≥1 jet

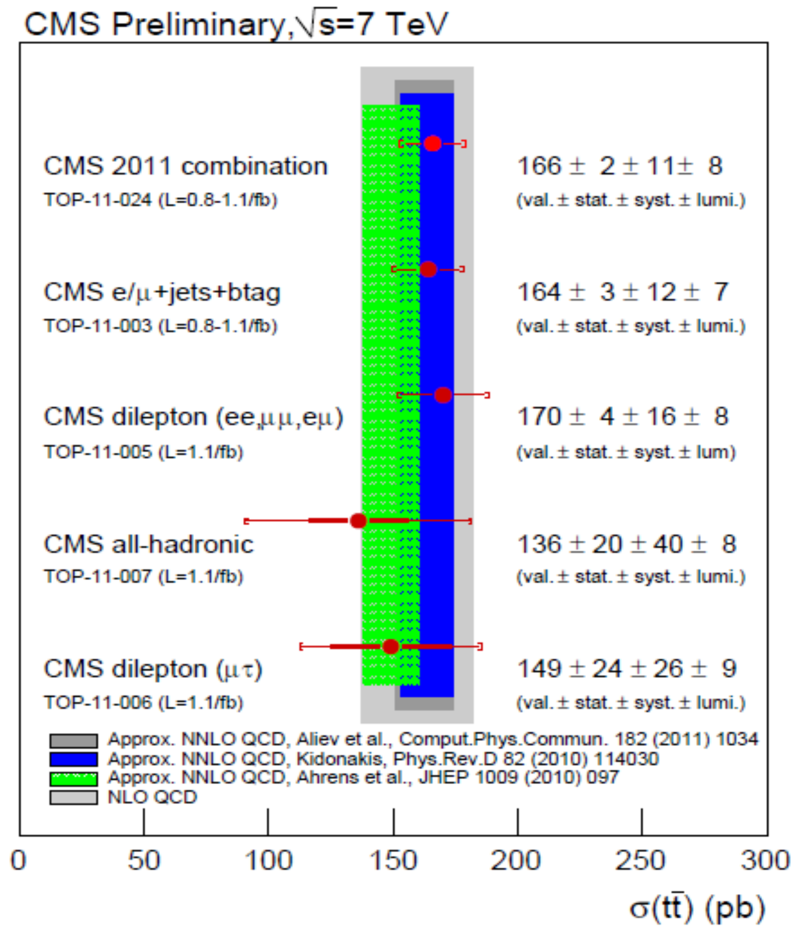


Quark jets (narrower) vs gluon jets (“fatter”)

Tau dilepton channel

Reconstruct mass in ttbar events with taus





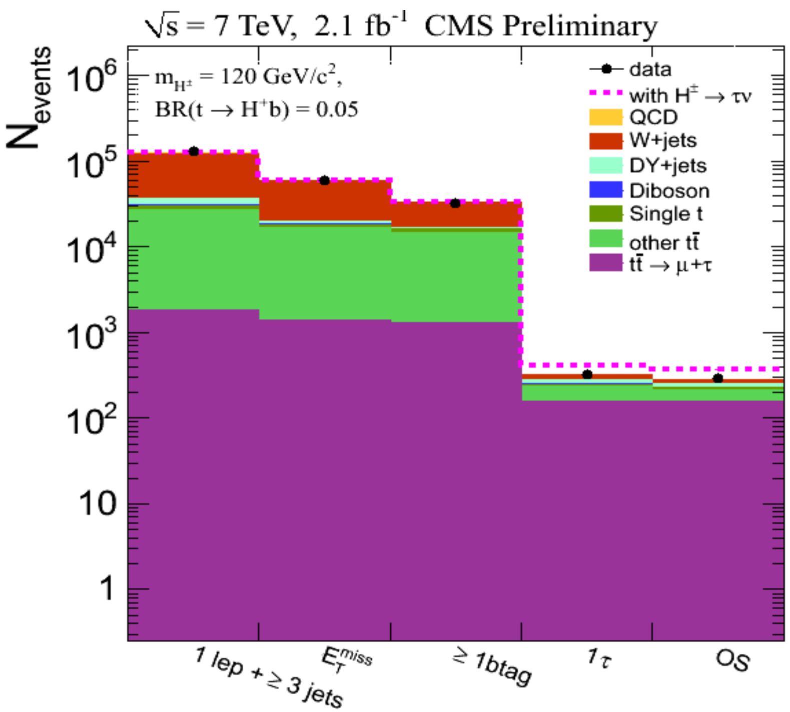
Good agreement between measurements and predictions (for all decay modes)

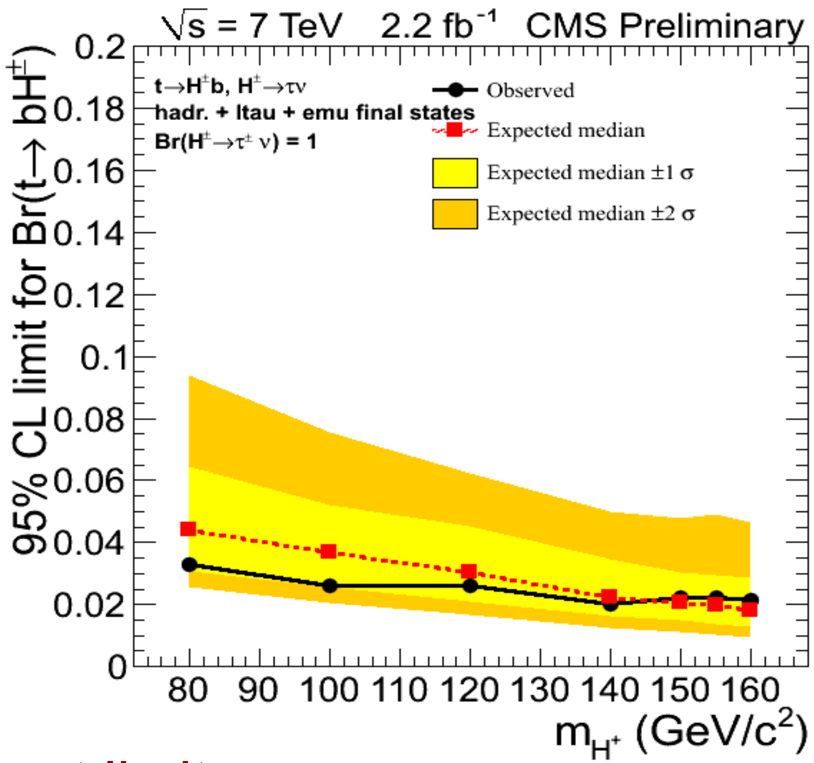
CONF-2011-119 $142 \pm 21\ (\text{stat.}) \pm^{20}_{16}\ (\text{syst.}) \pm 5\ (\text{lumi.})\ \text{pb}$ ATLAS

TOP-11-006 $\sigma_{t\bar{t}} = 151 \pm 15(\text{stat.}) \pm 23(\text{syst.}) \pm 7(\text{lumi.})\ \text{pb}$ CMS

Is there a charged Higgs?

- If anomalous tau production in ttbar decays there may be contribution from charged Higgs decays





Yields in agreement with expectations ⇒ set limits

$80 < m_{H^+} < 160$ GeV. $BR(t \to H^+ b) < 2-3\%$

CMS HIG-11-019

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