Top quark mass measurements in ATLAS

Teresa Barillari, MPP Munich

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Introduction

- The top-quark mass, m_{top}, is a fundamental parameter of the Standard Model (SM)
- Precise determinations of the SM parameters allow to challenge consistency tests of the SM and to look for signs of new physics beyond the SM (BSM)
- Plots show experimental results for: (left) the W mass (m_{W}) and top-quark pole mass ($m_{\mathrm{top}}^{\mathrm{pole}}$) with 1σ uncertainties in comparison with the SM and the MSSM prediction; (central) ellipses for the 1σ uncertainties in the mass of the Higgs, m_{H}, $m_{\mathrm{top}}^{\mathrm{pole}}$ plane confronted with the SM vacuum expectations; (right) ATLAS results on cross-section measurements compared and in agreement with the SM predictions

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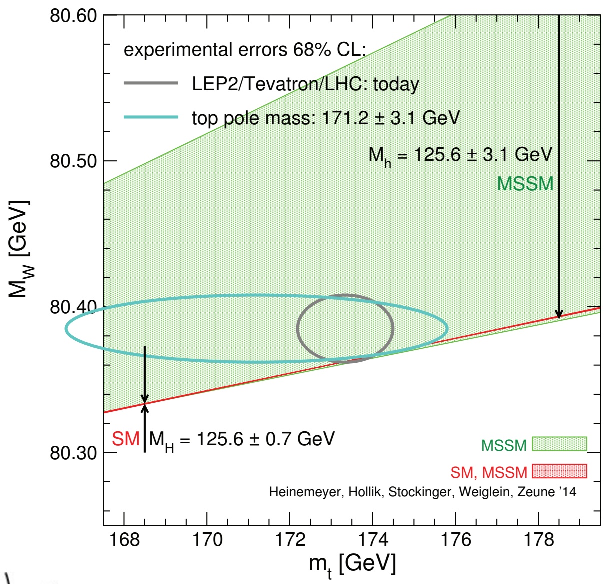
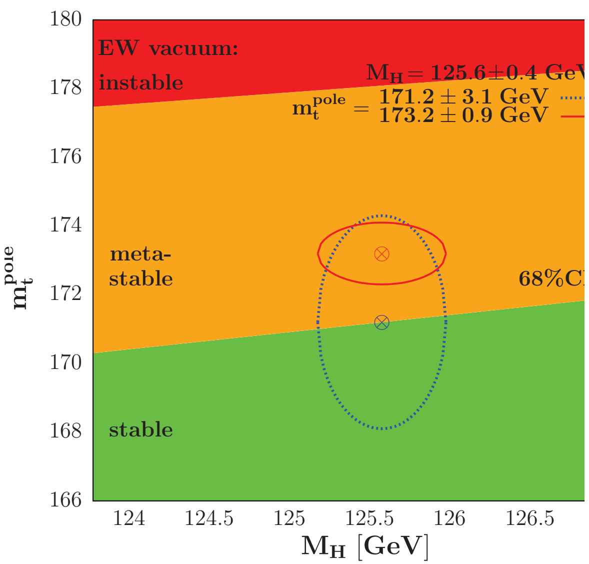
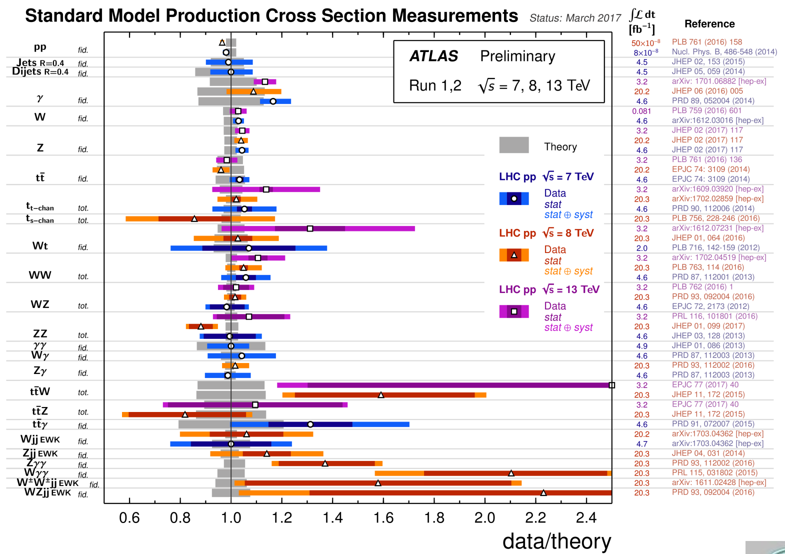
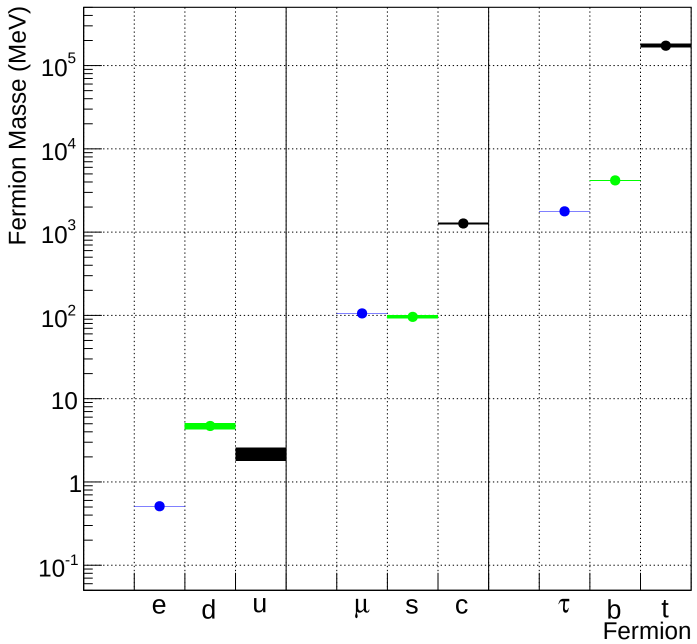


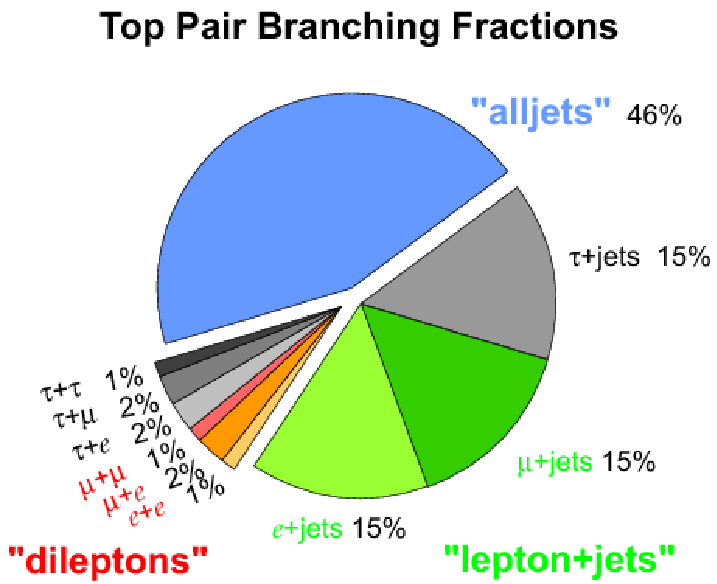




Top quark production

- The top quark is the heaviest known elementary particle, $m_{\rm top} \approx 173\,\mathrm{GeV}$ (left top plot)
- It decays before hadronization (lifetime $\tau =\sim 5\mathrm{x}10^{-25}\,\mathrm{s}$)
- Main top decay: $\mathrm{t} \rightarrow \mathrm{Wb}$
- The final states for the leading $\mathrm{t\bar{t}}$-production process can be divided in three classes:
  - All-jets (46.2%): $\mathrm{t\bar{t} \rightarrow W^{+}bW^{-}\bar{b} \rightarrow q\bar{q}'bq''\bar{q}'''\bar{b}}$
  - Lepton+jets (43.5%): $\mathrm{t\bar{t} \rightarrow W^{+}bW^{-}\bar{b} \rightarrow q\bar{q}'bl\bar{\nu}_l\bar{b} + \bar{l}\nu_l bq\bar{q}'\bar{b}}$
  - Dilepton (10.3%): $\mathrm{t\bar{t} \rightarrow W^{+}bW^{-}\bar{b} \rightarrow \bar{l}\nu_l bl'\bar{\nu}_{l'}\bar{b}}$





Top Quark Mass Measurements

- Different definitions of m_{top}:
  - The top-quark Monte Carlo (MC) mass, $m_{\mathrm{top}}^{\mathrm{MC}}$, parameter measured from comparison to MC events with top-quark decay products
  - The top-quark pole mass, $m_{\mathrm{top}}^{\mathrm{pole}}$ parameter, is the classic rest mass that enters the top propagator
  - The running top-quark mass, $\overline{MS}$ mass, parameter defined in a low-scale short distance scheme
- Typical $m_{\mathrm{top}}^{\mathrm{MC}}$ or just m_{top} analyses reconstruct top quark candidates in data and MC often using kinematic fits and likelihood fits based on templates, in one (m_{top}) or more (JES, bJES) parameters
- Though $m_{\mathrm{top}} \neq m_{\mathrm{top}}^{\mathrm{pole}}$
- "The uncertainty on the translation from the m_{top}^{MC} definition to a theoretically well defined short distance mass definition at low scale is currently estimated to be of the order of 1 GeV" arxiv:1405.4781, arXiv:1408.6080, Nucl. Phys. Proc. Suppl. 185 (2008):220-226
- Cross-section based methods measure a theoretically well defined mass e.g. the $m_{\mathrm{top}}^{\mathrm{pole}}$, though with not competitive precision $\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} \sim 5\% \rightarrow \Delta m_{\mathrm{top}}/m_{\mathrm{top}} \sim 1\%$
- In the following the latest m_{top} and $m_{\mathrm{top}}^{\mathrm{pole}}$ ATLAS results will be presented

Dilepton top-quark mass at 8 TeV

- $m_{\rm top}$ measurement from dilepton channel
- Events preselection:
  - Exactly two oppositely charged central leptons (ℓ)
  - In the same-lepton-flavor channels an $E_T^{Miss} > 60\,\mathrm{GeV}$ is required, with an invariant mass of the lepton pair $m_{\ell\ell} > 15\,\mathrm{GeV}$
  - In the $e\,\mu$ channel the scalar sum of p_T of the two ℓ and all jets is required to be $> 130\,\mathrm{GeV}$
  - Two jets with $p_T > 25\,\mathrm{GeV}$ and $|\eta| < 2.5$, one of this is a b-tagged jet
- Keep events with two b-tagged jets and two ℓ
- The combination with the lowest average invariant mass of the two ℓ-b-jet pairs, $m_{\ell b}^{\rm reco}$, with $30\,\mathrm{GeV} < m_{\ell b}^{\rm reco} < 170\,\mathrm{GeV}$ is retained
- A cut on the average p_T of the two ℓ-b-jet pairs $p_{T\ell b} > 120\,\mathrm{GeV}$ is applied to optimize the final $m_{\rm top}$ uncertainty

$$t\bar{t} \to W^{+}bW^{-}\bar{b} \to \ell^{\pm}\ell^{\pm}\nu\bar{\nu}b\bar{b}$$

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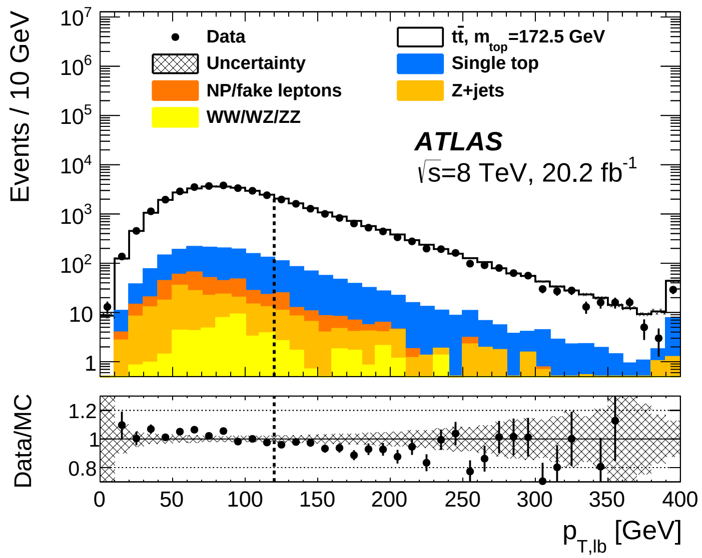

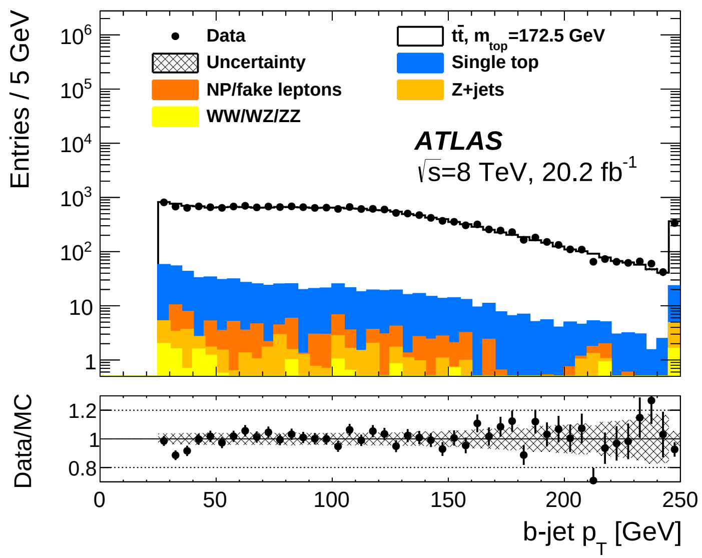

Dilepton top-quark mass measurement at 8 TeV

$t\bar{t} \rightarrow W^{+}bW^{-}\bar{b} \rightarrow \ell^{\pm}\ell^{\pm}\nu\bar{\nu}b\bar{b}$

- The analysis uses a template fit to $m_{\ell b}^{\text{reco}}$
- An unbinned likelihood maximisation gives the m_{top} value that best describes the data
- $m_{\text{top}} = 172.99 \pm 0.41\,(stat.) \pm 0.72\,(syst.)\,\text{GeV}$
- Biggest systematic uncertainties come from jet energy scale (JES) and relative b-to-light-jet energy scale (bJES)
- Result $\sim 40\%$ more precise that m_{top} measured @ 7 TeV
- It is the the most precise single result in this decay channel to date
- Combining this result with the ATLAS m_{top} measurements in the $t\bar{t} \rightarrow$ lepton + jets and $t\bar{t} \rightarrow$ dilepton channel @ 7 TeV, gives: $m_{\text{top}} = 172.84 \pm 0.34\,(stat.) \pm 0.61\,(syst.)\,\text{GeV}$
- The result is limited by the calibration of the JES and by the MC modeling of signal events

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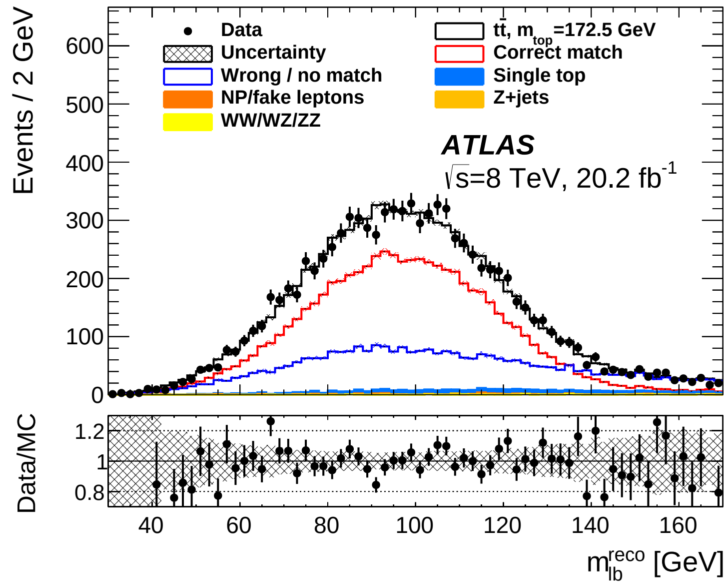
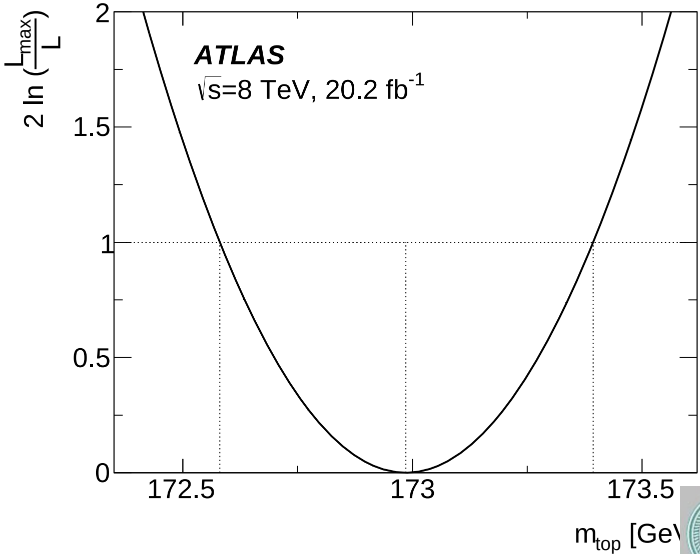


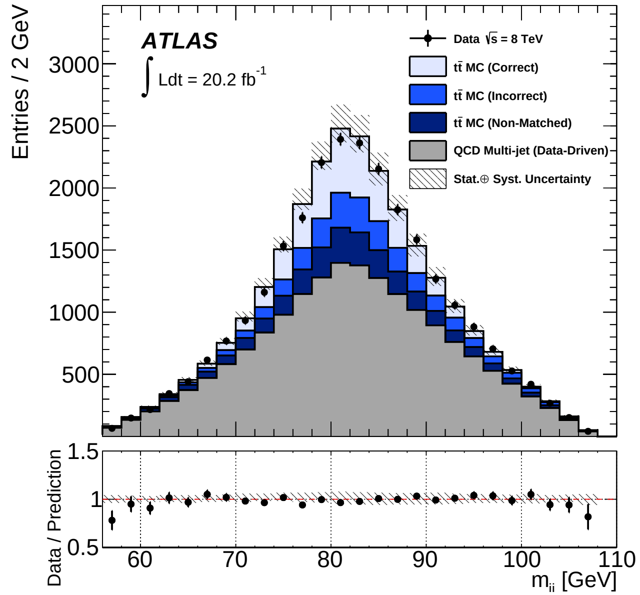


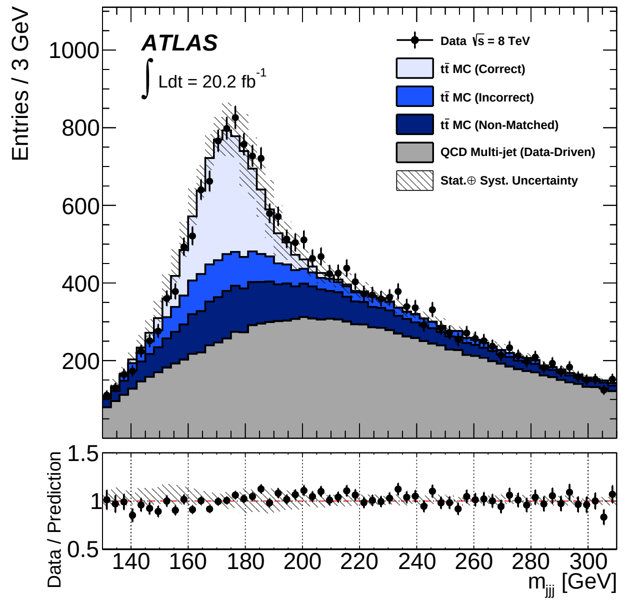
All-jets top-quark mass at 8 TeV

$t\bar{t} \rightarrow W^{+}bW^{-}\bar{b} \rightarrow q\bar{q}'bq''\bar{q}'''\bar{b}$

arXiv:1702.07546

- m_{top} measurement from all-jets channel is challenging because of the large multi-jets background arising from various QCD processes
- Events selection:
  - No leptons $\geq$ jets with $p_T > 60\,\text{GeV}$ and $|\eta| < 2.5$, two of them b-tagged
  - Small $E_T^{Miss} < 60\,\text{GeV}$
  - Topological cuts applied to reduce background: large distance of b-tagged jets; small distance of W, b pairs from best kinematic solution
- The jet assignment is accomplished by χ^2 fit to the $t\bar{t}$ system,
- A data-driven method is used to determine the large multi-jets background with regions defined by number of b-tags and proximity of W,b pairs



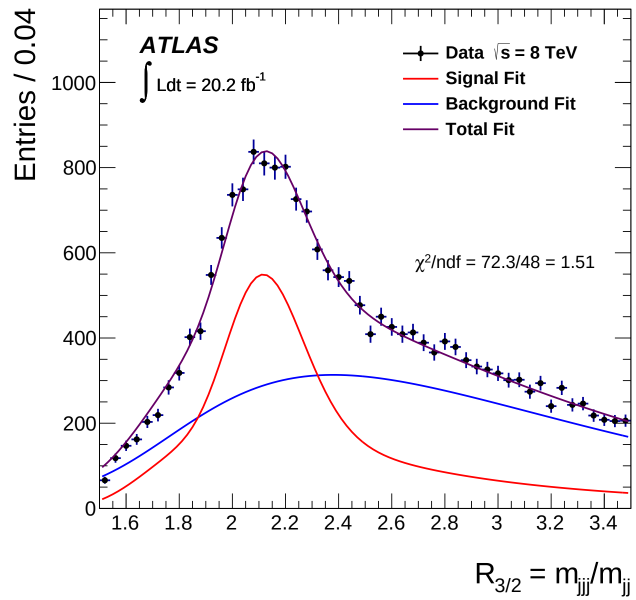


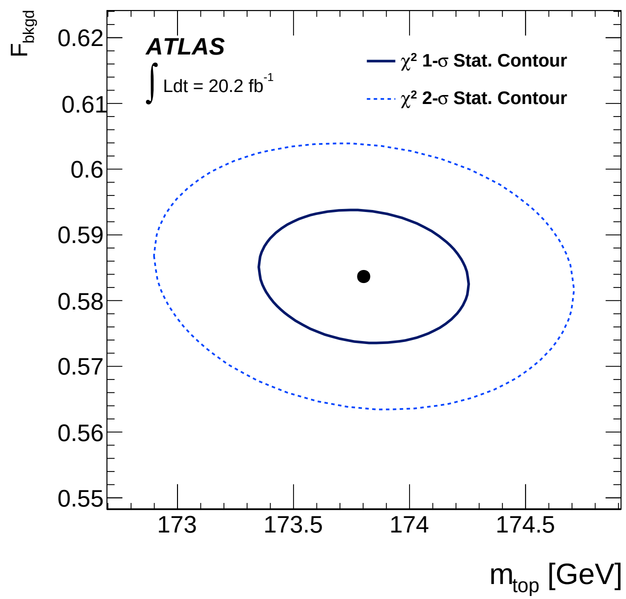
All-jets top-quark mass measurement at 8 TeV

$t\bar{t} \to W^+ b W^- \bar{b} \to \ell^\pm \ell^\pm \nu \bar{\nu} b \bar{b}$

arXiv:1702.07546

- The m_{top} measurement is extracted by using a template fit to the ratio of the three-jet to the dijet mass, $R_{3/2}$, with a binned minimum-χ^2 approach
- $m_{top} = 173.72 \pm 0.55\,(stat.) \pm 1.01\,(syst.)\,\mathrm{GeV}$
- Biggest systematic uncertainties come from JES, hadronisation modeling, and bJES
- This measurement agrees with the previous Tevatron and LHC m_{top} measurements
- Result $\sim 40\%$ more precise that m_{top} measured @ 7 TeV





Top-quark Pole Mass Measurements: Dilepton 7 & 8 TeV

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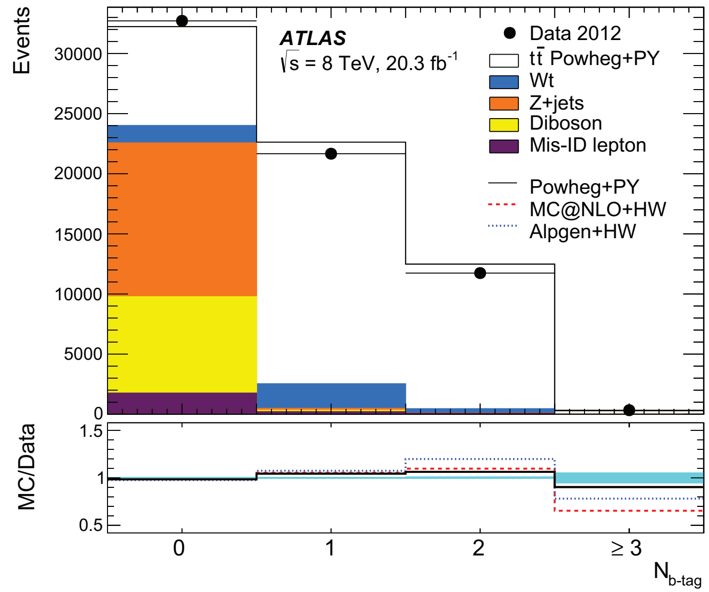

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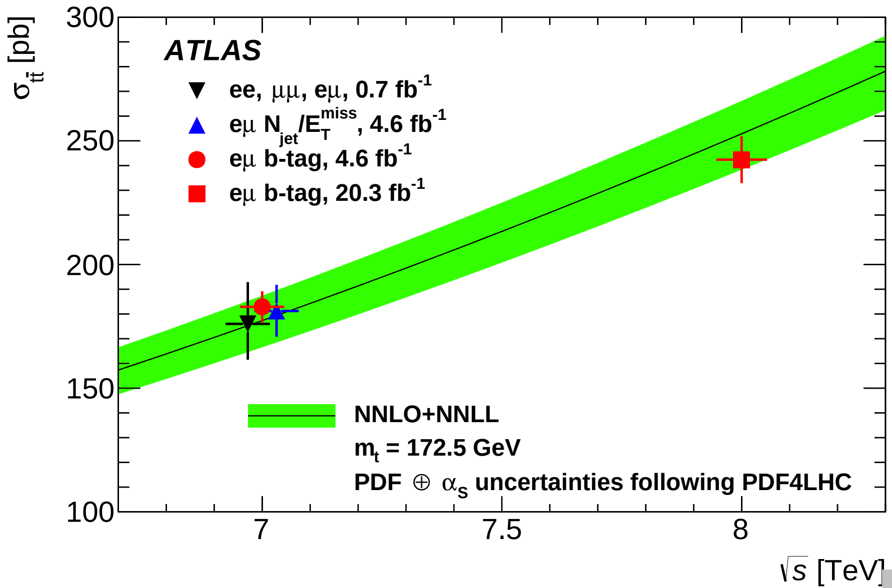

- m_{top}^{pole} measurement from total cross-section in the dilepton channel @ 7 and 8 TeV
- Production $\sigma_{t\bar{t}}$ measurement performed using $t\bar{t}$ events with opposite-charge $e\mu$ pair in the final state and exactly one or two b-tagged jets
- Main background: *Wt*
- $\sigma_{t\bar{t}} = 182.9 \pm 7.1$ pb (7 TeV)
- $\sigma_{t\bar{t}} = 242.4 \pm 10.3$ pb (8 TeV)

Top-quark Pole Mass Measurements: Dilepton 7 & 8 TeV

- Extraction of m_{top}^{pole} using a Bayesian likelihood approach, assumed $m_{top} = 172.5\,\mathrm{GeV}$
- Used different PDF + α_s sets
- Results obtained using PDF4LHC show small dependency of $\sigma_{t\bar{t}}$ on the assumed value of m_t arising from variations in the acceptance and Wt background
- $m_{top}^{pole} = 171.4 \pm 2.6\,\mathrm{GeV}$ ($7\,\mathrm{TeV}$)
- $m_{top}^{pole} = 174.1 \pm 2.6\,\mathrm{GeV}$ ($8\,\mathrm{TeV}$)
- Combining 7 and 8 TeV measurements: $m_{top}^{pole} = 172.9^{+2.5}_{-2.6}\,\mathrm{GeV}$
- Results compatible with m_{top} extracted using different techniques
- m_{top}^{pole} from diff. cross-section $t\bar{t} + 1$jet events at $7\,\mathrm{TeV}$ (arXiv:1507.01769v1) $m_{top}^{pole} = 173.7 \pm 1.5(stat.) \pm 1.4(syst.)^{+1.0}_{-0.5}(theory)\,\mathrm{GeV}$

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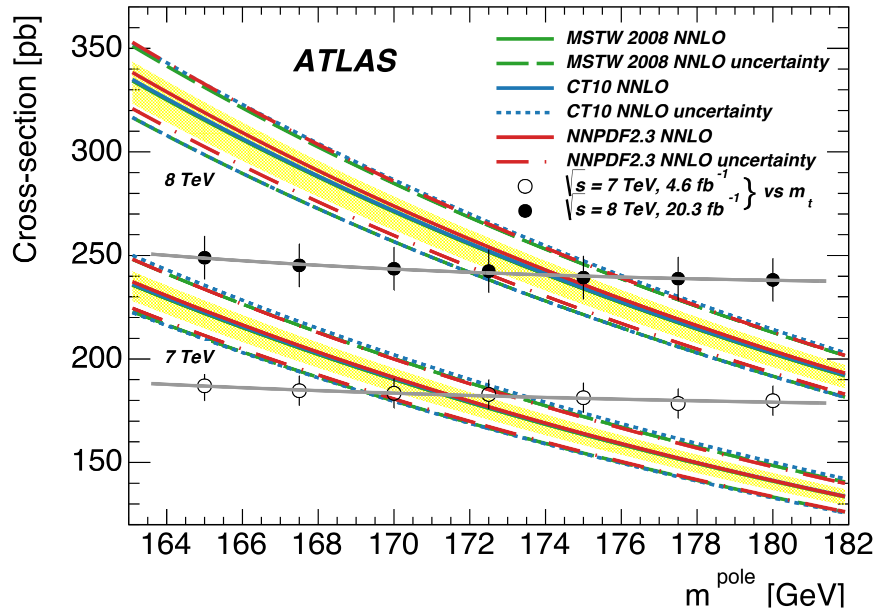
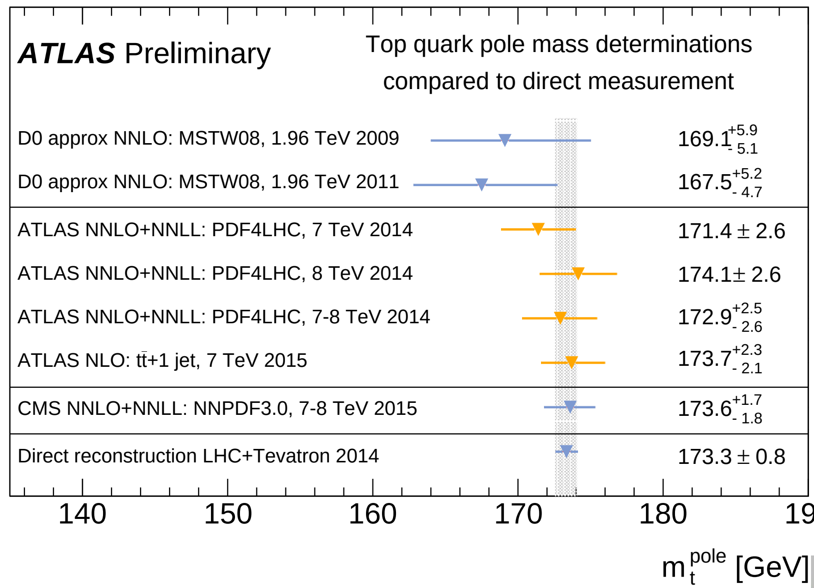
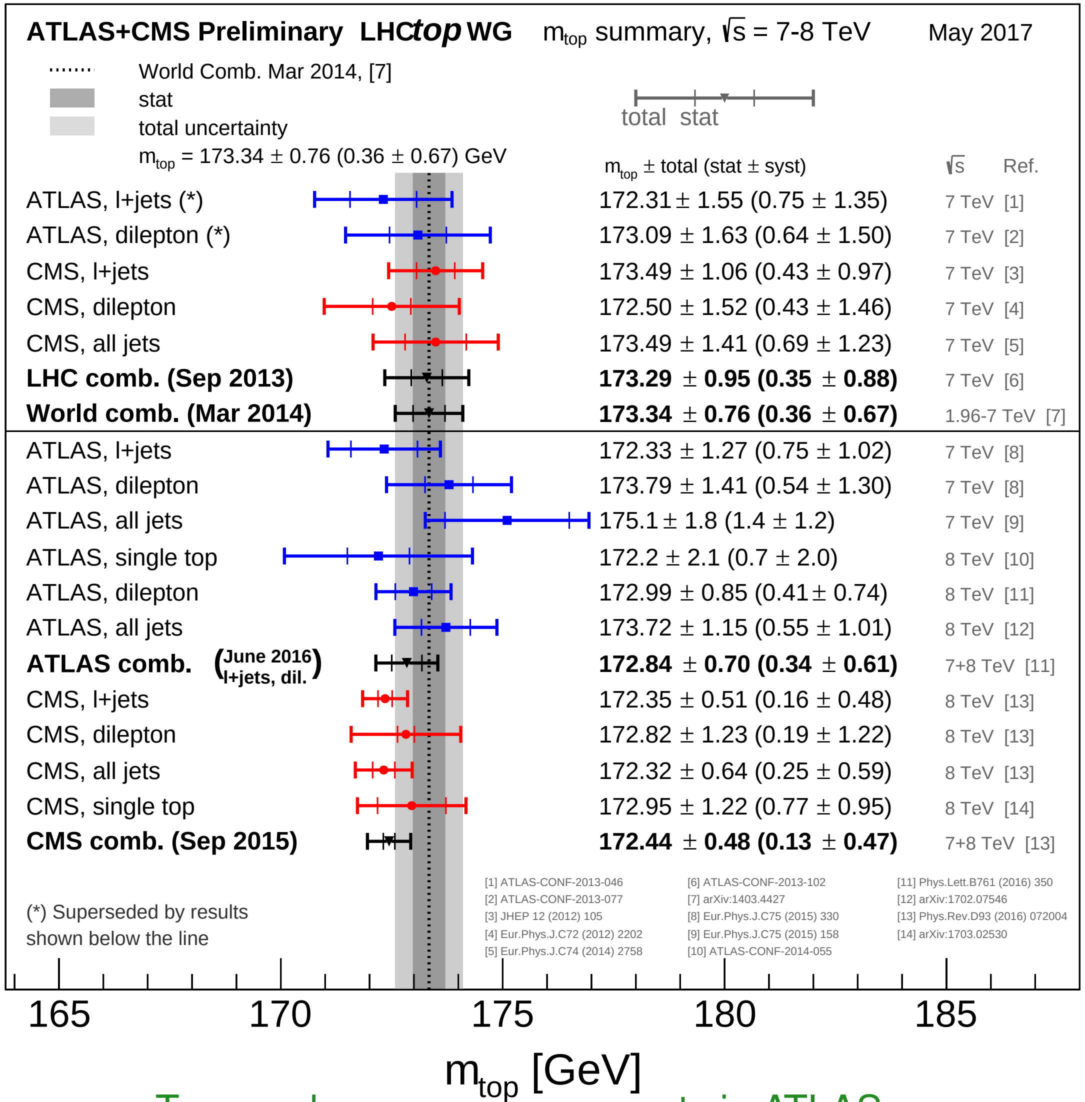




Summary direct m_{top} measurements

- Figure shows the latest results, and the previous results that are now superseded. The results are compared with the ATLAS, CMS, Tevatron and Tevatron+LHC m_{top} combinations



Conclusions

- Precise measurements of m_{top} are fundamental to provide inputs to test the self-consistency of the SM and search physics BSM
- Presented latest results of m_{top} and $m_{\text{top}}^{\text{pole}}$ measurements performed by the ATLAS experiments using Run1 data at LHC:
  $m_{\text{top}}^{\text{pole}} = 172.9^{+2.5}_{-2.6}\,\text{GeV}$
- Most precise m_{top} measurement in the dilepton channel
  $m_{\text{top}} = 172.99 \pm 0.41\,(stat.) \pm 0.72\,(syst.)\,\text{GeV}$
- Most recent m_{top} measurement in the all-jets channel
  $m_{\text{top}} = 173.72 \pm 0.55\,(stat.) \pm 1.01\,(syst.)\,\text{GeV}$
- m_{top} measurements dominated by systematic uncertainties
- Combining the dilepton m_{top} result @ $8\,\text{TeV}$ with the m_{top} measurements in the $t\bar{t} \rightarrow \text{lepton} + \text{jets}$ and $t\bar{t} \rightarrow \text{dilepton}$ channel @ $7\,\text{TeV}$:
  $m_{\text{top}} = 172.84 \pm 0.34\,(stat.) \pm 0.61\,(syst.)\,\text{GeV}$
- More analyses are undergoing
- We will continue looking at more interesting measurements done using Run2 data at LHC with the challenge to bring the systematics uncertainties down