Measurement of the top-quark mass in the $t\bar{t} \rightarrow$ dilepton channel with a template method, using the full Run 2 dataset in ATLAS

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On behalf of the ATLAS collaboration

Importance of the top-quark mass and goal

- The top-quark mass m_{top} plays an important role in the test of the consistency of the Standard Model (SM):

  e.g: **Direct measurement** vs **indirect determination** of m_{top} and M_W

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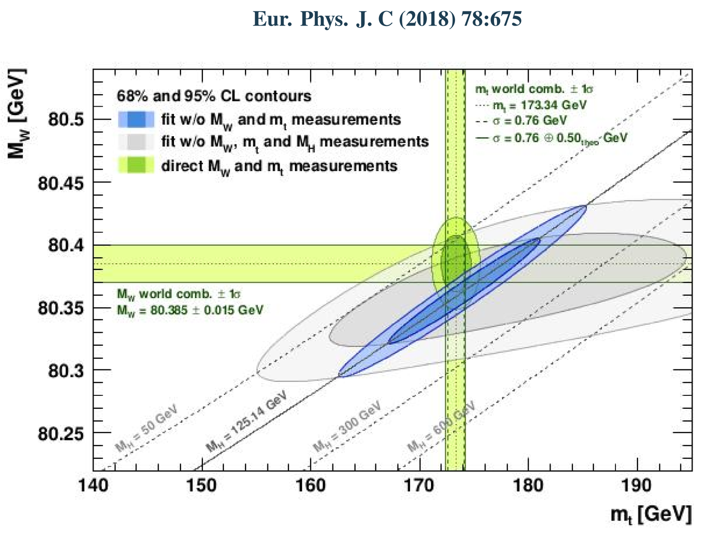


- Previous ATLAS result: top-quark mass measurement using template method at 8 TeV in the $t\bar{t} \rightarrow$ dilepton channel [1]

$$m_{\text{top}} = 172.99 \pm 0.41(stat.) \pm 0.74(syst.) \text{ GeV}$$

↪ estimator: $m^{reco}_{\ell b} = min\{\frac{m_{\ell_1,b_1}+m_{\ell_2,b_2}}{2}, \frac{m_{\ell_1,b_2}+m_{\ell_2,b_1}}{2}\}$

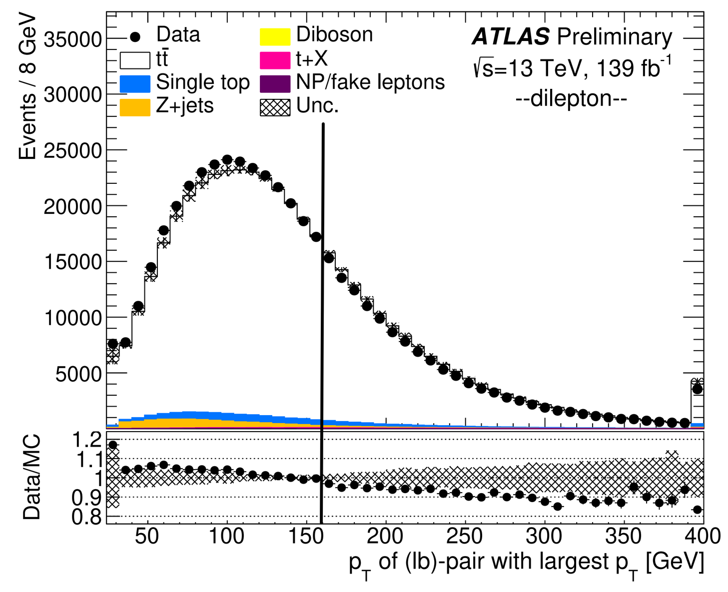
↪ removing events with low $p_{T,\ell b}$ reduces modelling and jet energy scale (JES) uncertainties

- Aim: perform a measurement of m_{top} in the $t\bar{t} \rightarrow$ dilepton channel with a template method, using the full Run 2 dataset collected with the ATLAS detector

Event preselection

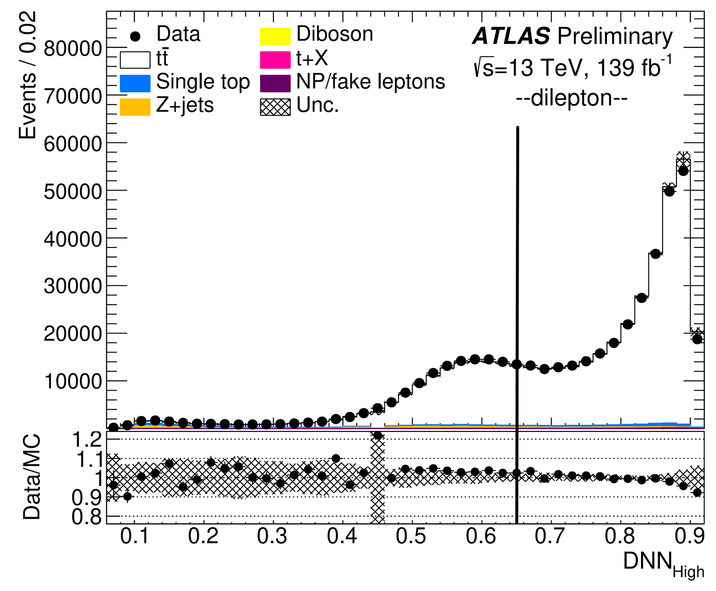
↪ Aimed at selecting the maximum amount of signal events, while minimising the contamination from background events:

- Two reconstructed leptons with opposite charge and with $p_T > 28$ GeV
- At least two reconstructed jets with $p_T > 25$ GeV, where exactly two of them must be b-tagged using the DL1r algorithm with the 70% working point
- For events with same-flavour leptons, $m_{\ell\ell} < 80$ GeV or $m_{\ell\ell} > 100$ GeV, and $m_{\ell\ell} > 15$ GeV



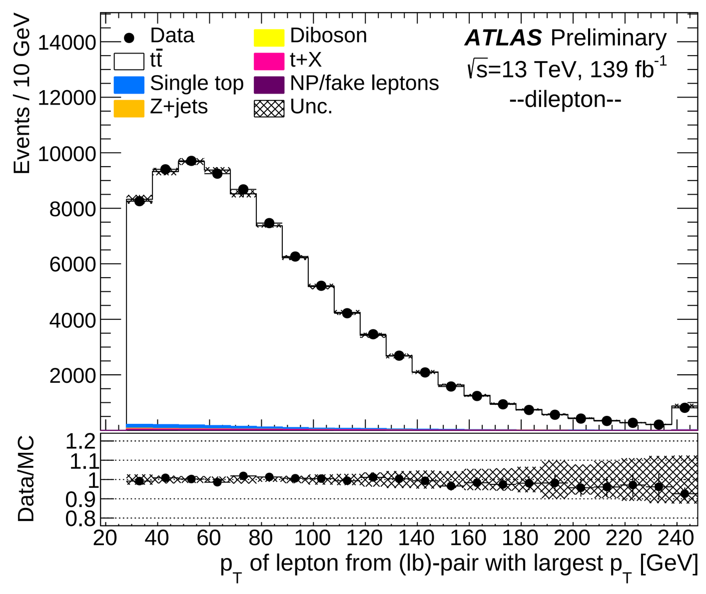
Event reconstruction

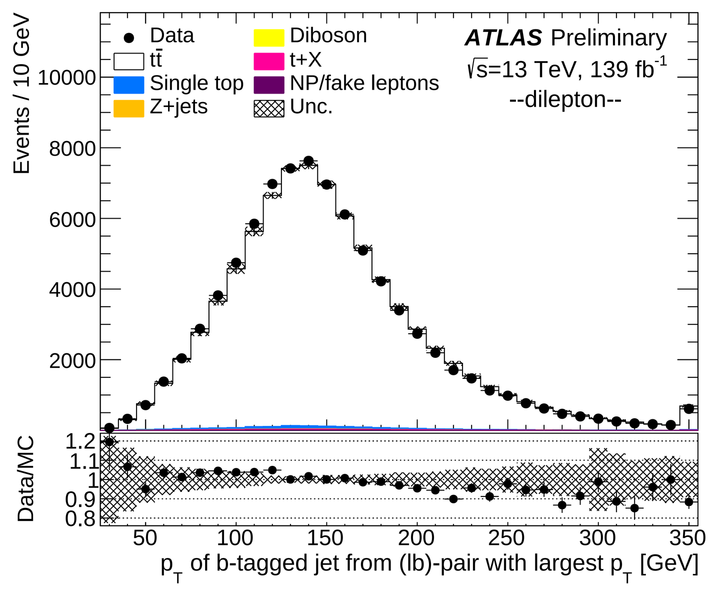
- Correct matching of **b-tagged jet with its corresponding charged lepton** is crucial to define an observable with a strong sensitivity to m_{top}
- Utilise a deep neural network (DNN) for this, which uses as input variables:
  - kinematic variables of the individual objects
  - kinematic variables and the invariant masses of all ℓb – pairs
- Chosen permutation: the one with the highest DNN value, labelled DNN_{High}
- DNN_{High} can be used to optimise the selection:
  - Correctly matched events have a large DNN_{High} value, compared to incorrectly matched and unmatched events
  - Monte Carlo (MC) prediction on DNN_{High} agrees to the data within uncertainty

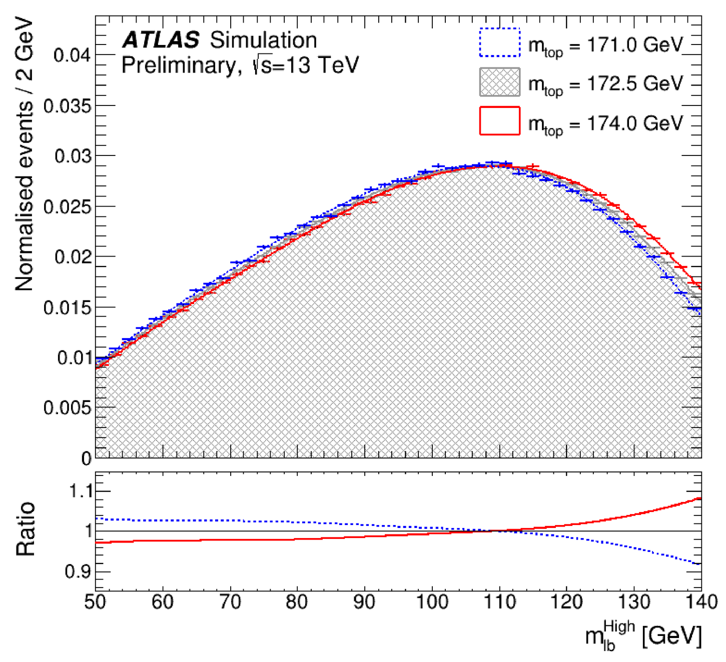


Analysis method: template method using unbinned maximum-likelihood fit

- Select ℓb – pair with the larger pair transverse momentum $p_{\text{T},\ell b}$
- Require:
  - $\text{DNN}_{\text{High}} > 0.65$
  - ℓb – pair transverse momentum $p_{\text{T},\ell b} > 160$ GeV
  - the selected ℓb – pair to contain the b-tagged jet with the higher p_T of the event







- Estimator: the value of $m^{\text{High}}_{\ell b}$ defined as the invariant mass of the ℓb – pair with the largest $p_{\text{T},\ell b}$ from the permutation with the highest DNN value
- Signal events: $t\bar{t}$ and single-top events

↪ Templates are generated using Powheg hvq interfaced with Pythia8. The diagram removal (DR) scheme is used to handle the interference between $t\bar{t}$ and tW.

↪ Parametrize the $m^{\text{High}}_{\ell b}$ templates from signal events by the sum of two Gaussian functions and a cosine function

- Background fraction after the final selection: 0.6%

Comparison of $t\bar{t}$ samples from the Powheg hvq and $bb4\ell$ generators

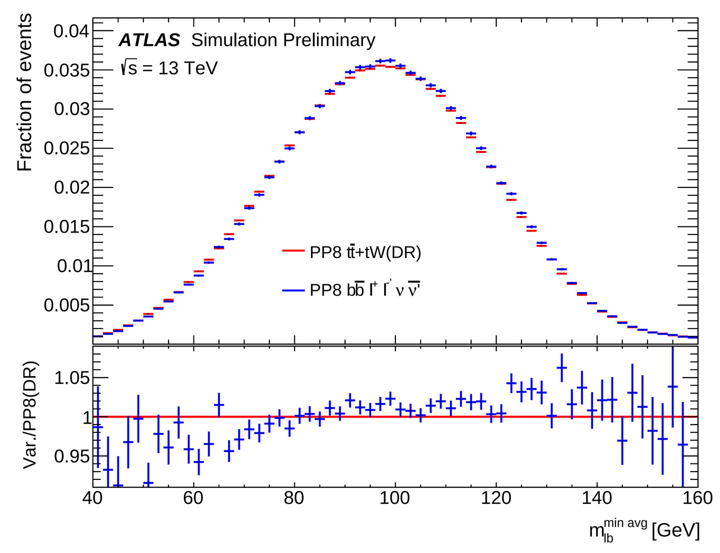
- Investigation of the differences in $m_{\ell b}$ distributions and their impact on the measured m_{top}
- $bb4\ell$ [2] denotes an MC generator for $pp \rightarrow \ell^+\nu\ell^{-\prime}\bar{\nu}^\prime b\bar{b}$ production which:
  - implements the interference between $t\bar{t}$ and tW
  - provides an exact NLO treatment of spin correlations and off-shell effects
  - can currently simulate only events with different-flavour leptons

  ↪ Events with same-flavour leptons are vetoed in this study
- Templates: build from Powheg hvq interfaced with Pythia8
  - $m^{\text{nominal}}_{\text{top}}$: the fitted m_{top} on pseudo-data simulated with the nominal generator
  - $m^{bb4\ell}_{\text{top}}$: the fitted m_{top} on pseudo-data simulated with $bb4\ell$
- Using the current analysis strategy:

$$m^{\text{nominal}}_{\text{top}} - m^{bb4\ell}_{\text{top}} = -0.23 \pm 0.14 \text{ GeV}$$

- Previous investigation documented in [3] using the same analysis strategy as in the m_{top} measurement at 8 TeV [1]:

$$m^{\text{nominal}}_{\text{top}} - m^{bb4\ell}_{\text{top}} = -0.36 \pm 0.08 \text{ GeV}$$



Uncertainty breakdown

	m_{top} [GeV]
Result	172.63
Statistics	0.20
Method	0.05 ± 0.04
Matrix-element matching	0.35 ± 0.07
Parton shower and hadronisation	0.08 ± 0.05
Initial- and final-state QCD radiation	0.20 ± 0.02
Underlying event	0.06 ± 0.10
Colour reconnection	0.29 ± 0.07
Parton distribution function	0.02 ± 0.00
Single top modelling	0.03 ± 0.01
Background normalisation	0.01 ± 0.02
Jet energy scale	0.38 ± 0.02
b-jet-energy scale	0.14 ± 0.02
Jet energy resolution	0.05 ± 0.02
Jet vertex tagging	0.01 ± 0.01
b-tagging	0.04 ± 0.01
Leptons	0.12 ± 0.02
Pile-up	0.06 ± 0.01
Recoil effect	0.37 ± 0.09
Total systematic uncertainty (without recoil)	0.67 ± 0.05
Total systematic uncertainty (with recoil)	0.77 ± 0.06
Total uncertainty (without recoil)	0.70 ± 0.05
Total uncertainty (with recoil)	0.79 ± 0.06

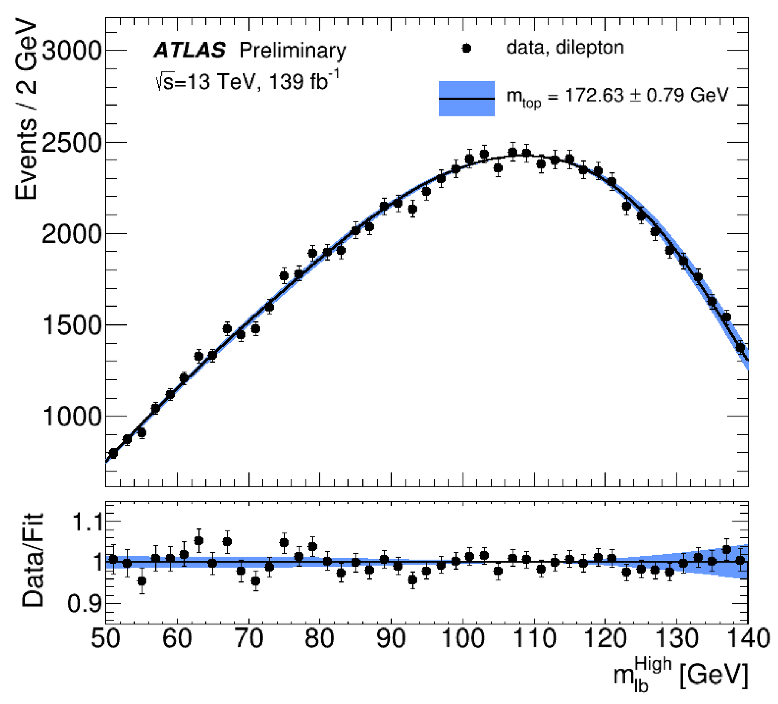
Result and Discussion

The measured top-quark mass is:

$$m_{\text{top}} = 172.63 \pm 0.20 \text{ (stat)} \pm 0.67 \text{ (syst)} \pm 0.37 \text{ (recoil) GeV}$$

- The systematic uncertainty is dominated by:
  - the modelling of the matrix-element to parton-shower matching
  - the jet energy scale
  - the modelling of colour reconnection
- Sizable uncertainty due to the modelling of recoil effects in the top-quark decay

↪ Same precision within statistical uncertainty with respect to the 8 TeV measurement in Ref.[1]



References

[1] Phys. Let. B 761 (2016)
[2] Eur. Phys. J. C 76, 691 (2016)
[3] ATL-PHYS-PUB-2021-042
[4] ATLAS-CONF-2022-058

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GRK 2044 Masse und Symmetrien nach der Entdeckung des Higgs-Teilchens am LHC