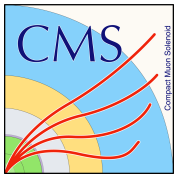


Recent studies on top quark properties and mass in CMS

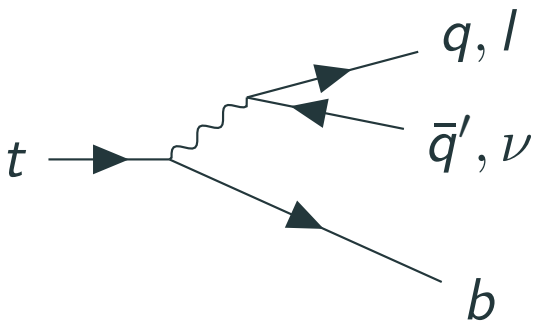
Dennis Schwarz
on behalf of the CMS Collaboration

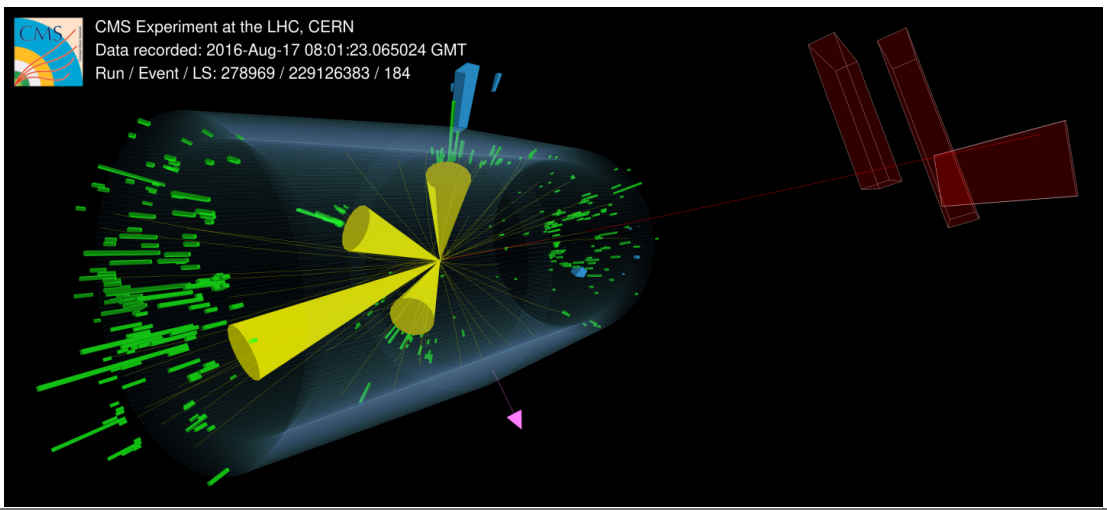
ICHEP 2022

The top quark

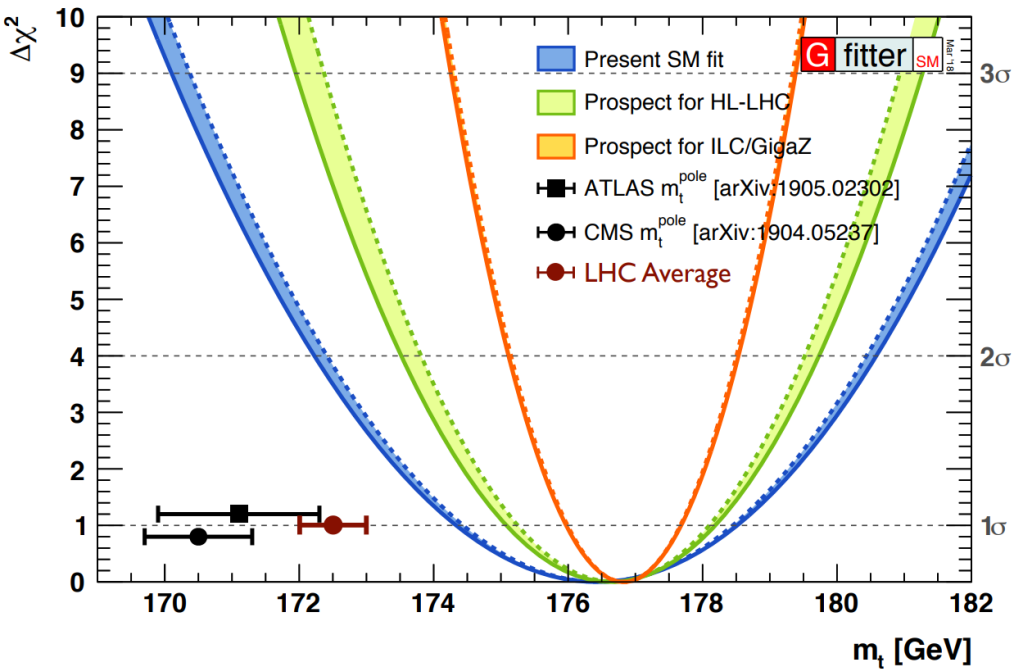
- Heaviest particle in the SM
- Yukawa coupling of ~ 1
- Sensitive to QCD and electroweak
- Preferred coupling to new physics?
- So far no signs in direct searches

$\rightarrow$ Precision measurements of its properties could reveal indirect effects





Top quark mass



Tensions between:

- Fit $\leftrightarrow$ measurements
- Direct $\leftrightarrow$ pole mass measurements

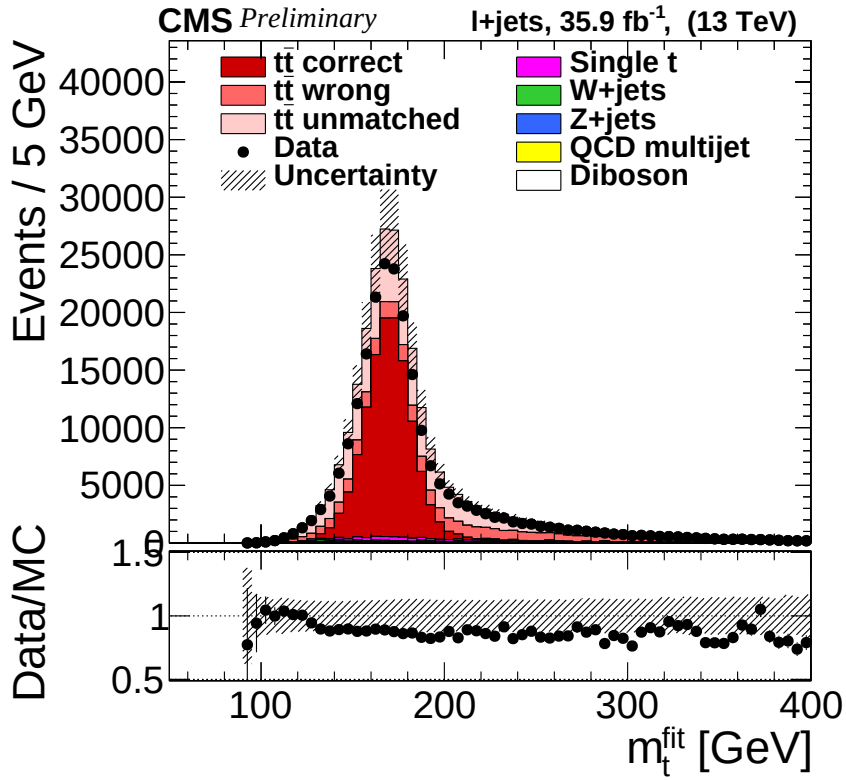
$\rightarrow$ Precisely measure m_t and explore full phase space

Measurement of m_t NEW!

[TOP-20-008]

- ℓ+jets channel of $t\bar{t}$
- Kinematic fit
- ℓ, 2 b jets, 2 light jets, p_T^{miss}
- Best hypothesis selected via $P_{gof} = \exp(-\frac{1}{2}\chi^2)$
- 5 observables constructed

Observable	P_{gof}
m_t^{fit}	≥ 0.2
m_{lb}^{reco}	< 0.2
m_W^{reco}	≥ 0.2
m_{lb}/m_t^{fit}	≥ 0.2
$R_{bq} = (p_T^{b1} + p_T^{b2})/(p_T^{q1} + p_T^{q2})$	≥ 0.2

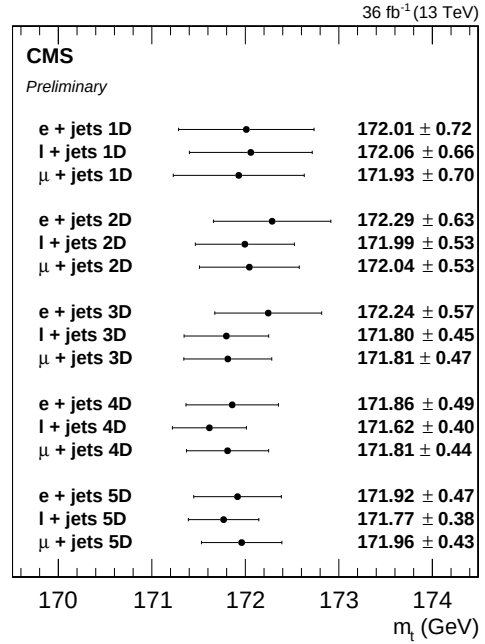


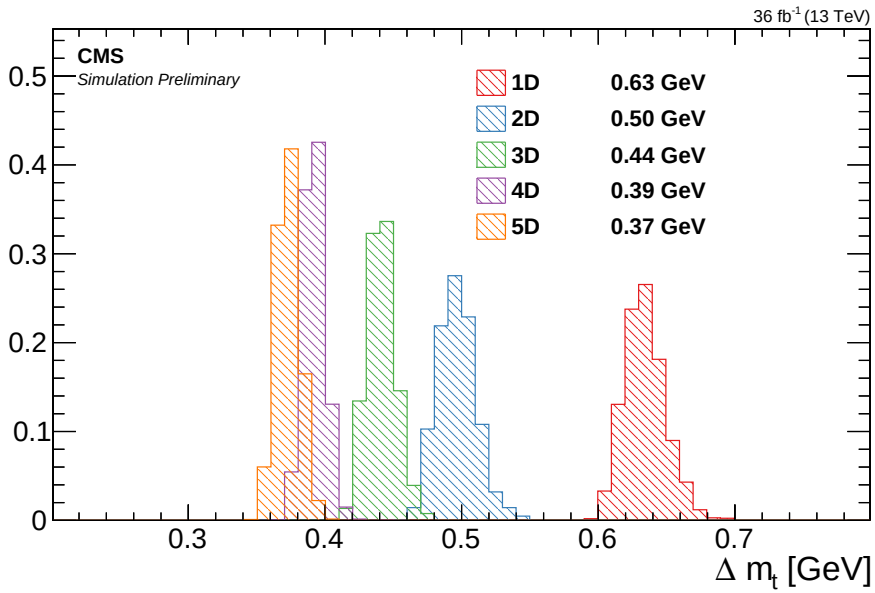
Measurement of m_t

NEW!

[TOP-20-008]

- Simultaneous likelihood fit
- Uncertainties as nuisances
- m_t^{fit}, $m_{\text{lb}}^{\text{fit}}$ and $m_{\text{lb}}/m_t^{\text{fit}}$ sensitive to m_t
- $m_{\text{W}}^{\text{reco}}$ constrains JES of light jets
- R_{bq} constrains b jets





Dominant uncertainties:

b jet JES, $\text{t}\bar{\text{t}}$ modeling (FSR+CR)

$$\boxed{m_t = 171.77 \pm 0.38 \text{ GeV}}$$

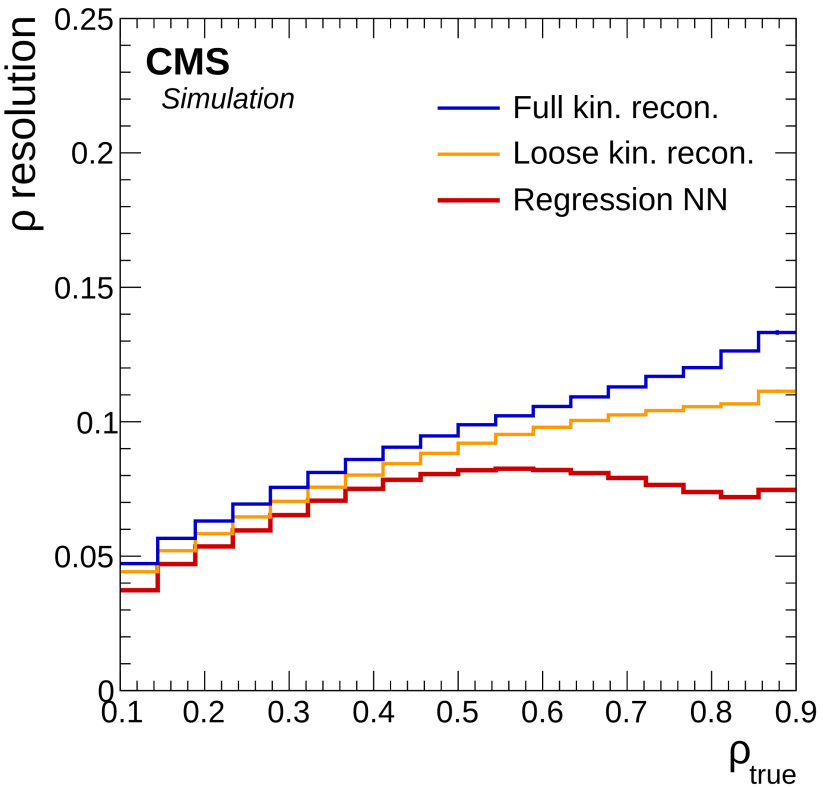
Most precise measurement of m_t!

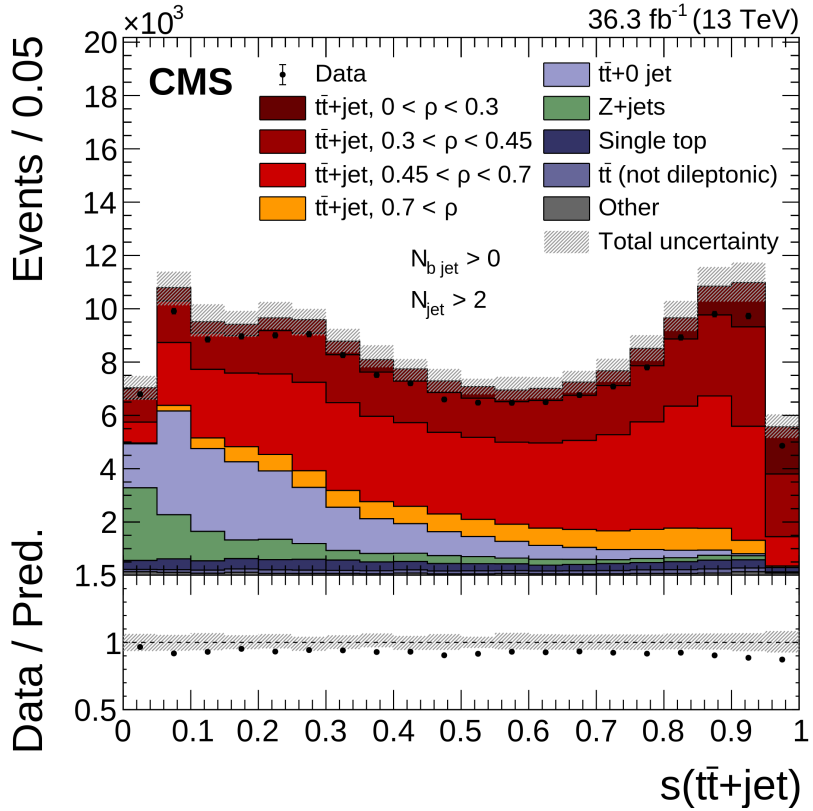
Measuring the pole mass

NEW!

[TOP-21-008, submitted to JHEP]

- $t\bar{t}$ +1jet in dilepton channel
- Differential cross section as a function of $\rho = \frac{m_0}{m_{t\bar{t}+\text{jet}}}$, $m_0 = 170$ GeV
- Full $t\bar{t}$ kinematic reconstruction using NN
- Second NN for event classification





Measuring the pole mass

NEW!

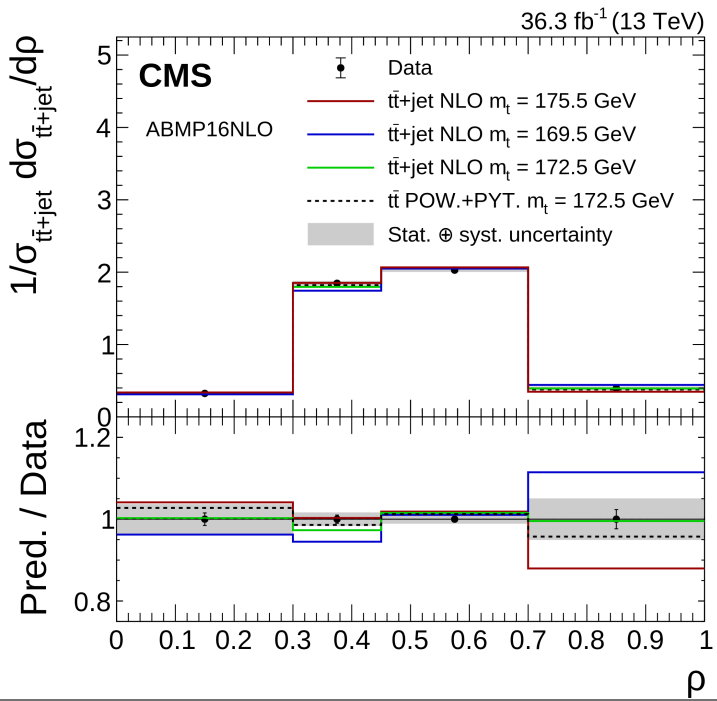
[TOP-21-008, submitted to JHEP]

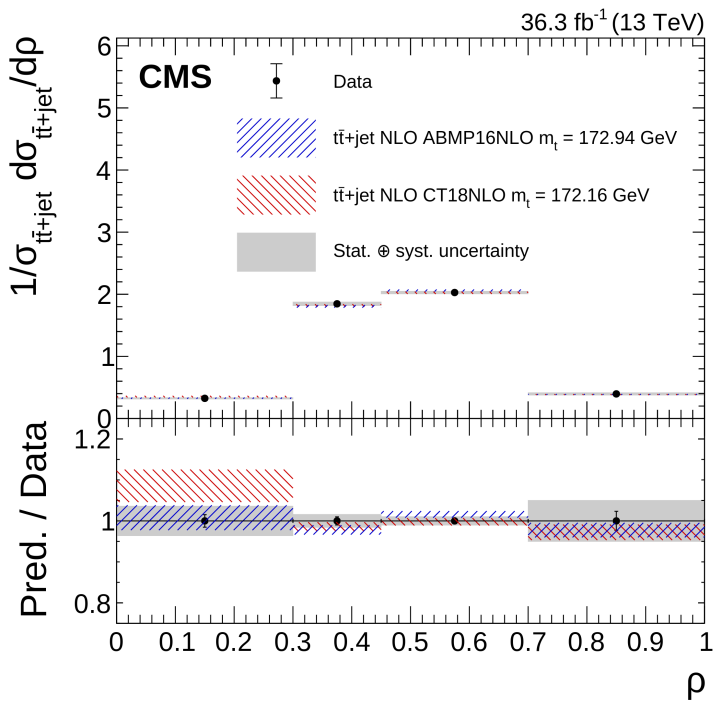
- Likelihood-based unfolding
- Fit constrains uncertainties
- Largest m_t sensitivity at $t\bar{t}$ threshold (large ρ)

More details: Sebastian's poster

$\rightarrow$ $\boxed{m_t^{\text{pole}} = 172.94^{+1.37}_{-1.34}\ \text{GeV}}$ (ABMP16NLO PDF set)

$\rightarrow$ $\boxed{m_t^{\text{pole}} = 172.16^{+1.44}_{-1.41}\ \text{GeV}}$ (CT18NLO PDF set)



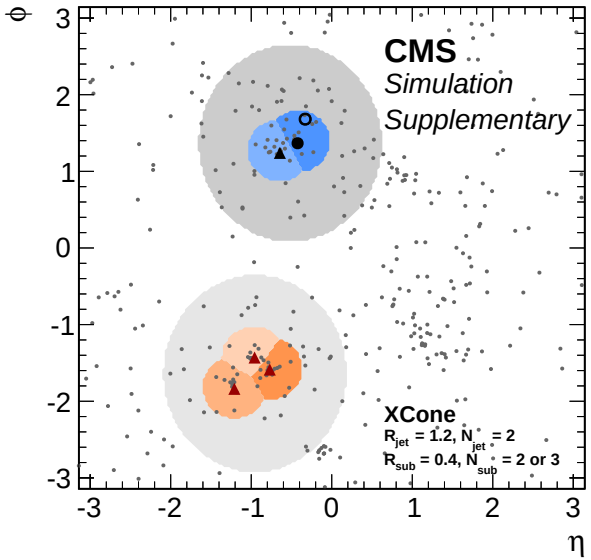


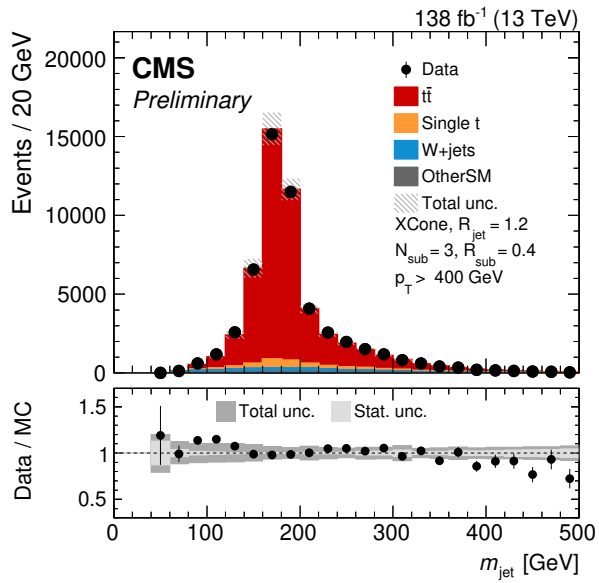
Measuring m_t with m_{jet} NEW!

[TOP-21-012], [Stewart et al, JHEP 11 (2015) 072], [Thaler & Wilkason, JHEP 12 (2015) 051]

- Differential $t\bar{t}$ cross section as a function of m_{jet}
- ℓ+jets channel in boosted regime
- Two-step jet clustering with XCone
- Previous measurement with 2016 data: $m_t = 172.6 \pm 2.5$ GeV

$\rightarrow$ Increase precision by calibrating jet mass scale and FSR modeling





Measuring m_t with m_{jet} NEW!

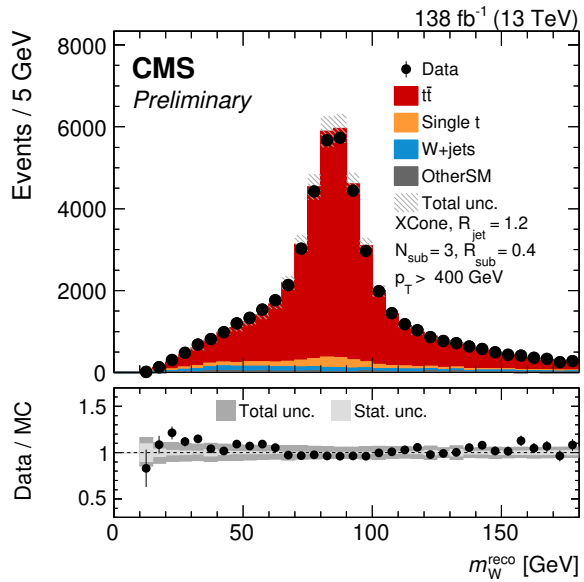
[TOP-21-012], [Thaler & Tilburg, JHEP 03 (2011) 015], [Thaler & Tilburg, JHEP 02 (2012) 093]

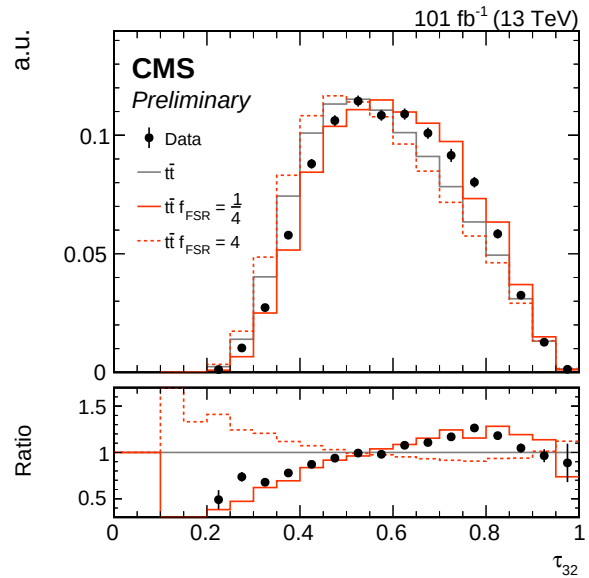
- Jet mass scale measured with reconstructed W
- Add flavour uncertainty to account for differences of b jets and light jets
- $\Delta m_t^{\text{old}}(\text{JES}) = 1.5$ GeV $\rightarrow$

$$\boxed{\Delta m_t(\text{JES+JMS+flavour}) = 0.39 \text{ GeV}}$$

- FSR modeling calibrated with jet substructure τ_{32}
- Tune MC to describe jet substructure in boosted regime
- $\Delta m_t^{\text{old}}(\text{FSR}) = 1.2$ GeV $\rightarrow$

$$\boxed{\Delta m_t(\text{FSR}) = 0.03 \text{ GeV}}$$





Measuring m_t with m_{jet}

[TOP-21-012]

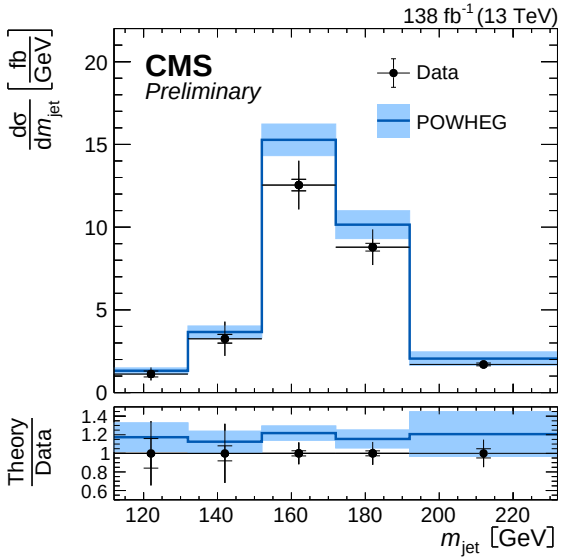
NEW!

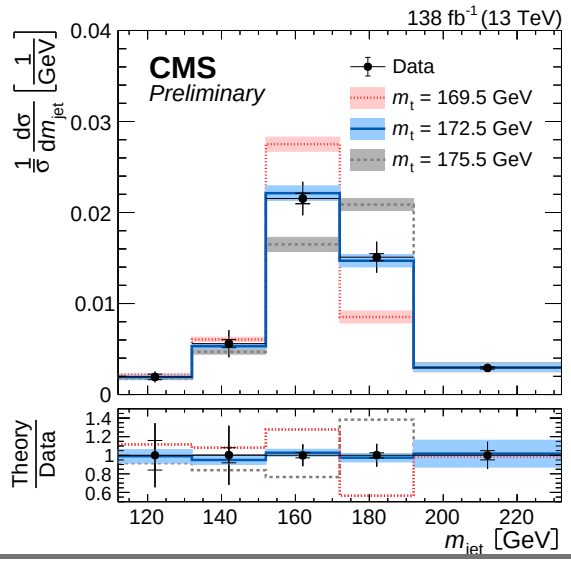
- Regularized unfolding with TUnfold
- Extract m_t from normalized distribution

$\rightarrow$ $\boxed{m_t = 172.76 \pm 0.81 \text{ GeV}}$

- Largely reduced uncertainties

Source	Uncertainty [GeV]
Statistics	0.22
JER	0.40
JMS	0.27
JMS flavor	0.27
Choice of m_t	0.37
h_{damp}	0.19
CR	0.19



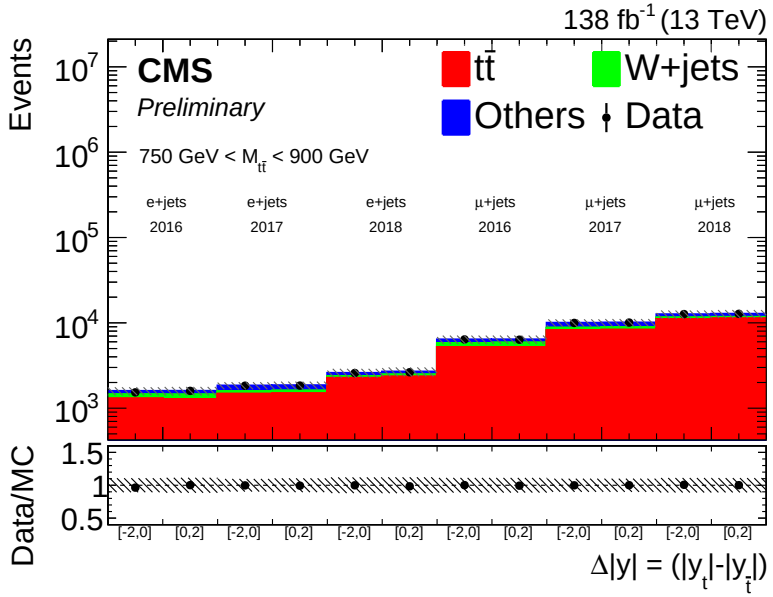


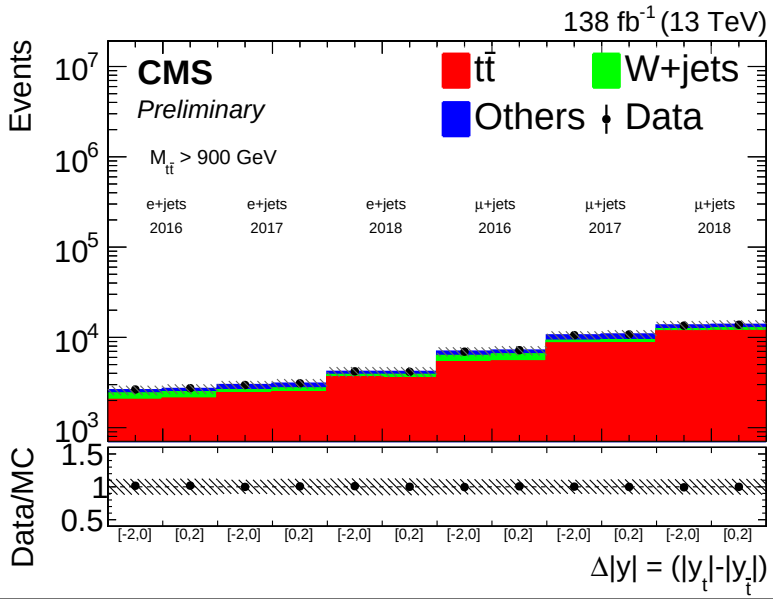
Charge asymmetry in $t\bar{t}$

[TOP-21-014]

NEW!

- Study of central-forward asymmetry in $t\bar{t}$
- Effect only in $q\bar{q} \rightarrow t\bar{t}$
- Boosted regime enriches $q\bar{q}$ production
- $A_C = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) + N(\Delta|y|<0)}$
  $(\Delta|y| = |y_t| - |y_{\bar{t}}|)$
- SM prediction $\sim 1\%$
- Could be influenced by BSM
- Measurement in ℓ+jets
- Bins of $m_{t\bar{t}}$

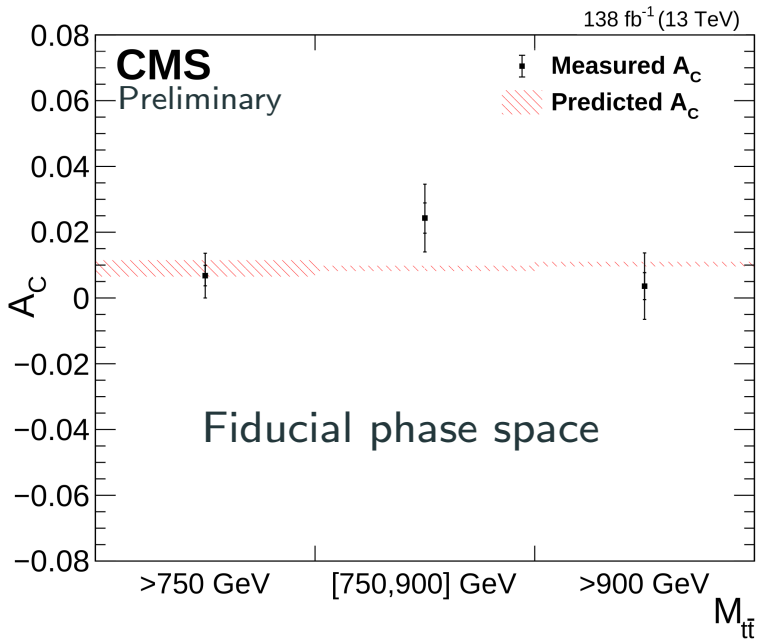


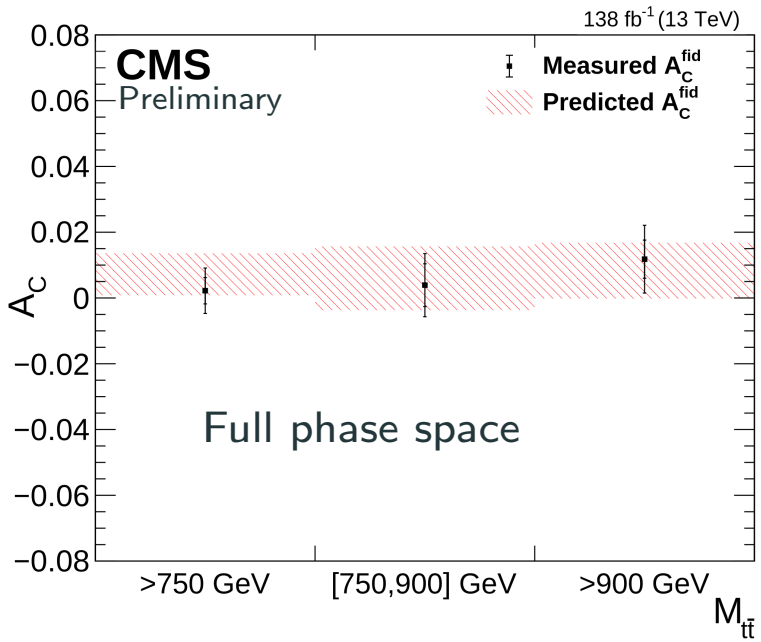


Charge asymmetry in $t\bar{t}$ NEW!

[TOP-21-014]

- Maximum likelihood fit and likelihood-based unfolding
- A_C also obtained in full phase space
- Good agreement with SM
- Largest uncertainties:
  QCD scales, FSR, Top p_T modelling, JEC





Summary

- We are within precision era of top physics at LHC
- Measurements of m_t:
  - Most precise direct measurement
  - Pole mass in $t\bar{t}$ +1jet
  - Improved precision in boosted m_{jet} measurement
  - (Run 1 ATLAS+CMS combination in Richard's talk)
- Charge asymmetry in boosted $t\bar{t}$
- Precision already superseding predictions