Measurement of the top-quark mass in the $t\bar{t} \rightarrow$ lepton+jets channel at $\sqrt{s} = 13$ TeV with ATLAS

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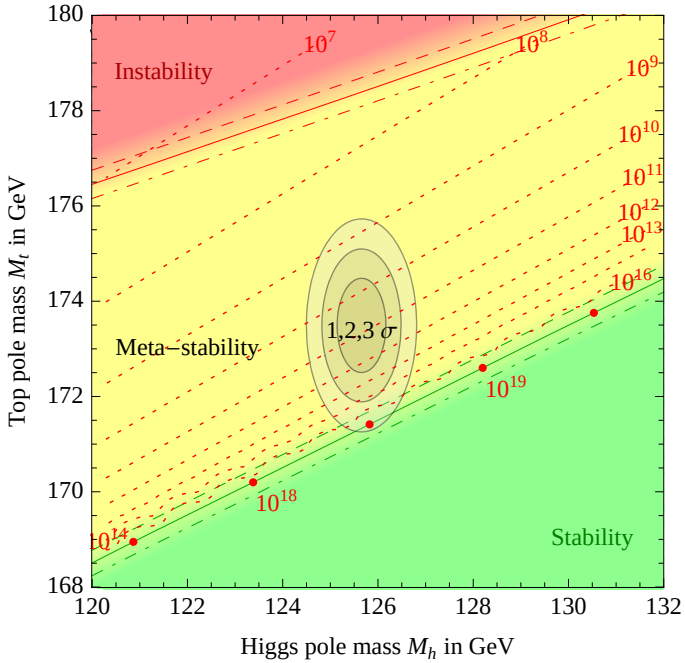
ATLAS EXPERIMENT

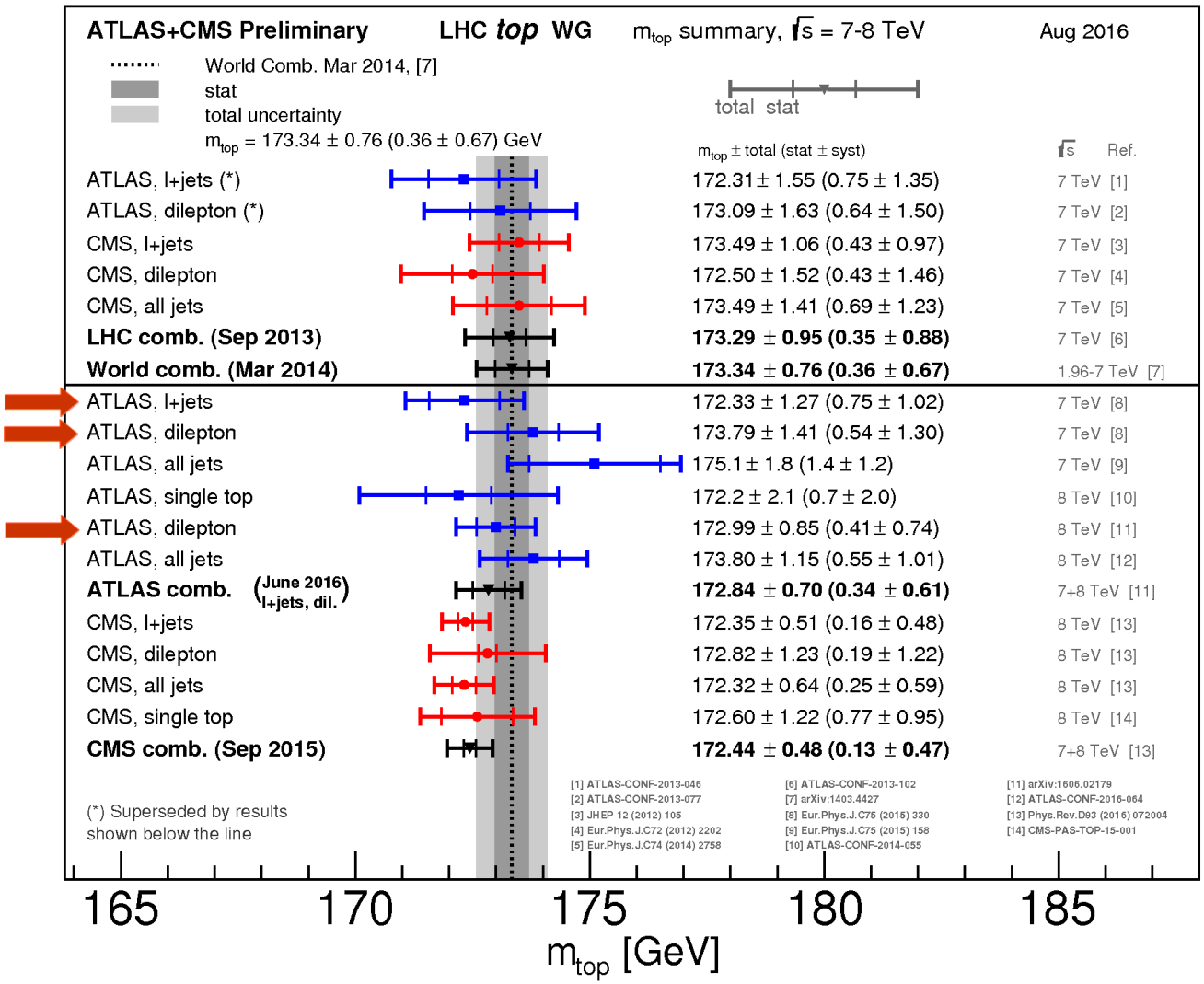
Why is the top-quark mass interesting?

- heaviest particle of the Standard Model (SM)
  $\hookrightarrow$ decays before forming bound states
- plays an important role in electroweak symmetry breaking
- deviations between measured properties and SM predictions offer tests for new physics
- important for the vacuum stability of the SM



▸ PoS EPS-HEP2013 (2013) 163

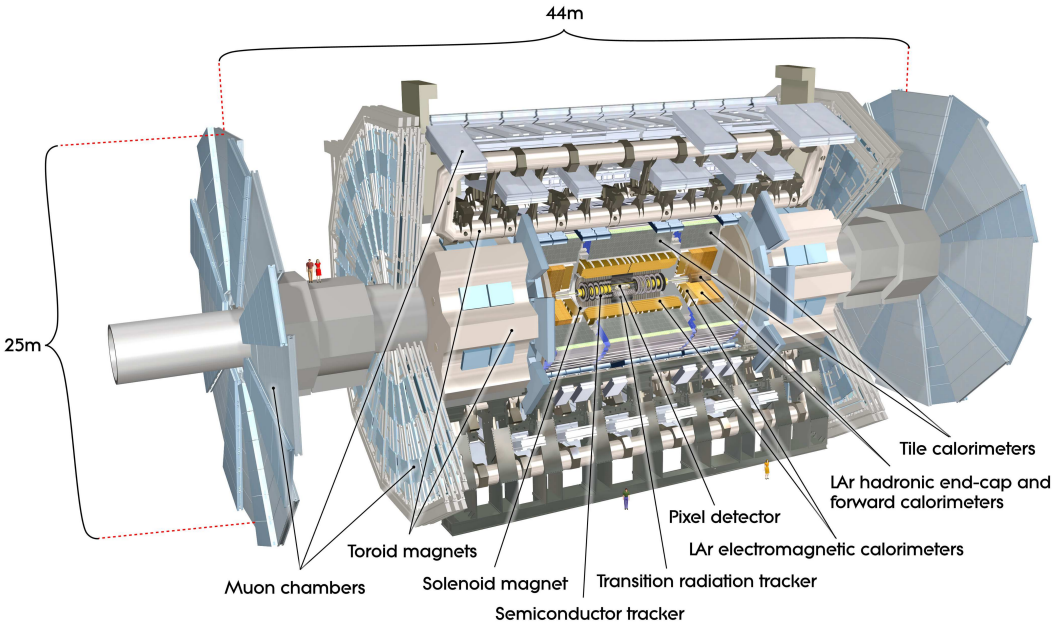
How well do we know the mass?

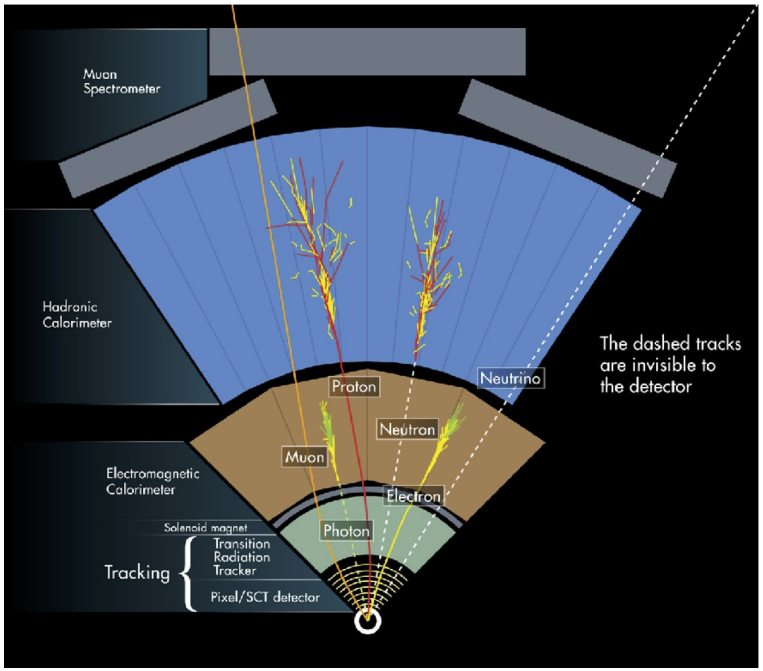


- Paper@ 7 TeV: Eur. Phys. J. C (2015) 75:330
- Paper@ 8 TeV dilepton: Physics Letters B 761 (2016) 350 - 371

The ATLAS experiment at the LHC

- multi- purpose detector
- almost full solid angle
- onion-shell structure





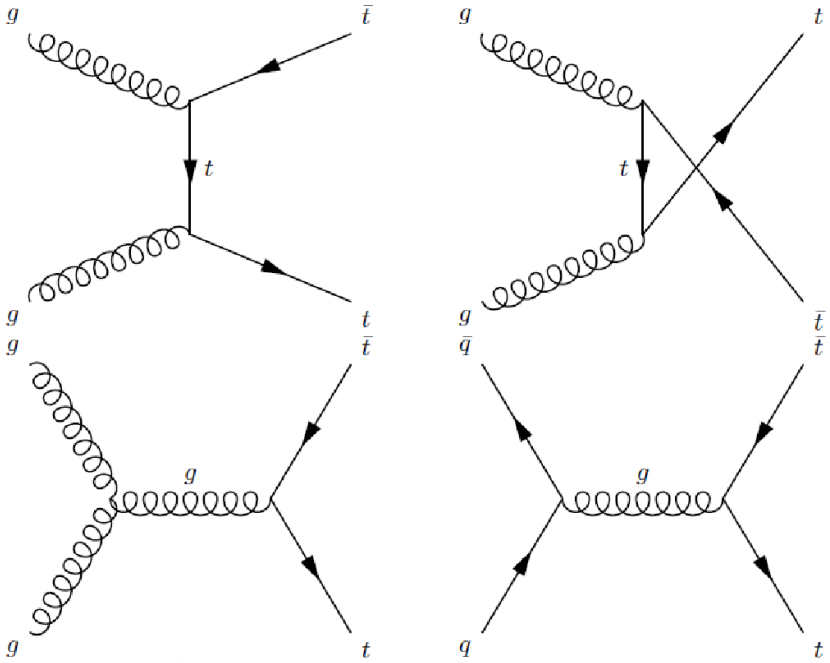
- ID: track, charge, momentum
- ECal: energy of e and γ
- HCal: energy of hadrons
- Muon system: tracks of muons

Top-quark pair production & top-quark decay

top-quark production at LHC

- $t\bar{t}$-production via strong interaction

  $\hookrightarrow$ gluon-gluon fusion
  $\hookrightarrow$ quark-antiquark annihilation



top-quark decay

- top quark decays almost exclusively into a b-quark and a W-boson
- characterised by the W-boson decay

  ➔ allhadronic: $t\bar{t} \longrightarrow bW(\rightarrow q\bar{q}) + \bar{b}W(\rightarrow q\bar{q})$
  ➔ dilepton: $t\bar{t} \longrightarrow bW(\rightarrow l_1\nu_{l_1}) + \bar{b}W(\rightarrow l_2\nu_{l_2})$
  ➔ lepton + jets: $t\bar{t} \longrightarrow bW(\rightarrow q\bar{q}) + \bar{b}W(\rightarrow l\nu_l)$

Event selection

E_T^{miss}:

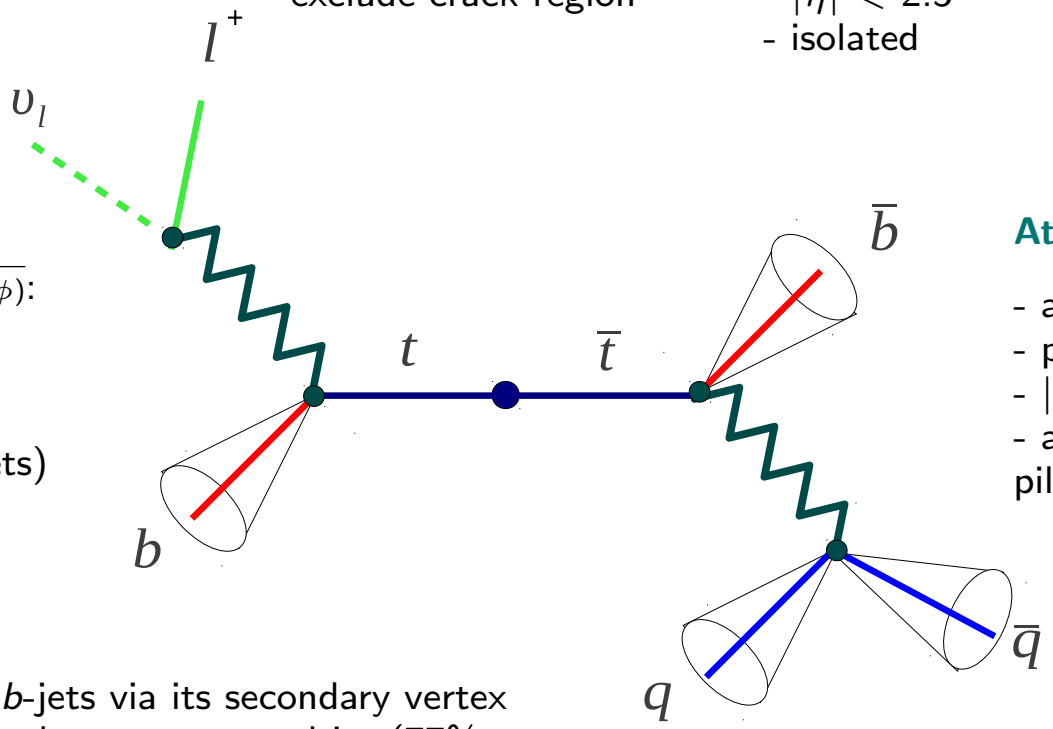
$E_T^{miss} > 20$ GeV

Electrons:

- $E_T > 27$ GeV
- $|\eta| < 2.47$
- isolated
- exclude crack region

Muons:

- combined muons (tracker+spectrometer)
- $p_T > 27$ GeV
- $|\eta| < 2.5$
- isolated



transverse W mass:

$m_{T,W} = \sqrt{2p_T^l p_T^\nu (1 - \cos(\Delta\phi))}$:

$m_{T,W} + E_T^{miss} > 60$ GeV (μ + jets)
$m_{T,W} > 30$ GeV (e + jets)

At least 4 jets:

- anti-k_t jets (R = 0.4)
- $p_T > 25$ GeV
- $|\eta| < 2.5$
- additional cuts to reduce pile-up influence

***b*-jets:**

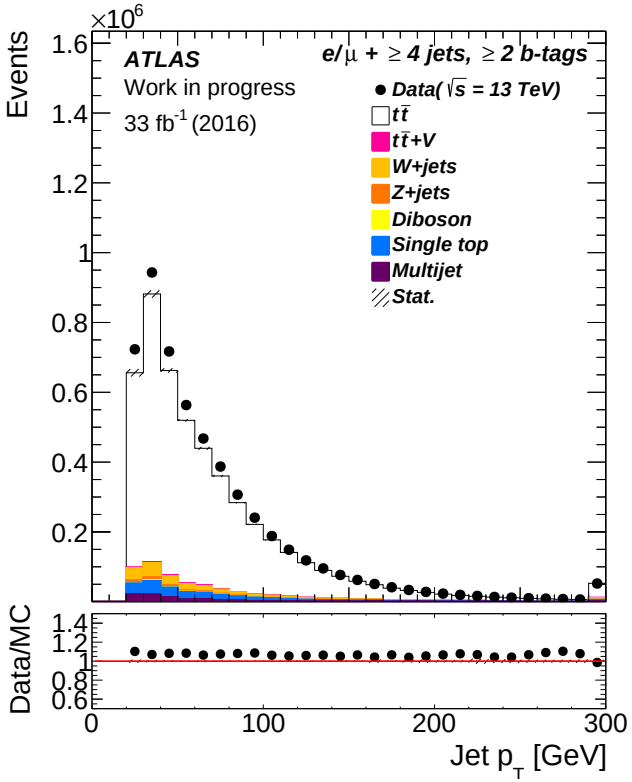
➔ identify *b*-jets via its secondary vertex
➔ require at least one tagged jet (77% efficiency)

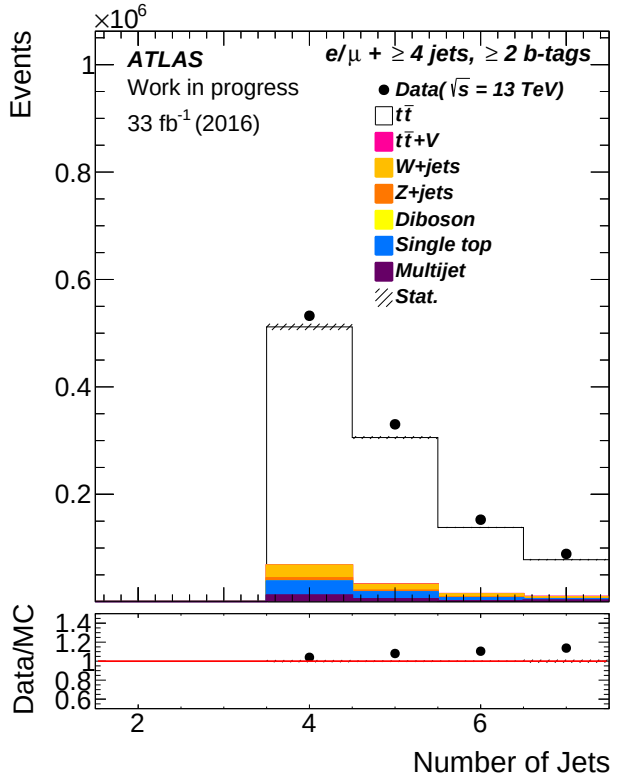
Data 2016, $\mathcal{L} = 33$ fb^{-1}

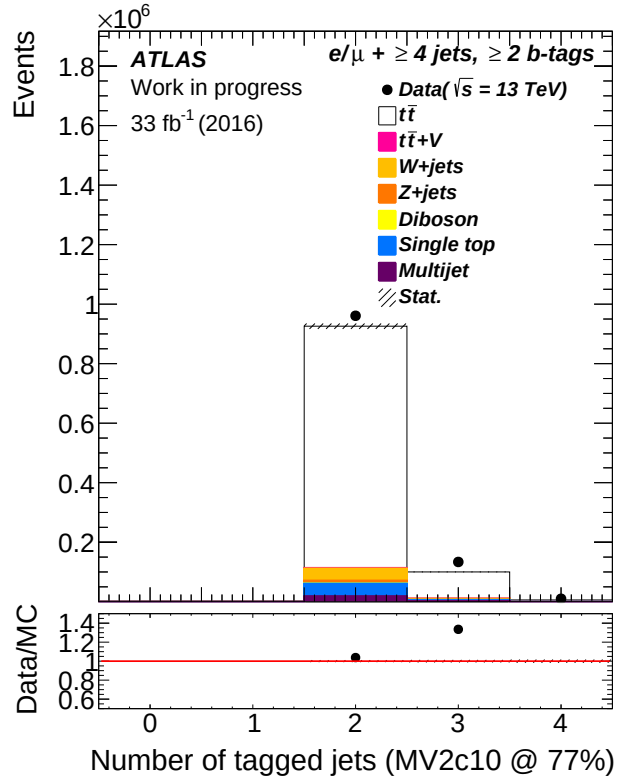
MC predicted process	Events	Statistical uncertainty
$t\bar{t}$(signal)	906500	630
Single top (signal)	46900	130
W+jets	43590	980
Z+jets	9220	270
Diboson	1678	24
Multijets	20324	1600
$t\bar{t} + V$	3438	9
Total signal+background	1031640	2000
Data	1104481	
Data/Prediction	1.071	0.002

- mass dependence of single-top $\Rightarrow$ include in signal
- background dominated by W + jets production

Global quantities: 13 TeV, $e/\mu+ \geq 4$ jets, ≥ 2 b-tags





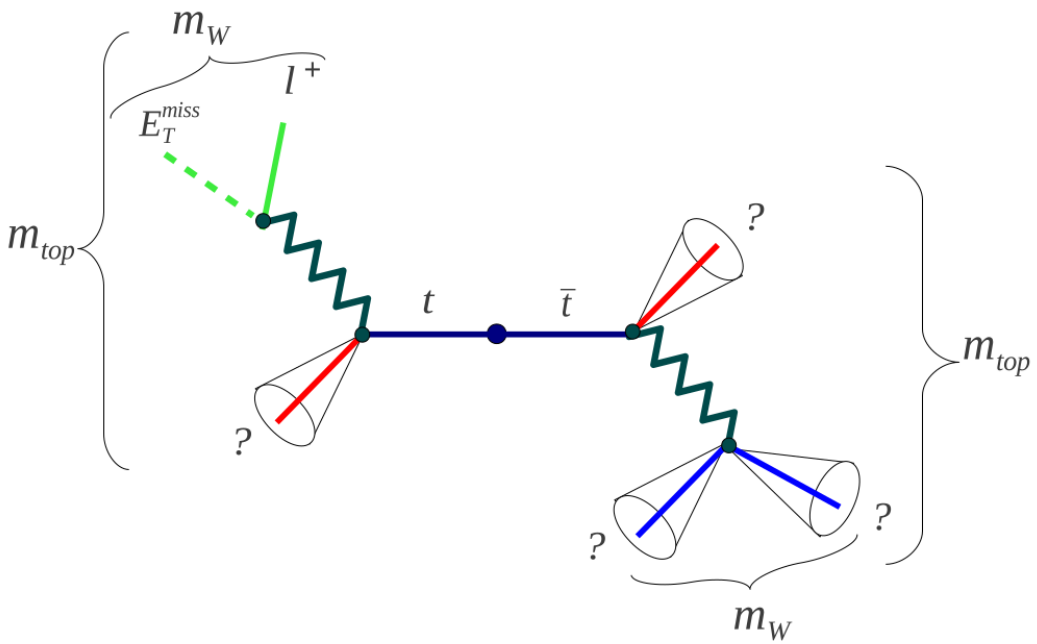


➔ disagreement in number of tagged jets, for 3 b-tag bin

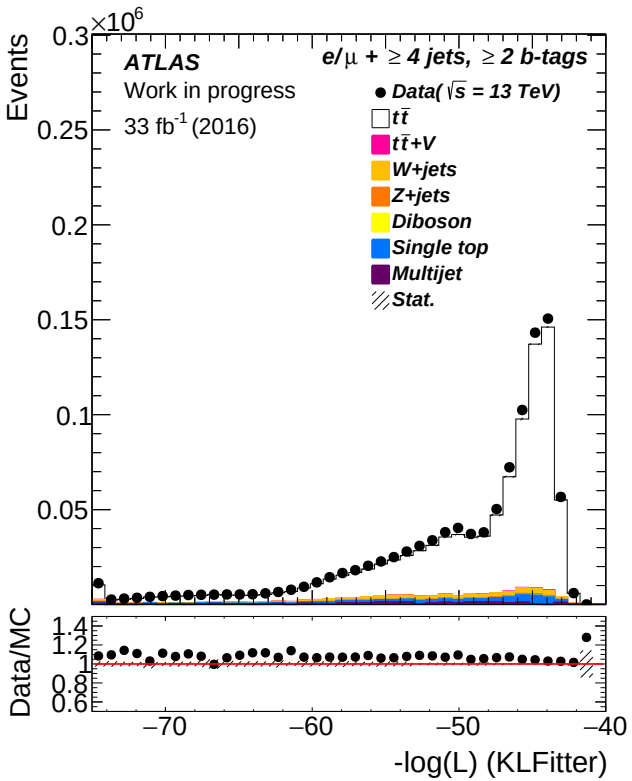
Event reconstruction

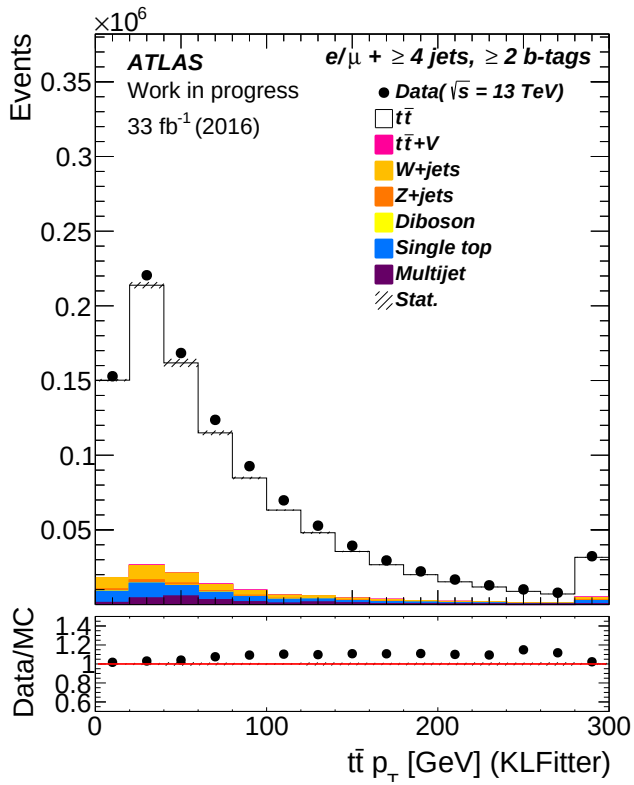
- 4 jet event $\Rightarrow$ 24 possible jet-parton assignments
- 12 permutations left since light jets from W-boson are indistinguishable
- Kinematic Likelihood fit with KLFitter ▸ NIM A 748 (2014) 18-25
- KLFitter input: charged lepton, missing E_T and up to six jets

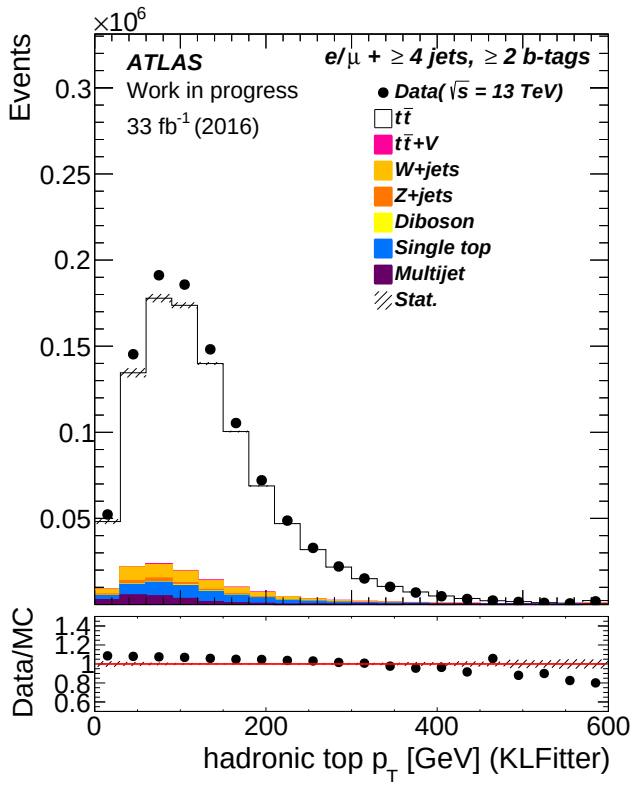
  $\Rightarrow$ **choose best permutation for calculation**



KLFitter quantities: 13 TeV, $e/\mu+ \geq 4$ jets, ≥ 2 b-tags







➔ slope in hadronic top p_T is well known with NLO+PS generators

Measurement is based on a 3D-Template method

- m_{top} has large uncertainties from JES and bJES

  $\hookrightarrow$ idea: reduce by simultaneous measurement of m_{top}, jet energy scale factor (JSF) and relative b-to-light-jet energy scale factor (bJSF)

  $\hookrightarrow$ need full reconstruction of $t\bar{t}$-final state

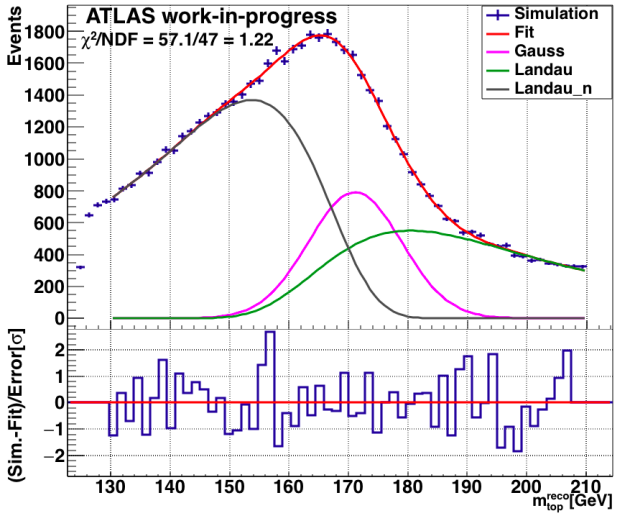
- m_{top}^{reco} from KLFitter reconstructed events
- m_W^{reco} from chosen jet permutation, sensitive to JSF
- R_{bq}^{reco} from chosen jet permutation, sensitive to bJSF

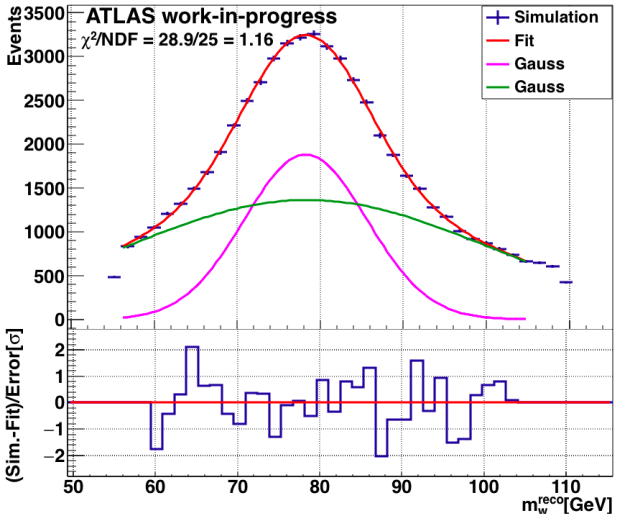
$$R_{bq}^{reco,2b} = \frac{p_T^{b_{had}} + p_T^{b_{lep}}}{p_T^{W_{jet1}} + p_T^{W_{jet2}}}$$

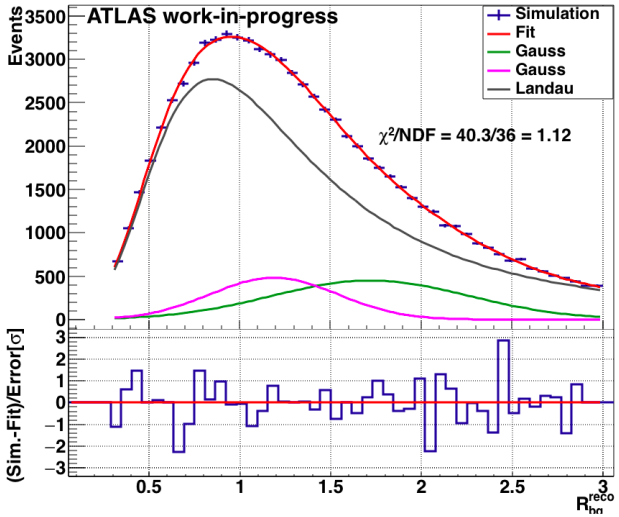
Determination of m_{top} :

- template parametrization of m_{top}^{reco}, m_W^{reco} and R_{bq}^{reco}
- unbinned likelihood fit is performed to data $\Rightarrow$ obtain m_{top}, JSF and bJSF

Signal templates $t\bar{t}$, m_{top}= 172.5 GeV, JSF = 1.0, bJSF = 1.0







Fit functions for signal

- m_{top}^{reco}: gauss+ landau + landau$_{mirror}$
- m_W^{reco}: gauss + gauss
- R_{bq}^{reco}: gauss + gauss + landau

Summary & Outlook

Current status

➔ established event selection and reconstruction with 13 TeV samples

- number of b-tagged jets not well described
- observed disagreement in reconstructed top p_T

➔ implemented first signal template parametrization

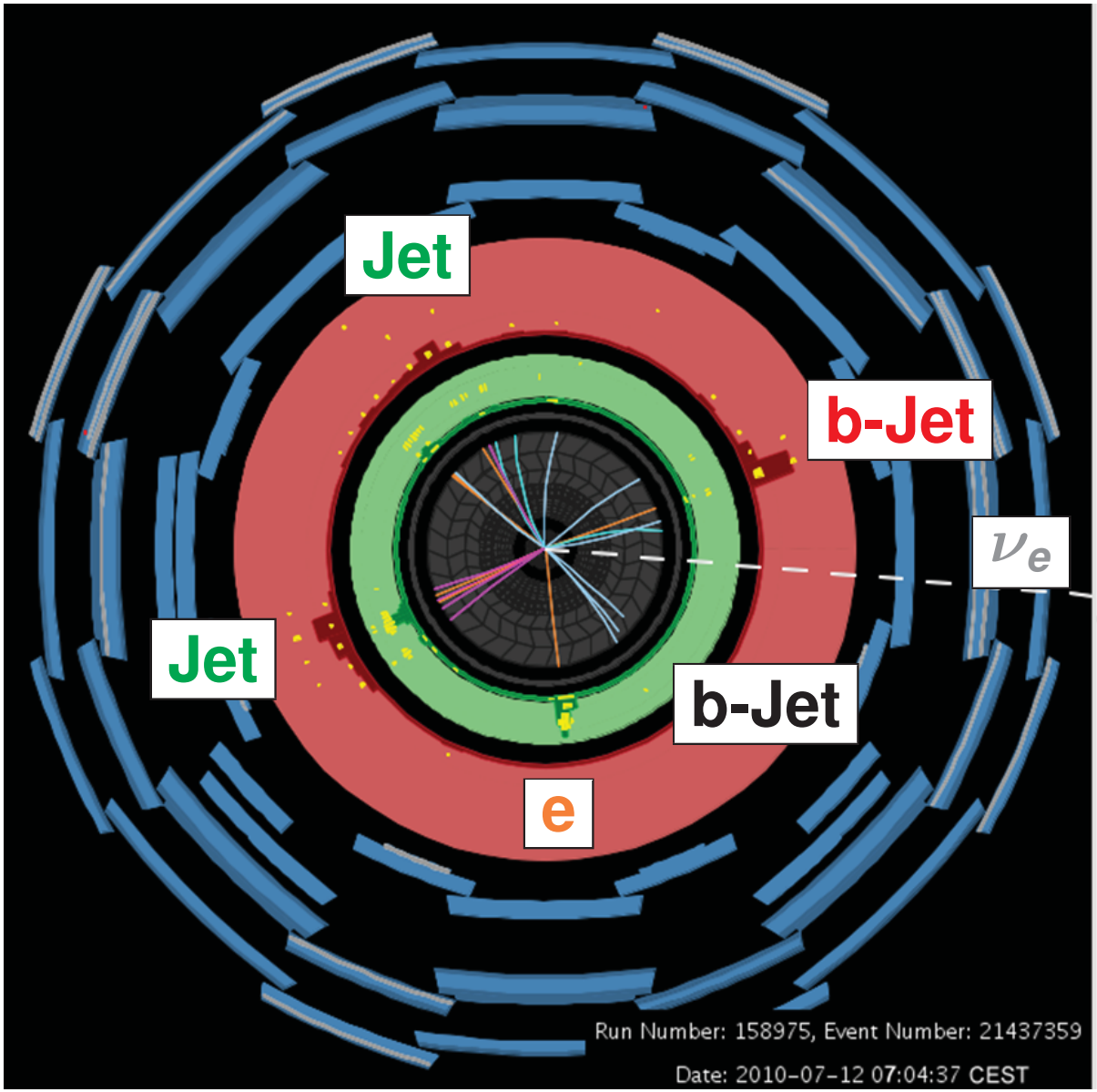
- chosen fit converge
- good description of simulated distributions

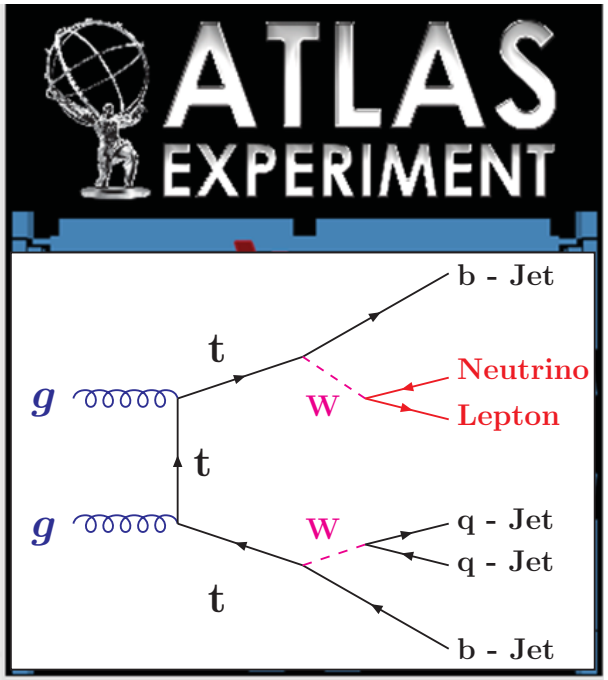
Next steps

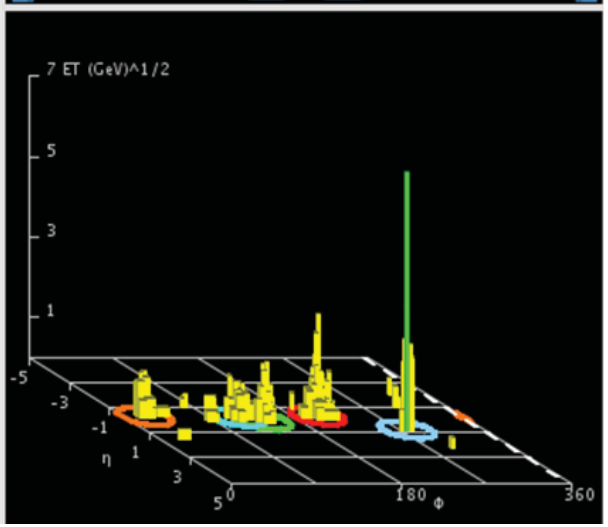
- include single top production into the signal parametrization
- full 3D parametrisation with unbinned Likelihood fit, closure tests

Backup

Event display, $tt \longrightarrow l + jets$







Reconstruction with KLFitter

➔ Definition of kinematic Likelihood:

- BW:Breit-Wigner distributions
- W: transver function discribe detector resolution
- different options to use b-tagging information

$$
\begin{aligned}
L = & BW(m_{q_1 q_2}|m_W, \Gamma_W) \cdot BW(m_{l\nu}|m_W, \Gamma_W) \\
& BW(m_{q_1 q_2 b_{had}}|m_{top}, \Gamma_{top}) \cdot BW(m_{l\nu b_{lep}}|m_{top}, \Gamma_{top}) \\
& W(\tilde{E}_{jet_1}|E_{b_{had}}) W(\tilde{E}_{jet_2}|E_{b_{lep}}) W(\tilde{E}_{jet_3}|q_1) W(\tilde{E}_{jet_4}|q_2) \\
& W(\tilde{E}_x^{miss}|p_{x,\nu}) W(\tilde{E}_y^{miss}|p_{y,\nu}) \left\{ \begin{array}{l} W(\tilde{E}_l|E_l) \\ W(\tilde{p}_{T,l}|p_{T,l}) \end{array} \right\}
\end{aligned}
$$

Settings:

- increased reconstruction efficiency, while using up to 6 jets
- veto: b-tagged jet in position of a light jet and vice-versa