Measurement of the Top Quark Mass in the $t\bar{t} \rightarrow$ lepton+jets channel at $\sqrt{s} = 13$ TeV with ATLAS

Sebastian Schulte, Andrea Knue, Stefan Kluth, Richard Nisius

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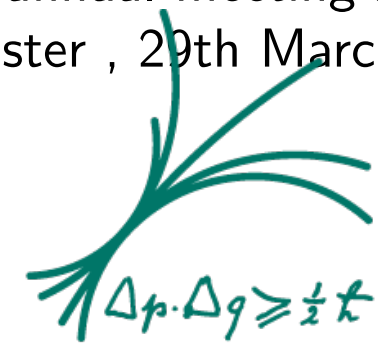
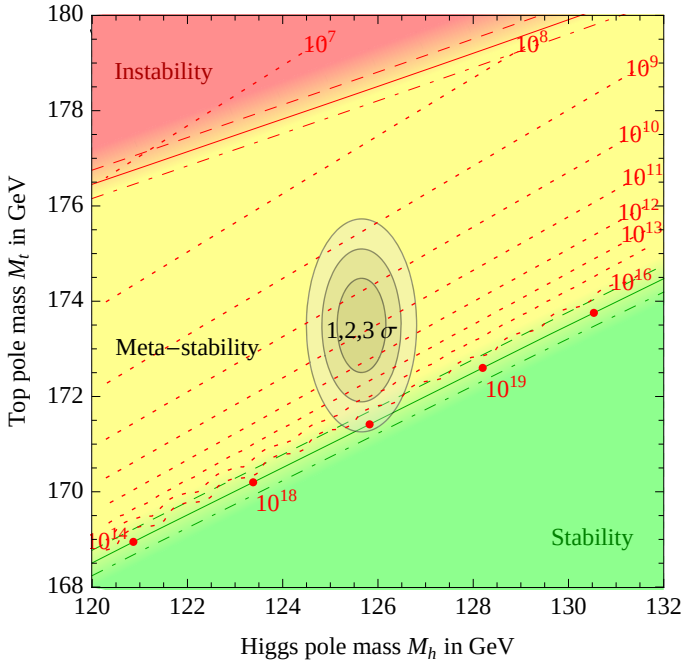
– MÃÂ¼nster , 29th March 2017 –



Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

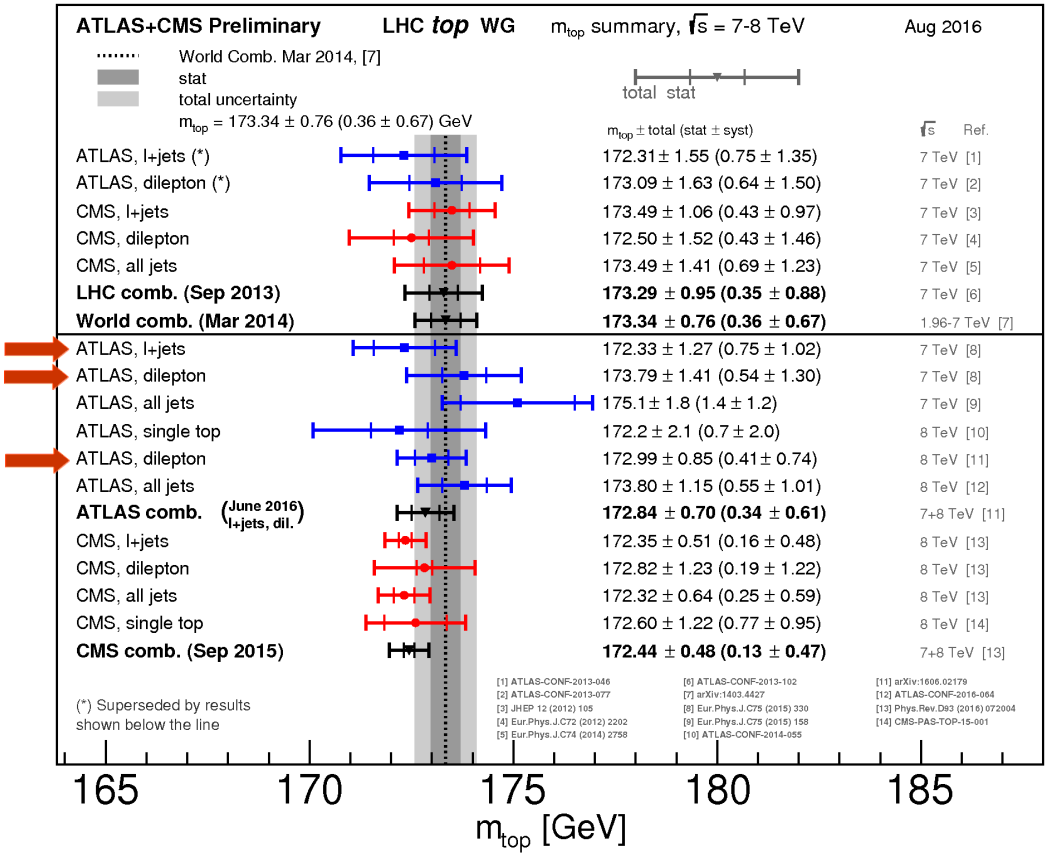
Why is the top-quark mass interesting?

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



▸ PoS EPS-HEP2013 (2013) 163

How well do we know the mass?

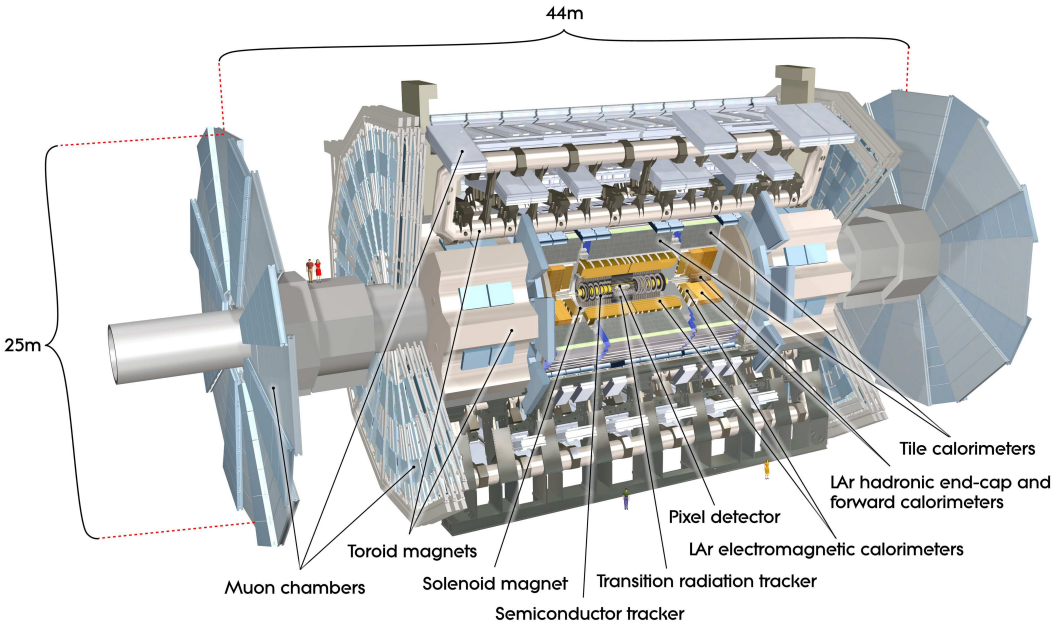


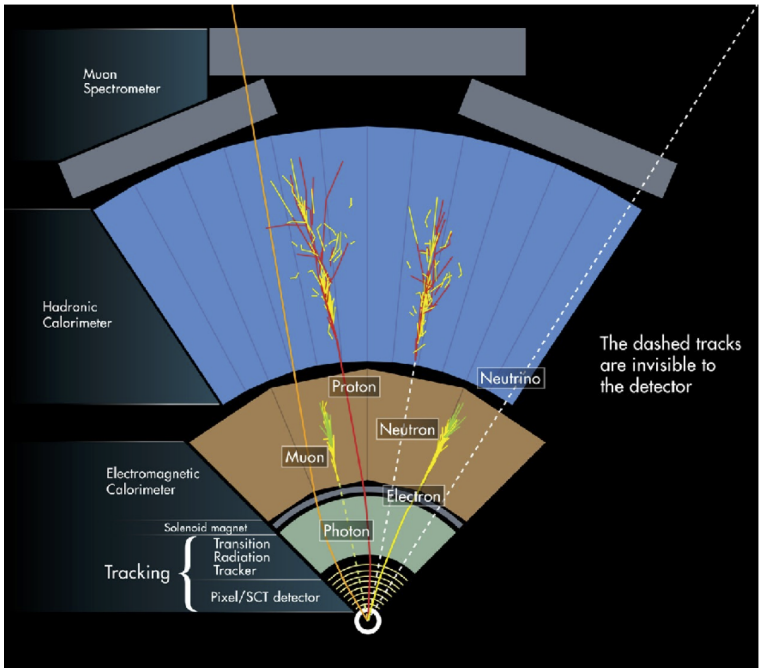
- Paper@ 7 TeV
- Paper@ 8 TeV dilepton

- world combination: $m_{top} = 173.34 \pm 0.76$ GeV
- CMS combination: $m_{top} = 172.44 \pm 0.48$ GeV

The ATLAS experiment at the LHC?

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



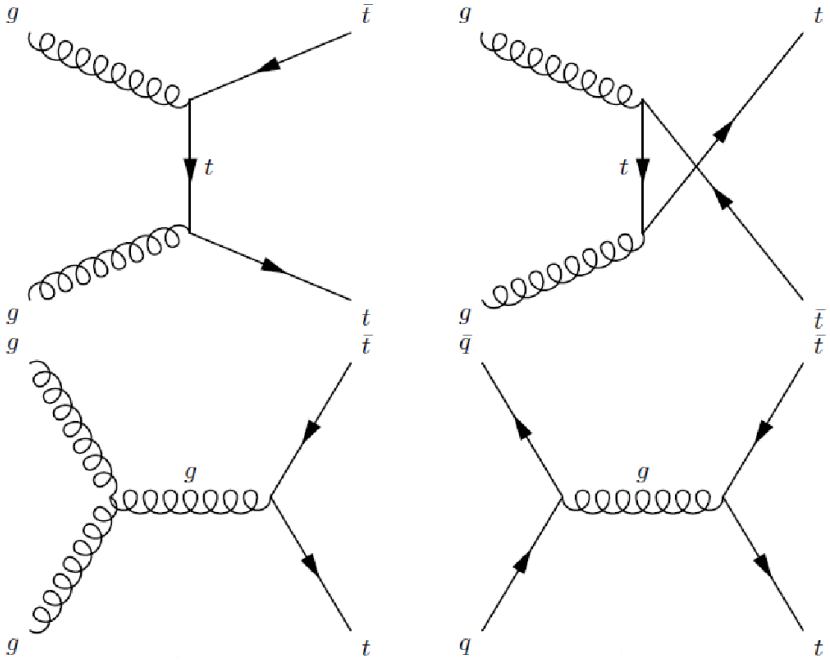


- ID: track, charge, momentum
- ECal: energy of e and γ
- HCal: energy of hadrons
- Muon System: tracks of muons

Top-quark pair production & top quark decay

top quark production

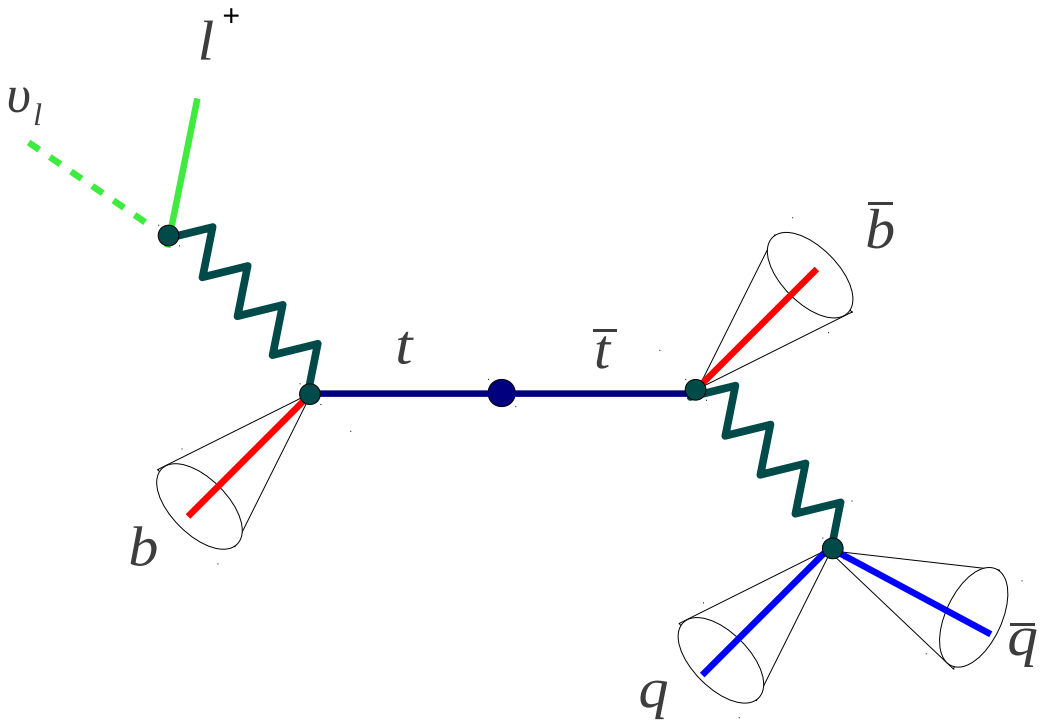
- dominant at LHC : $t\bar{t}$ production via strong interaction
  - $\hookrightarrow$ gluon-gluon fusion
  - $\hookrightarrow$ quark-antiquark annihilation
- require: $\sqrt{s_{parton}}$ has to be at least twice the top-quark mass



top quark decay

- top-quark decays almost exclusively into a b-quark and a W -boson
- different decay characterised by the W -boson decay
  - $\hookrightarrow$ quark-antiquark pair $\hookrightarrow$ leptonically
  - $\hookrightarrow$ charged lepton + corresponding neutrino

Event selection



Event selection

Electrons:

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

Muons:

- combined Muons (tracker+spectrometer)
- $p_T > 27$ GeV
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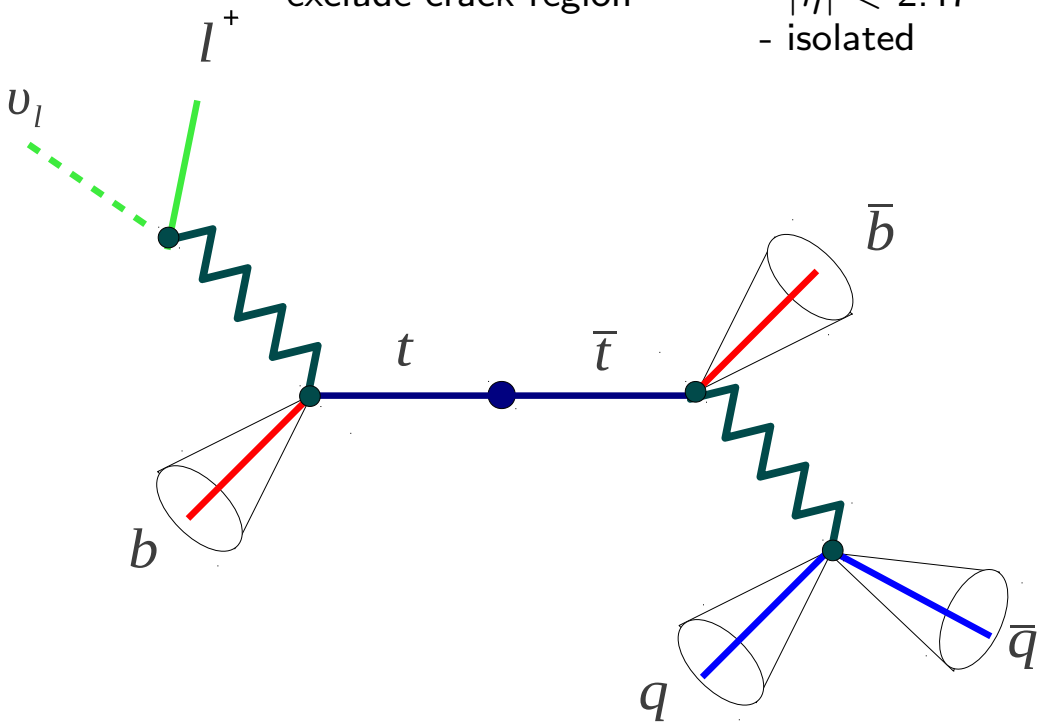

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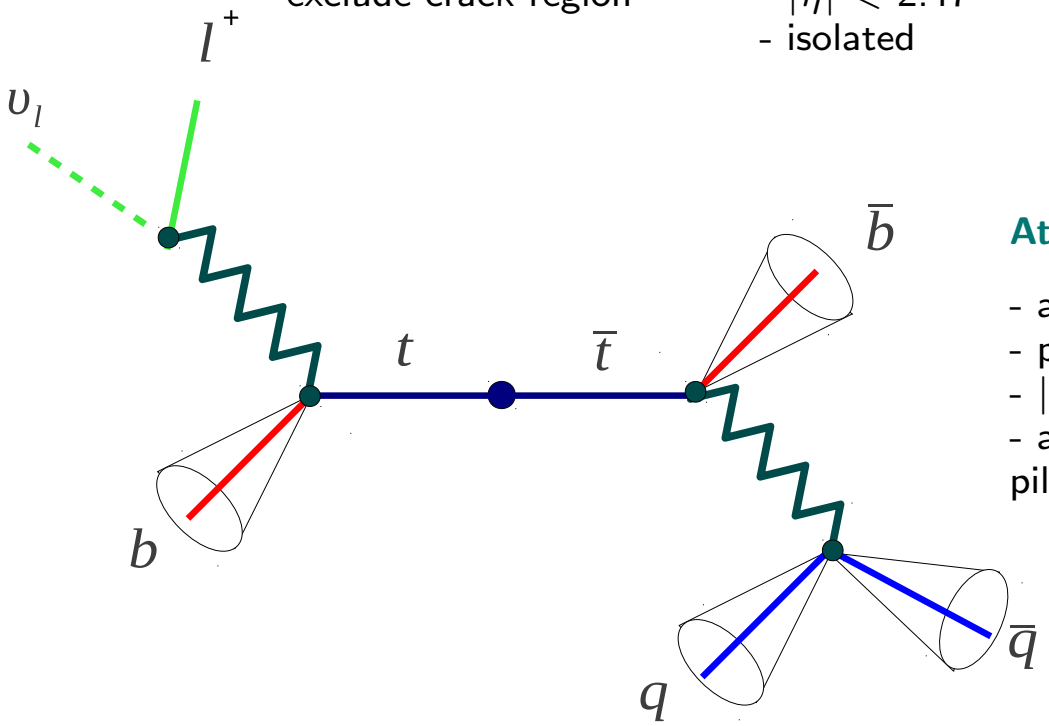

At least 4 Jets:

- anti-k_t jets (R = 0.4)
- $p_T > 25$ GeV
- $|\eta| < 2.4$
- additional cuts to reduce pile-up influence

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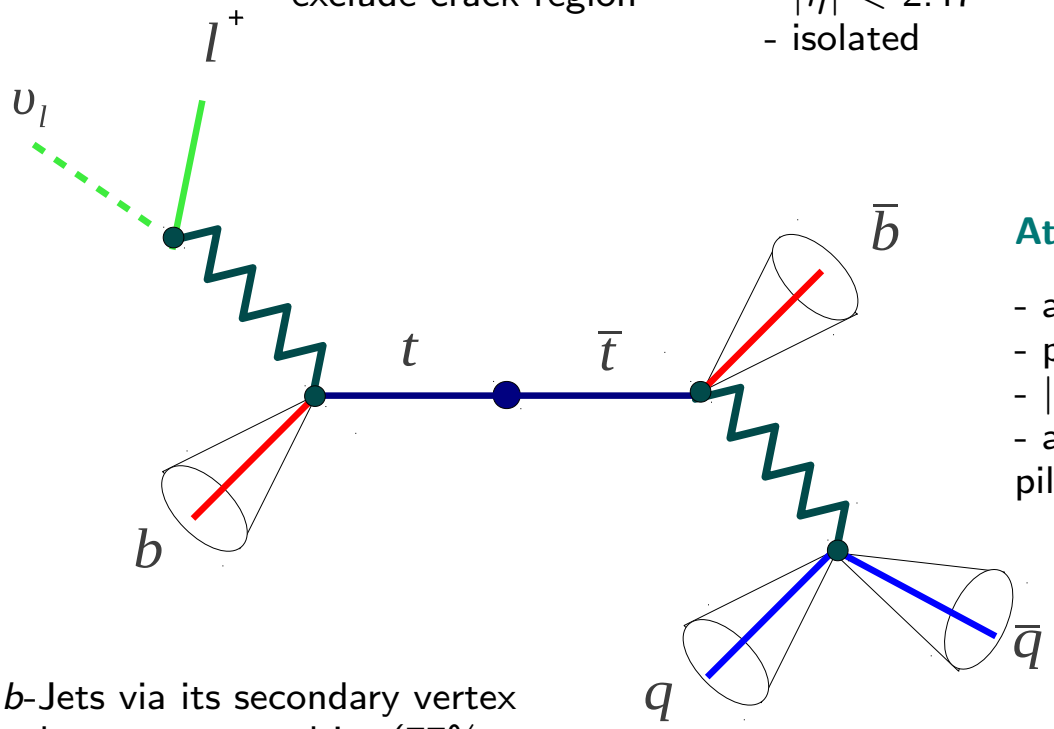

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***b*-Jets:**

➔ identify *b*-Jets via its secondary vertex
➔ require at least one tagged jet (77% Working point)

Event selection

E_T^{miss}:

$E_T^{miss} > 20$ GeV

Electrons:

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

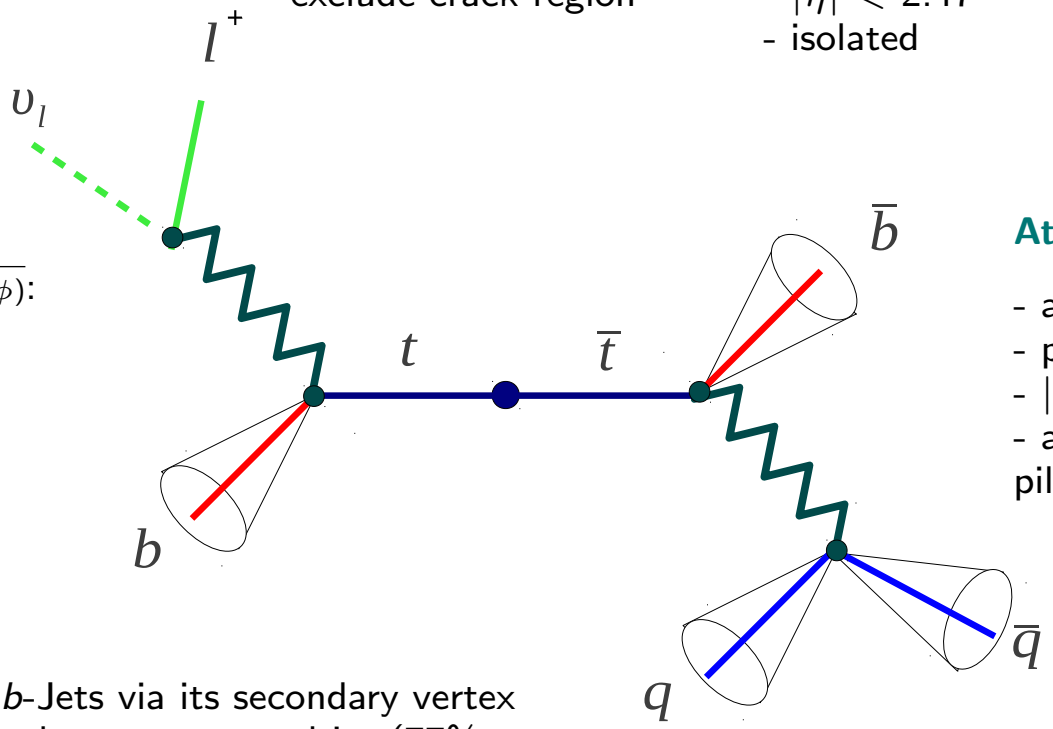
Muons:

- combined Muons (tracker+spectrometer)
- $p_T > 27$ GeV
- $|\eta| < 2.47$
- isolated

transverse W mass:

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

$m_{T,W} + E_T^{miss} > 60$ GeV



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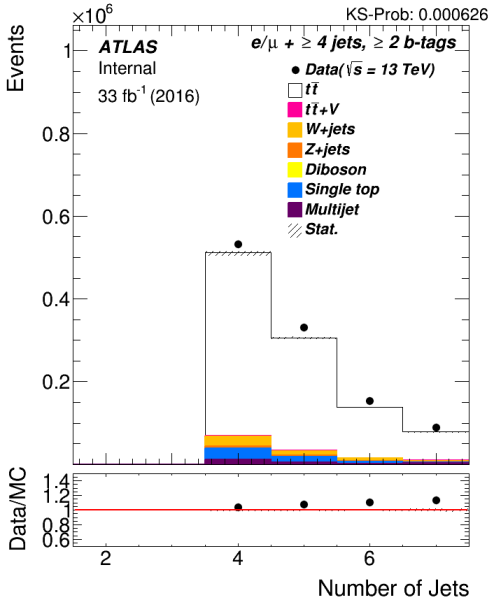
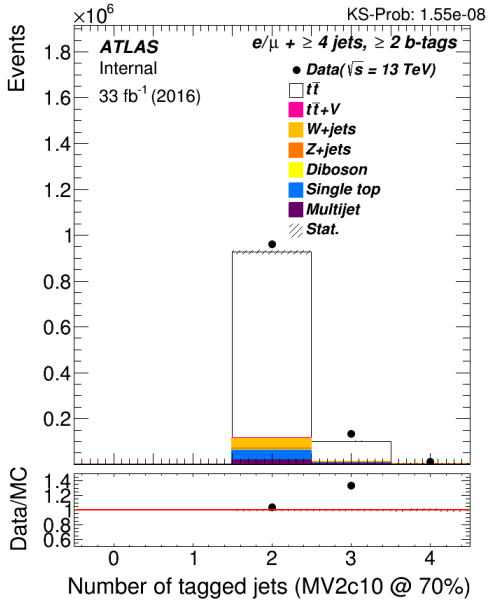
Event yields

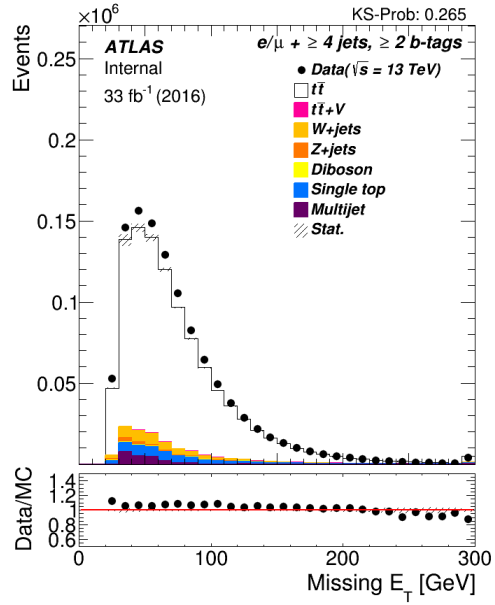
Process	Events	Stat. unc.
$t\bar{t}$	906502	629
W+jets	43586	978
Z+jets	9208	265
Diboson	1678	24
Single top	46902	132
Multijets	20324	1616
$t\bar{t} + V$	3438	9
Total sig+bkg	1031638	2013
Data	1104481	
Data/Pred.	1.07	

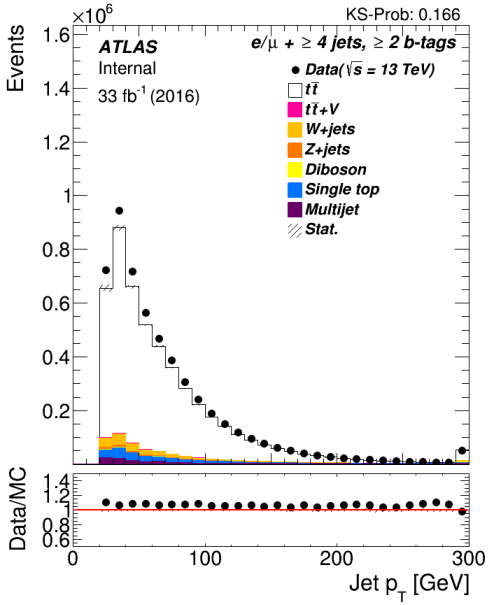
- background dominated by W + Jets
- mass dependence of single-top $\Rightarrow$ include in signal
- reduction of background via cuts on 2 b-tagged jets

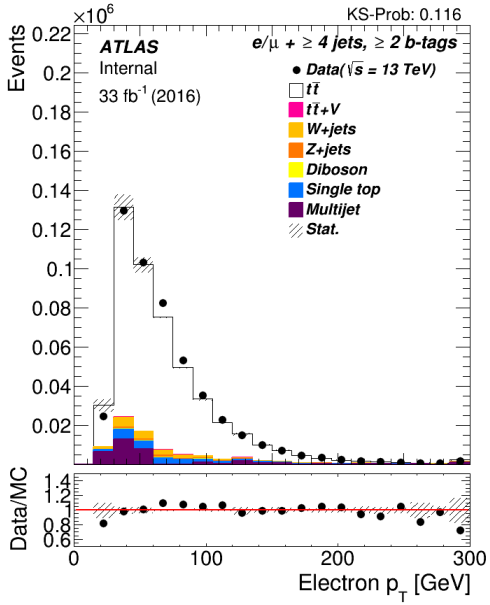
Data/MC 2016 , 33 fb^{-1}, $e/\mu+ \geq 4$ jets, ≥ 2 b-tags

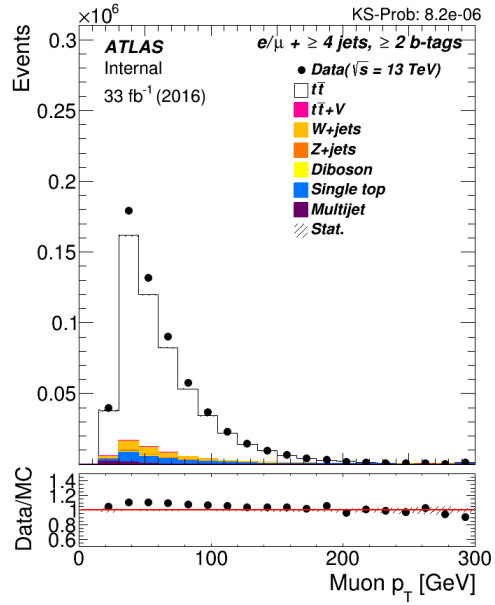








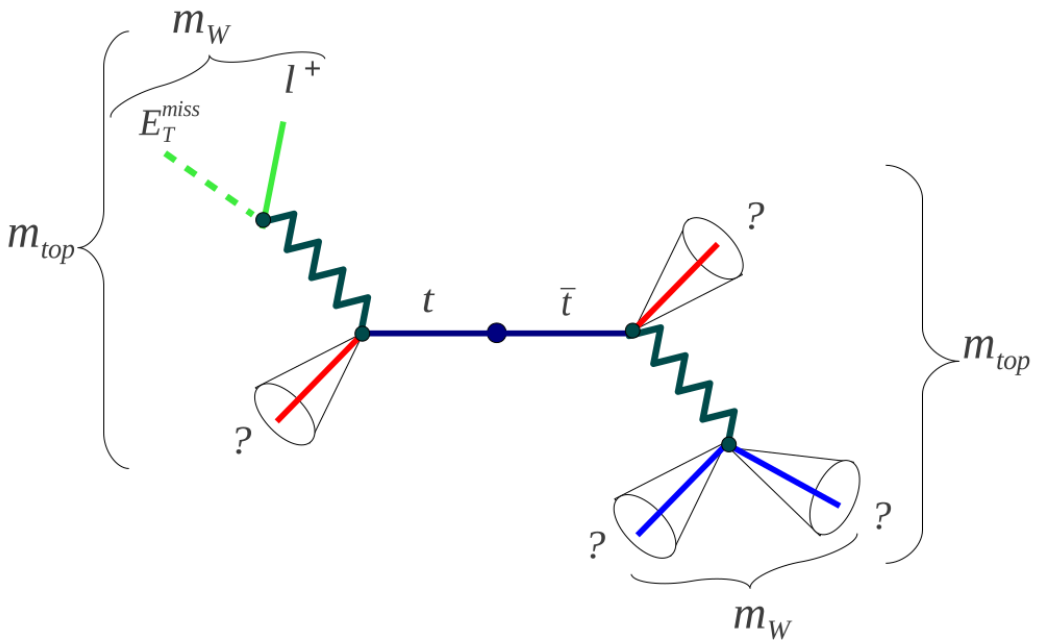




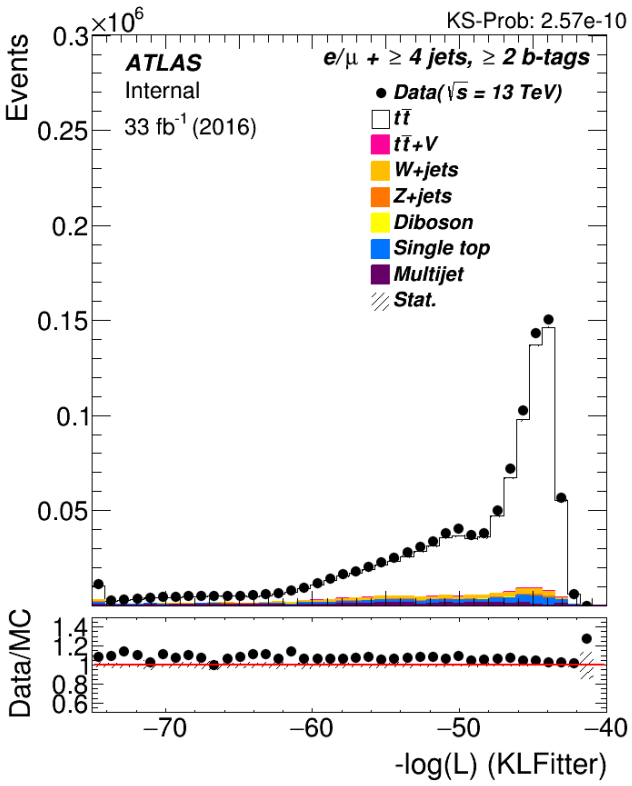
Event reconstruction

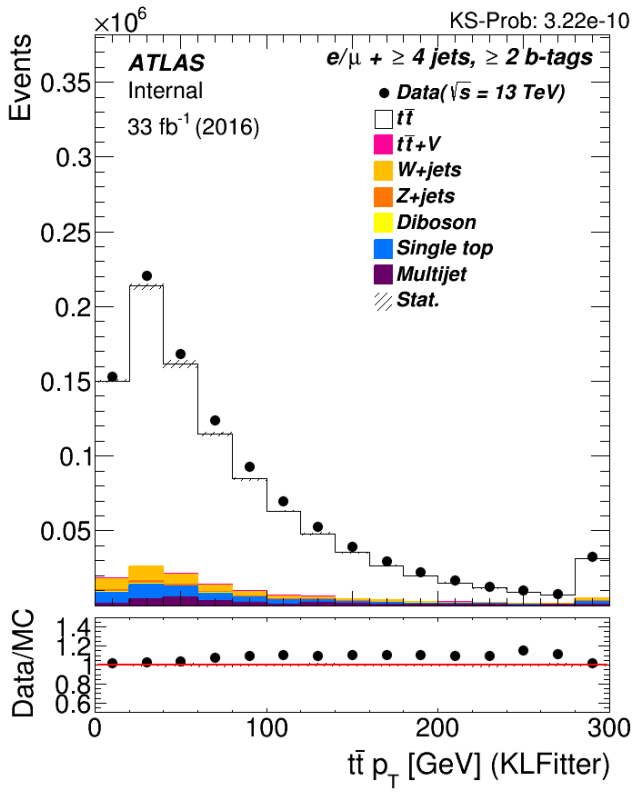
- 4 jet event $\Rightarrow$ 24 possible jet-parton assignments
- 12 permutations left since light jets from W-boson are indistinguishable
- Kinematic Likelihood fit with KLFitter ▸ arXiv:1312.5595
- KLFitter input: charged lepton, missing E_T and up to four jets

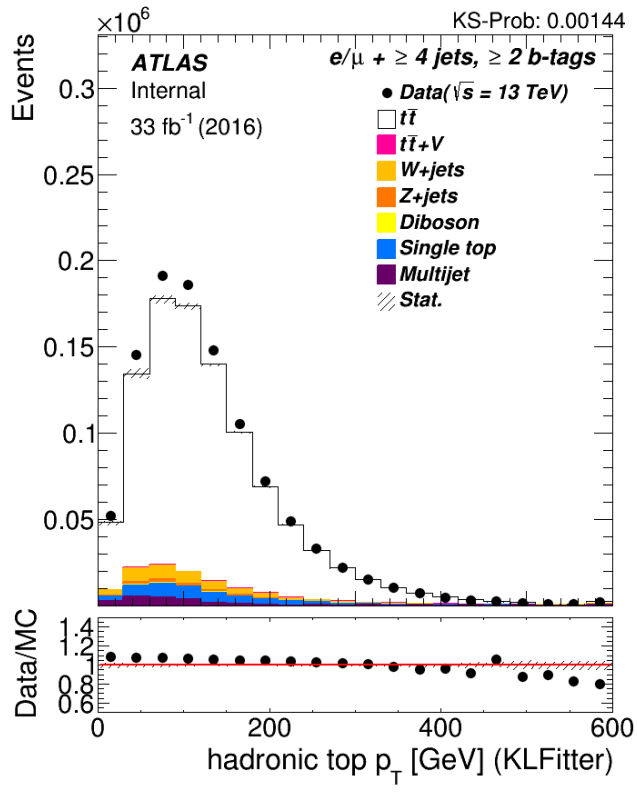
  $\Rightarrow$ **choose best permutation for calculation**



KLFitter Data/MC 2016 , 33 fb^{-1}, $e/\mu+ \geq$ 4 jets, $\geq$ 2 b-tags







How is the top-quark mass measured?

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 tt-final state

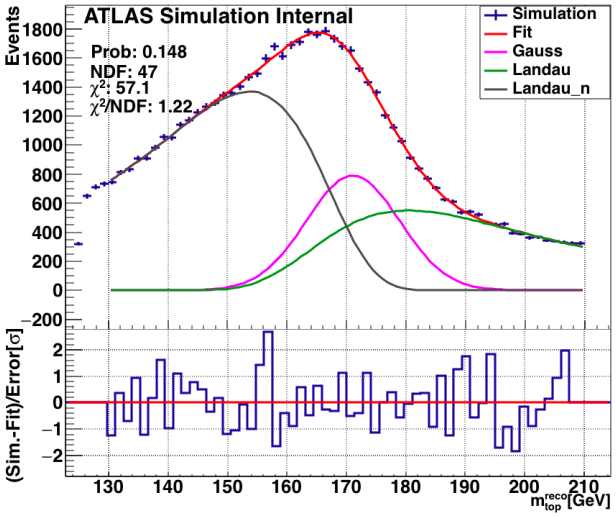
- variable 1: m_{top}^{reco} from reconstructed events
- variable 2: m_{W}^{reco} from chosen jet permutation, sensitive to JSF
- variable 2: R_{bq}^{reco} from chosen jet permutation, sensitive to bJSF

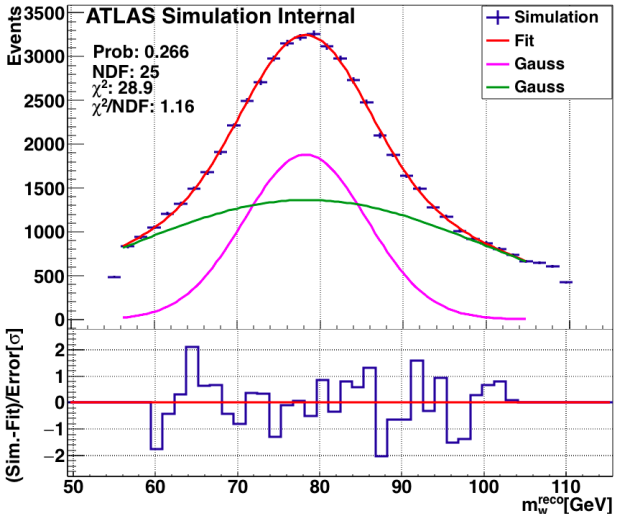
$$R_{bq}^{reco,1b} = \frac{p_T^{b_{tag}}}{(p_T^{W_{jet1}} + p_T^{W_{jet2}})/2} \qquad R_{bq}^{reco,2b} = \frac{p_T^{b_{had}} + p_T^{b_{lep}}}{p_T^{W_{jet1}} + p_T^{W_{jet2}}}$$

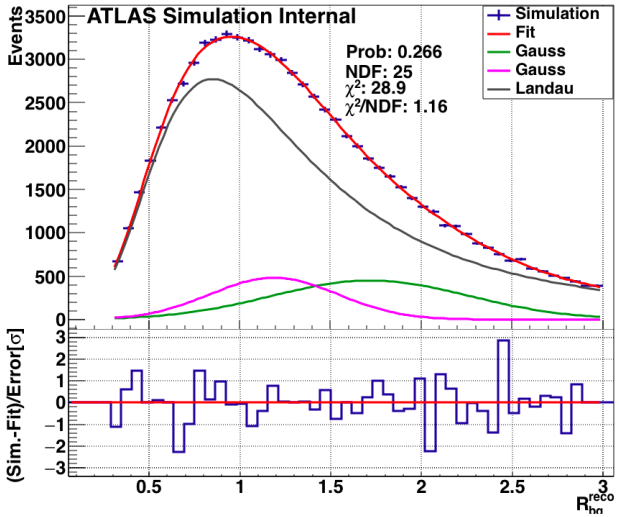
Determination of m_{top} :

- template parametrization of the 3 variables
- unbinned likelihood fit is performed

Signal templates $t\bar{t}$, 172.5 GeV







Fit (signal)

- m_{top}^{reco}: gauss+ landau + landau^{-1}
- m_{W}^{reco}: gauss + gauss
- R_{bq}^{reco}: gauss + gauss + landau

Settings

- 5 mass points from 170-175 GeV
- JSF = 0.96-1.04
- bJSF = 0.96-1.04

Summary & Outlook

Current status

- established event selection and reconstruction with 13 TeV samples

  $\Rightarrow$ data MC agreement: good for four jets one tag inclusive, except for b-tagging multiplicity, worse agreement for four jets, two b-tagged inclusive

- implemented the template parametrisation for several $t\bar{t}$ signal samples

  $\Rightarrow$ good description by the chosen functions, fit converge for all m_{top}

Next steps

- include single top production into the signal parametrization
- check closure & system. unc. with unbinned Likelihood fit

Backup

Object definition for 2016 data

Electrons

- E_T >27 GeV, $|\eta|$<2.47
- Gradient isolation, TightLH
- HLT_e26_lhtight_nod0_ivarloos, HLT_e60_lhmedium_nod0, HLT_e140_lhloose_nod0

Muons

- E_T >27 GeV, η <2.47
- Medium, Gradient isolation
- HLT_mu26_ivarmedium, HLT_mu50

Small-R jets

- antiKt R = 0.4, EM-Jets
- JVT >0.59 for p_T < 60GeV and $|\eta|$<2.4
- b-tagging: MV2_c10, 77% WP

MET/MTW

- E_T^{miss} > 20GeV
- $E_T^{miss} + m_T^W$ > 60GeV

AnalysisTop-02-04-24, with 25 fb-1 for 2016 data ▸ Top Mass Ntuple production

Reconstruction with KLFitter

- Definition of kinematic Likelihood:
  - W: transfer functions for detector response
  - BW:Breit-Wigner distributions
  - different options to use b-tagging information

Likelihoodfunction

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