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

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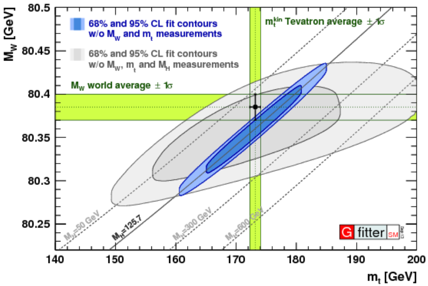
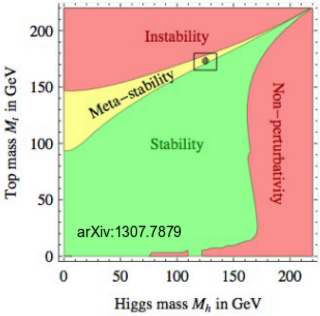
ATLAS EXPERIMENT

TECHNISCHE UNIVERSITÄT MÜNCHEN

Why measuring the top-quark mass?





- Heaviest particle of the Standard Model (SM)
- Top mass is close to electroweak symmetry breaking scale
- Significant contribution to radiative corrections
- Important for physics beyond the SM
- Important for the stability of our universe

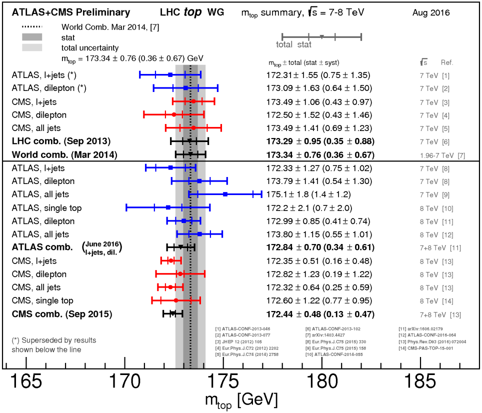
Previous results

World Comb. value (2014):

- $m_{top} = 173.34 \pm 0.76$ GeV

l+jets measurements with 3D-template method:

- 7 TeV (ATLAS):
  - ▸ Top Mass Ntuple production



How the Data is taken?

How is the top-qark mass measured?

Measurement is based on a 3D-Template method:

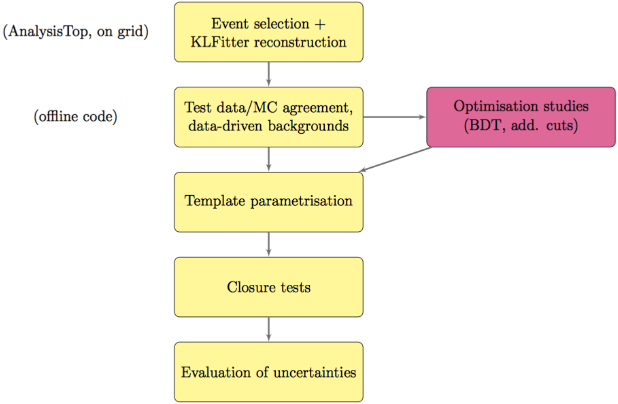
- Variable 1: m_{top}^{reco} from reconstructed Events
- Variable 2: m_{W}^{reco} from chosen jet permutation, sensitive to JSF
- Variable 2: R_{bq}^{reco} from chosen jet permutation, sensitive to bJSF

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

Determination of m_{top} :

- Need fully reconstruction of $t\bar{t}$-finale state
- Template parametrisation of the 3 variables
- Unbinned likelihood fit is performed

Workflow



1.png

Pre-selection

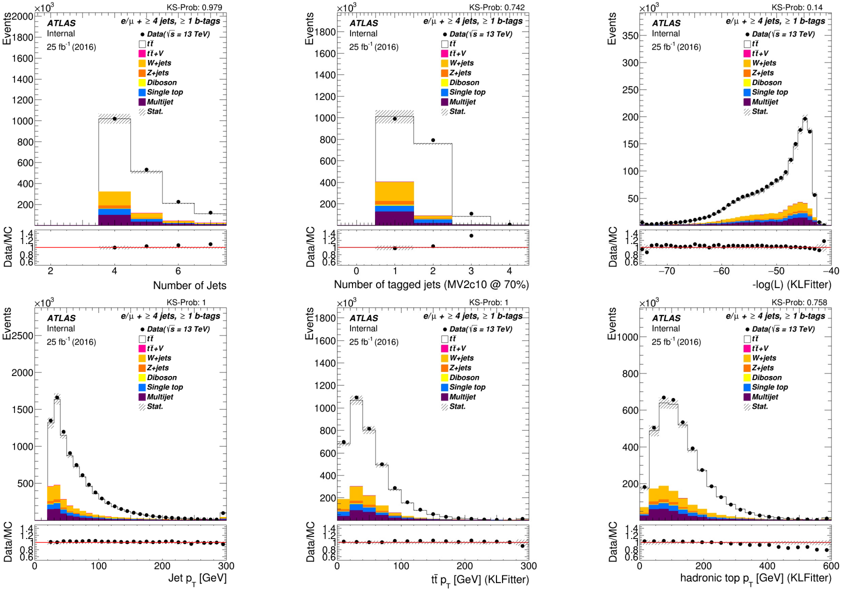
- At least one good primary vertex with five associated tracks
- Exactly one isolated high p_T lepton
- At least 4 central jets with highp_T
- 1 or 2 b-tagged jets
- Cuts on E_T^{miss} , m_T^W or $E_T^{miss} + m_T^W$
- W+jets normalization and HF fraction estimated from data
- Multijet background obtained from data in control region

Event yields after pre-selection

	One b-tagged jet	Two $b-$tagged jets	1+2 b-tagged jets
Data	168417	96105	264522
$t\bar{t}$ signal	121900 $\pm$ 7400	85100 $\pm$ 5500	207000 $\pm$ 12000
Single-top-quark signal	9300 $\pm$ 500	4220 $\pm$ 250	13490 $\pm$ 730
NP/fake leptons (data)	7400 $\pm$ 3700	700 $\pm$ 350	8100 $\pm$ 4100
W+jets (data)	23600 $\pm$ 7200	2780 $\pm$ 850	26000 $\pm$ 8000
Z+jets	3500 $\pm$ 1100	430 $\pm$ 130	4000 $\pm$ 1200
WW/WZ/ZZ	1033 $\pm$ 49	63.0 $\pm$ 6.1	1097 $\pm$ 53
Signal+background	168000 $\pm$ 11000	93300 $\pm$ 5500	260000 $\pm$ 15000
Expected background fraction	0.21 $\pm$ 0.07	0.04 $\pm$ 0.06	0.15 $\pm$ 0.06
Data/(Signal+background)	1.01 $\pm$ 0.07	1.03 $\pm$ 0.06	1.02 $\pm$ 0.06

- Background contamination dominated by W + Jets
- Mass dependence of single-top $\Rightarrow$ include in signal
- Reduction of background via cuts on 2 b-tagged jets
- **Good Data/MC agreement**

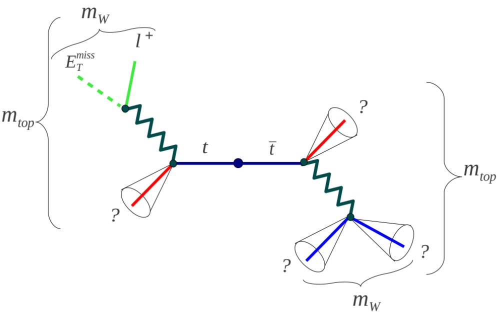
Data/MC agreement



$t\bar{t}$-final state

- 4 jet event $\Rightarrow$ 24 possible jet-parton assignments
- 12 permutations left since light jets from W are indistinguishable
- Kinematic liklihood fit with KLFitter

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



Reconstruction with KLFitter

- KLFitter input: charged lepton, missing E_T and at least four jets

  $\Rightarrow$ one or two b-tagged jets + untagged jets with highest p_T

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

Likelihoodfunction

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

3D-template technique

- Simultaneous determination of m_{top}, JSF and $bJSF$

  $\Rightarrow$ $JES/bJES$ uncertainties, become an additional statical component

- Templates are derived for m_{top}^{reco}, m_{top}^{reco} from MC samples

- Construct templates as function of m_{top}, JSF and $bJSF$ for signal and background

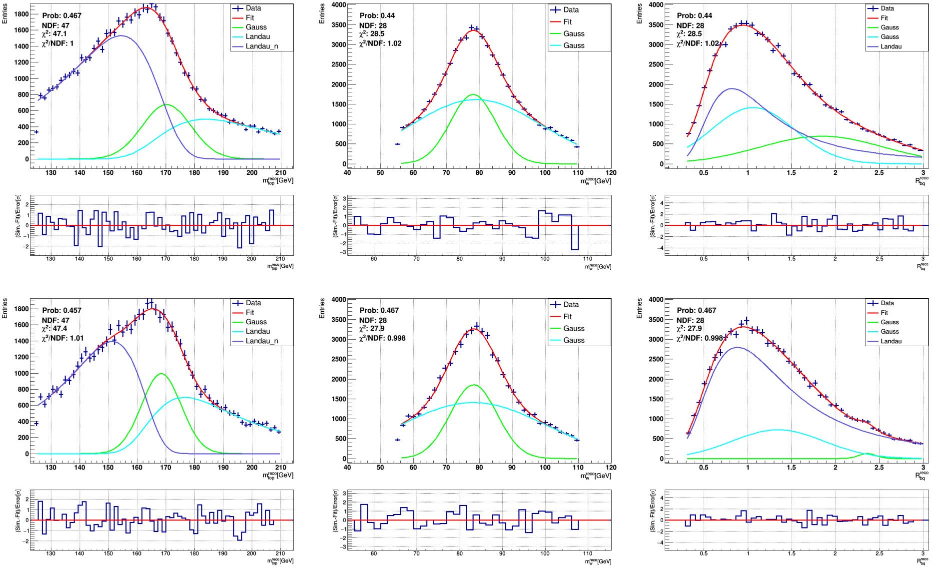
Fit (signal)

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

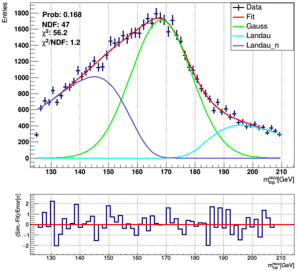
Settings

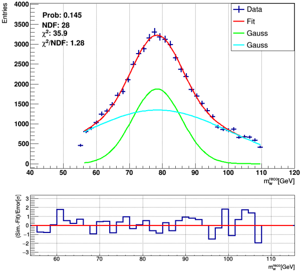
- $m_{top} \in \{170, 171.5, 173.5, 175\}$ GeV
- $JSF = 0.96 - 1.04$
- $JSF = 0.96 - 1.04$

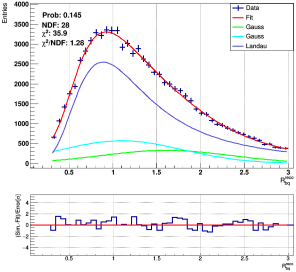
Signal $t\bar{t}$ only, 170 GeV & 171.5 GeV

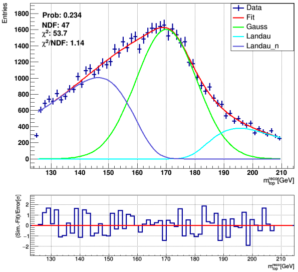


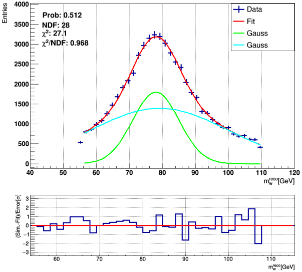
Signal $t\bar{t}$ only, 173.5 GeV & 175 GeV

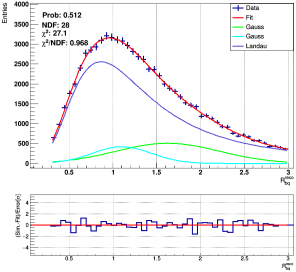












Parameter interpolation & Likelihoodfit

- Single top contains additional information $\Rightarrow$ add to signal

  $\Rightarrow$ **dependences of** $m_{top}^{reco}, m_{top}^{reco}$ **and** R_{bq}^{reco} **on** $mtop, JSF\, bJSF$

- Finally, an unbinned likelihood to the observed data distribution is performed to determine the physics parameter

$$
\begin{aligned}
L_{\mathrm{shape}}^{l+\mathrm{jets}}(m_{\mathrm{top}}, \mathrm{JSF}, \mathrm{bJSF}, f_{\mathrm{bkg}}) = \prod_{i=1}^{N} & P_{\mathrm{top}}(m_{\mathrm{top}}^{\mathrm{reco,i}} \mid m_{\mathrm{top}}, \mathrm{JSF}, \mathrm{bJSF}, f_{\mathrm{bkg}}) \\
& \times P_{\mathrm{W}}(m_{\mathrm{W}}^{\mathrm{reco,i}} \mid \mathrm{JSF}, f_{\mathrm{bkg}}) \\
& \times P_{\mathcal{R}_{\mathrm{bq}}}(R_{\mathrm{bq}}^{\mathrm{reco,i}} \mid m_{\mathrm{top}}, \mathrm{bJSF}, f_{\mathrm{bkg}}),
\end{aligned}
$$

- Verification of the internal fitting consistency via pseudo-experiments
- Optimization of the analysis to reject combinatorial background

Summery & outlook

Current status

- Did several vent 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 into the signal fits
- Perform the fit for all JSF and $bJSF$
- Use probability density functions for m_{top}^{reco}, m_{W}^{reco} and R_{bq}^{reco} in unbinned likelihood fit to the data for all events

Backup

Object definition for 2016 data

Electrons

- E_T >28 GeV, $|\eta|$<2.47
- Gradient isolation, TightLH
- HLT_e26_lhtight_nod0_ivarloos, HLT_e60_lhmedium_nod0, HLT_e140_lhloose_nod0

Muons

- E_T >28 GeV, η <2.47
- Medium, Gradient isolation
- HLT_mu26_ivarmedium, HLT_mu50

Small-R jets

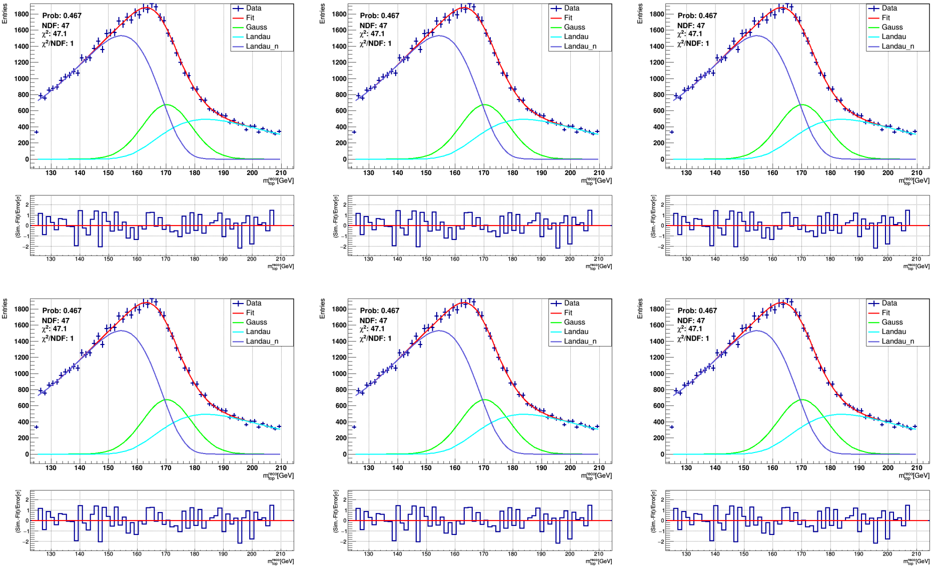
- antiKt R = 0.4, EM-Jets
- JVT >0.59 for $p_T < 60$GeV and $|\eta|$<2.4
- b-tagging: MV2_c10, 77% WP

MET/MTW

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

AnalysisTop-02-04-27, with 25 fb-1 for 2016 data Top Mass Ntuple production

Signal templates $t\bar{t}$ only for 173.5 GeV & 175 GeV



Template fit functions

$$L_{\text{shape}}^{l+\text{jets}}(m_{\text{top}}, \text{JSF}, \text{bJSF}, f_{\text{bkg}}) = \prod_{i=1}^{N} P_{\text{top}}(m_{\text{top}}^{\text{reco,i}} \mid m_{\text{top}}, \text{JSF}, \text{bJSF}, f_{\text{bkg}})$$
$$\times P_{\text{W}}(m_{\text{W}}^{\text{reco,i}} \mid \text{JSF}, f_{\text{bkg}})$$
$$\times P_{\mathcal{R}_{\text{bq}}}(R_{\text{bq}}^{\text{reco,i}} \mid m_{\text{top}}, \text{bJSF}, f_{\text{bkg}}),$$

$$P_{\text{top}}(m_{\text{top}}^{\text{reco,i}} \mid m_{\text{top}}, \text{JSF}, \text{bJSF}, f_{\text{bkg}}) = (1 - f_{\text{bkg}}) \cdot P_{\text{top}}^{\text{sig}}(m_{\text{top}}^{\text{reco,i}} \mid m_{\text{top}}, \text{JSF}, \text{bJSF}) +$$
$$f_{\text{bkg}} \cdot P_{\text{top}}^{\text{bkg}}(m_{\text{top}}^{\text{reco,i}} \mid \text{JSF}, \text{bJSF}) \;,$$
$$P_{\text{W}}(m_{\text{W}}^{\text{reco,i}} \mid \text{JSF}, f_{\text{bkg}}) = (1 - f_{\text{bkg}}) \cdot P_{\text{W}}^{\text{sig}}(m_{\text{W}}^{\text{reco,i}} \mid \text{JSF}) +$$
$$f_{\text{bkg}} \cdot P_{\text{W}}^{\text{bkg}}(m_{\text{W}}^{\text{reco,i}} \mid \text{JSF}) \;,$$
$$P_{\mathcal{R}_{\text{bq}}}(R_{\text{bq}}^{\text{reco,i}} \mid m_{\text{top}}, \text{bJSF}, f_{\text{bkg}}) = (1 - f_{\text{bkg}}) \cdot P_{\mathcal{R}_{\text{bq}}}^{\text{sig}}(R_{\text{bq}}^{\text{reco,i}} \mid m_{\text{top}}, \text{bJSF}) +$$
$$f_{\text{bkg}} \cdot P_{\mathcal{R}_{\text{bq}}}^{\text{bkg}}(R_{\text{bq}}^{\text{reco,i}} \mid \text{bJSF}) \;.$$