Top properties (m_{top} and W-hel.) in the semileptonic channel with Template and Matrix-Element Methods at ATLAS

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GEFÖRDERT VOM
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1. Statistical tools
2. Top mass studies
   - The Template Method
   - The Matrix-Element Method
3. W-Helicity studies
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4. Conclusion and outlook

Statistical tools

BAT - A Bayesian Analysis Toolkit

- developed in Göttingen, Munich and CERN
- stand-alone package (only dependent on ROOT)
- based on Markov Chain Monte Carlo (MCMC)
- estimation of parameters and errors
- performing a goodness-of-fit test

KLFitter

- perform a kinematic likelihood fit (Minuit, MCMC)
- find the best of 12 solutions
- provides fit parameters and errors
- note in preparation: ATL-COM-PHYS-2009-551

arXiv:0808.2552v1 [physics.data-an]

The Template Method

Procedure:

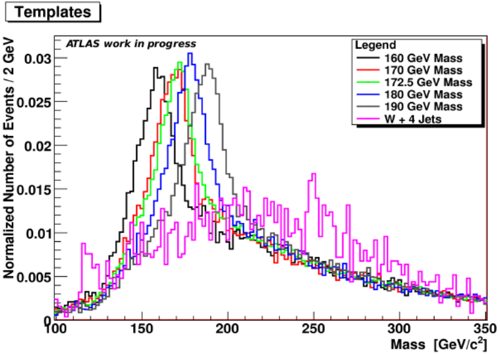
- Goal: Use Template Method tool (written by S. Guindon) to estimate top mass from first data
- Templates: ATLFastII samples (m_{top} = 160, 170, 172.5, 180 and 190 GeV)
- Use likelihood fit to determine the most likely combination
- background samples: W+4jets

Preselection:

- medium electron with $p_T > 15$ GeV and $\eta < 2.47$ (excl. crack)
- H1 Tower jets of size 0.4 with $p_T > 15$ GeV and $|\eta| < 2.5$
- overlap removal of jet if Δ R(e, jet) < 0.2

m_{top} [GeV]	160	170	172.5	180	190	W+4jets
Pre-selection	1.0	1.0	1.0	1.0	1.0	1.0
Electron with $p_T > 20$ GeV/c and $\|\eta\| < 2.5$	0.89	0.88	0.88	0.88	0.88	0.93
3 jets with $p_T > 40$ GeV/c 1 jet with $p_T > 20$ GeV/c and $\|\eta_{jet}\| < 2.5$	0.32	0.36	0.37	0.40	0.44	0.13
$E_T^{miss} \geq 20$ GeV	0.28	0.32	0.33	0.36	0.39	0.11
1 matched el. with Δ R ≤ 0.3	0.28	0.32	0.32	0.35	0.39	-
4 matched q with Δ R ≤ 0.3	0.06	0.07	0.07	0.08	0.10	-

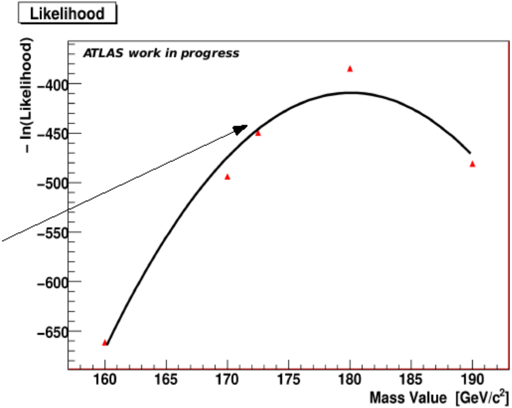
- Created using KLFitter with m_{top} as a free parameter
- W+jets sample: low statistics due to failing of minimization of KLFitter → fixed now!



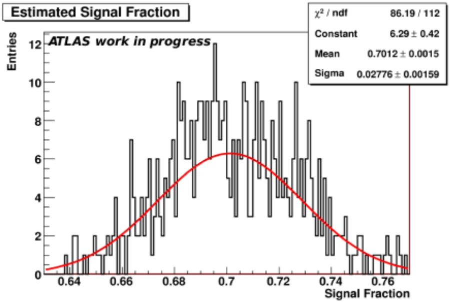
Calculate the likelihood using BAT

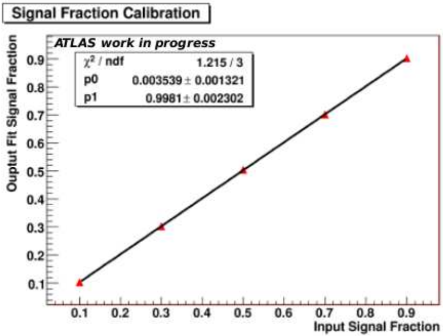
Use signal fraction as a free parameter:

- estimation of signal fraction and top mass
- limited number of data points
  ⇒ bias due to fit
- neighbouring points are more than a standard deviation away from the maximum
  ⇒ need more templates!



- Measurement of signal fraction from the Likelihood
- Input Signal fraction: 0.7 →

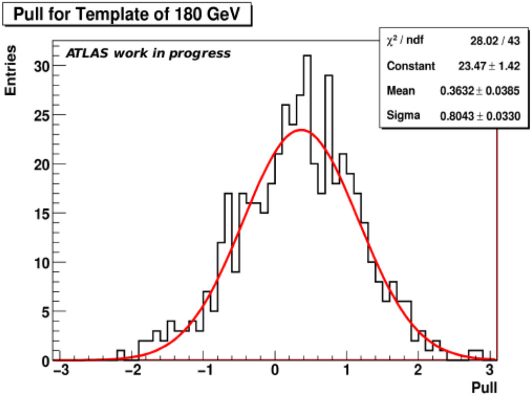




← Test of many different signal fractions.

Method check: pull distribution

- large separation of points
  $\Rightarrow$ large pull
- solution:
  use a parametrization of our templates
- then:
  extrapolation between points is possible



The Matrix-Element Method

Top mass studies with the Matrix-Element Method

Find probability distribution for param. $\vec{\lambda}$ with given data:

$$p(\vec{\lambda}|data) = \frac{d^n\sigma(\vec{\lambda})}{\sigma(\vec{\lambda})} \quad \Rightarrow \quad -\ln L = -\sum \ln p$$

Probability density for signal based on Fermis *Golden Rule*

$$d^n\sigma \propto d^n\sigma_{hs} = \frac{(2\pi)^4|\mathscr{M}|^2}{4\sqrt{(Q_1 Q_2)^2 - m_1^2 m_2^2}} dLIPS$$

$\Rightarrow \mathscr{M} \hat{=}$ transition probability between initial and final state

The Matrix-Element Method II

Detector resolution parametrized by Transferfunctions W

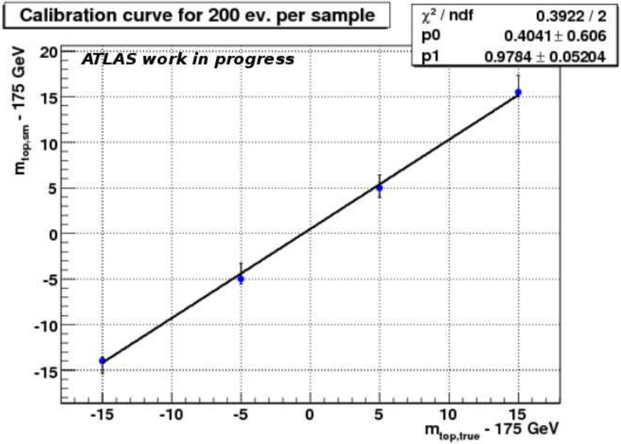
$$p_{sig}(\vec{x}; m_{top}) = \frac{1}{\sigma(m_{top})} \int d\vec{y} d^n\sigma_{m_{top}}(\vec{y}; m_{top}) W(\vec{x}, \vec{y})$$

$$d\sigma_{m_{top}}(\vec{y}; m_{top}) = \underbrace{\int d^n\sigma_{hs} dx_1 dx_2 f(x_1) x_1 f(x_2) x_2}_{\text{Convolution with PDFs}}$$

Here: just a "Proof of principle"

- tests on LO-level (signal only, $gg \rightarrow t\bar{t}$, electron channel)
- Madgraph-MC smeared according to ATLAS-resolution (double-Gaussians)
- tests with global JES: apply a multiplicative factor
- integration is done with Markov Chain Monte Carlo (BAT)

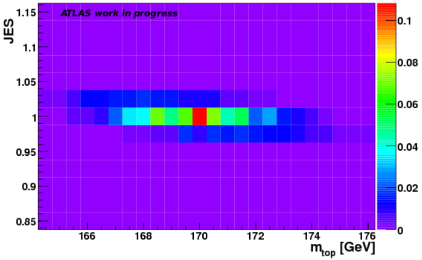
Calibration curve for 200 events (smeared LO MC)

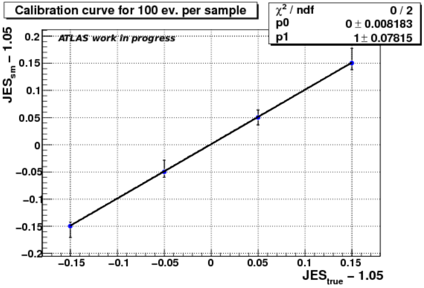


⇒ Method provides an unbiased estimator for the top quark mass

Studies with global JES:

- scale four-vectors with constant factor JES
- in analysis: $W(E_{true}, \frac{E_{meas}}{JES})/JES$



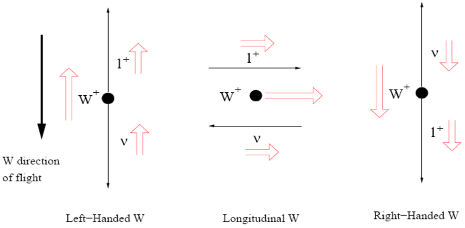


Used samples:

- $m_{top} = 170$ GeV/c^2
  JES = 0.8, 0.9, 1.0, 1.1
- 100 events per sample

binning too large
$\Rightarrow \chi^2 = 0$

W-helicity in the SM



Helicity fractions in SM:

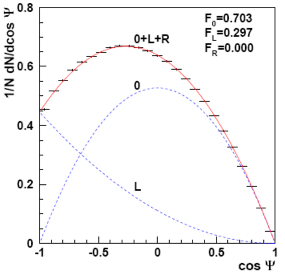
- longitudinal: $F_0 \approx 0.7$
- right-handed: $F_R \propto 10^{-4}$
- left-handed: $F_L \approx 0.3$

→ $\cos\Theta^* \hat{=} \cos$ (angle(b, $l^{\pm}$)) in W rest frame

→ angular distribution:

$$\frac{dN}{Nd\cos\theta*} = \frac{3}{2}\left(F_0\left(\frac{\sin\theta^*}{\sqrt{2}}\right)^2 + F_L\left(\frac{1-\cos\theta^*}{2}\right)^2 + F_R\left(\frac{1+\cos\theta^*}{2}\right)^2\right)$$

⇒ $\cos\Theta^*$ is one possible spin analyzer



W-Helicity studies using templates - signal only

Datasets from Protos-MC

- 1 SM dataset ($m_{\text{top}} = 172.5$ GeV, $\sqrt{s} = 10$ TeV)
- 3 datasets with $F_i = 1.0$
- produce templates by reweighting

↓

Samples are private production from Nuno Castro (Univ. of Granada)

↓

Official samples will be produced soon!

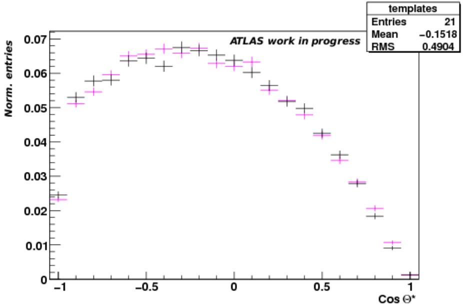
Event Selection (CSC-like):

1. cut on truth-level: no taus
2. 1 recon. lepton:
   - isolated electron, excl. crack:
   - $p_T > 20$ GeV, $|\eta| < 2.5$
   - isolated muon, $p_T > 20$ GeV, $|\eta| < 2.5$
   - remove muons overlapping with jets within $\Delta R < 0.3$
3. MET > 20 GeV
4. ≥ 3 jets with $p_T > 40$ GeV, $|\eta| < 2.5$
5. ≥ 4 jets with $p_T > 20$ GeV, $|\eta| < 2.5$ + remove jets overlapping with electrons within $\Delta R < 0.2$

W-Helicity studies using templates - signal only

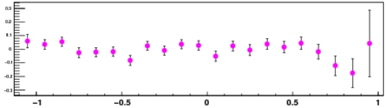
Analysis procedure

- make event selection described before (only for $e^{\pm}$)
- event reconstruction with a kinematic likelihood fitter (KLFitter)
  $\rightarrow$ Talk by Johannes Erdmann
- use best combination for reconstruction
- make templates $\rightarrow$ template fits



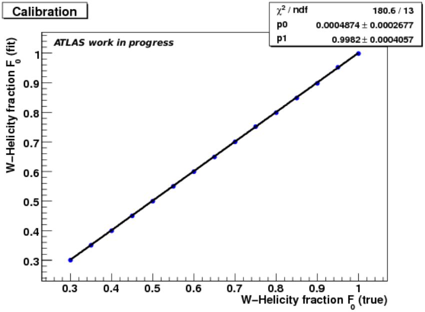
Angular distr. with true values: $\longrightarrow$

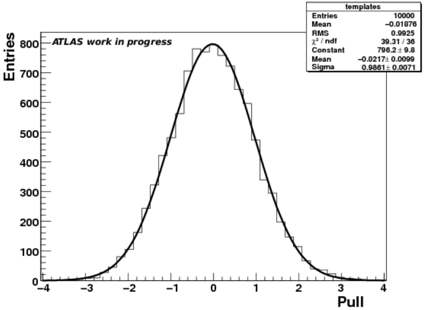
- black points: SM results
- pink points:
  reweighted samples with $F_i = 1$
  $\Rightarrow$ samples consistent within errors



First template fits

- 15 templates produced
  $\Rightarrow F_R = 0$
- 10,000 ensembles used
- Gaussian fit to distributions





- more templates used
  $\Rightarrow$ Pull only small

Conclusion and outlook: m_{top}

Conclusion

- template fitter allows to calculate any value, the signal fraction and corresponding errors
- Pull is too large (small number of templates)
- ME-Method provides an unbiased estimator for m_{top} and JES

Outlook

- Template Method:
  - more templates are needed: make a parametrization
  - if everything works: study b-tagging
- ME-Method:
  - apply matrix element method to NLO MC
  - in-situ calibration with light-JES and b-JES
  - include matrix element for background
  - include matrix element for $q\bar{q} \rightarrow t\bar{t}$

Conclusion and outlook: W - Helicity

Conclusion

- template method works on W-Helicity
- template method only a first test

Outlook

- Template Method:
  - include background templates
  - make multidimensional fit (F_0, F_L, F_R and f_{Sig})
- Matrix-Element Method:
  - apply Matrix-Element Method
    $\Rightarrow$ powerful tool for measurement of helicity fractions
  - ME-Method is very precise $\longrightarrow$ important for low statistics