Studies for a top quark mass measurement in the dilepton channel using the m_{T2} variable

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Method description

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- Select an observable which depends on the top mass
- Create a calibration curve from Monte-Carlo simulation samples with different top mass input
- Measure the chosen observable in data and obtain the top mass from the calibration curve
- Consider systematic uncertainties

Standard dilepton events selection

Standard dilepton events selection highlights

- Exactly two oppositely-charged leptons
- Electrons must satisfy $p_T > 25\ \mathrm{GeV}$, while muons must satisfy $p_T > 20\ \mathrm{GeV}$
- All leptons must satisfy $|\eta| < 2.5$
- At least two jets with $p_T > 25\ \mathrm{GeV}$ and $|\eta| < 2.5$
- For ee and $\mu\mu$ channels: $E_T^{miss} > 60\ \mathrm{GeV}$ and $|m_{\ell\ell} - m_Z| > 10\ \mathrm{GeV}$
- For $e\mu$ channel: $H_T > 130\ \mathrm{GeV}$

The m_{T2} variable

m_{T2} (stransverse mass)

- Formal definition[1]:

$$m_{T2} = \min_{\vec{p}_T^{(1)},\, \vec{p}_T^{(2)}} \left[\max\left[m_T(m_i, \vec{p}_T^{(1)}), m_T(m_i, \vec{p}_T^{(2)}) \right] \right]$$

- with:

$$\vec{p}_T^{(1)} + \vec{p}_T^{(2)} = \vec{p}_T^{miss}$$

$$m_T(m_i, \vec{p}_T) = \sqrt{m_v^2 + m_i^2 + 2(E_T^v E_T^i - \vec{p}_T^v \cdot \vec{p}_T)}$$

- where the i subscript stands for invisible particles and the v subscript stands for visible particles.

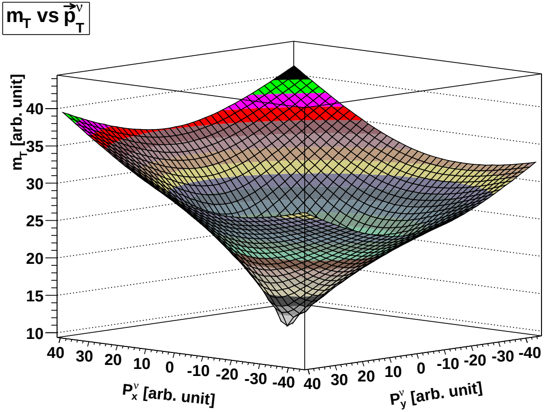
[1] C. Lester, D. Summers, Phys. Lett. B 463:99-103, 1999

m_{T2} (stransverse mass)

- Used in events with two missing particles
- Represents a lower bound for the parent particle mass
- For top dilepton:

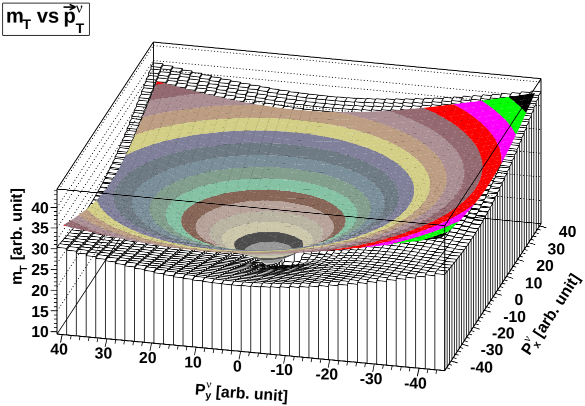
$$m_T(m_i, \vec{p}_T^{(i)}) \approx m_T(0, \vec{p}_T^{\nu_i}) = \sqrt{m_{b\ell}^2 + 2(E_T^{b\ell}\|\vec{p}_T^{\nu_i}\| - \vec{p}_T^{b\ell} \cdot \vec{p}_T^{\nu_i})}$$

m_T dependence on $\vec{p}_T^{\,\nu}$



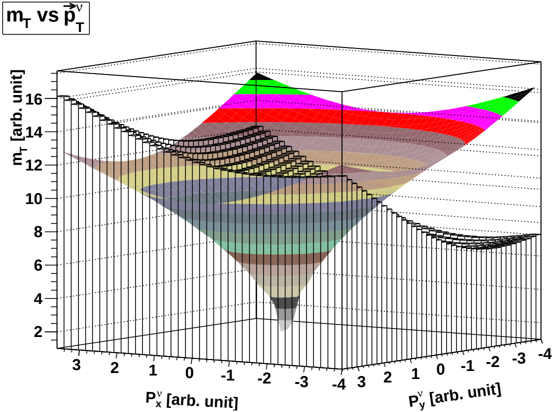
$$m_T(0, \vec{p}_T^{\,\nu}) = \sqrt{m_{b\ell}^2 + 2(E_T^{b\ell}\|\vec{p}_T^{\,\nu}\| - \vec{p}_T^{\,b\ell} \cdot \vec{p}_T^{\,\nu})}$$

m_{T2} (no m_T intersection)



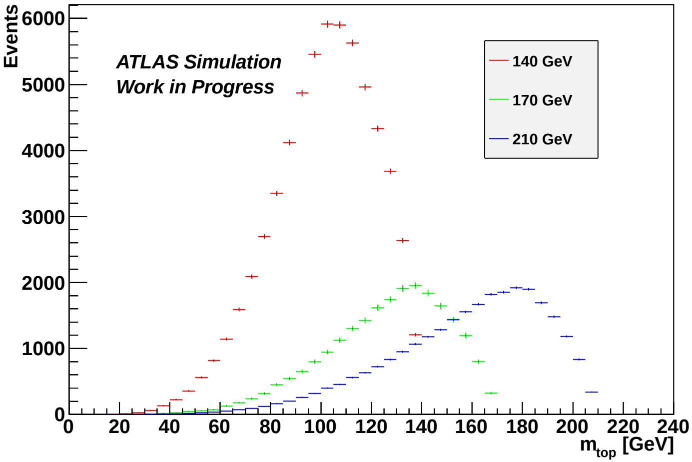
$$m_{T2} = \min_{\vec{p}_T^{\nu 1},\, \vec{p}_T^{\nu 2}} \left[\max \left[m_T(0, \vec{p}_T^{\nu 1}), m_T(0, \vec{p}_T^{\nu 2}) \right] \right]$$

m_{T2} (with m_T intersection)

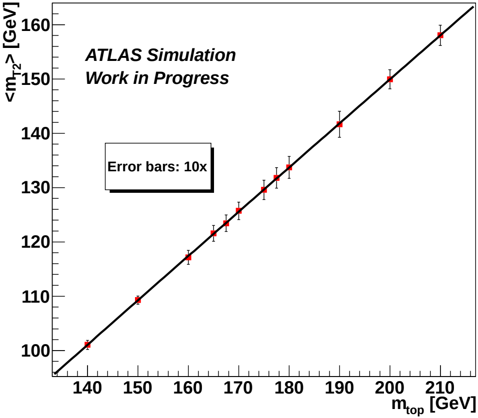


$$m_{T2} = \min_{\vec{p}_T^{\nu 1}, \vec{p}_T^{\nu 2}} \left[\max \left[m_T(0, \vec{p}_T^{\nu 1}), m_T(0, \vec{p}_T^{\nu 2}) \right] \right]$$

m_{T2} distributions for different input masses (Truth)



Calibration curve[2] (Truth)



[2]Second order polynomial fit

Systematic uncertainty

Systematic uncertainties

- Based on ATLAS top reconstruction group's final recommendations for release 16
- Main contributions to systematic uncertainties (More than 0.5 GeV):
  - Jet energy scale, b-jet energy scale, and pileup
  - Initial and final state radiation
  - Fake leptons estimation
  - MC generator (MC@NLO vs POWHEG) + HERWIG

Optimization cuts

- m_{T2}:
  - The leading lepton must satisfy $p_T > 40\ \mathrm{GeV}$
  - The sub-leading lepton must satisfy $p_T > 25\ \mathrm{GeV}$
  - The event must satisfy $U_T < 60\ \mathrm{GeV}$
  - The event must satisfy $m_{T2} < 220\ \mathrm{GeV}$

where:

$$U_T = \|\vec{p}_T^{(lep1)} + \vec{p}_T^{(lep2)} + \vec{p}_T^{(jet1)} + \vec{p}_T^{(jet2)} + \vec{p}_T^{miss}\|$$

Additional measurement

- Problem: The optimization cuts have little effect in the jet energy scale systematic uncertainty
  - Solution: Make an additional measurement with $\langle\, p_T^{(leptons)} \rangle$:

$$p_T^{(leptons)} = \|\vec{p}_T^{(lep1)} + \vec{p}_T^{(lep2)}\|$$

Measurement combination

The measurements are merged using the least squares method:

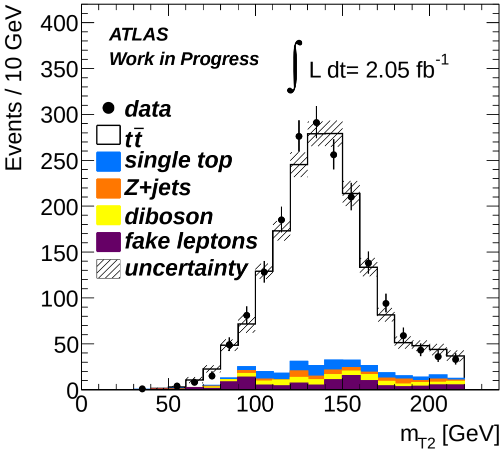
$$m_{comb} = wm_1 + (1 - w)m_2$$

$$w = \frac{\sigma_2^2 - \rho\sigma_1\sigma_2}{\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2}$$

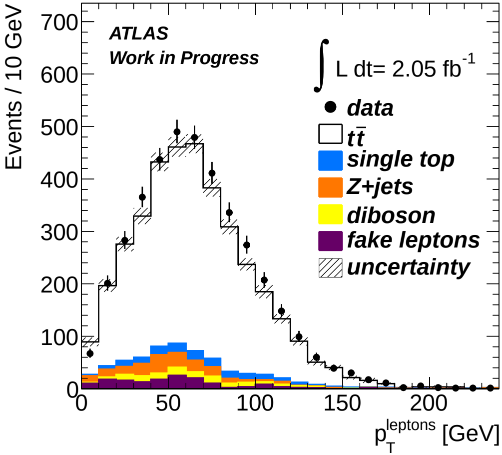
$$\sigma_{comb} = \sqrt{\frac{(1-\rho)\sigma_1^2\sigma_2^2}{\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2}}$$

Preliminary results

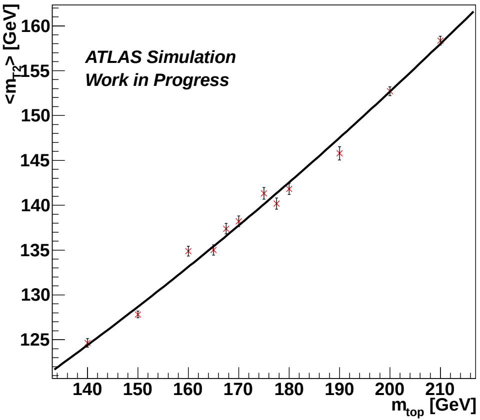
Agreement between MC and data 2 fb^{-1} (m_{T2})



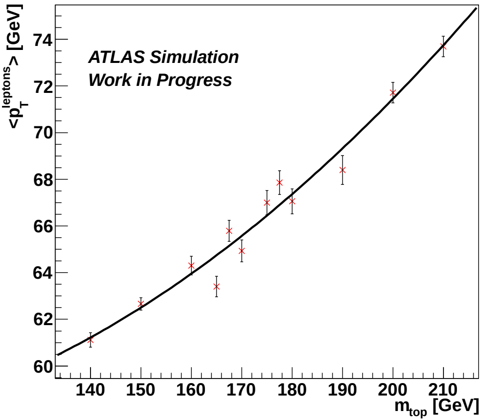
Agreement between MC and data 2 fb^{-1} ($p_T^{(leptons)}$)



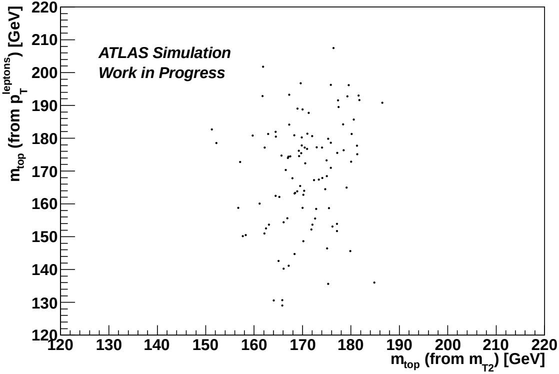
m_{T2} calibration curve (Reco)



$p_T^{(leptons)}$ calibration curve (Reco)



Correlation between the two measurements



Correlation coefficient: 0.17

Results on 2.05 fb^{-1} data[3]

All measurements in GeV	m_{T2}	$p_T^{(leptons)}$	Combined
Top mass	172.7	174.1	172.9
Stat. uncertainty	±1.4	±3.0	±1.2
Total systematic uncertainty	$^{+4.1}_{-4.6}$	$^{+3.4}_{-4.3}$	$^{+3.6}_{-4.2}$
JES^{Up}_{Down}	$^{+3.6}_{-3.6}$	$^{-2.2}_{+2.2}$	±2.8
ISR and FSR	$^{+1.4}_{-2.5}$	$^{+1.5}_{-3.1}$	$^{+1.1}_{-2.6}$
Fake leptons estimation	$^{+0.7}_{-0.1}$	$^{+1.0}_{-0.0}$	$^{+0.7}_{-0.0}$
MC Generator	±1.2	±0.4	±1.1

[3] ATLAS Work in Progress

Outlook

Outlook

- Perform optimization separately in each dilepton mode.
- Improve the calibration curve using mass variation samples with higher statistics.
- Use b-tagging
- Use stronger cuts.

Thank you!

Backup

Measurement combination

- The measurements are merged using the least squares method

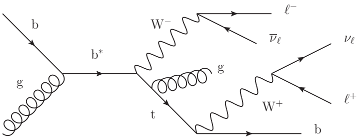
$$\chi^2(m_{comb}) = \sum_{i,j} (m_i - m_{comb})(V^{-1})_{ij}(m_j - m_{comb})$$

- For two measurements:

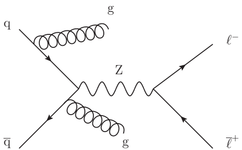
$$V = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}$$

Main background

- The main background sources are the following:
  - Single top quarks produced in electroweak interactions
  - Z-bosons with aditional jets
  - Dibosons (WW, WZ, ZZ)
  - Events with fake leptons



Single top



Z+jets