QCD background estimation for top-antitop resonances search in the lepton plus jets final state using 139 fb^{-1} of pp collisions at $\sqrt{s} = 13\,TeV$ with the ATLAS experiment at the LHC

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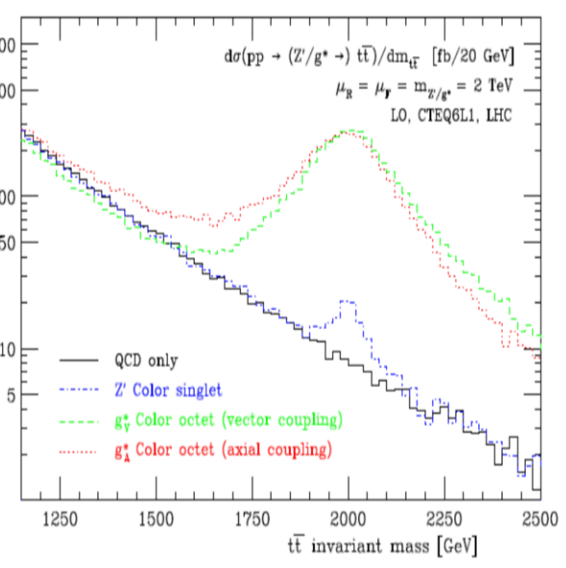
Abstract

A new approach to estimate the number of QCD back-ground events in search for new physics that produces resonances in the top-antitop mass spectrum at the LHC was developed. Due to the challenges associated with modelling of this background, the systematic and statistical uncertainties must hence be estimated from data directly. The method makes use of two models which predict the correlation of two key search variables, the missing transverse momentum E_T^{miss} and the transverse mass of the W boson variable MWT, in order to extrapolate from a QCD dominated control region to the signal region. The performance of the method was demonstrated by its application to pp collision data sample corresponding to 139 fb^{-1} of integrated luminosity collected in 2015-2017 by the ATLAS detector at the LHC with a centre-of-mass energy of 13 TeV. The improvements in the signal-to-background ratio using the variable in Monte Carlo analysis are estimated. The expected sensitivity for further refined search regions was investigated.

Motivation

o New physics in the top sector may happen in :
production, decay, association
o Most of the new physics signals in the top sector will distort mtt
- Many models predict resonances in production, for which a spectacular signature would be a peak in mtt
* Different spin states and different widths are possible :

- $t\bar{t} \rightarrow$ new scalars, ex: heavy Higgs
- new vectors: $Z'W'$ (ex: Technicolor)
- Colorons (color interaction)
- Randall-Sundrum models (RS)
- KK-excitations including gravitons (RS)



Event reconstruction and selection

- Signal signature
  - Exactly one muon with $p_T > 30$ GeV matched to Single lepton trigger
  - $E_T^{miss} > 20$ GeV and $E_T^{miss} + MWT > 60$ GeV
    $MWT = \sqrt{2 p_T(l) E_T^{miss} (1 - cos\phi_{lv})}$, where ϕ_{vl} the angle between the lepton and E_T^{miss}.
  - at least 1 b-tagging track jet
- We consdere in this work the boosted environment, on which the top-antitop system is highly energetic and the hadronic top decay products merge into a single large-radius (large-R) jet
- Background contribution to the analysis : SM $t\bar{t}$, W+jets, Z+jets, Multijets, Single top and Diboson
- To check background modelling for boosted muon channe, we build our control region (CR) by :
  - Inverting the impact parameter : $|\frac{d_0}{\sigma}| > 3$
  - Removing the cut on E_T^{miss} and $E_T^{miss} + MWT$
  - No isolation applied on Muon
- The aim of the study is to estimate the QCD contamination in the Control Region (CR) based on tightening the E_T^{miss} and $E_T^{miss} + MWT$ variables

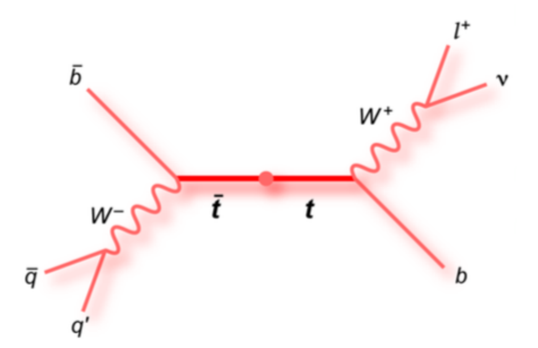


Figure 1: $t\bar{t} \rightarrow$ channel topology

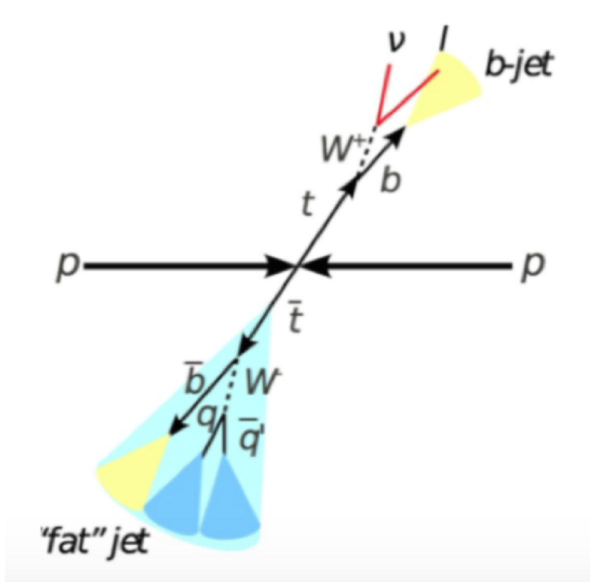
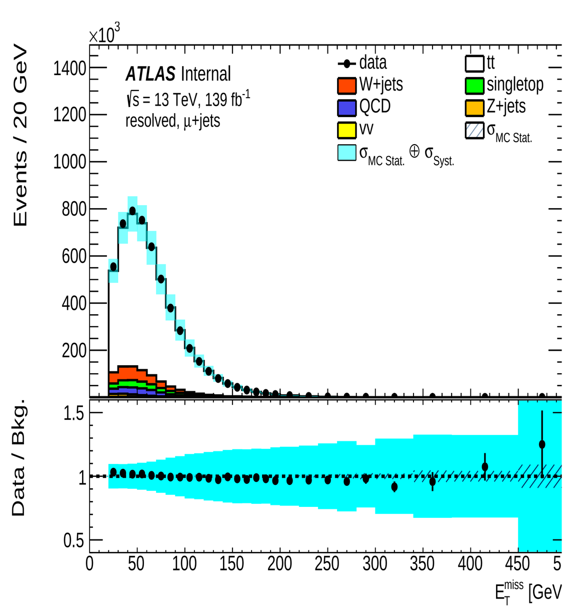
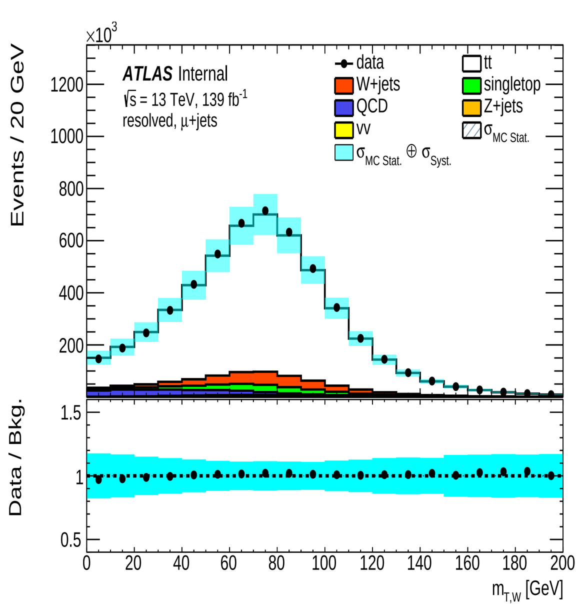
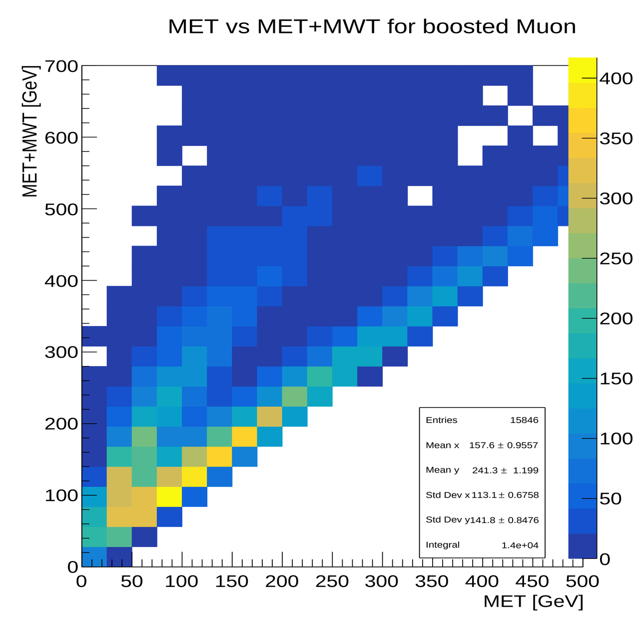


Figure 2: Boosted muon regim

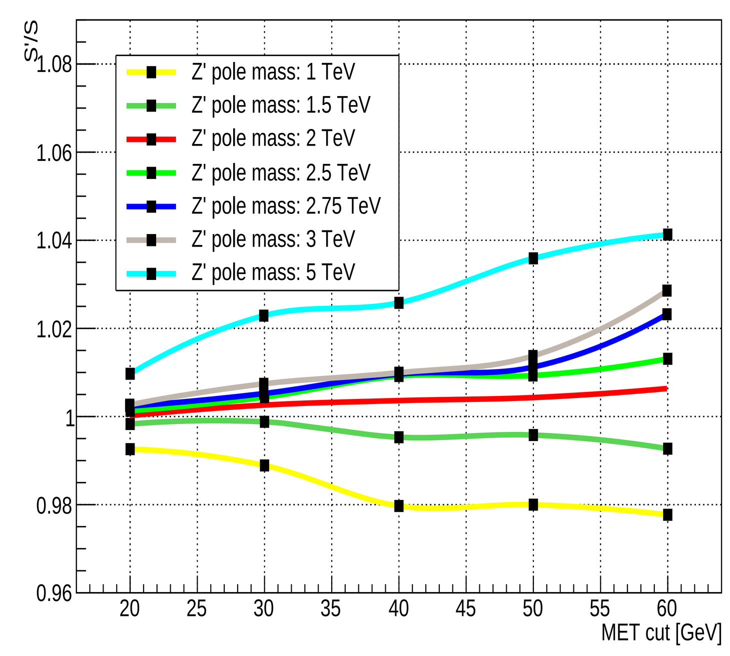


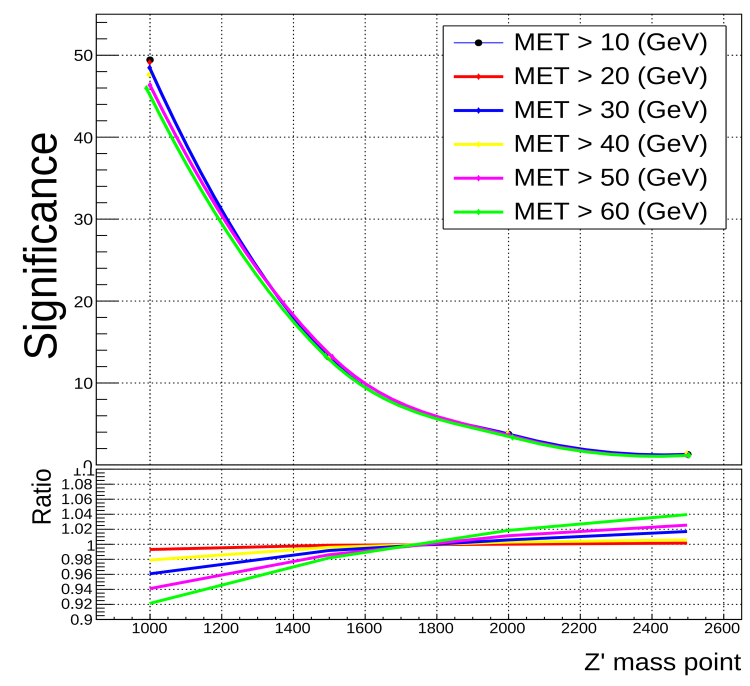




Tuning of E_T^{miss}

- A Scan of E_T^{miss} from 0 GeV to 60 GeV has been done in CR then we Extrapolate the QCD estimation to Signal Region (SR)
- QCD multijets is suppressed in the signal region with the same fraction of about 39% like obtained in the control region, when tightening the E_T^{miss} cut from 20 GeV to 60 GeV . The resulting event yield in the SR is about 525.5±95.5.

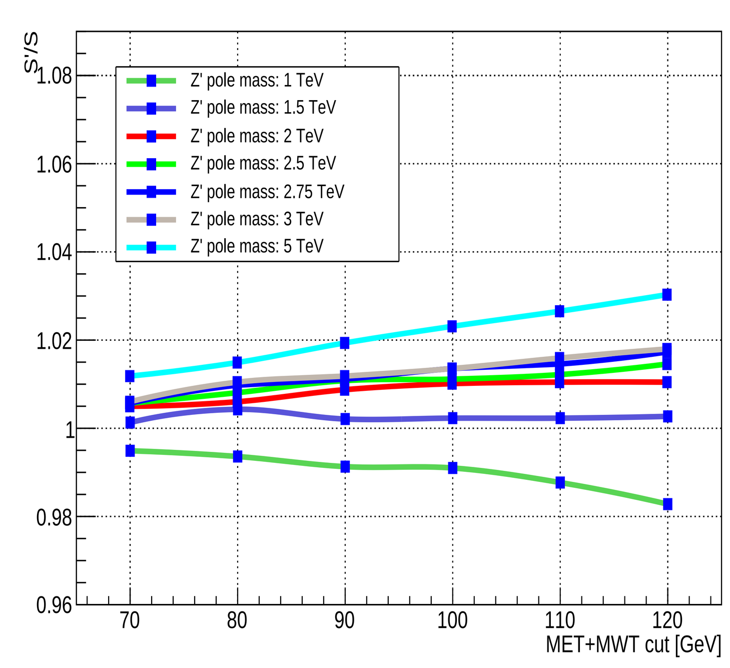


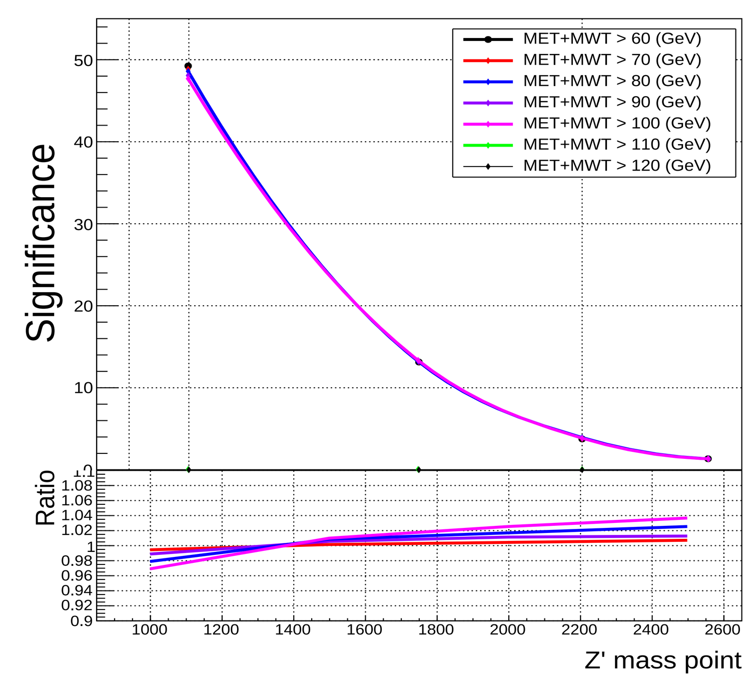


- The senstivity ratio between E_T^{miss} cuts (S'/S) still all time upper than 1 for the Z' mass point higher than 2 GeV

Tuning of $E_T^{miss} + MWT$

- A Scan of $E_T^{miss} + MWT$ from 60 GeV to 110 GeV has been done in CR then we Extrapolate the QCD estimation to Signal Region (SR)
- QCD multi-jets is suppressed in the signal region with the same fraction of about 53% like obtained in the control region, when tightening the $E_T^{miss} + MWT$ cut from 60 GeV to 110 GeV . The resulting event yield in the SR is about 253.3 ± 34.8 .

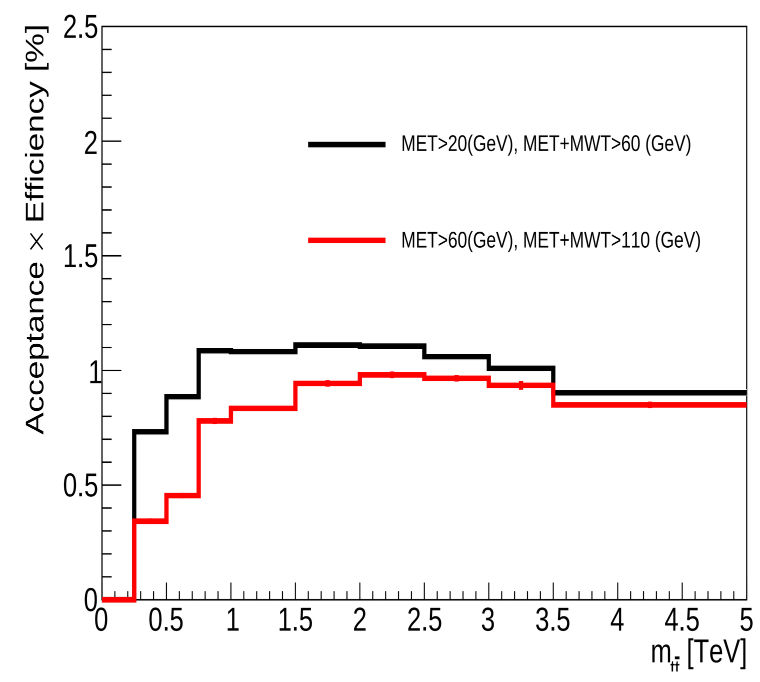


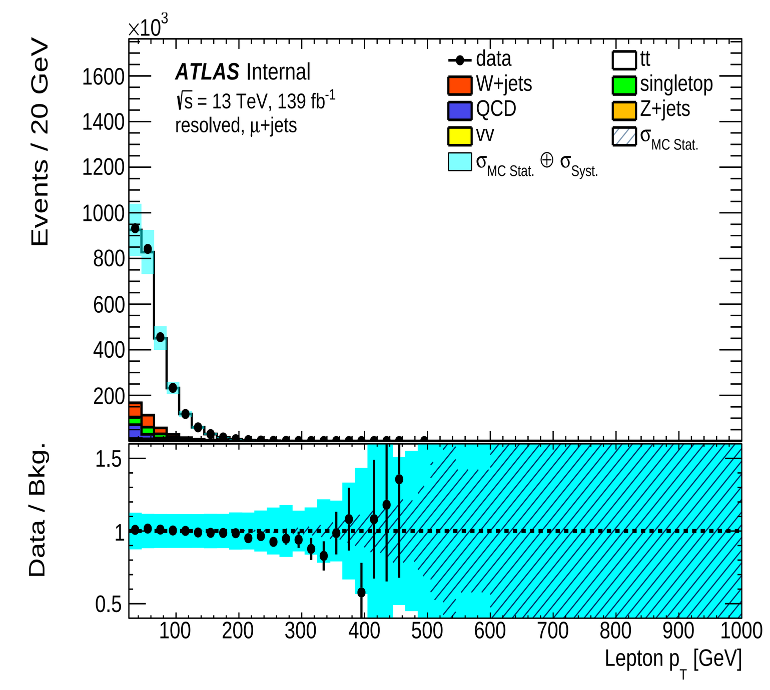


- The senstivity ratio between $E_T^{miss} + MWT$ cuts (S'/S) still all time upper than 1 for the Z' mass point higher than 1.5 GeV

Conclusions

- The Acceptance x Efficiency is not lost for the the high m_{tt} when we go from : " $E_T^{miss} + MWT > 20$ GeV and $E_T^{miss} + MWT > 60$ " to " $E_T^{miss} > 60$ GeV and $E_T^{miss} + MWT > 110$ " .





- We suppress multi-jet of about 39% x 53% with tighter cuts on " $E_T^{miss} > 60$ GeV and $E_T^{miss} + MWT > 110$ GeV" comparing to the nominal cuts " $E_T^{miss} > 20$ GeV and $E_T^{miss} + MWT > 60$ GeV".