Refinement of the search for BSM particles in the process Z' -> tt at sqrt(s) = 13 TeV with single-lepton boosted final state in the ATLAS experiment

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Introduction

Due to its mass close to the electroweak symmetry breaking scale, the top quark, besides having a large coupling to the SM Higgs boson, is predicted to have large couplings to new particles hypothesised in many BSM models[2]

This analysis is focused on implementing the selection criteria of a search for BSM Z' particles that decay into top-quark pairs in events containing a single charged lepton, large-R jets and missing transverse momentum.

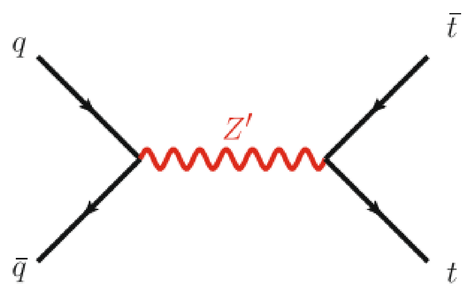

Figure 1: $Z' \to t\bar{t}$ [2]

Event selection criteria

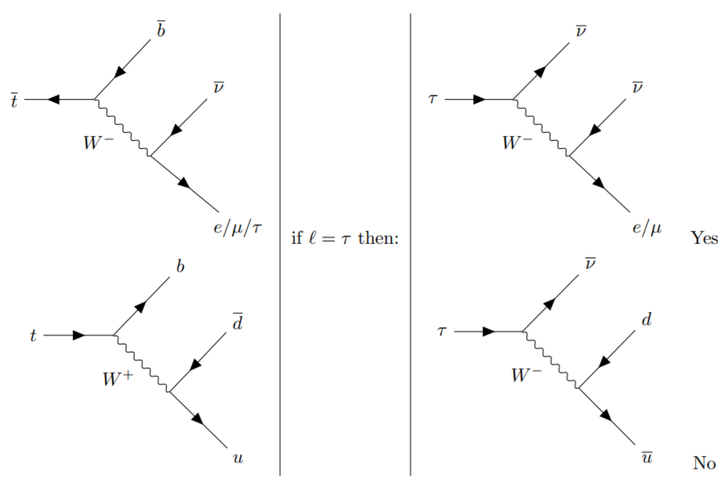

Figure 2: $t\bar{t}$ decays [2]

The analysis selection requires that the Z' decays into: One leptonic-top, meaning its products are a b-jet and a leptonic-W wich decays to one charged lepton and a neutrino, and a hadronic-top decaying to a b-jet and an hadronic-W, as described in 2

This analysis are being made using the data (*.root files) provided by CERNS's ATLAS Open Data initiative[1] and the program for data processing and analysis in Particle Physics ROOT.

The event selection criteria are applied to the following physics objects (and to the Missing transverse momentum E_T^{miss}:

Small-R jets	$R = 0.4$	$p_T > 25GeV$ $\|\eta\| < 2.5$ ($p_T < 60GeV$) ($\|\eta\| < 2.4$)	*jet-vertex tagger requirement 92% efficiency rejecting 98%
Large-R jets	$R = 1.0$ Subjets: $R = 0.2$ $p_T < 0.05 p_T^{totaljet}$	$p_T > 25GeV$ $\|\eta\| < 2.0$	*top-tagged 80% for selecting top-quark
Track-jets	$R = 0.2$	$p_T > 10GeV$ $\|\eta\| < 2.5$	*$n_{ch,part} >= 2$ $p_T > 0.4GeV$ and $\|\eta\| < 2.5$ *b-tagged *b-tagged small R jets [$\Delta R(j_{calo}, j_{track}) < 0.4$] 70% efficiency
Muon	Isolation: $\sum(p_T in \Delta R) < 0.06 p_T^\mu$ $10GeV/p_T^\mu < \Delta R < 0.3$	$p_T > 25GeV$ $\eta < 2.5$	*Not heavy flavor decays (is part of jet or μ?): $\Delta R(from, nearest, jet) >= 0.04 + 10GeV/p_T^\mu$ (μ stay) or $n_{tracks,of,jets} < 3$ (jet removed and μ stay)
Electron	Isolation: $\sum(p_T in \Delta R) < 0.06 p_T^\mu$ $10GeV/p_T^\mu < \Delta R < 0.2$ Different track from μ	$E_T > 25GeV$ $\eta < 2.5$ ($\eta < 1.37$ or $\eta > 1.52$)	*tight likelihood-based requirement *Not jet energy deposit (is e or $E_{deposit}$?): $\Delta R_{from,nearest,small,jet} < 0.02$ (jet removed) and *Overlap removal: $\Delta R_{from,new,nearest,small,jet} >= 0.4$ (e stay)

References

- ATLAS Collaboration, *Review of the 13 TeV ATLAS Open Data release* [online] Retrieved from: https://cds.cern.ch/record/2707171/files/ANA-OTRC-2019-01-PUB-updated.pdf, 2020.
- ATLAS Collaboration, *Search for heavy particles decaying into top-quark pairs using lepton-plus-jets events in proton–proton collisions at s = 13 TeV with the ATLAS detector* [online] Retrieved from: https://link.springer.com/article/10.1140/epjc/s10052-018-5995-6, 2018.

Event selection criteria

The event selection proceeds with the following steps:

Event cleaning requirement	■ All subsystems working acceptably ■ $n_{tracks\_associated\_with\_primary\_vertex} >= 2$
Charged-lepton selection	■ 1^{st} lep with $p_T >= 30GeV$ (matching trigger e) ■ If there is 2^{nd} lep it must have $p_T <= 25GeV$
Leptonic-W selection	■ $W \to l + E_T^{miss}$: $E_T^{miss} > 20GeV$ $E_T^{miss} + m_T^W > 60GeV$
b-tagging	■ $n_{b-taggedtrack-jet} >= 1$

Classification into Boosted or Resolved selection
Based on the hadronic activity:

Leptonic-top b-jet	■ Events required: $n_{small-R\_jet} >= 1$ ■ no b-tagging required ■ Not well separated from lepton: $(jet, lepton) < 1.5$ ■ If new $n_{small-R\_jet} > 1$ then highest p_T jet is chosen as j_{sel} ■ b_{jet} from: $t_{lep} \to b + W_{lep}$ ■ *Better resolution for $m_{t\bar{t}}$ than others based on b-tagging or info. of top candidate mass
Hadronic-top jet	■ Events required: $n_{large-R\_jet} >= 1$ ■ top tagging required ■ Well separated from Leptonic-top: $\Delta\Phi(j_{top}, lepton) > 2.3$ and $\Delta R(j_{top}, j_{sel}) > 1.5$ ■ If new $n_{large-R\_jet} > 1$ then highest p_T jet is chosen as hadronic-top jet ■ top_{jet} from: $Z' \to t_{lep} + t_{had}$

Mass reconstruction

An observable that approximates the mass of the "tt" system must be constructed by summing the four-momentum of the top-tagged large-R jet, the charged lepton and the b-tagged small-R jet associated with the lepton. in the analysis taken from the ATLAS Open Data examples[1], the neutrino momentum is not added, this is a way to take it into account, from [2]:

Hadronic-top candidate	Four momentum of the hadronic-top jet
Leptonic-top candidate	four-momenta of the charged lepton + four-momenta of the neutrino candidate + four-momenta of the $j_{sel}(Leptonic - top\_b - jet)$ ■ $E_T^{\nu_{candidate}} = E_T^{miss}$ ■ $P_t^\nu = E_T^{miss}$ ■ P_z^ν estimated assuming ν and l come from on-shell W and imposing W mass constraint ■ If no real solution found, a mismeasurement of E_T^{miss} is assumed and it is re-scaled and rotated by the minimal amount until a real solution is found ■ If more than 1 solution found, smallest absolute value is taken
$m_{t\bar{t}}$	Four momentum of the hadronic-top jet

Perspectives

- The task of this thesis is to reconstruct the complete "tt" system and either confirm or deny whether this makes a significant difference in the results of the analysis.
- The addition of the neutrino momentum introduces a challenge due to the reconstruction of its z component.

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