Search for a top-philic Z' boson in the final state with an electron or a muon and jets

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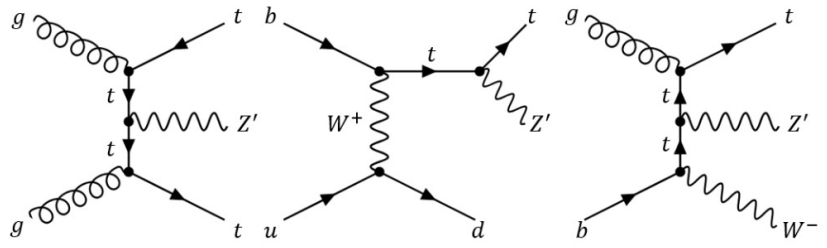
A search for a top-philic Z‘ boson in the final state with an electron or a muon and jets is presented. The top-philic Z’ boson is produced in association with a top quark and also decays to a top quark-antiquark pair, as it couplies exclusively to top quarks. The analysis aims to identify a heavy Z‘ boson that produces boosted top quarks, whose hadronic decay products are merged into large-radius jets. A machine learning algorithm (ParticleNet) is employed to identify such jets. The distribution of the invariant mass of the two most energetic top quark candidates is used in the search for a Z’ boson in the mass range of 0.5 to 3 TeV, with decay widths of 4%, 10%, 20%, and 50% relative to its mass. The results obtained are found to be in agreement with the standard model background prediction. Upper limits at the 95% confidence level are set for the production cross section of the Z‘ boson, for each of the decay widths as a function of its mass. These results represent the most stringent constraints to date on the existence of the top-philic Z' boson. The data were recorded by the CMS experiment at the CERN LHC in proton-proton collisions at $\sqrt{s}$ = 13 TeV and correspond to an integrated luminosity of 138 fb^{-1}.

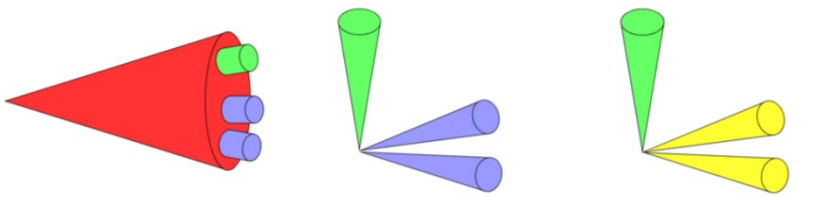
Introduction

- Discovery of Higgs boson motivates search for new physics
- If couplings to light-quarks are suppressed, Z’ can manifest via new mechanisms: t-quark fusion, b-quark fusion and VBF.
- Recently both ATLAS and CMS have the results for SM tttt measurement.
- We search for a Z’ associated with tops in the single lepton final state. (ttZ’, Z’->tt; 1l+jets)
- We use the Top-philic-Zprime_V1 UFO model.
- Z’ mass range: 0.5 TeV – 3TeV, width: 4%, 10%, 20%, 50%.



Analysis strategy

- A dedicated top reconstruction algorithm with different top decays:



Fully boosted top	Resolved hadronic top	Resolved leptonic top
$t_{(Wh+b)}$	t_{Wh+b}	$t_{W\ell+b}$

1. Reconstruct all top candidates (regardless of whether they share the same constituents)
2. Define a $\chi^2 = \left(\frac{\text{recoTop}mass - \text{gen}Topmass}{\sigma_t}\right)^2 + \left(\frac{\text{reco}Wmass - genWmass}{\sigma_W}\right)^2$ resolutions from simulation, and sort all tops in χ2-increasing order (boosted top have χ2 = 0)
3. Select a top candidate if χ2<5, and next top does not share constituents with previous one.

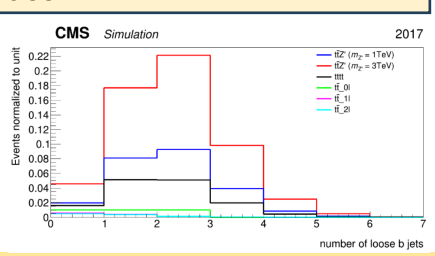
Final discriminating variable:
Z’ mass = invariant mass of the first 2 tops have the highest p_T

Event Selection

In order to improve the sensitivity of the analysis, the following selection is applied:

- ✓ Exactly 1 lepton
- ✓ Single lepton triggers
- ✓ Noise filters
- ✓ HT > 700 GeV (HT = sum of pt of all AK4 jets)
- ✓ MET pt > 60 GeV
- ✓ Number of jets >= 6
- ✓ event categorization: >= 2 boosted tops && >=1 loose b jets
- ✓ ST > 200 GeV (ST = sum of pt of all the tops)

similar with SM 4top (1l), but tightening further in number of jets, (≥6 instead of 4 and HT>700 instead of 500 GeV) as we look for events at high Z’ mass.



Background Estimation

- We define a CR that closely resembles the SR in composition, and applied rate parameter with CR and SR simultaneous fit.

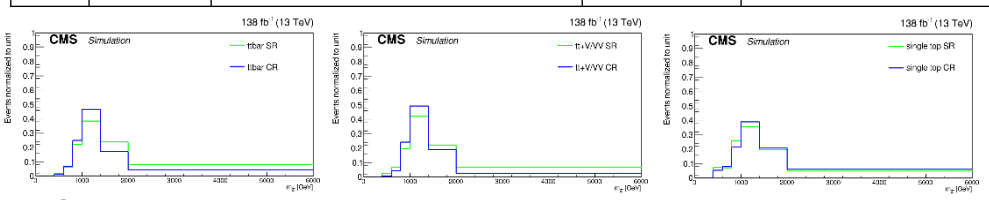
Signal Region	Control Region
Exactly 1 lepton	Exactly 1 lepton
Single lepton triggers	Single lepton triggers
Noise Filters	Noise Filters
HT > 700 GeV	HT > 700 GeV
MET pT > 60 GeV	MET pT > 60 GeV
N jets >= 6	N jets >= 6
>= 2 boosted tops && >= 1 loose b jets	>= 2 boosted tops && < 1 loose b jets
ST > 200 GeV	ST > 200 GeV

Signal efficiency

Eff	SR	CR
500 GeV	0.15070%	0.02310%
3 TeV	2.48830%	0.22740%

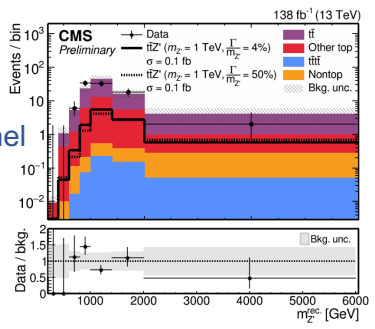
Background composition comparison

BKG	ttbar	other top (ttt, tt+boson, st)	tttt	Non top (bosons/DY)
SR	74.74%	20.72%	3.99%	0.55%
CR	67.86%	30.48%	0.51%	1.15%

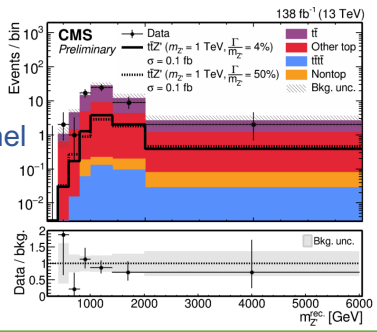


- Our control region appear rather similar to our signal region
- CR distribution

Muon channel

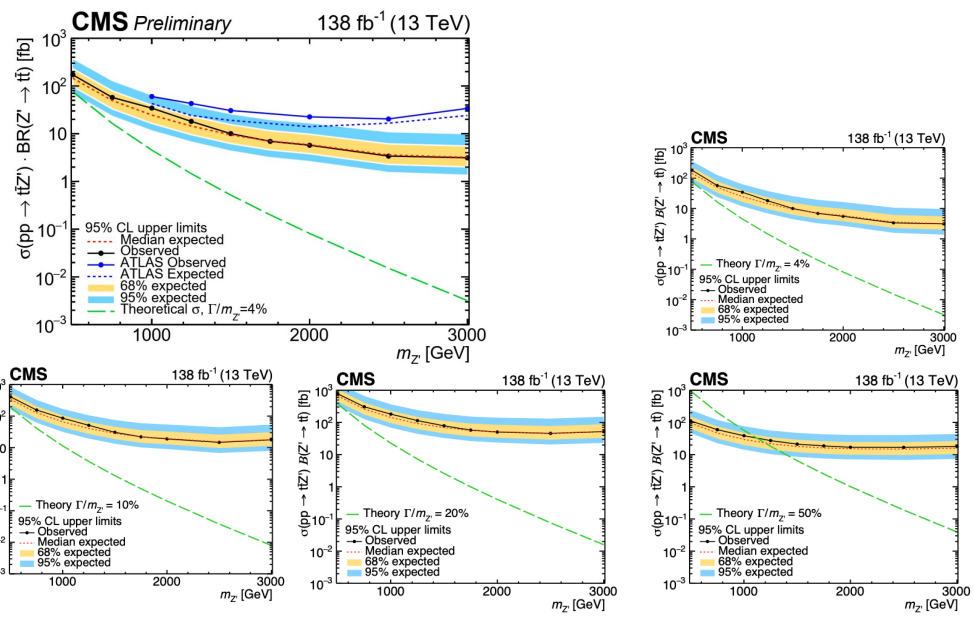


Ele channel



Results

- Expected upper limit on σ(pp → tt Z’) as a function to Z’ mass



- This is the first result of search for ttZ’ in single lepton final state in CMS
- We use a wider range than ATLAS from 0.5 TeV to 3 TeV
- We are slightly better than ATLAS result

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