Search for single production of a vector-like T quark decaying to tZ with CMS at $\sqrt{s} = 13$ TeV

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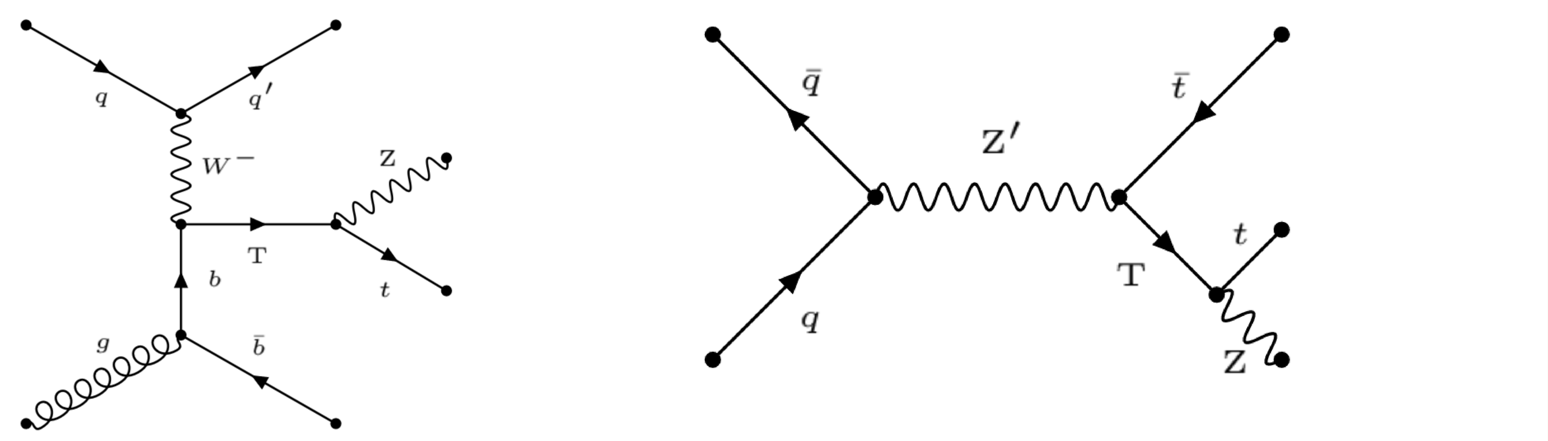
We present a search for single production of heavy vector like quarks (VLQ), carried out by the CMS collaboration analyzing LHC pp collisions at 13TeV. The vector like quark is a massive top quark partner that is searched for in a mass range between 0.7 and 1.7 TeV and a width between <1% and 30%. Single production can be dominant over pair production, depending on the mass of the new quark. The search is performed in a variety of final states including boosted topologies that can increase the sensitivity of the analysis.

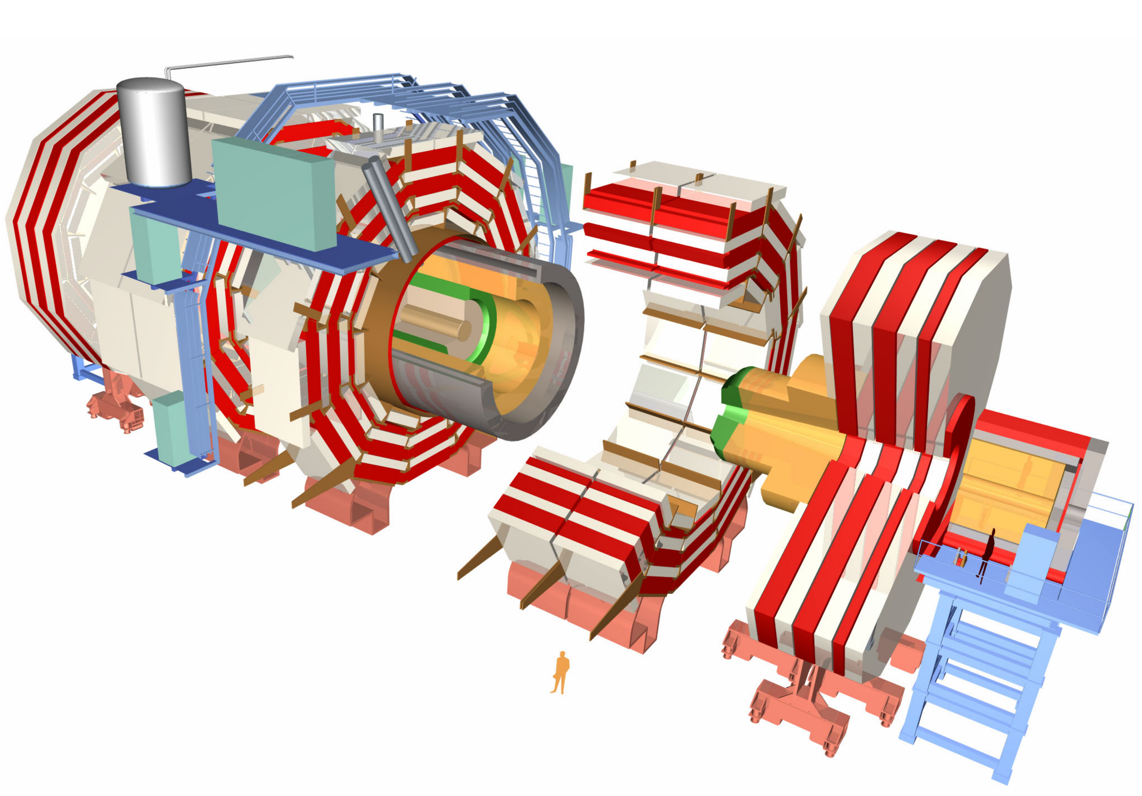
Introduction

1. Production of a T VLQ with a charge of $+2/3$ that decays to a Z boson and a top quark
2. Final state with Z boson decaying to electrons or muons and top quark decaying hadronically
3. The T quark can be produced in association with a bottom or a top quark
4. The T quark has three different decay channels into SM particles: bW, tZ, and tH
5. A T quark may also be produced with a top in the decay of a neutral spin-1 heavy Z′ boson



Production of a single T VLQ in association with a b quark (left) and production of a Z′ decaying to Tt (right).

The CMS detector



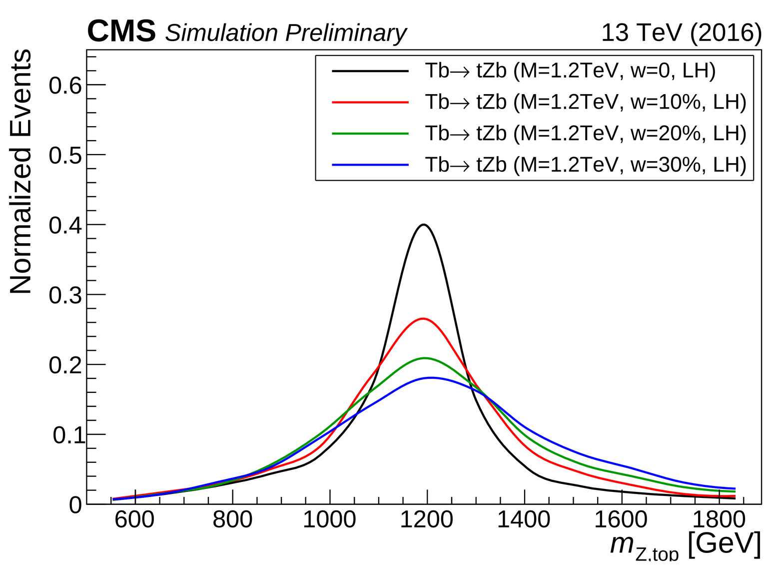
Compact Muon Solenoid

- General purpose experiment installed on the Large Hadron Collider
- The analysis uses the full dataset recorded during 2016 at a centre of mass energy of 13 TeV and corresponding to an integrated luminosity of 35.9 fb^{-1}

Experimental Strategy

Signal Characterization

1. T masses between 0.7 and 1.7 TeV (steps of 0.1 TeV), and three Z′ mass hypotheses: 1.5, 2.0, and 2.5 TeV
2. Four T quark width hypotheses are studied: negligible, 10%, 20% and 30% of the T mass
3. Singlet and doublet T quarks, with both left-handed and right-handed couplings to the SM particles
4. Couplings between T quark and SM particles are described with the coefficients C(bW) and C(tZ)



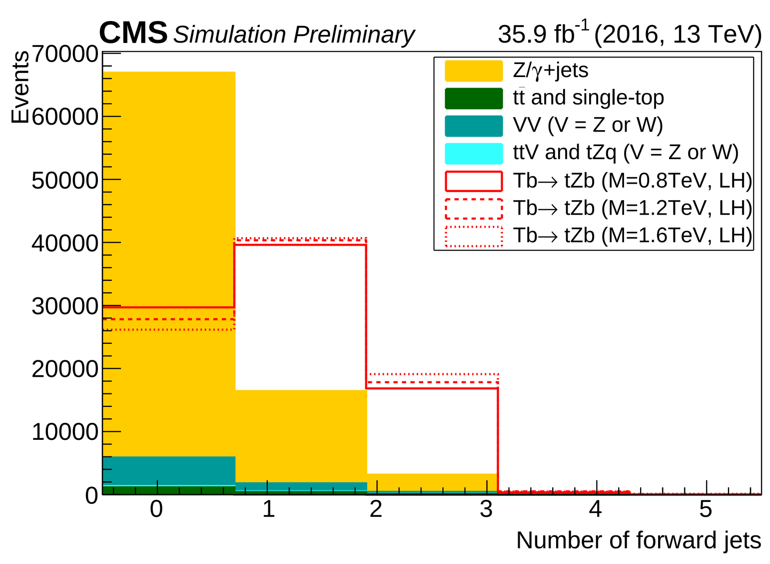
Event Selection

The top quark identified in three different scenarios

1. fully merged: a top tagged jet
2. partially merged: a W tagged jet and a b tagged jet
3. resolved: three AK4 jets are reconstructed, one b tagged

The presence of jets produced in the forward region of the detector is a particular characteristic of the single production of vector-like quarks and is utilized to further categorize the events.

Finally ten categories are defined depending on: leptonic decay of the Z boson, hadronic top reconstruction, presence or not of forward jets.



	2μ + 1t jet	2e + 1t jet	2μ + 1W jet + 1b jet	2e + 1W jet + 1b jet	2μ + 1b jet + 2 jets	2e + 1b jet + 2 jets
Leptons	2 muons	2 electrons	2 muons	2 electrons	2 muons	2 electrons
Lead lep p_T	>120 GeV	>120 GeV	>120 GeV	>120 GeV	>120 GeV	>120 GeV
$\Delta R(\ell, \ell)$	<1.4	<1.4	<0.6	<0.6	<0.6	<0.6
Jet	1 top jet		1 W jet, 1 b jet		3 AK4 jets (one b-tagged)	
top p_T	>400 GeV	>400 GeV	>150 GeV	>150 GeV	>150 GeV	>150 GeV
N(b jet)	≥1	≥1	≥1	≥1	≥1	≥1

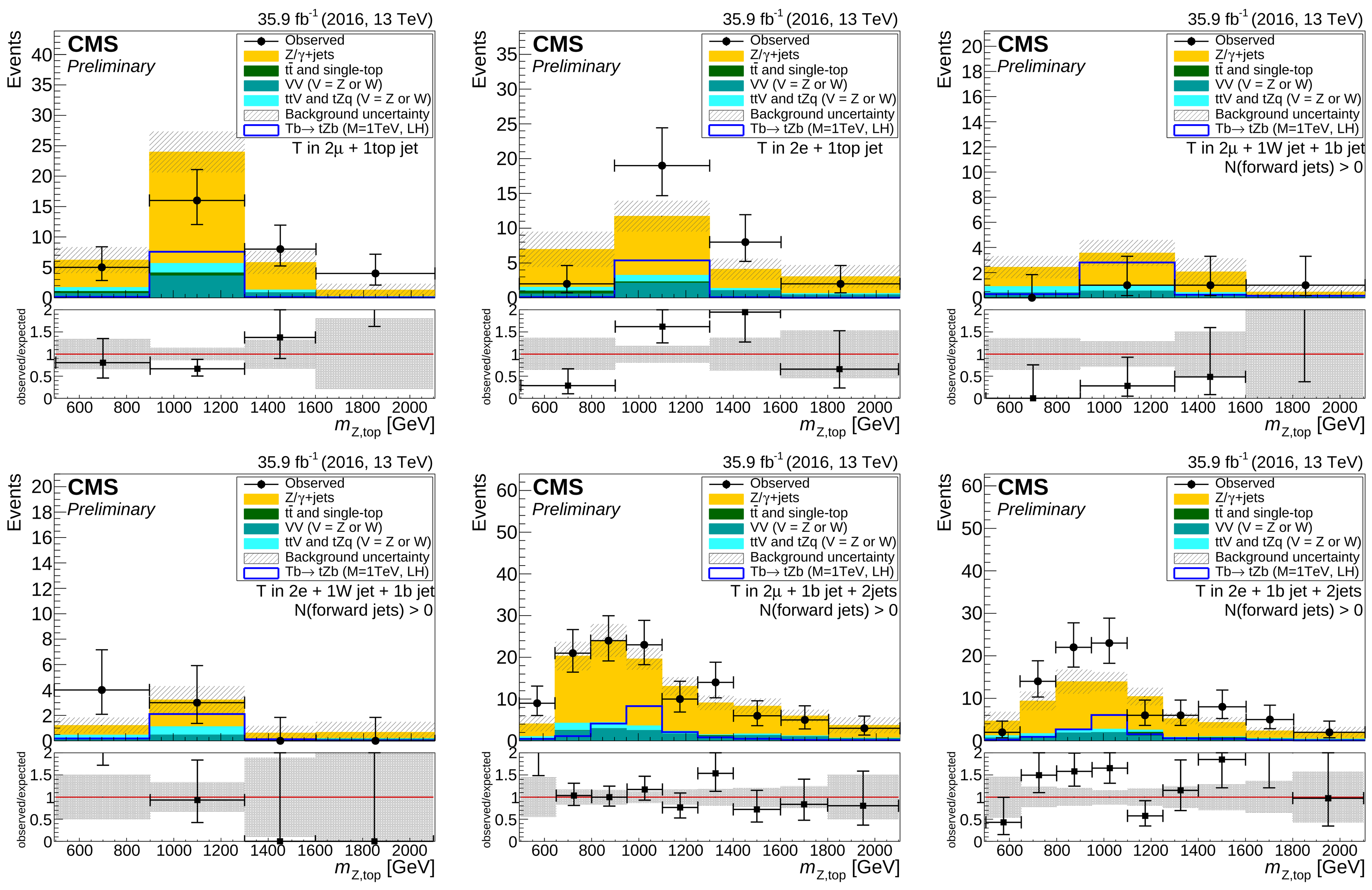
Background Estimation

Background estimate primarily based on control samples in data through the following formula:

$$N_{bkg}(M_{t,Z}) = N_{cr}(M_{t,Z}) \cdot \alpha(M_{t,Z}),$$

- $N_{cr}(M_{t,Z})$: number of events in the data sample in the control region
- $\alpha(M_{t,Z})$: ratio of number of events in signal region to the ones in control region, from simulation

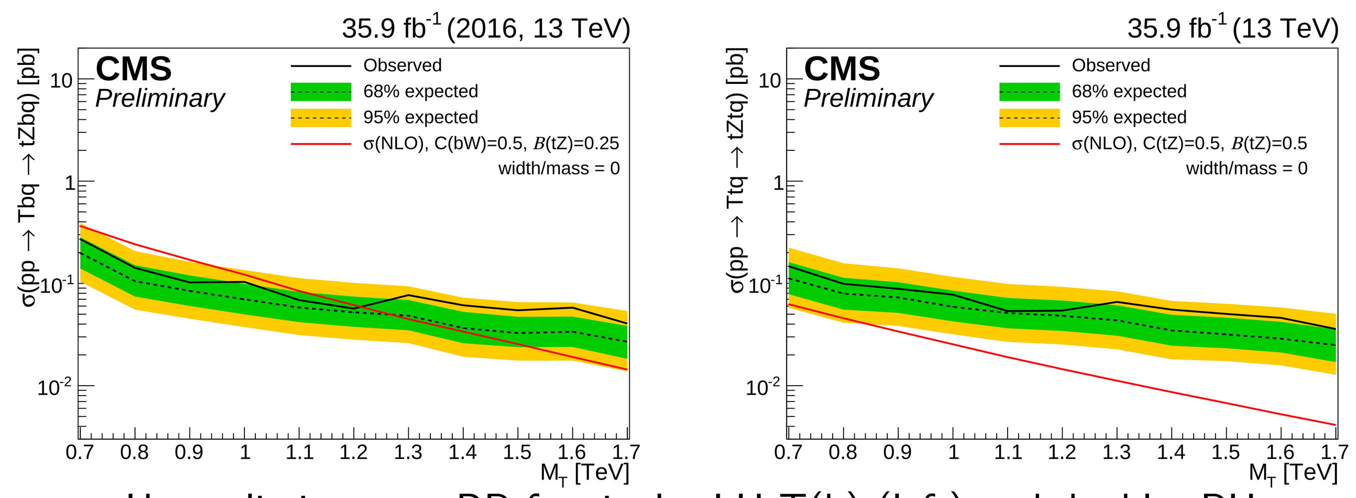
The control region from which the number of events is extrapolated into the signal region defined by full event selection, but applying a veto on the presence b tagged jets.



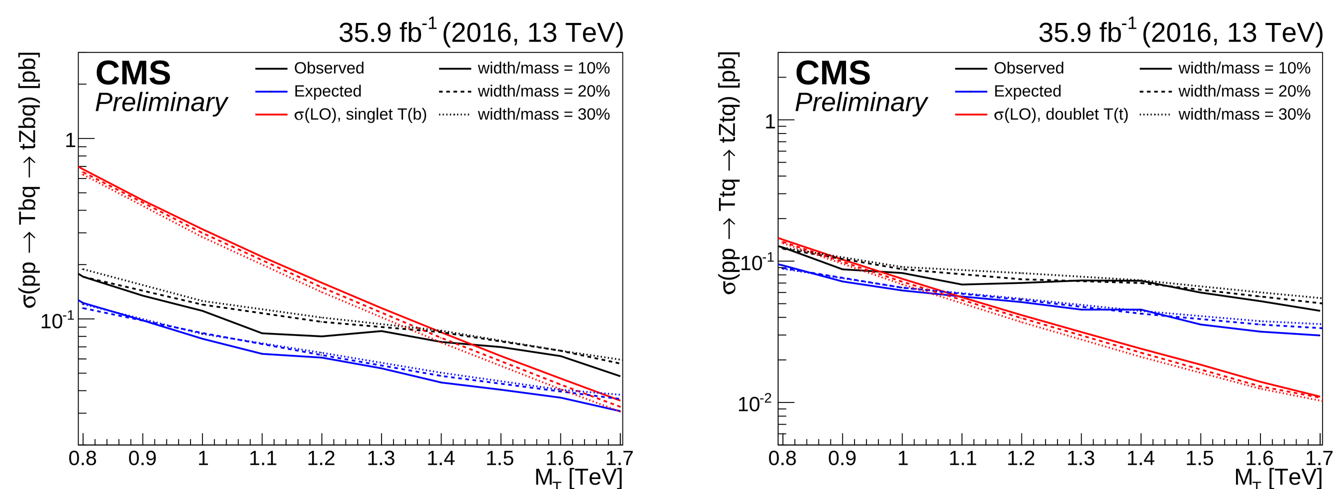
Systematic Uncertainties

The systematic uncertainties for the signal come from corrections that are applied to the simulation in order to match distributions in data. The uncertainty in the background estimate comes from five sources: statistical uncertainties data and simulation in the control region, the small differences between observation and prediction for a closure test, the uncertainty related to possible mismodelling of the Z+light quark and Z+b quark fractions in simulation, and the uncertainty from the b tagging efficiency differences in data and simulation.

Results



Upper limit on $\sigma\times$BR for singlet LH T(b) (left) and doublet RH T(t) (right) production modes, where the T has a negligible width.



Upper limit on $\sigma\times$BR for singlet LH T(b) (left) and doublet RH T(t) (right) production modes, for T width 10%, 20% and 30% of T mass

M(Z′) [TeV]	M(T) [TeV]	Observed	Expected
1.5	0.7	0.13	0.10
1.5	0.9	0.11	0.08
1.5	1.2	0.09	0.05
2.0	0.9	0.09	0.06
2.0	1.2	0.08	0.05
2.0	1.5	0.06	0.03
2.5	1.2	0.07	0.05
2.5	1.5	0.06	0.04

Upper limit on $\sigma(pp\to Z')\,\mathcal{B}(Z'\to Tt)$