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# Search for single T production in $T \rightarrow tZ(vv)$ decay mode

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# Introduction



#### **Standard Model**

Fermions: quarks, leptons

Mass: Yukawa coupling to the Higgs

Hierarchy problem

#### little Higgs, composite Higgs models

Fermions: Vector-like quarks

non-Yukawa coupling terms

Don't excluded by precision SM measurements

CMS Integrated Luminosity, pp,  $\sqrt{s}=$  13 TeV

- VLQs: hypothetical new spin -1/2 charge 2/3 particle
- VLQs offer a potential solution to the hierarchy problem of standard model
- Using all the Run2 data to search for VLQs









Single production of VLQs have larger phase space above 1TeV

- Three different decay channels into SM particles by the assumption of the model: bW, tH, tZ
- We will search for single produced VLQ T' decaying in top quark + Z boson in dineutrino channel





# Analysis strategy









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





• The signal selection efficiency for different categories list here:







- Main Background: Z+jets, W+jets, ttbar
- Using Data-driven method to get correction factors from control region in data
- Control regions for the main backgrounds are defined as:

#### ➢ Resolved category

Variable	SR	Z+jets CR	W+jets CR	ttbar CR
lepton	veto	veto	>=1	>=1
Number of midum b jet	>=1	=0	=0	>=1

#### Partially merged category

Variable	SR	ttbar CR
minΦ(MET,jet)	> 0.6	< 0.6

#### Fully merged category

Variable	SR	W/Z+jets CR	ttbar CR
Leotpn	veto	veto	1 loose muon or electron
minΦ(MET,jet)	> 0.6	> 0.6	No cut
Top jet	1 b-subjet	0 b-subjet	1 b-subjet



M<sub>T</sub> [GeV]



## **Background estimation test**





Comparison of data and the predicted background(resolved)



## **Systematics**



9

Source	Effect(%)	Туре
Luminosity	1.8	rate
Pileup	0.2-3	rate
b-tagging	0.5-1.2	rate
Top tagging	9-10	rate, shape
W tagging	7-8	rate, shape
Trigger efficiency	1-3	rate, shape
Prefiring	0.2-3	rate, shape
JES	2-18	rate, shape
JER	2-5	rate, shape
PDF	1-5	rate
$\mu_F$ 和 $\mu_R$	8-13	rate, shape
Background scale factors	5-30	rate, shape

The dominant systematics are: top tagging, W tagging,  $\mu_R$ ,  $\mu_F$ , background SF



## **Results-Resolved topology**





All background processes are derived from the fit to data



## **Results – Partially merged topology**







## **Results – Fully merged topology**







## **Results-limit**



95% confidence level(CL) exclusion limits on the production cross section of T' times BR



- Narrow width resonance: Cross section : greater than 602–15 fb. Masses: below 0.98TeV
- 10-30% width resonance : Cross section : greater than 836–16 fb Masses: below 1.4TeV
- 2D limit: The hashed red line indicates the boundary of the excluded region



# Summary



 Study of single production of VLQ in tZ (top hadronic, Z to neutrinos) has been shown all Run2 data

	Cross section@95%CL	Mass@95%CL
Narrow width resonance	>602-15fb	<0.98TeV(5%)
10-30% width resonance	>836–16 fb	<1.4TeV(30%)

- This is first result of MET + jets final state in CMS
- This is the current best published result on single-VLQ T' in the tZ(vv) decay channel.
- This result has been published in <u>PAS-B2G-19-004</u>





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# backup







## ≻Trigger

- HLT\_PFMETNoMu120\_PFMHTNoMu120\_IDTight
- HLT\_PFMET120\_PFMHT120\_IDTight

### > Lepton

- Loose electron ID, pt > 30GeV
- Loose muon ID, pt >30GeV

## > Jets

- CHS ak4 jets with jet pt > 30 GeV and passing the tight jet ID (2016 jet ID look here, 2017 look here and 2018 look here)
- PUPPI AK8 jets with pt > 200GeV
- DeepCSV b-tagger with medium WP for all Run2 data.
- $|\eta| < 2.4$  (or 2.4 <  $|\eta| < 4.0$  for forward jets)

## >MET

- MET pt > 200GeV
- 2016, 2017 and 2018 MET filters taken from here

#### ≻W/top tagging

- W jet: PUPPI AK8 Jet, pt>200GeV, 65< SD mass < 105GeV, tau21DDT < 0.43
- Top jet: PUPPI AK8 Jet, pt > 400GeV, 105< SD mass< 220 GeV, tau32 < 0.65 16</li>



## **Scale factor**











