Search for new resonances coupling to third generation quarks at CMS

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25TH INTERNATIONAL CONFERENCE ON SUPERSYMMETRY & THE UNIFICATION OF FUNDAMENTAL INTERACTIONS

Outline

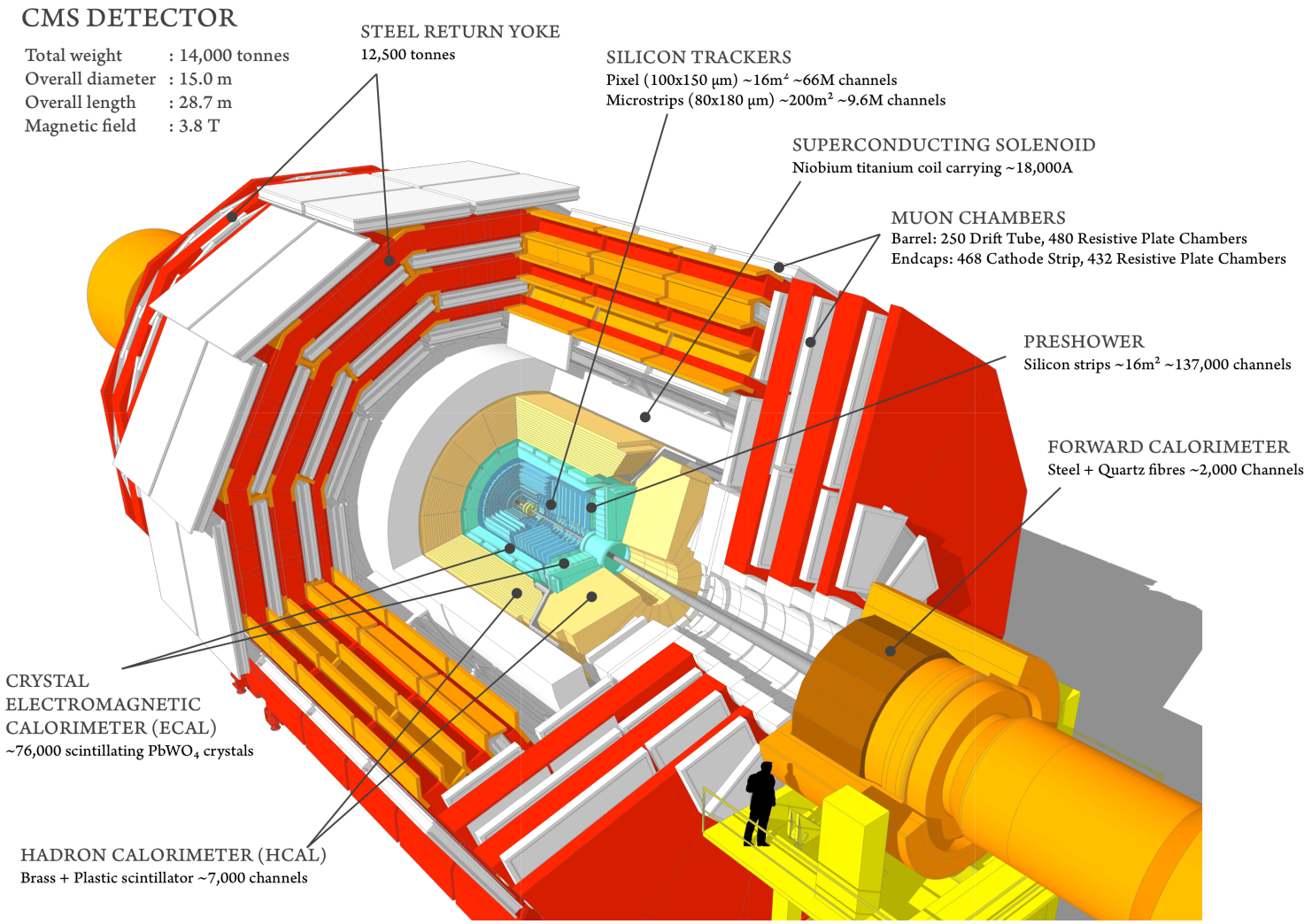
Introduction

Techniques

Scope of the talk

- $t\bar{t}$ resonance
- W' → tb
- Z' → Tt
- $t^*\bar{t}^*$ → tgtg

Summary

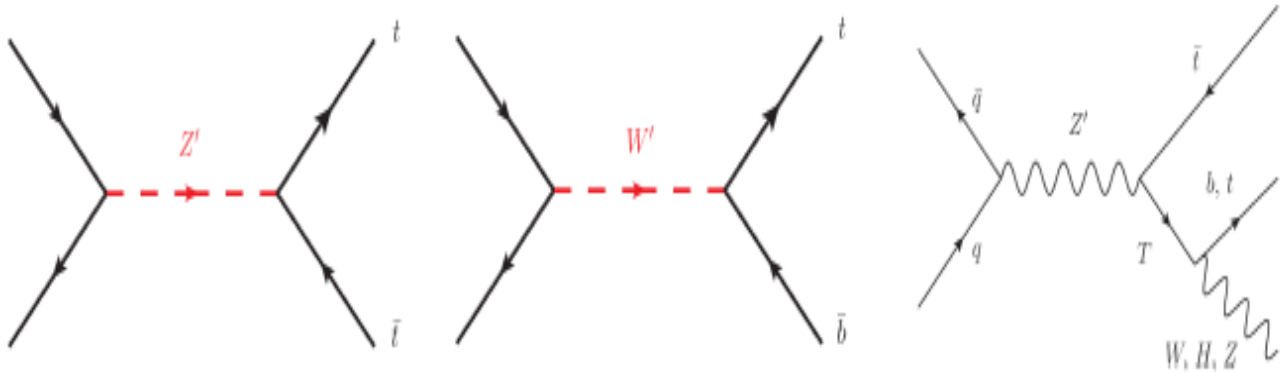


Introduction

Unsolved hierarchy problem leads to development of many BSM theories

Many such extensions of SM predict new interactions

- Enhanced coupling to third-generation quarks
- Leads to new heavy resonances decaying to third-generation quarks
  - Massive gauge bosons like Z' or W' *(PLB 387 (1996) 113, PRD 64 (2001) 035002, PLB 383 (1996) 345)*
  - KK excitations of gluons *(PRD 77 (2008) 015003)*
  - Gravitons in extensions of RS model *(PRL 84 (2000) 2080, PRL 83 (1999) 3370)*
  - Composite Higgs models *(JHEP 12 (2014) 126)*
  - Heavy gluon models *(JHEP 01 (2012) 157)*



Focus on high mass searches

- Experimental challenges
  - Identification of b-jets (at high pT)
  - Sub-structure based boosted top-tagging
  - Lepton isolation for boosted tops
  - Theoretical & modeling uncertainties on top physics

Techniques for boosted scenarios

Hadronic decays: use substructure property of fatjets

Methods: top-tagging

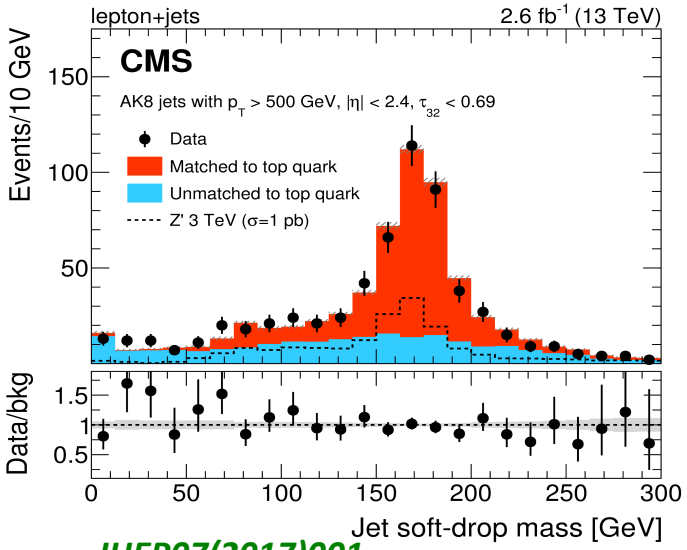
- Anti-k_T jets ($R = 0.8$) reclustered with CA algorithm
- Jet mass reconstruction: soft drop grooming
  - Removal of soft wide angle radiation
  - Reconstruct sub-jets
- N-subjettiness τ_n: probability jets contains n sub-jets
- B-tag sub-jet

$110 < m_{SD} < 210$ GeV
& $\tau_{32} < 0.69$ (Tagger)

B-tagging: CSV tagger

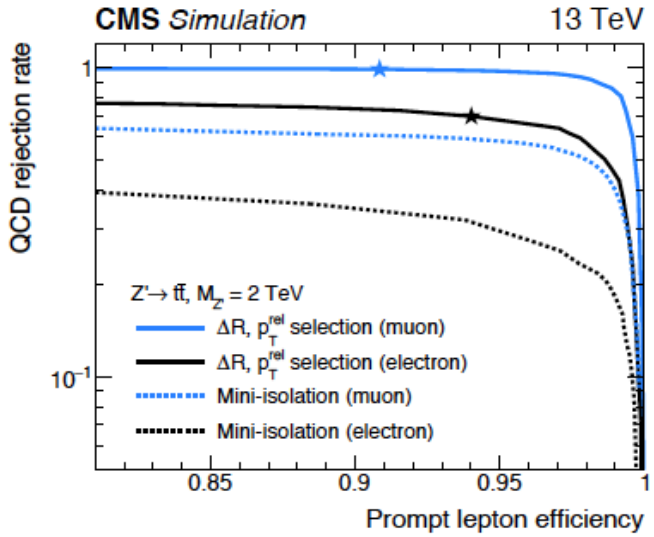
Leptonic decays: non-isolated leptons

- p_T dependent isolation cone
- Non-isolated leptons (2D cut)
  - $\Delta R(l, jet) > 0.4$ or
  - $p_T^{rel} > 20$ or (50,60) GeV



JHEP07(2017)001

CMS PAS B2G-15-002



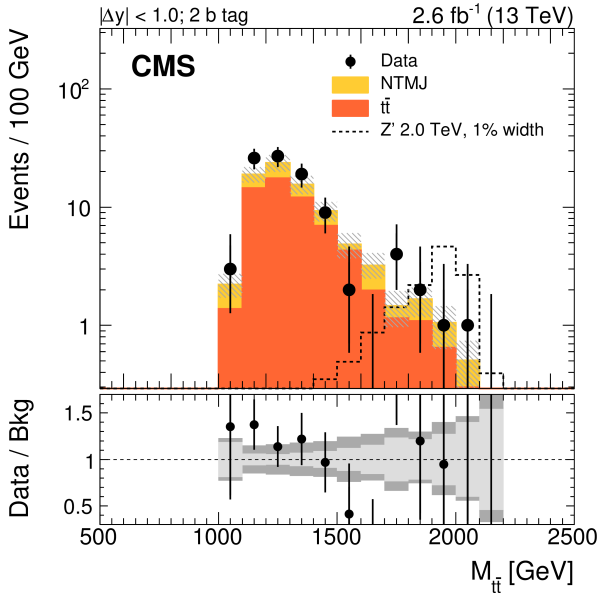
JHEP07(2017)001
arXiv:1704.03366

ttbar resonance

Resonance: Z'-like bosons, KK gluon resonance in RS model

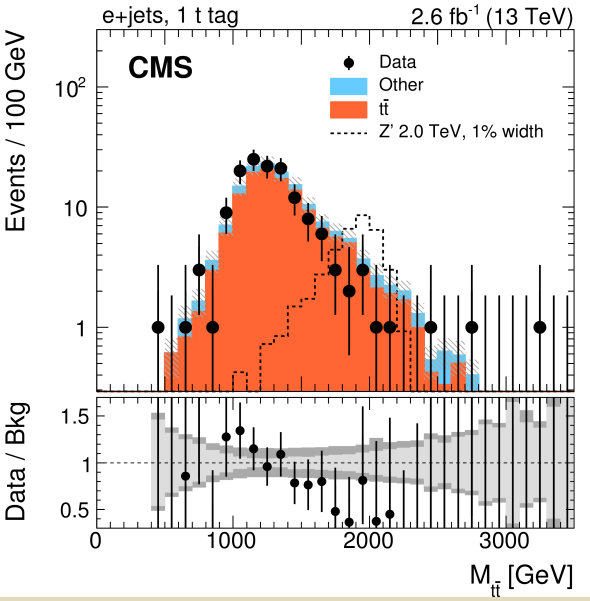
All hadronic channel

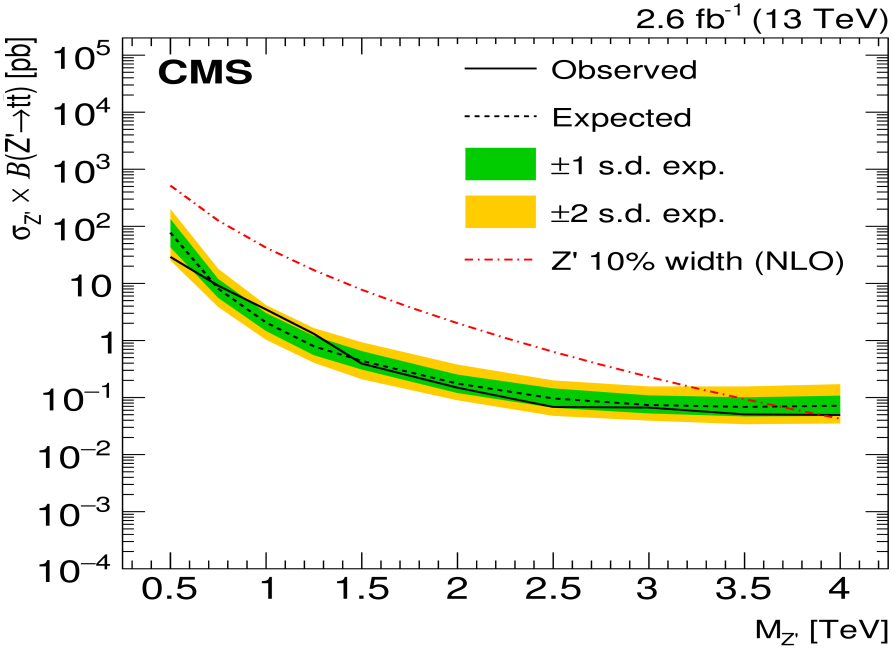
- Use 2 t-tag AK8 jets
- Back-to-back topology $|\Delta\phi| > 2.1$
- Backgrounds: SM $t\bar{t}$, non-top multijet (NTMJ)
- Categorization:
  - ($\Delta y > 1$, $\Delta y < 1$) x
    (0, 1, 2 b-tag)
    (Δy: rapidity difference between 2 AK8 jets)

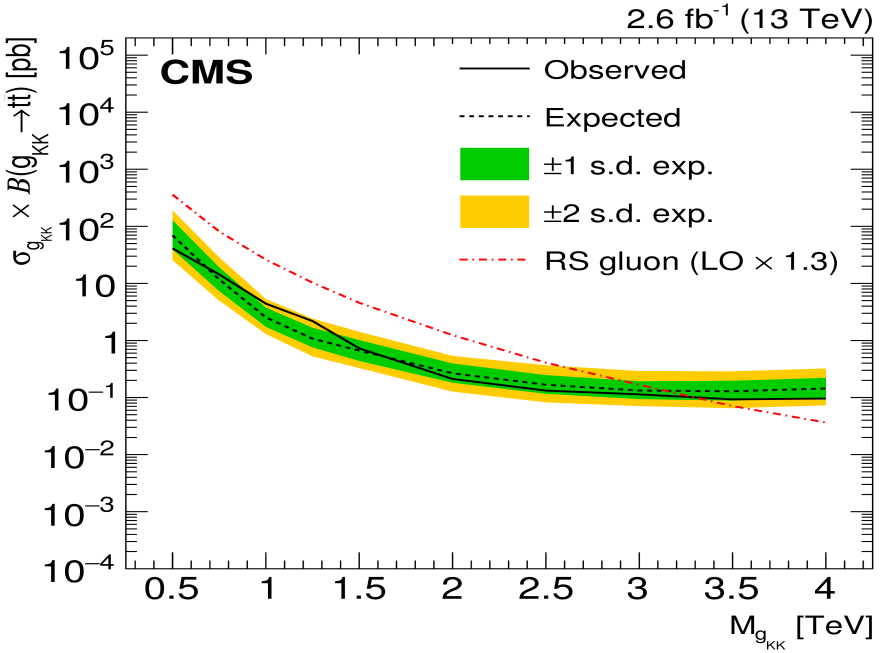


Semileptonic channel

- Use non-isolated (2D cuts) leptons, jets, E_T^{miss}
- Reconstruct M_{tt} from leptons, jets, E_T^{miss}
- Backgrounds: SM $t\bar{t}$, W+jets
- Mutually exclusively categorization:
  - (e, mu) x
    (1 t-tag, 0 t-tag & 1 b-tag
    0 t-tag & 0 b-tag)







Model-independent search

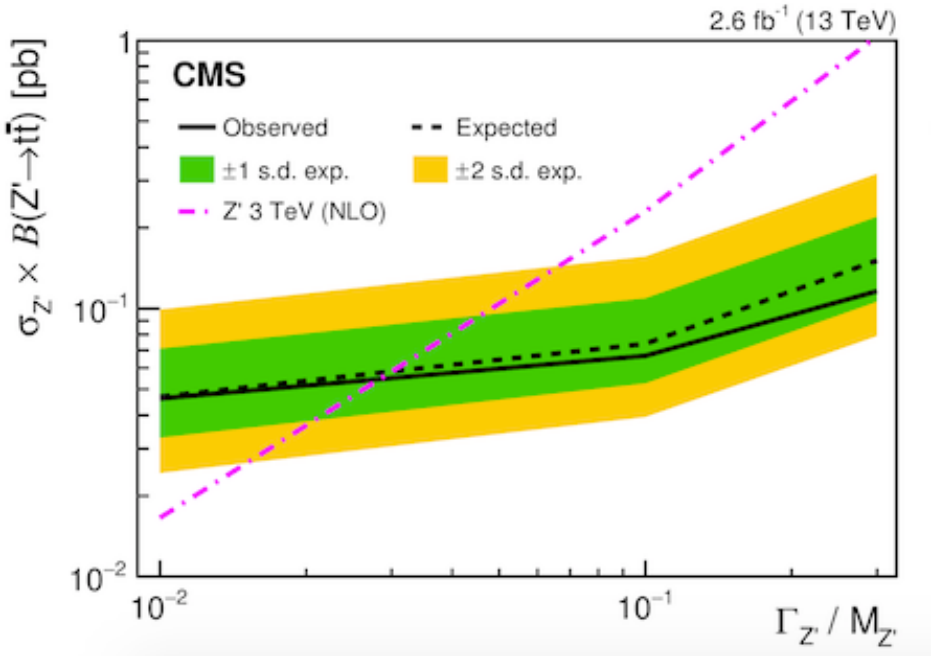
JHEP07(2017)001
arXiv:1704.03366

No excess observed

95% CL cross-section limits set as function of $M_{Z'}$

- Theoretical interpretation:
  - Z' & KK gluon excitations in RS model

Limits also presented as a function of width of Z'



CMS-B2G-17-010 ; CERN-EP-2017-196
arXiv:1708.08539

W' → t + b

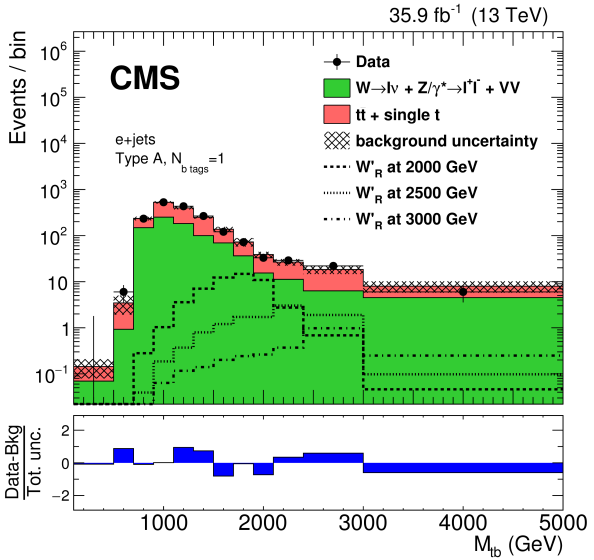
Heavy W' resonance decaying to tb
- Enhanced in some models
- Complementary to W' → *lν or WZ* searches

Hadronic or leptonic top decays

Backgrounds: ttbar, W+jets (main)
- Others: single-top, VV, Z+jets, multijet

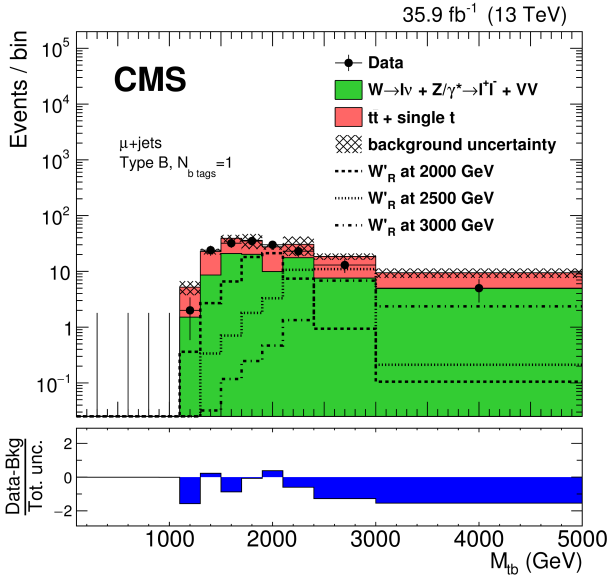
l+jets: (results from 2015 & 2016)
- High p_T e/μ (2D cuts), ≥ 2 jets, ≥ 1 b-tag, E_T^{miss}, p_T^t > 250 GeV
- top: $p_T(t)$ > 250 GeV, : m_T < 250 GeV, p_T^{j1+j2} > 350 GeV
- M_{tb} reconstructed from lepton, E_T^{miss}, &2 jets
- (e,μ) x (1,2 b-tags) x (Kinematical Type A, B)

Hadronic: (only 2015 results)
- 2 jets with 1 t-tag & 1 b-tag
- M_{tb} reconstructed from 2 AK8 jets



Type A: same selection

Type B: $p_T(t)$ > 650 GeV & p_T^{j1+j2} > 700 GeV Improves sensitivity to high signal masses

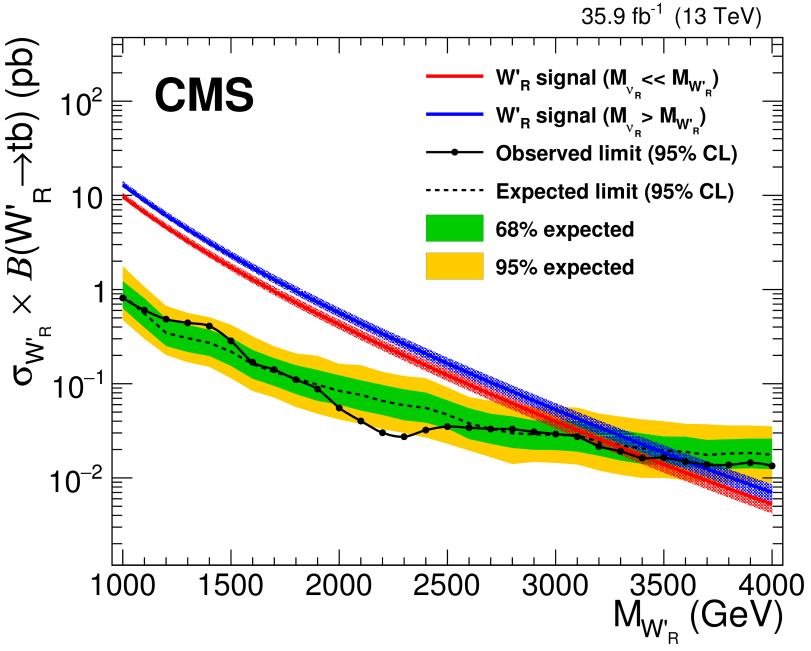


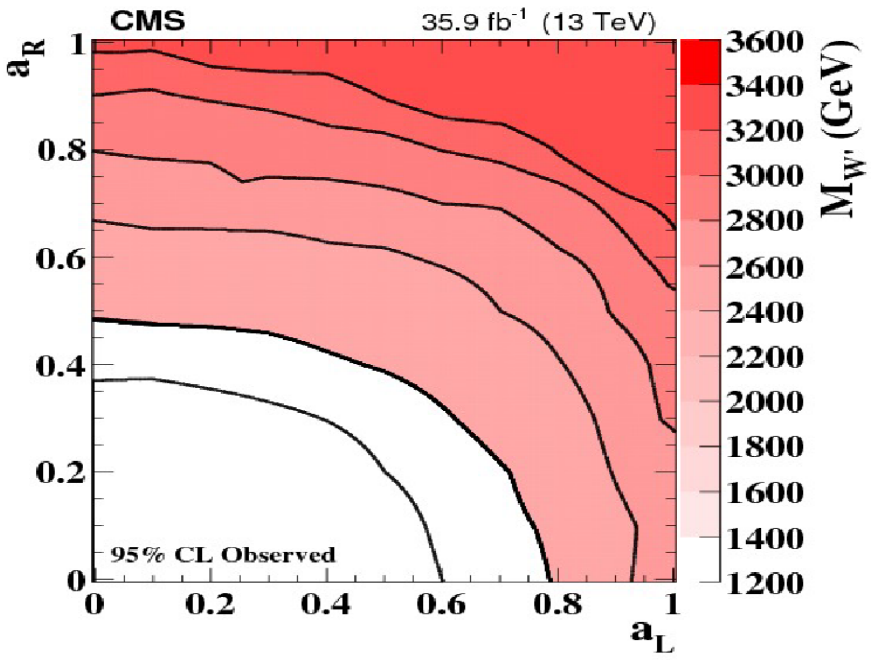
W' → t + b

No excess observed. Mass exclusion limits set for right handed coupling (W_R')

- Masses excluded up to 3.6 TeV
- Improvement w.r.t. 2015 results

Limits extended to scan of coupling strength plane (right & left handed)



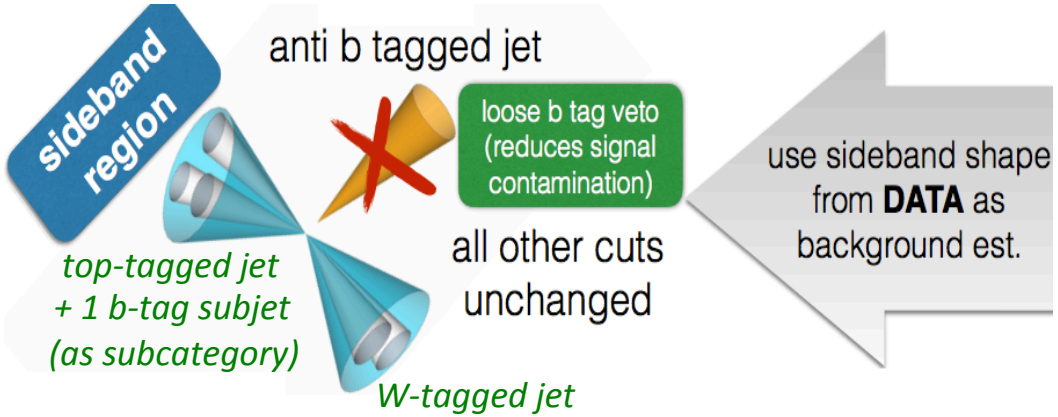


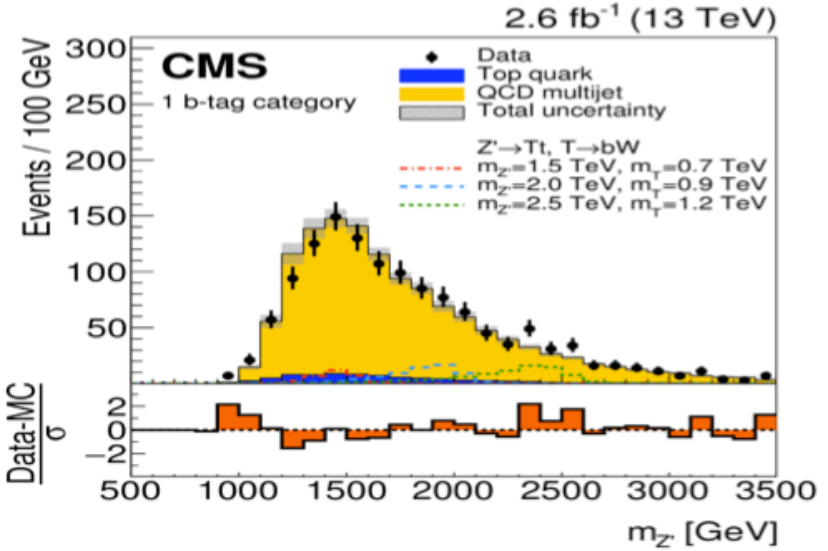
JHEP09(2017)053
arXiv:1703.06352

Z' → T + t

Z' decay to a vector-like T quark (VLQ) & top quark

- Models like composite-Higgs or warped extra dimensions
- Also sensitive to searches for single production of VLQ
  - *CMS-B2G-17-007/CERN-EP-2017-155 (*)*
- T decays into bW, tH, tZ (analysis optimized for bW)
- Fully hadronic search with top-tag + b-tag (AK4 jet) + W-tag
  - W-tag (tagger similar to top-tag) with : $70 < m_{SD} < 100$ GeV & $\tau_{21} < 0.6$
  - *ΔR (B-tag AK4, t-tag or W-tag)* > 0.8; $m_T > 500$ GeV
  - Categorization: SR 2 b-tag & SR 1 b-tag
    (presence or absence of b-tag subjet in t-tag)
  - $M_{Z'}$ reconstructed from the tagged jets
- Backgrounds: QCD (most important), single-top, ttbar
  - QCD: estimated from sidebands (inverting b-tag criteria on AK4 jets)





(*) Refer to VLQ at CMS talk from Atanu

Z’ → T + t

JHEP09(2017)053
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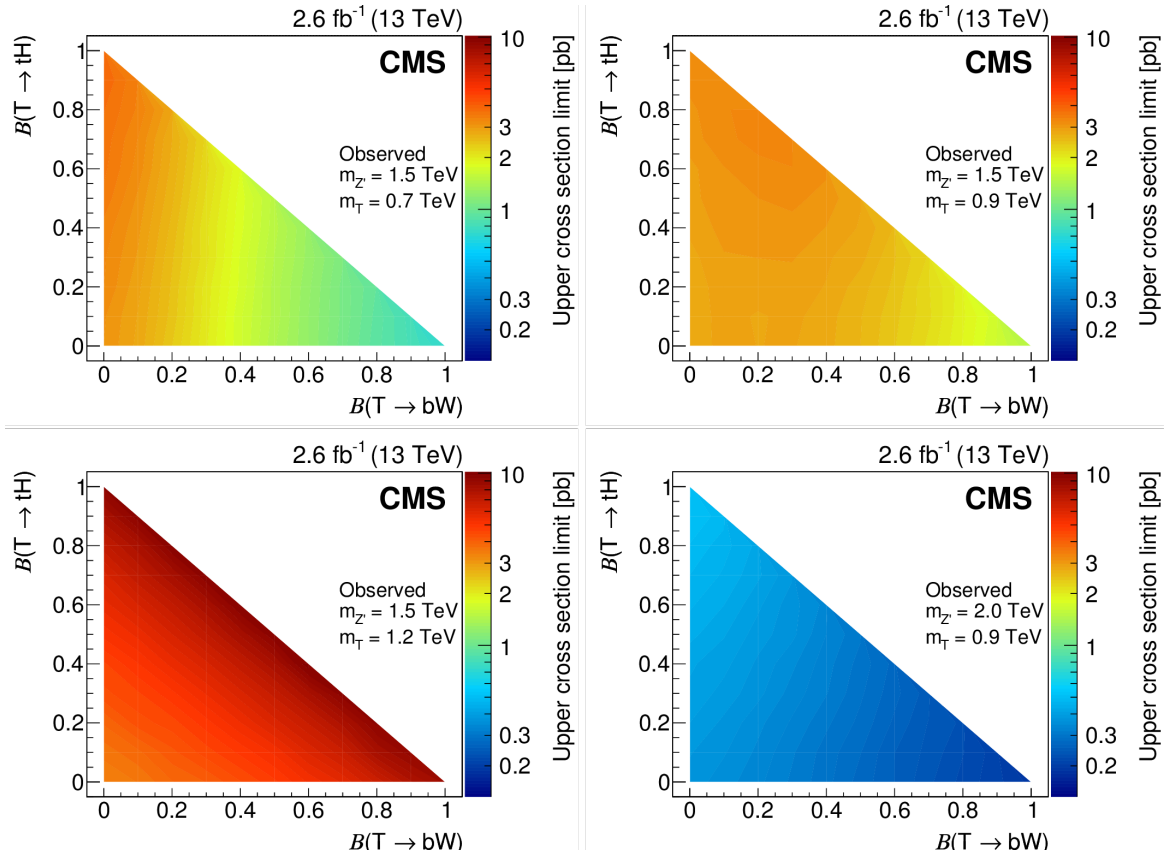
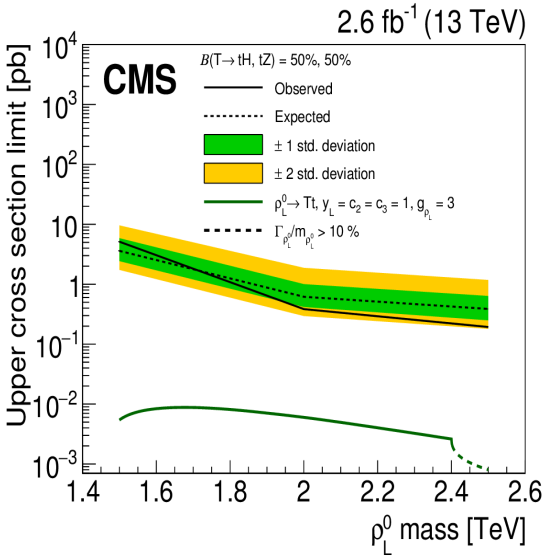


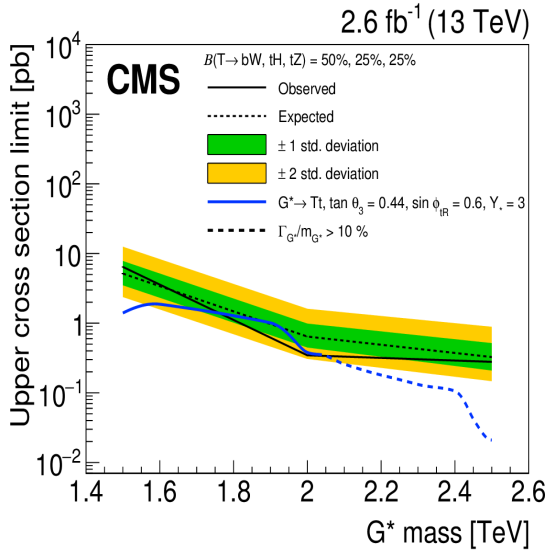
Cross-section limits for

- Various (Z’,T) mass combinations
- Scanning BR (T → bW, tH, tZ)

1D limits for 2 benchmark models

- more data needed for exclusion



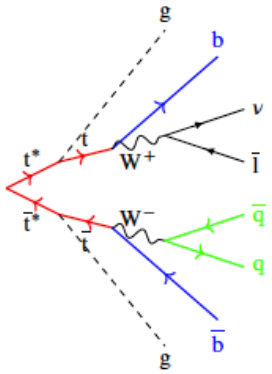


CMS-B2G-16-025 ; CERN-EP-2017-272
arXiv:1711.10949

$t^*\bar{t}^* \rightarrow tg + tg$

Pair production of excited top quarks (spin 3/2)

- *l+jets* channel
  - 1 isolated e/μ + E_t^{miss} + 6 jets (exactly 2 b-tagged)

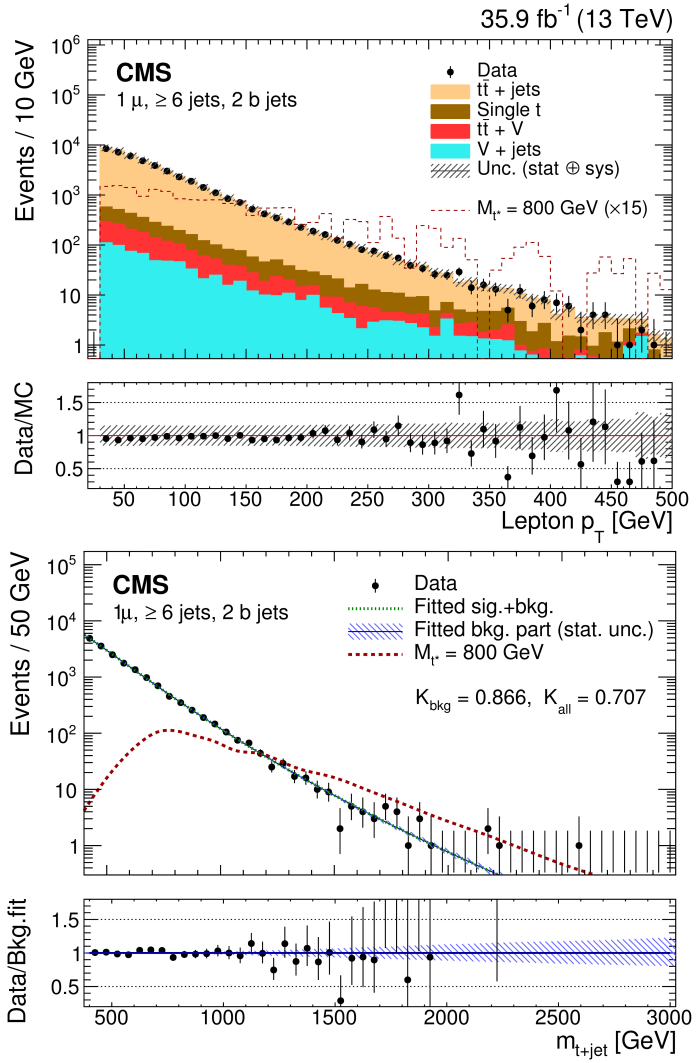


Resonance search in the m_{t+jet} spectrum

- Measure of jet-parton assignment used to reconstruct m_{t+jet}

$$S = \left(\frac{m_{qq'} - m_W}{\sigma_W}\right)^2 + \left(\frac{m_{qq'b} - m_t}{\sigma_{t,had}}\right)^2 + \left(\frac{m_{\ell\nu_l b} - m_t}{\sigma_{t,lep}}\right)^2 + \left(\frac{m_{qq'bg} - m_{\ell\nu_l bg}}{\sigma_{t^*}}\right)^2$$

- Data driven estimation
  - Signal + background fit for data
  - Parametric fit to background
- No significant excess found in data



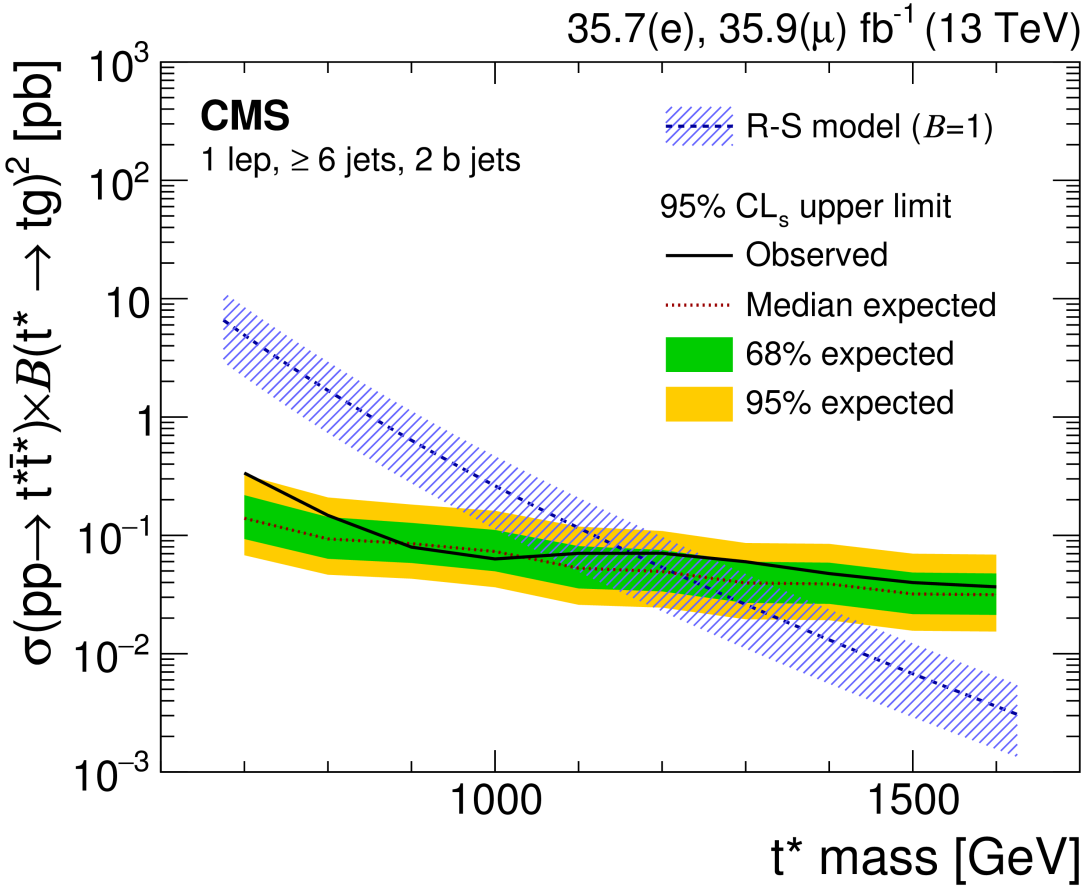
CMS-B2G-16-025 ; CERN-EP-2017-272
arXiv:1711.10949

$t^*\bar{t}^* \rightarrow tg + tg$

No deviation from SM prediction observed

t* masses below 1.2 TeV are excluded

First results obtained at 13 TeV



Summary

CMS has a rich search program for resonances with decays to third generation quarks: Z', W', t*, etc.

Results shown are obtained from 13 TeV data collected up to 2016. No deviation from SM observed.

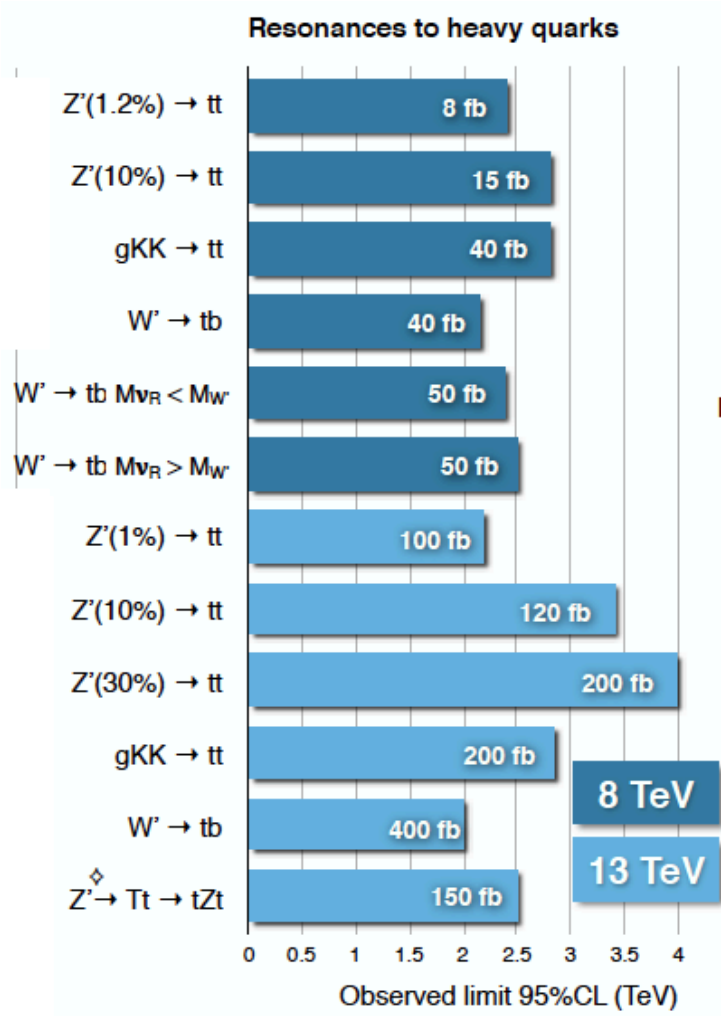
Wide range of boosted topologies studied.

Efficient sub-structure techniques used to reconstruct the boosted objects.

Various sophisticated algorithms used for tagging top, W/Z, b-jets.

Lot more data to analyze from 2017.

Stay Tuned!!



Thanks!

Back-Up

W’ → t + b

Limits from 2015 13 TeV data