Search for heavy BSM particles coupling to third generation quarks at CMS

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on behalf of the CMS experiment

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DER FORSCHUNG | DER LEHRE | DER BILDUNG

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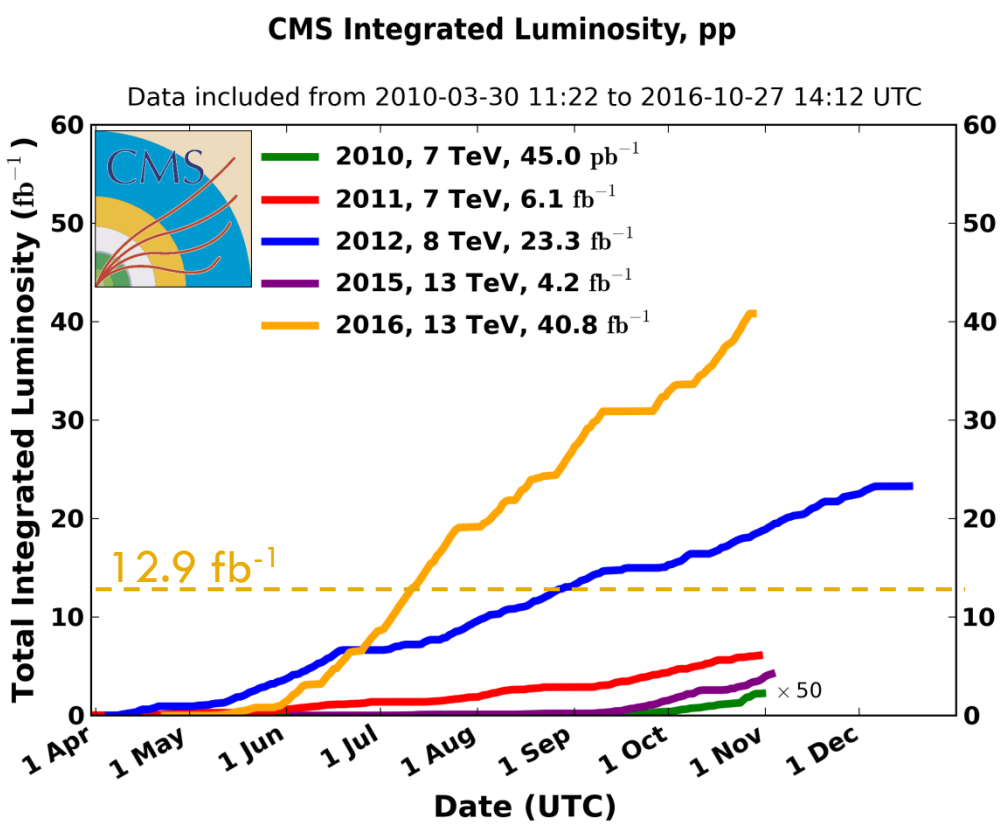
Introduction

- $m_t \sim 173$ GeV → large coupling to Higgs boson
- BSM particles with enhanced couplings to 3rd gen. quarks

new gauge bosons (Z', W'), **new fermions (vector-like)** (T', $X_{5/3}$), **new bosons coupling to quarks and leptons** (LQ)

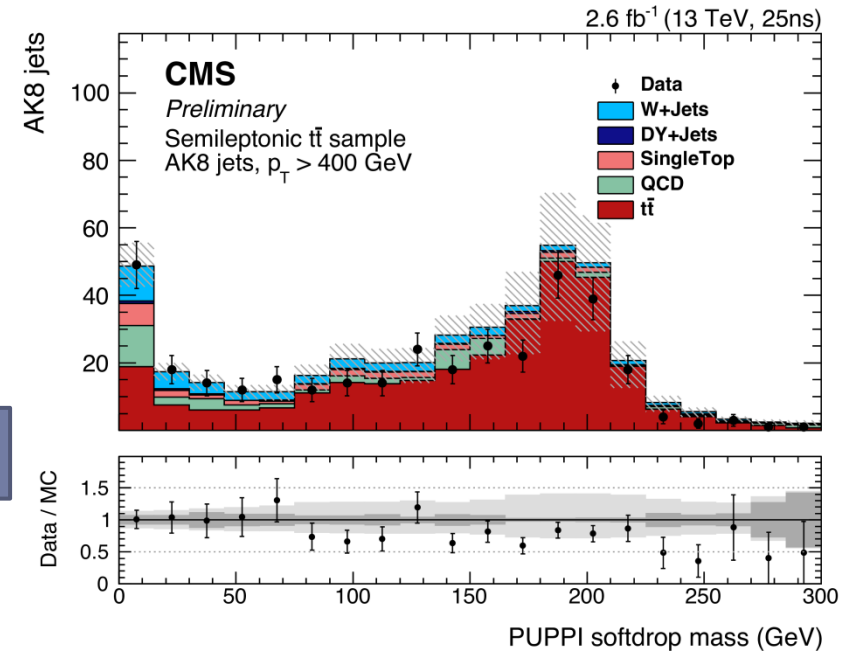


- T' → tZ (35.9 fb^{-1})
- $X_{5/3}X_{5/3}$ → tW tW (35.9 fb^{-1})
- W' → bt (35.9 fb^{-1})
- Z' → tt (2.6 fb^{-1})
- Z' → T't (2.6 fb^{-1})
- LQLQ → bτ bτ (12.9 fb^{-1})

Analysis tools I

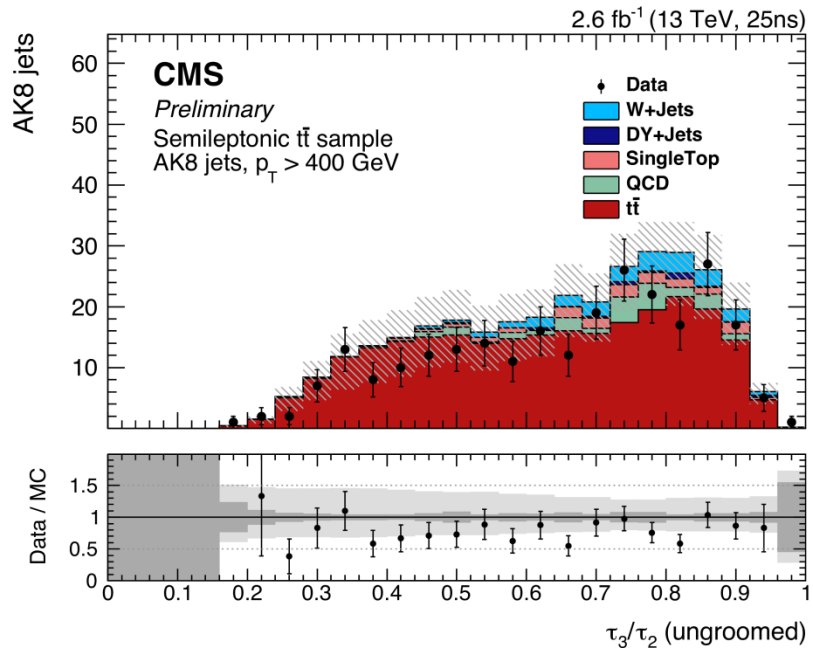
- decay of heavy objects
- → top (W) decay products collimated
- → reconstruction within anti-k_T jets R = 0.8

CMS PAS JME-16-003



<u>top tagging:</u>

- **m_{SD}** : jet mass, soft-drop grooming applied
  - removal of soft wide-angle radiation within large-cone jet
  - reconstruction of subjets
- **n-subjettiness τ_i :** measure for probability that large-cone jet contains i subjets
- **subjet b - tagging:** b tagging on subjets

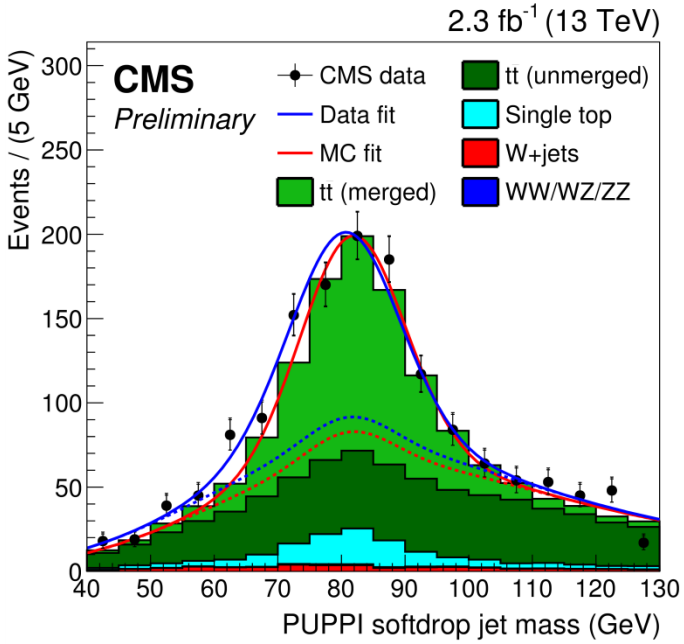


Analysis tools II

W tagging:

CMS PAS JME-16-003

- **m_{SD} or pruned jet mass**
  - pruning: remove particles not passing distance and p_T requirement during jet clustering
- **n-subjettiness : τ_2/τ_1**



special lepton isolation:

- p_T dependent isolation cone

$$R_{mini} \sim 1/p_T \ , \ 0.05 < R_{mini} < 0.2$$

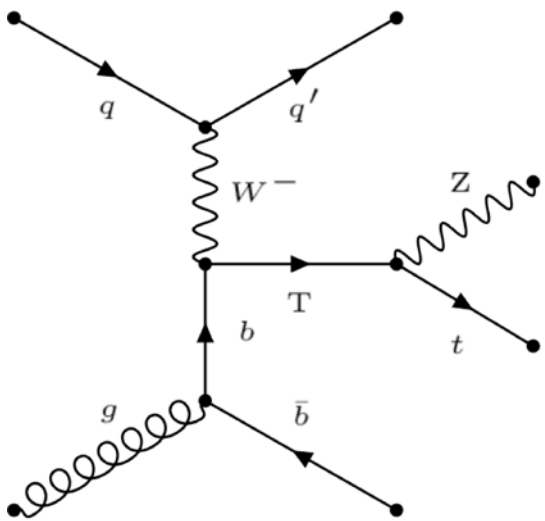
- non-isolated leptons

$$\Delta R(l, \text{jet}) > 0.4 \ || \ p_T^{rel} > 40 \text{ GeV}$$

T'→Zt (single prod.)

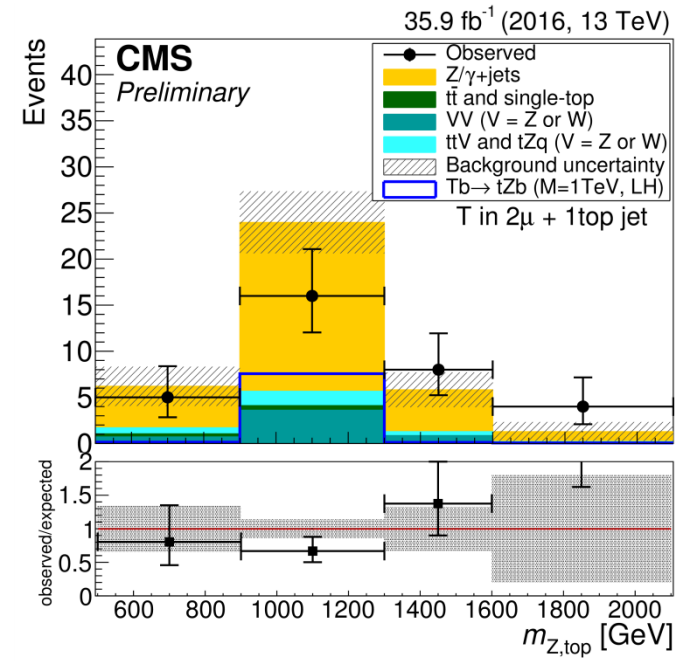
35.9 fb^{-1}

CMS PAS B2G-17-007

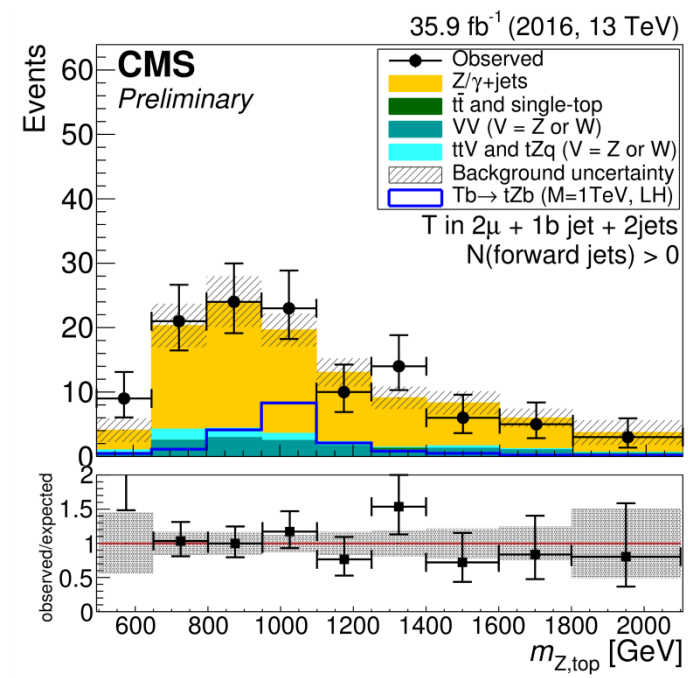


signature:

- two leptons ($M_{ll} \sim M_Z$)
- hadronically decaying top
- forward jet
- additional b/top quark

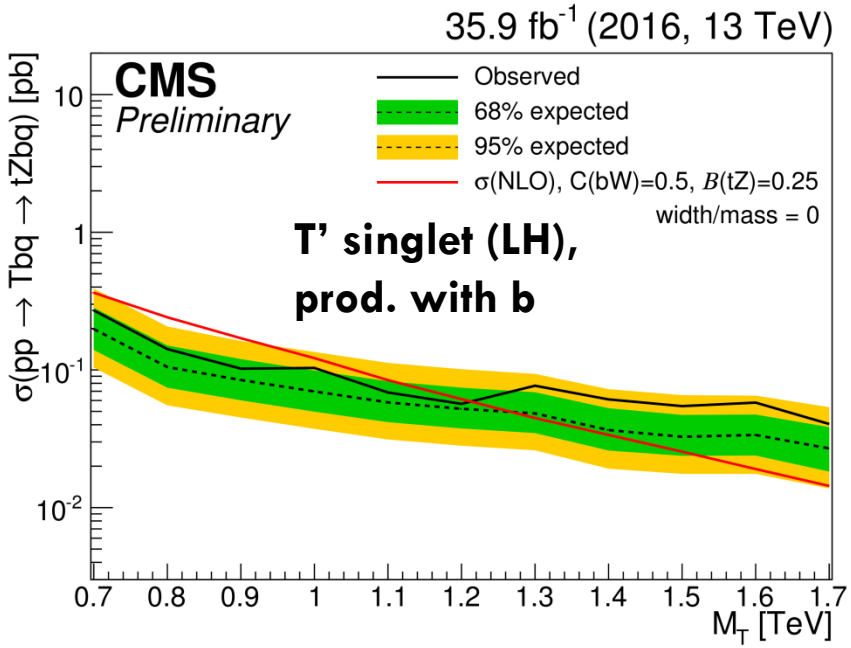


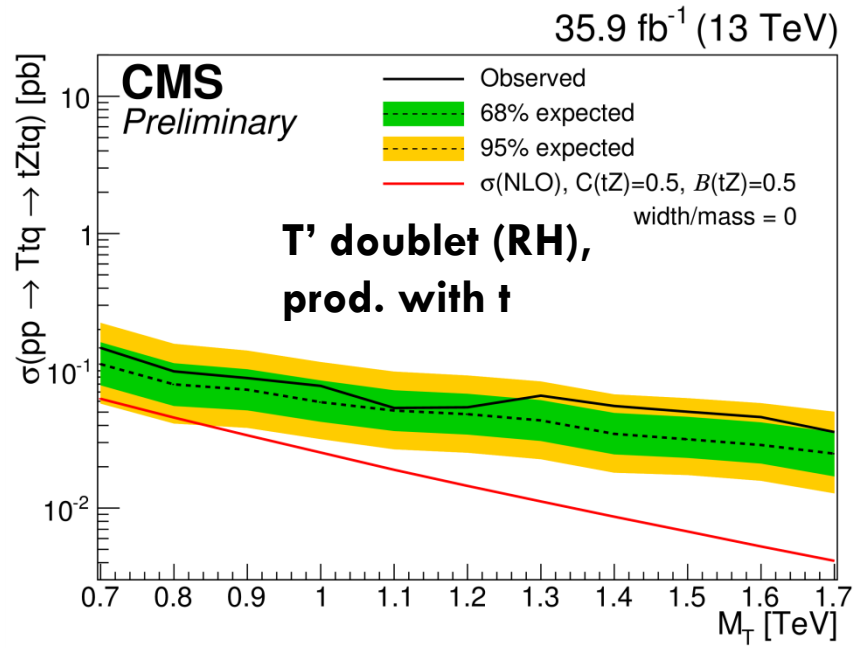
- 10 event categories
  - μμ or ee
  - no or ≥ 1 forward jet
  - top tag, W tag and b tag or three small-cone jets
- reconstruction of **T' candidate**



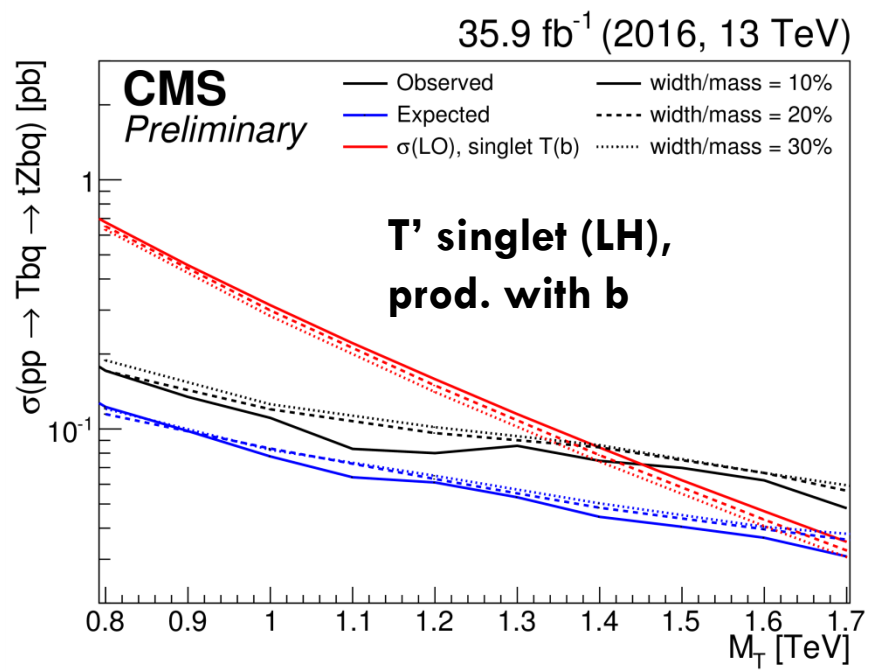
T'→Zt (single prod.)

35.9 fb^{-1}





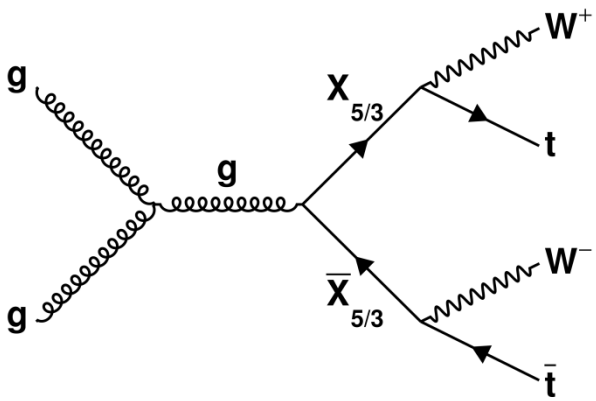
- production cross section dependent on mass & width (coupling)
- different T' widths probed
  - similar sensitivities
- interpretation as search for Z' →T't



$X_{5/3}\ X_{5/3} \rightarrow tW\ tW$

35.9 fb^{-1}

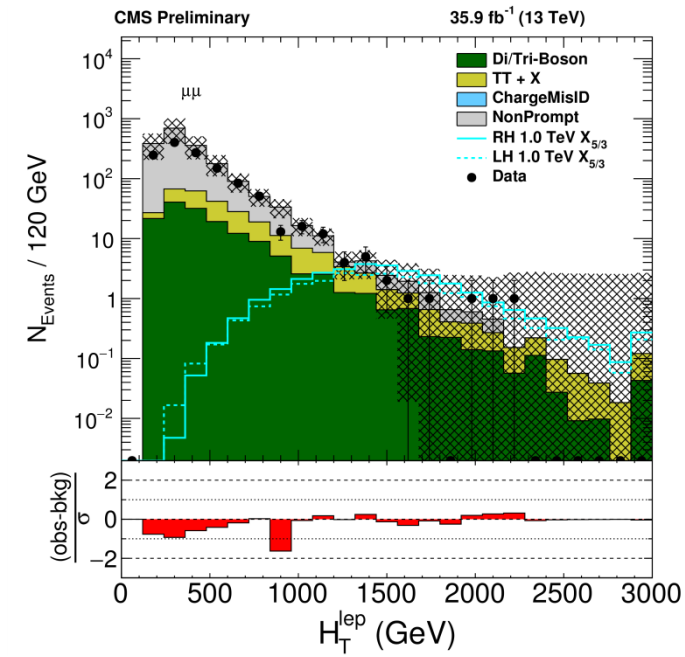
CMS PAS B2G-16-019



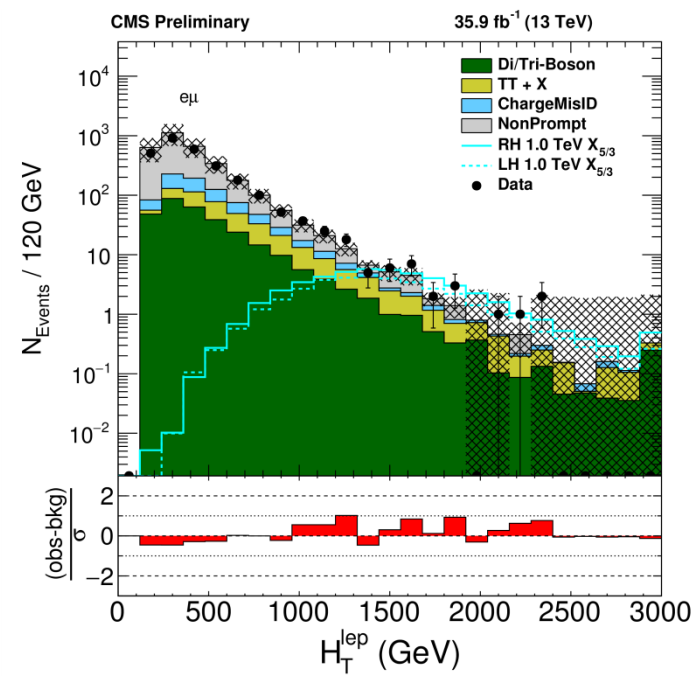
signature:

- same-sign di-lepton pair
- at least five additional particles (jets or leptons)

→ high $H_T^{lep} = p_T^{jets} + p_T^{lep}$



- p_T dependent lepton isolation
- data-driven estimation of backgrounds from charge mismeasurement & misidentified leptons



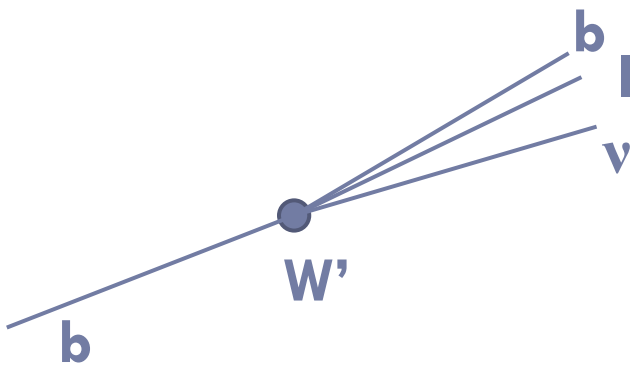
- exclusion of **right-handed (left-handed)** $X_{5/3}$ below **1.2 TeV (1.15 TeV)**

W' → tb

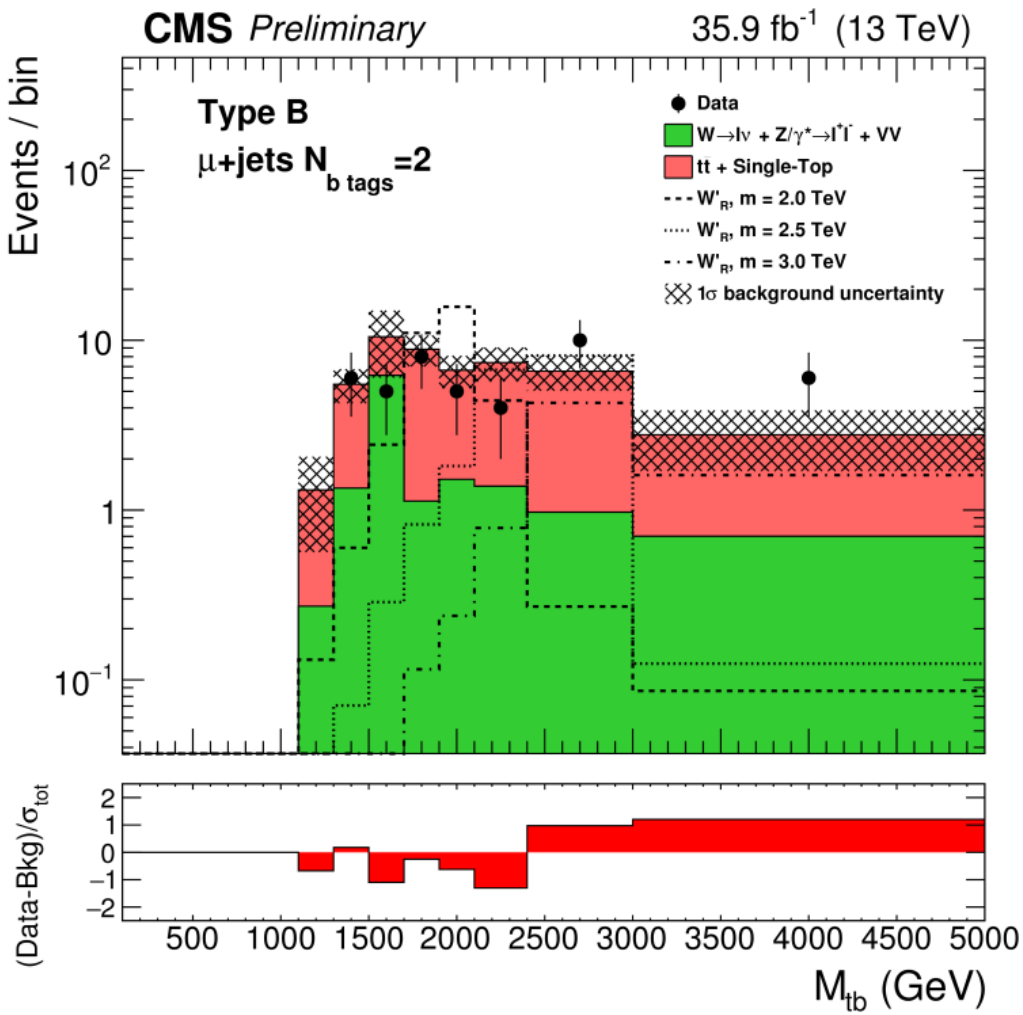
35.9 fb^{-1}

CMS PAS B2G-17-010

W' reconstruction using lepton, $\not{E}_T$ and 2 jets

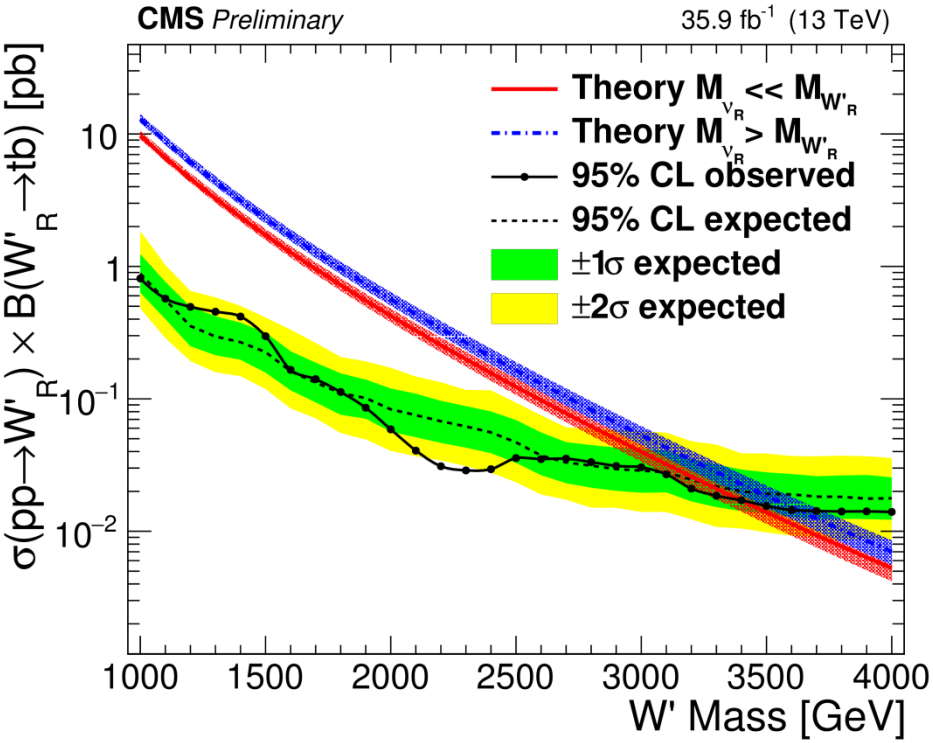


- type B : p_T^{top} > 650 GeV and p_T^{j1+j2} > 700 GeV
- type A: other
- categories based on
  - e / μ
  - 1 or 2 of leading-p_T jets b tagged
  - type A or type B

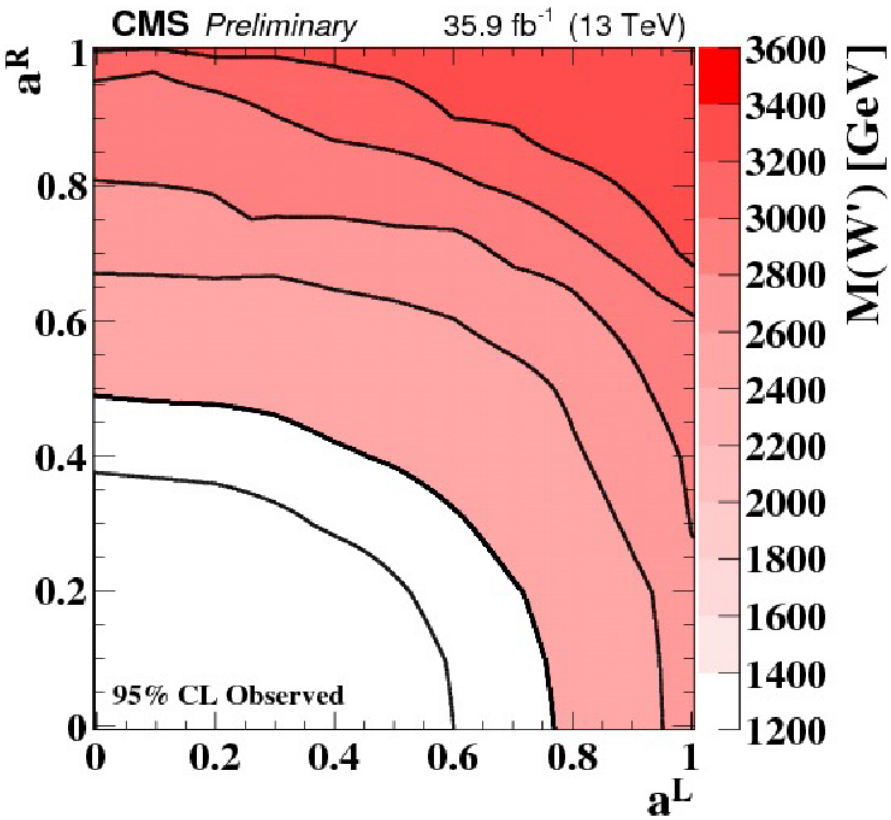


W' → tb

35.9 fb^{-1}



- exclusion below
  - $M_{W'R} >> M_{\nu R}$: **3.4 TeV**
  - $M_{W'R} < M_{\nu R}$: **3.6 TeV**
- right-handed couplings only



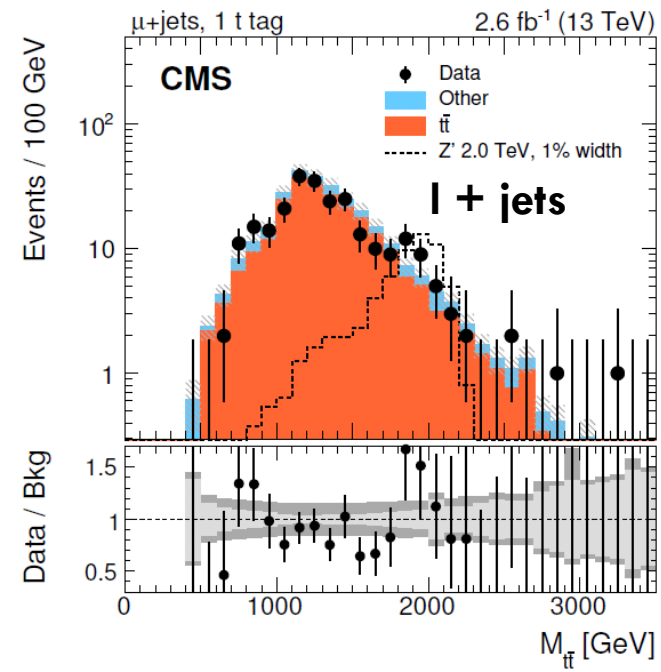
- arbitrary coupling strengths to left-handed (a_L) and right-handed (a_R) fermions

Z'→ $t\bar{t}$

2.6 fb^{-1}

arxiv:XXXX.XXXX

combination of l +jets and full hadronic analysis

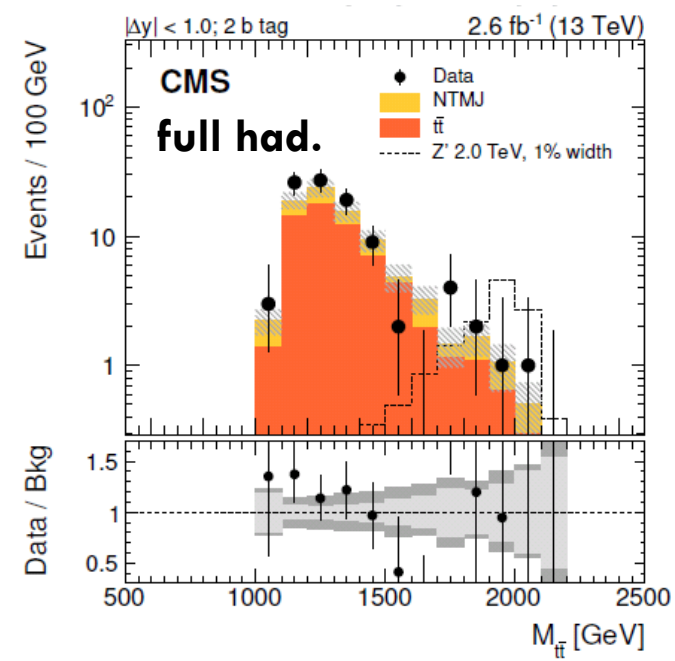


<u>l +jets channel:</u>

- non-isolated leptons
- categories based on top tags and b tags

<u>fully hadronic channel:</u>

- two top tagged jets
- 6 categories based on $|\Delta y|$ & number of jets with b tagged subjet

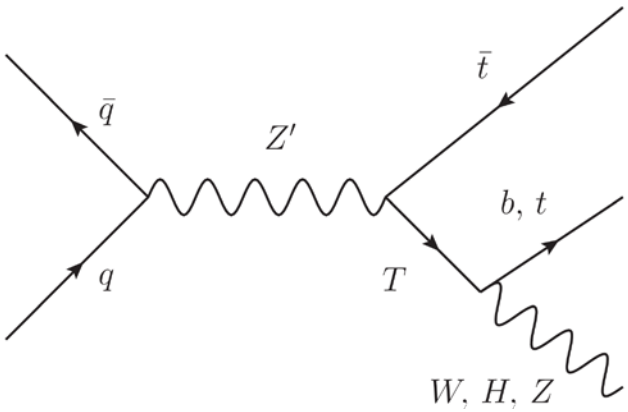


→ exclusion below **4 TeV** (Z' 30% width), **3.9 TeV** (Z' 10% width) and **3.3 TeV** (RS KK gluon)

Z' → T't

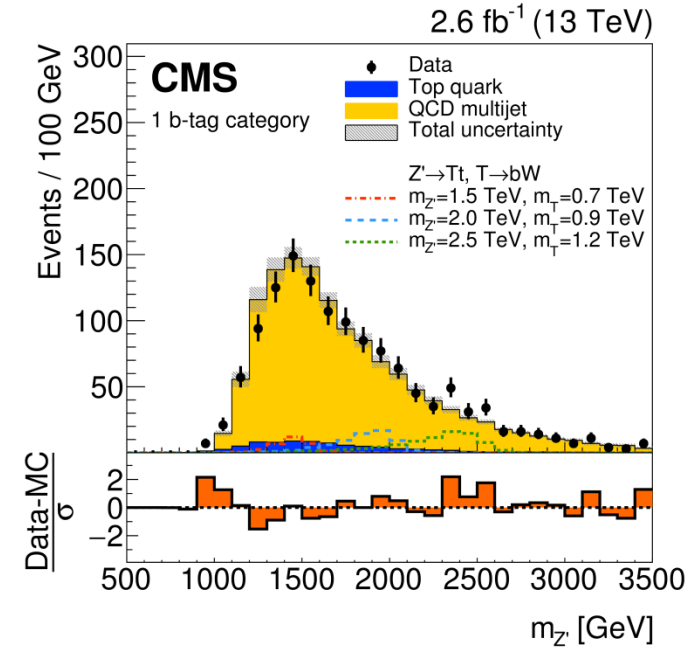
2.6 fb^{-1}

arxiv:1703.06352

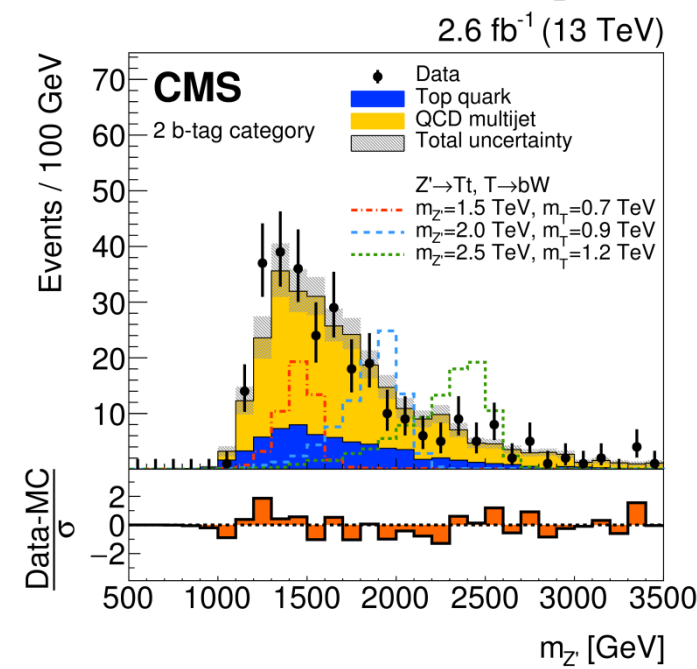


Z' & T' appear in same models, Z' →T't dominant if $m_t+m_{T'} < m_{Z'} < 2m_{T'}$

not covered by traditional searches



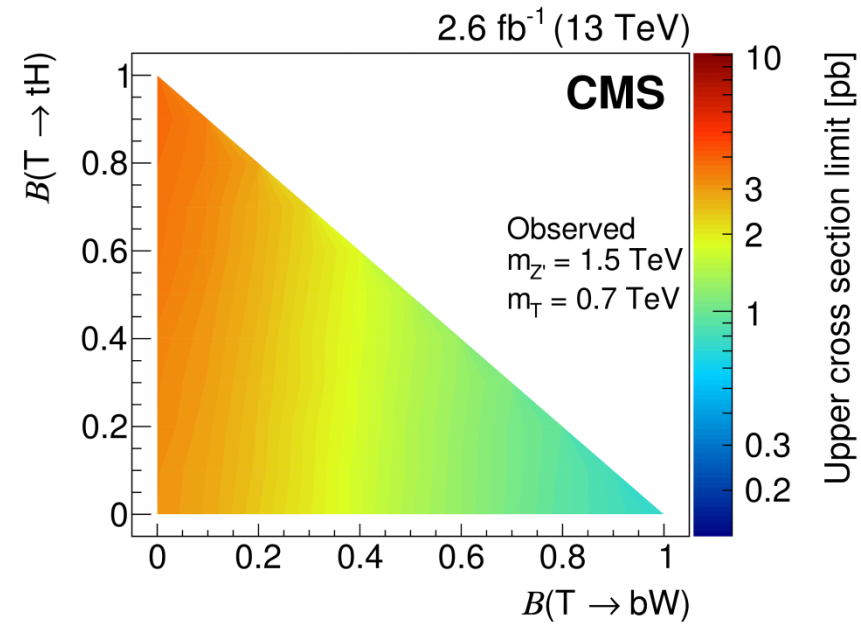
- full hadronic search, T'→bW
- boosted W (T'), boosted top (Z')
- W, top and b tagging
- → categorization based on subjet b tag and b tagged small-cone jets



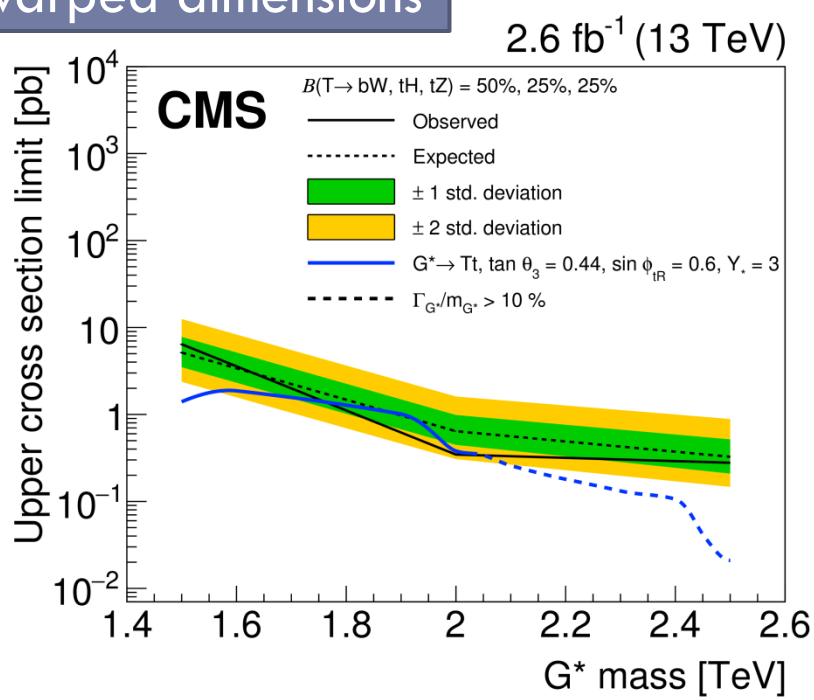
Z' → T't

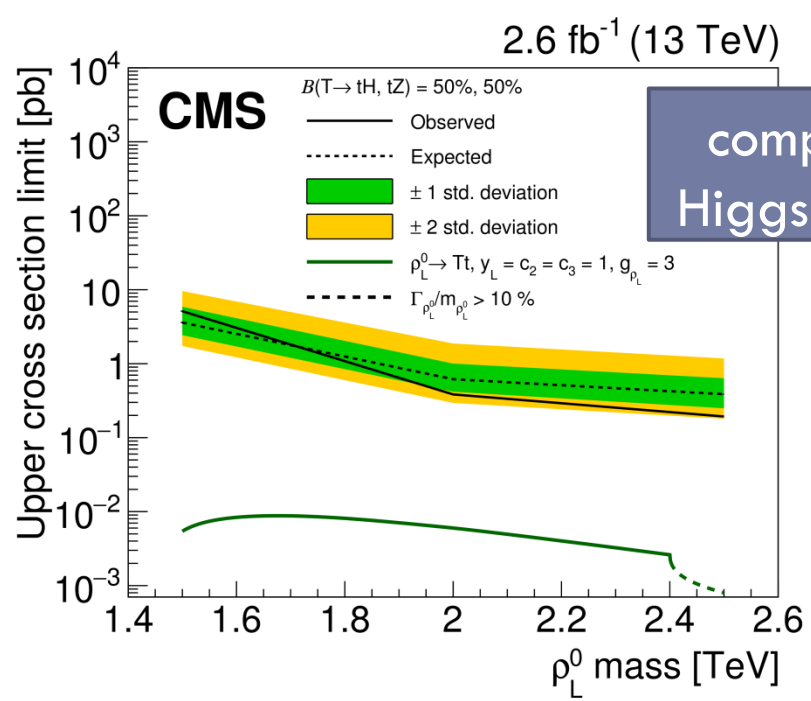
2.6 fb^{-1}

- multiple mass combinations for Z' & T'
- scan branching ratios of T'→ bW / tZ / tH
- two benchmark models



warped dimensions





composite Higgs model

LQ LQ → bτ bτ

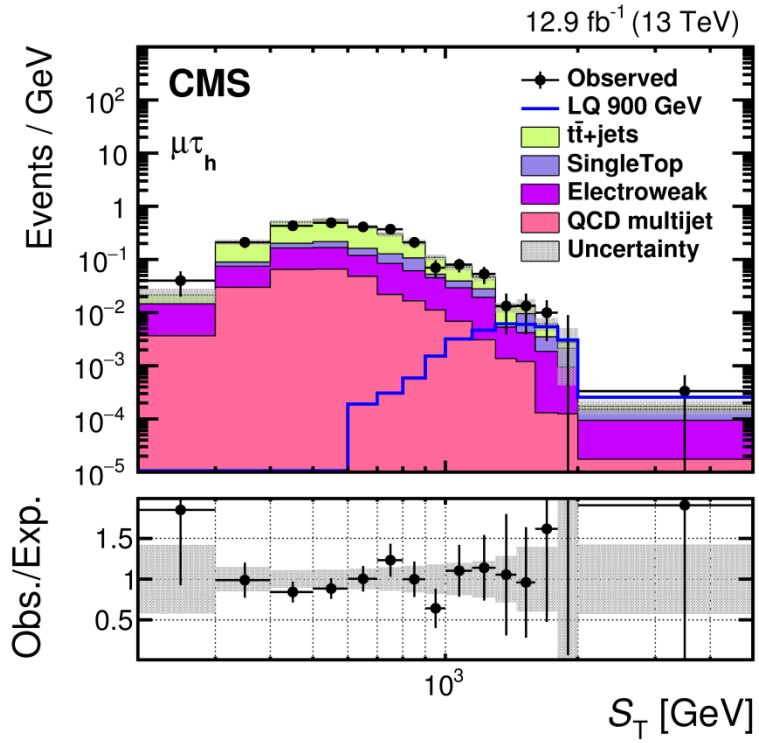
12.9 fb^{-1}

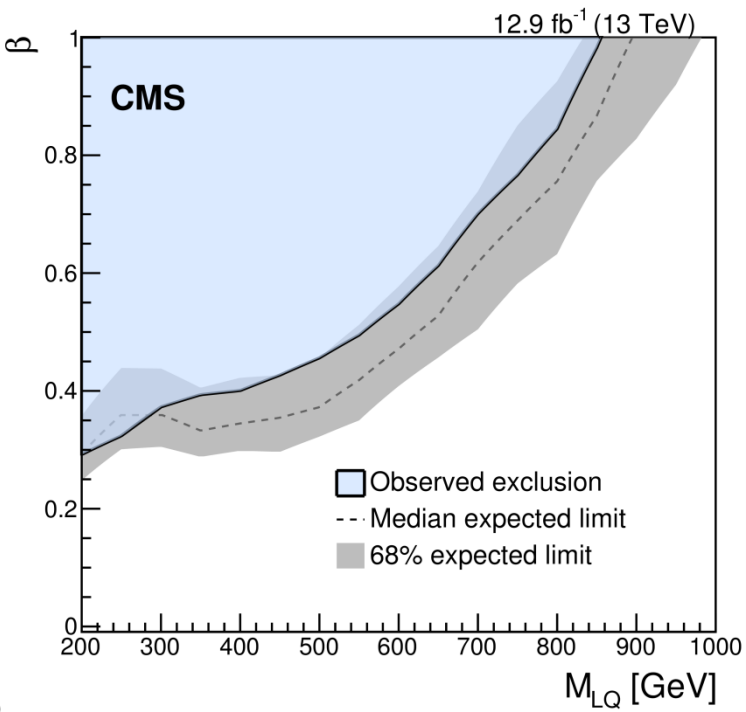
arxiv: 1703.03995

$$S_T = p_T^{e/\mu} + p_T^{jets} + \not{E}_T$$

signature:

- one hadronically decaying τ
- one e or μ from leptonically decaying τ
- ≥ 2 jets (one b tagged jet)





- BR (LQ→b τ) = 100% : **850 GeV excluded**
- also interpreted as $W'_R \rightarrow \nu_R\, \tau \rightarrow \tau\, q\, \bar{q}\, \tau$

Summary

- rich search program for heavy particles decaying into third generation quarks
- novel decay channels, benchmark models tested
- substructure tools become more important to maintain sensitivity
- many more results to come with 2016 data

Thank you for your attention!