Searches for New Physics in Top-like Final States

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on behalf of the CMS Collaboration
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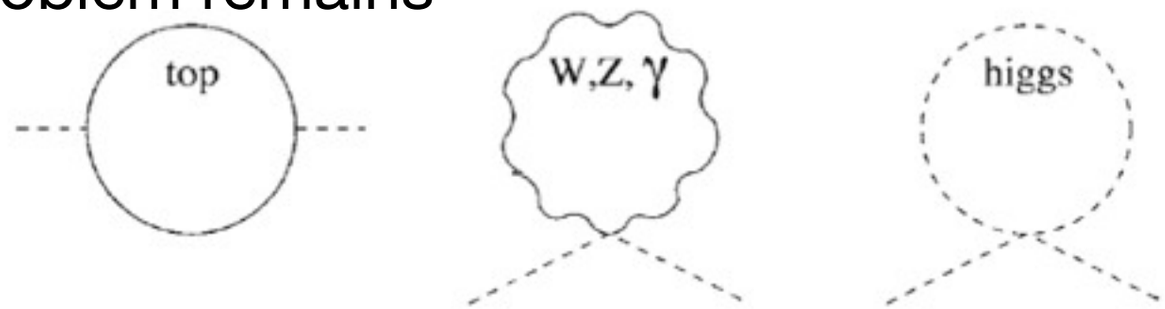
Introduction

❖ **A scalar boson (~125 GeV) has been discovered**

- Appears to be standard model (SM) Higgs boson
- Hierarchy problem remains



❖ **A number of new models proposed to solve hierarchy problem. For example, little Higgs models :**

- Introduce a vector-like top (T) quark and W' to cancel the divergencies from the top loop and the W loop, respectively.
- A triplet vector-like quark = ($T_{5/3}$, T, B).
- The above new particles could be related to a decay final state containing top quark like T→tZ, W'→tb, $T_{5/3}$→tW, B→tW, and so on.

❖ **The composite top quark is also an interesting model**

- Can be directly tested by search for an excited top quark (t*→t+gluon).

Searches for new particles

❖ **Top + jet final state**

CMS-PAS-B2G-12-010 : W' → t+b with 19.6 fb^{-1} at $\sqrt{s}$ = 8 TeV

Previous result : $M(W'_R) > 1.85$ TeV (EXO-12-001)

CMS-PAS-B2G-12-014 : t* → t+gluon with 19.6 fb^{-1} at $\sqrt{s}$ = 8 TeV

❖ **Top + W final state**

CMS-PAS-B2G-12-012 : $T_{5/3}$ → t+W with 19.6 fb^{-1} at $\sqrt{s}$ = 8 TeV

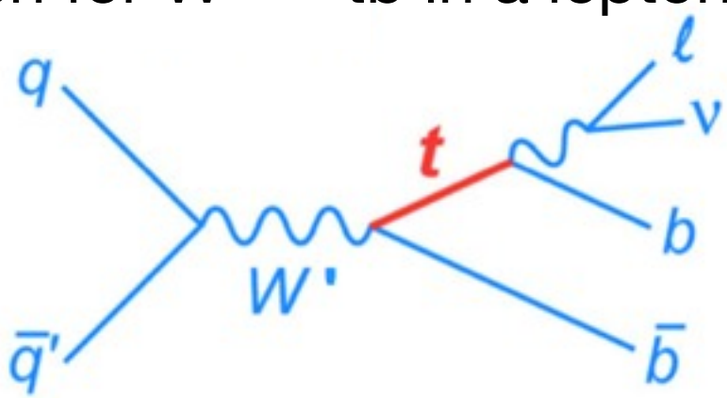
Previous result : $M(T_{5/3}) > 645$ GeV (B2G-12-003)

CMS-PAS-SUS-12-027 : b' → t+W with 9.2 fb^{-1} at $\sqrt{s}$ = 8 TeV

Previous result : M(b') > 675 GeV (B2G-12-004)

t+b resonance (I)

❖ Search for W' → tb in a leptonic final state



❖ An arbitrary combination of left- and right-handed couplings allowed

❖ Event selection :

Isolated lepton (e or μ), ≥ 2 jets, and ≥ 1 b-jet

❖ Mass reconstruction :

m(l+ν)=m_W, m(j+l+ν)↔m_{top}, m(top+another j)

❖ Additional selection :

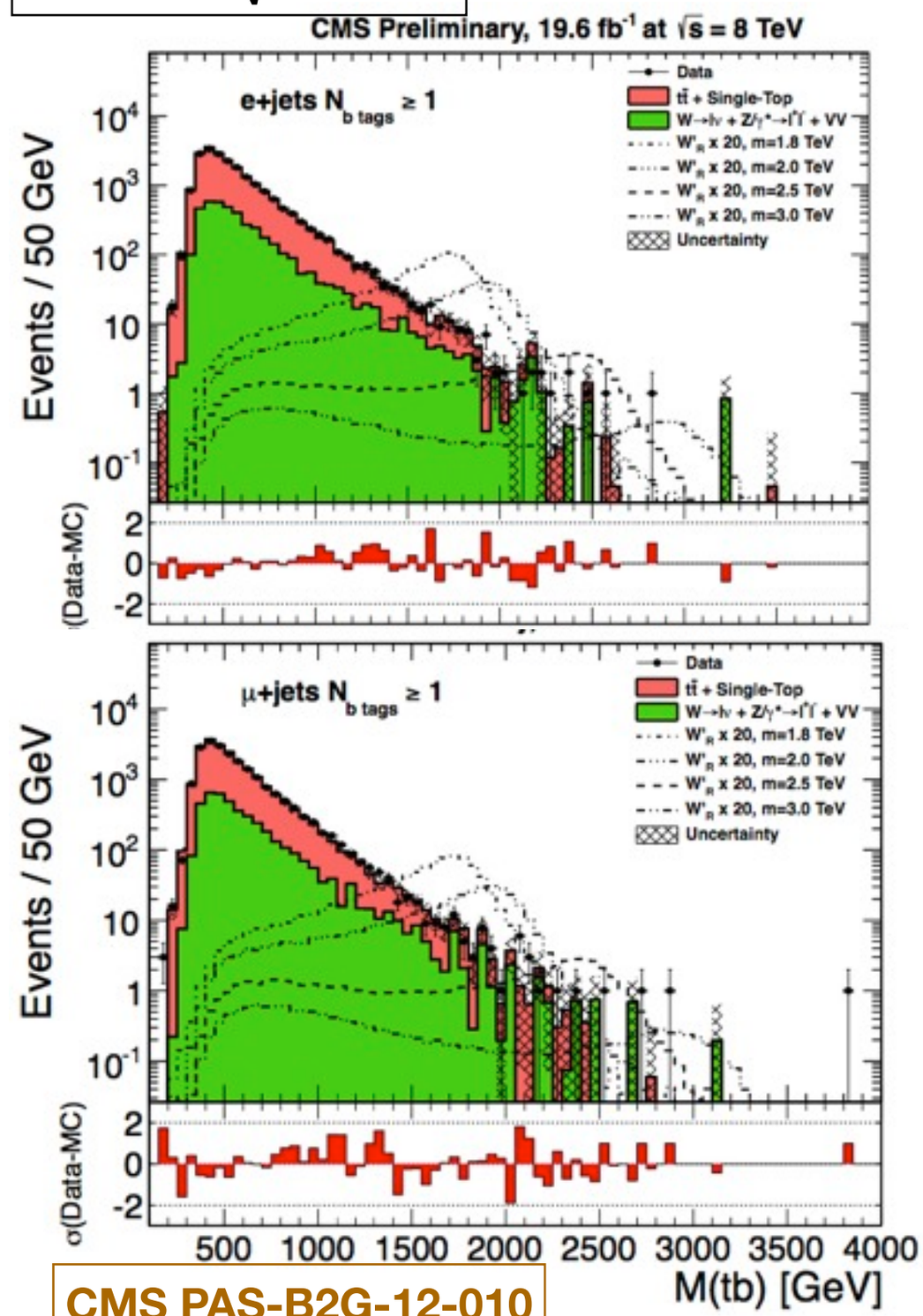
130 < m_{top} < 210 GeV, p_T(top), and p_T(j1,j2)

❖ Background modeling :

Wjet : Shape from the pre b-tag sample

$t\bar{t}$: Data/MC ratio function for p_T(top) obtained from a $t\bar{t}$-enriched region, and re-weight MC

19.6 fb^{-1}@ √s = 8 TeV

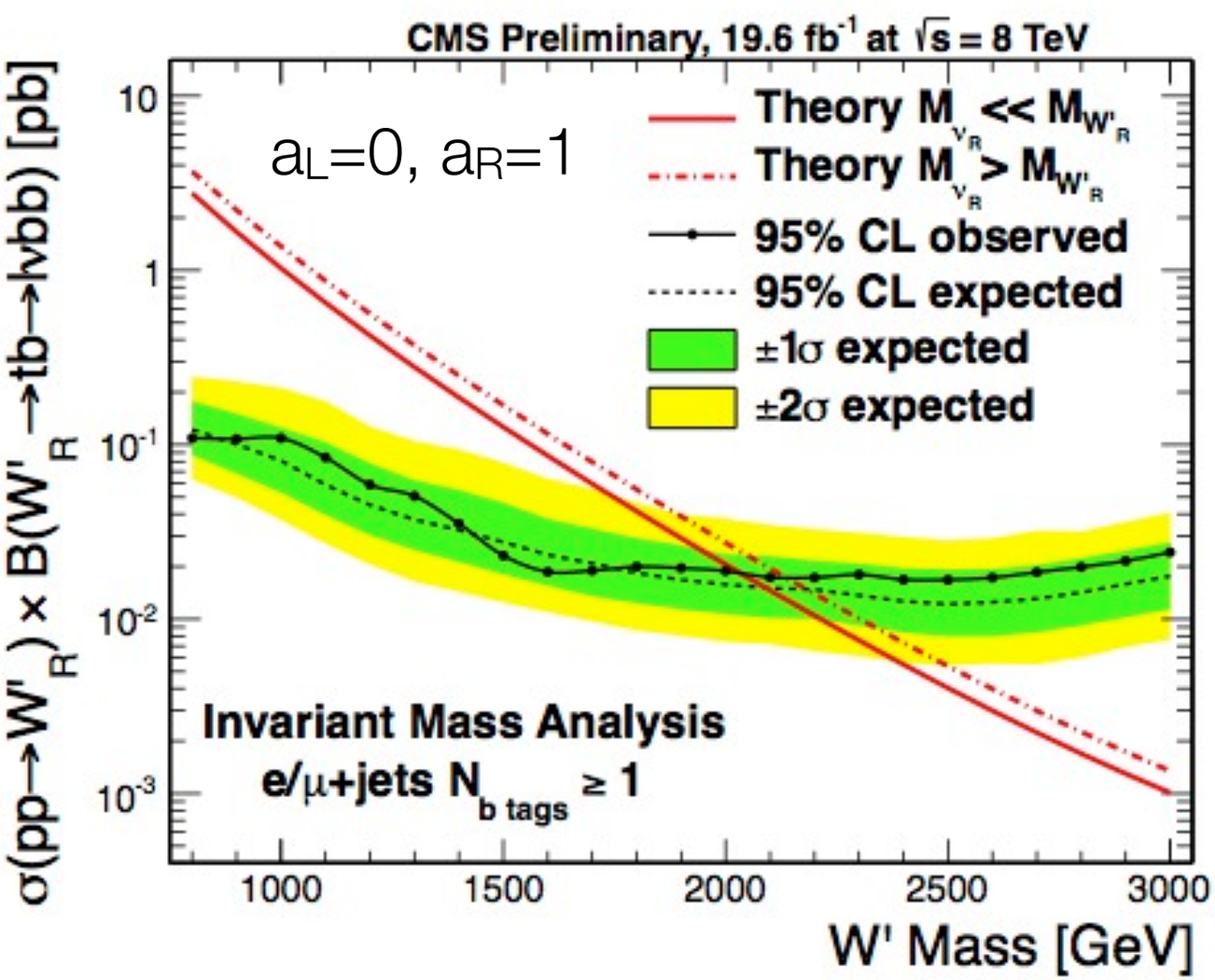


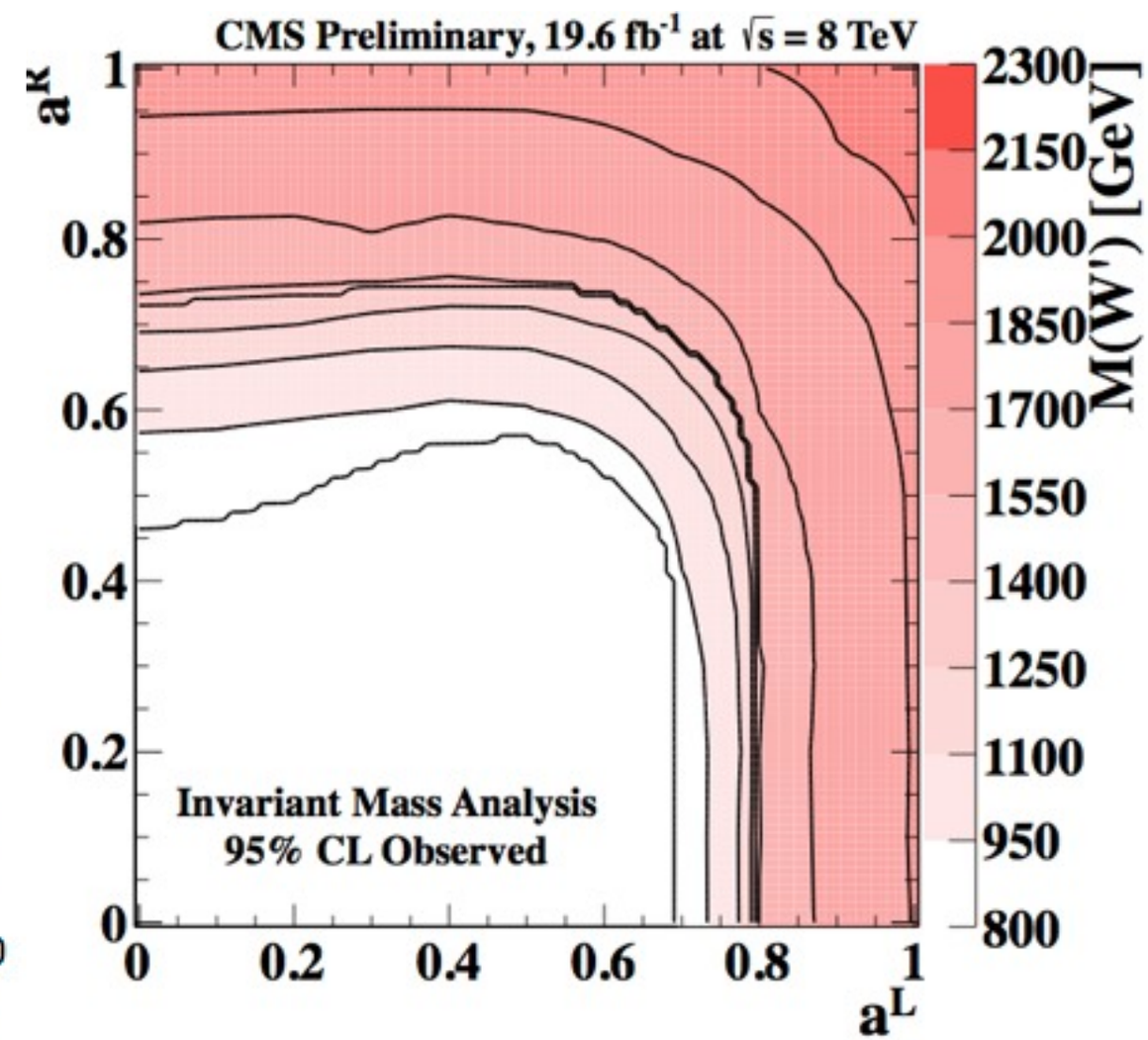
CMS PAS-B2G-12-010

t+b resonance (II)

❖ For W' bosons with right-handed couplings to fermions, we exclude masses below 2.03 TeV at 95% C.L.

❖ We also set limits on W' masses for arbitrary left- and right-handed couplings.





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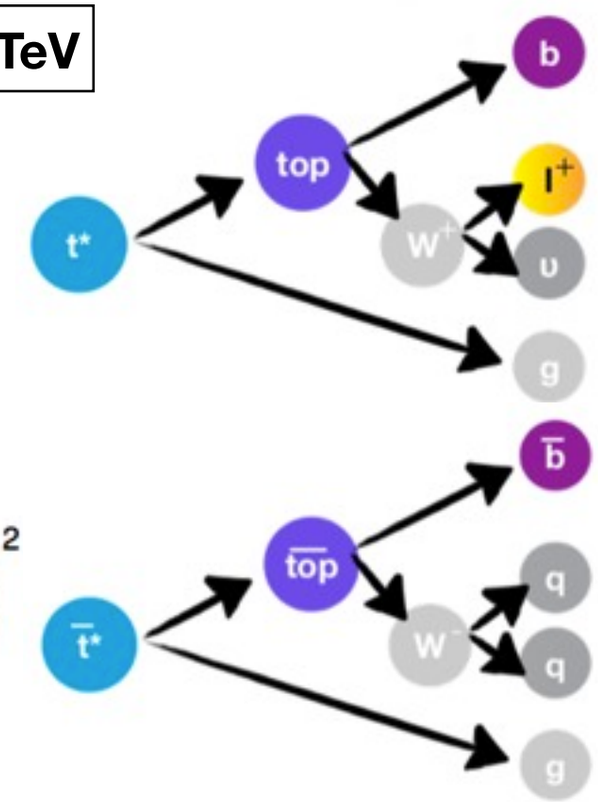
t + jet resonance (l)

19.6 fb^{-1}@ $\sqrt{s}$ = 8 TeV



- Search for pair-production of t*, decaying into t+gluon in a semi-lepton channel
- Event selection :

  Isolated lepton (e or μ), ≥6 jets, and ≥1 b-jet
- Mass reconstruction using kinematic fit

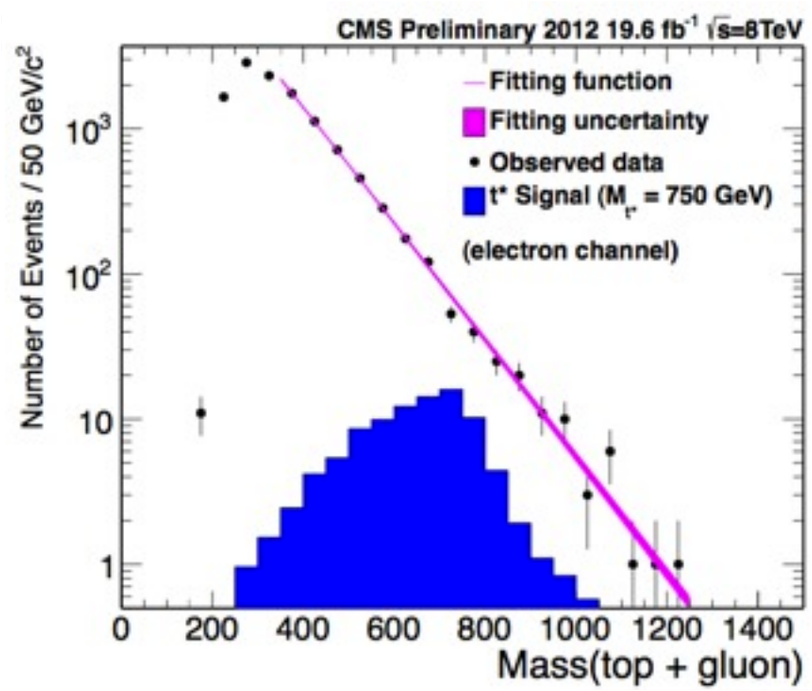
$$\chi^2 = \sum_{i=\ell,j_1\ldots j_6} \left\{ \left(\frac{p^i - p^i_{fit}}{\delta p}\right)^2 + \left(\frac{\phi^i - \phi^i_{fit}}{\delta \phi}\right)^2 + \left(\frac{\eta^i - \eta^i_{fit}}{\delta \eta}\right)^2 \right\}^2 + \left(\frac{k^x - k^x_{fit}}{\delta k^x}\right)^2 + \left(\frac{k^y - k^y_{fit}}{\delta k^y}\right)^2$$

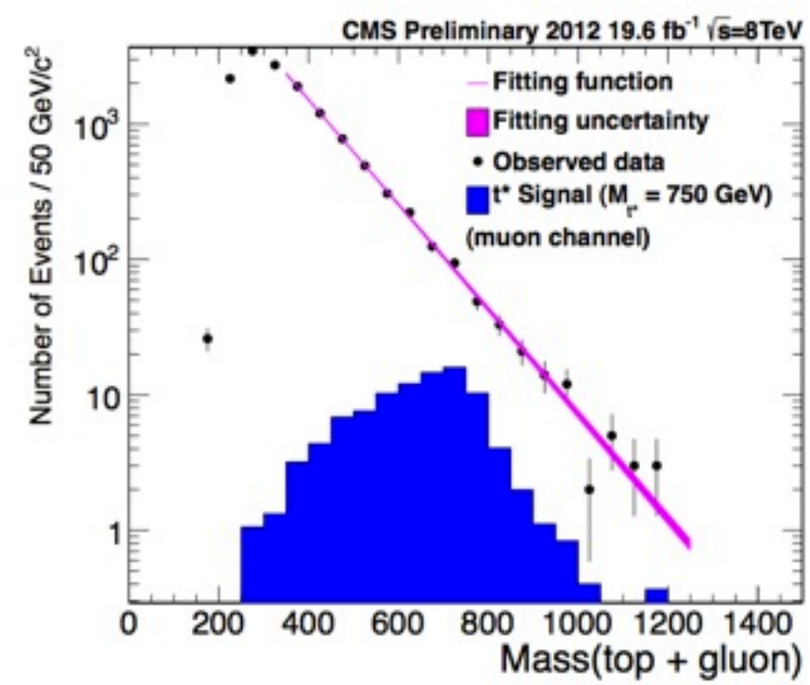
  where $\vec{k_T} = \binom{k^x}{k^y} = \vec{p_T} + \sum_{i=\ell,j_1\ldots j_6} \vec{p^i_T}$
- Background modeling :

$$bg(m) = \frac{a}{1+e^{(m-b)/c}}$$

- Global fit to data:

  bg(m,a,b,c) + α signal(MC)





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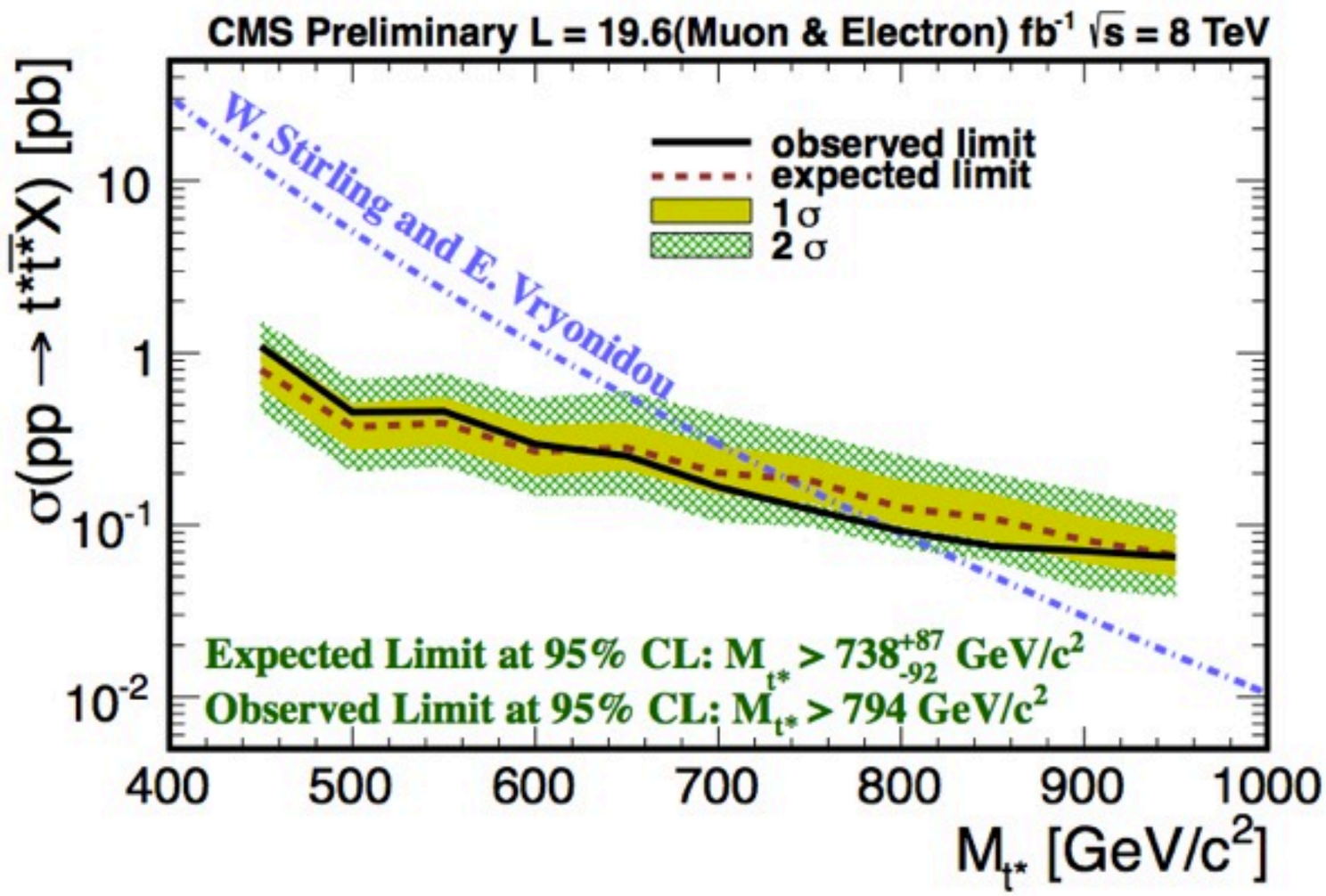
t + jet resonance (II)

- Interpreted in terms of a spin-3/2 top quark
- M(t*) > 794 GeV at 95% C.L.
  assuming 100% BR(t* → tg)



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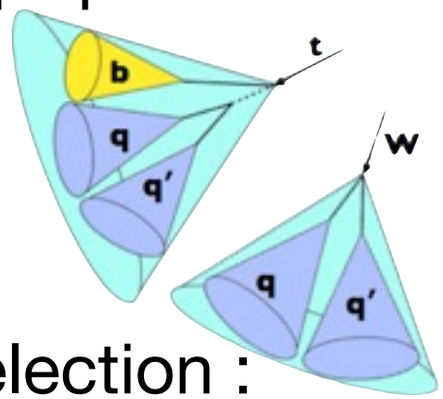
t+W resonance with charge 5/3 (I)

❖ Search for pair-production of $T_{5/3}$, decaying into tW in a same-sign dilepton channel

❖ Cambridge-Aachen (CA) jets for boosted top quark and W boson



❖ Event selection :

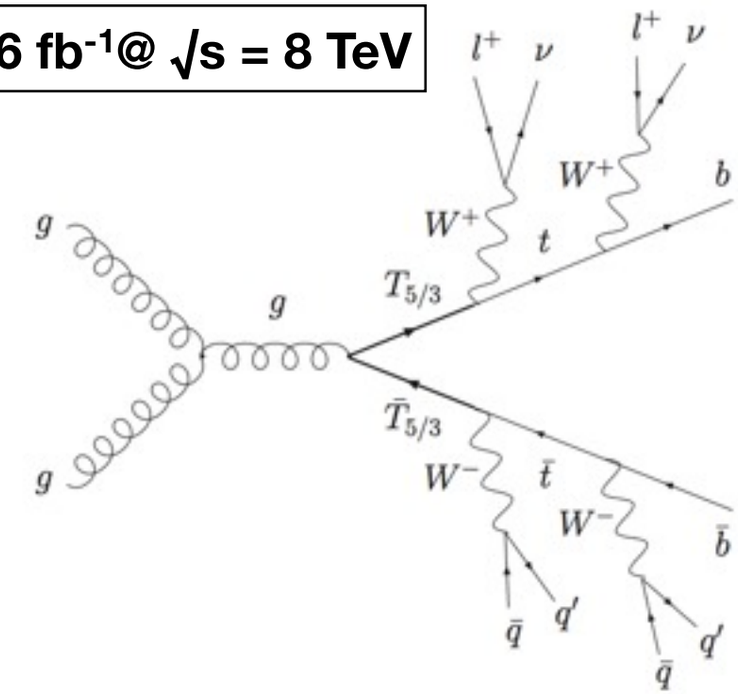
2 isolated leptons, Quarkonia veto,

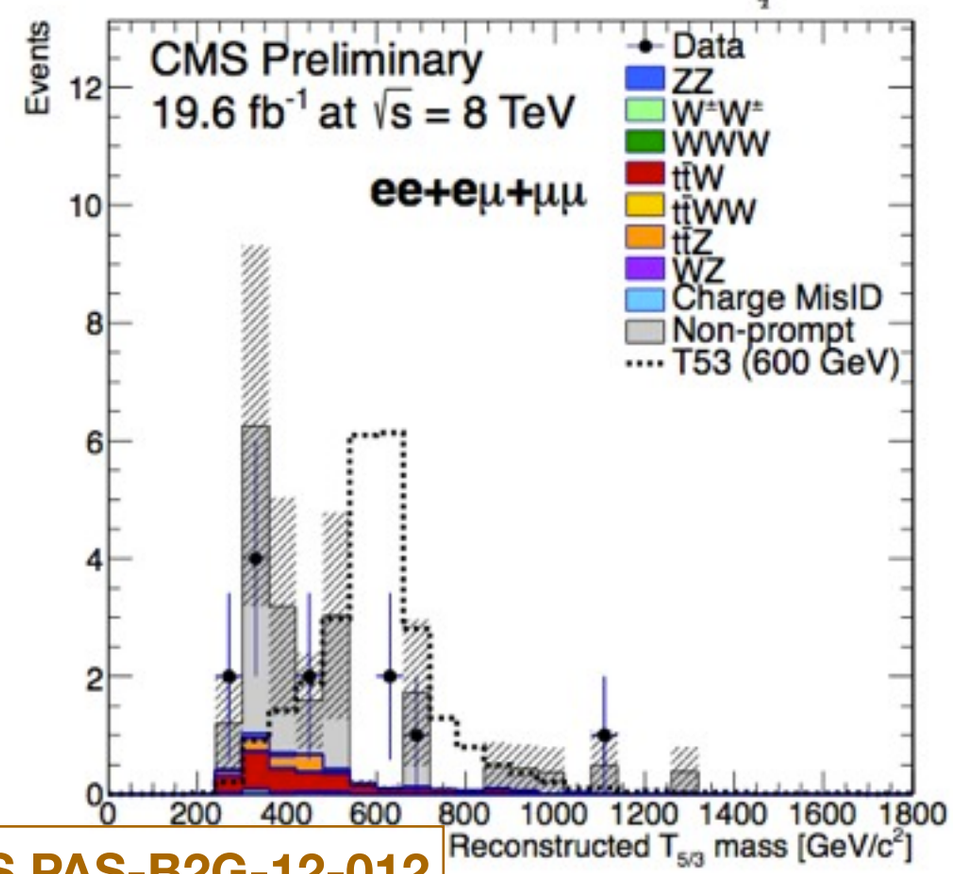
Z veto, and N(sub-jets and Ak jets) ≥ 5

❖ Mass reconstruction :

	CA Top	CA W	Ak jets
Combination1	V	V	
Combination2	V	-	V
Combination3	-	V	V
Combination4	-	-	V

19.6 fb^{-1}@ √s = 8 TeV





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t+W resonance with charge 5/3 (II)

❖ Background estimation :

- Same-sign prompt lepton

  WW, WZ, ZZ, ttW/Z, WWW processes. Obtained using simulated samples.

- Opposite-sign prompt lepton

  Charge mis-ID rate determined using Z-control sample

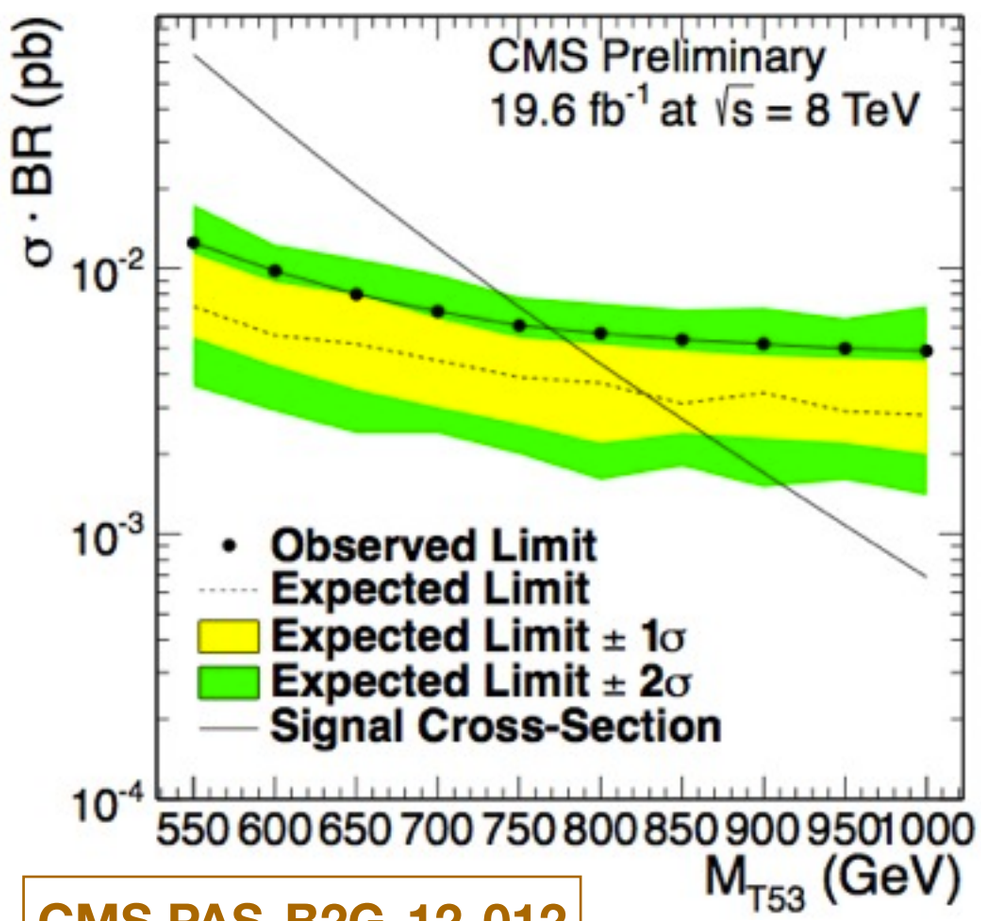
- Same-sign non-prompt ("fake") lepton

  Lepton(s) from heavy-flavor decay, decay in flight, or conversion. Fake rate measured in data.

❖ Exclusion limit :

$M(T_{5/3}) > 770$ GeV at 95% C.L.

assuming 100% $BR(T_{5/3} \rightarrow tW)$



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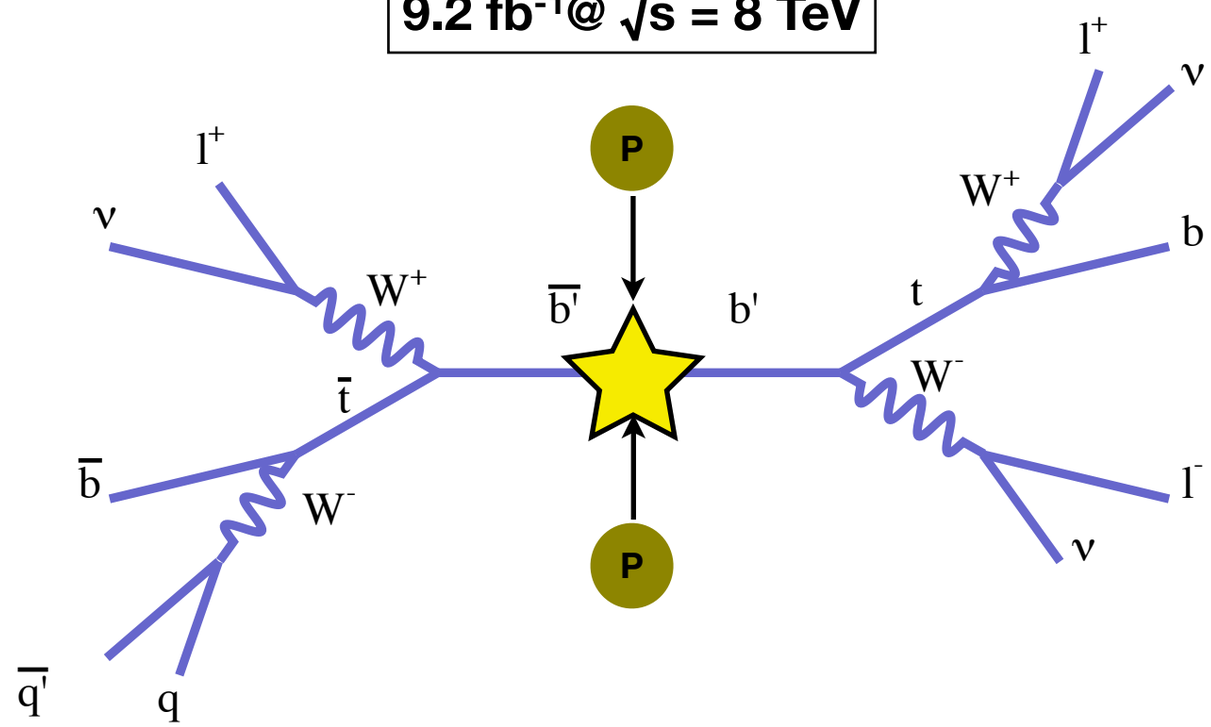
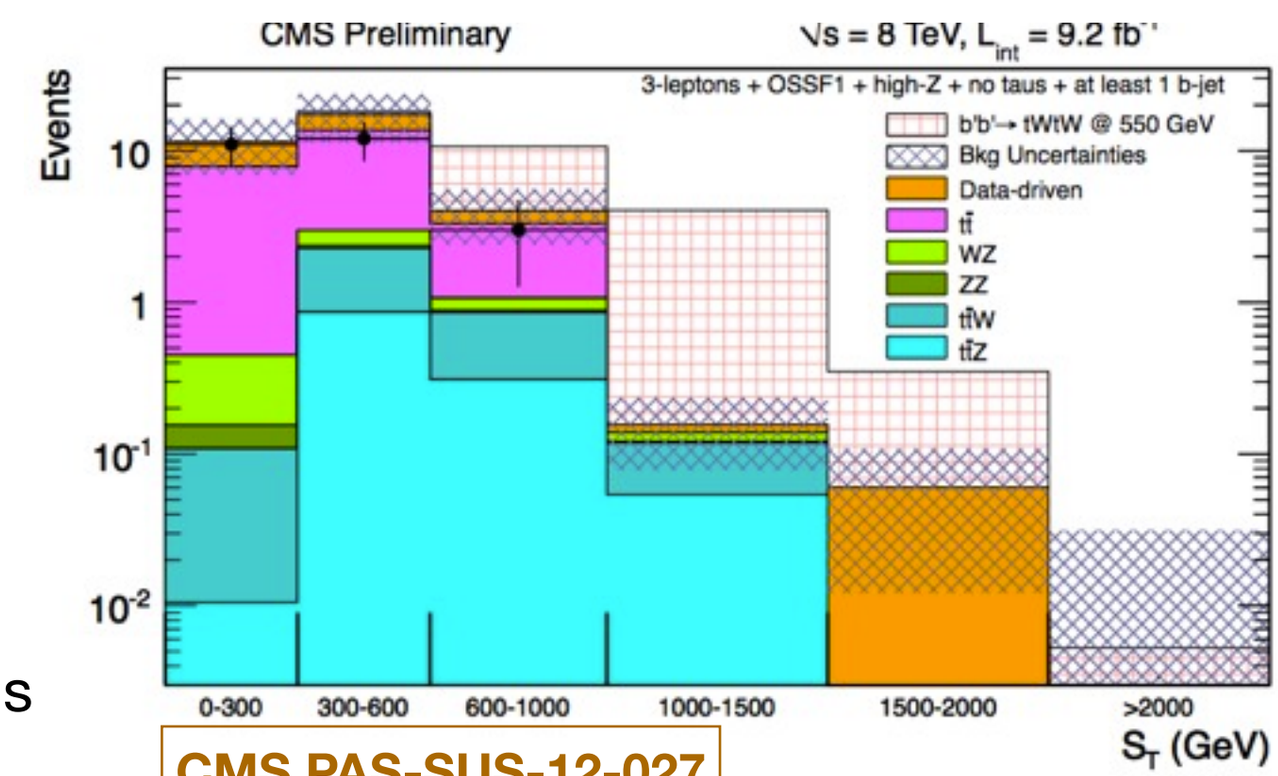
t+W resonance with charge 1/3 (I)

- Search for pair-production of b', decaying into tW in a multi(3 or 4)-lepton channel
- Event selection :
  - 3/4 isolated leptons
  - 1/2 opposite-sign same-flavor(OSSF) lepton pair(s)
  - One OSSF pair outside/inside the Z window
  - ≥ 1 b-jet
- $S_T = \not{E}_T + \sum(\text{lepton's } p_T) + \sum(\text{jet's } p_T)$
- Background estimation :
  - Data-driven methods take bkg contributions from misidentified/non-prompt leptons and asymmetric photon conversions into account
  - $t\bar{t}$, diboson, and $t\bar{t}W/Z$ using simulations

9.2 fb^{-1}@ $\sqrt{s}$ = 8 TeV





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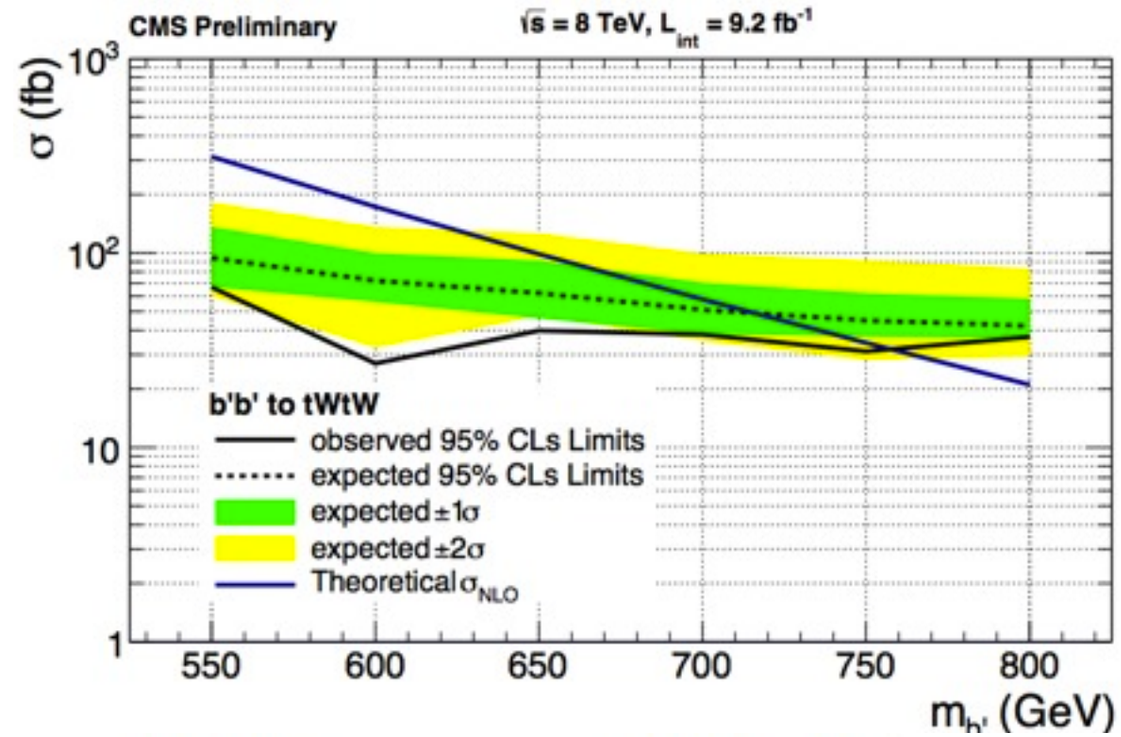
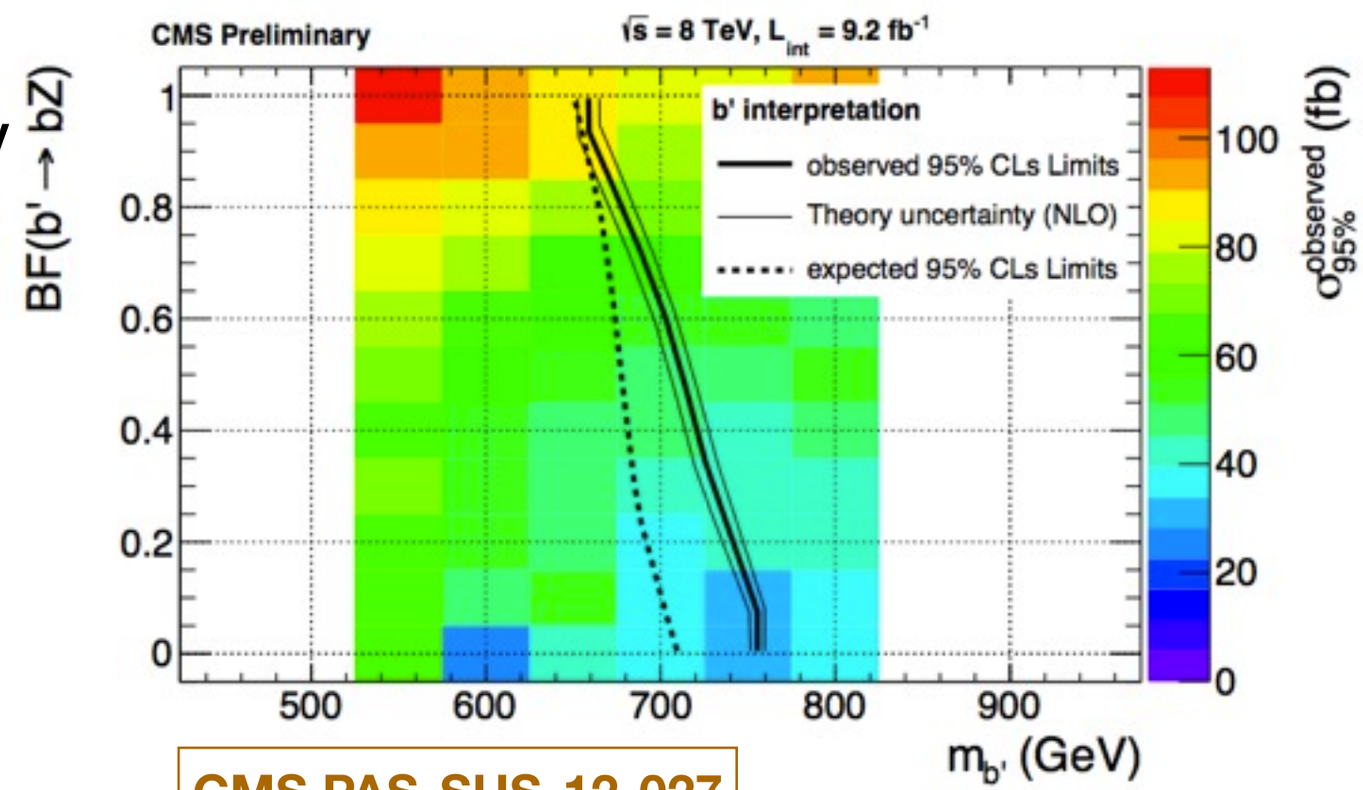
t+W resonance with charge 1/3 (II)

❖ For BR(b'→tW) = 100%, we excluded masses below 760 GeV at 95% C.L.



❖ BR(b'→tW) = 1-BR(b'→bZ)

❖ Limits vary from 660-760 GeV as the branching fraction is varied.



CMS PAS-SUS-12-027

Summary

❖ The CMS collaboration has performed a number of searches for new physics in top-like final states.

- *No evidence for new physics has been found*
- Set exclusion limits on the masses of resonances having a top-like final state :

Final state	Model	Lower mass limit	
top+jet	$W' \to tb$	2.03 TeV (W'_R) 19.6 fb^{-1} @8 TeV	CMS-PAS-B2G-12-010
	$t^* \to tg$	794 GeV 19.6 fb^{-1} @8 TeV	CMS-PAS-B2G-12-014
top+W	$T_{5/3} \to tW$	770 GeV 19.6 fb^{-1} @8 TeV	CMS-PAS-B2G-12-012
	$b' \to tW$	760 GeV 9.2 fb^{-1} @8 TeV	CMS-PAS-SUS-12-027

Thank you for your attention!