

Searches for Heavy Resonances at the LHC

Aram Avetisyan

Boston University

On behalf of the ATLAS and CMS Collaborations

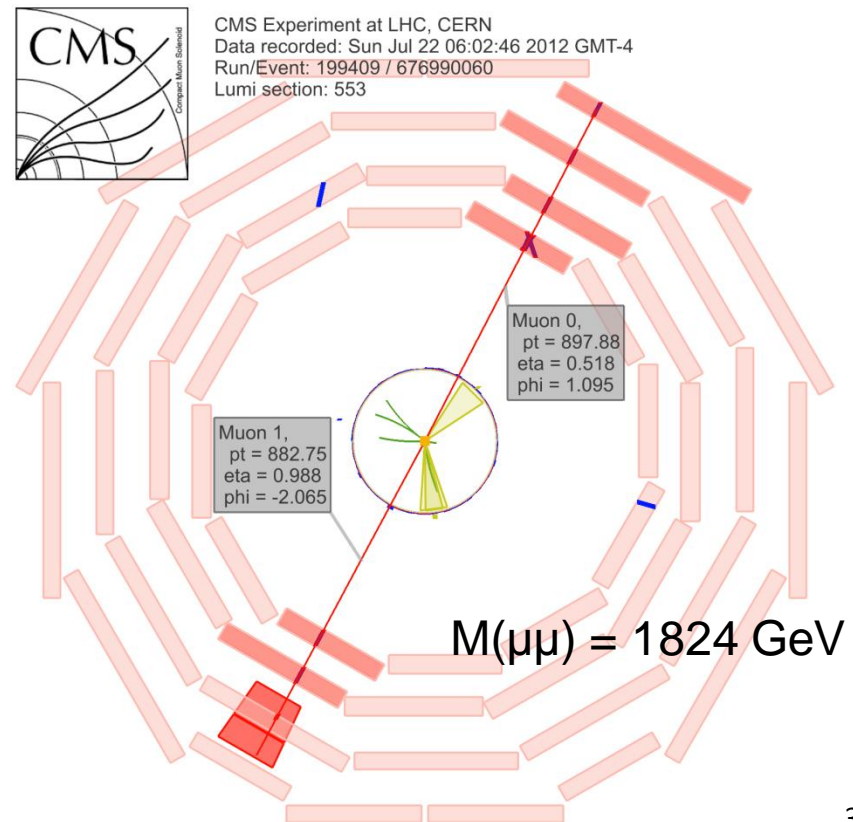
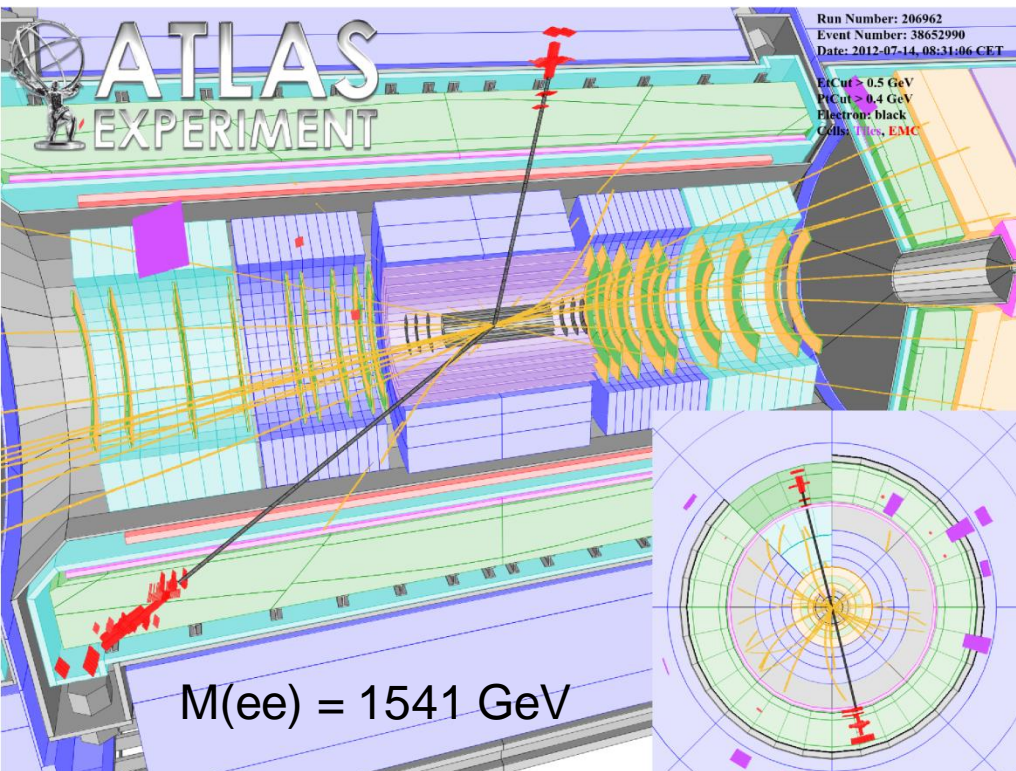
Recontres de Blois 2013

Introduction

- Several varieties of heavy resonances occur in many theories
 - Composite Higgs, Extra Dimensions, Little Higgs, Technicolor...
- This talk:
 - $Z' \rightarrow$ Dileptons
 - Dijet Resonances
 - $W' \rightarrow l\nu$
 - $W' \rightarrow tb$
 - $T_{5/3} \rightarrow tW$
- Two other talks with resonances today:
 - Marco Cardaci
 - $Z' / G^* \rightarrow t\bar{t}$
 - Sergio Grancagnolo (next talk)
 - Diboson resonances
 - Di-Bjets
 - Same-sign dileptons + b-tag

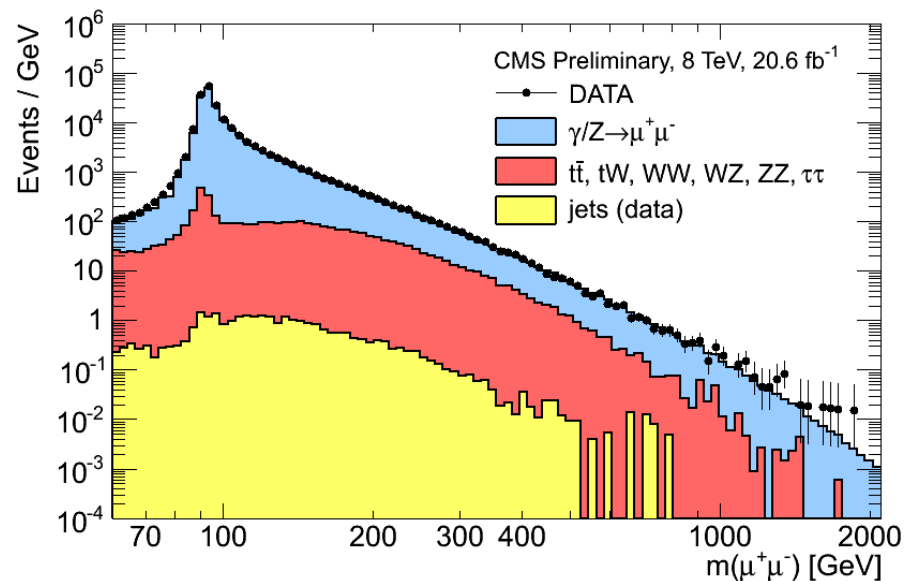
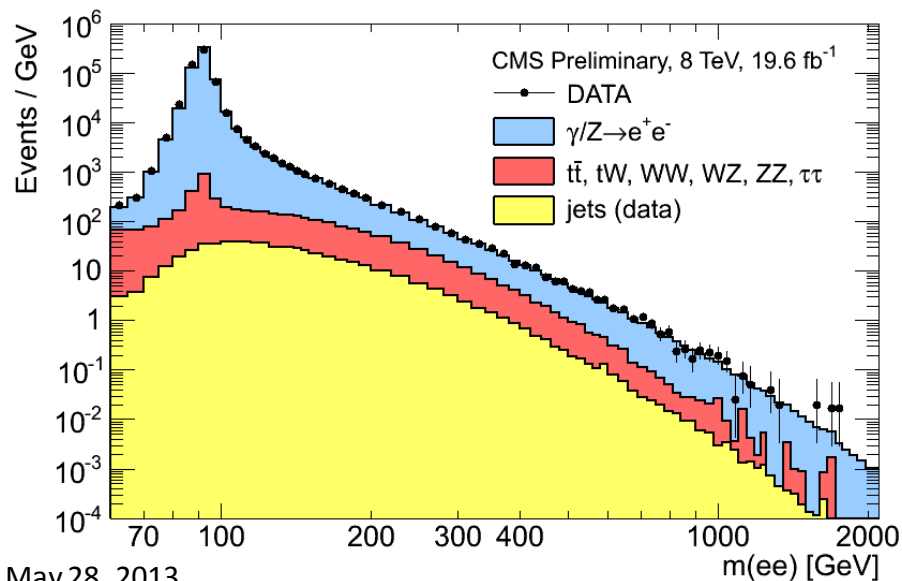
$Z' \rightarrow$ Dileptons

- Sequential Standard Model (SSM), Extra Dimensions, E6 Grand Unification, Superstrings, etc.
- General idea: bump-hunt in the Drell-Yan $M(l^+l^-)$ spectrum



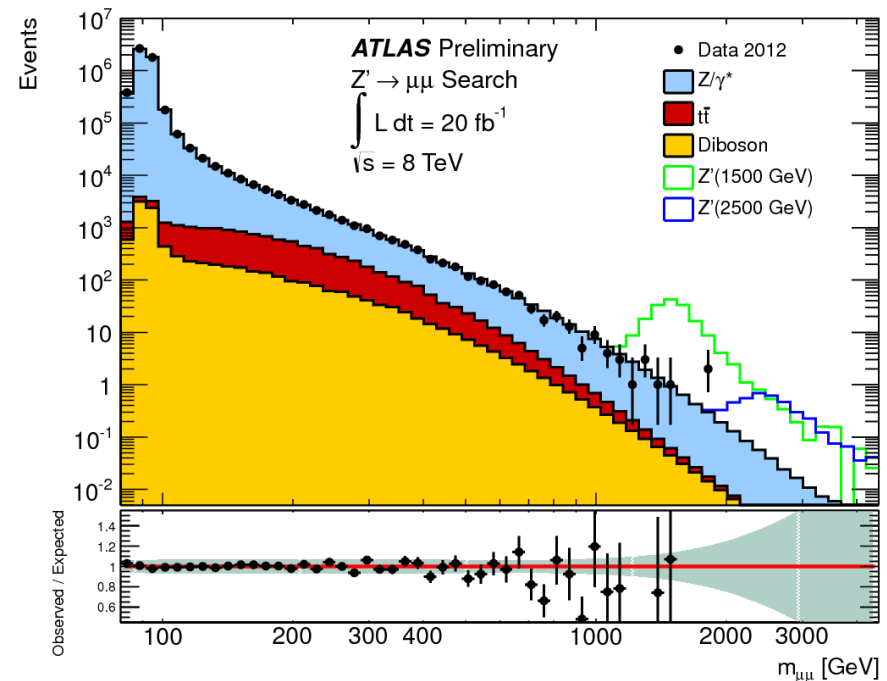
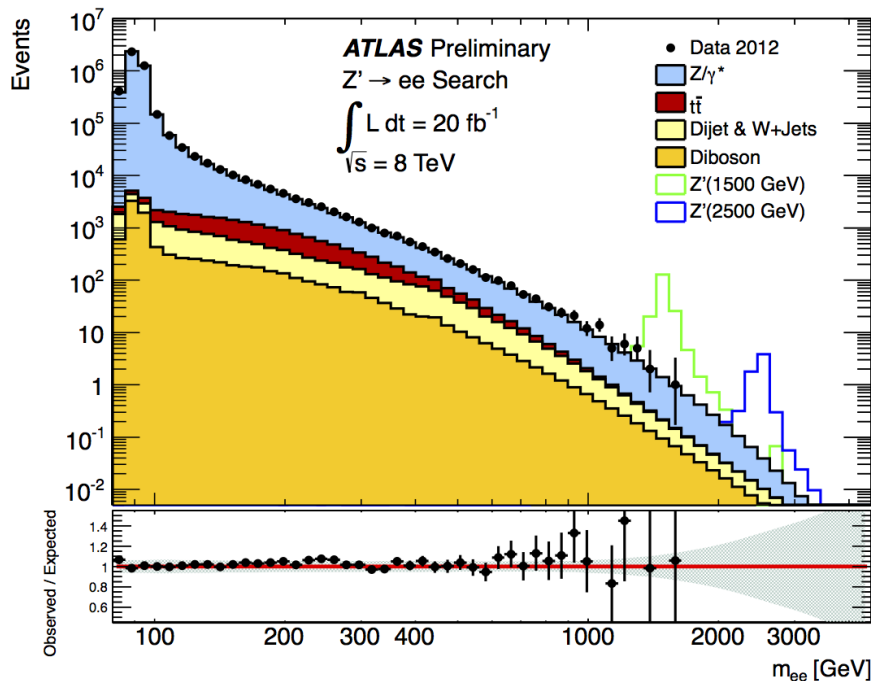
$Z' \rightarrow$ Dileptons

- Electrons: $p_T > 35$ GeV, must be isolated
 - Trigger on 33 GeV dielectrons
- Muons: $p_T > 45$ GeV, isolation, opposite charge
 - Single muon trigger ($p_T > 40$ GeV)
- Drell-Yan invariant mass spectrum normalized to $60 \text{ GeV} < M(\text{ll}) < 120 \text{ GeV}$

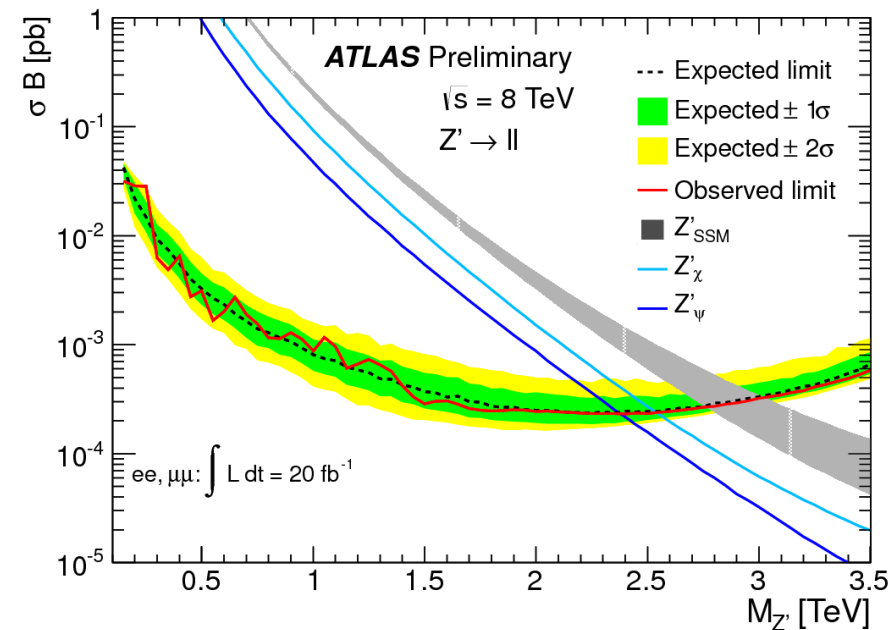
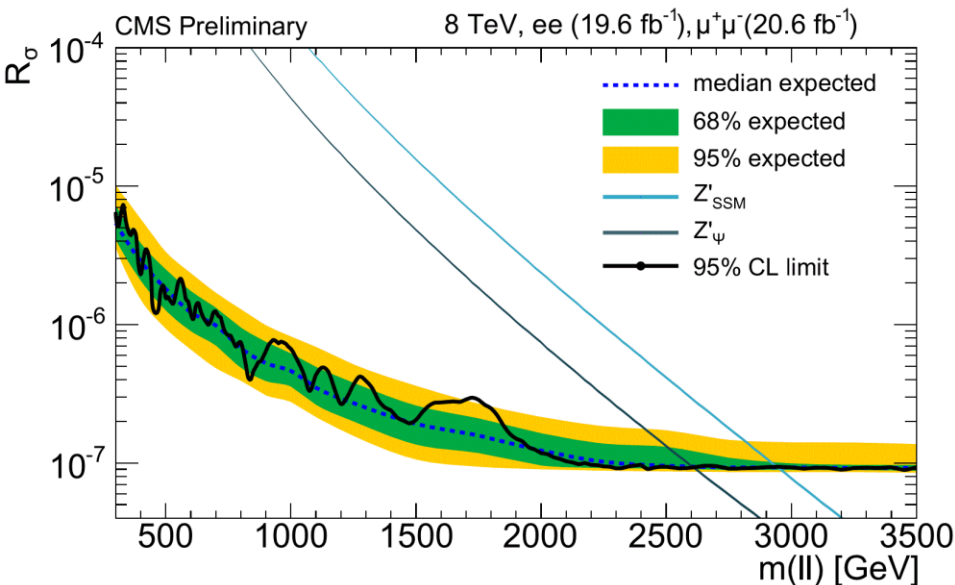


$Z' \rightarrow$ Dileptons

- Electrons: $p_T > 40$ (leading), 30 (second) GeV, isolation
 - Trigger on diphotons with $p_T > 35, 25$ GeV
- Muons: $p_T > 25$ GeV, isolation, opposite charge
 - Trigger on single μ with $p_T > 24$ GeV (iso) or $p_T > 36$ GeV (no iso)



- CMS:
 - $M(Z'_{SSM}) < 2.96$ TeV
 - $M(Z'_{\psi}) < 2.6$ TeV
 - Super-string inspired
- ATLAS:
 - $M(Z'_{SSM}) < 2.86$ TeV
 - $M(Z'_{\psi}) < 2.38$ TeV
 - E6 gauge group
- ATLAS and CMS make different assumptions about Z'_{SSM} width



$$R_{\sigma} = \sigma_B(Z') / \sigma_B(Z)$$

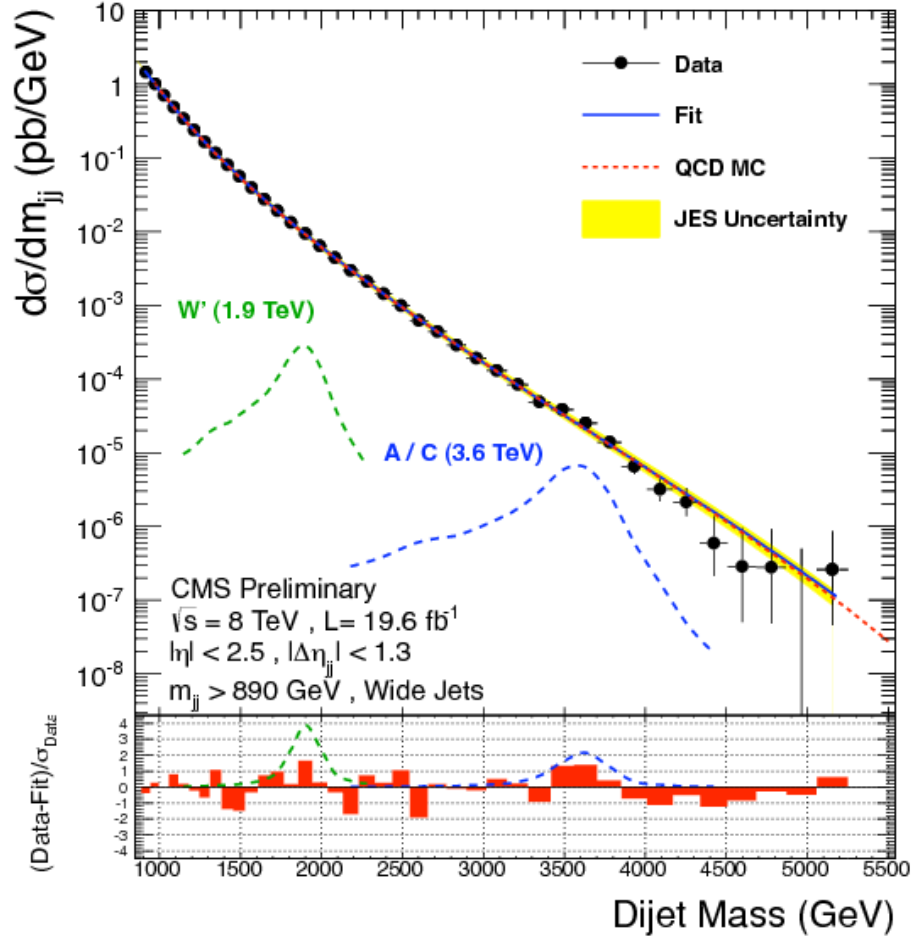
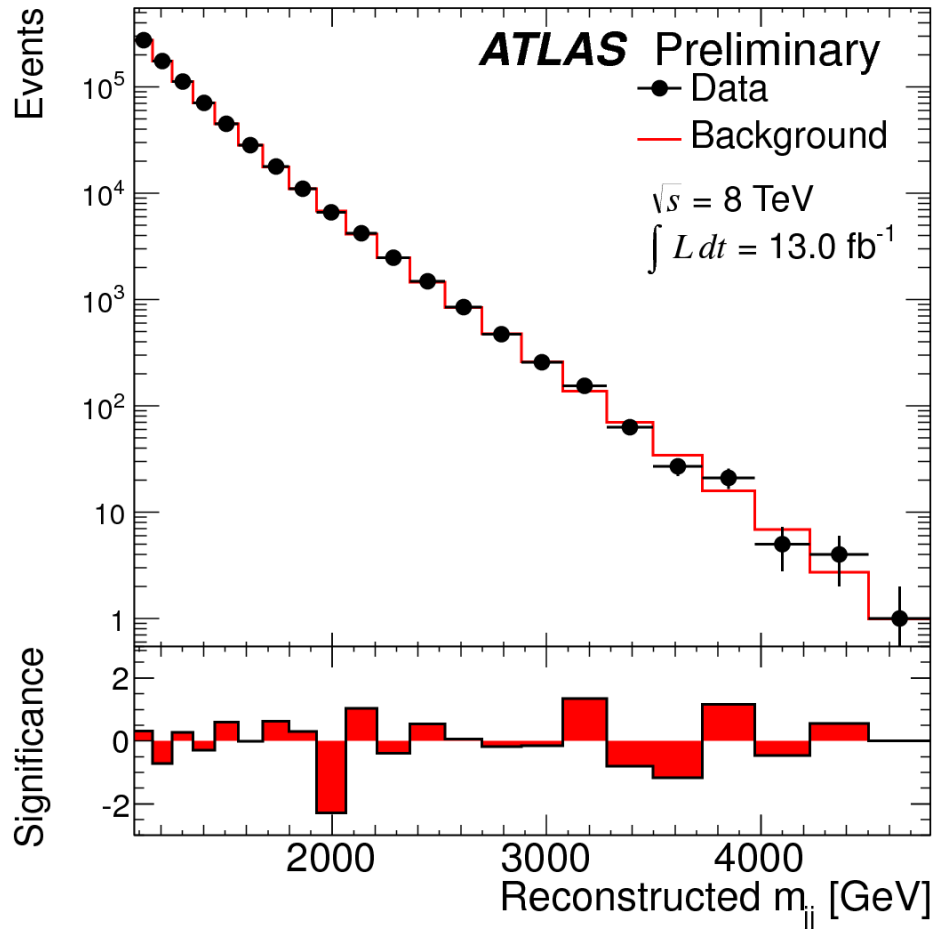
Dijets

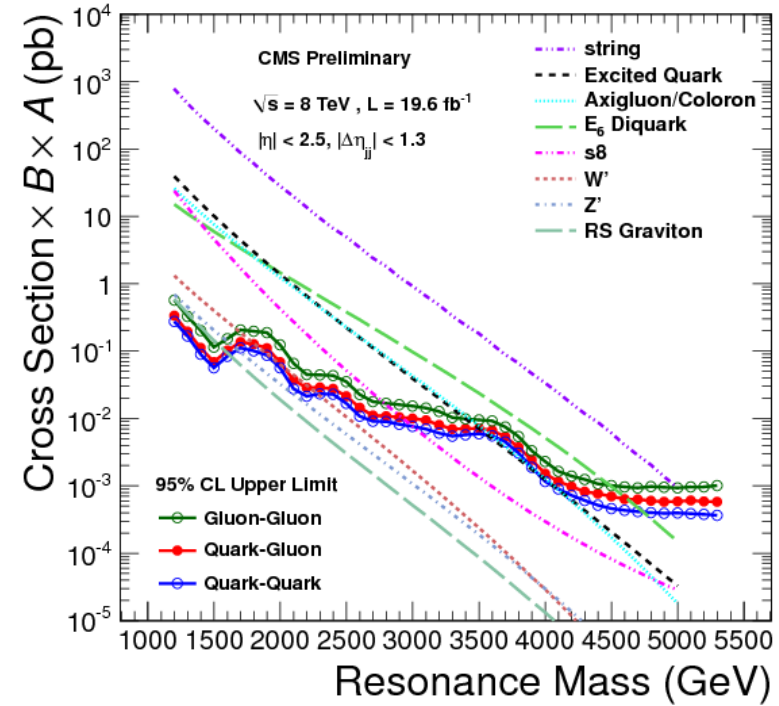
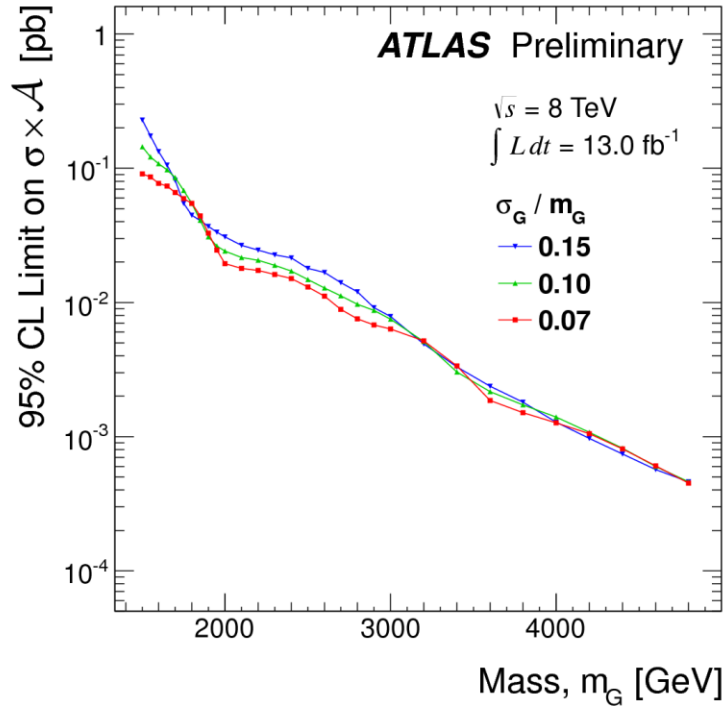
- Many models
 - String resonances, excited quarks, axigluons, colorons, s8 resonances, E6 diquarks, W' , Z' and extra dimensions
- Bump-hunting in the dijet mass spectrum:
 - Dominated by QCD multijet production

- Use a fit:
$$\frac{d\sigma}{dm_{jj}} = \frac{P_0(1-x)^{P_1}}{x^{P_2+P_3} \ln(x)}, \quad x = m_{jj} / \sqrt{s}$$

- ATLAS uses Anti- k_T , $R = 0.6$ jets
- CMS starts with Anti- k_T , $R = 0.5$ jets
 - Combines close ones into “wide” jets with $R = 1.1$

Dijet Spectra



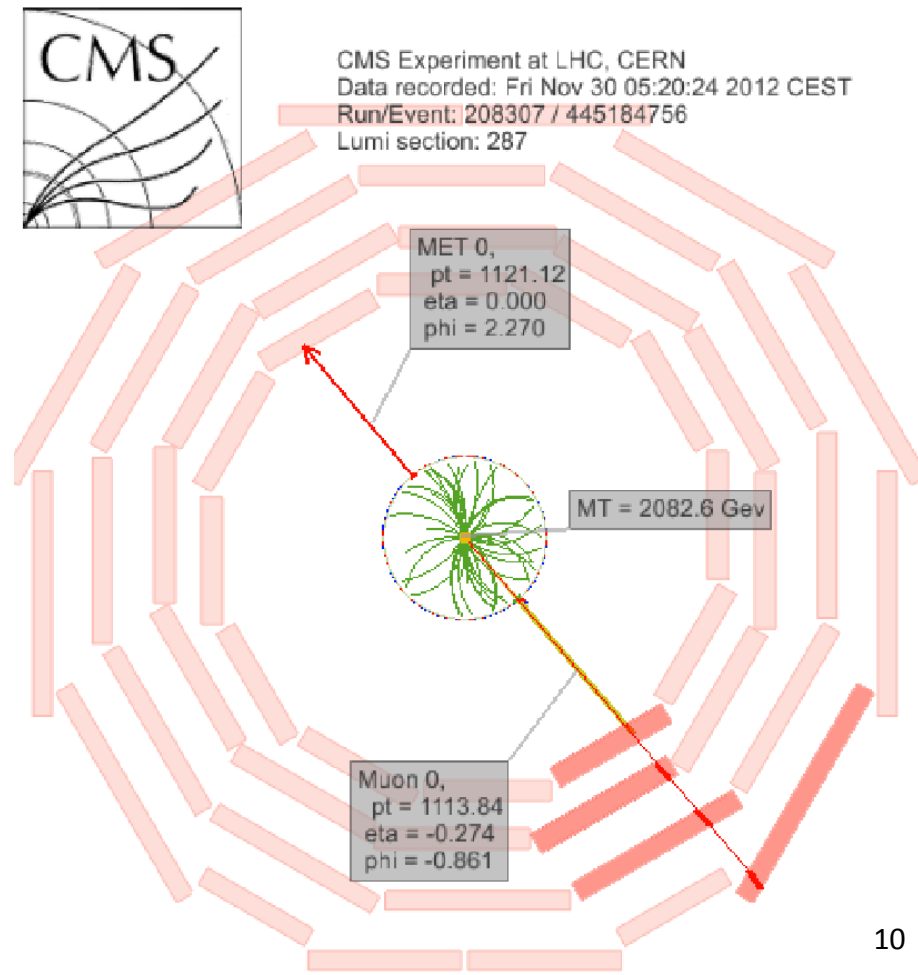


- ATLAS:
 - $m(q^*) < 3.84$ TeV
 - Cross-section limits on generic Gaussian resonances

CMS	Model	Final State	Obs. Mass Excl. [TeV]	Exp. Mass Excl. [TeV]
	String Resonance (S)	qg	[1.20,5.08]	[1.20,5.00]
	Excited Quark (q^*)	qg	[1.20,3.50]	[1.20,3.75]
	E_6 Diquark (D)	qq	[1.20,4.75]	[1.20,4.50]
	Axigluon (A)/Coloron (C)	q \bar{q}	[1.20,3.60] + [3.90,4.08]	[1.20,3.87]
	Color Octet Scalar (s8)	gg	[1.20,2.79]	[1.20,2.74]
	W' Boson (W')	q \bar{q}	[1.20,2.29]	[1.20,2.28]
	Z' Boson (Z')	q \bar{q}	[1.20,1.68]	[1.20,1.87]
	RS Graviton (G)	q \bar{q} +gg	[1.20,1.58]	[1.20,1.43]

W' Resonances

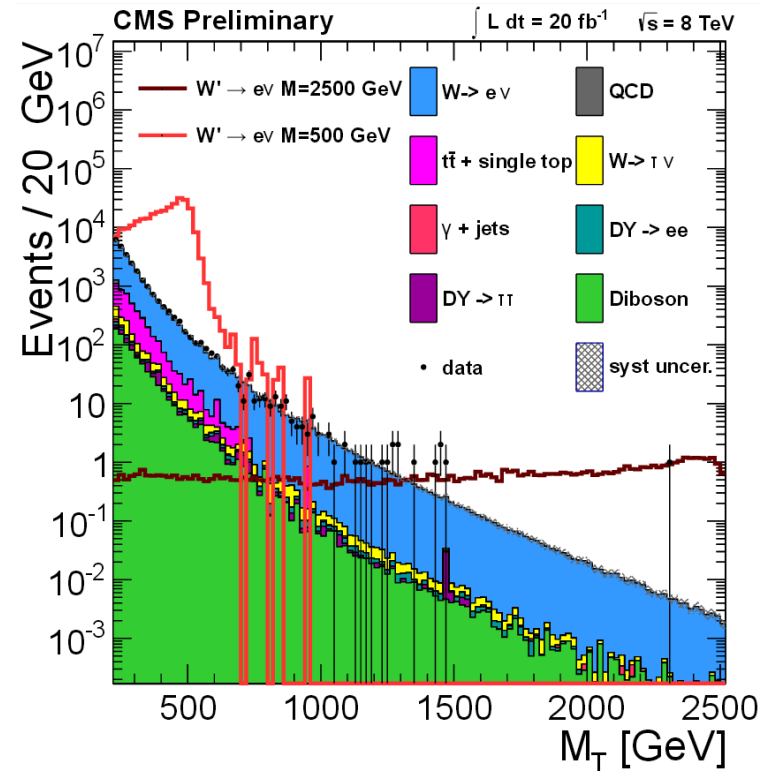
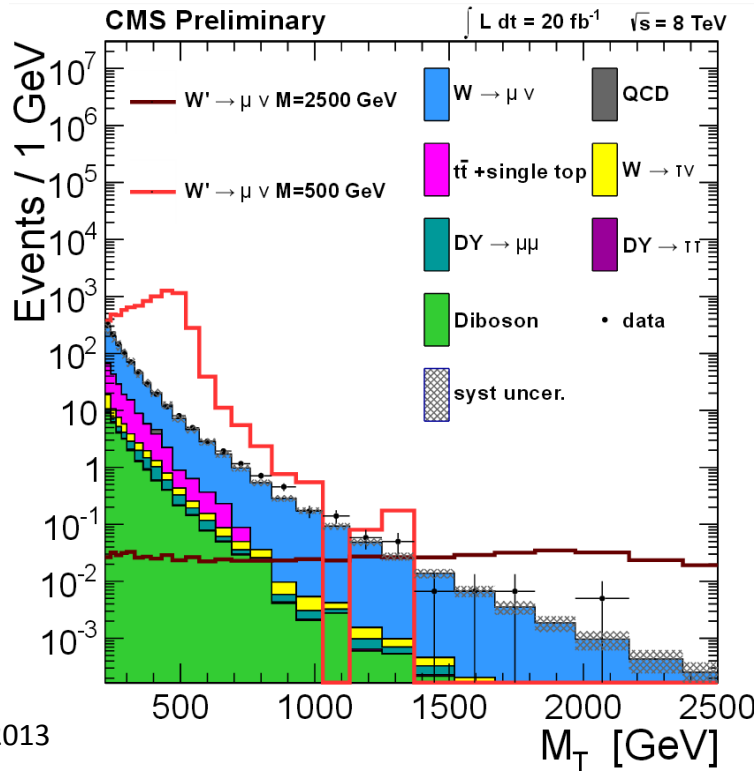
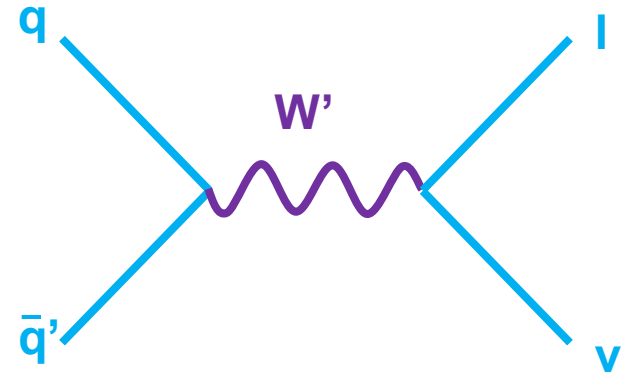
- W' heavy gauge bosons can be found in:
 - Sequential Standard Model, Extra Dimensions, Technicolor, Little Higgs, etc.
- W' final states:
 - $W' \rightarrow e\nu/\mu\nu$
 - $W' \rightarrow tb$
- May have both right and left-handed components
 - Left-handed may interfere with Standard Model W boson



$W' \rightarrow l\nu$

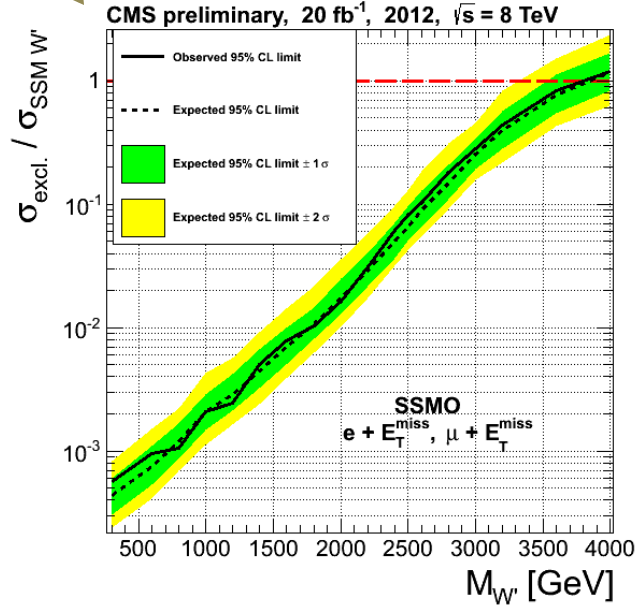
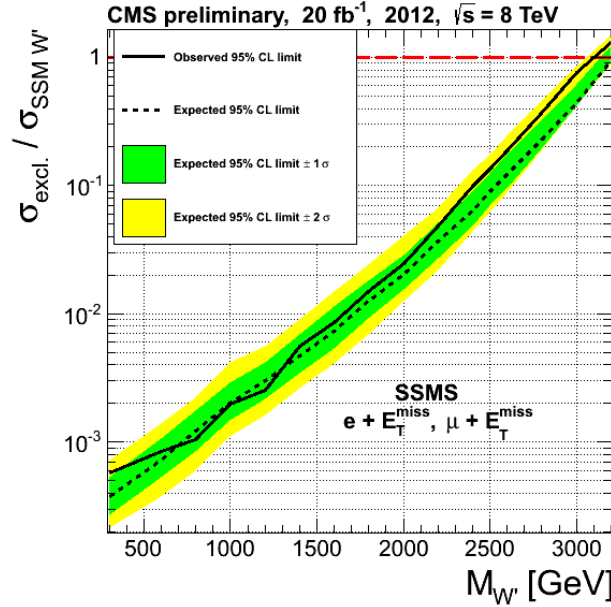
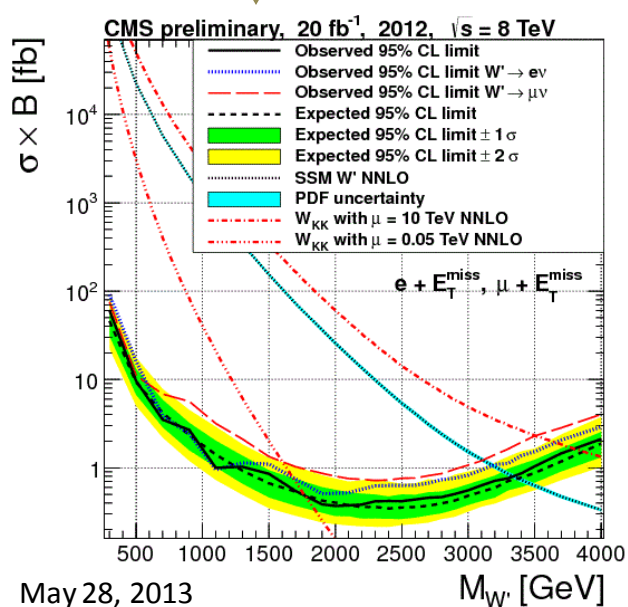
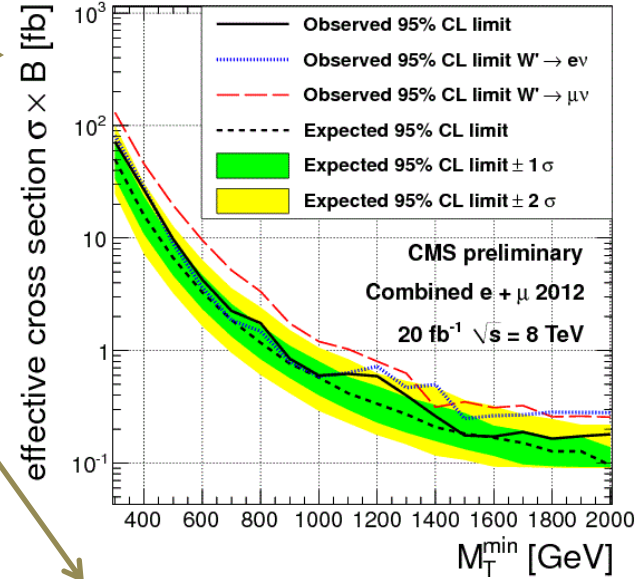
- Select events with high p_T leptons
 - 45 GeV muons, 100 GeV electrons
 - $\Delta\phi(l, \nu) > 0.8\pi$ and $0.4 < p_T(l)/M_{E_T} < 1.5$

$$M_T = \sqrt{2 \cdot p_T^l \cdot E_T^{\text{miss}} \cdot (1 - \cos \Delta\phi_{l,\nu})}$$



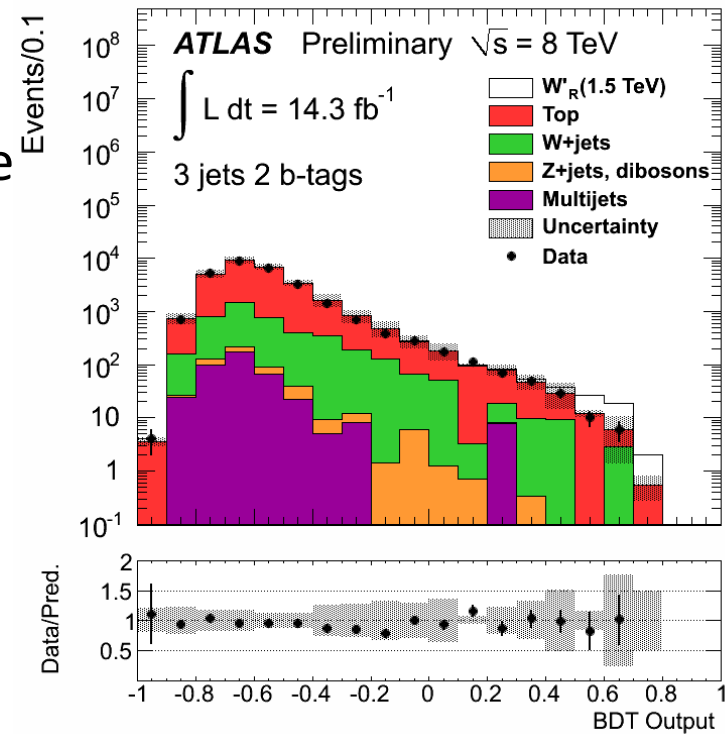
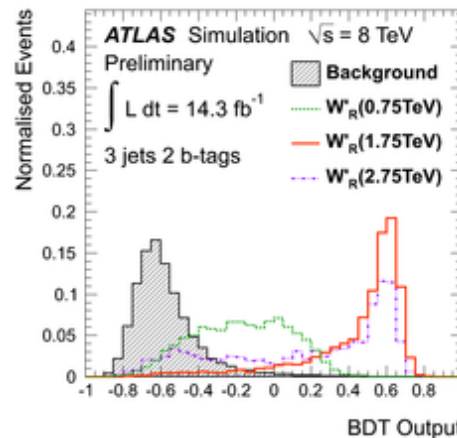
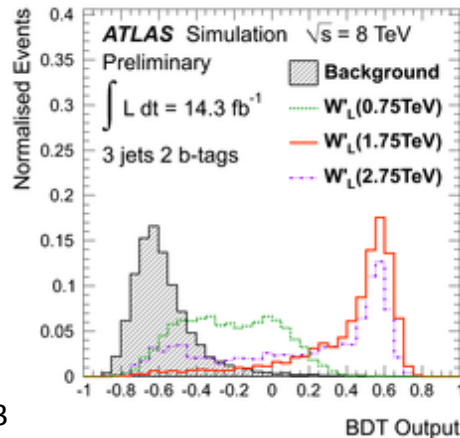
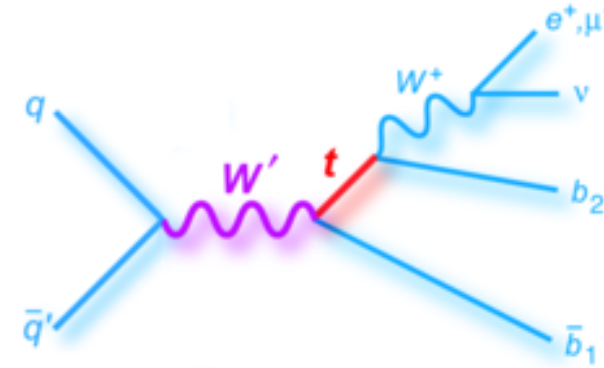
$W' \rightarrow l\nu$ Results

- Model-independent limit based on $M_T \rightarrow$
- SSM W' mass limits
 - 3.6 TeV (constructive interference)
 - 3.1 TeV (destructive interference)
 - 3.35 TeV (no interference)
- W_{KK}^2 : 1.7 TeV ($\mu = 0.05$) / 3.7 TeV ($\mu = 10.0$)



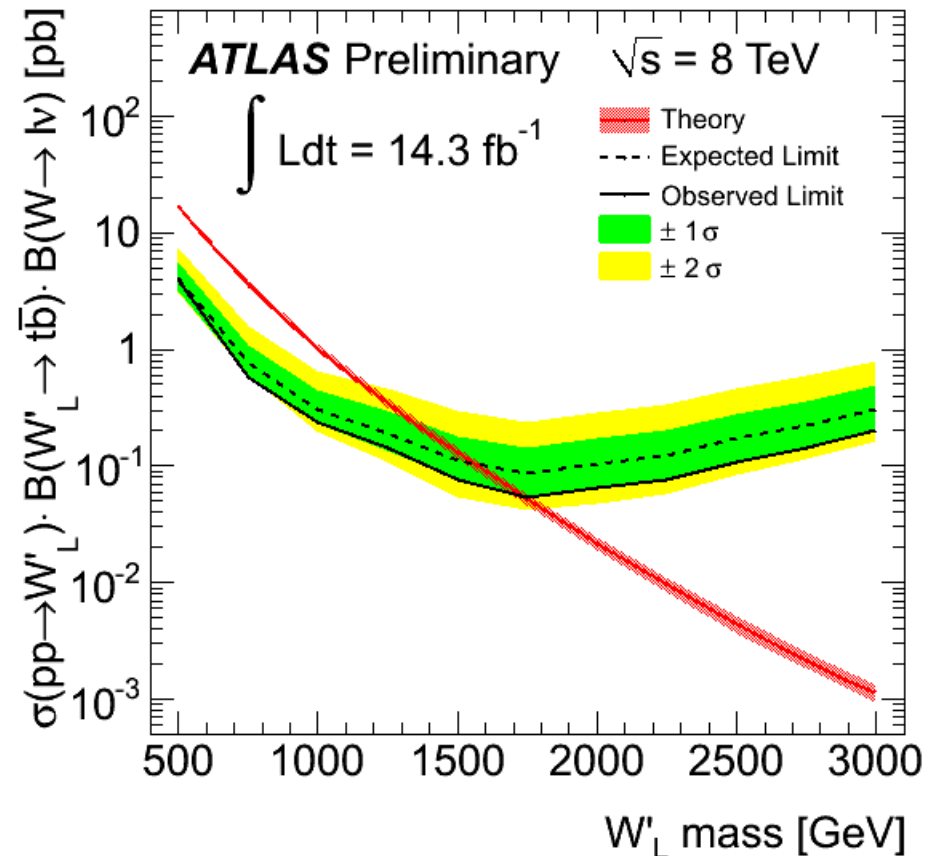
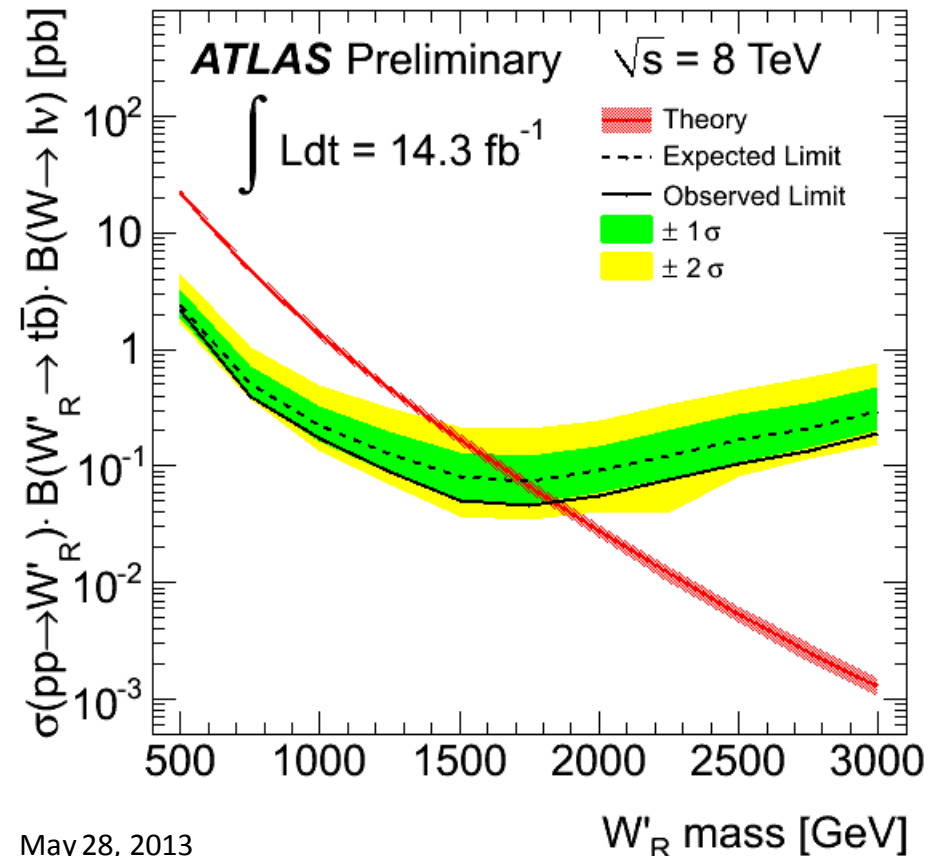
$W' \rightarrow tb$

- Important if leptonic decay is suppressed or 3rd generation decay is enhanced
- Require:
 - e or μ with $p_T > 30$ GeV
 - $ME_T > 35$ GeV; $ME_T + M_T(W) > 60$ GeV
 - Categories of 2 or 3 jets ($p_T > 25$ GeV) with 1 or 2 b-tags
 - BDT with 14 (13) variables in 2 (3) jet case
 - m_{tb} , $p_T(t)$, H_T , $p_T(l)$, $p_T(b_1)$, etc.



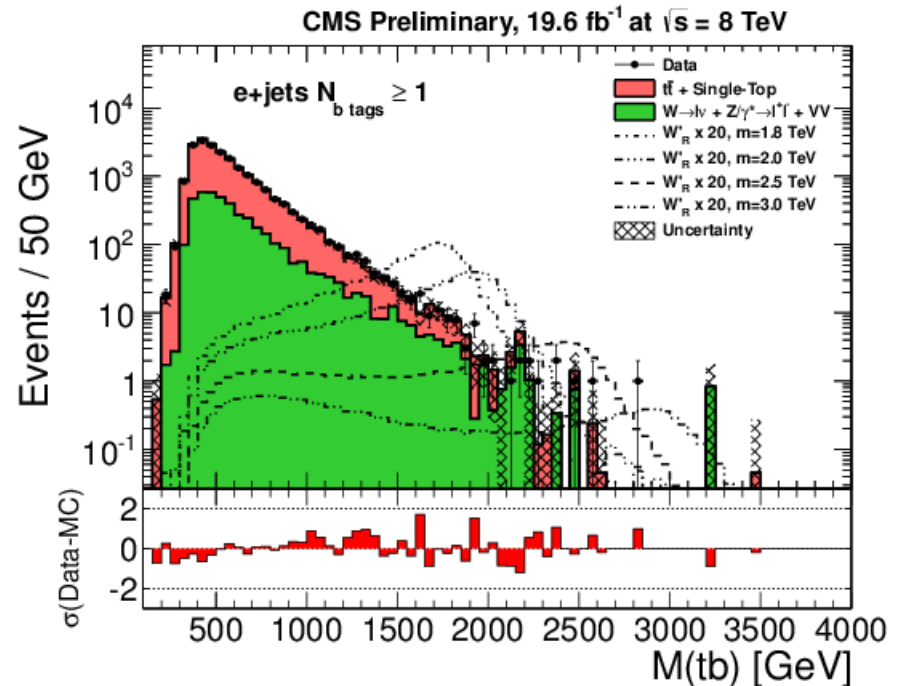
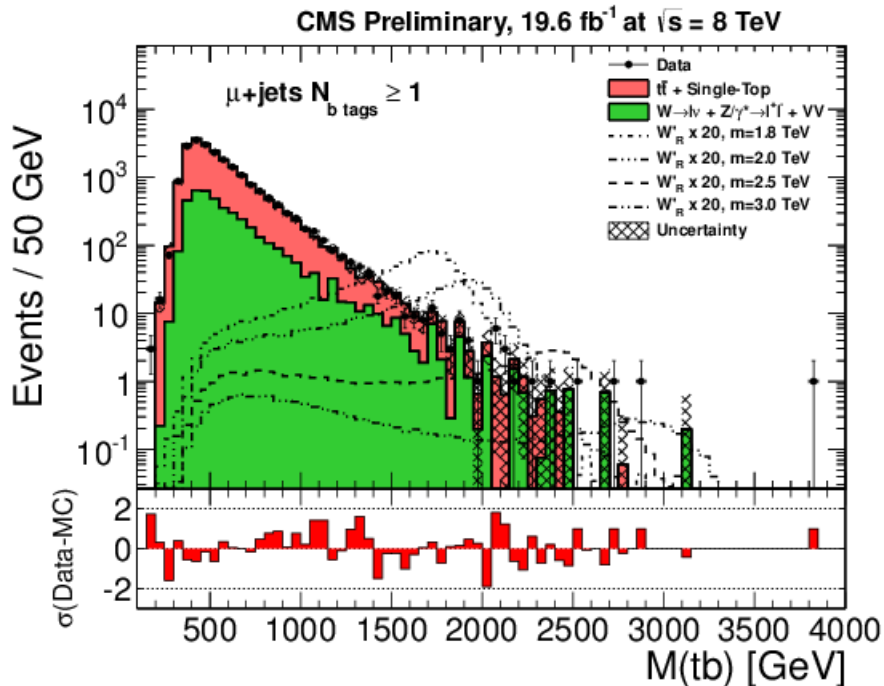
$W' \rightarrow tb$ Results

- Exclude $M(W'_R) < 1.84$ TeV
- Exclude $M(W'_L) < 1.74$ TeV
 - Interference with the SM is not considered



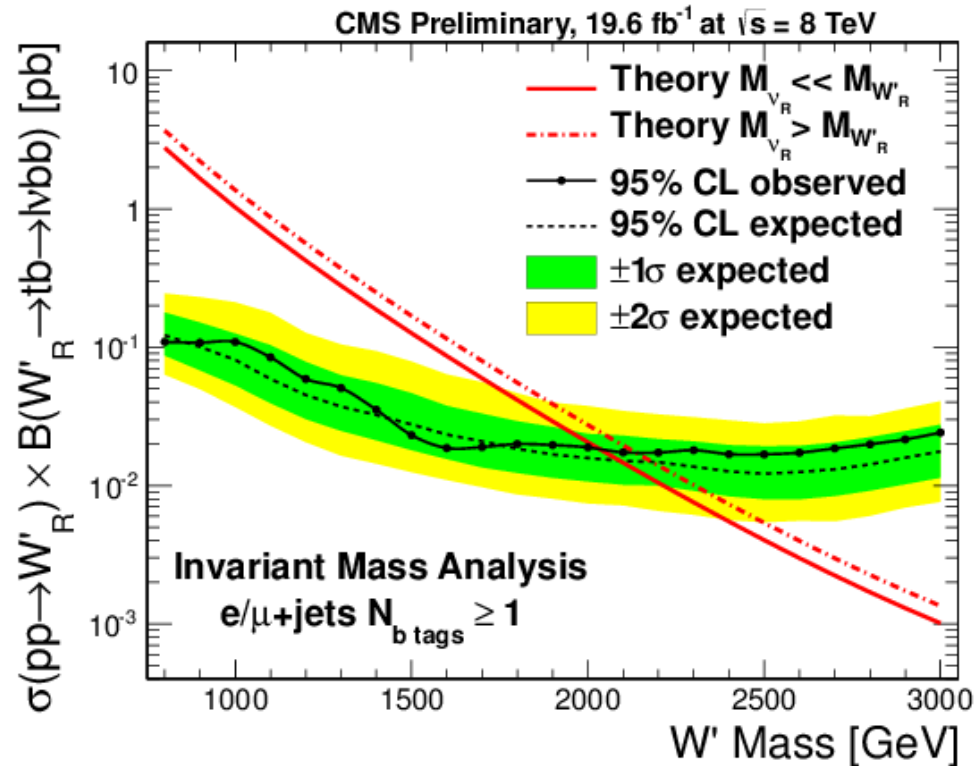
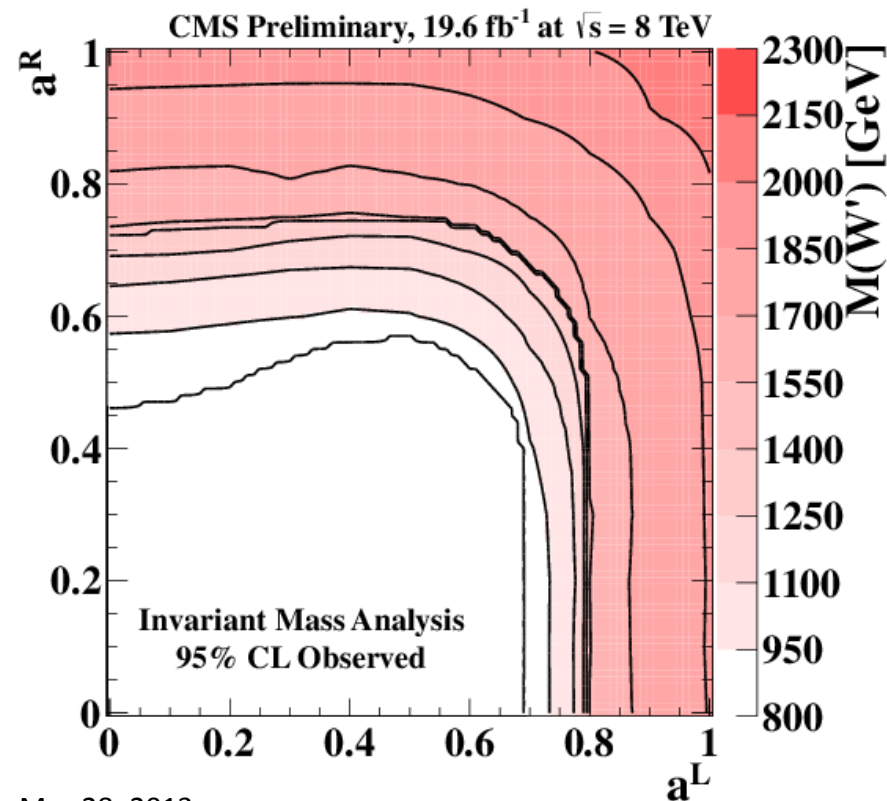
$W' \rightarrow tb$

- Exactly 1 lepton (e or μ) with $p_T > 50$ GeV
- At least 2 jets with $p_T > 120$ GeV (leading), 40 GeV (second)
 - One of the two leading jets must be b-tagged
- Missing $E_T > 20$ GeV



$W' \rightarrow tb$ Results

- Exclude W'_R masses below 2.03 TeV
- Consider arbitrary left and right-handed couplings to fermions
 - Accounts for Standard Model W interference

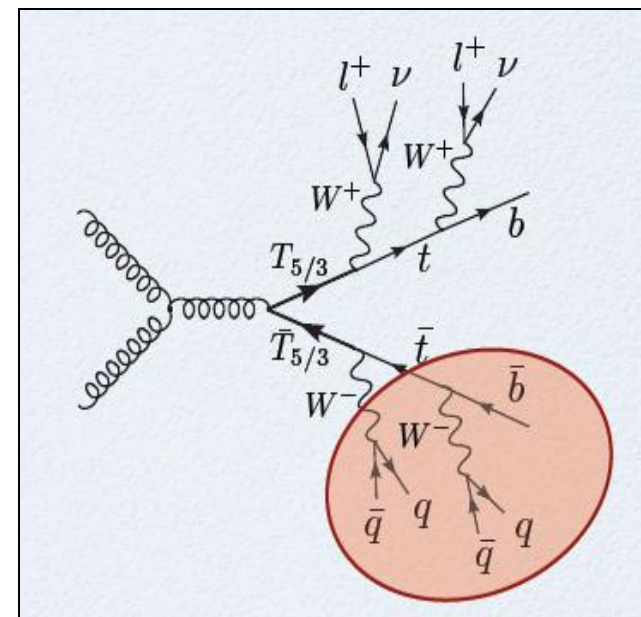


$$T_{5/3} \rightarrow tW$$

- Predicted by:
 - Composite Higgs, Extra Dimensions
- Consistent with 126 GeV Higgs
- Striking signature: same-sign dileptons

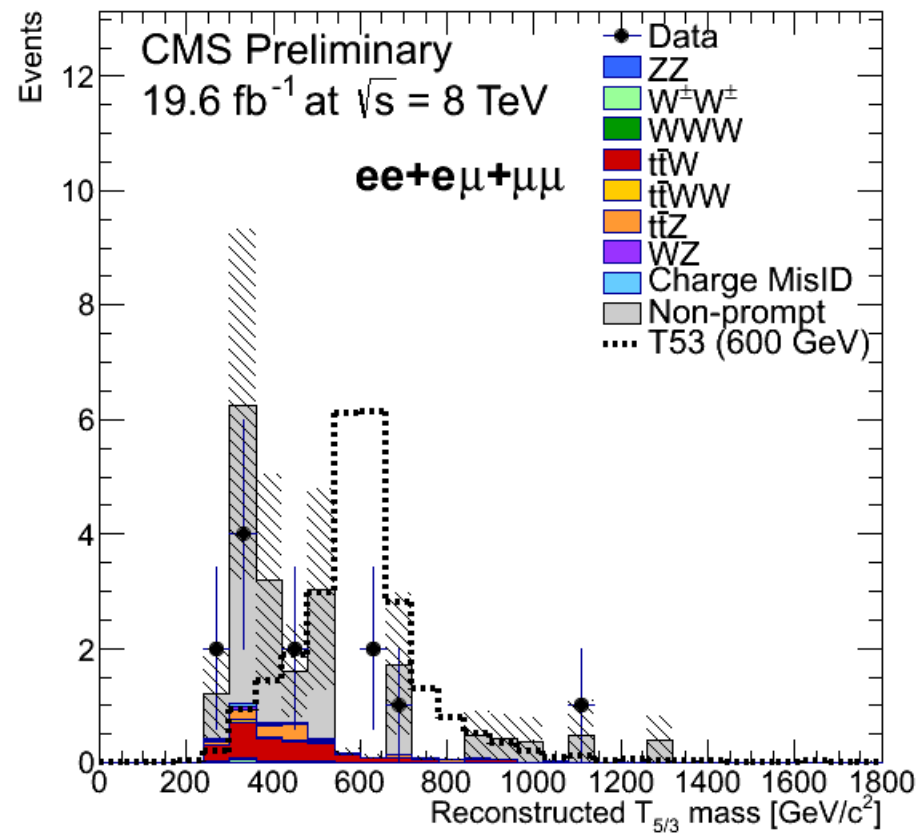
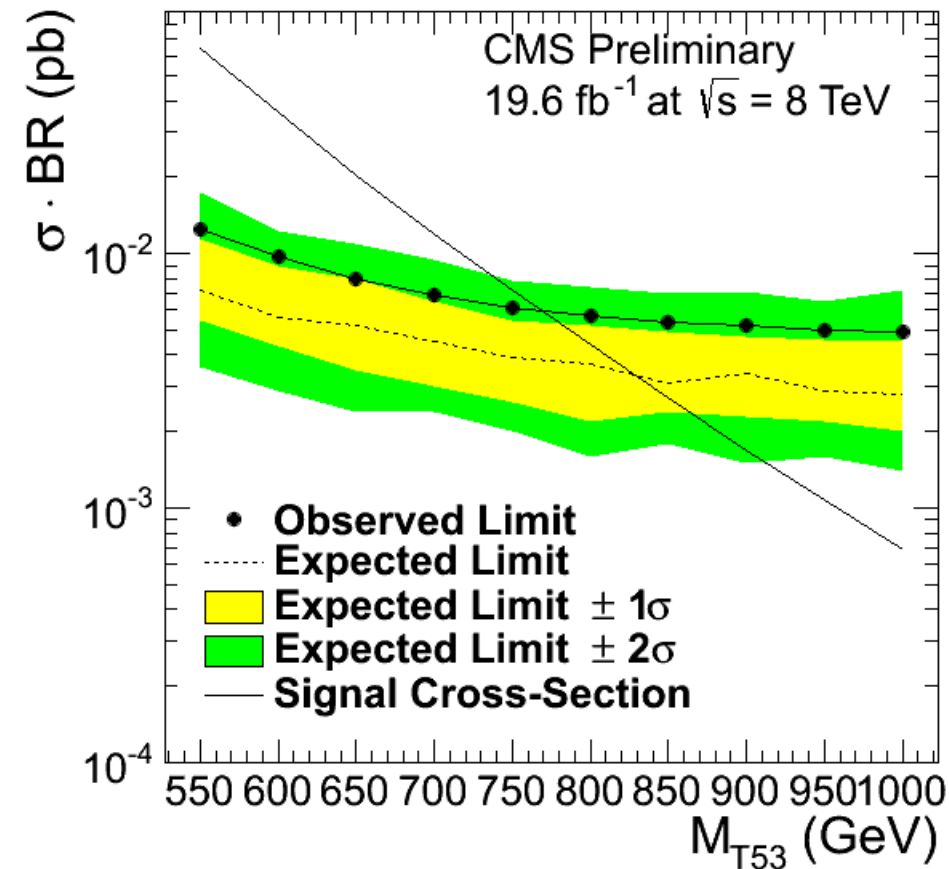
$$l^{\pm}l^{\pm} + 2b + 2W$$

- Selection:
 - Two same-sign leptons (e or μ) with $p_{\tau} > 30$ GeV
 - 5 or more “constituents” in addition to the two leptons
 - Boosted top jets count as 3 constituents, boosted W jets as 2 and all other jets and leptons as 1
 - H_{τ} = scalar sum of p_{τ} of all good jets and leptons > 900 GeV



$T_{5/3}$ Results

- Exclude $M(T_{5/3}) < 770$ GeV



Summary

- Searches for many different resonances performed at 8 TeV
 - Searches for specific models
 - Searches that can be interpreted with several models
 - Model independent searches
- No discoveries (yet)
- Analysis of the full LHC Run I datasets continues
 - More results coming soon
- <https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults>
- <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G>
- <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO>