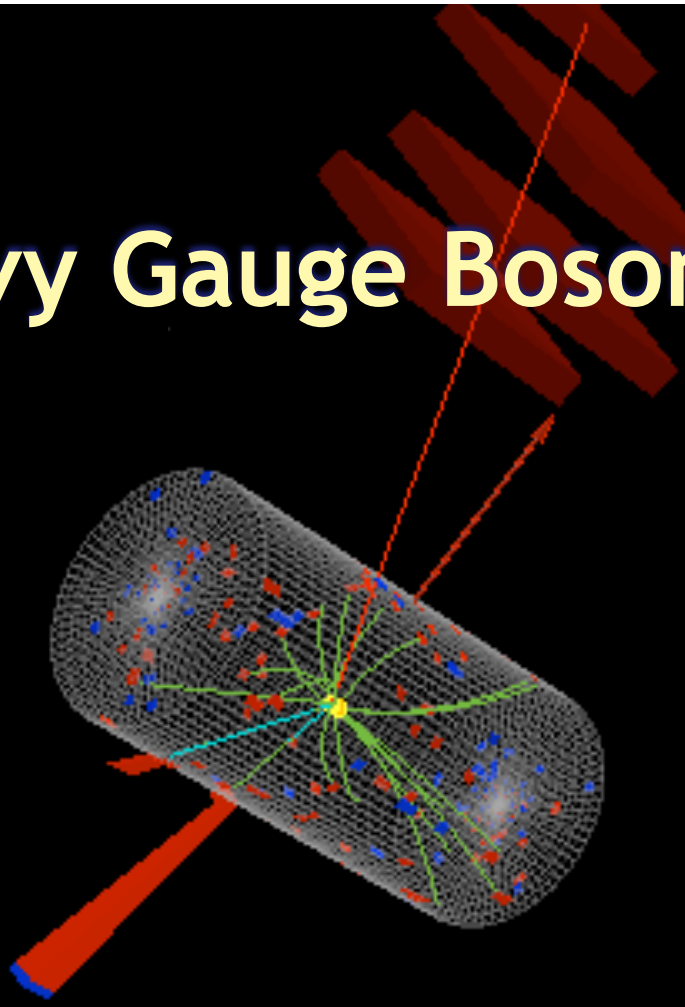
New Heavy Gauge Bosons at CMS



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Austrian Academy of Sciences

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New heavy gauge bosons

To solve known shortcomings of the Standard Model, extensions have been proposed. The SM gauge group $SU(3)_C x SU(2)_L x U(1)_Y$ can be extended by:

- An extra U(1) group, giving rise to a neutral heavy vector boson Z'
- An extra SU(2) group, giving rise to a charged heavy vector boson W'

Model examples:
- Sequential Standard Model (SSM): new bosons have similar couplings as W, Z in SM

- Left-right symmetric models: $SU(2)_L x SU(2)_R$

- Superstring-inspired E_6 models: $E_6 \rightarrow SO(10) x U(1)_\psi \rightarrow SU(5) x U(1)_\chi x U(1)_\psi$. Only one linear combination *G* leads to particles at the TeV scale: $G = \cos\theta\ U(1)_\chi - \sin\theta\ U(1)_\psi$. $\theta = 0$: ψ-model

- More complicated scenarios predict a tower of new gauge bosons (W^n, Z^n, or gravitons G^n), such as technicolor or extra dimension models.

$Z' \rightarrow l^+l^-$ (l = e,μ)

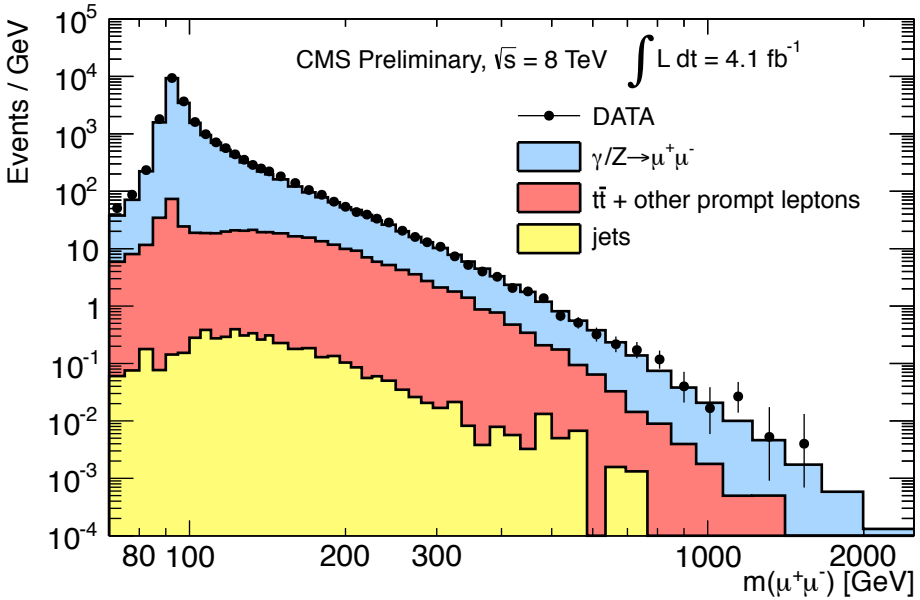
Many Z' models predict narrow resonances decaying to dileptons.

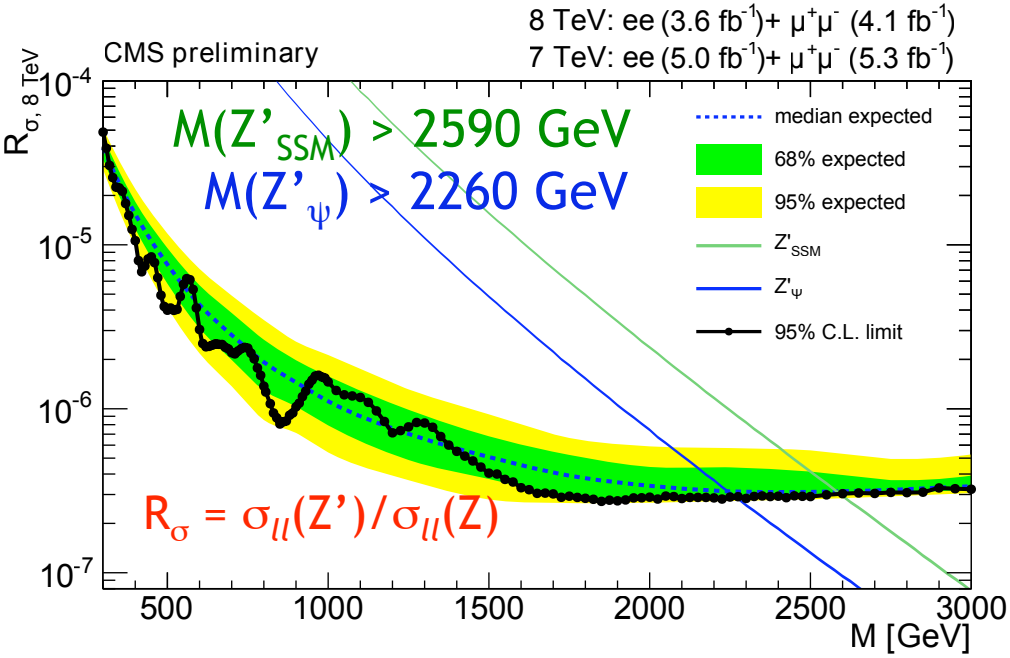
Event selection:

E_T (e_1,e_2) > 35 GeV, p_T (μ_1,μ_2) > 45 GeV, plus isolation criteria

Backgrounds:

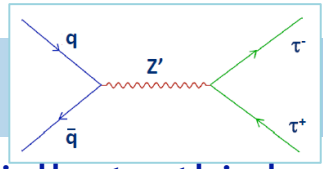
- Z/γ*, $t\bar{t}$, tW, VV, Z $\rightarrow \tau\tau$, multijets with ≥1 jet reconstructed as lepton
- estimated by fitting data with appropriate function





CMS PAS EXO-12-015, hep-ex 1206.1849, CMS PAS EXO-11-019

Z' → ττ



There are non-universal scenarios in which the Z' couples preferentially to third-generation fermions. Final states studied: $\tau_e\tau_\mu$, $\tau_e\tau_h$, $\tau_\mu\tau_h$, $\tau_h\tau_h$. ν's in final state do not allow to reconstruct mass of ττ system.

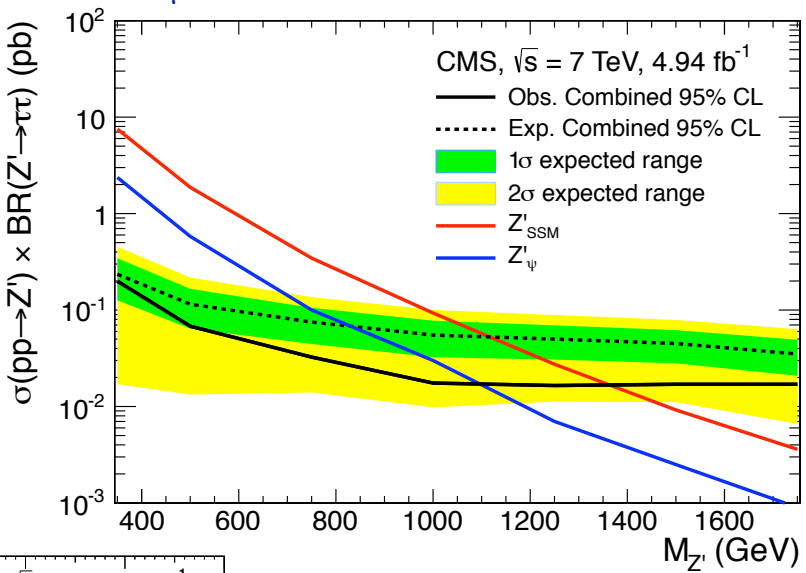
Event selection:

2 τ candidates with p_T between 15 and 35 GeV, $\eta < 2.1$, isolation criteria, no b-jets

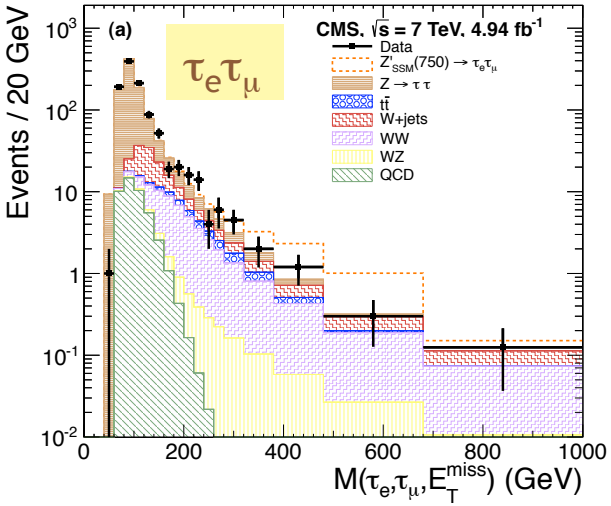
Backgrounds:

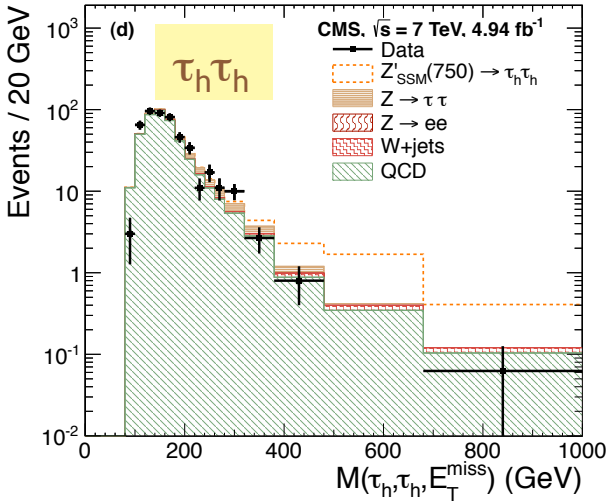
DY Z → ττ, W+jets, $t\bar{t}$, VV, QCD

Backgrounds are estimated from data where possible.



Effective visible mass





$M(Z'_{SSM}) > 1.4$ TeV

$M(Z'_{\psi}) > 1.1$ TeV

hep-ex 1206.1725
submitted to PLB
CMS PAS EXO-11-031

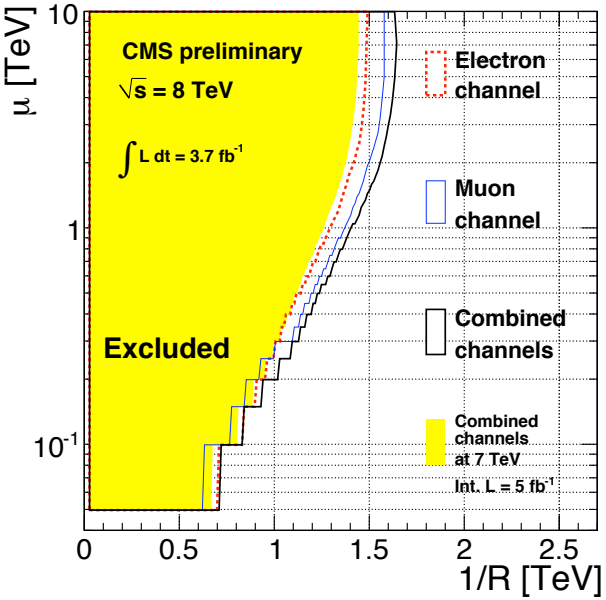
W' → *lν* without W-W' interference

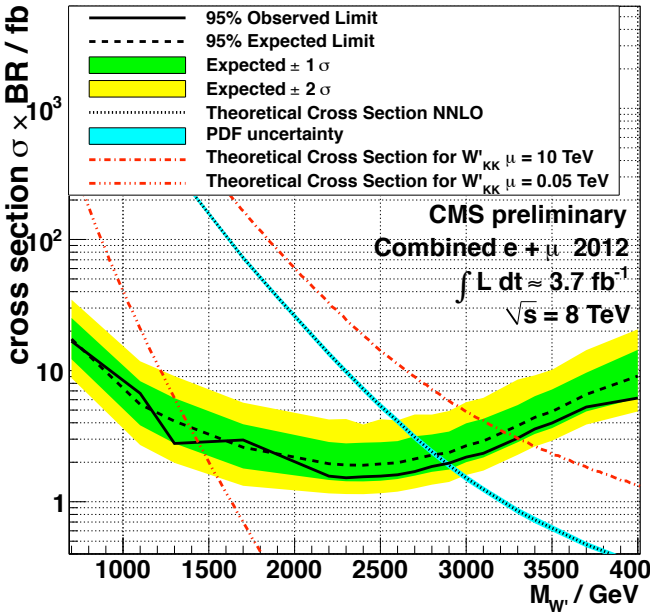
Models studied:

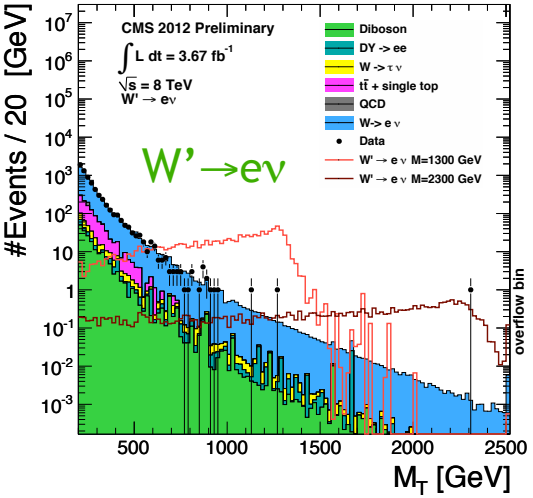
- W'_{SSM} with SM-like couplings, with W'_{SSM} → tb allowed
- Kaluza-Klein W^2_{KK} in split UED framework

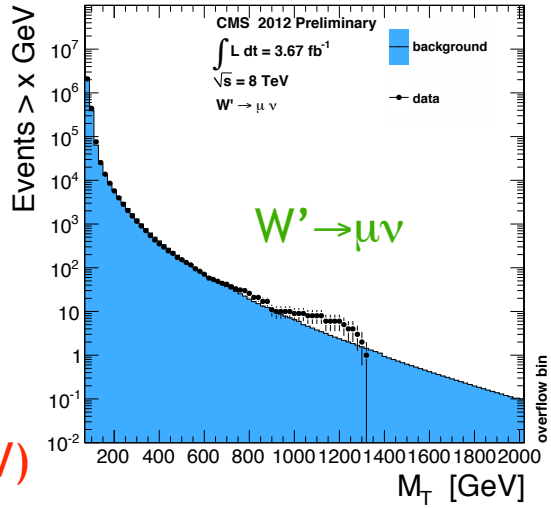
Event selection: ~back-to-back isol.l+E_T^{miss}, energy-balanced

Backgrounds: W → $l\nu$, QCD, $t\bar{t}$+single top, DY, VV from data









CMS PAS EXO-12-010

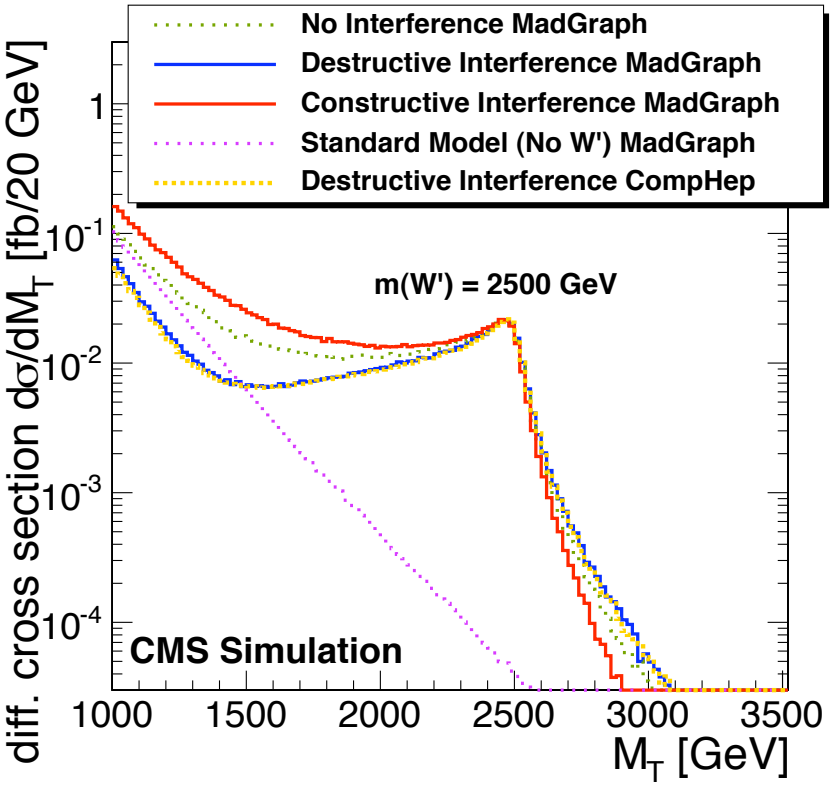
$M(W'_{SSM}) > 2.8$ TeV

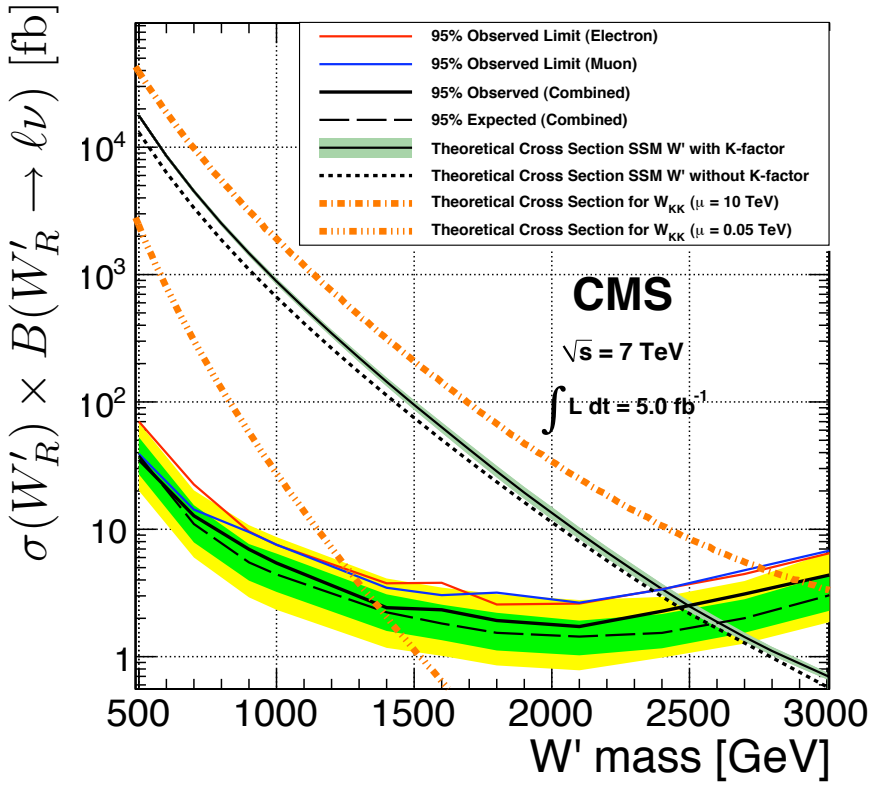
$M(W^2_{KK}) > 1.25$ TeV (μ = 0.05 TeV)

$M(W^2_{KK}) > 3.3$ TeV (μ = 10 TeV)

W' → *lν* with W-W' interference

A left-handed W_L' can interfere with the W. Studies were performed with 7 TeV data. Limits for a W_R' have also been derived.





hep-ex 1204.4764
submitted to JHEP

$M(W_R'_{SSM}) > 2.5$ TeV

$M(W_L'_{SSM}) > 2.63$ TeV (constructive interference)

$M(W_L'_{SSM}) > 2.43$ TeV (destructive interference)

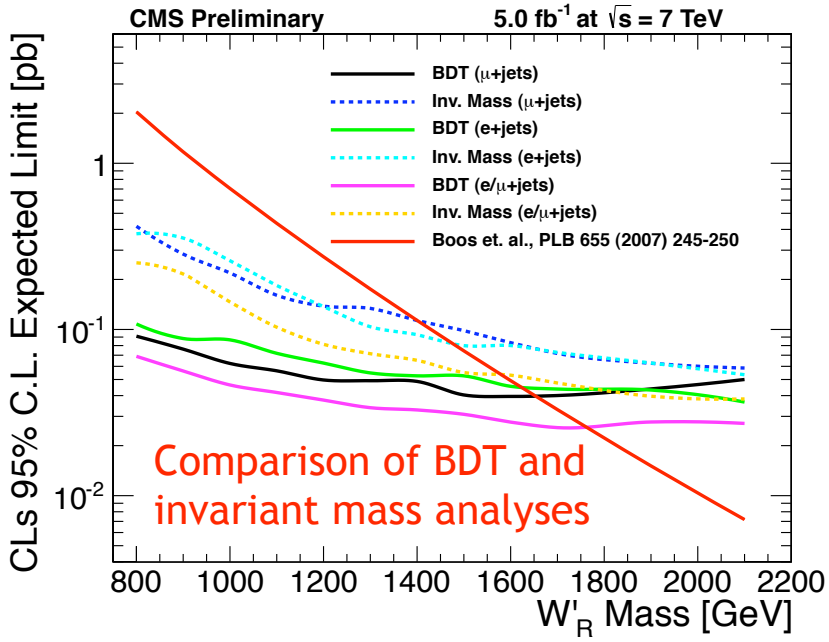
W' → tb

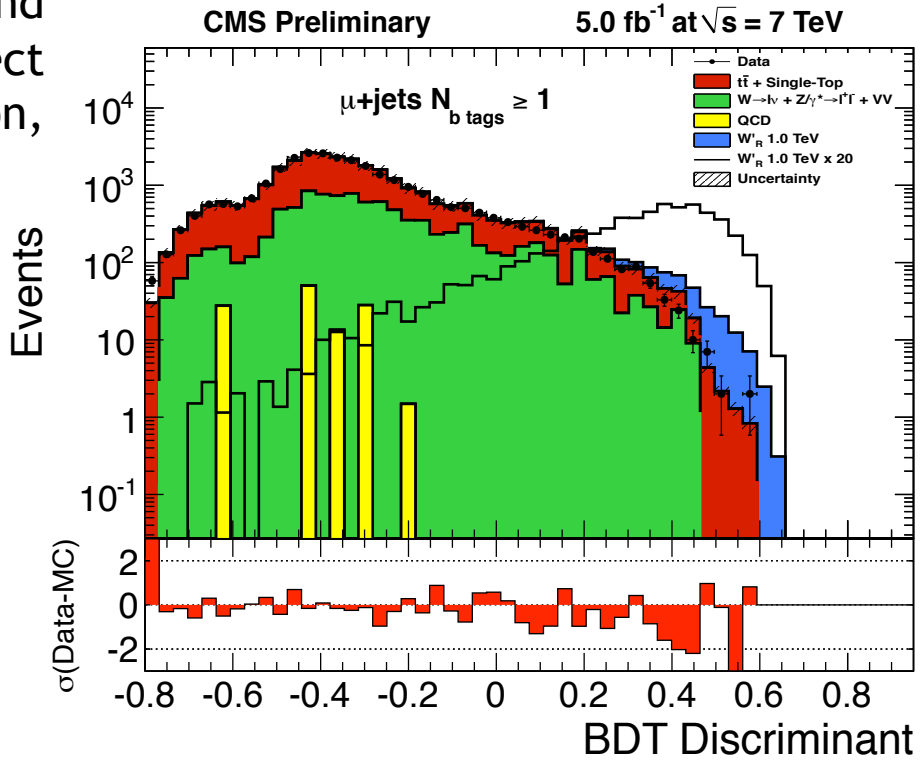
- W_R' decays to leptons suppressed if $M(\nu_R) > M(W')$ → search in hadronic final states important. Decay chain: W' → tb → Wbb → $l\nu$bb.

Event selection: isol.e(μ) with $p_T > 35(32)$ GeV, $E_T^{jet1(jet2)} > 100(40)$ GeV, ≥ 1 b-tag

Backgrounds: $t\bar{t}$+single top, W(→ $l\nu$)+jets, Z/γ* (→ ll)+jets, QCD, VV

New BDT analysis for signal/background discrimination with ~50 variables (object and event kinematics, top reconstruction, angular correlations).





CMS PAS EXO-12-001

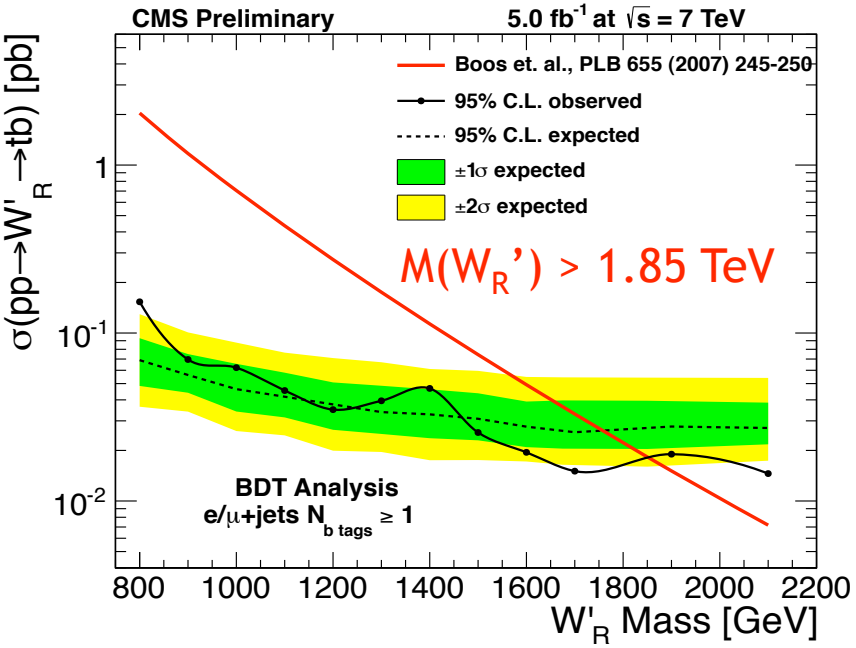
W' → tb

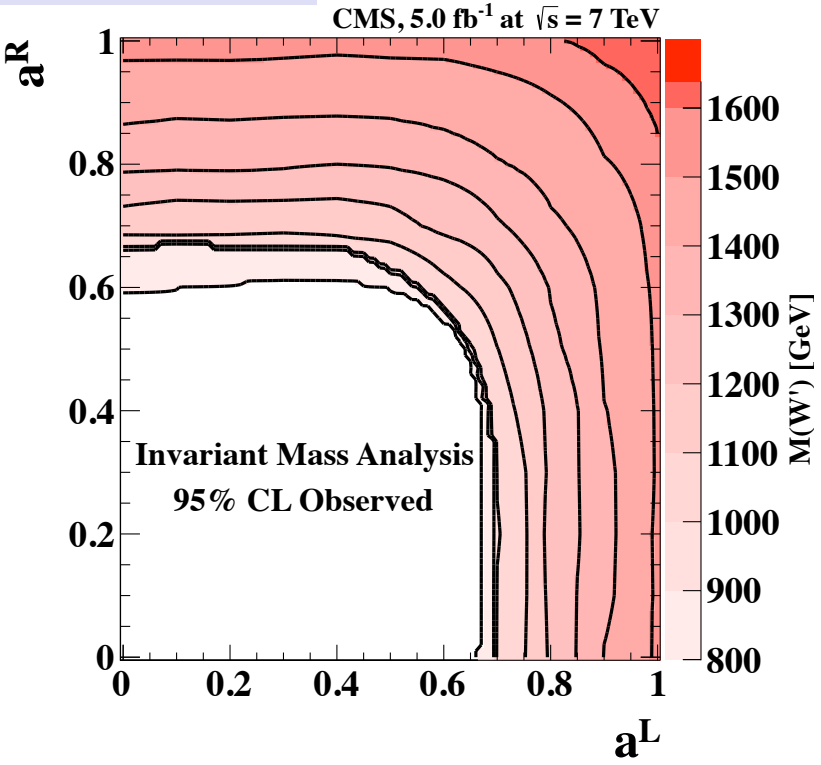
Most general model-independent LO Lagrangian for a W' coupling to SM fermions:

$$\mathcal{L} = \frac{V_{f_i f_j}}{2\sqrt{2}} g_w \bar{f}_i \gamma_\mu (a^R_{f_i f_j}(1+\gamma^5) + a^L_{f_i f_j}(1-\gamma^5)) W'^\mu f_j + h.c.$$

$$a^{L,R}_{ud} = a^{L,R}_{cs} = a^{L,R}_{tb} = a^{L,R}$$

Mass limit and constraints of W' gauge coupling for a set of left- and right-handed coupling combinations have been set:



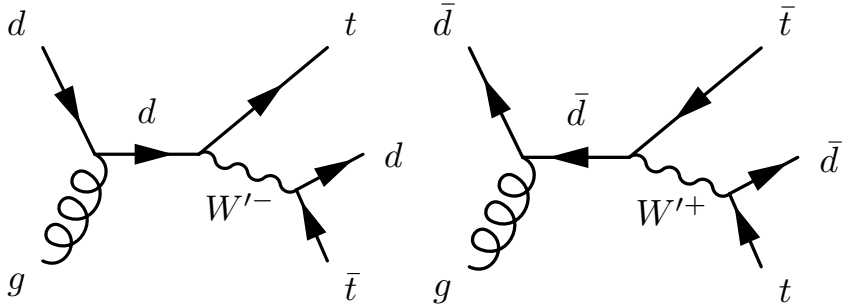


Contours of W' mass at which the observed 95% CL cross-section upper limit equals the predicted cross-section

W' → td

- Tevatron measurement of forward-backward asymmetry at high $t\bar{t}$ inv. mass

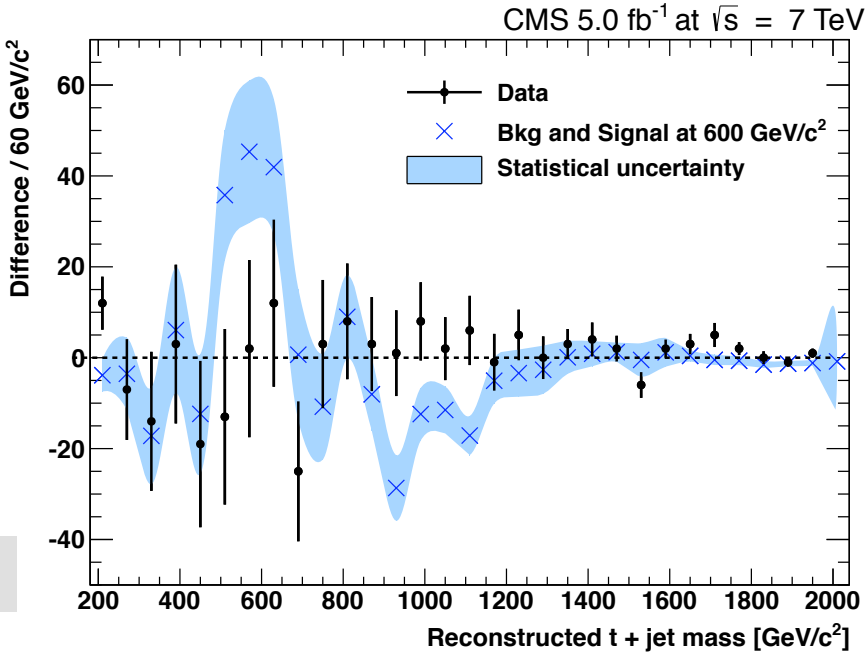
$$A_{FB}^{t} = \frac{N_t(\eta \geq 0) - N_t(\eta \leq 0)}{N_t(\eta \geq 0) + N_t(\eta \leq 0)}$$



- Possible explanation: light W'
- N(W'$^-$) > N(W'$^+$) at LHC -> aids in reconstructing the W'

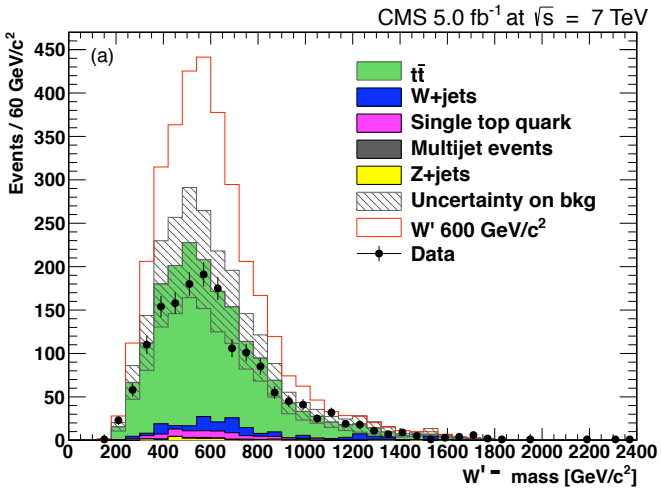
Decay chain:
pp → tW' → ttd,
with semileptonic t-decays plus a jet in final state.

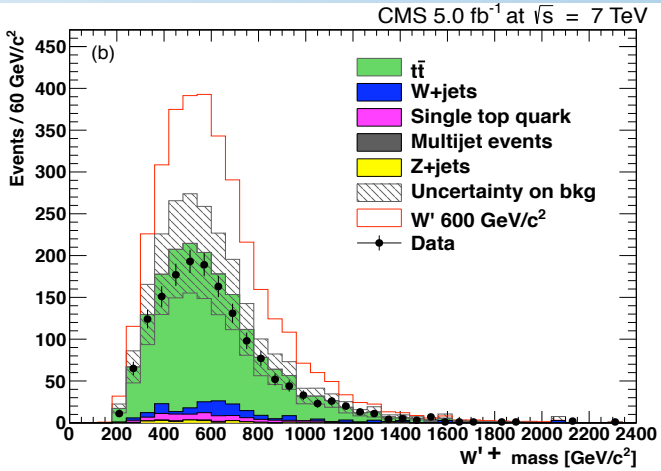
Difference of yields for t^-+d and t^++d invariant mass distributions (charge assignment from leptonic top decay):

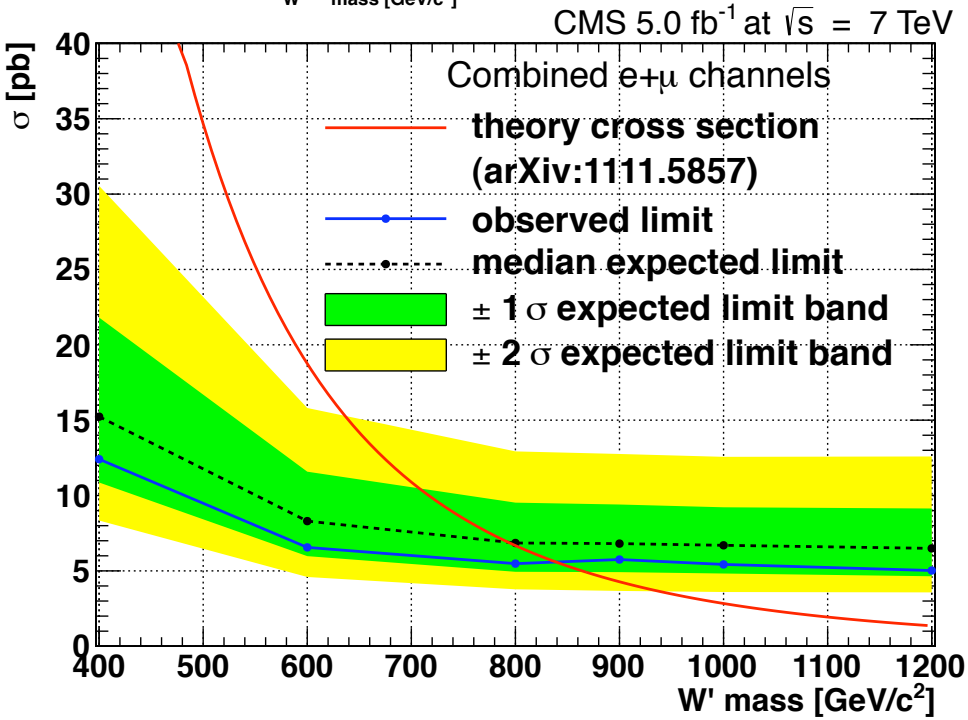


hep-ex 1206.3921, CMS PAS EXO-11-056

W' → td







M(W') > 839 GeV

$W', G_{RS} \rightarrow VZ \rightarrow$ wide jet + lepton pair

$W'_{SSM} \rightarrow ZW \rightarrow lljj$, $G_{RS} \rightarrow ZZ \rightarrow lljj$

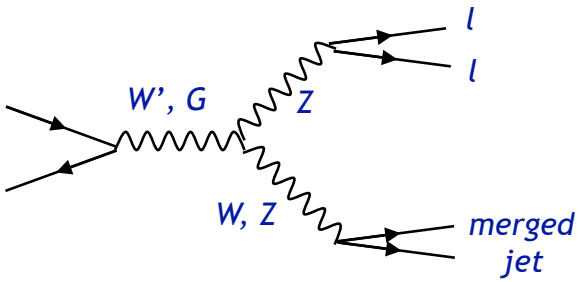
- 2-fermion systems boosted for heavy resonance

Event selection:

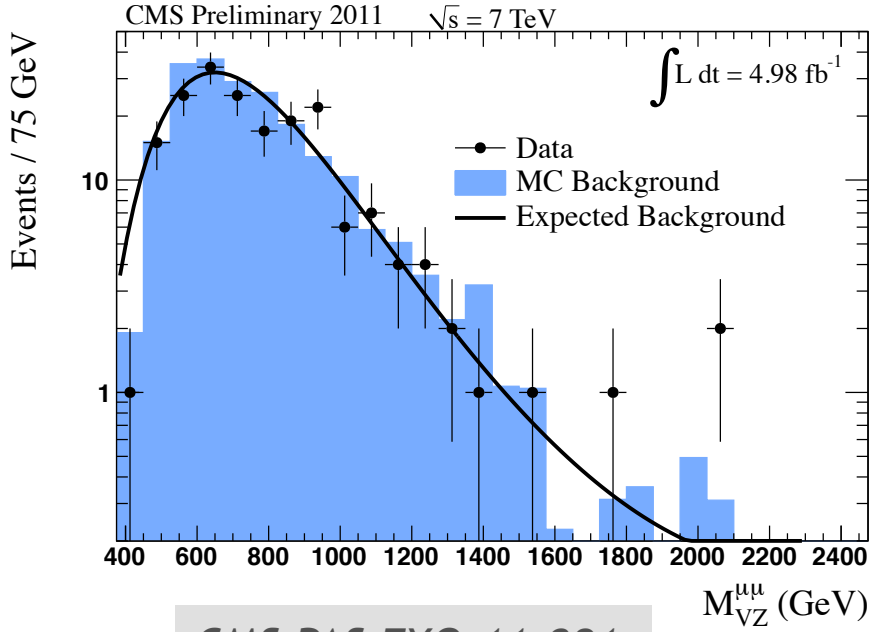
based on high-p_T Z candidates from lepton pair and wide jet well separated from leptons

Backgrounds: from data

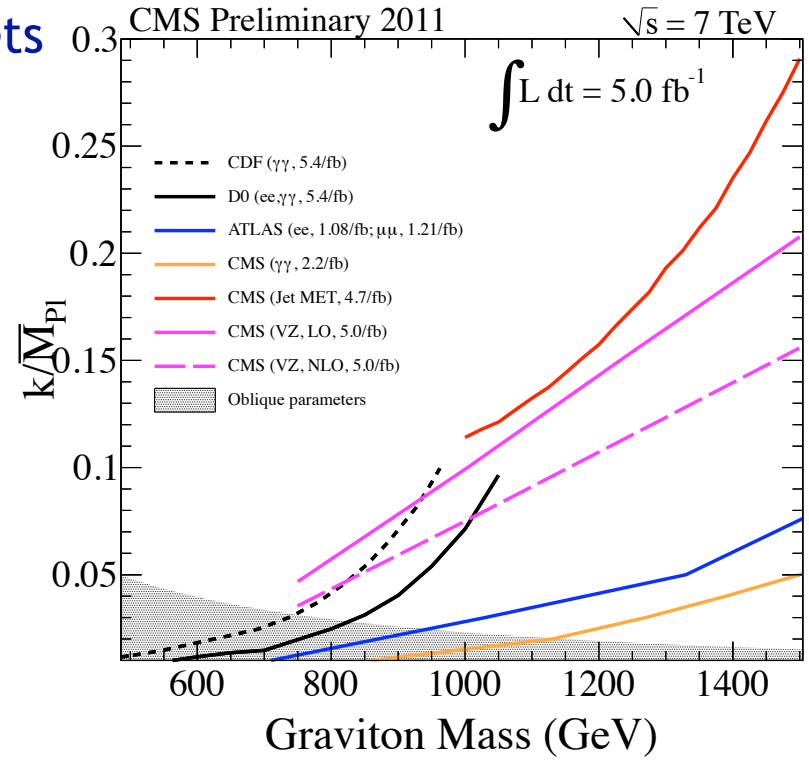
W+jets, $t\bar{t}$, γV+jets, Z/γ^*+jets, ZZ, VV+jets



95% CL exclusion limits



CMS PAS EXO-11-081



Conclusions

- CMS has studied scenarios for new heavy gauge bosons.
- Although no signals for new physics have been found yet, limits on masses and other quantities have been set.
- Details may be found here:

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

We are looking forward to more LHC data!