Exclusion Limits on Neutral, Mono and Doubly Charged Vector Bosons at LHC

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Introduction

- Many SM extensions propose solutions to different problems.
- Models based on gauge structure $SU(3)_C$ x $SU(2)_L$ x $U(1)_X$, known as **3-3-1 models**, have some appealing features:

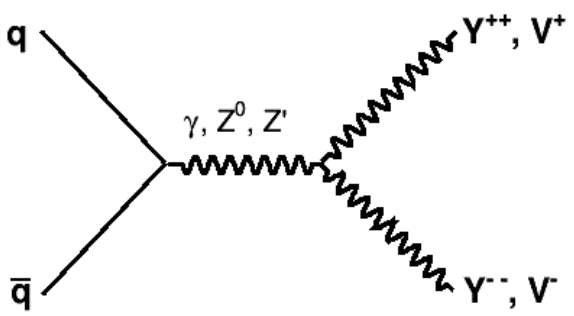
  ✔ provide an explanation for the family replication problem;
  ✔ provide some indication of why the top quark is the heaviest one;
  ✔ interesting new physics scenarios.

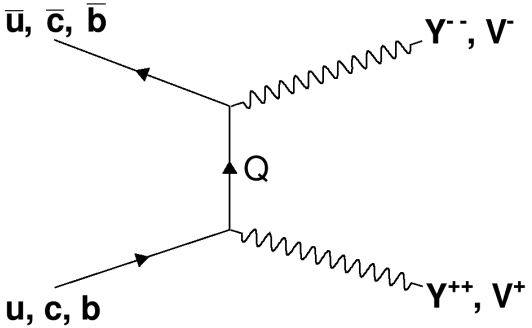
- There are five exotic gauge bosons in the model: one neutral (Z'_{331}) and four charged, called **bileptons** ($Y^{\pm\pm}$, $V^{\pm}$).
- The model also predicts a heavy leptoquark (Q).

Goal: Interpret different LHC searches in terms of 3-3-1 predictions.

Vector Bosons Production at LHC

- Resonant production of Z'_{331} and subsequent decay into two oppositely charged leptons
- Bileptons are produced in pairs through a Drell-Yan process intermediated by neutral gauge bosons, and via a t-channel with leptoquark exchange.





Bileptons Signature

Each doubly charged bilepton decay into a pair of same sign leptons. Mono charged bileptons decay into a lepton and a neutrino.

- $Y^{\pm\pm} \longrightarrow e^{\pm}e^{\pm}$
- $Y^{\pm\pm} \longrightarrow \mu^{\pm}\mu^{\pm}$
- $Y^{\pm\pm} \longrightarrow e^{\pm}\mu^{\pm}$
- $V^{\pm} \longrightarrow e^{+}\bar{\nu}, e^{-}\nu$
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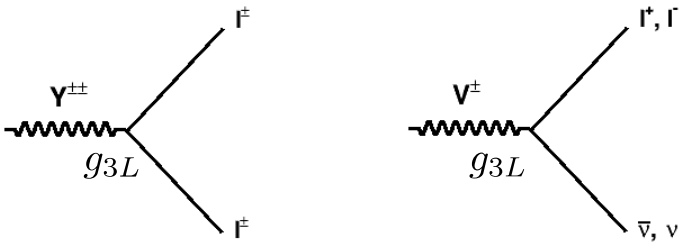

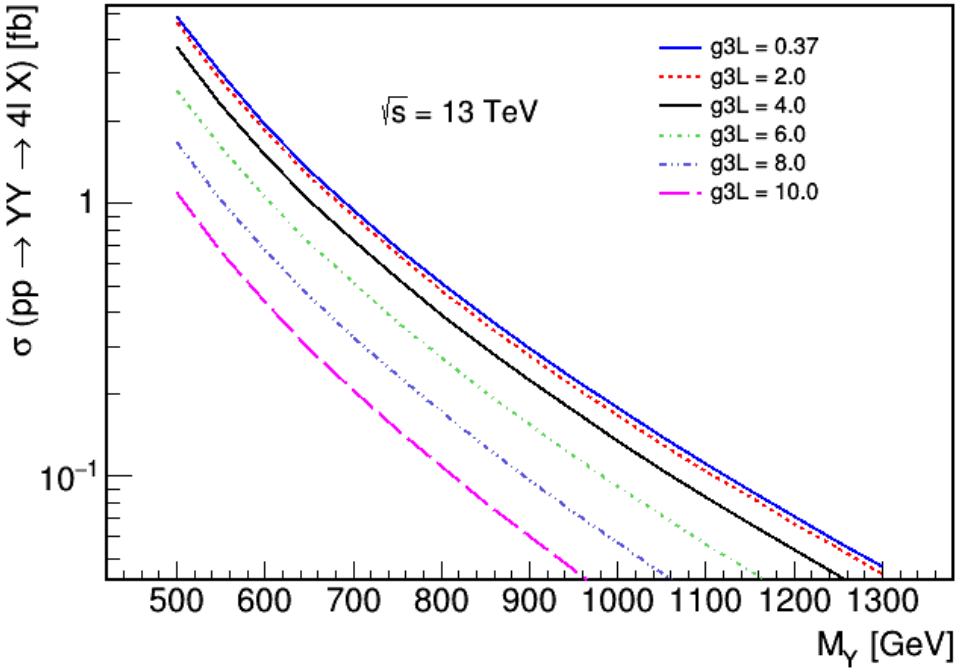

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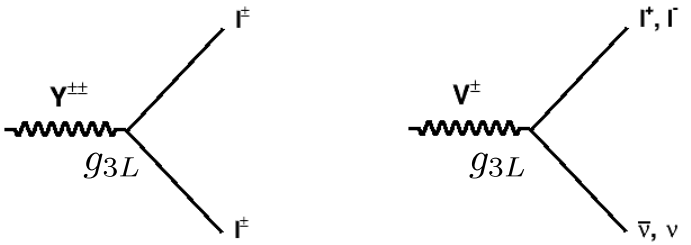
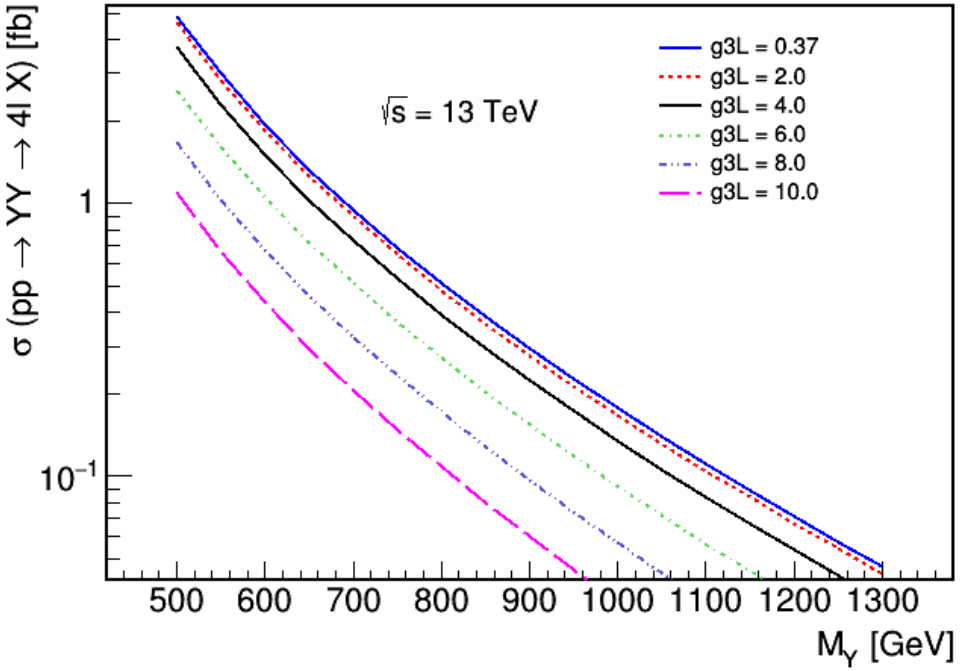
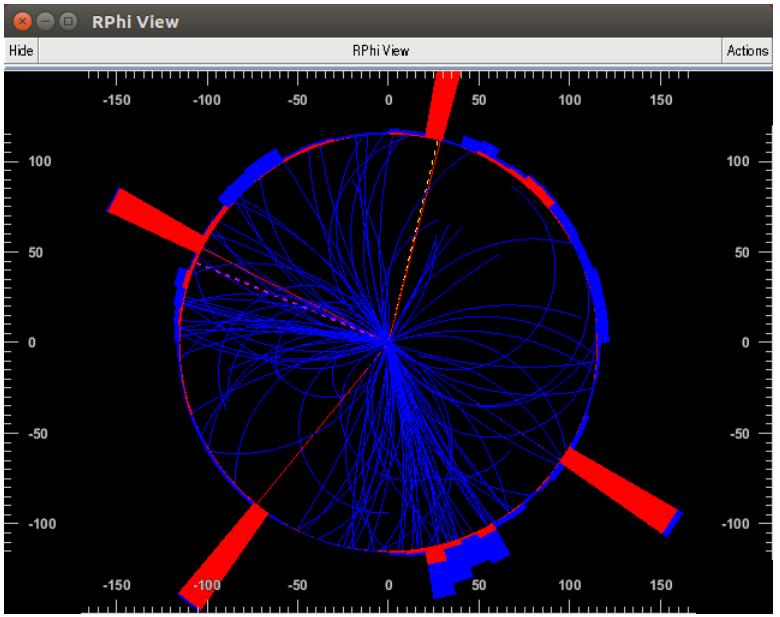
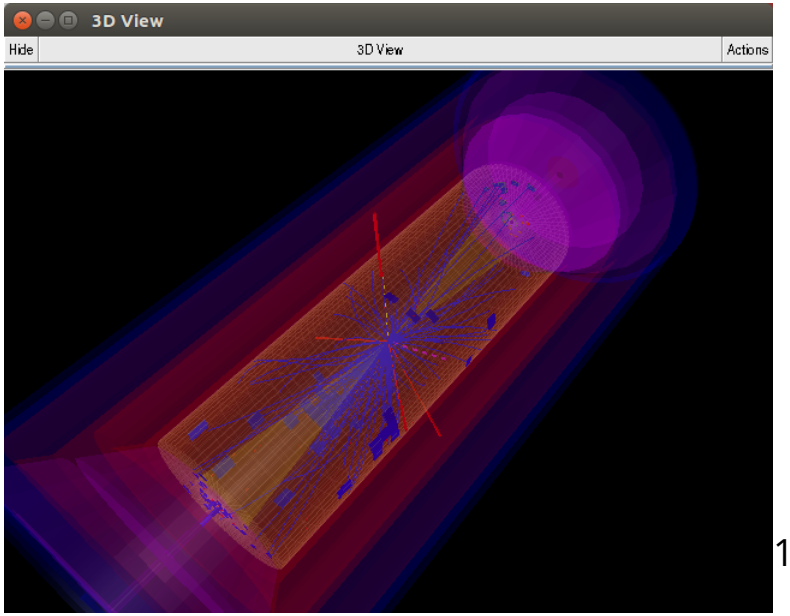




Signal Simulation

- CalcHep + PYTHIA8 + DELPHES (pile-up included)
- M_Q = 1.5 TeV
- $M_Y < M_Q$





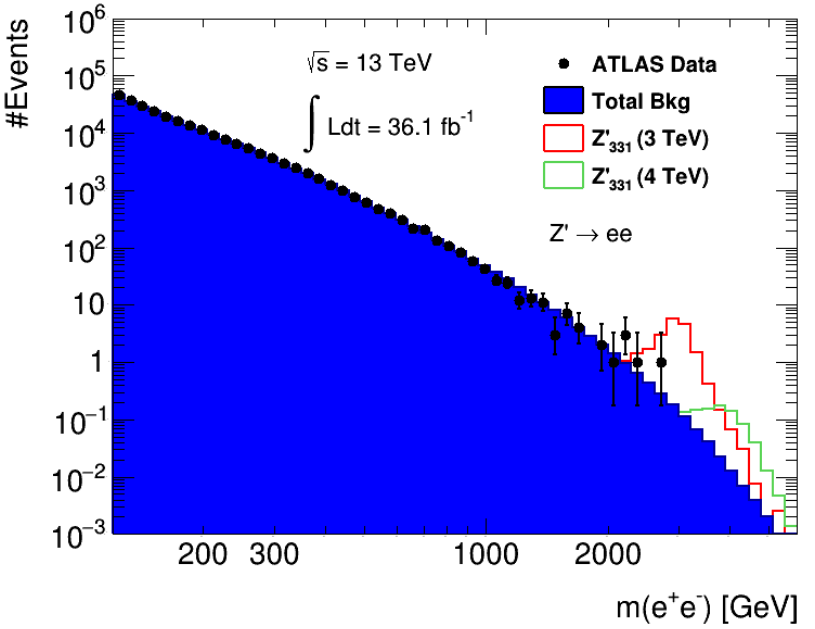
ATLAS published data corresponding to an integrated luminosity of 36.1 fb^{-1} at 13 TeV are used.

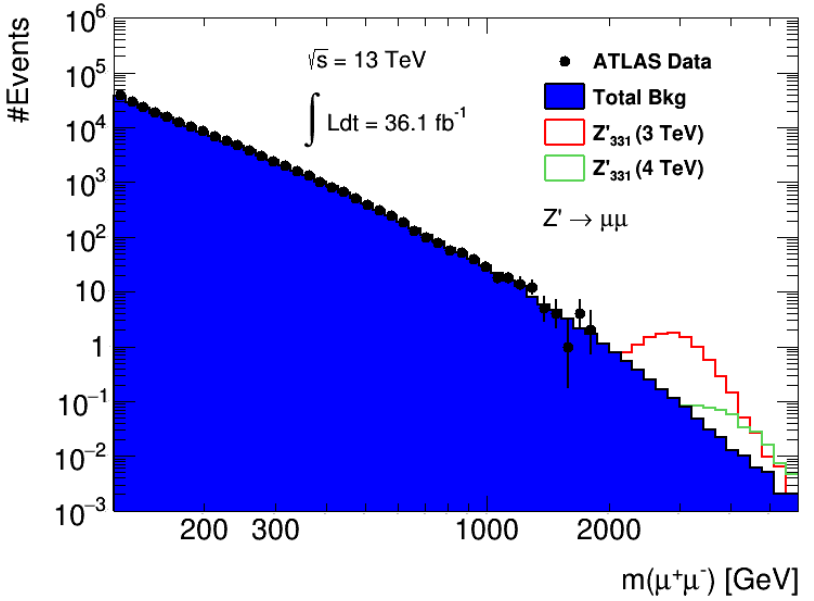
JHEP 1710 (2017), EPJ C78, 199, (2018), EPJ. C78, 995, (2018)

Limits on Z'_{331}

Event Selection

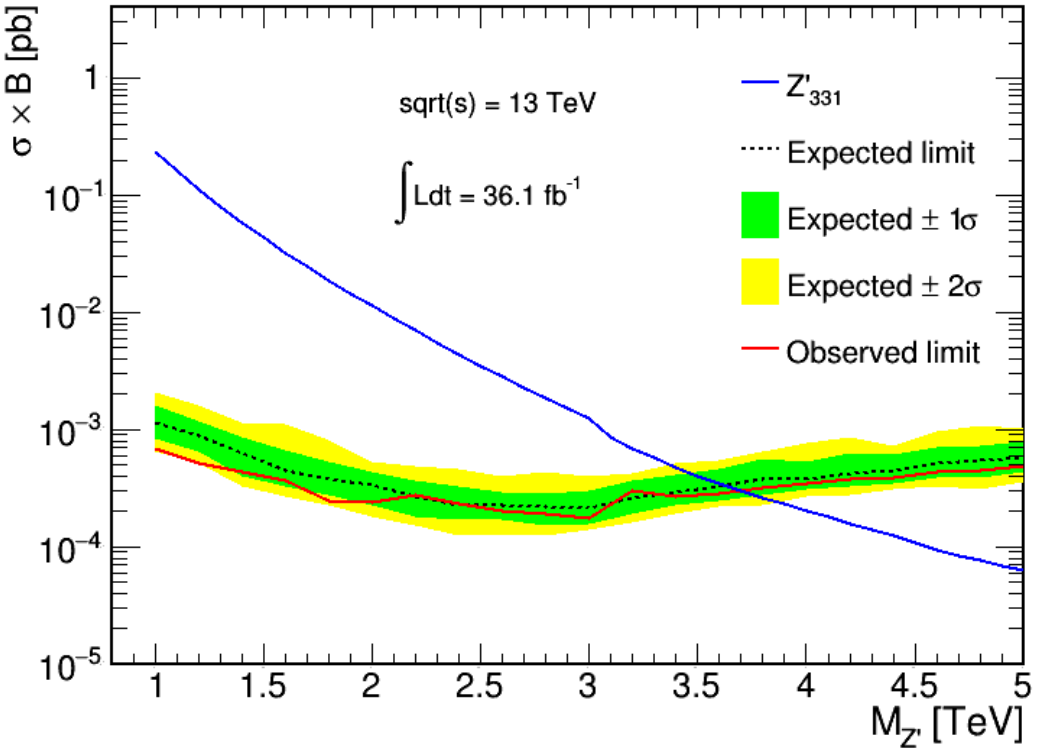
- At least one pair of same flavor lepton candidates (electrons or muons)
- In the muon channel, opposite charge candidates are required.
- $|\eta_\ell| < 2.5, \quad p_T^\ell > 30\ GeV$





Limits on Z'_{331}

To set limits, a Bayesian approach is applied with a flat prior probability distribution for σ x *Br*. Upper limits on the cross-section are translated into lower limits on the vector bosons mass.

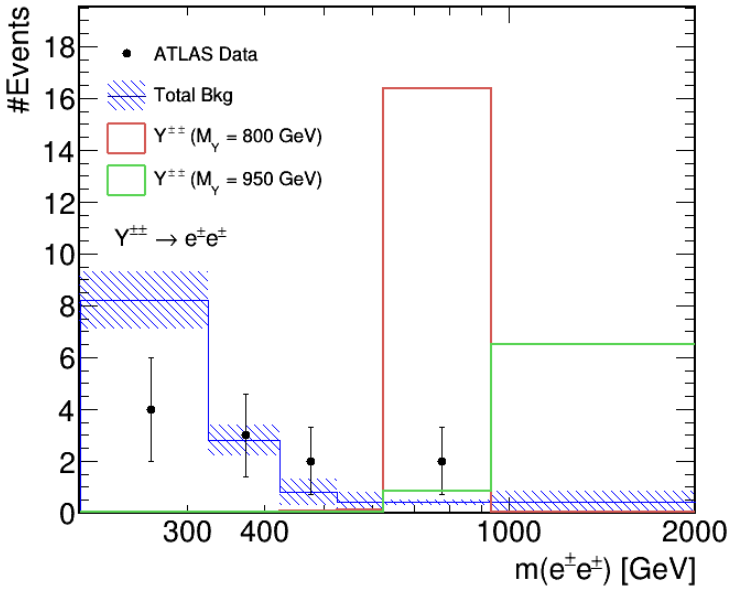


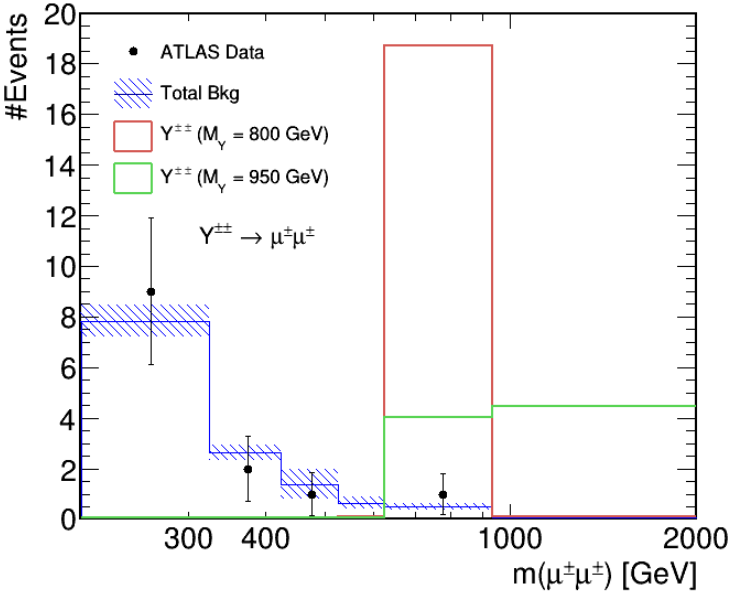
Observed Limit: 3.71 TeV
Expected Limit: (3.63 ± 0.16) TeV

Limits on $Y^{\pm\pm}$

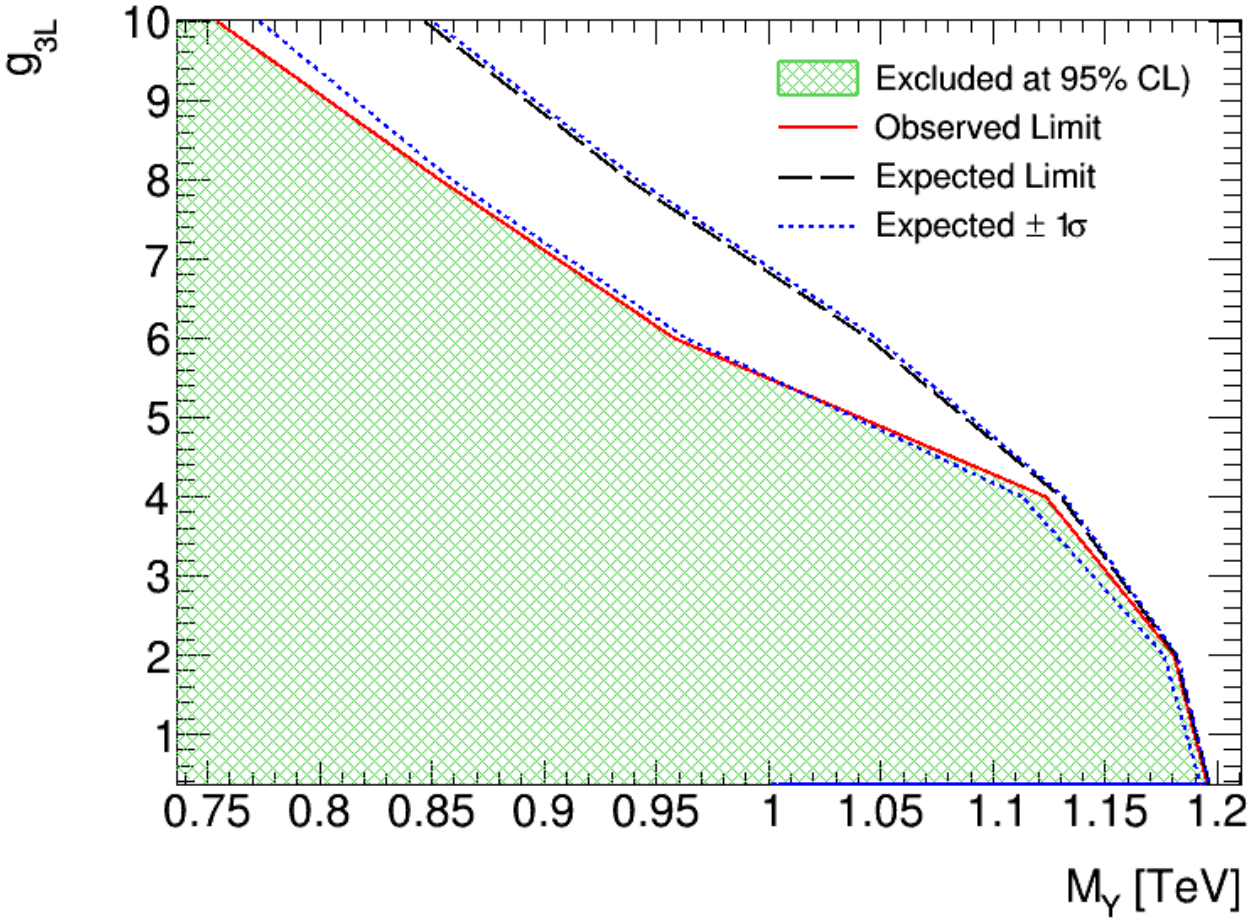
Event Selection

- $|\eta_\ell| < 2.5, \quad p_T^\ell > 30\ GeV$
- *b*-jet veto
- Three leptons event $(\ell^\pm\ell^\pm\ell^\mp)$
  - ✔ Exactly one same-charge lepton pair
  - ✔ $\Delta R(\ell^\pm\ell^\pm) < 3.5$
  - ✔ $p_T(\ell^\pm\ell^\pm) > 100\ GeV$
  - ✔ $\sum |p_T^\ell| > 300\ GeV$
- Four leptons event $(\ell^\pm\ell^\pm\ell^\mp\ell^\mp)$
  - ✔ $\sum C^\ell = 0$
  - ✔ $\bar{M} \equiv \frac{m^{++} + m^{--}}{2}$





Limits on $Y^{\pm\pm}$



Bileptons with masses between ~ 750 GeV and ~ 1200 GeV are excluded.

Previous limit @7 TeV: M_Y > 520 GeV (AAN, BM, PRD **94**, 2016)

Limits on $V^{\pm}$

Event Selection

- $|\eta_\ell| < 2.5, \quad p_T^\ell > 10\ GeV$
- *b*-jet veto
- Two opposite-charge leptons
  - ✔ Same Flavor $(e^+e^-, \mu^+\mu^-)$

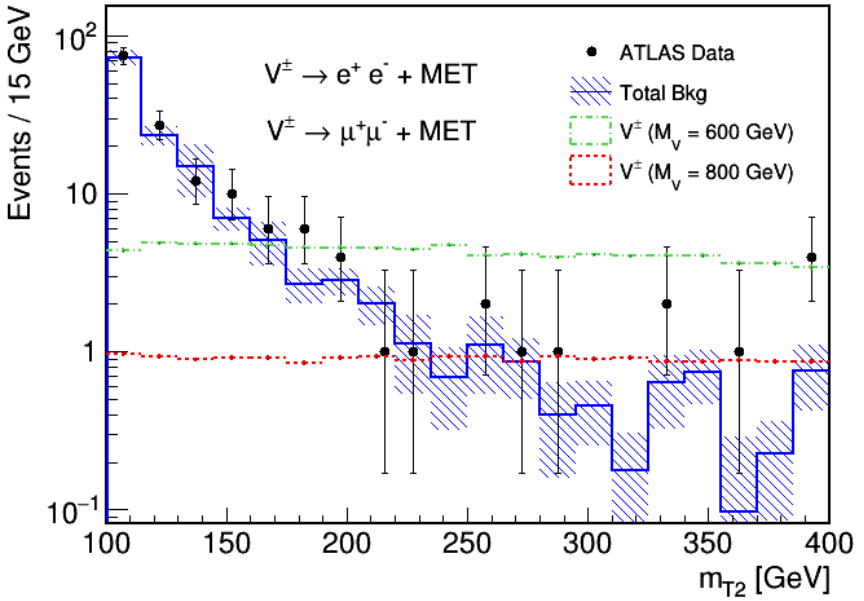
    $m_{T2}* > 100\ GeV$

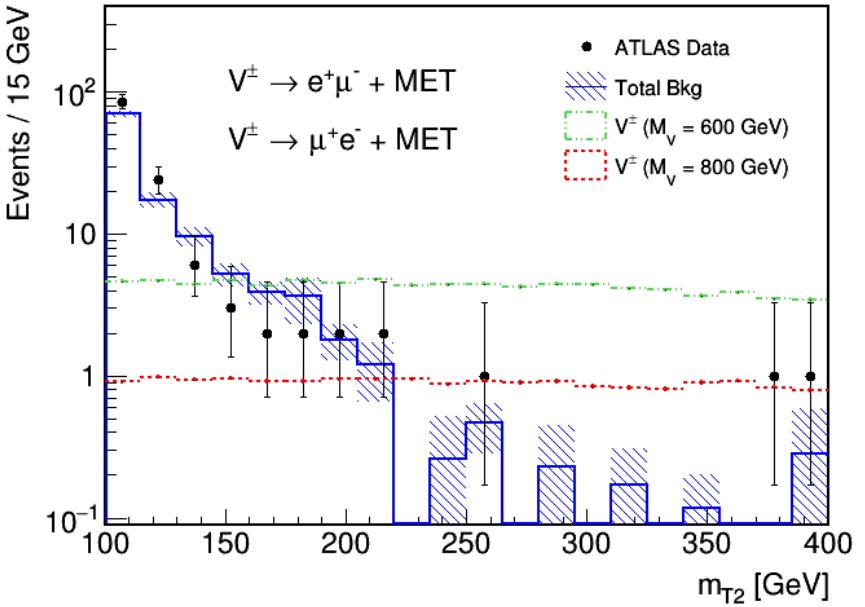
    $m_{\ell\ell} > 111\ GeV$

  - ✔ Different Flavor $(e^\pm\mu^\mp)$

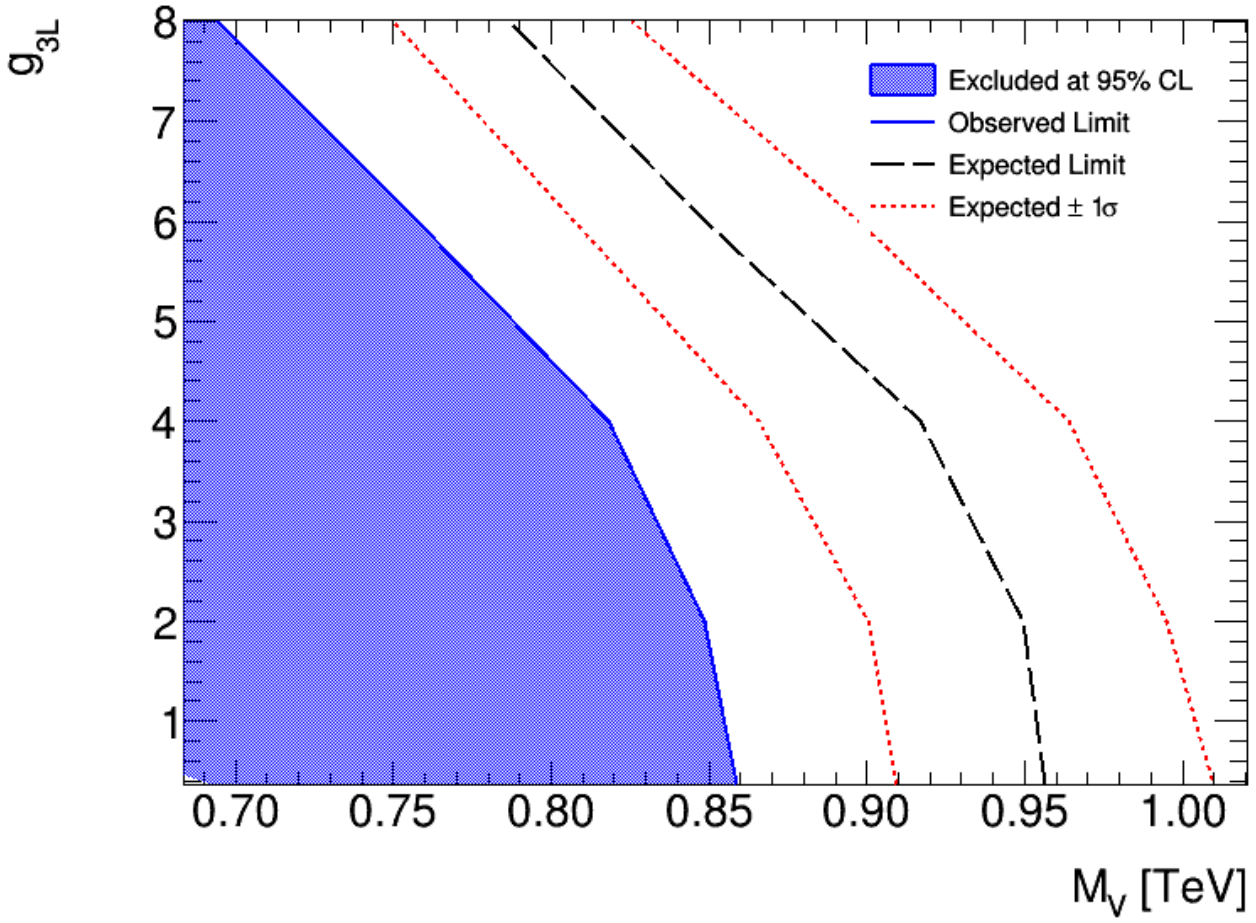
    $m_{T2} > 100\ GeV$

$*m_{T2}$ *is the stransverse mass*





Limits on $V^{\pm}$



First limits on mono-charged bileptons with LHC data.

Summary

- ATLAS searches with 36.1 fb^{-1} of data are interpreted in terms of 3-3-1 predictions.
- A Z'_{331} with mass below 3.7 TeV is excluded.
- Mono and doubly charged bileptons with masses up to ~ 850 GeV and ~ 1200 GeV, respectively, are excluded.
- These results represent the most stringent bounds on bileptons masses.

Back-up Slides

Stransverse Mass

$$m_{T2} = min\left[max\left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{miss} - \mathbf{q}_T)\right)\right]$$

$$m_T(\mathbf{p}_T, \mathbf{q}_T) = \sqrt{2(p_T q_T - \mathbf{p}_T.\mathbf{q}_T)}$$

See https://www.hep.phy.cam.ac.uk/~lester/mt2/ for details.

Signal Validation

Z’ SSM

	ATLAS		DELPHES	
	Obs.	Exp.	Obs.	Exp.
ee (TeV)	4.3	4.3	4.2	4.2
μμ (TeV)	4.0	3.9	4.0	3.9
ll (TeV)	4.5	4.5	4.4	4.4