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 $\text{SU(3)}_C \times \text{SU(2)}_L \times \text{U(1)}_X$, 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.

\[ Y^{±±} \rightarrow e^± e^± \]
\[ Y^{±±} \rightarrow μ^± μ^± \]
\[ Y^{±±} \rightarrow e^± μ^± \]
\[ V^± \rightarrow e^+ \bar{\nu}, e^- \nu \]
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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.

Limits on $Z'$

Event Selection

- At least one pair of same flavor lepton candidates (electrons or muons)
- In the muon channel, opposite charge candidates are required.
- $|\eta_\ell| < 2.5$, $p_T^\ell > 30$ GeV
Limits on $Z'_\text{331}$

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

Observed Limit: 3.71 TeV
Expected Limit: $(3.63 \pm 0.16)$ TeV
Limits on $Y^{±±}$

Event Selection

- $|\eta_\ell| < 2.5, \ p_T^\ell > 30 \ GeV$
- $b$-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 ($\ell^\pm \ell^\pm \ell^\mp \ell^\mp$)
  - ✔ $\sum C^\ell = 0$
  - ✔ $\bar{M} = \frac{m^{++} + m^{--}}{2}$

[Graphs showing data and plots for different mass distributions]
Limits on $Y^{±±}$

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

Previous limit @7 TeV: $M_γ > 520$ GeV (AAN, BM, PRD 94, 2016)
Limits on $V^\pm$

Event Selection

- $|\eta_\ell| < 2.5$, $p_T^\ell > 10$ 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 transverse mass*
Limits on $V^\pm$

First limits on mono-charged bileptons with LHC data.
Summary

- ATLAS searches with $36.1 \text{ fb}^{-1}$ 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

\[ m_{T2} = \min [ \max (m_T(p_T^{\ell 1}, q_T), m_T(p_T^{\ell 2}, p_T^{\text{miss}} - q_T)) ] \]

\[ m_T(p_T, q_T) = \sqrt{2(p_T q_T - p_T \cdot q_T)} \]

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

### Z’ SSM

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