Prospects for early discoveries at the LHC with dileptons, jets and no missing energy with the ATLAS detector

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- Leptoquark pair production
- Left-right symmetric models ($W_R \rightarrow l N_l \rightarrow l q l q$)

Analyses are for $\sqrt{s} = 14 \text{ TeV}$

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Signature

- Two high pt same flavor leptons
- Two highly energetic jets
- No missing energy

Basic selection

- Two isolated electrons or muons with $pt > 20 \text{ GeV}$, $|\eta| < 2.5$
- Lepton invariant mass above 70 GeV
 - analysis cut will be above Z mass
- Two jets with $pt > 20 \text{ GeV}$, $|\eta| < 4.5$

Major Background

- Top pairs
- Drell-Yan with two or more Jets

Additional backgrounds

- Vector boson pairs
- Multijet (with fake leptons)

Leptoquarks

Particle with lepton and quark quantum numbers

- Connect lepton and quark sector (appear naturally in GUT's)
- Limits on lepton flavor conservation and FCNC require LQ to (nearly) only couple to one quark and one lepton generation.
- Decay into charged and neutral leptons in principle possible: $\beta = \text{Br}(LQ \rightarrow q l^\pm)$
 $\Rightarrow$ Cross section for final state with two charged leptons reduced by β^2

pair produced in the strong interaction

$\Rightarrow$ Large production cross section

Invariant mass of lepton-jet pairs can be used to identify events

m_{LQ} in GeV	$\sigma(pp \rightarrow LQ \bar{LQ})$ (NLO) in pb
300	10.1 ± 1.5
400	2.24 ± 0.38
600	0.225 ± 0.048
800	0.0378 ± 0.0105

Event selection

Simple cut based selection:

- Baseline selection
- for muons: $p_t^\mu > 60 \text{ GeV}$ $p_t^{\text{jet}} > 25 \text{ GeV}$
- Cut on $S_T = E_T^{J1} + E_T^{J2} + p_T^{l1} + p_T^{l2}$

$$S_T > 490 \text{ GeV}$$

$$S_T > 600 \text{ GeV}$$

Invariant mass

$$M_{ee} > 120 \text{ GeV}$$

$$M_{\mu\mu} > 110 \text{ GeV}$$

Leptoquark mass

before S_T and m_{ll} cut

after S_T and m_{ll} cut

$$M_{12}^{ej} \in [320, 480]$$

$$M_{avr}^{\mu j} \in [300, 500]$$

Cut will depend on tested LQ mass (e.g. for 400 GeV LQ)

Systematic uncertainties

- Luminosity
- Lepton trigger and identification efficiencies
- Jet energy scale and resolution
- Lepton energy scale and resolution
- Background cross section
- Jet production in Drell-Yan events
- PDF's
- Monte Carlo statistics for background sample

Discovery reach for $\sqrt{s} = 14 \text{ TeV}$

Calculate probability that only background could produce the expected observation of signal and background. When that probability corresponds to 5σ or higher for a Gaussian distribution, we call it a 5σ discovery.

Leptoquark mass	Expected luminosity needed for a 5σ discovery	
	1st gen.	2nd gen.
300 GeV	2.8 pb^{-1}	1.6 pb^{-1}
400 GeV	11.8 pb^{-1}	7.7 pb^{-1}
600 GeV	123 pb^{-1}	103 pb^{-1}
800 GeV	1094 pb^{-1}	664 pb^{-1}

Left-right symmetric models ($W_R \rightarrow l N_R \rightarrow l j l j$)

Right-handed W can decay into a charged lepton and a Majorana Neutrino.

Study two example points:

- $m(W_R)=1800$ GeV $m(N_l)=300$ GeV ($\sigma=24.8$ pb)
- $m(W_R)=1500$ GeV $m(N_l)=500$ GeV ($\sigma=47.0$ pb)

For strongly boosted N_l its decay products will be close together.

Event selection

$$S_T > 700 \text{ GeV}$$

$$M_{ll} > 300 \text{ GeV}$$

W_R mass

After baseline
selection

After $M_{ll} S_T$ cuts

$M(lljj) > 1000 \text{ GeV}$

Majorana Neutrino Mass

After baseline
selection

After all cuts

Discovery reach for $\sqrt{s} = 14 \text{ TeV}$

For
 $m(W_R) = 1800 \text{ GeV}$
 $m(N_1) = 300 \text{ GeV}$
 both the cross
 section and the
 efficiency are small

Conclusion

Final states with two high pt leptons and two highly energetic jets look very promising for early data searches

Both leptoquarks up to 500-600 GeV and LRSM with $W_R \rightarrow l N_l \rightarrow l q l q$ could be discovered with about 100 pb^{-1}

For 10 TeV signal and background cross sections are a factor 2-3 smaller.

Studies to extract the backgrounds directly from data are underway.