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Searches for new physics in lepton+jet final states

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Results of searches for new particles such as leptoquarks, heavy neutrinos, and W bosons with right-handed couplings in final states with leptons (charged or neutral) and jets are presented. The emphasis is given to the recent results obtained using data collected at Run-II of the LHC.

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1. Introduction

A general effective model for LQs was proposed in 1987 by Buchmuller, Ruckl and Wyler [1]. An LQ will decay into a lepton and a quark, giving rise to a final state containing high-momentum leptons and jets. The decay into a charged lepton and a quark has branching fraction β; consequently, the decay into a neutrino and a quark has branching fraction $1-\beta$, where β is a free parameter. Thus, in this search for first and second generation LQs, we assume them to decay to charged leptons or the corresponding neutrinos along with jets. The corresponding branching fractions are β^2, $2\times\beta(1-\beta)$, and $(1-\beta)^2$, respectively. We consider two values of β: 1, which corresponds to LQs always decaying to the first final state; and 0.5, where 50% of LQs decay to the second final state, with 25% (25%) decaying to the first (third) final state.

In Ref. [2,3], we search for LQ decays in the first and second final states that are denoted as $\ell\ell$jj and $\ell\nu$jj, respectively. For the third generation scalar LQs we focus on the $\tau\tau$jj channel in which both of the τ leptons decay hadronically.

In the SM, neutrinos are considered to be massless. However, the observation of neutrino oscillations[4] implies a small but nonzero mass for neutrinos, prompting a corresponding extension of the SM. .The most prominent model that can generate light neutrinos is the so-called "seesaw" mechanism, which is realized in various schemes. In the simplest case, the small observed neutrino masses are a consequence of the existence of a hypothetical heavy neutrino. In this model, the SM neutrino mass is given by $m_\nu \sim y_\nu^2 v^2/m_{\mathrm{N}}$, where y_ν is the Yukawa coupling to the Higgs field, v the vacuum expectation value in the SM, and m_{N} the mass of the heavy neutrino state. $W_R \to \ell N_R \to \ell\ell W_R^* \to \ell\ell q\bar{q}'$, ℓ = e or μ.

2. Event selection for the first and second generation LQs

The $\ell\ell$jj final state is the result of pair-produced LQs each decaying to an electron and a jet, while the $\ell\nu$jj channel arises when one of the LQs decays to an electron and a jet and the other LQ to a neutrino and a jet. Events containing at least two charged leptons and two jets are thus selected, where the two leading p_{T} charged leptons and jets are used in the analysis.

2.1 Preselection

At the preselection, we go for a loose set of selection criteria to compare data with Monte Carlo (MC) simulated background predictions. For the eejj analysis, we select events with at least two electrons and two jets while for the $\mu\mu$jj channel events are selected with at least two muons and two jets. When additional objects satisfy these requirements, the two highest p_{T} leptons and jets are considered. The dilepton invariant mass M_{ll} is required to be greater than 50 GeV.The scalar p_{T} sum over the leptons and two jets, $S_{\mathrm{T}} = p_{\mathrm{T}}(\ell_1) + p_{\mathrm{T}}(\ell_2) + p_{\mathrm{T}}(\mathrm{j}_1) + \mathrm{p_T}(\mathrm{j}_2)$, must be at least 300 GeV. In the $\ell\nu$jj channel, we select events containing exactly one lepton, at least two jets, and $p_{\mathrm{T}}^{\mathrm{miss}} > 100$ GeV for the first generation LQs and $p_{\mathrm{T}}^{\mathrm{miss}} > 55$ GeV for the second generation LQs. The leptons and jets are required to be well seperated from $p_{\mathrm{T}}^{\mathrm{miss}}$. This helps reject events with $p_{\mathrm{T}}^{\mathrm{miss}}$ arising primarily from instrumental effects.

The transverse mass of the lepton $-$ $\mathrm{p_T^{miss}}$ system must be greater 50 GeV. Here and later, the transverse mass of a di-object system is defined as m_{T} $(\mathrm{obj}_1, \mathrm{obj}_2)$= $\sqrt{2p_{\mathrm{T}}(\mathrm{obj}_1)p_{\mathrm{T}}(\mathrm{obj}_2)(1-\cos\theta)}$, with θ being the angle between the p_T vectors of obj$_1$ and obj$_2$. The m_T criterion helps suppress the W+jets contribution. Finally, selected events must have $S_T > 300$ GeV, where $S_T = p_T(e) + p_T^{miss} + p_T(j_1) + p_T(j_2)$.

3. Event selection for the third generation LQs and W_R

Candidate events are required to have at least two τ_h candidates, each with p_T greater than 70 GeV and $|\eta| < 2.1$ and are well seperated from each other. Also, the events are required to have least two jets with $p_T > 50$ GeV and $|\eta| < 2.4$ and $\Delta R > 0.4$ between the jets and selected τ_h. Also $p_T^{miss} > 50$ GeV and the invariant mass of the τ_h pair, $m(\tau_{h1}, \tau_{h2})$, is chosen to be greater than 100 GeV.

For the independent search of W_R, events are selected with at least two charged leptons and two jets and the invariant mass of the four object system comprising the two leading leptons and two leading jets is reconstructed, which is then used as the final selection variable. The leptons and jets are required to be well separated from each other.

4. Backgrounds

The major backgrounds from SM processes in the $\ell\ell$jj channel are Z+jets and $t\bar{t}$, whereas single top, W+jets, diboson, and γ+jets contribute at a lower level. For the $\ell\nu$jj channel we have $t\bar{t}$ and W+jets as the major backgrounds. There is also an instrumental background from QCD multijet events with jets faking electrons. For the W_R and third generation LQ search, the $t\bar{t}$, production of a Z boson decaying to a τ_h pair plus associated jets from initial state radiation (Z+jets), and QCD multijet processes are the prevailing backgrounds in the signal region.

5. Results

We do not find any evidence for either scalar LQs or W_R signal in the data. Therefore, we proceed to set upper limits on their production cross section based on the full frequentist CLs, using the event yields. The upper limits at 95% confidence level on the predicted cross section at NLO are shown in Fig. 3. The intersection of the central value of the theoretical prediction with the obtained upper limit on cross section provides a limit on the mass. The limit for the β = (1,0.5) for the first and second generation LQs are (1435,1195) and (1525, 1140) GeV, respectively. For the third generation LQ and W_R we have the upper limits as 1020 and 4400 GeV, respectively.

References

[1] W. Buchmuller, R. Ruckl and D.Wyler, Phys. Lett. B, **191** (1987) 442.

[2] CMS Collaboration, CMS PAS (EXO-17-009).

[3] CMS Collaboration, CMS PAS (EXO-17-003).

[4] M. Tanabashi *et al.*(Particle Data Group), Phys. Rev.D **98** (2018) 030001.

[5] CMS Collaboration, CMS PAS (EXO-17-011).

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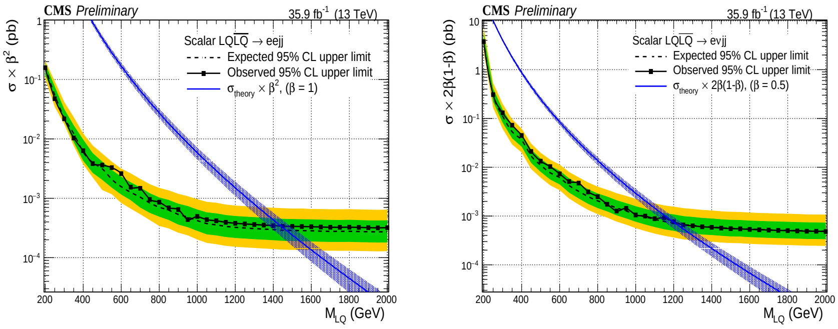

Figure 1: Observed and expected upper limits for first generation generation scalar LQ pair-production cross section times β^2 for eejj channel (left) and $2\beta(1-\beta)$ for the eνjj channel (right) and at the 95% confidence level. The median (dashed line), 1σ (green band), and 2σ (yellow band) expected limits are shown.

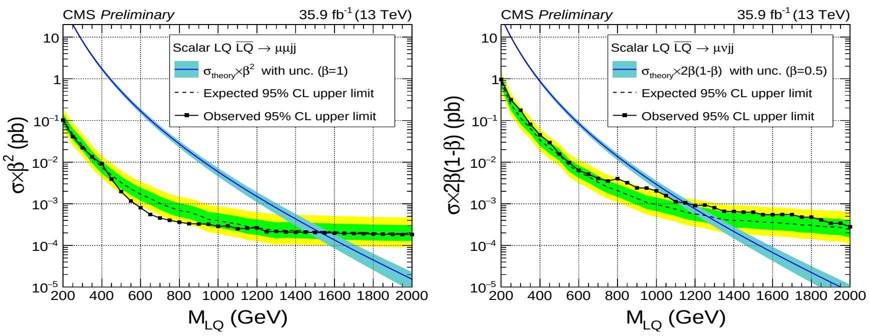

Figure 2: Observed and expected upper limits for second generation scalar LQ pair-production cross section times β^2 for $\mu\mu$jj channel (left) and $2\beta(1-\beta)$ for the $\mu\nu$jj channel (right) at the 95% confidence level[8]. The median (dashed line), 1σ (green band) and 2σ (yellow band) expected limits are shown.

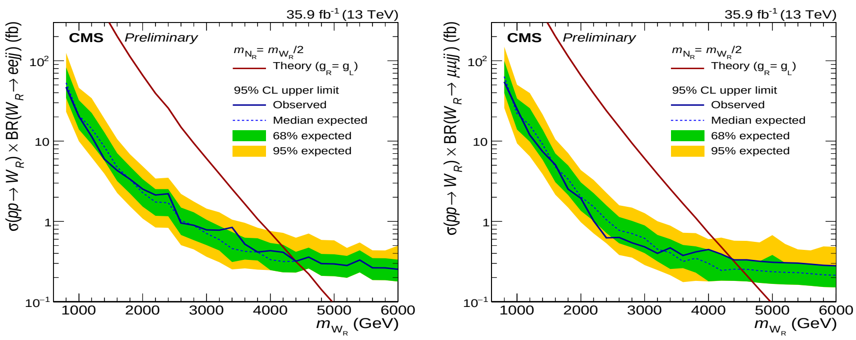

Figure 3: Limit on $\sigma(pp \to W_R) \times \mathrm{BR}(\mathrm{W_R} \to \ell\ell\mathrm{jj})$ with systematic uncertainties for the electron (left) and for the muon (right) channel[5].