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Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

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Danila Tlisov for the CMS Collaboration

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SEARCH FOR A HEAVY NEUTRINO AND RIGHT-HANDED W OF THE LEFT-RIGHT SYMMETRIC MODEL WITH CMS DETECTOR

Danila Tlisov on behalf of the CMS Collaboration ^a

INR RAS, Prospekt 60-letiya Oktyabrya 7a, Moscow 117312, Russia

Abstract. This work describes the first search for signals from the production of right-handed W_R bosons and heavy neutrinos N_ℓ ($\ell = e, \mu$), that arise naturally in the left-right symmetric extension to the Standard Model, with the CMS Experiment at the LHC using the 7 TeV pp collision data collected in 2010 and 2011 corresponding to an integrated luminosity of 240 pb⁻¹. No excess over expectations from Standard Model processes is observed. For models with exact left-right symmetry (the same coupling in the left and right sectors) we exclude the region in the two-dimensional parameter space that extends to $(M_{W_R}, M_{N_\ell}) = (1700 \text{ GeV}, 600 \text{ GeV})$.

1 The left-right (LR) symmetric model

The left-right (LR) symmetric extension to the Standard Model model [1–3] is attractive because it naturally explains the parity violation seen in weak interactions as a result of spontaneously broken parity. The model necessarily incorporates additional $W_R^\pm$ and Z' gauge bosons and heavy right-handed neutrino states N_ℓ and thus can also explain the smallness of the ordinary neutrino masses through the see-saw mechanism [4].

The strength of gauge interactions of $W_R^\pm$ bosons is described by the coupling constants g_R . Strict LR symmetry leads to the relation $g_L = g_R$ at M_{W_R} , which will be assumed throughout this paper. To simplify our study, we further assume that the mixing angles ($W_R - W_L$, $Z' - Z$, and $N_\ell - N_{\ell'}$) are small. The existing experimental limit on the W_R mass is in the range 739 – 768 GeV and depends on the heavy neutrino mass (the smaller number corresponds to the case when all three N_ℓ have masses smaller than M_{W_R}) [5].

We consider the leading production reaction at the LHC: $pp \rightarrow W_R + X \rightarrow N_\ell + \ell + X$. The right-handed neutrino decays into a charged lepton $\ell^\pm$ and an off-shell W_R^* which subsequently decays into a pair of quarks which hadronize into jets (j). This produces the final state $W_R \rightarrow \ell_1 N_\ell \rightarrow \ell_1 \ell_2 W_R^* \rightarrow \ell_1 \ell_2 jj$ ($\ell = e, \mu$), where ℓ_1, ℓ_2 have the same flavor. We use PYTHIA [6], with default CTEQ6L1 parton distribution functions [7], for the signal event generation and calculation of cross sections. We also study relevant background samples generated using PYTHIA, ALPGEN [8], and MADGRAPH [9].

^ae-mail: Danila.Tlisov@cern.ch

2 The CMS detector and object reconstruction.

This measurement was performed using 240 pb^{-1} of pp collision data collected in 2010 and 2011 by the CMS detector at a center-of-mass energy of 7 TeV. The central feature of the CMS apparatus is a superconducting solenoid, of 6 m internal diameter, providing a field of 3.8 T. Within the field volume are the silicon pixel and strip tracker, the crystal electromagnetic calorimeter (ECAL) and the brass/scintillator hadronic calorimeter (HCAL). Muons are measured in gas-ionization detectors embedded in the steel return yoke. In addition to the barrel and endcap detectors, CMS has extensive forward calorimetry. A detailed description of the CMS detector can be found elsewhere [10].

3 Object reconstruction and events selection.

Information about electron reconstruction and identification in CMS during this running period can be found in [11]. The muon identification strategy is based on both the muon detectors and the inner tracker, as described in [12]. We reconstruct jets from calorimeter towers using the anti- k_t clustering algorithm [13] with a cone of radius $R = 0.5$ and impose a minimum transverse momentum requirement of $40 \text{ GeV}/c$ on the jet candidates. We select $W_R \rightarrow \ell N_\ell$ candidates using the two highest E_T/p_t same-flavor (e or μ) leptons, and the two highest p_t jets that satisfy the above criteria. As the $W_R \rightarrow \ell N_\ell$ decay tends to produce high momentum leptons, we require $E_T(p_t) > 60 \text{ GeV}/c$ for at least one of the lepton candidates and $E_T(p_t) > 30 \text{ GeV}/c$ for another. In the electron channel, we reject the event if no electron candidate is found in the ECAL barrel region ($|\eta| < 1.44$).

4 Backgrounds

The background for $W_R \rightarrow \ell N_\ell$ decay primarily consists of events from Standard Model processes with two real leptons, such as $t\bar{t}$ and Z +jets. It is also possible for jets to be misidentified as leptons, which allows QCD multijet processes to contribute background events.

We estimate the $t\bar{t}$ contribution using simulated events, normalizing it to the cross section measured by CMS [16]. We cross check this normalization using a sample of reconstructed $e\mu jj$ events in data and simulation.

Our estimate of the Z +jets background contribution is based on observation of $Z \rightarrow ee, \mu\mu$ decays in simulation and data. We normalize the Z +jets contribution to the inclusive NNLO calculation [14, 15], and then rescale the expected distribution to data (accounting for background contributions) using the reconstructed dilepton mass region near the Z peak.

We take the remaining electroweak and top background estimates directly

from simulation, as their small cross sections severely limit their impact on the background level.

We determine the QCD multijet background from data using an estimate of the lepton fake rate. For each channel, we examine a sample of dijet events in data in order to determine the lepton fake rate.

5 Results

We limit contributions from Standard Model backgrounds by imposing requirements on the dilepton mass ($M_{\ell\ell}$) and the mass of the reconstructed W_R candidate ($M_{\ell\ell jj} > 520$ GeV). Electroweak backgrounds, primarily from Z+jets, are suppressed by requiring $M_{\ell\ell} > 200$ GeV.

We show the 95% C.L mass regions excluded for both channels in Figure 1, where we obtain these plots by comparing the observed (expected) upper limit using a single-bin Bayesian approach [17] with a flat prior and the expected cross section for each mass point. These limits extend to $M_{W_R} = 1700$ GeV, and exclude a wide range of heavy neutrino masses for $M_{W_R} = 1500$ GeV. Good agreement is seen between the observed and expected limits. More this analysis details can be found in [18].

Figure 1: The 95% confidence level excluded (M_{W_R}, M_{N_ℓ}) region for the electron (left) and muon (right) channels.

6 Conclusions

We have presented a search for right-handed bosons (W_R) and heavy neutrinos (N_ℓ) of the Left-Right symmetric extension of the Standard Model. The contribution from background top and electroweak processes is determined from simulated event samples and the expected rate is normalized to data whenever

possible. The background from QCD multijet events is estimated from data. The uncertainty for the backgrounds is estimated using data-driven methods. We find that our data sample is in good agreement with expectations from Standard Model processes. We use a Bayesian approach to set a limit on the W_R and N_ℓ masses that includes treatment of the systematic uncertainties as nuisance parameters. For models with exact left-right symmetry (the same coupling in the right sector) we exclude the region in the two-dimensional parameter space (M_{W_R}, M_{N_ℓ}) that extends to $M_{W_R} = 1700$ GeV.

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