The Compact Muon Solenoid Experiment
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Searches for new massive resonances decaying to leptons at CMS

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Abstract

Searches for new bosonic resonances decaying to a charged lepton plus neutrino ($W' \rightarrow l\nu$) or to two charged leptons ($Z' \rightarrow l^+l^-$), using the 2012 dataset from pp collisions at 8 TeV collected by the CMS experiment and corresponding to about 20 fb^{-1} , are presented. In absence of a significant deviation from the standard model predictions, upper limits on the new resonance production cross section times branching fraction are estimated.

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SEARCHES FOR NEW MASSIVE RESONANCES DECAYING TO LEPTONS AT CMS

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Abstract. Searches for new bosonic resonances decaying to a charged lepton plus neutrino ($W' \rightarrow l\nu$) or to two charged leptons ($Z' \rightarrow l^+l^-$), using the 2012 dataset from pp collisions at 8 TeV collected by the CMS experiment and corresponding to about 20 fb^{-1} , are presented. In absence of a significant deviation from the standard model predictions, upper limits on the new resonance production cross section times branching fraction are estimated.

1 Introduction

Several theories beyond the standard model (SM) predict the existence of heavy bosons, for example grand unified theories (GUT), theories with large extra dimensions and split universal extra dimensions (UED). Especially if the decay products contain electrons or muons, one is provided with a clear signature to search for new physics. A search for new resonances which a dileptonic decay, generally named Z' , and a search for new resonances where the decay channel consists of an electron or muon and a neutrino, named W' in the following, was performed with the Compact Muon Solenoid (CMS) experiment [1] at the LHC using the dataset collected in 2012 from pp collisions at a center-of-mass energy of 8 TeV. The Z' analysis [2] is described in section 2 and the W' analysis [3] in section 3. Results are presented in section 4.

2 Search for Heavy Resonances in the $ee/\mu\mu$ Channel

The dataset analysed corresponds to an integrated luminosity of 19.6 fb^{-1} and 20.6 fb^{-1} respectively for the dielectron and the dimuon channels. The result is interpreted in the context of the sequential SM Z'_{SM} with SM like couplings and the Z'_ψ model coming from GUT.

Electron candidates are reconstructed from an energy deposit in the electromagnetic calorimeter with an associated track in the tracker. They have to pass ID cuts and isolation criteria are applied to reject the jet background. The dielectron sample is obtained by selecting events with two electron candidates with a transverse energy $E_T \geq 35 \text{ GeV}$, and with at least one of them in the barrel region. Since the detector performance differs between the barrel and endcap regions the analysis is done separately for events with one and two barrel electron(s).

Muon candidates are reconstructed using both the inner tracker and the muon stations, with hits in all subsystems. Isolation criteria are also applied.

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In order to reject cosmic muons, a small transverse impact parameter with respect to the primary vertex is required. The dimuon sample is obtained by selecting events with two opposite charge muons with $p_T \geq 45$ GeV, coming from a common vertex.

The largest contribution from SM processes to the invariant mass spectra is the Drell-Yan (DY) process which represents the irreducible background and is estimated from simulations. Smaller contributions come from $t\bar{t}$, tW , and diboson production which are also taken from simulations and validated with the invariant mass spectrum of events with $e\mu$ in the final state which, when corrected for the different acceptances, should yield twice as many events. The background from misidentified jets is more important for the electron channel and is estimated from data with a fake rate method.

The invariant mass spectra of the dielectron and dimuon channels are shown in Figure 1.

Figure 1: Invariant mass spectra of the dielectron (left) and the dimuon (right) channels.

3 Search for Heavy Resonances Decaying to e/μ plus Neutrino

The dataset analysed corresponds to an integrated luminosity of 20 fb^{-1} . The results are interpreted in the context of various models. The sequential SM predicts a W' boson that behaves like a heavy version of the W with the addition that the $t\bar{b}$ channel becomes available if the mass of the W' is large enough. Left-right symmetric models predict right-handed W' which do not interfere with the W and yield a Jacobian peak much like the one from the W . In the framework of split-UED with bulk fermions SM particles get Kaluza-Klein partners that couple to fermions. Furthermore, a four-fermion contact interaction (CI) model predicts a distortion of the transverse mass spectrum that could also be detected.

Electrons and muons are selected with similar criteria as in the Z' analysis but, due to trigger constraints, the E_T threshold for the electron is at 100 GeV. The escaping neutrino gives rise to missing transverse energy (E_T^{miss}) which is

measured with a particle flow algorithm that aims at characterising all particles in an event. The E_T^{miss} variable is derived as the opposite of the transverse momentum vectorial sum of all the detected particles. The transverse mass (M_T) is defined as $M_T = \sqrt{2p_T^l E_T^{miss}(1 - \cos \Delta\phi_{l,\nu})}$, where $\Delta\phi_{l,\nu}$ is the azimuthal angle between the lepton p_T and the E_T^{miss} which has to be larger than 0.8π .

The decay of the W boson in a lepton and a neutrino gives the largest SM contribution to the transverse mass spectrum and is irreducible, thus taken from simulations as are the contributions from other SM processes like $t\bar{t}$, single top, diboson, DY and multijet events. After the selection, the background from cosmic muons is negligible.

The transverse mass spectra for the electron and muon channels are shown in Figure 2.

Figure 2: Transverse mass spectra of the electron channel (left) and the muon channel (right). The bottom plots show the ratio between the data points and the SM expected backgrounds.

4 Results

For the Z' analysis fully shape based Bayesian limits are set on the ratio of cross section times branching ratio between a Z' resonance and the Z resonance and are shown in Figure 3 (left). In taking the ratio for the limit setting procedure, one can omit several systematic uncertainties, notably the uncertainty on the luminosity. 95% confidence level (CL) lower limits on the resonance mass are derived for the Z'_{SSM} (2.96 TeV) from the sequential SM and the superstring inspired Z'_ψ (2.60 TeV).

For the W' analysis upper limits with 95% CL on the production cross section times branching fraction are calculated with a Bayesian multiple bin counting method with uniform prior for the signal and are shown in Figure 3 (right). Lower limits on the resonance mass of a non-interfering W'_{SSM} and a W' from split-UED with different bulk mass parameters μ are derived to be 3.35 TeV, and 1.7 TeV ($\mu = 0.05$ TeV) and 3.7 TeV ($\mu = 10.0$ TeV), respectively. To set limits on models that interfere with the W , the difference $\Delta\sigma$ in the M_T spectrum between a W - W' signal sample and a W -only sample is considered. Opposite sign couplings between the W' and the W increase the lower limit for the W' mass to 3.6 TeV while same sign couplings decrease it to 3.1 TeV. The limit on the binding energy scale for the CI model is calculated with a Bayesian method with a uniform prior separately for the electron and the muon channel and gives $\Lambda > 13.0$ TeV and $\Lambda > 10.9$ TeV respectively.

Figure 3: Upper limits at 95% CL on the ratio of cross section times branching ratio between a Z' and the Z (left) and on the cross section times branching ratio of the W' (right).

Acknowledgements

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- [1] CMS Collaboration, JINST **3**, S08001 (2008).
- [2] CMS Collaboration, Public Analysis Summary, **EXO-12-061**.
- [3] CMS Collaboration, Public Analysis Summary, **EXO-12-060**.