



Search for new Resonances in Dielectron and Dimuon Mass Spectra at $\sqrt{s} = 8$ TeV with CMS

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Abstract

A search for new massive resonances decaying to a dielectron or a dimuon pair is presented. The search uses the full dataset corresponding to an integrated luminosity of about 20 fb^{-1} of pp collisions at a center-of-mass energy of 8 TeV, collected by the CMS experiment in 2012. In absence of a significant deviation from the standard model predictions, 95% confidence level limits are set on the ratio of cross section times branching ratio of a new resonance to the cross section times branching ratio of the Z boson. A sequential standard model Z'_{SSM} and a superstring-inspired Z'_ψ of mass lighter than 2960 GeV and 2600 GeV, respectively, can be excluded at 95% confidence level.

Keywords: LHC, CMS, Physics beyond the standard model, Heavy Resonances, Z' search

1. Introduction

Several scenarios beyond the standard model (SM) (e.g. grand unified theories (GUT)[1], models with extra spatial dimensions[2]) involve new neutral bosons, with possibly masses in the TeV range, that could be detected at the Large Hadron Collider (LHC) at CERN. If such heavy bosons exist they would show up as a narrow peak in the high mass tail of the invariant mass spectrum that is dominated by the Drell-Yan (DY) process in these search channels. A search for new resonances, generally named Z' , with a decay to dielectrons or dimuons was performed [3] with the Compact Muon Solenoid (CMS) experiment[4] at the LHC using the dataset from pp collisions at a center-of-mass energy of 8 TeV collected in 2012. A shape analysis of the dilepton invariant mass spectra is performed for the search for new physics and the results are interpreted in the context of two specific models. The CMS detector is presented in section 2 and the analysis is discussed in section 3.

2. The CMS Detector

The CMS detectors main feature is a superconducting solenoid magnet with an internal diameter of 6 m, which generates an axial field of 3.8 T. Housed inside the solenoid are, from the interaction point outward, the silicon pixel and strip trackers, the crystal electromagnetic calorimeter (ECAL), and the brass/scintillator hadronic calorimeter (HCAL). Gas-ionisation muon detectors are located outside the solenoid in between the layers of the steel return yoke. The detector consists of a barrel part which houses the solenoid with tracker and calorimeters, and two endcaps with forward calorimetry and muon detectors that close the detector.

3. Search for new Resonances in the Dielectron and Dimuon Channels

The dataset for the dielectron and dimuon channels corresponds to an integrated luminosity of 19.6 fb^{-1} and 20.6 fb^{-1} , respectively, which is the full dataset collected at $\sqrt{s} = 8$ TeV pp collisions. The result of a shape based analysis of the dilepton invariant mass spectra is interpreted in the context of the Z'_{SSM} with

SM like couplings of the sequential SM [5] and the Z'_ψ model coming from GUT [1].

3.1. Event Selection

Electron candidates are reconstructed from an energy deposit in the ECAL with an associated track in the tracker. The electron candidates need to pass ID cuts, and satisfy the isolation criteria for the ECAL/HCAL energy deposit and the track to reject jet induced background. In order to reject electrons from photon conversions not more than one missing hit in the inner tracker is allowed. Events with two electron candidates with a transverse energy $E_T \geq 35$ GeV form the dielectron sample if at least one of the electron candidates is in the barrel region of the detector. A double electron trigger with loose calorimeter and tracker ID criteria and an E_T threshold of 33 GeV is used as the main signal trigger. As the detector performs differently in the barrel and endcap regions, the sample is split in events with one and two barrel electron(s), and the analysis is done separately for both channels. The efficiency of the electron candidate selection is measured with a tag and probe technique at the Z peak for different pseudorapidity regions of the detector and amounts to 88% in the barrel and 84% in the endcaps.

Muon candidates are reconstructed from tracks in the inner tracker and the muon stations and must have hits in all tracking subsystems. The muon candidate tracks are reconstructed independently in the inner tracker and the muon system and are then matched to form a global muon track spanning the whole detector from the primary vertex outwards. In order to reject background coming from jets isolation criteria are applied for the tracks. Muons from cosmic radiation are suppressed by requiring the track to have a small transverse impact parameter with respect to the primary vertex. Events with two oppositely charged muons with a transverse momentum $p_T \geq 45$ GeV coming from a common vertex form the dimuon sample. The requirement that the three dimensional angle between the tracks of the two muons must be smaller than $\pi - 0.02$ further suppresses events from cosmic muons. The signal trigger is a single muon trigger with a p_T threshold of 40 GeV and a pseudorapidity range $|\eta| < 2.1$. One of the muons has to be matched to the trigger object, which leads to the restriction of one muon to pseudorapidities smaller $|\eta| < 2.1$, while the second muon can have pseudorapidities up to $|\eta| = 2.4$. The efficiency of the muon candidate selection is 94% as measured with a tag and probe technique at the Z peak.

3.2. Backgrounds

The background coming from Drell-Yan (DY) production represents the largest and the irreducible background from SM processes. Events with at least two same flavour leptons in the final state, like $t\bar{t}$, tW , and di-boson production, form the reducible background with real leptons. All these background shapes are taken from simulations. The simulation of the reducible background is validated with the invariant mass spectrum of events with $e\mu$ pairs in the final state, which should yield twice as many events as the dielectron or the dimuon spectrum, after being corrected for the different acceptances and efficiencies. Figure 1 shows the opposite sign $e\mu$ invariant mass spectrum. Background from multijet events is estimated from the same sign $e\mu$ invariant mass spectrum from the difference between data and the simulated backgrounds, and then used for the opposite sign $e\mu$ invariant mass spectrum.

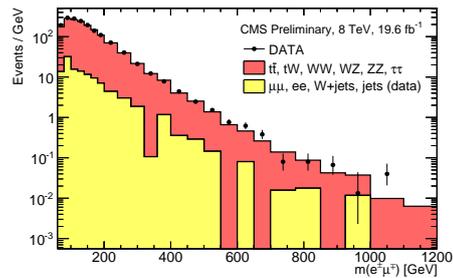


Figure 1: The observed opposite-sign $e^\pm\mu^\mp$ invariant mass spectrum used for the validation of the prompt lepton invariant mass spectrum.

The dielectron channel suffers more from background from misidentified jets than the dimuon channel. This background is estimated data driven by deriving a rate of jets from a jet enriched sample that pass the selection, which is then applied to a sample with two electron candidates that fail the selection. Jet background contributions with one misidentified electron candidate are added from simulated samples.

The dimuon event selection criteria suppress events with cosmic ray muons sufficiently to be negligible.

3.3. Results

The invariant mass spectra of the dielectron and dimuon channels are shown in Figure 2. The mass range around the Z peak from 60 GeV to 120 GeV is used for the efficiency measurements, energy scale calibration and the normalisation of the simulations. No new physics is expected in a range from 120 GeV to an invariant mass of 200 GeV where the high mass behaviour of the analysis is verified. Above invariant

masses of 200 GeV lies the search region. The events

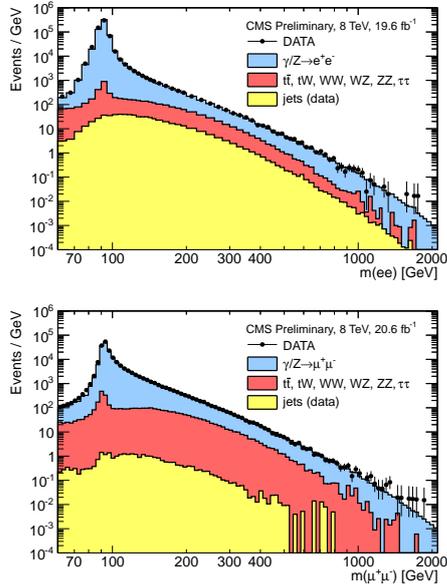


Figure 2: Invariant mass spectra of the dielectron channel (top) and the dimuon channel (bottom).

with the highest reconstructed invariant masses have $m_{ee} = 1776$ GeV and $m_{\mu\mu} = 1824$ GeV, respectively, for the dielectron and the dimuon channel.

As no significant excess is found in the invariant mass spectra, limits are set on the ratio of cross section times branching ratio between a new heavy resonance and the Z resonance. Taking the ratio for the limit setting procedure cancels or suppresses several systematic uncertainties, notably the uncertainty on the luminosity which was 2.6% for the 2012 data taking period. Uncertainties on the acceptance times efficiency (3–6%) and the mass dependent uncertainty on the background fit (2–20%) represent the main systematic uncertainties of the analysis. The combined limit for the dielectron channels and the dimuon channel is shown in Figure 3. 95% confidence level (CL) lower limits on the resonance mass are derived for the Z'_{SSM} from the sequential SM, and the superstring inspired Z'_ψ . For the former masses below 2.96 TeV, and for the later masses below 2.60 TeV can be excluded.

Acknowledgements

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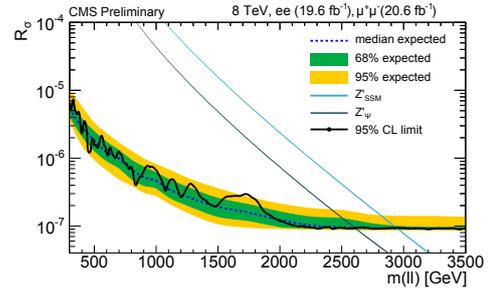


Figure 3: Combined upper limits at 95% CL on the ratio of cross section times branching ratio between a new heavy resonance and the Z resonance. Shown also are theory curves for a Z'_{SSM} model and a Z'_ψ model.

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