Search for new heavy resonances decaying into dielectrons or dimuons at CMS

G. Fasanella for the CMS Collaboration

Interuniversity Institute for High Energies (IIHE) - Université Libre de Bruxelles (ULB), Boulevard du Triomphe, B-1050 Brussels, Belgium

Email contact: giuseppe.fasanella@ulb.ac.be

Abstract

Resonances in the dielectron and dimuon decay channels arise in many well established theories beyond the standard model, like grand unified theories (GUT) or models proposing extra spatial dimension(s). This search uses up to 2.8 fb^{-1} of proton-proton (pp) collision data with $\sqrt{s} = 13$ TeV collected by the CMS experiment at the CERN LHC. In absence of a significant deviation from the standard model predictions, 95% confidence level limits are calculated.

1 Search for New Heavy Neutral Bosons @ LHC RUN2

The standard model (SM) of particle physics is a tremendously successful theory with a wealth of experimental evidence supporting it. Still there are some notable omissions such as the lack of a dark matter candidate and the complete absence of gravity. Therefore many theories of physics beyond the standard model (e.g. Grand Unification Theories [1], extra spatial dimensions [2]) have been proposed to address these omissions. A common signature of new physics beyond the standard model is a new massive neutral spin-1 particle which can decay to lepton pairs, hereafter referred to as a $Z^{'}$. If such heavy bosons exist they would manifest themselves as a narrow peak in the invariant mass spectrum that is dominated by the Drell-Yan (DY) process ($q\bar{q} \rightarrow l\bar{l}$) in these search channels.

This poster presents the result of a search for such a $Z^{'}$ in the electron-positron and muon-antimuon final states. This search uses up to 2.8 fb^{-1} of proton-proton (pp) collision data with $\sqrt{s} = 13$ TeV collected by the CMS experiment at the CERN LHC [3]. In general, the method is very similar to the previous CMS analysis performed at $\sqrt{s} = 8$ TeV [4].

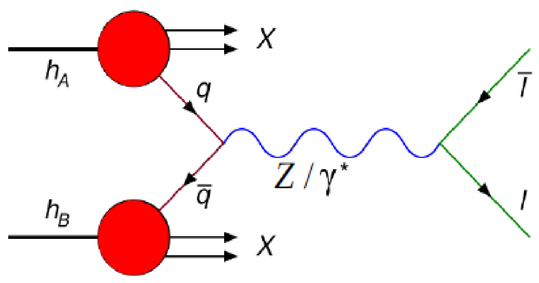


Figure 1: Drell-Yan process diagram

Event Selection

Dielectron channel:

- Events with two high energy electrons are selected, each of them with $E_T > 35$ GeV
- Identification (e.g. shower shape, HCAL/ECAL energy deposits) and isolation (e.g. energy deposit in the ECAL around the electron candidate) criteria are then applied
- The set of requirements for each electron constitutes the High Energy Electron Pairs (**HEEP**) selection

Dimuon channel:

- Events with two high energy muons are selected, each of them with $E_T > 50$ GeV
- The candidates must also satisfy identification (e.g. transverse impact parameter w.r.t the primary vertex, hits in pixel-silicon strips)
- To suppress backgrounds from jets misidentified as isolated muons, isolation criteria are also applied

Backgrounds

The **Drell–Yan process** is the most prominent (irreducible) background to the signal. However other processes (reducible backgrounds) have non negligible contribution: **multijet events from QCD processes** (where jets are misidentified as prompt leptons) and **top quark pair production events**, where the top quarks decay leptonically. Data-driven methods have been designed to estimate the contamination of each of these processes.

Dilepton invariant mass spectra

The observed mass spectra together with the predicted SM backgrounds are shown in figures 2-4 for both electrons and muons. The observed mass spectrum agrees well with that of the predicted SM background. When calculating the limits, the electron channel is split into two channels, barrel-barrel and barrel-endcap due to differing backgrounds and resolutions.

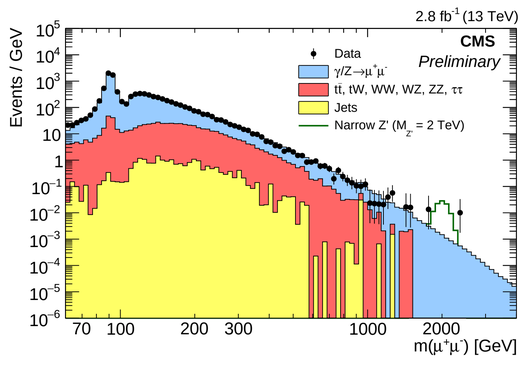


Figure 2: The invariant mass spectrum of $\mu^{\pm}\mu^{-}$ events.

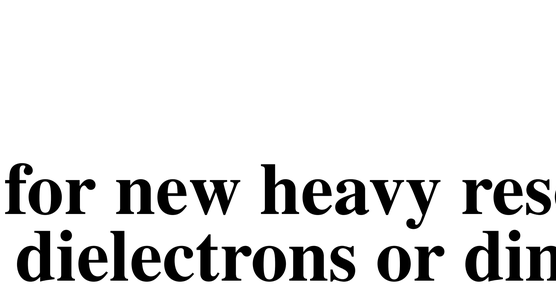
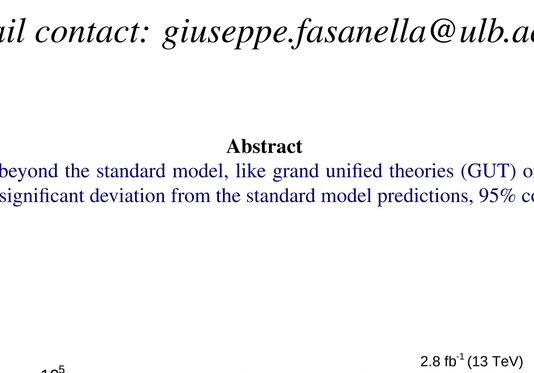


Figure 3: The invariant mass spectrum of $e^{+}e^{-}$ events.

Figure 3 shows the observed mass spectra for di-electron events splitted into two channels, barrel-barrel and barrel-endcap.



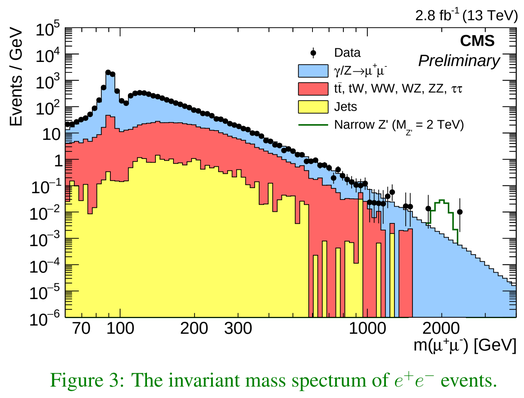


Figure 4: Invariant mass spectrum of $e^{+}e^{-}$ events splitted in the barrel-barrel (top) and barrel-endcap (bottom) channels.

Statistical analysis and results

The observed invariant mass spectra agree with expectations based on standard model processes. **Since no new physics is observed, limits are set** on the possible contributions from narrow heavy resonances. The variable under study is the ratio of the production cross section times branching ratio to two leptons for new heavy boson of spin 1 and the Z boson. This cancels several sources of systematic uncertainty, including the one related to the integrated luminosity.

Limits are set at the 95% confidence level using a Bayesian unbinned likelihood, with the likelihood integrated using the Metropolis-Hastings algorithm . The limit setting procedure is identical to that used in the 8 TeV analysis.

The signal pdf is modelled as the convolution of a nonrelativistic Breit-Wigner with a Gaussian.

The limits are shown in figures 5-7 for Breit-Wigner widths of 0%, 0.6% and 3% for the electron and muon channels, both separately and combined. The latter two widths correspond to the widths of the $Z^{'}_{\psi}$ and $Z^{'}_{SSM}$ respectively.

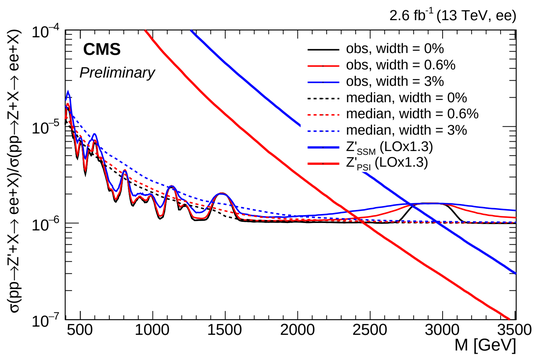


Figure 5: The observed limits obtained at a 95% confidence level for $Z^{'}$s of various widths for the electron channel.

Figure 6: The observed limits obtained at a 95% confidence level for $Z^{'}$s of various widths for muon channel.

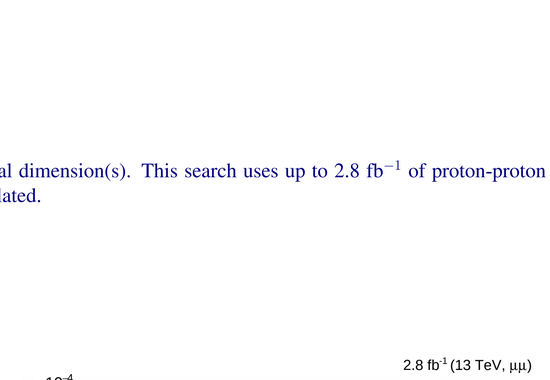


Figure 7: The observed limits obtained at a 95% confidence level for $Z^{'}$s of various widths for the electron and the muon channels combined.

Figure 8 shows the observed limits for an input width of 0.6% together with the 68% and 95% expected bands.

The limits exclude a $Z^{'}_{SSM}$ with a mass less than 3.15 TeV and $Z^{'}\psi$ with a mass less than 2.60 TeV. This surpasses the current best published limits of 2.90 TeV and 2.57 TeV respectively.

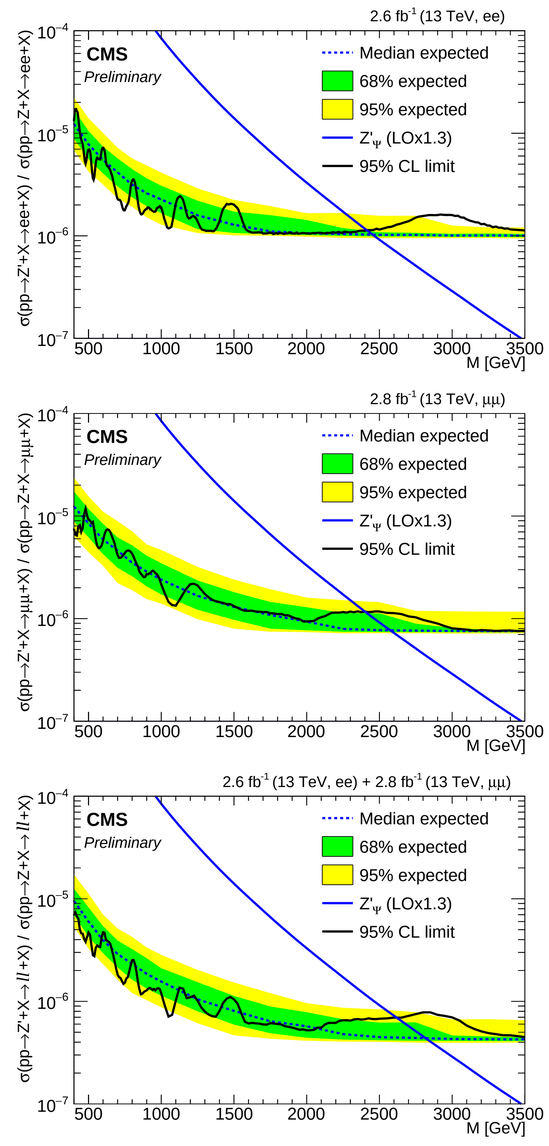


Figure 8: The observed limits obtained at the 95% confidence level for a narrow $Z^{'}$ for the electron channel (top), muon channel (middle) and the combined channel(bottom).

References:

[1] A. Leike, *The Phenomenology of Extra Neutral Gauge Bosons*, Phys. Rept. 317 (1999) 143, [hep-ph/9805494]

[2] L. Randall, R. Sundrum, *A Large Mass Hierarchy from a Small Extra Dimension*, Phys. Rev. Lett. 83 (1999) 3370, [hep-ph/9905221]

[3] The CMS Collaboration, *Search for physics beyond the standard model in dilepton mass spectra in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, CMS PAS EXO-15-005, approved for CERN Jamboree 2015

[4] The CMS Collaboration, *Search for physics beyond the standard model in dilepton mass spectra in proton-proton collisions at $\sqrt{s}$ = 8 TeV*, CMS PAS EXO-12-061, [hep-ph/1412.6302], paper submitted to JHEP