Search for narrow resonances in dilepton mass spectra in p-p collisions at √s = 13 TeV and combination with 8 TeV data at CMS

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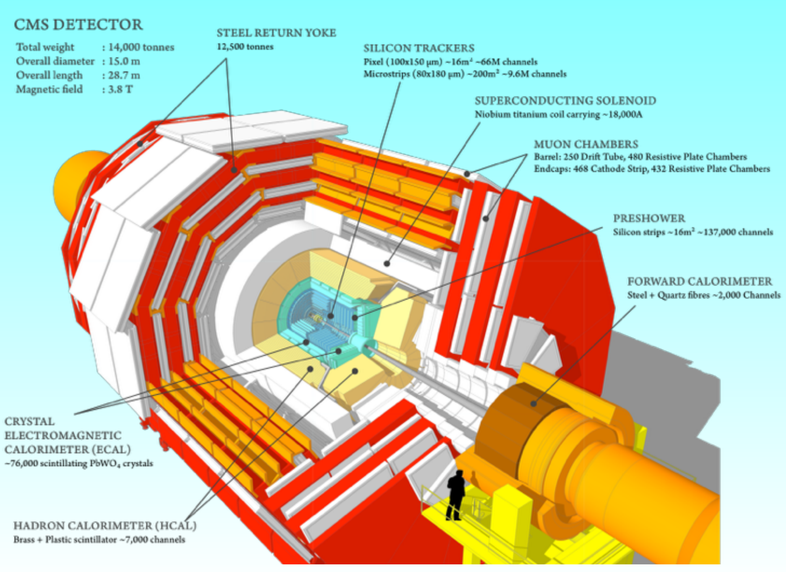
Abstract

A search for new narrow resonances in the dielectron and dimuon decay channels has been performed using data collected by the CMS experiment in 2016 from proton - proton collisions at a center of mass energy of √s = 13 TeV (corresponding to an integrated luminosity of 13 fb^{-1}) and combining 2015 13 TeV data (corresponding to a luminosity of 2.9 fb^{-1}) with a previous analysed set of data obtained at √s = 8 TeV (corresponding to a luminosity of 20 fb^{-1}). In the absence of a significant deviation from the standard model predictions, 95% confidence level limits are set on the ratio of the production cross section times branching fraction for high-mass resonances to that for the Z boson. For several models, lower limits on the resonance mass are derived.

The dilepton (ee or μμ) final state signature is a key search channel for various new phenomena expected in theories that go beyond Standard Model (SM). One of the most clean signature would be the observation of a narrow resonance in the invariant mass spectrum of lepton pairs, predicted by many models at the TeV scale. Examples include models described with extended gauge groups, featuring additional *U(1)* symmetries such as the Sequential Standard Model (SSM) [1] that includes a Z'_{SSM} boson with SM-like coupling, the Grand Unification Theories (GUT) inspired models, based on E_6 gauge group, with Z'_{ψ} boson and the Kaluza - Klein graviton (G_{KK}) of the Randall - Sundrum (RS) model of the Extra Dimensions [2].

CMS Detector



Event Selection

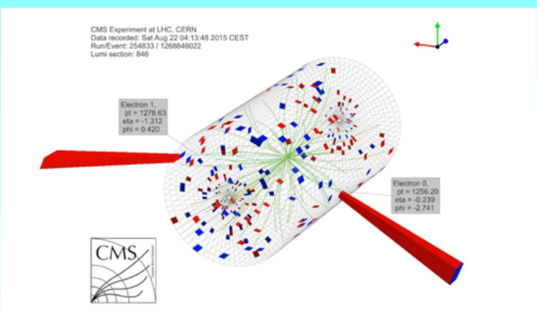
Electron pair selection:

- At HLT stage, $E_T > 33$
- For the offline reconstruction, $E_T > 35$ GeV and $|\eta_C| < 1.4442$ or $1.566 < |\eta_C| < 2.5$
- HEEP (High Energy Electron Pair) selection
- Isolation requirements
- At least one electron candidates must be in the Barrel region

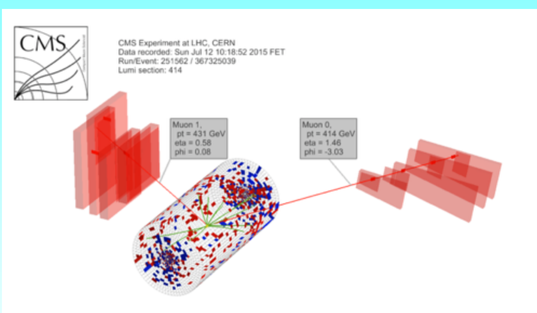
Muon pair selection:

- At HLT, $p_T > 50$ GeV/c and $|\eta| < 2.4$
- For the offline reconstruction, $p_T > 53$ GeV/c and $|\eta| < 2.4$
- High p_T Muon ID
- Isolation requirements
- Opposite charge
- Common vertex fit with $\chi 2$ / dof < 20
- Three - dimensional angle less than π - 0.02

Event display



Event display for a candidate electron - positron pair with an invariant mass of 2.9 TeV [3].



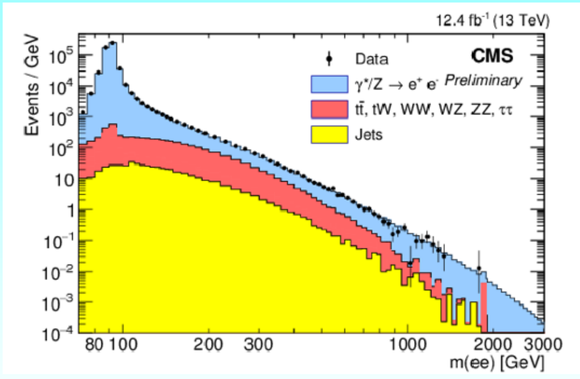
Event display for a dimuon candidate with an invariant mass of 920 GeV [4].

Backgrounds

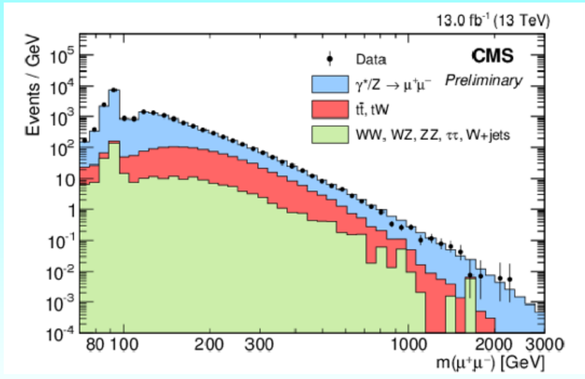
The dominant and irreducible SM background to a Z′ decaying to lepton pair (ee, μμ), arises from Drell-Yan ($Z/\gamma^* \longrightarrow e^+e^-/\mu^+\mu^-$) process. Additional sources of background are Drell-Yan $\tau^+\tau^-$, diboson (WW, ZZ, WZ), top - antitop quark (ttbar) and single top quark (tW) in which the two prompt leptons are from different particles. Multijet, W+jets and γ+jets processes contribute, mainly in the electron channel, due to non-prompt and misidentified leptons.

Dilepton invariant mass spectra

The observed invariant mass spectra, together with the predicted SM backgrounds are shown for both dielectron and dimuon events. No evidence for a signal deviation from the SM expectations is observed.



The invariant mass spectrum for the ee channel [5].



The invariant mass spectrum for the $\mu^+\mu^-$ channel [5].

Analysis strategy and results

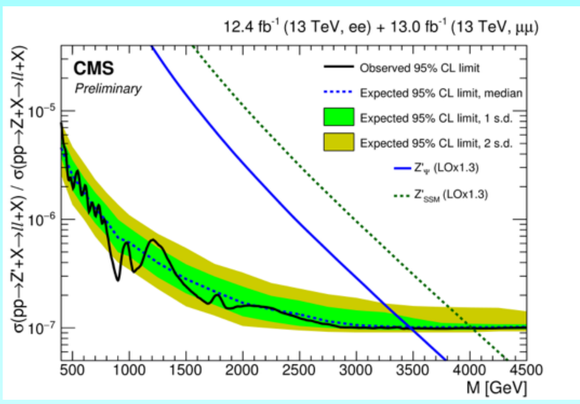
Using a Bayesian approach with an unbinned extended likelihood function, limits are derived for the production of a narrow spin-1 or spin-2 heavy resonance. The likelihood function is based on probability density functions that describes the signal and the background contributions to the invariant mass spectra:

- Signal —> parametrized by the convolution on a Breit-Wigner and a Gaussian function
- Background —> parametrization obtained by fitting the background distribution

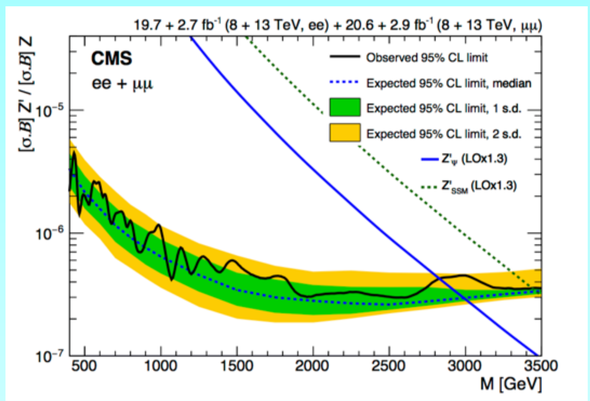
The limits are set on the parameter R_σ which is the ratio of the cross section for dilepton production through a Z′ boson to the cross section for dilepton production through a Z boson:

$$R_\sigma = \frac{\sigma(pp \to Z' + X \to \mu^+\mu^- + X)}{\sigma(pp \to Z + X \to \mu^+\mu^- + X)}$$

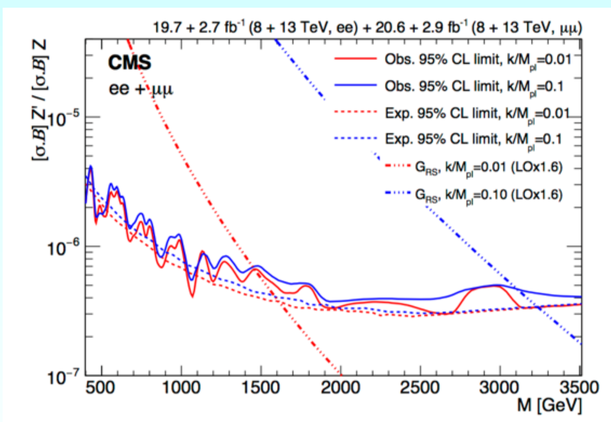
The Poisson mean of the signal yield is $\mu_s = R_\sigma \mu_Z R_\varepsilon$, where R_ε is the ratio of the selection efficiency times detector acceptance for the Z′ decay relative to that for the Z boson decay and μ_Z is the Poisson mean of the number of Z —> ℓℓ events.



The 95% CL upper limits for a spin-1 resonance extrapolated using data collected in 2016 at √s = 13 TeV combining ee and μμ channels [5].



The 95% CL upper limits for a spin-1 resonance extrapolated combining Run I dataset at 8 TeV with data collected during 2015 at 13 TeV [6].



The 95% CL upper limits for a spin-2 RS graviton combining dielectron and dimuon channels and combining 8 and 13 TeV data [6].

Conclusion

For the Z'_{SSM} particle and for the superstring inspired Z'_{ψ} particle, 95% confidence level lower mass limits are found to be 4.0 TeV and 3.5 TeV. The corresponding limits for Kaluza-Klein gravitons arising in the Randall - Sundrum model of extra dimensions with coupling parameters 0.01 and 0.1 are 1.46 and 3.11 TeV respectively.

References

[1]. "The Phenomenology of Extra Neutral Gauge Bosons", A. Leike, Phys. Rept. 317 (1999) 143, [hep-ph/9805494]
[2]. "A Large Mass Hierarchy from a Small Extra Dimension", L. Randall, R. Sundrum, Phys. Rev. Lett. 83 (1999) 3370, [hep-ph/9905221]
[3]. "Event Display of a Candidate Electron-Positron Pair with an Invariant Mass of 2.9 TeV", CMS-DP-2015-039 ; CERN-CMS-DP-2015-039
[4]. "First 48 pb^{-1} of data at 13 TeV: a few selected plots from Exotica non-hadronic analyses", CMS-DP-2015-037 ; CERN-CMS-DP-2015-037
[5]. "Search for a high-mass resonance decaying into a dilepton final state in 13 fb^{-1} of pp collisions at s√= s 13 TeV", CMS PAS EXO-16-031
[6]. "Search for narrow resonances in dilepton mass spectra in proton-proton collisions at s√= s 13 TeV and combination with 8 TeV data", arXiv:1609.05391 [hep-ex]