Search for Resonant and Nonresonant New Phenomena in High-mass Dilepton Final States at CMS

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1. Introduction

The presence of new resonant and nonresonant phenomena in high-mass dilepton final state is predicted in various new physics beyond the standard model

Resonant signatures

- Spin-1: Sequential standard model with SM-like couplings (Z'_{SSM}) and Grand unified theories based on the E_6 gauge group (Z'_ψ)
- Spin-2: Kaluza-Klein graviton excitation (G_{KK}) arising in the Randall-Sundrum model
- Dark matter particle interacting with SM fermions through a spin-1 mediator

Nonresonant signatures

- Continuum of spin-2 graviton excitations in the ADD model of large extra dimensions
- Four-fermion contact interaction from fermion substructure

Lepton flavor universality violation at TeV scale

- Looking for deviation from unity of the dimuon to dielectron ratio $R_{\mu^+\mu^-/e^+e^-}$

The search is based on 13 TeV pp collision data collected by the CMS experiment in 2016-2018, corresponding to an integrated luminosity of 140 fb^{-1}

2. Analysis Strategy

Resonant signatures

- Shape analysis within a narrow mass window centered at the resonance pole mass
- Results are interpreted using the ratio of the signal cross section to that of Z boson cross section R_σ → mass independent uncertainties cancel out

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

Nonresonant signatures

- Separating positive and negative cosθ* regions where cosθ* is the scattering angle in Collins-Soper frame → sensitive to interference effect
- Counting experiments in multiple exclusive mass and cosθ* bins

Lepton flavor ratio ($R_{\mu^+\mu^-/e^+e^-}$)

- Bin-by-bin migration due to detector effects in each channel is corrected to particle level by unfolding
- Differences in acceptance and efficiency between the channels are corrected by normalizing $R_{\mu^+\mu^-/e^+e^-}$ to unity in the mass region 200-400 GeV
- Remaining mass dependency is corrected by dividing $R_{\mu^+\mu^-/e^+e^-}$ measured in Drell-Yan simulation

3. Event Selection

Dielectron channel

- Standard double electron trigger with transverse energy (E_T) above 33 GeV

Requirements on each electron:

- E_T > 35 GeV and |η| < 2.5 except ECAL gap
- High energy electron identification and isolation

Requirements on each electron pair:

- No charge requirement
- At least one electron in ECAL Barrel

Dimuon channel

- Standard single muon trigger with p_T above 50 GeV

Requirements on each muon:

- p_T > 53 GeV and |η| < 2.4
- High-p_T muon identification and isolation

Requirements on each muon pair:

- Opposite charge
- 3D angle < π-0.02 for vetoing cosmic muons
- Common vertex fit χ^2 / ndof < 20

3. Standard Model Background & Invariant Mass Spectra

Dominant background: Drell-Yan process ($Z/\gamma^* \to e^+e^-$ or $\mu^+\mu^-$)

- Estimated from Monte-Carlo simulation
- Around 90% of the total background at 1 TeV
- Cross section at NLO is corrected to NNLO, including contribution from photon-induced process

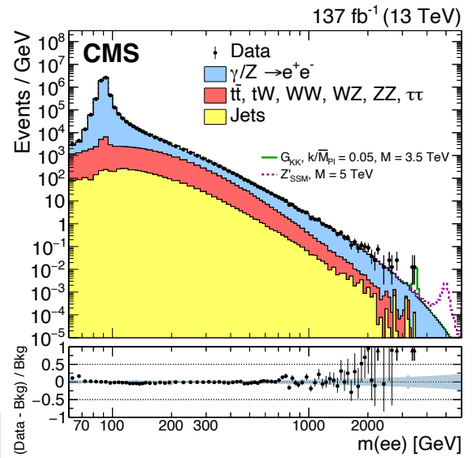
Secondary backgrounds: estimated from Monte-Carlo simulation

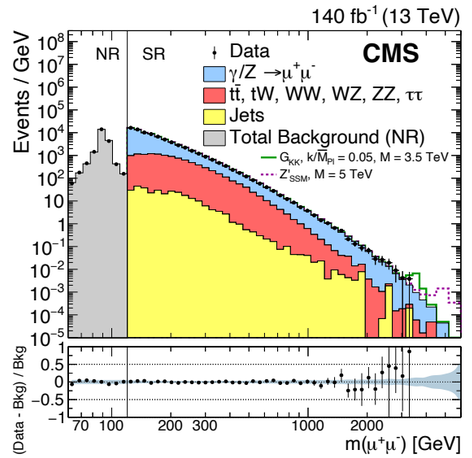
- Prompt: Top quark-antiquark (tt), Single top quark (tW), Diboson (WW, WZ, ZZ)
- Non-prompt: Drell-Yan tau-tau process ($Z/\gamma^* \to \tau^+\tau^-$)
- Validated in eμ final states → good data to MC agreement

Multi-jet background: estimated from Data

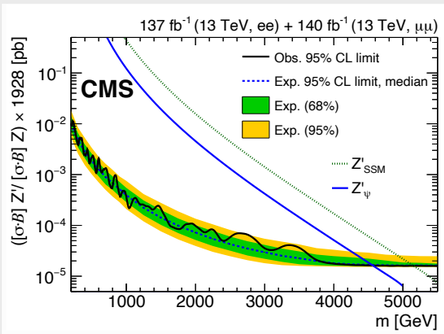
- Jets and non-prompt muons misidentified as a prompt muon
- Jets and photons misidentified as electron
- Estimated using multijet-enriched data control samples

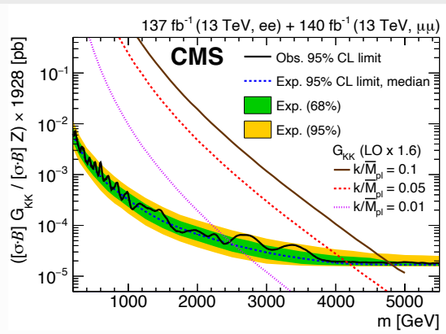
No significant deviation is observed from the SM prediction





4. Results

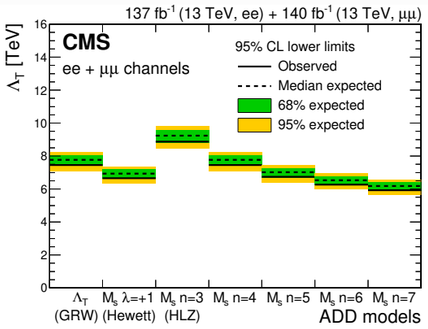


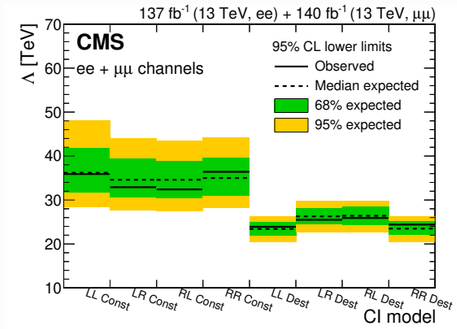


Upper limits on the production cross section times branching fraction to dileptons for spin-1 (left) and spin-2 (right) resonances, k/M_{Pl} is coupling parameter to SM particles

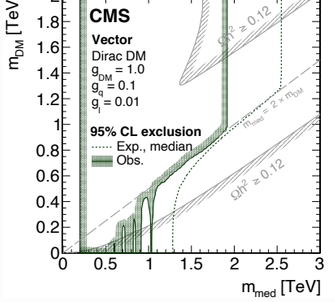
Lower limits on masses of spin-1 and spin-2 resonances [TeV]

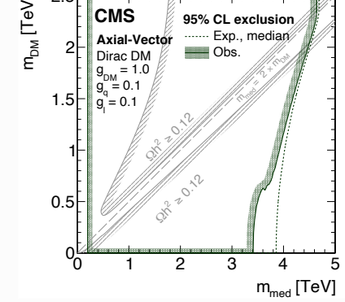
Z'_{SSM}	Z'_ψ	G_{KK} k/M_{Pl} = 0.01	G_{KK} k/M_{Pl} = 0.05	G_{KK} k/M_{Pl} = 0.1
5.15	4.56	2.47	4.16	4.78



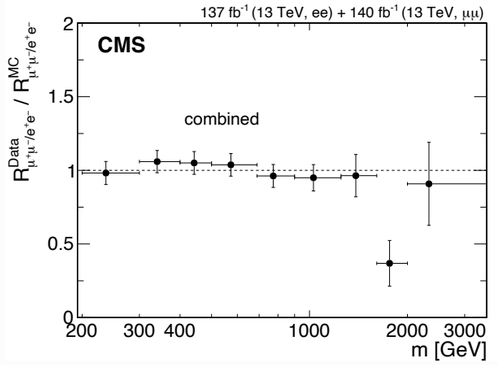


Lower limits on UV cutoff scale Λ_T in ADD model (left) and CI scale Λ (right)





Exclusion limits on the masses of the dark matter particle and of the mediator boson, assuming vector (left) or axial-vector (right) couplings



Ratio of differential dilepton production cross section in the dimuon and dielectron channels

- Good agreement with the SM expectation of unity is observed up to 1.5 TeV
- Deviation at higher masses originate from an excess of dielectron events, no experimental sources were identified

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