Searches for new heavy resonances in final states with leptons, photons, and jets at CMS

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Introduction

• Many models of beyond the standard model require new particles that couple to quarks and/or gluons and decay to photons, leptons and jets
  • Such as leptophobic Z’, Extra dimensions, Compositeness and Quantum Black Hole (QBH).
• Photons, leptons and jets in the final states are “classic signatures” to search for New physics

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• Look for bump in dijet mass spectrum
  • Separate searches by qq, qg, gg final state
• Select event with $|\Delta\eta| < 1.3$ and $|\eta| < 2.5$
• Close jets with $\Delta R < 1.1$ are combined into “wide jets” for the dijet mass

• **High mass**:
  • Become fully efficient after 1246 GeV
  • Use Particle Flow AK4 Jets
• **Low mass**:
  • Become fully efficient after 489 GeV
  • Use Calorimeter AK4 Jets
• No excess observed

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**Search for high/low mass dijet resonances**

CMS-EXO-16-056

2016 data (36 fb$^{-1}$)
We chose the simplified model recommended by the LHC DM working group to search for a DM mediator (arXiv:1603.04156).
Boosted dijet resonances

CMS-EXO-17-001 (JHEP 01 (2018) 097)

• Boosted dijet + associated ISR jet/photon
• Soft Drop (SD) is a technique to remove soft and wide angle radiation from parton shower etc. arXiv,1503.01088
• No excess observed
• Limits are set on the parameter space of a leptophobic axial-vector Z' benchmark model

CMS-EXO-17-001 (JHEP 01 (2018) 097)

2016 data (35.9 fb⁻¹)

Set limits on the Z boson production cross section, compare to Z' with coupling either 0.08 and 0.17.

We extend the previous limits below 100 GeV.
Dijet angular distributions
CMS-EXO-16-046 (arXiv:1803.08030)

- Looking for rise at low $\chi$, high $m_{jj}$

$$\chi = e^{2|\chi_{12}|} \sim \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

- New Physics will change the $\chi_{dijet}$ distribution at low $\chi_{dijet}$ at high $m_{jj}$

- $\chi_{dijet}$ is relatively flat for Leading QCD process
Di-bjet resonances search at 8 TeV

CMS-EXO-16-057 (arXiv: 1802.06149)

• Following the usual dijet searches, high mass resonance search with two b-tagged jets.
• Two signal regions due to the trigger requirement:
  Signal Reign 1: \( m_{jj} = [296 - 1058 \text{ GeV}] \)
  Signal Reign 2: \( m_{jj} = [526 - 1607 \text{ GeV}] \)
• No excess observed
• Limits are set on bottom quarks for spin 0, 1, and 2 resonances in the mass range of 325–1200 GeV.

The 95% CL upper limits on the universal coupling \( g'_q \) between the leptophobic \( Z' \) and quarks.
• Limits from other experiments and earlier CMS analyses are also shown.
Search for high-mass resonance in dilepton final state


- Look for bump in dilepton mass spectrum
- One of the most clean signatures
- Events with two same-flavor leptons (e/μ) are selected
- No significant excess observed

\[ M_{\mu\mu} \text{ (2016 data)} \]

\[ M_{ee} \text{ (2017 data)} \]

2016 data (36.3 fb\(^{-1}\)) + 2017 data (41.4 fb\(^{-1}\))

Obs. (Exp.) exclusion mass

\[ Z_{SSM} \]  
\[ Z_{\psi} \]  

\(< 4.7 \text{ (4.7) TeV}\)  
\(< 4.1 \text{ (4.1) TeV}\)
Search for the resonances in $\gamma + \text{jet}$ final state

EXO-17-002 (PLB 781 (2018) 390)

• If quark substructure exists, quarks may appear in excited states ($b^*$ or $q^*$).
• $P_T^{\gamma} > 200$ GeV and $P_T^{\text{jet}} > 170$ GeV

2016 data (35.9 fb$^{-1}$)
Conclusions

• Searching for heavy resonances is one of the most direct ways to find new physics at TeV scale.

• Many high mass di-jet, di-lepton and photonic resonance searches are performed.

• Limits are interpreted to constrain parameters of models predicting a narrow di-jet, di-lepton and photonic resonance.

• No signals of the new physics BSM has been found in data.

• CMS has begun exploring the full 13 TeV dataset. New exciting results are in the pipeline.