Search for a Narrow Resonance Produced in 13 TeV pp Collisions Decaying to Electron Pair or Muon Pair Final States

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Outline

• Physics motivations

• The CMS detector

• Z’ search in a Nutshell

• Results: exclusion upper limits at 13 TeV

• Summary
• The Standard Model (SM) is a successful theory supported by many experimental evidences, e.g. Higgs boson discovery, etc.

• SM has some omissions: hierarchy problem, absence of gravity, lack of dark matter . . .

• Many theories beyond the SM address these omissions
  • Predict new massive particles, heavy Z’ gauge bosons (motivation to search for dilepton resonances)

[Graph showing ratios of LHC parton luminosities: 13 TeV / 8 TeV]

http://www.hep.ph.ic.ac.uk/~wstirlin/plots/plots.html

$M_{Z'} = 3$ TeV
The CMS Detector

Total weight: 14000 t
Overall diameter: 15 m
Overall length: 21 m

ECAL: 76k scintillating PbWO_4 crystals
HCAL: Scintillator/brass Interleaved ~7k ch

3.8T Solenoid

MUON ENDCAPS
473 Cathode Strip Chambers (CSC)
432 Resistive Plate Chambers (RPC)

IRON YOKE
Preshower
Si Strips ~16 m^2 ~137k ch

Foward Cal
Steel + quartz Fibers ~k ch

Pixel Tracker
ECAL
HCAL
Muons
Solenoid coil

Pixels & Tracker
- Pixels (100x150 μm^2)
  ~ 1 m^2 ~66M ch
- Si Strips (80-180 μm)
  ~200 m^2 ~9.6M ch

MUON BARREL
250 Drift Tubes (DT) and
480 Resistive Plate Chambers (RPC)
Z’ Search in a Nutshell

• **Signal:** clean signature of two same flavour high-\( p_T \) leptons
  • Triggers used: HLT_Mu50 and HLT_DoubleEle33
  • Well isolated leptons from same primary vertex making \( \mu\mu \) or \( ee \) pair
  • **Muons:** \( p_T > 53 \) GeV, \(|\eta| < 2.4\)
  • **Electrons:** \( E_T > 35 \) GeV, \(|\eta| < 1.4442 \) or \( 1.566 < |\eta| < 2.5 \)
  • **Backgrounds:** irreducible \( Z/\gamma^* \), reducible \( tt\bar{t} \), \( tW \) and diboson, jet backgrounds, cosmic rays
• **Strategy:** search for a localised excess in \( m_{\ell\ell} \) spectrum, up to 5 TeV
• **Three width scenarios:** 0%, 0.6% (\( Z'_{\psi} \)) and 3% (\( Z'_{SSM} \))

Key Points
• Precise measurement of lepton energy, momentum scale and mass resolution
  • Huge dependence on detector alignment for high \( p_T \) leptons
  • Good understanding of the acceptance x efficiency of high \( p_T \) leptons
• Rely on simulations for evaluating the background shape, the mass resolution at high masses, and selection efficiencies
Dilepton Invariant Mass

Highest mass events observed in data
- Muon - 2.4 TeV
- Electron - 2.9 TeV

CMS PAS EXO-15-005
Dimuon Event @ 13 TeV
Already surpassed the current best published limits at 8 TeV data (20.6 fb⁻¹)

- Exclusion for $Z'_\text{SMM}$ up to 2.9 TeV and $Z'_\psi$ up to 2.57 TeV
Summary

• Search for a new massive gauge boson (Z’) decaying to ee or µµ final state has been performed, and results are presented

• Analysis performed using 2.6 fb\(^{-1}\) (Z’ \rightarrow ee) and 2.8 fb\(^{-1}\) (Z’ \rightarrow µµ) @ 13 TeV

• No significant excess over the standard model backgrounds prediction has been observed

• Limits have been derived for Z’\(_{\text{SSM}}\) and Z’\(_{\psi}\) models
  • Mass range less than 3.15(2.60) TeV has been excluded for Z’\(_{\text{SSM}}\)(Z’\(_{\psi}\)) models
Acknowledgments

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- CMS collaboration, in particular, our Exotica/Zprime colleagues
- All SPC 2016 staffs for organizing this event
Backup
Transverse Slice Through CMS

- 85% - 90% efficiency for collecting LHC delivered data
- High efficiency and resolution in object (e, μ, tau etc.) reconstruction
- The CMS detector provides good tracking and particle ID all around the interaction point ($0 < \phi < 2\pi$, $|\eta| < 3$)
Z' → ee Event Selection

- High energy electron pairs (HEEP) selection is used
- Cut-based selection designed to be highly efficient at high $E_T$
- Events categories: Barrel-Barrel (BB) or Barrel-Endcap (BE)
- The highest mass pair $M_{ee}$ is selected

<table>
<thead>
<tr>
<th>Variable</th>
<th>Barrel</th>
<th>Endcap</th>
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<tbody>
<tr>
<td>$E_T$ range</td>
<td>$&gt; 35$ GeV</td>
<td>$&gt; 35$ GeV</td>
</tr>
<tr>
<td>$</td>
<td>\eta_{e_i}</td>
<td>&lt; 1.4442$</td>
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<tr>
<td>isEcalDriven</td>
<td>=1</td>
<td>=1</td>
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<tr>
<td>$</td>
<td>\Delta\eta_{in}^{seed}</td>
<td>$</td>
</tr>
<tr>
<td>$</td>
<td>\Delta\phi_{in}</td>
<td>$</td>
</tr>
<tr>
<td>$H/E$</td>
<td>$&lt; 1/E + 0.05$</td>
<td>$&lt; 5/E + 0.05$</td>
</tr>
<tr>
<td>$\sigma_i,j$</td>
<td>n/a</td>
<td>$&lt; 0.03$</td>
</tr>
<tr>
<td>$E^{2x5}/E^{5x5}$</td>
<td>$&gt; 0.94$ OR $E^{1x5}/E^{5x5} &gt; 0.83$</td>
<td>n/a</td>
</tr>
<tr>
<td>EM + Had Depth 1 Isolation</td>
<td>$&lt; 2 + 0.03<em>Et + 0.28</em>rho$</td>
<td>$&lt; 2.5 + 0.28*rho$ for $Et&lt;50$ else</td>
</tr>
<tr>
<td>Track Isol: Trk Pt</td>
<td>$&lt; 5$</td>
<td>$&lt; 5$</td>
</tr>
<tr>
<td>Inner Layer Lost Hits</td>
<td>$\leq 1$</td>
<td>$\leq 1$</td>
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The total efficiency to trigger, reconstruct, and select a 1 TeV electron pair within the detector acceptance is predicted by the Monte Carlo simulation to be $75 \pm 8\%$ for barrel-barrel and $70 \pm 10\%$ for barrel-endcap electron pairs
Z' $\rightarrow \mu\mu$ Event Selection

**Muon Selection**

- Global muon and Tracker Muon
- $N_{(\text{muon hits})} > 0$; and $N_{(\text{muon stations})} > 1$
- $d_{xy}$ wrt PV < 2 mm; and $N_{(\text{pixel hits})} > 0$
- $N_{(\text{tracker layers})} > 5$; and $\delta p_T/p_T < 0.3$
- Tracker Iso ($\Delta R=0.3$) < 0.1; and $p_T > 53$ GeV

**DiMuon and Event Selection**

- good offline-reconstructed PV, opposite-sign muons
- $\chi^2$/d.o.f. of a common vertex fit < 20
- 3D opening angle $\alpha$ between the two muons momenta < $(\pi - 0.02)$ rad
- One of the muons matched within $\Delta R < 0.2$ to the HLT_Mu50 muon candidate

The total efficiency to trigger, reconstruct, and select a 1 TeV muon pair within the detector acceptance is predicted by the Monte Carlo simulation to be $89^{+11\%}_{-14\%}$