Search for Higgs to Dimuons

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DPF Meeting
July 31, 2017
Outline

• Run 1 $H^0 \rightarrow \mu^+\mu^-$ Analysis
• Run 2 $H^0 \rightarrow \mu^+\mu^-$ Analysis improvements
Motivation

• Higgs couples to muons
  – Precise mass resolution
  – Test of direct coupling to fermions
Run 1

- 5 fb$^{-1}$ at 7 TeV + 19.7 fb$^{-1}$ at 8 TeV
- Search for a narrow peak in the di-muon spectrum
  - Main backgrounds: Drell-Yan and ttbar
• Signal production: $ggH$ and $qqH$

• Separate by jet multiplicity into exclusive categories to maximize sensitivity
Object Selection

• **Trigger**
  – At least one isolated muon
    • $p_T > 24$ GeV
    • $|\eta| \leq 2.1$

• **Offline**
  – “Triggered” muon $p_T > 25$ GeV
  – Sub-leading $p_T > 15$ GeV
  – Tight muon selection
  – Jet $p_T > 30$ GeV, $|\eta| < 4.7$
Run 1 Categories

• VBF Tight
  – $p_T^{J(1,2)} > 40, 30$ GeV
  – $M_{jj} > 650$ GeV
  – bjet veto
  – $\Delta \eta(1,2) > 3.5$

• GF Tight
  – $p_T^{J(1,2)} > 40, 30$ GeV
  – $M_{jj} > 250$ GeV
  – bjet veto
  – $p_{T\mu\mu} > 50$ GeV

• Muon Categories:
  – $|\eta| < 0.8$ (B); $<1.6$ (O) $<2.4$ (E)

• 2Jet Loose
  – $p_T^{J(1,2)} > 40, 30$ GeV
  – bjet veto

• 0,1 Jet Tight
  – $p_{T\mu\mu} > 25$ GeV
  – bjet veto

• 0,1 Jet Loose
  – Fail all others
### Systematics

<table>
<thead>
<tr>
<th>Source</th>
<th>GF [%]</th>
<th>VBF [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDF [18]</td>
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<td>5</td>
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<tr>
<td>PS/UE</td>
<td>6–60</td>
<td>2–15</td>
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<td>$\mathcal{B}(H \rightarrow \mu^+\mu^-)$ [18]</td>
<td>6</td>
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<tr>
<td>Integrated luminosity [39, 40]</td>
<td>2.2–2.6</td>
<td>2.2–2.6</td>
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<tr>
<td>MC statistics</td>
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<td>Muon efficiency</td>
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<tr>
<td>Pileup</td>
<td>&lt; 1–5</td>
<td>&lt; 1–2</td>
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<td>Jet energy resolution</td>
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<td>Jet energy scale</td>
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<td>Pileup jet rejection</td>
<td>1–4</td>
<td>1–4</td>
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</tbody>
</table>

[Link to paper](#)
Results

• Expected and observed limits

\[ 7.4 \times \text{SM} \]
\[ (6.5 + 2.8 - 1.9) \]
Run 2 Analysis

35.9 fb\(^{-1}\) at 13 TeV

- **Trigger**
  - Isolated muon \(p_T > 24\) GeV

- **Offline**
  - 2 opposite sign muons
  - Triggered muon \(p_T > 26\) GeV
  - \(|\eta| < 2.4\)
  - \(p_T > 10\) GeV
  - Jets \(p_T > 30\) GeV \(|\eta| < 4.7\)
Analysis Improvements
• Improved muon trigger
  – Machine learning algorithm trained to better approximate muon momenta
  – Boosted regression trees encoded in lookup table in FPGA
Background Model

- FEWZ NNLO generator
  - better model the shape of the Drell-Yan background
  - Reduce the systematic uncertainty
    - Better agreement with the data

FEWZ 2.0: A code for hadronic Z production at next-to-next-to-leading order

Ryan Gavin\(^1\), Ye Li\(^1\), Frank Petriello\(^{2,3}\), and Seth Quackenbush\(^2\)
• Use machine learning to find better categories
  – ~10% improvement in expected limits
ML+ Categorizer

- Use machine learning upstream for event selection
- Plus categorization
  - ~25% improvement in expected limits
Results

• To be released in ~month

CMS PAS HIG-17-019

DRAFT

CMS Physics Analysis Summary

The content of this note is intended for CMS internal use and distribution only

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Stay Tuned

Search for standard model Higgs boson production in the $\mu^+\mu^-$ final state at CMS in $pp$ collisions at $\sqrt{s} = 13$ TeV
Thank You
Di-muon event