Standard Model Higgs search with CMS

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The CMS detector

- Silicon tracker $|\eta| < 2.5$, $B = 3.8T$ solenoid
  - $\sigma/p_T \approx 1.5 \cdot 10^{-4} p_T \oplus 0.005$

- Calorimetry $|\eta|_{\text{ECAL}} < 3$, $|\eta|_{\text{HCAL}} < 5$
  - ECAL: PbWO$_4$ crystals, high resolution $M(\gamma\gamma)$
    - $\sigma/E \approx 2.8%/\sqrt{E} \oplus 12%/E \oplus 0.3%$
  - HCAL: brass+Scintillator
    - $\sigma/E \approx 100%/\sqrt{E} \oplus 5\%$

- Muon Spectrometer: $B = 2T$ (solenoid return yoke)
  - $\sigma/p_T \approx 1\% @ 40 \text{ GeV}, \ |\eta| < 2.4$
2011 dataset and reconstruction

- Excellent performance of LHC and CMS in 2011
  - More than 5 fb\(^{-1}\) of pp collisions collected at 7 TeV CM energy
  - Peak luminosity \(3.5 \times 10^{33}\) cm\(^{-2}\)s\(^{-1}\)
  - Data taking efficiency 90%
  - 90% of collected data good for all analyses
  - Mean pileup 10 events

- A Particle Flow algorithm (PF) has been developed
  - Provides a global event description in form of a list of particles and avoids double-counting

- Large improvements in \(\tau\), jet and missing transverse energy (MET) measurement

13 reconstructed vertices in CMS tracker

Number of vertices in the second part of 2011 data
Higgs boson at LHC

- Indirect constraints from precision EW measurements
  - $M_H < 169$ GeV at 95% CL (standard fit)
  - $M_H < 143$ GeV at 95% CL (including direct searches, before LHC)

- Direct searches
  - LEP: $M_H < 114.4$ GeV excluded at 95% CL
  - Tevatron: latest results in previous talks
  - SM scalar boson favored at low mass, above the LEP limit
# Higgs boson channel at CMS

<table>
<thead>
<tr>
<th>Channel</th>
<th>(m_H) range (GeV)</th>
<th>Luminosity (fb(^{-1}))</th>
<th>Sub-channels</th>
<th>(m_H) resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>new (H \to \gamma\gamma)</td>
<td>110–150</td>
<td>4.8</td>
<td>2</td>
<td>1–2%</td>
</tr>
<tr>
<td>(H \to \tau\tau \to e\tau_h/\mu\tau_h/e\mu + X)</td>
<td>110–145</td>
<td>4.6</td>
<td>9</td>
<td>20%</td>
</tr>
<tr>
<td>new (H \to \tau\tau \to \mu\mu + X)</td>
<td>110–140</td>
<td>4.5</td>
<td>3</td>
<td>20%</td>
</tr>
<tr>
<td>new (WH \to e\mu\tau_h/\mu\mu\tau_h + \nu's)</td>
<td>100–140</td>
<td>4.7</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>((W/Z)H \to (e\nu/\mu\nu/ee/\mu\mu/\nu\nu)(bb))</td>
<td>110–135</td>
<td>4.7</td>
<td>5</td>
<td>10%</td>
</tr>
<tr>
<td>(H \to WW^* \to 2\ell2\nu)</td>
<td>110–600</td>
<td>4.6</td>
<td>5</td>
<td>20%</td>
</tr>
<tr>
<td>new (WH \to W(WW^*) \to 3\ell3\nu)</td>
<td>110–200</td>
<td>4.6</td>
<td>1</td>
<td>20%</td>
</tr>
<tr>
<td>(H \to ZZ^{(*)} \to 4\ell)</td>
<td>110–600</td>
<td>4.7</td>
<td>3</td>
<td>1–2%</td>
</tr>
<tr>
<td>(H \to ZZ^{(*)} \to 2\ell2q)</td>
<td>[130–164, 200–600]</td>
<td>4.6</td>
<td>6</td>
<td>3%</td>
</tr>
<tr>
<td>(H \to ZZ \to 2\ell2\tau)</td>
<td>190–600</td>
<td>4.7</td>
<td>8</td>
<td>10–15%</td>
</tr>
<tr>
<td>(H \to ZZ \to 2\ell2\nu)</td>
<td>250–600</td>
<td>4.6</td>
<td>2</td>
<td>7%</td>
</tr>
</tbody>
</table>

**Low mass**

**High mass**

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**Search mass range**

110–600 GeV

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**Expected combined 95% exclusion**

114.5–543 GeV

**Exclusion sensitivity at LEP lower limit**

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**CMS Preliminary, \(\sqrt{s} = 7\) TeV**

L = 4.6–4.8 fb\(^{-1}\)

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**Expected limits**

- Combined
- \(H \to bb\)
- \(H \to \tau\tau\)
- \(VH \to \tau\tau\)
- \(WH \to \tau\ell\mu\)
- \(H \to \gamma\gamma\)
- \(H \to WW \to 2\ell2\nu\)
- \(WH \to 3\ell3\nu\)
- \(H \to ZZ \to 4\ell\)
- \(H \to ZZ \to 2\ell2\tau\)
- \(H \to ZZ \to 2\ell2\nu\)
High mass channels

\[ H \rightarrow ZZ \rightarrow 2l2\nu \]
\[ H \rightarrow ZZ \rightarrow 2l2q \]
H→ZZ→2l2ν

- Most sensitive channel for high mass search
  - BR 6 times larger than ZZ→4l
- **Neutrinos implies mass resolution 7%**
- Only accessible for high mass (M_H >~ 250 GeV):
  - the two Z bosons are boosted
  - large MET due to invisible decay
- Main backgrounds
  - ZZ (irreducible)
  - Z+jets, tt, WZ

H→ZZ→llνν candidate
H→ZZ→2l2ν: results

- Two analyses: cut and count and $M_T$ fit
- Transverse mass definition:

$$M_T^2 = \left( \sqrt{p_T(\ell\ell)^2 + M(\ell\ell)^2 + E_T^{\text{miss}}^2} + M(\ell\ell)^2 \right)^2 - (p_T(\ell\ell) + E_T^{\text{miss}})^2$$

- No excess observed in data
- Expected 95% exclusion for $M_H$ in [290-480] GeV
- Observed 95% CL exclusion for $M_H$ [270-440] GeV

**MET after preselection**

- **BG estimation**
  - Z+jets estimated using $\gamma$+jet to model the MET distribution
  - Non resonant BG normalization from eμ events
  - ZZ and WZ from MC

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H$\rightarrow$ZZ$\rightarrow$2l2q

- Two opposite-charge, same-flavour leptons consistent with Z mass
- Two jets in Z peak with $p_T > 30$ GeV, within tracking acceptance
  - Analysis divided in 0/1/2 b-tag event categories
  - Use of quark-gluon discriminant based on jet shape/constituents
  - Additional use of angular likelihood discriminant at high mass
- Dominant Z+jets background estimated from $m_{jj}$ sidebands
H→ZZ→2l2q: results

- Full distribution of mZZ used to extract the signal (default) OR cut-and count
- Background modeled from m_{jj} sidebands: (60<m_{jj}<75 \text{ GeV}) \cup (105<m_{jj}<130 \text{ GeV})
- e\mu_{jj} used also as control sample (Z+jets free)

Sensitivity approaching SM cross-section in high mass region
Higgs $\rightarrow$ ZZ*: the golden mode

search-range: [110 - 600] GeV
max sensitivity: 180 GeV
ZZ$\rightarrow$4l: clean signature, narrow peak
$H \rightarrow ZZ \rightarrow 4l$ (4$\mu$, 4$e$, 2$e\tau$$\mu$)

- Clean channel: 2 high mass pairs of isolated electrons or muons
- **Narrow mass peak**
  - Very good mass resolution 1-2%
- Small BR $\sim 10^{-3}$ at high mass

- Background
  - irreducible: ZZ, Reducible: Z+jets, Zbb, tt, WZ
- Most important aspect:
  - highest possible lepton reconstruction and id efficiency down to very low $P_T$

**H-$\rightarrow$4$\mu$ candidate**

$M_{Z1} = 90$ GeV
$M_{Z2} = 25$ GeV
$M_{4l} = 119$ GeV
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**H→ZZ→ 4l: mass spectrum**

### Full mass range

- **Data:** 72
- **BKG exp.:** 67±6

### Low mass

- **Data:** 13
- **BKG exp.:** 9.5±1.3

In 100-160 GeV

<table>
<thead>
<tr>
<th>Channel</th>
<th>4e</th>
<th>4μ</th>
<th>2e2μ</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZZ continuum</td>
<td>12.27±1.16</td>
<td>19.11±1.75</td>
<td>30.25±2.78</td>
</tr>
<tr>
<td>Z+X</td>
<td>1.67±0.55</td>
<td>1.13±0.55</td>
<td>2.71±0.96</td>
</tr>
<tr>
<td>All background</td>
<td>13.94±1.28</td>
<td>20.24±1.83</td>
<td>32.96±2.94</td>
</tr>
<tr>
<td>m_H = 120 GeV/c²</td>
<td>0.25</td>
<td>0.62</td>
<td>0.68</td>
</tr>
<tr>
<td>m_H = 140 GeV/c²</td>
<td>1.32</td>
<td>2.48</td>
<td>3.37</td>
</tr>
<tr>
<td>m_H = 350 GeV/c²</td>
<td>1.95</td>
<td>2.61</td>
<td>4.64</td>
</tr>
<tr>
<td>Observed</td>
<td>12</td>
<td>23</td>
<td>37</td>
</tr>
</tbody>
</table>
P-values

- Largest excess observed at 119.5 GeV
  - local significance 2.5 \( \sigma \)
  - global significance 1.0 \( \sigma \) in the full mass range, 1.6 in the mass range 100-160 GeV

Exclusion

- SM scalar boson excluded at 95% CL for \( M_H \) in [134-158], [180-305] and [340-465] GeV
Higgs → WW*: the draught-horse

search-range: [110 - 600] GeV
max sensitivity: 160 GeV
WW → 2l2ν: high BR, clean signature, no mass peak
H→WW→ 2l2ν: strategy

- Most sensitive channel around $2xM_W$ 
  ($125 < M_H < 200$ GeV)
- **No narrow mass peak** (mass resolution ~20%)
- Two high $p_T$ isolated leptons + MET
- Main backgrounds
  - $WW$ (irreducible)
  - $Z$+jets, $WZ$, $ZZ$, $tt$, $W$ + jets
- BKG estimation crucial
  - Main BG estimated from data

Scalar $H$ boson + V-A structure of $W$ decay favors small $\Delta\phi$ between leptons
H→WW→ 2l2ν: selection

- **start with DY-dominated sample**, reduced by MET cut and Z-veto

- **top dominated sample** rejected with jet veto (=0, 1 or peculiar VBF 2 jets)

- **b-tagging veto** further reduces it

- **this is WW dominated sample**

- apply $m_H$ dependent cuts: kinematics strongly depends on the Higgs mass
  - $\Delta \phi_{ll}$, $p_T^1$, $p_T^2$, $m_{ll}$, $m_T$ cuts

  - $\Rightarrow$ background composition depends on $m_H$

- CMS, $\sqrt{s} = 7$ TeV, $L_{int} = 1.55$ fb$^{-1}$

  - data
  - $H(160) \to WW$
  - $W+jets$
  - di-boson
  - top
  - $Z+jets$
  - WW

  - expected (data-driven) vs observed (eg. 0-jet, $m_H=160$ GeV)
The pileup challenge

- Pileup worsen $E_T^{\text{miss}}$ resolution
- Two estimators considered:
  - particle-flow $E_T^{\text{miss}}$: charged + neutral component
  - track $E_T^{\text{miss}}$: only tracks consistent with nominal primary vertex $\Rightarrow$ reduced PU dependency
  - take the min of the two
- Project along $\ell\ell$-system ($Z \rightarrow \tau\tau$ rejection):

\[
\text{proj}E_T^{\text{miss}} = \begin{cases} 
E_T^{\text{miss}} & \text{if } \Delta\phi_{\text{min}} \geq \frac{\pi}{2}, \\
E_T^{\text{miss}} \sin(\Delta\phi_{\text{min}}) & \text{if } \Delta\phi_{\text{min}} < \frac{\pi}{2}
\end{cases}
\]

\[
\Delta\phi_{\text{min}} = \min(\Delta\phi(\ell_1, E_T^{\text{miss}}), \Delta\phi(\ell_2, E_T^{\text{miss}}))
\]
Shape analysis for 0 and 1 jet bins

- BDT trained at different masses, input variables:
  - $P_{\text{t,leptons}}, M_{\ell\ell}, \Delta \varphi_{\ell\ell}, \Delta R_{\ell\ell}, M_t$ (for dilepton system and each lepton)
- Overall uncertainties:
  - signal efficiency $\sim 20\%$
  - background $\sim 15\%$
  - shape systematics included
- Use a fit to BDT output distribution for CLs estimation
- Many cross checks made, using Matrix Element method, using fit with only $M_{\ell\ell}$ variable
- VBF (2jet bin): cut&count analysis

$M_H=130$ GeV

Most sensitive channel is $e\mu$ in 0-jet bin
higher s/b and smaller systematic errors
H → WW → 2l2ν: results

- No significant excess in the full mass range
- Multivariate analysis more sensitive, especially at low mass
- 95% C.L. expected exclusion for $M_H$ in [127-270] GeV
- 95% C.L. observed exclusion for $M_H$ in [129-270] GeV
- Slight excess at low mass in shape analysis
WH→WWW→ 3l3ν

- Similar to WW analysis
- Cut and count analysis with mass independent selection
- Main backgrounds estimated from data

<table>
<thead>
<tr>
<th>stage</th>
<th>WH (120) ( H \rightarrow ττ )</th>
<th>WH (120) ( H \rightarrow WW )</th>
<th>data</th>
<th>all bkg.</th>
<th>WZ ( \rightarrow 3lν )</th>
<th>ZZ ( \rightarrow 4l )</th>
<th>top+Z/γ*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-lepton preselection</td>
<td>2.1 ± 0.0</td>
<td>3.5 ± 0.1</td>
<td>950</td>
<td>968.3 ± 11.9</td>
<td>482.9 ± 1.8</td>
<td>78.4 ± 0.9</td>
<td>348.0 ± 9.7</td>
</tr>
<tr>
<td>min-MET &gt; 40 GeV</td>
<td>1.0 ± 0.0</td>
<td>1.8 ± 0.1</td>
<td>244</td>
<td>270.5 ± 4.4</td>
<td>208.2 ± 1.1</td>
<td>7.9 ± 0.3</td>
<td>54.5 ± 4.3</td>
</tr>
<tr>
<td>Z removal</td>
<td>0.4 ± 0.0</td>
<td>1.0 ± 0.1</td>
<td>40</td>
<td>47.9 ± 3.1</td>
<td>15.9 ± 0.4</td>
<td>0.7 ± 0.1</td>
<td>31.3 ± 3.1</td>
</tr>
<tr>
<td>top veto</td>
<td>0.1 ± 0.0</td>
<td>0.6 ± 0.1</td>
<td>12</td>
<td>14.2 ± 1.3</td>
<td>8.8 ± 0.4</td>
<td>0.4 ± 0.1</td>
<td>4.9 ± 1.3</td>
</tr>
<tr>
<td>( \Delta R_{ℓ+ℓ-} ) &amp; ( m_{ℓℓ} )</td>
<td>0.1 ± 0.0</td>
<td>0.5 ± 0.1</td>
<td>7</td>
<td>8.4 ± 0.9</td>
<td>5.7 ± 0.2</td>
<td>0.3 ± 0.1</td>
<td>2.6 ± 0.9</td>
</tr>
</tbody>
</table>

CMS document
HIG-11-034
Higgs→γγ: the low mass driver

search-range: [110 - 150] GeV
max sensitivity: < 125 GeV
narrow peak, large background
**H → γγ: basics**

- **E_T = 86 GeV**
- **E_T = 56 GeV**

- Small BR: ~2x10^{-3}
- Two isolated high E_t photons
- VBF channel has two additional jets from outgoing quarks
- **Narrow mass peak**
  - very good mass resolution 1-2%

- Signature: small mass peak over large smoothly decreasing background
  - Irreducible: 2γ QCD production
  - Reducible: γ+jet with 1 additional fake photon, DY with electrons faking photons
- Studied mass range: 110-150 GeV

**Z → ee** with both e in barrel, best resolution category
H→γγ: analysis strategy

- Select two photons with $p_T > m_{γγ}/3(4)$ with appropriate selection on shower shape and isolation
- Multivariate energy corrections for local and global electromagnetic cluster containment (resolution and energy scale corrections from $Z \rightarrow ee$)
- Primary vertex selection uses track recoil against di-photon system with conversion pointing where available (correct vertex in $\sim 83\%$ of events)

$SM \, Higgs \times 10$

$m_H = 120 \, GeV$
**H→γγ: inclusive analysis / VBF**

- 4 non-VBF event classes split based on the diphoton BDT classifier output
- BG is estimated by fitting to a polynomial in the full mass range (3rd to 5th order)
  - Possible BG bias is always less than 20% of the statistical error
  - Different BG estimation in cross check analysis gives consistent results
- VBF channel has lower yield but larger purity

<table>
<thead>
<tr>
<th>m_H=120 GeV</th>
<th>class 0</th>
<th>class 1</th>
<th>class 2</th>
<th>class 3</th>
<th>Dijet class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total signal expected events</td>
<td>3.4</td>
<td>19.3</td>
<td>18.7</td>
<td>33.0</td>
<td>2.8</td>
</tr>
<tr>
<td>Data (events/GeV)</td>
<td>4.5</td>
<td>55.1</td>
<td>81.3</td>
<td>229.1</td>
<td>2.1</td>
</tr>
<tr>
<td>resolution FWHM/2.35 (%)</td>
<td>0.9</td>
<td>0.9</td>
<td>1.2</td>
<td>1.7</td>
<td>1.1</td>
</tr>
</tbody>
</table>
**H→γγ: exclusion limits**

- Expected 95% CL exclusion: 1.2-2 x SM
- Excluded at 95% CL: 110.0-111.0, 117.5-120.5, 128.5-132.0, 139.0-140.0, 146.0-147.0 GeV
- Cut based analysis gives consistent results
  - arXiv:1202.1487, published by PLB
- Cross check MVA analysis also gives consistent results

**Expected from cut based analysis**

**Improvement ~20%**
H→γγ: p-values

- P-value: probability that a BG only fluctuation is more signal-like than observation

  - Largest excess around 125 GeV
    - Local significance 2.9 σ
    - Global significance 1.6 σ

- Look elsewhere effect (LEE) estimated in the mass range 110-150 GeV with toy experiments

Similar results as cut based
other low mass channels

\[ H \rightarrow \tau \tau \]
\[ H \rightarrow bb \]
\[ H \rightarrow \tau \tau \]

- **No narrow mass peak** \((\sigma_m \sim 20\%)\)
- Three different sub-channels for SM:
  - **VBF** production, two additional forward jets
  - **Boosted**: one jet with \(P_t > 150\) GeV
  - **gg-fusion**: 0 or 1 additional jets

- \(H \rightarrow \tau \tau \rightarrow \mu \mu\) also studied
- \(WH \rightarrow \ell \tau \rightarrow e \mu \text{th}, \mu \mu \text{th}\) also studied

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**CMS document**: HIG-12-007

arXiv:1202.3697

Published by PLB
- BKG too large, needs additional tag
- Exploit VH associated production with W and Z decaying leptonically
  - $W \rightarrow e, \mu$
  - $Z \rightarrow ee, \mu\mu, \nu\nu$
- Require boosted $bb$ system
- Mass resolution $\sim 10\%$

**ZH$\rightarrow$νν$bb$ candidate**

- $M_{bb} = 105$ GeV
- $P_{Tbb} = 226$ GeV
- MET = 198 GeV

Excluded at 95% CL

3-9xSM

arXiv:1202.4083
Published by JHEP
CMS Higgs combination

search-range: [110 - 600] GeV
all the modes analyzed by CMS with 4.7 fb$^{-1}$ are included
Combination strategy

- SM cross sections and branching ratios are assumed with their theoretical uncertainties and an overall signal strength multiplier is fit
- Method for CL calculation is LHC-type CLs
  - Frequentist CLs with profiled likelihood test statistics and log-normal treatment of nuisance parameters
- Here we show the latest results that include the new analyses presented here
- Results based on 2011 data have been recently submitted for publication
  - arXiv:1202.1488, published by PLB
• Expected: 95% exclusion $M_H$ in [114.5-543] GeV
• Observed: 95% exclusion $M_H$ in [127.5-600] GeV
  99% exclusion $M_H$ in [129-525] GeV
• 95% allowed mass range: 114.4-127.5 GeV
• Observed lower limit higher than expected because of excess in data at low mass
Low mass region zoom

- Minimum p-value observed at 125 GeV with local significance: $2.8 \sigma$
- Similar significance expected from signal
- Estimated global significance:
  - $0.8 \sigma$ in [110-600] GeV, $2.1 \sigma$ in [110-145] GeV,
The fitted $\sigma$ of the excess near 125 GeV is consistent with the SM Higgs boson expectation.

At low mass several channels show modest excess:

- At 125 GeV the mass-sensitive channels show an excess consistent with signal expectations.
- Consistent with signal and bkg-only hypothesis: more data needed.
• SM scalar boson search in >10 independent channels with the full 2011 dataset
• SM Higgs excluded in $M_H$ in [127.5-600] GeV at 95% CL
• Observe a modest excess around 125 GeV:
  • Local significance 2.8 $\sigma$, global significance 0.8 $\sigma$ (in the full search range) and 2.1 $\sigma$ (in 110-145 GeV)
  • The excess is consistent both with background fluctuation and also with a Higgs boson with mass about 125 GeV
  • if the Higgs exists, limited between 114.5 and 127.5 GeV

• In 2012 LHC is running at 8 TeV CM energy and high luminosity
  • should be able to discover or exclude the SM scalar boson down to the LEP limit
Backup
H$\rightarrow\gamma\gamma$ VBF analysis

- Exclusive dijet tag improves sensitivity by $\sim 10\%$
- Photon identification is the same
  - tighter lead photon $E_t$ cut ($E_t$ lead/$M_{\gamma\gamma} > 55/120$)
- Dijet tag selection on dijet variables
  - exploits two additional VBF high $p_T$ jets at large rapidity

$M_{\gamma\gamma} = 121.9$ GeV
$M_{jj} = 1460$ GeV

Dijet tag selection has high s/b, $\sim 1/3$
H → ZZ → 2l2τ channel

- All τ decays used
- Sensitivity about 4×SM
- Expect 10.2 events from BG
- Observe 10 events in data

95% Exclusion

CMS

\( \sqrt{s} = 7 \text{ TeV}, L = 4.7 \text{ fb}^{-1} \)

- DATA
- \( m_H = 200 \text{ GeV} \)
- \( m_H = 400 \text{ GeV} \)
- ZZ
- WZ/Z + jets

95% CL limit on \( \sigma/\sigma_{SM} \)

CMS

\( \sqrt{s} = 7 \text{ TeV}, L = 4.7 \text{ fb}^{-1} \)

- Observed
- Expected ± 1σ
- Expected ± 2σ
H → WW → 2l2ν: exclusion 100-300 GeV

CMS preliminary
H → WW (BDT based)
L = 4.6 fb⁻¹

95% CL limit on σ/σ_{SM}

median expected
expected ± 1σ
expected ± 2σ
observed

Higgs mass [GeV]
High-resolution channels combination ($ZZ + \gamma\gamma$)

95% CL limit on $\sigma/\sigma_{SM}$

CMS Preliminary
$\sqrt{s} = 7$ TeV
$ZZ + \gamma\gamma$, $L = 4.8$ fb$^{-1}$

Local p-value

CMS Preliminary, $\sqrt{s} = 7$ TeV, $H \rightarrow ZZ + \gamma\gamma$, $L = 4.8$ fb$^{-1}$
low-resolution channels combination ($WW + bb + \tau\tau$)
95 % CL exclusion

Full mass range

Low mass region

CMS Preliminary
\( \sqrt{s} = 7 \text{ TeV} \)
\( L = 4.6-4.8 \text{ fb}^{-1} \)

95% CL limit on \( \sigma/\sigma_{SM} \)

Higgs boson mass (GeV)
95 % CL exclusion for different channels

**Full mass range**

**Low mass region**

CMS Preliminary

$\sqrt{s} = 7$ TeV

$L = 4.6-4.8$ fb$^{-1}$

95% CL limit on $\sigma/\sigma_{SM}$

Higgs boson mass (GeV)

Higgs boson mass (GeV)
Fitted signal strengths at 119.5 GeV

![Graph showing signal strengths at 119.5 GeV for different decay modes: H → bb, H → ττ, H → γγ, H → WW, H → ZZ. The graph includes combined (68%) and single channel results.]

CMS Preliminary
\[ \sqrt{s} = 7 \text{ TeV} \]
L = 4.6 - 4.8 fb⁻¹
Projections for 2012 run

- 8 TeV vs 7 TeV is expected to increase the sensitivity by 10-20%
Local significance: $3.1 \sigma$

Global p-value significance:
- $2.1 \sigma$ in $[110-145]$ GeV
- $1.5 \sigma$ in $[110-600]$ GeV
Largest excess observed

- Fitted signal strength in the different channels and in combination

Highest excess at 124 GeV 2\textsuperscript{nd} highest excess at 119.5 GeV

- All investigated channels show consistent excess but the observed excess is also consistent with BG only
- Local p-value significance $\sim$2.3 $\sigma$
- Excess mainly coming from the 3 ZZ-$>4l$ events
- Deficit in that region in H-$\gamma\gamma$