Mass and Width
Experimental status

Meng Xiao (Johns Hopkins University)

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Introduction

• Mass: ZZ, γγ

• Width upper bound
  • on-shell: ZZ, γγ
  • off-shell: ZZ, WW

• Width lower bound: ZZ
Direct measurement from the mass shape

— Limiting factor: detector resolution

— HL projection depends on the detector description

Is the precision good enough for TH studies for YR?

**ATLAS**

- Run 1 $H \to 4l$, $\sqrt{s} = 7-8$ TeV, 25 fb$^{-1}$,
- Run 2 $H \to 4l$, $\sqrt{s} = 13$ TeV, 36.1 fb$^{-1}$

<table>
<thead>
<tr>
<th>Run</th>
<th>$m_H$ [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1 $H \to 4l$</td>
<td>124.51 ± 0.52 (± 0.52)</td>
</tr>
<tr>
<td>Run 1 $H \to \gamma\gamma$</td>
<td>126.02 ± 0.51 (± 0.43)</td>
</tr>
<tr>
<td>Run 2 $H \to 4l$</td>
<td>124.79 ± 0.37 (± 0.36)</td>
</tr>
<tr>
<td>Run 2 $H \to \gamma\gamma$</td>
<td>124.93 ± 0.40 (± 0.21)</td>
</tr>
<tr>
<td>Run 1 Combined</td>
<td>124.71 ± 0.30 (± 0.30)</td>
</tr>
<tr>
<td>Run 1 Combined</td>
<td>125.32 ± 0.35 (± 0.19)</td>
</tr>
<tr>
<td>Run 2 Combined</td>
<td>125.38 ± 0.41 (± 0.37)</td>
</tr>
<tr>
<td>Run 2 Combined</td>
<td>125.86 ± 0.27 (± 0.18)</td>
</tr>
<tr>
<td>ATLAS + CMS Run 1</td>
<td>124.97 ± 0.24 (± 0.16)</td>
</tr>
<tr>
<td>ATLAS + CMS Run 1</td>
<td>125.06 ± 0.24 (± 0.21)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CMS</th>
<th>Run 2 $H \to 4l$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS</td>
<td>124.86 ± 0.27 (4l+\gamma\gamma)</td>
</tr>
<tr>
<td>CMS</td>
<td>125.26 ± 0.21 (4l)</td>
</tr>
</tbody>
</table>

**CMS**

- Run 2, $\sqrt{s} = 13$ TeV, 35.9 fb$^{-1}$

- Limiting factor: detector resolution

- HL projection depends on the detector description

- Is the precision good enough for TH studies for YR?

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Width from on-shell

Direct measurement from the mass shape
— Limiting factor: detector resolution
— HL projection depends on the detector description

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<thead>
<tr>
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<th>ATLAS</th>
<th>CMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run1</td>
<td>&lt;2.6 GeV (ZZ)</td>
<td>&lt;1.7 GeV (ZZ+γγ)</td>
</tr>
<tr>
<td>Run2</td>
<td>-</td>
<td>&lt;1.1 GeV (ZZ)</td>
</tr>
</tbody>
</table>
Width from off-shell

Indirect measurement from the on-shell + off-shell mass
— Off-shell/on-shell ratio => width (couplings the same)
— High precision
— Not depend on the detector too much

<table>
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<tr>
<th>ATLAS</th>
<th>CMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run1 &lt;22.7 MeV (ZZ+WW)</td>
<td>&lt;13 MeV (ZZ+WW)</td>
</tr>
<tr>
<td>Run2 -</td>
<td>&lt;41 MeV (4l, 1/3 full data)</td>
</tr>
</tbody>
</table>

\[
\frac{\sigma_{\text{obs}}}{\sigma_{\text{exp}}} = \frac{1}{\kappa_{\text{on-shell}}^H} \frac{1}{\kappa_{\text{off-shell}}^H} \frac{1}{\Gamma_{\text{on-shell}}^H} \approx 1
\]

\[
\mathcal{L} \int = 8 \text{ TeV} : \mathcal{L}_{\text{L}} = 20.3 \text{ fb}^{-1}
\]

\[
\begin{align*}
105 \text{ GeV} & < m_t < 1600 \text{ GeV} \\
\text{Observed} & \quad \text{Expected}
\end{align*}
\]

Indirect measurement from the on-shell + off-shell mass:
- Off-shell/on-shell ratio => width (couplings the same)
- High precision
- Not depend on the detector too much
Width projection from off-shell

ATLAS projection
- Assuming k-factor unc 10%

At 3 ab⁻¹
\( \Gamma_H = 4.2^{+1.5}_{-2.1} \text{ MeV} \)
Width lower bound

H $\to$ ZZ $\to$ 4l, flight distance $\Rightarrow$ lifetime

— Limiting factor: detector
— HL projection depends on the detector description
— Low sensitivity, better constraints from off-shell projection
— No plan to perform the projection for HL YR

Run 1 result:

$cT_H < 57 \mu$m $\Rightarrow \Gamma_H > 3.5 \times 10^{-9}$ MeV
On-shell width: using interference

$gg, qg \rightarrow (H) \rightarrow \gamma \gamma$ interference at NLO

$\Rightarrow$ mass shift dependent of $\Gamma_H, p_T$

Use mass shift in different $p_T$ region to constrain $H$ width
— Effect most pronounced in low $p_T$, need careful experimental work

Studies from ATLAS
— Projection with 3 ab$^{-1}$: $\Delta m=130$ MeV, $\Gamma_H \sim 40-50 \Gamma_{SM}$

Studies from ATLAS
— Projection with 3 ab$^{-1}$: $\Delta m=130$ MeV, $\Gamma_H \sim 40-50 \Gamma_{SM}$

ATLAS Simulation Preliminary

\[ L = 3000 \text{ fb}^{-1}, \int f = 14 \text{ TeV} \]

After background subtraction

ATLAS Simulation Preliminary

\[ L = 3000 \text{ fb}^{-1}, \int f = 14 \text{ TeV} \]

Data fit to data

Undisturbed $H \rightarrow \gamma \gamma$

Interference correction

Corrected $H \rightarrow \gamma \gamma$

LHC HIGGS XS 2016

Expected mass shift in the SM

Expected mass shift due to interference

Statistical one-sided 95% CL, Neyman belt

Statistical one-sided 95% CL, Neyman belt

arXiv:1305.3854v2

arXiv:1610.07922
Summary

- Quite a complete list of mass and width measurements from Run1 and Run2
  - Some with already good precision, some quite far
- Projection of the measurements mostly depends on the detector effects
  - so far no intension to do mass and on-shell width
  - off-shell width projection from ATLAS available